An Integrated Planar Bluetooth and UWB Monopole Antenna with Dual Notched Bands Based on Etched Slot on the Patch and Split Ring Resonators on the Ground Plane

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***Abstract*— A novel, small profile, integrated Bluetooth and Ultra Wide Band(UWB) planar Monopole Antenna has been designed using a Microstrip feed with dual band notched characteristics. The bandwidth of the proposed antenna is 2.05 – 10.46GHz which covers Bluetooth (IEEE 802.15.1, 2.4 – 2.484 GHz) and UWB (IEEE 802.15.3a, 3.1 – 10.6GHz) but with dual band notches at 3.09 – 3.78GHz and 4.96 – 6.09GHz.**

***Keywords*— Ultra Wide Band (UWB), Bluetooth, Worldwide Interoperability for Microwave Access (WiMAX), Wireless Local Area Network (WLAN), Split Ring Resonator (SRR)**

I. Introduction

In the recent years, the area of UWB systems has received much attention from microwave engineers, especially after Federal Communications Commission (FCC) released its report in February 2002 [1] permitting commercial use of UWB (3.1 – 10.6GHz). UWB systems offer a lot of advantages such as low cost, low power spectral density, low space, high date rate over short ranges. Thus it is increasingly being used for short range high speed wireless communication systems.

One of the major challenges of any UWB system is the antenna design, which should maintain its characteristics over a huge bandwidth. The UWB includes WiMAX (3.3 – 3.6GHz) and WLAN (5.15 – 5.825GHz).Thus it is necessary for any UWB antenna to perform band notched operation to avoid potential interference.

Bluetooth (IEEE 802.15.1), on the other hand has been very successful in handheld and portable devices but works in the range 2.4 – 2.484 GHz, which is outside the spectrum of UWB systems. Presently, the portable devices using both Bluetooth and UWB spectrum are embedded with individual antennas working in specific frequency bands. Thus the overall system space required increases.

One possible solution is to have a single antenna system which would work in both the Bluetooth band and UWB, without compromising on performance, and notching the undesired frequency bands. This paper presents such an antenna system which works in the Bluetooth and UWB, while notching the WiMAX and WLAN bands.

In this paper, a small size planar monopole antenna has been proposed, that covers the Bluetooth band and UWB, but has band notched characteristics at 3.09 – 3.78GHz and 4.96 – 6.09GHz. The antenna geometry consists of an Outer patch (of radius R_0) with an Inner Circular Slot (of thickness t_{slot}). As a result the spectrum includes the Bluetooth frequency band along with UWB, notching the WiMAX band (IEEE 802.16, operating at 3.3 – 3.6GHz). A series of Split Ring Resonators (SRR) have been added on the opposite side of the antenna and parametrically optimized to realize a notch at a frequency range from 4.96 – 6.10GHz WLAN band (IEEE 802.11a, operating at 5.15 – 5.35GHz and 5.725 – 5.825GHz).

II. Structure and Design of Antenna

The geometry of the proposed microstrip fed monopole antenna is illustrated in Figure 1. The antenna is fed with 50Ω microstrip line and is designed on a Taconic TLY 5 (Lossy) substrate, dual layered PCB. The substrate has relative dielectric constant ε_r=2.2, tan δ=0.0009 and height h=0.787mm. The thickness of PEC metal on both the surfaces is 0.0035mm. Microstrip Feeding Technique is easy to fabricate, simple to match by controlling the thickness of the width and rather easy to model. The required width (w_f) of the microstrip feeding line is calculated for a characteristic impedance Z_0=50Ω [2]

$$\frac{w_f}{h} = \frac{2}{\pi}\left[B - 1 - \ln(2B-1) + \frac{\epsilon_r - 1}{2\epsilon_r}\left\{\ln(B-1) + 0.39 - \frac{0.61}{\epsilon_r}\right\}\right] \quad (1)$$

where, $B = \frac{377\pi}{2Z_0\sqrt{\epsilon_r}}$

Next, the radius of outer patch of radius R_0 which affects the lowest operating frequency of the antenna is determined by [3]

$$R_0 = \frac{F}{\{1 + \frac{2h}{\pi\varepsilon_r F}[\ln\left(\frac{\pi F}{2h}\right) + 1.7726]\}^{\frac{1}{2}}} \quad (2)$$

where $F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}}$, f_r= Resonant Frequency, ε_r= Dielectric Constant of the Substrate, h= Height of the Substrate.

