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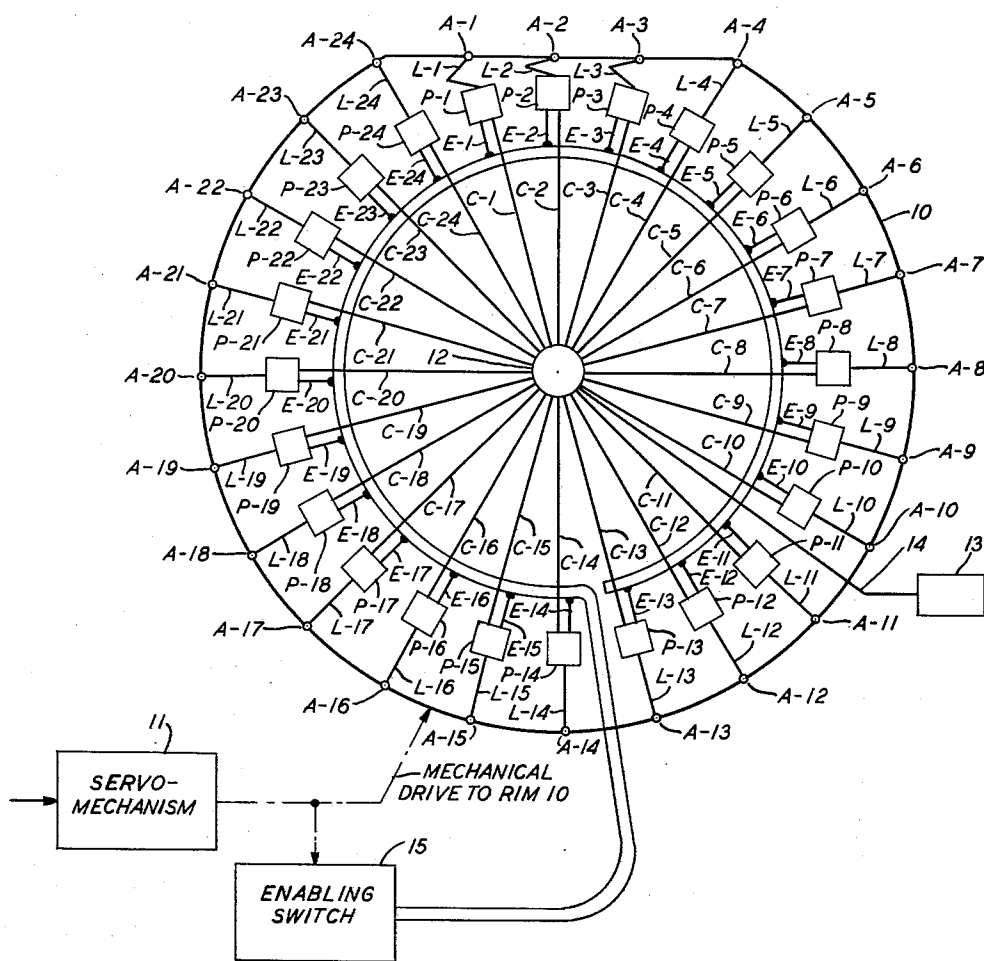
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MULTIPLE UNIT ANTENNA SYSTEM

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FIG. 1



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FIG. 2A

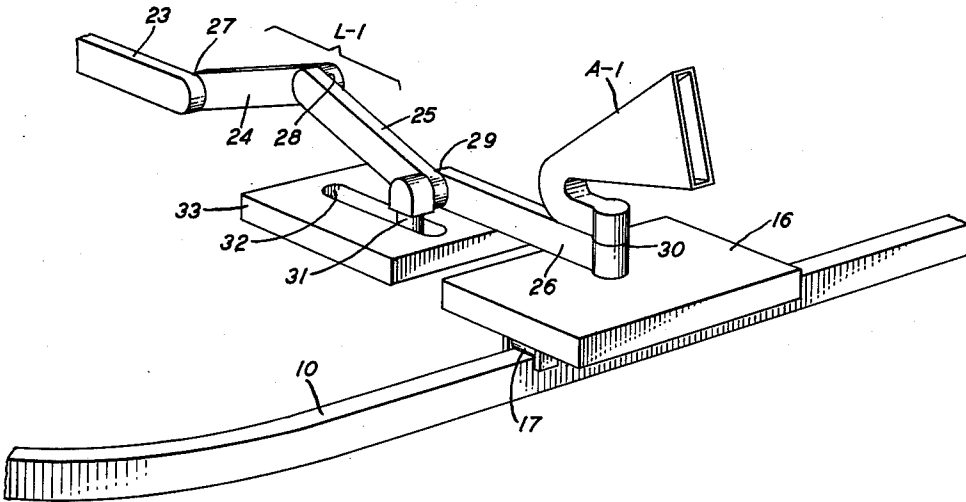
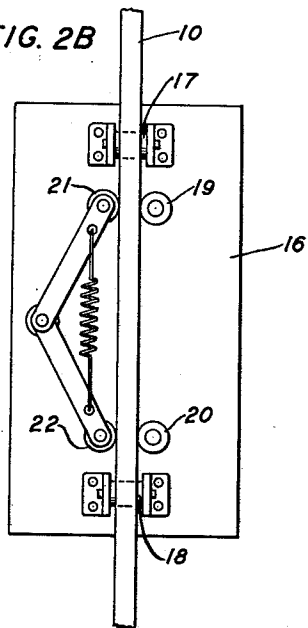


