Synthesis and Analysis of an Edge Feed and Planar Array Microstrip Patch Antenna at 1.8GHz

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Abstract

In this paper, a Microstrip Patch Antenna (MPA) at 1.8GHz has been presented. An edge feed MPA and a planar array MPA has been designed. Further analysis has been done to obtain antenna performance parameters and hence, prove its practicability and applicability as an efficient radiating system. Results obtained in terms of radiated fields, gain, directivity, VSWR and return loss shows that the system is well suited for the desired frequency of operations and best suitable candidate for the GSM system applications. Planar array MPA can be used for wireless communication system as it offers gain of 7dBi, radiation efficiency radiating system is 5.085% and having directivity of 13.77dBi.

Keywords- *Microstrip Patch Antenna (MPA), Planar Array MPA, GSM application, gain, directivity, radiation efficiency*

1. Introduction

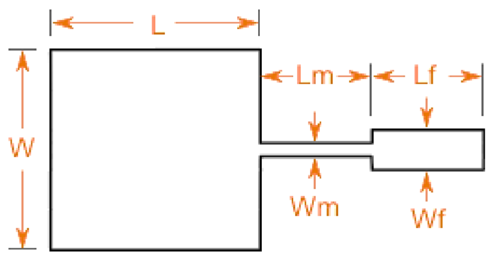
Antenna, a metallic radiating structure has become one of the most important components of any communication system. It plays an important role when it comes to wireless transmission of data or information. So, antenna designers are facing many challenges in designing a suitable antenna system, which can fulfill the growing demand of bandwidth for different multimedia applications, which require high data rate. In this paper, investigation has been done on an edge feed microstrip patch antenna and a multi element planar antenna. Major design problem related to using microstrip patch is the narrow band-width limiting the use of conventional patch as broadband antennas. But, inspite of its drawback, a MPA offers many advantages which make it fit to be used for communication systems. MPA is a low cost and easy to fabricate antenna. With the advancement in printed circuits, these antennas can be easily fabricated on circuit board.

Performance analysis of planar array has been performed; it significantly increases antenna behavior as compared to edge feed MPA. A planar array is formed using when different number of elements (radiators) is placed along grid in a plane. Planar array is also called as a rectangular array.Advantage of selecting planar is that it provides additional variables (parameters) which can be used to control antenna shape and radiationpattern. These arrays are thusefficientlyused and have capability to provide maximum antenna radiation in desired direction. This is achieved by minimizing the side lobes and un-wanted radiations. Applications of planar array include tracking radar, remote sensing, communications and many more.

Proposed antenna shows good and optimum behavior at the frequency of 1.8GHz. Planar array with high gain, good directivity and radiation efficiency has been synthesized and analyzed.

2. Antenna Theory &Design

Two different antenna has been designed and analysed. A edge feed microstrip patch antenna ("Antenna 1") and a 2 x 2 Planar Array Microstrip Patch Antenna ("Antenna 2").Antennas are shown in figure1.



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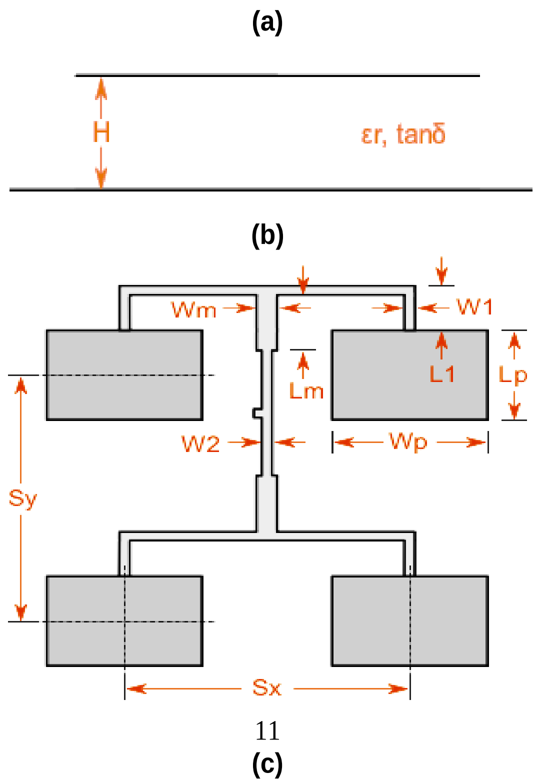

