Dec. 15, 1936. H. A. WHEELER 2,064,774

WAVE SIGNAL COLLECTING SYSTEM

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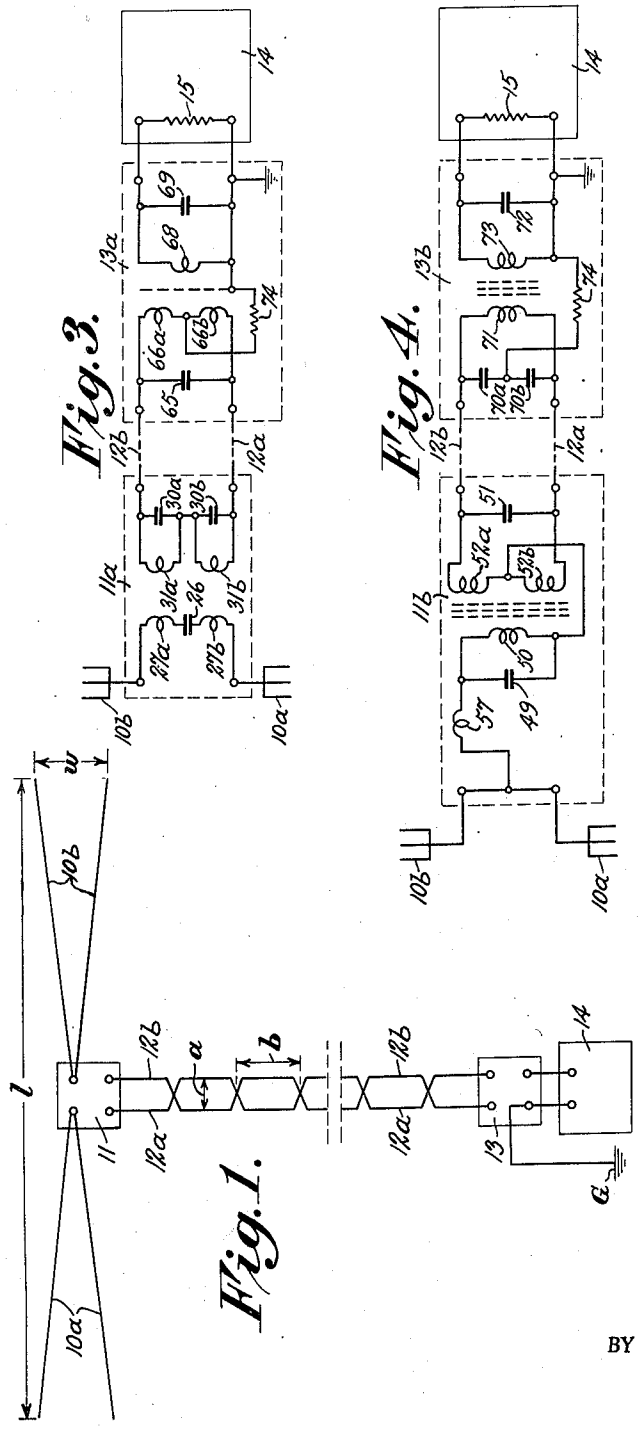


Fig. 1.

Fig. 3.

Fig. 4.

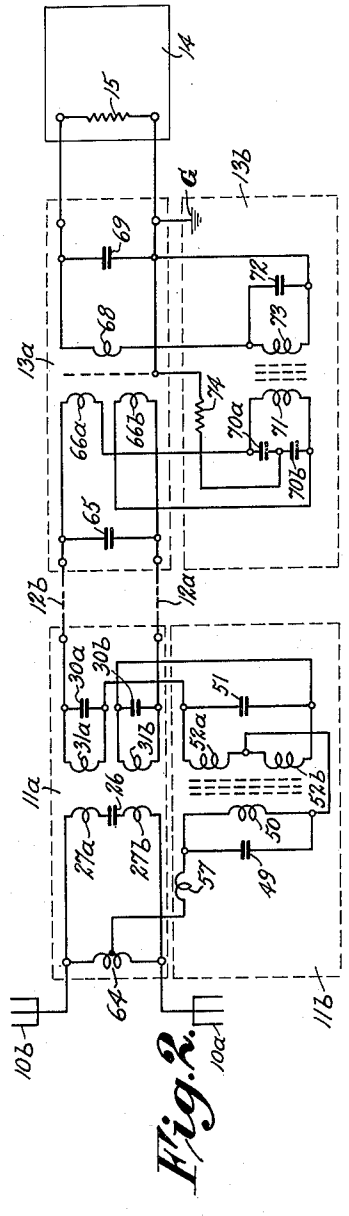


Fig. 2.

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Fig. 5a.

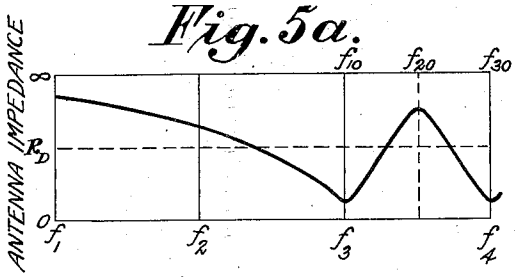


Fig. 5b.

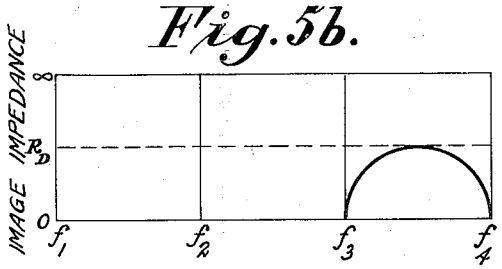


Fig. 5c.

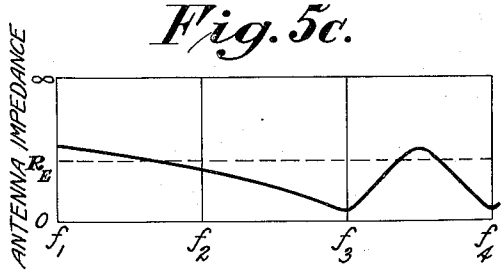


Fig. 5d.

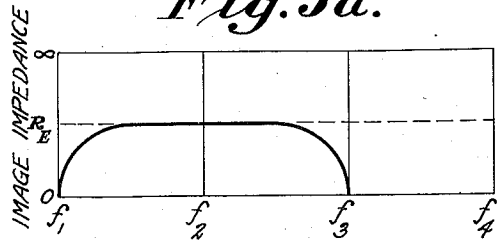


Fig. 6a.

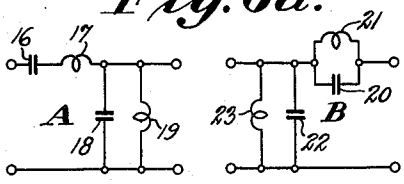


Fig. 6b.

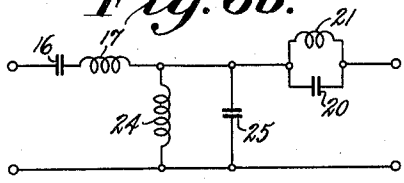


Fig. 6c.

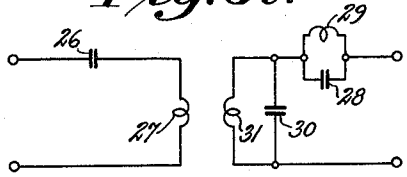
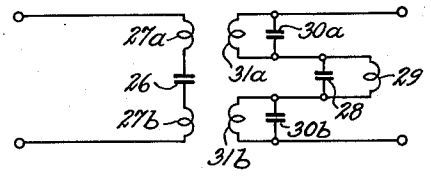


Fig. 6d.



