SERVICING SUPERHETERODYNES

By JOHN F. RIDER

SERVICING
SUPERHETERODYNES
(REVISED EDITION)

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PREFACE TO THE THIRD EDITION

NEARLY three years ago, when the revised edition of "Servicing Superheterodynes" was published, we wrote "Times change, so do superheterodyne receivers." That is as true today, as it was then . . . perhaps even more so.

Although this book has been revised again, we desire to impress one fact on the reader: the principles explained in the body of the book apply just as much today as they did years ago and if the reader is not thoroughly familiar with those principles, he can never hope to understand the various refinements which the superheterodyne circuit has undergone and which are treated in the Appendix.

These refinements have been made possible by a number of advances in tube and circuit design. Inasmuch as the basic arrangement of the superheterodyne receiver remains unchanged through all these advances, it was deemed advisable to keep the main part of this book as it was and to put the explanations of the developments in the Appendix . . . those developments which we believe have come to stay and be as much a part of a superheterodyne as the mixer tube. In addition to the new data, we have incorporated in the Appendix a completely revised and up-to-date list of the i-f. peaks of American superheterodynes.

JOHN F. RIDER.

March, 1937.

AUTHOR'S FOREWORD

THIS revised edition of "Servicing Superheterodynes" contains extensive elaboration upon most of the material which was published in the first edition. This new edition is in reality a new book, having been completely rewritten. Times change and so do superheterodyne receivers. The three years which have elapsed since the publication of the first edition have witnessed tremendous strides in superheterodyne design. The great year of tube development during 1932-1933 has been responsible for the development of numerous new circuit arrangements, which are to be found in the present day receivers.

At the time the first edition of "Servicing Superheterodynes" was published, the superheterodyne receiver was first becoming generally known to the public. As the years passed, so did the tuned radio frequency set pass out of popular favor to be replaced by the well liked and today, well behaved, superhet. Today, everything is the superheterodyne. Small receivers—large receivers—consoles—midgets, all are of the superheterodyne variety. The few t-r-f receivers, which are still being produced, are completely overwhelmed by the number of receivers based upon the heterodyne principles. And—if you please—these receivers are becoming more and more complicated daily.

This revised edition is not intended as a specific course covering general radio service work. In content we dwell upon the superheterodyne receiver. The greatest amount of space is devoted to the facts underlying the operation of those parts of the receiver which are not native to the t-r-f system, at least as the term is understood. We have omitted extensive reference to audio amplifiers, power packs, etc. This act was deliberate, because we felt that the man who reads this book has had his experience with audio amplifiers and power

packs during his acquaintance with the t-r-f receiver. We have practically shamed the loud speaker, by leaving it out entirely. We sincerely hope that the reader will not think that the volume suffers accordingly.

Since we are concerned primarily with the superheterodyne receiver, we feel that the greatest amount of space should be devoted to cover fully those points which are vital to comprehension of the subject and successful servicing of this type of radio receiver. Do not feel that too much space has been devoted to any one particular branch of the subject and too little space has been devoted to some other branch. We have considered the practical side of the subject as well as the theoretical. Based upon contact with service men throughout the United States, we elaborated upon those subjects, which, we were informed, represented the least understood phases of superheterodyne operation.

We are taking for granted that the man who is to apply the information contained in this volume is a service man or, at least, is capable of properly applying the data. We are further assuming that he is in possession of the four vital pieces of test equipment, namely, the set tester or the equivalent instrument, by whatever name it be known, a service oscillator, a tube checker, an output meter and an ohmmeter. We are further assuming that he is familiar with what is referred to as a "voltage test" and as a "resistance test."

The writer of these lines is a devoted follower of point-to-point resistance measurement, yet definite and frequent reference is made to voltage measurement as a basis of service analysis. The reason for these references is that we realize that all manufacturers have not as yet switched their service analysis to conform with the resistance measurement system. Someday, the Utopia will be reached and service work will follow upon a more practical plane. Today, a large number of voltage tables appear in service information, consequently, operation along voltage analysis lines is still prevalent. Such being the case, we, too, refer to such tables.

You will find numerous references to manufacturers service data, particularly in connection with alignment work. Although we make this statement in the text, we repeat it

here. The alignment data furnished in this volume, is general and to be applied where the specific information from the receiver manufacturer is not available. It is impossible to furnish complete information of this type in a volume such as this. With pardonable pride, we point our finger at Rider's Manual as the volume wherein you will find complete alignment data, if it is furnished by the receiver manufacturer. No doubt we have omitted from this copy of "Servicing Superheterodynes" reference to some of the special notes pertaining to alignment of certain manufacturers' receivers. We have tried to cover as much ground as possible consistent with the size limitations of this volume. At the same time, we feel certain that if you are in possession of the Manual referred to before, you will find whatever special instructions you may need and therefore, will not be inconvenienced.

May we at this time, suggest that you should in all cases possible, employ the receiver manufacturer's alignment instructions in preference to any other data. This is of great importance in connection with the alignment frequencies. The table of intermediate frequencies included herewith covers all of the American receiver manufacturers, up to the time of this writing. As to r-f and short wave alignment frequencies, we have not compiled such a list. Read the manufacturers' instructions for such data. It is by all means the most accurate.

Past experience has shown that many men not affiliated with the service industry will be readers of this volume. It is our sincere hope, that the contents of this volume will prove of interest to them as well as to the members of the radio service industry.

We wish to express our thanks to the engineers and service managers of the many radio receiver manufacturers in this country, for the kind co-operation in forwarding service data to the undersigned.

At the same time we wish to express our thanks to Mr. G. C. B. Rowe, who spent sleepless nights reading proof on this manuscript.

—JOHN F. RIDER.

June 28, 1934.

INTRODUCTION

I T IS not the function of this book to portray the historical background of the superheterodyne receiver. While it is true that its present day popularity does not mean that it is a development of recent years, it is nevertheless necessary to recognize that never in the history of the superheterodyne receiver, has it reached its present state of development.

Superheterodyne receivers were employed during the World War and its development at that time may be said to have been due to the vital need for the most sensitive receiver with the greatest degree of selectivity. Such names as Fessenden, Ferrié, Armstrong and Houck shall live forever in the radio field, as pioneers in superheterodyne research and development. Of course these names are famous for other accomplishments, but our concern is with the heterodyne type of receiver.

Strange as it may seem, the earliest type of superheterodyne still resembles the present day receiver, for, despite numerous developments in design, the basic principles of operation have not changed. An examination of radio literature ten or fifteen years old shows the superheterodyne encumbered by numerous controls; whereas the modern day receiver of this type, when viewed by glancing at the controls, resembles the simplest receivers of yesteryear.

The fame of the superheterodyne has always rested upon its marvelous sensitivity and high order of selectivity. With greater design knowledge in the hands of today's engineers and extremely more powerful tubes, the present day receiver dims the early, and then marvelous receiver, into oblivion.

Perhaps you have wondered about the difference between the superheterodyne and the tuned radio frequency receiver. To express the difference between the t-r-f and the superhet receivers, we must take note of what happens to the original signal transmitted from the broadcasting station.

To comprehend properly what follows, it might be well to

explain just a few of the terms, which will be encountered in this introductory text. A broadcasting station, which transmits signals, when received with a radio receiver and made audible through a speaker appear as speech, music or of any audible character, is said to transmit a *carrier wave* which is *modulated*. The carrier wave is spoken of as having a certain wavelength or being of a certain frequency. Both the frequency and wavelength designations identify the station. Thus station WABC operating in New York City is said to operate upon a wavelength of 348.6 meters or 860 kc. This means that the carrier wave radiated by this station has a wavelength of 348.6 meters and a frequency of 860 kc. Station WEAF operates upon a carrier of 454.3 meters and a frequency of 660 kc.

Now, the song, music, speech or whatever is to be transmitted to the listener is converted from sound impulses to electrical impulses and is superimposed upon the carrier wave. This action is known as modulation of the carrier wave by the audio frequencies representing the sounds present in the song, music, speech, or whatever is being transmitted. Hence the signal sent out from the broadcasting station consists of the carrier wave, which has a numerical frequency rating, and the modulating or audio frequencies superimposed upon the carrier. Just as a safeguard against misconception, let it be understood that reference to modulating frequencies and audio frequencies, as we are discussing them, does not necessarily limit the function of modulation to audio frequencies only. However, as far as we are concerned in this discussion, the modulating frequencies encountered in broadcast signals and as considered in the operation of the t-r-f and superheterodyne receivers are always in the audio range.

The Difference Between the T-R-F Receiver and the Superheterodyne Receiver.

In this introductory text we shall present but one major point, namely the basic difference between the aforementioned two types of receivers with respect to the passage of the received signal through the two systems. Both receivers have

one thing in common, namely that the modulated carrier wave transmitted by the broadcasting station induces a voltage across the antenna system, which voltage is passed into the receiver proper.

In the t-r-f receiver, this signal voltage is fed to the first of the radio frequency amplifying stages. The exact number of radio frequency amplifying stages used in the receiver is not of great moment. As the modulated carrier passes from one radio frequency amplifying stage to the next, the only change in the signal, with respect to the original signal received from the broadcasting station, is one of amplitude of the voltage representing the signal. As the signal passes from one amplifying stage to the next, it is always strengthened. Each radio frequency amplifying tube passes on to the next an amplified version of the signal fed into that stage. The original carrier frequency and the modulation characteristics are retained during the passage of the signal through the radio frequency amplifier.

If the broadcast station carrier is a 1000-cycle modulated 890 kc. wave, and the radio frequency amplifier is functioning in normal fashion, the signal voltage, which is passed out of the last radio frequency stage into the detector or demodulator, is a greatly strengthened 1000-cycle modulated 890 kc. signal. In the detector or demodulator tube, the modulation component or the 1000-cycle signal is separated from the 890 kc. carrier and passed into the audio frequency amplifying system and then into the speaker.

Special types of radio frequency band pass filters, automatic volume control circuits, tuning indicators, etc. do not enter into the problem at this time. What has been said describes the passage of the received broadcast carrier through a t-r-f receiver. For the purpose of comparison with the superheterodyne receiver, we wish to stress one significant point related to the t-r-f receiver. This is the condition that the *demodulation action takes place upon the amplified version of the originally received broadcast carrier.* Whatever selectivity is achieved in the t-r-f receiver is dependent solely upon the design and efficiency factor of the respective tuned radio frequency stages and circuits.

You must of course realize that the 890 kc. signal referred to above is purely illustrative. The same is true of the modulation frequency. The carrier frequency can be any figure within the tuning range of the receiver, be it of the broadcast, short wave or combination all-wave type. As far as the modulation frequency is concerned, it can be a single audio frequency or a number of frequencies comprising a complex sound.

What has been said in connection with the t-r-f receiver is *not* true in the superheterodyne receiver. That is to say, with respect to the passage of the originally received signal. The life of the numerical rating of the originally received modulated broadcast carrier is extremely short in the superheterodyne receiver. Whereas the numerical rating of the broadcast carrier frequency remains the same during the passage of the signal through the radio frequency amplifier in the t-r-f receiver until the demodulator tube is reached, the operation of the superheterodyne is such that the above is not the case.

In the superheterodyne receiver, the received broadcast carrier may be passed through a number of pre-selector stages, just as in the t-r-f receiver, but after having passed through these stages, if they are used, it is *mixed* with another locally generated unmodulated carrier, so as to produce a third carrier, which bears the modulation characteristics of the originally received broadcast carrier, but differs from the received broadcast carrier in numerical frequency rating. In direct contrast to the t-r-f receiver, the demodulation action in the superheterodyne receiver *takes place upon the modulated carrier newly created in the receiver.* This new carrier produced in the superheterodyne receiver is the result of the *mixing* of the received broadcast carrier and the locally generated signal produced by means of an oscillator, which is an integral part of the receiver.

A numerical example of the superheterodyne action would be of the following order. The 1000-cycle modulated 890 kc. broadcast carrier is received. This may or may not be passed through the pre-selector stages of the superheterodyne, depending upon the use of pre-selector stages. If such stages are not used, then this modulated carrier is passed through the

input tuned circuit, into the *mixer, translator* or *1st detector* or *modulator*. All mean the same tube. (Some call the tube a demodulator, because of its action upon the signals fed into this tube.) The local oscillator, which is a part of the superheterodyne receiver, is tuned in conjunction with the input or pre-selector circuits and is tuned to a frequency slightly higher than the incoming broadcast carrier. Let us say that the oscillator tuning is 1150 kc. The modulated broadcast carrier of 890 kc. and the locally generated *beating* or *heterodyning* signal of 1150 kc. are mixed in the mixer tube. The result is the production of a new carrier signal of 260 kc., which bears the same modulation component and characteristics as the original 890 kc. broadcast carrier. This newly created 260 kc. modulated signal, then is amplified and finally passed into the demodulator or 2nd detector tube, where the modulation component, constituting the audio signal, is separated from the carrier and passed into the audio amplifier. As you can see, the superheterodyne attains certain accomplishments not to be found in the t-r-f receiver. These accomplishments also constitute the difference between the two types of receivers.

A pictorial representation of the passage of a signal through
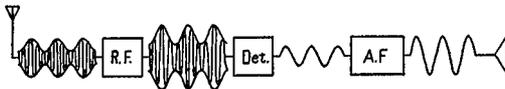
Fig. 1.   The passage of a signal through a tuned radio
frequency receiver

a t-r-f receiver and a superheterodyne is shown in figures 1 and 2.   Figure 1 illustrates the passage of the signal through the t-r-f receiver.   Figure 2 illustrates the passage of the signal through the superheterodyne.   In this illustration we assume the use of a pre-selector r-f amplifier.   Referring to figure 1, the wave illustrated between the antenna and the r-f amplifiers (R.F.) is the modulated broadcast carrier.   The fine lines within the envelope indicate the carrier and the wave envelope indicates the modulation component.   The box bearing the letters R.F. can be considered to be the complete r-f amplifying system.   Note that the waveform shown between

the r-f amplifiers and the detector or demodulator (Det. in box) is an enlarged reproduction of the signal fed into the r-f system. We have tried to show that the frequency of the modulated carrier remains unchanged by using the same number of cycles in both waveforms. The separation of the modulation component from the carrier is shown by the wavy line emanating from the detector and passing into the audio frequency amplifier (A.F.). Note that the waveshape of the a-f signal out of the detector is like the modulation component of the received carrier.

Now refer to figure 2. The received signal is like that in the case of the t-r-f receiver. The wave envelope is the same.
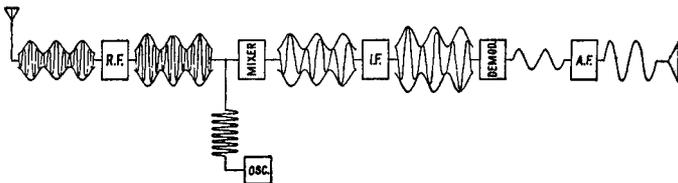
Fig. 2. The passage of a signal through a superheterodyne receiver

The number of cycles is the same for the carrier and the modulating signal. The amplified output of the pre-selector r-f system is an enlarged reproduction of the received signal. This signal voltage is fed into the mixer. In addition to the pre-selector stage output, the local signal oscillator (OSC) also feeds an unmodulated signal voltage into the mixer. The two signals combine and produce a third of a lower carrier frequency, but bearing the same modulation characteristics as the received signal. This is shown by the fact that the shape of the wave envelope of the signal out of the mixer is the same as that of the received modulated broadcast carrier. The fact that the newly created carrier has a lower frequency is shown by the reduced number of cycles within the wave envelope. This new modulated carrier, known as the i-f or intermediate frequency signal, is amplified in the i-f (I.F.) amplifier and passed into the demodulator (DEMOD.) or 2nd detector, where the modulating component is separated from

the i-f carrier and passed into the audio system. We hope that this pictorial illustration will aid comprehension of this elementary comparison of these two types of receivers.

THE ADVANTAGES OFFERED BY THE SUPERHETERO-DYNE RECEIVER.

At this stage, one would be tempted to ask why such a complicated maze of actions is to be preferred to the simpler process to be found in the t-r-f receiver. What if any, are the advantages offered by the superheterodyne receiver?

In order to appreciate properly the superiority of the super-heterodyne receiver and why this superior performance is available, we must recognize certain basic facts related to amplification with the vacuum tube, as associated with other vital factors pertaining to radio reception. Modern radio reception calls for maximum amplification, which means maximum sensitivity, accompanied by maximum selectivity, the highest order of quality of reproduction and a high degree of stability. The problem of amplification with the vacuum tube is closely tied to the frequency or frequencies at which the amplification is desired. Because of certain factors related to tube operation, experience has shown that the higher the frequency of a resonant circuit, which is a part of the ampli-fying system, the more difficult it is to secure a high amplifica-tion level and still retain stability of operation. Furthermore continuously variable tuned circuits, which cover a wide fre-quency band, present the problem of non-uniform amplifica-tion because of the changing characteristics of the circuit with changes in frequency, which means tuning. The early types of tuned radio frequency receivers covered a frequency band of from about 550 to 1500 kc. or slightly more than 2.7 to 1. Even with this comparatively narrow band, it was difficult to secure a high order of amplification with any semblance of stability. Even if the required amount of am-plification was secured, by using the required number of tubes and if the degree of stability was satisfactory, the difficulty of keeping four, five or six continuously tuned circuits in track, was quite appreciable.

With an increasing demand for a high order of selectivity, due to the increase in the number of broadcasting stations in operation, and the demand for high quality of reproduction, additional problems were added to receiver design, because selectivity and quality of reproduction are not generally compatible, at least not with the conventional types of tuned circuits. The necessity for band pass tuning was increasing daily, which type of r-f system requires even more tuned circuits and more accurate tracking than is required for the conventional system. All of these problems beset the tuned radio frequency receiver, but can be solved with the superheterodyne. Those facts, which enable the solution of these problems with the superheterodyne receiver, represent the points of superiority possessed by the superheterodyne.

In the first place, the sensitivity of the superheterodyne receiver is not dependent upon the intensity of the broadcast carrier. In other words, the output signal is not determined solely by the intensity of the received modulated broadcast carrier. A definite gain is attained during the process of frequency conversion within the superheterodyne receiver.

Second, it is possible to secure more uniform amplification over the tuning band with a superheterodyne receiver than with a t-r-f receiver, because the major portion of the amplification takes place at a fixed frequency, namely the intermediate frequency.

Third, since the major amount of amplification takes place at a fixed frequency and the numerical value of this frequency is much below the r-f and short wave bands, maximum amplification is possible without sacrificing stability.

Fourth, since the maximum amount of amplification takes place at a fixed frequency, it is possible to design this amplifying system so that selectivity and amplification are available with minimum impairment of tone quality, in other words minimum side band cutting.

Fifth, the process of frequency conversion creates a condition as if the channel separation between stations has been increased. This means greater selectivity. For the moment we can present this condition by saying that what would normally be a frequency separation of from 1 to 2 percent in a

tuned radio frequency receiver, becomes, because of the frequency conversion, about 3 to perhaps 6, 7 or 8 percent, in the superheterodyne.

All of these items become even more than normally pertinent when considering all-wave reception. For work of this type, the superheterodyne is far superior to the tuned radio frequency receiver. However, in due justice to the tuned radio frequency receiver, let it be said that it is always possible to secure equivalent selectivity, sensitivity and tone quality with a tuned radio frequency receiver, but such a tuned radio frequency receiver would require a greater number of tubes than is required for a superheterodyne to produce the same performance. Furthermore the tuned radio frequency receiver would be far more troublesome, because it would contain many more continuously tuned circuits. You may, after examining superheterodyne circuits come to the conclusion that they contain just as many tuned circuits as t-r-f receivers of equal number of tubes. You would be right, but the difference between the two, and this difference is important with respect to continued operation, is that the superheterodyne employs *fewer continuously variable circuits.*

It is possible that we have not included every point of advantage found in these two types of receivers. At any rate the tremendous increase in popularity of the superheterodyne receiver and the definite decline of the t-r-f receiver since 1930, is in itself definite and conclusive proof of its superiority.

CHAPTER 1

THE PRINCIPLES UNDERLYING THE OPERATION OF THE SUPER- HETERODYNE RECEIVER

I N VERY many respects the superheterodyne receiver is like the t-r-f receiver. As a matter of fact, the operation of the pre-selector or the r-f portion of a superheterodyne is like the r-f portion of the t-r-f receiver. The action of the demodulator or 2nd detector in the superhet is like the action of the detector in a t-r-f receiver. The audio and speaker systems can be classed as being identical in both cases, that is, with respect to basic principles of operation. For that matter, the i-f amplifier in the superheterodyne is nothing more than just another amplifier, tuned to a fixed frequency and governed by those rules which govern a tuned radio frequency amplifier, when adjusted to one particular setting.

From what has been said you no doubt have gathered that the part of the superheterodyne that differs from all other receivers is that related to the mixing process or the heterodyning action and its results. In this you are right. However, this discussion of superheterodynes is going to extend beyond the heterodyning action. It is going to include numerous other new ideas and modifications of old ideas as found in superheterodynes, because they are to be found only in superheterodynes due to the absence of t-r-f receivers of the type which would permit incorporation of these new developments.

If you make an effort to comprehend fully the heterodyne action, you have gained a very valuable point. You will be familiar with "why" and "how" the receiver works. However, more than knowledge of just the heterodyne action is required to enable proper servicing of these receivers. It is

our intention to present all of these facts. The reason we are making these statements is that we do not want you to lay this book aside after you have assimilated the information about the heterodyning principle and the production of the i-f signal. With just this information in your possession, you are not yet qualified to analyse many of the problems associated with defective superheterodyne receiver operation.

In a measure, the description offered in the Introduction, explaining how the superheterodyne receiver differs from the t-r-f receiver, is an explanation of the principles underlying the operation of this type of receiver. That description is extremely meagre, so that there is room for extensive expansion. Such expansion of this subject is the purpose of this chapter.

ACOUSTICAL BEATS.

The operation of the superheterodyne or heterodyne receiver is dependent upon the mixing of two signals so as to produce a third, generally known as a *beat* signal or *beat note*. In fact oscillator types of testing equipment, which depend upon this phenomenon for the production of the final output signal, are known as *beat note oscillators*.

This phenomenon of *beats*, produced by the mixing of two electrical voltages or signals, has its equivalent in sound or acoustics. We feel that a few words about acoustical beat notes may do some good in expediting comprehension of the electrical beats, because experimental verification is so much more easily possible at substantially no cost. When two audible sounds of slightly different frequency are heard at the same time and their relative intensities do not differ very greatly, an audible beat note will be heard. If the two original sounds are sustained, a new sound of varying intensity will be heard. This beat is heard because at a certain instant the phase relation between the two original sounds is such, that the two sounds aid each other, producing a more intense or stronger sound. At another instant the phase relation of the two sound waves is such that they tend to buck or neutralize each other, creating a decrease in the intensity or strength of the sound.

When two such sounds are sustained over a period of time, there will be an opportunity for the two waves to strengthen and neutralize each other. In between the two peaks representative of the moments when the two sound waves are exactly in phase and the moment when the two sound waves are exactly out of phase, will be periods when the two sound waves will partially aid and partially neutralize. The result is the production of what appears to be a wavering sound rising and falling in intensity. This wavering sound is the beat between the two original sounds. The rate at which this beat will rise to maximum intensity and fall to minimum intensity depends upon the relative frequencies of the two original sound waves. Thus, if you strike middle C upon the piano and keep the loud pedal pressed down so that the note will be sustained, and you also strike the adjacent white key, you will hear a beat between the two original notes. This beat will persist until such time as the intensity of the two original notes falls below a suitable level or until the intensity of one of the notes falls below a required level. The reason for mentioning the intensity level of the two original sounds which are so mixed, is that if one falls below a certain level, the beat note will be too weak to be heard by the ear.

If, for example, a 600 cycle sound is produced with a tuning fork and another tuning fork rated at 625 cycles is sounded at the same time, you will note a beat equal in numerical value per second to the difference between the two frequency ratings of the two tuning forks. In other words you will hear a beat sound which has a frequency of 625 — 600 = 25 cycles per second. It might be an interesting experiment to listen to the beat note produced by two automobile motors running at slightly different speeds. The beat is very easily discernible.

THE ELECTRICAL BEAT OR HETERODYNE PHENOMENON.

The production of what is known as a *beat* or *beat note* in an electrical circuit is the result of the presence in the same circuit of two voltages or currents of different frequency.

In as much as we are working with vacuum tubes when speaking about radio receivers, it might be best if we established as a basis for future discussion, the use of voltages when referring to the various items associated with different phenomenon, which are mentioned as we progress in this text. We shall omit reference to electrical current, since voltage rather than current is the significant issue wherever tubes are employed for amplification, detection and as an oscillation generator. It might also be well at this time to state that since it is customary in radio receiver practice to refer to signal voltages, we feel at liberty to use either of these words to denote the same subject when the nature of the subject permits. The desire to do this is founded on the premise that one or the other word may be better suited in conjunction with whatever may precede or follow at the time. We must try to remember that the sound that issues from a loud speaker, was, during its passage through the receiver or amplifier, in an electrical state. Prior to the conversion of the electrical equivalent of the sound, into sound, it was, while passing through the receiver, an alternating voltage.

To illustrate the production of electrical beats in an electrical circuit, let us discuss the units shown as figure 3. Here
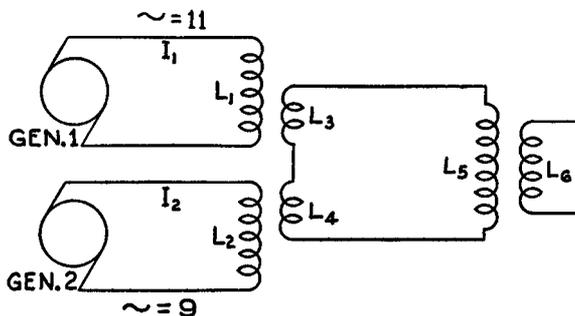
Fig. 3. Circuits in which two voltages or currents of different frequencies are combined

we have two a-c generators, namely "GEN 1" and "GEN 2." As indicated, generator 1 is producing an 11 cycle voltage. Generator 2 is producing a voltage of 9 cycles. The exact

amplitudes of these voltages is not important at the moment. We shall assume that they are sufficient for our needs and that they are of like magnitude. The electrical circuit illustrated contains two sets of windings. One set consists of four coils, L-1, L-2, L-3 and L-4. The other set consists of L-5 and L-6. If desired, you can consider these two sets of windings to be two transformers consisting of the number of coils and arranged in the manner shown.

By virtue of the positions of L-1 and L-2, an 11 cycle voltage is developed across L-1 and a 9 cycle voltage is developed across L-2. L-1 and L-2, being coupled to L-3 and L-4, the 11 and the 9 cycle voltages will be developed across L-3 and L-4 respectively. The L-5, L-6 transformer is included so that the voltage in the L-3, L-4, L-5 circuit can be transferred to a neighboring circuit.

We might at this time state that the choice of 11 and 9 cycle voltages is purely illustrative. These frequencies could be within the broadcast or short wave band just as readily and whatever description concerning the action within the circuit is quoted in connection with the 11 and 9 cycle voltages, would be equally true at the higher frequencies.

Suppose that we illustrate the presence of the 11 and 9 cycle voltages across the two windings L-3 and L-4 respectively. This is done in figure 4. Waveform A is that of the 11 cycle voltage and waveform B is that of the 9 cycle voltage. As is evident both voltages are of the same amplitude or value. Let us now see what happens in the L-3, L-4 circuit when these two voltages of different frequency are mixed. To determine the resultant voltage across the outside terminals of the series combination of windings L-3 and L-4, we must combine the two individual voltages. When combining two such voltages, it is necessary to consider not only amplitude, but also the phase relation between the two voltages. By phase relation we mean the polarity with respect to each other. It is assumed that the half cycle above the zero line is positive and the half cycle below the zero line is negative.

If you examine waveforms A and B in figure 4, you will

note that both start from zero (center line) and move in the
same direction. The time shown in both instances is 1 second,
as evidenced by the fact that 11 complete cycles are shown
for A and 9 complete cycles are shown for B. Starting from
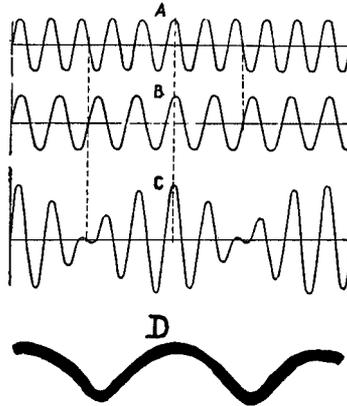
Fig. 4. Curve A, 11 cycle wave; Curve B, 9 cycle wave; Curve C, com-
posite wave; Curve D, waveform of complete cycle of amplitude variation,
which becomes beat note when Curve C, is acted upon by mixer tube

zero, you will note that while the two voltages are in phase at
the start, they do not remain in phase. You will note that
the negative alternation or half cycle occurs during the
time that the first half of the second cycle of the 9 cycle
wave is positive. Further that the second half of the second
cycle of the 9 cycle wave occurs during the time that the 11
cycle wave is passing through its positive half cycle. When
the alternations of these two voltages are of opposite polarity,
they are in effect acting against each other. In other words,
the two voltages are moving in opposite directions with re-
spect to the zero line. At an instant before the moment
designated by the first of the vertical dash lines, the two
voltages have reached their peaks in opposite directions. Mov-
ing in opposite directions and having different polarities, they
tend to neutralize each other. An instant later, as shown by
the first vertical dash line, both voltages pass through the zero
point.

Phase Relation.

As both voltage waves progress with respect to time, they aid and buck or neutralize each other. In other words, they are momentarily in exact phase and momentarily exactly out of phase. In between these peaks of aiding and bucking, we have various degrees of phase relationship and various degrees of aiding and bucking, which is less than the maximum. As is evident, the two voltages may be in exact phase when passing through their zero points and when passing through their peak points. The fact that the phase relation between these two voltages is a variable is due to the difference in frequency.

Since each of these frequencies is definitely fixed and since we assume that the constants of the circuits involved are definitely fixed and constant, we have a recurrent phenomenon of aiding and bucking. This phenomenon occurs at the same rate and with constancy just so long as the two original voltages are present in the circuit. To determine the resultant voltage in the circuit, that is, the combined voltage, we must determine the algebraic sum of the two voltages at each instant. In other words, we add or subtract the instantaneous values, depending upon polarity of the individual voltages at that instant. The waveform of the combined voltage appears as curve C in figure 4.

As is evident, the shape of this curve is no longer the same as that for either A or B or both. You will, however, note two significant features. The first is that the amplitude is not constant. The second is that the variation in amplitude seems to occur at a definite rate. As a matter of fact, if curves A, B and C were extended so as to show a longer duration of time, the fact that the amplitude variations in curve C do occur at a definite rate, would be immediately evident. By amplitude variations we mean the change in the height of the peaks in curve C, with respect to the zero line. Waveforms A and B do not show any variations in the amplitude of their respective peaks.

If you now examine waveform C and compare it with waveforms A and B, you will note that if, at any one instant, A or B voltage is at zero and the other has a finite positive

value, the resultant voltage is shown on the positive side of the zero line and has an amplitude equal to the positive value of the mixed voltage. If both A and B are of positive polarity, you will note that the resultant voltage is also positive and has an amplitude equal to the sum of the two original voltages at that instant. If A or B voltage is at zero and the other voltage has a finite negative value, the resultant voltage is shown on the negative side of the zero line and has an amplitude equal to the instantaneous negative value of the mixed voltage. If at any one instant, A is positive and B is negative, the resultant voltage has the polarity of the greater of the two voltages, and an amplitude equal to the difference in instantaneous values of the two voltages which are mixed. In other words, if A is positive and its instantaneous value is 4 units and B voltage is negative at the same instant and has a value of 3 units, the resultant voltage is shown on the positive side of the zero line and has a value of 4 — 3 or 1 unit. If both A and B are negative at the same instant, the resultant voltage is also negative and has a value equal to the sum of A and B peak voltages at that instant. These facts explain the reason for the variation in amplitude of the resultant or combined or mixed voltage.

As to the rate at which these definite amplitude variations occur, we must again refer to the phase relation between the two original voltages at any one instant. Since the two mixed voltages have fixed frequencies, the phase relation variation is definitely fixed. Because of this condition a complete cycle of amplitude variations occurs in a definite period of time. According to waveform C, for the two original frequencies, namely 11 and 9 cycles, the rate of a *complete cycle of amplitude variation* is 2 times per second or 2 cycles per second. As a matter of fact, when two such signals or voltages are mixed, the resultant voltage passes through a complete cycle of amplitude variation at a rate equal to the numerical difference between the two mixed frequencies. This rate of cyclic amplitude variation is the equivalent of the electrical *beat note*. Hence we can say that the beat signal, beat signal voltage or beat frequency is equal to the difference be-

tween the frequencies of the two voltages or signals which
have been mixed.

If curve A represented 1,000,000 cycles and curve B repre-
sented 1,010,000 cycles, the resultant voltage would show
complete cycles of amplitude variation at a rate equal to
1,010,000 — 1,000,000 or 10,000 cycles per second. In other
words a beat note or beat signal of 10,000 cycles would be
available in the mixer circuit. If waveform A was that for a
25,600,000 cycle signal and waveform B was that for a
25,775,000 cycle signal voltage, the resultant voltage would
contain a beat note equal to 25,775,000 — 25,600,000 or
175,000 cycles or 175 kc. We can further say that the
process of mixing two signal voltages of different frequency
results in the production of a *beat frequency*, which, when
the two original frequencies are of such numerical value that
they are within the broadcast or short wave range, of a
receiver, is called the *intermediate frequency*. It should also
be understood that the beat note is produced only after the
mixer tube acts upon the composite signal consisting of the
two different frequency signals. In other words this com-
posite signal must be demodulated, to produce the beat note.

Now, if coil L-6 were connected to demodulator device
which would act upon the composite wave curve C in figure 4,
the two cycle beat note shown as curve D, in figure 4, would
be produced. In actual practice, the mixer tube functions
as the demodulator of the composite wave and the beat note
voltage is developed across the tuned circuit in the plate
system of the mixer tube. This tuned circuit is the primary
of the first intermediate frequency transformer. Thus by
mixing an 11 and a 9 cycle voltage in the L-3, L-4, and L-5
circuit, we secure a voltage at a new frequency across the
tuned circuit coupled to the output of the mixer circuit. If,
as we stated, we mixed a 1,010,000 cycle voltage and a
1,000,000 cycle voltage, we would have across that tuned
circuit a voltage of 10,000 cycles.

Just for the sake of cleaning up certain points which may
be in doubt in your mind, the composite waveform C contains
both the 11 and the 9 cycle signals, in as much as a complex
wave can be analysed to show its component frequencies. All
complex waves consist of a number of sine waves. This
means that if L-6 were resonated at 11 cycles, a voltage at this
frequency would be available across the tuned circuit. Also,

if L-6 were resonated to 9 cycles, a voltage at that frequency would be available across the tuned circuit. However, since the purpose of the mixing process is to produce the beat, we feed the composite wave to the mixer tube, and take out of the mixer tube, a voltage at the beat frequency.

Whether or not an electrical beat note is audible depends upon its frequency. Naturally a signal in electrical form must be converted into sound before it is audible. If the beat note is within the audible range, say between 16 and perhaps 14,000 cycles, it must be passed into a reproducer, which will be capable of converting the electrical impulses within this frequency range, into sound. If for some reason, by virtue of a defect in a receiver, a beat note is produced, which has a frequency within the audio range, and this signal finds its way into the reproducer, that beat will be made audible, and if desired, will represent an interfering signal.

If the beat note produced in a certain part of the receiver is inaudible, but must be made audible, it must be acted upon in a definite manner, so as to be made audible. Much more concerning this subject will follow later in this text.

The process of mixing two electrical signal voltages is oftentimes referred to as the *heterodyning* of one signal with another, or the *beating* of one signal with another or against another. All of these terms designate one and the same thing, irrespective of where the beating or heterodyning takes place; whether it is deliberate on the part of the operator, or if it takes place beyond the control of the operator and the operator is confronted with whatever undesired conditions are created as a result thereof.

Beat Notes When One Frequency Is Modulated.

The use of sine waves in figure 4 to illustrate the production of a beat note is quite satisfactory for that purpose. However, it is not a complete picture of what takes place in a superheterodyne receiver. In actual practice, one of the signal voltages is modulated. This is the signal received from the broadcasting station. Only the locally generated signal in the superheterodyne is an unmodulated wave. In actual practice, as for example in a superheterodyne receiver, waveform B in figure 4 would, if it were modulated, constitute the signal from the broadcasting station and waveform A, would
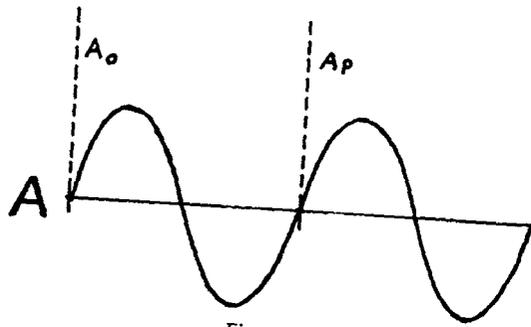
Fig. 5-A
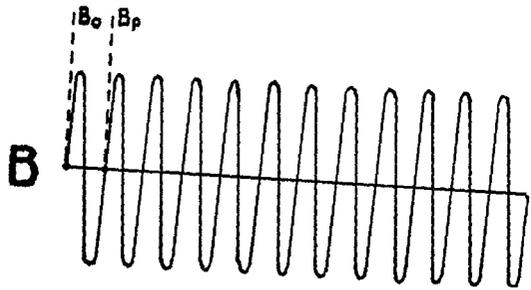
Fig. 5-B
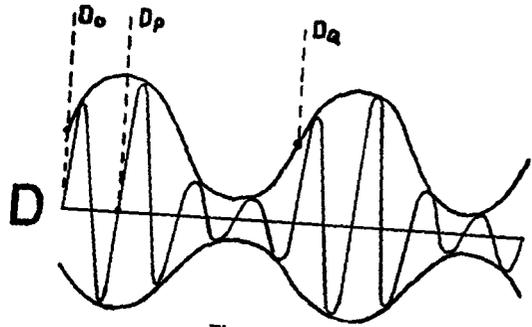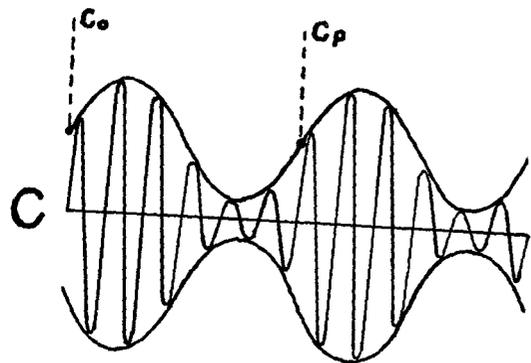
Fig. 5-C-D

Fig. 5. Production of beat note when one wave is modulated

be the locally generated signal. The process of mixing in the receiver is very much like the description of the action accompanying figure 4, for the fact that one of the signal voltages is modulated, introduces a new subject.

In the superheterodyne receiver, the mixing of the received modulated broadcast carrier and the locally generated heterodyning signal, or beating signal, takes place in a vacuum tube circuit, known as the *mixer, modulator, 1st detector* or *translator* tube. (In a way, the mixer tube is also a demodulator tube, because it demodulates the composite wave representing the signal and heterodyning frequencies. This appears to conflict with the statement that the tube is a modulator, but the term, modulator is still commonly used.) The fact that the receiver carrier is modulated, results in the presence of a modulation component in the beat note signal. To illustrate the exact shape and structure of the resultant modulated beat signal or intermediate frequency signal, is beyond the scope of this book. What we shall do is to offer an elementary concept of the appearance of this modulated i-f signal so as to expedite comprehension. Viewed strictly from the technical angle, the waveshape to be shown is not correct, because the real waveform is far more complex than the illustration, but as an example of the presence of the modulation component in the beat note, it will suffice.

Consider waveform A in figure 5. This can be assumed to represent two cycles of a 1000 cycle tone produced by a 1000 cycle tuning fork. It is supposed to be a pure sine wave. The distance between Ao and Ap is equal to one cycle or one-one thousandth part of a second. This audio tone shall be considered as being the modulating frequency superimposed upon the broadcast carrier at the broadcasting station. Waveform B in figure 5 is the 1,000,000 cycle (1000 kc.) carrier produced by the oscillators at the broadcasting station. The distance between Bo and Bp represents one cycle of this carrier or one-one millionth part of a second. When this 1,000,000 cycle carrier is modulated by the 1000 cycle tone, it appears as the modulated carrier with the wave envelope shown as C in figure 5. The exact percentage of modulation is not important at this time. Let us also call attention to the fact that the representation of the modulated carrier with respect

to amplitude, is not one which would be technically correct. We recognize this fact, but have shown it as it is because it facilitates understanding the action taking place.

The wave envelope of the modulated carrier resembles the shape of the original modulating tone shown as curve A. The distance between Co and Cp expressed in time is equal to one audio cycle or one-one thousandth of a second. The cycles shown within the envelope represent the number of cycles of the 1,000,000 cycle carrier, which would occur during one audio cycle. Normally this would be about 1000 r-f cycles during the duration of one audio cycle. If we mix the modulated 1,000,000 cycle signal with another unmodulated 1,240,000 cycle signal, we would, as stated in connection with figure 4, create a resultant signal voltage in which the peaks would occur at the rate of 240,000 cycles per second, or at a rate equal to the numerical difference between the frequency of the modulated carrier wave, which is 1,000,000 cycles, and the locally generated wave of 1,240,000 cycles. Now, mind you, the peaks of the resultant voltage occur at the beat frequency, or a complete cycle of peak variations would occur at the rate of 240,000 times per second, but the *amplitude of the peaks would vary in accordance with the modulation component originally contained in the received modulated carrier.* You must distinguish between the rate at which the peaks occur during 1000 audio cycles, which, when expressed in time, based upon the original modulating frequency, is one second and the manner in which the amplitude of these peaks varies during that same period. During this second of time, we would find 240,000 cycles for the beat note and the variation in amplitude of the peaks, which constitute the 240,000 cycle signal voltage, would vary in such manner that during the same period of time, the beat signal would be modulated with 1000 audio cycles. A true representation of this shape of this newly created modulated carrier is beyond the scope of this book. A simple version is shown as waveform D in figure 5.

Observe that the wave envelope of the modulated beat note is like that of the original modulated broadcast carrier. The distance Do to Dq represents one audio cycle, or one-one

thousandth part of a second. The distance Do to Dp represents one i-f or beat note cycle, in this case one-two hundred forty thousandth part of a second. During the time period Dc to Dq, 240 cycles of the beat note voltage would take place. During the duration of a complete 1000 cycle note, or one second, 240,000 cycles would take place. The fact that the beat note signal shown as curve D in figure 5 is not uniform, is due to the action within the mixer tube. Additional information relative to the function of the mixer or 1st detector tube is given under that caption, elsewhere in this text.

The choice of 1000 cycles as the modulating frequency, 1,000,000 cycles as the broadcast carrier frequency and 240,-000 cycles as the beat or i-f signal, is purely illustrative. Under normal conditions, the modulating frequencies can be of any one value or many values which are within the audio frequency band and which are representative of the audible sounds created within the broadcasting studio and which are to be conveyed to the listening public. As far as the broadcast carrier frequency is concerned, this can be of any value which has been assigned to a broadcasting station to which you wish to listen. As far as the locally generated signal is concerned, this would always have a frequency rating determined by the beat or intermediate frequency signal desired.

If we break down curve D in figure 5, we find the i-f carrier of 240,000 cycles or 240 kc. and the modulation component, originally contained in the modulated 1,000,000 cycle carrier. Therefore we have passed the modulation component through the process of carrier frequency conversion. Always bear in mind, operating conditions being normal, that no change has been effected in the modulation component frequency or frequencies, as the case may be. The same characteristics, the same relationship, the same everything, has been retained. We have converted a modulated broadcast carrier of 1000 kc. to a carrier of 240 kc., with the original modulation components.

The separation of the modulating component, which represents the audio signal, from the i-f carrier is the function of the demodulator or 2nd detector tube in the superheterodyne

receiver. The action of this tube in the superheterodyne is like that of the detector in the conventional t-r-f receiver.

THE INTERMEDIATE FREQUENCY SIGNAL.

Although we have made mention of the fact that the beat note or heterodyne signal produced by beating one signal against the other or by heterodyning one signal with another, is known as the intermediate frequency (i-f) signal, we have included this small paragraph to associate definitely the various terms used to denote the same signal. Irrespective of the values of the broadcast carrier frequency and the heterodyning or beating frequency, the resultant difference signal, is usually referred to as the i-f signal. This is true if its numerical value, that is, frequency, is any value from 25 kc. to 1000 kc. or higher. We wish to stress that reference to an intermediate frequency, as far as superheterodyne receivers is concerned, does not necessarily limit the numerical value to within any one particular band. This fact will become evident when we consider different types of superheterodynes.

By this time you probably realize one significant feature of the superheterodyne receiver. Whereas in the t-r-f receiver, the amplifier tuning is adjusted to accommodate the signal frequency, so as to secure the proper amount of amplification, in the superheterodyne receiver, the signal frequency is adjusted to accommodate the tuning of the amplifier. It is also possible that you may be somewhat confused by the reference that the i-f amplifier system is fixed tuned, whereas you know from experience that the i-f amplifier in a receiver is equipped with variable trimmer condensers. Nevertheless, the i-f amplifier, equipped with variable trimmers is still fixed tuned, because it operates only upon one frequency. Of course, the design of the amplifier may be such that when it is resonated to say 175 kc., that it also covers a band width of 5 kilocycles each side of the resonant peak, in order not to suppress the modulation side bands. The function of the trimmers is to allow proper reson nce at the fixed frequency, rather than continuous tuning as in the case of the t-r-f amplifier.

It might be well to say a few more words about the pro-

duction of the i-f signal before entering upon the discussion of another subject. Since we understand that the i-f signal is the beat note produced by mixing the received carrier with a locally generated signal and that the i-f signal is the numerical difference between the two frequencies, we can speak about related subjects. For the purpose of identification, let it be said that the locally generated signal, produced by the oscillator in the receiver is the *heterodyning* or *beating* signal. Since we are tuning in a station whose frequency is already established, and we must produce a beat or i-f signal whose frequency is established, we have a choice of two beating or heterodyning frequencies. One of these is *higher* in numerical value by the figure representing the i-f signal and the other is *lower* by the same amount. Thus if we are heterodyning a 1200 kc. signal so as to produce the required 456 kc. intermediate, we have a choice of 1200 — 456 or 744 kc. as the frequency of the beating signal or 1200 + 456 kc. or 1656 kc. as the frequency of the beating signal.

There is an optimum relation between the broadcast carrier frequency and the oscillator beating frequency, which shall be discussed at greater length later. In the meantime let it be understood that for reasons relating to superior design, it is customary to arrange the oscillator tuning, so that the beating frequency is *higher* than the received broadcast carrier frequency by the value of the intermediate signal or beat signal. This condition is to be found to exist in substantially every superheterodyne receiver, irrespective of the waveband covered by the receiver. This means broadcast, short wave and combination all-wave receivers.

Zero Beat Phenomenon.

A phenomenon associated with beat or heterodyning circuits, is that known as *zero beat*. A beat note is produced when two unlike frequencies are mixed. However, if two frequencies of like value are mixed, one of which is modulated and the other is not, a condition of zero beat is produced, which means that if the two carrier frequencies are *exactly* alike, there will be no beat note and the presence of the un-

modulated carrier will not interfere with the modulated carrier. Perhaps it will be well to qualify this statement, although it does not belong to the discussion in this part of the book. If such a modulated carrier and an unmodulated carrier are mixed in a vacuum tube circuit and the voltage values of the two carriers are beyond the limits prescribed by the operating potentials of the tube, the presence of the unmodulated carrier will create overload conditions, which will interfere with the normal passage of the unmodulated carrier. However, from the angle of beat notes only, such mixing will create no beat.

The zero beat is of importance in connection with calibration of testing oscillators, and as will be shown later, with the identification of checking frequencies during service operation.

Double Heterodyning.

From what has been said about the process of mixing signal voltages of different frequencies, it is not a far-fetched idea to visualize double mixing. In other words, it is possible to mix one locally generated signal with the incoming broadcast carrier so as to produce an output modulated i-f signal and then to mix again another locally generated signal with the i-f signal, so as to produce a second i-f signal. As we stated earlier in this text, the production of the modulated beat signal, is the same as if a new carrier were produced in the receiver and the modulation component present in the received broadcast carrier were superimposed upon this newly created carrier. As such, we can consider the first i-f signal to be a modulated carrier and to mix this signal with another local unmodulated carrier, so as to create another or second i-f signal, which too would bear the modulation characteristics of the first i-f signal and by virtue of that, would bear the modulation characteristics of the received broadcast carrier.

This process of double heterodyning is to be found in practice and will be described during the discussion of the different types of superheterodynes available upon the commercial market.

General Summary of the Principles Underlying Superheterodyne Operation.

What has been said about the production of a beat signal, by mixing two signal voltages of different frequency, just about covers the fundamental principle underlying the operation of the superheterodyne receiver. However, as has been stated earlier, do not think that this is all. There is much more to the operation of the receiver, as far as servicing is concerned. The layman who would want to know how the superheterodyne passes a signal would not need to know anything more than what has been said so far. As an individual interested in the servicing angle, there is much more you must know in order that you be enabled to distinguish defects by recognizing symptoms. You must understand the basic phenomena which control the production of the symptom.

The brief description of the mixing process to produce the beat signal does not conclude the subject. Many statements made in this chapter are general and have ramifications of importance. For example in connection with mixing, the important point to remember is the conversion of the frequencies. Do not be led to believe that such conversion can take place only through the use of a separate tube to supply the local oscillations. There are numerous arrangements suitable for this purpose. You will see later in this text, that the mixing process does not always operate upon the fundamental frequencies. You will also note that while we have placed much stress upon a modulated broadcast carrier as the signal wave received, such is not always the case. In certain instances, as for example in code receivers, the waves are not modulated. You will also note that there are ways and means of converting t-r-f receivers into superheterodyne systems by the addition of external heterodyning apparatus.

In fact all that we desired to accomplish in this first chapter, was to give you a general description of the heterodyne principle.

THE GENERATION OF AND THE RELATION BETWEEN HARMONICS

T HE subject of *harmonics* is of definite interest in connection with the superheterodyne receiver. First, because it played a very important role in the mixer circuit of one type of superheterodyne placed upon the market several years ago and second, because it is of extreme interest with respect to service problems and apparent defects in receivers.

It is too soon in this volume to discuss service problems. However, in order that we may be able to make free reference to harmonics as we progress in this volume, we feel it necessary to introduce the subject. Once you enter upon the servicing phase, you will realize the vast importance of knowing this subject thoroughly. This is one of the items referred to in the preceding paragraph, when we stated that there is much more to the study of the superheterodyne receiver than just the facts related to the mixing. The more complete your knowledge of harmonic generation and the relation between harmonics, the more easily will you be able to service superheterodynes and the more completely will you be able to employ your oscillator, a very vital piece of apparatus when working upon superheterodyne receivers. As a matter of fact, you will be able to work under the most adverse conditions created by emergency requirements.

When we speak of amplification and detection with vacuum tubes, we usually take for granted that the output from the tube is an amplified reproduction of the input signal, recognizing of course, the detector action in a detector tube as

against the strictly amplifier action in the amplifier tube. However, the conditions stated above are really true only under certain operating states. Namely, when the tube operating potentials are such that the output of the tube contains only a negligible order of *harmonics*. The operating characteristics of a vacuum tube used for detection and amplification are such, that the output of the tube contains frequencies which were not present in the input signal. In other words, the output contains harmonics. These harmonics are generated within the tube during the process of rectification and amplification. By a harmonic is meant *a component of a periodic quantity which is an integral multiple of the fundamental frequency.* If we break down this definition, it would appear somewhat on the following order: The *periodic quantity* designates any a-c voltage or current of any frequency, or a composite voltage or current consisting of a number of sine voltages or currents of different frequency. By *component* is meant a part of the whole, which in this case would be a wave of voltage or current, which is a part of the composite wave or current in the circuit. Expressed in relation to frequency, a component of a complex wave representative of a number of different frequencies would be one wave of one frequency. If this wave of a certain frequency was not present as a part of the voltage or current supplied to the circuit, and had a numerical frequency value, which was an integral multiple of the fundamental frequency of the current or voltage supplied to the circuit, or was an integral multiple of one of the fundamental frequencies of the voltages or currents fed into the circuit, then that wave would be a *harmonic* of the input signal or a *harmonic* of one of the input signals.

As a general rule, we have harmonics in all vacuum tube circuits. In amplification systems, we strive to keep the intensity of the harmonics at such a level, that they are negligible with respect to what effect they have upon the signal, when it is made audible. In detector systems, we usually experience harmonics. However, since the r-f or i-f carrier frequencies are bypassed, the harmonics are of negligible effect. As far as the a-f component is concerned, we try

to keep these harmonics at an absolute minimum. In power rectifier circuits, such as power packs, we experience a great number of harmonics of the line frequency. However, these harmonics are filtered to the best of our ability, since we desire a direct current output without any hum. In oscillator tubes, we experience a great number of harmonics which are not filtered, that is in the superheterodyne receiver, and they prove troublesome at times. The same is true of the harmonics of the i-f signal to be found in the demodulator circuit. This subject will receive much more space, later in this volume.

The statement was made earlier in this text that voltages and currents present in receivers can be converted into signals, some greatly desired and others entirely unwanted. Thus, if we have harmonic currents and voltages in receivers, these voltages and currents, when converted into signals, become harmonic signals. Harmonic signals are exact reproductions of the fundamental or original signals. Thus if we introduce a modulated 700 kc. signal into a certain r-f amplifying circuit and the circuit constants are such that harmonics will be produced, we would find in that circuit harmonic signals of such frequency that they would be integral multiples of the 700 kc. carrier, and would retain the modulation characteristics of the fundamental signal.

Difference Between Harmonics and Beats.

You must try to distinguish between the production of a signal which is a *harmonic* and the production of a signal which is a *beat*. In order to produce a harmonic of a fundamental in a tube circuit, we do not require the presence of more than *one* signal, namely the fundamental. However, in order to produce a beat signal, we require that *two* signals of different frequencies be present in the same system.

The exact intensity of harmonic signals is a variable, depending upon the nature of the circuit, operating conditions, etc. As stated, it is possible to keep these harmonics at very low levels in certain circuits, whereas in others, they are present by virtue of the function of the tube. Thus in amplifiers, we can keep harmonics at very low levels, whereas in rectifiers, detectors and oscillator systems, the output circuits are rich

in harmonics, because of the manner in which the tubes are used to accomplish their normal functions.

Unless special arrangements are made for the purpose of strengthening the harmonic voltages in certain circuits or parts of circuits, the intensity of the harmonics is always less than that of the fundamental signal. As stated in the definition of a harmonic, harmonic frequencies of a fundamental signal would be 2, 3, 4, 5, 6, 7, 8, 9, . . . etc. times the frequency of the fundamental signal. Fractional harmonics are not produced in vacuum tube circuits. However, the fact that we list harmonics up to the ninth, does not signify that every circuit which contains harmonics would have them up to the ninth. Neither does it mean that such circuit would not contain harmonics in excess of the ninth. It is possible that the circuit structure would be such that all harmonics higher than the third would have such a low value as to be beyond recognition, unless very special sensitive apparatus was used. Then again, it is possible that the fortieth harmonic of the fundamental would be easily established by simple means.

Harmonics may be produced for all fundamental frequencies, irrespective of the frequency of the fundamental. Whether or not the presence of these harmonics will be established depends upon the nature of the equipment used. Thus, it is possible to find in an audio circuit harmonics of the audio signals, which will be identified in one manner, and to have harmonics of r-f signals, which must be identified in another manner. The significant fact to bear in mind is that, weak or strong, harmonic voltages present in tube circuits are signals.

The expression that a signal or a voltage or a current is the 2nd harmonic of a fundamental, means that the frequency of that signal, voltage or current has a numerical value equal to twice that of the fundamental. Thus the 2nd harmonic of 456 kc. is 912 kc., of 1000 kc. is 2000 kc., of 2340 kc. is 4680 kc., of 11,500 kc. is 23,000 kc. etc. If an oscillator is producing a fundamental frequency of 1075 kc., then its 2nd harmonic would have a value equal to 1075 $\times$ 2 or 2150 kc. If an i-f signal of 175 kc. is fed into a demodulator

tube, the 2nd harmonic in the plate circuit of that demodulator tube would have a value equal to 175 × 2 or 350 kc. The progression of the order of harmonics is simply a multiplication of the fundamental frequency by the figure which represents the integral multiple. Thus the 3rd harmonic of 175 kc. is 175 × 3 or 525 kc. The 4th harmonic of the same signal frequency would be 175 × 4 or 700 kc., etc. If an oscillator produces a fundamental of 130 kc., its 2nd, 3rd, 4th, 5th, 6th, 7th and 8th harmonics would be 260 kc., 390 kc., 520 kc., 650 kc., 780 kc., 910 kc. and 1040 kc. respectively.

There is no first harmonic. Usually, the fundamental is considered as the first harmonic, since multiplying the fundamental frequency by 1, does not alter the figure.

As to the relative intensities of harmonics, certain circuits, that is, circuits containing certain component parts, may show stronger even than odd harmonics and in other circuits the reverse may be true. Then again certain units in circuits, may cause greater strength on a higher harmonic than upon a lower harmonic, Usually, the higher the harmonic, that is, the higher the multiple, the weaker the harmonic.

For rapid reference, we have tabulated a table of harmonics over a fundamental band of from 90 to 10,000 kc. This table includes the 2nd, 3rd, 4th, and 5th harmonics. Higher harmonics can be tabulated by simply multiplying the fundamental frequency by the order of the harmonic desired.

Fundamental	2nd Harmonic	3rd Harmonic	4th Harmonic	5th Harmonic
90 kc.	180 kc.	270 kc.	360 kc.	450 kc.
95	190	285	380	475
100	200	300	400	500
105	210	315	420	525
110	220	330	440	550
115	230	345	460	575
120	240	360	480	600
125	250	375	500	625
130	260	390	520	650
135	270	405	540	675
140	280	420	560	700
145	290	435	580	725

Fundamental	2nd Harmonic	3rd Harmonic	4th Harmonic	5th Harmonic
150	300	450	600	750
155	310	465	620	775
160	320	480	640	800
165	330	495	660	825
170	340	510	680	850
175	350	525	700	875
180	360	540	720	900
185	370	555	740	925
190	380	570	760	950
195	390	585	780	975
200	400	600	800	1000
210	420	630	840	1050
220	440	660	880	1100
230	460	690	920	1150
240	480	720	960	1200
250	500	750	1000	1250
260	520	780	1040	1300
270	540	810	1080	1350
280	560	840	1120	1400
290	580	870	1160	1450
300	600	900	1200	1500
320	640	960	1280	1600
350	700	1050	1400	1750
400	800	1200	1600	2000
450	900	1350	1800	2250
500	1000	1500	2000	2500
550	1100	1650	2200	2750
600	1200	1800	2400	3000
650	1300	1950	2600	3250
700	1400	2100	2800	3500
750	1500	2250	3000	3750
800	1600	2400	3200	4000
850	1700	2550	3400	4250
900	1800	2700	3600	4500
950	1900	2850	3800	4750
1000	2000	3000	4000	5000
1100	2200	3300	4400	5500
1200	2400	3600	4800	6000
1300	2600	3900	5200	6500
1400	2800	4200	5600	7000
1500	3000	4500	6000	7500
1600	3200	4800	6400	8000
1700	3400	5100	6800	8500
1800	3600	5400	7200	9000
1900	3800	5700	7600	9500

Fundamental	2nd Harmonic	3rd Harmonic	4th Harmonic	5th Harmonic
2000	4000	6000	8000	10000
2200	4400	6600	8800	11000
2400	4800	7200	9600	12000
2600	5200	7800	10400	13000
2800	5600	8400	11200	14000
3000	6000	9000	12000	15000
3200	6400	9600	12800	16000
3400	6800	10200	13600	17000
3600	7200	10800	14400	18000
3800	7600	11400	15200	19000
4000	8000	12000	16000	20000
4500	9000	13500	18000	22500
5000	10000	15000	20000	25000
5500	11000	16500	22000	27500
6000	12000	18000	24000	30000
7000	14000	21000	28000	35000
8000	16000	24000	32000	40000
9000	18000	27000	36000	45000
10000	20000	30000	40000	50000

With this table of harmonics as a reference we can consider harmonic relation. As a matter of fact the table serves an excellent purpose during the discussion of the occurrence of beats between harmonics, harmonics and fundamentals, etc. An examination of this table will show you that several different fundamentals will be productive of the same harmonic frequency, although the order of the harmonic of the same frequency will be different. This is quite an important item to bear in mind, not only when working upon super-heterodyne receivers, but at all times when using your test oscillator. At the moment we are not concerned with oscillator application, hence will not enter upon a discussion of that subject. We are focusing attention upon the table of harmonics. Obviously any fundamental which is an even or odd multiple of another will be productive of similar harmonic frequencies. Thus the 4th harmonic of the 90 kc. fundamental is 360 kc. Now, the 180 kc. fundamental is a multiple of the 90 kc. fundamental and its 2nd harmonic is 360 kc. The 8th harmonic of 90 kc. (not shown in the table) is 720 kc. and the 4th harmonic of 180 kc. is 720 kc.

We also note that the 3rd harmonic of 240 kc. is 720 kc. Furthermore, the 2nd harmonic of 360 kc. is 720 kc.

If one fundamental is three times the other, the 9th harmonic of the lower fundamental will be the same as the 3rd harmonic of the larger fundamental. In turn the 18th harmonic of the smaller fundamental will be the same frequency as the 6th harmonic of the larger fundamental; the 24th harmonic of the lower fundamental will be the same as the 8th harmonic of the higher fundamental, etc. As an example, let us consider 200 kc. as the lower fundamental and 600 kc. as the higher fundamental.

Harmonic Frequency	Fundamental 200 kc.	Fundamental 600 kc.
Fundamental 600 kc.	3rd harmonic	fundamental
1800 kc.	9th harmonic	3rd harmonic
2400 kc.	12th harmonic	4th harmonic
3000 kc.	15th harmonic	5th harmonic
3600 kc.	18th harmonic	6th harmonic
4200 kc.	21st harmonic	7th harmonic
4800 kc.	24th harmonic	8th harmonic

If we select two fundamentals, one of which is four times the other, the harmonic frequencies will be the same 8th of the lower fundamental and the 2nd of the higher fundamental; the 12th of the lower and the 3rd of the higher, the 16th of the lower and the 4th of the higher, etc. An example would be

Harmonic Frequency	Fundamental 200 kc.	Fundamental 800 kc.
Fundamental 800 kc.	4th harmonic	Fundamental
1600 kc.	8th harmonic	2nd harmonic
2400 kc.	12th harmonic	3rd harmonic
3200 kc.	16th harmonic	4th harmonic
4000 kc.	20th harmonic	5th harmonic

If we select two fundamentals, one of which is two times the other, the same harmonic frequencies will be produced when the order of the harmonic of the lower fundamental is two times the order of the harmonic of the higher funda-

mental. Thus the 4th harmonic of the lower and the 2nd harmonic of the higher fundamental, the 6th of the lower and the 3rd of the higher fundamental, the 8th of the lower and the 4th of the higher fundamental, the 10th of the lower and the 5th of the higher, etc. will be productive of the same frequency.

Such relations do not hold only for two fundamentals. If we select three or more fundamentals, each of which is a certain multiple of the others, a definite ratio will exist between the harmonic order, which will be productive of the same frequency signal. Thus, if we select three fundamentals, such as 200, 600 and 800 kc. the same frequencies will be produced for the following harmonics.

Harmonic Frequency	Fundamental 200 kc.	Fundamental 600 kc.	Fundamental 800 kc.
	3rd harmonic	Fundamental	
	4th harmonic		Fundamental
1200 kc.	6th harmonic	2nd harmonic	
1600 kc.	8th harmonic		2nd harmonic
1800 kc.	9th harmonic	3rd harmonic	
2400 kc.	12th harmonic	4th harmonic	3rd harmonic
3000 kc.	15th harmonic	5th harmonic	
3200 kc.	16th harmonic		4th harmonic

The above table does not by any means list all the harmonic orders which will be of like frequency. The few listed should be sufficient to illustrate how the ratio between the fundamentals is maintained in the harmonics.

Earlier in this discussion of harmonic relations, we made a reference to fundamentals which are even or odd multiples, being productive of like harmonic frequencies. Let it be understood that it is not necessary that this even or odd order be maintained. While it is true that there are no fractional multiples of a fundamental which will produce a harmonic, it is possible that similar harmonic frequencies will be produced when one fundamental is a fractional multiple of another. Thus if a 3:2 relation exists between the 135 and 90 kc. fundamentals, a 3:2 relation will exist between the harmonics. For example,

Harmonic Frequency	Fundamental 90 kc.	Fundamental 135 kc.
270 kc.	3rd harmonic	2nd harmonic
540 kc.	6th harmonic	4th harmonic
810 kc.	9th harmonic	6th harmonic
1080 kc.	12th harmonic	8th harmonic

Another example of fractional multiples would be 1000 kc. and 400 kc. or a 5:2 relation. In this case, similar harmonic frequencies will be produced as follows:

Harmonic Frequency	Fundamental 400 kc.	Fundamental 1000 kc.
2000 kc.	5th harmonic	2nd harmonic
4000 kc.	10th harmonic	4th harmonic
6000 kc.	15th harmonic	6th harmonic

As is evident the relation of 5:2 is maintained in the order of the harmonics, which will have the same frequency.

Once more we are going to repeat the statement that you should make yourself thoroughly familiar with harmonic relation, because you will find it of great help later. The individual who knows his harmonics can align a radio receiver with much greater speed and accuracy than the individual who must consistently check his oscillator setting, so as to learn just what frequency is being produced. As far as superheterodyne servicing is concerned, the man who comprehends why beat notes are being produced at certain points of the dial, that is, at certain frequency settings, is the man who understands the production of harmonics.

You can readily understand that it is impossible in a volume of this size to tabulate a complete list of harmonics of like frequency for fundamental frequencies of unlike value. Also that it is impossible to tabulate a list of harmonic frequencies for fundamentals which progress at a rate of 1000 cycles at a time. Thus the table given shows progression of fundamental in steps of 5 kc. between 90 and 200 kc., in steps of 10 kc. between 200 and 300 kc., in steps of 50 kc. between 350 and 1000 kc., in steps of 100 kc. between 1000 and 2000 kc., in steps of 200 kc. between 2000 and 4000 kc., in steps of 500 kc. between 4000 and 6000 kc., and in steps of 1000 kc. between 6000 and 10,000 kc.

The fact that this progression is not uniform is why the rate of progression under the harmonic headings is not uniform. If the fundamental frequencies advance in steps of unit quantities such as 1000 cycles or 1 kc., the rate of increase under the harmonic headings is in steps of the fundamental increase times the order of the harmonic. For example

Funda- mental	2nd Har- monic	3rd Har- monic	4th Har- monic	5th Har- monic	6th Har- monic
500 kc.	1000 kc.	1500 kc.	2000 kc.	2500 kc.	3000 kc.
501	1002	1503	2004	2505	3006
502	1004	1506	2008	2510	3012
503	1006	1509	2012	2515	3018
504	1008	1512	2016	2520	3024
505	1010	1515	2020	2525	3030

If the fundamental advances in steps of 1 kc., the frequency under the 2nd harmonic heading advances in steps of 2 kc., under the 3rd harmonic heading, in steps of 3 kc., under the 4th harmonic heading, in steps of 4 kc., etc. If we were showing harmonics up to the 20th or 30th, the frequency under the 20th harmonic heading would advance in steps of 20 kc. and under the 30th harmonic heading in steps of 30 kc.

Knowledge of harmonic relation is valuable in determining the fundamental when several harmonic frequencies have been established, although the actual fundamental is not known. Perhaps you have noticed that the numerical difference between adjacent harmonics of the same fundamental is equal to the fundamental frequency. Thus, if we determine the presence of a 3030 kc. signal and the next signal heard is determined as being a 2525 kc. signal with silence in between, and we are certain that only one fundamental (value unknown) is in existence, we can hazard the guess that the fundamental is 3030 — 2525 or 505 kc. This can be checked by determining the existence of another harmonic higher than 3030 or lower than 2525 kc. If the fundamental is 505 kc., then the harmonic just below 2525 kc. will be 2020 kc. or the harmonic just above 3030 kc., will be 3535 kc. Knowing only one frequency, as for example 3030 kc. does not permit a guess at the fundamental, since 3030 kc. may be the 6th harmonic of 505 kc.,

the 5th harmonic of 606 kc., the 4th harmonic of 757.5 kc., the 3rd harmonic of 1010 kc. and the 2nd harmonic of 1515 kc. However, the moment that we establish an adjacent harmonic, identification is possible. Thus, if we have determined that 2525 kc. and 3030 kc. are adjacent harmonics, we can omit the possibility of 606 kc. being the fundamental, because the 4th harmonic of 606 kc. is 2424 kc. If 606 kc. were the fundamental, which has a 3030 kc. harmonic, the adjacent harmonic frequency would be 2424 kc. We can dismiss 757.5 kc. as being the fundamental, because the 3rd harmonic is 2272.5 kc. We can also dismiss 1010 kc. as being the fundamental, because the 2nd harmonic is 2020 kc. The only possible fundamental which will produce adjacent harmonics of 2525 kc. and 3030 kc. is 505 kc.

So much for the subject of harmonic generation and the relation between harmonics. However, before closing, we would like to stress just one point. Do not, from what has been said about harmonic generation, make up your mind to the effect that the full range of harmonics is to be expected in all vacuum tubes, be they detectors, amplifiers or oscillators. Neither should you make it a practice, while doing service work, to imagine that all troubles experienced with super-heterodyne receivers are due to the unwanted presence of harmonics. You will, of course, experience symptoms which will point directly to the presence of harmonics and the trouble will be traceable directly to this cause. Yet, *all troubles are not of this nature.* More will follow later in this text as we discuss related items.

BEAT NOTES BETWEEN HARMONICS.

Without any attempt to discuss servicing problems, we will dwell briefly upon the subject of beat notes between harmonics. After all is said and done, a harmonic voltage developed in a receiver is the equivalent of a signal of that frequency. If two harmonics or if a harmonic and a fundamental not related to each other, with respect to the fundamental frequency, are mixed, a beat note will be produced exactly in the same manner as when two fundamentals of

unlike frequency are mixed. The numerical value of the beat note will be the difference in frequency between the two harmonics or between one fundamental and a harmonic of another fundamental.

Very little if any concern need be felt, with respect to the production of a beat, when several harmonics of the same fundamental frequency are present in a circuit, because the difference in frequency between any two such harmonics is the fundamental already in that circuit. Furthermore, the difference in frequency between two widely separated harmonics of the same fundamental results in the production of a signal frequency already in that circuit as one of the harmonics. What we have to concern ourselves about most, is the production of a beat due to the mixing of a harmonic of one fundamental and the harmonic of another fundamental or one fundamental and a harmonic of another fundamental.

Suppose for a moment that by virtue of a certain condition, which may be undesired, we have mixed in one circuit, an 800 kc. modulated carrier and a 1060 kc. locally generated signal so as to produce the desired 260 kc. intermediate frequency beat note for passage through the receiver. The oscillator which produces the local signal of 1060 kc. also produces a series of harmonics. The 2nd harmonic would be 1060 $\times$ 2 or 2120 kc. If, by chance, due to location of the transmitter with respect to the receiver, a 2380 kc. signal or an 1860 kc. signal found its way into the mixer circuit, there would be developed in the output circuit of that mixer system, as a result of the combination of the 2380 kc. signal and the 2nd harmonic of the 1060 kc. locally generated oscillations, a beat signal of 260 kc., which would bear the characteristics of the 2380 kc. signal, and two signals would pass through the i-f amplifying system. These would be the converted 800 kc. signal and the 2380 kc. signal. If the undesired carrier in the input system would be the 1860 kc. signal, this would mix with the 2nd harmonic of the 1060 kc. signal and produce the required 260 kc. beat or i-f signal for passage through the receiver. This is an example of the beat note produced between a fundamental and a harmonic of another fundamental. It is not essential that it be the 2nd harmonic, which is mixed

with the undesired carrier; it can be the 3rd or the 4th harmonic, or even a harmonic of a higher order. The probability of such signals appearing in the mixer circuit is not very great, yet it is a possibility and illustrates the phenomenon under discussion.

A situation more typical of what may actually be experienced in practice is the following. Suppose that a 600 kc. signal is being received. The receiver oscillator is adjusted to 860 kc. so as to produce the required 260 kc. beat note or intermediate frequency signal. The receiver is located adjacent to a powerful transmitter operating upon 1460 kc. Due to proximity or for some other reason, the 1460 kc. signal finds its way into the mixer tube. The result is that both the 600 kc. and the 1460 kc. signals appear in the output. The 600 kc. signal appears because the receiver oscillator, being tuned to 860 kc., produces the required 260 kc. beat. The 1460 kc. signal appears because the 2nd harmonic of the 860 kc. adjustment of the oscillator is 1720 kc. and when mixed with the 1460 kc. signal, produces the required 260 kc. beat note.

Another example of beats produced between a harmonic and a fundamental is of the following order. Suppose that a 456 kc. intermediate frequency or beat note has been produced by virtue of the proper mixing of the incoming carrier and the locally generated signal. If by chance, the 2nd harmonic of the 456 kc. beat, which is 912 kc., is allowed to mix with a 910 kc. carrier in the demodulator circuit, an audio beat equal to 912 — 910 or 2 kc. would be developed and be passed into the audio system, resulting in a 2000 cycle whistle as the background during the reception of the desired signal. For that matter, it is not essential that the beating signal be the 2nd harmonic of the i-f signal. It can, just as readily, be the 3rd or 4th harmonic of whatever intermediate frequency is being used.

