May 28, 1940. L. M. LEEDS 2,202,700

TRANSMISSION APPARATUS

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Fig. 1.

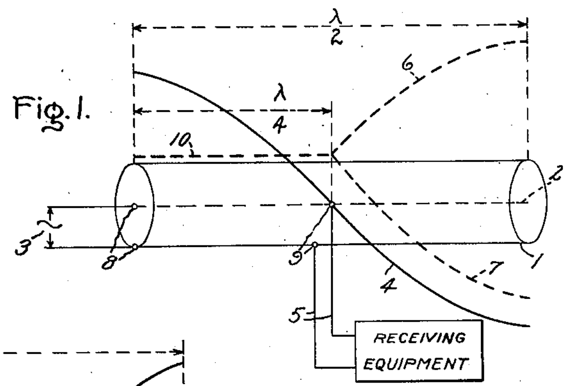

Fig. 2.

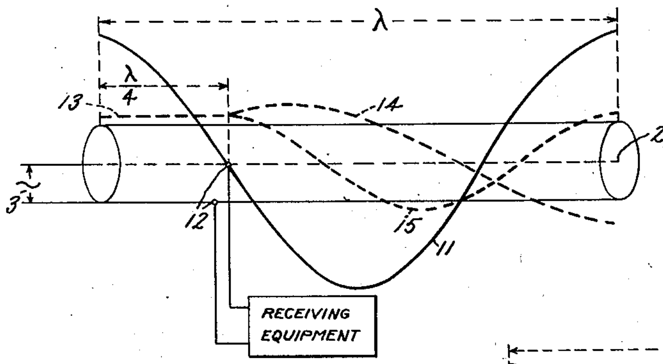

Fig. 3.

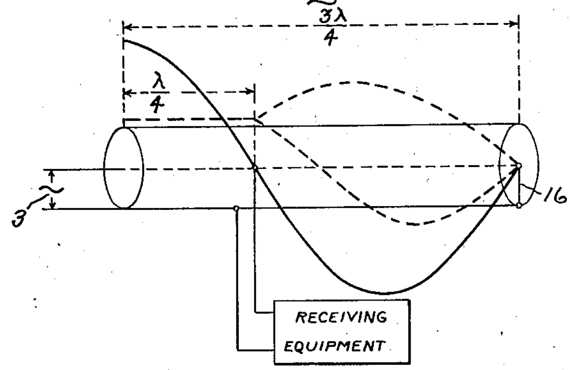

Fig. 4.

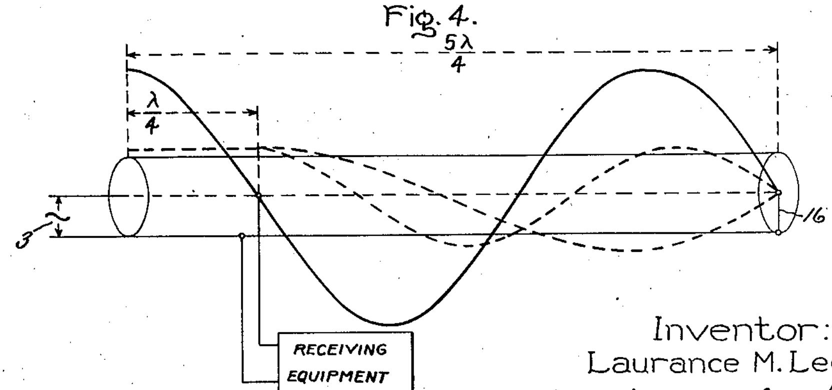

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Fig. 5.

