AMPLITUDE SCANNING OF AN ANTENNA ARRAY ON RECEIVING

Original Filed Sept. 3, 1958
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(Granted under Title 35, U.S. Code (1952), sec. 266)

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

The invention relates generally to scanning antenna systems, and more particularly to a novel method and means for scanning an antenna beam on receiving to generate many beams (multilobes) at many ports or terminals.

This application is a division of applicant's co-pending application, Serial No. 758,869, filed September 3, 1958, now U.S. Patent No. 3,085,204, entitled "Amplitude Scanning."

Prior devices have utilized cumbersome mechanical means to produce a rotation of the entire physical structure of an antenna in order to scan an antenna beam. Devices of this nature, in addition to being bulky, are expensive and limited in the rapidity of the scanning operation.

Electronic scanning antenna systems have been proposed wherein a variation of either the frequency or the phase of the energy along an array is utilized to produce a beam movement; however, either a change in antenna dimensions or complicated, expensive devices are necessary for an accurate control of a beam of radiated energy.

The method and means forming this invention for electronic scanning may be effected by various means which easily and accurately change only the amplitude to elements of an array. This can be accomplished by controlling a voltage applied to grids of amplifiers which feed separate radiating elements in an array or by utilizing low powered transmitting sources on each radiating element and amplitude modulating these sources.

Amplitude scanning also may utilize simple mechanical movement of antenna elements for varying the coupling and thereby the amplitude to the various elements.

Accordingly, it is an object of this invention to produce novel methods and means for scanning a signal receiving array by utilizing a variable gain radio frequency amplifier at each element of the array and combining the output of these amplifiers to produce a steerable directive receiving system or multiple beams from many receivers.

Other advantages, features and objects of the invention will become more apparent from the following description taken in connection with the accompanying drawing which is a partially schematic representation of an application of the amplitude scanning technique to an antenna array used for receiving a signal to produce multiple beams.

The mathematical approach to amplitude scanning is based on my copending application No. 615,208, filed November 10, 1956, now U.S. Patent No. 3,100,300, entitled Antenna Array Synthesis Method and Apparatus, wherein it is shown that quarter wave spaced radiators with alternate elements in phase quadrature may be used to synthesize any antenna pattern. An extension of the principles taught in that application would allow for the creation of a sharp antenna pattern wherein the pattern may be made to assume various angular positions by varying the amplitude of the feeding coefficients in accordance with the following analysis and theory.

In accordance with the theory presented in my aforementioned copending application, the shape of a beam to be generated may be idealized and generated at a given angle, \( \alpha_0 \), with the normal to an array and determine the coefficients \( C_a \) and \( B_a \).

In accordance with the technique of the above theory, a system is developed that approaches a uniformly illuminated array, wherein

\[
\frac{2}{\lambda d} = i = 1
\]

where \( d \) is the element spacing.

The mathematical terminology, being an extension of the principles of application Serial No. 615,208, follows the use of the specific terms given in said application.

A desired pattern is obtained by constructing an even function \( f_a, \psi (\alpha) = f_a (\psi) \) and adding to it an odd function \( f_o, \psi (\alpha) = f_o (\psi) \). The resulting pattern will then be a superposition of the two amplitude functions.

\[
\psi = \sin \alpha \text{ where } \alpha \text{ is measured from the normal to the array axis.}
\]

The desired pattern is then obtained by adding the two functions

\[
f_2 (\phi, \psi) = f_a (\phi, \psi) + f_o (\phi, \psi)
\]

where \( m \) is equal to \( n+1 \). The displacement of the main beam from the perpendicular to the array is given by \( \alpha_0 \) (note that \( \psi = \sin \alpha \) and \( \psi = \sin \alpha \)). The feeding coefficients for the array are given by the cos \( m \psi \) terms and sin \( m \psi \) terms. The desired fixed phasing on the array can be obtained by comparing the feeding coefficients of \( f (\phi, \psi) \) with the resolution of the radiated pattern in terms of phase on a transmission line as given in the aforementioned copending application. The spacing between adjacent elements is \( \lambda/4 \).

Mechanical movement of antenna elements to achieve a variation in coupling, which in turn produces a variation in amplitude to the various elements, and the utilization of angular positioning of an element on a two-wire line to achieve a predetermined coupling, is taught in my copending application, S. No. 613,011, filed October 1, 1956, now U.S. Patent No. 2,963,730, entitled Method and Means for Antenna Coupling. An extension of this theory involves the rotation of these elements to vary the coupling and therefore the amplitude of the signal to each dipole to cause the scanning of an antenna beam.

The drawing illustrates the scanning of an array, on receiving, using amplitude scanning techniques. Signals are received on the \( \lambda/4 \) spaced antenna elements. The line lengths are alternately changed at \( \lambda/4 \) values to create a 90° phase shift between the elements. These received signals are then fed to amplifiers to raise the signal above the noise level while at the same time maintaining the phase of the signal at the amplifier input. The power is then divided, in this example, to two pairs of three variable gain amplifiers 41 or attenuators, one set of which has the signal inverted 180° in a phase invert 42. The first, second and third of each pair go to separate addition buses 43, 44 and 45, respectively, and a summation of the signals from each element are combined on the buses to give three beams. The buss or sum lines, 43, 44, and 45, are assumed to sum signals.
without phase shift. This is practical, using superheterodyning techniques common to receivers. Note that the number of beams formed this way need not correspond to the number of radiating elements in the receiving array. The gain of amplifiers plus attenuator will be adjusted for each beam according to formula (column 2). A comparison of these beams may be used, for example, to determine the location of a communication or radar signal source. An application of amplitude scan on receiving, accomplished by using a variable-gain radio frequency amplifier at each element of the array and combining the output of these amplifiers, can be used to produce a steerable directive receiving system or multiple beams from many receivers.

Thus, it can be seen that amplitude scanning can be utilized for any antenna array having equispaced elements in phase quadrature. Different spacings between the elements would vary the pattern throughout the scan. Slight variations in phase as the amplitude is varied may be tolerated; however, an appreciable variation would cause a deterioration of the pattern as the beam is scanned.

Although the invention has been described with reference to particular embodiments, it will be understood to those skilled in the art that the invention is capable of a variety of alternative embodiments within the spirit and scope of the appended claim.

I claim:

A means for amplitude scanning a received signal comprising an array of antenna elements having a 90° phase shift between adjacent elements, means for dividing the received signal of each of said elements between at least two channels, means for phase inverting one of said divided signals 180°, variable gain amplifier means adapted to receive divided power from the signals of each of said channels and means for summing the resultant signals on each power level.

References Cited by the Examiner

UNITED STATES PATENTS

3,056,961 10/62 Mitchell ------------------ 333-100
3,085,204 4/63 Sletten ------------------ 343-854
3,087,158 4/63 Fisch --------------------- 333-100

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