Investigations on A New Proximity Coupled Dual-Frequency Microstrip Antenna for Wireless Communication

Jibendu Sekhar Roy and Milind Thomas

Abstract – **The investigations on a new proximity coupled dual-frequency microstrip antenna, which can be operated at GPS and Bluetooth frequency bands of wireless communication, are reported. The patch geometry consists of two square sections joined at the common corners and proximity coupled by a microstrip line. The results show that the antenna has sufficient bandwidth and gain necessary for the above frequency bands and may be used for wireless applications.**

Keywords – **Microstrip Antenna, Proximity Coupled, Dual-frequency, Wireless Communication.**

I. Introduction

In proximity coupled (also known as electromagnetically coupled) microstrip antenna configuration, the radiating patch, fabricated on a dielectric substrate, is excited by a microstrip line on another substrate, as shown in Fig.1. The equivalent circuit of proximity coupled microstrip antenna is shown in Fig. 2. Proximity coupled microstrip antennas and dipoles are suitable both for microwave and millimeter wave antenna elements due to various advantages like reduction of radiation loss from feeding network, improvement of impedance bandwidth etc. Investigations on proximity coupled microstrip antennas have been reported by many authors [1]–[6] including an easy design procedure of it [7].

In this paper, the characteristics of a new two-layer proximity coupled microstrip antenna are reported. The microstrip patch fabricated on dielectric substrate consists of two square sections of unequal patch dimensions, as shown in Fig.3 and this patch is proximity coupled at the common corner of the two patch sections by a microstrip line which is excited by a co-axial connector. Single layer patch of this shape excited by co-axial connector, was originally developed by one of the authors of this paper for dual-frequency operation [8]. But because of the fixed feed point at the common corner of the patch geometry, the impedance matching is very difficult for this antenna [8] and sometimes it may not be possible.

The problem of impedance matching was solved by short circuiting the two sections of the patch by shorting pins at the proper locations [9]. But in this case [9], gain and bandwidth are very low which may not be accepted for practical applications in wireless communications.

Jibendu Sekhar Roy and Milind Thomas are with the Electronics and Communication Engineering Department, Birla Institute of Technology (Deemed University), Mesra, Ranchi-835215, INDIA.
e-mail : drjsroy@rediffmail.com

