

[54] **SCANNING AERIAL SYSTEMS AND ASSOCIATED ARRANGEMENTS THEREFOR**

[72] Inventor: **John Richard Mark, Essex, England**  
 [73] Assignee: **The Marconi Company Limited, London, England**  
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 [51] Int. Cl.....**H01q 3/26**  
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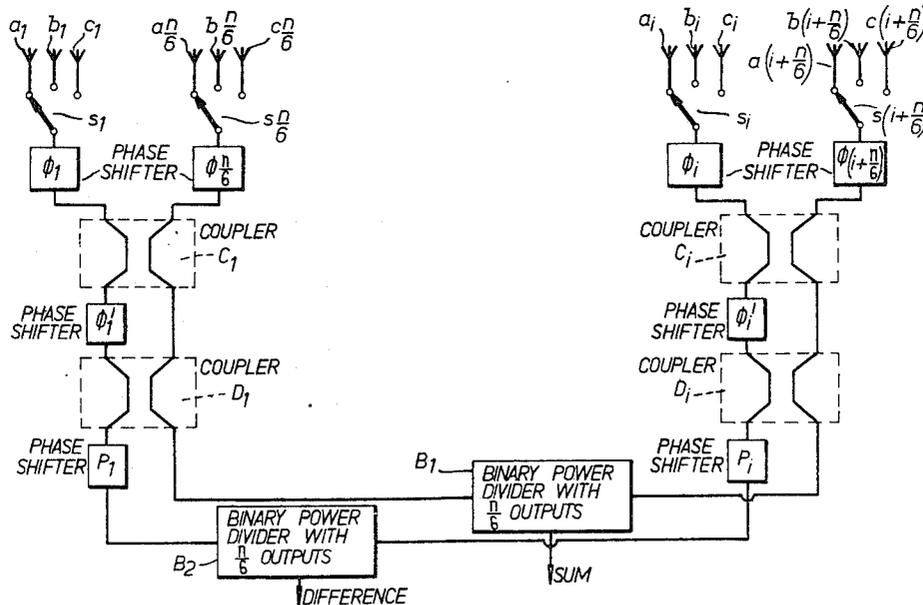
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**UNITED STATES PATENTS**  
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*Primary Examiner—Benjamin A. Borchelt*  
*Assistant Examiner—Denis H. McCabe*  
*Attorney—Baldwin, Wight & Brown*

[57] **ABSTRACT**

An electronic scanning aerial system and associated feeder arrangement has at least one circular aerial array. Elements of the array are divided into sets and units, each set comprising the same number of adjacent equally spaced elements and each unit comprising a number of different corresponding aerial elements, at least one in each set. A power dividing system provides power to different combinations of aerial elements, the combinations depending upon the general direction of radiation. The power dividing system includes a four port coupler, the ports remote from the aerial units being connected to two binary branching arrangements whereby sum signals are produced at one of the binary branching arrangements and difference radiation pattern signals at the other binary branching arrangement.

