# A 45 GHz GaAs FET MIC Oscillator-Doubler

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Abstract

A 45 GHz MIC oscillator-doubler using the gate-to-drain nonlinearity of a common- drain GaAs FET has been investigated. This oscillator-doubler has a high output power of 11.6 dBm, a high doubler efficiency of 9 dB and a high power efficiency of 1.6 %.

## 1. Introduction

During the past few years, various microwave integrated circuit (MIC) GaAs FET oscillators and doublers below 26 GHz have been fabricated and demonstrated with remarkably high performance (1),(2),(3),(4). Highly Stabilized oscillators using GaAs FETs in the millimeterwave region, however, have not been reported, and Gunn-diodes and IMPATT-diodes are mainly used (5).

In this paper, a 45 GHz MIC oscillator-doubler using a common-drain GaAs FET is described. A millimeterwave MIC oscillator with high frequency stability against temperature can be easily obtained by utilizing an oscillator-doubler and a dielectric resonator because in the fundamental frequency region of K-band, the value of the unloaded quality factor, $Q0$, of the dielectric resonator is twice or three times the value in the millimeterwave region (5). This oscillator-doubler has a performance of output power of 11.6 dBm, a doubler efficiency of 9 dB, and a power efficiency of 1.6 %.

## 2. Design

### 2.1 Characterization of Common-Drain GaAs FET

To estimate the nonlinearity of a common-drain GaAs FET, input and output impedances were measured against bias voltages. Figure 1(a) shows the input impedance, S11, plotted as a function of the gate voltage. Figure 1(b) shows the output impedance, S22, as a function of the source voltage.

These figures indicate that the nonlinearity between the gate and the drain is similar to that between the source and the drain for bias voltage variations. From these results, two types of output port configurations are expected to be realized for an oscillator-doubler. One is a gate output oscillator-doubler and the other is a source output one.

The 2nd harmonic contents which appear at the output ports of the two oscillator configurations were investigated using 4.5 GHz free-run fundamental oscillators. Figure 2 shows the output power at the fundamental and 2nd harmonic frequencies plotted as a function of the source voltage for two output port configurations. The power output at the 2nd harmonic frequency is almost same for the two configurations, although the source output configuration provides much output power at the fundamental frequency.

For the feasibility study of an oscillator-doubler, two types of output port configurations, i.e. gate output and source output, were further investigated at microwave and millimeterwave regions.

### 2.2 Circuit Configuration of Oscillator-Doubler

The circuit configurations of a 9 GHz and 45 GHz oscillator-doubler in the cases of the source output port configuration are illustrated in Fig. 3.

Figure 3(a) shows the 9 GHz oscillator-doubler, which has a fundamental oscillator circuit, a rejection circuit for the fundamental frequency, fo, and a matching circuit for the doubler frequency, 2fo.

This circuit is not suitable for a millimeterwave MIC oscillator-doubler, because the circuit has a large size and much loss.

An improved circuit pattern shown in Fig.3(b) is applied to the 45 GHz oscillator-doubler. The fundamental oscillator circuit and the rejection circuit at the frequency of 22 GHz-band are integrated in the compact size.

## 3. Experimental Results

### 3.1 A 9 GHz Oscillator-Doubler

The characteristics of a 9 GHz oscillator-doubler using a commercially available GaAs FET (FSX52) are shown in Fig.4. The GaAs FET has a gate length of 1 microns and a gate width of 600 microns. Dotted lines show the output power, Po, at the fundamental frequency (4.5 GHz) using only the fundamental oscillator circuit shown in Fig.3(a), and solid lines show the output power, P2, at the desired frequency (9 GHz) using the oscillator-doubler circuit shown in Fig.3(a). The result of Po minus P2 is the doubler efficiency of the oscillator-doubler. A doubler efficiency of 5 dB is obtained when the source voltage is -8 volts. The doubler efficiency tends to increase as the oscillating power at the fundamental frequency increases.

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### 3.2 A 45 GHz Oscillator-Doubler

Figure 5 shows experimental results of a 45 GHz MIC oscillator-doubler with the circuit pattern shown in Fig.3(b). A GaAs FET chip with a gate Ø.7 microns long and 12ØØ microns wide fabricated by electron beam lithography (6) was used in the experiment. The output power for both the gate output and the source output is 7 dBm at 25 °C. At Ø °C, the output power increased to 11.6 dBm, with a doubler efficiency of 9 dB and a power efficiency of 1.6 %, for the gate output configuration.

Figure 6 shows a photograph of the 45 GHz MIC oscillator-doubler. A GaAs FET chip is mounted on a metal carrier with alumina ceramic substrates Ø.3 mm thick. The size of the oscillator-doubler circuit is 1Ø mm x 6 mm. The output signal is led to a waveguide of WR-19 through a ridged type MIC-to-waveguide transducer.

## 4. Conclusion

A 45 GHz MIC oscillator-doubler with a common-drain GaAs FET and an improved circuit configuration has been investigated. This oscillator-doubler has an output power of 11.6 dBm, a doubler efficiency of 9 dB and a power efficiency of 1.6 %, respectively.

