June 19, 1934. E. J. STERBA 1,963,723

IMPEDANCE TRANSFORMER

Original Filed July 30, 1929

FIG. 1

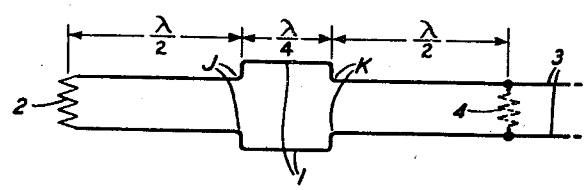
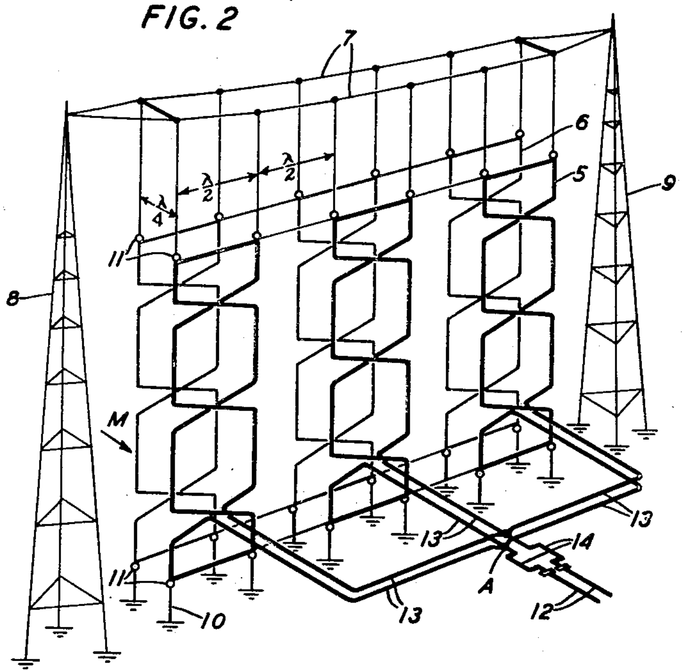


FIG. 2



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IMPEDANCE TRANSFORMER

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6 Claims. (Cl. 178—44)

This invention relates to transmission systems and particularly to radio frequency transmission systems. This application is a division of my application which issued as Patent 1,885,151, November 1, 1932.

As is well known, considerable energy loss results in the transmission of high frequency energy over transmission conductors which are open-ended or terminated by impedances having a value other than that of the surge impedance of the line. A part of this loss is due to the fact that the standing waves which are produced on the open-ended line by reflection radiate considerable energy. Heretofore, in order to obtain the proper surge impedance for the line, coil type impedance transformers or auto-transformers have been employed which, aside from being inaccurate, are comparatively costly.

It is one object of this invention to eliminate standing waves on transmission lines without the use of the conventional coil type surge impedance transformers.

It is another object of this invention to change the value of a load or terminating impedance, such as an antenna, to one equivalent to the surge impedance of the associated line in a simple and inexpensive manner.

According to one feature of this invention, a transmission line is connected to an antenna by means of a quarter wave length line whose surge impedance equals the square root of the product of the load and sending impedances of the line. The load impedance is thereby transformed into the proper impedance for terminating the line and as a result standing waves are eliminated from the line.

The invention will be more fully understood from the following description taken in connection with the drawing in which:

Fig. 1 represents a simple embodiment of the invention;

Fig. 2 a directional transmitting system and associated transmission line in which an impedance transformer is employed in accordance with the invention.

Referring to Fig. 1 an impedance transformer comprising two conductors 1, preferably made of copper tubing, is illustrated. The length of these conductors is a quarter wave length and their spacing is such that the resulting surge impedance is suitable for transforming the load impedance 2 into the surge impedance of line 3. The surge impedance of line 3 is represented on the drawing by dotted resistance 4. With respect to the line comprising conductors 1, the impedance of the line 3 is the sending impedance and impedance 2 is the load impedance. The surge impedance of the transformer comprising the two quarter wave length conductors may be determined mathematically as follows:

