March 29, 1949. G. H. BROWN ET AL 2,465,843

RADIO FREQUENCY POWER DIVISION NETWORK

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Fig. 1.

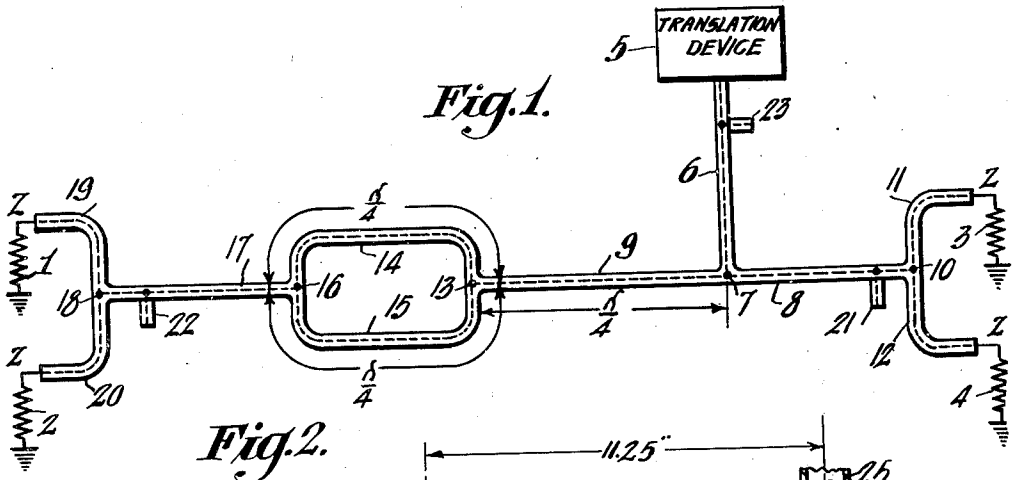


Fig. 2.

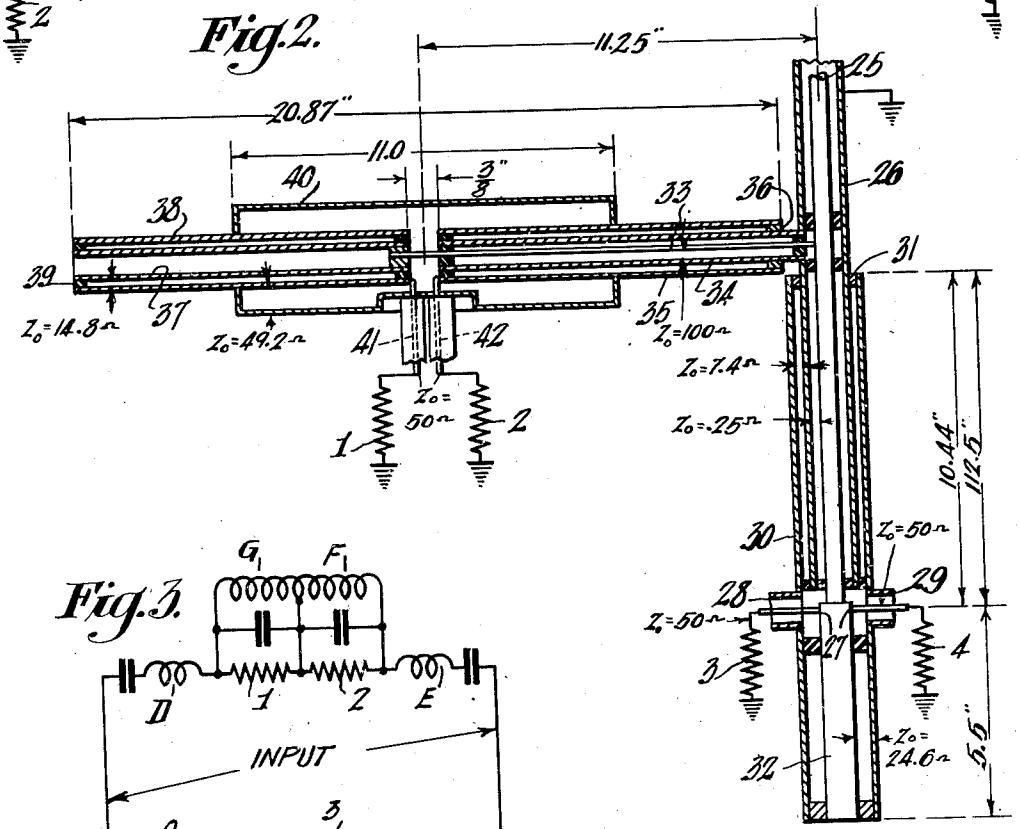


Fig. 3.

