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C1. Ultra high definition digital television broadcasting

The research and development activities in the next-generation ultra-high definition digital television (UHDTV) broadcasting are carried out by many industries and research institutes [Murayama, 2012][Nakamura, 2016]. The parameters for UHDTV have been defined in ITU-R BT.2020-2 [ITU-R, 2015]. The number of pixels is 7680×4320 in 8K UHDTV, which is 16 times larger than that of current HDTV. High dynamic range (HDR) television system has been considered to improve the image quality. The quantization levels for HDR is increasing to10-12 bits from 8 bits in the current HDTV [Borer, 2015]. The required bit rate to accommodate UHDTV exceeds 300Mbps if the video codec for the current HDTV system is used. In contrast, the frequency bandwidth for television broadcasting service is strictly limited. In the terrestrial television broadcasting in Japan, the frequency bandwidth available for one program is the only 6 MHz. We need more efficient video encoding and digital transmission techniques for establishing UHDTV.

HEVC/H.265 standard [ISO/IEC, 2015-3][ITU-T, 2016] has been employed for the advanced satellite broadcasting system [ARIB, 2014], whose test services has already been started in 2016. The more efficient video encoding scheme using adaptive use of super-resolution technique has been proposed for the terrestrial broadcasting system [Matsuo, 2015]. The future video coding scheme will be standardized in 2020. Using the sophisticated video coding schemes, the required bitrate for 8K UHDTV can be reduced to 50-70 Mbps.

In addition to the development of the efficient video encoding techniques, we require the high frequency utilization efficiency digital transmission techniques. The digital video broadcasting for the second generation terrestrial (DVB-T2) [DVB, 2015] employs Multiple Input Single Output (MISO) transmission based on Alamouti's space-time block code (STBC). The bit rate is up to 50 Mbps at the frequency bandwidth of 8 MHz. To further improve the frequency efficiency, the use of Multiple-Input Multiple-Output (MIMO) techniques has been considered. NHK has proposed 2×2 MIMO broadcasting using horizontal and vertical polarization antennae. As a modulation format, up to 4096-level QAM (Quadrature Amplitude Modulation) is employed. The concatenated use of LDPC (Low-Density Parity Check) code and BCH code, it can successfully reduce the required Carrier to Noise Power Ratio (CNR). The available bit rate of the proposed MIMO broadcasting system is up to 90 Mbps [Nakamura , 2016].

Alongside the video coding and digital transmission technologies, the layered division multiplex (LDM) technique has been proposed for achieving multiple services at the same frequency channel with different robustness [Zhang, 2016][Wu, 2012]. It provides flexible and efficient use of the spectrum and backward compatibility property.

(M. Okada)

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C2. Wireless Local Area Network (WLAN)

During November 2013-October 2016, one of the significant topics in WLAN related issues was the release of the IEEE 802.11ac standard. The number of wireless LAN devices with multi-user MIMO increased [Asai, 2014]. Although 802.11ad with high-throughput ability was also released, the number of devices conforming to the standard has been relatively small. One of the reasons for this is the connection distance. Improving the performance and extending the coverage of the system in the millimeter-wave band are important issues for achieving the broad-band internet connection anytime and everywhere [Sakaguchi, 2015]. Much research work has been conducted including in the areas of diversity connection [Nagayama, 2016] and beamforming [Takinami, 2016].

Radio-on-Fiber (RoF) is used for broadcasting repeater systems as a gap-filler in the UHF band. It can adopt to OFDM based systems [Yu, 2014], and is an excellent technique to enhance the coverage. A RoF system can form a linear-cell where many transmitters are placed along the fiber cable. It is also suitable as a wireless communication system in transportation systems [Dat, 2016]. Research work for the linear cell using a leaky coaxial cable with MIMO were also conducted to enhance the capacity and to achieve reliable connection [Hou, 2015].

Positioning is another research topic. Since a lot of access points are already placed, WLAN is a good infrastructure for positioning [Huang, 2016]. It is especially important in indoor environments where signals from global positioning system (GPS) satellite cannot be received [Yamamoto, 2015]. The position information can help with joining and seamless handover to the 60 GHz WLAN cell.

(S. Tsukamoto)

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C3. Microwave Passive Circuits

In relation to the development of recent wireless communication systems such as IoT (Internet of Things), M2M (Machine to Machine), and 5G (5th Generation), microwave passive circuits with high performance such as small-size, low-loss, wideband/multi-wand, and tunable are strongly required. Several approaches and new design techniques are currently investigated for their development purposes.

