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Design of Rectangular Microstrip Patch Antenna at 3.3 GHz Frequency for S-band Applications

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Abstract: Low-profile antennas are required for aircraft, satellites, radar, and a variety of other vehicles due to aerodynamic considerations. The "patch" or microstrip antenna is a narrow band antenna with a low profile and low gain. Patch antennas are becoming more popular as a result of their ability to be printed on a circuit board. Microstrip antennas can be rectangular, circular, elliptical, or any other regular form, but the most common configurations are rectangular and circular. This research constructed a rectangular patch antenna that operates in the 3.3 GHz (S-band) operating frequency based on a description of microstrip antenna working principles. Agilent ADS Momentum software is used to create and simulate the antenna model. Finally, by optimizing and matching to meets, the best performance parameters such as Gain, Directivity, Efficiency, Power Intensity, Radiated power, and Return loss are obtained.

Index Terms: Microstrip Patch Antenna, ADS (Advance Design System), Rectangular Shape, Gain of antenna, Directivity of antenna.

1. Introduction

The demand for small antennas in wireless communication has ignited microwave and wireless engineers' interest in research on compact microstrip antenna design in recent years [1-6]. Because of their simplicity and compatibility with printed-circuit technology, microstrip antennas (also known as patch antennas) are commonly employed in the microwave frequency area. They are easy to construct as stand-alone parts or as members of arrays. The fast development of microstrip antenna technology began in the late 1970s [12]. Basic microstrip antenna elements and arrays were reasonably well established in terms of design and modeling by the early 1980s. Antenna engineering is a relatively recent field. A microstrip antenna is a patch of metal on top of a grounded substrate that is normally rectangular or circular (though other forms are sometimes utilized). The substrate of a microstrip antenna is principally responsible for the antenna's mechanical strength [7]. Because of fast advancements in satellite and wireless communication, there has been a considerable need for low-cost, light-weight, compact low-profile antennas that can retain good performance over a wide frequency range. Microstrip antenna topologies have been the most popular method of realizing millimeter wave monolithic integrated circuits for microwave, radar, and communication applications throughout the years [11]. The basic principles of operation and CAD (Computer Aided Design) procedures for the rectangular microstrip antenna are covered in this study. For thin substrates, the CAD formulas are quite precise and illustrate the core assumptions. The CAD formulas may even be accurate enough for final design on thin substrates.

2. Antenna Design

Design parameters to design an antenna for our research paper are briefly in this section. It is very much important to select appropriate parameters to get better result. The following sub sections are preciously shown which things are consider for designing our antenna.

2.1. Choice of Substrate

Choosing a substrate is as important as the design itself. The substrate is a component of the antenna and plays an important role in its radiative properties. When selecting a substrate, many aspects are taken into account, including dielectric constant, thickness, stiffness, and loss tangent. To induce fringing and therefore radiation, the dielectric constant should be as low as feasible. A thicker substrate is also preferred since it improves the impedance bandwidth. However, because most microstrip antenna models employ a thin substrate approximation in the analysis, utilizing a thick substrate would result in a loss of accuracy. For obvious reasons, lossy at higher frequencies substrates should not be employed. The application determines whether a stiff or soft board should be used. When the substrate is at its highest point, the height h is typically $0.003\ \lambda 0 \leq h \leq 0.05\ \lambda 0$. The dielectric constant of the substrate, denoted by the letter ϵr, is typically in the range $2.2 \leq \epsilon r \leq 12$ [9]. The dielectric material selected in the design of the microstrip patch antenna, on the other hand, is RT/duroid5880, that has a dielectric constant of 2.2 and a height of 0.1588cm.

