# Compact Slotted Printed Monopole UWB Antenna

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## ABSTRACT
Slotted printed monopole antennas for ultra-wideband applications studied theoretically and experimentally have been presented. A circular slotted ground plane as radiator with circular base rectangular exciter, which is fed through microstrip line feed, is printed on a dielectric substrate. This circular base rectangular exciter with circular slotted ground achieves around 7.65:1 impedance bandwidth ratio for VSWR $\leq$ 2 (2.7 to 20 GHz). A reasonably good agreement between both simulated and experimental results is obtained.

## General Terms
Antenna, UWB.

## Keywords
Circular slotted antenna, Slot radiator, Slot exciter, Ultra Wide-Band, Printed monopole antenna.

## 1. INTRODUCTION
There is exorbitant rise in the applications of wireless communication systems, particularly for short range and large data transmission with the regulation passed by FCC in 2002 to use ultra wideband (UWB) spectrum as free spectrum [1]. This UWB system has numerous benefits such as low power consumption, immunity to multi path propagation and high speed transmission. The wireless terminal equipments require being handy and small for short range communication applications. One of the most important requirements of portable devices to have small size antenna and at the same time provides better performance characteristics. Size of the antenna affects, at a great extent, the bandwidth and gain, hence the data rate. The printed antenna reduces the volume of UWB antenna by replacing three dimensional planar antennas, so it becomes easy to incorporate the printed antenna in RF circuits. To fulfill these requirements many antennas have been studied and realized. For UWB applications, different kinds of printed monopole antennas with different types of radiating patch; ground plane and feeding techniques for UWB applications [2-4]; multi-resonating printed antennas [5] have been presented. Many slotted antennas like single ended or differentially fed elliptical disc monopole and dipoles[6], rectangular [7], elliptical [8], triangular [9], U-shape [10]and many [11] tuning stubs have been chosen for different types of wide slots, they have exhibited wide bandwidth characteristics. This is possible by matching the transition between the slot and the feed with exciter patch, to provide more efficient coupling between feed and slot. In slotted antennas minimum numbers of parameters like, slot shape, shape of exciter and the feed, need to be optimized.

In this paper, printed circular slot antenna is proposed for UWB applications. In this design, printed circular slot with microstrip line feed along with the circular base rectangular exciter has been provided for good matching between slot and the feed line and hence impedance bandwidth improves. This proposed antenna with substrate size of 36 mm x 36 mm, have achieved a bandwidth around 200% by optimizing slot, microstrip line and exciter. There is good agreement between simulated and measured results. This antenna exhibits stable omni-directional radiation pattern and gain over the entire band. The proposed designs are considered good candidates for UWB applications; slot antenna can be useful for wideband RADAR, satellite and many short range communication applications.

## 2. GEOMETRY AND DESIGN OF CIRCULAR SLOTTED PRINTED MONOPOLE ANTENNA
The printed circular slot antenna is shown in Figure 1. This antenna has been implemented to achieve UWB characteristics. In the shown configuration a $\lambda/4$ slot is cut in the ground patch. For a circular printed monopole antenna, the current distribution is confined to the edges of the patch, whereas for $\lambda/4$ slot the current spreads over the patch [12-13]. This spreading of current gives rise to higher order modes, hence wider bandwidth is achieved. This slotted radiator helps to reduce the size of monopole antenna. [3-4], [12-13]. By Babinet's principle the slot is resonated by selecting the dimensions of its complement (monopole) structure [12-13]. The circular slotted radiator has the lower edge resonance frequency corresponding to its longest length L as, $L = \lambda/4$ in dielectric medium for monopole radiator, where $\lambda_g = \lambda_0/(\sqrt{\varepsilon_e})$ for slotted monopole antenna with back side ground plane is at infinity so effective dielectric constant $\varepsilon_e = \varepsilon_r$

Therefore, $L = \lambda_0 / 4[\sqrt{(\varepsilon_e}]$ where, $\lambda_0 = 4L [\sqrt{(\varepsilon_e}]$ ,

$\varepsilon_r$ is the dielectric constant of the FR4 substrate, which for the present case is 4.3 and the L can be measured with the help of longest current path in radiating structure .

The lower edge frequency $f_L$ is calculated as given in (1) [2].

