60-GHz Transceiver for High-Speed Wireless LAN System

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Abstract

We have developed a 60-GHz Transceiver unit for high-capacity wireless LAN systems, employing state-of-the-art MMIC technology. This prototype showed sufficiently good performance in an ethernet-compatible 10-Mbps random access CSMA/CD wireless system, and proved its potential usefulness in various commercial products.

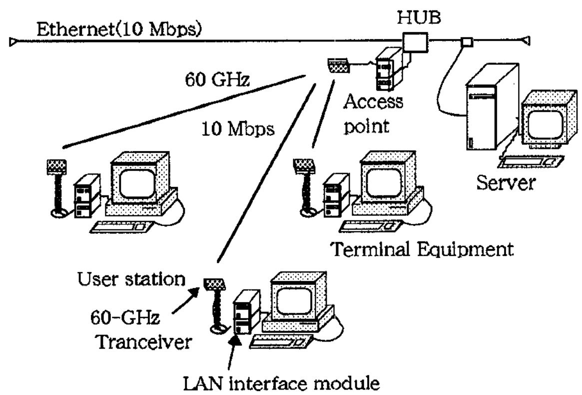

Fig. 1. 60-GHz wireless LAN system.

1. Introduction

Recently, an easy-to-move and easy-to-reconfigure high-capacity network for office environment has been sought. Additionally, microwave frequency bands have become saturated and there is growing necessity to exploit new frequency bands which have not yet been utilized for commercial applications. Internationally, utilization of the millimeter wave band has been recommended, and companies have been developing efficient devices such as HEMTs and HBTs and integrating these into MMICs to mark high performance and high productivity.
However, although there have been some basic studies, the actual design and fabrication of a distinctive system for a specific commercial application has been scarce, except in the area of automotive radar. It appears to be very important to build a complete distinctive system to study the commercial applicability. We have now developed a prototype system specifically designed for an indoor high-capacity wireless LAN system.

2. 60-GHz Wireless LAN System

The system has a 60-GHz RF module and a LAN interface module which contains a modem unit and a LAN interface unit (Fig. 1). The 60-GHz RF module functions as a frequency converter. The modem unit generates a 2-level FSK modulated signal and demodulates the received IF signal. The LAN interface unit connects the radio units to a wired ethernet by means of CSMA/CD (Carrier Sense Multiple Access with Collision Detection).

3. 60-GHz RF Transceiver Module

A schematic view of the 60-GHz RF transceiver

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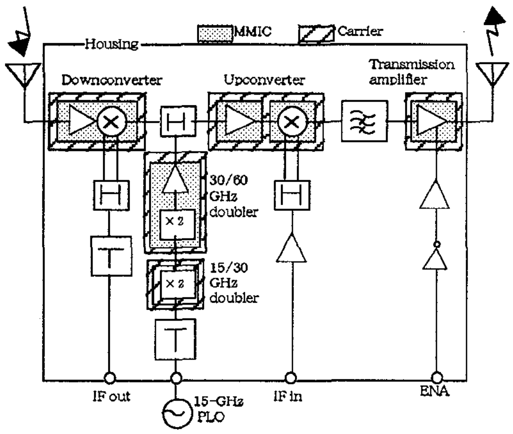

Fig. 2. Schematic view of the 60-GHz transceiver module.

module is shown in Fig. 2. The RF module consists of a millimeter wave unit and a 15-GHz PLO. MMICs and an MIC are mounted on five carriers(Fig. 3). The size of each carrier is 20 mm × 10 mm × 2 mm. A microstrip line filter and a microstrip line divider are mounted directly on a metal housing. The size of the housing is 150 mm × 85 mm × 18.1 mm. The PLO is connected by a rigid coax cable.
On the under side of the MMICs, bias circuits and planar antennas are implemented(Fig. 4). Planar antennas are directly connected to the housing via waveguide interfaces.

The characteristic figures of each component described below are typical figures measured under the same condition as each IC is implemented in the module.

