A 90 GHZ FM-CW-RADAR TRANSMITTER

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ABSTRACT

The design and the performance of an FM-CW-RADAR transmitter for 90 GHz set up with two synchronized and powercombined Impatt-oscillators are presented in this paper. The synchronising source consists of a 45 GHz-Gunn-oscillator which is simultaneously swept and doubled by the same varactor. The outputpower of the entire unit is 240 mW and the achievable sweep range amounts to 1 GHz.

Introduction

This paper describes the performance of an FM-CW-RADAR transmitter in the 90 GHz-range. In order to achieve sufficient power while exhibiting high spectral purity, the outputs of two synchronized Impatt-oscillators are combined using a 90°-hybrid. The master oscillator incorporates a 45 GHz-Gunn-diode and one Varactor-diode mounted in a common waveguide resonator. The varactor simultaneously doubles the frequency from 45 to 90 GHz and operates as a sweep device when its bias voltage is changed. The output power of the entire system is 240 mW, having the spectral purity of the Gunn-oscillator.

IMPATT-Oscillator

The simple, low-cost set up of the IMPATT-oscillator can be seen in fig. 1, showing the cross-section of the oscillator block mount.

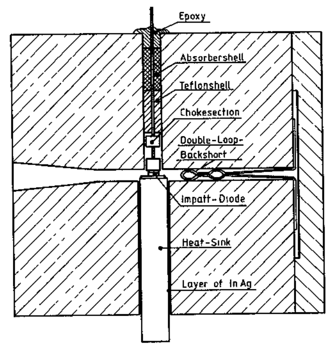

Fig. 1
IMPATT-oscillator

The diode is soldered on a copper heat sink covered with a thin layer of In Ag solder which is press fitted in the precisely machined hole. Moving this heat sink up and down and simultaneously optimizing the position of the sliding short, the diode can be matched to the reduced height waveguide.

In order to achieve excellent mechanical stability and good electrical performance, the choke has to be designed very carefully. The structure, centered by a teflon support shell, consists of two quarterwave long silver rolls which are stringed on a thin hardened steel needle. The attenuation of the choke is better than 30 dB at 90 GHz. An additional shell of absorber material gives defined conditions in the choke section and prevents residual RF-leakage. The front plane of the choke and the diode cap are covered with solder.

After optimizing the output power and adjusting the frequency, the unit can be fixed by heating up. Small mismatches caused by this solder procedure can be compensated by changing the position of the short and the bias current. Finally the choke is fixed by a small drop of epoxy. Some comments concerning the design of the sliding short.

The well known sliding short (i.e. [1]) is improved by use of a second loop one half wavelength behind the first; fig. 2.

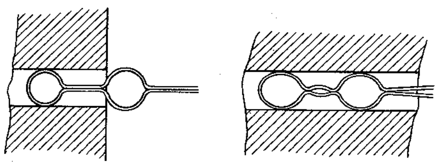

Fig. 2a Fig. 2b

Double loop sliding short.
Compression of the second loop leads to high contact pressure of the first one.

The diameter of the first loop is exactly the waveguide height whereas the diameter of the second loop is slightly bigger; the compression of the second loop leads to a high contact pressure of the first loop. The material used is fine rolled silver, which is strong enough to compensate some roughness occuring at the milled inner waveguide walls.

The output power of each IMPATT-oscillator is about 150 mW. Fig. 3a shows a spectrogramm of the unsynchronized oscillators, fig. 3b the spectrogramm under synchronisation

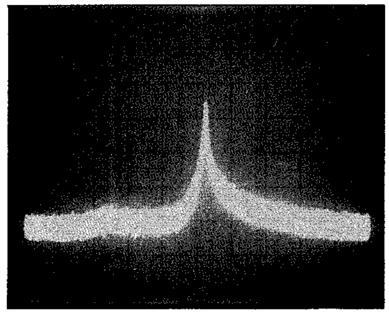

Fig. 3a

Spectrogramm of the powercombined not synchronized IMPATT-oscillators

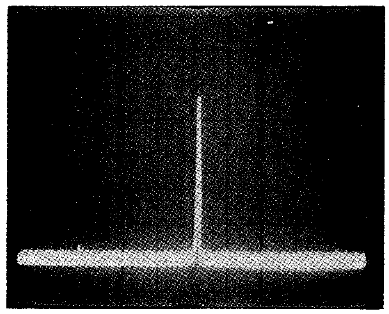

Fig. 3b

Spectrogramm of the powercombined synchronized IMPATT-oscillators
IF-Bandwith 300 kHz; Scan Width 10 MHz/div

Master Oscillator

In fig. 4 the design used for the master oscillator is shown.

