April 23, 1968 T. E. CONNOLLY 3,380,053

DUPLEXING MEANS FOR MICROWAVE SYSTEMS UTILIZING PHASED ARRAY ANTENNAS

Filed Dec. 22, 1966 2 Sheets-Sheet 1

FIG. 1

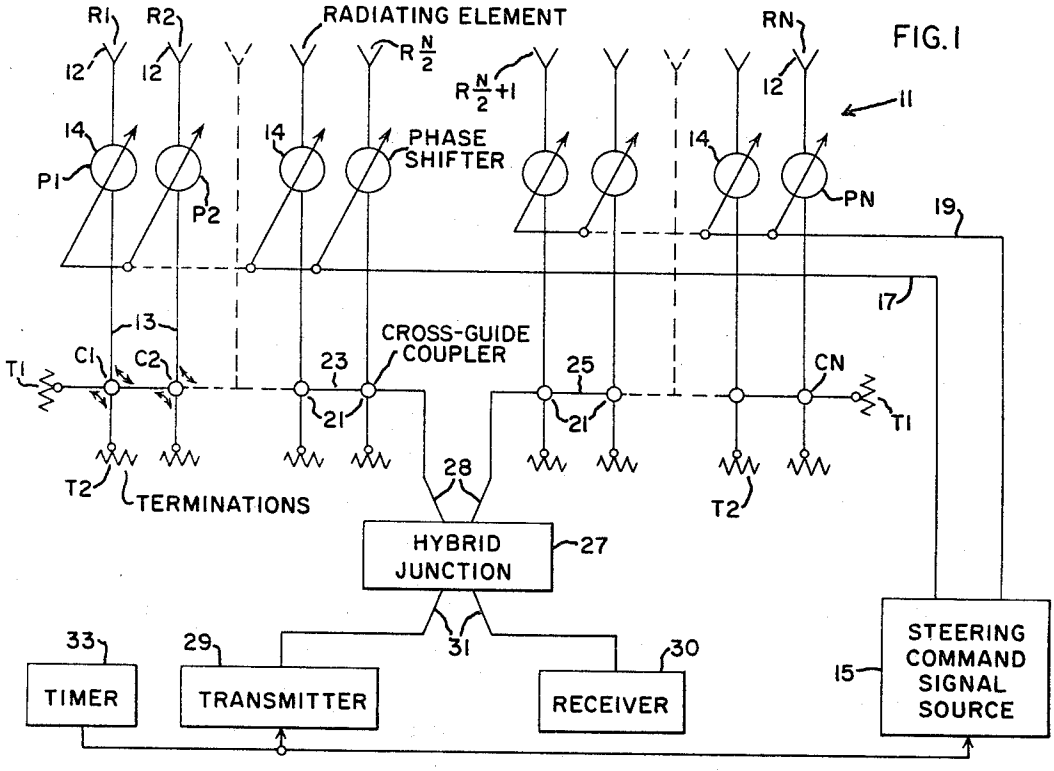
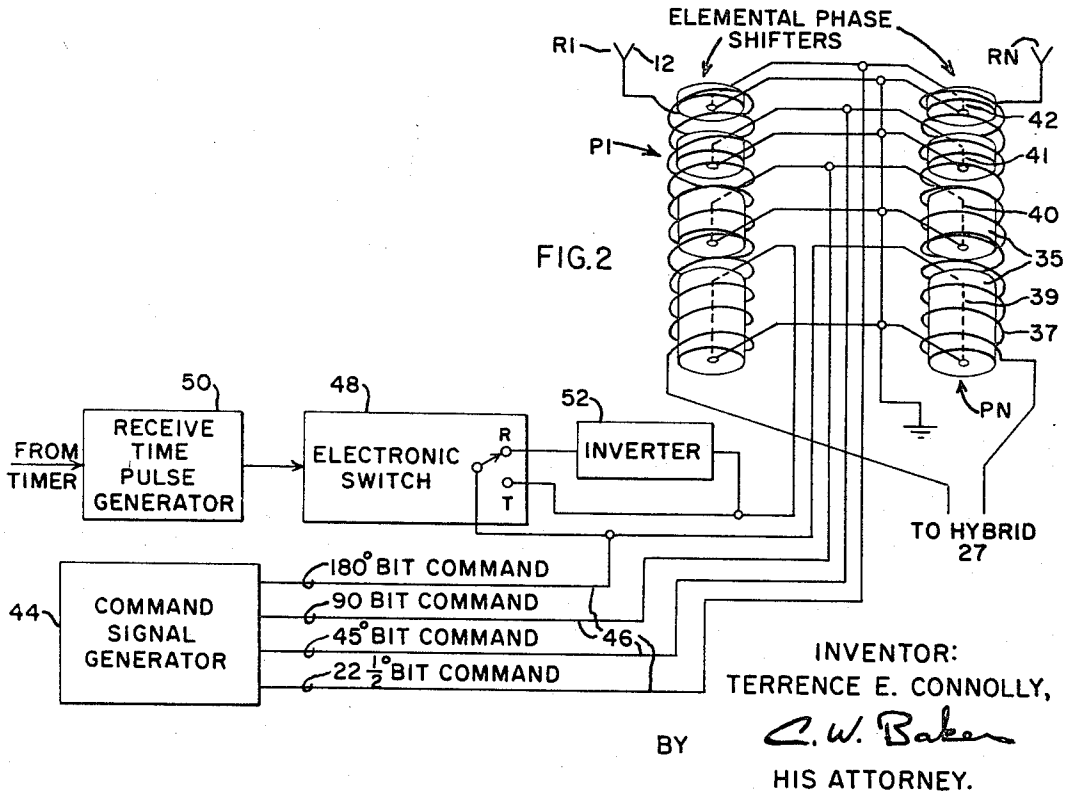


