A WIDEBAND, BACKSHORT-TUNABLE SECOND HARMONIC W-BAND GUNN-OSCILLATOR

H. Barth
AEG-TELEFUNKEN/Germany-W.
7900 Ulm
Postfach 1730

ABSTRACT

Today W-Band (75...110 GHz) Gunn-Oscillators are mostly built as 2nd harmonic oscillators. Because the fundamental frequency is below cutoff of the waveguide system, a backshort affects the output frequency only slightly. For the same reason, power combining and varactor tuning is extremely difficult.
This paper presents design and performance of a more than 15 GHz backshort tunable 2nd harmonic 90 GHz oscillator. Using a common waveguide cavity, designed for both the fundamental and the 2nd harmonic frequency, this oscillator is easily backshort and varactor tunable. It is also well suited for "in line" power combiners. Results for a three diode combiner are given. Finally, a varactor tuned 2 diode combiner with a tuning range of 1,5 GHz is presented.

Introduction

Today W-Band Gunn-Oscillators are mostly built as 2nd harmonic oscillators. Gunn-diode matching at the 2nd harmonic frequency 2 f_o is realized using a radial cap transformer[1]. Simultaneously, the cap capacitance together with the inductance of the line between RF-choke and cap form a quasicoaxial series resonator at the fundamental-frequency f_o, which is below the cut-off of the output waveguide. A backshort in this W-Band waveguide influences the fundamental-frequency f_o of the oscillator only slightly, but is necessary for optimizing the output power at 2 f_o, the desired output frequency. Mechanical tuning of this type of oscillator can be carried out by changing the diameter of the radial cap. However, changing the fringing capacitance of this cap by means of a quartz screw for example will also give a quite sufficient tuning range for many applications.
The oscillator presented here is very easily wideband tunable by means of a backshort. This is accomplished by embedding the diode into a waveguide in resonance at f_o as well as 2 f_o. Diode matching at 2 f_o is achieved by using a radial line transformer. At f_o this transformer acts only as a capacitance. The backshort for tuning the fundamental frequency f_o is embedded into a circular waveguide connected to the rectangular waveguide at one side. It contains a second, concentrically embedded backshort for optimization of the output power at 2 f_o. In contrary to the former oscillator type, 1, 2, this oscillator design provides the possibility of

- easy wideband backshort tuning
- power combining
- injection locking
- varactor tuning
- and passive stabilisation by means of an external high-Q-cavity.

Applying the described procedures in respect of the fundamental frequency f_o, the frequency of interest 2 f_o can be coupled out with outstanding good efficiency.

Oscillator-Design

Fig. 1 shows the set-up in principle.

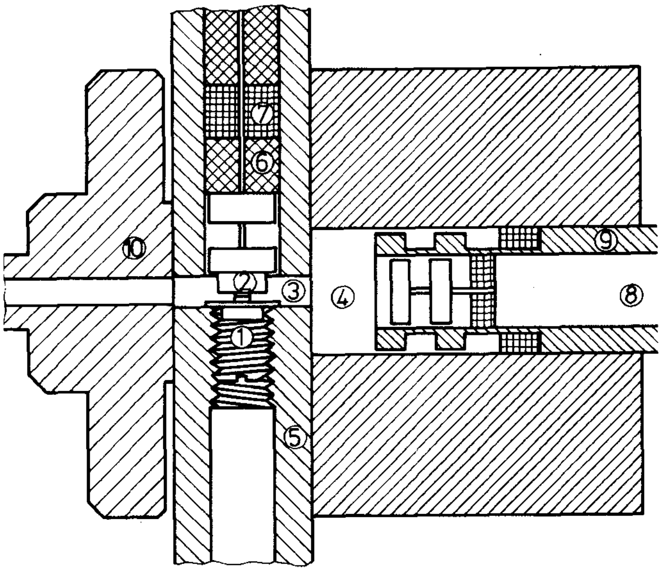

Figure 1: Oscillator Set Up

1 Gunn-Diode, 2 Radialline-Transformer, 3 Rectangular Waveguide, 4 Circular Waveg., 5 Diode Mount, 6 Teflon Ring, 7 Absorber Ring, 8 Backshort for 2 f_o, 9 Backshort for f_o, 10 Output Waveg. (W-Band)