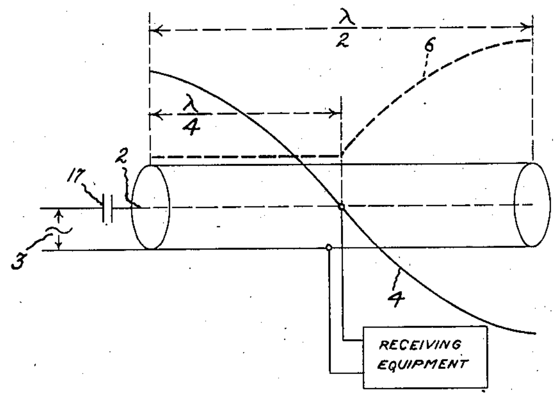
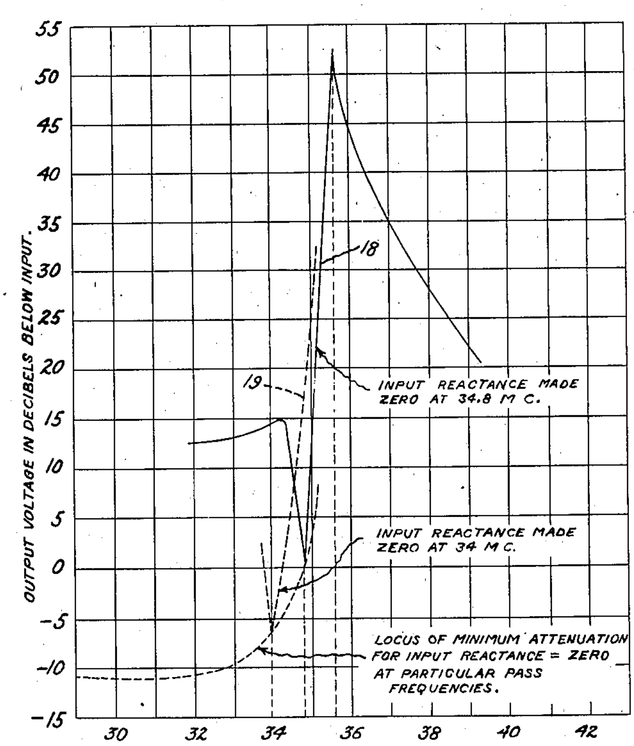


Fig. 6.



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TRANSMISSION APPARATUS

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Fig. 7.

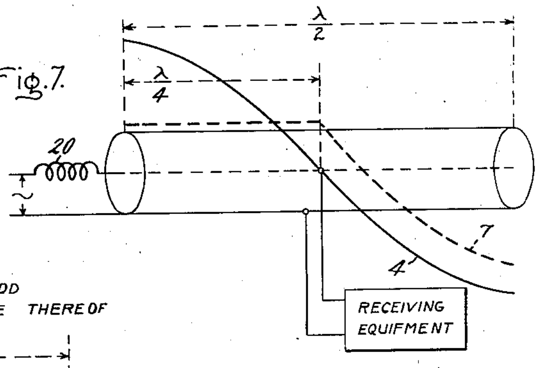


Fig. 8.

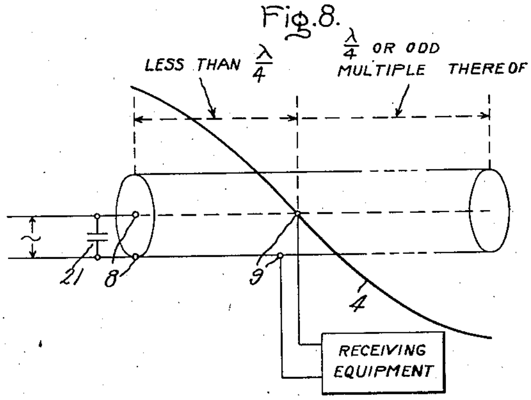


Fig. 9.

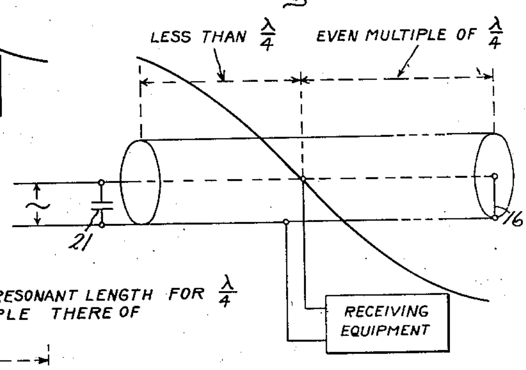


Fig. 10.

