A Dual Frequency Monopole Antenna with Double Spurlines for PCS and Bluetooth Applications

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Abstract **─** Design of a simple and compact dual frequency monopole antenna for applications in PCS (Personal Communication System) and Bluetooth system is presented. The first operating frequency is achieved from a traditional monopole antenna structure for the frequency of 1.9 GHz for PCS application while the second operating frequency is obtained from two spurline structures etched on the traditional monopole antenna structure for the frequency of 2.4 GHz for Bluetooth application. Both simulated and experimental results, such as reflection coefficients and VSWR (Voltage Standing Wave Ratio), are presented and discussed. The radiation pattern measurements are also performed. From the measured results, the first operating band covers between 1.851 and 1.98 GHz, and the second operating band covers between 2.28 and 2.53 GHz. The proposed antenna is compact and suitable to be used for applications in the PCS and Bluetooth system.

Index Terms **─** Double spurlines, dual frequency, monopole antennas.

I. INTRODUCTION

Printed antennas have become popular since the last decade. The design of printed antennas has received the attention of communication research community due to their applications in wireless communications and their major advantages such as low profile, ease of manufacture, low manufacturing cost, light weight, and compatibility with monolithic microwave integrated circuits (MMICs) [1-11], etc. Modern communication systems (GPS, PCS, WLAN, RFID, Bluetooth, etc.) often require antennas with compactness and low cost. Besides, the antenna structure should be simple and the fabrication technology should be uncomplicated.

Many printed antennas are reported in the literature for wireless communications. Remarkable antenna structures among them are: dual band planar branched monopole antenna [12], internal planar monopole antenna for mobile phones [13], CPW-fed L-shaped slot planar monopole antenna for triple band operation [14], dual band CPW-fed strip-sleeve monopole antenna [15], CPW-fed dual frequency monopole antenna [16], Y-shaped planar monopole antenna [17], dual band and 9-shaped monopole antenna for RFID and WLAN applications [18], multifrequency printed antennas with metamaterial particles [19], etc. Various antenna applications require different frequency bands for their wireless communication systems. For examples, PCS requires 1.85-1.99 GHz band for communication [20]. WLAN employs the 2.4 GHz and 5.2 GHz bands [21], and the 2.3-2.55 GHz band is used for Bluetooth applications [22]. The antenna size from the aforementioned antenna designs is large and some techniques are complicated. Also, wireless communication systems (PCS, GPS, WLAN, RFID, Bluetooth, etc.) require antenna structure with low cost and compactness. Therefore, the simpler antenna design and the compact antenna size are necessary for modern communication systems such as dual band antenna systems, and ultra-wideband antenna systems, etc.

Among the microstrip filter designs, spurline is a simple structure with the smallest structure compared to other structures [23]. Spurline is a defected microstrip structure (DMS) with L-shaped slot etched in the microstrip feed line. It provides resonance property with its compact size. Examples of spurline structures in microwave devices are: microstrip spurline filter with miniaturization and electronic tuning technique [24], miniaturized bandstop filter using meander spurline and capacitively loaded stubs [25], compact microstrip bandstop filter with spurline structures covering S-band to Ku-band [26], microwave coupled line filter from spurline structures [27], and harmonic suppression of microstrip ring resonator using double spurlines [28], etc.

In this paper, a novel approach to achieve a compact dual band printed monopole antenna is introduced. The

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attributes of compact size and resonance property of spurline structures are applied to the conventional printed monopole antenna for designing a novel compact dual band monopole antenna. The proposed monopole antenna can be tuned to completely operate in the following bands of PCS application (1.9 GHz) and Bluetooth communication system (2.4 GHz). The proposed antenna is simulated using an in-house Finite-Difference Time-Domain (FDTD) technique for reflection coefficients. Then, the VSWR is calculated from the reflection coefficients. The experimental results of the fabricated antenna prototype are presented and compared with the simulated results. The radiation pattern measurements of the proposed antenna are also performed.

This paper is organized as follows. In Section 2, an explanation on the design of the novel compact dual frequency monopole antenna is given. The results are presented and discussed in Section 3 followed by the conclusions in Section 4.

II. ANTENNA DESIGN

In the antenna design, FDTD is used to simulate our antenna design. FDTD is a simple electromagnetic simulation tool used to analyze the antenna from the time-dependent Maxwell's equations. The details of FDTD technique are available in [29]. FDTD's code is created using FORTRAN language.

