United States Patent [19]

Burnham

[11] **3,713,158**

[45] **Jan. 23, 1973**

[54] **DIGITAL FEED SYSTEM FOR ELECTRONIC ANTENNA ARRAY**

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[22] Filed: **April 26, 1971**

[21] Appl. No.: **137,320**

[52] **U.S. Cl.** .....**343/100 SA**, 343/854

[51] **Int. Cl.** **H01q 3/26**

[58] **Field of Search** .....343/100 SA, 854

[56] **References Cited**

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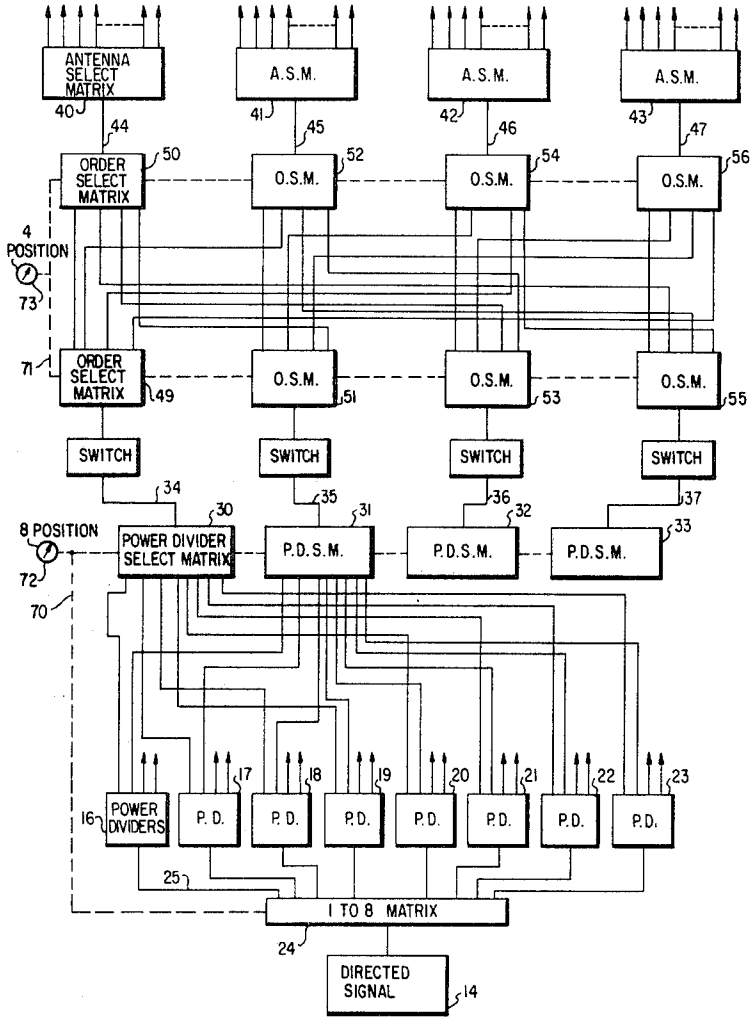
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[57] **ABSTRACT**

A scanning antenna array having plural antenna units and a digital feed system for reversibly energizing plural ones of said units in unison with groups of different fixed amplitude signals. The feed system includes fixed power dividers for generating (or receiving) the plural signals, and a multiple tier switching system for applying said different groups of signals to preselected groups of said units in a preselected or desired order.

