LOW-COST DESIGN OF A QUASI-OPTICAL FRONT-END FOR ON BOARD MM.WAVE PULSED RADAR

N. HAESE, M. BENLAMLIH, D. CAILLEU, P.A. ROLLAND

Centre Hyperfréquences et Semiconducteurs - U.A. CNRS N° 287
Université des Sciences et Technologies de Lille
59655 VILLENEUVE D'ASCQ CEDEX - FRANCE

Work supported by EEC programs (DRIVE V 1002 Prometheus PROCHIP)

ABSTRACT

The purpose of this paper is to describe a new design of a low-cost mm.wave pulsed radar for automobile applications. It is based on a quasi-optical approach and uses a limited number of microwave devices. Experimental results are provided.

INTRODUCTION

Several civilian applications of microwaves are emerging today mainly for road traffic telematics and safety. These applications need the development of low size low cost microwave and millimeter wave front ends. This paper presents a quasi-optical MIC design of a heterodyned pulsed radar for obstacle detection. The aim of this approach is to reduce circuit complexity and to limit the number of microwave devices used.

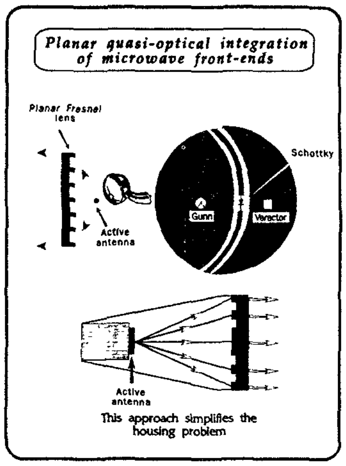

Figure 1

Millimeter wave quasi optical front-end design

The basic principle of this quasi-optical approach is illustrated figure 1 in the case of a FM-CW Doppler sensor [1] [2]. A planar active antenna illuminates a planar Fresnel lens in transmission [3] in order to reduce size and weight and to simplify the housing problem. The TM_{11} disc antenna shown in figure 1 is difficult to handle at millimeter wave frequencies if commercial packaged diodes are used because of its limited area. In order to increase this antenna area for easier hybrid integration of packaged devices we used an electromagnetic coplanar coupling between a disc and a ring planar antenna as shown figure 2a [4]. The disc antenna radiates in the TM_{11} mode while the ring antenna is operated in the TM_{12} mode. If these two coupled antennas are designed to resonate at nearly the same frequency the radiating pattern of this disc-ring antenna is close to the TM_{11} circular patch radiating pattern well suited for the illumination of the Fresnel lens as illustrated figure 2b. Figure 2c shows a typical radiated spectrum of such a pulsed active antenna at 60 GHz excited by a fundamental mode GaAs Gunn diode. The measured isotropic conversion losses of the quasi-optical mixer are plotted Figure 3 as a function of the IF frequency and are lower than 10 dB in the bandwidth of interest (200 - 500 MHz).

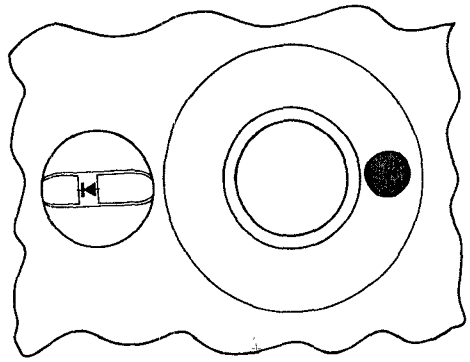

Figure 2a : Topology of the 60 GHz ring-disc active antenna

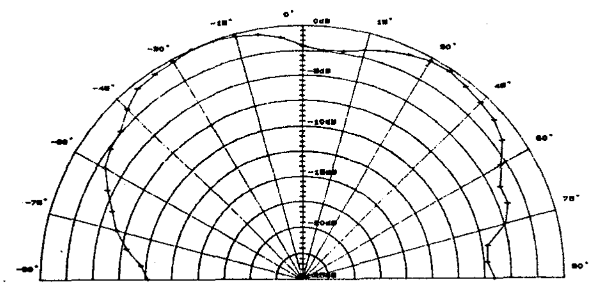

Figure 2b : Typical Radiation pattern of the active ring-disc antenna (Eplane).

