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Simplex Optimization Method of Miniaturizing Triangular Microstrip Patch Antenna at GSM Band

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Abstract

In this paper, smallest scalene triangular microstrip antenna was designed for GSM communication applications using simplex optimization method of miniaturization. The antennas were modeled using microstrip lines, and parameter data for smallest triangular element .The data is extracted from the momentum simulation and combined with the microstrip transmission line. The properties of antennas such as bandwidth, gain, cross polar isolation and the return loss have been simulated. Since the resonant frequency is of these antenna is 900MHz, these antenna is suitable for GSM network.

Keywords

Scalene Triangular Patch, Simplex Optimization, Microstrip, Agilent, and Cross Polar

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1. Introduction

Patch antennas are based on printed circuit technology to create flat radiating structure on top of a ground plane backed substrate [Al-Charchafchi and Wan-Ali, 2000]. 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.

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 [Olaimat and Dib: 2011]. 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 antennas [James and Hall, 1989].

In this paper, the triangular patch antenna (TPA) of 30^o-60^o-90^o 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 model and full

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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 as: (Balanis, 1982)

$$S = E \times H \tag{1}$$

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 (Richards, 1988; Gonca, 2005, Kwaha, 2011):

$$\left.\begin{aligned} E(x,y,z,t) &= \mathrm{Re}[E(x,y,z)e^{iwt}] \\ H(x,y,z,t) &= \mathrm{Re}[H(x,y,z)e^{iwt}] \end{aligned}\right\} \tag{2}$$

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

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

Hence, the time average Poynting vector can be written as (Gonca, 2005; Akande, 2003)

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

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.

3. 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:

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

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.

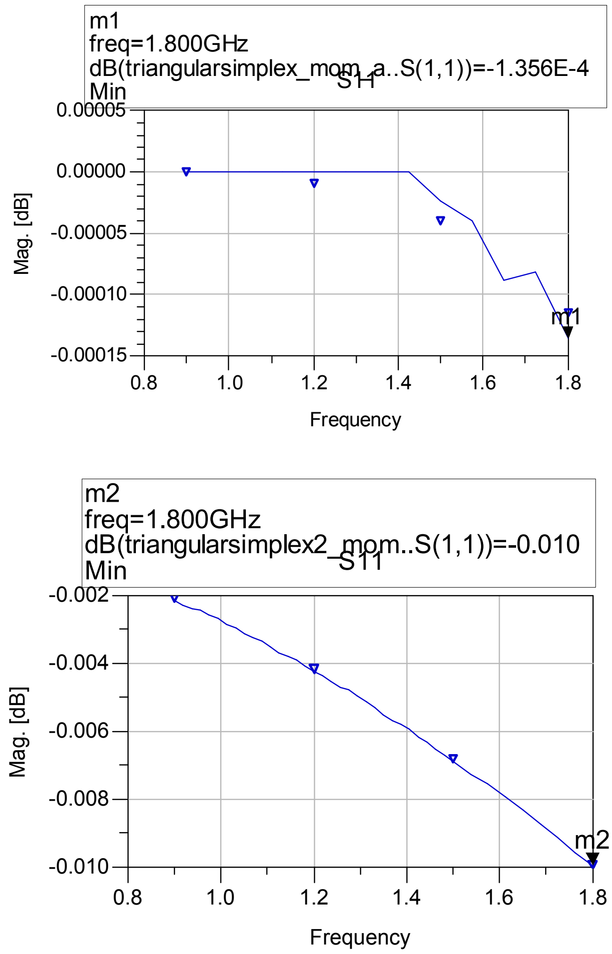


Figure 1. Simulated Return loss for triangular patch (0.00035) and (35).

4. 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, 2007 and Olaimat, 2011].

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

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 by (Gunney, and Jackson, 2001) as;

$$W = \frac{L}{2} \tag{5}$$

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.

Table 1. Showing the Simplex Optimization Calculation.

X	Y	Z	Check
A	B	C	Objective term
E	F	G	Area 1
H	I	J	Area 2
K	L	M	Area 3

Miniaturization by simplex method

The formation of constraint from the reference triangle was obtained by considering the perimeter of the triangle to form a linear equation of this form.

$$P = Ax + By + Cz$$

$$P = Ax + By + CZ - Objective\ function$$

$$Ex + Fy + Gz = Area(TPA1)$$

$$Hx + Iy + Jz = Area(TPA2)$$

$$Kx + Ly + Mz = (TPA3)$$

An augmented matrix from the constraint above using their variables was formed

Table 2. The values obtained using Mathematical Geometries.

