RADIO Technical Digest

TELEVISION
•
AMATEUR
PERIMENTAL
and
HORT WAVE
RADIO
•
LECTRONICS
•
Radio
ENGINEERING
SERVICE
OPERATING
MMUNICATIONS

HIGHLIGHTS FROM THIS ISSUE

25¢
U.S.A. & CANADA

SEPTEMBER AND OCTOBER, 1939

RADIO Technical Digest

● SEPTEMBER - OCTOBER, 1939 NUMBER 13 ●

Selections from the World Technical Radio Press

RADIO TECHNICAL DIGEST • **A. McMullen,** Managing Editor
Editors: **W. W. Smith, Ray L. Dawley, B. A. Ontiveros**
W. E. McNatt, Jr., Production Manager

25c per copy. By subscription: 12 issues, $2.50 in U. S. A., Canada, Newfoundland, Spain, and all Pan-American countries; elsewhere, $3.00 or 12s. 6d. (British postal orders accepted.)

Published every two months by Radio, Ltd., 1300 Kenwood Road, Santa Barbara, California. Entered as second-class matter January 25, 1939, at the Post Office at Los Angeles, California, under the Act of March 3, 1879, and re-entered at Santa Barbara, California, on August 30, 1939. Application for additional entry at East Stroudsburg, Pennsylvania, is pending.

Printed by Hughes Printing Co., East Stroudsburg, Pa.

¶ From Radio
July, 1939

A Portable
FREQUENCY STANDARD

By RUFUS P. TURNER

Construction and operating data for a secondary frequency standard employing a high-stability 100-kc. crystal oscillator and two multivibrators. This instrument is equivalent to several hundred crystal oscillators on spot frequencies throughout the radio spectrum and furnishes two crystal-controlled audio frequencies as well.

THE importance of knowing *exact* frequencies has increased with the growing popularity of e.c.o.-controlled transmitters. Contributory likewise to the current state of frequency consciousness is the amateur's increasing interest in radio physics and the more or less recent appearance of the new Federal regulations. All in all, the present situation, wherein the most exacting demands are made on frequency measuring gear, it is a far cry from the state of the art fifteen years ago when absorption wavemeters were universally used for frequency measurements and the accuracy of the most refined versions of these instruments was perhaps a quarter of one per cent. Apparatus in use at present permits the reading of radio frequencies within a very few hundredths of one per cent, performing the dual function of frequency generator and frequency identifier.

The initial progressive step was the laying aside of the absorption wavemeter, which identifies frequencies by virtue of its wavetrap action, in favor of electronic frequency meters which generate frequencies over a continuous range. With such a meter, used in conjunction with a heterodyne detector (monitor), it is possible to identify unknown frequencies by the highly accurate beat-note method. Since the electronic frequency meter is fundamentally a simple vacuum-tube oscillator which has been made as stable, electrically and mechanically, as is practicable, it still possesses most of the vagaries of the self-excited oscillator and has been replaced when greater accuracy is desired by systems embodying stable crystal control.

The simplest crystal-controlled checking device that has been employed for amateur calibration work has consisted of a low-powered crystal oscillator operating on 1750 kc. to provide harmonics at the low ends of all of the amateur bands. The utility of this instrument has been limited by the single spot frequency it provides in each band, and wherever great accuracy is dictated, we have drawn upon the experience of the commercials and laboratories and chosen a crystal frequency so low that its harmonics will be closely spaced throughout the various bands to provide a large number of checking points. Fundamental frequencies of 50 or 100 kc. have become conventional for this purpose, and amateur practice has been to employ the more readily obtainable 100-kc. bar.

A 100-kc. crystal oscillator provides spot frequencies every 100 kilocycles apart, these points extending to quite a high frequency before they finally grow too weak to be useful for the calibration of receivers, monitors, and variable signal generators, or the identification of unknown signals or presetting of an e.c.o.-controlled transmitter. These standard frequency points will have the same percentage accuracy as the controlling crystal. It is easily possible to attain a degree of stability not possible with an electron-coupled frequency meter or similar self-excited calibration oscillator. Thus, the single 100-kc. oscillator furnishes the equivalent of hundreds of separate signals, each generated by a separate high-stability oscillator.

• Simplest Standard

It will be apparent from the foregoing discussion that the most rudimentary form of frequency standard may actually employ only the basic unit of a conventional standard: a 100-kc. oscillator controlled by an accurately ground, low-drift crystal. It is imperative that the crystal operate on exactly 100 kc.; since various factors may bring about variations from this frequency, means must be provided for correcting the fundamental frequency. Generally this is accomplished by mounting the crystal in a variable-gap holder or by making some circuit component variable in order to shift the crystal frequency a few cycles above and below 100 kc. A few cycles change will be sufficient to correct for error due to the temperature coefficient of the crystal, shifting of tube characteristics, or aging of the crystal or circuit components.

The correction is made by bringing a suitable harmonic into zero beat with a satisfactory standard frequency signal, generally zero-beating this 50th harmonic (5000 kc.) with the 5-Mc. standard frequency signal broadcast regularly from the National Bureau of Standards station, WWV. The accuracy of the WWV signal is better than

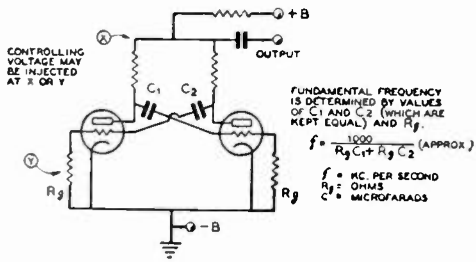


Figure 3. Basic multivibrator circuit and the approximate equation of its operation.

one part in five million (1 cycle at 5000 kc.) and the standard oscillator may be calibrated against it as accurately as it is possible to indicate zero beat. After careful correction, the standard oscillator will maintain its calibration within a few cycles over long periods of use.

Such a simple frequency standard is already in use in a number of amateur stations and service shops. It is limited in its usefulness, however, since it is very often necessary to have calibration points closer together than the 100-kc. spot frequencies, and it is for the purposes of supplying these intermediate points that recourse is had to the Abraham-Bloch multivibrator. One or more multivibrators controlled by the standard oscillator comprise a more complete frequency standard.

• The Multivibrator

The multivibrator, a type of relaxation oscillator none too familiar to most amateurs, may be regarded simply as a *frequency divider* and as such performs a function opposite to that of the more familiar frequency multipliers (doublers, triplers, quadruplers, etc.) found in amateur transmitters. Its circuit is surprisingly simple (see figure 3) and the cost of parts is so low that it hardly appears worthwhile to eliminate it from the amateur's frequency standard.

Operating alone, the multivibrator has little value. Its oscillations are highly unstable and ragged, as may be observed by listening to one of its harmonics on a selective receiver. It can, however, be controlled by a stable crystal oscillator, even when the latter is operating on a harmonic of the multivibrator fundamental, and in this controlled state the roughness of the output disappears and the multivibrator locks into step. In the controlled state, the multivibrator emits a signal on its own fundamental frequency (determined by the values of resistance and capacitance in its circuit[1]), this being a

[1] "A Convenient Method of Referring Secondary Frequency Standards to a Standard Time Interval," Clapp, *Proc. I.R.E.*, Feb. 1929; "Notes on Multivibrator Adjustment," Ephraim, RADIO, May, 1936; *Engineering Bulletin E-6*, p. 25, Bliley Electric Co.; "A New Type of Frequency Checking Device," Grammer, *QST*, June, 1938.

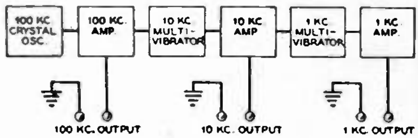


Figure 4. Functional block diagram of the complete standard.

subharmonic of the crystal frequency and possessing the same order of accuracy as the crystal oscillator. It is possible to synchronize a given multivibrator on more than one submultiple of the controlling frequency and the desired output frequency must be selected by adjustment of one of the grid resistors, made variable for the purpose, as will be pointed out later.

The multivibrator output is unusually rich in harmonics, a property which suits it ideally to the production of standard frequency points at high radio frequencies. At the same time, most multivibrators are operated at fundamentals which are audio frequencies and these are highly useful where accuracy of frequency rather than purity of wave form is desired. Successive multivibrators, each controlled by the preceding one, may be used to supply low frequencies all the way down to one cycle per second.

Multivibrators have been synchronized on 1/40 the controlling frequency, but for maximum stability and control, the frequency division is seldom carried out in a single multivibrator stage beyond 1/10 the controlling frequency. A 10-kc. multivibrator controlled by a 100-kc. standard oscillator provides crystal-controlled output on 10,000 cycles and its harmonics appear as spot frequencies equally spaced between each two adjacent 100-kc. points. The 100-kc. oscillator-10-kc. multivibrator combination is common in most complete standards. Multivibrator stages operating on lower frequencies than 10 kc. are employed primarily as generators of accurate audio frequencies, since their harmonics are too closely spaced for convenience in radio measurements.

The portable frequency standard shown on these pages employs a highly stable 100-kc. crystal oscillator and two multivibrators, one operating on 10 kc.; the other on 1 kc. Outputs are provided at 100 kc., 10 kc., and 1 kc. Amplifiers are placed between each stage for the purpose of isolation and building up the output voltage from the driving stage. The power supply is a.c.-d.c. since it was projected to use this instrument "on location" in a locality where both types of power are supplied. While voltage regulation of the plate and screen power supply and temperature control of the crystal are strongly recommended, these refinements were sacrificed for portability in this application. A functional block diagram of the unit is shown in figure 4.

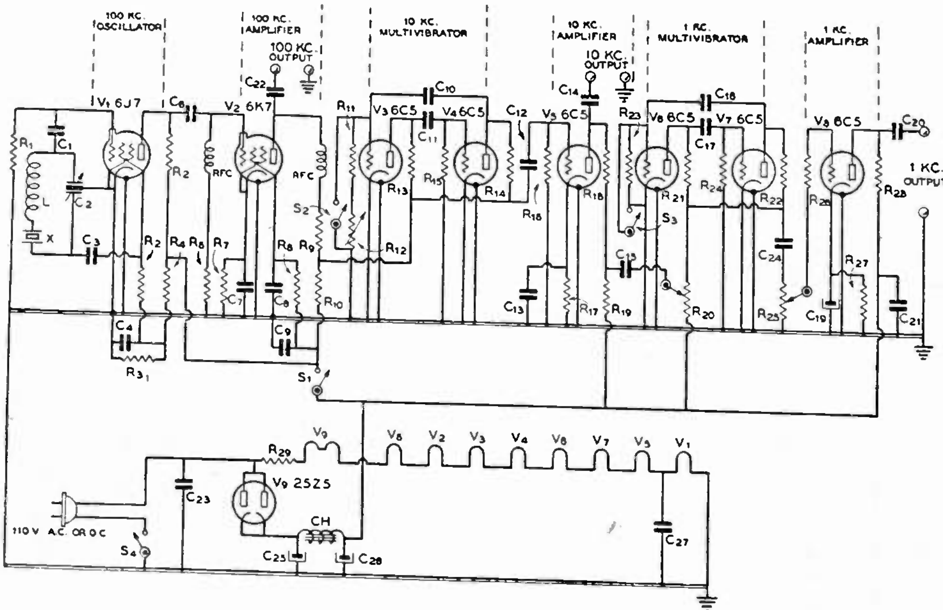


Figure 5. Schematic of the frequency standard with a.c.-d.c. power supply.

Values of components in figure 5.

X, L—Bliley SOC100 crystal unit

C_1—0.01-μfd. 200-volt tubular

C_2—350-μμfd. per section broadcast midget variable

C_3—0.01-μfd. 200-volt tubular

C_4—0.1-μfd. 200-volt tubular

C_5—0.1-μfd. 200-volt tubular

C_6—.001-μfd. mica

C_7—0.1-μfd. 200-volt tubular

C_8—0.1-μfd. 200-volt tubular

C_9—0.1-μfd. 200-volt tubular

C_{10}—.002-μfd. mica

C_{11}—.002-μfd. mica

C_{12}—.001-μfd. mica

C_{13}—0.1-μfd. 200-volt tubular

C_{14}—0.1-μfd. 200-volt tubular

C_{15}—.001-μfd. mica

C_{16}—.002-μfd. mica

C_{17}—.002-μfd. mica

C_{18}—.001-μfd. mica

C_{19}—10-μfd. 50-volt electrolytic

C_{20}—0.1-μfd. 200-volt tubular

C_{21}—0.1-μfd. 200-volt tubular

C_{22}—0.1-μfd. 200-volt tubular

C_{23}—0.1-μfd. 200-volt tubular

C_{24}—0.1-μfd. 200-volt tubular

C_{25}, C_{26}—40-μfd. 150-volt midget electrolytic

C_{27}—0.1-μfd. 200-volt tubular

R_1—1 megohm, ½ watt

R_2—½ megohm, ½ watt

R_3—100,000 ohm, 1 watt

R_4—0.14 megohm, 1 watt

R_5—½ megohm, ½ watt

R_6—½ megohm, ½ watt

R_7—1500 ohms, ½ watt

R_8—300 ohms, ½ watt

R_9—50,000 ohms, ½ watt

R_{10}—50,000 ohms, ½ watt

R_{11}—2500 ohms, ½ watt

R_{12}—5000-ohm wirewound potentiometer

R_{13}—20,000 ohms, 1 watt

R_{14}—200,000 ohms, 1 watt

R_{15}—25,000 ohms, ½ watt

R_{16}—½ meghom, ½ watt

R_{17}—2500 ohms, ½ watt

R_{18}—50,000 ohms, ½ watt

R_{19}—50,000 ohms, ½ watt

R_{20}—10,000-ohm wirewound potentiometer

R_{21}—250,000 ohms, 1 watt

R_{22}—20,000 ohms, 1 watt

R_{23}—150,000 ohms, ½ watt

R_{24}—150,000 ohms, ½ watt

R_{25}—½-megohm wirewound potentiometer

R_{26}—1000 ohms, ½ watt (necessary only if in a particular layout adjustment of R_{25} causes 1-kc. multivibrator frequency to jump)

R_{27}—2500 ohms, ½ watt

R_{28}—100,000 ohms, ½ watt

R_{29}—132-ohm filament-dropping resistor in line cord

S_1—S.p.s.t. toggle switch (100-kc. on-off switch)

S_2—S.p.s.t. toggle switch (10-kc. on-off switch)

S_3—S.p.s.t. toggle switch (1-kc. on-off switch)

S_4—S.p.s.t. toggle switch (power switch)

CH—30-henry, 50-ma. midget b.c.l. filter choke

RFC—2.5-mh. 125-ma. radio frequency choke

• Circuit and Mechanical Features

The 6J7 crystal oscillator is a highly stable modified Colpitts circuit in which the crystal is arranged as a filter in the frequency determining tank. Since the crystal impedance is lowest at its resonant frequency and rises very rapidly at all other frequencies, the crystal assumes control when the tank circuit is tuned to its frequency, or very close to this value. The circuit would oscillate at a frequency very close to 100 kc. if the crystal were not in the circuit, such are the proportions of the tank coil, L, and the tank condenser, C_2, (see figure 5).

The tank coil is built in the holder with the 100-kc. bar, the entire assembly being supplied as a unit (the Bliley SOC100), which is shielded and fits into a standard 5-pin tube socket.

The tank condenser, C_2, is a split stator, 350-$\mu\mu$fd.-per-section broadcast midget employed here as the correction control. This condenser permits variation of the crystal frequency over the narrow range of plus or minus 8 cycles at 100 kc. (plus or minus 400 cycles at the calibration frequency 5000 kc.). The crystal frequency drift due to temperature is less than 3 cycles per Mc. per °C.

The crystal oscillator is followed by a 6K7 resistance-coupled tetrode amplifier which serves to boost the low output voltage from the crystal stage and to isolate the oscillator and first multivibrator stages. This amplifier has been biased higher than is customary and radio-frequency chokes have been inserted in its grid and plate leads to accentuate the higher harmonics. On-off switching of the 100-kc. section of the standard is accomplished by a s.p.s.t. toggle switch, S_1, which interrupts the common B-plus lead to 100-kc. oscillator and 100-kc. amplifier.

100-kc. output is delivered to banana jacks on the front panel of the first amplifier. A portion of the r.f. voltage developed across the amplifier plate resistor, R_9-R_{10}, is injected into the plate circuit of the 10-kc. multivibrator to synchronize the latter.

The two 10-kc. multivibrator tubes are 6C5's in an asymmetrical circuit with grounded cathodes. The variable grid resistor, R_{12}, is a 5000-ohm wirewound rheostat with a slotted shaft mounted through the top of the chassis for screwdriver adjustment. The two feed-back condensers, C_{10} and C_{11}, are mounted very close to the tube socket terminals and must be of good grade mica type.

The 10-kc. multivibrator is followed by a 6C5 resistance-coupled amplifier which isolates the 10- and 1-kc. multivibrators and delivers controlling voltage to the latter. The 10-kc. output jacks are connected to this amplifier. A portion of the r.f voltage developed across the 10-kc. amplifier plate resistor, R_{18}-R_{19}, is injected into the plate circuit of the 1-kc. multivibrator through the synchronizing control, R_{20}, a 10,000-ohm wirewound potentiometer, which, like R_{12}, is mounted with a slotted shaft extending through the chassis top for screwdriver adjustment.

The 1-kc. multivibrator resembles the 10-kc. ditto except that its grid circuits are symmetrical and synchronization is accomplished by the adjustment of the variable plate resistor, R_{20}, instead of a variable grid resistor as in the 10-kc. multivibrator. This arrangement was found by experiment to afford more positive control and greater stability.

The 6C5, 1-kc. resistance-coupled amplifier stage following the 1-kc. multivibrator, delivers 1000-cycle output to the proper front panel jacks. The half-megohm variable grid resistor in this stage is the audio gain control occupying the lower center front panel position.

The multivibrators are separately controlled by s.p.s.t. toggle switches, S_2 and S_3 respectively, which short out one grid resistor in the *off* position. This arrangement allows plate current to be drawn constantly and contributes to the stability of the crystal oscillator.

The heaters of all of the tubes are wired in series *in the order shown* in figure 5. No shielded leads are employed in the customary positions (output connections, etc.) since the small capacity between conductor and shield has been found to bypass some of the useful higher r.f. harmonics. For the same reason, all output leads are kept away from the chassis and other grounded parts and large jack holes are cut in the front panel.

All wiring is as rigid and direct as possible. The operator who duplicates the frequency standard might well keep in mind when wiring up the parts that a measuring instrument is being constructed and that floppy, roundabout wiring will contribute markedly to the unreliability of the unit.

The filter is mounted beneath the chassis and close to the 25Z5 socket. In this unit, the choke is a 20-henry, 75-ma. broadcast midget type and the filter condensers each 40-μfd., 150-volt. The filament-dropping resistor, R_{29}, has a value of 132 ohms. A standard line-cord with self-contained resistor "lead" is used here in order to keep as much heat out of the interior of the unit as possible. It may not be possible to find a 132-ohm line cord resistor as a stock item, in which case the next largest size may be cut down with the aid of a reliable ohmmeter.

The unit is mounted on a 7″x 10″x2″ plated steel chassis and 7″x10″ aluminum panel. Aluminum was used for the panel simply because it engraves sharply. The correction condenser is mounted rigidly on the chassis and adjusted by means of a special vernier mounted behind the panel and controlled by a front of panel knob. This vernier is a National A-dial mechanism. The case shown in the front view photograph was formed from 0.060″ steel and spot welded. It is fastened to the front panel with five 6-32 machine screws, three spaced along the top edge and two on each side. Three more of these screws spaced along the bottom hold the panel to the chassis, and three similarly spaced hold the rear of the

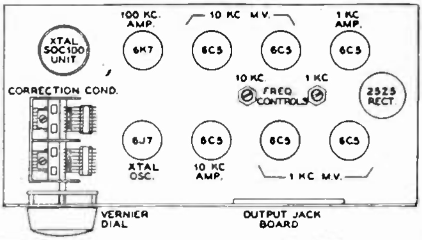


Figure 6. Mechanical layout of the standard, looking down on the chassis.

case to chassis. The mounting screws are finished in the same paint as the panel (or case) in order to avoid conspicuousness.

A liberal number of large holes are punched in the back of the case to permit ventilation, since the nine tubes in the unit generate considerable heat that must be carried away from the crystal. There is argument in some circles that it is more advisable to box up such an outfit as this tightly and allow the inside temperature to reach its peak level before using the instrument; however, measurements made here do not indicate that this peak temperature is a constant value.

In the writer's own application, it will be observed that the case has no lid. It is seldom necessary to go inside the cabinet, except for adjustments to the multivibrator frequency control resistors and two holes are provided (see top of cabinet in figure 1) for the insertion of a long blade screwdriver for this purpose. The front panel of the writer's instrument is finished in baked black wrinkle; the case in baked Western Electric grey wrinkle.

It is not necessary to make a Chinese copy of the layout and mounting shown here, since the instrument is not at all critical as to layout. The individual builder may exercise his own ingenuity with regard to layout and front panel arrangement without introducing any complication. Every available square inch of space has been used in the arrangement shown and it is hardly possible to reduce the size of the unit unless a double or triple deck scheme is used.

• Calibration and Use

After all wiring has been carefully checked and the tubes and crystal unit inserted, the frequency standard must be corrected and adjusted. For this purpose a good receiver covering either the 80- or 160-meter band and tunable also to 5000 kc. must be warmed up and disconnected from its regular antenna to prevent picking up outside signals.

First, determine that the 100-kc. section is operating by switching on the power supply, switching off all but the 100-kc. section, setting the correction condenser, C_2, to half-scale and locating the 100-kc. harmonics in the receiver which must be set for *c.w.* reception in the 80- or 160-meter band, (beat oscillator switched on if the receiver is a superheterodyne). The standard is coupled to the receiver by connecting a length of wire between the ungrounded 100-kc. output jack and the receiver antenna post. With most receivers, sufficient coupling will be obtained if the insulated end of the lead is simply looped around the antenna post. But if the signal intensity is too low with a particular receiver, additional coupling may be obtained by making a direct connection and, if necessary, also connecting the grounded 100-kc. jack to the receiver ground post.

If the 100-kc. oscillator and amplifier are operating correctly, strong harmonics of 100 kc. should be heard as the receiver is tuned through the band. There will be three of these harmonics in the 160-meter band (1800, 1900, and 2000 kc.) and six (3500, 3600, 3700, 3800, 3900, and 4000 kc.) in the 80-meter band occurring at the approximate dial settings for these frequencies. In order to establish that the points heard are 100-kc. harmonics and not outside signals, the 100-kc. switch may be thrown off and on. If the point disappears with the switch in the off position, it is a standard harmonic.

• Correction of Frequency

If the 100-kc. stages are found to be operating correctly, the crystal frequency may now be corrected to exactly 100 kc. in the following manner:

1. Switch off all stages of the standard, but leave the standard power on (to keep the filaments lighted) and keep the 100-kc output jacks connected to the receiver.

2. Connect a good outside antenna to the receiver and switch off the beat oscillator (if the receiver is a superhet) or cut out all regeneration (if the receiver is a regenerative t.r.f.).

3. Tune in sharply one of the standard frequency transmissions from WWV. These transmissions are made according to the following schedule:

A. 5000 kc. modulated at 440 c.p.s. daily except Saturdays and Sundays. 4:00 p.m. to 2 a.m., e.s.t.

B. 5000 kc. unmodulated except for short 1-second standard time pulses at 1000 c.p.s.
Every Tuesday and Friday (except legal holidays) 10:00 to 11:30 a.m., e.s.t.

C. 10,000 kc. unmodulated except for short 1-second standard time pulses at 1000 c.p.s.
Every Tuesday and Friday (except legal holidays) noon to 1:30 p.m., e.s.t.

D. 15,000 kc. unmodulated except for short 1-second standard time pulses at 1000 c.p.s.
Every Tuesday and Friday (except legal holidays) 2:00 to 3:30 p.m., e.s.t.

E. The transmissions under B, C, and D are also made on Wednesdays at the same hours but with 30% modulation at 1000 c.p.s.

It is recommended that the 5000-kc. signal be employed since 100-kc. harmonics grow markedly weak by the time higher frequencies such as 10,000 and 15,000 kc are reached, although finer correction is possible at the two higher frequencies.

4. When the WWV signal has been tuned in carefully, switch on the 100-kc. section and listen for a beat note between the proper harmonic of the crystal oscillator and WWV. If no beat note is observed, the crystal is oscillating exactly on 100 kc., but it is not likely that this condition will obtain, some low-pitched heterodyne being audible in virtually every case. Even if zero beat is indicated at the start, as a fortunate circumstance, it is a good precaution to make certain by swinging the correction condenser to produce a beat note.

5. Slowly adjust the correction condenser until zero beat with WWV is obtained. It will be observed that the beat note obtained in the very beginning is so low in frequency that the correction condenser need be rotated over only a very small arc to reduce to zero beat and swing to the other side. It is emphasized here that this adjustment is a very important one that should be made with the utmost care; the accuracy of the standard can never be any better than the precision with which zero beating is carried out. For this reason, it is strongly recommended that zero beat be indicated by an oscilloscope rather than by ear, since the human ear reaches its low-frequency threshold of hearing a considerable number of cycles higher than actual zero beat. The condition of absolute zero beat indicates that the correction is complete; that is, that the crystal is oscillating exactly on 100 kc.

• Synchronizing the Multivibrators

After the correction has been completed, disconnect the receiving antenna, switch on the beat oscillator of the receiver and make a note of the dial settings for the various 100-kc. harmonics in the 80- or 160- meter band. The multivibrators are now synchronized with the corrected 100-kc. oscillator as follows:

1. With the 100-kc. section running, if the 10-kc. multivibrator is switched on (1-kc. multivibrator off), and is operating correctly, a number of somewhat weaker intermediate signals will be observed between each two 100-kc. harmonics. There will be nine such intermediate points if the multivibrator is synchronized at 10 kc. Eight intermediate points indicate that the multivibrator is locked in step at approximately 11 kc., and 10 points indicate that it is synchronized at approximately 9 kc., etc. To synchronize at the desired frequency, 10 kc., R_{12} is adjusted slowly, noting that at particular settings of this resistor the frequency of any one of the intermediate points will *suddenly jump* to a new value. (This characteristic frequency jump is an indication of correct operation—smooth variation of frequency with the adjustment of R_{12} indicates absence of control by the injected 100-

kc. voltage). Increasing R_{12} will decrease the frequency of synchronization, and vice versa. The correct setting of R_{12} will give 9 standard frequency points between any two adjacent 100-kc. points on the receiver dial. If quickly switching the 10-kc. stage on and off causes the multivibrator to jump to a different frequency, the setting of R_{12} should be reduced slightly.