Figure 1 (a) Top View of Edge Feed MPA ("Antenna 1"), (b) Side View of "Antenna 1" and (c) Top View of 2 x 2 Planar MPA Array

Differents steps are involved in design procedure of "Antenna1". Dimension of the patch antenna for desired frequency, relative permitivity and substrate has been obtained using different conventional equations of the microstrip patch antenna systems. These equations are as follows:

$$W = \frac{c}{2f_0}\sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

$$L = \frac{c}{2f_0\sqrt{\epsilon_{eff}}} - 2\Delta L \quad (2)$$

$$L_{eff} = L + 2\Delta L \quad (3)$$

$$\Delta L = 0.412\,h\left[\frac{(\epsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.813\right)}\right] \quad (4)$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-\frac{1}{2}} \quad (5)$$

In these equations, f_0, c and h, are central resonant frequency, c is speed of light and h is the substrate thickness.

"Antenna 2" is a 2x2 planar array. Antenna arrays are formed to improve the radiation characteristics of antenna. This is achieved by selection of phase or amplitude distribution between the elements. Radiation pattern of array antenna is control by the phase of the system. In array antenna, a small side lobe level and small half power beamwidth is desired.

Elements of an array are kept identical, to make it simpler and cheaper, but not necessarily. Total Filed of array is given by vector addition of the fields radiated by the individual elements. For identical element array, current distribution is found to be same in each of the element but it also depends upon the spacing between the elements. Performance of an array depends upon type of array, displacements between elements, excitation phase and amplitude and the radition pattern of the individual element.

Different antenna design parameters used for antenna array are following;

$$(AF)_{xy} = \sum_{n=1}^{N}\left\{\sum_{m=1}^{M}\left[I_{m1}e^{j(m-1)(kd_x \sin\theta\cos\phi + \beta_x)}\right]\right\} \times \left[I_{n1}e^{j(n-1)(kd_y \sin\theta\sin\phi + \beta_y)}\right] \quad (6)$$

$$L_x = \frac{\lambda}{2\sin\theta_{cx}}, L_y = \frac{\lambda}{2\sin\theta_{cy}} \quad (7)$$

$$D_o = \frac{4\pi}{\lambda^2}A_{em} = \frac{4\pi}{\lambda_2}L_x L_y = \frac{\pi}{\sin\theta_{cx}\sin\theta_{cy}} \quad (8)$$

Normalized power pattern of the planar array is given by,

$$P(\theta, \varphi = 0) = b\left(\frac{4\pi L_x L_y}{\lambda^2}\right)\frac{\left[\sin\left(\frac{KL_x \sin\theta}{2}\right)\right]}{\left(\frac{KL_x \sin\theta}{2}\right)} \quad (10)$$

Here, AF is Antenna Factor of the antenna. N & M are the number of elements in X & Y direction respectively.L_x& L_y are the length in x- and y- axis. D_0 is the directivity of the array antenna.

Dimensions and parameters used for "Antenna 1" and "Antenna 2", operating at the frequency of 1.8GHz has been presented in Table 1 & 2 respectively.

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Table 1. Dimensions used for "Antenna1"

S. No.	Parameter	Dimension (mm)
1.	Patch Length (L)	53.59
2.	Patch Width (W)	65.84
3.	Matching Line Width(Wm)	1.602
4.	Matching Line Length(Lm)	31.74
5.	Feeding Line Width (Wf)	5.052
6.	Feeding Line Length (Lf)	30.99
7.	Substrate Height (H)	3.175
8.	Relative Permittivity(ε_r)	2.2

Table 2. Dimensions used for "Antenna2"

