Feb. 8, 1944. N. E. LINDENBLAD 2,341,408

ANTENNA FEED SYSTEM

Filed May 31, 1940

Fig. 1

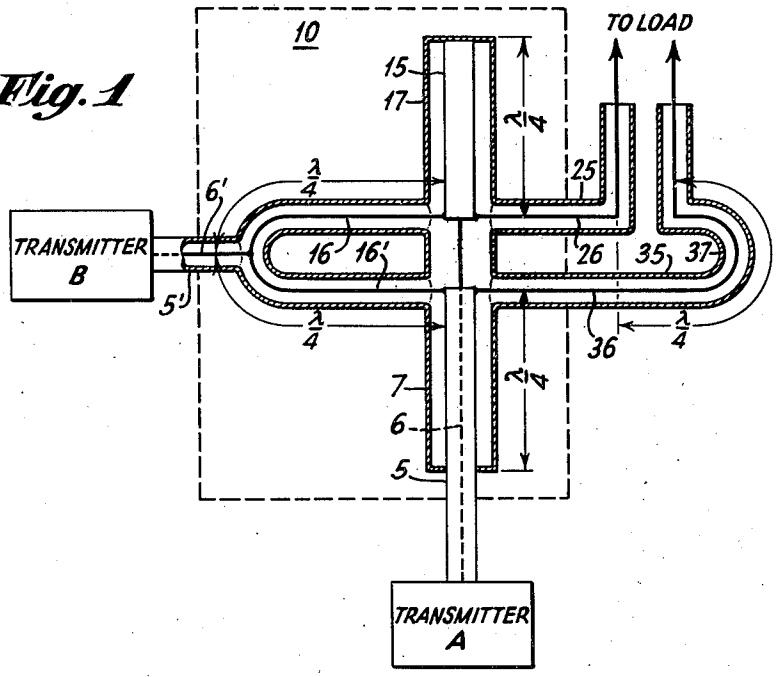
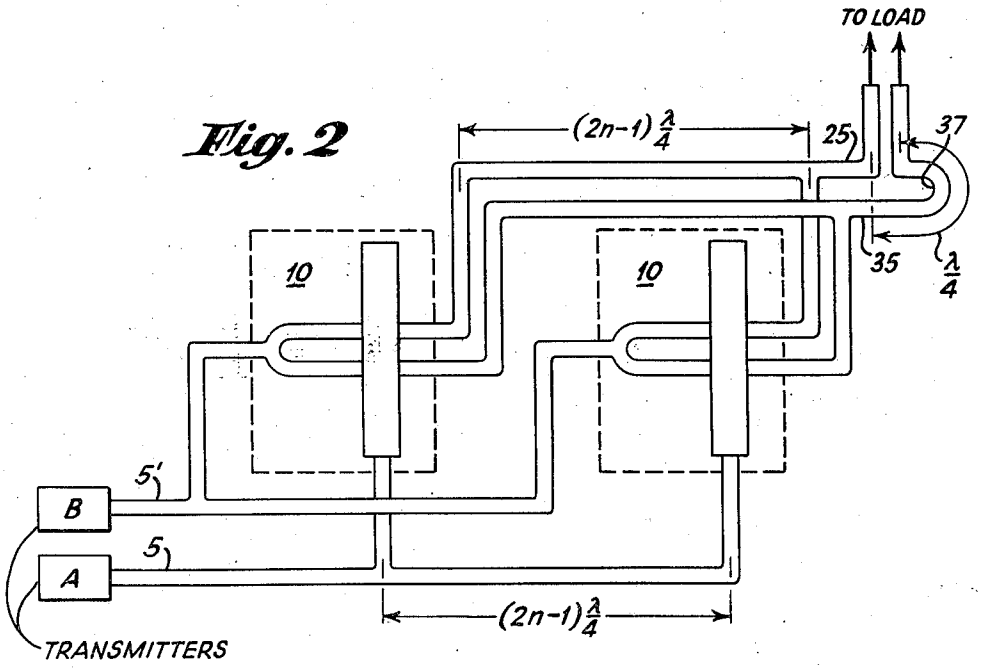


