Investigation Of Triangular Microstrip Patch Antenna On Six Different Substrates For X –Band Applications

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ABSTRACT

The performance characteristics of microstrip patch antennas depend on various characteristics like substrate material selection, patch dimensions, feeding techniques, thickness of the substrates etc.This paper presents the performance investigation of triangular microstrip patch antenna on six different dielectric substrates of same thickness or height (1.5mm).All these antennas are having different dimensions , but resonant frequency and height are same. The six dielectric materials which are investigated are Bakelite, FR4 Glass Epoxy, RO4003, Taconic TLC , RT Duroid and Polyester. The output parameters of all these antennas are simulated using IE3D software. Among the six triangular antenna, antenna with Polyester as a dielectric substrate gives optimum results in terms of Directivity, Gain, Bandwidth and Efficiency.

Keywords – Dielectric Substrates, IE3D Simulator, Microstrip Patch Antenna, Triangular Patch, Polyester.

1. INTRODUCTION

Microstrip patch antennas are used in many applications due to their small size, low cost, ease of fabrication, dual frequency operation and support of linear and circular polarization. However, their gain and bandwidth are very low. Several techniques are suggested by different authors for gain enhancement. Bandwidth is directly proportional to the patch dimension and inversely proportional to the dielectric constant of the substrate. Gain of the antenna is also largely depends on the dielectric constant of the dielectric substrates. Dielectric material must have very low water absorption capability as it increases the gain of the antenna. In this paper, different dielectric substrates are investigated on triangular microstrip patch antenna. The side of the equilateral triangle is calculated by using the values of resonant frequency, dielectric constant and velocity of light. The geometry is drawn and simulated using IE3D simulator as it is an integrated full wave simulation and optimization package for the analysis and design of 3D microstrip antenna. Among the popular geometries like rectangular, circular and triangular, triangular geometry is selected because it takes minimum patch area as compared to other two geometry.

2. DESIGN SPECIFICATION

The lowest order resonant frequency is given by –

$$f_r = \frac{2c}{3a\sqrt{\varepsilon_r}}$$

Where, $c = 3\times10^{10}\, cm/\sec.$
and

$a = side$
ε_r = dielectric constant of the substrate.

As the antenna is to be designed for X-band applications, the resonant frequency is selected to be 10 GHz. The side of the antenna for each of the six substrates is calculated from the above formula.

