A STUDY OF 30°-60°-90° SCALENE TRIANGULAR PATCH ANTENNA (TPA) AT 900MHZ

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ABSTRACT

In this work, two Triangular Patch Antennas (TPA) were designed and analyzed at 900MHz using the existing cavity model. The miniaturization process was achieved by shorting pin method with plastic (substrate) material of dielectric constant 2.25 considered as the substrate. The Electric (**E**) and Magnetic (**H**) fields radiation patterns characteristics of the TPAs designed were simulated at various thickness of the substrate (h=0.8mm,1.1mm,1.7mm and 2.0mm) with the aid of Microsoft Excel Softwarev.2007.The simulated results obtained show that the TPAs designed has broad beamwidth (>50^0) (omnidirectional radiation patterns). As the substrates thickness increases, the beamwidth of the radiation patterns increases for both **E** and **H** fields, in agreement with the TPA fundamental principles. Also, the results obtained are similar to that of the existing TPAs in the literatures, operating at the same frequency but different dimensions and dielectric materials. The gain (dB), VSWR, Return loss, Reflection Coefficient and Bandwidth was also calculated for the two TPAs considered in this study. The antennas can be employed in the telecommunication devices such as IPOD (pagers, IPAD), Mobile Phone Handsets, Laptops and other wireless devices.

Keywords: *Scalene triangle, Triangular Patch Antenna (TPA), Electric Field, Magnetic Field and Microsoft Excel.*

1. INTRODUCTION

Patch antennas are based on printed circuit technology to create flat radiating structure on top of a ground plane backed substrate described by Al-Charchafchi et al [1]. The advantage of such structures is the ability of building compact antennas with low manufacturing cost and high reliability. As electronic devices continue to reduce in size, the antenna designer is compelled to reduce the antenna size.There is the need to consider the effect of plastic (substrate) on the radiation patterns of the patches, since the electronic technology is moving towards the use of plastic as the major electronic material, and also the advantage of plastic material by Wikipedia [8].

Nonetheless, improvements in the properties of dielectric materials in design techniques have led to enormous growth in the popularity of Microstrip patch antennas. There are a large number of commercial applications of Microstrip patch antennas as explained by Olaimat and Dib [7]. However, many shapes of patches are possible, with varying applications, but the most popular are rectangular, circular, triangular (equilateral, isosceles) and thin strip.

Among the shapes that have attracted much attention lately is the triangular shaped patch antenna most especially scalene triangular patch. This is due to its small size and complexity in its design as it has more advantages over other shapes like triangular (isosceles and equilateral), circular, as well as rectangular patch antennaswas described by James and Hall [4].

In this paper, the triangular patch antenna (TPA) of 30°-60°-90°of area 35.57cm was designed using cavity and miniaturized model to obtain a smaller dimension. This variety of patches which has received little or no attention from scholars will extensively be studied in this paper.The radiation pattern, Voltage Standing Wave Ratio (VSWR), gain in dB of the TPA and the effect of substrate thickness on the electric(E) and magnetic field(H) field will be considered for the selected TPA.The obtained results would be compared with the existing right angle triangular patch.

2. METHODS OF ANALYSIS

There are three popular models for the analysis of microstrip antennas - viz transmission line model, cavity modeland full wave model. The transmission line model is the simplest. It gives a good physical insight but is less

accurate. The cavity model, which is used in this work, is quite complex but gives good physical insight and is more accurate. The full wave model is the most complex. It is very accurate in the design of finite and infinite arrays or stacked structures.