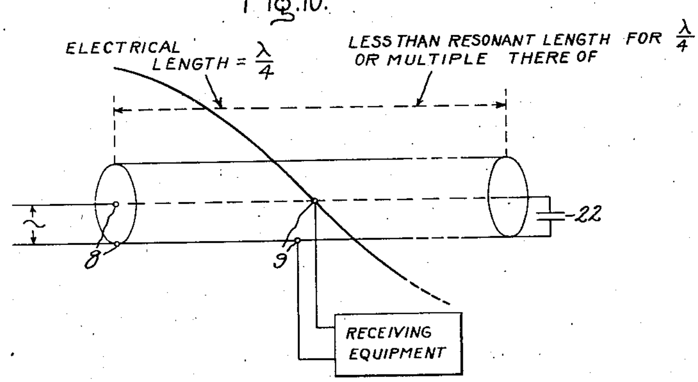
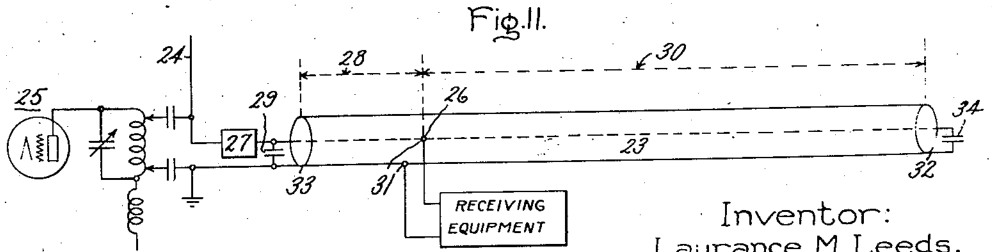


Fig. 11.



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by Harry E. Dunham
His Attorney.

Patented May 28, 1940

2,202,700

UNITED STATES PATENT OFFICE

2,202,700

TRANSMISSION APPARATUS

Laurance M. Leeds, Scotia, N. Y., assignor to General Electric Company, a corporation of New York

Application May 7, 1937, Serial No. 141,293

10 Claims. (Cl. 250—9)

This application is a continuation in part of my application Serial No. 55,584, filed December 21, 1935, for Transmission apparatus.

My invention relates to short wave apparatus and more particularly to frequency selective transmission apparatus for operation at short wave lengths.

One of the objects of my invention is to provide a short wave transmission system having an improved band elimination characteristic.

A further object of my invention is to provide such a system capable of efficiently transmitting currents of a desired frequency and of highly attenuating currents of undesired frequency even through the frequencies be spaced relatively closely in the short wave range of the frequency spectrum.

My invention is particularly adapted for use, for example, in police communication systems for efficiently separating oscillations to be received, for example, in an automobile receiver, from oscillations radiated from a transmitter at the same time and from the same automobile and which may be connected, for example, to the same antenna. One range of frequencies commonly employed for such communication extends approximately from thirty to forty-two megacycles. Since the receiver on a police automobile, or at a police station, for simultaneous transmission and reception must operate at a frequency different from that at which the associated transmitter operates, and since the frequency band is comparatively narrow, it is important that means be associated with the receiver which will greatly attenuate the transmitter frequency. In this way the spacing between transmitted and received frequencies may be reduced and the band may be more efficiently utilized. An object of my invention is to provide improved means for this purpose.

The use of concentrated inductances and capacitors connected in conventional frequency selective circuits is quite unsatisfactory for operation at short wave lengths because of excessive attenuation at the desired frequencies produced by reason of the high resistance of such circuit elements at the frequencies involved. In addition stray inductance and capacity undesirably affect the impedance values obtainable and thus reduce the selectivity of the apparatus and in general detract from the quality of the filter characteristic obtainable.

It has been found in accordance with my invention that these difficulties are greatly reduced by the use of the standing wave transmission line in the manner which I shall presently describe.

In transmission and receiving apparatus shown and described in the above-mentioned application, Serial No. 55,584, oscillations of an undesired frequency are impressed on a transmission line, together with oscillations of desired frequencies for reception by a receiving equipment. Oscillations of the undesired frequency are filtered from the receiving equipment, and desired frequencies are efficiently received, by connecting the receiving equipment to a point upon the transmission line, which is preferably of the concentric type comprising an outer conducting tube and a centrally disposed conductor, at which exists a nodal point of a standing wave of the undesired frequency. The nodal points of the standing waves of desired frequencies occur at points considerably displaced along the transmission line from the corresponding nodal points of the wave of undesired frequency, and, further, at the nodal points of the undesired frequency the amplitudes of oscillation of the desired frequencies are of considerable magnitude. Accordingly, by connecting the receiving equipment between the central conductor and the outer conducting tube of the concentric transmission line at one of the above-mentioned nodal points of the undesired frequency, the latter frequency is excluded from the receiving equipment whereas oscillations of a desired frequency are received.

