A NOVEL ARCHITECTURE FOR A MULTI POLARIZED, PERPENDICULARLY-FED, RADIATING ELEMENT

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Abstract Planar printed antennas, are often required to be fed by parallel feed-networks, which, when printed on the same substrate as the radiating elements, create mutual coupling, spurious radiation and excite surface waves. This considerably affects the array efficiency. Numerous architectures were proposed in the past; some of them use the multilayer structure (which by itself exhibits low efficiency), or perpendicularly fed structures. The latter consist of a substrate for the radiating element and another substrate which for the feed-network. The paper reviews some of the basic configurations proposed until now, and shows the specific improvements introduced by the proposed architecture.

1. INTRODUCTION

The goal of this effort was to design a wide-band circularly polarized printed element, which can be easily integrated in an array, and separates the radiating space from the beamformer. Specifically, we refer to types of arrays where the scanning is achieved in one plane my means of a microwave lens (such as a Rotman Lens or a Butler matrix) and a fixed beam in the other plane. Linearly polarized elements suitable for this purpose are well known: LTSA (with its variation), the quasi-Yagi dipole, and other types of printed dipoles. The main drawback of these elements is that *the only polarization achievable with these elements is linear and the polarization vector has to be parallel to the substrate.*

These limitations are significant and some effort was invested in the development of alternatives. In [1, 2], an aperture-fed patch fed by a perpendicular substrate is presented, in which the polarization of the element is perpendicular to the feeding substrate.

In this paper, a different approach is proposed. First, a single polarization version of a radiating element with the polarization vector perpendicular to the substrate is presented. Then, a multiple polarization element is proposed.

In [3], a similar concept is presented. The limitation of the element proposed in [3] is in the fact that the solution is achieved using *an egg-crate architecture* (3D). The element proposed here, is fed by a planar feeding network (2.5D).

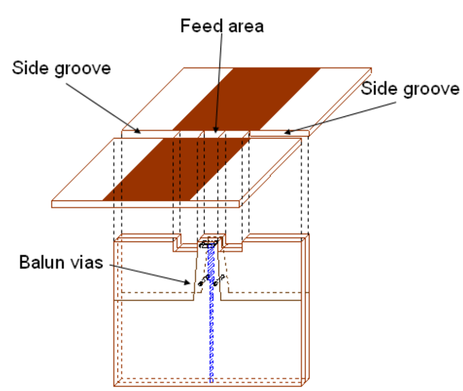
2. THE SINGLE POLARIZED ELEMENT

The element proposed is shown in Figure 1. It consists of a typical stripline turning into a printed twin-line; on the edge of the substrate it is shorted to one of the ground planes, feeding a printed dipole.

The compensation for the transition from a balanced transmission line to an unbalanced transmission line is done by means of a $\lambda/4$ balun which is realized as a short in the finite-ground stripline.

In the area where the stripline ground planes end, an array of vias define the back ground plane for the dipoles. Experiments were performed for cases in which an additional ground plane was added (parallel with the dipole plane). The measurements results were significantly different for the front-to-back, however quite similar as far as the input impedance.

The feeding circuit shown in Figure 1 consists of a 50Ω stripline, and a $\lambda/4$-33Ω transformer shorted at the feed point to one of the ground plane through a slot performed in one of the stripline boards. The geometry of the stripline edge as shown in Figure 1 is meant to enhance the mechanical rigidity of the antenna and has no electrical role. The substrate used is METCLAD 31 mil (62 mil altogether). The dipole is printed on 40 mil thick FR4. The geometry of the dipole is shown in Figure 2.



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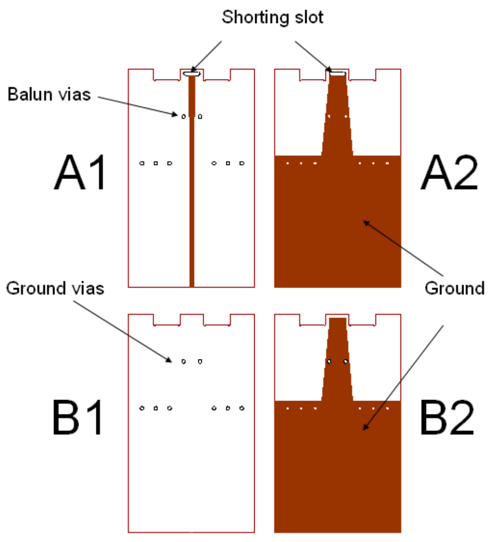
6–10 November 2006 (ESA SP-626, October 2006)



