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Bi-band Rectangular Array Antenna

Zaakri Safa[1], **Zenkouar Lahbib**[2], **Bri Seddik**[3]

[1, 2] Electronic and Communication Laboratory, EMI, Mohammed V University, Rabat-Morocco
zaakrisafa@gmail.com, zenkouar@emi.ac.ma

[3] Material and Instrumentation Groups, High School of Technology, ESTM,Moulay Ismail University, Meknes - Morocco, briseddik@gmail.com

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 microstrip line attached in the corner of the patch. This antenna covers two bands, the K and Ku bands, simultaneously. With the same parameters as the simple antenna, antenna arrays were designed, to improve the performances of the antenna and vary their operating frequencies. The configurations of the antenna arrays contain 2, 4 and 8 radiating elements.

Keywords: Antenna array, dual-band, corner fed, rectangular microstrip antenna.

1. 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).

2. ANTENNA ARRAY 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:

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

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

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

d is a distance between elements as shown in Figure 1,

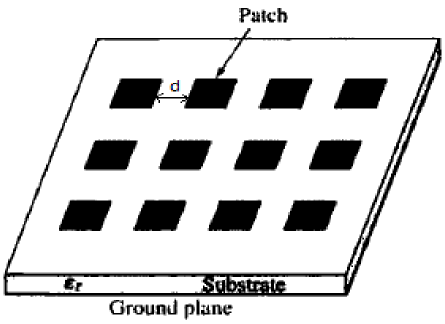

Figure 1: Array configuration (two-dimensional array)

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 microstrip 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 Figure 2. The dimensions of the rectangular radiating element are (7.46 × 6.54) mm^2. The substrate is in Arlon DiClad 880 of dielectric constant $\varepsilon_r = 2.2$ and thickness equal to 0.508 mm.

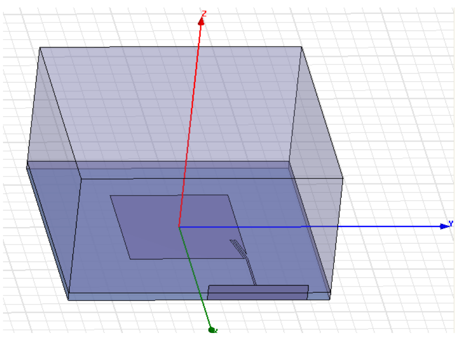

Figure 2: Configuration of a microstrip antenna dual-band(antenna 1)

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.

3. RESULTS AND DISCUSSION

The feeding technique of a rectangular microstrip antenna through the corner of the patch [13], as shows Figure 3, 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 Figure 3) 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 Figure 4 and Figure 5, the variation of S parameter according to the frequency by fixing dy and on the Figure 6 and Figure 7 the variation of S parameter according to the frequency by fixing dx are shown.

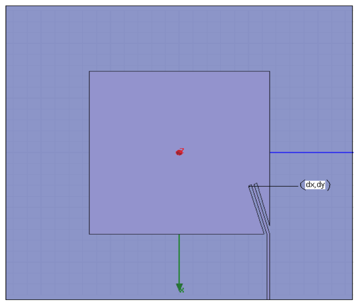

Figure 3: Feeding technique of dual-bande antenna

On the K band (on the Figure 4), 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 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.

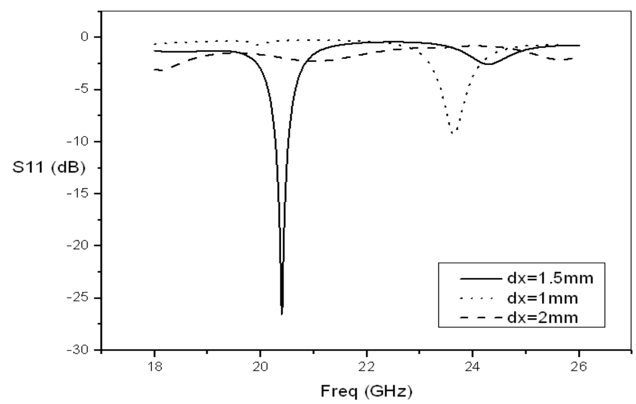

Figure 4: Variation of S_{11} according to the frequency on the K band with dy=2.6 mm

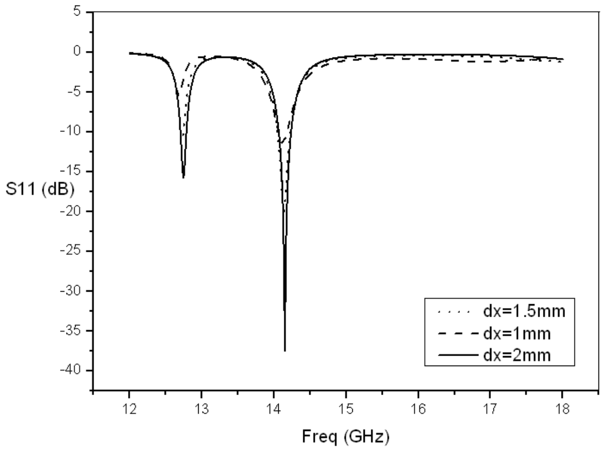

Figure 5: Variation of S_{11} according to the frequency on the Ku band with dy=2.6 mm

Most of the energy was absorbed by the antenna in position *dy*=2.5 mm (Figure 6 and Figure 7). The reflection coefficient 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.

