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Antenna transmission line systems for radio reception[†]

By C. E. Brigham*

In designing radio receivers radio engineers are careful and anxious to meet the desired characteristics in receiver design. Selectivity, sensitivity and fidelity are three of the most important qualifications which have presented serious problems to every engineer. With the changing of broadcasting conditions, new demands and improvements were necessary in the selectivity, sensitivity and fidelity requirements. Increased sensitivity, whether in tuned-radio-frequency or superheterodyne designs, has presented new problems such as cross-modulation, instability, whistles in superheterodyne reception due to low image ratio response, intermediate-frequency harmonics and reradiation. Increased sensitivity has also resulted in greater noise pickup from man-made interferences, especially in congested metropolitan areas. These are all interference problems to the radio engineer, most of which have been successfully eliminated, with the exception of noise.

With the desire for better fidelity it became necessary to improve the selectivity requirement of a radio receiver in preventing r-f. or i-f. sideband cutting of the higher modulated audio frequencies, by employing band-passed intermediate- and radio-frequency tuned circuits. With the improvements in the reproduction of higher audio frequencies in the speaker greater fidelity of reproduction is realized. In certain important areas, however, the faithful reproduction of high audio frequencies have resulted in serious complaints of noisy reception.

The granting of high power from 20 to 50 kw. by the Federal Radio Commission to a chosen few of the broadcasting stations has hastened the advancement of automatic volume control, or avc, in radio receivers. The automatic volume control development has been quite remarkable and it is common to experience receivers today holding a constant output on a station of 1000 microvolts field intensity and a station of 500,000 microvolts field strength without changing the position of the volume control. To hold a constant output at these extremely wide variations of input it has become necessary to allow the sensitivity of the receiver to vary automatically over wide limits, such that when no signals are impressed across the antenna and ground the sensitivity of the receiver is naturally high, resulting in serious noise pickup between stations while tuning.

From the foregoing it is seen that in the past few years improvements in the three essential performance features of a radio receiver have led to a type of interference which has only recently been taken into serious consideration by radio engineers. This type of interference is known as "inductive interference" or noise induction from man-made devices. The problems of interference and its elimination have always confronted the radio engineer. Interference from insufficient selectivity, cross-modulation, whistles in superheterodyne reception, have all been satisfactorily eliminated by the development of new circuits, tubes, and by better engineering. Quiet operation and uninterrupted by interference is the ideal requisite of radio performance today. It is

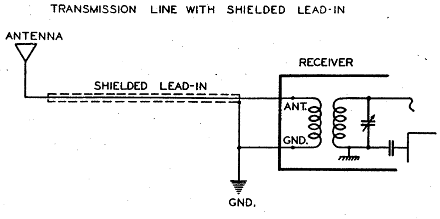


Fig. 1.

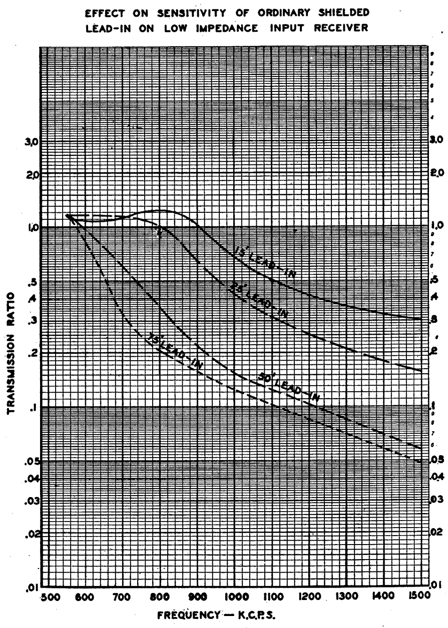


Fig. 2.

[†] *Presented before the Radio Club of America, December 14, 1932.*

**Chief Engineer, Kolster Radio, Inc.*

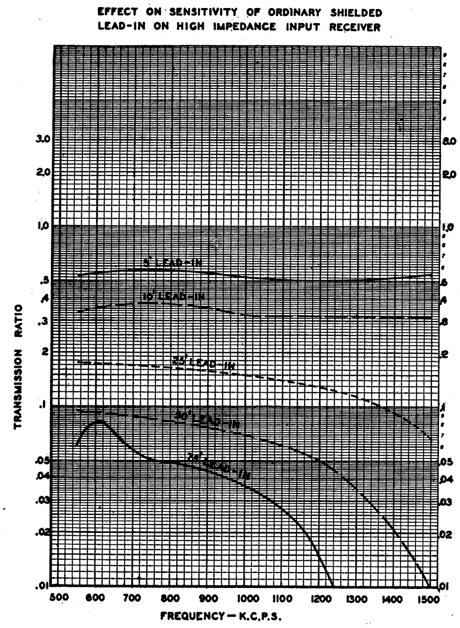


Fig. 3.

evident that today the noise level is being reached in the radio receiving system. The study of inductive interference or noise interference and how it may be eliminated or reduced considerably is the subject of this paper.

