Design and Characterization of Corporate Feed Rectangular Microstrip Patch Array Antenna

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Abstract— **The modern mobile communication systems requires high gain, large bandwidth and minimal size antenna's that are capable of providing better performance over a wide range of frequency spectrum. This requirement leads to the design of Microstrip patch antenna. This paper proposes the design of 4-Element microstrip patch antenna array which uses the corporate feed technique for excitation. Low dielectric constant substrates are generally preferred for maximum radiation. Thus it prefers Taconic as a dielectric substrate. Desired patch antenna design is initially simulated by using high frequency simulation software SONNET and FEKO and patch antenna is designed as per requirements. Antenna dimensions such as Length (L), Width (W) and substrate Dielectric Constant (ε_r) and parameters like Return Loss, Gain and Impedance are calculated using high frequency simulation software. The antenna has been designed for the range 9-11 GHz. Hence this antenna is highly suitable for X-band applications.**

Keywords— Corporate Feed, Microstrip Patch Antenna, Patch Parameters, SONNET, Taconic substrate

I. INTRODUCTION

Communication between humans was first by sound through voice. It has been only very recent in human history that the electromagnetic spectrum, outside the visible region has been employed for communication, through the use of radio. One of humankind's greatest natural resources is the electromagnetic spectrum and the antenna has been instrumental in harnessing this resource.

Microstrip patch antennas (also just called *patch antennas*) are among the most common antenna types in use today, particularly in the popular frequency range of 1 to 6GHz. This type of antenna had its first intense development in the 1970s, as communication systems became common at frequencies where its size and performance were very useful. At the same time, its flat profile and reduced weight, compared to parabolic reflectors and other antenna options, made it attractive for airborne and spacecraft applications. More recently, those same properties, with additional size reduction using high dielectric constant materials, have made patch antennas common in handsets, GPS receivers and other mass-produced wireless products [1].

Conventional microstrip antennas in general have a conducting patch printed on a grounded microwave substrate, and have the attractive features of low profile, light weight, easy fabrication, and conformability to mounting hosts. However, microstrip antennas inherently have a narrow bandwidth and bandwidth enhancement is usually demanded for practical applications.

In addition, applications in present-day mobile communication systems usually require size reduction and bandwidth enhancement are becoming major design considerations for practical applications of microstrip antennas. Various parameters of the microstrip antennae and their design considerations are discussed in subsequent sections. Section II explains the structure of microstrip patch antenna and section III includes different feeding techniques for the excitation of microstrip patch antenna. Section IV is about the design procedures for Microstrip patch antenna using corporate feed technique. Section V deals with the simulation set up with results and discussions in addition to the analysis of a comparative performance. Section VI gives conclusion and anticipated future work.

II. MICROSTRIP PATCH ANTENNA

In recent years the area of microstrip antenna has seen many inventive works and is one of the most dynamic fields in communication field. For simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common. Among these the rectangular and circular patches are the most extensively used patches [3].

Although there are many variations on patch antenna design, the basic configuration is shown in Figure 1, where L is then length (relative to the feed point) and W is the width. In the simplest configuration, L = W = λ_{eff} /2, or an electrical one-half wavelength, including the shortening effect of the dielectric constant (ε_r) of the material between the patch and the conducting surface (*substrate*) below [1].

Microstrip patch antennas consist of very thin metallic strip (patch) placed on ground plane where the thickness of the metallic strip is restricted by t << λ_0 and the height is restricted

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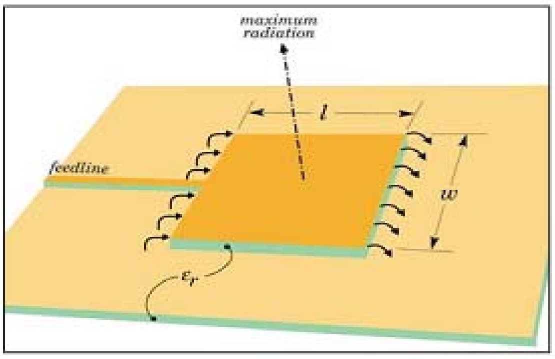

Fig. 1. *Microstrip Patch Antenna*

by $0.0003\lambda_0 < h < 0.05\lambda_0$ and their dielectric constants are usually in the range of $2.2 < \varepsilon_r < 12$ [2].

