Compact Z-Shaped Flexible Microstrip Antenna for UHF ISM Band Application

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***Abstract*— This paper presents, compact design of Z-shaped microstrip antenna on flexible substrate for UHF ISM band (902 – 928 MHz) wireless application. The proposed antenna is resonating at 916 MHz with impedance bandwidth of 5 MHz. The triangular shaped slots are cut at the non-radiating edge of compact rectangular microstrip antenna. The antenna radiates in broadside direction with peak gain of 8 dBi. The designed and simulated antenna geometry has been fabricated using economical and flexible foam substrate having size of 14 × 9 cm^2. The fabricated antenna prototype has been tested and measured results are observed in good agreement. The parametric analysis has been carried out to optimize the triangular slot dimensions and presented in this research work.**

Keywords—compact, flexible, microstrip, UHF

I. Introduction

In today's world of wireless communication, wireless systems need to be compact and handheld. Antennas are the integral part of any wireless system. These antennas need to be compact in size, should provide high gain and desirable bandwidth. Microstrip antennas (MSAs) are found to be suitable to fulfill the need to handheld wireless systems. Ease of fabrication, low profile and conformability are some of the advantages of MSA. However, at lower UHF range of frequencies the MSA offers large size, narrow bandwidth, low gain and high cross-polarization in radiation. Therefore, it is challenging task to design compact and high gain MSA at lower UHF range of frequencies. The objective of this research work is to design MSA using flexible substrate to realize compact, high gain MSA which offers low cross polarization in radiation in UHF band. In the continuing research, various research groups have reported different technique to realize the compact antenna for wearable applications [1-6]. The metasurfaces embedded wearable MSA has been reported in [1]. The antenna comprises printed coplanar waveguide (CPW) fed monopole for exciting the metasurfaces. The use of metasurface reduces the back lobe radiation and helps to enhance the gain. The reported gain of antenna is about 2.99 dBi at 2.65 GHz having size of 39.4×33.4 mm^2. Koch fractal geometry-based design with meandering slits and defected ground structure on vinyl polymer-based flexible substrate has been presented in [2]. The size reduction in reported MSA has been achieved using Koch fractal and meandering slits. Further, defected ground has been used to realize the compact antenna design. The authors have experimented and reported wearable hexagonal shaped MSA on flexible foam substrate [3]. The antenna resonates at 2.45 GHz wireless body area network (WBAN) application. The reported antenna exhibits circular polarization radiation and offers bandwidth of 70 MHz and gain of about 9 dBi. Geo-textile fabric material based microstrip patch antenna loaded with metamaterial has been reported by J. G. Joshi *et al.* [4]. The antenna comprises 'T'-shaped radiator surrounded by four split ring resonators (SRRs). The reported antenna is primarily applicable for public safety band. The loading of SRRs reduces the resonating frequency of patch, thereby realizing compact wearable MSA. The use of planar inter digital capacitor structure with stub on polyester substrate have been reported in [5]. The reported combination acts as resonator and realizes compact antenna structure on wearable substrate. J. G. Joshi *et al.* in [6], experimentally investigated wearable microstrip patch antenna. The reported antenna uses metamaterial embedded rectangular slot to realize compact structure. The antenna resonates at 5.10 GHz with bandwidth and gain of 97 MHz and 4.92 dBi respectively.

In the reported literature, it has been studied that, the fabrication complexity of reported MSAs is more and all the antennas are designed at higher frequencies. Realizing compact MSA is more challenging at UHF range of frequencies. Therefore, in this paper, the slot cut methodology have been implemented to realize the compact antenna geometry at UHF frequency. This paper is organized in following section. Section II discusses the detailed design of proposed Z-shaped MSA. The obtained results are discussed in section III and the paper is concluded in section IV.