2.1 Triangular Patch with Bakelite

Dielectric constant, $\varepsilon_r = 4.78$

Loss tangent, $\tan\delta = 0.03045$

Height $= 1.5\ mm$

$$a = \frac{2\times3\times10^{10}}{3\times10\times10^{9}\sqrt{3.2}}$$

$$= 0.915cm = 9.15mm$$

2.2 Triangular Patch with FR4 Glass Epoxy

Dielectric constant, $\varepsilon_r = 4.36$

Loss tangent, $\tan\delta = 0.013$

Height $= 1.5\ mm$

$$a = \frac{2\times3\times10^{10}}{3\times10\times10^{9}\sqrt{4.36}}$$

$$= 0.9575cm = 9.575mm$$

2.3 Triangular Patch with RO4003

Dielectric constant, $\varepsilon_r = 3.4$

Loss tangent, $\tan\delta = 0.002$

Height $= 1.5\ mm$

$$a = \frac{2\times3\times10^{10}}{3\times10\times10^{9}\sqrt{3.4}}$$

$$= 1.085cm = 10.85mm$$

2.4 Triangular Patch with Taconic TLC

Dielectric constant , $\varepsilon_r = 3.2$

Loss tangent, $\tan\delta = 0.002$

Height $= 1.5\ mm$

$$a = \frac{2\times 3\times 10^{10}}{3\times 10\times 10^{9}\sqrt{3.2}}$$

$$= 1.1175cm = 11.175mm$$

2.5 Triangular Patch with RT Duroid

Dielectric constant, $\varepsilon_r = 2.2$

Loss tangent, $\tan\delta = 0.0004$

Height $= 1.5\ mm$

$$a = \frac{2\times 3\times 10^{10}}{3\times 10\times 10^{9}\sqrt{2.2}}$$

$$= 1.3475cm = 13.475mm$$

2.6 Triangular Patch with Polyester

Dielectric constant, $\varepsilon_r = 1.39$

Loss tangent, $\tan\delta = 0.1$

Height $= 1.5mm$

$$a = \frac{2\times 3\times 10^{10}}{3\times 10\times 10^{9}\sqrt{1.39}}$$

$$= 1.696cm = 16.96mm$$

3. ANTENNA GEOMETRY

3.1 Bakelite

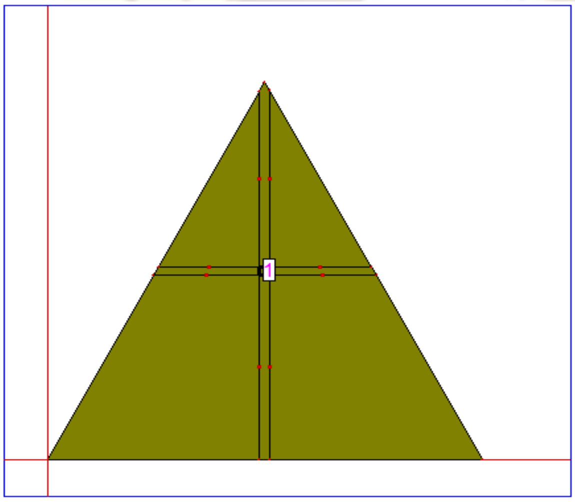

Fig.1 Triangular patch on Bakelite

The triangular patch geometry is fabricated with the given data for side, dielectric constant, resonant frequency and loss tangent of Bakelite. Probe to feed is given on x= 4.57, y=4.57.

3.2 FR4 Glass Epoxy

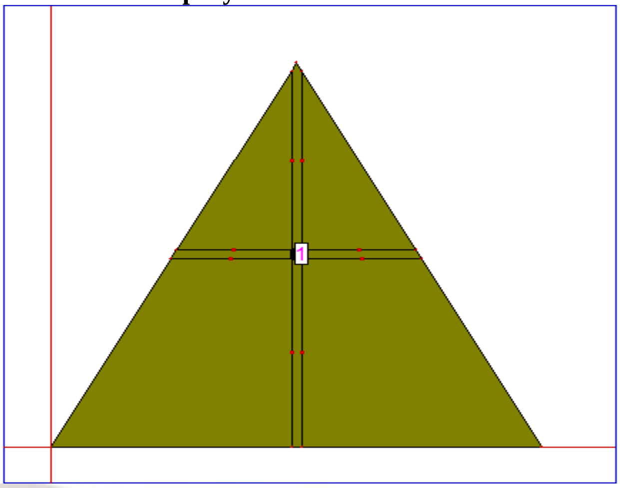

Fig.2 Triangular patch on FR4 Glass Epoxy

The triangular patch geometry is fabricated with the given data for side, dielectric constant, resonant frequency and loss tangent of FR4 Glass Epoxy. Probe to feed is given on x=4.8, y=4.8.

3.3 RO4003

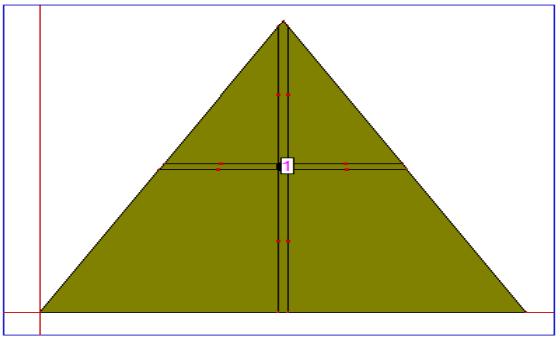

Fig.3.3 Triangular patch on RO4003

The triangular patch geometry is fabricated with the given data for side, dielectric constant, resonant frequency and loss tangent of RO4003. Probe to feed is given on x=5.425, y=5.425.

