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Design of Bluetooth Integrated Circular Patch Ultra Wide Band with Ground Slot for WLAN Applications

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KEYWORDS

UWB, Bluetooth, Microstrip, Circle Patch DGS, SIR

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ABSTRACT

A microstrip feedline dual band circular monopole antenna operating over Bluetooth (2.4 – 2.48 GHz) and Ultra wideband (UWB: 3.1-10.6GHz) frequency bands is designed and investigated for wireless applications. The UWB frequency is achieved by modifying the patch radiating monopole by adding slots and destructive ground plane. Further, with the addition of a slot in the radiation patch that is placed in the central portion of the radiating patch and then etching a half wavelength circular arc from the radiating patch a dual band frequency operation archive over Bluetooth and UWB band. The proposed antenna is simulated using electromagnetic simulation software Ansoft HFSS Ver 15.0. The proposed antenna is realized on FR-4 dielectric substrate having a dielectric constant of 4.4 and loss tangent of .02. The antenna covers the dual bands of operation i.e. Bluetooth (2.4-2.48GHz) bandwidth obtained 182.3 MHz and UWB (3.1-10.6 GHz) bandwidth obtained 8.999 GHz with reflection coefficient < -10dB and value of VSWR <2. The antenna also exhibits stable radiation patterns for the entire UWB and aforementioned integrated lower frequency bands.

INTRODUCTION

The need for people to exchange information quickly and easily accessible whenever and wherever causes technological developments, especially wireless communication (wireless) to increase. The solution to meet the needs of a single antenna that includes multiple frequency bands that are considered capable of providing demand for wireless systems is a multiband antenna. Multiband antennas that are able to provide to meet these needs are UWB and Bluetooth antennas, both applications are applications that are often used to integrate multiband antennas.

UWB (Ultra Wideband) is an application that aims to get high data transfer rates using a very wide frequency spectrum and can operate at speeds of 1 Gbps with a range of 10 meters and large power deliveries at various frequencies having relatively low power consumption then governed by the UWB receiver. The system is categorized as ultra-Wideband communication when the fractional bandwidth is greater than 20% [1]. Modulation is not needed in UWB technology, this is because the information signal is a pulse that has a narrow period (under ns) so that the required antenna is very small. The more pulses sent (time domain) the smaller the bandwidth needed (frequency domain) and vice versa [1].

Bluetooth is a wireless technology that uses frequency hopping transceiver as a provider of data and voice communication services between Bluetooth hosts with a range of 10 meters in real time that operates in the 2.44GHz frequency band. Bluetooth devices can be connected to other devices with a transmission speed of around 1MB / s and require low power consumption. Short range radio link is a technology found in Bluetooth with the aim of replacing portable cable connections and reducing power complexity.

Designing a dual band antenna can be used in two methods. The first method is to design an antenna that works at a frequency of 2-10.6 GHz and breaks down unnecessary waves between Bluetooth and UWB by using the notching method. The second method, integrating a lower band frequency (Bluetooth), can add a quarter of a wavelength or half a wave to its resonance strip at a specified work frequency. The antenna design as of this

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writing uses the second method with a circle as the shape of the patch antenna. At this writing a circular patch microstrip antenna design with the addition of a "circular arc" slot aims to increase the frequency of Bluetooth applications. The slot is a Bluetooth merger based on the surface wave distribution, after the desired UWB antenna characteristics are obtained, the surface wave distribution is observed at the Bluetooth frequency. In accordance with the characteristics of a circle patch that has a very small current in the middle of the circle which causes the current to radiate alongside the patch. A half-wavelength arc circle patch shape is inserted in the UWB loop patch which will resonate via the Bluetooth band (2.4-2.48 GHz

Here, the UWB frequency band is achieved by modifying the circular patch and the modified ground plane with the DGS technique for better impedance matching. DGS technique is done by etching the ground plane which forms a slot on the substrate of the ground plane which aims to suppress the surface waves that occur on the substrate. Next, a half-wavelength "arc" is etched just below the slot on the patch to resonate via the Bluetooth band. The overall dimensions of the antenna are 35 × 27 × 1.6 mm^3. The designed antenna is simulated in Ansoft HFSS Ver 15.0 simulation software. Details of antenna design perceptions and simulation results are explained in sections 2 and 3 respectively. Finally the conclusion is defined in section 4.

