60 GHz SHORT RANGE TRANSCEIVERS AND APPLICATIONS FOR MINIMUM DELAY SPREAD LAN

Y. Takimoto, H. Yatsuka, A. Inoue, T. Yokoyama, T. Aoyagi,
K. Ohata, T. Saito, T. Negishi* and N. Okubo**

Advanced Millimeter Wave Technologies Co.
YBP, Hodogaya Yokohama, Japan
*NEC and **Fujitsu

ABSTRACT

The authors describe the design and measured performances of the developed 60 GHz band MMICs, fabricated brass-board models of millimeter-wave application systems such as high and ultra-high speed wireless LAN, wide-band analog signal transmission and low bit-rate contactless ID systems, and the demonstrated performance of the wireless LAN system in a Minimum Delay Spread (MDS) configuration set in our new conceptual propagation test room.

INTRODUCTION

To the exploding demands of the personal and multimedia wireless systems in future, the millimeter-waves are extremely expected to be used widely due to the huge frequency bandwidth. Where, it is also expected that the millimeter-wave MMICs are key devices for realizing high performance, high volume production and low cost.

The authors selected four representative models demonstrating the features of millimeter-waves; such as (a) high speed (10 Mbit/s) wireless LAN, (b) ultra-high speed (100-155 Mbit/s) transceivers, (c) a wide-band analog signal transmission system, and (d) a low bit rate contactless ID system. Those systems are well utilizing the wide-bandwidth, short wavelength, and specific propagation characteristics so that they are capable of providing from low to ultra-high speed data or wide-band analog signal transmission, very compact circuits, high gain and sharp beam antennas suitable for LAN transceivers in a pico-cell zone and reduced multi-reflection realized by Minimum Delay Spread (MDS) configuration[1,2].

Those models are widely employing millimeter-wave MMICs, which have been developed in our laboratories, and have been tested on the basic performances. The LAN transceivers have been additionally subjected to the various radio propagation conditions including the MDS configuration.

In our knowledge, it is the first time to demonstrate the 60 GHz wireless LAN consisting three terminals in the TDMA and CSMA mode, and to demonstrate 100 and 155 Mbit/s data transmission in 60 GHz multi-reflection condition.

SYSTEMS DESIGN

The authors have selected the following four representative systems, for featuring millimeter-wave applications as shown in Table 1:

- 60 GHz high speed wireless LAN compatible with 10 Mbit/s Ethernet signal packets,
- 60 GHz ultra-high speed wireless LAN to be used in the Minimum Delay Spread (MDS) configuration for transmitting 100 through 155 Mbit/s data,
- 60 GHz wide bandwidth analog signal e.g. NTSC/ MUSE(HDTV) transmission system, and
- 60 GHz contactless ID system transmitting low bit rate digital signals.

In designing those systems, varied parameters are allotted to respective system. For example, transmitting signals are 9.8 kbit/s, 10, 100, and 155 Mbit/s digital, and wide-band analog signals; modulation procedures are FSK, FM, AM in 60 GHz, PSK in IF band; antenna beams are shaped beam, narrow/high-gain beam, and wide beam; system connections are one-to-one/one-way and one-to-many/both-way; maximum distances are 160 meter long to 2 meters.

Even though the parameters are widely varied, it is preferable to limit the variation of MMIC functions and performances. Therefore, the four types of models have been designed using eight kinds of MMICs and a few MICs.

The developed MMICs are cited in References [3] and [6-11], and photos of the fabricated four kinds of brass-board models are shown in Figs. 3 through 7.