3.4 Taconic TLC

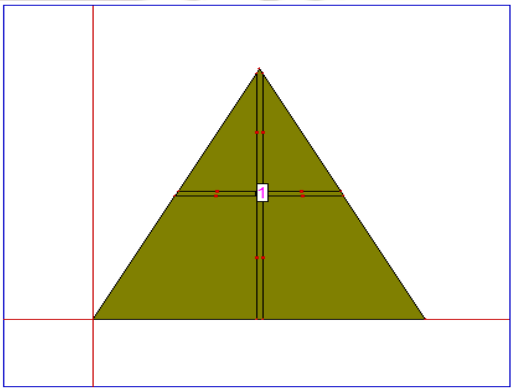

Fig.4 Triangular patch on Taconic TLC

The triangular patch geometry is fabricated with the given data for side, dielectric constant, resonant frequency and loss tangent of Taconic TLC. Probe to feed is given on x=5.6, y=5.6

3.5 RT Duroid

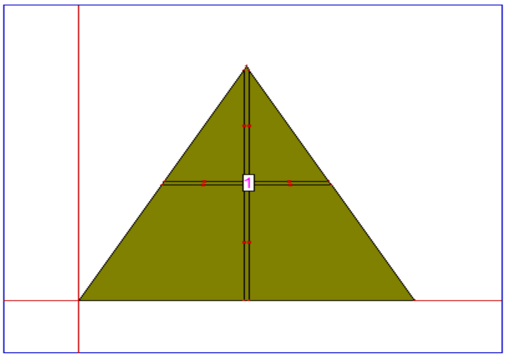

Fig.5 Triangular patch on RT Duroid

The triangular patch geometry is fabricated with the given data for side, dielectric constant, resonant frequency and loss tangent of RT Duroid. Probe to feed is given on x=6.75, y=6.75.

3.6 Polyester

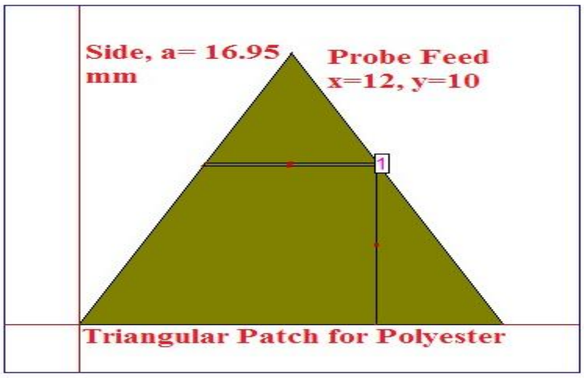

Fig.6 Triangular patch on Polyester

The triangular patch geometry is fabricated with the given data for side, dielectric constant, resonant frequency and loss tangent of Polyester. Probe to feed is given on x=12, y=10.

4. SIMULATED RESULTS

4.1 Bandwidth Calculation

The bandwidth can be calculated from the following formula-

$$BW = \frac{f_h - f_l}{\left(\frac{f_h + f_l}{2}\right)} \times 100\%$$

Where, BW is bandwidth, f_h and f_l are highest and lowest frequency.

4.2 RETURN LOSS VS FREQUENCY

4.3 4.2.1 Bakelite

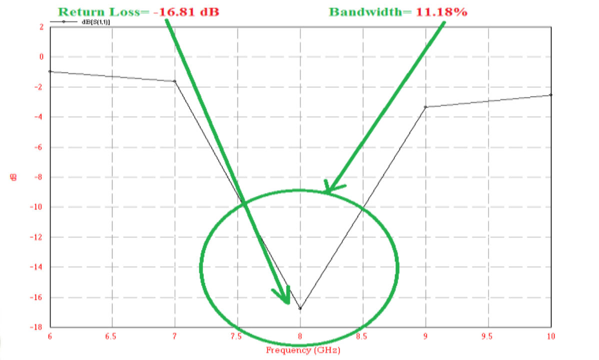

Fig.7 Bakelite

The Return loss of Bakelite is -16.81dB and Bandwidth is 11.18%.