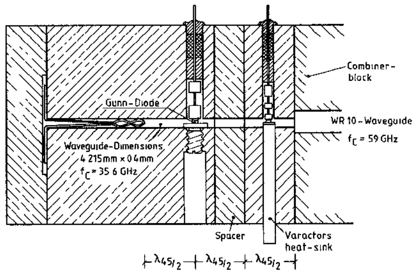

Fig. 4
Basic dimensions of the master-oscillator

Varactor- and Gunn-mount are built up using reduced height waveguide technique. The cut-off-frequency of the waveguide is chosen in such a way, that one guide-wavelength at 45 GHz amounts to three wavelength at 90 GHz. The basic dimensions are shown in fig. 4. The distance between the diodes is varied by spacers to compensate parasitics.

Power output can be optimized by a spacer-iris combination. The diodes are soldered in the same way as shown above. The time-dependent elastance $S(\omega_0 t)$ of the 45 GHz pumped varactor can be expanded in a fourier series, see [2], giving the following normalized fourier coefficients S_k / S_{max}

$$S_k/S_{max} = \frac{1}{2\pi}\int_0^{2\pi}\left(\frac{\Phi + V_0 + 2V_1\cos\omega_0 t}{V_B+\Phi}\right)^{\gamma}\cos k\omega_0 t \, d\omega_0 t \qquad k = 0, 1, 2$$

with

$V_1^2 \sim P_{pump}$; Φ = contact potential;
V_B = Breakdown voltage
S_{max} = maximum elastance (at V_B)

The doubler efficiency ε can be calculated from:

$$\varepsilon = \frac{\frac{f_c}{2f_0}\cos\Theta - 2\frac{S_2}{S_1}}{\frac{f_c}{2f_0}\cos\Theta + \frac{S_{max}}{2S_2}}$$

with

$$\Theta = \tan^{-1}\frac{S_0}{(R_2+R_S)4\pi f_0}$$

f_c = cut-off frequency of the varactor,
f_0 = pump frequency (45 GHz),
R_2 = impedance seen by the varactor at 90 GHz, and
R_S = series resistance of the varactor.

Because of the bias voltage dependence of S_0, S_1 and S_2 the following three effects can be explained:
firstly:
frequency change by changing S_0, which is desired,
secondly:
an undesired efficiency modulation by changing S_0, S_1 and S_2, and
thirdly:
variations of the inner matching conditions caused by frequency changing, which are undesired, too.

In a tuning range of 1 GHz the output power of the master oscillator varies about 3 dB. But together with the power addition the effective output power modulation of the entire system amounts to only . 1 dB.

The data achieved are
Input power at 45 GHz : 120 mW
Output power at 90 GHz : 20 mW
Efficiency of the doubler: 15 %

A significant feature should also be pointed out: Due to the frequency doubling the virtual quality factor of the oscillator, measured by synchronisation or pushing, is extremely high (more than 20,000). Such a VCO is obviously predestined for synchronisation applications.

Power-Combiner

Fig. 5 shows the coupler system for power-combining and a connection to a balanced mixer.

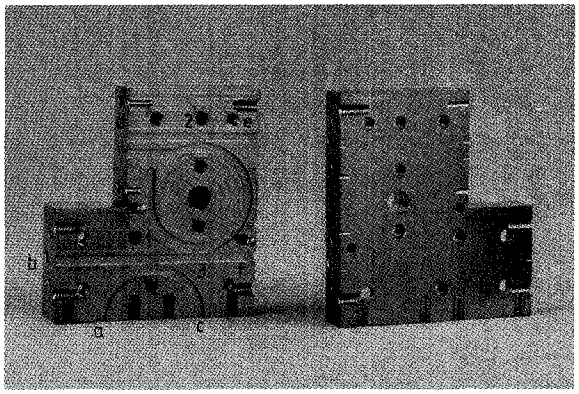

Fig. 5
Power-combiner, dismantled

1 3 dB-coupler for power combining
2 3 dB-coupler for the balanced mixer
3 15 dB-coupler, couples out the LO-Power
a IMPATT port b IMPATT port
c master oscillator port d mixer connection e receiver input
f transmitter output

Coupler 1 is a short-slot coupler working as a 90^{o}-hybrid and makes possible the synchronizing and the power-combining [3]. Coupler 2 supplies the mixer with the necessary driving power and achieves decoupling of the signal and LO-branches. The coupler 3 supplies the mixer diodes with about -15 dB of the emitted power via coupler 2.

To suppress interactions of the IMPATT-oscillators with each other by reflections, the master oscillator is connected to coupler 1 via an isolator.

The hybrids have a coupling attenuation of 3.5 dB and a directivity of more than 20 dB at 90 GHz.

The output power of the entire system is 240 mW. The driving power per mixer-diode amounts to + 6 dBm giving a SSB-conversion loss of the self biased mixer of 6 dB.

The maximum sweep range is about 1 GHz.

Acknowledgement

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References

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