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HIGH GAIN AND LOW COST ELECTROMAGNETICALLY COUPLED RECTAGULAR PATCH ANTENNA

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Abstract: **This paper present high gain and wideband electromagnetically coupled patch antenna. A multisection step shape feed line structure is introduced in order to increase impedance band width. A parasitic reactance reduction from feed line, minimize spurious radiation by using a wide band impedance matching capability of Electromagnetic coupling feed line [2]. The rectangular patch most widely used configuration because readily allows theoretical analysis design antenna array and which has impedance bandwidth and gain of array which can be used for second generation and third generations of mobile communications system. It can also be used in high power mobile communications base stations. Thus we proposed low cost because it can be constructed with air dielectric substrate. The simulated results shows that the improved performance of the proposed antenna compared to the traditional microstrip feed line antenna. We proposed a novel radiating element with multisection transformer matching to realize strong radiating power, low reflection, and low cross-polarization, simultaneously. The simulated performances of low-sidelobes of proposed antenna were demonstrated in this paper. The design is investigated at the center frequency of 2.135 GHz; and simulated through HFSS software and CST microwave studio software. Both software simulated results are identical. The measurement results indicate that the proposed antenna exhibits a broad bandwidth of 37% in which the return loss is below -10 dB and from the simulations results, impedance matching is near about 85% at frequency of 2.135 GHz However, the antenna structure can also be easily scaled to other frequency bands such as GSM1800, GPS, ,3G UMTS, etc.**

Index Terms: **Broad bandwidth, Electromagnetic coupling, multisection step shape feed line, Universal Mobile telecommunication system (UMTS), Global positioning system (GPS).**

I. INTRODUCTION

A widely used microwave antenna is the rectangular microstrip antenna. One of the attractive features of this antenna is its simplicity in construction. The number of users of second generation and third generation mobile communications is growing fast and maintaining capacity has always been a challenge as the number of services and subscribers are increased. So to overcome the capacity demand required by the growing number of subscribers, cellular radio systems have to enhance year by year. The need for 2G and 3G antenna systems in the current cellular systems structure require high power, high gain antenna best suited the current scenario. Also there is a reutilization of the existing base stations and there is need to increase the channel capacity in large channels user areas and to increase the range of the cells in highly populated areas . The mobile communications make use of the UHF frequency range, which is suitable in many aspects, but still does not allow enough channels to the users. The mobile base station now days increasing continuously but it is very difficult to acquire the land or multistory top floor because there is high installation cost as well environmental issue from government regulation act. The cellular system technology with power control and the time-division multiple access (TDMA) and the code division multiple access (CDMA) technologies already improve channel capacity significantly. In addition to those, the control of the antenna radiation pattern is seen as a very promising way to improve the capacity of the cellular systems. The antenna radiation pattern can be controlled electronically if an antenna array technology is used. Therefore there is a need to develop an antenna that could serve as a controlled high power high gain antenna system for mobile communications. If the narrow bandwidth of the microstrip antenna can be widened, then it can used for second generations, third-generations and upcoming fourth generation of mobile communications systems and in which we are mainly focused to increase the band width as well as gain of the antenna. UMTS, known as the most popular mobile communication technology, allows high quality sound and data transmission between mobile phones developed for third generation users. If the proposed antenna is used as elements to form an array, then that array will possesses the attributes to provide the necessary

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bandwidth, scanning capabilities, beam width and low side lobe levels.

II. SINGLE PATCH ANTENNA STRUCTURE AT 2.135 GHz

Rectangular patch is the most widely used configuration because its shape readily allows theoretical analysis. The maximum coupling occurs when distance from port is approximately equal to half the length of the patch. The design parameters for the optimized rectangular patch antenna are listed below fig. 2. A photograph of the fabricated rectangular patch antenna is shown in fig. 2. The rectangular patch and the ground plate were constructed using 0.3 and 1 mm thick copper metal plates, respectively and loss tangent (0.0009) is considered. Multisection stepping feed line and rectangular patch cross section is shown in fig. 1.

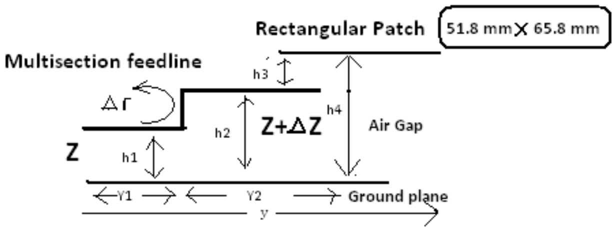

Fig. 1: Shows Cross section of multisection step feeding and electromagnetically coupled rectangular patch.

