Tri-Window Printed Monopole Antenna with Wideband Characteristics for Portable Communication Devices

Bilal Ahmed, Ilyas Saleem, H. Zahra, Hunaina Khurshid, S. Muzahir Abbas

Department of Electrical Engineering
COMSATS Institute of Information Technology, Islamabad, Pakistan

bilalahmed_33@yahoo.com, ilyas-saleem@hotmail.com, hijab.zahra@ymail.com,
hunaina.eng@live.com, muzahir_abbas@comsats.edu.pk

***Abstract*- A tri-window printed monopole antenna with wideband characteristics is proposed in this paper. Compact size, uniform gain and stable radiation patterns at high frequencies make the proposed design a good candidate for its integration in portable communication devices. FR-4 with dielectric constant 4.4 and height 1.6mm has been used as substrate. Antenna having overall dimensions of 28.7 × 24.8 × 1.6 mm^3 exhibits wideband characteristics ranging from 2.27 to 7.35 GHz at VSWR ≤ 2 applicable for WiBro (2.3–2.4 GHz), Bluetooth (2.4–2.484 GHz), Wi-Fi/WLAN/Hiper LAN/IEEE 802.11 2.4GHz (2412–2484 MHz), 3.6GHz (3657.5–3690.0MHz) and 4.9/5.0GHz (4915–5825MHz, 5.15–5.35 GHz, 5.47–5.725 GHz), LTE band 7 (2.5–2.69GHz), LTE band 22 (3.41-3.6 GHz) and WiMAX 2.3GHz (2.3–2.5GHz), 2.5GHz (2500–2690 MHz), 3.3GHz, 3.5GHz (3400–3600MHz) and 5.8GHz (5.6–5.9GHz).**

***Keywords* - Monopole, Wideband, Slot, Tri-Window, Partial ground, Portable communication devices.**

I. INTRODUCTION

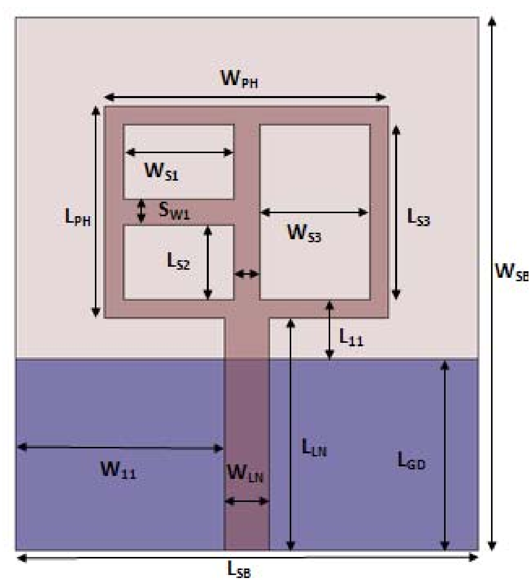
Recently weight and magnitude of wireless portable devices decreased tremendously and variety of IEEE's standards are serving in order to accommodate the constraints that emerge during the designing phase and user requirements. Wideband antennas provide interoperability and multi-standard connectivity for both high and low mobility users [1]. Wideband functionality has been achieved using many techniques including H-shaped microstip feed line [2], conformal strip-fed cylindrical dielectric resonator [3], printed monopole with elliptical patch [4], circular microstrip with L-probe [5], folded wideband monopole [6], slot-coupled stacked-patch array [7], suspended plate patch [8, 9], co-planar waveguide antennas [10-14] and many others.

Thick substrates used in [2, 3] than the proposed prototype. Substrate used in [4] is not commonly used in manufacturing of wireless systems. In [7] substrate stacking has been done, which is practically difficult to implement because of the unpredictable interferences introduced by the binding materials. The design in [9] has patch mounted in air at a distance from the substrate making its physical stability vulnerable. Antenna sizes of [10, 12, and 14] are quite immense. They yield smaller bandwidths with similar gain in the comparative bands.

