1.25Gbps Wireless Gigabit Ethernet Link at 60GHz-Band

Keiichi Ohata, Kenichi Maruhashi, Masaharu Ito, Shuya Kishimoto, Kazuhiro Ikuina[1], Takeya Hashiguchi[1], Kazuhiko Ikeda[2], and Nobuaki Takahashi[2]

Photonic and Wireless Devices Research Labs., NEC Corporation, 2-9-1 Seiran, Otsu, 520-0833 Japan
[1]Functional Materials Research Labs., NEC Corporation, 4-1-1 Miyazaki, Kawasaki, 216-8555 Japan
[2]NEC Engineering Ltd., 1753 Shimonumabe, Kawasaki, 211-8666 Japan

Abstract — **A 1.25Gbps 60GHz-band full duplex wireless Gigabit Ethernet link has been developed. Direct ASK modulation and demodulation scheme is adopted for the 60GHz-band transceiver. CPW MMIC's and planar filters are flip-chip mounted in TX and RX LTCC MCM's. The wireless Gigabit Ethernet link has a function to convert an optical fiber link to a wireless link seamlessly combining a 60GHz-band transceiver with a 1000Base-SX optical in/out module. The size is 159×97×44mm³.**

I. Introduction

Demands for high-speed multimedia data communications, such as a huge data file transmission and real-time video streaming, are markedly increasing, so that the wireless transmission with 1Gbps and beyond data rate is very attractive. 1.25Gbps Gigabit Ethernet networks using optical fibers and UTP cables are becoming to be widely used, however, the speed of conventional wireless LAN systems (IEEE801.11b, 11a etc.) is limited to less than 100Mbps. A very wide unlicensed 60GHz-band (59-66GHz in Japan) is suitable for ultra high speed wireless communications with Gbps class of data rate. An S400 (400Mbps) wireless 1394 adapter was demonstrated for the first time by the authors [1]. An MMIC chipset for 1Gbps wireless links was reported [2]. However, low-cost high-producible module technologies are required for commercial use of 60GHz-band systems. We have proposed low-cost multi-chip module (MCM) concept based on the multilayer Low-Temperature Co-Fired Ceramic (LTCC) technologies [3], and fabricated 60GHz-band Coplanar Waveguide (CPW) MMIC's, planar filters and MCM's for 500Mbps and 1.25Gbps transmissions [4]-[8]. In this paper we demonstrate a compact wireless Gigabit Ethernet link for the first time utilizing these technologies.

II. Wireless Gigabit Ethernet Link Configuration

Wireless Gigabit Ethernet link has a function of a media converter to connect a fiber link to a full duplex wireless link seamlessly with 1.25Gbps data rate. Fig.1 shows the wireless Gigabit Ethernet link configuration. The data input and output interface is a 1000Base-SX optical transceiver module. The transmitting data from the optical module is input to the millimeter-wave transmitter after the waveform reshaping through the clock and data recovery circuit (CDR). The received data from the millimeter-wave receiver is input to the optical transmitter after the waveform reshaping through the CDR. The direct ASK modulation and demodulation scheme is adopted for the millimeter-wave transceiver because of a simple configuration with high data rate. The transmitter consists of a 30GHz band oscillator, a 30 to 60GHz band frequency doubler, an ASK modulator, a bandpass filter and a power amplifier. Higher than 1.5Gbps ASK modulation can be realized using a Traveling Wave Switch (TWSW) with low insertion loss and high isolation [9]. The modulator has a high speed data driver consisting of an FET pull down circuit to convert CDR output signal level (0.8Vp-p) to the on/off (-1.5V/0V) level for the switch. For the oscillator, a free running one with the phase noise of about –80dBc/Hz at 1MHz off-carrier can be used, however, a DRO is adopted to meet with the permitted frequency tolerance of 500ppm for the unlicensed 60GHz-band in Japan. The receiver consists of a low noise amplifier, a bandpass filter, a demodulator (detector) and a post limiting amplifier for the output signal to be converted to the pseudo ECL (PECL) level. A pair of separate carrier frequency of f1 and

