

April 10, 1945.

R. W. CLARK

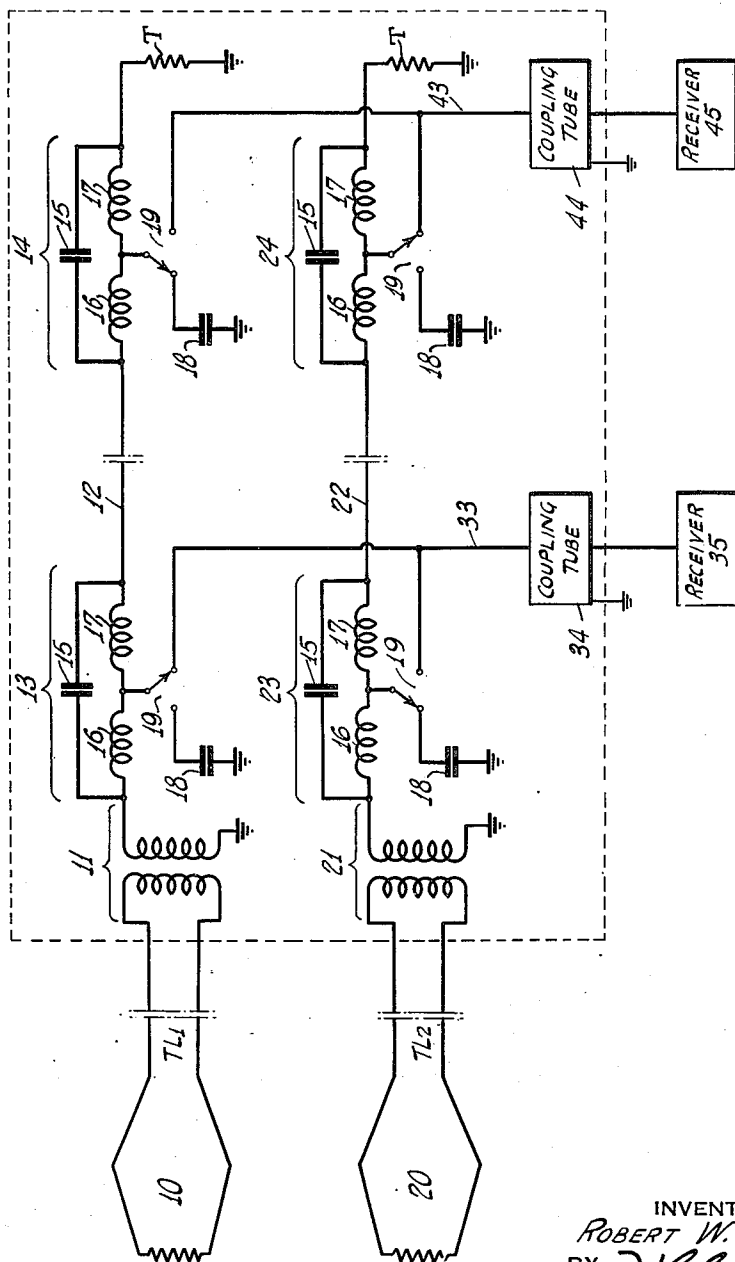
2,373,458

TRANSMISSION LINE COUPLING SYSTEM

Filed March 21, 1942

4 Sheets-Sheet 1

Fig. 1.



