

March 26, 1940.

H. E. CURTIS

2,194,543

HIGH FREQUENCY NETWORK STRUCTURE

Filed April 13, 1938

2 Sheets-Sheet 1

FIG. 1

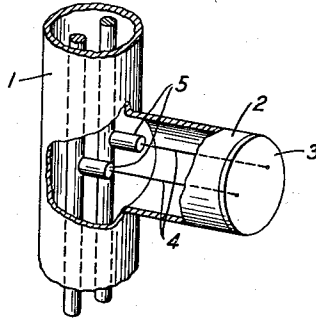


FIG. 2

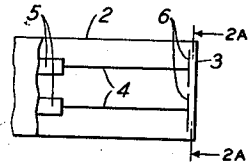


FIG. 2A

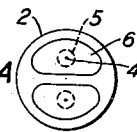


FIG. 2B

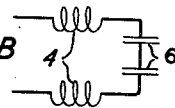


FIG. 3

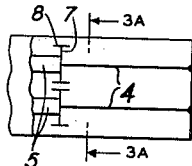


FIG. 3A

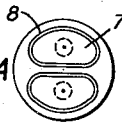


FIG. 3B

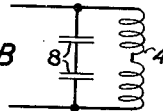


FIG. 4

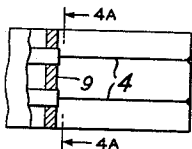


FIG. 4A

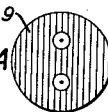


FIG. 4B

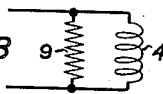


FIG. 5

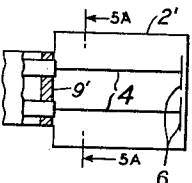


FIG. 5A

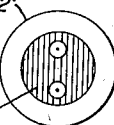


FIG. 5B

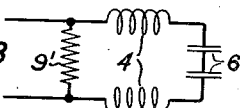


FIG. 6

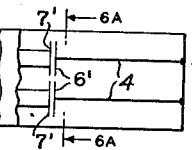


FIG. 6A

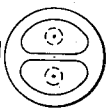


FIG. 6B

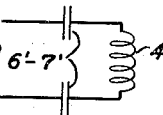


FIG. 7

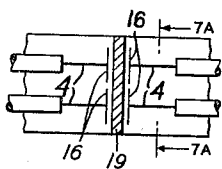


FIG. 7A

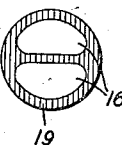
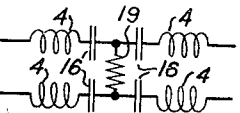


FIG. 7B



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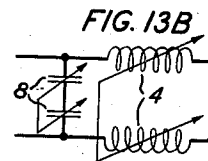
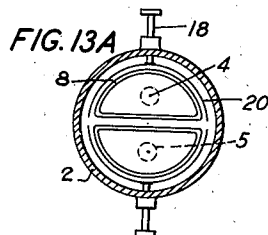
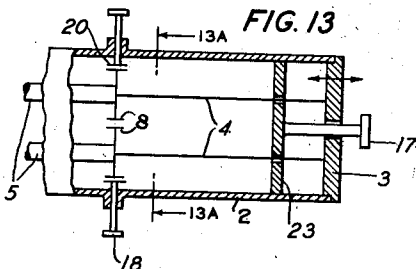
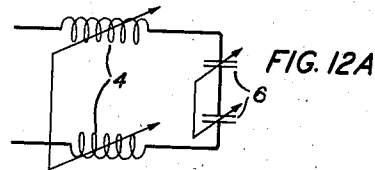
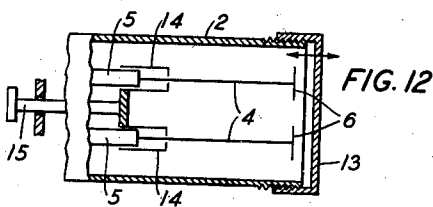
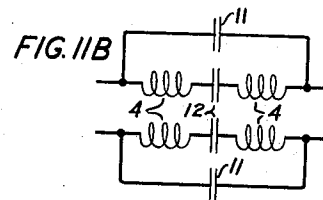
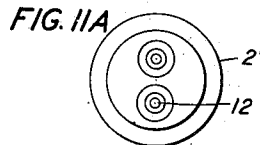
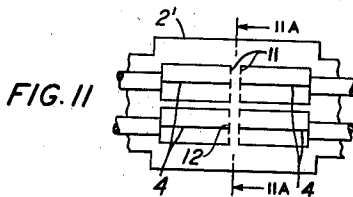
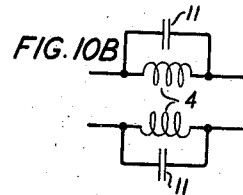
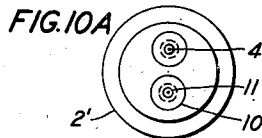
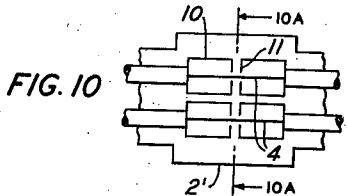
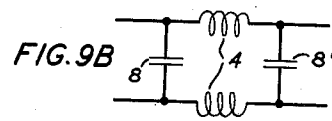
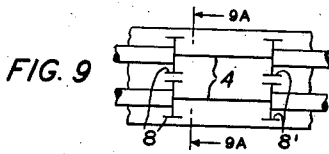
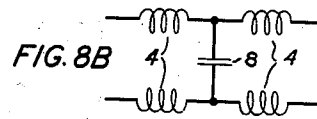
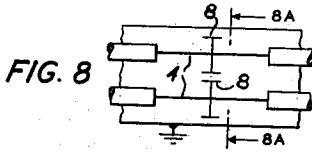
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## UNITED STATES PATENT OFFICE

