MM-Wave Frequency Discriminator Aids Reduction of Oscillator Chirp

by

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ABSTRACT

A 60 GHz frequency discriminator was developed to analyze the transient frequency behaviour and chirp of pulsed Gunn and IMPATT oscillators. The bandwidth and resolution of the discriminator amount to. 7 GHz and about 5 µV/(mW.MHz). To watch centerfrequency and chirp simultaneousely while shaping the bias pulse simplifies the tuning procedure of pulsed oscillators significantly. In this manner the chirp of a 5W/100nsec IMPATT oscillator was tuned to below ± 20 MHz.

Introduction

Several methods are known to make frequency chirp of pulsed oscillators visible. The most popular are spectrum analysis, mixing with a CW-signal to obtain a beat figure, observing the width of a wavemeter dip and using a phase-detector.

The latter requires an injection locking source which has to lock the oscillator under test during the complete duty cycle. The wave-meter method is only narrow-band and read out errors arise at very short pulses due to the finite time constant. Both the wave-meter method and the beat figure method require continuous adjustment of the frequency reference used (dipfrequency or CW-oscillatorfrequency). In Spectrum analysis interpretation is very difficult and needs a lot of skill.

All mentioned methods are fairly narrowband and therefore there is a need for a broadband measurement technique which furthermore allows direct reading of output power, centerfrequency and chirp. Such a technique would be helpful in pretuning oscillators for coherent radar systems and power combiners.

This paper describes a solution to this problem employing a base-band frequency discriminator.

Principle of Operation

The discriminator consists of three broadband finline detectors /1/, a powersplitter and two seriescoupled parallel resonant cavities, Fig. 1. A variable

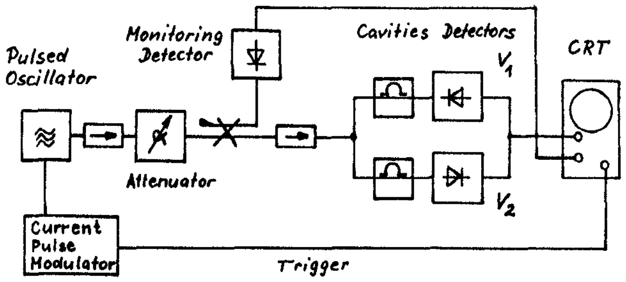

Fig. 1 Blockdiagram of the discriminator

attenuator in combination with a monitoring detector is used for input power calibration. The powersplitter provides the two arms of the discriminator set-up with two identical portions of the incident RF power. The two cavities dip the portions to zero at sligthly different frequencies about the desired center-frequencies. The powers are rectified by the detectors giving opposite polarity voltages V_1 and V_2. The sum voltage is displayed by a CRT versus time.

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Fig. 2 shows the swept frequency response of the two individual branches of the discriminator and their sum voltage. The peak to peak bandwidth depends on the

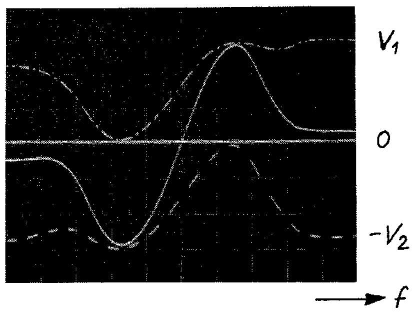


Fig. 2 Swept frequency responses
detector 1 -.-.- detector 2 ---
discriminator ——

number of half wavelengths n in the cavities determining the Q-factor and on the resonance peak attenuation set by the diameter ∅ of the couplinghole shown in Fig. 3.

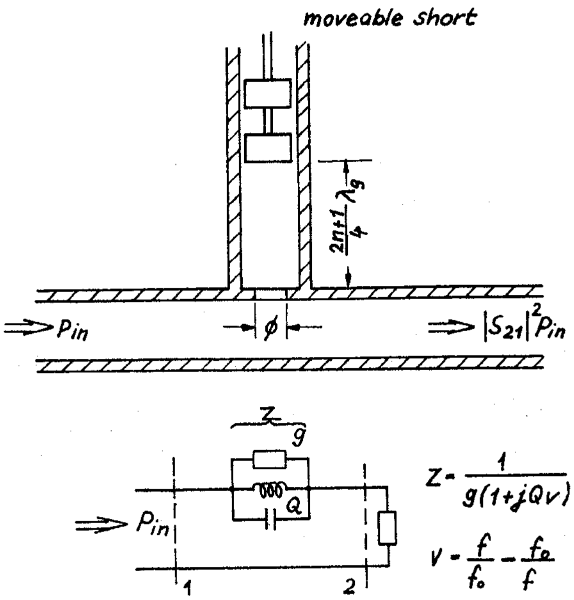


Fig. 3 Seriescoupled parallel resonant cavity, equivalent circuit

A rather good approximation for the dipbandwidth of the single cavity is to assume the lumped element equivalent circuit shown in Fig. 3 and to calculate the insertion loss $|S_{21}|^2$.

$$S_{21} = \frac{1}{1 + Z/2}$$

with

$$Z = \frac{1}{g(1+jQv)} \quad \text{and} \quad v = \frac{f}{f_0} - \frac{f_0}{f}$$

$$|S_{21}|^2 = \frac{1 + Q^2 v^2}{\left(\frac{1}{2g}+1\right)^2 + Q^2 v^2}$$

The output voltage of the detector is approximately proportional to $|S_{21}|^2$.

$$V_{det} \propto |S_{21}|^2 = \frac{1 + Q^2 v^2}{S^{-2} + Q^2 v^2}$$

$S^{-2} = (1/2g+1)^2$ represents the insertion loss of the cavity at resonance fo. The maximum achieveable peak to peak bandwidth b_{pp} of the discriminator is the width b of the dip at $|S_{21}|^2$

$$|S_{21}|^2 = \frac{1-S^2}{2}$$

Hence

$$b_{pp} = b \approx \frac{f_0}{QS}\sqrt{\frac{1-3S^2}{1+S^2}} \approx \frac{f_0}{QS}$$

From the measurement results of the experimental discriminator 20 lg S = -22 dB and Q ≈ 1000 the bandwidth was calculated as b ≈ 750 MHz which conforms with the measured bandwidth of roughly 700 MHz.