A similar condition due to incorrect alignment would be of the following type. Suppose that a receiver is tuned to 700 kc. and the beat or i-f signal required for the receiver is 175 kc. However, instead of being tuned accurately to 175 kc., the local signal generator (oscillator) is tuned to

produce a beat of 174 kc. In other words instead of being tuned to 875 kc., the local oscillator is tuned to 874 kc. The beat note produced would pass into the i-f system, since a difference of 1 kc. would not interfere with the passage of the signal. Intermediate frequency transformers are usually designed to possess band-pass characteristics and such a 175 kc. transformer would cover a range of at least 171 to 179 kc. Now, if by chance the 700 kc. broadcast carrier would find its way into the demodulator tube circuit, it would mix with the 4th harmonic of the 174 kc. intermediate, which would be 174 × 4 or 696 kc. and produce an audio beat of 4 kc. as a background to the signal. However, if the original oscillator adjustment had been accurately made to 175 kc., the 4th harmonic would be 700 kc., resulting in *zero beat* and no background whistle from this cause. However, the presence of the 700 kc. broadcast carrier in the demodulator circuit would be accomplished only by the existence of an undesired condition, which would more than likely create other undesired effects.

A problem such as outlined above is frequently encountered during service work. More detailed discussion will follow later in this text. We now can embark upon the discussion of different types of superheterodyne receivers and the breakdown of a commercial system, so as to determine the exact function and characteristics of the different sections of superheterodyne receivers.

CHAPTER 3

EXPLANATION OF THE DIFFERENT
TYPES OF SUPERHETERODYNE
CIRCUITS

BEFORE attempting to discuss the various types of
superheterodyne circuits it might be well, in order to
avoid repetition, to mention those parts of a super-
heterodyne receiver which are common to the different types
of this receiver. Certain parts of the different types of super-
heterodyne receivers are similar, if not identical. It is true
that the last three years have witnessed certain receiver circuit
developments, which are native to the superheterodyne and
are seldom found in tuned radio frequency receivers. How-
ever, the reason that these developments are not in tuned radio
frequency receivers is that such receivers have not been pro-
duced extensively during the past three years. Had they
been made, some of these developments could just as readily
be applied to t-r-f receivers as to the superheterodyne.

Referring to those parts which are common to all types of
superheterodyne receivers and do not require discussion in this
chapter, we can exclude the speaker and the power supply
system. Nothing extraordinary can be said about these units
as employed in superheterodyne receivers. Audio systems are
somewhat in the same class. While it is true that all audio
frequency amplifier circuits are not alike in actual design,
variations do not typify in any way the superheterodyne
receivers. Hence the audio system, too, can be omitted from
this chapter. Under the circumstances, reference to various
types of superheterodyne circuits will mean those parts of
the receivers which are different with respect to circuit design

and function and which have been known to identify types of superheterodyne receivers.

The Standard or Conventional Superheterodyne Receiver.

It is difficult to establish the definition of standard or conventional. Perhaps the best explanation is that which is generally understood to exist when casual reference is made. A superheterodyne receiver which would be classed as being of conventional nature, without any technical embellishments, such as noise suppression, tuning meters, AVC, etc. would appear as shown in figure 6 and would contain the following components:

1. The r-f amplifier or pre-selector.

The presence of a tuned radio frequency amplifying stage is not imperative in order to establish the receiver as being of conventional design. Whether or not a pre-selector or r-f stage is used in a superheterodyne receiver seems to be determined by the price of the receiver. Small, low priced receivers do not incorporate pre-selector stages, whereas the medium and high priced, larger receivers incorporate such a stage of amplification, sometimes two stages.

2. The 1st detector, mixer, frequency changer, translator, or whatever term may be used to denote the tube.
3. The oscillator employed to generate the beating or heterodyning signal.

The normal conception of a standard superheterodyne circuit is one wherein a separate tube is used for the mixing purpose and a separate tube is used for the oscillator. Modern practice makes use of two sets of tube elements contained in one envelope, so that the tube is a combination mixer and oscillator. However, such a mixer-oscillator must not be confused with what is known as the autodyne system, wherein one tube, with but one set of elements is employed as the mixer-oscillator. The modern mixer-oscillator of the 6A7 type is in reality two tubes within one envelope, so that the statement of a standard superheterodyne being one in which a separate

tube is used as a mixer and another tube or set of tube elements is used as the oscillator, still holds true. Referring once more to the modern mixer-oscillator, we acknowledge that the heater and cathode are common to both the mixer and oscillator elements.

> 4. The intermediate frequency or i-f amplifier.
> 5. The 2nd detector or demodulator.

Once again we encounter the possibility of having these two tubes or functions combined in one envelope. However, the use of one or the other arrangement does not influence the classification of the receiver.

> 6. The audio frequency amplifier.
> 7. The speaker.
> 8. The power supply unit, a-c, d-c or battery.

Referring to the diagram in figure 6, the solid wavy line is the broadcast carrier, the dot-dash line is the unmodulated
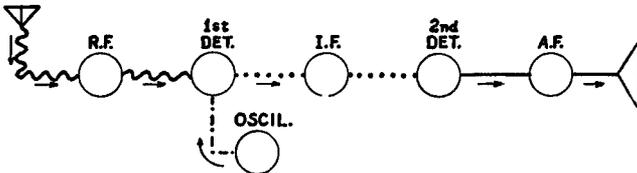
Fig. 6. The passage of signal currents through a standard
superheterodyne

wave generated by the local oscillator and fed into the mixer. The dotted line is the beat or i-f signal passed through the intermediate frequency amplifier into the demodulator. The solid straight line is the a-f signal passed through the a-f amplifier into the speaker. The use of a single circle for the r-f, i-f and a-f amplifier systems, does not indicate that but one tube is used for each of these functions. It is possible that two or more tubes are used. This does not alter the classification of the receiver circuit.

The number of tuned circuits, the number of tuning controls or the wave bands covered by the receiver have no bearing whatsoever upon whether the circuit is standard or not.

GANG CONDENSER

'35 R.F. '24 1st DET. '39 I.F. '24 2nd DET. R.F. CHOKE COIL '47 PWR.

ANT.

GND.

PILOT LIGHT 2.5 V

27 OSC.

FIELD COIL 1050 Ω

YELLOW BLUE RED BLACK WHITE BLACK RED

BROWN

BLACK 5 V. BLACK

RED 390 V. BLACK-WHITE TRACER 390 V. RED

GREEN 100-110

BLUE 110-120

HUM ADJUSTER

YELL 10V. 2.5V YELLOW

'60

BLACK-RED TRACER

CHOKE COIL 400 Ω

SWITCH

K-60-60~A.C.
K-62-25-60~A.C.

(95 WATT)
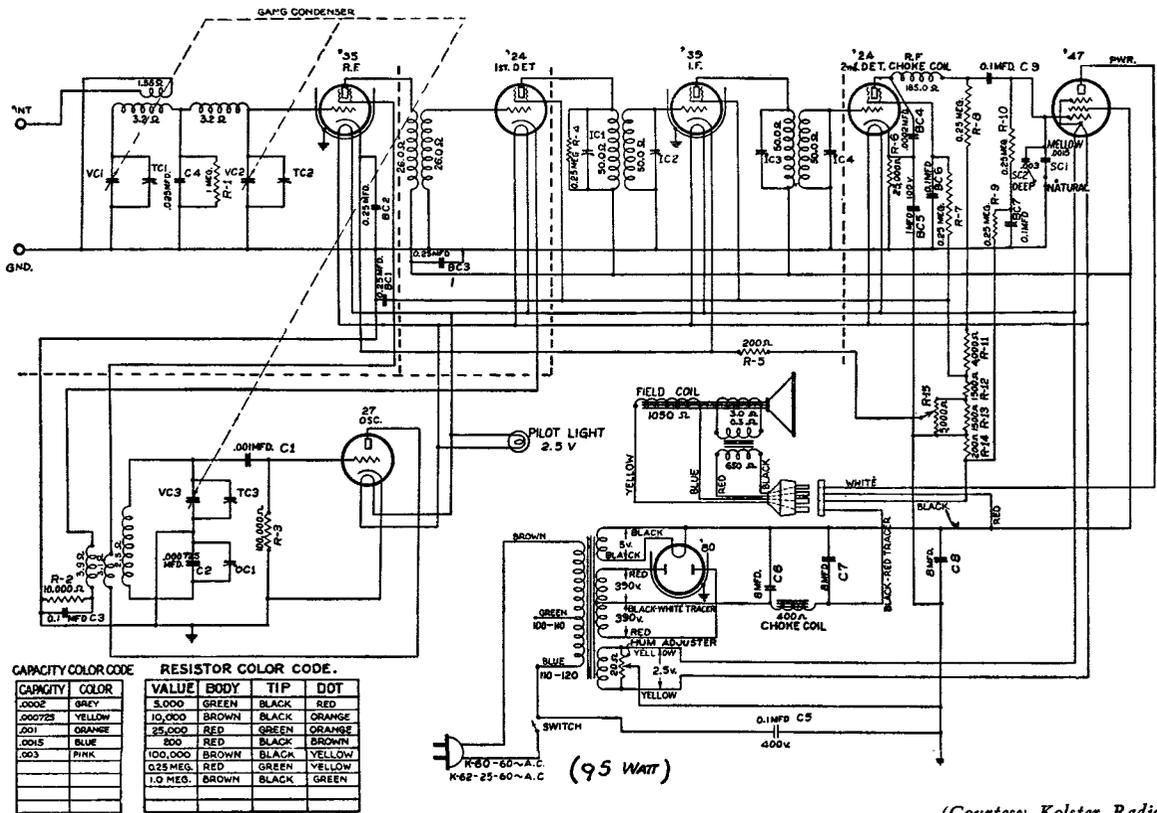
CAPACITY COLOR CODE	
CAPACITY	COLOR
.0002	GREY
.000725	YELLOW
.001	ORANGE
.0015	BLUE
.003	PINK

RESISTOR COLOR CODE.			
VALUE	BODY	TIP	DOT
5,000	GREEN	BLACK	RED
10,000	BROWN	BLACK	ORANGE
25,000	RED	GREEN	ORANGE
200	RED	BLACK	BROWN
100,000	BROWN	BLACK	YELLOW
0.25 MEG.	RED	GREEN	YELLOW
1.0 MEG.	BROWN	BLACK	GREEN

(Courtesy Kolster Radio)

A standard type of superheterodyne circuit may have one, two, or three tuning controls. It may employ any number of r-f stages or a-f stages. It may be designed to cover the broadcast band, short wave band or both. One standard superheterodyne circuit may contain all of the modern technical developments, such as reflexing, AVC, QAVC, flasher tuning, tone control, etc. Another standard superheterodyne circuit may not contain the most modern developments or technical embellishments, as we called them before, yet be standard as far as superheterodyne operation is concerned.

An example of a modern superheterodyne of the standard circuit variety without any special control circuits and typifying the arrangement shown in figure 6 is illustrated in figure 7. This is an a-c receiver, equipped with a band-pass input system feeding a tuned r-f pre-selector stage. One tube is used for the purpose of mixing the broadcast carrier and the local signal generated by a separate oscillator. The mixer tube is designated as the 1st detector. A single tube is used as an i-f amplifier. Another tube is the 2nd detector or demodulator and a single tube is used in the output a-f stage. Another tube is employed in the rectifier system. The basic circuit of this receiver is standard, despite the fact that a band-pass type of pre-selector circuit is used. This receiver, having only one tuning control, is no more standard as far as circuit arrangement is concerned, than the superheterodyne of years ago, wherein three or four tuning controls were employed. It stands to reason that this receiver is more modern than its predecessor, as far as performance is concerned, yet the circuits in both cases were standard. The later receiver will out-perform the earlier model, because of better tube design, better coil design, better transformer and speaker design, but none of these features represent factors which influence the basic circuit design with respect to the function of the respective components.

THE AUTODYNE TYPE OF SUPERHETERODYNE.

The *autodyne* type of superheterodyne is one variation from what we classify as standard. The passage of signal currents

through this type of superheterodyne is shown in figure 8. The primary difference between this and the standard type of superheterodyne circuit is that a single tube, of no special design, functions as the combination mixer and oscillator. Obviously this single tube is performing the work of two individual tubes used in the standard type of circuit, or of the special dual tube in a single envelope used in some of the modern standard circuits. The difference between the auto-dyne tube and the dual set of elements, single envelope type, is that the former is a regular tube, whereas the latter is a specially designed, recently developed tube. The use of the conventional three or four element tube as a combination mixer and oscillator is not new. This type of arrangement has been used for many years in the radio amateur ranks for the reception of continuous waves in the short wave and long wave field. It is also used in the "Second Harmonic" type of superheterodyne described elsewhere in this chapter. The everyday short wave regenerative detector circuit, operated in such manner that the detector tube is oscillating, is an example of autodyne operation.
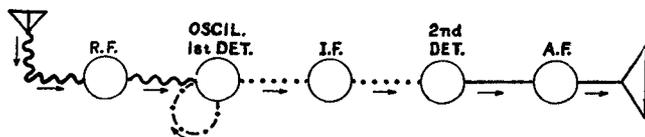
Fig. 8. The passage of signals through an autodyne type of superheterodyne

The autodyne mixer is simultaneously oscillating and performing the function of a mixer tube or 1st detector tube. Referring to figure 8, the wavy line represents the r-f signal, the dot-dash line, the locally generated beating or heterodyning signal, the dotted line, the i-f signal and the solid straight line, the a-f signal. Neglecting the circuit arrangement of the autodyne mixer-oscillator, the balance of the superheterodyne receiver is like that used in the standard system. Without any attempt to discuss the autodyne circuit at this time, we can describe the elementary process of operation by saying that the r-f signal is fed into the autodyne

mixer-oscillator, which tube is at the same time oscillating at a frequency higher than the incoming r-f carrier by the numerical value of the required beat or intermediate frequency. The tuning of the autodyne mixer is operated in conjunction with the r-f tuning circuit. The two tuning circuits are in track, but differ in frequency adjustment by the value of the intermediate frequency. A much more complete discussion of the autodyne circuit will be found in the next chapter under the mixer circuits heading. Such autodyne operation has one definite disadvantage: that the input circuit of the mixer tube is not tuned to the incoming broadcast carrier frequency. More about this later.

SECOND HARMONIC SYSTEM.

Once more, we refer to a system which will receive more extensive description later. Its inclusion at this time is imperative on the grounds that the operation of certain parts of the circuit differs from the conventional or standard.

The second harmonic type of superheterodyne was used quite a great deal several years ago by RCA and Brunswick. As a matter of fact, the first group of superheterodyne receivers released prior to the 60 series were of this type. The receiver differs from the standard in the arrangement employed in the mixer system. The circuit is somewhat similar to that of the autodyne, as is shown in the next chapter, but instead of producing a beat or i-f signal by mixing the incoming carrier with the locally generated fundamental, the beating or heterodyning signal is the 2nd harmonic of the fundamental of the oscillator portion of the autodyne system. In order to accomplish this, the input circuit of the mixer tube consists of two tuned circuits. One of these is resonated to the incoming carrier. The other circuit, a parallel resonant circuit, is in series with the grid circuit between the high end of the tuned input and the control grid. The feedback system, or oscillator feedback coil, is coupled to the second tuned circuit. This second tuned circuit is adjusted to a frequency which is half the numerical value of the figure required to beat with the incoming carrier and to produce the required

beat note. Thus, if we tune the receiver to 1000 kc., the input circuit of the mixer is tuned to 1000 kc. In the receivers mentioned, the beat note or intermediate frequency was 50 kc. In order to produce this beat, a beating frequency of 1000 plus 50 or 1050 kc. is required. This beating frequency was used, but not as the fundamental of the oscillator system. Instead, the oscillator system, (the second tuned circuit) was adjusted to 525 kc., so that its 2nd harmonic was the required 1050 kc. In other words, the beating action takes place between the fundamental broadcast carrier and the 2nd harmonic of the oscillator fundamental. This circuit possesses the virtue of enabling very accurate tuning of the input carrier, thus increasing selectivity and sensitivity. More about this later.

SUPERHETERODYNE CONVERTERS.

The superheterodyne converter is a detector and oscillator unit, sometimes incorporating an r-f pre-selector stage, whereby a tuned radio frequency receiver can be converted into a superheterodyne. This is accomplished by employing the converter to perform the function of creating an intermediate frequency signal, which signal is fed into the tuned radio frequency receiver. The intermediate frequency signal output of the converter constitutes the signal input to the t-r-f set, just as if it were a regularly received modulated broadcast carrier. However, instead of tuning the radio frequency amplifier in the t-r-f receiver to a number of different broadcast frequencies, the t-r-f receiver tuning remains fixed at the frequency of the signal from the converter. In other words, the tuned radio frequency amplifier within the t-r-f set is functioning as the i-f amplifier of the improvised superheterodyne. The tube which is the regular detector in the t-r-f receiver now is called upon to function as a second detector.

This is one example of an intermediate frequency which does not lie within the usually understood band of from 50 kc. to perhaps 300 kc. In this instance, the i-f peak would be at some figure within the broadcast band of from 545 kc. to 1500 kc.

Such superheterodyne converters have as a general rule been used for the reception of short wave signals with a conventional tuned radio frequency receiver. However, since the converter unit functions as a beat note or i-f signal source, the band to be covered is simply a matter of design. If one desired, a tuned radio frequency receiver could be converted into a broadcast band superheterodyne by utilizing a converter, which was designed to cover the broadcast band. As a matter of fact present-day superheterodyne converters are available with all-wave coverage, covering the band from 500 to 18,000 kc. and are just as readily suitable for operation with t-r-f receivers as they are with superheterodynes. As a matter of fact, the use of a short wave converter with a superheterodyne is described in this chapter.

It is possible to compare the improvised superheterodyne which employs a separate detector or mixer tube and a separate oscillator tube and the t-r-f receiver as the i-f amplifier, 2nd detector and a-f amplifier, with a standard design superheterodyne. While it is true that the mixer and oscillator systems are not a physical part of the t-r-f receiver, the basic design of the complete system, inclusive of all parts, is like that of the standard superheterodyne circuit.

An example of how such a converted superheterodyne operates would be as follows. Suppose that the converter used consists of a r-f buffer stage, the mixer or first detector and the oscillator tube. Such a unit is shown in figure 9, the schematic of an RCA short wave converter. Let us further assume that the converter has a tuning range of from 7000 kc. to 1500 kc. The intermediate frequency at which the converter operates is 560 kc. The power supply for the converter is secured from the t-r-f receiver power system, with the possible exception of the heater current for the tubes. Of course, if the converter is so designed, it can secure its power supply from its own power system, or if it is of the battery type, from batteries. The converter shown in figure 9 is of the a-c variety and secures its heater current from a separate self-contained power transformer. The plate and screen voltages are secured from the t-r-f or whatever receiver is employed in conjunction with the converter.

Let us assume that we desire to listen to a 4000 kc. signal. The converter is adjusted to 4000 kc. Since the oscillator tuning condenser, properly tracked so that its output, when mixed with the received carrier, will produce the required 560
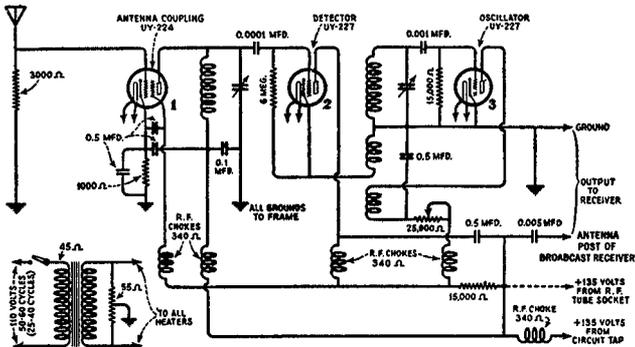
Fig. 9.   Short-wave superheterodyne converter
(Courtesy RCA-Victor Co.)

kc., is operated simultaneously with the tuning control, the converter will supply a 560 kc. beat signal output, which bears the modulation characteristics of the originally received 4000 kc. short wave carrier. The output circuit of the converter is connected to the antenna-ground post of the t-r-f receiver. The normal antenna lead, from the antenna to the antenna post of the receiver, is removed. The ground terminal may remain connected or it may have to be removed, depending upon the exact circuit. The t-r-f receiver is tuned to a frequency of 560 kc., by manipulating the tuning controls, be they one or more than one, just as if there were no converter in existence and the receiver was being tuned to a 560 kc. station.

During the operation of the short wave converter, the t-r-f receiver tuning remains fixed at 560 kc., since the radio frequency amplifier is acting as the i-f amplifier of the improvised superheterodyne. Irrespective of the tuning adjustment of the short wave converter, whether it is tuned to one or the other end of its waveband or to any frequency within its range, the t-r-f receiver tuning remains fixed at 560 kc.

Concerning the beat note or i-f output of such converters, it has been customary to select such frequency values as will lie outside of the normal broadcast band, yet within the usual limits of the average tuned radio frequency receiver. For example, 525 kc. is a frequently used figure, because there are no broadcasting stations operating upon 525 kc., yet this frequency is within the tuning band of the average radio receiver normally rated as covering the 540 to 1500 kc. band. Other designers have selected intermediate frequencies which approximate some value between 600 and 1000 kc. It is to be understood that whatever i-f peak is selected, that value is definite. In view of the possibility that some local broadcasting station may be operating upon the i-f peak of the converter at the locality where the unit is in use, provision is made for changing the beat note or intermediate frequency output of the converter. Any such change in converter output requires that the t-r-f receiver be adjusted to the new beat note of intermediate frequency.

Because of what follows, we would like to call to your attention several pertinent facts concerning the converter shown in figure 9. The first is that the beat note or intermediate frequency output of the converter is a single frequency, constant in value irrespective of the tuning adjustment of the mixer and oscillator circuits. The second, is that both the mixer and the oscillator circuits are continuously variable and are tuned for each specific station desired. The third, is that the r-f tube functions as a buffer stage. One purpose is to keep all oscillations due to the oscillator out of the antenna system, thus precluding the possibility of the converter acting as a miniature transmitter. At the same time, a certain amount of amplification is secured because of the presence of the tube, and interaction between the antenna and mixer is eliminated.

Another superheterodyne converter similar in structure to that shown in figure 9, is illustrated in figure 10. This is the Stewart-Warner R 301 A, B and E. In this unit, the aerial feeds directly into the mixer tube through a tuned r-f transformer. The beating signal is secured from another tube, the oscillator. With respect to the mixer and oscillator circuits,

the two converters shown in figures 9 and 10 are substantially identical. The r-f buffer stage is absent in figure 10. The heater current is supplied from a local power transformer. The plate voltages are secured from the receiver used in conjunction with the converter. This converter, like that shown

Fig. 10. Two-tube short-wave converter

(Courtesy Stewart Warner Radio)

in figure 9, provides a single output beat note. In other words, the intermediate frequency output is a single signal. As in the case of figure 9, the selection of any station within the frequency or waveband of the converter is a matter of tuning the converter to that specific station.

A unique type of superheterodyne converter is shown in figure 11. An analysis of the operation of this unit illustrates the possibilities of the beat phenomenon. As far as circuit arrangement is concerned, this converter is not much different from those shown. However, the most important feature is found in the fact that the beat output is *not* of a single frequency. When this converter is used with a receiver, *the receiver tuning determines the selection of the specific station desired.* The function of the converter is to produce a beat or i-f signal for every station within a certain wavelength band. As is evident from the circuit in figure 11, neither the mixer or oscillator circuits are continuously tuned. The

various condensers shown in these circuits function as a means of adjusting the mixer circuit to respond over a certain band and the oscillator system to resonate at a certain specific frequency. Expressed in another manner, the mixer circuit simultaneously responds to all signals within a certain wave or frequency band. The oscillator circuit on the other hand produces a signal of a definite and single frequency. This one
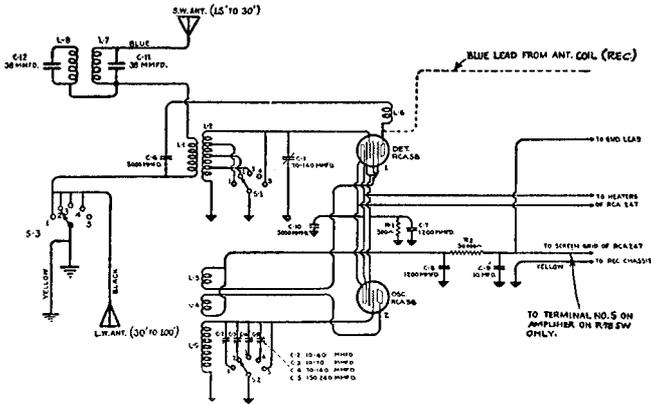
Fig. 11.   A-c. superheterodyne converter for four wave bands

beating signal beats against all of the signals within any one band adjustment of the mixer circuit, thus producing in the output circuit, a number of different beats or i-f signals, all of which are present in the output at the same time and it is up to the receiver used with the converter to pick out the required beat note representative of the desired short wave signal.

The mixer circuit is adjustable to four different short wave bands. In turn the oscillator circuit is adjustable to four different beating frequencies, one beating or heterodyning frequency for each short wave band. Contrast this with the normal type of superheterodyne operation. In this converter we may encounter ten or even fifteen different i-f signals, each of which is different and bears the modulation charac-

teristics of the broadcast carrier which was heterodyned by the oscillator signal. In the usual superheterodyne arrangement, the adjustment of the oscillator is such that the oscillator frequency varies each time that the mixer circuit is tuned to a different station. Instead of providing one beat note for all stations within the range of the unit, this converter supplies a different beat note for each short wave station, unless two different stations within the same band are operating upon the same carrier frequency, in which case the same beat note will exist.

It might be well to quote an example illustrating the operation of this converter, because it is so different from the usual arrangement. When the respective switches are in position No. 1, the mixer circuit is adjusted for the 19 meter band and is responsive over a complete frequency band of from 14,650 kc. to 15,600 kc. The actual active portion of this band, with respect to broadcasting stations classified as being within the 19 meter band, is from 15,100 to 15,340 kc. When adjusted to the 19 meter band, or switch position No. 1, the oscillator is resonated to 14,100 kc. This is a fixed frequency, which simultaneously heterodynes all stations within the frequency band governed by position No. 1 of the mixer circuit control switch. Suppose for a moment that we can receive four stations within the 19 meter band. These are operating upon 15,110 kc., 15,150 kc., 15,200 kc., and 15,310 kc. All of these signals are present in the mixer circuit. Since the oscillator is beating against all of these signals at the same time, we will have in the output of this converter, four different beat or i-f signals, each bearing the modulation characteristics of the original broadcast carriers. These four i-f signals will have the following frequencies:

$$15,110 - 14,100 \text{ or } 1,010 \text{ kc.}$$
$$15,150 - 14,100 \text{ or } 1,050 \text{ kc.}$$
$$15,200 - 14,100 \text{ or } 1,100 \text{ kc.}$$
$$15,310 - 14,100 \text{ or } 1,210 \text{ kc.}$$

With the converter connected to the receiver, it is up to the receiver to select which of the four broadcast carriers is desired. This is accomplished by resonating the *receiver* (by tuning the receiver) to the i-f signal representative of the

station. Thus, if we desired to listen to the 15,200 kc. station, the receiver would be made responsive, by tuning to the 1100 kc. output of the converter. By alternately changing the receiver tuning from 1010 kc. to 1050 kc., then to 1100 kc. and finally to 1210 kc., we could listen to all four short wave stations without any interference between stations.

The operation of the converter is of like order upon the other three bands. On bands 1 and 3, the oscillator frequency is *lower* than the carrier frequency band. On bands 2 and 4, the oscillator frequency is *higher* than the carrier frequency band. You must, of course, understand that the four stations spoken about in connection with band 1 are not all that can be received within that band. The number of stations within range of the unit depends entirely upon the location of the converted superheterodyne receiver.

The design of this converter is such that all broadcasting stations within each frequency band, fall within 950 to 1300 kc. upon the tuning dial. Perhaps it will be well to illuminate this type of operation, so as to remove all doubt concerning the selection of the beat note frequencies by means of the receiver. The receiver can select the proper beat or intermediate frequency, because *all of these beat or intermediate frequencies are present in this converter output.* The receiver has nothing to do with the production of the i-f signal. By virtue of the tuning of the receiver, it is made responsive to any one of the number of i-f signals present in the output of this converter. Once more we repeat that every signal which finds its way into the mixer circuit, because it is within the frequency band governed by the existing switch position, is *heterodyned at the same time,* and a resultant beat for that signal is in the output of this converter.

The beat frequencies quoted in connection with short wave band No. 1 may exist upon the balance of the bands and it is also possible that a number of other beat frequencies will be produced. The determining factor is the carrier frequency of the received signal and the oscillator adjustment for that specific band. Thus, for band No. 2, the oscillator frequency is fixed at 12,900 kc. For band No. 3, the oscillator frequency is fixed at 8450 kc. and for band No. 4 the oscillator

frequency is fixed at 7250 kc. If the converter is set for band No. 4 and the station received has a carrier frequency of 6150 kc., the beat frequency will be 7250 — 6150 or 1100 kc. On the other hand, if the received carrier has a frequency of 6300 kc., the resultant beat frequency will be 7250 — 6300 or 950 kc.

It is significant to note that the i-f signals produced in this converter fall within the broadcast band, so that the receiver used with the converter must be a broadcast receiver. Furthermore, while it is true that the normal run of broadcasting stations operating in the 19 meter zone fall within the 950 to 1300 kc. band upon the broadcast receiver, the range of beat notes produced over the entire band controlled by the respective converter switches extends over the complete broadcast band. For example, the range controlled by switch No. 1 is from 15,600 kc. to 14,650 kc. or about 950 kc. With the oscillator producing the 14,100 kc. heterodyning signal, the lowest beat note is of 550 kc. and the highest is of 1500 kc., thus covering the entire tuning range of the broadcast receiver. A similar condition exists upon the other frequency bands.

It is not imperative that the converters described thus far be used with t-r-f receivers. It is possible to employ a short wave superheterodyne converter with a superheterodyne receiver, providing that the receiver is tuneable to the beat or intermediate frequency output of the converter. As a matter of fact, short wave conversion with the use of two oscillators is quite a common practice.

SHORT WAVE CONVERSION WITH TWO OSCILLATORS.

This method of operation entails the use of a broadcast range superheterodyne and a short wave superheterodyne converter. The converter may consist of any number of tubes required to produce the correct operating conditions. It may consist of two tubes, a mixer and an oscillator, or three tubes, such as an r-f amplifier, a mixer and an oscillator, or even four tubes, such as an r-f stage, a mixer, an oscillator and a separate amplifier operating upon the beat note or i-f output
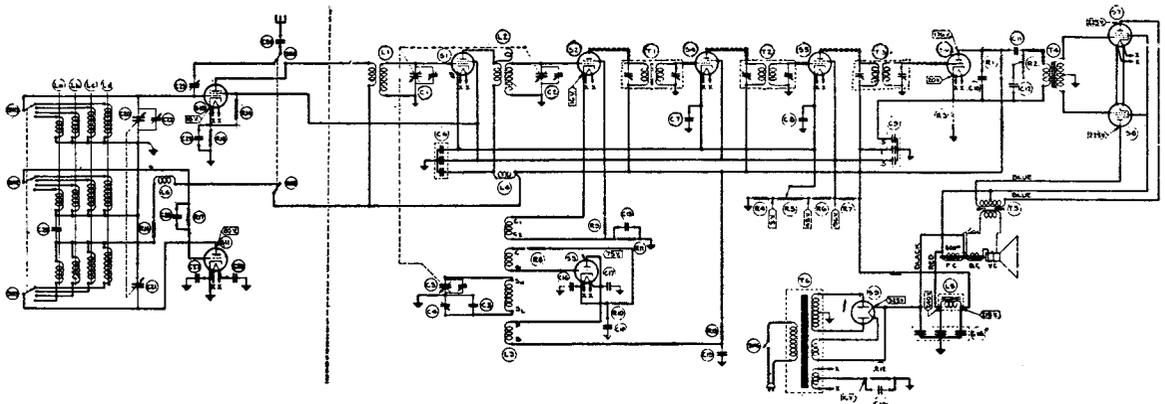
Fig. 12. A superheterodyne receiver connected to a short wave converter, which is shown to the left of the dotted line. All voltages are derived from the receiver's power supply

(Courtesy Silver-Marshall M'f'g. Co.)

of the converter mixer. The type of power supply used in the converter is of little importance at this time.

The converter is connected to the antenna-ground terminals of the broadcast range superheterodyne. The design of the converter can be such as to produce a single beat note of fixed frequency, as described in connection with figures 9 and 10, or it may be of the type shown in figure 11. Whatever the type converter used, its beat signal must fall within the broadcast band of the broadcast receiver. Once the converter beat signal has been fed into the broadcast superheterodyne, it functions just as if a broadcast carrier of identical frequency had been passed into the receiver. Naturally the broadcast receiver is tuned to the i-f output of the converter.

Suppose that we consider a typical example. Figure 12 illustrates the schematic of a superheterodyne receiver employed with a short wave converter. The converter portion is to the left of the vertical dotted line and the conventional broadcast band superheterodyne receiver consists of all of the components indicated to the right of the vertical dotted line. According to the schematic wiring diagram, all operating voltages are secured from the broadcast receiver power supply system. As a matter of fact that converter is a part of the complete receiver, but identical conditions would exist were this converter a distinctly separate unit.

Suppose that the short wave station being received is operating upon 4350 kc. The short wave converter output is rated at an intermediate frequency of 650 kc. This means that the converter oscillator would be adjusted to 4350 + 650 or 4350 — 650 kc. In the first case it would be 5000 kc. and in the second case, it would be 3700 kc. As it happens, the oscillator frequency invariably is higher than the carrier, hence is adjusted to 5000 kc. The broadcast receiver is rated at an i-f peak of 175 kc.

The 650 kc. beat signal from the converter is fed into the broadcast receiver, which is tuned to 650 kc. This signal now is acted upon by the oscillator in the receiver, which is adjusted to 650 + 175 kc. or 825 kc. The resultant 175 kc. signal is passed through the i-f amplifier, is demodulated, passed to the audio system and then to the speaker. As is evi-

dent, we started with a 4350 kc. signal and ended up with a 175 kc. signal by means of double frequency conversion. The first changed the 4350 kc. signal to 650 kc. and the second changed the 650 kc. signal to 175 kc. This 175 kc. signal contained the modulation characteristics of the original 4350 kc. short wave signal. During this process of frequency conversion, two heterodyning or beating frequencies were employed, namely 5000 kc. and 825 kc.

ALL-WAVE SUPERHETERODYNES.

The fact that a superheterodyne is capable of covering the all-wave bands, does not introduce another type. Its mention at this time, is simply for the purpose of clarifying the problem, if it has arisen in your mind. The various interesting features of all-wave superheterodyne receivers are reserved for the chapter devoted to the breakdown of the individual parts of a complete receiver.

THE SUPERHETERODYNE CODE RECEIVER.

There now are on the market a number of superheterodyne receivers which are intended for broadcast speech and code reception. Although these receivers fall within the standard variety classification, we deem it worthwhile to make reference to a type of superheterodyne receivers, not equipped with a converter, yet utilizing two oscillators. These receivers are as a rule tuneable over the short wave band only, but they can be extended to cover all bands with very little difficulty. The interesting feature is the use of one of the oscillators at all times, but the second oscillator is used only when receiving continuous wave (c-w) code signals. The first oscillator is the conventional tube used to produce the heterodyning signal for all reception, modulated or unmodulated, that is speech, music or c-w code. Irrespective of the nature of the received signal, this oscillator is required in order to produce the heterodyning signal so as to develop the i-f signal. The c-w oscillator on the other hand is not used during the reception of modulated signals. It is used only when receiving c-w code signals. Thus, for modulated carrier wave reception only one

oscillator is used, whereas for c-w code reception, both oscillators are used.

The necessity for the c-w oscillator is established by the nature of the received carrier. Whereas the normal broadcast signal is a modulated carrier containing audio frequency modulations and after conversion of frequencies to the intermediate value, these audio frequencies are separated from the i-f carrier in the demodulator tube and are passed into the a-f system to be made audible by the loud speaker, c-w transmission does not employ a modulated carrier. The transmitted wave is not modulated; it is simply interrupted in accordance with the transmission of the code signals, namely dots and dashes. A dot would be transmission of the carrier for a short period, whereas a dash would be transmission of the carrier for a longer period. Dots and dashes properly combined constitute letters, which are formed into words.

Consequently, the regular heterodyning oscillator in these short wave code reception superheterodynes changes the carrier to the intermediate frequency. Now, this i-f carrier is not modulated, so that if it is passed into the demodulator in regular fashion, there would be no audio component in the output of the demodulator, because the interruptions of the original short wave carrier are still existent upon a carrier (the i-f signal), which has a frequency beyond audibility. In order to make these interruptions representative of the code signals audible, it is necessary to again convert the beat note, which now is at an inaudible frequency, to an audible frequency. Interruptions of this audible beat then can be interpreted into code signals. In order to facilitate comprehension, let us assume that a code transmitter, operating upon 13,000 kc., is in use. The operator keeps his key down so as to produce a test signal. The process involved to make this signal audible in such a superheterodyne as we are discussing is of the following order.

The 13,000 kc. signal is heterodyned by the regular oscillator so as to produce the required 456 kc. intermediate frequency signal. This means that the regular oscillator is adjusted to 13,456 kc. This 456 kc. signal is an unmodulated carrier, since the original 13,000 kc. signal is an unmodulated

carrier. The 456 kc. intermediate signal then is passed into the demodulator tube. The c-w oscillator is producing another heterodyning signal. Usually, the adjustment of the c-w oscillator is such that when beating against the i-f signal, it will produce a 1,000 cycle audio beat note. For that matter, the c-w oscillator may be variable in tuning within definite limits, so that it can produce a resultant beat of any frequency within, say, from 500 to perhaps 3000 cycles. Assuming the desired audio beat to be 1000 cycles, the c-w oscillator would be tuned to 457 kc. The output of the demodulator then would contain an audio beat note, in the form of a 1000 cycle tone. This 1000 cycle tone would be the equivalent of the original 13,000 kc. unmodulated carrier. Just as long as the key was kept down, so as to produce a long dash at the transmitter, this 1000 cycle tone would be audible in the speaker connected to the receiver. If the transmission were interrupted by momentarily releasing the key, a momentary interruption would occur in the 1000 cycle sound issuing from speaker. If the key at the transmitter were operated so as to form code signals by producing dots and dashes, or short and long interruptions in the transmission, the same dots and dashes would be heard in the receiver, in the form of interruptions of the 1000 cycle tone issuing from the loud speaker. The 1000 cycle tone exists as long as the transmitter key is pressed and ceases when the transmitter key is released.

Continuous wave receivers of the superheterodyne variety are not necessarily limited to short wave reception. The action outlined before would be identical if the c-w transmission were being carried on by a 40 kc. long wave station transmitter, instead of a 13,000 kc. short wave transmitter. The same i-f frequency would be used and the same output tone would be used. For that matter, it is possible to adjust the c-w oscillator so that the output tone is a 200 cycle signal, thereby increasing the ability of selecting between stations which are operating on almost identical frequencies. A receiver of the type suitable for broadcast and c-w reception, employing two oscillators is shown in figure 13.

In some instances, the c-w oscillator is a part of the demodulator tube system; in other words, the tube functions as
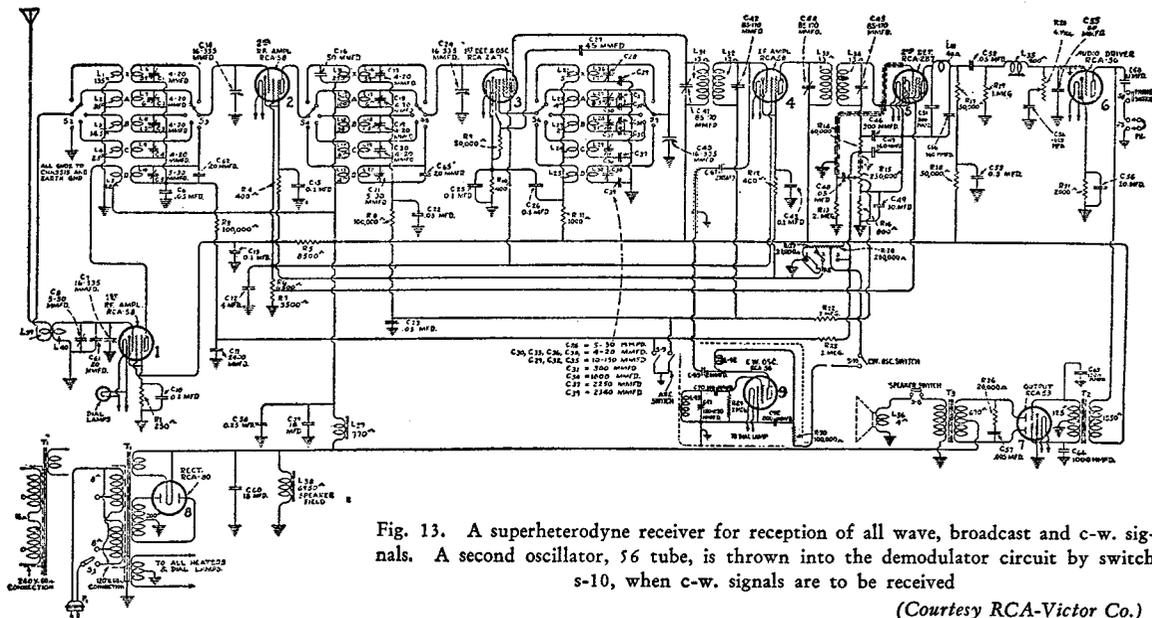
Fig. 13. A superheterodyne receiver for reception of all wave, broadcast and c-w. signals. A second oscillator, 56 tube, is thrown into the demodulator circuit by switch s-10, when c-w. signals are to be received

(Courtesy RCA-Victor Co.)

an oscillator and demodulator. Its oscillatory circuit is switch controlled, so that it can be converted into an ordinary demodulator by operation of the switch and vice-versa. When used as an autodyne demodulator and oscillator, the tuned circuit is oscillating at that frequency, which, when mixed with the i-f signal will produce the required audio beat. Incidentally, this same principle is used in the simple oscillating detectors of the conventional detector and audio amplifier type of short wave receivers.

What has been said in this chapter, just about covers the various types of superheterodyne receivers which have been in use and which now are in use. We can now advance into the function of the individual parts of such receivers and consider more of the special details associated with these parts.

FUNCTION AND CHARACTERISTICS OF INDIVIDUAL PARTS OF THE SUPER-HETERODYNE RECEIVER

T HIS chapter is devoted to a discussion of the function and characteristics of the different parts of a super-heterodyne receiver. As you will note no attempt is made to assemble these parts into a receiver. Such is entirely unnecessary, for the simple reason that we are concerned with this type of receiver as a whole and not with any one particular make of superheterodyne. It is, however, highly important that you digest what is said concerning the operating characteristics of these parts, because of their bearing upon the service problem. You will no doubt find occasion to correlate facts contained in this chapter with data furnished in chapters 2 and 3 concerning beat note and harmonic generation.

A salient fact to bear in mind, when reading this chapter, is that the information furnished about any one part of a superheterodyne is applicable irrespective of the type of super-heterodyne receiver in question, provided that the part being discussed is found in that particular type of receiver. Fortunately, because of general utility, certain statements pertaining to operation, defects, symptoms and trouble shooting of the respective parts are universally applicable.

THE RADIO FREQUENCY AMPLIFIER.

The function of the radio frequency amplifier in the super-heterodyne receiver does not differ from that used in the t-r-f receiver. Both serve the purpose of amplifying the received

signal at the carrier frequency and both serve as means of providing the means of selecting between stations. However, in contrast to the multi-stage systems used in t-r-f receivers, the average superheterodyne receiver seldom uses more than one stage of radio frequency amplification. In some few isolated cases two such stages are used, but those superheterodyne receivers which employ r-f stages usually limit this part of the receiver to a single stage. Very many do not use any r-f amplification.

Adjacent Channel Selectivity.

Instances are known when the receiver is equipped with two stages of r-f amplification, with one stage being used over a certain wave or frequency band and both stages being used over the remaining band, which invariably is the highest frequency band. Based upon conclusions generally reached after consideration of t-r-f receivers, one wonders how it is possible to secure the required amount of *adjacent channel* selectivity with such few stages of tuned radio frequency amplification. By *adjacent channel* selectivity is meant the ability to choose between broadcasting stations operating upon adjacent channels, which would be upon frequencies about 10 kc. apart, the usual mode of frequency allocation in the United States.

As has been stated earlier in this text, the t-r-f receiver depends solely upon its tuned r-f circuits for its selection between stations. If two broadcasting stations are operating upon 1000 kc. and 1010 kc. respectively, the frequency difference at the antenna is 10 kc. or about 1.0 percent. This frequency difference is maintained throughout the entire r-f amplification system, because the frequency relation between the two carriers remains the same. In order to secure the required amount of selective powers, a cascaded series of tuned radio frequency amplifiers are produced, so that the cumulative resonance curve will be so sharp as to reject the station 1.0 percent away in frequency or, at least, to reduce its intensity to such a level that it will not create discernible interference. The ability to separate two such stations, when both utilize considerable power, is well nigh impossible in the

average tuned radio frequency receiver, even if three or four stages of tuned radio frequency amplification are used. At least to do so without interfering with tone quality by cutting the modulation side bands and without creating a state of excessive regeneration.

Stage for stage, the radio frequency amplifier used in the superheterodyne and the radio frequency amplifier used in the t-r-f receiver are beset with identical problems. The fact that one or two stages of tuned radio frequency amplification are used in the superheterodyne receiver does not alter the inherent characteristics of the individual r-f stages. However, the selective power of the r-f stages used in the super-heterodyne appears to be increased beyond that of the same stages in a t-r-f receiver because of other functions present in the superheterodyne. Let us see how this is accomplished. We shall assume that the intermediate frequency used in the superheterodyne receiver is 260 kc. Variations of this i-f peak and its consequent advantages and disadvantages will be considered later.

Let us assume that the one station tuned in is operating upon a carrier frequency of 1000 kc. and that a 1010 kc. station of reasonable power, sufficient to interfere when listening to the 1000 kc. station with a t-r-f receiver, is also in operation. In the r-f system, these two stations are 1.0 percent apart in frequency. If both are heterodyned, because the interfering station finds its way into the mixer circuit, one beat note will have a frequency equal to 1260 — 1000 kc. or 260 kc. and the other will result in a beat note equal to 1260 — 1010 kc. or 250 kc. The two stations are still 10 kc. apart, but we now are operating at approximately 260 kc., instead of around 1000 kc. Whereas the frequency separation was 1.0 percent at the original carrier frequency, it is slightly more than 3.8 percent at the intermediate frequency, figuring that the desired station beat note being the 260 kc. signal and the undesired station beat note as being 250 kc. With a multi-stage accurately tuned intermediate frequency amplifier or with a single stage accurately tuned intermediate frequency amplifier, wherein at least two transformers with four tuned circuits are used, this frequency difference is sufficiently great

to furnish the required amount of selectivity and enable the operator to choose the 1000 kc. station and to eliminate or reject the 1010 kc. carrier.

A graphical picture of this apparent increase in adjacent channel selectivity due to frequency conversion is shown in figure 14. The line A represents the percentage difference


```
1%
  A AT BROADCAST FREQUENCY

3.8 % AT 260 KC.
                  B

5.7 % AT 175 KC.
                      C

7.6 % AT 130 KC.
                        D

   1   2   3   4   5   6   7   8
  PERCENTAGE  DIFFERENCE
```
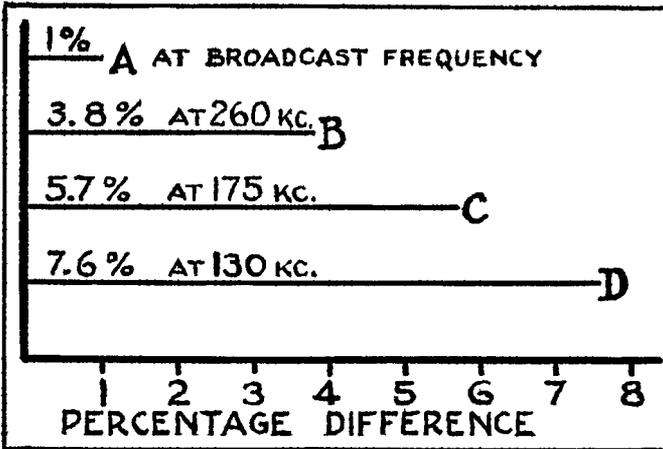
Fig. 14. The apparent increase in adjacent channel selectivity due to frequency conversion

between the desired and undesired carriers at the broadcast frequency. The line B represents the percentage difference between the two same carriers after frequency conversion to an intermediate frequency, both carriers being heterodyned by the same oscillator signal at the same frequency. With suitable design of the i-f transformers, so that they approximate flat-top band-pass characteristics, complete separation between the two stations is possible.

It is obvious that the percentage of frequency separation between two broadcast carriers is dependent upon the frequencies of the two carriers. Thus two broadcast stations operating upon 600 and 610 kc. respectively are separated by about 1.6 percent at the carrier frequency. When heterodyned to produce a 260 kc. i-f signal, the previously men-

tioned frequency separation is still existent, since the two
stations are still 10 kc. apart. If on the other hand, the de-
sired and undesired broadcasting stations are operating upon
1450 and 1460 kc., the frequency separation at carrier fre-
quencies is only about .7 percent, whereas after conversion,
the 3.8 percent remains. The advantage of increased adjacent
channel selectivity is secured in the superheterodyne, just
where it is needed, at the higher broadcast frequencies, where
the percentage of frequency separation is the lowest.

The importance of perfect adjustment of the r-f stages in
the superheterodyne is self-evident. Only by accurate adjust-
ment of trimmers is it possible to maintain the greatest
separation between two stations, at carrier frequencies. Every
attempt by perfect alignment to separate two adjacent chan-
nel broadcast carriers, which would tend to interfere, enables
more satisfactory operation of the i-f amplifier and more per-
fect freedom from adjacent channel interference. Two broad-
cast stations' carriers, which are separated by about 3 percent
in frequency, would be separated about 10 to 12 percent in
the i-f amplifier.

Calculation of the percentage difference between two beat
signals produced by a situation such as outlined, shows that
the numerical value of the beat note of the intermediate fre-
quency signal also displays an effect upon the ability to sepa-
rate two broadcast carriers operating upon adjacent channels.
Let us assume for the moment that instead of 260 kc., the
intermediate frequency is 175 kc. in one receiver and 130 kc.
in another receiver. Both receivers are confronted with the
problem of separating two broadcast carriers of 1000 kc. and
1010 kc. The separation in the r-f portion of the receiver is,
as has been stated, 1.0 percent. In the 175 kc. i-f amplifier,
the two beat notes are of 175 kc. and 165 kc. The difference
in frequency is only 10 kc., but the percentage difference now
is about 5.7 percent. In the case of the 130 kc. i-f system,
the percentage difference between the two stations is about
7.6 percent. These differences are shown graphically in figure
14, as lines C and D, representative of the percentage of fre-
quency separation in the i-f amplifier, operating at 175 kc.
and at 130 kc. for the 1.0 percent separation between the two

broadcast carriers. Obviously, the lower the frequency of the beat note or the value of the intermediate frequency, the greater is the ability of the receiver to separate stations operating upon adjacent channels. In other words, there is a definite gain in adjacent channel selectivity as the intermediate frequency is lowered.

It is because of this gain due to the frequency conversion, that it is possible to operate a superheterodyne receiver without any r-f stages, providing that the mixer input circuits are designed with care, so that they will operate at maximum efficiency. At the same time, it is well to state that another problem related to superheterodyne operation makes it impossible to operate with an exceptionally low i-f peak, in order to take advantage of maximum adjacent channel selectivity.

IMAGE FREQUENCY.

The problem referred to in the previous paragraph is known as the "image signal" or as the "image frequency." If you recall, we made the statement during the discussion of beat phenomenon that the heterodyning or beating signal can be lower or higher than the carrier frequency, and still develop any required beat or intermediate signal. These two carrier frequencies, which have such values as to beat properly against the heterodyning signal and produce the required beat, are the image frequencies for each other. In other words, if the desired carrier is 1000 kc. and the required beat or i-f signal is 130 kc., the heterodyning oscillator will normally be adjusted to 1000 kc. + 130 kc. or 1130 kc. By virtue of the beat action, there is another carrier, which, if present in the circuit, can beat against the 1130 kc. signal and produce the required 130 kc. signal. This frequency would be higher than the heterodyning frequency by the amount of the beat. In other words, if a 1260 kc. signal is also present when the 1000 kc. signal is present, both will be heard in the speaker, because both are being heterodyned. Because of the frequency relation between the 1000 kc. signal and the 1260 kc. signal and the 130 kc. intermediate, the 1260 kc. signal is the image frequency for the 1000 kc. signal, when the oscillator is

adjusted to beat at a higher frequency than the desired carrier.

The relation between the carrier frequency and the hetero-dyning signal frequency is quite important in determining the image signal or frequency. Only when the heterodyning sig-nal is *higher* than the desired carrier frequency by the value of the intermediate signal, is the image frequency higher than the desired carrier. In this case it is higher than the desired carrier by an amount equal to twice the value of the inter-mediate frequency. Thus, 1260 kc. is higher than 1000 kc., by 260 kc., which is twice the intermediate frequency of 130 kc.

An example of a different image frequency for the same 1000 kc. desired carrier is the following: Let us assume that the intermediate frequency remains at 130 kc. However, instead of operating the heterodyning oscillator at a frequency higher than the desired carrier, it is operating at a frequency *lower* than the desired carrier. Accordingly, this heterodyning oscillator would be tuned to 1000 — 130 or 870 kc. *The image frequency is that signal, which, when mixed with an 870 kc. signal, will produce the required beat.* This would be 870 — 130 or 740 kc. Thus we can have two image frequencies, depending upon the frequency relation between the desired carrier and the heterodyning oscillator. In the first case, with the heterodyning oscillator frequency higher than the desired carrier, the image signal for the 1000 kc. carrier and the 130 kc. intermediate is 1260 kc. In the second case, with the heterodyning oscillator adjusted to a frequency lower than the desired carrier, the image signal for the 1000 kc. carrier and the 130 kc. intermediate is 740 kc.

You can readily comprehend, that if the desired carrier is the 740 kc. signal, the intermediate frequency is 130 kc. and the heterodyning oscillator is operating at a frequency equal to the carrier plus the i-f, the image frequency is the 1000 kc. signal. This problem of image frequency, or image signal, exists in all types of superheterodynes irrespective of the carrier frequencies or wave bands covered or the value of the intermediate. However, as the intermediate frequency is increased, the image frequency moves further away from the desired carrier frequency, which is an aid, because it does not

place so much responsibility upon the r-f system, wherein it is easier to reject definitely an undesired signal which differs by a large amount from the frequency of the desired carrier.

For example, if we tuned in the 1000 kc. signal and the intermediate frequency was 260 kc. and the beating signal frequency was 1000 + 260 kc. or 1260 kc., the image frequency would be 1260 + 260 or 1520 kc., which is 520 kc. away from the desired carrier and incidentally is beyond the broadcast tuning range of a broadcast band receiver. The higher the intermediate frequency, the more easily can the image signal be eliminated, because it is easier to reject the undesired station in the radio frequency amplifier portion of the receiver. If the receiver does not employ an r-f amplifier, the selection of stations is governed by the tuning properties of the mixer input circuit. The higher the intermediate frequency, the easier is it to eliminate the image frequency, because the tuned input to the mixer is called upon to separate stations, which differ radically in frequency.

When speaking about image frequency problems in connection with superheterodyne servicing, be certain to determine first the frequency adjustment of the oscillator and the intermediate frequency. Without this information, it is impossible to establish the image frequency for any desired carrier frequency. Fortunately the common practice of operating the heterodyning oscillator at a value which is the sum of the desired carrier frequency and the intermediate frequency, simplifies the problem of determining the image frequency.

If we summarize the function of the r-f amplifier in connection with what has been said so far about adjacent channel selectivity and image frequency, we would say that the r-f amplifier functions primarily to eliminate image frequency and it is up to the intermediate frequency amplifier to produce the required adjacent channel selectivity, although the help of the r-f system in fulfilling the last named requirement is very necessary.

To combat image frequency troubles properly when the receiver is located in close proximity to a number of broadcasting stations, it is necessary that a very high order of

selectivity be maintained in the radio frequency amplifier or in the tuned input circuits of the receiver.

Experience has shown the existence of what we call, perhaps because of the lack of a better name, a second harmonic image. This is the signal which beats against the second harmonic of the oscillator, when listening to some carrier being heterodyned with the fundamental. Fortunately, this difficulty is not common and is found only in such localities where short wave, or the higher frequency, broadcasting stations operating in the broadcast band, are close to the receiver. Also when some trouble develops in the tuning system, so that its powers of selectivity are impaired. It may also occur when the i-f amplifier and oscillator systems are not properly aligned. (The i-f and oscillator systems receive separate mention later in this chapter.)

An example of such second harmonic difficulties is the following: The desired station is operated upon 570 kc. The intermediate frequency is 260 kc. The heterodyning oscillator is adjusted to 830 kc. The usual superheterodyne oscillator is quite rich in harmonics and has quite a strong 2nd harmonic, or 1660 kc. If this signal beats against an undesired 1400 kc. signal, which has found its way into the mixer circuit, and this undesired signal is quite strong, it will appear in the output as interference with the desired 570 kc. signal. The reason that the 1400 kc. signal appears in the output is because the frequency difference between 1660 kc. and 1400 kc. is 260 kc., or the value of the intermediate. It therefore is up to the r-f system or the tuned input system to keep all frequencies other than the desired signal frequency, out of the mixer stage.

Cross Talk.

Cross talk is the term applied to designate interference between signal carriers. Generally this phenomenon is brought about by faulty operation of the radio frequency amplifier tubes and by insufficient selectivity in the radio frequency amplifier. The first type of cross talk is that which appears in the form of a signal, which is received at some point on the tuning dial, where it does not belong; that is, the fre-

quency setting of the dial is not correct for the reception of the station. For example, if two stations, operating upon 740 and 1450 kc. respectively, reach the grid of an r-f tube, which is being operated near cut-off, with the volume control set for minimum, heterodyne detection will result in the production of a difference frequency signal of 1450 — 740 kc. or 710 kc. and this signal will be heard when the receiver is tuned to or near the 710 kc. point. If some other station is being received at the 710 kc. setting of the tuning dial, the heterodyne signal will interfere. If no desired station is on the air at the 710 kc. setting, the heterodyne signal will be audible.

An r-f tube operated as stated is functioning as a detector of weak signals. The heterodyne signal thus produced is passed through the coupling unit between the r-f tube and the mixer and is heterodyned in normal fashion by the receiver oscillator and is audible in the output. Such cross talk occurs frequently when insufficient selectivity is available in the r-f system or when the selective powers of the tuning unit located between the antenna and the mixer tube are not capable of rejecting all unwanted signals. The solution to heterodyne detection in the r-f tube is to increase selectivity so that at least one unwanted signal, if not both, will not be present in the circuit. Heterodyne detection will not take place with but one signal at the r-f tube grid. Another means of curing this difficulty is to employ such r-f tubes as will allow proper volume control without causing the tube to function near the cut-off point. Incidentally, cross talk difficulties of the aforementioned type have been partially eliminated by the use of variable-mu tubes in place of the regular triodes and screen grid tubes.

Another example of cross talk due to improper operation of the r-f tube and insufficient selectivity is the following: If the receiver is adjusted to 1400 kc. and the r-f tube is operated in such manner that detection takes place and another powerful unwanted signal finds its way to the grid of the r-f tube, the signals of the unwanted station will modulate the r-f variations due to the desired signal. This modulated desired signal will pass into the mixer tube and

will be heterodyned in normal fashion and will be audible in the speaker. Changing the operation of the r-f tube so that it is functioning as an amplifier and not as a detector and improving the selectivity so that the unwanted station is rejected is the only means of eliminating such cross talk or cross modulation.

Another form of difficulty, which may be experienced when r-f tubes are improperly operated and insufficient selectivity exists, is the production of harmonics within the r-f tube, of the powerful unwanted station, and reception of this station upon two points of the tuning dial. This "repeat" point has nothing to do with the repeat point occasioned by the beat phenomenon, and which will be described later. For example the signal of a very strong station operating on, say, 580 kc. will find its way to the grid of the r-f tube. If this signal is sufficiently strong to cause a normally operating tube to swing positive or if the tube is improperly operated as a detector, instead of an amplifier, a signal equal to 580 $\times$ 2 or 1160 kc. will be present in the plate circuit. If the receiver is tuned to 1160 kc., so as to listen to some station actually operating upon that frequency, the powerful unwanted local station will also be heard. If there is no station operating upon 1160 kc., then the powerful 580 kc. local station will be audible when the receiver is tuned to 580 kc. and also when it is tuned to 1160 kc. No amount of tuning adjustment will eliminate the 1160 kc. station, as long as the 580 kc. signal finds its way to the grid of the input tube and the tube is functioning in such manner as to produce harmonics in the output circuit.

Still another type of cross talk is that which appears as an interfering signal present when the desired station is transmitting an unmodulated carrier, that is, during the time between actual studio program transmissions. One situation is the presence of two different local stations operating upon slightly different frequencies, in the input circuit. Even if the desired station is much more powerful than the undesired station, during the time that the desired station has its microphone "off the air," the signal of the undesired station will modulate the unmodulated carrier of the desired station and

the signal will be audible. However, if the desired station goes off the air, that is, its carrier is no longer transmitted, the unwanted station disappears. This phenomenon has been experienced with local as well as distant stations and does not
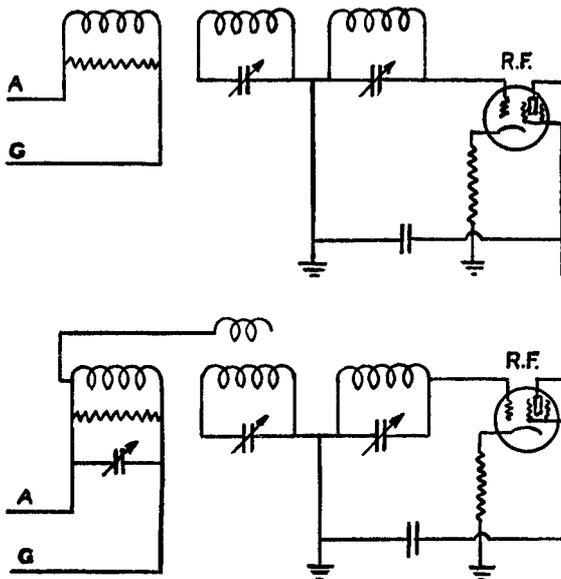
Figs. 15 and 16. R-F. Amplifiers

seem to be dependent upon detector action in the r-f tube. It is, of course, much more prevalent under such conditions. The most practical remedy under all conditions is improved selectivity.

One form of cross talk develops in superheterodyne receivers when an undesired station, operating at a frequency close to that of the desired station, finds its way to the mixer and the output of the heterodyning oscillator is low. By advancing the oscillator output, so that the resultant signal voltage, consisting of the heterodyning signal and the desired signal, saturates the mixer tube, it is possible to drive its sensitivity so low that the undesired signal is not heard. Such cross talk

is to be expected more with receivers that do not employ a pre-selector stage, than with those that employ such a pre-selector. Accompanying such cross talk is a decided drop in normal output, because of the reduced oscillator signal output.

Radio Frequency Amplifier Circuits.

The types of radio frequency amplifier circuits used in superheterodyne receivers differ in but small measure from
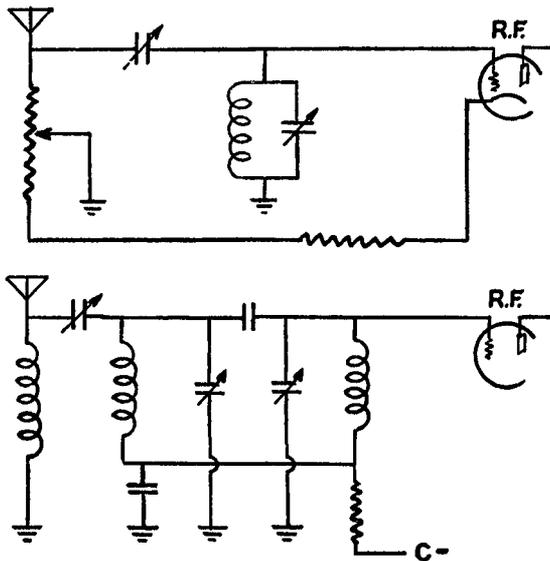
Figs. 17 and 18.   Examples of R-F. Amplifiers

those employed in tuned radio frequency receivers. Examples of modern radio frequency coupling circuits are shown in figures 15, 16, 17, 18, 19, 20, 21 and 22. In each case the circuits are used in existing commercial superheterodyne receivers. The r-f systems in figure 15 to 22 inclusive show the use of the coupling units between the antenna and the pre-selector r-f stage. It is possible to consider these systems as also being in use between the r-f tube and the mixer circuit and also between the antenna system and the mixer, in which

case, the r-f tube is omitted, but the r-f transformer is still in use. As is evident, all of these circuits are intended for operation upon a single frequency band, that is either short
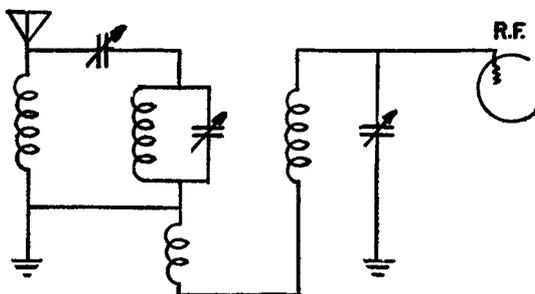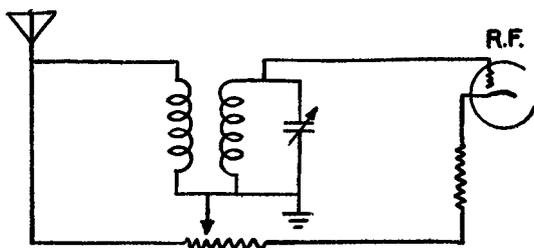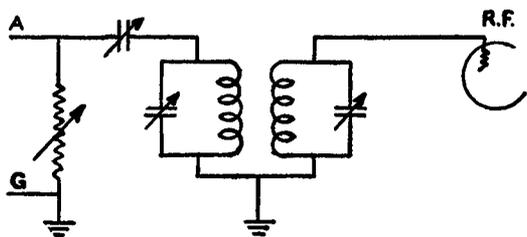
Figs. 19, 20 and 21. R-F. systems with volume control

wave, long wave or broadcast, but one band only. In substantially every case, several resonated circuits are employed so as to provide the maximum amount of selectivity.
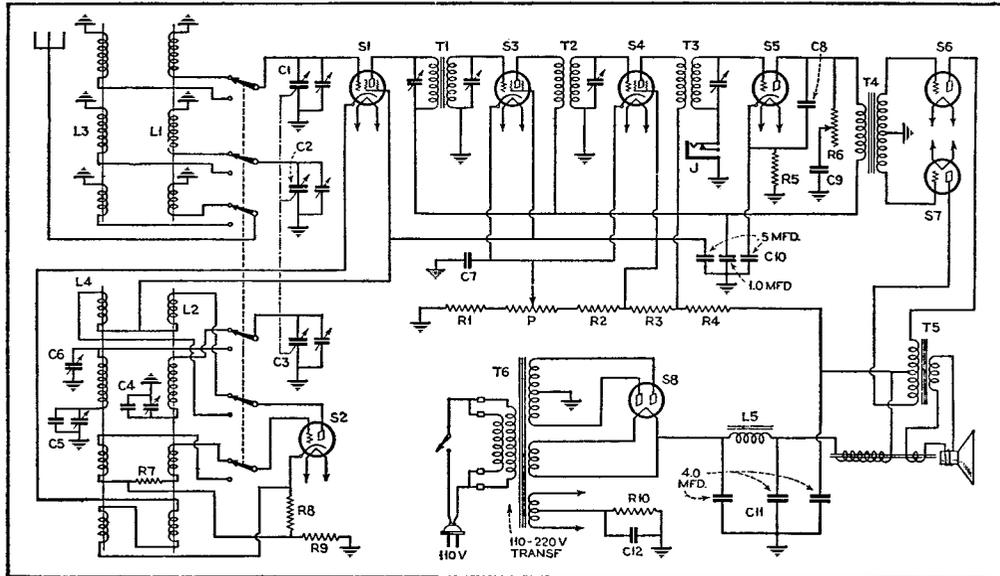
Fig. 23. Superheterodyne with linked multi-wave radio-frequency arrangement. See three upper coils on the left

Multi-wave receivers employ the simple type of tuned circuit, with some arrangement whereby selection of the proper coils for each band is achieved. An example of a linked multi-wave r-f arrangement is shown by the three upper coils in figure 23. This is the schematic of a complete superhetero-
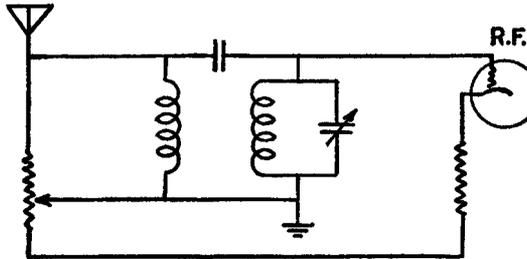
Fig. 22. The manual volume control in the antenna circuit of the above r-f. stage controls the bias on the grid of the radio-frequency amplifier

dyne receiver, but only the three r-f coils are of interest to us. The receiver is intended to cover two wave bands. The windings directly beneath the two designated as L-3 and L-1 are the antenna windings. The two coils L-3 and L-1 are tuned by condenser C-2 and constitute the link circuit between the antenna and the mixer tube input circuit. The tuned circuit located in the mixer tube grid system consists of the coils directly above L-3 and L-1 and the tuning condenser C-1. The equivalent r-f transformer for a complete set of coils as used in figure 23, is shown as figure 15, except for the fixed resistor across the antenna coil.

Instead of using individual tuned coils in the r-f transformers of multi-wave systems, some receivers make use of tapped windings. The switches controlling the wave length or frequency range, contact the taps upon the coils. For actual circuits of the r-f transformers employed in multi-wave superheterodynes, we refer you to the section devoted to wave-changing arrangements.

Neutralized Radio Frequency Amplifiers.

Some of the older superheterodyne receivers made use of several neutralized stages of tuned radio frequency amplification. Special discussion is not necessary in as much as the process of neutralization of these stages is exactly as carried out for neutralized t-r-f receivers.

Regenerative Radio Frequency Amplifiers.

Regeneration in the radio frequency amplifier deserves attention. Not because it is common practice to arrange a regenerative control in this part of the receiver, although such features have been used in some of the older receivers, but because it pays to stress the fact that such regeneration should be avoided. The presence of a certain amount of regeneration augments the sensitivity of the system, but if regeneration is carried to extreme, tone quality will be impaired to a very marked degree and the receiver as a whole will prove very unstable.

Volume Control in Radio Frequency Amplifiers.

An examination of figures 15 to 22 will afford an idea of the types of manual volume control circuits, which were used in the early superheterodynes released soon after their commercial acceptance for broadcast reception. The modern receiver makes use of automatic volume control, but the problems which beset superheterodyne receiver operation, because of incorrect manipulation of the manual controls in the r-f circuit, are still of importance. In many instances dual forms of control were used. The manipulation of the control simultaneously varied the r-f tube control grid bias and also varied the signal voltage across the coil in the antenna system or coupled to the antenna system.

Control grid bias and screen grid bias variation forms of manual volume control were applied to the early types of superheterodyne receivers and resulted in the difficulties mentioned as cross talk. This was particularly true when ordinary triodes or the conventional type of screen grid tubes, were used. The adoption of the variable mu tube, resulted in

definite improvement, but there are still in use a number of
the older receivers employing the '27 and '24 type of tube. It
is for the benefit of those who may be called upon to service
these receivers, that we suggest the use of r-f volume controls
in the antenna circuit, when the receiver employs type '27
tubes in the r-f system, and the use of variable mu tubes in
place of the '24s. Automatic volume control, old and new,
is discussed at length in a separate chapter devoted to that
subject.

Image Frequency Control Circuits in R-F Transformers.

Some r-f transformer units, usually employed between the
antenna and the mixer tube, contain special arrangements
intended to minimize image frequency type of signal inter-
ference. The presence of the special circuit is occasioned by
the fact that the r-f tube and its associated tuning circuits
are omitted. Since it is the function of the r-f system to
provide freedom from image signals, omission of the r-f tube
and its associated tuning circuits requires that some special
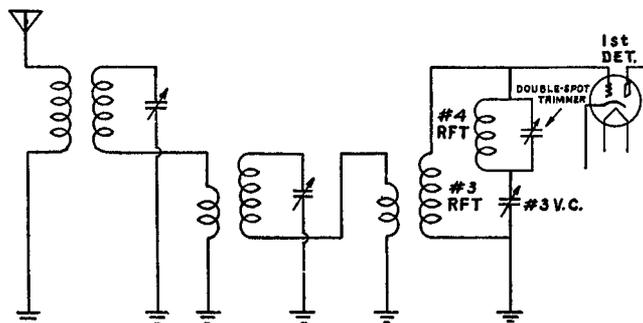
Fig. 24. The double-spot circuit for minimizing image frequency
interference

means be provided in the coupling circuit used between the
antenna and the mixer. One such circuit is shown in figure
24. This is the arrangement known as the "double spot"
circuit utilized by Atwater-Kent in some of their superhetero-
dyne receivers, particularly in the 70, 72, 74, and 76 series.
Full instructions covering the alignment of this circuit is to be

found in the chapter devoted to alignment and general appli-
cation of test oscillators.

As is evident, three tuned circuits are employed in this r-f
coupling assembly in order to secure the maximum amount
of selectivity at the carrier frequency. The combination of
No. 3 r-f transformer and the double spot unit (No. 4 r-f-t)
and the two associated condensers constitute a double tuned
circuit, that is, a circuit simultaneously resonant to two fre-
quencies. The complete circuit is made resonant to the de-
sired carrier frequency. This circuit tracks with the tuning
condensers of the antenna r-f transformer and the link r-f
transformer. The circuit consisting of the No. 4 r-f trans-
former and the double spot trimmer are made resonant to the
image frequency. Bear in mind that the double spot circuit
is also a part of the No. 3 r-f transformer circuit, which is
resonant with the desired carrier, but the double spot circuit
by itself is resonant with the image frequency only. In a
sense the double spot circuit is a trap, which keeps signals of
this frequency out of the complete circuit, hence from being
applied to the control grid of the mixer or 1st detector tube.
To accomplish this end, this circuit is tuned to a frequency
equal to the broadcast carrier frequency plus twice the inter-
mediate frequency.