4.2.2 FR4 Glass Epoxy

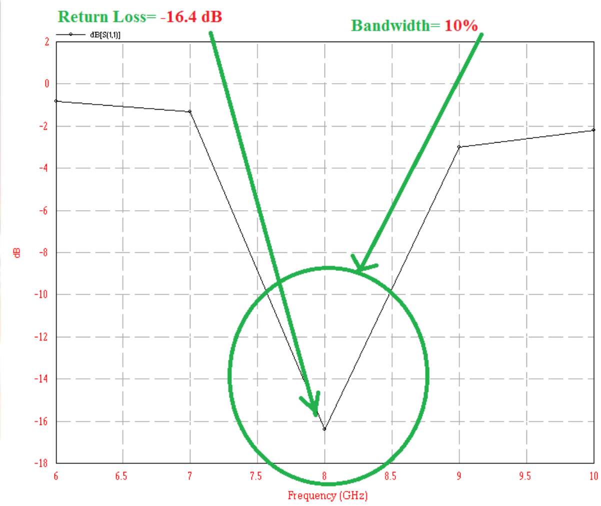

Fig.8 FR4 Glass Epoxy

The Return loss of FR4 Glass Epoxy is -16.4dB and Bandwidth is 10%.

4.2.3 RO4003

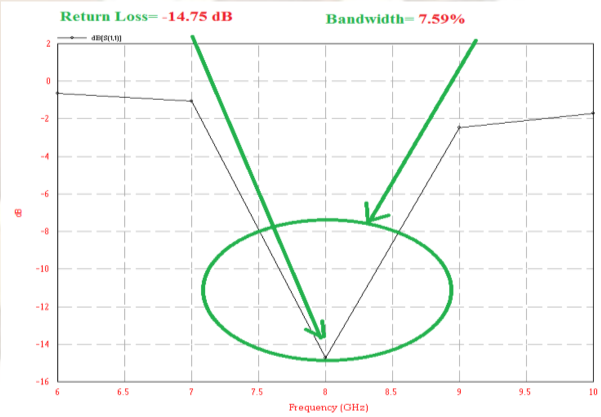

Fig.9 RO4003

The Return loss of RO4003 is -14.75dB and Bandwidth is 7.59%.

4.2.4 Taconic TLC

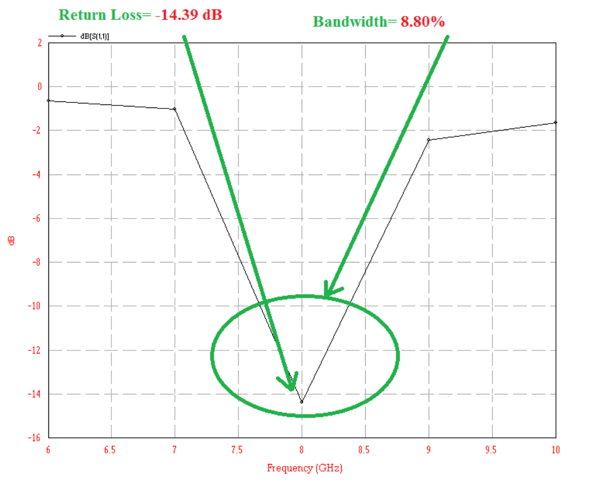

Fig. 10 Taconic TLC

The Return loss of Taconic TLC is -14.39dB and Bandwidth is 8.80%.