FIG. 2



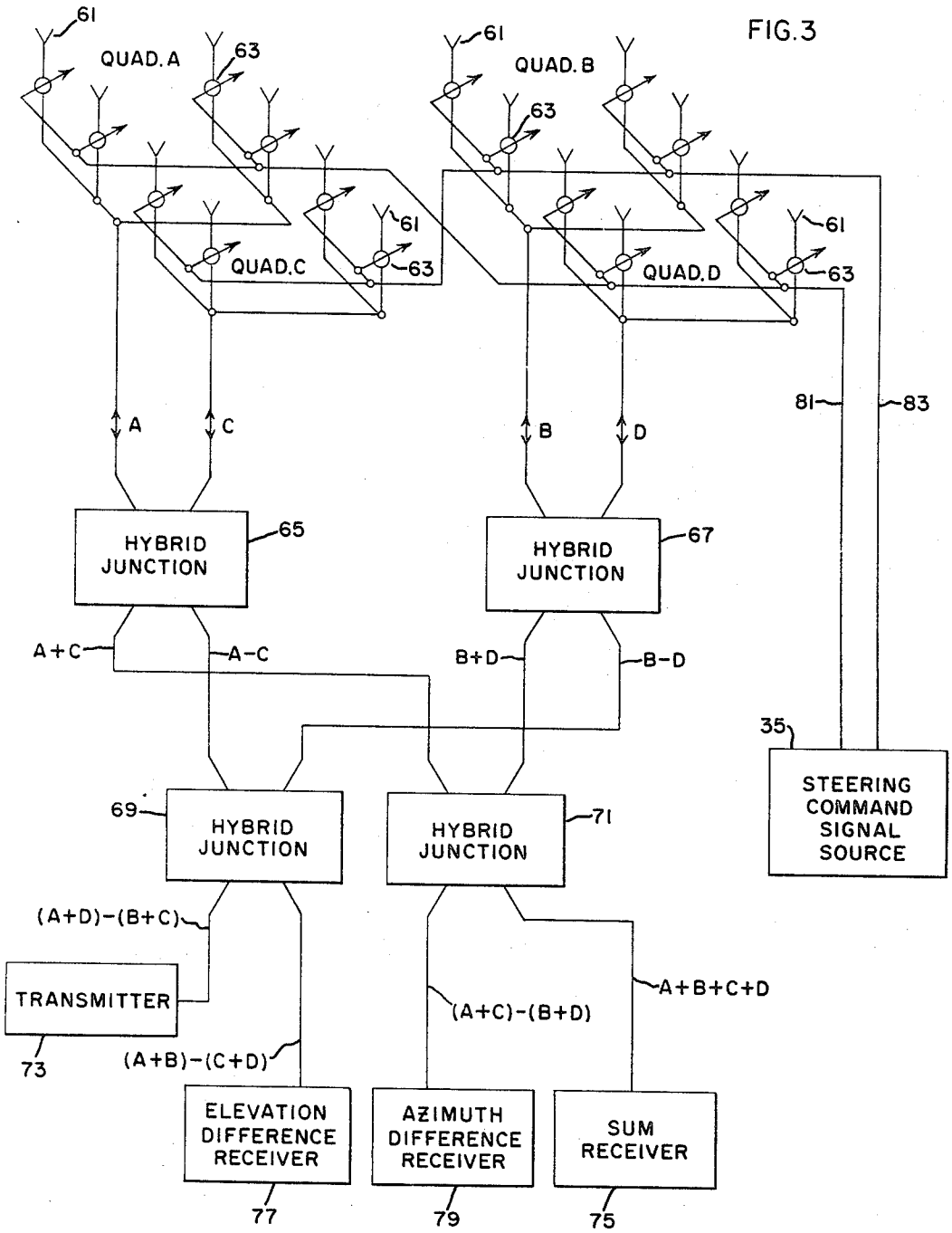
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FIG. 3