Inductive interference in radio receivers is caused by inductive coupling to the receiver system from the noise making devices. Noises in the home are produced from such devices as sparking motors or generators, electric refrigerators, oil burners, electric heating appliances, vacuum cleaners, the shutting on and off of electric lights, violet ray machines and the like. Outside the home some of the most severe sources of noise interference result from high tension power lines, trolley lines, electric elevators, dial telephones, etc.

Noise interference may be introduced into the radio receiver system by four ways:

1. The receiver chassis.
2. The power supply system.
3. The antenna.
4. The antenna lead-in.

Of these four, noise interference is the greatest on the antenna lead-in.

Experimentation and experience have shown that little noise interference is being introduced in the present-day receiver chassis, due to its comparatively complete shielding, except from such powerful noise interference devices as the violet ray machine and doctor's or dentist's equipment. It has been found that household noise interfering devices do not radiate at distances much greater than twenty feet, which makes it possible to locate the receiver proper at some point remote from the noise making device. In receivers designed prior to this year, where careful shielding of the radio-frequency and the intermediate-frequency circuits were not employed, noise pickup on the receiver chassis became an important factor. In the receiver chassis of the superheterodyne type it has been found that the radio-frequency grid circuits are much more subject to noise pickup than the intermediate-frequency grid circuits and on the audio system there is very little pickup.

For best results and perfect assurance against noise pickup on the chassis itself complete shielding of the receiver should be employed, including all grid leads, top of grid tube caps and the antenna and ground leads to the input of the receiver. A test for determining the effect of the completeness of shielding of the receiver chassis parts is to turn the volume control to the maximum position and with the antenna and ground leads free, but not exposed, tune for the local broadcasting stations. If the shielding is effective no broadcasting stations will be heard, or only the very powerful local stations will be heard faintly.

Proper Filtering

Noise from the power supply system is possible if the power supply circuit in the receiver is not properly filtered. A copper shield between the primary and secondary windings, properly grounded to the receiver chassis frame, is found to be an effective filter against both line noises and radio-frequency pickup. A condenser from one side of the a-c. line to ground is another but less effective method of line filter.

The antenna is the second worse offender in picking up noise interference. Next to the antenna lead-in, its position and the way it is installed are of the utmost importance. Unfortunately the public, including radio engineers, have been extremely lax in the installation of antenna systems and much education will be required before full realization is effected in the proper installation of the antenna for quiet operation and freedom from noise interference. It is extremely important that the antenna be erected outside the source of interference. The location of the antenna is the only limitation in the successful elimination of noise interference. Since the purpose of the antenna is to collect the radio-frequency energy sent out by the broadcasting station and the amount of this energy is determined by the antenna length, its height above nearby obstacles and its distance from the broadcasting station, a long, high outdoor antenna is most essential. An antenna on the roof of any building and especially of a large apartment, hotel, or office building is exposed to a great variety of electrical disturbances. These disturbances are made up of "natural static" and man-made static." Little can be done to suppress natural or atmospheric static, but an efficient antenna system can do much in the elimination of man-made static. The antenna should be at least thirty feet above surrounding obstacles. It is important that the location and direction of the antenna be considered in reducing noise. The antenna should be at right angles to exposed electric light, power or telephone lines and should not cross above or below these lines.

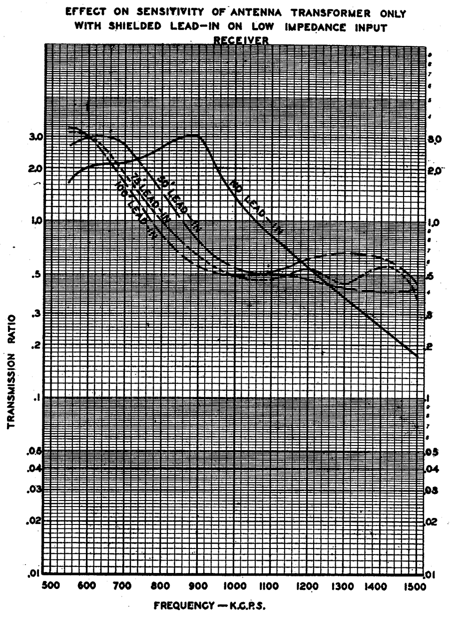


Fig. 5.