The separate 10-kc. audio output may be utilized by plugging headphones, speaker or amplifier into the two 10-kc. output jacks.

2. The 1-kc. multivibrator is synchronized in a somewhat similar manner:

A. The 100- and 10-kc stages are switched on with the 1-kc. stage, R_{25} set for full output, and the ungrounded 1-kc. output jack connected *directly* to the antenna post of the receiver. The other coupling lead is transferred from the 100-kc. jack to the 10-kc. output and loosely coupled to the antenna circuit. For this adjustment a selective single-signal receiver must be used with the crystal filter set for *maximum* selectivity.

B. It will be observed that several somewhat weaker signals appear between each two adjacent 10-kc. points as the receiver is tuned through a narrow range. These are harmonics of the 1-kc. multivibrator and will be 9 in number if the multibrator is synchronized on 1 kc. In the same manner outlined in the directions for adjusting the 10-kc. multivibrator, the setting of R_{20} is varied until exactly 9 points are counted between any two 10-kc. points on the dial. When this condition exists, headphones, speaker or amplifier connected to the 1-kc. output jacks will be supplied with acurate 1000-cycle voltage.

C. In the absence of a sufficiently selective receiver, the 1-kc. stage may be adjusted by means of a dependable beat frequency audio oscillator. Output voltages from the 1-kc. stage and the beat frequency oscillator (set to 1000 cycles per second) are fed into the grid circuit of a suitable mixer tube and R_{20} is adjusted to select the proper synchronization frequency determined by zero beat with the 1-kc. signal from the beat frequency oscillator.

The frequency standard may be used directly for receiver or monitor calibration by coupling the 100-kc. output into the receiver or monitor, as described earlier, switching on both the 100-and 10-kc. stages, and tuning the receiver or monitor to locate a series of calibration points. A curve, showing the relation of dial settings to frequencies can then be prepared from the data obtained.

A frequency meter may be calibrated by coupling its output circuit into a receiver already coupled to the frequency standard. In this operation, the receiver is tuned to zero beat with successive 10- or 100-kc.

points and the frequency meter adjusted to zero beat with those points. The frequency meter calibration curve would show dial settings (meter) against standard frequencies.

An oscillator, signal generator, or transmitter is set to a desired frequency by coupling its output into a receiver or monitor which is also coupled to the frequency standard. The desired frequency, as generated by the standard, is located on the receiver or monitor dial, and the oscillator or transmitter is adjusted to zero beat with this same point. If the desired frequency is intermediate to any of the standard frequency points, it may be obtained by interpolation on the dial of the receiver or monitor.

If any unknown signal is close enough to a standard signal to create a beat note, the frequency of the note, as measured by a reliable beat frequency oscillator, will be the deviation in cycles from the standard frequency. Drift in self-excited oscillators may be checked in this fashion. The oscillator is first set to zero beat with a standard frequency point and its deviation checked at suitable intervals.

Other uses will become apparent. The frequency standard represents the ultimate in frequency measuring gear and will provide large dividends in the certainty and security that go with knowing exact frequencies. It is an exceedingly useful tool in the station or laboratory, and once used becomes indispensable. Graduate to the frequency standard!

(See page 51 for photographs)

Braille Dial for the Blind

FOR use at the Blind Institute, Brisbane, a receiver was fitted with a special touch-type dial on which were punched in relief, and in Braille characters, the call-signs of the principal stations. When in actual use by a blind person there was not the slightest hesitancy in selecting the desired station.—Radio and Electrical Retailer, Sydney.

¶ From Bell Laboratories
Record June, 1939.

MEASURING TRANSMISSION SPEED of the *Coaxial Cable*

By J. F. WENTZ

WHEN we pick up the telephone to answer a call we never realize that our "hello" takes any time to reach the caller's ear. It is a fact that on any call we can make, even to distant countries, this time is so short that it seems only an instant before the answer returns. The lines and apparatus which transmit our speech have been so designed that delays due to them are always a small fraction of a second. If it took even half a second to traverse the connection from talker to listener, its effect on transmission would become noticeable. The total transmission time including instruments, terminals, and miles of line should be short enough not to react appreciably on ease of conversation.

We cannot always control the transmission time of all the various components that make up the complete circuit, and for some very long circuits only the highest speed lines can be used. One of the advantages of the coaxial cable with which we are now experimenting between New York and Philadelphia is its high transmission speed. The waves of carrier current that bear the voice over the line travel with a velocity of around 170,000 miles per second. Over even the longest circuit we might have in the United States, perhaps 4,000 miles, current traveling at this speed would require less than one-fortieth of a second to pass through the coaxial cable itself. Delays of this magnitude are not objectionable for telephone purposes, and are even less important for television. Variations in the delay for different frequencies, however, are more im-

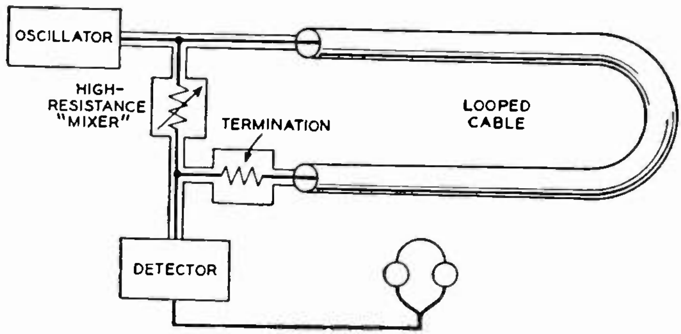


Figure 1. Method of measuring phase delay when cable can be looped to bring the two ends together.

portant, and they are much more important for television than for telephone signals.

● Simplest Method of Measurement —Looped Cable

A 170-kilocycle carrier requires 1/170,000 of a second for one complete cycle. On a cable with a speed of 170,000 miles per second, therefore, such a wave will travel one mile in the time taken by one cycle; the current received at a distance of one mile and the current sent out are "in phase" because they rise and fall together. Similarly, if the cable is one-half mile long, the carrier will require the time of only one-half cycle to traverse it, and the currents at the two ends will be "out of phase," one rising while the other is falling. If a half-mile length of cable is looped so that both ends are at the same place, the sent and received currents can be made to "buck" each other, resulting in zero current in a receiver. This is the simplest method of measuring the delay, and figure 1 shows the essential apparatus that is involved.

● Accuracy

The accuracy of the measurement on any length of cable depends mostly on how closely the frequencies for which the particular length of line represents odd multiples of half a wave-length can be determined. These are the frequencies at which sent and received currents are exactly out of phase. If there are no variations in the properties of the cable from one frequency to the next, these frequencies will occur at regularly spaced intervals, and the speed will be constant at all frequencies. Our cables can never reach this phase perfection and still be efficient, and so for sending television pictures it is necessary to correct them with a "phase equalizer."

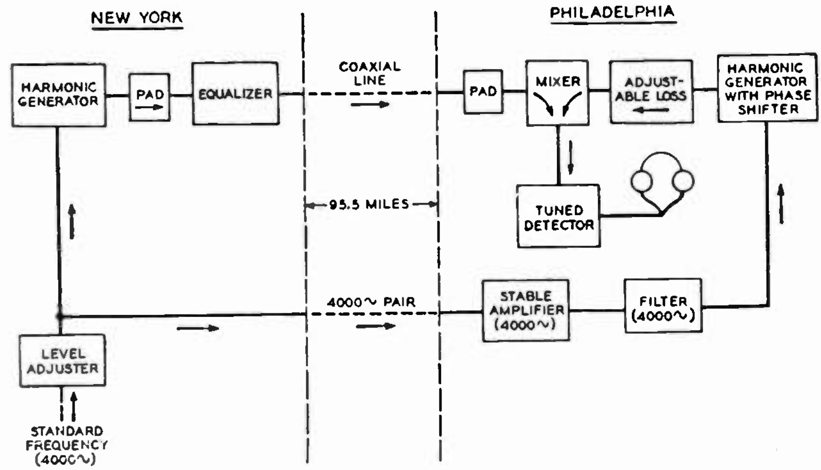


Figure 2. Method of measuring phase delay on a "straightaway" test.

- "Straightaway" Measurements —Cable Ends Remotely Separated

The measuring method described above is very satisfactory where two long identical lines that can be looped are available. For a "straightaway" measurement, where the two ends of the cable are many miles apart, some means had to be devised to supply a reference current at the receiving end which had some fixed-phase relation to the sending current. To do this, the method shown in figure 2 has been employed. Here the sending wave is generated by a harmonic generator. This device takes a low frequency of a few kilocycles and turns it into a much-distorted signal which is very rich in harmonics. The wave shapes of the input and the output with their relative position in time are shown in figure 3. Such a wave when analyzed is found to contain harmonics to a very high order—the narrower the peak the larger the high-order harmonics.

- Frequency Generators

The generators built for the tests between New York and Philadelphia delivered at least 250 harmonics of 4 kc., all at about the same level of one milliwatt. A useful property of this generator is that the various harmonics have a fixed-phase relation to the fundamental if the shape of the peak is always the same. In this way a generator is provided that has many high frequencies all fixed with respect to time by the 4-kc. input to the circuit. Any number of degrees phase shift of the 4 kc. can be translated into phase shift of a particular harmonic simply by multiplying by the order

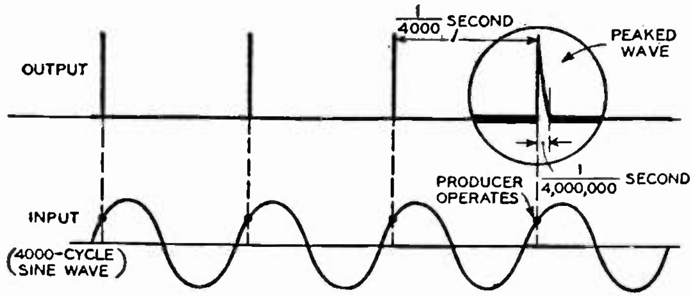


Figure 3. The harmonic generator produces a peaked wave that provides for a large number of equal-value harmonics from a 4-kc. fundamental frequency.

of the harmonic. A phase shifter with a calibrated dial was installed in the amplifier that is a part of the harmonic-generator circuit so that any length of line could be matched at any harmonic of 4,000 cycles up to 1,000 kilocycles.

- New York-Philadelphia Tests

In actual measurements, identical harmonic producers, driven by the same low-frequency source, are used at each end of the cable. The Bell Laboratories' 4-kc. standard is used as a reference. It operates one harmonic producer at New York which sends into the coaxial line all multiples of 4 kc., reduced to a level that will not overload the repeaters at the tops of the peaks. The standard frequency is also transmitted to Philadelphia on a pair of wires without repeaters, where, after filtering out any noise which the pair has picked up, the same 4 kc. is used to operate harmonic producer no. 2. Its output is sent into a mixer together with the signal received from the coaxial circuit. After the detector has been tuned to any one harmonic, the amplitude and phase can be adjusted to give no response in the phones. This is the condition that means the harmonic from the line is just 180 degrees out of phase with the same harmonic coming from producer no. 2. In general, tuning to the next harmonic results in some reading on the detector, and the amount the phase dial has to be changed to reestablish the correct balance represents the difference in phase delay for a 4-kc. interval.

During the time taken for two such readings we must assume that the lines themselves do not vary, and that the voltage delivered to the harmonic generators does not change its amplitude. By frequent checks it was proved that the variations encountered in either the line or the harmonic generator were negligible.

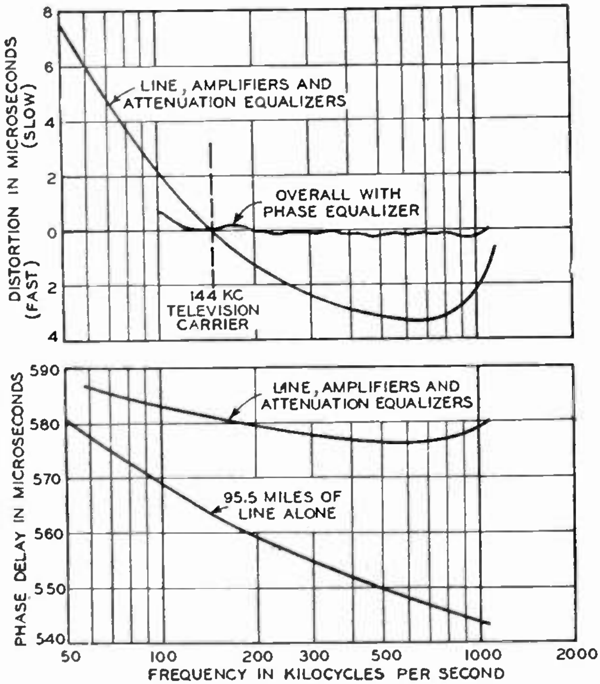


Figure 4. Phase delay, below, and distortion, above, for various conditions of the coaxial circuit.

• Results

Some of the results obtained by this method are shown in figure 4. The cable was first measured without amplifiers and equalizers. This was done by determining the absolute time of transmission for each of the nine 10.5-mile sections, and then adding the results. The carrier current which bears the voice of a subscriber using channel 59, which is the one assigned to 300 kc, can be seen to take 555 microseconds to traverse the cable. Since it travels 95.5 miles it is going at the rate of 172,000 miles per second. The effect of the line amplifiers and attenuation equalizers is to increase the delay at all frequencies, but to a much greater extent for the high than for the low frequencies. As a result the curve for delay of the line with amplifiers and attenuation equalizers is above that for the line alone, but is much flatter.

As already noted it is the difference in delay for the various frequencies that is ordinarily of greatest importance, and this difference in delay with respect to some reference frequency is known as the delay distortion. A distortion curve for the line with amplifiers and attenuation equalizers is plotted in the upper part of figure 4 for a reference frequency of 144 kc. Over the entire band used for 240 telephone channels (60-1020 kc.) the distortion is less than ten microseconds. For telephone purposes no better phase equalization is needed. Over a band of 4,000 cycles, which is used for one telephone channel, the distortion is negligible for speech. When a phase equalizer is added, the result is "practically a dead-heat finish for all the frequencies" in the television range which covers the band above 100 kc. A curve for the distortion with the phase equalizers included is also plotted in figure 4.

Further refinements in delay-measuring equipment are being called for as frequency range is extended. For the 1,000-kc. television trial,* an accuracy of about five or ten degrees at the upper frequencies was sufficient for the 240-line picture used for tests. For the 441-line television, which has been adopted as standard, future cables will have to be measured to better accuracy and for frequencies up to 3,000 or 4,000 kilocycles.

---

* *Bell Laboratories Record,* February, 1938, p. 188.

●

Lucite

THE new DuPont plastic called Lucite, which has received much publicity because of its ability to persuade light rays to travel other than in a straight line, will find many uses around the amateur station. It is an excellent u.h.f. insulation, the power factor being as good as anything we have seen.

The material is relatively inexpensive, and easily worked with ordinary shop tools. While it is a thermo-plastic and like Victron and celluloid will not stand much heat without becoming soft, this property makes it easy to bend and form into desired shapes merely by heating it.—Radio.

¶ From T. & R. Bulletin
May, 1939

Insulating Materials for the Higher Frequencies*

By G. F. BLOOMFIELD, Ph.D., D.I.C.

THE importance of utilizing low-loss materials for insulation and dielectric purposes at the higher frequencies cannot be over-emphasized. In recent years some excellent low-loss materials have become available in the ceramics, frequentite, steatite, etc., and these have already largely replaced the older materials, such as ebonite or bakelite, for high-frequency equipment. Unfortunately, these ceramic materials suffer from the inherent disadvantage that they cannot be readily manipulated in the workshop, so that the experimenter is restricted to a limited number of standardized parts which lend themselves readily to mass production.

During the past twelve months a new material, Polystyrene, has become available to the radio amateur and to the trade under the names of Trolitul, Victron, Styron, Resoglaz, Rhodolene and Distrene, and, as certain grades of this material are every bit as good as, or in some cases even better than, quartz, mica and the ceramics, while at the same time the new material (available in bulk as sheet, rod, tube or film) can be sawn, drilled and manipulated generally as readily as ebonite, some notes on its properties and manipulation may not be without interest.

Some theoretical considerations of dielectric loss are here put forward to indicate in what circumstances power loss in an insulating material may be expected, and to show how the properties of a material can to some extent be predicted from a knowledge of its molecular structure and chemical composition.

*A lecture delivered to the London membership at the I.E.E. on February 24, 1939.

- Nature of Dielectric Loss

The criterion of a low-loss material is essentially that it shall have medium or low dielectric constant and a low power factor. The dielectric constant of an insulating medium may be considered as a measure of electrical displacement for a given electric force; it is in the nature of a movement of electricity which reaches a defined value when the electric force is applied. Matter consists of positive and negative charges bound together by the forces of attraction between them and when an electric field is applied there is a tendency for the charges to move in opposite directions against these restoring forces of attraction. In the case of a molecule in which charges tend to become concentrated at opposite ends of the molecule, e.g., water:

$$\overset{+}{\mathrm{H}}\text{—}\overset{-}{\mathrm{OH}}$$

there is also a tendency for the molecule as a whole to rotate and set itself in the direction of the field. Such a molecule is termed a "polar molecule": it can be considered as a tiny magnet which tries to set itself in the direction of the field at any instant. The charged portions of the molecule do not necessarily separate, such would be termed ionization; the molecule only tends to rotate as a whole and the extent to which it does rotate is dependent upon the magnitude of the charges, the size of the molecule, viscosity of the medium, temperature, etc. Highly polar molecules have high dielectric constants, e.g., water 80, non-polar molecules, low dielectric constants, e.g., petroleum 2. In many insulating materials, and notably in synthetic resins, the structure of the molecule is that of a chain of small units linked together end to end or crosswise as in a lattice. The small unit of the chain or lattice may be termed a "repeater unit" which can be either polar or non-polar.

- Ionic Movements

In an alternating field the movement of charged ions or the rotation of the polar molecule or repeater unit has to follow the alternations of frequency and since the molecular and ionic movements are opposed by the forces of attraction between molecules and viscosity influences within the medium, there is in general a lag behind the alternations of the electric field, that is a power loss in the material. A measure of the power loss is obviously the power factor, usually expressed as the tangent of the angle of lag, i.e., tan δ. As frequency increases from zero the greater is the loss factor up to a point at which the frequency becomes so high that the particles cease to respond, and their contribution to the loss factor and to the dielectric constant becomes zero; in other words, the power factor decreases again. In the intermediate region the loss factor passes through a maximum, termed a region of dielectric absorption. If the internal friction is low the absorption takes place at high frequency; if it is high as in glasses and many crystalline solids, the

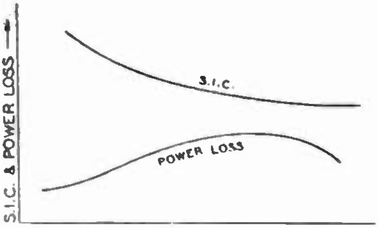


Figure 1.

absorption occurs at low frequency. Yager, in a recent paper[1] has studied changes in dielectric constant and loss factor with frequency, and his results illustrate this effect quite strikingly. A typical curve is shown in figure 1.

- Application to Insulating Materials

The type of molecules and electrical displacements in common insulating materials must next be considered. In substances like glass, mica, porcelain, and many resins, the charges are largely ionic and frequently arise from traces of soluble impurities dissolved in molecules of water, bound within the structure of the material or absorbed on to its surface; in such materials leakage current is largely ionic and increases with rise of temperature which further increases the ionization—such an effect is cumulative and a point is ultimately reached at which breakdown occurs. If this effect is concentrated in a surface layer of absorbed moisture, the familiar phenomenon of "tracking" occurs.

Water

Water has already been quoted as an example of a highly polar molecule, represented H—OH; it is disadvantageous in an insulating material not only because of its polarity but also because it can ionize substances dissolved in it, leading to ionic charges. Thus, although bakelite resin, for example, contains only 3 per cent or less of water, its power factor has been observed to fall by 30 per cent on drying.[2] Hydrocarbons—that is, compounds of carbon and hydrogen, are non-polar: if a hydrocarbon radical—i.e., a group of carbon and hydrogen atoms—is introduced into the water molecule there is a marked drop in dielectric constant:

Water	HOH	80
Methyl alcohol	CH_3OH	35.4
Ethyl "	C_2H_5OH ...	26.8
Propyl "	C_3H_7OH ...	21.8
Butyl "	C_4H_9OH ...	17.8
Amyl "	$C_5H_{11}OH$ ..	16.0

and so on.—OH is a highly polar group—it confers polar properties on any compound into which it is introduced. Conversely, a hydrocarbon group reduces the polar properties of a compound into which it is introduced.

Benzene

Perhaps the least polar substance which it is possible to imagine is

[1] Yager, J. Electrochem. Soc., Preprint 74-24.

[2] Hartshorn, Megson & Rushton, Journ. I.E.E., 1938, 83, 474.

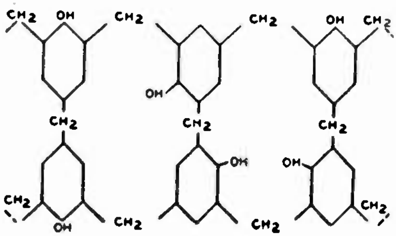


Figure 2.

benzene, since its molecular structure is that of a symmetrical hexagon: its dielectric constant is 2.29. If we introduce the polar—OH group into the benzene molecule we have phenol: its dielectric constant is 15. If, on the other hand, we introduce a hydrocarbon, the dielectric constant is not greatly increased; thus, ethyl benzene has a dielectric constant 2.47. Referring again to phenol, this can be treated with formaldehyde to obtain the well-known insulating material bakelite, the structure of which is possibly of the form in figure 2.

In this network the polar phenol is not so free to suffer displacement as in the free state, consequently the dielectric constant is much lower, namely, 4.0 in the pure resin. It has been shown that by the introduction of further hydrocarbon groups into this network, both dielectric constant and power factor are reduced,[2] as would be expected from the foregoing theoretical considerations.

Bakelite

In the course of the chemical reactions producing bakelite considerable water is formed, and in a thick specimen this water is removed only with extreme difficulty. In a network structure of the type just indicated there are plenty of open spaces in which molecules of water can be retained; moreover, a polar molecule has the further property of attracting other polar molecules, e.g., water, to it. Consequently, bakelite generally contains several per cent of water which has its own effect in increasing dielectric constant and power loss.

In the manufacture of laminated bakelized sheet such as Paxolin, paper is impregnated with bakelite in a premature stage of formation, and is subsequently consolidated under the influence of heat and pressure, the heat causing the "premature" bakelite to form the familiar hard resin. Dry paper has quite a low power factor (.0025) and low dielectric constant, but, unfortunately, bakelite resin is itself somewhat pervious to moisture, so that although every care is taken to minimize the water content by impregnating with resin from which most of the water formed by the chemical reaction has already been eliminated, laminated materials suffer many of the disadvantages of bakelite. The chief advantage of the laminated materials is of course in their very much greater mechanical strength.

Rubber

Rubber has a non-polar hydrocarbon structure, its dielectric constant is 2.34 and its power factor .002. It is, however, more familiar in the vulcanized state, either partially vulcanized as in flex or fully vulcanized as in ebonite. Vulcanization consists of a linking-up of rubber molecules with introduction of sulphur, which confers some polarity upon the molecule, and the dielectric constant is raised to 2.5 to 3.0, and the power factor to 3 to 5, times that quoted above, or to an even higher figure if the rubber contains a mineral filler (see table 2). The drawback of ebonite is that exposure to air or light causes oxidation giving rise to surface acidity resulting in a lowered surface resistivity.

Celluloid

Celluloid and cellulose acetate have highly polar structures—the power factors and dielectric constants are accordingly high.

Polystyrene

Polystyrene has a purely non-polar hydrocarbon structure and its power factor is extraordinarily low. Other similar hydrocarbon resins which will probably very shortly be available are polyindene and polyethylene.

- Sources of Power Loss

Since factors contributing to power loss and dielectric constants are:

1. displacement of ionic charges.
2. rotation of polar molecules as a whole.
3. rotation of polar groups within polar molecules,
4. rotation of the repeater unit,

the curve relating power loss and

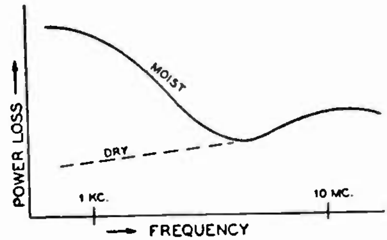


Figure 3.

frequency does not in general show any one well-defined maximum as would be expected if one factor alone were responsible for loss. Usually the maximum is broad and ill defined, frequently there is more than one maximum. The laminated bakelites, for example, show a maximum just above 10 Mc. when quite dry, but when moist a low-frequency maximum also appears, attributed to ionization in the absorbed water (figure 3).

The maximum at 10 Mc. appears to be common to all bakelites containing a cellulose filler, whether paper, wood-flour or fabric, and urea resins show the same effect. It is postulated that this absorption is a function of the cellulose; it largely disappears when the cellulose filler is replaced by a mineral such as mica or talc, and the introduction of such a filler has the added advantage of rendering the material less sensitive to moisture pickup, thus reducing the low-frequency absorption. This forms the basis of many of the low-loss materials now on the market.

In polystyrene the dielectric constant has been found to be inde-

TABLE 1

Some Properties of Mineral Insulators

Material	S.I.C.*	Power Factor at		
		1 Mc.*	10 Mc.†	60 Mc.†
Quartz	3	.001	.00011	.00011
Mica	6.5	.003	.00016	.00016
Frequentite	5.9		.0007	.0006
Steatite	6.5		.0017	.0015
Mycalex	6.1	.002		
Porcelain	5	.008		

* T. & R. BULLETIN, Sept., 1936, p. 106.
† From a German source.

pendent of frequency up to at least 35 Mc.[1] and the loss factor is also independent of frequency—it behaves, therefore, as the almost perfect dielectric. Further, there is no variation of dielectric loss with temperature at high or low frequencies.[3] The water absorption of polystyrene is nil—prolonged immersion in water does not affect its excellent electrical properties and it is therefore well suited for outdoor work.

