

April 22, 1941.

N. E. LINDENBLAD

2,238,904

SHORT WAVE COMMUNICATION SYSTEM

Original Filed April 28, 1936 3 Sheets-Sheet 1

Fig. 1

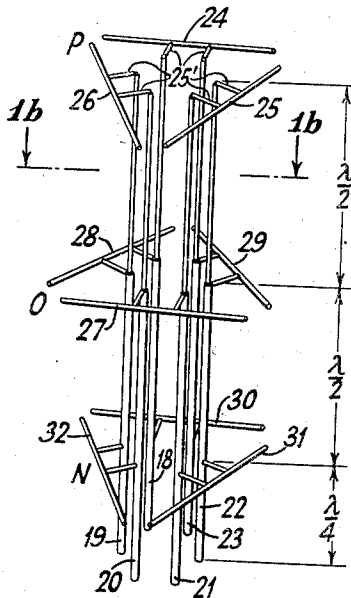


Fig. 1a

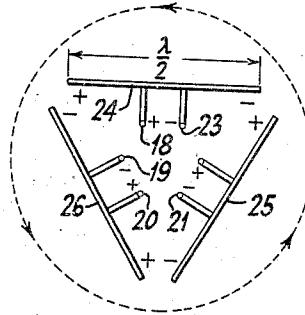


Fig. 1b

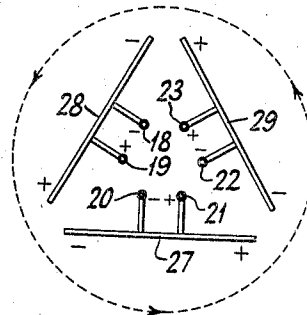
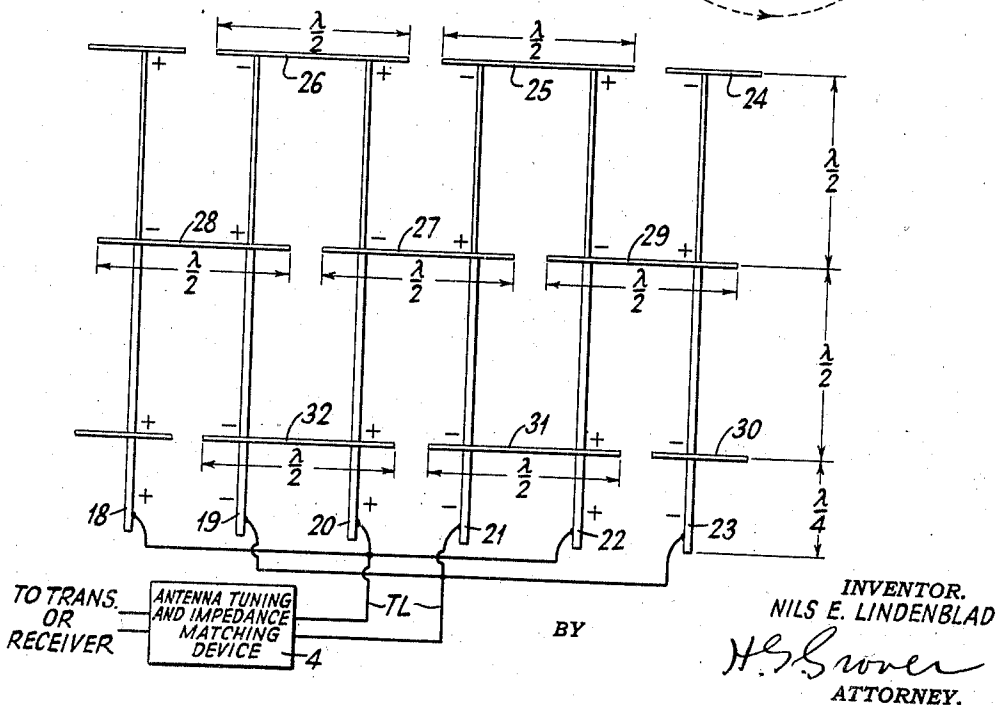


