INDOOR AND OUTDOOR LINKS USING MILLIMETER-WAVE HIGH-SPEED WIRELESS SYSTEMS

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ABSTRACT

Wideband communications are required for various applications such as high-speed wireless local-area-networks (W-LANs), wireless personal-area-networks (W-PANs) and video transmissions. 60 GHz band is one of possible frequencies for such wider frequency requiring systems. Within this band, various kinds of wireless data transmissions are expected to develop without license.

In this paper we introduce both an Ad hoc wireless access and a vertically-connected wireless link systems we developed, and propose a network architecture by using both millimeter-wave systems, which enables both video and data signal transmissions through broadband wireless connections. Concept, overview and the developed system specifications for a broadcasting signal transmission as well as data transmission are presented.

1. INTRODUCTION

Wideband communications are required for various applications such as high-speed W-LANs as well as W-PANs and video transmissions. 60 GHz band is one of possible frequencies for such wider frequency requiring systems. In Japan, 60 GHz millimeter-wave (mmW) band (59-66 GHz) is used for license-exempt fixed and mobile wireless systems under certain technical requirements. Within this band, various kinds of wireless data transmissions are expected to develop without license.

On a demand for short-range communications with higher data rate, an Ad hoc wireless access system [1, 2] using millimeter-wave for high-speed data transmission has been proposed as a wireless indoor connection offering easy connectivity and network flexibility. To expand the distance of millimeter-wave links as well as overcome blocking and shadowing problems, an access point terminal, as a repeater, is used to connect several mobile terminals in the system.

On the other hand, a vertically-connected wireless link (VCWL) [4-6] has been proposed as a reliable and economical means for wireless outdoor transmission of communication channels and video signals within individual building such as a residential apartment, a hotel, a hospital and a school. The system enables video signal transmissions using broadband wireless connections. Simultaneous data transmission with video signals is possible through the system.

In this paper we propose a network architecture by using the mmW links mentioned above, which enables both video and data signal transmissions using broadband wireless connections. Concept, overview and the developed system specifications for a broadcasting signal transmission as well as data transmission are presented.

2. AD HOC WIRELESS ACCESS SYSTEM

2.1 SYSTEM CONCEPT

Figure 1 shows an example of the system being used in a meeting room and in a house. In the left Figure, each attendee has a notebook PC equipped with the proposed system. Attendees can share the presenter's material on their PCs, and some other information document, which is suddenly introduced, can also be shared by everyone. The slide data is also transmitted to a projector. In the right Figure all equipment such as games machines, wearable display glasses, and TV sets are mutually connectable when this system is used. It is possible not only to share information but also to control this equipment. Other places where this system could be used include a railway station, inside a train or a bus, and a store.

There are two scenarios of wireless links; a link between mobile terminals (MTs) and a link between MTs using access point terminals (APTs).

Link between MTs: The ad hoc system brings together several wireless terminals as they are needed, and they communicate with each other over a temporal network. High-speed data transmission is also offered within a small area. For mmW transmissions, the transmission distance is short because of the low radiated power (10 mW for unlicensed utilization) and high propagation path loss. Multipoint-to-multipoint connections are possible for small area, however, expanding the communication area is conceivable when several networks are connected using multi-hop connection.

Link between MTs using APTs: The drawback using mmW is its short distance of communications. When there are

many MTs and multi-hop connections are available between MTs, long distance connection is possible. The other solution is using APTs. Figure 2 shows an utilization example at exhibition hall, in which MTs are communicating through APTs. In this case APTs work as a repeater. Three small spot-area is connected through three APTs. When APTs are connected to external IP networks, MTs can access the networks using APTs. In this scenario, MTs under the spot-area can communicate each other having longer distance.

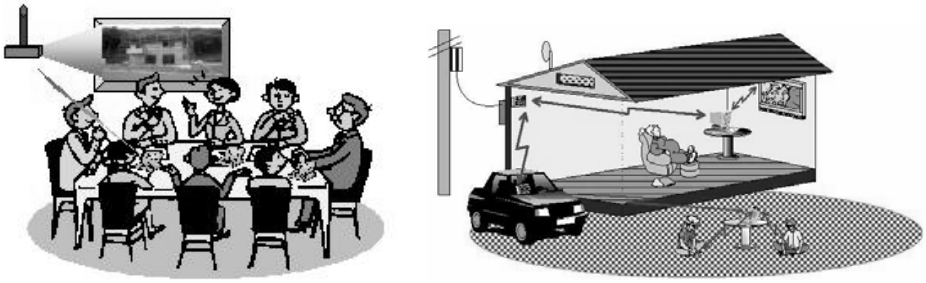

Figure 1 An utilization example in a meeting room (left) and in a house (right).

