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Designing of Rectangular Microstrip Patch Antenna for IMT Advance (4G) with Best Impedance Matching

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***Abstract*—This paper describes the best impedance matching for wireless microstrip patch antenna i.e IMT Advance (4G) applications. A good impedance matching between the line and patch without any additional patching elements heavily depends upon feeding technique used. This Paper describes proximity coupled feeding technique and gives a better understanding of design parameters of an antenna and their effect on return losses, bandwidth, VSWR and resonant frequency. Finally simulation is done using design software HFSS. The proximity coupled feeding technique provides a wide bandwidth with best impedance matching and minimum return loss.**

***Index Terms*— Microstrip patch antenna, proximity coupled feeding technique, return loss, bandwidth, resonant frequency, 4G, HFSS.**

I. INTRODUCTION

In the today's environment, technology demands antennas which can operate on different wireless bands and should have different features like low cost, minimal weight, low profile antennas that are capable of maintaining high performance over a large spectrum of frequencies. This technological trend has focused much effort into the design of Microstrip patch antennas.

With a simple geometry, patch antennas exhibits many advantages on other conventional antennas [1]:

- Capable of providing both linear and circular polarization.
- Inexpensive to fabricate using modern day printed circuit board technology,
- Compatible with microwave and millimeter-wave integrated circuits (MMIC),
- Ability to conform to planar and non planar surfaces.

Microstrip antennas (MSA) have some disadvantages also like narrow bandwidth, low gain etc. Broad banding is the main problem, for solving this problem there are many broad-banding techniques available. Bandwidth can also be enhanced by using parasitic patches [12], by using thick substrates or by using U-slot within the patch.

There is an increase in demand for microstrip antennas with improved performance for wireless communication applications are widely used for this purpose because of their planar structure, low profile, light weight, moderate efficiency and ease of integration with active devices. Almost all the important wireless applications lie in the band starting from 900 MHz to 5.8 GHz [6].

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In Modern wireless communication systems, An IMT-Advanced system is expected to provide a comprehensive and secure all IP based mobile broadband solution to laptop computer wireless modems, smart phones, and other mobile devices. Facilities such as ultra broadband internet access, IP telephony, gaming services, and streamed multimedia may b provided to users.

IMT-Advanced intended to accommodate the quality of service (QoS) and rate requirement set by further development of application like mobile broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV, but also new services like High – Definition Television (HD TV). 4G may allow roaming with wireless local area networks, and may interact with digital video broadcasting systems. It was meant to go beyond the International Mobile Telecommunication-2000 requirements, which specify mobile phones systems marked as 3G[6,14].

4G proposes an all IP based network with packet switched delivery for efficiently meeting the needs of the future generation networks like the high data rates (up to 100 mbps for mobile nodes where as 1 Gbps for fixed or low mobility nodes), seamless mobility, availability of wide range of service to mobile users and expanding the services to maximum users over a large geographic area. It also proposes the convergence amongst the mobile, wireless, and wired networks, it has provisions for the QoS (Quality of Service) requirements as per users demands. It promises to match the QoS to those of wired communication and supports global roaming. In practice, IEEE 802.11 IMT-advance standards consist of 2.2-GHz (1710–2690 MHz) and 2.8-GHz (2700–2900 MHz) and 3.8 GHz (3400-4200MHz) frequency bands [6, 14].

II. RESEARCH BACKGROUND

One of the important aspects of microstrip patch antenna is the variety of feeding technique applicable to them. Microstrip patch antennas have radiating elements on one side of a dielectric substrate and thus may be fed by a variety of methods. Matching is usually required between the feed line and the antenna input impedances. A good impedance matching condition between the line the patch without an additional matching elements depends heavily on feeding technique used. These techniques can be classified into two categories-

- Contacting and
- Non-contacting

In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch.

The feeding techniques used for the excitation of microstrip patch antenna are:

- The microstrip line feed (contacting schemes)
- Coaxial probe(contacting schemes)
- Aperture coupling (non-contacting schemes)
- Proximity coupling (non-contacting schemes)

A. Proximity Coupled Feed [1]

This type of feed technique is also called as the electromagnetic coupling scheme. Two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%) due to overall increase in the thickness of the microstrip patch antenna. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances [1, 8].