2,194,543

## HIGH FREQUENCY NETWORK STRUCTURE

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Application April 13, 1938, Serial No. 201,763

10 Claims. (Cl. 178-44)

This invention relates to high frequency electrical translating systems and more particularly to reactive elements and networks appropriate for oscillatory, terminating and translation circuits in radio frequency signaling systems.

An object of the invention is to provide a unitary structure that has frequency selective characteristics and that is electrically balanced or symmetrical with respect to ground potential. A more specific object is to provide a structure of this kind that is adapted for use in conjunction with balanced transmission circuits generally and more especially with balanced transmission circuits comprising a pair of shielding conductors.

Another object is to provide for ready variability of the frequency selective properties of such elements and networks.

In accordance with the present invention the foregoing objects and other objects that will appear hereinafter are realized in various structures utilizing the reactive properties of short sections of transmission lines. It can readily be shown that a short-circuited transmission line, the length of which is short compared with the length of the waves applied to it, has the characteristic of a substantially pure inductance, and that the magnitude of the inductance is substantially proportional to the absolute length of the line. In the important case of a short-circuited transmission line comprising a pair of cylindrical conductors symmetrically disposed within a cylindrical conducting shield, a maximum inductive effect, for a shield of given diameter, is obtained when the spacing ratio is 0.486, that is, when the conductors are so arranged that 0.486 represents the ratio of the separation between each conductor and the axis of the shield on the one hand and the internal radius of the shield on the other. For such a short-circuited transmission line the total inductive effect  $L$  at any frequency for which the length of the line is short compared with the wave-length is:

$$L = 4 \log_e 0.60 \times \frac{c}{b} \text{ abhenries per centimeter} \quad (1)$$

where  $c$  represents the inner diameter of the shield and  $b$  the outer diameter of the enclosed conductors. It is evident from Equation 1 that the larger the diameter ratio

$$\frac{c}{b}$$

the larger the inductance, and it will be noted that the inductance is a function of the length of the line.

The nature of the present invention will appear more fully in the following description of various typical preferred embodiments illustrated in the accompanying drawings.

Fig. 1 shows a shielded pair line with a two-terminal structure in accordance with the invention branching therefrom;

Figs. 2 to 6 show schematically longitudinal sections of modified forms of two-terminal network structures, Figs. 2A to 6A show corresponding cross-sectional views thereof, and Figs. 2B to 6B represent the respectively corresponding equivalent electrical circuits;

Figs. 7 to 11 show schematically longitudinal sections of four-terminal network structures in accordance with the invention, and Figs. 7A to 11A and Figs. 7B to 11B represent the respectively corresponding cross-sectional views and equivalent circuits thereof;

Figs. 12 and 13 show two-terminal network structures adapted for ready adjustment, Figs. 12A and 13B represent the respective equivalent circuits thereof, and Fig. 13A is a cross-sectional view corresponding to Fig. 13.