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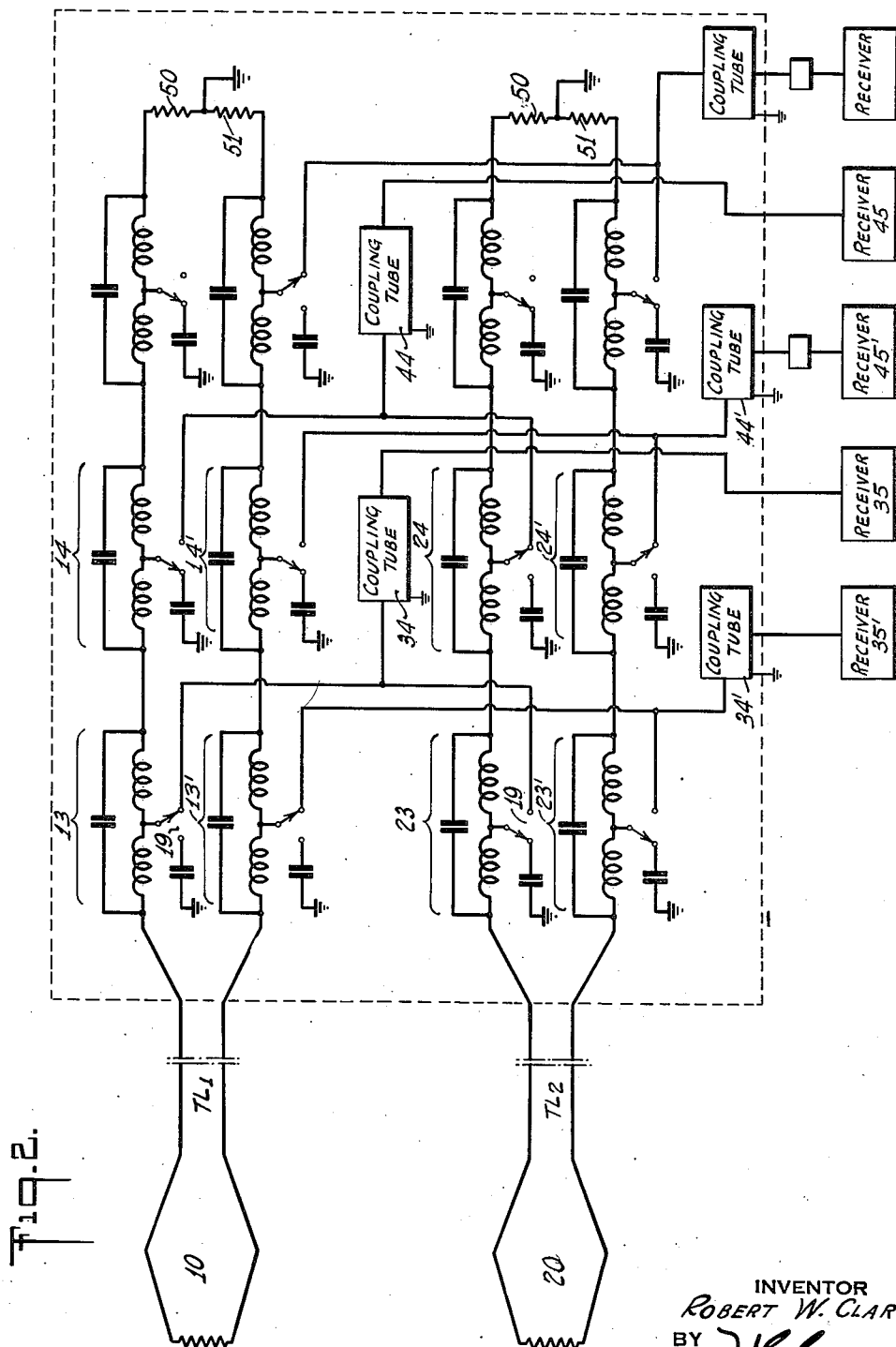
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4 Sheets-Sheet 2



