Commission C

2008-2011 Triennial Report

Takashi Ohira, Commission Chair
Marco Luise, Commission Vice Chair

1. Scope of Activities

Commission C promoted research and development in:

(a) Radio-Communication and Telecommunication systems;
(b) Spectrum and Medium Utilisation;
(c) Information Theory, Coding, Modulation and Detection;
(d) Signal and Image Processing in the area of radio science.

The design of effective radio-communication systems included scientific, engineering and economic considerations. The commission emphasised research into scientific aspects, and provides enabling technologies to other areas of radio science.

2. International Events Sponsored or Cosponsored by Commission C

2.1 International Symposium on Signal System and Electronics "ISSSE 2010"
Sponsors: Commissions C and D
Venue: Nanjing, China
Date: Sept. 16-19, 2010
Chair: Prof. Wei Hong, South East University, China

ISSSE2010 was held in Mandarin Garden Hotel, Nanjing, China on September 16-19, 2010. This symposium is held every three years, and is organized under the guidance and with sponsorship of the international steering committee of the URSI Commissions C and D. It has a long tradition of moving around the world; the last three previous conferences were held in Tokyo (Japan 2001), Linz (Austria 2004) and Montreal (Canada 2007). This event is co-sponsored by Southeast University, IEEE MTT-S, Antenna Society of Chinese Institute of Electronics (CIE),

Microwave Society of CIE, IEEE Nanjing Section. ISSSE2010 began with keynote speech: Progress in antennas and propagation for body area networks by Professor Peter Hall, University of Birmingham, UK. We organized twenty scientific sessions, six poster sessions, and one student paper contest. The symposium was totally successful with more than one hundred presented papers, and number of participants exceeded one hundred and seventy. The symposium provided a broad international forum and nice opportunity for the scientists and engineers to present their new ideas and exchange information on research in the fields of communications, signal processing, electronic devices, circuits, and systems.

2.2 Asia-Pacific Radio Science Conference "AP-RASC 2010"
Sponsors: URSI and Institute of Electronics, Information, and Communication Engineers (IEICE)
Venue: Toyama, Japan
Date: Sept. 22-26, 2010
Chair: Prof. Kazuya Kobayashi, Chuo University, Japan
Asia-Pacific Radio Science Conference was held at Toyama International Conference Center, Toyama, Japan on September 22-26, 2010. The AP-RASC is the Asia-Pacific regional URSI conference held between the URSI General Assemblies. The objective of the AP-RASC is to review current research trends, present new discoveries, and make plans for future research and special projects in all areas of radio science, especially where international cooperation is desirable, and a particular emphasis is placed on promoting various research activities in the Asia-Pacific area. AP-RASC 2010 organized seventy four scientific sessions and ten poster sessions. One of the key features in this event was Wireless Power Transmission jointly convened by commissions C, B, and H. Commission C contributed in total eighty eight papers to the success of fourteen scientific sessions and one poster session.

2.3 URSI XXX General Assembly and Scientific Symposium "URSI-GASS 2011"
Sponsor: Union of Radio Science International
Venue: Istanbul, Turkey
Date: Aug. 13-20, 2011
Char: Prof. A.H. Serbest
The XXX General Assembly and Scientific Symposium of the International Union of Radio Science (URSI GASS 2011) was held at Lütfi Kırdar Convention and Exhibition Centre in the beautiful historical center of Istanbul, Turkey on August 13-20, 2011. The XXX General Assembly and Scientific Symposium had a scientific program consisting of plenary lectures, public lectures, tutorials, posters, invited and contributed papers organized around the ten Commissions of URSI. In addition, there were workshops, short courses, special programs for young scientists, student paper competition, programs for accompanying persons, and industrial exhibits. Over 1,500 scientists from more than fifty countries participated in the Assembly. Commission C convened a session on Wireless Power Transmission involving satellite power system, and twelve other scientific sessions. We also organized a tutorial lecture on Six-port Wave Correlator Theory and Practical Application to RF Network Analysis by Professor Toshiyuki Yakabe, University of Electro-Communications, Japan. Authors from our commission presented one hundred papers inevitable to the great success of this event.

3. Activity Reports from Member Nations

3.1 France Section: Jacques Palicot

France Section of Commission C has sixty five members. We co-organized the following three important events. The first one is the second Ecole de printemps MIMO: de la théorie à la mise en œuvre (COST 2100 – URSI) 9-11 March 2009, ENSTA-ParisTech. The advanced training course was attended by more than 130 young researchers and engineers. This event was co-organized by the European COST 2100 action. The program is available on the site http://uei.ensta.fr/cost2100_TS.

The next is Journée "Techniques des Télécommunications Avancées", vendredi 27 November 2009, SUPELEC Campus de Rennes. With more than 100 participants both from academia and industry, the day was very successful. The program is available on the site http://palmyre.univ-ubs.fr/

The last is Journée GDR/ISIS, 10 ans de Radio Intelligent : bilan et perspectives, Lundi 9 May 2011, Amphi Thévenin, Télécom Paris Tech. This event was very important for the French coginitive radio community, because it was the opportunity to draw the state of the art ten years after the beginning of cognitive radio. Joe Mitola, the "father" of cognitive radio was invited to give his view of the future of cognitive radio. More than one hundred twenty people participated in this lecture.