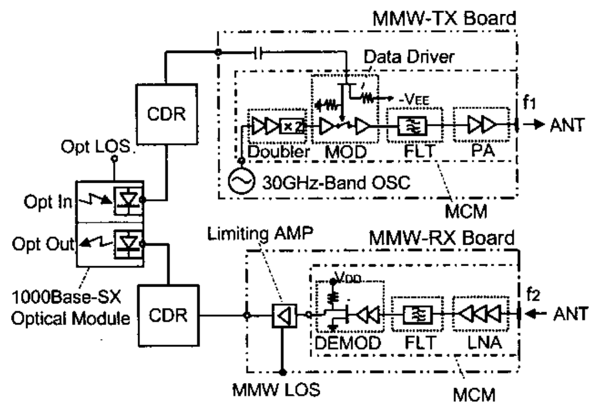

Fig. 1 Wireless Gigabit Ethernet link configuration.

0-7803-7694-3/03/$17.00 © 2003 IEEE

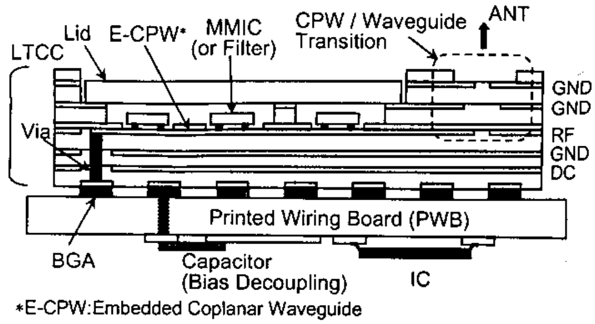

Fig. 2 Millimeter-wave transceiver module structure.

f2 about 3GHz apart is adopted for the duplex link in order to attain the isolation between the transmitter and receiver. Alarms for millimeter-wave loss of signal (MMW LOS) and for optical loss of signal (Opt LOS) are indicated using LEDs.

III. TRANSCEIVER MODULE TECHNOLOGY

The features of our millimeter-wave transceiver module shown in Fig. 2 with high productivity are

(a) Coplanar MMIC's and planar filters.
(b) Flip-chip mounted multilayer LTCC MCM.
(c) Antenna/MCM/PWB 3D compact transceiver module using Ball Grid Array (BGA) connection.

MMIC's are based on 0.15μm AlGaAs/InGaAs hetero-junction FET (HJFET) technologies. Flip-chip bandpass filters are planar dielectric waveguide type with CPW input and output ports in the alumina substrate [7], [8]. The MMIC and filter chips are mounted in LTCC packages by the thermo-compression flip-chip bonding using stud bumps with high reliability. The transmitter and receiver MCM's are mounted on printed wiring boards (PWB's) by BGA assembling. A 30GHz-band oscillator is mounted on the transmitter board. Flat array antennas are placed on the transmitter and receiver MCM's. 60GHz-band signal is fed to the antenna through a coupling slot in the MCM. The transmitter and receiver boards are set on a base-band circuit board consisting of an optical transceiver, CDR's and power supply circuits.

MMIC's were designed to have wider responses than the required bandwidth from 59 to 64GHz. A doubler chip shows higher than 0dB conversion gain. A modulator chip has higher than 4dB gain. A 2-stage power amplifier chip exhibits 12dB linear gain and 14dBm saturated output power. A 3-stage low noise amplifier chip shows higher than 18dB gain. A demodulator chip has higher than 10mV output for an input power of higher than –30dBm. The chip size of all MMIC's is $2.5\times1.15mm^2$. Fig. 3 shows fabricated

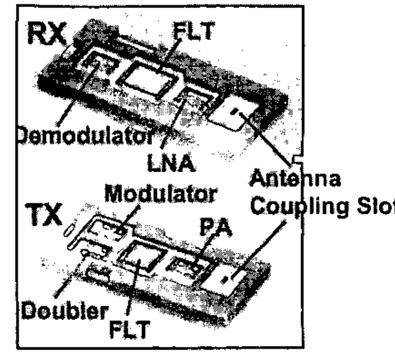

Fig. 3 Transmitter and receiver MCM's photograph.

