Dipole Phased-Array Antenna above circular patched EBG substrate with Reduced Specific Absorption Rate for Fourth Generation Mobile Phone Applications

Mr. Kamlesh T. Kaharpardeshi
M.Tech Student,
Digital Communication Engg.
Patel College of Science & Technology,Bhopal.

Prof. Syed Uvaid Ullah
Assistant Professor & HOD,
Dept. of Electrical and Eelectronics Engg.
Patel Institute of Technology, Bhopal.

Prof. Sameena Zafar
Assistant Professor & HOD,
Dept. of Electronics & communication Engg.
Patel College of Science & Technology, Bhopal

Abstract

In this paper we propose a new type of mobile handset antenna structure to reduce the specific absorption rate (SAR) in human head. The design and analysis of two element dipole phased-array antenna above circular shaped EBG substrate is discussed. As a reference model, a conventional rectangular patch EBG substrate is used. The frequency band considered is 3.4 to 3.8 GHz, which is suitable for fourth generation mobile application. The working of the complete unit is analyzed. The proposed design was found to reduce the local SAR in a head model; the radiation efficiency was also improved. The SAR reduction also depends on the phase difference of the phased-array antenna. CST MICROWAVE STUDIO® is used for antenna simulation and SAR calculation.

Keywords— Antenna arrays, Electromagnetic band-gap (EBG) structure, handset antenna, specific absorption rate (SAR)

.

1. Introduction

With the rapid growth in the use of cellular phones the exposure of human head to electromagnetic radiation has increased. The specific absorption rate (SAR) is a defined measure to evaluate the power absorbed by biological tissue. The specific absorption rate (SAR), defined as:

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

is equivalent to the tissue heating rate, where the symbols σ for electrical conductivity, ρ for mass density, c for specific absorption rate and dT/dt for the changing rate of the temperature in body tissue have their typical meanings.

Recent radiation protection standards specify threshold values for averaged SAR averaged over tissue masses of 1 or 10 gm, respectively, which should not be exceeded by any cellular mobile phone apparatus.The safety guidelines for EM wave exposures, have been established by international standardization bodies [1], [2]. The SAR value is influenced by various Antenna parameters such as antenna positions relative to the human body, radiation patterns of the antenna, radiated power. The SAR in life tissue can be reduced by reducing the power radiated by the mobile antenna toward the human head.

Lots of work is going on to find out the different ways to reduce radiation toward human life tissues. Some of the initial work suggested the use of RF shields; which is not a convenient solution for mobile applications. Some studies inserted a reflector between the radiator and the head [3]. But as the reflectors are good conducting surfaces; they reverse the phase of impinging electromagnetic waves. Due to that, an antenna needs to be placed at the distance one-quarter wavelength (λ/4) from the reflector to ensure the constructive interference between the incident and reflected waves. Another disadvantage of metallic sheets is supporting surface waves. This fact disallows the realization of antennas with a very low profile. Another study applied a ferrite sheet to reduce the magnetic field around the antenna [4]. In wireless technology, the profile of the radiated energy beam depends on antenna properties. Due to this fact, a specified radiation pattern of the antenna is required for most cases. In order to improve the antenna performance, a novel breakthrough based on so-called metamaterials emerged in the last two decades [5], [6]. Metamaterials are a kind of a material with electromagnetic properties not found in nature. Recent studies suggest the use of electromagnetic band-gap (EBG) substrate for reduction of SAR [7], [8]. Most of the energy emitted by an antenna is formed into surface waves and leads to distorted radiation pattern and very poor front-to back ratio. EBGs represent a promising way to overcome some of these problems and to make possible to design e.g. high-gain, compact antenna arrays with the desired radiation properties in a relatively simple way [9], [10]. SAR can be decreased by reducing the back-radiation coming from the antenna and the ground plane [11], the substrate materials and its dielectric properties also plays important role in SAR reduction [12].

