VOL. 14, NO. 9, MAY 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

BROADBAND DIPOLE ANTENNA FOR DOA SYSTEMS APPLICATIONS

Martha Gonzalez J., Carlos Suárez F. and Gustavo Puerto L.
Faculty of Engineering, Universidad Distrital Francisco José de Caldas, Colombia
E-Mail: csuarezf@udistrital.edu.co

ABSTRACT

This paper presents an antenna design with Right Hand Circular Polarization (RHCP) for applications in estimation systems of Direction of Arrival (DOA). The antenna is composed by orthogonal bowties dipoles or "Bow-Tie" and it is placed in front of a ground plane, achieving a wide impedance bandwidth and Axial Ratio (AR). The center frequency is $2.2GHz$ and has a $72x72x25\,mm$ total size. Measurements results of the implemented prototype showed a maximum gain of $6.88\,dBi$ and 42.34% impedance bandwidth for a $|S11| < -10\,dB$ and 26.91% axial ratio for $|AR| \leq -3dB$.

Keywords: bowtie antenna, circular polarization, RHCP, axial ratio, DOA.

1. INTRODUCTION

Direction finding (DF) is defined as the determination of unknown radio transmission sources locations [1]. DOA (Direction of Arrival) systems allows to increase the signal-to-noise ratio (SNR), extend radio coverage, improve privacy and implement service recognition in wireless communication systems. There are several situations where location and monitoring of radiation sources are required such as in civil and military contexts [2].

The antenna plays an important role in DOA systems, design specifications on this paper are stablished based on [3]- [4]. In [3], the polarization diversity is considering important to increase the sensitivity coming from different directions offering a more reliable solution. In [4] is mentioned that common antenna types used for DF are dipoles, monopoles, loops, reflectors, horns and spirals. Reflectors and horns have high gain and can be made to be broadband and spirals can receive vertical and horizontal polarized signals. Furthermore, directivity is an important indicator of the antenna's ability to isolate the location of a transmitting signal. In accordance with this, a high gain, broadband and directive antenna is designed. The principle of design for this proposal is based in [5] where two orthogonal simple dipoles are configured, connecting them in parallel through a common transmission line. The phase difference is 90º and proper dipole lengths are chosen, when these conditions are accomplished is demonstrated that it can generate circular polarization.

The design of Microstrip antennas with circular polarization and wide bandwidth axial ratio is complex in most cases, in this sense, a circular patch design with circular polarization and reconfigurable sense of rotation is presented in [6] achieving 27.39% impedance bandwidth for a reflection coefficient magnitude $S11 < -10dB$ in the range from$2.295\ GHz$ to $3.025\ GHz$, a maximum gain of$6.04\ dBi$and a 13% axial ratio bandwidth for -3dB reference. Moreover, a design with circular ring geometry short-circuited and reconfigurable sense of rotation is presented in [7] where a 33.33% impedance bandwidth in$1.9GHz$ - $2.66GHz$frequency range for a reflection coefficient less than -10 dB was achieved, a 6.1dBimaximum gain was obtained and 8% axial ratio bandwidth for -3dB reference.

On the other hand, in [8] is presented an antenna design with circular polarization, resonant dielectric technology is used with circular sectors geometries, achieving a double resonance frequency with 15.2% axial ratio (5.47-6.37 GHz) and 15.46% (5.43-6.34 GHz) respectively, while impedance bandwidths are 58.5% (4.24-7.75 GHz) and 48.3% (4.65-7.6 GHz) respectively. Likewise, in [9] the design of arrays of antennas with circular polarization in "leaky-wave" technology is proposed, achieving 67% impedance bandwidth and 8.9% axial ratio bandwidth for -3 dB reference.

Finally, in [10] a proposal of dipole antennas with unique sense of rotation RHCP is presented, this geometry has a ring and two orthogonal Bow-Tie arms in each surface of RO4003 substrate. The achieved results were a 52.1% impedance bandwidth for 1.05-1.79 GHz frequency bands and 37.7% axial ratio for 1.12 to 1.64 GHz range and it has 6.9dBi as a maximum gain.

This paper presents an antenna design with circular polarization; this is composed by orthogonal Bow-Tie dipoles placed in front of ground plane. The used geometry is similar to the approach presented in [10], where dipole arm connection to a central ring generates circular polarization. In this antenna design is important to consider the dimensions because the size must be suitable for the integration into a circular array for DOA system. The geometry involves the number of elements and the separation between them, which is related with the frequency selected [11]. This particular solution must satisfy directivity, gain, axial ratio and adaptation bandwidth requirements.

