Oct. 25, 1949. K. POSTHUMUS 2,485,773

DEVICE FOR THE ALTERNATING VOLTAGE SUPPLY OF A LOAD

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Fig. 1.

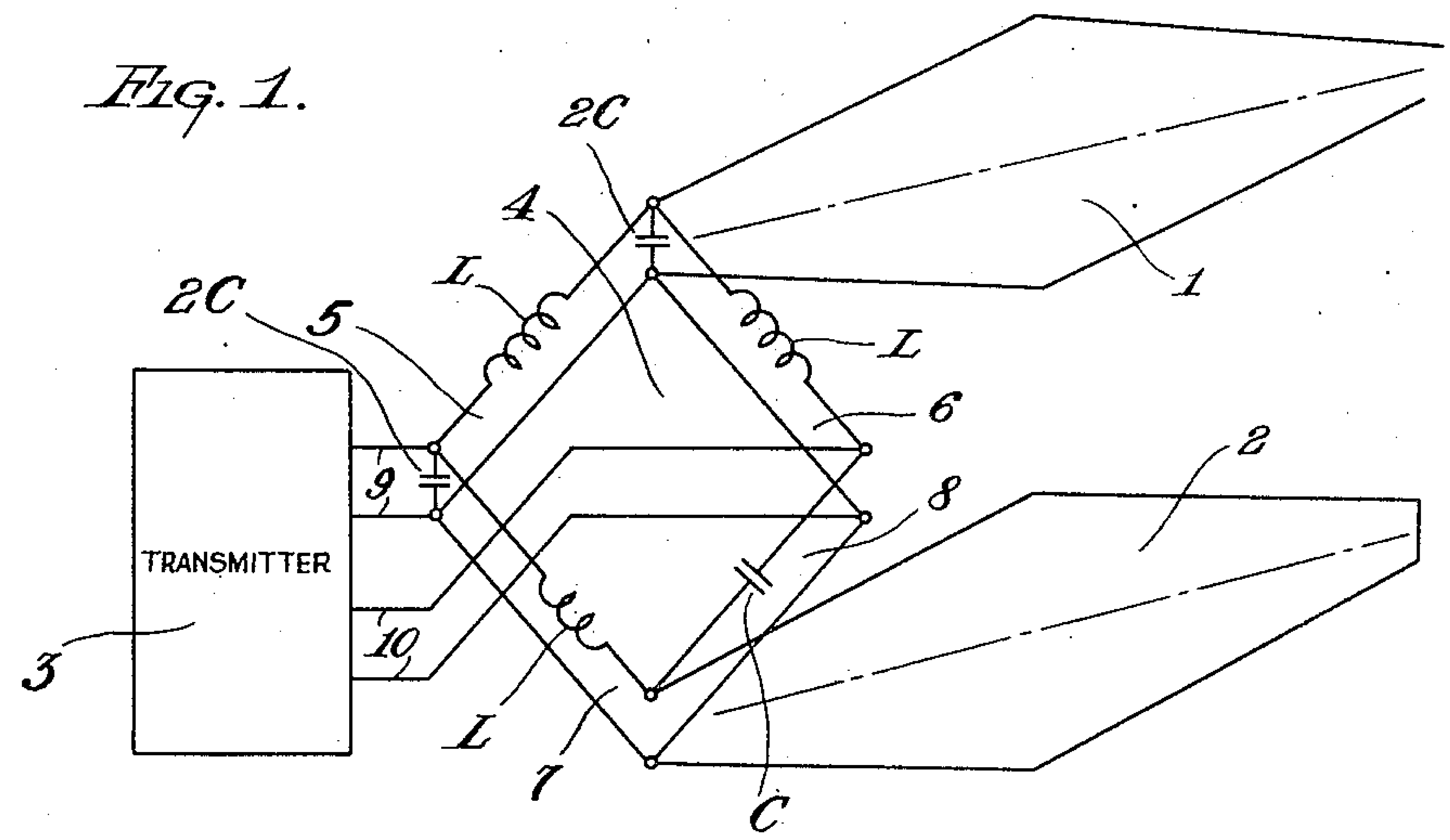
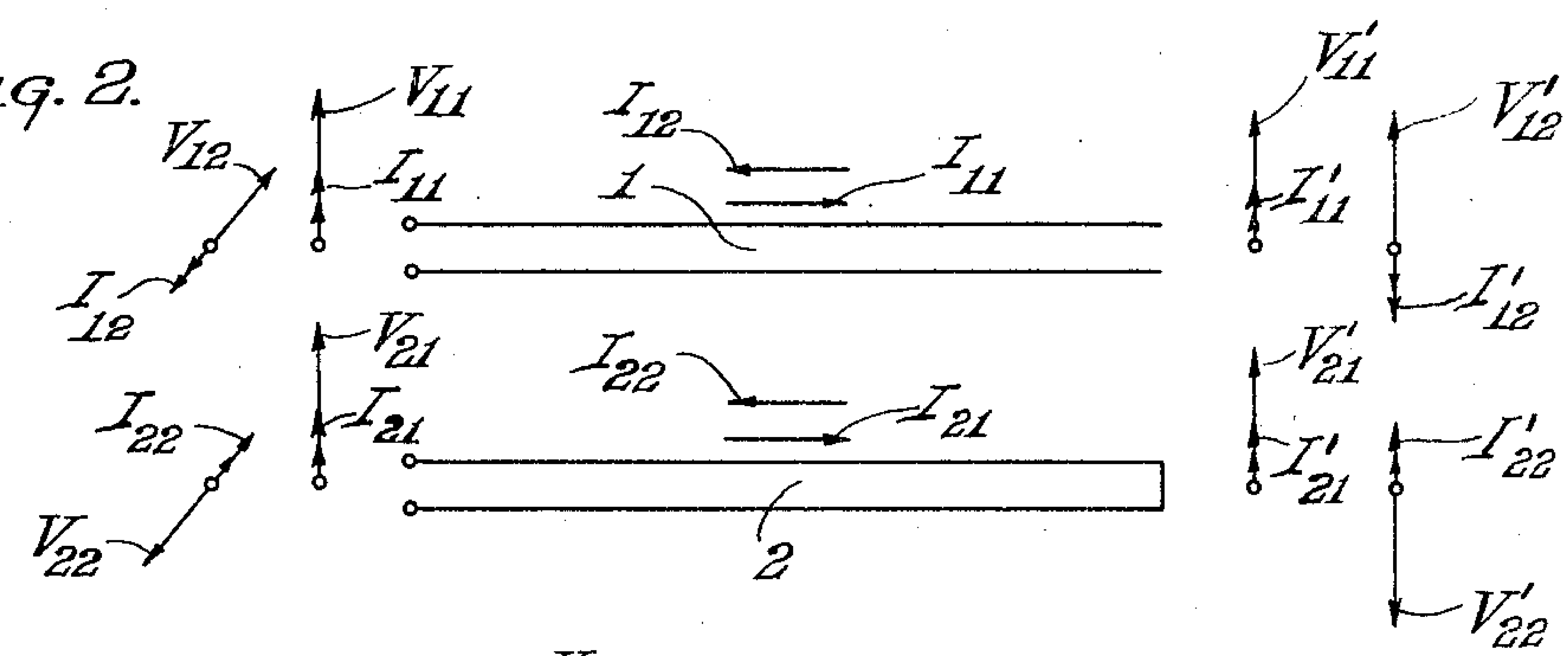