II. Antenna Design

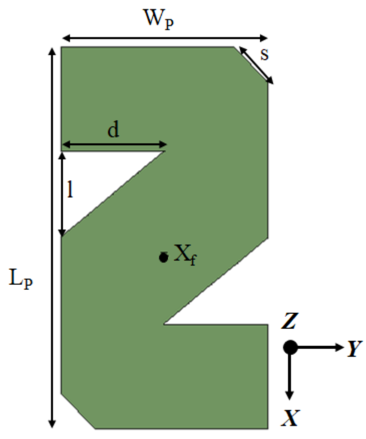

Fig. 1 Z-shaped MSA

Fig. 1 depicts geometrical design of Z-shaped MSA on flexible substrate. The rectangular patch is initially designed to resonate at 1.25 GHz using equations reported in [6]. Using symmetry of rectangular shape, the half portion has been cut to obtain 50% size reduction. The obtained length L_P and width W_P of designed MSA is 11 cm and 6 cm respectively. The antenna is fed at location X_f = 0.5 cm using SMA connector. Further, to shift the resonating frequency of this MSA, two right angle triangular shaped slots are cut at non-radiating edge of rectangular MSA thereby realizing Z-shaped geometry. The dimensions of triangular slot are optimized and considered as l = 2.5 cm and d = 3 cm. These dimensions are optimized using parametric analysis carried out on slots simultaneously. The electrical length of surface current has been extended and the resonant frequency has been shifted to desired lower UHF band of application. However, poor impedance matching is also observed in resonant frequency. To overcome this limitation, diagonally opposite corners of compact rectangular MSA has been cut having s = 1.5 cm. The designed antenna has been simulated using CAD Feko [7] antenna simulator using flexible foam substrate having thickness of 0.4 cm and relative permittivity of 1.07. The designed and simulated MSA has been fabricated and the simulated and measured results are presented in Section III.

III. Results and Discussion

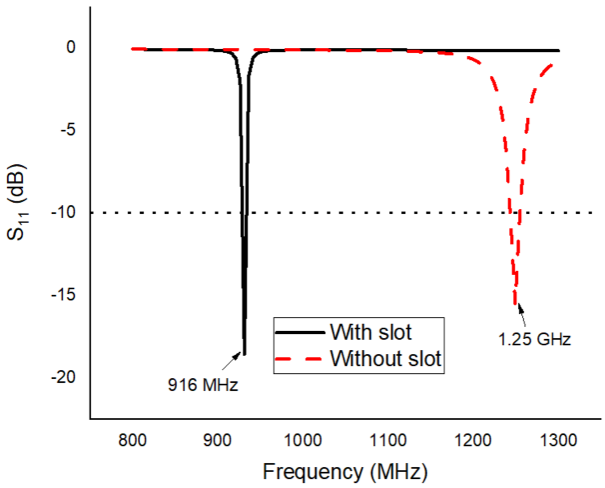

Fig. 2 Return loss of Z-shaped MSA with and without slots

Fig. 2 presents the return loss characteristics of Z-shaped MSA with and without right angle triangular shaped slots. From Fig. 2, it can be observed that, without slot compact rectangular MSA is resonating at 1.25 GHz resonating frequency. By cutting right angle triangular slot inside radiating patch, the resonant frequency shifts towards lower side and the designed antenna resonates at 916 MHz with 5 MHz of bandwidth, which is desired resonating frequency in UHF ISM band of wireless application. Thus, size reduction of about 36.46% has been achieved by cutting the slots. The overall reduction of size is more than 80%, thereby realizing compact antenna geometry.

The parametric analysis on depth ‘d’ of right-angle triangular slot has been carried out. The parameter ‘d’ has been varied as d= 1cm, 2cm and 3 cm respectively, while all other geometrical parameters has been kept constant. This effect of change of depth ‘d’ on return loss characteristics has been studied and depicted in Fig. 3. It has been observed that, by enhancing the depth of slot, the electrical length of surface current gets increased and therefore, the resonant frequency has been shifted to lower side realizing compact Z-shaped MSA. For, the depth value d=3cm, the antenna is resonating in desired band of frequency. Also, for change in parameter ‘d’, poor impedance matching has been observed. Therefore, to obtain the better impedance matching, diagonal corners of rectangular MSA has been cut with side length s = 1.5 cm.

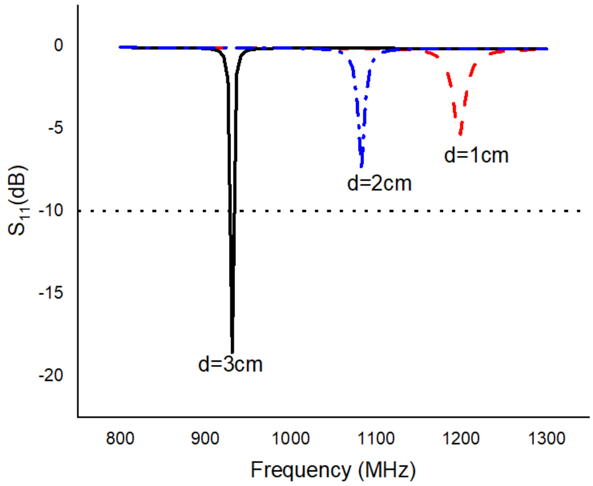

Fig. 3 Effect of depth ‘d’ on return loss

Fig. 4 (a - b) presents E-plane and H-plane radiation pattern respectively. The proposed design of Z-shaped MSA radiates in broadside direction in both plane with peak gain of 8.7 dBi. The cross polarization in both the planes are well below of -20 dB.

