Study of Retrodirective Passive Microstrip Antennas and Less Efficient Structures

F. J. Cruz-Rodriguez* and H. Jardón-Aguilar*

*Com. Sec., Dept. of Electrical. Engineering, Centre for Research and Advanced Studies of IPN
Av. IPN 2508, Col. San Pedro Zacatenco, C.P. 07360, México D.F., email: fjcr008@gmail.com

Abstrac — **The study and design of retrodirective passive antennas is presented. A comparison with other kind of less efficient structures like flat plate and corner reflector is shown. The radiation patterns for two and four elements antenna are given. The radiating element used is a rectangular patch with recessed microstrip line feed.**

Keywords — **Retrodirective, microstrip, antenna, passive, array, RCS, Van-Atta**

I. Introduction

Retrodirective or Van-Atta antennas have the characteristic of radiating a wave in the same direction as it is arriving. The antenna consists of elements arranged and connected properly by transmission lines so that the signals received from an incident wave by the antenna are reradiated in phase back in the direction of incidence.

The retrodirective antennas have been used in very different applications because of their advantage respect other kind of less efficient structures and conventional antennas. Some of these applications are: increment of the radar cross section (RCS), mitigation of multipath problems, RFID systems, protection of vehicular systems, repeater points in link radio communications systems, etc. They have a big set of important characteristics, for example: totally autonomy, cost, size, simplicity, etc.

Two retrodirective passive antennas were studied, one with two radiating elements, the other with four. As element was chosen a patch, one with recessed microstrip-line feed, both antennas have linear structure. Also, their behaviour is compared with the retrodirective characteristics of a flat plate and of a corner reflector. Two linear retrodirective passive microstrip arrays, two and four-element linear array, the flat plate and corner reflector are studied in computer software in order to present comparative results between all of them.

Thus, the paper is organized as follows: The design of a microstrip antenna is addressed in section II; section III presents the design of a retrodirective passive microstrip antenna. The experimental results are given in section IV. Section V expounds the conclusions of the obtained results.

II. DESIGN OF MICROSTRIP ANTENNA

For the design of this antenna it was considered the selection of a Duroid substrate RT5880 with a 2.2 dielectric constant (ε_r), thickness substrate (t) of 1.27 mm and thickness copper conductor (e) of 0.035 mm, the operation frequency is 1.8 GHz.

Figure 1 shows the patch antenna dimensions like a single element. Here W_p and L_p are the width and large of the patch (65.88 mm x 54.53 mm) respectively; W_S and L_S are the width and large of substrate (232.54 mm x 222.28 mm) respectively; W_f is the feed line width (3.95 mm) for 50 Ω input impedance. In figure 2 is depicted the theoretical behaviour of the characteristic impedance of the feed line for different width in this specific substrate, W_M and y_0 are the width and length of the slot (1 mm x 19.48 mm) respectively; y_0 is the theoretical position of the slot in order to have a good match between the patch antenna and the feed line.

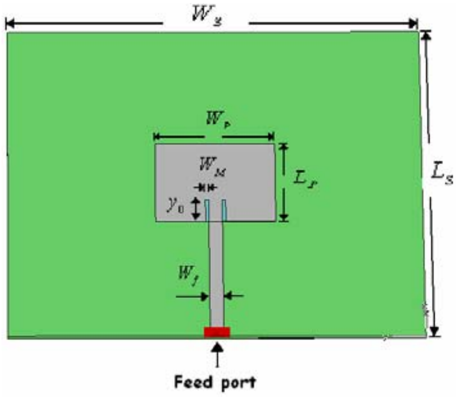

Fig. 1 Patch antenna dimensions

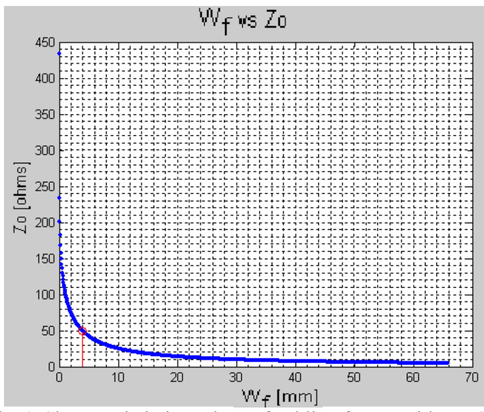

Fig. 2 Characteristic impedance feed line for Duroid RT5880

This patch antenna is simulated in the CST software simulator [15] in order to study its characteristics. The results are shown in table 1.

The return loss of the element is shown in figure 3, in this figure it can be seen the good match between the feed line and the patch, and the wideband. The radiation patterns are shown in figure 4 (a) and figure 4 (b).