III. MICROSTRIP ARRAY ANTENNA'S AND FEED NETWORKS

Microstrip antennas are used not only as single element but also very popular in arrays [4]. 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. Microstrip patch antennas can be fed by a variety of methods. These methods 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 four most popular feed techniques used for the microstrip patch are Edge feed and Pin feed, both of which are contacting schemes and other two are aperture coupling and proximity coupling, both of which are non-contacting schemes. In the microstrip array, elements can be fed by a single line or multiple lines in a feed network arrangement [5], [6]. Feeding methods are classified as,

- Microstrip Line Feed
- Coaxial Feed
- Aperture Feed
- Proximity Feed
- Series feed network
- Corporate feed network

A. *Microstrip Line Feed*

In this type of feed technique, a conducting strip is connected directly to the edge of the Microstrip patch as shown in Fig. 2.The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure [5], [7].

The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element [3]. This is achieved by properly controlling the inset position.

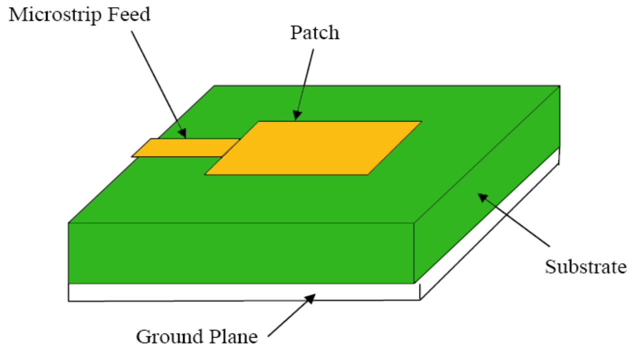

Fig. 2. *Microstrip Line Feed*

Hence this is an easy feeding scheme, since it provides ease of fabrication and simplicity in modeling as well as impedance matching. However as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna [5]. The feed radiation also leads to undesired cross polarized radiation.

B. *Coaxial Feed*

The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. As seen from Fig. 3 the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane. The main advantage of this type of feeding scheme is that the feed can be placed at any desired location within the patch area in order to match its input impedance. This feed method is easy to fabricate and has low spurious radiation. For a thick dielectric substrate, this scheme is especially suitable for broad bandwidth applications. The pin fed technique, thus becomes natural choice for the Wi-MAX applications of patch antennae used for compact and mobile devices.

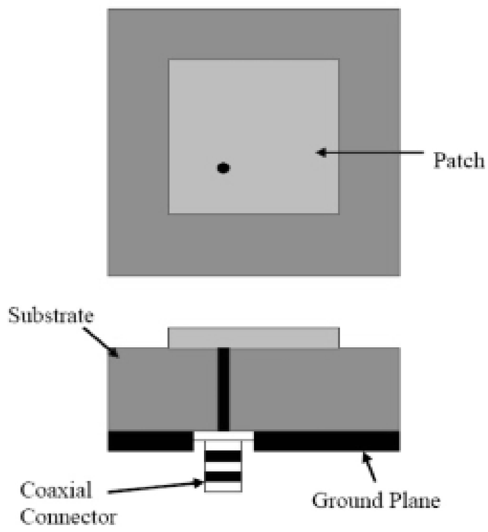

Fig. 3. *Microstrip Pin Feed*

C. *Microstrip Series Feed Network*

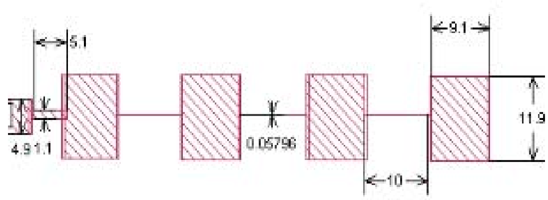

Fig. 4. *Microstrip Series Feed Network*

A series feed microstrip array, as shown in Fig. 4, is formed by interconnecting all the elements with high impedance transmission line and feeding the power at the first element. Here two successive patch elements are matched by using quarter wavelength transformer method. Since, the feed arrangement is compact so the line losses associated with this type of array are lower than those of the corporate feed type [6].

The main limitation of the series feed arrays is the large variation of the impedance and beam-pointing direction over a band of frequencies.