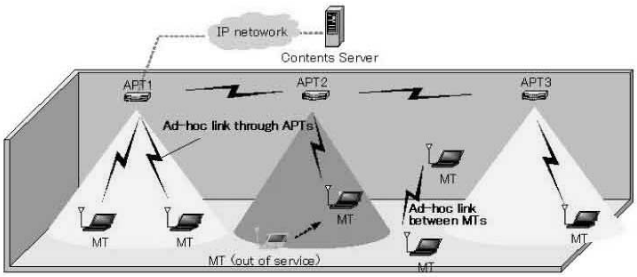

Figure 2 An utilization example at exhibition hall.

2.2 DEVELOPED SYSTEM

To examine the realization of the link using APTs shown in Figure 2, we developed 6 MTs, 3 APTs and two types of modems. Figure 3 (a) and (b) shows photograph of the APT and the RF part of MT, respectively. MMIC-based modules and antennas are equipped into these bodies. A PC and modem set, which is shown in Figure 4(a) and (b), are connected to the RF part of MT. Main specifications for P-to-P link between APTs and for P-to-MP link between APT and MTs are shown in Table 1. As long as the link between MTs (not using APTs) is performed, not only the DQPSK modem but also the OFDM modem can be used selectively. The main specifications of the OFDM modem is shown in the Table.

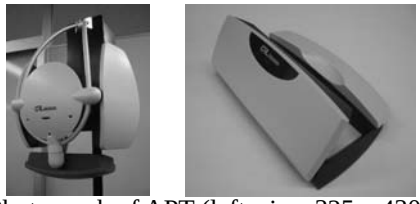

Figure 3(a) Photograph of APT (left, size: 325 x 430 x 161 mm),
and (b) RF part of MT (right, size: 127 x 212 x 38 mm).

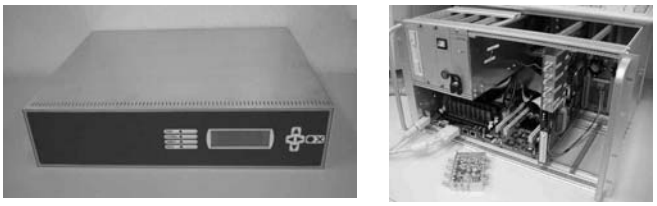

Figure 4(a) 4-multicarrier DQPSK modem (left), and (b) BPSK/QPSK/16QAM-OFDM modem (right).

Table 1 Main specifications of system using multicarrier-DQPSK modem.

	P-P link	P-MP link using DQPSK modem	P-MP link using OFDM modem
RF Frequency	62.9 GHz (APT1-APT2 link) 65.9 GHz (APT2-APT3 link)	73.0 GHz (APT1-MT and APT3-MT links) 73.6 GHz (APT2-MT link)	
Transmision scheme	TDD Self-heterodyne [3]	TDD Self-heterodyne [3]	
Transmission power	1 mW	10 mW	
Antenna gain	23.5 dBi	6, 8.5, 12.5 dBi (selectable)	
Modulation scheme	4-Multicarier DQPSK	4-multicarier DQPSK	BPSK (R=1/2, 3/4), QPSK (R=1/2, 3/4), 8PSK (R=1/2), 16QAM (R=1/2, 3/4) -OFDM (selectable)
Transmission Air Rate	622 Mbps	622 Mbps	271 Mbps @16QAM-OFDM
Protocol	CSMA based	CSMA based	HiperLAN2 based