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RADIO FREQUENCY POWER DIVISION NETWORK

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3 Claims. (Cl. 178—44)

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This invention relates to radio frequency power division networks of the type required for allocating the output of a transmitter to the various radiator sections of a multi-element directive antenna. Such networks are also used with identical connections for determining the directivity of multi-element antennas used for reception, as well as for other purposes where a predetermined distribution of radio frequency power is required.

The principal object of the present invention is to provide an improved network for the distribution of radio frequency power, capable of efficient operation over a relatively wide band of frequencies.

Another object is to provide a network of the described type wherein the output power ratios remain constant, independent of frequency.

A further object is to provide a network of the described type including means for cancellation of the reactances unavoidably introduced by certain elements of the network.

These and other objects will become apparent to those skilled in the art upon consideration of the following description with reference to the accompanying drawing, of which Figure 1 is a schematic diagram illustrating a power division network designed in accordance with prior art practice; Figure 2 is a schematic diagram of a power division network in accordance with the present invention; and Figure 3 is a schematic diagram of the equivalent circuit of the system of Figure 2. Similar reference characters indicate similar elements in the drawing.

In the design of directive antenna arrays, it is common practice to employ a series of laterally spaced radiator elements or groups of radiator elements, energized with graduated powers. For example, a common type of array comprises four spaced groups of radiators with each of the two center groups supplied with four times the power delivered to each of the two outer groups. Ordinarily, all of the groups are identical, so that each presents the same impedance.

Figure 1 illustrates a typical prior art arrangement for providing the required power division. Four loads 1, 2, 3 and 4, each having an impedance Z, are to be energized from a translation device 5 in such manner that each of the loads 1 and 2 receives 10 percent and each of the loads 3 and 4, 40 percent of the power output of the device 5. Although the loads 1, 2, 3 and 4 are represented in the drawing as resistors, it is to be understood that they may be radiator elements or groups of radiator elements or in fact any load device.

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The translation device 5 is connected through a coaxial transmission line 6 to the junction point 7 of a pair of similar transmission lines 8 and 9. The line 8 is connected from point 7 to the junction point 10 of a pair of lines 11 and 12, leading respectively to the loads 3 and 4. The length of the line section 8 is unimportant except that it must be considered in determining phase relationships between the currents in the loads 3 and 4 and loads 1 and 2. The line 9 is one-quarter wavelength long, or an odd multiple thereof, and terminates at the junction 13 between two similar quarter wave lines 14 and 15. The other ends of the lines 14 and 15 are also connected together at a junction 16 and to a line 17. The line 17 leads to the junction 18 between two lines 19 and 20, which are connected to the loads 1 and 2 respectively.

It is assumed that the characteristic impedances of all of the line sections in the system are equal to the impedances Z of the loads 1, 2, 3 and 4. The lines 11 and 12 present an impedance of Z/2 to the line 8 at the point 10. A matching stub 21 is provided on the line 8, and adjusted so that the impedance presented thereby at the point 7 is Z. Similarly, the lines 19 and 20 present an impedance Z/2 at the point 18, and a matching stub 22 is provided on the line 17 which thus presents an impedance Z at the point 16.

The two parallel quarter wave lines 14 and 15 act like a single quarter wave line having a characteristic impedance of Z/2, and thus reflect the impedance Z to the point 13 as an impedance Z/4 at the point 13. The line 9, being also a quarter wave section, inverts the impedance Z/4 at the point 13 to present an impedance 4Z at the point 7. Thus the line 6 looks into an impedance 4Z, presented by the line 9 and an impedance Z in parallel therewith, presented by the line 8. One-fifth of the energy transmitted by the line 6 will flow into the line 9 and four-fifths of the energy will flow into the line 8. The energy transmitted by the line 9 will be divided equally between the loads 1 and 2 so that each receives 10 percent of the input power. Similarly, each of the loads 3 and 4 receives 40 percent of the input power. Mismatch of the line 6 at the point 7 is corrected by means of a stub 23.

The above-described network provides the required power division at one frequency. However, if the frequency is altered, the line sections 9, 14 and 15 are no longer one-quarter wavelength, and the stubs 21, 22 and 23 no longer provide complete suppression of standing waves. Thus the efficiency of the system as a whole decreases,

and the ratios of the powers delivered to the several loads are altered.

In the practice of the present system, the desired power ratios are obtained by connecting the loads 3 and 4 in parallel with each other to the input, and effectively connecting the loads 1 and 2 in series with each other to the input. With this arrangement, the power ratios are maintained constant regardless of frequency. Certain resonant elements are required to provide the series connection. Other resonant elements are provided to compensate their reactances over a wide band of frequencies to maintain efficient operation of the system as well as accurate power division.

