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BEAM SWITCHING AND STEERING OF SPIRAL-MODE MICROSTRIP ANTENNAS

Johnson J. H. Wang, Glenn D. Hopkins and Victor K. Tripp
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia USA

Introduction The use of spiral-modes for beam switching and steering has been known for over three decades, beginning with the patent by Wheeler [1] to the recent book by Corzine and Mosko [2]. However, the spiral antennas have been of the cavity-loaded type, which are bulky and lose one-half of their power in the dissipative cavity. As a result, the cavity-loaded spirals are not suitable for many applications, such as wideband mobile/personal systems. Recently, the spiral-mode microstrip antenna [3] was developed, which offers multioctave bandwidths of the cavity-loaded spiral antenna and the low profile and conformability of the microstrip patch antenna. However, previous reports have been for single mode-1 operation, this paper presents the multimode operation of the spiral-mode microstrip antenna, in particular the potential for steering and switching of antenna beam by selecting or combining modes, or both.

The Multimode Spiral-Mode Microstrip Antennas Figure 1 shows an Archimedian spiral spaced 1/4-inch above a ground plane of 18-inch diameter. The four center terminals of the spiral arms are fed by a network, shown in the same figure, to generate mode 1 and mode 2. The bandwidth of the antenna itself can be as wide as 900%. The bandwidth of the feed network can also be as wide; however, in practice a network with a narrower, but sufficient, bandwidth is often chosen based on other considerations such as cost and physical size. In our prototype a network of 2:1 bandwidth was employed for operation in the 1-2 GHz range.

As is well known, the radiation of planar spiral antennas takes place on circular concentric rings; mode-1 radiates on a ring with a circumference of about one wavelength, and mode-2 radiates on a ring with a circumference of about two wavelengths, and so on. One can switch between mode-1 and mode-2 to change the radiation pattern from an apple-shaped (unidirectional) mode-1 pattern to a doughnut-shaped (omnidirectional) mode-2 pattern . Two or more modes can be combined with proper amplitude and phase relationship to have the antenna beam steered to a certain direction either on a real-time basis or as pre-selected. These will be demonstrated by the computed and measured patterns in the following.

Computed Radiation Patterns Figure 2 illustrates computed 3-dimensional radiation patterns showing the amplitudes and phases versus two spatial angles for mode-1 (unidirectional) and mode-2 (omnidirectional). It also shows a similar 3-D amplitude pattern for a combination of these two modes, which has a directional beam that can be steered around over azimuth and elevation angles.

Measured Radiation Patterns Figure 3 shows measured radiation patterns in polar plots over elevation angles in (a) and (b) and over azimuth angles in (c) and (d). (Ground plane is parallel to the earth.) The linearly-polarized patterns in (a) and (b) show mode 1 (apple shaped) and mode 2 (with a null in the center) and the combined mode 1 and mode 2 (in solid line and skewed to one side in (a) and the other side in (b)). (c) and (d) are rotating-linear azimuthal patterns (conical cuts) at a fixed elevation angle near the peak of the patterns for the combined modes for two different phase settings; as shown, the peak of the pattern is rotated by about 130° by the phase steering.

The Compact Multimode Spiral-Mode Microstrip Antennas The multimode spiral-mode microstrip antennas as described above have diameters of about 8 inches at 1 GHz (two-wavelengths circumference) and 16 inches at 500 Mhz. In many mobile/personal radio systems, these dimensions are too large for hand-held units, and are marginal for briefcase units. The compact units employ the array concept which reduces the diameter of the antenna to as small as one-third (1/3) of the regular size; this is accomplished at the sacrifice of bandwidth or efficiency, or both.

Applications Applications for multimode spiral-mode microstrip antennas are many; immediate ones include hand-held, briefcase-mounted, and vehicular-based mobile radio communication systems. The beam switching and steering capability allows aiming at different directions, overcoming multipath problems, and noise and interference rejection.

References

1. M. S. Wheeler, "Spiral Antenna Apparatus for Electronic Scanning and Beam Position Control", U.S. patent No. 2,990,548, dated June 27, 1961, filed Feb. 26, 1959.
2. R. G. Corzine and J. A. Mosko, *Four-Arm Spiral Antennas*, Artech House, Norwood, MA, 1990.
3. J. J. H. Wang and V. K. Tripp, "Design of Multioctave Spiral-Mode Microstrip Antenna," *IEEE Trans. Ant. Prop.*, Vol. 39, March 1991; also patents pending.