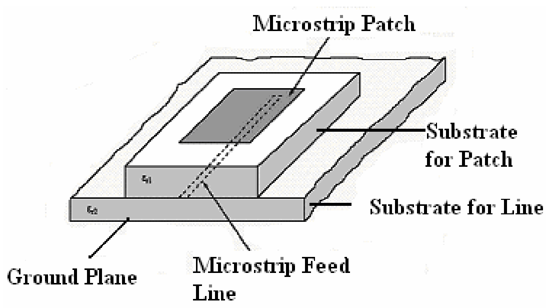

Fig. 1 Proximity Coupled Microstrip Antenna

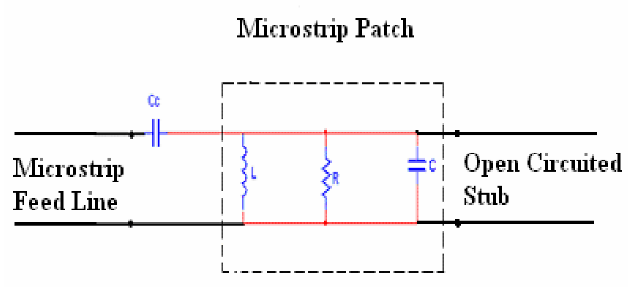

Fig. 2 Equivalent Circuit of Dual-Frequency Proximity Coupled Microstrip Antenna

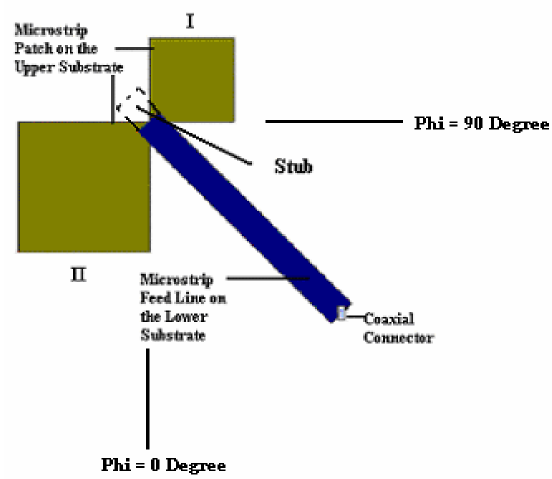

Fig. 3 Antenna Geometry of the Dual-Frequency Proximity Coupled Microstrip Antenna

In this paper, these problems are solved, that is, the proposed proximity coupled microstrip antenna has sufficient gain and bandwidth required for wireless communication. The dimensions of the two sections of the patch were adjusted to obtain two operating frequencies at GPS (Global Positioning Satellite System) and Bluetooth frequency bands with sufficient bandwidths. The GPS system uses low earth orbiting satellites that transmit signals continuously to the earth based receivers. There are two categories of GPS services: civilian and military. Civilian GPS system operates at a center frequency of 1575.42 MHz (L1 band) with a bandwidth of 20 MHz [10]. The require polarization is circularly polarized with axial ratio of 3dB or better and required antenna gain is 4 dBi. A user terminal may use linearly polarized antenna, but in that case it will suffer 3 dB power loss. The radiation pattern of the GPS antenna should have a wide hemispherical coverage in the upper half plane. Bluetooth is a well-established short-distance (10 meters) wireless communications standard which uses 2.4 GHz – 2.484 GHz frequency of ISM (Industrial, Scientific and Medical) band with a bandwidth of 84 MHz. Bluetooth communication uses omnidirectional antenna [11, 12], but linearly polarized directional antenna can be used for short distance communication. The Method of Moments using IE3D software are used. IE3D simulating software (developed by Zeeland Software Inc., USA) is a full wave electromagnetic simulation for the microwave and millimeter wave integrated circuits. The primary formulation of the IE3D software is an integral equation obtained through the use of Green's function. The computed reflection coefficient and gain of the antenna are compared with measured results.

II. SIMULATED RESULTS

In the antenna configuration, shown in Fig.3, the radiating patch on the upper substrate is excited due to electromagnetic coupling with the microstrip line on the lower substrate. The part of the microstrip line appearing beyond the common corner is stub section and the length of this stub is important for impedance matching. The two resonance frequencies are due to the two fundamental modes of two square sections of unequal dimensions.

The method of moment using IE3D software is used for the analysis of proximity coupled microstrip antenna. The antenna was excited to resonate at GPS (1.575 GHz) and Bluetooth (2.400 GHz – 2.484 GHz) frequency bands. In the simulation, for proximity coupled microstrip antenna, the following parameters were chosen: Dielectric constant = 4.36, Substrate (Glass Epoxy) thickness (h) -1.57 mm, loss tangent = 0.0001. The dimension of section I was 43.4 mm X 43.4 mm. and the dimension of section II was 27.5 mm. X 27.5 mm. The length of the microstrip feed line which appears across the common corner of the patch geometry (Fig. 3) is stub length. This stub length is important for impedance matching. The best impedance matching at 1.575 GHz and 2.442 GHz bands were found when the stub length was 7 mm. The dimension of the microstrip feed line was 90 mm. X 9.5 mm. At both the frequencies radiation patterns of the antenna show broadside maximum. The broadside gain of the dual-frequency antenna at 1.575 GHz and 2.442 GHz are 5.1 dBi and 5.51 dBi respectively. The computed radiation pattern at 1.576 GHz and 2.442 GHz are shown in Fig. 4 and Fig. 5 respectively. The antenna is linearly polarized antenna. The cross polarizations at both the frequencies (1.575 GHz and 2.442 GHz) are studied in simulation where cross polarization for non-resonant higher order modes are not taken into consideration. At both the frequencies cross polarization is less than –22 dB in both the principal planes. The cross polarization increases when the feed point is near the center of the patch [13]. In the proposed structure the antenna is proximity coupled at the common corner of the patch geometry, far from the center of the patch, and hence the structure provides less cross polarization.