Fig. 2



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Patented Feb. 8, 1944 2,341,408

UNITED STATES PATENT OFFICE

2,341,408

ANTENNA FEED SYSTEM

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Application May 31, 1940, Serial No. 338,177

12 Claims. (Cl. 178—44)

This invention relates to electrical transmission systems and, more particularly, to a system for feeding a load, such as an antenna system, simultaneously with energy from two transmitters operating at different frequencies.

One of the objects of the present invention is to enable two transmitters operating at different frequencies to feed the same load system simultaneously over different branch circuits in such a manner that there is no reaction between the transmitters over a wide range of frequencies.

A further object of the invention is to provide an arrangement for coupling a pair of independent single-sided transmission lines to a pair of transmission lines delivering the energy from both of said independent lines in a phase quadrature relationship at the load terminals.

Still a further object of the present invention is to enable two transmitters operating at different frequencies to feed a turnstile antenna without interaction between the transmitters.

In accordance with a feature of the invention there is employed between one transmitter and the load circuit a transformer for converting from a single-sided circuit to a circuit balanced with respect to ground. Across the balanced circuit is connected a half wave loop circuit with the second transmitter connected to its midpoint. Energy from the second transmitter is thus introduced into the balanced or "push-pull" circuit in a "push-push" relationship. Then, in order to obtain a phase quadrature relationship at the output one side of the balanced circuit is made a quarter wave longer than the other. The energy on one conductor at the point of connection of the load has, therefore, a relationship with respect to the other, carrying phases ϕ_A and ϕ_B from the two transmitters, of $\phi_A \pm 180° \pm 90°$ and $\phi_B \pm 90°$.

The present invention further contemplates the provision of means for counterbalancing any reactive components introduced into the lines due to the heretofore mentioned connection between the single-sided and push-pull circuits.

Further objects, features and advantages of the present invention will appear from the following detailed description which is accompanied by a drawing in which Figure 1 shows an embodiment of the invention, while Figure 2 shows a modification of the form shown in Figure 1.

Referring, now, to Figure 1, there is shown a single-sided transmission line in the form of a concentric cable having an outer sheath 5 and an inner conductor 6, and energized from transmitter A. I have also shown a pair of lines adapted to be energized in a push-pull relationship, one of said lines being composed of an outer sheath 25 and an inner conductor 26 and the other being composed of an outer sheath 35 and an inner conductor 36. The outer sheaths 5, 25 and 35 may be grounded if desired. The inner conductor 26 has a direct conductive connection to inner conductor 6 through conductor 15 and is therefore energized in the same relationship as the inner conductor 6. The other inner conductor 36 is directly connected to the end of the sheath 5 of the single-sided line from transmitter A and is therefore energized in phase opposition to the inner conductor 26. In order to completely uncouple the last quarter wave section of the single transmission line 5, 6 from the remainder of the same so that one side of the balanced circuit is not shorted, I have provided an outer shell 7 surrounding the end of sheath 5. The shell 7 is a quarter of the length of the operating wave long and is connected to sheath 5 of the single transmission line at its end remote from the open end of sheath 5. The length of the conducting path within the outer shell 7 and including the outer surface of sheath 5 is of such length that the point of connection of conductor 36 is electrically freed from the outer conductor of the transmission line 5, 6 as far as radio frequency potentials are concerned. This effect is due to the fact that the length of the conducting path including the outer surface of sheath 5 and the inner surface of shell 7 is substantially equal to a half wavelength of the operating frequency of transmitter A and therefore presents a distinctly high impedance thereto at the point of connection of conductor 36. Furthermore, no radiation can take place from the current flowing along the outer surface of sheath 5 since the current flowing along the inside of the outer shell 7 is equal and of opposite direction. Thus it will be seen that at the frequency for which the junction is designed the balanced line will not be subject to any unbalancing effects from the connection to the single line. This condition is, however, true only when the surrounding section approximates a quarter of the length of the operating wave. If the frequency is changed or if the operating frequency is widely modulated some current will leak over the edge of sheath 5 of the single transmission line, and the push-pull output circuit will be unbalanced. In order to overcome this effect and maintain perfect balance over a wide frequency band, I employ a second quarter wave shell section 17 arranged in an end-on relationship with and having the same