2. Dipole Phased-Array Antenna and Model Geometry

2.1 Antenna Array

For some applications single element antennas are unable to meet the gain or radiation pattern requirements. Combining several single antenna elements in an array can be a possible solution. Arrays of antennas are used to direct radiated power towards a desired angular sector. The number, geometrical arrangement, and relative amplitudes and phases of the array elements depend on the angular pattern that must be achieved. Once an array has been designed to focus towards a particular direction, it becomes a simple matter to steer it towards some other direction by changing the relative phases of the array elements; a process called steering or scanning.

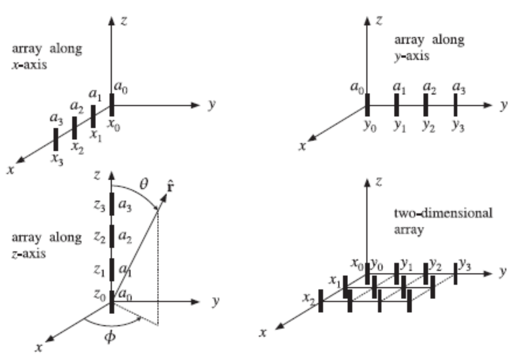

Figure 1: Typical array configurations

Figure 1 shows some examples of one- and two-dimensional arrays consisting of identical linear antennas. A linear antenna element, say along the z-direction, has an Omni directional pattern with respect to the azimuth angle φ. By replicating the antenna element along the x- or y-directions, the azimuth symmetry is broken. By proper choice of the array feed coefficients, any desired gain pattern g (φ) can be synthesized [13]. Anomalous Behaviour in the Radiation Patterns of a dipole located in a dielectric medium 1 at certain distance from the interface to a different dielectric medium 2 is presented in [14].

2.2 Model Geometry

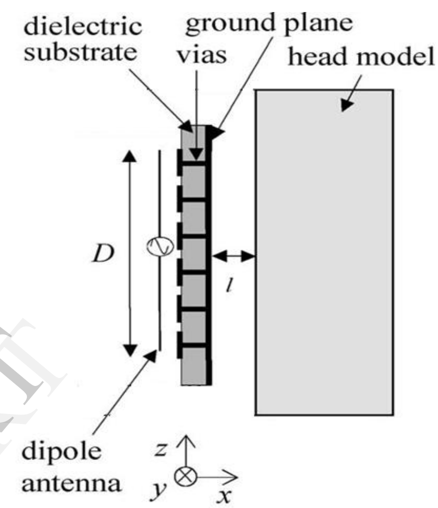

Figure2. Relative positions of antenna and head model

A dipole antenna above an EBG substrate is examined. Fig.2. illustrates the geometry of the antenna in proximity to a simplified head model. The distance between ground plane and head model is 10mm. The dipole length is 36 mm, and its radius is 0.2 mm, so the driven frequency becomes 3.5 GHz. A circular shaped mushroom-type EBG was considered. The dimensions of the EBG patch are set from the following formulas [15]:

$$L = \mu_0 h \quad (1)$$

$$C = \frac{W\varepsilon_0(1+\varepsilon_r)}{\pi}\cosh^{-1}\left(\frac{2W+g}{g}\right) \quad (2)$$

Where u_0 is the permeability of free space and ϵ_0 is the permittivity of free space. From the equivalent inductance and capacitance obtained from (1) and (2), the approximate centre frequency of the band-gap is obtained.

The use of an antenna array enables better performance with high gain and fast data-rate transmission rates in wireless communications. Fig.3. illustrates the geometry of proposed Dipole

Phased – Array Antenna with circular patch EBG structure. Two element array used is consist of two identical dipole antennas Ant1 and Ant2. The distance between the antennas is 20mm.The area of the ground plane was set at 43× 83 mm [10]. The relative permittivity of the substrate is 6.15, corresponding to that of the Rogers RT/Duroid 6006 laminates. A total of 32 (8× 4) EBG patches are used, and the distance between the dipole phased-array antenna and the EBG ground plane is set at 7.5 mm.