A number of properties of practically all of the common insulating materials are shown in Table 1 and 2. Comparative power-loss figures have been calculated from the product of dielectric constant and power factor and these are shown in Table 3. It is apparent from these figures that Trolitul is definitely better than the ceramics, while Styron is slightly superior even to quartz and mica.

- Practical Test

The relative efficiency of insulating materials can be readily tested by inserting a thin sheet between the plates of a small parallel plate condenser of a few micro-microfarads capacity connected in parallel with the tank condenser of an oscillator or driven circuit. It is necessary to re-tune the tank condenser to resonance or to the original frequency in the case of an oscillator, a small reduction in this capacity being required to compensate for the slight increase in capacity of the parallel plate condenser on inserting the dielectric. If there is no loss at all in the dielectric there will be no change in the plate current of the valve when the dielectric in inserted; loss is indicated by a rise in plate current. If samples of several materials are available of comparable thickness, they may be compared one with another. Results obtained by this method are shown in Table 4: there is considerable increase in plate current with practically all materials tested other than the polystyrenes. Differences in the order of the materials at the two test frequencies are due to the variation of loss factor with frequency as has already been explained.

[3] J. Tech. Phys. (U.S.S.R.), 1933, 3 831.

TABLE 2

Properties of Plastics for Electrical Insulation

Material	Specific gravity	Tensile Strength 1,000 lbs. /in.²	Water Absorption % in 24 hrs.	S.I.C.	Power Factor	Frequency
Raw Rubber ..	0.93			2.5	.002	1 kc.
Elbonite, Pure .	1.2	4.3	.02	3.27 3.18 3.15 3.13	.0035 .0084 .0080 .0072	1 kc. 1 Mc. 10 Mc. 35 Mc.
Elbonite, Filled.				3-4.5	.012 .03	1 kc. 1 Mc.
Bakelite, Cast .	1.3	5-12	.01-.05	5-10 5-7	.025-.2 .005-08 .01-.045	60 cycles 1 kc. 1 Mc.
Bakelite, Wood-flour Filler .	1.3-1.5	6-11	.2-.6	5-12 4-9 4.5-8 5.8 5.6	.04-.3 .04-.18 .035-.10 .073 .079	60 cycles 1 kc. 1 Mc. 10 Mc. 35 Mc.
Bakelite, Paper-laminated ...	1.3-1.5	6-13	.02-.05	4-6	.02-.05	1 Mc.
Bakelite, Mica Filler	3.0	10		6.4 5.6 5.4 5.3	.056 .050 .050 .049	1 kc. 1 Mc. 10 Mc. 35 Mc.
Shellac	1.1-2.7	1-2	1.5	15.0 6.0	.2 .07	60 cycles 1 Mc.
Urea Resin, Wood-flour Filler	1.5	8-13	1-2	6.6 6.3 5.7 5.5 5.3	.034 .022 .030 .038 .042	60 cycles 1 kc. 1 Mc. 10 Mc. 35 Mc.
Celluloid	1.4	5-9	1-3	7 6.2	.06-.14 .05-.10	60 cycles 1 Mc.
Cellulose Acetate	1.3	4-10	1.4-3	5-7.5 4-6 4-5	.025-.07 .03 90°	60 cycles 1 kc. 1 Mc.
Perspex ...... (Diakon) ...	1.18	7-9	0.3	4-6 3.4 3.0 2.9 2.8	.06-.08 .05 .02 .018 .017	60 cycles 1 kc. 1 Mc. 10 Mc. 35 Mc.
Polystyrenes:—. Styron	1.05-1.07	5.5-7.5	Nil	2.6 2.64	.0003 .0001	60 cycles 1 kc.-35 Mc.
Trolitul				2.5 2.6	.0001 .0002 .0003 .00058 .00125 .0007	800 cycles 750 kc. 3 Mc. 6.5 Mc. 13.6 Mc. 60 Mc.
Polyindene				3	.0004	1 Mc.

• Polystyrenes

As far back as 1911 polystyrene was proposed as an insulating covering for electrical work but the price at that time was prohibitive (it was actually discovered over a century ago). Only in the last few years has progress in its manufacture

TABLE 3
Relative Power Losses

Material	Frequency, Ccyles				
	60 cycles	1 kc.	1 Mc.	10 Mc.	35 Mc.
"Styron"	1	1	1	1	1
"Trolitul"		2	4	10	13 (9)
Polyindene			6		
Quartz			15	2.6	(2.6)
Mica			35	5.6	(5.6)
Mycalex			60		
Frequentite				21	(18)
Steatite				55	(50)
Ebonite		58	135	125	115
Porcelain			200		
"Perspex" (Diakon)	475	850	325	250	235
Filled Ebonite		200	600		
Urea-Formaldehyde.	265	700	850	1050	1100
Cellulose Acetate	120- 600	600- 900	1200		
Bakelite, Cast	120-2500	150-2500	300-1500		
" Wood-flour	250-4500	800-8000	750-4000	2100	2200
" Mica		1800	1400	1350	1300
Shellac	3750		2100		
Celluloid	450-1200		1500-3000		
Vinylite		385	250	190	145
Koroseal		6100	1900	900	500

( ) at 60 Mc.

enabled it to be placed on the market at a price comparable with other insulating materials. The raw materials are quite cheap but great care is necessary in making the solid polystyrene from the liquid styrene, since traces of chemical impurities can have a serious influence on the power factor; similarly, the use of solvents in manufacture is undesirable.

The power factor of commercial Trolitul has been determined at quite high frequency and shows a slight rise from .0003 at 3 Mc. to .001 at 13 Mc. This rise is contrary to the observations of Yager,[1] working with Styron, and is probably accounted for by traces of impurity in the German material. Unfortunately, no precise information about the British material Distrene is yet available, but tests by the author indicate that it has about the same properties as Trolitul. It is, however, believed that more recent supplies may have a power factor as low as .0002 at 40 Mc.

Polystyrene comes on to the market in the form of a coarse whitish powder not unlike soda. When heated above 70° C. it becomes rubberlike and plastic and can be moulded under heat and pressure into the more familiar sheet, rod and tube; the best conditions for moulding are 140 and 160° C. and 500 lbs. per sq. in. Sheet is made by moulding in a shallow tray, rod and tube by forcing the hot material through a nozzle. If the hot rod, as it comes from the nozzle is wound upon a mandril a spiral results, suitable for use in a coaxial cable for television. The hot rod can be drawn into thread of remarkable toughness and flexibility.

TABLE 4

Practical Tests at Radio Frequency

At 1.75 Mc.: C.O. Test Circuit: Capacity of Plates 3μμfd. At 35 Mc.: Ultraudion Test Circuit: Capacity of Plates 5μμfd. Test Samples 1/16 inch thickness.

Dielectric	1.75 Mc. Test		35 Mc. Test	
	Plate current ma.	Increment	Plate current ma.	Increment
Air	2.66	—	5.3	—
Styron	2.66	0.00	5.3	0.0
Trolitul	2.66	0.00	5.4	.1
Coloured Trolitul	2.70	.04	5.5	.2
Distrene	2.70	.04	5.4	.1
Perspex	2.84	.18	7.0	1.7
Mipolam	2.86	.20	6.9	1.6
Ebonite	2.86	.20	6.9	1.6
Urea Resin	3.24	.58	7.6	2.3
Cellulose Acetate	3.32	.66	8.1	2.8
Celluloid	3.44	.78	8.2	2.9
Bakelite	3.84	1.18	8.1	2.8

Similarly, tough and flexible film is also available. Sheet is available from 1/16 of an inch thickness upwards, rod and tube of almost any diameter and wall thickness. Thread can be drawn down to the fineness of hair, film is made from .01 mm. upwards (approximately ½ mil.). Small articles of standardized dimensions are most conveniently made by a process known as "injection moulding," in which the hot material is forced into a closed mould, as soon as the material has sufficiently cooled the mould being opened and the article ejected, the process then being repeated. Such machines run quite automatically, powdered material is fed in at one end and finished articles come out at the other, requiring only the attention of one operator to fill the hopper and to pick up and trim the finished articles if necessary.

Owing to the excellent moulding properties of polystyrene, it is rapidly finding its way into the luxury trade, especially in view of its excellent clarity, high polish and brilliance and high refractive index. In this connection a word of warning. In order to obtain even better moulding properties, oils, etc., are incorporated in certain grades of polystyrene not intended for high-frequency work, and these may adversely affect the power factor. For high frequency work, therefore, only the highest grade of glass-clear colorless quality is permissible: in this respect material obtained from a reputable manufacturer can be used with confidence.

• Manipulation of Polystyrene

The property of softening at rather low temperatures, upon which depend the moulding properties of polystyrene, is, of course, disadvantageous in the finished article, and up to the present this drawback has not been overcome. In amateur requirements, softening through heat is only likely to occur in isolated instances, such as in a valve base, and here the difficulty can be overcome, as it is really only necessary to have the bottom carrying the pins made in polystyrene—the supporting walls being made in another material more resistant to heat. Great care, of course, is necessary in soldering on to metal in contact with polystyrene as the metal can easily be made hot enough to melt the material. The most satisfactory precaution is to wrap blotting paper around the base of the metal and adjacent polystyrene, and to keep this thoroughly wet with cold water. In drilling, the drill is preferably withdrawn once or twice and allowed to cool; water is a good lubricant. In sawing, the material should be clamped securely between boards so that the sheet is gripped along the whole length to be cut, in close proximity to the line of cutting; the work should be kept well flooded with water. A newly cut edge can be cleaned beautifully by scraping with a knife. For polishing, sawdust and oil, or whiting and oil, or simply an oily cloth are recommended.

Polystyrene is highly resistant to acids, alkalies, oils, and alcohol, but dissolves in certain solvents such as benzene or amyl-acetate, and pieces can be stuck together by means of a solution of scraps of dissolved polystyrene, preferably in benzene, since this has no polar characteristics. Such a solution is also most useful for securing wire in coils, chokes, etc.

• Recognition of Polystyrene

Polystyrene is recognizable by a very characteristic odor when worked, and a test can easily be applied by rubbing with a file; it is also characterized by a metallic sound when struck or dropped. It exhibits a characteristic fluorescence in ultra-violet light. Its low specific gravity is a confirmatory test.

• Appendix

Since the above article was contributed a most interesting and informative article on polystyrene has been published in the March issue of *Industrial and Engineering Chemistry* (Industrial Edition). Figures for a commercial polystyrene show power factor .0002 to .0003 and dielectric constant 2.55 to 2.60 over the range 60 cycles to 20 Mc., while at ultra-high frequency the power factor is given as 0.0004 in the wavelength range of 60-150 cm. It is stated that polystyrene has proved a useful low-loss material at 1 to 2 cm. wavelength, and it has even been used for windows transparent to infra-red radiation at 0.005 cm. wavelength!

It is also pointed out that at visible light frequency the "dielectric constant" corresponds to the square of the refractive index, i.e., 2.5 in the case of polystyrene, which is practically the same as in the radio frequencies. This provides strong evidence of the absence of any marked region of dielectric absorption through the entire range of radio frequencies, and even into the region of visible light!

¶ From Aero Digest
June, 1939

ULTRA-HIGH FREQUENCIES *for* FEDERAL AIRWAYS

By HENRY W. ROBERTS

THE lifeblood of our domestic air commerce pulsates along the 25,500-mile radio-equipped network of our Federal Airways System.

That network of airways must constantly shape itself to our national needs, anticipate their growth and grow with them. There is a definite relationship between the expansion of the aeronautical industry and the expansion of the Federal Airways System; every advance in the industry must go hand in hand, or better, be preceded by an advance in the Federal Airways System.

The usefulness of this system is expressed in its *traffic capacity* and its *geographical extent.*

The saturation point in the traffic capacity of our airways is fortunately still far away, although it is much closer than many realize. With the number of aircraft using our airways doubled—and that time is not far distant—the traffic capacity of our present airways would be overtaxed.

In geographical expanse, our radio range network now serves little more than the principal air routes, the arteries. There exists, today, a definite need for radio range routes for secondary airways, especially to west of Chicago. And, as the aeronautic industry grows and extends into smaller communities, those communities will need to be linked to the arterial routes, to form a thoroughly integrated nation-wide airways system.

In peace or war, aeronautics plays a vital role in the life of the nation. Numbers of available aircraft are not enough: means must be provided for its most effective utilization—

airports and airways. These are the pivotal factors governing the future expansion of the aeronautical industry.

- Present Network

Since 1927, when the Aeronautics Branch and Airways Division of the Department of Commerce were organized and took over from the Post Office Department some 2700 miles of airways and 17 radio communications stations; or since 1928, when the first (and only) radio range was installed, the Federal Airways System grew rapidly. In the ten fiscal years, 1927 to 1937, some $12,000,000 was spent in all on the construction of the entire Federal Airways System; from 1932 to 1937 inclusive, when only $4,-350,000 was spent on *all* airways construction, including radio aids, the Federal Airways System fell far behind the national needs.

In the fiscal year 1938, a comprehensive program of airways modernization and new construction was initiated by the Bureau of Air Commerce and a $7,000,000 appropriation obtained from Congress, of which $5,037,800 was to be spent in that fiscal year. This much-needed program was ably prosecuted and brought to completion by the Civil Aeronautics Authority on April 1, 1939, and by May 1, the CAA added another 1500 miles of new airways.

Today the Federal Airways System has 231 new and modernized radio ranges, 100 ultra-high frequency cone-of-silence markers, 21 ultra-high frequency fan markers, 7000 additional miles of teletype circuits, 12 airways traffic control centers, and a large quantity of such long-needed new equipment as 150 new automatic gasoline-driven emergency power generators. In addition, the CAA is taking over three radio stations (at Denver, and Akron, Colo. and Hayes Center, Neb.) from United Air Lines, and 15 ultra-high frequency markers from the State of Pennsylvania.

After July 1, when an additional $2,000,000 under the original $7,000,000 appropriation becomes available, work will be started on an additional 1969 miles of airways[1]; these will cost $1,237,100. An additional $724,700 is to be spent on miscellaneous additions and improvements.[2]

This work will represent approximately the ultimate extent of the original long-wave low-frequency conception of our radio range network; no more frequencies are

[1] Omaha-Bismarck 471 mi.; El Paso-Albuquerque, 255 mi.; Tulsa-Kansas City, 216 mi.; Billings-Great Falls, 190 mi.; Bangor-Caribou, 140 mi.; Dayton-Goshen, 143 mi.; Baltimore-Buffalo, 298 mi.; and Huron-Minneapolis, 256 mi.

[2] $90,000 for relocating airway aids on Tucson-Rodeo leg, Phoenix-El Paso airway; $162,500 for purchase and installation of 65 additional ultra-high frequency cone-of-silence markers for balance of the RA type radio ranges; $44,000 for installation of additional simultaneous radio range; $87,000 for installation of three additional medium and low-power radio ranges; $11,200 for two additional teletype weather reporting stations; $330,000 for 55 standby radio transmitters at existing radio stations.

available in the already stretched 195-415 kc. band where all radio ranges, airport traffic control and weather forecasting have their being, and no additional frequencies adjacent to this band can be had.

• Ultra-High Frequencies

This saturation point in available frequencies was foreseen in time, and, paralleling new knowledge of ultra-high frequencies gained throughout the world in recent years, specialized domestic research into the possibilities of adapting ultra-high frequency radiations to radio navigation of aircraft was being diligently prosecuted, by both BAC and CAA, for some years past.

Research disclosed that ultra-high frequency radiations, in addition to providing a vastly greater number of available frequencies, also possessed certain propagation characteristics which rendered them ideally suited to the needs of aircraft radio navigation and communication (*Aero Digest*, Nov. and Dec., 1937). It was found that ultra-high frequency radiations are more easily controllable as to pattern, free from static interference, and (at frequencies above 40 Mc.) free from the phenomenon of "skip": they propagate but little beyond the optical distance from the transmitting antennas, and are not reflected back to earth by the electrically charged Kennelly-Heaviside layer, but pass on through.

As a result of numerous hearings before the Federal Communications Commission, several ultra-high frequency bands have been allocated to aeronautical use, or assigned to the Government who in turn allocated those bands to aeronautics. At present the following bands are allocated for use in radio navigation of aircraft: several channels in the 60-66 Mc. band, for radio ranges and point-to-point and point-to-ship radiotelephone and radiofacsimile; 75 Mc. for cone-of-silence, fan, and high and low approach markers; 93 and 110 Mc. for instrument landing; and 125-130 Mc. for airport traffic control and airport localizers, and possibly radio ranges. For communications, four channels in the 34-39 Mc. band have been assigned for student instruction, and the entire 140,100-143,800 kc. band for all airline communications.

This far-sighted planning appears to have assured for aeronautics a number of channels and frequencies sufficient for its present and immediate future needs. Additional services for more remote future needs can be provided, it is felt, among frequencies higher than 150 Mc.

We are now on the verge of a vital change in our entire conception of aircraft radio navigation and communication. The old low frequency system is about to be abandoned, the ultra-high frequency era is about to be ushered in.

• The First Steps

Introduction of ultra-high frequency equipment on our airways began about 18 months ago with the purchase and installation of 100 cone-of-silence and 21 fan markers, all operating on 75 Mc. These, however, were auxiliary aids, and were used in addition to the basic low frequency radio range network.

The most important step, the beginning of the change over of the entire radio range network from low to ultra-high frequencies is now about to be undertaken. Bids have been prepared by the CAA for the construction and installation of eight (possibly nine) ultra-high frequency radio range stations for the New York-Chicago airway. CAA hopes to let contracts for these stations not later than September, and have the construction completed in January 1940. These u.h.f. radio ranges will be of the vertically polarized four-course type with *A* and *N* quadrant definition, operating in the 60-66 Mc. band.

The route which they will serve will closely parallel the present AM-1, and it is now tentatively proposed to locate the ranges as follows: 1 — Newark; 2 — near Allentown, probably at New Media; 3—Kylertown or Black Moshanon; 4—near Mercer; 5—near Cleveland; 6—near Toledo; 7—near Goshen; 8—near Chicago. A ninth beacon may be required for better demarcation of the route at the southern tip of Lake Michigan; this, if found needed, will be located at Gary or Lansing.

American Airlines, TWA and United Air Lines will equip a number of their ships on the New York-Chicago run with u.h.f. radio range receivers in addition to standard radio equipment, and will fly the route with the aid of both the u.h.f. and the l.f. radio ranges, checking and comparing the two.

These full scale service tests should not be construed as experimental work: the u.h.f. radio ranges today are so highly developed and so far superior to the existing l.f. ranges that CAA's only apprehension is that the u.h.f. installation will be so well liked that their immediate adoption will be urged at once. Meanwhile the CAA, doing their best to evolve the best possible system, firmly intend to make the same full scale service tests along this route with the same beacons using horizontally polarized four-course radiators and horizontally polarized two-course radiators, the latter representing a radical departure from our basic radio range system, but offering enticing possibilities.

For some months past the CAA has maintained two experimental four-course u.h.f. ranges at Pittsburgh and Indianapolis; these are being continuously used by American and TWA flights serving these cities; a third u.h.f. range has recently been completed at Burbank, and is now available for use by American, TWA, United and Western Air Express. The new CAA Experimental Station at Indianapolis has under construction a fourth u.h.f. range, and also has a 125-Mc. mobile radio range unit recently delivered to them by the Washington Institute of Technology. This latter unit will be used for both experimental work and for the selection of radiator sites on the New York-Chicago airway; it is equipped with vertically polarized four-course, horizontally polarized four-course, and horizontally polarized two-course antenna arrays.

An especially promising type of a two-course beacon, now being perfected, provides 90 and 150 c.p.s. course definition for visual course indication, or for aural course indication with a recently developed aural converter which steps up these sub-audio frequencies to an audible level. Positive orientation with respect to the transmitting station would be provided every 30 seconds by interrupting the course-defining modulations with the station call letters alternately transmitted along each course, followed by proper orientation letter: *E* and *W* for ranges with east-west courses, *N* and *S* for ranges with north-south courses. Preliminary tests appear to indicate a far simpler orientation procedure, greater ease of following a course along several ranges, and considerable simplification of airway traffic control problems.

• Future Steps

The low frequency radio range network became obsolete in only ten years, will be discarded in another five. Problems of radio navigation of aircraft are now better understood, and the new u.h.f. network, if executed with the same painstaking care and thoughtful planning which characterized its development stages, should serve us well many times ten years, and probably indefinitely.

Following the completion of full scale service tests on the New York-Chicago route, and after the final decision on the type of beacon to be adopted has been made, additional routes will be changed over to the ultra-high frequencies. Present plans, necessarily as yet tentative, contemplate making the next change-over on the Seattle-Chicago route flown by Northwest Airlines, to be followed by the Seattle-San Diego, Seattle-Salt Lake City, and San Francisco-Salt Lake City routes flown by United. The Los Angeles-Salt Lake City-Great Falls route, flown by Western Air Express, would complete the changeover of the radio ranges serving that mountainous terrain. Next would come the changeover of the two remaining transcontinental routes, Los Angeles-Kansas City-New York (TWA), and Los Angeles-Fort Worth-New York (AA), and the final link between Salt Lake City and Chicago on UAL's transcontinental route. Eastern routes, with their electrically satisfactory terrain, will be the last to be changed over.

The existing l.f. radio range network, however, will not be abandoned outright with the introduction of the u.h.f. ranges, but will be maintained in skeletonized form until such time as all aircraft—commercial, military and private—are able to make the necessary change-over of their receiving equipment. This will probably take about five years, or even longer.

It would be presumptuous to say that we, today, can accurately forecast airways needs many years from now. Those future needs may in time require certain modifications, certain auxiliary aids, and possibly new apparatus which we cannot yet even conceive. We know now that Adcock type ground direction finders and omni-directional rotary radio beacons at certain locations will in all probability form an integral part of the airways system of tomorrow. Research and development must not be allowed to lag once the u.h.f. system has been perfected. New equipment and new ideas will always be proposed, and the CAA should be in a position to investigate their merits and be able to differentiate between genuine improvements and ill-advised, though not necessarily unworkable, schemes.

The transition from the l.f. to the u.h.f. system must necessarily go slowly, and we must contain ourselves in patience, realizing that we are building this system not for today, but for tomorrow and the day after. The next few years will call for the utmost understanding and cooperation between the industry and the CAA. This cooperation must be given by all—without stint.

"It Can't Happen Here"

JUST about the ultimate in customer service is being delivered by a speaker manufacturer in Australia. When brush fires destroyed a great number of outland homes, notice was posted by this company that any loudspeaker salvaged would be completely rebuilt and returned to the owner, no matter in what condition it was received . . . **entirely at the company's expense!**

¶ From Service
June, 1939

Your Cathode-Ray Oscilloscope

By J. H. REYNER

In this thorough discussion of the instrument, users of the cathode-ray oscilloscope will find many interesting and important features concerning its application to the alignment and adjustment of receivers and speech equipment, and interpretation of waveforms thereby obtained.

THE examination of wave forms is only one of the many applications of the cathode-ray tube. In fact, any detailed discussion of its other possibilities is quite impracticable in the space allotted here. We can, however, consider some of the more important of these applications. The first of these is the alignment of receivers.

A cathode-ray tube can be made to operate at an instantaneous electronic voltmeter, the movement of the spot being made to correspond with the amplitude of the signal at any instant. This principle is used to plot resonance curves of the tuned circuits in a receiver.

An average signal generator applies a steady frequency to the input of the receiver and the voltage output may be noted at some convenient point by a v.t. voltmeter or by an output meter. As the frequency of the signal generator is varied the voltage developed (i.e., the response of the receiver) changes, reaching a maximum at resonance and falling away on either side.

- Frequency Modulator

For cathode-ray alignment, the frequency of the signal generator is caused to vary slightly over a small range of, say, 25 kc. on each side of the mean value. Thus, if the apparatus is set so that the mean value coincides with the resonance point of the receiver, the frequency actually varies from 25 kc. below resonance to 25 kc. above and back again. This excursion is usually enough to cover the whole of the normal response since a modern set gives only a negligible output 25 kc. off resonance.

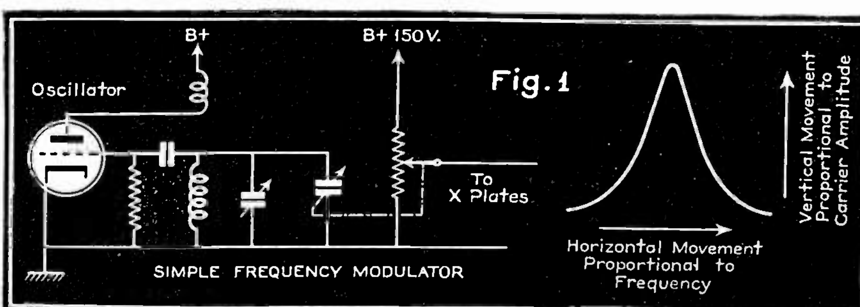
Let us assume that this variation in frequency is achieved by an additional trimmer condenser connected in parallel with the main condenser of the signal generator. Then as we rotate this condenser the output voltage will rise from practically zero to a maximum and back again. Suppose that instead of an output meter we connect a cathode-ray tube so arranged that the vertical movement of the spot is proportional to the voltage at any instant. Then as we rotate the trimmer on the signal generator, the cathode-ray spot will rise and fall.

Suppose now that we gang with the trimmer condenser a potentiometer connected to a battery, and take the slider of this potentiometer to the X plates of the tube as shown in figure 1. Then as the spindle is rotated an increasing voltage will be applied to the X plates, causing the spot to move in a horizontal direction. But we have already seen that the rotation of the spindle causes the spot to rise to a maximum and fall to zero again, so that the combined effect of the two motions will be to produce a resonance curve as indicated.

If the operation is carried out slowly we shall not see the whole resonance curve at once (unless the tube is one which has a very long afterglow). If, however, we could arrange that the operation was carried out fairly rapidly, say 60 times per second, then a series of successive traces would be obtained all lying one on top of one another and we should obtain the impression of a stationary image in exactly the same way as we do with waveforms. One method of accomplishing this is to connect the spindle to an electric motor and set this in rotation. This is the basic principle of the frequency modulator.

• Mechanical Systems

There are several precautions required in this simple arrangement. The shape of the trimmer condenser must be so arranged that the frequency is directly proportional to



the rotation. Then if the potentiometer on the spindle is linear, the horizontal position of the spot will be proportional to the frequency at every point, and a true representation of the resonance curve will result.