S. No.	Parameters	Dimension (mm)
1.	Patch Width (Wp)	65.84
2.	Patch Length (Lp)	54.44
3.	Line 1 Width (W1)	219.6 μm
4.	Line 1 Length (L1)	63.22
5.	Line 2 Width (W2)	970.8 μm
6.	Matching Line Width (Wm)	1.532
7.	Matching Line Length (Lm)	31.77
8.	Patch Spacing in X-direction (Sx)	133.2
9.	Patch Spacing in Y-direction (Sy)	133.2
10.	Substrate Height (H)	3.175
11.	Relative Permittivity (ε_r)	2.2

3. Simulation

This section presents the simulation results obtained for the proposed designs, "Antenna 1" and "Antenna 2". Antennas have been modeled and analyzed antenna simulation software's. Different antenna parameters have been analyzed to obtain the antenna behavior. Figure 2 shows 3D view of the modeled antenna.

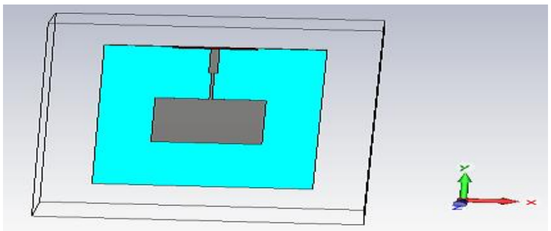

Figure 2(a) Modeled Edge feed Microstrip Patched Antenna ("Antenna 1")

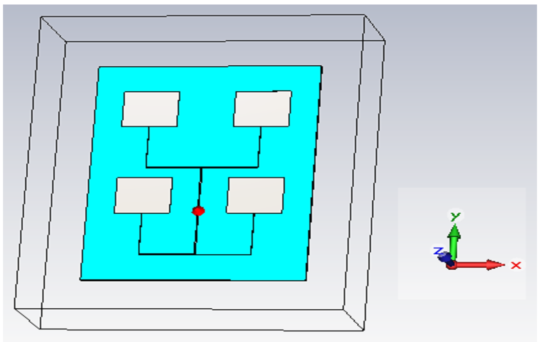

Figure 2(b) Modeled 2 x 2 Planar Microstrip Patched Antenna ("Antenna 2")

3.1 Input Impedance

Antenna impedance correlates voltage and current which are present at the input of the antenna system. Impedance contains real and imaginary part. These parts have their own significance. Real part gives the value of either power which is being transmitted or being absorbed within the antenna itself and imaginary part signifies the non-radiating power. Both of the proposed antennas are resonating at 1.8GHz because they contain only the real impedance value and have very low imaginary part. Input impedance vs frequency plot of "Antenna 1", is shown in Figure 3. Figure 4 shows the 3D simulation plot of far-field of "Antenna 2". It is found that antenna is also having only the real part of impedance at 1.8GHz and imaginary value is zero. Line impedance of the system at frequency 1.8GHz is found to be 70.3044 Ohms.

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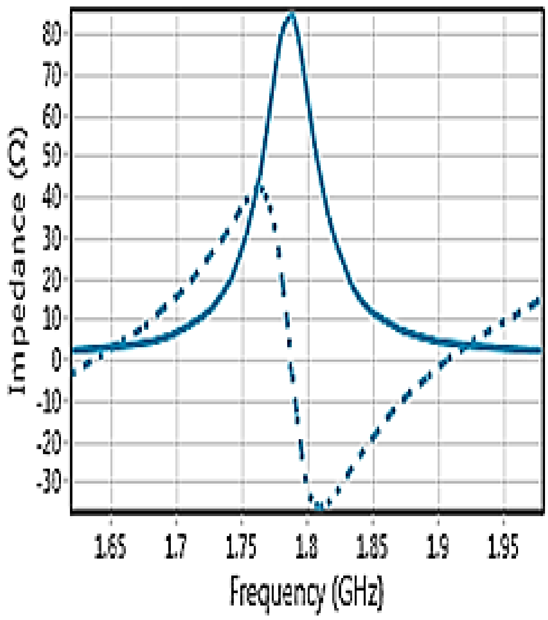

Figure 3 Input Impedance Vs. Frequency plot of "Antenna 1"