The sending end impedance Z_1 of any transmission line such as the line comprising conductors 1 having a known terminating impedance such as impedance 2 is given on page 99 of Fleming's book entitled "The Propagation of Electric Currents in Telephone and Telegraph Conductors" 3rd Edition, as Equation (61), which is:

$$Z_1=Z_0\frac{Z_r\cosh Pl+Z_0\sinh Pl}{Z_0\cosh Pl+Z_r\sinh Pl} \qquad (1)$$

where

Z_1=sending impedance
Z_0=surge impedance of the line
Z_r=terminating impedance of the line
P=propagation constant per unit length
l=length of the line

Dividing the numerator and denominator of the above equation by $\sinh Pl$ and rearranging we have

$$Z_1=\frac{\dfrac{Z_0Z_r\cosh Pl}{\sinh Pl}+Z_0^2}{\dfrac{Z_0\cosh Pl}{\sinh Pl}+Z_r}=\frac{Z_0^2+Z_0Z_r\coth Pl}{Z_r+Z_0\coth Pl} \qquad (2)$$

If there is no loss in the line the propagation constant is a pure imaginary, and

letting λ= the wave length
and B= the total phase shift
then $Pl=jB$, where B=

$$B=\frac{2\pi l}{\lambda}$$

But the

$$\coth jB=-j\cot B=-j\cot\frac{2\pi l}{\lambda}=\coth Pl$$

Substituting in Equation (2), we have

$$Z_1=\frac{Z_0^2-jZ_0Z_r\cot\dfrac{2\pi l}{\lambda}}{Z_r-jZ_0\cot\dfrac{2\pi l}{\lambda}} \qquad (3)$$

Assuming the length of the line is such that

$$l=\frac{n\lambda}{4}$$

and that "n" is any odd number, such as "1", then, in Equation (3)

$$\cot\frac{2\pi l}{\lambda}=\cot\frac{\pi}{2}=0$$

and, substituting in Equation (3), we have

$$Z_1=\frac{Z_0^2}{Z_r}$$

or

$$Z_0=\sqrt{Z_1 Z_r} \quad (4)$$

If "n" is any even number, as for example, "2", then, in Equation (3)

$$\cot\frac{2\pi l}{\lambda}=\cot\pi=\infty$$

And, substituting in, and separating the terms of Equation (3) we have,

$$Z_1=\frac{Z_0^2}{Z_r-jZ_0(\infty)}-\frac{jZ_0Z_r(\infty)}{Z_r-jZ_0(\infty)}=o-\frac{jZ_0Z_r(\infty)}{Z_r-jZ_0(\infty)}=Z_r$$

It appears, therefore, from the above that the terminating or receiver impedance "Z_r" will have the same value as the sending impedance "Z_1" at points an even multiple of a quarter wave length apart along a transmission line having a surge impedance Z_0. Also, if Z_1 is the ideal impedance for terminating a transmission line, the actual impedance Z_r in which the line is terminated may be transformed into this ideal impedance by connecting the impedance Z_r to a line a quarter wave length or an odd multiple thereof long and whose surge impedance is designed to have a value of Z_0 which satisfies Equation (4). Consequently, lines an odd multiple of a quarter wave length long may be employed as step-up or step-down impedance transformers, in place of the usual coil transformers or other similar cumbersome apparatus.

Referring again to Fig. 1, the impedance at point J will be the same as impedance 2 since point J is an even multiple of a quarter wave length from impedance 2 along the transmission line. This impedance is transformed by means of the quarter wave line transformer comprising conductors 1 into an impedance at point K, which, because of the half wave length separation, has a value equal to that of impedance 4 and is, by assumption, the proper impedance for terminating the transmission line 3.

In Fig. 2 a perspective view of a complete unidirectional radiating or absorbing array such as disclosed in my Patent 1,885,151 mentioned above, is shown, together with an associated transmission system in which one embodiment of the invention is utilized. The active antenna or exciter 5 consists of three panels arranged in a row and in the same vertical plane each panel comprising two vertical sections spaced a distance equal to one-half of the wave length for which the system is designed. For convenience, only three panels are shown but of course it should be understood that any number of panels within a certain limit may be employed. Each vertical section comprises four half wave radiating elements, the top and bottom elements being folded at the mid-point toward the center of the panel in such a manner that the outermost half of each top and bottom element is horizontal and therefore easily joined, as shown in the drawing, to the corresponding element of the adjacent section. Half wave length elements inclined slightly to the horizontal are utilized as transmission lines to connect alternate radiating elements of one vertical to the radiating elements of the adjacent vertical corresponding in position to the elements intermediate to said alternate elements.

