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3,226,724

MULTIPLE ANTENNA MULTIPLEX SYSTEM

Filed July 5, 1963

3 Sheets-Sheet 1

FIG. 1

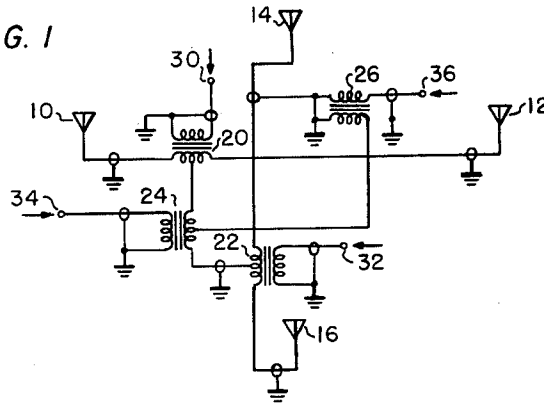


FIG. 2

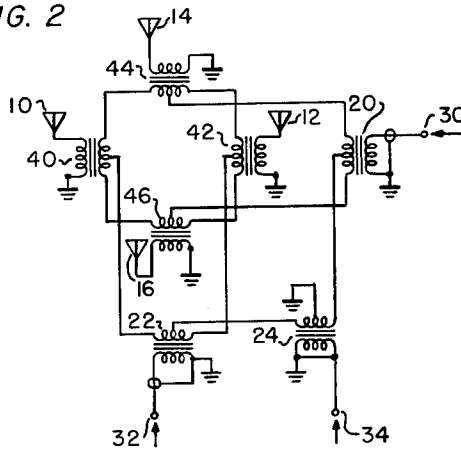
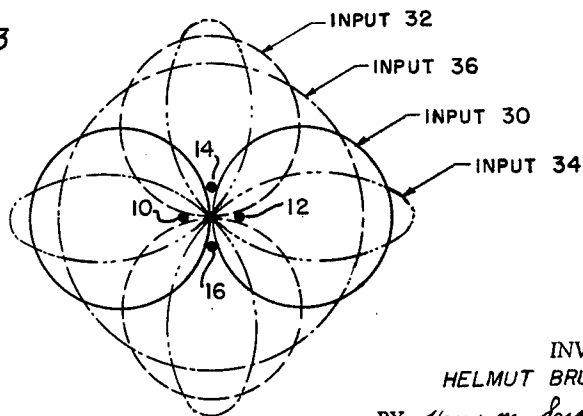


FIG. 3



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FIG. 4

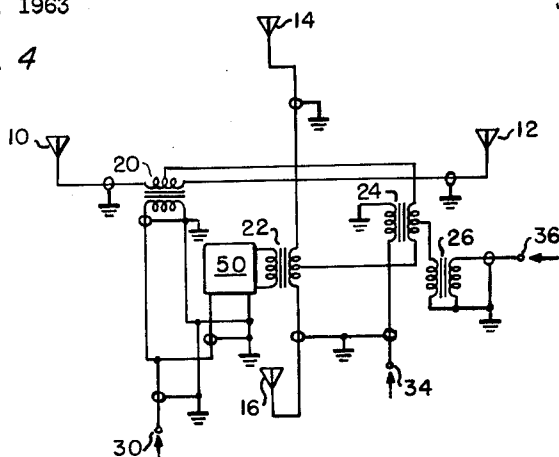


FIG. 5

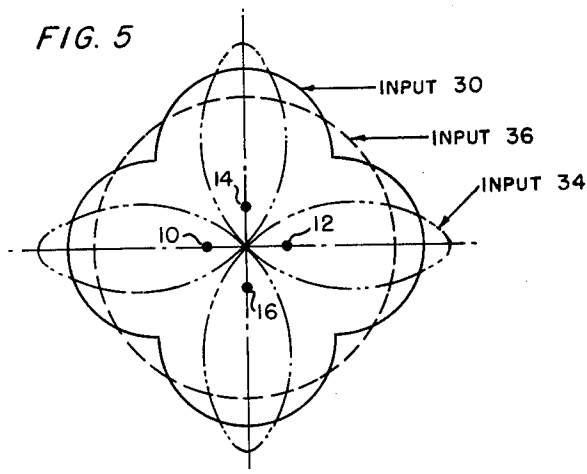
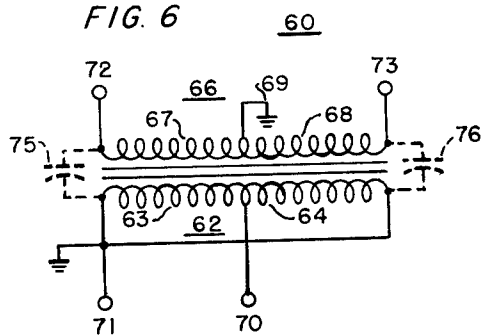


