COMPACT MODIFIED EBG BASED PATCH ANTENNA FOR WIMAX APPLICATIONS WITH REDUCED SAR

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ABSTRACT:: *A compact modified mushroom like EBG having cross slots with via at center is presented in this manuscript for SAR (Specific Absorption rate) reduction. A coaxial fed, square microstrip patch antenna is designed using CST Microwave studio suite. The designed antenna operates within the WiMAX frequency band ranging from 3.3 to 3.6 GHz frequency band. The designed EBG was coupled with antenna and simulated in CST studio suite. Results of SAR calculation with and without EBG are presented which shows an impressive reduction of about 82%. The SAR value along with a 2mm size reduction in the EBG unit cell is also observed. The EBG unit cell size is 10mm×10mm. The overall dimensions of the antenna are 45mm×45mm×1.5mm.*

1. INTRODUCTION:

The use of mobile phones is increasing with a high rate due to extensive advance in wireless communication. The arrival of smart phones in the market has further added to the time one remains busy on his cell phone. The cell phone antenna transmits electromagnetic radiations in all directions because base station can be located in any direction with respect to mobiles subscribers. This implies that portions of these radiations are directed towards user body. According to world health organization (WHO) these radiations are carcinogenic in nature, so to reduce the harmful effect of these radiations is the cry of the day.

A portion of the energy emitted by antenna is formed into surface waves which results in a distorted radiation pattern and poor front to back ratio [1]. These uncontrolled electromagnetic radiations pose a threat to human body specially head region. There is a need to control these radiations so that we may enjoy the use of portable devices without any threat to our health. Globally, a parameter known as Specific Absorption Rate (SAR) is used to quantize the harmful effect in terms of energy absorption in human tissue. Mathematically, it is defined as the power absorbed per mass of tissue and has units of watts per kilogram (w/kg) [2].

$$SAR = \frac{\sigma E^2}{\rho}$$

Where σ and ρ are the conductivity and density respectively.
SAR is averaged over 10gm or 1gm mass of tissue for which the standard values are 2 watt/Kg and 1.6 watts/Kg respectively. SAR value can be decreased by reducing the back radiation coming from antenna and blocking the surface waves [3].

Several approaches have been proposed for SAR reduction in past years. Some studies inserted a reflector between antenna and head but as the reflectors are conducting surfaces they reverse the phase of impinging EM waves [4]. Due to this an antenna needs to be placed at the distance one quarter of wavelength (λ/4) from the reflector to ensure constructive interference between the incident and reflected waves. Another technique is the use of highly directive antennas inside mobile phone which will help in reducing radiations towards the human head [5]. But the adoption of highly directive antennas certainly degrades signal reception from other directions.

Nowadays, researchers are interested in EBG structures due to its amazing properties. These are periodic structures that prevent the propagation of electromagnetic waves in a specified band of frequency. These structures offer high surface impedance to suppress surface waves, thus it helps in SAR reduction. EBG structure acts as LC filter in a specified band to block the flow of surface waves [6].

In some studies mushroom like EBG has been proposed for SAR reduction, which introduces inductance, resulting from current flowing through via and capacitance, due to gap effect between adjacent patches [7]. Author study reveals that mushroom-like EBG is more effective than UC-planer EBG for SAR reduction. In [8], author study a rectangular shaped mushroom type EBG was coupled with a microstrip dipole patch antenna and about 42% SAR reduction was observed. Another approach in [9] proposes a square metamaterial (SMM) for SAR reduction and claims 53% reduction in peak SAR. Several other geometries such as jureslum JC-EBG was proposed in [10] and double spiral EBG was proposed in [11].

In this paper a new and unique design of EBG structure has been proposed for SAR reduction. The proposed design is coupled with a coaxial fed square patch antenna whose center frequency is 3.5GHz, which is WiMAX (World Wide Interoperability for Microwave access) which is a family of wireless communication standards based on IEEE 802.16 set of standards providing a multiple physical layer and media access control(MAC) options. WiMAX technology gives a wireless alternative to cable and DSL for last mile broadband access. A total of twelve unit cells surrounds the patch. The proposed design brings 82% reduction in SAR value.