A top view cross-section is also shown in Fig. 2c. The Gunn-Diode is embedded within a rectangular waveguide. In order to achieve the maximum frequency tunability, the cutoff wavelength is chosen to

$$\lambda_{g f_o'} = 3 \lambda_{g 2f_o'} \quad (1)$$

which leads to

$$3 \cdot \sqrt{\frac{f_o'}{c_o} - \frac{1}{\lambda_c^2}} = \sqrt{\frac{2f_o'}{c_o} - \frac{1}{\lambda_c^2}} \Rightarrow \lambda_c \approx \sqrt{1.6}\, \lambda_{f_o'} \quad (2)$$

f_o being the fundamental frequency of the oscillator at midband.
The length of the diode mount is made approximately $\lambda_{g f_o'}/2$. Connecting a backshort loaded circular to one side and a W-band-waveguide to the other, a resonance cavity for both f_o and 2 f_o is formed. The circular waveguide and rectangular waveguide of the

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diode mount have the same cut-off-wavelength. This cavity is unloaded for f_o, and for the 2nd harmonic frequency 2 f_o it is terminated by the waveguide impedance of the W-band-Waveguide.
The backshort for f_o contains, concentrically arranged, another backshort for 2 f_o. The latter is taken to optimize the output power at $2 f_o \neq 2 f_o'$, because the resonance condition (equ. 1) for both frequencies f_o and 2 f_o can be fulfilled only for one particular frequency f_o', being the midband frequency.
Gunn-diode prematching is accomplished by a $\lambda\, 2f_o'/4$ -radial-line transformer[3], giving a high transformation ratio.
The RF-choke as well as the backshort are airgap insulated.
They are designed to give good isolation for f_o and 2 f_o respectively. RF-leakage is prevented by using rings made from absorber material. Undefined resonance in the choke-structures cannot occure.

Measurement Results

Power and Frequency Measurement

In order to demonstrate the 2nd harmonic operation, three different types of output coupling were used to test the described diode mount at the fundamental frequency f_o and at the desired output frequency 2 f_o respectively.
Fig. 2 displays the utilized coupling configurations. Set up 2a gives nothing else but a fundamental mode oscillator; the described second harmonic oscillator is shown in 2c. The evanescent mode coupled version, given in 2b was chosen to simulate the 2nd harmonic operation while examining the fundamental frequency behaviour.

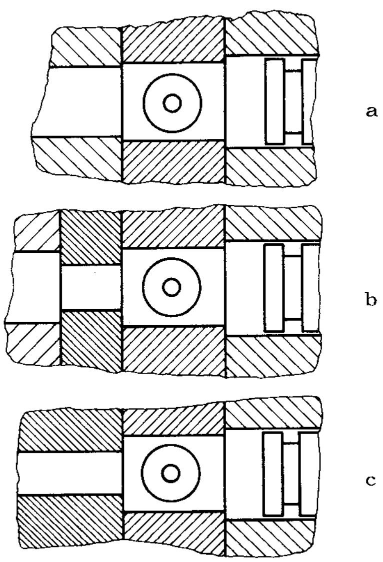

Figure 2: Oscillator-Test-Configurations
2a: Fundamental frequency is strongly coupled out
2b: Fundamental frequency is weakly coupled out
2c: 2nd harmonic frequency is only coupled out

Fig. 3 shows the plot frequency vs backshortposition for these three oscillator configurations. The curves 2b and 2c agree quite well. Only a small difference Δf_1 can be seen. The frequency deviation Δf_1 is caused by the load coupling at f_o, which is small in the case of 2b but not zero as it is in 2c. The matched load for f_o in the case of 2a of course causes a higher frequency deviation Δf_2.