FIG. 6



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FIG. 7

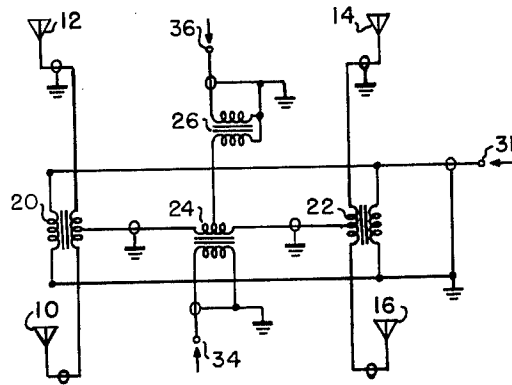


FIG. 8

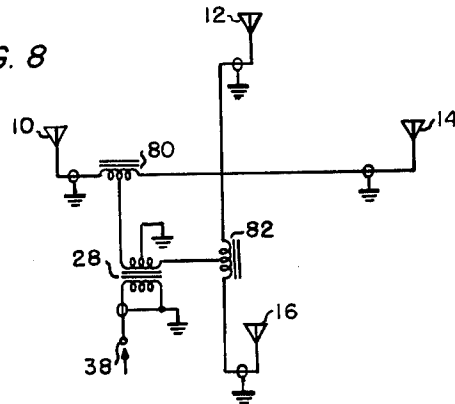
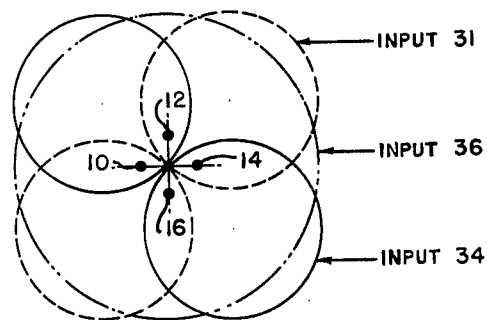


FIG. 9



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MULTIPLE ANTENNA MULTIPLEX SYSTEM

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7 Claims. (Cl. 343-853)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment of any royalty thereon.

This invention relates to antennas, and particularly to multiple element, circular, antenna arrays. More particularly, this invention relates to a circular antenna array that is multiplexed to permit simultaneous transmission and reception of signals, from several separate stations, at separate frequencies, without interference between the various stations.

Many situations require the use of two or more radio sets, simultaneously, in one location or even in one vehicle. The use of separate antennas for each set is unsatisfactory since the distances that it is possible to establish between antennas, under certain conditions is not great enough to prevent interaction between the antennas. The antennas act as parasitic elements to each other causing pattern distortion and cross-modulation. Furthermore, the pattern distortion depends on the frequency of the radio sets and is not predictable. The use of a single element antenna for several radio sets, which is called multiplexing, requires filters, which are unwieldy for the wide range of frequencies involved.

It is therefore an object of this invention to provide an improved multiplexing system that will couple several radio sets to a common antenna array, with a minimum of power transfer between them.

It is a further object of this invention to provide a multiplex antenna with broad band elements, individually matched, that can be used by several radio sets simultaneously.

These and other objects are accomplished by mounting four identical antenna elements with their axes parallel to each other about the corners of a square. The antennas are connected, through hybrid transformers, to the various inputs; a first hybrid transformer, connecting directly to one pair of the antenna elements, a second hybrid transformer connecting directly to another pair of antenna elements, and a third hybrid transformer connecting, through the first two hybrid transformers, to the first two pairs of antennas, which are now acting as single units. Still another hybrid transformer connects between ground and the third hybrid transformer to operate all of the antenna elements simultaneously.

Thus each of the inputs is connected to the antenna element or elements without interference from the other input signals or the other antenna elements. Each of the antenna elements is separately tuned and matched to its feed line.

