

Analysis and Design of Microstrip Patch Antenna For Triple Band Applications

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Abstract: Analysis and Design of Microstrip Patch antenna for a digital communication system For Narrow Band (DCS)/2.4-GHz and 5.5 GHz WLAN-Band Triple Band frequencies application is presented. The two resonant modes of the proposed antenna are associated with various arms of the monopoles, in which a rectangular resonator contributes for the 5.5 GHz WLAN resonant frequency and two various arms are responsible for DCS/2.4 GHz resonant frequency. The experimental results show that the designed antenna can provide excellent performance for DCS/2.4-GHz WLAN and 5.5 GHz WLAN-Band frequencies systems, including sufficiently wide frequency band, moderate gain, and nearly omnidirectional radiation coverage. The outcome of the experimental results along with the design criteria are presented in this paper.

Index Terms: Digital communication system (DCS), WLAN-band 2.4/5.5 GHz for communication, monopole antenna.

I. Introduction

The Rapid development of modern wireless communication urges on the need of dual band or multiband antennas. Patch antennas have found wide spread application in wireless communication industry due to their attractive features like ease of fabrication, low cost, and nearly

omnidirectional radiation characteristics. Recently, the design of dual band or multiband antennas has received the attention of antenna researchers. Numerous designs of dual frequency Patch antennas have been demonstrated, including the use of a combination of two parallel monopoles excited by a coplanar waveguide (CPW) feedline [1], microstrip excited triangular monopole with a trapezoidal slit [2], Patch antenna based on tapered meander line geometry [3], and parallel line loaded Patch antenna [4] etc. Most of the monopole antennas reported in the literature are mounted above a large ground plane which increases the complexity of the system.

In this paper, we propose a novel design of triple frequency Patch antenna excited by microstrip feed line with a rectangular optimum ground plane. The principle of triple frequency operation is to introduce various resonating lengths to a simple strip Patch antenna. Experimental results demonstrate that the impedance matching of the proposed antenna depends upon the ground plane dimensions and frequency tuning can be achieved by tuning the two resonant lengths. Parameters of the antenna are experimentally optimized and the radiation and reflection characteristics of a prototype suitable for digital communication system (DCS)/2.4-GHz WLAN and 5.5 GHz WLAN-band application are presented. Details of the design and experimental results are also presented and discussed.

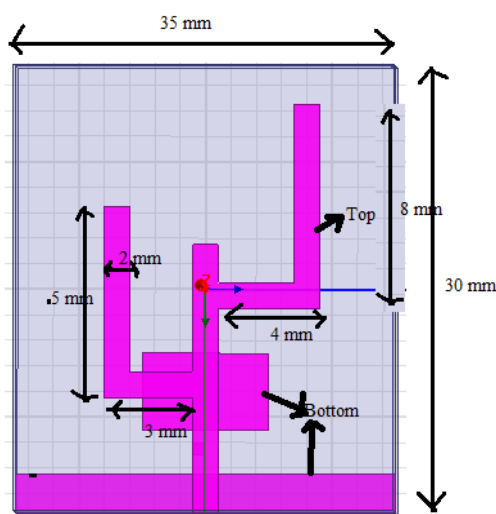


Fig. 1 Geometry of purposed Antenna with optimized dimensions

II. Antenna Design

The following section describes the design procedure to modify a simple circular strip monopole antenna for triple band characteristics. Fig. 1 shows three configurations of planar monopole antennas.

Antenna is circular strip $\lambda/2$ radius monopole excited by a 50- Microstrip line with a rectangular optimum ground plane of $\lambda/2$ width. Even though wide bandwidth is achieved with this configuration the antenna occupies an area of 84% compared to a standard circular patch resonating at the same frequency.

