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Design and Comparison of a Compact Tapered Triangular Single and MIMO Antenna with Polarization Diversity for Wideband Applications

V.W.Sonone[1,] Dr.A.N.Gaikwad2, Dr.N.B.Chopade3
[1] *(E & TC Department,Bhivrabai Sawant Polytechnic,Pune,India)*
[2] *(E & TC Department,Babasaheb Naik College Of Engineering, Pusad.India*
[3] *(E & TC Department,Pimpri Chinchwad College of Engineering,Pune,India)*
Corresponding Author: V.W.Sonone

Abstract *— In wireless communication applications high data rates is the prime requirement. This demand necessities the need of inclusion of more number of antennas in wireless applications. These systems require an antenna with optimum bandwidth and polarization diversity. This paper discusses a compacted modified triangular antenna that functions at 2.45 GHz. The modified tapered triangular antenna structure gives the miniaturization. Also adding partial ground enhances bandwidth of MIMO microstrip antenna. The structure to be designed is a 2×2, microstrip fed tapered triangular MSA. The patches are kept orthogonal to produce polarization diversity. Antenna to be implemented has been structured on FR4 substrate with dielectric constant of 4.4. The antennas are simulated and the results for triangular single and 2X2 MIMO antenna are compared. 2X2 multi input multi output design gives a large bandwidth from 1.58 GHz to 3.96 GHz corresponds to 99.16% impedance bandwidth at VSWR 2:1. The pattern for radiation of single tapered triangular antenna is directional and that for multi input multi output is nearly omnidirectional in azimuth plane and bidirectional in elevation plane. The antenna to be implemented possesses a gain of 3.3dBi with overall size very compact. This antenna is most suited for WLAN, Wi-Fi, & WiMAX applications.*

Keywords— *miniaturization, partial ground, multiple-input– multiple-output (MIMO), polarization diversity, wideband and tapered antenna.*

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I. Introduction

As the data rates are high ,improved channel capacity, less power consumption for multipath propagation through multiple antennas [1] , multiple input multiple output antenna are commonly used in wireless communication these days. Antennas having number of operating bands and omni-directional radiation is mostly used. Defected ground structure is the popularly known technique to design an antenna, used for wide range applications [2].Use of multiple transmitters and receivers gives a high boost in data throughput and link coverage, with no extra bandwidth requirement. Due to this feature it has gained attention in wireless applications. In MIMO systems, this is obtained by increased spectral efficiency. These properties make MIMO a significant part of new standards such as IEEE 802.11n, 4G, 3GPP Long Term Evolution, Wi-MAX and HSPA+. Using number of antennas, more paths can be used that increases the ability of a link as in [3].In [4], a radiator having two slots of F shape, with DGS ground structure for operating in triple band is discussed. A square ring with DGS offers isolation by reduction in surface waves on limited inside the dielectric as in [5]. Two antennas with E-shaped patch and multi-slots for WiMax usage (5.2– 6.0 GHz), is elaborated in [6]. In [7], a rectangular antenna with slots for improvement in bandwidth is discussed. The diversity idea is used to the multi input multi output antenna that is to be implemented. This gives improved results for return loss and mutual coupling. Polarization diversity used is linear where signals are transmitted and received by means of antennas that are horizontally and vertically polarized. Non dependent and uncorrelated signals are obtained on each of the antenna as a effect of orthogonality of two distinct polarizations .This gives a potentially full-rank MIMO channel and thus improves channel capacity.

In this discussion a compacted and wideband microstrip 2x2 MIMO antennas are designed, analyzed, and investigated. The MIMO antenna to be implemented reverberate in the WLAN, Wi-Fi, 2G, 3G, LTE, UTMS, & WiMAX bands and are used in a wide range of applications. Section 2 describes the simulation of single and 2x2 multi input multi output microstrip patch antenna. Section 3 discusses the results of simulated antennas.

II. Antenna Design

The dielectric chosen is FR4-epoxy substrate having relative permittivity of 4.4 and the thickness of 1.53mm. The resonant frequency of the rectangular patch antenna, of length L and width W can be calculated using the following formula.

Geometry

Step 1: Calculation of Lambda (λ_0)-
Lambda (λ_0)=c/f=3x10^8/2.45x10^9
(λ_0)=60mm at 2.45 GHz
Step 2: Calculation of center frequency, f_c
The center frequency will be approximately given by:

$$f_c \approx \frac{c}{2L\sqrt{\varepsilon_r}}$$

$$L = \frac{c}{2f_c\sqrt{\varepsilon_r}} \quad \text{------------ (1)}$$

Where f_c=is centre freq=2.45GHz ε_r=4.4 and c=3x10^8
L=29.83mm

Step 3: Calculation of Width:

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad \text{------------- (2)}$$

For c=3*10^8 m/s, f_r=2.45GHz, ε_r=4.4

We get W=38.22 mm.