The receivers which employ this double spot circuit have
intermediate frequency amplifiers peaked at 130 kc. Further-
more, the heterodyning oscillator is adjusted to operate at the
proper frequency higher than the received carrier. Accord-
ingly, the double spot circuit is adjusted to track with the
other pre-selector condensers, but the double spot circuit is
always tuned 260 kc. *higher* than the frequency of the pre-
selector circuits. Thus, if the pre-selector circuits are tuned
to 910 kc., the double spot circuit is automatically adjusted
to the image frequency of 910 kc., which is 1170 kc. This
frequency difference of 260 kc., between the pre-selector and
the double spot circuits, *with the double spot circuit 260 kc.
higher than the pre-selector circuits, is always maintained,
irrespective of the frequency setting of the pre-selector cir-
cuits, that is, the tuning dial of the receiver.*

Another type of image frequency suppressor circuit, usually used when the r-f stage is omitted, is shown in figure 25. The circuit is properly resonated to the desired carrier frequency. By virtue of the tap upon the winding, the circuit

Fig. 25. By the tap in the radio-frequency coil, the circuit suppresses interference caused by the image frequency signal
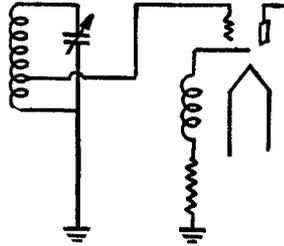
successfully suppresses the image frequency. Naturally the position of the tap is governed by the circuit constants and the intermediate frequency used in the receiver.

THE MIXER TUBE.

The function of this tube in the superheterodyne receiver has been mentioned several times. It serves to combine or mix the broadcast carrier signal with the locally generated heterodyning signal. This tube is known by many names, among which are mixer, 1st detector, frequency changer, translator and even demodulator, although, there is but partial concurrence upon the last named term, particularly in view of the fact that many engineers refer to the tube as a modulator, in direct contrast to the term, demodulator. Since space does not permit an exposition of the exact process taking place within this tube, under different conditions, we shall consider the tube essentially as a frequency changer, and stop there.

It is customary to speak about the resultant signal voltage developed within this tube, by virtue of the mixing process, as the difference in frequency between the received broadcast carrier and the locally generated heterodyning signal. A complete statement of the frequencies present in the output circuit of the mixer tube, must include the sum frequency as

well as the difference frequency and also harmonic frequencies, particularly of the difference frequency.

The mixer tube is associated with one of the advantages afforded by the superheterodyne signal. This is, that the i-f signal intensity is not controlled solely by the amplitude of the received broadcast carrier. In other words, the mixing process results in an increase in i-f signal output, consequently in total signal output. This does not mean that the presence of a strong heterodyning signal, beating against a weak carrier, is going to cause an increase in signal output, which is directly proportional to the amplitude of the heterodyning voltage. Actually the amplitude of the difference frequency or i-f signal is more dependent upon the amplitude of the broadcast carrier. However, the fact that a strong signal has been mixed with the weaker broadcast carrier does provide an advantage. Experiment has shown that this gain, due to the mixing process, assuming that the heterodyning voltage is several times as strong as the carrier voltage, amounts to between 15 to about 25 percent. This statement is particularly true in the case of linear detection in the mixer tube, which, as it happens, is the usual method employed, because of the condition that the heterodyne signal voltage is of substantial amplitude. By linear detection is meant detection which produces a rectified output current that is directly proportional to the signal being rectified. The general run of single function mixer circuits employed in modern-day receivers resemble everyday grid bias type of detector systems. Some of the earlier superheterodynes employed grid condenser-grid leak types of 1st detectors or mixers, but these have been replaced with what can be classified as being a strong signal detector.

There are to be found in use today a number of different types of mixer circuits. These systems differ in function as well as circuit. For the sake of clarity, we shall discuss those mixer systems which are also performing the role of oscillators, namely autodyne circuits, separately from the single function mixers. Speaking about types, it is of more importance to dwell upon circuit variations than upon tube variations. Substantially every single function mixer is like any other single

function mixer, despite the fact that the tubes used may differ in these types and the possible location of the coupling unit, linking the mixer with the separate oscillator, may be differently located.

Single Function Mixer Circuits.

By single function is meant a system, which acts to mix the broadcast carrier and the heterodyning signal, thus performing a single function, in contrast to dual function autodyne type mixers, wherein the tube acts not only as a mixer of the broadcast carrier signal and the heterodyning signal, but also generates the heterodyning signal.

Figure 26 illustrates a typical single function mixer system employing a triode tube. Very little discussion is required. The coil designated C.C. serves to couple the mixer to the separate oscillator or heterodyne signal generator. In some
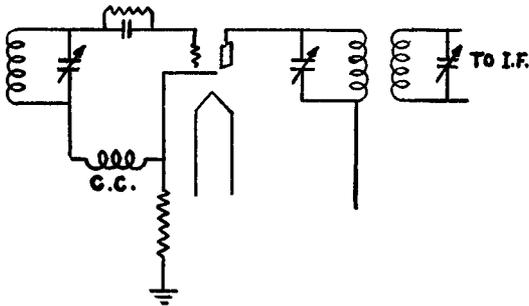
Fig. 26. A single-function mixer circuit using a triode

of the older superheterodyne receivers, this coupling coil was located in the high end of the grid circuit. In later models it was altered to where it is shown. In many modern receivers, employing tubes of this type, the coupling coil is located in the cathode circuit of the mixer; that is to say, the coupling coil is shown wired into the cathode circuit. Its actual physical location is within coupling relation to the oscillating system, so that the heterodyning signal will be properly fed to. the mixer.

Another example of a single function mixer system employing the screen grid tube is shown in figure 27. With the exception of the difference in tubes, the omission of the grid leak and grid condenser and the placement of the coupling coil, figures 26 and 27 are substantially the same. In both instances, the resistor in the cathode circuit provides the fixed bias. The tuned winding in the plate circuit of both tubes is the primary of the i-f transformer.

Variations of coupling the heterodyne oscillator to the
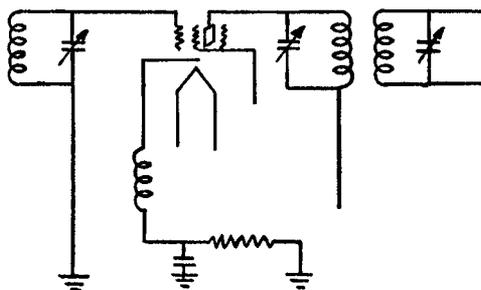
Fig. 27. A single-function mixer circuit employing
a screen-grid tube

mixer tube are along the following lines. In some instances, the oscillator signal is fed to the mixer via a series resistor-capacitor arrangement connected between the oscillator control grid and the mixer control grid. In other instances, when the mixer tube is of the screen grid variety, the coupling coil is wired into the screen circuit. In still other systems, the coupling is via a small fixed condenser connected between a tap upon the oscillator grid coil and the cathode of the mixer tube. In some battery operated systems, the coupling coil is wired into one of the filament leads of the mixer tube.

Simple single function mixers, which employ pentode tubes, would be similar in structure to the circuit shown in figure 27. It is possible that the coupling coil would not be located in the cathode circuit. If design permitted, it might be linked to the oscillator at some point along the input winding, which is resonated to the broadcast carrier. The fact that a

single tuned input circuit is shown in these mixer systems does not establish that only one resonant circuit is used. It is possible that this tuned input circuit may be a part of a three winding r-f transformer with a tuned link circuit between the mixer input circuit and the tube preceding the mixer or the antenna system.

These schematic diagrams of single function mixer systems are offered purely as general reference data. It is very likely that the actual circuit used in the receiver contains many more units, such as resistors and bypass condensers. These circuits are to be viewed from the angle of type, rather than actual detail of the components to be found in specific receivers. In view of what was said earlier in this text, we wish to call to your attention that maximum selectivity is attained, because the input circuit is accurately resonated to the broadcast carrier frequency.

Incidentally, while speaking about mixer circuits, we might mention that tone quality is, in a measure, influenced by the operating potentials applied to these tubes, because of the effect created upon the modulation components of the broadcast carrier frequency. Incorrect operating potentials applied to the mixer tube may create a condition which is the equivalent of a change in the percentage modulation of the received carrier. It is also significant to note that the adjustment of the intermediate frequency transformer, connected into the plate circuit of the mixer, is of great importance with respect to the intensity of the i-f output and the presence of the required modulation sidebands. No amount of adjustment of the i-f transformers, connected in the plate circuit of the i-f tube, will help, if the adjustment of the i-f transformer in the mixer plate circuit is imperfect. These facts are applicable in general to all types of mixer tubes and not only to the two simple single function systems shown in figures 26 and 27.

Autodyne Mixer Systems (Dual Function).

One of the simplest forms of mixer circuits is the autodyne arrangement, wherein the tube performs a dual role. It acts simultaneouly as a mixer and also as an oscillator, to provide the heterodyning signal. This is possible, because the vacuum

tube possesses the property of simultaneously acting as a detector tube and as an oscillator. Its operation as an oscillator depends upon proper feedback or interaction between the plate circuit and the input circuit or at least some other circuit in the same tube, which is associated with the electronic stream passing to the plate. If the autodyne circuit is of the conventional variety, wherein the plate and grid circuits are coupled and the coil in the grid circuit comprises the tuned oscillatory circuit, oscillations will start when the feedback reaches a magnitude which is sufficient to overcome the effective resistance of the tuned circuit in the grid circuit, and these oscillations will heterodyne with whatever other signals find their way into that circuit. The resultant beats are rectified in the detector tube and the difference-frequency currents in the output circuit develop the difference-frequency voltage across whatever unit is connected in the plate circuit.

An example of an early autodyne type of mixer, employing a simple triode is shown in figure 28. Tube D is the combination mixer and oscillator. The plate coil is coupled back
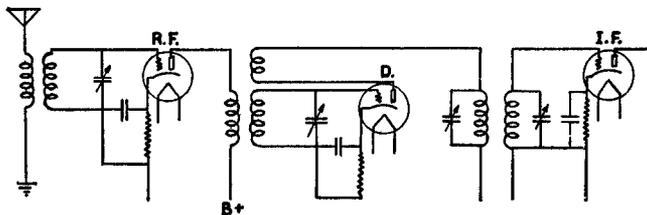
Fig. 28. An early type of autodyne mixer employing a triode tube

to the tuned grid coil. The tuned circuit functions as a part of the heterodyning oscillator circuit and also as a part of the detector circuit. The tuned winding in the plate circuit of the tube D is the primary of the intermediate frequency transformer. The difference-frequency currents in the plate circuit develop a maximum voltage across this i-f transformer primary, because the winding is resonated to the difference or i-f frequency. The resonant frequency of the tuned circuit in the grid circuit of the autodyne tube is determined by the frequency of the heterodyning oscillations required to beat

against the received carrier and to produce this beat or i-f signal. This means that if the received carrier is 1000 kc. and the required beat is 175 kc., the tuned circuit in the grid will be resonated at 1000 + 175 kc. or 1175 kc. Irrespective of the frequency of the desired carrier, the adjustment of the oscillating system is always 175 kc. higher than the frequency of the broadcast carrier. This system has been used for many years in the short wave amateur field for code reception. Actually it is better suited for such work than for normal broadcast operation at the usual intermediate frequency values, for reasons which will be stated below.

Since the input circuit of the autodyne mixer is resonated to the heterodyning signal frequency, it stands to reason that the circuit is detuned from the frequency of the received broadcast carrier. Consequently, the amplitude of the broadcast carrier signal voltages developed across the tuned circuit is less than would exist at perfect resonance. Consequently, there is a certain loss encountered at this point. However, a part of this loss is offset by the fact that there is existent a certain amount of regenerative amplification. Furthermore, the effective resistance of the tuned circuit is somewhat lower than would normally exist if the tube were not oscillating. The exact amount of loss due to detuning and the amount of compensation secured by virtue of the actions stated is not of importance at this time. Of far greater importance is the possibility of interference from some station which is operating upon a frequency not far removed from that of the desired station. Since the heterodyning signal developed in the tube will heterodyne any and all frequencies which get into the tuned circuit, it is imperative that proper pre-selection be available ahead of the autodyne tube, otherwise interference may be very pronounced.

The problem of interference due to the presence of unwanted signals is greatly influenced by the numerical value of the intermediate signal. Obviously, the higher the i-f peak, the more distant is the resonant frequency of the autodyne tube input circuit from the desired broadcast carrier. If operation were carried on at 25 or 50 kc. intermediate fre-

quency, then the percentage of detuning at 550 kc. would be between 5 and 10 percent respectively, and at about 1500 kc. it would be slightly less than 2 percent and slightly more than 3 percent respectively. However, if the intermediate frequency is 175 kc., or perhaps 260 kc., the percentage of detuning is quite appreciable. At 550 kc. and with a 175 kc. intermediate, the percentage of detuning would be almost 32 percent. With a 260 kc. peak, it would be about 47 percent. The degree of detuning over the normal broadcast band with 175 kc. or 260 kc. intermediates would be extremely high. However, over the short wave band, it would be quite satisfactory to operate in this manner, because the extent of the detuning for a 175 kc. peak (175,000 cycles) at say 12,000 kc. or 12,000,000 cycles, is only about 1.5 percent. A 260 kc. peak at the same carrier frequency means detuning of slightly more than 2 percent.

The reception of code signals, where a 1000 cycle beat is required, is possible with great satisfaction with an autodyne mixer-oscillator. The low difference frequency means that the oscillating circuit is tuned to almost the received carrier frequency. A very high degree of selectivity is available, even without any pre-selector circuits.

Summarizing the simple autodyne mixer-oscillator in a superheterodyne, we can see the need for definite and positive pre-selection. We can see the suitability of the system when the intermediate frequency is low, so that minimum interference will develop in the mixer input circuit. However, a low intermediate frequency spells trouble from image frequency. On the other hand, a high intermediate frequency spells trouble from the viewpoint of interference and reduced sensitivity because of the greatly detuned state of the mixer input circuit. The most satisfactory solution is that which seems to have been taken by many manufacturers, namely, the use of a separate tube for the mixer function and another tube for the oscillator function. The recent development of the single envelope multi-tubes has strengthened this opinion very much.

From the angle of alignment of such an autodyne system, it is obvious that the entire circuit must be intact. There is

no r-f alignment, because the tuned circuit is resonated to the heterodyning frequency. If there is to be any alignment of such a system, it must be done in conjunction with alignment of the r-f stages. Judgment upon the oscillator tracking can be made only by passing the difference frequency or i-f signal into the intermediate frequency amplifier and checking the total signal output from the receiver. This means that the i-f stages must be perfectly aligned at the required frequency, otherwise tracking of the heterodyning signal circuit will not be perfect. The original test signal for the oscillator circuit tracking is a regular broadcast signal, such as is used for r-f circuit adjustments. The i-f circuits can be aligned at the intermediate frequency, which signal is fed into the control grid of the mixer oscillator tube. For such alignment, the autodyne tube need not be connected to the oscillating circuit, providing that the source of the i-f signal makes it possible to apply the required control grid bias to the autodyne tube. For that matter, it is possible to feed the i-f signal into the autodyne tube without any changes. While it is true that a beat note will be produced in the output of the tube, only the required i-f signal will appear across the i-f transformer in the tube output circuit, because this winding is resonated to that frequency.

Lecault Mixer.

A unique type of mixer is shown in figure 29. This circuit never appeared in commercial superheterodynes, but was used
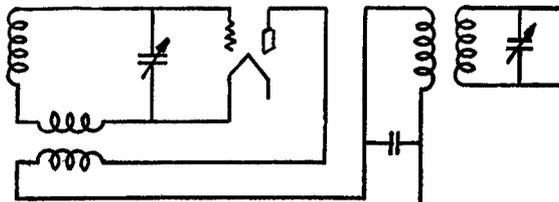
Fig. 29.   The voltage developed across the oscillator coil is applied to the mixer tube's plate

in an extremely popular kit receiver of the superheterodyne variety. In this system, the plate of the mixer tube is joined

with one end of the oscillator coil and the voltage developed across the oscillator coil is applied as the plate voltage to the plate of the mixer tube. As is evident from figure 29, this voltage is also coupled to the tuned input circuit of the mixer tube. Referring to figure 29, the open end of the i-f transformer primary joins one end of the oscillator tube grid coil, neither the tube or coil being shown in the schematic. The i-f frequency developed in the output circuit of the mixer is applied to the i-f transformer.

Second Harmonic Type Autodyne Mixer-Oscillator.

Another early form of autodyne mixer is employed in the second harmonic type of superheterodyne. This system was used in a number of RCA and Brunswick superheterodynes several years ago. In circuit arrangement, the system is somewhat similar to the conventional autodyne of figure 28, but is sufficiently different to overcome some of the faults of the simple arrangement. Figure 30 illustrates the second harmonic type of circuit. The primary difference between this and the previously mentioned arrangement is that the input circuit of the mixer is tuned to resonance with the incoming carrier, so that maximum selectivity is obtained. This is made possible by utilizing a dual tuned input circuit. One circuit is tuned to the broadcast carrier. The other circuit in the input side of the tube is coupled to the plate feedback coil and con-
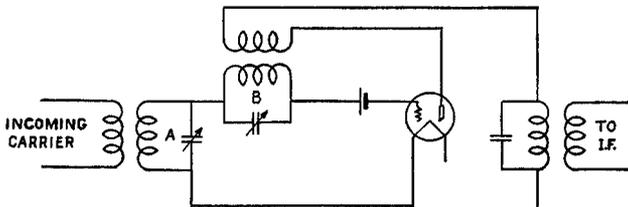
Fig. 30. The second harmonic type of autodyne mixer

stitutes the oscillating system. This oscillatory circuit is resonated to produce a fundamental frequency which is exactly half of the heterodyning frequency, as determined by

the peak of the intermediate frequency transformer, located in the plate circuit of the autodyne mixer.

Circuit A is resonant to the received broadcast carrier, thus establishing maximum selectivity. Circuit B is tuned to the fundamental heterodyning frequency, which, of course, is a variable, depending upon the received broadcast carrier and is tracked with the r-f tuning condenser. However, the frequency which heterodynes the broadcast signal is not the fundamental frequency as determined by the tuning of circuit B. Instead, the second harmonic of this fundamental beats against the received carrier and produces the required 50 kc. intermediate frequency. A numerical example is as follows: let us assume that the broadcast carrier is 1100 kc. The intermediate frequency signal required is 50 kc. This means that the heterodyning signal frequency should be 1100 + 50 or 1150 kc. Now, the heterodyning frequency is actually the second harmonic of the fundamental signal, being produced in the oscillating circuit, so that the fundamental is 575 kc. and this is the resonant frequency of circuit B, when circuit A is tuned to 1100 kc.

As you no doubt realize, the fundamental heterodyning signal of 575 kc. is also beating against the 1100 kc. broadcast carrier. However, this difference frequency does not appear in the i-f system, because that system is resonated to 50 kc., the frequency difference between the 1100 kc. broadcast carrier and the second harmonic of the 575 kc. heterodyning signal. Higher harmonics of this fundamental are also beating against the broadcast carrier, but do not appear in the intermediate frequency amplifier, because of the reasons stated. If the broadcast carrier has a frequency of 610 kc., the fundamental frequency of circuit B is 330 kc. or one-half of the 660 kc. signal required to produce the 50 kc. beat. In all of the discussion concerning this second harmonic system, we are taking for granted that the heterodyning signal has a frequency *higher* than the broadcast carrier. If the heterodyning frequency is *lower* than the broadcast carrier, the fundamental frequencies would be 50 kc. lower than the values quoted.

Referring to figure 30, the winding coupled to circuit B is

the plate feedback coil, responsible for the production of oscillations in the circuit. The winding shunted by a fixed condenser, located in the plate circuit of the autodyne mixer, is the resonated i-f transformer primary.

Viewed from the service angle, alignment of this mixer stage would be somewhat along the following lines: the i-f stages are aligned by applying a test voltage at the intermediate frequency to the autodyne tube through a break-in adapter to the control grid, so as to isolate the receiver tuning circuits in the grid system. Proper provisions are made for the application of the bias voltage. After the i-f circuits are known to be in tune, an external r-f signal at some broadcast band frequency is applied to the control grid of the autodyne tube, via a small coupling condenser. During this test, the oscillator portion of the autodyne circuit must be in operation. Circuit B then is aligned for maximum output from the receiver. Then an r-f signal is fed into the receiver proper and circuit A aligned for maximum resonance and output.

Dynatron Autodyne Mixer-Oscillator.

A fairly recent, although not generally applied type of autodyne mixer-oscillator is the dynatron oscillator arranged to function also as a mixer. The use of the screen grid tube and the application of such potentials that this tube serves as a dynatron oscillator, will receive additional mention during the discussion about oscillators. However, since the tube has been used as a combination mixer and oscillator, we feel that it should be included at this time; still, we cannot fail to recognize that by virtue of the manner in which this tube is used as a combination mixer and oscillator, it belongs in the dual tube-single envelope grouping. This statement is made with full recognition of the fact that the tube, usually a 24 or 24-A is but a single tube, with but one complete set of elements. On the other hand, due to the manner in which the tube is employed, that is, the regular plate as the anode for one function and the screen as the anode for another function, we are inclined to recognize it as the forerunner of the present-day dual tube-single envelope type of vacuum tube. Once more we will qualify the statement by saying that we are

familiar with the fact that the condition productive of oscil-
lations in the dynatron does not exist in the dual tube-single
envelope type of vacuum tube. Accordingly, we will com-
promise with ourself by showing the dynatron oscillator, as
such among the oscillators, and make brief reference to the
dynatron mixer-oscillator when speaking about tubes such as
the 6A7.

Figure 31 illustrates the use of a screen grid tube as a dyna-
tron oscillator and mixer. The dynatron characteristic is re-
lated to the oscillator portion only and not to the mixer part
of the complete circuit. Although it is not shown in the
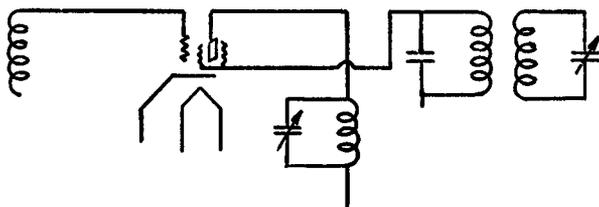
Fig. 31. A screen-grid tube is here used as a dynatron oscillator
and mixer

schematic, the winding connected to the control grid of the
tube, should be assumed as being properly tuned to the broad-
cast carrier frequency. According to the schematic wiring
diagram, the mixer portion consists of the control grid, cathode
and screen grid. The oscillator portion consists of the cathode,
control grid, screen and plate, although the actual oscillatory
circuit is located in the plate circuit only and the conditions
which determine the state of oscillation are existent in the
screen and plate circuits. The ability of developing sustained
oscillations in the parallel resonant circuit located in the plate
circuit of the tube is dependent upon the creation of a nega-
tive resistance state in the plate circuit. This is accomplished
by maintaining certain operating potential relations between
the screen grid and the plate of the tube, all other potentials
remaining constant. A more complete exposition of the ac-
tion of this tube as an oscillator follows later when the dyna-
tron oscillator, as an oscillator, is discussed.

In the meantime, we shall assume that the proper oscillatory state is created and that the frequency of the heterodyning signal, determined by the fundamental frequency of the tuned circuit in the plate circuit of the tube, is of the correct value so that the proper beat note is produced across the i-f transformer primary shown in the screen circuit. Naturally this frequency voltage is developed across the i-f transformer primary because of the difference-frequency current flowing in the screen circuit. The difference-frequency current is the resultant of the presence of the broadcast carrier current and the oscillator circuit current. Incidentally, in contrast with the normal vacuum tube oscillator, which requires the presence of two coils coupling two circuits in order that oscillations be generated, the dynatron characteristics of the screen grid tube, make such oscillation generation possible with only one coil.

Modern Autodyne Mixer-Oscillator Systems.

There are to be found in use today a large number of similar, yet different arrangements of autodyne mixer-oscillator arrangements. Substantially, all are alike, yet there are enough peculiarities to be found in these systems to justify the presentation of some of them. Nothing is to be gained by showing a schematic of each and every circuit, which is different from another, since visual inspection of the receiver itself will not provide any illuminating information concerning the exact circuit used. In each and every case, it is necessary to refer to whatever service data and schematic specifications are available. For such data, we recommend Rider's "Perpetual Trouble Shooter's Manual." What we are interested in achieving is to afford for your guidance a cross-sectional view of autodyne mixer-oscillators of modern vintage. You will see that they are very definitely different from the early arrangements and that every effort has been made to overcome previous disadvantages.

Figure 32 shows a type 36 tube used as a combination mixer

and oscillator.   This is an exact reproduction of this part of the schematic wiring diagram of the Electric Auto-lite 062-A receiver.   The input of the mixer is coupled to the preceding
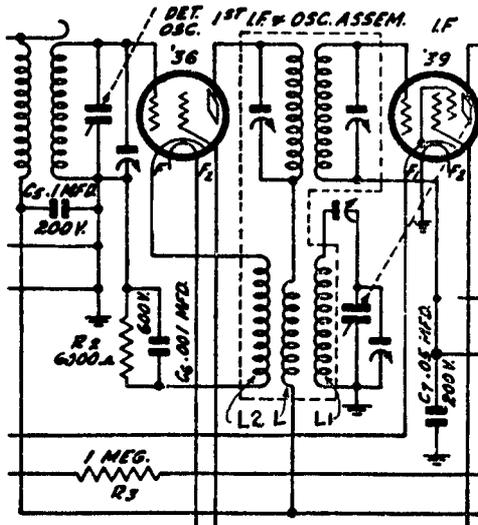
Fig. 32.   An example of a screen grid tube used as a
mixer and oscillator
(Courtesy Electric Auto-Lite Co.)

r-f tube through an r-f transformer.   The plate circuit of the tube contains the tuned i-f transformer primary and the plate coil L.   This coil L is coupled to the winding L-2 located in the cathode circuit of the autodyne tube.   This coupling furnishes the link between the input and output circuits.   The resonance of the feedback circuit is controlled by the frequency setting of the "tank" circuit consisting of the winding L-1, tuned by its associated condensers.   The tuned i-f transformer primary affords a very low impedance to the flow of the oscillatory current through the plate circuit.   On the other hand, the difference-frequency signal voltage, produced as a result of the mixing, develops the maximum signal voltage

across the i-f transformer primary and is not influenced by either L or L-1, despite the fact that L-1 is coupled to L.

Another version of a similar circuit is shown in figure 33. This is used in the TCA AC-340 receiver. The input circuit of the autodyne mixer-oscillator is coupled to the r-f tube
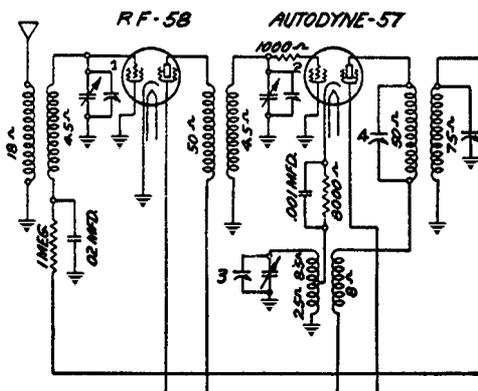
Fig. 33. The 57 tube functions as a mixer and
oscillator. Note coil arrangements
(Courtesy Transformer Corp. of America)

through a conventional tuned radio frequency transformer. The output circuit contains the primary of the i-f transformer and the plate coupling coil. This coil is in turn coupled to a tuned circuit, which in turn contains a coil, part of which is in series with the cathode. Thus the resonant frequency is determined by the fundamental period of the resonant circuit coupled to the cathode. At the same time, the portion of coil which is in the cathode circuit, acts as the link whereby the heterodyning signal is fed into the mixer tube.

The schematic wiring diagram of the Majestic model 400-A receiver, shown in figure 34, contains a somewhat unconventional arrangement in the autodyne mixer-oscillator. The mixer portion is like the rest, but the oscillator section differs from the usual. The plate winding contains the plate feedback coil in series with the primary of the first i-f transformer. The oscillator feedback coil is coupled to a tuned circuit con-

sisting of L-1, C-11, C-12 and the other associated condensers. Note that the tuned portion of the oscillator system is connected into the suppressor circuit.
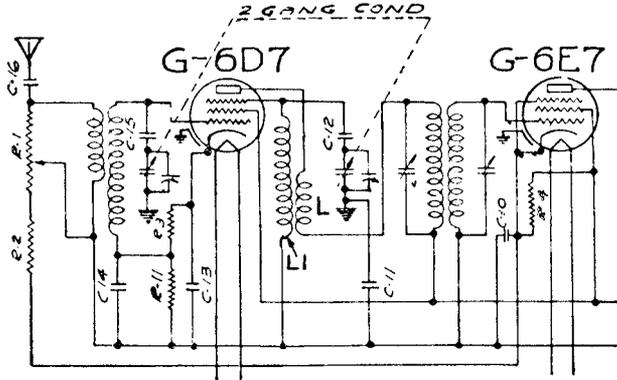
Fig. 34. A variation of the autodyne circuit. Note oscillator
(Courtesy Grigsby-Grunow Co.)
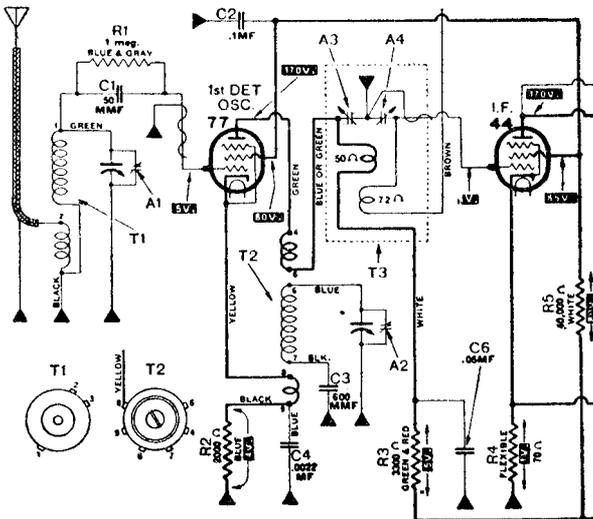
Fig. 35. Note coil arrangements in tank circuit
(Courtesy Atwater-Kent)

The Atwater-Kent 424-534 auto radio receiver uses an autodyne arrangement similar to that to be found in figure 32. The A-K system is shown in figure 35. Note that T-2 is the oscillator transformer and that T-3 is the intermediate frequency transformer. The winding immediately to the right of the designation T-2 is the plate feedback coil, which is coupled to the "tank" circuit, consisting of the coil indicated by the arrow adjacent to T-2 and the associated condensers. This circuit determines the resonant frequency of the heterodyning signal. The input circuit coil is shown directly beneath the tank circuit coil, and is found wired into the cathode circuit.

Service considerations of such circuits involve certain definite modes of progress. Since the oscillator and mixer tube are one, it is impossible to remove the tube, as is done in certain cases during alignment. Alignment requires first that the i-f stages be properly adjusted. This means that an
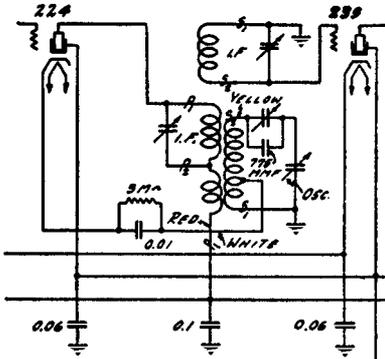
Fig. 36. Note coil assembly between the two tubes. The plate feed back coil—the lower portion of those in the plate circuit—is the only one coupled to the oscillator circuit. See Fig. 37 for coil arrangement

(Courtesy U. S. Radio & Television Corp.)

i-f signal of proper frequency is fed into the mixer-oscillator system. If desired and proper provision is made to maintain the correct control grid bias upon the tube, the control grid lead to the r-f transformer can be removed from the tube cap and the oscillator lead substituted in its stead. If desired, the i-f signal can be fed into the tube's control grid without removing the r-f lead. The tuning dial would be adjusted to some setting which is not productive of a broadcast carrier signal, that is, detuned. After the i-f stages have been aligned,

the oscillator stage is adjusted by feeding an r-f signal at some broadcast frequency into the control grid of the mixer tube. After the oscillator has been aligned, the r-f stages are aligned, by feeding an r-f signal into the antenna-ground terminals of the receiver.

These details are simple. A much more elaborate description of the actual operation involved during alignment will follow later in this volume.

An autodyne mixer-oscillator system popular in some U. S. Radio and Television receivers (now Grunow Radio) and in some Montgomery-Ward superheterodynes is shown in figure 36. Examine the assembly located between the mixer-oscillator and the i-f amplifier tubes. The tuned winding shown connected into the input circuit of the i-f tube is the secondary of the i-f transformer. The winding, within what appears to be a complicated assembly and which is marked I-F, is the primary. This primary is in series with another coil and connects to the plate voltage supply. Apparently coupled to the i-f transformer primary and plate feedback coils is a tuned circuit. This winding, associated with the tuning condenser marked OSC and with a tap which connects to the cathode of the mixer-oscillator, is the resonant circuit of the oscillator system. Although all of these windings are within one unit, only the plate feedback coil is coupled to the resonant circuit. The i-f primary is coupled to the i-f secondary as shown in figure 37.

The tap upon the oscillator transformer secondary and connected to the cathode circuit serves as the coupling link between the tuned oscillator system and the input of the tube and also supplies the heterodyning signal to the input of the mixer tube. The frequency of the heterodyning signal is determined by the resonance of the oscillator transformer secondary. It stands to reason that the heterodyning oscillator condenser tracks properly with the input r-f transformer condenser.

The various autodyne systems shown thus far have been of the single waveband type. At this writing we do not have record of such autodyne systems being used in multi-wave receivers, but such an arrangement is perfectly feasible. The

circuit remains as illustrated in figures 32 to 36, except that
the various tuned circuits, i.e. the r-f input to the mixer and
the resonant oscillator circuits, are tapped for the respective
wavebands and the proper taps or circuit constants are con-
trolled by means of the various switches. The possibility of
such circuit arrangement will become evident after you have
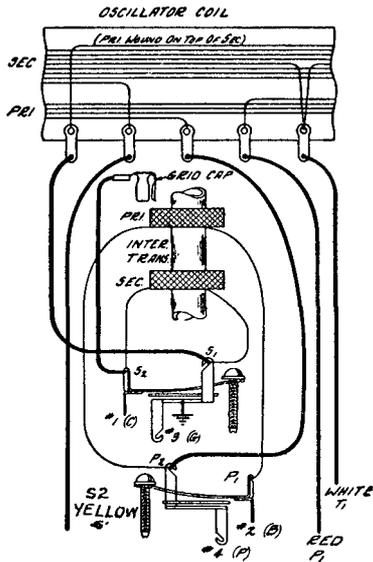
Fig. 37. Physical arrange-
ment of oscillator and I-F
coils shown in Fig. 36
(Courtesy U. S. Radio & Television Corp.)

examined the various wave changing arrangements shown dur-
ing the discussion of that subject.

OSCILLATORS.

The function of the oscillator in the superheterodyne re-
ceiver has been mentioned numerous times in the text offered
so far. Its primary purpose is to generate a steady, unvarying
and non-wavering unmodulated wave or signal of pre-
determined frequency, for the purpose of heterodyning the
received broadcast carrier, thus producing the required beat

note or intermediate frequency signal. The exact value of the frequency of the generated wave is dependent upon numerous factors, such as, the constants of the circuit, the frequency of the received carrier and the required beat note or intermediate frequency.

Based upon how the oscillator is used in a superheterodyne receiver and what is to be accomplished because of its presence in the superheterodyne receiver, certain requirements must be fulfilled. These requirements when tabulated appear as follows:

1. The voltage output must be sufficient for the existing need.
2. The voltage output or the signal output must be substantially constant over the entire frequency band of the unit.
3. The frequency adjustment must remain permanent, once made. There must be no wavering or drifting from the pre-determined frequency adjustment.
4. The harmonic generation properties of the oscillator must be kept at a minimum.
5. Minimum radiation from the components of the oscillator system.
6. Proper tracking with associated circuits.

If these six requirements are fulfilled, very little, if any, trouble will be experienced from the heterodyning signal generator in the superheterodyne receiver. It might be well to mention that the tabulation here presented pertains to the heterodyning signal generator or oscillator in the superheterodyne receiver and not to service test oscillators. Much more can be said in the form of requirements about such units, and much more will be said when such units are discussed.

Before entering into greater detail about requirements of heterodyning oscillators, we feel that certain other pertinent facts should be discussed. These facts pertain to how the oscillator is employed in the superheterodyne receiver. At different times during this discussion, you will note the relation between requirements and use.

Oscillator Adjustment.

Generally speaking, the frequency adjustment of the heterodyning oscillator is such that it is at all times set to a *higher* frequency than the frequency of the received broadcast carrier or the signal to be heterodyned. As a matter of fact, it

can be said that this is true in substantially every superhetero-dyne receiver. One particular exception to this statement is the RCA short wave converter mentioned earlier in this text. The amount by which the heterodyning oscillator is set to a frequency higher than the signal to be heterodyned is the numerical value of the intermediate frequency. Thus, if the intermediate frequencies of three different receivers are 130, 175 and 456 kc., the oscillators in these three receivers will generate signals of a frequency which would be 130, 175 and 456 kc. higher than the broadcast carrier signals being received.

There is a definite reason for a *higher* rather than a *lower* frequency adjustment of the oscillator. The reason is one associated with greater ease of design and more economical construction. The actual reason is that by adjusting the oscillator to beat at a *higher* frequency, a short tuning range is required to cover the tuning band of the receiver, be it a single waveband receiver or one with a number of wavebands. Suppose that the tuning band of a single band receiver is from 525 to 1500 kc. This is the equivalent of a ratio of about 2.86 between the minimum and maximum frequencies covered by the receiver. Let us further suppose that the intermediate frequency in the receiver is 175 kc. If the oscillator is adjusted to beat at a higher frequency, the lower limit is 525 + 175 or 700 kc. and the upper limit is 1500 + 175 or 1675 kc. The ratio between the upper and lower limits is about 2.39. Now, if the oscillator is adjusted to beat at a lower frequency, the lower limit is 525 — 175 or 350 kc. and the upper limit is 1500 —175 or 1325 kc., equal to a ratio of approximately 3.78. The higher the ratio of any one tuning circuit, wherein one coil and one major tuning condenser are used, the more difficult is its design; the more necessary is it to secure a very low minimum capacity, so as to secure the required tuning range. The design of the coils and the associated circuits is also more complicated, because all contribute to the minimum capacity, which capacity must be kept very low, since it is the determining influence in the tuning range to be achieved with the combination of inductance and ca-

pacity. The design of special coils, which will have very low distributed capacity, is more detailed and expensive than that of coils which are permitted to have a normal amount of distributed capacity. The design of variable tuning condensers, which have exceptionally low minimum capacity, is also more complicated and expensive than the design of a condenser which is permitted to have a normal amount of minimum capacity. Considered from the angle of cost and detail of design, every advantage is secured when the heterodyning oscillator is designed to beat at a frequency higher than the frequency of the received broadcast carrier.

Why Oscillators Work.

We said a few words about the generation of sustained oscillations in connection with autodyne mixer-oscillator systems. We deem a more extended discussion much worth while, because the oscillator as a unit plays such a tremendously important role in the service field. At the same time, from what information can be gathered, the state of comprehension of the oscillator action is not as prevalent as it really should be.

A tube can be spoken of as being in an oscillatory state, when it is converting d-c power applied in the plate circuit into a-c power available from the output circuit. This definition naturally assumes that there is no a-c input of any nature to the tube. In other words we are interested in drawing a line of demarcation between a power amplifier tube and an oscillator. Actually, the oscillator tube is functioning as a power converter.

The ability of a tube to function as an oscillator is predicated upon its ability to amplify. By virtue of this ability, the output is greater than the input and the tube can be arranged to supply its own input. When this state exists the tube will generate sustained oscillations at a pre-determined frequency, depending upon the constants of the circuit. What we normally term "feedback" in a circuit is the equivalent of feeding a part of the output back to the input. When this feedback, which may be accomplished in as many ways as it is possible to link the plate circuit with the grid circuit, occurs in a cer-

tain manner and when it reaches a certain state, the generation of oscillations will start. When the feedback is decreased beyond a certain level or when other conflicting conditions arise, the generation of oscillations will cease.

Referring to the feedback action, it is essential that the alternating voltage fed back from the output to the input circuit must be in such phase that it will aid in the grid or input circuit. The normal action of the vacuum tube is such that the a-c voltage developed in the plate circuit is approximately 180 degrees out of phase with the a-c voltage fed into the grid circuit. Consequently, in order that oscillation generation start, the voltage fed back from the plate circuit must be 180 degrees out of phase with the a-c voltage existing in the plate circuit. Under such conditions, the voltage fed back and the a-c voltage at the grid will be in phase. Another requirement is that the feedback be sufficient to develop enough power in the plate circuit, so that it will be able to supply its own input voltage.

The starting of oscillations in a vacuum tube circuit is dependent upon the occurrence of an instantaneous change in the operating conditions of the grid or input circuit, that is, the presence of an initial impulse. This instantaneous change is accomplished when the switch is closed to light the heater. The very first impulse representing some change in operating conditions results in the application of an instantaneous change in the voltage applied to the grid of the tube. This causes an amplified variation in the plate circuit. Since the plate circuit is coupled back to the grid circuit, a portion of the voltage change developed in the plate circuit is fed back to the grid circuit, in the form of voltage variation greater than the original which started the operation. This is repeated until the amount of feedback is sufficient to cause sustained oscillations. In properly designed circuits, this state of sustained oscillation generation is arrived at in very short time. The final steady state may be reached a few seconds later, but the generation of oscillations starts instantaneously, when the source of electrons reaches its proper emitting state.

Assuming that the phase of the voltage fed back from the plate circuit to the grid circuit is correct, it is necessary that

another condition be fulfilled in order that oscillations start. This condition is that the amount of feedback be sufficient to neutralize or offset some of the effective resistance of the tuned circuit in the oscillator system. This is true irrespective of how the inductance constituting the respective circuits is resonated, be it by means of the usual variable condenser or by means of the inter-electrode capacity. Only after the effective resistance has been neutralized or offset to a certain degree, will the circuit start to oscillate or the tube start generating oscillations. The feedback action, which takes place in oscillators, is like the feedback action which takes place in regenerative detectors and even regenerative radio frequency amplifiers. The presence of feedback voltage in a circuit is the equivalent of feeding into that circuit negative resistance to offset the positive resistance of that circuit. This positive resistance is not necessarily the direct current resistance of the wires, but also includes the a-c resistance offered by the various components of the circuit to the flow of alternating current. In effect it represents those factors which combine to create a loss of power in the circuit or the absorption of power.

Reduction of the effective resistance increases the selective powers of a circuit and in a way improves the operating characteristics of the coil or circuit. In an oscillator system, a certain amount of feedback is required to overcome the effective resistance of the components of the circuit. The greater the losses in the circuit or the lower the efficiency of the circuit, the greater will be the amount of feedback required to overcome these losses so that the circuit will be able to oscillate. If the losses for one reason to another are excessively great, the maximum amount of feedback available in the system is not sufficient and the tube will not generate sustained oscillations.

Excessive losses of this type need not be represented in the design of the inductances used in the circuit. The inductances may be perfect, but the associated condensers may be extremely poor and the cumulative effect will be excessive resistance. Of course the high loss part of the system may be the coil or perhaps some metallic object adjacent to the coil.

Whether or not a circuit will oscillate depends upon the tube used and the operating potentials. Certain tubes will generate oscillations more readily than others and will do so at lower operating potentials. The potentials involved encompass every element within the tube.

Grid bias voltage has a definite effect upon the ease of starting oscillations automatically. If the initial impulse is of such low order that it cannot cause a variation in the plate circuit, because of the condition that the bias is so high that the tube is operating below cut-off, oscillations will not start automatically. It is imperative that the grid bias voltage be of such magnitude as to allow satisfactory operation and still allow the instantaneous impulse, previously referred to, to start the process of oscillation generation.

The Frequency of Oscillations Generated.

The frequency of the oscillations developed in an oscillator, such as that used in a superheterodyne receiver, are dependent substantially upon the constants of the inductance and capacities present in the resonant circuit. However, the associated vacuum tube inter-electrode capacities also influence the total capacity across the inductance being tuned and consequently manifest an effect upon the frequency. The operating potentials applied to the tubes likewise have an effect, so that whenever the problem of resonance adjustment or alignment comes to the fore, it is essential that the circuit be in its correct operating state: a state exactly the equal of that existing when the receiver is in use. This means all leads in their correct locations, all shields in place and all operating voltages at their correct values.

Since the tube has an effect upon the frequency being generated, it stands to reason that when a tube is changed there is a likelihood of a change in the constants of the circuit. Some receivers employ oscillator systems which contain frequency stabilized arrangements, whereby changes in operating potentials as well as tube changes result in very little, if any, change in the frequency of the oscillations being generated.

The frequency of any circuit is influenced by the proximity of other circuits or metallic masses, because these adjacent

circuits by virtue of interaction will change the apparent inductance of the circuit. The same is true if some undesired metallic mass is adjacent to the resonant circuit. The presence of some undesired and adjacent tuned circuit may result in the generation of oscillations at two frequencies, as determined by the frequencies of the two circuits and the effect of the interaction. These three conditions must be recognized in connection with superheterodyne oscillator systems.

Parasitic Oscillations.

Oscillators are oftentimes afflicted with the simultaneous generation of frequencies much higher than the desired frequency in addition to the desired frequency. Such a phenomenon is due to the presence of small, local oscillatory circuits composed of small values of inductance in the form of leads resonated by stray capacities. The total absence of such circuits is highly desirable in all-wave receivers. The usual remedy is the use of as short leads as possible and the insertion of fixed resistors in those circuits, which may be productive of parasitic oscillations, taking care at the same time not to alter the frequency and resistance characteristics of the desired oscillatory circuits. The usual location of such resistors is a matter of 'hit and miss' experiment and a visual inspection of the system to disclose unnecessary long leads or location of leads in such positions as may be influenced by existing stray capacities.

Intermittent Operation or Howling Oscillators.

Under certain conditions, related to the grid circuit and bias voltages, oscillations produced by oscillators may appear to be modulated at certain audio frequencies. This condition as a general rule is indicative of intermittent operation of the oscillator at a rate equal to the periodicity of the howl, which may be low or high pitched.

With this much in back of us, we can proceed to consider requirements of oscillators employed in superheterodyne receivers.

Requirements of Superheterodyne Oscillators.

The six requisites of oscillators suitable for superheterodyne use were listed earlier in this chapter. Each of these can be discussed at greater length without any superfluous comment. Each deserves a more complete description. Hence the following.

Sufficient Voltage Output.

In order to realize one of the advantages available with the superheterodyne receiver, namely, the gain secured through the mixing process, it is essential that the voltage of the heterodyne signal be several times as great as that of the broadcast carrier signal fed into the mixer tube. At any rate, the oscillator must furnish considerable power to the mixer tube, so that the mixer tube, while not overloaded, is saturated. Operating in this manner, a greater freedom from cross-talk due to the presence of another weak interfering station would result. At the same time the oscillator should not be furnishing so much excess voltage as to result in radiation and especially strong harmonics. Insufficient oscillator output, due to whatever condition may create such an effect, will have a tendency to reduce the signal output from the receiver and to reduce sensitivity.

Constant Output Voltage.

Since the i-f signal is dependent to a certain extent upon the heterodyning signal voltage, it is logical that whatever the value of the oscillator signal voltage, that value should be maintained as constant as possible over the tuning range of the receiver. Fluctuating heterodyning signal level will result in fluctuating output and a variable degree of sensitivity. If the oscillator signal output fluctuates at some audio rate or even at a rate below the normal audio band, the periodicity of the fluctuation will appear as a background to the broadcast carrier signal as it issues from the speaker. Constant but variable level output from the oscillator will cause a variable degree of sensitivity in the receiver. This, added to the normal variation in sensitivity due to the tuning characteristics

of r-f amplifiers, would result in exaggerated variations of overall sensitivity. Incidentally, the statement that a heterodyne oscillator should provide constant voltage output over the frequency band requires qualification to the extent that a more ideal arrangement would be an output which would compensate for sensitivity deficiencies of the r-f system; that is, the oscillator output would be greater over the portion of the tuning band where the r-f sensitivity is low. However, we cannot concur with the idea of decreasing the oscillator output over the portion of the band where the broadcast carrier signal level is high, because better detection is attained in the mixer tube if the heterodyning signal voltage is substantially greater than the broadcast carrier signal voltage. We assume linear detection, which is the usual arrangement in commercial superheterodyne receivers.

Permanent Frequency Adjustment.

In the early days of superheterodyne operation, one of the major complaints was frequency drifting. In other words the frequency of the heterodyne oscillator would not remain fixed, although the tuning would not be changed. At times the drift was sufficient to detune the station completely. At other times, the drift would amount to just a few kilocycles, just enough to cause distortion, because all of the sidebands were not present in the i-f signal. Sometimes the drift occurred at a fairly rapid rate and extended over perhaps five to ten kilocycles at the high end of the scale and an effect similar to fading was the consequence.

In order that frequency drifting be eliminated, it is essential that the oscillator tuning condenser plates be free from vibration. It is further necessary that the dielectric constant of the dielectric employed in the oscillator padding and series condensers remain constant over a period of time and not change with age or atmospheric conditions. Trimmers adjusted by means of screws must maintain their adjustment. The tension upon the plates must remain uniform. Some of the early tubes were subject to momentary shifting of the electrodes and the result was a change in inter-electrode capacity and the constants of the circuit. Most of the oscillators

used were not frequency stabilized and operating voltage variations would cause a definite drift in the frequency of the oscillator signal output.

Many of these problems have been overcome in modern receivers. The use of rubber cushioned condensers, more perfect design with respect to dielectric materials, better constructed tubes, improved voltage regulation in the power supply unit, the use of a thermostatically controlled trimmer in the oscillator circuit, more uniform tubes, and circuits which, while not frequency stabilized, are not so much influenced by minute changes in tube constants, have greatly relieved the situation. Be that as it may, it is necessary to recognize the possibility of frequency drift as one of the reasons why certain conditions, as outlined, occur and that one requirement of a good oscillator system is freedom from frequency drifting.

Supplementary to the above is the fact that proper design of an oscillator calls for rigid construction of coils used in the respective circuits, so that once set the frequency will remain constant. Condenser plates must be mounted in such manner that there is no play at the bearings. The average receiver with the speaker self-contained vibrates enough during operation to shift the position of the tuning condenser plates, if there is any play at the bearings. It is essential that shielding units be permanently fastened so that their effects, already compensated for in the design, will remain unchanged. Loosening of the shield would tend to change the constants of the circuit. Coil windings must remain in place during operation, unless one or more turns are deliberately changed during alignment. Coil mountings in general must be such that no change occurs in whatever interaction exists during normal operation. Any such change in the coupling between coils, will change the inductance and consequently the frequency setting at any one position of the tuning dial.

Minimum Harmonic Content.

The operation of the usual oscillator is such that it is rich in harmonics. These harmonics are abundantly present in the output circuit, unless special precautions are taken to keep

them at a minimum. The majority of oscillators used in superheterodyne receivers contain resistors located in such positions as will keep harmonic generation at a minimum. This is the desired condition. Excessive harmonic output from the heterodyning oscillator is apt to cause trouble because of possible beats between the harmonic signal and some undesired broadcast carrier or between a harmonic of the oscillator and a harmonic of the i-f signal.

The means employed to keep harmonics at a minimum can become inoperative without interfering with the normal function and operation of the heterodyning oscillator unit. Just what symptoms would indicate the generation of excessive harmonics is difficult to establish. The presence of beat notes, normally non-existent would be one means of identification. In order to make certain that the defect is what it is thought to be, it is necessary to determine the frequencies which combine to produce the beats. At the same time, a d-c resistance test upon the respective resistors in the oscillator circuit and measurement of the operating potentials is required. If the generation of harmonics is due to incorrect operating potentials, this will become evident when the measurements are made. If the generation of excessive harmonics is due to some fault in the circuit, this will become evident when the point to point test is made. This subject is one of those which constitutes a real problem as far as identification is concerned, for it is very possible that the harmonic generation is normal, but the beat is due to the presence of an undesired interfering station. Hence the effort to determine the existence of excessive harmonics must be accompanied by an effort to eliminate possible interfering stations.

Tracking of Oscillator Circuit.

In order to produce consistently the required beat or i-f signal, it is imperative that the oscillator circuit track properly with the remainder of the tuning system. In modern receivers, tuning of the broadcast carrier and the heterodyning signal circuits is accomplished with one control. In earlier receivers a separate control was provided for the oscillator. This gave rise to one particularly annoying effect. This was

the "repeat" point, occasioned by the fact that it was possible
to produce the required i-f signal by adjusting the oscillator
circuit to a frequency higher than the carrier and also by
adjusting the oscillator to a beating frequency lower than the
carrier.

Single control with perfect tracking eliminates the repeat
point, because the oscillator frequency always is higher than
the broadcast carrier frequency.   Hence, the desired station
can be received only at one point on the dial, because only at
one setting of the tuning and oscillator condensers is the
proper beat or i-f signal produced.   We are assuming normal
operating conditions.

It is essential that the oscillator condenser track properly
from the angle of receiver sensitivity, output signal strength,
distortion and possible beat signals forms of interference.   All
of these are directly influenced by the accuracy of adjustment
of the oscillator condenser, which means the accuracy of the
frequency of the heterodyning signal.   Sensitivity and signal
output are closely related in this matter, because perfect ad-
justment of the oscillator system will result in the maximum
amplitude beat signal of the correct frequency for amplifica-
tion in the i-f amplifier system.   Distortion is in the form of
loss of the side bands, if the beat signal does not have the
proper peak.   The i-f amplifier will admit signals several kilo-
cycles off the rated peak, but under such conditions it is possi-
ble that only one-half of the frequencies contained in the
resonance curve of the i-f signal will be amplified in the i-f
amplifier, because the system is not responsive to signals which
differ radically from the rated peak of the system.   Beat signal
interference may result because of interaction between the
harmonics of the i-f signal in the demodulator plate circuit
and some broadcast carrier, which may find its way into the
demodulator plate circuit.

Types of Oscillator Systems.

We have mentioned the principles underlying the operation
of an oscillator system.   The methods of securing feedback
are quite numerous, but the types of oscillator circuits found

in superheterodyne systems are not very numerous. As a general rule, they are very much alike, although there may be several types in use. With the exception of the dynatron oscillator, there are four general methods of coupling the output circuit of the oscillator to the input circuit of the same tube. These are: 1. internal grid to plate capacity of the tube; 2. inductive coupling between the plate and grid cir-

TO MIXER TUBE CATHODE

B+

TO MIXER TUBE CATHODE
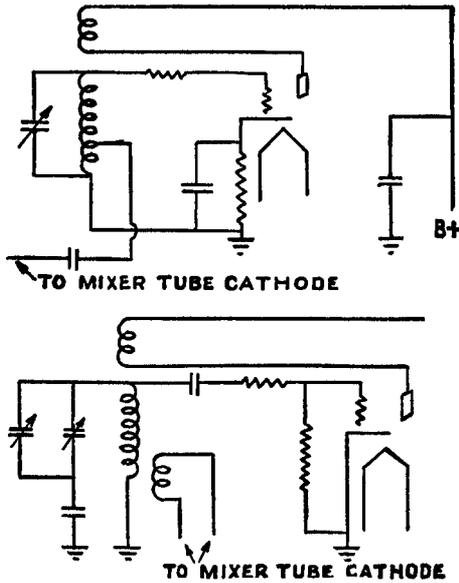
Figs. 38, 39. Examples of feed back oscillator circuits

cuits; 3. capacity coupling between the output and input circuits and 4. resistance-capacity coupling between output and input circuits.

Of these four systems, the most commonly used arrangement is inductive coupling. Examples of several types of superheterodyne oscillator circuits, which are of conventional nature and which use the standard run of triode tubes or the screen grid tube other than the dynatron are shown in figures 38, 39, 40 and 41. In figure 38 is shown an ordinary plate feedback or tickler type of oscillator circuit, which is coupled

to the mixer by means of a fixed condenser connected to a
tap upon the grid coil. A slightly more elaborate arrangement
of the same circuit is shown in figure 39. The fixed and vari-
able condensers associated with the grid coil are the trimmers.
The resistor-condenser arrangement in the grid circuit serves
to suppress harmonic production. This oscillator is coupled
to the mixer tube of the receiver with a small coil wired into
the cathode circuit and inductively coupled to the oscillator
grid coil. In battery receivers, this coupling coil could be in
the mixer filament system.

A very popular type of oscillator circuit for superheterodyne
use is illustrated as figure 40. This circuit is similar to that
shown in figure 39, but contains a special system of tuning
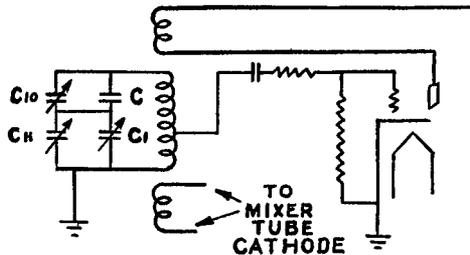
Fig. 40. Good tracking of the condensers is
assured by the arrangement here shown

and trimmer condensers whereby perfect tracking of the oscil-
lator and other tuning condensers is attained. The main
tuning condenser is C-1. The value of C usually is twice the
value of C-1 at its maximum capacity setting. The trimmer
C-11 is used to adjust the mimimum capacity across the tuned
circuit, hence it serves to adjust the oscillator system at the
low wavelength end of the scale or at the high frequency.
The trimmer C-10 adjusts the oscillator circuit capacity at
the high wavelength end of the scale or is the low frequency
trimmer. In some instances, that is, in modern circuits, the
condenser represented by C-10 in figure 40, is omitted; in
other words the oscillator trimmer used is that for the high
frequency end of the scale. The resistance-capacity network
in the grid circuit is used for harmonic suppression. The dis-

advantages of excessive harmonic generation in the oscillator
have been discussed previously.

An oscillator circuit utilizing a "tank" is shown in figure
41. Note that the grid and plate circuits do not contain the
tuned inductance. Instead, the grid and plate circuits are
inductively coupled to a "tank" circuit, which is resonated to
the desired frequency. The tank is, of course, a part of the
complete oscillator circuit and acts as the link between the
grid and plate circuits. The mixer tube is coupled to the
oscillator system via a coil wired into the mixer tube system,
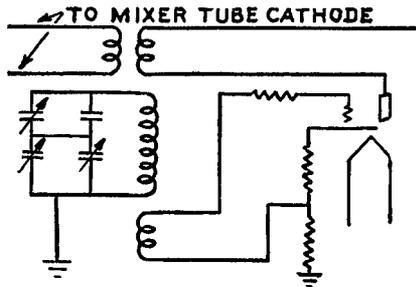
Fig. 41. An oscillator circuit in which is
included a "tank"

but located on the oscillator winding form. The arrange-
ment of the tuning and trimmer condensers across the tank
coil is the same as that used in figure 40. Specific values for
the components of these circuits is not necessary, since refer-
ence to Rider's "Perpetual Trouble Shooter's Manual," avail-
able in four volumes at this writing, will furnish whatever
specific data or values are required for the receiver in question.
In all of the oscillator circuits shown, the resonant frequency
is determined by the constant of the tube circuits. It is true
that other factors influence the actual resonant frequency, but
when viewed from the angle of servicing, the problem of
properly aligning the oscillator to the other circuits is solved
by correct adjustment of the tuning and trimmer condensers
located in the resonant circuit.

The physical location of the coils, which constitute the
oscillator system, is a matter of individual design. As a gen-

eral rule, the various windings connected to the oscillator tube and coupled to the oscillator system are located upon a single winding form. However, in the case of multi-wavelength range receivers, two arrangements will be found in general use. In dual wave systems, wherein but two wavebands are covered, all windings are usually on the same form and are tap controlled. In the case of multi-range receivers, a different set of coils and forms is used for each wavelength range. This is not a set rule. In some instances, a single form carrying tapped windings, switch controlled, is used as the oscillator coil system.

An example of a multi-range oscillator system utilizing a triode tube is shown in figure 42. Inductances L-12, L-13,
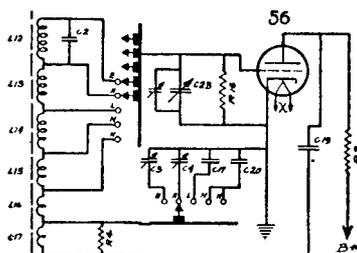
Fig. 42. The sliding switch determines the proper amount of inductance for this oscillator

L-14, and L-15 are in the grid circuit and constitute the resonated system. The sliding switch controls the winding in the circuit. Another example of a multi-range oscillator circuit is shown in figure 43. A set of switches controls the required windings for the grid and plate circuits respectively to suit the required waveband. The coil designations indicate the coils in the circuits for the same waveband. Thus, coil F in the grid circuit and coil F in the plate circuit are used together, coil E in the grid circuit has its equivalent coil E in the plate circuit, etc. The control switches are simultaneously operated. For that matter, these switches are joined to other switches (not shown) which connect the proper r-f and mixer tuned windings (not shown) into the circuit. Addi-

tional examples of such multi-range oscillator circuits are shown in connection with the single envelope dual-tube mixer-oscillator circuits.

Tuned Plate Oscillator Circuit.

All the oscillator circuits shown so far, other than the "tank" systems, employed tuned grid windings.   Here is an
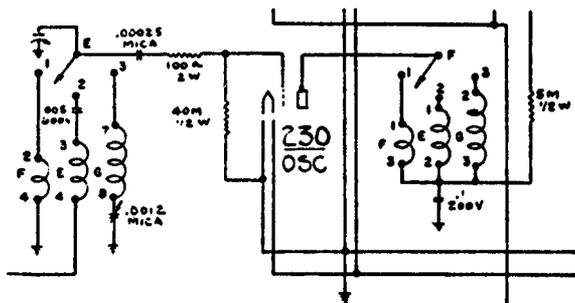
Fig. 43.   This one of a set of switches controls the oscillator windings
(Courtesy Colonial Radio Corp.)
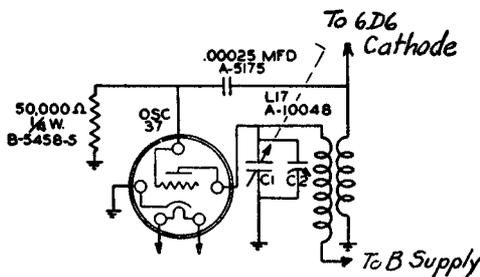
Fig. 44.   Tuned plate circuit oscillator
(Courtesy Sparks Withington Co.)

example of a tuned plate circuit type of oscillator, as used in some of the Sparton receivers.   See figure 44.   The plate coil L-17 is tuned by condensers C-1 and C-2, the latter being the equalizing or trimmer condenser.   The grid circuit is coupled to the plate circuit of the oscillator tube via the .00025 mfd condenser.   The grid leak for the oscillator tube is a 50,000 ohm resistor.   The grid winding of the oscillator

tube is also wired into the cathode circuit of the 6D6 1st detector or mixer tube. In order that such plate tuned circuits be used, it is not necessary that the grid circuit be arranged as shown in figure 43. It is possible to couple the grid coil to the plate circuit as shown and to have some other means of coupling the oscillator to the mixer tube. The frequency of the oscillator signal is determined by the frequency adjustment of the tuned plate circuit. As a matter of fact, quite a few autodyne mixer-oscillator systems make use of tuned plate circuits as a means of producing the required heterodyning signal.

Single Envelope Dual Tube Oscillators and Mixers.

In reality, this type of circuit is a combination mixer and oscillator and consists of a single tube containing a common cathode and heater and two sets of tube elements. The tube used is generally known as a *pentagrid converter*. One portion of the tube consists of the common heater and cathode, a control grid and a grid type of anode or plate. These elements are used for the oscillator section of the tube. The mixer section of the tube employs the common cathode and heater, a separate control grid, a screen grid and a conventional plate or anode. This type of tube, which is really two tubes in one, is typified by the 6A7, 2A7 and 1A6.

Digressing for a moment, another type of single envelope dual function tube is the 6F7, which also finds use as a combination mixer and oscillator, although not of the electron coupled type. At the moment, we are concerned with the 6A7 tube and its equivalent types.

If you can familiarize yourself with the electrode arrangement and the function of the tube, you should experience very little difficulty when servicing receivers which employ such systems. The a-c type of tube contains a heater, a cathode as the source of electrons, five grids and a plate. The battery type of tube has one less element, since the filament is the electron emitter. In the battery type of pentagrid converter, the cathode is absent. An illustration of the electrode arrangement with designating specifications is shown in figure 45. In as much as the usual methods of showing this

tube in schematic wiring diagrams corresponds with the arrangement shown, it is quite simple to identify the structure and the related components when examining wiring diagrams. It is significant to note that the element employed as the anode or plate for the oscillator portion of the tube is really a grid,

ELECTRODE ARRANGEMENT

K=CATHODE
1=OSCILLATOR CONTROL GRID
2=OSCILLATOR ANODE -GRID
3&5=INTER CONNECTED GRIDS —
            IDENTIFIED AS SCREEN
4=SIGNAL CONTROL GRID FOR MIXER FUNCTION
P=PLATE

TYPE 2A7 OR 6A7

C=0.1 μf.
C₁=}GANGED VARIABLE CONDENSERS
C₂=}
C₃=PADDING CONDENSER
C₄=GRID CONDENSER OF 200 μμf.
L₁=OSCILLATOR GRID INDUCTANCE }COUPLED
L₂=OSCILLATOR PLATE INDUCTANCE}
M=MUTUAL INDUCTANCE OF L₁ & L₂
R₁=OSCILLATOR GRID LEAK
R₂=SELF BIASING RESISTOR
R₃=VOLTAGE REDUCING RESISTOR OF 20,000 OHMS(USED
    ONLY WHEN PLATE VOLTAGE IS OVER 200 VOLTS)

Fig. 45, above. Element arrangement of a-c. pentagrid tube
Fig. 46. In this circuit the coupling between the mixer and oscillator is electronic

employed as a plate. The electrode arrangement for the battery type 1A6 tube is like that for the 2A7 and 6A7, except that the cathode is absent. The identifying numbers associated with the respective grids remain unchanged. A typical pentagrid converter circuit is shown in figure 46. The numbering of the elements shown within the envelope is identical to that shown in figure 45. In operation, the cathode K, grid No. 1 and grid No. 2 form the oscillator portion of the tube.

Electrons emitted from the cathode can be controlled in their flow to the oscillator anode, (grid No. 2) by grid No. 1. The oscillator grid circuit, therefore, can be made to oscillate at any desired frequency, as determined by the constants of the oscillator circuit, so that the electron stream, in flowing through grid No. 1, will be modulated at this frequency. The modulated electron stream comes under the influence of grid No. 3, which is operated at a positive potential with respect to the cathode. As a result, the electron stream is accelerated toward the plate P by this grid. At the same time, grid No. 3 tends to isolate grids No. 1 and No. 2 from grid No. 4 and with grid No. 5 isolates the plate P from the other elements, so as to avoid all undesired interaction.

The incoming broadcast carrier signal applied to grid No. 4 further modulates the electron stream, already modulated at the oscillator frequency, thus producing components of plate current, the frequencies of which are the various combinations of the oscillator frequency and the incoming broadcast carrier frequency. The primary circuit of the i-f transformer in the plate circuit is tuned to the difference frequency, hence this signal appears across the secondary. If you examine figure 46, you will note that there is no form of inductive or capacitative means of linking or coupling the mixer and oscillator circuit, as was shown in connection with the triode tube mixers. Such coupling arrangements are not required with these single envelope, dual element tubes. The coupling between the oscillator and mixer tubes is electronic. The stream of electrons emitted from the cathode in the a-c tube and from the filament in the battery type of tube links both tube portions.

With the exception of the absence of external inductive or capacitative coupling between the mixer and the oscillator portions of the tube, the tube can be considered as being two tubes without any special circuit qualifications or complications. This fact becomes evident after an examination of the basic circuit shown in figure 46 and after an examination of some of the wave-changer systems shown elsewhere in this volume. Naturally, because of the nature of the coupling between the two circuits, there is no occasion to fear what-

ever troubles may arise from variations in either inductive or capacitative coupling in the usual separate tube mixer and oscillator circuits.   Concerning operating voltages, it is well to remember that each set of elements receives its own voltage.   It is true that some of the elements are operated from
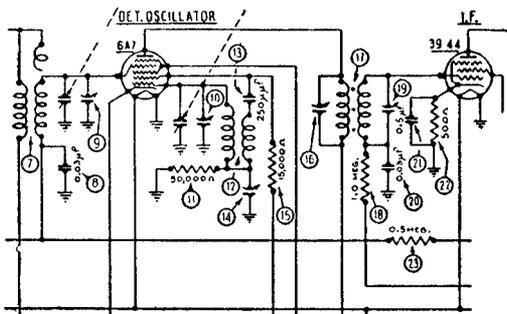
Fig. 47.   Note carefully the use of the tube elements in this combination circuit

(Courtesy Philco Radio & Television Corp.)

the same voltage feed line, but the fact that the two sets of elements are within the same envelope does not remove the need for care with respect to proper operating potentials. Whatever operating facts are applicable to separate mixer and oscillator tubes are applicable to this dual tube.

One example of the average superheterodyne arrangement utilizing the a-c type of tube, namely the 6A7, is shown in figure 47, the circuit used in the Philco model 800 receiver. Transformer 7 is the r-f input to the mixer portion of the tube.   Transformer 12 consists of the grid and plate windings of the oscillator portion.   You will note that the grid winding is tuned by means of the major tuning condenser and the high frequency trimmer 10 and the low frequency trimmer 14.   Shunt plate supply is used.   The i-f transformer 17 is connected into the plate circuit.   Note that the oscillator grid is grid number 1 and that the plate coil for the oscillator portion of the tube is connected to grid number 2.   The r-f input joins grid number 4.   Grids 3 and 5 are the screen grids.   This is a typical circuit to be found in the majority of the single

band superheterodynes, which employ this type of tube. *Incidentally, some diagrams showing the 6A7S tube produced by Grigsby-Grunow (Majestic) show the oscillator portion anode, as a plate instead of as grid number 2.* We are speaking about wiring diagrams in Rider's "Perpetual Trouble Shooter's Manual."

Another example of the 6A7 used as mixer and oscillator is the arrangement used in the Stromberg-Carlson 55 and 56 receivers, illustrated in figure 48. L-4 is the mixer tube grid winding resonated to the broadcast carrier signal. L-7 is the
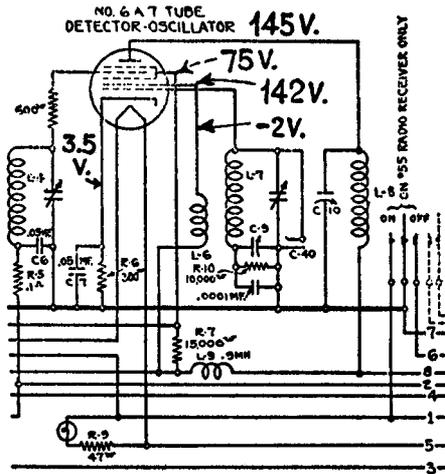
Fig. 48. A temperature controlled condenser, C-40, prevents frequency drifting in the oscillator circuit

(Courtesy Stromberg Carlson)

oscillator portion grid winding, joined to grid number 1. L-6 is the oscillator plate winding, joined to grid number 2. If you examine the oscillator grid circuit, you will note what normally appears to be a phone jack, but which bears the condenser designation C-40. This is a temperature controlled condenser, the purpose of which is to prevent, or at least minimize, frequency drift, due to temperature variations. The i-f transformer in this receiver is a three winding affair. Coil L-8 is the primary. The other windings are not shown

A dual band receiver utilizing the 6A7 tube as a mixer and oscillator is shown in figure 49. This is the oscillator and mixer portion of the Emerson 33 LW series of receivers. In this diagram, the tube elements are shown vertically, rather than on a horizontal plane, but the sequence remains the same. The receiver covers two bands and the switches are shown set for the long waveband. Note that the broadcast carrier circuit is connected to grid number 4. When the switch in this circuit is closed, the lower coil is short circuited and the receiver is set to tune over the broadcast frequency spectrum. The oscillator portion contains the two sets of coils connected to grids number 1 and number 2. The grid
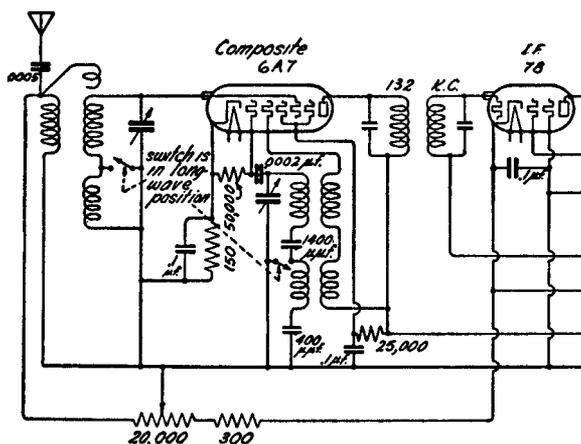
Fig. 49. Oscillator coils are connected to grids 1 and 2, the the latter acting as the oscillator plate
(Courtesy Emerson Radio & Phonograph Co.)

circuit is tuned by means of the various condensers illustrated. When the switch is closed in this circuit, the lower coil is shorted. However, both plate coils are in the circuit at the same time.