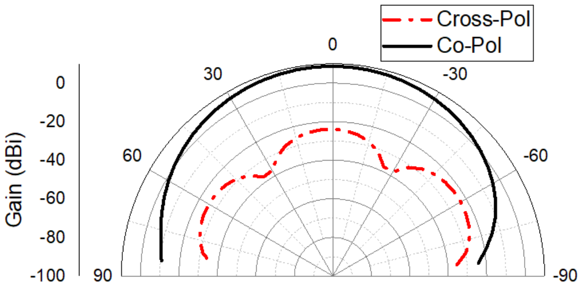

Fig. 4 (a) E-Plane radiation pattern

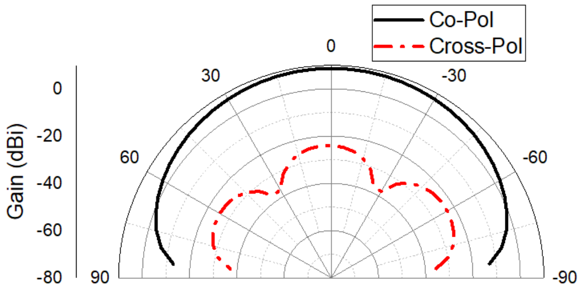

Fig. 4 (b) H-Plane radiation pattern

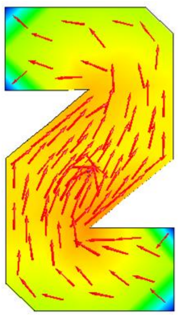

Fig. 5 Surface current distribution of Z-shaped MSA

Fig. 5 depicts the surface current distribution of Z-shaped MSA at 916 MHz resonant frequency. It can be observed that, the electrical length of surface current has been enhanced to due to slots. Therefore, the resonant frequency has been shifted to lower side and compact design has been obtained.

The designed and simulated Z-shaped MSA has been fabricated using foam substrate having size of 14 × 9 $cm^2$and depicted in Fig. 6(a). The flexible copper foil is used for patch and ground plane. SMA connector having 0.62 mm radius is used to feed this MSA. This fabricated prototype has been tested using Obzor TR1300/1 vector network analyzer and the return loss characteristics is measured. The simulated and measured return loss characteristics has been compared and presented in Fig. 6(b).

Fig. 6(a) Photograph of fabricated prototype

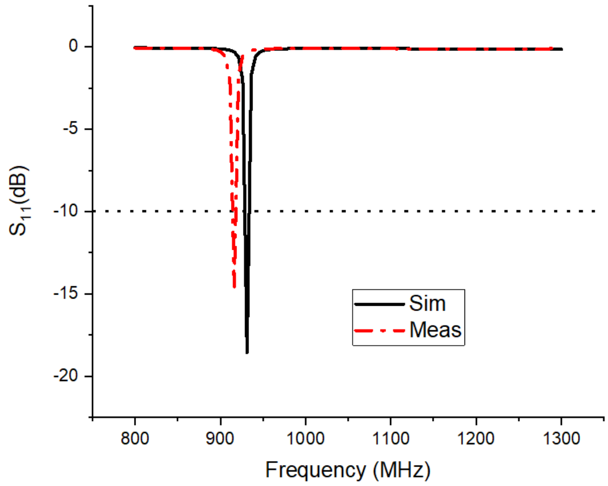

Fig. 6(b) Comparison of simulated and measured return loss

Slight shift towards lower frequency has been observed in the measured return loss characteristics. However, the measured frequency is well within the desired band of application. The measured impedance bandwidth is 3 MHz compared to simulated impedance bandwidth.

IV. CONCLUSION

In this paper, compact Z-shaped microstrip antenna using foam substrate has been proposed for UHF ISM wireless band. The Compact design of Z-shaped geometry resonating at 916 MHz with 5 MHz of impedance bandwidth. The proposed antenna offers high gain of more than 8 dBi with lower cross polarization in radiation. The designed and simulated antenna has been fabricated and tested. The measured results are found in good agreement with simulated results. The presented microstrip antenna can be useful for UHF ISM wireless band.

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