

Conception of Bi-band Rectangular Microstrip Array Antenna

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Abstract— Narrow band is the major inconvenient of the microstrip antenna. However, various multiband techniques are proposed towards several applications. A simple configuration of the rectangular microstrip antenna allows operating a system of satellite communication in two bands. The configuration consists of a single radiant element and substrate with low dielectric constant. The antenna is fed by a micro-strip line attached in the corner of the patch. This antenna covers two bands, the K and Ku bands, simultaneously. With the same parameters as simple antenna, other shapes are compared with rectangular array antenna, to improve the performances of the antenna and vary their operating frequencies. The designated configurations of the antenna arrays contain 2, 4 and 8 radiating elements.

Index terms— Rectangular microstrip antenna, antenna array, corner fed, dual-band.

I. INTRODUCTION

Recently, the modern telecommunications has been using devices covering two or more frequency bands simultaneously. Indeed, microstrips antennas that allow to guarantee this request must have more or less complex configurations. However, the antennas arrays offer a major interest to improve and change the performances of the single antenna [1-4].

The conception of dual-band microstrips antennas uses various feeding techniques. However, other configurations, such as aperture, U-shape and shorting pines are also used [1-6]. Techniques used to increase the bandwidth are also valid to reach a functioning in dual-band [1-2]. Thus, for multilayer configurations, the electromagnetic coupling or the coupling by crack, with adjustment of the air gap, can be used to operate the antenna in double band [7-9]. Hybrid configurations by connecting a circular antenna to a waveguide were conceived for a functioning in double band [8-9]. Moreover, novel microstrip antennas are described for this type of functioning [10-12].

In this paper, the rectangular patch antenna operate in Ku and K bands, whose the intervals of frequency, respectively, [12 -18] GHz and [18 -28] GHz. The designed configurations are formed by

single patch (antenna 1), two patches (antenna 2), four patches (antenna 3) and eight patches (antenna 4).

II. ANTENNA ARRAYS CONFIGURATIONS

Many theoretical studies on antenna arrays have been published [2-5]. Linear arrays antenna is the basic configuration, can be applied to planar arrays. Each element is an electric or magnetic current source, which gives rise to a radiated field, the solution to Maxwell's equations [3].

Arrays of antennas are used to direct radiated power towards a desired angular sectors. The number, geometrical arrangement and relative amplitude and phases of the array elements depend on the angular pattern that must be achieved. The most basic property of the array is that the relative displacements of the antenna elements with respect to each other introduce relative phase shifts in the radiation vectors, which can then add constructively in some directions or destructively in others [4].

By definition, the radiation vector is the three-dimensional Fourier transform of the current density,

$$F(k) = \int J(r') e^{jk \cdot r'} d^3r' \quad (1)$$

Thus, the radiation vector of the translated current will be:

$$F_d = \int e^{jk \cdot r} J_d(r) d^3r = \int e^{jk \cdot (r'+d)} J(r') d^3r' = e^{jk \cdot d} F \quad (2)$$

d is a distance between elements as shown in Fig. 1,

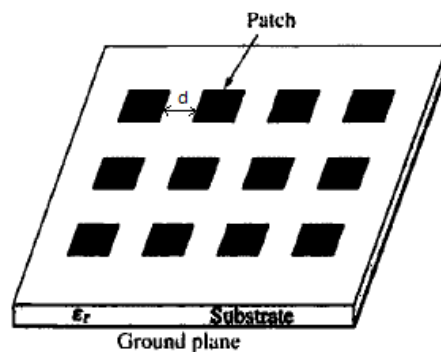


Fig. 1. Array configuration (two-dimensional array)

A single-element is usually not enough to achieve technical needs. That happens because its performance is limited. A set of discrete element, which constitute an antenna array. The geometry and type of element characterize an antenna array. For simplicity, implementation and fabrication reason, the elements are chosen in such a way so as to be identical and parallel. For the same reason, uniformly spaced linear array are mostly encountered in practice [13].

The proposed structure is simulated using Ansoft HFSS. A single layer corner fed rectangular microstrip antenna for dual band has been developed [14]. Corner fed micro-strip array antennas are proposed. First the dimensions of the patch and the feed line are to be determined and the feed line is to be placed properly to resonate at Ku band only.

This paper proposes the microstrip antenna double band with the same size of the microstrip antenna working in Ku band. The geometry of the rectangular microstrip antenna dual-band is showed on the Fig. 2. The dimensions of the rectangular radiating element are (7.46×6.54) mm². The substrate is in Arlon DiClad 880 of dielectric constant $\epsilon_r = 2.2$ and thickness equal to 0.508 mm.

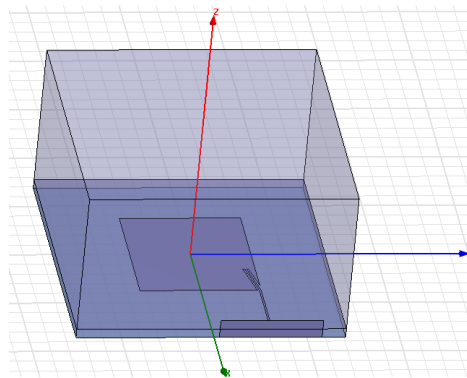


Fig 2. Configuration of a microstrip antenna dual-band (antenna 1)

Recently, the antennas arrays have been widely used to multiply the performances of the simple antennas in diverse domains such as the wireless communication, where the antenna array allows covering cellular communication coverage, also in the satellite systems [15-17]. The simple structure of microstrip antenna, previously, was used to form three configurations of antennas with 2 patches, with 4 patches and with 8 patches.

