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MULTIFUNCTION CIRCULARLY-POLARIZED BASE-STATION SMM ARRAY ANTENNA

J. J. H. Wang, J. K. Tillery, M. A. Acree, and K. E. Bohannan
Wang Electro-Opto Corporation
1335 Capital Circle
Marietta, Georgia 30067 USA

I. Introduction

With the advent of the wireless revolution, communication systems such as cellular phones, Personal Communications Systems (PCS), Community Antenna Television or cable TV (CATV), Wireless Local Area Network (WLAN), etc. are all driven by technology and market forces toward higher performances. An ongoing thrust is to develop and install smaller base-station antennas with higher performances as well as low cost and aesthetic appeal and community acceptance [1]. A general consensus in the antenna community is that the next-generation base-station antennas should have most, if not all, of the following features: (1) smart beam tracking to mitigate multipath problem, (2) multifunction and multiband, (3) circular polarization for more stable linkage, (4) polarization diversity, (5) photonic remoting for low loss, low cost, and small size, (6) low profile and aesthetic appeal.

This paper presents a unique prototype design having all these desirable features for next-generation base-station antennas. It is based on the SMM (spiral-mode microstrip) antenna [2], for which some of the above features have been explored and established before [3-5].

II. A prototype base-station array design

The basic prototype design is a cylindrical beam-steered array with SMM antenna elements, as shown in Figure 1. The elevation pattern of the array is narrowed by using two to six elements vertically depending on the specific design specification. The wideband, multifunction capability, circular polarization, polarization diversity, low-profile, and aesthetic appeal are achieved by using the enabling SMM antenna technology. Antenna remoting using fiber-optic transmission and control offers many recognized advantages over conventional full-microwave systems, and is employed here. The basic prototype design shown in Figure 1 is on a conical cylinder 17-inch high, with upper and lower diameters at 15.25 inches and 10 inches, respectively. It can accommodate multiple systems spanning over a wide range of frequencies. The slight cone shape is for orientation of the elevation pattern to be slightly downward. A straight cylinder can also be used, in which case the elevation beam must be tilted downward by electrical phasing of the array elements. The array can be covered by a radome and hidden from view, appearing as part of a tree trunk, for example.

With the proliferation of wireless systems, base-station antennas must perform multiple functions in order to reduce the number of antennas under the constraints of limited space due to cost and community restrictions. The SMM antenna is the only low-profile antenna that has a bandwidth over 30%; in fact, it has a wide frequency span of 10:1. Thus, the prototype model, designed for 0.7-2.5 GHz, can easily operate as both cellular and PCS (as well as other functions such as paging, GSM, etc.) base-station antennas. This wide bandwidth also makes the SMM antenna less susceptible to detuning than narrowband antennas.

III. Circular polarization to mitigate multipath problem

The antenna is circularly polarized. The advantages of circular polarization over linear polarization for base-station antennas for both cellular and PCS systems have been widely recognized by practitioners in the field [6]. A circularly-polarized base-station antenna used in conjunction with linearly-polarized subscriber equipment can minimize polarization mismatch, since polarization alignment between antennas is seldom perfect. Also, a circularly-polarized wave can reach inside a building and into a shadow zone (of hills, large vehicles, edges of structures, etc.) with minimal dead spots.

IV. Optoelectronic switching for azimuthal adaptive beam steering

The array is adaptively steered azimuthally to track mobile units to ensure stable microwave link in spite of multipath fading, loss of coverage, etc. Here we employ the inherent phase pattern of the SMM antenna for beam steering, instead of expensive conventional phase shifting devices [7]. Figure 2 shows a conical cut of the linear phase pattern of an SMM antenna, which is employed to provide phase switching, making the antenna an integrated **frequency-independent antenna/phase-shifter.** As exemplified in Figure 3, the measured phase shift is a near constant of 90° over 0.7-2.5 GHz for a 90° spatial rotation. Figure 4 shows the feed region of a 4-arm SMM antenna/phase-shifter in which there are four optoelectronic switches which rotate the antenna by photonic control. The switches require no bias, need low optical power, and therefore are not intrusive as other switches are. The accuracy of this optoelectronic phase switching appears adequate for the present application.