Fig. 1c



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Fig. 2

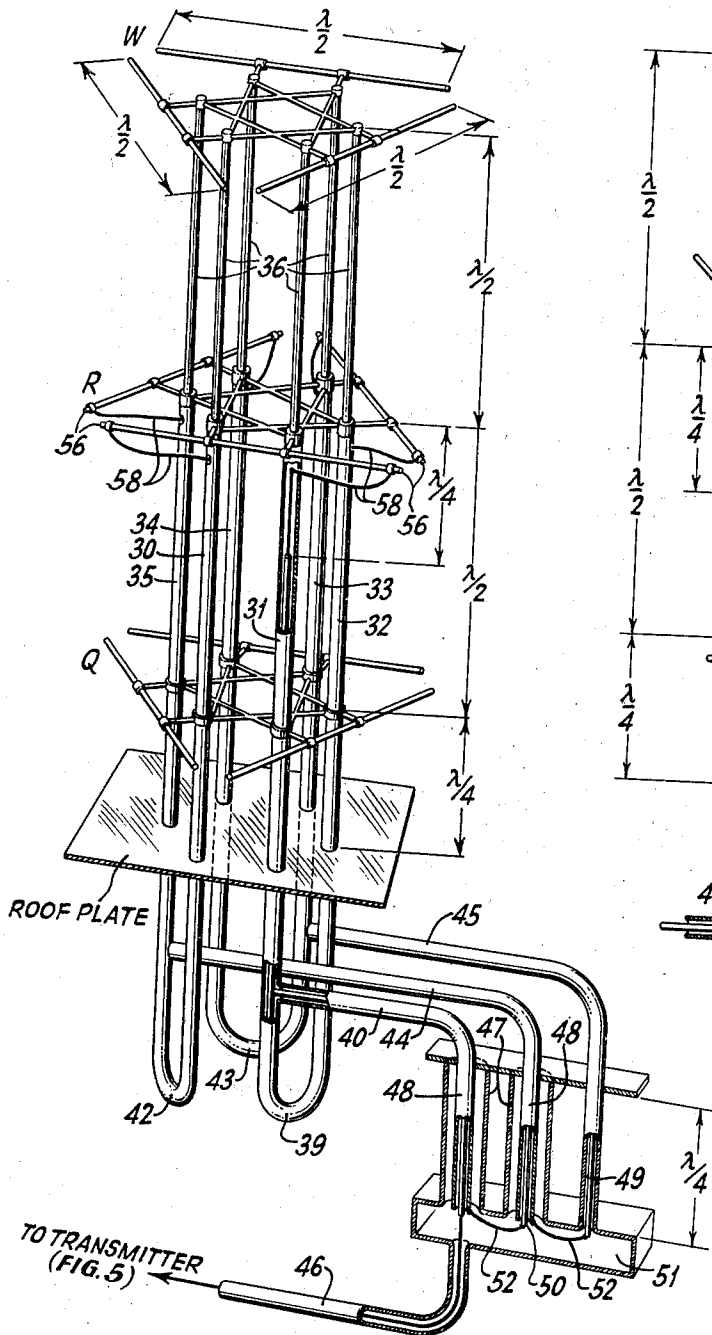
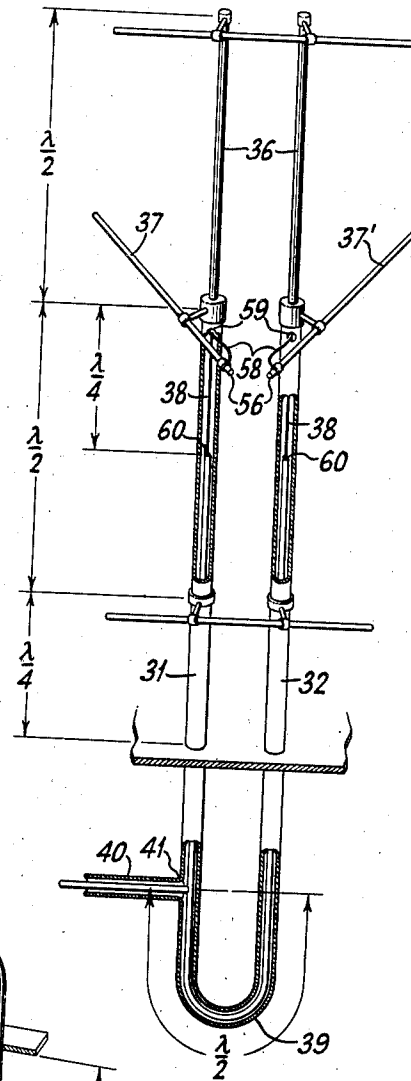


Fig. 3



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Fig. 4

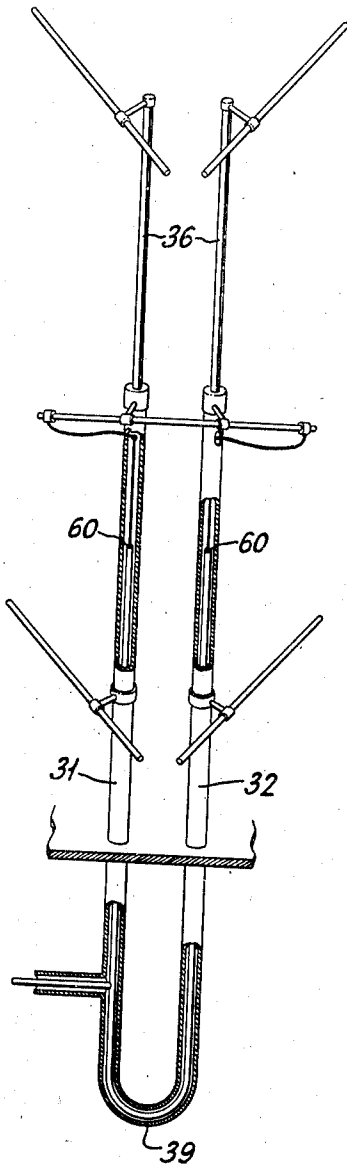
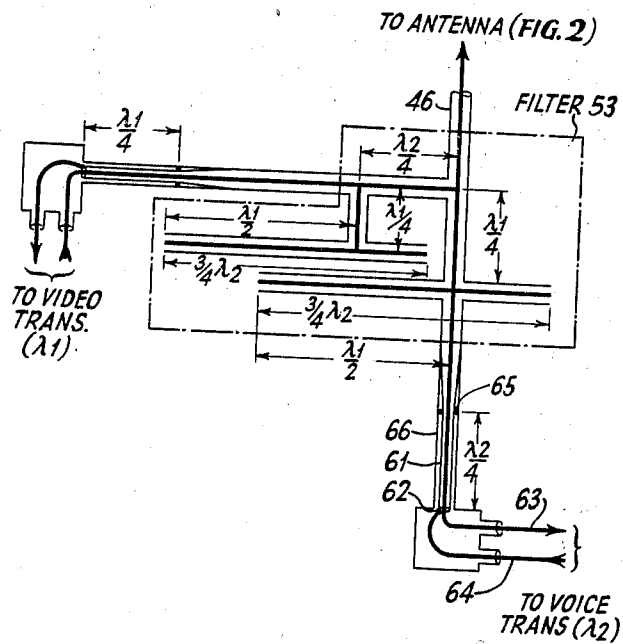


Fig. 5



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UNITED STATES PATENT OFFICE

2,238,904

SHORT WAVE COMMUNICATION SYSTEM

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Original application April 28, 1936, Serial No.
76,745. Divided and this application January
6, 1938, Serial No. 183,571

26 Claims. (Cl. 178-44)

This invention is a division of United States Patent No. 2,131,108, granted September 27, 1938, on an application Serial No. 76,745 filed April 28, 1936, and relates to transmission line systems and feeders for high frequency loads, such as antenna systems.