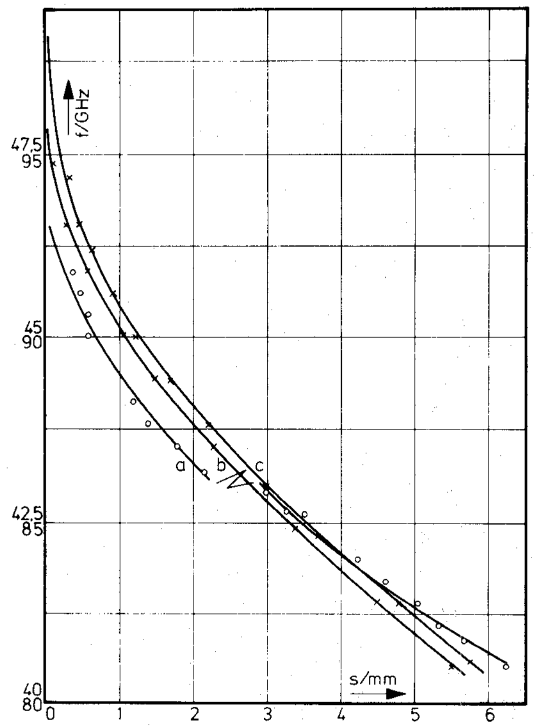

Figure 3: Frequency vs. Backshortposition of configurations shown in Fig. 2

Fig. 4 shows output power as a function of frequency for the configurations 2a and 2c.

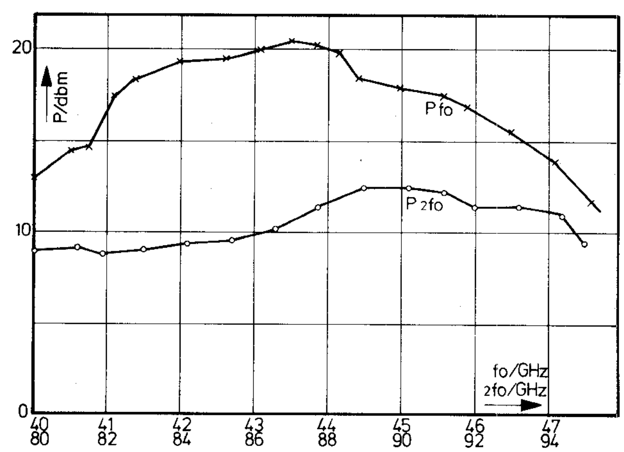

Figure 4: Output Power vs. Frequency backshort tuning at fundamental and 2nd harmonic frequency.

The maximum output power of the 2nd harmonic oscillator is 12.5 dBm at 90 GHz, the fre-

quency, the radial-line transformer was designed for.
As a consequence of terminating the cavity at f_o, the power maximum of 18 dBm occurs at 44 GHz and not at 45 GHz as may be expected. The spectra of the oscillator at f_o and 2 f_o are given in Fig. 5. The spectra do not dif-

