Design of Compact Linearly Polarized Microstrip Patch Antenna for Wireless Communication

Tazeen Shaikh and Rukhsana Khan

***Abstract*—A single probe-fed square patch antenna cut from a rectangular patch, having symmetric pattern of T slots is designed. The software used to model and simulate the microstrip patch antenna is Zeland Inc's IE3D software. IE3D is a full-wave electromagnetic simulator based on the method of moments. The proposed antenna is capable of generating resonant frequency with single feeds. The 50Ω feed position can be achieved by the feed points placed along the axis of the square patch. Experimental result for the characteristics of microstrip antenna are presented and discussed in this paper.**

***Index Terms*—MSA (Microstrip antenna), RMSA (Rectangular microstrip antenna), LP (linear Polarization).**

I. Microstrip Patch Antenna

Patch antennas play a very significant role in today's world of wireless communication systems. The prospect of this design is to obtain a small size, light weight and low cost miniaturized antenna with good antenna characteristics and ease of integration using feed-network.

II. Rerectangular Microstrip Patch Antenna

A RMSA is design for a resonant frequency of 2.4 GHz. This RMSA is cut into square patch having T slots of unequal length and width to get a symmetric pattern so as to reduce the total area on the patch. An RMSA operating at frequency *fo* = 2.4 GHz with length (*l*) = 39mm, width (*w*) = 48mm, *tan* δ = 0.001, total area = 1872mm^2 is designed. There are numerous methods to increase the bandwidth of antennas, including increase of the substrate thickness and the use of a low dielectric substrate, hence duoroid having $_r$ = 2.4, thickness (*h*) = 1.58mm is selected. This paper presents linearly polarized microstrip antenna for wireless communication system which is suitable for the 2.217GHz of operation as shown in fig.1a and fig.1b get a symmetric pattern so as to reduce the total area on the patch. An RMSA operating at frequency *fo* = 2.4 GHz with length (*l*) = 39mm, width (*w*) = 48mm, *tan* δ = 0.001, total area = 1872mm^2 is designed. There are numerous methods to increase the bandwidth of antennas, including increase of the substrate thickness and the use of a low dielectric substrate, hence duoroid having $_r$ = 2.4, thickness (*h*) = 1.58mm is selected. This paper presents linearly polarized microstrip antenna for wireless communication system which is suitable for the 2.217GHz of operation as shown in fig.1a and fig.1b

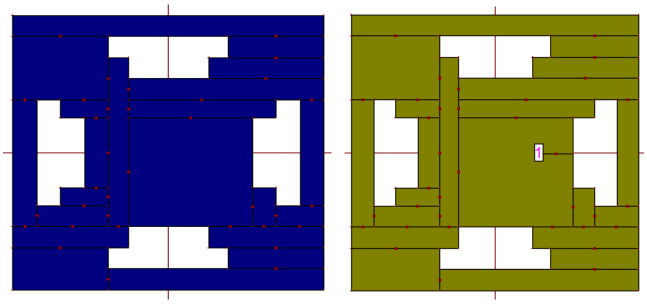

Fig.1 a. Patch Antenna Layout Fig.1 b. Patch Antenna with co-axial feed

III. Design of Rectangular Microstrip Patch Antenna

First a rectangular patch antenna is designed using the following design equations [1]

Width of patch:

$$W = \frac{c}{2f0\frac{\sqrt{\varepsilon r+1}}{2}} \tag{1}$$

Effective dielectric constant:

$$\varepsilon e = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}[1+\frac{10h}{W}]^{\wedge}(-0.5) \tag{2}$$

$$fo = \frac{c}{2\sqrt{\varepsilon r}}[\left(\frac{m}{L}\right)^{\wedge}2+\left(\frac{n}{W}\right)^{\wedge}2]^{\wedge}0.5 \tag{3}$$

Effective length is given by

$$Le = L + 2\Delta L = [(\lambda/(2\sqrt{\varepsilon r})] \tag{4}$$

where:

c = 3x10^8 m/s.

h = height of substrate.

r = dielectric constant of the substrate.

