DUAL BAND PRINTED BOW-TIE ANTENNA FOR WLAN/ WIMAX APPLICATION

S. K. Vijay[1,2], N.Hassan[3], M. R. Ahmad[3], B. H. Ahmad[3], S. Rawat[4] and K. Ray[5]

[1]Department of Electronics & Communication Engineering,
Amity University, Jaipur, 302015
Rajasthan, India.

[2]Department of Electronics & Communication Engineering,
Ganga Institute of Technology & Management, Kablana,
124104 Haryana, India.

[3]Faculty of Electronic and Computer Engineering,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian
Tunggal, Melaka, Malaysia.

[4]Department of Electronics & Communication Engineering,
Manipal University, Jaipur, 302015
Rajasthan, India.

[5]Department of Physics,
Amity University, Jaipur, 302015
Rajasthan, India.

Corresponding Author's Email: [5]kray@jpr.amity.edu

Article History: Received 5 March 2019; Revised 24 July 2019; Accepted 7 October 2019

ABSTRACT: In this paper a dual band printed bow-tie antenna for WLAN and WiMAX application has been presented. A planar bow tie antenna consists of defected ground and symmetrical shape split ring resonator (SRR) is presented to apply to the dual band application. A triangular microstrip patch with the defected ground is used as initial bow tie antenna which worked on WiMAX Band. Further initial design (primary antenna) added with SRR to operate over 2.4-2.8 GHz for Bluetooth, Wi-Fi, ZigBee, WLAN Applications and 3.4-4.2 GHz which includes Worldwide Interoperability for Microwave Access (WiMAX) and C-band down link frequency band for satellite communications. The proposed antenna has been made on 1.6 mm thick FR-4 substrate with a size of 50x28 mm². The proposed antenna has very wide bandwidth with the value of VSWR less than 2.

KEYWORDS: *Modified Bow-Tie; WLAN Band; WiMAX Band; Multi-Band Antenna; SRR*

1.0 INTRODUCTION

Since last two decades printed antennas widely used for communication with high data rates and more gain. Current investigation on printed antennas is very vigorous due to the constant demands of numerous wireless communications such as WLAN in the 2.4-2.4835 GHz, 5.15-5.35 GHz, and 5.725-5.852, Wi-Fi in the 2.4 GHz, WiMAX in the 2.495-2.695 GHz, 3.2-3.7 GHz, and Bluetooth at 2.4 GHz. To achieve all wireless application multi-band antenna with compact size, lightweight, wide bandwidth, relatively low-cost, ease of fabrication and maintenance of operation desirable. A bowtie antenna is made from a bi-triangular sheet of metal with the feed at its vertex. This type of antenna is used extensively in many wireless applications with a wider bandwidth, higher gain, lower front to back ratio, lower cross-polarization level and also compact in size. In recent years many bow-tie antenna reported in many kinds of literature for various wireless application [1-15].

Researchers reported the application of bow tie in log periodic array design at UHF band with a reduction in size and very good front to back ratio (FBR) [1]. The author used bow-tie shape printed dipole antenna in the place of strip dipole element on the FR-4 substrate. Again in another report Coplanar feed used in bow-tie design with triple band application printed on FR 4 substrate [2]. The author also used the U shape and capacitively loaded loop (CLL) slot to achieve dual notch band characteristics [2]. A novel modified bow-tie slot antenna printed on FR 4 substrate with tuning stub for 2.4, 5.2 and 5.8 GHz applications [3]. The author used a rectangular strip to optimize the impedance of feeding and also working band [3]. Researchers also reported slot antenna in the design of bow-tie antenna, printed on FR4 substrate, for the application like 2.4, 5.2 and 5.8 GHz [4]. A microstrip antenna comprises of a bow tie section and L shaped slot on the ground plane, printed on FR4 substrate for 2.4 GHz (2.4-2.484 GHz) and the 5.8 GHz (5.725-5.825 GHz) bands [5].