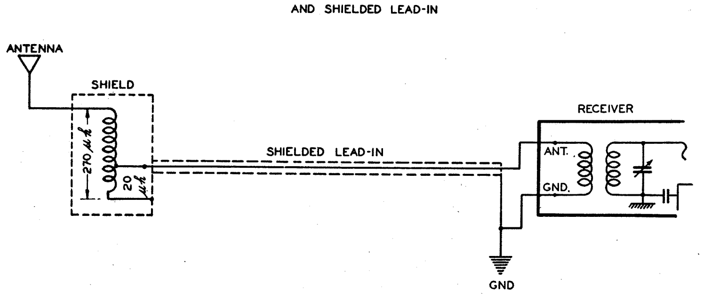


Fig. 4.

Since the antenna lead-in is necessarily subject to close proximity to the electrical disturbances by having to run near a side of buildings, pass exposed power and telephone lines, and inside of rooms to the input of the radio receiver, it is natural that this lead-in picks up most of the "man-made static" from the electrical disturbances. The

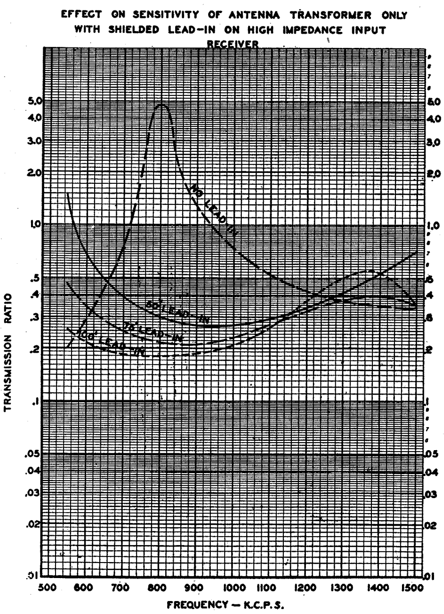


Fig. 6.

problem of shielding this lead-in, without attenuation or losses to the received signal over the wide broadcast frequency range is a very interesting one. This problem today is two-fold since there are two types of input circuits used in receiver designs; the low impedance input and the high impedance input. By low impedance input system is meant an antenna circuit coupled to the first tuned radio-frequency circuit by means of a low impedance inductance of 10 to 50 microhenrys which is naturally periodic above 1500 kc. By high impedance is meant an antenna coupled to the first tuned circuit by means of a high impedance inductance of approximately 3 millihenrys which is naturally periodic below the broadcast range of 550 kc.

Shielded Lead-In

In the past it has been customary to employ an ordinary shielded lead-in for the elimination of noise on the antenna lead-in, where the lead-in consisted of a single rubber and cotton covered conductor inside a copper braid. This is the simplest type of transmission line system as shown in Fig. 1. The effect of the ordinary shielded lead-in on the sensitivity of the radio receiver of the low impedance type is shown in Fig. 2. The curves are plotted with abscissa covering the broadcast frequency range and the ordinate showing the transmission ratio. By transmission ratio is meant the ratio of the microvolt sensitivity as measured across the antenna and ground of the receiver chassis to the microvolt sensitivity as measured across antenna and ground at the beginning of the transmission line system. It is noticed that serious attenuation becomes effective above 700 kc., increasing with the length of the shielded lead-in, due to the by-passing capacity effect of the lead-in. Attenuation is even much more serious on a high impedance input receiver with the ordinary shielded lead-in wire as shown in Fig. 3. Even five feet of shielded lead-in wire on a high impedance input receiver affects the attenuation in the order of six decibels. Such simple systems usually recommend antenna lengths from 200-400 feet long to make up for the losses in the shielded lead-in. Although effective as far as minimizing noise interference on the antenna lead-in, antenna lengths for the ordinary shielded lead-in became impractical for the complete elimination of noise, especially with the high impedance input receivers.

It is known in transmission line theory that low impedance transmission lines are not subject to inductive interference and also considerable less attenuation exists under the proper conditions.