Square patch from Rectangular Patch:

This rectangular patch is than cut in the form of a square having length *Ls* = 39mm and width *Ws* = 39 mm reducing the surface edges. The square patch integrates four T shaped slots which form a symmetric pattern on the x and y axis. The co-ordinates at which the four cross slot are placed are: T shape 1 (*x* = 0, *y* = 13.5), T shape 2 (*x* = 0, *y* = -13.5), T shaped 3 (*x* = 13.5, *y* = 0) and T shaped 4 (*x* = -13.5, *y* = 0). For the rectangular patch cut into square patch the area reduces by 18.75%. Furthermore, T shaped slots etched in the

Manuscript received May 11, 2012; revised July 31, 2012.
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DOI: 10.7763/IJIET.2012.V2.189

square patch reduces the surface area of the proposed antenna.

This rectangular patch is than cut in the form of a square patch having length Ls = 39mm and width Ws = 39 mm reducing the surface edges. The square patch integrates four T slots on the x axis and y axis. For the rectangular patch cut into square patch the area reduces by 18.75%. Furthermore, T slots are etched in the square patch reduces the surface area of the proposed antenna. The calculation of patch dimensions is based on the transmission line model [2]. A substrate of low dielectric constant is selected to obtain a compact radiating structure that meets the demanding bandwidth specification [3].

Coupling of power through a probe is one of the basic mechanisms for the transfer of microwave power. The probe can be an inner conductor of a coaxial line in the case of coaxial line feeding .The coaxial cable is attach to the back side of the printed circuit board and coaxial center conductor after passing through the substrate is soldered to the patch metalisation. The location of the feed is determined for the given mode so that the best impedance match is achieved. Excitation of the patch is achieved through the coupling of the feed current Jz to the Ez field of the patch mode [3], [4]. The coupling constant can be obtained as:

$$\text{Coupling} = \iiint EzJzdv \tag{5}$$

$$= \cos\left(\Pi xo/ L\right) \tag{6}$$

where L=resonant length of the patch

Xo= offset of the feed point from the patch edge.

The above expression shows that coupling is maximum for a feed located at a radiating edge of the patch (Xo=0 or L).

After selecting the patch dimensions L and W for a given substrate, the next task is to determine the feed location (x_o, yo) so as to obtain a good impedance match between the generator impedance and the input impedance of the patch element. It is observed that the change in feed location gives change in impedance hence provides a simple method for impedance matching [5]. We see that if the feed is located $x_o = x_f$ and $0 \leqslant y_f \leqslant W$, the input resistance at resonance for the dominant mode TM_{10} mode can be expressed as

$$R_{in} = R_r \cos^2\left(\Pi \mathrm{xf/L}\right) \qquad R_r \geqslant R_{in} \tag{7}$$

where x_f is the inset feed distance from the radiating edge and Rr is the radiation resistance at resonance when the patch is fed at a radiating edge. The radiation resistance R_r with an estimated accuracy of 10% average for $h \leqslant 0.03\lambda 0$ and $\varepsilon_r \leqslant$ 10 are given as

$$R_r = V_o^2 / 2P_R \tag{8}$$

$$= \varepsilon_{re} \quad Z_{oL}\, 120 I_2 \tag{9}$$

where Z_o is the characteristic impedance of which the patch is a segment.