The quantity associated with radiated EM wave is the Poynting vector given by Balanis, [2], as:

$$S = E \times H \quad (1)$$

Where S is instantaneous Poynting vector, E is instantaneous electric field intensity and H is instantaneous magnetic field intensity. The complex fields E and H are related to their instantaneous counterparts by Balanis [2].

$$\left.\begin{array}{l} E(x, y, z, t) = \text{Re}[E(x, y, z) e^{iwt}] \\[2mm] H(x, y, z, t) = \text{Re}[H(x, y, z) e^{iwt}] \end{array}\right\} \quad (2)$$

Using and the identity $\text{Re}(Xc^{iwt}) = \dfrac{1}{2}(Xe^{iwt} + X^* e^{iwt})$ equation (1)can be rewritten as;

$$S = \frac{1}{2}\text{Re}[E \times H^*] + \frac{1}{2}\text{Re}[E \times He^{iwt}]$$

Hence, the time average Poynting vector can be written by Garg Ramesh et al., [6] as:

$$S_{av} = \frac{1}{2}\text{Re}[E \times H]Wm^{-2}$$

The factor ½ appears because the E and H fields are peak values and not rms.This research aims to design and implement a circular microstrip patch antenna suitable for use at microwave frequencies.

2.1   Cavity Model Analysis

Since the walls of the cavity, as well as the material within it are lossless, the cavity would not radiate and its input impedance would be purely reactive. Hence, in order to account for radiation and a loss mechanism, one must introduce a radiation resistance *RR* and a loss resistance *RL*. A lossy cavity would now represent an antenna and the loss is taken into account by the effective loss tangent (δ*eff*) which is given as:

$$\delta_{eff} = \tan\delta + \frac{\Delta}{h} + \frac{P_r}{\omega_r W_r} \qquad (3)$$

ω_r is the angular resonant frequency

W_r is the total energy stored in the patch at resonance

tan δ is the loss tangent of the dielectric

$P_r$is the power radiated from the patch

Δ is the skin depth of the conductor,

h is the height of the substrate

Q_c represents the quality factor of the conductor.

Thus, the above equation describes the total effective loss tangent for the Microstrip patch antenna.

3.   ANTENNA DESIGN PROCEDURES

For this work, the TPA was designed using cavity model. Assuming perfect magnetic side walls, the resonant frequency is defined by Jackson, [3]and Olaimat and Dib [7].

$$f_{m,n} = \frac{2c}{a\sqrt{3\varepsilon_r}}\sqrt{n^2 + mn + m^2} \qquad (4)$$

Where; c is the velocity of light in free space,

m and n are integers (mode indices),

ε_r is the substrate relative permittivity,

a is the length of the patch,

$$\varepsilon_r = 2.25.$$

The width is given byGunney, [6] and Jackson,[3] as;

$$W = \frac{L}{2} \qquad (5)$$

Where;

W=width of the patch

L=length of the patch

At resonant frequency of 900MHz, the side lengths and areas corresponding to each shape can be calculated using equations *(1)* and *(2)* to obtain the dimension for TPA1. The TPA with the smallest dimension was obtained using shorting wall method of miniaturization as shown in the Table 1.
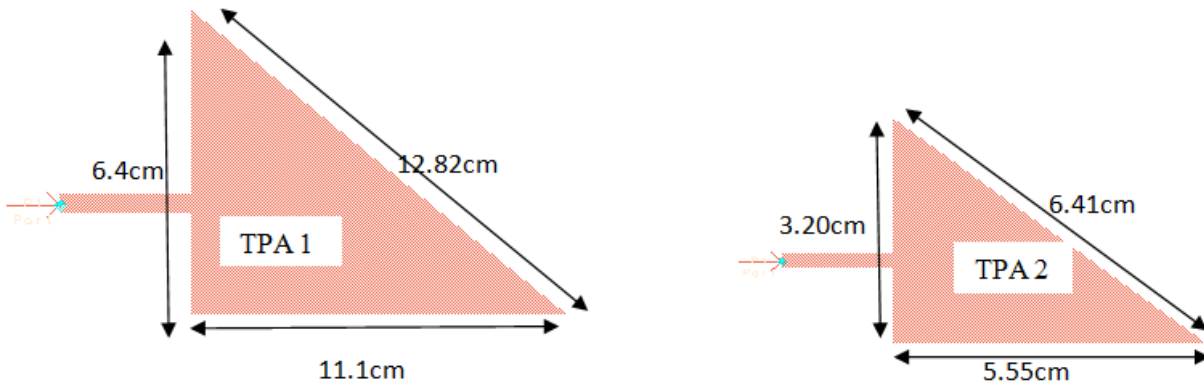

Figure 1: Diagram showing the dimension of the two TPA considered.