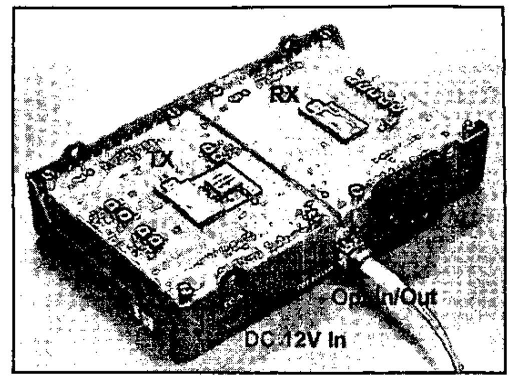

Fig.4 Internal view of wireless Gigabit Ethernet transceiver.

transmitter and receiver MCM's. The sizes are $27.9\times12.6\times1.6mm^3$ and $29.2\times12.6\times1.6mm^3$, respectively. A completed wireless Gigabit Ethernet transceiver before attaching antennas is shown in Fig. 4.

IV. TRANSCEIVER MODULE PERFORMANCE

Fig. 5 shows frequency responses for the transmitter output power. 30GHz-band 0dBm CW signal is input to the doubler chip in the transmitter MCM by an RF probe. The peak output power for the ASK modulated 60GHz-band signal is plotted versus frequency. Fig. 5 (a) is for f1 of 60.3GHz and (b) is for f2 of 63.13GHz. The frequency response is reflecting that of the filter in the transmitter MCM, and is effective for reducing the bandwidth of ASK modulated 60GHz-band signal. The output powers are 10.4dBm and 8.7dBm at f1 and f2, respectively.

The receiver performance is shown in Fig. 6. The bit error rate (BER) is plotted against the received power for the f1 carrier at 1.25Gbps data rate. The minimum received power for less than 10^{-9} BER is –46dBm. The eye pattern at –43dBm receiver power is also shown in Fig 6. Good eye opening can be seen.

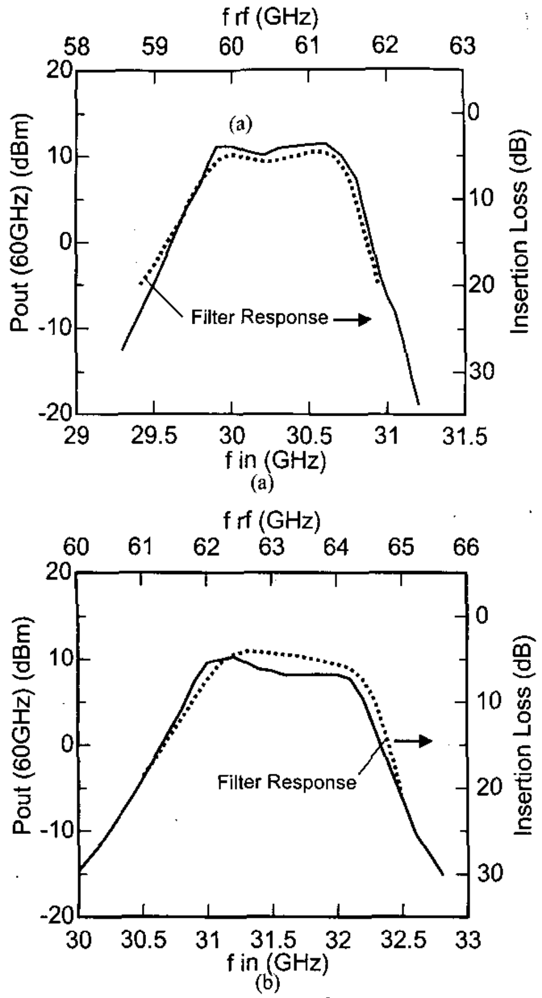

Fig. 5 Frequency response of peak output power for TX MCM. (a) f1 of 60.3GHz, (b) f2 of 63.13GHz.