One of the objects of my present invention is to effect certain improvements in the system of my above-mentioned prior application whereby the facility of employment of the system is increased and its operating characteristics are improved. One of these improvements relates to the relations between the impedance of the receiver input and that of the transmission line. In accordance with my present invention the receiver input impedance may be equal to the surge impedance of the line. A further improvement resides in means for reducing the reactive impedance of the line thereby to reduce the attenuation of the line or to render it actually negative.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawings.

Referring to the drawings, Figs. 1 to 4 illustrate systems incorporating standing wave transmission lines of different length, wherein the input impedance of the receiving equipment is made equal to the surge impedance of the transmission line; Figs. 5 to 7 illustrate the use of tuning means for reducing the attenuation of the desired frequency; Figs. 8 to 10 illustrate the use of tuning means to facilitate initial adjustment of the transmission line; and Fig. 11 illustrates the use of my invention in connection with a shortwave, two-way radio system.

In Fig. 1 a section of a concentric transmission line is shown comprising an outer conducting tube 1 and an inner centrally disposed conductor 2. If oscillations be impressed upon the conductor 2 at the input end of the line, as indicated at 3, a standing wave will be produced upon the line having, as indicated by curve 4, a maximum at the opposite or free end of the line since the transmission line is open circuited at that end, a minimum value at a point one-quarter of a wavelength of the impressed oscillations from the free end, and a maximum value at a half wavelength from the free end. As the curve 4 indicates an undesired frequency, the receiving equipment is connected to the transmission line at the nodal point of the undesired wave, as by conductors 5, whereby, as described in the above prior application, voltage of the undesired frequency is substantially excluded from the receiving equipment but voltage of any other frequency present may be received, for example, desired frequencies indicated by curves 6 and 7, respectively lower and higher than the undesired frequency.

Instead of so arranging the receiving equipment that the input impedance thereof has a value of a very high order, approaching infinity, in accordance with my present invention the equipment is so arranged that the input impedance equals substantially the surge impedance of the transmission line. It has been found that by thus making the receiver input impedance equal to the transmission line surge impedance, the receiver voltage, i. e., the voltage of the wave or waves of desired frequency, between the input terminals 8 and the output terminals 9 of the transmission line, is substantially constant, as shown by the dotted line 10 forming the left-hand continuation of curves 6 and 7, whereas when the receiver input impedance is of the high value above mentioned the receiver voltage varies in value between the input and output points of the transmission line.

It will be seen that in operation of systems in accordance with my invention, such as illustrated in Fig. 1 for example, the standing wave 4 of the undesired frequency is unaffected by making the input impedance of the load circuit, which is represented by the receiving equipment, less than the high value, approaching infinity, employed in the system disclosed in my above-mentioned prior application. At the undesired frequency, represented by curve 4, the impedance of the line at the load circuit point is extremely low, approaching zero as a limit, and therefore the shunting effect caused by the connection of the load circuit, whose impedance is substantially greater than the line impedance at the point 9, does not disturb the standing wave pattern of the wave of undesired frequency. In the present case, in accordance with my invention, the load circuit impedance is made substantially equal to the line surge impedance. But for waves of other frequency, such as the waves of desired frequencies 6 and 7, the line impedance at the point 9 is substantially greater than the line surge impedance, and the shunting effect of the load circuit, whose impedance is substantially equal to the line surge impedance, is very pronounced and, in fact, serves as a matched termination for the line section between input 8 and load point 9, resulting in traveling waves between these two points for waves of desired frequency. Beyond point 9, however, standing waves of these other frequencies occur, point 9 being in effect the input point for standing waves in the section between this point and the free end of the line. Thus, in such systems as shown in Fig. 1, there are present in the transmission line: a standing wave of the undesired frequency, this wave occurring all along the line between the input end and the free end thereof; traveling waves of the desired frequencies, which occur between the input end and the output point, or that point at which the load represented by the receiving equipment is connected; and standing waves of the desired frequencies, which occur between the output point and the free end of the line.

