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Performance Analysis of Microstrip Patch Antenna Based On Dielectric Materials

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Abstract
Performance parameters of microstrip patch antenna up to a large extend depends on the parameters of substrate. This may be the dielectric constant of substrate or it may be the height of the substrate. In this research a 2.4 GHz microstrip patch antenna with different substrate is designed and analyzed using High Frequency Structure Simulator. The two substrates' materials used are FR-4 and RT-5880 with the relative permittivity of 4.3 and 2.2 respectively.
Index Terms— Microstrip patch antenna, VSWR, Bandwidth, Directive gain.

1. Introduction

With the development of modern wireless communication, the demand to evaluate the performance parameters of antenna is increasing day by day. This research presents the evaluation of performance parameters of microstrip patch antenna by considering the different substrates for the design of patch antenna. The two substrates' materials used are FR-4 and RT-5880 with the relative permittivity ranging from 3.8 to 4.8 with center value of around 4.4 for FR-4, relative permittivity of around 2.2 for RT-5880. The thickness of FR-4 pcb is around 1.57mm, the thickness of RT-5880 pcb is around 1.6 mm The structure of microstrip patch antenna includes a radiating patch on one side of substrate and ground on other side of patch as shown in Fig (1). Signal to be radiated is applied between patch and ground using microstrip line. The frequency and efficiency of radiation for Patch antenna depends on the dimensions, structure, and material of both patch and substrate. Radiation frequency and efficiency of a patch antenna is dependent on the length of patch antenna and width of patch antenna respectively. The optimized expressions proposed for design of patch antenna are [1-5].

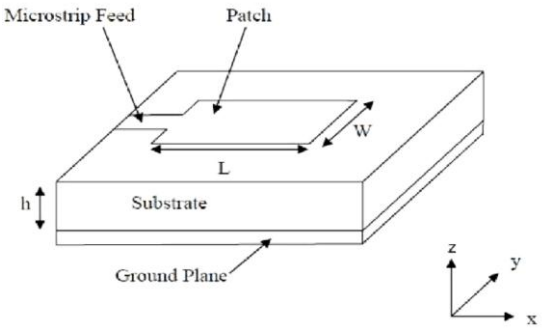

Figure 1. Microstrip Patch Antenna

For radiating a signal of frequency (*f*), required patch antenna width (*w*) is

$$w = \frac{c_o}{2\,f\sqrt{\frac{\varepsilon+1}{2}}} \quad \text{----------(1)}$$

Here ε is the permittivity of the substrate.

Here $c_o = 10^8 m/s$ is velocity of light.

The effective optimized permittivity of medium is

$$\mathcal{E}(eff) = \frac{\mathcal{E}+1}{2} + \frac{\mathcal{E}-1}{2}\sqrt{1+12\,\frac{h}{w}} \quad \text{----------(2)}$$

h is substrate height.

Optimized required Patch antenna length *(L)* is

$$L = \frac{C}{2f\sqrt{\mathcal{E}}} - 2\Delta l \quad \text{----------(3)}$$

Here Δl is extension in length of patch due to available fields.

$$\frac{\Delta l}{h} = .412\,\frac{[\varepsilon\,(eff)+.3]\left[\frac{w}{h}+.264\right]}{[\varepsilon\,(eff)-.258]\left[\frac{w}{h}+.8\right]} \quad \text{----------(4)}$$

Based on above equations The optimized Patch antenna dimensions for radiating signal of frequency 2.4 GHz in this study are as presented below

Table 1

S. No.	Name of Parameter	Value
1	Resonant Frequency	2.4 GHz
2	Patch Length	5 Cm
3	Patch width	4.15 cm
4	Substrate Material	FR4
5	Substrate height	.16 cm
6	Feed width	.493 cm
7	Feed Length	6.15 cm

As we have to investigate the effect of Dielectric material so in above mentioned parameters of patch antenna we are only changing the substrate material as presented in table2.

Table 2

S.No.	Performance Parameter	Rectangular Patch antenna with RT-5880 as substrate Dielectric constant 2.2	Rectangular Patch antenna with FR4 as substrate Dielectric constant 4.4
1	Input Impedance	42.65 Ω	18.10 Ω
2	VSWR	6	19
3	S_{11}	-3 dB	-.9 dB
4	Gain	7 dB	-5.4 dB

High frequency structure simulator is used to design and simulate microstrip patch antenna.

2. Results and Discussion

The structure of Rectangular Patch antenna using RT-5880 as substrate and designed using High Frequency Structure Simulator for 2.4 GHz is shown in Fig (2).