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 rate 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.

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

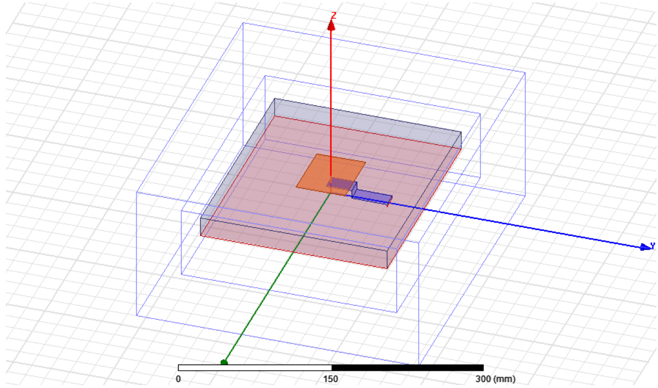

Fig. 2: Rectangular patch antenna designed in HFSS

Where, Patch Length = 51.8 mm
Patch width = 65.8 mm
Substrate height =20.4 mm
Width of feed strip =8.84 mm

We initially worked on a multisection matching transformer to achieve appropriate impedance matching using electromagnetic coupling. It was built to radiate high power with high gain at center frequency of 2.135 GHz. Fig. 2 shows the structure of the high gain patch antenna after optimization. It consists of a metal plate (patch) suspended above a ground plane. Multisection 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.

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 [2]. 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.

III. SIMULATED RESULTS BY HFSS AND CST MICROWAVE STUDIO SOFTWARE:

. The proposed antenna geometry is designed by using HFSS which is a full wave finite element electromagnetic (EM) simulator and CST Microwave studio. The return loss variations obtained via HFSS and CST Microwave studio for antenna with air-like substrate are plotted in Fig. 3a and 3b, respectively and as it is clearly observed that the results have similar characteristics. As it can be seen from the Fig. 3, microstrip rectangular patch antenna with air-like substrate

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exhibits broadband characteristic from 1.65GHz to 2.40 GHz (41.9% impedance bandwidth) for S11 ≤ -10dB threshold level and it covers whole UMTS band (1.9-2.2GHz). However, it is large in size with the dimensions of 51.8mm x 65.8mm x 20.4 mm and practical for UMTS mobile transmitter base stations.

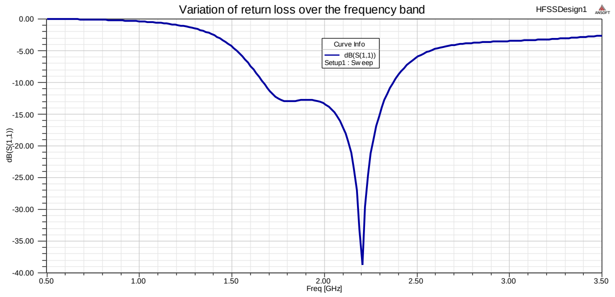

Fig. 3a

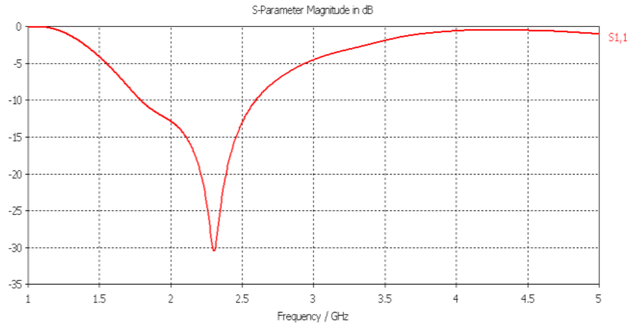

Fig. 3b

Fig. 3: Return loss variations obtained for antenna with air substrate (a) HFSS results (b) CST MICROWAVE results.

In Fig. 3c, the simulated radiation patterns at the center frequency, fc = 2.135 GHz, on E and H planes, are plotted. According to the Fig. 3c, both microstrip patch antennas produces a good broadside radiation pattern at 2.135 GHz and the peak gain is obtained to be around 8.4dB in HFSS simulation and 8.382dB in CST Microwave simulation. Furthermore, half-power beam width is calculated for E-Plane, where ϕ = 0° and for H-Plane, where ϕ = 90°.