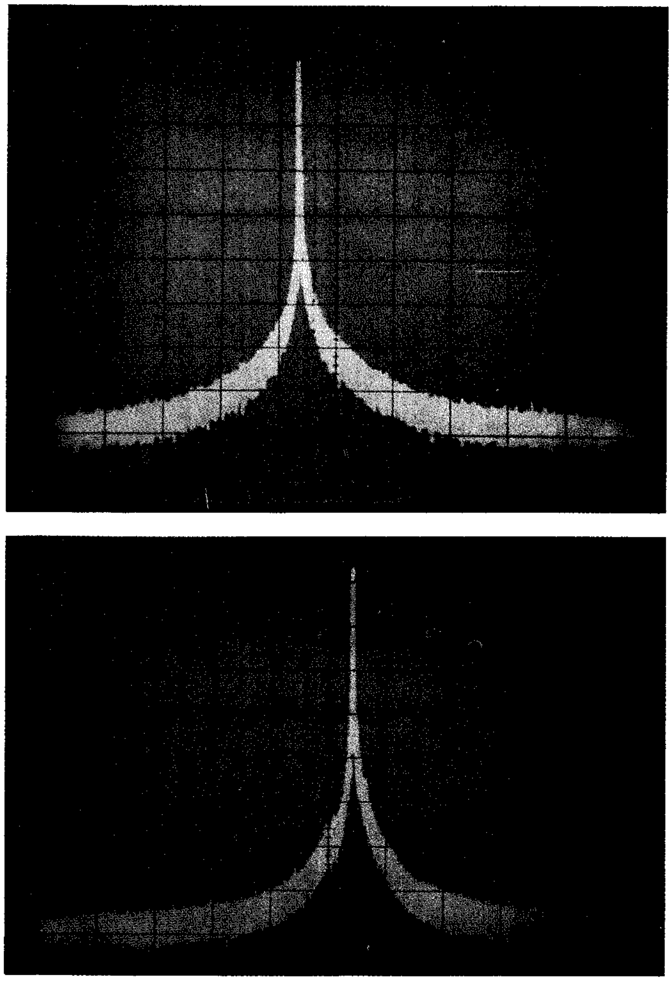

Figure 5: Spectra at 45 and 90 GHz

IF-Bandwidth	10 kHz
Scanwidth	1 MHz/div
Vert. Resolution	10 dB/div

fer very much from each other. As a result the noise-to-carrier ratio at 1 MHz off carrier amounts to -106 $dB_c/_{Hz}$ at f_o and -108 $dB_c/_{Hz}$ at 2 f_o. For the f_o-spectrum, a high Q-cavity stabilized oscillator was employed. The same oscillator but frequency doubled was used for the 90 GHz measurement.

Backshort Tuning

As experience has shown, wideband backshort tuning of the presented oscillator strongly depends on the form of the radialline transformer.
The conventional disc-hat type, described in [1] and shown in Fig. 6a, has its own resonance frequency f_o determined by the length l, the diameters $\emptyset_1$ and $\emptyset_2$. Thus, the entire oscillator contains two coupled cavities but only the waveguide cavity can be tuned. Thus, the disc-hat transformer in the described oscillator circuit leads to a limited

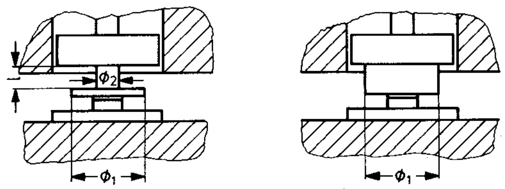

Figure 6: Radial Line Transformers

tuning range of only 6 GHz, as can be seen in Fig. 7.

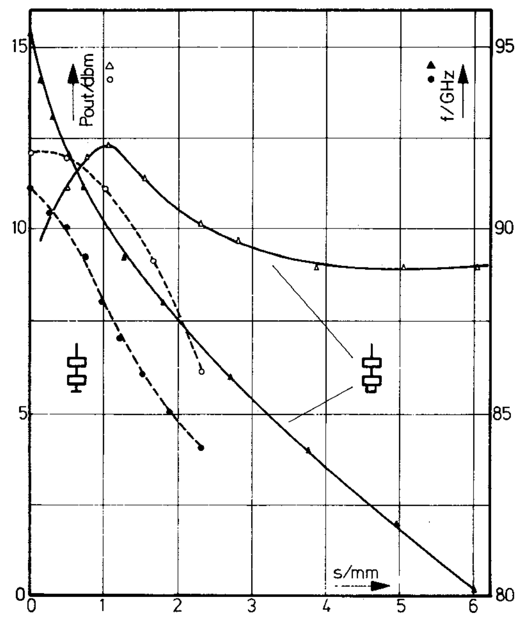

Figure 7: Power and Frequency vs. Backshort-position for the two types of Radial Line Transformers

To avoid this effect, a radial line transformer having no resonance in the fundamental frequency range was used (Fig. 6b). It only acts as a capacitive load for the waveguide cavity. Thus, the achieved tuning range is very wide.
As shown in Fig. 7, giving plots of output power and frequency vs. backshort position, about 17 % bandwidth can be tuned at a power output ripple of ± 1.5 dB. With a higher ripple, a tuning range of more than 22 % was obtained.
The electronic tunability with bias voltage is shown in Fig. 8. The tuning range of 300 MHz ist limited at low bias voltage, where bias oscillations occur and at high bias voltage by an assumed burn out voltage of 5.5 V. The corresponding slope is 500 MHz/V. A plot of power vs. bias voltage is also given in Fig. 8.

Power Combining

To estimate the power combining capability of an oscillator it is important to know its external quality factor Q_{ext} • Q_{ext} was measured by load pulling as well as by injection locking at both frequencies f_o and 2 f_o.