FIG. 2B



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MULTIPLE UNIT ANTENNA SYSTEM

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9 Claims. (Cl. 343-100)

This invention relates to multiple unit antenna systems and in particular to such systems having steerable beams.

Inasmuch as the main lobe of an antenna sensitivity pattern is often referred to as a beam this term is used in the same sense in this specification. Furthermore, as used herein a pencil beam is a narrow beam having a substantially symmetrical cross section while a fan beam is narrow in one plane passing through the axis of the beam and wide (with relatively high gain throughout this width) in a second plane passing through the same axis and substantially perpendicular to the first plane.

Various prior art arrangements use pluralities of antennas in concert for either transmitting or receiving purposes. Such arrangements are of great value when transmitting large amounts of power or receiving weak signals as more than one antenna contributes to the composite result.

In several prior art plural antenna arrangements, non-directional antennas are arranged in a circle with their currents controlled in phase with respect to one another to produce a composite beam that is steerable in an azimuthal sense. This beam is relatively narrow in its azimuthal plane and relatively wide in its elevational plane. Because the antennas are not in a linear array, however, the energies received or transmitted by the antennas do not have the same phase inter-relationships for all directions in the elevational plane of the beam. This results in the gain in this plane decreasing too rapidly to either side of its maximum value for the beam to be considered a good fan beam but not sufficiently rapid for the beam to be considered a good pencil beam.

By replacing the nondirectional antennas in the above described arrangement with directional units, the composite beam is not only made steerable in an elevational sense but the beam width in the elevational plane is reduced. The beam, however, still does not have either a good fan or pencil beam shape for the same reasons presented above with respect to the nondirectional arrangement.

An object of the present invention is to produce, when using a plurality of antennas in concert, a steerable beam which is considered to be a good fan beam.

Another object of the present invention is to produce, when using a plurality of antennas in concert, a steerable beam which is considered to be a good pencil beam.

These and other objects are achieved in accordance with the present invention by producing what in effect comprises a rotatable linear array that has substantially the same phase inter-relationships between all of the energies received or transmitted in the elevational plane of the composite beam of the array.

The present invention in one of its broader aspects comprises a plurality of antennas nominally located at substantially equal angular intervals on the circumference of a circle and adapted to move in a radial sense so that all of the antennas in any group of at least three consecutive antennas may be moved into substantially linear alignment. Furthermore, flexible transmission paths of substantially equal electrical lengths connect the antennas to the receiving or transmitting apparatus while control circuits enable only those antennas in linear alignment. Because the active antennas are in a linear alignment and their transmission paths are of equal electrical lengths, the energies received or transmitted by the antennas have

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substantially the same phase inter-relationships for all directions in the elevational plane of the composite beam. As a result of these phase inter-relationships, embodiments of the present invention produce well defined fan beams when using nondirectional or directional antennas while well defined pencil beams are produced by further increasing the directivity of the antennas.

Whereas the above described prior art arrangements require variable phase shifting devices for azimuthal beam steering, a feature of the present invention is that beam steering is accomplished by maintaining substantially equal the electrical lengths of the antenna lead lines while moving one or more of the antennas in a radial direction. In particular, in accordance with the present invention the composite beam is steerable in an azimuthal sense by moving successive antennas into and out of linear alignment with their neighbors to produce, in effect, a rotating linear array in which each antenna is fed by a constant electrical length transmission path.

In one embodiment of the invention a plurality of non-directional antennas are located at substantially equal angular intervals on a rim. The rim is circular with the exception of a straight section which subtends an angle at least equal to three times the angular interval between the antennas. At least three successive antennas are therefore located on the straight section of the rim. The rim is rotated with respect to the antennas by a servomechanism. When the rim is rotated successive antennas move into and out of linear alignment with their neighbors. Flexible transmission lines of substantially equal electrical lengths connect the antennas to a plurality of normally disabled amplifiers, respectively. The amplifiers are in turn connected to a branching network of transmitter or receiver apparatus. An enabling switch synchronized with the servomechanism enables the amplifiers associated with three of the antennas located on the straight section of the rim. A continuously rotating linear array is in effect produced by applying a continuously changing input to the servomechanism. As appreciated by those skilled in the art, the beam may also be made to sweep back and forth through a given azimuthal angle by appropriate inputs to the servomechanism.