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A circular slot has been cut on the radiating patch to obtain a notch at WiMAX frequency band. The notched frequency if approximated by [4]

$$f_c = \frac{nc}{2\pi r\sqrt{\varepsilon_{r,eff}}} \quad (3)$$

where $\varepsilon_{r,eff}$ = Effective relative dielectric constant ≈ $(\varepsilon_r+1)/2$, n=Mode Number, r = Ring radius, c=Speed of Light in Free Space.

In this case, only the fundamental mode (i.e. n=1) has been considered. The Ring radius (R_{ring}) and width (t_{slot}) of the circular slot has been optimized to get the desired notched frequency band.

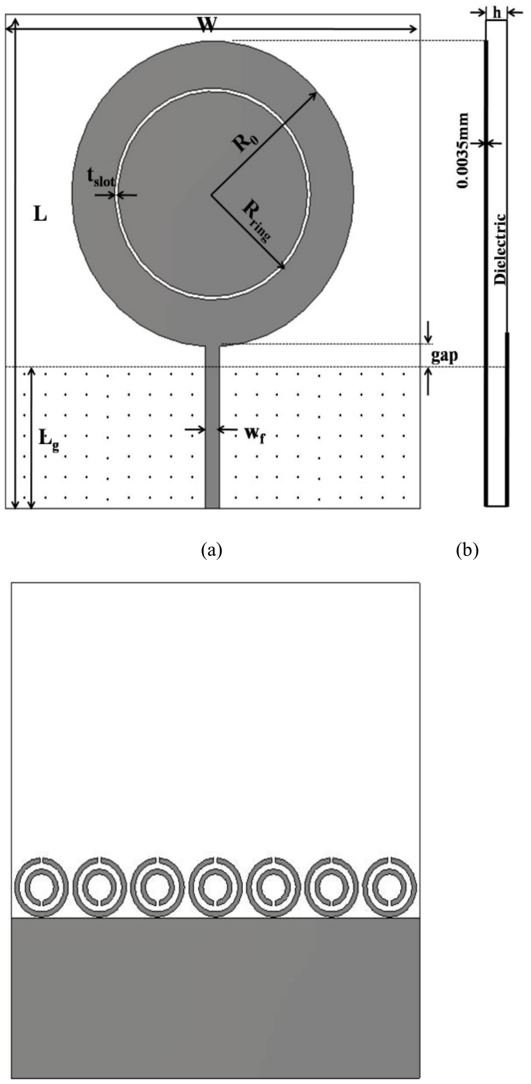


Figure 1. Proposed Antenna Geometry (a) Front View, (b) Side View and (c) Back View

Split Ring Resonator (SRR) has been introduced to provide a notch in the WLAN frequency band. Split Ring Resonator (SRR), originally proposed by Pendry [5], is a small sized high Q resonator which can be used to produce Band Notched characteristics in a planar antenna [6]. In a SRR, two similar split rings are coupled by means of a strong distributed capacitance in the region between the rings. A SRR consisting of a pair of concentric annular rings with splits at the opposite ends is considered in this project to implement the band notch characteristics (Figure 2). The resonant frequency of SRR is given by [7]

$$\omega_0 = \sqrt{\frac{2}{\pi r L_e C_0}} \quad (4)$$

where $r=(r_1+r_2)/2$ is the average radius of the SRR, r_1= Outer radius, r_2=Inner radius, L_e= Equivalent Inductance, C_0= Capacitance per unit length between the two rings.

An array of SRR has been used rather than using a single SRR structure to optimize the Gain response at the higher frequency end. The presence of SRR array acts as cascaded parallel LC circuit. This offers high input impedance to the incoming signal corresponding to its resonance frequency thereby causing reflection. The distance between each pair of SRR has been tuned to eliminate the spurious notched bands in undesired frequencies.