Another difficulty is that with a normally constituted condenser a rotation of 180 degrees will provide the maximum change of capacitance, and any further rotation will cause the plates to come out of mesh again so that the capacity begins to decrease. The voltage developed by the potentiometer, however, is continually increasing, so that we obtain two resonance curves side by side, one being the mirror image of the other.

These difficulties can be overcome but this method has lost favor mainly because of the mechanical difficulties due to wear of the potentiometer and the like. In some instances the motor employed has been a synchronous type which makes one complete revolution in one period of the a.c. supply. It becomes unnecessary to have a potentiometer, for it is possible to supply a.c. directly to the horizontal plates. The spot will then move over the screen and back again in one period, thus maintaining synchronism with the rotating condenser.

This method has the disadvantage that it shows the two response curves traced on the initial and return stroke of the condenser superposed, as indicated in figure 3. Once again, the images are mirror images and are apt to be confusing.

- Electronic Methods

Because of these difficulties modern frequency modulators usually adopt an electronic method of modulation. It is known that the grid-cathode or the plate-cathode reactance of a vacuum tube depends upon operating conditions. The simple circuit of figure 4, for instance, includes a tube with a resistive plate circuit. Under these conditions the input capacitance is

$$C_{eff} = C_{gc} + C_{gp}\,(1 + A),$$

where C_{gc} and C_{gp} are the grid-cathode and grid-plate capacitances respectively and A is the amplification of the stage.

Consequently, if the amplification A can be varied the effective input capacitance can be changed. The stage gain can be altered quite easily by varying the bias, and by suitable choice of tube and operating conditions it is possible to ensure that this change is linear with respect to the control voltage. If such a circuit is connected across an oscillator, the frequency generated can be varied by altering the bias on the tube.

This form of circuit can very conveniently be used with an oscilloscope by connecting the grid of the control tube to the oscilloscope sweep circuit. This is generating a gradually increasing voltage and if a suitable proportion of this voltage is applied to the grid of the control tube, the input capacitance and hence the frequency output from the oscillator can be varied in unison. The sweep voltage is already causing the spot on the cathode-ray

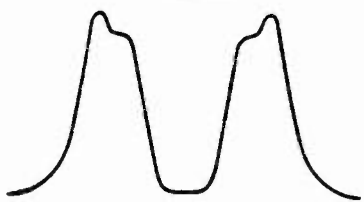


Fig. 2

DOUBLE IMAGE OBTAINED WITH FIG. 1 CIRCUIT.
THE CURVES ARE SHOWN ASYMMETRICAL TO DEMONSTRATE THE MIRROR IMAGE EFFECT.

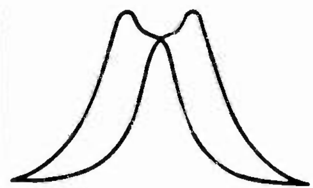


Fig. 3

DOUBLE IMAGE OBTAINED WITH SYNCHRONOUS CONDENSER

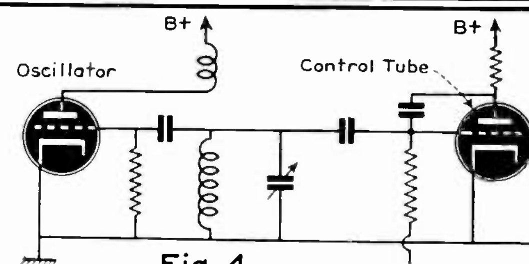


Fig. 4

SIMPLE ELECTRONIC FREQUENCY MODULATOR.
SOMETIMES THE GRID-ANODE CAPACITANCE OF THE CONTROL TUBE IS DELIBERATELY INCREASED AS SHOWN.

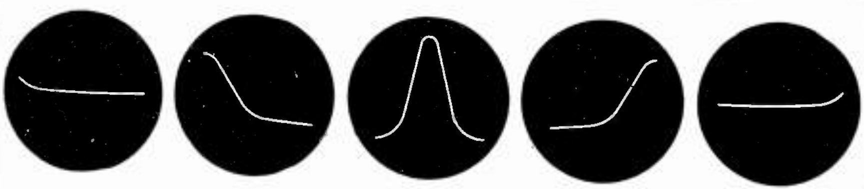


Fig. 5

PROGRESSIVE IMAGES, AS FREQUENCY SETTING OF FREQUENCY MODULATOR IS ALTERED. NOTE THAT DUE TO THE SELF-CENTERING ACTION OF THE CATHODE-RAY TUBE, THE BASE LINE WILL APPEAR TO SHIFT.

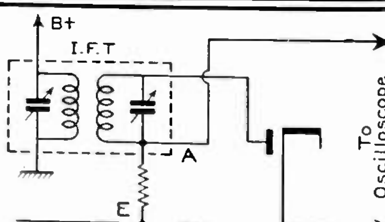


Fig. 7

POINT OF CONNECTION OF OSCILLOSCOPE.

screen to move horizontally and at the same time the frequency from the oscillator is changing, so that the output from the set is varying in similar fashion.

There are various other forms of frequency control circuits with which the reader will doubtless be familiar since they are used in receivers embodying automatic frequency-control. Since we are concerned in this article with the cathode-ray tube it is not proposed to go into any further detail on this point. Any convenient method of frequency modulation can be used for the purpose.

• Image Form

It is interesting to consider the practical results of applying such a frequency modulated signal to a receiver or to any of the tuned circuits. Assuming again that the cathode-ray tube is so connected that the height of the spot indicates the voltage output from the receiver, let us see what happens for a frequency-modulated input. When the frequency is off resonance there will be no response and therefore the pattern on the screen of the cathode-ray tube will be a horizontal line (since it is being deflected horizontally by the sweep voltage). As the signal generator dial is varied its frequency will ultimately come within the range of the receiver setting. When it does so a resonance curve will appear on the screen. It will start by a lifting of one side of the line and as the generator dial is steadily rotated, the whole of the pattern will gradually appear, as it were from the wings, and will pass slowly across the screen and off the other side.

The reason for this is clear on little consideration. Suppose the receiver is tuned to 1000 kc. and its total tuning network provides a cutoff at anything outside the band 980-1020kc. Let us assume further that the bandwidth of the frequency modulator is 50 kc. total, i.e., 25 kc. on each side of the mean frequency. When the mean frequency reaches 955 kc., the input frequency at one end of its excursion will just reach 980 kc., and since at this point the receiver begins to exhibit some response there will be a slight lifting of the line on the cathode-ray screen at one end.

When the signal generator reaches 980 kc. one half of the resonance curve will appear, for over that part of the excursion which runs from 980 to 1005 kc. the receiver is responding, while on the other half no response is present. When the mean frequency reaches 1000 kc. the image will be in the middle of the screen, and as the frequency is made still higher the image passes off the screen on the other side. The general effect is as illustrated in figure 5.

• Self-Centering Action

Figure 5 also illustrates an effect common to many oscilloscopes—that of the self centering of the image. Since the plates are usually coupled to the work through isolating condensers a d.c. potential cannot be sustained. Hence even if the impulses applied to the plates are all in the same direction the pattern on the screen will not lie entirely in the top (or bottom) half of the tube.

The isolating condenser will settle at a mean level such that the positive and negative charges acquired over the complete cycle are equal. This will cause the zero line to shift, and in fact as the process of tuning is carried out the base of the curve will shift downwards, often quite slowly if the time constant of the coupling circuit is long, as it should be.

The same thing will happen when examining an asymmetrical waveform, and in such cases a change of amplitude will be followed by a shifting of the pattern on the screen. This does not mean that something is wrong but it is apt to be confusing unless the reason for the shift is understood.

Many oscilloscopes, of course, are provided with shift controls, which are simple potentiometers applying d.c. potentials to the plates so that the position of the image on the screen may be altered at will.

Figure 6 (a), page 52, shows a resonance curve taken with an electronic frequency modulator of the type just discussed. This is a curve for the primary of an i.f. transformer. Figure 6 (b), page 52, shows the response of the complete transformer showing a nice double hump.

Inspection of the curves, however, shows that the width of the second curve is greater than that of the first. This should not be, for the purpose of the double circuit is usually to give better selectivity—i.e., a narrower band width. Figure 6 (b) was actually taken with the circuits not correctly tuned. As the circuits are tuned correctly the humps come closer together and the optimum adjustment gives a band width definitely less than for a single circuit.

In practice therefore the trimmers should be adjusted for minimum bandwidth the top of the curve being either peaked or slightly double-humped depending on the type of set. The point is referred to further in figure 9, page 52.

- Connection to Receiver

Where should the oscilloscope be connected to obtain these response curves? Although an output meter is normally connected across the output stage of the receiver, this is not practicable with a cathode-ray tube. The most usual position is to connect it across the detector, i.e., across the points shown in figure 7 which represents a typical diode detector. The voltage developed across this diode resistance is proportional to the instantaneous value of the carrier, so that when the circuit is in tune there is a large d.c. voltage across the points A E and as the tuning falls off the d.c. voltage decreases in proportion. If we connected the plates of the cathode-ray tube directly across these points, we should immediately fulfill the requirement that the height of the spot on the screen was proportional to the instantaneous signal strength.

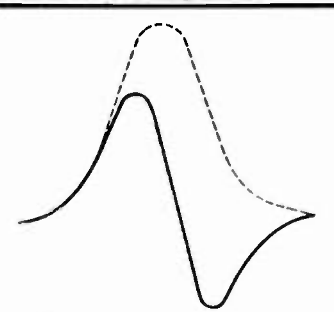
As already explained, however, most oscilloscopes are not directly connected to the work but are isolated from d.c. through a condenser and leak. It is essential therefore that the time constant of this condenser-leak combination shall be large enough to sustain any applied voltage for at least 1/50 second. If the voltage on the diode resistance rises, the coupling condenser is charged and this charge immediately begins to leak away. If this leak is too rapid, the effective voltage across the condenser will fall short of the true voltage and, worse still, when the voltage begins to fall again the condenser will charge up in the opposite direction and a curve of the form shown in figure 8 will be obtained instead of the true resonance curve (shown dotted).

- Long Time Constant

The time constant required to avoid this happening is much longer than is necessary to transmit the ordinary low musical frequencies of 50 or 100 cycles, and a product CR of at least 1 megohm-microfarad is desirable.

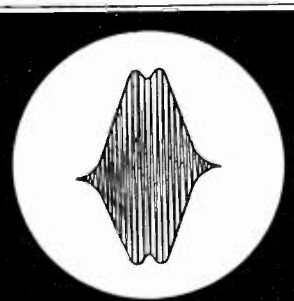
It is possible to ensure that the condenser and leak in the oscilloscope do conform to this requirement, but the time constants of the couplings in the average radio receiver are by no means as good as this. Therefore, if the oscilloscope is connected at any stage later than the actual diode resistance it is almost certain that this distorted resonance curve will result.

The voltage developed across the diode resistance is not enough in most cases to provide a satisfactory movement of the spot on the cathode-ray screen, so that the voltage has to be passed through the amplifier of the oscilloscope, and it is essential to make sure that the time constants both of the input and output circuits of this amplifier conform to the stringent requirements just specified.



DISTORTED CURVE OBTAINED DUE TO INADEQUATE TIME CONSTANT

Fig 8



IF THE SIGNAL IS NOT RECTIFIED A MODULATION ENVELOPE OF THIS TYPE RESULTS

Fig. 10

When testing a complete receiver it should be remembered that, due to a.v.c. the voltage developed across the diode load tends to remain constant. In aligning a receiver the procedure is to introduce frequency-modulated signals (through the i.f. peak) to the grid of the last i.f. tube and to note the ouptut on the diode. This will give a broad resonance curve of the type shown in figure 9. The input is then transferred one stage farther back and the input suitably reduced. The resonance curve will then appear as before but narrower, and if there is any band-pass action in the tuning circuit it will probably show up better than on the first test.

The process is continued until the mixer is reached, after which the signal is introduced on to the antenna posts (at broadcast frequency), until the final response curve on the screen is that of the complete receiver.

At each stage the trimmers of the i.f. transformers or r.f. circuits may be adjusted until the maximum response is obtained and until the response is symmetrical and of minimum width. Figure 9 (c) shows the effect of a detuned i.f. transformer in which the hump has appreciably slipped. It is worth noting in passing that the reading given on a normal output meter would be very much the same for this resonance curve as for that shown in the previous figure, whereas there can be no question as to which adjustment gives the better quality.

• Alternative Connections

It is sometimes convenient to determine the response of a single circuit either on the bench or in course of examination of some part of a receiver prior to the normal detector. In such a case it is practicable to use the amplifier in the oscilloscope itself, converted to a detector by increasing the cathode resistance so that it operates as a plate-bend detector. Alternatively, an additional rectifier may be connected up external to the set and the output from this fed to the oscilloscope. The advantage of this method is that it is possible to examine any individual circuit in the receiver without necessarily coming off the end of the tuning chain.

Actually, it is not necessary to rectify the signals at all, for if the oscilloscope is connected across the tuned circuits themselves, the spot will move rapidly up and down at a radio frequency and the amplitude of this line will vary according to the tuning of the receiver. If this is done a filled-in resonance curve of the type shown in figure 10 (actually a modulation envelope in which the top of the pattern shows the resonance curve and the bottom shows the same curve upside down) will be obtained. In some cases it is convenient to adopt this technique. It is necessary, of course, either to have sufficient voltage to operate the tube directly or else to use an amplifier which is capable of handling the radio frequency signal, at any rate, to some extent.

It should be remembered that the

cathode-ray tube is no respecter of sense—that the resonance curve may well appear upside down. It is not always easy to reverse it, for if the leads are changed over it is quite possible that some hum may be introduced with unpleasant effects, so that it is preferable to work the resonance curve upside down if it happens to appear this way.

If the amplifier in the oscilloscope overloads before full deflection is obtained the resonance curve will show a sharp flat top. Make sure therefore that the amplifier is linear over the full range of deflection.

Generally speaking the full gain of the amplifier should be used and the input to the set kept as low as possible to avoid overloading the earlier stages.

Hum, superposed on the image will cause puzzling effects, making the image appear lopsided or producing a continual expansion and contraction of the band width. See that when no input is applied the trace on the screen is a horizontal straight line and does not exhibit any ripple. A slight reduction of the gain of the oscilloscope amplifier sometimes helps.

In any case it is best to operate the sweep at 60 cycles and to synchronize off the power line. (Most oscilloscopes have provision for this.) The image will then be quite steady.

A form of frequency modulator often used is the constant bandwidth type in which a mixing arrangement is used. A small oscillator is arranged to operate at some frequency outside the bandwidth to be examined. This oscillator is frequency modulated by one of the electronic methods already discussed. This wobbulated oscillation is mixed with another oscillation from the signal generator such that the difference between the two gives the frequency required. For example, if the local frequency modulated oscillation is operating at 2000 kc. and the signal generator is set at 2450 kc., then the beat output will be 450 kc. and will be frequency modulated.

The advantage of this method is that the bandwidth of the frequency modulation is determined entirely by the fixed oscillator, and if this is adjusted to say 50 kc. overall, then whatever the final beat frequency chosen whether it be i.f. or r.f., it remains frequency modulated by this same 50 kc., so that the scale of the resonance curve appearing on the cathode ray screen is unchanged.

This method is quite popular. It has one disadvantage that a number of subsidiary resonance curves can appear on the screen which makes searching a little confusing. It is necessary therefore to know the frequency to which the receiver is tuned within a fair approximation and to see that the signal generator is correctly set to deliver somewhere around this frequency. Then as the generator dial is rotated the resonance curve will appear and may be easily recognized.

If there is any difficulty, a convenient test is to alter the dial setting of the receiver. If the arrangement is working correctly this will cause the resonance curve on the screen to move to one side or the other in exactly the same way as the variation of the unmodulated signal generator setting does. If the oscillation is a subsidiary one, however, it will not be affected by this alteration. Alteration of the setting of the modulated signal generator setting will always cause the curves to move whether they are true or spurious.

• Parasitic Oscillations

Occasionally one finds a parasitic oscillation sitting on the resonance curve as illustrated in figure 11, page 52. This is due to a relatively low frequency beat between two of the various oscillators in the system, or possibly even due to interference from a signal actually received on the set at the time. It corresponds in fact with the birdies often experienced with superhet receivers. It may usually be ignored since it does not affect the lining up, but if it is troublesome it can be removed by altering the tune of the i.f. slightly.

The presence of such a parasitic does not necessarily indicate that birdies will be noted in actual reception, because the beat may be arising from interaction with the oscillator in the frequency modulator which will not be present in actual reception.

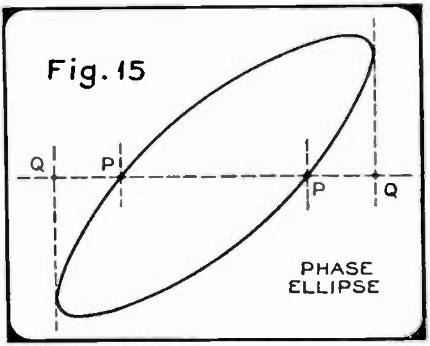
• Modulation Patterns

We can conclude with a brief review of the other uses of the oscilloscope. One is the checking of the modulation of a transmitter (or signal generator). The simplest method is to apply the modulated signal to the Y plates, either directly or through the amplifier if this will handle r.f., and to set the sweep to some sub-multiple of the *modulation* frequency. A band pattern will then appear of the type shown in figure 12, page 53.

Until the sweep is synchronized the pattern will be confused being brighter in the middle. As the sweep frequency control is altered the pattern will resolve itself into the correct modulation pattern and the application of synchronism (or suitable adjustment of the frequency if the synchronism is automatic) will cause the pattern to lock.

The modulation pattern should be symmetrical and the depth of modulation is given by $\frac{a - b}{a + b}$ where a is the maximum and b the minimum height of the pattern.

An alternative method is to apply the modulated wave to the Y plates and the modulation voltage to the X plates. This will produce a trapezoidal figure as shown in figure 13, page 53, which is the modulation pattern of a small service signal generator. On the left is the pattern produced by the sweep circuit method, while on the right is the trapezoidal form. The same expression for modulation depth holds, so that for full modulation the trapezium becomes a triangle.



A wide ellipse, typical characteristic of an average amplifier. If overloading occurs at any stage, the curve will be distorted.

One advantage of the second method is that it shows modulation defects more easily. Thus in the example there is distortion in the modulating system, as evidenced by the fact that the sides of the trapezium are not straight, while there is also phase displacement as shown by the double pattern.

Phase shift in the modulating system causes the pattern to appear as if wrapped round a cylinder. Figure 14, page 53, illustrates this more clearly.

- Phase Angle

Phase shift is very easily disclosed with a cathode-ray tube. The two voltages to be examined are applied to the X and Y plates respectively and their amplitudes adjusted to be approximately equal. If there is no phase shift, the pattern formed is a straight line, but with any difference of phase the figure degenerates into an ellipse.

The phase angle can be estimated by tracing the ellipse on a piece of transparent paper and estimating the distances PP and QQ as shown in figure 15. Then $\sin\phi = PP/QQ$, ϕ is the phase angle. This expression holds irrespective of the relative amplitudes of the two voltages but examination is simplified if the amplitudes are roughly equal. If a graduated cover scale is provided, PP and QQ may be estimated directly.

The input and output of an

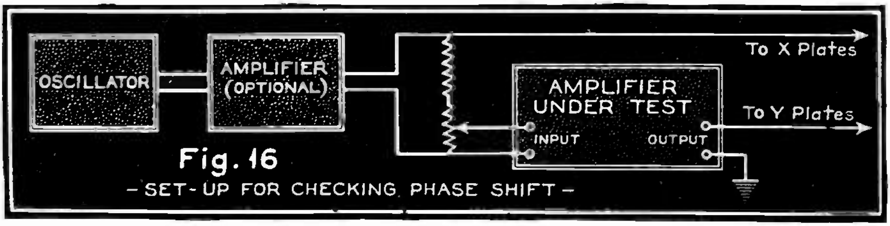


Fig. 16
— SET-UP FOR CHECKING PHASE SHIFT —

amplifier or any single stage, for example, can be checked by this means. Start with a source of input large enough to provide a reasonable deflection on the tube. If your oscillator does not give enough output use an amplifier first. Any phase shift in this preliminary stage will not matter.

Across the input connect a potentiometer as shown in figure 16 and feed the amplifier with a suitable proportion such that its output is of the same order as the original (full) input. If your amplifier is good the pattern will be a narrow ellipse or even a straight line.

(See pages 52 and 53 for photographs)

A Radio Slide Rule

A NEW slide rule has recently been designed by J. F. Morrison of the Broadcast Development Department of the Bell Laboratories to facilitate the work of the radio engineer. This slide rule, manufactured by the Keuffel and Esser Company, is similar in appearance to the duplex rule and has on one side the usual A, B, C, CI, D and trigonometric scales. The conventional L scale has an added designation "db" and is used for the conversion of ratios of power, voltage, and current in reference to the D scale. The LC product for a given frequency, the value of inductance or capacity to resonate a reactive circuit, and the transformation of vectors from rectangular to polar form or vice versa, are among the operations which can be performed on the F or frequency scale, also on this side of the rule. The reverse side of the rule carries a number of special scales arranged for solving problems relating to propagation of radio waves over a plane earth. The rule is thus capable of solving a wide range of special radio problems in addition to the usual type of problem solved with the slide rule, and makes a very convenient tool for the radio engineers.—Bell Laboratories Record.

A Portable
FREQUENCY STANDARD

(Discussed on pages 4-16)

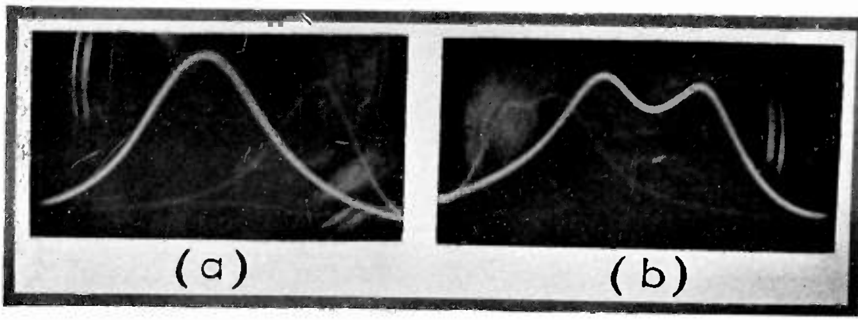
● Figure 1. The frequency standard is entirely self-contained. Outputs are provided on 100, 10, and 1 kc. at the jacks on the right, and any stage may be switched off by means of the toggle switches along the bottom. The audio gain control (lower center) regulates the level of the 1000-cycle output. The correction control (left) permits variation of the crystal frequency plus or minus 3 cycles on the fundamental.

● Figure 2. Inside the "Kc. Box." The special crystal unit, oscillator, multivibrator, amplifier, and rectifier tubes may be identified with the layout diagram, figure 6.

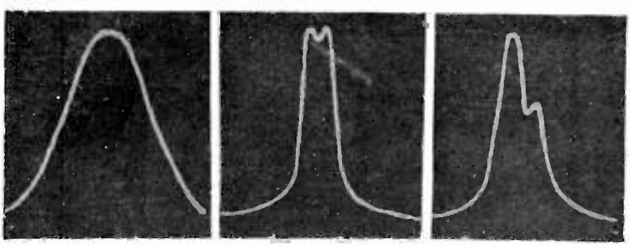
Your CATHODE-RAY OSCILLOSCOPE

(Discussed on pages 39-50)

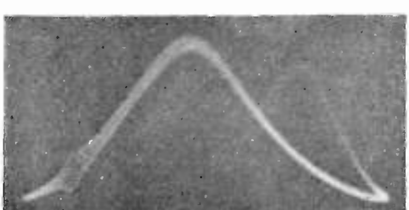
(Illustrations courtesy Service)



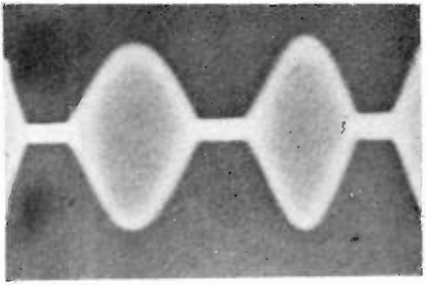
• Figure 6. The resonance curve for the primary of an i.f. transformer is shown at (a). The curve for the entire transformer is shown at (b).



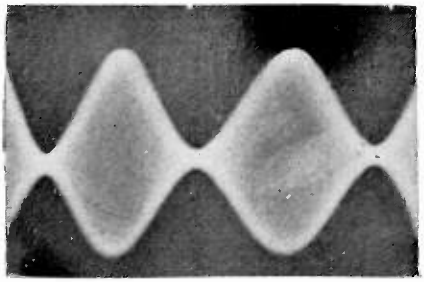
• Figure 9. Various types of resonance curves, showing a broadly tuned single stage; a band-pass i.f. system; and the effect of detuning on an i.f. transformer.



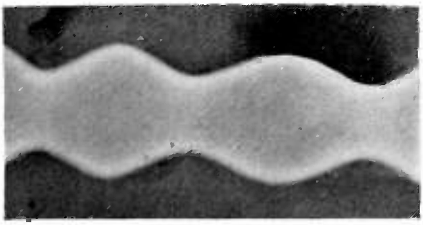
• Figure 11. Occasionally one finds a parasitic oscillation sitting on the resonance curve.



• a.—Considerable overmodulation occurring.



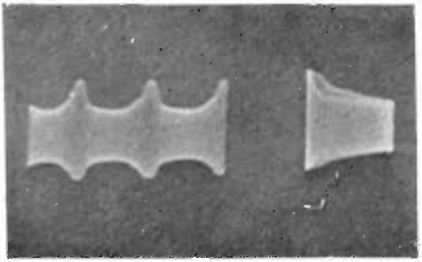
• b.—Carrier modulated approximately 100%.



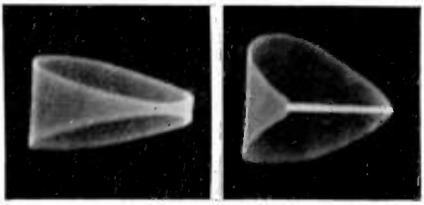
• c.—Insufficient modulation—only 25%.

• Figure 12. (a, b and c) One of the many uses of the oscilloscope is the checking of the modulation of a transmitter.

• Figure 13. Applying the modulated wave to the Y plates and the modulation voltage to the X plates will produce a trapezoidal figure.

