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HIGH GAIN PLANAR ARRAY WITH FIVE RECTANGULAR PATCHES FOR SECOND GENERATION AND THIRD GENERATION MOBILE COMMUNICATION SYSTEM

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Abstract: This paper presents the design, simulation and characterization of a compact second generation mobile communication and third generation mobile communication for high power antennas for base transmission station with five element planar array with rectangular patches .The concept of electromagnetic coupling is used for impedance matching over a Universal mobile telecommunication bandwidth using a multisection matching transformers. Five patch elements designed array are produced at central frequencies of 2.135 GHz and relative bandwidth larger than 41.9% for return loss less than -10 dB. Results of Arrays are simulated by HFSS software and CST microwave studio software produced peak gain of more than 34 dB.

Keywords: High power antennas, Multisection matching transformer, Rectangular patches, Second generation and third generation, universal mobile telecommunication bandwidth.

I. INTRODUCTION

High gain and high power (HGHP) microwave applications require the design of special type of antennas. Antennas arrays must be compatible with the bandwidth, the impedance and with the radiation characteristics (gain, directivity, and polarization) of the system [1]. For HGHP applications, more than one constraint have to be considered, particularly high-power, high gain for antenna array and their weight values, and location of elements of antenna array and coupling coefficients between the elements .This antenna array provides high compactness which is necessary for highly populated cities [2]. Implementing this proposed system, we are able to start third generation provide within the old second generation system, without replacement of second generation system. So overall installation cost for this combined system would be comparatively low than implementing second and third generation system as a separate entity. In this paper, our work is focused on the new design of a UMTS band (relative bandwidth > 41.9%) antennas array to achieve high gain in a particular direction or in a specific location [2].

The rectangular patches are one of the solutions to obtain a compact antenna .But common geometry has a narrow bandwidth of around 1%.Therefore this work was undertaken to obtain a patch with a greater bandwidth, high power and high gain. Wideband patches have already been obtained, with a related bandwidth of 50% and a low profile. They are mainly used in telecommunications, as their designs are not suited to high power high gain for 2G and 3G applications [10]. We propose here a new type of multisection matching transformer electromagnetic coupled rectangular patch array which is particularly designed for the high power and high gain applications [2]. This paper is a part of a Master degree Thesis undertaken at the Jabalpur Engineering College. We first present the design and the experimental characterization of a single antenna that operates at 2.135 GHz. We then outline the simulated results of the high power high gain rectangular patch antenna. Finally, by HFSS and CST Microwave Studio simulations, we adapted a design of a higher frequency antenna. The first results on a 2.135-GHz broadband patch design are presented which comes under the UMTS band.

II. SINGLE PATCH ANTENNA STRUCTURE AT 2.145 GHZ

A. Design of Rectangular patch:

We initially worked on a single patch antenna that was planned to be combined with the multisection matching transformer strip feed line to achieve appropriate impedance matching using electromagnetic coupling. It was built to radiate high power with high gain at centre frequency of 2.135 GHz. Fig 1a shows cross section structure of an antenna element and Fig. 1b shows the simulated three

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dimensional structure of the single high gain rectangular patch antenna after design process keeping percentage bandwidth as a major issue in mind . It consists of a metal plate (patch) suspended above a ground plane. Two feed line microstrip steps are used to avoid unnecessary loss of power and also reflections are eliminated and to achieve large bandwidth that suited the requirement of 2G and 3G systems. The patch and multisection microstrip feed line dimensions adjust the working frequency and the bandwidth. The length of the patch is 51.8 mm and is 65.8 mm wide. The patch is suspended above the ground plane at a height of 24.4 mm is 51.8 mm and is 65.8 mm wide. The patch is suspended above the ground plane at a height of 24.4 mm.