The tuning procedure of the discriminator is rather simple using a CRT-display of the form shown in Fig.4 .

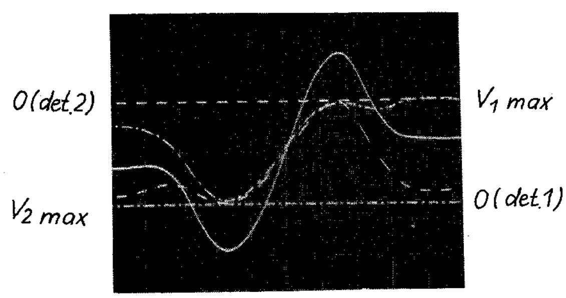
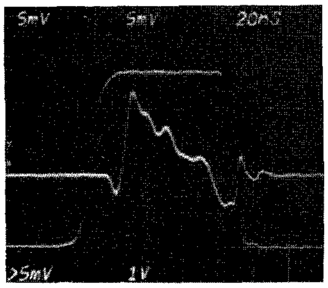


Fig. 4 CRT-display for tuning the discriminator

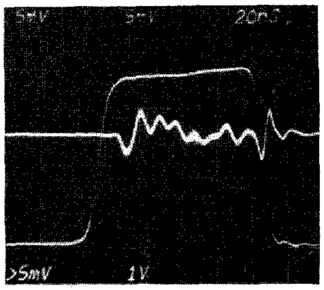
Here, the zero line of detector 1 is shifted close to the maximum output voltage of detector 2. In this manner it is easy to match the slopes of both curves to get maximum linearity and bandwidth of the discriminator. Fig. 4 also shows the sum output of the detectors the swept frequency response of the discriminator.

Results

Several pulsed oscillators have been analyzed using the discriminator set to .7 GHz bandwidth. In this case the resolution amounts to 5 µV (mW.MHz). Fig. 5a shows the transient frequency behaviour of a 60 GHz pulse generated by a 5W/100 nsec IMPATT oscillator. Bias pulse shape is shown below. The chirp width is roughly 400 MHz.



5a



5b

Figs. 5 Chirp and reduced chirp of an IMPATT-oscillator
discriminator response 100 MHz/div.
bias current pulse 2 A /div.

Fig. 5b shows the behaviour after consequent bias pulse shaping. This was done using a pulse synthesizer /2/ combining ten 10 nsec sub-pulses to one 100 nsec pulse. Rise and fall-time of a so formed 15 V/8 A pulse is 10 nsec. A pulsed .5 W/100 nsec Gunn oscillator is investigated in Fig. 6 . No shaping of the bias pulse was done. The chirp was about 200 MHz. After

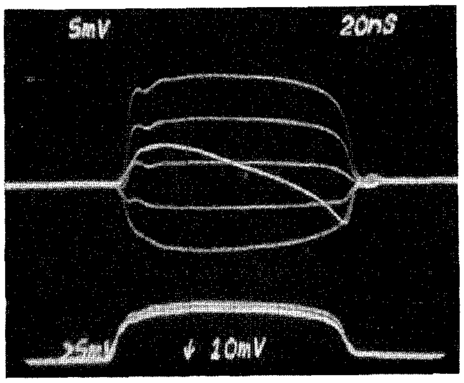


Fig. 6 Chirp of a Gunn oscillator
(100 MHz calibration lines)
lower curve: Monitoring detector output

synchronizing the pulsed oscillator by a CW Gunn oscillator the locked output power was used to calibrate the discriminator display.

Using a balanced mixer as a phase detector, the phase-time characteristics of the locked pulse oscillator was observed and is displayed in Fig.7 . As can be seen, the phase measurement method is equivalent to the frequency measurement method as shown in Fig. 6 .

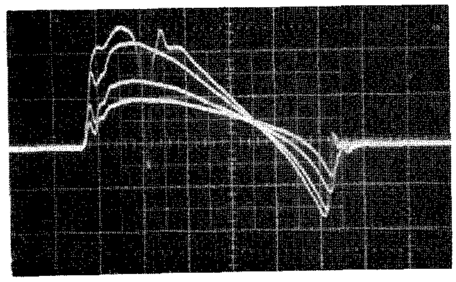


Fig. 7 Phase detector response
Phase $\phi = \sin^{-1}(\frac{div}{3})$
Locking gains: 15 dB, 20 dB, 25 dB, 27 dB.
For 27 dB, oscillator is partly unlocked.

for a relatively low chirp. Yet, if the chirp width is much higher then the lockingrange of the synchronized oscillator the phase measurement method fails completely. For such a case the frequency measurement method is much more simple and straigthforeward.

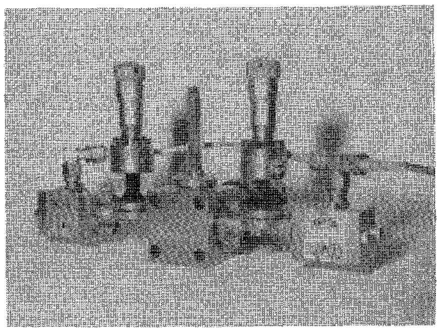


Fig. 8 60 GHz frequency discriminator

Acknowledgement

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