Sept. 4, 1956 G. STAVIS ET AL 2,762,045

ANTENNA FEED SYSTEM

Filed Oct. 8, 1952

2 Sheets-Sheet 1

Fig. 1

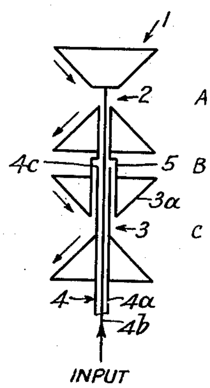

Fig. 2

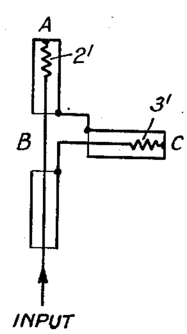

Fig. 3

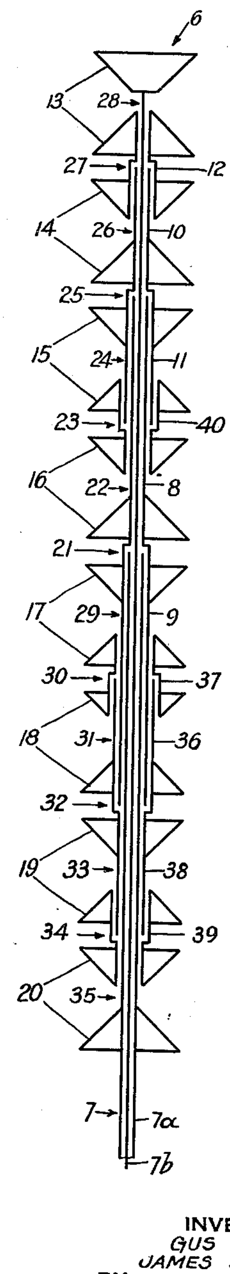

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Fig. 5

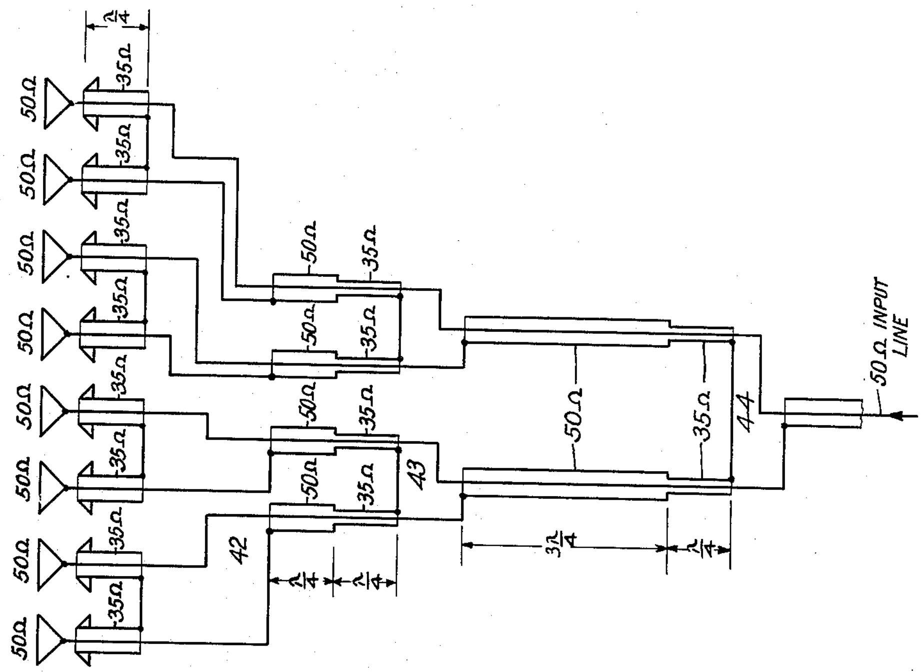
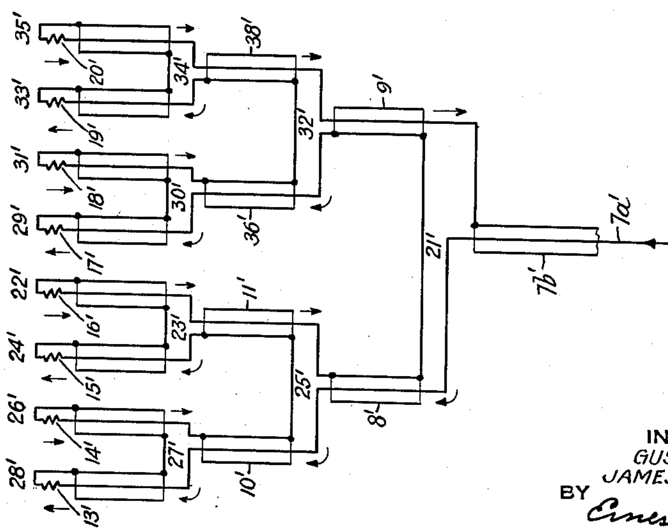