4.2.5 RT Duroid

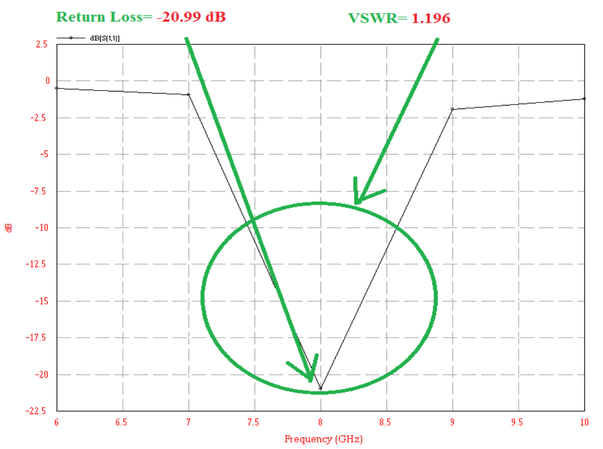

Fig.11 RT Duroid

The Return loss of RT Duroid is -20.99dB and Bandwidth is 15%.

4.2.6 Polyester

Fig.12 Polyester

The Return loss of Polyester is -23.07dB and Bandwidth is 17.5%.

4.3 Gain vs. Frequency Graph

4.3.1 Bakelite

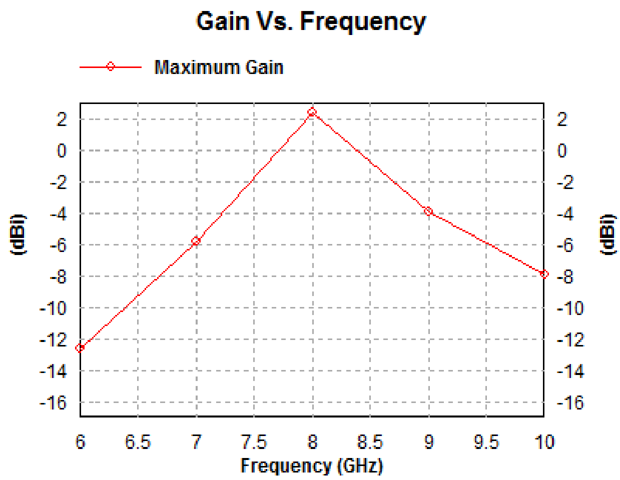

Fig.13 Bakelite

The Gain of Bakelite is 3dBi at 8 GHz frequency

4.3.2 FR4 Glass Epoxy

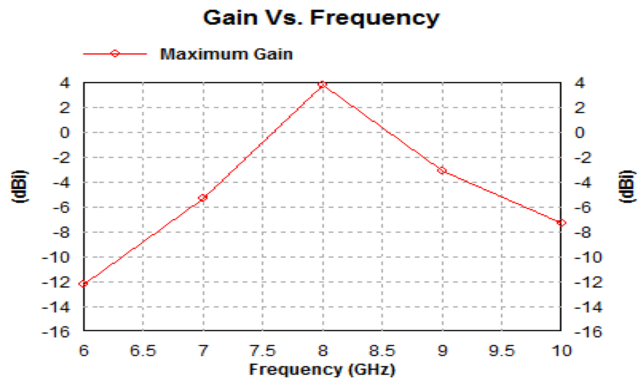

Fig.14 FR4 Glass Epoxy

The Gain of FR4 Glass Epoxy is 4dBi at 8GHz frequency.