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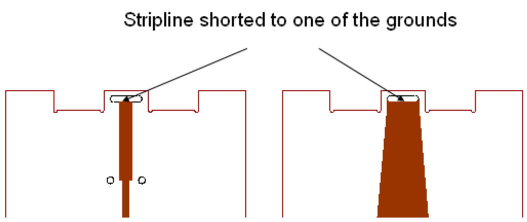

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Figure 1 a. The geometry of the perpendicularly-fed dipole element
b. The geometry of the stripline feed design
c. The geometry of the feeding area

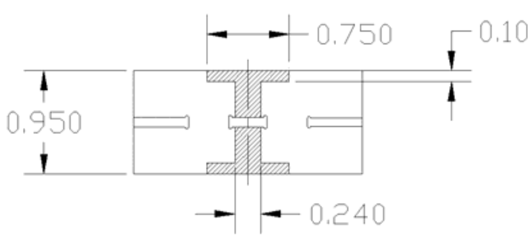


Figure 2 – The geometry of the dipole (dimensions are in inches)

3. LINEAR ARRAY OF 8 ELEMENTS

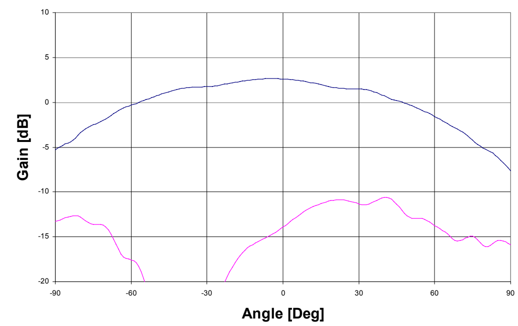
An eight element 20 dB Chebyshev linear array was designed and manufactured.

Table I summarizes the measured results for this array across the 2.2-2.7 GHz band. Measured patterns at 2.4 GHz (azimuth and elevation) pattern are shown in Figure 3. Figure 4 shows the measured return loss. and Figure 5 shows a picture of the array.

As shown in Figure 3a, the cross polarization pattern is not symmetric; which was expected, since the feeding geometry is not absolutely symmetric. However, the measurements show almost 20 db cross polarization in the broadside direction.

Table I – Summary of Array Performance

Frequency [GHz]	SLL [dB]	Gain [dB]	Beamwidth [°]	
			Azimuth	Elevation
2.1-2.7	<-19.5	>10.5	90°-110°	13.5°-12.5°



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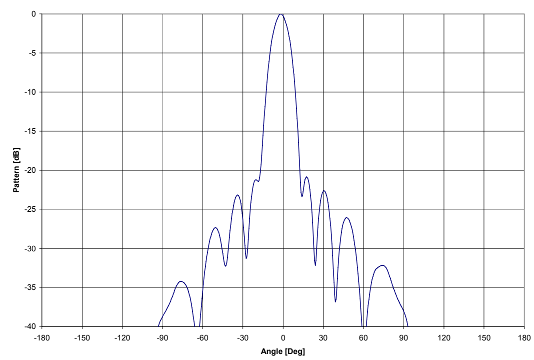

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Figure 3 - Measured patterns at 2.4GHz
a. E-plane, b. H-plane

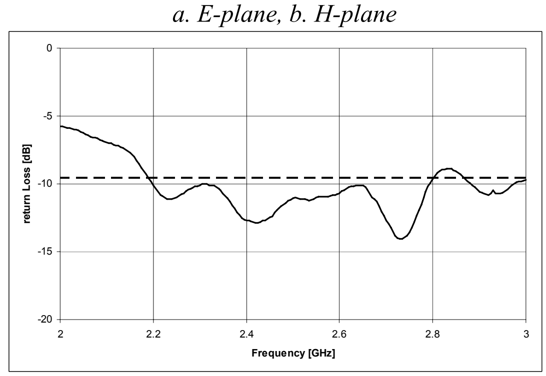


Figure 4 – Measured return loss

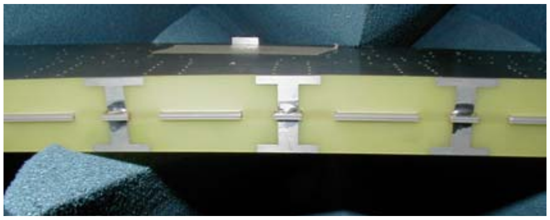


Figure 5- Photo of the array

4. THE MULTIPOLARIZED ELEMENT

The architecture proposed consists of two back-to-back microstrip substrates perpendicularly feeding a pair of crossed dipoles (Figure 6). Each half-dipole is individually fed by a microstrip line. The four microstrip lines are fed separately and by suitably arranging the phase of each feed, all polarizations are achievable: ie. linear (horizontal, vertical and ±45°), and circular (RHCP or LHCP). In all polarization modes, the polarization vector is independent of the orientation of the substrate.

