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Scanning Performance of Wide Band Connected Arrays of Dipoles

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Abstract— A prototype array of dual polarized connected dipoles has been manufactured. The feed structure is composed by two orthogonal 8×8 elements for each polarization (128). The operational frequency ranges from 6 to 9 GHz (40% relative bandwidth). Preliminary measurement results are presented. The results are encouraging and perfectly matching simulations. However, the common mode excitation of the vertical feeding lines is significant when scanning towards wide angles.

I. INTRODUCTION

The realization of wide band, wide scanning angle, phased arrays with good cross-polarization performance has been the object of many recent investigations. Although tapered slot antennas have very broad bandwidth, they are known to produce high cross polarization components, especially in the diagonal cuts (45°), [1]. On the other hand, conventional phased array based on printed radiating elements can achieve only moderate bandwidths (~25%), [2]-[4]. A novel trend in this field is the use of planar long dipole or slot antennas periodically fed at Nyquist intervals to effectively achieve an amplitude and phase aperture distribution without necessarily using separate antenna elements. This concept was originally proposed by Hansen, [5], and further theoretically developed in [6], showing the wideband characteristic of such array. The first practical demonstration of a planar connected array antenna was given in [7]. Thanks to the planarity of the radiators, the low cross-polarization level is among the most important features of such antenna solutions.

This paper reports the development of a phased array of connected dipoles, designed for applications requiring dual polarization, in the operational frequency band 6-9 GHz. The impedance transformation from the wave impedance of the free space, 377 Ohms, at the aperture level, to 50 Ohms at the connector, is performed with two wavelengths long transmission lines, printed on vertical printed circuit boards in an egg-crate configuration (Fig. 1). A transition from coplanar strip-lines (CPS) to coplanar waveguide (CPW) and then to micro-strip (MS) performs the balanced to unbalanced conversion, together with a wideband impedance transformation (Fig. 2).

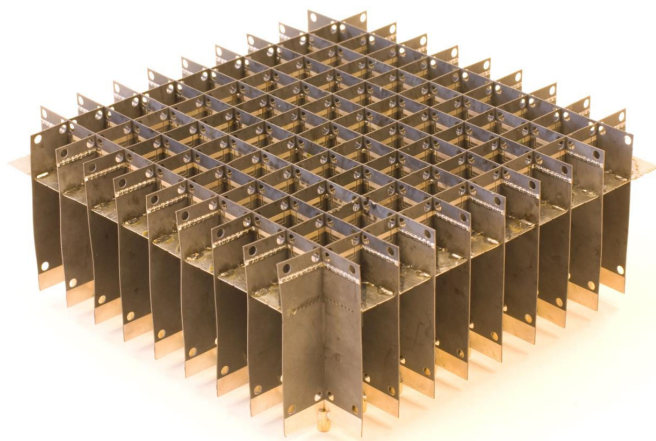


Fig. 1 Prototype 128-elements dual-polarized array for 6-9 GHz experiments.

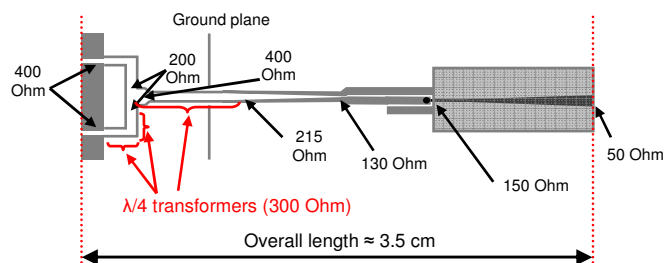


Fig. 2 Feeding lines of the unit element of the array. Impedance transformation from 400 to 50 Ohms is performed.

II. DESCRIPTION OF THE ARRAY

The prototype array is shown in Fig. 1. The dipoles are printed on one side of a low permittivity ($\epsilon_r=2.2$) thin Duroid substrate, and electrically connected to form a unique long dipole periodically fed. The element spacing is 15.52 mm, which is about half wavelength at 9 GHz. The single element is depicted in Fig. 2, with the relative impedance values at different cross sections of the feeding lines. A double feed configuration in each periodic cell has been adopted in order to decrease the reactive capacitance associated with the

feeding gaps. This arrangement of the feeding lines, implemented with a CPS power divider (Fig. 3), improves the bandwidth of the array, [8]. A ground plane is included at a height of approximately $0.3 \lambda_0$ (with λ_0 being the wavelength at 9 GHz) from the centre of the dipole, acting as a backing reflector.

