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A Low Profile Polarization Diversity Antenna Built on an Artificial Magnetic Conductor

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Introduction

In this paper we introduce a low profile antenna system appropriate for polarization diversity. It is a two-port, linearly polarized antenna consisting of two orthogonal bent-wire monopoles placed in close proximity to an artificial magnetic conductor. This compact antenna, only $\lambda/50$ in total height, is appropriate for many mobile wireless systems were diversity gain is desired for high data rate communications. Furthermore this antenna is directive into one hemisphere, with a good front to back ratio, allowing it to be placed directly on a lossy dielectric body without significantly compromising the radiation efficiency or VSWR.

Antenna Design

The heart of this antenna is an engineered periodic surface that we call an artificial magnetic conductor, or AMC. It was introduced by Dan Sievenpiper *et. al.* as a high-impedance surface [1, 2, 3]. When wire radiators are placed in close proximity to this surface, its high-impedance property can be exploited over a limited bandwidth to make effective radiators [1, chpt. 9], as though the antenna were placed against a magnetic conductor. However, as originally identified by Sievenpiper, this surface can have an additional critical function, and that is to create a surface wave bandgap whereby a TE surface wave mode is leaky in the bandgap. This existence of a leaky fundamental TE mode is supported by recent theoretical analyses from Burghignoli *et.al.* [4]. We have adopted the nomenclature AMC to describe an electrically thin periodic surface, which has both high-impedance and surface wave bandgap properties, over similar but limited frequency bands.

Our AMC is designed as shown in Figure 1. It has an anticipated +/- 90^o reflection phase bandwidth of $BW = 2\pi(h/\lambda_o) = 8.9\%$ where λ_o is the free space wavelength at the AMC resonance (defined by 0^o reflection phase). The measured reflection phase in Figure 2 shows a bandwidth of approximately 140 MHz (8.1%), and a resonance near 1735 MHz. The unit cell size is 213 mils square. A two metal layer capacitive FSS is realized with overlapping patches separated by 2 mils of polyimide. The capacitance of the FSS layer is ~ 2.6 pF/sq. Vias of .020" diameter connect each FSS patch to ground.

Figure 3 shows photos of the diversity antenna. We refer to the horizontal printed strips spaced .031" above ($\sim \lambda_o/200$) the AMC as bent-wire monopoles, since they are essentially vertical monopoles bent over to be parallel to the surface. Each monopole is 1.64" (~.24 λ_o) in length, 0.050" in width, and end-loaded with a trimmer cap to permit tuning for optimum return loss. The antenna's total height is .0126", or λ_o/50 at 1870 MHz.

Measured Performance

The measured return loss and the mutual coupling are shown in Figure 4. The –6 dB return loss bandwidth is slightly greater than 100 MHz, from at least 1850 to 1950 MHz. Mutual coupling is lower than –27 dB over at least 1.8 to 2.0 GHz. Increasing the thickness 'h' will improve bandwidth. Note that the best impedance match is achieved near 1890 MHz, whereas the AMC is resonant near 1735 MHz. This increase in antenna resonant frequency over the AMC resonance is typical of severely truncated AMC ground planes.

The E-plane gain patterns at 1880 MHz for each port are shown in Figure 5. A broadside pattern with a peak gain of +3 dBil and a front-to-back ratio of 7 dB is observed. Figure 6 shows that antenna efficiency, measured in e-tenna's Satimo chamber [5] , which exceeds 50% over a band of at least 1850 MHz to 1950 MHz.

Conclusions

A low profile (λ/50 in total height) polarization diversity antenna is presented which employs the high-impedance property and the surface wave bandgap property of an artificial magnetic conductor to obtain a good front to back ratio of about 7 dB in a footprint as small as 0.31λ sq. (1.9" sq. at 1900 MHz). This two-port antenna has a peak gain of approximately +3 dBil from each port, and has a worst case mutual coupling between ports of only –27 dB over the PCS band (1850 MHz to 1990 MHz). The merits of this diversity approach over a conventional 2-port probe-fed patch antenna are (a) 5 dB to 10 dB improvement in mutual coupling, (b) an improvement in return loss bandwidth, assuming a patch of the same height with ε_r=3 or greater, and (c) improved radiation efficiency when placed directly on lossy dielectric bodies.

In addition to its use as a polarization diversity antenna, this pair of co-located elements may be fed in phase quadrature to implement a circularly polarized antenna.

References

[1] Daniel F. Sievenpiper, High-Impedance Electromagnetic Surfaces," Ph.D. dissertation, UCLA electrical engineering department, filed January 1999.