3.1. Downconverter

There are two critical functions of the downconverter; low-noise amplification of the received signal and downconversion with suppression of the image signal.
These functions have been implemented on a single InGaP/AlGaAs/GaAs HEMT MMIC [1]. Low-noise amplification is achieved by the four-stage LNA. The downconversion and the image-rejection functions are realized by the single-balanced drain-injection mixer with 90-degree couplers at the LO and RF ports. In cooperation with a 90-degree IF coupler, the image-rejection mixer cancels undesired lower sideband signals, and downconverts desired upper sideband signals to IF signals. The conversion gain of the downconverter is 16.5 dB, the noise figure is 4.0 dB, and the suppression ratio of the lower sideband image signal compared to the upper sideband desired signal is 10 dB.

3.2. Transmission amplifier

The transmission amplifier is a four-stage AlGaAs/GaAs HEMT MMIC. Its gain is 20.7 dB. In the user station, the transmission amplifier is controlled by ENA(transmission enable signal) and is also used as a burst switch.

3.3. Upconverter

The upconverter consists of two AlGaAs/GaAs HEMT MMICs, a two-stage local buffer amplifier, and a local cancellation mixer. The local cancellation mixer is a drain-injection single-balanced mixer which has 180-degree couplers at the RF and LO ports. Together with a 180-degree IF coupler, it combines the RF signal and cancels LO signal, using phase differences injected into and transmitted from each mixer. The conversion gain of the upconverter is -18 dB and the LO signal suppression ratio to the RF signal is -1 dB. To compensate LO suppression and to reduce the LSB signal, the transmission microstrip line filter is inserted after the upconverter.

3.4. 15/30-GHz doubler

The 15/30-GHz doubler is made of an AlGaAs/GaAs HEMT MIC. The conversion gain is -3 dB.

3.5. 30/60-GHz doubler

The 30/60-GHz doubler consists of a single

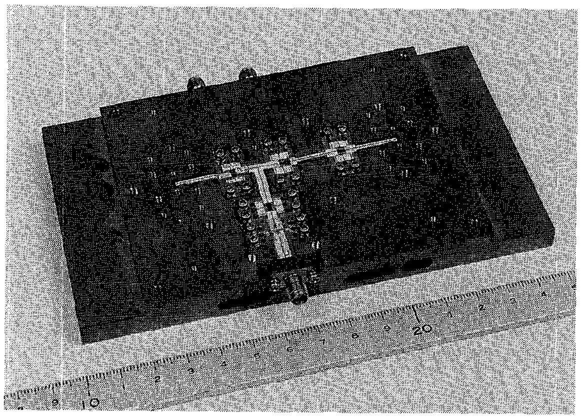

Fig. 3. 60-GHz transceiver module :
MMIC side.

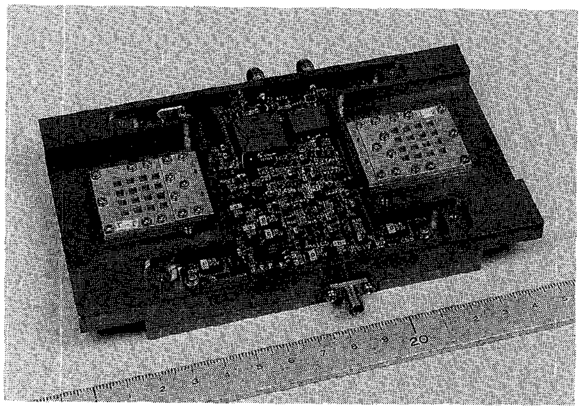

Fig. 4. 60-GHz transceiver module :
Antenna side

AlGaAs/GaAs MMIC which has a 30/60-GHz doubler circuit[2], followed by a four-stage amplifier implemented in order to inject enough LO power for the up- and downconverters. The conversion gain is 9.6 dB.