The inset distance is selected such that R_{in} is equal to the feed line impedance, usually taken to be 50Ω. Although the feed point can be selected anywhere along the patch with, it is better to choose $yf = W/2$ if $W \geqslant L$ so that $TM0n$ (n odd) modes are not excited along with the TM_{10} mode [6]. Determination of exact feed point requires an iterative solution for impedance to match .The above equation provides a useful solution for the purpose. Kara has suggested an expression for xf that does not need calculation of radiation resistance [4]. It is approximately given as

$$X_f = L/2\ \sqrt{[\varepsilon_{re}(L)]} \tag{10}$$

where $\varepsilon_{re}(L)$ is defined

$$\varepsilon_{re}(L) = [(\varepsilon_r+1)/2]+[(\varepsilon_r-1)/2]\ F(L/h) \tag{11}$$

Radiation Efficiency ε_r: The radiation efficiency is defined as the ratio of radiated power P_r to the input power P_i that is

$$\varepsilon_r = P_r / P_i \tag{12}$$

The input power gets distributed in the form of radiated power, surface wave power, and dissipation in the conductors and dielectric [5], [7].

It has been observed that radiation efficiency depends on the substrate thickness and permittivity, and is not effected very much either by the patch shape or feed. Numerical values indicate that radiation efficiency is almost independent of aspect ratio W/L of the rectangular patch [6], [7].

BANDWIDTH: If the antenna input impedance can be matched to its feeding structure across a certain frequency range, that frequency range will define the antenna bandwidth (BW) [4], [7], [8]. The bandwidth can be specified in terms of the return loss or the voltage standing wave ratio (VSWR). The typical values for micro strip antennas are VSWR<2 or return loss (S_{11} in db) < -10db [9]. Furthermore, the BW is inversely proportional to the quality factor (Q) and given by

$$BW = \frac{VSWR-1}{Q\sqrt{VSWR}} \tag{13}$$

The minimum quality factor is given by

$$Q_{\min} = \frac{1+3(koR)^2}{(koR)^3 * \left[1+(koR)^2\right]} \tag{14}$$

where R is the minimum sphere radius which completely encloses the antenna.

IV. Geometry and Design Procedure

The proposed design structure incorporates four T slots pattern providing linear polarization with single feed. The Table I shows the parameter of the proposed patch antenna.

TABLE I: Parameters of the Proposed Patch Antenna

Parameter	Value in mm
L	39mm
W	48mm
Area of RMSA	$1872mm^2$
Ls	39mm
Ws	39mm
Slot 1 L1 W1	15mm 3mm
Slot 2 L2 L2	10mm 3mm
Total Area	$1221mm^2$

V. Simulated Results

The behaviour of the antenna is simulated and optimized using Zeland IE3D software. The IE3D (Zeland Software) is an integrated full wave electromagnetic simulation and optimization package for the analysis and design of microstrip antennas based on method-of-moments.

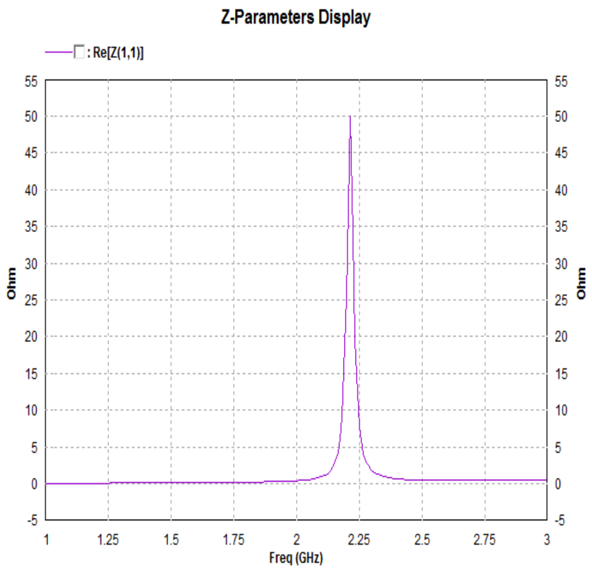

Fig. 1. Graph of Impedance vs. frequency for Patch Antenna Impedance=50 Ohms at frequency=2.217GHz