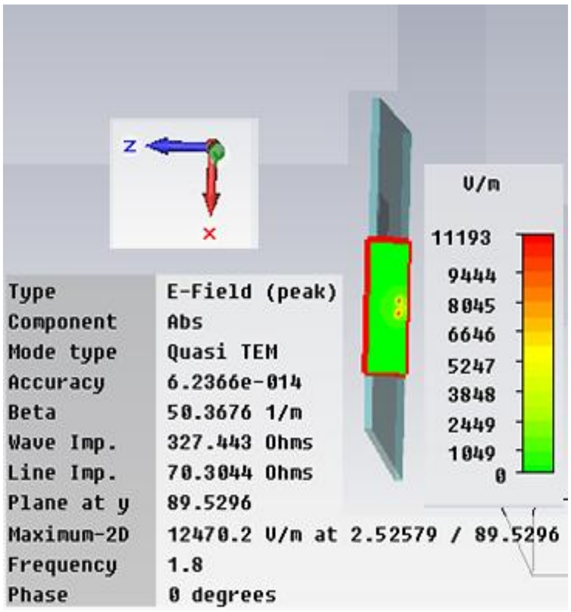

Figure 4 Input impedance of "Antenna 2" at 1.8GHz.

3.2 Return Loss

Ratio of input to output power is defined as the S-parameters or the reflection coefficient. It is also called as return loss parameters. Proposed antenna is a single port excited device, So, S11 Vs. frequency curve of antenna is shown in figure 5. Antenna resonating at 1.8GHz has bandwidth of 5% at -25dB return loss.

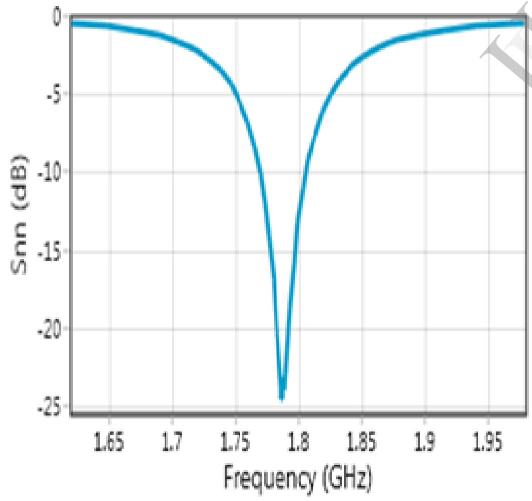

Figure 5 S_{11}Vs. Frequency plot of proposed Antenna

3.3 VSWR

VSWR stands for Voltage Standing Wave Ratio, and is also referred to as Standing Wave Ratio (SWR). It defines the ability of antenna as a radiator.VSWR of antenna should be real because it is a parameter which indicates the radiating nature of the antenna as well as matching of antenna to the transmission line. So, higher VSWR value indicates mismatch of antenna impedance while the smaller value of VSWR indicates good antenna matching. Figure 6 shows the VSWR vs. Frequency curve of proposed antenna. VSWR value is found to be 1.2 at resonating frequency of 1.8GHz.A VSWR, value of 1.2, indicates reflected power of 3% (-20.8dB).

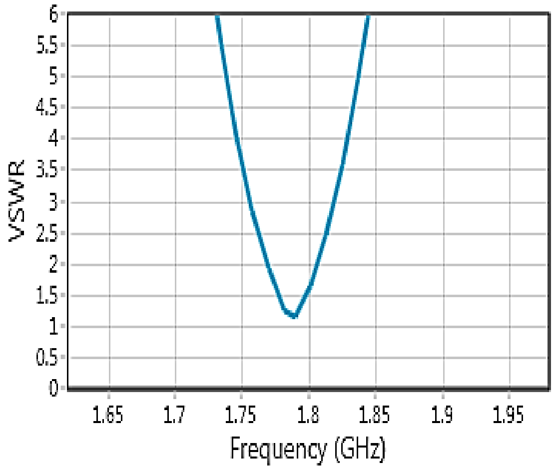

Figure 6 VSWR Vs. Frequency plot of proposed Antenna

3.4 Radiation Pattern

A radiation pattern defines the variation of the power radiated by an antenna in a desired direction to that of undesired direction. Figure7 (a) presents the gain of the "Antenna 1". Maximum gain of system is found to be 5dBi. Figure 7 (b) presents the gain of the "Antenna 2" which has a maximum value of 7 dBi at 1.8GHz.