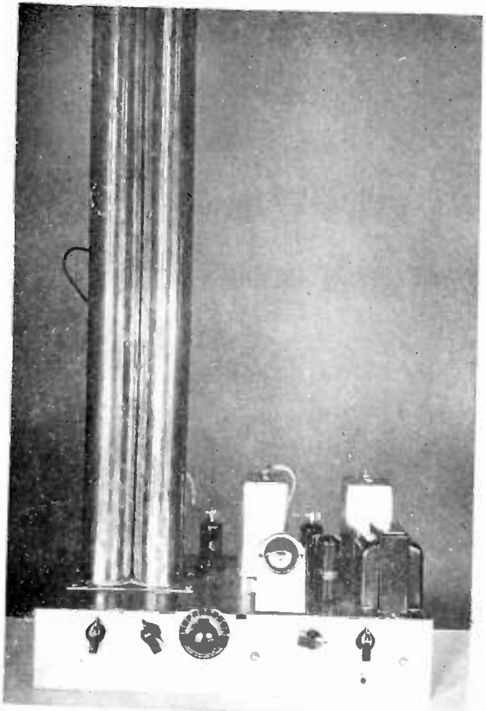


• Effect of phase-shift in the modulating system.

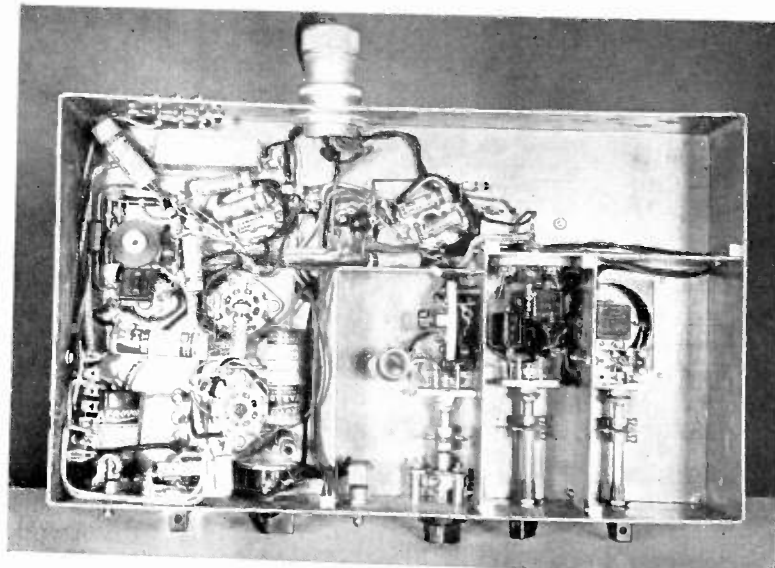


Ultra-Sensitive 56Mc. Receiver

(Discussed on pages 55-65)



• Figure 1. Concentric line tuned acorn superheterodyne for 56 Mc.



• Figure 5. Bottom view of the receiver. At right-center of chassis may be seen the end of one concentric line.

¶ From Radio
June, 1939

ULTRA-SENSITIVE
56 Mc. Receiver

By ARTHUR AVERY and E. H. CONKLIN

FOR several years it has been recognized that conventional tuned circuits at ultra-high frequencies do not develop enough impedance either to provide high gain or reasonable selectivity because of the vanishing L/C ratio resulting from the more or less fixed tube, circuit and tuning condenser minimum capacities.[1] A very considerable improvement in the tuned circuits themselves can be obtained readily by using sections of transmission lines, instead of lumped inductances in the form of coils.[2,3] Calculations show that a Q on the order of several thousand, or an impedance as high as a megohm, can be obtained without difficulty.

Due to the time it takes electrons to travel between tube elements, gain at very high frequencies falls off. This electron transit time causes a more perceptible difference in time between the release of an electron and its arrival, which shows up as a change in phase, making the grid-filament path a conductor rather than a very high resistance. This conductance at any given frequency can be expressed in equivalent ohms, and the effect of placing the tube across the tuned circuit is that of putting a relatively low resistor (and some capacity) across it. This in turn reduces the Q of the circuit, making it tune broadly and dropping the stage gain. The use of small acorn tubes permits obtaining much more benefit from an excellent tuned circuit.

While there has been some hesitancy to use acorn tubes because of their cost, the gain obtainable is really cheaper than getting it later by adding another stage. The improvement in signal-to-noise ratio

---

[1] A. P. Kauzmann, "New Television Amplifier Receiving Tubes," *RCA Review,* January, 1939.

[2] Reber and Conklin, "High-Frequency Receivers—Improving Their Performance," RADIO, January, 1938, p. 112.

[3] Reber and Conklin, "An Improved U.H.F. Receiver," RADIO, January, 1939, p. 17.

with acorns cannot be obtained later in the set except by sharpening the i.f. band width, a dodge that is available as well with acorns in the r.f. stages.

Inasmuch as the set noise level in a receiver should be determined in the tuned input circuit to the first tube—subsequent tubes merely amplifying both the signal and noise—it follows that a high gain first stage is very important. Regeneration does not improve the signal to noise ratio in this stage because both are amplified; it may serve, however, to ride over the noise contributed by a subsequent low gain stage. More than one r.f. stage will increase the overall gain and the image ratio (no images have yet been heard on this receiver except from a powerful oscillator in the same room), but will not materially improve the signal-to-noise ratio unless the mixer stage is inefficient. If the latter is true, more front-end gain will, of course, help to ride at a high level over the mixer noise. Very quickly the conclusion is reached that a really good u.h.f. receiver should have a stage of concentric line tuned acorn r.f. followed either by an efficient mixer or another r.f. stage. So let us see what can be done with one.

- A Practical Receiver

Several articles have appeared discussing the r.f. end of u.h.f. receivers for operation much below five meters.[2,3] The 56-Mc. superheterodyne (figure 1, page 54) built by Mr. Avery is, however, the first complete job for that band that we have seen. With it, the five-meter band sounds definitely *alive*. With no antenna, resonance in the first tuned circuit is obvious in that the electric eye closes as the mixer frequency is crossed. The high Q of the lines is apparent from the selectivity—it is next to impossible with separate r.f., mixer and oscillator controls to run across the band in less than several minutes. It is a practical necessity to gang at least the r.f. and mixer tuning.

For a comparison we tested the receiver against a commercial set, on the same antennas and signals. The commercial job on the W9CLH vertical 8JK brought in W8CVQ (135 miles) on January 1. At another location with a much less efficient antenna, the "organ pipe" set could bring in 10 per cent modulation on a signal 30 miles away but not even the carrier could be found on the commercial job that had proved itself on dx a few days before. There is no doubt in our minds that the new receiver uses design principles that should be incorporated into the front end of every u.h.f. converter or receiver worthy of the name.

- Pipe Construction

Most amateurs tend to avoid building anything so radically different as this receiver, unless design data are readily available. Constructional difficulties are easily overcome if details and probable results are known in advance. The receiver to be described here uses a pair of lines 28½ inches long and 2 inches in diameter made of copper-plated brass 0.020 inch thick. The inner

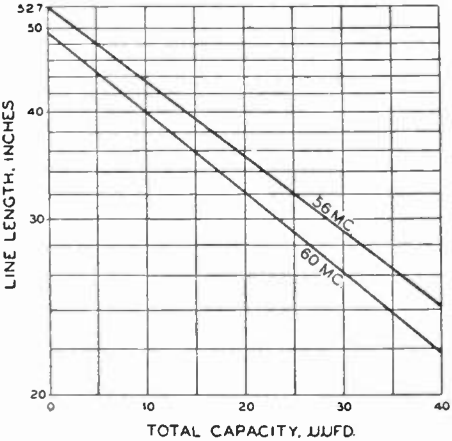


Figure 2. Capacity necessary to resonate short concentric lines with a 3.86 ratio of conductor sizes (81 ohms characteristic impedance).

• • •

conductor is ½-inch copper tubing; it can be made an inch longer than the outer pipe for convenience in making connections. These lines just reach 55 megacycles with acorn tubes, a 17.5-μμfd. condenser and a small (3 μμfd) trimmer on the first one which has no tube plate capacity hung across it.

These dimensions can be altered considerably. The diameter can be increased to 3 or more inches, which will increase the gain but will not alter the tuning capacity if the same ratio of conductors is used. The gain can be increased also by lengthening the pipes, which will reduce the necessary tuning capacity and improve the band-spread. Some improvement in gain and bandspread also can be obtained while reducing the tuning capacity, by making the inner conductor smaller—say, 1/10 of the outer conductor diameter instead of ¼. The method of calculating in advance the resonant frequency of various lines has been covered in separate articles by one of the authors.[4]

The chart in figure 2 gives the necessary capacity to resonate lines of different lengths, based on a 3.86 ratio of conductor sizes which results from using ½- and 2-inch pipes, with a 0.035-inch wall on the outer one. A horizontal line can be drawn at the desired line length, and the capacity range needed to tune between the 56- and 60-Mc. lines read off. Assuming 7-μμfd. circuit and tube capacity and 3-μμfd. condenser minimum, it will require a line about 40 inches long and a condenser of 4-μμfd. maximum capacity to get full bandspread without use of a padder condenser. Good bandspread with shorter lines can, of course, be attained by add-

---

[4] E. H. Conklin, "Transmission Lines as Circuit Elements," Radio, Part I, April, p. 43; Part II, May, p. 43.

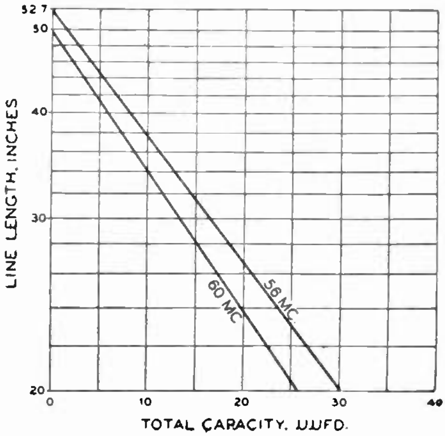


Figure 3. Capacity necessary to resonate short concentric lines with a 10.3 ratio of conductor sizes (140 ohms characteristic impedance.)

• • •

ing a padder to the mixer circuit, and reducing the tuning capacity to that just sufficient to cover the band.

Figure 3 gives the same data for a 10.3 ratio, resulting from use of a 3/16-inch inner conductor with the same outer conductor. It is seen that with short lines much less tuning capacity in addition to the circuit and tube capacities is necessary to reach the band. This can be helpful in obtaining satisfactory bandspread and, inasmuch as a higher impedance can be obtained with this higher ratio, there is much to recommend it if the lines are going to be somewhat shorter than the maximum possible with the 10-$\mu\mu$fd. circuit capacity generally encountered.

The length used should be that of the inner conductor, even though it may extend into the tube compartment. The same holds true of rectangular cross section lines folded into the chassis rather than extended upward.

Figures 2 and 3 are applicable at half the frequency by doubling the line length and capacity scales. It will be seen that the 28-Mc. band can be reached by adding capacity to each circuit, sacrificing some gain but making "coil changing" unnecessary. Presumably, the 2½-meter band can be reached by screwing in a shorting screw at the proper point in each line.

The outer conductor was slotted on a metal circular saw from about six inches to fifteen inches from the shorted end to pass an insulated wire fastened to an "866" clip sliding on the inner conductor (put in before the insulator was doped in place). This provided a means of matching and coupling the inner conductor of a concentric line feeder. With a balanced feeder, holes drilled in the outer pipe, to pass long machine screws threaded into the inner conductor, would have served to connect a balanced-to-un-

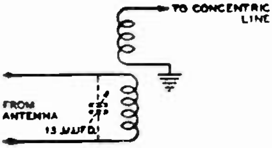


Figure 4. Balanced-to-unbalanced antenna coupling transformer. Coils are 5 turns, 7⅜ inch diameter, winding length ⅝ inch, but should be altered for maximum signal strength.

balanced antenna coupling unit, as shown in figure 4.

The inner conductor can be mounted in the outer pipe by any of several methods. A spacer or insulator will be necessary near the open end, and a shorting disc at the closed end (away from the acorn tube and tuning condenser). While squares could have been used, the victron insulator and metal shorting disc on this receiver were cut out slightly oversize with a circle cutter (the victron was drilled from both sides and tapped out) to fit the inside of the outer pipe, then drilled to pass the inner pipe. With the insulator in place, the shorting disc was soldered with *Aluminumweld* (hard) solder and a 59c alcohol blowtorch. Then the insulator was fastened with a liberal amount of *Q-max* dope. At the open end, the large pipes were soldered into holes cut in a 3 x 5 inch piece of the chassis material so that this could be bolted to the chassis. The discs from this cutting were used as the shorting discs.

It is suggested that the pipes be mounted three inches between centers, to give desirable room in the chassis compartments.

- Cost of Pipes

Copper tubing with a 0.035″ wall is available from any branch of Revere Copper and Brass, Inc. (230 Park Ave., New York City). Short lengths of two-inch tubing cost 37c a foot, or $3.30 for ten feet. Three-inch tubing is $1.10 a foot or $7.60 for ten feet. Stove pipe, three feet long, made of aluminum sheet can be obtained in three- or four-inch diameters for under a dollar. Inasmuch as most of the resistance occurs in the inner conductor, it is probably not absolutely necessary to use a copper or copper-plated brass outer conductor.

Solid inner conductor can be used, and can carry d. c. by insulating both ends, by-passing the "shorted" end for r.f. instead of using a shorting disc.

- Chassis Layout

The complete receiver, minus the separate voltage regulated power supply, is pictured in figure 1. The two pipes are distinguished rising up out of the picture from the top of the chassis at the left. The black wire half way up is the antenna connection. These pipes should be lined up the other way—fore and aft—or a flexible connection should be provided for the r.f. and mixer tuning condensers so that these circuits can be ganged. The photograph shows separate controls for each circuit.

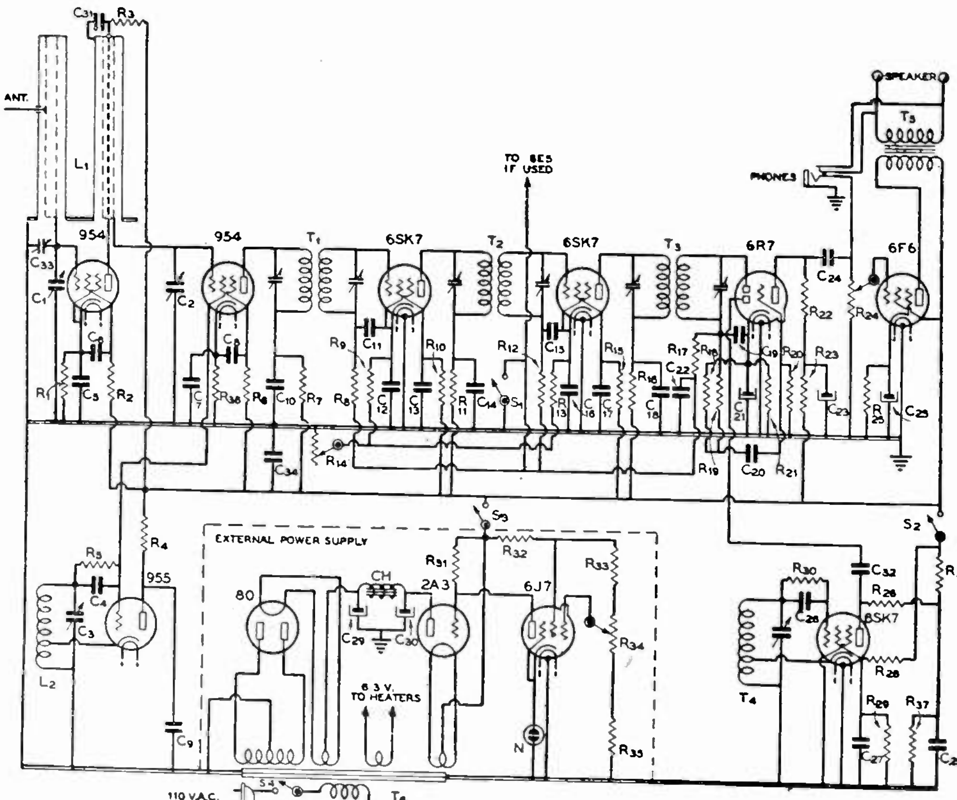


Figure 6. Circuit diagram for concentric line tuned superheterodyne.

Values of circuit components.

C_1, C_2, C_3 — 17.5 μμfd. midget
C_4—.0001-μfd mica
C_5, C_6, C_7—.0005-μfd. mica
C_8—.01 - μfd. 400-volt tubular
C_9—.006-μfd. mica
C_{10}—.01-μfd. 400-volt tubular
C_{11}, C_{12} — 0.1-μfd. 400-volt tubular
C_{13}—.01-μfd. 400-volt tubular
C_{14}, C_{15}, C_{16} — 0.1-μfd. 400-volt tubular
C_{17}, C_{18} — .01-μfd. 400-volt tubular
C_{19}—.0001-μfd. mica
C_{20}—.01-μfd. 400-volt tubular
C_{21}—10-μfd. 25-volt electrolytic
C_{22}—0.1-μfd. 400-volt tubular
C_{23}—4-μfd. 450-volt electrolytic
C_{24}—.01-μfd. 400-volt tubular
C_{25}—10-μfd. 50-volt electrolytic
C_{26}—.0001-μfd. mica
C_{27}, C_{28} — .01-μfd. 400-volt tubular
C_{29}, C_{30}—8-μfd. 450-volt electrolytic
C_{31}—.0005-μfd. mica
C_{32}—Twisted push-back wire
C_{33}—3-30-μμfd. trimmer, wide open
C_{34}—.01-μfd. 400-volt tubular
R_1—1500 ohms, ½ watt
R_2—100,000 ohms, ½ watt
R_3—2000 ohms, ½ watt
R_4—100,000 ohms, 1 watt
R_5—50,000 ohms, ½ watt
R_6—100,000 ohms, ½ watt
R_7—2000 ohms, ½ watt
R_8—100,000 ohms, ½ watt
R_9—300 ohms, ½ watt
R_{10}—100,000 ohms, ½ watt
R_{11}—2000 ohms, ½ watt
R_{12}—100,000 ohms, ½ watt
R_{13}—300 ohms, ½ watt
R_{14}—500-ohm potentiometer
R_{15}—100,000 ohms, ½ watt
R_{16}—2000 ohms, ½ watt
R_{17}—1 megohm, ½ watt
R_{18}—500,000 ohms, ½ watt
R_{19}—50,000 ohms, ½ watt
R_{20}—500,000 ohms, ½ watt
R_{21}—800 ohms, ½ watt
R_{22}, R_{23} — 50,000 ohms, ½ watt
R_{24}—500,000-ohm potentiometer
R_{25}—600 ohms, 10 watts
R_{26}—100,000 ohms, ½ watt
R_{27}—250,000 ohms, ½ watt
R_{28}—500,000 ohms, ½ watt
R_{29}—5000 ohms, ½ watt (see text)
R_{30}—50,000 ohms, ½ watt
R_{31}—500,000 ohms, ½ watt
R_{32}—10,000 ohms, 1 watt
R_{33}—25,000 ohms, 1 watt
R_{34}—10,000-ohm potentiometer
R_{35}—5000 ohms, 1 watt
R_{36}—2000 ohms, ½ watt
R_{37}—10,000 ohms, ½ watt (see text)
T_1, T_2—3500-kc. interstage i.f. transformer
T_3—3500-kc. plate-to-diode i.f. transformer
T_4—3500-kc. beat-oscillator transformer
T_5 — Pentode-to-voice-coil transformer
T_6—750 v. c.t., 125 ma.; 6.3 v., 3.6 a.; 5 v., 3 a.; 2.5 v., 3.5 a.
CH — 30-hy. 75-ma. choke
S_1, S_2, S_3, S_4—S.p.s.t. toggle
N—1-watt neon bulb with resistor removed
L_1—Concentric lines (see text)
L_2—See text

The knob with the dial is the variable ratio (Crowe planetary) drive for the oscillator. This is not at present provided with a concentric line tuned circuit. Behind the lines is the first i.f. transformer. The balance of the i.f. circuit progresses to the right across the back of the chassis. When the picture was taken, a 6H6 diode detector and 6C5 first audio were used, but these have been replaced with a 6R7, combining both tubes. This made room for a 6SK7 single-ended pentode beat oscillator, for which a shielded tuned circuit was mounted next to the tube socket, just behind and to the left of the audio transformer, at the right. The 6F6 pentode second audio tube is seen between the transformer and the 6E5 electric eye.

• The R.F. End

It is surprising how little actual wiring is necessary in an r.f. stage of this type. By-pass condensers can be built into the sockets,[3] in which case they should have a substantial capacity. The small tube clips are insufficient for this purpose. As far as we know, there is no entirely satisfactory acorn socket available at this time. Ordinary condensers do not by-pass effectively above 56 Mc. The underside photograph, figure 5, shows sockets on the wrong sides of the shield; it is the grid end that should project out the bottom of the sockets into the next compartment. The sockets and the compartment walls to which they are attached, are best made removable to facilitate mounting the tubes without chipping out their seals.

The circuit diagram of figure 6 is followed. The grid and plate leads to the r.f. tube can be run on insulated wires through the inner conductor, making parallel feed possible without chokes or condensers, except for the decoupling at the shorted end of the line. With cathode bias as shown, the grid connection can be made directly to the inner conductor. The small trimming condenser on the first line makes up for the plate capacity that is present on the mixer line but not on the antenna or input line. This is helpful in tracking these circuits.

• R.F. Biasing

A change that appears advisable is the elimination of cathode bias, substituting bias cells, battery, or bias from the power supply. It is too difficult to satisfactorily by-pass the cathode resistor, making for oscillation; and even a slight amount of inductance in the cathode lead, common to plate and grid circuits, is undesirable.[1] The grid and plate r.f. circuits should be returned as close to the cathode as possible.

• 954 Mixer

The mixer has been tried only with suppressor injection. RCA 954 tubes were found to give better gain both here and in the r.f. stage than 956's. They operate very well as mixers at this frequency, and have been recommended by RCA for the purpose. With suppressor injection and a 955 triode oscillator, there is a slight amount of "pulling" of the oscillator frequency when the mixer is tuned through resonance; this amounts to about a half kilocycle. It is noticeable only when using the beat oscillator but probably would vanish if the oscillator is ganged with the other circuits. A pentode oscillator of the electron-coupled variety, or better isolation and decoupling than we used, may be sufficient to eliminate the slight pulling.

Any oscillator tube can be used, presumably, although stability is better with the acorns that do not heavily load the tuned circuit.

The oscillator coil used was wound with no. 12 tinned wire, 8 turns, ½-inch diameter, winding length 1⅛ inches. The cathode tap is 2¼ turns from the grounded end. This coil may have to be changed to make its circuit track with the others if they are to be ganged. There are several ways that a concentric line can be used without requiring a cathode tap, the most promising of which appears to be an untuned-grid tuned-plate circuit, or its equivalent with the line in the cathode or screen, to leave the plate free for electron coupling. If the cathode method is used, the heater leads can be brought up through the inner conductor the cathode hooked to the inner conductor without a by-pass to ground. The grid coil can be self-resonated to about 58 Mc.

The plate and screen voltages on acorn tubes, particularly pentodes, should be held below rating in order to assure long life. Element spacing is so small that a little extra heat may allow grids to weld together if there is any vibration; and too much plate or screen current is to be avoided.

- I.F. Amplifier

This receiver uses standard 3500-kc. i.f. transformers. The 6K7 tubes were replaced by 6S7's which seem to be a little better, but single-ended 6SK7's are recommended to keep all r.f. leads within the chassis. Some trouble with oscillation in the i.f. system was cured by grounding the tube shields directly at the sockets instead of on a ground bus.

- Diode and A.V.C.

Only one diode plate is used. It made no difference when a 6H6 diode and 6C5 audio were replaced with a single 6R7, except that we accidentally brought the diode return to the wrong side of the audio cathode bias resistor, placing bias on the diode, which cut off all weak signals and set noise.

The a.v.c. is straightforward. While the electric eye is a convenience, the a.v.c. has not yet been of value. Possibly with fading dx signals during the summer, it will be more helpful. The r.f. and mixer tubes, which are of the sharp cutoff type, do not receive a.v.c. voltage.

The audio needs no comment. The pentode second stage is used only for speaker reception.

- Beat Oscillator

The single-ended 6SK7 pentode was selected for the beat oscillator, to provide electron coupling without having a grid lead hanging out in the air. If this circuit and the first stages are adequately decoupled and shielded, there will be no trouble with harmonics. We coupled the oscillator to the diode plate through a condenser made by twisting insulated wire together, but apparently not even this much coupling is necessary. In order to cut down the oscillator output to eliminate harmonics, we put resistors from screen to ground to reduce screen voltage. When the voltage was as low as it would go without stopping the oscillation, the same thing was tried with the plate. Possibly the screen voltage could then have been reduced further but we have not done any more with it. The voltages cannot exceed 2.5 and 7 with the present resistors. With a 3500-kc. oscillator, the harmonics fall almost the width of the band apart, so are not troublesome. Still, they can be heard weakly even with this low power oscillator, which speaks well for the sensitivity of the front end. There is something to be said for a 4-Mc. i.f. using the harmonics of the b.f.o. for band markers.

- Decoupling

No clearly defined need for decoupling was encountered; possibly because it was liberally included in the circuits. That it is not yet complete is indicated because the set will pick up a local oscillator signal (through the power supply or other leads not completely shielded). This is not a "trouble," as it never occurs in normal operation.

The idea in decoupling is to provide two paths for r.f. from each hot lead—one low reactance path through a by-pass condenser to ground, as an alternative to the other high reactance or resistance path to the power supply source. It reduces or eliminates coupling through the supply leads. To make it most highly effective, a series resistor in each supply or bias lead should be by-passed on both sides to ground, preventing pick-up of radiated energy on the supply lead from backing up into the tubes. The decoupling resistor at the shorted end of the pipes could be by-passed again on the power supply side; the same with the other acorn screen and plate decoupling resistors, and those on the beat oscillator. No additional precautions are necessary on the i.f. stages, though.

- Power Supply

A voltage-regulated power supply has been used, but with the acorn tube oscillator, it is not clear that the excellent regulation and stabilization is necessary. The voltage adjustment can be varied considerably without altering the oscillator frequency. The regulator does improve the filtering substantially; hum is heard when the neon tube goes out. Also, noise due to line surges seems to be eliminated. A 6SJ7 instead of 6J7 will eliminate the dangling grid lead.