ANTENNA DESIGN

The geometry of the designed antenna is as shown in fig. 1. The designed antenna is realized on a 1.6mm thick FR-4 dielectric substrate with 35 × 27 mm^2, surface area and feed by a strip line of 50 Ω impedance. The relative permittivity 4.4 and Loss tangent of the substrate is 0.02 respectively. Equations (1-2) are used for the proposal of circular monopole antenna [1]. Where 'a' is the radius of the circular patch, ε_r is the dielectric constant of the substrate and h is the thickness of the substrate (in cm).

The radius *(a)* of the circular patch is calculated by:

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

$$\text{Where, } F = \frac{8.791 \times 10^9}{f_r\sqrt{\varepsilon_r}} \quad (2)$$

EVOLUTION OF UWB

The basic design of the antenna with the patch calculations performed does not cover the entire UWB bandwidth range. The calculated circular patch produces a bandwidth range of around 1 GHz. Henceforth, the design is boosted by employing the slots in the ground plane and produces a bandwidth range of 3 - 11 GHz (reflection coefficient ≤ -10dB.

Antenna 1 is the basis of the initial design using 5.4 GHz reference frequency that does not meet the UWB bandwidth width criteria. Antenna 2 is an advanced characteristic of antenna 1 with the addition of a 2.44GHz Bluetooth working frequency and almost satisfies the desired UWB bandwidth. Antenna 3 is the final result of the desired antenna design, all parameters are measured according to the antenna's basic specifications.

BLUETOOTH INCORPORATION

The integrated of Bluetooth in this thesis is based on the distribution of surface waves, after obtaining the desired UWB antenna characteristics, the surface wave distribution is observed at the Bluetooth frequency. In accordance with the characteristics of a circle patch that has a very small current in the middle of the circle which causes the current to radiate alongside the patch. A half-wavelength arc circle patch shape is inserted in the UWB loop patch which will resonate via the Bluetooth band (2.4-2.48 GHz). The center frequency (f_{ib}) of Bluetooth is 2.44 GHz and $\frac{\lambda}{2}$ [5, 20, 22, 23].

$$\lambda = \frac{c}{f_{ib}\sqrt{\frac{(\varepsilon_r + 1)}{2}}} \quad (3)$$

The length of the "circular arc" is assumed to be the same as the circumference of the "circular arc", which is the circumference of the circle ($2\pi \times r_1$), so to find $r_1 (\lambda = 2\pi \times r_1)$ mm. The smaller fingers (r_2) are obtained from the difference in distance from r_1, which is 0.25 mm from each shift. Optimization is needed to get the expected parameters, as long as the optimization from the midpoint distance results in a dielectric loss occurring on the substrate. The loss results in no current contained in the circular patch on the Bluetooth working frequency.

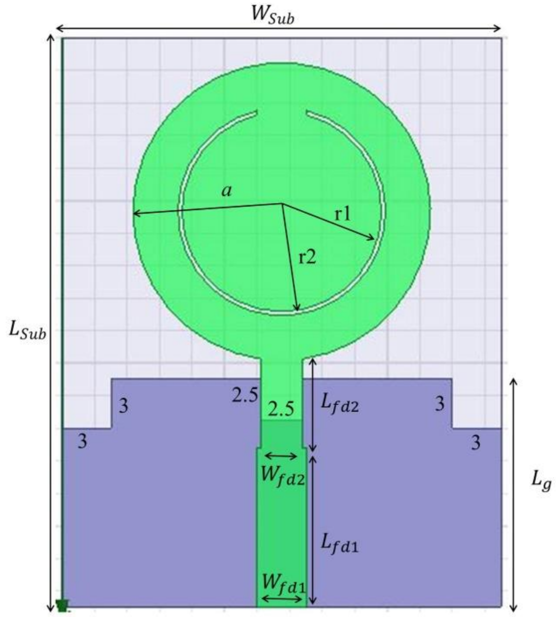

Figure 1: Geometry of the design antenna [Lsub=35, Wsub=27, *a*=9.15, r1=5.9, r2=5.7, Lfd1=9.8, Wfd1=3.1, Lfd2=5.5, Wfd2=2.5, Lg=21] (All the dimension are in millimeter).

The results of the modification of the slots produce working frequencies close to the specified specifications, from the results of the design by adding the dimensions of the slots can produce return loss values.