A novel Koch-like fractal shape bow-tie antenna printed on FR4 substrate, which is suitable for the WLAN 2.4 GHz applications [6]. In another report novel bow antenna reported with completely omitting the ground surface for omnidirectional characteristics and also by a reduction in size under a quarter wavelength for RFID application [7]. Sayidmarie and Fadhel [8] reported self-complementary antenna in bow-tie shape, further author also bends the feed. Bow-tie antenna is proposed here for UWB application. Garg and Srivastava [9] presented multi-resonant bow-tie antenna for S-band and C-band corresponding to several wireless applications, further author also cuts the many slits on the patch and analyzed for multi banding. Another bow tie antenna presented for DVB and WLAN systems application with asymmetric feed line and various slots in patch [10]. Another model where two different size bow tie antenna feed on the same microstrip line reported for GPS and WLAN application [11]. Liu et al. [12] presented loading of metamaterial to improve gain of bow-tie antenna. Dastrnaj [13] reported wideband end fire antenna in bow-tie shape for multiband application. Transparent silica substrate used to develop wideband bow-tie antenna at x band application in [14], where author improves antenna parameter without affecting scattering parameter. A typical application of bow-tie antenna for MRI imaging at UWB operation presented in [15]. The comparison of the proposed design with the different previously reported antenna in the literature is enumerated in Table 1.

Table 1: Comparison of previously reported literature

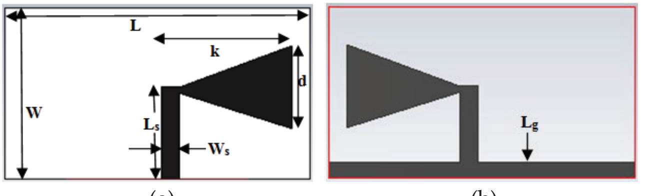
Reference	Substrate	Size	Frequency Application	Bandwidth	Gain
[1]	FR-4, Ɛr= 4.4	130mm*257mm	1-6 GHz	5 GHz	5.5 to 7.3 dBi
[2]	FR-4, Ɛr= 4.4	70mm* 78.5mm	Triple band antenna(2.24-2.70,3.24-4.24, 4.84-6.00GHz)	0.46 GHz, 1 GHz & 1.16 GHz	3.7/2.2/4.0 dB
[3]	FR-4, Ɛr= 4.4	35mm*35 mm	2.4,5.2 and 5.8 GHz	1.41 GHz & 1.31 GHz	0.21–1.36 dBi, 2.94–3.30 dBi & 1.79–3.79 dBi
[4]	FR-4, Ɛr= 4.4	60mm*45 mm	Dual band (2.4/5.2/5.8 GHz) WLAN Application	0.23 GHz & 1.26 GHz,	2.55/3.65 dB
[5]	FR-4, Ɛr= 4.4	27mm*27 mm	Dual band, WLAN(2.4 and 5.8GHz)	0.084 GHz & 0.10 GHz	
[6]	FR-4, Ɛr= 4.4	60mm*40 mm	UWB, PCS, WLAN, WiFi, WiMAX(2.4GHz)	0.045 GHz	3.5-7dBi
[7]	FR-4, Ɛr= 4.4	75mm* 75 mm	UHF RFID (915MHz)	0.124 GHz	2 dBi
[8]	FR-4, Ɛr= 4.4	65mm*30 mm	UWB(2.75-11.58 GHz)	8.83 GHz	1.5-5 dBi
[9]	FR-4, Ɛr= 4.4	40mm*40 mm	Wi-Fi, Wi MAX(3GHZ and 5.2GHz)	0.5 GHz & 0.5GHz	2.25dB
[10]	FR-4, Ɛr= 4.4	226mm*157mm	DVB/WLAN(660MHz, 2450MHz, and 5500MHz)	450MHz to 6GHz	0.13/1.04/0.04 dBi
[11]	FR-4, Ɛr= 4.4	50mm*50 mm	Dual band; GPS and WLAN (1.54 & 5.73GHz.)	0.67 GHz & 1.13 GHz	
[12]	FR-4, Ɛr= 4	220mm*168mm	GPR application (0.5-1.2 GHz)	0.7 GHz	7 dB