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DUPLEXING MEANS FOR MICROWAVE SYSTEMS UTILIZING PHASED ARRAY ANTENNAS

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6 Claims. (Cl. 343—16)

ABSTRACT OF THE DISCLOSURE

This invention is directed to the provision of duplexing between transmitter and receiver in radar and communications systems. It has application to systems utilizing phased array antennas in which adjustable phase shifters in the feed lines to each of the radiating elements of the array provide beam forming and steering control for the transmit and receive beams, and in which two opposite sides of the array connect to 3 db terminals of a hybrid junction also providing sum and difference terminals to which the transmitter and receiver connect. In such systems transmit-receive duplexing may be accomplished without need for discrete duplexing devices by providing control signals to the phase shifters on each side of the array effective to establish a phase relation between them during transmission intervals which differs by approximately 180° from that maintained during reception intervals, to thus commutate the sum and difference terminals of the hybrid in a way such that on transmit the sum terminal connects to the transmitter and on receive it connects to the receiver.

Background of the invention

A wide variety of radar and communications system applications, both civil and military, entail the use of microwave antennas which are monostatic in the sense that the antenna both transmits and receives on a time shared basis. Monostatic systems, whether those in which the antenna comprises but a single radiating element or those in which the antenna includes many hundreds of radiating elements as in a complex phased array, require the implementation of a duplexing function for switching the antenna between transmitter and receiver. Such duplexing serves the purpose, on transmit, of protecting the receiver and directing all of the transmitted energy to the antenna, and on receive it serves to direct the received signal to the receiver with little if any dissipation of the received energy in the transmitting circuit. The present invention relates generally to means for providing this necessary duplexing function, and more specifically to its provision in microwave systems of the type utilizing phased array antennas.

Conventionally the duplexing function in array as well as other antenna systems has been performed by high power devices such as gas tubes, multipactors, semi-conductor switches and phase shifter plus hybrid combinations. These various known devices, appropriately applied, satisfactorily serve their intended purpose though necessarily at the expense of some additional complexity attributable to the presence of the device itself, and, in the case of many of these devices, to the additional power supply or control means necessary to their operation. The present invention affords the desired duplexing function in phased array antenna systems by modification of the interconnection and control of elements necessarily included in such systems for other purposes. It causes these necessary elements to provide this additional function as well, without need for discrete duplexing devices or their associated equipment.

Summary of the invention

This invention has as a primary objective the provision, in a microwave system utilizing a phased array antenna, of means for accomplishing the duplexing function necessary for monostatic operation of the system without use of specific duplexing elements, by interconnection and control of various of the antenna feed elements to provide this additional function. More specifically, the invention provides radar and communication systems of the type including an array antenna comprising a plurality of symmetrically arranged sub-array units each fed through an elemental phase shifter, in which transmit-receive duplexing is accomplished by connection of the two sides of the antenna through a hybrid junction providing sum and difference terminals, and by commutating the sum and difference signals to and from these terminals by reversal of phase commands to the phase shifters of one side of the array with respect to those of the other on switching between transmit and receive.