TABLE 1
Element parameter

Parameter	Value
Frequency	1.8 GHz
Gain	7.19 dB
Side lobe level (E-plane)	-16.3 dB
Side lobe level (H-plane)	-19.2 dB
Beam width (E-plane)	87.1^0
Beam width(H-plane)	75.8^0
Radiation Efficiency	0.8113
Input impedance	51.5 Ω
Wideband (-10 dB)	19.77 MHz (1.09%)
Return loss (S_{11})	-23.1 dB

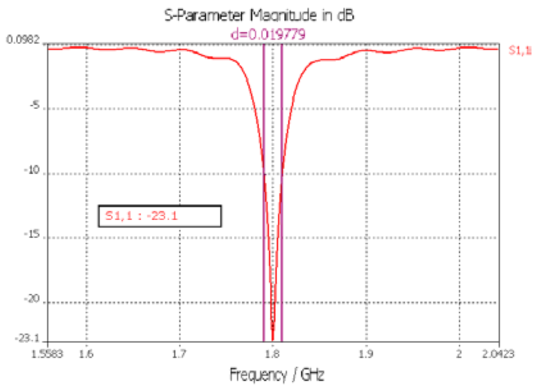

Fig. 3 Return loss variation in different frequencies

III. DESIGN OF RETRODIRECTIVE PASSIVE MICROSTRIP ANTENNA

Once the radiating element was designed, it is proceeded to develop the retrodirective arrays. The retrodirective passive antennas are built interconnecting all radiators elements by pairs, with the objective of re-radiating the energy that the opposite element received, symmetry in the array is a very important characteristic that must be considered in order to have a re-radiate phenomenon, if this characteristic is not considered, the retrodirective array will not work properly [14].

The feed line length is an extremely important parameter of the retrodirective passive antenna, in order to get a conjugated phase. For computing the feed line length it is necessary to consider the three next cases [1]:

- For d=0.50λ, the feed line length l=0.64λ+pλ.
- For d>0.50λ, the feed line length l=0.25λ+p0.50λ.
- For d<0.50λ is not recommended.

Where d is the distance between adjacent radiating elements, λ is the wavelength in the substrate, p is an integer number and l is the feed line length, this consideration is important because it includes the coupling factor between adjacent radiating elements.

In our design, the value of the distance between adjacent radiator elements was calculated to be equal to $0.6\lambda_0$ (100 mm) in order to neglect the coupling between elements. Then the microstrip-line length should be l=0.25λ+p0.50λ.

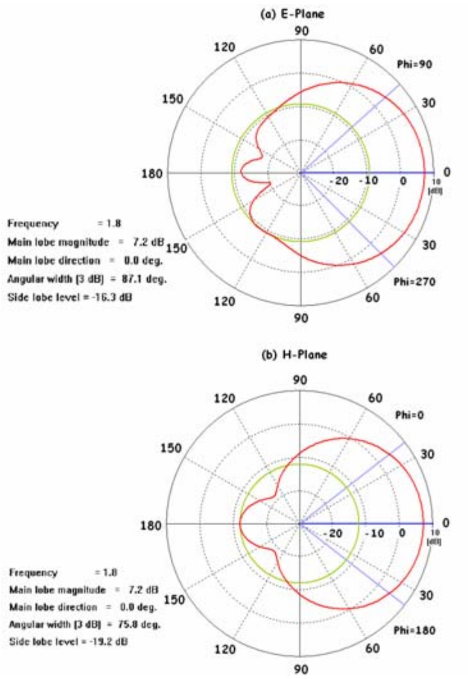

Fig. 4 (a) Radiation pattern in the electrical plane; (b) Radiation pattern in the magnetic plane

The two-element array has a feed line length of 152.2 mm (p=2), the four element array has a feed line length of 395.8 mm (p=6). Both arrays are shown in the figure 5 (a) and 5 (b).

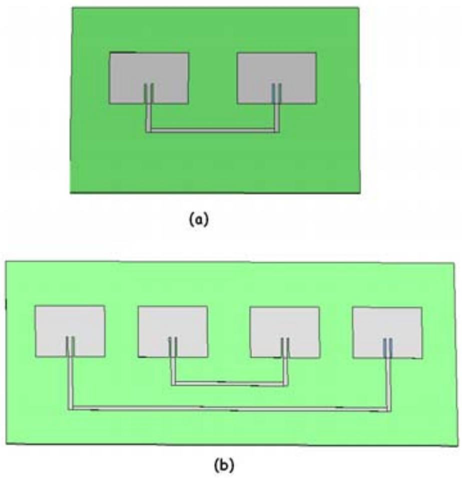

Fig. 5 (a) Two element retrodirective passive linear array; (b) Four element retrodirective passive linear array

IV. EXPERIMENTAL RESULTS

The retrodirective and RCS characteristics of these two Van-Atta antennas as well as of the flat plate and corner reflector were studied by using the CST [15]. In figure 6 is given the RCS of a flat plate for different incident angles, from this figure it can be found that the flat plane reflects efficiently within an angle of 19.4^0 (angle where the RCS intensity decreases 3 dB).