Some of the objects of the invention are; to provide a rigid and practical ultra high frequency antenna structure for use on the tops of high buildings wherein the feeders themselves form supports for the radiating elements; to match the surge impedances of the radiating elements to the impedances of the supporting feeders; to obtain an impedance match between a plurality of branch feeders and a main feeder without introducing excessive circulating energy in the system; to provide an impedance matching device in the form of a concentric transmission line; to enable the connection and impedance matching of a single concentric conductor system to a plurality of concentric conductor systems; and to couple a concentric transmission line to a pair of conductors adapted to have oppositely flowing currents thereon with means for preventing the flow of current on the exterior of the outer conductor of the concentric line.

The invention includes among its features:

(1) An antenna system formed of a plurality of units in different parallel planes, each unit of which comprises an equilateral triangular affair having a plurality of half wavelength conductors which are angularly disposed at substantially 60° with respect to one another, the conductors in one unit being fed at points intermediate the ends while the conductors in a parallel plane are fed from the ends.

(2) A feeder in the form of a concentric line having inner and outer conductors whose relative diametrical dimensions vary to produce desired changes in impedance of the feeder.

(3) An arrangement for feeding an antenna system directly from the same elements which support the aerial or radiating conductors.

(4) A quarter wavelength sheath surrounding the outer conductor of a concentric line and coupled thereto for providing a high impedance to current of the operating frequency at the open end of said sheath.

Among the advantages obtained by the present invention is the provision of a novel type of impedance matching circuit which is compact, mechanically rigid, and electrically self-shielding.

Other objects, features and advantages will appear from a reading of the following description, which is accompanied by drawings wherein

like reference numerals indicate like parts throughout the figures.

Fig. 1 illustrates an antenna embodiment of the invention employing aerial elements which form sides of one or more equilateral triangles, and wherein the aerial elements are fed from the supporting rods;

Figs. 1a and 1b are given for the purpose of exposition and show the current distribution pattern in the aerial elements of adjacent triangular units;

Fig. 1c is a view showing the system of Fig. 1 unfolded in a single plane in order to more completely illustrate the structure of Fig. 1 and the manner in which the various elements thereof are energized;

Fig. 2 illustrates a preferred embodiment of antenna, impedance matching system, and feeder system in accordance with the invention;

Fig. 3 is a detail of the system of Fig. 2 showing one pair of supporting feeders and associated apparatus in order to more clearly illustrate the principles of the invention;

Fig. 4 discloses an alternative arrangement to that of Fig. 3 for feeding the doublets of the different triangular units; and

Fig. 5 illustrates a circuit arrangement of filter and impedance circuit which may be employed in feeding energy from a plurality of transmitters to an antenna system of the type shown in Fig. 2.

Fig. 1 shows one satisfactory antenna embodiment for achieving wide frequency band communication. Here there are provided six transmission lines comprising three pairs of vertical feeders 18, 19; 20, 21 and 22, 23, each of which connects with a two-wire transmission line TL extending to high frequency apparatus through antenna tuning and impedance matching device 4 (note Fig. 1c). These three pairs of feeders form a six wire cage in which adjacent feeders are of opposite phase. Such a cage arrangement of feeders is known to give very little radiation even when the spacing is an appreciable fraction of a wavelength, for example, an eighth of a wavelength. The fact that these feeders can be separated without producing radiation is utilized in making the cage serve as a support for the triangular radiating units N, O and P. Each unit comprises three half-wavelength doublets forming sides of an open equilateral triangle. Unit P contains doublets 24, 25 and 26; unit O contains doublets 27, 28 and 29; and unit N contains doublets 30, 31 and 32. The feeders 18, 19, 20, etc., are in the form of

rigid pipes on which the individual doublets of the equilateral triangular units may be mounted directly, or, as shown in the drawing for mechanical and electrical reasons, supported through metallic brackets 25'. All brackets 25' are of the same length and the impedance of these including the vertical feeders are matched to the impedance of the doublets at spaced points on the doublets intermediate the ends thereof in well known manner. In other words, each doublet is arranged to introduce a load which matches the vertical feeders at the points of connection so that a minimum or no standing wave is set up on the vertical feeders. Since the phase lag introduced by the additional length of brackets 25' is the same in all triangular units N, O and P, they do not affect the phase relations between the triangular units. The units are here shown spaced one-half wavelength apart, correspondingly located doublets of which are located one wavelength apart. Since adjacent equilateral triangular units are one-half wavelength apart, the same feeder will have opposite polarities at the points of connection so spaced, for which reason it is necessary to reverse the order of polarity connection of the individual doublets of the adjacent triangular units so that the currents in adjacent triangles may have the same direction. This current direction is illustrated in Figs. 1a and 1b as being counterclockwise, although it will be appreciated that the direction of the currents in all the equilateral triangular units N, O and P may be reversed. Figs. 1a and 1b are plan views of the triangular units P and O, respectively, and indicate how the individual doublets of each unit on each level are fed from different feeder wires. It will be observed, among other things, that the doublets of adjacent triangular units, such as P and O, are differently positioned, while those of alternately located units, such as P and N, are similarly positioned. Referring to Fig. 1a as an example, it will be seen that feeders 18 and 23 feed doublet 24 of unit P, whereas in the adjacent lower unit O, (note Fig. 1b) these two feeders help feed two different doublets. The manner of feeding all doublets of the triangular units N, O and P will be more clearly understood from an inspection of Fig. 1c, which is an unfolded view of the antenna structure as it would look if the feeders and doublets were all placed in a single plane.

When feeding the system of Fig. 1, as shown in Fig. 1c, it may be desirable to change the dimensions of the feeders 18, 19, 20, etc., abruptly at successive levels at which they connect with the different triangular units, because of the abrupt change in load impedance on the feeders as the feeders extend past a level of a triangular unit and approach the top of the antenna. In Fig. 1 the diameters of the feeders decrease toward the top of the antenna system, as shown, with a consequent increase in impedance of the feeders.

