60GHz-BAND ULTRA-MINIATURE MONOLITHIC T/R MODULES FOR MULTIMEDIA WIRELESS COMMUNICATION SYSTEMS

K. Ohata*, T. Inoue*, M. Funabashi*, A. Inoue*, Y. Takimoto*
T. Kuwabara, S. Shinozaki**, K. Maruhashi**, K. Hosoya** and H. Nagai*****

***Advanced Millimeter Wave Technologies Co. Ltd.**
c/o NEC Corporation, 2-9-1 Seiran, Otsu, Shiga 520, Japan
****NEC Corporation, Japan**
*****NEC Engineering Ltd., Japan**

ABSTRACT

60GHz-band ultra-miniature FM/FSK transmitter/receiver modules utilizing a complete MMIC chip set including dielectrically stabilized VCO and local oscillator for wireless LANs and video signal transmission systems are reported. The 0.9cc transmitter module exhibits 11.5MHz/V modulation sensitivity and 10.2dBm output power with -2.8ppm/℃ frequency stability. The receiver module has 9.2dB downconversion gain and 5.4dB DSB noise figure.

INTRODUCTION

There have been increasing demands for transmitting multimedia information of very high speed digital data and wide-band image signals such as video and HDTV signals, through compact and handy systems. 60GHz-band wireless communication systems are useful for such demands because of high potentials of realizing very compact equipment, of easy beam forming, of utilizing wide bandwidth and of adopting picocell zoning owing to high attenuation loss of the radiated signals[1]. This paper reports 60GHz-band ultra-miniature transmitter/receiver modules utilizing a complete monolithic-IC chip set for high speed wireless LANs and video signal transmission systems for the first time. The outstanding feature is the use of 60GHz-band MMIC oscillators stabilized with the dielectric resonator (DR), which are a voltage controlled oscillator (VCO) as an FM/FSK modulator and a local oscillator (LO), realizing very simple and compact modules.

* On leave from NEC Corporation.

RF CIRCUIT CONFIGURATION

The block diagram of the RF front-ends are shown in Fig.1, which are very simple, can be fabricated in compact size, and are effective to reduce the cost of millimeter wave systems. The transmitter module consists of a voltage controlled oscillator (VCO) as an FM/FSK modulator and two power-amplifiers. The final amplifier-block acts as a burst on/off switch in LAN operation, which is required to have high isolation, as well as an output amplifier. The output power is desinged to be 10dBm (10mW) for indoor communication use. The receiver module consists of a low noise amplifier (LNA), a mixer and a stabilized local oscillator (LO).

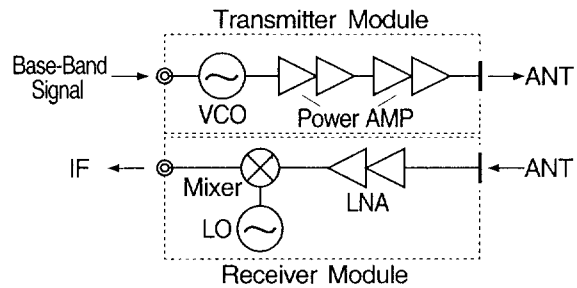


Fig.1 Block diagram of RF front-ends.

MMIC CHIP SET

A 60GHz-band MMIC chip set for wireless communication systems has been developed based on 0.15μm gate N-AlGaAs/InGaAs heterojunction FET (HJFET) MMIC technologies.

A VCO chip is shown in Fig.2. For frequency modulation, a drain DC-biased HJFET is integrated as a varactor. The drain DC-bias brings smooth change in the gate capacitance with gate

0-7803-3360-8/96/$5.00 © IEEE

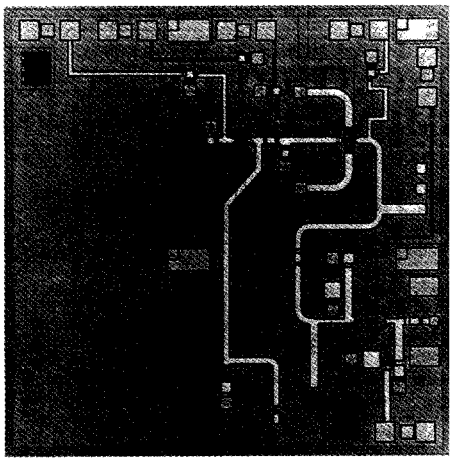


Fig.2 60GHz-band MMIC VCO chip. (Before attaching DR)

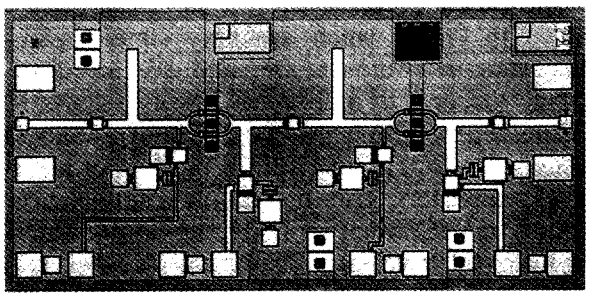


Fig.3 Two-stage wide-band power-amplifier chip.

