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Explored the impact of a variety of substrate materials on microstrip patch antenna

Padmavati * and Harshavardhan Reddy

Department of ECE FET (Co-ed), Kalaburagi, Karnataka, India.

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Abstract

According to recent study, adopting the correct dielectric substrate for the future generation of wireless communications can improve antenna performance. In this paper, an attempt is made to design a microstrip feed line microstrip antenna structure for S band application using a variety of substrate materials like Rogers RT Duroid 5870, Rogers RO3003, FR4- epoxy, Bakellite and Glass with relative permittivity of (εr) 2.33, 3, 4.4, 4.8 and 5.5. Analyse S11, VSWR and observe the impact of various parameters by changing height for all substrate in terms of return losses. Ansoft HFSS 13.0 antenna software was used to design and create the matching network of a Microstrip Patch Antenna at 2.4 GHz.

Keywords: Rogers RT Duroid 5870; Rogers RO3003; FR4- epoxy; Bakelite; Glass; S-band

1 Introduction

Wireless communications has grown to the point where it is now a major industry, a field that was formerly reserved for specialized uses, most notably military, but has now become a significant market for the general public. Smartphones, GPS, WiFi, and radars are just a few examples of new applications that have emerged as a result. Conversely, the shape of microstrip patch antennas is often considered to be the most suitable because of their simple model, compact design, light in weight, and flat shape that allows conformal operation. It has recently gained popularity due to its ease of feeding, fabrication, and favorable radiation properties [1]. They are employed in a variety of applications, including wireless technology, telecommunication networks as well as contemporary multipurpose radar [2–4]. On the other side, planning this patch necessitates determining the structure, feeding, and specifications of the patch, as well as the effectiveness, size, and cost of the substrate. The dielectric constant (r) of the microstrip patch antenna substrate varies between 2.2 and 12 [5–7]. The depth and dielectric constant of the substrate are the fundamental essential steps in patch antenna design; these factors significantly effect on the antenna's operation. Increases in the bandwidth parameter can be caused by increasing the substrate thickness and/or decreasing the substrate dielectric constant value. [8].

In this paper, A 2.4 GHz ISM band rectangular shape patch antenna fed by 50Ω microstrip feed line is intended and simulated using Ansoft HFSS 13.0 antenna software with a different substrate materials such as Rogers RT Duroid 5870, Rogers RO3003, FR4- epoxy, Bakellite and Glass at 0.16 cm and 0.32 cm height. The proposed antenna characteristics are analyzed in the following sections.

2 ANTENNA Design

The suggested rectangular patch antenna was intended using five unlike substrate materials at 0.16 cm and 0.32 cm height: Rogers RT Duroid 5870, Rogers RO3003, FR4- epoxy, Bakellite and Glass having relative permittivity of (ε_r) 2.33,

* Corresponding author: Padmavati
Department of ECE FET (Co-ed), Kalaburagi, Karnataka, India.

3, 4.4, 4.8 and 5, respectively. The dimensions of the patch were calculated using the following equations (from 1 to 4) while considering a rectangle-shaped patch antenna on the substrate. The following equation [9-13] is used to calculate the radiating element's parameter width (w):

$$w = \frac{c}{2 f_o \sqrt{\frac{\varepsilon_r + 1}{2}}} \qquad (1)$$

Here 'c' represents the light-speed, ε_r is the substrate's dielectric constant, and f_o is the antenna's resonance frequency. Then, using the two formulas [9], we estimated the patch rectangular antenna's effective permittivity (ε_{eff}) and the fringing length antenna (Δl), also known as the "open end effect."

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-\frac{1}{2}} \qquad (2)$$

$$\Delta l = 0.412 h \left(\frac{(\varepsilon_e + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_e - 0.258)\left(\frac{W}{h} + 0.8\right)} \right) \qquad (3)$$

Considering these two values, we were able to compute the patch antenna length as follows:

$$L = \frac{c}{2 f_0 \sqrt{\varepsilon_{reff}}} - 2\Delta L \qquad (4)$$

We designed a patch antenna using Ansoft HFSS 13.0 antenna software based on the preceding equations, and the resultant patch antenna layout is illustrated in Figure1. It comprises of a rectangular patch having groove modification on the dielectric substrate, it receives its stimulation via a microstrip line feed because this is the simplest and straightforward technique for feeding a microstrip patch antenna [9]. Table 1 shows the computed size specifications for the radiating element (L, W) as well as the imitation length and width of the line (L_f, W_f) for five unlike substrate materials.