Referring to Figure 2, the input power is applied to a coaxial line comprising an inner conductor 25 and an outer conductor 26. The inner conductor is connected at a point 27 to the inner conductors of a pair of coaxial lines 28 and 29, which correspond to the lines 11 and 12 of Figure 1 and are connected to the loads 3 and 4 respectively. The outer conductors of the lines 28 and 29 are connected to a tubular conductor 30, which extends coaxially over the conductor 26, and is connected thereto at a point 31. The conductor 26 terminates within the conductor 30 at a point one-half wavelength from the point 31. The conductor 30 extends substantially one-quarter wavelength beyond the end of the conductor 26, and is connected at its lower end to the lower end of the conductor 25. The lower quarter wave portion 32 of the inner conductor 25 is of larger diameter than the upper portion. The dimensions of the various elements indicated on the drawing are suitable for loads of 50 ohms impedance, and for operation throughout a frequency range of substantially 390 to 725 megacycles per second.

Referring to Figure 3, the portion of the system thus far described is represented by the group of elements designated generally by the reference character A. The conductors 25 and 26 constitute a 25 ohm coaxial line connected to the input terminals. The conductors 26 and 30 cooperate as a 7.4 ohm half wave line, short-circuited to function as the series resonant circuit B. The conductors 30 and 31 cooperate to function as a quarter wave 24.6 ohm line, short-circuited to act as the parallel resonant circuit C.

The loads 1 and 2 are coupled to the input line 25, 26 through a line balance converter of the general type described on page 855 (Figure 96D) of Radio Engineer's Handbook, by F. E. Terman. The line balance converter includes an input line comprising inner and outer conductors 33 and 34 connected respectively to the conductors 25 and 26. A half wave sleeve 35 extends over the conductor 34 and is connected thereto at its end 36. The inner conductor 33 is connected to a conductor 37, of the same diameter as the conductor 34, surrounded by a half wave sleeve 38 and connected thereto at its outer end 39. A further half wave sleeve 40 surrounds the inner portions of the sleeves 35 and 38, with its ends connected to their respective midpoints. Two output lines 41 and 42 corresponding to the lines 19 and 20 of Figure 1, are connected to the loads 1 and 2. The inner conductors of the lines 41 and 42 are connected respectively to the inner ends of the sleeves 35 and 38. The outer conductors of the lines 41 and 42 are connected to the outermost sleeve 40.

The sleeve 38 and the conductor 34 constitute a half wave 14.8 ohm line, short-circuited to function as the series resonant circuit D (Figure 3). Similarly the conductor 37 and the sleeve 38 constitute the series circuit E of Figure 2. The inner portion of the sleeve 35, together with the surrounding portion of the sleeve 40, constitutes a quarter wave short-circuited line of relatively high impedance, corresponding to the parallel resonant circuit F of Figure 2. Similarly, the inner portion of the sleeve 38 and the surrounding portion of the sleeve 40 comprise the parallel resonant circuit G. The conductors 33 and 34 constitute a 100 ohm coaxial line.

Current flowing into the line 33, 34 goes through the series impedance 37, 38 (D) to the inner conductor of the line 41, thence through the load 1 to the outermost conductor 40, which is at ground potential. Current flowing through the inner conductor 33 causes equal and opposite current to flow through the conductor 34. This current flows across the series impedance 34, 35 (E) to the line 42, and through the load 2 to the conductor 40. Thus the powers delivered to the loads 1 and 2 are equal, and their sum is necessarily equal to the power delivered to the line 33, 34.

If the frequency of the input power is varied, so that the resonant lengths specified above are no longer one-half wave, one-quarter wave, etc. as stated, the operation will still be the same since the connections of the loads 1 and 2 are symmetrical with respect to the input line 33, 34. However, the reactances of the quarter wave sections 35, 40 and 38, 40 will vary with variation in frequency. These variations will be substantially fully compensated over a wide range of variation in frequency by complementary variations of the reactances of the half wave sections 34, 35 and 37, 38.

Since the loads 3 and 4 are equal in impedance and are connected in parallel, the power applied to them through the line 25, 26 will be equally divided. Variation with frequency of the reactance of the quarter wave section 30, 32 is compensated by complementary variation in the reactance of the half wave section 26, 30. Since the line 25, 26 presents an impedance of 25 ohms, and the line 33, 34 presents an impedance of 100 ohms, one-fifth of the power of input will flow to the loads 1 and 2 while the remaining four-fifths will flow to the loads 3 and 4.

