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SOLID STATE MM-WAVE OSCILLATORS WITH LARGE TUNING RANGE

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Summary

We describe broadband mechanical tunable oscillators using GaAs and InP Gunn diodes. Tuning ranges are 72 to 102 GHz (GaAs), 115 to 138 GHz (GaAs with frequency doubler) and 76 to 113 GHz (InP). Output powers are in the range from 2 mW (GaAs-Doubler) to 54 mW (InP). Experimental results and a model calculation are presented.

Introduction

Solid state oscillators are convenient local oscillators for heterodyne receivers in the millimeter wavelength range. We use phase locked millimeter wave oscillators in receivers for observing interstellar molecular lines , using the Cologne 3-m radio telescope located on Gornergrat in the Swiss Alps. In this application, remote-controlled broadband tunability is of prime interest. The power requirement for Schottky barrier mixers of about 1 mW (50-200 µW when cooled to 20 K) is easily fulfilled.

GaAs Gunn diodes are useful up to about 120 GHz (1). Due to their harmonic oscillation mode (2), they can be tuned at the fundamental frequency from about 30 to 60 GHz, so that their output power at the first harmonic can be used from 60 to 120 GHz. Frequencies above 120 GHz can be produced with the fundamental frequency output of a Gunn diode oscillator followed by a frequency doubler. The InP devices have a higher frequency limit and can be tuned at their fundamental frequency up to at least 120 GHz.

This paper describes three prototype oscillators: a GaAs harmonic oscillator, a fundamental mode GaAs oscillator followed by a frequency doubler, and an InP oscillator covering the complete WR-10 waveguide band.

GaAs Gunn oscillator (71-102 GHz)

Fig. 1 shows a cross sectional view of the oscillator. The Gunn diode is mounted in a WR-10 (75-110 GHz) waveguide tapered to half height and terminated in a non-contacting backshort. The fundamental mode waveguide is a half height WR-19 (40-60 GHz) guide, terminated by non-contacting backshorts on both sides to form a waveguide resonator. The Gunn diode is coupled to this resonator via a short coaxial line.

A disk with a radius of approximately a quarter wavelength at the harmonic frequency is connected to the end of this coaxial line. It acts as a radial line transformer at the output frequency (3).

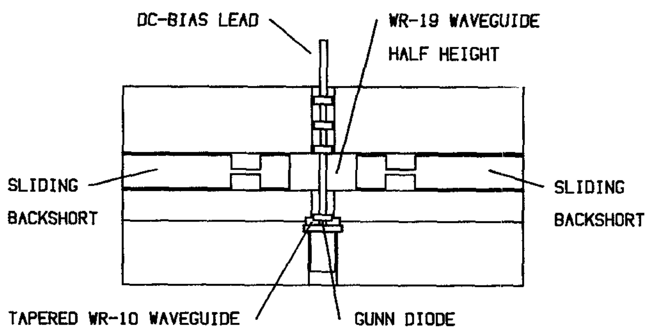

Fig.1 Cross sectional view of oscillator

Fig. 2 shows the output power of the oscillator versus frequency. In Fig. 3, the experimental tuning characteristic (frequency versus resonator length) and a calculated curve using the equivalent circuit of Fig. 4 are shown.

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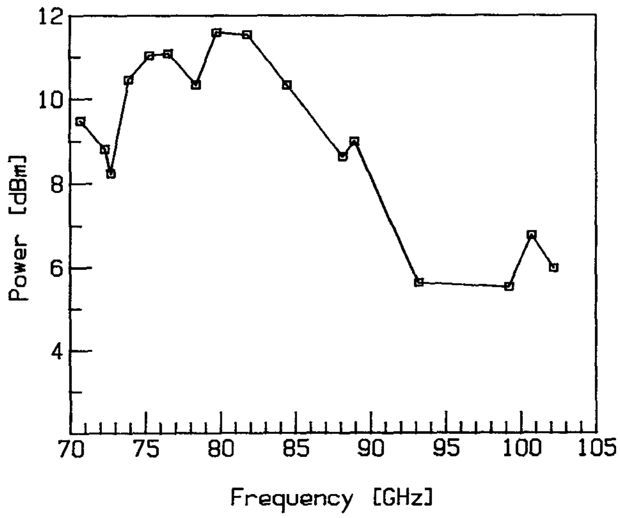

Fig.2 Output power versus frequency

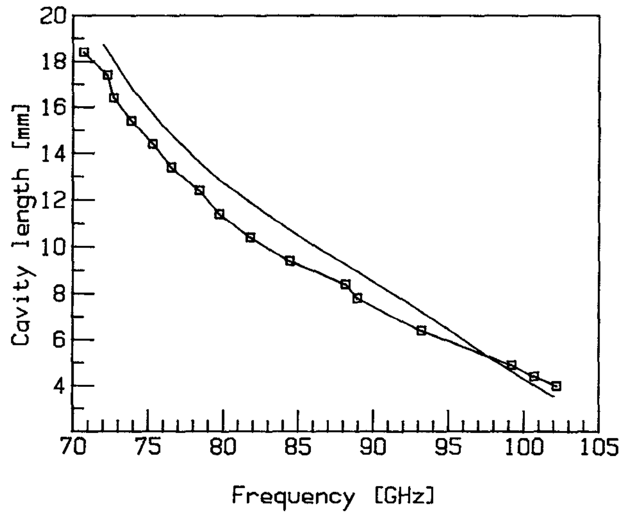

Fig.3 Comparison of experimental (boxes) and calculated tuning characteristics

In this circuit (4), C_D and G_D are the capacitance and conductance of the device, and L_p and C_p are the package parasitics. For C_D we assumed a value of 0.2 pF, for L_p 0.1 nH and for C_p 0.18 pF (4).