- Adjustment

This set was first lined up by touching the second i.f. tube grid, thus bringing in 80-meter signals, and tuning the following i.f. transformer. Tuning is surprisingly sharp. Then the stage ahead is touched and another i.f. transformer tuned, and so on. The receiver can be lined up more conveniently if there is available another receiver that can tune to the i.f. frequency. The first detector grid clip is removed on the separate receiver and connected to the grid of the second i.f. tube on the 56-Mc. job. When the two chassis are connected together, a signal can be run through the second i.f. and detector, and the transformer can be adjusted. The receiver can then be moved up to the first i.f. and the operation repeated on the middle i.f. transformer, and the same on the mixer.

Then the r.f. end can be attacked. In testing, we used the front end as a converter for the separate receiver, just hooking onto the grid cap of the r.f. tube in the separate receiver. When the oscillator and mixer tuning were adjusted, tube noise could be heard with the i.f. wide open. The r.f. stage brings up the noise enough to close the electric eye, so the gain can be decreased substantially for the same signal level.

The antenna coupling is adjusted for best signal. For this purpose, an oscillator set up one or two hundred feet away is very helpful. Of course, a properly tuned antenna is a great help, and may mean the difference between hearing 20 miles or 150 miles fairly consistently; an improved receiver may be of excellent sensitivity, but when it will go down to the noise level in the first tuned circuit, additional improvement must come by increasing the signal fed into the first circuit.

No noise silencer was incorporated in the original model but with as much "hop" as the set has, one will probably operate very well.

Whether used as a converter, superheterodyne, or superregen, the acorn and concentric line combination, at least for the first stage, seems destined to replace all other tubes and circuits in u.h.f. receivers which have any claim to being "sensitive."

Microscopic Bearings

COMPLETE ball bearings only 1.5 millimeters (about 1/16 inch) in overall diameter are now being produced in Switzerland. These bearings, no larger than a pin head, are being used to replace jewel bearings in clockwork, meters and precision apparatus of all types. The bearings are said to show a great reduction in friction over the jeweled bearing.
—Ohmite News.

¶ From Communications
June, 1939

Television ECONOMICS

By Dr. ALFRED N. GOLDSMITH

THERE is one matter of outstanding importance which greatly affects the broadcasters and the lookers alike. This matter is the proposed discontinuance of present broadcast station procedure whereby the public is admitted to the studio or permitted to view the actual broadcast. It cannot be too strongly urged that the public and non-official observers shall be completely excluded from television studios from the very beginning of that art. In the first place, it is bad showmanship to show the public the various detailed and sometimes disillusioning methods which are used in production. In the second place, studio personnel should be interested in the home audience and their specific and immediate production job only—and not be compelled consciously or unconsciously to pose for a gaping gallery. In the third place, the cost of providing adequate viewing facilities for the public would be unwarranted, particularly in view of the difficulty of placing the observers in such positions that they are not blinded by the lights.

- Recognition of Responsibilities to Televiewers

It has been repeatedly stated by the writer that the entertainment industry should be conducted by "sellers of illusion and vendors of glamor." Through receiver costs and its own time and attention, the public seeking radio entertainment pays for entrance into a new world created by the entertainer; and it is both unwise and unfair to destroy the remoteness, entertainment appeal, and psychological novelty of this created world by showing the public "how the wheels grind and turn." Broadcasting now has the rare and unique opportunity to rid itself of an unnecessary and purely extraneous element which should be foreign to the entertainment industry, namely the intrusion of the public into the routine of entertainment production. If the advertising sponsor and his agency will forget their personal preferences and remember that the major function of broadcasting is to entertain the audience of prospective purchasers *in the home*, they will wisely refrain from requesting the trivial gratification of inviting any portion of the public or their own affiliates to witness the production in the studio. It will be a disappointment to the public, a liability to the advertiser, an annoyance to the broadcaster, and a financial drain on all concerned if this note of caution is not immediately heeded.

- Wave Propagation

Ultra-high-frequency transmission is accomplished by direct (line-of-sight) rays, by reflected rays (mirrored by the ground, lateral obstacles, or more remote structures), by diffracted or refracted rays, and by sky waves (which occasionally are reflected back from overhead to the ground over extended paths even on these very high frequencies). Desired reception is usually by means of the direct ray; and only the direct or reflected rays are of practical importance in successful reception.

Differences of opinion exist as to the more desirable plane of polarization of the wave for reception with lowest noise level. European opinion tends toward vertical polarization, but American practice has favored horizontal polarization. Accordingly, in America antennas of the dipole or doublet type are placed with their length horizontally.

As a broad guide, receiving antennas should be placed as high as possible, in the line of sight toward the transmitting station and with directivity toward that station, and as far back on the roof of a building as may be conveniently possible and thus away and partly shielded from streets carrying heavy traffic, in order to minimize the reception of electrical disturbances originating in automobile ignition systems.

- Exclusion of Video "Echoes"

One novel factor in television reception is the practical importance of avoiding video echoes. If a television signal reaches the receiver over two paths having different lengths from the transmitter, there will be produced two images separated to an extent dependent upon the path difference. The modulation frequencies in television are so high that the echo effect can readily become noticeable. It can be shown that the horizontal displacement between the original picture and the echo picture, expressed as the corresponding number of picture-element widths, is closely equal to the path difference in feet between the two received wave trains divided by 125. The picture produced on a 12″ kinescope (assumed to be 7.5″ by 10″) has a picture-element width of about 0.017″. It is clear that path differences of the order of several hundred feet will give noticeable doubling of the image, and that even smaller differences may detract from picture definition. Accordingly, it is important in television installations that the antenna shall not respond to powerful reflected waves (or else *only* to them), and also that the antenna and its transmission line shall be so terminated as to avoid repeated reflections in that part of the receiving system.

When trouble is experienced from television echoes in a particular installation, a directional receiving antenna can sometimes be rotated so as to eliminate either the reflected or the direct signal, selecting whichever may be most practical in that specific case. It is not unusual to find a reflected signal which is stronger than the direct signal and which should therefore be selected for reception, if possible. In determining the most suitable receiving arrangements, a convenient test means is to mount a light doublet in portable fashion on the end of a long pole, and thus to determine experimentally the preferred location and orientation of the antenna. Sometimes improvements result if a second unloaded dipole is placed near the receiving dipole in order to reduce the effect of reflecting surfaces or to increase the reception of the direct wave.

• Utilization of Long-Wire and Beam Antennas

Reception is generally fairly simple at distances well within the service range, but becomes somewhat more of a problem toward the boundaries of the service area where electrical noises may cause trouble. Where such difficulties are experienced, an increase in the generated antenna signal voltage and greater directivity of the antenna system are desirable. One method of securing these results is to use long-wire antennas. There are practical limitations to this method. Thus, an antenna which is 8 times as long as the simple dipole (that is, which is 4 wavelengths long), produces only about twice the signal obtained from the dipole, and further, it produces this full signal only from transmitters lying in four particular directions. When using such long antennas, it is sometimes requisite to damp the antenna either by a terminating resistor or otherwise in order to secure wide-band response and also to prevent excessive delay before the antenna currents reach a steady-state condition.

The so-called "vee beam" antenna consists of two straight arms, each of one wave length, which are mounted at an angle to each other. The center of the open angle should point toward the transmitting station, reception being best in that direction and least at right angles thereto. The receiving characteristic is bi-directional, and the directivity is superior to that of a simple dipole.

Another useful form is the diamond or rhombic antenna. This consists of 4 arms, each of 1 wavelength. The transmission line connects to one of the acute angles of the diamond, and a terminating impedance is inserted in the other acute angle (this impedance having a theoretical value of 700 ohms for the surge impedance, but giving satisfactory operation in practice for values in the range from 400 to 800 ohms). The rhombic antenna is mono-directional and has the advantageous feature of acceptably receiving a 2.5-to-1 frequency band.

The double-doublet antenna, while less directional than the rhombic antenna, also covers a similar frequency range when provided with an appropriate transmission line.

Practice in antenna installations has not been standardized. One recommendation has been to use a half-wavelength dipole for more distant locations. So far as economy in installation and minimum space requirements are concerned, the antennas range in the following order: simple dipole, vee-beam, double dipole, rhombic antenna.

Near the transmitting station, excessively powerful signals may overload the receiving set, producing, for example, cross modulation between the picture and sound in the first receiving tube. When this readily recognizable effect occurs, it becomes necessary to reduce the signal voltages reaching this tube by the insertion of circuit resistance in such fashion as not to cause transmission-line impedance mismatching and consequent reflection echoes.

It is particularly necessary at points where weak signals are involved that directional antennas of considerable length shall be connected to the receiver through transmission lines with careful impedance matching since not only may echoes otherwise be received but reflected waves in an improperly engineered system of this sort may even throw the receiver out of synchronism through reflected pulses. Receiving antennas for television tend more to be a "hand-tailored" job than for audio installations. They also tend to favor reception from a single station and for a limited frequency band to a greater extent. These limitations are particularly troublesome in locations far removed from the transmitter or where electrical disturbances are particularly heavy. Not only should the antenna be electrically efficient but it should also be sightly and resistant to the weather as well as unchanging in its electrical characteristics. It is usually entirely justifiable to spend more for antenna materials and installation in a television instance than for audio broadcasting. The electrical requirements are more stringent, and the receiving equipment more costly; accordingly it is poor economy to use low-efficiency television receiving antennas.

• Antenna Reflectors

As mentioned above, reflectors back of an antenna will sometimes increase the signal strength and reduce static coming from other directions than the signal. This applies as well to directional antenna systems. Static and electrical disturbances show themselves in various ways. Most disturbances (for example, those from automobile ignition systems) cause "spottiness," that is, transient white or black splotches generally extending parallel to the scanning lines of the picture and irregularly distributed over the picture. At best they detract from entertainment value, and at worst they practically ruin picture quality. The necessary signal strength to over-ride disturbances from automobile ignition systems has been stated to be at least 5 μv/m in city locations. When only more usual disturbances and those inherent in the receiver are considered, a satisfactory picture is stated to be obtained with a signal strength of 1 μv/m. Suburban and rural signal strengths above 5-10 μv/m have been said to be satisfactory, but such values represent a lower limit of service.

- Video Effects of Interference

Interference from diathermy generally appears as broad dark bands horizontally across the picture which may obliterate the picture altogether, or as "watered-silk" patterns which produce a peculiar shimmering or wavering of the picture. In either case, audience enjoyment is reduced or destroyed. In view of the relatively high power of diathermy outfits, and their frequent proximity to the television receiver, there seems to be no practicable solution for the elimination of such interference other than careful shielding (and even oscillator-frequency selection) of the diathermy outfit. Inherently the general acceptance and economic success of television thus becomes largely dependent upon the shielding of automobile ignition systems and diathermy outfits. Since television will be established and grow in individual districts, the problem of handling such interference sources on a nation-wide scale, and in a fashion which is fair to all concerned, presents some troublesome angles.

Desirable and preferable as self-regulation would be for the gradual elimination of such interference, its failure might well lead to legislative enactments having the same aim. Some indication that such a trend is possible is found in a European country where official bodies are developing rules for the elimination of interference resulting from such sources as mentioned above. It is planned to place these rules before the local Government for later possible embodiment in the form of law.

The disturbance effect on the picture of relatively near lightning will depend partly on the severity of the storm, the number of discharges during a unit time, the distance of the storm, the signal carrier frequency and band width, the signal modulation method, the signal strength and requisite receiver gain, the picture brightness, and the response characteristic (linearity) of the kinescope. A quantitative statement relative to such effects is not now available; qualitatively it may be said that for brief and infrequent periods each year some visible lightning interference with average-strength signals sent by present methods will be noticed.

• Reception Transmission Lines

In view of the ultra-high frequencies and correspondingly ultra-short wave lengths used for television, and considering the necessary separation between the receiving antenna and the receiving set, a transmission line becomes necessary. Such a transmission line should be weather-proof in the outside run, sightly, capable of convenient concealment indoors (for example, behind or above picture molding or under carpets or in like locations), and should cause minimum loss of signal voltage or distortion of signal over its length.

The simplest form of transmission line is a twisted pair of insulated conductors. The rubber-insulated type of twisted pair causes a loss of signal strength of approximately 1.5-2 db per wave length at 50 Mc. For lengths up to 40 or 50 feet, this is usually acceptable. For longer runs, open-wire lines or coaxial cable may be used, and such transmision lines are desirable as well toward the outer portions of the service area where signal losses in the transmission line may noticeably detract from service. The open-wire lines (consisting of 2 wires 1-2 inches apart) show the diminished loss of about 0.1 db per wave length. From the installation viewpoint, they present greater difficulty.

• Impedance Matching

The transmission line and its terminations at the antenna and receiver require matching. The twisted-pair lines show a low impedance whereas the open-wire lines show a higher impedance. Fortunately, rough impedance matching of the transmission lines is fairly satisfactory. Thus if the resonant impedance of a simple doublet antenna has a theoretical value of 72 ohms, little difficulty is experienced if transmission lines presenting an impedance up to say 130 ohms are connected to such an antenna.

If marked unbalance exists in a transmission line, considerable signal voltage may be picked up in the line itself with a resulting reduction in picture quality. Transmission-line construction is of greater relative importance in video than in audio installations, and it pays to do a thorough job in this part of the television system even at somewhat increased cost.

In urban locations, the suitable antenna location may be within a restricted area, and space for transmission lines may be limited. In large apartment, office, and institutional buildings and the like, it may be most convenient and economical to distribute television signals throughout the building by means of a centralized system. Such distribution may be at radio frequencies, using one or a group of antennas and amplifiers to feed the transmission lines, and with suitable output (or receiver-coupling) circuits throughout the building. Alternatively, several specific programs may be selected and distributed at video frequencies. The former method requires that each user shall have a complete television receiver but ultimately provides full freedom of choice of program to the user. The latter method enables the use of slightly less elaborate terminal equipment for each user, may however somewhat restrict his extent of choice of programs, and has the advantage of transmitting lower frequencies throughout the building with diminished line losses in a properly engineered installation. Nevertheless, such a system requires great care to avoid frequency or phase distortion, as well as internal electrical echoes. Up to the present, centralized television installations have not been developed to the point where definite conclusions can be drawn as to the most economical and desirable form of installation. In part this may depend upon the number of available programs in a given vicinity, the separation of their respective carrier frequencies, the number of individual outlet stations in the building, and the average, minimum, and maximum runs.

Five Hours of Music On One Record

A NEW method recently developed in France permits an entire program of five hours duration to be recorded on a single normal size phonograph record. The procedure employed is not the usual one of mechanically cutting a wax master disk, but is analogous to that used by the motion picture industry wherein the sound is changed to a series of light pulses and recorded photographically on a film. In this case, however, instead of a continuous film, the light variations are focused and recorded in a spiral path on a large sensitized disk. When the complete program has been recorded, the disk is developed and a photographically reduced copy made to obtain a new disk of normal size.

Reproduction is accomplished by exploring the disk with a constant intensity light beam which reflects from the surface through a system of lenses into a photoelectric cell. The amount of light reaching the cell is dependent upon whether the particular spot being scanned is light or dark. The cell changes the varying pulses back into electrical energy. This is amplified to the proper level and in turn is changed back into the original sound.

¶ From Service
April, 1939

Public Address . . . in the FACTORY

By L. W. MARKO

THE successful p.a. specialist is one who keeps his ear to the ground in the search for new applications of sound systems. In the now ordinary applications such as amusement places, schools and the like, it is becoming increasingly difficult to get the business because of competition; for the same reason, the profits are oftentimes something less than could be desired. But if you work out an uncommon application and can sell a prospect on the idea the job is likely to be yours without competition and it is in such jobs that the greatest profits lie.

Such an application, not entirely new but still new enough to be uncommon, is the use of radio sound systems in factories to improve working conditions and better employee relations. Perhaps this appears to be a rather intangible objective and one which would be hard to sell to an employer but "let's look at the record" as Al Smith used to say.

• Historical Notes

The fundamental idea dates back many, many years. Story tellers and readers have been employed in European industry for a century or more, and in Cuba it is the accepted practice in the cigar factories to have a reader whose sole duty it is to read to the workers from morning to night—news, fiction, anything which will interest them. The direct advantage is that conversation is reduced and production is stepped up accordingly.

Such schemes have failed of adoption by American industry in years past primarily because it is mechanized and where there are machines there is enough noise to make the old reader idea impractical, The use of a sound system overcomes this obstacle, however, with the result that a number of plants have introduced the modern equivalent of the reader in the form of a continuous fare of broadcast programs by means of loudspeakers suitably located throughout the work rooms.

• A Typical Test Installation

An installation was made, for instance, in the dry cleaning plant of the Kent Stores, Inc., Flushing, L. I., where 300 employees are engaged in routine work of a type that involves both the hands and the mind. The installation consists of a 7-tube radio, a 30-watt amplifier and six loudspeakers, representing a total investment of approximately $250.

After this system had been in service for 2 years, I. Paul, manager and one of the owners of the business, stated,

"If the cost of this radio equipment had been ten times as great we would not hesitate to install it as the music is reflected in a more even-going and contented personnel."

• Results

Some of the facts gleaned from this demonstrate the practical utility of such an installation:

In 1929, when this plant employed only 30 workers, overtime brought the working day up to 12 hours during the peak season. As an experiment a small portable radio was introduced and played during overtime hours. To the amazement of the management overtime fatigue decreased and production increased to a level equal to or exceeding regular-time production.

The use of the radio was then extended into regular hours and was put into operation during normal fatigue periods. Here again the management came in for a surprise because a distinct let down in the work was noticed when the set was shut off. As a result of these findings, full-time operation of the radio was inaugurated with definitely beneficial effect, as indicated by the manager's statement quoted above.

Except for occasional broadcasts of national interest, the radio fare is entirely musical as this was found best suited to the requirements of this particular plant. The equipment is installed in the manager's office with the loudspeakers mounted overhead at suitable points throughout the workroom. Volume is maintained at a level just high enough to overcome the noise of the machines.

• Similar Application Successful

Another example is found in the experience of the Hatch Hosiery Mills, Belmont, N. C. Here the work is of such a character that all types of radio programs are utilized. The practice is to keep tuned to the local station (WBT, at Charlotte) during the day but at night when distant stations are more dependable the night shift is given its choice of stations. J. Mack Hatch, president of the company, *credits the radio installation with a 3 per cent increase in production.* Furthermore, in a recent conversation, he said:

"It is the finest thing in the world and the most effective method we have discovered for increasing the speed of work without the slightest inconvenience or burdening of workers."

Thus for the serviceman who dares to venture off the beaten path here is a relatively new field where radio-sound systems show results that can be measured in terms of dollars and cents; where the competition is less keen, the pay prompt and the profits worthwhile.

"Electronics" Reports . . .

A NEAT and original way of stripping silk and cotton insulation from the ends of wires used in radio and similar applications is in use at the Stromberg-Carlson Telephone Manufacturing Company's plant. It consists of a relatively simple machine in which incandescent resistance metal electrodes take the place of the ordinary stripping knives. The insulation is burned off rather than stripped mechanically. This method has the advantage that no fine strands of the insulation are left to interfere with making good soldered joints and there is no chance that the wire will be nicked with possible resultant failure through bending at the nick in subsequent service.

Portions of the wire to be stripped are brought between the incandescent electrodes only momentarily, but long enough for the insulation to be removed where the contact is made. As only this area is raised to the ignition temperature, the remaining insulation on the wire is not affected. To avoid having the products of combustion or any burning particles of the insulation enter the room, these are drawn off through an exhaust pipe connected to a suction fan and having a closed compartment in which solid particles collect. Use of this machine solves problems which heretofore have given trouble in the plant named as well as in other plants where stripping of similarly insulated wires has to be done.

THE motorcycles of the Beverly Hills Police Department are not only equipped with receivers for picking up broadcasts, but are also provided with a transmitter enabling the officers to communicate with headquarters. The transmitter, using five tubes and weighing six pounds, is carried in two compact units behind the driver's seat. The officer is also provided with a miniature camera for making photographic records.

¶ From Radio News
June, 1939

As I See It*

By JOHN F. RIDER

With characteristic thoroughness, Mr. Rider delves into several phases of the industry which are or may be fertile fields for the serviceman.

DID you ever run up against a radio receiver in which a serviceman had incorporated some of his own ideas? We have, and it most certainly was no pleasure. Not that we are condemning the change, but it should have been *identified.* Very often some of the old radio receivers, being called upon to operate under more difficult local conditions, are improved by some minor change—or in some instances a serviceman not so thoroughly versed in radio incorporates a change to effect some remedy, wrong though it may be. These changes should be identified.

• Time Savers

Remember you may be the other guy in the next job. Give the other bird a break so that he'll do as much for you. Not that we are starting a chain letter series, but such little effort is required to record the change, that there is no justification for not recording the data upon a sheet of paper and attaching the envelope to one of the walls of the cabinet so that it will be found by the next man. As a matter of fact you yourself may be called in to repair the receiver and, knowing the change you made, it will prove of inestimable value.

Of course we can speak about a number of ridiculous changes which have been made by servicemen, but that is not the question. Whether or not the change can be condoned is not of importance at the present moment. Servicing is tough enough as it is without complicating matters more by making changes in a receiver without letting the next man know about them. Once more, give the next fellow a break, you may need one yourself.

* This department appears each month in *Radio News.*

• Shatterproof Glass

Here is a suggestion for what it is worth. It should be of interest to the manufacturers of television receivers and is founded upon a very narrow escape. Make the window in front of the cathode-ray oscillograph tube of shatterproof glass. The average maid or housewife handling a vacuum cleaner or a broom can very easily without much thought bang the modern receiver cabinet and all that happens is a scratch or a dent. However, some of the television receivers shown in picture form have an open window. If this window is of the conventional glass, it can be easily broken and there is no doubt about the fact that it will be broken in more than one case. Shatterproof glass will protect the oscillograph tube.

• A Lot of Juice

Speaking about television receivers, it is never too early to speak about the danger of high voltages. The receivers we have at hand operate with several thousand volts applied to the cathode-ray tube. As a matter of fact, there are numerous places where the voltage is from 1000 to 4500. To play blindly with such voltages is ridiculous and no doubt some organization will offer insulated gloves to the service trade. They'll need them when servicing time comes around and it is not as far distant as you think.

Several television kits will be offered for sale during the next few months. These kits will be built and as can be expected will not work well the first time assembled. Not that the basic design is incorrect, but that the man who assembles the unit will not do a perfect job the very first time. No doubt, a serviceman will be called in and he will find it necessary to measure the various operating voltages.

When he does, it will be a good idea to work with one hand in his pocket. No, not nonchalance—*just safety*. As a matter of fact it will be a grand idea to learn not to be wise. Remember, you can't duck an electric shock, and it sure can throw you a long way, if not for a total loss.

• $1.00 Factory Service Charge

A number of servicemen have been stirred up by the $1.00 factory service policy established for these $6.95 to $9.95 receivers. It's not as bad as it looks and dollars to doughnuts, many thousands of these receivers will be serviced by the regular run of servicemen, that is, if their service routine and their service equipment is modern enough to enable them to work rapidly and efficiently. Some servicemen feel that the receiver manufacturers have bent backwards just to take business away from the established service group. Such is not the case. Plants must be kept going and one way to help keep these plants running is to make a secondary market and it is these cheap jobs. It is our guess that the factories will not receive many of these receivers back for service. Let's see why.

Suppose that we consider you as the customer. You buy one of these receivers and as is to be expected, the service problem is not of great moment when you buy the receiver, so you do the natural thing and throw the shipping carton away. After all, there is no place for an empty shipping carton in the average home. The receiver is guaranteed for one year, but the tubes are guaranteed for only 90 days. Furthermore, the year's guarantee applies only if the receiver has not been tampered with, etc. So, some time passes and the receiver goes bad. It is past the tube warranty period, so that while the $1.00 charge still applies the tubes represent an extra expense.

Well, you have decided to return the receiver. It must be packed and packed securely because the warranty does not apply if the unit is damaged in transit. There is nothing difficult about such packing, but after all you're not a shipping clerk and you must have the carton and you're worried about it becoming damaged in transit. While you're hunting for the carton, which you threw away, you give some thought to the actual shipping. You do not have a scale, so cannot weigh the package and determine the amount of postage, which means that you will have to take the package to the post office. Oh, if this were only a letter, which you could conveniently drop into a mail box. But it is not, and it must be shipped. Of course, during all this time, you hope that the dollar bill you will put into the box will not go astray and will be found when the package is opened.

Well, you decide that the carton is not available. You must seek corrugated or some kind of heavy paper wrapping, something in which you can pack the receiver securely. Just then you begin wondering. How long will it take to get the receiver back after service? Will it arrive in perfect shape after having been serviced? What will the mailing charge be? Maybe the local serviceman can repair the receiver. After all, you can afford to pay at least $1.50 because the factory charge is $1.00 and it will cost at least 25 cents each way for mailing. Maybe, it might be best to pay the local serviceman $2.00 and have the receiver back in a day or two. Oh, what's the use of packing and taking the thing to the post office, gambling on your ability as a packer? If you're a poor packer, the service charge might be more than you would have to pay to the local serviceman. Maybe you should not pack the job at all; instead, talk to the serviceman tomorrow.

And that's just what you do. You don't pack the set and you go see the serviceman. If he is a salesman, he'll sell you the idea of bringing the set to his shop. Pay him $2.00 or possibly more, and you're content. Basically you're a lazy individual. You like your comfort and you're not a shipping clerk. And it's a nuisance to pack after a day's work. And the post office is closed anyway. These are the reasons why tens of thousands of these midgets will get into the hands of the independent serviceman. These are the reasons why hundreds of thousands of books are sold by mail—you know, the ten-day free trial—send it back if you don't like it. Well, you seldom send it back. You pay the price because you're lazy.

• Facsimile Notes

We have played around quite a bit with facsimile lately and with the interest growing, it might be well to state some salient items of interest, points which might prove of value to those servicemen located in areas served by facsimile systems.

Excellent pictures can be received when conditions are correct, but very poor pictures will be received if conditions are not correct. This is in contrast to normal radio reception at the very high frequencies. Many of us marvel at the ease with which we can pick up domestic and foreign short-wave broadcasts with practically no antenna, poor locations, etc.