Briefly stated, one presently preferred embodiment of the invention as applied to a microwave system utilizes a phased array antenna including a plurality of radiating elements of dipole or other suitable type arranged in linear, planar or three-dimensional array, the radiating elements being divided into paired sub-arrays disposed generally symmetrically with respect to the array center. They array transmit and receive beams may be either phase or frequency steered in one plane or mechanically steered in that plane if desired, but in at least one plane beam control is accomplished by a plurality of elemental phase shifters each interposed in the feed line to one of the array radiating elements and adjustable to control the magnitude of phase shift of signals communicated to and from the radiating element, through at least 180° of phase shift. The array and feed structure thus constituted connects to the transmitter and receiver through a four-terminal hybrid junction having two 3 db terminals each of which connects to one of the paired sub-array units, and two sum and difference terminals which commutate or reverse their sum and difference signals depending upon the phase relation of signals appearing at the two 3 db terminals. A steering command signal generator provides control signals for adjusting the elemental phase shifters as necessary for beam forming and steering, and these signals are programmed during reception intervals to establish between the elemental phase shifters of each pair of sub-array units a phase difference of approximately 180° from that effected during transmit periods, thus commutating the sum and difference terminals of the hybrid. These terminals then are connected to the transmitter and receiver with the sum terminal on transmit being connected to the transmitter and with the sum terminal on receive being connected to the receiver, to provide duplexing between transmitter and receiver. The invention is particularly advantageous in systems utilizing digital phase shifters as these simplify control of the 180° phase shift necessary for duplexing, and also offers particular advantage as applied to a two-dimensional array providing monopulse operation in both azimuth and elevation.

Brief description of the drawings

The invention will be further understood and its various objects, features and advantages more fully appreciated by reference to the appended claims and to the following detailed description when read in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a block diagram of a microwave transmitting and receiving system providing transmit-receive duplexing in accordance with the invention;

FIGURE 2 is a block diagram of a steering command signal source and illustrates its connection to elemental phase shifters of an array such as that of FIGURE 1; and

FIGURE 3 is a schematic diagram of a microwave transmitting and receiving system in accordance with the invention, incorporating a planar array antenna and providing monopulse operation in both elevation and azimuth.

Description of the preferred embodiments

With continued reference to the drawings, wherein like reference numerals have been used throughout to designate like elements, FIGURE 1 illustrates the invention as embodied in a radar system of the type comprising a linear array antenna utilizing elemental phase shifters for transmit and receive beam forming and steering. The antenna may employ corporate or parallel feed if preferred, but as illustrated is of the series feed configuration described in Patent No. 3,258,774 to Richard R. Kinsey, assigned to the assignee of the present invention. Reference is made to that patent for more comprehensive descriptions of this series feed arrangement, since its details are not part of the present invention.

As shown, the antenna designated generally by reference numeral **11** comprises a plurality of radiating elements **12** (also designated **R1**, **R2** . . . RN in FIGURE 1) arranged in linear array and grouped into two subarray units with the units of such pair being generally symmetrically disposed with respect to the array center. The branch feed line **13** connecting to each of the radiating elements **12** has interposed therein an elemental phase shifter **14** (also designated **P1**, **P2** . . . PN in FIGURE 1) which operates on signals transmitted therethrough to impart differing phase shifts of magnitude determined by control signals applied to the phase shifters by a steering command signal source **15** over connections **17** and **19**, each of which supplies control signals to the phase shifters of one sub-array unit of the pair. The construction and operation of the elemental phase shifters **14** will be more fully described with reference to FIGURE 2, and for a still more detailed description reference may be made to Patent No. 3,290,622 to Hair, assigned to the assignee of the present invention.

Each of the branch feed lines **13** from the radiating elements of the left hand side of the array connects through a cross guide coupler **21** (also designated **C1**, **C2** . . . CN in FIGURE 1) to a common feed line **23**, and the feed lines **13** on the right similarly connect to a common or series feed line **25**, with terminations T_1 for the series feed line and T_2 for each of the branch lines being provided for matching purposes. The structure and operation of the cross guide couplers **21** preferred for these connections is described in detail in another Kinsey Patent No. 3,230,483, also assigned to the assignee of the present invention.

The two halves of the antenna array connect through a hybrid junction **27** to the transmitter **29** and receiver **30**, both of which may be of conventional construction and operation. Hybrid junction **27**, which likewise may be of conventional construction, is of the four port type providing two 3 db terminals **28** for connection to opposite sides of the antenna array and two sum and difference terminals **31** for connection to the transmitter and receiver, these latter terminals **31** being operative to commutate or reverse their sum and difference outputs upon reversal of phase or polarity of signals applied to one of the 3 db terminals relative to signals applied to the other. Such commutation of sum and difference signals in hybrid junctions is characteristic of various of the several known forms of hybrid junction including the so called "rat race" or ring junction and the magic tee, and any of these conventional hybrids having this necessary characteristic may be used.

