A Simple Multiband Printed Bowtie Antenna

Y. Tawk, *Student Member, IEEE*, K. Y. Kabalan, A. El-Hajj, C. G. Christodoulou, *Fellow, IEEE*, and J. Costantine, *Student Member, IEEE*

***Abstract*—This letter presents a new approach for the design of a multiresonant printed bowtie antenna. Several techniques were attempted to obtain one antenna which is operational in the 2, 3, and 5 GHz bands corresponding to many wireless applications. The idea of creating different slot configurations on different parts of a single antenna is the basic principle. A prototype of the final antenna design was fabricated tested and a good agreement was found between simulated and tested results.**

***Index Terms*—Bowtie antennas, circular slots, hexagonic slots, Wi-Fi, WiMAX.**

I. Introduction

A bowtie antenna is made from a bitriangular sheet of metal with the feed at its vertex [1]. It is used extensively in many applications such as ground penetrating radars [2]–[4] and mobile stations [5]. A bowtie antenna can be printed on a substrate where each arm is placed either on the upper or lower surface of the substrate. The feeding of such structure is done by designing appropriate striplines that are connected to a coaxial feed which is placed on one of the edges of the substrate.

A lot of previous research was done on the printed bowtie antenna to improve its wide-band characteristics. In [6], a double-sided printed bowtie antenna for ultrawide band (UWB) applications is presented. The frequency band considered is 3.1–10.6 GHz, approved by the Federal Communications Commission as a commercial UWB band. In [7], a double-sided rounded bowtie antenna (DSRBA) for ultrawide-band (UWB) communication was proposed. The antenna covers the UWB spectrum and shows that significant improvements in performance can be achieved by using antennas with rounded patches instead of using conventional flat-ended ones. The design of a bowtie antenna fed by broadside-coupled striplines (BCS) for the 2.4 GHz ISM band is described in [8]. The two fins of the bowtie are on the two sides of the substrate. A quarter wave transformer is used to transform the microstrip line input to the BCS feed. It is shown that the bowtie antenna with a 90° extended angle exhibits the widest bandwidth. A novel slot bowtie antenna with very compact size that could be used as an on-chip or stand-alone antenna for an UWB system is discussed in [9]. The proposed antenna is a rectangular patch with a slot bowtie on it and printed on a Teflon substrate. The authors of [10] worked on a modified printed bowtie antenna to simultaneously cover the operations in the C and X-bands from 5.5 to 12.5 GHz. The presented antenna has an end fire radiation pattern that makes it suitable for integration in single and dual polarized phased array systems. In [11], a back-to-back bowtie slot antenna fed by a coplanar waveguide (CPW) is designed to operate at Ka band around a center frequency of 38 GHz. The antenna structure is printed on a substrate with a dielectric constant of 2.2 and a height of 0.245 mm. The coupling from the coplanar line to the both slot radiating elements is accomplished via an aperture located within the ground plane to which the coplanar line is connected. This configuration provides omnidirectional patterns from the two slot bowtie antennas radiating in opposite direction.

In this letter, the idea of introducing different slot configurations inside the bowtie arms is investigated. Circular and hexagonal slots are introduced leading to double resonances in the 2 and 3 GHz bands besides the resonance in the 5 GHz band.

TABLE I
ANTENNA DIMENSIONS

Part	Width (x-direction)	Length (y-direction)
1	1.87 mm	6 mm
2	2.8 mm	4.6 mm
3	2.6 mm	11.9 mm
4	1.4 mm	3.2 mm
5	22 mm	30 mm
6	22 mm	30 mm
7	50 mm	6 mm

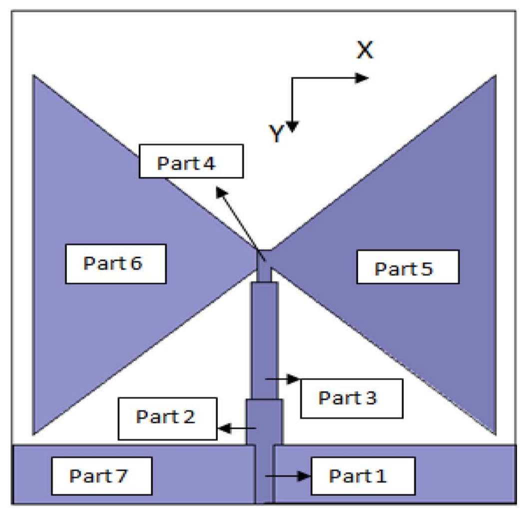


Fig. 1. First antenna design.