**7 Claims, 4 Drawing Figures**



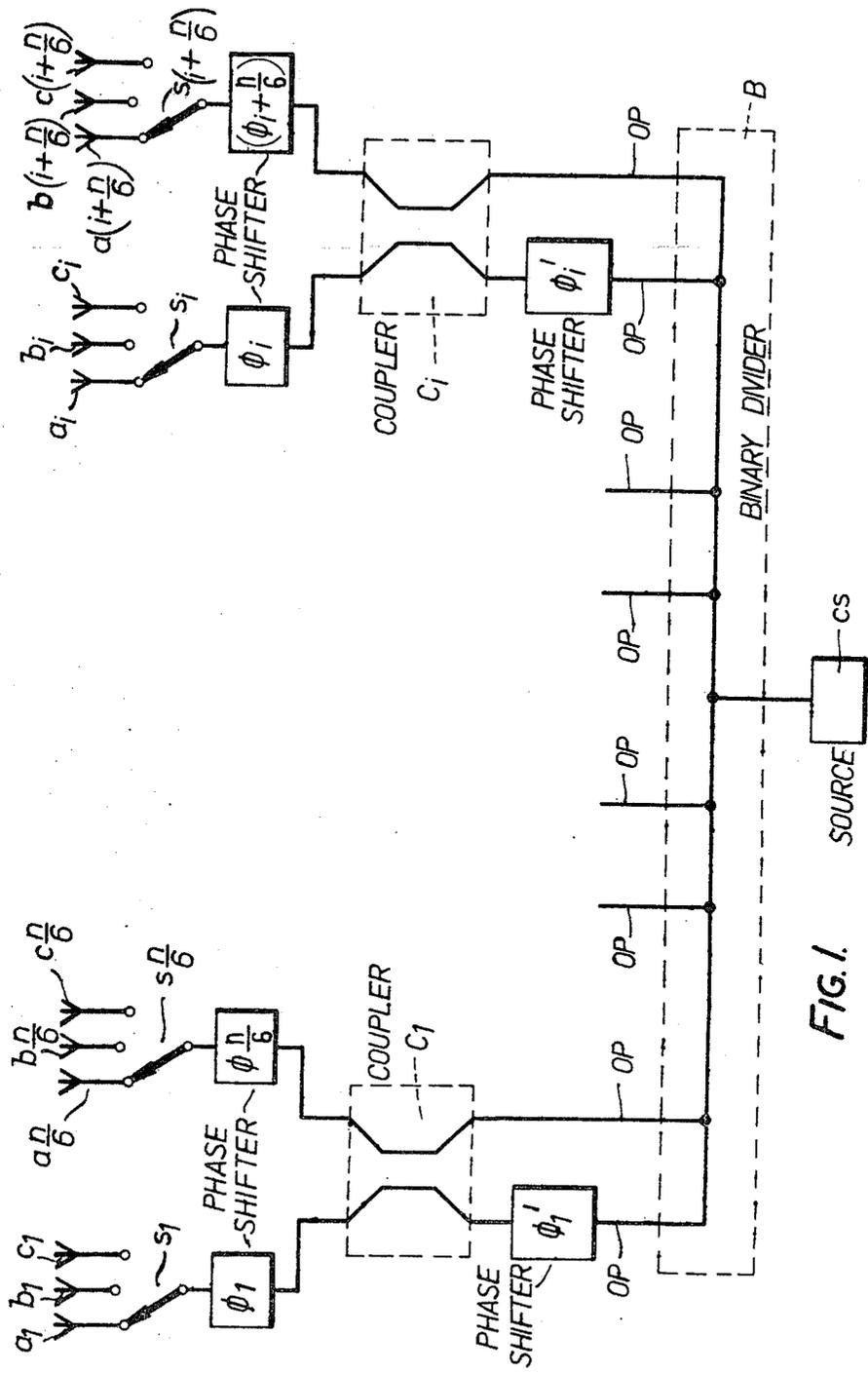


FIG. 1.