[2] Dan Sievenpiper, Lijun Zhang, Romulo F. Jimenez Broas, Nicolaos G. Alexopoulos, and Eli Yablonovitch, "High-impedance electromagnetic surfaces with a forbidden frequency band," *IEEE Trans. Microwave Theory and Techniques*, Vol 47, No. 11, November 1999, pp. 2059-2074.

[3] Eli Yablonovitch and Dan Sievenpiper, "Circuit and Method for Eliminating Surface Currents on Metals," US Patent No. 6,262,495 issued on July 17, 2001.

[4] Paolo Burghignoli et. al. "Low Frequency Dispersion Features of a New Complex Mode for a Periodic Strip Grating on a Grounded Dielectric Slab," *IEEE Trans. Microwave Theory Tech.*, Vol. 49, No. 12, Dec 2001, pp. 2197-2204.

[5] P. O. Iverson, Ph. Garreau, and Dennis Burrell, "Real-Time Spherical Near-Field Handset Antenna Measurements," *IEEE Antennas and Propagation Magazine*, Vol 43, No. 3, June 200, pp. 90-94.

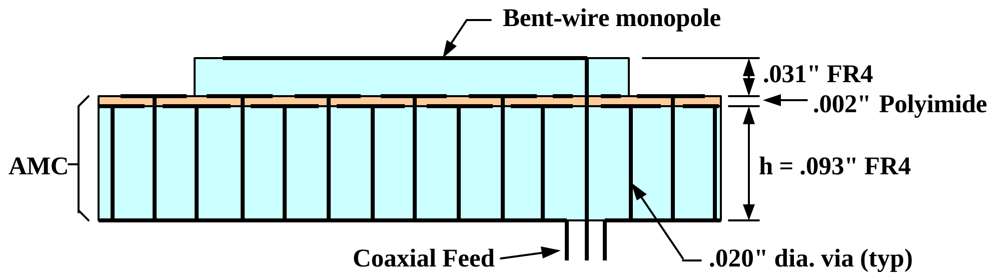

Figure 1. Profile view illustrating the design of the bent-wire monopole antenna element integrated with an artificial magnetic conductor (AMC).

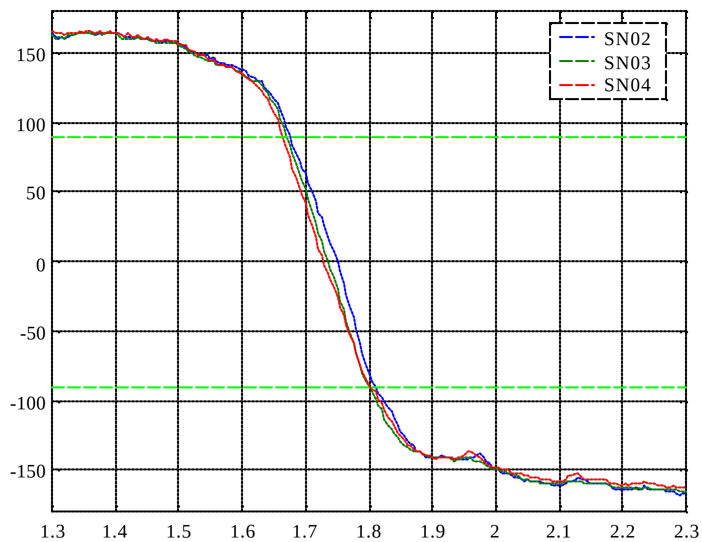

Figure 2. Measured reflection phase of the AMC used in this diversity antenna design (SN 02).