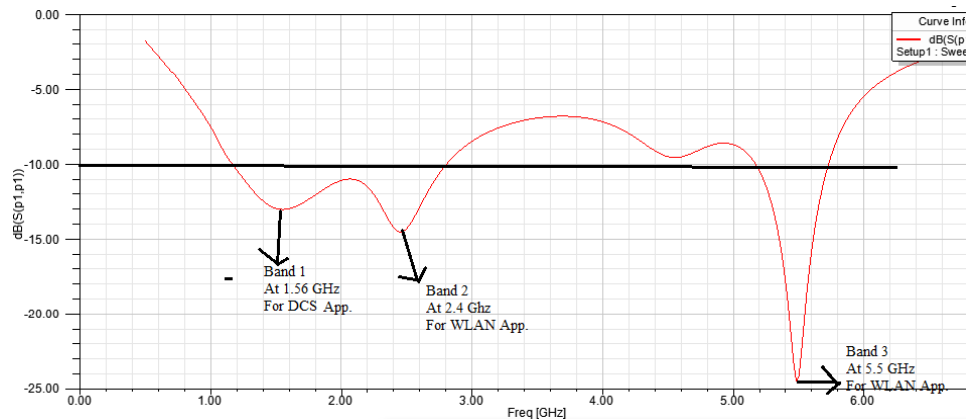


Fig. 2 Shows the Simulated S11

The antenna is modified by meandering the strip monopole to the arms like radiating structure in order to achieve compactness. The antenna with ground plane width $\lambda/4$ requires a resonant length of 0.62λ to obtain the resonant frequency at the desired value. Since the strips like radiating structure is a top loaded planar strip, the capacitive coupling between the horizontal strip and ground plane adds a capacitive reactance at the input impedance of the patch monopole which lowers the bandwidth of operation. However, Antenna offers a size reduction of 75% compared to a standard rectangular patch resonating at the same frequency. This Antenna is a modified version of purposed antenna with two strips like radiating structure to obtain two different current paths resulting in dual band operation.

The strips 1 and 2 of the Patch Antenna must be loaded at a distance of $\lambda_{r1}&2/4$ from the ground plane and rectangular resonator must be loaded at a distance of $\lambda_{r3}/4$ from the ground plane for obtaining good impedance matching and radiation characteristics. The designed antenna is printed on standard FR4 substrate of thickness $h=1.6$ mm and relative permittivity $\epsilon_r=4.4$. The strip Patch is excited by a 50 Microstrip line with rectangular ground plane. The length and width of the rectangular ground plane is optimized for maximum bandwidth without affecting the impedance matching. For the design convenience the

The length the strips of the Patch is set are 8 mm & 12 mm, width of 50- Microstrip line for dual band operation and the third resonator is 10×6 mm. The proposed triple frequency antenna owns three different resonant paths of two strips and one rectangular resonator. Tuning the length can fix the first two resonances at 1.5 GHz 2.4 GHz while tuning the length can fix the third resonance at 5.5 GHz.

III. Result Discussion

Typical proposed antenna was simulated and characterized using HFSS v11 and HP8510C vector network analyzer. The antenna was simulated with the HFSS in order to obtain the proper dimensions of the antenna. Fig. 2 illustrates the reflection characteristics of Patch antenna configurations.

Antenna resonating at 1.5, 2.4 GHz and 5.5 GHz offers a wide bandwidth of 700 MHz (1.40 GHz–2.10 GHz), 800 MHz (2 GHz = 2.8 GHz) and 1 GHz (5-6 GHz). But the dimensions of the antenna are comparable to that of standard rectangular patch antenna. Antenna resonating at 5.50 GHz offers 1 GHz bandwidth with an area reduction of 76% compared to that of conventional patch antenna. The Antenna offers three distinct resonant modes at 1.5 GHz and 2.40 GHz and 5.5GHz respectively. The lower impedance bandwidth due to the resonant two strips patch, determined by 2:1 VSWR is 700 MHz (1.40–2.10 GHz), which meets the requirement of DCS system similarly for WLAN operation 800MHz (2.4GHz). The upper resonance due to the length reaches 5.50 GHz (5–6 GHz), which covers the WLAN-band for communication application.