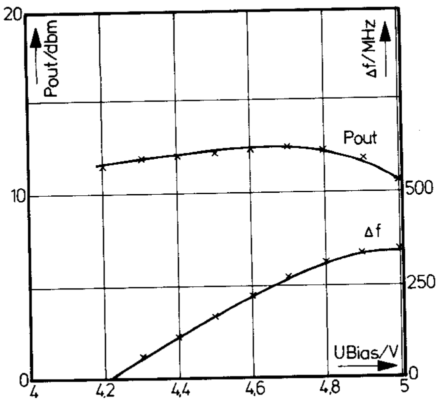

Figure 8: Output Power and Frequency vs. Bias Voltage of the 2nd harmonic oscillator

The achieved values are

$Q_{ext f_o} \approx 45$ and $Q_{ext 2 f_o} \approx 10\,000$!

The extremely high Q-factor at 2 f_o results from the buffer effect of 2nd harmonic operation, and causes a rather narrow locking range.
Thus, mutual coupling at 2 f_o between two or more diodes is very poor.
However, power combining at the fundamental frequency f_o is a common technique and can be achieved very easily with the presented diode mount.
Fig. 9 shows an "in line" 3 diode combiner. Since the Q-factor at f_o is only 45, mutual coupling between the diodes is sufficient for an operation in a 500 MHz bandwidth. Because the three mounts fulfill the condition $\lambda_g f_o' = 3 \lambda_g 2f_o'$, a field distribution along the diode mounts like that shown in Fig. 9 can be assumed in principle. Thus,

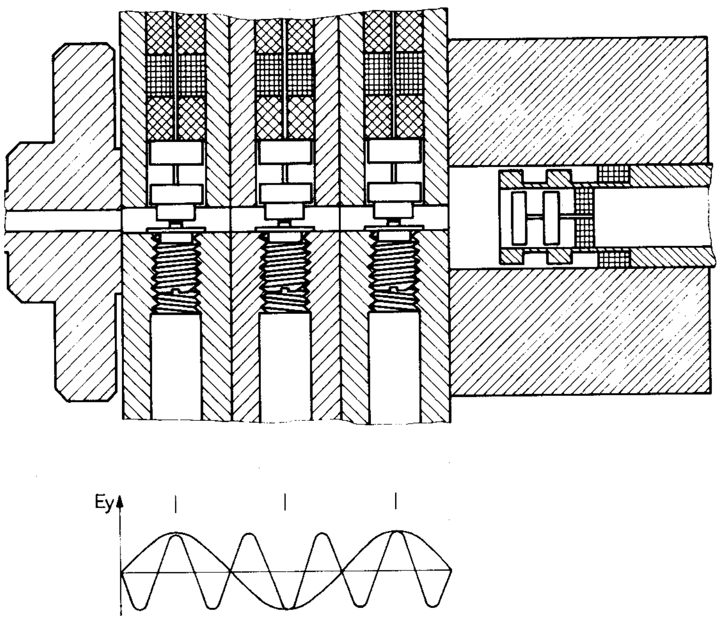

Figure 9: 3 Diode Combiner

power combining at both frequencies f_o and 2 f_o can be achieved.

For an output frequency of 90 GHz the output power of this 3 diode combiner is 60 mW with a corresponding combining efficiency of 85 %.

Varactor Tuning

Replacing the Gunn-diode in the middle of the 3 diode-combiner described above by a varactor-diode results in a voltage controlled 2-diode-oscillator. A tuning range of 1.5 GHz was achieved for a maximum output power variation of 3 dB. Because of the nonlinearity the varactor acts as a tuning capacitance for the fundamental frequency and gives a contribution to the output power generation at 2 f_o by means of frequency conversion.
Thus, the "effective combining efficiency" was better than 100 % for the two employed Gunn-diodes. Maximum output power of this 2 diode VCO is 55 mW at 90 GHz.

Conclusion

It has been shown, that 2nd harmonic oscillators can be made wideband tunable by backshort tuning the fundamental frequency. To this end the cavity has to be in resonance for both frequencies f_o and 2 f_o.
A tuning range of 15 to 20 GHz at a center frequency of 87.5 GHz has been achieved.
In addition, this type of oscillator cavity allows injection locking at the fundamental frequency, the base for power combining at f_o and 2 f_o. Instead of backshort tuning varactor tuning at 2 f_o is easy to realize by influencing the fundamental frequency.

References

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