Step 4: Calculation of feed width:
Feed width is calculated by using

$$Z_0 = \frac{60}{\sqrt{\varepsilon_r}} \ln\left(8\left(\frac{H}{W_f}\right) + 0.25\left(\frac{W_f}{H}\right)\right) \quad \text{-------- (3)}$$

We get W_f =2.84mm

Step 5: Calculation of Feed length (Fl):
Feed length (F_l) =lam/4*sqrt (4.4)
F_l=14.5mm

Step 6 : Calculation of Substrate dimension-
Ls=L+2*6h=29+2*6*1.6=49mm

Ws=W+2*6h=38+2*6*1.6=58mm

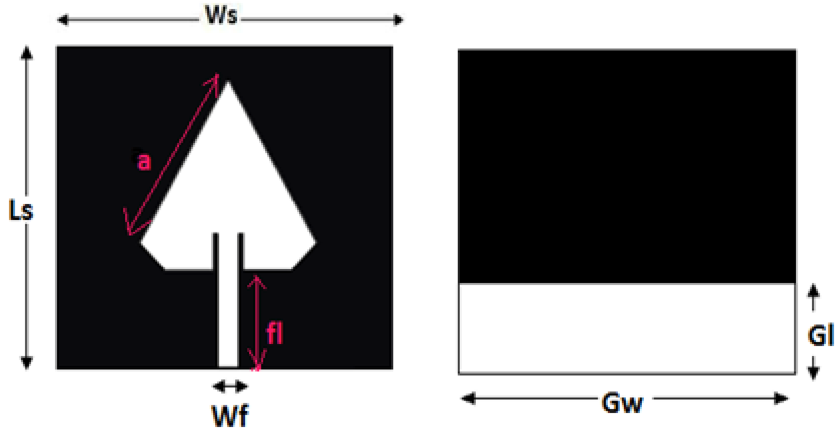

Figure.1 geometry of the simulated single taper patch antenna

Fig. 1 shows the simulated single patch with partial ground. Black part is Substrate and white part is ground. The optimum dimension of this patch is given table1.

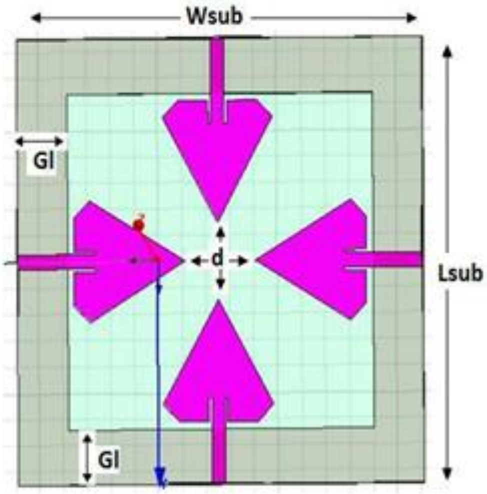

Figure 2. Proposed 2 x2 tapered triangular MIMO patch antenna

The single tapered patch antenna with dimension is seen in Fig. 1. As in the Fig. the ground is the partial ground.Fig. 2 shows the 2x2 tapered triangular MIMO patch antenna. The dimensions of the antenna that is to be implemented along with other design parameters are given below. The planned two element array is designed on FR4 material with dielectric constant εr=4.4, loss tangent of 0.02 and having thickness =1.53 mm.

Sr.No	Parameters	Dimensions(mm)
1.	a	29.83
2.	Ws	58.0
3.	Ls	49
4.	Ws	58.0
5.	fl	14.5
6.	Wf	2.84
7.	d	14.6
8	Gl	13.0
9.	Lsub	85.0
10.	Wsub	85.0

Table.1.Optimized Dimension table of proposed antenna

III. Results and Discussions

The results of simulated antennas are studied. Results are for single antenna and for 2x2 MIMO. Fig. 3 shows the results of return loss for the single antenna and fig. 4 for simulated two-element MIMO antenna.