Inventor:  
 John Richard Mark  
 BY Baldwin Wight & Brown  
 Attorneys

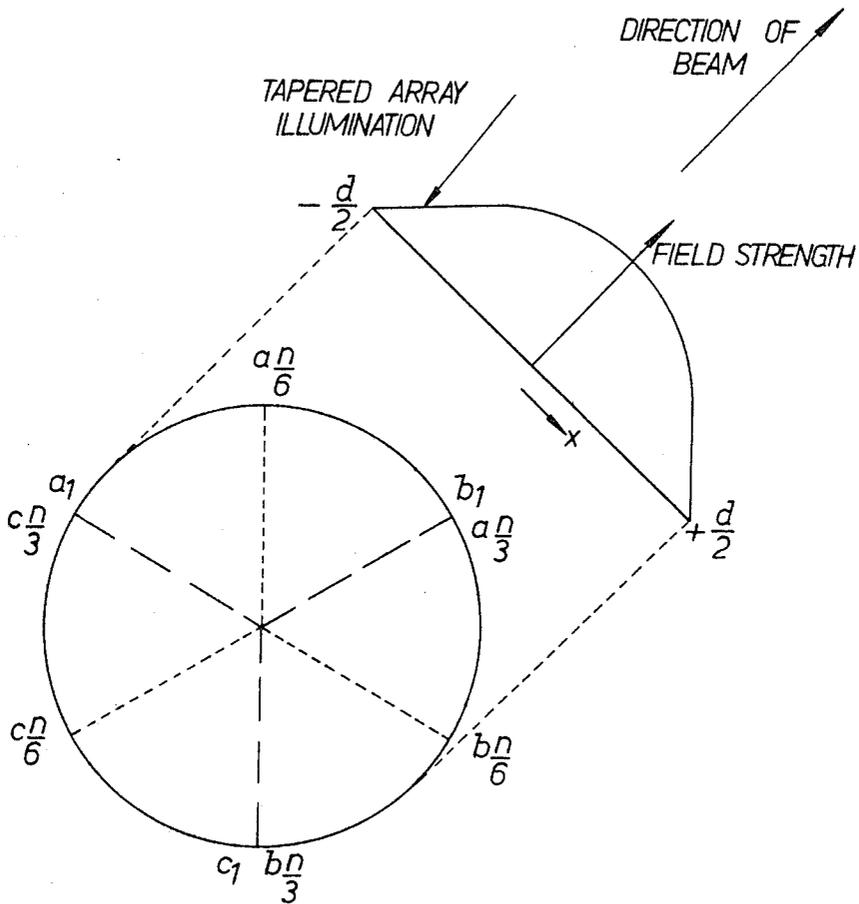


FIG. 2.

