

Aug. 20, 1940.

P. H. SMITH

2,212,214

ELECTRICAL TRANSMISSION SYSTEM

Filed Feb. 9, 1935

3 Sheets-Sheet 1

FIG. 1

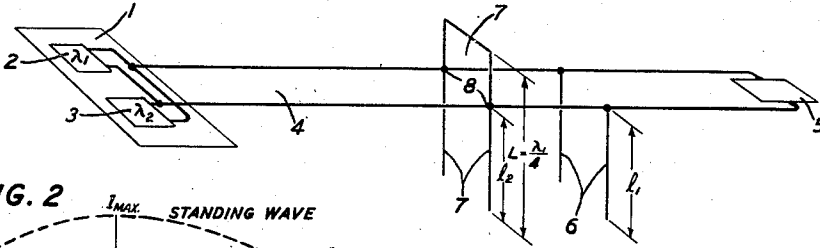
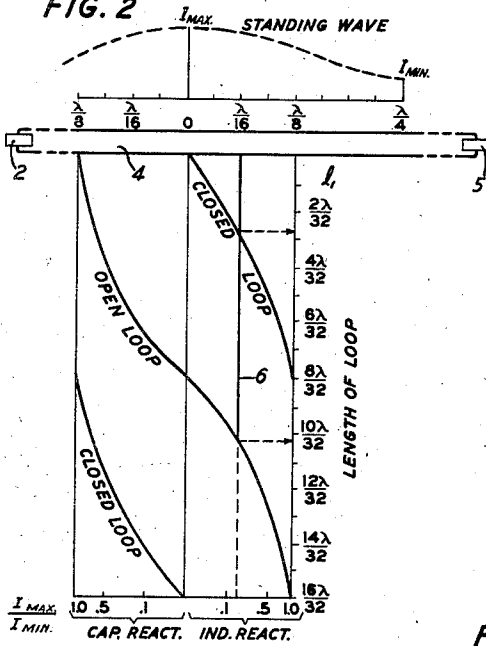


FIG. 2



PERCENTAGE OF MAXIMUM REAL IMPEDANCE

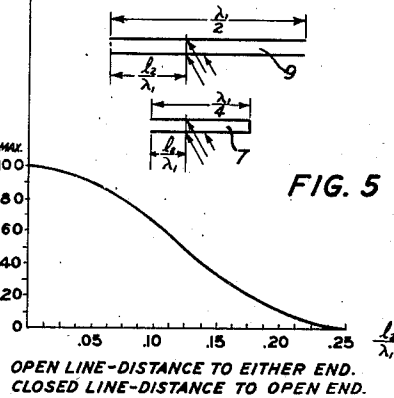


FIG. 5

OPEN LINE-DISTANCE TO EITHER END.
CLOSED LINE-DISTANCE TO OPEN END.

FIG. 4

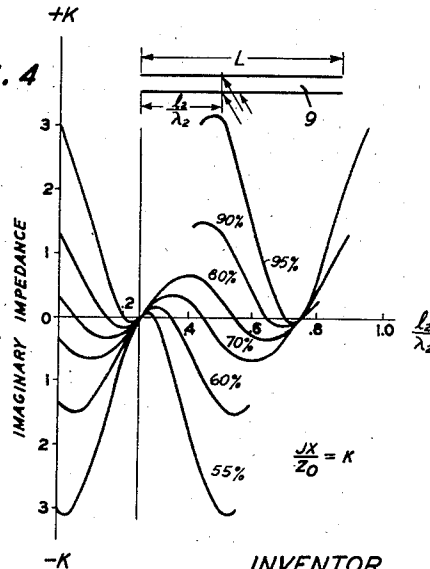
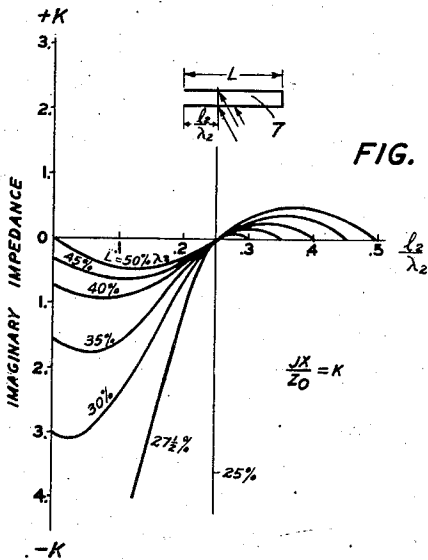


FIG. 3



INVENTOR
P. H. SMITH
BY *A. J. Zerbarini*
ATTORNEY

Aug. 20, 1940.