[13]	FR-4, Ɛr= 4.4	34mm*34 mm	S band (3.3-4 GHz), C band (4-8 GHz), X band (8-12 GHz) & Ku band (12-15.3 GHz)	11.9 GHz	4.48 dB
[14]	Silica Ɛr= 3.9	5mm*5 mm	X band	6 GHz	
[15]	Rogers 5880 Ɛr= 2.2	24mm*27 mm	MRI(0.4-1 GHz)	0.6 GHz	
Present work	FR-4, Ɛr= 4.4	50mm*28 mm	Dual Band for WiMAX and WiFi Application	0.40 GHz & 0.80 GHz	2.2 dBi & 4.2 dBi

In this paper, the effects of SRR integrated near the feed line of the radiating patch have been investigated. The SRR implemented both sides of the substrate to produce dual band resonance. However, dual band resonance can also be produced with slot on patch or ground but conventional method has limitation of RF power leakage. The limitation of conventional method can be diminished with SRR as coupling element near the feed line of radiating patch. The SRR alters the effective impedance of the resonator due to coupling effect and produces resonance for dual bands. The proposed antenna has added advantage of its compact size and successful creation of dual band resonance characteristics.

2.0 METHODOLOGY

The initial design is a bow-tie antenna designed on FR4 substrate with a dielectric constant of 4.4 and 1.6 mm thickness. The radiating element is a triangular bow tie shape patch design on both sides of the substrate. The feeding method used here is a microstrip feed. The length and width of the microstrip feed line are chosen to attain the characteristics impedance of 50 Ω. The bottom side of the antenna embedded a partial ground structure which provides wideband frequency. The commercially available software CST has been used here for simulation and optimization. The primary antenna has been shown in Figure 1.



(a) (b)

Figure 1: (a) Top view and (b) bottom view of the primary

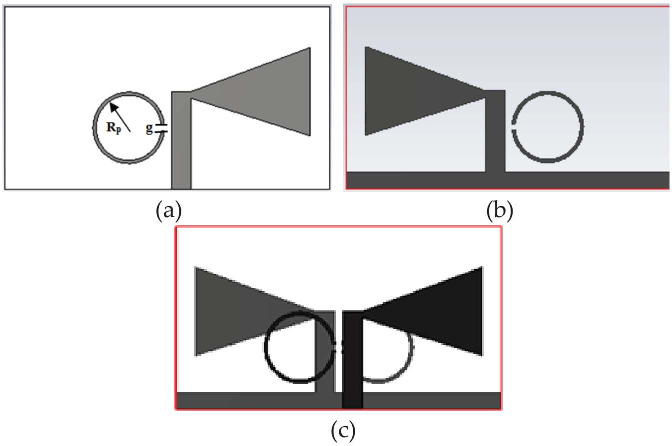


Figure 2: (a) Top view, (b) Bottom view and (c) perspective view of the proposed antenna

Multiband antenna design has been accomplished in two steps; initially, an antenna with bow tie characteristic has been designed. Now further the ground of the antenna has been modified. So due to the modification of the ground, the resonant frequency shifted to 3.80 GHz. The WiMAX band from 3.2 GHz to 3.7 GHz covered up by the primary design. To make this antenna multiband, the SRR is loaded near the bow tie shape. The suggested design displayed in Figure 2 has produced very good resonance for 2.4-2.8 GHz and 3.4-4.2 GHz band. Microstrip feed line method used to match 50 Ω characteristic impedance. The length and width of the feed line demonstrated in Table 2. The dimensions of the antenna mentioned in Figure 1 and Figure 2 have been shown in Table 2.

Table 2: Dimensions of antennas mentioned in Figure 1 and Figure 2

Variable	W	L	R_P	L_S	W_S	L_g	k	d	g
Size (mm)	28	50	5.5	15	3	2.5	25	13.6	1

3.0 RESULTS AND DISCUSSION

The compared scattering parameters of the primary antenna and SRR loaded antenna (proposed antenna) has been displayed in Figure 3. The graph demonstrates that the primary antenna has a resonant frequency at 3.80 GHz. The value of reflection coefficient S_{11} (dB) is -23.20 dB, indicates that the antenna has good impendence matching and less power reflection. Figure 3 demonstrates that presented antenna (primary) has a broad bandwidth of 880 MHz from 3.41 - 4.29 GHz, and covers WiMAX band and C band downlink for satellite communication applications.

