W BAND WHISPERING GALLERY DIELECTRIC RESONATOR MODE OSCILLATOR

D. CROS* - C. TRONCHE** - P. GUILLON* - B. THERON**

*I.R.C.O.M., University of Limoges, 123 av. A.Thomas, 87060 Limoges Cédex France
**A.T.E.S., 26 av. J.F. Champollion, 31037 Toulouse Cédex France

ABSTRACT

This paper presents the utilisation of planar millimeter wavelength whispering gallery dielectric resonator modes for designing a W band Gunn diode oscillator.

An oscillator has been realised in W band, the performances of which are better than those obtained by using conventional metallic resonator.

INTRODUCTION

In recent years, there has been considerable interest in the development of millimeter wave integrated circuit components and subsystems. The purpose of this paper is to show faisability of a Gunn diode oscillator using a dielectric resonator whose dimensions are relatively large in millimeter wavelengths band. In W band, the solutions proposed using generally a microstrip resonator or metal cap as resonant circuit offer low quality factor and so the phase noise and the frequency stability don't allow to use these oscillators without adding exterior circuit. So for setting the oscillator's frequency, a solution consists to use dielectric resonators which have high quality factor [1] [2]. Unfortunately in millimeter wavelength band, the cylindrical resonators used on their conventional TE, TM or hybrid modes are impratically small. But in this wavelength a range when they are used on their WG modes, these cylindrical DR have dimensions larger than normal. The various advantages of those resonator modes allowed already their utilisation for designing W band directional filters and power combiners [3]. Here we propose to use WG dielectric resonator modes to realize W band oscillator.

WHISPERING GALLERY MODES DESCRIPTION

The electromagnetic characteristics of WG modes are essentially function of the dielectric resonator radius and permittivity.

Most of the modal energy is confined between the cylindrical boundary and an inner modal caustic, so those WG modes can be excited in thin dielectric disks, the diameter 2a of which is greater than its thickness h (figure 1).

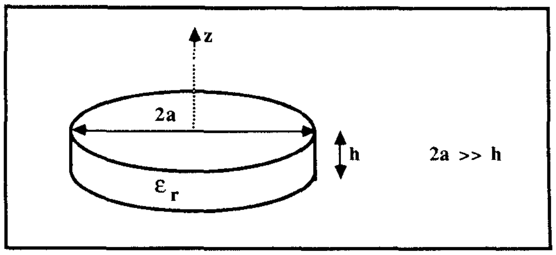

Fig - 1 -
Planar dielectric resonator

When used on their WG modes these planar dielectric resonators are relatively large even in millimeter wavelength band. These resonators are very interesting because they are compatible with the design of millimeter wavelength integrated devices [3].

Moreover, acting on these modes, radiations losses are negligeable and the unloaded quality factor or these WG modes is only limited by the value of loss tangent of the material used to realise the dielectric resonator. The quality factor very large can be used for setting the oscillator's frequency.

WG modes are classed as either $WGE_{n,m,l}$ or $WGH_{n,m,l}$ where n,m,l denote respectively their azimutal, radial and axial variations. For the first family, the electric field is essentially radial while it is essentially axial for the second ones. WG modes are periodic according to the azimutal number n. The number of modes in a given bandwith increases with the diameter of the dielectric resonator. All these WG modes properties can been shown in table I, where for two differents resonators diameters resonant frequencies and Q values were measured for both modes families.

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$\varepsilon_r = 9{,}6$	2a = 5 mm	h = 0,65 mm
WGH Modes		**WGE Modes**
$WGH_{11,0,0}$		$WGE_{8,0,0}$
f_0 = 93,36 GHz	Q_L = 780	f_0 = 90,22 GHz Q_L = 910
$WGH_{12,0,0}$		$WGE_{9,0,0}$
f_0 = 99,44 GHz	Q_L = 1260	f_0 = 97,26 GHz Q_L = 1080

$\varepsilon_r = 9{,}6$	2a = 6 mm	h = 0,7 mm
WGH Modes		**WGE Modes**
$WGH_{13,0,0}$		$WGE_{11,0,0}$
f_0 = 90,25 GHz	Q_L = 1080	f_0 = 93,11 GHz Q_L = 1050
$WGH_{14,0,0}$		$WGE_{12,0,0}$
f_0 = 95,14 GHz	Q_L = 1200	f_0 = 98,34 GHz Q_L = 1300
$WGH_{15,0,0}$		
f_0 = 99,94 GHz	Q_L = 1320	

Table - 1 -
Q_L and resonant frequencies measurement

OSCILLATOR CONFIGURATION

Using these WG resonator dielectric modes, a planar Gunn diode oscillator has been formed. The oscillator configuration is described in figure 2. The circuit is formed on a 0,127 mm thick substrate of relative dielectric constant ε_r=2,2. The active element used is a packaged Inp Gunn diode. The cut off frequency for the transfered electron effect has been predicted to be approximately a factor of two higher in Inp than AsGa [4].