2.2. Element Length

Because the patch length determines the resonant frequency, choosing the resonant length also means choosing the frequency of resonance. In the case of a rectangular patch, the length L of the patch is often in the range of $0.3333\ \lambda 0 < L < 0.5\ \lambda 0$, where $\lambda 0$ is the wavelength of free space. The patch is chosen to be extremely thin, such that $t << \lambda 0$ (where t is the patch thickness) is achieved [9] .Because the real patch is 'longer' due to the fringing fields, the patch length should be somewhat less than half the dielectric wavelength. The effective length of the patch is given as

$$L_{eff} = \frac{c}{2f_r\sqrt{\mathcal{E}_{reff}}} - 2\Delta L \qquad (1)$$

Where

$$\Delta L = h0.412\frac{(\mathcal{E}_{reff}+0.3)(\frac{w}{h}+0.264)}{(\mathcal{E}_{reff}-0.258)(\frac{w}{h}+0.8)} \qquad (2)$$

And

$$\mathcal{E}_{reff} = \frac{\mathcal{E}_r+1}{2} + \frac{\mathcal{E}_r-1}{2}(1+12\frac{h}{w})^{-\frac{1}{2}} \qquad (3)$$

Hence,
f_r = Resonance frequency
$\mathcal{E}_{reff}$ = Effective dielectric constant
L_{eff} = Effective length of the patch
$\mathcal{E}_r$ = Dielectric constant
w = Width of the patch
h = Height of the material
c = Speed of light in free space

2.3. Element Width

For an efficient radiator, Bahl [10] recommended using a practical element width given by Width of the patch;

$$w = \frac{c}{2f_r}\sqrt{\frac{2}{(\mathcal{E}_r+1)}} \qquad (4)$$

Where,
f_r = Resonance frequency
$\mathcal{E}_r$ = Dielectric constant

2.4. Design Specifications

The proposed rectangular patch antenna has been designed using following specifications:

Name of Substrate metal = copper
Dielectric constant, ε_r= 2.2
Velocity of light = $3x10^8$ m/s
Loss tangent = 0.001
Conductivity = 5.8×10^7
Height of substrate (h) = 1.588 mm
Operating frequency, (f_r) =3.3 GHz
Dimension of the patch:

Width, W=42.5 mm
Length, L=29.5 mm

Dimension of microstrip feed line:

Width, W=4.8 mm
Length, L=13.0 mm

2.5. Patch antenna structure

In ADS Momentum, a rectangle patch with TM010 mode is created. The patch measures 29.5 millimetres in length, 42.5 millimetres in width, and 20 millimetres in height. The substrate has a permittivity of 2.2 and a resonance frequency of 3.3GHz. The substrate is RT Duroid 5880, which has a height of 1.588mm. Microstrip transmission line (λ/4) feed was used to activate the rectangular patch. The mathematical answer may be found in [8.] ADS Momentum was used to create this patch. Following design, the antenna patch was simulated in ADS Momentum to get directivity, gain curves, 3D visuals of far field radiation, and a 3D image of the planned antenna patch. Fig.1 shows the design of the single rectangular patch antenna.

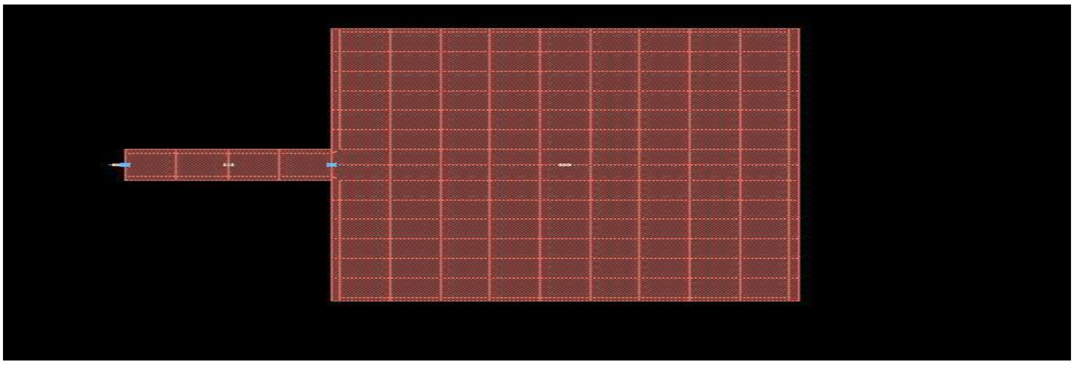

Fig. 1. A rectangular patch with microstrip feed line.

3. Simulated Result of Patch Antenna

In this section, we will discuss important results obtained for proposed antenna. We discuss S11 parameters, bandwidth, current distribution, radiation patterns and other important antenna parameters such as antenna efficiency, radiation efficiency and antenna gain for all the antenna structures obtained from simulation and measurement.

