Designing of Inset-fed Microstrip Rectangular Patch Antenna for PCS applications

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***Abstract*— A Rectangular Micristrip Patch antenna with inset fed technique for personal communication services application is presented. The proposed antenna can create resonance at 1.9 GHz. Dielectric material of εr=2.3 and height of h=1.6mm is used for antenna construction. Transmission line model is proposed for antenna dimensions calculation, and fabrication is done using photolithographic technique. Simulation is performed with the help of Advanced Design system (ADS) software and is excited with a 50Ω Microstrip line using inset feed technique. Fabricated antenna is tested with Network Analyzer to measure VSWR, S11 parameter and in Anechoic Chamber antenna parameters like gain, beamwidth are measured. Radiation patterns for vertical and horizontal planes in azimuthal plane are also drawn. Measured values are compared with simulated values and are discussed.**

***Keywords*— Transmission Line model, S-parameters, Personal Communication Services (PCS)**

I. Introduction

An In personal communication service applications data has been transferred over a short distance with in frequency range 1850-1990 MHz. Especially in PCS for wireless data transmission Microstrip Patch Antennas are widely implemented. Attractive features like low profile, light weight, low cost, high efficiency and easy of installation makes patch antennas to be useful in wireless communications properly. Patch antennas of different shapes like rectangular, square, circular and triangular shapes available. However, in this design we choose rectangular shape because of easiness in calculation and implementation.

In this paper patch antenna is designed based on transmission line model. This model have its own shortcomings, particularly it is applicable to only rectangular (or square) patch geometries. However, the analysis provides a reasonable interpretation of the radiation mechanism while simultaneously giving simple expression for the characteristics. The microstrip element treated as line resonator with transfer field variations. The field varies along the length, which is usually λ/2, and radiation occurs mainly from the fringing fields at the open circuited ends. But along the width the field does not vary. Voltages and currents vary sinusoidal from open ends as shown in figure 1. At the center line along the width impedance become zero. This is called virtual ground. Moving towards the open end from virtual line, and reaching 50 Ω impedance width line, usually it is 1/3rd length from the virtual ground line, a microstrip line of 50Ω is inserted using inset feed technique to excite the antenna.

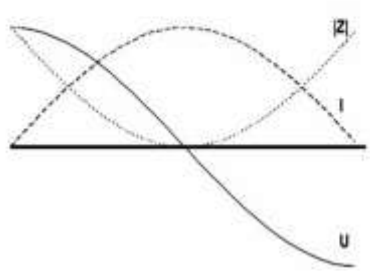

Figure 1 variation of voltage (U), current (I), and impedance (Z) along Patch length

In this paper, rectangular microstrip patch antenna with microstrip inset feed is proposed. The patch is mounted on dielectric substrate with ε_r=2.3 and thickness of 1.6 mm. Because of inset fed technique an error of 1% in resonance frequency occur and it is found that it has lower VSWR <2 and S_{11} value of -12.41dB at 1.884 GHz Below figure 2 shows the photographic view of proposed antenna.

Figure 2 Photographic view of Proposed Patch antenna

II. Antenna Design

The proposed antenna is designed with the fallowing specifications:
Resonant frequency (f_o) : 1.9GHz
Dielectric constant (ε_r) :2.3
Thickness of dielectric (h) : 1.6 mm

The formulae in [1] for calculations of physical dimensions of patch are given by

$$W = \frac{c}{2 f_o \sqrt{\frac{\varepsilon_r + 1}{2}}} = 61.46mm$$

$$L = L_{eff} - 2\Delta L = 51.428mm$$

Where L_{eff} and ΔL are the effective length and extended length due to fringing effects of field. These values are calculated using fallowing formulas as

$$L_{eff} = \frac{c}{2 f_o \sqrt{\varepsilon_{reff}}} = 53.1mm$$

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} = 0.836mm$$

Here ε_{reff} is effective relative permittivity due to inhomogeneous of media and its value is calculated as below

