Monolithic Microwave Integrated GaAs Electromagnetically-Coupled Antenna

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Abstract- **Monolithic antenna on GaAs to be used in miniature active sensors is presented. After a first study of technological processes and the characterisation of various substrates in K-band, the feasibility of an antenna, operating in K-band, electromagnetically-coupled and integrated on GaAs by monolithical realisation, has been demonstrated. A low profile (1mm) and wide bandwidth (2.3 GHz around 25 GHz) antenna is obtained.**

Index Terms - **Active antennas, GaAs MMIC**

I. INTRODUCTION

In recent years, there has been growing interest in the development of communication systems for localisation identification of objects, automatic tolling and livestock management. Compared to other techniques, the use of microwaves in such systems offers a variety of advantages including contactless information and large bandwidth for high-speed data transfer.

These systems ask for compact antenna design. The use of electromagnetic-coupled antenna in the range of millimeter waves allows to obtain small-sized and light antennas. Up to now, most active multilayer antennas were realised by reporting the active components directly on the antenna substrate [1]. In order to avoid bad connections due to air gaps and provide an accurate feeding position the antennas are fully realised by means of technological photolithography processes. A microwave proximity-fed antenna [2] is realised through the technological optical processes and a bandwidth of 400 MHz is obtained for a single resonator at 26 GHz.

This paper reports on a monolithical electromagnetically-coupled antenna on GaAs substrate. This structure avoids any interaction between the resonator and the transmission line and allows to process on the two sides of GaAs substrate : on one side the antenna and on the other side the active components. However this structure requires more technological processes (thermal constraint because of thicker dielectric substrate, two-side alignment).

II. DESCRIPTION OF THE ANTENNA

A. Structure of the antenna

The structure of the antenna is presented in Fig. 1. It is a two-layer structure whose radiating part is a single resonator. This patch is deposited on a dielectric substrate with a low relative permittivity ε_{r1} giving a good radiating efficiency. To avoid any interaction with the resonator, the transmission line is built on the opposite side of the antenna on a high-permittivity substrate with a relative permittivity ε_{r2}. The patch is fed by electromagnetic coupling to a 50–Ω microstrip feedline through a slot-aperture in the ground plane [3]. Furthermore, this design allows both a reduction of the complexity of the feeding network (which is reduced to a simple transmission line) and reduces the losses,
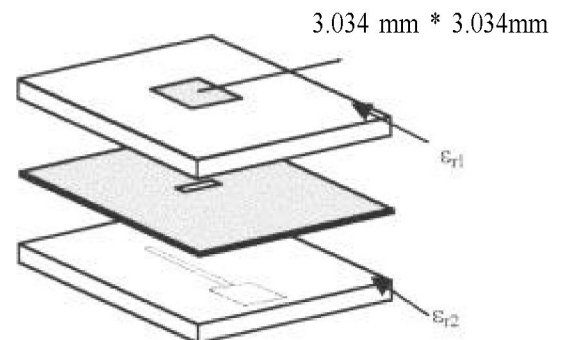

3.034 mm * 3.034mm

Figure1 : Multilayer structure of the antenna

B. Dimensions of the antenna

The CAD software Ensemble [4] is used to design the antenna. 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 Sommerfeld

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 [4]. However no detailed technological knowledge of 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 properties of the GaAs substrate are : hr = 460 μ m, ε_{r1} = 12.8 and tan δ_1 = 0.08. The thickness of the polymer is h_2 = 300 μ m and a relative permittivity of ε_{r2} =2 is taken in first step to determine the design of the antenna.

The width of the square resonator is 3.034 mm. The size of the coupling aperture is 2x0.4 mm^2. The size of the single resonator antenna is 10 mm^2 and the thickness of the antenna is thinner than 0.8 mm.