Manuscript received April 17, 2008; revised May 22, 2008. First published June 10, 2008; current version published December 30, 2008.

Y. Tawk, C. G. Christodoulou, and J. Costantine are with the Electrical and Computer Engineering Department, University of New Mexico, Albuquerque NM 87131-0001 USA (e-mail: yatawk@ece.unm.edu; christos@ece.unm.edu; jmc08@ece.unm.edu).

K. Y. Kabalan and A. El-Hajj are with the Electrical and Computer Engineering Department, American University of Beirut, P.O. Box 11-0236, Lebanon (e-mail: kabalan@aub.edu.lb; elhajj@aub.edu.lb).

Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/LAWP.2008.2001027

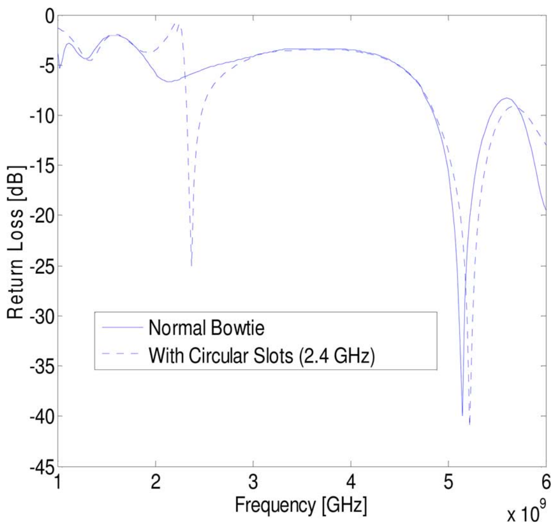


Fig. 2. Return loss for different antenna designs.

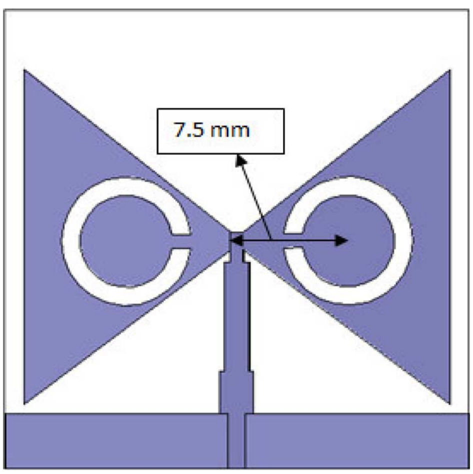


Fig. 3. Antenna structure for the case of circular slots.

II. Different Printed Bowtie Designs

The initial design consists of a normal bowtie antenna on the top and bottom parts of RO3006 substrate (50 mm $\times$ 50 mm) with a dielectric constant of 6.15 and a height of 1.27 mm. The first step is to choose the appropriate dimensions for the arms of the bowtie so that the first band of interest (5 GHz) is covered. The second step is to find a way to feed the structure. The solution is to design striplines so that their impedances yield 50 Ohms [12]. The first simulated design is shown in Fig. 1 and the corresponding S11 plot is shown in Fig. 2. The dimensions for the different parts of the antenna are shown in Table I. These dimensions will be taken as reference for all successive designs. It is essential to note that Parts 2, 3, and 4 lie on the top and bottom sides of the substrate, while Parts 1 and 5 on the top side and Parts 6 and 7 on the bottom part.

In the second design, another resonance is produced by using circular slots [13]. The size of the circular slots determines the specific resonant frequency. Two dimensions of circular slots are chosen to give resonance at 2.4 or 3.5 GHz. In fact, to get resonance at 2.4 GHz the inner radius of the slot was optimized at 5 mm, the outer radius at 7 mm and the opening was found to be 1.5 mm as shown in Fig. 3. As for the 3.5 GHz case, the inner radius is 3.25 mm, the outer radius is 6 mm and the opening