3.1. Radiation pattern

ADS Momentum is used to measure the radiation patterns of a patch antenna. It is possible to obtain E-plane patterns. Fig.2 depicts the antenna's radiation pattern

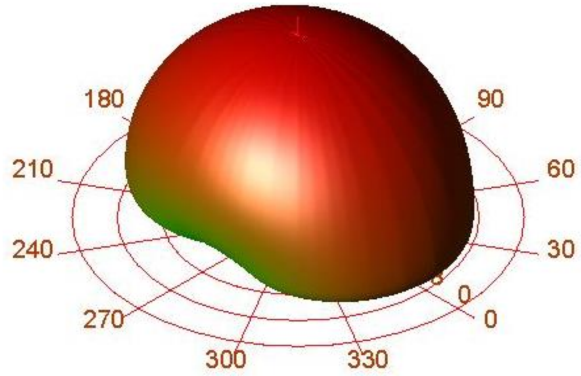

Fig. 2. 3D far field radiation pattern.

3.2. Return Loss

The ADS Momentum simulations assist us in acquiring information regarding the antenna's reflection coefficients. Because we are just employing one probe, all of the coefficients of the S-matrix will be 0 (zero), with the exception of the S11 parameter, which represents the input reflection coefficient. The performance of the rectangular patch antenna may be easily understood by looking at the S11 Parameter graph. The curve of the S11 parameter, as simulated by Momentum, is shown in Fig.3. Fig.3 clearly demonstrates that the single patch antenna resonates at 3.30 GHz with a minimum magnitude of roughly -5.325 dB at the frequency shown in the figure. The relevant phase fluctuation with frequency is seen in Fig.4.

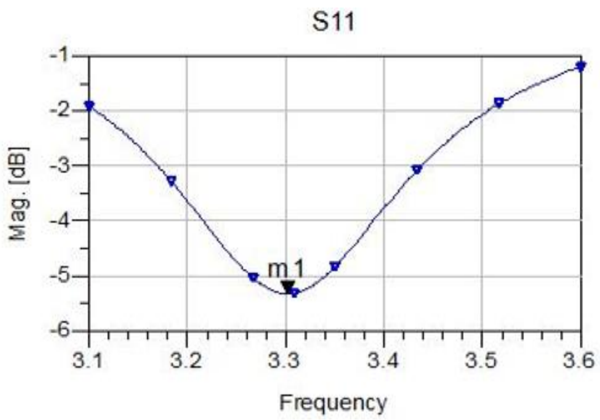

Fig. 3. Return loss (S11 parameter) from ADS Momentum.

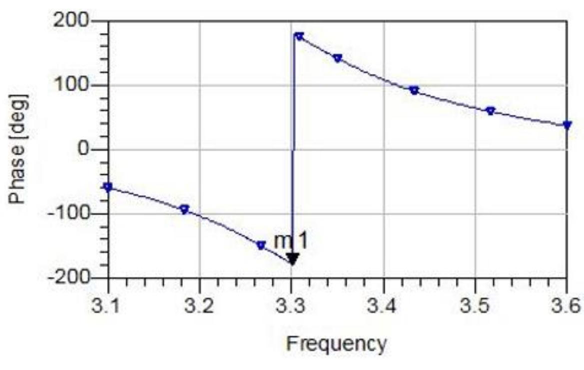

Fig. 4. Variation of phase with frequency.

3.3. Directivity and Gain

The gain (G) of an antenna is proportional to its directivity (D). The amount to which an antenna focuses energy in one direction over other directions is referred to as directivity. If an antenna is 100 percent efficient, then directivity equals gain, and the antenna would be an isotropic radiator. Considering that all antennas will emit more in one direction than they will emit in another, gain is defined as the amount of power that may be gained in one direction at the expense of power lost in all of the other directions. As shown in Fig.5, the directivity (D) and gain (G) curves are in close proximity to one another, resulting in G = 7.59 dB and D = 7.70 dB.