Table 1 Main Performances of Fabricated Brass-Board Models

BB model	High-speed Wireless LAN Type A	Type B	Ultra-high Speed Wireless LAN Type A	Type B	Wide-Band Analog Signal Trans	Contactless ID Card System
Commu System	TDMA/TDD	Full Duplex/FDD	One Way	One Way	One Way	Half Duplex
Modulation	2-FSK	2-FSK	QPSK(IF)	8-DPSK(IF)	FM	FSK/AM
Trans Sig	10 Mbps	10 Mbps	100 Mbps	155 Mbps	NTSC/MUSE(HDTV)	9 6 kbps
Trans Power	10 dBm	3 dBm	6 dBm	-10 dBm	10 dBm	-3 dBm
Freq (Hub)	59 1 GHz	59 4 GHz	59 9 GHz	59 9 GHz	-	59 5 GHz
(Terminal)	59 5 GHz	59 9 GHz	-	-	59.3 GHz	-
Freq Stability	< 200 ppm	< 100 ppm	< 200 ppm	< 4 ppm	< 200 ppm	-
NF	12 dB	6 dB	12 dB	6 dB	12 dB	-48 dBm (Min Rx. Power)
Ant. Gain(Hub)	0 dBi	5 dBi	0 dBi	0 dBi	8 dBi(Cosecant Square Beam)	19 dBi
(Terminal)	15 dBi	19 dBi	15 dBi	15 dBi	20 dBi	19 dBi

MODULES AND BRASS-BOARD MODELS

We have tried two kinds of module assemblies installing MMICs.

Multi-chip packaging assembles MMICs and connecting microstrip lines on Al_2O_3 substrate into a metal

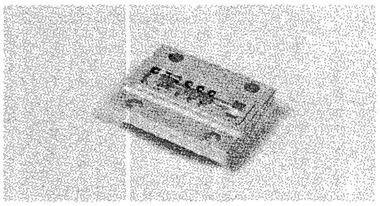
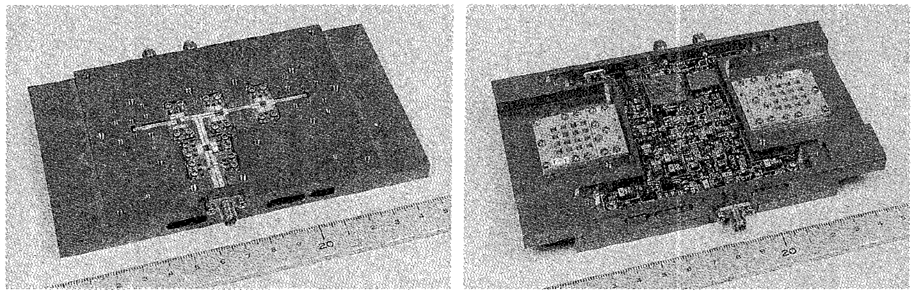


Fig. 1 Multi-chip Packaging



(a) MMICs Mounted Side (b) Antenna and IF Circuit Mounted Side
Fig. 2 Modular Board Module

package of 20.5 x 8.5 x 5 mm^3 as shown in Fig. 1, which have been designed to allow the RF signal to be transmitted through a waveguide mount settled in the back-side of the package. The package can be hermetically shielded for reliability improvement[4].

Modular board modules adopt a mother-board, mounting flat array antennas on one-side, and sub-board assemblies attached with discrete MMIC on the other side as shown in Fig. 2. It features that the performance of every applied MMIC can be assured, because of the in-advance testing. We recognize this modular board as one-step to the flat-antenna-integration with active devices[5].

Using those functional modules, 60 GHz brass-board models have been fabricated.

(1) 10 Mbit/s high-speed wireless LAN transceivers:

For being used in the MDS configuration, the transceivers are designed in a simple configuration not using the space-diversity, diplexer, forward error correction (FEC) codec and adaptive delay equalizer; which configuration will result in low cost.(Fig. 3)

In the transceiver, a 60 GHz VCO MMIC operating as the FM/FSK modulator, power amplifier MMICs, and an image-rejection down-converter MMIC are used. Between the transceiver and a personal computer, there are two kinds of connecting interfaces; one applies a fixed TDMA format containing a hub burst and terminal bursts, the other applies a CSMA/CD scheme in the wireless transmission link. Using those transceivers, the proposed 60 GHz LAN has been successfully demonstrated as transmitting data signals compatible with the 10 Mbit/s Ethernet packets.

(2) 100/155 Mbit/s ultra-high speed transceivers:

In order to evaluate the millimeter-wave transmission characteristics on ultra-high speed data of 100 and 155 Mbit/s, we have fabricated two kinds of 60 GHz Tx and Rx units, where 100 Mbit/s DQPSK (Differential Quadrature Phase Shift Keying) IF modulation and 155 Mbit/s eight-phase DPSK IF modulation are adopted. The basic performances have been taken in loop-back connection with waveguide as shown in Figs. 4 and 5.