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WAVE SIGNAL COLLECTING SYSTEM

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Fig. 7a.

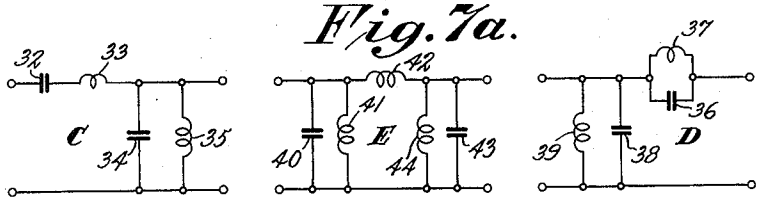


Fig. 7c.

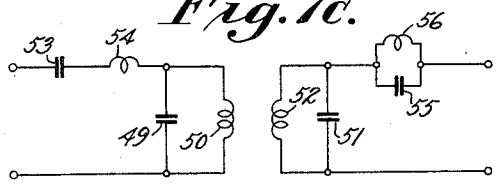


Fig. 7b.

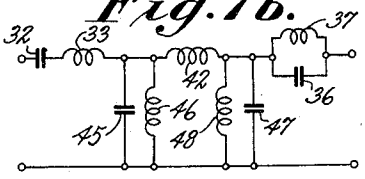


Fig. 7d.

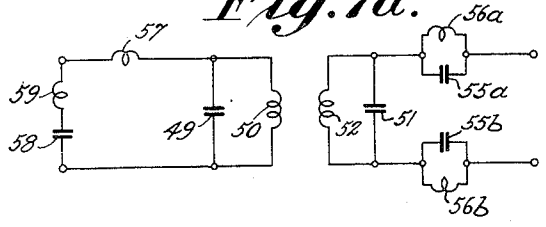


Fig. 9.

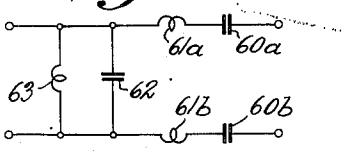
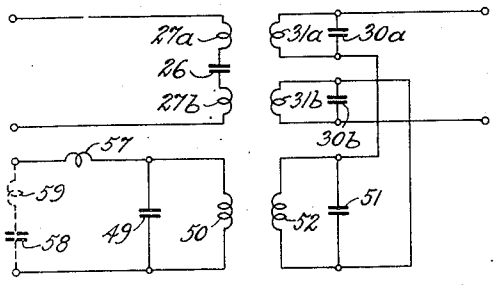


Fig. 8.



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UNITED STATES PATENT OFFICE

2,064,774

WAVE SIGNAL COLLECTING SYSTEM

Harold A. Wheeler, Great Neck, N. Y., assignor to Hazeltine Corporation, a corporation of Delaware

Application June 10, 1935, Serial No. 25,735

28 Claims. (Cl. 250—33)

My invention relates to wave-signal-translating systems such as radio receiving antennas and coupling systems therefor, and particularly to such systems which have the characteristics of maximum signal-to-noise ratio and approximately uniform response throughout a wide range of frequencies.

It has heretofore been appreciated that certain limits upon the satisfactory operation of a radio receiver are determined by the signal-to-noise ratio at the input of the receiver. A high noise level has the effect not only of limiting the usefulness of the receiver to the reception of signals of intensity on the order of, or greater than, the noise level, but also seriously interferes with the satisfactory reception of moderately strong signals well within the useful range of sensitivity. It is also known that a very considerable portion of the disturbing noise arises from local electrical disturbances or waves from electrical devices and appliances, the ignition systems of internal combustion engines being a particularly troublesome source of noise. Such electrical disturbances or waves are troublesome only for a relatively short distance from their source, their intensity falling off approximately inversely as the distance. Therefore, it is possible substantially to limit or eliminate the effects of these local electrical disturbances by positioning the antenna remote from the source of noise. A considerable elevation of the antenna is particularly satisfactory in reducing the effect of local disturbances.

However, such a disposition of the antenna usually places it at a considerable distance from the radio receiver or other signal-translating device, with the result that the lead-in wire or ground connection to the antenna then intercepts the disturbing electrical waves, tending to nullify the benefits of the remote positioning of the antenna. This pick-up of local electrical disturbances is part'cularly troublesome in the high-frequency ranges of the radio-frequency spectrum, in which the signal voltage induced in an ordinary antenna is at a relatively low level. It has heretofore been proposed to insert a transmission line between the antenna and the receiver, or a shielded lead-in and ground connection. These devices are effective in reducing the noise level, but the response characteristic of these devices alone is so unsatisfactory as to render them impractical of general utilization.

The wave-signal-collecting systems of the prior art have also been seriously deficient with respect to the uniformity of response over the long wave, or general broadcast, and the short wave portions of the radio-frequency spectrum. Not only are there wide differences among the impedances of the antenna, the line and the input circuit of the receiving set or signal-translating device, but there is also a wide variation of the antenna impedance as between the several broadcast bands and, in addition, over any particular band. Such differences or mis-matchings of the impedances of the component portions of the signal-collecting system result in reflection or transition losses in the transfer of the signal from the antenna to the receiver, materially reducing the signal-to-noise ratio and/or the sensitivity of the receiver.

While the effect on the response characteristic of the system of variation of the impedances of the component portions of the collecting system over the radio-frequency spectrum may be reduced to a considerable extent by tuning these circuits over the band or bands to be received, such an arrangement introduces additional complications into the radio receiver, such as the difficulty in aligning the collecting system with the remaining tunable circuits of the receiver, due to variations of the resonant frequency of the antenna circuit in accordance with the design and installation of the antenna. This problem of the variation in response of a signal-collecting system is very closely related to that of the signal-to-noise ratio discussed above, since, over those portions of the band or bands in which the response of the collector system is relatively low, the effect is that of decreasing the signal-to-noise ratio.

It is an object of my invention, therefore, to provide an improved wave-signal-translating system which will overcome the above-mentioned disadvantages of the arrangements of the prior art and which will be simple, efficient and reliable in operation.

It is a particular object of my invention to provide an improved wave-signal-collecting system in which the signal-to-noise ratio is substantially increased throughout the operating range of the system.

It is a further object of my invention to provide an improved wave-signal-collecting system which has a substantially uniform and maximum responsiveness, both as between the several bands within the operating range of the system and over each of the several bands, and in which this characteristic is secured without resorting to adjustable tuning of any part of the system.

It is a still further object of my invention to provide an improved wave-signal-collecting sys-

tem which has a substantially optimum signal-to-noise ratio throughout its operating range and which has also a substantially uniform and maximum responsiveness throughout the range.

In accordance with my invention, the signal-to-noise ratio of a signal-collecting system is increased, particularly over the short wave portion of the radio-frequency spectrum, by utilizing a doublet antenna, remote from the receiver or other signal-translating device and from the local source of electrical disturbances or noise, and by interconnecting the antenna and the receiver by a transmission line in which the received signals are manifested by balanced or circulating currents flowing in opposite directions in the conductors of the transmission line. Disturbing noises are represented by unbalanced or parallel currents flowing in the same direction in both conductors of the line, cancelling each other in the input circuit to the receiver.

