EBG Configured Wideband Sensing Antenna for Smart RF Applications

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Abstract -- **The association of quantum effect with microwave application has become protagonist of modern era of wave applications. The effective impedance variation may easily be encountered with respect to alteration into path distribution of E-M wave. The effect of quantum theory is directly affected with respect to band gap insertion in various materials with different dielectric constant. In this paper, the antenna design is accomplished by band gap insertion, resulting in better trade-off in size and bandwidth calculations. The antenna geometry is also modified to reduce overall captured area. Passive geometry with respect to patch gives reradiating current distribution and hence results in improved bandwidth of micro-strip patch antenna about 32.05 percent at operating frequency 2.31 GHz. Scattering loss parameter S_{11} is measured. The antenna is widely suitable for large number of advance applications such as cognitive radio sensing networks, IoT and smart wide RF scanning devices as per FCC standard.**

Keywords: Micro-strip patch antenna, Reradiating current distribution, Electromagnetic bandgap geometry (EBG)

I. INTRODUCTION

THE micro-strip patch antenna is simple in fabrication; it is a metallic patch on one side of thin grounded dielectric material referred as substrate. With specific range of dielectric material, the antenna may be used for various microwave frequency ranges [1 - 3]. Several wireless applications avail advantages of using micro-strip patch antenna, *viz*. easy installation, conformal to fabricate on any surface, cost effective, easy-to-feed etc. The scope of improvement is seen due to its low bandwidth, low capacity of power handling, less effective polarization capacity [4, 5]. It is part of ongoing research to enhance the parametric properties of micro-strip patch antenna without putting any compromise in its dimensional characteristics. It shows the design of an efficient antenna with reduced size and enhanced bandwidth with effective radiation pattern [6]. To overcome the limitation of micro-strip patch antenna, the design aspect is revised, and the modifications are also done in substrate ground keeping other materialistic factors unaltered.

Such an antenna is an impedance matching device between transmission lines [7] to free space hence the transfer of power depends upon the impedance synchronization, better the impedance matching, better the power the transmission to the free space and *vice versa*. Therefore, an alteration in dielectric substrate structure results in tremendous variation in antenna parameters. This paper represents the effect of passive elements associated with active part of the micro-strip antenna design. The feed current and the radiating current elements were seen very differently with improved radiation pattern.

The electromagnetic band gap (EBG) geometries have been taken up into consideration to change the impedance profile of micro-strip patch antenna[8-10]. These structures may offer very high impedance regions for operating frequency range chosen from microwave frequencies. The geometrical cut sections on the ground surface will turn up into combination of various passive reactive elements on excitation of antenna with feed current. This reactive part of surface geometry of dielectric substrate completely depends upon the feed frequency. Hence, the overall surface will form band gaps for electromagnetic waves. Such electromagnetic band gap structures in association with micro-strip antenna results in reduction of surface wave and hence reduction in return losses [11-15]. By this way, the voltage standing wave ratio is significantly low over the zone of operating frequency.

There are various approaches to analyse micro-strip antenna, having certain constraints with each of the antenna design modeling. Among all, the method of moments is highly popular due to fast and accurate analytical capacity. It is basically full wave model of surface wave current and polarization current [16-18]. All modeled transient integral can be represented into polynomial of algebraic variables, choosing appropriate constants, equations can be turned into linear solutions and can be solved using machines. It has low physical interpretation but high accuracy [19]. This method helps in determination of typical parameters of antenna more precisely and clear conclusion can be obtained [20].

II. PROPOSED CONFIGURATION

The proposed antenna geometry of its upper surface is shown in Fig. 1 and ground surface with deformities equivalent is depicted by Fig. 2.