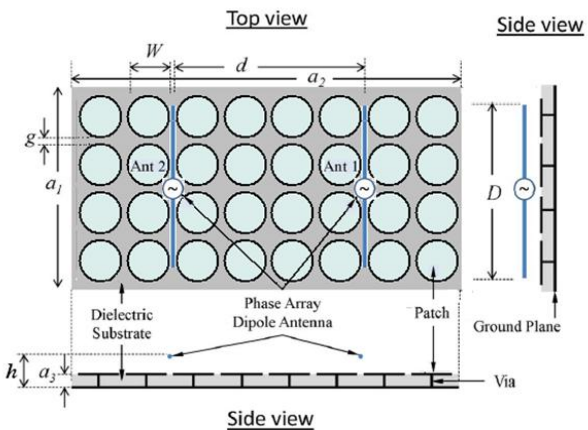

Figure3. Geometry of the proposed Dipole Phased –Array Antenna above circular patched EBG substrate.

a1=43mm, a2=83mm, a3=3mm, D=36mm, d=20mm, W=9mm, g=1mm and h=7.5mm

For comparison of the SAR performance of the proposed structure, performance of a dipole phased-array antenna above a square patched EBG substrate is also studied. Use of the EBG substrate give better SAR and gain results as compared to that of PEC substrate[7][16].

3. Computational Methodology and Results

3.1 Methodology

Computer Simulation Technology Microwave Studio (CST MWS) is a device used as a major simulation tool dependent on the finite-difference time-domain method (FDTD). An unvarying meshing scheme was chosen to make major computation which is devoted to make major computation which is devoted to inhomogeneous mark boundaries for the fastest and faultless result. A fraction of the cubic human head model with dimensions of 150 × 150 × 35mm^3 is utilized for this analysis [16], [17].