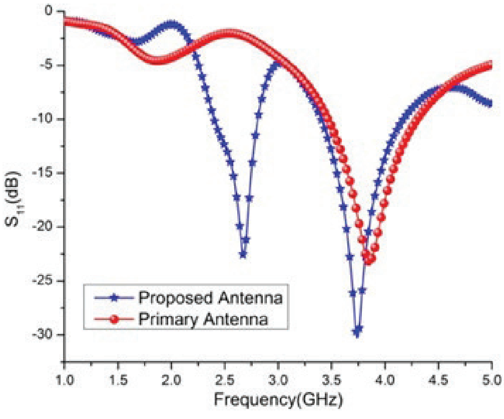


Figure 3: Simulated S_{11} of primary antenna and proposed antenna

When the SRR implemented in the bow tie shape antenna, it displays the dual band performance. The first band starting from 2.4 GHz to 2.8 GHz which covers Bluetooth at 2.4 GHz, Wi-Fi at 2.4 GHz, ZigBee at 2.5 GHz, lower WLAN band (2.45 GHz) and also some part of WiMAX (2.495-2.695 GHz). The second band has bandwidth covers WiMAX band (3.25-3.85 GHz) and C band downlink frequency (3.8-4.2 GHz). The second band has a 0.8 GHz bandwidth. The VSWR versus frequency have been displayed in Figure 4. From Figure 4, it can be seen that VSWR is less than 2 for the entire passband and very high value at all other bands.

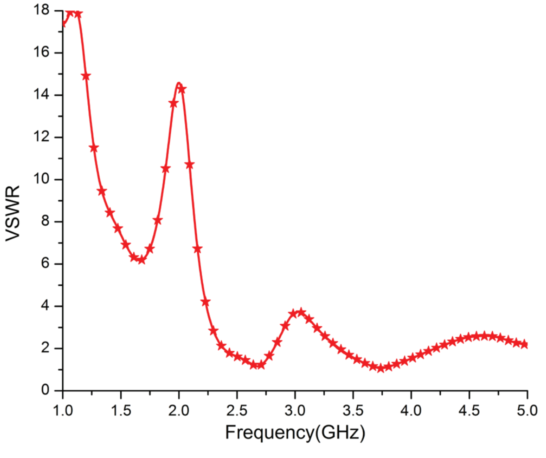


Figure 4: Simulated VSWR of proposed antenna

SRR on patch length variation is a function of gap "g" according to gap variation band frequency also varied and S_{11} (dB) result has been shown in Figure 5.

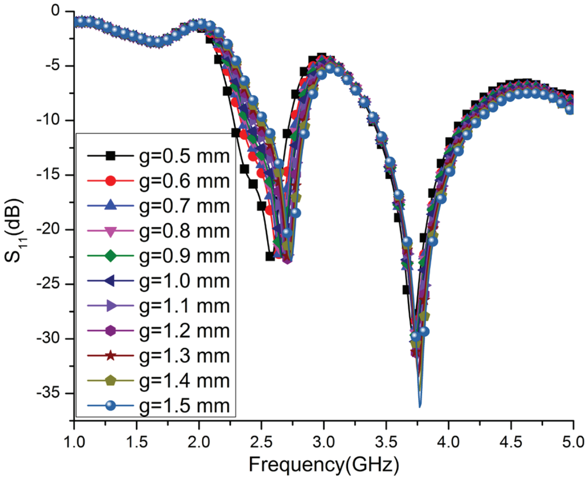


Figure 5: Simulated S_{11} of proposed antenna at variation in SRR gap width

Similarly, symmetrical SRR width is also a function of inner radius "Rp" and the result has been shown in Figure 6. From Figure 6, it can be seen that during optimization of symmetrical SRR there are no significant changes on the primary frequency bands (3.8-4.2 GHz), while it has been optimized for 2.5 GHz frequency band.