V. Prototype model and measured results

The prototype model shown in Figure 1 has been built and limited measurements have been performed. Figure 5 shows the measured VSWR of an array element. Figure 6 shows an example of measured azimuthal element gain pattern, which can be switched photonically as discussed above in a simple, low-cost manner. Figure 7 shows examples of measured elevation patterns at several cellular and PCS frequencies. Experimental data have demonstrated that the present SMM array antenna is a unique approach that meets all the six requirements for future-generation base-station antennas as outlined in Introduction.

VI. Computer simulation results

Computer simulation of the array is being performed by employing the radiation zone theory for spiral antennas. So far the calculated patterns are in general agreement with measured data, with deviation observed to be less than 1-2 dB for most patterns.

References

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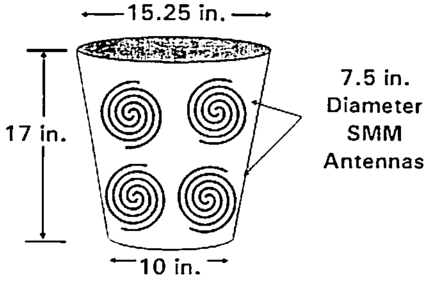

Figure 1. A prototype SMM base-station antenna covering 0.7-2.5 GHz.

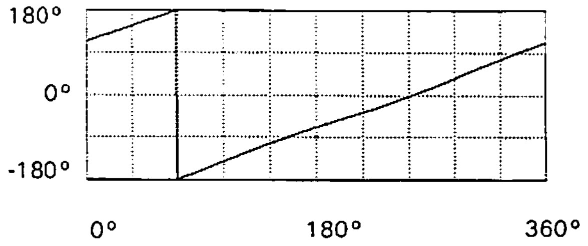

Figure 2. Measured phase pattern (conical cut) of an SMM antenna at 2 GHz.

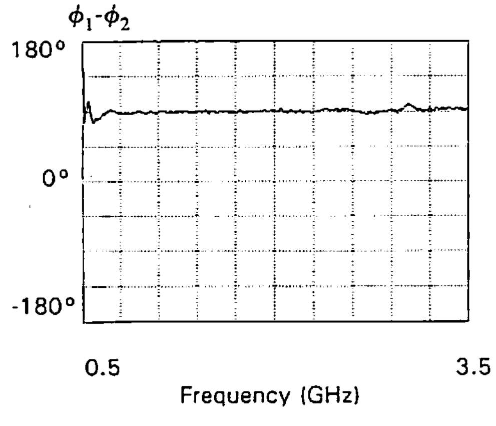

Figure 3. Measured phase shift (ϕ_1-ϕ_2) due to angular rotation of 90°.

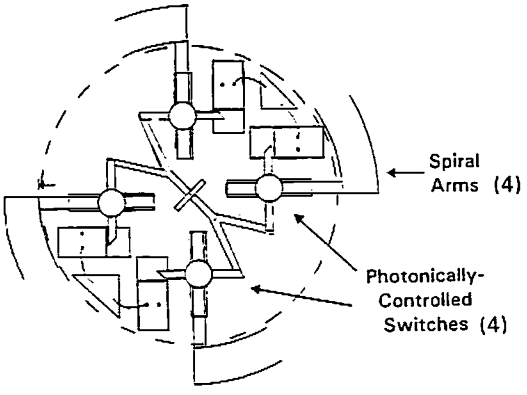

Figure 4. Feed region of an integrated SMM antenna/phase-shifter.

