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# CONCEPTION OF INTEGRATED POLYMER ANTENNAS FOR CHARACTERISATION OF DIELECTRIC PROPERTIES

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## ABSTRACT

To design microstrip antennas (1), we have to know the relative permittivity and losses of the antenna substrate. In the case of polymers, these electrical properties are given at 1 MHz by the constructor and are not the same ones at other frequencies. We decide to take this problem back to front and realise K-band antennas to obtain the electrical properties of the polymer (2) in the K-band (from 20 to 30 GHz).

## INTRODUCTION

Compact antenna are required for millimeter-wave active applications, such as tracking or people identification. To obtain small-sized and light antennas, we have to realise them by means of photolithography processes and to use thick dielectric polymer, whose electrical characteristics are only known at 1 MHz. There are several measurement methods to determine the relative permittivity and the losses of a dielectric in K-band (3,4). However, to realise the measurement prototype, it is necessary to add many technological steps (as baking on hotplate for instance) to the process that allows to realise antennas, which can change the electrical properties of the dielectric. We decided to realise different antennas: firstly to determine the electrical properties of the dielectric and secondly to verify these obtained values.

## ANTENNA SUBSTRATE AND DESIGN

We report on integrated proximity-fed antennas, the configuration of which allows the optimisation of both the antenna and active substrates. The active component substrate is gallium arsenide and the substrate of the antenna is an ultrathick dielectric polymer, Amoco Ultradel 7505 (2) (a photosensitized epoxy resin). The antenna configurations are presented in figures 1 and 2. The resonators are made on a polymer substrate and the transmission lines are made on a GaAs substrate, whose thickness, relative permittivity and losses are respectively 400  $\mu\text{m}$ , 12.8 and  $\tan\delta_1 =$

0.08 in the 18-26.5 GHz band. The first antenna, whose photography can be seen in figure 3, is presented in figure 1. The resonator is electromagnetically coupled to the transmission lines through the polymer.

The design of the second antenna (figure 2) is presented in figure 4. The driving patch is electromagnetically coupled to a microstrip line. The driving patch is loaded by parasitic ones and they form the array of the antenna. These parasitic patches are electromagnetically influence-coupled together.

## TECHNOLOGICAL PROCESS

The fabrication process (Figure 5) is realised in clean rooms:

The resin 1400-27 is deposited by spin-coat operation on a GaAs substrate (Figure 5, A). Following a pre-bake on hotplate for 3 min at 100°C, it is exposed to near ultraviolet light to create the desired pattern (Figure 5, B). We develop using 1400-27 developer. The exposed resin is removed in the developer (Figure 5, C). A plating plane is deposited by thermal evaporation of Titane and then of Au on the resin 1400-27 (Figure 5, D). The operation of lift-off allows us to remove the resin, where it has been exposed and to obtain transmission line fabrication (Figure 5, E).

Polymer is then applied by spin-coating to achieve the wanted thickness of the dielectric. Following a pre-bake at 100°C on a hotplate, the polymer is exposed to near ultra-violet light. A pre-bake in a 175°C nitrogen oven is made, then we develop using D510 developer and finally a post-bake on a hotplate is made during about 3 minutes. Then the resonator is deposited on the polymer by thermal evaporation of Ti and Au.

Then the resin is deposited by spin-coat operation (Figure 5, G) and we follow again the processes described in B, C, D, E Figures. We realise a square element.

## EXPERIMENTAL RESULTS

The antennas mounted in K-cell are shown in figures 3 and 4. A K-cell (5) allows the transmission between microstrip line (of the microstrip antenna) and K-connections (of the measurement systems). We measure the frequency evolution of  $S_{11}$  with the HP- 3561A dynamic signal analyser and the gain of the antenna with HP-E4418A power meter in 18-26.5 GHz (Figures

6, 7). The measured resonant frequencies are respectively 26 GHz in the case of the single square resonator, whose dimension is taken as 1.86 mm, and 25.7 GHz in the case of the 3 element-array, whose the spacing between the elements is 0.5 mm. The measured gain of antennas are respectively 1 dB and 3 dB at the resonant frequencies.