Inventor:  
John Richard Mark  
BY Baldwin Wight & Brown  
Attorneys

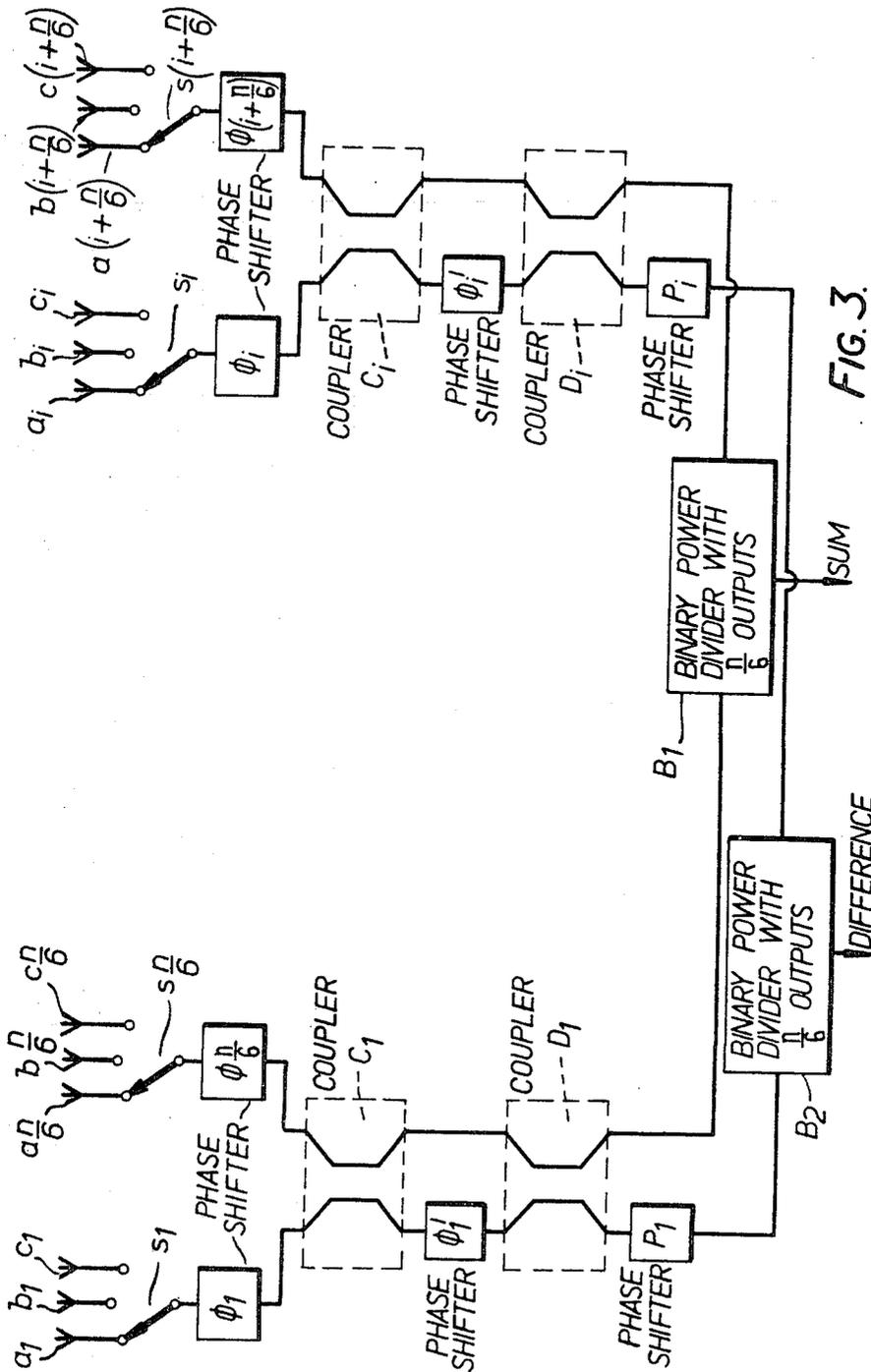


FIG. 3.

Inventor:  
 John Richard Mark  
 BY Baldwin Wight & Brown  
 Attorneys

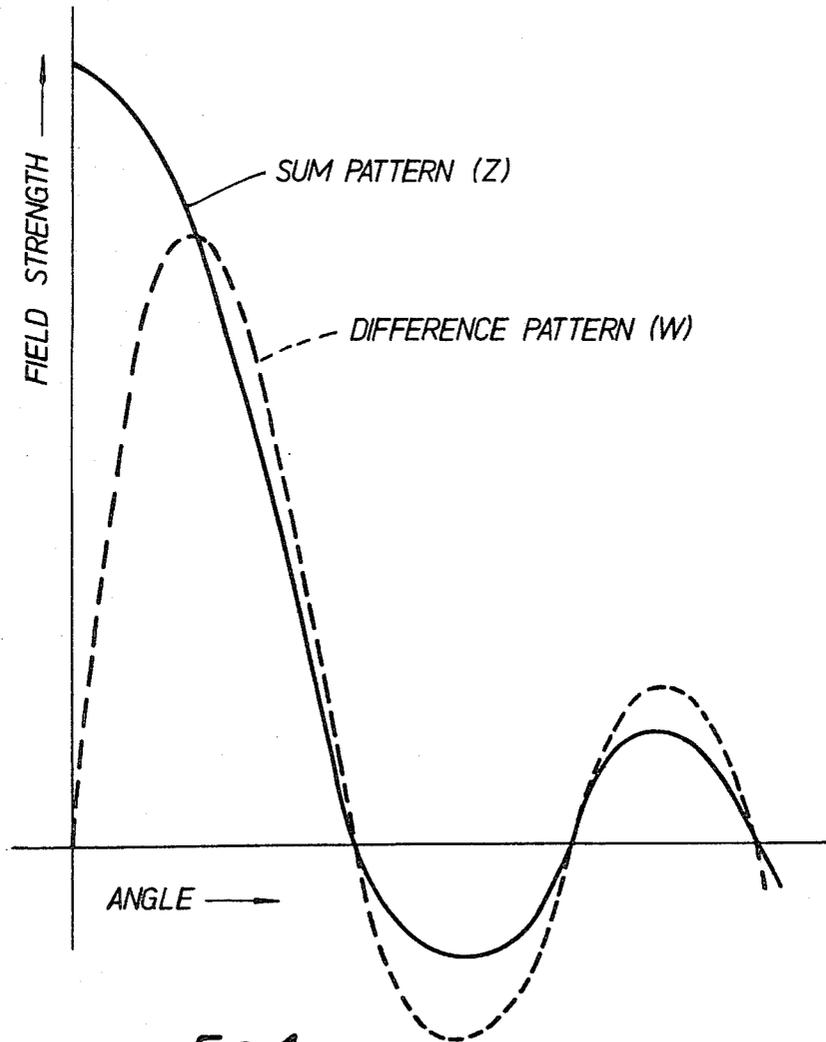
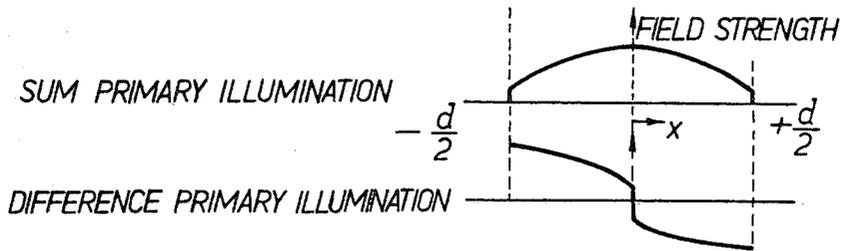


