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Research Article

Analysis of Substrate Material Variation on Circular, Rectangular and Non Linear Microstrip Patch Antenna

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Abstract

This paper deals with analysis of Rectangular, Circular and Non-LinearMicrostrip patch antenna with respect to Bandwidth (BW), Voltage Standing Wave Ratio (VSWR) and Return Loss (RL) while achieving specific selective frequency and Bandwidth. Rectangular Microstrip Antenna (RMSA), Circular Microstrip Antenna (CMSA) and Non Linear Microstrip Antenna (NLMSA) has been designed with various dielectric materials like FR4 Glass Epoxy, ARLON 450, and TACONIC 35 and analyzed. The performance of these antennas was measured for 2.4 GHz frequency using co-axial feeding technique with High Frequency Structure Simulator (HFSS). Optimization of patch dimensions is designed to get better performance parameters such as BW, VSWR and RL. The graphical comparison of all these performance parameters with respect to material and shape variation gives directions to select better Microstrip Antenna for any wireless Local Area Network (LAN) application.

Keywords: *BW, VSWR, RL, RMSA, CMSA, NLMSA, HFSS, Dielectric, Parameter Analysis, Microstrip Antenna.*

1. Introduction

Communication systems are rapidly switching from wired to wireless network in which antennas are used in transmitting the signal through electromagnetic waves in free space. There is always a need of variety of antennas based on geometrical shape, size, frequency range, capacity in terms of power radiation, bandwidth of transmission etc. The size of the antenna depends on transmission frequency. Interestingly, these antennas are categorized based on the range of frequencies used, e.g. Radio Frequency (RF) antennas, Microwave (MW) antennas etc.

A Microstrip patch antenna is one of microwave antenna that offers a low profile, i.e. thin and easy manufacturability and provides a great advantage over traditional antennas. Patch antennas are planar antenna used in wireless links and other microwave applications.. A patch is typically wider than a strip and its shape and dimension are important features of the antenna(Veeresh G. Kasabegoudara*al*, 2010).Microstrip patch antennas are probably the most widely used type of antennas today due to their advantages such as light weight, low volume, low cost, compatibility with integrated circuits and easy to install on the rigid surfaces. Furthermore, they can be easily designed to operate in dual-band, multi-band application, dual or circular polarization. They plays important role in many commercial applications like mobile communication, Wireless Local Area Network (LAN) or remote wireless data logging. However, Microstrip patch inherently have narrow bandwidth and are usually demanded for such practical applications (Wen Ling *al*, 2009).

While designing Rectangular Microstrip Antenna (RMSA), Circular Microstrip Antenna (CMSA) and Non Linear Microstrip Antenna (NLMSA), the substrate thickness is 1.6 mm while dielectric materials used are *FR4 Glass Epoxy*, *ARLON 450* and *TACONIC 35* with dielectric constant 4.4, 4.5 and 3.5 respectively. The process of measurement of performance parameters presented in this paper will be used for deciding the methodology to get best results at 2.4 GHz operating frequency with most widely used co-axial feeding technique as it gives proper impedance matching (V.V.Khairnar *al*, 2013).

For specific applications, systems usually have some requirement for specific parameters (Jai Yi Sze *al*, 2001). For example, for portable devices, the antennas must be small in size and embeddable with Specific selectivity of frequency and bandwidth with optimum bandwidth and return losses. Under such circumstances it is necessary to test the design before it actually get manufacture with specific material to reduce the cost of antenna and get an idea of feasibility of the proposed design.

With the help of various shapes and material used Microstrip antenna can be made wide range of resonant frequencies, polarization patterns and Voltage Standing Wave Ratio (VSWR). Due to its operational features such as high selectivity and very narrow frequency bandwidth,

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it is suitable for mobile and government security systems where narrow bandwidth is priority (B. J. Kwaha *al*, 2011). They are also used on laptops, microcomputers, mobile phones etc. Next three sections of this paper demonstrate the analysis of Rectangular Microstrip Antenna (RMSA), Circular Microstrip Antenna (CMSA) and Non Linear Microstrip Antenna (NLMSA) with dielectric materials FR4 Glass Epoxy, ARLON 450 and TACONIC 35.