Hybrid junction **27** is connected to the transmitter **29** and receiver **30** in an arrangement such that the one of the terminals **31** on which the sum signal appears when in-phase signals are simultaneously applied to the two 3 db terminals connects to the transmitter, and the terminal on which the sum signal appears when oppositely phased signals are applied to the two 3 db terminals connects to the receiver. Then, depending on the phase relationship of signals at its 3 db terminals **28**, the hybrid will commutate its sum and difference terminals **31** in a way such that the sum terminal during transmit is that connected to the transmitter and the sum terminal during receive is that connected to the receiver, to thus accomplish the desired duplexing function.

To provide this commutation and the resultant duplexing between transmit and receive, the steering command signal source **15** is programmed to set the elemental phase shifters **14** of the two sub-array units on opposite sides of the array center to a common polarity or phase relationship during transmit, so that the terminal **31** of the hybrid to which the transmitter connects then is functioning as a sum terminal and the hybrid accordingly will divide the transmitter output power substantially equally between the two halves of the array. Since under these conditions any power entering the 3 db terminals **28** of the hybrid junction is directed to the sum terminal which now is that connected to the transmitter, and since ideally none of the transmitter power entering the sum terminal is passed by the hybrid to the difference terminal connected to the receiver **31**, it will be seen that the receiver is protected against application of the transmitter signal so that the transmit function of the duplexer is now being performed.

On receive, the steering command source is programmed to reverse the polarity or phase relationship of one sub-array unit or side of the array with respect to the other, so as to commutate the sum and difference signals at terminals **31** of hybrid junction **27**, to thus direct the sum signal to the receiver **30** and any difference signal to transmitter **29**. Under these conditions substantially all the energy received by the antenna combines in the hybrid junction and is supplied to the receiver as the sum signal input to it; only the difference if any is connected to the transmitter and dissipated.

For applications such as communications systems wherein fast switching between the transmit and receive functions may not be required, an operator-controlled manual input may be used for effecting the steering command signal change required between transmit and receive for duplexing in the manner just described. Generally, however, automatic means for accomplishing this command signal switching will be preferable, and in radar applications these means may conveniently be made to operate under control of the same timing signal which pulses the transmitter modulator. This timing pulse, shown as generated by the system timer **32** in FIGURE 1, may be used to synchronize the switching of steering command signals in any desired manner such as by use of the electronic switch arrangement illustrated in FIGURE 2 and described hereinafter by reference to that figure.

As will be obvious to those skilled in the art, the 180° phase difference or phase reversal necessary for duplexing operation in accordance with the invention may be obtained either (1) by programming a 180° phase change to one side of the array between transmit and receive, (2) by programming 90° phase changes of opposite sign to the two sides of the array, (3) by programming any other two phase changes which total 180° to the two sides of the array, or (4) if the elemental phase shifters used are nonreciprocal in function as will be explained in greater detail with reference to FIGURE 2, then by omitting the 180° phase change signal which would otherwise need be applied between transmit and receive in order that the transmit and receive beams point in the same direction. It will also be appreciated that of the various forms of hybrid junction usable in the duplexing arrange-

ment of this invention, some such as the "rat race" are themselves operative to introduce a phase difference between the two 3 db terminals of the junction. Where such hybrid is to be used the steering command signals will, of course, need be programmed to factor out the phase disparity thus introduced, or a phase shifter of fixed value, either 90° or 180° phase shift as appropriate, may be inserted into the connection to the proper one of the two terminals of the hybrid junction to compensate for phase shift therein.

With reference now to FIGURE 2, there is illustrated in greater detail a steering command signal source and an elemental phase shifter construction suitable for use in the microwave transmitting and receiving system of FIGURE 1. Only a single phase shifter **14** and associated radiating element **12** is shown as constituting the sub-array on each side of the array in FIGURE 2; it will be understood that normally each sub-array will include a plurality of radiating elements with each fed through an elemental phase shifter and with the elements disposed in linear or other array.

