CIRCULARLY POLARIZED SLOT FED PATCHES AND CONICAL BEAM ARRAY

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1 - INTRODUCTION

Many types of printed antennas have been used to generate circular polarized conical patterns [1, 2, 3, 4 , 5]. In this paper, the slot fed patch antenna [6] is considered (figure 1) and the four elements array is described. This antenna is attractive because the feed network is located behind the ground plane ; then a large space is available to realise the feeding lines and associated circuit without constraint due to patches printed on the upper opposite side.

2 - ANALYSIS OF ONE ELEMENT USING CAVITY METHOD

The slot coupled microstrip antenna has been analysed by cavity method [7]. The patch antenna is considered as a cavity surrounded by four perfect magnetic walls, and excited by volumic magnetic currents. Radiation losses and stored energy related to the E_z component of the cavity lead to the Y_{ant} admittance at the slot plane, given by the following analytical formula [8]:

$$Y_{ant} = \sum_m \sum_n \frac{-j\,16\,\omega\,\varepsilon\,A_{mn}^2}{k^2 - k_{mn}^2}\,\frac{1}{t}\left\{ \sin\left(\frac{m\pi x_o}{a}\right)\cos\left(\frac{n\pi y_o}{b}\right)\operatorname{sinc}\left(\frac{m\pi\,wa}{b}\right)\frac{k^a\left[\cos\left(\frac{n\pi La}{2b}\right) - \cos\left(k^a\frac{La}{2}\right)\right]}{\left[k^{a2} - \left(\frac{n\pi}{b}\right)^2\right]\sin\left(k^a\frac{La}{2}\right)}\right\}^2$$

Where $A_{mn} = \sqrt{\frac{\varepsilon_{om}\varepsilon_{on}}{ab}}$ $\qquad \varepsilon_{op} = \begin{cases} 2 & \text{if } p \neq 0 \\ 1 & \text{if } p = 0 \end{cases}$ $\qquad$ and $\qquad k^2_{mn} = (m\pi/a)^2 + (n\pi/b)^2$

Obviously strong variations of the electric field occur near the slot ; the resultant E_x and E_y components add a reactive power and a susceptance part to the total admittance patch antenna. This **Yap** susceptance is easily computed as two parallel short-circuit slot-lines :

$$Y_{ap} = -\frac{2j}{Z_{ca}}\operatorname{cotg}\left(k^a\frac{La}{2}\right)$$

Where k^a is the slot wave number and Z_{ca} is the characteristic impedance of the slot line. Figure 2 shows that, in the final equivalent circuit, the slot microstrip transition is modeled by a slot line to microstrip line transition transformer (figure 2). Finally the input impedance is given by :

$$Z_{in} = \frac{\left(\Delta V / V_o\right)^2}{Y_{ant} + Y_{ap}} - j\,Z_{cl}\operatorname{cotg}\left(k^l L_s\right)$$

Where L_s is the length of the open stub, k^l is the wave number and Z_{cl} is the characteristic impedance of the microstrip line. It must be noticed that the fundamental mode TM_{10} is considered here ; then only xo has a strong effect on the input impedance. The role of yo is limited to the high order modes effects.

3 - THE CIRCULARLY POLARISED ELEMENT

The cavity analysis has been tested successfully on many examples [8]. It is interesting to use the effect of an offset-fed slot position (xo,yo) and the effect of a tuning stub to match the antenna, and in order to get enough place to put another perpendicular slot. The two slots can be excited with a 90° hybrid coupler or a quarter wave transformer as described in [9],to obtain a circularly polarized antenna (figure 3).The design parameters of a first antenna (n°1) are given on figure 4-a which shows the input impedance of a matched antenna at 2.5 GHz ; the theoretical curve is in a good agreement with experiments. Figure 4-b shows the diagram of a single element obtained by a spinning-linear-dipole technique. The axial ratio is about 1 dB in the broad side direction, but reaches 3 or 4 dB from 35° to 45°. In order to get similar E and H plane patterns, an air gap patch has been built [8].The design parameters for this antenna (n°2) are given on figure 5 where is plotted the input impedance (figure 5-a). The E and H plane patterns are shown on figure 5-b.