Novel directional couplers with waveguide- [Ishibashi, 2015][Kim, 2016] and planar-type [Abe, 2016], and their applications have been reported. Microwave power dividers have been also developed by using lumped-element circuits [Okada, 2015, 2016], a planar structure [Wang, 2015], and the power combiner with MS line input and waveguide output has been developed [Ravindra, 2015]. The reversed-phase coupler with a very loose coupling can be obtained [Matsuda, 2016] using parallel ring-lines. Moreover, several planar filters and resonators have been developed for millimeter-wave and THz applications [Shimizu, 2015][Chen, 2015, 2016], chipless RFID tags [Sakai, 2016], and base stations [Ishizaki, 2015], and several types of BPF and design methods have been reported [Tamura, 2016][Ohira, 2015, 2016]. Furthermore, tunable filters [Motoi, 2016][Wada, 2016] and the triplexer [Tani, 2016] based on BPFs have been also reported.

Several SIW (Substrate Integrated Waveguide) components such as microstrip line-waveguide transition [Uemichi, 2016], E-band filter [Kiumarsi, 2015], 60GHz band BPF [Uemichi, 2015][Dong, 2016] have been proposed. These circuits are useful for millimeter-wave and more high frequency regions. Multi-layer and LTCC circuit components and their design methods have been also developed [Michishita, 2015][Tajima, 2016].

Moreover, study and development of metamaterials including CRLH transmission lines have been actively performed in these years. Several applications using the negative order resonance of CRLH stub lines have been reported [Tanaka, 2015, 2016], and its application to antenna system has been developed [Michishita, 2015][Ueda, 2016][Nagayama, 2016].

(T. Kawai)

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C4. Wireless Interconnection for Microelectronics

The increase in capacity of wireless communication has been remarkable in recent years. To meet these demands, various technologies such as massive MIMO technologies [Lu, 2014] and short range MIMO technologies [Nishimori, 2011] [Hiraga, 2012] have been researched and developed. The orbital angular momentum (OAM) multiplexing is one of the most promising technologies. [Mahmouli, 2013] demonstrates transmission of 4-Gbps uncompressed video using OAM wireless channel in 2013. [Yan, 2015] reports on an experimental measurement and analysis of multipath-induced channel crosstalk effects in a mm-wave communications link using OAM at 28 GHz in 2015. [Yan, 2016] reports an experimental demonstration of a 32-Gbps wireless link using OAM and polarization multiplexing with spiral phase plates in 2016.

[Cagliero, 2016] proposes a new general concept, the "OAM-link pattern," which takes into account the peculiar phase structure characterizing these waves in 2016. [Tian, 2016] propose three practical methods for beam axis detection and alignment, that is, double parallelogram array method, double UCA method and single UCA method. D. Lee, et al. present a simple but practical Rx antenna design method. Exploiting the fact that there are specific location sets with phase differences of 90 or 180 degrees, the method allows each OAM mode to be received at its high SNR region. D. Lee, et al. also introduce two methods to address the Rx SNR reduction issue by exploiting the property of a Gaussian beam generated by multiple uniform circular arrays and by using a dielectric lens antenna.

(Y. Yamaguchi)

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C5. Measurement Methods for Small Antennas

Measurement cables connected to small antennas for measurements sometimes cause significant error. The influences of cables should be paid attention to carefully especially in case sizes of antennas or housings on which antennas mounted are small. This report shows analysis method which can analyze the influence of measurement cables and methods how to reduce the influences.

(1) Analysis method related to influences of measurement cables

Though it is well known fact that cables connected to antennas or housings to measure antenna characteristics sometimes cause errors, methods how to evaluate the significances of the errors has not been developed. Power radiated from an essential antenna, which means an antenna in condition without measurement cable, is fed by balanced mode on the measurement cable. On the other hand, unwanted radiation power caused by connecting measurement cable is fed by unbalanced mode on the measurement cable. The significance of the influence of the measurement cable can be described by the ratio of the balanced and unbalanced modal conductances. Recently, modal analysis method for a small antenna has been proposed [Yanagi, 2016] which can also be applied to investigate the significance of the influence of measurement cable. S-parameter method is applied to extract balanced and unbalanced conductances from antenna impedance with measurement cable. The modal power radiated from antenna with measurement cable connected can be analyzed by the modal ratio of balanced and unbalanced conductances [Yanagi , 2016].