In practice, it is difficult to obtain a complete impedance matching of the feeders throughout their lengths, since this would call for large changes in diameter of the feeders. A slight mismatch of the feeders, especially if the voltage nodal points of the thus created standing wave portion of the total energy on the feeder (since some standing waves are created with a mismatch) are located mid-way between adjacent triangular units, is not, however, detrimental to the system, since in this condition the polarities at the terminals of each half wave section between adjacent triangular units is reversed and

of equal amplitude, regardless of whether there is a standing or traveling wave in the section.

If now we consider a case where the maximum point of a standing voltage wave on the feeders instead of a minimum falls midway between adjacent triangular radiating units, we may have a very different mode of tuning, if at the same time the impedance offered by the individual doublets across the feeders is inductive. The case then is similar to the situation described in my United States Patent No. 1,821,386, granted September 1, 1931, wherein there is obtained an infinite phase velocity along the feeders so that all points along each feeder is at the same phase. In this particular case the adjacent triangular units do not need to have the order of connection of the individual radiating doublets changed as shown in Figs. 1 to 1c, and instead all triangular units may have their correspondingly located doublets similarly located along the feeder line. Because of this phase phenomenon, there is no need to employ any particular spacing between adjacent units. It is evident that a system built to operate according to the principles above set forth in connection with Fig. 1 will have this second degree of freedom (or tuning) just described at a lower frequency. The entire feeders and those portions of the individual radiating doublets in the triangular units falling outside the tapping points on the doublets are then effective capacities which are tuned by the portion of the radiating doublets between the tapping which are effective inductances. This last mode of oscillation, however, is not preferred, since it calls for a greater ratio of circulating energy in the system to radiated energy from the system which tends to give the system a lower power factor and consequently sharper tuning, a feature not desirable in connection with communication on wide frequency band high definition television signals.

It should be noted that the system of Figs. 1 to 1c hereinabove discussed, which show a plurality of triangular units stacked in parallel planes, have been energized from the base of the antenna structure. From what has been said before in connection with these figures, it will be apparent that due to the half wavelength or multiple of a half wavelength spacing between the triangular units, the units will be excited with voltages of equal magnitude, whether the characteristic impedances of the vertical feeders connecting these units are matched or unmatched. This is because at half wave intervals along the feeders there must appear the same magnitudes of current and voltage save for an ordinarily unappreciable ohmic loss. A disadvantage of these arrangements when the stacked triangular units are fed at the base is the cumulative error of both phase and amplitude along the length of the feeders which occurs in the presence of sidebands due to the deviation of the sideband wavelengths from the particular wavelength for which the triangular units are correctly spaced. Thus while the tuning characteristic of each triangular unit of the system of Fig. 1 may be sufficiently broad to accommodate the sidebands without appreciable change in amplitude in the radiating elements, the cumulative effect mentioned will disturb, to some extent, the radiation pattern and, therefore, at the distant point of reception cause an apparent greater change in received amplitude than that which is actually caused by the tuning characteristic of the triangular units. The system of Fig. 2, now to be discussed in

connection with Fig. 3, shows one preferred embodiment in accordance with the invention and overcomes, to a large extent, the foregoing disadvantage by minimizing the cumulative error just referred to. This is achieved, in brief, by connecting only the center triangular unit R directly to the source of energy by means of feeder lines and coupling the other triangular units W and Q, respectively above and below the center unit, to this center unit R. For this purpose there are employed sections of concentric transmission lines 30 to 35 respectively, whose inner conductors are directly connected to the doublets of the center triangular unit and whose outer conductors serve as coupling feeders for the doublets of the lower triangular unit Q, there being provided an extension 36 of the outer conductor for serving as a coupling feeder for the uppermost triangular unit W. These self-contained concentric transmission line feeders provide, among other things, a clean mechanical design of structure.

Fig. 2 shows three equilateral triangular units Q, R and W in parallel planes at different levels, spaced one-half wavelength apart, and fed by three pairs of vertical feeders. In order to more clearly explain the manner in which the doublets of Fig. 2 are fed by and matched to the vertical feeder lines, Fig. 3 shows, in simplified manner, a single pair 31, 32 of the feeders of Fig. 2 with the associated doublets of the different triangular units connected to this pair. Since the other pairs of feeders, namely 33, 34 and 30, 35, are connected in similar manner to the other doublets of the triangular units, what is set forth herein-after likewise applies to these other feeders and their associated doublets.

The middle doublets 37, 37' which are the ones primarily receiving energy from the inner conductors 38 of the transmission lines 31, 32 are at their ends 56 connected to feeders 58 running more or less parallel with the doublets 37, 37'. These feeders 58 connect the ends 56 of the doublets to the ends 59 of the inner conductors 38 of the concentric lines 31, 32. These ends 59, as described later, have an impedance which is rather high, for which reason it is advantageous to make the last quarter wavelength of the inner conductor 38 of the concentric line have a higher ratio between diameters of inner and outer conductors than the rest of the system. As is known, it is the diametrical ratio and not the actual size of the conductors which determines the characteristic or surge impedance of the line. This quarter wave link of 38 then, by having a load higher than its surge impedance at its upper end 59, will offer an impedance lower than its surge impedance at the lower end 60. This lower impedance at the lower end 60 then matches the rest of the transmission line system below it. This line system below 60 can then have reasonable mechanical dimensions.