The operation frequency of DOA system depends on the application. In this context, radio spectrum UHF bands from 1.8 GHz to 2.8 GHz are available for use in Wireless Local Area Networks (2400-2484 MHz), Industrial Scientific and Medical applications (2400-2484 MHz) and Global System Mobile Communication (1800-1900 MHz) [12].

This paper is organized as follows: Section II introduces the dipole Bow-Tie microstrip antenna design, including equations, geometry description and parametric analysis required for design optimization. Section III presents both the simulation and measurements results of the prototype and in section IV is summarized the paper.

2. DESIGN

The antenna is designed at a central frequency of 2.2 GHz on a substrate with dielectric constant$\varepsilon_r = 3$, loss tangent $tan\delta = 0.0014$ and thickness $h = 1.524\ mm.$

Figure-1 shows top and bottom antenna views, respectively, with circular polarization and RHCP sense of rotation, two small metal sections are visible (one per face) which are connected directly to the Bow-Tie dipole arms with the central circular ring.

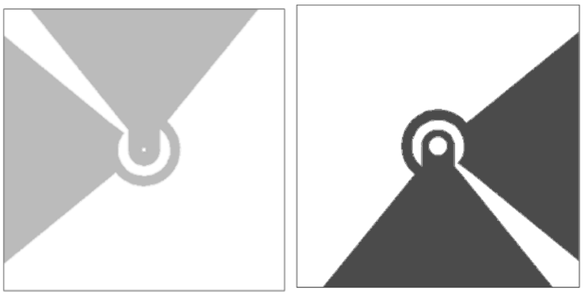

Figure-1. Top and bottom antenna radiator.

Figure-2 shows the antenna side view, on bottom part is located a ground plane with coaxial cable, this cable allows antenna feeding. Also, the substrate that contains two Bow-Tiegroup arms on each side (top) is showed in this figure. The antenna excitation is performed through a coaxial shield connection to the Bow-Tie arm located on the bottom substrate and the inner conductor is placed over the substrate and connects to the arm located vertically as shown in Figure-2. The structure is suspended at a height$H$ between the radiator and the ground plane.

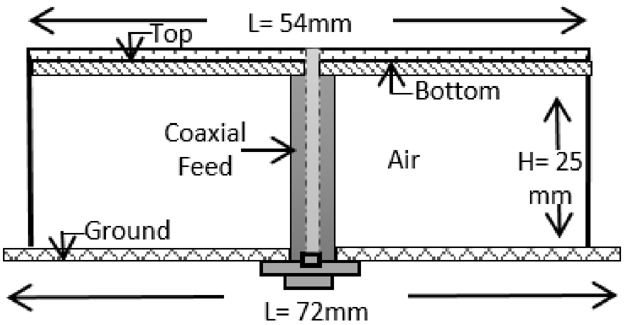

Figure-2. Side "Bow-Tie" antenna view.

The coaxial cable length is equal to a quarter wavelength of the central frequency [13], it was made with the coaxial cable Belden RG58 that has a velocity of propagation(v_p) of$0.67c$ (c, light velocity)

Figure-3 shows the frontal view of the proposed geometry, which is composed by two dipoles arms with Bow-Tie geometry set at 90º (between consecutive arms), in such a way that each dipole arms group are located on the substrate on opposite sides. This figure indicates five design variables (α,L,W,W_r,R) used for theantenna design optimization.

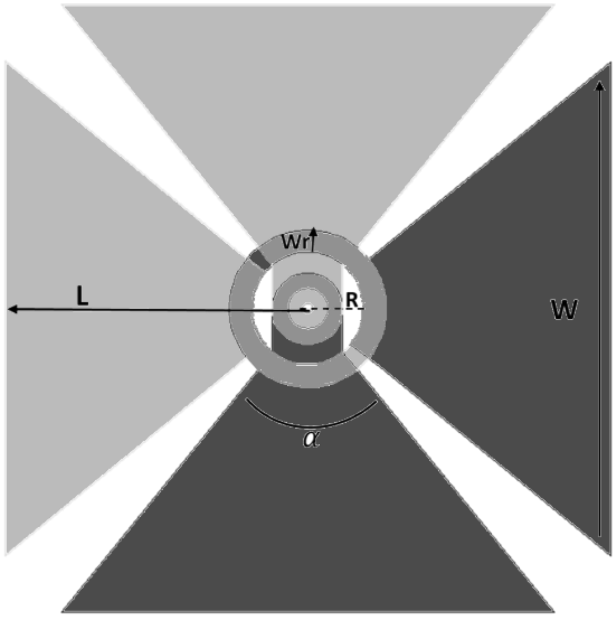

Figure-3. Two faces "Bow-Tie" antenna frontal view.