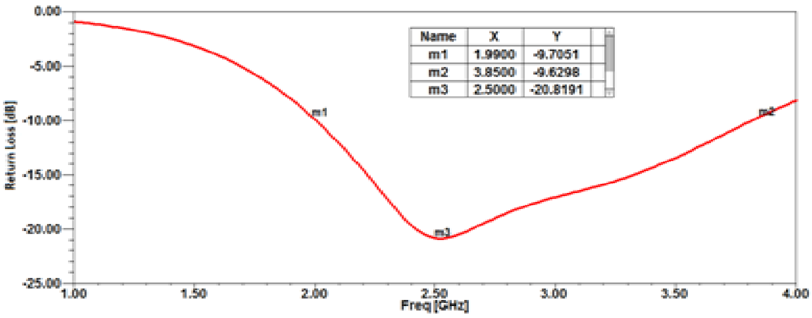

Figure 3: Return loss of simulated single antenna

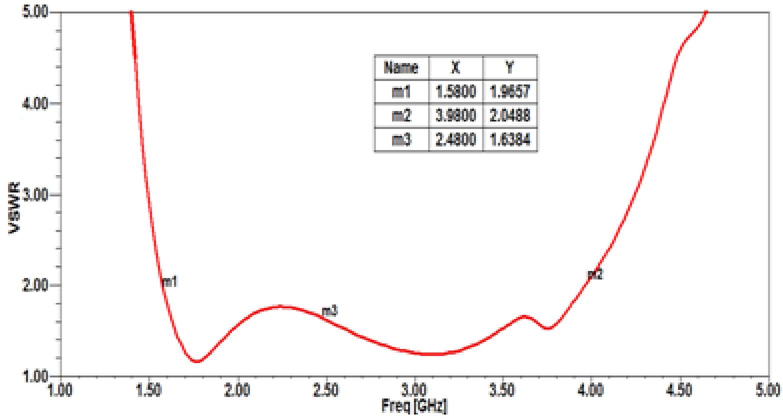

Figure 4: Return loss of 2 X 2 MIMO patch antenna

When the load is mismatched the whole power is not delivered to the load there is a return of the power and that is called loss, and this loss that is returned is called the "Return loss". This Return loss is determined in db.Fig. 3 show that the value of Return loss is -20.91dB at 2.5GHz. Fig. 4 gives the results of return loss for the simulated 2x2 MIMO antenna. From the return loss graph, it can be seen that the value is below -12 db for the entire band of 1.58GHz to 3.96 GHz .The lowest value of Return loss is -22.2 db.

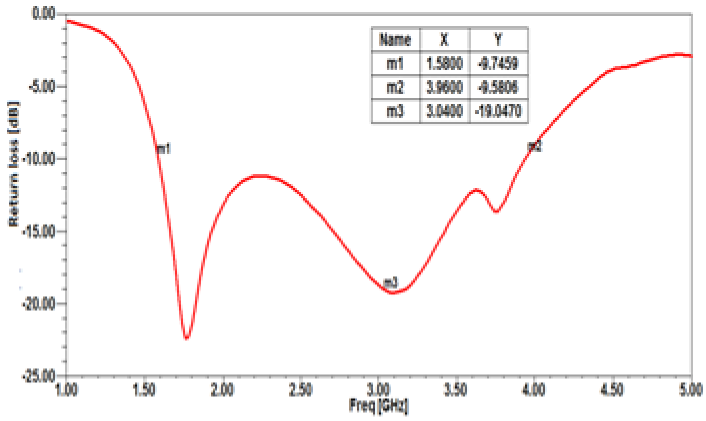

Figure **5: VSWR of simulated single antenna**

From fig. 5, the VSWR value is below 2 for 2.45 GHz frequency.

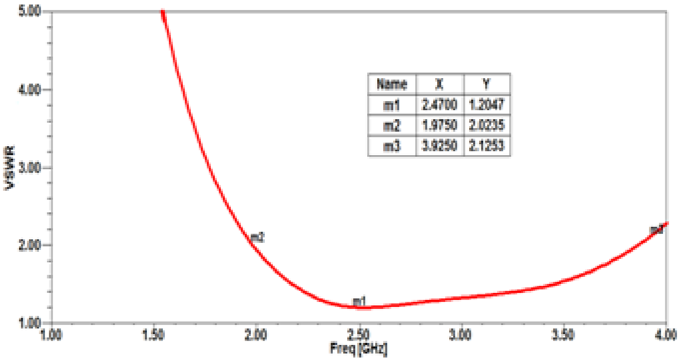

Figure 6: VSWR of simulated 2 X 2 MIMO antennas

From fig. 6 it can be mentioned that the VSWR lies below the value 2 for wider range of frequency, from 1.58 GHz to 3.96 GHz. The value of VSWR between 1 and 2 shows that antenna radiates efficiently.