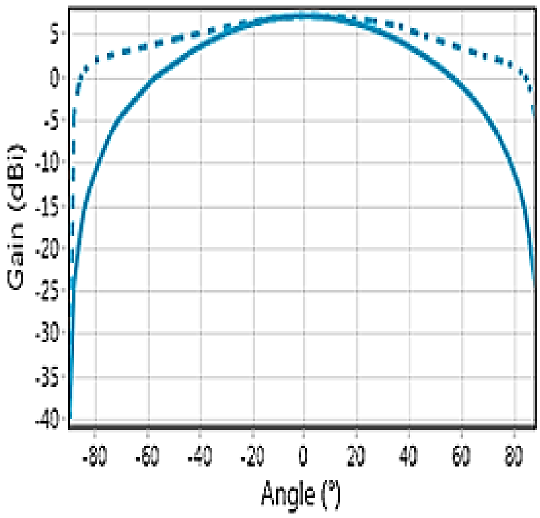

Figure 7(a) Radiation pattern in terms of Gain for an "Antenna 1".

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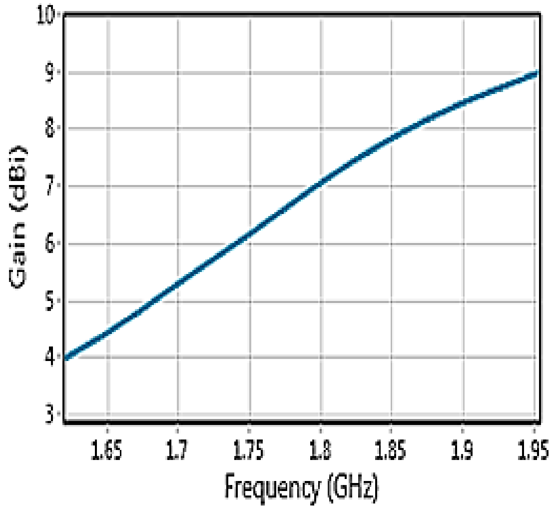

Figure 7(b) Gain vsFrequency plot of "Antenna2"

Figure 7(c) shows the radiation pattern of "Antenna 2". Standard spherical coordinates are used, where θ is the angle measured off the z-axis, and φ is the angle measured counterclockwise off the x-axis.

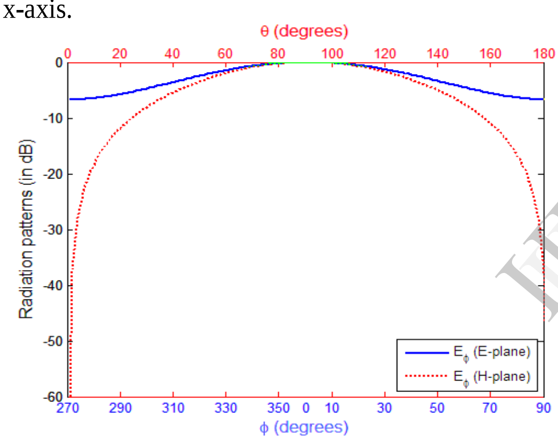

Figure 7(c) Radiation pattern of "Antenna 2"

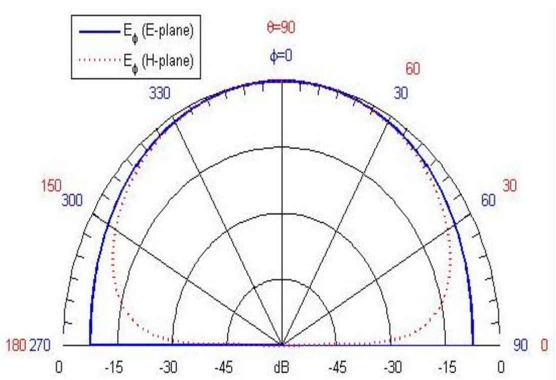

Figure 7(d) E and H plane pattern of "Antenna 2"

Radiation pattern in terms of field parameters is shown in Figure7 (d). It shows that H-plane has maximum value in θ= 90^0 while E-plane has the minimum value in this direction and maximum value in φ = 0^0.

