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Analysis and Design of Compact Planar Branched Monopole Antennas for DCS/2.4 GHz & WLAN Applications

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Abstract— A compact triple band planar antenna for a digital communication system (DCS)/2.4-GHz and 5.5 GHz WLAN-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 omnidirectioal 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. Planar monopole 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 monopole 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], monopole antenna based on tapered meander line geometry [3], and parallel line loaded monopole 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 monopole 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 monopole 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.

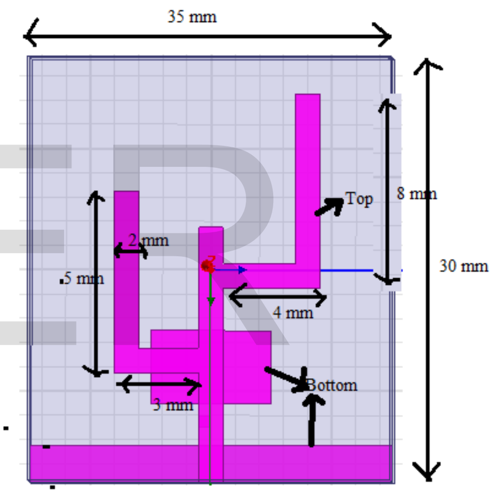
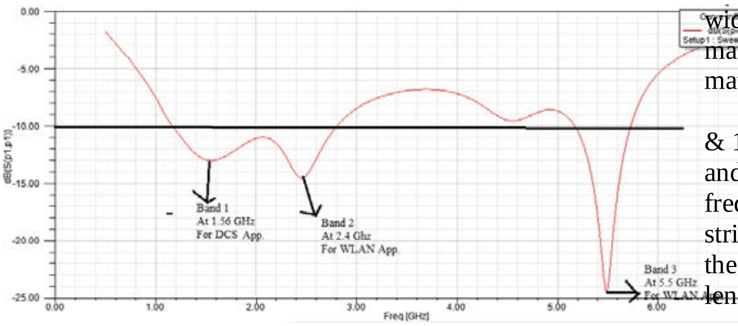


Fig. 1 Geometry of purposed Antenna with optimized dimensions

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 rectangular strip of length λ/2 monopole excited by a 50- Microstrip line with a rectangular optimum ground plane of λ/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.



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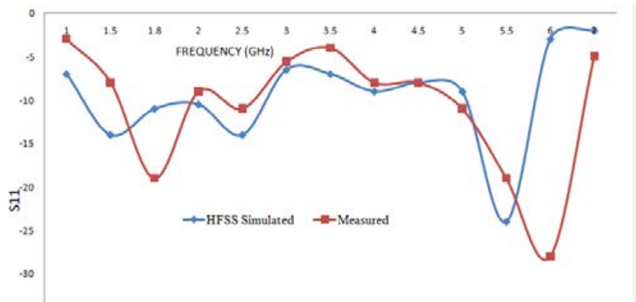

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Fig. 2 (a) Shows the Simulated S11 and (b) shows the comparison between simulated and measured S11 of purposed antenna with optimal dimensions.

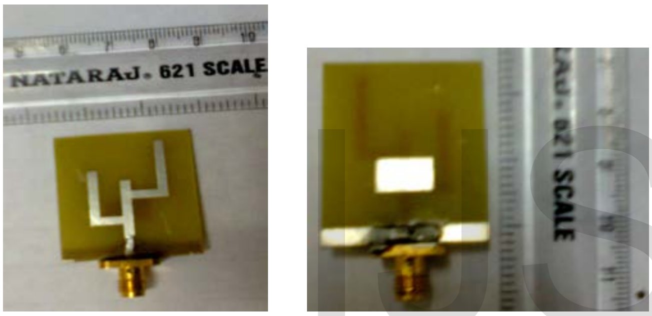


Fig. 3 Fabricated monopole antenna (Top View and Bottom View).

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 λ/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 planar monopole which lowers the bandwidth of operation. However, Antenna offers a size reduction of 71% 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 [1].