Table 1: Obtained dimensions for the TPAs calculated using the Geometrical Method at 900MHz with $\varepsilon_r = 2.25$

	Dimensions in cm	Angles in Degree	Area in cm	Length in cm	Geometric
TPA 1	12.82, 11.1, 6.4	30°-60°-90°	35.82	12.82	Cavity Model
TPA 2	6.41, 5.55, 3.20	30°-60°-90°	8.88	6.41	$\lambda/2$

3.1 The Simulation of Electric field E (θ) and Magnetic Field H (θ)

Radiation characteristics: A Microstrip antenna is basically a broadside radiator, which has a relatively large beam width and low, gain characteristics. Adopting the Electric **E (θ)** for rectangular patch by Kraus *et. al.,* 2002 [5] as.

$$E(\theta) = \frac{\sin\left(\frac{k_0 h}{2}\cos\theta\right)}{\frac{k_0 h}{2}\cos\theta}\cos\left(\frac{k_0 L}{2}\cos\theta\right) \quad (6)$$

The null of equation (3) is obtained when the denominator is zero, therefore equation (6) then becomes

$$E(\theta) = \sin\left(\frac{k_0 h}{2}\right)\cos\left(\frac{k_0 L}{2}\cos\theta\right) (7)$$

The magnetic field (H) equation is also given by Balanis, 1997[2] as:

$$H(\theta) = \frac{\sin\left(\frac{k_0 W}{2}\cos\theta\right)\sin\theta}{\frac{k_0 W}{2}\cos\theta} \quad (8)$$

The equation now becomes;

$$H(\theta) = \sin\left(\frac{k_0 W}{2}\cos\theta\right)\sin\theta (9)$$

The patches are put under test with different substrate thickness to observe the radiation performance behavior and it was observed that the beamwidth increases as the thickness increases with is in agreement with the microstrip patch principles. The radiations were simulated using Microsoft Excel Software.2007. The results and pattern obtained are shown below.

Table 2: Beamwidth in Degrees for different Substrate thickness for TPA Configuration (Electric Field and Magnetic Field)

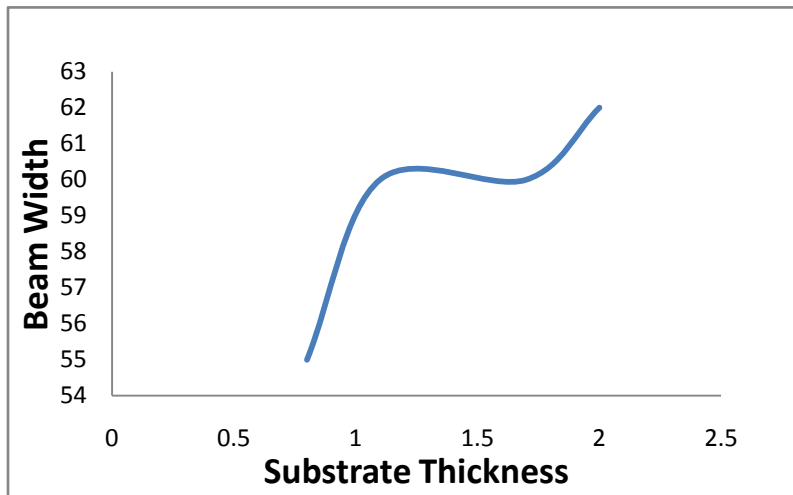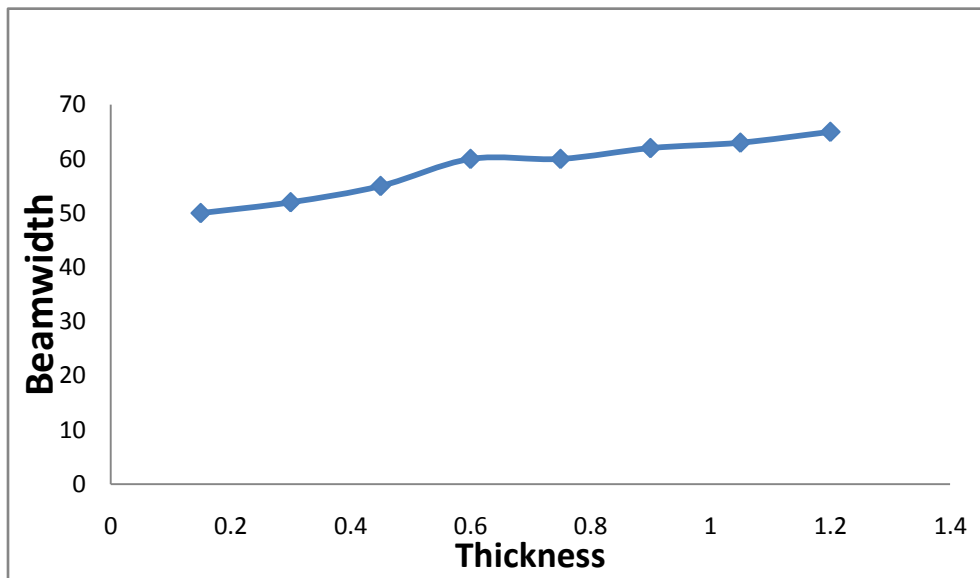| Area(cm^2)	h=0.8mm	h=1.1mm	h=1.7mm	h=2.0mm
35.57	60	60	62	65
8.88	55	60	60	62