This oscillator-doubler provides a highly stable millimeterwave local oscillator for use in a radio equipment, if a dielectric resonator with a high unloaded Q value, QØ, is used in the circuit to stabilize the fundamental oscillation at the K-band.

The oscillator-doubler will provide new applications for GaAs FETs as highly stable oscillators in a millimeterwave region.


## 5. Acknowledgement

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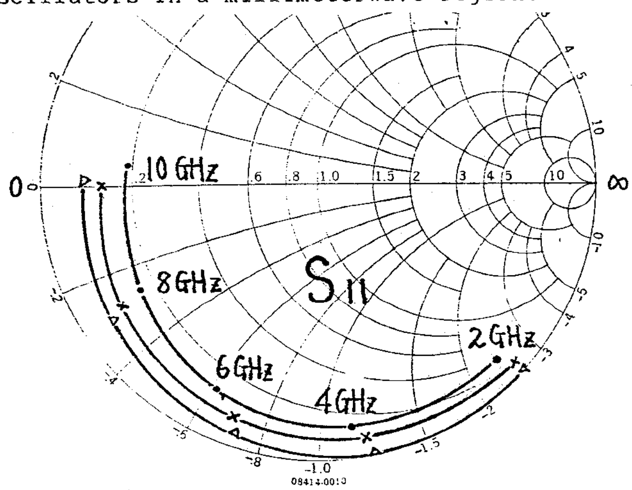
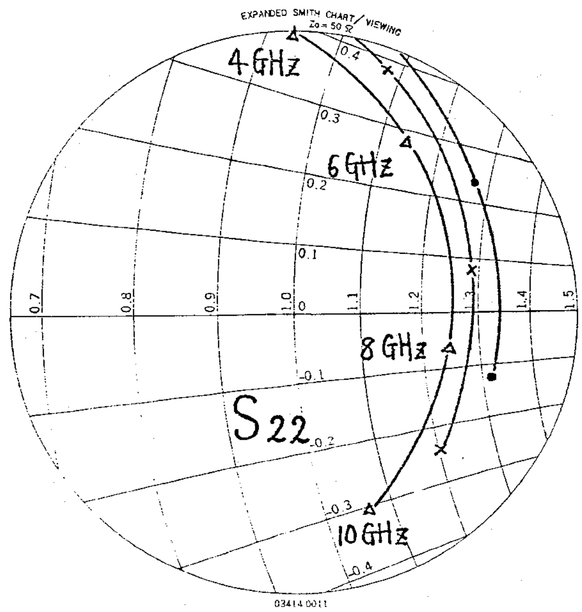



(a) INPUT IMPEDANCE
(Vsd = -8 v const.)

•—• Vgs = -0.15 v
x—x Vgs = -0.92 v
Δ—Δ Vgs = -2.2 v




(b) OUTPUT IMPEDANCE
(Vgs = -1.8 v const.)

•—• Vsd = -3 v
x—x Vsd = -6 v
Δ—Δ Vsd = -10 v

Fig.1 Input and output impedances.

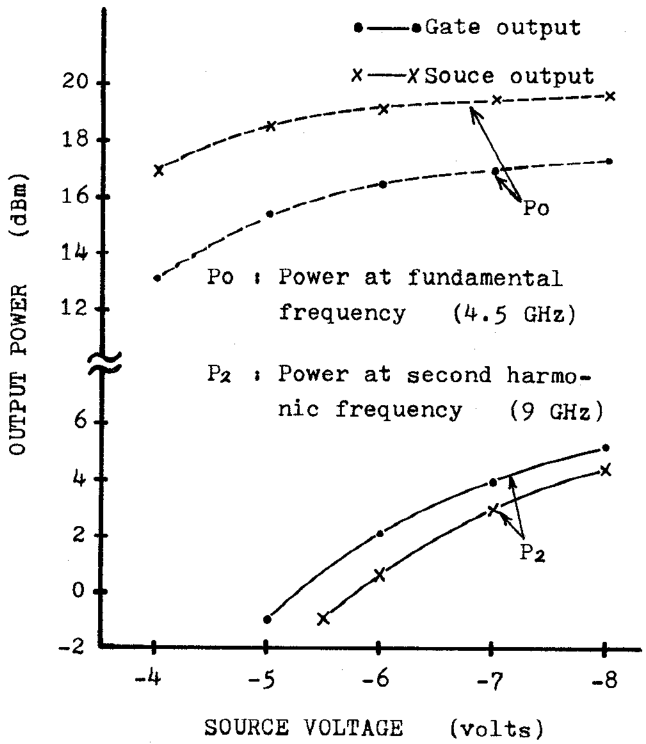



Fig.2 Charactristics of a free-run oscillator.