The characteristics of antenna configurations are showing in fig. 1 from the fig. it can be inferred that for antenna top loading a rectangular strips monopole decreases the bandwidth due to the capacitive coupling between the horizontal rectangular strips and ground plane but with a large reduction in overall size of the antenna. For bandwidth enhancement is observed for the lower resonant frequency as the rectangular strip 1 increases the inductive reactance. But for the higher resonance degradation in bandwidth is observed due to the increased capacitive coupling. The Antenna with triple band characteristics offers an area reduction of 67%

compared to conventional patch antenna. The Fig. 3(a) and (b) gives the radiation patterns at 1.5, 2.4 and 5.5 GHz respectively. The antenna is linearly polarized along the direction.

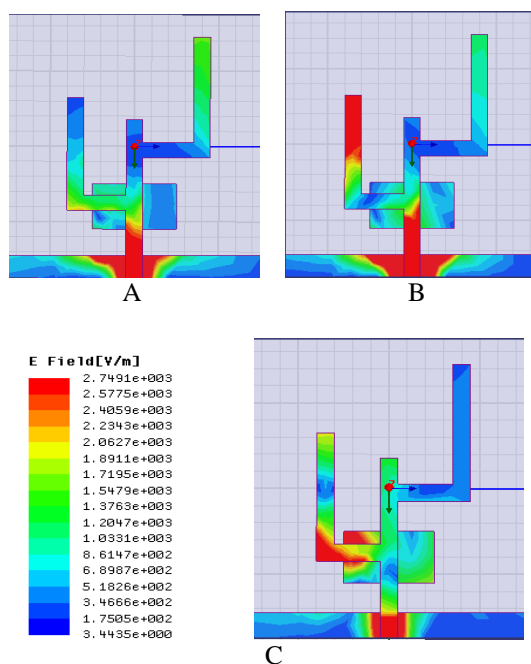


Fig. 4 shows the current distribution at different-3 frequencies of purpose antenna at (A) at 1.5 GHz, (B) 2.4 GHz and (C) 5.5 GHz

Fig. 4 shows the simulated current distributions at different Three frequencies For The Narrow band Applications. In Fig. 3(a-c) at different frequencies, the current distributions mainly flow along the transmission line, The impedance nearby the feed-point no changes acutely making less than 10 dB reflection at the desired band.

The radiation intensity corresponding to the Omidirectionally radiated power is equal to the power accepted by the antenna divided by 4π . This can be expressed as;

$$G = 4\pi U(\phi, \Theta) / P_{in} \quad 1$$

Fig. 5 presents the simulated gain for antenna. The antenna gain in the operating frequency bands is about 5–6 dBi. The variation in gain in over all bandwidth is 1 dBi.

