ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

Effect of Substrate Material Variations On RMSA, CMSA and NLMSA

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ABSTRACT: This paper deals with analysis of performance parameters of RMSA, CMSA and NLMSA 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, ROGERS, and PAPER EPOXY 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) and experimentally fabricated antennas are analyzed with Vector Network Analyzer (VNA). 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 application.

KEYWORDS: BW, VSWR, RL, RMSA, CMSA, NLMSA, HFSS, VNA, Dielectric, Parameter Analysis.

I. INTRODUCTION

Printed microstrip radiators were first proposed in 1953, the first MSA appeared in 1974, last couple of year MSA became popular because its low volume, light weight and low cost. 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 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

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, ROGERS and PAPER EPOXY 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

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, it is suitable for mobile and government security systems where

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narrow bandwidth is priority. 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, ROGERS and PAPER EPOXY.

Due to rapid advancements in this field it is necessary to develop to antenna design systems so Computer Aided Design tool available in the market gives lot of flexibility while designing MSA. Ansoft Simulation software (HFSS) is used to design microstrip antennas and fabricated using printed circuit board design technology. Both fabricated MSA and simulated antenna performance results are compared.

II. ANALYSIS OF RMSA

The basic RMSA Patch design equations are given by:

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

Where,

w = Patch Width, λ_0 = Wave Length, ϵ_r = Dielectric Constant and

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

$$\frac{\Delta L}{h} = \frac{(\epsilon_{reff}+0.300)\,(\frac{W}{h}+0.264)}{(\epsilon_{reff}+0.258)\,(\frac{W}{h}+0.800)} \qquad \text{......................} \ (3)$$

Where,

ΔL = Line Extension, W = Patch Width, h= Substrate Thickness

ϵ_{eff} = Effective Dielectric Constant ΔL = Line Extension, w = Patch Width

ϵ_{reff} = Effective Dielectric Constant, L = Patch Length, λ_0 = Wave Length

For FR4 Glass Epoxy and ROGERS the width of patch is 28 mm and length of patch is 42 mm and for PAPER EPOXY 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 Fig.1. We simulate Rectangular Microstrip antenna on HFSS.

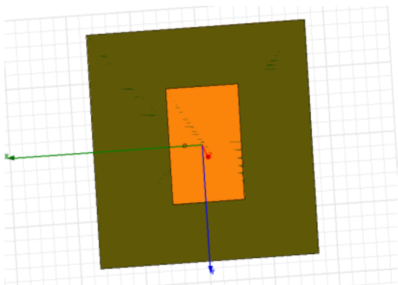

Fig.1 Rectangular Microstrip Antenna

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 center frequencies are also observed to calculate the bandwidth of RMSA.

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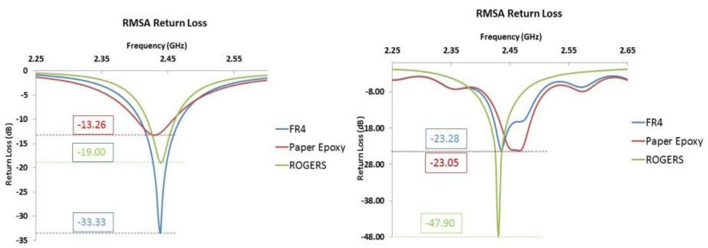

Fig. 2 Return Loss for RMSA (Simulated and Fabricated)

The Summary of observed lower, higher and central frequencies along with return loss and calculated bandwidth for FR4 Glass Epoxy RMSA is as shown in Table 1.

Table 1: Summary of RMSA

RMSA Parameters	FR4		ROGERS		PAPER EPOXY	
	HFSS	VNA	HFSS	VNA	HFSS	VNA
FL (GHz)	2.4045	2.4040	2.4183	2.3951	2.4020	2.4172
Fc (GHz)	2.4357	2.4282	2.4394	2.4312	2.4297	2.4658
FH (GHz)	2.4657	2.4856	2.4612	2.4569	2.4582	2.5011
Bandwidth (MHz)	61.2	81.6	42.9	61.8	56.2	83.9
Return Loss (dB)	-33.330	-23.281	-19.004	-47.901	-13.260	-23.05
VSWR	1.090	1.151	1.261	1.035	1.550	1.129
Rin	48.23	43.498	47.34	48.982	43.54	48.847

III. ANALYSIS OF CMSA

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

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

Where,

a= Patch Radius, F= Operating Frequency, h = thickness of substrate, ε_r = Dielectric Permittivity of Substrate also,

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

Where,

a_e= Effective Patch Radius

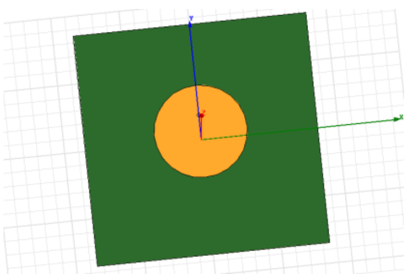

Fig.3 Circular Microstrip Antenna

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Vol. 3, Issue 12, December 2014

For FR4 Glass Epoxy, ROGERS the radius of circular patch is 17 mm and for PAPER EPOXY 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 center frequencies are also observed to calculate the bandwidth of CMSA.