A somewhat more elaborate system is shown in the RCA-Victor 121, 122 receiver, illustrated in figure 50. The circuit shown includes the r-f and oscillator-mixer portions of this tube. In this instance the dual tube is a 2A7. The windings L-5 and L-6 are used for the broadcast band and L-7 and L-8

are used for the short waveband. Switches S-3 and S-4 control the presence of these windings in the circuit. Note that the moving arm of switch S-4 connects to grid number 4, which is the control grid for the mixer portion of the dual tube. Switches S-5 and S-6 are used in the oscillator portion of the tube and control the presence of windings L-9, L-10, L-11 and L-12, in the oscillator circuit. With S-5 and S-6 set to the L-W position, which is for the broadcast band, L-9 is connected to grid number 1, which is the control grid for the oscillator portion of the tube, and L-12, which is the short wave primary is short circuited, leaving L-10, connected to the oscillator plate, which is grid number 2. When the

Fig. 50. Note carefully the various switches for changing the wavebands

(Courtesy RCA-Victor Co.)

switches S-5 and S-6 are set to the S-W position, L-11 is joined to the oscillator control grid and L-10 is short circuited, leaving L-12, joined to the oscillator plate, which is grid number 2.

Very little more need be said about these dual tubes. As in the case of all oscillator circuits, measurement of operating potentials during operation is limited to point to point measurements. The usual routine methods of checking through cables and plugs is not very satisfactory, because it interferes

with the normal operation of the oscillator tube. As a matter of fact, the usual run of voltage tables which accompany service literature, contains specific voltage values for the mixer or detector portion of these tubes and does not include the oscillator. However, if measurements are to be made, they should *not* be made with the usual cabled type of equipment. Use loose leads connected to the various testing instruments.

Dynatron Oscillator.

The dynatron oscillator was shown in schematic form as a part of an autodyne mixer-oscillator in figure 31. If you will glance at that diagram and consider the control grid joined to the cathode or to a grid bias voltage source and the screen connected to a voltage source, rather than to the i-f transformer included in the illustration, you will visualize the usual screen grid type tube dynatron oscillator. The parallel resonant circuit remains connected into the plate circuit. Usually a type 24 tube is used for this purpose. The average screen grid tube has a peculiar plate current-plate voltage characteristic. Normally, plate current increases with an increase in plate voltage. But when a screen grid is present in the tube and the voltage applied to the screen is greater than the plate voltage, secondary emission of electrons will take place from the plate to the screen. In order that this condition be attained, it is necessary that a certain voltage relationship exist between the screen voltage and the plate voltage. Over a certain range of voltages, such secondary emission takes place and an increase in plate voltage, within certain limits, results in a *decrease* in plate current, rather than in an increase. The reason is greater secondary emission over that range of plate voltages. During this state, the plate resistance is *negative*, rather than the normal positive. Any device, which possesses negative resistance, will produce sustained oscillations, provided certain other conditions are fulfilled. If a parallel resonant circuit is connected into the plate circuit of a screen grid tube, which is being operated within the aforementioned plate voltage and screen voltage range, and if the impedance of the resonant circuit is as great or is greater than the negative resistance of the tube, then the tube will generate sus-

tained oscillations of a frequency determined by the constants of the resonant circuit. This is the tuned circuit in the plate circuit of the tube.

Numerous types of dynatron oscillators have been used, although not to a very great extent in commercial receivers. One of the claims made for this type of oscillator is greater stability over a range of operating potentials. However, since the system has not been extensively used in superheterodyne receivers, it is not necessary to delve into its operating ramifications.

Dual Oscillators.

As stated earlier in this text, some few receivers make use of dual oscillators in a single receiver. There is nothing special that can be said about such oscillators. Whatever has been said as being true about any one particular oscillator, is just as readily applicable to the two oscillators to be found in superheterodyne receivers.

Multi-Range Oscillators.

There is nothing special which can be said about multi-range oscillators other than what has been said about oscillators in general. Naturally, alignment of such multi-range units is more complicated than for a single band, but this subject receives special attention later in the volume. The few examples of dual wave receiver systems as shown in this chapter give you an idea of how circuits are changed. More examples of various waveband switching arrangements are given later. As far as the oscillator function is concerned, it makes little difference if the unit is designed for a single wave or for a number of waves. Whatever is applicable to one wave is applicable to each of the other wavebands. Whatever problems related to the wavebands and switching may arise, they have no bearing upon the oscillator action. Those problems are related to the switching mechanism, troubles due to faulty contacts, improper alignment, defective coils, etc. It is, of course, possible that one of these troubles may interfere with the satisfactory production of the heterodyning signal.

In that event, it becomes necessary to determine why the tube does not oscillate, which still is beyond the concrete subject of oscillator action and function.

The Intermediate Frequency Amplifier.

The function of the intermediate frequency amplifier is to amplify the modulated beat note or i-f signal produced by mixing the incoming broadcast carrier with the locally generated signal. We made the statement that this signal can be classified as a newly created carrier, which retains the modulation characteristics of the originally received broadcast carrier. If the aforementioned is true, then the intermediate frequency amplifier really is a radio frequency amplifier, operating at a fixed longer wavelength or at a fixed frequency lower than normally found in a radio frequency amplifier. The term "intermediate frequency" is used to differentiate between the frequencies to be found in the r-f band, short wave band, the a-f band and a band of frequencies lower than normally understood when radio frequency is mentioned, yet higher than the frequencies understood to be in the audio band or even in the very long wavelength group.

Obviously, the i-f amplifier differs from the r-f amplifier in two ways. First is the fact that the i-f system operates upon a fixed frequency with certain side band limits. Second, the frequency is lower. With these two exceptions, anything ever said about an r-f amplifier is applicable to the i-f system. Similar types of tubes are used. Methods of applying voltages are identical in both cases. The difficulties which arise in radio frequency amplifiers by virtue of the presence of tuned circuits are to be experienced in i-f amplifiers, except for the fact that in the latter they occur at one fixed frequency.

Thus if we consider regeneration, everything which is true at one frequency in the case of the r-f amplifier, is true in the case of the i-f amplifier at the peak frequency. If we consider the subject of distortion due to cutting of sidebands in the r-f amplifier, the same thing is true in the i-f amplifier at the peak frequency. If we consider distortion in the r-f amplifier because the control grid bias is excessive, be it a fixed

bias or an automatically controlled bias, the same is true in the i-f amplifier. As a matter of fact troubles of this type, if they occur in the tube which immediately precedes the demodulator tube, can be extremely troublesome, because that will result in audio beat note production, as well as distortion.

Whatever the requirements of r-f amplifier with respect to a 10 kc. band pass, the same is true of the i-f amplifier. In fact, triple tuned circuits used in r-f systems to enable proper selectivity and suitable band pass, will be found in i-f systems. If the r-f system is called upon to pass 10 kc., the i-f system is called upon to pass 10 kc. If side band suppression in the r-f system interferes with quality of reproduction, just so does side band suppression in the i-f system interfere with quality reproduction.

Having considered points of similarity, let us now consider some of the points of dissimilarity between r-f and i-f systems. The first is the fact that the i-f amplifier operates upon a fixed frequency. The second is that the i-f amplifier operates upon a fixed frequency very much lower than is to be encountered in r-f amplifiers employed in the normal run of broadcast receivers. The third is the modern practice of employing tubes for a number of functions in addition to intermediate frequency amplification. The fourth difference is found in the dual tuning of each i-f transformer. In substantially every instance, both primary and secondary windings are tuned to the resonant frequency. While it is true that these points of dissimilarity have little bearing upon the actual servicing of the superheterodyne receiver, it is well to realize these facts. The special applications of tubes as i-f amplifiers and other functions will receive due attention in connection with special tube applications, although some of the circuits appear in this chapter. The matter of tuned primary and secondary windings receives its due in connection with alignment procedure.

With few exceptions, namely unconventional application of tubes, the modern intermediate frequency amplifier does not differ very much from the earlier types used years ago. Also the majority of amplifiers are alike in today's receivers. Where certain tubes are used in special ways inclusive of i-f amplifi-

cation, that same or very similar sytem will be found in other receivers as well, so that a great deal of similarity exists between receivers. Thus, if you become familiar with the structure of i-f amplifiers in general, you will automatically be familiar with the i-f structure in the majority of superheterodynes.

Before embarking upon types of i-f amplifiers and circuit structure, we think it would be advisable to consider a few pertinent items associated with the selection of the numerical value of the intermediate frequency. This type of information may not have any concrete bearing upon servicing, but it will no doubt clarify some questions which may have arisen in your minds concerning the reasons why so many different peak frequencies are used and what influence the peak has upon operation.

Selection of Intermediate Frequency.

As you no doubt realize, the intermediate frequency employed in any receiver, which you may be called upon to service, has already been decided and there is no changing this value. As a general rule, the intermediate frequency transformers are so designed that the best performance is attained at the pre-determined peak. Consequently, even if it were possible to tune the unit to some frequency other than that originally intended, the proper response would more than likely not be available. Furthermore, any such change requires revision of the oscillator tracking arrangement. This part of the receiver, like the i-f system, is definitely designed to produce a certain difference frequency, hence revisions would be required and these revisions are not within the realm of the service man in the field.

Nevertheless, there is definite value in knowing the pros and cons of the numerical value of the intermediate frequency. It will help understand why values have been changed in production and just what factors influence this numerical figure. It will further explain some of the apparently mysterious effects which may be observed with superheterodyne receivers under certain conditions. It will explain certain mystifying forms of interference. Consequently we feel that it is worth-

while to devote the required amount of attention to the subject.

We have made mention of the fact that the lower the numerical value of the intermediate frequency, the greater is the adjacent channel selectivity. We have further mentioned that the higher the value of the intermediate frequency, the greater the freedom from image frequency form of interference. Now, it is logical that a single intermediate frequency cannot be both high and low, so as to provide best operating conditions with respect to the two forms of interference named. Consequently, it is necessary to arrive at a compromise figure which will function best all around.

Strange as it may seem, practical common sense reasoning plays a very important part in all design work, after the engineering work has been completed. The reason for this is that theory, which controls the actual engineering, does not include the practical side. Judging by what has taken place during the past fifteen years of superheterodyne design, we cannot help but come to the conclusion that the problem of adjacent channel selectivity has never been as prominent as the need for freedom from image frequency response. In other words, there has been a definite trend towards higher and higher intermediate frequencies. The early superheterodyne receivers employed i-f peaks which ranged between 30 and 100 kc. Today's superheterodyne receivers employ intermediate frequencies between 110 kc. and 485 kc. Superheterodyne short wave converters employ i-f peaks which range from 525 to as high as 1300 kc. Neglecting converters, the higher value of intermediate frequencies seems to predominate, although a tremendously large number of receivers produced during the years 1930 to 1932 employed 175 kc.

What with better designed circuits and allocation of widely separated operating frequencies to stations in any one locality, there is available a general freedom from adjacent channel selectivity. Hence we must pay attention to image frequency problems and to whatever other items are influenced by the value of the peak frequency. In this connection it is necessary to recognize the presence of the intermediate frequency amplifier as a series of tuned circuits, which contain tubes and

a multiplicity of connecting leads. Also the existence of stations which operate upon frequencies within the intermediate range. As a last consideration, we must also recognize design problems related to image suppression circuits in the frequency range higher than the normal broadcast range. At all times and under all conditions, bear in mind that common sense practice plays a tremendously important role.

From all that has taken place in superheterodyne design during the last few years, we feel quite safe in saying that intermediate frequencies below 100 kc. will seldom if ever be used. Of course, this is not a positive statement, since we do not know what the future holds in store, but such appears to be the case at the present time. Since the primary advantage of a low intermediate frequency is good adjacent channel selectivity and a high order of amplification and since a proper degree of adjacent channel selectivity now is available, by virtue of better design of resonant circuits and modern tubes enable sufficiently high amplification at higher intermediate frequencies, there is no reason for using low intermediate frequencies, which, while possessing certain favorable points, also possess numerous unfavorable points. Hence we can forget the low intermediates and consider those numerical values between 110 and 485 kc.

Concerning the higher values of intermediate frequency, we have favorable and unfavorable points to recognize. One very important point in favor of the high value is that greater freedom from image frequency or of interference is available without the use of any special circuits. This is important, because of the recent interest in short wave reception. The design of short wave circuits to contain special image suppression systems, such as outlined earlier in this text, is not a simple task. Consequently, by using a high enough intermediate frequency, it is possible to secure good image frequency rejection without the necessity of using special image suppression circuits.

Several items which make the selection of a high intermediate frequency a poor choice pertain to amplification consistent with stability, greater shielding problems and the fact that the 2nd and 3rd harmonics, the former being all important, fall

within the broadcast carrier band. However, by suitable design, it has been possible to effect a compromise in amplification consistent with stability and to arrange the various leads in the receiver so that there is general freedom from troubles which originate because the 2nd and 3rd harmonics fall within the broadcast band. As to shielding of intermediate frequency amplifier, much more than has been done, can be done. Shielding of this system is not as good as can be, as is evidenced by certain forms of interference being experienced with superheterodyne receivers located in certain parts of the United States and Canada. For that matter, this type of interference, to be discussed in a subsequent paragraph, may be experienced in many parts of the world.

In the effort to effect a compromise, so that the best operation is secured, recognition is accorded to the importance of the exact numerical value of the intermediate frequency. In order to minimize troubles due to beats between the harmonics of the intermediate frequency and some signal carrier, many manufacturers have selected i-f peaks which are of such numerical value that they are integral multiples of 5, rather than 10. The reason for this is that broadcast station carrier frequencies are allocated in steps of 10 kc. and by selecting intermediate frequencies which end with the number 5, instead of with a cipher, the odd harmonics if present, while they may fall within the broadcast carrier frequency band, will at all times differ from a carrier frequency by 5.0 kc.

A choice of such an i-f peak is by no means absolute assurance of freedom from troubles created when the intermediate frequency peak harmonics beat against signal carriers, but it is at least a step towards minimization of such troubles. You may at this time be thinking about some i-f peaks such as 455 kc., 465 kc. and 485 kc., which possess a 2nd harmonic which falls directly upon a signal carrier frequency. While this is true, you will also find upon analysis that these high peaks are used in all-wave receivers or in receivers where major economy was desired and the high peak permits the exclusion of special image suppression circuits. At the same time the 2nd harmonics of these frequencies fall upon such broadcast channels as are but little used, or at least used by the least im-

portant stations.   Thus the 2nd harmonic of 455 kc. is 910 kc., a channel employed exclusively by Canadian stations.   If this i-f peak is used in American made receivers, very little trouble would be experienced in most places in the United States, except possibly, in sections close to the Canadian border.   The 2nd harmonic of the 465 kc. peak is 930 kc., a channel used by only six U. S. broadcasting stations, although, there are several Canadian stations operating upon the same channel.   However, the 465 kc. i-f peak is used in extremely few receivers.   As to 485 kc., which is used in a number of American receivers, the 2nd harmonic is 970 kc., a channel used by only three U. S. broadcasting stations.

In order to secure the greatest freedom from image frequency troubles, minimization of beats between the i-f peak harmonics and signal carriers, and also freedom from the reception of commercial stations, which operate upon frequencies within the i-f peak range, many manufacturers employ i-f peaks between 170 and 270 kc., with exact numerical values which are fractional multiples of 5 and 10.   In other words, the i-f peak figure terminates in a decimal, such as 0.5 kc.   Typical values are 172.5 kc., 177.5 kc., 181.5 kc., 252.5 kc. and 262.5 kc.   Whenever such decimal values are used, the image signal, must differ from the desired signal frequency by a number which ends in 5, such as 345 kc. for a 172.5 kc. peak, 355 kc. for a 177.5 kc. peak, 505 kc. for a 252.5 kc. peak and 525 kc. for the 262.5 kc. peak.   The 181.5 kc. peak requires an image frequency of 363 kc.

Since the broadcasting stations are allocated frequencies in steps of 10 kc., there are no image frequencies for any desired signal frequency in a receiver which employs i-f peaks of the order named.   For example, if the receiver employs 172.5 kc., the image for a 600 kc. signal would have to have a frequency of 600 + 172.5 + 172.5 or 945 kc.   The frequencies closest to this are 940 kc. and 950 kc. If the peak is 262.5 kc. for another receiver tuned to 700 kc., the image frequency would be 700 + 262.5 + 262.5 or 1225 kc.   The closest operating frequencies are 1220 kc. and 1230 kc.   Obviously, speaking theoretically, there are no real images for such i-f peaks.

in the tubes. I-f peaks must be of such value that 3:2 and 2:3 relations between the harmonics of the undesired carrier signal and the heterodyning oscillator do not produce the required beat. This situation is greatly aggravated if the i-f amplifier is not tuned accurately. For example, let us assume that a 600 kc. signal is desired. The receiver operates upon an i-f peak of 130 kc. Consequently, the heterodyning oscillator will be adjusted to 600 + 130 or 730 kc. A powerful 660 kc. transmitter is located in the same town. Normally, this separation of 70 kc. in the i-f amplifier, assuming both carrier fundamentals in the mixer system, is sufficient to allow discrimination between the desired and the undesired signals in the i-f amplifier. However, if the r-f or mixer tubes are being operated in such manner than a second harmonic is being produced, the 2nd harmonic of the 660 kc. signal will produce a 1320 kc. signal. In turn the 2nd harmonic of the 730 kc. adjustment of the heterodyning oscillator tuned to beat against the 600 kc. desired signal, will be a 1460 kc. signal. The two will mix to produce a beat of 140 kc. If the i-f amplifier is not properly adjusted, the 140 kc. signal will get through and interfere with the regular signal or it is possible that if the 600 kc. signal is weak and originates in a distant town, the local 660 kc. signal will blanket the 600 kc. setting upon the dial and it will be impossible to receive the distant station. Sharp tuning of the i-f amplifier and operation of the pre-selector or even the mixer tube so that interfering stations do not produce second harmonics, greatly relieves this situation. It is interesting to note that 175 kc. shows up well in this matter, as being a very desirable frequency. For that matter, all i-f peaks which end with 5 or a fraction are preferable to peaks which end in a cipher, that is, as far as operation of the receiver is concerned. However, as far as alignment is concerned, the adjustment of the test oscillator and checking of this oscillator adjustment by means of standard broadcast stations is far more easily accomplished if the i-f peak is an integral multiple of 10, than for any other combination.

remedies are discussed in the chapter devoted to troubles and trouble shooting in superheterodyne receivers.

It is interesting to note in connection with the choice of i-f peaks for use in the American receivers that these commercial station frequencies receive a great deal of attention. Obviously, the most practical solution when selecting an i-f peak is to choose one which is different from any of the frequencies used for commercial transmission and one which is not employed in the United States or, if total freedom is not available, to select one which is used the least number of times. In practically every case, some form of tone modulation is used in these transmitters, so that if the signal finds its way into the i-f amplifier, it will be audible in the speaker, even if the amplifier is not in an oscillatory state. Many of these c-w transmitters employ self-rectifying oscillators, so that some form of interference will be audible.

456 kc. has become quite popular of late and while we are not absolutely certain of the exact reasons behind the selection of this value, we are tempted to believe that it is due to two major conditions. The first is that it is sufficiently high to obviate the necessity of using special image suppression circuits, which are not practical in short wave or combination wave receivers. The second is that its 2nd harmonic is near a broadcast channel which is not used by American stations. This harmonic has a frequency of 912 kc. and the 910 kc. channel is reserved for Canadian stations. The 920 kc. channel used by U. S. broadcasting stations is sufficiently far away not to be troublesome. However, this frequency is apt to be troublesome in the Rocky Mountain area, the Southwest and in some parts of Pennsylvania, due to the presence of airway stations operating upon a carrier of 278 kc. The second harmonic of this carrier may cause some interference.

Another factor which influences the choice of the intermediate frequency is related to harmonics of broadcast signal carriers and harmonics of the heterodyning oscillator. We made mention of the possible troubles due to beating of the heterodyning oscillator harmonic against the harmonic of a strong local undesired carrier, which finds its way into the r-f or mixer portion of the receiver and produces harmonics

in the tubes. I-f peaks must be of such value that 3:2 and 2:3 relations between the harmonics of the undesired carrier signal and the heterodyning oscillator do not produce the required beat. This situation is greatly aggravated if the i-f amplifier is not tuned accurately. For example, let us assume that a 600 kc. signal is desired. The receiver operates upon an i-f peak of 130 kc. Consequently, the heterodyning oscillator will be adjusted to 600 + 130 or 730 kc. A powerful 660 kc. transmitter is located in the same town. Normally, this separation of 70 kc. in the i-f amplifier, assuming both carrier fundamentals in the mixer system, is sufficient to allow discrimination between the desired and the undesired signals in the i-f amplifier. However, if the r-f or mixer tubes are being operated in such manner than a second harmonic is being produced, the 2nd harmonic of the 660 kc. signal will produce a 1320 kc. signal. In turn the 2nd harmonic of the 730 kc. adjustment of the heterodyning oscillator tuned to beat against the 600 kc. desired signal, will be a 1460 kc. signal. The two will mix to produce a beat of 140 kc. If the i-f amplifier is not properly adjusted, the 140 kc. signal will get through and interfere with the regular signal or it is possible that if the 600 kc. signal is weak and originates in a distant town, the local 660 kc. signal will blanket the 600 kc. setting upon the dial and it will be impossible to receive the distant station. Sharp tuning of the i-f amplifier and operation of the pre-selector or even the mixer tube so that interfering stations do not produce second harmonics, greatly relieves this situation. It is interesting to note that 175 kc. shows up well in this matter, as being a very desirable frequency. For that matter, all i-f peaks which end with 5 or a fraction are preferable to peaks which end in a cipher, that is, as far as operation of the receiver is concerned. However, as far as alignment is concerned, the adjustment of the test oscillator and checking of this oscillator adjustment by means of standard broadcast stations is far more easily accomplished if the i-f peak is an integral multiple of 10, than for any other combination.

Types of I-F Amplifiers.

Neglecting those i-f amplifiers which employ reflex circuits or special devices such as tuning flashers, crystal traps or filters, tuning gates, etc., we can say that the conventional forms of intermediate frequency amplification differ very little in the majority of receivers. Naturally, you will find variations of circuits, but none of these are radically different from others.

As far as the general run of i-f amplifiers go, the exact nature of the receiver does not influence the design of the i-f system. It stands to reason that a receiver intended for c-w reception wherein the sidebands may be limited to 500 or 1000 cycles, will have more sharply tuned i-f stages than a receiver which is intended for speech reception. However, the fact that a receiver is intended for single wave band broadcast reception, does not make its i-f amplifier different from that required or intended for use in a combination all-wave receiver. By the same token a superheterodyne receiver intended for auto radio use, will not use an i-f amplifier which is different from that intended for a home broadcast superheterodyne or for a ship installation. The i-f peaks used may differ in these types of receivers and the types of tubes may differ, but as far as function and circuit design are concerned, the amplifiers will be similar. Since the i-f amplifier operates at a fixed frequency, it is not influenced by the tuning range of the receiver. Thus whatever facts you may glean about i-f amplifiers in general, you will find them to be applicable to substantially all amplifiers, irrespective of the utility or intended function of the receiver wherein the i-f amplifier is used.

You must, of course, realize that certain i-f amplifiers are more effective than others, but those reasons which provide the greater efficiency are related to the design of the actual components. More complicated networks may provide more accurate tuning or better selectivity. Certain special transformers are more than likely native to one receiver only or perhaps to the production of one particular manufacturer. Of these special transformers there may be very many, but in every case they are affiliated with certain manufacturers. In

such cases it is essential to understand the special transformer and its purpose. As far as i-f amplification is concerned, that remains the same in all systems, complex or simple. In view of the fact that the various volumes of Rider's "Perpetual Trouble Shooter's Manual" contain full details of complete receiver circuits, only the special i-f amplifier units will be shown in this chapter.

A conventional type of i-f amplifier without any special innovations is shown in figure 51. This is a two stage unit employing screen grid tubes. Note that the first and second i-f transformers are used with variable trimmers, whereas the third transformer is used with fixed tuning. This combination is not necessarily standard. It is possible to use variable trimmers on all of the transformers or to use fixed tuning
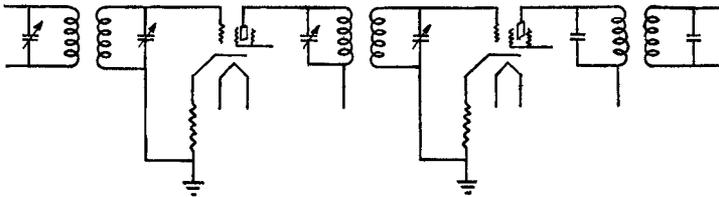
Fig. 51. Two stage i-f. amplifier using screen grid tubes

condensers to resonate the various windings or a combination of fixed and variable condensers in conjunction with each individual transformer. You will further note that the bias voltages are developed across the cathode bias resistors. This is not always the case in some of the older receivers and seldom is found in the modern receivers. Modern receivers invariably employ automatic volume control, so that the grid return leads would join the AVC circuit and the bias resistors would be used to establish the fixed minimum bias. Furthermore, the majority of today's superheterodynes employ but a single stage of i-f amplification. Many of the older receivers employ two and three stages in this part of the receiver.

An example of a special type of i-f transformer, which was used in numerous RCA-Victor and General Electric receivers, is shown in figure 52. The circuit structure of the complete

system is quite conventional, but this transformer is interesting. The three windings L-10, L-11 and L-12 comprise the complete transformer. By means of the sliding arm on the resistor, volume control is effected. Another special type of transformer used as a part of a conventional circuit in some RCA-Victor receivers is shown in figure 53. In this illustration, L-10, L-11 and L-12 comprise the special three winding transformer. L-11 feeds a signal to the AVC tube. L-12 is shunted by a volume control resistor, which feeds the 2nd i-f tube. If you examine the structure of the remainder of the i-f circuit, you will note that the circuit is quite conventional, with the exception of this one transformer. Although these two transformers are of special type, they still contain certain points of similarity with respect to ordinary two winding

Fig. 52, right. Special i-f. transformer with volume control shunted across part of secondary

Fig. 53, below. A variation of the three-winding i-f. transformer. L-12 is not directly connected to L-11, as in Fig. 52.

(Courtesy RCA-Victor Co.)
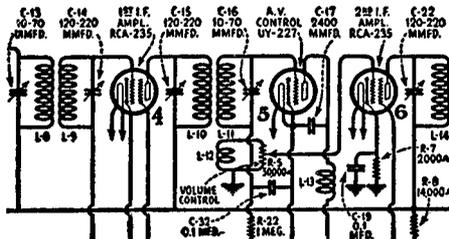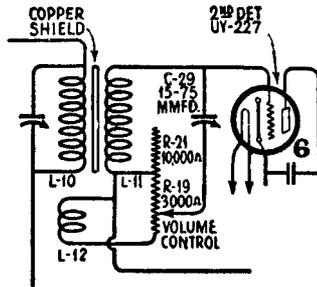
units. Namely, the primary and one secondary winding is resonated to the i-f peak, so that as far as far as alignment is concerned, these special transformers are handled just as if they were standard units.

As a general statement concerning i-f amplifiers as a whole, irrespective of the exact nature of the component transformers, we can say that each i-f stage contains four circuits which must be aligned, since each such stage contains two transformers, an input and an output transformer. However, in amplifiers which contain more than one stage, one transformer is always common to two stages. This is so because the output transformer of one stage is the input transformer for the stage of i-f amplification following. Accordingly, we can assume that a single stage of i-f amplification employs two transformers and four circuits must be aligned. In a two stage amplifier, three transformers are used and six circuits must be aligned. In a three stage amplifier, four transformers are used and eight circuits must be aligned. In some instances, particularly in the older. type superheterodynes, fixed tuning was used on some primaries, so that one circuit less need be aligned for each such fixed tuned circuit.

An example of a three winding i-f transformer is shown in figure 54. The primary winding is untuned. The link is tuned to the i-f peak and the output circuit likewise is tuned
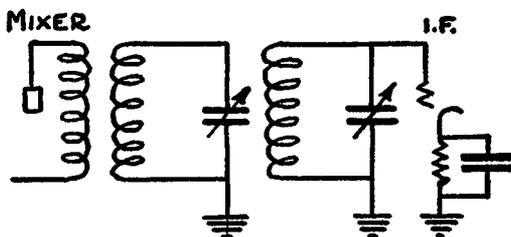
Fig. 54. A three-winding i-f. transformer with untuned primary

to the i-f peak. The middle circuit, or link circuit, couples the primary to the output or secondary winding. The exact connections to these windings are not of importance at the moment. However, the primary winding would connect to the output circuit of the mixer tube or to the output circuit of an i-f stage. The middle winding would normally connect to ground and the secondary winding or output winding

would normally be connected into the input circuit of the i-f tube or the demodulator tube, whichever tube follows. In this three winding transformer, two tuned circuits are used. Transformers of this type are found frequently in Stromberg-Carlson receivers.

An example of a single tuned circuit type of i-f transformer is shown in figure 55. A combination of inductive and capacitative coupling is used to link the untuned primary with the tuned secondary. Only the secondary circuit is tuned. It is not a fixed condition that both forms of coupling
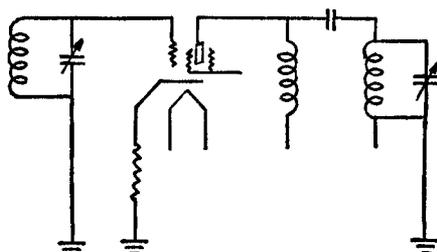
Fig. 55. An untuned-primary i-f. transformer having capacitative coupling between the windings

are used. In some instances, only capacitative coupling is used between the two windings. Another example of a single tuned circuit type of i-f transformer is to be found in some Atwater-Kent receivers, wherein the primary winding is tuned and is located in the plate circuit of the i-f tube. The balance of the coupling unit consists of a condenser and a resistor. The condenser acts as a coupling or blocking condenser and the resistor is the grid leak for the demodulator tube. (See Atwater-Kent Models 165Q, 525Q, 425, 665 in Rider's "Perpetual Trouble Shooter's Manual" Volume IV Special Section.)

Special Adaptations of I-F Amplifier Tubes.

An example of a special adaptation of an i-f amplifier circuit is shown in figure 56. Here you see the 6B7 tube used as an i-f amplifier and for AVC purposes. Note the output i-f transformer, which resembles the three winding trans-
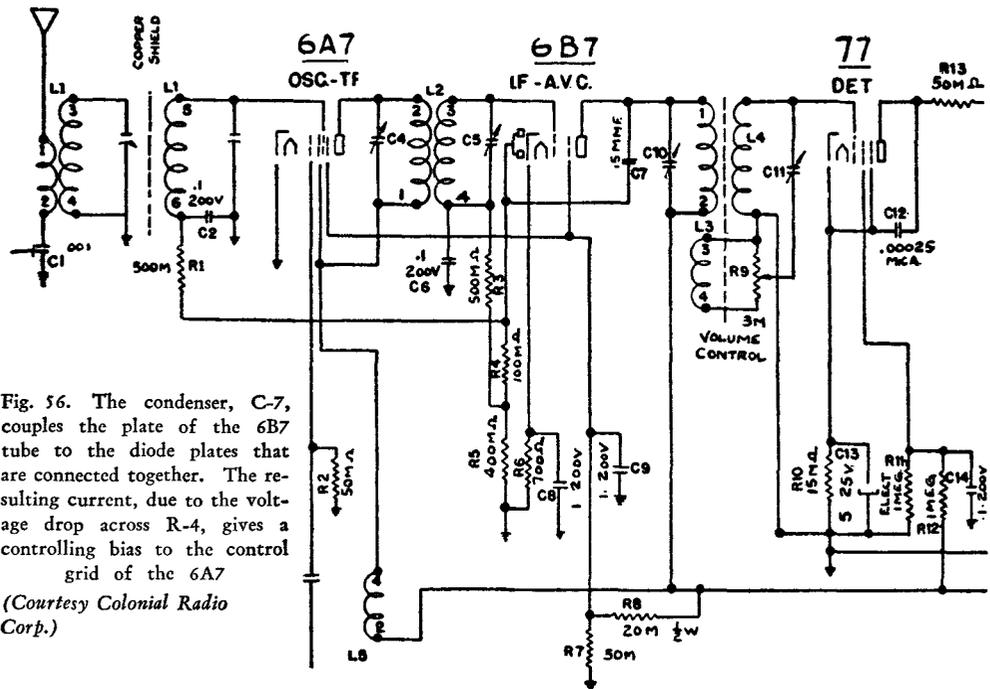
Fig. 56. The condenser, C-7, couples the plate of the 6B7 tube to the diode plates that are connected together. The resulting current, due to the voltage drop across R-4, gives a controlling bias to the control grid of the 6A7

(Courtesy Colonial Radio Corp.)

former shown in figures 52 and 53, although it is not exactly like those illustrated before.   In operation this system functions in the following manner: The i-f signal is secured from the mixer (oscillator-translator) and is fed into the triode portion of the 6B7.   It is amplified in the usual manner and fed into the primary winding of the i-f transformer in the plate circuit of the 6B7.   At the same time, a small condenser C-7 joins the plate of the 6B7 i-f amplifier to the two diode plates, thus feeding back a part of the amplified i-f signal to the diode plates.   *This is not reflexing, because the two functions are produced by two different parts of the tube.*   The diode current resulting flows through the 100,000 ohm resistor, R-4, and the 400,000 ohm resistor R-5.   Also it flows through the 700 ohm resistor, R-6, but this unit is not important at this time.   By virtue of the direction of current flow, the top end of R-4 is negative with respect to any other part of the cathode circuit.   By joining the grid return of the 6A7 tube to this point, a controlling bias is applied to the oscillator-translator tube.   The minimum fixed bias for the latter tube is applied by means of the 50 ohm cathode resistor R-2.   The minimum bias for the 6B7 is supplied by R-6.   To peak such an i-f system, it would be necessary to render the AVC circuit inoperative or to apply such a weak signal, if possible, as to cause the AVC circuit to be inactive.   Whether this could be done is doubtful.

The operation of a tuning flasher by means of the i-f signal is shown in figure 57.   This system is used in the Silvertone 1722, 1732 series.   The illustration shows just this part of the complete receiver.   (For the complete circuit, see Volume IV of Rider's "Perpetual Trouble Shooter's Manual.")   The 78 tube is the regular i-f tube used in the receiver.   The tuned i-f transformer primary associated with the letter A, is the primary of the i-f transformer, which links the i-f tube with the demodulator tube.   The last named tube is not shown in the schematic.   Another i-f transformer T is joined to the plate circuit of the i-f amplifier.   This transformer uses litz wire so as to provide an extremely high "Q" factor.   In other words, it tunes very sharply.   When a signal is fed to the 78 tube, this signal, properly amplified, appears across the two

tuned primaries in the plate circuit of the 78 tube. A portion of the signal is fed to the demodulator and a portion of the signal is applied across the diode plate-cathode circuit of the 6B7 tube.

The control grid of the 6B7 is connected to point (2) and the cathode is connected to point (1). As the signal is tuned
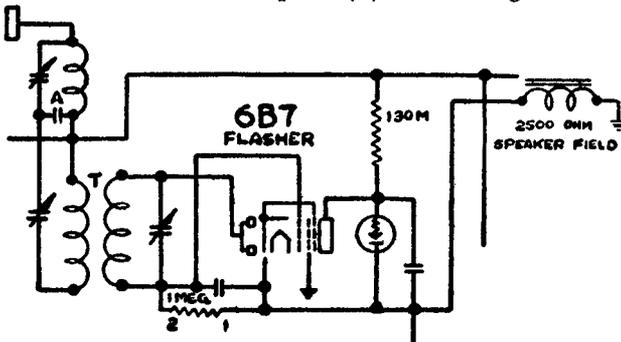
Fig. 57. Flasher circuit incorporated in the i-f. amplifier
(Courtesy Colonial Radio Corp.)

in on the regular tuning dial, the proper i-f signal is produced and fed into the 6B7. The voltage across the 1.0 megohm resistor increases because of the diode current and the control grid bias applied to the 6B7 increases. The cumulative effect is to reduce the plate current of this flasher tube. The plate current for the tube flows through the 130,000 ohms resistor. Since there is but one maximum voltage available across the maximum B plus to cathode of the complete tube system, the greater the voltage drop across the 130,000 ohms resistor in the plate circuit of the 6B7 flasher, the less is the available voltage across the flasher unit, shown within a circle and connected across plate to cathode of the 6B7. Without any signal input, the plate current is maximum, the drop across the 130,000 ohms unit is maximum and the flasher is not illuminated. However, when the signal is applied, the plate current decreases for the reason stated before, and the drop across the 130,000 ohm unit is decreased, resulting in an increased voltage being available across the flasher and causing the neon lamp to glow. Because of the sharp resonance curve

of transformer T, it is necessary that the signal be tuned in very accurately before the flasher circuit will become operative. Until the signal is accurately tuned in, the drop across the 130,000 ohms resistor is very high.

Knowledge of just what takes place in this circuit is very important when it becomes necessary to adjust the flasher circuit. Obviously, if the flasher transformer T is not properly aligned to the exact peak of the i-f signal, the tuning indicator will not operate. On the other hand, if the other i-f transformers are "off tune," the voltage developed across the secondary of transformer T at maximum resonance may not be sufficient to actuate the flasher. To align the flasher i-f transformer, it is necessary to tune in a station whose strength is just about enough to operate the flasher. Then retune the receiver accurately by means of an output meter or by means of listening to the signal intensity. If the flasher transformer is off tune, the flasher will be extinguished, despite the fact that the signal has increased. When you know that the receiver is accurately tuned, then adjust the flasher transformer trimmers so that maximum glow of the neon lamp is obtained. If you examine the schematic wiring diagram of this receiver, you will see that with the exception of this flasher tuning indicator and possibly the AVC system, the i-f amplifier is of conventional order.

Another example of a special i-f arrangement, that is in one tube, is the 6B7 utilized to perform four roles, viz: i-f amplifier, delayed AVC, demodulator and a-f amplifier. This is shown in figure 58. This arrangement will be found in quite a few modern superheterodynes. Perhaps it is premature to speak about functions other than intermediate frequency amplification, but since the opportunity presents itself, we feel that a complete discussion of the action taking place within this tube will not be out of place. The 6B7 is a duo-diode pentode. The i-f signal is fed into the control grid of the pentode portion of the tube. This signal is amplified in normal manner and appears across the primary of the i-f transformer in the plate circuit. Connected in series with this i-f transformer primary, is the primary of the audio frequency transformer. However, because of the extremely high im-

pedance of the i-f transformer primary, the major portion of
the i-f voltage in the plate circuit is developed across the
tuned i-f transformer primary. This winding is coupled to
the secondary of the transformer, which is not tuned. The
i-f signal developed across the secondary is fed to one of the
two diode plates. Detection takes places in the diode plate-
cathode circuit which contains the i-f transformer secondary,
the 200,000 ohms fixed filter resistor, the active portion of the
200,000 ohms potentiometer, as determined by the position of
the moveable arm and the 1000 ohm potentiometer in the

Fig. 58. The 6B7 tube
here performs four func-
tions: i-f. amplifier, de-
layed AVC, demodulator
and a-f. amplifier. The
upper diode plate is used
for demodulating and the
lower one for AVC

*(Courtesy Emerson Radio
& Phonograph Co.)*

cathode circuit. In the arrangement used, the upper diode
plate is used for detection and the lower diode plate is used for
AVC. Referring once more to the detector circuit, the a-f
currents flowing in this circuit pass through the active portion
of the volume control unit. This means that an a-f voltage
is developed across this control. By varying the position of
the moving arm on this 200,000 ohms potentiometer, the
amount of resistance in the circuit is varied, hence the voltage
developed across the active portion of the unit is varied. This
constitutes the a-f volume control, because the a-f voltage
developed across the unit is fed back to the control grid of the
pentode portion of the tube through the .01 mfd fixed con-

denser and the tuned secondary of the i-f transformer located in the control grid circuit of the tube. The input i-f transformer secondary being resonated to the intermediate frequency, has no effect upon the audio frequencies being fed to the control grid. This signal is amplified in normal manner and amplified audio frequency currents appear in the plate circuit. These currents flow through the resonated i-f transformer primary and through the a-f transformer primary. Since the i-f transformer primary is tuned to the intermediate frequency, the impedance to audio frequency currents is extremely low and the maximum voltage is developed across the a-f transformer primary, is fed to the a-f transformer secondary and then to the a-f tubes.

Concerning the AVC action, a portion of the i-f signal fed to the upper diode plate is also fed to the lower diode plate via the .0005 mfd condenser connected between the two diodes. Rectification takes place between the lower diode plate and the cathode. The direction of this current flow is such that the diode is negative with respect to the cathode. The d-c component in this AVC circuit develops a d-c voltage across the 1.0 megohm resistor, which voltage is fed to whatever tubes are being controlled, via the resistor-capacity filter system, consisting of the 1.0 megohm resistor and the 1.0 mfd condenser. The 0.5 megohm resistor in the control grid circuit controls the flow of the a-f currents, so that they will maintain their correct paths to the control grid of the tube. The .0005 mfd condenser between the control grid return and cathode, acts as the bypass condenser for that circuit. By suitable adjustment of the normal bias to the diode plates in the 6B7 circuit, it is possible to render the AVC tube circuit inactive until the signal reaches a definite magnitude, thus assuring maximum sensitivity at very low signal levels.

The important consideration in this discussion is the means of securing intermediate frequency amplification. The fact that the signal is fed from the plate circuit of the pentode portion to the diode circuit does not constitute real reflex action. If any reflexing is being accomplished, it takes place with the a-f signal, rather than when the i-f signal is being applied.

The arrangement shown in figure 58 with respect to the flow of i-f currents is substantially the same in all instances when the 6B7 tube is used. For that matter, the circuit structure is substantially the same for all such duo-diode pentodes, as far as i-f amplification is concerned. In some instances, the a-f signal may be fed back to some other tube, but, when the duo-diode pentode is used as an i-f amplifier, the manner of securing intermediate frequency amplification is as outlined.

I-F Amplifier With Crystal Filter.

Although this circuit should normally be presented in line with different types of i-f amplifier systems, we deem it worth-
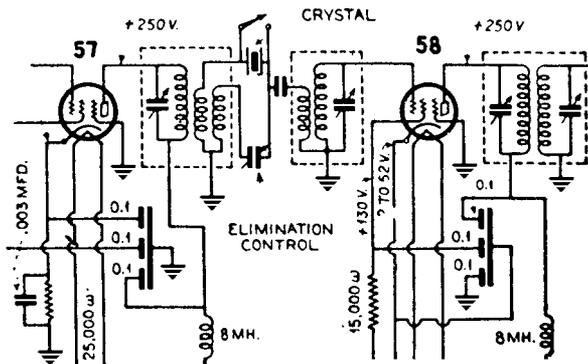
Fig. 59. The crystal incorporated in this i-f. amplifier tends
to reject everything but the i-f. peak
(Courtesy Hammarlund M'f'g. Co.)

while to allow it its own subhead. As in the case of earlier examples, this special arrangement is again a special transformer system. With the exception of this one i-f transformer network, the balance of the i-f amplifier is quite conventional. The circuit shown in figure 59 is used in the Hammarlund "Comet Pro," Crystal Model. The crystal filter located in the i-f amplifier is utilized to afford the greatest amount of adjacent channel selectivity, which condition is greatly influenced by the selectivity powers of the i-f amplifier. The tuned circuits ahead of the mixer tube also play an important part in separating stations operating upon adjacent channels, but in as

much as any two different signals, which may find their way into the mixer circuit, will be heterodyned, it is up to the i-f amplifier to select the desired signal, which has been heterodyned to the correct i-f peak and to reject the undesired signal, which has been heterodyned to a frequency higher or lower than the desired signal by the original frequency difference between the two carriers.

The Hammarlund receiver being intended for amateur band transmission must possess selectivity powers far in excess of a normal broadcast band receiver, because amateur code stations, operating on certain particular bands definitely assigned for the purpose are not allocated individual operating frequencies. Consequently, a number of stations may be operating upon exactly the same frequency or on frequencies a fraction of a kilocycle apart. Consequently, the 10 kc. separation between broadcasting stations may be reduced to 0.1 kc. or 0.05 kc. or perhaps 1.0 kc. separation between amateur (ham) stations, and it is up to the receiver to select between these stations. In order to accomplish this end, a crystal filter is used in one of the i-f amplifier transformer networks. This crystal is cut in such manner that its natural frequency is the i-f peak of the receiver. In this instance it is 465 kc. It could just as readily be 200 kc., 345 kc., or whatever other frequency is desired by the designer of the receiver. The crystal, when located in the tuned transformer circuit, will allow the passage of signals which have a numerical frequency, equal to the resonant frequency of the crystal, but will reject all other frequencies. For signals equal to its natural vibratory period, the impedance of the crystal is low, whereas for other frequencies, even as low as 1.0 kc. off resonance, the impedance of the crystal becomes high and those signals are greatly attenuated. Provision is made so that the crystal can be "cut" into the circuit or removed from the circuit. It is usually in the circuit when listening to code signals, where a frequency difference of perhaps 500 to 1000 cycles exists between the desired and the undesired stations. According to the manufacturer of the receiver, the crystal control is suitable for use during phone reception on the grounds that while side bands are cut, the voice still is intelligible. With the

crystal in the circuit as shown, information from the receiver manufacturer states that a signal 1000 cycles off the exact i-f peak, is attenuated about 10 percent.

There is no doubt about the tremendous advantage of such a crystal filter in the i-f amplifier as a means of securing the utmost in adjacent channel selectivity, when the i-f amplifier need have a band pass characteristic. However, where an 8 kc. or a 10 kc. total band pass is required, such a single crystal cannot be used satisfactorily.

Some time ago, a broadcast superheterodyne receiver made its appearance wherein a crystal was used in the i-f amplifier. The purpose of the crystal was to provide the utmost in adjacent channel selectivity. The side band suppression taking place in the circuit was to be offset by the use of an audio amplifier which had an operating characteristic of such shape as to compensate for the side band suppression in the i-f system. This was the Stenode receiver. It never gained the engineering favor its sponsors thought was its due.

Referring again to figure 59, the switch connected across the crystal enables its removal from the circuit, in which case, the i-f transformer possesses the required band pass characteristics so that it is suitable for the reception of broadcast music or speech. No doubt you realize that the use of a crystal of this kind is not influenced by the wavelength or frequency range of the receiver. The crystal is suitable for use in the i-f amplifier if the receiver is a single band broadcast receiver or if it is a short wave receiver or a combination all-wave receiver.

Characteristics of I-F Amplifiers.

The i-f amplifier in the superheterodyne must accomplish certain ends. First it must amplify to the fullest extent provided for by the design of the system, namely the tubes and the transformers. Second, it must amplify without distortion related to the side band frequencies. There must be minimum side-band suppression. At the same time, the amplifier must be selective in its own right. By this we mean that it must provide maximum attentuation of all frequencies other than the peak frequency and the normal side bands. Third, its

tubes must operate as amplifiers at all times, even when volume control bias has been applied so that the signal output is minimum. At no time must any one of the i-f amplifiers function as a rectifier due to change in the operating characteristic of the tubes. Fourth, the tubes must not be overloaded as a result of excessive signal input for normal bias or insufficient bias for normal signal input. Fifth, the amplifier must not operate close to the point of oscillation. Sixth, the i-f amplifier must not pick up any external signals, Seventh, the i-f amplifier system must not radiate any signals. The i-f amplifier which lives up to these seven requirements would be classed as ideal.

Unfortunately, however, this ideal state is not always realized. The average amplifier performs well when normal conditions exist, but when an abnormal state is created, then we must pay heed to what is taking place. The i-f amplifier can be a prolific source of trouble. Any condition which will cause incorrect operation of the amplifier tubes, as for example excessive bias or operation at the cut-off or such a change in operating potentials as will make a normal signal input produce the effects of excessive input, will give rise to distortion. This distortion may appear as an apparent change in modulation, accompanied by a falling off of signal output. If the conditions are such as to be productive of second harmonics of the i-f signal, undesired beat notes may be created in the demodulator circuit. This condition is greatly aggravated if the shielding of the i-f system leads and components is not perfect and interaction is permitted between the i-f system and some part of the input circuit.

If shielding of the i-f amplifier is not perfect and external signals are picked up by the various grid leads and other components, these signals will appear in the output as interference signals. Not only do unshielded grid leads act as means of external interference signal pickup, but if the actual shielding is imperfect, because of imperfect contacts between the various shield sections, the shields themselves act as pickup units and feed signals directly into the i-f transformers and adjacent leads. Not only do shields and leads function as pickup devices, but the tubes themselves perform that function, unless

the i-f tubes are properly shielded. There is every need for as perfect shielding of the i-f amplifier and every one of its components as for the most sensitive part of the entire receiver. Investigation discloses that sufficient attention is not paid to the i-f amplifier in commercial receiver design and that a large number of complaints voiced in the field would never arise, if the complete i-f unit, inclusive of tubes, were properly shielded and isolated from all external influences. Further details concerning operating characteristics of i-f amplifiers as encountered during service calls are discussed in the chapter devoted to trouble shooting in superheterodynes.

A few of the early type superheterodynes, particularly those made by RCA-Victor, employed i-f transformers which were designed to have a flat top tuning characteristic. The normal peak was about 175 kc. and the frequency band covered by the flat top extended about 4.0 kc. each side of the peak. Today, the i-f transformers are designed to provide a suitable band pass, but when aligned, are aligned at but one frequency, namely the peak frequency. In the flat top tuned transformers referred to first, the alignment process involved tuning the transformers in such manner that substantially the same response was had over the 8.0 kc. range.

Whereas 175 kc. was the predominant frequency years ago, such is no longer the case. It would be difficult to establish just what frequency is used most often. Furthermore, certain manufacturers employed certain i-f peaks in the early production of superheterodynes. In other words certain i-f peaks were identified with certain manufacturers. That is no longer true. A manufacturer may use any one of a number of different i-f peaks during a certain production run. After a period of time, the i-f peak is changed although the model number remains the same. During a season's production, it is very likely that a manufacturer may make use of three, four or even more different intermediate frequencies, so that it is really vital to know at just what frequency, the i-f amplifier is peaked. You cannot take any one peak for granted, despite the fact that a previous receiver of identical manufacture and model number was known to have employed a certain i-f peak. It is always imperative to

investigate the service information you have on hand concerning the specific receiver at hand. You will find, if you are in possession of Rider's "Perpetual Trouble Shooter's Manual," that upon numerous occasions i-f peaks have been changed in identical models and identification marks were placed upon the chassis, to denote the exact production run.

THE SECOND DETECTOR.

The second detector or demodulator in the superheterodyne receiver serves the same function as the usual detector in the tuned radio frequency receiver. Assuming that the i-f signal in the superheterodyne receiver is a modulated carrier, the demodulator or second detector separates the audio frequencies comprising the modulation component from the carrier component. In other words, this tube demodulates the modulated beat note.

Since this book takes for granted that the reader is familiar with the function of the detector in the t-r-f receiver and since this book is not intended as a complete text covering vacuum tube theory and phenomenon, it is unnecessary to devote a great deal of time to the actual process of detection. For the person vitally interested in that phase of radio phenomenon, we suggest the bibliography listed in the appendix. However, modern second detector functions are combined with other functions performed by the same tube or by other elements contained in the same envelope. This is in contrast to what took place years ago, hence it becomes quite important to consider the various circuit combinations associated with the action of the second detector tube. As far as actual servicing of the superheterodyne receiver is concerned, we feel that it is far more important for the service man to understand the various circuit arrangements, than to be thoroughly versed in the phenomenon of demodulation, but completely at a loss when attempting to analyse troubles which may be associated with the demodulator circuit. The radically rapid rate of development of vacuum tubes during the past three years and the rapid rate of circuit development, has just about pushed the single function demodulator tube of the triode or

screen grid type, into obsolescence. Today, the second de-
tector is associated with i-f amplification, a-f amplification,
delayed AVC and noise suppression circuits.

However, irrespective of the manner in which the demodu-
lation action is accomplished or the number of other functions
associated with the tube or tube elements which perform the
action of demodulation, the process of demodulation is a func-
tion in itself. This is true even if the action simultaneously
includes the production of the AVC voltage, because the pro-
duction of the AVC voltage in such cases depends upon the
flow of the detection current and even if the AVC circuit is
inoperative so that the proper AVC potentials are not applied
to the tubes being controlled, detector action may still take
place.

A major item associated with the detector or demodulator
action and which is important as far as successful servicing of
the superheterodyne receiver is concerned, is the recognition
of the signal currents which flow in the output circuit of the
demodulator tube. Usually the output circuit of the detector
tube is construed as being the plate circuit of the tube. That
is true when a triode or screen grid tube is used as the detector
and the a-f feed circuit is the plate system. In some of the
modern tubes, the demodulator action takes place between the
one or both of the diode plates and the cathode or between
the control grid and cathode in the conventional triode tube
used as a diode. Consequently, the general definition of the
demodulator output circuit would be that circuit which con-
tains the audio frequency currents.

During the process of demodulation harmonic currents of
the original signal are produced in the output circuit of the
detector tube. This is true to a varying degree, depending
upon the operating potentials and the general mode in which
the tube is used, in substantially every detector tube. In some
cases the intensity of the harmonics is greater than in others,
but they are present nevertheless and troubles due to such
harmonics must be avoided at all times. Also the fundamental
frequency is present in the output and troubles due to this
carrier frequency must be avoided. The troubles which arise
because of the fundamental and harmonics of the carrier fed

into the tube arise when coupling is permitted to exist between the output circuit of the demodulator tube and some other part of the complete radio receiver, which may be carrying carrier currents of some other frequency. This means that the antenna system, r-f pre-selector system, mixer system, oscillator system and i-f amplifier in the receiver must be isolated by some means or other from the demodulator output circuit. If this is not done or if coupling is permitted to exist and the external signal finds its way into the mixer tube, undesired interference beat notes will be produced and, if these beats occur at an audio rate, they will be passed into the audio amplifier and made audible in the speaker.

For example, if a 910 kc. signal is being received on a superheterodyne which employs a 456 kc. peak, and coupling is allowed to exist between the output circuit of the demodulator and the antenna system, the 2nd harmonic of 456 kc., which is 912 kc., will beat against the 910 kc. signal and produce a 2000 cycle beat note. This can occur at two points of the receiver. The mixing process can take place in the demodulator tube or the 912 kc. signal can be fed into the regular mixer in conjunction with the desired 910 kc. signal and the beat note produced in the mixer will carry a 2000 cycle component, which will appear as a background whistle impossible to eliminate, unless the coupling aforementioned ceases to exist.

The possibility of beat notes due to coupling between the demodulator output circuit and some other part of the receiver is very great and myriad combinations are available. Thus, if the receiver employs an i-f peak of 181.5 kc. and the receiver is tuned to a 910 kc. signal carrier and for some reason the heterodyning signal of 1091.5 kc. gets into the demodulator grid circuit, a beat note of 1500 cycles is apt to be present in the audio system. This beat is the difference frequency between the heterodyning oscillator signal of 1091 kc. and the 6th harmonic of the 181.5 kc. i-f peak. The 6th harmonic may sound quite high, but it has been found present in many test cases. Many more examples can be cited, but they are unnecessary at this time.

In the early type superheterodynes, which utilized the conventional triode or screen grid tube, the plate circuit contained intermediate frequency filters for the purpose of keeping i-f signal currents out of the audio circuit. The field of the choke used in this filter was often found to be quite extensive and much trouble originated from this source. In some instances these chokes were located in metal cans, which were grounded to the chassis. What applied to those units years ago is still applicable to those receivers. Not only is it necessary to shield, or at least isolate, these i-f chokes, but it is best to effect precautions against coupling to the leads, which connect to these chokes and to the condensers associated with this i-f filter system. This is a general statement and applicable to all receivers which utilized such filter systems.

Modern receivers employ resistance-capacity filters in the demodulator output circuit. This does not mean that these new circuits are free from the effects of undesired coupling. They are anything but free from undesired beat note production, unless care is exercised. In very many cases the output system of the modern demodulator tube is passed through shielded leads, so as to isolate the circuit from neighboring circuits.

Referring once more to those demodulator output circuits which contain filters, perfect condition of the components of the filter network is essential to successful operation of the receiver. If the associated bypass condensers are not intact so that the filter operates effectively, coupling difficulties will arise.

Diode Demodulators.

Diode or two element detectors have been used for many years, but never with the abundance to be found today. Quite a large number of superheterodyne receivers employ diode detector circuits, wherein a normal triode of the filament or the indirect heater type, depending upon the class of power supply, is arranged as a two element demodulator. Linear detector performance plus the fact that strong signals are handled with ease, has made the system quite popular. The ar-

rangement of the triode tube elements for diode detection is accomplished in several ways. One of these is to join the plate and cathode or electron emitter and to apply the signal carrier between the control grid and the electron emitter. Another method is to join the control grid and plate and to apply the signal carrier between the electron emitter and the plate and the grid is used as a single tube electrode. As a general rule such diode demodulators are employed as single purpose tubes, that is, to perform the demodulation function. AVC and a-f amplification is accomplished by means of other separate tubes. This is in contrast to the method of employing the duo-diode triodes and pentodes, some of which have been mentioned in connection with i-f amplifiers.

The diode detector does allow of its used as a combination demodulator and source of automatic volume control voltage. An example of a general circuit is shown in figure 60. While this circuit is not native to any one particular radio receiver, it is generally typical of all such diode-AVC systems. The

Fig. 60. A typical example of a diode detector used as a combination demodulator and AVC tube. Note that plate and cathode are connected
(Courtesy Fada Radio)

plate and cathode are joined. The i-f transformer is of the untuned type, because during one-half of the signal voltage cycle current flows through the secondary of the winding and

the circuit is highly damped. This condition nullifies all the advantages of tuning to resonance, hence the transformer secondary is not tuned. However, let it be known that all superheterodynes do not use such untuned secondaries. In some instances the input winding is tuned, just as if a regular triode or screen grid detector were being employed and current was absent from the tuned circuit.

Rectification takes place in the control grid and composite cathode-anode circuit. As stated before, some diode tubes join the control grid and plate to comprise one anode. The load circuit applied to the rectifier is that path through which the rectified current flows and across which the audio and the pulsating d-c voltages are developed. In figure 60, the load circuit is the series combination of resistors R and R-1, connected between the low side of the untuned i-f transformer secondary and the cathode. During one-half of the signal cycle, current flows through the load resistors. This current is of a pulsating character and contains the audio component. As a result, a d-c voltage and an a-f voltage are developed across the load circuit. The d-c voltage, properly apportioned, is used to supply the automatic volume control bias. The a-f voltage is fed to the a-f tube.

By suitable selection of the values of R and R-1, the proper value of voltage for AVC purposes is available at whatever portion of the load circuit is tapped for that purpose. The diagram in figure 60 shows the i-f grid return connected to the junction between R and R-1. This lead supplies the AVC bias voltage for the i-f and whatever other tubes are to receive the automatically varying bias. The amplitude of this bias voltage, assuming a fixed impedance load, is dependent upon the amplitude of the carrier voltage supplied to the rectifier, because the diode tube is a linear rectifier. The value of the bias supplied to the controlled tubes is the voltage developed across resistor R-1. This is so because of the location of the tap upon the load circuit, which, as far as d-c voltages are concerned, is like the usual voltage divider in the conventional power rectifier. The direction of the current flow through the load circuit is such that all points along the divider (R and R-1) are negative with respect to the cathode of

the diode tube. The bias developed across part or the whole divider, as the case may be, is applied to the steady fixed minimum bias normally applied to the i-f tubes by means of the bias resistor used in that circuit, and not shown in figure 60.

The audio voltage developed across the entire diode tube load is applied to the a-f tube via a filter or decoupling resistor R-3, functioning in conjunction with the bypass condenser connected to ground. Resistor R-3 and this condenser bypass all i-f to ground and isolate the a-f tube from the rectifier circuit. This i-f bypass combination keeps all currents of all frequencies, other than the desired a-f currents, out of the a-f system.

As we stated, all diode demodulator-AVC systems are not identical to that shown in figure 60, but when a single triode tube is used as a combination diode detector and AVC voltage source, the operation of the circuit is substantially as described. You will find, if you examine service schematics, that some combination diode detector-AVC circuits contain many more components than are shown in figure 60. These components embellish the circuit so as to secure greater isolation of the associated systems, better filtering or limitation of current flow to certain prescribed paths, the addition of a manual volume control and maybe tone control, etc. However, the operation of the circuit is like that stated. An example of a diode rectifier used with noise control is described elsewhere in this volume.

Another example of a diode detector or demodulator is shown in figure 61. The tube performs two functions, namely that of a demodulator and also supplies the automatic volume control bias. In this instance, in contrast to figure 60, the control grid and plate are interconnected and utilized as a single element. The signal voltage is applied between the cathode and the composite anode. The load resistor is the 120,000 ohms unit connected between the cathode and the low end of the i-f transformer secondary. The d-c component in the rectified output develops a d-c voltage across this unit in accordance with the intensity of the input carrier; that is, the input i-f signal. The intensity of this d-c voltage varies with the intensity of the carrier. The AVC voltage thus pro-

duced is applied to the i-f, mixer and r-f tubes through the common filter resistor of 490,000 ohms.

Since the rectified current flows through the load resistor, an a-f voltage is developed across this resistor. This circuit shows a unique method of taking the voltage of the demodulator load circuit. The volume control is connected across the demodulator load resistor through a fixed condenser. The mov-

Fig. 61.   Another AVC and demodulator combination.   Note that the grid and plate are connected

(Courtesy Zenith Radio Corp.)

ing arm of the volume control unit enables control of the a-f voltage fed to the a-f tubes.

A more detailed explanation of the method of procuring the AVC voltage will be found in a subsequent section of this chapter, which is devoted to automatic volume control circuits. The arrangement shown in figure 61 is used in the Zenith chassis model 2054, receiver models 475,750,765,767. Similar circuits are to be found in a large number of other receivers produced by other manufacturers. It is possible that the arrangement of securing the a-f voltage from the diode demodulator tube is native only to the receiver named, but of this we are not certain. The actual demodulator circuit shown is quite frequently used in modern radio receivers.

It is significant to note the absence of the usual r-f choke-condenser combination previously referred to as the r-f or i-f filter in the ordinary triode or screen grid detector plate circuit. This does not mean that the output or load circuits of

the diode tubes do not contain those frequencies which were troublesome in the earlier types of detector arrangements. Every load circuit is bypassed with a bypass condenser of such value as to control effectively the path of the various frequencies higher than the audio component, which are present in the output system. It is essential that the presence of these currents be recognized and that the output circuit be isolated from all possible forms of coupling with any part of the entire receiver, which precedes the output circuit of the demodulator tube.

Triode-Pentodes.

Figure 62 illustrates the use of a 6F7 as a triode pentode. The triode portion is used as a detector or demodulator and the pentode portion is used as an a-f amplifier. The heater and cathode are common to both sets of tube elements. The cir-
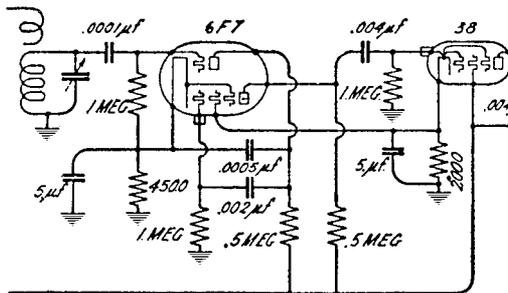
Fig. 62. The 6F7 is used here as a demodulator and
a-f amplifier. This is not a reflex circuit
(Courtesy Emerson Radio)

cuit shown is not a reflex arrangement, because the tube contains two independent sets of elements. We might mention at this time that the schematic shown is taken from a t-r-f receiver, rather than from a superheterodyne, but the circuit is just as readily applicable to the superheterodyne receiver. However, the tube, used as a triode pentode, is employed in superheterodynes as a combination i-f and a-f amplifier. See figure 68. This tube is also used as a combination mixer and oscillator. The triode portion is used as an oscillator and

the pentode portion is used as the mixer tube. Circuits show-
ing the use of the 6F7 as a mixer and oscillator will be found
in Volume IV of Rider's "Perpetual Trouble Shooter's Man-
ual." No doubt subsequent volumes of this manual will con-
tain many additional circuits wherein this tube will be found.
When used as a mixer-oscillator, the system is not of the auto-
dyne variety, because each function is achieved by a separate
set of tube elements. To a certain extent the 6F7 is like the
6A7, except for the fact that the oscillator anode grid in the
6A7 is replaced by a regular plate in the 6F7.

See special circuits for illustration of reflexing with the 6F7.

*Duo or Duplex Diode Triodes and Pentodes For Demodulation
    and Other Uses.*

A discussion of demodulators of the duo-diode triode or
pentode type is complicated by the fact that these tubes per-
form several functions and that the demodulation circuit is
electrically interlocked with other circuits, such as i-f ampli-
fication, delayed AVC and a-f amplification. Although the
demodulator circuit is intact in itself, it does contain units
related to other circuits, so that in order to discuss all of the
component parts shown, it becomes necessary to describe all
functions which are performed with the tube. Such shall be
done.

The last two years have witnessed the development of what
is known as the duplex or duo-diode triodes and pentodes.
The forerunner of these tubes was the standard triode inter-
connected as a diode or two element rectifier. The various
duo-diode triodes and pentodes have provision for diode de-
tection of either the half-wave or full-wave variety. In other
words, one portion of the tube consists of such elements that
will perform as a diode rectifier.

The duo-diode triode of the a-c type consists of a heater, a
cathode, two diode plates, a control grid and the regular
plate or anode. Thus there are two sets of elements within
the same envelope. The heater and cathode are common to
both sets. The diode portion consists of the cathode and the
two diode plates and the triode portion consists of the cathode,
the control grid and the large anode or plate. The duo-diode

pentode typified by the 6B7, already illustrated in schematic form, consists, when of the a-c type, of a heater, a cathode, two diode plates, a control grid, a screen grid, a suppressor grid and the large anode or plate. The diode portion of the tube consists of the cathode and the two diode plates. The pentode portion of the tube consists of the cathode, the control grid, the screen grid, the suppressor grid and the large plate or anode. The cathode and heater are common to both sets of elements.

These tubes when intended for d-c or battery use contain a filament as the source of electrons, in place of the cathode-heater combination. The heater in the a-c tube serves to raise the temperature of the cathode to the electron emitting level.

The diode portion of these combination tubes, when used as half wave rectifiers, which arrangement requires that the two diode plates be joined, is the equivalent of a normal triode tube used as a diode, or that of a half wave rectifier such as the 281. Of course, the tube should not be confused with a power rectifier such as the 281, as far as actual use is concerned. Recognizing its use for the rectification of signals, we can compare its operation with that of the normal diode or two element rectifier. An example of the type 75 duo-diode triode is shown in figure 63. Note that the two diode

Fig. 63. Note that the two diode plates of this duo-diode triode tube (type 75) are connected and rectification takes place between them and the cathode. The distribution of the a-f current through the resistor R-5 and the volume control, connected between R-5 and ground, should be thoroughly understood

(Courtesy Sears-Roebuck)
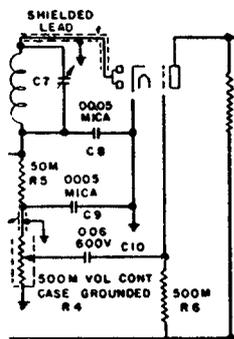
plates are joined so as to comprise a single element. Rectification takes place between the diode plate and cathode. Then the rectified currents flow through the 50,000 ohm resistor R-5

and the 500,000 ohm volume control. Now the currents, due to the process of rectification, contain the audio frequency component and also develop a d-c drop across whatever units are employed in the load circuit. Consequently, we have a d-c and an audio voltage developed across R-5 and the volume control resistor. The direction of the rectified current flow is such that all points above ground along the load circuit voltage divider are negative, hence an automatically varying d-c voltage, dependent upon the intensity of the signal carrier, is available by tapping the divider circuit. This is done in figure 63. The junction shown at the top end of the 50,000 ohms resistor R-5 is connected to the control grids of the controlled tubes preceding the demodulator. The AVC bias is fed to these tubes.

Referring once more to figure 63, it is not imperative, in order to secure the proper bias, to connect the controlled circuit grid return leads to the most negative portion of the diode circuit voltage divider. The correct point along the divider is determined by the bias voltage required for the automatically controlled tubes. Naturally, the selection of the correct placement of the AVC voltage supply lead is a matter of design and is established when the receiver is designed. The service man has nothing to do with the selection of this tap. The various condensers associated with the diode tube load circuit are the bypass condensers required to keep the various currents in their allotted paths and so minimize interaction. Condenser C-8 serves to bypass the entire load circuit, as far as the input i-f signals are concerned. The usual resistance-capacity filters employed in the AVC supply lead, so as to isolate the diode tube divider from the remainder of the tube circuits, is not shown in figure 63. If you examine the wiring diagrams shown in Rider's "Perpetual Trouble Shooter's Manual" you will easily locate these decoupling or filter resistors.

We stated that the rectified current contained the audio component. This component develops an a-c voltage across the load circuit. By means of the moving arm upon the volume control unit, any value of audio voltage between zero and the maximum developed across the 500,000 ohm volume

control can be supplied to the control grid of the triode portion of the tube. This audio signal voltage is fed to the control grid via the blocking condenser C-10. The 500,000 ohm resistor R-6 is the grid leak. This signal is amplified in the regular manner and appears in the plate circuit. The resistor in the plate circuit is the plate load for the triode portion of the combination tube.

At the time that the duo or duplex diode triode was first announced as the Wunderlich tube and other similar tubes like the type 55, one of the features claimed for the tube was the advantages accruing as a result of full wave rectification. The advantage was the theoretical elimination of carrier frequency filtering, or the use of bypass condensers, chokes, etc., for the sole purpose of keeping the carrier frequency out of the subsequent tube control grid circuits. At the same time, the tube is suitable for AVC and audio frequency amplification. More than likely the reason for its limited use in receivers is the fact that the half wave rectifier arrangement, which requires carrier frequency filtering, provides about twice

Fig. 64. This duo-diode triode tube is here used as a full-wave rectifier, AVC and a-f amplifier. The diode plates will be seen to be connected differently than those in Fig. 63. The a-f volume control in this circuit is shunted across the load resister, 150,000 ohms, whereas in the previous figure, 63, it was in series with it

(Courtesy Galvin M'f'g. Co.)
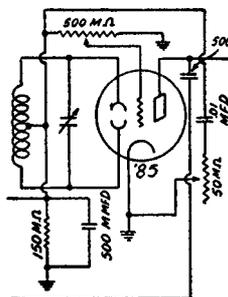
the signal output available with full wave rectification. An example of the full wave duo-diode triode used as a full wave rectifier, AVC and a-f amplifier is shown in figure 64. Note that both diode plates are used in a different manner from that found in figure 63. A center tapped or split input winding is used. Also note the manner in which the a-f volume control is arranged. Whereas the previous tube system uses a series arrangement for the divider, this circuit employs a shunt arrangement, wherein the a-f volume control shunts the load

resistor, the 150,000 ohm fixed resistor. A tone control is connected across the a-f input circuit. The AVC tap is at the top end of the 150,000 ohm fixed resistor. The arrangement of the units as shown in figure 64 is not necessarily compulsory because of full wave rectification in the diode circuit. A series arrangement for securing the AVC and a-f voltage can be used.

Another example of the duo-diode triode used as a half wave rectifier and audio amplifier is shown in figure 65. Note the use of an r-f choke in the a-f lead circuit. An extremely simple example of the duo-diode triode used for half wave rectification and a-f amplifier is shown in figure 66. The load resistor is also the a-f volume control.
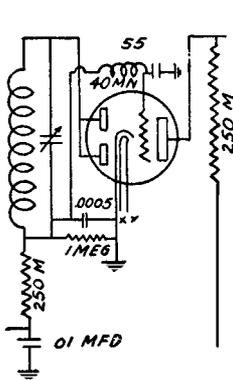
Fig. 65, left. The 55 tube is used as a half-wave rectifier and a-f amplifier. Note the use of the r-f choke coil
(Courtesy Franklin Radio Corp.)

Fig. 66, right. The 500,000 ohm volume control is also the load resistor in the cathode circuit
(Courtesy Pierce-Airo Co.)
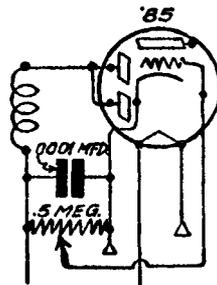
Viewed from the servicing angle, it is significant to note that the operating potentials at the diode plate elements cannot be measured with the usual run of testing equipment. While it is true that a fixed potential exists between the diode plates and the cathode, assuming the use of a fixed bias, measurement of this potential by working between the diode plates and the cathode is not very satisfactory, because of the high resistances found in the circuit. This is true when the measurement is made without any signal input. If a fixed bias is used, the proper points for checking are the cathode and the ground or chassis, whichever is the junction of the cathode.

Measurement of operating voltages during the passage of a signal is out of the question, because it will interfere with the normal operation of the receiver. The usual run of operating voltage tables given for duo-diode triodes or pentodes apply to the triode or pentode portion of the tube. If the tube circuit is of such design that a separate diode plate is used for AVC, operating voltages in the AVC circuit cannot be measured with the normal run of testing equipment. For that matter, grid voltages in diode biased full wave rectifiers cannot be determined with the normal run of testing equipment, because the bias is developed by the signal and testing equipment applied to the circuit would load the system to such extent as to interfere with the true existing voltages.

Duo-Diode Pentodes.

As far as the diode portion of the tube is concerned, the duo-diode pentode is identical to the duo-diode triode. The primary difference between the two types of tubes is the presence of the suppressor and screen grids in the pentode portion of the combination tube. This becomes evident when you compare figures 63 and 67. The former is the duo-diode triode and
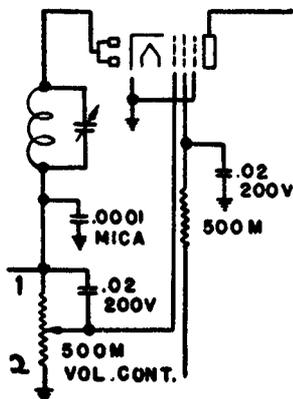
Fig. 67. The duo-diode pentode at the right is employed as a second detector, AVC and a-f amplifier tube. The main difference between this circuit and that of Fig. 63 is that the AVC bias in Fig. 67 is taken from the top of the 500,000 ohm volume control. Full-wave rectification may be had with this tube as with the type 75

(Courtesy Colonial Radio Corp.)

the latter is substantially the same circuit network for the duo-diode pentode. The primary difference between the two circuits is that the AVC bias in figure 67 is taken off from the

top end of the a-f volume control and one resistor is omitted
from the circuit. The functions of the tubes shown in figure
63 and 67 are the same. Both act as demodulators, provide
AVC and also amplify at an audio frequency. Full wave
rectification can be employed just as readily with duo-diode
pentodes as with the other type of tube.