The length of the radial line is l_{rad}. X_r is the impedance of the tuning cavity shown in the lower part of Fig.4. It consists of the fringing capacitance of the disk, a coaxial line l_1 corresponding to a part of the disk extending into the coaxial line and the coaxial line l_2 connecting the device to the resonator waveguide. Coupling between the coaxial line and the shorted waveguides (Z_{wg}, l_{bsh}) was calculated according to the equivalent circuit in (5).

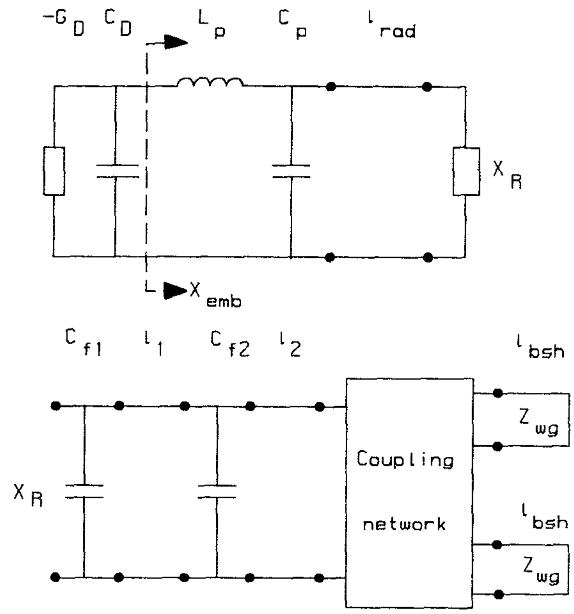

Fig.4 Equivalent circuit used for calculations

For the oscillation frequency ω the conditions

$$\omega C_D + (X_{emb}(\omega))^{-1} = 0$$

$$d/d\omega \; (\omega C_D + (X_{emb}(\omega))^{-1}) > 0$$

must be satisfied.

With this equivalent circuit model, the influence of the oscillator dimensions on the tuning characteristic can be studied. A higher accuracy in the prediction of the oscillation frequency than that shown in Fig. 3 would require a nonlinear analysis of the Gunn diode itself and can not be expected from this simple circuit. In addition, the calculations suffer from the fact that the diode parameters are not known precisely and are not easily measured.

Oscillator with integrated frequency doubler (115 to 138 GHz)

Fig. 5 shows a cross section of this oscillator. The power from a fundamental mode Gunn oscillator in a reduced height WR-15 (50-75 GHz) waveguide is coupled to a post in the same waveguide. A GaAs varactor (6P2, R. Mattauch, Univ. of Virginia) mounted in a reduced height WR-8 (90-140 GHz) guide is connected to this post via a low pass filter. The cutoff frequency of this filter lies between the fundamental and the first harmonic frequency. The fundamental frequency waveguide is also terminated by two backshorts to form a waveguide resonator. At the center of the tuning range, the distance between the Gunn diode and the post coupling to the varactor is about half of the waveguide wavelength.

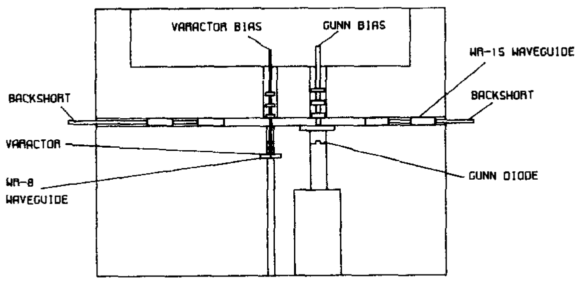

Fig.5 Construction layout of the Gunn-doubler oscillator

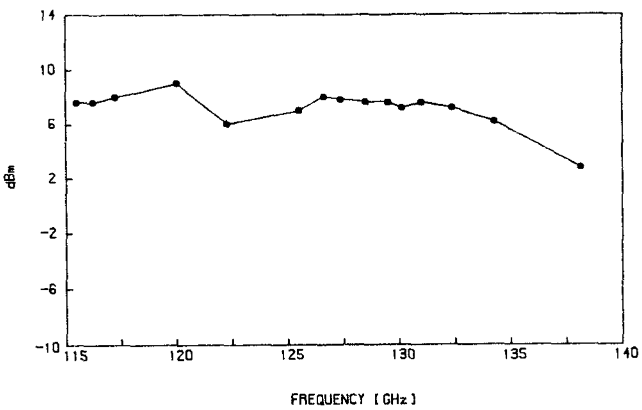

Fig. 6 Measured harmonic output power versus frequency

The oscillator can be tuned electronically via the Gunn diode voltage and also via the varactor voltage, which is advantageous for stabilization by a phase locked loop.