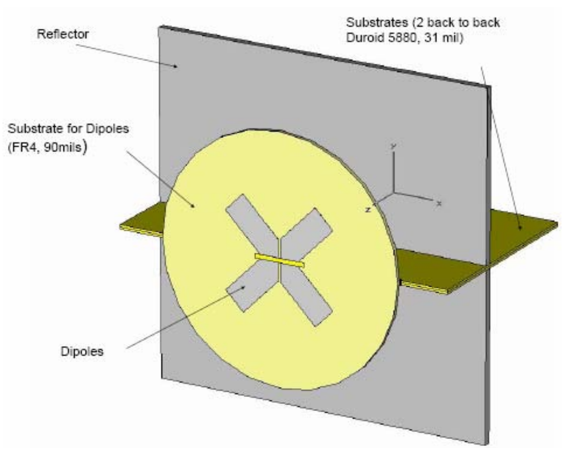


Figure 6 - The proposed radiating element

5. DESIGN

The basic idea of the proposed architecture is to feed each half-dipole independently from the other half dipoles with reference to a common ground. By properly phase feeding each of the half-dipoles, all the main polarizations can be created. Table II summarizes the polarization options and Figure 7 shows the port notation. Considering the field orientations, each half-dipole is fed out of phase with respect to its ‘counterpart’. Table II ignores this, assuming that the feed network takes care of that.
The four half-dipoles are individually fed by microstrip lines and are separated by λ/4 from a planar reflector. A square hole in the reflector, allows the microstrip line to pass through, with no interaction between the reflector and the lines, and very little impact on the front-to-back ratio of the antenna. A λ/4 slot was introduced in the ground plane to minimize the mutual coupling between the co-planar lines.

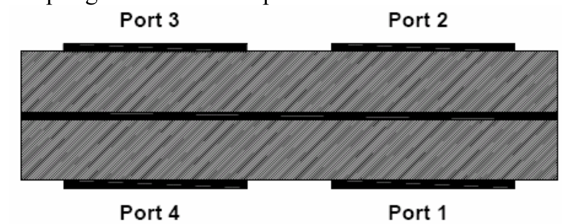


Figure 7 – Port notation

Table II – The Ports Phase for Various Polarizations

Polarization	Port1	Port2	Port3	Port4
Vpol	180	0	0	180
Hpol	180	180	0	0
+45°	180	Loaded	0	Loaded
-45°	Loaded	180	0	Loaded
RHCP	0	90	180	270
LHCP	270	180	90	0

6. RESULTS

The circular polarized (LHCP) version was designed using CST Microwave Studio and IE3D. The layout is absolutely symmetric with respect to both x- and y-axes. The simulated and measured S-parameters are shown in Figure 8.

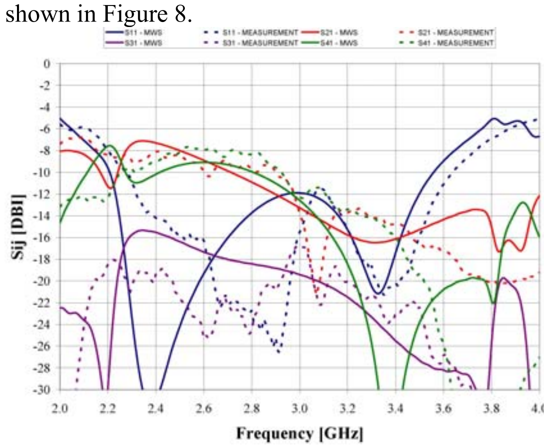


Figure 8 – S-parameters

As shown in Figure 8, the mutual coupling between ports is still relatively high, probably due to surface waves. In the future, the possibility of introducing slots in the substrate itself will be investigated. The return loss is less than 10 dB over a more than 50% bandwidth.
Figure 9, summarizes the main parameters of the antenna such as gain, axial ratio, and the crosspolarization level with respect to the peak of the copolarization pattern (both on-axis). It seems that the antenna operates very well over of more than 25% assuming:
a. Axial ratio (on boresight) <2.5 dB (on-axis)
b. Crosspol level<-20 dB (on-axis)

c. Gain<Max Gain-1dB
d. Return Loss<-10dB
Figure 10 shows simulated axial ratio pattern results for the circular polarization case, and Figure 11 shows the measured spinning linear patterns at 2.2 GHz, 2.5 GHz and 2.7 GHz

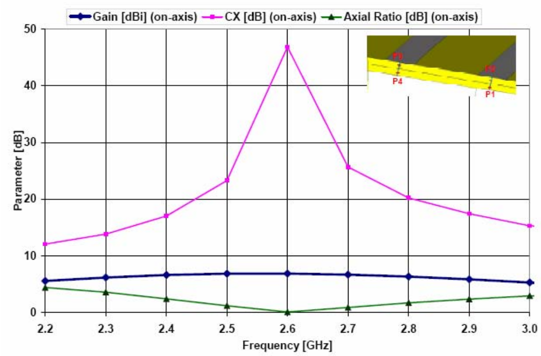


Figure 9 – Antenna performance for the circularly polarized case.