4 - ARRAY DESIGN AND RESULTS

The main objective was to check the feasibility of a circularly polarized conical beam antenna exhibiting a maximum of the main beam equal to 35°. A two layers antenna structure (antenna n°1 without air gap) has been chosen. Four circularly polarised elements are used and positioned on a circle with the radius R_a. The elements angular orientation are arranged in the 0°, 90°, 180°, 270° fashion. The same radius R_a previously used for annular slots [1] was kept for this array : $R_a = 40$ mm. The fabricated array and feed hybrid power dividers are illustrated in figure 6 (with matched loads on the islated port). Simple design considerations show that it is possible to use only 50 Ω microstrip lines. Figure 7 shows the input impedance of the matched array ; the bandwith is about 7 % around 2.5 GHz. Figure 8 shows the conical beam pattern at 2.5 GHz for $\varphi = 0°$: the axial ratio at 35° versus azimuthal angle φ (figure 9) varies from 0.2 dB to 4 dB when the theoretical value varies from 1.4 dB to 2.6 dB (figure 9). The difference is due probably to mutual coupling effects ($d < 0.5\lambda o$, where d is the distance between two patches), different E plane and H plane patterns of each element, and diffraction effects on the edges of the limited ground plane ($\lambda_o \times \lambda_o$). The measured gain is about 7 dB in $\varphi = 0°$ and $\theta = 35°$. In order to get identical E and H plane patterns an air gap patch with higher thickness t can be used. Morever further results will be presented at the conference for the air gap antenna (n°2) .

5 - CONCLUSION

The previous microstrip array shows the attractive possibilities of feeding offered by the slot coupled patches. The actual performances are moderate. In the future it will be necessary to take into account the effect of mutual coupling for larger beam angle (40° to 45°) ; on the contrary when the beam angle is small then the spacing between the elements increase and mutual coupling can be neglected. Then a good ellipticity and a larger bandwith can be obtained with arrays of air gap patches.

6 - REFERENCES

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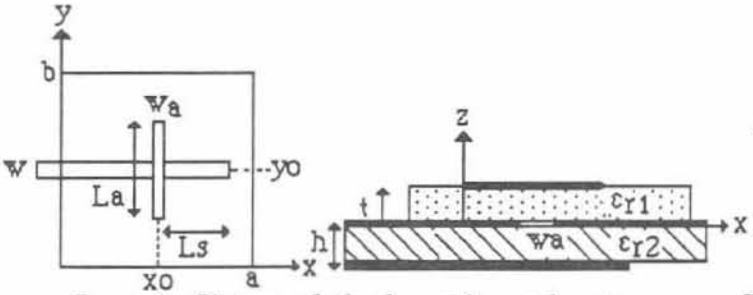