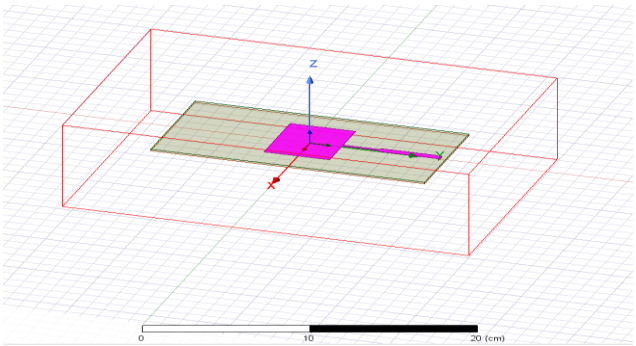

Figure 2. Structure of Rectangular Patch antenna

Input Impedance of designed antenna for RT-5880 is shown in Fig (3). Obtained Input impedance is 42.65 Ω. The scattering parameter at Port 1 is measured to be -3 db. and is shown in Fig (4). This indicates a good matching between source and antenna.

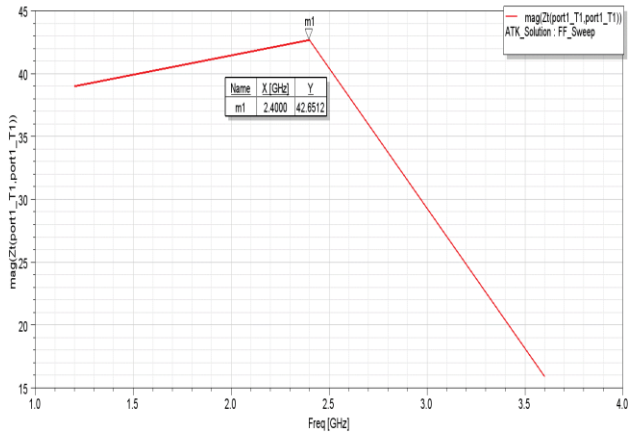

Figure 3. Input impedance of Rectangular Patch antenna for RT-5880

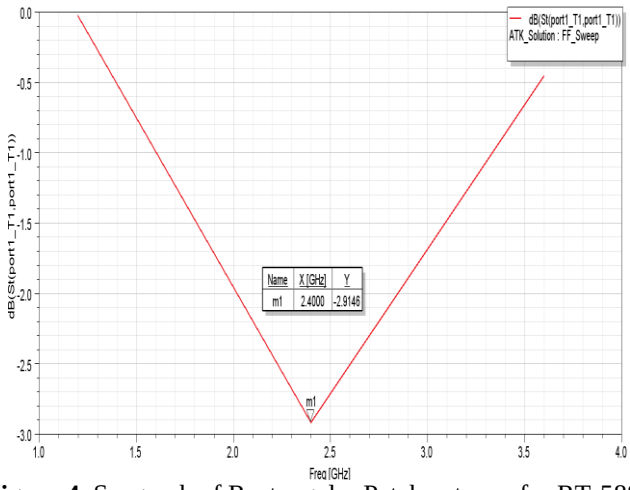

Figure 4. S_{11} graph of Rectangular Patch antenna for RT-5880

VSWR of designed dipole antenna is shown in Fig (5). Obtained VSWR is around 6 which indicate good matching between source and load.

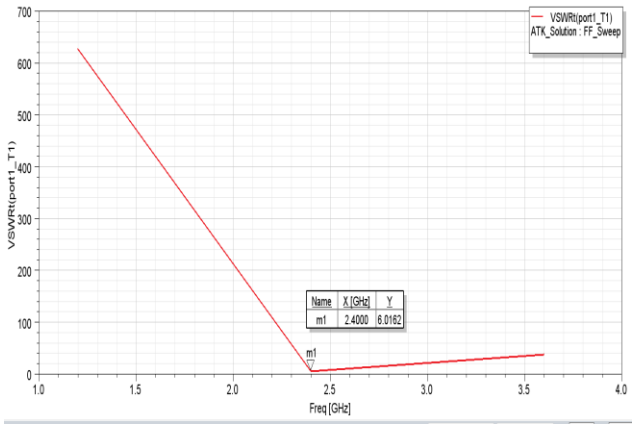

Figure 5. VSWR graph of Rectangular Patch antenna for RT-5880.

The Radiation Pattrn of designed dipole antenna is shown in Fig (6). A gain of 7 dB is achievable from designed dipole antenna.

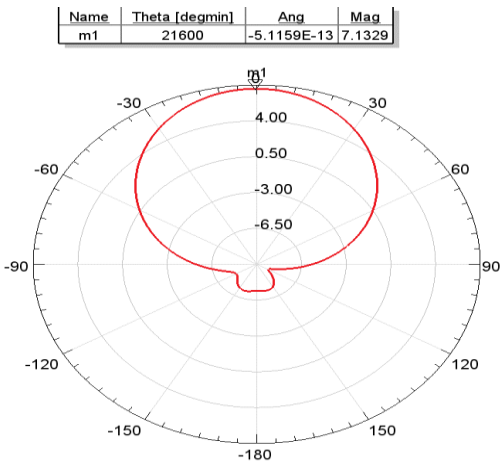

Figure 6. Radiation Pattern of Rectangular Patch antenna RT-5880.