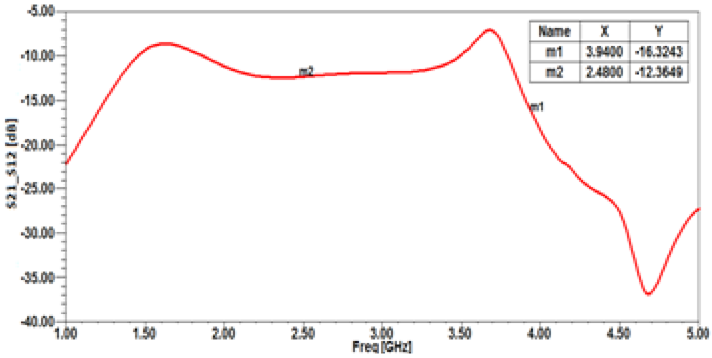

Figure 7: mutual coupling of simulated 2 x 2 MIMO

Fig. 7 depicts that for the simulated antenna mutual coupling is below -12dB throughout the entire band. It can be said that the antenna array has almost a directional radiation type. It is also observed that the antenna produces comparatively steady pattern with resonant frequency.

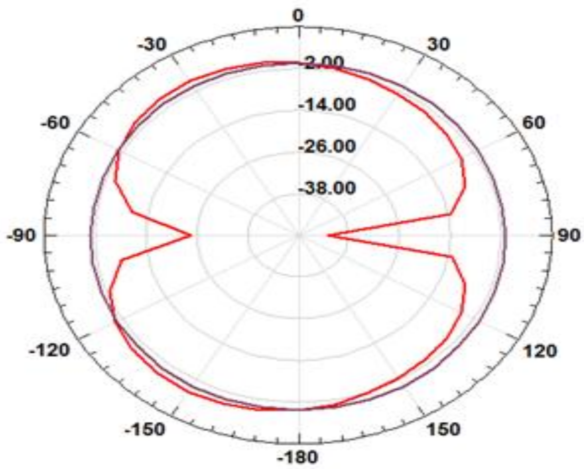

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Figure 8: Radiation pattern E plane for simulated single antenna

From fig. 8 it can be mentioned that the radiated patterns of antenna are directional in both E-plane & H plane at frequency 2.45GHZ

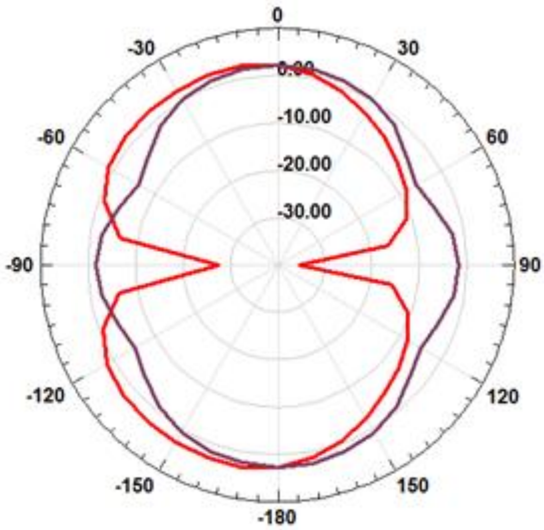

Figure 9: Radiation pattern E & H plane for 2 X 2 MIMO patch antenna

Figure 9 depicts that the radiated pattern of 2X2 simulated MIMO antenna is omnidirectional and bidirectional in H plane and in E plane respectively.

IV. Comparison Table

For improvement in gain & bandwidth of this antenna, partial ground is introduced .As seen from the table, single tapered triangular patch antenna, and multi input multi output antenna are described. It can be said that for the multi input multi output antenna both gain & bandwidth of antenna are improved.

Sr. No.	Shape of MSA	Freq (GHZ)	Return Loss (dB)	VSWR	Band width (MHZ)	Gain (dB)
1.	Single Proposed patch antenna	2.14-3.22	-19.00	1.60	1080	2.0
2.	2x2 MIMO Proposed patch antenna	1.58-3.96	-22.2	1.21	2380	3.3

Table 2: Comparison Table

V. Conclusion

The low cost, efficient and a compacted multi input multi output MSA (2x2) using Polarization diversity for wideband is implemented and optimized to work over entire band from 1.58 to 3.96 GHz. This structure offers a maximum gain of 3.3 dB, R.L< -10 dB and isolation more than -13 dB is obtained. The radiated pattern of tapered triangular MIMO antenna is omnidirectional in azimuth plane and bidirectional in elevation plane. A newly-designed polarization diversity multi input multi output antenna with wide bandwidth of dual slant ±45° polarization is presented here. Tapered techniques reduce size of MIMO antenna. The radiation patterns, gains and S parameters of four multi input multi output antenna elements have also been virtualized. The results obtained validate that the wideband MIMO diversity antenna which is discussed is appropriate for WLAN, Wi-Fi, 2G, 3G, LTE, UTMS, & WiMAX applications etc.

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