Fig. 4



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ANTENNA FEED SYSTEM

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Application October 8, 1952, Serial No. 313,636

6 Claims. (Cl. 343—790)

This invention relates to an antenna feed system and more particularly to a series coaxial line feed for a vertical antenna array.

In many antenna systems, such as are used in the art of aerial navigation, it is desirable to utilize a vertical array comprising a stack of dipoles, disc cones, or biconical radiators. Assuming each of the radiating elements has an equal impedance, it is desirable that each of the elements in the vertical array be fed with equal currents in phase. In the past it has been found that the difference in the lengths of line necessary to couple the first or topmost radiating element and the last or bottom element to the source of energy has caused such vertically stacked arrays to be highly frequency sensitive, i. e. the radiation from the topmost element would be altered in phase with respect to that from the lower elements as frequency is changed due to the longer length of feed line necessary to couple the energy to the topmost antenna. It has also been found desirable to feed such an antenna system without having the transmission line lie in the radiation field of the antenna system in order to prevent unwanted distortions of the antenna pattern.

One of the objects of this invention, therefore, is to provide means for feeding an antenna system comprising a vertical stack of radiating elements in such a manner that each antenna carries the same current with the same phase over a substantially broad band of frequencies.

Another object of this invention is to provide means for feeding in series from a coaxial transmission line an antenna system having a vertical array of dipoles with a transmission line which lies wholly within the radiating surfaces.

A further object of this invention is to provide means for feeding a broad band antenna system having a vertical array of radiating elements which is substantially independent of the physical spacing between radiating elements.

A feature of this invention is the use of a concentric coaxial cable wherein "breaks" in the outer conductor are used as feed points or the points across which the dipoles receive their energy. At each break in the outer conductor of the coaxial feed line, the energy divides into two parts, the path of one part being the continuation of the coaxial line upward and the path of the other being formed by the outer surface of the outer conductor of the lower feed line and the inner surface of the larger diameter feeding the lower antennas. In this manner the length of line from the source of energy to any dipole may always be kept constant regardless of the physical spacing between radiating elements and in addition the phase of all the currents in the radiation elements is equal and the direction of the current flow on each radiator is identical so that the radiations from all the radiators are additive.

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a diagrammatic illustration of one embodiment of the series coaxial antenna feed system of this invention for use with a simple form of vertical antenna array having two biconical dipole radiators;

Fig. 2 is an equivalent circuit diagram of the antenna system shown in Fig. 1;

Fig. 3 is a diagrammatic illustration of one embodiment of the series coaxial antenna feed system of this invention for use with a vertical array having eight biconical dipole radiation elements;

Fig. 4 is the equivalent circuit diagram of the antenna system shown in Fig. 3; and

Fig. 5 is the equivalent circuit diagram of an antenna array shown in Fig. 3 in which means for matching the impedance of said array to a transmission line is provided.