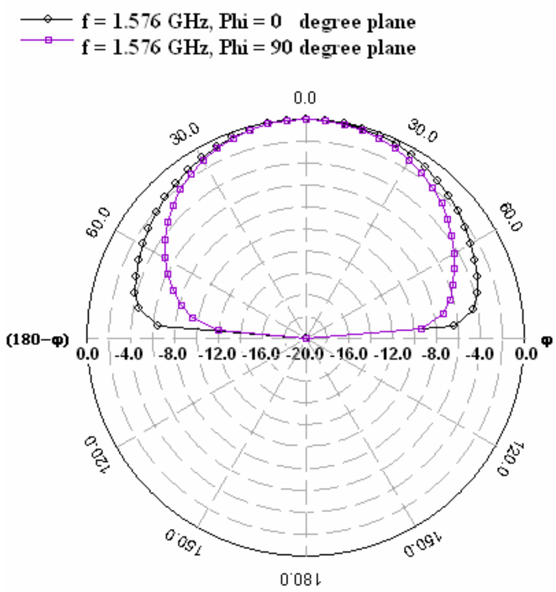

Fig. 4 Computed Radiation Pattern of Dual-Frequency Microstrip Antenna at 1.576 GHz

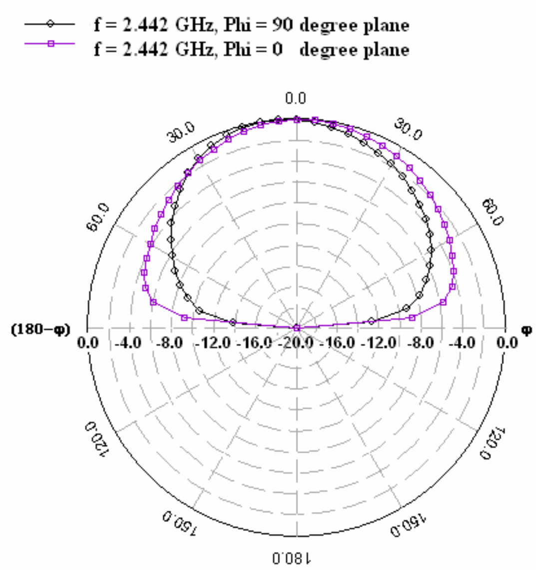

Fig. 5 Computed Radiation Pattern of Dual-Frequency Microstrip Antenna at 2.442 GHz

III. Measured Results

The proximity coupled microstrip antenna was fabricated on a Glass Epoxy substrate with dielectric constant 4.36 and substrate thickness of 1.57 mm. Same substrate was used for microstrip patch (on the upper substrate) and microstrip line (on the lower substrate). The antenna was connected by a coaxial SMA connector and measurement was performed by a vector network analyzer (Model No. N5230A, 10 MHz – 20GHz, Agilent Technologies). The stub length was adjusted to be 7 mm. The simulated and the measured return losses for the antenna are compared in Fig. 6.

The difference in measured and simulated return losses are due to the fact that antenna was not designed using multilayered fabrication. The microstrip patch was designed on one substrate and the feed line was designed on another similar type of substrate and after proper alignment these two are joined together by very thin adhesive gum. In the simulation, the effect of gum has not been considered.

The computed and measured resonance frequencies and –10 dB return loss bandwidths are compared in Table-I.

The gain of the antenna was also measured by the vector network analyzer. In this case two identical dual-frequency proximity coupled microstrip antennas were designed and transmission coefficient (S_{21}) was measured. The two antennas were separated by a distance ‘r’ which must be more than the minimum distance to receive far field. One antenna was connected to the port 1 of the network analyzer and other antenna was connected to the port 2 of the network analyzer. That is, one antenna was treated as transmitting antenna and the other was treated as receiving antenna.