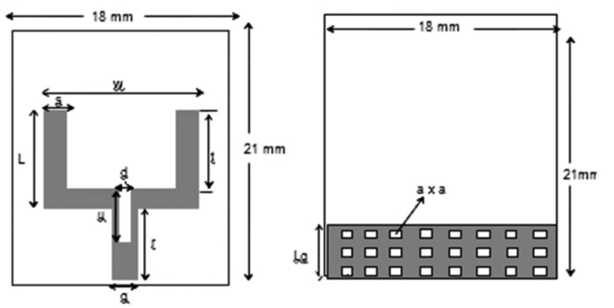

Figure 1. Antenna Schematic front and bottom view.

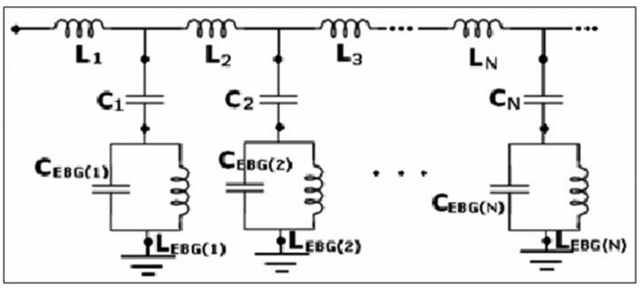

Figure 2. Ground deformities equivalent diagram.

The base antenna is taken up as simple square patch with basic ground properties. The dimension of the antenna is taken up from micro-strip patch antenna mathematical equation for its length and width calculation using a dielectric substrate of dielectric constant 4.2. The material is commercially available as FR-4 material. The antenna geometry is modified with the fabrication of two passive patches in association of with active feed elements. The overall antenna geometry is also provided with the insertion of uniform deformation on ground plane. This deformation is an actual pathway for generation of electromagnetic band gap structure within the dielectric slab. The standard height of the dielectric slab is 1.6 mm and on excitation of antenna may result in virtual path variation for radiation current due to improved antenna geometry. The proposed configuration will lead various enhancements in performance parameters with respect to conventional antenna structure of similar dimensions. The proposed antenna has the following design configuration shown in Table 1.

The proposed antenna is designed with the ground deformities and studied for various parametric performances. The antenna design simulation is recorded for large range of frequency in GHz. The scattering loss parameters show the proposed antenna may exhibit a usable band of frequency from 1.79 GHz to 2.59 GHz band with satisfactorily low return losses at cantered frequency around 2.31 GHz also, it exhibits VSWR<2 within matched bandwidth shown in figure 3.

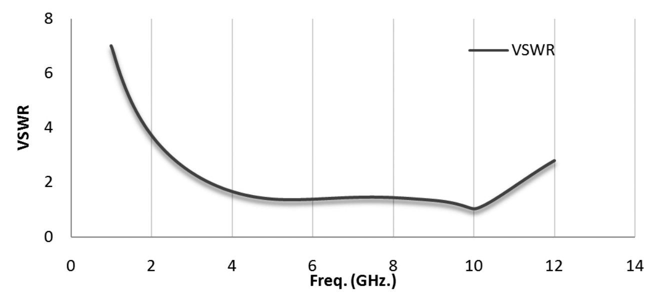

Figure 3. VSWR versus frequency curve.

The proposed antenna is fabricated to validate the simulation observations as shown in Fig. 4. The results gives a tremendous move in the direction of design of new geometry and its further applications in wireless technology. The radiation pattern is more bidirectional with broadside pattern. The gain of the antenna is also found suitable under the excitation at port one. The repeated structure of ground deformities could be able to enhance the bandwidth as depicted in simulation results. Design architect with respect to dielectric medium has also become significant, various parameters found appropriate over the effect of substrate properties. The impedance matching and reduction of surface wave is also seen while introducing EBG structure. These are periodic structures produced at the ground surface. EBG structure enhanced control on return loss at port one: now the return loss parameter has more dip around centre frequency.

