Performance Optimization of Microstrip Patch Antenna Array for WLAN and LTE 4G Technologies.

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Abstract- **In this paper, array microstrip patch antenna are designed and analyzed for WLAN and LTE 4G technologies, which operating at S- band frequency. Design simulation and optimization processes are carried out with the HFSS and MATLAB software. Antenna arrays are used to achieve higher gain. The larger the number of antenna elements is better the gain of antenna array would be achieved. A propose multiple elements antenna array topology of microstrip patches for use in wireless applications is introduced in this paper. The Active element pattern technique is applied for analyzing microstrip array, which reduces analysis problem and computation. The operating frequency range is from 1 to 3 GHz. The array is mounted on a low-cost FR4 substrate and is fed by a standard 50 Ohm coaxial feed. The simulation of the proposed antenna has been carried out using Ansoft HFSS and MATLAB software.**

Index Terms- Long Term Evolution (LTE), Microstrip Patch antenna, Return Loss (S).

I. INTRODUCTION.

In recent days LTE supported technologies are being implemented globally and therefore, the need of antennas supporting LTE bands are increasing day by day. From this perspective, designing an antenna that will support two different LTE bands will allow roaming in different parts of the world which is much needed. Networks using the LTE-3 and LTE-7 bands will be available in ITU region 1, 2 & 3 and they are already employed in most of the developed countries [1]. The goal of this proposed work is to design and simulate a single element one-band micro-strip antenna for LTE and WLAN band which can be used in near future for roaming.

With all of the technological advances, and the simultaneous existence of various cellular networks, the impact of services on network efficiency has become even more critical. Many more design scenarios have been developed with not only 3rd generation “3G” networks but also with the evolution of 4th generation “4G” networks. Furthermore, interoperability of these networks has to be considered, including multi-band antennas. Recently, Microstrip antennas have been one of the most innovative topics in antenna theory, design and are increasingly finding application in a wide range of modern microwave systems with multi-band.

Microstrip patch antenna in wireless communication is gaining importance as a most powerful technological trend. Its immense potential promises significant change in near term future of wireless application fields. Current technological trend has focused much more attention towards microstrip patch antenna. Single microstrip patch antenna has some advantages (low cost, light weight, conformal & low profile), but it has few disadvantages too, such low gain, low efficiency, low directivity and narrow bandwidth. These disadvantages can be overcome by implementation of many patch antennas in array configuration. Here, term array stands for geometrical and electrical arrangements of patch elements. As we increase number of patch elements to form an array, improvement in performance is observed [2] [3].

In this paper, we present the basic characteristics and structure of a microstrip antenna, modeling and analyzing the behavior of a four element rectangular microstrip patch antenna array. Configurations of a symmetrical 1×4 patch array have been analyzed and an optimum frequency range of the patch antenna array has been arrived. It is inferred that for any patch array configuration, optimized antenna characteristics can be obtained, depending upon element spacing. The effects of surface waves and mutual coupling can be minimized by optimizing the inter element spacing in both the planes. The antenna provides frequency close to the designed operating frequency with an acceptable Directivity and Gain. When antenna structure is closely spaced, the return loss improves. It has been shown that with the increasing array spacing, the gain of the antenna gets reduced significantly.

II. MICROSTRIP ANTENNA STRUCTURE PRINCIPLE AND OPERATION.

A microstrip antenna basically consists of a planner radiating structure over a ground plane separated by an electrically thin layer of dielectric substrate as shown in Fig. 1. As the resulting printed circuit board is very thin, the microstrip antennas are also known as paper thin antennas. The patch conductor can have multitude of shapes rectangular and circular patch antennas are the most widely used [4].

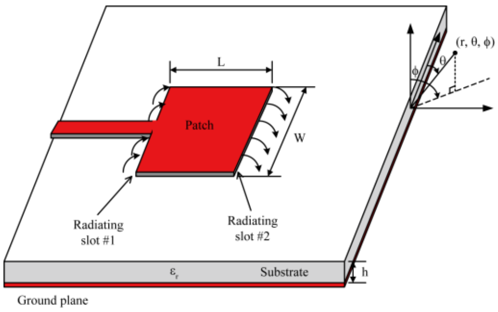

Fig. 1. Patch ant microstrip antenna and coordinate system**.**

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The summarize of basic operation electrical characteristics of microstrip antenna considering the basic microstrip antenna with rectangular with probe feed. When operating in the transmitting mode the antenna is driven with a voltage between feed probe and ground plane. This excites the current on the patch and the ground plane. The dielectric substance is usually thin. So, the dielectric field components paralleled to the ground plane must be small throughout the substrate. The patch element resonates when its length is near λ/2, leading to relatively large field and current amplitudes [4].