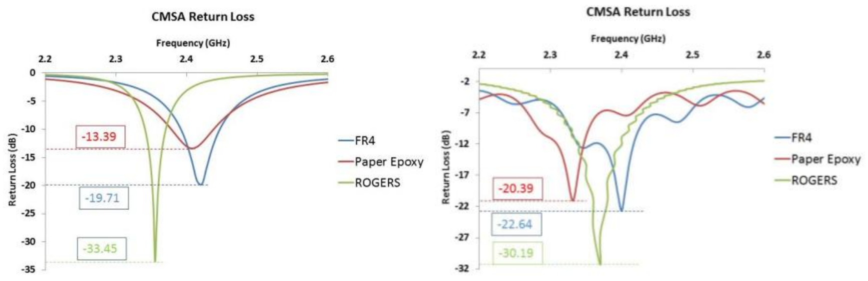

Fig.4 Return Loss for CMSA (Simulated and Fabricated)

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

Table 2: Summary of CMSA

RMSA Parameters	FR4		ROGERS		PAPER EPOXY	
	HFSS	VNA	HFSS	VNA	HFSS	VNA
FL (GHz)	2.3847	2.3267	2.3412	2.3355	2.3784	2.2826
Fc (GHz)	2.4148	2.3929	2.3554	2.3646	2.4078	2.3333
FH (GHz)	2.4403	2.4150	2.3706	2.4107	2.4382	2.3576
Bandwidth (MHz)	55.6	88.3	29.4	75.2	59.8	75.0
Return Loss (dB)	-19.71	-22.64	-33.45	-30.19	-13.39	-20.39
VSWR	1.230	1.184	1.043	1.086	1.540	1.203
Rin	43.97	50.160	48.03	34.419	39.57	48.130

. IV. ANALYSIS OF NLMSA

For FR4 Glass Epoxy, ROGERS and PAPER EPOXYthe 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.

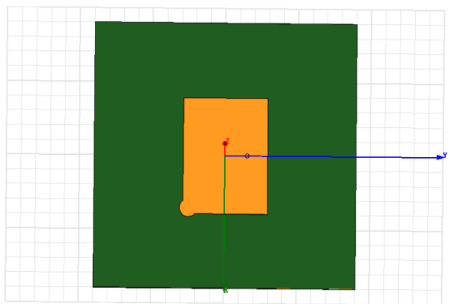

Fig.5 Non Linear Microstrip Antenna

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ISSN (Online): 2278 – 8875

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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 Fig.5.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 center frequencies are also observed to calculate the bandwidth of NLMSA.

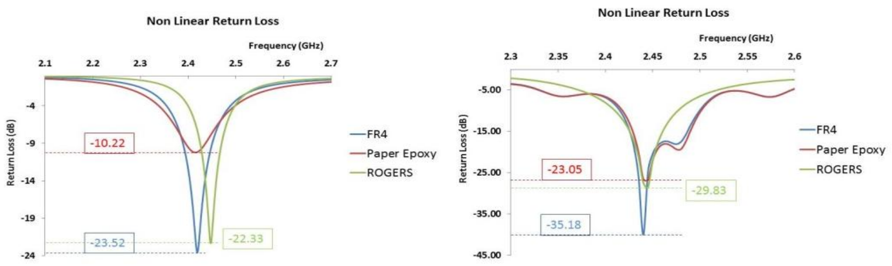

Fig.6 Return Loss for NLMSA (Simulated and Fabricated)

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

Table 3: Summary of NLMSA

RMSA Parameters	FR4		ROGERS		PAPER EPOXY	
	HFSS	VNA	HFSS	VNA	HFSS	VNA
FL (GHz)	2.3924	2.4150	2.4279	2.3973	2.4068	2.4172
Fc (GHz)	2.4196	2.4415	2.4476	2.4437	2.4156	2.4371
FH (GHz)	2.4468	2.4967	2.4673	2.4790	2.4235	2.5011
Bandwidth (MHz)	54.4	81.7	39.4	81.7	16.7	83.9
Return Loss (dB)	-23.52	-35.18	-22.339	-29.831	-10.220	-23.054
VSWR	1.230	1.053	1.193	1.095	1.890	1.170
Rin ()	49.17	49.102	47.53	44.264	34.07	51.917

Fig. 7 shows antennas are fabricated from simulation results; these fabricated antennas are tested using VNA to measure antenna performance parameters for substrate materials i.e. FR4 Glass Epoxy, Paper Epoxy and Rogers.