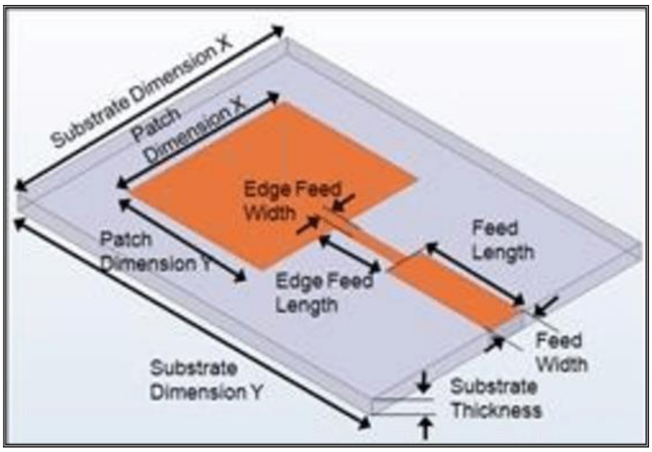

Figure 1 Proposed antenna's geometrical view

Table 1 The proposed patch antenna's physical specifications

Substrates	ε_r	Loss tangent	Thickness	Length of the patch	Width of the patch	Edge feed length	Edge feed width	Feed length	Feed width
Rogers RT Duroid 5870	2.33	0.0012	0.16 cm	4.02 cm	4.84 cm	2.292 cm	0.179 cm	3.719 cm	0.475 cm
			0.32 cm	3.92 cm	4.84 cm	2.292 cm	0.358 cm	3.719 cm	0.95 cm
Rogers RO3003	3	0.0013	0.16 cm	3.55 cm	4.42 cm	2.082 cm	0.13 cm	3.351 cm	0.402 cm
			0.32 cm	3.47 cm	4.42 cm	2.082 cm	0.261 cm	3.351 cm	0.804 cm
FR4- epoxy	4.4	0.02	0.16 cm	2.94 cm	3.8 cm	1.797 cm	0.072 cm	2.854 cm	0.306 cm
			0.32 cm	2.87 cm	3.8 cm	1.797 cm	0.145 cm	2.854 cm	0.612 cm
Bakellite	4.8	0.002	0.16 cm	2.82 cm	3.67 cm	1.737 cm	0.062 cm	2.751 cm	0.286 cm
			0.32 cm	2.75 cm	3.67 cm	1.737 cm	0.124 cm	2.751 cm	0.573 cm
Glass	5.5	0	0.16 cm	2.64 cm	3.47 cm	1.647 cm	0.047 cm	2.596 cm	0.258 cm
			0.32 cm	2.57 cm	3.47 cm	1.647 cm	0.095 cm	2.596 cm	0.515 cm

3 Results and discussion

The comparative simulation results of Reflection Coefficient (S_{11}) and VSWR of proposed antenna on different substrate materials at 0.16 cm and 0.32 cm height is depicted in Figure 2 and Figure 3 respectively. The performance parameters of antennas for various dielectric materials are depicted in Table 2.