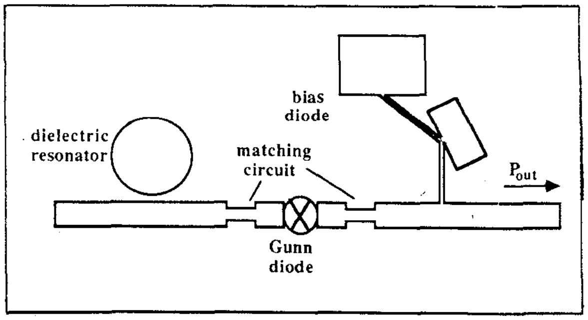

Fig - 2 -
Oscillator configuration

The Gunn diode reports in the circuit must to allow in one hand a good thermal dissipation and on the other hand to change the diode without broking substrate. The cross view of this part of circuit is shown in figure 3.

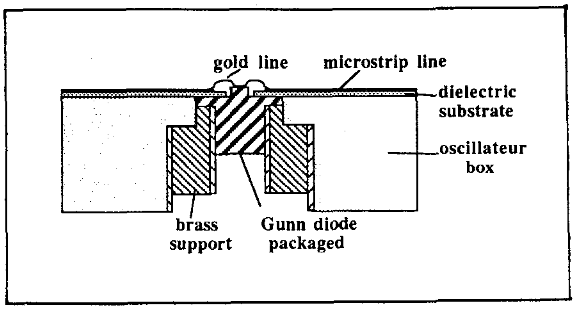

Fig - 3 -
Cross view of the Gunn diode report circuit

The dielectric resonator used in its WG modes is of relative dielectric constant ε_r=24, diameter 2a=3,2 mm, thickness h=0,4 mm and loss tangent tgδ=1.10^{-3} at about 100 GHz. When this resonator is excited by using a microstrip line, two WGE resonant frequencies modes were measured one at 91,5 GHz ($WGE_{9,0,0}$), the other at 98,5 GHz ($WGE_{10,0,0}$) (figure 4). For this second mode ($WGE_{10,0,0}$), the experimental results obtained for the added quality factor Q_L and transmission coefficient S_{12} are plotted on figure 5. To respect the oscillations conditions, the load impedance was matched to the diode impedance with a quarter wavelength line matching transformers. The Gunn bias circuit is realised by using the same principle.

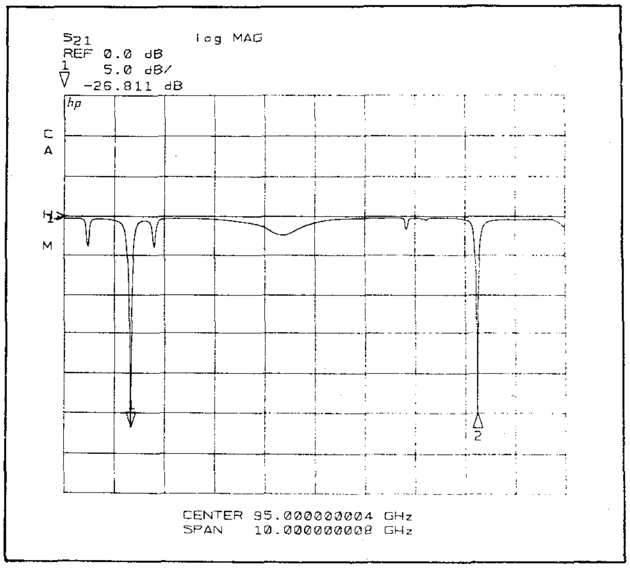

Fig - 4 -
Resonant frequencies of WGE dielectric resonator modes

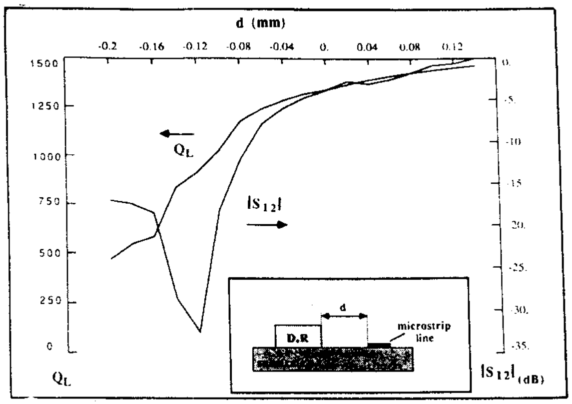

Fig - 5 -
Q_L and $IS_{12}I$ variations as a function of d

Since most standard measurement equipments millimeter wavelength frequencies uses waveguides, it was necessary to develop well matched, broadband transitions from planar to waveguides devices.

Among the three basic types of waveguide to microstrip transitions [5] ridged waveguide taper, fine line taper, and E plane probe transitions, we have choosen the last one, because it didn't require DC block.

The E plane probe transition [6] consits of a printed microstrip circuit, a portion of which extends into the waveguide through an aperture in the broad walls (figure 6). A metal strip supported by the substrate serves as a probe to couple the energy to the waveguide. At the microstrip feed point, a quarter wave impedance transformer is used to match the probe input impedance to a 50 ohm-line. Such a transition have been realized and tested. The measurement frequency responses for two transitions connected back to back with a 20 mm long microstrip line between them is shown in figure 7.