However, in the case of short-wave facsimile transmission, the proper type of antenna is required outdoors. Furthermore, the receiver used should be free from oscillator drift so that the signal fed into the recorder remains constant in level. Freedom from noise is imperative. We usually tolerate a certain amount of noise in a radio broadcast, but noise will just about ruin a facsimile picture.

In contrast to normal broadcast reception, where we accept whatever signal is received, a definite signal level is required in a facsimile receiver, otherwise the picture will be very light, if recorded at all. In this connection, it is true that the criterion is the voltage at the recording stylus, which means that given sufficient amplification at the receiving point, and if the original signal is clear, proper facsimile pictures can be obtained with comparatively low signal level at the antenna. However, if a complete facsimile outfit is purchased, it requires a certain signal input level in order to develop a good picture.

Granting trials and tribulations during the present experimental period, the quality of the paper used is also a factor. We have found that all rolls of paper are not the same—that is, all rolls intended for the same outfit. Some rolls produce a picture of better contrast than others.

At the present writing 11 stations are transmitting facsimile pictures on frequencies within the conventional broadcast band and 3 stations are broadcasting over the high-frequency band. From well established sources we learn that this total number will be increased at least two-fold before 1939 passes. With regular schedules maintained, interest cannot help but grow and it might not be a bad idea for service stations located in towns where facsimile is being broadcast and where a good signal is available, to use the transmission as a means of attracting attention to the store. As a matter of fact, it is not such a bad publicity stunt for use by department stores or other establishments. The idea can be sold.

• Open Your Eyes and Look Around

It has always been our contention that the sphere of operation of the radio serviceman has been too narrow. He has lived radio receivers and has felt that therein were the boundaries of his life. That's been a fallacy and is daily becoming more so.

Granted that the average serviceman has found it difficult to keep apace with radio receiver developments, he is forced into the position where he must expand his field of knowledge and his field of activity. Consider for the moment the newly exploited wireless record players. Records were dead for years. The radio industry ruined the phonograph business. However, persevering people felt that the record business was not dead. Campaign after campaign was tried until interest picked up and phonograph record sales began to mount.

Then came the wireless record player. Whether any one particular device is better than another is of no consequence. The fact remains that here is a miniature transmitter which will require service. The cost of the device is sufficiently high so that service is justified. The nature of the device is such that some time or other something can go wrong. That something is wrong can be discerned instantly by reduced signal output or distortion. Small as the device may be, the serviceman must know something about the operation of a transmitter. He must know something about modulation, the operation of oscillators, the operation of pickups, the relation between audio and radio frequencies in a transmitter, the operation of motors, etc.

We recognize that motors and pickups have been used in receivers equipped with phonograph turntables, but very little attention was focused upon those subjects. All the interest centered upon the receiver circuits. A process of modulation occurred in the mixer tube in the conventional superheterodyne receiver, but all attention was focused upon the circuit, rather than the operation.

The problem of modulation appeared in every test oscillator used by radio servicemen for the past 18 years, but we never paid any attention to what took place in the oscillator; we were concerned with its use as a signal source and its frequency range and its accuracy.

We never know what the future has in store. No one can say what radio equipment will be in every automobile. Already we have heard about, as a matter of fact, have seen some equipment, the micro-wave transmitter used in traffic control, the idea being that instead of sounding a horn, which is audible, micro-wave is radiated and is picked up by the car ahead and he drives to one side to let the man behind pass him. Maybe all cars will be equipped with transmitters, so that Mr. Vandermillion can tell his butler to chill the champagne and Mr. Joe Doaks can tell his wife to heat the stew, he is on his way home. Who knows?

• Another Example

Take the cathode-ray oscillograph as another example. Thousands were sold and thousands are on the shelves gathering dust. Maybe you're not fully familiar with its operation, but is that any reason why you should not become familiar with how it works? Men who have had the instrument for years admit that they do not know how it works —that they have not found the full application in radio servicing.

Maybe the device is not applied as easily as you would like. Maybe the device does not have all of the radio applications you would like. But it is still a good unit. You already have the unit. Why not try to think about future applications? It is used in television. Maybe it will not be used forever, but it will be used for quite some time and is being used today. The tube has applications in industry. It is being used in connection with any number of different industrial applications, vibration checking in moving equipment from such widely varied field as establishing the resonant period of rotating grinding wheels, to what element in a business machine is the source of the noise. Learn how the cathode-ray oscillograph works. It will never do you any harm and may do you much good.

It is used in the automotive field. Facsimile is being used to make records of operations in the clock industry. There is no limit to the application of the various devices now being offered to the radio serviceman in fields far removed from radio. There is every justification for assimilating as much data as possible concerning present developments. Not that we dream of one service organization taking care of all types of service work, but that an organization is prepared to go into various fields and perhaps find a spot better suited to the individual or to the organization. And it is not an impossibility that a good radio service organization located in a mill town or factory town can build up a perfectly good clientele among the factories for the servicing and possibly even installation of radio equipment in industry.

• Town and Country

We got a letter the other day from a serviceman who has an establishment here in New York and in the course of this letter he made a statement that set us to thinking. The gist of his statement was that he made it a practice to take in small receivers for servicing in the hopes that eventually he would be called in to service the large receivers he almost always saw in the homes where they had the little four-tube jobs. Furthermore, he admitted that in most cases he took a financial licking or at the best broke even on the majority of such jobs.

As I see it that serviceman has a problem. Here he is operating in a city with an unstable population and by that we mean that a good fat percentage of the inhabitants of Father Knickerbocker's town think it absolutely imperative that they move from one apartment to another every couple of years. It's true they may move only a block or two, but in a city of this size that's sometimes the equivalent of moving to a different town in other parts of the country. As soon as they move, they are besieged with advertisements for a new milkman, a new butcher, and, of course, a new radio serviceman. And being as susceptible to the written blandishments as the average New Yorker is, the chances are that when his receiver goes bad, he picks up the phone and calls in the new serviceman, totally forgetting the fellow who fixed up his little job last year. It's tough, but it's true.

On the other hand, the same procedure in suburban districts or in the country might be considered good business practice. In the first place most people in small towns own their homes, they do not even think about selling them every year or two. Therefore the serviceman who just breaks even on fixing up a so-called "secondary" receiver has a right to expect that he will be called upon to repair the large set if it needs attention. Business in small towns is conducted differently than it is in cities—everyone knows everybody else and if a serviceman does a good job once for a family, he is their serviceman from then on. Suburban folk have their tradespeople and it just never enters their heads to change except for a mighty good reason. We could quote you case after case where people in small towns have done business for twenty, thirty and even more years with the same merchants. Once confidence is established, that's all there is to it.

No, we do not think that the serviceman in a large city whose clientele who lives in apartments and hotels should take a licking at random in the hope of future business. It's too much of a risk. Where a loss is inevitable, it must be taken; as a business-getter it's no good.

F. C. C. Office of Information

THE Federal Communications Commission has authorized the establishment of a permanent Office in Information, to be responsible for the collection and dissemination of information for the press and the public regarding the Commission's decisions and other matters and to have such other functions as the Commission may determine.

The Office of Information will be headed by a Director of Information and Special Assistant to the Chairman, with an Assistant Director of Information, and will embrace the work of the Information Office, the Information Reference Room, the Press Room, and related activities. Provision was made for it to function under and be responsible directly to the Commission, replacing the Press Section, a unit in the administrative branch.

¶ From Electronics
June, 1939

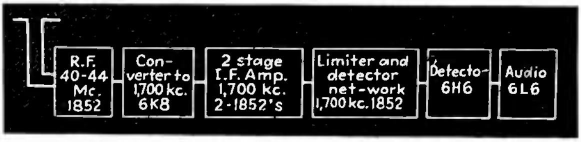
A RECEIVER *for* FREQUENCY MODULATION

By J. R. DAY

The first published data for the construction of an f-m receiver. Using but seven tubes, the circuit displays a sensivity of the order of 5 microvolts, is flat from 30 to 15,000 cps within 2 db, and may be constructed from standard components.

THE frequency-modulation receiver described here is representative of many others, some more elaborate, and some more simple. It was selected because its design and and construction embrace all the features that distinguish frequency modulation receivers from amplitude modulation receivers. This receiver has proved capable of rendering noise-free and high quality audio from very small signals, corresponding to a field strength of from one-tenth to one one-hundredth the value that would be necessary in the case of amplitude modulation, in the absence of outside interference, and in addition possesses the advantages relating to the suppression of noise originating outside the receiver that have been demonstrated for wide-band frequency modulation.

At the outset it might be well to recall a few generalities. A frequency-modulated wave is a radio-frequency carrier wave whose frequency is caused, at the transmitter, to vary linearly above and below its nominal value in accordance with the desired modulation. It is also a distinguishing and important feature of Major Armstrong's method that the maximum deviation of the transmitter frequency is several



Block diagram of the receiver is shown above. Except power supply, but seven tubes are used.

times the value in cycles of the highest frequency present in the modulation. The transmitter output, during modulation, therefore covers a considerable bandwidth, and the receiver must be designed to handle it adequately. Transmissions at present use a maximum deviation of ± 75 kc. The receiver described here when properly aligned will handle such a transmission with negligible amplitude and frequency distortion.

- Circuit Operation

The block schematic diagram shows that the antenna current is received at a high frequency, is amplified, converted to a lower intermediate frequency, amplified further, passed through a current limiter, converted to amplitude modulation, and finally demodulated. Since the magnitude of the recovered audio is a function of the time rate of change of the frequency of the carrier current it follows that, unless the phase shift of the various circuits up to the detector is linear, there will be amplitude distortion. It is not hard to keep the distortion due to this to less than 1 per cent of the peak amplitude of the recovered audio, with thoroughly practical values of the circuit parameters. Observing this precaution the amplification from antenna to current limiter grid may be increased or decreased as necessary or convenient, only providing that there is sufficient gain at all times to provide adequate limiting action in the limiter stage. The receiver of the circuit diagram represents a middle ground in the way of sensitivity, and the values given are merely for the purpose of guidance, at the frequencies indicated.

- R. F. Section

The two tuned circuits at 7 meters do not provide a very high image ratio with an intermediate frequency of 1700 kc. However, consideration of the results shown by Weir will disclose that the requirements here are less stringent than would be the case were this receiver for amplitude modulation. The two r.f. circuits and the oscillator in this case are operated from a single control, but for the purposes of an experimental receiver a separate control for the beating oscillator, enabling tuning both above and below the carrier frequency, would naturally give greater flexibility. Also the use of a higher intermediate frequency would better serve circumstances requiring a higher image ratio. The measured image response ratio of the receiver is about 18-to-1. Naturally the Q of the r.f. coils is low enough to insure linear transmission and phase shift over the range of ± 100 kc. The resistor loading the grid of the 6K8 type tube was put there only because a wide variation in the input resistance at 40 megacycles among tubes was experienced. It appears that the new 6SA7 type is somewhat better in this respect. Some regeneration in the r.f. section can be tolerated provided it does not unduly sharpen the transmission characteristic. The step-up in the antenna coil is about 5, and the gain of the 1852 stage to the converter grid is 12. At the time it appeared the 6K8 type offered advantages in stability at high frequencies that governed the choice. The 6SA7 now appears to be superior in this respect also.

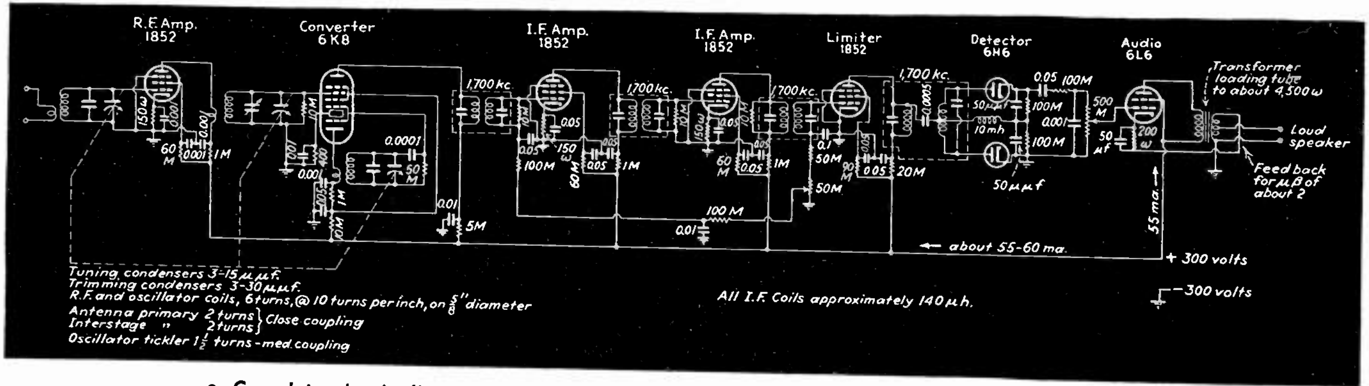
Frequency modulation of the oscillator voltage is particularly to be avoided. This may occur in a variety of ways including plate supply ripple, tube, coil, and condenser microphonic response, and heater-cathode leakage in the case where the cathode is above ground. Ripple frequency filtering in the plate supply, rigidity of coil and condenser, microphonic isolation of the tube, and large d.c. bias from heater to cathode will ordinarily remedy these ills. In bad cases it may be found desirable to by-pass, and perhaps filter, the heated leads for r.f. at the socket. Chokes (very small) of about 5 microhenries and 0.001 microfarad condensers will fill the bill nicely. It should be pointed out that these effects are generally very small and would not be appreciable if the overall reproduction were not so uncommonly quiet. The conversion gain of the stage is about 4.

• I.F. Amplifier

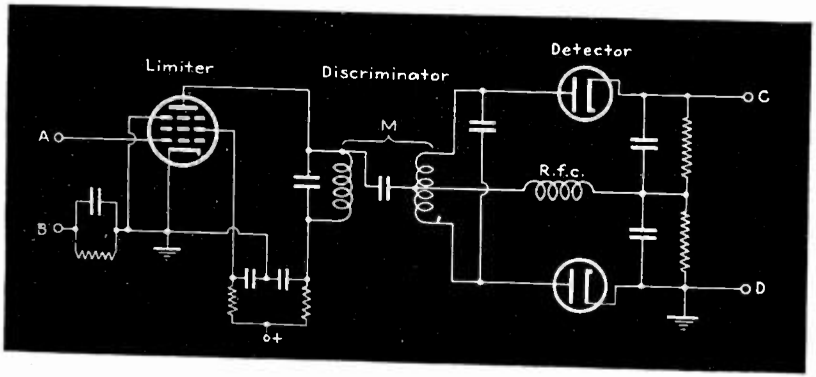
The intermediate frequency amplifier is perfectly orthodox, and can probably be considerably improved. The 1852's give a gain of approximately 70 per stage. A gain of 50 per stage would materially lessen the hazards of unwanted feedback. Ready-made double-tuned i.f. transformers are available to the trade for quite a variety of high intermediate frequencies. Several of these can be modified very simply to conform to the needs of this receiver. The coils used here were of 140 microhenries inductance and the necessary bandwidth obtained by manual adjustment of the coil spacing on the dowel, in conjunction with the indicated loading. In this case the coils were small universal-wound units of about 3/32 inch width, and the optimum coil spacing is about 3/8 inch between centers.

• Sensitivity

The sensitivity of the receiver cannot be compared directly with the sensitivity of an amplitude-modulation receiver, for obvious reasons, but it is possible to state a minimum signal level, required at the input of the frequency modulation receiver, to produce adequate limiting action. A voltage level of about 6 volts is required at the grid of the limiter tube to insure proper



• Complete circuit diagram of the receiver. I.f. transformers for 1700 kc. are now available commercially and may be modified readily for wide-band reception.



• Limiter, discriminator and detector circuit, in which the essential demodulation functions of the receiver are performed.

limiter action. The gains per stage prior to this grid are, from the antenna coil inward, as follows: 5, 12, 4, 70, and 70, or a total of 1,100,000 times. Accordingly, a six-volt signal can be developed from a minimum input of between 5 and 6 microvolts. It should be noted that this is the minimum signal required for limiting action against the effects of external noise. If there is no external noise to contend with, the discrimination against tube noise is active even with signals as weak as a fraction of a microvolt.

• Resistance Loading of I.F. Coils

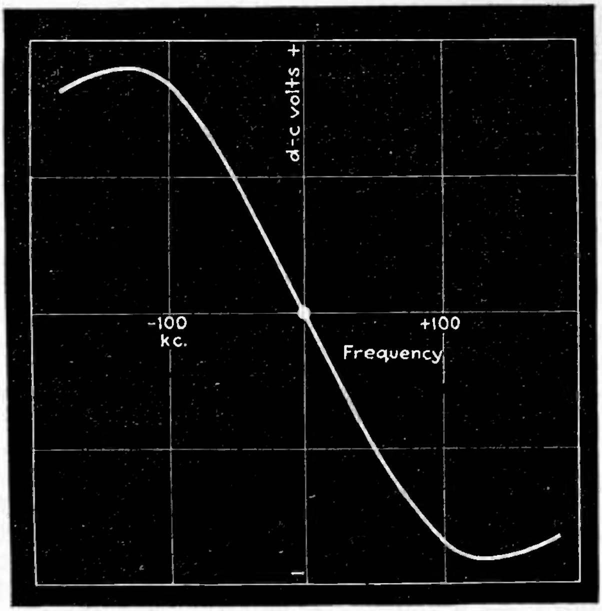
The resistance loading on the i.f. coils performs a number of related functions. As mentioned before, the variation of phase angle with frequency of each coupling circuit should be linear for an interval above and below the carrier equal to the maximum frequency deviation in the transmission. A conservative figure is ± 100 kc. for transmissions swinging ± 75 kc., and would represent a limit of "over-designing" beyond which there would be no benefits. In the absence of elaborate equipment for measuring the phase angle, and in the absence of the stamina required to compute it, a cheap way to insure success is to put one's faith in the old adage that for symmetrical circuits the phase shift is linear over the range where the transmission is constant. As a guide the individual i.f. stages should be adjusted to be symmetrically tuned and to be down 1 db at the edges of the band. Symmetry is important, as stagger tuning brings in some rather unpredictable factors and can easily make a graph of the phase angle look like a bed-spring—to say nothing of what the recovered audio can sound like. The resistance loading shown is of course instrumental in obtaining the desired "steady-state" transmission characteristic. It does something else of equal importance. Since the coupling circuits contain L, C, and R, and the currents carried are varying rapidly through the resonant frequency of the combination, transient or free-oscillation currents result. The character of these currents and their harmfulness as spurious responses is controlled by the ratio L/C and by R. The higher the damping produced by R the less pronounced will be this response. In amplifiers handling frequency modulated currents it is important that this transient current be kept to a certain low level and that it be rapidly damped out, for the highest modulation frequencies of importance (this phenomenon is clearly of greater significance the higher the modulating frequency). Using sine-wave modulation, distortion in a frequency modulation receiver due to non-linear phase angle and related defects will be characterized by the usual types of wave malformation. But this second type of distortion will appear very plainly as a damped transient of a short initial period superimposed on each half-cycle of the recovered sine-wave. The transient does not change greatly as the audio frequency is raised, being mainly dependent on the circuit rather than the precise nature of the excitation, and hence is a comparatively greater disturbance to a high frequency modulation wave than to a low. This and related phenomena are described and analyzed by Roder and by Carson and Fry. The equivalent damping shown for the circuits of this receiver is ample to insure freedom from these effects. Reasonable departure from the limits and values given here will not cause aurally detectable distortion, and experience will show the experimenter that the specifications given in this description are safe by quite a margin.

- Limiter Amplifier

The current limiter amplifier is a coupling stage intended to remove from the carrier variations in amplitude, and to excite the conversion network with a current varying only in frequency and phase. There are a number of ways of doing this, none of them perfect. The circuit will begin to "limit" with an r.f. input of three volts peak, will have leveled off at five volts, and will "drive down" slightly as the input is increased to 100 volts. This "driving down" is due to plate and screen voltage regulation as rectification occurs. As operated, this limiter is a grid-cathode rectifier and hence develops a voltage negative to ground on the resistor from coil to ground in the grid circuit. This voltage may be used for a.v.c. or manual r.f. gain control by applying a part of it to one or more amplifier grids. It is important, though, not to use such a gain control voltage to an extent that might endanger the efficacy of limiting, as exemplified by a limiter grid driving voltage of say 7 volts minimum. The voltage across this resistor or the current in it may be used as a very broad tuning indicator, and, if the stages preceding the limiter are linear, as a measure of the signal strength. It is convenient to note here that up through the limiter circuit there are no requirements whatever on the linearity with amplitude of any of the amplifier circuits. Although this property in the receiver does not permit the economies that it allows in the transmitter it is none the less attractive, and neatly removes one headache for the designer of a high-quality receiver.

- Discriminator Device and Audio Recovery

The network effecting the change from frequency to amplitude modulation, for the purpose of recovering the audio by ordinary means, is in the plate circuit of the limiter and consists of the familiar discriminator device as used in some types of automatic frequency control. The analysis of this circuit is ably given by Roder. Here again the coupling must be relatively "tight", in order that the peak separation should comfortably exceed the maximum frequency deviation. The circuit as shown for 1700 kc. uses coils of 140 microhenries inductance, coupled a bit more tightly than the amplifier coils, that is, for a peak separation of about 250 kc. The diode load shown is sufficient to preserve



Operating characteristic of the discriminator circuit shown opposite, showing audio output amplitude against frequency deviation.

linearity over the operating range. It will be found that, when the coupling is adjusted, the primary trimmer affects mainly the symmetry above and below mid-frequency of the peaks, while the secondary trimmer mainly affects the cross-over, which should be accurately nailed to the center of the i.f. channel. The recovered audio when the tube ahead is limiting will be found to be between 20 and 80 volts peak for a transmitter swing of ± 75 kc. The operating conditions of the limiter tube for the most part determine the maximum audio output of the detector as shown. It should be noted that the detector output voltage consists of the sum of two voltages, one from each diode. This is a true push-pull effect, and is of aid in balancing out any unwanted modulation that appears on the diodes in the push-push sense. A 6B8 type tube can be used as a combined limiter detector, but it necessitates a grounded common cathode and shunt diode loads, and hence a two-grid audio input. Also, being a remote cut-off tube, it has a somewhat higher limiter threshold. Since the average value of the voltage across the two diode loads in series is zero when the carrier is exactly in tune, and goes positive and negative for deviations from "in-tune", it makes a convenient and accurate tuning indication. A center set voltmeter which will not load the diodes unduly, makes a suitable indicator.

The resistance capacity combination intervening between the diode load and the audio volume control is a so-called "restorer", and is for the purpose of equalizing the present transmission characteristic. At the transmitter the highs are accentuated in the manner familiar as predistortion. This results in a high signal to noise ratio in the high audio frequencies, and for the case of frequency modulation does so without sensibly increasing the danger of side-channel interference. Further, in a frequency modulated system, the random noise voltage per fixed frequency interval increases as the mean frequency. Therefore the net advantage accruing is greater for the frequency modulated than for the amplitude modulated system, where the noise energy per interval is sensibly constant as the mean frequency is varied.

- Audio Power and Fidelity

The recovered audio in this receiver is large enough to drive one 6L6 to full output even with the indicated feedback (mu-beta of 2.14 at 400 cycles), and the loss in the restorer. The single 6L6 will turn out 6 watts of single frequency with very low distortion. The high quality afforded by the system and the receiver permits the use of a high listening level without aural distress. However, the full use of even this single tube output will endanger the average apartment dweller's relations with his neighbors.

The writer earnestly hopes that experimenters will do their listening with this type of receiver using good loud-speaker equipment. The electrical fidelity from modulator input at the transmitter to voice coil at the receiver, in the case of this receiver and many others like it, is good to within 2db from 30 to 15,000 c.p.s., with single frequency distortion not exceeding 2 per cent r.m.s. for full modulation. Obviously, it would be unfair and wasteful to use poor loudspeaker equipment with such a device.

- Alignment and Testing

The most precise method of aligning and testing a receiver like this is a point by point procedure. With a signal from some suitable generator on the grid of the limiter tube, and a high resistance d.c. voltmeter across the diode output, the discriminator transformer is tuned so that for constant voltage on the limiter grid the voltage across the diodes varies linearly through zero at mid i.f. range from 75 kc. above to 75 kc. below. It is desirable to keep the peaks as close together as is consistent with linearity in the ± 75 kc. range.

The next step is to put a milliammeter in series with the limiter grid resistor and, working back stage by stage with a signal generator, to adjust the coil couplings, loads and tuning until the transmission characteristic of each stage and of all in cascade is symmetrical and flat across the operating range. It will be found that a symmetrical amplifier that is flat for the operating range to within ± 1 db, and that is sufficiently damped, will transmit a frequency modulated current of total deviation equal to the range with virtually perfect freedom from distortion. It is possible to compensate double-peaked circuits by single-peaked circuits, in the usual way, provided symmetry and freedom from feedback are maintained, in such a manner that no appreciable distortion will occur. However, since the action then occurring can be quite complex and is not easily subject to analysis, this method is not generally to be recommended. It is important to bear in mind the nature and origin of the two types of amplitude distortion mentioned above during the lining-up process.

A wide-swing frequency modulated oscillator with provision for a low-frequency saw-tooth sweep will provide a quick visual method of alignment of all circuits. For experimental purposes there are, however, some drawbacks. In the first place, relatively careful calibration of frequency deviation is necessary. The visual accuracy of cathode-ray tube indications is limited. And, finally, there is a strong temptation when using this sort of equipment to align the receiver "over-all" and perhaps unwittingly to indulge in interstage compensation for the sake of a smooth looking transmission characteristic. If this method is used the voltage on the limiter grid resistor (with by-pass reduced so as to shunt out only r.f.) is convenient for vertical deflection when aligning the i.f. stages and converter.

The alignment of the r.f. section consists of simple peaking, as the coil and tube damping are more than enough for the purpose.

• Antenna Requirements

Although the sensitivity of the receiver is high, and the natural noise-reduction inherently good, a good dipole with associated transmission line will repay the effort. There is nothing out of the run of ordinary short-wave practice in the collection of the signal. Only under very unfavorable circumstances and at considerable distances from the transmitter are special devices such as reflectors, indicated.

Electronic Sleuth

ELECTRON tube equipment came into use when a Geiger counter was employed to find $12,000 worth of radium which had been lost in a Cambridge hospital. The platinum tube in which the radium had been contained was melted, and the radium was dispersed through the ashes, but it is expected that 90% of it can be recovered—Electronics.

