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A 26-GHz HIGH PERFORMANCE MIC TRANSMITTER/RECEIVER FOR DIGITAL RADIO SUBSCRIBER SYSTEMS

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Abstract

A high-performance 26-GHz transmitter/receiver using FSK modulation has been developed. All RF components are fabricated using MIC technology and integrated into a compact module. Transmitting power of 21 dBm and a receiving noise figure of 8.7 dB are obtained.

1. INTRODUCTION

In recent years, there have been increasing demands for high-speed digital communication services, including computer data, facsimile and video transmission. In order to meet these demands, the Dendenkosha Subscriber Radio (DSR) system has been developed at the Yokosuka Electrical Communication Laboratory [1][2]. This system is a point-to-multipoint communication system, as shown in Fig.1, which uses Time Division Multiple Access (TDMA) in the 26-GHz band. A compact and inexpensive transmitter/receiver had to be built in order to realize this system. The application of microwave integrated circuits (MICs) was considered to be the best method for meeting these space and cost requirements. A 26-GHz MIC transmitter/receiver using amplitude-shift-keying (ASK) modulation was previously reported [3]. The purpose of this paper is to present an improved design and performance of the 26-GHz MIC components and transmitter/receiver module which has been achieved using frequency-shift-keying (FSK) modulation. The main features of the present work are as follows:

(1) An FSK modulation method has been adopted to reduce the required carrier-to-noise ratio (CNR) and the modulator has been designed and produced using MIC technology.
(2) Transmitting power and receiving noise figures have been improved by minimizing circuit losses which are usually fairly large in high-frequency MICs.
(3) A highly reliable and high performance transmitter/receiver module has been constructed by integrating the MIC components. Measurements of the bit error rate confirm excellent overall performance.

2. TRANSMITTER/RECEIVER CONFIGURATION

The MIC transmitter/receiver configuration is shown in Fig.2. It is composed of (1) an MIC transmitter/receiver, (2) an antenna and transmit-receive filters, and (3) IF/base-band (BB) sections. The MIC transmitter/receiver consists of an FSK modulator, ON/OFF switch for TDMA control, transmitting power monitor, receiving mixer, receiving local oscillator and circulators. These components are integrated by using MIC technology. The FSK modulator is driven by a 16.384-MHz pulse driver in the IF/BB sections. The modulated signal is switched and converted into a burst mode for the TDMA system.

3. MIC COMPONENTS

3.1 FSK MODULATOR

The FSK modulator is composed of an IMPATT diode, a dielectric resonator and a varactor diode. The circuit configuration of the modulator is shown in Fig.3. A band reflection type has been adopted because a stable oscillation can be easily obtained with low stabilization loss. The IMPATT diode used here is an encapsulated Si DDR type with a diamond heatsink. The diode is embedded into a dielectric substrate and connected to microstrip lines with Au ribbons. The dielectric resonator is made of $Ba(Zn_{1/3}Nb_{2/3})O_3$ - $Ba(Zn_{1/3}Ta_{2/3})O_3$ and has a loaded Q of 3000. A quartz spacer is inserted in order to avoid degradation of unloaded Q. In order to achieve a stable oscillation, the device line ($-Z_D$) and load line (Z_L) were measured and plotted on a Smith chart, as shown in Fig.4. The intersection of the lines corresponds to load impedance where an oscillation occurs. FSK modulation is achieved by a resonance circuit consisting of a varactor diode and a microstrip line. Linearization of differential modulation characteristics has been achieved by optimizing the coupling between the varactor diode and the dielectric resonator [4].

Output power of 24 dBm (+1.5 dB) and frequency error of 50 ppm are obtained over the temperature range from -10°C to 45°C. The junction temperature increase is less than 150°C which ensures high reliability. Modulation sensitivity is 3.7 MHz/V and modulation linearity (DG) is less than 1% in a deviation range of ±8 MHz. The RF spectrum of the FSK modulator with a modulation index of 1.0 is shown in Fig.5.

3.2 TDMA SWITCH

An ON/OFF switch, referred to as a TDMA switch, is used to transmit signals in a burst mode. This switch has to attain a high ON/OFF ratio and low insertion loss so as to prevent burst-signal interference and to utilize effectively the FSK modulator output. The switch consists of three PIN diodes and Au wires, as shown in Fig.6. It operates as a low-pass filter when the diodes are in the OFF state and as a short

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circuit when they are in the ON state. The performance of the switch is greatly dependent on the wire inductance and diode parameters (Cj, Rs) in the millimeter wave band. The results of theoretical investigations indicate that a high quality diode chip (Cj = 0.1 pF, Rs = 1.5 ohm) and low inductance (L = 0.15 nH) are necessary to achieve insertion loss less than 1 dB and an ON/OFF ratio greater than 60 dB, as shown in Fig.6. The switch circuit, including diodes, wires and microstrip line portions, has been packaged and high reliability has been verified.