In another embodiment of the invention a plurality of directional antennas are arranged in a manner identical to the above described embodiment using nondirectional antennas. Because the antennas are directional, mechanical apparatus is provided to rotate the antennas so that the individual beam axes of the linearly aligned antennas are perpendicular to the direction of alignment. This produces a more desirable composite beam configuration. When it is desired to steer the beam in elevation as well as in azimuth, additional mechanical apparatus is provided to rotate the antennas in an elevational sense.

Other objects and features of the invention will become apparent from a study of the following detailed description of several embodiments of the invention.

In the drawings:

FIG. 1 shows schematically an embodiment of the invention in one of its more general forms; and

FIGS. 2A and 2B show a mechanical arrangement that may be employed when practicing the invention with directional antennas.

The embodiment of the invention shown schematically in FIG. 1 comprises a plurality of antennas A-1 through A-24 located at substantially equal angular intervals on a rim 10. Rim 10 is circular with the exception of a straight section shown at the top of the diagram. This straight section subtends an angle at least equal to three times the angular interval between the antennas so that at least three successive antennas are in linear alignment. As shown in FIG. 1, antennas A-1, A-2 and A-3 are in linear alignment. Rim 10 may be rotated with respect

to antennas A-1 through A-24 by a servomechanism 10 in response to an input signal. As the rim is rotated with respect to the antennas, successive antennas move into and out of alignment with their neighbors to produce in effect a rotating linear array.

Antenna A-1 is connected by flexible transmission line L-1 to a normally disabled amplifier P-1. The remaining antennas are similarly connected by flexible transmission lines L-2 through L-24 to normally disabled amplifiers P-2 through P-24, respectively. Flexible transmission lines L-1 through L-24 are of substantially equal electrical lengths. Amplifiers P-1 through P-24 are connected to a branching network 12 by transmission lines C-1 through C-24, respectively. Transmission lines C-1 through C-24 are also of substantially equal electrical lengths. Network 12 is in turn connected to either a receiver or a transmitter 13 by a transmission line 14.

When the embodiment of FIG. 1 is used for transmitting purposes amplifiers P-1 through P-24 provide gain in a direction toward antennas A-1 through A-24 whereas when the embodiment is used for receiving purposes the amplifiers provide gain in a direction toward network 12.

The enabling inputs of amplifiers P-1 through P-24 are connected to an enabling switch 15 by enabling leads E-1 through E-24, respectively. Switch 15 is synchronized with servomechanism 11 so that the amplifiers associated with three successive antennas located on the straight portion of rim 10 are enabled. Because the transmission paths between antennas A-1 through A-24 and network 12 are of substantially equal electrical lengths and antennas associated with the enabled amplifiers are in line, the energies received or transmitted by the activated antennas have substantially the same phase interrelationships for all directions in the elevational plane of the composite beam. As a result of these phase interrelationships, the embodiment of FIG. 1 produces a well defined fan beam when using nondirectional or directional antennas and a well defined pencil beam when using directional antennas having still higher degrees of directivity.

As shown in the schematic arrangement of FIG. 1 antennas A-1, A-2 and A-3 are in linear alignment and amplifiers P-1, P-2 and P-3 are enabled. As rim 10 is rotated in a clockwise direction, the linear array comprising antennas A-1, A-2 and A-3 is rotated until antenna A-4 comes into line and antenna A-1 drops out of line. At this time, amplifier P-1 is disabled while amplifier P-4 is enabled, thus producing a new linear array. As subsequent antennas fall into line and become energized while others fall out of line and become de-energized, a rotating linear array is in effect produced. Rim 10 may also be rotated in a counterclockwise direction to produce in effect a counterclockwise rotating linear array. Furthermore by alternately rotating rim 10 in clockwise and counterclockwise directions, a sector may be repetitively scanned.