(2) Measurement methods: S-parameter method

S-parameter method is one of the effective methods to reduce the influence of measurement cables. Two ports of a network analyzer are connected signal line and ground of an antenna. Balanced mode impedance which is equivalent to essential antenna impedance without cable can be extracted numerically from full-2-port S parameters. This method can reduce the influence of measurement cable significantly. The method can be applied not only for impedance measurement but also for radiation measurement. Other tips to improve measurement accuracy together with basis of the method are summarized in [Sasamori, 2014].

(3) Measurement methods: Utilizing Fiber Optics

Application of fiber optics, instead of coaxial cable, to feed antenna can remove almost completely the influence of the measurement cable. However, it requires additional equipment which transform optical to RF (or RF to optical) signal. The equipment causes error because it is usually made of metal [Yamaura, 2015]. The smaller size of the converter is important to improve measurement accuracy. In the article [Yamaura, 2015], combination of PV module to supply DC current and smaller PD module as converter has been proposed. Total size of measurement equipment is reduced to 15*10mm and accurate measurement has been conducted.

Measurement system utilizing fiber-optics has also been applied to measure a small antenna on a housing 3-dimensionally [Nguyen, 2014]. Further, RF signal source for propagation characteristics measurement inside closed space has also been fed by fiber-optics to reduce influence of metallic cables [Yanagi, 2014].

(T. Fukasawa)

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C6. 300-GHz-Band Wireless Links

A terahertz (THz) transmitter capable of transmitting digital data at a rate exceeding 100 gigabits (= 0.1 terabit) per second over a single channel using the 300-GHz band has been developed. This technology enables data rates 10 times or more faster than that offered by the fifth-generation mobile networks (5G), expected to appear around 2020.

The THz band is a new and vast frequency resource expected to be used for future ultrahigh-speed wireless communications. The research group has developed a transmitter that achieves a communication speed of 105 gigabits per second using the frequency range from 290 GHz to 315 GHz. This range of frequencies are currently unallocated but fall within the frequency range from 275 GHz to 450 GHz, whose usage is to be discussed at the World Radiocommunication Conference (WRC) 2019 under the International Telecommunication Union Radiocommunication Section (ITU-R).

In 2016, the speed of a wireless link in the 300-GHz band was demonstrated with great enhancement by using quadrature amplitude modulation (QAM) [Katayama, 2016]. In 2017, six times higher per-channel data rate was shown, exceeding 100 gigabits per second for the first time as an integrated-circuit-based transmitter. At this data rate, the whole content on a DVD (digital versatile disk) can be transferred in a fraction of a second.

A transmitter with 10 times higher transmission power than the previous version's were developed, which made the per-channel data rate above 100 Gbit/s at 300 GHz possible. We usually talk about wireless data rates in megabits per second or gigabits per second. But we are now approaching terabits per second using a plain simple single communication channel. Fiber optics realized ultrahigh-speed wired links, and wireless links have been left far behind. Terahertz could offer ultrahigh-speed links to satellites as well, which can only be wireless. That could, in turn, significantly boost in-flight network connection speeds, for example. Other possible applications include fast download from contents servers to mobile devices and ultrafast wireless links between base stations.

Another, completely new possibility offered by terahertz wireless is high-data-rate minimum-latency communications. Optical fibers are made of glass and the speed of light slows down in fibers. That makes fiber optics inadequate for applications requiring real-time responses. Today, you must make a choice between 'high data rate' (fiber optics) and 'minimum latency' (microwave links). You can't have them both. But with terahertz wireless, we could have light-speed minimum-latency links supporting fiber-optic data rates.

(M. Fujishima)

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C7. Terahertz Technology

In this period, terahertz bands have been attracting great interest for high throughput wireless communication systems such as FMCW RADAR, phase imaging, nondestructive material characterization and spectroscopy. In order to realize these systems, RF transceiver LSIs based on InP based HBT [Song, 2014], Si CMOS

[Katayama, 2016] and SiGe BiCMOS [Sarmah, 2016] technologies have been reported. Especially, transceiver LSIs using Si CMOS technologies have been demonstrated for high data rate communications [Wang, 2014], [Kang, 2014], and FMCW RADAR [Jaeschke, 2014], and spectroscopy [Han, 2013]. Thus, it is expected that Si CMOS technologies are formidable cost effective solutions to the III-V compound semiconductor ones.

Vector modulation methods are widely employed such as QPSK [Song, 2014], 32QAM [Katayama, 2016] and 64QAM [Takano, 2016] to increase the data rate.

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