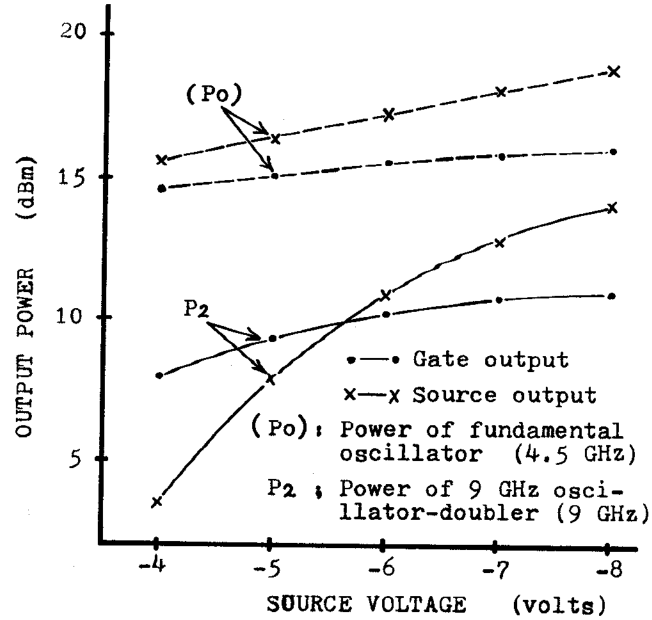
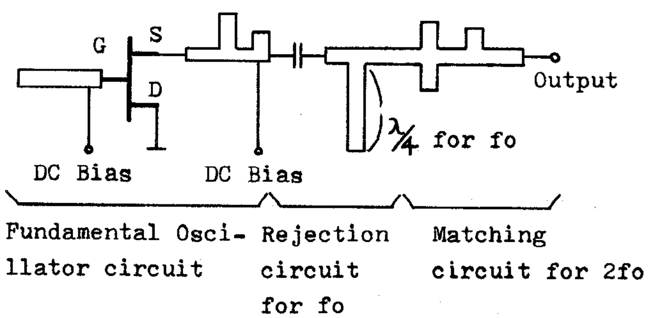
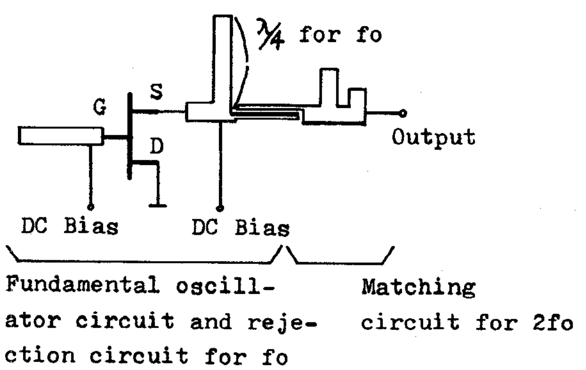



Fig.4 Charactristics of a 9 GHz oscillator-doubler.




(a) Circuit configuration for a 9 GHz oscillator-doubler.




(b) Improved circuit configuration for a 45 GHz oscillator-doubler.

Fig.3 Oscillator-doubler configuration.

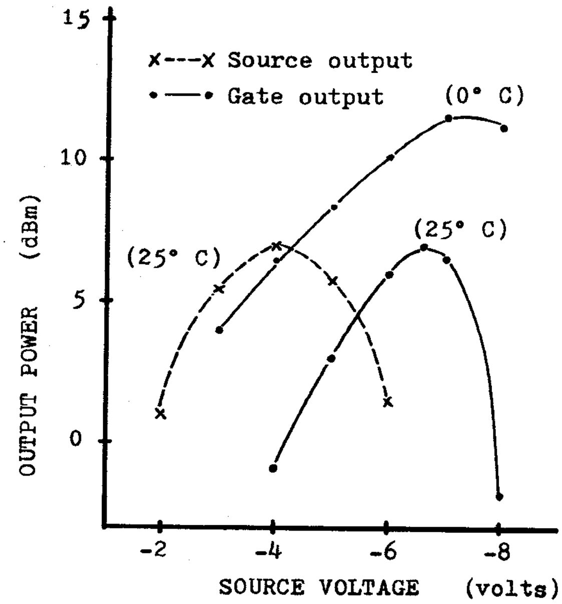



Fig.5 Charactristics of a 45 GHz oscillstor-doubler.

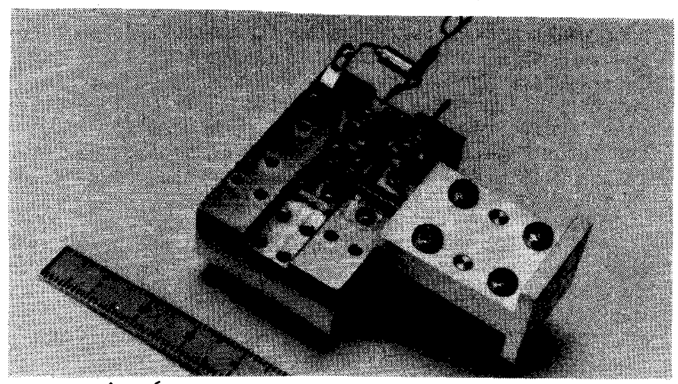


Fig.6 Photograph of a 45 GHz MIC oscillator-doubler.