When directional antennas are used in practicing the invention, it may be desirable in order to produce a better defined beam to rotate the linearly aligned antennas in an azimuthal sense so that the center lines of their individual beams are perpendicular to the direction of alignment. FIGS. 2A and 2B show a mechanical arrangement that may be used with each of the antennas to perform this function. As shown in FIG. 2A, antenna A-1 is mounted on a carriage 16 which in turn is mounted on rim 10. The underside of carriage 16 is shown in greater detail in FIG. 2B. Carriage 16 includes a first pair of fixed rollers 17 and 18 which ride on top of rim 10 and a second pair of fixed rollers 19 and 20 which ride against the outer surface of rim 10. A pair of spring loaded rollers 21 and 22 ride against the inner surface of rim 10 and assure that rollers 19 and 20 are in contact with the outer surface of the rim. Antenna A-1 is mounted on carriage 16 so that the elevational plane of its beam

is perpendicular to the line passing through the centers of rollers 19 and 20. This plane is, therefore, always perpendicular to the direction of alignment when carriage 16 lies on the straight portion of rim 10.

As shown in FIG. 2A, flexible transmission line L-1 comprises waveguide sections 23, 24, 25 and 26 which are joined in that order by rotary joints 27, 28 and 29. Waveguide section 26 is connected to antenna A-1 by a rotary joint 30. A projection 31 on rotary joint 29 extends into a guide slot 32 in a plate 33. Waveguide section 23 and slot 32 are in radial alignment. As antenna A-1 is moved inwardly and outwardly in a radial sense by the rotation of rim 10, flexible transmission line L-1 folds and unfolds, respectively, but the electrical length of this line remains substantially constant.

Although not shown in FIG. 2A, conventional mechanical means may be provided for controlling in an elevational sense the directivity of antenna A-1.

The arrangement shown in FIG. 2A may also be used when practicing the invention with nondirectional antennas. When using nondirectional antennas, this arrangement may be simplified. In particular, the antennas need not be fixed in an azimuthal sense on their carriages and therefore rotatable joint 30 may be eliminated from each arrangement.

Although only one specific embodiment of the invention has been described in detail, it is to be understood that various other embodiments may be devised by those skilled in the art without departing from the spirit and scope of the invention. When, for example, only a given sector is to be scanned, it is only necessary to provide antennas on that portion of the circle that resides in the sector to be scanned. In addition, more than one beam may be produced. In the embodiment of FIG. 1, for example, rim 10 may have more than one straight portion with switch 15 also enabling antennas located on the additional straight portions so that several linear arrays are produced. Furthermore, various other mechanical arrangements may be devised to move the antennas in a radial sense.

What is claimed is:

1. In combination a plurality of antennas nominally located on the circumference of a circle at substantially equal angular intervals, means for radially moving said antennas to linearly align at least one of any group of at least three consecutive antennas, a branching network, transmission paths of substantially equal electrical lengths connecting said antennas to said network, at least a part of each of said transmission paths being flexible, and means for disabling all of said transmission paths except for a predetermined number associated with said antennas in linear alignment.

2. A combination in accordance with claim 1 in which said antennas are directional in nature and means to rotate said antennas are provided to cause the axes of the individual beams of the antennas in linear alignment to be substantially perpendicular to the direction of alignment.

3. A combination in accordance with claim 2 and means for controlling said antennas in elevation.

4. In combination a plurality of antennas nominally located on the circumference of a circle at substantially equal angular intervals, means for radially moving said antennas to linearly align at least one of any group of at least three consecutive antennas, a branching network, a plurality of flexible transmission paths, means connecting one extremity of each of said paths to said antennas, respectively, a plurality of gating means respectively connecting the other extremities of said paths to said network, the electrical path lengths between said antennas and said network being substantially equal to one another, and means for enabling only a predetermined number of said gating means associated with said antennas in linear alignment.

5. A combination in accordance with claim 4 in which said antennas are directional in nature and means to

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rotate said antennas are provided to cause the axes of the individual beams of the antennas in linear alignment to be substantially perpendicular to the direction of alignment.

6. A combination in accordance with claim 5 and means for controlling said antenna in elevation.

7. A combination comprising a circular rim having at least one straight portion, a plurality of carriages mounted on said rim at substantially equal angular intervals, a plurality of antennas mounted respectively on said carriages, a branching network, a plurality of flexible transmission paths, means connecting one extremity of each of said paths to said antennas, respectively, a plurality of gating means respectively connecting the remaining extremities of said paths to said network, the electrical path lengths between said antennas and said network being substantially equal to one another, means for rotating said rim with respect to said carriages, and means for enabling

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only a predetermined number of said gating means associated with said antennas located on said straight portion of said rim.

8. A combination in accordance with claim 7 in which said antennas are directional in nature and means to rotate said antennas are provided to cause the axes of the individual beams of the antennas on said straight portion of said rim to be substantially perpendicular to said straight portion.

9. A combination in accordance with claim 8 and means for controlling said antennas in elevation.

References Cited in the file of this patent

UNITED STATES PATENTS

2,432,134	Bagnall	Dec. 9, 1947
2,466,354	Bagnall	Apr. 5, 1949