An inactive antenna or reflector 6 also consisting of three panels is symmetrically located a quarter of a wave length to the rear of and parallel to the exciter; but unlike the exciter the panels of the reflector are not conductively associated with the transmission system.

The panel of the exciter and reflector are supported and kept in position in the usual manner by means of elevated support 7 extending between towers 8 and 9 and by means of grounded guy wires 10. Each panel is insulated from the ground wires and the elevated supports by means of insulators 11. The colinear radiating elements of each section and the horizontal elements on the same level are interconnected by suitable guy wires properly insulated, which for the sake of clearness, have been omitted from the drawing.

Directly associated with the exciter is a transmission system in which the impedance transformer is utilized. The system comprises a main trunk line 12 connected to a source of radio frequency energy which is not shown on the drawing and to three branch lines 13 at junction point A, one branch line 13 being associated with each panel. The reference numeral 14 refers to an impedance or line transformer which is inserted at junction A. The length of each branch line 13 is equal to an even multiple of one quarter of the wave length transmitted; and the length of the conductors comprising transformer 14 equals an odd multiple of a quarter wave length. The transmission system is illustrated as lying in the same horizontal but this is not a necessary condition and at convenient points the line may extend in a vertical direction.

In the operation of the system shown in Fig. 2 energy supplied from the power source over line 12 is transmitted by virtue of impedance transformer 14 to the individual panel of the exciter with substantially no reflection loss. As seen from junction A the terminating impedance is equivalent to the three panel impedances in parallel since each of the three branch lines is an even multiple of a quarter wave length long. This terminating or load impedance is transformed by means of transformer 14 into an impedance equivalent to the surge impedance of the main line 12.

The energy supplied to the exciter 5 is radiated in the manner already explained in my copending application mentioned above. Energy is propagated from the vertical elements only, the radiation from the horizontal elements being neutralized. The system is uni-lateral and because of the number of verticals a concentrated directional effect is obtained in a low lying angle of fire in the direction represented by arrow M.

Although the invention has been illustrated and described in connection with a particular type of radio system it is to be understood that it is applicable to any high frequency aerial or transmission system and that it is not to be limited to the specific embodiment described.

What is claimed is:

1. The method of preventing wave reflection on a transmission line connected to a load impedance utilizing another transmission line a quarter wave length long or an odd multiple thereof, which comprises determining the surge impedance of the first mentioned line, spacing the conductors of the second mentioned line so that the square of its surge impedance divided by the load impedance equals the surge impedance of the first mentioned line and inserting the second mentioned line between the first mentioned line and the load impedance.

2. In a high frequency transmission system, a

first line a quarter wave length long or an odd multiple thereof, a terminating impedance connected to one terminal of said line, a second line connected to the opposite terminal of said first line, the square of the surge impedance of the first line being equal to the product of the terminating impedance and the surge impedance of the second line.

3. In a high frequency transmission system, a line comprising a plurality of conductors each having a length equal to one quarter of the wave length for which the system is designed or an odd multiple thereof, a load impedance connected to the said line, a source of energy, a main line connected between said quarter wavelength line and the source, the load impedance and the surge impedance of said main line having different values, the spacing of the conductors being arranged to prevent reflection of waves into said source.

4. In a high frequency transmission system, a transformer comprising a pair of conductors each having a length equal to a quarter wave length or an odd multiple thereof, an impedance, a source of energy, the impedance being connected to one end of the transformer, a transmission line connecting said source to the other end of the transformer, said transformer having a surge impedance equal to the square root of the product of the impedance and the surge impedance of the line.

5. In a high frequency system, an antenna, a translation system, an impedance transformer comprising a plurality of conductors a quarter wave length long or an odd multiple thereof, transmission lines connecting said antenna and translation system to opposite terminals of said transformer, the square of the surge impedance of the transformer divided by the antenna impedance being equal to the surge impedance of the transmission line connecting said transformer and translation system.

6. In a high frequency system, a plurality of radiating elements, an impedance transformer comprising a plurality of lines a quarter wave length long or an odd multiple thereof, a transmitter, a transmission line connecting each of said elements to said transformer, a transmission line connecting said transmitter to said transformer, the electrical constants of said transformer being such that the square of the surge impedance of the transformer equals the product of the surge impedance of the last mentioned transmission line and the resultant impedance of the radiating elements.

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