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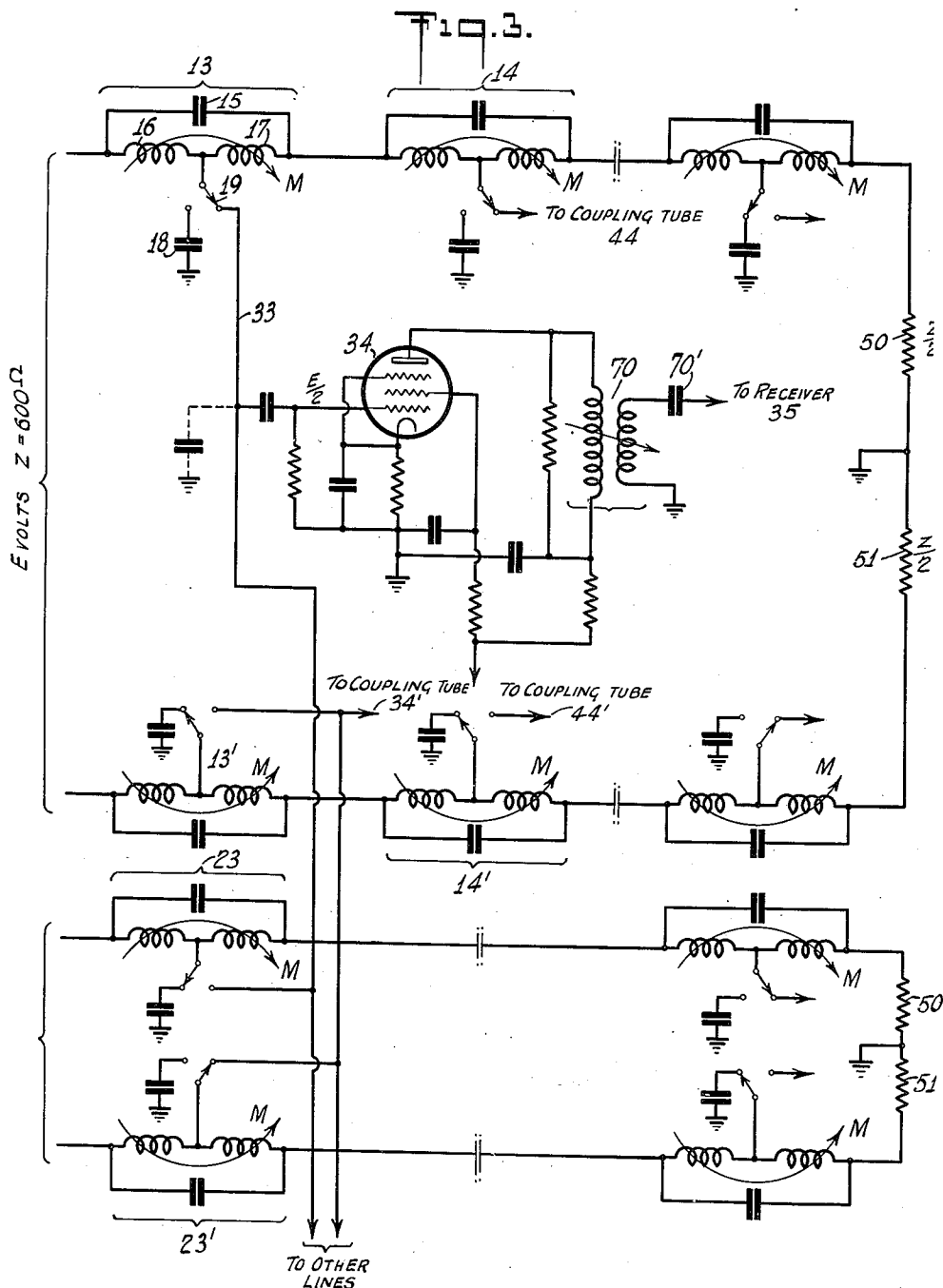
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4 Sheets-Sheet 3



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Fig. 4.

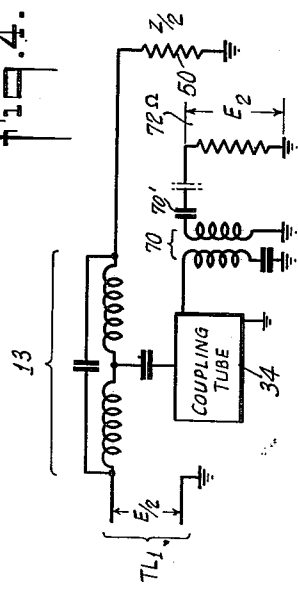


Fig. 5.