We are now testing its propagation error-rate characteristics in the MDS configuration using narrow and wide beam antennas, as well as the 10 Mbit/s transceivers.

(3) Wide-band video transmission system:

We have also fabricated a brass-board model for evaluating the feasibility of wide-band analog transmission in a long range propagation up to 160 meters, as shown in Fig. 6. On the transmission test of CCTV, commercial TV, HDTV-compressed MUSE signals, the effectiveness of the system is confirmed.

(4) Contactless ID system:

As a sample of a low bit rate transmission system, we have fabricated a 60 GHz ID system using a high-gain AM signal demodulating MMIC and narrow beam flat antennas as shown in Fig. 7. This system features low bit rate data of 9.6 Kbit/s, AM/FM double modulation, battery driven transponder, limited target area radiated with narrow beam, and sensing distance of 2.6 meters. The limited target area ID sensing will be the most effective when being applied to the mobile toll gate system, warehouse locating or automatic factory lines, owing to the tolerances to weather and dusty condition.

MINIMUM DELAY SPREAD LAN CONFIGURATION

As shown in Fig. 8, the Minimum Delay Spread (MDS) indoor LAN organizes pico-cell zones of about 10 meter diameter, provided with a hub station antenna attached to the

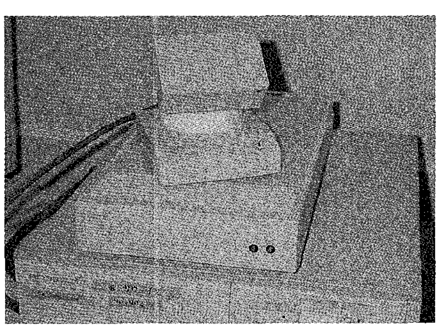


Fig. 3 10 Mbit/s LAN Transceiver

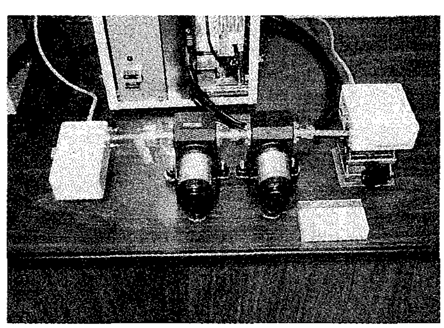


Fig. 4 100 Mbit/s Transceiver

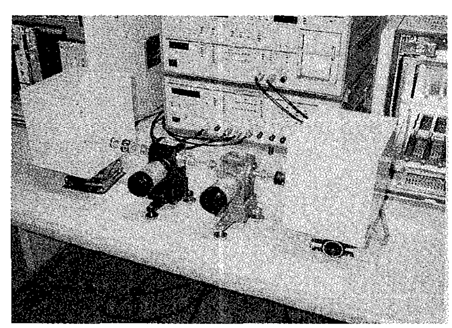


Fig. 5 155 Mbit/s Transceiver

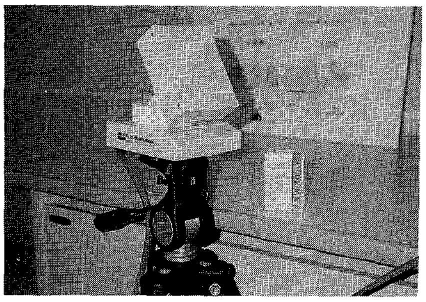


Fig. 6 Wideband Video Transmission System

Fig. 7 Contactless ID System

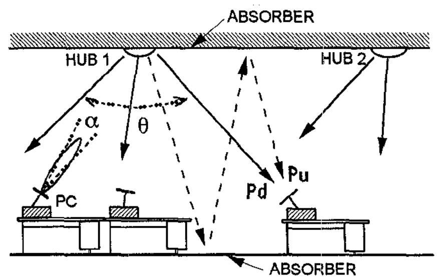


Fig. 8 MDS LAN Configuration

ceiling in the center of the each zone and several wireless subsidiary terminal stations in the zone. The limited use of line-of-sight millimeter-waves, propagating in rather vertical direction, is effective to reduce the shadowing possibility which may be caused by the worker's moving, and to reduce the undesired signal reception. In order to reduce the multi-path interferences, partial usage of radio wave absorber is useful. Our system considerations resulted the absorber area is sufficient to partially cover the ceiling around the hub station antenna, if the system uses directional beam antennas in the subsidiary wireless terminals (Fig. 9).