D. *Microstrip Corporate Feed Network*

Another popular microstrip antenna feeding system is the corporate feeding. Corporate feed arrays are general and versatile. This method has more control of the feed of each element and is ideal for scanning phased arrays, multi beam arrays. The phase of each element can be controlled using phase shifters while amplitude can be adjusted using either amplifiers or attenuators [5], [8]. The corporate feed network is used to provide power splits of 2n (i.e. n = 2; 4; 8; 16; etc.). This is accomplished by using either tapered lines or using quarter wavelength impedance transformers [4], [6]. Here, in the Fig. 5, the patch elements are connected by using the quarter wavelength impedance transformer method.

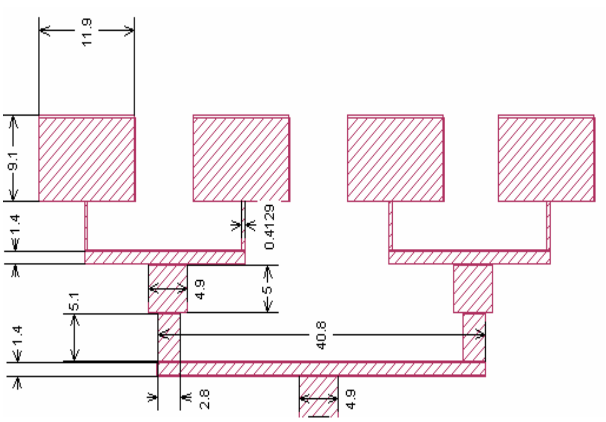

Fig. 5. *4-elements corporate feed microstrip array antenna*

IV. Design Consideration For patch antenna

There are three important parameters which are to be considered carefully for the designing a rectangular microstrip patch antennae for mobile devices.

- Frequency of operation (f_0): The antenna has been designed for the range 9-11 GHz; hence this antenna is highly suitable for X-band applications. The default resonant frequency chosen for this research design simulation is 10GHz.
- Dielectric constant of the substrate (ε_r): The dielectric material chosen for this design is Taconic which has dielectric constant of 2.2.
- Height of dielectric substrate (h): For the Microstrip patch antennae to be used in cellular phones, it is essential that the antennae are kept light and compact [9]. Hence, the height of the dielectric substrate is is chosen as 2.87 mm.

By substituting $C = 3\times10^8$ m/s, $\varepsilon_r = 2.2$ and $f_0 = 10$ GHz, we can easily determine the values of antenna dimensions.

A. *Design Procedure*

1. *Calculation of Width (W)*

The width of the patch element (W) is given by

$$W = \frac{C}{2 f_o \sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

2. *Calculation of Effective dielectric constant (ε_{reff})*

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

3. *Calculation of the Effective length*

$$L_{eff} = \frac{C}{2 f_o \sqrt{\varepsilon_{reff}}} \tag{3}$$

4. *Calculation of the length extension*

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

5. *The actual length (L) of patch*

$$L = L_{eff} - 2\Delta L \tag{5}$$

By using above mathematical computation equation, the patch parameters have been designed for the Taconic substrate. The results are summarized in table 1. Table 1 represents the patch width and patch length obtained for Taconic substrates.

TABLE I

Microstrip Patch Parameters	**Microstrip Patch Parameters**	
	Patch Element Measures	***f_0 = 10GHz, ε_r=2.2, h=2.87mm***
W	Patch Width	0.012m or 12 mm
ε_{reff}	Effective Dielectric Constant	2.78
L_{eff}	Effective Length	8.9 mm
ΔL	Length Extension	1.2887 mm
L	Actual Length	6.3 mm

V. SIMULATION RESULTS AND DISCUSSIONS

The software used to simulate the microstrip patch antenna is high frequency simulation software FEKO Suite 6.1 Version for calculating various parameters. The design was then simulated on SONNET 3D Planar High-frequency Electromagnetic software. The model was designed to match 50 ohm of the corporate feed. Fig. 6 shows the Corporate fed microstrip patch antennae designed using FEKO suite 6.0 version.