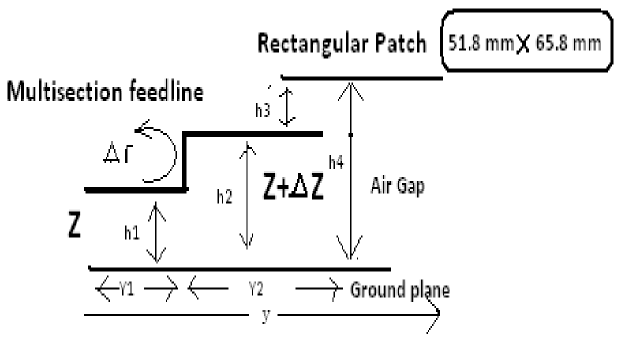

Fig. 1a: Shows Cross section of multisection step feeding and electromagnetically coupled rectangular patch.

Where h1 = 3mm h3 = 8.56 mm
h2 = 11.84 mm h4 = 20.4 mm

A change in reflection coefficient is given by:

$$\Delta\Gamma = \frac{(Z+\Delta Z)-Z}{(Z+\Delta Z)+Z}$$

Matching point impedance at a distance y ,

$Z(y) = Z_0 e^{ay}$ Where a = multisection stepping constant

$$a = \frac{1}{L}\ln\left(\frac{Z\ell}{Z_0}\right)$$

Z_0= initially calculated impedance while length, width, height and dielectric material is considered.

$Z\ell$= Impedance of multisection matching transformer feed line.

Percentage Bandwidth = Upper frequency minus lower frequency over the center frequency of the bandwidth.

$$B.W.\% = \frac{fu - f\ell}{fc} \times 100$$

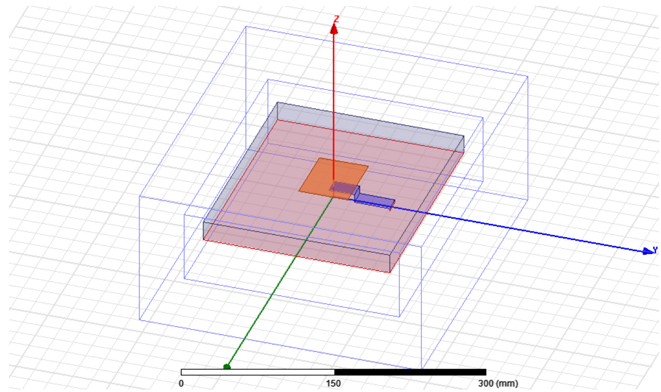

Fig. 1b: Structure of high gain Patch antenna

Multisection feeding has been preferred for several reasons such as to achieve minimum reflection coefficient, larger bandwidth, ease of impedance matching, to avoid unnecessary loss of power [3]. It was simulated on HFSS Software .We are using in this structure, the air as dielectric .Also the dielectric strength can be easily increased for a given high-voltage pulse, by avoiding electric field reinforcements and by inserting dielectric materials like FR4.The volume area between the patch and ground plane (thickness 20.4 mm; $\varepsilon_r = 1$) is filled with air. This insulator has no influence on the main performance of the antenna in the working frequency bandwidth. The height between the stand and the ground plane is adjusted to 20.4 mm to ensure sufficient electric insulation. This value appears to offer a good compromise between the S11 parameter and high voltage considerations. Fig. 2 is a monitoring of the E-field in the structure of the antenna.

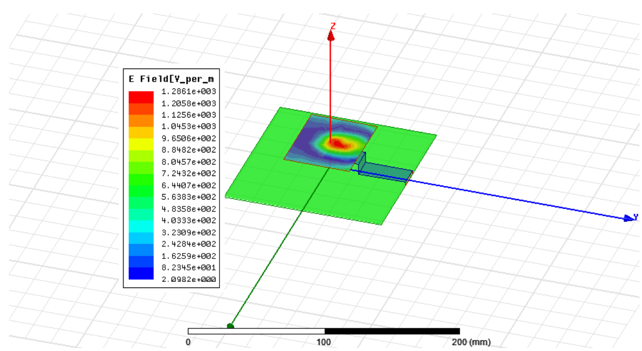

Fig.2: Monitoring of E-field in the structure of the antenna

The transmission antenna is a Universal mobile telecommunication system antenna directly connected to a real-time high-bandwidth scope. The gain achieved in the far field direction is presented in Fig. 3. The maximum measured gain is 8.37 dB at 2.135 GHz in simulation. The relative bandwidth in gain (−10dB) is 41.9% for the simulation. Fig. 4 shows simulated radiation patterns in the

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H and E planes at 2.135 GHz. The pattern is symmetrical in the H plane (symmetry plane of antenna).