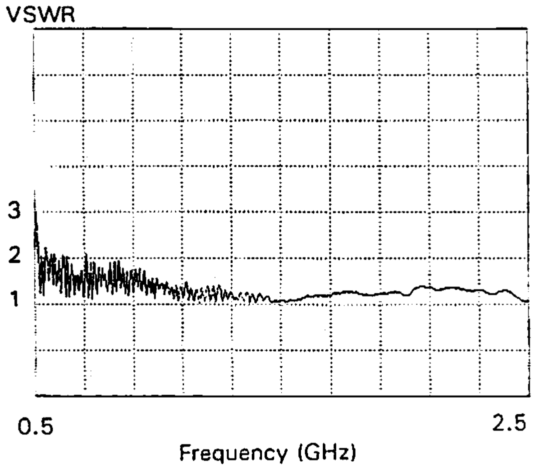

Figure 5. Measured VSWR.

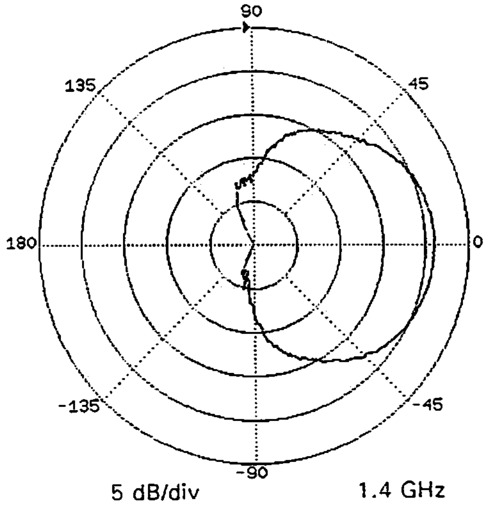

Figure 6. Measured azimuth pattern.

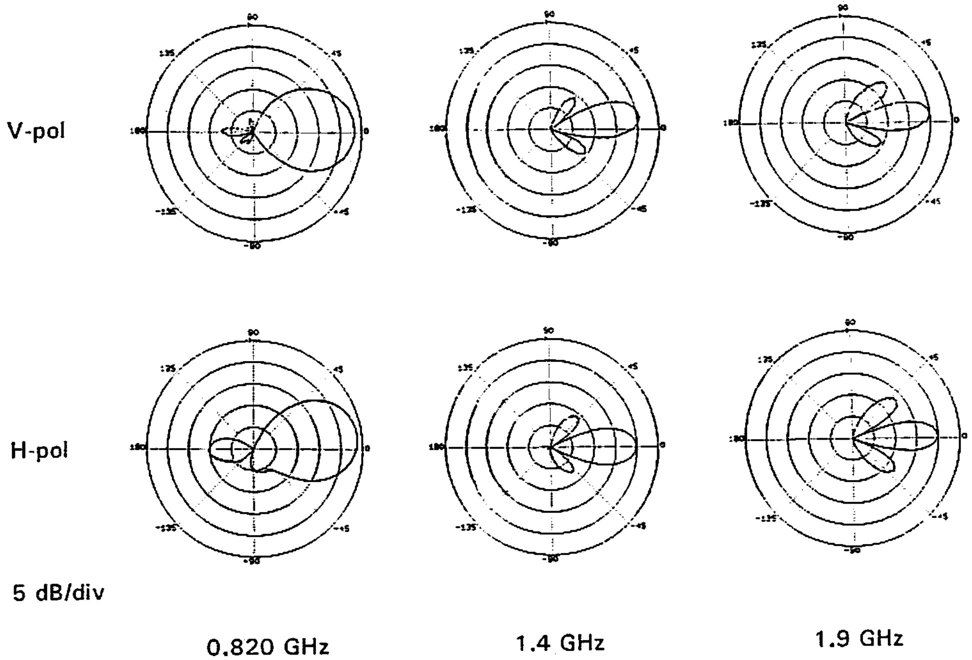

Figure 7. Measured elevation patterns.