4.3.3 RO4003

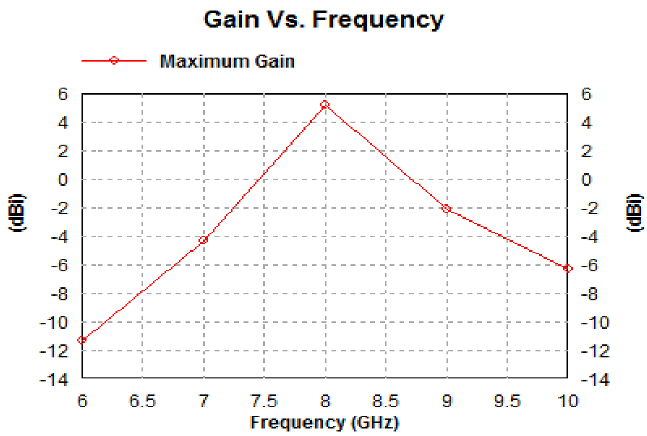

Fig.15 RO4003

The Gain of RO4003 is 5dBi at 8GHz frequency.

4.3.4 Taconic TLC

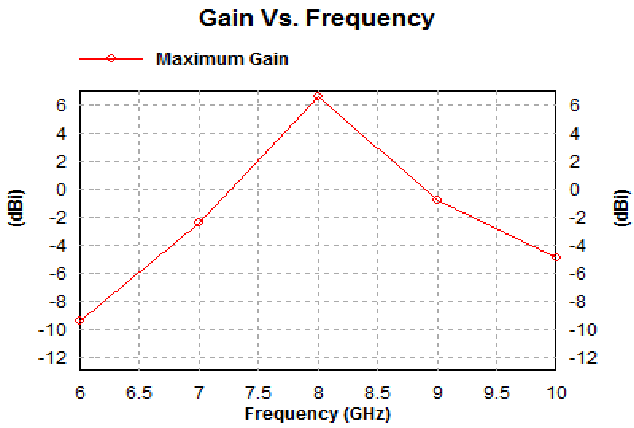

Fig.16 Taconic TLC

The Gain of Taconic TLC is 5.5dBi at 8GHz frequency.

4.3.5 RT Duroid

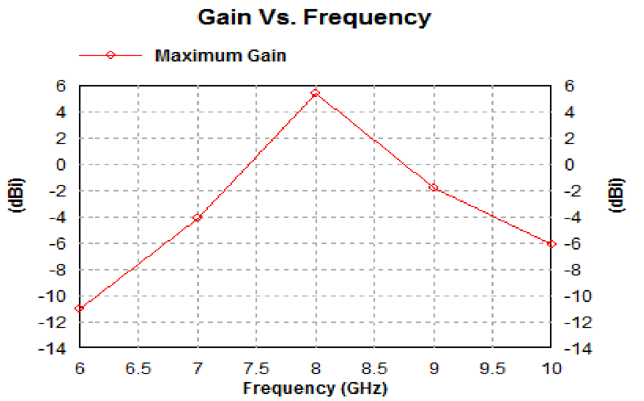

Fig.17 RT Duroid

The Gain of RT Duroid is 6.5 dBi at 8GHz frequency.

4.3.6 Polyester

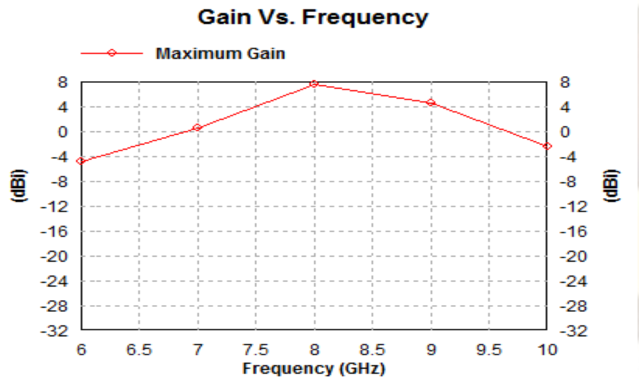

Fig.18 Polyester

The Gain of Polyester is 7.02 dBi at 8GHz frequency.

