A 50-GHz Compact Communication System for Video Link Fabricated in MIC

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ABSTRACT

A 50 GHz transmitter and a receiver for video and voice communication from 1 to 10 miles have been developed. The RF assemblies of the system consist of a 25 GHz DRO, a 25 GHz FM modulator, and 25/50 GHz frequency doublers. Those are fabricated in MIC using chip form GaAs FET's. The transmitting power of 10 dBm and the receiver noise figure of 13 dB were obtained.

INTRODUCTION

Studies on low cost, compact size, light weight millimeter-wave systems using planar hybrid integrated circuit technologies have been rapidly increased in those few years [1,2]. For the millimeter-wave communication systems, of particular interest is the development of frequency stable and inexpensive signal sources. Most commonly used devices to generate millimeter-wave signals are the two-terminal devices such as Gunn and IMPATT diodes. However, oscillators with those active devices have some drawbacks, such as high operating temperature due to poor DC-to-RF efficiency, and therefore it is difficult to adapt them for the microwave integrated circuits (MIC). One possible way to solve the difficulty is to use a low frequency transistor oscillator followed by a frequency multiplier. We have done a feasibility study on a GaAs FET frequency doubler fablicated in MIC operating at 50 GHz.

In this paper we present a very compact 50 GHz-band communication system, where GaAs FET frequency doublers are used. The RF assemblies in the system are made up of MIC's fabricated on alumina substrates where the active elements used are all GaAs FET's of chip form instead of two-terminal devices. The usage of GaAs FET's leads to an inexpensive millimeter-wave communication system because of easy circuit adjustment due to the excellent and stable performance. The main features of the present work are as follows:

(1) 25 GHz DRO (Dielectric Resonator Oscillator) with an excellent temperature stability is used as the local oscillator in the receiver.
(2) FM modulator in the transmitter is made of a 25 GHz DRO with a varactor tuned parasitic microstrip line resonator, and has a good modulation linearity.
(3) GaAs FET frequency doublers are employed in both the transmitter and the receiver to multiply a 25 GHz signal into a 50 GHz signal.

SYSTEM CONFIGURATION

The block diagram of a 50 GHz transmitter and a receiver is shown in Figure 1. In the figure, the blocks inside the doted lines indicate the MIC assemblies. The MIC assembly of the transmitter consists of a 25 GHz FM modulator, a two-stage buffer amplifier, and a 25/50 GHz frequency doubler, while the MIC assembly of the receiver consists of a mixer, a 25 GHz DRO, a single-stage buffer amplifier, and a 25/50 GHz frequency doubler. The FM modulator in the transmitter modulates the 25 GHz carrier signal by the baseband video and voice signals. The modulated signal is fed into the frequency doubler to yield a 50 GHz signal. In the receiver, the local signal is obtained also by doubling the output signal of the 25 GHz DRO. The receiving signal is mixed with the local signal and converted into a 1-GHz IF signal. Antennas are of Cassegrain type with a diameter of 400 mm.

CIRCUIT COMPORNENTS AND PERFORMANCES

WAVEGUIDE COMPORNENT

The microstrip-to-waveguide transitions are constructed with ridged waveguides. Each transition showed an insertion loss of 0.5 dB and a return loss of 15 dB over the frequency range from 47 to 52 GHz. E-plane waveguide bandpass filters, which has a bandwidth of 1 GHz, an insertion loss of 0.5 dB and a return loss of 15 dB, are used in the transmitter output and the receiver input.