V. Wireless Gigabit Ethernet Link Performance

Fig. 7 shows a wireless Gigabit Ethernet link photograph. As short range use within 10m, 6x8 array antennas with 10° beam width and 20dBi gain are assembled. 27dBi high gain antennas can also be assembled for longer range. The size is 159x97x44mm^3 and the weight is 300g. The eye pattern of the optical transceiver output (after O/E conversion) for 1.25Gbps received signal at error free transmission is shown in Fig. 8. Fig. 9 shows the transmitter output spectrum for f1 with 1.25Gbps data signal input from a Gigabit Ethernet board in a PC server. The occupied bandwidth defined as 99% power occupancy is 1.6GHz. As high as 1.23Gbps TCP IP throughput has been achieved at 7m wireless transmission, which is the same as that for

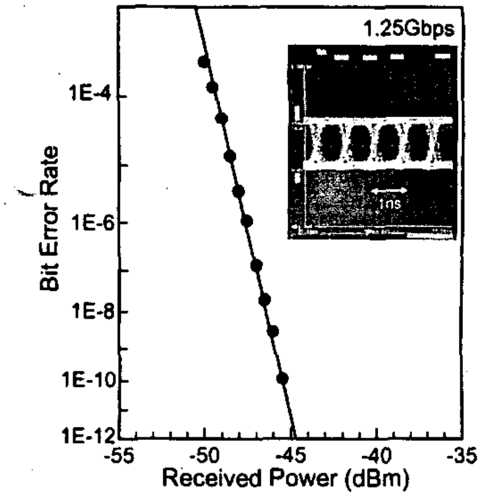

Fig. 6 Bit error rate performance and eye pattern for receiver.

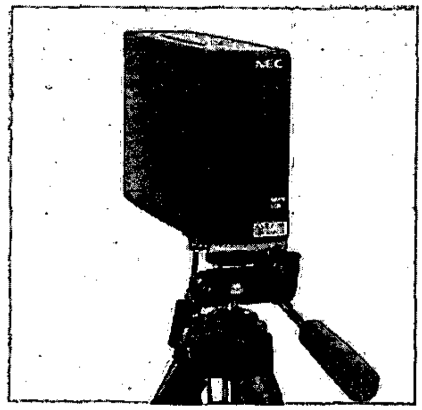

Fig. 7 Wireless Gigabit Ethernet link photograph.

the transmission through directly connected optical fiber. Performance for the wireless Gigabit Ethernet link is summarized in TABLE I, which is conformed to the technical regulation for the 60GHz unlicensed band in Japan.

The wireless Gigabit Ethernet link has advantages over the fiber link, such as instantaneous installation and transparency through the wall except for that made with the metal, suitable for the mass commercial use for the streaming and fast down loading of high definition video files, especially, to movable terminals for trains and cars.

VI. Conclusion

A 1.25Gbps 60GHz-band full duplex wireless Gigabit Ethernet link has been developed. Direct ASK modulation and demodulation scheme is adopted for the 60GHz-band

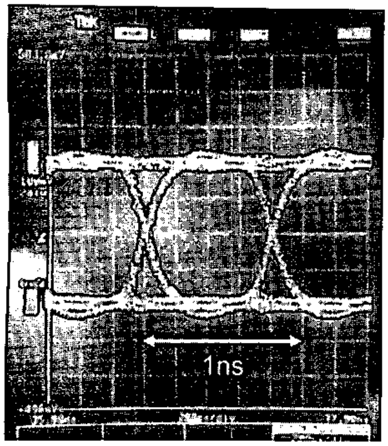

Fig. 8 Eye pattern for optical transceiver output converted from 1.25Gbps demodulated signal of 60GHz-band receiver.

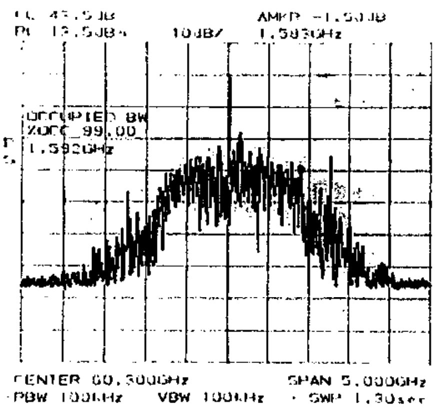

Fig. 9 Transmitter output spectrum for 1.25Gbps data input. (Center : 60.3GHz, Span : 5GHz)

TABLE I

WIRELESS GIGABIT ETHERNET LINK PERFORMANCE.