The electric field lines at the edge of the patch can be resolved into normal and tangential components. Only the near field radiates and from the far back patter for the antenna. The microstrip antenna, when operating in the transmitting mode. is driven with voltage source between the feed probe and ground plane. The electric field components parallel with the ground plane are small at the dielectric substrate is eclectically very thin. As the length of the patch is nearly there are large currents and field completed resonance. The resulting radiation is due to the magnetic current radiating in the presence of ground plane and induced surface current density on the patch conductor in the conductor in the presence of the ground dielectric substrate surface.

III. MICROSTRIP ANTENNA DESIGN

The Performance of the microstrip antenna depends on its dimension. Depending on the dimension, the operating frequency, radiation efficiency, directivity, return loss and other related parameters are also influenced. For an efficient radiation, the practical width of the patch can be written as [4].

$$W = \frac{c}{2f_r\sqrt{\frac{(\varepsilon_r+1)}{2}}} \tag{1}$$

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \tag{2}$$

Where

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \tag{3}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right))}{(\varepsilon_{reff}+0.258)\left(\frac{W}{h}+0.8\right)} \tag{4}$$

and the ground Plane are:

$$W_g = 6.h + W \tag{5}$$

$$L_g = 6.h + L \tag{6}$$

where f_r is the resonant frequency, L and W are the length and width of the patch element respectively and ε_r is the dielectric constant.

IV. ANTENNAS FOR 4G TECHNOLOGIES (WIMAX APPLICATIONS)

In the following subsections, each type of previously mentioned antenna types is thoroughly analyzed for better performance. The need of wireless communication has been growing very rapidly due to high demand, particularly for wireless data services. Wireless data services have been evolved and continue to grow using various technologies, such as 4G which evolves Long Term Evolution (LTE), as well as WiFi and WiMax technology. The impact of such diverse technologies is on the use of frequency band, and those in that different technologies will need to occupy different frequency allocations. WiMax technology, both for nomadic application and mobile application is likely to be a prominent candidate to serve for wireless data in the near future. Therefore WiMax applications occupying 2.5/3.5/5.8 GHz frequency bands.

The following Fig. 2, shows an antenna that has been designed to cover operating frequency of 2.5 GHz, and the quarter wavelength transformer method is used to match the impedance of the patch element with the transmission line. The design methodology is outlined and the overall size is 36×27 mm.

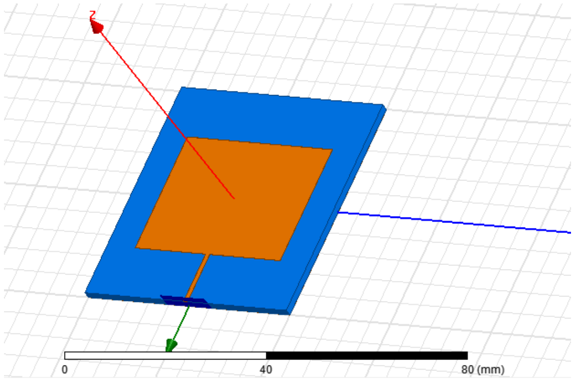

Fig. 2. 3D Geometry of a 2.5 GHz microstrip antenna for WiMax applications

V. SIMULATION RESULTS

Simulation results for return loss S11 values and 3D directivity pattern are illustrated in Fig. 3, and Fig. 4, respectively. The geometry of antenna designed simulation is performed. At the resonant frequency of 2.5 GHz the design is simulated in the frequency range of 2.45 to 2.53 GHz as shown Fig. 3. The 3D simulation plot of the far field radiation pattern for the patch antenna is shown in Fig. 4. The directivity for the antenna is 0.68 dB, It is obvious that the band antenna has an Omni-directional radiation pattern with maximum radiation in Z direction, perpendicular to the antenna. Such radiation pattern is appreciated in the WiMax applications.