Fig. 2.



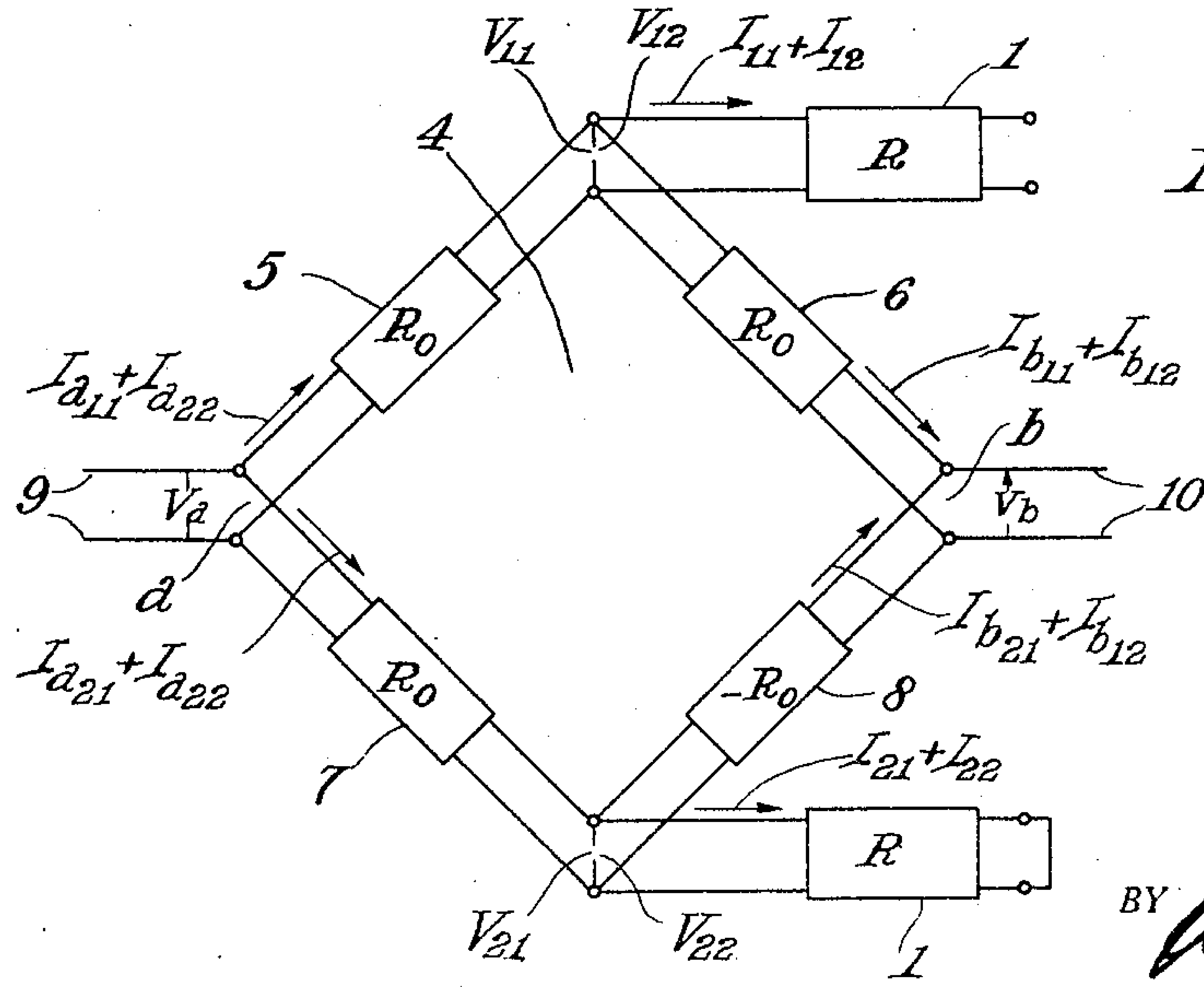


Fig. 3.

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DEVICE FOR THE ALTERNATING VOLTAGE SUPPLY OF A LOAD

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6 Claims. (Cl. 250—17)

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The invention relates to a device for the alternating voltage supply of a load consisting of two four terminal network having open and short-circuited output terminals respectively; it may be applied with particular advantage to a radio-transmitter comprising a rhombic aerial.

For sending out oscillations to be transmitted in one determined direction, use may be made of a rhombic aerial with which, in order to avoid the production of stationary waves in the aerial, the latter is closed at the end remote from the supply end by a resistance whose value corresponds to the surge impedance of the aerial.