In an attempt to employ a low impedance transmission line for the antenna lead-in between the antenna proper and the receiver chassis an arrangement has been used as shown in Fig. 4. With this arrangement an auto-transformer is used at the antenna end in conjunction with an ordinary shielded lead-in. When such a system is used on a low impedance input receiver its effect on sensitivity is shown in Fig. 5. It is immediately noticed the improvement this system has over the ordinary shielded lead-in system. Even with 100 feet of ordinary shielded lead-in wire between the auto-transformer antenna unit and the receiver chassis the maximum attenuation is only six decibels. However, when such a system is employed on a high impedance input receiver the attenuation for various lengths of shielded lead-in is shown in Fig. 6. These curves show maximum attenuation of over twelve decibels over a considerable portion of the broadcast frequency range. The improvement of the auto-transformer arrangement with the shielded lead-in wire over the ordinary shielded lead-in system is shown for the low impedance input receiver in Fig. 7. The attenuation above 900 kc. on the low impedance input receiver with the antenna auto-transformer is caused by detracking of the first r-f. tuned circuit by reaction of the transmission line. Retrimming of the first tuned circuit at 1400 kc. results in less attenuation.

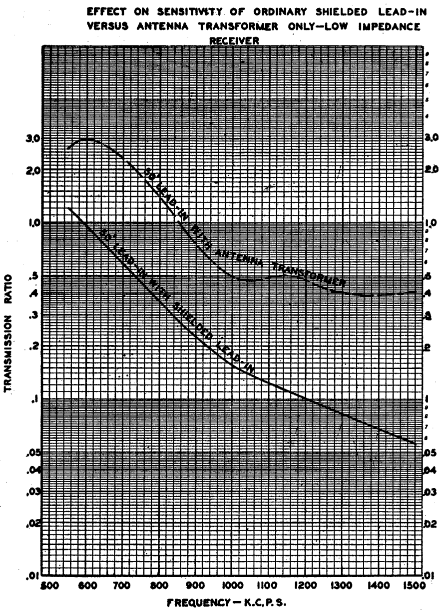


Fig. 7.

From the foregoing curves shown in the figures any transmission line system on a high impedance input receiver has disclosed bad attenuation over a considerable portion of the broadcast spectrum. This high loss of signal over such transmission line systems has been due to by-passing of the signal energy from the capacity of the conductor to ground shield and the mis-matching of impedances between the low impedance of the auto-transformer and the high impedance input.

Antenna—Input Balance

One arrangement in properly matching or balancing impedances between the antenna and input of the receiver is by employing auto-transformers at both the antenna and receiver as shown in Fig. 8. With this arrangement its effect on sensitivity of a high impedance input receiver is shown in Fig. 9. Compared with the attenuation curves in Fig. 6, which show the condition for the auto-transformer at the antenna end only, the improvement in the proper impedance matching is clearly demonstrated. It is noticed in Fig. 9 that even

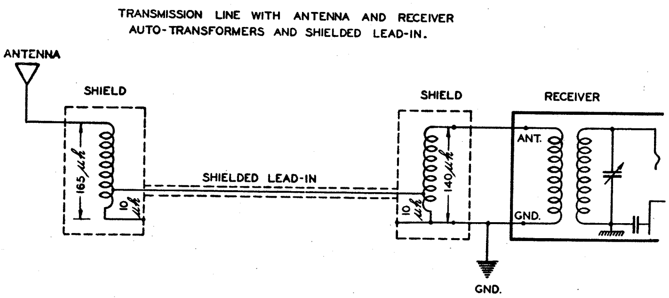


Fig. 8.

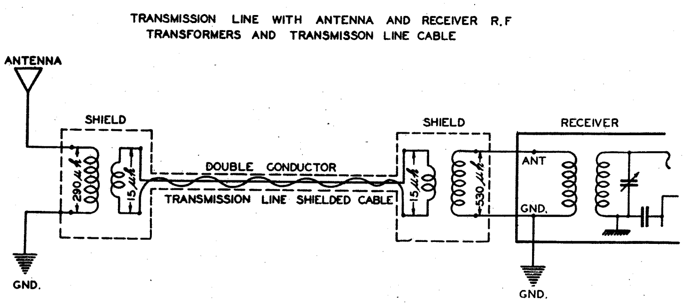

TRANSMISSION LINE WITH ANTENNA AND RECEIVER R.F TRANSFORMERS AND TRANSMISSON LINE CABLE

Fig. 10.

with 400 feet of shielded lead-in wire between the antenna and receiver auto-transformers no attenuation is noticed up to 1200 kc., and only a maximum of six decibels loss between 1200-1500 kc. The effect on sensitivity of the antenna and receiver auto-transformer transmission line system on a low impedance input receiver is similar to that obtained with the antenna auto-transformer alone with the shielded lead-in wire.

