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► To cite this version:

Serge Perrot, Christian Person, Laurent Carré, Hervé Lattard, Michel Ney. Proposed design solutions for low-cost flip-chip membrane devices for millimeterwave applications. 1999 IEEE MTT-S International Microwave Symposium, Jun 1999, Anaheim, United States. 10.1109/MWSYM.1999.780346 . hal-02399434

HAL Id: hal-02399434

<https://hal.science/hal-02399434v1>

Submitted on 25 Feb 2024

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Proposed Design Solutions For Low-Cost Flip-Chip Membrane Devices For Millimeterwave Applications

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Abstract

The membrane technology appears as a convenient solution for millimeterwave applications. An alternative low-cost polymer membrane process is proposed in this paper, and extended to the design of high performance antennas. Technological compatibility with standard process is also discussed, and an original Flip-chip concept is proposed for membrane antennas.

INTRODUCTION

In the last few years, developments of millimeterwave applications have generated new requirements for microwave integrated structures. Main efforts concern the minimization of losses and parasitics effects at such frequencies, under low cost and high performances considerations.

In this way, some original configurations have been proposed, like the thin-film membrane technology suggested by Rebeiz et al [1] in 1990; the numerous investigations performed on such semi-transparent substrate have underlined its great advantages in terms of electrical performances (lossless microshielded structures), of modal dispersion (TEM mode up to 100GHz) and technological sensitivity (oversized circuits).

This is specifically attractive for planar antenna design because the radiation element can be located on membrane section, with high radia-

tion efficiency and enlarged operating bandwidth. Nevertheless, thin film membranes are usually processed using semi-conductor technologies, and are not really optimized in terms of cost and technological compatibility (interconnection). We have proposed in 1998 [2] an alternative low-cost membrane process based upon a polymer thin-film dielectric sheet (BCB from Dow-Chemical). We demonstrate at once in this paper that this solution can be efficiently used for the design of optimum membrane antennas (in terms of bandwidth and interconnection possibilities). Furthermore, it can be efficiently used for implementing antenna arrays, the upper microshielded cavity being considered as a decoupling structure between the radiating elements and the feeding network.

Lastly, we investigate on the possibility of designing SMC (Surface Mounted Component) or Flip-Chip membrane antennas for mmwave applications. Previous verifications have been performed on usual Membrane transmission lines mounted on pre-formed alumina substrate. Experimental results are given and the technique is extended to the implementation of antennas in the form of flip-chip devices.

- I - Technological process

The generic structure is depicted in figure 1 and is constituted of a spin-coated high performance dielectric film ($\text{tg}\delta \approx 1\text{e-}4$, $\epsilon_r=2.7$) between top and bottom microshielded Copper



cavities. Therefore, standard dielectric and conductive materials are involved, in association with common etching procedures for both the cavities and the single top-side circuit pattern. This contributes at once to cost reduction, but can be also efficiently used for interconnection facilities between the membrane area and any external connected circuit.

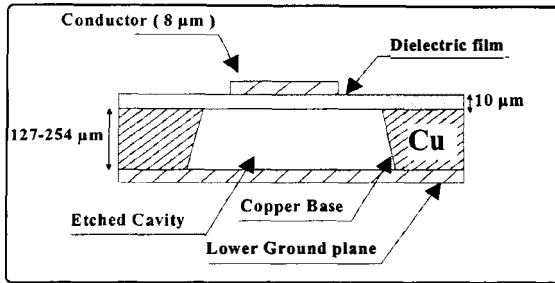


Figure 1 : Description of a polymer membrane structure (Microshielded lower cavity only).

We have made various investigations for defining different optimized membrane feeding structures. Thanks to the electrical characteristics of the BCB dielectric film, quite good results have been obtained, and compared successfully with 3D simulation results (HFSS).

- II -Designing MMwave antenna on BCB membrane technology

Preliminary investigations have shown the validity of the BCB membrane technology for passive filters and couplers [3].

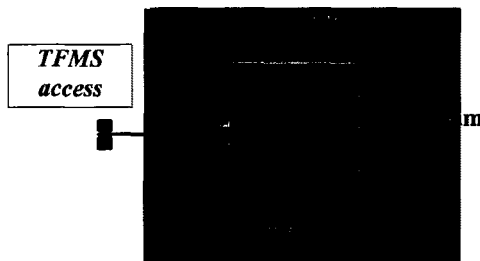


Figure 2 : Membrane patch antenna on BCB substrate.