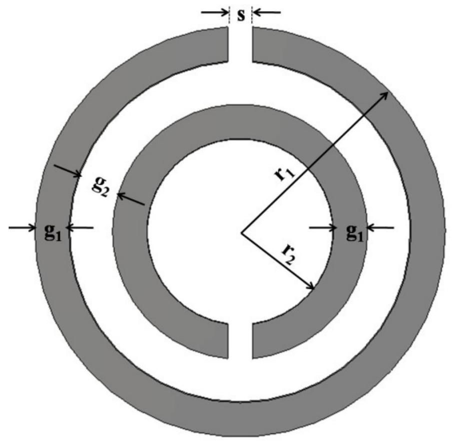


Figure 2. Slot type Split Ring Resonator Geometry

With the above design at hand, a series of steps have been performed and dimensions have been optimized to get the desired results. The optimized dimensions are as follows. The dimensions of the substrate are 55mm×50 mm (L×W). The Ground plane has the dimensions of 17.8mm×50mm (L_g×W). The width of the feed line w_f is 1.7mm. The radiating section of the antenna comprises of three elements: an Outer Patch with radius R_o=17mm; an Inner Circular Slot of radius t_{slot}=0.4mm; and SRR structures of dimensions r_1=3.3mm, r_2=1.5mm, g_1=0.55mm, g_2=0.70mm, s=0.4mm. Gaps of 0.5mm and 0.3mm have been kept between the SRR structures and SRR to Ground plane respectively. The gap between the Radiator section of the antenna and the Ground plane is 0.2mm. A SRR is illustrated in Figure 2.

III. RESULTS

All simulations were carried out using CST Microwave Studio, which is based on the Finite Integration Technique. Figure 3 presents the Return Loss (in dB) of the proposed antenna. As evident, the two notched bands for $s_{11} < -10dB$ ($s_{11} < -5dB$) are 3.09 – 3.78GHz (3.30 – 3.63GHz) and 4.96 – 6.10GHz (5.03 – 5.84GHz) respectively.

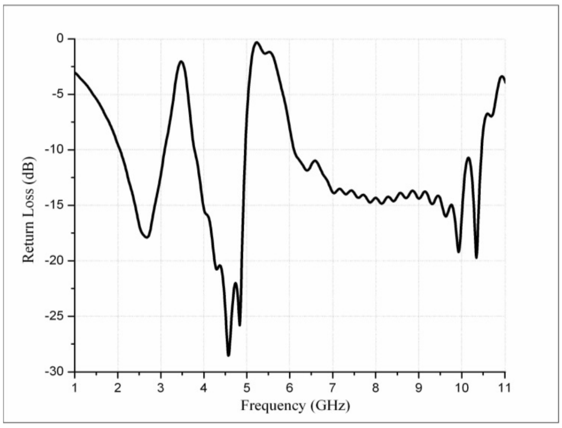


Figure 3. Return Loss of the proposed antenna

The corresponding VSWR plot has been shown in Figure 4. It also shows that the notched bands have the VSWR>2.