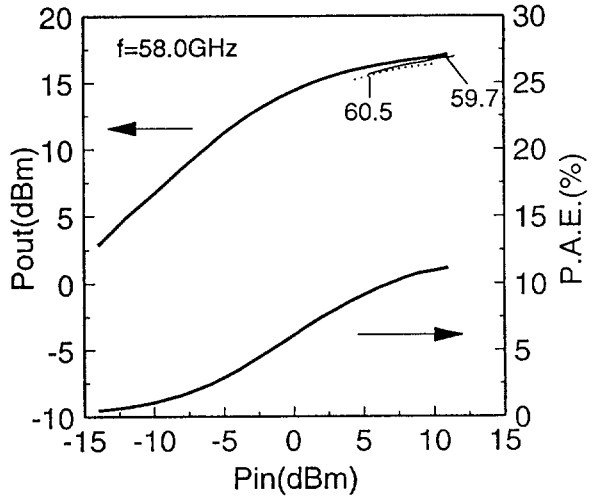


Fig.4 Power performance of the amplifier.

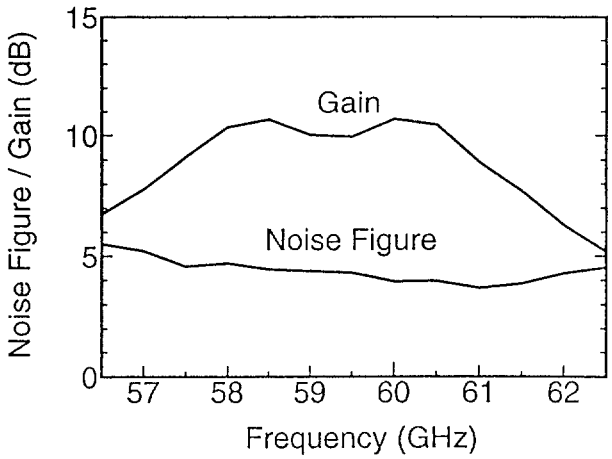


Fig.5 60GHz-band LNA performance.

voltage, which is effective for linear frequency controlling[2]. The oscillation is stabilized with a dielectric resonator (DR) to achieve low phase noise and high stability to the temperature. A rod-shaped TE01 δ -mode DR is directly attached on the MMIC chip. A buffer-amplifier is jointly integrated within the same chip to achieve high output power and better external interface. The chip size is 2.22× 2.22mm². The modulation sensitivity of 55MHz/V and output power of 6.9 dBm with the phase noise of -80dBc/Hz at 100kHz off-carrier have been obtained at 60.0GHz [3].

Figure 3 shows a two-stage wide-band power-amplifier chip[4]. The chip size is 1.07× 2.22mm². The features of this amplifier are wide-band operation using compact matching circuits based on the shorted stub, high stability with RC networks in the bias-lines and so forth, and power-optimum output matching circuits designed through large signal 200μm-wide DH(double hetero)-HJFET modeling. The developed MMIC amplifier exhibits a very flat gain of 14dB from 52.5GHz to 62.5GHz with high isolation of 30dB. The output power is higher than 16.5dBm (17.1dBm max.) as shown in Fig.4.

A two-stage LNA was designed to attain stable operation as well as high gain, optimizing the interstage matching circuit and bias networks. The chip size is 1.07× 2.22mm². The LNA exhibits 10.3± 0.4dB gain with less than 4.7dB(3.9dB min.) noise figure from 57.8 to 60.7GHz as shown in Fig.5.

Figure 6 shows a single-ended drain-mixer chip. The drain-mixer has an advantage of easy isolation of the RF signal from LO signal, resulting in a simple circuit configuration. The mixer has been designed to be biased in highly nonlinear operation for high conversion gain. The chip size

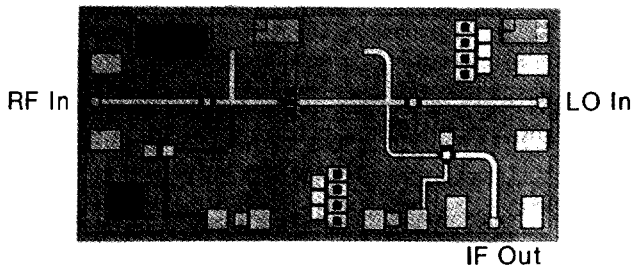


Fig.6 MMIC drain-mixer chip.