$$f_L = c/4L [\sqrt{(\varepsilon_e}] = c /4L k \quad (1)$$

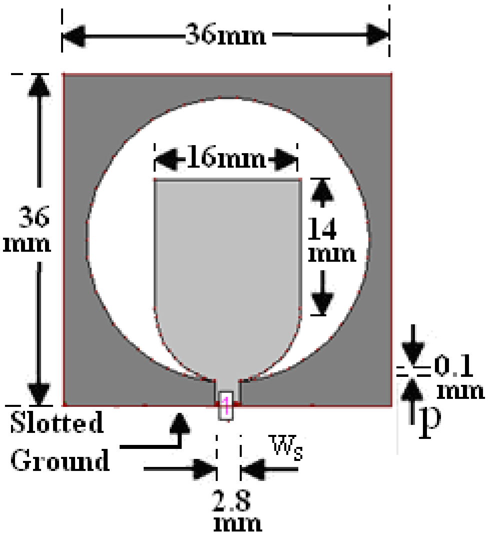


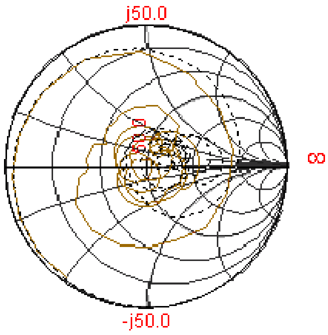

**Fig 1: Geometry of slotted Printed Monopole Antenna with exciter - circular base rectangular**

In this case correction factor k {= √ ($\varepsilon_{eff}$) } is taken as 1.1, as explained in [3-4]. The proposed antenna configuration is fabricated with low cost FR4 substrate with relative dielectric constant of $\varepsilon_r$=4.3, substrate thickness of, h=1.59 mm and loss tangent of, tanδ =0.01. It shows significant reduction in size, desired by wireless systems. Substrate size is reduced to almost 15-20% of reported printed monopole [3-4] antenna by keeping intact the impedance-bandwidth characteristics. Figure 1 shows antenna with substrate size of 36mm × 36mm, with slotted radius of R= 16mm, for suitable matching between the radiator, exciter and microstrip line feed, of width Ws = 2.8mm, with feed gap p = 0.1mm [6, 10] and, also, shows geometry of proposed exciter of Figure 1, rectangular of dimension 16mm × 14mm with semi-circular base of radius r = 8mm. The exciter dimensions and feed gap are optimized to improve the impedance-bandwidth characteristics at lower as well as at higher frequencies.

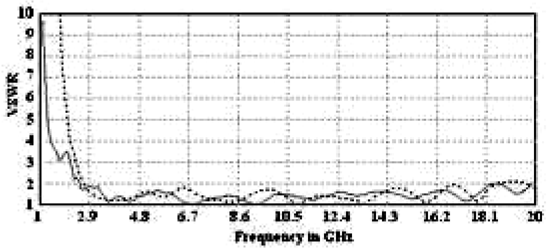
## 3. RESULTS AND DISCUSSION

The characteristics of the proposed antenna have been simulated by using IE3D software [14], the optimized configuration has been fabricated as prototype. The photograph is shown in Figure 2. Measurements were carried out to verify; impedance-bandwidth, return loss and radiation patterns. The simulated and measured input impedance loci and corresponding VSWR plots are shown in Figure 3. BW has been observed for proposed slotted antenna, the simulated and measured bandwidth for VSWR ≤ 2 is 17.3 GHz. Figure 4 shows the simulated maximum gain and the radiation efficiency. The maximum gain varies between 5 dBi and 6 dBi for the entire desired bandwidth and the corresponding radiation efficiency varies from 90% to 99%. These parameters make this antenna as efficient radiator for the entire range of impedance bandwidth.

**Fig 2: Photograph of the fabricated Printed monopole Antenna**




**(i)**




**(ii)**

**Fig 3: Theoretical and measured (i) Impedance Loci and (ii) VSWR for Circular base rectangular exciter (- - - - - - Simulated, —— Experimental)**

Theoretically radiation patterns were seen over the complete impedance bandwidth and experiments were performed to validate the same at various frequencies. These are shown for three different frequencies at 3 GHz, 6 GHz and 10 GHz are shown in Figure 5. The azimuthal radiation pattern is similar to Omni-directional and in the elevation it is figure of eight. At higher frequency, radiation patterns are similar to that at lower frequency. The simulated and measured azimuthal and elevation radiation patterns are in good agreement, as shown. The differences between the measured and simulated radiation patterns are due to manual alignment errors and reflections from the various objects present inside the laboratory, where measurements were carried out.

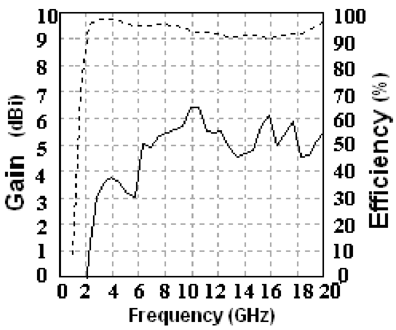
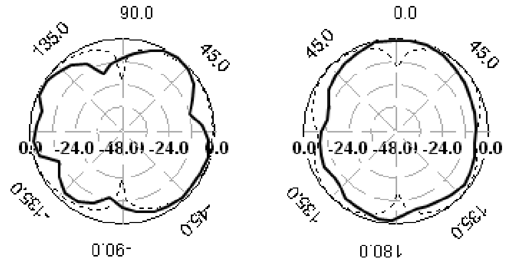
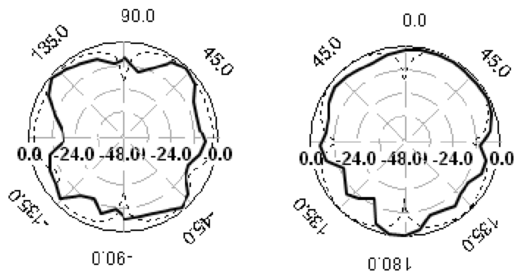