Carrier Frequency	60.3 / 63.13GHz
Output Power	10.4 / 8.7dBm
Occupied Bandwidth	1.6 / 1.9GHz
Antenna Beam Width	10°
Modulation	ASK (PCM)
Data Rate	1.25Gbps Full Duplex
Data Interface	1000Base-SX (850nm Multi-Mode Fiber)
Power Supply	12V / 3W
Size	159mmx97mmx44mm
Weight	300g

transceiver. A compact transceiv and planar filters, multilayer LTCC MCM's, and antenna/MCM/PWB 3D compact structure. The wireless Gigabit Ethernet link has a function to convert an optical fiber link to a wireless link seamlessly combining a 60GHz-band transceiver with a 1000 Base-SX optical in/out module. High TCP IP throughput of 1.23Gbps has been proven.

ACKNOWLEDGEMENT

The authors wish to acknowledge the support of Drs. H. Shimawaki, M. Kuzuhara, M. Ogawa, Y. Shimada and M. Mizuta, and also to thank M. Shintaku for data transmission evaluation.

REFERENCES

[1] K. Ohata, K. Maruhashi, J. Matsuda, M. Ito, W. Domon, and S. Yamazaki, "A 500Mbps 60GHz-band Transceiver for IEEE 1394 Wireless Home Networks," *30th European Microwave Conf. Proc.*, vol.1, pp.289-292, Oct. 2000.

[2] K. Fujii, M. Adamski, P. Bianco, D. Gunyan, J. Hall, R. Kishimura, C. Lesko, M. Schefer, S. Hessel, H. Morkner, and A. Niedzwiecki, "A 60GHz MMIC Chipset for 1-Gbit/s Wireless Links," *2002 IEEE MTT-S Int. Microwave Symp. Dig.*, pp.1725-1728, June 2002.

[3] K. Maruhashi, M. Ito, L. Desclos, K. Ikuina, N. Senba, N. Takahashi, and K. Ohata, "Low-cost Antenna-integrated 60GHz-band Transmitter/Receiver Modules Utilizing Multi-layer Low-temperature Co-fired Ceramic Technology," *2000 IEEE In't. Solid-State Circuits Conf. Dig.*, pp.324-325, Feb. 2000.

[4] K. Maruhashi, M. Ito, and K. Ohata, "A 60GHz-band Coplanar-MMIC Chipset for 500Mbps ASK Transceivers," *22nd GaAs IC Symp. Dig.*, pp.179-182, Nov. 2000.

[5] K. Maruhashi, M. Ito, K. Ikuina, T. Hashiguchi, J. Matsuda, W. Domon, S. Iwanaga, N. Takahashi, T. Ishihara, Y. Yoshida, I. Izumi, and K. Ohata, "60GHz-Band Flip-Chip MMIC Modules for IEEE1394 Wireless Adapters," *31th European Microwave Conf. Proc.*, Vol.1, pp.407-410, Sept. 2001.

[6] K. Ohata, K. Maruhashi, M. Ito, S.Kishimoto, K. Ikuina, T. Hashiguchi, N. Takahashi, and S. Iwanaga, "Wireless 1.25Gb/s Transceiver Module at 60GHz-Band," *2002 IEEE Int. Solid-State Circuits Conf. Dig.*, pp.298-299, Feb. 2002.

[7] M. Ito, K. Maruhashi, K. Ikuina, T. Hashiguchi, S. Iwanaga, and K. Ohata, "A 60GHz-band Planar Dielectric Waveguide Filter for Flip-chip Modules," *2001 IEEE MTT-S Int. Microwave Symp. Dig.*, pp.1597-1600, May 2001.

[8] M. Ito, K. Maruhashi, K. Ikuina, T. Hashiguchi, S. Iwanaga, and K. Ohata, " 60GHz-band Dielectric Waveguide Filters with Cross-coupling for Flip-chip Modules," *2002 IEEE MTT-S Int. Microwave Symp. Dig.*, pp.1789-1792, June 2002.

[9] H. Mizutani and Y. Takayama, "DC-110 GHz MMIC Traveling Wave Switch," *IEEE Trans. Microwave Theory Tech.*, vol.48, No.5, pp.840-845, May 2000.