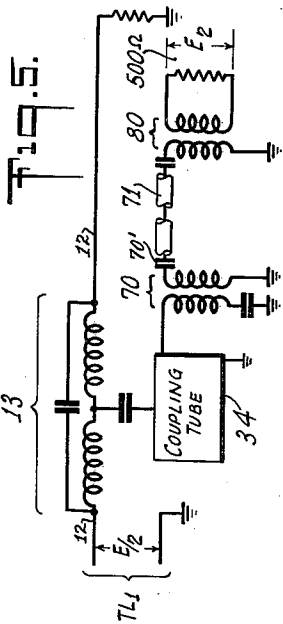


Fig. 6.

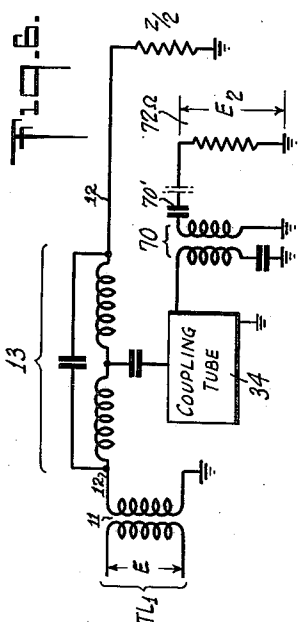
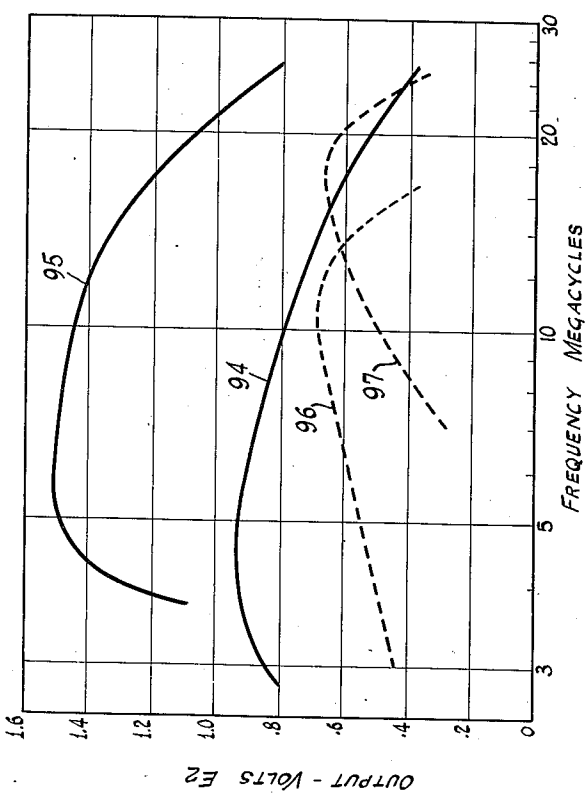


Fig. 7.



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UNITED STATES PATENT OFFICE

2,373,458

TRANSMISSION LINE COUPLING SYSTEM

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5 Claims. (Cl. 178-44)

The present invention relates to transmission line circuits and, more particularly, to coupling systems whereby any number of receivers may be selectively connected to a number of antennas without undesired reactions between the receivers or on the antenna circuits.

An object of the present invention is the selective switching of receivers and associated antennas without impedance mismatching or disturbances in the receivers.

Another object of the present invention is the provision of a switching system for selectively switching receivers to a number of antennas and transmission lines.

Still another object of the present invention is the connection of receivers to transmission lines without substantial reduction of the signal level.

With one or two receivers and a small number of transmission lines, the problem of switching receivers to the transmission lines may be solved a number of ways without much difficulty, but as the number of lines and receivers increases the switching problem becomes more complicated. Also, if all receivers are connected to one transmission line the impedance matching may reduce the signal level to such an extent as to be unusable. The coupling difficulties also increase with the band width of frequencies desired to be covered by the receiving system as a whole.