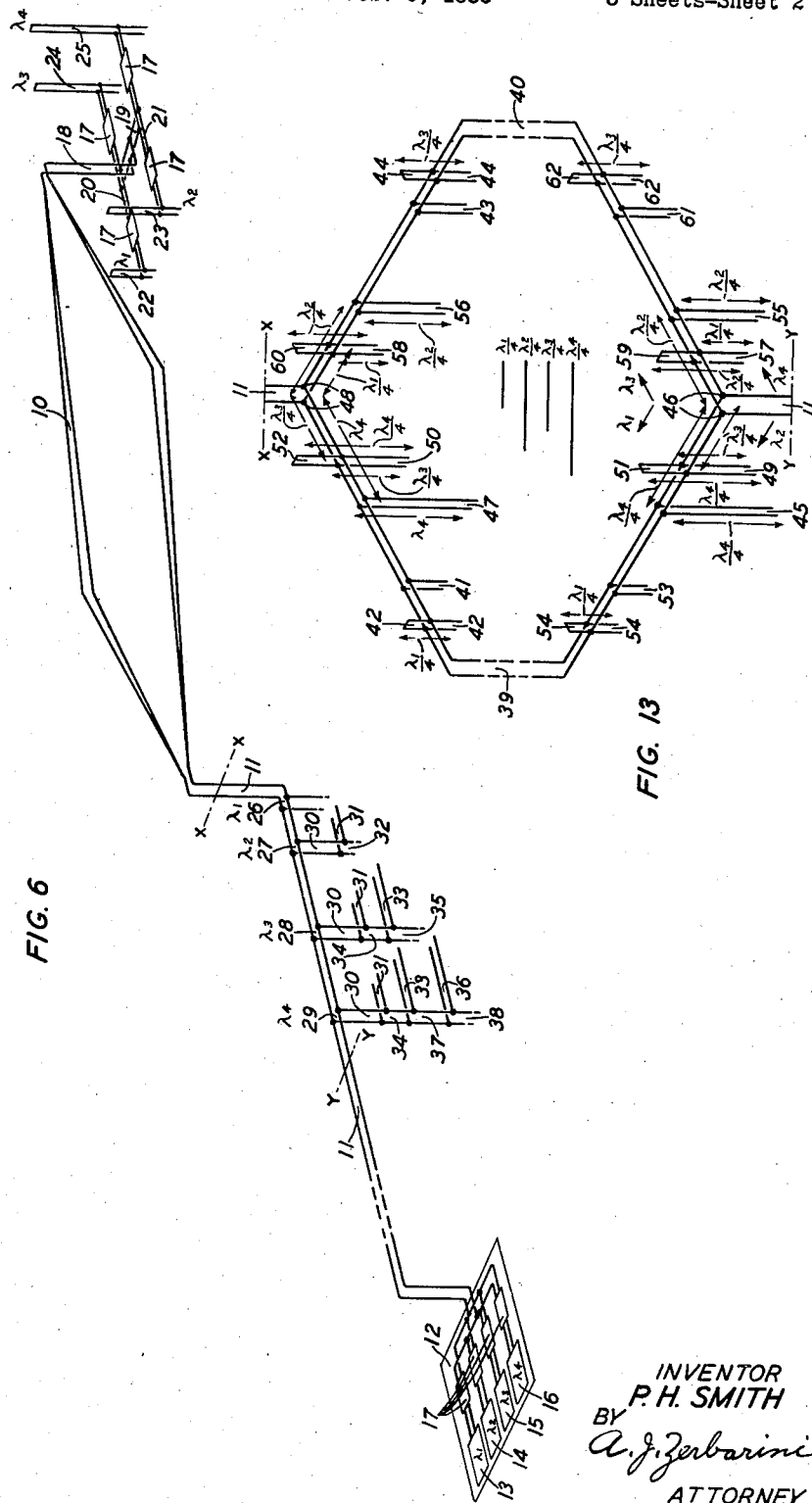
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INVENTOR
P. H. SMITH
BY
A. J. Zerbarini
ATTORNEY

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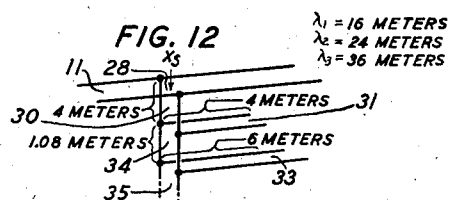
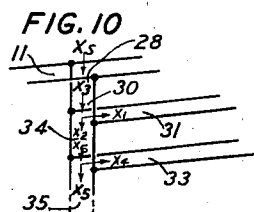
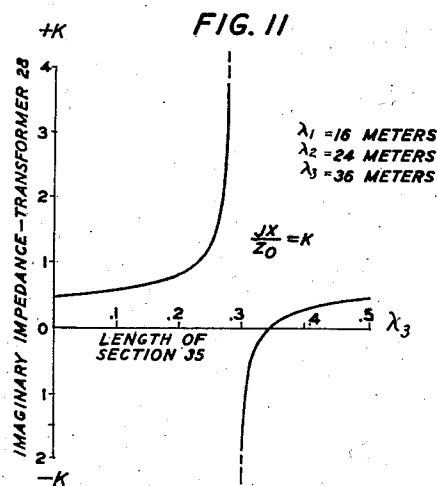
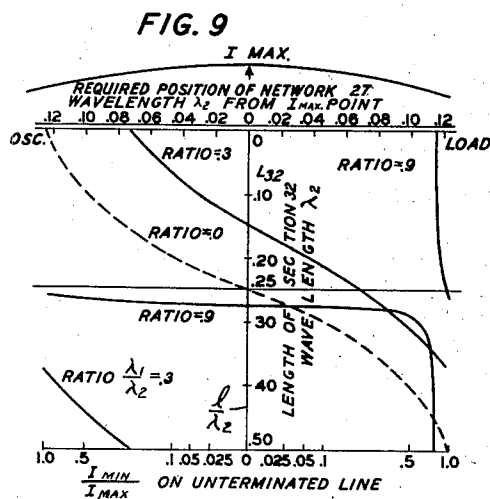
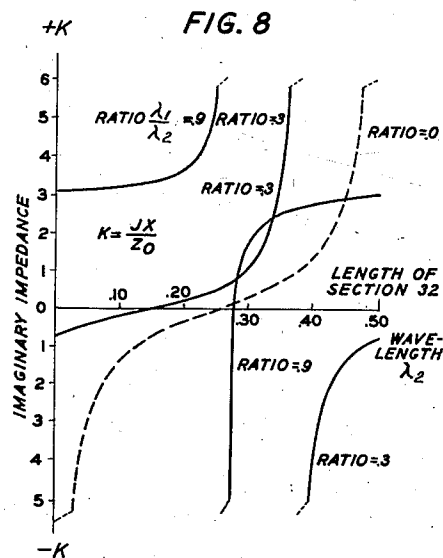
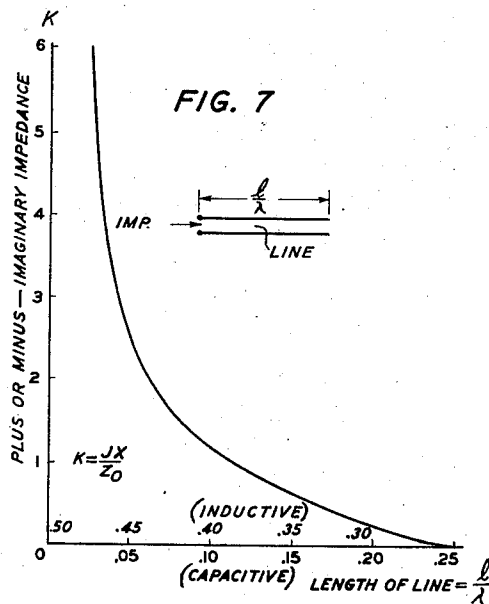
P. H. SMITH