A. FEKO Suite

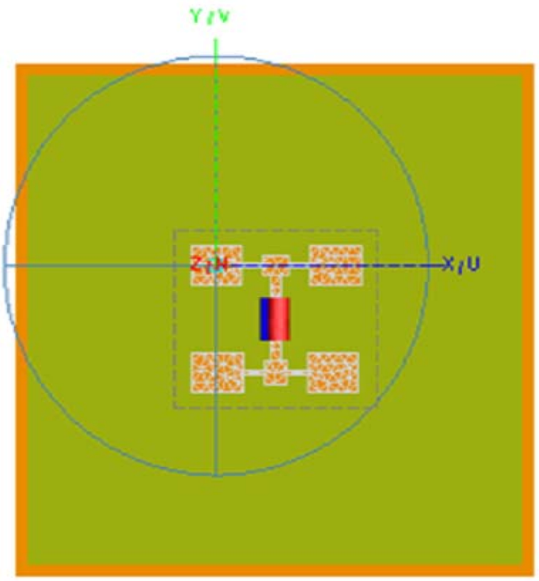

Fig. 6. *4-Element microstrip patch array Antenna using FEKO suite*

a) Return Loss

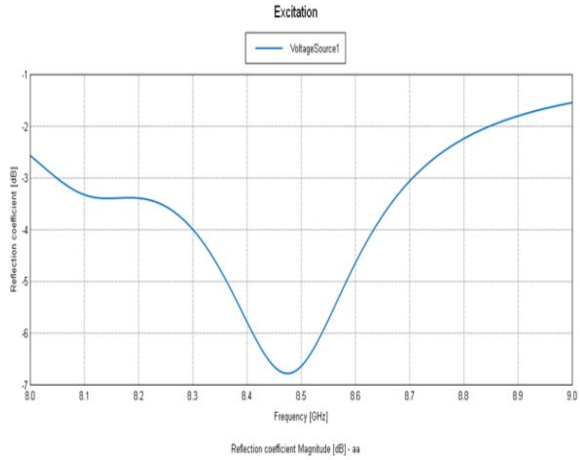

Fig. 7. *Return loss for four patch array antenna*

The resonance frequency of the designed antenna is 9-11GHz. Fig. 7 demonstrates that return loss is -6.8dB at 8.45GHz. The bandwidth can be determined from the Return Loss (*RL*).

b) Impedance

Most microwave applications are designed with an input impedance of 50Ω, so matching the antenna to 50Ω is our desire. The following are the impedance plot. The below figure shows the value of impedance is 65Ω.

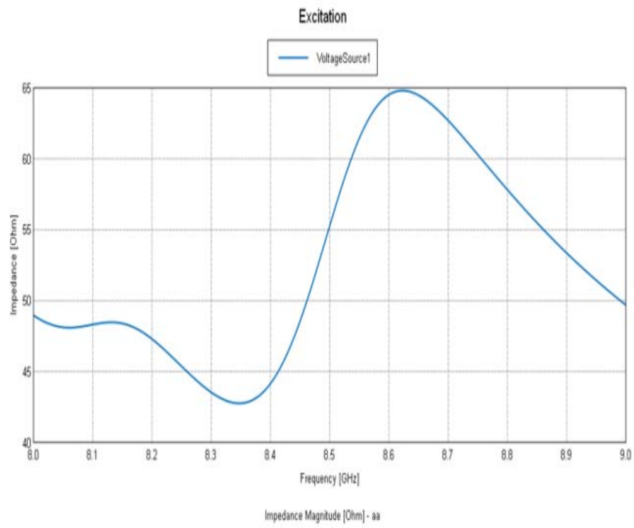

Fig. 8. *Impedance for four patch array antenna*

c) Gain

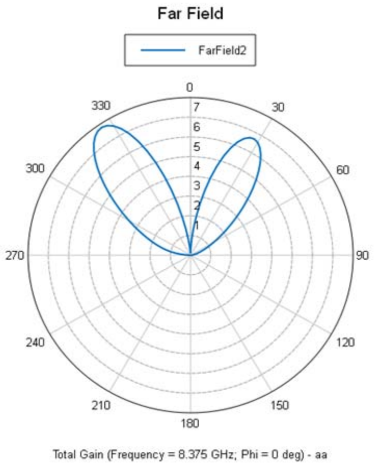

Fig. 9. *Gain for four patch array antenna*

Generally the gain should be above 6dB which will be achieved when we use array of antenna. The figure below shows the radiation pattern for four patch array antenna. Thus the gain obtained is 6.8 dB.

TABLE II.

Microstrip Patch Parameters from FEKO Software	Microstrip Patch Parameters	
	Patch Parameters	***Obtained Values***
F	Frequency (Hz)	8.475 Hz
Gain	Gain (dB)	6.8 dB
Return Loss	Return Loss (dB)	-6.8 dB

B. SONNET Suite Simulation Software

The microstrip patch antenna array design was then simulated on SONNET 3D Planar High-frequency Electromagnetic software with same design specifications.