The novel configurations of microstrips antennas dual-band with 2 patches (antenna 2), 4 patches (antenna 3) and 8 patches (antenna 4) is shown on Fig. 3 to Fig. 5.

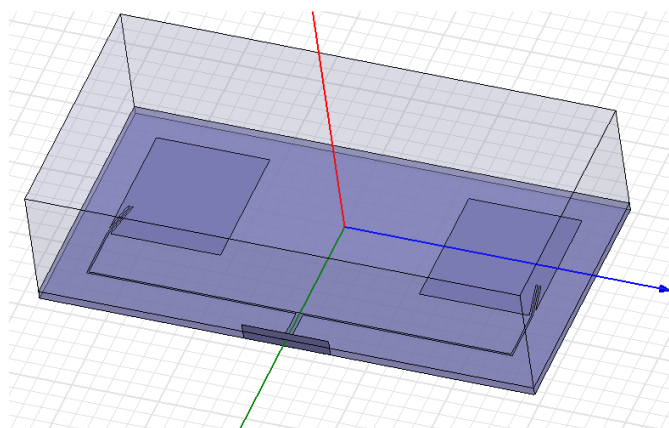


Fig. 3. Microstrip antenna with 2 patches (antenna 2)

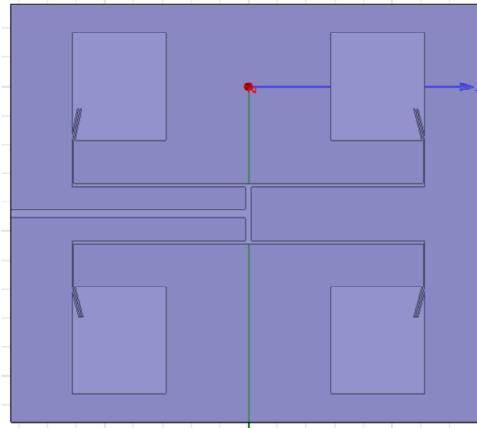


Fig. 4. Microstrip antenna with 4 patches (antenna 3)

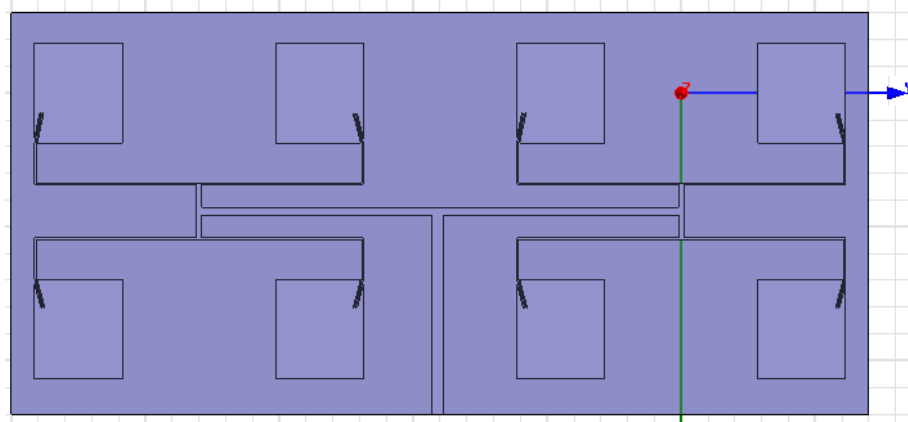


Fig. 5. Microstrip antenna with 8 patches (antenna 4)

III. RESULTS AND DISCUSSION

The feeding technique of a rectangular microstrip antenna through the corner of the patch, as shows Fig. 6, allows a functioning in double band. So, the position and the width of the microstrip line influence the performances of the antenna.

The line position (see Fig. 6) on the patch is indicated by dx and dy coordinates. These positions are determined by repetitive simulation of various positions. On every position, we fix one of the coordinates and we vary the other one. On Fig. 7 and Fig. 8, the variation of S parameter according to the frequency by fixing dy and on the Fig. 9 and Fig. 10 the variation of S parameter according to the frequency by fixing dx are shown.

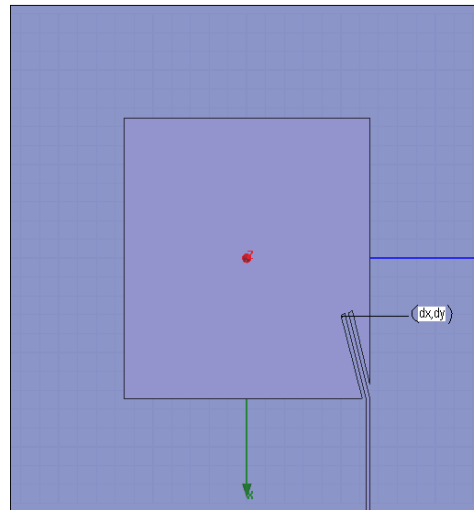


Fig. 6. Feeding technique of dual-band antenna

On the K band (Fig. 7), the best position of the feed line is the position equal to $dx=1.5$ mm, the return loss equal to 25 dB, compared with other positions. The results (see Fig. 8) of the positions $dx=1.5$ mm and $dx=2$ mm are better on the Ku band. However, considering the results on the K band, the return loss in the position $dx=1.5$ mm reached the minimum. Indeed, this position offers on the Ku band two frequencies with a return loss affected up to 20 dB.