2. Analysis of RMSA

The basic RMSA Patch design equations are given by

$$w = \frac{\lambda_0}{2}\sqrt{\left(\frac{2}{\epsilon_r+1}\right)} \quad (1)$$

Where,

w = Patch Width, λ_0 = Wave Length,

ϵ_r = Dielectric Constant and

$$L = \frac{\lambda_0}{2\sqrt{\epsilon_{reff}}}\Delta L^2 \quad (2)$$

$$\frac{\Delta L}{h} = \frac{(\epsilon_{reff}+0.300)\left(\frac{w}{h}+0.264\right)}{(\epsilon_{reff}+0.258)\left(\frac{w}{h}+0.800\right)} \quad (3)$$

Where,

ΔL = Line Extension,

w = Patch Width

ϵ_{reff} = Effective Dielectric Constant,

L = Patch Length,

λ_0 = Wave Length

h= Substrate Thickness

For FR4 Glass Epoxy and ARLON 450 the width of patch is 28 mm and length of patch is 42 mm and for TACONIC 35 the width of patch is 31.25 mm and length of patch is 47.40 mm. The co-axial feed point is used to excite antenna, which is located such that it provide proper impedance matching at the operating frequency as shown in **Figure 1**. We simulate Rectangular Microstrip antenna on HFSS.

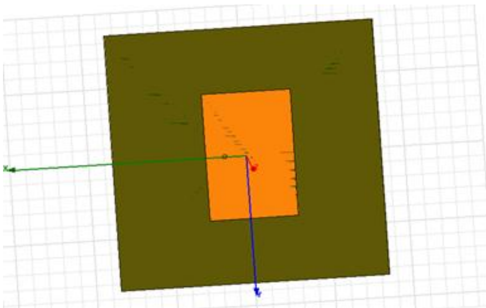

Fig.1 Rectangular Microstrip antenna

Figure 2 shows Return Loss for RMSA with all three types of materials. While observing Return Losses for all the three materials the lower, higher and central frequencies are also observed to calculate the bandwidth of RMSA. The Summary of observed lower, higher and central frequencies along with return loss and calculated bandwidth for FR4 Glass Epoxy, ARLON 450 and TACONIC 35 RMSA is as shown in **Table 1**.

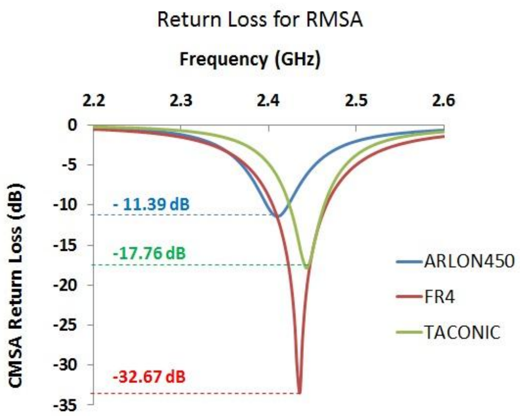

Fig.2 Return Loss for RMSA

Table 1: Summary of RMSA

RMSA Parameters	FR4	ARLON 450	TACONIC 35
Lower Frequency (GHz)	2.4057	2.3982	2.4227
Central Frequency (GHz)	2.4327	2.4132	2.4427
Higher Frequency (GHz)	2.4657	2.4232	2.4627
Bandwidth (MHz)	60	25	40
Return Loss (dB)	**-32.67**	**-11.39**	**-17.76**

3. Analysis of CMSA

The actual radius and effective radius of the circular patch can be obtained by:

$$a = \frac{F}{\sqrt{\left\{1+\frac{2h}{F\pi\varepsilon_r}\left[\ln\left(\frac{\pi F}{2h}+1.7726\right)\right]\right\}}} \quad (4)$$

Where,

a= Patch Radius, F= Operating Frequency,

h = thickness of substrate,

ε_r = Dielectric Permittivity of Substrate

and

$$a_e = a\sqrt{1+\frac{2h}{\pi a}\left[In\left(\frac{a}{2h}\right)+1.7726\right]} \quad (5)$$

Where,

a_e= Effective Patch Radius

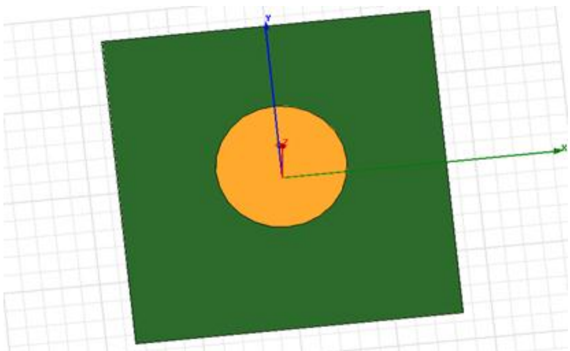

Fig.3 Circular Microstrip antenna

For FR4 Glass Epoxy, ARLON 450 the radius of circular patch is 17 mm and for TACONIC 35 the radius of circular patch is 18.7 mm also the co-axial feed point is used to excite antenna, which is located such that it provide proper impedance matching at the operating frequency as shown in **Figure 3**. We simulate Circular Microstrip antenna on HFSS.

