International Journal of Electrical and Computer Engineering (IJECE)
Vol. 7, No. 4, August 2017, pp. 1850~1857
ISSN: 2088-8708, DOI: 10.11591/ijece.v7i4.pp1850-1857

A New Design of a Wideband Miniature Antenna Array

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Article Info

Article history:

Received Nov 29, 2016
Revised Mar 27, 2017
Accepted Apr 11, 2017

Keyword:

Antenna array
Microstrip line
Patch antenna

ABSTRACT

In this work, we present a new configuration of a new miniature microstrip antenna array having a wide frequency band and with a circular polarization. The bandwidth is about 2GHz for a reflection coefficient under -10dB and centered on the ISM 'Industrial Scientific Medical' band at 5.8 GHz. To design such array, we have started the design by validating one antenna element at 10 GHz and after that by using the technique of defected ground, we have validated the antenna array in the frequency band [4 GHz -6 GHz] which will permit to miniature the dimensions. The final fabricated antenna array is mounted on an FR4 substrate, the whole area is 102.48 X 31.39 mm^2 with a gain of 5dBi at 4GHz.

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1. INTRODUCTION

Microstrip antennas have been more attractive in many fields such satellite communications and wireless applications. Among the advantages of planar antennas, we find their low profile, small size, light weight, low cost and ease of fabrication [1-6]. To feed such antennas, we have many simple techniques as microstrip-line and coaxial probe. These kinds of antennas are suitable for mobile devices and easy to integrate with active and passive microwave components. However, they have some disadvantages as the narrow bandwidth and low gain, by consequent, we have to think about a solution to increase the gain.

The use of antenna array [7-12] is one of the possible solutions permitting to get higher directivity and a pattern adjustment. One of the disadvantages of antenna array is the array area because of the association of many elements and the different microstrip lines network assuring the feeding of each antenna element. To resolve this problem many methods and techniques can be used as mentioned in [13-15].

In this paper we will present a new study on the design of a new miniature wideband antenna array with a circular polarization. The proposed array has the originality of its large frequency bandwidth and it is miniature in comparison with other antenna array studied in literature.

The different sections of this paper will be organized as follows:

a. The first section will discuss the design of the antenna element which will be used to define the final antenna array.
b. The second section will be about the different steps followed to design the antenna array with a discussion of the obtained simulation results.

2. ANTENNA ELEMENT DESIGN

To start the design of the antenna array, we have to define the antenna element which will be used in the array. The idea was to achieve an antenna element that functions in a high frequency band in order to have miniature dimensions of the final antenna and at the end we can insert this antenna in the array with an association of a technique permitting the shift of the frequency band to a low frequency bandwidth.

We have chosen to design an antenna at 10 GHz, in the same time we have applied a standard technique permitting the achievement of a circular antenna. The technique used is a method that eliminates the use of complex hybrid polarizer, which is very complicated to be used in antenna array. With a single patch antenna we can use a perturbation segment in the diagonal of the radiator to split the field into two orthogonal modes with equal magnitude and 90° phase shift [16-18].

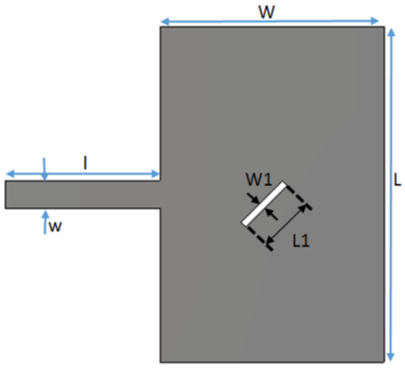


Figure 1. The proposed patch antenna element(L=9.12mm, W=6.1mm, l=4.21mm, w=0.75mm, W1=0.18mm, L1=1.6mm)

The configuration validated into simulation is presented in Fugure 1. The design is done by using CST-MW, the patch radiator is printed on an FR4 substrate having a thickness of 1.6mm, a loss tangent of 0.025 and a dielectric permittivity of 4.4. As shown in Figure 2, we have an antenna which functions around 10GHz with good matching input impedance and having a reflection coefficient under -40dB.