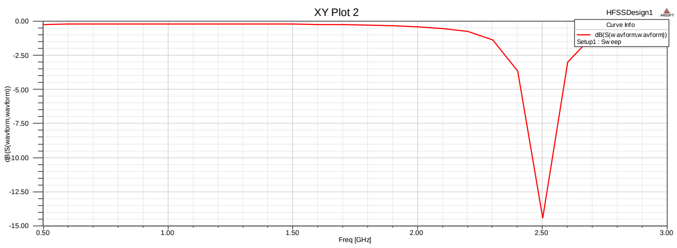

Fig. 3. Return loss Vs. Frequency plot of microstrip patch antenna.

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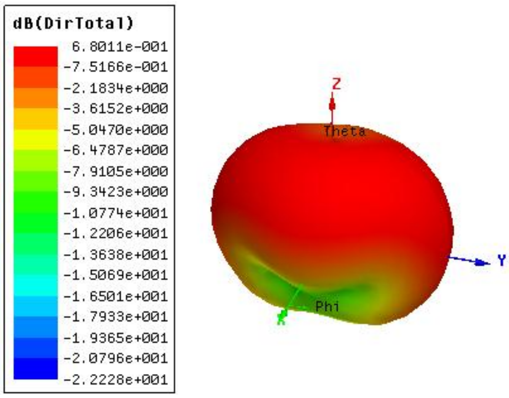

Fig. 4. The 3D normalized radiation pattern at 2.5 GHz.

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VI. PROPOSED SINGLE MICROSTRIP ANTENNA FOR 4G LTE.

One of challenge in designing a WiMax system is to design compact, low cost and small size with high gain antennas. The planar is considered as a good candidate for WiMax applications, because it is low profile, etched on a single substrate and can provide the feature of multi-band operation [5].

In this section, a 2.5 GHz microstrip antenna array is designed using optimization of rectangular patch as in prevision section. The geometry of a proposed antenna is shown in Fig. 5. The overall size of the antenna including the ground plane is 16×17.3 mm. The proposed design is single-layered, via-free and can therefore be easily fabricated at a very low cost. The design represents size reduction of approximately 55 % compared to conventional patch antennas operating at the same frequency.

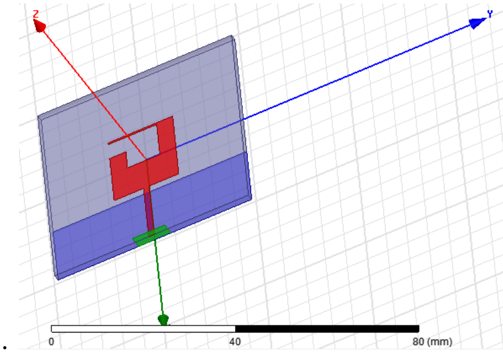

Fig. 5. 3D Geometry of a Proposed microstrip antenna in (mm) using HFSS.

The proposed antenna has been checked by using electromagnetic full wave simulation (HFSS). The simulated reflection coefficient of the proposed antenna is shown in Fig. 6. It is obvious that the reported antenna which can operate band is centered at 2.5 GHz with -10 dB bandwidth, which extends from 2.12 GHz to 2.65 GHz (S11= -17 dB). It is quite clear that this operating band meets the design requirements of WiMax standard operating frequency mentioned above.

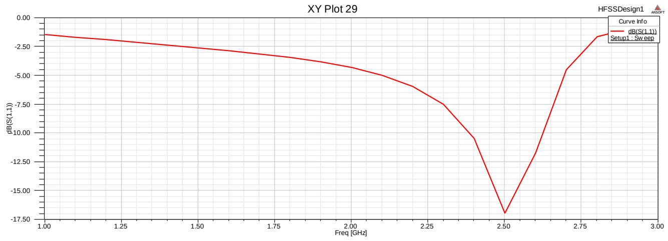

Fig. 6. Simulation Results of a Proposed Antenna.

The antenna radiation performance at the operating band has been checked by investigating the radiation pattern at each band 2.5 GHz center frequency. from Fig. 7, The directivity for the antenna is 0.49 dB, It is obvious that the band antenna has a more directional radiation pattern with maximum radiation in Z direction, perpendicular to the antenna. Such radiation pattern is appreciated in the WiMax applications.