The resistive component of the impedance presented by the line 33, 34 at its input terminals will not remain 100 ohms but will decrease to approximately 80 ohms at the limits of the frequency band. The branch line 25, 26 is loaded by the quarter wave line 32, 30 and the half wave line 26, 30 to simulate the load placed on the line 33, 34 by the line balance convertor. Thus the impedance presented by the line 25, 26 at its input terminals varies with frequency from 25 ohms at resonance to approximately 20 ohms at the limits of the band, remaining at all times exactly one-quarter of that presented by the line 33, 34. This provides accurate power division between the two pairs of loads 1, 2 and 3, 4 independent of frequency.

The lines 25, 26 and 33, 24 connected in parallel present an impedance of 20 ohms. In order to match this to a standard coaxial transmission line of, for example 50 ohms impedance, a line transformer comprising a series of quarter wave line sections of consecutively increasing characteristic impedances may be employed. This type of transformer, which is described and claimed in U. S. Patent No. 2,249,597, will op-

erate over a wide band of frequencies without variations in performance such as result from the use of matching stubs.

Thus the invention has been described as an improved power division network, providing efficient operation over a wide band of frequencies without variation in the ratio of the powers supplied to the several loads. The network includes two branch lines, one having an impedance equal to that of two loads in parallel and the other having an impedance equal to that of two loads in series. The first branch line is directly connected to a band of parallel loads. The second branch line is connected through a conventional line balance convertor to the other pair of loads. The line balance convertor divides the power applied thereto equally between the two loads. Thus the system operates as if two of the loads were connected across the input in series and two of the loads were connected across the input in parallel, providing accurate power division in the ratio 1:4:4:1. The line balance convertor is compensated for a reactance variation with frequency by means of a pair of short-circuited half wave lines connected across the output circuits. Variation of the resistive component of the line balance convertor is compensated by providing a correspondingly varying network on the first branch line, to maintain accurate power division between the two pairs of loads at all frequencies.

The invention covered herein may be manufactured and used by or for the Government of the United States for any governmental purpose without payment to me or assigns of any royalty thereon.

We claim as our invention:

1. A radio frequency power division network including four output transmission lines, each of said lines having a characteristic impedance of Z ohms, four loads each of impedance Z and each connected to one of said output lines, a pair of input terminals, a line balance convertor including an unbalanced input circuit and two balanced output circuits, two of said output lines being connected respectively to said convertor output circuits, a branch line having a characteristic impedance of 2Z ohms connected between said input terminals and said convertor input circuit, a second branch line having a characteristic impedance of Z/2 ohms connected at one end to said input terminals and at the other end to the other two of said output lines in parallel, two half wave short-circuited lines connected respectively to the output circuits of said line balance convertor to compensate variations with frequency of the reactance thereof, and a quarter-wave short-circuited line and a half wave short-circuited line connected to said second branch line to simulate the variation with frequency of resistance of said compensated line balance convertor.

2. A radio frequency power division network for two pairs of loads for dividing power from a radio frequency source among said loads, comprising a first parallel tuned circuit, said first parallel tuned circuit and each load of one of said pairs being connected in parallel in a first parallel connected circuit, a first series tuned circuit, said first series tuned circuit and said first parallel connected circuit being serially connected in a first series connected circuit, second and third parallel tuned circuits each connected in parallel respectively with one of the other pair of loads in second and third parallel connected circuits respectively, and second and third series tuned circuits, said second and third series tuned circuits and said second and third parallel tuned circuits being serially connected in a second series connected circuit, said first and second series connected circuits being connected in parallel to said source, said tuned circuits being tuned to a central operating frequency of said radio frequency source whereby the ratio of power division between said pairs of loads and between the loads of each pair is compensated with respect to frequency variations of said source to maintain the ratio of the division of power from the source among the loads substantially independent of such frequency variations.

3. A radio frequency power division network for two pairs of loads for dividing power from a radio frequency source among said loads, comprising a first parallel tuned circuit, said first parallel tuned circuit and each load of one of said pairs being connected in parallel in a first parallel connected circuit, a first series tuned circuit, said first series tuned circuit and said first parallel connected circuit being serially connected in a first series connected circuit, second and third parallel tuned circuits each connected in parallel respectively with one of the other pair of loads in second and third parallel connected circuits respectively, and second and third series tuned circuits, said second and third series tuned circuits and said second and third parallel tuned circuits being serially connected in a second series connected circuit, said first and second series connected circuits being connected in parallel to said source, said tuned circuits being tuned to a central operating frequency of said radio frequency source, said series tuned circuits being short-circuited transmission lines of multiple including unity half wavelength long at said central operating frequency, and said parallel tuned circuits being short-circuited transmission lines of odd multiple including unity quarter wavelengths long at said central operating frequency, and line balance convertors one connecting in circuit each said pair of loads, whereby the ratio of power division between said pairs of loads and between the loads of each pair is compensated with respect to frequency variations of said source to maintain the ratio of the division of power from the source among the loads substantially independent of such frequency variations.

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