Using equations (1) and (2) described in [13 - 15], the first dimensions are calculated for a width (W) and a length (L) of a Bow-Tie dipole, getting a width $W = 48.2\ mm$ and a length $L = 29.5\ mm$. Where ε_r is the substrate dielectric constant, f is the central design frequency and $c$is the light speed in vacuum.

$$W = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

$$L = \frac{0.375\lambda}{\sqrt{\varepsilon_r}} \tag{2}$$

First geometry optimization

This section shows the parametric analysis results simulated with five geometric main variables of the Bow-Tie dipole design, namely: $\alpha, L, W, W_r y R$ as seen in Figure-3, analysing their effect on the antenna performance in parameters such as: port adaptation (S_{11}) and axial ratio. The gain and radiation diagram have the same behaviour for the selected parametrics.

With$L$and Wdimensions calculated in the previous section and using the analysis presented in [13-15], an initial geometry ofthe Bow-Tiedipole with fixed sense of rotation (RHCP) is designed. Thereafter, a parametric analysis was performed to determine the optimal dimensions: $W = 44mm$, $L = 27mm$,$\propto = 78°$, $W_r = 2$ and $R = 5mm$. This antenna have a total size of $72x72x25\ mm$, the design was made for $f_0 = 2.2GHz$ central frequency and simulations results for the optimal geometry shows a maximum gain $G_{0-Max} = 7.39\ dBi$, an impedance bandwidth $BW = 45.73\%$ for a reflection coefficient magnitude with $|S11| < -10\ dB$and an axial ratio bandwidth$AR_{BW} = 29.93\%$ for $|AR| \leq -3dB$.

VOL. 14, NO. 9, MAY 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Showing up next, a parametric analysis is made to optimize the antenna performance, whose study was determined by the incidence of five geometric variables (α, L, W, W_r, R) on antenna performance in impedance and in axial ratio diagram. Figure-4shows some axial ratio simulations results for seven combinations of$\alpha, L$and Wparameters, from this figure the best combination with the greater axial ratio bandwidth with 3dB reference is: $\alpha = 78°$, $L = 27mm$and$W = 44mm$.

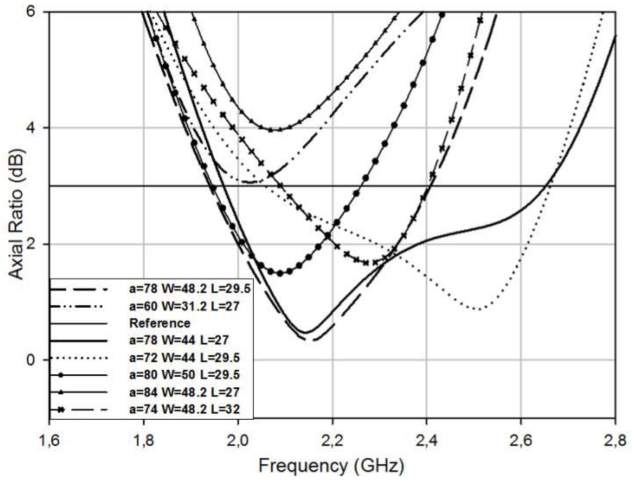

Figure-4. Axial ratio for seven combinations$\alpha, W$and L.

On the other hand, Figure-5 shows a reflection coefficient magnitude performance ($|S_{11}|$) for the same seven combinations of $\propto, L$ and W.

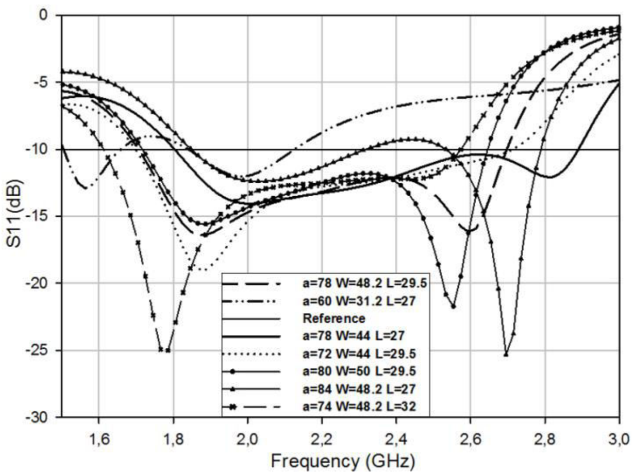

Figure-5. Reflection coefficient magnitude for seven combinations $\boldsymbol{\alpha}, \boldsymbol{W}$and $\boldsymbol{L}$.