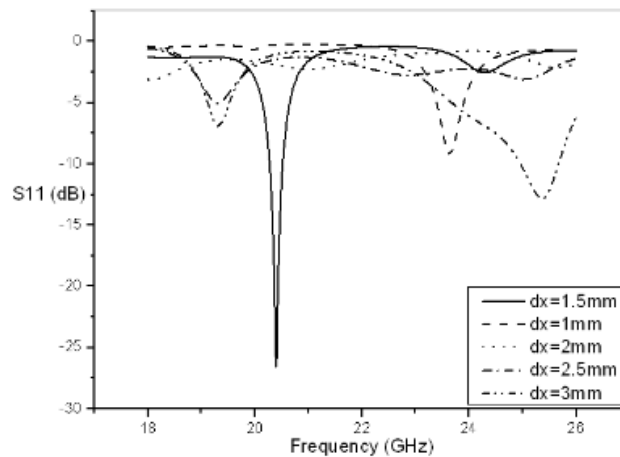


Fig. 7. Variation of S_{11} according to the frequency on the K band with $dy=2.6$ mm

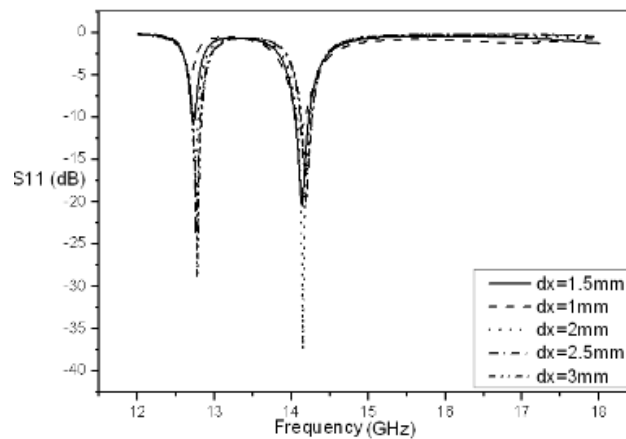


Fig. 8. Variation of S_{11} according to the frequency on the Ku band with $dy=2.6$ mm

Most of the energy was absorbed by the antenna in position $dy=2.5$ mm (Fig. 9 and Fig. 10). The return loss is approximately equal to 35 dB. So, the orderly 2.5 mm communicates the best results compared with the other positions and on the dual-band.

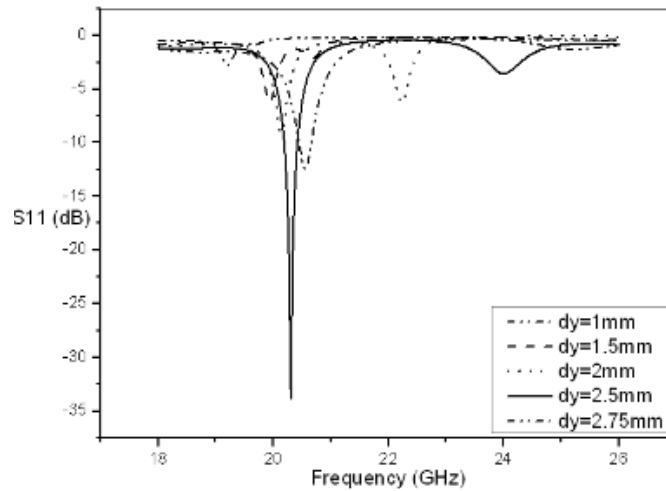


Fig. 9. Variation of S_{11} according to frequency on the Ku band with $dx=1.52$ mm

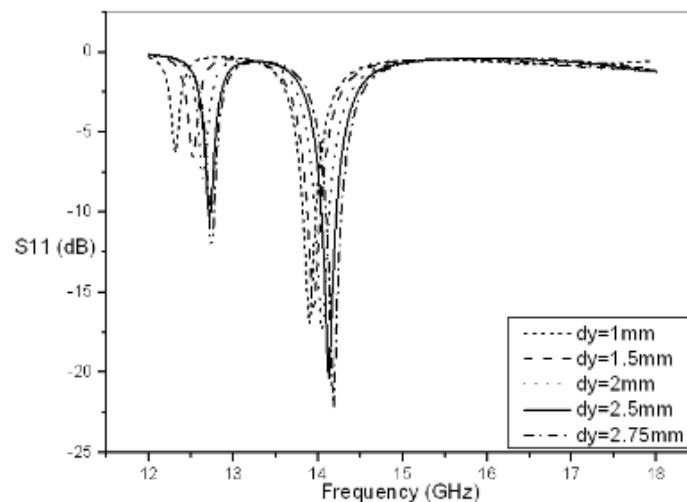


Fig. 10. Variation of S_{11} according to frequency on the K band with $dx=1.52$ mm

In conclusion, the best results on the K and Ku bands are obtained by fixing the values of dx at 1.5 mm and dy at 2.6 mm. Fig. 21 shows the radiation patterns of antenna 1. It is observed that the radiation pattern of antenna 1 on the K band shows end-fire radiation and on the Ku band, radiation shows the broadside radiation.