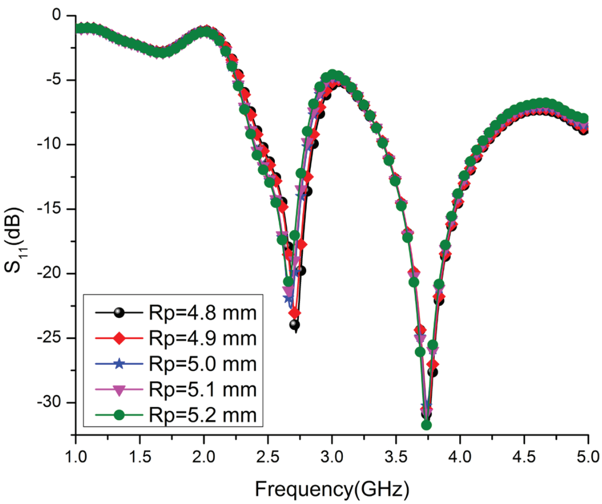


Figure 6: Simulated S_{11} of proposed antenna at variation in SRR width

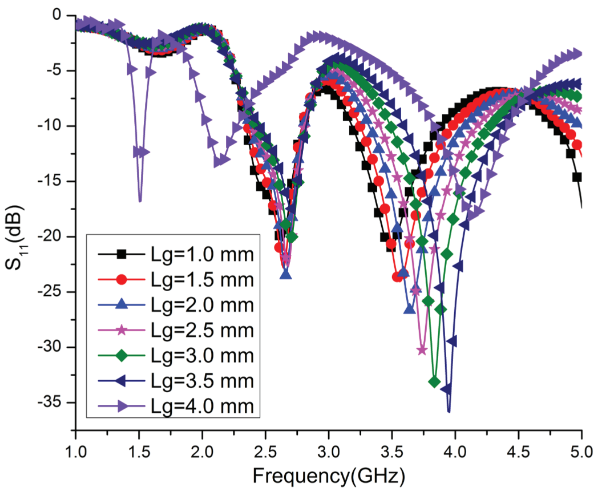
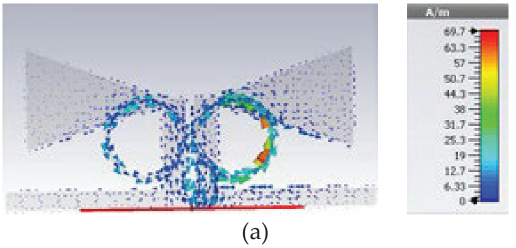


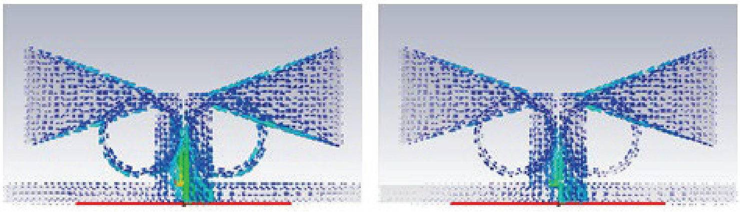
Figure 7: Simulated S_{11} of proposed antenna at variation in ground length

Further, ground length "Lg" also varied as shown in Figure 7. That can also be investigated from the vector current distribution shown in Figure 8. It can be seen that at 2.5 mm, it displayed good dual band characteristics. It can be seen that ground length can provide freedom to optimize the frequency bands.

Figure 8(a) shows the effect of SRR structures on vector current distribution, it can be seen that due to the SRR structures the current density is highly concentrated. It can be understood that the current density is accumulated on the edges of the SRR that is positive sign to create band pass filtering at 2.5 GHz. Furthermore, Figure 8(b) and Figure 8(c) show the effect of ground structure and SRR which is used to produce pass band resonance characteristics at 3.5 GHz and 4 GHz frequencies. Mutual inductance produced by SRR plays crucial role in producing dual band characteristics.