Approximately uniform responsiveness for the several frequency bands over which the system is to operate is secured by an electrical network which effectively changes the antenna connections from a balanced doublet, in the short wave portion of the operating range, to an unbalanced simple flat-top antenna, in the long wave portion of the radio-frequency spectrum, as, for example, below 6 megacycles. For short wave operation, the balanced antenna and balanced transmission line are coupled by a balanced impedance matching transformer or filter network, and the balanced line is coupled with the input circuit of the receiver, usually unbalanced, by an additional impedance matching and balancing transformer or filter network. Similarly, for long wave operation impedance matching networks serve properly to join the unbalanced antenna with the balanced transmission line, and the balanced transmission line with the unbalanced receiver input circuit. In this latter arrangement the transmission line may serve also as a ground lead or counterpoise for the antenna, or an independent ground lead may be provided, preferably in the immediate neighborhood of the antenna. In any of such arrangements, proper impedance termination is provided for the transmission line to minimize transition losses.

An important feature of my invention resides in utilizing as the impedance matching networks "constant-k" band-pass or wave filters, described more fully hereinafter. In accordance with another feature of my invention, the antenna inductance and capacitance are substituted for at least a part of the terminating inductance and capacitance of a "constant-k" band-pass filter half-section. A wave-signal-collecting system including the features described is characterized by a high signal-to-noise ratio throughout the long and short wave portions of the radio-frequency spectrum for which it is designed, and by an approximately uniform responsiveness both as between the several frequency bands and over each of the bands.

For a better understanding of my invention, together with other and further features thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

Referring now to the drawings, Fig. 1 is a schematic diagram of a complete wave-signal-collecting system embodying my invention; Fig. 2 is a circuit diagram of the coupling systems for interconnecting the signal collector or antenna and the transmission line, and for interconnecting the transmission line and a receiver or signal-translating device; Figs. 3 and 4 are approximately equivalent simplified circuit diagrams of the system of Fig. 2 when operating in the short wave and long wave bands, respectively; Figs. 5*a*–5*d* are graphs representing certain operating characteristics of the system of Fig. 2; Figs. 6*a*–6*d* are circuit diagrams illustrating the circuit transformations in developing the antenna-to-line impedance matching network in the short wave bands; Figs. 7*a*–7*d* are corresponding diagrams for the long wave band; Fig. 8 is a composite equivalent circuit diagram of the networks of Figs. 6 and 7; while Fig. 9 is a circuit diagram of an impedance network equivalent to the antenna, per se, when operating in the short wave band.

Referring now more particularly to Fig. 1 of the drawings, there is illustrated schematically a complete wave signal-collecting system embodying my invention and comprising a doublet made up of two pairs of oppositely extending conductors **10***a* and **10***b*, the wires of each pair preferably diverging outwardly from their common center. The antenna system is coupled by an impedance network **11** to one end of a transmission line, comprising a pair of conductors **12***a* and **12***b*, the other end of which is coupled by an impedance network **13** to a signal-translating device or other load device **14**, such as a radio receiver. A connection from one of the terminals of the network **13** or device **14** is made to ground G.

While any of a number of types of antennas may be utilized in connection with my invention, I prefer to use a doublet antenna of the type described for a number of reasons. Each pair of diverging wires constituting an arm of the doublet has an effective length, insofar as radiation is concerned, which is some thirty percent greater than its actual length, whereas the corresponding effective length of a one-wire doublet is only about 17 percent greater than its actual length. Two wires of equal length, diverging as illustrated, result in substantially the optimum utilization of space and weight in the design of an antenna for the purposes of this invention. Furthermore, such an antenna is characterized by a minimum variation of impedance with respect to frequency and a maximum average power factor over the usual range of frequencies, resulting in a better over-all efficiency or response characteristic and facilitating the proper matching of the impedance of the antenna with that of the transmission line.

As has been discussed above, uniformity of response of the system as a whole, together with maximum signal-to-noise ratio, may be secured by coupling the antenna and the transmission line, and the line and the load device by means of one or more band-pass filters. The circuit diagrams of such filters are shown in Fig. 2, in which the antenna **10***a*—**10***b* is coupled to the transmission line **12***a*—**12***b*, by the high-band filter **11***a* for balanced operation of both the doublet antenna and the line over a high-frequency band which may, for example, extend from 6 to 18 megacycles. Similarly, the low-band filter **11***b* couples the doublet, for unbalanced operation as a flat-top antenna, with the balanced line for operation over a low-frequency band of, for example, 0.55 to 6 megacycles. The two filters are uncoupled on the antenna side because of the balanced and unbalanced operation

over the high- and low-frequency bands, respectively. They are joined together on the line side and their operation is interdependent at frequencies in the neighborhood of the dividing frequency, for example, 6 megacycles. The two filters 11*a*, 11*b* are designed independently and then combined as will be explained more fully hereinafter.

Similarly, the filter 13*a* couples the balanced line 12*a*—12*b* with the load device 14 having an input circuit impedance indicated at 15, this input circuit usually being unbalanced, for operation over a high-frequency band. The filter 13*b* couples the line 12*a*—12*b* with the device 14 for operation over the low-frequency band. The filters 11*a*, 11*b* and 13*a*, 13*b* serve also to match the impedances of the circuits or devices which they couple to provide optimum operation over the desired frequency bands.

The principles underlying the design of the filters 11*a*, 11*b* interconnecting the antenna and the transmission line, together with the operating characteristics of these filters, may be more clearly understood by considering their development from simple symmetrical filter sections of well-known types. There is shown in Fig. 5*a* the impedance characteristic of an antenna system such as 10*a*—10*b*, operating as a doublet. It will be noted that the impedance has an extreme or maximum value at the lowest frequency of the band, decreasing to an opposite extreme or minimum value at the fundamental frequency f_{10}. Beyond the fundamental frequency f_{10}, the impedance varies cyclically above and below its mean value, having an extreme or minimum value at the fundamental frequency f_{10} and at a frequency f_{30}, which is approximately three times the fundamental frequency, and an opposite extreme or maximum value at f_{20}, which is approximately twice the fundamental frequency. The number of cyclic impedance variations beyond the fundamental frequency f_{10} depends primarily upon the length of the antenna and the band to be covered.

It is desired to match the impedance of the doublet antenna 10*a*—10*b* to the constant image impedance of the line 12*a*—12*b* by means of suitable filter circuits. It is also desirable that these filter circuits include transformer sections which avoid direct connections between the primary and secondary circuits of the filter and permit impedance transformation. For the purpose of explanation the characteristic of Fig. 5*a* is also divided into portions separated by the frequencies f_1, f_2, f_3 and f_4, which arbitrarily divide the entire frequency band to be covered into three bands. With respect to the antenna end of the filter circuits, the lower frequency band is from f_1 to f_3, while the upper frequency band is from f_3 to f_4. The several dividing frequencies preferably are related by a geometric progression; for example, f_1, f_2, f_3, and f_4 may have approximately the values 0.55, 1.8, 6 and 18 megacycles, respectively, in which case the mean constant of progression is 3.2.