FIG. 4.

Inventor:  
John Richard Mark  
BY Baldwin Wight & Brown  
Attorneys

## SCANNING AERIAL SYSTEMS AND ASSOCIATED ARRANGEMENTS THEREFOR

This invention relates to scanning aerial systems and associated feeder arrangements therefor and more specifically to space scanning aerial systems and associated feeder arrangements therefor of the kind in which at least one circular aerial array, i.e. an array comprising aerial elements lying on the circumference of a circle, is fed through a controllable feeder arrangement which is such that the aerial can scan space in azimuth without being mechanically moved. Such scanning, which is usually called and is herein called "electronic scanning" may simply be scanning in azimuth or there may be scanning in elevation as well.

FIG. 1 of the accompanying drawings is a schematic diagram of a known electronic scanning aerial system and associated feeder arrangement therefor, similar to one of the embodiments of the invention disclosed in our U.S. Pat. No. 1,171,626, whilst

FIG. 2 of the drawings is a representation of a plan view of the aerial array of FIG. 1 and incorporates a radiation diagram.

Referring to FIGS. 1 and 2, a plurality of aerial elements in three sets,  $a_1$  to  $a(n/3)$ ,  $b_1$  to  $b(n/3)$  and  $c_1$  to  $c(n/3)$ , are arranged around the circumference of a circle, each directed to radiate radially outward. Although, for convenience in drawing, the sets of aerials are represented, in FIG. 1, as though they were in a straight line, it is to be understood that they are not so in face and that the elements in the set  $a_1$  to  $a(n/3)$  are disposed along a first  $120^\circ$  arc of a circle, the elements in the set  $b_1$  to  $b(n/3)$  along the following  $120^\circ$  arc of the circle and the elements in the set  $c_1$  to  $c(n/3)$  along the remaining  $120^\circ$  arc of the circle. The subscripts used relate to the position of the element in its set along the arc of the circle. The total number of elements provided is normally a multiple of six.

The aerial elements are arranged to be fed in pairs, in dependence upon the directivity required. Thus for example, elements  $a_1$  and  $a(n/6)$  may be fed together, elements  $a_2$  and  $a(n/6 + 1)$  would be fed together and so on.

The feeding arrangements for the elements shown in FIG. 1 show, on the left as viewed, the arrangement for feeding in pairs any one of elements  $a_1$ ,  $b_1$  and  $c_1$  forming a unit, with any one of elements  $a(n/6)$ ,  $b(n/6)$  and  $c(n/6)$  forming a unit. To the right of the figure as viewed is shown the arrangement for the general case of feeding in pairs any one of elements  $a_i$ ,  $b_i$  and  $c_i$  forming a unit with any one of elements  $a(i + (n/6))$ ,  $b(i + (n/6))$  and  $c(i + (n/6))$  forming a unit, where  $i$  is any integral number from 1 to  $(n/6)$ .