Figure 2: Beamwidth against substrate thickness.

Figure 3: The beamwidth against thickness/lambda
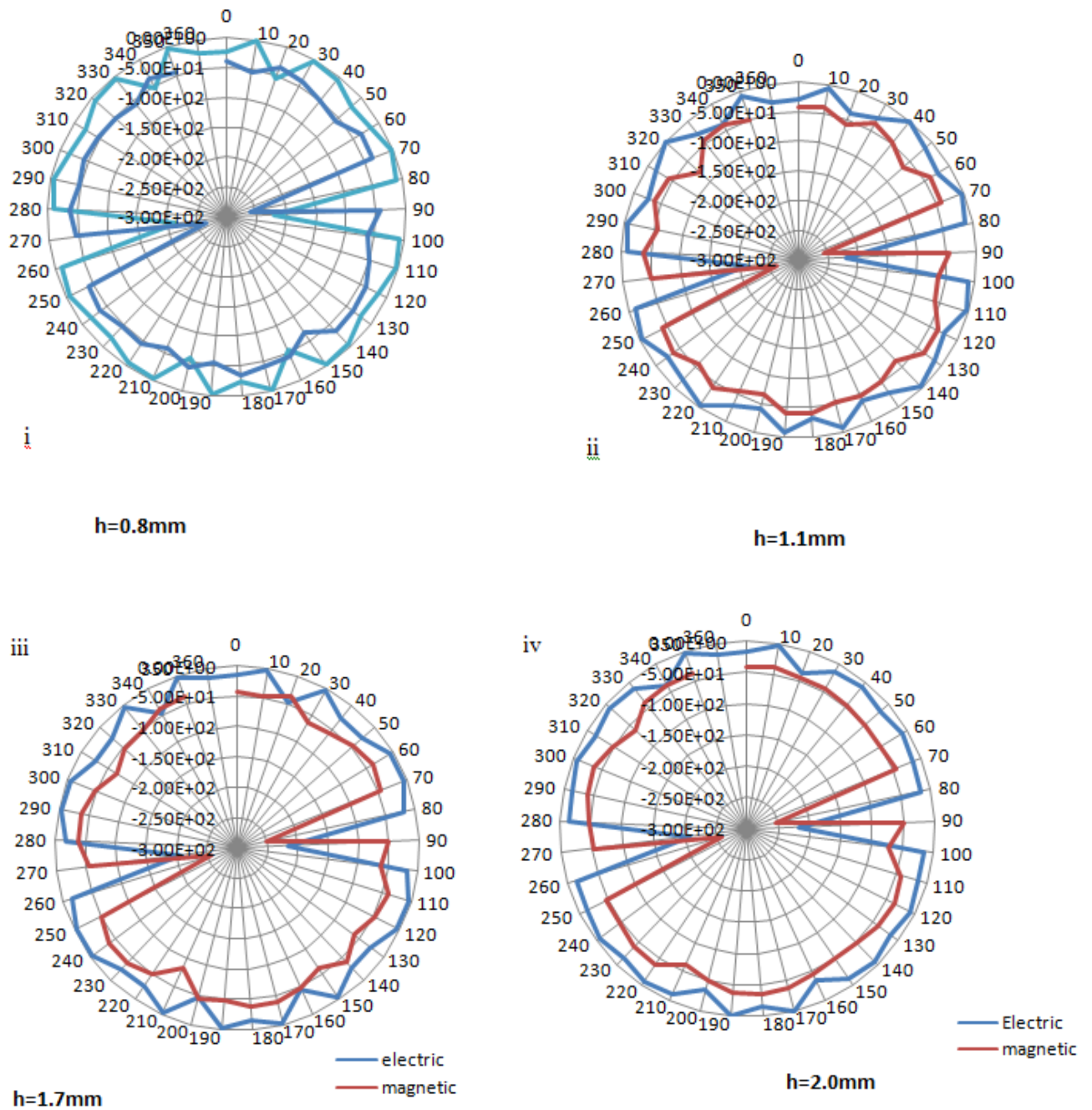