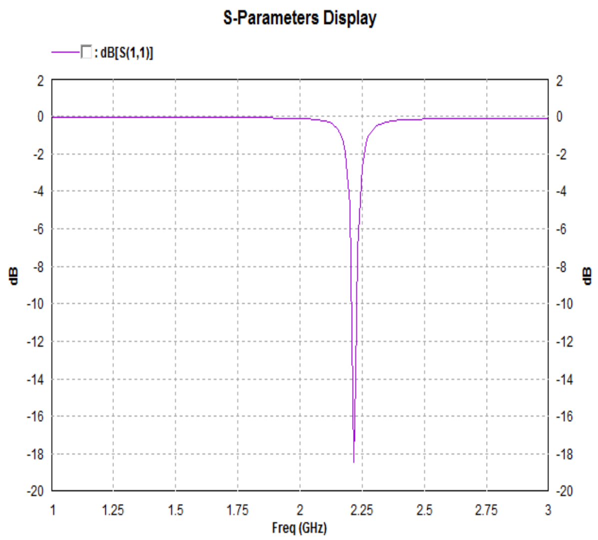

Fig. 2. Graph of return loss vs. frequency for patch antenna Return Loss=-18.5dB at frequency=2.217GHz

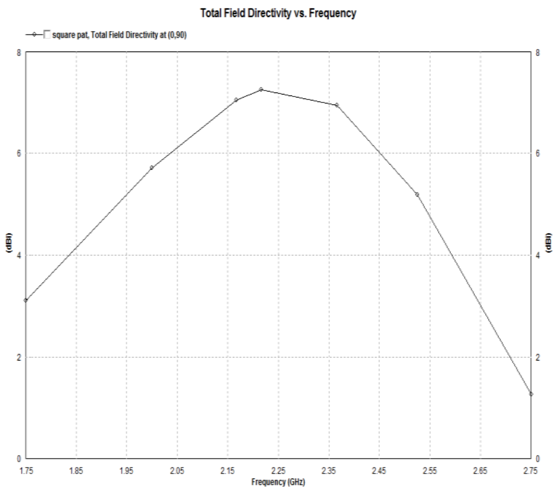

Fig. 3. Graph of Directivity vs. Frequency for Patch Antenna Directivity=7.3dBi at frequency=2.217GHz

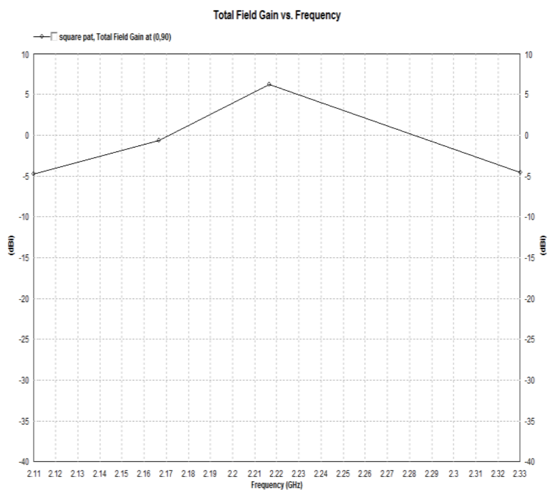

Fig. 4. Graph of Gain vs. Frequency for Patch Antenna Gain=6.2dBi at frequency=2.217GHz

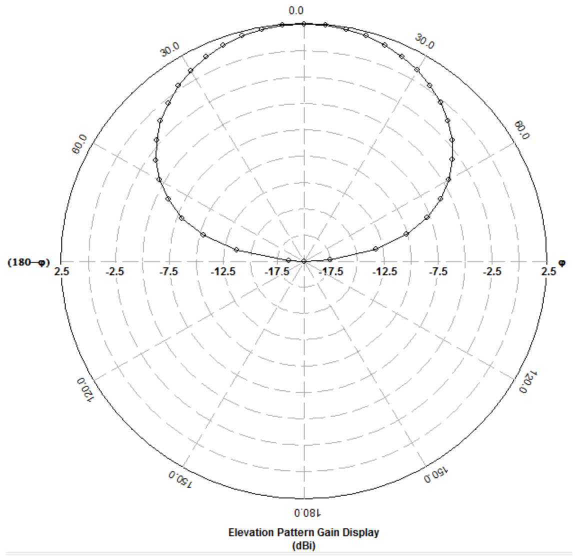

Fig. 5. 2-D Radiation Pattern (Elevation and Azimuth Pattern)