The reason why there is a high impedance obtained at the feed points 59 will now be given. In considering a single doublet 37, we know that its series resistance at its center, is 72 ohms. If we now consider two doublets directly connected in parallel, close together and connected to each other at the ends, we know that they are surrounded by a common radiation field. In parallel, the doublets form an entity having a 72 ohms resistance at the center, as before. The current causing the field is, however, divided between the two conductors of the parallel entity. If, however, the doublets are effectively in parallel and

the transmission lines connected only to one doublet at its center, the current division is half and half, the series resistance at the middle of one of them must then be four times that of a single doublet alone, for the same power. If the division of the current between the two doublets effectively in parallel is not equal, the series resistance at the middle of one is equal to 72 ohms multiplied by the square of the ratio of the total current in the system and that in the branch under consideration. Now, as a matter of fact, the inner conductors 38 of the two transmission lines 31, 32 are connected to the feeders 58 not at the middle of the system but at points farther out (although symmetrical). Due to the falling off of the current towards the ends of a doublet, it can be seen that, on an energy basis, the series resistance of the system is still further increased. The actual length of the feeders 58 between the ends of the doublets and the ends of the inner conductors 38 of the transmission lines is less than a quarter wave. In the concentric transmission lines, however, the center conductor current must have an equal and opposite counterpart in the interior of the outer conductor, which is called the shell current. This shell current in the outer conductor continues through the aperture in the outer conductor made for the end of the center conductor and continues across the mid portion of the system (star connection and center portion of main doublet) to enter in through the aperture of the other transmission line to again become the shell current. The star members and the portion of the main doublet intermediate two adjacent transmission lines feeding the same doublet serve to complete the path for the split doublet branch formed by the feeder. The current from the feeder branch, however, causes a certain voltage drop across the star members and the middle doublets which is not obtained in the top and bottom systems. This is equivalent to making the inductance of the mid portion of the mid system higher. The length of the doublets in the mid system therefore has to be somewhat less than in the top and bottom systems. The total voltage drop obtained across the mid section (stars and mid portions of the doublets) is, of course, what energizes the top and bottom systems.

In actual practice, due to the shunting effect of the bracing star connections, the doublets of all the units W, R and Q are very slightly longer physically than one-half wave, the doublets of the middle unit R being slightly shorter physically than the doublets of units W and Q. In one embodiment, the upper and lower doublets were about 4% longer than the physical length of one-half wave, whereas the middle doublets were only about 2% longer than one-half wave, although it will be understood that the electrical length of all the doublets of Q, R and W is a perfect half wave. This difference between the middle doublets and the upper and lower doublets is due to the connections of the feeders 58 to the ends of the middle doublets.

From the foregoing, it will be appreciated that it is not essential that feeders 58 be connected only to the ends 56 of the middle doublets, since they may be tapped to the middle doublets at intermediate points depending upon the impedance matching requirements of the system. Such impedance matching requirements, under certain conditions, may even call for the introduction of lumped reactances in some form in feeders 58.

For obtaining a 180° phase reversal between the adjacent concentric transmission lines 31 and 32, there is provided a U-shaped concentric line section 39 so connected to an energy supply line 40 that there is a path difference between lines 31 and 32 equal to half a wave as measured from the point of connection 41. In other words, the path to one transmission line 32 is half a wave longer from junction point 41 than to the other transmission line 31, and both paths are in parallel relation with respect to energy line 40. Other U-shaped concentric line sections 42 and 43 similarly couple the other concentric transmission lines 30, 35 and 33, 34 together, and are, in turn, connected to energy supply feeders 44 and 45. This mode of coupling is adequately described in United States Patent No. 2,155,652, granted April 25, 1939, to Albert Gothe et al., to which reference is made for a more detailed description. It will thus be seen that the six vertical concentric transmission lines 30 to 35, inclusive, of alternate phase, have been reduced to three energy supply feeders 40, 44, and 45 of the same phase. To obtain the desired impedance matching between the U-shaped line sections 39, 42 and 43 and their respective energy supply feeders 40, 44 and 45, the impedance of each feeder 40, 44 and 45 is respectively made to be equal to one-half the impedance of the U-shaped line section which it will be observed comprises two transmission lines in parallel. For example, if the impedance of each transmission line of the U-shaped section 39 is 48 ohms, then the impedance of energy feeder 40 should be 24 ohms for a connection which is free from reflection. The surge impedance of the U branches therefore must be twice that of the T branch feeding into the U. Since the surge impedance of a line is equal to $\sqrt{L/C}$, L must be doubled and C divided by two. This gives a factor of 4 under the square root, and thus the surge impedance is doubles. It is clear that this factor cannot belong to either L or C alone, since L increases as much as C decreases. L and C are in their turn determined by functions in which the variable, the ratio between shell and center conductor diameters, is under a logarithm. That then means that if L is to be doubled or C cut in half, the ratio of diameters must be squared. If L was to be made three times and C to be divided by three, the ratio would have to be cubed. It will be seen from this that line dimensions must be carefully chosen in order to avoid impossible mechanical dimensions.

It is now proposed to connect all three feeders 40, 44 and 45 of 24 ohms each to a single feeder. At first blush, one might consider simply paralleling the three feeders. However, if this is done, then for a connection free from reflection with a single feeder for energizing the three, there would be required a single feeder whose impedance is equal to that of the three feeders 40, 44 and 45 in parallel, that is, a single feeder whose surge impedance is only 8 ohms. Such a low surge impedance is, however, entirely impractical in this case inasmuch as a desirable ratio of four to one between inner and outer conductors of a concentric line gives a surge impedance of about 80 ohms, and in order to obtain an impedance of only eight ohms to match the three parallel lines 40, 44 and 45 there would be required a ratio between inner and outer conductors of the single feeder of the tenth root of four, an obviously impractical mechanical arrangement because the inner and outer conductors would then have an extremely small difference in diameter.

