Oct. 15, 1946. P. S. CARTER 2,409,542

HIGH FREQUENCY TRANSDUCER SYSTEM

Filed Nov. 20, 1942

Fig. 1.

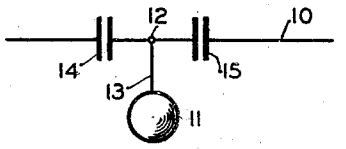


Fig. 2.

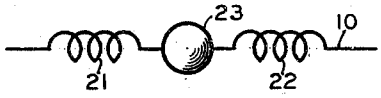


Fig. 3.

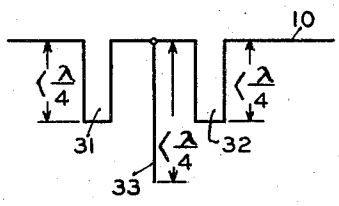


Fig. 4.

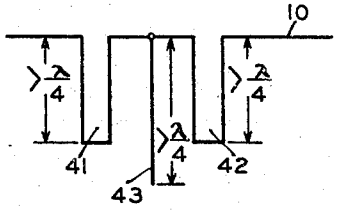


Fig. 5.

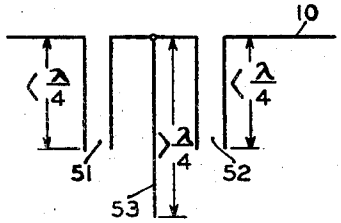
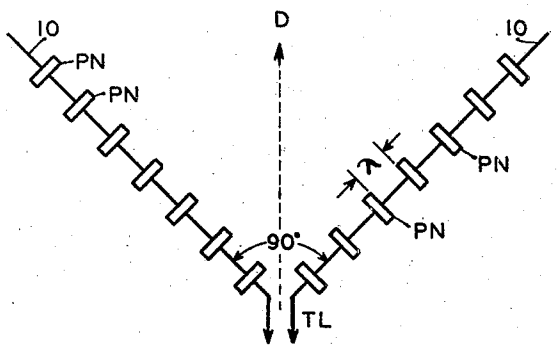


Fig. 6.



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HIGH-FREQUENCY TRANSDUCER SYSTEM

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Application November 20, 1942, Serial No. 466,321

13 Claims. (Cl. 250—11)

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The present invention relates to a means for shifting the phase of energy in high frequency transducer means and, more particularly, to phase shifting circuits for use in antenna systems.

An object of the present invention is to improve the directivity of antenna arrays.

Another object of the present invention is the provision of means for shifting the phase of high frequency energy in transmission lines without causing reflection.

Still another object of the present invention is the provision of means for causing predetermined phase differences of high frequency energy in different sections of an antenna array.

Still a further object of the present invention is the provision of means, as aforesaid, adapted to be placed between antenna sections, which will operate without the introduction of large amounts of reflection at the points where said means are inserted.

The foregoing objects and others which may appear from the following detailed description are attained in accordance with the principles of the present invention by providing phase shifting networks at points along a single wire in free space, said networks approximating in their action $\top$ or Π type circuits heretofore used in two wire circuits or one wire and ground transmission line systems. Such phase shifting networks may be used in long wire antenna systems to improve the directivity characteristic or they may be used to vary the directivity characteristic as desired. There are a number of antenna systems known in the prior art wherein the phase is shifted at certain positions along the wires by means of series capacity inductance coils or folded up sections of the antenna wire itself. When such methods of shifting phase are used high reflection takes place at each position of phase shift. This results in a considerable falling off in the current as it proceeds from the feed point of the system toward the far end. This undesirable action greatly decreases the directivity and the efficiency of the antenna system.

According to the present invention a three leg circuit, having suitably proportioned reactances in each leg, is used for shifting phase. By the proper proportioning of the reactances in each leg of the circuit the characteristic impedance may be made to match the characteristic impedance of the antenna wire. In this way the desirable phase shift may be obtained without reflection and substantially equal currents will result in each antenna section.

The present invention will be more fully understood by reference to the following detailed description which is accompanied by a drawing wherein Figure 1 illustrates in diagrammatic form an embodiment of the invention which may be used for advancing the phase of energy along a single wire conductor, while Figures 2 and 3 illustrate a modification which may be used for retarding the phase, Figures 4 and 5 illustrate further modifications of the present invention for advancing the phase of energy in a single wire line, and Figure 6 illustrates in plan view one application of the principles of the present invention to a V type antenna.