diameter as the outer shell 7. Within the second shell section 17 is an inner conductor 15 having the same diameter as the outer diameter of sheath 5 of the single transmission line 5. Though I have referred to shells 7 and 17 separately for convenience in description, it should be understood that in practice it may be found more convenient to form them in one continuous piece. The inner conductor 15 is connected at its inner end to the center conductor 6 of the single line and, also, to the center conductor 26 of one of the balanced lines. The other end of inner conductor 15 is electrically connected to the end of shell 17. The points of connection, and the dimensions of the parts are so chosen, that the junction is perfectly symmetrical with respect to a center plane perpendicular to the axis of shells 7, 17. With this construction it will be seen that looking from the push-pull line toward the junction along either conductor 26 or conductor 36, an exactly esimilar set of conditions is encountered. Therefore, for a wide frequency band, or for frequencies varying widely from the frequency for which the junction is designed, the reactive drain on conductor 36 due to an improper length of shell 7 is duplicated by an equal drain on conductor 26 by shell portion 17.

From the foregoing description it will be seen that transmitter A feeds transmission lines 25, 35 in a push-pull relationship through a single-sided line 5.

In order to simultaneously feed the same balanced push-pull lines from a second transmitter B, I have connected to the adjacent ends of shell 5 and conductor 15 a pair of conductors 16, 16'. The length of each of the conductors 16, 16' is equal to a quarter of the mean operating wavelength of the system. These conductors are connected to a single-sided transmission line from transmitter B and having a central conductor 6' and an outer sheath 5'. It will be seen that there is in effect a half wave loop connected across the adjacent ends of conductors 26 and 36. Such a half wave loop will, of course, not adversely affect the operation of the circuit as far as transmitter A is concerned. The energy from transmitter B is fed to conductors 26 and 36 through exactly equivalent lengths of line and is therefore in an in-phase or "push-push" relationship. Since it is desired to feed the energy from both transmitters to the load in a phase quadrature relationship, a loop 37 is placed in one of the transmission lines. This loop has a length such that one output transmission line is a quarter of the mean operating wavelength, or an odd multiple thereof, longer than the other.

Figure 2 shows a more complicated arrangement required to eliminate the still existing but balanced reactance of the coupling arrangement at frequencies remote from the mean operating frequency. The construction of each of the portions within the dotted box 10 is the same as shown in box 10 in Figure 1. In Figure 2 each of the input and output lines to boxes 10 are connected together through lines which differ in length by an odd multiple, including unity, of a quarter of the mean operating wavelength. Since all physical dimensions in each coupling unit are the same the reactance and resistance of both sections is exactly the same and due to the quarter wave spacing each compensates for the other on each side of the mean operating frequency. The theory upon which this depends is disclosed in more detail in a patent to E. C. Cork, et al., #2,165,961, granted July 11, 1939.

It will be noted that since the phase of energy in transmission line 35, 36 at its output end from each transmitter has a phase relationship with respect to the output end of the other line 25, 26, carrying phases ϕ_A and ϕ_B' of $\phi_A \pm 180° \pm 90°$ and $\phi_B \pm 90°$ phase rotations in opposite directions are obtained in the load circuit or antenna connected to the output. As long as there is no reflection, or only a moderate amount, from the antenna or load, there can be no transfer of energy between the transmitters.

