東北大学 電気通信研究所

研究室外部評価資料

(2013 年度-2018 年度)

Activity Report of Research Laboratory for External Review

April 2013 - March 2019
(FY.2013-2018)

Research Institute of Electrical Communication

Tohoku University

先端ワイヤレス通信技術研究室

Advanced Wireless Information Technology

A. 研究室名 / Research Laboratory

先端ワイヤレス通信技術研究室
Advanced Wireless Information Technology

B. 構成員 / Faculty and Research Staff (as of May 1, 2019)

教授 / Professor	
氏名 Name	末松 憲治 Noriharu Suematsu
分野名 Research Field	先端ワイヤレス通信技術研究分野 Advanced Wireless Information Technology
准教授 / Associate Professor	
氏名 Name	亀田 卓 Suguru Kameda
分野名 Research Field	先端ワイヤレスネットワーク技術研究分野 Advanced Wireless Network Technology
助教 / Assistant Professor	
氏名 / Name	本良 瑞樹 / Mizuki Motoyoshi (April 2014 -)

C. 研究目的 / Research Purpose

本研究室では地上系・衛星系を統合した高度情報ネットワークの実現を目指して，高信頼かつ電力消費の少ない先端ワイヤレス通信技術（Advanced Wireless IT）に関する研究を，信号処理回路・デバイス・実装技術から変復調・ネットワーク技術に至るまで，一貫して研究・開発を行っている．

Toward the realization of a ubiquitous and broad-band wireless network, we are actively engaged in the research work on dependable and low power consumption advanced wireless IT. We cover the whole technical fields from the lower to higher layers, i.e., signal processing, RF/Mixed signal device, antenna, MODEM and network technologies.

D. 主な研究テーマ / Research Topics

1. マルチワイヤレス通信システム用 1 チップ送受信機の研究
2. ディジタル RF 送受信機の研究
3. ミリ波，サブミリ波ビームフォーミングアンテナ・デバイスの研究
4. 体内通信用無線システム・デバイスの研究
5. 準天頂衛星を用いたロケーション・ショートメッセージ通信の研究
6. 地上系／衛星系統合ワイヤレス通信ネットワークの研究
7. 広帯域ワイヤレス通信用ディジタル信号処理の研究

1. 1-chip transceiver for heterogeneous wireless communication
2. Digital RF transceiver
3. Millimeter wave and submillimeter wave beamforming antenna and device
4. Wireless systems and devices for in-vivo communication
5. Location and short message communication using quasi-zenith satellite system
6. Terrestrial and satellite integrated wireless communication network
7. Digital signal processing for broadband wireless communication

E. 学術論文等の編数 / The Number of Research Papers

	2013	2014	2015	2016	2017	2018	Total
(1) 査読付学術論文 Refereed journal papers	3	2	5	1	2	8	21
(2) 原著論文と同等に扱う 査読付国際会議発表論文 Full papers in refereed conference proceedings equivalent to journal papers	0	0	0	0	0	0	0
(3) 査読付国際会議 Papers in refereed conference proceedings	14	12	11	12	9	9	67
(4) 査読なし国際会議・シンポジウム等 Papers in conference proceedings	1	2	0	3	3	3	12
(5) 総説・解説 Review articles	3	0	2	0	1	0	6
(6) 査読付国内会議 Refereed proceedings in domestic conferences	0	0	0	0	0	0	0
(7) 査読なし国内研究会・講演会 Proceedings in domestic conferences	48	31	27	34	31	28	199
(8) 著書 Books	0	0	0	0	0	3	3
(9) 特許 (成立/出願) Patents (Establishment / Publication before examination)	2/3	0/2	4/1	4/3	3/0	2/1	15 /10
(10) 招待講演 Invited Talks	6	5	4	1	2	7	25

F. 特筆すべき研究成果 / Significant Research Achievements (FY.2013-2018)

See Ref. 1. "#" mark indicates research carried out at a former organization.