3.5. Directivity

Directional property of the antenna is given by directivity of antenna. Directivity indicates the peak power radiation in a particular direction to the average power radiated by the antenna in all the direction. Directivity of "Antenna 1" is shown in figure 8 (a) and has value of 8.204dBi with radiation efficiency of 0.8% in the direction at 1.8GHz while the "Antenna 2" has directivity of 13.77dBi with radiation efficiency of 5.085% at 1.8GHz. Figure 8 (b), presents directivity of "Antenna 2".

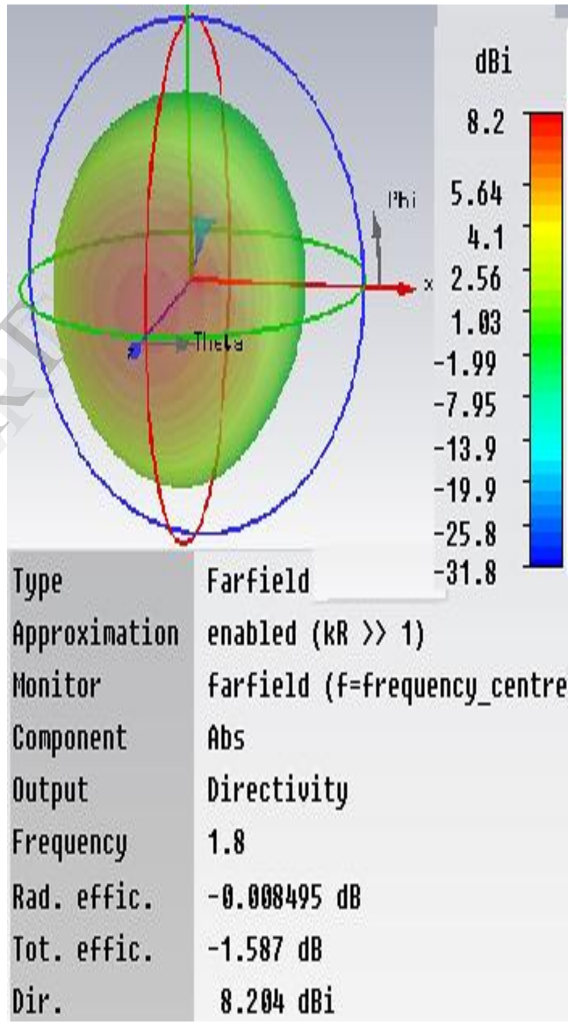

Figure 8(a).Directivity of "Antenna 1"

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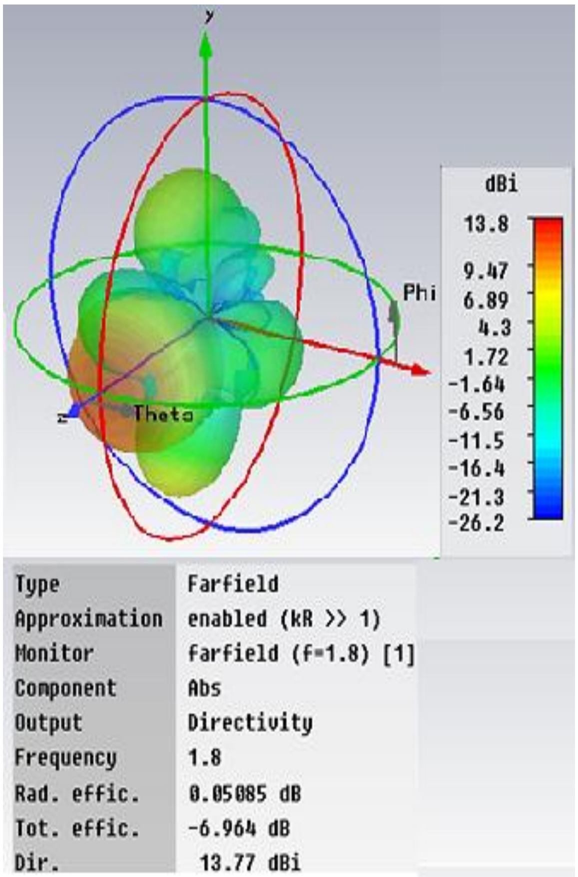