Duo-diode pentodes find frequent application in super-
heterodynes and it is quite common to find such tubes utilized
for simultaneous intermediate frequency amplification, audio
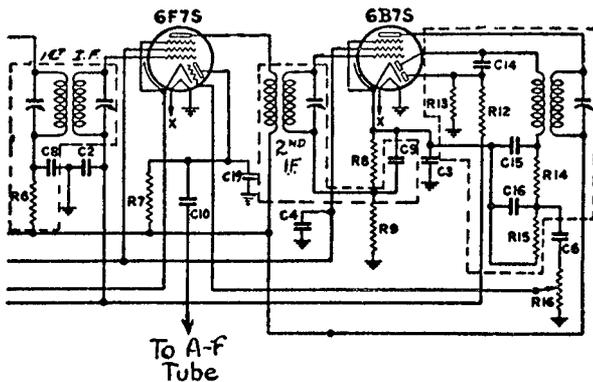
Fig. 68. The triode pentode, 6F7S, is used as an i-f and a-f amplifier
and the 6B7S is used for i-f amplification, demodulation and AVC
(Courtesy Grigsby-Grunow Co.)

frequency amplification, demodulation and separate AVC
See figure 58 and accompanying explanation. This does not
mean that all such pentodes are used in like manner. Figure
68 illustrates the use of a triode-pentode for intermediate fre-
quency and audio frequency amplification and a duo-diode
pentode for intermediate frequency amplification, demodula-
tion and separate AVC. This circuit is used in the Majestic
500 chassis, models 55, 59, 75, 195, 500, 560 and 566. Trace
the path of the signal voltage into the first i-f tube. This
tube is a triode-pentode. The amplified voltage appears across
the primary of the 2nd i-f transformer and is fed into the
pentode portion of the 6B7S, a duo-diode pentode. The
amplified i-f signal appears across the primary of the output

i-f transformer. This is the tuned winding. A corresponding signal voltage is induced across the untuned secondary winding and is fed to the two diode plates. One of these two plates secures its voltage via condenser C-14. The top diode plate is used for detection and the lower diode plate is used for AVC. Concerning the detector circuit, the rectified currents flow through the fixed filter resistors, R-14 and R-15, back to the cathode. The a-c component is fed to the volume control R-16 through the blocking or coupling condenser C-6. The moving arm feeds the desired amount of a-f voltage back to the control grid of the triode portion of the 6F7S triode-pentode. This signal is amplified and appears across the load resistor R-7. The blocking or coupling condenser C-10 feeds the amplified a-f signal to the control grid of the other a-f tube, which is not shown in the illustration.

Referring to the AVC section, (the lower diode plate), the rectified current flows through resistors R-8, R-9 and R-13. The proper amount of AVC voltage, secured by suitable selection of the tap upon the AVC voltage divider circuit, is fed to the i-f and other controlled tubes via the filter resistor R-12. The various condensers associated with the two diode circuits function in conjunction with the various resistors to maintain correct current paths.

POWER RECTIFIERS.

It is not our intention to dwell upon power rectifiers such as the 280 and 281, since they have received plentiful attention during the many past years of use. We shall focus our attention upon the 25-Z-5 rectifier tube, because it is to be found in a very large number of superheterodyne receivers. Other tubes like the 82, 83 and 84 and their "6Z" equivalents do not contain the interesting features to be found in the 25-Z-5.

The 25-Z-5 Rectifier.

This tube, quite commonly used in the modern universal AC-DC receiver, is in reality two half-wave rectifiers contained in one envelope. The envelope contains two anodes,

two cathodes and a double filament or heater. The anodes and cathodes are independent, whereas the two heaters have a common connection and are used in series. When employed as a conventional half-wave rectifier, the two anodes are joined in parallel and the two cathodes are joined in parallel. Because of the design of the rectifier, it is possible to employ each pair of anode-cathodes as individual half wave rectifiers independently of the other. At the same time, one set of elements, comprising a half-wave rectifier, can be employed to feed one load and the other set of elements, comprising a half wave rectifier, can be employed to feed another load. Since the complete rectifier with anodes and cathodes joined in parallel is rated at 100 milliamperes, it is easy to understand how each pair or set of elements, comprising a half wave rectifier, would be rated at 50 milliamperes.

A salient feature of the 25-Z-5 is the ability to supply an output voltage, when used on an a-c line, which, without recourse to a step-up power transformer, will be about twice the value of the input line voltage. In other words, the tube can be used in a voltage doubler circuit. The three items mentioned thus far are to be found in abundance in the universal AC-DC superheterodyne. We shall offer in this text, basic circuits illustrative of the various conditions mentioned. This will be followed by some examples of practical applications.

The 25-Z-5 As a Conventional Half-Wave Rectifier.

An examination of the basic half wave rectifier application of the 25-Z-5, as shown in figure 69, will bring to light the
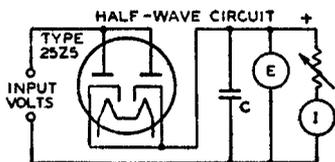
Fig. 69. The 25-Z-5 is connected as a half-wave rectifier. Note that the two plates and the cathodes are connected together respectively

fact that the rectifier is located in one leg of the power supply line. The condenser C represents the condenser normally connected across the output of the rectifier system. The normal

filter choke is not included, since the circuit shown functions as a means of illustrating the elements.

With a d-c input, the output voltage is practically constant regardless of the load. With a-c input, the output volt-
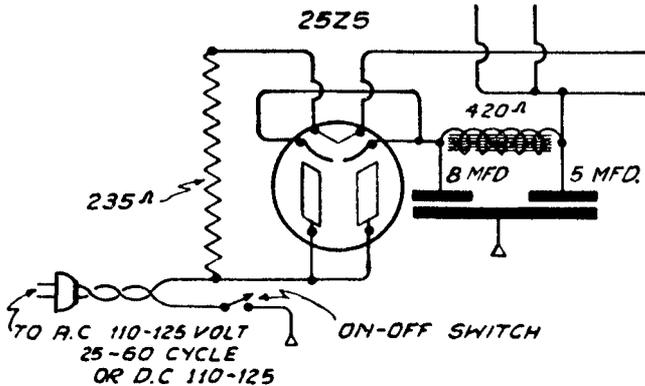
Fig. 70. The 235-ohm resistor is to reduce the voltage to the proper value for the heater of this 25-Z-5 used as a half-wave rectifier
(Courtesy Pierce-Airo)

age is determined to a large measure by the value of the filter condenser C. Furthermore, the regulation is also determined by the value of the capacity. The variable resistor across the output is the equivalent of the load resistor. I and E are current and voltage indicating instruments used for test purposes. For a constant load and constant value of filter capacity, the output voltage varies if the line voltage is changed. Based upon exact operating conditions and constants, an increase in line voltage from zero to 12 percent above 110 volts may cause an output voltage increase of from zero to about 18 volts. An equivalent reduction occurs if the line voltage is decreased from zero to 12 percent below 110 volts.

Two examples of how the 25-Z-5 is used as a conventional half wave rectifier in commercial receivers are shown in figures 70 and 71. The fixed resistor associated with the rectifier heater is the voltage reducing resistance. The lead emanating from the rectifier heater joins the filament or heaters of the tubes in the receiver. In some instances, the schematic

wiring diagram may show all the heaters in the receiver, iso-
lated from the remainder of the tube elements, inclusive of
the rectifier heater, in which case the rectifier envelope would

Fig. 71.   Another half-wave rectifier circuit taken from a
commercial receiver.   (*Courtesy Fada Radio & Electric Co.*)

contain the anodes and cathodes only; at least, it would be so
illustrated.   An example of this appears in figure 73.

The 25-Z-5 With Split Output.

By split output is meant the use of one half wave rectifier
section to supply one load circuit and the remaining half wave
rectifier section to supply voltage to some other load.   A
typical circuit is shown in figure 72.   The two anodes are
used in parallel.   Each related cathode is connected to its load
circuit.   It is the same as if two separate half wave rectifiers,
feeding to different loads, are joined into one leg of the power
supply circuit.   The advantage gained by employing the
25-Z-5 in this manner is one of increased output voltage.
Its use is possible when the total plate and screen current of
all the tubes in the receiver is less than that required for the
excitation of the speaker field.   The increased plate voltage is
available because of the nature of the voltage regulation of
the tube.   This characteristic is such that greater voltage is
available if two low current loads are applied to the two half
wave rectifiers, than if the sum total of these two current

loads is applied to the complete rectifier, used with the anodes paralleled and the cathodes paralleled. In other words, a 30 mil load on one half wave rectifier and a 40 mil load on the other half wave rectifier will provide higher output voltages, than when the two anodes and cathodes are paralleled and a 70 mil load is applied to the tube. Concerning figure 72, the upper set of elements supplies the receiver tube plate and screen voltages and currents. The lower set of elements supplies the speaker field excitation current.

The rectifier and receiver tube heater arrangements do not alter the anode-cathode structure of the rectifier. Their connections in the complete circuit are not altered by the arrangement of the rectifier elements. It is, of course, possible that one or more of the voltage supply leads, joined to one of the rectifier cathodes, may not be connected through the filter choke. This does not change the fundamental circuit. An example of a rectifier system, illustrating the man-

Fig. 72, right. The upper set of elements supplies the tubes' voltages and the lower set the excitation for the speaker field
(*Courtesy Fada Radio*)

Fig. 73, below. An example of how the power supply circuit and tubes' heaters are often shown
(*Courtesy Emerson Radio*)

ner in which the rectifier and receiver tube heaters may be shown upon the complete schematic, is shown in figure 73.

The 25-Z-5 As a Voltage Doubler.

We made mention of the fact that this rectifier enables voltage doubling without the use of a step-up transformer. The action is accomplished by so charging condensers that the charges are additive and when the condensers discharge across the filter system, the voltage across the filter circuit output is

equal to approximately twice the input a-c voltage. Naturally, such voltage doubling is possible only with a-c input. The circuit of the basic voltage doubler system, as found in commercial superheterodynes, is shown in figure 74. Let it be

Fig. 74. The 25-Z-5 tube is shown here connected as a voltage doubler. This is one of several possible arrangements for obtaining double voltage from an a-c line

known that this system is the most commonly used circuit, although it is not the only possible voltage doubler arrangement.

To comprehend the circuit, it is necessary to realize first the relation between the condensers C, which are charged by the rectifier output and the load circuit. Neglecting the actual charging action for the moment and assuming that the variable resistor represents all of the related units which follow after the condensers connected across the rectifier output, it is easy to see that when and if the two condensers C discharge, they discharge across the entire load. Thus, if a voltage is present across the two condensers, that voltage is present across the terminals of the load resistor. With this in mind, we can progress to a more complete presentation of the voltage doubler circuit.
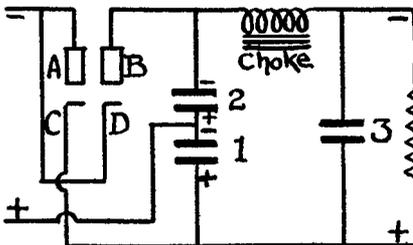
Fig. 75. A schematic explanation of Fig. 74. The tube is shown connected to an a-c line. Note that the polarities of the condensers 1 and 2 are additive, resulting in a doubling of the voltage at the resistance, which is the load

Let us consider the schematic shown in figure 75. This is the typical voltage doubler circuit on an a-c line. Note the two anodes "A" and "B" and their respective cathodes "C"

and "D." The fixed condensers (1) and (2) are those desig-
nated as C in figure 74. The third condenser (3) is the
reservoir unit. Suppose that at one instant the anode "A" is
positive with respect to the other side of the line. Current
will flow between "A" and "C" and condenser (1) will be
charged to some value approximating the line voltage, and
with the polarity shown. The drop in the rectifier is very
low. During the next half cycle, the other side of the line
becomes positive and condenser (2) will be charged to about
the line voltage and with the polarity shown. The current
path now is between anode "B" and cathode "D." You will
note in the wiring diagram that the polarities of the two con-
densers (1) and (2) are such that they are in series and ad-
ditive. Since the two charges are in series, the total charge

Fig. 76. How the throw-
ing of the selective switch
for AC or DC affects the
circuit of the 25-Z-5 rec-
tifier. Here the positive
lead of the filter has been
changed from cathode C
to the power line
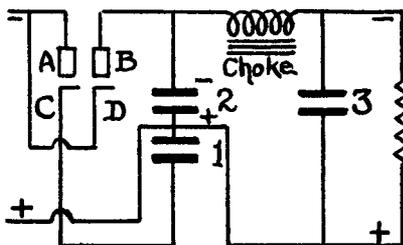
across the two outside terminals of the series combination is
approximately equal to the sum of the individual charges.
Since each condenser is charged to approximately the line
voltage, the total charge will be approximately twice the
value of the line voltage and the voltage doubling action has
been attained. Neglecting the voltage drop across the choke,
the voltage across the terminals of condenser (3) will be but
slightly less than the total voltage across condensers (2) and
(1) in series. The available output voltage then is distributed
as needed. Obviously, any defect in the rectifier or in the
series condensers will interfere with the voltage doubling
action.

What happens when the control switch in such an AC-DC
receiver is set to the d-c position? The required change in
circuit wiring is effected in the simplest manner. The trans-
position of one lead is sufficient to effect the change. Ex-

amine figure 76. The number of component parts has not changed. It is identical to the number used in the voltage doubler circuit. However, if you examine the circuit, you will note that the plus or positive lead in the filter system has been disconnected from cathode "C" and joined to the power line circuit. Tracing the circuit from the plus power lead, we pass through the load resistor or voltage divider, through the filter choke, from anode "B" to cathode "D" and so back to the negative side of the line. Condenser (3) is still the reservoir condenser and condenser (2) is still across the output of the rectifier. Condenser (1) is not used and neither is anode "A" nor cathode "C" used, when the circuit is connected to the d-c line. Two examples of AC-DC power
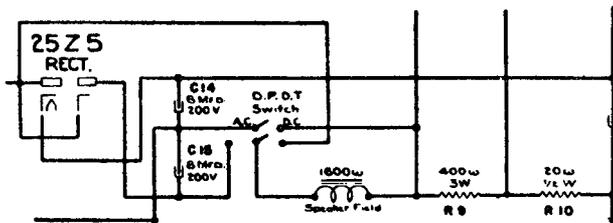
Fig. 77. Note how the throwing of the selective AC-DC switch
changes this voltage doubler circuit
(Courtesy Sears-Roebuck)

supply systems, using the 25-Z-5 in a voltage doubler circuit on a-c, are shown in figures 77 and 78. Note the different switching arrangements when changing to d-c.

AUTOMATIC VOLUME CONTROL SYSTEMS.

Automatic volume control serves to maintain the signal output from the receiver at a constant minimum level, irrespective of the intensity of the received signal. At least, the aforementioned is a general definition. Qualification of the statement is essential, because a definite minimum signal level input is required in order to fulfill the conditions set by the definition. If the input signal is of such low amplitude that it will not actuate the tubes in the receiver, that signal will not be heard. This means that AVC will not eliminate fad-

ing of signals. It will mitigate the intensity of signal varia-
tions due to fading when the lowest level of the received
signal is sufficiently great, but if the signal level is too low as
a result of fading, automatic volume control will not re-
store the signal.

As a general rule, automatic volume control is applied to

Fig. 78. Compare this method of changing from AC to DC
with that of Fig. 77

(Courtesy Fada Radio)

the r-f, mixer and i-f tubes in superheterodyne receivers. Not
necessarily to all of these tubes, but these are the tubes which
are automatically controlled. The control takes the form of
a signal controlled variable grid bias, whereby the mutual con-
ductance of the controlled tube is changed. Since the ampli-
fication is dependent upon the mutual conductance of the
tube, any reduction of the mutual conductance, by an in-
crease in the negative bias, will lower the signal voltage de-
veloped across the load impedance in the plate circuit of the
controlled tube. This is the equivalent of decreasing the am-
plification available in the controlled stage. When the AVC
circuit is not functioning, maximum sensitivity is available in
the controlled stage. When the AVC is functioning, the
amplification is determined by the existing constants of the
circuit, the variable being the control grid bias.

The source of AVC voltage is in radio receivers actuated by
the carrier. In some public address systems, the automatic
volume control operates upon the audio signal. In the re-
ceivers mentioned in this volume, the AVC voltage is a result
of rectification of the intermediate frequency carrier. The
actual intensity of the modulation component of the carrier
has very little influence upon the AVC voltage.

There are numerous forms of automatic volume control; in fact, there are too many to permit a full presentation in this volume. However, these systems operate upon the same basic principle and differ only in the exact circuit employed and the source and nature of the actuating signal. In some of the later receivers, the AVC circuit is interlocked with another tube for the control of noise. The problem of noise has been one which received a great deal of attention and was one of the bugbears of AVC. Unless prevented, noise is introduced by the fact that the various amplifier tubes are operating at maximum or full sensitivity or full gain during the time that the receiver is being tuned between stations.

As far as the basic principle is concerned, the AVC tube is the equivalent of a detector or rectifier tube. This is so if the AVC tube is a diode, triode, screen grid tube or pentode. With the exception of the diode tube, the other tubes operate by developing a d-c voltage in the plate circuit, which voltage varies in amplitude in accordance with the input control voltage, which, in turn, is the signal voltage from the i-f amplifier in the superheterodyne receiver. The voltage developed in the plate circuit of the control tube is fed to the various control grid circuits of the tubes which are being maintained at constant output or sensitivity levels. In the diode tube, or in the AVC diode circuit of duo-diodes, the control voltage is developed in the output circuit as a result of rectification.

We have devoted space to the explanation of the AVC action in combination diode demodulator AVC units and also in the AVC diode circuit of the duo-diode triodes and pentodes. Figure 56 illustrates the means whereby a duo-diode pentode is employed as an i-f amplifier and also for AVC. There are several other forms of automatic volume control. Some employ a separate tube, which may be a triode, screen grid tube or pentode and which functions to develop the AVC voltage. Still other systems are tied in with another tube circuit, which, in turn, controls the operating potentials of one of the a-f tubes. This type of circuit serves to control noise as well as output signal level.

An example of an AVC circuit, wherein a separate tube is used as the source of the AVC voltage, is shown in figure 79.

You will note that this AVC circuit has no connection what-
soever with the regular demodulator employed in the receiver.
Neither is it tied in with any other tube for channel control
or noise control. An examination of the circuit brings several
pertinent facts to light. The arrangement of the AVC tube
appears complex, yet it is quite simple. The tube is arranged
to function as a biased detector, securing its actuating voltage
from the i-f tube plate. All static operating potentials for
the AVC tube are secured from the voltage divider. The re-
sistor R supplies the control grid bias for the AVC tube and
determines the input voltage, which will actuate the control.
In other words, this bias determines the level of the signal in-
put required to bring the AVC action into operation. Until
the signal voltage from the i-f tube plate reaches certain pro-
portions, the AVC tube will not function.

Now, you may glance with askance at the grounded tap
upon the voltage divider consisting of R, R-6 and R-7. You
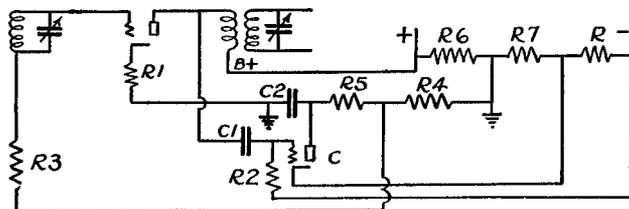
Fig. 79. The lower tube, C, is the automatic volume control tube,
the upper one being an i-f amplifier. Note carefully the functions
of the various resistors as explained in the accompanying text

no doubt are skeptical about the application of the AVC tube
plate voltage from this grounded point along the divider. If
you recognize that the low end of R is the most negative point
along the divider, you will appreciate the fact that all points
above this most negative point are positive. This means that
the grounded point along the divider is also positive. This
is so, despite the fact that we usually assume the ground to
be the most negative point along the system. Accordingly,
the plate, through resistors R-4 and R-5, is at a higher po-
tential than any point on R. Thus the plate of the AVC tube

secures a plus voltage from the divider, despite the fact that
its supply point on the divider is grounded.

The potential difference between the cathode and the con-
trol grid of the AVC tube is the voltage across R. The po-
tential difference between the plate and the cathode is the
voltage across resistor R-7. By suitable adjustment or
selection of the value of R, we can apply such a bias to the
control tube that no current flows through the resistors R-4
and R-5. The resistor R-2 is the grid leak for the AVC tube.

Now, if you examine the i-f tube circuit, you will note
that the cathode of this tube contains a resistor R-1. This
resistor is grounded and serves to supply the fixed minimum
no-signal bias for the i-f tube. The value of this resistor is
no doubt such that with the fixed no-signal bias applied, the
tube has such operating potentials as to be most sensitive and
to be capable of the greatest amplification. You will note
further that the i-f transformer grid return junctions with
one of the resistors in the plate circuit of the AVC tube.
During the period of no-signal in the i-f tube, there is no
plate current flowing in the AVC tube, hence the grid re-
turn path from the i-f transformer secondary to ground is
via the filter resistor R-3 and the AVC plate resistor R-4.
There being no plate current in the AVC circuit, no voltage
drop exists across the resistors R-4 and R-5. However, when
a signal is passed through the i-f tube, a portion of this signal
is also applied to the AVC tube. This signal overcomes a
portion of the bias applied to the AVC tube control grid and
plate current flows in the AVC tube plate circuit. Current
flow in this circuit means current flow through resistors R-4
and R-5. This means that a voltage drop is established across
these resistors. The polarity of the voltage developed across
R-4 and R-5 is such that a tap upon this series combination
will apply an increased bias to the i-f tube control grid. In
other words, the voltage across R-4 is of such polarity that
it is additive to the bias developed across R-1. The stronger
the i-f signal, the greater the voltage applied to the control
grid of the AVC tube and the greater the bias developed
across R-4 and applied to the i-f tube.

Quiet AVC.

Quiet automatic volume control or QAVC was made neces-
sary by the fact that the receiver amplifiers jump to maximum
sensitivity during the no-signal carrier period and noise de-
velops. It is possible, of course, to adjust the ordinary AVC
circuit so that it will function at the noise level, thus reduc-
ing the noise, but if this is done, it tends to reduce the sensi-
tivity of the receiver on weak signals. Therefore, in order
to make available maximum sensitivity to weak signals, yet
eliminate noise, AVC systems, interlocked with a special tube
used for noise suppression, have been developed.

These QAVC systems operate in two ways. One arrange-
ment provides for a signal which actuates the "Q" tube by
greatly decreasing the tube plate current. The plate of the
"Q" tube is joined to the plate or screen circuit of the first
a-f tube. During the absence of a signal, the plate current
of the "Q" tube is so high that a high voltage drop takes
place across a resistor which is common to the "Q" tube plate
circuit and the a-f tube screen or plate circuit. This high
voltage drop reduces the a-f tube plate or screen voltage to
such a level that the a-f tube is inoperative. When a signal
is received, it increases the bias on the "Q," tube, which in
turn reduces the plate current and releases the a-f tube; that
is, the a-f tube plate or screen voltage, whichever circuit is
being controlled, rises to its normal operating level and the
a-f amplifier functions. An example of such an arrange-
ment is shown in figure 80.

Referring to figure 80, the 37 tube is a diode demodulator
and AVC tube. The a-f voltage is fed to the 77 tube through
the a-f volume control A. A type 78 tube is used as the "Q"
tube. The presence of this tube in the circuit is controlled
by the switch S. Examining the diagram, you will note that
the control grid of the "Q" tube is tied to the output circuit
of the diode demodulator and AVC tube. Also that the plate
circuit of the "Q" tube is tied to the screen circuit of the a-f
tube. Note the 1.0 megohm resistor, which is common to the
voltage supply lead for the "Q" tube plate and the a-f tube
screen. With the "Q" tube in the circuit (switch S closed)

and no signal input to the 37 tube, there is no voltage at the control grid of the "Q" tube. The plate current is high. This means that a high voltage drop takes place across the 1.0 megohm resistor and the 77 tube screen voltage is so low that the tube is inoperative. Therefore, whatever noise that may exist in the receiver ahead of the a-f tube, is not heard in the speaker. Signal input to the 37 causes current flow through A, a negative voltage at the control grid of the 78 "Q" tube and the plate current in this tube decreases. This reduces
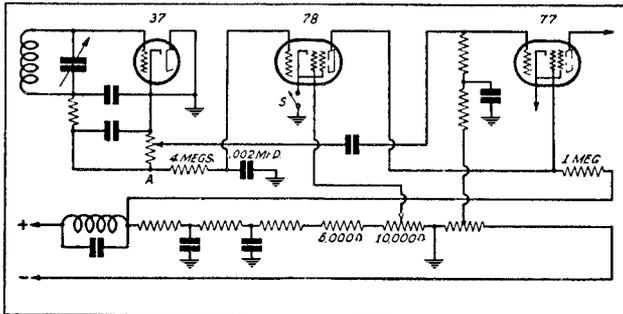
Fig. 80. The 37 is a diode demodulator and AVC, the 77 is an a-f amplifier and the "Q" tube is the 78. Note current distribution through the resistors. *(Drawing, Courtesy "Service" Magazine)*

the drop across the 1.0 megohm resistor and increases the voltage at the a-f tube screen, the tube amplifying in normal manner.

Another type operates somewhat along the following lines. The special systems used are an AVC tube, a channel control tube and a noise silencing tube. The AVC tube performs in normal manner and operates when a signal is present. The channel control and noise silencing tubes are interlocked in such manner that the absence of a signal carrier removes the bias from the noise control tube. This lack of bias increases the noise tube plate current. The plate circuit of the noise control tube is tied to the bias circuit of the first a-f tube. The noise tube plate current increases the a-f tube bias to cut-off, so that the tube is inoperative and noise signals do not pass through the a-f amplifier. When a signal carrier is tuned in, a bias is applied to the noise control tube. This reduces the

plate current and consequently reduces the a-f tube bias to the proper level, so that the tube functions in normal manner.

The tuned circuit feeding the channel control tube is so designed that exact resonance with the carrier is required in order to release the a-f tube via the noise silencing tube. The channel control is tuned sharply to the carrier frequency, neglecting the side bands. By carrier frequency, we mean the intermediate frequency signal because the channel control tube is fed from the i-f amplifier.

There are numerous modifications of the AVC and noise control arrangements described and shown in these pages. With the large number of receiver manufacturers trying to produce receivers which outperform one another, it is logical that many innovations and special circuit arrangements will be found. However, the basic underlying principles of these systems are very much alike. Full comprehension of these principles will do much towards enabling a complete and thorough analysis of any circuit utilized in a commercial radio receiver. If we were to show and describe each and every variation of AVC and associated control circuit, it would require every page in this volume without room for anything else.

From the service angle, AVC and related circuits present several interesting features. This is particularly true when the service man is interested in the measurement of operating voltages. Obviously, the voltages applied to the tubes as a result of a signal cannot be measured with routine equipment, unless the operator employs a vacuum tube voltmeter, which instrument is recommended by a few receiver manufacturers. The measurement of operating voltages with cabled apparatus is made more difficult by the condition created when the cables are introduced into the circuit. As a result, measurement of static voltages is about the limit of the potentials which may be measured. These may be determined by means of external instruments operated with test prods, which are used to make contact with the respective test points. Although some men may not agree with the writer, we are firm in the belief that the only satisfactory and generally applicable

method of checking AVC and related circuits is by means of point-to-point resistance measurement, or, as some concerns express the same basis, free reference point or selective analysis. Such work takes for granted that the condition of the tube or tubes involved is determined by a routine tube test.

Proper application of testing equipment is of extreme importance, particularly in the case of those circuits which may go bad without interfering with the operation of the receiver, other than for the absence of noise control or AVC. As it happens these circuits are predominant. Much confusion in the service field has been caused more by incorrect adjustment of various forms of AVC and noise control circuits than by the presence of a defect in the system itself. In very many instances, variable resistors and switches, which govern the presence or absence or degree of operation of the device, are incorrectly adjusted, although the fact is not recognized and many peculiar effects are created. Inclusion of this paragraph at this time is in the form of a warning. More extensive information is furnished in a subsequent chapter, devoted to trouble shooting and troubles in superheterodynes.

Visual Tuning.

Visual tuning is accomplished in two ways. One of these is the meter, which indicates the state of tuning by the reading upon the instrument and the other is the use of a glowing tube, such as a neon tube, which indicates maximum resonance by maximum length of a pencil of light or by maximum brilliancy. Some such form of indication is required, because of the presence of automatic volume control. Since the AVC circuit tends to maintain a constant signal output, it is difficult to judge when one is tuned to exact resonance. One way of judging is by the nature of the tone quality of the audible signal. This arrangement is not the most satisfactory, hence visual tuning is employed.

When speaking about meter type visual tuning indicators, one usually pictures the device as being employed to indicate maximum current flow through the tube as being representative of maximum resonance. Such is not the case. In fact, the reverse is true. Minimum indication upon the

meter, means closest approach to perfect resonance. Let us see how this is done.

The visual tuning meter is usually connected into some part of the r-f, mixer or i-f system. Its location is such that it is influenced by the AVC bias developed by the AVC tube and fed to the controlled amplifier tubes. The reason for its location in this position is that the current flow in such AVC circuit is minimum at maximum resonance, due to the application of the maximum automatic bias at maximum resonance. The visual tuning meter may be located in the cathode circuit or the plate circuit of the controlled tubes. During the no signal state, but with the receiver turned on, the current through the meter is maximum. This current is the steady plate current of the tubes electrically connected to the meter circuit. As a signal is tuned in and when it reaches the proper level, the AVC tube starts to function and to supply a controlling bias to the controlled tubes. This added bias reduces the plate current and the meter indication starts to decrease. As the receiver is tuned closer and closer to perfect resonance, the signal fed to the AVC tube becomes stronger and stronger. The stronger the signal fed to the AVC tube, the greater is the bias developed by that tube and the greater the reduction in plate current. Accompanying this reduction in plate current is the decreased reading upon the visual tuning meter, until at maximum resonance the meter indicates the minimum amount of current flow.

In order to remove confusion, visual tuning meter scales are reversed, so that when the state of no signal and maximum plate current exists, the meter scale points to zero or approximately so and when the signal is tuned in and the plate current decreases, the meter pointer moves towards the higher readings upon the scale and is maximum at absolute resonance. When working with such meters, it is necessary to bear in mind that as the meter pointer moves towards the high limits of the scale, the actual current flow through the instrument is decreasing. This is evident by the fact that the normal position of the meter pointer, when the receiver is not turned "on," is near the maximum resonance point. When the receiver is turned "on," the meter indicator moves over to the

zero point. As the signal is tuned in, the meter indicator moves up the scale.

Neon glow tube tuning meters depend upon the development of the breakdown voltage across the tube, by the reduction of a voltage drop across a resistor, which is associated with the neon tube elements. During the no signal period, the plate current in the tube circuits connected to the tuning indicator is maximum. The consequence is that the voltage drop across the neon tube control resistance is sufficiently great, so that the remaining voltage existent across the electrodes of the glow tube is not sufficient to cause a glow within the tube. The glow is due to ionization of the gas within the tube, by virtue of the potential existent between the electrodes.

As a signal is tuned in, the plate current decreases and the voltage drop across the control resistance decreases. Since the control resistance and the glow tube are joined to a voltage divider, a decrease in voltage drop across one section of the divider develops an increased voltage across the other section. As the signal is tuned in and the AVC tube functions, the voltage across the glow tube increases until the gas breaks down and glows visibly, indicating that a signal has been tuned in. Various ramifications of glow circuits provide for tuning by means of the length of the column of light within the tube. The greater the voltage developed across the glow tube, the higher the pencil of light.

Visual Tuning and Noise Gate.

An example of a visual tuning meter, which is also tied in with noise suppression, is shown in figure 81. This is the basic schematic of the Flashograph and Noise Gate arrangement. The tube contains four elements A, B, C and D. Elements A, B and C are allied with the tuning indicator. The voltage developed across A and B causes a pencil of light to climb element C. The actuating voltage is secured from the r-f and i-f plate circuits. The action of the AVC voltage causes the plate current in these tube circuits to decrease and produces a gradually increasing voltage across elements A and B.

The noise gate or noise suppression arrangement involves element D. This element is insulated part way up its length,

so that the uninsulated portion is exposed to the ionized gas, only after the discharge has passed up element C, to a predetermined level, thus assuring a definite signal level. If you examine the schematic diagram you will note that the cathode of the first a-f tube is joined to a tap upon the voltage divider. The location of this tap is such that a positive voltage is applied to the cathode and when the switch is set to the left
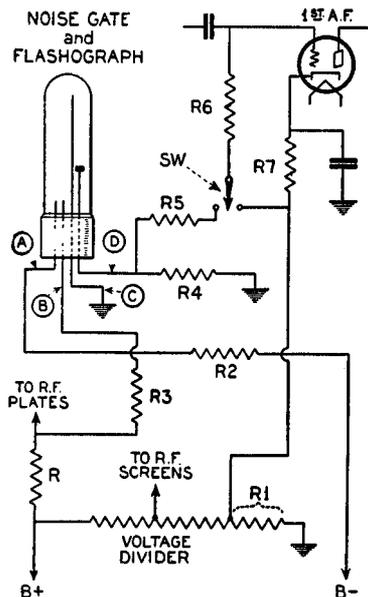
Fig. 81. The action of the AVC tube controls the voltage across the elements A and B of the Flashograph neon tube
(Drawing, Courtesy "Service" Magazine)

and the control grid of the a-f tube is returned to ground via R-4, R-5 and R-6, the a-f tube is biased to cut-off. This means that the audio system will not pass any signals. Now, when the discharge in the glow tube climbs up element C and reaches the height of the exposed portion of element D, the signal has reached a certain pre-determined level. At this time, another discharge takes place between element C and the exposed part of element D. Current then flows through

resistor R-4 and a voltage, of such polarity that it counter-
acts the excessive bias originally applied to the a-f tube con-
trol grid, is applied to the control grid of the a-f tube, and this
tube is released for normal operation. Since the original bias
voltage required for cut-off is of a fixed value, the counteract-
ing voltage developed across R-4 is also fixed, no matter how
strong the intensity of the signal, so that there is no con-
tinual variation of the bias applied to the a-f tube. To re-
move the noise gate from the circuit, the switch is set to the
right, so that the control grid is joined to the cathode bias
resistor. This does not interfere with the normal operation
of the tuning indicator.

There are several other types of tuning indicators, but lack
of space does not permit detailed explanations.

It might be well to add at this time that the AVC circuits
and tuning indicator circuits outlined are equally applicable
to short wave, broadcast and combination wave receivers.
AVC and tuning indicator circuits operate upon the i-f signal
and direct current respectively, so that the tuning range of
the receiver is not very important. Channel control circuits
likewise operate upon the i-f signal. Incidentally, do not con-
fuse channel control, as found in noise suppression systems,
with references to adjacent channel selectivity in r-f and i-f
amplifiers. Channel control in noise suppression systems does
not influence the selectivity available with the receiver. It
simply locks the audio system, so that noise signals do not
get through to the speaker until the station is correctly
tuned in.

Wave Band Changing Systems.

The early superheterodyne and other receivers, which were
supposed to operate over more than one carrier wave band or
carrier frequency band, usually employed a number of plug-in
coils. As a matter of fact such arrangements are still in use
in short wave receivers intended for amateur use. However,
multi-wave receivers intended for consumer use, such as the
broadcast listener, cannot very satisfactorily make use of
plug-in coils. Frankly, it would be asking too much of the
broadcast listener to change a group of coils each time that

he wished to shift tuning bands. As a result switch control of the wave bands came into prominent use.

Practically every dual-wave and multi-wave broadcast receiver employs switch control for changing tuning bands. The number of switches actuated by the wave band control depends entirely upon the number of tuned circuits used upon each of the wave bands. Thus, if the receiver utilizes a tuned input and tuned r-f pre-selector stage, the receiver would employ three sets of tuned circuits, which would be controlled by the single wave band control switch. In addition to the two circuits mentioned before, the oscillator is also to be added, thus making three sets of tuned circuits. Exclusive of the oscillator system, all tuned circuits preceding the mixer tube are controlled by switches, actuated by a single knob.

One of the primary considerations related to switch control, for that matter plug-in circuits as well, is the necessity for maintaining perfect contact between switch points and the rotating arm. In the case of plug-in coils, perfect contact between the coil form contact and the coil socket contact is imperative. By perfect electrical contact, we not only mean freedom from an open circuit, but we mean freedom from corrosion at the contacts. The existence of defects of this nature are bad enough upon the broadcast band, but when existent upon the high frequency band, noise becomes a major form of trouble. Lack of signal strength, dead spots, broad tuning and even total lack of signal are usual complaints. All of these can be solved, but noise can be troublesome beyond compare.

The nature of the circuits controlled by these wave band switches covers a variety of forms. In figure 50, we showed a wave band switching arrangement in a dual-wave receiver whereby complete r-f and oscillator transformers, each tuned with its own trimmer, were controlled by switches. These complete transformers were switched across the major tuning condensers. This is only one arrangement and by no means common to all makes of radio receivers. In contrast to the system shown, we suggest that you examine figure 82, which shows how the wave band changing is accomplished in another brand of radio receiver. This circuit also employs switches,

but instead of changing complete transformers, the following is done. For short wave operation, the r-f tube is left out of the tuned circuit by connecting the antenna to a special winding in the transformer which feeds the mixer-oscillator. This act is performed by switch 1. Simultaneously with the closing of switch 1, switches 2, 3 and 4 are also closed. The result of closing switch 2 is to short circuit the broadcast band r-f

Fig. 82. The r-f tube, 78, is only used on the broadcast band. The middle coil of the transformer becomes the r-f primary when switch 1 is closed
(Courtesy Colonial Radio Corp.)

transformer primary, so that the coil connected into the circuit by closing switch 1, is acting as the r-f transformer primary. Closing switch 3, shunts a short wave coil across the regular broadcast wave band r-f transformer secondary. The action is to reduce the total inductance of the secondary circuit, so that when tuned by the mixer input tuning condenser, the short wave band is covered. When switch 4 is closed, it short circuits one of the two coils connected in series

in the oscillator grid circuit. The coil that is shorted is the broadcast coil, thus leaving the short wave coil to be tuned by the oscillator tuning condenser. No change is effected in the oscillator plate circuit. The two coils, which are used in series for the broadcast band, remain intact, when the system is used for short wave reception.

The process of shunting a short wave coil across a broadcast wave coil for producing a final inductance of the proper value, which would be tuned by the main tuning condenser and so cover the short wave band, is quite common in many commercial dual-wave receivers. In some sets, a combination of tapping a coil and shunting one coil with another is also to be found. As a general rule, receivers, which employ the combination just named, are designed to cover but two wave bands. Tapping is used in the r-f and mixer circuits and shunting one coil with another is used in the oscillator circuit. The method of tapping the coil is quite conventional. A single winding form contains an inductance of such value as to cover the broadcast band, when tuned with the major tuning condenser. A tap upon this winding provides a much lower value of inductance for the short wave band. A series of switches connect the main tuning condensers and their trimmers across the tapped portion of the coil. In some instances, both primary and secondary windings of the transformers are altered with taps. In other cases, depending upon the frequency range of the lower of the two wave bands covered with the receiver, only the secondary winding is tapped.

Receivers intended to cover a number of different wave bands, say three, four or five wave bands, generally use one of two accepted arrangements. One of these arrangements is like that shown in figure 5 0, with respect to removing and inserting complete transformers. A receiver of this type is shown in figure 83. This is the RCA-Victor 140 series. The first r-f stage is used only on one tuning band, the highest frequency band covered by the receiver. All other bands, even the highest, involve the introduction of complete tuned transformers for the 2nd r-f tube, the mixer and oscillator circuits. None of the transformer windings are in series. Each set of
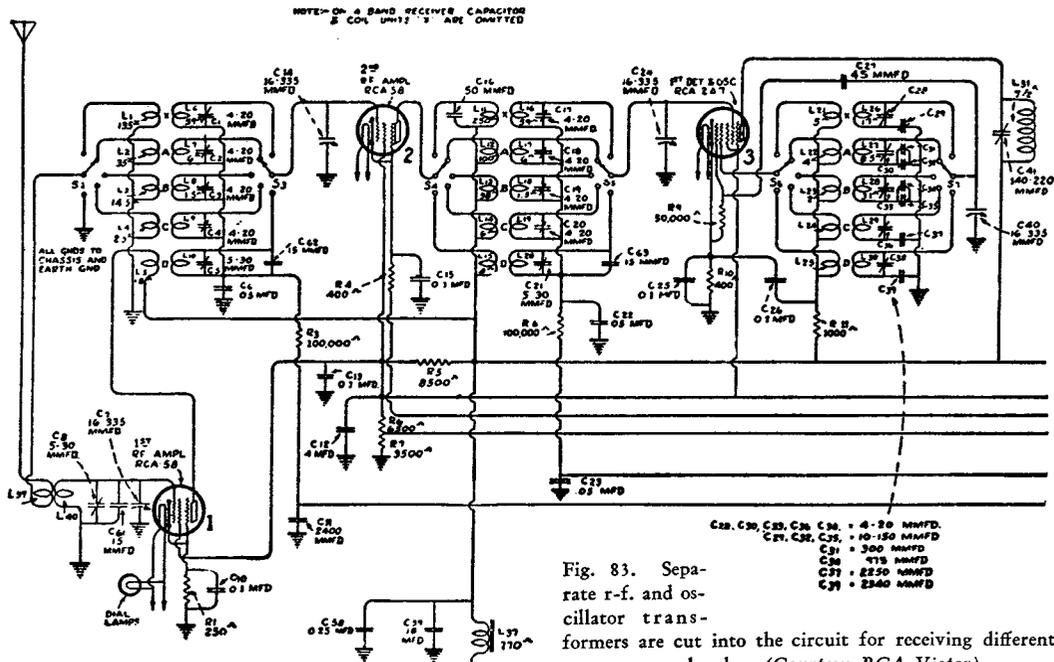
Fig. 83. Separate r-f. and oscillator transformers are cut into the circuit for receiving different wave bands. *(Courtesy RCA Victor)*

primary and secondary coils are separately controlled. Each of the tuned secondary windings is equipped with its own trimmer. When a transformer is inserted into the circuit, it is connected across the main tuning condenser. The oscillator grid windings are equipped with parallel and series trimmers and are connected across the main oscillator tuning condenser. Switches S-2, S-3, S-4, S-5, S-6 and S-7, change primaries and secondaries simultaneously. Alignment is carried out on each of the individual wave bands.

In contrast to the arrangement shown in figure 83, we find systems such as shown in figure 84. This is found in the Emerson S-755 series. The antenna circuit is untuned on the
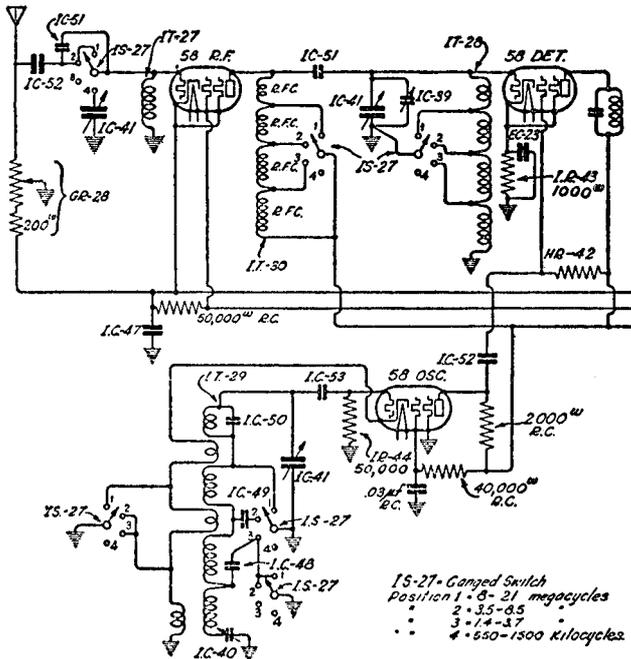
Fig. 84. Note the difference in the various transformers between those above and those in Fig. 83. *(Courtesy Emerson Radio & Phonograph Co.)*

short wave and the r-f input circuit is tuned only on the broad-
cast band.   The load upon the r-f tube is a tapped choke,
the sections of which are switch controlled, or if you wish,
the r-f tube plate load consists of a number of r-f chokes con-
nected in series.   The mixer input winding is tuned, with its
taps switch controlled.   A single main tuning condenser and
a single trimmer, tune the mixer input circuit.   The oscillator
grid coil is also a tapped coil, switch controlled and tuned by
a major tuning condenser, but with the individual wave band
sections equipped with series trimmers.   All the switches are
simultaneously operated by a single knob.

Various variations of the circuits shown in connection with
wave band changing are to be found in commercial super-
heterodyne receivers.   To discuss these systems is of little use,
since specific reference to complete schematic wiring dia-
grams is essential when service work is to be done.   In this
connection it is imperative that you check the wiring diagrams
in order to establish which coils are controlled when the con-
trol switches are set to certain positions.   This is particularly
so, when alignment calls for minor coil adjustments rather
than trimmer condenser adjustments.   For complete schematic
wiring diagrams, we refer you to Rider's "Perpetual Trouble
Shooter's Manual," of which four volumes are available at the
time of this writing.   If you are particularly interested in
superheterodyne receivers manufactured during the years
1933-34, we suggest Volumes III and IV of the aforemen-
tioned series.

CHAPTER 5

SPECIAL CIRCUITS AND TUBE APPLICATIONS

THERE are to be found in use today a number of special applications of tubes. Some of these are found in superheterodyne receivers, yet are not native only to superheterodynes. On the other hand, some of these circuits are to be found in receivers which are not of the super-heterodyne type, yet warrant discussion because of the possibility that sometime in the future, the tube circuit, now used in a t-r-f receiver, may be used in the superheterodyne. In view of the possibility that the tube circuit will be used, we include it in this book.

Phase Changers.

Resistance coupling to output tubes arranged in push-pull manner is to be found in a large number of receivers. However, the normal method of resistance coupling does not provide for real push-pull amplification in the output stage, unless the proper phase relation is established in the input circuit to the output stage. When a single tube feeds the output tubes, such as the detector tube, it has become quite prevalent to introduce a phase changing tube. The function of this tube is to feed a signal to one of the a-f tubes, which is 180 degrees out of phase with the signal being fed from the detector tube to the other of the output tubes. Thus the detector tube and the phase changer tube feed audio signals to the push-pull output stage through a resistance-capacity coupling arrangement, which has phase characteristics similar to those which would exist if the coupling unit between the detector tube and the output tubes were a push-pull input transformer.

Figure 85 illustrates the use of a phase changer tube. The 6B7 tube is in this case the demodulator. It could just as readily be any other type of tube used for demodulation purposes. The audio signal from the demodulator tube travels through two paths. One of these paths is through condenser C-1 to the control grid of the upper output tube. The other signal path from the demodulator is through C-2 and the associated resistor to the control grid of the type 37 phase
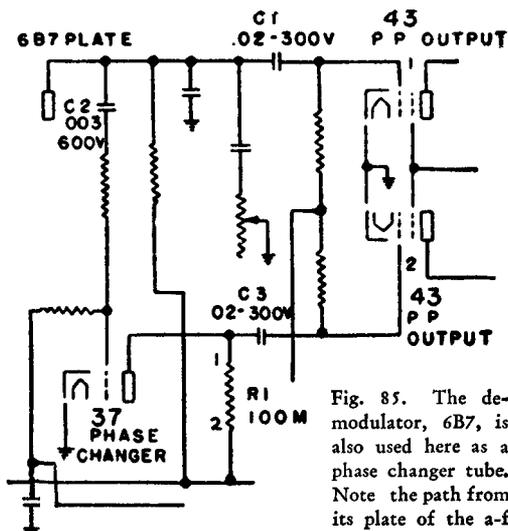
Fig. 85. The demodulator, 6B7, is also used here as a phase changer tube. Note the path from its plate of the a-f current

(Courtesy Sears Roebuck)

changer tube. Now, the operation of a vacuum tube is, under certain conditions, of such manner that the amplified signal voltage in the plate circuit is 180 degrees out of phase with the signal voltage applied to the control grid circuit. Consequently, the signal voltage, developed across the phase changer tube load resistor R-1 and fed to the lower output tube via the blocking condenser C-3, is 180 degrees out of phase with the signal voltage fed from the detector to the upper output tube. As a result the proper phase relation exists so that real push-pull amplification is secured.

By suitable selection of circuit constants, the signal voltage impressed upon the control grid of output tube 1 is the same as the signal voltage impressed across the control grid circuit of output tube 2, despite the fact that a certain amount of amplification takes place in the phase changer tube. For example, if the signal voltage normally supplied to the control grid of output tube 1 is 30 volts and the amplification available in the phase changer tube is 7.5, the value of the signal voltage applied to the phase changer tube control grid would be about 4, so that after amplification, output tubes 1 and 2 receive signal voltage of like amplitude and differing in phase by 180 degrees.

The phase changer-output circuit shown in figure 85 does not necessarily indicate the exact constants to be found in all receivers which utilize such an arrangement. The circuit and the mode of applying the phase changer tube can be considered as being generally applicable.

Automatic Tone Control And Noise Suppressor.

The model 110 Stewart-Warner receiver employs a novel arrangement whereby the input capacity of a vacuum tube is caused to vary over a wide range by virtue of the change in mutual conductance, caused by the application of an AVC voltage. The net result is noise suppression during the time when the signal voltage is low and noise is highest, because the AVC system is not functioning and therefore allows all tubes to operate at maximum sensitivity. Simultaneously with the noise supression action, a reduction occurs in the amplitude of the upper audio register. The system is inoperative during the passage of strong signals, so that there is no interference with the proper passage of the full range of audio signals.

The portion of the complete receiver, which performs the functions named, is shown in figure 86. The operation of the system is as follows: The i-f signal is applied across the diode-cathode circuit of the type 55 tube. Rectification takes place and the a-f signal appears across the 500,000 ohms potentiometer volume control, R-1. The moving arm picks off the desired a-f voltage and applies it to the control grid of the

triode portion of the 55. If you examine the wiring diagram, you will note that the amplified a-f signal is fed to the a-f tube through the .02 mfd condenser, D-4. Also that the plate of the triode portion of the 55 tube, is tied to the plate of the noise and tone control tube through resistors R-2 and R-3. In addition, the negative end of the a-f volume control is tied to the control grid of the noise suppressor tube. This means that the suppressor tube is tied in with the AVC
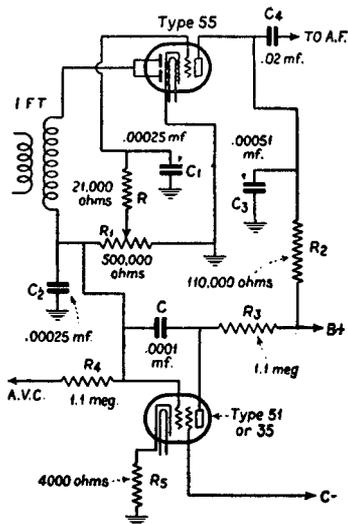
Fig. 86. This circuit suppresses noise when the set is being tuned and when the AVC system is not functioning. *(Drawing, Courtesy "Service" Magazine)*

system. A constant minimum negative bias is established between the control grid and cathode of the suppressor tube by means of the 4000 ohm bias resistor, R-5. The 1.1 megohm resistor R-4 is a filter or decoupling resistor in the AVC circuit.

You will note further the presence of a .0001 mfd fixed condenser connected across the grid and plate of the suppressor tube. If you look closely, you will note one very significant fact, namely, that the control grid-cathode circuit of

the suppressor tube is connected in effect across the a-f volume control resistor of the type 55 diode. The control grid of the suppressor tube joins one end of the volume control and the cathode of the suppressor tube, through the 4000 ohm bias resistor, joins the other end of the volume control resistor. In other words, the input capacity, whatever it may be, of the suppressor tube is connected across the output circuit of the diode part of the 55 diode-triode. From this point on, we must consider the action taking place within a vacuum tube.

The effective input capacity, or the dynamic capacity existing between the control grid and the ground, is a function of the various inter-electrode capacities, the mutual conductance of the tube and the operating potentials applied to the tube. As you realize the operating potentials applied to a tube govern the mutual conductance of that tube. One of the important inter-electrode capacities is that existing between the control grid and plate. The greater this inter-electrode capacity, the greater the reflected input capacity. In addition, the greater the mutual conductance of the tube, the greater is the input capacity. By working with high-mu tubes and by trying to realize the maximum mutual conductance of the tube, it is possible to secure a dynamic input capacity which would be several hundred times the static input capacity, that is, the capacity existing between the control grid and ground, when the tube is static or not operating.

Now, the normal internal grid to plate capacity of a vacuum tube is not very high, but by connecting an external condenser between the grid and plate elements of the tube, the total capacity, (internal and external) is made sufficiently high, so that the dynamic input capacity reaches a suitable level to act as a bypass. If by arranging the noise suppressor circuit in such manner that the input capacity of the tube can be employed as a condenser across the a-f volume control, variation of the proper factors will cause changes in the value of this capacity, and the net result is that, in effect, of a variable condenser operating over a wide range, and one which is high, when the AVC is not working and noise is great, and one which is low when the AVC is working and

the signal is loud, thus affording noise suppression and automatic tone control.

We said that the operating voltage influenced the mutual conductance. During the time that the diode 55 is not producing an automatic volume control bias, the mutual conductance of the suppressor tube is extremely high and its dynamic input capacity is very high, anywhere from several hundred to a thousand times as high as the static input capacity, and the suppressor tube is bypassing noise frequency signals developed across the a-f volume control. As soon as a signal is applied to the 55 tube, a negative voltage is applied to the control grid of the suppressor tube. Its plate resistance increases and its mutual conductance decreases. This relation continues to advance as the signal strength increases and the tone control action is minimized, due to the accompanying reduction in them of the dynamic input capacity. By suitable selection of constants and operating potentials, it is possible to arrange the noise suppressor tube action, so that it is most effective during the period when most noise is encountered and does not influence tone quality of normally strong signals.

Amplified and Delayed AVC.

Figure 87 illustrates the use of a 6B7 tube as used by Colonial as an AVC voltage source, wherein amplification is
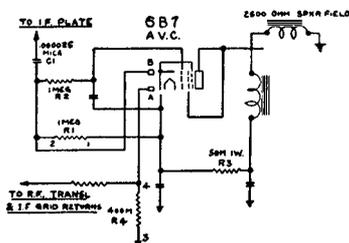
Fig. 87. This AVC circuit controls the amplification available with the controlled tubes, resulting in an i-f amplifier output that stays constant, no matter what the strength of the carrier

utilized to secure the final AVC voltage. A portion of the i-f signal is fed through C-1 to the diode plate "B." The resulting current, flowing through resistor R-1, creates a voltage drop across it, with point (1) positive with respect to point (2). This voltage is impressed upon the control grid

through resistor R-2. This increased negative control-grid bias decreases the plate current of the pentode portion of the tube, consequently the voltage drop across the plate circuit resistor R-3. As a result, the cathode bias with respect to ground, decreases. This is the equivalent of saying that diode plate "A" becomes positive with respect to the cathode. Current, therefore, flows from the diode plate "A" to the cathode, creating a voltage drop across R-4, with point (3) positive with respect to point (4). Since the grid returns of the r-f, translator and i-f tubes connect to point (4), the voltage drop across R-4 is impressed upon these grids as an automatic bias. This bias, which varies in accordance with the intensity of the signal from the i-f tube, controls the amplification available with the controlled tubes, so that the output of the i-f amplifier tends to remain at a constant level, regardless of original carrier signal strength. Because the cathode is about 15 volts positive with respect to the diode plate "A," the AVC action is delayed until the received signal is of sufficient strength to cause diode plate "A" to swing positive with respect to the cathode. In this way, the AVC action is delayed and full sensitivity of the receiver is maintained for weak stations.

Reflexed 6F7 and Rectifier Power Pentode.

This is another instance where we anticipate that the circuit used in a t-r-f receiver will find its way into the superhetrodyne; hence inclusion in this volume. Examine figure 88. This is a two tube t-r-f receiver made by International. The 6F7 performs three functions, namely, r-f amplification, detector and a-f amplifier. The 12A7 performs two functions, namely, an output power pentode and a half wave rectifier. This, too, is a tube, which we feel will eventually be used in superheterodynes, hence it is included.

Concerning the 6F7, the tube is a triode-pentode with a common heater and cathode. The heater is shown separately. The two elements below the cathode are the control grid and plate of the triode. The elements above the cathode are the control grid, screen grid, suppressor and plate of the pentode. The r-f signal is fed into the control grid of the pentode, res-

onance with the desired signal being obtained by means of the "tank" circuit coupled to the grid winding. The amplified r-f signal appears in the plate circuit of the pentode. This signal

Fig. 88. The 6F7 is an r-f and a-f amplifier and detector and the 12A7 is an output pentode and half-wave rectifier. *(Courtesy International)*

is fed back to the tuned circuit of the triode detector via the coupling condenser A-502-A. The choke in the plate circuit is a high impedance choke used to keep the r-f currents out of the output amplifier input circuit. The tuned circuit in the control grid circuit of the triode detector enables the development of the maximum signal voltage at resonance and provides maximum selectivity. The rectified signal then appears in the plate circuit of the triode portion. The voltage developed across the plate circuit resistor R-266 is passed back to the control grid circuit of the pentode part of the 6F7, via the blocking condenser A-341. The unit R-138 is the a-f volume control. The amplified a-f signal reappears in the plate circuit of the pentode portion and develops an a-f voltage across the load resistor R-266. The a-f signal is not hindered by the presence of the r-f choke in the 6F7 plate circuit or by the condensers A-502-A or A-243. The a-f signal then is fed to the control grid of the pentode portion of the 12A7.

Concerning the 12A7 rectifier pentode, the method of supplying the plate voltage to the pentode and the rectifier circuit

appears a bit confusing. There is nothing radical about the rectifier-pentode circuit, other than that the plate and screen-to-chassis circuit of the 6F7 and 12A7 constitutes the load on the rectifier. This becomes evident when you trace the circuit. The control grid return path for the pentode is through the grid leak R-258. For the 6F7, it is through the volume control resistor R-139. The return path from the plate of the two pentode plates to ground is through the cathodes of the respective pentodes.

Amplified Signal For AVC.

Several of the RCA-Victor receivers employ what appears, when examining the wiring diagram, to be two AVC tubes. However, such is not the case. One of these tubes is used for AVC action, whereas the other is used expressly for the purpose of amplifying a part of the i-f signal so as to provide a special signal for the AVC tube. The arrangement used is shown in figure 89. A screen grid tube is used as the AVC input amplifier and a triode tube used as a diode is used for AVC. The AVC tube has no connection whatsoever with
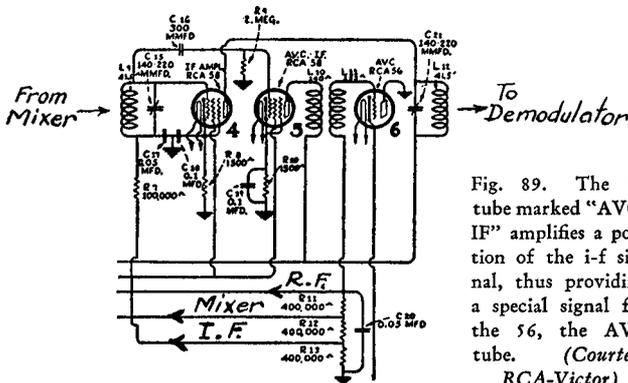
Fig. 89. The 58 tube marked "AVC-IF" amplifies a portion of the i-f signal, thus providing a special signal for the 56, the AVC tube. *(Courtesy RCA-Victor)*

the regular demodulator in the receiver. The first i-f amplifier tube and the AVC amplifier have their grids inter-connected through a .0003 mfd condenser, so that the i-f signal from the i-f transformer is applied to the i-f amplifier and

also to the AVC amplifier. The plate of the i-f amplifier tube feeds the i-f signal to a triode (56) demodulator, which is a single function tube. The various control voltages for the r-f, mixer and i-f voltages are secured from the voltage divider in the AVC tube circuit. The i-f transformer, which couples the AVC amplifier to the AVC tube, does not have trimmers.

High Fidelity.

At the time of this writing we hear rumblings of receiver design wherein provision is made for high fidelity audio, which means that response up to about 7500 cycles is provided for in the various amplifier circuits and in the speaker system. From what information comes to hand, future superheterodynes will no doubt contain means whereby the i-f amplifier transformers can be altered after correct tuning has been effected, so that high fidelity band pass through the i-f transformer will be available. As a matter of fact some of the i-f transformers equipped with volume controls of the type, which insert a resistance into the tuned secondary circuit, approach such a state. Examples of such transformers are to be found in figures 52 and 53.

More than likely, the revised edition of this volume to be published some time in the future will contain facts about receivers, which have been designed for high fidelity reception.

No I-F Amplifier Tube.

We include this mention although the circuit used is not really special. Several such superheterodyne receivers have appeared upon the market, wherein the i-f amplifier tube was omitted. The combination mixer-oscillator feeds the i-f signal to the demodulator tube through an i-f transformer. In one of these receivers, regeneration is employed in the demodulator circuit to offset the absence of another tuned i-f transformer and the loss in amplification due to the absence of the i-f tube. Among the manufacturers who have produced such receivers are RCA-Victor and Philco.

CHAPTER 6

TROUBLES AND SYMPTOMS
ENCOUNTERED IN SUPERHETERODYNES

THE process of restoring a defective radio receiver to its
original state of efficiency consists of three actions,
namely analysis or diagnosis of the defect in accord-
ance with the symptom displayed, trouble shooting or the
process of locating the defective circuit and component, and
the actual servicing or the removal of the defective part and
the replacement with a perfect part, or if the work is of the
adjustment kind, then the adjustment of the receiver.

In view of the fact that this book is not intended as a course
of study covering radio service in general and since we take
for granted that the reader of this volume is familiar with
general service procedure, it is not necessary to embark upon a
routine discussion of general servicing or the work involved
in making a replacement. The contents of Rider's "Perpetual
Trouble Shooter's Manual" will supply many of the routine
details missing from "Servicing Superheterodynes." We be-
lieve that if we list the symptoms and discuss the contributing
causes, you will be able to locate the defective circuit with
comparative ease and make whatever changes, replacements or
adjustments are required. However, since there are various
ramifications to alignment operations, particularly in view of
the numerous special types of circuit used, we are including as
a follow-up to the trouble shooting chapter, a chapter on the
application of r-f and i-f oscillators and output meters.

The subject of checking a radio receiver by means of re-
sistance measurement is a long one. As a matter of fact of such
length, that it warrants a volume of its own. Such is avail-
able as Rider's "Servicing Receivers by Means of Resistance

Measurement." No doubt you have had sufficient experi-
ence during the many years past, in making voltage measure-
ments upon radio receivers. Since each receiver is a separate
problem in itself, having its own operating voltages, we find
it necessary to rely upon you to make these voltage measure-
ments in accordance with the voltage tables which accom-
pany complete service data, such as found in the "Perpetual
Trouble Shooter's Manual" series compiled by the writer of
these lines. Accordingly, the tabulation of symptoms out-
lined in this chapter, is predicated upon the existence of nor-
mal operating potentials applied to the tube elements and the
presence of perfect tubes in the radio receiver. Only by as-
suming these two conditions, can we discuss trouble symptoms
with minimum duplication of references and effort. We are
assuming further that if the fault existent in the receiver is
of such type that it influences the operating potentials, as for
example shorted bypass condensers, shorted resistors, open con-
nections in voltage feed circuits, open resistors, etc., that fault
will be discovered by either a voltage test or a routine resist-
ance test.

Experience over many years has shown that the troubles
which are most difficult to remedy and which create the great-
est amount of confusion are those which exist during the time
that operating voltages are normal and to all appearances cir-
cuit components are normal. This is particularly true in the
case of the superheterodyne receivers, because many troubles
may exist with perfect operating voltages and perfect com-
ponents. As a matter of fact, this can occur to a far greater
degree than ever dreamed of in t-r-f receivers. Once more we
wish to reiterate that the discussion of the symptoms and con-
tributing causes as listed in this chapter, assume *normal operat-
ing potentials and perfect tubes.*

We are refraining from entering upon a detailed discussion
of audio amplifiers, speakers and power supply circuits. There
are numerous reasons for this stand. First is the fact that with
but few exceptions the structure of the audio amplifier em-
ployed in the basic superheterodyne receiver differs very little
from that used in t-r-f receivers. Examples of special varia-
tions, as for example, the circuit arrangements used in duo-

diode triodes, duo-diode pentodes and in reflex arrangements, have been given in the text. Second, the special 25-Z-5 tube used in universal AC-DC receivers was discussed separately and the vibrator type of rectifier also receives special attention. With these exceptions, the general run of power supply circuits used in superheterodynes differs very little from the arrangements used in t-r-f receivers. Third, the speaker circuit used in the superheterodyne is like that used in the t-r-f receiver, hence special discussion is not required. It is our opinion that this type of presentation eliminates all duplication of effort and enables a concise presentation of the pertinent facts. Each of the symptoms and contributing causes named in this chapter, unless special mention is made, has no influence upon the normal values of tube operating potentials.

We have classified troubles in superheterodyne receivers, exclusive of those conditions which will not interfere with operating potentials, under general headings. These are

> Undesired Signals
> Weak Signals
> Distortion
> Noise
> Dead Receiver

These five headings are quite broad in their coverage. Undesired signals and distortion represent two groups of troubles which are related to tube operating voltages and reference to this fact is made among the contributing causes. However, this should not be construed as being contradictory to what was said at the beginning of this chapter. The reference to voltages in both of these instances is that which pertains to the application of operating potentials in such manner as to change the operation of the tube from an amplifier to a rectifier. As a general rule, voltage tests are made with no signal input and with the volume control adjusted to maximum. During this state, the operating voltages would be found to be normal, yet the receiver distorts when in operation. You will find that the contributing cause refers to the application of excessive control grid bias, which condition cannot be de-

termined when measuring operating voltages with the volume control set for maximum signal. The state of excessive negative grid bias occurs when the receiver is adjusted for minimum signal. This is also true when the control bias is supplied by an AVC tube or a part of a complete circuit, which includes the AVC system. These facts should be borne in mind during the reading of the listing of the symptoms and contributing causes.

Symptoms and Contributing Causes.

In this listing we shall make brief mention of the possible reasons for the condition listed and you are to check the parts of the receiver referred to as the possible reason or reasons for the condition. The items contained in the listings to follow can be considered as being applicable to all types of superheterodyne receivers; that is, receivers of all wave bands and receivers intended for automobile use. The symptoms listed are in accordance with those which you may experience in actual practice. After having observed the action of the receiver which appears defective, make certain that you understand just what symptom exists. When signals or beats interfere, analyze the frequencies. Then seek the listing of the same symptom. It is possible that certain conditions are not covered in this list of symptoms and contributing causes, but we feel that we cover the majority experienced in practice. More than likely the contributing causes for the one which you may be experiencing and which is not listed, will become evident to you upon an analysis of the possible reasons in accordance with the basic underlying theory contained in this volume. Troubles experienced with superheterodyne type short wave converters are listed exactly as if these combination units were complete superheterodyne receivers.

1. **Interfering Station Is of a Frequency 10 kc. Away From the Desired Station.** This is a case of "adjacent channel" selectivity. The selection of the contributing cause is dependent upon whether the trouble arises at only one point on the dial or at several places along the tuning scale. If the trouble occurs at one spot, namely only one interfering station is encountered, then the trouble is excessive signal strength of the interfering station. Remedy would be reduction of aerial length or changing directional characteristics of antenna. If the trouble exists

over various parts of the complete tuning scale, consider the following causes:

a. Operation of the r-f and mixer systems with excessive control grid bias in order to maintain very low output level. If operation at high volume level mitigates complaint, reduce antenna length and signal input from antenna.

b. Coupling between antenna lead or circuit with tuned r-f or mixer or oscillator circuits, through channels other than normal. Check position of antenna and ground lead inside of receiver.

c. Imperfect shielding of r-f, mixer and oscillator circuits. See that all shields are properly grounded and that shield and shield base make good contact.

d. Possible pickup by r-f, mixer or oscillator tube grid leads or tube elements. Shielding of these tubes is possible remedy.

e. Slightly incorrect adjustment of r-f and/or mixer trimmers. Most likely to exist at "high" and "low" ends of the tuning scale.

f. Oscillator trimmer slightly "off," with r-f and mixer trimmers properly adjusted. The discrepancy may be slight, yet sufficient to cause trouble of this type. Can be checked by readjustment of i-f amplifier to new peak created by incorrect adjustment of oscillator, but this should not be tried, unless operator is completely familiar with all phases of superheterodyne operation.

g. Incorrect tuning of i-f transformers. Defect in i-f transformer circuit.

h. Defect in r-f or mixer or oscillator tuned circuits, whereby broadening of resonance curve is secured. This may be moisture soaked windings, presence of metallic mass, shorted turn, etc. Imperfectly grounded tuning condenser, excessive leakage in tuning or trimmer condensers, high resistance joints, poor connections, etc., are additional troubles related to a defect in the aforementioned tune circuits.

2. Interfering Station Is of a Frequency Equal to the Frequency of the Desired Station Plus Twice the Numerical Value of the Intermediate Frequency of the Receiver. This is a case of "image frequency" interference, in a receiver or converter which utilizes the heterodyning oscillator at a frequency higher than that of the desired station. Contributing causes may be:

a. Excessive signal strength of the interfering station.

b. Possible coupling between the antenna or ground lead and the mixer circuit or oscillator circuit.

c. Imperfect shielding of r-f, mixer and oscillator circuits, with consequent pickup by these circuits.

d. "Image frequency" suppressor circuits incorrectly tuned or defective.

e. Incorrect adjustment of low i-f, autodyne mixer circuit trimmers.

3. Interfering Station Is of a Frequency Equal to the Frequency of the Desired Station, Minus Twice the Numerical

Value of the Intermediate Frequency of the Receiver. This is another case of "image frequency" interference, in a receiver or converter which utilizes the heterodyning oscillator at a frequency lower than that of the desired station. See contributing causes listed for symptom number 2.

4. When Using Short Wave Converter, Interfering Station Is of Frequency Equal to Intermediate Frequency Output of Converter. This is a case of signal pickup by the broadcast receiver, which is the intermediate frequency amplifier for the superheterodyne short wave converter. In some instances, the signal pickup is made by the leads connected between the converter and the broadcast receiver, particularly when the converter secures its power from the receiver. In still other cases, the metal mass of the converter picks up the signal and feeds the signal to the t-r-f amplifier in broadcast receiver, which is tuned to the frequency of the interfering signal, hence is most responsive. This is particularly true when the broadcast receiver has its back exposed and the physical separation between the converter and the t-r-f receiver components is not very great. Other contributing causes are:

a. Imperfect operation of the i-f trap circuit in the converter, if one is used.

b. Pickup by the power leads to the converter and close proximity between the converter power lead and the receiver power lead. R-F filters in the converter or receiver power line lead are possible remedies.

c. Imperfect shielding of the feed lines between converter and broadcast receiver.

d. Local station of substantial power operating upon intermediate amplifier peak frequency. Slight shifting of this peak frequency by tuning of broadcast receiver and re-adjustment of converter may help solve the difficulty.

e. Pickup by converter antenna lead due to excessive strength of local transmitter and modulation of desired short wave carrier and passage through converter into receiver. The insertion of a trap circuit, tuned to the converter i-f peak in the antenna circuit feeding the converter, may solve the trouble. Such a trap is useful, if the converter is not already equipped with one.

5. When Using Short Wave Converter, Interfering Station Is of a Frequency Within 20 or 30 kc. of the Intermediate Frequency Output of the Short Wave Converter. This is a case of signal pickup, as in symptom number 4, except that the signals are not of the intermediate frequency. To the contributing causes listed for symptom number 4, add:

a. Imperfect tuning of the broadcast receiver t-r-f amplifier.

b. Defect in the tuned circuits of the broadcast receiver t-r-f amplifier.

6. Interfering Station Is of a Frequency Differing From the Frequency of the Desired Station by the Numerical Value of the Intermediate Frequency. This is a case of heterodyning between the two stations themselves, because both are present in the mixer system. Occurs when i-f peak is integral multiple of 10. Items to be checked are:

a. Incorrect location of the aerial lead in proximity to the mixer system.
b. Excessive strength of the interfering station.
c. Pickup by mixer tube circuit of strong local interfering signal.
d. Incorrect r-f and mixer trimmer adjustment in low i-f peak receivers.
e. Undesired coupling between r-f and mixer circuits.

7. Interfering Station Is of a Frequency Which Differs From the Desired Station Frequency by Slightly More or Less Than the Intermediate Frequency and a Heterodyne Whistle Is a Background for the Station. This is a case of heterodyning between stations and also the production of a steady beat note as a background, due to the difference-frequency between the heterodyning oscillator frequency and the interfering station carrier. A situation of this type is apt to occur in superheterodyne receivers which use intermediate frequencies that are integral multiples of 5 or fractional multiples of 10. For example, 172.5 kc., 175 kc., 262.5 kc., etc. Contributing causes are those listed under symptom number 6, and in addition, consider the following:

a. Coupling between the antenna or ground lead in the receiver to the oscillator tube.

Perhaps an illustration is justified. The desired station is operating upon 700 kc., the receiver is peaked at 262.5 kc., and the oscillator is set at 962.5 kc. If a 960 kc. signal finds its way into the mixer circuit, it will beat against the 700 kc. signal and, at the same time, will be mixed with the 962.5 kc. heterodyning signal. The signal due to the desired station and the signal due to the undesired station will bear the difference-frequency between the heterodyning oscillator frequency of 962.5 kc. and the 960 kc. signal or a 2500 cycle signal. This whistle will appear as a background to the desired, as well as the undesired signals. The same condition will occur if the undesired 960 kc. signal finds its way onto the oscillator circuit via undesired coupling.