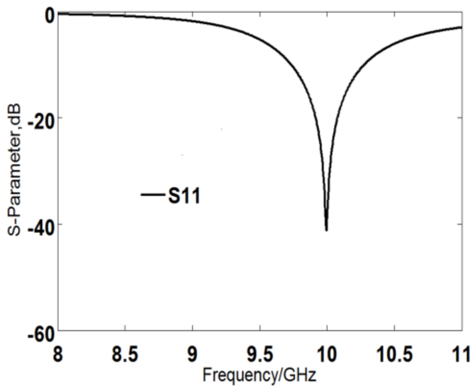
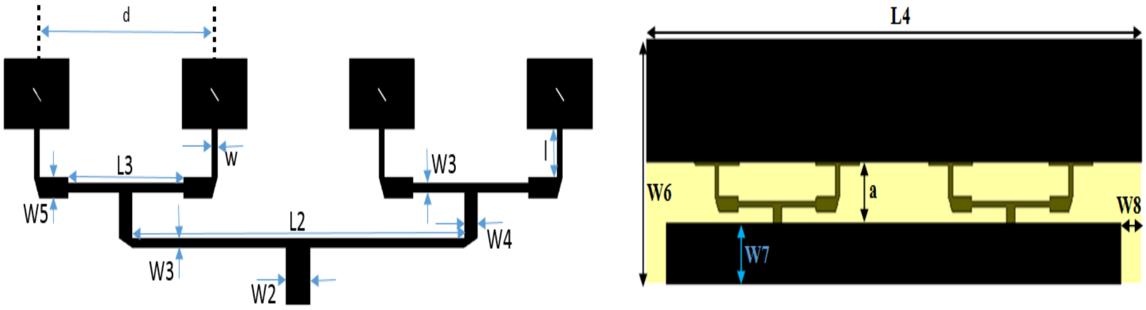


Figure 2. Reflection coefficient versus frequency

3. ANTENNA ARRAY DESIGN

After the validation of the patch element at 10 GHz, the idea was to construct the array by using this element and in the same time to shift the frequency band to a low frequency in order to miniature the final antenna array and to let the same performances in terms of matching input impedance, circular polarization with an increasing of gain and directivity. We have started to achieve the array by using microstrip lines and T-junction to feed each antenna element.

For the miniaturization of the array, we have used the technique of defected ground. In order to tune and to change the high bandwidth by a low one, we have used the optimization techniques integrated in CST-MW. The whole circuit is optimized and simulated taking into account a high meshing density. After many series of optimization and sweep we have reached the goal fixed by validating the proposed final antenna array structure depicted in Figure 3. This figure shows the top view of the array and the back view presenting the final structure of the optimized defected ground.



(a) Top View

(b) Back View

Figure 3. The proposed antenna array

The different optimized parameters of the final circuit are listed in Table 1.

Table 1. Dimensions of the proposed antenna array

Parameter	Value(mm)	Parameter	Value(mm)
l	4.21	W5	1.8
L2	46.6	W6	31.39
L3	16.2	W7	7.7
L4	102.48	W8	4
W2	3.38	d	24.96
W3	0.79	w	0.75
W4	1.8	a	8

The following Figure 4 demonstrates that the parameter a influences the matching input and the shift of frequency band. The final array has been validated into simulation permitting to have good matching input impedance along the frequency band [4 GHz -6 GHz] that presents a wide band with a reflection coefficient as illustrated in Figure 5, under -10dB.