This invention will be better understood and other and further objects of this invention will become apparent from the following specification and the drawings, of which

FIGURES 1 and 2 are circuit diagrams of embodiments of this invention;

FIGURE 3 is a polar diagram of the radiation patterns of the antenna array for each of the various inputs;

FIGURE 4 is a circuit diagram of another embodiment of this invention;

FIGURE 5 is the polar diagram of the radiation patterns of antenna array for the various inputs of the embodiment of FIGURE 4;

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FIGURE 6 is a diagram of a typical hybrid transformer suitable for use with this invention;

FIGURES 7 and 8 are circuit diagrams of further embodiments of this invention; and

FIGURE 9 is the polar diagram of the radiation patterns of the antenna array for the various inputs of the embodiments of FIGURES 7 and 8.

Referring now more particularly to FIGURE 1, the antenna array has radiating elements 10, 12, 14, and 16. Elements 10 and 12 are connected, through coaxial cables, to the opposing ends of the secondary winding of the hybrid transformer 20. The primary winding of the transformer 20 is connected, also through a coaxial cable, to the input 30. This type of hybrid transformer, as will be seen in FIGURE 6, has an unbalanced input and a balanced output.

The antenna elements 14 and 16 are connected, through coaxial cables, to the opposing ends of the second winding of the hybrid transformer 22. The primary winding of the hybrid transformer 22 is connected, through a coaxial cable, to the input 32.

The center tap of the secondary winding of the hybrid transformer 20 is connected, through a coaxial cable, to one end of the secondary winding of the hybrid transformer 24, and the center tap of the secondary winding of the hybrid transformer 22 is connected, through a coaxial cable, to the other end of the secondary winding of the hybrid transformer 24. The primary winding of the hybrid transformer 24 is connected, through a coaxial cable, to the input 34.

The center tap of the secondary winding of the hybrid transformer 24 is connected, through a coaxial cable, to the secondary winding of the transformer 26. The primary winding of the transformer 26 is connected, through a coaxial cable, to the input 36.

In operation, the signals applied to the input 30 are coupled to the antenna elements 10 and 12, through the transformer 20. The transformer 20 provides an impedance match between the source of signals, or input, at 30 and the load, or the radiating elements 10 and 12, which are driven in phase opposition by the opposing ends of the secondary winding of the transformer.

This means for coupling the radiating elements, driven in phase opposition and spaced from each other, to an impedance matching transformer, or push-pull output circuit, is well known in the art and many of the available techniques are applicable here. The output impedance of the transformer should be chosen to match the combined output load regardless of which coupling system is used.

The signals applied to the input 32 are coupled to the antenna elements 14 and 16, through the transformer 22. The transformer 22 is identical to transformer 20, and provides the same function in the same manner. All of the comments applied to transformer 20 apply to transformer 22.

The signals applied to the input 34 are also coupled to the antenna elements, through a transformer 24; however, since the secondary winding of the transformer 24 is coupled to the center taps of the secondary windings of the transformers 20 and 22, the signals applied to the input 34 are applied to the antenna elements 10 and 12 in one phase, and to the antenna elements 14 and 16 in the opposite phase. In other words the elements 10 and 12 function as one half of the antenna and the elements 14 and 16 function as the other half of the antenna.

Since the output of the transformer 24 is connected to the center taps of the other two transformer windings, it is obvious that the signals applied to the input 34 will not be coupled to the inputs 20 or 22, and vice versa.

Lastly, the signals applied to the input 36 are coupled to the primary winding of the transformer 26, and from

the secondary winding of the transformer 26 between ground and the center tap of the secondary winding of the transformer 24. This applies signals of one phase to all of the antenna elements simultaneously, since the secondary winding of the transformer 24 is directly connected, through the secondary windings of the transformers 20 and 22, to all of the antenna elements 10 through 16. In other words all of the elements of the antenna are now driven in phase and function as a single unit with respect to ground.

The circuit of FIGURE 2 is similar to that of FIGURE 1 although it has a difference in the manner of coupling the antennas to the transformers. In FIGURE 2, each of the antenna radiating elements has its own coupling transformer, which has its own, hybrid, coupling circuit. Each of the antenna elements 10 through 16 is connected to a corresponding one of the single windings of the hybrid transformers 40 through 46. The center-tapped windings of the transformers 40 through 46 are connected in series.

The center tap of the winding of the transformer 44 is connected to one end of the secondary winding of the transformer 20. The center-tap of the winding of the transformer 46 is connected to the other end of the secondary winding of the transformer 20.

In operation, the current from the secondary winding of the transformer 20 is cancelled in the center-tapped windings of the transformers 44 and 46, but is applied across the center-tapped windings of the transformers 40 and 42 simultaneously to reach the single windings of the transformers 40 and 42 which are connected to the antenna elements 10 and 12, with the polarities of the windings in phase opposition to each other.