Television Pickup

OVER TELEPHONE CABLE PAIRS

ON the evening of May 20 events at the 6-day bicycle race in progress at Madison Square Garden were "telecast" by the National Broadcasting Company in a half-hour program of sight and sound. The facilities for carrying the television signals from Madison Square Garden to the National Broadcasting Company were furnished by the New York Telephone Company and the Bell Laboratories as an experiment in television transmission.

The television signals were picked up by the N.B.C. "telemobile" unit from the edge of the track at the Garden, and were transmitted over existing telephone cables to the Circle central office on West 50th Street and thence over a similar circuit to the N.B.C. studio at Radio City. Special amplifiers, attenuation equalizers, and phase equalizers were provided at the Circle office and at both terminals. The adjustment of the overall circuit was such that the signal was delivered at Radio City without noticeable impairment. Although the illumination available was far less than is used for studio pick-up, the results were felt to be distinctly satisfactory.

This accomplishment has created considerable interest because of the use of pairs in ordinary telephone cable rather than the coaxial conductor, which has been generally associated with the transmission of television signals. The use of ordinary telephone cable, under certain conditions and properly arranged and equipped, for the transmission of such a wide range of frequencies as television requires, was discussed in a paper by A. B. Clark of Bell Laboratories before the American Institute of Electrical Engineers in January, 1935. The recent experimental accomplishment is a practical demonstration of the possibility which he then described. The energy loss of television currents, however, in passage over a mile of ordinary telephone cable is about a million times greater than over a mile of coaxial cable. A series of measurements on the cable must precede its use, there must be some alterations in it, and the provision of amplifiers and of special apparatus for equalization of attenuation and phase. The recent experiment, therefore, does not imply that ordinary cable pairs can be economically used for television except over comparatively short distances. What the experiment does show, however, is the possibility of using telephone cable to pick up television news and carry it over short distances to main lines of coaxial cable or to nearby transmitting stations.

—Bell Laboratories Record

¶ From General Radio Experimenter, May, 1939

Toward A More Silent Subway

THE other day in New York City's Eighth Avenue Subway, crowds of harassed commuters, battling for seats, were thwarted by the closed doors of a car marked "No Passengers." Inside was a group of engineers who had installed the most up-to-date of testing instruments in preparation for a trial express run between 5th and 125th Streets. When the train got under way, Mr. V. A. Schlenker, New York acoustical engineer, concentrated on the fluttering stylus of a recorder operating from a General Radio Sound-Level Meter. The results of this test run were of critical importance both to the subway and to the Firestone Rubber Company, for on one mile of track between 81st and 99th Streets, Central Park West, Firestone had made a trial installation of rubber tie plates, designed to reduce the noise and vibration of the trains and prevent undue transmission through the subway foundations to adjacent buildings.

- Purpose of New Plates

These tie plates are hard rubber pads, about five inches square and one inch deep, assembled in a steel harnessing jacket and installed under the track at each tie. Should they absorb enough vibration, the pads would prolong the life of the trucks and the rails. Buildings adjacent to the subway, often receivers of transmitted vibration, would also benefit from the installation, and, more important from the commuter's point of view, the clatter, din, and sidesway of the cars would be diminished, to the great relief of the underground New Yorker's nervous system.

At fifty miles an hour, top speed, the northbound express roared up the trial run, and Mr. Schlenker noted on the sound-level record the beginning and the end of the treated mile marked off by flares of lights placed beside the track. Afterward, the sound-level record was checked accurately with the graphs of speed and acceleration. The corrected record showed that the noise in the car was less on the rubber-studded mile. Later measurements with the sound-level meter in a west side hotel, whose foundations abut the subway opposite the installation, showed a noise reduction of twelve decibels. This represents a reduction of the subway sound in the hotel to one-quarter its former level.

• Substantial Improvements

The results obtained using a vibration pickup with the sound-level meter were even more revealing. The rubber installation was responsible for a three-decibel decrease in floor vibration in a car racing ahead at fifty miles an hour, and in the steel columns supporting the northbound track there was a seven-decibel reduction. In the hotel, again, the meter registered eleven decibels of vibration improvement.

In New York's current enthusiastic campaign for lessening the city tension by eliminating unnecessary noise, the test mile along Central Park West is a forward stride.

Electromagnetic Horns

HOW HORNS are useful in directing radio waves, just as they are for sound waves, was demonstrated recently before the Institute of Radio Engineers by Dr. George C. Southworth, Bell Telephone Laboratories. Using a wave only 3½ inches long, sent down a metal tube into a horn ten feet long and two and a half feet square at its mouth, Dr. Southworth showed that practically all the energy was shot out in a narrow beam. Giving the waves this kind of send-off, Dr. Southworth said, is as good as a 500-fold increase in power for an antenna of the ordinary type. One of his transmitters was about the size of a big flashlight and when he pointed it toward the open throat of the big horn, the beam of waves immediately set a loudspeaker into action. Evidently the horn's directivity was as useful on the receiver as the transmitter, both for the purpose of increasing signal pick-up and discriminating against unwanted signals, as the speaker demonstrated by shooting a beam at the side of the horn.

Reviewing briefly some experiments which he performed before the same audience last year, Dr. Southworth explained how very short radio waves could be sent down a metal tube, or guided by a cylinder of insulating rubber. At the end of such a tube a film of graphite on paper would act as a resistance to absorb the waves. Or they could be radiated into space; Dr. Southworth showed how varying amounts of energy could be drawn from the tube, depending on the way it flared out into the horn.—Communications.

THE TECHNICAL FIELD

in Quick Review

●

RADIO TECHNICAL DIGEST briefly summarizes for its readers the contents of leading radio articles in current technical publications, some of which may appear later in Radio Technical Digest.

COMMUNICATIONS

Bryan Davis Pub. Co., Inc.
19 E. 47 St., N.Y.C.
25c a copy—$2.00 yearly

JULY, 1939

IMPEDANCE MEASUREMENTS ON BROADCAST ANTENNAS, PART II, *by Donald B. Sinclair*.—The series-resonance and bridge methods of measuring impedance are discussed. Correction errors are taken under consideration, and specific measurement technique is suggested.

THE POLYRHETOR, *by G. T. Stanton*.—An interesting and unique sound system which has been installed at the General Motors exhibit—"Highways and Horizons"—at the New York World's Fair. A 12-foot drum which carries 24 loops of sound track film is synchronized with a continuous chain of cars moving around the exhibit in such a manner that the commentator's voice, as it issues from the loudspeaker in each car, is describing the portion of the exhibit which is overlooked by that particular car.

SOUND EFFECTS CONSOLE, *by W. W. Strathy*.—The description of a convenient, portable, three-turntable console for studio production use. A newly developed method of "spotting" records is incorporated which is both simple and so accurate that it is possible to start a record with a given word, or with a given note in the case of musical recording.

TELEVISION FUNDAMENTALS, *by F. Alton Everest*.—Part IV of this series deals with the history and construction of the cathode-ray tube and its applications as a television reproducer.

TELEVISION ECONOMICS, PART VI, *by Dr. Alfred N. Goldsmith*.—A discussion of some of the problems relating to the construction and operation of television broadcast receivers. Chassis, tubes, and Kinescopes are among the points covered.

SOUND MOTION PICTURE FILMS IN TELEVISION, PART III, *by John A. Maurer*.—Mr. Maurer gives data on the fidelity obtainable with sound tracks today, and advances the results of his experiments toward the increasing of this fidelity.

JUNE, 1939

IMPEDANCE MEASUREMENT ON BROADCAST ANTENNAS, *by Donald B. Sinclair*.—Part One of a detailed review of the specific solutions evolved for the measuring of antenna impedances and their correlation to provide a generally applicable solution.

AUTOMATIC THRESHOLD CONTROL FOR RADIO TELEGRAPH AND TELEPHONE RECEIVERS, *by Lee Hollingsworth*.—A new and improved quiet-tuning and noise-squelching circuit. Its application to the prevention of momentary overloading of receivers and the accompanying distortion.

FREQUENCY RESPONSE CONTROL NETWORK, *by Bernard Ephraim*.—The design of networks which will allow easy adjustment of audio frequency response characteristics of an amplifier to compensate for the acoustical properties of individual locations.

MOLDED CABINETS FOR RADIO RECEIVERS, *by F. D. Swanson*.—A discussion of the design considerations, both mechanical and artistic, of plastic cabinets for receivers. Molding presses, molds, and economic factors are also covered.

SOUND MOTION PICTURE FILMS IN TELEVISION, PART II, *by John A. Maurer*.—The comparative merits of 35 mm and 16 mm film for use in television work. 16 mm film is deemed by the author to be superior in many respects to the larger size film. Factors important in the manufacture of film for television work are discussed.

THE FUNDAMENTALS OF TELEVISION ENGINEERING, PART III, *by F. Alton Everest*.—Television cameras. The theory and operation of the Zworykin Iconoscope and the Farnsworth Image Dissector.

electronics

50c a copy—$5.00 yearly
McGraw-Hill Pub. Co., Inc.
330 W. 42 St., N.Y.C.

JULY, 1939

THE ORTHICON.—An improved form of the Iconoscope which uses low velocity electrons, obtaining thereby greater efficiency, freedom from spurious signals and linear output.

APPLICATION OF COPPER OXIDE RECTIFIERS, *by Leo L. Beranek*.—The use of small CuO rectifiers for metering and in modulation applications in conjunction with audio frequencies.

C-R TUBE PHOTOGRAPHY, *by T. A. Rogers and B. L. Robertson*.—The relation of screen characteristics and "writing speed" to lens apertures and exposure time. The proper developers, papers, and emulsions for various types of screen pictures are discussed.

A HIGH-QUALITY RADIO BROADCAST RECEIVER.—A receiver designed by Lincoln Walsh which has exceptional audio response characteristics and innovations to eliminate 10 kc. heterodyne whistles, chatter caused by carriers beating against adjacent station sidebands, and crosstalk.

A PROGRAM FAILURE ALARM, *by H. A. Chinn and R. B. Moe*.—A program rectifier and relay arrangement, with adjustable time delay, which notifies broadcast station operators when an audio circuit fails by lighting a bullseye and setting off a sparkless a.c. buzzer.

SOUND, WATER, AND FIRE.—A description of one of the most elaborate sound systems ever installed, at the Lagoon of Nations at the New York World's Fair. Twenty-seven inch speakers, and a total of two kilowatts of audio power are used.

A COMPACT REMOTE AMPLIFIER, *by R. S. Duncan.*—A battery operated remote amplifier which uses 1.4-volt tubes and features extreme portability and compactness. The frequency characteristic is within 2 db from 70 to 800 cycles. The size is 12 by 7 by 3 inches.

INSTALLATION OF COAXIAL TRANSMISSION LINES, PART I, *by J. B. Epperson.*—Details of installation procedure for broadcast transmission lines. Methods of inserting solder couplings, Concentric-line failures, etc. are discussed.

JUNE, 1939

TELEVISION IN THE FIELD.—A report of the experiences of television in its first month of public service. Some of the mistakes which have been discovered in sales methods are discussed, as are installation problems, sets and prices, and program schedules and techniques.

PLASTIC CABINET DESIGN NOTES, *by Herbert Chase.*—Mr. Chase uncovers some of the pitfalls to be avoided in the design of plastic receiver cabinets.

ELECTRONICS IN ACTION.—A progress report on the activities and advances made during the past year in the electronics field. Includes a discussion of new products which have recently appeared.

A RECEIVER FOR FREQUENCY MODULATION, *by J. R. Day.*—Constructional data on a seven-tube receiver using standard components which is capable of doing justice to the frequency-modulation broadcasts.

A LOW-DISTORTION LIMITING AMPLIFIER, *by E. G. Cook.*—A remote cutoff pentode amplifier is used to obtain limiting action with a decrease in distortion.

ELECTRONIC CONTROL FOR SHIP STEERING, *by Britton Chance.*—A light beam, phototubes, and prisms mounted on a magnetic compass are used to keep a ship on a straight course.

●

QST devoted entirely to AMATEUR RADIO

25c a copy—$2.50 yearly
American Radio Relay League
West Hartford, Conn.

AUGUST, 1939

FREQUENCY MODULATION FUNDAMENTALS, *by Daniel E. Noble.*—An explanation of the basic differences between amplitude and frequency modulation systems, and the latter's advantages in overcoming noise and interference.

THE TWO-BAND THREE-ELEMENT ROTARY, *by E. E. Schroeder.*—The use of respaced elements and separate matching stubs to allow operation on both the ten- and twenty-meter bands with a single three-element rotary beam.

LOW-PASS FILTERS FOR TIME DELAY CIRCUITS, *by James H. Owens.*—Mr. Owens advocates the substitution of a low-pass filter for the usual RC circuits used for obtaining a time constant in automatic modulation control circuits. More rapid operation with less distortion is claimed for the system.

PORTABLE-EMERGENCY TRANSMITTERS.—Five variations in compact equipment design. There are several new ideas on small transmitter construction and design and a wealth of useful tuning and adjustment kinks and hints.

POLYSTYRENE: ITS ELECTRICAL AND MECHANICAL CHARACTERISTICS, *by Herbert S. Riddle*.—A discussion of the insulating material known by the trade name "Victron". Hints as to the proper methods for mechanical working of the substance form the major portion of the article.

"5 AND 10" FROM SHACK OR CAR, *by S. Gordon Taylor*.—The construction of a compact transmitter which will work from either a vibrator pack or from an a.c. outlet. An 89 tritet crystal oscillator is used to drive an 807 final, the latter being modulated by a class-B 6N7.

JULY, 1939

STEPPING UP RECEIVER PERFORMANCE, *by J. P. Veatch and D. D. Kahle*.—Exemplifying the use of two intermediate frequencies to provide high selectivity and image radio and a new noise silencing arrangement. Several other features designed to increase the overall efficiency of high frequency receivers are also discussed.

A HURRICANE EMERGENCY TRANSMITTER AND POWER SUPPLY, *by Gale M. Smith*.—A crystal controlled 19-30 transmitter for emergency use is here described complete with universal power pack for home or car use. The 19 is used as a crystal oscillator and doubler, the 30 as the power amplifier. A vibrapack is used as a portable source of power, and is incorporated on the main a.c. power-supply chassis. If desired, B-batteries may also be employed.

ROTATING THE ROTARY, *by Gilbert Williams*.—How to use a ¼-h.p., 1700-r.p.m. reversible motor to rotate a close-spaced array at the speed of 1.2 r.p.m. A simple V-belt and pulley reduction system is used.

HIGH-EFFICIENCY GRID MODULATION IN A PORTABLE 14-MC. PHONE TRANSMITTER, *by Frank L. Denton*.—The circuit design and tuning procedure of a highly compact 40-watt phone transmitter using the new Terman-Woodyard method of obtaining high over-all efficiency. The new grid-modulation system gives plate efficiencies of the same order as with plate modulation. It resembles the Doherty amplifier in principle but is much more readily adaptable to Amateur work.

SIMPLICITY ON 112 MC., *by B. W. Griffith*.—The old reliable T N T circuit put to work with some of the newer tubes, such as the 35T or HK24, with exceptional results.

THE "DOUBLE PITCHFORK" ANTENNA, *by W. J. Breuer*.—An inexpensive vertical array which requires small space and with which the directivity can be changed by merely flipping a switch at the base of the array to change the phasing. Transmitting tests show an average front-to-side ratio of 5 S points.

RADIO

30c a copy—$2.50 yearly
RADIO, Ltd.
7460 Beverly, Los Angeles

JULY, 1939

SIMPLICITY IN AN ELECTRON-COUPLED EXCITER, *by Leigh Norton.*—Describing an e.c.o. unit in which the disadvantages of having the cathode hot for r.f. are obviated. A 6K8 with the cathode grounded for r.f. and the triode section operated as a tickler-feedback Hartley forms the nucleus of the unit. The electron-stream coupling between the triode section and the hexode output circuit gives the necessary circuit isolation. The 6K8 is followed by an untuned class-A 6F6 and a 6L6 doubler stage. Ganged tuning between the oscillator and the output stage maintains equal output over the frequency range of the exciter.

THE OVERGROWN "LAZY H," *by W. W. Smith.*—A new form of the well-known "Lazy H" array. By increasing the lengths and spacings of the element slightly, two adjacent amateur bands may be covered with a single antenna. Another advantage to the extended version is that it may be fed by an untuned line without need for a matching stub.

AN 1852 CONVERTER FOR FIXED-STATION SERVICE, *by E. H. Conklin and Victor Ruebhausen.*—Describing a 28- and 56-Mc. converter for use ahead of an ordinary communications receiver. By using the communications receiver as an i.f. channel at 6 Mc., a great deal of gain may be realized from the 6C5-1852 converter.

FILAMENT TUBES IN THE MOBILE TRANSMITTER, *by Ray L. Dawley.*—Mobile transmitter designs are legion but practically all of them have one fault in common—their heater current during idle periods causes undue battery drain over a period of time. This article describes a mobile transmitter in which filament-type tubes are used to eliminate current consumption during idle periods. A 6A4 tri-tet oscillator, 6A4 doubler and push-pull 01A's or 112's comprise the r.f. section. 18 watts input to the final amplifier results in about 12 watts of output.

COMPACTING THE THREE-ELEMENT ROTARY, *by C. M. Weagant.*—An unusual rotatable array in which the end eighth wave of each element has been bent down at right angles. Besides resulting in a more compact antenna, this system apparently gives greater gain than the more usual straight-element affair.

MULTI-METERING THE TRANSMITTER, *by Emile Milles.*—A description of methods of using a single meter for a multiplicity of purposes in the transmitter. The proper method for calculating the values of the various series and shunt resistors necessary is shown.

PHONE BREAK-IN WITH LOUDSPEAKER OPERATION, *by J. Evans Williams.*—Describing a circuit which overcomes the disadvantage of having to wear headphones to prevent received signals from actuating the voice-operated transmitter control system. Essentially, the circuit consists of a system for utilizing a received signal to block the transmitter speech amplifier.

OPTIMUM SPEECH CHARACTERISTICS FOR DX, *by J. W. Paddon.*—A discussion concerning the most useful portion of the audio frequency spectrum for long distance voice communication. After correlating a large amount of experimental data based on actual communication the author finds the range from 250 to 3000 cycles to provide best intelligibility.

RADIO NEWS
AND
SHORT WAVE RADIO

25c a copy—$2.50 yearly
Ziff-Davis Pub. Co.
608 S. Dearborn St., Chicago

AUGUST, 1939

PERPETUAL ANALYZER-TUBE TESTER, *by William H. Mitsch.*—Describing an inexpensive combination analyzer and tube tester. The unit employs the free-point system, with wire jumpers being used to make up the various connections. Full-scale working drawings are given.

1940 RADIO NEWS "ALL PURPOSE" TRANSMITTER-RECEIVER, PART TWO, *by Karl A. Kopetzky and Oliver Read.*—The second article concerning this transmitter. In this installment the complete circuit is explained and constructional details are given. The transmitter is a phone-c.w. arrangement covering all bands from 10 to 160 meters. A single T-55 is used in the final-amplifier stage.

SOLVING THE INTERMITTENT, *by "Tester" Bradley.*—The first of a series on this type of servicing problem. Several hints on locating intermittent troubles and a rather complete listing of likely causes are given.

1-TUBE AUTO-RADIO U. H. F. CONVERTER, *by McMurdo Silver.*—Another of the popular auto-radio converters. This one uses a 6K8 tube and covers the 5- and 10-meter amateur bands.

WHAT'S THAT NOISE? *by Charles Magee Adams.*—A discussion of the character of the sound produced in radio receivers by different types of electrical apparatus. Hints for eliminating the interference, when found, are included.

SIMPLE 112-118 MC. TRANSCEIVER, *by M. N. Beitman*—A constructional article describing compact transceiver for use in the 112-116 Mc. amateur band. A 76 is used as an oscillator and superregenerative detector and a 41 as modulator and audio amplifier.

5-20 M XMTR OF NOVEL DESIGN, *by Frank C. Jones.*—Describing the transmitter built by Mr. Jones for use on the 56-Mc. band at the Golden Gate International Exposition. To make the transmitter more versatile for general amateur use, provisions for operation on the 10- and 20-meter bands have also been included. Two HK 24's are used in the final amplifier, and this stage is modulated by another pair of the same type tubes.

JULY, 1939

A PURE-TONE 12-WATT P. A. SYSTEM, *by Seymour Berkoff.*—The author describes his method of overcoming frequency-response deficiencies in loudspeakers. Principles involved are those of boosting bass and treble frequencies by selective filters which are a combination of inductance, capacity and resistance. Mechanical alterations on small filter chokes required to produce the needed inductance are also described.

AUDIO FREQUENCY BRIDGE, *by Chas. E. Diehl.*—A simple bridge circuit, built from inexpensive parts, is utilized for the measurement of capacitance and inductance. Indication of balance (measurement) in the circuit is by absence of tone (in earphones) from a 1000-cycle audio oscillator. Calibration is easily obtained by use of known values across the test points, in conjunction with a 1000-cycle audio-frequency source.

COMPACT HIGH-FIDELITY REMOTE RECEIVER CONTROL, *by Ernest A. Zadig.*—The unit described accomplishes remote control of a receiver by use of a constant-strength, modulated carrier emitted by the remote control unit. A small loop serves as both transmitter tank inductance and radiator. Constructional and operating notes, circuit diagram and sources of trouble are thoroughly discussed.

HOMEMADE RELAYS THAT WORK, *by Howard Burgess.*—A description of rebuilding "junked" relays of the automobile generator or "B" eliminator type into effective overload relays, or into "push-to-talk" systems for the amateur. Mechanical operations are described in detail, as well as several applications of the finished units.

1940 RADIO NEWS "ALL PURPOSE" TRANSMITTER RECEIVER, *by Karl A. Kopetzky and Oliver Read.*—In the first of three installments, the authors present design features and requirements for a crystal- or e.c.-controlled 200-watt c.w. or phone transmitter, operating on one of 5 amateur bands. A six-band superheterodyne receiver is included in the unit, which operates from either 110 v.d.c. or a.c. Numerous other features of the design are listed. The article is accompanied by many photographs of the finished unit as well as of its component units.

SERVICEMAN'S PRACTICAL VACUUM-TUBE VOLTMETER, *by Arthur D. Williams.*—A presentation of the operation and construction of a vacuum-tube voltmeter utilizing the 6E5 as an indicator. Practical examples of application are described as a guide for those who may be unfamiliar with the instrument.

SOMETHING NEW IN U. H. F. TRANSMITTERS, *by Le Roy Lindberg.*—A 10-meter, 75-watt 'phone transmitter in which the grid and plate circuits of the push-pull final amplifier utilize a "High Q Loop" designed by the author. The "High Q Loop", which is described in detail, is accredited with a minimum of losses in presenting the proper Q to the final amplifier.

●

SERVICE

A Monthly Digest of Radio and Allied Maintenance

25c a copy—$3.00 yearly
Bryan Davis Pub. Co., Inc.
19 E. 47 St., N.Y.C.

JULY, 1939

ELECTROLYTIC CONDENSERS, *by Stanley Walters.*—Discussion of the inherent characteristic resistance in parallel with an electrolytic condenser, and its influence in the rate-of-discharge of the condenser. The application of this characteristic to a typical time delay relay circuit is outlined. The article is presented with equations and curves to simplify application designs.

FREQUENCY MODULATION, *by J. Snivas.*—An article describing the operation of General Electric's Model GM125 frequency modulation receiver. Requirements of this type of receiver are compared against those of a receiver for amplitude modulation.

LOUDSPEAKER ENCLOSURES, *by Maurice Apstein.*—A most comprehensive thorough investigation and discussion of modern loudspeaker enclosures and baffles. The theory of each is described, with illustrations of application by various radio receiver and loudspeaker manufacturers. Recent developments, both in theory and practice, are included.

SIGNAL TRACING IN DIODE DETECTORS, *by John F. Rider.* Abstracted from *"Servicing by Signal Tracing"*, by the author the article delves thoroughly into the operation of the diode detector, with detailed discussion of several circuit arrangements.

WIND CHARGERS, *by John H. Potts.*

—A presentation of installation requirements, operation capabilities and conditions for wind chargers. Preferred methods are outlined for their installation and care. Also described are the various systems used to prevent excessive propeller speed when high winds prevail.

JUNE, 1939

DEFLECTING CIRCUITS FOR TELEVISION RECEIVERS, *by Madison Cawein.* A discussion concerning the need, application and design of television deflection circuits. Waveform, deflection generators, synchronization, deflection amplifiers and adjustments are covered.

CRYSTAL PICKUP INSTALLATION, *by Ralph P. Glover.*—Although, on the face of it, the installation of a crystal pickup would appear to be a rather simple task, unusual receiver circuits sometimes complicate things. This article discusses pickup characteristics and shows approved methods of connecting them into representative receiver circuits.

FORD-PHILCO F1640, *by Eugene Triman.*—Describing an auto receiver employing a single push button for progressive station selection. A small solenoid rotates a wafer selector switch which picks out pretuned circuits for the various stations.

THE T&R BULLETIN
A JOURNAL FOR RADIO EXPERIMENTERS

1/6 a copy
Radio Society of Gt. Brit.
53, Victoria St., London

JULY, 1939

SUNSPOTS, MAGNETIC STORMS, AND RADIO CONDITIONS, *by E. J. Williams.* — Observations on solar and magnetic activity for the period from May, to April, 1939, with a review of conditions on the 10-meter amateur band for the same period. Profusely illustrated with graphs.

THE FRANKLIN MASTER OSCILLATOR IN AMATEUR TRANSMISSION, *by E. L. Gardiner.*—Describing the application of the Franklin oscillator, in which a separate tube is used to provide feedback, for amateur frequency-control use. Due to the small amount of coupling necessary between the tubes and the frequency - controlling circuit, the oscillator is exceptionally stable.

A 56 MC. CRYSTAL-CONTROLLED PORTABLE TRANSMITTER, *by D. N. Cornfield.*—A constructional article describing a 5-watt, 56-Mc. transmitter. Three tubes are used in the very compact unit, which is designed for maximum economy in power-supply requirements.

Oh Yes....
Your Subscription

Radio Limited
7460 Beverly Blvd.,
Los Angeles, Calif.

I want 12 issues of "Radio Technical Digest". Here is my $2.50.

Name ______________________________

Street ______________________________

City ______________________________

ANOTHER PUBLICATION
BY THE
EDITORS OF
RADIO