Considering the different advantages offered by the BCB membrane structure (i.e. low relative permittivity (<1.1), backside reflecting cavi-

ty, connection facilities), the implementation of planar membrane patch antennas was investigated in the Ka band (fig. 2).

The structure was designed using 2.5D CAD software (IE3D from Zealand Software), except for the 3D transitions between TFMS input lines (on BCB substrate) and membrane feeding striplines. The antenna can be easily matched because of the wide available characteristic impedance levels for transmission lines on membrane section.

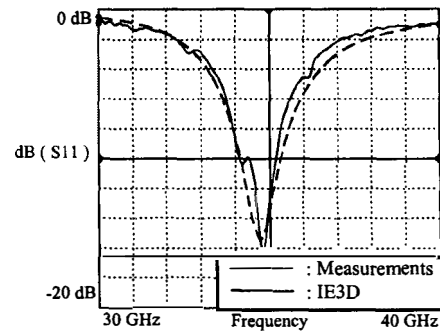


Figure 3 : Simulated and experimental results on return loss. (Antenna dimensions : W = 5mm, L = 3.7)

Resonant frequency : Fr = 34.87 GHz

Bandwith (TOS = 2) : Bp = 1.1 GHz

A good agreement is observed between theoretical and experimental results (figure 3); the operating bandwidth is of about 3 % for a return loss lower than -10dB. The upper copper cavity can be simultaneously used as a shielding structure, for minimizing parasitic interferences between the feeding line and the radiating fields, but also as a tuning element for controlling the beamwidth radiation pattern.

- III -Leading to membrane antenna array

A) Basic Antenna arrays :

The BCB membrane technology offer quite a great flexibility for designing integrated membrane antenna arrays, mainly because of the various possibilities concerning the feeding network optimization. Indeed, different topologies are available (fig. 4), with specific advantages.

The first one (fig. 4a) makes for a minimization of dispersion and radiating element parasitic interferences, because of the membrane characteristics (low permittivity value). On the other hand, a combination of membrane and TFMS sections (fig. 4b) leads to a significant reduction of discontinuities effects (1 or 2 dB reduction of parasitic coupling and reflection), thereby improving cross-polarization levels.

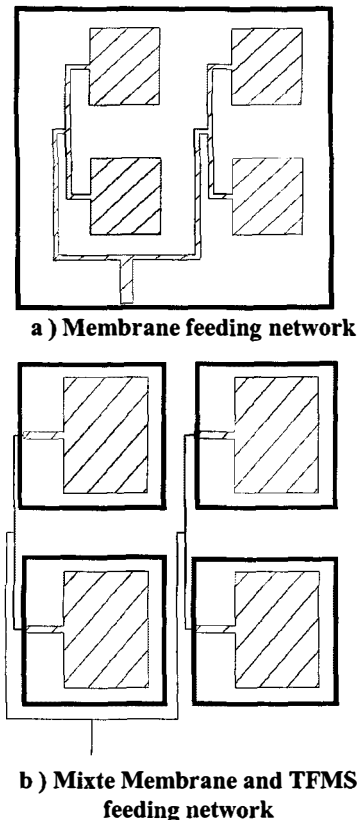



Figure 4 : Different topologies for antenna arrays on BCB membrane substrate.

( Membrane sections)

B) Extension to Flip-chip membrane antennas

Some limitations can be encountered when designing planar membrane antennas; indeed, the bigger is the membrane section area (for implementing a complete array as mentioned on figure 4b for example), the bigger will be the

problems concerning the membrane planarity and homogeneity. In addition, the technological compatibility with external functions (active MMIC functions, IF modules, biasing,..) is not really optimum, because bounding and interconnections have to be considered. This contributes to significant electrical distortions, mainly at mmwave frequencies.

For these reasons, we propose the development of flip-chip membrane antennas (or array). Indeed, flip-chip structures are drawing more an more attention for their several advantages (compactness, small parasitic inductances and high yield rate) and will be probably universally used for active MMIC components in the future, as well as for sensitive passive functions like filters.