Referring to Fig. 1, a series coaxial feed in accordance with the principles of this invention is shown for use with an antenna system wherein two biconical radiators are to be fed. The antenna system comprises a vertical stacked array of radiating elements **2** and **3** shown in the form of biconical dipole elements. The energy input is coupled to a coaxial feed line **4** having an outer conductor **4*a*** and an inner conductor **4*b*** wherein a "break" **4*c*** in the outer conductor **4*a*** is used as a feed point or the point across which dipoles **2** and **3** receive their energy. In the case of the lower half of the antenna system **1**, at the center point B the outer conductor **4*a*** of the coaxial feed line **4** is broken at **4*c*** so that the energy divides into two parts. Part of the energy continues to flow upward via a continuation of the feed line **4** into the upper section of antenna system **1** and the remainder flows around to the outside of what formerly was the outer conductor **4*a*** of coaxial feed cable **4** and which now becomes the inner conductor for the new feed cable made up of the said cable's outer conductor **4*a*** as an inner conductor and the larger diameter conductor **5** bearing the upper conical elements **3*a*** of the lower radiating element **3** of the antenna system **1**.

Referring to Fig. 2 wherein the equivalent circuit diagram for the antenna system illustrated in Fig. 1 is shown, it may be assumed for simplifying this description that the impedances of the dipoles are equal to the characteristic impedance of the cable which connects point A (center of biconical radiating element **2**) with point B (center of antenna system **1**). Thus the impedance seen looking in at point B toward the upper dipole **2** is equal to the dipole impedance. The impedance looking at the lower dipole **3** which is fed by a coaxial cable made up of the outer conductor **4*a*** at the input gap and a skirt **5** which surrounds this, it is seen that if this combination has a surge impedance equal to the impedance of the lower dipole (which may be assumed the same as the upper dipole impedance) then the impedance across the gap at the end of the outer conductor **4*a*** of the lowermost cable and the outer conductor of the uppermost cable is equal to the impedance of the lower dipole. Consequently, the impedance presented to the feed or input cable **4** will be twice the impedance of either dipole, or if the dipoles are of unequal impedance, then the sum of these appears to be the load at point B.

In the simplest case wherein the dipoles have identical impedances, it is obvious that the input path will divide equally between the two, and if the length of line between points AB and AC are made equal, then the currents in the dipoles **2** and **3**, as shown by the arrows in Fig. 1, will have the same direction of flow. That is, the current relationships will hold regardless of the physical distance between the radiating elements **2** and **3** so long as the location of point B is at the electrical center between points A and C. Since breaking the outer conductor of a coaxial transmission line and inserting a load between the broken ends effectively places the load in series with the line, this feed system may be termed a series feed.

Referring to Figs. 3 and 4 of the drawing, a series coaxial feed system and its equivalent circuit diagram is shown for use with an antenna array having eight biconical dipole radiating elements. A source of energy is coupled to coaxial feed line 7 comprising an outer conductor 7*a* and an inner conductor 7*b*. The outer conductor 7*a* is broken at the electrical center 21 of the antenna array 6. One-half the energy continues to flow upward along conductor 8 which is a continuation of outer conductor 7*a* and the other half of the input energy flows around the outside of outer conductor 7*a* which now acts as the inner conductor for a feed cable formed by conductor 7*a* and skirt 9 acting as the outer conductor for this lower feed cable. At point 25 which is located halfway between point 21 and the top of antenna array 6, conductor 8 is again broken and one-half of the energy flowing along conductor 8 flows to conductor 10 which is a continuation of conductor 8. The other half of the energy in conductor 8, i. e. one quarter of the original input energy, flows downward through a new coaxial cable composed of the outer surface of conductor 8 acting as the inner conductor and skirt 11 which acts as the outer conductor for the new coaxial feed line. The conductor 10 is broken at point 27 which is halfway between point 25 and the top of antenna array 8 so that one-half the energy flowing along conductor 10 continues to flow up and feed biconical elements 13 and one-half the energy of conductor 10 flows downward through new coaxial feed lines composed of conductor 10 acting as the inner conductor and skirt 12 which acts as the outer conductor. The energy flowing through this new coaxial conductor feed biconical radiating element 14. Since the original input energy has been halved at three different breaks 21, 25, and 27, the energy feeding radiating elements 13 and 14 is equal to one-eighth the original input energy.