2013-2018 年度の研究成果（論文・特許など）のうち，前半（2013-2015 年度）と後半（2016-2018 年度）それぞれで代表的な数件（2-3 件程度ずつ）について，参考資料を引用して，その特徴と学術的意義などを簡単に紹介する．英文のみ，もしくは和文と英文で記載．要約は 300 字程度．論文誌の要約/Abstract のコピー可．学術面での国際的インパクトならびに社会的影響を 100 字程度で記載．
必ずしも当該期間内に発表・出版したものに限るのではなく，例えば過去に発表したものでもこの期間内に成果が得られたり，評価されるようになったりしたものも含むものとする．
インパクトファクターや被引用件数など，できる限り第三者が定量的に評価できる指標を用いてアピールすること．それらの指標にはそぐわない場合には，その事情とそれに変わる適当な評価指標・尺度を示すこと．

[2013-2015]

1. S. Yoshida, Y. Suzuki, T. T. Ta, S. Kameda, N. Suematsu, T. Takagi, K. Tsubouchi, "A 60-GHz Band Planar Dipole Array Antenna Using 3-D SiP Structure in Small Wireless Terminals for Beamforming Applications," IEEE Trans. Antennas Prop., vol.61, no.7, pp.3502-3510, July 2013. [IF: 4.435 (JCR, 2018)], [Times Cited: 14 (Web of Science)]

Abstract: 60-GHz band planar dipole array antenna structure in a small wireless terminal is proposed for wide coverage area beamforming applications. Several substrates are stacked vertically by using 3-D system-in-package (SiP) technology, and the element antenna is installed on the substrates. A planar dipole antenna is used as an element antenna because it has a wider bandwidth than conventional patch antennas, which are widely used in 60-GHz band beamforming applications. Conventional dipole array antennas have a 1-D structure, or a 2-D structure arranged in multilayered substrate, resulting in narrow beamforming coverage area. The proposed structure has a wide beamforming coverage area because of the wide antenna spacing around 1/2 wavelength. Design using numerical and 3-D electromagnetic field simulation indicates that a 4x2 arrangement is a feasible structure for a small wireless terminal with wide coverage area. Measurement results show that the designed array antenna has a wide coverage area, covering 75deg. and 95 deg. in the theta and phi directions, respectively, with gain exceeding 10 dBi. The proposed planar dipole array structure using 3-D SiP technology is feasible as a 60-GHz band 2-D beamforming antenna in small wireless terminals.

International impact on both academic and social aspects : This work is a part (antenna / module part) of "millimeter wave and submillimeter wave beamforming antenna and device." This is one of the pioneer works which showed the feasibility of low cost millimeter-wave phased array antenna transceiver module. Following this work, millimeter-wave 2-D type array antenna module has been developed and becomes popular as collision anti-collision RADAR for automobile, but it is still expensive for broad-band wireless communication. From 2020, 28GHz-band 2-D antenna module will be applied to mobile handsets for 5G wireless communication. Our proposed antenna module configuration has been focused not only in domestic conference but in international conferences, such as EuMC2011 (invited), IEEE EDAPS2011 (invited) and IJST2013(invited).

2. T. T. Ta, S. Tanifuji, A. Taira, S. Kameda, N. Suematsu, T. Takagi, K. Tsubouchi, "A Millimeter-Wave WPAN Adaptive Phased Array Control Method Using Low-Frequency Part of Signal for Self-Directed System," IEEE Trans. Microw. Theory Techn., vol.63, no.8, pp.2682-2691, August 2015. [IF: 3.756 (JCR, 2018)], [Times Cited: 1 (Web of Science)]

Abstract: In this paper, we propose a self-directed adaptive phased array control method using the low-frequency part of the signal for a millimeter-wave wireless personal area network, which can reduce the hardware requirement and power consumption compared with those of the conventional digital beamforming method. The

signal from each element antenna of the antenna array is phase shifted and down converted to the baseband and then divided into two paths. The first paths are low-pass filtered to extract the low-frequency part of the signals for beamforming control. The second paths from all antennas are combined in-phase in an analog domain and then sampled by two high-speed A/D converters for demodulation. A beamforming algorithm using the sampled low-frequency part of the signal is also proposed. The beamforming calculation time is established as a function of the signal-to-noise ratio, the bandwidth of the low-frequency part, and the required phase control accuracy. The calculated values match the measured results. Using the IEEE 802.15.3c specifications with an eight-element array antenna, the calculation time is less than 5 s for initial beam establishment and less than 30 s for beam tracking. Therefore, high-speed beamforming is possible while reducing the power consumption.

International impact on both academic and social aspects: This work is another part (beamforming and device (IC) part) of "millimeter wave and submillimeter wave beamforming antenna and device." The developed beamforming / beam-control architecture and related RFIC core circuit technology were transferred to Japanese industries.