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. Means for supplying energy to a high frequency load simultaneously at two different frequencies, a first and a second source of oscillations, each of said sources being adapted to supply one of said different frequencies, a pair of transmission lines coupled to said load, means for applying energy from the first of said sources to said pair of transmission lines in a push-pull relationship, means for applying energy from the second of said sources in an in-phase relationship, one of said lines having a length from said load to said means an odd multiple, including unity, of a quarter of the mean operating frequency longer than the other whereby energy is supplied to said load from both of said sources in a phase quadrature relationship.

2. In combination, a first single transmission line having an outer sheath and an inner conductor and a pair of transmission lines, a connection from the inner conductor of said single line to a conductor of one of said pair of lines, a connection from the sheath of said single line to a conductor of the other of said pair of lines, an outer shell surrounding the end portion of said single line, said shell being connected to said sheath at a distance equal to a quarter of the mean operating wavelength from the end of said single line, and a balancing circuit including an inner conductor connected to the inner conductor of said single line and having a diameter equal to the diameter of the outer sheath of said single line and an outer shell having a diameter equal to the diameter of the first outer shell and connected thereto, the inner conductor and outer shell of said balancing circuit being connected together at a distance equal to a quarter of the mean operating wavelength from the end of said single transmission line, a second single transmission line having an outer sheath and an inner conductor, a connection from its inner conductor to each of said pair of lines, said connections each having a length equal to a quarter of the length of the mean operating wavelength, one of said pair of lines being a quarter of the mean operating wavelength longer than the other.

3. In combination, a first single transmission line having an outer sheath and an inner conductor and a pair of transmission lines, a connection from the inner conductor of said single line to a conductor of one of said pair of lines, a connection from the sheath of said single line to a conductor of the other of said pair of lines, an outer shell surrounding the end portion of said single line, said shell being connected to said sheath at a distance equal to a quarter of the mean operating wavelength from the end of said single line, and a balancing circuit including an inner conductor connected to the inner conduc-

tor of said single line and an outer shell connected to said first outer shell, the inner conductor and outer shell of said balancing circuit being connected together at a distance equal to a quarter of the mean operating wavelength from said last connections, a second single transmission line having an outer sheath and an inner conductor, a separate connection from its inner conductor to each of said pair of lines, said separate connections each having a length equal to a quarter of the length of the mean operating wavelength, one of said pair of lines being a quarter of the mean operating wavelength longer than the other.

4. In combination, a first single concentric line having an outer sheath and an inner conductor, a pair of concentric transmission lines each having an outer sheath and an inner conductor, a connection from the inner conductor of said single line to an inner conductor of one of said pair of lines, a connection from the end of the sheath of said single line to the inner conductor of the other of said pair of lines, an outer shell surrounding the end of said single lines and its junction with said pair of lines, said shell being connected to the outer sheath of said single line at a distance equal to a quarter of the mean operating wavelength from the end of said sheath, and a balancing circuit, including an inner conductor having a diameter equal to the diameter of the outer sheath of said single line connected to the inner conductor of said single line and an outer shell having a diameter equal to the diameter of said first outer shell and forming an extension thereof, the inner conductor and outer shell of said balancing circuit being connected together at a distance equal to a quarter of the mean operating wavelength from the end adjacent the end of said single line, a second single transmission line having an outer sheath and an inner conductor, a pair of connections from its inner conductor to said pair of lines, said pair of connections each having a length equal to a quarter of the length of the mean operating wavelength, one of said pair of lines being a quarter of the mean operating wavelength longer than the other.