5 Claims, 2 Drawing Figures



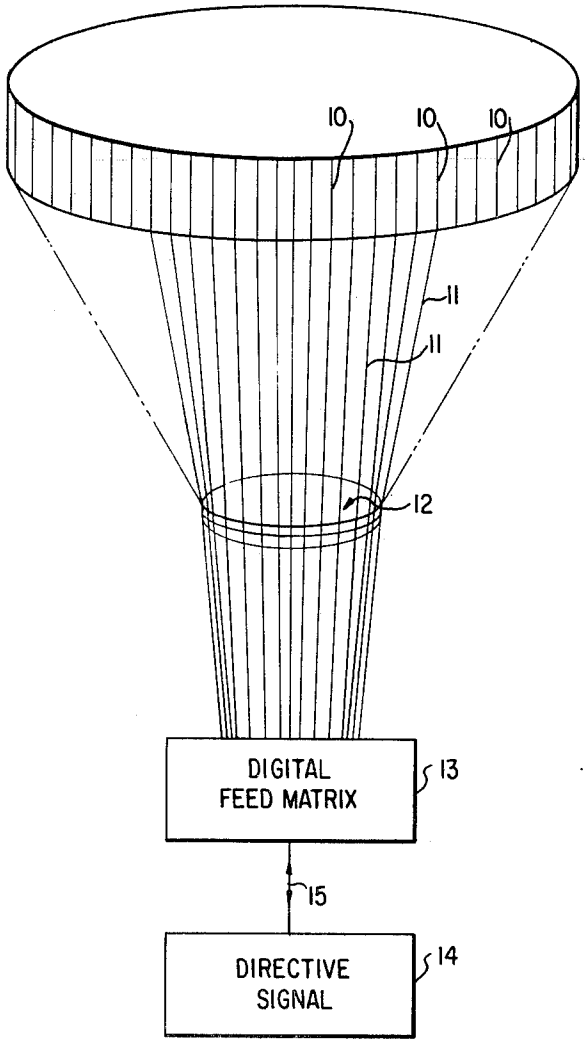


FIG. 1

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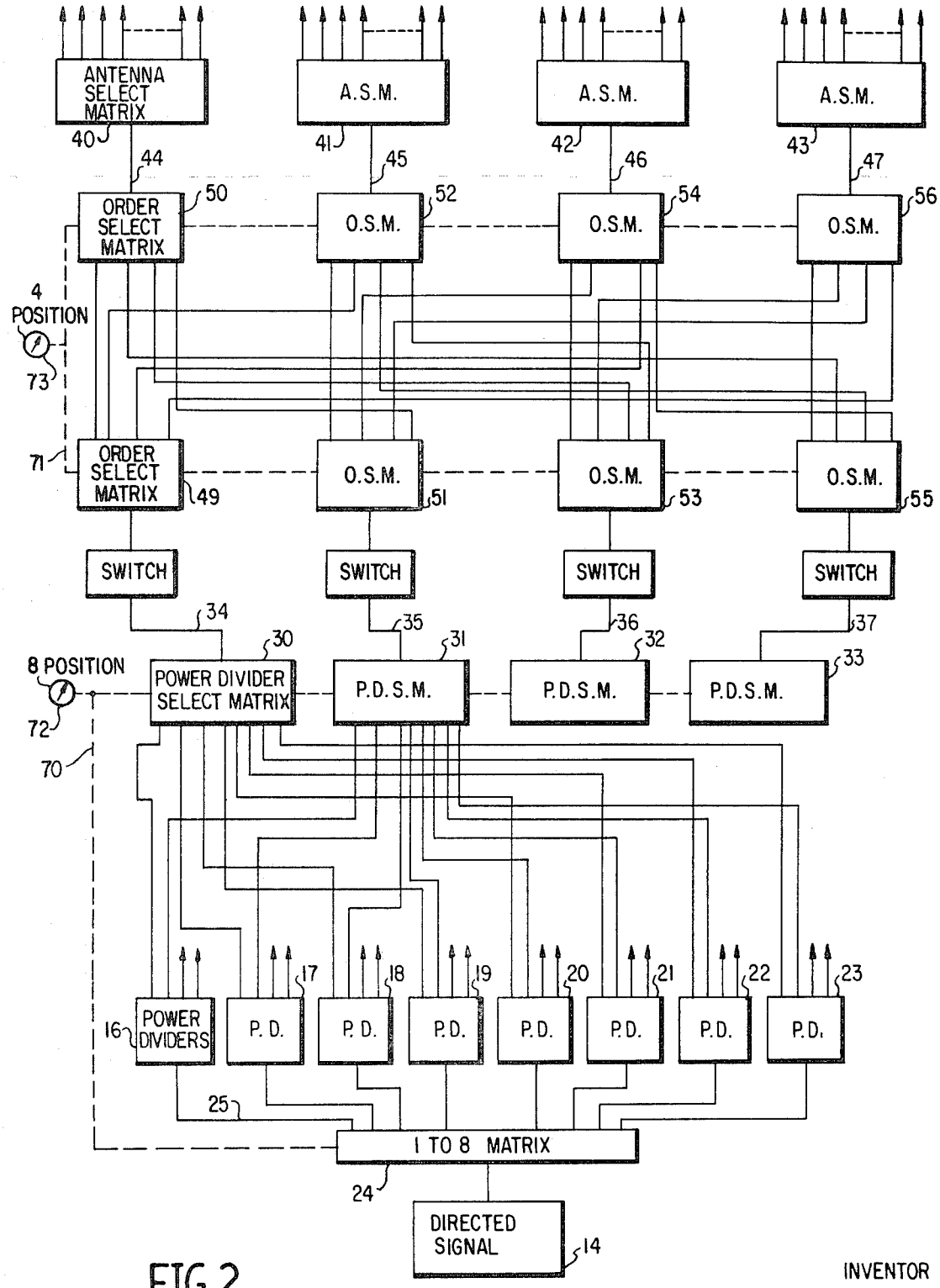