Referring now to the energy which flowed downward from gap 25 along the coaxial feed line composed of the outer surface of the conductor 8 as the inner conductor and skirt 11, it is seen that this energy will be halved at gap 23. Half the energy will continue to flow downward and feed biconical radiating element 16 while half of the energy will flow upward along skirt 40 as an outer conductor and the outer surface of conductor 11 as the inner conductor. This energy will be fed to biconical radiating element 15. It is seen that the energy feeding radiating elements 15 and 16 has been halved at points 21, 25, and 23, thus allowing one-eighth of the original input energy to be fed to radiating elements 15 and 16.

Referring now to the energy flowing downward from the break at point 21 along the outer surface of conductor 7*a* as the inner conductor and skirt 9 as the outer conductor, it is seen that this energy is halved at gap 32, one-half continuing to flow along conductor 38 which is a continuation of conductor 9 and the other half flowing upward along coaxial feed line composed of the outer surface of conductor 9 as an inner conductor and skirt 36 as an outer conductor. This energy flow upward is halved at gap 30 where one portion continues upward and feeds antenna radiating element 17 while the other portion flows downward through the outer surface of conductor 36 as an inner conductor and skirt 37 as an outer conductor to feed radiating element 18. The original input energy has been halved three times at points 21, 32, and 30 before it reaches radiating elements 17 and 18; thus these elements are each fed with one-eighth of the original input power.

Referring to the energy that flowed downward from point 32 along conductor 38, it is seen that this energy is halved at point 34 where half continues to flow downward and feed radiating element 20 whereas half flows upward along the outer surface of the conductor 38 and skirt 39 as an outer conductor. This energy flowing upward feeds antenna element 19. Thus, the original input energy has been halved at points 21, 32, and 34, allowing one-eighth of the original input energy to be coupled to each of the radiating elements 19 and 20.

Thus, from the division of power it is seen that each of the radiating elements 13 through 20 is coupled to one-eighth of the original signal energy input. In Fig. 4 the equivalent points of Fig. 3 have been designated by the same reference characters plus a prime. From Fig. 4 it is seen that the currents on each of the radiating elements will not only be equal but will also be in phase. Also from the foregoing description it will be readily apparent that since the eight biconical radiating elements are connected in series to the source of energy, the impedance looking into the antenna array is equal to eight times the impedance of any single radiating element.

Referring to Fig. 5, an eight-element antenna array is shown wherein by a judicious choice of matching section impedances the total impedance of the antenna array is made equal to the impedance of a single biconical radiator. Assuming for purposes of explanation that each biconical element has a nominal impedance of 50 ohms and it is desirable to match a 50 ohm cable, then the choice of matching section impedances for each section of line is shown in Fig. 5. Thus for the first length of line between any biconical radiator and the next feed point or gap in an outer conductor, the 50 ohm impedance of the radiator can be transformed down to 25 ohms by making the surge impedance of the quarter wavelength of line equal to 35 ohms. Thus at any feed point or gap there are two dipoles in series effectively, and if the impedance looking into each dipole section is 25 ohms, that brings the total series impedance at the feed point back to 50 ohms. If the length of line between points 42 and 43 is made equal to a half wavelength, the first quarter wavelength of this can be made 50 ohms and the total can be transformed back to 25 ohms by another section of 35 ohm line which is a quarter wavelength long. At point 43, therefore, there are two 25 ohm loads connected in series totaling 50 ohms which matches the 50 ohm section line which is placed between points 43 and 44. This section of line is 50 ohms for three-quarters of a wavelength and the total length of this section is equal to a full wavelength with its last quarter wavelength having an impedance of 35 ohms. Thus looking at the input end of this line, it is equal to 25 ohms. Thus at point 44 we again have two 25 ohm loads connected in series making a total of 50 ohms which matches the input feed line. We have found that at no point in the feed system does the standing wave ratio exceed 1.4:1 and the relatively low mismatch at all the junctions renders the impedance transformation relatively broad band, with a very small net change in impedance over a relatively wide band in frequencies.