A sketch of the spurline structure on microstrip line is shown in Fig. 1 (a) [23]. Usually, the narrow line provides the inductance (L) while the slot gap exhibits the capacitance (C) [25]. A simple circuit model with a parallel RLC circuit is shown in Fig. 1 (b). The radiation effect and loss are represented by a resistor (R). The resonant characteristics are modeled by L and C. Based on the transmission line theory [25], the circuit parameters can be determined using the following equations:

$$R = 2Z_0\left(\frac{1}{|S_{21}|} - 1\right), \tag{1}$$

$$C = \frac{\sqrt{0.5(R+2Z_0)^2 - 4Z_0^2}}{2.83\pi Z_0 R \Delta f}, \tag{2}$$

$$L = \frac{1}{(2\pi f_0)^2 C}, \tag{3}$$

where Z_0 is the 50 Ω characteristic impedance of the transmission line, f_0 is the resonant frequency, S_{21} is the transmission coefficient at the resonant frequency, and Δf is the -3 dB bandwidth of S_{21}. Due to the resonance obtained from the spurline structure and the compactness of the structure, the spurline structure is employed to design the proposed antenna.

The radiating element of the proposed antenna is designed by using the conventional monopole antenna theory for the first frequency band at 1.9 GHz for PCS, and then the second frequency band at 2.4 GHz for bluetooth application is designed by adding the spurline structures to the conventional monopole antenna.

The initial design for the first frequency band is designed with the length of one quarter wavelength at the frequency of 1.9 GHz. The initial length is 39.5 mm. The antenna is fabricated on an ARLON AD260A dielectric substrate of thickness of 1 mm, relative permittivity of 2.60, and loss tangent of 0.0017 [30]. The antenna is fed by a 50-microstrip line of length of 15 mm (G) and width of 2.8 mm (W_f). The second frequency band is designed with spurline structures etched on the conventional monopole antenna. The length of the spurline structures is equal to 24.5 mm (L2), one quarter wavelength at the frequency of 2.4 GHz.

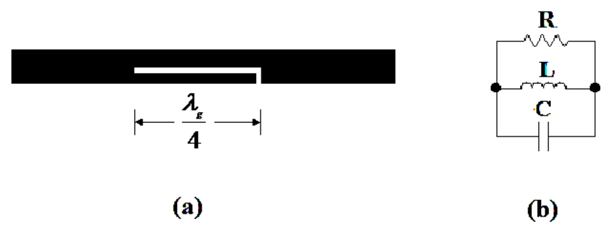

Fig. 1. Sketch of a spurline structure on a microstrip line and its RLC equivalent circuit.

After the proposed antenna is initially designed, its dimensions are optimized to obtain the operating frequencies of 1.9 GHz and 2.4 GHz. The geometrical configuration of the proposed antenna is shown in Fig. 2. The geometrical parameters are carefully adjusted and the proposed antenna dimensions are finally obtained. The prototype of the antenna is fabricated using the printed circuit board etching technology following the parameters given in Table 1. A photograph of the proposed antenna is shown in Fig. 3.

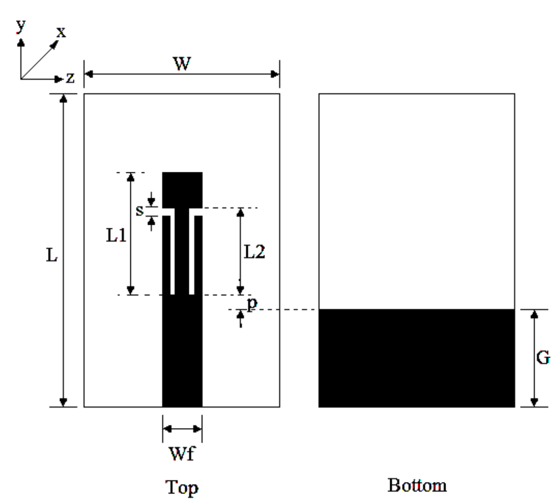

Fig. 2. Sketch of the proposed antenna.