Other shapes are studied, the circular sector and triangular microstrip antennas. We change the shape of the patch but all other parameters are the same as found in literature antennas [14]. The gain is increased by changing the shape of the patch. Table I, II and III present a comparison between different shapes of patch antenna.

3.1. RESULTS FOR SINGLE PATCH

We added the circular sector and triangular antenna as shown in Fig. 11. Fig. 12. shows the simulated return loss for triangular and circular sector microstrip antennas.

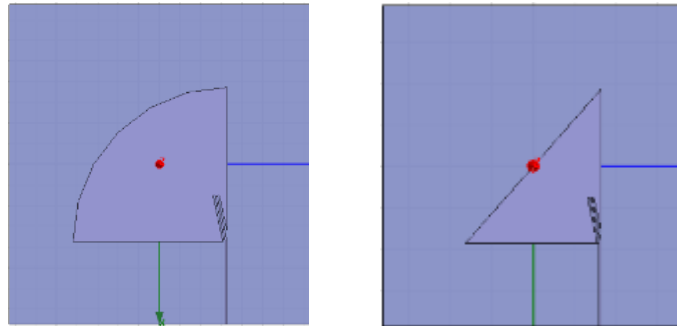


Fig. 11. Circular sector and triangular patches antenna

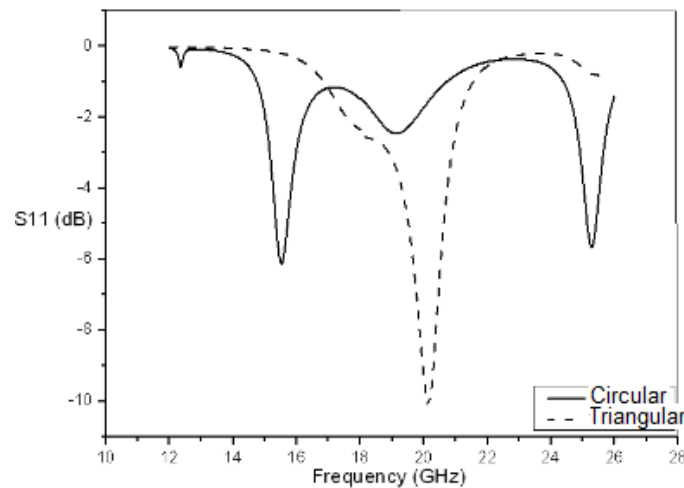


Fig. 12. Variation of S_{11} according to frequency for circular sector and triangular antenna

Table I: Result of different shape of single antenna

	Triangular antenna	Circular antenna	
Resonance frequency (GHz)	20,13	15,52	25,29
Return loss (dB)	-10,1	-6,12	-5,65
Total Gain (dB)	3	6	

3.2. RESULTS FOR 1×2 ARRAY

The antenna 2 is designed from the antenna 1. The configuration of this antenna (see Fig. 3) contains two similar patches outstripped at a distance equal to 18 mm. The result of simulation in the Ku and K bands and comparison between different shapes are represented on Fig. 13. The radiation patterns are shown in the Fig. 22.

From Fig. 14 and the result shown in Table II, adding the other patch increase the bandwidth of frequencies on both band and the circular sector micro-strip antenna improve the gain of antenna. Thereby, it causes a change in the radiation of the antenna. On K band, the radiation pattern shows the broadside radiation characteristic.

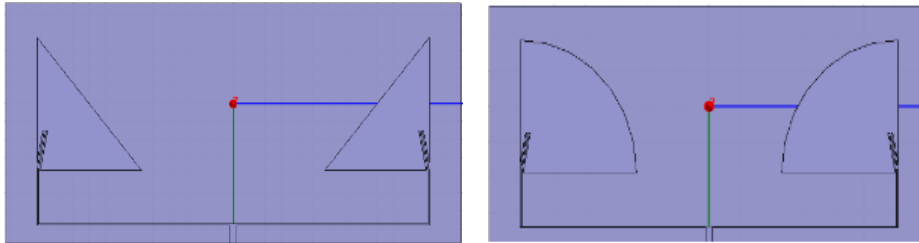


Fig. 13. Triangular and circular sector patches antenna

Table II. Result of different shape with two patches

	Rectangular antenna		Triangular antenna	Circular antenna		
Resonance frequency (GHz)	12,78	14,44	19,05	20,02	15,49	23,81
Return loss (dB)	-27,44	-15,1	-23,7	-22,61	-8,29	-20,17
Total Gain (dB)	2		2	6		