Referring now to Fig. 1, there is shown an elemental combination adapted to introduce a shunt inductance across a balanced transmission line 1 that comprises a pair of shielded conductors. The inductance element is in the form of a balanced transmission line structure branching from the line 1 and it comprises a cylindrical metallic shield 2, a metallic end cap 3, and a pair of fine wires 4 which are at one end attached to the end cap 3 and at the other end connected through metallic leads 5 of larger diameter to the respective conductors of line 1. Preferably the plane of the latter conductors is perpendicular to the axis of shield 2 and wires 4 so as to preserve electrical and mechanical symmetry. The magnitude of the shunt inductance provided by the arrangement illustrated in Fig. 1, it will be seen from Equation 1, depends on the length of the wires 4 and on the ratio of the respective diameters of the shield 2 and the wires 4. Operating frequencies of the order of a megacycle per second and higher are contemplated in this example and in the others that are to follow. Supposing, for specific example, that the frequency is 100 megacycles per second corresponding to a wave-length of 300 centimeters, it may be noted that if the short-circuited line structure were a quarter wave-length long, 75 centimeters, i. e., it would be anti-resonant and the electrical equivalent of an inductance and capacitance in parallel relation, and that if it were a half wave-length long it

would be resonant and the electrical equivalent of an inductance and capacitance in series relation. In the embodiment illustrated in Fig. 1, however, it is contemplated that the line structure shall be sufficiently less than a quarter wave-length that its electrical equivalent is substantially inductive.

Figs. 2 and 2A illustrate a modification of the structure shown in Fig. 1 in which the wires 4 are terminated in metallic plates 6 which lie parallel to but spaced apart from the end cap 3. With this arrangement the equivalent circuit, as indicated in Fig. 2B, comprises the inductance of the shielded wires in series relation with a capacitance dependent on the size and spacing of the plates 6. It is a feature of the construction that the capacitance elements are so disposed that they retain the electrical symmetry or balance of the structure with respect to ground, and that for any particular circuit application connection can be made to the electrical mid-point of the structure simply by connecting to the center of the end cap 3. It is a feature also that the condition of resonance can be attained by suitably determining the magnitude of the capacitance and without resort to sometimes unwieldy lines of half wave-length.

Another modification is illustrated in Figs. 3 and 3A where the equivalent circuit as shown in Fig. 3B comprises an inductance and capacitance in parallel relation. In this case the incoming leads 5 are terminated in a pair of transversely disposed metallic plates 7 which carry on their respective peripheries flanges 8 which are in capacitive relation with the shield and, along a diameter, with each other. With this combination it is possible to obtain the characteristics of a quarter wave-length line although the actual length of the line is much less than a quarter wave-length.

Figs. 4 and 4A illustrate how the structure shown in Fig. 1 can be modified in another direction to provide the circuit equivalent of an inductance and a resistance in parallel relation. For this purpose a disc 9 of resistive material is provided which constitutes a resistive shunt across the input end of the structure as shown in the equivalent circuit comprising Fig. 4B. Series resistance may be obtained in this case and in all other cases herein disclosed by constituting the wires 4 of a resistive metal or alloy.

Figs. 5 and 5A show the application of the resistance disc 9' to the damping of a tuned circuit structure of the kind shown in Fig. 2. In this case the tuned circuit, as shown in Fig. 5B, comprises balanced inductance and capacitance as in Fig. 2B with a resistive shunt across the input terminals. The structure illustrates also an application of the fact that a greater inductance per unit length may be obtained by increasing the diameter of the shield as well as by decreasing the size of the wires 4.

Figs. 6 and 6A show an alternative form of series tuned structure having an equivalent circuit of the kind shown in Fig. 6B. The capacitance elements in this case are provided by a pair of metallic plates 7' terminating the input leads, in combination with juxtaposed metallic plates 6' respectively connected to the wires 4.

A balanced four-terminal translation circuit is shown in Figs. 7 and 7A and the equivalent circuit thereof is shown in Fig. 7B. In this embodiment a transverse resistance disc 19 is provided near the center of the structure and the shielded wires 4 are broken and the four proximate ends

thereof terminated in metallic plates 16, each of which is in capacitive relation with the disc 19. The four sections of wire provide the four inductance elements of the equivalent circuit, the plates 16 provide the four series capacitances and the disc 19 constitutes the shunt resistance. The translation structure may be interposed in a two-wire shielded line, for example, and utilized for selectively passing a substantially single frequency determined by the relative magnitudes of the inductive and capacitive elements, or a wider band of frequencies dependent on the damping effect of the shunt resistance 19.