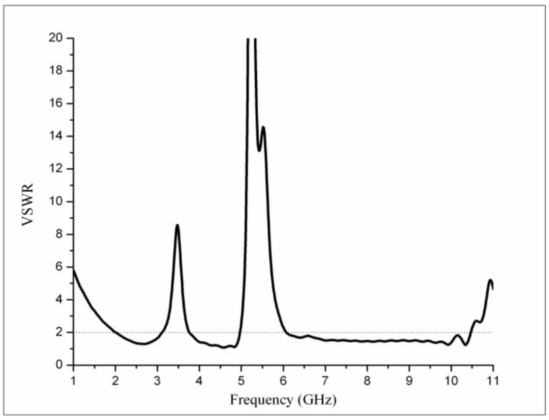
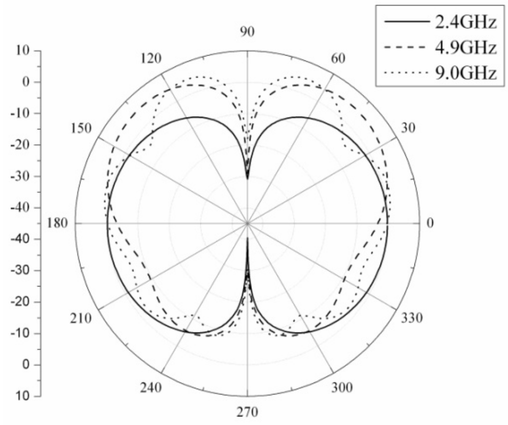
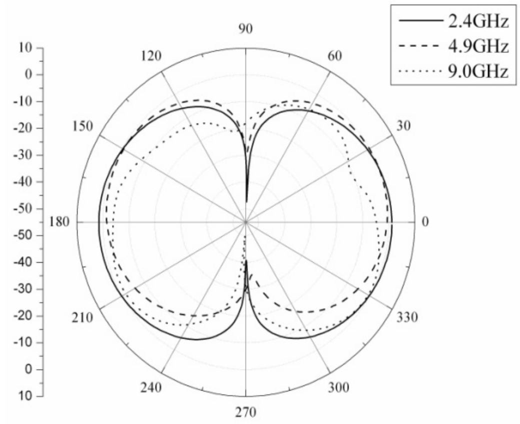


Figure 4. VSWR of the proposed antenna

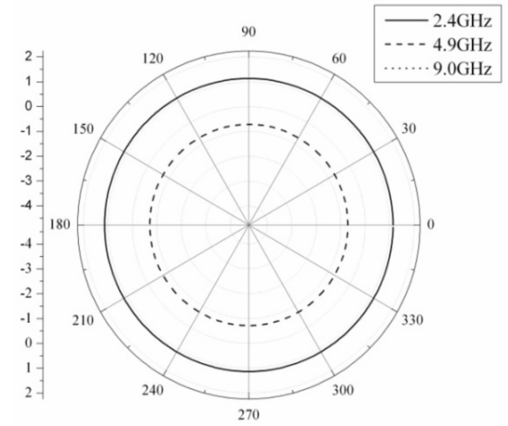
The radiation characteristics of the antenna have been studied and presented in Figure 5. The radiation pattern at the passband frequencies of 2.4GHz, 4.9GHz and 9GHz are shown in three different cuts, i.e., in the x-y, y-z, x-z planes. Omnidirectional farfield patterns are obtained in the x-z plane while the x-y and y-z planes show dipole like farfield patterns.



(a)



(b)



(c)

Figure 5. Radiation Patterns (a) X-Y pattern, (b) Y-Z pattern and (c) X-Z pattern

Figure 6 illustrates the Realized Gain of the antenna. The gain decreases sharply below 0dB for the notched frequency bands (-0.95 dB at 3.5GHz, -6.40 dB at 5.2GHz and 0.33 dB at 5.8GHz). The passband gain ranges from 1.5 dB to 5.5 dB.

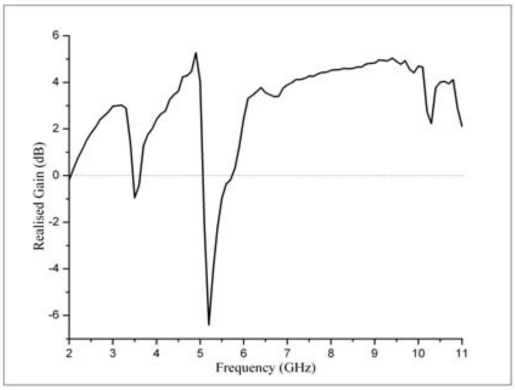


Figure 6. Realised Gain of the proposed antenna

IV. CONCLUSION

In this paper, a small profile monopole antenna has been presented which works in the Bluetooth and UWB frequency range. The WiMAX and WLAN frequency bands have been notched by the use of circular slots and SRR arrays respectively. Sharp notches have been observed at the notched frequency bands. Excellent radiation patterns have been observed. The realized gains at both the Bluetooth and UWB bands are satisfactory.

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