8. Interfering Station Appears During Lapse of Modulation Transmission From Desired Station Without Any Change of Dial Setting. (Reception May Be Fuzzy or Blurred at Times

or Accompanied by Wobble or Low Pitched Hum.) This is a case of receiving two stations, which are widely separated in distance, but due to a high sensitivity level of the receiver, they are received at the same time. Such a condition does not constitute a fault in the receiver. The only logical remedy is to reduce the sensitivity of the receiver so that it is least responsive to the undesired station. Such a condition usually arises when seeking distance reception and working at high volume adjustment. The wobble or low pitched type of interference, which accompanies such reception, is due to the difference-frequency between the two stations. While it is true that both are supposed to be working upon the same frequency, the Federal Radio Commission allows a tolerance of 50 cycles in operating frequency. This means that the frequency difference between two stations, supposedly on the same carrier frequency, may be between zero and 100 cycles.

9. Police Call or Short Wave Interference of a Frequency Higher than the Tuning Range of the Receiver. This can be explained in two ways. It is possible that the interfering signal is the "image" for some station operating upon the high frequency end of the tuning dial when the receiver intermediate frequency is high, or, in the average superheterodyne, the interfering station finds its way into the mixer circuit and beats against one of the harmonics of the heterodyning oscillator to produce the desired intermediate. Check

a. Excessive signal strength of the interfering station, due to location.
b. Excessive strength of heterodyning oscillator harmonics.
c. Undesired coupling between antenna or ground circuit and mixer or oscillator tube.
d. Pickup by power peaks in receiver and proximity of these leads to tuned circuits in receiver.
e. Imperfect shielding in receiver.
f. Change in antenna length or directional characteristic so as to be least responsive to undesired station.

Interfering signals, such as stated above, are tunable and may occur at different points along the tuning scale, depending upon the harmonic relation between the signal and the heterodyning oscillator frequency.

10. Intermittent Code or Speech Signal Type of Interference Which Is not Tunable and Is a Background to all Desired Stations and Is Heard Irrespective of the Setting of the Receiver. This type of trouble is due to pickup by the intermediate frequency amplifier, inclusive of the tubes. The interference is localized to places where airway range and beacon stations operate and to the localities bordering upon the coast line of the United States, inclusive of the Great Lakes; for that matter, wherever direction stations operate. This type of interference oftentimes emanates from powerful stations several thousand miles away. The higher the degree of regeneration, in an i-f amplifier, the more likely is the system to respond to such forms of interference. Midget type receivers with regenerative detectors oper-

ating at an intermediate frequency are prone to respond to such forms of interference. Some contributing causes as the following:

a. Antenna or ground or power line lead near i-f amplifier.
b. Imperfect shielding of i-f amplifier circuit.
c. Imperfect condition of i-f unit shields.
d. Absence of shielding over i-f amplifier tubes.
e. Excessive regeneration in the i-f amplifier or regenerative demodulator.
f. Pickup by power line and passage through transformer.
g. Excessive negative control grid bias on i-f tubes.

Interfering signals of the type stated above and also previously mentioned may be due to "floating" shields. In other words, the upper part of the shield is not properly grounded to the shield base. This may be due to electrolysis action or corrosive action between the two parts of the complete shield. The result is that the top half of the shield is floating. This mass of metal acts as an antenna and picks up the interfering signal and actually feeds it into the coil, which it was supposed to shield from external fields. Interference of the type mentioned, is neither fixed or constant. It may be experienced during certain periods of each hour in certain localities and in others it may be experienced during the entire period of use. In still other places, there will be no interference. U. S. Coast Guard Beacon stations operate on frequencies between 260 and 320 kc. Airway beacon stations operate right on the intermediate frequency band. Commercial short wave stations of various service classifications, likewise operate all over the i-f band.

11. **Interfering Signal from Nearby Power Transmitter Blankets Certain Spots Upon Tuning Dial and Does Not Interfere with other Distant Stations.** A condition of this type is created by the fact that harmonics of the interfering station mix with harmonics of the heterodyning oscillator, when the receiver is tuned to the desired stations. No particular relationship appears to exist between the fundamental frequencies of the stations, which are blanketed by the local fundamental, yet definite relations exist between the harmonic of the interfering fundamental and the harmonics of the heterodyning oscillator, with respect to the intermediate frequency. It is impossible at this time to list all of the possible combinations for all of the intermediate frequencies now in use. You will have to identify this situation by recognizing what is taking place and by making one or two computations. After all is said and done, the remedy is what matters and in this instance, the following should be checked:

a. Excessive pickup of the local station. Too much aerial length or coupling between the antenna circuit and the tuned circuits in the receiver.

b. Operation of the r-f or mixer circuits at such a low level, that the control grid bias applied results in the operation of the amplifier tubes as rectifiers and the production of harmonics in the output circuit.

c. Excessive harmonic content of the heterodyning oscillator. Possible defect in the circuits which control the harmonic output.

d. Alteration of the antenna system so that it is less responsive to the local signal.

e. See discussion about Harmonics and Harmonic Relation.

In the event that you are interested in identification of a situation such as this, consider the following: Suppose that a powerful 900 kc. station is located in your town. The receiver in question employs a 175 kc. peak. If this 900 kc. station is very strong, so that it will find its way into the average receiver, it will interfere when the receiver is tuned to 550 kc., because 900 kc. is the image for 550 kc. with 175 kc. intermediate. It will come through again, unless care is taken to keep it out, when the receiver is tuned to some station between 640 and 650 kc. because the second harmonic of the 900 kc. signal and the second harmonic of the oscillator will produce an intermediate signal, which will get through the i-f amplifier. The same is true when the receiver is tuned to between 660 and 670 kc., in which case the third harmonic of the 900 kc. signal will beat against the third harmonic of the oscillator signal and produce an i-f beat, which will get through the i-f amplifier. The same will happen when the receiver is tuned to about 780 kc., because the difference frequency between the third harmonic of the 900 kc. signal and the third harmonic of the oscillator will again produce a beat, which will get through the i-f amplifier. Since the presence of the 900 kc. signal in the output is dependent upon its presence in the mixer circuit and upon the harmonics of the heterodyning oscillator, this example of interference can also be used to explain the reason why repeat point reception may exist at apparently irregular points along the tuning scale.

12. Interfering Signal from Powerful Local Station Appears at Several Points along the Tuning Dial. (Repeat Tuning with Single Dial Receiver.) See explanation offered in connection with symptom number 11.

13. Heterodyne Whistle at 690 KC. In Receiver Peaked at 115 KC. This is due in this case, to heterodyning between the sixth harmonic of the intermediate frequency peak and a 690 kc. carrier. The pitch of the heterodyne signal may be high or low, depending upon the exact adjustment of the oscillator, with respect to the beat note desired; that is, the exact value of the i-f peak. If the i-f signal differs from the rated value by 250 cycles, and the fourth harmonic of this signal beats

against a fundamental, the audio beat thus produced would be about 1000 cycles. It is, of course, possible that there will be no beat note at the 690 kc. setting, because the sixth harmonic of the 115 kc. i-f may be extremely weak. Then again it is possible, depending upon the operation of the demodulator tube, the location of the antenna lead, the condition of the r-f filter circuits in the demodulator tube output circuit and carrier signals in the antenna circuit, that beats will be heard, not only at the 690 kc. setting, but at higher settings representative of the seventh, eighth and higher harmonics. Reasons behind the production of such undesired beats are as follows:

a. Defective r-f filter in the demodulator output circuit. Examine choke, if used, and bypass condensers. Ungrounded choke or condensers. Defective connections. Defective shielding. Check position of demodulator tube control grid, screen grid and plate circuit connections.

b. Undesired coupling between antenna or ground leads and output circuit of demodulator tube. Also input circuit of demodulator tube. Aerial and ground circuit leads should be far removed from demodulator tube electrode circuits.

c. Check shielding of i-f transformers and i-f tube.

d. Check shielding of demodulator tube.

e. Check for overloading of demodulator part of tube used in demodulator tube socket.

14. Interfering Signals at Frequencies Which Fall at the High End of the Tuning Dial When Tuning Dial Is Set to Lower Half of the Tuning Band.

Such a problem may be created by the existence of one of two conditions. The presence of the interfering signal is due to beat note production between the fundamental signal carrier and the harmonic of the oscillator when it is adjusted to a lower frequency signal. Thus, if the receiver employs a 175 kc. peak and the receiver is tuned to 550 kc., the heterodyning oscillator frequency is 725 kc. The second harmonic of this frequency is 1450 kc. If this signal is allowed to beat against either a 1270 kc. signal or a 1280 kc. signal, beat notes of 170 and 180 kc. respectively, will be produced. These are apt to pass through the 175 kc. peaked i-f amplifier and be audible in the output. A situation such as this may exist in receivers which are peaked at frequencies other than 175 kc. Items to check are:

a. Location of the aerial lead in close proximity to the mixer tube.

b. Excessive pickup from the interfering station.

c. Excessive harmonic output from heterodyning oscillator. Check harmonic suppressor resistors and condensers in oscillator circuit.
d. Check shielding of oscillator and mixer coils.

15. Heterodyne Whistle at Several Broadcast Frequencies in Receivers Peaked at Frequencies Between 120 KC. and 480 KC. For contributing causes and details, see explanation listed under symptom 13.

IF Peak In Receiver KC.	Broadcast Frequencies at Which or Near Which Beat Notes May be Experienced, if the Condition Listed Under Symptom 13 Exist						
	KC.	KC.	KC.	KC.	KC.	KC.	KC.
120				600	720		
125					750		
130				650	780		
172.5			690	860	1040		
175			700	875	1050	1225	1400
177.5			710	890	1065	1240	1420
178			710	890	1070	1240	1420
180		540	720	900	1080	1260	1440
181.5		540	730	910	1090	1270	1450
252.5		760	1010	1260	1515		
260		780	1040	1300	1560		
265	530	795	1060	1325	1590		
370	740	1110	1480	1850	2220		
445	890	1335	1780	2225	2670		
450	900	1350	1800	2250	2700		
455	910	1365	1820	2275	2730		
456	910	1370	1820	2280	2740		
460	920	1380	1840	2300	2760		
465	930	1395	1860	2325	2790		
470	940	1410	1880	2350	2820		
480	960	1440	1920	2400	2880		
485	970	1455	1940	2425	2910		
525	1050	1575	2100	2625	3150		
535	1070	1605	2140	2675	3210		
550	1100	1650	2200	2750	3300		
600	1200	1800	2400	3000	3600		
950	1900	2850	3800	4750	5700		
1000	2000	3000	4000	5000	6000		
1010	2020	3030	4040	5050	6060		
1300	2600	3900	5200	6500	7800		

16. Heterodyne Whistle at Various Frequencies When Using Converter. This condition is created by coupling between the broadcast receiver t-r-f amplifier, used as the i-f amplifier, and the antenna circuit of the converter. Check items listed under symptom 13,

with the detector in the broadcast receiver considered to be the demodulator. For frequencies at which these beat notes will occur, see listing under symptom 13, with the converter i-f peak listing shown under the heading "IF Peak In Receiver."

17. Interfering Signal of Constant Audio Frequency as Background to All Desired Signals with Receiver Equipped with CW Oscillator. This form of trouble is not serious. More than likely it is due to a defect which prevents cutting out the CW oscillator, when the switch intended for that purpose is operated.

18. Heterodyne Whistle as Each Station Is Tuned In. Such a condition may be due to imperfect adjustment of the neutralized systems, if they are used in the receiver, or to those items which will tend to cause an oscillatory state in the r-f or i-f amplifiers or in the mixer tube circuit. Check the following:

a. Incorrect adjustment of r-f or i-f neutralizing condensers, if they are used.

b. Open grounds at shields or shield contacts.

c. Poor contact at r-f, mixer or i-f and demodulator screen, control grid or plate circuits. Open condensers or other defects related to these units in these circuits.

d. Incorrect location of control grid or plate leads in r-f, mixer and i-f circuits.

e. Shorted grid filter resistors in r-f, mixer and i-f circuits.

f. Open bypass condensers in AVC voltage feed circuits.

19. Whistle or Growl Background to All Stations. As a general rule this condition is created by imperfect operation of the oscillator circuit of either the single function or the autodyne type. It is also possible that i-f amplifier is oscillating. Check the following:

a. Excessive regeneration due to application of unbalanced operating potentials.

b. Excessive resistance in grid circuits. See "Oscillator Howl."

c. Imperfect bias resistors.

d. Presence of parasitic oscillatory circuits within oscillator system.

e. Imperfect bypass condensers across bias and grid filter resistors.

f. Oscillatory condition in i-f amplifier or a-f amplifier.

20. Desired Station May be Tuned In at Several Points Along Tuning Dial. (Receiver With Separate Oscillator Tuning Control.) This action is quite in order with receivers of this type, because several adjustments of the oscillator dial setting will provide heterodyning frequencies which, when mixed with the desired station carrier, will produce the i-f beat. The solution lies in acquainting the operator of the receiver with the facts and teaching the man to track the tuning condenser dial with the oscillator tuning dial, when tuning the receiver.

21. Station Can Be Tuned In at Two Points on Tuning Dial. (Single Control Superheterodyne.)

Several conditions may create such a fault. One of these is excessive signal strength combined with operation of the receiver at a low level by means of high negative grid bias on r-f and mixer tubes. The fundamental signal may find its way into the r-f circuit, where, because of possibly excessive grid bias, second harmonic production takes place, and when the receiver is tuned to a frequency approximating the second harmonic of the station, response will be had. For that matter, if the station is of sufficient strength, its second harmonic will be tunable and response will be had when the receiver is tuned to the second harmonic of the station. Another possible reason is incorrect tracking of the oscillator condenser. Maybe incorrect tracking of the image frequency suppressor circuit condenser or some defect in this circuit exists, so that instead of keeping its resonant signal out of the circuit, it feeds this resonant signal into the circuit. You might check all of the following:

a. Oscillator trimmer adjustment.
b. R-f tuning condenser trimmer adjustment.
c. Excessive pickup from station. Reduce pickup.
d. Mixer circuit trimmers.
e. Incorrect location of aerial leads.
f. Imperfect shielding.
g. Excessive control grid bias on r-f and mixer tubes.

22. Heterodyne Whistle At Signal Frequencies Which are Slightly Lower or Higher Than Harmonic Frequencies of I-F Peak.

A condition of this type is due to undesired coupling between the mixer input or output circuit and the demodulator input or output circuit. What actually happens is that the i-f signal harmonic beats against the signal produced by the heterodyning oscillator. This is different from the beat note produced as a result of the mixing of the i-f signal harmonic and carrier signal frequencies, as outlined in symptoms 13 and 14.

An example of the present case is as follows: Suppose that the i-f peak is 115 kc. The sixth harmonic of this signal is 690 kc. In order to receive a 570 kc. carrier signal, the heterodyne oscillator would be adjusted to 685 kc. If the mixer circuit and the demodulator system were coupled, a beat note of 5.0 kc. would be carried by the 115 kc. intermediate frequency signal or a 5.0 kc. audio signal would be produced in the demodulator circuit. Under similar circuit conditions, a zero beat would result when the receiver is tuned to 690 kc., because the seventh harmonic of 115 kc. is 805 kc., which is the frequency of the heterodyning oscillator. However, when the receiver is tuned to 800 kc., a 5.0 kc. beat would be produced, because the eighth harmonic of 115 kc. is 920 kc., whereas the signal from the oscillator would have a frequency of 915 kc. Zero beat would exist with the receiver tuned to 920 kc., but a 5.0 kc. beat would result when the receiver was tuned to a

signal carrier of 1030 kc. As a matter of fact, there are two signal frequencies which would produce a 5.0 kc. beat, wherever a single frequency was mentioned. Thus, an 810 kc. and a 1040 kc. signal would produce 5.0 kc. beats.

Similar conditions exist at other signal frequencies for other i-f peaks. Calculation of the relation between the frequencies at which the beats occur and the i-f will show the existence of a fault of this type. Items to be checked are:

- a. Incorrect placement of leads in mixer and demodulator tube circuits.
- b. Proximity of mixer tube leads and demodulator tube circuit leads to some wire in some other circuit, which may act as a coupling link between the mixer and demodulator.
- c. Imperfect shielding of mixer and demodulator units.
- d. Imperfect ground contacts or open ground contacts to shields.
- f. Imperfect filtering in AVC circuits which are common to demodulator tube and mixer tube.

23. Receiver Operative Over Only a Portion of the Tuning Dial. (Single Control Superheterodyne.) In the majority of cases, such a condition is due to faulty operation of the heterodyning oscillator. However, a similar situation can be created because of other defects and it is best to check all of the following:

- a. Oscillator trimmer condenser out of alignment.
- b. Shorted turns in autodyne mixer tube plate coil.
- c. High resistance in oscillator or autodyne mixer tube tuned circuits.
- d. Imperfect alignment of r-f, mixer or oscillator trimmers in multi-wave band receivers or defective tuned circuits.
- e. Defective coupling between oscillator input and output circuits. Defective coupling between oscillator and mixer.
- f. Defective switch contacts in tuned circuits of dual wave receivers.
- g. Leak or short circuit between tuning condenser plates, when the tuning dial is to a certain point, that is, where the receiver becomes inoperative.
- h. A combination of oscillator trimmers and i-f trimmers incorrectly adjusted.
- i. A combination of r-f trimmers and i-f trimmers incorrectly adjusted.
- j. Imperfect operation of tuning range switches.
- k. Imperfect grounding of shields around tuned coils causing shields to act as absorbing masses.
- l. Imperfect grounding of unused portions of windings in multi-wave band receivers.
- m. Defective resistor or condenser in oscillator tube circuit.
- n. Excessive bias in receivers, where bias is governed by frequency setting of oscillator.
- o. Excessive leakage between tube elements across socket terminals.
- p. Effect of antenna upon autodyne mixer-oscillator.

q. Incorrect adjustment of antenna trimmer in high frequency receivers.

r. Poor oscillator tube.

24. Interfering Signal Appears During Operation of Receiver and Disappears Without any Adjustment of the Receiver. This phenomenon is occasioned by the fact that the interfering station is operating upon exactly the frequency to which the receiver is tuned. The appearance of the signal is due to a periodic change in the intensity of the signal at your receiver. Normally the signal is so weak as to be inaudible. After a period of time it becomes stronger and is heard. There is nothing wrong with the receiver. The only possible remedy is to reduce the sensitivity of the receiver to the point where the undesired signal will not be audible, despite the moment of maximum intensity. This condition is similar to the fading characteristic.

25. Interfering Signal Appears After Receiver Has Been In Operation for Some Time and Disappears If Receiver Is Shut Off for a few Minutes and then Again Placed Into Operation. Generally speaking, this condition is created by what is known as "oscillator frequency drift." In other words, the frequency of the oscillator output changes after the receiver has been in use for a while, although no change in tuning is effected by the operator. Experience shows that the following items are oftentimes responsible for this automatic change in frequency of the oscillator output.

a. Defective bypass condensers connected across the various resistors, which limit the voltage applied to the elements of the oscillator tube. Defective in this instance does not mean short circuited. Instead intermittent operation, high resistance contacts to the leaves of the condenser coil, high resistance joints and excessive leakage.

b. Moisture absorption by the dielectric of the solid dielectric trimmers used in the various oscillator tuned circuits.

c. Imperfect ground connection to the tuning condenser rotor in the oscillator and to the oscillator coil shield, if one is used. Corrosion between the oscillator coil shield and the coil shield base.

d. Defective resistances in the oscillator circuit, particularly in the grid circuit. Resistance which varies in value during operation, because of changes in current flow as the frequency of the oscillator circuit is varied, will cause frequency drift.

e. Imperfect mounting of oscillator coils and windings. Variation of the position of the windings will cause a change in frequency output.

f. Variation in the spacing between the tube elements within the tube envelope, as a result of heat developed.

g. Fluctuations in the applied operating voltage.

As a matter of fact one commercial receiver in particular employs a thermostatically controlled trimmer condenser as a means of overcoming

frequency drift. If the frequency drift is due to some condition created as a result of heat developed during the time that current flows through the circuits, shutting off the receiver restores the various units to their "cold" values and when the receiver is again started, the original incorrect values exist. Oscillator drift is quite important on short waves.

26. **Frequent Need for Retuning.** This is a case of oscillator drift or of imperfect mounting of the tuning condenser gang. Too much play may cause a slight shift in the setting of the tuning condenser because of the vibrations created by operation of the speaker within the same cabinet. See listing under symptom number 25.

27. **Interfering Signal Appears after Period of Use Although RF, Mixer and Oscillator Circuits are Perfectly Aligned and Desired Signal Strength Is Substantially Normal.** This is not a frequent complaint, but upon several occasions was found to be due to defective i-f trimmers, particularly in receivers which employed one i-f transformer. If one of these condensers changes its tuning adjustment, the effect is to broaden the resonance curve of the transformer and signals, which normally were rejected by the i-f system, appear in the output. Reasons for such changes in the i-f peaking are as follows:

a. Defective dielectric in i-f transformer.
b. Absorption of moisture of i-f trimmer dielectric.
c. Cracked dielectric.
d. Worn adjusting screw thread.
e. Temporary short circuiting of turns in the i-f transformer windings.
The usual remedy is replacement of the trimmer, if the trouble lies in the trimmer, or replacement of the entire i-f transformer.

28. **Frequent Readjustment of I-F Trimmers.** See listing under symptom number 27. Disregard references to interfering signal, unless experienced in practice.

29. **Oscillator Howl.** In some cases an audio howl background to all signals can be traced to the heterodyning oscillator circuit. Many superheterodyne receivers employed oscillator systems wherein certain resisters were located in the control grid circuit and the bias resistor was omitted from the cathode circuit. Some of these oscillators developed an audio howl, which means that in addition to generating the desired heterodyning carrier, the carrier was modulated at some audio frequency, due to the operation of the oscillator with the resistor in the grid circuit. This value ranged from 2000 to about 3000 ohms. A remedy was the removal of the resistor from the grid circuit and its insertion into the cathode circuit, to function as a bias resistor. Naturally the grid circuit is completed at the point where the resistor was removed and a suitable bypass condenser is connected across the bias resistor, that is, if such a condenser is not already in the circuit.

Weak Signals.

When the subject of weak signals is mentioned, there is a great deal to think about, because innumerable defects, major and minor, are productive of this complaint. To attempt to portray in full all reasons for this complaint would require half the pages in this volume. Such is obviously impossible. Consequently, we shall do the next best thing, and consider the subject of weak signals from the angle of the new ideas to be found in present day receivers and which were absent in the old type t-r-f receivers. In as much as we are concerned with superheterodynes in particular and since there are certain items to be found in this type of receiver, which are not in t-r-f systems, it might be well to consider these items in their relation to weak signals.

As previously stated, it is our intention to omit detailed discussion concerning audio frequency amplifiers and power packs, with the exception of the vibrator type of voltage source. In this connection, we shall focus our attention upon the workings of the vibrator and its associated power transformer. From this point on, the operation of the unit is no different than the conventional power pack and does not justify discussion at this time. We realize fully that too much can never be said about the servicing of radio receivers with special attention to the different parts of receivers. Yet, we feel that we have a certain objective and that objective is a discussion of the superheterodyne principle and its workings, rather than a detailed course of study of general radio service work.

We feel that if we can present a detailed exposition of factors which are productive of weak signals, and are related more to superheterodyne operation than to t-r-f receiver operation, the purpose of this book will have been fulfilled. The man who will use this volume is familiar with general service routine; with such items as the actual means of locating an open circuit or a short circuit. We further feel that years of experience with t-r-f receivers have acquainted service men with knowledge of how to measure voltage and of the routine involved in locating the defective resistor or condenser,

when the voltage measurement indicates the presence of such a defect. It is our belief that the man who reads this book, having worked upon t-r-f receivers, is familiar with the general service problems associated with audio frequency amplifiers and loud speakers. Consequently, by dwelling upon those items which are native to the modern superheterodyne and which are not to be found in t-r-f receivers, we attain the greatest value for this volume. Such shall be the case. During the discussion of weak signals, we are going to consider the radio frequency amplifier, the mixer circuit, the oscillator, the i-f amplifier, the AVC system with its various circuit modifications and interlocked systems, wave changing arrangements and short wave superheterodyne converters.

It is our intention to consider the reasons for weak signals with the understanding that fixed operating potentials are normal. This does not mean, however, that all component resistances are correct, because it is possible that certain defects in circuit resistances, particularly in the tuned circuits, may exist, yet not influence the operating potentials. Accordingly, reference to a possible defect in certain units, as for example grid resistors, coils, high resistance joints at switches, etc., means that resistance checking to determine the presence of the fault is in order. (If you are not familiar with the process of checking receivers by measuring the d-c resistance between specified points, which incidentally is essential to the servicing of modern receivers, we refer you to Rider's "Servicing Receivers By Means Of Resistance Measurement" available from John F. Rider, Publisher, 1440 Broadway, N. Y. C.) Our reason for analysing symptoms with the premise that operating voltages are correct, is to eliminate from the discussion all those factors, which, if defective, would influence operating voltages, cause weak signal response and complicate matters. As it happens, weak signal output due to incorrect operating is easily discovered by measurement of the applied voltage or measurement of the resistances in the fixed voltage supply circuits. This type of work is no doubt well known to the readers of this page, because of such routine work carried out upon t-r-f receivers. By assuming

that the fixed operating potentials are correct, we are enabled
to remove from all doubt the condition of the power supply
device. However, as stated earlier in this text, we shall con-
sider the vibrator type of power supply unit, as a separate
device, with respect to theory underlying its operation and
servicing.

We are further going to assume that the audio amplifier is
in good condition and that the speaker is in good condition.

Another item, which we wish to discuss at this time, is the
vacuum tube. The statement has been made that this chap-
ter on trouble shooting and symptoms is written with the
understanding that the tubes used in the receiver are in perfect
shape; that a separate tube test would establish the condition
of the tubes. Two exceptions should be noted. One of these
is the AVC tube in various forms, namely the separate diode,
triode or pentode used for AVC, noise suppression and channel
control and the oscillator tube. The neon glow tube used
for visual tuning is also excluded. The tube references made
above will be considered in the text for the simple reason that
a tube may be perfect for various forms of use in a radio
receiver, yet be unsuited for use in an AVC circuit.

May we state at this time that we recognize the possibility
of a dead receiver with perfectly normal operating potentials.
A routine method of locating the possible reason for the con-
dition of the receiver will be outlined in brief at the con-
clusion of the discussion concerning symptoms and trouble
shooting.

**30. Weak Signals Over a Part of the Tuning Range.
(Sometimes Accompanied by Distortion.)** It is a pretty good
guess to say that a problem of this type is due to incorrect trimmer
alignment in the r-f, mixer or oscillator circuits, particularly so, if the
fault exists over a section of the complete tuning range, starting with
minimum or maximum and response, both as to signal intensity and tone
quality, is satisfactory over the balance of the tuning range. Obviously
the r-f and mixer tubes do not possess the power of discrimination as to
the selection of a frequency band over which these systems will work
best. Hence the trouble must lie in the tuned circuits. However, it
might be advantageous to give heed to the thought that perhaps the
oscillator circuit is generating a beating signal which is not of uniform
intensity, but which decreases in intensity as the tuning range approaches
its minimum or maximum limits. This is particularly true if the design

of the oscillator circuit is such that the oscillator tube secures its grid bias as a result of grid current. All in all, the following should be checked:

a. Alignment of r-f, mixer (also autodyne) and oscillator trimmers over the part of the band where the receiver affords low output.

b. Unsuited antenna system.

c. The condition of the oscillator tube may not be the best.

d. Defective coupling between input and output circuits of oscillator tube. (Some oscillator circuits employ both inductive and capacitative coupling.)

e. Defective coupling between oscillator and mixer tubes.

f. The resistors or condensers in the oscillator circuit may be defective.

g. Incorrect adjustment of antenna trimmer.

h. Defective tuning condenser, created when condenser rotor is revolved past certain point in arc of travel.

i. All other items listed under symptom 23.

The relationship between weak signals and distortion arises from the fact that misaligned circuits will not pass the complete modulation sidebands. In the case of the heterodyning oscillator, incorrect alignment results in the generation of an i-f signal which is not exactly in accordance with the peak of the i-f system and only certain frequencies contained in the modulation sidebands are passed. Such is possible over a certain part of the tuning band, without interfering with perfect operation over the remainder of the tuning band.

31. Weak Signals Over Certain Wave Bands of a Multi-Wave Band Receiver. See explanation and listing of possible reasons under symptom number 30 and also consider the following:

a. Poor contacts at wave band switches.

b. Defective coupling coils brought into play for those wave bands.

c. Defective ground contacts.

d. Defective coils.

e. Imperfect shielding and interaction between coils.

f. Defective image suppressor circuit. (These trap circuits are usually removed from the receiver circuit, when wave band is changed to short waves.) Will interfere, if allowed to remain in system.

g. Synchronous operation of all wave band switches not obtained.

h. Defective bypass condensers. Effect more pronounced at high frequencies.

i. Poor ground.

32. Weak Signals Over a Part of Tuning Range, When Converter Is Used. See explanation and listing under symptom number 30. Consider those possible causes as are to be found in the converter. Add the following:

a. Grounded antenna lead between converter and broadcast receiver.

b. Defective ground connection between converter and broadcast receiver.

    c. Defective i-f amplifier (t-r-f amplifier in broadcast receiver). (The possibility of a defect of this type exists in those converter combinations wherein the actual tuning is done by tuning the i-f amplifier.)

    d. Defective range switch in converter which comes under the classification (c) above. (See converters in this volume.)

33. Weak Signals Over the Entire Tuning Range. A condition of this type, if accompanied or not accompanied by broad tuning, calls for a general examination of the receiver. It is possible to guess at the probable location of the trouble by noting the broadness of tuning or the presence of interfering stations. It is further possible to guess at the probable location by noting the action of the visual tuning meter. Such guess work is not worth while. It is far more practical and satisfactory to make a routine test of the receiver. It may require the expenditure of an unnecessary amount of time in certain cases, but it will pay in time and effort in the long run. In view of this we shall list all of the possible troubles, located in the circuit ahead of the audio amplifier, which may contribute to the creation of a state, resulting in weak signal output. To avoid repetition of words and needless expenditure of space, the word "defective" when used in this tabulation and applied to coils, condensers, transformers, resistors, junctions, switches, etc., means "open circuited," "short circuited" or as having "high resistance contacts or connections." Consider the following possible reasons for weak signal ouput. Operating voltage is assumed to be normal.

    a. Defective antenna or ground system, with respect to length, height, nature of shielding and other related items.

    b. Defective r-f, mixer, oscillator and i-f transformers of all types used in short wave converter combinations and single and multi-wave band superheterodynes, inclusive of autodyne mixer-oscillators.

    c. Lack of correct coupling between windings of r-f, mixer, oscillator and i-f transformers as stated in (b).

    d. Defective wave changing switches.

    e. Defective trimmer condensers in r-f, mixer, oscillator and i-f transformer circuits.

    f. Incorrect alignment of r-f, mixer, oscillator or i-f trimmers.

    g. Defective image suppressor circuit.

    h. Grounded r-f, mixer, oscillator or i-f transformer circuits.

    i. Shorted turns in r-f, mixer oscillator and i-f transformer circuits, which condition is related to incorrect alignment, although replacement of the transformer must be made.

    j. Defective grid filter circuit resistors and condensers tied in with the AVC circuit.

    k. Defective operation of channel control systems which "lock" audio amplifier tube.

    l. Too low control voltage in delayed AVC system.

    m. Excessive AVC control voltage, due to gas in AVC tube, or some other defect which establishes tube unfit for AVC use.

n. Defective input transformer to channel control tube, which is interlocked with AVC and noise suppression circuits, thereby "locking" audio system.

o. Defective crystal control circuit in i-f amplifier, when used.

p. Defective tuning condensers.

q. Incorrect alignment of main tuning condenser gang.

r. Low oscillator output.

s. Excessive AVC voltage due to defective circuit elements.

t. Shorted turns in r-f, mixer, oscillator and i-f transformers.

u. Defect in flasher transformer, which, if existent in certain circuits, will reflect back into the related i-f transformer and impair operation.

v. Defective link between AVC or demodulator tube or channel control tube and noise suppressor circuit.

w. Gassy noise suppressor tube.

x. High resistance connections to or within tuning condensers and r-f, mixer, oscillator and i-f trimmers, inclusive of units used in all wave bands of multi-wave band receiver.

y. High resistance connections to, or within bypass condensers in r-f, mixer, oscillator and i-f tube control grid, screen, cathode, suppressor and plate circuits, wherever used.

z. Open tube element in triode tube used as diode demodulator.

As is appears, this is quite a formidable list. Yet if we were confronted with trouble of this type, we would pay the greatest amount of attention to those items which are related to imperfect alignment. If readjustments failed to correct the condition, then we would consider the remainder in whatever order is most convenient. As a general rule, distortion accompanies weak signal reception, which is due to incorrect alignment, but this should not be accepted as a general statement covering all causes for weak signals. The method of checking a receiver of this type, is described briefly under the symptom "Dead Receiver."

It might be well to bear in mind in connection with weak signals, that voltage measurement is not possible at the elements of AVC tubes. This is one of the reasons why point-to-point resistance measurement is replacing voltage measurement as a basis of analysis. If you have checked the AVC tube and know that it is good, then check the resistance of the various circuits in the AVC system.

34. Weak Signals With Wrong Tuning Indicator Indications.

This reference to tuning indicators covers meters, employed in one way or another and flashers of various kinds. In connection with flashers, it is necessary to understand that there are two major methods of securing indications with these units. The most prevalent arrangement, namely, the glow developed when the signal is tuned to maximum reso-

nance has been described. Another, but different arrangement, causes the tube to flow when the receiver is detuned and the glow, illuminates the word "Detuned." When the signal is tuned in, the glow ceases and the word "Tuned" appears. In contrast to the popular method of causing the AVC voltage to decrease the plate current of the r-f and i-f tubes and thus develop the correct glow voltage across the neon tube, the other method employs the neon tube in such manner that the glow voltage is across the tube during the time that the receiver is detuned. When the receiver is tuned, a portion of the AVC voltage is applied to the control grid of the vacuum tube which has the neon tube in its plate circuit. The plate current of this tube flows through the neon tuning indicator. When a signal is tuned in, the negative bias received from the AVC circuit, decreases the tube plate current and causes the tuning indicator tube to cease glowing. Thus, the operation of the AVC circuit is the same in all the systems, but the final effect differs in these two methods of employing the neon tuning indicator. Consequently, when trying to reconcile the weak signal response with the tuning indication, it is necessary that you know just how the tuning indicator is used. This information must be secured from the wiring diagram.

Obviously, tuning meters can be employed in the two methods described in connection with neon tube indicators. While we cannot at the moment, recall a tuning meter used in the plate circuit of a 6B7 demodulator and AVC tube, its use is quite practical. In the meantime, the following possible causes for the symptom named are offered for your consideration:

  a. Excessive AVC voltage.
  b. Defective channel control circuit components.
  c. Defective glow tube voltage limiting resistors.
  d. Defective condensers associated with the glow tube.
  e. Incorrect adjustment of glow tube voltage control resistor, when used in receiver.
  f. Defective indicator.

The above named causes do not include improper adjustments of the unit itself, as for example the focusing of the pilot light in Philco "Shadowgraph" or the spring adjustment in other indicators which use springs.

35. Lack of AVC Action. This is usually indicated by non-uniform signal output and blasting as the receiver is tuned. Also excessive noise background. Once again, in order to correlate the condition

with its possible causes, it is necessary to know just what type of circuit is used. When this information is available, consider the following:

a. Defective channel control circuit, if this system is tied in with the AVC circuit.

b. Open coupling condenser which feeds AVC tube.

c. Excessive cathode voltage in delayed AVC systems.

d. Shorted AVC tube control grid circuit.

e. Grounded filter resistor or condenser in main AVC voltage supply line.

f. Grounded bypass condenser in control grid circuit of controlled tubes.

g. Tube unsuited for AVC use. (Try replacement.)

h. Grounded bypass condensers in AVC tube circuit or in other control tube circuits tied in with AVC tube.

i. Open coil which feeds AVC diode plates.

j. Open tube element in triode tube circuit used as diode AVC.

As stated earlier in this text, AVC and associated circuits actuated by signal voltages, cannot as a rule be checked by measuring fixed operating potentials. While it is true that the voltages at the voltage divider, which supplies the fixed potentials to the AVC and associated tubes, can be measured with a voltmeter, the operating potentials at the tube elements cannot as a rule be determined with any great degree of accuracy due to the high resistance usually used in these circuits. Consequently, more faith is placed in resistance measurement. Furthermore, the customary arrangement of AVC circuits is such that routine cabled voltmeter tests are not very practical, despite the fact that fixed voltage of measurable value is present at the respective tube element terminals upon the tube socket. In duo-diode type AVC circuits, the only measurable voltage is that which constitutes the fixed potential established between the diode and the cathode for delayed action. Although we have taken for granted that the tube is good, we depart from the set rule of not listing tube troubles, by suggesting item (g). Very often a tube is suitable for use as an amplifier, yet is unsuited for AVC work.

We are adding a separate paragraph concerning the AVC amplifier for the AVC tube, described under the heading "Special Circuits and Applications" in the preceding chapter. To the list shown before, add the following as being applicable to receivers which employ such systems.

k. Defective AVC amplifier tube.

l. Defective i-f transformer feeding AVC tube.

36. Excessive AVC Action. Usually this condition creates weak signal output, so that the subject is listed as cause (m) under symptom 33. However, the reasons for excessive AVC operation in any one of the forms in which it may occur, are of the following order, bearing in mind that circuit constants must be included because resistance measurement is the only way of checking these circuits.

a. Gassy AVC tube.

b. Defective voltage control resistors in fixed voltage supply circuits. (By defective is meant a reduction or increase in ohmic value of the resistors, depending upon the exact function of the resistor in the AVC circuit. Filter resistors are not included in this mention, because their function is to filter or de-couple and not to establish the value of the voltage at various points in the circuit.

c. Leakage between AVC tube elements or terminals on socket.

d. Incorrect adjustment of bias control.

e. Defective resistor, which establishes fixed diode plate-cathode voltage.

f. Defective bypass condensers in AVC circuits.

g. Shorted condenser, which feeds AVC tube control grid.

h. Leakage between primary and secondary of i-f transformer, which feeds AVC diode plate.

37. Noise Between Stations With Receiver Equipped With Noise Squelch Circuits. It is assumed that the noise level is quite normal, but exists because the noise squelch circuit does not function properly. Possible reasons for such a state are:

a. Incorrect setting of, or defective noise control switch.

b. Open circuit bteween noise control tube and audio tube which is "locked" while tuning receiver.

c. Deactivated noise control tube.

d. Open circuit between noise control tube control grid and source of control bias for noise control tube.

e. Defective units in circuit which develops bucking voltage to release "locked" audio system.

f. Open external grid-plate condenser in automatic noise and tone control tube circuit. (See circuit description under heading "Special Circuits and Applications.")

g. Defective electrode in neon tube type of noise gate.

h. Ungrounded cathodes in noise control tube.

i. Defective channel control circuit or system. (See Lack of Channel Control.)

If you will note, we make special reference to the fact that the receivers being considered are those which are equipped with noise squelch circuits. Receivers not so equipped come under the classification of ordinary t-r-f receivers, because reasons for noise in the average superheterodyne are the same as reasons for noise in t-r-f receivers, which subject has received attention for years and does not involve any new features for discussion in this volume. However, so as not to ignore the subject entirely, we can list such reasons as defective resistors, condensers, soldered joints, tube prong and socket contacts, loose wires, loose shields, high resistance leaks across corroded junctions, dirt and dust between the plates of tuning condensers, minute arcing between the terminals of power transformers, chokes, audio transformers, etc., noise pickup, r-f noise interference due to the operation of gaseous rectifiers, defective antenna and ground sys-

tems, excessive regeneration, gassy tubes, etc. All of these items have been experienced in connection with t-r-f receivers and methods of locating the defective units in superheterodynes do not differ from the methods employed in t-r-f receivers.

38. Lack of Channel Control. Channel control circuits are tied in with either a visual tuning indicator or with a noise suppressor tube. In the case of the tuning indicator, the function of the unit is to enable very accurate adjustment of the tuning. This is accomplished by securing the actuating voltage for the tuning flasher circuit from an extremely sharply tuned i-f transformer. Only by tuning the receiver very accurately, it is possible, (assuming that the tuning flasher i-f transformer is in proper working order), to cause the flasher to glow. Whereas the regular i-f transformer in the receiver is tuned to allow perhaps 5.0 kc. sidebands, the tuning flasher transformer is tuned right to the i-f peak with very little tolerance either side. The sideband signals are not required in this circuit. Possible reasons for faulty operation of the tuning flasher of this type are:

a. Incorrectly tuned tuning flasher i-f transformer.
b. I-f peak output from mixer tube not exactly the peak rating of the receiver. (In this connection if the receiver response appears normal, it is better to readjust the tuning flasher i-f transformer in resonance with the mixer output, than to realign the r-f and oscillator circuits.)
c. Gassy tuning flasher control tube.
d. Defective load resistor in diode-cathode circuit, if this circuit develops the bias required to reduce the control tube plate current so as to operate flasher.
e. Grounded bypass condenser across tuning flasher.
f. Defective glow tube voltage control resistor.
g. Defective bias resistor for tuning flasher control tube.
h. Defective plate voltage control resistor in tuning flasher control tube circuit.
i. Defective channel control i-f transformer.

If the channel control is tied in with noise suppression, consider all of the applicable items listed above and add to that, the items related to noise suppression, which are listed under the symptom "Dead Receiver."

39. Howl and Other Similar Sounds Exclusive of Normal Noise. It is somewhat difficult to find a title for the various types of sounds which may issue from the loud speaker in a receiver which employs some form of reflexing. If you can imagine peculiar audio sounds which may appear as sustained audio tones of one or more frequency, sometimes constant and sometimes interrupted, you have an idea of what we mean. As a general rule, these sounds result from the presence of regeneration in the various circuits of the receiver. Due to open or defective units, currents are not maintained in their proper paths and interaction between the various circuits takes place. Perhaps it is not

proper to qualify these sounds as occurring only in reflexed receivers. They may occur in all types of superheterodyne receivers. However, reference to various forms of trouble related to the r-f, mixer and i-f amplifiers and created by virtue of undesired coupling between circuits, has been described in accordance with the resultant phenomenon, namely, the beat notes produced. However, such undesired coupling, when existent in reflexed demodulator, i-f amplifier, and a-f amplifier circuits, will be productive of audio sounds, which are not tunable as beat notes are. Such sounds usually exist irrespective of the setting of the tuning dial, and can therefore be recognized. It might be well to say at this time that the effect of undesired coupling may appear as a hiss rather than as a distinct audio note, and may be accompanied by distorted reproduction. Possible reasons for such troubles, assuming that the d-c resistance constants of voltage supply circuit are correct, are as follows:

a. Open or leaky bypass condensers.
b. Defective filter or de-coupling resistors.
c. Improper location of grid or plate leads.
d. Incorrect values of bypass condensers and filter resistors.
e. Leakage between tube elements in tube or through socket terminals.
f. Gassy tubes.
g. Ungrounded bypass condenser usually used in pentode plate circuit, from pentode plate to ground.
h. Close proximity of converter to unshielded broadcast receiver.
i. Tuning condenser not properly floating.
j. Excessive vibration of receiver cabinet.
k. Microphonic tubes.
l. Incorrectly adjusted neutralizing condensers, when used.
m. Especially slow heater demodulator tube.

40. Distortion. (All Circuit Constants Are Normal.) Distortion may exist with weak signals, normal signals or excessively strong signals. Rather than compile a list for each of these classifications, we shall tabulate all possible reasons in one list. They are as follows:

a. R-f, mixer or oscillator circuits out of alignment.
b. I-f trimmers out of alignment.
c. Overloading of tubes.
d. Excessive control grid bias when receiver is operated at low volume.
e. Insufficient control grid bias, not measurable because of high resistance in the circuits.
f. Gassy tubes.
g. Incorrect time constant in AVC circuits.
h. Excessive regeneration in circuits.
i. Presence of undesired carrier.
j. Incorrect channel control adjustment.
k. Poor filtering of carriers in demodulator circuit.
l. Open or defective bypass condensers in reflexed tube circuits.
m. Defective tone control units, manual or automatic.
n. Defective phase changer tube and circuit, when used.

o. Incorrect polarity of dual speaker voice coils.

p. Overloading of tubes.

q. Speaker voice coil out of adjustment.

r. Presence of i-f crystal trap during broadcast reception.

s. Presence of CW oscillator, adjusted to very low frequency beat, in circuit during broadcast reception.

t. Defective r-f, mixer, oscillator or i-f transformers, causing slightly off-resonance condition.

u. High resistance leak between plate circuit of one tube and grid circuit of succeeding tube, through coupling unit.

v. Defective coupling or blocking condenser in r-f, i-f and a-f circuits.

w. Defective local-distance switches, which control bias applied.

x. Speaker diaphragm torn.

y. Sympathetic audio sounds, due to loose screws, transformer cores, etc., which vibrate in sympathy with certain audio frequencies.

z. Open bypass condensers in tube circuits. (We have added this possible cause, although we assumed normal circuit constants. As a general rule, such a condition will cause excessive regeneration or the production of various audible sounds, such as stated under symptom 39.)

aa. Incorrect adjustment of continuously variable tone frequency compensation circuits where used.

bb. Excessively sharp tuning of i-f transformers intended for flat top characteristics.

cc. Apparent change in modulation due to improper operation of mixer tube.

dd. Insufficient strength of heterodyning signal.

41. Dead Receiver. Due to the nature of the condition, it is necessary to include as a part of this classification, intermittent operation, because, during the time that the receiver is inoperative, it is the equivalent of a "dead" receiver. Furthermore, in order to arrive at a suitable basis of presenting possible reasons for the condition and in order to quote a rapid and effective method of localizing the fault, it is necessary to assume that the d-c resistance of the circuits, which supply the fixed operating potentials to the various tubes, are correct, at least for the high values of resistance. In this connection we must add the qualification that circuits, which contain a low resistance winding and a high ohmic value of resistance in the form of a resistor, may appear normal during the resistance test of the circuit, yet may contain a defect in the low resistance winding. In view of the high ratio between the low d-c resistance winding and the fixed resistor in the circuit, a small variation in the resistance of the coil will not be evident when coil and resistance are checked as a single unit. As a matter of fact, it is quite impossible to check collectively two such units, because of the tolerance limits of the resistor. However, by assuming that the voltage path through the circuit is intact, we assume that normal voltages are present at the various tube elements.

We take this stand, on the grounds that the tests we shall recommend are applicable under conditions to be named, and would be made before the routine point-to-point test or voltage measurement test, whichever is made by the operator. In order to permit of the application of what we call the "process of elimination," we must assume satisfactory circuit continuity, although not necessarily normal values for all of the units in the circuit. We further assume that the nature of the defect which causes the "dead" state, is such that it is possible to turn the power switch "on" without danger of damaging units in the receiver. If this is not the case, that is, the defect is of such type that overloading of the power pack or the battery form of supply takes place, the routine test to be described is not applicable in its entirety. The most satisfactory test under such conditions is a complete point-to-point resistance test from antenna to the speaker, inclusive of all components within the receiver.

We appreciate the difficulty of establishing whether or not the fault is of such type that if the receiver is turned "on," it will damage some parts, but that is one of the problems of servicing. In any description of this type, we must decide upon a basis of operation, hence the selection of the premise stated. Of course, the safest method of locating the fault, providing that it is of the type which will manifest its presence during a routine point-to-point test, is to make the test with the receiver disconnected from the power line and with the tubes out of the sockets. After this test is completed and it has been determined that the fault is not one of circuit constants, the test for resonance and open condensers can be applied. If, however, the fault lies in one of the transformers, r-f, mixer, oscillator, i-f or audio systems, it will become evident during the point-to-point test. The replacement is made or the remedy applied and the receiver placed into operation without need for any further tests, other than what would be a routine check-up of the alignment.

Based upon an analysis of experience in the field, we have come to the conclusion, that the safest method of operation when you are confronted with a problem such as has been outlined is to procede as follows:

1. **Disconnect the receiver from the power line and with all tubes in the sockets, check the d-c resistance across the output of the rectifier tube. If the measured value approximates the d-c resistance of the filter choke or chokes, as the case may be, you can be certain of the existence of a short circuit somewhere in the system, thereby establishing the fact that you cannot turn on the power for routine testing, because of the possibility of damaging some of the units in the receiver. As a matter of fact, if the measured d-c resistance across the rectifier tube output is greater than the d-c resistance of the filter choke, which may be the speaker field, it is unsafe to test with the power on, unless the measured value of resistance is substantially greater than the filter choke. This establishes sufficient resistance across the rectifier**

output to prevent damage to the rectifier tube or other parts in the receiver. A qualification with respect to the resistance across the rectifier output must be made when the tube is of the 25-Z-5 or equivalent type. Tubes of this type can be applied in such manner that the speaker field winding secures its excitation current from one of the sets of elements in the tube. Consequently, the resistance across the anode and cathode of this tube, used as a half wave rectifier, may not approximate the value stated. Therefore, the application of the preliminary test, as stated, must be made after an examination of the schematic wiring diagram, so as to establish the circuit structure.

2. If test 1 is favorable, and the power pack employs a step-up transformer, the next step is to make a routine d-c resistance test of the secondary windings upon the transformer.

3. If test 2 is favorable, a simple d-c resistance test upon the primary winding will establish its condition, with respect to the application of power to the receiver as a unit. The original power may come from a vibrator operated from the storage battery or from the d-c or a-c power line. (For information concerning Vibrators, see the chapter devoted to that subject.)

The three tests named above consume very little time, and enable the application of the "process of elimination" without fear of any damage. Naturally, if one of these three tests indicates a fault, further checking is necessary to determine the location of the fault, before the process of elimination can be applied. As a matter of fact, the probabilities are that once the fault has been located by means of the routine point-to-point test, further checking is unnecessary. The reason for keeping the tubes in the sockets during test 1, is to include possible short circuits or grounded elements, located within the tube, in the system. If test 1 shows the existence of a short circuit somewhere in the system, the next step is to make the same test with the tubes out of the sockets, so as to establish definitely that the fault is external of the tubes. In this connection, we realize that the fault may be of such type which occurs only after the tubes or the other units in the receiver have been subjected to the heat created during operation of the receiver. That is a chance you take and this can be determined only after all other tests have been made.

Now then, assuming that the nature of the defect is such that the receiver can be placed into an operating state, that is, the power turned on, possible reasons for the "dead" condition are:

a. Short circuited r-f transformer primaries, link circuits and/or secondaries, inclusive of the tuning condensers connected across these windings.

b. Defective coupling coils or open circuit coupling condensers in r-f transformers of either single resonant circuit or band pass type.

c. Short circuited mixer tube input transformer primaries or secondaries inclusive of the tuning and trimmer condensers connected across the coils comprising the unit.

d. Short circuited r-f, mixer, oscillator or i-f transformer primaries, link circuits, when used, and/or secondaries, inclusive of whatever units are connected in shunt with these windings.

e. Defective or open coupling coils or condensers in r-f, mixer, oscillator and i-f transformers.

f. Short circuited a-f transformer primaries or secondaries, inclusive of units connected in shunt with these windings.

g. Open blocking condensers in r-f, mixer, oscillator, i-f, demodulator and a-f tube circuits.

h. Open primary in any parallel feed transformer circuit.

i. Open coupling condenser in all parallel feed circuits.

j. Open condenser or resistor in harmonic suppressor circuit of oscillator tube system.

k. Open coupling condenser in autodyne mixer tube plate circuits.

l. Open circuited image suppressor winding or condenser.

m. Short circuit across winding in output transformer primary or secondary or voice coil.

n. Open circuit in output transformer secondary, hum bucking coil or voice coil.

o. Defective tuning range control switch.

p. Short circuit or open circuited series trimmers in oscillator circuits.

q. Short circuited bypass condensers in tuned circuits. (It is possible to ground tube elements of certain r-f, mixer and i-f tubes without placing a very heavy current drain upon the rectifier, because of the high resistances usually found in the respective circuits, with the exception of the cathodes.)

r. Gassy AVC tube resulting in application of cut-off bias.

s. Defective AVC elements resulting in application of excessive bias.

t. "Locked" audio system. (See Channel Control and Visual Tuning Meter and Noise Gate references.)

All the possible reasons for a dead receiver as listed from (a) to (t) involve a defective unit or circuit. There are in addition to the aforementioned reasons, several more which are not related to actual physical defects in the components. These are:

u. Incorrect alignment of r-f, mixer, oscillator or i-f trimmers.

v. Incorrect alignment of Second Harmonic circuit in that receiver.

w. Incorrect alignment of oscillator circuit in autodyne mixer-oscillator.

x. Incorrect tuning of channel control which locks audio system.

After due consideration of these twenty-four possible reasons, you can readily realize that any system of testing which helps localize the trouble, is in a way reducing the number of possible reasons for the existing fault. Accordingly, the process of elimination applied for the sole purpose of

determining whether the trouble lies in the systems ahead of the demodulator or in the systems after the demodulator, cannot help but be of aid. In connection with this division of the circuits in the receiver, we feel that receivers equipped with channel control and noise suppression circuits and AVC systems should be divided in such manner that the r-f, mixer, i-f, oscillator, AVC and demodulator tubes comprise one section and the a-f, channel control, noise suppressor systems comprise the second group. The power pack is obviously common to both.

If the receiver consists of a converter and a broadcast receiver, the first section would consist of all of the tubes in the converter, the r-f tubes in the receiver and the detector tube in the receiver. The second section would constitute the remainder of the tubes. Receivers equipped with a CW oscillator are no different from the ordinary superheterodyne, for the simple reason that the CW oscillator does not come into play until the remainder of the receiver has been restored to perfect condition. Normal defects in the CW oscillator would be immediately localized to that unit because, first, the trouble would become evident only when the CW oscillator was connected into the system and would be absent, when the CW oscillator was cut out of the system. Second, defects of the type which influence circuit constants would become evident during the point-to-point resistance test.

Receivers equipped with two oscillators, one for broadcast band heterodyning and the other in a short wave converter, are handled exactly as if they were single oscillator systems.

As far as this preliminary test is concerned, three items are involved. Two of these are to be found in every service station. They are a test oscillator capable of furnishing a modulated carrier covering the 100 kc. to 15,000 kc. band, and an output meter. The third is simple to construct and is the simplest of vacuum tube voltmeters. Do not be alarmed at this suggestion to own a vacuum tube voltmeter. It is nothing more than a simple bias detector tube. In fact it is nothing more than a simple AVC voltage producing system, equipped with some sort of an indicator device. The purpose of this unit is for indication, rather than for quantitative analysis. The circuit of such a unit, is shown in figure 90.

To determine if the receiver system inclusive of the demodulator is in operation and if the amplifier system, after the demodulator, is in operation, the vacuum tube voltmeter is connected across the output of the demodulator tube. If the tube is of the diode type, the instrument is connected across the load resistor. The same applies if the demodulator tube is of the duo-diode triode or duo-diode pentode type. If the demodulator tube is a conventional triode or screen grid tube, it is best to connect the vacuum tube voltmeter across the load unit, be it the transformer primary or the plate coupling resistor, in the plate circuit of the demodulator tube. The output meter is connected across the speaker voice coil. The test oscillator is connected across the antenna and ground terminals of the receiver.

The test oscillator is adjusted to produce a modulated carrier of some

frequency within the range of the receiver. If the receiver employs a converter, the test should first be made without the converter in the circuit and then with the converter in the circuit.

If the receiver employs a channel control or a noise suppressor system which locks the audio system, both the channel control and the noise suppressor system should be made inoperative by means of the switch or variable control furnished for that purpose. If possible, the AVC circuit should also be made inoperative, although this is not imperative.

When applying the test signal and cutting out the channel and noise control systems, make certain that you are familiar with the circuit used and whatever special arrangements are involved. This information is necessary in view of the second test, if the first test proves negative. This is of particular importance if the receiver employs a multi-function tube as the demodulator. As a matter of fact you may have difficulty locating the load circuit of the demodulator system, unless you are familiar with the circuit used.

When the test signal is applied, note the indication upon the vacuum tube signal indicator and upon the output meter. If the vacuum tube voltmeter indicates a signal, which indication appears as a definite change in the reading upon the plate current meter, and the output meter does not indicate a signal and no signal issues from the speaker, you have localized the fault as being located between the demodulator tube and the speaker. For that matter, if you connect the output meter across the primary of the output transformer, instead of across the speaker voice coil, and use the speaker, you will have a further check, by observing if a signal is indicated upon the output motor and no signal issues from the speaker. This localizes the trouble as being in the output circuit of the output transformer or directly in the speaker circuit.

If, however, no signal is indicated upon the vacuum tube voltmeter, you must make the second test, so as to determine if the system ahead of the demodulator is at fault. Remove the vacuum tube signal indicator unit from the circuit. The output meter remains connected as before. Remove the test oscillator from the input circuit of the receiver and tune the unit so that it is producing a modulated signal of a frequency equal to the i-f peak of the receiver. Now connect the output of the test oscillator across the i-f transformer which feeds the demodulator tube. Whether you connect the test oscillator to the control grid and cathode or diode plate and cathode, depends upon the type of demodulator tube used. The safest bet is to connect the test oscillator across the secondary terminals of the i-f transformer, which feeds the demodulator tube. If the demodulator and a-f amplifier circuit are in good condition, a signal will be

indicated upon the output meter. If the output and speaker systems are in good shape, the signal will also be audible in the loud speaker.

If no indication is obtained upon the output meter and no signal is heard in the speaker, the only operation left is a routine test of the complete receiver. There exists the possibility that the demodulator system is not functioning. Since both of the tests include the demodulator tube, it might be best, before making the routine test, to check the demodulator circuit, so as to determine possible defects. At the same time all of the tubes should be checked. If for some reason, you cannot make the routine point-to-point test and have only the voltage table at hand and the circuit of the receiver, then make a routine voltage test, followed by the continuity test based upon the electrical values indicated upon the receiver.

If an a-f oscillator is handy, all doubt concerning the demodulator tube can be removed. This is done by feeding an a-f signal into the first a-f tube and noting the output response. Bear in mind that during these tests, the idea is to see if the system is operative, rather than to secure quantitative figures relative to the amount of amplification available. We are interested in localizing a fault. That is all.
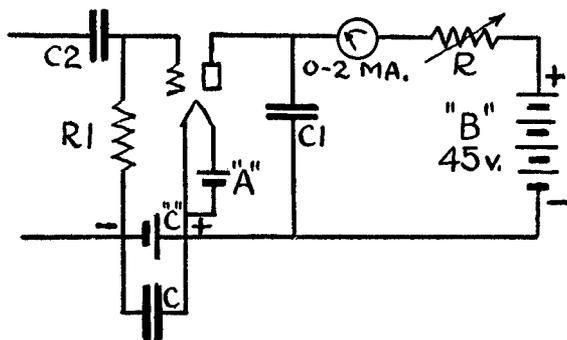
Fig. 90.   A simple battery operated vacuum-tube voltmeter
that can be easily built

Concerning figure 90, this is a simple battery operated vacuum tube voltmeter suitable for comparison work. The meter is a Weston 0-2 D.C. milliammeter. The tube is a '30. A, B and C batteries are 2. volts, about 5 to 12 volts and 45 volts respectively. The C bias battery should be of the variable type. The variable resistor R is a 50,000 ohm unit with linear variation. A wattage rating of .5 watt is ample. R1 is 500,000 ohms. C and C-1 are of 1. mfd each. C-2 is .5 mfd. In operation, about 25,000 ohms of resistor R is in the circuit. The bias voltage is about 5. volts negative. Operate slightly above cut-off. As the signal is applied to the vacuum tube voltmeter, the plate current will increase. For our tests we are not concerned with the extent of this increase, but solely with the fact that the presence of a signal is indicated.

APPLICATION OF TEST OSCILLATORS

THE test oscillator has always played an important role in the servicing of radio receivers. It is indeed unfortunate that its value is not appreciated as much as it should be. It is extremely difficult to understand why the test oscillators sold by instrument manufacturers as a whole are so much fewer in number than the quantity of set testers, analyzers, diagnometers and units of similar type. Let us hope that the reason for such a condition is that many service men build their own oscillator units. This we doubt, yet hope that it is true.

While it used to be possible for the average service men to operate without a service oscillator when servicing t-r-f receivers, we doubt very seriously, if that same man will be able to service properly modern single, dual and multi-band receivers, without possessing a good test oscillator, which will cover the i-f, broadcast and short wave bands. Many types of oscillators are available; some are expensive and others are within the average price class. Whichever is selected, the unit must cover the bands stated and be capable of supplying a modulated carrier at these frequencies. If provision is included for cutting out the modulating signal, so much the better.

As to the frequencies covered by the oscillator, the ideal arrangement is that system which provides fundamental frequencies. However, it is quite satisfactory to cover the broadcast band by means of harmonics of the fundamental intermediate frequencies. While it is true that many oscillators depend upon the harmonics of the i-f signals for the short wave signals, still other oscillators provide certain fundamentals in the short wave band and use harmonics of the lower order to cover the complete short wave band. The advantage of having the greatest number of fundamentals with which to work lies in the reduction of errors on the part of the operator and in the reduction of errors in calibration. In other words, an error of 1.0 percent at 260 kc. is only 2.6 kc., which while substantial, still allows satisfactory alignment. But, if alignment at 2600 kc. is desired and the 1.0 percent error exists at the 260 kc.

setting and the 2600 kc. signal is the 10th harmonic of the 260 kc. fundamental, the error at 2600 kc. is going to be 26 kc., which is so great as to make alignment entirely unsatisfactory. The original error of 1.0 percent, or 2.6 kc., may be the fault of the operator in making his adjustment, but whatever it is, it should be the absolute minimum. Errors will occur and it is up to you, when using harmonics of fundamentals, to make certain that the error is the lowest possible. The advantage of having fundamentals within the short wave band is that the possible error, by virtue of using harmonics, is kept at a minimum.

No doubt you are familiar with the fact that an oscillator calibrated at i-f frequencies is suitable for use as a signal source when aligning tuned circuits resonated at broadcast and short wave frequencies. Such use is possible if the i-f oscillator is rich in harmonics, as is usually the case. It is customary in oscillators intended for service work to provide fundamentals over the i-f band of from about 100 kc. to 200 kc. Harmonics of these frequencies, up to the third, provide the frequency coverage of the high intermediate frequencies of from 200 to 480 kc. Another fundamental band of from about 550 to 1500 kc. is available for broadcast

Fig. 91. A service test oscillator that uses harmonics for the higher frequencies necessary for testing. *(Courtesy Weston Elec. Inst. Co.)*

frequency alignment. Harmonics up to about the tenth are used to align short wave circuits. Then again some oscillators provide a series of fundamentals up to about 25,000 kc., thus keeping the use of harmonics at a minimum. For complete information relative to harmonic generation and the relation between fundamentals and harmonics, please refer to Chapter 2.

An example of a service test oscillator which combines an expansive band of fundamentals and provides for the use of harmonics for the very high frequencies is shown in schematic form in figure 91. This is a schematic of the Weston 694 test oscillator. The carrier is modulated when desired and can be obtained in unmodulated form by cutting out the modulator tube, which is switch controlled. Unfortunately, space does not permit a full page diagram.

The information relating to alignment as offered in this chapter, assumes that a suitable oscillator is in the possession of the service man. Frankly, we shall not present details relative to the use of broadcast stations as sources of test signals, as a means of replacing the test oscillator, because it means no end of grief to the service man. If an alignment job is to be done well, it requires a good oscillator. The service man who is not equipped with an oscillator will get by in a few cases, but he is doomed to failure when working upon modern receivers.

Adjustment of AVC When Aligning.

It is important to pay attention to the AVC system when aligning a radio receiver, which incorporates such a circuit. The channel control and noise suppressor circuits mean very little in this work, because, during alignment, the receiver operates with a signal input. However, if you are not certain of your capabilities, the best thing to do is to nullify the action of the channel control and noise suppressor circuits. As to the AVC system, you have a choice of operations. You can if you wish feed a very weak signal into the receiver so that its amplitude at the demodulator or AVC tube is not sufficiently great to set the AVC circuit into operation. Circuits which incorporate delayed AVC are much easier to handle than the ordinary diode circuits, wherein an AVC voltage is impressed upon the controlled tube at very low signal levels. In order to accommodate all systems, the suggestion is made to adjust the audio volume control to maximum and feed the weakest possible test signal into the receiver. This is determined by the lowest output meter indication which will permit alignment operations.

In certain instances you will find that the AVC action in the receiver does not permit alignment by means of the output meter located in the speaker circuit. In other words, the signal required to operate the meter must be so strong as to set off the AVC system, and peaking under such conditions is very unsatisfactory, because the AVC circuit tends to keep the signal out of the i-f tubes at a constant level, irrespective of signal

input above a certain level. This means that accurate peaking is impossible, because the AVC action starts soon after you have reached an approximation of the i-f peak. Further peaking does not increase the indication and you cannot tell whether you have reached the peak or have passed beyond the proper point.

Where the AVC tube is of the type which can be removed from the receiver, without impairing the operation of the remainder of the tubes, such must be done. If on the other hand, the circuit of the receiver shows that it is possible to ground the voltage feed circuit of the AVC tube without interfering with receiver operation, that should be done. If the circuit of the receiver is such that the AVC tube must be left intact, because that function is a part of another, or the tube used is a multi-purpose tube and satisfactory alignment is not possible by means of the output meter, you have three alternatives: one is to apply the vacuum tube voltmeter across the unit which develops the AVC voltage, and thus secure an indication proportional to the AVC voltage produced. The second, is to employ the tuning meter or tuning indicator as a guide. Maximum indication or maximum length of the tuning light beam is an indication of maximum resonance. This basis for alignment can be used only if you are thoroughly familiar with the manner in which the tuning indicator is used. If, for example, the tuning indicator functions as in some Howard receivers, where the beam is extinguished when the signal is tuned in, you may find it difficult to peak accurately with the tuning light as a guide. If, however, the tuning light is of the moving column type, wherein the length or the height of the column increases while tuning to exact resonance, it can be used as a fairly accurate guide. The third alternative is to change the grid circuit of the i-f system during alignment, so that the AVC voltage is not applied to the i-f tubes, in which case, the output meter system of indication will be satisfactory. This change in the i-f amplifier is not very intricate. It means disconnecting the i-f grid filter resistance, which junctions with the AVC circuit, and connecting this resistor temporarily to the most negative part of the i-f cathode circuit or to the chassis. After alignment is completed the i-f grid circuit is restored to its original condition. If it is any easier and the circuit permits, the coupling condenser connected between the i-f output and the control grid or diode of the AVC tube is opened. This will nullify the action of the AVC system and alignment by means of the output meter will be satisfactory. More than likely you will arrive at the most satisfactory solution, after an examination of the wiring diagram.

Progress During Alignment.

There has been discussion about the progress during alignment. Should one start with the r-f or pre-selector tubes and work towards the demodulator, or should one start with the alignment of the i-f stages and progress towards the

antenna system? Receiver manufacturers in their service literature recommend that alignment start with the i-f amplifier transformers and work back towards the antenna system. If however, you are positive that some other part of the receiver requires alignment as the means of remedying the trouble in the system, you would naturally start at that point. For general alignment, the i-f system is first. This choice is quite natural when you realize the position occupied by these units. In the first place the i-f amplifier is vital to the entire alignment process, because all signals during alignment must pass through the i-f amplifier. Furthermore, perfect tracking of the r-f and oscillator units requires that the i-f amplifier be properly aligned. In this discussion of i-f amplifiers, bear in mind that we are also including the r-f amplifier in the t-r-f receiver, utilized as an i-f amplifier, when working with a superheterodyne converter.

If the receiver consists of a broadcast superheterodyne utilized with a short wave converter, the i-f amplifier referred to is the i-f amplifier in the broadcast superheterodyne.

Following the i-f amplifier adjustment is the adjustment upon the r-f and mixer input circuits. This is followed by the oscillator adjustment. If the receiver is of the multi-wave band type, the same procedure holds true for the respective tuning bands. If the receiving system consists of a short wave converter used with a superheterodyne broadcast receiver, the following is the progress:

1. Superheterodyne broadcast receiver.
    a. I-f amplifier.
    b. R-f and mixer circuits.
    c. Oscillator circuit.
2. Short Wave Converter (connected to broadcast receiver).
    a. Detector.
    b. Oscillator.

Alignment When Autodyne Mixer Is Used.

The presence of an autodyne mixer does not complicate matters. The progress of alignment advances in the manner already described. The fact that the plate circuit of the autodyne tube or the screen circuit of the autodyne tube is tied in with the oscillator system as well as the i-f transformer does not hinder any operations related to the alignment of the i-f amplifier system.

Alignment Frequencies.

The appendix to this volume contains a tabulation of intermediate frequencies employed in the majority of American superheterodyne receivers. As a matter of fact this list was compiled from Rider's "Perpetual Trouble Shooter's Manual," including the contents of the four volumes available at the time of this writing and also a part of the contents of Volume V, which will be published during December, 1934 or January, 1935. As to r-f and oscillator alignment frequencies, it is impossible to quote exact values for all of the superheterodyne receivers now in use. The specific information relative to alignment frequencies in the circuits named, will be found as a part of the complete service data furnished in Rider's Manuals. The alignment information furnished in this chapter is general data. It will be found to apply to a large number of receivers, yet if you have Rider's Manuals in your possession, we suggest that you refer to the service data contained in those volumes in order to determine the exact alignment frequencies as recommended by the manufacturer for that particular receiver.

We are particularly anxious to stress the aforementioned point and also that the future reference to the adjustment of r-f and oscillator and mixer condensers in such manner that at the start, the condensers are fully meshed, *is general and not specific to every receiver.* Service information in Rider's Manual states specific instructions concerning the setting of the condenser plates for certain receivers. In some instances, the plates of the condenser are supposed to be *out of mesh;* in other instances, they are to be partially meshed, as determined by a certain test block which the manufacturer recommended, and in still other cases, the condensers are fully meshed. The need for specific instructions concerning the alignment of multi-wave band receivers cannot be stressed too highly. Any effort to furnish specific alignment data covering all American made radio receivers in this volume of "Servicing Superheterodynes," would require a volume of at least twice as many pages as are to be found in this entire book. Obviously, such specific data is impossible. See Rider's Manual.

Adjustment of I-F Transformer Trimmers.

A modulated i-f oscillator is required for the alignment of the i-f transformers; that is to say, a modulated signal at the peak frequency of the i-f system is required. This signal can

be the fundamental of the oscillator or one of its harmonics Whichever it is, the oscillator must be tuned accurately. Whether this oscillator is an independent unit with its own power supply, or if it secures its operating potentials from the receiver, is of no consequence. The operation of the device remains the same. For the sake of universal application, we shall consider the oscillator to be a completely self-contained device.

To align intermediate frequency transformers, it is usually necessary to "pull" the chassis. The location of the respective i-f transformer trimmers must be determined. Once again we are forced to stress the necessity of referring to specific service data contained in Rider's Manuals, in order to locate the trimmers. Usually, the trimmer units are a part of the associated i-f transformers, but in some instances, these transformers are located in such manner and they are invisible and access to the trimmers is had through holes in the side or bottom of the chassis. The service data contained in the manuals compiled by the author indicate the position of the respective trimmers. Such data covering the receiver industry cannot be given in full detail in this chapter.

After the chassis has been "pulled," adjust the test oscillator to the correct frequency. Apply the signal output indicating device in accordance with the information given in this chapter under the heading "Adjustment of AVC When Aligning." Short circuit the receiver antenna and ground posts with a .5 mfd condenser. To feed the test signal to the i-f amplifiers, you work through the mixer tube. The "A" or "high" lead from the test oscillator is connected to the mixer tube control grid. If you wish you can remove the control grid lead connected to the input mixer tuning condenser from the control grid cap of the mixer tube and substitute the lead from the test oscillator. The "G" lead from the test oscillator is connected to the rotor plates of the mixer input tuning condenser. Connection to the chassis is not always correct, because the tuning condenser rotor plates may be insulated from the chassis, and unnecessary condensers are inserted into the test circuit. It is important, however, that the d-c path from the control grid of the mixer tube to the cathode be uninterrupted. If this path is interrupted, the control grid bias will not be applied to the tube. Do not take for granted that the attenuator in the test signal oscillator provides a complete path. Some of the ouput circuits contain a fixed condenser. It is best if you examine the schematic of the receiver upon which you are working and note the structure of the control grid circuit of the mixer and make your connections accordingly. In some cases you may find that you cannot remove the control grid lead to the mixer tube. In that event, leave the lead intact and connect the test oscillator, as if there were no lead in the receiver, from the input tuning condenser to the control grid cap. If this is done, remember that the tuning dial of the receiver should be set

at some frequency, which is not the fundamental or a harmonic of the i-f frequency. In other words, if the i-f peak is 175 kc., adjust the tuning dial of the receiver to some frequency other than 175 $\times$ 2, 175 $\times$ 3, 175 $\times$ 4, 175 $\times$ 5, etc. The same is true if the i-f peak is of any other value. When adjusting the i-f system, have the receiver *detuned* from a harmonic of the intermediate frequency.

Concerning the "G" lead from the test oscillator, you will find that joining that lead to the ground post on the receiver is usually satisfactory. Make certain that the contact between the test oscillator leads and the receiver junction points is firm. The i-f tubes to be used must be in their sockets. All shields must be in place, if at all possible. Do not align i-f transformers with the transformer shields removed. Even tube shields, if used, should be in place.

If the receiver to be aligned has a separate oscillator tube, which is not associated with the mixer tube, remove that oscillator tube. If you desire to keep the receiver voltages constant with the receiver oscillator tube out of the socket, connect a 20,000 ohm fixed resistor between the plate and cathode terminals of the oscillator tube socket for type '27 tube or its equivalent, or a 100,000 ohm resistor between the stated terminals, if the oscillator tube is of the screen grid type. We are ready for alignment. Two methods are available. This time the choice is involuntary. It is determined by the design of the circuit; that is, whether the i-f transformers are peaked by simply resonating the primary and secondary circuits or if the i-f transformers are arranged for flat top tuning. Flat top tuning of i-f transformers is the subject of another part of this section, hence we shall concern ourselves with ordinary alignment.