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In Figure 1 is shown a phase advancing circuit in a conductor 10 which may be one conductor of a V type antenna, or the single ungrounded conductor of a wave antenna. The shunt reactance required for advancing the phase is obtained by the use of a disc or sphere 11, having a high capacity to the surrounding space, connected to the antenna wire 10 at junction point 12 by means of a connecting wire 13. The connecting wire 13 is in effect an inductance in series with the capacity provided by metallic body 11. The effective value of inductance is determined by the length of wire 13. At either side of junction 12 is placed a series condenser such as that indicated by 14 or 15. Condensers 14 and 15 are of equal capacity.

If it is desired to retard the phase along conductor 10 the circuit of Figure 2 may be used. In this circuit two series inductive reactances 21 and 22 are inserted along the length of conductor 10. Between the two inductances 21 and 22 is located a metallic body 23 in the form of a sphere or disc. The metallic body 23 has a considerable capacity to the surrounding space, the value of capacity being determined by the size of the metallic body.

In Figure 3 is shown a modification of the structure of Figure 2 wherein the inductances 21 and 22 of Figure 2 are substituted by closed loops 31 and 32 each of equal length. Their length is so chosen as to be less than one quarter of the operating wavelength whereby their effect in the circuit is equivalent to that of series inductances. A straight wire 33 has been substituted for the metallic body 23 of Figure 2, the length being somewhat less than a quarter of the operating wavelength of the system whereby its effect is that of a shunt capacity to ground.

In Figure 4 there is shown another structure for obtaining the same result as that obtained from Figure 1. Here, the series loops 41 and 42 each have a length greater than a quarter of the oper-

ating wavelength whereby their effect is capacitive and the straight open wire **43** has a length greater than the quarter wavelength whereby it is equivalent to a shunt inductance.

Figure 5 shows a further structure for obtaining the same result as that of Figure 1 and Figure 4, that is, advancing the phase of energy flowing along conductor **10**. Here, the series capacities are provided by open sections of lines **51** and **52** each having a length less than a quarter of the operating wavelength. The straight open ended conductor **53**, having a length greater than a quarter of the operating wavelength, operates in the same manner as conductor **43** of Figure 4 to produce the equivalent of a shunt inductance.

In applying these circuits to practice, the characteristic impedance of the circuit is made equivalent to the characteristic impedance of the antenna wire **10** by properly proportioning the series and shunt reactance elements. Thus no reflection is introduced at the point of insertion of each phase shifting unit, and the currents in wire **10** at each side of the point of insertion are equal.

There is a large number of applications of the present invention, of which one is shown in Figure 6 as an example. Assume that it is desired to design a V antenna with the radiating conductors 8 wavelengths long. The antenna is connected by means of transmission line TL to suitable transducer means such as a transmitter or receiver. Without phase shifting devices in the wires the most effective included angle between the wires would be of the order of 35 degrees for a maximum additive effect of the main radiation lobes. If the angle between the wires is made 90 degrees as used in antennas having wires one wavelength long and the phase along the wires is advanced at 7 points along the antenna wire by means of phase shifting networks PN, as shown in Figure 6, so that the combined radiation from each pair of one wavelength conductors is in phase with all of the others, a much more directive system results. Phase shifting networks PN may be of the type shown in Figures 1, 4 or 5. Furthermore, the radiation resistance of the antenna system as a whole is very greatly increased because of the improved phase relationship between adjacent sections.

While I have particularly shown and described several modifications of my invention, it is to be distinctly understood that my invention is not limited thereto but that improvements within the scope of the invention may be made.

I claim:

1. A phase shifting network for insertion in a single wire carrying high frequency energy including series reactance elements and at least one reactance element adapted to function as a shunt reactance in said network, said last named element including a length of conductor having a substantial capacity to the surrounding space, said series reactance elements including conductors so disposed as to have inappreciable radiation resistance and having a length greater than one quarter of the operating wavelength whereby they are inductive in effect the reactances of said elements being so proportioned that the characteristic impedance of said network is equal to the impedance of said single wire to prevent reflection of energy at the point of insertion of said network.

2. A phase shifting network for insertion in a single wire carrying high frequency energy including series reactance elements and at least one reactance element adapted to function as a shunt reactance in said network, said last named element including a length of conductor having such length that its effect on said network is inductive, said series reactance elements including conductors so disposed as to have inappreciable radiation resistance and having a length less than one quarter of the operating wavelength whereby they are capacitive in effect the reactances of said elements being so proportioned that the characteristic impedance of said network is equal to the impedance of said single wire to prevent reflection of energy at the point of insertion of said network.