The aerial elements are fed from a common source CS (which may be a transmitter or a receiver) via a binary divider B having as many output paths OP as there are elements in a set, i.e.  $(n/3)$ . The output paths OP are applied in pairs to the two input ports of a different  $-3$ db coupler  $C_i$ , of which there are  $(n/6)$ . One of each pair of output paths OP is connected to its associated  $-3$  db coupler through a different phase shifter  $\phi'_i$ , which, of course, again there are  $(n/6)$ , one for each  $-3$ db coupler. The two output ports of the coupler  $C_i$  are connected via respective phase shifters  $\phi_i$  and  $\phi(i + (n/6))$  to the input terminal of a respective switch  $S_i$  and  $S(i + (n/6))$ .

Switch  $S_i$  connects the phase shifter  $\phi_i$  to the elements  $a_i$ ,  $b_i$  or  $c_i$  of a unit at will, whilst switch  $S(i + (n/6))$ , corresponding connects phase shifter  $\phi(i + (n/6))$  to elements  $a(i + (n/6))$ ,  $b(i + (n/6))$  or  $c(i + (n/6))$  of a unit.

To explain the operation it will be assumed that a beam is required to be produced in the direction of the  $a(n/6)$  radial. All the switches  $S_i$  are operated to select the "a" elements. The phase shifters  $\phi_i$  are adjusted to give the required power division between the switches  $S_i$  and  $S(i + (n/6))$  appropriate to the illumination taper required, whilst the phase shifters  $\phi_i$  and  $\phi(i - (n/6))$  are adjusted to produce in-phase signals at a reference plane in space which is perpendicular to the  $a(n/6)$  radial. To effect small beam shifts about the direction of the  $a(n/6)$  radial the phase shifters  $\phi_i$  and  $\phi(i + (n/6))$  may be adjusted. For larger beam shifts, the switches  $S_i$  have to be re-operated. For example, if the beam direction is moved from the  $a(n/6)$  radial to the  $a((n/6) + 1)$  radial, the switch  $S_i$  in the case must be switched from element  $a_i$  to element  $b_i$ , and the phase shifters re-adjusted.

The control of the switches  $S_i$  and the phase shifters to obtain a beam sweep of  $360^\circ$  is well known and will not be described in further detail herein. In practice the switches  $S_i$  are normally controlled by a computer.

Arrangements as described above provide a sum radiation pattern.

The present invention seeks to provide improved space scanning aerial systems and associated feeder arrangements therefor of the kind referred to in which sum and difference radiation patterns may be obtained.

According to this invention, an aerial and associated feeder system adapted to provide electronic scanning of space comprises an aerial system consisting of a plurality of aerial elements spaced along a circular arc, said elements being divided into sets and units each set consisting of the same plurality of adjacent equally spaced elements and each unit consisting of a plurality of different corresponding aerial elements, at least one in each set; and a power dividing feed system divided into unit feeder arrangements each leading to the aerial elements of two different units through switch means whereby different pre-determined combinations of aerial elements may be selected for connection to the unit feeder arrangement therefor to determine the general direction of radiation, there also being provided, in the path to at least one of the two units fed by each unit feeder arrangement, adjustable phase shifter means for adjusting said general direction of radiation and wherein each unit feeder arrangement includes a four port  $-3$ db coupler, the first of the two ports remote from the aerial units of each of the said couplers being connected to a first binary branching arrangement and the second of the two ports remote from the aerial units of each of said couplers being connected via adjustable phase shifter means to a second binary branching arrangement whereby in operation sum radiation pattern signals are obtainable by said first binary branching arrangement and difference radiation pattern signals are obtainable by said second binary branching arrangement.

The aerial and associated feeder system described above is suitable for transmission, in which case signals applied to the single path of the first binary branching

arrangement are transmitted in accordance with a sum radiation pattern whilst signals applied to the single path of the second binary branching arrangement are transmitted in accordance with a difference radiation pattern. The aerial and associated feeder system described above is equally suitable for reception, in which case sum radiation pattern signals appear on the single path of the first binary branching arrangement and difference radiation pattern signals appear on the single path of the second binary branching arrangement.

Preferably each of the adjustable phase shifter means leading to said second binary branching arrangement is a two-bit phase shifter adapted to provide a phase delay of either zero or  $2\pi$  radians.