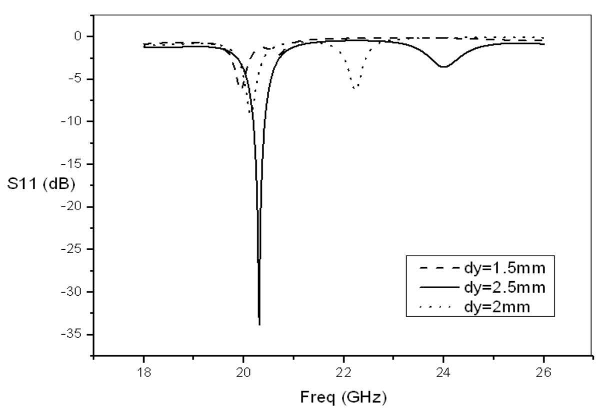

Figure 6: Variation of S_{11} according to frequency on the Ku band with dx=1.52 mm

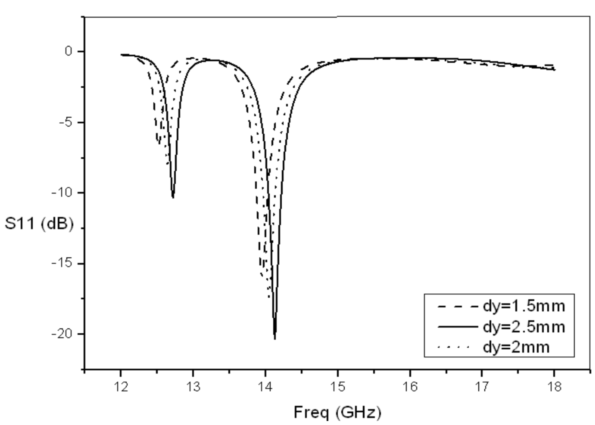

Figure 7: Variation of S_{11} according to frequency on the K band with dx=1.52 mm

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. 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. The antenna 2 is designed from the antenna 1. The configuration of this antenna contains two similar patches outstripped at a distance equal to 18 mm. The result of simulation in the Ku and K bands is represented on Figure 8. Adding the other patch increases the bandwidth of frequencies on K band. Thereby, it causes a change in the radiation of the antenna. On K band, at 14.4 GHz, the radiation pattern shows the broadside radiation characteristic.

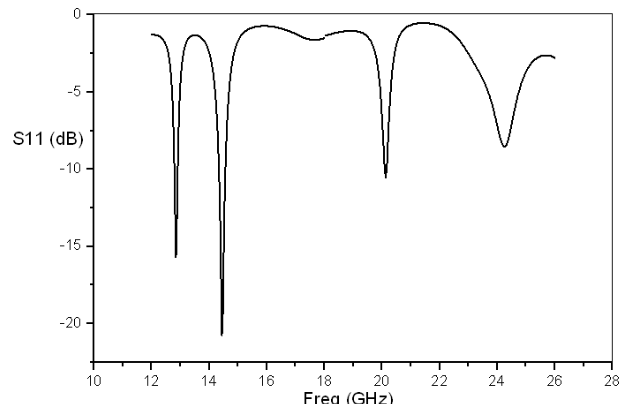

Figure 8: Variation of S_{11} according to frequency for antenna 2

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. The results of software HFSS, on both bands, are represented on Figure 9 and Figure 10. At all resonant frequencies, the radiation patterns show broadside radiation characteristic.

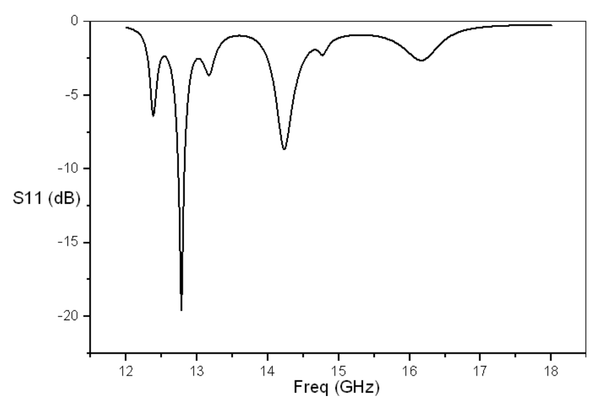

Figure 9: Variation of S_{11} according to frequency on band Ku for antenna 3

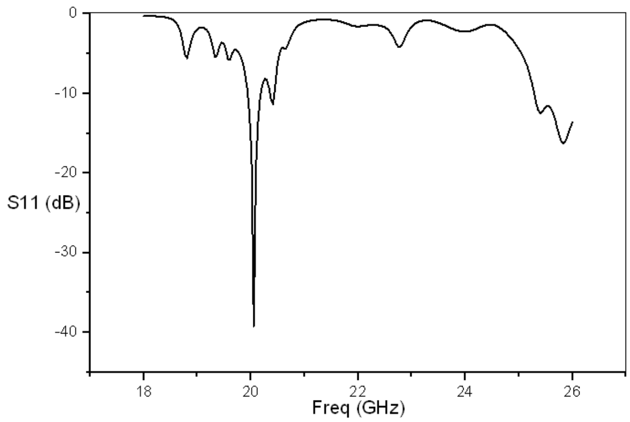

Figure 10: Variation of S11 according to frequency on band K for antenna 3

The last configuration consists of 8-elements (antenna 4) of the same size. For antenna 4, the variation S11 is represented in Figure 11.