3.6. planar antenna

Two planar antennas are attached to RF modules, one for transmission and the other for reception. Planar antennas for user stations have sixteen elements, and for access points, one element. They transmit and receive circularly polarized waves so as to reduce the interference caused by the waves reflected odd

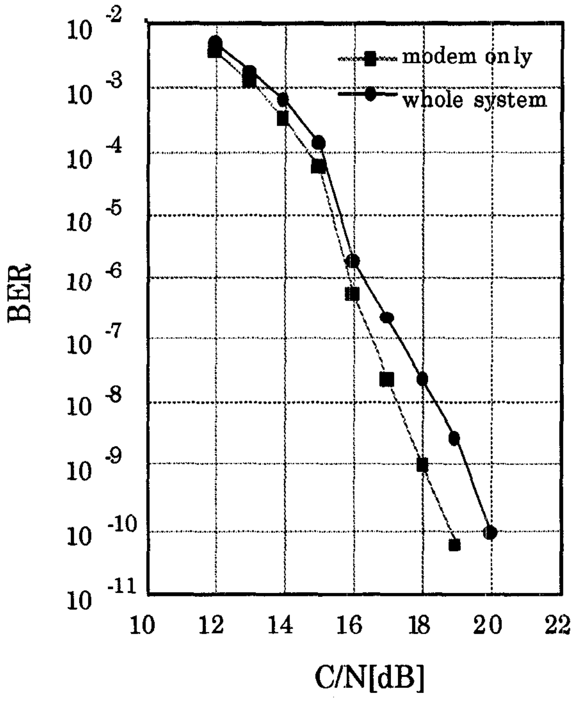

Fig. 5 C/N vs. BER

times in an indoor environment, taking advantage of the reversal in the direction of circulation which occurs at each reflection. The antenna gain for user stations is 19.5dBi and for access points, it is 5dBi. The Half-power beam width of the antennas for user stations is 14.5degrees, narrow enough to avoid receiving interferences. For access points, it is 60 degrees, which is wide enough to cover a good service area.

4. Performance

The performance of the whole unit is summarized in Fig. 6
C/N-BER is measured and shown in Fig. 5. Just the same as Ethernet, Manchester encoding/decoding is used so the bit transmission rate is 20Mbps, the twice as high as the information transmission rate. No error correction method is employed. The whole system BER, through RF module, is compared here with modem only condition, which indicates that the C/N deterioration caused by

RF modules is not greater than 1dB at 10^{-8} of BER, but it has the tendency to steadily grow as the requited BER becomes tight.
Minimum received power level at which good communication (BER of more than 10^{-7} at 20Mbps is secured) will be available is measured to be -69dBm at an RF unit input point in an experiment with a user station and an access point connected by waveguides. The threshold level is set at this condition in the modem so that the lower level noise will not be accepted. In this system, the total antenna gain with those of both an access point and a user station added each other is 24.5dB (Max.) as mentioned before, which corresponds to the theoretical maximum coverage of about 20m. However, in a real condition, because antennas of an access point and every user station will not directly be put face to face, and some fading effects mostly caused by reflections from walls, ceilings, and other objects inside a room may also cause degradation, a practical user area is about 10-15m.

5. Conclusion

Using state-of-the-art MMICs, we successfully implemented a wireless communication system aimed at commercial applications in the 60-GHz band. The performance of our CSMA/CD system sufficiently ensured the applicability to a high-speed wireless LAN system in an indoor small-area environment.
Real time moving picture (MPEG1) transmission experiments were successfully conducted, which indicates that this system is capable of commercial use.
It is confirmed that our CSMA/CD system's performance was on par with that of a wired ethernet system.

Transmission frequency (access point) (user station)	59.4 GHz 59.9 GHz
IF frequency	1.36 GHz/1.86 GHz
LO frequency	58.04 GHz
Transmission power	2.3 dBm
LO signal leak	-12.2 dBm
Image signal leak	-21.8 dBm
Conversion gain	12.67 dB
Noise figure	5.2 dB
Image suppression ratio(USB/LSB)	12.5 dB

Fig. 6. Performance of the 60-GHz module.

References

[1] T.Saito, N.Hidaka, K.Ono, Y.Ohashi, and T.Shimura, "60-GHz MMIC Image-Rejection Downconverter Using InGaP/InGaAs HEMT," 1995 IEEE GaAs IC Symposium Technical Digest, pp. 222-225

[2] Y.Kawasaki, K.Shirakawa, Y.Ohashi, and T.Saito, "30-GHz Oscillators for a Millimeter Wave Monolithic Transceiver," 1994 Asia-Pacific Microwave Conference Proceedings vol.III, pp. 931-934