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ELECTRICAL TRANSMISSION SYSTEM

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3 Sheets-Sheet 3



INVENTOR
P. H. SMITH
BY *A. J. Zerbarini*
ATTORNEY

UNITED STATES PATENT OFFICE

2,212,214

ELECTRICAL TRANSMISSION SYSTEM

Phillip H. Smith, Boonton, N. J., assignor to
Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application February 9, 1935, Serial No. 5,694

33 Claims. (Cl. 178-44)

This invention relates to electrical transmission systems and especially to methods and means for preventing wave reflection on multi-frequency radio transmission lines.

Wave reflection which occurs on an open-ended line and produces losses and undesired radiation may be suppressed by connecting a pure resistance equal to the line characteristic impedance across the terminals of the line. In the case of lines designed for single frequency operation and terminated in a complex load unequal to the line characteristic impedance, standing waves resulting from reflection may be suppressed by means of an impedance transformer which changes the load impedance into the line characteristic impedance. A transformer for satisfactorily matching a complex load to a line is described in my Patent 2,041,378 granted May 19, 1936. In the case of lines terminating in a complex load and designed for multi-frequency operation, considerable difficulty has been encountered in suppressing standing waves at the various frequencies for the reasons, among others, that the complex load impedance varies with frequency and the impedance of the device for suppressing reflection at one particular frequency often renders the elimination of standing waves at the other frequencies difficult.

It is one object of this invention to suppress standing waves on a line in a simple and economical manner.

It is another object of this invention to suppress on a multi-frequency line standing waves at each of the frequencies.

It is a further object of this invention to suppress, on a multi-frequency line, standing waves at one frequency without affecting the operation of the system at other frequencies.

According to one embodiment of this invention, as incorporated in a high frequency system comprising means for simultaneously or non-simultaneously supplying three different frequencies to an antenna, standing waves are eliminated for the wave of the shortest wave-length by means of a short auxiliary line connected in shunt to the main line at a point near the antenna. The exact position of this shunt line with respect to a current maximum point of this wave, and the length or impedance value of the auxiliary line corresponding to this exact position, are determined in accordance with the method disclosed in my patent mentioned above. For the intermediate wave-length reflection is prevented by means of a distributed network having a critical position and a critical impedance value as as-

certained in accordance with the method referred to above, the network being located nearer the transmitting end of the line and comprising an open-ended line one-half of the shortest wave-length long and a short auxiliary line of critical length connected in shunt to the open line at the mid-point thereof. The network presents a large or infinite impedance to the shortest wave and functions for this wave as if removed. Reflection is prevented for the wave of longest length by means of an auxiliary line network having a critical value and position, this network being located still nearer to the transmitter and having an infinite impedance for waves of the shortest and intermediate wave-lengths.

According to a different embodiment, a multi-frequency line is terminated satisfactorily by a network comprising two branch lines included in the main line, one of the branch lines including means for terminating the main line at two frequencies and the other including means for terminating the line at the two remaining frequencies. Each branch line also includes means for rejecting waves for which the line is terminated by the other branch line.

The invention will be more fully understood from the following specification taken in connection with the drawing on which like reference characters designate elements of similar function and on which:

Fig. 1 illustrates a two-frequency radio transmission system including a network for suppressing standing waves at both frequencies;

Figs. 2, 3, 4, and 5 are curves used in explaining the operation of the system of Fig. 1;

Fig. 6 illustrates a radio transmission system which includes a network for suppressing standing waves at each of four frequencies;

Figs. 7, 8, 9, 10, 11, and 12 are curves and diagrams useful for explaining the operation of the system of Fig. 6;

Fig. 13 is a perspective end view of a network which may be substituted for that shown in the system illustrated by Fig. 6.

Referring to Fig. 1, reference numeral 1 designates a multi-frequency source of radio frequency comprising transmitters 2 and 3 which supply two waves having, respectively, a length λ_1 and a length λ_2 . These transmitters may supply said waves at the same time or different times and preferably include filters for preventing interaction of the two transmitters. Reference numeral 4 designates a line and numeral 5 a complex load unequal to the characteristic impedance of the line. Reference numeral 6 designates an im-

pedance transformer, such as that disclosed in my patent mentioned above, for transforming the load impedance 5 into the characteristic impedance of the line at the frequency corresponding to wave-length λ_1 . Reference numeral 7 designates another impedance transformer comprising a short-circuited auxiliary line tapped at intermediate points 8 by the main line 4. This transformer functions to suppress standing waves having a frequency corresponding to λ_2 and also functions for the wave-length λ_1 as if removed from the main line 4.

Considering waves of wave-length λ_1 , the impedance transformer 6 has a critical position with respect to a current maximum point of the standing wave-length λ_1 and a critical value corresponding to the critical position, the critical value or length l_1 and position being determined after determination of the ratio of the current maximum and minimum amplitudes from the curves of Fig. 2 which correspond to Fig. 2 of my patent mentioned above. From Fig. 2 also, the critical value of reactance and the critical position with respect to a selected current maximum point of the wave of wave-length λ_2 are determined, the ratio of the current maximum and minimum amplitudes for this wave being previously ascertained. The impedance of transformer 7 at wave-length λ_2 varies with the position of the tapping points 8 inasmuch as this short-circuited impedance transformer is not

$$\frac{\lambda_2}{4}$$

long and therefore not resonant at the frequency corresponding to wave-length λ_2 .