The heretofore known use of a cathode follower tube connected to a transmission line and feeding a number of receivers in parallel is disadvantageous from the gain standpoint. The impedance of several receivers in parallel is of such a low value that a considerable loss of signal level results in the coupling circuit. The use of separate cathode follower tubes for each receiver is also disadvantageous for, while this system has more gain than the former system, it has a very serious disadvantage in that the input capacity for each tube with the associated wiring is of the order of 20 micromicrofarads. Thus, where, say, seven receivers are to be connected to one transmission line, the total shunt capacity across the line is of the order of 140 micromicrofarads. This capacity at 20,000 kilocycles has an impedance of 60 ohms and across a 600 ohm line causes a considerable mismatch with a consequent loss of gain. These disadvantages led to the development of the system of the present invention.

The present invention is based on the fact that where a number of filter sections are connected

in series the total shunt capacity may be divided into smaller parts by the number of sections. For example, if as above, there are 7 tubes of 20 micromicrofarad input capacity each and if 7 filter sections are used, the shunt capacity of each section may be the capacity of one tube. A filter section known as the bridge-T circuit is readily adaptable for this circuit since, with proper design, the voltage across the shunt capacitor of the filter equals the input voltage to the filter. The filter may readily be designed to present a constant impedance to the line and to possess substantially no attenuation over a predetermined wide band of frequencies. If the shunt capacity of each filter section is constituted by a tube input capacity the voltage on the tube grid is equal to the voltage applied to the filter input. Therefore, each coupling tube will have applied to its grid the full transmission line voltage. If a fixed capacitor having a capacity equal to the input capacity of the coupling tube is arranged to be substituted for the tube capacity when the tube is switched out of connection with the line, no disturbance of the characteristics of the line will result from a switching of the tube into and out of the line.

The present invention will be more fully understood by reference to the following detailed description, which is accompanied by drawings in which Figure 1 illustrates an embodiment of the present invention, while Figure 2 illustrates a modification thereof; Figure 3 illustrates in more detail a portion of the modification of Figure 2; Figures 4, 5 and 6 illustrate in diagrammatic form the essential elements of various modifications of the coupling circuits of Figures 1, 2 and 3, while Figure 7 is a family of curves illustrating the frequency characteristics of the modifications shown in Figures 4 to 6.

Referring, now, to Figure 1, reference numerals 10 and 20 indicate a pair of separate antennas, connected by transmission lines TL1 and TL2 to matching networks 11 and 21. The matching networks 11 and 21 are designed to couple the balanced transmission lines TL1 and TL2 to unbalanced or single-sided transmission lines 12 and 22. These coupling networks may be designed to cover a comparatively broad band of frequencies and supply full line voltage across the unbalanced line. Each transmission line is terminated by a resistor T having a resistance equal to the surge impedance of the line whereby reflection back into the line of energy arriving at the end of the line is prevented. In the high potential or ungrounded side of the unbalanced trans-

mission lines 12 and 22 are connected a plurality of bridge-T networks 13, 23, 14, 24. Each of the bridge-T networks is identical in construction and comprises the capacitance 15, the inductances 16, 17 and a shunt capacity. Coils 16 and 17 are wound in the same direction and connected in series so the flux of each coil aids the other as indicated by the arrows M of Figure 3. The capacity 15 across the coils 16 and 17, while indicated as a physically separate capacity, in many cases, may be entirely constituted by the inherent self-capacity of coils 16 and 17. The shunt capacity may be condenser 18 or the input capacity of coupling tubes 34, 44, depending upon the position of single pole double throw switch 19. In the position where condenser 18 is out of the circuit the switch 19 connects the midpoint between coils 16, 17 to the input lead 33 or 43 of the coupling tubes 34 and 44. The output circuits of tubes 34 and 44 are connected to receivers 35 and 45.

It will now be seen that since the potential from the moving arm of switch 19 to ground in each of the coupling networks is equal to the full line potential of transmission lines 12 and 22, the full line voltage from either line may be applied to the input circuits of either or both of tubes 34 and 44, thus selectively energizing receivers 35 and 45 from either the antenna 10 or antenna 20, as desired.