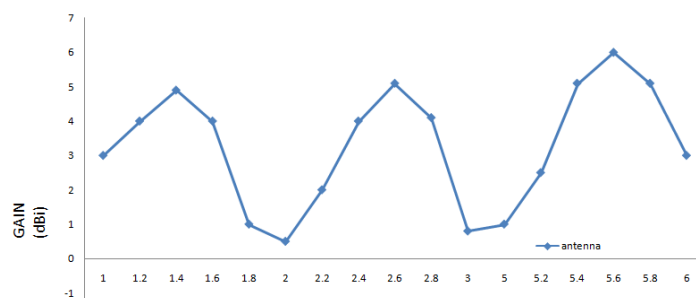


Fig. 5- Simulated gain of antenna

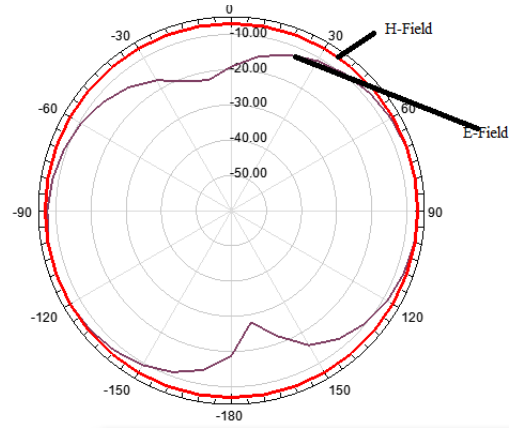
It is assumed that the antenna is receiving a signal in the direction of maximum gain. It is also common for the gain to be expressed in decibels and referenced to an isotropic source ($G = 1$), as shown;

$$G \text{ (dBi)} = 10 \text{ Log } (G/1) \quad 2$$

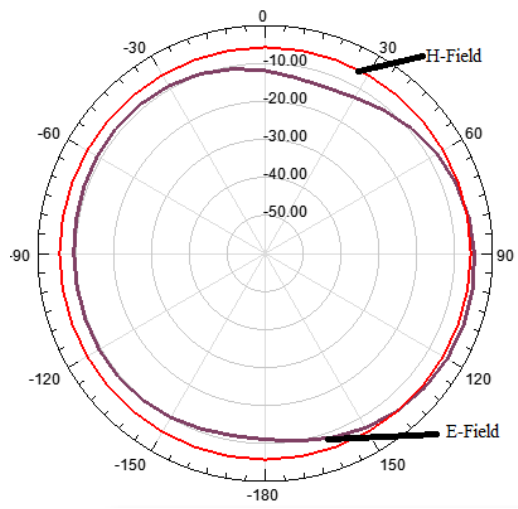
Another parameter is the radiation pattern of the antenna. This parameter is highly dependent on the application of the antenna. In the case of the antenna our group designed, we had to have an omnidirectional radiation pattern. This means that the radiation pattern had to be spread evenly 360 degrees around the antenna.

The reason for this is because since the location of the transmitter is not fixed, you want to spread the radiated signal out as far as possible so the receiver will be able to pick up the transmitted signal.

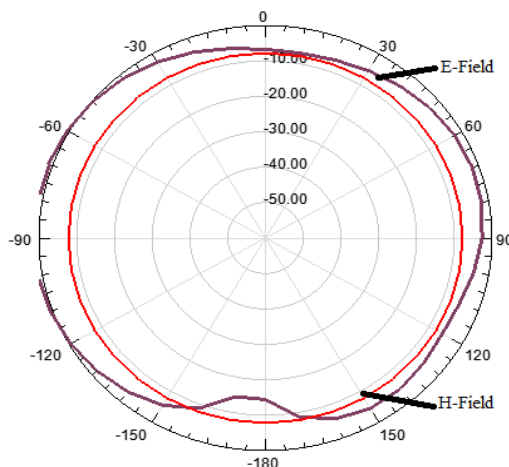
The simulated radiation patterns of antenna in the E-plane (xz-plane) and H-plane (yz-plane) for three different frequencies 1.5, 2.4 and 5.5 GHz are shown in Figs. 6 (a-c). The patterns in the H-plane are quite omnidirectional as expected. In the E-plane, the radiation patterns remain roughly a dumbbell shape like a small dipole leading to bidirectional patterns.



A



B



C

Fig. 6- Simulated radiation patterns of antenna at 1.5, 2.4 & 5.5 GHz E-Field and H-Field

It has been seen that this antenna has the nearly Omni-directional radiation pattern like normal monopole antennas. However, the Omni-directional radiation properties have a little deterioration as frequency increases. Over the entire bandwidth, it's similar to a conventional wideband monopole antenna.

IV. Conclusions

A novel design of a triple frequency planar monopole antenna has been proposed. With two different resonant radius of circular patch, the proposed antenna offers triple band operation with 67% area reduction compared to a conventional patch antenna. Sufficient bandwidth, moderate gain, and omnidirectional radiation characteristics of the proposed compact dual band antenna reflects its efficacy in mobile and wireless communication applications.

