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Characterization of a radiator of eight arms with circular polarization

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SUMMARY

The cross antenna is a printed structure of average profile and circular polarization, which consists of a conductor or tape on a ground plane that follows the contour of a cross with four or more arms and a diameter of about 1.5 wavelengths developed by Antoine Roederer. The antenna is feeded by means of a coaxial line and is finished in an impedance of load, for what it is represented by a behavior of travelling wave. Though in principle the antenna was designed for applications in mobile communications in Band L (1500 MHhz), we present in this work the experimental characterization of an antenna of cross of eight arms that is employed at 10 GHz, with the principal intention of serving as feeder of a parabolic reflector for satellite communications.

Key words: *cross antenna, circular polarization, radiation of the antenna, experimental characterization.*

1. INTRODUCTION

The cross antenna belongs to the family of radiators of travelling wave, formed by a microstrip with a ground plane, the feeding in an end and one loads in another; it has right or left circular polarization depending on the position of the feeding and the load [1]; it can be used in independent form or as primary radiator of parabolic reflectors with big ratio among focal length and diameter. The advantage of the cross antennas over others of average gain (*12-15 dBi*) is their dimensions, i.e. longitudinal dimension is much smaller than the antennas of helix, bugle, etc. shapes.

In comparison with other printed antennas, as patches or crossed dipoles, the cross antenna has the advantage to reduce the problems of connection and therefore of feeding, what is demonstrated clearly in the results obtained in this work.

2. THE STRUCTURE

The geometry of the antenna is presented in Figure 1, a tape in cross form, printed on an ground plane to a distance of a fraction of the wavelength of work. The line is fed in an end, by means of a coaxial cable and it is finished in the other end by a load. The length of the cross branches is selected so that there is a phase's shift in the current, between one and the contiguous one, of $2\pi+2\pi/N$, where N is the number of branches. As the electrical field is broadcast by every branch turns $2\pi/N$, the total field will have circular polarization, if attenuation does not exist along the tape; actually it must look for that the attenuation may be lower.

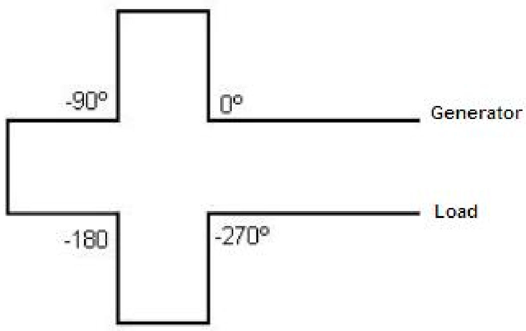

Fig. 1 Cross antenna

For an antenna of four arms, the long arms have a length of $\lambda_e/2$ and the short arms $\lambda_e/4$, where λ_e represents the effective wavelength, determined by the dielectric of the microtape. Two successive pairs of long arms broadcast a parallel field to the conductor, with amplitude decreasing towards the end of the line. The short arm introduces a phase's shift of *90°* between the fields broadcast by successive pairs and in addition it contributes with the field in the perpendicular direction.

Like other antennas of travelling wave, the current decays exponentially throughout the line, although in this case with undulations due to reflections in the folds. The power loss or reflection at the end of the line is controlled by means of the load impedance and can be limited on a small percentage of the total power also fitting the height of the line on the earth plane (typically $\lambda_e/20$ to $\lambda_e/4$). On the other hand, the length of the line can be optimized by changing the number of arms and returns of the antenna (typically between *5* and $15\ \lambda_e$), on which also the bandwidth of the antenna depends, that oscillates around *5%*. The reflected waves by successive folds tend to cancel themselves, for that reason, its influence is small in the total behavior of the radiator [2, 3].

The bandwidth of the antenna depends on the number of arms and returns, but like other antennas of travelling wave, the bandwidth is around *5%*.

An important element in the antenna is the load impedance, although the form of the antenna causes that the current diminishes when traveling through it, leaving very little energy in the load terminal, the impedance in the end must practically eliminate it, on the other hand it is used to fit the axial relation of the circular polarization. Roederer [1] also mentions that the adjustment of the load impedance can reduce the crossed polarization.

In this work the same impedance measured to the entrance of the antenna was used as load impedance, considering the symmetry of the structure. The value of the input impedance was obtained by making measurements of impedance in open circuit and short circuit and by using the well-known expression [2]:

$$Z_0 = \sqrt{Z_{cc} Z_{ca}} \quad (1)$$

The experimental work was divided in two stages. First was the characterization of the input impedance and the second was measurement of connection of impedance, gain and pattern of radiation, in two-way traffic calculating the axial relation, constructing antennas for two dielectrics: Duroid and air, with different separation from the ground plane.