## RETROSIMULATION

The CAD software Ensemble (6) is used for retrosimulation. The Ensemble Design simulation engine is based on a full-wave approach using the mixed-potential integral equation formulation in conjunction with the method of moments. It takes into account all mutual effects. In the mixed-potential integral equation approach, the field everywhere in space is expressed in terms of the unknown electric and magnetic surface currents on the finite-shape conductors and apertures through the use of the appropriate scalar and vectorial Green's functions. The Green's functions for a layered medium are generally expressed in terms of a semi-infinite spectral integral known as the Sommerfield integral. The simulation engine uses both electric and magnetic currents to modelise structures with patches on metal layers and apertures on infinite ground layers. The solution process in the simulation engine involves decomposing the integral equation into a matrix equation by applying the method of moments to solve for the unknown current (6). However no detailed technological knowledge on the analytical development of the simulation engine is required to use Ensemble Design. We define the different substrates by thickness, relative permittivity, losses, permeability and the metallisation by conductivity and thickness.

The thickness of the polymer is  $h_2 = 40 \mu\text{m}$ . The properties of the GaAs substrate are :  $h_1 = 400 \mu\text{m}$ ,  $\epsilon_{r1} = 12.8$  and  $\tan\delta_1 = 0.08$ . These values are well-known and constant. The resonant frequency depends on the relative permittivity when the gain and the matching depend on the losses. The relative permittivity ( $\epsilon_{r2}$ ) and the losses ( $\tan\delta_2$ ) of the polymer are varied in order to fit the measured results. We obtain a relative permittivity of  $\epsilon_{r2} = 2$  to have the resonant frequency at 26 GHz and losses of  $\tan\delta_2 = 0.1$  to obtain a gain of 1 dB and matching of  $S_{11} = -30 \text{ dB}$  at the resonant frequency (Figure 6).

We do simulations for this 3 elements antenna with relative permittivity and losses obtained for the single element antenna, and compare with measurement of 3 elements antenna (Figure 7). The gain and the matching at the resonant frequency show the same gain and a slight discrepancy for the matching (-15 dB instead of -18 dB expected). We observe a discrepancy of the resonant frequency (25.7 GHz when measured instead of 25.2 GHz when simulated). The measured resonant frequency (25.7 GHz) agrees with a relative permittivity of  $\epsilon_{r2} = 1.8$

## CONCLUSION

We have obtained a relative permittivity  $\epsilon_{r2}$  between 1.8 and 2, and losses  $\tan\delta_2$  equal to 0.1 for the polymer in the 18-26.5 GHz band by means of experimental measurement : frequency evolution and gain of a microstrip antenna integrated on the polymer layer. The discrepancy between the relative permittivity obtained with the first antenna and the second one is equal to 12 % and can be attributed to K-cell measurements, but not to the technological processes or dimensions of the antennas (2  $\mu\text{m}$ .accuracy) The losses of the dielectric are well determined but appear too important for electronic applications.

## PERSPECTIVES

Other antennas, such as electromagnetically-coupled through a slot, have been investigated, but are limited by too important losses due to thicker dielectric (7). A comparative study with other electrical properties characterisations (3, 4) is being investigated.

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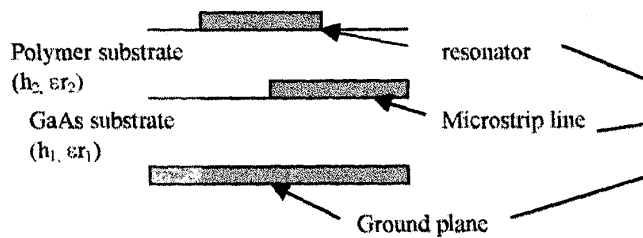