The foregoing difficulties are overcome in accordance with the invention by arranging a circuit whereby the three T feeders 40, 44 and 45 are connected in series and joined to the single feeder 46. By means of this feature of the present invention, the impedance required for the single feeder 46 is three times that of one of the feeders 40, 44 or 45, in other words 72 ohms. This value of impedance is practical and one which the main line or single feeder 46 can be designed to provide. As can be seen, two of the three T branches, 40 and 44, are surrounded by a shell 47 which makes the outer conductor of the T branch an intermediate shell 48 for the length of a quarter wave. On account of its length, this intermediate shell 48 has a very high impedance on its outside. Now, then, the current in the center conductor 49 of the branch 45, which has no outer shell, becomes the shell current for the middle branch 44 and the current of the center conductor 50 of the middle branch 44 becomes the shell current for the branch 40. The current in 49 cannot go on the outside of the intermediate sleeve 48 of the middle branch 44 due to the high impedance of the quarter wave conductor 47; but must go on the inside and become the shell current for the middle T branch 44, as already stated. The shell current of the branch 45, i. e., the current in the outer conductors, follows the cover 51 and becomes the shell current for the main line 46. The center conductor current of the right hand branch becomes the center conductor current of the main line 46. The three T branches are thus connected in series and in phase with the main line 46. Due to the necessary introduction of cross connectors 52 in this system, it is rather important to make the three T branches 40, 44 and 45 successively longer by an equal amount. Since the voltage of the main line 46 is divided by three, a third for each T branch, or since there are three T branches in series, the surge impedance of each branch must be a third of the surge impedance of the main line 46. The ratio of the shell and center conductor diameters of the T branches 40, 44 and 45 must therefore be the cubic root of the ratio in the main line 46 as already stated.

Fig. 4 shows an alternative method to that of Figs. 2 and 3 of connecting a pair of concentric transmission lines, such as 31, 32, to the doublets of three triangular units, and differs from Fig. 3 only in showing that the concentric lines 31, 32 may both feed the same doublet in the middle level, instead of different doublets, while feeding different doublets in the upper and lower levels.

Where it is desired to employ two transmitters on the same antenna system at slightly different frequencies, (λ_2 and λ_1) as for instance the video and audio transmitters for transmitting television programs, a filter system shown in Fig. 5 may be inserted between the main line 46 of Fig. 2 and the transmitters proper. This filter system, shown in box form and designated 53, is described in great detail in United States Patent No. 2,128,400, granted August 30, 1938, to which reference is herein made. Obviously the purpose of this filter system is to prevent the energy from one transmitter from entering the circuits of the other transmitter while permitting both transmitters to freely feed energy into the antenna system.

Since main feeder 46 is a single concentric line and since the transmitters in the above mentioned case of Fig. 5 are preferably of the push-pull type, it now becomes necessary to adapt the

single concentric transmission line system to a push-pull transmission line system for connecting to the balanced circuit of the transmitter. In this instance, the U-shaped phase transforming arrangement described above in connection with elements 39, 42 and 43 of Fig. 2 was not found suitable for providing the proper load impedance required by the push-pull transmitter. This will be evident from the fact that the main line 46 has an impedance of 72 ohms and the total impedance across both legs of the U-phase transforming arrangement would have to be 288 ohms, i. e., each leg of the U would have an impedance of 144 ohms. Such an impedance of 288 ohms is for most transmitters too high to draw full power. This difficulty is overcome in accordance with another aspect of the invention which provides a push-pull impedance equal to the impedance of the single concentric conductor line which again effects phase transformation. This circuit comprises a quarter wave concentric line 61 whose inner and outer conductors are each connected at one end 62 to the center conductors 63 and 64 of a pair of push-pull concentric line branches. An outer metallic sleeve 66 surrounds the line 61 for its entire quarter wavelength, and is joined to the outer conductors of the push-pull branches, as shown. To understand the operation of the circuit, let us visualize the circuit from the transmitter end from which there are fed currents of opposite direction in the two push-pull branches, as indicated by the arrow marks. Since in a single concentric conductor line the center conductor current and the shell current on the inner surface of the outer conductor are opposite to each other in direction, but of the same magnitude, it follows that the inner conductor of one branch of the push-pull circuit should continue as the inner conductor of the single concentric line 61 while the inner conductor of the other push-pull branch should continue as the shell current of the line 61. To prevent short circuiting of the push-pull branch connected to the outer conductor of line 61, it is necessary for the shell of line 61 at point 62 to present a high impedance on its outer surface, in which case all current arriving over conductor 64 will travel over the inner surface of the shell of line 61. This is achieved by making sleeve 66 a quarter wavelength and connecting its upper end to the outer conductor of line 61. Since lines 63 and 64 are effectively in series, each must have a surge impedance equal to half the surge impedance of the line 61; consequently, there will be a surge impedance across 63 and 64 of a value equal to the surge impedance of single concentric line 61. In order not to alter the physical configuration of the system between filter circuit 53 and the push-pull branches, one may taper both the inner and outer conductors of the single transmission line leading from the filter to the line 61. In order not to change the surge impedance along the tapered section, the diametrical ratio of the conductors in this section should be constant. To preserve neatness of appearance, the metallic sleeve 66 is extended beyond quarter wave line 61 to form a continuation of the transmission line leading from filter 53.

It will be understood, of course, from what has gone before, that the invention is not limited to the precise arrangements illustrated and described, since various modifications may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. In combination, first and second concentric feeder lines of predetermined impedance, each having inner and outer conductors, a main concentric line having an impedance at least equal approximately to the sum of the impedances of said first and second feeder lines, and a circuit for matching the impedance of said main line to said two feeder lines and for coupling them together comprising a connection from the inner conductor of said main line to the inner conductor of said first feeder line and a connection from the outer conductor of said first feeder line to the inner conductor of said second feeder line, quarter wavelength metallic sleeves surrounding the outer conductors of said feeder lines from the above mentioned points of connection, and means for connecting said sleeve together and to the outer conductor of said main line.

2. In combination, first, second and third concentric feeder lines of predetermined impedance, each feeder having inner and outer conductors, a main concentric line having an impedance equal approximately to the sum of the impedances of said three feeder lines, and a circuit for matching the impedance of said main line to said feeder lines and for coupling them together comprising a connection from the inner conductor of said main line to the inner conductor of said first feeder, a connection from the outer conductor of said first feeder to the inner conductor of said second feeder, a connection from the outer conductor of said second feeder to the inner conductor of said third feeder, quarter wavelength metallic sleeves surrounding the outer conductors of said first and second feeders from said above mentioned points of connection, and means for connecting said sleeves together and to the outer conductor of said main line.