For the characterization of both impedance and reflection, an analyzer of networks HP8510, was used; the measurement of pattern of radiation was obtained by a generator of RF Wiltron 68147B and an analyzer of spectrum Advantest R3272. An antenna of a bugle shape of *12 dBi* was used as reference. The feeding power was of *10 dBmW*.

The constructed antennas are symmetrical of a return, with eight arms, loaded with their characteristic impedance. The geometry of the antenna is presented in Figure 2, works to a frequency of *10 GHz*, with a wavelength of *3 cm* for air and *1.96* for the Duroid ($\varepsilon_r=2.33$). The Table 1 shows the geometric characteristics, where λ_e represents the effective wavelength.

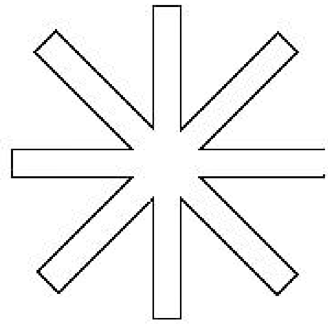

Fig. 2 Scheme of the antenna

For the case of the Duroid an antenna with a thickness of dielectric of *3.6 mm* was constructed, and, for the second, an antenna of copper wire, mounted on a ground plane. This construction gave greater flexibility to determine the effect of the height of the antenna on the ground plane, as much in the pattern of radiation so in the coupling. In order to give mechanical stability, to hold its position and to change the height, it was supported by small located fragments of Teflon in some points of the structure.

Table 1 Geometric characteristics

Arm length	$1\ \lambda_e$
Arm width	$0.25\ \lambda_e$
Cross diameter	$2.5\ \lambda_e$
wire diameter	$0.01\ \lambda_e$

3. LOAD IMPEDANCE

The symmetry of the antenna is supposed to have the same impedance in both ends, reason why the first passage of the experiment was its determination. The impedance in short circuit was moderate as well as in open circuit and from those values the input impedance was calculated using Eq. (1). Table 2 shows measurements and the calculation in several frequencies.

They appear in Figures 3, 4 and 5 as graphs of the coefficient of reflection for an antenna in short circuit, open circuit and with impedance of load of *50 Ω*. In Figure 6, there is the impedance of the antenna with load of *50 Ω*.

Table 2 Measurement and calculation of impedance

f (*GHz*)	*Zcc measurement*	*Zca measurement*	$Z_o = (Zcc*Zca)^{1/2}$
8	47.8+j15	45+j17	46.4+j16
8.5	47.3+j28	54.7+j13.4	51.5+j21
9	65+j4.5	56.6–j13.5	61.4–j5.1
9.5	27.4+j12	28.6+j14.4	28+j13.2
10	59+j0.3	72.8–j11.2	65.7–j4.8
10.5	54.8+j16.3	48.7– j0.2	52.2+j7.5
11	84–j1.3	72.3+j13	78.3+j6.4
11.5	57.6–j23.8	62.6–j22	60–j23
12	43.8–j18	46.2–j16.7	45–j17.4

