Performance Analysis of Textile AMC Antenna on Body Model

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***Abstract*— The focus of this paper is to present a low profile, and highly efficient monopole antenna integrated with artificial magnetic conductor (AMC) using textile materials with a compact footprint for off-body communication in the ISM 5.8 GHz band. In addition, effect of structural deformation in terms of antenna bending on the performance of monopole antenna with and without AMC reflector is examined into two perpendicular planes. Finally, this paper explores human body loading effect on the proposed antennas conformed to a human arm model of averaged tissue properties.**

***Keywords*— artificial magnetic conductor (AMC); textile antennas; wearable antennas**

I. INTRODUCTION

In recent years, demand for compact and low profile wearable antennas is increasing, as they provide mobility and eliminate wearer's discomfort and restrictions imposed by the wireless electronic devices. In group of wearable antennas are built using textile materials. Textile antennas must be subtly crafted into clothing to allow conforming to human body. The loading effect due to the lossy and dispersive nature of the body tissues, causes radiation degradation and frequency-detuning problems when antennas operate in close proximity to the human body. This brings the challenge of designing miniaturized wearable antenna with reliable performance [1].

In literature [1-3], researchers have shown that artificial magnetic conductor (AMC) and electromagnetic band-gap (EBG) structures may act as isolator, reducing the effects of the ambient environment on antenna, thereby avoiding the deterioration of the communication range and the adverse biological effects.

II. ANTENNA DESIGN

The proposed antenna consists of a coplanar waveguide (CPW) fed monopole antenna designed on 3.6 mm thick Pellon fabric substrate with a dielectric constant ε_r = 1.8, and loss tangent $tan\delta$ = 0.008. The monopole antenna is backed with 4 × 6 AMC array measuring 102 mm × 68 mm. AMC reflector is designed using 1.8 mm thick Pellon fabric substrate. Pure Copper Taffeta fabric of conductivity σ = 2.5 × 10^5 S/m provided by LessEMF [4] is used as electrotextile in antenna design. It's worth mentioning that, bearing in mind the requirements of wearable antennas, the selection of an appropriate materials is an important step in the textile antenna design.

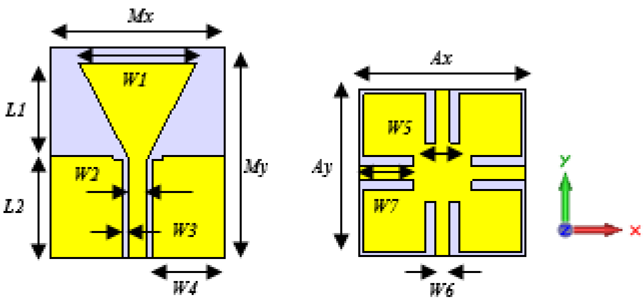


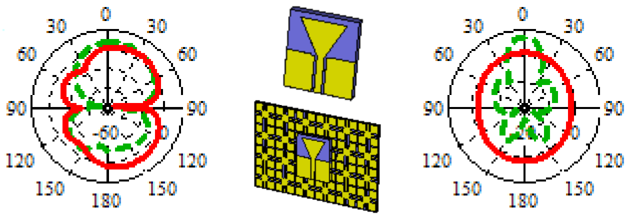
Fig. 1. Configurations of (a) CPW fed monopole antenna, and (b) AMC unit cell. The optimized dimensions in *mm* are *Mx* = 27, *My* = 34, *Ax* = 17, *Ay* = 17, *L1* = 15.5, *L2* = 16.5, *W1* = 19, *W2* = 3, *W3* = 0.4, *W5* = 3.5, *W6* = 1.3, and *W7* = 5.5.

Geometries of the monopole antenna and AMC unit cell are based on the proposed designs in [5-6], respectively. By tuning the geometrical dimensions of both monopole antenna and AMC unit cell using CST Microwave Studio (MWS) software [7], the desired impedance matching and radiation properties are achieved at 5.8 GHz. Fig.1 shows the proposed prototypes of the monopole antenna and AMC unit cell. The AMC reflector was designed by reflection phase characterization using the methodology described in [3]. AMC acts as a perfect magnetic conductor (PMC) in a specific frequency range in which it provides in- phase reflection characteristics. In the proposed cell, the exact point of zero reflection phase is located at 5.8 GHz with a narrow bandwidth of 370 MHz (5.61 GHz to 6.00 GHz) within ±90° phase values.

III. RESULTS AND DISCUSSION

First, performance of planar monopole antenna without AMC reflector and with it (referred to as AMC antenna) is studied in free space condition. Fig. 4 and Table I summarize our findings. Good impedance matching is maintained for both cases within frequency range of interest, despite the reduction in -10 dB S_{11} bandwidth after integration of the AMC layer.

The effectiveness and usefulness of the AMC as a reflector can be assessed by the free space radiation patterns shown in Fig. 2. The monopole antenna alone has a dipole like pattern in its E-plane and an omnidirectional pattern in its H-plane. The AMC antenna, in contract, has a quasi-hemispherical pattern in both planes. This shows an increase in the front-to-back (FBR) ratio and antenna gain achieved by the in-phase reflection of the AMC reflector (values are listed in Table I).