4.4 Efficiency vs. Frequency Graph

4.4.1 Bakelite

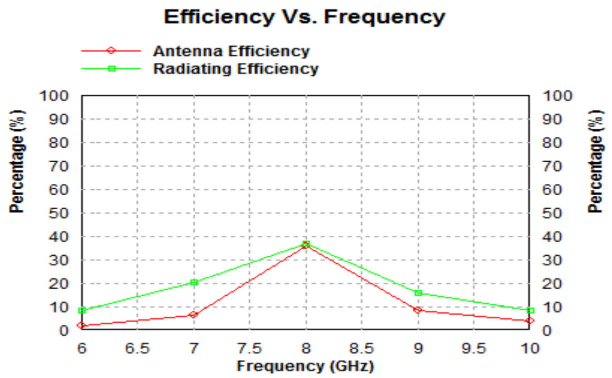

Fig.19 Bakelite

The Efficiency of Bakelite is 38% at 8GHz frequency.

4.4.2 FR4 Glass Epoxy

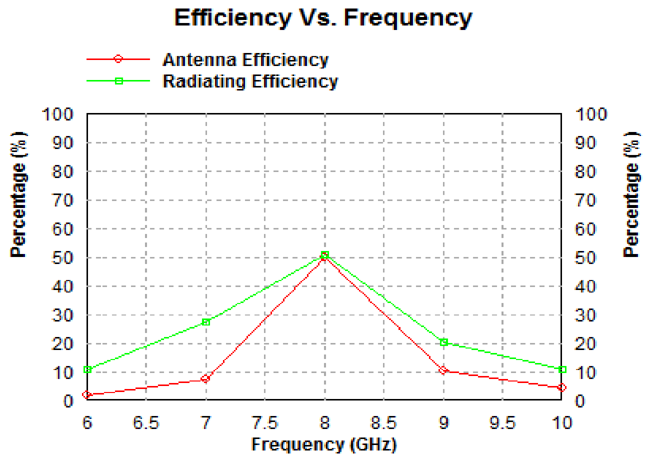

Fig.20 FR4 Glass Epoxy

The Efficiency of FR4 Glass Epoxy is 50% at 8GHz frequency.

4.4.3 RO4003

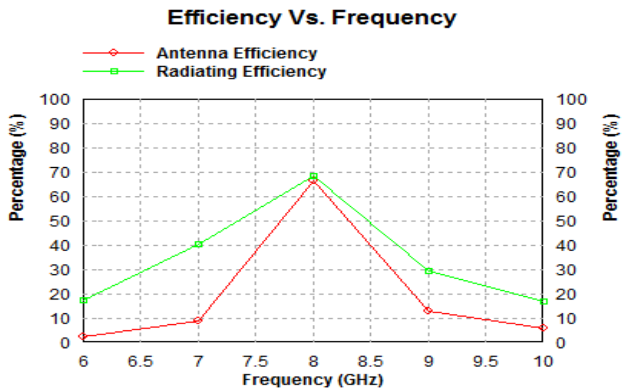

Fig.21RO4003

The Efficiency of RO4003 is 67% at 8GHz frequency.

4.4.4 Taconic TLC

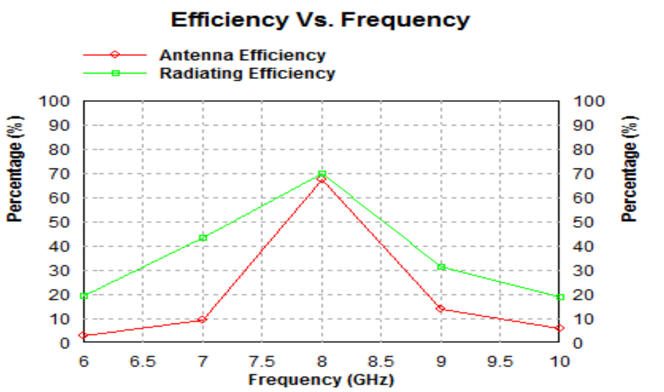

Fig.22 Taconic TLC

The Efficiency of Taconic TLC is 70% at 8GHz frequency.