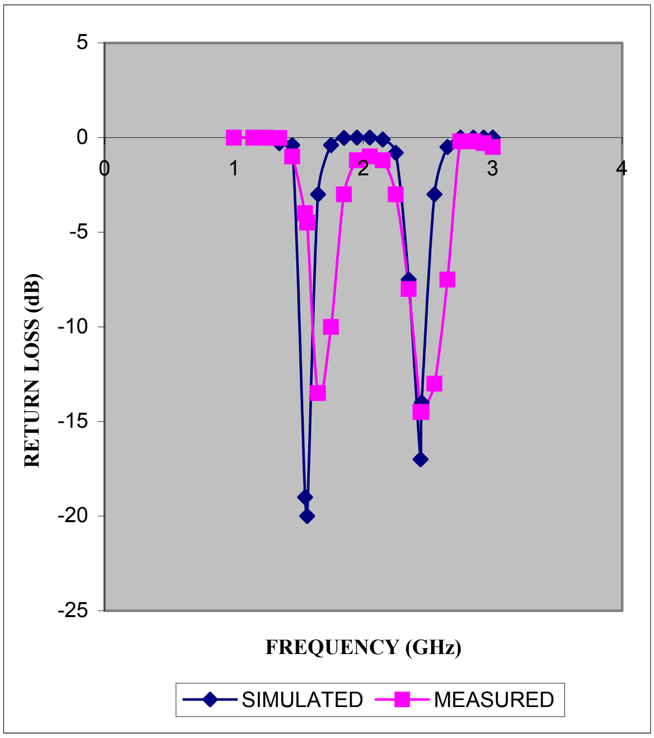

Fig. 6 Comparison Between Simulated and Measured Return Losses of Dual-Frequency Proximity Coupled Microstrip Antenna

The transmitted power (P_t) and the received power (P_r) can be related to the S_{21} by the expression

$$P_r / P_t = | S_{21} |^2$$

Then Friis transmission formula can be re-written as

$$| S_{21} |^2 = (G_r^2 \cdot \lambda^2)/(4\pi r)^2$$

where gain of transmitted antenna (G_t) and received antenna(G_r) are same. That is, gain of the receiving antenna is

$$G_r = (4\pi r) | S_{21} |$$

The gains of the antenna is measured at 1.575 GHz band and 2.442 GHz band and the measured gains at these frequencies were 4.6 dBi and 5 dBi respectively. The variation of simulated and measured gain with frequency are shown in Fig. 7.

TABLE-I
COMPARISON BETWEEN COMPUTED AND MEASURED RESULTS

	Res. Freq. (GHz)	–10 dB Return Loss BW(MHz)	Res. Freq. (GHz)	–10 dB Return Loss BW(MHz)
Computed Results	1. 575	50	2.442	110
Measured Results	1. 6	70	2.448	150

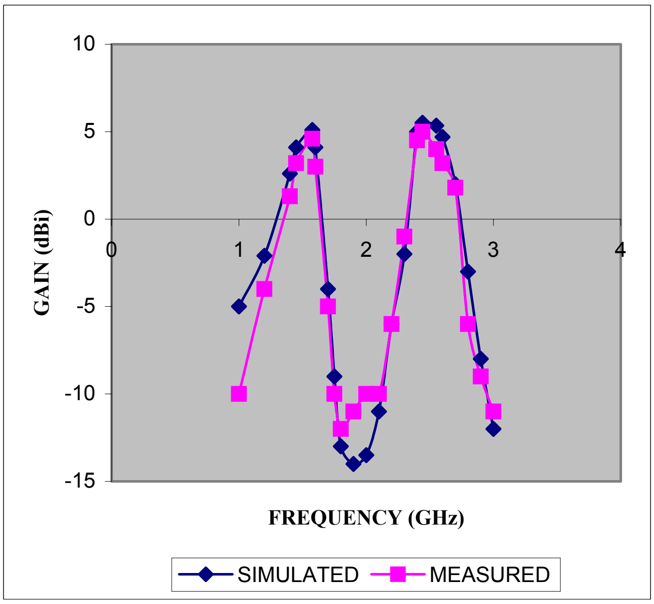

Fig. 7 The Variation of Simulated and Measured Gain with Frequency of Dual-Frequency Proximity Coupled Microstrip Antenna