25GHz DRO

The oscillator circuit is schematically shown in Figure 2. The circuit consists of a GaAs FET chip, a dielectric resonator, dc bias circuits, a dc block, and a matched load. The 25 GHz DRO is fabricated on a 0.25-mm thick alumina substrate. The GaAs FET used here has a 0.5 x 600 micron gate (Idss=100 mA, Vp= -2 V). The oscillator circuit is of Colpitts type in a common-drain configuration with the source output port. The oscillator is stabilized by a $TE_{01\delta}$-mode dielectric resonator which is placed on the alumina substrate and magnetically coupled to the microstrip line with a 50-Ω load at the end. The dielectric resonator, made of a material system of $Ba(Zn_{1/3}Nb_{2/3})O_3$-$Ba(Zn_{1/3}Ta_{2/3})O_3$ [3], has an unloaded Q of 2000, a relative dielectric constant of 35, and a resonator-frequency temperature coefficient of +11 ppm/°C at 25 GHz. The dimensions of the cylindrical dielectric resonator are 2.8 mm in diameter and 0.9 mm in thickness. Oscillator temperature drift was compensated by choosing the appropriate value of the temperature coefficient of the dielectric resonator and partly by optimizing the coupling between the microstrip line and the dielectric resonator.

Figure 3 shows the measured results of the temperature characteristics of the DRO. Average frequency stability of 0.2 ppm/°C was obtained over -20 °C to 60 °C temperature range with a power output of more than 13.6 dBm at 24.75 GHz. A voltage pushing figure of the DRO was typically 1 MHz/V at 20 °C. Operating voltage and current are 8 V and 70 mA. The oscillation efficiency $[Posc/(V_D \times I_D)]$ was approximately 5%.

25GHz FM MODULATOR

Figure 4 shows the circuit of the 25 GHz FM modulator. The modulator possesses the same kind of 25 GHz DRO as described above and a varactor-tuned parasitic microstrip line resonator. The dielectric resonator used has almost the same characteristics as used in the DRO except a resonant-frequency temperature coefficient of +22.5 ppm/°C. The varactor diode has a capacitance of 0.5 pF at a bias voltage of -4 V and a quality factor of 750 at 1 GHz. The varactor diode is inserted between a 3/4 wavelength open stub and a 1/4 wavelength open stub and connected them to form a wavelength microstrip line resonator whose resonant

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frequency varies in accordance with the control voltage (Vt) of the varactor diode. Modulation linearity was adjusted by varing the coupling between the varactor diode and the dielectric resonator.

Figure 5 shows the linearity performance of the FM modulator under the same dc power condition as in the 25 GHz DRO. The center oscillation frequency is 25.233 GHz and output power was more than 13.5 dBm. Modulation sensitivity was 2.8 MHz/V and modulation linearity was less than 2% in a deviation range of ±4 MHz. The temperature characteristics of the FM modulator is shown in Figure 6. Output power of more than 13.2 dBm and avarage frequency stability of 2 ppm/°C were obtained over the temperature range from -20 °C to 60 °C.

25/50 GHz FREQUENCY DOUBLER

Figure 7 shows the circuit configuration of the doubler. It has an input matching circuit for the input frequency of 25 GHz, a GaAs FET in a common-source configuration, a rejection stub of 25 GHz signal at the output port, and 50 GHz output matching circuit. The GaAs FET has a gate length of 0.5 microns and a gate width of 360 microns (Idss= 80 mA,Vp= -3 V). The GaAs FET chip is mounted on a metal pedestal between two 0.2-mm thick alumina substrates. Since conversion efficiency of the doubler is strongly influenced by impedance adjustment of the input and output matching circuits, some fine-tuning of the matching circuits was needed.

Figure 8 shows the input-output power characteristics. With an input power level of 19 dBm, an output power of 10 dBm at 50.46 GHz was obtained which was sufficient for local signal for the mixer and the transmission output in this system. The bias conditions were then Vgs= -2.9 V and Vds= 2.3 V. The drain current was 10.5 mA and the gate current was less than 10 μA. The 1-dB bandwidth was approximately 0.7 GHz.

Figure 9 shows the output power as a function of gate bias voltage. The maximum output power of 10 dBm was obtained when the gate bias was nearly at the pinch-off.

MIXER

A conventional single balanced hybrid mixer is employed in the receiver where two silicon Schottky barrier beam-lead diodes are used. A typical conversion loss of 9 dB was obtained at 8 dBm local power.