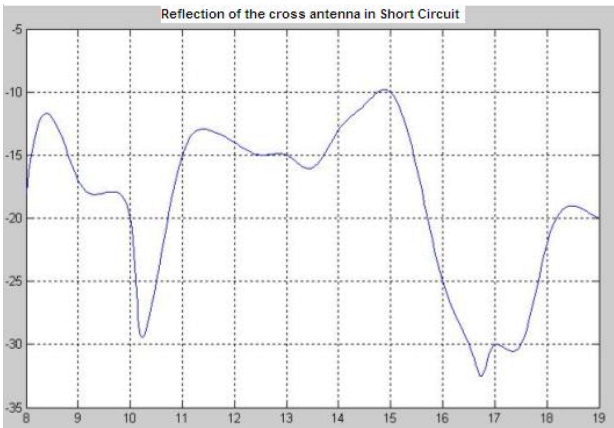

Fig. 3 Reflection in short circuit

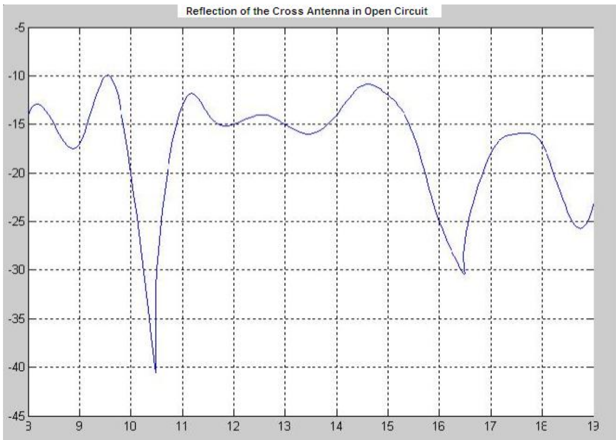

Fig. 4 Reflection in open circuit

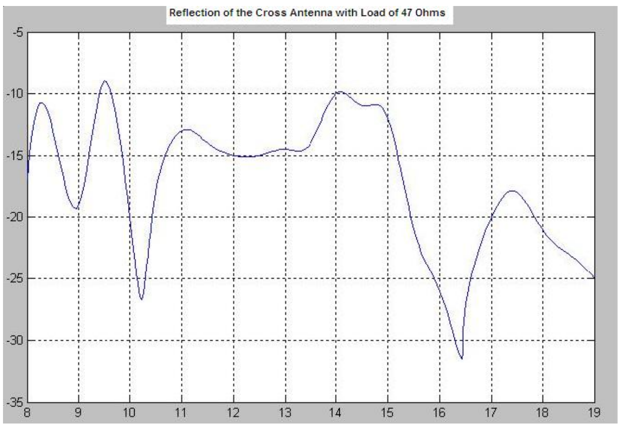

Fig. 5 Reflection with load of 50 Ω

It is interesting to observe that in these graphs the characteristics of resonance in *10.2* and *16.4 GHz*, behave almost without variations, with the three different loads. The result is a sample of the presence of the travelling wave in the work frequency and of the easy thing to obtain that behavior with the cross antenna. Similar results are obtained by investing the feeding terminals and load what is not presented in this paper.

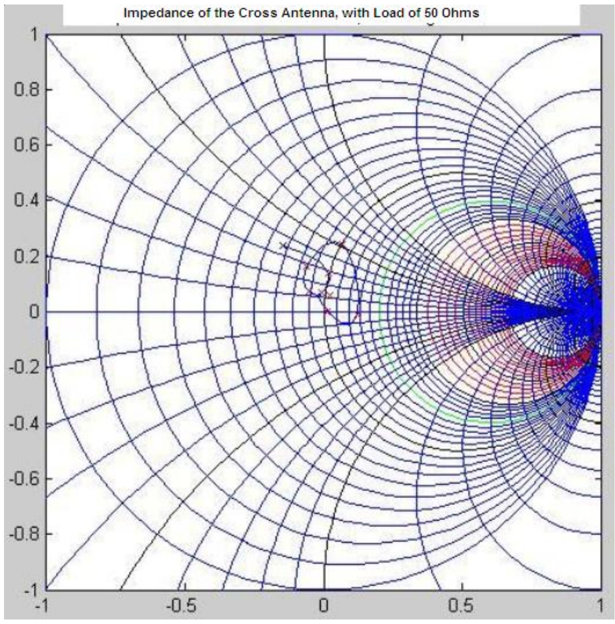

Fig. 6 Impedance with load of 50 Ω

4. RADIATION PATTERN

The characteristics of radiation of the antenna depend on their separation from the ground plane. This is the reason why the study was performed for 4 antennas, 1 of Duroid and 3 of Dielectric air.

The air dielectric antennas were constructed of copper wire 30 AWG, which represents a relation of *0.011* λ. The antennas were mounted on ground plane and they were supported with small pieces of Teflon in places strategic to hold the position and a uniform separation with the conductive plane. Three antennas with separations of *2*, *4* and *8 mm* were constructed. The fields for the plane were moderate of $\phi=0°$ and $\phi=90°$, in order to be able to determine the axial relation. The results are shown in Figures 7 up to 12.

The antenna of Duroid was realized on a material of double conductive plate, one of them used like ground plane and the other to hold the antenna. The relative permitivity of the Duroid is of *2.33*, what is the reason why the wavelength of *10 GHz* is of *1.965 cm*, the width of the dielectric is *3.6 mm*. The results for $\phi=0°$ and $\phi=90°$ are shown in Figures 13 and 14.

The gains obtained from the antenna bugle pattern and the axial relation, calculated by the comparison of the maximum values of gain of the orthogonal patterns, are shown in Table 3, at the direction of maximum radiation.