C. Optimised technological process
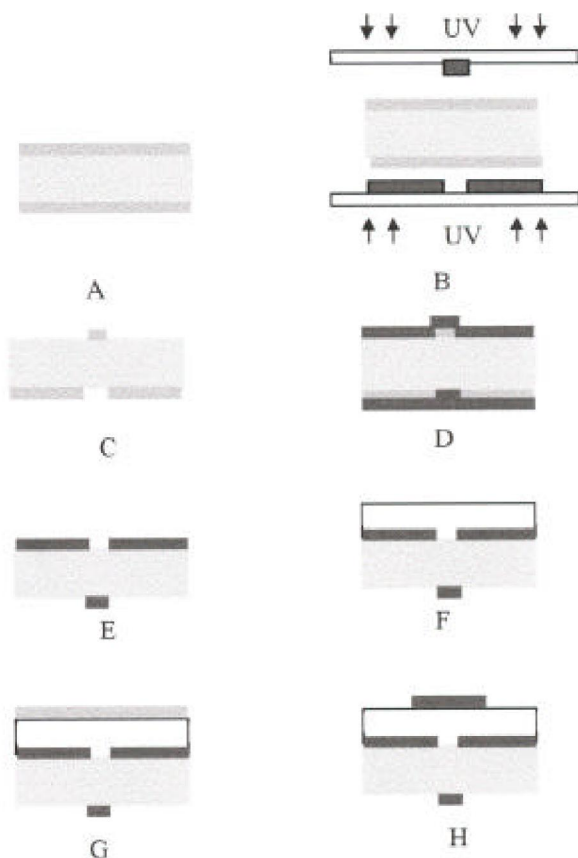
The optimised process is the following one (Fig.2).

Figure 2 : Technological process

On one side of the GaAs substrate a transmission line is deposited by thermal evaporation of Ti (200 Å) and Au (5000 Å) and on the other side (ground plane) a slot is made : the resin 1400-27 is deposited by spin-coating operation on both sides of the GaAs substrate (Figure 2, A). Following a pre-bake on a hotplate for 3 min at 1OO°C, it is exposed to near ultraviolet light to create the desired patterns (Figure 2: B). We develop using 1400-27 developer. The exposed resin is removed in the developer (Figure 2, C). A plated plane is deposited by thermal evaporation of Titane and then of Au on the resin 1400-27 (Figure 2, D). The lift-off operation allows us to remove the resin where it has been exposed and to obtain transmission line and slot fabrication (Figure 2, E).

Resin Su-8 [5] is then applied on the ground plane by spin-coating to achieve the wanted thickness of the dielectric. Following a pre-bake at 100°C on a hotplate and a bake in a 105°C oven during 5 hours, the resin is exposed to near ultra-violet light. These different steps polymerize the resin Su-8 and have been optimised to avoid thermal constraints. Then the resin is deposited by spin-coating operation (Figure 2: G) and we follow again the processes described in figures B, C, D, E. We realise a square element.

The alignment through a thick dielectric needs to use a see-through dielectric.

D. Technological constraints

During the technological realisation of the antenna. we were confronted with thermal constraints. On the figure 3, we can see the result of cooling of Resine Su-8 on GaAs substrate : the GaAs substrate - 460 urn thick - has been broken by action of 300 urn of Resine Su-8 during the temperature decrease from 105°C to 25°C.

Figure 3 : Thermal constraints

To solve this problem we used a slow decrease of temperature associated with a silicium substrate sticked under the GaAs substrate in order to rigidify it. This solution allowed to realise antenna with resine Su-8 substrate.

E. Antenna in K-cell

In order to characterise microstrip antennas at 25 GHz, we use K-cell [6]. A K-cell allows the connexion between the transmission line of antenna and the ports

of the measurement set-up. In figure 4.a we can see how the microstrip line antenna is connected to a K connector.

The originality of this K-cell is in the insert shape (Figure 4.b)) due to the structure of antenna : the microstrip line and the resonator are each on a side of the antenna. The slot in the insert allows the radiation of the antenna. The size (Figure 4.b) a, b, c) of the slot is calculated to prevent any coupling between the resonator and the K-cell. The height d of the insert depends on the mechanical constraints due to the diameter of the screw.
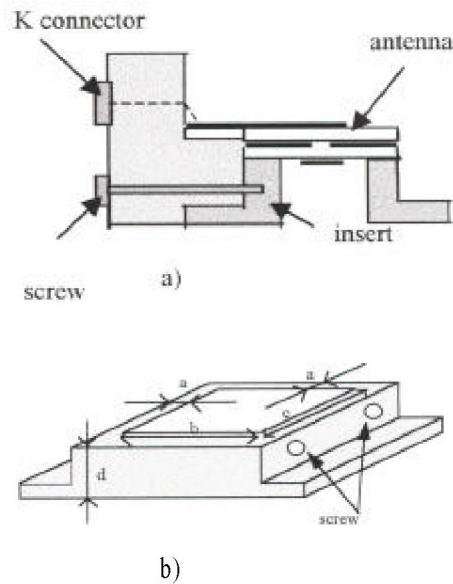