To complete the analysis, is important to study the incidence of the internal radius (R) and width (W_r) dimensions of the central excitation ring. In this regard, Figure 6shows these two dimensions effect in the axial ratio, for ring widths $W_r = 1, 2, 3\ mm$ and internal ring radio= $4, 5, 6\ mm$, keeping dimensions of the remaining variables in $\alpha = 78°$, $L = 27\ mm$ and $W = 44\ mm$, W_r is changed setting $R = 5$, when a width of the optimal ring is found in $W_r = 2$, R is changed to analyze the ring separation effect. Similarly, Figure-7 shows the reflection coefficient magnitude performance ($|S_{11}|$) forWr and$R$.

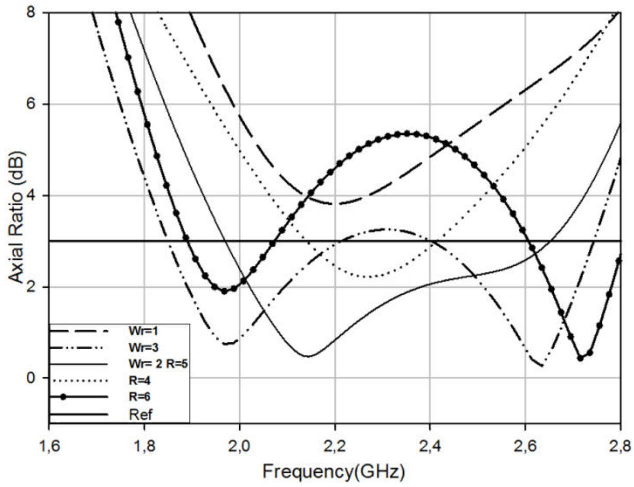

Figure-6. Axial ratio for Wr and R parametric.

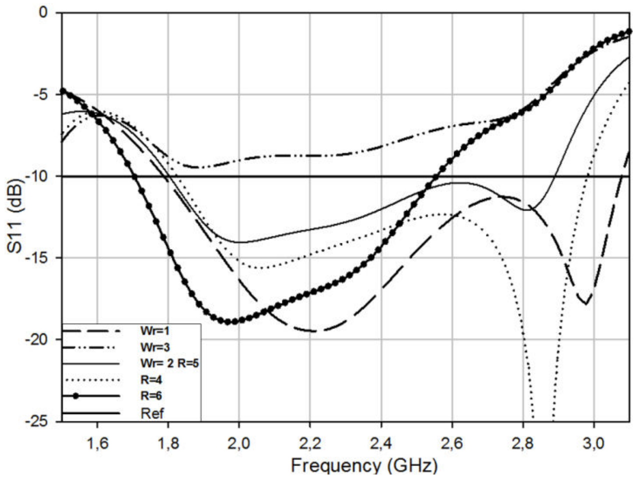

Figure-7. Reflection coefficient magnitude in function of Wr and R.

3. RESULTS

The constructed antenna is shown in Figure-8 and Figure-9, which shows the SMA connector, nylon screws and nuts used to support the suspended structure, the coaxial cable that is used as a balun, the radiant patch of $57 \times 57\ mm$on top and bottom faces and a copper ground plane with 0.5 mm thickness.

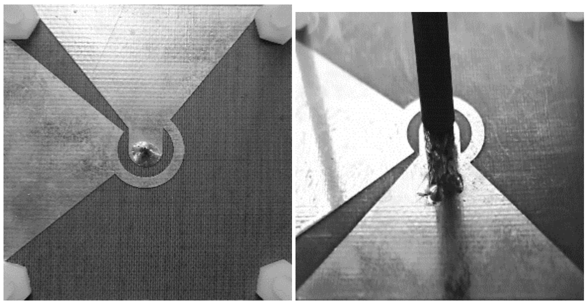

Figure-8. Top and bottom fabricated antenna view.

VOL. 14, NO. 9, MAY 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Figure-9. Side fabricated antenna view.

Characterization results of different measured and simulated antenna parameters are shown in Table-1 with its respective error percentage.

Table-1. Antenna results measured vs simulated.