figure 1 : Slot coupled microstrip patch antenna

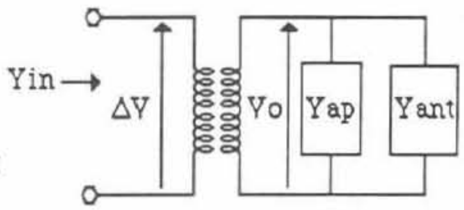


figure 2 : Equivalent circuit of antenna

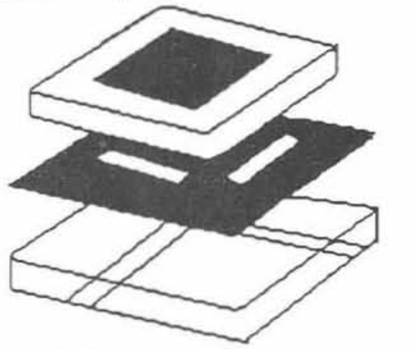


figure 3 : Dual slot coupled patch antenna

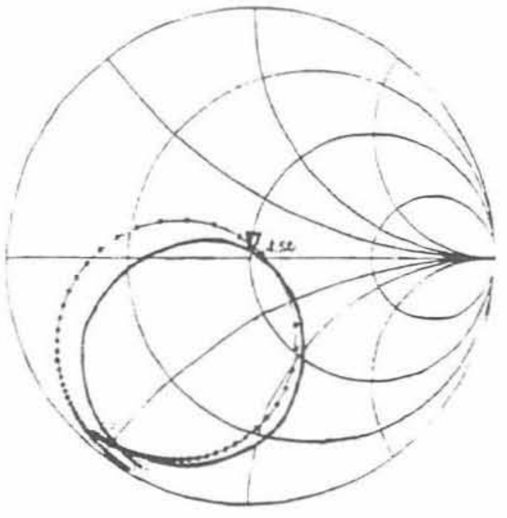


figure 4-a : Antenna N°1: input impedance

a=b=35mm, ε_{r1}=2.55,t=1.6mm,wa=2mm
La=12mm, xo=8.5mm, yo=17.5mm
ε_{r2}=2.55,h=0.76mm,Ls=9mm ($\neq\lambda g/4$)
o o o theory ; ____ Experiment

START 2.3 GHz
STOP 2.7 GHz

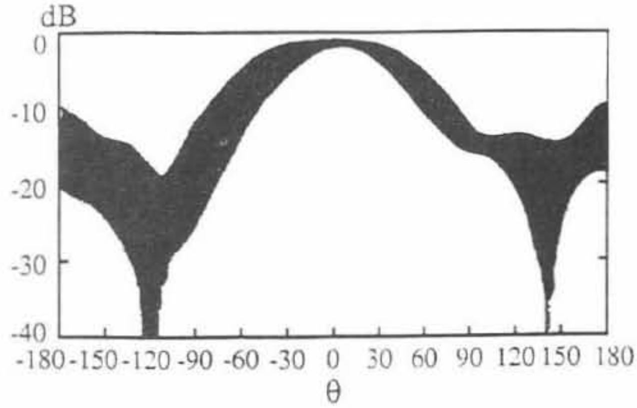
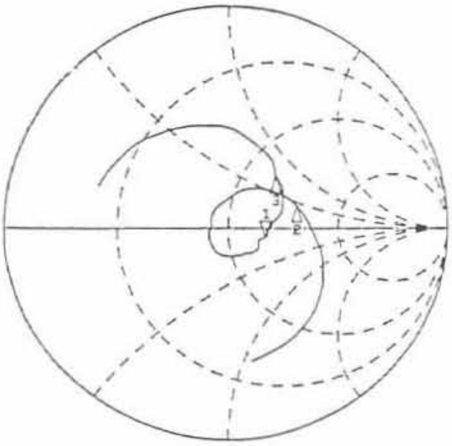


figure 4-b : Radiation pattern of a single CP element at 2.5 GHz



START 2.3 GHz
STOP 2.8 GHz

figure 5-a : Input impedance of air gap CP element
Δ2 : 2.41 GHz ; Δ1 : 2.5 GHz ; Δ3 : 2.62 GHz

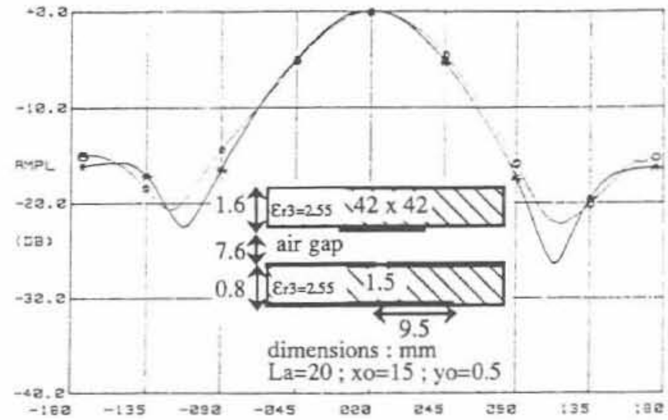


figure 5-b : Antenne N°2 : Radiation pattern of a single air gap CP element at 2.5 GHz
o-o-o E plane ; *-*-* H plane

