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Massive Multiple Access Wireless LAN Using Ultra-Wideband Waveguide Floor Tiles

Akihito Noda, Akimasa Okada, Yudai Fukui, Yuichi Masuda and Hiroyuki Shinoda
Graduate School of Frontier Sciences, The University of Tokyo
5-1-5 Kashiwanoha, Kashiwa-shi, Chiba 277-8561
Email: Akihito_Noda@ipc.i.u-tokyo.ac.jp, {okada, fukui, masuda}@hapis.k.u-tokyo.ac.jp, hiroyuki_shinoda@k.u-tokyo.ac.jp

***Abstract*—The unlicensed band for ultra-wideband (UWB) radio systems, 3.1–10.6 GHz, is an attractive frequency resource for indoor high-speed wireless communications. Recently we have proposed a scheme to use the UWB's frequency range for wireless local area networks (WLANs) using off-the-shelf 2.4-GHz WLAN devices and dedicated frequency converters. The signals converted into the UWB's frequency range are transferred through special floor tiles that guide microwaves with low loss. This demo shows a prototype system consisting of the frequency converters and two-dimensional communication (2DC) tiles.**

I. Introduction

Wireless communication is recently used as the only means to connect smartphones and tablet PCs to a local area network (LAN), as well as the primary means to connect laptop PCs to a LAN. Emerging technologies such as the Internet of things (IoT) and machine-to-machine (M2M) communications will accelerate the demand for broadband wireless connections.

The unlicensed band for ultra-wideband (UWB) radio systems, 3.1–10.6 GHz [1], is an attractive frequency resource for indoor high-speed wireless communications. The most significant problem with the UWB is the restriction of extremely low power, -41.3 dBm/MHz in terms of equivalent isotropically radiated power (EIRP). This is 50-dB lower than that of conventional wireless LAN (WLAN) devices.

As suggested in our previous works [2], [3], two-dimensional communication (2DC) technology [4] is effective for transferring the low power UWB signals with low loss. A 2DC system as large as an entire room's floor can be constructed with multiple small (e.g., 50-cm square) 2DC tiles.

A concept of using the UWB's frequency range as an alternative spectral resource for conventional WLANs has been proposed in [3]. In the system, an adapter attached to an ordinary 2.4-GHz WLAN device converts the 2.4-GHz signals into another higher frequency in the UWB's band.

Conceptually, the upconverted frequency can be arbitrarily chosen from the frequency range of UWB radio, 3.1–10.6 GHz. Assuming 20-MHz bandwidth for each WLAN channel, 375 channels can be allocated without interference in this frequency range, and a massive multiple access WLAN system will be achieved.

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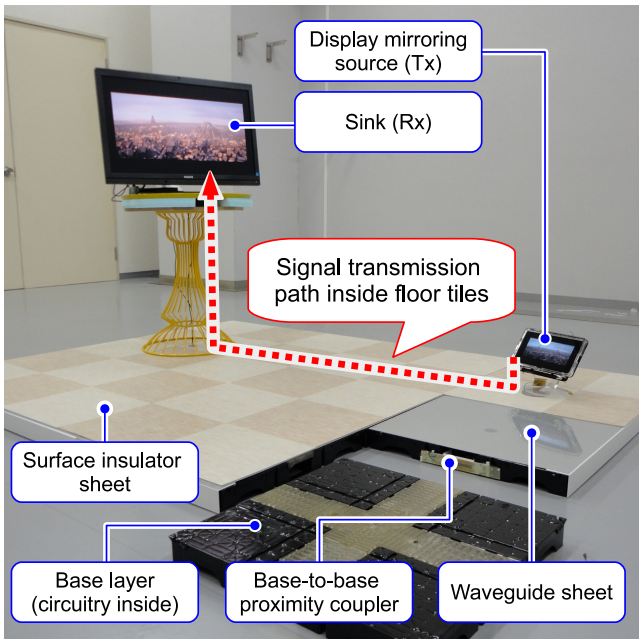

Fig. 1: UWB 2DC through multiple waveguide floor tiles. Wireless display mirroring (high-resolution movie streaming) between a tablet PC and a large desktop monitor is performed through the 2DC system. A waveguide sheet is also embedded on the desktop. Between a proximity coupler on the tile surface and the desktop waveguide sheet is connected with a coaxial cable.

In this demo, we present an actual implementation example of the concept. Some bulky components used in [3] are integrated into a compact circuit board. We also present some applications including high-resolution video streaming through the system, as shown in Fig. 1.