The key features of [15-18] are used for making this compact antenna with commonly available substrate. Owing to its ease of fabrication, stability of design and reasonable gain on the entire bandwidth; the tested design becomes a suitable candidate for installation in many portable systems

II. ANTENNA DESIGN

To ensure compactness, antenna dimensions have been calculated at a resonant frequency of 4.2 GHz. Fig.1 shows the simulated and fabricated prototype.



(a) Design

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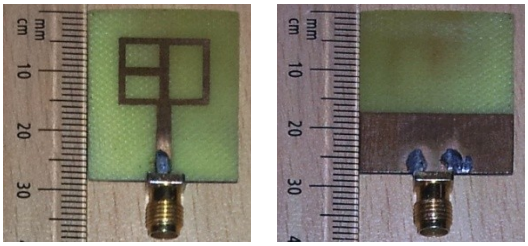


(b) Patch / ground plane of fabricated prototype

Figure 1. Proposed antenna.

Antenna consists of a window shaped rectangular slots subtracted from the patch, printed on 1.6 mm thick FR4 epoxy substrate having relative permittivity of 4.4 and dielectric loss tangent of 0.02. To ensure wide impedance bandwidth, ground plane covers lower portion of the substrate. Fig. 2 shows a graph between bandwidth and the ground length referenced from the port side.

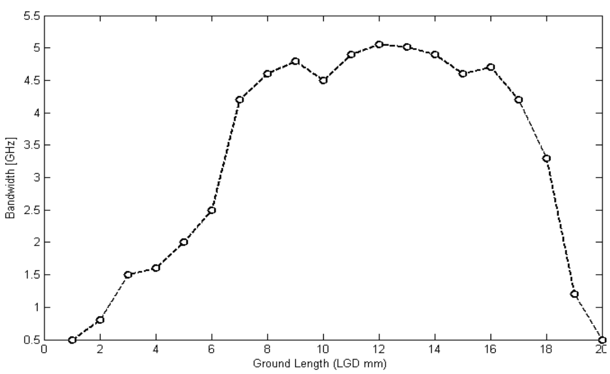


Figure 2. Bandwidth versus ground length.

The width W_{PH} and length L_{PH} of the patch were calculated using (14-6) and (14-7) of [19]. Microstrip feed line having length (L_{LN}) is approximated as $\lambda/4$; where λ is the free space wave length of the resonant frequency while the width has been calculated using (14-19b) of [19] which can only be satisfied if (1) is valid.

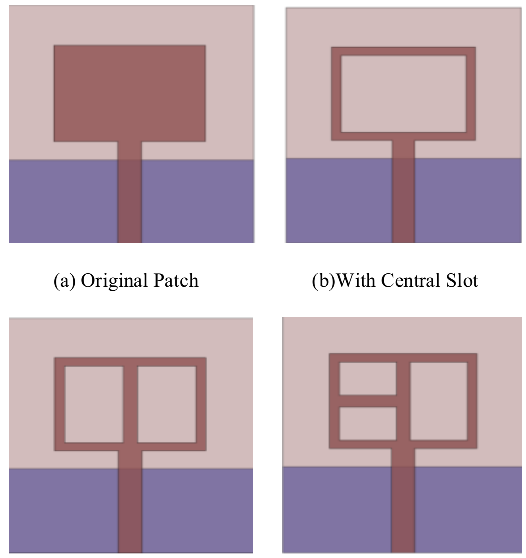
$$\frac{\textit{Feed Line Width}}{\textit{Substrate Height}} > 1 \qquad (1)$$

The length (L_{SB}) and width (W_{SB}) of the substrate are expressed using the general design equations, (2) and (3).

$$W_{SB} \approx W_{PH} + 6H_{SB} \qquad (2)$$

$$L_{SB} \approx L_{PH} + 3H_{SB} + L_{LN} \qquad (3)$$

Figure 3 shows all the design iterations with Fig. 3(a) showing the original geometry. The proposed patch has a central slot of approximately 9.3 x 13.2 mm^2 subtracted from the centre of the patch as shown in Fig. 3(b). A straight slot (L_{S3} x S_{W1}) is extended from the bottom face of the patch to the top face as shown in Fig. 3(c) and a cross slot (S_{W1} x W_{S1}) is extended from the middle of the left face to the middle straight slot as shown in Fig. 3(d). Table I states the optimized dimensions for the proposed design.