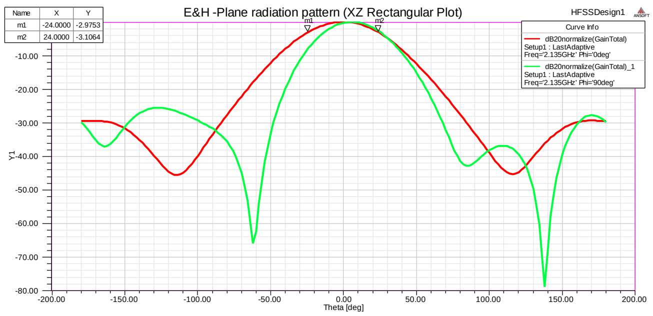

Fig. 3 Electric and magnetic (phi = 0° and phi = 90°) radiation pattern comparison for single rectangular patch.

B. Patch and multisection impedance transformer:

The following section proposed a simple solution using a quarter-wave transformer that can be extended to multisection design for broader bandwidths [4]. It is having a 50-Ω patch with a 50-Ω multisection feed line and also with 50-Ω wave port .In a transmission line with a characteristic impedance Z_0, no loss, loaded by ZL, the impedance at a distance y from the load is defined by :

$$Zy = Z_0 \frac{Z\ell + jZ_0 \tan(\beta y)}{Z\ell - jZ_0 \tan(\beta y)}$$

When y = λ/4, $Zy = \frac{Z_0^2}{Z\ell}$

The equivalent output impedance Zy is 50Ω. ZL is the impedance of the antenna (50 Ω). Z_0 must be equal to 50 Ω to obtain a good match. Here it is observed that from the simulations results impedance matching is near about 85% at frequency of 2.135 GHz as shown in fig 4. It can be extend by consideration of different constraints through deep optimization process.

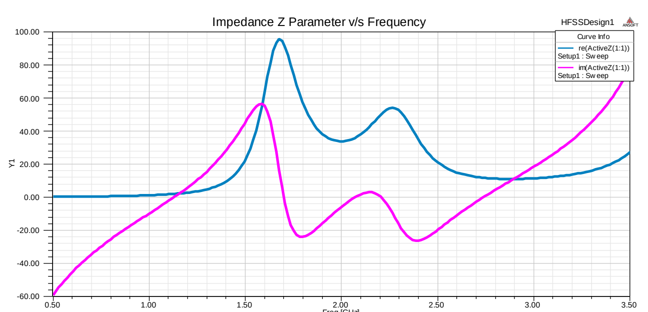

Fig. 4 : Impedance real and imaginary part of antenna combined with multisection stepping feed line.

The impedance simulated results by HFSS software is given in above fig. 4. The impedance real part of the patch antenna combined with the multisection step feed line oscillates between 41 and 50 Ω in the operating bandwidth.

III. DESIGN OF FIVE-PATCH ANTENNA ARRAY

This section presents the study of an array of broadband patches to improve the gain and radiated field. Five patch antennas are combined to form an array. Fig. 5 shows this array and its size.

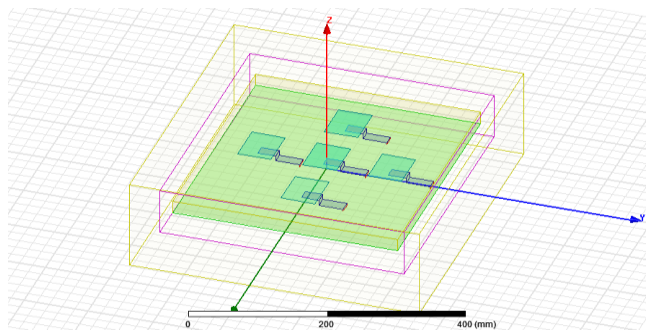

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Fig. 5 Structure of the high gain rectangular patch antenna