3. A system in accordance with claim 2, characterized in this that said last means connects together the quarter wavelength sleeves at their two adjacent ends, and also to the outer conductor of said third feeder.

4. A circuit for coupling together a pair of concentric lines adapted to have opposite instantaneous currents therein with a single concentric line and for matching the impedances between them, comprising connections from the inner conductors of said pair of lines to the inner and outer conductors of said concentric line, a metallic sleeve a quarter of a wavelength long surrounding said single line and connected to the outer conductor of said single line at the end of said sleeve which is remote from said connections, said sleeve at its other end being connected to the outer conductors of said pair.

5. A circuit for efficiently coupling together a push-pull type of system having a pair of conductors with oppositely flowing instantaneous currents therein and a concentric feeder line having an inner and an outer conductor, comprising a connection from one conductor of said pair to said inner conductor of said concentric line and a connection from the other conductor of said pair to the outer conductor of said concentric line, the surge impedance of said concentric line being equal to the sum of the surge impedances of said pair of conductors, and means surrounding said concentric feeder line for at least a portion of the length thereof for preventing the current of the operating frequency flowing over said last conductor of said

pair from flowing over the outer surface of the outer conductor of said concentric line.

6. In combination, a transmission line conductor having two loads connected thereto at points spaced along said line, the diameter of said conductor at one point of connection to one of said loads being different than its diameter at the other point of connection to the other load.

7. In combination, first, second and third concentric feeder lines of predetermined impedance, each feeder having inner and outer conductors, a main concentric line having an impedance equal to the sum of the impedances of said three feeder lines, and a circuit for matching the impedance of said main line to said feeder lines and for coupling them together comprising a connection from the inner conductor of said main line to the inner conductor of said first feeder, a connection from the outer conductor of said first feeder to the inner conductor of said second feeder, a connection from the outer conductor of said second feeder to the inner conductor of said third feeder, quarter wavelength metallic sleeves surrounding the outer conductors of said first and second feeders from said above mentioned points of connection, and means for connecting said sleeves together and to the outer conductors of said main line and third feeder.

8. The method of coupling a concentric line feeder in series relation to a pair of other concentric feeder lines, each of said concentric lines having an inner and an outer conductor, which comprises connecting the end of the inner conductor of said first feeder to the end of the inner conductor of one feeder of said pair, connecting the outer conductor of said first feeder to the outer conductor of said one feeder of said pair at a predetermined point on said last outer conductor removed from its end, connecting the outer conductor of said one feeder of said pair to the inner conductor of the other feeder of said pair, and connecting the outer conductor of said last feeder to the outer conductor of said first feeder.

9. In combination, first and second concentric, feeder lines of predetermined impedance, each having inner and outer conductors, a main concentric line having an impedance equal approximately to the sum of the impedances of said first and second feeder lines, and a circuit for matching the impedance of said main line to said two feeder lines and for coupling them together including a connection from the inner conductor of said main line to the inner conductor of said first feeder line and a connection from the outer conductor of said first feeder line to the inner conductor of said second feeder line, and a connection from the outer conductor of said second feeder line to the outer conductor of said main line.

10. The method of coupling a plurality of concentric lines, each having a predetermined impedance of substantially the same value, to a concentric line having an impedance equal substantially to the sum of the impedances of said plurality of lines, which comprises coupling all of said lines together in series relationship, whereby the inner conductor current of one line of said plurality becomes the outer conductor current of another line of said plurality.

11. The method of coupling a concentric line having a predetermined impedance to a pair of other concentric lines which are in push-pull relation, said other lines each having an imped-

ance substantially equal to half the impedance of said first line, which comprises connecting the inner conductor of said first line to the inner conductor of one of said pair, connecting the outer conductor of said first line to the inner conductor of the other of said pair, connecting the outer conductors of said pair together and through a connection of predetermined length to the outer conductor of said first line.

12. In a high frequency coupling arrangement, a first circuit comprising a pair of concentric lines each having an inner and an outer conductor, the inner conductors of said lines adapted to have opposite instantaneous currents therein, a second circuit comprising a single concentric line also having an inner and an outer conductor, and means coupling said circuits together, said means comprising a connection from the inner conductor of the concentric line of said second circuit to the inner conductor of one concentric line of said first circuit, a connection from the outer conductor of the concentric line of said second circuit to the inner conductor of the other concentric line of said first circuit, a sleeve surrounding the outer conductor of said line of said second circuit from a point adjacent the junction points of said first circuit and said second circuit for a distance substantially an odd multiple of a quarter of the operating wave from said junction points, a connection from said sleeve at said distance removed from said junction points to the outer conductor of said line of said second circuit, and connections from said outer conductors of said first circuit to the end of said sleeve adjacent said junction points.

13. The method of coupling a pair of concentric lines in series relationship having a predetermined value of impedance across both of said lines to a single concentric line having a substantially identical impedance, which comprises connecting the end of the inner conductor of said single line to the end of one inner conductor of said pair through a path devoid of concentrated reactance, connecting the end of the other conductor of said single line to the end of the other inner conductor of said pair also through a path devoid of concentrated reactance, and connecting the outer conductors of said pair together and to a point on the outer conductor of said single line removed from its end.

14. A feeder system for high frequency electrical currents, comprising a conductor and a conducting sheath surrounding said conductor, an auxiliary conductor associated with said sheath for preventing currents of the operating frequency from flowing over the outer surface of said sheath, said auxiliary conductor being concentric with and surrounding said sheath and having a length substantially an odd integral multiple including unity of a quarter of the wavelength at which the system is arranged to operate, one end of said auxiliary conductor being open and positioned adjacent the end of said sheath, the other end being directly connected to the outer surface of said sheath.

15. A feeder for electric currents of high frequency, said feeder comprising a conductor, a conducting sheath surrounding said conductor, an auxiliary conductor surrounding said sheath and electrically connected thereto at one end, the other end of said auxiliary conductor being open and positioned adjacent the end of said sheath, said auxiliary conductor having such length and being so arranged that it combines with a portion of the outer surface of the sheath,

measured from the end thereof, of a length substantially the same as the length of said auxiliary conductor, to form a circuit of high impedance to the travel of undesired waves along the outer surface of said sheath.