3.3 RECEIVING MIXER

A balanced mixer is used as the receiving mixer. Fig.7 shows the configuration of mixer which consists of microstrip lines, slotlines, Au wires and two beam-lead Schottky barrier diodes. In this figure, solid lines indicate microstrip lines on the substrate surface, while dotted lines indicate slotlines on the reverse side. This type of mixer is suited for a high frequency region. A conversion loss of 5.5 dB is typically obtained at 12 dBm local power. Isolation between local and signal input ports is greater than 20 dB.

4. MIC TRANSMITTER/RECEIVER PERFORMANCE

MIC components are assembled and integrated into the transmitter/receiver module. Connection losses are fairly large in millimeter-wave bands due to imperfect electrical contact at the substrate ground conductor [3]. In order to obtain good contact between the two substrate grounds, an Au sheet is inserted. Measured loss is evaluated to be less than 0.1 dB. Another cause of fairly large losses may lie in the circulators and filters. Ferrite-disk type circulators [5] and cylindrical cavity type ($TE_{011}{}^{0}$) filters have been adopted to reduce excess losses. Careful consideration has been given to ensure the reliability of the transmitter/receiver. Encapsulated IMPATT and varactor diodes are used. PIN diodes are packaged with the surrounding circuits, and beam-lead diodes are sealed with the Si coating materials. Narrow gaps in microstrip line circuits, e.g., the DC block, are also sealed.

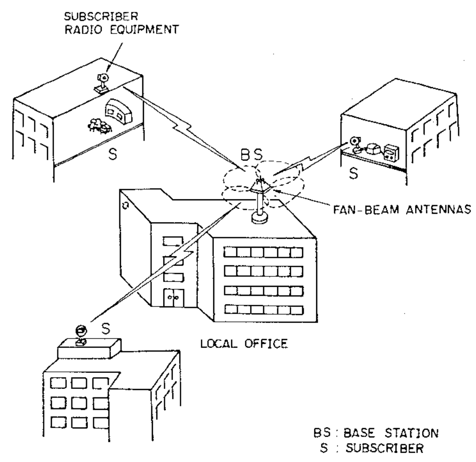

Fig.1. Dendenkosha subscriber radio system. The system uses TDMA and subscribers transmit data to a base station through assigned time slot.

Photograph of the subscriber radio equipment is shown in Fig.8. The areas of the MIC transmitter and receiver alone are 2.7 cm^2 and 3.2 cm^2, respectively. This compact MIC transmitter/receiver is equipped in the rear of the antenna.

The major characteristics of the transmitter/receiver are summarized in Table 1. The transmitting power is 21 dBm and the frequency stability of the transmitter is within 50 ppm for the temperature range between -5°C and 45°C. The ON/OFF ratio of the transmitting power is greater than 60 dB. The receiving noise figure is 8.7 dB. Fig.9 shows the measured bit error rate of the newly developed FSK equipment compared with that for previously reported ASK equipment. The required CNR has been considerably improved by adopting FSK.

5. CONCLUSION

A new 26-GHz band MIC transmitter/receiver employing FSK modulation has been developed for the DSR system. MIC technology has been adopted for all RF active and passive circuits, thereby realizing very compact and inexpensive subscriber radio equipment with excellent performance and high reliability. The new equipment has been successfully tested in a year-long field trial. MIC technology can be further extended to produce a transmitter/receiver which can operate in even higher frequency bands.

ACKNOWLEDGMENT

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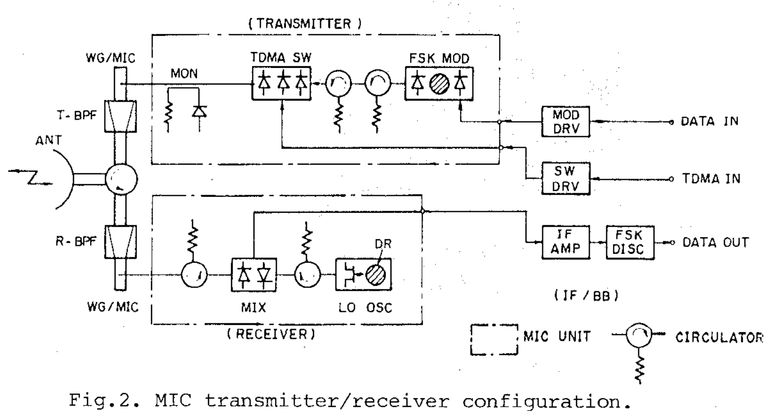

Fig.2. MIC transmitter/receiver configuration.