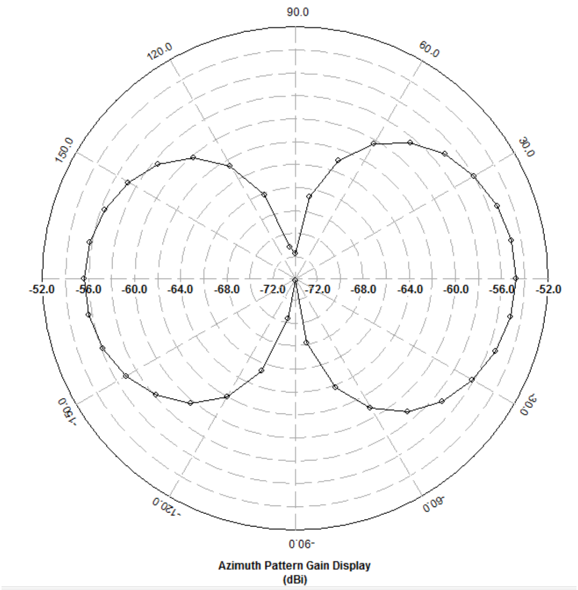

Fig. 6. 3-D Radiation Pattern

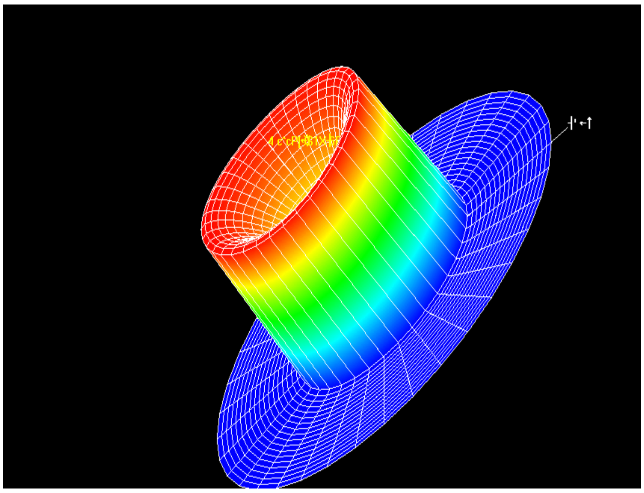

Fig. 7. 3-D Radiation Pattern (Mapped 3-D)

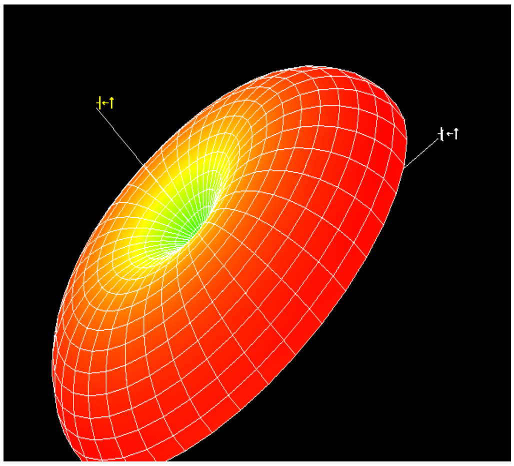

Fig. 8. 3-D Radiation Pattern (True 3-D)