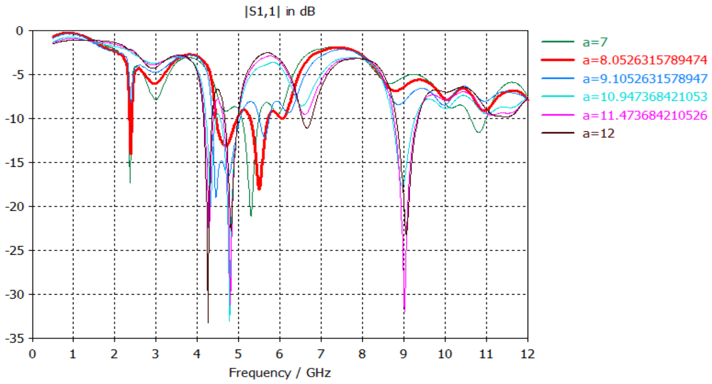


Figure 4. Variation of reflection coefficient versus frequency

After the validation of the reflection coefficient, Figure 6, presents the gain versus frequency. As we can see we have a maximum of gain around 7 dB at 4GHz and a decrease of gain outside the bandwidth.

In general, we have an acceptable gain for the array which can be more raised if we have a complete ground but in this study we are looking for an array miniature and wideband. Therefore the use of defected ground permitting to reach that has a little influenced the level of antenna array gain.

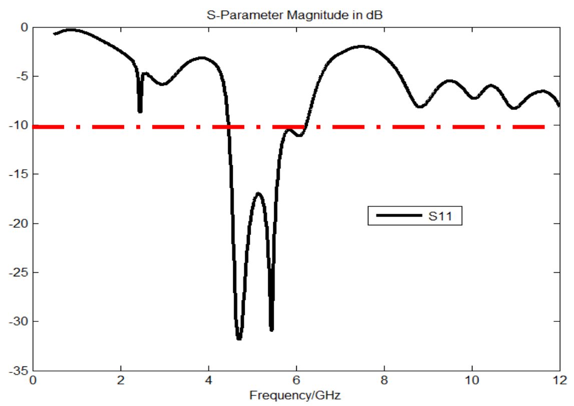


Figure 5. Variation of reflection coefficient versus frequency

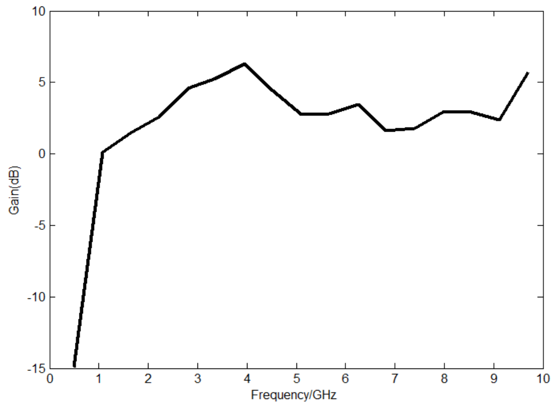
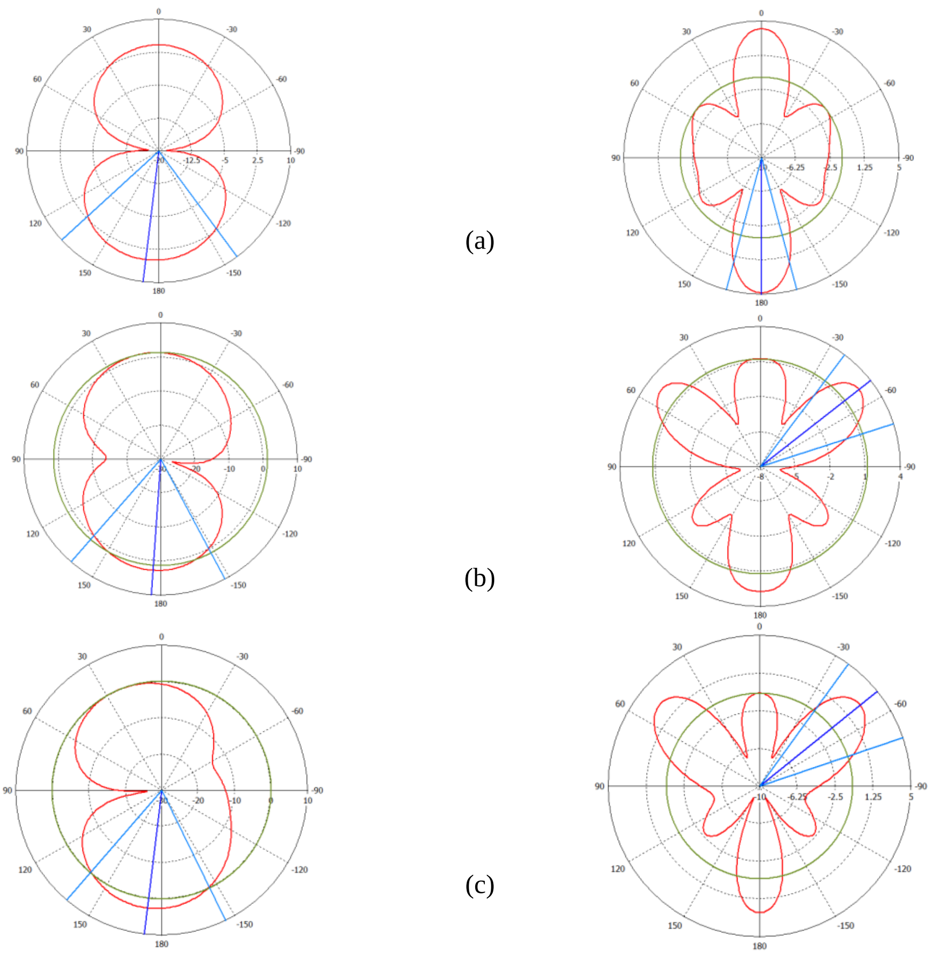