In the design of the high-frequency band-pass filter it is necessary to provide a termination the image impedance curve of which over the band approximates the impedance curve of the antenna. The antenna impedance, as shown in Fig. 5*a* over the band f_3—f_4, is approximated by the image impedance of a constant-*k* half-section with mid-series termination facing the doublet. (For a more complete description of the several types of symmetrical band-pass filter sections utilized in the preferred embodiment of this invention and discussed herein, reference is made to a textbook of T. E. Shea—Transmission Networks and Wave Filters, D. Van Nostrand Co., 1929.) In Fig. 6*a* a half-section of this type is illustrated at A, comprising the mid-series condenser and inductances 16 and 17, respectively, and the mid-shunt condenser and inductances 18 and 19, respectively. Such a half-section permits the insertion of a transformer since it includes both series and parallel inductances which may represent the self- and mutual reactances, respectively, of one side of a transformer. The image impedance at the left-hand terminals of the filter A is shown in Fig. 5*b*, in which it is seen that the image impedance has extreme values, that is, maximum and minimum values, at the same frequencies as the antenna impedance. The circuit constants of this filter are so chosen that its image impedance in the frequency band f_3—f_4 has a form and geometric mean value which approximate the form and geometric mean value, respectively, of the impedance of the antenna in the same band. The circuit constants of a filter section of the type illustrated are usually computed in terms of the maximum image impedance, designated R. It is general practice to assign an arbitrary value to R of, say, 100 ohms for the purpose of computation. The circuit impedances are then multiplied by the ratio R_D/R, where R_D is the desired maximum value of image impedance, as indicated in Fig. 5*b*. It is to be noted that, in multiplying the circuit impedances as described, the inductances are multiplied by the ratio R_D/R while the capacitances are divided by this ratio. The value R_D is somewhat greater than the geometric mean value of the antenna impedance in the band f_3—f_4, shown in Fig. 5*a*. By the term "approximately the same form" is meant that the two impedance curves are both convex upwardly, or vice versa, and similarly positioned in the frequency spectrum. That is, the filter circuit A is designed to present to the antenna 10*a*—10*b* an image impedance which approximates the antenna impedance over the high-frequency band f_3—f_4.

It is then necessary to insert between the filter section A and the line 12*a*—12*b* an additional filter section or sections which permit joining the low-band and the high-band filters 11*a*, 11*b* at the line terminals. It is found that a half-section filter, as shown at B, Fig. 6*a*, satisfies these requirements. The filter section B includes the parallel connected mid-series condenser 20 and inductance 21 and the mid-shunt condenser 22 and inductance 23. The section B may be so proportioned that its mid-shunt image impedance is supplementary to that of the section A so that these two sections may be directly interconnected. The filter section of the type of section B is particularly suitable because of the fact that it includes the mid-series elements 20, 21 which can be replaced by the low-band filter without substantially affecting the operation of the high-band filter, as will be explained more fully hereinafter.

By the use of well-known equivalent circuit transformations, the high-band filter 11*a* of Fig. 2 can be derived from the half-sections A and B of Fig. 6*a*. For example, if the adjacent terminals of the sections A and B are interconnected, the condensers 18 and 22 can be combined into a single condenser 25 and the inductances 19 and 23 can be combined into a single inductance 24, since these elements are all con-

nected in parallel. This transformation is shown in Fig. 6*b*. Similarly, it is well-known that the inverted-L connection of inductances **17** and **24** of Fig. 6*b* is the equivalent of a transformer in which the primary inductance is equal to the sum of inductances **17** and **24**, and in which each of the mutual inductance and the self-inductance of the secondary circuit is represented by the inductance **24**. The result of this transformation is the circuit of Fig. 6*c* in which the inductances **27** and **31** are proportioned as just described. The other circuit elements of Fig. 6*c* are also identified by different reference numerals, since it is usually required, in transforming the circuit of Fig. 6*b* to that of Fig. 6*c*, to multiply all of the impedances of the primary and secondary circuits to match the impedances of their connected circuits or devices.

The circuit of Fig. 6*c* may be rearranged as shown in Fig. 6*d*, for balanced operation, by giving to inductances **27***a* and **27***b* a combined value equal to that of the inductance **27** and, similarly, by dividing the condenser **30** and inductance **31** into two portions represented by the elements **30***a*, **31***a* and **30***b*, **31***b*. In general, the inductances **27***a*, **27***b* will not have a value half that of the inductance **27**, nor the inductances **30***a*, **30***b*, half that of the inductance of the winding **30**, because of the mutual inductance between corresponding portions; however, if such corresponding sections are shielded from each other so that their mutual inductance is negligible each may have a value of one-half that of their corresponding whole element. It is seen that the circuit of Fig. 6*d* is identical to that of the high-frequency filter **11***a* of Fig. 2, with the exception only that the elements **28** and **29** are transposed into the low-band filter **11***b*, described hereinafter, and that the inductance **29** has been divided into equal portions **29***a*, **29***b*, to afford a mid-tap connection.

Similarly, the band-pass filter **11***b* for operation over the low band, for example, 0.55 to 6 megacycles, may be designed to match the antenna **10***a*—**10***b* with the line **12***a*—**12***b*. In the low-frequency band the antenna operates as an ordinary flat-top antenna, rather than as a doublet, so that the antenna is unbalanced with respect to ground. The two wires of the transmission line operate in parallel as a counterpoise and ground connection. The low-band filter is, therefore, required to couple the unbalanced currents induced between the antenna **10***a*—**10***b* and the antenna end of the line, to the balanced transmission line.

The effective antenna impedance in the low-frequency band f_1—f_3 is shown by the curve of Fig. 5*c*. There is no ordinary type of filter the image impedance of which closely approximates the antenna impedance over the band f_1—f_3, as shown in Fig. 5*c*. Therefore, resort is had to a different principle in the design of this filter as compared with the design of the high-band filter. In the low-band filter **11***b*, the antenna impedance is to be considered as being substituted for some of the reactance elements at that end of the filter section. In order to avoid the dissipation which would occur if a terminating resistance were added at the same end of the filter, the filter is to be terminated either in a section which will tolerate a short circuit or in one which will tolerate an open circuit, without seriously impairing the properties of the filter.

In Fig. 5*d* there is shown the curve of image impedance of a constant-*k* half-section band-pass filter with mid-series termination, such, for example, as is indicated by the section C of Fig. 7*a*. As indicated in Fig. 5*d*, the image impedance is zero at the cut-off frequencies so that the mid-series termination will tolerate a short circuit without substantially affecting the properties of the filter. The half-section C comprises the mid-series condenser **32** and inductance **33** and the mid-shunt condenser **34** and inductance **35**. The considerations which govern the design of the right-hand half-section B of Fig. 6*a*, discussed above, are similarly applicable to the selection of the right-hand half-section of the low-band filter **11***b*. This half-section, indicated at D, Fig. 7*a*, is similar to the section B, Fig. 6*a*, and comprises the mid-series condenser **36** and inductance **37**, connected in parallel, and the mid-shunt condenser **38** and inductance **39**.

While the sections C and D could be merged into an equivalent network including a transformer section, as was done in the case of the high-band filter, in this arrangement the transformer would have to have a coefficient of coupling very close to unity in order to cover the entire low-frequency band from f_1 to f_3. This requirement may be made less severe by the addition of a transformer filter section, such as the section E, Fig. 7*a*. The sections C and D both have constant-*k* mid-shunt image impedances and therefore can properly be joined by the transformer section E. The section E comprises the mid-shunt condenser **40** and inductance **41**, the series inductance **42** and the mid-shunt condenser **43** and inductance **44**.