III. COMPARISON OF MEASUREMENT AND SIMULATIONS

The measurements of the performance of the array have been performed only partially because for budget reasons it was not possible to include a complete feeding network that would allow the simultaneous excitation of all the elements in phase. However, the scattering parameters of some of the central elements were measured and their comparison with the results of full wave simulations allowed us to qualitatively interpret the behaviour of the array. The S11 parameter of an almost central port is presented in Fig. 3. While this parameter alone is not sufficient to assess if the array is operating as expected, it is apparent that it presents relatively high values, in the order of -8 dB's, in two sub-bands 5-6 GHz and around 8 GHz. The second of these two bands is actually inside the desired operational band (6-9 GHz). Triggered by this observation, simulations of the entire structure including the feeding network have been performed, for the first time.

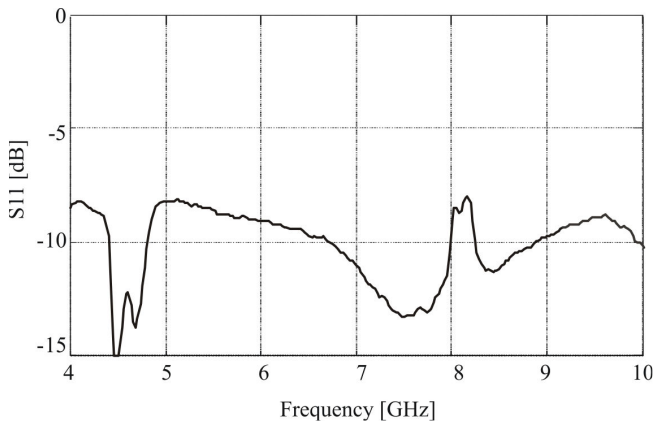


Fig. 3 Measured reflection coefficient of a central element of the array.

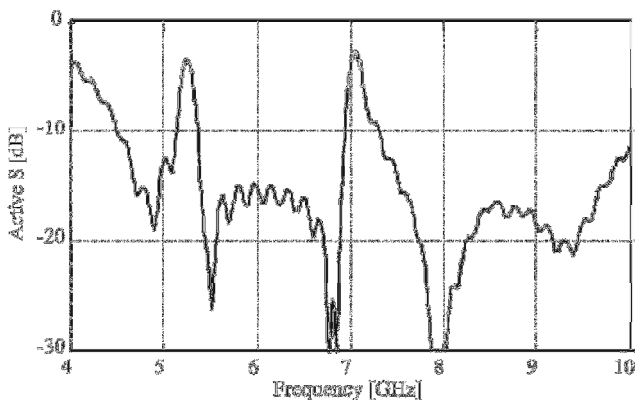


Fig. 4 Active reflection coefficient for an infinite array when radiating toward $\theta=0^\circ$ and $\phi=0^\circ$.

Assuming an infinite periodic array analysis, simulations were carried out via CST Microwave Studio. The reflection coefficient in the presence of the feeding lines was significantly different from those that were simulated in the design phase without the inclusion of the long matching network. In Fig. 4 the simulated active reflection coefficient when the array is radiating toward $\theta=0^\circ$ and $\phi=0^\circ$ is reported. It is apparent that the array is completely mismatched at 5.25 and 7 GHz. At those frequencies, the simulations explicitly show the coexistence of common and differential modes in the long transmission lines. A schematic view of the electric current distribution along the feeding lines is shown in Fig. 5. The structure on the left hand side represents the current at 7 GHz, in correspondence of a common mode resonance, while the right hand side picture shows the current at 8 GHz, with the designed differential mode being dominant.