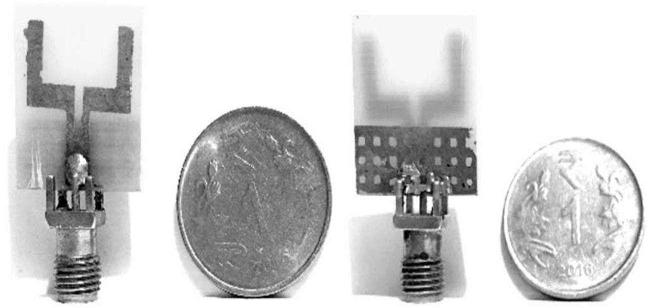

Figure 4. Fabricated antenna Front and Rear view.

TABLE 1 -- ANTENNA CONFIGURATION AND OPTIMIZATION

Antenna	Design Parameters (mm)									
	r	**s**	**t**	**u**	**d**	**q**	**Lg**	**Wg**	**a**	**d/u**
Design 0	8	2	6.5	1	1	3	7.5	18	1	1
Design 1	8	2	6.5	5	1	3	7.5	18	1	0.2
Design 2	8	2	6	6	1	3	7.5	18	1	0.16
Design 3	8	2	6.5	7	1	3	7.5	18	1	0.14

The antenna is absolutely resonating at 2.3 GHz and the -10dB cut off frequencies are more symmetrical around centre frequency. The antenna parameter is observed on full wave simulator, which works on method of moments. The modelling is found high accuracy with less physical insight. Antenna radiation pattern, return loss parameters, VSWR are shown in simulation results of MoM simulator. The process effectiveness is observed through the electrical equivalence of the slot strip as shown in Fig. 5.

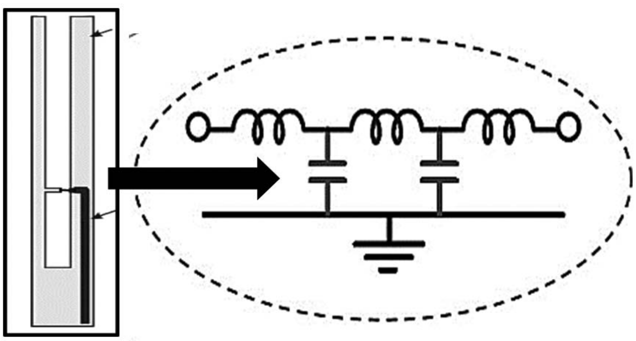

Figure 5. Equivalent diagram of slot.

III. RESULTS & DISCUSSION

Now the various models are simulated on high frequency structure simulators and the effective parametric study is carried out. With respect to variation in slot length, the multiple designs have different behavior for return loss characteristics as shown in Fig. 6. First reduction in the local coefficient *d/u* causes the design evolution of the design 1, most suitable candidate under this category. While, further reductions may cause slight alteration of parameters to drastic change in the operating frequency zone as design 3. Hence, accepting design 1 as good structure for further discussion under the current distribution and radiating parameter characteristics. As a matter of current distribution Fig. 5 gives the port field fringes in radiating patch. The simulated input impedance is also found matched over the operating frequency range in Fig. 6.

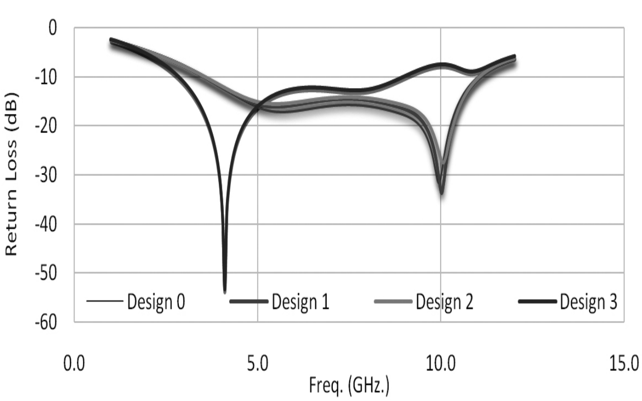

Figure 6. Scattering parameters for multiple designs.