(a) Original Patch (b)With Central Slot

(c) With Straight Slot (d) With Cross/Straight Slot

Figure 3. Design variants.

TABLE I. ANTENNA DIMENSIONS.

Parameters	Value (mm)
W_{SB}	24.8
L_{SB}	28.7
L_{GD}	10.3
W_{11}	11.2
W_{LN}	2.4
W_{S1}	5.9
L_{S2}	4.0
W_{S3}	5.9
L_{S3}	9.4
H_{SB}	1.6
L_{LN}	2.2
L_{11}	3.2
S_{W1}	1.4
W_{PH}	15.2
L_{PH}	11.4

III. ANALYSIS AND RESULTS

Antenna has been simulated and optimized using Ansoft HFSS (High Frequency Structural Simulator). Fabricated results are obtained using the Network Analyzer of Agilent Technologies, model N5242A. Figure 4 shows variation in measured and simulated results, which is due to manual fabrication of antenna.

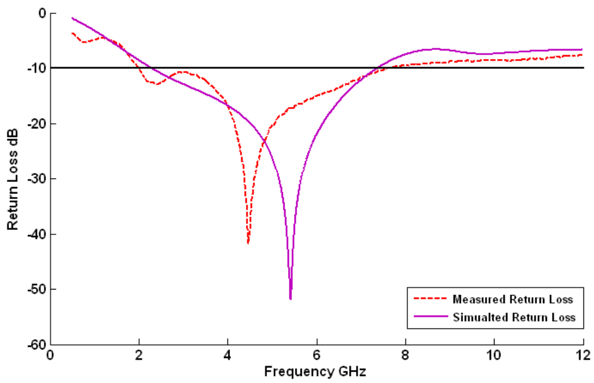


Figure 4. Measured and simulated return loss.

Figure 5 show the variations in return loss and impedance bandwidth by varying size of central slot shown in Fig. 3(b). It can be seen from Fig. 5 that increase in the area of central slot improves return loss and increases an impedance bandwidth, however the gain of the antenna is insufficient in the pass band and the side of the patch opposite to the feed line also becomes deficient of the current density.

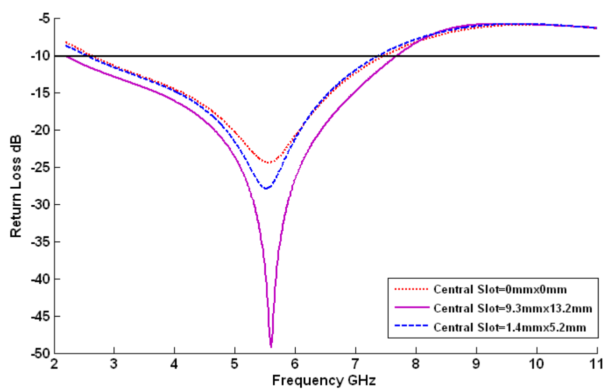


Figure 5. Effects of the central slot on return loss.

The feed line is extended from feed point to the top of the patch to form a straight printed patch (L_{S3} x S_{W1}). This helped in attaining omni-directional high gain patterns but introduced a dip at high frequency due to the introduction of more radiating edges. A comparative study of the width variation of the straight slot is shown in Fig. 6, from which it can be seen that reduction in the width of the extended line improves the return loss characteristics significantly.

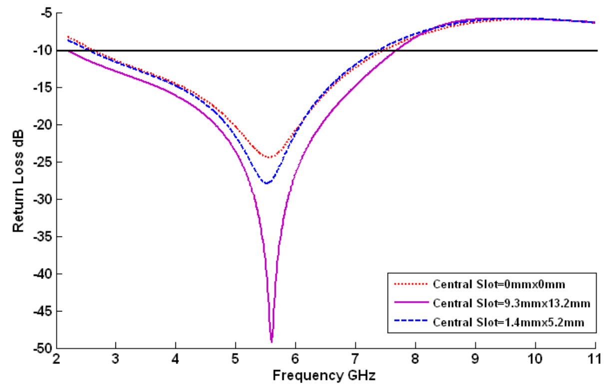


Figure 6. Effects of the straight slot on return loss.