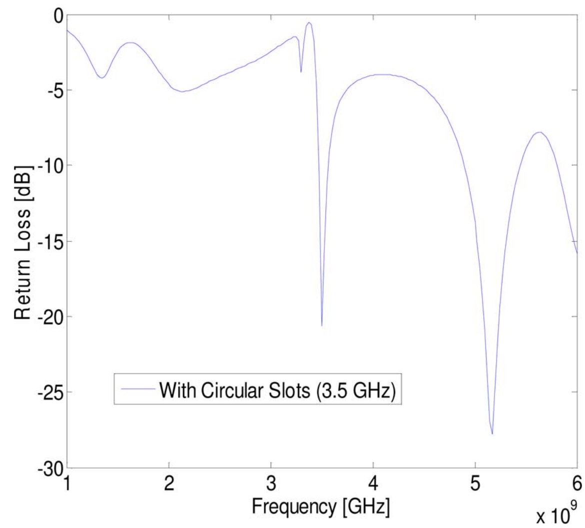


Fig. 4. Return loss for the case of circular slots.

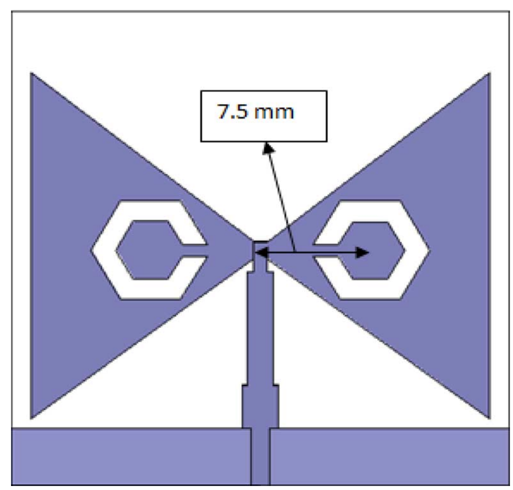


Fig. 5. Antenna structure with slots in the form of a polygon.

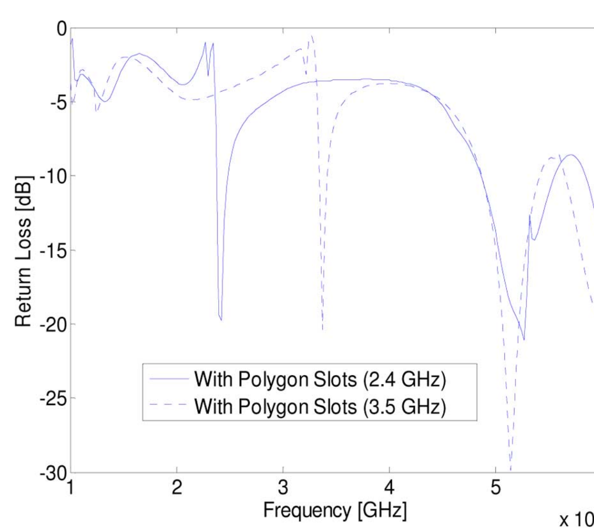
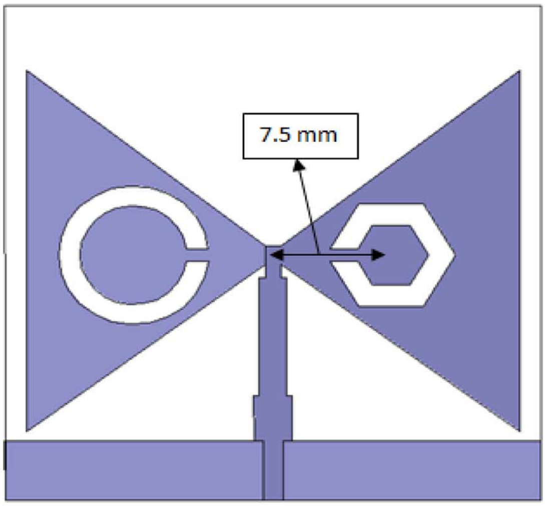
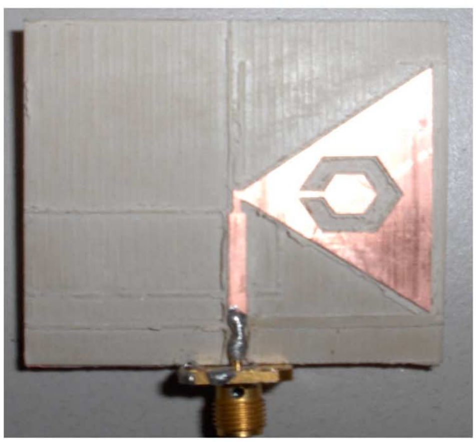