Table 1: Dimensions of the proposed antenna

Parameters	W	L	G	W_f	L1	L2	s	p
Value (mm)	30	60	15	2.8	30	24.5	0.5	2

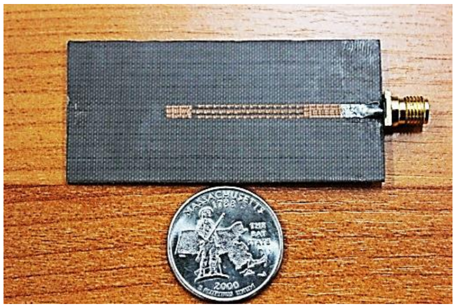

Fig. 3. A photograph of the proposed antenna.

III. RESUTS AND DISCUSSIONS

Figure 4 shows the simulated and measured reflection coefficients (S_{11}) against frequency for the proposed monopole antenna. It is quite clear that there are two resonant frequencies at 1.9 GHz and 2.4 GHz from the results. The reflection coefficient measurements are performed using the Agilent HP-E5071B vector network analyzer. The measured lower resonant mode achieves a -10 dB impedance bandwidth of ranging from 1.851 GHz to 1.98 GHz with respect to the center frequency of 1.915 GHz, and the measured upper resonant impedance bandwidth ranges from 2.28 GHz to 2.53 GHz with respect to the center frequency of 2.38 GHz. From the graph, it is clearly seen that the measured results for the proposed antenna are in good agreement with the simulated results.

The VSWR of the proposed antenna is obtained through the FDTD simulations and the experimental measurements. As shown in Fig. 5, the measured VSWR are in good agreement with the simulated VSWR. The simulated and measured VSWRs achieve a 1:2 ranging from 1.85 GHz to 1.98 GHz for the first resonant frequency and ranging from 2.28 GHz to 2.53 GHz for the second resonant frequency.

The far-field range is the minimum distance that reduces the phase variation across the proposed antenna enough to obtain a good radiation pattern for the antenna. The far-field radiation patterns for the proposed monopole antenna are also examined as the following setup in Fig. 6. The distance between the horn antenna and the proposed antenna is 25 cm. The measured radiation patterns of the proposed monopole antenna at 1.9 GHz and 2.4 GHz are illustrated in Fig. 7 and Fig. 8, respectively. It is noticed that the proposed antenna exhibits a traditional dipole antenna pattern at Y-Z plane, and an omni-directional pattern at the X-Z plane for both resonant frequencies.

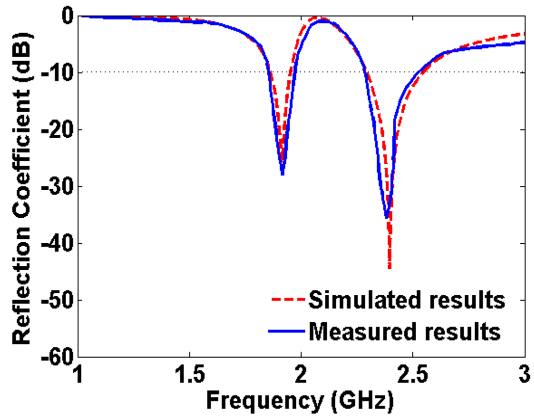

Fig. 4. Reflection coefficients of the proposed antenna.

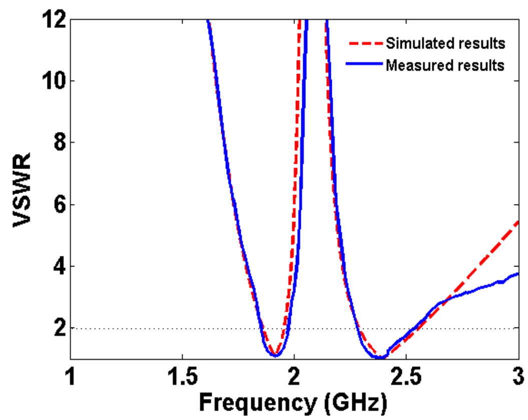

Fig. 5. VSWR of the proposed antenna.

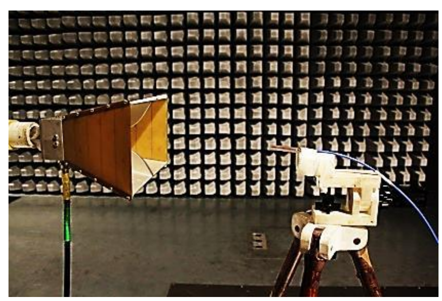

Fig. 6. Radiation pattern measurement setup.