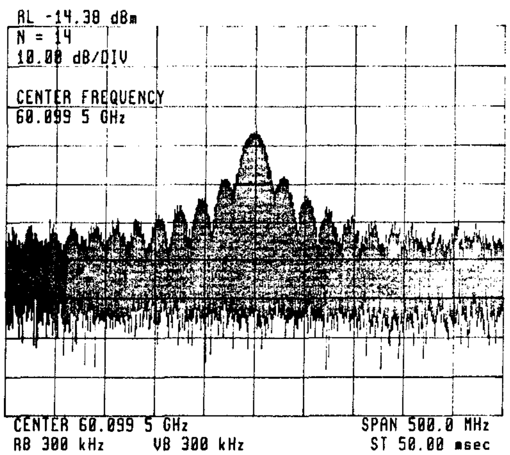

Figure 2c : Radiated spectrum of the pulsed 60 GHz ring-disc active antenna.

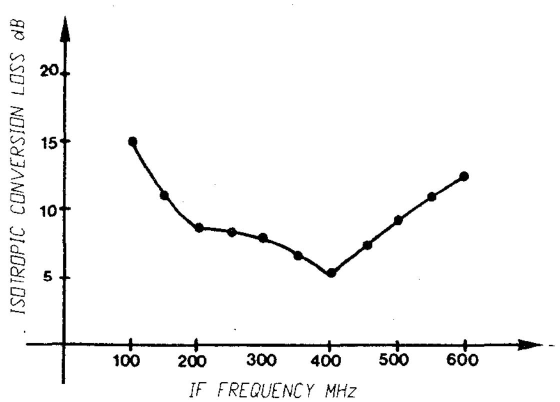

Figure 3 : Isotropic conversion losses of the 60 GHz quasi optical mixer as a function of the IF frequency.

Now in order to reduce the circuit complexity we have tried to reduce the number of devices used. A pulsed radar with heterodyne detection classicaly needs a transmitter and a local oscillator to pump the mixer diode. In our new design the same Gunn or IMPATT diode acts both as the transmitter and the local oscillator by using modulated bias pulse shapes as illustrated figure 4a. During phase 1 a very short (15 to 50 ns) pulse of high amplitude is applied to the device that oscillates at frequency F_1. During phase 2 a reduced amplitude pulse is applied to the device that oscillates at frequency F_2 and acts as a local oscillator. The reflected short pulse is then down-converved at the IF frequency $|F_2-F_1|$ which is of the order of a few hundred MHz. The pulse shape during phase 2 is adjusted in order to reduce the frequency chirp resulting from the diode heating. Figure 4b shows such an operation in the case of the echo of a car located at about 30 m a head of the radar front-end.

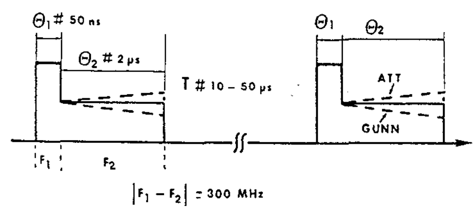

Figure 4a : Modulated bias pulse used in the single diode design.

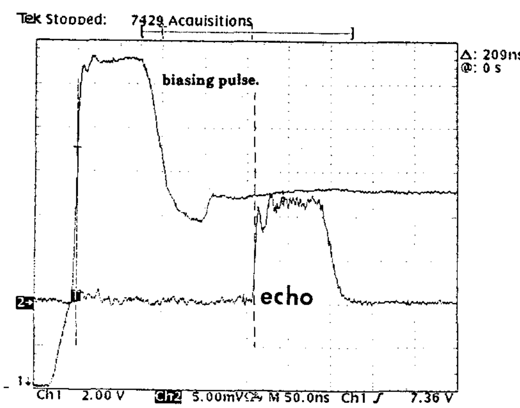

Figure 4b : Operation of the single diode quasi optical tranceiver.