2. PROPOSED ANTENNA DESIGN:

The substrate is made from FR4 having permittivity of 4.3 and a thickness of 1.5mm. Substrate dimensions are 45mm×45mm. Ground plane is made from copper having same dimensions as that of substrate. Patch is in the form of a square (19mm× 19mm) having a thickness of 0.035mm. The feeding technique used is coaxial probe. The inner diameter (d=1.91mm) and outer diameter (D=6.5mm) were calculated in CST studio. In this case the best feeding point was found to be at a vertical distance of 3.8mm from the center. Fig.1 shows the front view and side view of antenna.

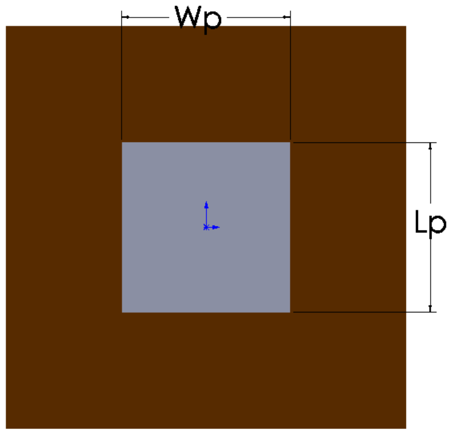


Fig. 1: Antenna without EBG Structures

3. PROPOSED EBG DESIGN:

The proposed EBG is a modified mushroom like with cross slots. The unit cell size is 10mm×10mm which is 2mm less than the conventional mushroom EBG for 3.5 GHz. Each EBG unit cell has a via of diameter 0.5mm at the center which forms a conducting path between patch and ground through the substrate. All slots are of 0.2mm width. The unit cell dimensions and cell arrangements are shown in Fig 2.

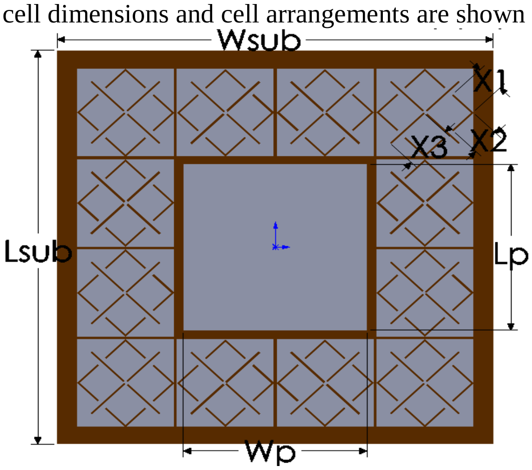


Fig.2: Antenna with EBG Structures

EBG unit cells are arranged in a single layer around patch. The gap width (g) between two cells is 0.3mm. The EBG cells are 0.95mm apart from patch and 2.05mm apart from substrate boundaries. A total of 12 unit cells are used as shown in Fig. 2(b). Various human models are used for SAR calculation like SAM phantom, Hugo model and voxel model [6]. In this paper, a cylindrical model having three layers is designed for SAR calculation as shown in Fig 3. The outer layer is made of skin material having permittivity of 31.29 mm. The middle layer is made of bone with a permittivity of 12.61 mm. The inner layer is made of brain having permittivity of 38.11 mm. The EBG is arrangement is basically performed by a periodic sequence and may be represented by the following equation:

$$K = \frac{\pi}{x}$$

Where, K is the wave number at stop band frequency and x is the period of cell separation. So in the periodic arrangement of EBG structures the suppression harmonics depends only on cell filling or cell spacing. The following concept has been explored by [12].

Table 1. Dimensions of design

Ws	45mm	g (gap width)	0.3mm
Wp	19mm	Dia of via	0.5mm
h	1.6	Slots width	0.2mm
ε	4.3	ε_1	31.29
a	10mm	ε_2	12.61
b	3mm	ε_3	38.11
c	10mm		

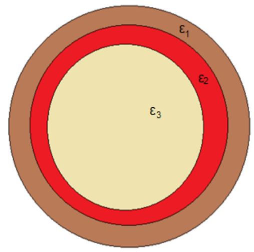


Figure 3. Head model for SAR calculation

4. RESULTS AND DISCUSSION:

The design was simulated in te CST microwave studio. The S_{11} (return loss) parameters with EBG and without EBG are shown in Fig 4. Antenna without EBG has resonant frequency at 3.495 GHz having a bandwidth of 102.5 MHz. With EBG the resonant frequency has shifted to 3.6 GHz with a bandwidth of 98.26 MHz. For SAR calculation, the cylindrical design is placed at a distance of 10mm from antenna.

