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# Low Cost Millimeterwave Aperture Coupled Antenna Array on Polymer Membrane Substrate

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## Abstract

The membrane technology appears as a convenient solution for high frequency applications. The development of low-cost millimeterwave antenna arrays is discussed in this paper, using polymer dielectric film as a membrane support. An original membrane aperture coupled antenna array is proposed and compared with a planar microstrip approach. Experimental and theoretical results are presented on several topologies.

## INTRODUCTION

Millimeterwave systems are increasingly involved in new commercial communication equipments and systems. In many case, millimeter front-ends are based upon a combination of monolithic and hybrid integrated circuits. Planar circuit technologies ( CPW or Microstrip ) are usually employed for the implementation of passive functions like filters and antennas, as well as for the interconnections between separated sub-systems and modules. Therefore, the integration of passive elements remains a critical point both for electrical and cost motivations. For instance, the CPW technology is undoubtedly interesting for the development of hybrid active functions, because parasitic elements induced by mounting operations can be minimized thanks to the ground planes proximity. Nevertheless, microstrip and especially membrane technologies are really dedicated to the integration of antennas and small-bandwidth filters regarding either radiation efficiency or parasitic coupling and

losses, around 40 or 60 GHz.

We investigate on the development of an alternative ultra-low-cost membrane technology based on the use of organic and polymer dielectric substrates [ 1 ] for the realization of antenna arrays. Indeed, this solution is quite efficient for optimising interconnections between the feeding network and the radiating elements.

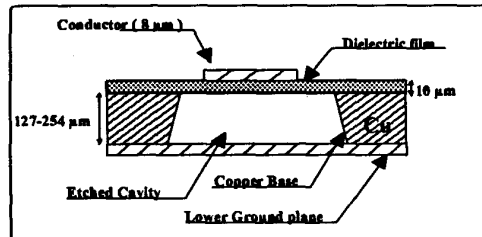
In a previous work, we proposed different hybrid solutions for realizing antenna arrays through an optimal combination of a feeding network and surface mounted membrane antennas on an alumina motherboard [ 2 ].

In this paper, we first present experimental and theoretical results on a single membrane antenna with its associated feeding port made on a thin dielectric substrate(TFMS section) which is simultaneously as considered thin dielectric film (40  $\mu\text{m}$ ) in the membrane region. In a second part, comparisons between the electrical performances of a 4x4 membrane antenna array and an equivalent design on a classical substrate ( Duroid ) are provided. Finally, we present an 4x4 aperture coupled antenna array, using a backside microstrip feeding network, and upper membrane antennas. This solution appears to be very attractive resulting in a significant reduction of cross-polarisation effects, and a better control of the side-lobes and efficiency.

## - Alternative Membrane Technology : Interconnections and Measurements. -

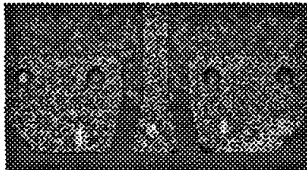
In previous paper, we have proposed new alternative membrane-technologies by means of

polymer membrane film and etched copper cavities(fig.1). The excitation of membrane sections is performed by using TFMS(Thin Film Micro-Strip) transitions. Indeed, this structure is obviously the most suitable topology for properly exciting the TEM membrane mode.



**Figure 1** : Description of a polymer membrane structure (Microshielded lower cavity only).

The TFMS lines are also well suited for ensuring a correct probe excitation of the structure. In this way, we have developed GCPW to TFMS transitions(fig. 2). The ground plane continuity is obtained by means of 20 μm via-holes located at the interface between CPW probe section and membrane TFMS access.

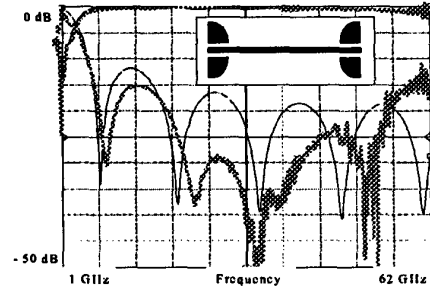


**Figure 2** : GCPW to TFMS transition at input ports on BCB substrate

Via-holes usually bring undesired drawback for both electrical and cost considerations.