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} = 2.21$$

By knowing the quality factor (Q) and resistance (R), the input impedance Z_{in} along width edge is given as

$$Z_{in} = jX_f + \frac{R}{1 + 2Q\left(\frac{f}{f_o} - 1\right)} = 148.5\Omega$$

Feed point location (x) is an important parameter in antenna design because it will decide how antenna can radiate energy properly. If perfect matching takes place between antenna feed point and given input feed line, then all given input power radiate with out any reflections. Generally x value is $1/3^{rd}$ length from the virtual ground line along the length of the patch. This x value is given by the fallowing formula

$$x = \frac{L}{\pi} \sin^{-1}\left(\sqrt{\frac{Z_i}{R_e}}\right) = 10.46mm$$

Spurious radiation is present along the edges of the patch. So ground plane is chosen in such a way that it will cover radiation and values of length and width of ground plane are L_g = L+6h = 38.44 mm and W_g = W+6h = 46.86 mm. The gain of the antenna and beamwidths in both E plane and H Plane are calculated using fallowing formulas

$$G = 4\Pi A/\lambda^2 = 5.46dB$$

In E- Plane

$$\theta_{BE} = 2\cos^{-1}\left(\frac{7.08}{3\beta_0^2 W^2 + \beta_0^2 h^2}\right) = 100.67^0$$

In H-Plane

$$\theta_{BH} = 2\cos^{-1}\left(\frac{1}{2\left(1 + \frac{W\beta_0}{2}\right)}\right)^{1/2} = 123.43^0$$

To excite the antenna, a 50 Ω mictostrip line is used. The line length and width is calculated using line calculator tool in ADS software. Those values are L_f= 26mm, W_f=4mm and spacing s= 4mm. Layout of proposed antenna is designed with the help of Momentum tool in ADS software and is simulated. Below figure 3 shows the layout diagram of proposed antenna.

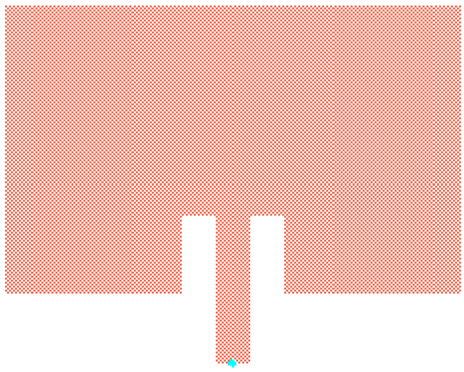

Figure 3 Layout diagram of antenna in Momentum tool of ADS

III. FABRICATION AND TESTING

Fabrication is the process in which the designed antenna is realized. Dimensions of the designed antenna are given in coordinate form and a master drawing is generated using Autocad software. With the master drawing generated, the artwork layout is generated on the photoresist coated Mylar film. . Figure 4 shows photographic negative view. Positive film is developed using this artwork layout and photo reduction technique if necessary. Fabrication is carried out on substrate material metal on the both sides using photolithographic process which involves cleaning, deposition of photoresistive layer, resist exposure, resist development, inspection, etching, stripping etc.

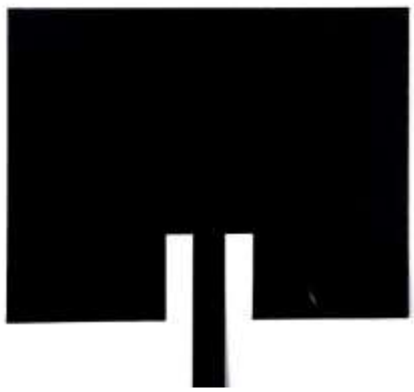

Figure 4 photographic negative view of patch antenna

Two important parameters to understand the performance of the antenna are VSWR, S_{11} parameter. To measure these parameters Network Analyzer is used. A Network Analyzers measure the magnitude and phase characteristics of networks, amplifiers, components, cables, and antennas. They compare the incident signal that leaves the analyzer with either the signal that is transmitted through the test device or the signal that is reflected from its input.

Radiation patterns both in azimuthal plane has been drawn in Anechoic Chamber. Figure 5 shows the testing of antenna in Anechoic Chamber. It consists of definite volume enclosed by microwave absorber walls made by radiation absorbing material. These walls reduce reflections from the boundary walls and increase the polyurethane foam in the shape of pyramids. So accurate far-field pattern of small antennas can be measured and also other parameters like gain, beamwidth.