Figure 6. The antenna array gain versus frequency

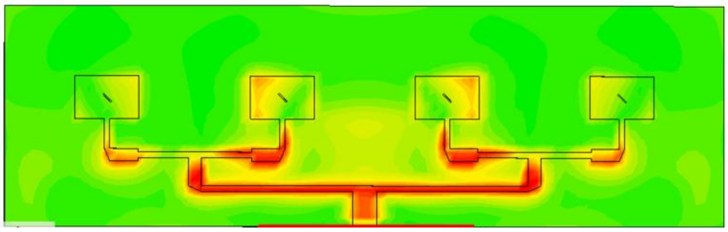


E Plane H Plane

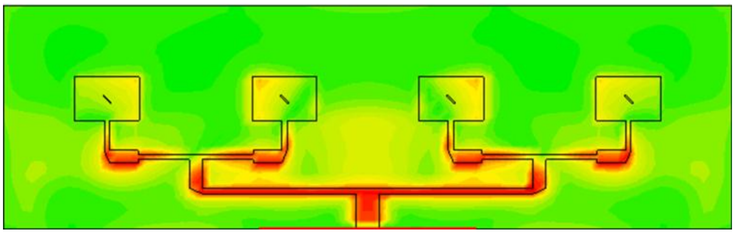
Figure 7. The radiation pattern in the E and H plane: . a: @ 4.5 GHz, b: @ 5 GHz & c: @ 6 GHz

For the behavior of the of array antenna in terms of radiation, we can analyze the different radiation patterns of the array in the E and H plane as depicted in Figure 7. As seen we have a multi directional antenna array beam.

For current density, Figure 8, shows that the density of the current are concentrated around the T-junctions power dividers to feed the fourth antennas.



(a)

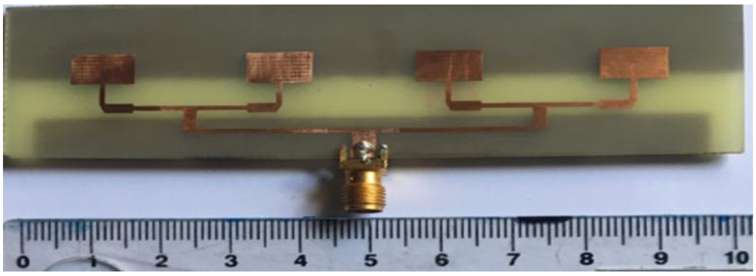


(b)