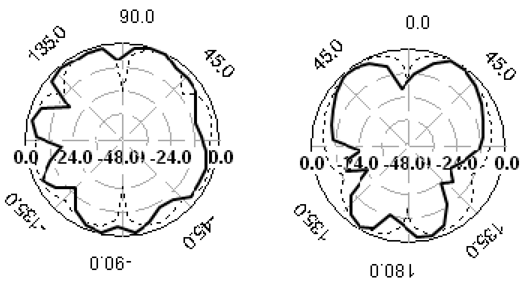

**Fig 4: Maximum Gain and radiation efficiency (- - - - efficiency, ── gain)**



**(a) (i)** **(ii)**



**(b) (i)** **(ii)**



**(c) (i)** **(ii)**

**Fig 5: Radiation pattern for circular slotted with Circular base rectangular exciter antenna at (a) 3 GHz , (b) 6 GHz and (c) 10 GHz (i) Azimuthal and (ii) Elevation radiation patterns, Simulated ( ----- ) and measured ( ------- )**

## 4. CONCLUSIONS

To improve the impedance bandwidth of antenna, a simple and an effective way is to incorporate a slot that behaves like quarter-wavelength, monopole resonant structures such as circular slotted radiator. The proposed antenna is designed, numerically optimized; prototype fabricated and verified its characteristics. It has shown reasonably good impedance matching, bandwidth and radiation characteristics over entire bandwidth even beyond UWB range. The measured and simulated bandwidths of this antenna is 17.3 GHz, with impedance bandwidth ratio is around 8:1. This is very useful band for many wireless communication applications including UWB.

## 5. REFERENCES

[1] Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, ET Docket 98-153, Federal Communications Commission, FCC 02-48, First Report And Order, Adopted: February 14, 2002 Released: April 22, 2002.

[2] Narayan Prasad Agrawall, Girish Kumar and Ray,K.P., " Wide-Band Planar Monopole Antennas", IEEE transactions on antennas and propagation, vol. 46, no. 2, pp294-295, February 1998.

[3] Ray,K.P., and Y. Ranga,Y. "Ultra wideband printed elliptical monopole antenna", IEEE Transactions on Antennas and Propagation, Vol. 55, pp. 1189 - 1192, 2007.

[4] Ray, K.P. "Design aspect of printed monopole antennas for ultra-wide band application", Hindawi Publishing Corporation, International journal of antennas and propagation, Vol. 2008, doi:10.1155/2008/713858. 2008.

[5] Nader Behdad, and Kamal Sarabandi, "A multiresonant single-element wideband slot antenna", IEEE Antennas and wireless propagation letters, Vol. 3, 2004, pp.5-8, 2004.

[6] Johnna Powell and Anantha Chandrakasan, "Differential and Single Ended Elliptical Antennas for 3.1-10.6 ghz Ultra Wideband Communication", IEEE 0-7803-8302-8/04, 2004.

[7] Sadat, S., Fardis, M., Geran, F. and Dadashzadeh, G. "A Compact Microstrip Square-Ring Slot Antenna For Uwb Applications". Progress In Electromagnetics Research, PIER 67, pp.173–179, 2007.

[8] Elboushi, A., Ahmed, O.M., and A. R. Sebak, A.R., "Study Of Ellpitical Slot Uwb Antennas With A 5.0-6.0GHz Band-Notch Capability", Progress In Electromagnetics Research C, Vol. 16, pp.207-222, 2010.

[9] William, J., and Nakkeeran, R. 2010. Development of CPW-Fed UWB Printed Slot Antenna. In Proceedings of National Conference on Communication (NCC2010), at IIT Chennai.

[10] Pengcheng Li, Jianxin Liang, and Xiaodong Chen. Study of Printed Elliptical/Circular Slot Antennas for Ultrawideband Applications. IEEE Transactions On Antennas And Propagation, VOL. 54, NO. 6, pp.1670-1675, JUNE 2006.

[11] Saed, M.A. "Broadband Cpw-Fed Planar Slot Antennas With Various Tuning Stubs", Progress In Electromagnetics Research, PIER 66, pp.199–212, 2006 .

[12] Balanis, C. A. 2005. Antenna Theory: analysis and design. 3rd edition, John Wiley & Sons Ltd, New Jersey.

[13] John D Kraus. 1997. Antennas. 2nd edi, Tata McGraw Hill Publishing Company Limited, India.

[14] Zeland Software Inc., IE3D ver. 12, 2007.