The method of ascertaining the proper position on transformer 7 of the tapping points 8 for obtaining the value of impedance necessary to suppress standing waves of wave-length λ_2 and corresponding to the given position of the transformer 7, will now be explained. The short auxiliary line or transformer 7 may be viewed as two sections, one on each side of the tapping points 8. The impedance of the closed section may be written

$$Z_1 = Z_0 \tanh(\alpha' + j\beta') \quad (1)$$

and the impedance of the open section may be written

$$Z_2 = Z_0 \coth(\alpha + j\beta) \quad (2)$$

these equations being obtained from the textbook by J. A. Fleming entitled "The Propagation of Electric Currents in Telephone and Telegraph Conductors", third edition, pages 81 and 97, where Z_0 =characteristic impedance of each section and main line

$$\alpha = \text{attenuation factor} = \frac{r l_2}{2Z_0} \quad (3)$$

$$\alpha' = \text{attenuation factor} = \frac{r}{2Z_0}(L - l_2) \quad (4)$$

$$\beta = \text{wave factor} = \frac{2\pi l_2}{\lambda_1} \quad (5)$$

$$\beta' = \text{wave factor} = \frac{2\pi}{\lambda_1}(L - l_2) \quad (6)$$

r =resistance per loop of unit length

$$L = \text{total length of transformer 7} = \frac{\lambda_1}{4}$$

l_2 =distance from open end to tap points 8

At frequencies but slightly off resonance, the parallel resultant, Z_s , of Z_1 and Z_2 is essentially

imaginary, and since the sections are of very low loss or low resistance, this resultant reduces to

$$Z_s | i.p. = \frac{jZ_0}{\tan \beta' - \cot \beta} \quad (7)$$

which is the equation for the curves of Fig. 3. On Fig. 3 the percentage designations associated with the various curves represent the different percentages of the longer wave-length λ_2 which the length "L" of transformer 7 having a length

$$\frac{\lambda_1}{4}$$

may have. Knowing the characteristic impedance Z_0 , the actual imaginary impedance $\pm jx$ may be determined from Fig. 3 and the relation

$$\frac{\pm jx}{Z_0} = K$$

Using the particular curve of Fig. 3 corresponding to the known ratio of wave-length λ_1 and λ_2 , and knowing the critical value of impedance as indicated above, the tapping points 8 on transformer 7 may be ascertained.

In place of transformer 7 a transformer 9 comprising two open-ended sections may be employed. The parallel resultant

$$Z_s'$$

of transformer 9, it can be shown, is

$$Z_s' | i.p. = \frac{-jZ_0}{\tan \beta + \tan \beta'} \quad (8)$$

which is the equation for each of the curves of Fig. 4.

The impedance transformers 7 and 9 function to suppress standing waves as explained above having a wave-length λ_2 and function as if removed for wave-length λ_1 , as may be seen from the following. At resonance, which occurs when the closed transformer 7 is

$$\frac{\lambda_1}{4}$$

or an odd multiple thereof and when the open transformer 9 is

$$\frac{\lambda_1}{2}$$

or a multiple thereof long, the parallel resultant Z_s is essentially real in the case of lines of low attenuation and may be written, for the closed transformer 7,

$$Z_s | r.p. = \frac{Z_0}{\frac{\alpha'(1 + \tan^2 \beta')}{\tan^2 \beta'} + \alpha(1 + \tan^2 \beta)} \quad (9)$$

and for the open transformer 9,

$$Z_s | r.p. = \frac{Z_0}{\alpha(1 + \tan^2 \beta) + \alpha'(1 + \tan^2 \beta')} \quad (10)$$

The real impedance Z_s is a maximum at the open end of the line and varies with frequency. However, for any particular frequency, that is, for constant values of β and β' the impedance looking into the line at an intermediate tapping point is a function only of the attenuation α and α' . The attenuations α and α' depend upon the position of the tapping points 8. Fig. 5 illustrates the relation between the impedance at an intermediate tapping point and the maximum impedance in the case of a line short-circuited at one end and in the case of a line open at both ends. As shown on the curve of Fig. 5 the impedance varies from a maximum designated 100 per cent to zero. The maximum is a very high value and depends upon

the characteristic impedance and the construction of the line. Ordinarily it is of the order of several hundred thousand ohms. In the case of the closed transformer it will be seen that the impedance is sufficiently large, except when the tapping point is very near the short circuit, to function as if removed for λ_1 . In the case of the open line it acts as if removed except when the tapping point is near the center.

Referring to Fig. 6, reference numeral 10 designates a multi-frequency transmitting rhombic antenna of the type now well-known in the art. This antenna is connected by means of a main transmission line 11 to a multi-frequency source 12 comprising transmitters 13, 14, 15 and 16 for simultaneously or nonsimultaneously supplying, respectively, frequencies having wave-lengths corresponding to λ_1 , λ_2 , λ_3 and λ_4 . These transmitters are each connected to the main line 11 through a filter 17 designed to pass only the frequency supplied by the associated transmitter. The far end terminals of antenna 10 are connected by means of lines 18, 19, 20 and 21 to a four-frequency dissipating network comprising terminating impedances 22, 23, 24 and 25 for rendering the antenna unidirectional at frequencies corresponding, respectively, to wave-lengths λ_1 , λ_2 , λ_3 and λ_4 . Impedances 22, 23, 24 and 25 are each quarter-wave closed lines at frequencies corresponding, respectively, to λ_1 , λ_2 , λ_3 and λ_4 , and are each connected to the antenna 10 through a filter 17 designed to pass only the frequency corresponding to that for which the associated transformer is designed. Each impedance functions to suppress, at the respective frequency, standing waves on the antenna and to dissipate energy.