Normally said phase shifter means provide zero phase delay when corresponding elements in the units are selected and a phase delay of  $2\pi$  radians when elements which do not correspond in the units are selected.

Preferably again corresponding elements in adjacent sets are spaced arcuately by  $120^\circ$ .

Preferably again, each unit feeder arrangement includes between said  $-3\text{db}$  coupler and the two units fed thereby, and prior to said phase shifter means are provided to adjust said general direction of radiation, a hybrid unit whereby equal power is fed to each of the two units. Preferably the last mentioned hybrid unit is a further  $-3\text{db}$  coupler.

The invention is illustrated in and further described with reference to FIGS. 3 and 4 of the accompanying drawings which illustrate one example, in this case a modification of the system illustrated in FIGS. 1 and 2, of a space scanning aerial system and associated feeder arrangement therefor in accordance with the present invention.

Referring to FIG. 3, the arrangement of the aerial elements  $a_i$  to  $a(n/6)$ ,  $b_i$  to  $b(n/6)$  and  $c_i$  to  $c(n/6)$  in sets and units, the switches  $S_i$ , phase shifters  $\phi_i$  and  $\phi'_i$  and  $-3\text{db}$  couplers  $C_i$  is similar to that shown in FIG. 1 and like references are used for like parts.

Again the feeding arrangements for the elements shown in FIG. 3 show, on the left as viewed, the arrangement for feeding in pairs any one of elements  $a_i$ ,  $b_i$  and  $c_i$  with any one of elements  $a(n/6)$ ,  $b(n/6)$  and  $c(n/6)$ , whilst to the right of the figure as viewed is shown the general case of feeding in pairs any one of the elements  $a_i$ ,  $b_i$  and  $c_i$  with any one of elements  $a(i + (n/6))$ ,  $b(i + (n/6))$  and  $c(i + (n/6))$ .

In place of the binary divider B, having  $(n/3)$  outputs of FIG. 1, two binary dividers B1 and B2 are provided, each having  $(n/6)$  output paths. One output path of the binary divider B1 and one output path of the binary divider B2 are connected in pairs to the two input ports of a different further  $-3\text{db}$  coupler  $D_i$  of which there are  $(n/6)$ . Between each output path of the binary divider B2 and the input port of the respective coupler  $D_i$  is provided a two-bit phase shifter  $P_i$ . Again, of course, there will be  $(n/6)$  two-bit phase shifters  $P_i$ . The two output paths of each further coupler  $D_i$  are connected, as the pairs of output paths of binary divider B in FIG. 1 are connected, to the input ports of respective ones of the couplers  $C_i$ , one of the two output paths in each case being connected directly and the other via a respective one of the phase shifters  $\phi'_i$ .

Each two-bit phase shift  $P_i$  is such as to produce a phase change of either zero or  $\pi$  radians.

With the arrangement described above with reference to FIG. 3, each of the further  $-3\text{db}$  couplers  $D_i$  provide (assuming reception) the sum  $Z_i$  of the signals received through switches  $S_i$  and  $S(i + (n/6))$  at the port connected to binary divider B1 and the difference  $W_i$  at the port connected to binary divider B2. For a given beam direction, i.e. for given settings of the switches and phase shifters, the sum signals  $Z_i$  will all be in-phase and add in the binary divider B1 to provide a sum signal Z. The difference signals  $W_i$  whilst in phase with each other, will be either in phase or in anti-phase with the sum signals in dependence upon the settings of the switches  $S_i$ .

To appreciate this more clearly, assume that a target is in the direction of the  $a(n/6)$  radial. The switches  $S_i$  and phase shifters  $\phi_i$ ,  $\phi(i + (n/6))$  and  $\phi'_i$  are set up to produce a sum pattern with the main beam directed at the target. If a signal is now transmitted at the target, a reflection from the target arrives at the aerial to produce a signal in each of the  $a_i$  elements. These signals pass the switches and phase shifters and are incident at the couplers  $C_i$  as in-phase signals. These may be represented by  $P_i$  and  $P(i + (n/6))$ .