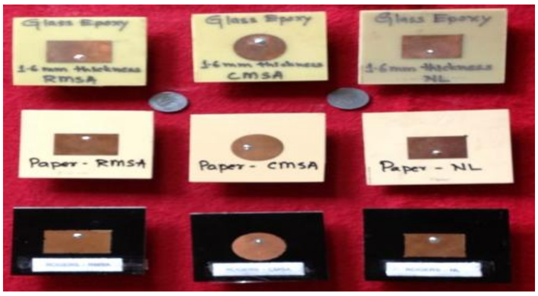

Fig. 7 Material variation Fabricated Antennas

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V. ANALYSIS OF RETURN LOSS AND VSWR

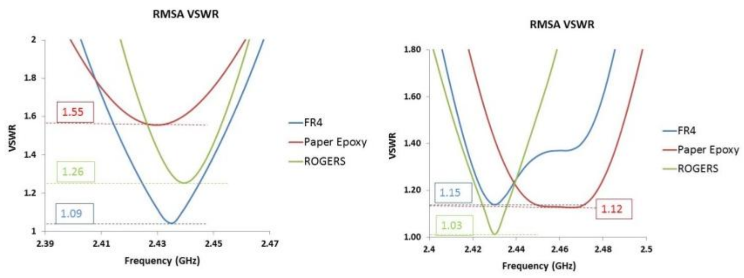

Fig. 8 VSWR for RMSA (Simulated and Fabricated)

Fig. 8 shows VSWR for simulated and fabricated antennas with substrate materials FR4 Glass Epoxy, Paper Epoxy and Rogers for RMSA.

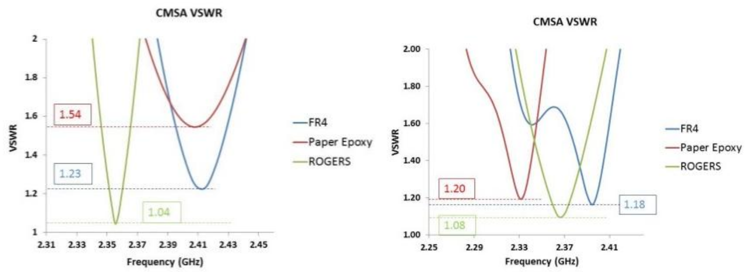

Fig. 9 VSWR for CMSA (Simulated and Fabricated)

Fig. 9 shows VSWR for simulated and fabricated antennas with substrate materials FR4 Glass Epoxy, Paper Epoxy and Rogers for CMSA.

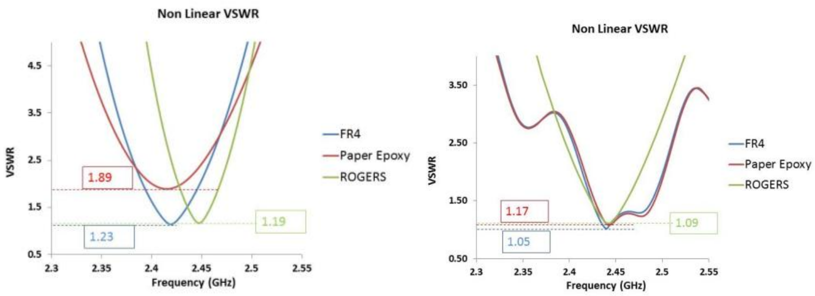

Fig. 10 VSWR for NLMSA (Simulated and Fabricated)

Fig. 10 shows VSWR for simulated and fabricated antennas with substrate materials FR4 Glass Epoxy, Paper Epoxy and Rogers for NLMSA.

The antenna has an acceptable performance with Return Loss ≥-10 dB. The antenna has an acceptable performance with VSWR ≤ 2. Also the impedance matching of the proposed antennas exhibits good matching using co-axial feeding technique. All above MSA are designed with HFSS and fabricated, tested using VNA at 2.4GHz operating frequency in ISM band. Also, return loss and VSWR results are measured from simulation and on VNA with substrate materials FR4 Glass Epoxy, Paper Epoxy and Rogers for NLMSA.

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VI. CONCLUSIONS

The High Frequency Structure Simulator and fabricated VNA testing analysis of performance of RMSA, CMSA and NLMSA using coaxial feeding techniques for various substrate materials such as FR4 Glass Epoxy, ROGERS and PAPER EPOXY 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 all antennas is closer to 80 MHz (i.e. Bandwidth of ISM Band) also which is matched with the conventional antenna. The Return Los and VSWR of simulated and fabricated antenna have been maintained up to the acceptable level with RMSA, CMSA and NLMSA.

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BIOGRAPHY

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