SOLID STATES DEVICES AT 50 GHZ

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Abstract

This paper reports the features and some performances of a transmitting frequency converter, a receiving frequency converter and a local oscillator at 50 GHz. The output power of the transmitting converter is 12 dBm and the front end noise figure of the receiving converter is below 10.3 dB. The power and the frequency stability of the local oscillator are 20 dBm and within $\pm 7 \times 10^{-5}$ ($0 \sim 60°C$), respectively.

Introduction

A guided millimeter-wave transmission system, "W-40G", is presently under development at the Electrical Communication Laboratories, NTT, Japan[1].

The high-frequency portion of the repeater is composed of receiving and transmitting frequency converters, a common local wave supply, 1.7 GHz IF amplifiers, etc. These frequency converters and IF amplifiers employ GaAs Schottky barrier diodes and Si transistors, respectively.

This paper presents the features and some performances of the transmitting and receiving frequency converters and the local oscillator at 50 GHz, which have been developed for the above system.

Millimeter-Wave Diodes

A GaAs Schottky barrier diode and a GaAs planar p-n junction varactor are employed in the converters and in the frequency multiplier, respectively. An IMPATT diode is also used in the millimeter-wave amplifier. The frequency multiplier and the IMPATT amplifier construct the local oscillator. Diodes are mounted in wafer-type diode packages. The diode package is hermetically sealed[2] at the waveguide windows and at the coaxial terminal as shown in FIG. 1 in order to ensure a high reliability and good performances. A hermetic seal protects the diode from contamination and a sealed wafer-type diode is expected to give a broader bandwidth and to reduce loss at a higher frequency compared with the conventional encapsulated diode.

The junction diameters of the diodes for the converters and the multiplier were determined by considering the compromise between the power handling capacity of a diode and the circuit loss of a diode mount[3, 4]. A diode of a larger diameter has a greater power capacity but is accompanied by a larger circuit loss.

The diameter of an IMPATT diode also governs the maximum dc input power and efficiency. It was determined so that the junction temperature should not exceed 230°C at the operating condition.

Transmitting and Receiving Frequency Converters

Both transmitting and receiving frequency converters consist of a Schottky barrier diode mixer and an IF amplifier as shown in FIG. 2. The height of the waveguide is reduced compared to that of the standard (R-500) waveguide. The diode for the receiving converter is biased foreward but for the transmitting converter it is biased backward by the dc drop of a resistor connected in the dc circuit. The input and output impedances of the IF amplifier were sufficiently matched to the mixer IF impedance. So that no circulators nor any matching network was needed between the IF amplifier and the mixer. The impedance mismatch causes the increase in the noise figure or the degradation of output power of a frequency converter. And a long matching network causes the ripples in the frequency response. This direct coupling of a mixer and an IF amplifier has solved these problems successfully.

FIG. 3 shows the millimeter-wave output power of the transmitting converter as a function of IF power when the local power is 18 dBm. It is clear from the figure that the output power of 12 dBm is obtained with the compression of 1 dB. FIG. 4 shows the overall front end noise figure and the output power versus temperature. Both changes with temperature variation ($0 \sim 40°C$) are within 0.4 dB.

The estimated conversion loss of the mixer portion of the receiving converter and noise figure of the IF transistor amplifier (gain = 35 dB) at the room temperature are 5.4 dB and 3.7 dB, respectively.

The frequency response is shown in FIG. 5.

Local Oscillator

FIG. 6 shows the block diagram of the 50-GHz solid-state local oscillator. The frequency and power level are shown in the figure. It is composed of a frequency stabilized 25-GHz Gunn oscillator[5], a frequency doubler and a millimeter-wave IMPATT amplifier. In order to insure a high reliability of the multiplier diode the output power of the 25-GHz oscillator is kept comparably low and the frequency is doubled into 50 GHz. The oscillation frequency, the frequency stability and the output power of the stabilized Gunn oscillator are 24.29 GHz, within $\pm 7 \times 10^{-5}$ ($0°C \sim 60°C$) and 21.4 dBm, respectively.

The frequency doubler is of a cross-waveguide type[6] and employs a GaAs p-n junction varactor. FIG. 7 shows the typical example of output power, conversion loss, bias voltage and diode dc current of the doubler as a function of the input power. The average conversion loss was within $3.8 \sim 4.5$ dB when the output power is about 20 dBm. The bias voltage and diode dc current are arround -6 V and 120 μA, respectively, at the operating point. No spurious oscillations were observed over the whole temperature range.