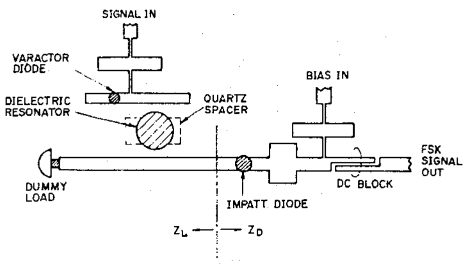

Fig.3. Circuit configuration of FSK modulator.

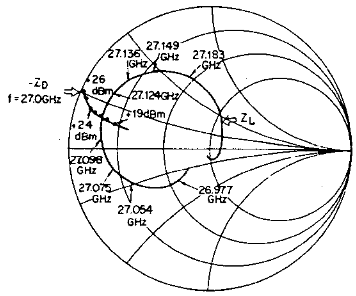

Fig.4. Relation between device line and load line.

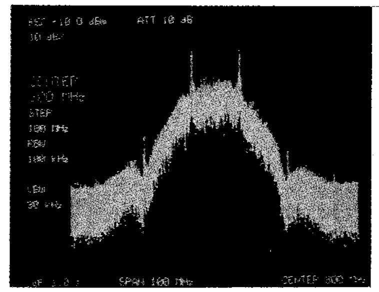

Fig.5. Output spectrum of FSK modulation.

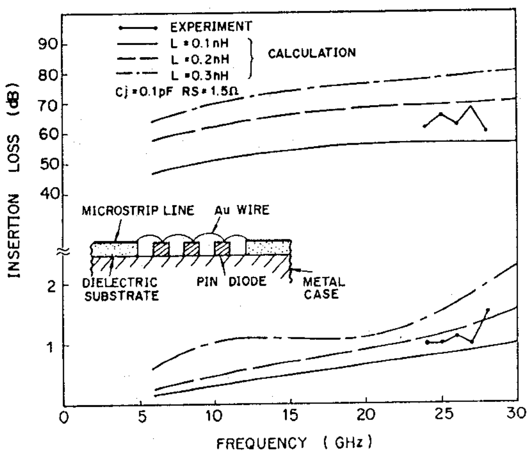

Fig.6. Configuration and insertion loss of TDMA switch.

TABLE 1 MIC TRANSMITTER/RECEIVER CHARACTERISTICS

Item	Characteristics
RF frequency	26-GHz band
Modulation method	FSK
Modulation index	1.0
Clock rate	16.384 MHz
Transmitting power	21 dBm
ON/OFF ratio	60 dB
Frequency stability	50 ppm (-10°C∿45°C)
Power variation	1.5 dB (-10°C∿45°C)
Receiving noise figure	8.7 dB
Local leak	-50 dBm
IF frequency	300 MHz
Power consumption	30 W
Dimension	6.5 cm×3.9 cm×1.5 cm

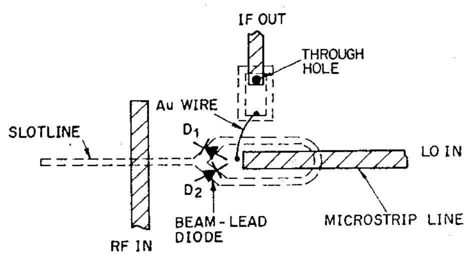

Fig.7. Circuit configuration of balanced mixer.

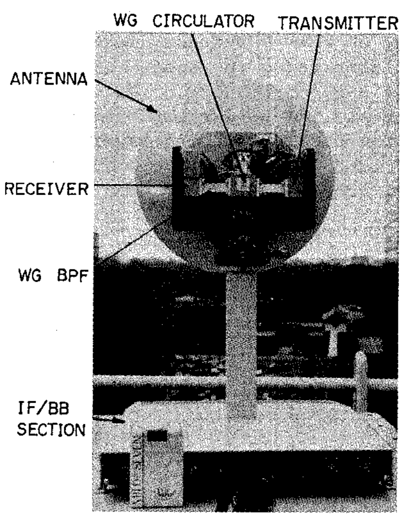

Fig.8. Photograph of subscriber radio equipment.

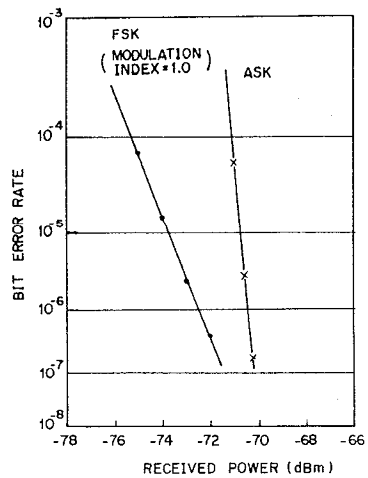

Fig.9. Measured bit error rate of FSK and ASK.