FIG. 2

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DIGITAL FEED SYSTEM FOR ELECTRONIC ANTENNA ARRAY

STATEMENT OF THE INVENTION

This invention relates to scannable antenna arrays systems and is particularly concerned with such systems having digitally switchable corporate feed systems for scanning the array in precise descrete narrow steps.

BACKGROUND AND SUMMARY OF THE INVENTION

In an earlier application of the same Assignee, filed on Dec. 28, 1970, Ser. No. 101,639, there is disclosed an electronically scannable antenna system employing an antenna array and lens wherein plural feeds or antenna units are energizable in unison with different amplitude signals to scan the beam in narrow spatial increments.

According to the present invention there is provided a digital feed system wherein a plurality of groups of different amplitude fixed signals are produced or resolved by means of a network of fixed power dividers, and a multiple tiered or cascaded network of switching matrices are employed to selectively apply each of the different groups of signals or codes in unison to preselected groups of the antenna units to scan the beam in fixed increment steps. By automatically actuating the multitiered switches in a preselected sequence the beam may be progressively displaced in equal spatial and timed steps along a given axis.

DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic view, in perspective, illustrating a preferred circular antenna array and digital feed system, and

FIG. 2 is a block diagram illustrating details of a preferred digital feed system according to the invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Referring to FIG. 1, the antenna array in a preferred embodiment is comprised of a series of antenna units **10** equally spaced apart from one another in a circular configuration to scan a full 360° region in space, as is disclosed in the earlier patent application above referred to. Each of the antenna elements **10** may itself comprise a vertical array of elements for producing a beam of given beam shape. Each of the units **10** is fed by a lead **11** or coaxial cable which, in turn, receives its signal after passage through a Luneberg or geodesic lens **12**. The function of lens **12** is to so adjust the phase of plural signals energizing the antenna units so that when plural ones of said antenna are energized in unison, the array produces a planar wavefront beam directed radially outwardly from different angular locations of the circular array.

The lens **12** is, in turn, energized by a plurality of signals derived from a digital feed matrix **13**. The lens **12** receives energization by a circular array of probes, corresponding in number and circular arrangement to the number and arrangement of antenna units **10** and the function of the feed matrix is produce the appropriate group of signals and apply these in unison to the appropriate group of probes on the lens **12** so as to circularly scan the beam in space. When the system functions as a transmitter, the feed matrix is energized by a transmitter source **14** and should the system function as a receiver, the feed matrix applies the directionally received signal to the receiver **14**.

FIG. **2** schematically illustrates a preferred digital feed matrix according to the invention for producing eight groups or codes of four different amplitude signals each, and selectively applying each of these groups of signals in unison to groups of four different probes on the lens (or four antenna units of the array).

In a preferred system the antenna array includes a total of **256** antenna units **10** disposed in the circular array of FIG. **1** and a like number and arrangement of probes on lens **12**.

It is desired to selectively energize these antenna units in groups of four antennas at a time; with each such group of four antennas being sequentially energized by a total of eight groups of signals. For example, initially the antenna units **1**, **2**, **3**, and **4** of the array are sequentially energized by the following groups of different amplitude signals:

	Antenna (1)	(2)	(3)	(4)
Group 1	.60	1.0	.60	00
Group 2	.50	.99	.67	.08
Group 3	.43	.97	.76	.10
Group 4	.34	.93	.82	.18
Group 5	.26	.88	.88	.22
Group 6	.18	.82	.93	.34
Group 7	.10	.76	.97	.43
Group 8	.08	.67	.99	.50

Following the energization of antenna units **1**, **2**, **3**, **4** above, by these groups of different amplitude signals, the next sequence of four antenna units of the array, numbers **2**, **3**, **4**, and **5**, are sequentially energized by the same groups of signals in the same order. Following this, the next following group of antenna units **3**, **4**, **5**, and **6** are sequentially energized in the same manner, and so forth.