Figure 8 shows the RCS of a corner reflector for different incident angles. When the incidence angle is minor or equal to 28^0 the corner reflector has good efficient retrodirectivity.

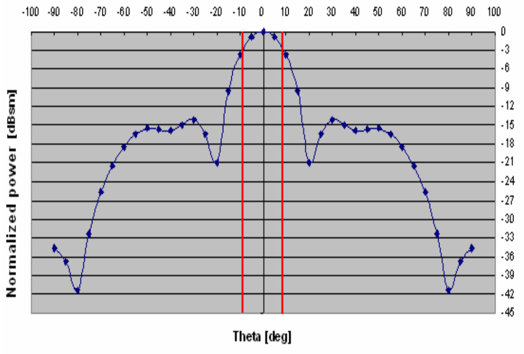

Fig. 6 Flat plate's RCS

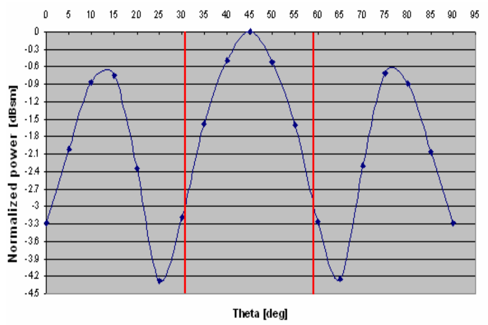

Fig. 7 Corner reflector's RCS

Here the retrotransmitting characteristics of the two and four element Van-Atta antennas are shown in figure 8. It can be seen that for different incidence angles both antennas re-transmit in the same direction, or in a very close direction.

The figure 8 (a) and 8 (b) show the RCS of two specific angles, for $\phi_i=10^0$ and $\phi_i=20^0$ respectably, for the two element array. In both cases, it exists a little difference of 1 and 2 degrees, they are very close to the incident angle.

The figures 8 (c) and 8 (d) show the RCS of four element array, for these it exists a difference of 2 degrees in both cases.

The figure 9 shows the two element array's RCS for different incident angles, this array can retransmit efficiently with an angle of 96.12^0. This results exhibits that the most simple Van-Atta antenna has a wider angle of retransmission than the corner reflector, and this one has a wider angle than a flat plate.

The four element array's RCS for different incident angles is given in figure 10, this array can retransmit efficiently with an angle of 64.2^0.

Overlapping the two RCS graphics (of two and four element arrays) it is possible to see that the two element retrodirective array has a better response angle, but when overlapping both graphics without normalization, the four element array has a better RCS magnitude, in other words, the four element array generates a better RCS but in a minor angle interval. This effect can be seen in the figures 11 (a) and 11 (b).

There exists another parameter that can be measured, the beam pointing error (BPE), it is the difference between the real incident angle and the retransmission one. Figure 12 shows the BPE graphic for both arrays. In figure 12 it is possible to see that the two element array's BPE is bigger than four element array's BPE, it means that, in general, the four element array has a closer retransmission angle respect to the incident one.