By the introduction of the cross slot (S_{W1} x W_{S1}) at the middle of the patch, a notch is introduced in the bandwidth removing the undesired upper band while maintaining the omni-directional patterns and the original bandwidth. Return loss characteristics for various lengths of the cross slot have been shown below in Fig. 7.

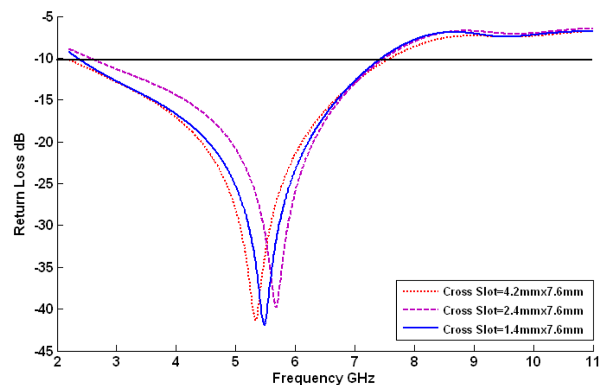
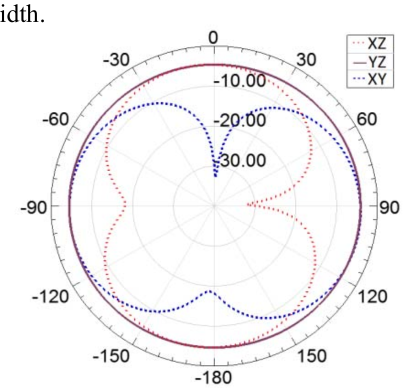
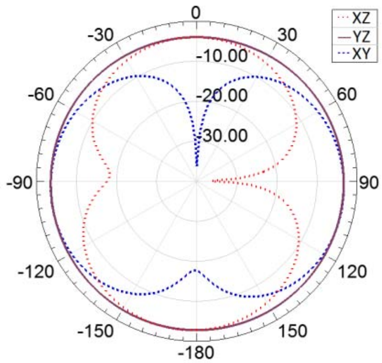


Figure 7. Width variation of the cross slot.

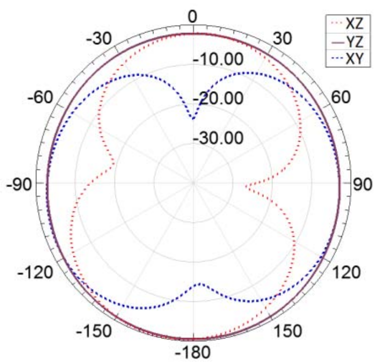
Simulated radiation patterns in principal planes at key frequencies have been shown in Fig. 8. These plots indicate the uniformity of radiation pattern and gain throughout the entire bandwidth.



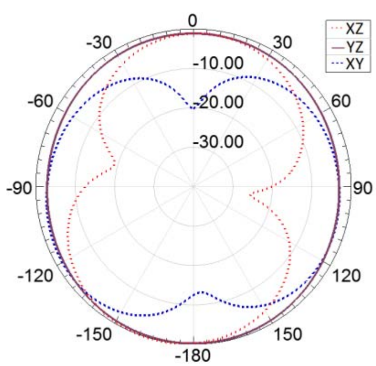
(a) 2.5 GHz



(b) 3.5 GHz



(c) 5.2 GHz



(d) 5.8 GHz

Figure 8. Radiation Patterns

IV. CONCLUSION

In this work a simple, compact, low profile, light weight, inexpensive and realizable printed antenna has been proposed, which shows good impedance matching resulting in higher return loss and sufficient gain in the pass band. Good rejection characteristics in undesired bands have also been found. Agreement in the measured and the simulated results ensures physical application of this antenna. Due to the small size both in terms of the area and volume, this prototype can be integrated with many portable wireless communication systems incorporating the modern standards of WLAN, Bluetooth, HyperLAN, WiFi, WiBro (Wireless Broadband), WiMAX, CMMB (China Multimedia Mobile Broadcasting) and LTE band 7/22 with a high degree of efficiency.

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