Experimental results

A complete radar mock up was built at 60 GHz using a GaAs Gunn diode for power generation and a biased GaAs Beam Lead schottky diode for mixing. A simplified signal processing unit was developed to ckeck the validity of this simplified quasi-optical approach as illustrated on the block diagram of Figure 5. The main microwave characteristics of this radar were :

. Frequency : 60 GHz
. Peak radiated power from the planar active antenna : 27 dBm
. Fresnel lens beamwidth : ± 1.5° (3 dB)
. Fresnel lens diameter : ∅ = 15 cm
. IF : 350 MHz
. Quasi optical mixer isotropic conversion Loss : L iso = 8 dB

The main result obtained with this prototype is shown Figure 6 where the measured distance of a target of 1 m^2 radar cross section is plotted and compared to the actual one. A very good accuracy was achieved for range measurements from 15 to 100 m.

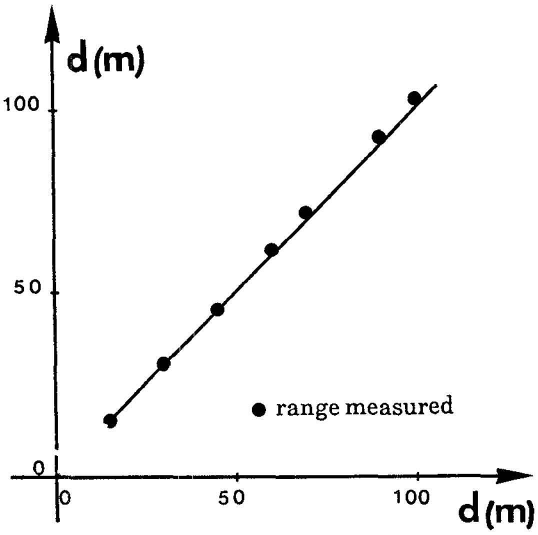

Figure 6 : Experimental range measurements.

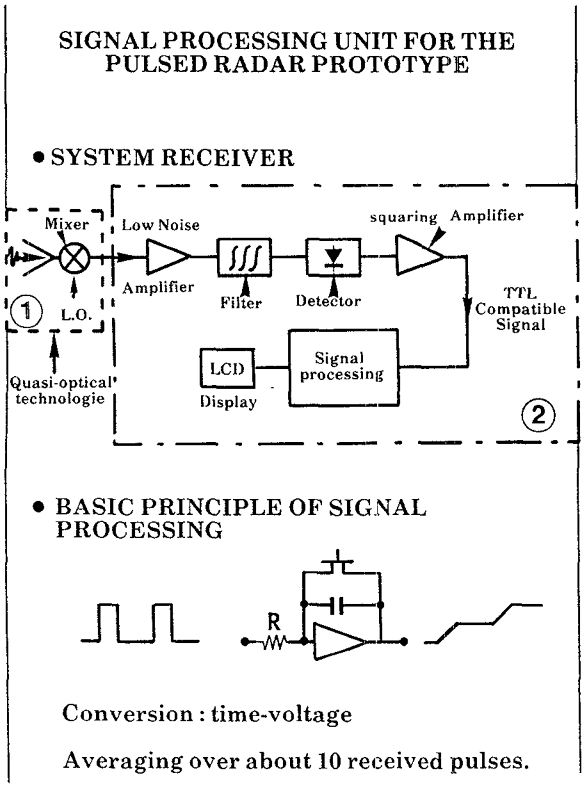

Figure 5 : Block diagram of the pulsed radar mock up.

CONCLUSION

A quasi-optical 60 GHz pulsed radar was developed for obstacle detection with the objective of low size and low cost which resulted in a simplified design of the millimeter wave front end. This mock up however provided interesting experimental results for range measurements up to 100 m, showing that this quasi-optical integration could be a possible alternative for low cost mass production of microwave Transmit Receive Units.

REFERENCES

[1] Patent, n° 8903656, april 89.
N. HAESE, P.A. ROLLAND, P. DELOOF "Antenne active d'émission et de réception dans le domaine des microondes"

[2] DRIVE V 1002 . Final report on activity WP8, November 90.

[3] D. BLACK, J.C. WILTSE "Millimeter-wave characteristic of phase correcting Fresnel zone plates" IEEE MTT, Vol. MTT-35, december 1987, p. 1122-1129.

[4] E. MOTTA CRUZ, K. MAHDJOUBI, C. TERRET, J.P. DANIEL "Antenne Disque-Anneau", JINA Nice (France) 1989.