IV. Conclusion

The investigations on a new two-layer proximity coupled dual-frequency microstrip antenna are reported. The antenna shows good impedance bandwidth and good gain at GPS and Bluetooth frequency bands of wireless communication. The measured results agree well with the simulated results. However, the size of the proximity coupled microstrip antenna, reported here, is not very small. Cutting slots on the two sections of the patch, the size of the proximity coupled microstrip antenna may be reduced. The antenna described in this paper is linearly polarized. There are many design techniques to produce circular polarization using square patch out of which popular methods are [4, 13] cutting single or multiple slits on the patch and with a chamfered (corner-truncated) square patch. Work is going on to achieve good circular polarization with good axial ratio over a wide bandwidth combining above two methods.

Acknowledgement

The authors like to acknowledge University Grants Commission (UGC), New Delhi for providing financial assistance during this research work.

References

[1] D. M. Pozar and S. M. Voda, “A Rigorous Analysis of a Microstrip Fed Patch Antenna”, *IEEE Trans. Antennas and Propagat.*, Vol. AP-35, pp. 1343 – 1350, 1987.

[2] J. S. Roy, S.K. Shaw, P. Paul, D.R. Poddar and S.K. Chowdhury, “Some Experimental Investigations on Electromagnetically Coupled Microstrip Antennas on Two Layer Substrates”,*Microwave and Optical Technology Letters*, Vol.4, No.6, pp. 236-238, 1991.

[3] S. M. Duffy, “An Enhanced Bandwidth Design Technique for Electromagnetically Coupled Microstrip Antennas”, *IEEE Trans. Antennas and Propagat.*, Vol. AP-48, No. 2, pp. 161 – 164, 2000.

[4] K. L. Wong, *Compact and Broadband Microstrip Antennas*, Wiley, New York, 2002.

[5] S. Gao and A. Sambell, “Broadband Dual Polarized Proximity Coupled Circular Patch Antenna”, *Microwave and Optical Technology Letters*, Vol. 47 No. 3, pp. 298 – 302, 2005.

[6] H. Rmili, J-L. Maine, H. Zanger and T. Olinga, “Design of Microstrip-Fed Proximity-Coupled Conducting- Polymer Patch Antenna”, *Microwave and Optical Technology Letters,* Vol. 48 No. 4, pp. 655 – 666, 2006.

[7] G. Splitt and M. Davidovitz, “Guidelines for Design of Electromagnetically Coupled Microstrip Patch Antennas on Two-Layer Substrates”, *IEEE Trans. Antennas and Propagat.*, Vol. AP-38, pp. 1136 – 1140, 1990.

[8] J. S. Roy and J. Ghosh, “A Multifrequency Microstrip Antenna”, *Microwave and Optical Technology Letters*, Vol. 46, No.1, pp. 63 – 65, July 2005.

[9] J. S. Roy, N. Chattoraj and S. Swain, “Short Circuited Microstrip Antennas For Multi-band Wireless Communications”, *Microwave and Optical Technology Letters* , Vol. 48, No. 12, pp. 2372 – 2375, Dec.2006.

[10] B-H. Wellenhof, H. Lichtenegger and J. Collins, *GPS: Theory and Practice*, Springer, New York, 1997.

[11] R. V. Nee and R. Prasad, *OFDM for Wireless Multimedia Communications*, Artech House, 2000.

[12] Tom Siep, *An IEEE Guide: How to Find What You Need in the Bluetooth Spec*, IEEE Standard Office Publisher, 2000.

[13] R.Garg , P. Bhartia , I. J. Bahl, A. Ittipiboon, *Microstrip Antenna Design Handbook*, Artech House 2001