Performance and Optimization of Gunn Self-Oscillating Mixer

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Abstract—**Dependence of performance of a Gunn Doppler self-oscillating mixer on the oscillator loaded quality factor, bias voltage and bias circuit resistance is investigated theoretically and experimentally. The analysis is based on consideration of stability principle and average voltage-current characteristic of a Gunn oscillator. Location of the operating point of the best performance of a Gunn Doppler self-oscillating mixer is defined. Results of the work can be used for tuning a Gunn Doppler self-oscillating mixer.**

I. Introduction

GUNN oscillator used as self-oscillating mixer (SOM) is considered to be an attractive system when a simple, low cost Doppler radar required. A Gunn SOM has been studied by many authors [1]–[4]. In previous analyses, however, no work was made to define properties of a Gunn oscillator which yield the best performance of a Doppler SOM. This work describes how to tune a Doppler SOM for functioning with maximum sensitivity.

In this work conventional X-band waveguide Gunn SOM was investigated. Gunn oscillator cavity supported $\lambda/2$ resonance mode. Sliding short was used to tune the cavity. The oscillator was loaded by a horn antenna looking toward a reflector. The reflector was placed at a constant distance from the antenna and swung with a constant excursion. Let us define how the cavity length l, the bias voltage V_B and the resistor R taking out Doppler signal should be set for the SOM.

II. Conversion Gain

Conversion gain of the SOM is defined as

$$G = P_{\text{dopp}}/P_{\text{in}} \tag{1}$$

where $P_{\text{dopp}} = (I^2_{\text{dopp}}R)/2$ is the power of Doppler signal at the bias resistor R and $P_{\text{in}} = \Gamma^2 P_{\text{out}}$ is the microwave power reflected from the load. Fig. 1 shows the gain and bias FM sensitivity $\Delta f/\Delta V_B$ as functions of the cavity length l. Note that the gain and the FM sensitivity are correlated. This can be explained as follow. The FM sensitivity of the oscillator is inversely proportional to the loaded quality factor Q_L, so the conversion gain is governed by the Q_L. The rule underlying the behavior of the SOM states that a Gunn diode current is a function of microwave voltage amplitude, and the microwave voltage amplitude, according to the oscillator stability principle

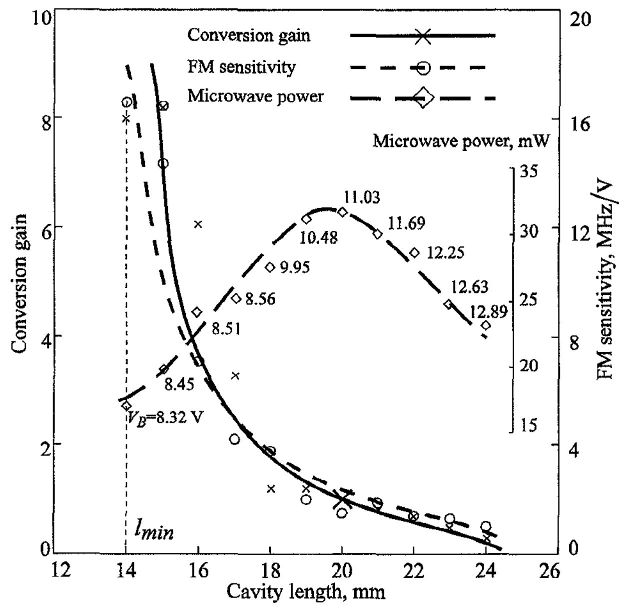

Fig. 1. Conversion gain, bias FM sensitivity and microwave power as functions of cavity length. For each setting of cavity length bias voltage was adjusted to obtain maximum microwave power. The conversion gain is normalized at the operating point of maximum available microwave power: l = 20 mm, V_B = 11.03 V.