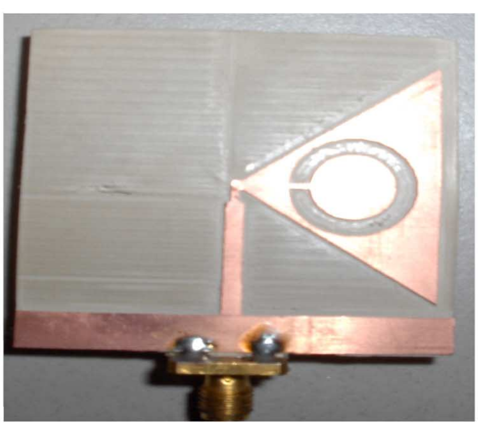
Fig. 6. S11 plot for the case of the slots in the form of a polygon.



(a)



(b)



(c)

Fig. 7. (a) Final bowtie design. (b) Fabricated top side. (c) Fabricated bottom side.

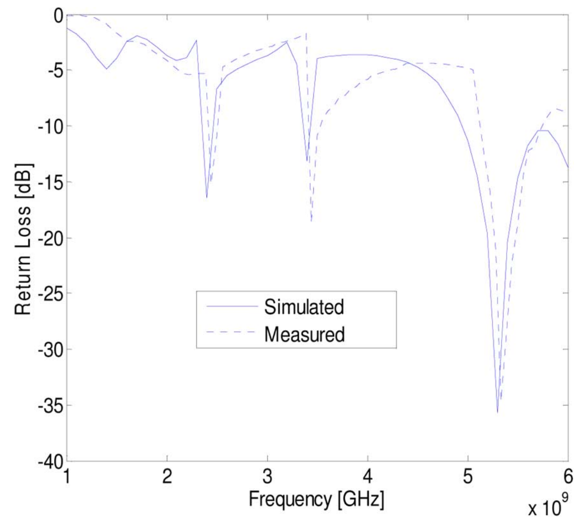


Fig. 8. Simulated and measured S11 plot.

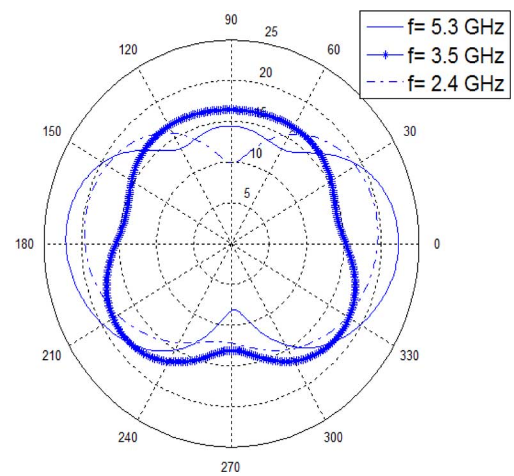


Fig. 9. Antenna radiation pattern.

TABLE II
ANTENNA GAIN

Frequency [GHz]	Gain [dB]
2.4	1.8
3.5	1.5
5.3	4.5

is 2 mm. For both cases, the center position of the slots is 7.5 mm. The corresponding S11 plots for the two cases are shown in Figs. 2 and 4.

In the third design, the effect of taking slots in the form of six sided polygon is investigated. It was found that by choosing appropriate slot dimensions a second resonant frequency can be produced. The slot that produces a resonance at 2.4 GHz has a 7.2 mm side length for the outer polygon and 5.2 mm for the inner polygon. Also to get resonance at 3.5 GHz the outer/inner polygon side length must be 6 mm/4 mm as shown in Fig. 5. The S11 plots for both cases are shown in Fig. 6. For both cases, the opening is 1.2 mm and the slot center position is 7.5 mm.

III. Multiband Printed Bowtie Design

From the simulations that were presented, one can notice that the incorporation of circular or polygon shaped slots produce a second resonance. In fact, the challenging point is to try to optimize the dimensions of the slots to the corresponding resonant frequency. All simulations were done using HFSS v10.1.