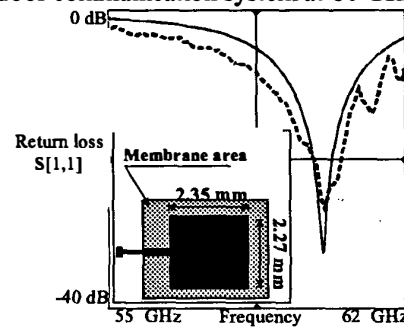
We investigate on the development of broadband transitions by replacing the previous via-holes by an electromagnetic coupling[3]. Then, large coupling phenomena can be achieved through capacitive resonant structures connected to both CPW ground planes of the feeding ports. The shape and the area of such ground pads matching topologies determine the effective operating bandwidth of the transition, in accordance with the dielectric substrate thickness. A back to back GCPW to TFMS transition has

been measured on a wide frequency range(fig.3). An operating bandwidth greater than 55 GHz (for a -10 dB return loss) is achieved, with a center frequency of 40 GHz, and insertion losses lower than -0.4dB/mm.



**Figure 3** : Back to back CPWG to TFMS transition (— : Simulation, - - - : measurements)

This kind of interconnection has been successfully used for the characterization of a millimeterwave membrane antenna (fig.4) designed for an indoor communication system at 60 GHz.



**Figure 4** : Return loss of a basic membrane antenna at 60 GHz(— : Simulation, - - - : measurement)

A proper excitation of the membrane section can be achieved and such transitions can really be considered for interconnecting basic membrane functions and active circuits.

**- Planar Millimeterwave antenna arrays : Microstrip or membrane approach ? -**

Regarding efficiency and radiation patterns, significant improvements are observed when developing basic patch antennas on a membrane environment. Unfortunately, the dimensions of the radiating elements are increased, and strong

interactions between the feeding network and the patch can be encountered when designing planar antenna arrays.

Two 4x4 antenna arrays have been designed at 40 GHz to estimate the performances of such array when implemented using a membrane or a microstrip technology. The same excitation coefficients have been chosen for both array [ 0.5 1 1 0.5 ] for achieving a 20° -3dB beamwidth, with -20dB side-lobes rejection.

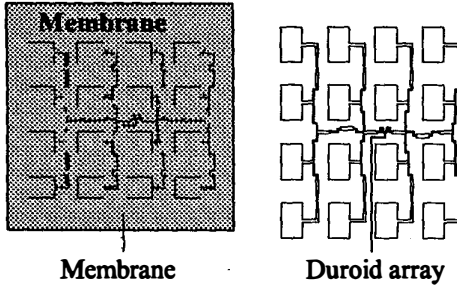


Figure 5 : Design of the two 4x4 arrays

As depicted on figure 6a, side-lobes appear with the membrane configuration (upper than -15 dB) with a significant degradation of the cross-polarization level (around -15dB). These two phenomena are related to the high parasitic radiation effects of the feeding network. However, the efficiency of this array is quite good (55%) and the evaluated gain is around 16 dB.

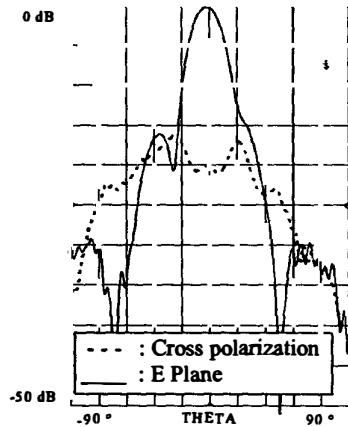


Figure 6a : Experimental results for the Membrane array

In comparison, the microstrip array (Fig 6b) appears to be less sensitive to the radiation effects of the feeding network; it is unfortunately characterized by a reduced efficiency (Gain = 12 dB).

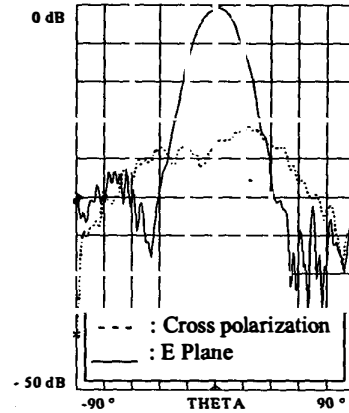


Figure 6b : Experimental results for the 4x4 Duroid array

Therefore, to ensure a maximum efficiency and to reduce the effect of the feeding network on the radiation pattern, an alternative technological solution was chosen for designing membrane antenna array.