(a) (b)

Fig. 2. Simulated radiation patterns of monopole antenna with (dashed green) and without (solid red) AMC reflector at 5.8 GHz; (a) E-plane, and (b) H-plane.

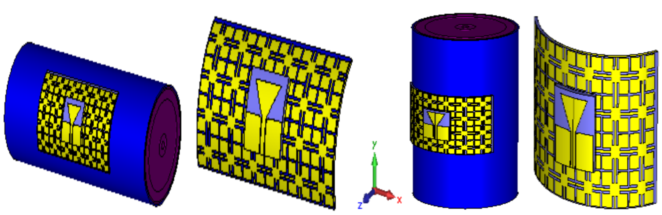
IV. Further Studies and Discussion

A. Effects of Structural Deformation on Wearable Antennas

Before investigating the human body loading effect, we first examine monopole and AMC antennas performance under bending conditions in free space for two bending directions: E- and H-plane. The chosen curvature radius (R = 50 mm) is reasonable representation for the human arm. Fig. 3 shows simulations set up for AMC antenna.

B. Effect of Human Body Loading on Wearable Antennas

To validate the on-body performance, simulations with the monopole and AMC antennas wrapped onto cylindrical human arm model (R=50 mm) of total length L= 200 mm are performed. Averaged human arm phantom properties of ε_r = 21.2 and σ = 3.38 S/m at 5.8 GHz [8] are used during simulations. An additional layer of Pellon fabric of 1.8 mm thickness is used to account for clothing. Fig. 3 shows simulations set up for AMC antenna.



(a) (b)

Fig. 3. Structurally bent AMC antenna in (a) H-plane direction, and in (b) E-plane direction. Human arm model (left), and free space (right).

Fig. 4 and Table I summarize the obtained results. Antennas bending in both directions in free space condition resulted in shifting the resonance frequency toward lower values and in a reduction in antennas' gains and FBR. However, AMC antenna retains its impedance matching when placed close to human arm model.

V. Conclusion

In summary, monopole antenna and AMC reflector based on textile materials design and simulation in the vicinity of the arm model have been presented. The proposed design provides the flexibility, and isolation from the human body for off-body communication devices. Efforts are currently underway to fabricate the proposed prototypes and perform experimental measurements.

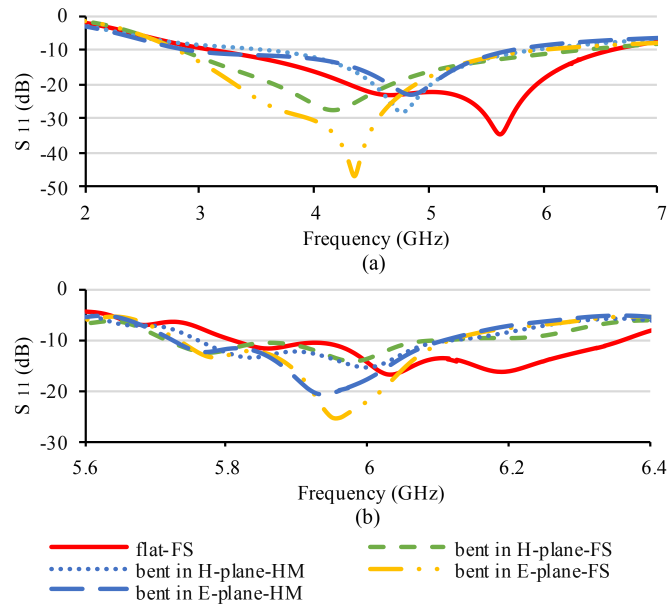


Fig.4. S_{11} summary of (a) monopole antenna, and (b) AMC antenna. Free Space (FS) and Human Model (HM).

TABLE I. Performance Summary of Monopole and AMC Antennas at 5.8 GHz

Scenario	Gain (dBi)	FBR	f_r^a (GHz)	B.W^b (GHz)	S_{11} (dB)
Flat monopole, FS	3.96	15.16	5.63	3.50	-25.68
Flat AMC, FS	7.57	27.75	6.02	0.56	-9.80
Bending Antennas in E-plane Direction					
Bent monopole, FS	2.83	6.40	4.36	3.22	-10.80
Bent monopole, HM	2.43	27.99	4.90	2.83	-9.48
Bent AMC, FS	4.18	17.87	5.95	0.39	-12.64
Bent AMC, HM	3.37	23.59	5.94	0.42	-11.92
Bending Antennas in H-plane Direction					
Bent monopol, FS	3.14	5.40	4.12	3.40	-12.22
Bent monopole, HM	3.69	32.16	4.78	2.27	-10.43
Bent AMC, FS	6.36	17.04	5.98	0.42	-11.98
Bent AMC, HM	5.95	30.15	5.99	0.43	-11.39

[a] Resonance Frequency (f_r), and [b] Bandwidth (B.W).

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