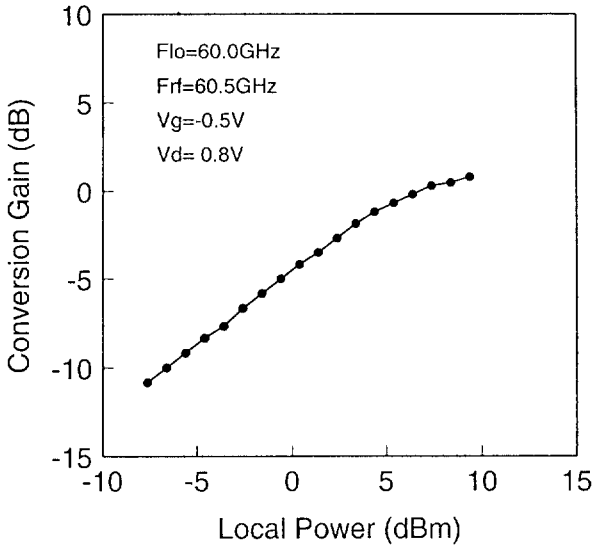


Fig.7 Drain-mixer conversion gain.

is 1.07× 2.22mm². The developed mixer has a conversion gain of 0.5dB at 60.5GHz for 7dBm LO power and 500MHz IF as shown in Fig.7, which is the state of the art performance for the MMIC drain-mixer at millimeter wave range.

Figure 8 shows an LO chip[4]. The LO consists of a dielectric resonator oscillator (DRO) and a

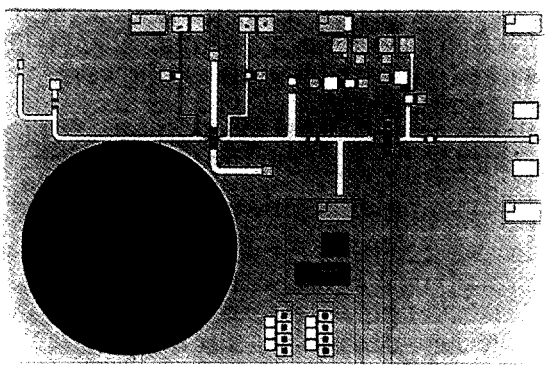


Fig.8 MMIC LO photograph.

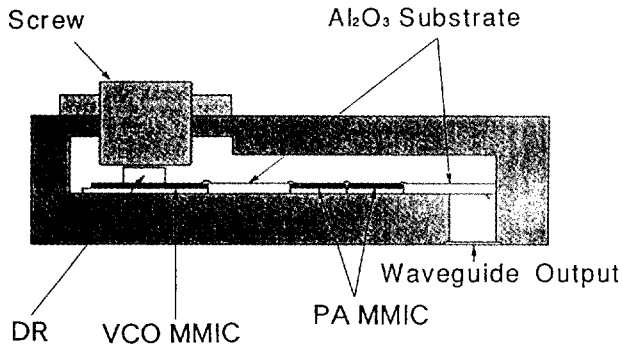


Fig.9 Transmitter module cross sectional structure.

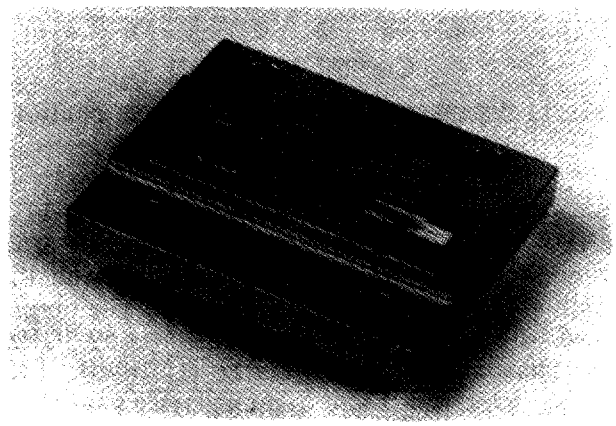


Fig.10 Transmitter module photograph.
(Cap is removed.)

wide-band single-stage buffer-amplifier. The chip size is 2.22× 3.37mm². The output power of 10.1dBm with low phase noise of -90dBc/Hz at 100kHz off-carrier and high frequency-stability of 1.6ppm/℃ has been obtained at 59.1GHz.