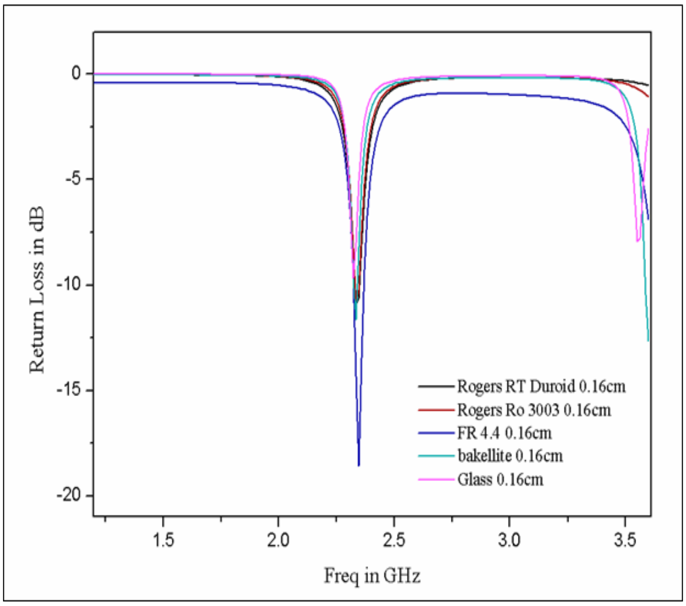

Figure 2 Reflection Coefficient at 0.16 cm height

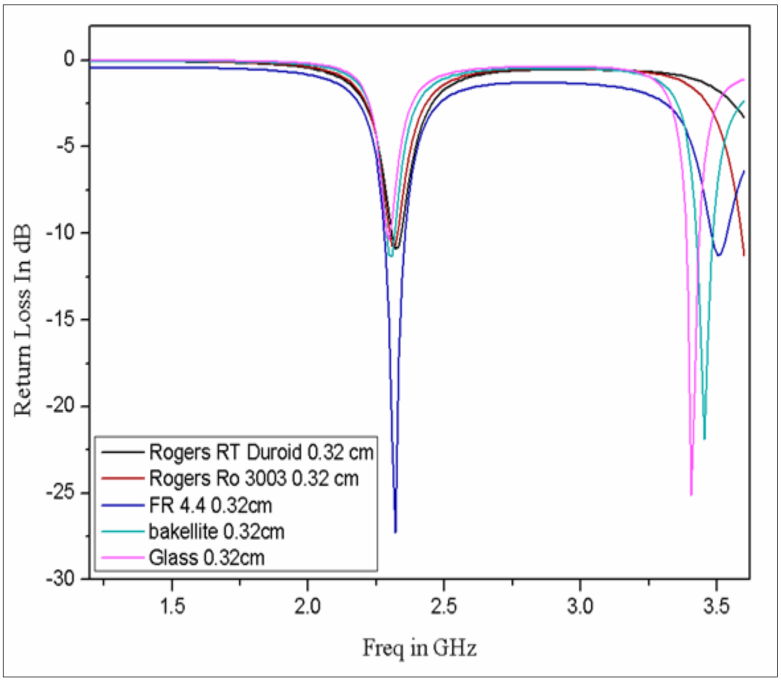

Figure 3 Reflection Coefficient at 0.32 cm height

Table 2 The performance parameters of antennas for various dielectric materials

Substrates	Thickness	Resonance frequency	Return Loss	Bandwidth in MHz	VSWR	Gain in dB
Rogers RT Duroid 5870	0.16 cm	2.33GHz	-10.9dB	20	1.78	6.9
	0.32 cm	2.32GHz	-10.9dB	45	1.79	7.5
Rogers RO3003	0.16 cm	2.3GHz	-10.9dB	30	1.79	6.99
	0.32 cm	2.32GHz	-10.7dB	40	1.82	7.59
FR4- epoxy	0.16 cm	2.34GHz	-18.57dB	50	1.26	3
	0.32 cm	2.32GHz	-27.31dB	83.7	1.09	4.8
Bakellite	0.16 cm	2.33GHz	-11.66dB	24	1.7	6.4
	0.32 cm	2.29GHz	-11.19dB	36	1.74	7
Glass	0.16 cm	2.32GHz	-9.68dB	--	1.97	7
	0.32 cm	2.29GHz	-10.34dB	24	1.87	7.26

From the above results it can be observed that the antenna simulated on a FR4- epoxy substrate shows better performance compared to other substrate materials and achieves an **83.7MHz** bandwidth with **-27.31dB** return loss. This is the low cost and easily available substrate material and can be used for ISM band applications.

The simulated 2-D radiation pattern of proposed antenna on a FR4- epoxy substrate at resonant frequency 2.34GHz for phi equal to 0^0 and 90^0 is shown in figure 4 for height equal to 0.16 cm. It is clearly indicates that radiation is broadside in direction with small backward radiation. Similarly the simulated 2-D radiation pattern of proposed antenna on a FR4- epoxy substrate at resonant frequency 2.32GHz for phi equal to 0^0 and 90^0 is shown in figure 5 for height equal to 0.32 cm. It is clearly indicates that radiation is broadside in direction with small backward radiation.