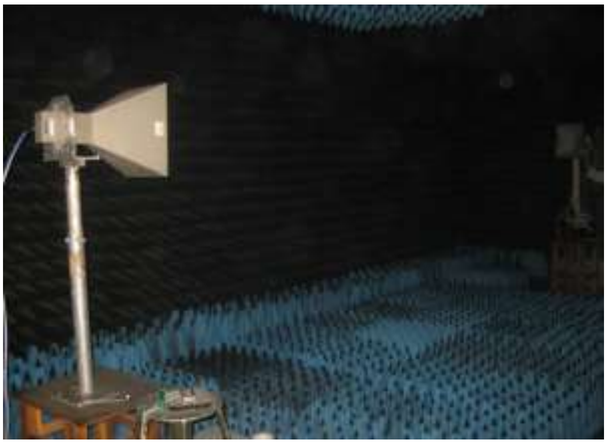

Figure 5 Testing of antenna in Anechoic chamber

IV. Results and Discussions

This section describes the simulation and measured results of proposed rectangular microstrip patch antenna. Return loss is the difference, in dB, between forward and reflected power measured at any given point in RF system and, like VSWR, does not vary with the power level at which it is measured. The simulated plot of return loss against frequency is shown in figure 6.

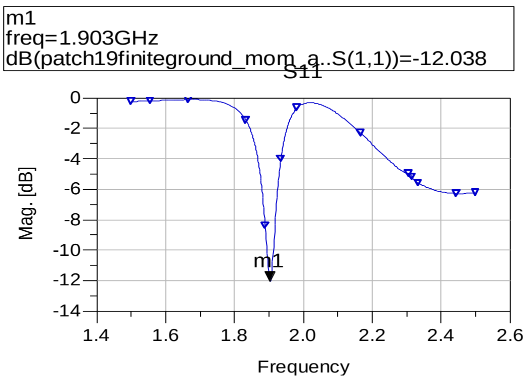

Figure 6 Simulated S-parameter variations with frequency

The return loss of -12.038 dB at 1.903 GHz is obtained. VSWR is 1.132 at 1.90GHz. Using Network Analyzer return loss S_{11} and VSWR are measured and low return loss is at 1.884 GHz. Figure 7 shows the variation of VSWR as a function of frequency and is 1.9894, 1.1328, and 1.9490 at 1.87 GHz, 1.884 GHz, and 1.895 GHz frequency respectively. VSWR <2 is the important result and is resonant at 1.884 GHz frequency. The return loss of -12.41dB is obtained at 1.884 GHz frequency which is agreed with simulated result.

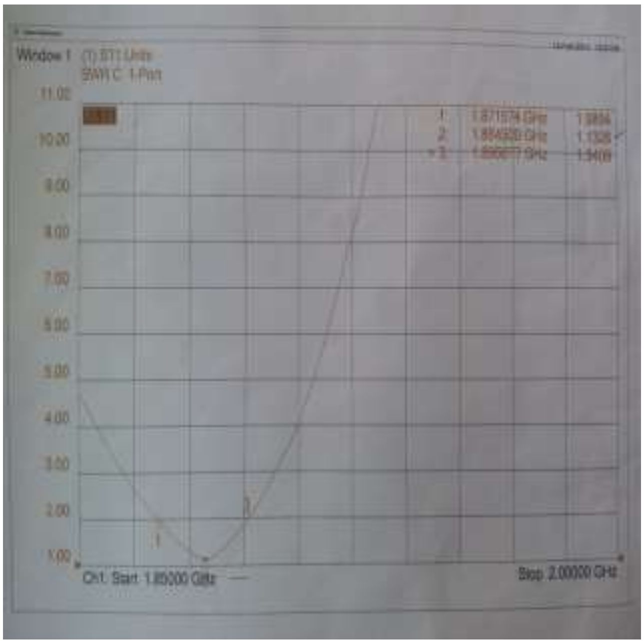

Figure 7 VSWR measurement using Network Analyzer

In anechoic chamber using standard horn antenna and based on three elements antenna method the gain is calculated and is 7.9dB, which is comparable with calculated value of 5.46 dB. Table 1 shows the gain measurement in anechoic chamber with standard horn antenna. Radiation pattern in Vertical and horizontal plane are drawn at 1.87 GHz and is shown in figure 8

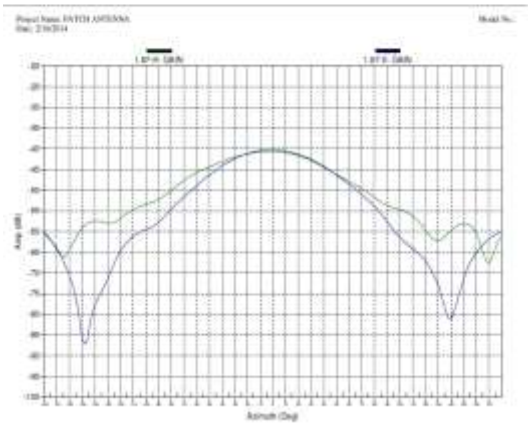

Figure 8 Radiation pattern in both Vertical and Horizontal plan

Below tables show complete antenna designed specifications and the comparisons of simulated, measured and calculated values.