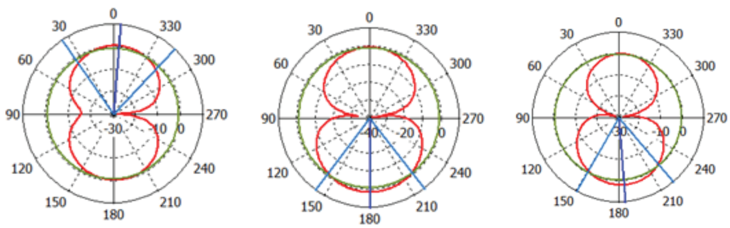


(a)



(b) (c)

Figure 8: Vector current distribution at various frequencies: (a) 2.5 GHz, (b) 3.5 GHz and (c) 4 GHz



(a) (b) (c)

Figure 9: Simulated radiation pattern: (a) 2.5 GHz, (b) 3.5 GHz and (c) 4 GHz

The radiation patterns of the proposed antenna at 2.5 GHz, 3.5 GHz and 4 GHz have been presented in Figure 9. The antenna displays good omnidirectional radiation pattern for 2.5 GHz, 3.5 GHz and 4 GHz with an omnidirectional pattern for H-field and dipole like the pattern for E-field. The dipole like radiation pattern in E plane indicates that reported design behaves like dipole type radiator.

Figure 10 shows that the gain of the reported design is greater than two. For all the passband frequencies like 2.37-2.8 and 3.38-4.3 GHz, the gain of the antenna is almost constant around 4 dB and also for other bands gain is very less. The significance of realized gain is 3.5 dB at 2.5 GHz and 4.1 dB at 3.5 G Hz. It is noticeable that gain values alter according to radiation angles in the E and H plane.

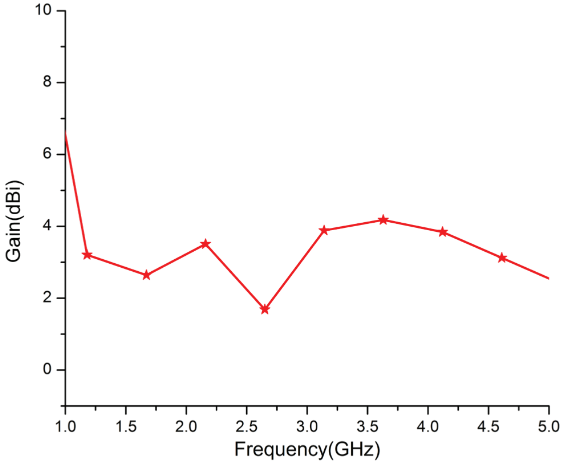


Figure 10: Simulated gain vs. frequency of the proposed antenna

4.0 CONCLUSION

The main objective of this paper is to implement SRR structure to design dual band antenna deprived of any complex design and any slots in the patch. Initially a triangular shape bow tie designed for WiMAX band application with the bandwidth of 880 MHz. Then SRR implemented near the radiating bow tie shape to achieve another band at 2.5 GHz. The proposed design effectively resonated for dual band applications like Bluetooth/ Wi-Fi/Zig-Bee/lower WLAN application (2.4 GHz), WiMAX (3.5 GHz) and a downlink frequency of C-Band at 3.8-4.2 GHz frequency. The SRR improves the limitations of creating slots on radiating surface or ground surface of conventional methods and produces satisfactory performance. Antenna ground length and SRR parameters also optimized to produce good dual band characteristics. The antenna has a simple structure and miniaturized size of 50 x 28 mm^2. The results and analysis of the discussed antenna verifies that implementation of SRR method is a better alternative over conventional methods to achieve dual band resonance.

ACKNOWLEDGEMENT

The authors express sincere thanks to Prof. S L Kothari, Vice President, ASTIF, AUR for his support and encouragement.