The test oscillator is adjusted for about half the maximum output and the manual volume control in the receiver is arranged for maximum output. If a volume control tube is used, see that it becomes inoperative or is removed.

With the test oscillator generating the required signal, adjust the secondary circuit trimmer of the i-f transformer nearest the demodulator tube, as shown upon the diagram. This would be the second i-f transformer in a single-stage system and the third i-f transformer is a two-stage i-f system. Align the trimmer until the maximum indication is secured upon the output meter. Without disturbing the adjustment of the secondary circuit trimmer, align the primary circuit condenser (if it is of the adjustable type) of the same i-f transformer until maximum deflection on the output meter is secured. Then repeat the alignment upon the secondary and primary circuits respectively of the other i-f transformer or transformers, as the case may be, working towards the mixer tube.

After all of the i-f trimmers have been aligned, it is good practice to recheck each one. If desired, a complete checkup can be made by removing the test oscillator connections to the mixer tube, replacing the control grid lead or resoldering the grid lead in the case of the '27 type mixer, replacing the receiver oscillator and feeding a modulated r-f signal into the aerial circuit of the receiver by properly connecting the "A"

and "G" terminals of the test oscillator to the aerial and ground posts of the receiver. Tune the receiver to the frequency of the test oscillator and note the output meter indication. Then carefully readjust each i-f trimmer for maximum output meter indication. A test of this type is possible only when you are certain that the r-f and oscillator circuits in the receiver are tracking perfectly.

Flat Top Tuning of I-F Transformers.

Flat top tuning adjustments differ from the conventional peak adjustments in that the primary and secondary circuits of the i-f transformer are closely coupled and a definite amount of interaction between the primary and secondary windings is desired. Furthermore the tuning of the respective circuits is such that a plus or minus frequency variation will give the same output. This means that the actual adjustment is made over a range of i-f frequencies rather than at a single peak frequency.

An example of this is the following: Whereas the conventional i-f transformer is peaked at say 175 kc. the flat top tuned transformer is peaked at frequencies between say 171 and 179 kc., or about 4 kc. each side of the 175-kc. peak setting. In order to enable such operation, it is important that the i-f oscillator have a vernier adjustment whereby one can vary the i-f oscillator in steps of 1 kc.

The first step is the peaking of the transformer, just as if it were to be used as a peaked transformer. (See "Adjustment of IF Transformers.") What is to follow is applicable to whatever peak frequency is used and the usual band pass considered in such flat top tuning is about 4000 cycles (4 kc.) each side of the peak for the flat top. The remaining 1 kc. each side of the peak is automatically secured by the resonant characteristic of the circuit. If the flat top were arranged for 5000 kc., the resistance present in the system would spread the response curve of the transformer beyond the 5 kc. limits each side of the peak.

After the transformer to be adjusted for flat top tuning has been peaked, the flat top adjustment follows. This consists of slowly varying the test oscillator frequency over a band of about 8 kc. with the peak-frequency as the mid point. In a 175 kc. peak system this test oscillator frequency band would be from 171 kc. to 179 kc. Simultaneous with the variation of the test-oscillator frequency is the tuning of the primary and secondary circuit trimmers, until the output at the upper and lower frequency limits is the same and a variation of about 2.5 kc. each side of the 175 kc. adjustment of the test oscillator does not produce any change in indication upon the output meter connected to the receiver. To make such an adjustment the first time will be quite difficult, but experience will enable flat top tuning at a rate as rapid as for ordinary peak tuning. Fortunately very few receivers make use of such tuning in the i-f stage. An example of its application is the RCA 80 series and the equivalents in the Westinghouse, General Electric and Graybar lines.

In the event that a "local-distance" switch is used and it controls a resistance inserted into one of the i-f transformer secondary circuits, this

switch must be set to "distance" when adjusting the tuning of the transformers.

Determining Unknown I-F Peak.

It is possible that you may be called upon to align the i-f amplifier in a receiver, for which you do not have any data and the correct i-f peak is not known. The following will describe how the numerical value of this peak can be found.

You require a test oscillator which is capable of supplying modulated signals over the 130 kc. to 270 kc. band. An output meter is not required. The speaker will be satisfactory, providing, of course, that the receiver is in an operative state. Feed the i-f signal from the test oscillator into the receiver. Use the tactics employed for regular alignment. Starting at the highest frequency adjustment of the 130 to 270 kc. range or its equivalent range with slightly lower or high limits, tune slowly towards the lower limit of the frequency range. You may find two or more points at which a signal appears in the speaker. Whether you find three, two or just one such point, depends upon the i-f peak used in the receiver and the frequency range of the oscillator. If you are checking a commercial broadcast receiver with a peak frequency between 130 and 265 kc. and the test oscillator produces signals over a frequency range of from 130 to 270 kc., two signal points will be experienced with all receivers which employ i-f peaks rated at from 260 to 270 kc.

Starting at the uppermost end of the test oscillator tuning dial, the first signal which appears is the fundamental. The second signal represents the passage of a harmonic of the fundamental being produced by the test oscillator. Thus if the first signal was heard when the test oscillator was adjusted to 260 kc. and the test oscillator can tune as low as 130 kc., the second signal will be heard when the test oscillator is producing the 130 kc. fundamental signal. Now, the signal heard when the test oscillator is tuned to 130 kc., is *not* the 130 kc. signal; it is the 2nd harmonic of 130 kc. or 260 kc. You will note further that the first signal at 260 kc. is the stronger of the two. To all appearances the peak frequency of the receiver is 260 kc. You may doubt this on the grounds, that it is possible that the first signal heard in the receiver, when the test oscillator was adjusted to 260 kc., is not the fundamental 260 kc. signal, but a harmonic of this fundamental. From practical experience we know that the highest i-f peak used in the average superheterodyne is not greater than 480 kc., although converter units employ as high as 1300 kc. Therefore we can check to see if the i-f peak is a harmonic of 260 kc. Is it 520 kc.? If so, a signal should be heard when the test oscillator is adjusted to 173.3 kc., since 520 kc. is the 3rd harmonic of 173.3 kc.

The absence of a signal when the test oscillator is adjusted to 173.3 kc. is pretty substantial proof that the first deduction was correct. Using the test oscillator range stated, three signals would be heard if the receiver were peaked at 480 kc. At 480 kc., the first signal would appear

when the test oscillator was adjusted to 240 kc. The second signal would appear when the test oscillator was adjusted to 160 kc. and the third signal would appear when the oscillator reached its low point of 120 kc. which is usually possible with an oscillator rated at from 130 to 270 kc.

It is possible that the receiver employs flat top tuned i-f transformers, in which case the signal will appear strong over a narrow band of test oscillator frequencies. This band is between 3.0 to 5.0 kc. in width each side of the absolute peak. In this case the peak adjustment rating of the system is equal to the exact test oscillator frequency, midway between the limits of the strong signal.

When seeking to determine unknown peak frequencies, you may find that signals appear when the oscillator is adjusted to some odd value. This is quite natural, since the fundamental, which has a harmonic equal to the i-f peak, may be an odd frequency. Thus a signal will appear in a 252.5 kc. peak receiver when the test oscillator is adjusted to that frequency and again when it is adjusted to 126.25 kc. Then again, in a receiver which is peaked at 460 kc., signals will appear at 230 kc. oscillator fundamental and again at 153.3 kc. A third may appear at 115 kc., if the test oscillator will reach that frequency.

The Adjustment of R-F, Mixer and Oscillator Trimmers.

(This reference to r-f and mixer trimmers does not include the special image suppressor circuits, which require trimmer adjustment.)

Before starting upon this description, it might be well to make brief mention of some facts pertaining to r-f trimmer condensers. As a rule r-f trimmers are located adjacent to the various tuning condenser sections, usually mounted upon one of the dielectric side supports. The number of such trimmers used for each tuned section depends entirely upon the design of the receiver. In the majority of cases, each tuned section has two trimmers, a high- and a low-frequency adjustment unit. The high-frequency trimmer is as a rule intended to line up the section between 1400 and 1200 kc. with the former figure being more popular. The low-frequency trimmer is intended for adjustment between 600 and 650 kc., with the former frequency being more popular. Where a single trimmer is used, adjustment is usually at the high end of the frequency spectrum.

Another type of trimmer arrangement consists of the use of a slotted end plate upon the tuning condensers, one such slotted plate for each tuning section. An example of such

a condenser appears in figure 92. This illustration is taken from an RCA service manual and shows the five slots upon the end plate of the tuning condenser and the screw adjustments for the various line-up frequencies. Each screw controls one plate of the slotted group. As is evident, the line-up adjustment is made at five different frequencies.

Certain things must be borne in mind during the alignment of trimmer condensers. These are: first, the tube to be used

ADJUSTING SCREW FOR 1120 K.C.	ADJUSTING SCREW FOR 840 K.C.	ADJUSTING SCREW FOR 700 K.C.	ADJUSTING SCREW FOR 600 K.C.	ADJUSTING SCREW FOR 550 K.C.
A	B	C	D	E
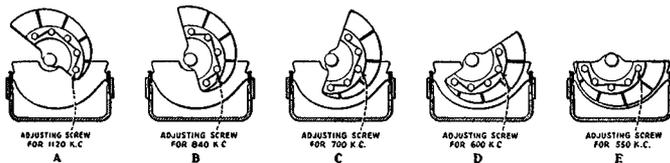
Fig. 92. The slotted end plates of a variable condenser for lining-up purposes

(Courtesy RCA Victor Co.)

in the socket must be in place. Second, if a tube shield is used over the tube, it, too, must be in place and in firm contact with the shield base, thus assuring a good ground. Third, the operating voltage applied to the tubes must be that used when the receiver is placed into every-day operation. Fourth, all connecting leads must be in place, as found when the receiver is used for normal broadcast reception. All of these items influence the adjustment of the trimmer. This is so because each of these items represent capacity across the r-f coil and the trimmer adjustment is governed by the total capacity across the coil or r-f transformer. The fifth, and by far not the least important consideration, is that all trimmer adjustments be made upon a wood-top table rather than a metal-top table. One or more of the transformers utilized in the receiver are located upon the underside of the chassis and may be influenced by the metal top, be it insulated, coated, or otherwise.

Referring once more to the oscillator, the frequency band on the oscillator which is selected for the alignment of the receiver is that which is either the fundamental band equal to the receiver tuning band, or that band which, in order to

produce the required test signals for the receiver, involves the lowest order of harmonics.

To align the receiver, it may or may not be necessary to "pull" the chassis, i.e., remove it from the cabinet. Of course, all power circuits remain intact, so as to allow use of the receiver. The speaker remains connected. After the chassis has been removed from the cabinet, it is necessary to arrange some means whereby one can judge the frequency adjustment of the condensers according to the dial indications. In other words a pointer must be arranged. In some instances, the complete indicating assembly remains intact when the chassis is removed, but in other cases the pointers are part of the escutcheon plate upon the front of the cabinet. The location of the temporary pointer must be such that the dial settings correspond EXACTLY with the settings when the chassis is placed within the cabinet. A safe arrangement in the event that the pointer is a part of the escutcheon plate is to mesh the condenser fully, with the chassis in the cabinet and make a mark upon the dial showing the location of the pointer for this setting of the condenser. This is a safer arrangement than making such a mark when the condenser plates are adjusted for some frequency between minimum and maximum. The temporary pointer can be a piece of No. 18 or No. 20 wire fastened to the chassis and bent and placed in such fashion that one end is parallel to the horizontal lines upon the drum dial.

As previously mentioned all receivers are not intended for r-f alignment at like frequencies. What is to follow does not apply to the adjustment of the Atwater Kent r-f systems in supers utilizing the double spot circuit. This shall receive special mention. The most popular "high" alignment frequency is 1400 kc.

With the chassis "pulled" and ready for the alignment adjustments, the test oscillator is tuned to generate a 1400 kc. signal (fundamental or harmonic) and the test oscillator volume control is set at about half maximum output. Allow the test oscillator tube to reach a steady temperature. Connect the output meter across the voice coil of the speaker or across the secondary of the output transformer. It is best if the output meter is connected across the combination of the voice coil and the output transformer secondary. Such an arrangement will enable audible recognition of an oscillatory state. Adjust the receiver volume control for about half maximum output.

Then connect the "A" terminal of the test oscillator to the antenna post of the receiver and the "G" terminal of the test oscillator to the ground post of the receiver. (See instructions relative to AVC action, elsewhere in this chapter.) Adjust the test oscillator attenuator to afford a weak test signal. Adjust the receiver manual volume control to maximum signal, consistent with AVC action described. If the receiver manual control is in the a-f circuit, adjust to maximum. From this point on, we speak in generalities.

Now fully mesh the gang condenser. Make certain that the tuning dial lines up with the condenser plates. Usually when the condensers

are fully meshed, the tuning indicator will point to a line beyond the normal tuning band. In some cases, when the condensers are fully in mesh, the condenser cannot be moved any further. Now adjust the test oscillator to 1400 kc. and adjust the receiver tuning dial to the 1400 kc. point. If no signal is heard, try retuning the receiver. If the signal is tuned in at some other frequency indication upon the tuning dial, try several other frequency adjustments of the test oscillator and receiver so as to establish that the tuning dial does not line up properly with the frequency adjustment of the condenser. Such will be the case, if the trouble is a matter of dial shift. However, the trouble under such circumstances is not incorrect alignment, but rather dial shift. Hence we shall assume that the dial is correctly set.

With the test oscillator tuned to 1400 kc. and the receiver dial set to 1400 kc., adjust the trimmers (high frequency) in the various r-f and mixer circuits, so that maximum output is secured. It is necessary at this time to state that some receivers are not equipped with high frequency trimmers. Instead the end plates upon the condensers are cut so that the different parts of the entire plate may be bent to increase or decrease capacity. In some instances, the end plate of the ganged condenser sections is so mounted that both ends may be bent in or out to increase or decrease capacity. The last named arrangement is used in many Sparton receivers. (Incidently in these Sparton receivers, the oscillator condenser should be adjusted before the r-f and mixer unit are touched. Dial correction is also accomplished by varying the oscillator condenser. For full instructions, we refer you to Rider's Manual, Volume IV.) The reference made to 1400 kc. as the high frequency adjustment peak usually applies to single wave band (broadcast) receivers. Receivers equipped for dual wave band reception, (broadcast and police calls) are usually adjusted at 1720 kc. at the high end. In some instances, this adjustment takes place between 2400 kc. and 2500 kc.

At this stage, you must determine if the high frequency trimmer adjustment concludes that type of work. Receivers which are equipped with slotted end plate condensers, as shown in figure 91, require adjustment at each of the alignment frequencies. This means that the test oscillator is adjusted to the next alignment frequency, and the trimmer adjustments are made. This operation continues until adjustments have been made on all of the alignment frequencies.

After the r-f and mixer circuits have been adjusted at the high frequency end of the scale, the receiver oscillator high frequency trimmer (if one is used) is aligned for maximum output. In some instances, the receiver does not have a high frequency oscillator trimmer. The oscillator trimmer usually used, is adjusted at from 600 to 700 kc., depending upon the exact receiver. To adjust the oscillator low frequency trimmer, retune the test oscillator to 600 kc. or whatever the correct frequency may be. Now adjust the receiver to the 600 kc. dial setting or whatever the correct dial setting may be. Now, while rocking the main condenser back and forth by slowly shifting the tuning a few divisions

both sides of exact resonance, adjust the oscillator low frequency trimmer for maximum output. Repeat the entire alignment operation to ensure greatest accuracy.

Adjusting Double-Spot Circuit (Atwater Kent Receivers)

This system is native to the Atwater Kent receivers and is included because normal discussion of superheterodyne trimmer alignment does not include such circuits. The schematic of the system is shown in figure 23.

The adjustment of the double-spot circuit requires a test oscillator (modulated) and tunable to 1500 kc. with an adjustment whereby an extra strong and a normal 1500 kc. signal are available. The output meter is connected across the voice coil. The output of the test oscillator is connected across the aerial and ground posts of the receiver. With the test oscillator adjusted to the normal 1500 kc. signal output, the pre-selector trimmers are adjusted for maximum response, particularly trimmer number 3 in figure 23. Then switch the adjustment of the oscillator so that the extra strong 1500 kc. signal is being secured. Now tune the receiver to 1240 kc. and adjust the double-spot trimmer, so that minimum signal is indicated upon the output meter. It is possible that a certain indication will be observed upon the output meter showing that total elimination is not secured. This is normal, but care must be exercised to see that whatever the indication, it is the minimum possible by fine adjustment of the double-spot circuit trimmer. Then change the test oscillator to the normal 1500 kc. signal, retune the receiver to 1500 kc. and readjust trimmer number 3 for maximum output indication. Then tune the receiver to 1240 kc. and adjust the oscillator for the extra strong 1500 kc. signal output. Now carefully readjust the double-spot trimmer for minimum signal indication upon the output meter. Repeat these adjustments until further adjustment of number 3 trimmer does not increase the output of the receiver and further adjustment of the double-spot circuit trimmer does not reduce the output of the receiver at 1240 kc. to a greater extent.

Adjusting Other Image Suppression Circuits.

There are in use numerous continuously tuned image suppression trap circuits. The function of these circuits is to minimize image interference, by preventing the passage of the image signal to the mixer tube. Consequently, the image suppression circuit is tracked with the other tuned circuits in the receiver and is always maintained at a frequency adjustment which is higher than the receiver dial setting by a figure equal to twice the intermediate frequency. Consequently, when such image suppressor circuits are to be adjusted for any one dial setting upon the receiver, the test oscillator must be

tuned, as was stated, to a frequency higher than the dial set-ting by the quantity stated.

To adjust such a circuit used in a receiver, which is peaked at 175 kc., the receiver dial would be adjusted to 1200 kc. The test oscillator however, would be tuned to 1200 kc. plus 350 kc. or 1550 kc. The 1550 kc. signal would be passed into the receiver, as if it were an ordi-nary broadcast signal. However, as we desire freedom from this signal, the test oscillator is adjusted to afford maximum output, so that when aligning the image suppressor circuit, we will try to eliminate the strong-est possible signal. In contrast to the usual process of alignment, where we try for maximum signal, when aligning the image suppressor circuit, we desire *minimum* signal output at the speaker. To secure this condi-tion, it is necessary to adjust very accurately the image suppressor circuit. Furthermore, if, as in the case of the Atwater Kent receiver, the image suppressor circuit is a part of another tuned circuit, perfect alignment must exist at the desired frequency as well as at the image frequency.

Adjusting Trap Circuits.

A few receivers which employ high intermediate frequencies, make use of trap circuits located in the input circuit of the receiver and tuned to the intermediate frequency. Adjustment is carried out as follows: The test oscillator is adjusted to the i-f peak. The output leads from the test oscillator are connected to the antenna and ground posts of the receiver. The volume control in the receiver is set at maximum and the test oscillator attenuator is adjusted for maximum output. The i-f signal is fed into the receiver and the trap circuit is adjusted for minimum response. Wurlitzer uses such a trap circuit in some of their receivers. It is tuned to 485 kc. Majestic employed such a trap circuit in their short wave converters. The circuit was tuned to 1000 kc. Other manu-facturers also use this system. Refer to service information for specific adjustment frequencies.

Adjustment of Neutralized I-F Systems in "60" Series RCA and Equivalent Superheterodynes.

Neutralization is carried out at the intermediate frequency. A dummy tube is required. This tube must be identical to the tubes used in the i-f amplifier, except that one heater prong has been cut short, so that the tube heater will not become incandescent when the dummy tube is inserted into the socket. The test signal is fed into the receiver in normal manner. The dummy tube is inserted into the stage to be neutralized, replacing the good tube in that stage. The volume control is set to maximum. The signal heard through the speaker should be very weak. Now adjust the neutralizing condenser for minimum signal. Repeat with the second stage amplifier, by using the dummy tube in the second stage.

Adjusting R-F Compensating Condenser in "60" Series RCA and Equivalent Superheterodynes.

The compensating condenser is accessible through the back of the chassis, near the 1st detector or mixer tube. To adjust procede as follows: Secure a non-metallic screw driver. Place receiver into operation and tune to some station between 1000 and 1500 kc. The source of the test signal may be a test oscillator or a broadcasting station of moderate intensity. Do not use high level signal input. The test signal must be modulated. Now adjust the receiver volume control for maximum output, *not necessarily the maximum setting of the control.* Adjust the compensating condenser screw until the receiver oscillates. This will cause a whistle when the test signal is tuned in. Now turn the screw slowly, in the opposite direction until the receiver just ceases to oscillate. It is possible that this adjustment will not be generally satisfactory for all levels of signal input. This means that a supplementary adjustment may be required, if the test signal supplied to the receiver is weaker than the signal strength which may be experienced in actual practice. To check this, advance the test oscillator output and see if the receiver will again break into oscillation. If it does, it is necessary to advance the compensating condenser screw adjustment until the oscillatory condition ceases. The 1st detector or mixer tube is second from the extreme right, when facing the front of the chassis and reading from right to left.

All-Wave Receiver Alignment.

The development of the all-wave receiver has introduced several new ideas in connection with alignment work. As a general rule, service men feel that the alignment of such a receiver is an extremely complicated matter, particularly after examining the wiring diagram and noting multiplicity of coils and condensers. Yet we feel, after a certain amount of practical experience, that service men experience more mental hazards than actually exist. If you are familiar with your oscillator and the phenomenon of harmonics, your greatest problem will be the location of the trimmers, rather than the actual alignment.

We have illustrated in figures 83 and 84, two types of r-f transformer arrangements in all-wave receivers. Figure 83, which shows the RCA 140 series receiver and incidently the General Electric K-80, as well, employs separate tuned transformers for each wave band. You will note that each of these transformer has its own trimmer condenser, which is automatically inserted into the circuit when the associated trans-

former is connected into the circuit. As such, alignment upon this receiver and upon all receivers of this type, that is, receivers which switch complete tuned transformers into the circuit for each wave band, progresses as if the receiver were a single wave band system of the broadcast variety. You of course understand that the receiver covers quite a range of signal frequencies. However, alignment upon each band is carried out at the proper signal frequency, as if there were absolutely no other bands in the receiver. Thus if you are aligning on the broadcast, you adjust the correct trimmers at the correct frequencies, totally disregarding the other coils in the receiver. If you adjust the receiver at one of the other bands, you do so at the correct frequency for that wave band and forget all about the broadcast band and the other lower bands.

If you examine the circuit, you will note that all of the r-f, mixer and some of the oscillator coils are tuned by parallel trimmers, operating in conjunction with the three main condensers. However, two of the oscillator windings are also equipped with series trimmers, so that when aligning, you must recognize the number of trimmers involved, but at the same time, you must also appreciate the type of circuit and the mode of wave changing. As was stated earlier in this text, when this type of receiver was discussed, the various r-f, mixer and oscillator transformers are entirely independent of each other and alignment advances along such lines. No adjustments are to be made upon the main tuning condensers, unless, for some reason, one or more of these units are damaged. Whatever alignment takes place is effected upon the respective circuit trimmers. This information is not limited to the specific receiver named, but is applicable to all receivers which employ such independent, switch controlled transformers.

If you examine the wiring diagram, you will note that the i-f system in this all-wave receiver is like the i-f system in any other type of superheterodyne. To repeat what was said once before, the design of the i-f amplifier, other than its i-f peak, is not influenced by the signal frequency range of the receiver or the number of individual wave bands covered by the receiver. Consequently, while there may be 10, 12, 14 or as many as 20 trimmers adjustments in an all-wave receiver, the number of i-f trimmer adjustments is determined by the number of tuned i-f circuits, which are equipped with trimmers. Once these i-f trimmers are adjusted at the i-f frequency, there is no need for further contact with the i-f system during the alignment of the r-f, mixer and oscillator transformers. At no time should you attempt to correct a fault existent in the r-f, mixer or oscillator systems; by retuning the i-f transformers.

As to the actual alignment, you must determine, by examination of the specific service literature, the exact frequencies at which alignment takes place. That which may apply to one receiver does not necessarily apply to the other. This is so despite the fact that four wave band receivers of different manufacture will more than likely cover the same four wave bands. There is, however, one definite similarity between the majority if not all of these receivers. All of the circuits equipped with parallel trimmers, which are to be adjusted, are adjusted at the high frequency end of the wave band covered by that transformer. Thus if one wave band covers the broadcast range of from 540 to 1500 kc., high frequency alignment takes place at about 1400 kc. If this circuit were equipped with a low frequency series condenser, the low frequency adjustment would be made at about 600 kc. If the next band operates over a range of from 1500 kc. to about 4000 kc., the high frequency adjustment is made at some frequency between 3800 kc. and 4000 kc. If this circuit is equipped with a low frequency series trimmer, adjustment would be made at about 1710 kc., which is quite a popular frequency. If another wave band covers from about 3900 kc. to about 10,000 kc., high frequency adjustment would be made at about 10,000 kc. If the next band covers from about 9500 kc. to about 18,000 kc., high frequency adjustment is made at some frequency between 15,000 kc. and 18,000 kc. Low frequency adjustments, if they are to be made, would be made at some frequency, slightly higher than the low limit for that circuit.

Now, it is possible that difficulty is experienced at the low frequency end of one of these scales when there is no series trimmer for low frequency adjustment in the circuit. What to do under such conditions? To attempt to increase the capacity of the main tuning condenser, controlling that part of the receiver, is asking for trouble, because any such move would throw all of the other circuits controlled by that main tuning section out of track. The only suitable solution for the wave band involved is to make some adjustment upon the transformer itself, which would increase its inductance, or possibly decrease its inductance, as desired. This means moving coils turns closer or moving them apart or, if the design of the coil is such, as in the case of the two specific receivers named, to move the end coils. Moving these end coils towards the panel, along the winding form, increases the inductance. Moving these end coils farther away from the panel is to decrease the inductance. If coil turns are to be moved, moving them closer increases the inductance and moving the end turns further apart, decreases the inductance. Concerning such operations, always move the end turns, never the turns at the center of the winding.

We assume that you are sufficiently familiar with the operation of your oscillator, so that you can secure whatever test signal frequencies you require. In this connection may we bring two paramount points to your attention. The first is that you can never know too much about the operation of your oscillator and the frequencies which that unit is capable

of producing. The second is that you should exercise the utmost care when tuning the oscillator to the desired frequency. This is particularly true when you are operating with harmonics of a fundamental and the high frequency signal is a high order harmonic of the fundamental. The importance of correct adjustment of the test oscillator, so as to facilitate correct adjustment of the receiver circuits, is described under the caption "Apparent Mis-Alignment of All-Wave Receivers," later in this chapter.

We want it expressly understood that the instructions which have been given concerning the alignment of an all-wave receiver, apply to the two receivers named, and are generally applicable to the majority of all-wave receivers. However, it is possible that the manufacturer of a certain receiver has outlined his own method of alignment, which is a part of the service literature covering that receiver, as appearing in Rider's Manual. If such is the case, we respectfully request that you refer to that data, rather than employ the instructions furnished in this chapter. If you lack specific instructions, then you will find the data furnished herewith of value.

The second type of transformer arrangement shown in figure 84 is aligned in a manner very similar to that already described. However, it seems that the manufacturers who produce such receivers request that the first step in alignment takes place upon the broadcast frequency and that the first adjustment should be the oscillator circuit. The receiver is tuned to the broadcast adjustment frequency and the dial setting checked. After this is done, the low frequency series trimmer is adjusted and then if the receiver also employs a high frequency parallel oscillator trimmer, that unit is adjusted. This is followed by the r-f and mixer tube trimmer adjustments at the broadcast frequency. Then the wave band is switched and the high frequency trimmers adjusted first, followed by the low frequency trimmers. Generally speaking the alignment of both types of transformers is substantially the same. You have a choice of aligning the oscillator circuit at the various frequencies and follow through with the r-f and mixer circuits at the various frequencies, or to complete the alignment of all of the circuits at the various frequencies.

During alignment operations, keep the signal input from the test oscillator at the lowest possible level, consistent with the ability to obtain an indication upon the output meter.

Double Peak Alignment.

One of the important considerations of all alignment opera-
tions irrespective of the wave bands covered by the receiver,
is the fact that when adjusting the oscillator trimmer, you
may experience a double peak.   In other words, you may
turn the control screw clockwise for a certain distance and
tune in the signal and then you may turn the oscillator trim-
mer control screw counter-clockwise for a certain distance
and again tune in the signal.   At the same time, the tuning
adjustment of the receiver has not undergone any change.
What has happened is that the two positions of the oscillator
trimmer represent the two frequency adjustments of the
oscillator, which provide the difference-frequency required for
the i-f amplifier.   If you recall, we stated that it is possible
to produce the required i-f peak by setting the heterodyning
or beating oscillator to a frequency lower than the desired
signal frequency and also by setting the heterodyning oscil-
lator to a frequency higher than the desired carrier.

Therefore, it is important when adjusting the oscillator trimmer to
be certain that the adjustment you class as being correct, that is, as
providing the maximum output is in conformity with the design of the
receiver.   Practically every superheterodyne receiver, at least of American
make, employs a heterodyning frequency which is higher than the desired
carrier.   The reasons for this are no doubt of equal interest all over the
world, and while we are not certain of the fact, we are prone to believe
that the majority of superheterodyne receivers, the world over, employ a
similar relation between the heterodyning and the desired signal frequen-
cies.   (See chapter devoted to the subject of oscillators, for the reasons
referred to above.)   When working upon the oscillator trimmers, the
adjustment which represents the highest frequency, or lower capacity,
between the two settings stated, is the correct one in receivers which em-
ploy the oscillator, at a frequency higher than that of the desired signal.

Apparent Mis-Alignment of All-Wave Receivers.

In the all-wave receiver which uses but one oscillator, a
very confusing condition may be experienced.   Such a condi-
tion consists of an apparent case of mis-alignment upon the
short waves and perfect alignment upon the complete broad-
cast band.   As a general rule this is a sign of incorrect align-
ment of the oscillator condenser upon the broadcast band.

However, the discrepancy may be so small as to pass unobserved upon the broadcast band, but when tuned to the short wave band, the same discrepancy creates a very great difference in the i-f frequency produced. The following is an illustration of what we have in mind.

Let us suppose that the intermediate frequency in the receiver is 175 kc. Let us further suppose that the oscillator adjustment is high by about .1 percent in excess of the rated frequency difference required to produce the intermediate-frequency signal. When tuned to a 600 kc. carrier, the intermediate frequency produced would have a value of about 175.775 kc., which of course is negligible. At 1400 kc., assuming the same variation in oscillator adjustment, the intermediate frequency would be about 176.575 kc. Once more this variation is negligible. However, when we are tuned to a carrier of, say, 15,000 kc. a similar variation of .1 percent would produce an intermediate frequency of about 190.175 kc., and it is very possible that the signal would not be heard or the receiver would lack sensitivity.

A variation of .1 percent must be acknowledged to be very small and is an indication of the extreme accuracy of alignment which must be obtained in receiver of this type. A warning is therefore given against any attempt to align such receivers at the broadcast frequencies. Alignment is required at the high-frequency end of the scale; namely, between the 10,000 kc. and 6000 kc. ranges.

In view of the fact that the broadcast frequency range adjustment is satisfactory, it is best to attempt alignment by working upon the short wave coils rather than upon the oscillator condenser. Select the coil used for the short wave band upon which the receiver appears to lack sensitivity, or is out of alignment. With the testing oscillator in operation, move one of the outside turns of the short wave oscillator winding towards or away from the other turns upon the coil. A great amount of variation may not be required to create perfect alignment of the system for that wave band. By adjusting this coil, the alignment upon the other wave bands is not interfered with.

APPENDIX

RECENT ADVANCES IN THE SUPERHETERODYNE

MANY changes have taken place in the superheterodyne receiver since the last revision of this book. No part of the superheterodyne receiver has escaped the rigid scrutiny of engineers who have been working in the design laboratory toward the goal of improved receiver performance. These efforts have evolved not a different but rather an improved superheterodyne receiver.

If we begin at the most logical starting place in the superheterodyne circuit, the signal circuit, we note that the primary development has been an extension of the tuning range to as high as 75 mc. in receivers intended for home use. This extension of the frequency range has been accompanied by improved signal-to-noise ratio as well as increased sensitivity. In the mixer or first detector circuit, the outstanding development has been an improved tube and circuit which are especially designed to operate more efficiently at the higher frequencies. Naturally enough the i-f. amplifier has come in for its share of attention with the result that the i-f. amplifier of a modern receiver shows a selectivity which is a close approach to the ideal selectivity curve. Extensive improvements have also been made in the audio system, with the object of improving the fidelity of reproduction. Research in this field has produced refinements in audio amplifier design, new tubes capable of delivering the necessary high power outputs and, last but not least, improvements in speaker and cabinet (acoustic) design.

In spite of the tremendous advances that have been steadily made in the superheterodyne circuit, the basic principles, which we have explained at length in other sections of this book, are still applicable. One who would understand the operation of the present day superheterodyne receiver must understand the evolutionary stages through which the receiver has passed. As we study the superheterodyne receiver, we observe that it has developed by refinements in the design of the component parts rather than by radical changes in the mode of operation.

The evolution of the modern first detector circuit is an admirable illustration of the truth of this statement. We have seen this circuit change from the early autodyne first detector, using a triode tube to accomplish the dual function of oscillator and detector, to the autodyne screen grid first detector, to the screen grid detector and separate oscillator, to the pentagrid converter, and finally to the type 6L7 first detector, which converts the signal frequency to the intermediate frequency with extremely high

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efficiency—even at the ultra-high frequencies where other systems fail because of interaction between the oscillator and signal circuits.

Even the most recent development—automatic frequency control—is not a basic change in the superheterodyne receiver, but rather can be considered as a refinement and innovation which makes possible more perfect tracking between the oscillator and signal circuits so as to produce always the correct intermediate frequency. Thus one who would understand the operation of automatic frequency control must first understand why it is necessary that certain frequency relationships exist between the signal and the oscillator frequencies and why these are so important from the viewpoint of proper operation of the superheterodyne receiver.

We have said enough to show you that it is not the principles and functions of the superheterodyne receiver which have changed as changes in design have been made, but rather the manner in which the various basic functions are carried out. In this Appendix we intend to discuss and explain some of the outstanding changes which have taken place in the superheterodyne receiver within the past few years.

The R-F. Tuning System.

The tremendous frequency range which is covered in the modern superheterodyne is the result of extensive research directed toward improvement in the design of the coil and switching system. The tendency in modern receiver design is to incorporate the entire r-f. and oscillator coil system, including the switching arrangement, the alignment adjustments for the various bands, and the r-f., first detector, and oscillator tubes, in a separate unit which can be readily removed from the rest of the chassis upon which it is mounted. These units have received various names, among which are the "Sentry Box" of General Electric, the "Magic Brain" of RCA, the "Centromatic Tuning" of United American Bosch, etc. This type of construction has the advantage of divorcing the r-f. unit proper from the rest of the receiver, of decreasing the length of the r-f. leads, and of making possible more rapid servicing.

It is only natural that the increased tuning range of the modern superheterodyne has introduced numerous problems in connection with the design of the r-f. system. In general the new circuits differ from the previous all-wave or multi-band circuits that we have shown in this book in only small details, the general layout being similar. Reference to the circuits being used in the 1937 line of receivers shows that both the tapped coil system as well as the separate individual coil system is being used. Both these systems of coil arrangements are shown and described on pages 196 and 197. It is difficult to say which of these systems will finally supplant the other, but it seems probable that the widespread adoption of automatic frequency control will result in the displacement of the tapped coil system by the individual coil arrangement. In support of this statement is the fact that all the receivers which employ automatic frequency control almost without exception employ an individual coil for each wave band.

The 6L7 Mixer or First Detector.

One of the important factors which has made possible the improved performance the modern superheterodyne receiver shows on the short-wave bands, and especially the ultra short-wave bands, is the development of the 6L7 tube.   This tube overcomes the difficulties experienced in previous first detector circuits due to coupling between the oscillator and signal circuits, as a result of which the gain at the higher frequencies was considerably reduced.

Referring to the typical mixer circuit shown in Fig. 93, the first grid of the 6L7 is the radio-frequency or control grid to which the incoming signal is applied.   By making this grid of the remote cutoff type (va-
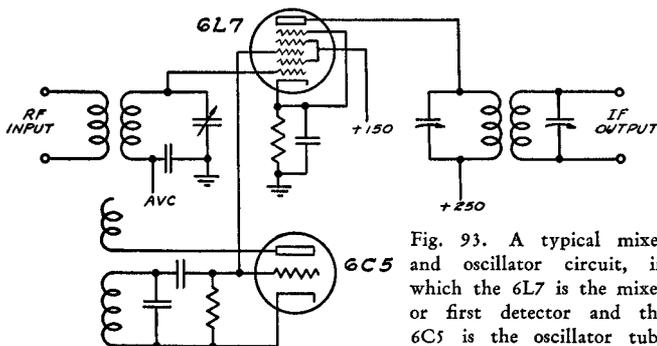
Fig. 93.   A typical mixer and oscillator circuit, in which the 6L7 is the mixer or first detector and the 6C5 is the oscillator tube

riable mu), distortion and cross-modulation are minimized and it is possible to apply automatic volume control voltage to the signal grid.   The second grid operates to accelerate the electrons and also acts as a screen between the signal grid and the remaining grids.   The third grid is the oscillator grid, which receives the voltage developed by a separate oscillator tube in a conventional circuit.   Since the amplification factor of this grid is relatively high, it is possible to secure good conversion efficiency with a relatively small oscillator input.

The fourth grid, which acts as a screen and is internally connected to the second grid, functions to increase the plate resistance of the tube. This high plate resistance is desirable so as to reduce the damping effect on the first i-f. transformer into which the mixer plate is coupled.   The fifth and last grid is connected internally to the cathode and acts to suppress the secondary emission from the plate.   In this way operation at low plate voltages is made possible and, as well, the plate resistance is maintained at a relatively high value.

Because of the fact that the oscillator signal applied to grid number 3 is large (in comparison with the signal voltage), a large component of the plate current is at the oscillator frequency.   Furthermore, since there is a

small signal voltage applied to number 1 grid, the amplification of the tube for the oscillator component of the voltage applied to grid number 3, varies at a rate equal to the signal frequency. In other words, the oscillator component of the plate current can be said to be modulated by the voltage applied to the signal grid, so that, as explained in the early part of this book, a frequency equal to the difference between the signal and oscillator frequencies is produced. This is, of course, the intermediate frequency.

The 6L7 has been shown to possess a number of advantages over its predecessor the 6A7. One of these is of particular importance from a servicing viewpoint: decreased reaction between the oscillator and signal circuits which simplifies the proper alignment of the circuits.

Because of its other properties, the 6L7 has been used in some applications as a radio-frequency or intermediate-frequency amplifier in receivers where the voltage available for automatic volume control is especially low; in these applications the AVC voltage is applied to both the signal and oscillator grids.

Before we leave the r-f. and oscillator portion of the superheterodyne, several points should be mentioned. There seems to be a rather well-defined tendency toward the use of iron-core coils in the oscillator circuits of the two lowest frequency bands, that is the broadcast band and the band below this. Another popular place for iron core tuning is the wave trap in the antenna circuit. These coils are adjusted by the movement of the iron core into and out of the field of the coil. This makes possible the use of fixed mica condensers to replace the usual variable oscillator padders.

Adjustment at the low-frequency end of the band is accomplished by moving the iron core by means of a screw, making possible an accurate adjustment of the oscillator inductance. The condenser gang must, of course, be rocked and, in fact, the mechanics of making this adjustment at the low-frequency end of the band are identical with the procedure followed when a low-frequency padding condenser is used instead of the inductance adjustment.

It is extremely important that the adjustment at the high-frequency end of the band be repeated after adjusting the inductance. This follows because the inductance adjustment is even more important in changing the tracking at the high-frequency end of the band than it is at the low-frequency end. If the inductance adjustment has to be changed appreciably, it may be necessary to repeat the high and low frequency adjustments several times until no further improvement can be obtained.

In this connection, the use of air trimmers and carefully impregnated coils and condensers, has gone far toward eliminating the need for frequent alignment. Much attention has also been paid to the effect of humidity and temperature upon receiver operation. The elimination of mica compression trimmers in both the radio-frequency and the intermediate-frequency amplifiers of many receivers, as well as careful impregnation of

vital parts, has been especially instrumental in eliminating the hitherto disastrous effects of humidity and temperature.

With the inclusion of ultra short-wave bands in many receivers, the need for and importance of careful placement of r-f. wiring needs to be emphasized. The r-f. coil on these bands generally consists of only a single turn. So important is the total length of this turn that a change of a small fraction of an inch will shift the circuit sufficiently to bring the oscillator and r-f. circuits into synchronism, and thus destroy the tracking.

We cite this as an example of the great importance of not disturbing any of the "hot" wiring associated with the r-f. and oscillator circuits. Not only will a change in the placement of this wiring necessitate realignment, but sometimes even realignment will not restore the original efficiency of the receiver before the position of the wiring was changed. In many cases, the movement of certain leads in the r-f. section is so critical that a change in their placement is sufficient to cause the receiver to produce a sustained "howl" over certain portions of the dial. The remedy, of course, is the proper "dressing" of the leads in question. It sometimes happens that these leads are moved in shipping or transit; this is, of course, beyond the control of the serviceman. The best that he can do is to see that in replacing various parts in the r-f. and oscillator circuit, the wiring is restored to its original placement. In this same connection, it is highly preferable to use parts which have not only the same electrical characteristics, but also the same physical dimensions—in other words, it is preferable to use genuine replacement parts which are identical to the original unit in every respect. The use of parts which differ in physical size may so upset the circuit balance through stray capacitive coupling, that it will be impossible to restore the receiver to its original operating condition.

The I-F. Amplifier.

The changes which have appeared in the design of the i-f. amplifier in the past few years, have been directed toward attaining the ideal response curve which shows a flat top over a range of 10 kc. on either side of the i-f. peak and the response of which drops rapidly on either side of resonance. This, of course, is necessitated by the fact that unless the response of the i-f. amplifier is sufficiently broad, the higher audio frequencies are attenuated.

However, the conditions in the various bands and, in fact, within the broadcast band itself, are such that it is not always possible to use a broadly peaked i-f. amplifier. This comes as a result of interference between adjacent channels, which are separated by only 10 k.c., so that the sidebands of one frequency interfere with those of an adjacent channel. Where it is desired to receive a comparatively weak signal on a channel which is adjacent to one that is strong, it is especially desirable to have a selectivity which is considerably greater that that necessary for faithful reproduction of the upper audio frequencies.

The need for an i-f. amplifier which is capable of meeting the diverse

conditions encountered, has resulted in the production of numerous types
of i-f. amplifier circuits which provide a variable degree of selectivity
under the manual control of the listener. Thus, a broad degree of selec-
tivity is provided for high fidelity reception and at the same time a turn
of the selectivity control makes it possible to increase or sharpen the selec-
tivity when the conditions require it.

Methods for Providing Variable Selectivity.

The selectivity can be controlled in many ways to accomplish this de-
sirable feature. Among the simplest of the methods is the type which uses
a variable degree of coupling between the primary and secondary of the i-f.
transformers. The circuit used in the Zenith Stratosphere receiver is an
example of this type of control. As the arrows indicate in Fig. 94, the
coupling in the first and second i-f. transformers is continuously variable.
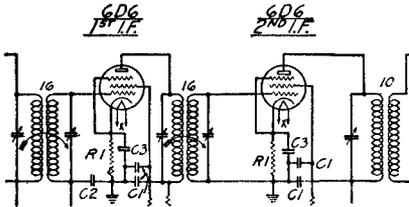
Fig. 94, left. The
curved arrows indicate
variable coupling be-
tween the i-f. trans-
former windings, making
possible variable selec-
tivity. (Courtesy Zenith
Radio Corp.)

Fig. 95, right. The se-
lectivity is varied in this
set by switching the
closely-coupled tertiary
windings into the sec-
ondary circuits
(Courtesy Wells-Gardner
& Co.)
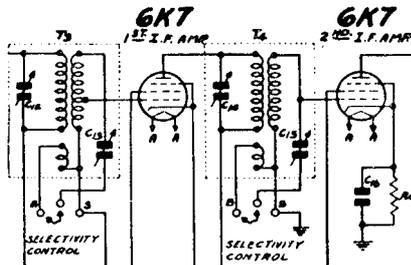
With the coupling between primary and secondary at a minimum, the
selectivity of the circuit is greatest and the selectivity of the i-f. amplifier
decreases progressively as the coupling is increased.

The method shown in Fig. 95 eliminates the need for a mechanical
movement of the coils by employing an auxiliary winding which is closely
coupled to the primary winding. When the fidelity switch is in the selec-
tive position, the auxiliary winding is not connected in the circuit, so that
the transformer functions to provide a *sharp* degree of selectivity, because
the primary and secondary are loosely coupled. When the selectivity switch.
is thrown into the *broad* position, the auxiliary winding is placed in series
with the secondary tuned circuit and therefore becomes a part of it. This

auxiliary winding, furthermore, is very closely coupled to the primary, so that the net effect is an overall *increase* in the coupling between the primary and secondary windings. As a result of this increase the overall selectivity of the receiver is decreased so as to permit high-fidelity reception. Note that the coupling in both the first and second i-f. transformers is controlled in this way by means of the two sections of the fidelity control. The coupling in the third i-f. transformer is fixed at all times.

A slightly different variation of the same principles is used in the Fairbanks-Morse 100. Reference to Fig. 96 shows that the secondary is composed of three sections—L2, L4, and L5. L1 and L2 are loosely coupled
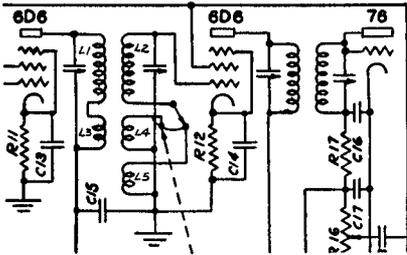
Fig. 96. The manner in which the degree of selectivity is varied in this i-f. transformer is explained in the accompanying text (*Courtesy Fairbanks-Morse Home Appliances Inc.*)

to each other and constitute the major portion of the primary and secondary inductance respectively. L3 and L4 are tightly coupled, while the coupling between L5 and the primary is loose. With the switch in the *broad* position, L5 is out of the circuit and the secondary winding consists of L2 and L4. Since L4 is closely coupled to L3, the coupling between the secondary and primary windings is sufficiently great so that a broad response is obtained. With the switch in the *sharp* position, the closely coupled L4 is replaced by L5, which has the same inductance, but is loosely coupled. Thus, in this position the overall coupling between the primary and secondary is low and the frequency response is sharp. The tuning is not disturbed when changing from the sharp to the broad selectivity position, because L4 and L5 have the same inductance.

Three Winding I-F. Transformers.

Up to the present point our discussion has been limited to i-f. transformers wherein selectivity is a function of the coupling between *two* tuned circuits. A type of three winding transformers in common use is shown in Fig. 97.

This is a partial schematic of the Stromberg Carlson Model 70. Note that the first and second i-f. transformers consist of three tuned circuits. Transformers of this type operate in the following manner: The primary and secondary windings are loosely coupled, while the tertiary (third) winding is closely coupled to the secondary winding. When the resistance in series with the tertiary winding is greatest, the tertiary tuned circuit draws very little current and consequently practically no reaction occurs

between it and the other windings. Thus, the transformer operates as an ordinary loosely-coupled two-winding transformer to provide sharp selectivity and reduced band-width. In the maximum selectivity position, a switch operated by the selectivity or fidelity control, opens the tertiary tuned circuit.

Now, let us see what takes place as the resistance in the tertiary tuned circuit is decreased. This circuit, being tuned to the i-f. peak, acts as a load across the secondary winding, takes energy from it, and results in a broadened response. This effect is most pronounced, of course, when all resistance is out of the circuit, for then a maximum current flows in the tertiary circuit and a maximum broadening of the frequency response results.
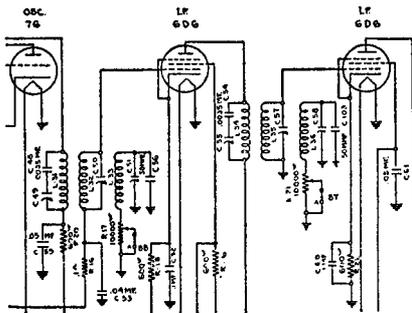
Fig. 97, left. By varying the 10,000-ohm rheostat in series with the third winding of the i-f. transformers, the degree of selectivity is controlled. When maximum selectivity is desired, the switch in this circuit is opened *(Courtesy Stromberg-Carlson Tel. Mfg. Co.)*

Fig. 98, right. The three-winding i-f. transformer, T5, is used to make possible an increased gain in the i-f. stage by stabilizing the amplifier. *(Courtesy Atwater-Kent Mfg. Co.)*
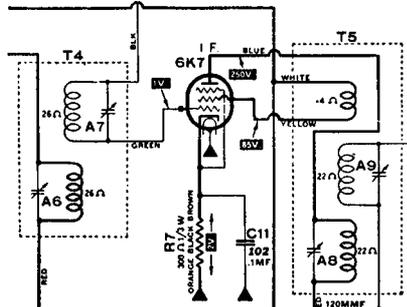
While on the subject of three-winding transformers, the function of the transformer used in the Atwater Kent 856, Fig. 98, is not to provide a control over the selectivity, but to make possible increased gain in the i-f. stage by stabilizing the amplifier. This, as can be seen from the schematic, is accomplished by using the third winding to feed back a portion of the voltage from the plate to the screen circuit in the correct phase to prevent any tendency toward oscillation. For a complete discussion of the effect of coupling upon selectivity, we suggest that you consult "An Hour A Day With Rider on Resonance and Alignment."

Automatic Frequency Control.

Beyond a doubt one of the most important advances in the design of superheterodynes in recent years has been the development of automatic frequency control, generally abbreviated to a.f.c. This is an arrangement which operates automatically to keep the receiver tuned accurately regardless of errors made in the setting of the variable tuning condenser. This development should not be confused with automatic systems of tuning, which enable the selection of the desired station by means of a remote control device. However, it so happens that automatic frequency control simplifies considerably the design of automatic and remote-tuning devices by reducing the accuracy required in the setting of the tuning condenser.

To understand the operation of a.f.c., it is first necessary to appreciate that whether or not a superheterodyne receiver is tuned correctly depends upon the frequency at which the oscillator is working. For correct tuning, the oscillator frequency must be higher (or lower) than the signal frequency by an amount exactly equal to the i-f. peak. If the oscillator
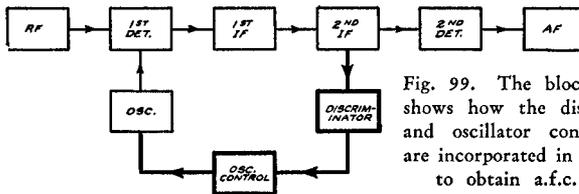
Fig. 99. The block diagram shows how the discriminator and oscillator control tubes are incorporated in the circuit to obtain a.f.c. action

frequency happens to be different from this required value, then a mistuned condition is created and, as a result, the signal passes through the i-f. amplifier asymmetrically. Not only does this result in the production of distortion, but it also decreases the sensitivity of the receiver and generally increases the noise background as well.

In this connection, the exact tuning of the r-f. circuits is relatively unimportant, since the selectivity of the r-f. system in a superheterodyne is considerably less than the selectivity of the i-f. amplifier. On the other hand, the extreme importance of the oscillator frequency is due to the fact that upon its correct setting depends the entire gain and selectivity of the i-f. amplifier.

To begin with, you should understand that any a.f.c. system functions by controlling the frequency of the oscillator so that it is always higher (or lower) than the signal frequency by an amount equal to the i-f. peak of the receiver. To accomplish this control over the oscillator frequency —so as to correct for inaccuracies in the setting of the tuning condenser and for oscillator drift—two new elements are introduced into the receiver circuit. These are shown in Fig. 99 and are called the *discriminator* and the *oscillator control stage.* The i-f. signal is fed to the discriminator, consisting of a specially tuned transformer and its associated diode circuit. As a result of the arrangement of this circuit, a control voltage is produced

which varies in magnitude and polarity in accordance with the frequency of the signal passing through the i-f. amplifier. When this frequency is *higher than the i-f. peak,* then the discriminator produces a *negative* control voltage and similarly, when this frequency is *lower than the i-f. peak,* the discriminator produces a *positive* control voltage. Zero control voltage is produced when the signal frequency is exactly equal to the i-f. peak. This variation of the a.f.c. voltage with the frequency of the signal applied to the discriminator is shown in Fig. 100.

The control voltage produced in the discriminator circuit, is applied to the grid of the oscillator control tube, which is arranged so that it varies the frequency of the oscillator in accordance with the value of grid bias
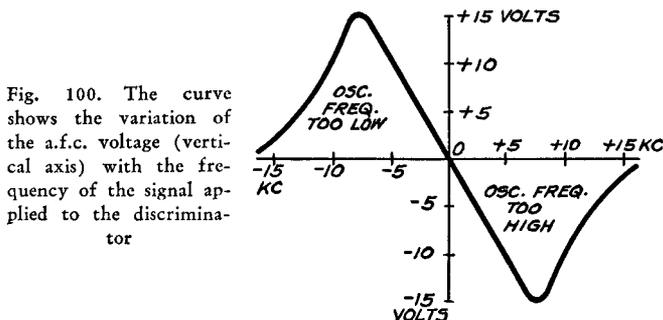
Fig. 100. The curve shows the variation of the a.f.c. voltage (vertical axis) with the frequency of the signal applied to the discriminator

applied to the control tube. When this bias is negative, the frequency of the oscillator is lowered, and similarly, when the bias is made more positive, the frequency of the oscillator is raised. As a result of this connection between the discriminator circuit and the oscillator frequency, the a.f.c. voltage acts to maintain the frequency of the oscillator so that the signal will always pass through the i-f. amplifier at the i-f. peak.

The Discriminator.

At the present time the discriminators which are used in a.f.c.-equipped receivers all operate on the same basic principle, although there are differences in minor details. The circuit which we shall take as a model in explaining the operation of the discriminator is shown in Fig. 101.

To begin with, you will note that the primary winding L_1 of the discriminator transformer is coupled inductively to the secondary winding L_2 and that in addition the voltage present across the primary winding of the transformer is transferred into the rectifier network by means of the coupling condenser C, which has a low reactance at the intermediate frequency. As a result of this combined inductive and capacitive coupling to the secondary circuit, the net voltage which produces the rectified cur-

rent through the load resistors, R1 and R2, is made up of two parts, one of which is due to the induced voltage and the other which is due to the primary or capacitively coupled voltage. It so happens that these voltages do not have the same phase and, in fact, the phase of these voltages depends upon the frequency of the signal which is applied to the network— that is, upon the frequency of the i-f. signal.

When the signal frequency is the same as the resonant frequency of the primary and secondary tuned circuits, then it turns out that the voltage produced across R1 is equal and opposite to that across R2, so that no net
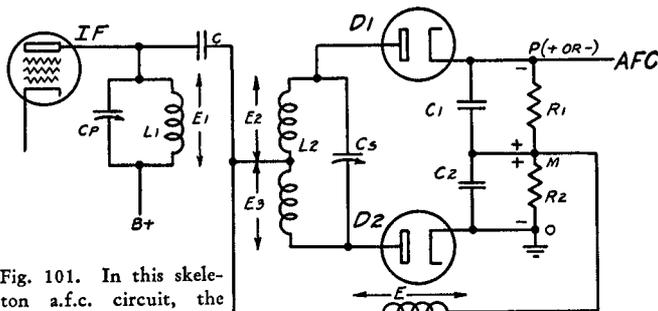
Fig. 101. In this skeleton a.f.c. circuit, the two diodes (D1 and D2) of the 6H6 are shown separately. For complete circuit see Fig. 102

control voltage is produced. Similarly, when the i-f. signal is higher than the i-f. peak, then a net negative control voltage is produced and when the signal frequency is lower than the i-f. peak, a net positive voltage is produced at P.

The Oscillator Control Circuit.

We are now ready to consider the circuit which receives this control voltage produced by the discriminator and, as a result, automatically controls the oscillator frequency. The job which the oscillator control circuit performs can be summarized thus: (1) When the oscillator frequency has the correct value for perfect tuning so that the i-f. signal comes through at the i-f. peak, then the zero control voltage produced by the discriminator acting through the oscillator control stage does not change the oscillator frequency. (2) When the oscillator frequency is too high in value so that the i-f. signal comes through *above* the i-f. peak, then the negative control voltage produced by the discriminator acting through the oscillator control stage, lowers the oscillator frequency to the correct value. (3) When the oscillator frequency is too low in value so that the i-f. signal comes through *below* the i-f. peak, then the positive control voltage produced by the discriminator acting through the oscillator control stage, raises the oscillator frequency to the correct value.

Alignment of A.F.C. Circuits.

The most important consideration in the alignment of receivers equipped with automatic frequency control is that by far the greater part of the procedure is identical with that associated with receivers not so equipped; all the existing rules of good alignment practice are still applicable and should be observed. Expressed in a slightly different manner, a.f.c. alignment is an operation which is supplementary to the regular alignment procedure. However, so important is it, that improper adjustment will result in the production of distortion, faulty dial calibration, and generally unsatisfactory performance.

You will note from Fig. 102 that the only tuned circuits associated with the operation of the a.f.c. system are those in the discriminator transformer. The proper alignment of an a.f.c.-equipped receiver resolves itself, then, into the proper adjustment of the trimmers Cp and Cs, in addition to the ordinary alignment procedure. When the discriminator is properly adjusted, both Cp and Cs are tuned so that the primary and secondary are resonant at the i-f. peak of the receiver.

Control-Tube Cathode-Current Method.

A method which can be used to effect an alignment of both the primary and secondary trimmers of the discriminator transformer depends
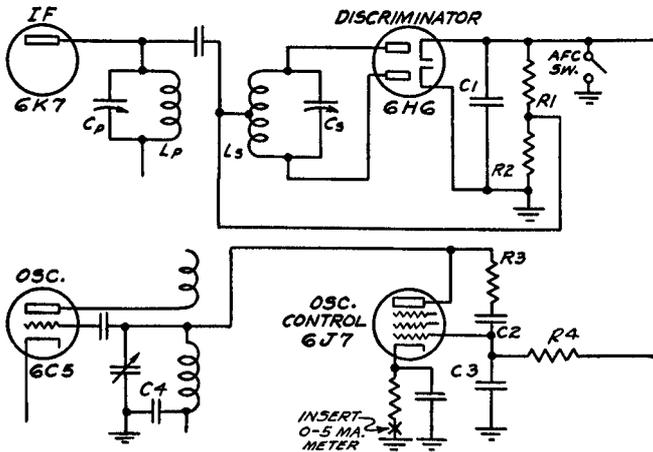
Fig. 102. A complete a.f.c. circuit. The trimmers, Cp and Cs, must be exactly adjusted to the i-f. peak of the receiver

upon the fact that the cathode current of the oscillator control tube varies in accordance with the a.f.c. voltage applied to its grid. In using this method, the cathode circuit of the control tube is broken (see Fig.

102) and an 0-5 range milliammeter inserted. In this way the control tube is used as a vacuum-tube voltmeter.

The first step is to note the reading of the milliammeter with the a.f.c. switch off. Connect a signal generator to the grid of the tube which works into the discriminator transformer and adjust its frequency to the i-f. peak of the receiver. Turn on the a.f.c. switch, and raise the output of the signal generator until a change in the meter reading is noted. The proper adjustment of Cp is effected by setting this trimmer so that the greatest deviation from the initial current is obtained. If the deflection obtained is too small, it can be increased either by slightly turning the secondary trimmer or by raising the signal generator output.

The final adjustment of the secondary trimmer follows this operation. With the a.f.c. switch on, Cs is adjusted so that the plate current is the same as the initial current with the a.f.c switch off. This adjustment is very critical and should be carefully made. As a final check, there should be no change in the plate current as the a.f.c. switch is turned on and off.

Where a push-pull a.f.c. circuit is used, the meter must be inserted in the plate return circuit of one of the control tubes. This must be observed, since with this system the cathode current remains essentially constant as the a.f.c. voltage varies.

The a.f.c. circuit can be conveniently tested under ordinary operating conditions. To check the accuracy of the discriminator alignment, set the a.f.c. switch in the off position and accurately tune in a local station in the broadcast band. If the alignment has been properly carried out, then there will be no change in the received signal as the a.f.c. switch is turned on. If a hiss or distortion appears, then the adjustment of Cs must be repeated. The operation of the a.f.c. action can be checked approximately by noting whether or not the receiver will hold a signal of medium strength over a range of about 10 kc. on either side of the correct dial setting without distortion.

The following are some of the precautions which should be observed in connection with the adjustment of a.f.c. systems:

1. The receiver should be turned on 15 minutes before it is aligned, to allow it to reach its normal operating temperature.
2. The alignment of the r-f., oscillator, and i-f. amplifier must be made in the conventional way with the a.f.c. switch in the off position.
3. The same frequency setting of the signal generator, which is used to align the i-f. amplifier, must be used to align the discriminator.
4. There are generally three adjustments of the secondary discriminator trimmer which will give the proper indication. These occur with the trimmer set at maximum capacity, at minimum capacity, and at some intermediate position. The last adjustment is the correct one and can easily be recognized because of the critical control which it has over the a.f.c. voltage.
5. The oscillator control tube should not be changed once the alignment has been completed, as a tube having a different mutual conductance will change the dial calibration.

6. Inadequate a.f.c. action may be due to low mutual conductance of the oscillator control tube—try another tube.

7. It is desirable that all alignment operations, including those with the a.f.c switch in the off position, be made with the line voltage set at a value which corresponds to the average line voltage experienced at the customer's home. Failure to observe this precaution may result in poor dial calibration and asymmetrical a.f.c. control.

We regret that lack of space prevents us from going into a more complete discussion of the many other factors which are related to a.f.c. circuits. However, this subject is fully covered in "An Hour a Day With Rider on Automatic Frequency Control."

A New Type of Cross Modulation.

In previous parts of this book, the conventional types of cross modulation were explained in some detail. In this section a new type of cross modulation is discussed which has made its appearance in sections of the country which are located in the vicinity of high powered broadcast stations.

Representative of this new interference effect, are numerous cases that have occurred in the vicinity of New York, where both WJZ and WOR operate 50-kilowatt transmitters within ten miles of each other. WOR operates on 710 kc., while WJZ operates on 760 kc. Almost invariably, in localities not far distant from these stations, it was found that WOR and WJZ interfered with WNYC (810 kc.) and WEAF (660 kc.). That is, it was possible to hear the programs of WJZ and WOR while listening to the program of either WEAF or WNYC and in many cases the interference was so strong that satisfactory reception was virtually impossible.

Similar types of cross modulation have been reported in the vicinity of San Francisco, Chicago, Cincinnati, and other parts of the country. The difficulty is not general throughout the area where it is experienced, but only where a high field intensity exists (of the order of 0.5 volt per meter) and then only in certain locations. It may exist in a given house, whereas an adjacent house is free from the trouble—although the same receiver is used in each case. In places where the cross modulation occurs the effect is substantially the same on all makes of receivers.

Observation and experiment have shown that this cross modulation effect is not due to any defect in the receiver itself, but rather to the presence of a rectifying element somewhere external to the receiver. As a result of this rectification, a number of new frequencies are produced, all of which carry the original modulation of the signal, and these frequencies are responsible for the cross modulation.

The most common source is in the power wiring, the effect being present generally where the power mains are of the exposed overhead type. The rectifying element may be a poor ground connection, it may be an oxidized copper conductor in contact with another copper surface, and may even be electrolytic in nature, if the soil where the power wiring is

grounded be moist. Another possible source of rectification is in certain types of lightning arrestors.

When such conditions exist, namely exposed wiring in a region of high signal strength and the presence of a rectifying element—even though it be a relatively poor rectifier—the interfering frequencies will be generated. These frequencies will then be picked up by the antenna and introduced into the receiver.

If you have been experiencing trouble from this type of cross modulation, the first step is to eliminate all poor contacts and joints which may be present in the antenna and ground circuits. These connections should be clean and preferably soldered. If the cross modulation still persists, one or more of the following remedies will clear up the situation:

1. Ground the neutral of the house wiring at the house in addition to retaining the ground at the distribution transformers.
2. Use an improved ground at the receiver.
3. Install r-f. bypass condensers from the power line to ground at the point where it enters the house, near the receiver, or in both places.
4. In some cases, it is necessary to install r-f. chokes in the line, as well the bypass condensers.
5. Relocate the antenna so that there is less pickup from the power line to the antenna or lead-in. Use a shielded lead-in where necessary.

In determining the source of the trouble and its location, a small battery set equipped with a short antenna is useful. With its aid the place where the interfering frequencies are being produced can be determined with little effort, so that the appropriate steps can be taken.

The above remedies have been found very effective in eliminating a great deal of trouble which has been due to the presence of r-f. voltages on the power lines and house wiring. Familiar experiences of this type are those in which the output of the receiver varies in accordance with whether certain light switches are turned on or off. Cases have also been reported where the cross modulation effect was so related to the lighting circuit that it was produced only when a certain switch was closed.

These cases have been cleared up by the same general procedure described above, which operates on the basic principle of the removal of r-f. potentials from the power line and the elimination of any rectifying elements or contacts.

Superheterodyne Oscillator Innovations.

An analysis of some of the latest superheterodyne receivers shows some innovations in the manner in which the oscillators of the sets are employed. It is possible that this explanation will help clarify some problems which may have already arisen, in the event that you, who read these lines, have had the opportunity of working upon some of these receivers.

It is a well-known fact that in the conventional superheterodyne receiver, the frequency at which the oscillator operates is *higher* than that of the received carrier. The normal design of the conventional receiver, irrespective of the number of bands used, is that this relation between the oscillator frequency and the received carrier frequency is maintained constant.

However, in some of the new receivers, a somewhat different arrangement is employed. These receivers are usually of the dual-band variety, wherein one band covers the normal broadcast-frequency spectrum from 1600 kc. to about 540 kc., and a short-wave band, which covers from about 2520 kc. to about 1460 kc. Where a variation of this system is used, the high-frequency band covered is from 3900 kc. to about 1540 kc.

The innovations we speak of are of two varieties: one is that wherein the oscillator frequency is *higher* than the received carrier over the broadcast band by an amount equal to the intermediate frequency, and wherein
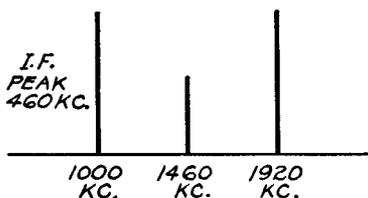
Fig. 103, left. In the broadcast band, the image frequency is higher than the received carrier by an amount equal to twice the intermediate frequency

I.F. PEAK 460 KC.

1000 KC.   1460 KC.   1920 KC.

CARRIER   1000 KC.
OSCILLATOR   1000 + I.F. = 1460 KC.
IMAGE   1000 + 2 I.F. = 1920 KC.

Fig. 104, right. This diagram illustrates the shift of the image frequency when the high-frequency band is being received

I.F. PEAK 460 KC.

1600 KC.   2060 KC.   2520 KC.
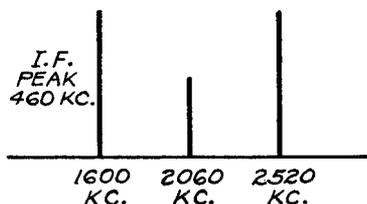
CARRIER   2520 KC.
OSCILLATOR   2520 − I.F. = 2060 KC.
IMAGE   2520 − 2 I.F. = 1600 KC.

the same oscillator frequency is lower than the received carrier on the short-wave band by a value equal to the intermediate frequency. Perhaps an example or two will clarify. For example, if the broadcast band covered is from 1600 kc. to 540 kc., and the intermediate frequency is 460 kc., the frequency range of the oscillator is from 2060 kc. to 1000 kc. This frequency band can be used to heterodyne another band of frequencies, which is 460 kc. higher at all times. In other words, if a short-wave band, with

a high limit of 2520 kc., and a low limit of 1460 kc., is mixed with this oscillator band of from 2060 kc. to 1000 kc., the required intermediate frequency of 460 kc. will be produced throughout the band. An example of such a receiver is the Stewart-Warner R-142-A and R-142-AS chassis, which are used in the Models 1421 to 1429 receivers.

In this connection it is interesting to note that the relation between the image frequency and the carrier frequency changes as the tuning band is changed. For example, if you refer to Fig. 103 you will find that for any received carrier on the broadcast band, the image frequency is higher than the received carrier by an amount equal to twice the intermediate frequency. This condition is applicable to all conventional types of superheterodyne receivers. However, when the receiver we mentioned is tuned to the high-frequency band, the oscillator frequency is *below* the carrier, so that the image frequency, which is *higher* than the received carrier on the broadcast band, is *lower* than the received carrier on the high-frequency band. Again we repeat that the reason for this is that the operation of
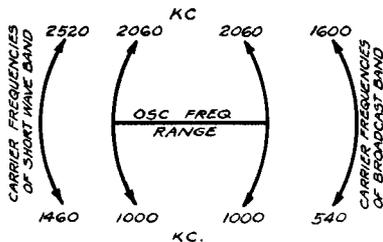
Fig. 105, left. The same range of oscillator frequencies is used for both the broadcast and short-wave bands in some Stewart Warner sets

Fig. 106, right. The second harmonic of the oscillator frequency is used for heterodyning on the short-wave band in certain RCA receivers
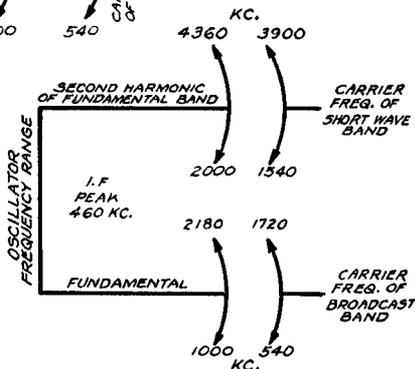
the receiver is such that the oscillator frequency is lower than the received carrier frequency. The shift of the image is shown in Fig. 104.

In this type of receiver only the radio-frequency and mixer circuits are changed when bands are switched. The oscillator circuit remains unchanged and is maintained intact for both the broadcast and the short-wave bands. This is shown in Fig. 105.

The second type is that which is used in the RCA T5-2 receiver

In this set the tuning range of the oscillator circuit remains intact, but when the radio-frequency circuits are set for the short-wave band, the heterodyning frequency is the second harmonic of the fundamental oscillator band. This is shown in Fig. 106. For example, the broadcast range of the receiver is from 540 to 1720 kc. With an intermediate frequency of 460 kc. and the oscillator frequency *higher* than the carrier frequency, the heterodyning frequency band extends from 1000 to 2180 kc. The short-wave band range is from about 1540 kc. to approximately 3900 kc., and this band is heterodyned by the second harmonic of the fundamental range of the oscillator, namely by frequencies of from 2000 kc. to 4360 kc. This band represents the second harmonic of the fundamental range of from 1000 to 2180 kc.

Receiver Poor on Weak Signals But Apparently Normal on Strong Signals.

In some receivers which employ separate mixer and oscillator stages, wherein a resistive and capacitive form of coupling is used between the oscillator and the mixer, a condition develops wherein the receiver seems to perform normally on strong signals, such as local broadcasts, but is poor on weak signals.

Possible defects are:
    a. rosin joint in coupling circuit between mixer and oscillator
    b. low oscillator output
    c. open coupling condenser
    d. open coupling resistor

APPENDIX

INTERMEDIATE PEAK FREQUENCIES OF

COMMERCIAL RECEIVERS

This list is by no means complete. For further details on commercial radio receivers refer to Rider's Manuals

AIR KING

Model	KC
Atlas 5-Tube Universal All-Wave.	456
Knave	456
Royalty	456
5-Tube Atlas Universal AW	456
7-Tube BC Super	175
27, 28A	456
37, 39	456
47, 48, 57, 58	456
52, 54	456
66	456
70	456
209, Prince	456
211, 224, 225	456
213, King	456
221, 222, 223	456
Regent, Autocrat, Council	
227, 228, 229	456
Premier, Palace, Pirate	
600	456

ALL-AMER. MOHAWK
See WURLITZER

ALLIED RADIO

Model	KC
P	175
Knight 6 tube	175
Knight 7 tube	175
Knight 7-tube Super '32	175
Knight 12 tube	177.5
Knight (12-tube Super)	177.5
Knight 118 AVC	175
Knight 118 AVC Super	175
Knight E-9830	177.5
Knight E-9831	177.5
80 AC	456
F-9501	456
F-9505	456
F-9511	456
G-9511-13	465
F-9515	456
G-9515, G-9881	456
G-9517, G-9882	175
F-9531, F-9591	456
G-9533 (two types)	465
F-9541	175
G-9545, G-9547, G-9549	465
G-9553	456
G-9557	456
G-9561, G-9563, G-9565, G-9567	456
G-9561, G-9563, G-9565, G-9567, Late	465
F-9571	465
G-9575, G-9605 incl.	456
F-9591	456
F-9610	485

Model / KC

Model	KC
G-9611, G-9613	465
G-9615	465
G-9617, 9619, 9621, 9623, 9625, 9627	465
G-9629, 9631, 9633, 9635, 9637, 9639	465
F-9631	456
G-9643, 9645	465
F-9660	177.5
F-9616	175
F-9640	177.5

AMER. FOUNDATION FOR BLIND

Model	KC
U	175
30	175

AMRAD CORP.

Model	KC
F-516	450
F-546	450
F-616	450
F-626	450

ANSLEY RADIO

Model	KC
B-1	456
D-3, D-4, D-6	175
U-3	175
U-8	175

ARVIN
See NOBLITT-SPARKS

ATWATER KENT

Model	KC
72 Chassis H-1, H-2	130
80, 80-F	130
82-D	130
82, 82-F	130
82-Q	130
83, 83-F	130
84, 84-F	130
84-D	130
84-Q	130
85, 85-F	130
85-Q	130
86, 86-F	130
87	130
87-D	130
89, 89-F, 89-P	130
90, 90-F	130
91-B, 91-C, 91	260
92	130
92-F	130

ATWATER KENT—Cont.