Figure 1 : Structure of proximity-fed antenna



Figure 3 : Single element antenna mounted in a K-cell

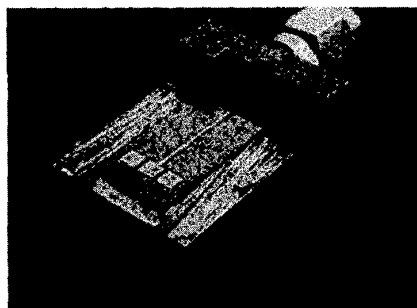


Figure 4 : 3 elements antenna mounted in a K-cell

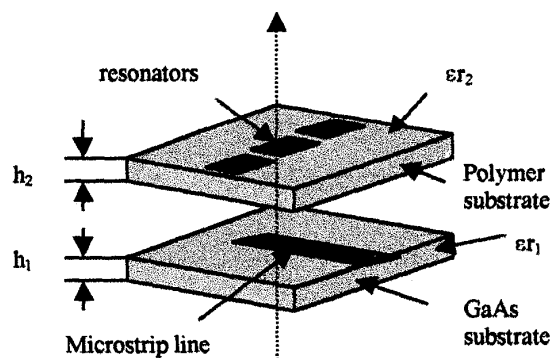


Figure 2 : Exploded view of proximity-fed 3 elements antenna

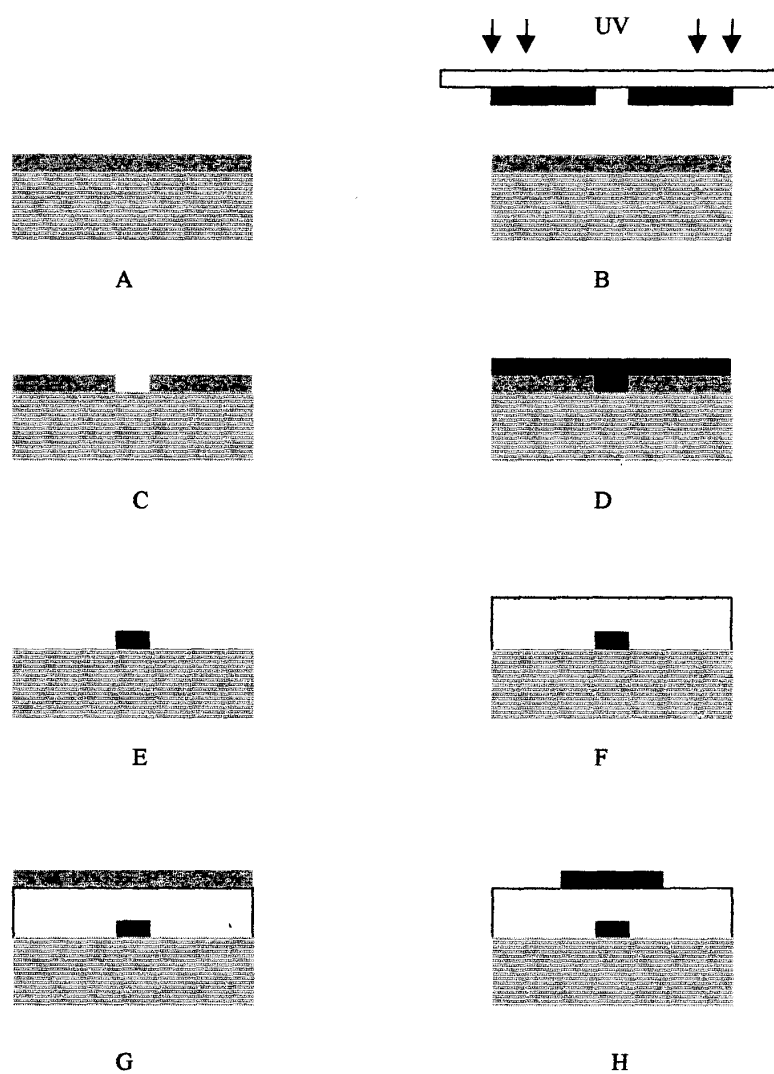


Figure 5 : Technological process

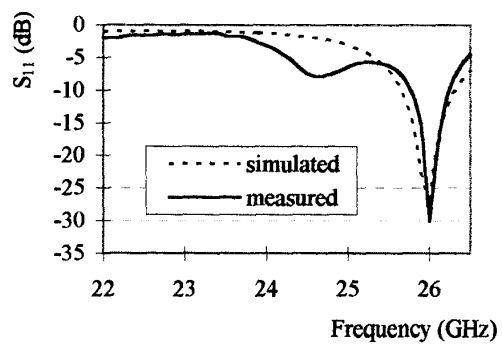


Figure 6 : Experimental and simulated results (single element antenna)

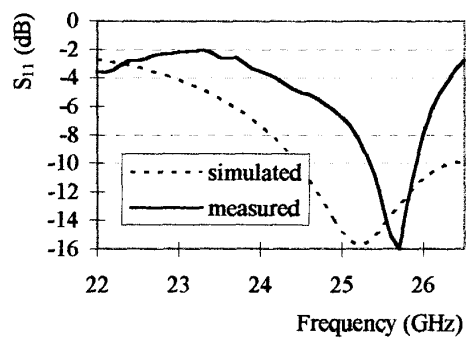


Figure 7 : Experimental and simulated results (3elements antenna)