The IMPATT amplifier is a linear amplifier at 48.58 GHz which uses the negative resistance of an IMPATT diode. In this circuit the condition between "oscillation" and "amplification" is continuously controllable with only adjusting a variable waveguide short[7]. The output versus input of an IMPATT amplifier is shown in FIG. 8. The output power and the gain of the amplifier are 20.7 dBm and 4.2 dB, respectively, when the input power is 16.5 dBm. In this case the dc input power is 4.3W and so ΔT_j (junction temperature elevation) = 173°C is presumed. FIG. 9 shows the power level and the frequency variation of the local oscillator versus temperature. The change of power level caused by temperature variation is very small, namely, $+0.1 \sim -0.3$ dB for the temperature range of $0 \sim 50°C$. The frequency variation was less than 6 MHz over the whole temperature range. The power consumption of the local oscillator is around 20W including that of the current stabilizer.

Overall Characteristics

The amplitude and delay characteristics were measured at the IF stages using the above mentioned solid state devices, IF amplifier, a millimeter-wave attenuator, etc as shown in FIG. 10. The obtained amplitude frequency characteristics were within ±0.5 dB for the frequency band of 600 MHz and within $+0.5 \sim -1.2$ dB for 800 MHz. The delay characteristics were within 0 ~ −0.55 nsec for 600 MHz and within +2.5 ~ −0.85 nsec for 800 MHz.

Acknowledgement

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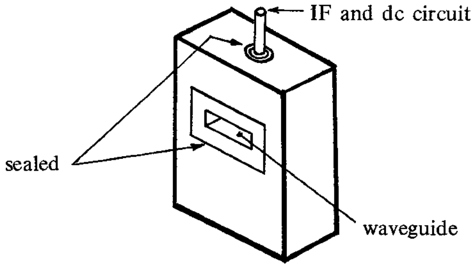
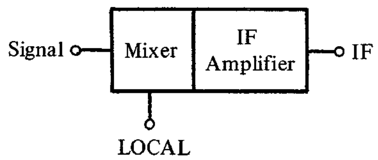


(The width of waveguide is the same as the standard size (R-500), but the hight is reduced)

FIG. 1 THE WAFER-TYPE DIODE PACKAGE.



(Mixer and IF Amplifier are connected directly)

FIG. 2 THE FREQUENCY CONVERTER

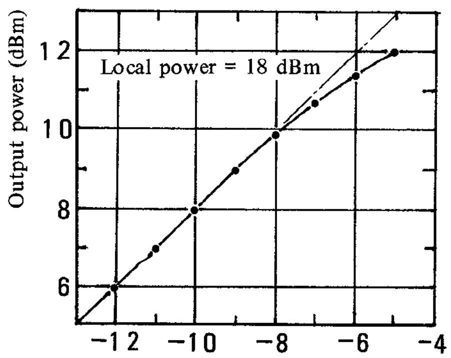


FIG. 3 A TYPICAL EXAMPLE OF THE OUTPUT POWER VS. IF INPUT POWER OF THE TRANSMITTING CONVERTER.

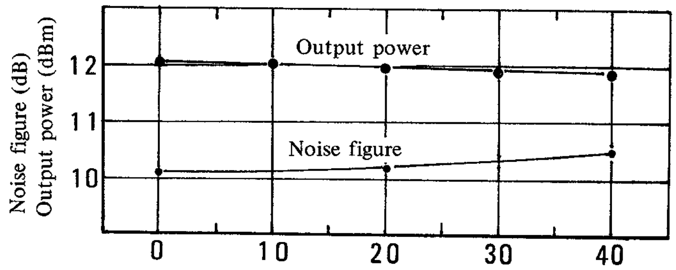


FIG. 4 THE FRONT END NOISE FIGURE AND OUTPUT POWER VS' TEMPERATURE.

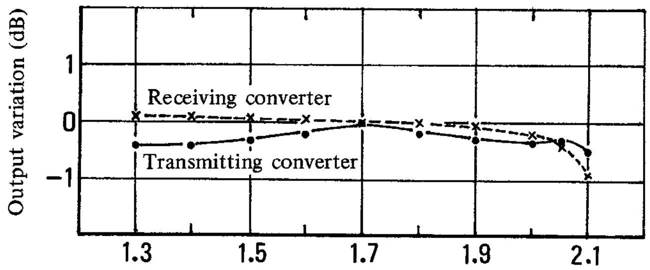


FIG. 5 THE OUTPUT VARIATION VS. FREQUENCY.