Fig. 2 is similar to Fig. 1 with the exception that the transmission line has a length equal to a wavelength of the undesired frequency indicated by curve 11, this curve having two nodal points and the receiving equipment being connected preferably to the inner conductor 2 at that nodal point, 12, which is one-quarter wavelength of the undesired frequency from the input end of the transmission line. The input impedance of the receiving equipment being made equal, as above explained, to the surge impedance of the transmission line, the receiver voltage, indicated by dotted line 13, becomes constant, between the input and output terminals, for desired frequencies, indicated by curves 14 and 15, which are respectively lower and higher than the undesired frequency.

It will readily be seen that any transmission line arranged similarly to those illustrated in Figs. 1 and 2 and open circuited at the free end may be employed which has a length equal to an even multiple of one-quarter wavelength of the wave of undesired frequency.

In Figs. 3 and 4, instead of the open-circuited transmission lines of Figs. 1 and 2, transmission lines are illustrated which are short-circuited at the free end by a connection 16 between the inner conductor and the outer conductor, nodal points in the latter transmission lines occurring at points spaced from the short circuited end by a half wavelength of the undesired wave or any multiple thereof. As in the system illustrated in Figs. 1 and 2, in the system of Figs. 3 and 4 the receiver input impedance is made equal to the transmission line surge impedance, the receiver voltage for desired frequencies thereby becoming constant between the input and output terminals of the transmission lines. It will be understood that any short-circuited transmission line similar to those of Figs. 3 and 4 may be employed which has a length equal to an odd multiple of one-quarter wavelength of the wave of undesired frequency.

In Fig. 5, which illustrates similarly, to Fig. 1, a half wave, open-circuited concentric transmission line filter, the receiving equipment is arranged to receive a desired frequency, indicated by curve 6, which is lower than the frequency of the undesired wave, indicated by curve 4. The transmission line input impedance or driving point impedance is slightly inductively reactive at the desired lower frequency 6. In order to tune out or neutralize this inductive reactance I provide a capacitance element 17 connected in series relation with the transmission line, as by connection between a terminal of the oscillator source 3 and the inner conductor 2.

As illustrated in Fig. 6, assuming a certain undesired or elimination frequency such as 35.6 megacycles, the full line curve 18 indicates the attenuation for the case where the tuning is such that the transmission line inductive reactance is tuned out or made zero by capacitance 17 at a desired or pass frequency, which the receiving equipment is to receive, of 34.8 megacycles. It will be seen that the attenuation at this given desired frequency, 34.8 megacycles is reduced nearly to zero, whereas in a similar system wherein the inductive reactance of the transmission is not tuned out, the attenuation of a desired frequency similarly close to the undesired or elimination frequency is of appreciable magnitude. Further, in Fig. 6, the dotted curve 19 indicates the attenuation for the case where the tuning is such that the transmission line inductive reactance is tuned out by capacitance 17 at a pass frequency of 34 megacycles. In the latter case it will be seen that the attenuation of the wave of desired or pass frequency is still less than in the case of the 34.8 megacycle wave. The attenuation, in the case of the 34 megacycle pass frequency has, in fact, a negative value, which indicates a transmission gain between oscillation source 3 of Fig. 5 and the receiving equipment, whereas in the system not provided with the tuning capacitance 17, under the assumed condition of undesired frequency 35.6 megacycles and desired frequency 34 megacycles, an appreciable positive attenuation of the desired frequency is present, which indicates a transmission loss.

Referring to Fig. 7, the receiving equipment is arranged to receive a desired frequency, indicated by curve 7 of Fig. 7, which is higher than the frequency of the undesired wave, indicated by curve 4. The reactance of the transmission line at this desired higher frequency becomes capacitive and is tuned out by an inductance element 20 instead of the capacitance 17 of Fig. 5. The attenuation of desired frequencies close to the undesired frequency then approaches close to zero or even becomes negative, similarly to the case illustrated in Figs. 5 and 6, where the desired frequency is lower than the undesired frequency.