The invention has for its object to provide a supply system wherein the closing resistance is suppressed. Instead of a single rhombic aerial use is made in this case of an aerial system which comprises two rhombic aerials which are open and short-circuited respectively at the ends, which aerial system is, as is well-known, equivalent to the said single rhombic aerial.

According to the invention, for the supply of the two rhombic aerials use is made of a bridge circuit which comprises an impedance-inverting four terminal network in each of its branches whilst the phase displacement occurring between the output current and the input voltage of one of the four terminal network is opposite to the corresponding phase displacement in the other four terminal network. The rhombic aerials are connected in this case in two mutually opposite angular points of the bridge circuit whereas to the two other angular points are applied voltages of different values which are taken from the source of supply.

The supply system according to the invention may be utilized not only for supplying two rhombic aerials in the manner indicated above but also in general for the supply of a load consisting of two four terminal network having open and short-circuited terminals respectively.

The circuit-arrangement according to the invention is equivalent to a circuit-arrangement wherein the load formed by the two four terminal network is located directly between the pairs of supply terminals.

As the impedance-inverting four terminal network are preferably utilized symmetrical π-cells tuned to the operating wavelength, owing to which an ohmic load occurs for the operating wavelength in the supply points of the bridge circuit and, besides, the bridge circuit itself can be realized with the aid of a small number of components.

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The invention will now be explained more fully with reference to the accompanying drawing.

Fig. 1 represents a circuit-arrangement of an advantageous mode of a realization of a device according to the invention in conjunction with a load consisting of two rhombic aerials.

Figs. 2 and 3 represent substitution diagrams for the rhombic aerials and the circuit-arrangement according to Fig. 1 respectively, which serve to elucidate the operation of the device according to the invention.

In Fig. 1 the load to be supplied consists of two rhombic aerials **1** and **2** of which the one is open at the free end and the other is short-circuited at the corresponding end. The aerials are supplied from a transmitter **3** through the intermediary of a bridge circuit **4** whose branches are formed by impedance-inverting four terminal network **5**, **6**, **7** and **8** respectively, which are constructed as symmetrical π-cells tuned to the operating wavelength. The transverse and longitudinal reactances of these four terminal network consist of a reactances of opposite signs and have the values indicated in the figure. The longitudinal reactances of the four terminal network **5**, **6** and **7** are inductive whereas the longitudinal reactance of the four terminal network **8** is capacitative so that in the first-mentioned four terminal network the phase displacement between the output current and the input voltage is opposite to the corresponding phase displacement in the last-mentioned four terminal network.

The rhombic aerials **1** and **2** are connected in mutually opposite angular points of the bridge circuit whilst the two other angular points are coupled, through the intermediary of lines **9** and **10** (which in reality preferably have the same length) to the output circuit of the transmitter **3** in such manner that at the angular points of supply voltages of mutually different amplitudes are set up. Between these two supply voltages must be maintained in this case a phase difference chosen in accordance with the dimensions of the rhombic aerials.

The operation of the device shown in Fig. 1 will now be explained with reference to Figs. 2 and 3. With the indices utilized hereinafter for the distinction of the different currents and voltages the first index-figure always refers to the rhombic aerial **1** or **2** whilst the second index-figure indicates whether the current and voltages concerned correspond to the wave referred to hereinafter as the "advancing wave" (index 1) or to the reflected wave (index 2).

As has been mentioned hereinbefore, it is possible to utilize, instead of a single rhombic aerial in which advancing waves are produced, two rhombic aerials which, at the free ends, are open and short-circuited respectively. In this case these two rhombic aerials must be excited in such manner that stationary waves being 90° out of phase are set up in them. The stationary wave in each of the two rhombs may be imagined to be resolved into two advancing waves opposed in direction, as indicated in Fig. 2 by I_{11}, I_{12} and I_{21}, I_{22}. In the rhombic aerial **1** which is open at the free end (on the right-hand side in the figure) a wave advancing from the left to the right is produced due to the fact that a voltage V_{11} with a current I_{11} is applied to the supply end (on the left-hand side in the figure) whilst at the free end there occurs a voltage V'_{11} and a current I'_{11}. Moreover, a wave produced by reflection and advancing from the right to the left is set up due to the voltage V'_{12} and the current I'_{12} which prevail at the free end so that at the supply end there occur V_{12} and I_{12}. In this case the currents occurring at the free and open end must be equal and in anti-phase, i. e. $I'_{11}=-I'_{12}$ whereas the corresponding voltages must be equal and in phase, i. e. $V'_{11}=V'_{12}$.