Connected across the main transmission line 11 are four impedance networks 26, 27, 28 and 29 for suppressing standing waves on the main line 11 at the frequencies corresponding, respectively, to wave-lengths λ_1 , λ_2 , λ_3 and λ_4 . Each transformer has, at the wave-length at which it functions to suppress standing waves, a critical value and a critical position with respect to the current maximum point of the respective standing wave, in accordance with the teaching of my copending application. Each transformer or network changes the load impedance, comprising the antenna 10 and the portion of the line 11 and associated equipment located between the antenna 10 and point of connection of the transformer, into the characteristic impedance of the line. Considering any transformer, the transformer has a large impedance, and so functions as if removed, at the frequencies at which the line is terminated at points nearer the load or antenna. Thus transformer 27 is anti-resonant at wave-length λ_1 , transformer or network 28 anti-resonant at the wave-lengths λ_1 and λ_2 and transformer 29 anti-resonant at wave-lengths λ_1 , λ_2 and λ_3 . In the preferred embodiment the transformers or networks are arranged in order according to the length of the waves they are designed to suppress, the transformer designed for suppressing the shortest wave being located nearest to the antenna 10. This arrangement is not a necessary condition, however, and the transformers may be arranged in any manner. Also, if desired, each transformer may be rendered anti-resonant at all of the frequencies except the one at which it functions to suppress standing waves.

The theory explaining the operation outlined above of the various transformers will now be discussed. Transformer 27 comprises an open line, a half wave-length long, at the wave-length

λ_1 , line sections 30 and 31 each being a quarter wave-length long at λ_1 . This half wave-length line constitutes an infinite impedance, substantially, for wave-length λ_1 and the network 27 therefore functions as if removed for wave-length λ_1 . A short auxiliary line 32 of either adjustable or predetermined length is connected to the midpoint of the half wave-length line just described for the purpose of rendering the impedance of the transformer 27 equal to the value chosen in accordance with the method described in my copending application. The connection at the midpoint does not affect the operation of the half wave-length line comprising sections 30 and 31 inasmuch as the impedance at the midpoint of the half wave-length is zero at λ_1 . For a given known ratio

$$\frac{\lambda_1}{\lambda_2}$$

the relation between the impedance of the transformer 27 at λ_2 and the length of the short line 32 may be calculated, the impedance of sections 30 and 31 being calculated or known at λ_2 .

Fig. 7 shows the relation between the impedance looking into an open-circuited line similar to line 32 and the length

$$\frac{l}{\lambda}$$

in wave-lengths, where λ is the wave-length of the wave supplied to the line. The actual impedance may be obtained after ascertaining the characteristic impedance Z_0 of the line from the relation

$$\frac{jX}{Z_0} = K$$

where K is obtained from Fig. 7. The curves of Fig. 8 illustrate, each for a different ratio of λ_1 to λ_2 , the relation between the length of adjustable section 32 and the calculated impedance of the network 27. The curves of Figs. 2, 7 and 8 may be combined for convenience as illustrated by the curves of Fig. 9, and the length of section 32 may be quickly determined. Thus referring to Fig. 9 the position of transformer 27 with respect to a given maximum current point may be determined from the known or measured ratio of the current maximum and minimum amplitudes at λ_2 , that is

$$\frac{I_{\max}}{I_{\min}}$$

Knowing the ratio

$$\frac{\lambda_1}{\lambda_2}$$

and therefore the proper curve of Fig. 9 to use, the length of section 32 may be determined on the vertical scale.

Transformer 28 is in a sense an extension of transformer 27 and is anti-resonant at λ_1 and λ_2 . This transformer includes in effect an open half wave-length line at λ_1 , sections 30 and 31. It also includes an open half wave-length line at λ_2 , section 33 being a quarter wave-length long at λ_2 and sections 30, 31 and 34 constituting electrically a quarter wave-length line at λ_2 . The adjusted, or predetermined, length of section 35 is such as to render the impedance of the network 28 equal to the value necessary to suppress standing waves at λ_3 on main line 11. It is believed to be apparent that transformer 29 includes an open half wave line at λ_1 , an open half wave line at λ_2 , and in addition an open half wave line at λ_3 , section 36 being a quarter wave-length long at λ_3 , and

sections 30, 31, 33, 34, and 37 being electrically equivalent to a quarter wave-length line at λ_3 . The length of section 38 is such as to render the impedance of the network 29 equal to the previously determined critical value for suppressing standing waves on main line 11 at λ_4 .

Referring to Fig. 10 the method of determining the length of section 34 of transformer 28 will now be explained. In the first place the length of the section 35 may be disregarded inasmuch as it is in shunt with a zero impedance point on a half wave-length line at λ_2 . The physical lengths of all the other sections of the network, except section 34, are easily determined since the actual wave-lengths λ_1 and λ_2 are known, these known lengths being expressed in terms of wave-length λ_2 . The problem is therefore reduced to a determination of the parallel impedances X_1 and X_2 which when combined with the impedance of section 30 at λ_2 anti-resonate transformer 28 at λ_2 . The length

$$\frac{\lambda_2}{2}$$

minus the length of section 30 at

$$\frac{\lambda}{2}$$

determines the length whose reactance, let us say, is X_3 . Reactance X_3 may be determined from Fig. 7. Now,

$$X_3 = \frac{X_1 X_2}{X_1 + X_2}$$

X_1 is known and is

$$X_1 = -jz_0 \cot \frac{2\pi L_{31}}{\lambda_2} \quad (11)$$

where

$\frac{L_{31}}{\lambda_2}$ is the length of section 31 expressed as a fractional part of the wave-length at λ_2 . X_2 is, therefore, readily obtainable and is

$$X_2 = \frac{X_3 X_1}{X_1 - X_3} \quad (12)$$

Expressing X_2 in terms of a length of open-circuited transmission lines as above indicated we have

$$X_2 = -jz_0 \cot 2\pi \frac{L_{33} + L_{34}}{\lambda_2} \quad (13)$$

where z_0 is the surge impedance or characteristic impedance of the section and L_{33} and L_{34} are the lengths of sections 33 and 34, respectively, or

$$2\pi \frac{L_{33} + L_{34}}{\lambda_2} = \cot^{-1} \frac{jX_2}{Z_0} \text{ in radians} \quad (14)$$

therefore

$$\frac{L_{34}}{\lambda_2} = \frac{\cot^{-1} \frac{jX_2}{Z_0}}{2\pi} - \frac{L_{33}}{\lambda_2} \quad (15)$$

where

$$\frac{L_{33}}{\lambda_2}$$

and

$$\frac{L_{34}}{\lambda_2}$$

are expressed as a fractional part of a wave-length at λ_2 .