Model	KC
93	1,000
94, 94-F	130
96	130
96-F	130
99	130
99-F, 99-P	130
112	472.5
126, 136, 416, 446	264
135Z, 215Z	264
137	125
145, 325	264
E-145, E-145X	125
155	262.5
165 (2nd type), 185, 525	264
165-Q, 525-Q	264
168	125
184, 184-X	450
185-A	264
188, 188-F	130
206, 376 (1st type)	472.5
206D, 376D, Early	472.5
P216, P336	472.5
217, 427, 667	264
217-D, 427-D, 667-D	264
228	130
228-D	130
228-F	130
228-Q	130
236	125
237-Q, 467-Q, Early	472.5
246	262.5
255	450
260, 260-F	130
275	264
285-Q, 415-Q	450
286, 356	472.5
305-Z, 565-Z	264
310, 510	130
312, E312	472.5
317, 337, Early	472.5
328, 328X	472.5
337	472.5
385-Q, 625-Q	264
387, Late	264
387, 427-Q	264
P412, E412, P412X, E412X	472.5
424	264
425, 665	264
435	450
447	472.5
448	130
465Q, 655Q	264
469, 469-F	130
469-D	130
469-Q	130
475, 735	264
480	472.5
485Q, 515Q	450
487	472.5
509	472.5
511	472.5
534 (2nd type)	450
545	450
556	264
558-D	130
559	472.5
534	450
555	262.5
558-Q	130
558	130
567, 567-F	130
E608, E648	472.5
612	130
627	130
636	262.5
649, Early	472.5
657Q, 747Q	472.5
666	264
708, 808	472.5
710	472.5

Model	KC
P710	472.5
711	472.5
725, P725, P725X	450
P755, P755X, P875, P875X	264
756, 756-B	262.5
E765	472.5
768Q, 978Q	472.5
776	264
788	472.5
808-A	472.5
810	472.5
812	130
816, 926, 936 (1st)	264
825 AC-DC	264
856, 976, Early	264
944	450

AUDIOLA RADIO

	KC
7 Tube Super Pent. '31	177.5
8 Tube Super Pent. '31	177.5
9 Tube Super Pent. '31	177.5
10 Tube Super	177.5
9-T-45	177.5
23-S-7	177.5
23-S-8	177.5
23-S-8Q	177.5
23-S-10	177.5
23-S-12	177.5
23-S-12, Revised	177.5
33-A-6	177.5
33-S-6	177.5
33-T-4	456
33-S-5	456
33-S-7	456
33-S-10-SW	456
23-T-8-LW	177.5
33-S-6-B	456
34-C-5 AC-DC	456
34-S-5-AVC	456
34-S-5-LW	456
346, B-6	177.5
346, B-7	177.5
347	177.5
1931 Super	175

AUSTIN RADIO

	KC
S	175
SP	175

AUTOCRAT RADIO

	KC
5	456
5-SA	456
6-D-32	175
90-SL	175
505	456
518, 618	456

AUTOMATIC RADIO

	KC
A-5	480
J-50	480
J-60	480
J-80	456

BALKEIT RADIO

	KC
L-8	175
GT-16A	456
G-18A, G-19B	456
GT-20, GT-200X	456
GT-33	456
55	175
59	456
60, 70	456
69	456
100	175
GT-156BA	456

BARKER BROS.

Model	KC
L	262
M	262
P, 2 types	262

BELMONT

70-A	175
71-C	175
100	175
404, Early	465
415	465
522	465
523	465
525	456
530	456
540	456
541	456
544, 545	465
550	456
555	465
556 (Export)	465
566	465
575	175
578, 2 types	465
580	175
585, Series A, B	370
585, Series C, D	465
586, Series A	465
587	465
601	465
625	175
640	370
650	175
660	175
666	465
670	175
670-A	175
675	370
680	175
685	465
686	465
746	465
750	175
755	465
775	370
777B	465
777C	465
778	465
786	465
787	465
822	465
845	465
856	465
878	465
879	465
880, Series A, B	175
880, Series C	465
1050	175
1070	465
1170, 1172	465
1171	465

BOSCH

See UNITED AMER. BOSCH

BRETING RADIO

12	432

BRUNSWICK

3 NC 8	180
3 NW 8	180
5 NC 8	180
11, 12, 16, 33-AC	175
17, 24, 25	175

BUICK

Model	KC
See UNITED MOTORS SERVICE	
980393	262

BULOVA WATCH

600, 601, 605, 610	175
M-701	175
C-751	175
G-781	175

CADILLAC MOTOR CAR

06W	262
6-Q	175
2721 (072)	262
2722 (072A)	262

CAPEHART CORP.

202	465
203	465
400-A	180
400-B	180
400-D	465

CASE ELECTRIC

601, Chassis 16 SM	262.5
701, Chassis 16 SME	262.5
801, 802, Chassis 27 SME	262.5
1001, Chassis 19 RSME	262.5
1101, 1102, Chassis 110 RSME	262.5

CAVALCADE RADIO

357	456
359	456
3511	456

CHAMPION RADIO

5-Tube, 3-Band	465
6-Tube, 3-Band	465
52 (47 output)	456
52 (42 output)	456
52-DWG	465
400	175
500	456
501	456
521-U-D	456
525	456
526 DW	456
558	456
600	175
601	175

CLIMAX

AB, ABX, Early	456
ABX, Late	456
HE, J	456
SBT, JEBT	456
M	456
6-Tube Batt.	456
35	456
50 to 59 incl.	456
66	456
90 to 99 incl.	456
90B to 99B incl.	456

COLONIAL

44	175
47, 48	175
50	175
51	175

COLONIAL—Cont.

Model	KC
52	175
55	1,000
56	175
62	175
69	175
71	175
73	175
76	175
106-B	175
150	480
164	175
182	175
250, 279, 300, 301, 500	175
250 AC, 279 AC, 300 AC, 301 AC, 500 AC	175
T-345	175
T-397	175
C-399	175
400	175
C-495	175
501, 501 AC	175
C-595	175
600, 600-A	175
601	175
602	175
603	480
604	445
605	175
650	480
651	480
652	480
653	480
654	480
655	480
656	175
657	480
658	480
659	175
662	480
C-695	175
700, 701, 702	175
C-995	175

COLUMBIA PHONOGRAPH

Model	KC
32, 34	175
C-80-A	175
C-80-B	175
C-90	175
120-B	175
C-800	175

CONTINENTAL RADIO & TEL.

Model	KC
M-1	456
L2, ML156, ML266	456
Z-2	456
L4, ML 4	456
Z-4	456
L-5	456
L-6	456
L-7	456
X-8	456
A-31	456
137X, 150X, 171X	456
X-541	456
X-641, X-741	456

CORONA RADIO

Model	KC
110	456

CROSLEY

Model	KC
4A1	456
4B1, Battery Forty	456

Model	KC
5A1	181.5
5A3, Battery Fiver	181.5
5B3, Battery Fiver	456
5M3 Chassis, Fiver Jr.	456
5V1 Chassis, DeLuxe Fiver, L-B Chassis	181.5
5V2, Fiver DeLuxe	181.5
6B1, Battery Six	456
8B3, Battery 8 AF	456
50, 50 LB, Chassis 5H1	456
51, Chassis 5C2	181.5
Dual Sixty, Chassis 6V2, Dual Sixty-LB	181.5
Sixty One, Chassis 6H2, Sixty One LB	456
72, 72-LB, Chassis 7H2	456
72, 72-LB, Chassis 7H3	456
80AW, 80AW-LB, Chassis 8H1	456
96	181.5
98	181.5
99	181.5
102	181.5
103	181.5
119	181.5
120	175
121, Series A	175
121, Series B	175
122	175
123	175
124	175
124-1	175
125	175
126	175
126-1	175
127	175
127-1	175
128	175
129	181.5
129-1	181.5
131	175
132-1	181.5
133	181.5
134	181.5
134-1	181.5
135	181.5
136-1	181.5
137	181.5
141	181.5
143	181.5
146	181.5
146-1	181.5
148	456
150	181.5
154	456
155	456
156	456
A-156	262.5
157	181.5
158	181.5
159	456
160	181.5
163	456
164	181.5
166	456
A-166	262
167	456
168	181.5
169	456
169, Revised	456
170	181.5
171	181.5
172	456
173, 173-5	456
174	456
175	181.5
176	456
178	456
179	181.5
180	181.5
181	456
182	456
184	456

CROSLEY—Cont.

Model	KC
A-266	262
A-366	262.5
415	450
416	450
425	450
435	450
505, 525	450
515, 5515, Fiver	450
516, 5516, 6516	450
526, 5526	450
534	456
535	450
536, 5536	450
545	450
546	450
555, 5555	450
556	450
566	450
605	450
614, 6H3	456
615, Cruiser	450
616	450
626	450
629, 644, Chassis 666 & 5666	450
634, 649, Chassis 656 & 5656	450
635, Buccaneer	450
636	450
645, 32 DC Six	450
646	450
655, Olympia	450
714	456
715, Corsair	450
725, Viking	450
744, 745, Chassis 716	450
759, Chassis 736	450
769, Chassis 726	450
814	456
815, Battery 8	450
816	450
855, Merrimac	450
865	450
915, Clipper	450
916	450
926	450
955	450
1014, Centurion	456
1016	450
1026	450
1055, Constitution	450
1155	450
1199	450
1216	450
1316	450
1336	450
1516	450
6615	450
6625	450

DELCO APPLIANCE

Model	KC
RB-1	175
RC-1	175

DELCO RADIO

See UNITED MOTORS SERVICE

Model	KC
3026	175

DETROLA

Model	KC
Roadmaster	456
5-Tube Super, Midget	459
5B	370
5D	455
5W	370
5-WG	370
5X	370
6A	262
6M, 6R	262

Model	KC
6W	370
6X	370
6ZM	370
7A	262
7ZM	370
10ZM	456
100	456
101	456
101-A	456
102	456
103	480
106	456
106-E	456
108	456
109	456
111	262
114	456
116	456
503	456
1200	175

DEWALD

Model	KC
B-A-G	175
BAH	175
B-A-H-9	175
B-A-M	465
BLG	115
K-A-F	175
50	175
51	175
52	175
55	456
55-R	456
55-X	456
56	455
58-EX	456
58-L, 59	456
58-R	455
59	456
60	455
61	456
62	175
80	456
81	456
81-R	456
100	456
500-A	130
501	456
503-4	456
505	456
505-F	456
505-R	456
510	456
517	456
520	456
522	456
527	456
553	456
553-4S	456
570	456
600	456
605	175
606, 617	175
607	456
609, Late	456
610, 610-LW	456
611, 611-LW	456
612, 612-LW, 615, 615-LW	456
616	456
618, 618LW	456
619	456
620, 620LW	456
621, 621LW	456
630	456
640	175
AC-746-7M	175
802, 803	456
804, 805	456
804, 804S, 805A, 805C	456
811-A	456
1100	456

EMPIRE

Model	KC
30	175
40	175
40 SW	456
51	175
60	175
71	175
74	462.5
450-A	456
460-B	456
470-C	456
480-C	456
575	175

ESPEY MFG. CO.

Model	KC
674	456
675	456
5111	456

FADA

Model	KC
NF	125
RN	470
RX	125
RY	470
45, 45-Z (KU)	175
48, 49 (KW)	175
51 (KO)	175
53, 57 (KOC)	175
55 (RG)	175
66 (KY)	175
73, 85 (RE)	175
74, 76, 83, 88, 89 (RA)	175
78, 79 (RC)	175
101 (RK)	175
102 (RP)	175
104-B (RV)	175
105, 106, 107 (RN)	470
112 (RS)	470
126, 127, 128 (NK)	262.5
131, 132 (RU)	265
133, 134, 135, 78-10, 79-10, 97-10	265
141 (NA)	265
150, 2 types	456
151, 152 (NE)	265
155	456
156	456
157	456
160 Series	456
166, Motoset	175
167	456
168	456
170	456
190	456
192	456
211	456
250, 2 types	456
260	456
262	456
270	456
271	456
272	456
273	456
280	456
281	456
290	456
291	456
311	456
1462, 2 types	456
1462, Revised, above Serial 22102	456
1463	456
1556	456
1582	456
1583	456

FAIRBANKS MORSE

Model	KC
B6	177.5
C-6 Auto	177.5
12C6, Chassis 120	456

Model	KC
40	456
41	456
54	456
56	456
57TO	456
58T1, 58T2, 58C1	456
61	456
63	456
64 Battery	456
64, Auto	177.5
66	456
67	456
69, 68T6, 69T7	456
71	456
72T3, 72C2, 72C3	456
74 Auto	177.5
82	456
90	456
91T4, 91C4, 91C5	456
100	456
110 (Temporary)	456
346	177.5
347	177.5
816, 840, 32-Volt	177.5
5106, 5107, 5108, 5109, 5111, 5112, 5141, 5143 (51)	456
5212, 5212-A, 5241 (52)	456
5312, 5312-A, 5341 (53)	456
6010, 6044, Chassis 60	456
6210, 6244, Chassis 62	456
7014, 7040, 7052 (70)	456
8110, 8141, Chassis 81	456

FEDERATED PURCHASER

Model	KC
6-A, 12-A	175
8-A	465
8B, 9B, 11B	456
14-A	175
29C, 30C, 31C	456
31-40	175
32-A, 36-A	175
32C, 33C	456
35, 40	175
38-A	456
39-A, 43-A, 44-A, 86, 87	485
42T0B, 42C1B	456
43T1B, 43C1B	456
49	456
65, 66	455
73T3B, 73C3B	456
79, 80	175
88	455
93, 94, 96, 97	370
117	465
121	456
228, 229	456
248	175

FIRESTONE

Model	KC
R-1651AS, R-1651WS, Air Chief, Chassis R-165	456
R-1661, Air Chief, Chassis R-166	456

FORD MOTOR CAR

See also PHILCO

Model	KC
N, Center Control	260
Ford-Lincoln Auto Set Built by Zenith	252.5

FORDSON

Model	KC
FP	456
FP Battery (173501 up)	456
FP (330001 up)	456
FU	456
FW	456
FP-32V	456

FRANKLIN

Model	KC
53	456
54-L	456
63-L	130
94	450
100	175
102	175
200	175

FREED MFG. CO., INC.

FE-52, FE-56, FE-58	456
357-L	132
357-P	456
369-S	456

FREED TEL. & RADIO

A-7	456
A-9	456
51 DC	175
58 AC	175
72, 74, MB-7	175
FE-98	175
354	456
355	456
360, 360X	175
365, 365X	456

JESSE FRENCH EXP.

5X, 6X, 7X	175

JESSE FRENCH & SONS

U-1	175

GALVIN

Golden Voice	262
Dual 6	262
Twin 8	262
J-8	175
S-10	175
44	456
50	262
55	456
57, 62	456
60	262
66	456
75, 79	262
77	456
77-A	456
80	262
100, Type 1	262
100, Type 2	262

GAMBLE-SKOGMO

2-QDM-578	456
5-Y	175
06-A	175
6-U	262
07-A	175
7J-512, 7J-574	456
11-B	456
20C7, 20C8	456
22-CM-576	456
26-B-5	175
26-FM-552	456
26-R-1	175
26S1	175
27C1, 27C5	175
31-BT	465
34BT	465
36-L	456
46-L-1	175
51-C	175
70	262
71C	175
77-A	456

Model	KC
85	263
92D, 92M	175
400-A, 410-B	456
404	465
430	456
516, Symphony	456
Z516	175
Z-521	175
525	456
Z-530	175
540	456
550, Battery, AC	456
566	465
575	175
578	465
580	175
585, Series A, B	370
585 Series C	465
586-A	465
650	456
660	175
670	175
670-A	175
675	370
680	175
686	465
750	175
770	465
777C, 777L	465
778-A	465
780, 780B	456
810, 850B	456
1050	175
2056AW	456
2078-D	455
2090	262
2092, 2094	262
3084, 3086, 3132, 3134, 3140..427 & 455
3128	455
6953-A	465
7735, 7742, 7755	465

GAROD

26	456
31, 31LW, M-33, M-33LW	456
M-32, M-32LW	456
35SW	456
49, 49M	456
60	456
73, 73LW	456
104, 104M	456
311	456
511-A, 511-G, 511-P	456
514	456
514M	456
520	456

GENERAL ELECTRIC

S-22	175
S-22-A	175
S-22-D, S-42-D	175
H-31	175
H-32	175
B-40	175
C-41	175
M-41	460
M-42	460
S-42	175
S-42-B	175
K-43	460
M-49	460
D-50	175
E50, E52	465
K-50-P, K-51-P	175
K-50, K-51	175
L-50, L-51	175
M-50	460
D-51	175
E-51	465
H-51	175

GEN. ELECTRIC—Cont.

Model	KC
M-51	460
M-51-A	460
A-52, A-55	465
B-52	175
K-52, K-53	175
M-52	460
A-53	465
L-53	175
A-54	465
K-54-P	175
K-55	175
K-58	175
A-60	175
C-60	175
K-60	175
K-60-P, K-65-P	175
N-60	175
C-61	175
E-61, E-62, E-63	465
M-61	460
C-62	460
K-62	175
M-62	460
A-63, A-65	465
K-63	175
M-63	175
A-64, A-67	465
K-64	370
K-64-D	370
K-65	175
M-65	370
K-66	175
C-67	175
M-68	370
M-69	460
A-70, A-75	465
C-70, C-75	460
J-70	175
E-71, E-72, E-76	465
D-72	175
H-72	175
J-72	175
J-75	175
K-78	175
E-79	465
K-79	175
J-80	175
K-80, K-80-X, K-85	445
A-81	175
B-81, B-86	175
E-81, E-86	465
M-81	460
A-82, A-87	175
J-82	175
A-83, A-85	175
J-85	175
K-85	445
M-85	460
J-86	175
M-86	460
K-88	445
K-88-X	445
M-89	460
A-90	175
E-91, F-95	465
H-91, H-91-R	175
J-100	175
E-101, E-105, E-106	465
J-105	175
K-105	175
K-106	106
M-106	460
J-107	175
K-107	175
J-109	175
A-125	465
J-125	175
J-125-A	175
M-125	460
E126	465

Model	KC
K-126	175
M-128	175
M-128-R	175
E129	465
M-129	460
S-132	175
E155	465

GENERAL HOUSEHOLD

Model	KC
410, 411, Chassis 4NB	465
450 (4A)	455
460, 461, 460X, 461X, Chassis 4B, 4BX	455
470, (Chassis 4C)	490 or 465
500 (Chassis 5-A)	
501	455
501, 520, 530, 550 (Chassis 5-B)	455
502, 503	455
502, 503 (Chassis 5-C)	465
510, Chassis 4NB	465
532, Chassis 5H	465
542 (5J)	465
550 (5B)	455
551, 553 (5K)	465
555, 572, 573, Chassis 5L, 5Q	465
560, Chassis 5E	455
564, Chassis 5R	465
566, Chassis 5S	465
570, 571, Chassis 5D, 570X, 571X, Chassis 5DX, 570Z, 571Z, Chassis 5DZ	455
573 (5Q)	465
580, 581, Chassis 5G	465 or 490
614, 618, 625	262
620, 621, Chassis 6HB	465
631, 643	465
640, 641, Chassis 6J	465 or 490
650, 651 (6A)	262
660, 661, 662 (6C)	262
670, 671, Chassis 6D; 690, 691, Chassis 6F	455
680, 681, Chassis 6G	465 or 490
690, 691, Chassis 6F	455
700, 701	262
700, 701, (Chassis 7-A)	262
711 (7NB)	455
720, 721, Chassis 7DB	465
723, 731, 735, 733, Chassis 7M	465
750, 751, 752, 753 (7B)	262
760, 761, Chassis 7C	465
801	262
801, (Chassis 8A)	262
821, (Chassis 8B)	262
823, 831, 833, 835, Chassis 8H	455
861, (Chassis 8D)	455
871, Chassis 8E	455
901, 902	262
901, 902 (9A)	262
921, Chassis 9C	262
941 (9E)	455
1101	262
1101 (9B-2A)	262
1151, 1152, Chassis 11A	262
1151, 1152, 1161, 1162, Chassis 11A (type 2), Chassis 11B	262
1161, 1162 (11B)	262
1171, Chassis 11C	455
1191, 1191 B (11G)	465
1241, Chassis 12A	455
1291, 1297, Chassis 12B, 12W	465
1541, Chassis 15W	455

GENERAL MOTORS

Model	KC
211	175
216, 217, 219, 250, (S-1A, S-1B)	175
220	175
251 (S-2A, S-2B)	175
252 to 258 inclusive	175
281	535

GILFILLAN

Model	KC
5C, 5T, 32, 35, 41	175
5X, 34, 55A, 55B	450
6C, 6T	262.5
7A, 700	175
8C, 8T, 47, 50	262.5
8X	265
52A, 54A	460
55A, 55B	450
62B-X	175
63B, 63X	460
78 B, 78X	460
116B, 116X	460
501T	460
510, 520	175
515, 525	460
521T-C	460
615, 625	262.5
715, 725	460
723T-C	460
815, 825	262.5
831T-C	462
1131C	462

GOODYEAR

540	456
575	175
580	175
585 Series A, B	370
585 Series C	465
670	175
675	370
711T	175
731T-C	460
777, Series A & B	465
1331C	462

GRAYBAR ELECTRIC

GT-7	175
GB-8	175
GB-8-A	175
GT-8	175
GT-8-56	175
GT-8-69	175
GB-9	175
GT-10-69	175
GT-10-88	175
GT-10-99	175
GC-14	175
GG-15	175
GB-100	175
340	180
600	175
GB-700	175
GB-770	175
GB-989	175

GREBE

HS-3	175
HS-4	175
HS-5	175
HS-6	175
HS-7	175
HS-8	175
HS-12	175
61-R	456

GRIGSBY-GRUNOW

10 Chassis, 11, 58, 204, 294	1,000
15, 15-B, 150 Chassis, 151, 153, 154, 155, 156	175
20 Chassis, 21, 22, 23	175
25 Chassis, 251, 253, 254	175
25-B Chassis, 251-B, 253-B, 254-B	175
35 Chassis, 351, 353	175
44, 49, 194 (Chassis 440)	456

Model	KC
50 Chassis, 51, 52	175
55 Chassis, 56, 57, 58	175
55, 59, 75, 195, 560, 566 (Chassis 500)	456
60 Chassis, 61, 62	175
66	175
95, 105 (Chassis 520)	175
114	175
116	456
120 Chassis, 121	175
120-B Chassis, 123	175
150	175
200 Chassis, 201, 203, 204	175
210 Chassis, 211, 214, 215	175
220 Chassis, 221, 223	175
290 Chassis, 291, 293, 294	175
300 Chassis, 303, 304, 307	175
310-A Chassis, (2 types), 311	175
310-B Chassis, (2 types), 314, 315	175
320 Chassis, 324	175
330 Chassis, 331, 336, 77	175
340 Chassis, 344	175
360 Chassis, 363	175
370 Chassis, 371, 373	456
390 Chassis, 393	175
400 Chassis, 411, 413	456
460, 461, 463	175
490, 491, 493	175

GRUNOW

See GEN. HOUSEHOLD

GULBRANSEN

06W	262
V6Z2	262
Z6Z1	262
10	175
13	175
20	175
23	175
53	175
92, 93	175
322	175
352	262
362	262
392	175
872	175

HALLICRAFTERS

Super Skyrider	465
S8A	465
S9, SX9	465

HALSON

Roadmaster	456
AW6	456
6L6	456
20 B	456
50S	456
50X	456
NS 50	456
60L	456
60M	456
MA63	456
66 AW	456
100, 100M	456
520	456
530	456
535	456
536	456
580	456
610 Dual Wave	456
620	456
630	456
770 AW	456

HAMMARLUND

Model	KC
Comet Dec. '31	465
Comet July '32	465
Comet Pro	465
Comet All-Wave	465
"Comet Pro" AVC	465
Super Pro	465

HETRO ELECTRICAL

Model	KC
6-Tube AC	456
6-Tube, AC-DC	456
8-Tube Superhet	456
9-Tube Air-Ace	456
F-5 to F-8 incl. Series FA	456
6LB, 6SB	456
F- 9 to F-12 incl. Series FA	456
F-13 to F-20 incl. Series FA	456
F-21 to F-28 incl. Series FA	456
22, 2 types	115
31, 2 types	175
71	456
207, 257	456
209, 259	456
295	456
297	456
412	456
466	456

HOODWIN

Model	KC
6 Tube DC	175
6 Tube Batt.	175
Internation Aero	485

H. H. HORN

Model	KC
5	465
5A	465
5MT	465
5MTD	465
7MT	465
9MT, 9MTC	1,600
10MT	1,600
17MT	1,600
24	465
36	465
51	465
52	465
55	465
58	465
59, 69, 90	175
62	465
63	465
66MT	465
70, 71	175
76	465
77	465
79, 99, 109	175
83	465
101-B, 102	175
101, 110	175
156	465
156AW	465
158	465
535	465

HOWARD

Model	KC
A (SW Converter)	680
EX	140
EX, Dual Range	140
F	465
M	175
Q	170
W, Explorer, (Type 1)	465
W, Explorer (Type 2)	465
Grand	465
S-2, S-7	175
X-2, X-3, X-8	175

Model	KC
HA-3	456
HA-4	175
HA-6	465
Z-4	175
5-3	456
R-9	465
B-13	456
E-14, E-107	456
20, 25, 30, 32 (O)	175
CC-23, CC-24	456
35, 40 (H)	175
35-A	175
35-A (Chassis AVO)	175
45, 60 (AVH)	175
57-A	456
57-AUS	456
E-57	456
58	465
60	456
60-SW	456
67LW	465
68	465
77 Long Wave	465
77-C, 77-T	465
99 Long Wave	465
99-C, 99-T	465
420	175
400 Chassis K	175
626, 1626, 67T, 67C	465
670-A, HA-1	175

HUDSON-ROSS

Model	KC
59	456
69	456
80	456

INSULINE

Model	KC
AVC Super seven, LW	115
AVC Super six LW	115
AVC Super six	175
Classic	132
Elite	132
"Icasix" (2 bands)	462.5
Super Conqueror	115
Super seven	175
Unaradio 5-tube	132
Uni-nine	115

INTERNATIONAL

Model	KC
A, B, Kaydette	262.5
CB (Battery)	262.2
CM	262.5
CM	262.2
CMS	262
CS	175
JS	175
KS	175
A-7, BW, CD	262.5
A-7, BW, CD (DAC)	262.5
A8, 9, 10	262.5
A-8, A-9, A-10, AD-11, AD-12 (Chassis DAS)	262.5
DA-8, DA-9, DA-10, D-11, D-12, D-14 (Chassis D, DSP)	262.5
D-11, 12, 14	262.5
ES-19, ES-20, ES-30 (Chassis ES)	262.5
ES-25	262.5
40, 41, 43, 44, Jewel	448
52	448
53, 553	448
AW-55	445
60	262
61, 661	448
65	262
66X, 86, 96	448
70	262
71	456
71C	456

INTERNATIONAL—Cont.

Model	KC
72	448
77, 777, 778, 779	448
85	456
87	448
90, Early	262
90, Late	456
105, EL-105, 1050	456
120, 1200, 2200	448
380 & 381 Series	456
400	448
500	448
930 & 931 Series	456
1240 Series	456
1650 Series	456
4110 Series	456
5140 Series	456
5240 Series	456

INTEROCEAN

Model	KC
500, 515, 516, Chassis 2037	175
520, 521 (Chassis 2035)	175
530, 531, 533 (Chassis 2038)	175

JACKSON-BELL

Model	KC
25	175
27	175
28	175
29	175
33	840
86	175
87	175
88	175
89	175
89-A	175
99	175
205	465

JACKSON RESEARCH LABORATORY

Model	KC
NJ-8	175

KENNEDY

Model	KC
52	175
53-SW	1,000
54-SW	1,000
54	1,525
56	175
62	175
62-A	175
64	175
66, 66-A	175
164-B	175
266-B, 366-B	175
563-A	175
882-62D	175
882-64C	175

KINGSTON PRODUCTS

Model	KC
55	456
500, 500-A	456
600-A, 600-B, 610-B, Early	182.5
600-A, 600-B, 610-B, Late	172.5
700, 700-A, 700-B	456

KOLSTER

Model	KC
K-60, K-62, K-70, K-72	175
K-63, K-73, K-103	175
K-80, K-82	175
K-83, K-93, K-114	175
K-90, K-92	175
K-110, K-120, K-122	175

Model	KC
K-113, K-123	175
K-130, K-132	175
K-133, K-143	175
K-140, K-142	175

LAFAYETTE
(See also WHOLESALE)

Model	KC
P.A. Tuner	456
S-W. Converter	540 to 560
L-1, L-2, L-3, L-4	175
A-7, M-69, M-70	115
AM-8	115
AM-10	115
LW-10	175
10C10	175
L-11, L-12	175
A-15	175
L-16, L-17, L-18, L-19	175
A-20	175
AM-20	175
E-20, E-204	115
AM-25	115
AM-26	175
L-30	262.5
M-35, 37, 53	175
M-47	520
B-51, B-52, B-53, B-54	175
B-60	175
C-60	175
B-62	175
C-79, C-80	456
80-M, 2 types	175
137-X, 150-X, 171-X	456
143, 144, 149	456
151, 154, 186, 188	465
324	456
S-17762	262

LANG

Model	KC
UG-5B	456
MA-7	175
MD-7	175
SA-7	175
SA-8	175
MA-8	175
MD-8	175
40-UL	470
50-AS	470
50-UP, 60-UP	470
50-US	470
60-AA	470
80-UA	470
502-US	456
503-US	470
503-AS	175
503-UT, 523-UT	470
703-US	175

LARKIN

Model	KC
84	175
88	175
90	175
91	175

LEUTZ

Model	KC
C-10	47

LEWOL

Model	KC
63	262.5

LINCOLN

Model	KC
R-9	480

R. H. MACY

Model	KC
410 AC-DC	456
706-70623	456

MAJESTIC

See GRIGSBY-GRUNOW

MAJESTIC RADIO & TELEV.

65, 66, 650	456
75, 76, 750	456
85, 86, 850	456
1050	456

MID-WEST

Miraco Pentode 11-Tube Super	175
Regal	456
Royale	456
18 tube Imperial	456
5-35	465
5-36	456
6-37	456
6-37 Auto	175
7-35, 7-36	456
7-37 Battery	465
7-37	456
8-33, 2, 3 gangs	450
8-33	456
RT-9, G-9, F-9, H-9	456
9-31	175
9-34	456
10-34	456
10-A-33-34	456
10-35	456
10-36	456
10-37	456
11-31	175
11-36	456
11-37	456
12-33	450
14-37	456
14-37A	456
RT-16, A-16, B-16, D-16, PR-16, RM-16	456
16-33	450
16-34	450
16-35	456
16-37	456
18-36	456
18-36A	456
18-37	456

MISSION BELL

10A	252
11	252
14	456
16	465
16 Auto	456
17, 18	262
19, 19A	252
25-A	252
40	456
40 All Wave	465
41 AW	465

MONTGOMERY WARD

Auto Radio	262
13, 15, 16, 16X, 17, 18, 18X	262
17	175
62-1, 62-2	175
62-7, 62-8	175
62-9	175
62-11, 62-12, 62-14, 62-27, 62-19	175
62-20, 62-20X (62-25)	175

Model	KC
62-22, 62-30 (62-21)	262
62-29 (11-12)	175
62-38, 62-40, 62-50	262
62-89	175
62-91	175
62-93	175
62-96	262
62-97, 62-99, 62-97X, 62-99X	262
62-98	262
62-101, 62-101X	262
62-103, 62-105	175
62-104	262
62-106, 62-107, 62-121	175
62PC55	465
62PC64	175
62PC68	175
62-70, 62-70X, 62-72, 62-72X	456
62-114, 62-116	175
62-118	262.5
62-120, 62-122, 62-126, 62-128	175
62-124, 62-129	456
62-130	175
62-132, 62-137	456
62-134, 62-134X, 62-139, 62-139X, 62-167	456
62-135, 62-135X, 62-150, 62-150X, 62-154, 62-154X	370
62-136, 62-138	175
62-140, 62-140X, 62-148, 62-148X,	175
62-147, 62-147X, 62-156, 62-156X, 62-164, 62-164X, Series A	370
62-147, 62-147X, 62-156, 62-156X, 62-164, 62-164X, Series B & C	465
62-166	175
62-169, 62-171	465
62-173, 62-175, 62-176, 62-177, 62-188, 62-193	456
62-178, 62-181, 62-189, 62-211	175
62-179, 62-194, 62-206, 62-216, 62-218	456
62-185, 62-187, 62-190, 62-196. Three types	456
62-192, 62-195	456
62-197	456
62-199	175
62-202	175
62-203, 62-205, 62-208, 62-212, 62-217, 62-219	456
62-207, 62-209, 62-221	456
62-215	456
62-226, 62-228, 62-259, 308-318-408-418	456
62-229	175
62-230, 62-240	465
62-233	465
62-235, 62-248	465
62-236	175
62-242	175
62-251, 62-255, 62-338 & 62-428	465
62-261, 62-311, 62-411	456
62-307, 62-407	465
62-326, 62-336, 62-426, 62-436	456
62-316, 62-416	465
62-310, 62-410	456
62-313, 62-413	456
62-325, 62-415	465
62-425	465
77, 95	175
87	262
811 (62-1711)	175
1111 (62-1611)	175
1238 (62-1838)	262
1355 (62-1955)	262

MOTO-METER

MotoVox 10-A	175

MOTOROLA

See GALVIN

NATIONAL

Model	KC
AGS	500

NOBLITT SPARKS

Arvin 10-A (2nd Type)	175
Arvin 15	175
Arvin 16	175
Arvin 17	175
Arvin 18	170
Arvin 25	175
Arvin 27	175
Arvin 28	175
Arvin 30-A (3rd Type)	175
Arvin 33	175
Arvin 35, Early & Late	175
Arvin 37	175
Arvin 41	456
Arvin 45	175
Arvin 51	456
Arvin 51-B	456
Arvin 61, 62	456
Arvin 61-B, 62-B	175
Arvin 61M, 62M	456
Arvin 81	456
Arvin 81M	456
Arvin 417, 467	456
Arvin 517, 527	456
Arvin 517-B, 527-B	456
Arvin 617, 627	456
Arvin 617-B, 627-B	456
Arvin 927	456
Arvin 1127	456
7	170
10-A	175
20-A	175
20-B	175
30-A	175

NORCO

4 Super	250

OZARKA

93	175
93-A	175
93-B	175
94-AVC	175

PACIFIC RADIO EXCHANGE

Spero Super	175

PACIFIC RADIO CORP.

5SW	456
6V	465
A60B	465
61	456
31A	465
101 Auto	456
101 & 101C	456
102	175
102B	262.5
321-36	465
321-37	465
480	456
682	465
3280	465
6320	465
6322	465
6370	465
7370	465
14370	465

PACKARD BELL

Model	KC
5	460
25	460
35	460
35A	460
36	460
45M	460
46	460
47M	460
48	458
50	460
65	465
65 Auto	460
67	460
76	465
86	465

PACKARD RADIO

4 Tube Super 5	465
6 Tube Auto	470
4, 24, 24-C	235
85	470

PATTERSON

PR-16, Series A & C	458
60 Series	465
70-AW, 107-AW, 207-AW, 210-AW	262
75AW, 175AW, 275AW, 375AW	458
80-AW, 84-AW, 508-AW	262
85AW, 185AW, 285AW, 385AW	432
86AW	458
87, 87A	465
104-AW, 510-AW	262
105AW, 1105AW, 2105AW, 3105AW	432
106AW	458
107-A, 107	465
126AW	458
127, 127A	465
186-AW, 286-AW, 386-AW	458
1106-AW, 2106-AW, 3106-AW	458
1126-AW, 2126-AW, 3126-AW	458

PETER PAN

Also see JACKSON-BELL

B	465
25AV, 25UV	255
45	465
56	465

PHILCO

C, D, E, H, J, N, R, Q,	260
DPV	260
G	260
T2-CT2, HT2, T5,-CT5, PT5	260
T3-MT3, RT3, ST3, T6, FT6	260
4	1,000
5	460
6	260
7	175
T7, T8	260
8, 12	175
9	260
T9, T11, T12, T14, T15	260
10	260
10 (Code 122)	260
11	260
12	260
14	175
14, 91	260
14 (121, 122, 123)	175
14 (221, 222)	260
15	175
16	460

PHILCO—Cont.

Model	KC
17	175
18	260
19, 26, 27	260
19-128	260
22-L	260
22-L, 22	260
23	260
23-X	260
28	460
29, 29TX	460
32	260
34, 34-A	460
35	260
35, 36	260
37	175
37-9	470
37-10, 37-11	470
37-33	470
37-34	470
37-38	470
37-60	470
37-84	470
37-89	470
37-116	470
37-600	470
37-602	470
37-604	470
37-610	470
37-611	470
37-620	470
37-623	470
37-630	470
37-640	470
37-641	470
37-643	470
37-650	470
37-660	470
37-665	470
37-670	470
37-675	470
37-690	470
37-2620	470
38, 38-A	460
39, 39-A	460
43	450
43, 25	460
44	460
45	460
47	260
47DC (121-221)	260
48	175
49	260
51, 51-A	175
51, 51-A, 52, 24, 551	175
53	450
53	460
54	460
57	460
57, 58	460
59	460
60	460
66	460
70, 70-A	260
71	260
80	450
80	460
81	460
84	460
89	260
89, 19	260
90, 90-A	175
90, 90-A (with two '45s)	175
90, 90-A (with 2-47's)	260
90, 90-A (with one '47)	260
91 (121-221)	260
91(221, 222)	260
97	460
111, 111-A	175
112, 112-A	175
116	460

Model	KC
116, 116-A	175
118	260
144	460
200, 200-X	175
201	260
211, 211-A	175
212, 212-A	175
270, 270-A	260
270, 270-A, 370	260
470, 470-A (SW-IF)	1,000
(Broadcast IF)	260
490 (SW-IF)	1,000
(Broadcast IF)	175
503	260
504	460
505	460
506	460
507	260
509	260
570	260
600	460
602	460
604	460
610	460
611	460
620	460
623, 623A	460
624	460
640	460
641	460
642	460
643, 643A	460
645	460
650	460
651	460
655	460
660	460
665	460
680	460
700	460
800	260
802	260
805	260
806	260
809	260
810PV	260
811PV	260
816	260
817	260
818	260
819, 819H	260
826	260
P1417, G1418, N1418	260
P1421	260
L1424	260
P1430, S1431	260
N1433H, N1433, G1436	260
F1440	260
C1450, C1452	260
2620	460

PILGRIM

Model	KC
D, DE	456
DA, DAE	456
DB, DF	456
G, GE	456
GB, GF, GBE, GFE	456
GH, GHE	456
NT, NTE	456
NTH, NTHE	456
RJH, RJHE	456

PILOT

Model	KC
SW Converter	550
4 Tube DC	482.5
2	456
B-2	456
D-3	456
7, 8, 81, 84 (Dragon A-W. Super)	115

PILOT—Cont.

Model	KC
8, 81	115
10-AC	115
11	115
F-14	456
18	456
20	456
28	115
39	115
41	115
41	456
X-41, Y-41	456
43, X43, 45, X45, Y43, Y45	456
53	115
55	115
63	456
X-63, X-65	456
X-68, X-69	456
73, 75	456
X-73, X-75	456
81	482
103, 105	456
108, 109	456
114, 115	456
123	456
125	456
S-148, S-164	175
C-153, C-154	175
153, 155	456
C-162, C-165	175
183, 185	456
193, 195	456
203, 205	456
213, 215	456
253, 255	456
293, 295	456
304, 305	456
364, 365	456
393, 395	456
1010	115

PLAZA MUSIC

Model	KC
5 Tube Super	456
6 Tube Long Wave	175
7 Tube Super	175
711 Super	175

PRECISION RADIO

Model	KC
6-Tube A-W Superhet	465
8-Tube A-W Superhet	465
511	465

RCA

Model	KC
SW Adaptor	1,000
9-Tube General Purpose	445
9-Tube General Purpose A-W	445
R-2-S	175
SWA-2	1,075
4T	460
R-4, R-6	175
4X, 4X3, 4X4	460
T4-8, T4-9	460
T4-8A, T4-9A	460
5BT	460
5M	260
5T	460
T5-2	460
5X2	460
5X, 5X3, 5X4	460
5T4	460
5T5	460
6K, 6T	460
6M, 6M2	260
6K2, 6T2	460
T6-1, C6-2	460
BT6-3, BC6-4, BT6-10	460
BT6-5, BC6-6	460
6BT, 6BK, 6BT6, 6BK6	460

Model	KC
H-6 Hudson	260
T6-7, C6-8	460
T6-9	460
T6-11, C6-12	460
R-7A	175
R-7-LW	110
7U2	460
7T, 7K, 8T, 8K	460
R-7, R-9	175
R-7, R-9 AC, Superette	175
7U	460
7X	460
T7-5	460
C7-6	460
D7-7	460
BT7-8, BC7-9	460
T7-12, C7-14	460
8U2	460
8T2, 8T11, 8K11	460
R-8, R-12	175
8BT, 8BK, 8BT6, 8BK6	460
8U	460
T8-14	460
C8-15	460
T8-16	460
C8-17	460
T8-18, C8-19, C8-20	460
D8-28	460
9K	460
9K2, 9T	460
9U, 9U2	460
C9-4, T9-10	460
C9-6, T9-9	460
T9-7	460
T9-8	460
D9-19	460
10K, 10T	460
R-10	175
T10-1	460
T10-3	460
R-11	175
C11-1	460
D11-2	460
T11-8	460
13K	460
C13-2	460
15K	460
15U	460
C15-3	460
RE-16-A	175
RE-18	175
RE-19	175
RE-20	175
R-21	175
R-22	175
D22-1	460
RO-23 (SW IF)	1,075
(Broadcast IF)	175
25 DC	175
RAE-26	175
R-28	175
R-28-BW	175
R-28-BWC	175
R-28-P	175
M-30	175
P-31	175
M-34	175
R-37, R-38	175
R-37-P, R-38-P	175
R-40-P	175
RE-40	175
R-43	175
R-50, R-55	175
R-51	180
R-51-B, R-53-B	175
RAE-59	175
62	180
64	180
66	175
R-70	175
R-71, R-72	175
R-71-B	175

RCA—Cont.

Model	KC
R-73	175
R-73, R-74, R-75, R-76	175
R-73-A	175
R-75	175
R-77	175
R-78	175
R-78 (Noise Suppression)	175
RAE-79	175
80	175
RE-80	175
RE-81	175
82	175
RAE-84	175
R-90	175
R-90-P	175
M-101	175
103	460
M-104, M-108	175
M-105	175
M-107	175
M-109	175
110, 111, 115	175
112	175
114	175
M-116	175
117, 214	460
118, 211	460
119	460
120	175
121, 122	370
M-123	175
124	175
125, 225	460
126-B	460
127	370
128, 224	460
128E, 224E	460
128, 226	460
135-B, 235-B	460
ACR-136	460
140, 141, 141-E, 240	445
140, 141, 141-E, 240, AVR-1	445
142-B, 241-B	175
143, 242, 243	460
210	175
220, 222	175
221	370
223	175
236-B	460
260	175
261	175
262, 263	460
280	175
281	460
301	460
310	175
Duo 320	370
Duo 321	370
Duo 322	460
Duo 322-E	460
327	370
330	175
331	175
Duo 340	445
340, 340-E	445
341	460
Duo 380	175
Duo 380-HR	175
Duo 381	460
AR-4229	175
23590-2	175

R K RADIO LABS.

Model	KC
RK-60-G	175
RK-60-L	115
521, 522	465
534	465
631, 633	465

RADIO CHASSIS

Model	KC
Auto set	175
L-5-D	456
A-6-D	175
L-6-D	115
L-6-W	125
AC-36	175
QAC-36	175
LSA-36	175
LSA 37	175

RADIO CIRCULAR

Model	KC
W	456
5-Tube Dual Battery A-W Superhet	456
5-Tube Dual A-C. A-W. Superhet.	456
5-Tube AC-DC Dual A-W Superhet.	456
817	456

RADIO PRODUCTS

Model	KC
5-Tube AC Super, Chassis A-1	456
5-Tube AC, Chassis X8	456
6-Tube AC, Chassis A3	456
6-Tube AC-DC Super, Chassis B-2.	456
6-Tube AC Super, Chassis L-2	456
6-Tube AC-AW, Chassis M1	456
6-Tube Battery, Chassis Z4	456
6-Tube AC-AW, Chassis Z2	456
6-Tube AC-AW Super, Chassis Z-3	456
6-Tube Batt. Super, Chassis Z-5	456
7-Tube AC Super, Chassis L-4	456
7-Tube 6 Volt Battery, Chassis L7.	456
7-Tube AC-AW, Chassis L5	456
8-Tube AC, Chassis L6	456
29C, 30C, 31C	456
32C, 33C	456

RADIOBAR

Model	KC
505	175
508, 526, 210-B	262
510	262

RADIOTROPE

Model	KC
70-R	262
71-R, 72-R, 73-R	262

RADOLEK

Model	KC
951	265
956	465
958	465
10926	456
10927	456
10928	456
10931	456
10943	456
10951	262
10956	465
10963 (60 cycles)	456
10964 (25 cycles)	456
10967	456
10969	456
10970	456
11908	456
11910	456
11911	456
11935	465
11947	456

REMLER

Model	KC
Best "115KC"	115
10	180
10-3	250
10-4	450

REMLER—Cont.

Model	KC
15	180
15-3	180
17	180
19	180
21	180
21-3	250
21-4	450
26	450
26, Above Serial 54760	450
30, 40	450
35 Auto	450
36	250
37	250
40	450
41	450
42	450
42SW	450
43	450
44	450
45	450
46 "Scottie"	450
52	450
53	450
53-C	450
60	450
63	450
64	450
71	450
88	450

REPUBLIC INDUSTRIES

Model	KC
Sky Hawk Patrician	175
Sky Hawk RC-5, RC-6	175
TR-5B	175
SL-5-D	175
BP-5E	115
CS-6	115
SL-6	115
TL-6C	175
SL-6-D	175
42	175
51	175

SCOTT LABS

Model	KC
All-Wave Super	470

SEARS-ROEBUCK

Model	KC
A-1	480
249	175
550	265
1320, 1322, 1324	175
1390, 1400, 1402, 1404, 1406	175
1430	175
1462	175
1480, 1482, 1484	175
1506	175
1580, 1582, 1584	175
1570, 1572, 1574	175
1590, 1592	175
1597, 1598, 7050	175
1600	1,000
1630	175
1640	175
1650	175
1652, 1654	175
1660	175
1670	175
1700	175
1704, 7070, 7071, 7072, 7073, 7074	480
1705	175
1706, 1707	480
1708	175
1709	175
1710	175
1711-A, 1744, 1745, 1852, 1853, 7090-A	480
1711, 7090	175

Model	KC
1711A, 7090A	480
1712, 1713	175
1714	175
1715	175
1720, 1725, 7065	175
1721	175
1722, 1732	175
1726X	175
1730	175
1731	456
1733	480
1743, 7140	456
1743A	456
1750	175
1760	480
7075, 7076, 7077, 7078, 7091, 7092, 7093, 7094	480
1801, 1801A	456
1802, 1803	445
1802-A, 1803-A, 1807	445
1804, 1805, 1808, 1820, 1826	480
1805A, 1808A, 1826A, 1841	175
1806, 1823, 1829	445
1809, 1811, 1833, 1845	175
1821, 1827	480
1822, 1831, 7164	445
1824, 1830	445
1825-A	175
1828	480
1832	480
1832-A	445
1835	456
1840, 1842	480
1850, 1851, 1862, 1868, 1870	175
1854	175
1854A	175
1855	480
1857	175
1857-A, 1867	175
1858	175
1863	175
1864	175
1869	456
1869X, 7157	456
1900	456
1903, 1953	456
1904, 1904-A, 1906, 1908, 1911, 1914, 1938, 1954, 1964, 1964-A, 1984	175
1905, 1915, 1955, 1965	175
1909, 1942, 1944, 1972	175
1910	456
1917, 1967, 1967A	385
1918, 1968	385
1918A, 1968A	385
1919, 1929, 1982A, 1999 (345X)	175
1920, 1926, 1980	480
1922, 1932, 1982, 1992	480
1922-A, 1932-A, 1982-A, 1992-A	175
1923, 1933, 1983, 1993, Chassis 334, 334X	175
1925, 1935, 1985, 1995	456
1926, 1928, 1978, 1980A	480
1927X, 1937X	456
1933A, 1983X	175
1936, 1996, Chassis 359, Early; Chassis 359X, Late	175
1942, 1972, 1994	175
1945	385
1946, Early Chassis 388, Late, Chassis 388X	385
1954X	456
1970	456
1981, 1981C, 1941	262.5
1981CX	262.5
1986, 1987, 4403, 4463, 4484, 4563, 4564, 4584, 3 Types (Colonial)	262
1986, 1987, 4403, 4463, 4464, 4563, 4564, 4484, 4584 (Stew't Warner)	262
1988, 4401, 4402, 4461, 4462	465
1989, 4408, 4420, 4520	465
1992X	456
1993X	456

SEARS-ROEBUCK—Cont.

Model	KC
1998	262
3808	262
4404, 4406, 4424, 4444, 4524, 4544, 3-Volt Models	465
4405, 4407, 4428, 4448, 4548, Two Types	465
4409, 4413, 4442, 4443, 4522, 4523, 4542, 4543	465
4419, 4459, 4519, 4559	465
4422, 4423, 4524A, 4542A	465
4426, 4426A, 4427, 4446, 4447, 4526, 4526A, 4546, 4546A	465
4428A, 4448A, 4528A, 4548A	465
4429, 4449, 4529, 4549	465
4431, 4432, 4435, 4436, 4531	465
4439, 4440, 4455, 4456, 4539	465
4441, 4451	465
4450, 4550	465
4468, 4490	262
4465, 4485, 4565, 4585	465
4472, 4473, 4533	465
4486, 4586	465
4587	465
4488, 4588, 4488A, 4588A	465
4488B, 4588B	465
4566	262
4587A	465
4593	262
4498, 4499, 4598	465
4569, 4589	262
7043, 7044, 7045, 7046, 7047	175
7048	175
7049	175
7066	175
7068	265
7106, 7111X, 7112, 7114	456
7116	456
7117, 1859-A	370
7124, 7132	456
7127, 7133, 7139	456
7128	175
7136, 7137	456
7139	456
7140	456
7141, 7142	456
7143	456
7144	456
7150	456
7154	456
7155	456
7156	175
7158	456
7167	456
7170	262.5
7171	465
7172	456
7172X	456
7181, 7182	465

SENTINEL

Model	KC
6A	456
10M	370
10MF	370
11M	465
14A	465
19A	465
20A	465
31B	465
32B	465
33B	465
34B	465
35B	465
36L	465
37B	465
38B	465
39B	465
40A	465
44A	465
46A	465

Model	KC
47A	465
48A	465
49B	465
50B	465
52A	465
53A	465
54A	465
55U	465
56U	465
60B	465
63B	465
65B	465
66B	465
67L	465
68B, 68BE	465
70A	465
71U	465
105-B	175
108	175
108-A, 110	175
109	175
114	175
116	465
118	175
261	175
261, 262, 521	175
501, 502	465
513	262
550	175
550 (Revised)	265
560, 561	265
570	262, 465
599	265
600	265
600 Auto	265
602	265
603	265
614	175
622, 623	465
634, 635	465
660 Battery	465
810	175
1010	175
1020A, 1030A	115
1040	465
5000, 5100	465
4300	465
5500	370
5600	465
5700, 5721	465
5800	465
6101, 6102	465
6200, 6234, 6241	465
6315, 6317, 6321	465
6317, 6321	465
6700	465
6800	465
6900	465
7100	465
7100B	465
7200	465
7200-B	465
7700, 7732, 7741	465
8100B	465
8200-B	465
9100	465

SETCHELL CARLSON RADIO PRODUCTS

Model	KC
30	456
32	456
33	456
40	456
50	456
51	456

SHELLY

Model	KC
48	458
67	460

SILVER-MARSHALL

Model	KC
A	175
B	175
C	175
D, E.	175
F	175
G	175
J	175
R	175
V	175
Z DeLuxe	472.5
Bearcat Midget	175
Z-10	465
Z-13	472.5
36-A	175
714	175
716, 683	175
724	175
726	175
727	465
728	175
729 SW	465
738	1,000
739	650
773	175
4801, 4802	175

SIMPLEX

Model	KC
AA	456
B	175
D, DE	456
G, GE	456
GB, GBE	456
GH, GHE	456
J	175
K	175
K (DC)	175
L	175
N	175
N (DC)	175
P	175
P, AC	456
P (AC)	175
P (DC)	175
P, 32-V	456
P, Dual Band, Above Serial 600001	456
Q	175
R (DC)	175
U, AC-DC, Above Serial 640001	456
U-E, AC-DC, Above Serial 215001	456
W	456
W All Wave	456

SONORA

Model	KC
70	262
71, 72, 73	262
84, 85	262
86, 87	262

SPARKS-WITHINGTON

Model	KC
9X, 13, 14, 14-A, 15X, 620X	172.5
10	172.5
12	172.5
14	172.5
15	172.5
16, 16-AW	172.5
16, 16-AW (BC Rec.)	172.5
16-AW, 26-AW (SW Rec.)	900
17, 18, 28X, 111X, 750-A, 750X, 870-A, 870X	172.5
18	172.5
25, 26	172.5
26-AW	172.5
27	172.5
27, 27-A, 28	172.5
27-A	172.5

Model	KC
27X	172.5
28	172.5
30	172.5
30-A, 30-B, 30-C	172.5
33	172.5
33-A, 33-B	172.5
34	172.5
35	172.5
36	172.5
44P	172.5
45	172.5
46P	172.5
53 AC-DC	456
54	172.5
56	172.5
57, 57-A, 57-B, AC-DC	456
58	456
60 (SW Converter)	900
61, 61-A, 61-B, 62	172.5
61, 62	456
63, 63AX	456
65, 66	456
65-T, 66-T	456
67, 68, 68-XS, 685, 691	345
70, 77, 775	345
71, 71-B	456
72	172.5
72 PQ	172.5
73	456
73-AX, 73-BX	456
74	172.5
75	456
75-A, 475-A, 478-A	456
75AX, 475AX, 478-AX	456
76	456
78	172.5
78, 478	172.5
80, 83, 84, 85-XS, 86X, 835	456
81	456
81-A	456
82	456
104, 135	456
105X, 105-XS	456
111X	172.5
134, 136	456
333	456
417-X	456
427X, 437X, 457X	456
506, 566, 594	456
516, 516X, 546X	456
517, 517B, 517W, 517X, 557, 567	456
536, 536X	345
537, 577	456
547X	456
616, 616-X, 666, 666-X	345
616-M, 616-MX, 666-M, 666-MX	345
617, 617X, 667, 667X	345
620X	172.5
636-MX	345
655	456
676, 686	172.5
716X, 766	456
726X, 776, 776X, 776XP, 776XS	456
750-A, 750X	172.5
766	456
766X	456
766-XP, 766-XS	456
785	172.5
827X, 827XD, 997X	456
870-A, 870X	172.5
966, 966X	456
977	456
987	456
1066, 1016X	456
1116X, 1166, 1166X, 1176, 1186, 1196	456
1116X, 1166-XP, 1166-XS, 1176-XP, 1176-XS	456
1167	456
1466, 1476	456
1567	456

STAR

Model	KC
6-U	262
062	262

STEINITE

203, 600, 605, 630, 635, 642, 643....175
700, 705, 706, 725, 642-B 175

STEWART-WARNER

102-A, B & E	177.5
R-102-A, B & E	177.5
R-104	177.5
R-104-A, B & E	177.5
105 (SW IF)	1,525
(Broadcast IF)	177.5
105 Chassis (50 to 59)	177.5
R-106	177.5
109 Chassis (1090 to 1099)	177.5
R-110	177.5
R-111, R-115	456
R-112	456
112 (1121)	456
R-116	456
R-117	177.5
R-117 Chassis	177.5
R-119	177.5
R-120	177.5
R-120 (1201, 1209)	177.5
R-123, R-123A Chassis	456
R-125 Series	456
R-126 Series	456
R-127 Chassis	456
R-136, R-136P, R-136X Chassis	456
1090 to 1099	177.5
1171, 1172, Chassis R-117	177.5
1181, 1182, 1183. Chassis R-118	177.5
1201 to 1209 incl.	177.5
1231 to 1239 incl. Chassis R-123, R-123A	456
1251 to 1259 incl. Chassis R-125 Series, Chassis R-125A and 125X.	456
1261 to 1269. Chassis R-126A, R-126P, R-126X	456
1271 to 1279. Chassis R-127 Series, Chassis R-127-X	456
1281D to 1289D. Chassis R-128D	456
1301 to 1309, Chassis R-130	456
1311 to 1319. Chassis R-131	177.5
Firestone R-1322. Chassis R-132	177.5
Firestone R-1332. Chassis R-133	456
1341 to 1349, Chassis R-134	456
1361 to 1369. Chassis R-136	456
1371 to 1379. Chassis R-137	456
1381 to 1389. Chassis R-138	456
1391D to 1399D, Chassis R-139D	456
1401 to 1409, Chassis R-140	456
1421 to 1429, Chassis R-142A, R-142AS	456
R-1431 Auto	177.5
1441 to 1449, Chassis R-144AS	456
1451 to 1459, Chassis R-145, Chassis R-145X	456
1461 to 1469, Chassis R-146. R146X.	456
1471 to 1479, Chassis R-147, R147X, R-147P	456
1481 to 1489, Chassis R-148	456
1491 to 1499, Chassis R-149, Chassis R-149X	456
1601 to 1609, Chassis R-160	177.5
1611-D to 1619-D, Chassis R-161-D.	456
1621-D to 1629-D, Chassis R-162-D.	456
1631-D to 1639-D, Chassis R-163-D.	456
1641-D to 1649-D, Chassis R-164-D.	456
1671 to 1689, Chassis R-167-S, R-168	456
1691 to 1695, Chassis R-169	262
1711 to 1719, Chassis R171	465
1721 to 1729, Chassis R-172	262
1731 to 1739, Chassis R173	456

STROMBERG-CARLSON

Model	KC
Compact	175
19, 20	175
22, 22-A	175
25, 26	175
27	175
29	175
33	260
37	175
38, 39, 40	175
48, 49, 50, 51	175
55, 56	175
58L, 58LB, 58T, 58TB, 58W, 58WB	465
61L, 61LB, 61T, 61TB, 61W, 61WB	465
61Y, 61Z	465
62, 63, 62B, 63B	465
65, 66, 67	465
69 All Wave Selector	545
70, 70B, 72, 72B, 72D, 74, 74B, 74D	260 or 370
80	465
82, 82-B	465
83, 83-B	465
84, 84-B	465
115	465
125AC-DC	465
126AC-DC	465
127AC-DC	465
130H, 130HB, 130L, 130LB, 130M, 130MB, 130R, 130RB, 130U, 130UB	465
140 Series	465
145L, 145LB, 145P, 145PB	465
150 Series	465
160 Series	465
180 Series	465

SUPERTONE PRODUCTS

Superba 465

L. TATRO PRODUCTS

EN6-4	457
IN-25	457
P-54	177.5
P-54 (Recorder)	177.5
AK-54, AM-54	175
L-74, N-74	175
L-74, N-74 (Lieut. Gov. and Gov.)	175
O84	177
O94	175
094 (President)	175
H-465, I-465	456
A-525, B-525	456
L-525	456
C-625, D-625	177.5
J-665, K-665	177.5
F-725	177.5
M-4616	456
O-4626, P-4626	456
Q-5636, R-5636, S-5636	456
T-6216	177.5
W-6236, X-6236, Y-6236	456

TRANSFORMER CORP. OF AMERICA

TC-20, TC-21	465
TC-50	175
TC-52	115
TC-60	456
AC 80, 81, 90	175
AC 84, 85	175
90-A, 91	175
AC 94, 25-94	175
AC 100	175
AC 100 Series	465
120-139	175
AC 160, 25-160	175

TRANS. CORP.—Cont.

Model	KC
200	600, 1,000, 1,500
220	175
240	490
241	175
260	175
280	175
300	175
320	175
340	175
360	175
420	175
422, 423	465
425	465
440	465
480	465
490	175
500	175

TRANSITONE

See PHILCO

TRAV-LER

Model	KC
5 Tube 6 Volt Battery	456
S-8	175
S-9	175
522	456
525, 6-Volt DC	456
542	456
635-M	456
642	456

TRIANGLE

Model	KC
6P, Imperial	465

TROY RADIO

Model	KC
5L5, 5U5, 15, 15-5	465
42	465
46	465
51B5	465
52	465
TR53, TR53C, TR53CH	465
54	465
56	175
62BC, 62BU	465
62C, 62PC, 62L, 62U	465
TR68 Auto	465
75, 75C, 75CH, 75PH AC	465
75, 75C, 175 AC-DC	465
75, 75B, 75C Batt.	465
77, 77C	465
84	465
84C, 84PC, 84U	465
TR-86	465
151-5	465
153C, TR153 AC-DC	465

TRUETONE

See WESTERN AUTO SUPPLY

UNITED AMER. BOSCH

Model	KC
05	465
10	175
20-J, 20-K, 20-L	175
31, 32	175
36, 37	175
40, 41	175
45-A, 45-C	175
79-C	175
91, 92	175
100 Auto	175
108	175
119, 129	456
139, 149, 169	456

Model	KC
140-A	456
150	175
160	175
207A	465
236, 237	175
242, 243	175
242, 243 AC	175
250, 251	175
260, 261	517.5
305, 305-A	456
305-A	456
306	465
307	175
312, 313	175
352	175
357	175
360	456
360, 361, 364	456
370	265
376	456
376BT, 376F, 376S	456
385	463
386	463
402	456
405	456
420	456
420, 421	456
430, 430J, 430T, 431, 431J, 431T, 434, 434J, 434T	450
440C, 440T, 441C, 441T, 444C, 444T	456
450L, 450H, 451L, 451H, 454L, 454H	450
460	456
460, 461, 464	456
462A, 462Y	456
470, 471, 474	456
480, 481, 484	456
500	456
501, 502, AC-DC	456
502	456
503	456
505	465
510, 510E	465
515	465
WX-517-209, WX516-209	465
524A	456
536	456
565K, 565W	465
575F, 575Q	465
585Y, 585Z	465
595M, 595P	465
600	465
601	465
602, 602T, 602C	465
604, 604B	465
605, 605C	465
610, 610A	465
620, 625	465
634A	175
636, 637	175
640	465
650 (Preliminary)	465
660C, 660T	465
670C, 670S	465
680	465
736A2, 737A2, 738A2	175
812	175
838	175

UNITED MOTORS SERVICE

Model	KC
626 Delco	262
627 Delco	262
628 Delco	262
629 Delco Late	262
629 Delco Early	450
630 Delco	262
1101 Delco	181.5
1102, 1103, Delco	456
1104 Delco	456

UNITED MOTORS—Cont.

Model	KC
1105 Delco	450
1106 Delco	465
1107 Delco	450
1108 Delco, Glass Tubes	490
1109 Delco	455
1110 Delco	455
2035	262
3201, 3202, Delco Late	456
3201, 3202, Delco Early	262.5
3203, 3204, Delco	456
3205 Delco	450
3206, 3207 Delco	450
4036, B-O-P	262
4037	262
4048	455
4051, 32 Volts	181.5
4052 AC-DC	456
4054	262
6010 Delco	450
364441 Chevrolet	262
393884 Oldsmobile	262
405046 Oldsmobile	262
405057, 405062 Oldsmobile	172
405063 Oldsmobile	172
544245 Buick-Pontiac	262
544267 Pontiac	262
544268 Pontiac	262
600153 Chevrolet	262
600249 Chevrolet	262
600565 Chevrolet	262
600566 Chevrolet	262
601038 Chevrolet	175
601176 Chevrolet	262
601177 Chevrolet	262
601574 Chevrolet	175
601586 Chevrolet	262
601662 Chevrolet	262
601814 Chevrolet	262
980393 P-P-O	262
980455 B-P-O	262
980459 B-P-O	262
985100 Chevrolet	262
985200 Chevrolet	262
985300 Chevrolet	262
985301 Chevrolet	260
985400 Chevrolet	260

U. S. RADIO & TELEVISION

Model	KC
5-A	455
7	262
7-D	455
8	262
9, 19	262
10	262
10-C	262
12, 120	262
24	455
25	455
69	262
99	262
112-A	1,000
1006, 1007	262
3040, 3056	455
3070	262
3092, Chassis 513	455

UNIVERSAL BATTERY

Model	KC
613V	465
802	456
803	456
5010	465
5032	465
6110, 6310	456
7232, 7332	465
7332	465
8210, 8410	465

VOCO RADIO

Model	KC
V-60	175

WARE

	KC
SBA	175
SBB	175
SBF	175
S-1	175
SB-45	175

WARWICK

	KC
4-Tube AC	456
5-Tube AC	456
5-Tube Auto	456
6-Tube Auto	262.5
7-Tube Batt.	456
501	456
525	456
530	456
551	456
600	456
611	175
700	456
725	456

WELLS-GARDNER

	KC
O-C Series (20C5)	456
ODM Series	456
OEL Series	456
OF Series	456
OOA	175
O2A	175
2B Series (22B5)	456
2CM Series	456
2DL Series	456
O5A	262
O5AA	262
O5BA	262
5-B	262
5D Series	456
5-E Series (25E1, 25E5)	175
5F	456
5H	456
5KL	456
5Y Series (25Y1)	175
O6A	175
6B Series (26B1, 26B5)	175
6C Series	456
6D Series	175
6F Series	456
6G Series	456
6K Series	175
6L Series	175
6N Series	175
6R Series	175
6S Series	175
6-U	262.5
O6W	262
V-6-Z2	262
Z-6-Z1	262
O7A	175
7C Series (27C1, 27C5)	175
7-D	456
7E Series	456
7FL	456
7GM Series (37G508, 37G566)	456
7H Series (37H508, 37H566)	456
7J	456
7K Series	456
7L Series	456
7LL Series	456
7Q	456
7P	456
7RL	456
9C Series	456
022	175

WELLS-GARDNER—Cont.

Model	KC
35G510, 35G560 Chassis	175
40, 40-A	175
50	175
052	262
062	262
073	175
092	175
92, 93	175
502	175
572	175

WESTERN AUTO SUPPLY

Model	KC
670	175
S-716	175
S-717	175
S-719	262
S-720	175
S-721	175
S-724	175
S-725, S-726	456
S-727	456
S-732, S-733	262
S-735	175
S-740	262.5
S-743, 1312	177.5

WESTINGHOUSE ELEC. SUPPLY

Model	KC
WR-100	456
WR-101	456
WR-102-A	465
WR-103, WR103A	465
WR-116, WR-316	465
WR-201	456
WR-203, WR-303	456
WR-204, WR-304	465
WR-205, WR-305	465
WR-208	456
WR-211	465
WR-212, WR-312	465
WR-214, WR-314	465
WR-306	465
WR-315	465 & 100
WR-500	175
WR-501	172.5
WR-601	456
WR-603, WR-606	465
WR-604, WR-607	465
WR-605, WR-608	465

WESTINGHOUSE INTERNATIONAL

Model	KC
WR-22	175
WR-39	445
WR-41	175
WR-42	175
WR-45	460
WR-46	460
WR-47	460
WR-48	460
WR-49	460
WR-50	460
WR-102	456
WR-103	465
WR-116, WR-316	465
WR-116X, WR-316X	465
WR-209	465
WR-209X	465
WR-210, WR-310	465
WR-211	465
WR-211X	465

Model	KC
WR-212, WR-212X, WR-312, WR-312X	465
WR-214X, WR-314X	465
WR-311X	465
WR-311	465

WESTONE

Model	KC
40	456
70-70C-11-12	456

WHOLESALE RADIO

Model	KC
Auto Radio	262
L-1	175
10	175
20	175
L-20	262
80-M, 80-MA	175

WILCOX-GAY

Model	KC
2-S-5	175
2-S-5, 25A5	175
2-T-5	175
2-VA-7	175
2-VA-7, 2V7, 2W10	175
2-VB-7	175
3-D-5	175
3-J-5, 3-K-5	175
3-S-5-66	175
3-PA-6-66	115
3-R-6	175
3-T-6-66	175
3A8	515
3C10	515
3-D-5, 3E5	175
3-F-7	115
3J4	175
3-J-5, 3-K-5	175
3JC5	175
3JD5, 3JG5	115
3JE5	175
3JF5	175
3G6, 3H6, 3GA6, 3HA6	175
3-JM6, 3JQ6	175
3-KD-5, 3PB8	115
3KE5	175
3-S-5, 3SA5	175
3-SB-5	175
3-PA-6, 3P6	115
3-R-6	175
3-T6, 3TA6, 3TB8	175
3-VB-6	175
3-V-6, 3-VA-6	175
3-LB-7, 3L7	175
4-C-5	175
4-CD-5	175
4-B6	175
4-E-6	115
4JA6, 4JB6	456
4J6, 4JC6	456
4JB6	456
4G7	456
4-D-10	175
4-DB-10	175
4H11	456
5B5, 5BC5	456
5BA5	456
5A6	456
5BE6	456
5E7	456
5EA7	456
5EB8	456
5E8, 5E9	456
5F8	456
6A5	175
6D6	175
6F6, 6FB6, A-18, A-19	175

WURLITZER

Model	KC
C-4, M-4	456
P-5	456
SU-5	456
SA-5	175
B-6	175
SA-6	175
S-7	175
S-8	175
SW-8	485
S-10	175
S-50	175
U-50, U-55	485
A-60	485
S-63	175
SA-65	175
DC-65	175
B-80	175
S-80	175
SW-80	485
SW-88	485
SA-90	175
SA-91	175
SA-91-A	175
SA-110	175
SA-120	175
SA-130	175
SA-133	175
450	456
460	175

ZENITH

Model	KC
AH, CH, RH, 090, 90, V-8, Chassis 2012 Series	175
BH	175
LH, MH, WH (2022)	175
8-Tube Super, Chassis 2051	485
12-Tube Super, Chassis 1203	456
4-B-106, 4-B-131, 4-B-132, Chassis 5406	456
4F133, Chassis 5407	456
4P26, 4T26, 4P51, 4T51, Chassis 5401	456
4T26, 4T51, Chassis 5403	456
4V31, 4V59, Chassis 5405	456
5F134, 5F166, Chassis 5518	456
5-M-90, Chassis 5510	456
5M191, 6M192, 6M193, 6M194, 8M195	456
5-S-29, 5-S-56, Chassis 5513, 5513A	252.5
5-S-119, 5-S126, 5-S-127, 5-S-150, 5-S-151, 5-S-161, Chassis 5516	456
6-B-107, 6-B-129, 6-B-164, Chassis 5635	456
6-D-116, 6-D-117, 6-D-118, Chassis 5633	456
6-M-90S, 6-M-90D, Chassis 5630	252.5
6-M-91D, 6-M-91S, Chassis 5631	252.5
6-M-92, Chassis 5632	252.5
6-S-27, 6-S-52, Chassis 5619	252.5
6-S-128, 6-S-137, 6-S-147, 6-S-152, 6-S-157, Chassis 5634	456
6V27, 6V62, Chassis 5621	456
7	175
7-D-119, 7-D-126, 7-D-127, 7-D-138, 7-D-151, 7-D-148, 7-D-162, 7-D-168, Chassis 5707	456
7-M-91D, 7-M-91S, Chassis 5706	252.5
7-S-28, 7-S-53, Chassis 5704	456
8S129, 8S154, Chassis 5801	456
9-S-30, 9-S-54, 9-S-55, Chassis 5903	456
10S130, 10S155, 10S156, 10S160, 10S147, 10S-153, 10S157, Chassis 1004	456
12-L-57, 12-L-58, Chassis 1202 & 1202A	456
12U158, 12U159, Chassis 1203	456

Model	KC
16-A-61, 16-A-63 Stratosphere, Chassis 1601-C, 1601-P	456
91, 92, (1st type)	175
91, 92 (2nd type)	175
91, 92 (3rd type)	175
103	175
210-5, 211-5, 270-5	125
210, 220	175
210, 220, 2022 A & B Chassis	175
215, 216, 225, Chassis 2044	175
230, 240, 244, 245, 2036 Chassis	175
250, 260, 272 (SW-IF)	1,000
(Broadcast IF)	175
410, 411, 420	175
410, 411, 420 (Chassis 2030-2040)	175
430, 440	175
430, 440, Chassis 2033	175
460	485
462	252.5
462, Chassis 2057	252.5
500, 501, 503, 514, 515, 516, 600, 604, 606, 610, 616, 618, (2037)	175
500, 501, 503, 514, 515, 600	175
520, 521, Chassis 2035	175
530, 531, 533	175
604, 606, 610, 616, 618	175
650-HD, 651-HE, 660-TD, 661-TE	252.5
663, 664	456
666, Chassis 5616, 668, Chassis 5626	252.5
680 Hudson	252.5
701	456
701 AC-DC	456
702	456
705, 706, 707, 711, 712, 750	485
705, 706, 707, 711, 712, 750, Chassis 2052 A, B & C	485
715, 755, 756, 474	175
715, 755, 756, 474 Chassis 2053	175
730, 735	175
740	175
760, 765, 767, 475	175
760, 765, 767, 475 Chassis 2054 Ser.	175
770, 775, 780, 476, 476A Chassis 2032	175
770-B, 775-B, 476-B Chassis 2059	175
801	456
805, 845, Chassis 5502	252.5
806, 807, S847, 850 Chassis 5504, 5505	252.5
808, 809, 860, 861, Chassis 5605, 5607	252.5
811, 862, 865, 866, 1162, Chassis 5609, 5610 AC-DC	252.5
812, Chassis 5608	125
814, 815, 864, 1161 Chassis 5611, 5612	125
825, 827, 829, 870 Chassis 5701-2-3	485
S-829, S-870, S-871, 1170 Chassis 5701R, 5702R, 5703R	252.5
835, 880, Chassis 1001, 1001-A	485
862, 865, 866	252.5
908, 909, 960, 961, 1117 Chassis 5614	252.5
S-908, S-909, S-961, 1167 Chassis 5618	252.5
945, 950 Chassis 5508, 5509	252.5
970, 975 Chassis 5902	175
980, 985, 990 Chassis 1201, 1201-A	485
Stratosphere 1000Z Chassis 2501-C, 2501-P	485
2056, 2056-I, Chassis	485
5519	456

ZEPHYR

	KC
DA	456
NT	456
TA	456