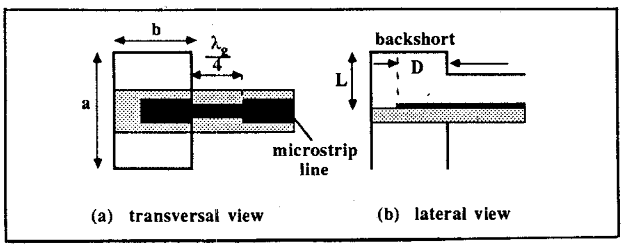

Fig - 6 -
Microstrip waveguide transition

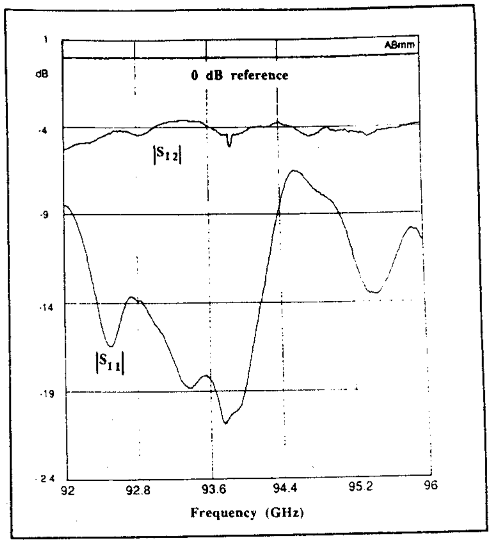

Fig - 7 -
$IS_{ij}I$ parameters of two E probes transitions back to back

MILLIMETER W BAND OSCILLATOR

The experimental response of the oscillator is shown in figure 8. The dielectric resonator is excited in its $WGE_{10,0,0}$ mode. The oscillation frequency is 98,387 GHz. The output power is 6 dbm for a bias voltage of 4,5 volts and a current of 0,5 A. On figure 8, where vertical scale is 10 db/div and horizontal scale is 100 kHz/div, we can note the sharp of the response.

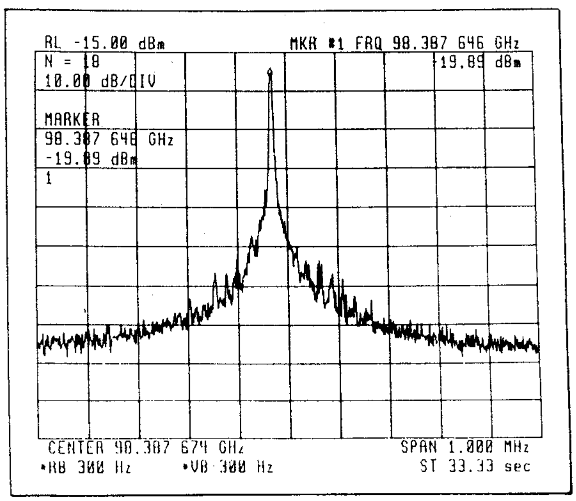

Fig - 8 -
Dielectric resonator oscillator response

To evaluate the WG mode oscillator characteristics, its spectrum had been compare with that of metallic cavities oscillator [7] (figure 9).

In this case, the dielectric resonator is used in its $WGE_{9,0,0}$ mode and the oscillator frequency is 91,7 GHz. We can note that noise is lower in WG mode oscillator that in cavity one's.

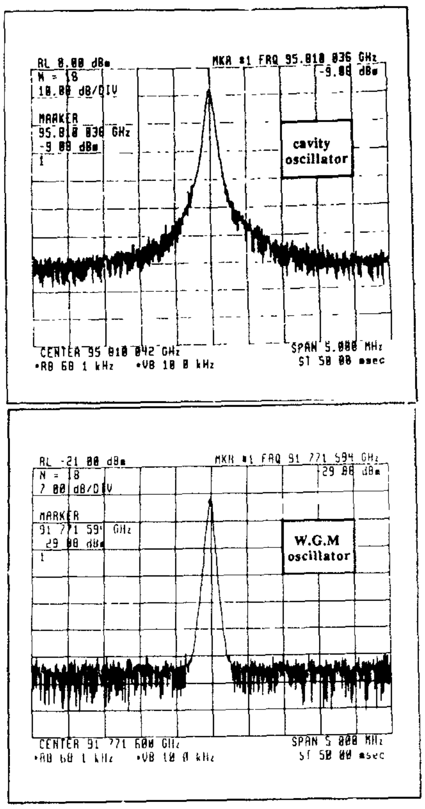

Fig - 9 -
Comparison between WGM oscillator and cavity one's

CONCLUSION

This paper shows the feasibility of a planar Inp Gunn diode dielectric resonator oscillator operating in 90-100 GHz band and which has been realised using the WG dielectric resonator modes.

Next steps will be to use HEMT transistors to supply diode in W band oscillator devices, to reduce power consumption of the oscillators and increase the reliability.

This type of oscillator could be used for radiometer application.

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