Transformer 28 has an input reactance X_s at λ_3 which is controllable by means of the adjustable section 35 between plus and minus infinity neglecting losses. In practice it appears that a

cut and try method of adjusting this length is satisfactory. It may be calculated as follows:

Referring to Fig. 10 all dimensions except the length of section 35, which has a reactance X_s , of the network 28 are known and may be expressed in terms of λ_3 . The input reactance indicated as X_s at λ_3 is:

$$X_s = \frac{X_4 X_5}{X_4 + X_5} \quad (16)$$

the correct algebraic sign being applied to the reactances. For a given adjustment of section 35, X_4 and X_5 are computed at λ_3 from Fig. 7. A particular length of open-circuited transmission line in terms of λ_3 may next be found having the same reactance as X_s by means of Fig. 7. This new representative length when added to the length of section 34 permits the computation of reactance X_2 from Fig. 7. X_2 is then combined with X_1 and the resulting reactance is also represented by a line of length which may be readily calculated from Fig. 7. This second representative length when added to the length of section 30 allows the calculation of the input reactance of the whole network 28.

If the reactance of the network 28 be computed for a series of lengths of the adjustable element 35, a smooth curve may be plotted to show the input reactance of transformer 28 as a function of the length of the adjustable section 35 for a fixed set of wave-lengths λ_1 , λ_2 and λ_3 . Knowing the desired value of network impedance X_s according to the method of my copending application, the length of the adjustable section 35 may be ascertained from the curve. Fig. 11 illustrates the curve obtained when λ_1 equals 16 meters, λ_2 equals 24 meters and λ_3 equals 36 meters; and Fig. 12 illustrates the actual arrangement when these wave-lengths are employed.

It is believed to be apparent that, in accordance with the method described above, the length of section 37 of transformer 29 may be ascertained and also the length of the adjustable section 38.

Referring to Fig. 13 a perspective end view of a four-frequency network is illustrated, which network may be substituted for the equipment shown included between the line XX and YY of Fig. 6. In the system of Fig. 13, branch lines 39 and 40 are inserted in the main line 11. As in the system of Fig. 1, in branch line 39, transformers 4 and 42 function to suppress standing waves having a wave-length λ_1 and λ_2 , respectively; and in branch line 40, transformers 43 and 44 suppress standing waves having a wave-length of λ_3 and λ_4 , respectively. Transformers 42 and 44 are anti-resonant, respectively, at λ_1 and λ_3 since they constitute closed auxiliary lines a quarter wave-length long at these respective wave-lengths.

The auxiliary line 45 having a length equal to one-quarter of λ_4 and located at a distance of one-quarter of λ_4 from junction 46 offers an infinite impedance to waves having a wave-length of λ_4 . Auxiliary line 47 is similarly dimensioned and similarly positioned with respect to junction 48 and blocks the flow of waves of wave-length λ_4 . Auxiliary lines 49 and 50, each having a length of

$$\frac{\lambda_3}{4}$$

and located at a distance of one-quarter of λ_3 from junctions 46 and 48, respectively, function

to keep waves of λ_3 from entering the line 39. The closed line comprising sections 49 and 51 and the closed line comprising sections 50 and 52, each constitute an infinite impedance at λ_4 inasmuch as they are each one-quarter of a wavelength at λ_4 . The transformers 45 and 49, 51 each produce a disturbance or standing waves at λ_1 and λ_2 which are canceled by transformers 53 and 54. This is apparent since antenna 10 and multi-frequency source 12 may, in accordance with the reciprocity theorem, be considered interchanged for the purpose of eliminating the standing waves produced by transformers 45 and 49, 51.

The arrangement on line 40 is similar to that on line 39. The transformers 55 and 56 function to prevent the flow of currents of wavelengths λ_2 and transformers 57 and 58 function to block λ_1 , as indicated by the dimensions of these transformers. The shorted line comprising section 57 and 59 and the shorted line comprising sections 58 and 60 function as if removed for λ_2 . Transformer 61 functions to suppress the standing wave set up by transformers 55 and 57, 59 at λ_3 and transformer 62 functions to suppress the standing wave produced at λ_4 by transformers 55 and 57, 59.

Although the invention has been described in connection with certain embodiments and apparatus, it is understood that it is not to be limited to such embodiments and apparatus. Obviously different apparatus may be employed for suppressing standing waves on a line at a number of different frequencies in accordance with the invention.

What is claimed is:

1. A method of suppressing standing waves on a radio transmission path between a source and a load at a plurality of frequencies, which comprises transforming for one frequency the load impedance into the characteristic impedance of the path at one point in said path, similarly transforming the load impedance for another frequency at a point nearer the source in the same path, and preventing at the last-mentioned point reflection at the first-mentioned frequency.

2. A method of matching at a plurality of frequencies a load impedance and the impedance of the associated line connected to a multi-frequency source, utilizing a plurality of reactive devices, which comprises matching at a first point on the line the load and line impedances for a first frequency, connecting to the line at a second point nearer the source a particular reactive device having an infinite impedance value at the first frequency, and adjusting said particular device to match the load and line impedance for the second frequency.

3. In a radio system, an antenna adapted to operate on a plurality of frequencies and a translation device, a transmission line connected therebetween, said line over a portion of its length being divided into parallel paths each for a different plurality of operating frequencies, and means in each path for matching the antenna impedance and the line characteristic impedance for the frequencies corresponding to that path.

4. In a radio transmission system, a line connecting a multi-frequency source to a load, a shunt impedance for suppressing a standing wave of a given frequency connected to said line and having a value dependent upon the ratio of the current maximum to the current minimum of said standing wave, another shunt impedance for suppressing a standing wave of a lower fre-

quency connected across the line at a point nearer the source and having a value dependent upon the ratio of the current maximum to the current minimum of the wave of said lower frequency, said last mentioned shunt impedance having a large impedance at the first mentioned given frequency.