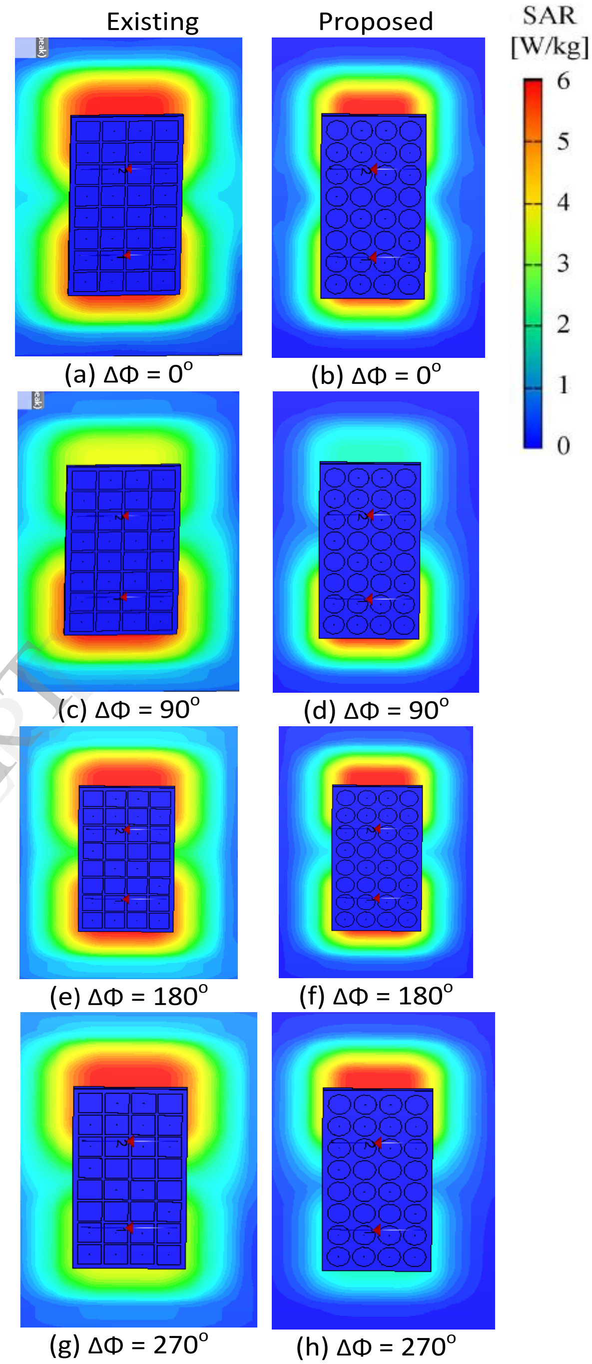

Figure 4. SAR distribution using existing and the proposed EBG structure for different values of ΔΦ

The electrical constants of the muscle tissues and remaining details are taken from [18] and [19]. In the modeling, the resolution of the cell is 0.5 × 0.5 × 0.5 mm^3, and this resolution is chosen so that the gap width has at least two cells in the EBG structure. The antenna is operated in the frequency range of 3.4–3.8 GHz.

3.2 Results and Discussion

The effect of the phase angles of Ant 1 and Ant 2 on the SAR distribution is computed by the FDTD method [19] - [21]. The SAR distribution in the head model depends upon the phase difference between the signals of Ant1 and Ant2. When Ant 1 and Ant 2 both have an identical, arbitrary phase, SAR hotspots are located near the two dipole antenna positions in the human model. Also the distribution is symmetrical, owing to the same phase. The results illustrated that the SAR distributions are different when ΔΦ is varied. A higher SAR located near Ant 1 is observed when the phase difference between Ant 1 and Ant 2 is 90^{o}, as shown in Fig. 4(c) and (d). The phase difference–SAR diagram of the dipole phased-array antenna above the square patched EBG substrate (previous) and the circular patched EBG substrate (proposed) is shown in Fig. 5. The results also indicated that the SAR variability mainly depends on the phase difference between the two antennas. The results have shown that the SAR was reduced for all phase differences when the proposed EBG substrate is employed.

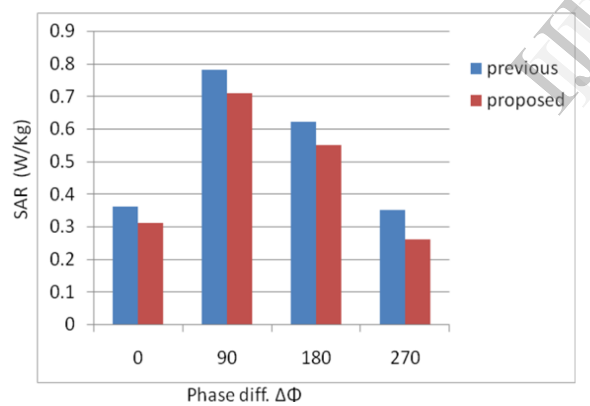

Figure 5. Phase difference–SAR diagram of the dipole phased-array antenna above the existing and the proposed EBG substrate.

For all the values of the ΔΦ, the SAR distribution is less in the proposed design as compared to that of [10]. The numerical comparison of the SAR values is given in table 1.

Table 2 give the comparison of radiation efficiency between the two structures; the radiation efficiency with the proposed structure is 96% which was 94% with the previous structure.