The strips 1 and 2 of the monopole 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 ε_r=4.4. The strip monopole 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

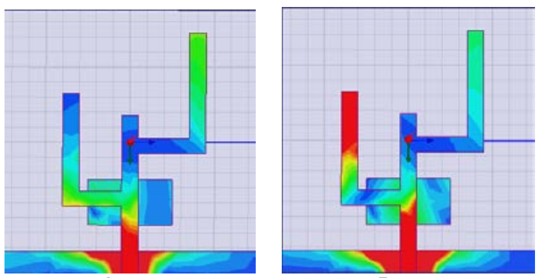
The length the strips of the monopole is set are 8 mm & 12 mm, width of 50- Microstrip line for dual band operation and the third resonator is 10×6 mm. The proposed triple frequency antenna owns three different resonant paths of two strips and one rectangular resonator. Tuning the length can fix the 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 v13 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 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. This 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 71% 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.



A B

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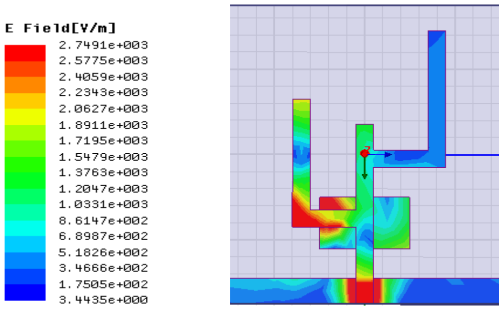

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Fig. 4 shows the current distribution at different-2 frequencies of purpose antenna at (A) at 1.5 GHz, (B) 2.4 GHz and (C) 5.5 GHz

Fig. 4 shows the simulated current distributions at different frequencies. 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 isotropically radiated power is equal to the power accepted by the antenna divided by 4π. This can be expressed as;

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

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.

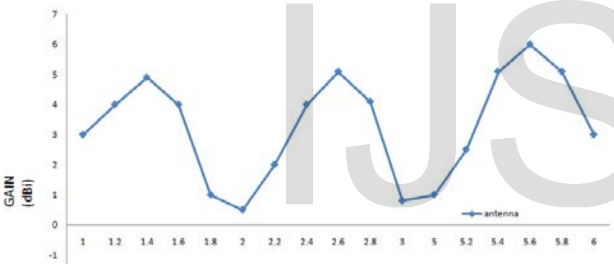


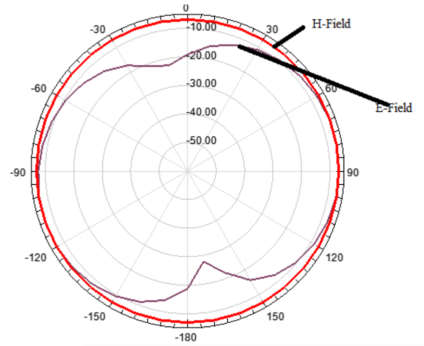
Fig. 5- Simulated gain of antenna

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;

$$G\,(dBi) = 10\,\mathrm{Log}\,(G/1) \qquad 2$$

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.



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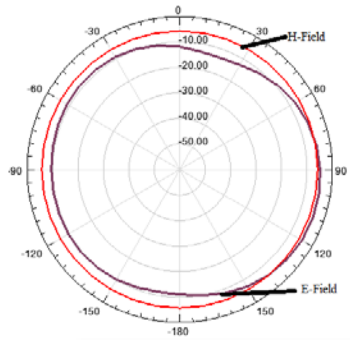

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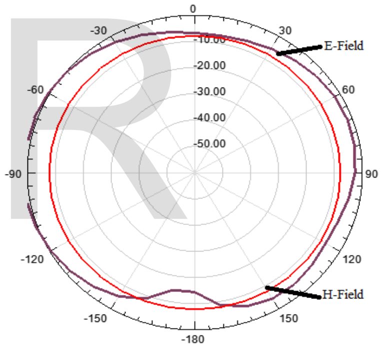

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Fig. 6- Simulated radiation patterns of antenna at 1.5, 2.4 & 5.5 GHz E-Field and H-Field

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.

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