II. Demo System

A. Active Tile 2DC

In the demo system, UWB signals are transferred through the 2DC tiles while microwave emission outside the tiles is suppressed. For proximity (non-contact) coupling between the tile and the WLAN device on the tile, a UWB 2DC coupler [5] is used.

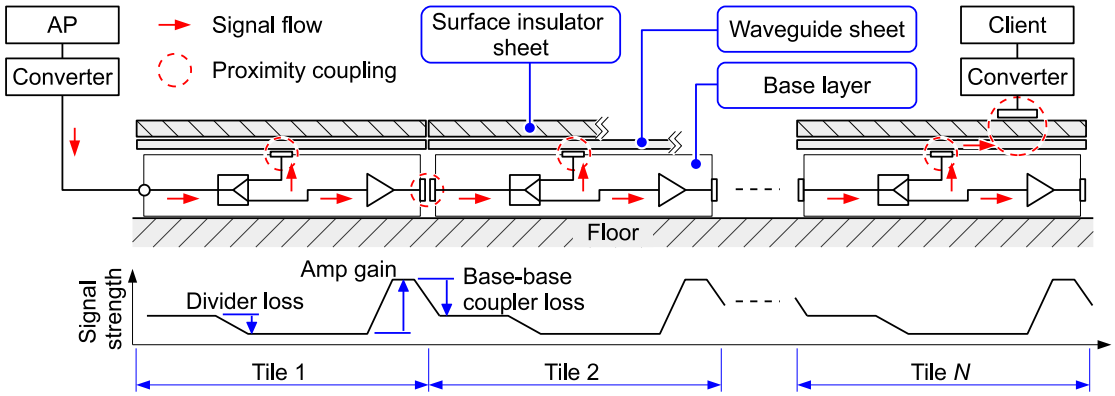

Fig. 2: Schematic diagram of signal distribution system in active-tile 2DC. Only the broadcasting signal paths from the access point (AP) at the left-hand side end are shown. Using dedicated converters, off-the-shelf 2.4-GHz WLAN AP and client can be connected through the system. The signal strength transition in the base layers is also shown.

A schematic diagram of the demo system is shown in Fig. 2. Although only the downlink (broadcasting) path from an access point (AP) to a client is shown in the figure, actually the uplink path separated from the downlink is also implemented. The uplink and downlink are separated by direction-dependent frequency shift (DDFS) [6], i.e., different two frequencies are used for the uplink and the downlink, to avoid oscillating positive feedback loops while using amplifiers in the paths.

The signal strength transition in the system is also shown in Fig. 2. For better scalability of the system, the amplifiers compensate the signal attenuation due to the dividers and to the proximity couplers connecting adjacent tiles. The proximity coupler [7] is used in order to reduce the additional workload of 2DC floor tiles installation compared with conventional raised floor panels.

The system also support ad-hoc communication as well as the communication between the AP and the client. Since the upconverted frequency used in an ad-hoc pair can be chosen to avoid interference with other ad-hoc pairs, massive multiple access WLAN system can be realized.

B. 2.4-GHz-UWB Converter

The 2DC tile system is designed to operate in the UWB frequency range. An adapter device converts signal between the 2.4-GHz original WLAN frequency and UWB's frequency.

For the demo system, the converter device is developed based on the circuit proposed in [6]. At the AP-side, in the transmitting operation, the 2.4-GHz WLAN signal is upconverted into 8.4 GHz, and transmitted into the 2DC tile system. At the client-side, the 8.4-GHz signal is picked up from the tile and downconverted into the 2.4-GHz original signal. On the other hand, when the client transmits the signal, the 2.4-GHz signal is upconverted into 7.4 GHz, and the 7.4-GHz signal received at the AP-side is downconverted into 2.4 GHz. These frequency conversions are performed by the converters. Attenuating the transmitted signal to meet the UWB spectral mask and amplifying the received signal to avoid further degradation in signal-to-noise ratio (SNR) are also done in the converter.

III. Conclusion and Prospects

In this work, we have developed UWB 2DC floor tiles and adapter devices for a massive multiple access WLAN system. The 2DC tiles can be installed without significant increase in installation workload compared with ordinary raised floor panels, and the adapter circuit can be integrated into a tiny module board. By choosing the upconverted frequency appropriately from the UWB's frequency range, more than 300 channels can be allocated for the WLAN system without interference, assuming 20-MHz bandwidth for each channel. This massive multiple access WLAN system should be used by devices that are touching the floor or other surfaces where 2DC tiles can be embedded. Even moving devices such as cleaner robots can communicate through the 2DC tiles. By confining the WLAN signals from these devices into the 2DC tiles, the aerial WLAN bandwidth available for other devices that really need the aerial connection will be increased.

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