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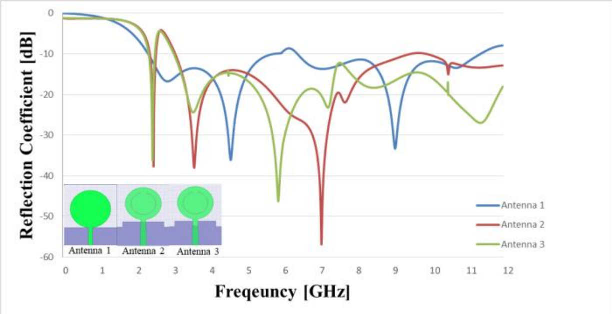

Figure 2: Evolution of UWB and Bluetooth in terms of simulated S_{11}

The basic circular patch provides an impedance bandwidth from 2.4 - 5.75 GHz. The addition of the dimensions of the "circular arc" slot is placed on the radiation patch which aims to get the impedance bandwidth in the entire UWB range. Radiation that occurs in the radiation patch is located around the "circular arc", this cause a current that is concentrated around that section. While the antenna that has not been inserted slot "circular arc" there is no current in the radiation patch.

Antenna 1 shows the reflection coefficient (S11) of the circular patch antenna which produces an impedance band of 2.4 - 5.75 GHz, these results do not meet UWB characteristics. Antenna 2 is done by adding a circular arc slot to get the Bluetooth frequency and a slot in the ground plane to get the UWB impedance bandwidth. Additions made to antenna 2 for the Bluetooth part have been fulfilled, but have not gotten maximum results from the UWB characteristics. Antenna 3 is reinserted in the ground plane at the back of the feedline, which makes the entire UWB frequency range available.

SIMULATION RESULTS

PARAMETRIC ANALYSIS UWB ANTENNA

The performance of dual band antennas depends on several determinants such as the gap (g) between the ground plane and radiation patch, the radius of the "circular arc", the width and length of the symmetrical and asymmetrical slots. The shape of the ground plane and its size are also factors that affect the antenna performance.

The initial design of the antenna dimensions was the radius of the circle (a = 9.5) with a substrate area of 35mmx27mm. The gap (g) between ground plan and radiation patch, aims to provide optimal results to the antenna impedance bandwidth. The gap that is designed can vary in several sizes, where the size of the gap starts from 0.5mm to 1.5mm. In several measurements and characteristics of the gap dimension change, for the 0.5mm gap and the 1.5mm antenna designed it starts rejecting the specified reference frequency. The optimal design to achieve UWB frequency ranges is done by placing 3mmx3mm pair slots in the corners of the ground plane. Slot placement affects the lower frequency impedance bandwidth value of 3GHz-4.34GHz and for higher edge frequencies is from 5.3GHz - 11GHz. After inserting a pair of slots in a ground level corner, S11 does not cover the entire UWB range. Therefore the design is re-optimized by placing a slot directly behind the bait on the ground level. It has been witnessed that for 2.5mm × 2.5mm slots, the entire UWB range is achieved by showing S11≤-10dB.

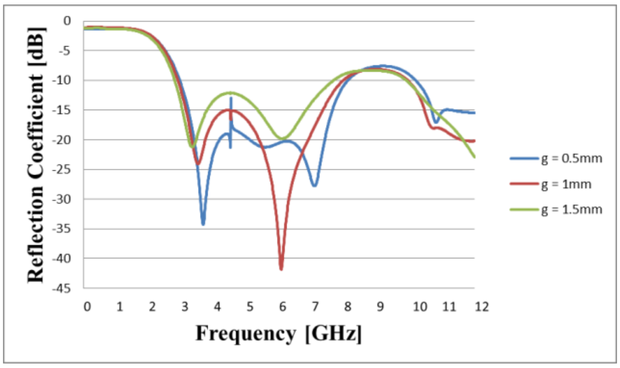

Figure 3: Reflection Coefficient versus Frequency graph for the variation in gap "g"

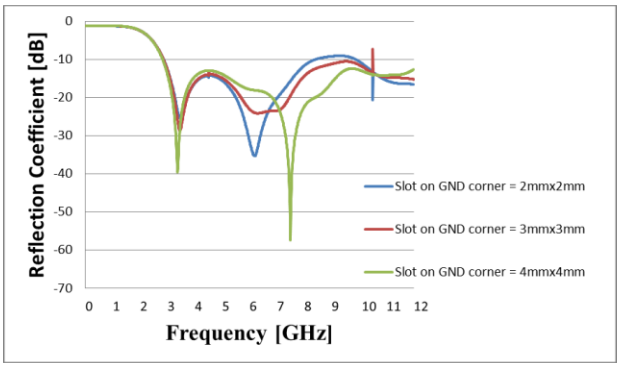

Figure 4: Reflection Coefficient versus Frequency graph for the variations in the slots at the corners of the ground plane