5. In a radio transmission system, a single path connecting a multi-frequency source to a load, and a plurality of impedances each for transforming at a different one of the transmitted frequencies the load impedance into the characteristic impedance of the path, at least one of said impedances having an infinite impedance value for all the transmitted frequencies except that at which it functions to match the load and line impedances.

6. In a radio transmission system, a single path connecting a multi-frequency source to a complex load impedance unequal to the characteristic impedance of the path and means comprising a portion of said path and at least one impedance connected in shunt to said path at an intermediate point thereof for suppressing standing waves produced by said load at the transmitted frequencies.

7. In a radio transmission system, a line connecting a multi-frequency source to a load, impedance means connected in shunt to said line for suppressing standing waves at one of the frequencies transmitted, a second impedance means connected in shunt to said line at a point nearer said source for suppressing standing waves at a frequency lower than the first mentioned frequency, said second means having a relatively large impedance at said first mentioned frequency.

8. In a radio transmission system, a line connecting a multi-frequency source of radio energy to a load, impedances connected to different points of said line, each for suppressing at a different frequency standing waves on the line between said source and the point of connection for said impedance, each impedance being anti-resonant at the frequencies at which standing waves are suppressed by means of impedances located nearer the load.

9. In a radio system, a plurality of sources for supplying currents of different frequencies, a load, a line connecting said sources to said load, a shunt impedance for suppressing standing waves at a given frequency connected across the line and having a value and position dependent upon the ratio of the maximum and minimum amplitudes of the standing waves at said frequency, a second shunt impedance connected across the line at a point nearer said source for suppressing standing waves at a lower frequency and having a value at the lower frequency and a position dependent upon the ratio of the maximum and minimum amplitudes of the standing wave at said lower frequency, the second impedance being anti-resonant at the first mentioned frequency.

10. In a radio transmission system, means for supplying two currents of different wave-length, a load, a main line connecting said means and load, an auxiliary line impedance for suppressing the standing wave of the shorter wave-length connected in shunt to said main line at a point less than one-eighth of said wave-length from a maximum current point of said wave, a second auxiliary line impedance for suppressing the standing wave of the longer wave-length having a length equal to one-quarter or a multiple

thereof of the shorter wave-length, said auxiliary line being connected at an intermediate point thereof in shunt to the main line at a point on said main line nearer said means and less than one-eighth of the longer wave from a maximum current point of said longer wave.

11. A radio transmission system comprising means for supplying a plurality of currents having different wave-lengths, a load, a main line connecting said means and load, a distributed impedance for suppressing the standing wave having the shortest wave-length connected to said main line at a point less than one-eighth of said wave-length from a maximum current point of said standing wave, a second distributed impedance for suppressing a standing wave having a longer wave-length connected to said main line at a point nearer said means and less than one-eighth of said longer wave-length from a maximum current point of the standing wave of longer wave-length, said second impedance comprising an open line having a length equal to one-half or an odd multiple thereof of said shorter wave-length and a line connected to the mid-point of said open line, the length of said last mentioned line being dependent upon the ratio of the two wave-lengths.

12. A radio transmission system in accordance with claim 11, a shunt distributed impedance for suppressing a standing wave having the longest wave-length connected to said main line at a point still nearer the said means and less than one-eighth of said last mentioned wave-length from a maximum current point of said longest wave, said shunt impedance being anti-resonant at frequencies corresponding to said shortest and longest wave-lengths.

13. In a radio system, a main line, a multi-frequency source, a complex load having an impedance unequal to that of said main line, a plurality of branch lines each connected between said load and included in said main line, and means included in each branch line for suppressing at more than one of the transmitted frequencies standing waves produced by waves traveling on the branch line.

14. In a radio system, a main line connecting a multi-frequency source to a load impedance, branch lines included in said main line, transforming means comprising distributed impedance included in each branch line for transforming at two frequencies the load impedance into the line characteristic impedance, filtering means comprising distributed impedance included in each branch line for preventing the flow of current of the remaining frequencies, and impedance means included in each branch line for eliminating at the two first mentioned frequencies the effect of said filtering means.

15. In a radio system, a main line connecting a source for supplying current of source for supplying current frequencies f_1 , f_2 , f_3 and f_4 to a load, two branch lines included in said main line, means included in one branch line for preventing the flow of current of frequencies f_1 and f_2 and for suppressing standing waves on said main line having frequencies f_3 and f_4 , and means included in the other branch line for preventing the flow of current having frequencies f_3 and f_4 and for suppressing standing waves having frequencies f_1 and f_2 .

16. In combination, a transmission line, means for impressing alternating currents of a plurality of predetermined frequencies on said line, a load connected with the end of said line, means for

matching the load impedance to the surge impedance at all and any one of said frequencies without impeding the passage of currents of said frequencies through the line, the impedance matching means consisting solely of fixed impedance devices permanently bridged across the line, and portions of the line conductors between impedance device junctions therewith and the load.

17. In combination, a transmission line, means for compressing alternating currents of a plurality of predetermined frequencies on said line, a load connected with the end of said line, means for matching the load impedance to the surge impedance at all and any one of said frequencies without impeding the passage of currents of said frequencies through the line, the impedance matching means consisting solely of fixed impedance devices permanently bridged across the line, portions of the line conductors between impedance device junctions therewith and the load, and a fixed impedance device permanently bridged across a portion of at least one of said impedance devices.

18. In combination, a transmission line, means for impressing alternating currents of a plurality of predetermined frequencies on said line, a load connected with the end of said line, means for matching the load impedance to the surge impedance at all and any one of said frequencies without impeding the passage of currents of said frequencies through the line, the impedance matching means consisting solely of wire networks permanently bridged across the line, and portions of the line conductors between network junctions therewith and the load.

19. In combination, a transmission line, means for impressing alternating currents of a plurality of frequencies on said line, and a plurality of fixed impedance devices permanently bridged across the line and so proportioned that they present substantially infinite impedance, each at a different frequency.