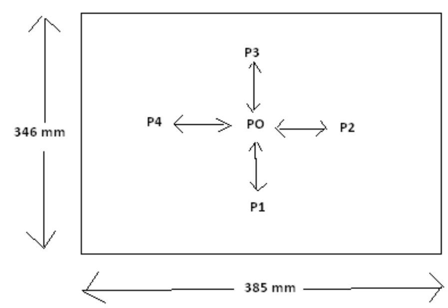

Fig.5a. represents the symmetric array elements locations of rectangular patch antennas

Distance between E- plane patches is 48.7 mm and H-plane patches are 34.7 mm [1]. Fig.6 shows the coupling parameters (Sij) that represent the coupling coefficients between the patches and also return loss parameters simulated when excitation is simultaneously applied to all the antennas. The value of excitation weight of P0 is 0.268 volt and that of P1, P2, P3 and P4 are same and the value is 0.183 volts during the simulation process in HFSS software. The simulated results by HFSS software shows that the coupling losses between the E- and H- plane of microstrip patch antennas ranges from 20 dB to 28 dB. In this case, the coupling loss is considerable [3]. The maximum measured peak gain is 34 dB at 2.14 GHz in simulation. The peak realized gain is 33.61 dB in the far field simulation. The array provides a gain increase in 25.63 dB. Radiation efficiency is 94%.

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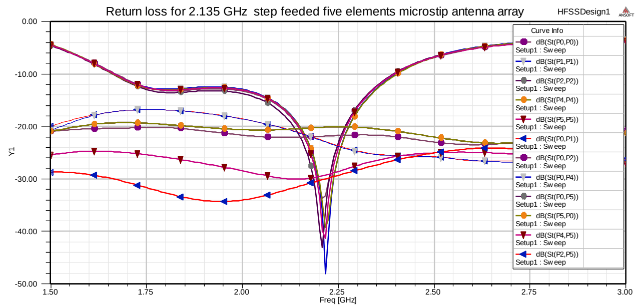

Fig. 6: shows the coupling parameters representing the coupling coefficients between the patches and also return loss parameters.

Multisection feeding microstrip line are used to match as shown in fig.6, to achieve a good matching between the wave port, multisection feed line and rectangular patches. Real part of rectangular patch antenna is equal to characteristic impedance of multisection feed line which is shown in fig. 7 using smith chart. So that the bandwidth can be increased by 84% by employing such multisection feed line construction in each case. Such type of construction provides higher bandwidth of 41.9% and distance from the port to load also verified by using this smith chart which is approximately 36mm.

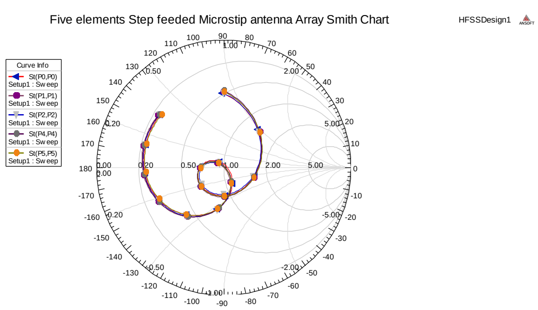

Fig. 7: Smith chart for a five elements planar array

Multisection feeding microstrip line are used to match as shown in fig.5, to achieve a good matching between the wave port, multisection feed line and rectangular patches[4]. Real part of characteristic impedance of rectangular patch antenna is equal to of multisection feed line which is shown in fig.4. So that the bandwidth percentage can be increased by 84% by employing such multisection feed line construction in each case of patches in the proposed antenna array. Such type of construction provides higher bandwidth of 41.9%

In the Smith chart the impedance matching observed graphically by simulation software HFSS and CST microwave studio which gives the voltage reflection coefficient values in form of polar plot.