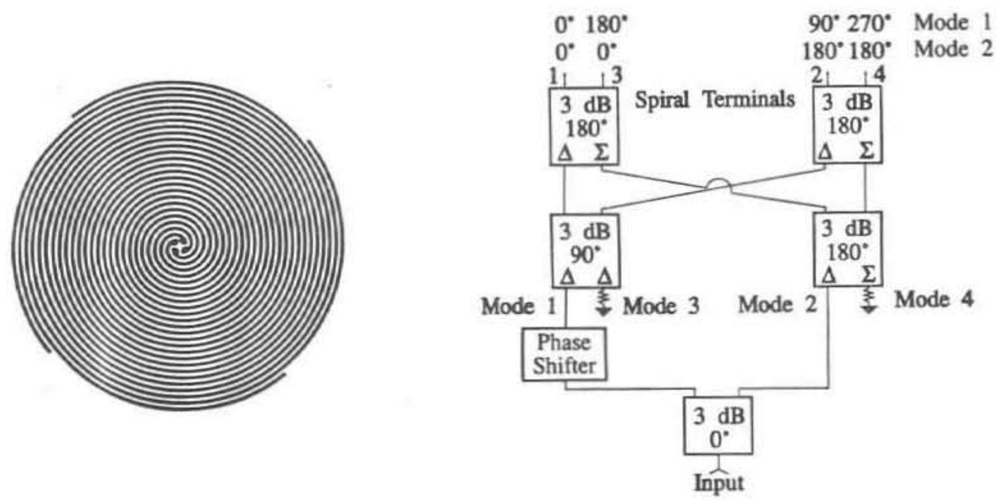


Fig. 1 A dual-mode spiral-mode microstrip antenna and its feed network.

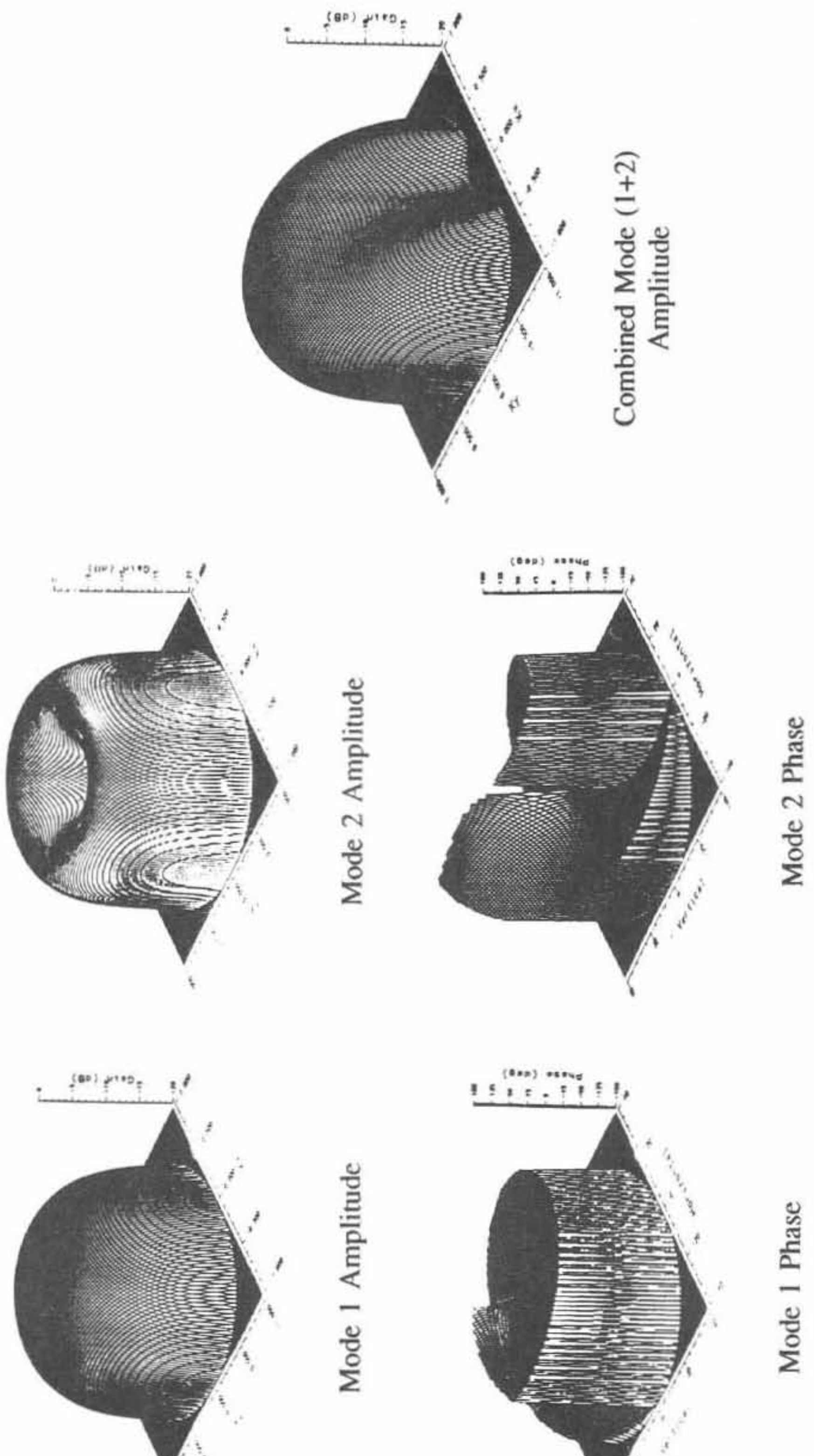
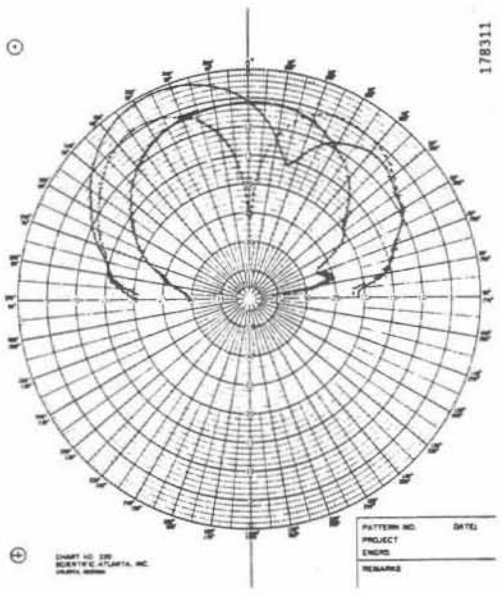
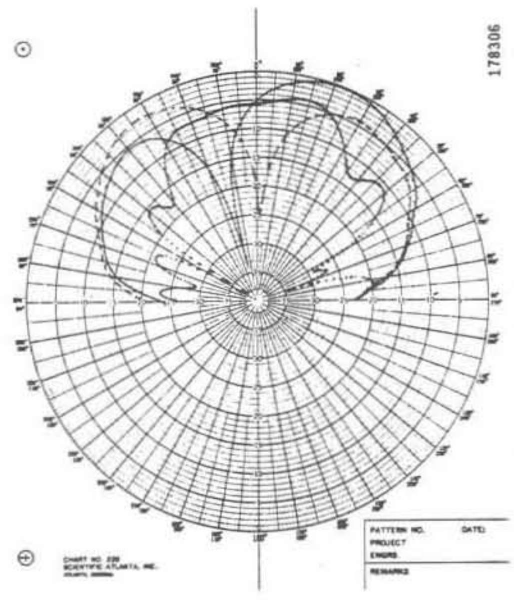