Furthermore, if R represents the surge impedance of the rhombic aerial, we have

$$V_{11}=RI_{11} \quad (1) \quad \text{and} \quad V_{12}=-RI_{12} \quad (2)$$

The ratio thus determined by the surge impedance and the mutual phase of the corresponding voltages and currents are valid along the whole of the rhombic aerial. Due to the damping

$$V_{11}>V'_{11}=V'_{12}>V_{12}$$

between the voltages V_{11} and V_{12} there exists a phase difference which depends upon the length of the aerial. The voltages and currents above referred to are represented in Figure 2 as vectors.

In a similar manner there occur, due to a voltage V_{21} applied to the supply end, in the rhombic aerial **2** short-circuited at the free end a wave I_{21} advancing from the left to the right and a wave I_{22} advancing in the opposite direction. The voltages V'_{21} and V'_{22} set up at the short-circuited end are again equal, but now they are in anti-phase, the currents being equal and in phase.

If the surge impedance of the rhombic aerial **2** is also equal to R, the following relations are valid:

$$V_{21}=R.I_{21} \quad (3) \qquad \text{and} \quad V_{22}=-R.I_{22} \quad (4)$$

whilst furthermore

$$V_{21}>V'_{21}=-V'_{22}>V_{22}$$

The various vectors are represented in the figure in the same way as with the rhombic aerial **1**.

If now the voltages V_{11} and V_{21} are equal and in phase, V_{12} and V_{22} are automatically in anti-phase, i. e.

$$V_{11}=V_{21} \quad (5) \qquad \text{and} \quad V_{12}=-V_{22} \quad (6)$$

Along the whole of the aerial systems the currents I_{11} and I_{21} are in this case likewise in phase and the currents I_{12} and I_{22} in anti-phase in corresponding points, with the result that upon superposition of the two rhombic aerials the waves advancing from the right to the left neutralize one another and that only the waves advancing from the left to the right are operative, which is just desirable.

The above-described current and voltage conditions arise automatically if currents or voltages of the correct amplitude and phase are supplied to the supply ends.

Only the first alternative, which is utilized in Figure 1, will be discussed hereinafter; the other (dual) possibility needs no further explanation after the detailed exposition.

If for the impedance-inverting four terminal network **5**, **6**, **7** and **8** in Figure 1 there applies at the operating frequency ω:

$$\omega L=\frac{1}{\omega C}=R_0$$

there exists, as is well-known, between the input voltage and input current V_i and I_i respectively and the output voltage and output current V_u and I_u respectively in the four terminal network **5**, **6** and **7** the following connection:

$$V_i=jR_0J_u \text{ and } V_u=-jR_0I_i \quad (7)$$

whilst for the four terminal network **8** we have:

$$V_i=-jR_0I_u \text{ and } V_u=+jR_0I_i \quad (8)$$

Taking the above into account, it is possible to draw for the bridge circuit represented in Figure 1 the substitution diagram shown in Figure 3. If the supply voltages occurring in the supply angular points a and b of the bridge circuit amount to V_a and V_b respectively, we have:

$$V_a=jR_0I_{11}=jR_0I_{21} \quad (9)$$
$$V_b=-jR_0I_{12}=+jR_0I_{22} \quad (10)$$

The current occurring in the supply point a is composed of four components I_{a11}, I_{a12}, I_{a21} and I_{a22}, which correspond to V_{11}, V_{12}, V_{21} and V_{22} respectively.