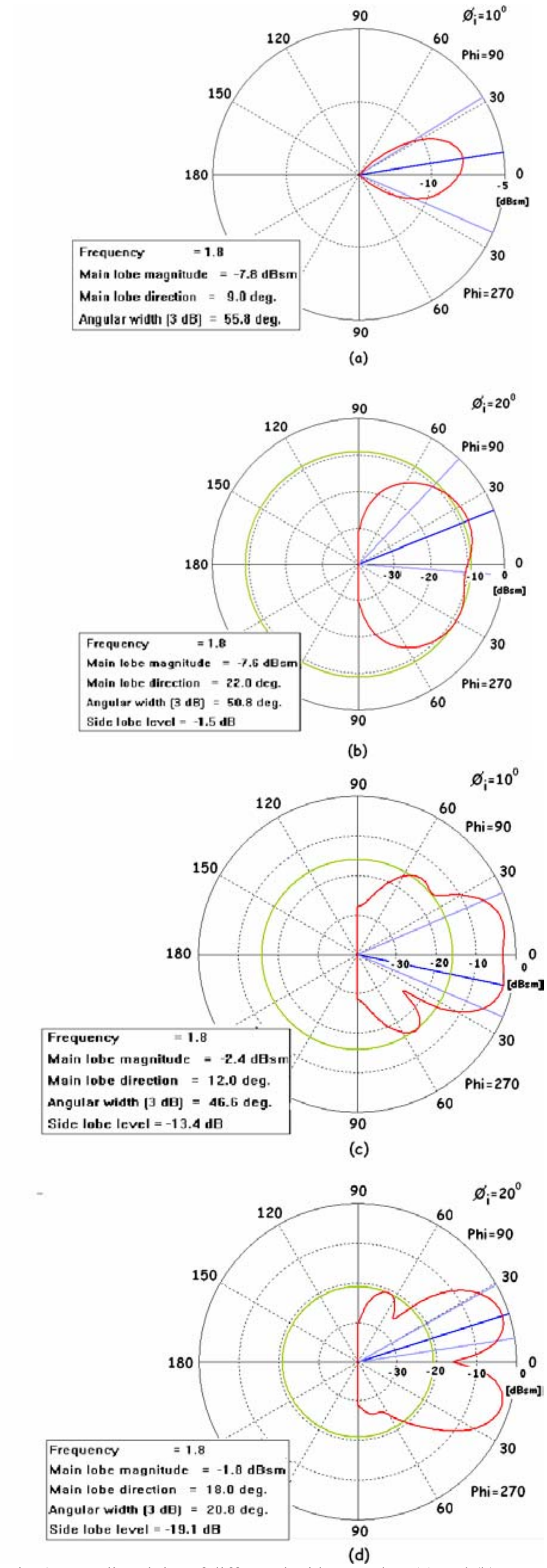

Fig. 8 Retrodirectivity of different incident angles; (a) and (b) two-element array, (c) and (d) four-element array

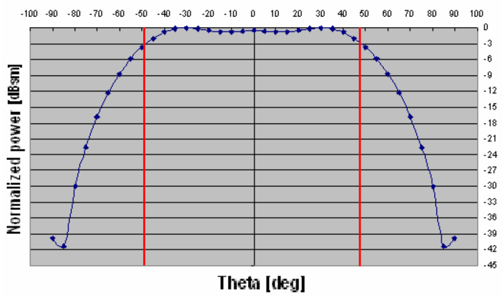

Fig. 9 Two-element retrodirective array's RCS

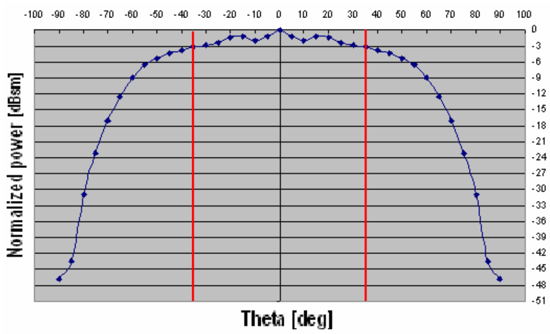

Fig. 10 Four-element retrodirective array's RCS

ACKNOWLEDGMENT

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V. CONCLUSIONS

The retransmitting characteristics of two and four element Van-Atta antenna were studied. The most simple retrodirective antenna has better retransmitting characteristics than the corner reflector.

From the RCS graphics it could be seen that the flat plate was the worst reflector between all the four structures presented in this paper, the corner reflector is a good reflector but it had a small response angle interval, the two and four element retrodirective arrays were better reflectors.

And finally, if a retrodirective array has few elements, it has been found a bigger response angle interval than in a larger array, where the array can retransmit efficiently, but the shorter array has a bigger BPE than the larger one.

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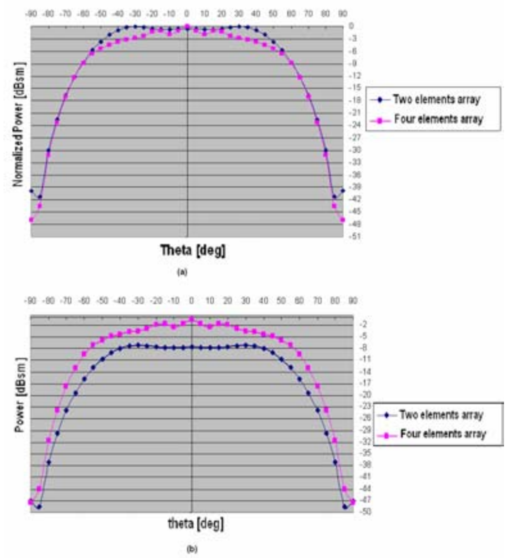

Fig. 11 (a) Normalized overlapped graphics; (b) Without normalization overlapped graphics

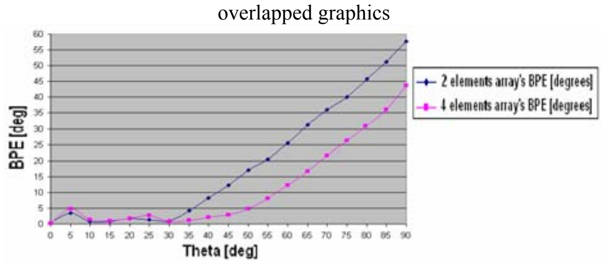

Fig. 12 BPE graphics for both arrays