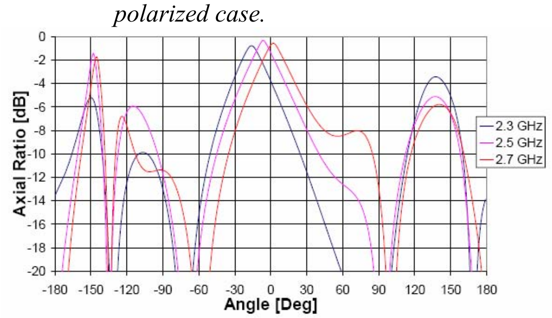
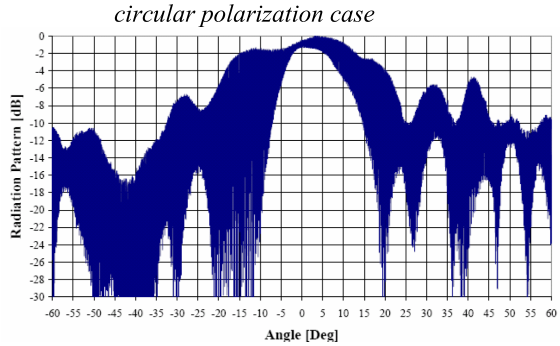


Figure 10 - Simulated axial ratio pattern results for the circular polarization case



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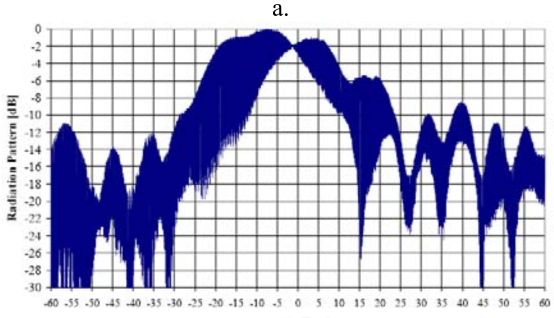

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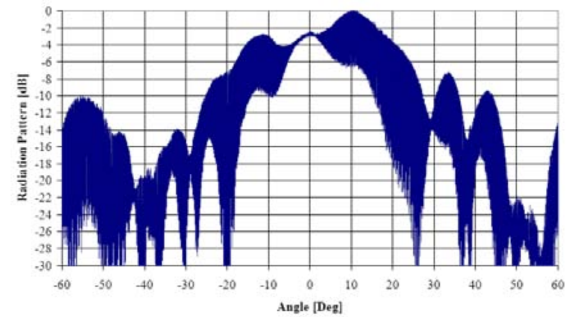

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Figure 11 - The measured spinning linear patterns at: a. 2.2 GHz, b. 2.5 GH, c.2.7 GHz.

7. COMMENTS

The measured results show, relatively good agreements with the simulation predictions. In general, with some exceptions, the measured s-parameters do follow the trends indicated by the simulations. Even though the peak of the copular pattern is fixed, the minimum crospolarization location scans with frequency. That can be seen in measurements (Figure 11) as well in the simulated results (Figure 10). Since this effect occurs in both measurements and simulations, this is a real effect that has still to be investigated. The only source of circular asymmetry is the shared microstrip ground-plane. Its effect still has to be investigated too.

8. CONCLUSIONS

A New Architecture for a Multi Polarized, Perpendicularly-Fed, Radiating Element was presented. More work has to be done in the improvement of the crosspolarization and axial ratio beamwidth. A number of options are available, such as the shaping of the shared microstrip ground-plane and the redesign of the baluns feeding the dipoles.

9. REFERENCES

1. David M. Pozar, Robert W. Jackson Jr.; An aperture coupled microstrip antenna with a proximity feed on a perpendicular substrate*, IEEE Transactions on. Antennas and Propagation*, vol. 35, pp. 728 - 731, June 1987.
2. Naftali I. Herscovici, D. M. Pozar; Full-wave solution for an aperture-coupled patch fed by perpendicular coplanar strips, *IEEE Transactions on. Antennas and Propagation*, vol. 42, pp. 544 - 547, April 1994.
3. Aleksander Nesic, Sinisa Jovanovic, Ivana Radnovic; Wideband printed antenna with circular polarization, *1997 IEEE International Antennas and Propagation Symposium Digest*, vol. 35, pp. 1882 - 1885, June 1997.