Figure 4 : a) K-cell
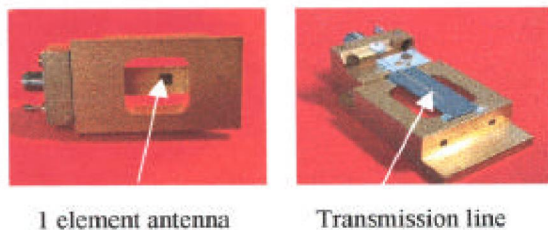b) insert (a=5 mm ; b=15 mm : c=15 mm ; d=9 mm)

Figure 5 : Antenna installed in a K-cell for characterisation

III. EXPERIMENTAL RESULTS

The antenna was built and mounted in a K-cell [6] (Fig.5.) to allow to measure the frequency evolution of the S_{11} parameter (Fig.6) and the radiation patterns (Fig.7) at the resonating frequency.

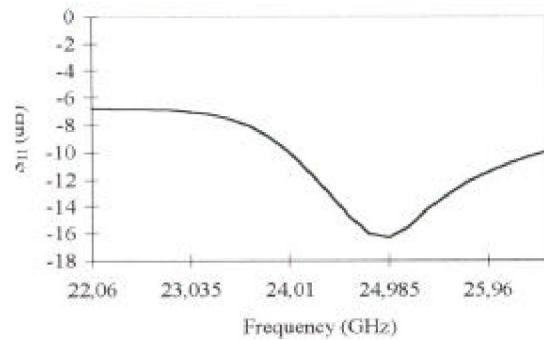*A. Frequency evolution of the S_{11} parameter*

Figure 6 : S_{11} measured vs frequency for the single resonator antenna

The resonating frequency is 24.985 GHz : moreover the measurements show a wide bandwidth (Fig.6) : 2.3 GHz for this single resonator antenna. It can be noted that the bandwidth measured for a single electromagnetically-coupled resonator is very wide (2.3 GHz) compared with a 1 element proximity-fed antenna *(400 MHz) [2].*
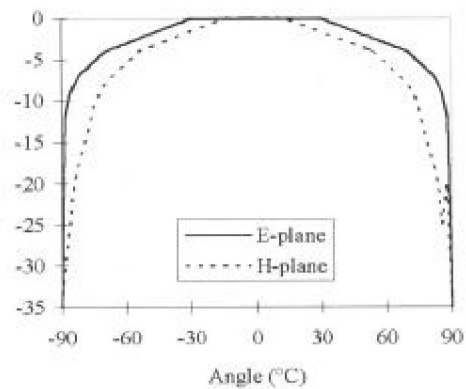
B. Radiation patterns

Figure 7 : Radiation patterns in the E-plane and H-plane

They have been measured at 24.985 GHz. We can see in figure 7 the aperture angle. It is equal to 60 °C in the E-plane and 44 °C in the H-plane. As for every l-element microstrip antenna, we can note that the aperture angle is large.

C. Gain

The measured gain is 0.5 dB at 24.985 GHz : this low value can be explained by important dielectric losses.

D. Substrates of Monolithic Microwave Integrated GaAs Antenna

It must be noted that the commercial polymers. used as antenna substrates. are only characterised at 1 MHz by the maker. so that the electrical characterisation of polymer properties after the technological processes optimisation is required in K-band to obtain an accurate design of the antenna [7].

IV. CONCLUSION

The feasibility-study of monolithical antenna on GaAs substrate in K-band for active antenna applications has been presented. Size reduction. full integration. wide bandwidth have been obtained for this antenna. but however a too low gain due to important dielectric losses is obtained An accurate characterisation of the electrical properties of the polymer in K-band is being investigated.

V. REFERENCES

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