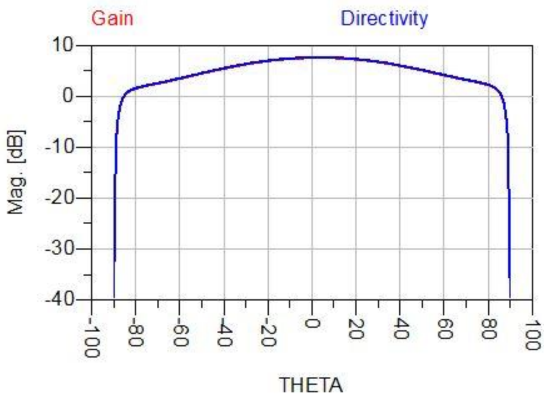

Fig. 5. Directivity and gain curve in 2D momentum visualization window.

3.4. Current Distribution

It is possible to acquire and display the current distribution graph for patch antenna, as illustrated in Fig.6. A change in current distribution results in a change in the performance characteristics of the antenna.

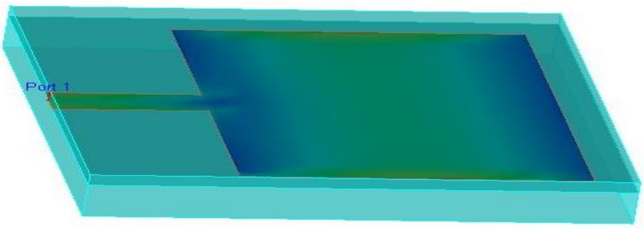

Fig. 6. Current distribution for patch antenna.

3.5. Smith Chart Observation

As seen in Fig.7, ADS Momentum also mimics the graph for the input reflection coefficient on the smith chart. In the Smith chart, the single rectangular patch antenna resonates approximately at 3.30 GHz, where it has the lowest impedance. This is also highlighted by the m2 marker, which indicates the spot where the antenna has the lowest impedance. The impedance of the antenna, as determined by the Smith chart, is RA=Z0 (0.297-j0.003) ohm.

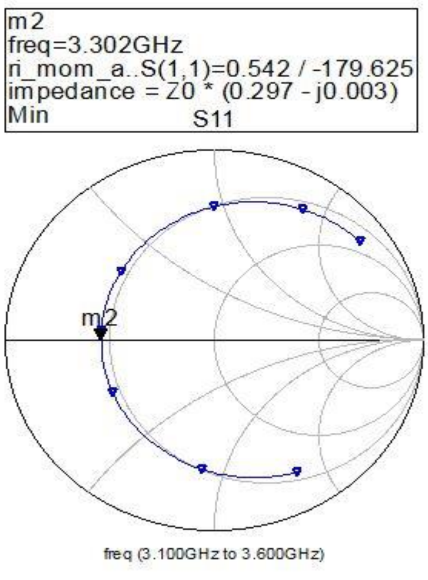

Fig. 7. Smith chart result.

4. Conclusions

Micro strip antennas have developed as a fast expanding field of investigation. Because of their light weight, compact size, and ease of manufacture, the applications for which they might be used are virtually unlimited. One drawback is the fact that they have a naturally limited bandwidth. Recent investigations and experiments, on the other hand, have shown solutions to overcome this hurdle. A variety of ways have been used, including adjustment of the patch form and experimenting with substrate properties. The ADS Simulator was used to simulate our proposed antenna. The following are the simulated results of ADS at 3.30GHz: In this case, Directivity is 7.70 dB, Gain is 7.59 dB, Effective angle (steradians) is 2.13396, the return loss is -5.325 dB, Efficiency is 97 percent, Total radiated power is 0.0017211W, Maximum intensity is 0.000806525 Watts.steradian. The proposed RT DUROID 5880 substrate Rectangular-Shaped microstrip antenna is capable of operating at 3.30 GHz (S- Band), making it an excellent choice for widespread wireless communication applications. Many new shapes will be introduced in the future to replace the conventional shapes, depending on the need. In the field of microstrip patch antennas, there are many different shapes to choose from. The design of slots on the patch and the creation of defective structures in the ground plane for the purpose of increasing bandwidth and establishing multiband operation, which is a component of this technology, are extremely promising in terms of future implications.

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