[2016-2018]

1. K. Akimoto, S. Kameda, N. Suematsu, "Optimum Allocation Scheme for User Fairness of Location-Based Virtual Sector Method Solving Hidden Terminal Problem in WLAN," IEEE Trans. Veh. Tech., vol. 67 no.9, pp.8363-8371, Sept. 2018. [IF: 5.339 (JCR, 2018)], [Times Cited: 0 (Web of Science)]

Abstract: The hidden terminal problem degrades the uplink system throughput of wireless local area network (WLAN) seriously. In this paper, we propose the optimum allocation (OA) scheme of the location-based virtual sector (VS) method which solves the hidden terminal problem without large overheads like request-to-send and clear-to-send (RTS/CTS) packets. The VS method forms sectors virtually to make short-distance mobile terminal (MT) groups using MTs' location information. In the group, the all MTs can sense the transmission of all other MTs. In the proposed method, rough time slot control is implemented for inter-sector control which does not need a highly-functional centralized controller. The proposal OA scheme of the VS method improves the fairness among MTs by optimizing active periods of VS according to the number of MTs in each VS. By computer simulations, we show that the proposed method can increase the system throughput from the RTS/CTS and improve fairness among MTs.

International impact on both academic and social aspects: This work is related to research topics "Terrestrial and satellite integrated wireless communication network" and "Heterogeneous wireless communication". In order to improve the multiple access performance of WLAN, we proposed virtual sector method by using location information of terminals obtained from satellite of GPS. Access control methods using location information are one of the most important viewpoints in the more crowded network condition in the era of beyond 5G and massive connect IoT, and this work is a pioneering study for beyond 5G and massive connect IoT.

2. T. Maehata, S. Kameda, N. Suematsu, "1-bit Band-Pass Delta-Sigma Modulator with Parallel IIR Form for Concurrent Multiband Digital Transmitter," IEICE Trans. Commun., vol.E100-B, no.7, pp.1152-1159, July 2017. [IF: 0.580 (JCR, 2018)], [Times Cited: 2 (Web of Science)]

Abstract: We propose architecture for a 1-bit band-pass delta-sigma modulator (BP-DSM) that outputs concurrent multiband RF signals. The proposed BP-DSM consists of parallel bandpass filters (BPFs) in the feedback loop to suppress the quantization noise at each target frequency band while maintaining the stability. Each BPF is based on second-order parallel infinite impulse response (IIR) filters. This architecture can unify and reconfigure the split BPFs according to the number of bands. The architecture complexity is proportional to the bandwidth of each RF signal and is independent of the carrier spacing between the bands. The conventional architecture of a concurrent multiband digital modulator, reported previously, has multiple input ports to the dedicated BPF at each band and so it cannot be efficiently integrated. Measurements show that the proposed architecture is feasible for transmitting a concurrent dual-band and a triple-band by changing the 1-bit digital data stream while keeping a data transmission rate of 10 Gb/s. We demonstrate that the proposed architecture outputs the signal with LTE intra-band and inter-band carrier aggregation on 0.8 GHz, 2.1 GHz and 3.5 GHz, each with 40MHz bandwidth in 120MHz aggregated bandwidth, whose bandwidth surpasses the bandwidth with carrier aggregation of LTE-A up to 100 MHz. Adjacent channel leakage ratios of -49 dBc and -46 dBc are achieved at 3.5 GHz in the concurrent dual-band and triple-band, respectively.

International impact on both academic and social aspects: This work is a transmitter part of our R&D project of “direct digital RF transceiver.” Digital RF technology has been developed and applied to below 6GHz wireless applications. By replacing the IC die consumptive RF/analog circuit blocks by digital signal processing/circuits, digital rich/small transceivers can be realized. Since this technology is based on the Nyquist theory, the operational frequency of the circuit is limited by the Nyquist frequency (= 1/2 of sampling clock frequency), limiting the operational RF frequency range of existing digital RF technology to below 6 GHz. We proposed “direct digital RF technology” which utilizes the higher-order Nyquist Zones. Since proposed transceiver architecture does not require an RF local oscillator and up/down converters, it is suitable for microwave/MMW multi-antenna systems such as Digital Beam Forming (DBF) and Massive MIMO for Beyond 5G and future millimeter-wave wireless systems. Our proposed architecture has been focused not only in domestic conference but in international conferences, such as GSMM2018 (keynote), IEEE RFIT2018 (invited), KJMW2017 (plenary) and IEEE MTT-S IMaRC2015 (invited).