Table 1. SAR results of previous and proposed methods

Phase difference ΔΦ [^{o}]	SAR value averaged over 10g in existing EBG [W/Kg]	SAR value averaged over 10g in proposed EBG [W/Kg]
0^{o}	0.35	0.31
90^{o}	0.77	0.72
180^{o}	0.61	0.56
270^{o}	0.34	0.27

Table 2. Radiation Efficiency comparison

	Radiation efficiency
Previous Structure	94%
Proposed Structure	96%

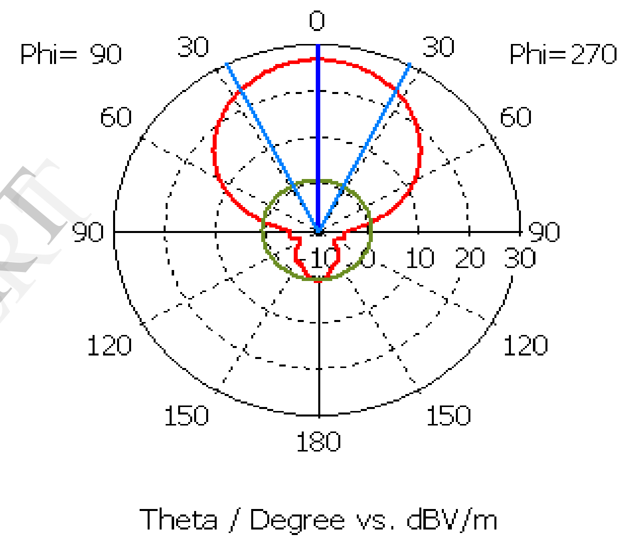

Figure 6. Radiation pattern for the dipole phased-array antenna above the proposed EBG substrate for ΔΦ=0^{o} .

The 3-db angular width of the proposed structure is found to be 53.7degree as shown in fig6. The back lobe level is also reduced by 2dB owing to reflection characteristics produced by modified structure. The reduction of side-lobe level is helpful for reducing the SAR in the head model. Far field plot for Abs component of the proposed design is shown in figure 7.

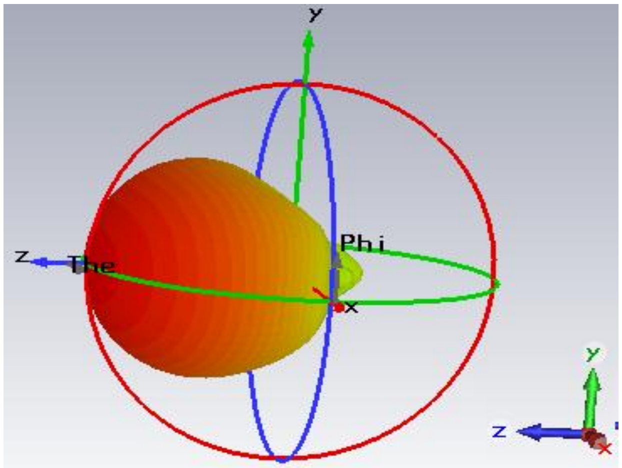

Figure 7. Far Field Plot

4. Conclusion

Study of Phased-Array Dipole Antenna above different EBG structure is discussed here. The proposed structure has found to reduce SAR with improved radiation efficiency and directivity. The results indicated that the use of proposed structure could provide an SAR reduction for antenna array of over 11%. The radiation efficiency is also improved by 2%. The SAR is also affected by the phase difference of the antenna array.

References

[1] International *Commission on Non-Ionizing Radiation Protection (ICNIRP)*, "Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz)," *Health Physic*., vol. 74, pp. 494–522, 1998.

[2] IEEE Standard for Safety Levels With Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, C95.1, 1999.

[3] R. Y. S. Tay, Q. Balzano, and N. Kuster, "Dipole configurations with strongly improved radiation efficiency for hand-held transceivers," I*EEE Trans Antennas Propag.*, vol. 46, no. 6, pp. 798–806, Jun. 1998.

[4] L.K. Ragha , M.S.Bhatia "Evaluation of SAR Reduction for Mobile Phones Using RF Shields," *International Journal of Computer Applications* (0975 – 8887) Volume1 – No. 13,2010.

[5] M. R. I. Faruque, M. T. Islam, M. A. M. Ali. "A New Design of Metamaterials for SAR Reduction," *Measurement Science Review*, Volume 13, No. 2, 2013.