Figure 4 (i-iv): Showing the E and H Far Field and H-field Pattern of 30^0-60^0-90^0 A= 35.57cm^2 TPA at 900MHz.
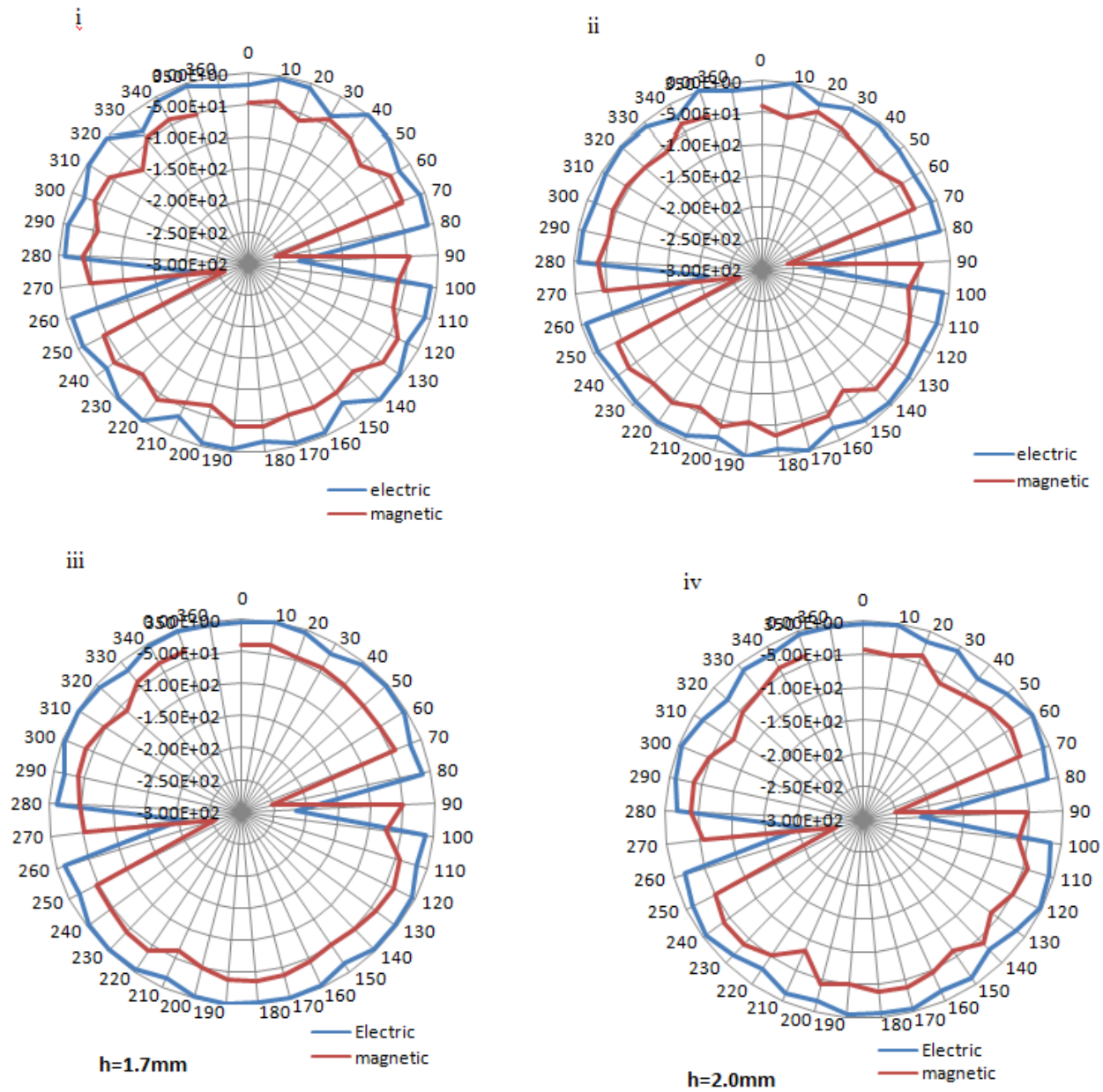
i