4.4.5 RT Duroid

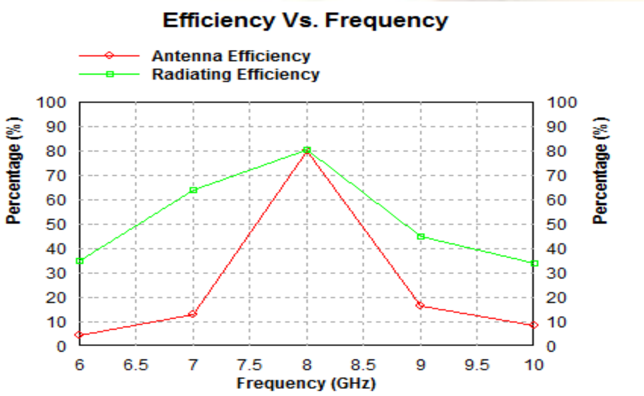

Fig.23 RT Duroid

The Efficiency of RT Duroid is 80% at 8GHz frequency.

4.4.6 Polyester

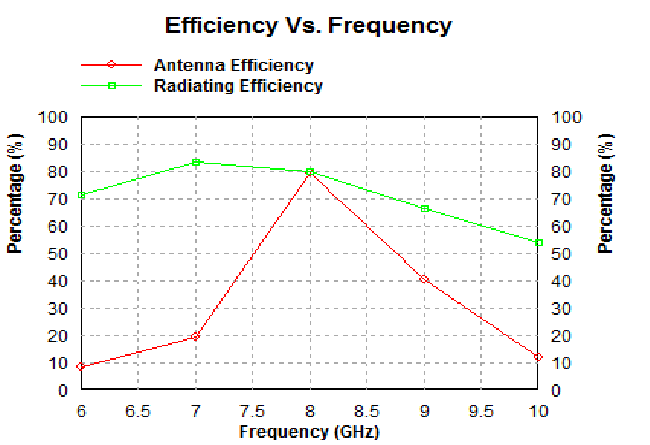

Fig.24 Polyester

The Efficiency of Polyester is 80% at 8GHz frequency.

5 FINAL TABLE

Parameters	Bakelite	FR4 Glass Epoxy	RO4003	Taconic TLC	RT Duroid	Polyester
Side (mm)	9.15	9.575	10.85	11.175	13.475	16.96
Return Loss (dB)	-16.81	-16.14	-14.75	-14.39	-20.99	-20.07
VSWR	1.284	1.369	1.448	1.472	1.196	1.151
Directivity (dBi)	6.5	6.5	7	7	7.5	8.029
Gain (dBi)	3	4	5	5.5	6.5	7.02
Band width (%)	11.18	10	7.59	8.80	15	17.50
Efficiency (%)	38	50	67.5	70	80	80

6 CONCLUSION

Six different triangular microstrip patch antennas are investigated using six different dielectric substrates Bakelite, FR4 Glass epoxy, RO4003, Taconic TLC, RT Duroid and Polyester. Results are found to be best in the case of Polyester as it gives 80% efficiency with a bandwidth of 17.5%. The reason for increase in bandwidth is due to the increase in size of the Polyester based antenna geometry compared to the other substrate based geometry as bandwidth is directly proportional to area of aperture or antenna size. Also, Polyester has lowest dielectric constant among the six substrates which also increases the bandwidth because bandwidth is inversely proportional to dielectric constant or permittivity. Polyester gives a Gain of 7.02 dBi as compared to second best Gain of 6.5 dBi of RT Duroid, thus a increase of 15.38%. Also, the Directivity is 8.029 dBi, 7.05% more than RT Duroid. The reason for this is that for a fixed substrate thickness h, the resonant length and directivity increase with decrease in dielectric constant. Polyester has a very low water absorption capability factor which makes it an ideal dielectric substrate for antenna radiation. Its tensile strength is very high which is 450 to 850 MPa.

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