BUFFER AMPLIFIER

Buffer amplifiers in both the transmitter and the receiver were used to supply sufficient input power to the frequency doublers and minimize frequency pulling effect on the 25 GHz DRO's. The single-stage amplifier in the receiver provided an output power of 17 dBm and the two-stage amplifier in the transmitter provided an output power of 20 dBm to the doublers. Linear gains of the single-stage and the two-stage amplifier were 4 dB and 8 dB.

SYSTEM PERFORMANCE

All MIC compornents were assembled and integrated into compact units together with the IF and baseband circuits and power supplies. The dimensions of both units are 120 x 130 x 200 mm. Each Cassegrain antenna has 43 dBi gain and 1° beamwidth. The voltage of a DC-power supply is 12 V, and total dissipation powers of the transmitter and the receiver are 4.2 W and 6.8 W. Table I summarizes major characteristics of the system. Figure 10 shows internal views of the MIC assemblies. Figure 11 shows external views of the transmitter and the receiver.

CONCLUSIONS

A high performance millimeter-wave communication system in the 50 GHz band was realized by using GaAs FET MIC circuitries. The system contains a 25 GHz DRO, a 25 GHz FM modulator, and 25/50 GHz frequency doublers. The transmitting power of 10 dBm and the receiver noise figure of 13 dB were obtained. The frequency stability of less than ±100 ppm was obtained over the temperature range from -20 °C to 60 °C.

From all those excellent performances it was shown that the MIC technology can be a practical way to design millimeter-wave circuitries in this frequency band.

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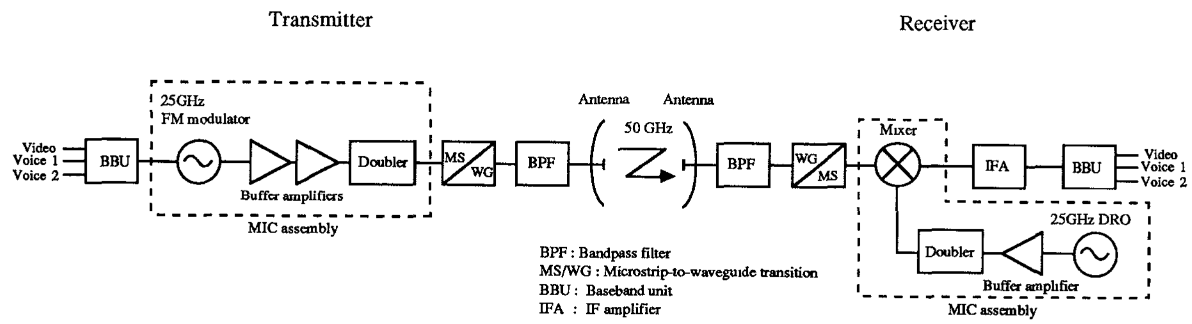