Figure 4 shows Return Loss for CMSA with all three types of materials. While observing Return Losses for all the three materials the lower, higher and Central frequencies are also observed to calculate the bandwidth of CMSA.

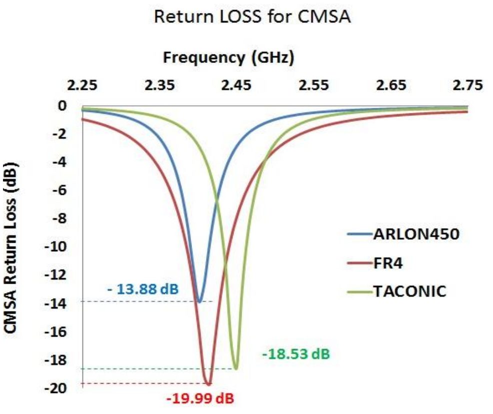

Fig.4 Return Loss for CMSA

Table 2: Summary of CMSA

CMSA Parameters	FR4	ARLON 450	TACONIC 35
Lower Frequency (GHz)	2.3865	2.3880	2.4350
Central Frequency (GHz)	2.4100	2.4008	2.4499
Higher Frequency (GHz)	2.4400	2.4130	2.4639
Bandwidth (MHz)	52	25	28.9
Return Loss (dB)	**-19.99**	**-13.88**	**-18.53**

The Summary of observed lower, higher and central frequencies along with return loss and calculated bandwidth for FR4 Glass Epoxy, ARLON 450 and TACONIC 35 CMSA is as shown in **Table 2**.

4. Analysis of NLMSA

For FR4 Glass Epoxy, ARLON 450 and TACONIC 35 the width of patch is 28 mm, 27.8 mm and 31.1 mm also, length of patch is 36.9 mm, 36.2 mm and 40.5 mm respectively.

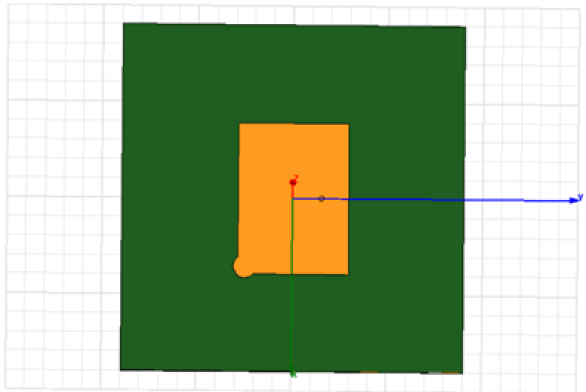

Fig.5 Non Linear Microstrip antenna

The co-axial feed point is used to excite antenna, which is located such that it provide proper impedance matching at the operating frequency. We simulate rectangular Microstrip antenna on HFSS. There is residual change at one corner of antenna as shown in **Figure 5**. This change has been made in a such way that the result should be best as compared to regular shape of antennas (RMSA, CMSA) which are already been used in Microstrip antenna industries while using them in most of the applications.

Figure 6 shows Return Loss for NLMSA with all three types of materials. While observing Return Losses for all the three materials the lower, higher and central frequencies are also observed to calculate the bandwidth of NLMSA.

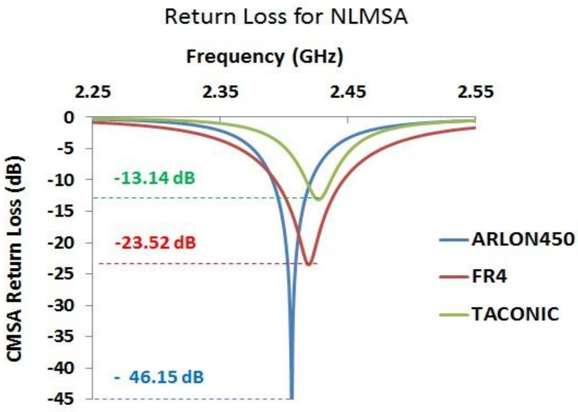

Fig.6 Return Loss for NLMSA

The Summary of observed lower, higher and central frequencies along with return loss and calculated bandwidth for FR4 Glass Epoxy ARLON 450 and TACONIC 35 NLMSA is as shown in **Table 3**.