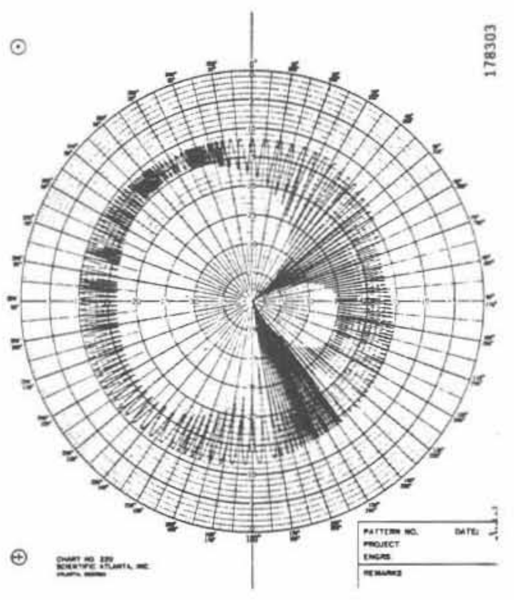
Fig.2 Computed radiation patterns for mode-1, mode-2, and their combination.



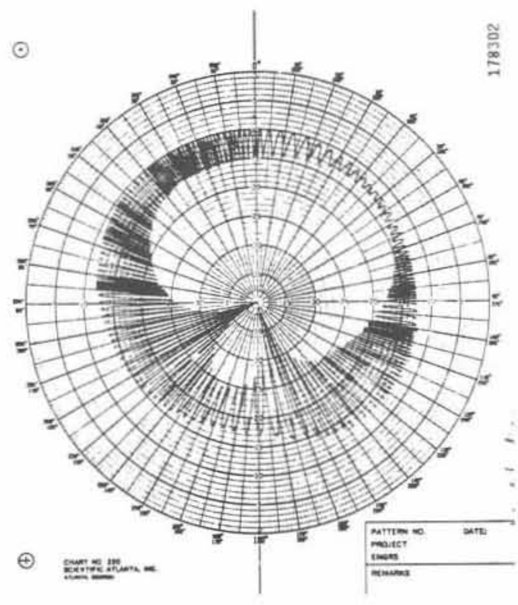
(a) Elevation patterns for model, mode 2, and combined mode 1 and mode 2 (solid) at a certain phase setting



(b) Elevation patterns for case (a) with its combined mode 1 and mode 2 (solid) beam steered by a new phase setting



(c) Azimuthal pattern of combined mode 1 and mode 2 at a certain phase setting



(d) Azimuthal pattern of case (c) with its beam steered by a new phase setting

Fig. 3 Measured radiation patterns showing multimodes and beam steering.