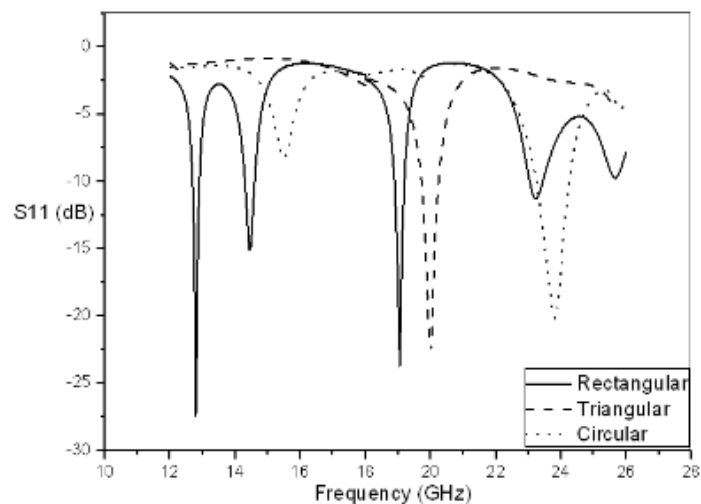


Fig. 14. Variation of S_{11} according to frequency for antenna 2 and comparison to circular sector and triangular antenna

3.3. RESULTS FOR 2×2 ARRAY

Four elements arrays (antenna 3) are fed by one port by the microstrip line. However, the position of four similar patches is in the form of a matrix of 2×2 (see Fig. 4 and Fig. 15). The results of software HFSS, on both bands, are presented in Fig. 16. The radiation patterns on each resonant frequencies of the antenna 3 are shown in Fig. 23. At all resonant frequencies, the radiation patterns show broadside radiation characteristic.

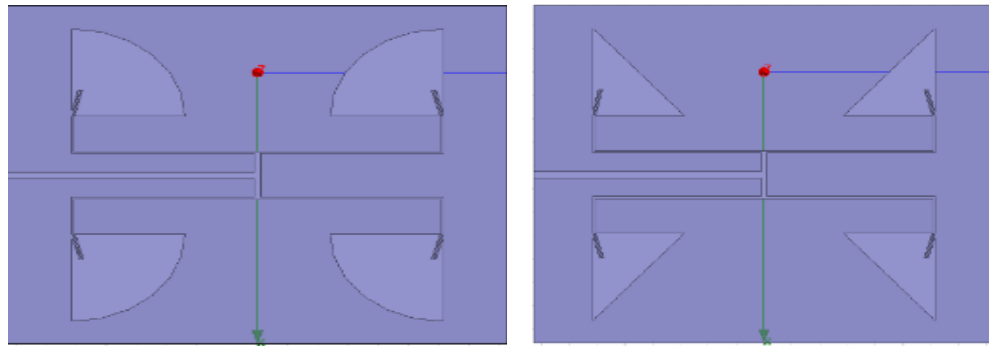


Fig. 15. Circular sector and triangular patches antenna

Table III. Result of different shape with four patches

	Rectangular antenna			Triangular antenna			Circular antenna			
Resonance frequency (GHz)	12,66	20,26	24,7	12,9	18,96	20,26	25,43	12,6	16,36	19,77
Return loss (dB)	-14,55	-23,45	-15,68	-10,76	-14,27	-15,81	-19,17	-9,7	-11,11	-9,48
Total Gain (dB)	5			3			10			

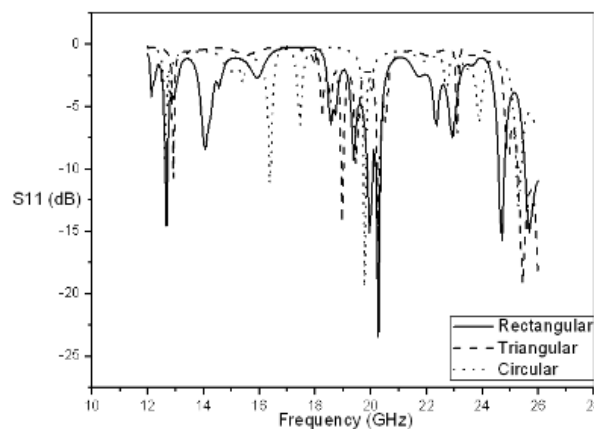


Fig. 16. Variation of S_{11} according to frequency for antenna 3 and comparison to circular sector and triangular antenna

3.4. RESULTS FOR 4x2 ARRAY

The last configuration consists of 8-elements (antenna 4) of the same size. The rectangular and circular sector microstrip array antenna with eight elements is shown in Fig. 5 and Fig. 17. The result of simulation by HFSS is shown in Fig.18 and Fig. 19. For antenna 4, the result radiation is steered the end-fire to broadside (see Fig. 20).