3. VCWL SYSTEM

Figure 5 (a) shows a concept of a system using VCWL within a residential apartment. This system links the rooftop unit to individual units set up on balconies. Telecommunication signals, provided from other networks such as existing wireless LAN (Ethernet signals), broadband fixed wireless access systems (FWAs), a digital subscriber line (DSL), or satellite media, are input into the transceiver located on the rooftop unit of the building. They are then simply up-converted to mmW band and transmitted over the air to the transceivers set up on the balconies. The transceiver in each unit receives the mmW signals, simply down-convert them to IF signals, and input them into the modem and television set. Since this system does not need any wired connections, such as coaxial cables or optical fibers, it will provide an inexpensive solution to the reception problems encountered by individual apartment unit dwellers, while in general setting up coaxial cables is expensive. Satellite video services such as digital broadcasting provided by broadcasting-satellite (BS) and communications-satellite (CS) can also easily be adapted to VCWL. Figure 5 (b) and Table 2, respectively, shows the developed system and the main specifications for aiming of transmitting BS broadcasting signals. A 23-dBi high-gain antenna is used to expand the distance between Tx and Rx.

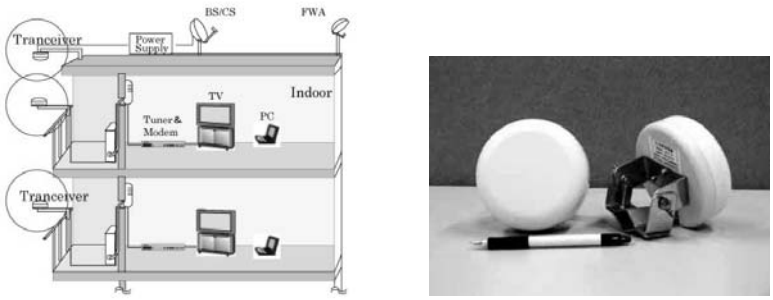

Figure 5 (a) System using VCWL (left), and (b) developed system (right).

Table 2 Main specifications.

RF frequency	60.045-60.345 GHz
Local oscillator	59.010 GHz
IF frequency	1.035-1.335 GHz
Transmit power (at antenna input)	+10 dBm
Antenna gain	23 dBi (Tx, Rx)
Size of Tx (or Rx)	11 cm (as diameter of the shape)
Weight of Tx (or Rx)	600 g (including metal fittings)

4. ARCHETECTURE INVOLVING VCWL AND AD-HOC SYSTEMS

All equipments including PCs, TVs and home electrical appliances can be expected to have a link mutually based on the broadband wireless link. Figure 6 shows the network architecture for a possible connection in a building. The home gateway/server is put into the home, which can change the signal format between outdoor and indoor systems and/or to storage the video images, where TV broadcasting signals are distributed with data signals through VCWL. VCWL is only used for TV viewers. Ad hoc link can also enable direct connection outside the home.

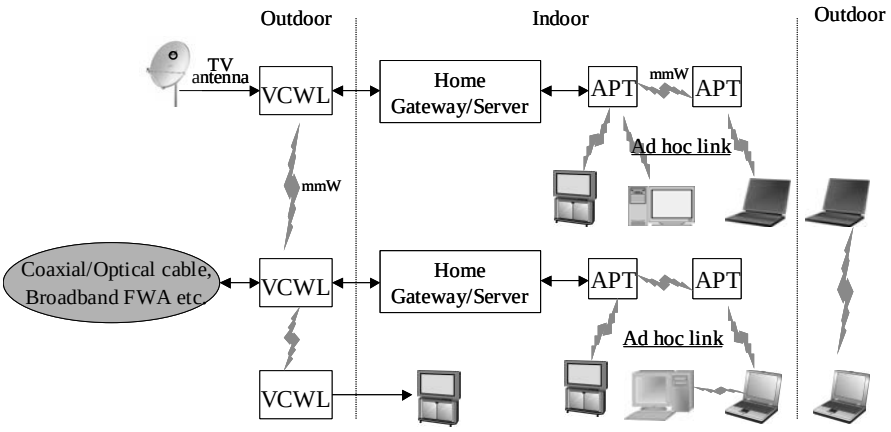

Figure 6 Indoor and outdoor links using VCWL and Ad-hoc systems in a building.

5. CONCLUSIONS

A network architecture using the mmW links has been given after introducing the VCWL and Ad-hoc system we developed, which enables both video and data signal transmissions using broadband wireless connections. The evaluation test of wireless connection for both VCWL and Ad-hoc system has successfully done. The link evaluation by employing whole systems shown in the Figure 5 will be performed in the future.

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