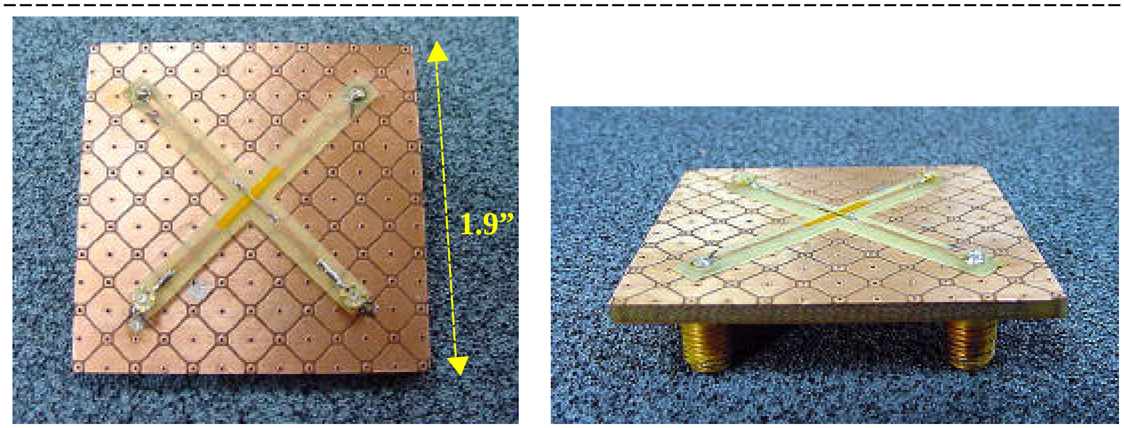

Figure 3. Top and side views of the dual linearly polarized diversity antenna

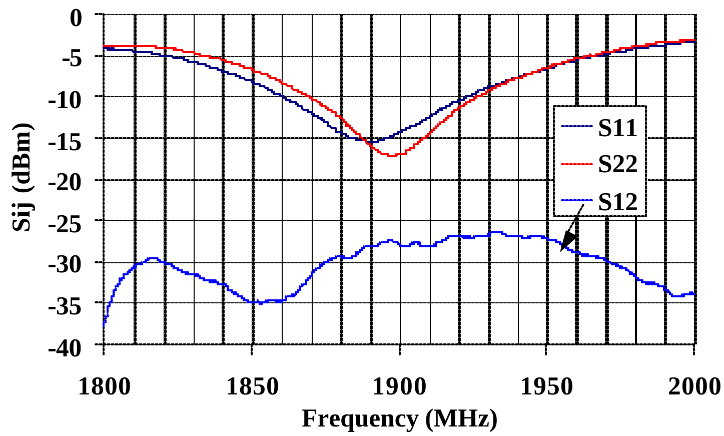

Figure 4. Measured return loss and mutual coupling for the two-port diversity antenna.

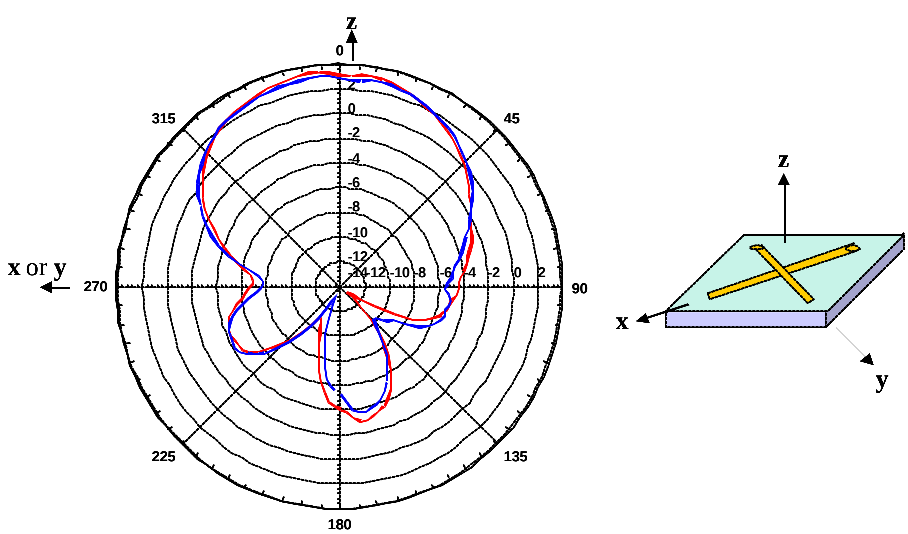

Figure 5. Measured E-plane gain patterns (E_q, dBil) for ports 1 and 2 at 1880 MHz.

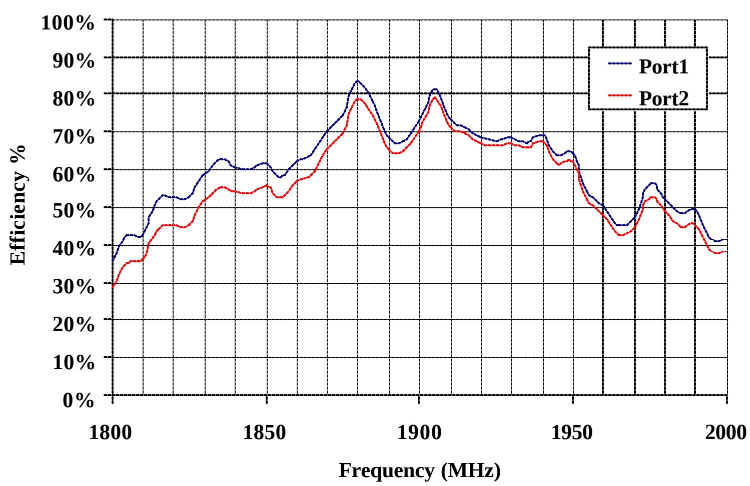

Figure 6. Measured radiation efficiency of the AMC diversity antenna.