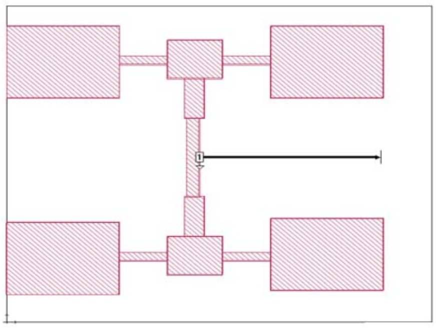

Fig. 10. *Four patch array antenna*

A. Return Loss

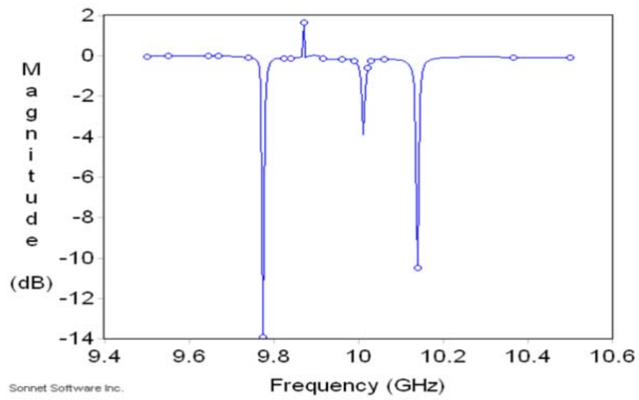

Fig. 11. *Return loss for four patch array antenna*

The resonance frequency of the designed antenna is 9-11GHz. Fig. 11 demonstrates that return loss is -6.8dB at 8.45GHz. The bandwidth can be determined from the Return Loss (*RL*).

B. Gain

The figure below shows the radiation pattern for four element microstrip patch array antenna. Thus the gain obtained is 20dB which is high and good when compare to the gain obtained from FEKO Simulation.

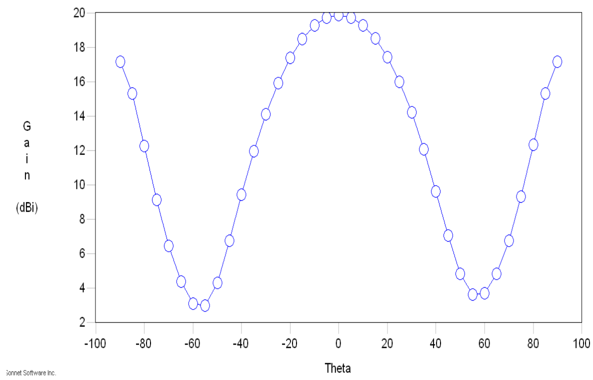

Fig. 12. *Gain for four patch array antenna*

TABLE III.

Microstrip Patch Parameters from SONNET Software	Microstrip Patch Parameters	
	Patch Parameters	***Obtained Values***
F	Frequency (Hz)	9.8 Hz
Gain	Gain (dB)	20 dB
Return Loss	Return Loss (dB)	-14 dB

C. Comparative Study

We have studied that corporate feed Microstrip patch antenna gives gain of 20dB at a frequency of 9.8GHz and less return loss when it is simulated using Sonnet software. The simulated values are given in Table II. Previously the desired antenna design was simulated using FEKO Lite simulator. The simulated results are given in Table I. It shows that it gives gain of 6.8dB at a frequency of 8.475GHz which less when compare to simulated values from SONNET simulator. Each simulator divides the patch differently for computation of antenna dimensions and measurements. May be due to this, results from SONNET simulator have better performance.

VI. CONCLUSION

A method of comparative simulation between FEKO Simulator and SONNET high frequency simulation software is proposed. These designed antennas are simple, minimal size and high efficiency for the applications in GHz frequency ranges. There acceptable parametric outcomes such like the Return Loss, Gain and Efficiency for the corporate feed patch antenna is tabulated in Table 4. From the comparative study of different analysis of corporate feeding technique, it is concluded that microstrip antenna simulated using SONNET Suite provides a bandwidth enhancement of around 20dB. And also it has achieved the best return losses at the desired frequency region, which is at 9.8 GHz. In future, the work will be carried out for antenna's with different feeding techniques.

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