According to (7) we have now:

$$I_{a11}=j\frac{V_{11}}{R_0};\ I_{a12}=j\frac{V_{12}}{R_0}$$

$$I_{a21}=j\frac{V_{21}}{R_0};\ I_{a22}=j\frac{V_{22}}{R_0}$$

Since according to (6) $V_{12}=-V'_{22}$ we have,

$$I_{a12}+I_{a22}=0$$

and the resulting current which occurs in a amounts to

$$I_{a11}+I_{a21}=\frac{j}{R_0}\cdot(V_{11}+V_{21})$$

or in connection with (5):

$$I_{a11}+I_{a21}=2\cdot\frac{j}{R_0}V_{11} \quad (11)$$

Since it follows from (1) and (9) that

$$V_{11}=\frac{R}{jR_0}\cdot V_a \quad (12)$$

the resulting current in a becomes after substitution of the previously mentioned value of V_{11} in (11):

$$I_{a11}+I_{a21}=2\cdot\frac{V_a}{R_0^2}R \quad (13)$$

which is consequently in phase with V_a.

The current occurring in the supply point b is likewise composed of four components which are indicated by I_{b11}, I_{b12}, I_{b21} and I_{b22} and which correspond to V_{11}, V_{12}, V_{21} and V_{22} respectively.

According to (7) and (8) we have:

$$I_{b11}=-j\frac{V_{11}}{R_0};\ I_{b12}=-j\frac{V_{12}}{R_0}$$

$$I_{b21}=+j\frac{V_{21}}{R_0};\ I_{b22}=+j\frac{V_{22}}{R_0}$$

Since according to (5) $V_{11}=V_{21}$ we have

$$I_{b11}+I_{b21}=0$$

and the resulting current occurring in b amounts to:

$$I_{b12}+I_{b22}=\frac{j}{R_0}(-V_{12}+V_{22})$$

or in connection with (6)

$$I_{b12}+I_{b22}=2\cdot\frac{j}{R_0}V_{22} \qquad (14)$$

It follows from (4) and (10) that

$$V_{22}=-\frac{R}{jR_0}\cdot V_b \qquad (15)$$

After substitution of this value of V_{22} in (14) we get:

$$I_{b12}+I_{b22}=-2\cdot\frac{V_b.R}{R_0^2} \qquad (16)$$

The resulting current in b is consequently in anti-phase with respect to the voltage, which implies that energy taken from the point b is supplied to the transmitter **3**.

As results from (13) and (16) the power W dissipated between the supply point a and b of the bridge circuit amounts to

$$W=2\cdot\frac{R}{R_0^2}(V_a^2-V_b^2)$$

As may be deduced from (1), (2), (3) and (4) in combination with (12) and (15), each of the two rhombs radiates half the power consumed in total which was aimed at.

In the above it was implicitly assumed that between the voltages V_a and V_b in the supply angular points of the bridge circuit there exists the correct phase displacement. In order to enable the exact adjustment of the required phase displacement, the phase of one of the supply voltages should preferably be regulable with the aid of means known in themselves for this purpose. It should be taken into account in this respect that the ratio between the amplitudes of these voltages V_a and V_b only depends upon the damping in the circuit arrangement so that in adjusting the phase it must be possible to maintain unaltered the amplitudes of V_a and V_b. In connection therewith the supply voltage of regulable phase may be taken from a rotating field or, for example, the length of the supply line **10** may be made adjustable, in which event, if required, separate means for regulating the amplitude of the supply voltage V_b may be utilized. The length of the supply lines **9** and **10** should preferably be so chosen that the voltages set up at the supply ends of these lines are in phase or in antiphase, in which event the lines may be connected directly to the output circuit of the transmitter **3**.

A particular advantage of the device represented resides in that simply by interchanging the supply ends of one of the rhombic aerials **1** and **2** it is possible to modify the main direction of radiation of the aerial system. Viewed in the projection on the plane of one of the rhombs, the main direction of radiation obtained after the reversal of the polarity is opposite to the initial main direction of radiation.

Finally it may be observed that upon variation of the operating wavelength the inverting four terminal network must be tuned, of course, to the new operating wave length and, moreover, that in this case the phase displacement between the supply voltages must be modified. The existence of the correct phase displacement between the supply voltages can be ascertained with the aid of means for determining the radiated power, which has in this case an extreme value.