As is disclosed in greater detail in the earlier application referred to, the sequential energization of each group of antennas by the different groups of fixed amplitude signals serves to incrementally displace the beam emitted by the array in descrete steps about a full 360° in space. In a preferred antenna system, the switching of one group of signals to the next group serves to incrementally displace the beam from the same antennas by an angle of 0.176°.

Thus from each group of four antennas of the array the beam is precisely displaced in eight angular steps of **0.176°** each, and then the next four adjoining antenna units are sequentially energized to displace the beam in the same manner from the next four antennas.

FIG. **2**, shows a preferred feed system **13** for performing these functions. As shown there is provided eight fixed power dividers **16** to **23**, inclusive, with each fixed power divider producing a different group or code of four different amplitude signals on each of four output lines, and having a single input line **25** for receiving or transmitting power to and from an adjustable position switch **24**. The adjustable eight position

switch 24 selectively applies energy to (or receives energy from) any one of the eight power dividers 16 to 23, inclusive; interconnecting that selected power divider with the directive signal receiver or power source 14.

For selecting any one of these eight groups or codes of signals, there is provided four lower tier switching matrices 30 to 33, inclusive with each having eight input lines and a single output line. As shown, the first left hand signal from power divider 16 is connected to an input line leading to the first lower tier matrix 30; the second signal from power divider 16 is connected to the second lower tier matrix 31; the third signal from divider 16 to the third matrix 32 and so forth. Similarly each of the other power dividers has its output lines connected to each matrix. All four of these lower tier matrices are ganged together for common operation with input matrix 24. Accordingly when these lower tier matrices are switched to their first position, the first fixed power divider unit 16 is selected and is interconnected by matrix 24 with the directive signal receiver or transmitter 14. Additionally the four descrete signal outputs of the first power divider 16 are selected by the four lower tier matrices and applied at the output lines 34, 35, 36, and 37 of the lower tier switching matrices. In a similar manner, in the second selected position of the lower tier switching matrices, the four discrete outputs of the second power divider 17 are selected and applied at the four outputs 34 to 37 of the lower tier switching matrices, and the input to power divider 17 is interconnected by matrix 24 to source 14.

As generally discussed above, in a preferred circular antenna array system of FIG. 1, there is provided a total of 256 antenna units 10. For selecting any four of such units at a time there is provided a series of four upper tier switching matrices 40, 41, 42, and 43. Each of the upper tier switching matrices has a single input line 44 to 47, inclusive, as shown, that is selectively connectable to any one of 64 output lines. The output lines of the first upper tier matrix 40 are each connected to every fourth lens probe or antenna unit, such as antennas 1, 5, 9, 13, 17, 21 and so forth; those of the second upper tier matrix 41 to the next series of every fourth antenna unit, such as antennas 2, 6, 10, 14, 18, and so forth; whereas those of the third and fourth upper tier units 42 and 43 are likewise each connected to a different series of every fourth antenna units. Accordingly by means of these four upper tier matrices 40 to 43 any desired group of four different antenna units may be selected from the 256 units of the array.

For example, presupposing all four upper switching units 40 to 43 are switched to select their first left hand output line, then antenna units 1, 2, 3, and 4 are each connected to the input lines 44, 45, 46, and 47, respectively. Should upper switching unit 40 then be actuated to its second position to select antenna unit 5, while not changing the previous selection of switching units 41, 42, and 43; then the antennas 5, 2, 3, and 4 are selected. In a similar manner by appropiately actuating each switching unit in succession, each succeeding group of four antennas may be selected as follows:

Antennas

(1st Position 40,41,42,43)	1 2 3 4
(Actuate Switch 40)	5 2 3 4
(Actuate Switch 41)	5 6 3 4
(Actuate Switch 42)	5 6 7 4
(Actuate Switch 43)	5 6 7 8

However, since the order or arrangement of the antenna units selected is varied by this mode of actuation of the upper switching units, and since it is desired to uniformly scan the antenna array in equal steps about a full 360° arc in space, a plurality of pairs of intermediate switching units 49 to 56, inclusive, are provided to interconnect the appropriate lower tier switches 30 to 33, inclusive, with the upper tier switches 40 to 43, inclusive.