5. In combination, a first single concentric transmission line having an outer sheath and an inner conductor, a pair of concentric transmission lines each having an outer sheath and an inner conductor, said first single line being branched into two branches, one of said branches being an odd multiple, including unity, of a quarter of the operating wave longer than the other of said branches, a connection from one of said pair of lines to each of the inner conductors of said branches, a connection from the inner conductor of the other of said pair of lines to the end of the outer sheath of each of said branches, said connections differing in length by an odd multiple, including unity, of a quarter of the operating wavelength, an outer shell surrounding the end of each branch of said single line, said shells being connected to the outer sheath of said branches at a distance equal to a quarter of the length of the operating wave from the end of each branch, said outer shell extending beyond the ends of said branches, and an inner conductor within the extending portion of said shells and connected to the inner conductors of said branches, each of said outer shells and said last mentioned inner conductors being connected together a distance equal to a quarter of the length of the operating wave beyond the point of connection to said inner conductors, a second single concentric transmission line having an outer sheath and an inner conductor, a half wavelength loop connected across the end of each of said first single line branches, connections from a midpoint on each of said loops to said second single line, said last connections differing in length by an odd multiple, including unity, of a quarter wavelength; one of said pair of lines being a quarter wavelength longer than the other whereby phase quadrature output is obtained.

6. In combination, a pair of transmission lines adapted to supply energy to a load in a phase quadrature relationship, means for energizing said transmission lines in a push-pull relationship entirely from a first source of oscillations of one frequency, and means for simultaneously energizing said lines in an in-phase relationship entirely from a second source of oscillations of a different frequency, one of said pair of lines being a quarter of the mean operating wavelength longer than the other.

7. In combination, a first and a second transmission line and a pair of concentric transmission lines, each of said lines having an inner conductor and an outer shell, each of said first and second transmission lines being connected to a source of oscillations of different frequencies, a coupling circuit for energizing the inner conductors of said pair of lines in a push-pull relationship from only the source connected to said first transmission line, connections from the inner conductors of said pair of lines to the inner conductor of said second line for simultaneously energizing said pair of lines in an in-phase relationship from only the source connected to said second line.

8. In combination, a pair of transmission lines adapted to supply energy to a load in a phase quadrature relationship, means for energizing said transmission lines in a push-pull relationship entirely from a first source of oscillations, and means for simultaneously energizing said lines in an in-phase relationship entirely from a second source of oscillations, one of said pair of lines being a quarter of the operating wavelength longer than the other, and means connected to one of said pair of lines for neutralizing the undesired unbalance on said pairs due to the reactance of said first means.

9. In combination, a pair of transmission lines and a first and a second single transmission line, each connected to a source of high frequency energy, a coupling circuit for energizing said pair of lines in a push-pull relationship from one of said single lines, connections from said pair of lines to the other of said single lines for simultaneously energizing said pair of lines in an in-phase relationship, said coupling circuit including means for maintaining said pair of transmission lines balanced, a second coupling circuit connected to said one single line and said pair of lines, a second set of connections from said pair of lines to said other single line, the connections of said second coupling circuit and said second set of connections differing in length from said first mentioned connections by an odd multiple, including unity, of a quarter of the mean operating wavelength.

10. An arrangement as set forth in claim 7 in which a second set of coupling circuits and connections connecting said single lines and said pair of lines is provided, said second set being displaced from those set forth in claim 7 with respect to the energy on said lines by a distance

equal to an odd multiple, including unity, of one quarter of the mean operating wavelength.

11. In combination, a pair of sources of alternating current energy, a first and a second transducer means, connections from each of said sources of energy to each of said transducer means, each of the connections from said first transducer means to said sources being one quarter of the operating wavelength longer than the corresponding connections from said second transducer means to said sources, a load, and connections from said transducers to said load, the connections from said second transducer to said load being one quarter of the operating wavelength longer than the corresponding connections from said first transducer means to said load.

12. In combination, a source of alternating current energy, a first and a second transducer means, connections from said source of energy to each of said transducer means, the connection from said first transducer means to said source being one quarter of the operating wavelength longer than the connection from said second transducer means to said source, a load, and connections from said transducers to said load, the connection from said second transducer means being one quarter of the operating wavelength longer than the connection from said first transducer means to said load.

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