The elemental phase shifters shown in FIGURE 2 are of ferromagnetic type providing digitally controllable phase shift, and are of the construction described in the Hair Patent 3,290,622 previously referred to. As more fully explained in Hair, a range of digital phase shifts is provided by use of a plurality of coaxially arranged cylindrical segments **35** of ferromagnetic material, with each such segment being of a different length proportioned to the magnitude of the phase shift to be effected thereby. Each cylindrical segment **35** has a remanent circumferential DC magnetization therein oriented in one of two opposing directions. An RF energy propagating helix **37**, which conducts the signal energy between the radiating element **12** and the hybrid which connection is made to the transmitter and receiver, is wound about the segments **35** and produces a rotating RF magnetic field within each of them disposed in orthogonal spatial relationship with the DC magnetization.

Separate DC control windings **39–42** are coupled one through each segment **35** and are selectively energized to individually switch the remanent DC magnetizations, thereby applying to the RF energy a total phase delay that is the sum of the individual delays of the various segments. In the embodiment illustrated, the longest of the segments **35** is made of length such as to introduce a 180° phase shift between its two states of remanent DC magnetiziation; the shorter segments are of length such as provide phase shifts of 90°, 45° and 22½°, respectively. By selective energization of one or more of the DC control windings through these segments **35**, the phase shift introduced by the element may be digitally adjusted to a value corresopnding to the delay of any one or more elements in any desired combination, as explained in detail in the aforementioned Hair patent.

For programming the operation of these elemental phase shifters, a command signal generator **44** provides places shift commands to each of the segments of the elemental phase shifters via leads **46**. Depending on whether the elemental phase shifters are remanent in operation as are those described in the Hair patent or non-remanent as in the case of certain other forms of ferromagnetic and semiconductor phase shifters, the 180° bit, 90° bit and other bit commands to the phase shifters may take the form of positive or negative pulses operative to switch from one remanent state to the other, or may take the form of DC voltages of sustained duration, but in any event the relationship between the command signals supplied over leads **46** by generator **44** is such to establish a phase relation between the signals transmitted through the elemental phase shifters of each side of the array such that the array beam is steered to the desired position.

Transmit-receive duplexing in accordance with the invention is particularly easily accomplished in an array antenna system utilizing digital phase shifters including 180° phase bit as just described. This permits the desired 180° phase reversal of one side of the array between transmit and receive by control of the command signal to but a single segment of the phase shifters on one side of the array, and to accomplish this only very simple implementation is required. Where the command signal generator **44** is of a programmable computer type, it may simply be programmed to reverse the command signal to all the elemental phase shifters on one side of the array, i.e., to reverse polarity of the command signal to the 180° bit elements on one side of the array, to provide the desired 180° difference in phase shift through the elemental phase shifters between transmit and receive. Alternatively, where the phase shifters include 90° bits, then instead of modifying the command to the 180° elements on one side of the array the same result may be achieved by reversing the polarity of command signals to the 90° bits on both sides of the array, so that these equal and opposite 90° phase changes total the desired 180° phase shift.

FIGURE 2 illustrates another arrangement for accomplishing this result, utilizing an electronic switch **48** driven by a receive time pulse generator **50** driven in synchronism with the system timer (not shown). The electronic switch **48** operates during the transmission period to connect, through terminal "T" in FIGURE 2, the 180° bit command directly to the corresponding phase shifter segment, and operates during periods of reception to make this connection through terminal "R" to an inverter **52** which operates to reverse the polarity of the command signal and thus effect a 180° reversal in phase shift by the phase shifters on the side of the array to which the inverted command signal connects. In this way the desired duplexing action may be achieved with little additional circuitry and with the same accuracy of control of the necessary 180° phase shift for duplexing that is characteristic of array beam forming and steering in systems utilizing phase shifters of this type.

Phase shifters of the particular form described in the aforementioned Hair patent enable still further simplification of control by virtue of the fact they are non-reciprocal in operation. They therefore require a 180° phase shift command to the 180° segments on switching between transmission and reception if, as is usua'ly desired, the transmit and receive beams are to point in the same direction. Duplexing in accordance with the invention may be provided in such systems merely by omitting the normal phase reversal command to one or the other of the two sides of the array. It is apparent that this requires no additional circuitry and may in fact permit the omission of some control wiring otherwise necessary.

The duplexing technique of this invention has additional advantages when applied to a planar array and particularly to such an array utilizing phase-phase steering. FIGURE 3 illustrates such an array in which the aperture is fed in four quadrants and a hybrid network is provided for monopulse reception providing sum and difference outputs in both azimuth and elevation. In FIGURE 3 each of the quadrants A–D comprises a plurality of radiating elements **61**, four such elements being shown in each quadrant in the illustrated embodiment. Each radiating element **61** is fed through an elemental phase shifter **63**, which may be of the same construction and operation described with reference to FIGURE 2, and the various elements of each quadrant may be interconnected in series feed or corporate feed configuration as preferred.