16. In combination, a plurality of concentric, feeder lines of predetermined impedance, each having inner and outer conductors, a main concentric line having an impedance equal approximately to the sum of the impedances of said plurality of feeder lines, and a circuit for matching the impedance of said main line to said plurality of feeder lines and for coupling them together comprising a connection from the inner conductor of said main line to the inner conductor of one of said feeder lines and a connection from the outer conductor of said one feeder line to the inner conductor of another of said feeder lines, a quarter wavelength metallic sleeve surrounding the outer conductor of said one feeder line from the above mentioned points of connection, and means for connecting said sleeve at one end to the outer conductor of said one feeder line and at its other end to the outer conductor of said main line.

17. In combination, first, second and third concentric feeder lines of predetermined impedance, each feeder having inner and outer conductors, a main concentric line having an impedance equal to the sum of the impedances of said three feeder lines, and a circuit for matching the impedance of said main line to said feeder lines and for coupling them together comprising a connection from that end of the inner conductor of said main line nearest said feeders to the adjacent end of the inner conductor of said first feeder, a connection from the adjacent end of the outer conductor of said first feeder to the adjacent end of the inner conductor of said second feeder, a connection from the adjacent end of the outer conductor of said second feeder to the adjacent end of the inner conductor of said third feeder, metallic sleeves surrounding the outer conductors of said first and second feeders from said above mentioned ends, and means for connecting said sleeves together and to the outer conductor of said main line, and at points one-quarter of a wavelength from said ends of the feeder lines which they surround to the outer conductors thereof.

18. In combination, a plurality, including first and second, of concentric substantially feeder lines of predetermined impedance, each having inner and outer conductors, a main concentric line having an impedance at least equal approximately to the sum of the impedances of said plurality of feeder lines, and a circuit for matching the impedance of said main line to said plurality of feeder lines and for coupling them together comprising a connection from the inner conductor of said main line to the inner conductor of said first feeder line and a connection from the other conductor of said first feeder line to the inner conductor of said second feeder line, means coupling the outer conductor of said second feeder line to the outer conductor of said main line, metallic sleeves surrounding the outer conductors of said first and second feeder lines from a point adjacent the junction points of said first and second feeders, and means for connecting said sleeves to the outer conductors of the feeder lines which they surround at points one-quarter of a wavelength from said junction points and for connecting said sleeves to the outer conductor of said main line.

19. In combination, a transmission line in the form of a pair of conductors having opposite instantaneous polarities thereon, a load connected across said pair of conductors at one location, another load connected to each of said pair of conductors at another location, said conductors having one diametrical dimension at said one location and a different diametrical dimension at the other location.

20. A feeder system for high frequency electrical currents, comprising a conductor and a conducting sheath surrounding said conductor, a pair of conductors adapted to have oppositely flowing currents thereover coupled to said first conductor and conducting sheath, and an auxiliary conductor associated with said sheath for preventing currents of the operating frequency from flowing over the outer surface of said sheath, said auxiliary conductor being concentric with and surrounding said sheath and having a length substantially an odd integral multiple including unity of a quarter of the wavelength at which the system is arranged to operate, one end of said auxiliary conductor being open and positioned adjacent the end of said sheath, the other end being directly connected to the outer surface of said sheath.

21. In combination, a single transmission line having an outer sheath and an inner conductor and a push-pull pair of balanced transmission lines, a connection from the inner conductor of said single line to a conductor of one of said push-pull lines, a connection from the sheath of said single line to a conductor of the other of said push-pull lines and an outer shell surrounding the end portion of said single line, said shell being connected to said sheath at a distance equal to the quarter of the length of the operating wave from the end of said single line.

22. Means for coupling a single concentric line having an outer sheath and an inner conductor to a push-pull pair of concentric transmission lines each having an outer sheath and an inner conductor comprising 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 length of the operating wave from the end of said sheath.

23. Means for coupling a single concentric line having an outer sheath and an inner conductor to a push-pull circuit having a pair of conductors adapted to be energized in an opposing phase relationship comprising a connection from said inner conductor to one of said pair of conductors, a connection from the end of said outer sheath to the other of said pair of conductors and an outer shell surrounding the end of said single line and its junction with said pair of lines, said shell being connected to said outer sheath at a distance equal to a quarter of the length of the operating wave from the end of said sheath.

24. Means for coupling a single concentric line having an outer sheath and an inner conductor to a push-pull circuit having a pair of conductors adapted to be energized in an opposing phase relationship comprising a connection from said inner conductor to one of said pair of conductors, a connection from the end of said outer

sheath to the other of said pair of conductors and an outer shell surrounding the end of said single line, said shell being connected to said outer shell at a distance equal to a quarter of the length of the operating wave from the end of said sheath.

25. In combination, a concentric line having an inner conductor and an outer conductor, a source of high frequency energy coupled to said line and means for presenting at a predetermined point on the outer surface of said outer conductor a high impedance to the energy of said source comprising an auxiliary conducting sleeve surrounding said outer conductor, a connection between said sleeve and said outer conductor, the distance between said predetermined point and said connection being an odd multiple, including unity, of a quarter of the wavelength of said energy.

26. In combination, a concentric line having an inner conductor and an outer conductor, high frequency apparatus coupled to said line and means for presenting at a predetermined point on the outer surface of said outer conductor a high impedance to the operating frequency of said high frequency apparatus comprising an auxiliary conducting sleeve surrounding said outer conductor, a connection between said sleeve and said outer conductor, said sleeve surrounding said outer conductor for an effective electrical distance corresponding to an odd multiple, including unity, of one quarter of the wavelength of the operating frequency of said apparatus from the point of connection between said sleeve and said outer conductor to said predetermined point.

NILS E. LINDENBLAD.