[5], is the attribute, which changes in respond to the variation of the load and keeps the diode admittance equal to the negated value of the load admittance. Therefore, to get higher Doppler current we should have higher variation of the diode admittance caused by an excursion of the load admittance. Let us plot in Fig. 2 variation of the diode susceptance and the load susceptance in the cases of high Q_L and low Q_L, assuming that variation of the load susceptance is the same in both cases. Fig. 2 shows that induced variation of the diode susceptance $(\partial B_D/\partial f)\Delta f$ increases when the Q_L decreases. Consequently, the shorter the cavity, the lower the Q_L, and the higher the gain we obtain.

We can decrease the cavity length l until the slope of the load susceptance $\partial B_L/\partial f$ becomes equal to the slope of the diode susceptance $\partial B_D/\partial f$ at the operating point. At this condition the oscillator becomes unstable and mode switching occurs. This means that the highest gain is observed for the shortest cavity that still supports oscillation of the resonance mode ($l_{\min}$ in Fig. 1).

We can easily define desired settings for the bias voltage V_B and the resistor R if we plot in Fig. 3 average voltage-current characteristic of the oscillator. Fig. 3 shows that Doppler

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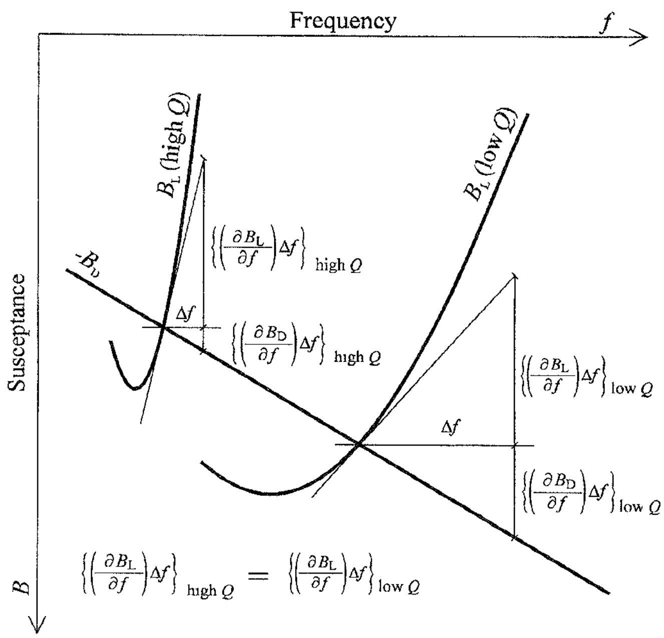

Fig 2 Relation between diode susceptance and circuit susceptance.

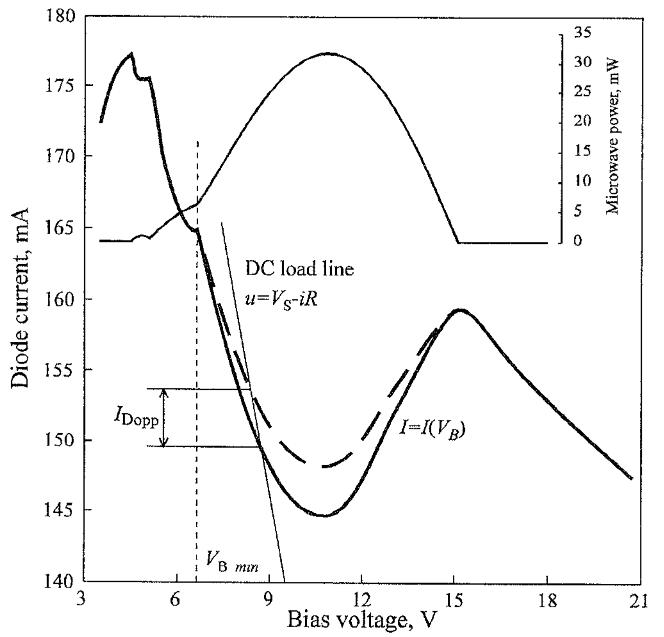

Fig. 3. Average voltage-current characteristic of the oscillator measured for two different positions of moving object and radiated microwave power asfunction of bias voltage. Cavity length l = 16 mm.