Figure 7 plots the measured radiation patterns of the proposed antenna at 1.9 GHz with the measured antenna gain of 2.11 dBi, while Fig. 8 illustrates the measured radiation patterns of the proposed antenna at 2.4 GHz with the measured antenna gain of 2.15 dBi.

The size of the proposed antenna is compared with other antennas in Table 2. From Table 2, it is found that the size of the proposed antenna is smaller than other antennas.

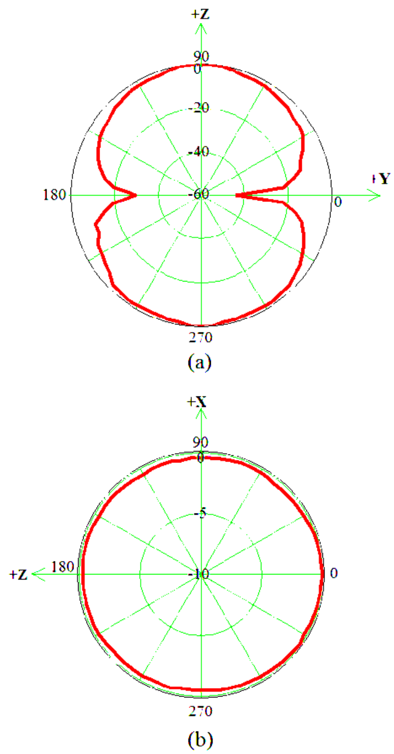

Fig. 7. Radiation patterns of the proposed antenna at 1.9 GHz: (a) Y-Z plane and (b) X-Z plane.

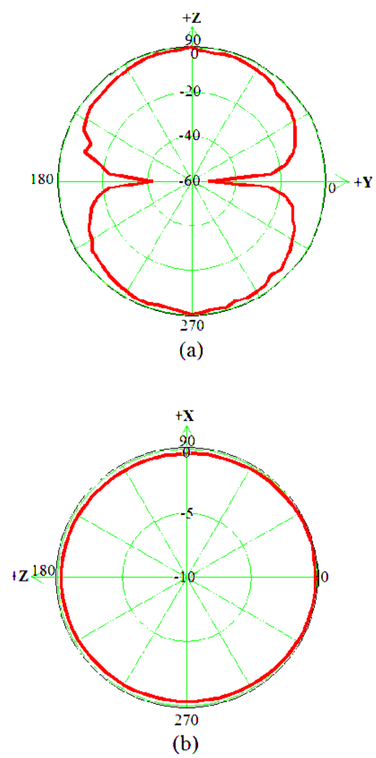

Fig. 8. The Radiation patterns of the proposed antenna at 2.4 GHz: (a) Y-Z plane and (b) X-Z plane.

Table 2: Size comparison for antennas

Antenna	Overall Dimension	Operating Frequency (GHz)
Antenna in [13]	40 mm x 65 mm	1.8
Antenna in [14]	57 mm x 68 mm	0.9, 1.87, 2.18
Antenna in [15]	50 mm x 110 mm	0.9, 1.8
Antenna in [16]	56 mm x 60 mm	1.80, 2.46
Proposed antenna	30 mm x 60 mm	1.9, 2.4

IV. CONCLUSION

A new design of compact dual frequency monopole antenna constructed by a traditional monopole antenna structure and two spurline structures is proposed. The lower operating frequency (1.9 GHz) is obtained from the traditional monopole antenna while the upper operating frequency (2.4 GHz) is obtained from the spurline structures etched on the traditional monopole antenna. The measured results such as reflection coefficients and VSWR are obtained and compared with the simulated results. Moreover, the radiation pattern measurements are also performed. The proposed antenna exhibits a traditional dipole antenna pattern at Y-Z plane, and an omni-directional pattern at the X-Z plane for both 1.9 GHz and 2.4 GHz. The proposed antenna covers dual bands for PCS and Bluetooth applications. The proposed antenna is simple in design and compact in size. Hence, the proposed antenna may be a suitable candidate for the dual frequency operations in PCS and Bluetooth applications. This technique can be applied to other operating frequency bands for various dual band applications.

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