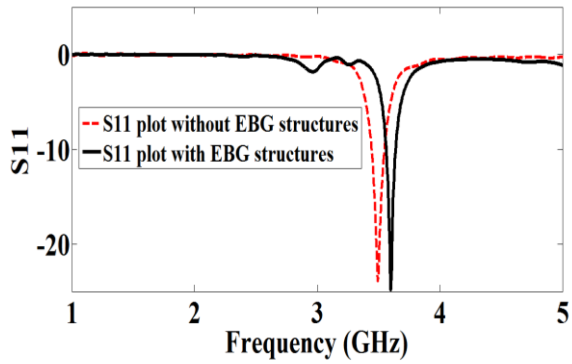
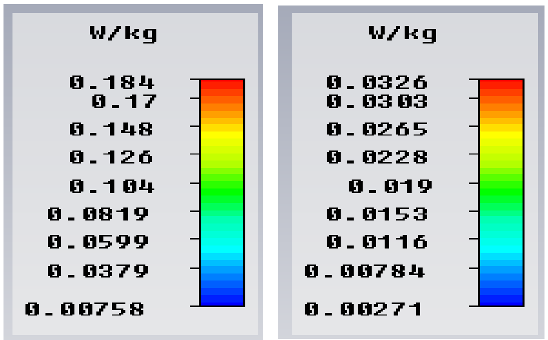


Fig 4. Return loss graphs

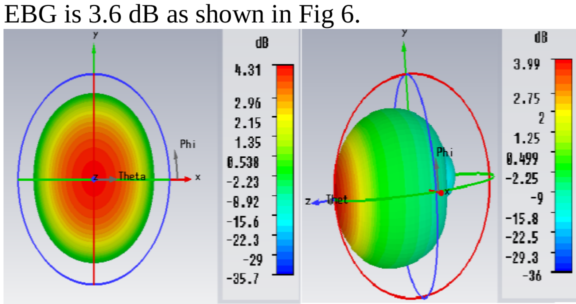
Antenna without EBG has maximum SAR value of 0.184 W/Kg. After placing EBG the maximum SAR value is calculated to be 0.0326 W/Kg, showing about 82% reduction. The comparison of SAR value with and without EBG is shown in Fig 5.



(a) (b)

Fig. 5. SAR calculation results,(a)Without EBG (b) With EBG

The gain of the antenna without EBG is 4.31 dB and with EBG is 3.6 dB as shown in Fig 6.



(a) (b)

Fig 6. Gain of Antenna with and without EBG (a)Without EBG (b) With EBG

5. Radiation pattern of proposed antenna:

The radiation pattern of the proposed antenna at 3.6 GHz is shown in 7. The radiation pattern is performed for both E and H-plane.

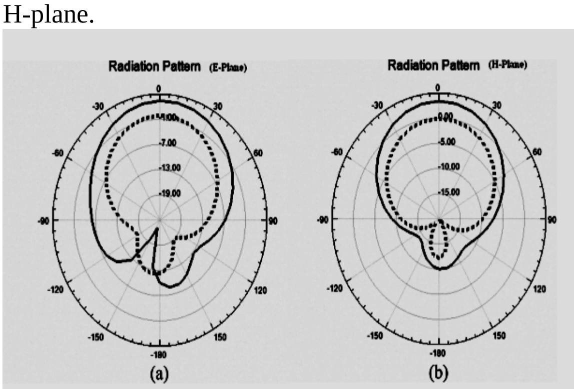


Fig 7. Simulated radiation pattern of the proposed antenna (a(E-plane (b) H-plane

CONCLUSION:

The proposed EBG is very effective in SAR reduction, which was the main objective of this research. SAR reduction up to 30% is presented in the literature discussed. The proposed EBG has 82% reduction in SAR which is very impressive and high achievement. Also a 2mm size reduction in each unit cell is attained. Antenna results are acceptable and proposed antenna is a good candidate to be implemented for WiMAX based applications.

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