Antenna array consist of five elements. Each element is having the same port impedance equal to 50 ohms and thus their transmission line characteristics are identical which are as follows:

1. Magnitude of reflection coefficient of each element from smith chart is 0.0846 and calculated result (by using equation 5.1) is 0.098.
2. Voltage standing wave ratio of each element from smith chart is 1.40 and calculated result (by using equation 5.3) is 1.21.
3. Phase of reflection coefficient of each element from smith chart is 158° and calculated result (by using equation 5.2) is 154°.

$$\Gamma = \frac{z_L - 1}{z_L + 1} = |\Gamma| \, e^{j\theta} \quad ; \qquad \text{equation (5.1)}$$

$$\theta = \pi + 2\beta l \quad ; \quad -180° < \theta < 180° \qquad \text{equation (5.2)}$$

Where $z_L = Z_L / Z_0$ is normalized impedance
$z_L = (0.812 + j\,0.052)\,\Omega$ (calculated value)
Z_L And Z_0 are load impedance and characteristic impedance
of each element in proposed array.

$$VSWR = (\Gamma + 1) / (\Gamma - 1) \quad ; \qquad \text{equation (5.3)}$$

IV. SIMULATED FAR-FIELD RADIATION PATTERNS FOR PROPOSED ANTENNA ARRAY

The proposed antenna array geometry is designed by using HFSS which is a full wave finite element electromagnetic (EM) simulator In Fig.8, the simulated radiation patterns at the centre frequency, fc = 2.14 GHz, on E and H planes, are plotted. According to the Fig.8, antenna array produces a good broadside radiation pattern at 2.14 GHz and the peak gain is obtained to be around 33.61dB.The rectangular plot for normalized electric and magnetic field radiation patterns are shown in fig. 8a and 8b respectively.

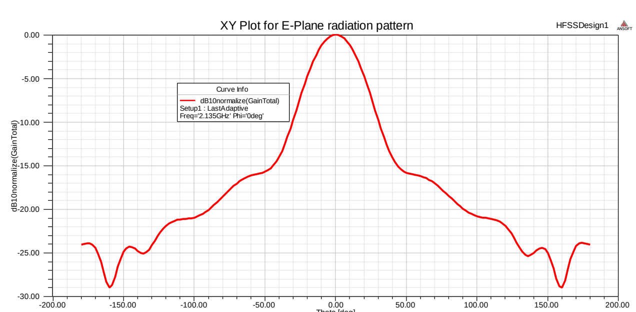

Fig. 8a

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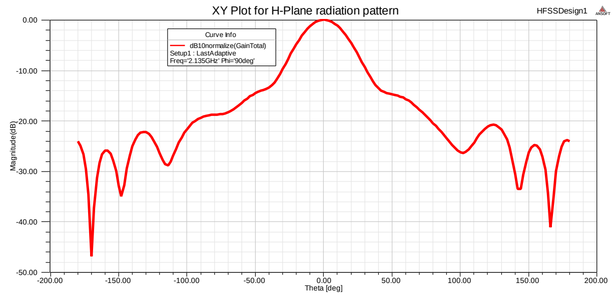

Fig 8b

The polar plot for normalized electric and magnetic field radiation patterns are shown in fig. 9a and 9b respectively