In tuning out the transmission line reactance at the desired frequency as above explained in connection with Figs. 5 to 7 by means of the series reactances 17 and 20, the peak attenuation at the undesired or elimination frequency is unaffected by the series reactances since the resistive component of the transmission line input impedance is very much higher in value than the value of the series reactance required for the tuning.

In Fig. 8, which illustrates open circuited concentric transmission line filters similar to those illustrated in Figs. 1 and 2, in accordance with my present invention in order to facilitate the initial adjustment and tuning of the filter, the input end thereof or the section thereof between the input terminals 8 and the output terminals 9 is initially constructed of a physical length slightly less than one-quarter of the wavelength of the undesired frequency. The input impedance of the filter then exhibits inductive reactance, and to tune out or neutralize this reactance a capacitance 21 is provided in shunt with the transmission line filter conductors at the input end of the filter.

The transmission line filter arrangements illustrated in Fig. 9 are the same in construction and operation as those of Fig. 8 except that in Fig. 9 the concentric line is of the short-circuited type, having a connection, 16, at the free end of the line, between the inner and outer conductors similarly to the filters illustrated in Figs. 3 and 4.

In the filters illustrated in Fig. 10, the initial adjustment is further facilitated by initially constructing the outer section of the filter or that section between the output terminals 9 and the free end, or end opposite the input end, slightly less in physical length than one-quarter wavelength, or multiple thereof, of the wave of undesired frequency, depending on the electrical length of filter desired. The outer section then being shorter than the resonant length for the undesired frequency is built up to resonance by means of a capacitance 22 connected between the inner and outer conductors at the outer or free end of the transmission line.

It has been discovered that the initial shortening and subsequent tuning of the filters in accordance with my present invention has an added advantage, in that, in certain cases the filter input impedance is materially increased when the line is thus shortened by certain small percentages, with a consequent gain in efficiency of the system.

Fig. 11 represents an application of my invention to a two-way, short-wave radio system and particularly to a system of this character for use on a police automobile or at a police central radio station. Oscillations of a frequency to be received are impressed upon a transmission line 23 of the standing wave type hereinabove described, from an antenna 24, which in addition to its function as a receptor of radiant energy may also act as the radiating element for transmitting equipment a portion of which is indicated at 25. The transmitting equipment operates at a frequency different from that frequency which it is desired to receive through the transmission line. Therefore the receiving equipment is connected to the transmission line 23 at a point 26 corresponding to a nodal point of voltage of the frequency at which the transmitting equipment 25 operates. In accordance with my present invention, the input impedance of the receiving equipment is made equal to the surge impedance of the transmission line as described in connection with Figs. 1 to 4; the reactance component of the input impedance of the transmission line is preferably tuned out by a reactance, indicated by 27, in series in the transmission line as described in conection with Figs. 5 to 7. The transmission line section 28 at the input end thereof is preferably physically slightly shorter than one-quarter of the wavelength at which the antenna 24 operates, and is tuned, as described in connection with Fig. 8, by a capacitance 29 shunted across the conductors of the transmission line; and the outer section 30 of the transmission line, between the output terminals 31 and the free end 32 or end opposite to the input end 33, is preferably slightly less in physical length than required for resonance for the wavelength at which the antenna operates, and is built up to resonance by a capacitance 34 connected across the conductors of the transmission line at the free end 32 as described in connection with Fig. 10.

It will be understood that the transmission line 23 has an input impedance at the antenna end which is high as compared with the impedance of the antenna which might be utilized at 24 in the wave band above referred to. The transmission line input impedance may be of the order of several thousand ohms, for example as high as twenty thousand ohms, whereas the impedance of the antenna, utilized upon an automobile, for example, is only a relatively few ohms. This wide difference in the line input impedance and the antenna impedance aids materially in eliminating from the receiving equipment the transmitted wave. Since the power transmitted from the transmitter equipment 25 divides between the antenna 24 and the transmission line 23 in inverse proportion to these impedances, it is, therefore, but a negligibly small portion of the transmitted power which penetrates the transmission line. It will be understood further that where the receiver input impedance is substantially equal to the line surge impedance, the filter input impedance is substantially equal to its surge impedance over the range of frequencies for which reception is desired. When applied, for example, to a police communication system as illustrated in Fig. 11, reflection losses, which would occur if the filter input impedance were not matched to the antenna impedance, are obviated.