	Dimensions in cm	Angles in Degree	Area in cm	Length in cm	Geometric
TPA 1	12.82, 11.1, 6.4	30º-60º-90º	35.82	12.82	Cavity Model
TPA 2	6.41, 5.55, 3.20	30º-60º-90º	8.88	6.41	$\lambda/2$
TPA 3	3.20,1.66,2.80	15,75,90	1.55	3.20	$\lambda/4$
TPA 4	1.60,0.80,1.40	30,60,90	0.56	1.60	$\lambda/8$
TPA 5	1.78,0.0005,1.48	0.02,89.89,90	0.00037	1.78	Simplex optimization

Table 3. Comparison table for simulated results and the existing one.

Parameters	Olaimat Work	Cavity Triangle Simulated	Simplex Optimization
Resonant Frequency MHz	800	1800	1800
Gain dB		-18.31	-28.40
Directivity dB		5.28	5.30
E(θ)degree		89	86
H(θ) degree		85	86
Efficiency%		0.43	0.043
Return Loss(dB)		-0.010	-1.356E-4

Replace the older values with new value using the formulas by

$$a^1 = a - b \times \frac{c}{p} \tag{6}$$

a^1 = new value

a = old value

b = preceding value

c = next value

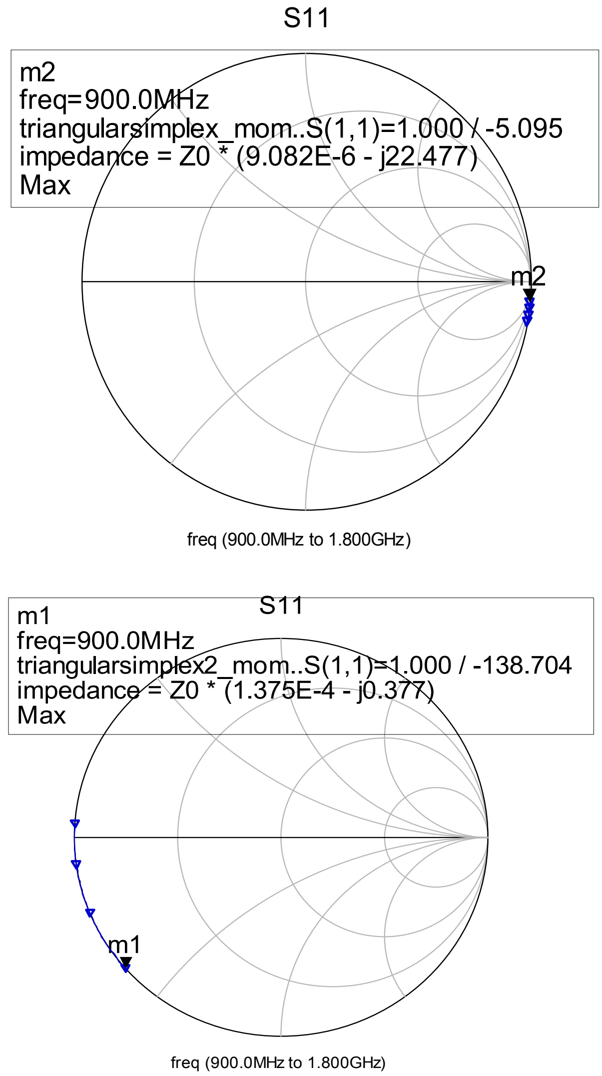


Figure 2. Simulated Input Impedance for triangular patch (0.00035) and (35).

5. Results and Discussion

The results obtained from the simulation using ADS2009 were compared with existing work done by Olaimat and Dib, 2006. The results show a perfect correlation with the work and the radiation patterns ,gain and directivity were obtained.