This method is advantageous to reduce harmonic radiation of microstrip patch antenna implemented in a multilayer substrate. The goal of the design is the suppression of the resonances at the 2nd and 3rd harmonic frequencies to reduce spurious radiation due to the corresponding patch modes to avoid the radiation of harmonic signals generated by non-linear devices at the amplifying stage. The study shows the possibility of controlling the second harmonic resonance matching by varying the length of the feeding line. On the other hand, the suppression of the third harmonic is achieved by using a compact resonator [11, 12].

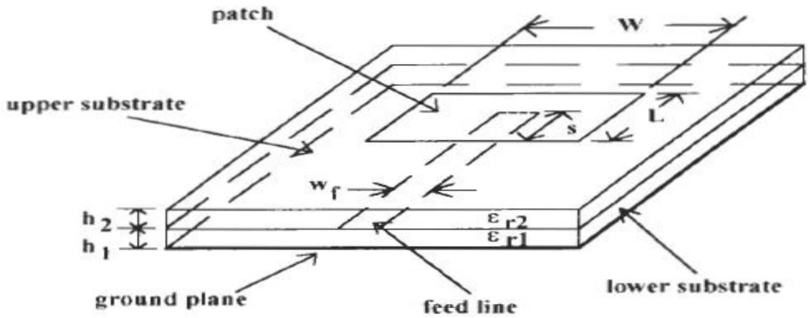

Figure 1. Proximity Feeding Techniques

III. PROPOSED APPROACH

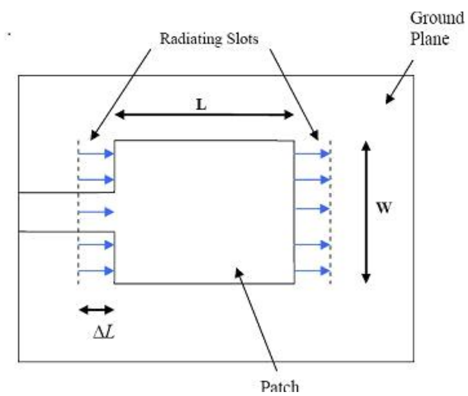

Figure 2. Microstrip Patch Antenna with Parameters

In the typical design procedure of Rectangular Microstrip Patch antenna, three essential parameters are:
1. Frequency of Operation (f): The resonant frequency of the antenna must be selected appropriately. Wireless communication system uses a wide range of frequency. Hence antenna design for wireless system must be able to operate in this frequency range. The resonant frequency selected for my design is 2.2 GHz.
2. Dielectric Constant of the Substrate: The dielectric constant of the substrate material plays an important role in patch antenna designing. A substrate with a high dielectric constant reduces the dimensions of the antenna but it also affects the antenna performance. So, there is a tradeoff between size and performance of the antenna. For my design substrate material is FR4 with dielectric constant 4.4.
3. Height of Dielectric Substrate (h): For the Microstrip Patch antenna to be used in Communication System, it is essential that antenna is not bulky. Hence the height of dielectric substrate should be less. Height of dielectric substrate for my design is 1.6 mm for FR4. Various formulas for designing a microstrip patch antenna are written below [2, 7, 9].

Calculation of effective dielectric constant, $\varepsilon reff$, which is given by:

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

Calculation of the length extension L, which is given by:

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

For efficient radiation, the width W is

$$W = \frac{c_0}{2f_o\sqrt{(\epsilon_r + 1)/2}}$$

Now to calculate the length of patch becomes

Where the Effective length of the patch L_{eff} is: $L_{eff=} - 2\Delta L$
The transmission line is applicable to infinite ground planes only. However for practical considerations, it is essential to have a finite ground plane. It has been shown that similar result for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimension is approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be:-
Microstrip antenna suffers some disadvantages like spurious feed radiation, surface wave excitation and narrow bandwidth etc. For a typical substrate thickness and a typical substrate permittivity (= 2.2) the bandwidth is about 3%.By using a thick foam substrate, bandwidth of about 10% can be achieved. By using special feeding techniques (proximity or aperture coupling) and stacked patches, bandwidth of over 50% has been achieved. However, such configurations lead to a larger antenna size. In order to design a compact Microstrip patch antenna, various efforts have been made by researchers all over the world to improve the bandwidth of a patch antenna [1,2].