The sections C, D and E can be merged into their electrical equivalents, as indicated in Figs. 7*b*, 7*c*, and 7*d*. In Fig. 7*b* the mid-shunt condensers **34** and **40** are combined into the single condenser **45**, the mid-shunt inductances **35** and **41** into the inductance **46**, the mid-shunt condensers **38** and **43** into the condenser **47**, and the mid-shunt inductances **39** and **44** into the inductance **48**. It is seen that the inductances **46**, **42** and **48** comprise a pi section which may be replaced by an equivalent transformer. Such a transformation is shown in Fig. 7*c*, in which these inductances are converted into a transformer comprising inductances **50** and **52**. The other circuit elements of Fig. 7*b* are also indicated by different reference numerals in Fig. 7*c*, since the primary circuit of Fig. 7*c* preferably has all of its impedances multiplied by such a factor that the mid-series capacitance **53** is equal to the effective capacitance of the antenna at the lowest frequency f_1. The mid-series image impedance of the primary circuit will then have a maximum value R_E which approximates the mean value of antenna impedance over the band f_1—f_3, as indicated in Fig. 5*c*. On the other hand, the secondary circuit of Fig. 7*c* preferably has all of its impedances multiplied by such a factor that the nominal value of its image impedance is equal to the impedance of the line **12***a*—**12***b*.

The circuit of Fig. 7*c* is modified to that of Fig. 7*d* in order that the secondary circuit may operate into a balanced line. To this end, the mid-series condenser **55** and inductance **56** are divided into parts represented by the condensers **55***a* and **55***b* and the inductances **56***a* and **56***b* of Fig. 7*d*.

The circuit of Fig. 7*c* is modified also in Fig. 7*d* by the substitution of the antenna impedance, indicated at **58**, **59**, for a portion of the mid-series reactance **53**, **54** of Fig. 7*c*. The condenser

58 represents the capacitance of the antenna at the frequency f_1 which, as stated above, is equal to that of the condenser 53 by the design of the filter circuit. The inductance 59 is that required to tune the antenna capacitance 58 to the fundamental frequency f_{10} (Fig. 5a). Inductance 57 is the difference between inductances 54 and 59. The circuit of Fig. 7d is the equivalent of a filter having at its antenna end a mid-series termination on short circuit.

In Fig. 8 is shown the combination of the high-band filter of Fig. 6d and the low-band filter of Fig. 7d. The primary circuits are unchanged, but the secondary circuits are combined in a particular manner. The low-band filter elements 51, 52 operate as a mid-series reactance arm for the high-band filter, as shown in Fig. 8, while the high-band filter elements 30a, 31a, 30b, 31b function as the mid-series reactance arm for the low-band filter, as shown in Fig. 8. In other words, each filter circuit proper operates as a mid-series reactance arm for the other filter. While the circuit constants of each of the filters may not be ideal for use as the mid-series reactance arm of the other, the value of these reactances is not critical, so that these constants may be selected primarily to satisfy the design of their respective filter sections, and the response of the filters over their respective bands will be reasonably satisfactory while the cut-off frequencies will be unaltered.

The filter circuits 11a, 11b may be designed in accordance with the formulas set forth in the textbook of Shea, noted above.

The effect of connecting together the high-band and low-band filters at the line terminals, as shown in Fig. 8, is to merge the image impedance curves of the two filters into a single curve over the band f_1—f_4, which is similar to that of a single band-pass filter with constant-k mid-shunt termination. However, this feature of interconnecting at one end two band-pass filters designed to cover contiguous bands is not, per se, a part of the present invention but is disclosed and claimed in my copending application Serial No. 25,736, filed June 10, 1935. This copending application also sets forth modified and simplified formulas for designing the separate filters.

In general, the same principles as are applied above in the substitution of the antenna impedance for a portion of the mid-series termination in the low-frequency band may be applied as an alternative method of computing the constants of the high-band filter. In Fig. 9 is shown a constant-k half-section with mid-series condensers 60a and 60b and inductances 61a and 61b and mid-shunt condenser 62 and inductance 63.

The filter section of Fig. 9 may be designed for connection to the left-hand terminals of Fig. 6a. The combination of Figs. 6a and 9 is a complete filter which is characterized by a mid-shunt termination on open circuit on its left-hand end. The impedance of Fig. 9 on the right-hand side, as viewed from the remainder of the filter, is then substantially the same as that of the doublet antenna. Therefore, the circuit of Fig. 9 may be considered the equivalent of the doublet antenna and that part of the complete filter may be replaced thereby without disturbing the characteristics of the composite filter network. In other words, certain of the reactance elements at the left-hand end are replaced by the substantially equal reactance of the doublet antenna.

It will be seen that the derived circuit of Fig. 8 is identical to that comprising the high-band and low-band filters 11a, 11b of Fig. 2, the input terminals of the high-band filter being connected to the inner ends of the doublet antenna, which are interconnected through an inductance 64. The input terminals of the low-band filter are connected, respectively, to the mid-point of the inductance 64 and to the junction of coils 52a and 52b, comprising half-sections of the coil 52 of Fig. 8, to provide a ground connection for the antenna 10a—10b when operating as a simple, flat-top antenna in the low-frequency band. As an alternative, this latter connection may be independently grounded, preferably in the immediate neighborhood of the antenna, as directly underneath. As a further alternative, this latter connection may be independently grounded and also connected to the junction of coils 52a and 52b. The inductance 64 acts as a choke coil with respect to balanced operation of the doublet antenna in the high band. The two halves of this coil are effectively connected in parallel and have relatively small impedance to unbalanced currents characteristic of operation in the low band. Similarly, the two halves of inductance 52 and the two halves of inductance 31 are effectively in parallel with respect to unbalanced currents and therefore present very little impedance thereto. The effective inductance of the halves of the inductances 64, 52 and 31, in parallel, are considered as part of inductance 57. The transformer comprising the windings 50, 52a and 52b of the low-band filter preferably is provided with a thinly laminated or finely divided iron core.

The high-band and low-band filters 13a and 13b, interconnecting the line 12a—12b with the input circuit 15 of the device 14, may be of any of a number of types but are preferably designed in accordance with the principles discussed above, modified, however, to provide interconnections between both corresponding ends of the two filters. Further, it may be desirable to extend somewhat the frequency band covered by the filters 13a, 13b beyond that covered by the filters 11a, 11b, for example, from 0.5 to 20 megacycles, to ensure that the entire band will be satisfactorily covered by the receiver. The filters 13a, 13b can be designed to cover this broader band more easily than can the filters 11a, 11b. Essentially, each of the filters 13a, 13b is the equivalent of a pi section symmetrical filter including a transformer coupling. Both the primary and secondary circuits of the two filters are effectively in series, so that they operate effectively in parallel between line 12a—12b and the input circuit 15 of the device 14. The high-band filter 13a comprises a mid-shunt condenser 65, the primary windings 66a and 66b in series, the secondary winding 68 and mid-shunt condenser 69. Similarly, the low-pass filter 13b comprises the mid-shunt condensers 70a, 70b, connected in series to provide a neutral ground connection, and the primary winding 71, the secondary winding 73 and the mid-shunt condenser 72. The transformer 71—73 is preferably provided with an iron core of the type described above. A conductive shield is preferably interposed between the primary windings 66a, 66b and the secondary winding 68, as indicated. The low-band filter 13b is designed to pass a band f_1—f_2, while the high-band filter is designed to pass a band f_3—f_4. The two filters cooperate to pass the intermediate band f_2—f_3. The several circuit elements of the filters 13a, 13b are so proportioned that the image imped-

ance of the line 12a—12b is approximately matched to the impedance 15 of the input circuit of the receiver 14. The principles of design of the filters 13a, 13b are not described in the same detail as the antenna-to-line filters, both because any of a number of types of filters may be used for this purpose and because of the fact that this feature, per se, forms the subject matter of my copending application Serial No. 25,737, filed June 10, 1935.