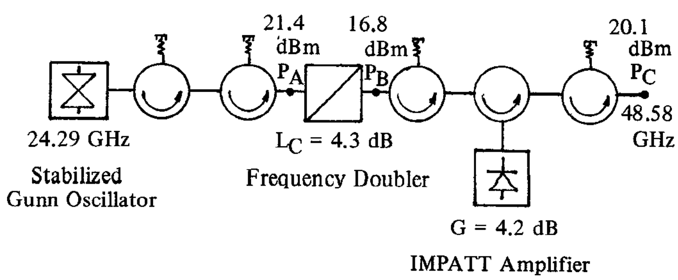
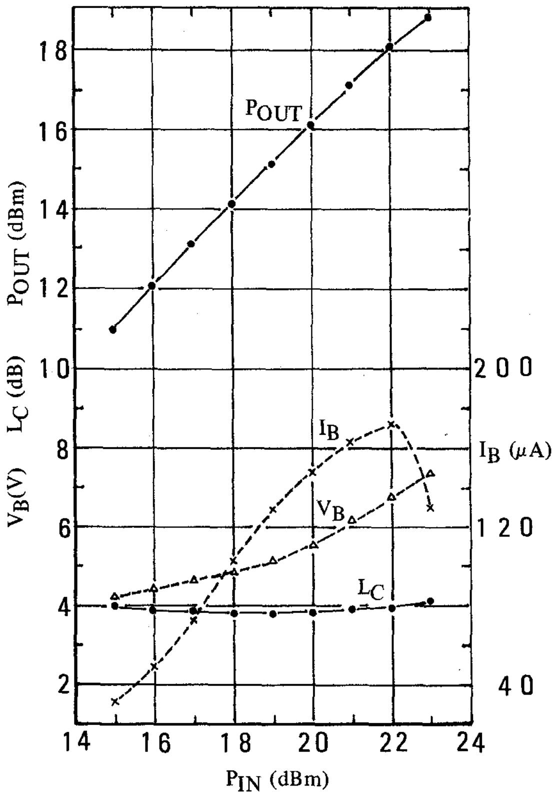


FIG. 6 THE BLOCK DIAGRAM OF THE 50-GHZ SOLID-STATE LOCAL OSCILLATOR.



P_{IN} : Input power P_{OUT} : Output power
I_B : Diode dc current V_B : Bias voltage
L_C : Conversion loss

FIG. 7 THE OUTPUT POWER, CONVERSION LOSS AND BIAS CURRENT AND VOLTAGE VS. INPUT POWER OF FREQUENCY DOUBLER.

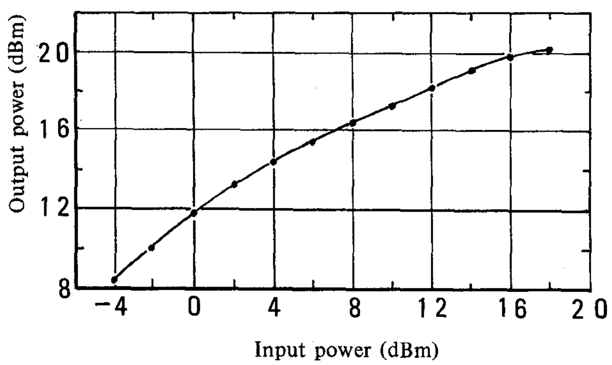
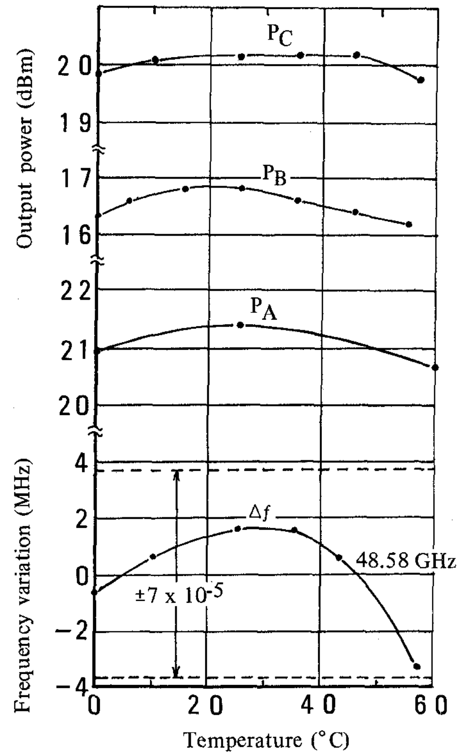


FIG. 8 THE OUTPUT VS. INPUT OF A 50-GHZ IMPATT AMPLIFIER.



Each curve corresponds to the power at the point in FIG. 6

FIG. 9 THE OUTPUT POWER AND FREQUENCY VARIATION OF THE LOCAL OSCILLATOR VS. TEMPERATURE.

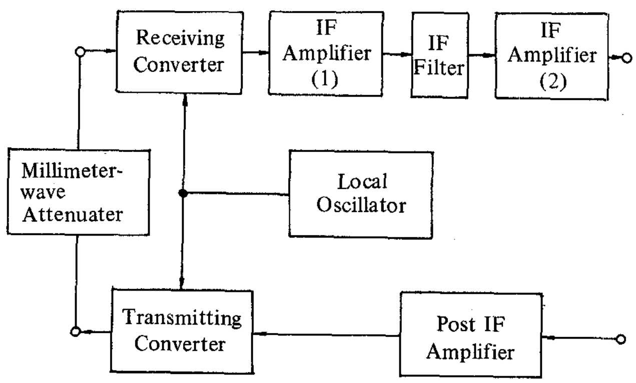


FIG. 10 THE ARRANGEMENT USED FOR MEASURING THE OVERALL CHARACTERISTICS.