A. Fringing Effect

Because of dimension of the patch are finite along the length and width, the fields along the edges of the patch undergo fringing. Most of the electric field lines reside in the substrate and parts of some lines in air. As a result, this transmission line cannot support pure transverse electric- magnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Hence, an effective dielectric constant must be obtained in order to account for the fringing and the wave propagation in the line as shown in figure.

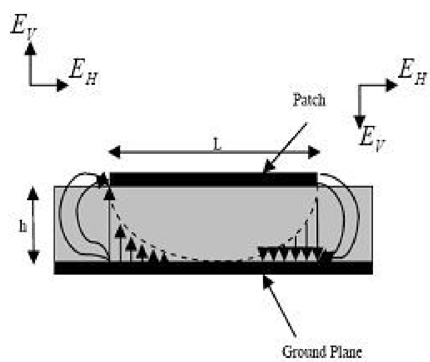

Figure 3. Fringing Effect

The value of effective permittivity is slightly less than permittivity of dielectric substrate because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air. The fringing fields along the width can be modeled as radiating slots and electrically the patch of the microstrip antenna looks greater than its physical dimensions [1,5].

IV. DESIGNING AND SOFTWARE USED

HFSS software will be used for proposed design. Ansoft HFSS (High Frequency Structure Simulator) is an integrated full-wave electromagnetic simulation and optimization package for analysis and design of 3-dimensional micro strip antennas and high frequency printed circuits and digital circuits such as microwave and millimeter-wave integrated circuits (MMICs) and high speed printed circuit boards (PCBs).
HFSS utilizes a 3D full-wave Finite Element Method (FEM) to compute the electrical behavior of high-frequency and high-speed components. With HFSS, engineers can extract parasitic parameters (S, Y and Z), visualize 3D electromagnetic fields (near- and far-field), and generate Full-Wave SPICE™ models to

effectively evaluate signal quality, including transmission path losses, reflection loss due to impedance mismatches, parasitic coupling, and radiation.

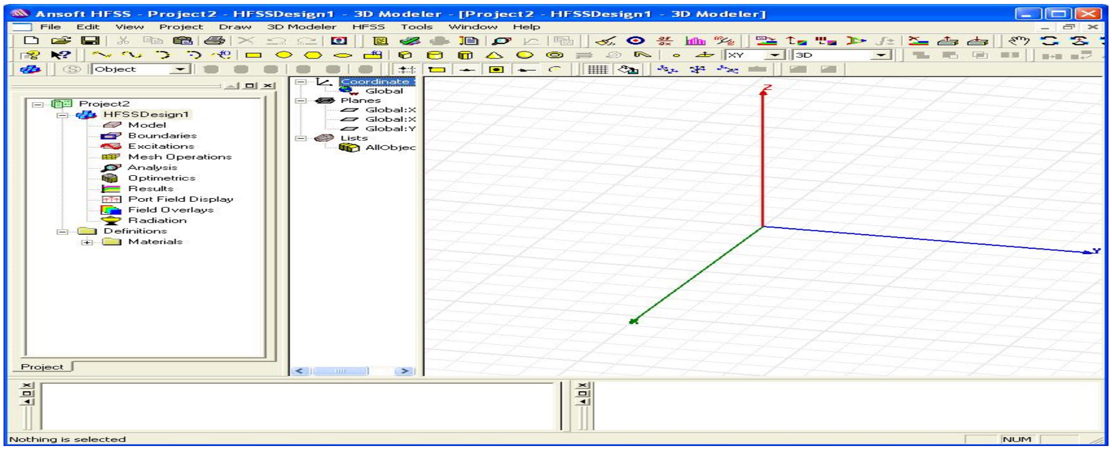

Figure 4.HFSS-3D window

V. CONCLUSION

Finally, the optimum result of best impedance matching of rectangular patch antenna on FR4 substrate for IMT advance (4G) applications is investigated. The performance properties are analyzed for the optimized dimensions and the proposed antenna works well at the required (1.71-2.69) GHz IMT advance (4G) frequency band.

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