Table 3: Summary of NLMSA

NLMSA Parameters	FR4	ARLON 450	TACONIC 35
Lower Frequency (GHz)	2.3955	2.3908	2.4172
Central Frequency (GHz)	2.4195	2.4060	2.4268
Higher Frequency (GHz)	2.4444	2.4212	2.4364
Bandwidth (MHz)	53.6	30.4	19.2
Return Loss (dB)	**-23.52**	**-46.15**	**-13.05**

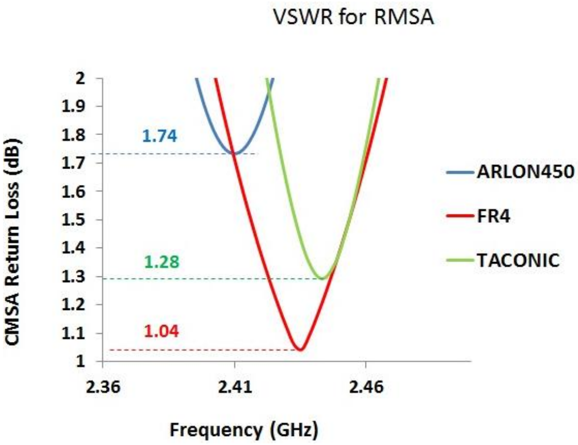

Fig. 7 VSWR for RMSA

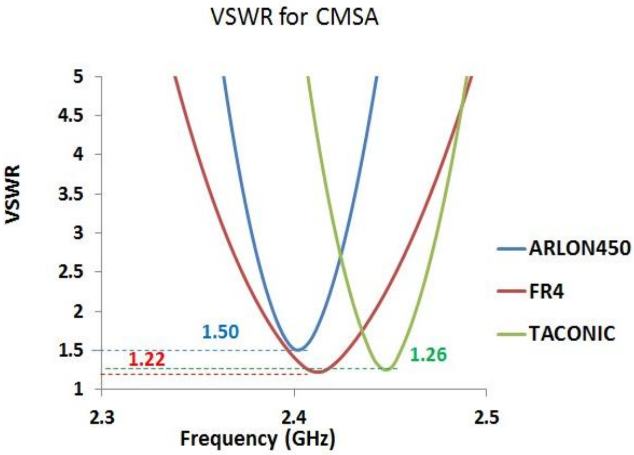

Fig. 8 VSWR for CMSA

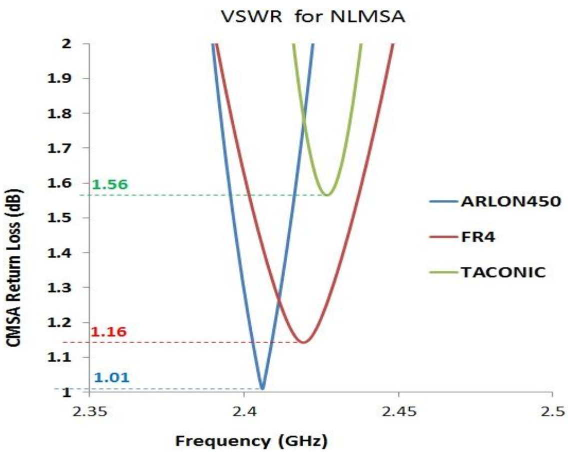

Fig. 9 VSWR for NLMSA

5. Analysis of VSWR

Figure 7 to Figure 9 shows VSWR variations for RMSA, CMSA and NLMSA respectively with substrates using FR4 Glass Epoxy, ARLON 450 and TACONIC 35.

Figure 2, Figure 4 and **Figure 6** shows that the antenna had an acceptable performance with Return Loss ≥ -10 dB.

Similarly **Figure 7 to Figure 9** shows that the antenna had an acceptable performance with VSWR ≤ 2. Also the impedance matching of the proposed antennas exhibits good matching using co-axial feeding technique.

Conclusions

The High Frequency Structure Simulator analysis of performance of RMSA, CMSA and NLMSA using coaxial feeding techniques for various substrate materials such as FR4 Glass Epoxy, ARLON 450 and TACONIC 35 presented in this paper shows that making residual change in conventional antennas it is possible to design and maintain the bandwidth of Non-Linear antenna. Interestingly, the bandwidth of the antenna is less than 80 MHz (ISM Band) which is very close to the conventional antenna wherein the Return Los and VSWR has also been maintained up to the acceptable level with RMSA, CMSA and NLMSA.

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