Figure8(b). Directivity of "Antenna 2"

4. Discussion

Substrates used for the placement of antenna plays an important role;its height affects performance of antenna. Antenna having thicker substrate gives way to surface wave while a thinner one will have more copper loss (metallic loss). In case of edge feed MPA, resonant frequency can be controlled by changing the length of patch parametrically. Patch width affects the bandwidth of the system. High band-width is achieved by a wider patch MPA.

Fabrication complexity of "Antenna 2" is more, than that of "Antenna 1" but has advantage over the "Antenna 1". "Antenna 2" which also resonates at the center frequency of 1.8GHz, same as "Antenna 1", but it has good gain and good directivity value as compared to "Antenna 1". Radiation efficiency of "Antenna 2" is much better than that of "Antenna 1".

5. Conclusion

In this paper two different antenna systems has been synthesized and analyzed. Techniques of improving the antenna performance by incorporating antenna array have been investigated. Observation obtained shows; the array has 28.57% more gain than that of the single element system. Directivity of planar array is increased by 40.42% and radiation efficiency is also moved from 0.8 % (single element system) to5.085% (array antenna) in multi-element antenna.

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6. Acknowledgment

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7. References

[1]C. A. Balanis,"Antenna Theory-Analysis and design", Second Edition, John Wiley & Sons., New York, 1997.

[2] R. J. Mailloux, J. F. McIlvenna, and N. P. Kernweis, "Microstrip array technology," IEEE Trans. Antennas Propag., vol. 29, no. 1, pp. 25–37, Jan. 1981.

[3] E. Levine, G. Malamud, S. Shtrikman, and D. Treves, "A study of microstrip array antennas with the feed network," IEEE Trans. AntennasPropag., vol. 37, no. 4, pp. 426–434, Apr. 1989.

[4] J. H. Cloete and L. J. du Toit, "Linear patch array pattern degradation due to corporate feed radiation," in Proc. IEEE AP-S Int. Symp., vol. 2, Syracuse, NY, 1988, pp. 466–469.

[5] Pozar, D.M. and Schaubert, D.H., Microstrip Antennas, IEEE Press, Piscataway, NJ, 1995.

[6] Targonski, S.D., Waterhouse, R.B., and Pozar, D.M., Wideband aperture coupled microstrip patch array with backlobe reduction, Electron. Lett., vol. 33, pp. 2005–2006, Nov. 1997.

[7] Serrano-Vaello, A. and Sanchez-Hernandez, D., Printed antennas for dual-band GSM/DCS 1800 mobile handsets, Electron. Lett., vol. 34, pp. 140–141, Jan. 22, 1998.

[8] Huang, J., A technique for an array to generate circular polarization with linearly polarized ele- ments, IEEE Trans. Antennas &Propagat., vol. 34, pp. 1113–1124, Sept. 1986.

[9] Pozar, D.M., Scanning characteristics of infinite arrays of printed antenna subarrays, IEEE Trans. Antennas &Propagat., vol. 40, pp. 666–674, June 1992.

[10] Rowe, W.S.T. and Waterhouse, R.B., Comparison of broadband millimetre-wave antenna structures for MMIC and optical device integration, IEEE Antennas & Propagation Symposium, Salt Lake City, Utah, pp. 1406–1409, July 2000.

[12] Buckley, M. J., "Synthesis of shaped beam antenna patternsusing implicitly constrained current elements," IEEE Trans. OnAntennas and Propag., Vol. 44, 192–197, February 1996.

[13] Marcano, D. and F. Duran, "Synthesis of antenna arrays usinggenetic algorithms," IEEE Antennas and Propagation Mag.,Vol. 42, 12–19, June 2000.

[14] Cui, B., J. Zhang, and X. W. Sun, "Single layer micro-stripantenna arrays applied in millimeter-wave radar," Journal ofElectromagnetic Waves and Applications, Vol. 22, No. 1, 3–15,2008.