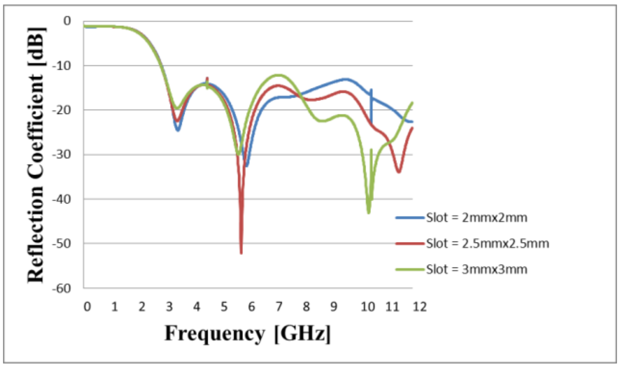

Figure 5: Reflection Coefficient versus Frequency graph for the variations in the slot (behind feed) in the ground plane

PARAMETRIC ANALYSIS DUAL BAND ANTENNA

Dual band antennas can be achieved by inserting a half-wavelength circular arc placed in the center of the patch that emits to resonate at Bluetooth frequencies. The "circular arc" dimension is almost half the wavelength of the central Bluetooth frequency, which is 2.44 GHz. Optimization is done to find the perfect position in the insertion of "circular arc" half wavelength. At this writing, optimization is done by varying the length of the arc and the width of the difference between the radiuses of the "circular arc".

r1 and r2 are circular arc radii and the difference in radius

between the two is adjusted by optimization. Varying the width of the "circular arc" in geometry, affects the value of the impedance bandwidth at the Bluetooth frequency. The variation in the length of the "circular ac" determines the resonant frequency at the Bluetooth center frequency. Arc length (slots for arcs) can be calculated from half the wavelength produced. Parametric analysis shows the results of the length and width of the Bluetooth frequency of 2.32 - 2.5 GHz with a maximum of -36 dB. The final dimensions of the "circular arc" are r1 = 5.9mm and r2 = 5.7mm.

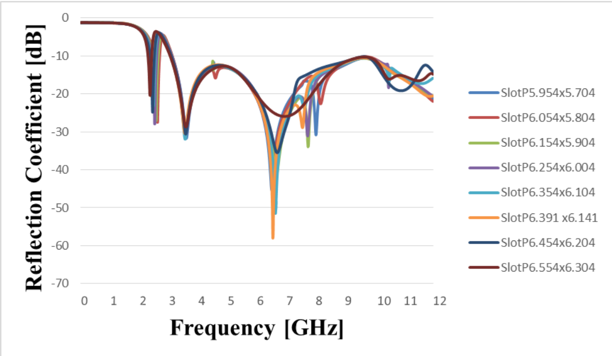

Figure 6: Reflection coefficient versus frequency graph for different “circular arc”

Figure 6 shows the results of the modifications made to the dimensions of the "circular arc" slot. Modifications were made to see how much influence the dimensions have on the changing working frequency of Bluetooth. Bluetooth reflection coefficient value at 2.44 GHz working frequency is -24.8175 dB.

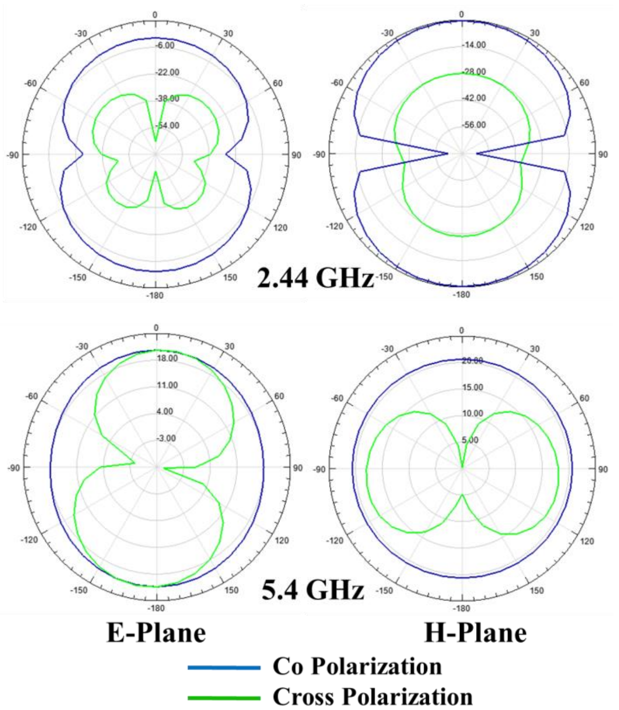

Figure 7: Simulated Radiation Patterns perceived in E-plane and H-plane at 2.44GHz and 5.4GHz

Figure 7 shows the antenna simulation radiation pattern which takes several working frequencies of 2.44 GHz and 5.4 GHz. The reference is used as a reference to see how much radiation the Bluetooth and UWB applications emit. The radiation pattern on the E-Plane shows the shape of the pattern forming a "dumbbell 8", this happens because the current that goes to the antenna and radiated by the antenna passes through the slot located on the patch. The current passing through the slot forms an electric field pattern with a maximum liquid field found at the edge of the patch (i.e. bidirectional in nature).