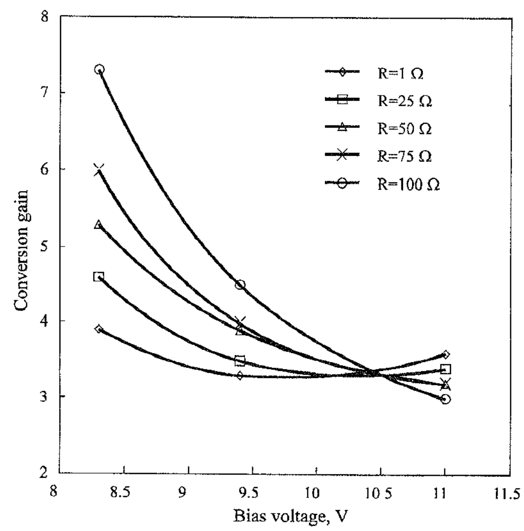

Fig 4. Conversion gain as function of bias voltage and resistor forcavity length l = 16 mm. The conversion gain is normalized at the operating point of maximum available microwave power: l = 20 mm, V_B = 11.03 V.

current I_{dopp} can be increased by means of increasing R till the slope of the dc load line becomes equal to the slope of the diode current curve $\partial I/\partial V_B$ at the operating point. The highest R we can employ is terminated by the minimum slope of the current curve. If the $1/R$ will be smaller than the minimum slope of the current curve, it will not be possible to place the operating point at the negative resistance region of the average voltage-current characteristic. The minimum slope of the current curve is observed at the lowest voltage that supports oscillation of the resonance mode ($V_{B\,\min}$ in Fig. 3). Hence the lowest voltage supporting the resonance mode determines the highest gain for a fixed cavity length. See Fig. 4 for experimental verification of the bias circuit settings.

III. Sensitivity

Sensitivity of the SOM is defined as the power of Doppler signal at the bias resistor, provided that Γ^2 is constant. Maximum sensitivity at the same time with stability of oscillation is regarded as the best performance of the SOM. Using (1) we can derive that the sensitivity S depends on both the conversion gain G and the radiated microwave power P_{out}.

$$S = G\Gamma^2 P_{out} \tag{2}$$

Therefore, the sensitivity may not be the highest at the point of maximum gain, because the radiated microwave power decreases there (see Fig. 1 and Fig. 3). Another aspect is that maximum gain is observed at the point where oscillation vanishes. These two features should be considered when setting the operating point of the SOM. Practically, to locate the operating point we must first define the cavity length and the bias voltage at which oscillation of the resonance mode vanishes. This is the point of maximum conversion gain. Now we should set the R which enables to put the operating point at the negative resistance region. Then we should increase the cavity length and the bias voltage so much, that variation of the load will not be able to cause the mode switching. By means of increasing the bias voltage and the cavity length we ensure stability of oscillation and at the same time we may get higher sensitivity due to the increase of the radiated microwave power.

IV. Conclusion

The results of present work provide information for setting up a Gunn Doppler SOM. It was defined that maximum conversion gain of the SOM is observed at the point where oscillation vanishes. It was shown that neither at the point of maximum conversion gain, nor at the point of maximum radiated microwave power the SOM operates with the best performance. Location of the optimal operating point of a Gunn Doppler SOM is defined by compromise between the conversion gain and stability of oscillation.

REFERENCES

[1] S. Nagano and T. Akaiwa, "Behavior of a gunn diode oscillator with a moving reflector as a self-excited mixer and a load variation detector," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-19, pp. 906–910, Dec. 1971.

[2] Y. Takayama, "Doppler signal detection with negative-resistance diode oscillators," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-21, pp. 89–94, Feb. 1973.

[3] F. R. Pantoja, "Homodyne and heterodyne studies of GaAs and InP millimeter-wave Gunn mixers," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-33, pp. 1249–1253, Nov. 1985.

[4] M. Claassen and U. Güttich, "Conversion matrix and gain of self-oscillating mixers," *IEEE Trans. Microwave Theory Tech.*, vol. 39, pp. 25–30, Jan. 1991.

[5] C. Sun, "Transferred electron devices," in *Handbook of Microwave and Optical Components*, K. Chang, Ed., vol. 2. New York: Wiley, 1990, pp. 285–286.