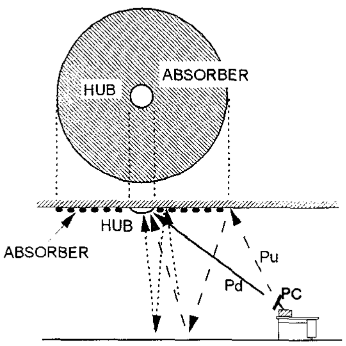


Fig. 9 Effective Usage of Absorber in MDS LAN

This MDS LAN configuration brings a simple terminal circuit, that means frugal reductions of the route diversity, diplexer, adaptive delay equalizer, FEC codec, and brings a low system cost finally; which will accelerate the initial introduction of the millimeter-wave LAN application systems.

PROPAGATION TEST ROOM

We are confirming the effectiveness of the proposed MDS LAN system through the propagation experiment of measuring the multi-path reflected wave power to the line-of-sight signal power in the new conceptual propagation test room of 7.2 x 7.2 x 3.2 m^3 in size, where the reflection loss of ceiling, walls, and floor can be changed in three ways independently, and in board-wise (Fig. 10).

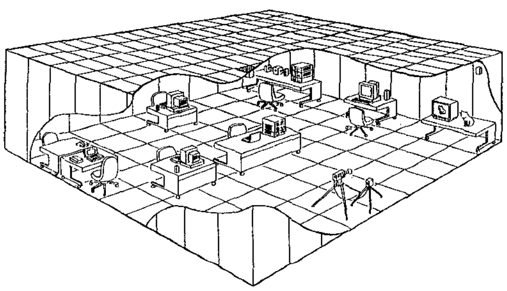


Fig. 10 Propagation Test Room

The ceiling and walls are concealed with panels of 800 x 400 x 5 mm^3 and floor is with panels of 800 x 800 x 10 mm^3, each front side of the panels is pasted with aluminum sheet of 1 millimeter thick (reflection loss is 0 dB), and the back is with a-quarter-wavelength type 1 mm thick absorber sheet (more than 20 dB loss at 60 GHz). When those panels are removed, the original construction materials appear and show respective reflection losses. In this way, the reflection loss of the room can be changed uniformly or partially; 0 dB, 20 dB, and 8 dB, where 8 dB is realized with rock-wool cement board.

PROPAGATION TEST-SET

The propagation evaluation equipment shown in Fig. 11 has measured the three kinds of reflection states of the room using the same kinds of antennas as used in the hub station (0 dBi gain) and in the subsidiary terminal station (15 dBi gain).

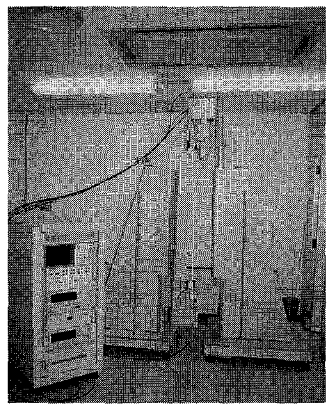
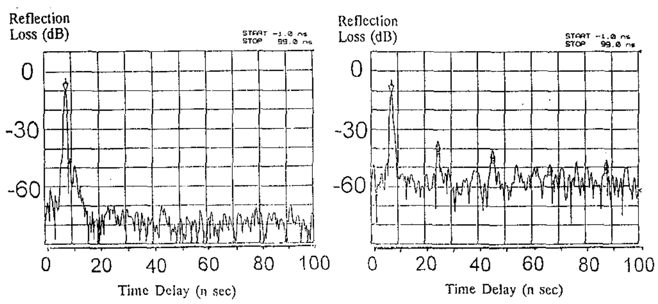


Fig. 11 Propagation Test Equipment

Fig. 12 shows the received level of the multi-reflection signals v.s. the delay time referring to the transmit time of the line-of-sight wave. Well-absorbed room condition shows the line-of-sight wave only can be observed (Fig. 12a), and full reflection room condition shows many reflection waves appear in respective time delay (Fig. 12b).