InP oscillator (76 to 113 GHz)

This oscillator uses a Varian VSB-9122AJ InP diode in a WR-8 waveguide. The frequency of operation is established by a radial disk resonator. The diameter of the resonator is about half of the wavelength at the highest frequency. The large tuning range, covering the complete WR-10 waveguide band, is accomplished by moving the diode together with the disk resonator in the waveguide (6). Moving the diode further towards the upper waveguide wall increases the fringing capacitance of the radial line, thus lowering the oscillation frequency. A backshort behind the diode serves for impedance matching and is adjusted by maximizing the output power.

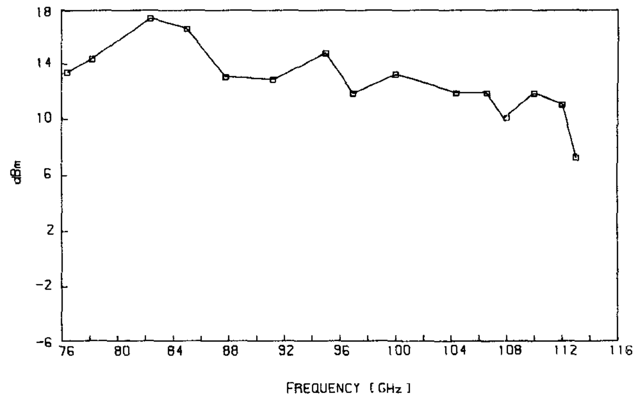

Fig. 7 Output power versus frequency

Since the tuning range is covered by a mechanical movement of only 0.7 mm, special attention has been paid to the tuning mechanism, requiring the use of a differential micrometer screw. Fig. 8 shows the electronic tuning range of the InP oscillator.

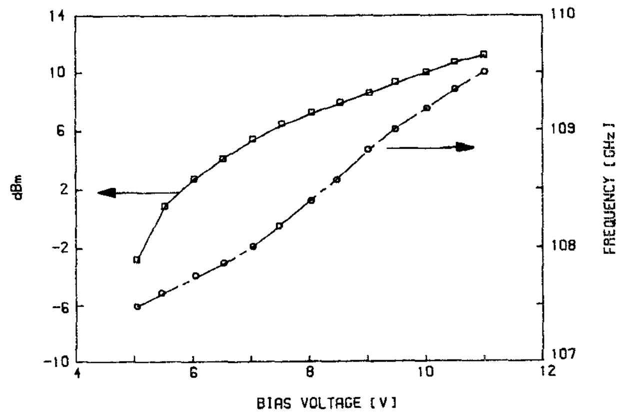

Fig.8 Typical electronic tuning range of InP oscillator

FM noise behavior

In Fig. 9 we compare the FM noise behavior of the oscillators using a spectrum analyzer with a harmonic mixer. The measurement limit of this method is -50 dBm/Hz. The data points at 100 MHz were taken by heterodyne techniques having a noise limit of about -170 dBm/Hz. The data show a slightly higher noise for the InP device than for the GaAs oscillator, but this may be due to the different resonators used.

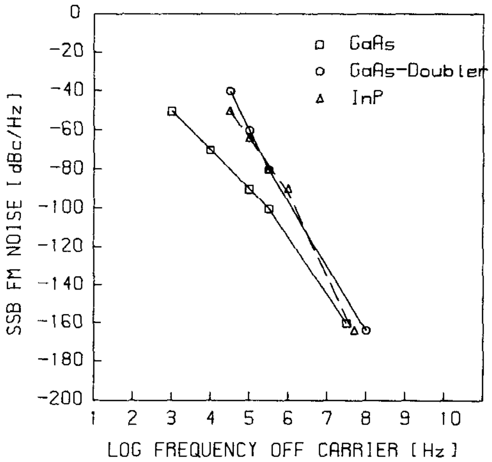

Fig.9 Comparison of FM noise of the described oscillators

Temperature stability

The temperature frequency drift after the initial warm up was measured using a spectrum analyzer. The 72 to 102 GHz GaAs oscillator shows a drift of 1.5 MHz/°C, the InP oscillator 0.8 MHz/°C, and the oscillator with doubler 16 MHz/°C.

Table 1 summarizes the characteristics of the oscillators described here.

TABLE 1

	GaAs	GaAs/Doubler	InP
Freq. range(GHz)	71-102	115-138	76-113
Min. power(mW)	3.2	2	6
Max. power(mW)	14	8	54
Electronic tuning range (MHz)	70	200	1000
Temp. drift(MHz/°)	1.5	16	0.8

Conclusion

We have presented three concepts for broadband tunable oscillators covering frequencies from 71 to 138 GHz. Use of an InP device allows instantaneous tuning over the whole WR-10 waveguide band with output power above 6 mW. The larger tuning range and higher power output of the InP device should lead to improved application possibilities.

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