Another effective method in obtaining the proper impedance matching between the antenna and receiver input over a low impedance transmission line system is by the use of simple antenna and receiver r-f. transformers as shown in Fig. 10. In this arrangement the two transformers are connected by means of a twin conductor shielded cable. Such a system gives attenuation curves on a high impedance input receiver similar to the curves shown in Fig. 9.

Link Circuit Balanced to Ground

In locations where the electrical disturbance is particularly violent, such as with violet ray machines, it is possible for the inductive interference to get in upon the transmission line. To take care of such a possibility the transmission line, particularly the link circuit, should be carefully balanced to ground. Such an ideal system is shown in Fig. 11. Due to the capacity effect of the windings a copper shield is used between the primary and secondary windings to prevent any noise transfer which is not balanced to ground. Although the copper shields do not affect the inductance value of the windings, the mutual inductance is decreased on account of the physical space required for the shields. A tuned antenna system as shown in Fig. 11 allows a uniform attenuation over the broadcast frequency band. With a 500 foot transmission line an average of only six decibels of attenuation is obtained over the broadcast spectrum.

Shielded transmission line systems with proper impedance matching and carefully designed to give little or no attenuation over the complete broadcast frequency range, serve as ideal systems for the elimination of man-made static. The type of transmission line system used, whether of the antenna and receiver auto-transformer type; the simple antenna and receiver r-f. transformers; or the more complicated and elaborate tuned antenna and receiver balanced system, is at present one of preference. It may suffice to say that such systems give remarkable results in the elimination of man-made static where heretofore noise interference was so great as to drown out the radio reception. Successful installations in congested theatre districts, newspaper rooms, office buildings, etc., have proven the value of such transmission line systems for radio reception.

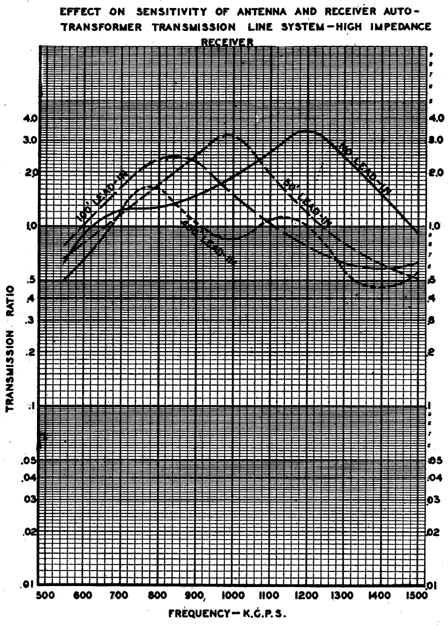

EFFECT ON SENSITIVITY OF ANTENNA AND RECEIVER AUTO-TRANSFORMER TRANSMISSION LINE SYSTEM—HIGH IMPEDANCE RECEIVER

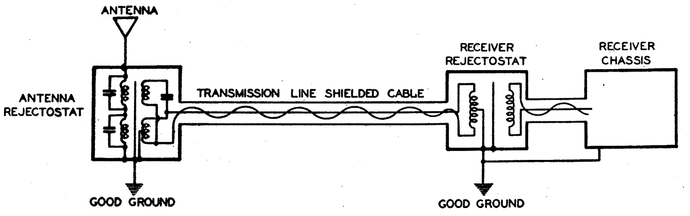
Fig. 9.

These transmission line systems, properly balanced and employing correct impedance matching, do not require an excessive aerial length. A flat top at least 75 to 100 feet long and at least 30 feet above the roof of any building or obstacles, is more than sufficient. It is vital and important that the antenna be erected outside the field of the electrical interference. If the lead-in to the antenna unit is long, it should never be shielded as loss in signal will result. If it is found that the noise interference is getting on this lead-in some means must then be provided for locating the antenna unit nearer the antenna proper.

A perfect installation may be ruined by the reradiation of noise from other antenna structures, power and telephone lines in close proximity to the antenna proper of the transmission line system. It has been found that violent noise interference such as from violet ray and X-ray machines, is picked up by neighboring antenna wires, telephone and power lines, which in turn radiate interference to the antenna of the transmission line system.