References

- [1]. H. D. Chen and H. T. Chen, "A CPW fed dual frequency monopole antenna," *IEEE Trans. Antennas Propag.*, vol. 52, no. 4, pp. 978-982, Apr. 2004.
- [2]. H. M. Chen, "Microstrip fed dual frequency printed triangular monopole antenna," *Electron. Lett.*, vol. 38, pp. 619-620, Jun. 2002.
- [3]. B. Sun, Q. Liu, and H. Xie, "Compact monopole antenna for GSM/DCS operation of mobile phone handsets," *Electron. Lett.*, vol. 39, pp. 1562-1563, Oct. 2003.
- [4]. T. Sukiji, Y. Kumon, and M. Yamasaki, "Double folded monopole antenna using parallel line or co axial cable," *Proc. Inst. Elect. Eng.*, vol. 149, pp. 17-22, Feb. 2002.
- [5]. C.A.Balanis,(2005), *Antenna Theory:Analysis and Design*,3/e, Hoboken New Jersey: John-Wiley and Sons.
- [6]. [B.F.Wang and Y.T.Lo.(1984). :” Microstrip Antenna fo dual frequency operation”, *IEEE Trans. Antennas Propag.*vol. AP-32(9),pp.938-943.
- [7]. S.Maci, G.Biffi Gentili and G. Avitabile.,(1993).”Single-Layer Dual-Frequency Patch Antenna”,*Electron Lett*, vol.29(16),pp1441-1443.
- [8]. M.L.Yazidi, M.Himdi and J.P.Daniel,(1993).”Aperture Coupled Microstrip antenna for dual frequency operation”, *Electron Lett.*, vol29(17), pp 1506-1508.
- [9]. Y.M.M.Antar, A.I.Ittipiboon and A.K. Bhattacharya.,(1995).’A dual frequency antenna using a single patch and an inclined slot”, *Microwave Opt. Technol. Lett.* Vol.8(6),pp.309-311.
- [10]. H.Nakno and K.Vichien,(1989).”Dual frequency square patch antenna with rectangular notch”, *Electron. Lett*vol 25(16),pp. 1067-1068.
- [11]. Constantine A. Balanis, *antenna theory analysis and design*, john wiley & sons.
- [12]. Jeffrey H. Reed, *An Introduction to Ultra Wideband Communication Systems*, Prentice Hall,
- [13]. *Handbook of Microstrip ANTENNAS* Edited by J R James & P s Hall.
- [14]. J. Liang, C Chiau, X. Chen and C.G. Parini, \Study of a Printed Circular Disc Monopole Antenna for UWB Systems", *IEEE Transactions on Antennas and Propagation*, vol. 53, no. 11, November 2005, pp.3500-3504.
- [15]. J. Liang, L.Guo, C.C.Chiau, X. Chen and C.G.Parini, \Study of CPW-Fed circular disc monopole antenna", *IEE Proceedings Microwaves, Antennas & Propagation*, vol. 152, no. 6, December 2005, pp. 520-526.
- [16]. Warren L. Stutzman , Gary A, *Antenna Theory and Design*, New York: John Wiley and sons Inc, 1997.
- [17]. Fan Yang , Yahya Rahmat-Samii, *Reflection Phase Characterizations of the EBG Ground Plane for Low Profile Wire Antenna Application*, *IEEE Transactions of Antennas and Propagation* , Vol. 51, No. 10, October 2003.
- [18]. Li Yang, Zhenghe Feng, Fanglu Chen, and Mingyan Fan, *A Novel Compact Electromagnetic Band-Gap (EBG) Structure and its Application in Microstrip Antenna Arrays*, State Key Lab on Microwave & Digital Communications, Tsinghua University Beijing, 100084, P. R. China.