Next in the final design, a tri-band printed bowtie antenna is presented. The idea is to take either circular or polygon shaped slots on each arm of the bowtie, where each slot will produce a resonance at a given frequency depending on its dimension beside the one that will be produced from the bowtie arms. The simulated and fabricated antenna geometry is shown in Fig. 7 and the corresponding S11 plot in Fig. 8. The agreement between the computed and the tested results is close.

The circular slot has the same dimension as the one that gives a resonance at 2.4 GHz in the previous section, and the polygon shaped slot has the same dimension as the 3.5 GHz case discussed previously. Such antenna can be used for many wireless applications such as: WLAN and WiMAX.

The simulated antenna radiation patterns at $\Phi = 0^{\circ}$ (E-plane) for the three resonant frequencies are shown in Fig. 9.

The antenna gain at $\Phi = 0^{\text{o}}$ and $\theta = 0^{\circ}$ for the three resonant frequencies is given in Table II:

IV. Conclusion

This letter introduces a new technique to obtain a multi resonant antenna that can be used for several wireless applications. The basic idea consists of inserting different slot configurations on the bowtie arms. It was shown that by taking circular or polygon shaped slots; resonances were obtained in the 2 GHz and 3 GHz bands. The final design consists of incorporating the two types of the slots inside the arms of the bowtie.

Acknowledgment

The authors would like to thank Mr. C. Santiago and Rogers Corporation for all their assistance and support.

References

[1] C. Balanis, *Antenna Theory, Analysis and Design*. New York: Wiley, 2005.

[2] D. Uduwawala, M. Nougren, P. Fucks, and A. W. Sunawardena, "A deep parametric study of resistor-loaded bowtie antennas for ground penetrating radar applications using FDTD," *IEEE Trans. Geosci. Remote Sens.*, vol. 42, no. 4, pp. 732–742, Jun. 2004.

[3] Y. Nishioka, O. Maeshima, T. Uno, and S. Adachi, "FDTD analysis of resistor-loaded bowtie antennas covered with ferrite-coated conducting cavity for subsurface radar," *IEEE Trans. Antennas Propagat.*, vol. 47, pp. 970–977, Jun. 1999.

[4] M. Birch and K. D. Palmer, "Optimized bowtie antenna for pulsed low-frequency ground-penetrating radar," *Proc. Soc. Photo Opt. Instrument. Eng.*, vol. 4758, pp. 573–578, 2002.

[5] Y. Lin and S. Tsai, "Analysis and design of broadside-coupled striplines-fed bowtie antennas," *IEEE Trans. Antennas Propagat.*, vol. 46, pp. 459–460, Mar. 1998.

[6] K. Kiminami and T. Shiozawa, "Double-sided printed bowtie antenna for UWB communication," *IEEE Antennas Wireless Propagat. Lett.*, vol. 3, pp. 152–153, 2004.

[7] T. Karacolak and E. Topsakal, "A double sided rounded bowtie antenna for UWB communication," *IEEE Antennas Wireless Propagat. Lett.*, vol. 5, pp. 446–449, 2006.

[8] Y.-D. Lin and S.-N. Tsai, "Analysis and design of broadside coupled striplines fed bowtie antennas," *IEEE Trans. Antennas Propagat.*, vol. 46, pp. 459–560, Mar. 1998.

[9] K. Y. Yazdandoost and R. Kohno, "Slot antenna for ultrawide-band system," in *Proc. IEEE/ACES Int. Conf. Wireless Commun. Appl. Comput. Electromagn.*, Apr. 2005, pp. 212–216.

[10] A. A. Eldek, A. Z. Elsherbeni, and C. E. Smith, "Wide-Band modified printed bowtie antenna with single and dual polarization for C and X band applications," *IEEE Trans. Antennas Propagat.*, vol. 53, pp. 3067–3072, Sep. 2005.

[11] M. Nedil, T. A. Denid, and L. Talbi, "A new back-to-Back slot bow-tie antenna for millimeter-wave applications," in *Proc. Can. Conf. Electr. Comput. Eng.*, May 2003, vol. 3, pp. 1433–1436.

[12] J. R. James and P. S. Hall, *Handbook of Microstrip Antennas*, ser. IEE Electromagnetic Waves. London, U.K: Peter Peregrinus, 1989, vol. 28.

[13] Y. Tawk, "Bowtie antenna design for wireless applications," Master's thesis, American Univ. Beirut, Lebanon, 2007.