(a) Well Absorbed Condition (>20 dB)

(b) Full Reflection Condition (0 dB)

Fig. 12 Time Domain Data of Propagation Test Room

Fig. 13 shows the desired line-of-sight signal to the nearest interference signal ratio (D/I) v.s. horizontal distance of the subsidiary terminal from the center of the pico-cell zone, measured in three room conditions where the partial ceiling area around the hub station is covered with absorbers of radius 1.2, 2 and 4.4 meters, and the rest of the ceiling and the whole floor are fully covered with metal plates. The figure shows that sufficient D/I ratio (>30 dB for example) can be obtained within 4.5 meter distance in the cases of using 2 and 4.4 meter absorbers, contrasting that the ratio within 3 meter distance is not more than 30 dB in the full-reflection condition. It also shows that every D/I ratio line in the distant area comes to almost the same level; it is because the discrimination of the interference signal there depends only on the narrow beam characteristics of the terminal antenna. The authors have further analyzed that the depressed part in the middle distance of the 1.2 meter absorber is caused by the gain curve ripples of the hub station antenna, and it can be improved if using a smoother gain curve antenna, such as dielectric lens or Gaussian beam antenna.

This experiment proves the validity of the MDS LAN configuration when it is applied to multi-reflection surroundings, especially.

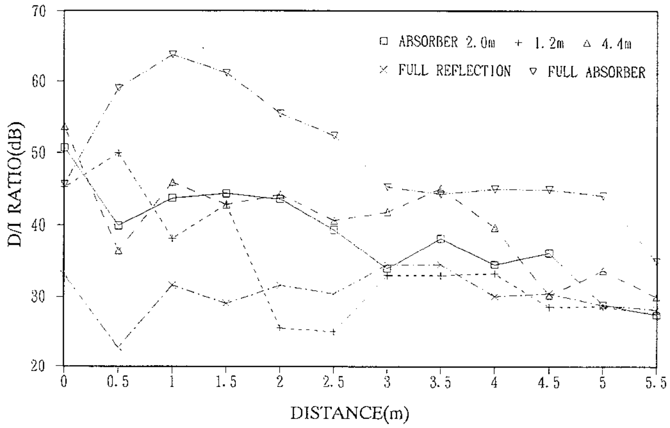


Fig. 13 Desired to Interference Ratio (D/I) v.s. Distance

PROPAGATION TEST WITH 60 GHz LAN SYSTEM

In addition, the authors have subjected high-speed and ultra-high speed 60 GHz LAN transceivers to the propagation experiment to obtain the error rate evaluation in the propagation testing room, too. The room conditions are well absorbed, 8 dB absorbed, and full reflected as shown in Fig. 14.

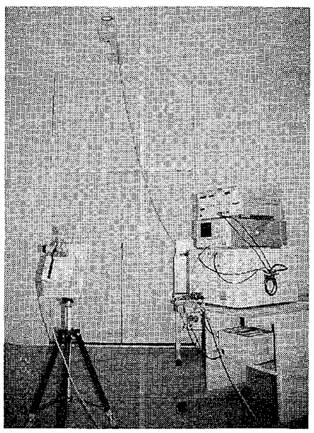


Fig. 14 MDS LAN Simulation using 60 GHz 155 Mbit/s TX and RX

The experiment shows that the 10 Mbit/s LAN system works quite well in the ordinary room condition of about 8 dB reflection and in the well absorbed conditions, and works with small errors in the full-reflection depending on its location.

The 100-155 Mbit/s MDS LAN system will be tested pricisely in the same reflection conditions of 10 Mbit/s transceiver testing.

CONCLUSION

The authors have fabricated and tested 60 GHz short range transceivers for high and ultra-high speed indoor LAN systems, a wide-band analog transmission system and a contactless ID use. The developed MMICs are mounted on two kinds of modules and performed well in the 60 GHz system.

Through the propagation experiment using the test set in the propagation test room, it has been clarified that the MDS configuration is useful to obtain a higher D/I ratio when applied to full-reflection environment, and that a smoother gain curve antenna is required in the indoor LAN system.

The proposed MDS LAN system is expected to be further bit error rate evaluation.

The MDS LAN will be widely used in the initial introduction of the millimeter-wave applications, featuring a simple and low cost transceiver without expensive route diversity, diplexer, and complicated high-speed delay equalizers, in return for pasting radio absorber around hub antennas.

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