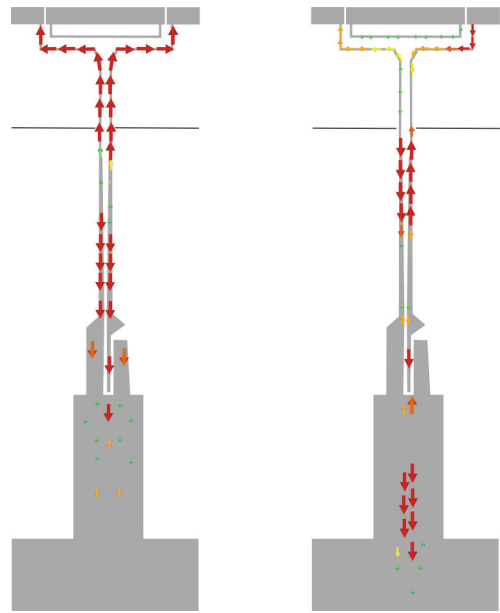


Fig. 5 Vector surface current distribution at 7 GHz (left hand side) and 8 GHz (right hand side). Common modes are excited in the first case, while differential mode is dominant at the second frequency.

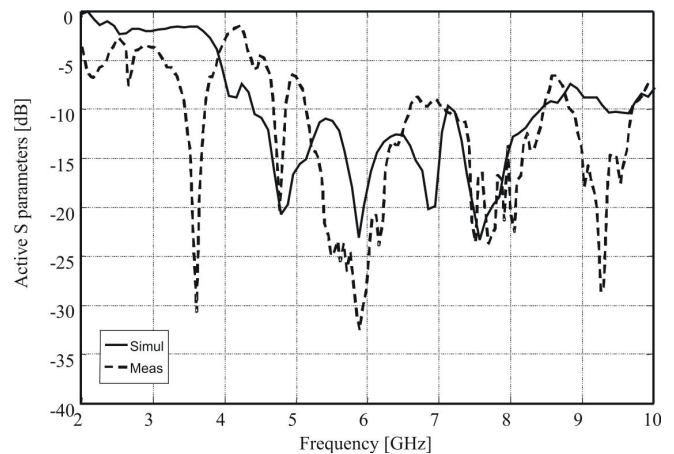


Fig. 6 Active reflection coefficient of a central element of the finite array; comparison between simulations and measurements.

It should be noted that these resonances are sharp and the radiation patterns, not reported here for brevity do not indicate polarization degradation. However the same simulations realized for the array radiating toward $\theta = 45^\circ$ and $\phi = 45^\circ$ also show significant increases of the cross polarized field levels. In practice, the scanning performance of the prototype array is limited by common modes excited in the vertical feeding lines. Needless to say that the infinite array configurations, while of great help in understanding the physics, overestimate the coherence of these standing waves. As a result one can expect that the finite array is in reality better behaved.

At this aim, Fig. 6 shows the active reflection coefficient of a central port of the finite array prototype when scanning toward broadside. The curves pertinent to measurements and to simulations are reported. Note that the measurements include the summation of all significant co-polarized S parameters for the investigated port, while the equivalent simulations are performed using the full wave simulator tool CST and account for the entire finite array (8x8 elements). In this finite array case, the resonances appear to have almost disappeared with respect to the infinite array case in Fig 4. In any case, the comparison between simulations and measurements is relatively good, indicating that the numerical tools are able to described efficiently the wave phenomena in place.

IV. CONCLUSIONS

The preliminary measurements performed on the S parameters have been presented. The comparison with full wave simulations that include the entire array indicates that the prototype has been well manufactured, just as designed. Unfortunately, the elevation angles until which it can be used maintaining good polarization purity is limited to about 20° . For larger angles, the common mode currents excited on the vertical feeding lines portion becomes dominant and can have

a disruptive effect not only on the reflection coefficients but also on the purity of the polarization of radiated fields. The problem of common mode being compatible with connected dipole structures has been recently described by other authors [9]. The solution to this specific threat to the wide angle scanning performances is presently being addressed. A suitable solution appears to be the introduction of ad hoc designed common mode rejecting circuits, realized via printed circuit board transformer.

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