It has been found that the equipment in accordance with my present invention operates to exclude undesired frequencies, at short waves for example, with still greater efficiency than the similar equipment shown and described in my above-mentioned prior application. That is, the present equipment has a still more desirable band elimination characteristic. When operating in the 30 to 42 megacycle band with equipment in accordance with my present invention adapted for police operation, oscillations radiated by a transmitter mounted on the automobile carrying the equipment were almost completely eliminated from the radio receiver by use of my invention although the frequency which it was desired to receive was spaced somewhat less than one megacycle from the frequency at which the transmitter operated. By use of my present invention even considerably closer spacing than the spacing last mentioned may be used while still almost entirely eliminating from the receiver the oscillations of the transmitter frequency.

Also the present invention, wherein the receiver input impedance is made equal to the filter surge impedance and the filter input reactance is tuned out at the receiver frequency, gives a much more desirable pass characteristic, and allows reception at a greater distance than heretofore. In fact, it has been found as a result of comparative tests in the operation of radio equipped police cars, that with the car at a certain distance from the central radio station, signals between car and station were scarcely audible or entirely inaudible when the radio system was operated without the improvements in accordance with my present invention. When, however, with the car at the above distance from the station, the radio equipment was so connected and adjusted as to cause the concentric transmission line filter to operate as hereinabove described, the signals became at once not only audible but markedly strong.

While I have shown particular embodiments of my invention for purposes of illustration it will be understood that I do not wish to be limited thereto since different modifications may be made without departing from the spirit and scope of my invention, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, a source of oscillations having a desired frequency and an undesired frequency, a transmission line, a load device, means to connect said source to said line at one end thereof to have waves of each of said frequencies impressed thereon and to cause standing waves of said undesired frequency to exist throughout the length of said line, and means to connect said load device to said line at a nodal point of said standing waves, said load device having an input impedance substantially equal to the surge impedance of said line, whereby only a traveling wave of said desired frequency exists on the portion of said line between said end of said line and the point of connection thereto of said load device.

2. In combination, a source of oscillations having a desired frequency and an undesired frequency, a transmission line, a load device, means to connect said source to said line at one end thereof to have waves of each of said frequencies impressed thereon and to cause standing waves of said undesired frequency to exist throughout the length of said line, and means to connect said load device to said line at a nodal point of said standing waves, said load device having an input impedance substantially equal to the surge impedance of said line, whereby only a traveling wave of said desired frequency exists throughout the section of said line between the points of connection thereto of said source and said load device, and only a standing wave of said desired frequency exists on said line between said point of connection thereto of said load device and the end of said line opposite to said first-named end.

3. In combination, a source of oscillations having a desired frequency and an undesired frequency, a standing wave transmission line, means to connect said line to said source to have waves of each of said frequencies impressed on said line, the standing wave of said undesired frequency having at least one node of voltage at a point at which the wave of desired frequency has substantial voltage, receiving equipment having an input impedance substantially equal to the surge impedance of said line, and means to connect said receiving equipment between the conductors of said line where a node of voltage of said undesired frequency exists.

4. In a signal system comprising a source of oscillations having a desired frequency and an undesired frequency, and receiving equipment adapted to receive said desired frequency, a standing wave transmission line, means to connect said line to said source to have waves of each of said frequencies impressed on said line, the standing wave of said undesired frequency having at least one node of voltage at a point at which the standing wave of desired frequency has substantial voltage, said receiving equipment having an input impedance substantially equal to the surge impedance of said line, means to connect said receiving equipment between the conductors of said line where a node of voltage of said undesired frequency exists, and reactance means in series with said line and said source to neutralize the reactance of said line at said desired frequency.

5. In a signal system comprising a source of

oscillations having a desired frequency and an undesired frequency, and receiving equipment adapted to receive said desired frequency, a standing wave transmission line having input terminals and output terminals, means to connect said source to said input terminals, means to connect said equipment to said output terminals, said receiving equipment having an input impedance substantially equal to the surge impedance of said line, said output terminals being located at a point of said line which is separated from the free end of said line by an electrical distance equal to a predetermined number of quarter-wave-lengths of said undesired frequency, the physical length of the section of said line between the said input terminals and said output terminals being slightly less than one-quarter of the wavelength of said undesired frequency whereby the input impedance of said line exhibits reactance, and means including a reactance in shunt with said line at the input end thereof to cause said section to have an electrical length equal to one-quarter the wavelength of said undesired frequency.