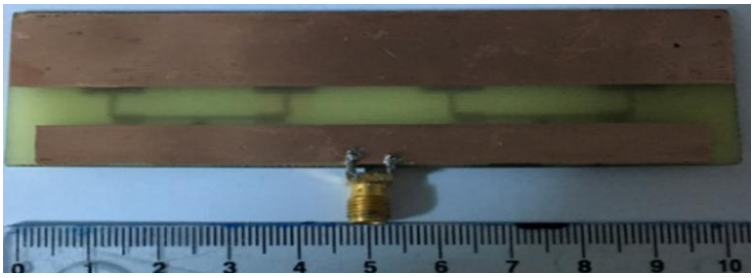
Figure 8. The current density: (a) @ 5.8 GHz, (b)@ 5.45GHz

4. ACHIEVEMENT AND MEASUREMENT

After the validation of the proposed antenna array into simulation, we have fabricated this circuit by using LPKF machine, the photo of the achieved antenna array is shown in Figure 9.



(a)



(b)

Figure 9. A photograph of the fabricated antenna array (a) Top Face (b) Back Face

The calibration Kit used for the test is 3.5 mm from Agilent Technologies. The proposed antenna array was tested by using a R&S VNA, the obtained measured and simulated results are illustrated in Figure 10.

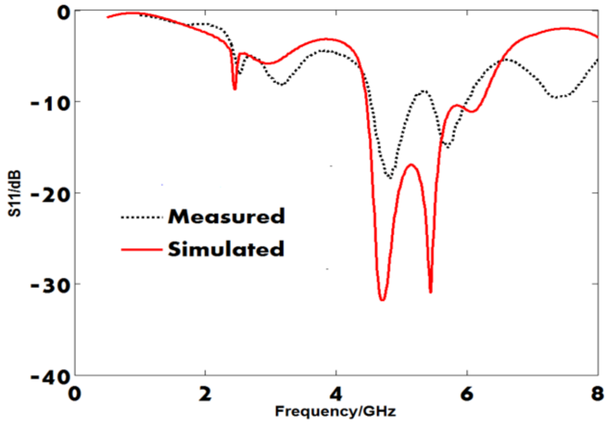


Figure 10. Measured and simulated results vs frequency

The measured results permit to obtain an antenna array which functions between 4.53GHz and 5.98GHz, with a reflection coefficient which isn't under -10 dB at 5.32GHz..Which is due to the characterization of the substrate which can present a difference concerning the permittivity and conditions of fabrication. The final circuit validates the idea of using DGS to miniature the antenna array which functions in a low frequency band having dimensions of an antenna validated at 10 GHz.

Table 2 below presents a comparison between the proposed antenna array study and other configuration in literature:

Table 2. Performance of the proposed antenna and other structures

	Bandwith(Ghz)	Demensions (mm^2)	Gain (dB)	Relative bandwidth
Proposed antenna array	4-6	102.48 - 31.39	5	37.59%
Structure 1[19]	9.5-10.6	114-61.2	4.25	11%
Structure 2[20]	24.05-24.25	Not plane, length 160 mm	1.6	0.8%
Structure 3[21]	2.32-2.58	Not plane, length 325 mm	3	10.6%

From this table we can conclude that the proposed and validated antenna array presents good performances in copmaraison with other structures validated in literature, in terms of dimensions, gain and relative bandwidth.

6. CONCLUSION

In this work we have presented a synthesis of the achievement of a wideband miniature microstrip antenna array suitable for wireless applications respecting the FCC rules and regulations governing UWB. The final circuit presents a circular polarization which eliminates the need of antenna orientation in the plane perpendicular to the propagation direction between transmitting and receiving antennas. The dimensions of the fabricated antenna array are miniature in comparison with the standard dimensions in the frequency band [4 GHz -6 GHz] which is due to the use of the defected ground structure however it decreases a little the final gain. The methodology followed to design such antenna array can be used to match the same array to another frequency band with miniature dimensions.

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