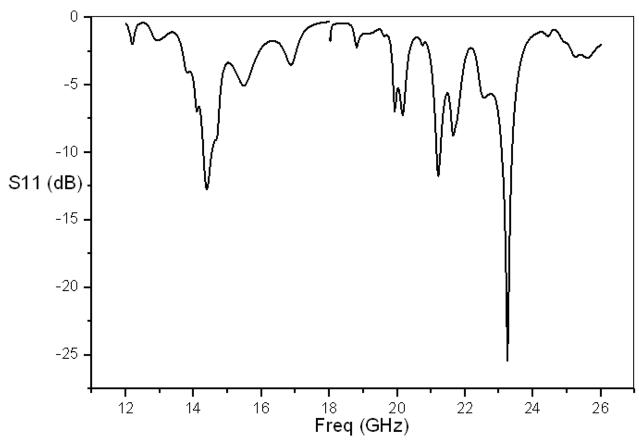

Figure 11: Variation of S parameter according to frequency of antenna 4

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 from18 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. The antenna 1 is resonating at two frequencies on the K band, 12.72 GHz and 14.16 GHz and the frequency 20.5 GHz on the Ku band. We integrate another patch on the same substrate. Antenna 2 formed by two patches allows increasing the bandwidth on the K band. The antenna 3 allows functioning in dual-band with two resonant frequencies, 12.77 GHz and 20.04 GHz with a respective bandwidth of 91.8 MHz and 270.5 MHz (see Table 1).

The variation of return loss shows the resonant frequencies of antenna 4. It is observed an increase of bandwidth for all resonant frequencies. 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 $\varphi = 0°$ plane) and the H-plane (E_φ is the $\varphi = 90°$ plane) of the rectangular microstrip antenna arrays at all resonant frequencies have proofed that this antenna presented the various resonant frequency. It is observed that the radiation characteristic of all proposed antennas is improved as multi-directional radiation to unidirectional. However, from Figure 12 the radiation patterns of all frequencies of Ku and K bands of antenna 4 are situated in one side.

Table 1: Simulations results

Antenna	Resonant frequency (GHz)	S Parameter (dB)	Bandwidth (MHz)
Antenna 1	12.72	-11.59	50.0
	14.16	-21.34	187.4
	20.5	-13.43	261.1
Antenna 2	12.84	-15.63	131.0
	14.44	-20.67	241.5
	20.13	-10.45	91.2
Antenna 3	12.77	-19.53	91.8
	14.22	-8.57	---
	20.04	-39.17	270.5
Antenna 4	14.36	-12.69	265.4
	21.2	-11.54	128.7
	23.24	-25.29	327.0

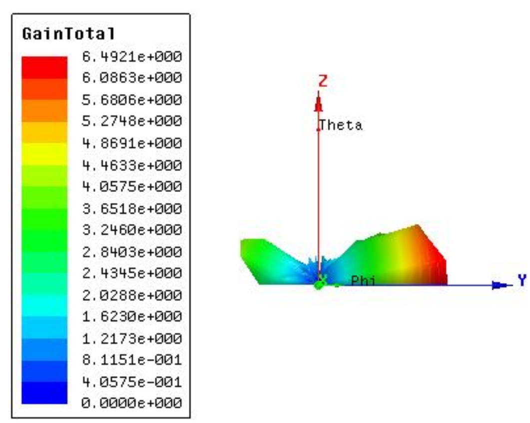

Figure 12.a: 3D Radiation patterns of antenna 4 in K band

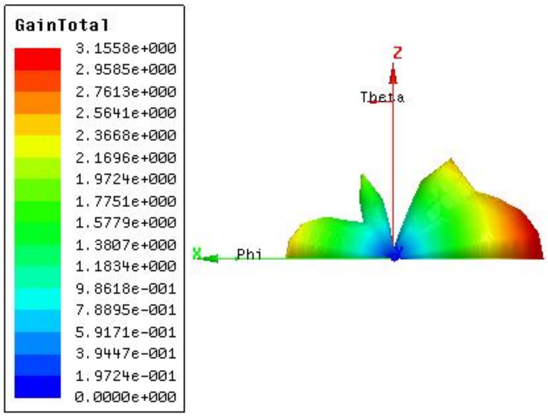

Figure 12.b: **3**D Radiation patterns on antenna 4 in Ku band

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

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