Analysis shows that

$$Z_i a_i \cos \frac{1}{2} \phi'_i + 1(i + (n/6)) \sin \frac{1}{2} \phi'_i$$

and

$$W_i a_i \sin \frac{1}{2} \phi'_i - 1(i + (n/6)) \cos \frac{1}{2} \phi'_i.$$

Thus the amplitude factors  $\cos \frac{1}{2} \phi'_i$  and  $\sin \frac{1}{2} \phi'_i$  may be seen to be interchanged when the difference signal  $W_i$  is produced as compared to when the sum signal  $Z_i$  is produced.

The effect on the primary illumination is illustrated in FIG. 4. In order to produce the difference pattern efficiently, the phases of excitation in the two halves of the aperture should be in opposition. This condition is met with the initial aerial settings above described, provided only small beam movements are required. Consequently, for this initial setting, all of the phase shifters  $P_i$  are set to give zero phase shift. Consider now a beam shift to the  $a((n/6) + 1)$  radial. The switch  $S_i$  moves to element  $b_i$  and the  $a(n/6)$  element moves to the left hand side of the aperture. The difference signal  $W_i$  is no longer the signal received from a left hand element minus that received from a right hand element, but is reversed.

In order to make difference component  $W_i$  add correctly to the other difference components  $W_i$ , phase shifter  $P_i$  is adjusted to provide a radian phase shift of difference component  $W_i$ .

In general terms, if  $S_i$  and  $S(i + (n/6))$  are switched to the same element type ( $a$ ,  $b$  or  $c$ ) then phase shifter  $P_i$  is set to give zero phase change. In other cases the phase shifter  $P_i$  is set to give a  $\pi$  radian phase shift.

I claim:

1. An aerial and associated feeder system adapted to provide electronic scanning of space said system comprising an aerial system consisting of a plurality of aerial elements spaced along a circular arc, said elements being divided into sets and units each set consisting of the same plurality of adjacent equally spaced elements and each unit consisting of a plurality of different corresponding aerial elements, at least one in each set; and a power dividing feed system divided into unit feeder

arrangements each leading to the aerial elements of two different units through switch means whereby different predetermined combinations of aerial elements may be selected for connection to the unit feeder arrangement therefor to determine the general direction of radiation, there also being provided, in the path to at least one of the two units fed by each unit feeder arrangement, adjustable phase shifter means for adjusting said general direction of radiation and wherein each unit feeder arrangement includes a four port -3db coupler, the first of the two ports remote from the aerial units of each of the said couplers being connected to a first binary branching arrangement and the second of the two ports remote from the aerial units of each of said couplers being connected via adjustable phase shifter means to a second binary branching arrangement whereby in operation sum radiation pattern signals are obtainable by said first binary branching arrangement and difference radiation pattern signals are obtainable by said second binary branching arrangement.

2. A transmitting system in accordance with claim 1 wherein signals applied to the single path of the first binary branching arrangement are transmitted in accordance with a sum radiation pattern whilst signals applied to the single path of the second binary branching arrangement are transmitted in accordance with a dif-

ference radiation pattern.

3. A receiving system in accordance with claim 1 wherein sum radiation pattern signals appear on the single path of the first binary branching arrangement and difference radiation pattern signals appear on the single path of the second binary branching arrangement.

4. A system as claimed in claim 1 wherein each of the adjustable phase shifter means leading to said second binary branching arrangement is a two-bit phase shifter adapted to provide a phase delay of either zero or  $2\pi$  radians.

5. A system as claimed in claim 1 wherein said phase shifter means provide zero phase delay when corresponding elements in the units are selected and a phase delay of  $2\pi$  radians when elements which do not correspond in the units are selected.

6. A system as claimed in claim 1 wherein corresponding elements in adjacent sets are spaced arcuately by  $120^\circ$ .

7. A system as claimed in claim 1 wherein each unit feeder arrangement includes between said -3db coupler and the two units fed thereby, and prior to said phase shifter means provided to adjust said general direction of radiation, a hybrid unit whereby equal power is fed to each of the two units.

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