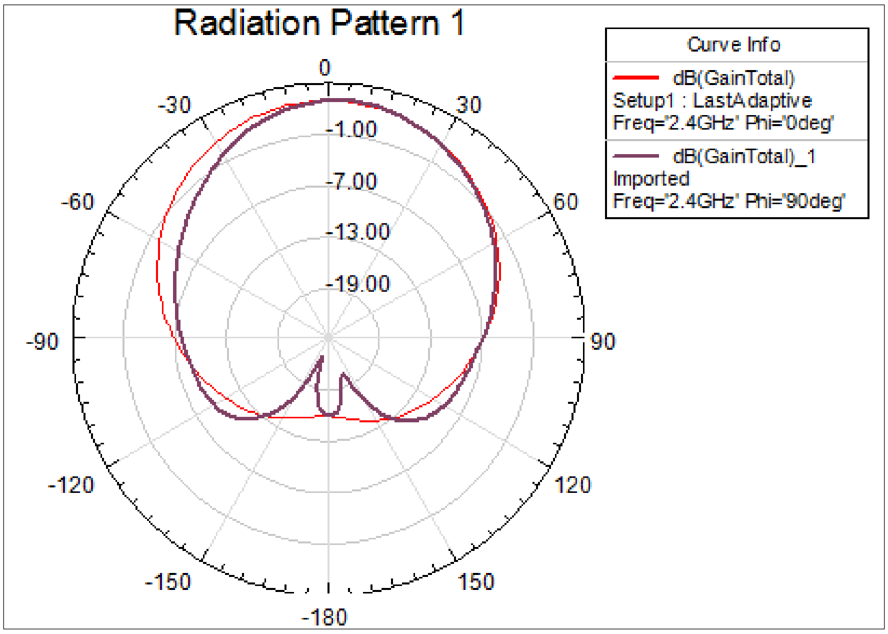

Figure 4 Radiation pattern of FR4- epoxy substrate at height 0.16 cm

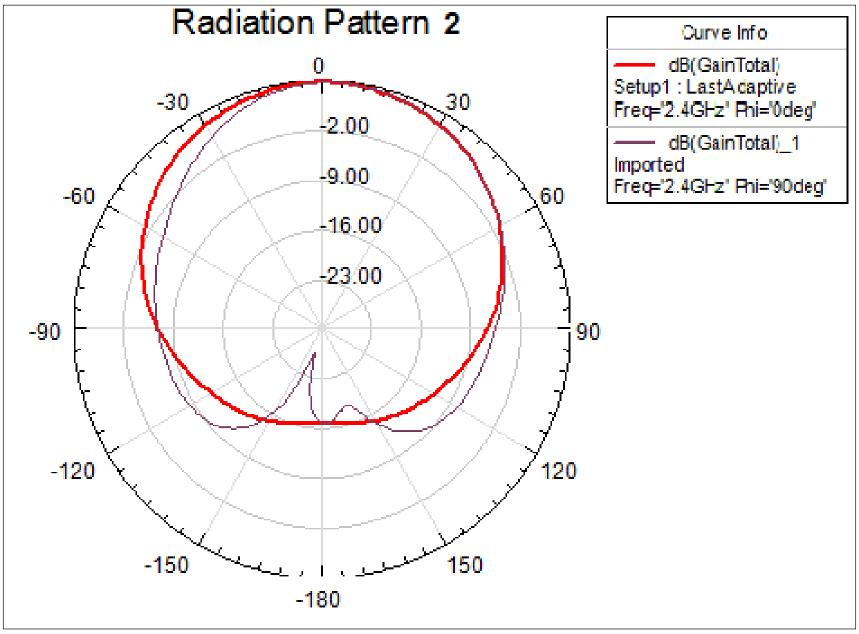

Figure 5 Radiation pattern of FR4- epoxy substrate at height 0.32 cm

4 Conclusion

In this work, we explored the impact of a variety of substrate materials on microstrip patch antenna at working frequency of 2.4 GHz. Comparisons were made between the obtained results for the antenna properties of gain, bandwidth, and return loss using a variety of substrate materials like Rogers RT Duroid 5870, Rogers RO3003, FR4-epoxy, Bakellite and Glass with relative permittivity of (ε_r) 2.33, 3, 4.4, 4.8 and 5.5. The outcomes showed that the FR4-epoxy substrate is generally good, low cost and easily available substrate material for ISM band applications.

Compliance with ethical standards

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Disclosure of conflict of interest

The author(s) declare that they have no conflicts of interest.

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