20. In combination, a transmission line, means for impressing high frequency alternating currents of two predetermined frequencies on one end of said line, a load connected with the other end of said line, means for matching the load impedance to the surge impedance at both and either one of said frequencies without impeding the passage of currents of said frequencies through the line, the impedance matching means consisting of two units each consisting solely of a fixed impedance device permanently bridged across the line and the line conductors between the junction of the impedance device therewith and the load.

21. In combination, a transmission line, means for impressing high frequency alternating currents of a plurality of predetermined frequencies on one end of said line, a load connected with the other end of said line, means for matching the load impedance to the surge impedance at all and any one of said frequencies without impeding the passage of currents of said frequencies through the line, the impedance matching means consisting solely of a fixed impedance device for each frequency permanently bridged across the line and the line conductors between the junction of each impedance device with the line and the load, and an increasing number of impedance elements bridged across a portion of each different impedance device, none across the first, one across the second, two across the third, three across the fourth.

22. In combination, a transmission line, means

for impressing alternating currents of a plurality of predetermined frequencies on said line, a load connected with the end of said line, means for matching the load impedance to the surge impedance at all and any one of said frequencies without impeding the passage of currents of said frequencies through the line, the impedance matching means consisting solely of a fixed impedance device for each frequency permanently bridged across the line and line conductors between the junction of each impedance device therewith and the load.

23. In combination, a transmission line, means for impressing alternating currents of a plurality of predetermined frequencies on one end of said line, a load connected with the other end of said line, means for matching the load impedance to the surge impedance at all and any one of said frequencies without impeding the passage of currents of said frequencies through the line, the impedance matching means consisting solely of fixed impedance device for each frequency permanently bridged across the line and line conductors between the junction of each impedance device therewith and the load, each impedance device being substantially infinite at another frequency than its matching frequency.

24. In combination, a transmission line, means for impressing alternating currents at a plurality of predetermined frequencies on one end of said line, a load connected with the other end of said line, means for matching the load impedance to the surge impedance at all and any of said frequencies without impeding the passage of currents of said frequencies through the line, the impedance matching means consisting solely of a pair of straight conductors for each frequency permanently bridged across the line and line conductors between the junction of each pair of conductors therewith and the load, and impedance devices bridged across certain pairs of conductors.

25. In combination, a transmission line, means for impressing alternating currents of a plurality of predetermined frequencies on one end of said line, a load connected with the other end of said line, means for matching the load impedance to the surge impedance at all and any one of said frequencies without impeding the passage of currents of said frequencies through the line, the impedance matching means consisting solely of a pair of straight conductors for each frequency permanently bridged across the lines and the line conductors between the junction of each straight conductor pair therewith and the load, and conductor loops bridged across certain pairs of straight conductors.

26. In combination, a transmission line, means for impressing alternating currents of a plurality of frequencies on the line, a load connected to the end of the line, a fixed impedance device permanently bridged across one section of said line substantially matching the load impedance to the surge impedance when current of one frequency is impressed on the line, and presenting substantially infinite impedance at the other frequency, and a second fixed impedance device permanently bridged across another section of said line substantially matching the load impedance to the surge impedance when current of another frequency is impressed on the line and presenting substantially infinite impedance at said one frequency.

27. In combination, a two-wire transmission line, means for impressing high frequency alter-

nating currents of two frequencies on the line, a load connected to the end of the line, a fixed impedance consisting of a wire network permanently bridged across one section of said line substantially matching the load impedance to the surge impedance when current of one frequency is impressed on the line, and presenting substantially infinite impedance at the other frequency, and a second fixed impedance also consisting of a wire network permanently bridged across another section of said line substantially matching the load impedance on the line and presenting substantially infinite impedance at said one frequency.

28. In combination, a transmission line, a plurality of alternating current devices of different frequencies, connections between said devices and the line, and fixed impedances permanently bridged across said connections, short-circuiting each connection at frequencies other than that of the associated device, and preventing the reflection of waves into the devices.

29. In combination, a transmission line, a plurality of sources of alternating current of different frequencies, connections between said sources and the line, a load connected to the end of the line, and fixed impedances permanently bridged across said connections effectively short-circuiting each connection at a frequency other than that of the associated source, and preventing the reflection of waves into the sources.

30. In combination, a high frequency load adapted for operation on a plurality of different frequencies, a transmission line connecting said load to high frequency apparatus, a first reactance permanently bridged across said line for matching the impedance of said line and load for one frequency to be used thereby, and a second reactance permanently bridged across said line and somewhat removed from said first reactance for matching the impedance of said system for another frequency, said second reactance being so designed as to present substantially infinite impedance to energy of said first frequency.

31. In combination, a high frequency load adapted for operation on a plurality of different frequencies, a transmission line connecting said load to high frequency apparatus, a first reactance permanently bridged across said line for matching the impedance of said line and load for one frequency to be used thereby, and a second reactance permanently bridged across said line and somewhat removed from said first reactance for matching the impedance of said system for another frequency, said second reactance being so designed as to present substantially infinite impedance to energy of said first frequency, characterized in this that both of said reactances consist of two conductor line sections.

32. In combination, a high frequency load adapted for operation on a plurality of different frequencies, a transmission line connecting said load to high frequency apparatus, a first reactance permanently bridged across said line for matching the impedance of said line and load for one frequency to be used thereby, and a second reactance permanently bridged across said line and somewhat removed from said first reactance for matching the impedance of said system for another frequency, said first reactance being designed to present substantially infinite impedance to energy of said other frequency and said second reactance being so designed as to present

infinite impedance to energy of said first frequency.

5 33. In a radio system, a line connecting a multi-frequency source to a load, a distributed impedance connected in shunt to said line between the source and the load for suppressing the standing wave of one frequency, a second distributed impedance connected in shunt to said line at a point between the source and the first-mentioned im-

pedance, for suppressing the standing wave of another frequency, each impedance having a value related to the ratio of the minimum and maximum amplitudes of the standing wave suppressed thereby and at least one of the impedances having a substantially infinite impedance value at the frequency at which the other impedance functions to suppress the standing wave. 5

PHILLIP H. SMITH.