Parameter	Measure	Simulation	% Error
BW1 (%)	42,34	46,11	8,181
G (dBi)	6,88	7,41	7,054
AR (%)	26,91	29,73	9,48

Based on this results, is observed that this antenna operates from $1.86GHz$ frequency to $2.86GHz$ corresponding to a reflection coefficient bandwidth of 42.34%. Results are shown in Figure-10.

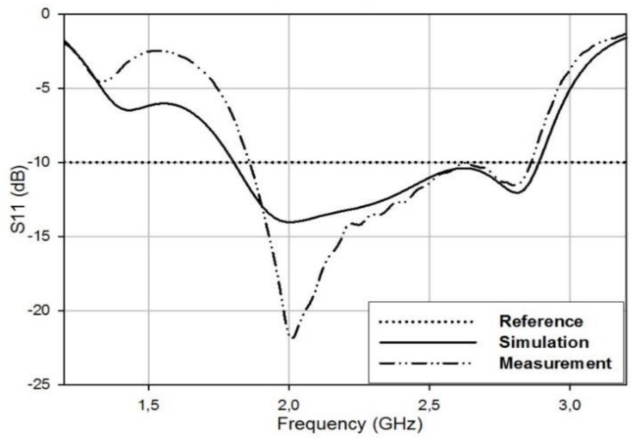

Figure-10. Reflection coefficient measured vs simulated.

The2D radiation pattern is shown in Figure-11, this antenna has high directivity, it is good for DOA systems because all RF energy is concentrated in a particular direction, allowing a greater reach.

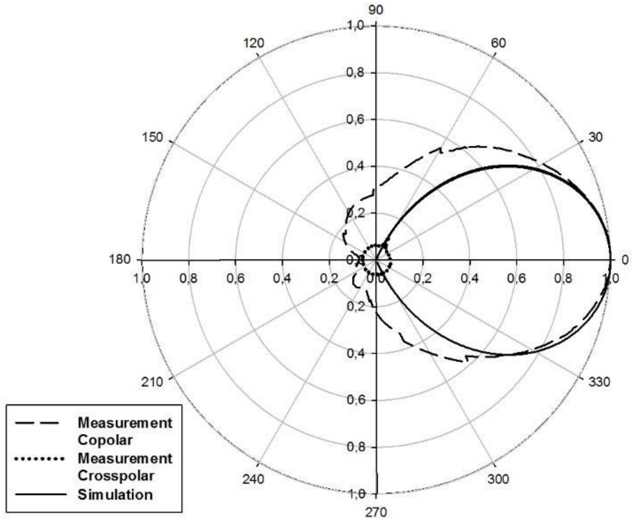

Figure-11. 2D Radiation Pattern measured vs simulated.

The gain diagram is shown in Figure-12, the highest gain peak represents a 6.88 dBi gain at 2.1 GHz and a gain value greater than 4 dBi is observed for a40% bandwidth from 1.74GHz to 2.62GHz, with a tendency in approximately 6.3 dBi. The measurement presents a 7% error when compared tothe simulation results.

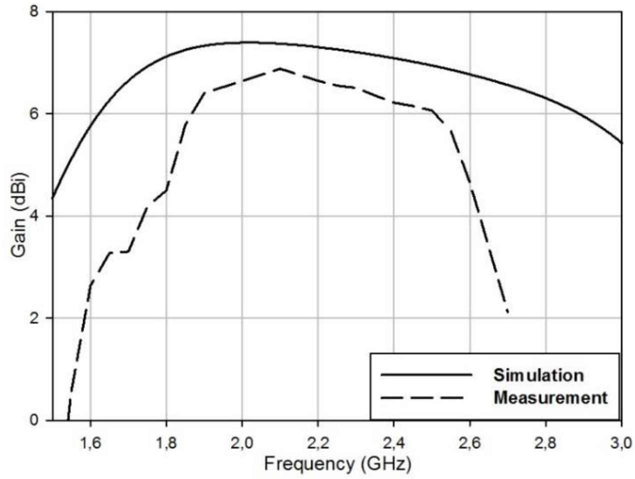

Figure-12. Gain measure vs simulation.

The measured and the simulated axial ratio is shown in Figure-13, results show a 9% error respect to the simulation, the axial ratio with $3dB$ reference corresponds to 26.51%, from 1.93 GHzfrequency to 2.53 GHz.