T/R MODULES

The cross sectional structure of the transmitter module is shown in Fig. 9, and a fabricated module is shown in Fig.10. A VCO chip and two power-amplifier chips are mounted in a metal package with a microstrip-line/waveguide transition. A metal cap has a fine screw to be placed above the DR for mechanical tuning of the oscillation frequency. The package size excluding the flange part is 20.5×8.5× 5mm³, that is, 0.9cc. Figure 11 shows frequency control characteristics together with output power against the control

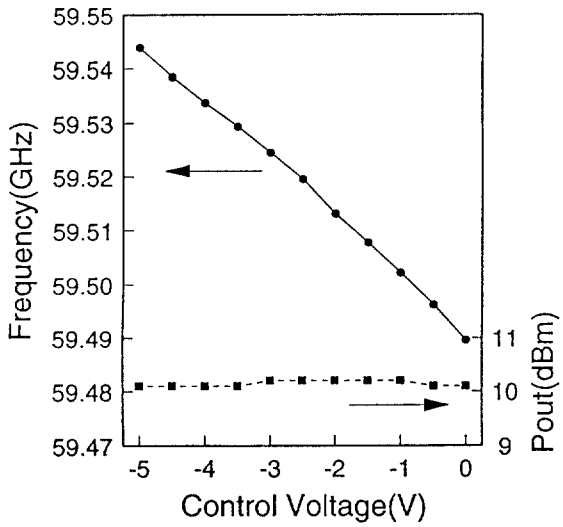


Fig.11 Frequency and output power vs. control voltage of the transmitter module.

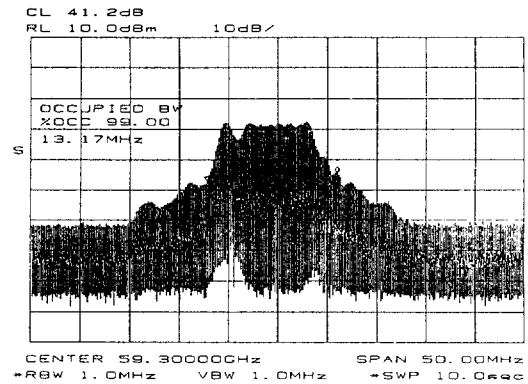
voltage input. The modulation sensitivity is 11.5 MHz/V, which was adjusted using an attenuator in order to have good interface matching with the nominal input voltage of the Ethernet. The output power is fairly constant of 10.2dBm at 59.5GHz. The phase noise is -71dBc/Hz at 100kHz off-carrier. The frequency stability is -2.8ppm/℃ . Figures 12(a) and (b) show FM and FSK modulation spectra with NTSC test pattern signal input and 10Mbps digital signal input, respectively. Good modulation with its index of 1 can be seen. These results indicate that this transmitter module is very promising for practical indoor use.

A receiver module was fabricated using a similar package, assembling the LNA, mixer and LO chips. A conversion gain of 9.2dB with 6.2dB DSB noise figure has been obtained at 59.5GHz for 500MHz IF. The best noise figure is 5.4dB for 300MHz IF.

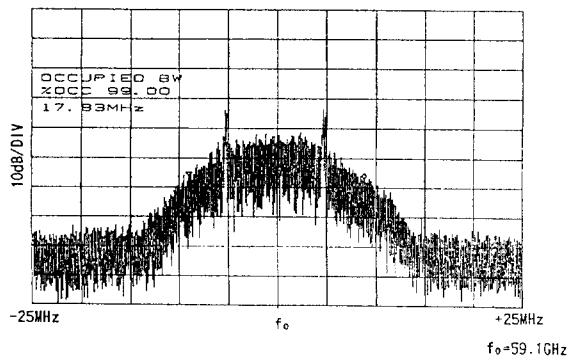
The 60GHz-band monolithic DR-stabilized oscillators are effective to realize these ultra-miniature transmitter/receiver modules for practical use.

CONCLUSION

60GHz-band 0.9cc FM/FSK transmitter/receiver modules utilizing a complete MMIC chip set including DR-stabilized oscillators for multimedia wireless communication systems have been developed. These modules are applicable to wireless LAN systems with higher than 10Mbps data rate,



(a) FM : NTSC test pattern signal input.



(b) FSK : 10Mbps digital signal input.

Fig.12 Modulation spectra of the transmitter module.

and video signal and compressed HDTV signal (MUSE) transmission systems[5].

REFERENCES

[1]Y.Takimoto,"Recent activities on millimeter wave indoor LAN system development in Japan," 1995 IEEE MTT-S Int'l Microwave Symp. Dig., pp. 405-408.

[2]K.Ohata et al.,"A millimeter wave monolithic VCO with an integrated heterojunction FET as a varactor," 1994 European Microwave Conf. Proc., pp.1667-1672.

[3]T.Inoue et al.,"60GHz dielectrically stabilized monolithic voltage controlled oscillator," 1995 European Microwave Conf. Proc., pp.281-284.

[4]K.Ohata and T.Saito,"High-performance millimeter-wave MMIC's for wireless communication systems," URSI ISSSE'95 Proc., pp.119-122.

[5]Y.Takimoto et al.,"60GHz short range transceivers and applications for Minimum Delay Spread LAN," to be prsented at 1996 IEEE MTT-S Int'l Microwave Symp.