Fig. 1 Block diagram of a 50 GHz transmitter and a receiver

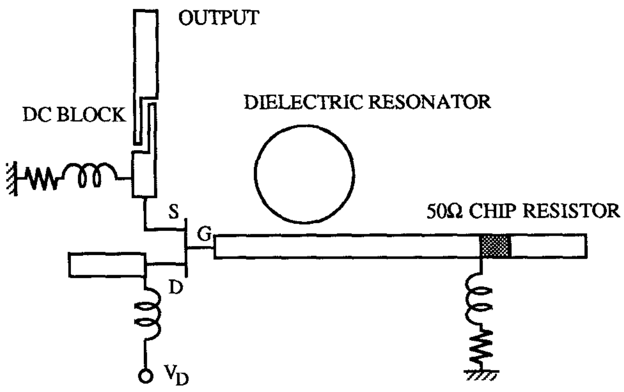

Fig. 2 Circuit of the 25 GHz DRO

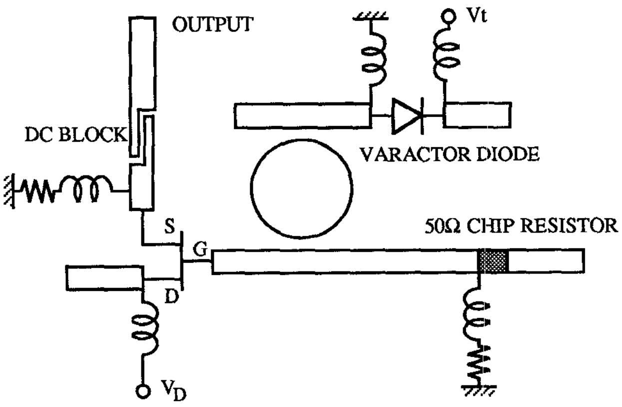

Fig. 4 Circuit of the 25 GHz FM modulator

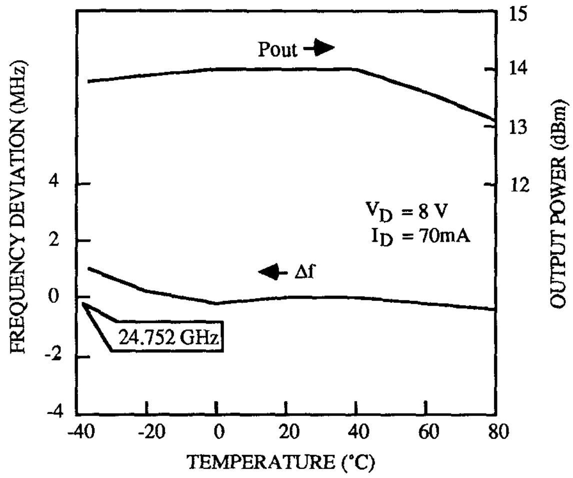

Fig. 3 Temperature characteristics of the 25 GHz DRO

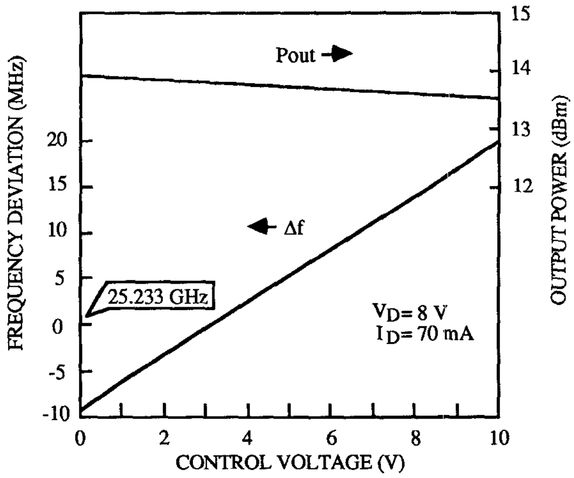

Fig. 5 Linearity performance of the 25 GHz FM modulator

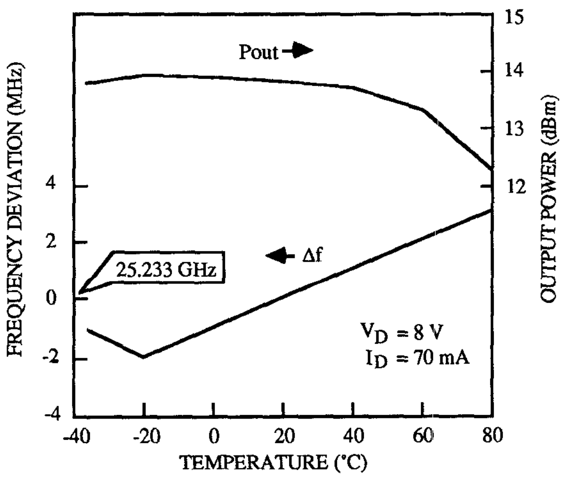

Fig. 6 Temperature characteristics of the 25 GHz FM modulator

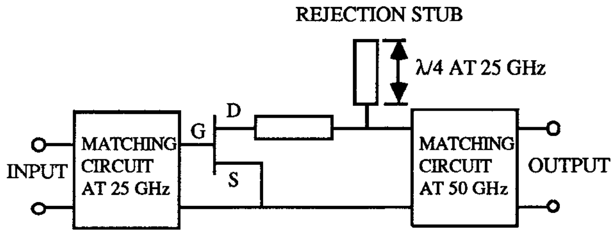

Fig. 7 Circuit of the 25/50 GHz frequency doubler

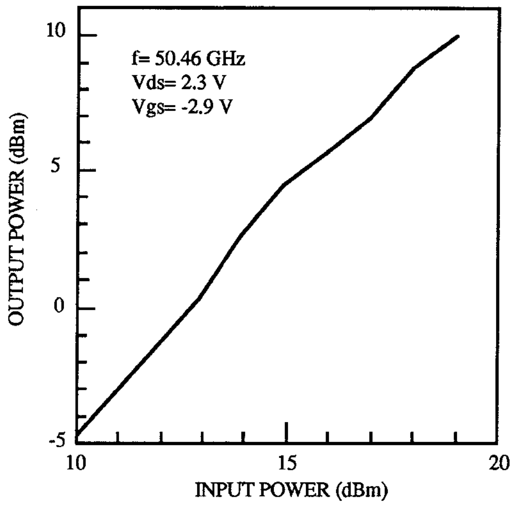

Fig.8 Input-output power characteristics of the 25/50 GHz frequency doubler