Table 3 Gains and axial relation

ANTENNA	*G dB*	*R.A. dB*
2 mm	*13.1*	*2.0*
4 mm	*11.8*	*1.2*
8 mm	*12.0*	*1.3*
Duroid	*11.0*	*2.0*

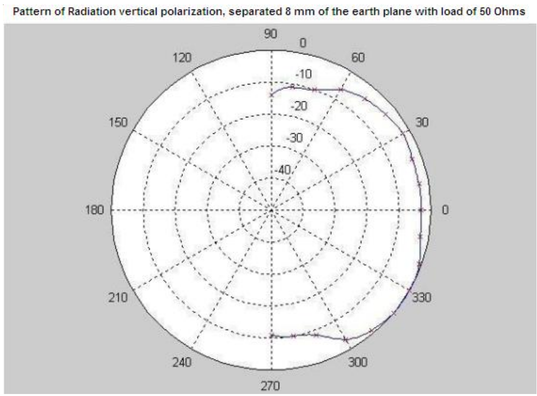

Fig. 7 Dielectric air, separation 8 mm, ϕ=0°

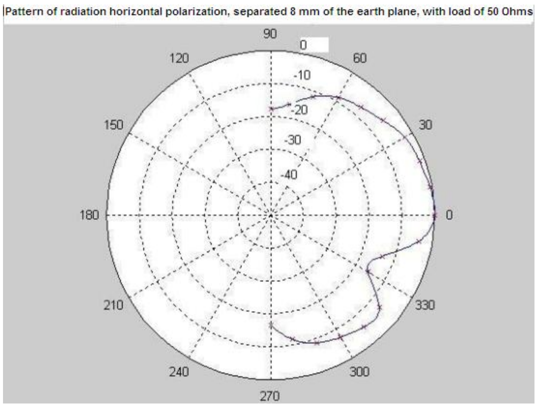

Fig. 8 Dielectric air, separation 8 mm, ϕ=90°

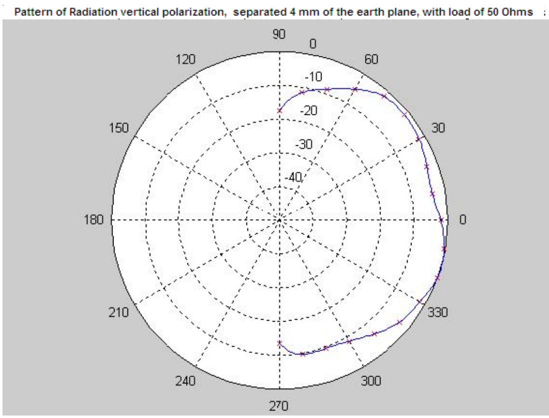

Fig. 9 Dielectric air, separation 4 mm, ϕ=0°

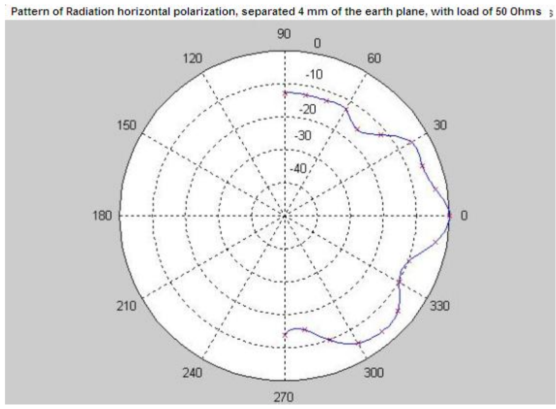

Fig. 10 Dielectric air, separation 4 mm, ϕ=90°

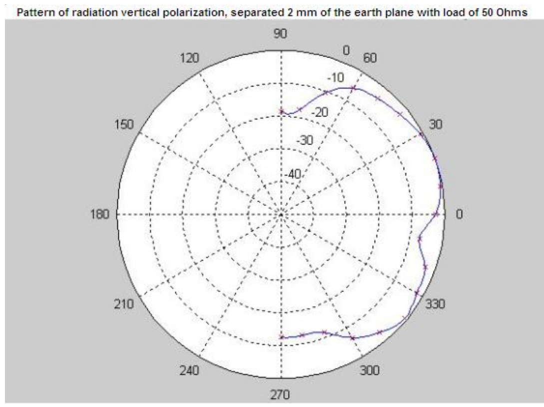

Fig. 11 Dielectric air, separation 2 mm, ϕ=0°

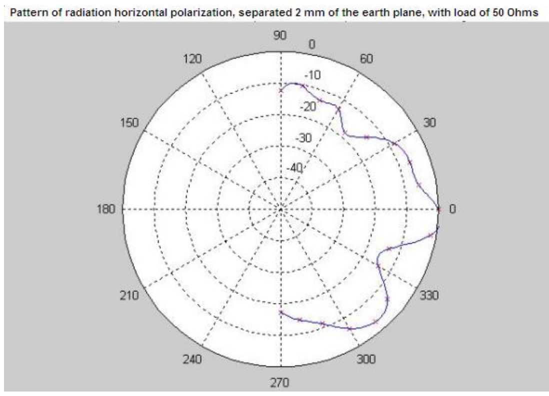

Fig. 12 Dielectric air, separation 2 mm, ϕ=90°

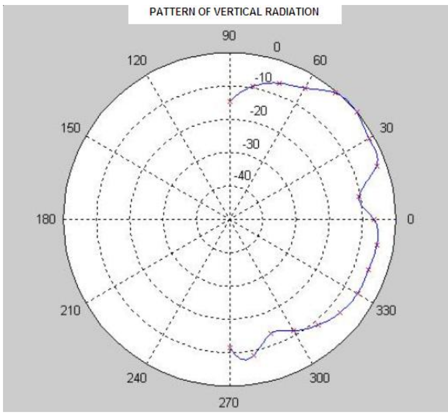

Fig. 13 Dielectric duroid, separation 3.6 mm, ϕ=0°

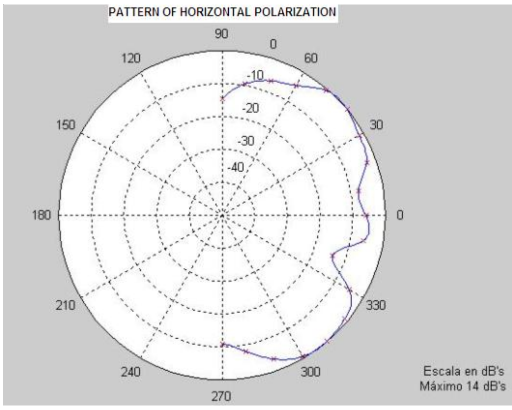

Fig. 14 Dielectric duroid, separation 3.6 mm, ϕ=90°

5. CONCLUSIONS

We have presented experimental results of cross antennas with different structural characteristics, the facilities in the construction and mainly the facilities whereupon stable and repeatable characteristics in extreme conditions are obtained. The input impedance with different loads, and in the same form, results of gain, comparable with bugle antennas, are used for reference. They are ideal for applications in communications with frequencies of microwaves, or used separately or like primarily radiators of parabolic reflectors.

The reflection results show that the antenna resonates to the design frequency, without much problem, for different load impedances, which takes us to conclude that a wave of progressive current exists, that is to say, the reflected wave in the final end is almost null, corresponds to this type of antenna. The measurements with a load of *50 Ω*, that appear in the Smith chart, are comparable with the calculated results and also show that the impedance in a considerable bandwidth (*8* to *20 GHz*), stays near the center of the letter. On the other hand, the gain is very similar to the one of the bugle with the advantages that they have in relation to the weight and the dimensions in addition to a very acceptable axial relation in the maximum of radiation.