**- Aperture coupled Membrane antenna arrays -**

An aperture coupled antenna array has been realized by using a two layers substrate topology. Radiating patches are implemented on an upper membrane layer while the feeding network is located on a backside duroid substrate.

**a) Global cavity membrane array :**

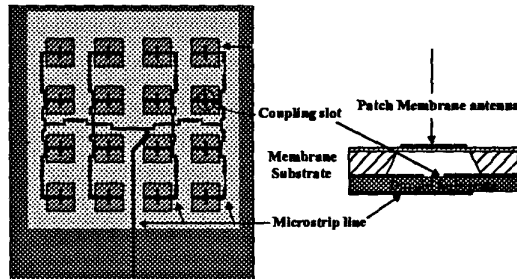
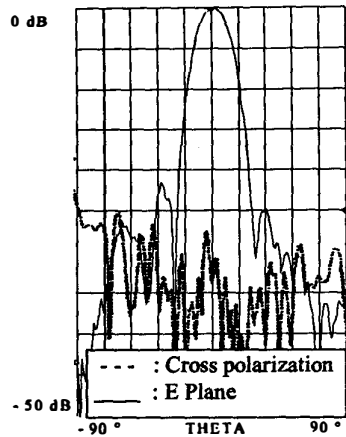


Figure 7a : Design of the aperture coupled array

The figure 7a describes a first configuration of

an aperture coupled array based upon the proposed hybrid implementation ( $F_0 = 40$  GHz,  $-3$  dB beamwidth =  $20^\circ$ , side-lobes level  $< -20$  dB).

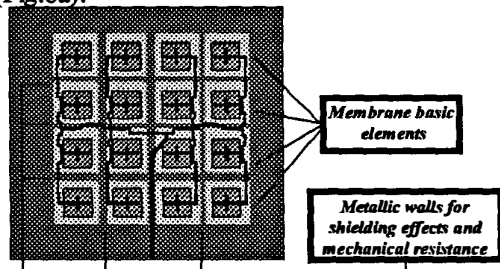


**Figure 7b** : Experimental results of the aperture coupled array with the global cavity approach

According to measurements (Fig.7b), the reduction of the cross-polarization is easily achieved with this technological solution (lower than  $-25$  dB). Furthermore, the alignment mismatch does not have great influence on measured performances and the antenna gain is increased in comparison with the Duroid antenna array (average gain 15.5 dB).

**b) Grid cavity membrane array :**

Moreover, the parasitic lateral coupling between membrane patch antennas can be reduced by controlling the backside membrane cavity dimensions nearby each radiating elements (Fig.8a).

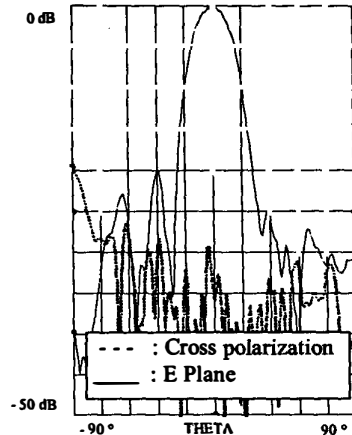


**Figure 8a** : Design of the new aperture coupled array

This is also a convenient solution for increasing

the mechanical resistance of the membrane film.

According to measurements (Fig.8b), this new approach is a good solution for simplifying the report of the membrane antenna layer. In term of performance, the grid cavity membrane array gives results comparable with the previous one (Fig. 7b).



**Figure 8b** : Experimental results of the aperture coupled array with the grid cavity approach.

**CONCLUSION**

This paper proposes an original design solution in order to develop very efficient antenna arrays for millimeterwave systems. According to measured results, the membrane solution appears more and more attractive both from cost and performance points of view. This technology offers numerous interconnection possibilities, and by fact, it gives to this solution a real opportunity of standardization.

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