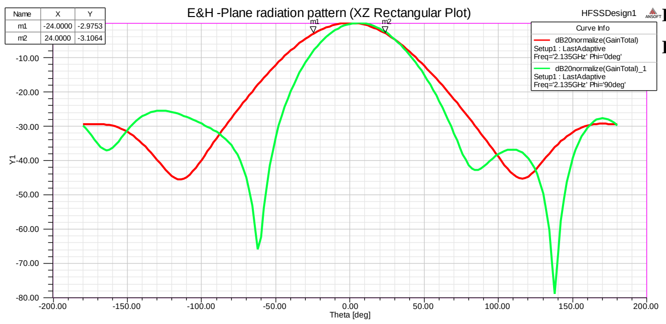

Fig. 3c: Shows E and H - plane pattern for 8.382-dB standard-gain rectangular patch at 2.135 GHz.

Half power beam width is the power pattern (in dB) yields the 48° angular separation between two half power points (-3 dB) relative to maximum value (resonance frequency point) of the pattern[3]. From above fig.3c half power beam width = 48°.

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IV. FAR FIELD RADIATION PATTERN PLOTS

Fig. 4a and 4b shows the polar plot for radiation pattern in the E plane and H plane for frequency 2.135 GHz. The pattern is symmetrical in the E and H plane (the symmetry plane of antenna). The relative bandwidth obtained is higher than 37%. The peak gain obtain is equal to 8.4 dB.

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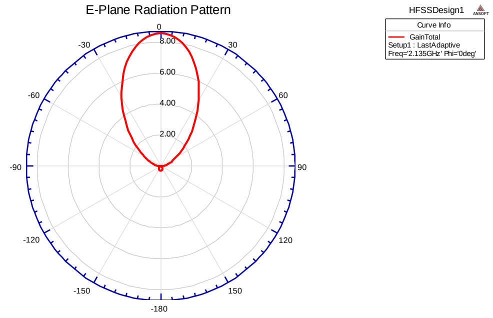

Fig. 4a: principal E-Plane radiation pattern

In principal E -Plane radiation pattern which is YZ plane (considering antenna construction figure.2) containing the electric field vector and the direction of maximum radiation taking position phi at 0°.

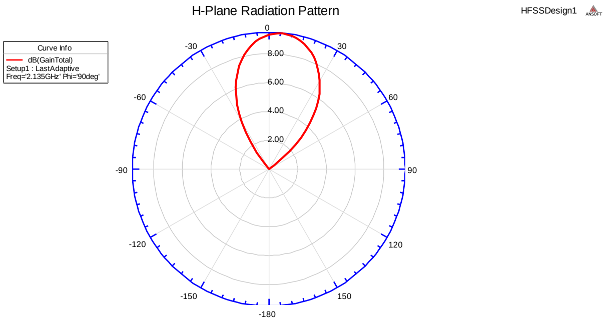

Fig. 4b: principal H -Plane radiation pattern

In principal H-Plane radiation pattern which is XZ plane (considering antenna construction fig. 2) containing the magnetic field vector and the direction of maximum radiation taking position phi at 90°.

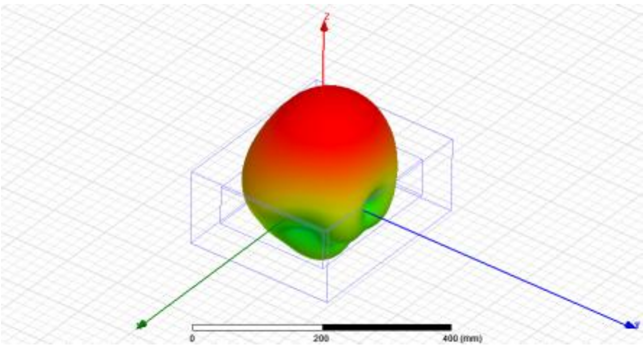

Fig. 4c

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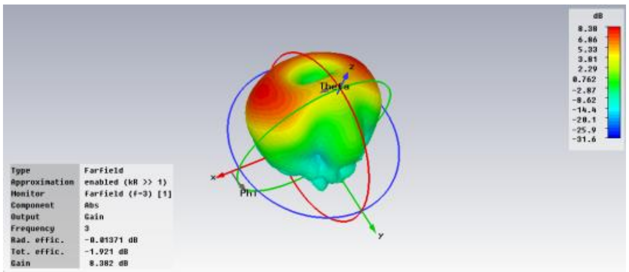

Fig. 4d

Simulated radiation patterns by HFSS and CST microwave software are in fig. 4c and 4d respectively. Both radiation pattern are identical and gain obtain in direction of maximum radiation is 8.4 dB and 8.38 dB respectively.