Each sub-array unit or quadrant A–D in FIGURE 3 connects to one of the two 3 db terminals of two hybrid junctions **65** and **67**, respectively, having their sum and difference branches connected as shown to the 3 db branches of two other hybrid junctions **69** and **71**. The

sum and difference terminals of these latter hybrids connect to the transmitter **73** and to three receivers **75, 77** and **79** which provide the sum, azimuth difference and elevation difference outputs, respectively. The interconnection of hybrids **65–71** to accomplish monopulse operation and duplexing in accordance with the invention is perhaps best understood by reference to the quadrant signal designations A, B, C and D, which illustrate the action of the respective hybrids during the reception interval.

As shown, hybrid junction **65** accepts the A and C signal inputs, and provides a sum (A+C) output to hybrid junction **71** and a difference (A—C) output to hybrid junction **69**; hybrid **67** accepts the B and D quadrant signal inputs and provides a sum (B+D) output to hybrid **71** and a difference (B—D) output to hybrid **69**.

Hybrid **69** accepts its (A—C) and (B—D) inputs and provides an (A+B)—(C+D) output signal, which constitutes the elevation difference signal, to the receiver **77**, and provides an (A+D—(B+C) output commonly termed the "skew channel" signal to the transmitter **73**. This skew channel output normally is zero or at least negligibly small. Hybrid junction **71** accepts its (A+C) and (B+D) inputs and provides an (A+C)—(B+D) output signal, constituting the azimuth difference signal, to receiver **79**, and an (A+B)+(C+D) or sum signal output to the sum receiver **75**.

On transmit, hybrid junction **69** divides the transmitter power output equally between the hybrids **65** and **67**, which again divide the energy transmitted to them equally between each of the four quadrants of the array. To provide the desired commutation of function of the hybrids **65–71** on switching between transmit and receive, the elemental phase shifters of one diagonally opposed pair of the qudrants A—D then are reversed in phase with respect to the other diagonally opposed pair. As shown, quadrants A and D are supplied with their phase shift commands over a common lead **81** and the other diagonally opposed pair of quadrants, namely B and C, are provided with their phase command signals over a different lead **83**. Both these leads connect to a steering command signal source **85** which conveniently may take the form illustrated in FIGURE 2 and described with reference to that figure.

For duplexing in this planar array, the transmitter is directly connected to the terminal of hybrid **69** which is made to function as a "sum" terminal during the transmission interval, by supply of control signals of like polarity to all four quadrants of the array. In re-phasing for reception, the control signals to the phase shifters of either pair of diagonally opposed array quadrants A and D or B and C are reversed in phase. This causes the hybrids **69** and **71** to pass to their associated receivers a "sum" beam and two monopulse difference beams, and to pass to the transmitter terminal a skew channel signal normally of little if any energy content. As with a line array, this duplexing function may be accomplished with digital phase shifters by a single phase reversal command to the 180° bit, or in the case of nonreciprocal digital phase shifters duplexing may be achieved simply by deleting phase reversal commands to the 180° bits on phase shifters in the diagonal quadrants.

As will be apparent from the foregoing description of the invention, no discrete duplexing components are required in microwave systems in accordance with the invention. This is a substantial advantage, affording as it does significant reductions in weight and cost. Also, no additional RF loss is incurred for the duplexing function, no additional cooling is required for discrete duplexers, and any power level that can be radiated by the array can safely be duplexed because the power is distributed over same number of phase shifter elements in duplexing as in beam forming. The isolation between transmitter and receiver afforded by duplexing in accordance with the invention is essentially equal to the isolation of the central hybrid and so may be qiute high. As with any duplexer, of course, additional receiver protection such as RF limiters will usually be desirable particularly in radar operation.

The invention may be applied in many different forms and to many different types of radar and communication systems. For example, both the single hybrid and the four-hybrid quadrant forms of the invention as above described may be used in large antenna arrays employing a plurality of like single or quadrant-grouped hybrids with each connected to a separate portion or sub-array of the antenna. The invention also finds use in reflective antennas utilizing array feed, where the feed includes elemental phase shifters enabling the necessary phase reversal for duplexing as above explained.