Where a broader frequency band is to be covered than can be conveniently taken care of by the coupling networks 11 and 21, such as a band covering from 5 to 20 megacycles, a system such as shown in Figure 2 may be used. Here, each of the transmission lines TL1 and TL2 are terminated by a pair of series connected resistors 50 and 51, the midpoint between the resistors being grounded. The sum of the resistances of resistors 50 and 51 is equal to the surge impedance of the line. In each conductor of the transmission lines are connected a plurality of bridge T networks, as described with reference to Figure 1, the shunt capacity being, as before, connected to ground. The networks in one conductor of each line are numbered as in Figure 1, while the complementary networks in the opposite conductor of each line have the same reference numerals primed. The arrangement of the bridge T networks, the coupling to the tubes 34, 44 and the arrangement of switch 19 is as before described. Additional coupling tubes 34', 44' are provided to selectively couple receivers 35', 45' to conductors 12 and 22' through coupling networks 13', 23', 14', 24'. A third set of coupling networks and an associated receiver is shown but is not separately described since its operation is the same as of the previously described similar elements. With this arrangement half of the available voltage across either of the transmission lines TL1 and TL2 is available at the input of each of the coupling tubes but, to compensate for this loss in potential, there is an increased band width due to the elimination of the coupling networks 11 and 21 of Figure 1.

Figure 3 illustrates in more detail the arrangement of one of the coupling tubes, say tube 34, showing in detail the connection of the grid of the tube 34 to the bridge T networks 13, 23 and the output impedance matching network, including transformer 70 and coupling condenser 70'. Coaxial cables usually used to connect a receiver to a transmission line carrying a desired signal may have an impedance of 72 ohms. While such cables may be directly coupled to the output cir-

cuit of tube 34 it is undesirable from the power standpoint to do so since the resultant power gain of the tube is then less than unity. However, if the output circuit of tube 34 is designed on a basis of 500 ohms impedance and a 500 ohm to 72 ohm coupling network, such as that constituted by transformer 70, and capacity 70' is interposed between the cable and the output circuit, the cable and output circuit each face their own impedance and optimum results are attained. If tube 34 is of the type generally designated by type number 6AC7 (1852) a coupling to gain of four is readily obtainable. The output of the impedance matching transformer 70 is 72 ohms and directly feeds the coaxial line connected to the associated receiver 35. If the receiver has a nominal input impedance of 100 ohms it may be connected directly across the coaxial line. For receivers of 500 ohm input impedance another coupling transformer similar to transformer 70 for transforming the impedance in the opposite direction may be connected between the coaxial line and the receiver, the 500 ohm side being connected to the receiver.

The system shown in Figures 2 and 3 has an over-all power gain of two. This may be shown as follows:

Let E be the voltage on the balanced transmission line TL1 and Z equal the line impedance of 600 ohms. For a 72 ohm receiver input,

$$\frac{Z}{8}$$

approximates the receiver circuit impedance.

Since

$$\frac{E}{2}$$

equals the voltage on the grid of tube 34, due to gain in tube 34, the signal voltage on the 72 ohm circuit at the terminals of impedance matching transformer 70 equals the grid signal voltage. Therefore, the power in transmission line TL1 equals

$$\frac{E^2}{Z}$$

and the power in the receiver feed line must be equal to

$$\left(\frac{E}{2}\right)^2 \frac{2}{Z} = \frac{2E^2}{Z}$$

Figure 4 shows in very much simplified diagrammatic form the essential elements of one of the coupling networks of Figure 2, the coupling tube 34 (in conventional box form) and impedance matching transformer 70. The voltage

$$\frac{E}{2}$$

is considered as being applied across half the transmission line and half of the transmission line being terminated by a resistor 50 having an impedance of

$$\frac{Z}{2}$$

The voltage E2 appearing at the output of impedance matching transformer 70 is considered as connected directly across a receiver input circuit having an impedance of 72 ohms. With this particular arrangement a response curve of output volts E2 applied against the frequency in megacycles is shown in Figure 7 as curve 94. It

will be seen that a frequency band of from 3 to better than 20 megacycles is covered with about a 2 to 1 variation in voltage.