REFERENCES

[1] J. Yeo and J. Lee, "Planar log-periodic bow-tie dipole array antenna with reduced size and enhanced front-back ratio", *Microwave and Optical Technology Letters,* vol. 54, no. 6, pp.1435-1441, 2012.

[2] Q. Zhang, L. M. Si, Y. M. Wu, Y. Liu, and X. C. Lv, "Design of a coplanar bowtie antenna for WLAN and WiMAX application", in 3rd Asia-Pacific Conference on Antennas and Propagation, Harbin, 2014, pp. 284-286.

[3] J. H. Yoon and Y. C. Lee, "Modified Bow-Tie Slot Antenna For the 2.4/5.2/5.8 GHz WLAN Bands with a Rectangular Tuning Stub", *Microwave and Optical Technology Letters,* vol. 53, no. 1, pp. 126-130, 2011.

[4] L. C. Tsai, "A Dual-Band Bow-Tie-Shaped CPW-Fed Slot Antenna for WLAN Applications", *Progress In Electromagnetics Research C,* vol. 47, no. 4, pp.167-171, 2014.

[5] M. Abioghli and R. A. Sadeghzadeh, "A New Compact Dual-Band Bow-tie Microstrip Antenna for WLAN Applications", *Institute of Electronics and Telecommunication Engineers Journal of Research,* vol. 59, no. 6, pp. 693-697, 2013.

[6] A. C. Bhosale and V. U. Deshmukh, "Design of Bow-tie Microstrip Antenna with Fractal Shape for WLAN Application", *International Journal of Electronics & Communication Technology*, vol. 3, no. 4, pp. 445-449, 2012.

[7] L. A. Fonseca, A. C. Lisboa, R. Adriano and E. J. Silva, "Optimized Limited Size Printed Bowtie Antenna for UHF RFID Readers", *Journal of Microwaves, Optoelectronics and Electromagnetic Applications,* vol. 16, no. 4, pp. 922-931, 2017.

[8] K. H. Sayidmarie and Y. A. Fadhel, "A Planar Self-Complementary Bow-Tie Antenna for UWB Applications", *Progress In Electromagnetics Research C*, vol. 35, no. 1, pp. 253-267, 2013.

[9] D. Garg and S. Srivastava, "Multi Band Compact Bow-Tie Slot Antenna for WLAN Applications", in Asia-Pacific Symposium on Electromagnetic Compatibility, Singapore, 2012, pp. 597-600.

[10] C. C. Hung, C. M. Peng, and I. F. Chen, "Printed Modified Bow-Tie Dipole Antenna for DVB/WLAN Applications", *International Journal of Antennas and Propagation* ,vol. 2013, pp. 1-6, 2013.

[11] H. W. Liu, F. Qin, J. H. Lei, P. Wen, B. P. Ren, and X. Xiao, "Dual-Band Microstrip-Fed Bow-Tie Antenna for GPS and WLAN Application", *Microwave and Optical Technology Letters,* vol. 56, no. 9, pp. 2088-2091, 2014.

[12] L. Liu, C. Zhang, Y. Liu and Y. Hua, "A High Gain and Directivity Bow Tie Antenna Based on Single-Negative Metamaterial," *Journal of Microwaves, Optoelectronics and Electromagnetic Applications,* vol. 17, no. 2, pp. 246-259, 2018.

[13] A. Dastranj, "Modified end-fire bow-tie antenna fed by microstrip line for wideband communication systems," *Journal of Electromagnetic Waves and Applications,* vol. 32, no. 13, pp. 1629-1643, 2018.

[14] X. Zhang, C. J. Chung, S. Wang, H. Subbaraman, Z. Pan, Q. Zhan and R. T. Chen, "Integrated Broadband Bowtie Antenna on Transparent Silica Substrate," *IEEE Antennas and Wireless Propagation Letters,* vol. 15, pp. 1377–1381, 2015.

[15] P. Takook, M. Persson, J. Gellermann, and H. D. Trefná, "Compact self-grounded Bow-Tie antenna design for an UWB phased-array hyperthermia applicator," *International Journal of Hyperthermia,* vol. 33, no. 4, pp. 387–400, 2017.