[6] J.-N. Hwang and F.-C. Chen, "Reduction of the peak SAR in the human head with metamaterials," *IEEE Trans. Antennas Propag.*, vol. 54, no.12, pp. 3763–3770, Dec. 2006.

[7] Ryo Ikeuchi and Akimasa Hirata, "Dipole Antenna above EBG Substrate for Local SAR Reduction"; *IEEE* VOL. 10, 2011.

[8] J. Horák, Z. Raida, "Influence of EBG Structures on the Far-Field Pattern of Patch Antennas," *Radioengineering*, Vol. 18,No. 2, pp.223-229, June 2009

[9] P. Kovács, T.Urbanec, "Electromagnetic Band Gap Structures: Practical Tips and Advice for Antenna Engineers," *Radioengineering*, vol. 21, No. 1,pp. 414-421, April 2012.

[10] Alka Verma "EBG Structures and Its Recent Advances In Microwave Antenna," *IJSRET*, Volume 1, Issue 5, pp 084-090, August 2012.

[11] A.H.Kusuma, A.F.Sheta, I.Elshafiey, M.Alkanhal, S.Aldosari, Z.Siddiqui, and S.A. Alshebeili "A Novel Low SAR PIFA for Mobile Terminal," *IEEE Trans.indoor and mob.comm. 21th international symposium*, pp.1117-1121,2010.

[12] N.A. Husni, M.R.Iqbal Faruque, M.T.Islam,N.Misran, "Effects of Substrate Material and Dielectric Properties on Electromagnetic Energy Absorption Over GSM Bands" *Journal Of Emerging Technologies In Web Intelligence*, Vol. 5, No. 2, pp.151-155,May 2013

[13] Robert S. Elliot , *An Introduction to Guided Waves and Microwave Circuits*, 2nd Ed. John Wiley & Sons Inc., 2002.

[14] L.E.García-Muñoz, E.Ugarte-Muñoz, J.Montero-de-Paz, A. Rivera-Lavado, and D.Segovia-Vargas," Anomalous Behavior in the Radiation Patterns," *IEEE Trans. on Antennas and Propagation*, Vol. 61, No. 2, pp.973-976, Feb. 2013.

[15] F. Yang and Y. Rahmat-Samii, "Microstrip antennas integrated with electromagnetic band-gap (EBG) structures: A low mutual coupling design for array applications," *IEEE Trans. Antennas Propag.*, vol. 51, no. 10, pp. 2936–2946, Oct. 2003.

[16] Effects of Phase Difference in Dipole Phased-Array Antenna Above EBG Substrates on SAR; Kwok-Hung Chan,Ryo Ikeuchi and Akimasa Hirata, *IEEE* VOL. 12, 2013

[17] Hirata, S. Mitsuzono, and T. Shiozawa, "Feasibility study of adaptive nulling on handset for 4G mobile communications," *IEEE Antennas Wireless Propag. Lett.*, vol. 3, pp. 120–122, 2004.

[18] S. Gabriel, R. W. Lau, and C. Gabriel, "The dielectric properties of biological tissues: I. literature survey ," *Phys. Med. Biol*., vol. 41, no. 11, pp. 2231–2249, Nov. 1996.

[19] Khitam El Wasife, "Power Density and SAR in Multi-Layered Life Tissue at Global System Mobile (GSM) Frequencies," *Journal of Electromagnetic Analysis and Applications*, 2011, 3, 328-332.

[20] S.Paker, L.Sevgi, "FDTD Evaluation of the SAR Distribution in a Human Head Near a Mobile Cellular Phone," *ELEKTR_IK*, VOL.6, NO.3, pp.227-242, 1998.

[21] T. Wessapan, S.Srisawatdhisukul, P.Rattanadecho, "Specific absorption rate and temperature distributions in human head subjected to mobile phone radiation at different frequencies," *International Journal of Heat and Mass Transfer* vol.55, pp. 347–359, 2012.