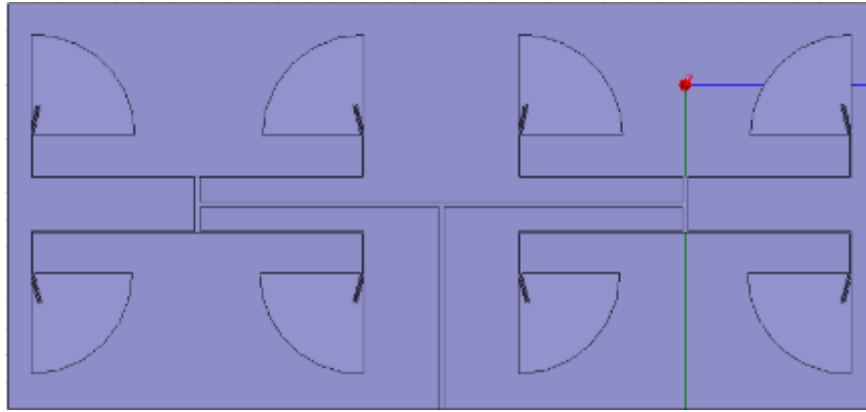


Fig. 17. Circular sector array microstrip antenna

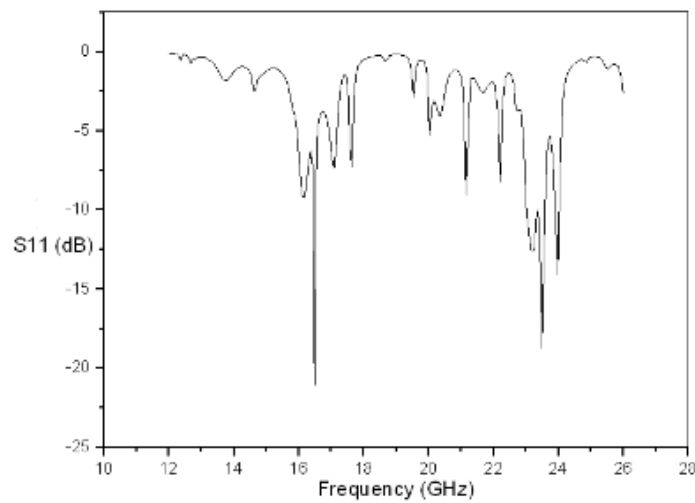


Fig. 18. Variation of S parameter according to frequency of circular sector microstrip antenna

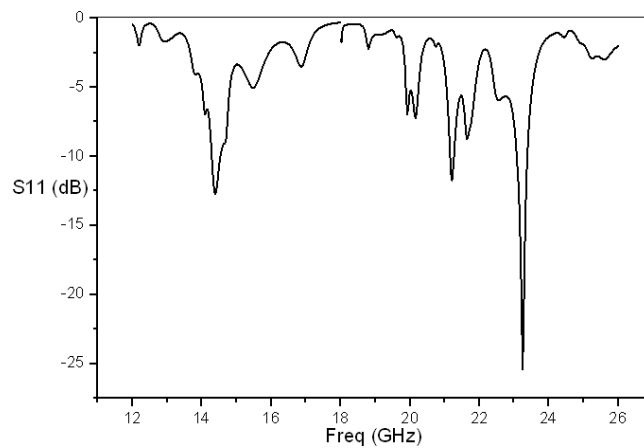


Fig. 19. Variation of S parameter according to frequency of antenna 4

The frequencies of the proposed antennas are generated in the range of frequencies of the K band from 12 GHz to 18 GHz and the Ku band from 18 GHz to 26 GHz. The variation of S parameter according to the frequency, to the antenna 1, shows the functioning on the K and Ku bands simultaneously (see figures from Fig.7 to Fig. 10).

The variation of return loss shows the resonant frequencies of antenna 4. It is observed an increase of bandwidth for all resonant frequencies and gain reaches 10dB for circular sector microstrip antenna. Radiation patterns of all the proposed antennas are simulated using Ansoft HFSS at their resonating frequencies. The radiation patterns in the E-plane (E_θ is the $\varphi = 0^\circ$ plane) and the H-plane (E_φ is the $\varphi = 90^\circ$ plane) of the rectangular microstrip antenna arrays at all resonant frequencies are shown in Fig. 21, Fig. 22, Fig. 23 and Fig. 24. It is observed that the radiation characteristic of all proposed antennas is improved as multi-directional radiation to unidirectional. However, from Fig. 24 the radiation patterns of all frequencies of Ku and K bands of antenna 4 are situated in one side.