Two other forms of translation structures are shown in Figs. 8 and 8A and 9 and 9A, respectively, with respective equivalent circuits as in Figs. 8B and 9B. In Fig. 8 a shunt capacitance is provided at the electrical mid-point of the structure by a capacitance structure of the kind described with reference to Fig. 3, whereas in Fig. 9 two such capacitive structures 8 and 8', are utilized, one at the input terminal and the other at the output terminal. Both structures may be utilized, for example, as low-pass filters.

In Figs. 10 and 10A is shown a four-terminal network structure which is equivalent to two series inductance elements each shunted by a capacitance as indicated in Fig. 10B. The series inductance is obtained by means of the line wires 4 as hereinbefore, and the shunting capacitance by metallic cup-like members 10 each surrounding a portion of the wires 4 and each terminated in an annular lip or internal flange 11 disposed in capacitive relation with the corresponding portion of another axially aligned member 10. The amount of series capacitance is largely determined by the areas and spacings of the lips 11.

Figs. 11 and 11A illustrate a modification of the network structure shown in Fig. 10, the modification being that the wires 4 are each interrupted at their mid-points by a pair of juxtaposed plates 12 which effectively introduce a series capacitance in the inductive arms of the network as appears in the equivalent circuit shown in Fig. 11B. The equivalent circuit is otherwise the same as that in Fig. 10B and is similarly derived.

Whereas the network structures shown hereinbefore have been described as being of the fixed type, Figs. 12 to 13A show two preferred forms of structures in which the reactance elements are capable of ready adjustment for any particular circuit application. The structure shown in Fig. 12 provides inductance and capacitance in series relation as indicated in Fig. 12A. From the input leads 5 the pair of line wires 4 extend to the right and are terminated in metallic plates 6 disposed in capacitive relation with an adjustable metallic end cap 13 which may be adjusted to vary its separation from the plates 6 and thereby to vary the magnitude of the series capacitance in the circuit. To vary the effective length of the wires 4 and thereby to vary the amount of series inductance in the circuit, metallic cylindrical caps 14 are provided, each adapted to slide over the end of one of the input leads 5 with one of the wires 4 extending through a central aperture in the end of the cap. A rod 15 of insulating material mechanically connected with the caps serves to adjust their positions.

The structure shown in Figs. 13 and 13A has the characteristics of a capacitance and inductance in parallel relation. The inductive wires 4 are permanently connected between the input leads 5 and the metallic cap 3, and a metallic piston 23 having openings therein through which

the wires 4 pass serves to adjust the effective length of the line and thereby to vary the amount of series inductance in circuit. An insulating rod 17 extending from the piston 23 through an aperture in the end cap 3 can be used to effect the necessary adjustments. The shunt capacitance element comprises a structure of the general kind illustrated in Fig. 3, but arcuate metallic members 20 are disposed between each metallic plate and the shield 2. Respective radially disposed rods 18 of insulating material extend through apertures in the shield and are connected with the respective arcuate members 20 so that the relative positions thereof between the flanges 15 8 and the shield 2 may be adjusted. The total amount of shunt capacitance is dependent on the positions of the members 20.

Whereas only a few typical embodiments have been illustrated and described in this specification, it will be understood that the invention comprehends such other embodiments as come within the spirit and terms of the appended claims.

What is claimed is:

1. In a system for the transmission of ultra-short electromagnetic waves over a pair of conductors enclosed within a metallic sheath, a localized reactive circuit therefor comprising a metallic chamber electrically associated with said sheath and a pair of conductors within said chamber that are electrically connected with the first-mentioned pair of conductors and that are short as compared with the length of said waves, the ratio of the transverse dimensions of said chamber to the diameter of the conductors enclosed thereby being of a greater order of magnitude than the corresponding ratio of the transverse dimensions of said sheath and the conductors enclosed thereby, said termination having the electrical properties of an inductance electrically balanced with respect to ground potential.

2. A combination in accordance with claim 1 including in addition a balanced capacitive element, said element comprising a pair of metallic means each electrically connected with a respective one of said conductors within said sheath and having juxtaposed surfaces providing a lumped capacitance, said metallic means being symmetrically disposed with reference to said chamber to preserve the electrical balance of the system.