In other words the antenna radiating elements 10 and 12 are fed in phase opposition as they are in the circuit of FIGURE 1 to produce the same radiating pattern, which is seen in FIGURE 3.

The transformer 22 associated with the input 32 feeds the center taps of the windings of the transformers 40 and 42 to apply signals in phase-opposition to the antenna elements 14 and 16 in the same manner as that described for the antenna elements 10 and 12.

The transformer 24 connects the input 34 to the center-taps of the secondary windings of the transformers 20 and 22, exactly as the corresponding elements do in FIGURE 1, to energize antenna elements 10 and 12 simultaneously and in phase, and elements 14 and 16 simultaneously and in phase with each other but in phase-opposition with the elements 10 and 12.

In this embodiment, however, there is no direct connection between the antenna elements and the secondary windings of the transformers 20 and 22, as there is in FIGURE 1; consequently, energy applied through the center-tap of the secondary winding of the transformer 24 would have no direct contact with, and would not apply any signal to, the actual radiating elements.

FIGURE 3 shows the polar diagrams of the radiation patterns of the antenna elements 10 through 16, which are also shown in horizontal projection. These patterns apply to both FIGURES 1 and 2, since both, basically, feed opposing vertical radiators out of phase. The inputs 30 and 32 feed pairs of single elements out of phase and have the familiar FIGURE 8 lobe patterns, which are at right angles to each other, as are the pairs of antennas themselves. The input 34 has the quadruple lobes of the four elements acting as a pair of double elements; and the input 36, which applies only to FIGURE 1, has the circular pattern of a single radiator for the four elements in phase.

FIGURE 4 shows another variation of the basic concept of FIGURE 1. The first input, which is 30 in both figures connects directly to its hybrid transformer 20 as in FIGURE 1, but in FIGURE 4 it also connects to a phase shifting network 50 which produces a ninety degree phase shift in the signal applied to 30 before applying it

to the transformer 22. This drives the elements 14 and 16 ninety degrees out of phase with the antenna elements 10 and 12, while both carry the same signal.

This produces the more nearly omnidirectional radiation pattern shown in FIGURE 5 for the input 30. This would be desirable where the sharp nulls of the FIGURE 8 radiation pattern are more of a handicap to the system than the sacrifice of the extra input 32 of FIGURE 1.

The other inputs and transformers of FIGURE 4 are the same as those in FIGURE 1. Their functions are the same and they are not effected by the combining of the two inputs 30 and 32.

FIGURE 3 shows the polar diagram of the radiating antenna elements with the inputs connected as shown in FIGURE 4. It is noted that while the pattern for the input 30 is changed, the patterns for the other two inputs 34 and 36 are the same as in FIGURE 3.

FIGURE 6 shows a typical hybrid transformer 60 having an unbalanced input winding 62 and a balanced output winding 66. In this case the primary, input winding, consists of two halves 63 and 64, wound in the opposing sense and connected in parallel to the terminals 70 and 71. The secondary, output winding, 66 consists of the two halves 67 and 68, wound in the same sense, center-tapped at 69, and connected in series to the terminals 72 and 73. The symmetrical arrangement of the primary windings with respect to the secondary windings, that is possible with this arrangement, minimize the unbalance due to the stray capacitances which are shown as 75 and 76.

This is a well known type of hybrid transformer, and is entirely suitable for use in the systems described herein. However it is obvious that other types of hybrid transformers, also well known, that can perform the same function, would also be suitable for use here.

FIGURE 7 shows still another variation of this invention. In this case, the inputs to the transformers 20 and 22 are connected in parallel and to the input terminal 31. Here, as in the variation of FIGURE 4, all four antenna elements are utilized for the signals applied to any of the inputs. Two of the elements are driven in the same phase, and the other two elements are driven in the opposite phase for a signal applied to the input 31. Depending on the connections to the output windings of the transformers 20 and 22, either the elements 10 and 14 can be in phase or the elements 12 and 14 can be in phase, which is the case here. The other two elements will be in the opposite phase.

The other inputs and transformers are seen to be the same as in FIGURE 1 and will function in the same way. However it is noted that in FIGURE 7 the adjacent antenna elements are connected to each of the transformers 20 and 22 rather than the diagonally opposing elements as in FIGURE 1. This causes a change in the radiation pattern, as will be seen in FIGURE 9.