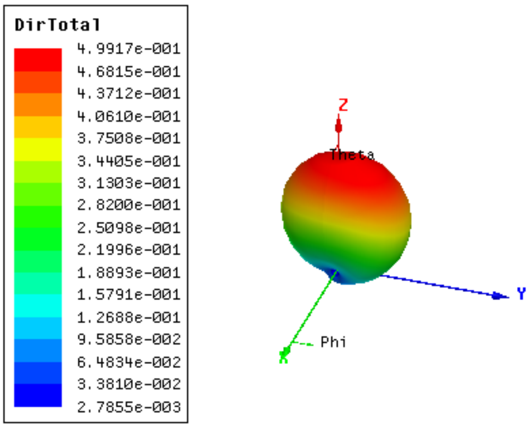

Fig. 7. The 3D Normalized Radiation Pattern at 2.5 GHz.

The surface current intensity of the miniaturized patch antenna at 2.5 GHz is displayed in Fig. 8. The distribution is very similar to a conventional at its resonant frequency.

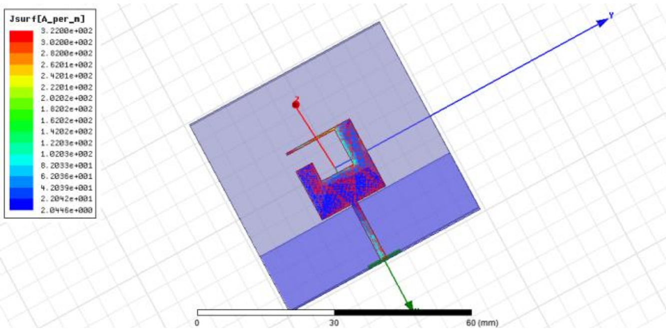

Fig. 8. Current distribution on proposed antenna.

The currents flow along the antenna edges and the maxima occur at their centers, and shows the meandering of the surface current on the radiating slot patch. This results in an increase of the length of the equivalent surface current path.

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VII. PRPOSED MICROSTRIP ARRAY ANTENNA FOR 4G TECHNOLOGIES (WIMAX APPLICATIONS)

Microstrip Antenna arrays are used to scan the beam of an antenna system, to increase the directivity, gain and enhance various other functions which would be difficult with single element antenna. In the microstrip array, elements can be fed by a single line or multiple lines in a feed network arrangement [6]. 1×4 linear array antenna with element separation of 0.35λ is showing in Fig. 9, with quarter-wave transformer (QWT) technique is used to provide impedance matching for different type of microstrip lines which produce the feeding network.

Continuing with the work on the single patch antenna, a 4×1 linear antenna array was created and is shown in Fig. 9. The inner patches have exactly the same dimensions as described in the previous section, while the outer ones have the length L = 17.3 mm and the width W = 17.3 mm. The size of the ground plane and the substrate is 190 mm x 65 mm and the distance between each patch is 0.35λ mm.

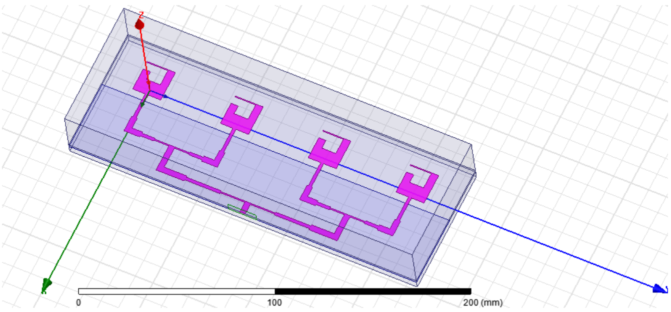

Fig. 9. 3D Geometry of a proposed microstrip array antenna in (mm) using HFSS.

The patch antennas are fed through a feeding network where the power is divided between four patch antennas, as seen in Fig. 9. Due to impedance mismatch between the patch antenna and the transmission line, a quarter-wave impedance transformer is used. Typically, the patch antenna has an impedance of the transmission line 50Ω, which is necessary in order to ensure that there is good impedance matching between the patch antennas and the transmission lines.