The circuit in Figure 5 is similar to that shown in Figure 4, except that a second impedance matching network 80 is shown, matching the impedance of the 72 ohm coaxial line 71 to a high impedance receiver input. The effect of the addition of the second impedance matching network is shown in curve 95 of Figure 7. In this modification a frequency band of from 4 to 20 megacycles is covered with a variation in output voltage from about 1.1 volts to 1.5 volts.

In Figure 6 the modification of Figure 1 is shown in a much simplified form wherein the impedance matching network 11 is used to transform from a balanced transmission line TL1 to an unbalanced line 12.

The impedance matching network 11 of Figure 6 may be so designed as to cover the frequency band from 5 megacycles to 13 megacycles, as shown by curve 96 of Figure 7, while with a slightly different design of impedance matching network 11 the band of frequencies from 12 megacycles to 21 megacycles may be covered. For either type of impedance matching transformer 11 the filter sections 13 remain the same. Providing there is no necessity of receiving frequencies in the two bands simultaneously on the same antenna, this method of using two separate types of impedance matching networks will give about 6 decibels more gain than the wide band system shown in Figures 4 and 5 but means of switching the coupling networks 11 must be provided. It must be clearly understood that the curves of Figure 7 were made on the basis of constant input voltage for each curve but the same input voltage was not used for all curves so that the curves cannot be directly compared one with the other on the basis of relative efficiency.

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

I claim:

1. A transmission line system including at least one two-wire transmission line balanced with respect to ground, each of said wires including series connected reactances of a bridge-T filter circuit, said filter circuit including further reactances connected from said wires to said ground, further transmission lines unbalanced with respect to ground, and means for selectively substituting a coupling impedance of one of said further lines for at least a part of one of said further reactances.

2. A transmission line system including at least one two-wire transmission line carrying high frequency currents of equal and opposite instantaneous amplitudes with respect to a point of zero reference potential, each of said wires including series connected reactances of a bridge-T filter circuit, said filter circuit including a further reactance connected from said wire to said

point of reference potential, further transmission lines adapted to carry high frequency energy at a potential alternating with respect to said point of reference potential, coupling tubes each having an output circuit associated with said further transmission lines and an input circuit, and means for selectively substituting an input circuit of each of said coupling tubes for at least a part of one of said further reactance elements.

3. A transmission line system including a number of two-wire transmission lines each balanced with respect to ground and means for selectively connecting any one of a plurality of transmission lines unbalanced with respect to ground to any of said two-wire lines without disturbing their balance, including a plurality of bridge-T filter circuits connected to said two-wire lines, said filter circuits each having series reactance elements connected in a conductor of each of said two-wire lines and further reactance elements connected from each conductor of said two-wire lines to ground, said reactance elements being so proportioned that the potential across each further reactance is equal to one-half the potential across the two-wire lines, and means for selectively substituting an input circuit of any of said unbalanced transmission lines for at least a part of one of said further reactance elements.

4. A transmission line system including a number of two-wire transmission lines each balanced with respect to ground and means for selectively connecting any one of a plurality of transmission lines unbalanced with respect to ground to any of said two-wire lines without disturbing their balance, including a plurality of bridge-T filter circuits connected to said two-wire lines, said filter circuits each having series reactance elements connected in a conductor of each of said two-wire lines and further reactance elements connected from each conductor of said two-wire lines to ground, said reactance elements being so proportioned that the potential across each further reactance is equal to one-half the potential across the two-wire lines, a coupling tube having an output circuit associated with each of said unbalanced lines and an input circuit, and means for selectively substituting an input circuit of any of said coupling tubes for at least part of one of said further reactance elements of said bridge-T filter circuit.

5. A transmission line system including a number of transmission lines each having a pair of ungrounded conductors, means for connecting series reactance elements of T type filter networks in each of said conductors, means for connecting the shunt reactance elements of each of said elements to ground and means for selectively substituting an input circuit of a thermionic discharge tube for at least a part of said shunt reactance elements in any of said number of transmission lines and means for coupling a transducer device to an output circuit of said thermionic discharge tube.

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