FIGURE 9 shows the polar diagrams of the radiating antenna elements connected as in FIGURE 7. With adjacent antenna elements now in phase for the signals applied to both 31 and 34, the patterns will be the same, but at right angles to each other. The pattern for the input 36, which combines all of the elements in one phase, will again be omnidirectional.

FIGURE 8 shows a supplementary variation of the circuit of FIGURE 7 with differential chokes 80 and 82 connected to the antenna elements that are in opposite phase. In this case choke 80 is connected between elements 10 and 14, and choke 82 is connected between elements 12 and 16. The high impedance of the chokes, and the center-taps, isolate the antenna elements from the additional input 38 during the application of signals to the inputs 31, 34, or 36, and vice-versa. The center-tapped chokes also provide a direct connection from the transformer 28 to the antenna elements to operate as diagonal pairs instead of as adjacent pairs, as in FIGURE 7.

It should be noted that the actual connections of the chokes would be at the output terminals of the transformers, rather than at the antenna elements themselves, in order to keep the effective coaxial line between transformers at a minimum length.

In the event that a remote station lies in one of the null directions of one of the antenna lobe patterns, it is obvious that the corresponding local transmitting or receiving station can be switched to one of the other inputs whose lobe pattern does not have a null in that direction.

What is claimed is:

1. An antenna array having a plurality of inputs, that can function simultaneously without interaction, comprising a first, a second, and a third hybrid transformer, each having a primary winding and a center-tapped secondary winding; a fourth transformer having a primary winding and a secondary winding; a first pair of antenna elements connected to the ends of said secondary winding of said first hybrid transformer, a second pair of antenna elements connected to the ends of said secondary winding of said second hybrid transformer, said first and second pairs of antenna elements forming a square; the center-taps of said secondary windings of said first and said second hybrid transformers being connected to the ends of said secondary winding of said third hybrid transformer; the center-tap of said secondary winding of said third hybrid transformer being connected to one end of said secondary winding of said fourth transformer, the other end of said secondary winding of said fourth transformer being connected to ground; a first source of radiant energy connected to said primary winding of said first hybrid transformer; a second source of radiant energy connected to said primary winding of said second hybrid transformer; a third source of radiant energy connected to said primary winding of said third hybrid transformer; and a fourth source of radiant energy connected to said primary winding of said fourth hybrid transformer.

2. A multiplex antenna system comprising at least three hybrid transformers having primary windings and center-tapped secondary windings; four antenna elements positioned at the corners of a square, one end of a secondary winding of a first of said hybrid transformers being connected to a first of said antenna elements, the other end of said secondary winding of said first of said hybrid transformers being connected to a second of said antenna elements, one end of a secondary winding of a second of said hybrid transformers being connected to a third of said antenna elements, the other end of said secondary winding of said second of said hybrid transformers being

connected to a fourth of said antenna elements, one end of a secondary winding of a third of said hybrid transformers being connected to the center-tap of said secondary winding of said first of said hybrid transformers, the other end of said secondary winding of said third of said hybrid transformers being connected to the center-tap of said secondary of said second of said hybrid transformers; a fourth transformer having a primary winding and a secondary winding, one end of said secondary winding of said fourth transformer being connected to the center-tap of said secondary winding of said third of said hybrid transformers, the other end of said secondary winding of said fourth transformer being connected to ground; and means for connecting a source of radiant energy to the primary windings of each of said transformers.

3. A multiplex antenna system as in claim 2 wherein said means for connecting a source of radiant energy to the primary winding of said second hybrid transformer includes a ninety degree phase-shifting network connected between said source of radiant energy and said primary winding of said second hybrid transformer, and the same source of radiant energy is used for both said first and said second hybrid transformers.

4. A multiplex antenna system as in claim 2 wherein said first and said second antenna elements are positioned at one set of the diagonally opposing corners of said square, and said third and said fourth antenna elements are positioned at the other set of the diagonally opposing corners of said square.

5. A multiplex antenna system as in claim 2 wherein said first antenna element is adjacent to said second antenna element, and said third antenna element is adjacent to said fourth antenna element.

6. A multiplex antenna system as in claim 2 wherein said primary winding of said second hybrid transformer is connected in parallel with said primary winding of said first hybrid transformer, and the same source of radiant energy is used for both said first and said second hybrid transformers.

7. A multiple antenna system as in claim 5 wherein said first antenna element is also adjacent to said fourth antenna element, and said third antenna element is also adjacent to said second antenna element.

No references cited.

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