3. A combination in accordance with claim 1 including in addition a transverse resistive barrier disposed across said chamber and in electrical contact with both of the conductors enclosed thereby.

4. In a high frequency transmission system, a network structure having the characteristics of inductance and capacitance in series relation symmetrically disposed with respect to ground, said structure comprising a section of shielded pair, a metallic cap closing one end of the shield thereof and a pair of metallic plates each in capacitive relation with the inner surface of said cap and connected respectively to the proximate terminals of the conductors comprising said pair, whereby a series inductance effect is derived from said conductors and a series capacitive effect from said metallic plates and cap, all of said conductors and plates being so constructed and arranged as to provide electrical and mechanical symmetry.

5. In a high frequency transmission system, a network structure having the characteristics of inductance and capacitance in parallel relation

and symmetrically disposed with respect to ground, said structure comprising a section of shielded pair, a metallic cap closing one end of the shield thereof and constituting a short circuit for the conductors comprising said pair, a pair of metallic plates each disposed transversely and connected to one of said conductors, a peripheral metallic flange on each said plates, said flanges being in capacitive relation with each other and with said shield whereby a balanced shunt capacitance effect is obtained, and the length of said conductors between said end cap and said plates being small compared with the operating wavelength whereby a balanced shunt inductive effect is obtained.

6. A combination in accordance with claim 5 comprising in addition a metallic plate interposed between each of said flanges and said shield, and means for adjusting the relative distances between the flanges and the plates and between the plates and the shield, whereby the magnitude of the equivalent shunt capacitance can be controlled.

7. In a transmission line comprising a shielded pair for transmission of waves at frequencies above a megacycle per second, a low-pass filter structure incorporated in said line, said filter structure comprising a length of said line short compared with the operating wave-length, in which the conductors comprising said pair are of substantially reduced diameter so as to obtain an enhanced series inductive effect, and at least one shunt capacitance structure within said length of line, said capacitance structure comprising a pair of metallic plates transversely disposed and connected with a respective one of said conductors, and a peripheral metallic flange on each of said plates, said filter structure being so constructed and arranged as to preserve the electrical balance, with respect to ground, of the line in which it is incorporated.

8. In a line comprising a shielded pair for the transmission of ultra-high frequency waves, an electrically balanced network structure incorporated in said line and having electrical properties of a network comprising a capacitance in one series arm and an inductance in a parallel-connected series arm, said structure comprising a portion of said line, the length of which is small compared with the operating wave-length, in which the conductors comprising said pair are of greatly reduced diameter whereby a series inductive effect is obtained, and a pair of metallic cup-like members coaxially disposed around each of said conductors with their open ends juxtaposed, each of said members having at its open end an internal metallic flange in capacitive relation with the flange of the other member comprising the pair, whereby a series capacitive effect dependent on the area and spacing of said flanges is obtained.

9. In an ultra-high frequency transmission system, a transmission line comprising a shielded pair and a network structure at the end thereof having the characteristics of inductance and capacitance in series relation symmetric with respect to ground potential, said structure comprising a section of said shielded pair, the length of which is small compared with the operating wave-length, in which the conductors comprising said pair are of greatly reduced diameter, a metallic barrier closing the end of the shield, a pair of metallic plates connected to said conductors and in capacitive relation with the inner face of said barrier, said barrier being adapted

- for longitudinal adjustment to control the series capacitance introduced by said plates, a metallic extension coaxially disposed on each of said conductors and arranged to slide over the ends of the conductor portions of normal diameter whereby the effective length of said conductors of reduced diameter and the corresponding series inductive effect can be adjusted independently of the adjustment of series capacitance.
- 10 10. In a high frequency transmission system, a shielded pair comprising conductors of normal diameter and a network structure at the end thereof having the electrical characteristics of inductance and capacitance in parallel shunt relation and in balanced relation with respect to ground, said structure comprising a section of shielded pair the length of which is small compared with the operating wave-length, the conductors of said section being of small diameter as compared with said conductors of normal diameter, short-circuiting means comprising a metallic piston having apertures through which said conductors of small diameter pass and means for adjusting the longitudinal position of said piston to control the inductance of the network structure, a pair of transversely disposed metallic plates at the respective junctions of said conductors of normal and small diameter, a peripheral flange on each of said plates and a metallic plate between each of said flanges and said shield, and means for adjusting the position of said plates to control the shunt capacitance of said structure independently of the adjustment of the inductance.
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