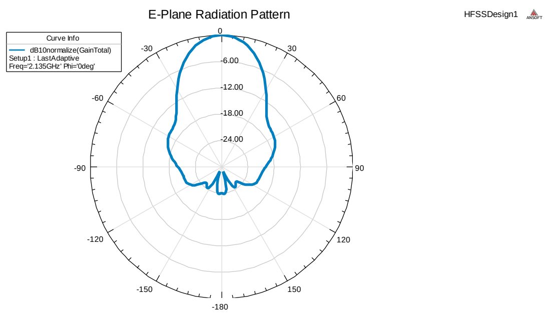

fig. 9a

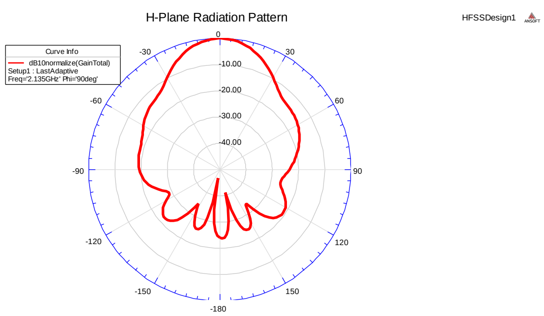

fig. 9b

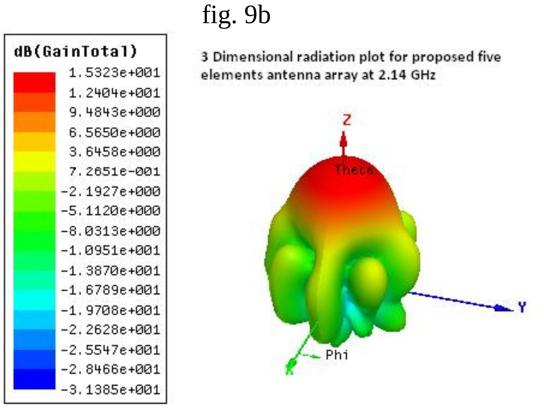

Fig. 9c: Three dimensional radiation polar plots

The three dimensional radiation patterns for five element array by keeping the same phase excitation between the elements in the normal direction (broadside) and different magnitudes. It is observe that maximum radiations finally oriented in z – direction. Here to achieve such radiation pattern, the phase excitation between the elements keeps constant. The principle of electronic scanning phased array operation can be accomplish by controlling the progressive phase difference between the elements for any desired direction..

V. CONCLUSION

The proposed five elements microstrip antenna array is capable of radiating high electromagnetic fields. Implementation of this antenna array is very simple and provides electromagnetic performances such as broad bandwidth, high gain, good impedance matching, low thickness, and high power capabilities which are suitable for mobile base stations and suits current second, third generation and upcoming fourth generation of mobile communication. The proposed antenna array has high directivity (38) and the relative gain obtained is higher than 34 dB. It is also linearly polarised. The thickness of the antenna is less than 20.4 mm at the central frequency. Finally, the recent simulated results on the 2.14-GHz rectangular patch array have evidenced that it is possible to improve matching and bandwidth by adding reflection (Sii) and coupling parameters (Sij). The focus must be therefore definitely on the length of the multistep feed line and gap between patch and multistep feed line and position point between patch and feed line. However even though there is some inductive reactance of magnitude around 2.6 ohm still exist in proposed antenna. We suggest that it can be minimize by proper optimization process. Based on the results, we could suggest that proposed array can be further optimize in terms of coupling parameters and size of array by using FR4 dielectric materials and dimensions of rectangular patches, multistep feed line position and size. The focus must be therefore definitely on the position of the antennas and the distance between them.

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REFERENCES

[1] Constantine A. Balanis, “Antenna Theory analysis and design.”
[2] Joo Seong Jeon , KT Freetel Seoul, Korea “Design of wideband patch antennas for PCS and IMT -2000 service”
[3] D. M. Pozar, “Microstrip Engineering,” Willey India Edition”, Edition third, pp.126,1989
[4] Samuel Y. Liao,” Microwave Devices and circuits”
[5] W. Kian and Z. N. Chen, “On a broadband elevated suspended-plate antenna with consistent gain,” IEEE Antennas Propag. Mag., vol. 50, no.2, pp. 95–105, Apr. 2008.

[6]. M. Beruete, I. Campillo, J. S. Dolado, J. E. Rodríguez-Seco, E. Perea, F. Falcone, and M. Sorolla, “Very low profile and dielectric loaded feeder antenna,” IEEE Antennas Wireless Propag. Lett., vol. 6, pp. 544–548, 2007
[7] S.A. Long, M. W. McAllister and G. L. Conway, “Rectangular dielectric resonator antenna,” IEEE Transactions on Antenna and Propagations, vol.31, pp. 406-412. 1983
[8] S. K. Pavuluri, C. Wang, and A. J. Sangster, “High efficiency wideband aperture-coupled stacked patch antennas assembled using millimetre thick micro-machined polymer structures,” IEEE Trans. AntennasPropag., vol. 58, no. 11, pp. 3616–3621, Nov. 2010.
[9] K.F. Lee, et al., “Experimental and SimulationStudies of the Coaxially Fed U-slotRectangular Patch Antenna,” IEE Proceedings-Microwave Antennas and Propagation,Vol. 144, No. 5, 1997, pp. 354–358..
[10]. K.L. Wong and W.H. Hsu, “Broadband Triangular Microstrip Antenna with Ushaped Slot,” Electronics Letters, Vol. 33,No. 25, 1997, pp. 2085–2087