Ga As Gunn Oscillators Reach the 140 GHz Range

Helmut Barth, Dr. Wolfgang Menzel

AEG-TELEFUNKEN Ulm, Federal Republic of Germany

Summary

Design and performance of an 135 GHz, 3rd harmonic oscillator utilizing a 45 GHz Ga As-Gunn device is described. The nonlinear capacitance of the Gunn-device is used for frequency triplication. Hence an idler circuit for the 2nd harmonic wave is built in. This raises the efficiency of fundamental wave to 3rd harmonic wave conversion considerably. Output power was measured as 3 mW.

Introduction

For low noise, low power applications, especially for local oscillators, Gunn oscillators have proven to be a good choice in the design of mm-wave systems. With Ga As Gunn devices, a fundamental mode operation up to about 65 GHz is possible, while a few mW of power can be generated in a second harmonic mode operation up to about 100 GHz. Above this frequency, power decreases rapidly. Recently, it has been shown that In P Gunn devices are able to perform in a fundamental mode up to at least 100 GHz /1/, and in a second harmonic mode, they should work at even higher frequencies.

At present, however, In P Gunn devices provide problems concerning availability, maturity of technology and price. Therefore, the frequency range of Ga As Gunn oscillators was extended up to 140 GHz using a third harmonic operation with optimized circuit design, that means with an idler circuit for the second harmonic wave and tuning facilities for fundamental, second and third harmonic frequencies. In this way, it was possible to achieve a power of 3 mW at 135 GHz.

Design Aspects

The existence of nonlinear capacitances in Gunn-devices is well known as well as the fact that nonlinear capacitances can be used for frequency multiplication (i.e. /2/, /3/ and /4/).

Consequently, this led to the idea to design a 3rd harmonic wave oscillator using a Gunn-device for both power generation at the fundamental mode and frequency triplication.

For optimum operation of such a 3rd harmonic mode oscillator, three different circuits are required:
- a cavity to excite the fundamental frequency f_o
- an idler circuit for the 2nd harmonic wave
- some kind of a transformer to match the 3rd harmonic wave

All these circuits have to be arranged very close around the Gunn-device; otherwise multimode operation caused by longline effects cannot be avoided.

Set Up of the Oscillator-Tripler

Fig. 1 shows the scheme of the oscillator-tripler. The Gunn-device is mounted in a moveable heat sink which is fitted into the oscillator mount in such a way that it is possible to adjust the vertical position of the device D. Adjustment can be done by means of a fine threatened screw (8). The diode

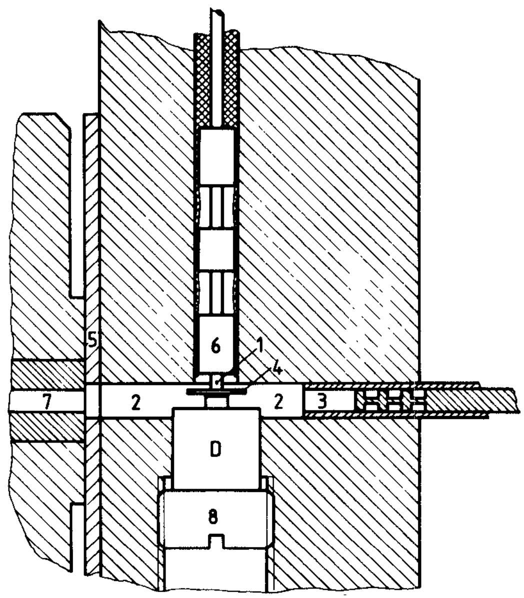

Fig. 1 Oscillator set up

1 Coaxial cavity
2 Waveguide cavity (idler)
3 T-band waveguide
4 T-band backshort
5 W-band spacer
6 Tefloninsulated bias filter
7 Output waveguide (T-band)
8 Tuning screw

0149-645X/85/0000-0367 $01.00 © 1985 IEEE 1985 IEEE MTT-S Digest

is biased through a five section coaxial filter (6) designed to stop the frequencies f_o, 2 f_o and 3 f_o. A short section of coaxial line (1) acts for the fundamental wave as an inductor. The disc(4) at the end of this line section has different functions for the 3 frequencies. For the fundamental frequency it acts as a capacitor. This capacitor and the line section form a resonant circuit for the fundamental frequency f_o. A change of the diode position by means of the tuning screw (8) changes the capacitance and hence the resonance frequency of the resonator.