Grounding of the transmission line system is of next importance. Improper or insufficient grounding may mean failure in the performance of the transmission line system in eliminating noise. This ground wire should be as short as possible. Any piece of pipe is not necessarily a good ground, neither are soil pipes found on the tops of large buildings and apartment houses. Metallic water drains (many times dry) and steel structures are also not good grounds. A water pipe is the best type of ground which can be obtained. Grounding at both the receiver and antenna ends has often been found to be extremely important in eliminating noise interference, especially in metropolitan areas. In very extreme cases where the noise interference is particularly violent, and where the shielded transmission lead-in cable is several hundred feet long, it may be found necessary to ground the sheath of the transmission line cable at several points. When more than 100 feet of transmission cable are used, it is good practice to ground the cable every 100 feet. Although the grounding is very important, no definite procedure and recommendation in grounding can be given on account of inconsistent results obtained due to length of ground leads, resistance of grounds and types of grounds. The type of grounding employed on one installation may or may not be correct for another installation in a different location. When having difficulty with noise interference it is

Fig. 11.



highly recommended that experimentation be made with different grounding systems until the source of noise interference is eliminated.

In conclusion, the importance in reducing man-made static is shown by the great number of transmission line kits which have recently been brought on the radio market.

The logical place to eliminate man-made static is at the source of interference, but this is such a costly and difficult procedure, especially in these times, that radio manufacturers have been forced to solve this problem independently.

However, manufacturers of electrical appliances and power companies have coordinated with the radio manufacturers for the past few years in combatting noise interference in radio reception. The Joint Coordination Committee on Radio Reception of the National Electric Light Association, the National Electric Manufacturers' Association, and the Radio Manufacturers' Association are meeting four times a year on this one subject of noise elimination.

Until such time as these noises are reduced at the source the antenna transmission line system is one answer to the reduction of man-made static, and more enjoyable radio entertainment with freedom of interference.

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Book Review

THE RADIO CONSTRUCTION LIBRARY. 1932 *EDITION. By James A. Moyer and John F. Wostrel. Published by McGraw-Hill Book Co., Inc., New York City. Price* $7.50. (1,087 *pp.;* 605 *Illustrations; Cloth.*)

The Radio Construction Library is composed of three well known books on practical radio that have in the past years become popular with students and service men as study and reference guides for the understanding of radio fundamentals.

The revised printing maintains the same treatment employed in the preceding editions with some added material including the more important developments in electronics and television which have resulted during the past few years. Although written to have a general appeal among persons engaged in the radio industry, the Library appears to be of most practical value to student experimenters and radiotricians. Engineering mathematics have been omitted in the explanation of radio principles; however, the clarity of operating procedures of various equipment is well treated, and although somewhat concise and superficial at points, is consistent with the purpose of the works.

All of the three volumes are generously illustrated with drawings and schematics as an aid in elucidating the text. There occurs in the first two volumes a noticeable repetition of subject material which it appears could have been restricted to one book alone. Each text may be considered as an independent work, the study being arranged in order of progressive sequence with each of the three different topics of study constituting the Library.

Volume 1 on *Practical Radio* is a text of the underlying fundamentals applied to radio communication in general. As the initial volume of the group, this book is more or less elemental in treatment, considering the "skeleton framework" of receiving and transmitting apparatus.

The second volume is entitled *Practical Radio Construction and Repairing,* and herein the authors delve into the more important idiosyncrasies of radio receiving apparatus. Information is given about the components constituting various receiving circuits and the common methods of procedure followed in "trouble shooting." The last chapter is devoted to television, wherein a simple receiver is explained with regards to its construction and operation.

Radio Receiving Tubes comprises the subject of treatment for the third book of the series in which volume an interesting study of the operation of thermionic-electronic vacuum tubes is outlined. The introductory chapter, reviewing the development of the vacuum tube, presents an especially appropriate opening for the ensuing chapters which are particularly well prepared to render this entire reading decidedly instructive and easily conceivable. The last chapter, considering the various industrial applications of vacuum tubes, is an effort to present to the reader a conspectus of the universal applicability of the modern Aladdin lamp and the accomplishments it has brought to mankind. Doubtlessly more applications have been omitted than included; however, when we consider the innumerable roles to which the vacuum tube has been applied it becomes readily apparent that such a treatment, in order to be thorough, would easily constitute another volume. Hence we feel that the authors' treatment is in consistence with the purpose of their book. Thus, this chapter might be considered as a collateral appendix to the text in general.——*Reviewed by Louis F. B. Carini.*

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