While in this description of the invention only certain presently preferred embodiments have been illustrated and described by way of example, many modifications will occur to those skilled in the art and it therefore should be understood that the appended claims are intended to cover all such modifications as fall within the true spirit and scope of the invention.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. In combination in a microwave transmitting and receiving system:

array antenna means including a plurality of radiating elements disposed in spaced array;

feed means connecting said radiating elements into paired sub-array units and including a plurality of elemental phase shifters disposed in series relation with said radiating elements and adjustable to variably control phase shift of signals transmitted and received by the radiating elements associated therewith, for transmit and receive beam forming;

transmitter means;

receiver means;

hybrid junction means interposed between said feed means and said transmitter and receiver means, said junction means comprising two 3 db terminals each connecting through said feed means to the radiating elements of one said sub-array unit and further comprising sum and difference terminals connecting to said transmitter and receiver, said junction means being responsive to reversal of phase of one of two signals simultaneously applied to its 3 db terminals to commutate the sum and difference signals produced thereby at its terminals connecting to said transmitter and receiver;

and steering command signal generating means connected to supply phase command signals to each of said elemental phase shifters for beam forming and including means operative during receive intervals to effect a phase relation between the phase shifters of each sub-array unit pair differing approximately 180° from that effected therebetween during transmit intervals, to thus commutate the sum and difference signals at the terminals of said hybrid connecting to said transmitter and receiver, said terminals being arranged to connect the sum terminal on transmit to the transmitter and the sum terminal on receive to the receiver to thus provide duplexing between the transmitter and receiver.

2. A microwave system as defined in claim **1** wherein said elemental phase shifters are digital in function and provide discrete phase adjustments of approximately 90° or a multiple thereof, whereby said 180° approximate phase difference between transmit and receive may be effected by change of not more than two phase command signals to said elemental phase shifters.

3. A microwave system as defined in claim **2** wherein said digital phase shifters provide a discrete phase adjustment of approximately 180° and are latching and nonreciprocal in operation, whereby said 180° approximate phase difference between transmit and receive may

be effected by supply of a 180° phase change signal to the elemental phase shifters of one only of said sub-array units of each pair between transmit and receive intervals.

4. A microwave system as defined in claim 1 wherein said radiating elements are disposed in two-dimensional array, wherein said feed means connect said radiating elements into a plurality of sub-array unit pairs including at least one pair generally symmetrically disposed with respect to the array center in each of said two dimensions, and wherein said hybrid junction means comprises a plurality of junctions each providing sum and difference signals for one sub-array unit pair.

5. A microwave system as defined in claim 1 wherein said radiating elements are disposed in planar array divided into quadrants by elevation and azimuth planes with each such quadrant constituting one of said sub-array units, wherein said hybrid junction means comprises four junctions the first and second of which have their 3 db terminals each connecting through said feed means to the radiating elements of one said quadrant and their sum and difference terminals each connecting to one of the 3 db terminals of the third and fourth junctions, wherein said steering command signal generating means supplies phase command signals operative to establish said 180° approximate phase difference between one pair of diagonally related quadrants and the other such pair, and wherein said receiver means comprises a sum receiver and elevation and azimuth difference receivers each connected to one of said third and fourth junction sum and difference terminals to provide monopulse operation in elevation and azimuth.

6. A microwave transmitting and receiving system comprising:

an array antenna including a plurality of radiating elements divided into paired sub-array units with the sub-array units of each such pair being disposed generally symmetrically with respect to the array center;

an elemental phase shifter connected in series relation with each of said radiating elements and including means adjustable to control the magnitude of phase shift introduced thereby for transmit and receive beam forming;

a transmitter;

a receiver;

a four-terminal hybrid junction including a first terminal connecting to said transmitter, a second terminal connecting to said receiver, and third and fourth terminals each connecting to one of said sub-array units, said hybrid being operative to divide signal input at its first terminal substantially equally between its third and fourth terminals and thus equally between said two sub-array units connected thereto, said hybrid being further operative to combine simultaneously received signal inputs at its third and fourth terminals and transmit the sum and difference to said first and second terminals respectively if the input signals are of a first predetermined phase relation and to transmit said sum and difference signals to said second and first terminals respectively if the input signals are of a second predetermined phase relation reversed with respect to the first;

and steering command signal generating means connected to supply to said elemental phase shifters control signals operative to establish said first and second predetermined phase relations during transmission and reception intervals, respectively.

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