The confined parameters of proposed antenna are evaluated through empirical study of various class of antenna under characteristics mode. The design 1 parameters of this class of antenna is fabricated using FR-4 material with substrate dimensions 21x18 mm^2 and thickness 1.5 mm. Patch is fabricated as U-shape with slotted feed strip on EBG inserted optimized ground plane and its electrical equivalent diagram supports the functioning. The small deviation is seen between the measured and simulated result due to impedance variation at the connecting feed. The gain of the antenna is also analyzed over the frequency sweep and found good over the entire operating range. The prototype of proposed antenna is developed and the measured and simulated return losses are compared in Fig. 7.

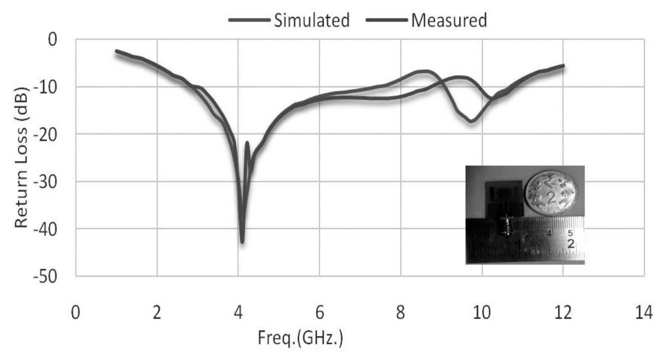

Figure 7. Plot of return loss versus frequency.

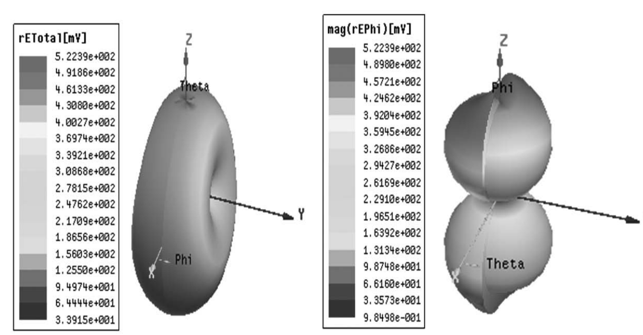

Figure 8. 3D plot at 4.5 GHz and 9 GHz radiation pattern.

Measured impedance bandwidth is found ultra-large, featuring return-loss below -10 dB in 3.5-11.1 GHz range. Radiation pattern measured at distinct frequencies of operation depicts good dipole pattern and response for wider range of excitation within operating bandwidth (Fig. 8). In respect to multiple design aspects, optimized results are obtained for the proposed antenna geometry. Comparison among various designs indicates that design 1 is the best option for various smart sensing applications (Fig. 9). Responses are summarized in Table 2.

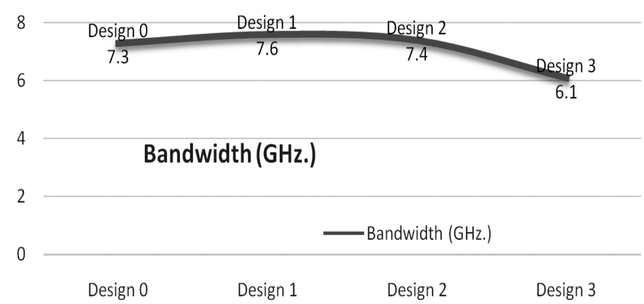

Figure 9. Graphical representation of parameter variations.

Table 2 -- SUMMARY OF RESULTS

Parameters Square patch MSA	**Proposed Antenna**
Bandwidth (MHz) 23% S11< -10 dB	32.3%
VSWR at port 1 1.079 (2.39)GHz	1.121 (2.3) GHz

IV. CONCLUSION

The Proposed antenna design shows a good return loss more than -10dB. This indicates good impedance matching is achieved in designing the patches and feed lines. The S_{11} < -10 dB comparison graphs show that the resonant frequency has a dynamic range movement in the magnitude of return losses over the band of designated frequencies range. Also, the design gives a better compromise between the enhancement of bandwidth with sustainability of antenna size and reduction in feed active area. Hence, the proposed antenna may become a high utility for smart wireless sensor networks for cognitive and IoT based wide band applications.

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