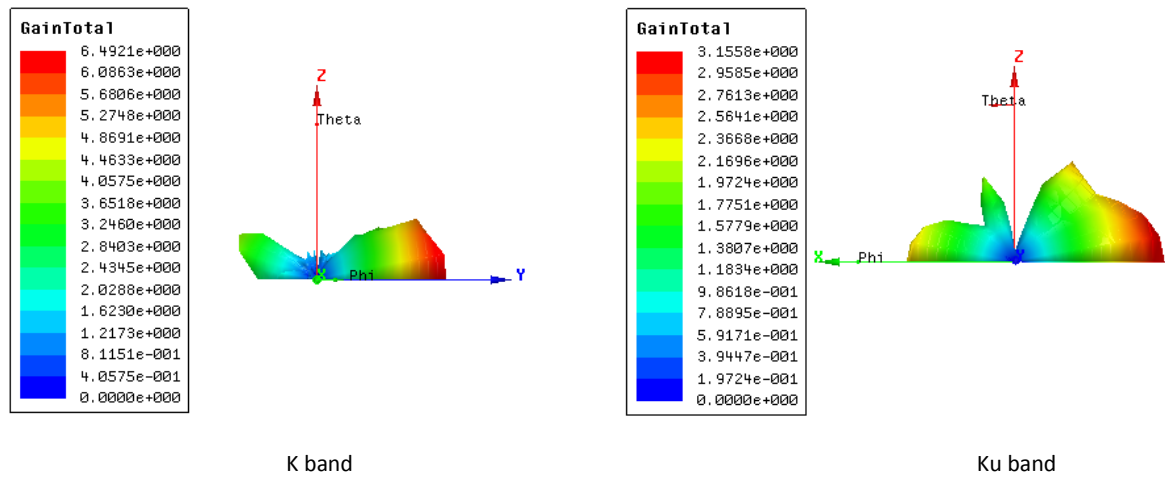


Fig. 20. 3D Radiation patterns of antenna 4

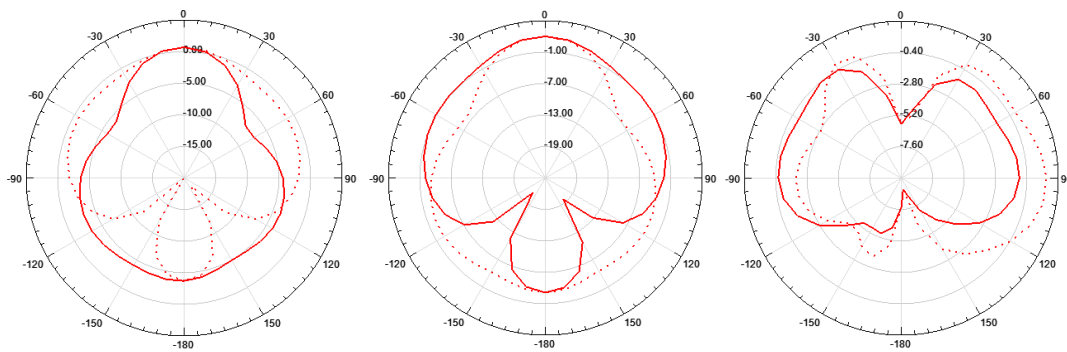


Fig. 21. Radiation patterns of antenna 1 in resonance frequencies: — E-plane, --- H-plane

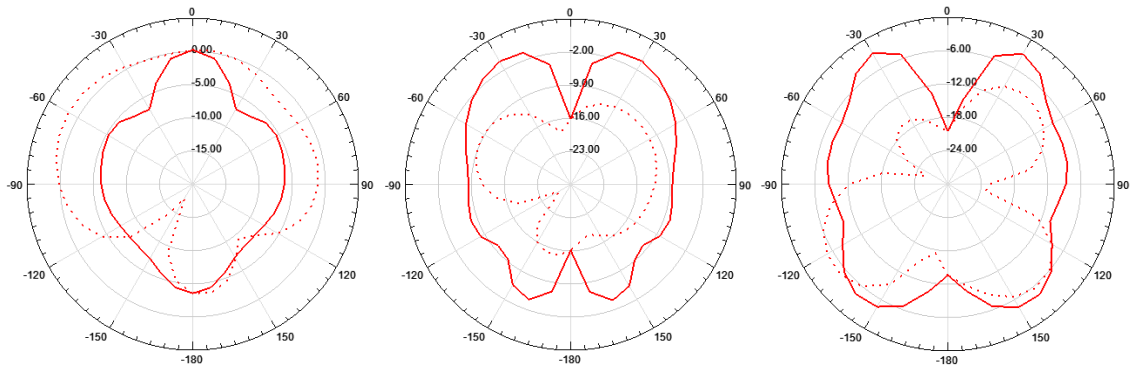


Fig. 22. Radiation pattern of antenna 2 in resonance frequencies: — E-plane, ----H-plane

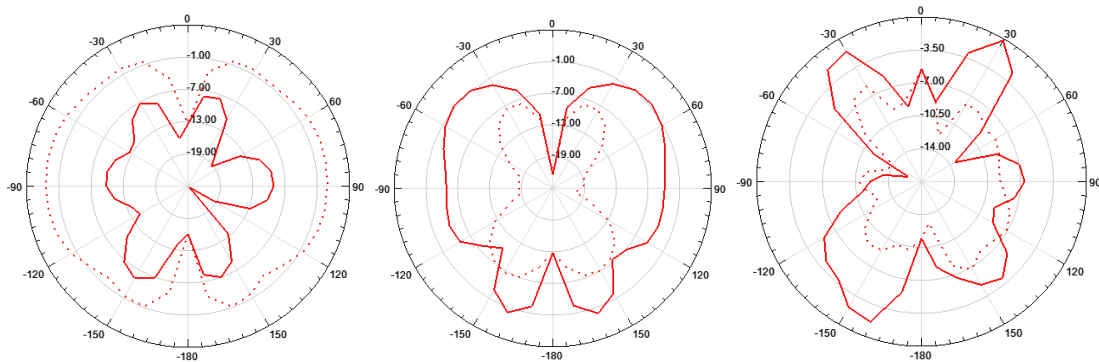


Fig. 23. Radiation pattern of antenna 3 in resonance frequencies : — E-plane, ----H-plane