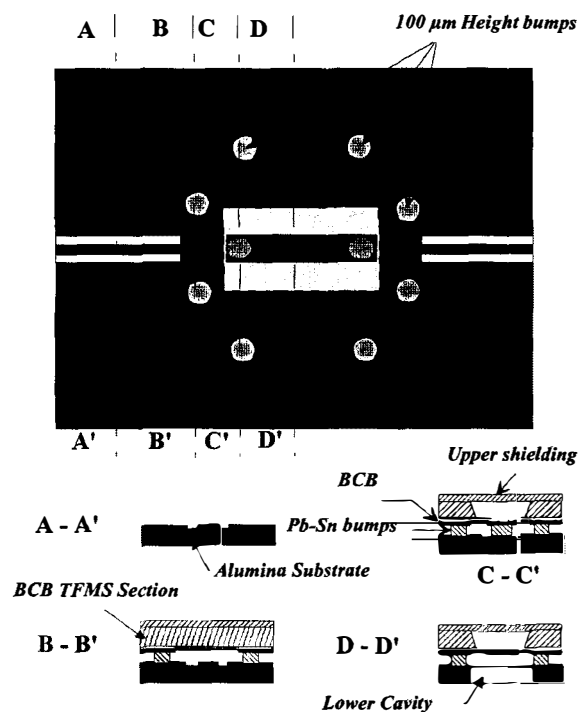


Figure 5 : " Flip-chip " Membrane : Description of the different transitions for a simple transmission line.

At first step, we have designed a back-to-back transition from a coplanar waveguide to a membrane microstrip line. The center membrane sec-

tion is directly report, as a membrane flip-chip component, on an alumina motherboard by means of a 50 μm height conductive glue (fig 5).

In practice, the bump height appears to be twice the value we predicted. However, by including this technological dispersion, a **good** agreement between simulation and measurement (fig 6) has been achieved.

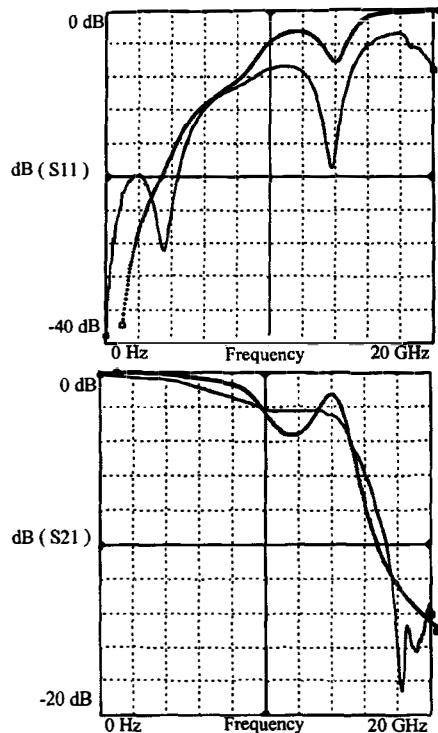


Figure 8 : Back to back transition with flip-chip membrane section : Simulated and experimental [S] parameters. (Effective bump heights taken into account)

We are presently developing flip-chip antennas to be mounted on an alumina pre-formed substrate, using similar transitions and feeding lines. Once again, several solutions exist for controlling the network as presented on figure 7.

CONCLUSION

This paper proposes an original technological solution in order to develop very low-cost membrane antennas for millimeterwave applications.

In addition, the proposed antenna configurations are quite attractive regarding interconnexion possibilities, and design flexibilities. The flip-chip membrane antenna concept is quite original and could solve numerous problems commonly encountered with antenna array designs. It can be extended to any passive membrane function and becomes a real opportunity for the standardization of the membrane technology.

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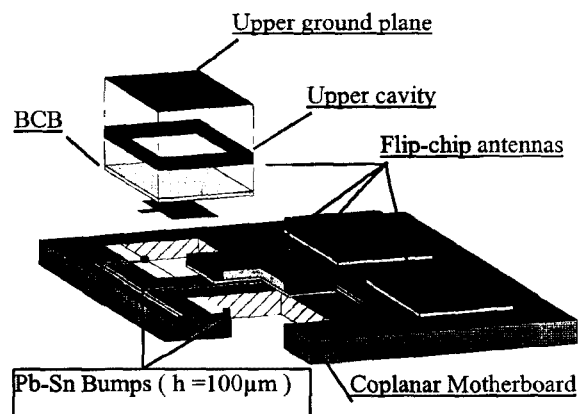


Figure 7 : Flip-chip antenna array