G. 特筆すべき活動 / Significant Activities (FY.2013-2018)

See Ref. 2-9. "#" mark indicates research carried out at a former organization.

研究室外部評価参考資料の 2 以降を参照しながら，2013-2018 年度のなどの活動の中から特筆すべきものを取り出し，前半（2013-2015 年度）と後半（2016-2018 年度）に分けて簡単に紹介する．英文のみ，もしくは和文と英文で記載.

[2013-2015]

As a result of the great east Japan earthquake on March 11, 2011, terrestrial communication infrastructure, such as optical fiber networks and cellular base stations, was seriously damaged. Some seashore cities and towns lost almost all telecommunication tools for sending their message to the outside of the disaster area. Therefore, they could not get the sufficient rescue operations timely. To prevent such a telecommunication crisis, he decided to start the development of next generation satellite communication systems/terminals which will be usable even in severe disasters. Prof. Noriharu Suematsu became a national project leader of disaster-resilient very small aperture terminal (VSAT) with a governmental funding of JPY 2,500,000,000 (STG 19,500,000) and his group (including Associate Prof. Suguru Kameda) successfully developed and demonstrate multi-mode portable VSAT terminals base on software defined radio technology. They were invited to present this outcome at major microwave conferences such as EuMC2014 in Rome and at Asia Pacific Microwave Conference (APMC) 2014 in Sendai, Japan. Based on this R&D project, Japanese Local Authorities Satellite Communications Organization (LASCOM), the biggest satellite communication network provider in Japan, decided to introduce new generation (3G) systems. Prof. Noriharu Suematsu and his colleagues have been engaged in the design/selection/evaluation of this 3G system with LASCOM. For their contribution and devotion, the prize of Tohoku Regional Bureau of Telecommunications, Ministry of Internal affairs and Communications was awarded in 2015.

[2016-2018]

Triggered by the great east Japan earthquake on 2011, the Quasi-Zenith Satellite System (QZSS), planned to be operated by the Japanese government with the main mission of supplementing and reinforcing the global positioning system GPS, was added an additional function with a safety confirmation system. In the QZSS safety confirmation system, a mobile terminal (MT) transmits a short message packet of several hundred bits via a QZSS geostationary satellite to an unaffected control hub station (HUB). At this time, the MT needs to communicate directly with a geostationary satellite at an altitude of about 36,000 km using a limited transmission power of about 1 W and a low-gain terminal transmitting antenna that is nearly omnidirectional. In order to increase the data rate and capacity of the QZSS safety confirmation system, Prof. Noriharu Suematsu and Associate Prof. Suguru Kameda proposed synchronous spread spectrum and code division multiple access (synchronous SS-CDMA). In the proposed system, each MT can calculate its own location and time precisely, and synchronize its own clock and frequency using the highly accurate QZSS and GPS signals. Since each MT controls the transmission timing by using calculated distance between MT and satellite, each uplink signal arriving at the satellite is synchronized with each other. Because HUB can receive short messages synchronously without interference with other messages, it can accommodate 3 million MTs per hour. Associate Prof. Suguru Kameda became a project leader of Grant-in-Aid for Scientific Research (B) of JPY 12,800,000 (STG 100,000). He also got fund of KAKENHI Fund for the Promotion of Joint International Research (Fostering Joint International Research) of JPY 10,800,000 (STG 84,000), and collaborated with WINLAB, Rutgers, the State University of New Jergey, US. As a result of the projects, the feasibility of proposed method is successfully verified based on field trials by using real signals from satellites. In the actual safety

confirmation system “Q-ANPI” that has been launched service from November 2018, a part of our proposals has been implemented by NEC Corporation and related companies. Prof. Noriharu Suematsu and Associate Prof. Suguru Kameda were invited to present this outcome at the International Conference on Solid State Devices and Materials (SSDM 2017). For their contribution and devotion, Associate Prof. Suguru Kameda received M. Ishida Foundation Research Award 2017 and Encouragement Award 2019 from the Miyagi Foundation for the Promotion of Industrial Science.

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