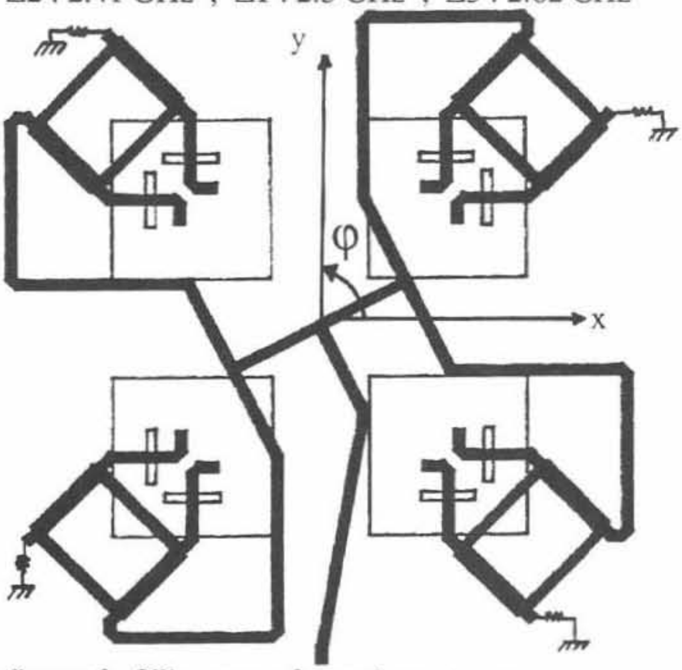
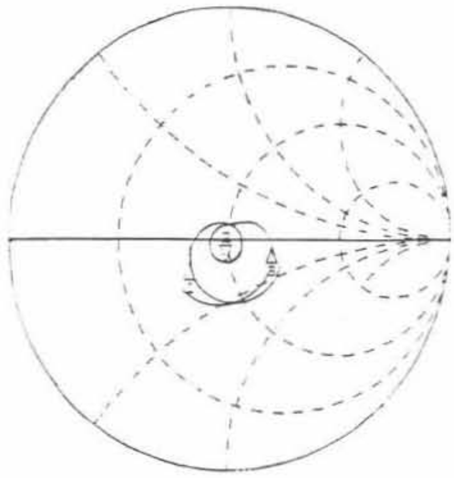


figure 6 : Silhouette of tested array antenna



START 2.3 GHz
STOP 2.7 GHz

figure 7 : Input impedance of array
Δ1:2,416 GHz ; Δ2:2,5 GHz ; Δ3:2,588 GHz

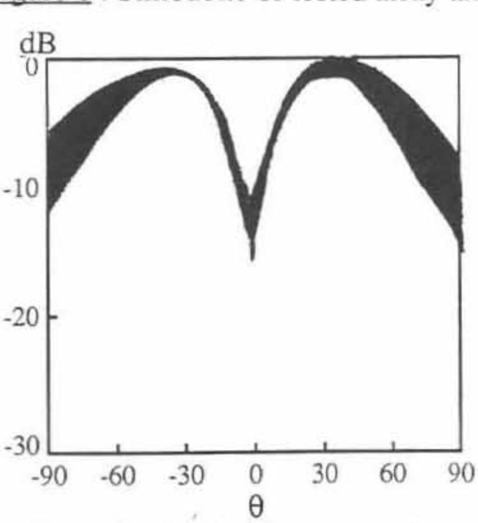


figure 8 : Conical beam radiation pattern at 2.5 GHz and φ = 0°

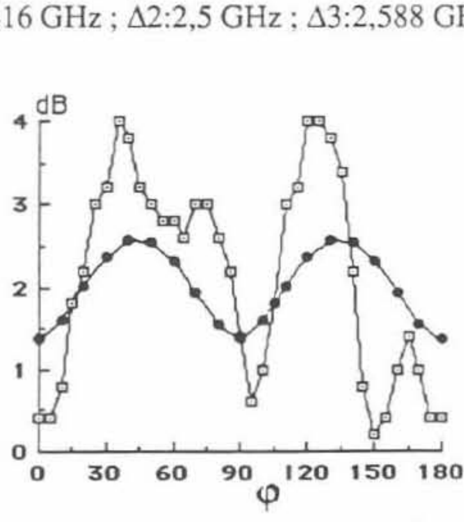


figure 9 : Ellipticity versus azimuthal angle
●-●-● Theory ; ⊡-⊡-⊡ Experiment