As shown, each pair of intermediate switches, such as 49 and 50 comprise a pair of switch matrices having a single input line and four output lines that are selectively connectable to the input line. The single input lines of the lowermost of the pairs of intermediate switches 49, 51, 53, and 55 are each connected to the output line of a different one of the lower tier matrices 30 to 33, inclusive, and the single line of the uppermost intermediate tier switches 50, 52, 54, and 56 are each respectively connected to the inlet line of a different one of the upper tier matrices 40 to 43, respectively. The remaining four lines of each intermediate tier switch are so interconnected with each other switch matrix of the pairs as to change the order of the four antennas selected by the upper tier switches. Thus when the upper tier matrices select antenna units 5, 2, 3, and 4 (in that order) as described above, the intermediate tier switches may change this order of energized antenna units to 2, 3, 4, and 5 so that each of the groups or codes of signals produced by the power dividers 16 to 23 can be successively applied to each succeeding four antenna units in a uniform order as follows:

Antenna Units	1 2 3 4
Antenna Units	2 3 4 5
Antenna Units	3 4 5 6
Antenna Units	4 5 6 7
Antenna Units	5 6 7 8
Antenna Units	etc.

It will be noted that all of the intermediate tier switches 49 to 56, inclusive, are ganged together for common actuation to four different switching positions, as indicated by the dotted line 71. In the first switching position of the intermediate tier matrices the outputs of each of the four lower tier matrices 30 to 33 are connected to the input of that upper tier matrix that is directly above. For example, lower tier matrix 30 is connected to upper tier matrix 40; lower 31 to upper 41; lower 32 to upper 42; and lower 33 to upper 43. In the second position of intermediate tier switchs the output of matrix 30 is switched to the input of upper 41; lower 31 to upper 42; lower 32 to upper 43; and lower 33 to upper 40. In this manner when upper tier matrices select the antenna units in the order of 5, 2, 3, and 4, for example, the intermediate tier switches are actuated to their second position to energize these selected antennas in the desired correct order of antennas units 2, 3, 4, and 5. Similarly, when the upper tier matrices select the next group of antennas in the order 5, 6, 3, and 4, the intermediate tier switches are actuated to their third position to rearrange and energize the selected antennas in the desired order of units 3, 4, 5, and 6.

Consequently by means of the upper tier matrices and the intermediate tier switches, each succeeding group of four antennas, out of the entire array of 256 antennas, may be selected in a desired regular succeeding order; and by switching the lower tier matrices each of these regularly selected groups of antennas may be successively energized in sequence by eight groups of fixed amplitude voltages to progressively scan the antenna beam in precise accurate steps.

Many variations may be made by those skilled in this art and this invention is accordingly to be considered as limited only by the following claims.

What is claimed is:

1. A digital switching system for scanning antenna arrays comprising:

a plurality of fixed power dividers arranged in given order, each having plural output lines interconnected in differing preset power division ratio to a common input,

a plurality of lower tier switching means for simultaneously selecting the plural outputs of any of the fixed power dividers and applying the selected outputs to a like number of lower tier terminals in the same order,

a plurality of upper tier switching matrices, equal in number to the lower tier matrices, for selectively connecting plural antenna elements of an array to a like number of upper terminals,

each upper tier switching matrices having a plurality of outputs connected to different antenna elements than other matrices, and a common input selectively connectable to any one of the outputs,

the adjoining outputs of each upper tier matrix being connected to nonadjoining antenna elements of the array in arithmetical progression, with each upper tier matrix staggered in order of connection with a preceeding upper tier matrix,

and a plurality of intermediate tier matrices, equal in number to the upper tier matrices, for interconnecting the lower tier terminals and upper tier terminals and selectively interconnecting each lower terminal to any one of the upper terminals, thereby to interconnect the antenna elements of any selected group with the lower terminals in a desired order.

2. In the switching system of claim 1, at least two power dividers each having at least two outputs, at least two lower tier matrices, at least two upper tier matrices and at least two intermediate tier matrices; said antenna array having at least three elements and said multiple tier matrices being actuable to sequentially interconnect the two outputs of each power divider to each adjoining pair of antenna elements in regular order.

3. In the switching system of claim 1, eight power dividers, each having four outputs, four lower tier matrices, four upper tier matrices, and said antenna array having 256 elements.

4. In the switching system of claim 1, said lower tier switching matrices being interconnected for operation in unison and said intermediate tier matrices being interconnected for operation in unison.

5. A digital feed system for interconnecting groups of antenna elements of an array in unison successively with plural groups of power dividers comprising:

a plurality of power dividers each having plural output lines providing different ratios of power division,

switching means for selectively interconnecting to the output lines of any divider,

and antenna element selecting switches for selecting any group of a plurality of adjoining elements and applying these to the plural output lines of the selected power divider in regular order.

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