As described briefly above, the transmission line 12a—12b serves to interconnect the output terminals of the band-pass filters 11a, 11b to the filters 13a, 13b interposed between the line and the receiver 14. The line may consist of a pair of spaced wires separated at intervals by transposition blocks of insulation material, as indicated schematically in Fig. 1. Such a line has negligible attenuation and has the advantages of both simplicity and low cost. As an alternative, the line 12a—12b may comprise a pair of twisted insulated wires, which has the advantage of convenience in installation but the disadvantage of appreciable attenuation.

As stated above, the line 12a—12b operates as a balanced transmission line over the high-frequency band and also as a counterpoise and ground connection when the antenna operates as a simple flat-top antenna over the low-frequency band. In case the length of the line is longer than one-half wave length of the highest frequency of the selected band, as is usually the case, the impedance of the line as a ground connection depends materially on the nature of the termination of the line relative to ground at the receiver end. If the wires are connected effectively to ground through either a very low impedance or a very high impedance, the line tends to resonate at its natural frequencies, causing the line impedance to ground at the antenna end to have high maximum values at its alternate natural frequencies and minimum values at intermediate frequencies.

The undesirable impedance variations of the line as a ground connection can be substantially avoided by terminating the two wires in parallel through a resistance to ground at the receiver end. This resistance should be approximately equal to the image impedance relative to ground of the two wires connected in parallel. This expedient renders the impedance of the line as a ground connection approximately uniform and approximately equal to the value of the terminating resistance. In Fig. 2 this terminating resistance is indicated at 74. Such terminating impedance should be included even though an independent ground connection is provided for operation in the low-frequency band, as suggested above.

It is believed that the general principles of operation of the above-described system will be clear from the foregoing detailed description of the circuit arrangement and the principles involved in its design. However, the operation in the two frequency bands may be summarized by reference to Figs. 3 and 4, which are simplified diagrams including only the principal circuit elements functionally active in the high-frequency and low-frequency bands, respectively.

The simplified diagrams of Figs. 3 and 4 are useful as an aid in visualizing the operation of the system in the high and low bands, respectively, and, although they are not an exact representation of the equivalent circuits in these two bands, they may constitute a reasonably close approximation at the extreme frequencies of the bands f_1 and f_4. The diagrams of Figs. 3 and 4 are based upon the assumption that the reactances of the inductances of the low-band filter are so high and the reactances of the capacitances thereof are so low in the high-frequency band that their effect may be neglected; and similarly, that the reactances of the capacitances of the high-band filter are so high and the reactances of the inductances thereof are so low in the low-frequency band that their effect may be neglected.

Referring specifically to Fig. 3, the antenna 10a—10b operates as a balanced doublet and the high-band filter 11a is effective to couple the balanced antenna currents to the balanced line 12a—12b as balanced or circulating currents therein, at the same time approximately matching the impedance of the doublet antenna to that of the line over the high-frequency band f_3—f_4. The circulating currents in the line 12a—12b are coupled by the high-band filter 13a to induce unbalanced currents in the input circuit 15 of the receiver 14. During operation in the high-frequency band, any local electrical disturbances or transients intercepted by the line 12a—12b will flow to ground through the two conductors in parallel, through the coils 66a and 66b in opposition, and through the terminating resistance 74 to ground. These disturbing or noise-producing currents thus cancel out and produce no effect upon the input circuit 15 of the device 14.

When operating in the low-frequency band, as illustrated in Fig. 4, the low-band filter 11b serves to couple the unbalanced currents of the antenna 10a—10b, operating as a simple flat-top antenna, as balanced or circulating currents in the line 12a—12b. The low-band filter 13b, similarly, couples the balanced or circulating currents of the line 12a—12b into the unbalanced input circuit 15 of the device 14. In this band the line 12 may serve also as a ground lead for the simple antenna, the connection being made at the junction between coils 52a and 52b so that the ground currents flow in parallel through the conductors 12a, 12b, through the balancing condensers 70a, 70b, and the terminating resistor 74 to ground. The ground currents thus produce no effect upon the input circuit 15 of the device 14. At the same time the resistor 74 provides a proper terminating impedance substantially equal to the image impedance of the two conductors of the line in parallel to ground, minimizing the variations of the line impedance to ground in series with the antenna circuit and securing optimum operation over the low-frequency band.

While the wave-signal-collecting system described above may be designed for operation over a wide range of operating conditions, there are given herewith, by way of example only, the circuit constants of a particular system embodying my invention in the form described above. The following circuit values were realized as closely as possible and include such effects as inherent capacitance or inductance of other related circuit elements:

System

Megacycles

f_1=0.55
f_2=1.8
f_3=6
f_4=18

Antenna (Refer Fig. 1)

Meters
l=20
w= 2
Height=10

Antenna-to-line filter

R_D= 500 ohms
R_E=1,080 ohms
Element 64= 45 microhenries
27a+27b= 9.8 microhenries
31a+31b= 5.6 microhenries
57= 32 microhenries
50= 225 microhenries
52a+52b= 124 microhenries
59= 3 microhenries
26= 44.2 micro-microfarads
30a, 30b= 63 micro-microfarads each
49= 59 micro-microfarads
51= 98 micro-microfarads
58= 240 micro-microfarads

Transformer 27a, 27b, 31a, 31b

Coefficient of coupling=67.8%

Transformer 50, 52a, 52b

Coefficient of coupling=89.3%

Transmission line (Refer Fig. 1)

a= 5 centimeters
b= 1 meter (approximately)
Length=40 meters
Maximum image impedance=500 ohms

Line-to-receiver filter

Frequency band = 0.5–20 megacycles
Receiver input impedance (15) =400 ohms
Element 66a+66b= 27 microhenries
68= 21 microhenries
71=262 microhenries
73=210 microhenries
65= 16 micro-microfarads
*69= 20 micro-microfarads
70a, 70b=386 micro-microfarads each
72=242 micro-microfarads

*Capacitance 69 was physically a part of the inherent capacitance between coil 68 and the adjacent shield.

Transformer 66a, 66b, 68

Coefficient of coupling=84%

Transformer 71, 73

Coefficient of coupling=84%

While I have described what I at present consider the preferred embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from my invention, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true scope and spirit of my invention.

What I claim is:

1. In a wave-signal-collecting system for receiving signals of any frequency within a given band, an antenna having an impedance varying substantially over said band, a transmission line, a signal-translating device coupled to said transmission line and operative over said frequency band, an impedance network interconnecting said antenna and said line including two band-pass filters effectively in parallel, one of said filters being proportioned to pass a lower portion of said band and being connected to said antenna so that it operates as an unbalanced antenna and serving to translate unbalanced antenna currents to balanced currents and transfer the latter to said line, the other of said filters being proportioned to pass the remaining upper portion of said band and being connected to said antenna so that it operates as a balanced antenna and serving to transfer balanced antenna currents to said line as balanced currents, each of said filters having an image impedance presented to said antenna of a geometric means value approximating the geometric mean value of said antenna impedance over the band.

2. In a wave-signal-collecting system for receiving signals of any frequency within a given band, an antenna having inherent reactance, a transmission line, a signal-translating device coupled to said transmission line and operative over said frequency band, an impedance network interconnecting said antenna and said line including two band-pass filters effectively in parallel, one of said filters being proportioned to pass a lower portion of said band and being connected to said antenna so that it operates as an unbalanced antenna and serving to translate unbalanced antenna currents to balanced currents and transfer the latter to said line, the other of said filters being proportioned to pass the remaining upper portion of said band and being connected to said antenna so that it operates as a balanced antenna and serving to transfer balanced antenna currents to said line as balanced currents, the inherent reactance of said antenna for balanced and unbalanced operation being substituted for at least a portion of the terminating impedances of said upper- and lower-band filters, respectively, at their antenna ends.