3. A phase shifting network for insertion in a single wire carrying high frequency energy including series reactance elements and at least one reactance element adapted to function as a shunt reactance in said network and connected to said wire between said series reactance elements, said last named element including a length of conductor having a length greater than one quarter of the operating wavelength so that its effect on said network is inductive the reactances of said elements being so proportioned that the characteristic impedance of said network is equal to the impedance of said single wire to prevent reflection of energy at the point of insertion of said network.

4. A phase shifting network for insertion in a single wire carrying high frequency energy including series reactance elements and at least one reactance element adapted to function as a shunt reactance in said network, said last named element including a length of conductor having such length that its effect on said network is inductive and terminated at its free end by a body having a substantial capacity to surrounding space, said series reactance elements including conductors so disposed as to have inappreciable radiation resistance and having a length less than one quarter of the operating wavelength whereby they are capacitive in effect the reactances of said elements being so proportioned that the characteristic impedance of said network is equal to the impedance of said single wire to prevent reflection of energy at the point of insertion of said network.

5. A phase shifting network for insertion in a single wire carrying high frequency energy including series reactance elements and at least one reactance element adapted to function as a shunt reactance in said network, said last named element including a length of conductor having a length greater than one quarter of the operating wavelength so that its effect on said system is inductive and terminated at its free end by a body having a substantial capacity to surrounding space, said series reactance elements including conductors so folded as to have inappreciable radiation resistance and having a length less than one quarter of the operating wavelength whereby they are capacitive in effect the reactances of said elements being so proportioned that the characteristic impedance of said network is equal to the impedance of said single wire to prevent reflection of energy at the point of insertion of said network.

6. A phase shifting network for insertion in a single wire carrying high frequency energy including series reactance elements and at least one reactance element adapted to function as a shunt reactance in said network, said last named element including a length of conductor having such length that its effect on said network is capacitive, said series reactance elements in-

cluding conductors so folded as to have inappreciable radiation resistance and having a length greater than one quarter of the operating wavelength whereby they are inductive in effect the reactances of said elements being so proportioned that the characteristic impedance of said network is equal to the impedance of said single wire to prevent reflection of energy at the point of insertion of said network.

7. A phase shiftinging network for insertion in a single wire carrying high frequency energy including series reactance elements and at least one reactance element adapted to function as a shunt reactance in said network and connected to said wire between said series reactance elements, said last named element including a length of conductor having such length that its effect on said network is inductive, said series reactance elements including sections of two wire transmission line having lengths less than a quarter of the operating wavelength open circuited at one end and at the other end connected in series with said single wire the reactances of said elements being so proportioned that the characteristic impedance of said network is equal to the impedance of said single wire to prevent reflection of energy at the point of insertion of said network.

8. A phase shifting network for insertion in a single wire carrying high frequency energy including series reactance elements and at least one reactance element adapted to function as a shunt reactance in said network, said last named element including a free ended conductor having a length greater than one quarter of the operating wavelength whereby its effect in the network is inductive, said series reactance elements including sections of two wire transmission line having lengths less than a quarter of the

operating wavelength open circuited at one end and at the other end connected in series with said single wire the reactances of said elements being so proportioned that the characteristic impedance of said network is equal to the impedance of said single wire to prevent reflection of energy at the point of insertion of said network.

9. An antenna system including a wire having a length at least equal to several times the operating wavelength of said system, and phase shifting networks connected to said wire at intervals of one wavelength, said phase shifting networks being constituted according to claim 2.

10. An antenna system including a wire having a length at least equal to several times the operating wavelength of said system, and phase shifting networks connected to said wire at intervals of one wavelength, said phase shifting networks being constituted according to claim 4.

11. An antenna system including a wire having a length at least equal to several times the operating wavelength of said system, and phase shifting networks connected to said wire at intervals of one wavelength, said phase shifting networks being constituted according to claim 5.

12. An antenna system including a wire having a length at least equal to several times the operating wavelength of said system, and phase shifting networks connected to said wire at intervals of one wavelength, said phase shifting networks being constituted according to claim 7.

13. An antenna system including a wire having a length at least equal to several times the operating wavelength of said system, and phase shifting networks connected to said wire at intervals of one wavelength, said phase shifting networks being constituted according to claim 8.

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