6. In a signal system comprising a source of oscillations having a desired frequency and an undesired frequency, and receiving equipment adapted to receive said desired frequency, a standing wave transmission line having input terminals and output terminals, means to connect said source to said input terminals and to connect said equipment to said output terminals, said receiving equipment having an input impedance substantially equal to the surge impedance of said line, the free end of said line being open-circuited, the physical length of the section of said line between said output terminals and said free end of said line being slightly less than the length of one-quarter of the wave of undesired frequency times an odd number whereby said section is of less than resonant length at said undesired frequency, and means including a capacitance connected between the conductors of said line at said free end thereof to build up said section to resonance at said undesired frequency.

7. In a short wave signal system including a short wave antenna, a transmitter connected thereto, and a receiving equipment, a standing wave transmission line, means to connect said line to said antenna to impress between the two conductors of said line at the end thereof adjacent said antenna oscillations of the wave-length at which said transmitter is adapted to operate and oscillations of a wavelength slightly different from said first-named wavelength, means to excite on said transmission line standing waves of each of said wavelengths and to produce on said line a node of voltage of said first-named wavelength, said receiving equipment being adapted to operate at said second-named wavelength and having an input impedance substantially equal to the surge impedance of said line, and means to connect said equipment to said line at the point thereof where exists said node of voltage.

8. In a short wave signal system including a short wave antenna, a transmitter connected thereto, and a receiving equipment, a standing wave transmission line, means to connect said line to said antenna to impress between the two conductors of said line at the end thereof adjacent said antenna oscillations of the wavelength at which said transmitter is adapted to operate and oscillations of a wavelength slightly different from said first-named wavelength, the standing wave of said first-named frequency having a node of voltage at a point of said line at which the standing wave of said second-named frequency has substantial voltage, said receiving equipment being adapted to operate at said second-named frequency and having an input impedance substantially equal to the surge impedance of said line, means to connect said equipment between said conductors where said node of voltage exists, and reactance means in series with one of said conductors to neutralize the reactance of said line at said second-named frequency.

9. In a short wave signal system including a short wave antenna, a transmitter connected thereto, and a receiving equipment, a standing wave transmission line, means to connect said line to said antenna to impress between the two conductors of said line at the end thereof adjacent said antenna oscillations of the wavelength at which said transmitter is adapted to operate and oscillations of a wavelength slightly different from said first-named wavelength, said receiving equipment being adapted to operate at said second-named frequency and having an input impedance substantially equal to the surge impedance of said line, means to connect said equipment to said line at a point thereof spaced from said end by a distance slightly less than one-quarter of the wavelength of said first-named frequency whereby the input impedance of said line exhibits inductive reactance, said point being separated from the free end of said line by an electrical distance equal to a predetermined number of quarter-wave-lengths of said undesired frequency, and means including a capacitance connected between said conductors at said end of said line to neutralize said reactance.

10. In a short wave signal system including a short wave antenna, a transmitter connected thereto, and a receiving equipment, a standing wave transmission line, means to connect said line to said antenna to impress between the two conductors of said line at the end thereof adjacent said antenna oscillations of the wavelength at which said transmitter is adapted to operate and oscillations of a wavelength slightly different from said first-named wavelength, the waves of said first-named frequency having a node of voltage at a point of said line at which the wave of said second-named frequency has a substantial voltage, said receiving equipment being adapted to operate at said second-named frequency and having an input impedance substantially equal to the surge impedance of said line, the free end of said line being open circuited, means to connect said equipment to said line between said conductors where said node of voltage exists, the physical length of said line between said point and the free end of said line being slightly less than the length of one-quarter the wave of said first-named frequency times an odd number whereby said section is of less than resonant length at said first-named frequency, and means including a capacitance connected between the conductors of said line at said free end thereof to build up said section to resonance at said first-named frequency.

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