3. In a wave-signal-collecting system for receiving signals of any frequency within a given band, an antenna having an impedance varying substantially over said band, a transmission line including a pair of conductors, a signal-translating device coupled to said transmission line and operative over said frequency band, an interconnection between said antenna and said line whereby said conductors serve as parallel ground leads for said antenna, said line having an impedance toward parallel currents tending to vary substantially over said band, an impedance network interconnecting said antenna and said line including two band-pass filters effectively in parallel, one of said filters being proportioned to pass a lower portion of said band and being connected to said antenna so that it operates as an unbalanced antenna and serving to translate unbalanced antenna currents to balanced currents and transfer the latter to said line, the other of said filters being proportioned to pass the remaining upper portion of said band and being connected to said antenna so that it operates as a balanced antenna and serving to transfer balanced antenna currents to said line as balanced currents, each of said filters having an image impedance presented to said antenna of a geometric mean value approximating the geometric mean value of said antenna impedance over the band, and means including resistance coupled between ground and the ground end of said line for minimizing variations in the impedance of said line toward parallel currents.

4. In a wave-signal-collecting system for receiving signals of any frequency within a given band, an antenna having an impedance varying substantially over said band, a transmission line, an impedance network interconnecting said antenna and said line including two band-pass filters effectively in parallel, one of said filters being proportioned to pass a lower portion of said band and being connected to said antenna so that it operates as an unbalanced antenna and serving to translate unbalanced antenna currents to balanced currents and transfer the latter to said line, the other of said filters being proportioned to pass the remaining upper portion of said band and being connected to said antenna so that it operates as a balanced antenna and serving to transfer balanced antenna currents to said line as balanced currents, each of said filters having an image impedance presented to said antenna of a geometric mean value approximating the geometric mean value of said antenna impedance over the band, a signal-translating device, and a pair of band-pass filters coupling said line and said device, said filters being proportioned substantially to match the image impedance of said line and that of said device over their respective bands.

5. In a wave-signal-collecting system for receiving signals of any frequency within a given band and including an antenna and a signal-translating device, the combination of a transmission line including a pair of conductors for interconnecting said antenna and said device, an interconnection for said antenna and said line whereby said conductors serve as parallel ground leads for said antenna, said line having an impedance toward parallel currents tending to vary substantially over said band, other means including said transmission line for separately transferring to said translating device signal currents collected by said antenna, and means including resistance coupled between ground and the ground end of said line for minimizing variations in the impedance of said line toward parallel currents.

6. In a wave-signal-collecting system for receiving signals of any frequency within a given band and including an antenna and a signal-translating device, the combination of a transmission line including a pair of conductors for interconnecting said antenna and said device, an interconnection for said antenna and said line whereby said conductors serve as parallel ground leads for said antenna, said line having an impedance toward parallel currents tending to vary substantially over said band, means for coupling into the antenna end of said line as circulating currents the signal currents induced between said antenna and the antenna end of said line, means for coupling the circulating currents from the other end of said line to said signal-translating device, and means including resistance coupled between ground and the ground end of said line for minimizing variations in the impedance of said line toward parallel currents.

7. In a wave-signal-collecting system for receiving signals of any frequency within a given band and including an antenna and a signal-translating device separated by a distance of at least one-half wave length at the highest frequency in said range, the combination of a transmission line including a pair of closely spaced conductors for interconnecting said antenna and said device, an interconnection for said antenna and said line whereby said conductors serve as parallel ground leads for said antenna, said line having maximum values of impedance toward parallel currents at its alternate frequencies of resonance within said range, means for coupling into the antenna end of said line as circulating currents the signal currents induced between said antenna and the antenna end of said line, means for coupling the circulating currents from the other end of said line to said signal-translating device, and means including resistance coupled between ground and said other end of said line for minimizing the maximum values of the impedance of said line toward parallel currents.

8. In a wave-signal-collecting system for receiving signals of any frequency within a given band and including an unbalanced antenna and a signal-translating device, the combination of a balanced transmission line including a symmetrical pair of conductors for interconnecting said antenna and said device, an interconnection for said antenna and said line whereby the antenna currents flow to ground as unbalanced currents in said line, said line having an impedance toward unbalanced currents tending to vary substantially over said band, other means for transferring antenna currents to said translating device over said line as balanced currents, and means including resistance coupled between ground and the ground end of said line for minimizing variations in the impedance of said line toward unbalanced currents.

9. In a wave-signal-collecting system for receiving signals of any frequency within a given band and including an unbalanced antenna and a signal-translating device, the combination of a balanced transmission line including a symmetrical pair of conductors for interconnecting said antenna and said device, an interconnection for said antenna and said line whereby the antenna currents flow to ground as unbalanced currents in said line, said line having an impedance toward unbalanced currents tending to vary substantially over said band, means for coupling into the antenna end of said line as balanced currents the unbalanced signal currents induced between said antenna and the antenna end of said line, means including a center-tapped impedance for coupling the balanced currents from said line to said translating device while maintaining the balance of said line, and a resistance substantially equal to the image impedance between said line and ground effectively connected between the center tap of said impedance and ground for minimizing the variations in the impedance of said line toward unbalanced currents.

10. In a wave-signal-collecting system for receiving signals of any frequency within a given band and including an antenna and a signal-translating device, the combination of a transmission line including a pair of conductors for interconnecting said antenna and said device, an interconnection for said antenna and said line whereby said conductors serve as parallel ground leads for said antenna, said line having an impedance toward parallel currents tending to vary substantially over said band, other means including said transmission line for separately transferring to said translating device signal currents collected by said antenna, and means including resistance coupled between ground and the ground end of said line for minimizing variations in the impedance of said line toward parallel currents and presenting to said translating device an image impedance substantially matching that of said device over said band.

11. In a wave-signal-collecting system for receiving signals of any frequency within a given band and including an antenna and a signal-translating device, the combination of a transmission line including a pair of conductors for interconnecting said antenna and said device, an interconnection for said antenna and said line whereby said conductors serve as parallel ground leads for said antenna, said line having an impedance toward parallel currents tending to vary substantially over said band, a band-pass filter for interconnecting said antenna and line effective approximately to match the antenna impedance and the image impedance of the line over said band, a second band-pass filter for interconnecting said line and the signal-translating device effective approximately to match the image impedance of said line with the input impedance of said device over the band, and means including resistance coupled between ground and the ground end of said line for minimizing variations in the impedance of said line toward parallel currents.

12. In a wave-signaling system for translating signals of any frequency within a given band, the combination of an antenna having an impedance varying substantially over said band, a signal-translating device operative over said frequency band, and a band-pass filter interposed between said antenna and said translating device, said filter having an image impedance presented to said antenna of a geometric mean value approximating the geometric mean value of said antenna impedance over the band.

13. In a wave-signaling system for translating signals of any frequency within a given band, the combination of an antenna having an impedance varying substantially over said band, a signal-translating device operative over said frequency band, and a band-pass filter interposed between said antenna and said translating device, said filter having an image impedance presented to said antenna of a geometric mean value approximating the geometric mean value of said antenna impedance over the band and of a form which approximates the form of said antenna impedance and similarly positioned with respect to said band.

14. In a wave-signaling system for translating signals of any frequency within a given band, the combination of an antenna having an extreme value of impedance at an edge frequency of said band, a signal-translating device operative over said frequency band, and a band-pass filter interposed between said antenna and said translating device, said filter having its cutoff frequency at said edge frequency and having an image impedance presented to said antenna of a similar extreme value at said edge frequency and of a geometric mean value approximating the geometric mean value of the antenna impedance over said band.