For the fundamental wave, the W-band waveguide (2) is below cut off, but the 2nd harmonic wave can propagate. The 2nd harmonic wave is prematched to the waveguide by a resonant transformation achieved by the disc and the bore hole for the choke acting mainly as a ring resonator. The idler circuit is formed by terminating the W-band waveguide on both sides with T-band waveguide (7) and (3). Because the second harmonic wave is below cut off, these waveguide sections act as backshorts for the 2nd harmonic wave while only the third harmonic wave is able to propagate. Providing a sliding fit for waveguide (3) and inserting waveguide spacers (5) between oscillator mount and output waveguide (7), the idlercircuit (2) is adjustable and can be tuned for optimized performance.

For the output frequency the disc works as a radial waveguide transformer and performs some kind of pretuning of the output power. By a sliding backshort inserted into waveguide (3) the output power can be optimized.

The bias filter mentioned above is calculated by means of "supercompact" and has a frequency response shown in Fig. 2.

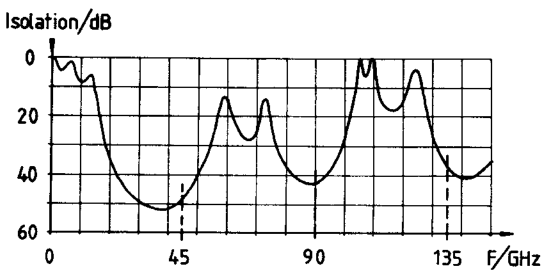

Fig. 2 Frequency response of the bias filter

Isolation versus frequency

Results

Fig. 3 shows the influence of the length variation of the idler circuit formed by the W-band waveguide region on the 3rd harmonic output power.

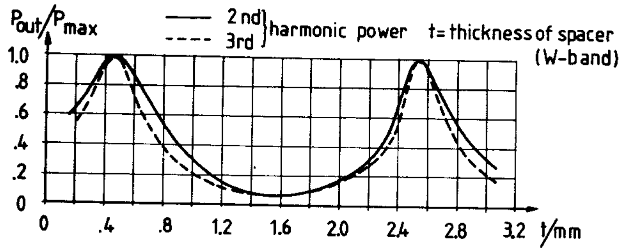

Fig. 3 Influence of the idler circuit

Output power of the 3rd harm. wave versus distance of 2nd harmonic backshort and 2nd harmonic power inside the idler circuit versus distance of 2nd harm. backshort; measured through a 5 mm-T-band spacer for simulation of 3rd harm. operation

In Fig. 4 the output power versus T-band backshort position is shown.

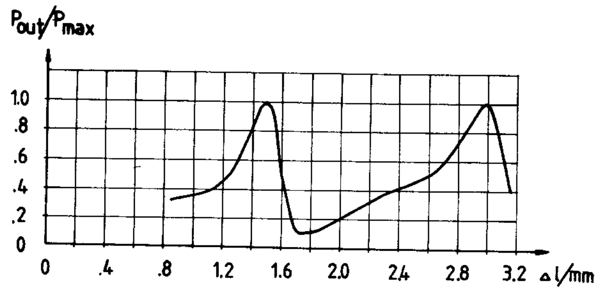

Fig. 4 Influence of variation of backshortposition to the output power

Max. output power at 135 GHz was 3 mW. At higher frequencies the performance of the oscillator is deteriorated rapidly, because in this design, the second harmonic wave starts to propagate in the T-band waveguide region, and the idler circuit is no longer working. This however, can be avoided by reducing the waveguide dimensions from T-band.

Conclusion

It has been shown that 3rd harmonic mode oscillators in the mm-wave-range above 120 GHz become very efficient if an idler circuit is used for the 2nd harmonic wave. The very strong influence of this idler circuit to the 3rd harmonic output power confirms the hypothesis that the nonlinear capacitance of the Gunn-device pumped by the selfgenerated fundamental wave is responsible for the frequency multiplication.

One may suppose, that 2nd harmonic mode oscillators in the mm-wave-range are working in the same way. As a verification for that, some results in the band around 70 GHz can be taken, showing very high efficiencies up to one half this value of those of fundamental mode oscillators, while from calculations for a nonlinear resistive characteristic, far lower efficiencies should result.

Using In P Gunn-devices, the frequency range can be extended with this type of oscillator above the 200 GHz limit. For this case, the parasitics of the housing for this type of Gunn-devices might be the main problem.

References

/1/ Fank et.al., Eu MC 84

/2/ B.G. Bosch, Gunn Effekt Elektronik, Telefunken Röhren

/3/ P.A. Borodovskiy, A.F. Buldygin, Parametric Gunn-Diode Frequency Converter, Radio Eng. and Electr. Physics Vol. 18; 1973

/4/ Penfield/Rafuse, Varactor Applications, The M.I.T. Press 1952