ii

iii

iv

h=1.7mm

h=2.0mm

Figure 5(i-iv): Showing the E and H Far Field Pattern of 30°-60°-90° A=8.88cm^2 TPA at 900MHz.

Table 5: Comparison of TPAs with the Existing TPA

	TPA	Frequency (MHz)	Area (cm^2)	Type of Dielectric	Thickness of the Dielectric	Dielectricconstants	Beamwidth
Olaimat *et. al.* (2011)	15°-75°-90°	897	12.09	FR4	1.60mm	4.60	> 50°
TPA 1	30°-60°-90°	900	35.57	Plastic	1.70mm	2.25	> 60°
TPA 2	30°-60°-90°	900	8.88	Plastic	1.70mm	2.25	> 60°

Table 6: Calculated Gain, VSWR, Return loss, Reflection Coefficient and Bandwidth for TPA 1 and 2

	TPA	Gain (dB)	VSWR	Return loss	Reflection Coefficient	Bandwidth MHz	Beamwidth Degree
TPA 1	30°-60°-90°	2.330	1.443	14.83	0.1813	3.32	>50
TPA 2	30°-60°-90°	3.823	1.389	15.76	0.163	3.5	>50

4.   RESULT AND DISCUSSION
The designed triangular patches are put under test at various substrate thickness (0.008 – 0.02mm) to observe the radiation performance with the aid of Microsoft Excel 2007, the radiation patterns at **E and H –** plane were simulated in decibel **(dB)** and the beamwidth were determined various substrate thickness **(h)** using 3dB measurement (HPBW) , as shown in Table 3: which shows the beamwidth of the TPAs, Angles and the Area in cm. Figures 4 (i-iv): show the **E** and **H** field simulated for TPA 30°, 60°, 90° of area 35.57cm^2 at varying substrate thickness (h) the beamwidth obtained are 60, 60, 62, 65 as the substrate thickness **(h)** increases the beamwidth also increases. Figures 5(i-iv): also explained the effect of the substrate thickness on the TPA 30°, 60°, 90° of 8.8cm^2 at 900MHz, this also shows a perfect increase in the beamwidth of the patch from 55 to 62 degrees, Figure 2 and Figure 3 show the relative effect of the substrate thickness on the beamwidth as the thickness increases the beamwidth also increases.

5.   CONCLUSSION
The results of the radiation patterns of Electric Field and Magnetic Field for 30°-60°-90°and other TPA obtained in the miniaturization processes show that at the same resonant frequency, the beam width and a linear polarization can be obtained using this shape30^o-60°-90°with smaller area compared to other shapes.The antennas designed demonstrated high performance ability within the desired band. TPAs considered in this study have no theoretical analysisin literatures thereby giving this study a timely priority within the scope of the study.

6.   REFERENCES
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