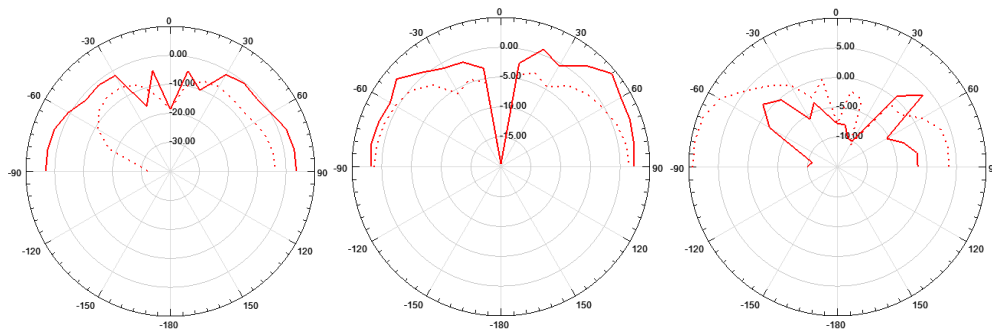


Fig. 24. Radiation patterns of antenna 4 in resonance frequencies: — E-plane , ----H-plane

IV. CONCLUSION

The new configurations proposed the antennas arrays, based on the configuration of the corner fed rectangular antenna, operate on double band. These antennas are miniature and compact, their integration in the satellite communication systems will be easier and more important. Indeed, this result will be taken advantage of by the satellite systems needing a functioning multi-band. Each configuration has its own operation and its advantages over others. More can be achieved by adding another radiating element. Another shape, triangular and circular, improves the operation of the antenna in both bands. The circular sector microstrip antenna is better than other forms. This diversity

demonstrates the ability of microstrip antennas to adapt to all applications by varying feeding techniques and design of radiation element.

REFERENCES

- [1] K. Girish, and K. P Ray, "Broadband Microstrip Antennas", *Artech House antennas and propagation library*, 2003.
- [2] C. Zhi Ning, and Y. W. C. Michael, "Broadband Planar Antennas: Design and Applications", *Institute for Infocomm Research*, Singapore, 2006.
- [3] L. Josefsson, P. Persson, "Conformal array antenna theory and design", *IEEE Antennas and Propagation Society*, Sponsor, pp. 15-40, 2006.
- [4] S. J. Orfanidis, D. Ramaccia, and A. Toscano, "Electromagnetic waves and antennas", *Dept of Electrical and Computer Engineering*, Rutgers University, Piscataway, NJ 08854.
- [5] J. R. James, and P. S. Hall, "Handbook of Microstrip Antennas", *IEE Electromagnetic waves serie 28*, 1989.
- [6] W. Ren, "Compact dual-band slot antenna for 2.4/5 GHz WLAN application," *Progress In Electromagnetics Research B*, vol. 8, pp. 319-327, 2008.
- [7] K. S. Ruy, and A. A. Kishk., "A dual-polarized shorted microstrip patch antenna for wideband application", *Dept of Electrical Engineering*, the University of Mississippi, MS 38677.
- [8] K. S. Vinod, and A. Zakir, "Dual band U-shap microstrip antenna for wireless communication", *International Journal of Engineering Science and Technology*, vol. 2, pp. 1623-1628, Jun. 2010.
- [9] D. M. Pozar, "A review of aperture coupled microstrip antennas: History, Operation, Development, and Applications," *Electrical and Computer Engineering*, University of Massachusetts at Amherst, May. 1996.
- [10] C. B. Smith., "Wideband Dual-Linear Polarized Microstrip Patch Antennas," *Texas A&M University*, Dec. 2008.
- [11] S. Bri, S. Zaakri, A. Nakhli, and A. mamouni, "Simulations of dual and broadband patch antenna," *European Journal of Scientific Research*, vol. 60, no. 2, pp. 237-249, 2011.
- [12] A. A. Abdelaziz, "Bandwith enhacement of microstrip antenna," *Progress In Electromagnetic Research*, PIER, pp. 311-317, 2006.
- [13] Sahalos, and N. John, "Orthogonal method for array synthesis: theory and the ORAMA computer tool", *Book publisher by John wiley & sons*, 2006.
- [14] M Wang., W. Wu, and D. G. Fang, "Uniplanar single corner-fed dual-band dual-polarization patch antenna array," *Progress in Electromagnetic Research letters*, vol. 30, pp. 41-48, 2012.
- [15] S. Goa, J. L. W. Li, and A. Sambell, "FDTD analysis of a dual frequency microstrip patch antenna," *Progress in Electromagnetics Research*, PIER, vol. 54, pp. 155-178, 2005.
- [16] Y. S. H. Khraisat, "Design of 4 element rectangular microstrip patch antenna with high gain for 2.4GHz applications," *Modern Applied Science*, vol. 6, no. 1, 2012.

- [17] G. Cakir, L. Sevgi, "Design, simulation and tests of a low cost microstrip patch antenna arrays for the wireless communication," *Turk j Elec Engin*, vol. 13, no. 1, 2005.