What I claim is:

1. A system for energizing a load consisting of two rhombic antennas having open and short circuited output terminals respectively, said system comprising a four branch bridge each branch of which is defined by a four terminal phase-shifting network, one of the networks in said bridge providing a 90 degree phase displacement in one direction, the remaining networks in said bridge each providing a 90 degree phase displacement in the reverse direction, the input terminals of one of the antennas being connected to one vertex of said bridge and the input terminals of the other antenna being connected to the opposing vertex of said bridge, a source of alternating voltage, means to apply a first voltage from said source to another vertex of said bridge, and means to apply a second voltage from said source to the vertex of said bridge opposing said another vertex, the value of said second voltage being different from said first voltage.

2. A system for energizing a load consisting of two rhombic antennas having open and short circuited output terminals respectively, said system comprising a source of high frequency energy having a predetermined wavelength, a four branch bridge each branch of which is defined by a four terminal phase-shifting network, each network being constituted by a symmetrical Pi section of inductive and capacitative elements tuned to the wavelength of said source, one of the networks providing a 90 degree phase displacement in one direction, the remaining networks each providing a 90 degree phase displacement in the reverse direction, the input terminals of one of the antennas being connected to one vertex of said bridge and the input terminals of the other antenna being connected to the opposing vertex of said bridge, means to apply a first voltage from said source to another vertex of said bridge, and means to apply a second voltage from said source to the vertex of said bridge opposing said another vertex, the value of said second voltage being different from said first voltage.

3. A system for energizing a load consisting of a pair of four terminal networks having open and short-circuited output terminals respectively, said system comprising a four branch bridge each branch of which is defined by a four terminal phase-shifting network, one of the networks in said bridge providing a 90 degree phase displacement in one direction, the remaining networks in said bridge each providing a 90 degree displacement in the reverse direction, the input terminals of one of the load networks being connected to one vertex of said bridge and the input terminals of the other load network being connected to the opposing vertex of said bridge, a source of alternating voltage, means to apply a first voltage from said source to another vertex of said bridge, means to apply a second voltage from said source to the vertex of said bridge opposing said another vertex, and means to adjust the phase displacement between said first and second voltages.

4. A system for energizing a load consisting of two rhombic antennas having open and short-circuited output terminals respectively, said system comprising a source of high frequency energy, a four branch bridge each branch of which is defined by a four terminal phase-shifting network,

each network being constituted by a symmetrical Pi section of inductive and capacitative elements tunable to a desired wavelength, one of the networks providing a 90 degree phase displacement in one direction, the remaining networks each providing a 90 degree phase displacement in the reverse direction, the input terminal of one of the antennas being connected to one vertex of said bridge and the input terminals of the other antenna being connected to the opposing vertex of said bridge, means to apply a first voltage from said source to another vertex of said bridge, means to apply a second voltage from said source to the vertex of said bridge opposing said another vertex, and means to adjust the relative phase displacements of said first and second voltages.

5. A system for energizing a load consisting of two rhombic antennas having open and short-circuited output terminals respectively, said system comprising a source of high frequency energy having a predetermined wavelength, a four branch bridge each branch of which is defined by a four terminal phase-shifting network, each network being constituted by a symmetrical Pi section of inductive and capacitative elements tuned to the wavelength of said source, one of the networks providing a 90 degree phase displacement in one direction, the remaining networks each providing a 90 degree phase displacement in the reverse direction, the input terminals of one of said antennas being connected to one vertex of said bridge and the input terminals of the other antenna being connected to the opposing vertex of said bridge, a first transmission line for applying a first voltage from said source to another vertex of said bridge, and a second transmission line for applying a second voltage from said source to the vertex of said bridge opposing said another vertex, said lines having respective lengths effecting a predetermined phase displacement between the first and second voltages applied to said bridge.

6. A system in accordance with claim 5 further including means for interchanging the connections of the input terminals of said antennas to said one vertex and said vertex opposing said one vertex of the bridge.

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