TABLE 1 GAIN MEASUREMENT

Frequency in GHz	STD Horn PrH (dB)	A.U.T PrA (dB)	Difference in Pr Level PrH-PrA	STD (SA) HORN Gain(dBi)	Gain A.U.T (dBi)
1.88	-32.9	-40.27	-7.3	15.2	7.9

TABLE 2 CALCULATED PARAMETERS

Width (W)	61.46 mm
Effective permittivity(ε_{reff})	2.21
Effective length (L_{eff})	53.1 mm
Extended length (ΔL)	0.836 mm
Length (L)	51.428 mm
Ground length (L_g)	61.028mm
Ground width (W_g)	71.06 mm
Feed position (x)	10.46 mm

TABLE 3 DIELECTRIC MATERIAL PROPERTIES

Substrate			Conductor	
Dielectric constant	Substrate thickness	Loss tangent	Copper thickness	Conductivity
2.3	1.6 mm	0.02	20 um	$5.8X10^7$

TABLE 4 COMPARISONS OF CALCULATED, SIMULATED, MEASURED VALUES

Parameters	Calculated	Simulated	Measured
Frequency	1900MHz	1874 MHz	1884MHz
Gain	5.46 dB	5.67dB	7.9 dB
Beam width	100^0	105^0	90^0

V. CONCLUSIONS

The design and performance of rectangular microstrip patch antenna for PCS applications is described here. This patch antenna has been designed on tikonic material of dielectric constant of 2.3 with loss tangent 0.02. The microstrip inset feed technique is used to excite the antenna. The simulated results are verified by measured results. The maximum achievable gain is 7.9dB which is appreciably good. The designed antenna has resonant frequency occurred at 1.884GHz with VSWR of 1.13. Finally, any rectangular patch antenna is designed with this procedure with good resonant frequency.

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REFERENCES

[1] [1].R. Garg, P. Bhartia, I. Bahl, and A. Ittipiboon, Microstrip Antenna Design Handbook, ArtechHouse, 2001.

[2] [2].W. Menzel andW. Grabherr, "A microstrip patch antenna with coplanar feed line," *Microwave Guided Wave Letters*, vol. 1, no. 11, pp. 340–342, Nov. 1991.

[3] [3].K. Wong and W. Hsu, ―A broadband patch antenna with wide slits,‖ in IEEE Antennas and Propagation international Symposium, vol. 3, (Salt Lake City, Utah),pp. 1414– 1417, IEEE, July 2000.

[4] [4] .D. M. Pozar and D. H. Schaubert, Microstrip Antennas: The Analysis and Design of Microstrip Antennas and Arrays, IEEE Press, 1995.

[5] [5].F. E. Gardiol, "Broadband Patch Antennas," Artech House.

[6] [6] .S K Behera, "Novel Tuned Rectangular Patch Antenna As a Load for Phase Power Combining" Ph.D Thesis, Jadavpur University, Kolkata.

[7] [7] .D. R. Jackson and J. T. Williams, "A comparison of CAD models for radiation from rectangular microstrip patches," Intl. Journal of Microwave and Millimeter-Wave Computer Aided Design, Vol. 1, No. 2, pp. 236-248, April 1991.

[8] [8]. D. R. Jackson, S. A. Long, J. T. Williams, and V. B. Davis, "Computer- aided design of rectangular microstrip antennas", ch. 5 of Advances in Microstrip and Printed Antennas, K. F. Lee, Editor, John Wiley, 1997.

[9] [9].D. M. Pozar, "A reciprocity method of analysis for printed slot and slot- coupled microstrip antennas," IEEE Trans. Antennas and Propagation, vol. AP-34, pp. 1439-1446, Dec. 1986.

[10] [10] Rogers Corporation, High Frequency Circuit Materials Product Selector Guide, 1991-2002.

[11] [11] K.L. Wong, "Compact and Broadband Microstrip Antennas", John Wiley & Sons,NY, 2002.

[12] [12] R. A. Sainati, CAD of Microstrip Antenna for Wireless Applications, Artech House, Boston. London, 1996.