VOL. 14, NO. 9, MAY 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

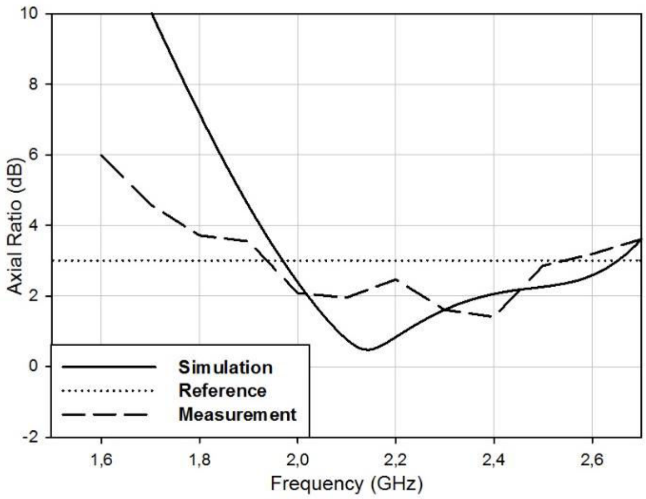

Figure-13. Axial Ratio measure vs simulation.

4. CONCLUSIONS

A RHCP Bow-Tie dipole microstrip antenna design featuring $72x72x25\ mm$ size, 42.34% reflectioncoefficient bandwidth and 26.91% axial ratio with a $6.88\ dBi$maximum gain was presented, it operates in 1.86 GHz to 2.86 GHz frequency band.

Proposed antenna is suitable for applications of direction of arrival for its characteristics in radiation, gain response, frequency operation, size and bandwidth in adaptation and axial ratio.

ACKNOWLEDGEMENTS

This investigation makes part of DOA antenna array project. The authors wish to thank and acknowledge Colciencias and Universidad Distrital Francisco José de Caldas for the economic support on this investigation and for encourage investigation in Colombia.

REFERENCES

[1] Nabila H., Suryana J., Izzuddin A. 2017. Modified half bowtie antenna for direction finding. 11th International Conference on Telecommunication Systems Services and Applications (TSSA).

[2] Cheng S., Lee K. 2012. Reducing the Array Size for DOA Estimation by an Antenna Mode Switch Technique. Progress in Electromagnetics Research. 131: 117-134.

[3] Gripp T., Fabiani B., Silveira E., Nascimento D. 2017. Design of a microstrip antenna array with polarization diversity for DoA application. IEEE International Microwave and Optoelectronics Conference (IMOC).

[4] Chandran S. 2006. Advances in Direction of Arrival Estimation. Artech House. pp. 3-18.

[5] Bolster M., September 1961. A New Type of Circular Polarizer Using Crossed Dipoles. IRE Transactions on Microwave Theory and Techniques. 9: 385-388.

[6] ESuárez C., Martín C., Puerto G. 2016. Short-circuited patch antenna with circular polarization and reconfigurable sense of rotation for small-sized satellite application. Información Tecnológica [online]. 28(6): 125-132.

[7] Suárez C., Méndez D., Pineda A., Puerto G. 2016. Patch antenna with reconfigurable sense of rotation for CubeSat satellite applications. Dyna rev.fac.nac.minas [online]. 83(199): 157-164.

[8] Chowdhury R., Kumar R. 2018. Investigation on Different Forms of Circular Sectored-Dielectric Resonator Antenna for Improvement in Circular Polarization Performance. IEEE Transactions on Antennas and Propagation.

[9] Huo X., Wang J., Li Z., Li Y., Chen M., Zhang Z. 2018. Periodic Leaky-Wave Antenna with Circular Polarization and Low-SLL Properties. IEEE Antennas and Propagation Letters. 17: 1195-1198.

[10] Tran H., Xuat S., Park I. 2014. Single-Feed, Wideband, Circularly Polarized, Crossed Bowtie Dipole Antenna for Global Navigation Satellite Systems. Journal of Electromagnetic Engineering and Science. 14: 299-305.

[11] Suárez C. 2017. Fundamentals for analysis and design of antenna arrays. Universidad Distrital Francisco José de Caldas.

[12] S. Lucyszyn. 2006. Frequency Spectrum and Applications. Radio frequency electronics, Imperial College London.

[13] Durgun A., Balanis C., Birtcher C., Allee D. 2011. Design, Simulation, Fabrication and Testing of Flexible Bow-Tie Antennas. IEEE Transactions on Antennas and Propagation. 59: 4425-4435.

[14] Balanis C. 2016. Antenna Theory: Analysis and Design. Wiley & Sons. pp. 492-496.

[15] Rakibul M. 2017. Study and implementation of wideband bow-tie antennas. Ms. Science Theses, Georgia Southern University, Georgia.