VIII. SIMULATION RESULTS OF MICROSTRIP ARRAY ANTENNA

A. *Return Loss Plot*

Fig. 10, shows the S11 parameter for the 1×4 linear patch antenna array. From the Fig. 10, it can be seen that the patch antenna array reflects the least around the frequency 2.5 GHz, with the S11 = -27 dB. The bandwidth for the patch antenna array can be obtained from "Fig. 10", and is around B ≈ 1.2 GHz,

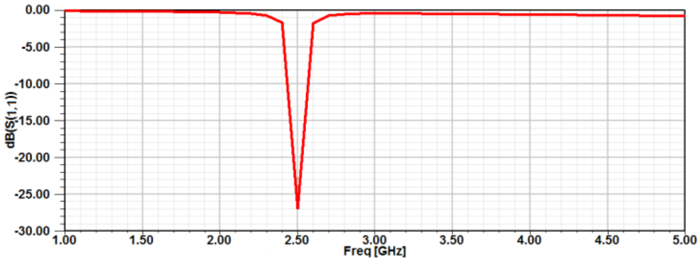

Fig. 10. Return loss Vs. Frequency plot of microstrip array patch antenna.

c- *Gain and Directivity*

Fig. 11, gives the view of gain and directivity in 3D far-field polar plot. It is observed from far-field the value of gain is 4.84 dB and the directivity is 4.97 dB. By improving the design by increase patches 4x1 and cut on the patch, the gain and directivity have increased.

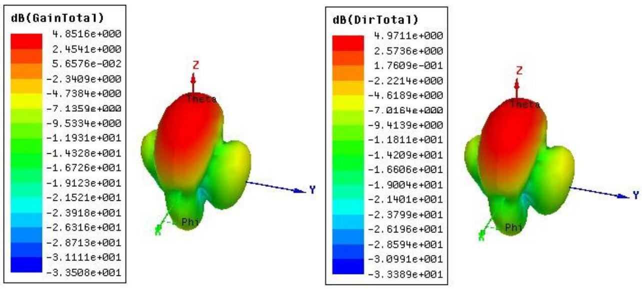

Fig. 11. Gain and directivity of the Proposed microstrip antenna array 1x4,

C. *Average Current Distribution*

The average current distribution provides the information about radiating side and non-radiating side of the antenna. Typically, antenna resonance occurs at half wavelength length. The current distribution of the microstrip antenna is known to be congested in the middle and gradually lesser at edges of the patch. Fig. 12, illustrates the current distribution of 4-elements corporate-series feed microstrip array antenna.

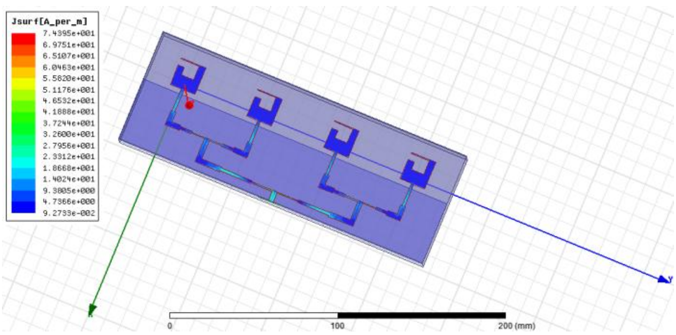

Fig. 12. Average current distribution at 2.5 GHz.

It is clear from the Fig. 12. that the amount of current declines at the edge of elements, and has reduced the mutual coupling between antenna elements without

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which good isolation without using any extra structure as DGS or EBG.

IX. CONCLUSION

Microstrip Patch antenna configured in an array format with 1x4, a number of patch elements has been analyzed. These designed antennas are very simple, cost effective and high efficiency for the applications in GHz frequency ranges. A 1X4 microstrip antenna for 4G LTE band has been successfully designed with 50Ω feed. The antenna simulation gives us 2.5 GHz operation with return loss below -10dB. The bandwidth for the patch antenna array around B ≈ 1.2 GHz. Antenna performance efficiency is nearly 80% in 2.5 GHz band the antenna is properly working in the designated band of 4G (WiMAX application).

On the other hand, it has been presented. The designed antenna has a very compact size, It has 55% size reduction compared to conventional patch antenna. The antenna demonstrates almost typical directional radiation pattern at the operating frequency with better gain is 4.84 dB and the directivity is 4.97 dB, Due to its small size, light weight and conformal properties, these analyzed microstrip patch antenna arrays are useful for WLAN and LTE 4G Technologies.

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