V. SMITH CHART RESULTS AND IMPEDANCE PLOTS

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.

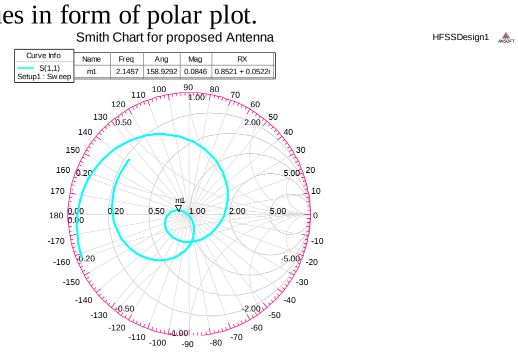

Fig. 5a

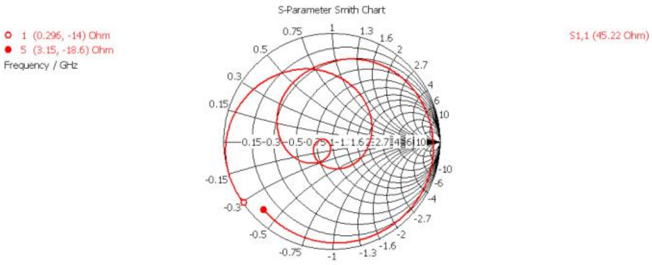

Fig. 5b

From simulation results and calculations through the parameters all results are verified and nearly equal to each other. Following results are as:

1. Magnitude of reflection coefficient from smith chart is 0.0846 and calculated result (by using equation 5.1) is 0.098.

2. Voltage standing wave ratio from smith chart is 1.40 and calculated result (by using equation 5.3) is 1.21.

3. Phase of reflection coefficient from smith chart is 158° and calculated result (by using equation 5.2) is 154°.

For proposed antenna and multisection feed line, characteristic impedance Z_0 is terminated with a port impedance [4]. From the smith chart, value of reflection coefficient is calculated as given below:

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

$$\theta = \pi + 2\beta l \quad ; \text{equation (5.2)}$$

$$-180° < \theta < 180°$$

Where $z_L = Z_L / Z_0$ is normalized impedance

Z_L and Z_0 are load impedance and characteristic impedance respectively.

VSWR =. (Γ + 1) / (Γ – 1); equation (5.3)

The multisection step feed line has a tendency to maintain high impedance matching level over the entire frequency band [3]. Thus there will be no standing waves on the feed line (SWR: 1), although there will be standing waves on the λ/4 matching section [4]. Also, the above condition applies only when the length of the each step of multisection matching section is λ/4, or an odd multiple λ/4 , so that a perfect match is achieved at frequency 2.135 GHz , but mismatch will occur at other frequencies as shown in fig 5c.

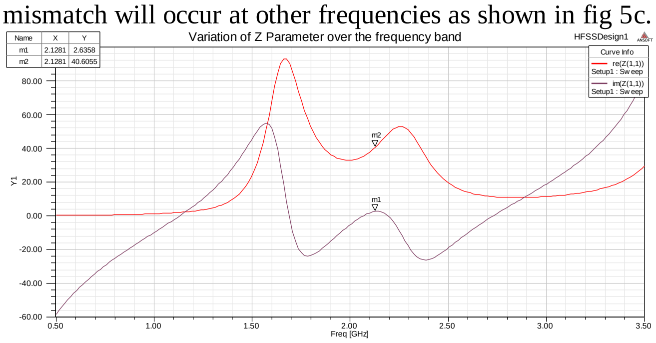

Fig. 5c :

In rectangular plot fig 5c, Z parameter plot for proposed antenna has matched impedance value is (40.6 + j2.6) Ω and it can be perfectly matched to 50 Ω by proper optimization process including removal of factors producing inductive reactance.

VI. CONCLUSION

The antenna is the key for the creation of a compact system capable of radiating high electromagnetic fields. Engineers always have to make compromises to deal either with electromagnetic performances (wide band, high gain, good impedance matching), low thickness, and high power capabilities [2]. This paper has proposed a new design of a Broadband patch antenna for High power high gain applications. The relative gain obtained is higher than 8.4 dB. Finally, the recent simulated results on the 2.135-GHz patch antenna has evidenced that it is possible to improve matching and bandwidth by adding reflection parameter [2]. The focus must be therefore definitely on the length of

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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.

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