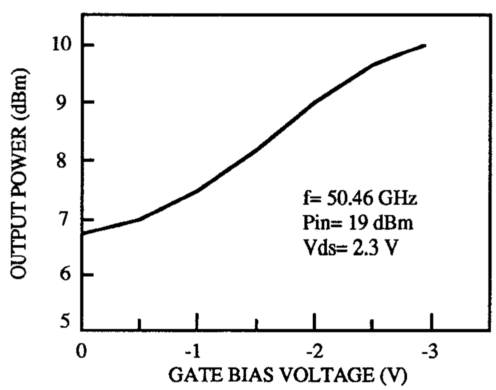

Fig. 9 Output power vs. gate bias characteristics of the 25/50 GHz frequency doubler

Table I

Major characteristics of the 50 GHz communication system

Frequency	50.46 GHz
Transmitting power	10 dBm
Noise figure	13 dB
Frequency stability	±100 ppm (-20~60 °C)
Modulation	FM
Frequency deviation	16 MHz pp
Intermediate frequency	960 MHz
IF bandwidth	27 MHz
Video signal bandwidth	4 MHz
Audio signal bandwidth	15 KHz

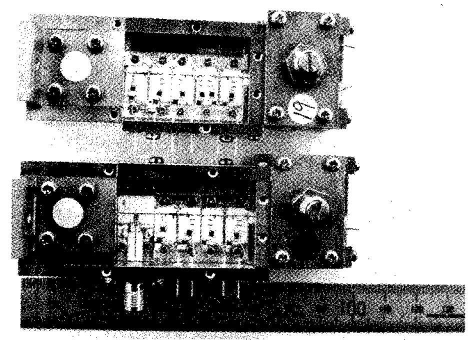

Fig. 10 Internal views of the MIC assemblies (upper side : transmitter, lower side : receiver)

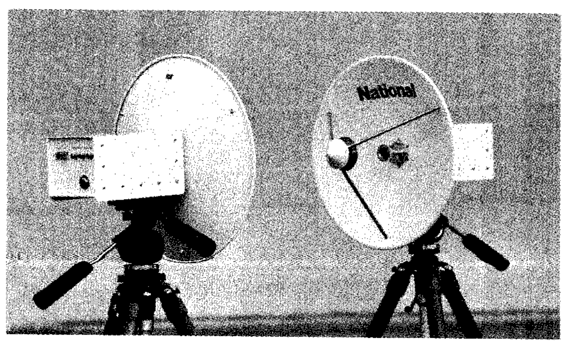

Fig. 11 External views of the transmitter and the receiver