The analysis of the radiation patterns, also shows stability, the separation with the ground plane affects a little the distribution of electromagnetic field in the plane *ϕ=0°*, but the difference is very marked in the orthogonal plane. In this case the patterns become more directors, with one better distribution for a separation of *4 mm*; nevertheless, in three cases, a deformation between *-30°* and *-60°* exists. The report of Roederer [1] shows the same deformation, what is not so marked, although he constructs to *1.5 GHz*, whereas to the frequency of our work, the wavelength is almost 7 times smaller and the dimensions of the resistance or the characteristics of the connector could be the difference.

The work continues mainly to reduce the effect of the connector, to improve the axial relation and for the effect of the second frequency of resonance.

6. REFERENCES

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KARAKTERIZACIJA OSMOKRAKOG RADIJATORA S KRUŽNOM POLARIZACIJOM

SAŽETAK

Križna antena je otisnuta struktura prosječne profitne i kružne polarizacije koja se sastoji od provodnika ili trake na ravnini zemlje koja prati konture križa s četiri ili više krakova i promjera od oko 1.5 valne duljine koju je razvio Antoine Roederer. Antena se napaja pomoću koaksijalnog voda, a završava u impedanci opterećenja zbog čega se ponaša poput progresivnog vala. Premda je, u načelu, antena nastala zbog primjene u mobilnoj komunikaciji na valnoj dužini L (1500 MHz), u ovom radu predstavljamo eksperimentalna obilježja jedne osmokrake križne antene koja radi na 10 GHz, s osnovnom namjerom da služi kao napajač paraboličkog reflektora za satelitsku komunikaciju.

Ključne riječi: *križna antena, kružna polarizacija, zračenje antene, eksperimentalna obilježja.*