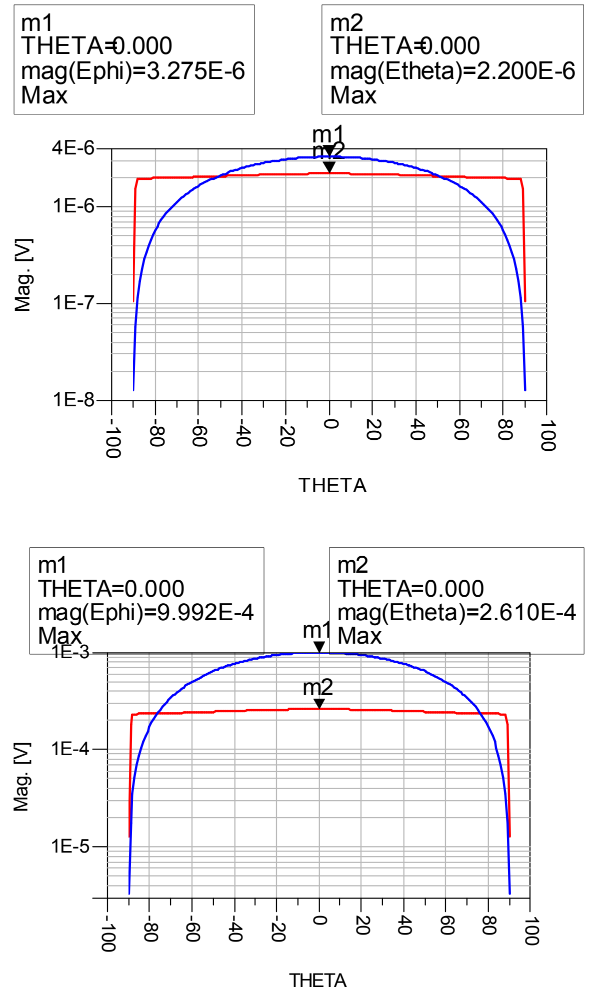
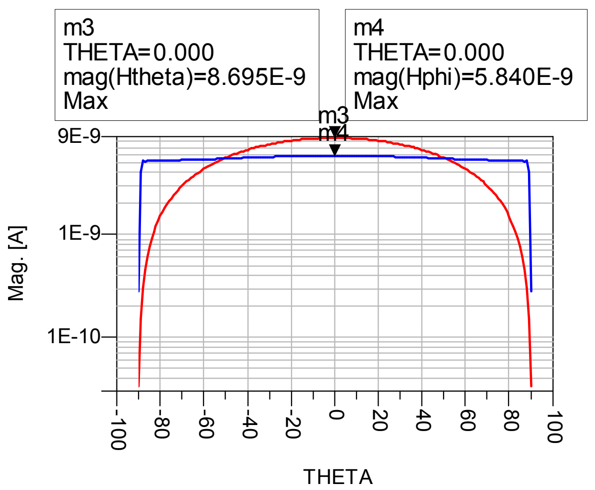


Figure 3. Simulated Radiation Pattern E(Q) for triangular patch (0.00035) and (35).



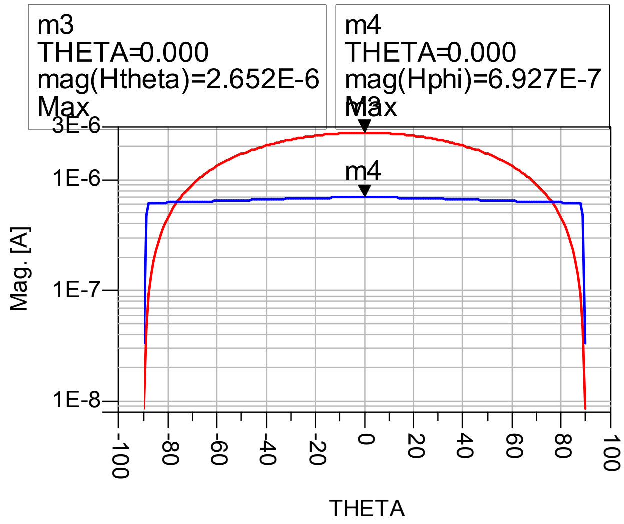


Figure 4. Simulated Radiation Pattern H(Q) for triangular patch (0.00035) and (35).

6. Conclusion

The results of the radiation patterns of Electric Field, Magnetic Field for the smallest and other TPA obtained in the miniaturization processes show that the same resonant frequency, the beamwidth and a linear polarization can be obtained using this area 0.000035m with smaller area compared to other shapes. The antennas designed demonstrated high performance ability within the desired band. Up to our knowledge, no theoretical analysis of the smallest TPA exists in the literature.

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