Input Impedance of designed antenna for FR4 is shown in Fig (7). Obtained Input impedance is 18.10 Ω. The scattering parameter at Port 1 is measured to be -.90 db. and is shown in Fig (8). This indicates a good matching between source and antenna.

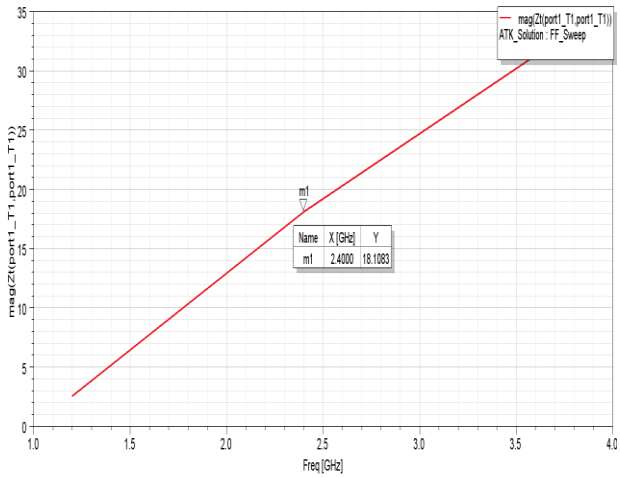

Figure 7. Input impedance of Rectangular Patch antenna for FR4

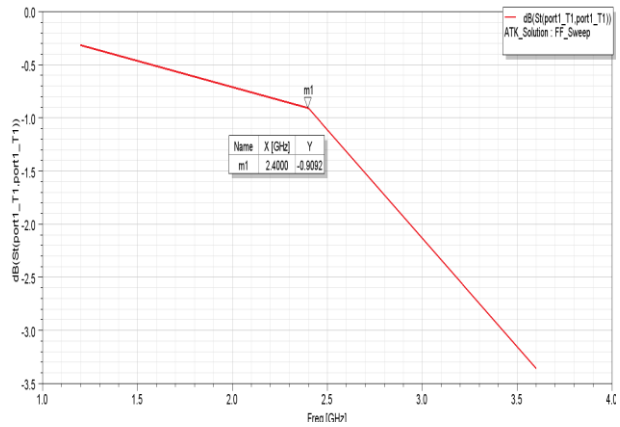

Figure 8. S_{11} graph of Rectangular Patch antenna for FR4

VSWR of designed Rectangular Patch antenna for FR4antenna is shown in Fig (9). Obtained VSWR is around 19.

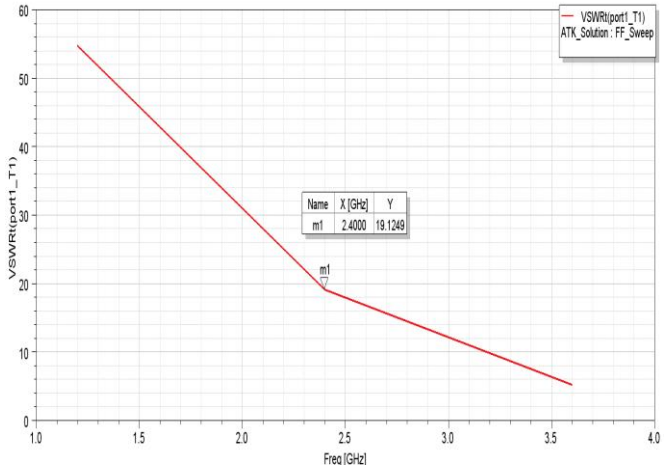

Figure 9. VSWR graph of Rectangular Patch antenna for FR4.

The Radiation Pattrn of designed FR4 Rectangular Patch antenna is shown in Fig (10). A gain of -5.4 dB is achievable from designed dipole antenna.

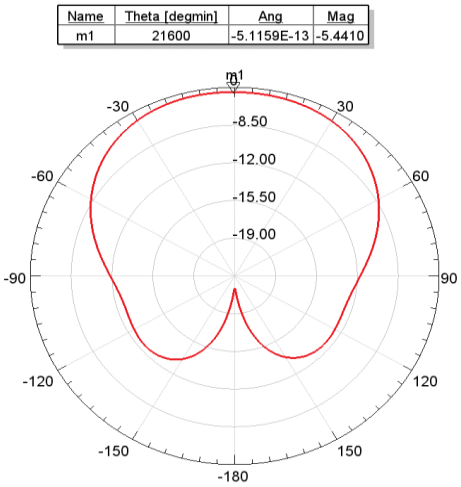

Figure 10. Radiation Pattern of Rectangular Patch antenna FR4.

Conclusion

A Rectangular Patch antenna using FR4 and RT-5880 as substrate material and designed and simulated using HFSS. Substrate height is kept constant in both antennas. A comparison of these antennas is presented below

From the results it can be concluded that for same height of substrate performance of patch antenna deteriorate with increase in dielectric constant of substrate.

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