While we have described above the principles of our invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of our invention as set forth in the objects thereof and in the accompanying claims.

We claim:

1. An antenna array comprising a plurality of radiation elements disposed in axial alignment, a source of input energy, a first coaxial feed line to couple said energy to said antenna array having an inner conductor and an outer conductor having a gap therein to provide a first feed point symmetrically located with respect to the radiation elements to be fed, a hollow conductor skirt concentric with said outer conductor extending from a position adjacent to said gap to a second feed point to provide a second coaxial feed line to couple a portion of said energy to a portion of said elements, and outer conductor means extending from a position adjacent to said gap in a direction opposite to said skirt to a third feed point to provide a third coaxial feed line to couple the remaining energy to the remaining elements.

2. An antenna array according to claim 1, wherein said radiation elements comprise half wave resonant disc-cone radiating elements coaxial with said feed lines.

3. An antenna array feed system to couple equal amounts of energy in phase to a plurality of radiation elements of equal impedance disposed in axial alignment comprising a first coaxial feed line having an inner conductor and an outer conductor and a gap therein to provide a first feed point located half-way between the uppermost and lowermost radiation elements, a hollow conductive skirt concentric with said outer conductor extending from a position adjacent said gap to a second feed point providing a second coaxial feed line to couple one-half of said energy to one-half of said radiating elements, and outer conductor means extending from a position adjacent said gap in a direction opposite the said hollow conductor to a third feed point to provide a third coaxial feed line to couple the remaining one-half energy to the remaining one-half of said radiating elements.

4. An antenna array according to claim 3, wherein each of said coaxial feed lines are disposed internally of and coaxial to at least a portion of said radiators whereby the antenna pattern of said radiating elements is not disturbed by said feed line.

5. A broad band antenna array comprising a plurality of half wave resonant radiation elements disposed in axial alignment, a source of energy to be coupled to said elements, a first coaxial feed line having an inner conductor and an outer conductor having a gap therein to provide a first feed point symmetrically located with respect to the elements to be fed across which said energy is divided, a hollow conductor skirt concentric with said outer conductor extending from a position adjacent to said gap to a second feed point located at a point symmetrically situated with respect to one-half of the radiation elements to provide a second coaxial feed line to

couple one-half of the input energy to said one-half of the radiation elements, outer conductor means extending from a position adjacent said gap in a direction opposite the said hollow conductor to a third feed point symmetrically located with respect to the other half of the said radiation elements to provide a third coaxial feed line to couple the remaining portion of said divided energy to the said other half of the radiation elements said energy being divided such that the voltage at said first feed point is equal to the sum of the voltages across said second and third coaxial feed lines.

6. An antenna array feed system to couple equal amounts of energy in phase to a plurality of radiation elements of equal impedance disposed in axial alignment comprising a first coaxial feed line having an inner conductor and an outer conductor and a gap therein to provide a first feed point located half-way between the uppermost and lowermost radiation elements, a hollow conductive skirt concentric with said outer conductor extending from a position adjacent said gap to a second feed point providing a second coaxial feed line to couple one-half of said energy to a portion of said elements, outer conductor means extending from a position adjacent said gap in a direction opposite the said hollow conductor to a third feed point to provide a third coaxial feed line to couple the remaining one-half energy to the remaining elements, and a plurality of matching section impedances to transform the input impedance of the feed lines to any two adjacent elements to the impedance of a single element.

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