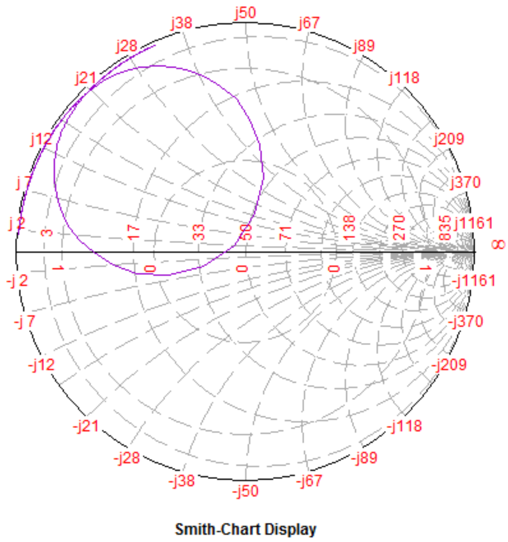

Fig. 9. Smith Chart

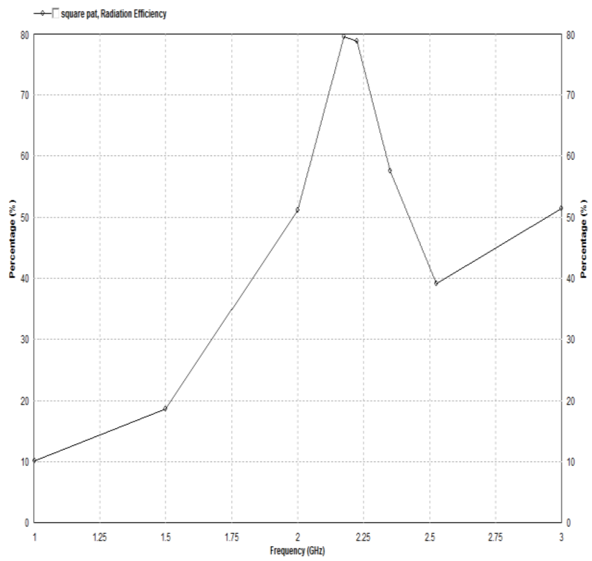

Fig. 10. Graph of Radiation Efficiency for Patch Antenna Radiation Efficiency= 79% at frequency=2.217GHz

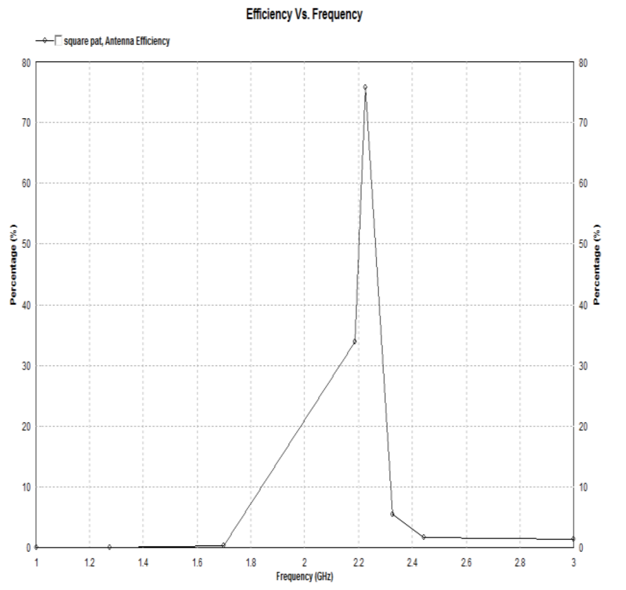

Fig. 11. Graph of Antenna Efficiency for Patch Antenna
Antenna Efficiency= 78.2% at frequency=2.217GHz

VI. CONCLUSION

A compact microstrip antenna with a single feed placed on the axis is presented. After simulation, 2.217GHz frequency operation obtained can be subjected to various applications in today's modem wireless communication world. The above antenna geometry allows linear polarization of the radiated field by appropriately locating the feeds. In the proposed design a size reduction of 34.78% is been achieved with a VSWR= 1.28 and radiation and antenna efficiency of 79% and 78.2% respectively.

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