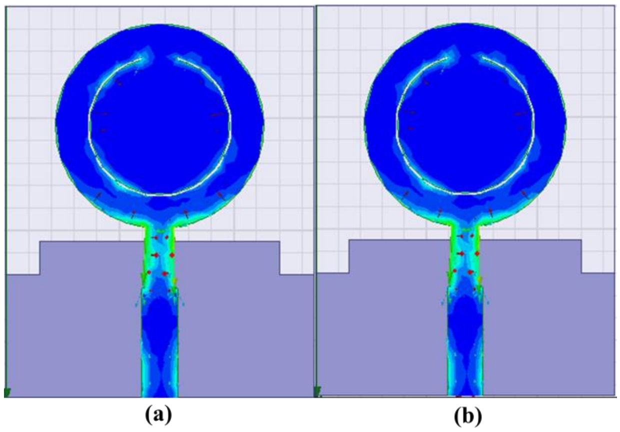

Figure 8: Surface current circulation antenna (a) 2.44GHz and (b) 5.4GHz

Figure 8 shows the circulation of surface currents in the radiating patch. The frequency measured to see surface currents is 2.44 GHz for bluetooth and 5.4 GHz for the resonant frequency of the UWB application used. Surface currents in the "circular arc" slot appear to emit the least current, this is due to the slot where there are route changes that occur in the patch circle. Figure 8.a shows that at 2.44 GHz, surface currents that coalesce around the "circular arc" are inserted to resonate in the Bluetooth band. Figure 8.b shows that there is stronger current along the patch border and less current around the "circular arc" at the 5.4 GHz frequency.

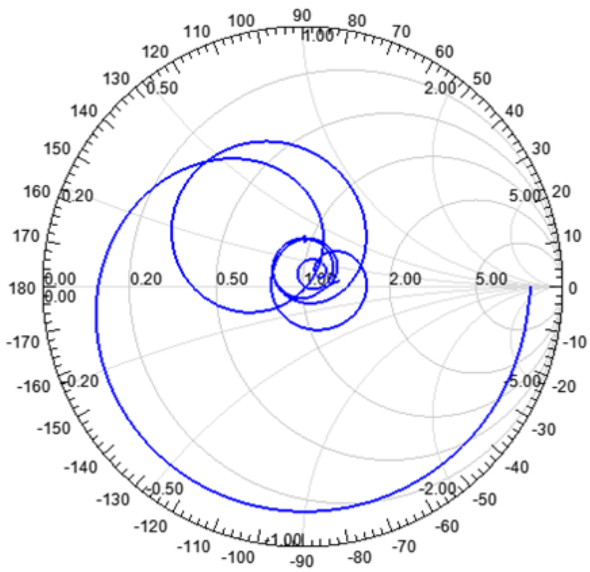

Figure 9: Simulated Smith Chart

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Figure 9 shows a smith chart simulation. The Smith chart generally shows two large circles that cross from 1 and 2, the chart shows that the antenna that is made there is a dual band that works. Some circles have a narrow density, this shows in one band there are several working frequencies that can work in one band. The reflective behavior of the antenna has an impedance value that matches the VSWR value that is close to 1 in the band contained on the smith chart.

CONCLUSIONS

A microstrip feedline dual band circular mono-pole antenna covering a Bluetooth band (2.4-2.48 GHz) and an Ultra Wide Band (3.1-10.6 GHz) for wireless applications. The methodology used in antennas is by inserting a "circular arc" into the radiating patch, this is needed to route the direction of surface currents that occur on the radiating patch so that it will result in resonance in the Bluetooth band. Inserting a "circular arc" is done by etching a radiating patch in the shape of a "circular arc". Bluetooth band has a maximum peak reflection coefficient of -24.8 dB. The reflection coefficient value is obtained by optimizing the dimensions of the "circular arc" engraved on the patch radiating. The addition of DGS slots in the ground plane increases the bandwidth produced and affects the dimensions of the antenna used. The SIR (Stepped Impedance Resonator) technique influences the resulting return loss, increases the antenna performance in terms of return loss and VSWR becomes better. The SIR technique is carried out on the minimized dimensions of the feedline.

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