15. In a wave-signaling system for translating signals of any frequency within a given band, the combination of an antenna having similar extreme values of impedance at both edge frequencies of said band, a signal-translating device operative over said frequency band, and a band-pass filter interposed between said antenna and said translating device, said filter having its cutoff frequencies at said edge frequencies and including a constant-k termination presented to said antenna having extreme values of image impedance at said edge frequencies similar to those of said antenna and a geometric mean value of image impedance approximating the geometric mean value of the antenna impedance over said band.

16. In a wave-signaling system for translating signals of any frequency within a band whose edge frequencies differ approximately in the ratio of one to three, the combination of an antenna having its fundamental and overtone frequencies equal respectively to said edge frequencies and having minimum impedance at said edge frequencies, a signal-translating device operative over said frequency band, and a band-pass filter interposed between said antenna and said translating device, said filter having its cutoff frequencies at said edge frequencies and including a constant-k mid-series termination presented to said antenna having an image impedance of minimum value at said edge frequencies and of geometric mean value approximating the geometric mean value of the antenna impedance over said band.

17. In a wave-signaling system for translating signals of any frequency within a given band, the combination of a balanced antenna having an impedance varying substantially over said band, a balanced signal-translating device operative at frequencies in said band, and a band-pass filter interconnecting said antenna and said signal-translating device and proportioned to transfer balanced currents therebetween, said filter having an image impedance presented to said antenna of a geometric mean value approximating the geometric mean value of said antenna impedance over the band.

18. In a wave-signaling system for translating signals of any frequency within a given band, the combination of an antenna having inherent reactance and an impedance varying substantially over said band, a signal-translating device operative over said frequency band, and a band-pass filter interposed between said antenna and said apparatus, said filter having a mean image impedance at its antenna end approximating that of said antenna over said band, the inherent reactance of said antenna being substituted for at least a portion of the terminating impedance of said filter at its antenna end.

19. In a wave-signaling system for translating signals of any frequency within a given band, the combination of an antenna having inherent reactance and an impedance varying substantially over said band, a signal-translating device operative over said frequency band, and a band-pass filter interposed between said antenna and said apparatus, said filter having a cutoff frequency at an edge frequency of said band, an extreme value of image impedance at said edge frequency, a terminating impedance of a similar extreme value, and a mean value of image impedance approximating that of said antenna over said band, the inherent reactance of said antenna being substituted for reactance elements of the terminating impedance of said filter having approximately equal impedance over said band.

20. In a wave-signaling system for translating signals of any frequency within a given band, the combination of an antenna having inherent reactance, a signal-translating device operative over said frequency band, and a band-pass filter interposed between said antenna and said apparatus, said filter having at its antenna end a constant-k mid-series termination on short circuit, the inherent reactance of said antenna being substituted for reactance elements of the termi-

nating impedance of said filter having approximately equal impedance over said band.

21. In a wave-signaling system for translating signals of any frequency within a given band, the combination of an antenna having inherent reactance, a signal-translating device operative over said frequency band, and a band-pass filter interposed between said antenna and said apparatus, said filter having at its antenna end an equivalent constant-k mid-shunt termination on open circuit, the inherent reactance of said antenna being substituted for reactance elements of the terminating impedance of said filter having approximately equal impedance over said band.

22. In a wave-signaling system for translating signals of any frequency within a given band, the combination of a capacitive antenna, a signal-translating device operative over said frequency band, and a band-pass filter interposed between said antenna and said apparatus, said filter having at its antenna end a constant-k mid-series termination on short circuit, the inherent capacitance of said antenna being substituted for a series capacitance element of said termination of a value approximating that of said antenna at the lower edge frequency of said band.

23. In a wave-signaling system for translating signals of any frequency within a given band, a balanced antenna, a signal-translating device operative over said frequency band, and two band-pass filters interposed effectively in parallel between said antenna and said translating device and proportioned to pass respectively a lower portion and the remaining upper portion of said band, the lower-band and upper-band filters being connected so as to transfer to said translating device currents corresponding respectively to unbalanced and balanced currents from said antenna, and said filters being at the end adjacent said translating device connected together and relatively proportioned so as to present to said device a resultant image impedance approximating that of a continuous-band filter passing said given band.

24. In a wave-signaling system for translating signals of any frequency within a given band, an antenna, a signal-translating device operative over said frequency band, and two band-pass filters interposed effectively in parallel between said antenna and said translating device and proportioned to pass respectively a lower portion and the remaining upper portion of said band, the lower-band and upper-band filters being connected so as to transfer to said translating device currents corresponding respectively to balanced and unbalanced antenna currents, said filters being at the end adjacent said translating device connected together and relatively proportioned so as to present to said device a resultant image impedance approximating that of a continuous-band filter passing said given band, and each of said filters including a transformer section for approximately matching the impedance of said antenna and that of said device.

25. In a wave-signaling system for translating signals of any frequency within a given band, an antenna, a signal-translating device operative over said frequency band, and two band-pass filters interposed effectively in parallel between said antenna and said translating device and proportioned to pass respectively a lower portion and the remaining upper portion of said band, the lower-band and upper-band filters being connected so as to transfer to said translating device currents corresponding respectively to balanced and unbalanced antenna currents, one of said filters at the end adjacent said translating device being composed of reactance elements forming a part of the other filter and symmetrically disposed therein, said filters being so proportioned that, at said end, they present a resultant image impedance approximating that of a continuous-band filter passing said given band.

26. In a wave-signaling system for translating signals of any frequency within a given band, an antenna, a signal-translating device operative over said frequency band, and two band-pass filters interposed effectively in parallel between said antenna and said translating device and proportioned to pass respectively a lower portion and the remaining upper portion of said band, the lower-band filter being connected to said antenna so that it operates as an unbalanced antenna and serving to translate unbalanced antenna currents to balanced currents and transfer the latter to said device, and the upper-band filter being connected to said antenna so that it operates as a balanced antenna and serving to transfer balanced antenna currents to said device as balanced currents, said filters being, at the end adjacent said device, connected together and relatively proportioned so as to present to said device a resultant image impedance approximating that of a continuous-band filter of the same band width.

27. In a wave-signaling system for translating signals of any frequency within a given band, the combination of an antenna characterized by an impedance having a maximum value at the lowest frequency of said band, decreasing in value to an intermediate frequency of said band and, over the remaining portion of said band, passing through one or more cyclic variations from its mean value, a signal-translating device operative over said frequency band, and a band-pass filter interposed between said antenna and said translating device, said filter having an image impedance presented to said antenna of substantially the same mean value as said antenna impedance over the portion of said band below said intermediate frequency and of a form and magnitude which approximate the form and magnitude, respectively, of said cyclic variations of said antenna impedance over at least a portion of said band corresponding to one of said cyclic variations.

28. In a wave-signaling system for translating signals of any frequency within a given band, the combination of an antenna characterized by an impedance having a maximum value at the lowest frequency of said band, decreasing in value to an intermediate frequency of said band and, over the remaining portion of said band, passing through one or more cyclic variations from its mean value, a signal-translating device operative over said frequency band, and a composite band-pass filter interposed between said antenna and said translating device including a component filter having an image impedance presented to said antenna of substantially the same mean value as said antenna impedance over the portion of said band below said intermediate frequency and an additional component filter for each of said cyclic antenna impedance variations, having an image impedance presented to said antenna of a form and magnitude which approximate the form and magnitude, respectively, of the corresponding cyclic variation of said antenna impedance.

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