We had our bureau election in March 2010: Jacques Palicot has been elected as Chairman and A Sibille and JC Imbeaux were elected as vice-Chairmen. The commission is involved in the preparation of URSI GA 2011. We are convener or co-convener of six sessions, and we will chair these sessions. Nine papers from the french Commission C will be presented C06 Green Communications, C13 Signal Processing Advances for Cognitive Radio, C11 Power Amplifier Considerations for Software Radio Systems, DBC Signal Processing Antennas, Poster: RFID and Signal Processing Antennas, and CBD Vehicular Communications.

We contributes to scientific books including (1) MIMO from theory to implementation by Alain Sibille, Claude Oestges, and Alberto Zanella: Academic Press 2010. (2) De la radio logicielle a la radio intelligente by Jacques Palicot: Hermes Lavoisier 2010. (3) Radio engineering from software radio to cognitive radio by Jacques Palicot: Wiley 2011.

3.2 Brazil Section: Marcelo S. Alencar

In spite of the world economic crisis, the Brazilian telecommunication market continues to grow strong. By the end of 2007, 173.3 million subscribers had access to telecommunication services in Brazil, an increase of 16.3% from the previous year. The main services, according to information from the Brazilian National Telecommunications Agency (Anatel), were divided into 39.3 million subscribers of the fixed line telephony service, 121.3 million subscribers of the mobile communication service, in which GSM is the dominant technology with 94.9 million subscribers, 5.3 million subscribers of cable television, 7.7 million subscribers of wide band Internet, and 44.9 million Internet users. A total of 11.442 million television sets were sold in Brazil, including 801 thousand LCD devices and 197 thousand equipped with plasma screens. More than 94,6% of the households had television sets, by the end of 2007. In the first quarter of 2009, 212.4 million subscribers had access to telecommunication services, in which 41.7 million subscribers of the fixed line telephony service, 153.7 million subscribers of the mobile communication service, GSM is the dominant technology. There were 6.6 million subscribers of cable television, 10.4 million subscribers of wide band Internet, and 64.8 million Internet users. More than 96% of the households have television sets. Regarding the service availability in

2007, 90.4% of the population had access to mobile communication services. In addition, 47.9% is served by four telecom operators, 35.1% is served by three operators, 3.6% is served by two operators and 3.7% is served by only one operator. In 2007, 30 satellites owned by foreign companies, and 10 owned by Brazilian companies, were authorized to operate in the country. A total of 135 Earth stations were licensed, of which 97 were operated by foreign companies. In the first quarter of 2009, 96.6% of the population had access to mobile communication services, 80.4% were served by four or five telecom operators, 5.0% were served by three operators, 4.6% were served by two operators, and 6.6% were served by only one operator. Regarding the number of localities, in 2007, 59.5% of the cities could count on mobile communication services and 8.7% had cable television or Multipoint Multichannel Distribution System (MMDS) services. The gross operational revenue of the telecom sector was US$ 94.85 billion, which represented an increase of 9.8% in relation to 2006, and corresponded approximately to 6.2% of the Brazilian gross national product. In 2009, a total of 85% of the municipalities were served by mobile telecommunication services. There were 8.4% of cities with cable television or MMDS. The gross operational revenue of the telecom sector estimate for 2009 was US$ 98.44 billion. The figure for 2008 was US$ 98.89 billion. In 2010, 37.642 municipalities are served by the basic telephone service, and 97.1% of the population has access to mobile telecommunication services, which represents 86.7% of the municipalities.

Regarding the composition of the telecom market, in terms of gross operational revenue, in 2007, the industry segment had US$ 10.48 billion, the fixed telephony companies had US$ 42.99 billion, the mobile companies had US$ 36.17 billion, the cable television companies had US$ 4.01 billion, and the trunking companies had US$ 1.20 billion. The figures for the first quarter of 2009 were: industry segment, US$ 5.0 billion; fixed telephony companies US$ 19.3 billion; mobile companies, US$ 16.5 billion; cable television companies, US$ 2.7 billion; and trunk companies, US$ 0.8 billion. In 2007, the sector employed 329,5 thousand persons, an increase of 8.7% regarding 2006: 28.4 thousand in the industry, 50,6 thousand in deployment services, 108.2 thousand in telecommunication services, which included: 32.3 thousand in fixed telephony service, 29.5 thousand in mobile communication service, 12.2 thousand in cable television, 34.1 thousand in the remaining services (broadcast, and Internet service providers), 142.3 thousand in call centers. By the end of 2007, 1,007 companies were registered by Anatel as telecommunications service providers in Brazil, from 814 companies in 2006. Among the licensed companies, six operate the fixed telephony service, 81 were authorized to operate in more than one concession area, 735 operate the multimedia communication service, 154 operate the cable or subscriber television service, 31 operate the mobile communication service. In 2008, 1393 telecom companies operated in Brazil. This figure increased to 1639, in 2009. Among the licensed companies, six operate the fixed telephony service, 99 were authorized to operate in more than one concession area, 1,327 operate the multimedia communication service, and 31 operate the mobile communication service.

In 2009, there were 411.5 thousand employees in the telecom market, an increase of 19.5% from 2008, of which, 37.8 thousand work in the industry, 50.6 thousand in deployment services, 144.2 thousand in telecommunication services, and 179 thousand in call centers. In 2010, four or five telecommunication operators serve 78.6% of the population, three operators serve 6.2%, two operators serve 4.8% and only one operator serves 7.3% of the population. The gross operational revenue for the telecommunications sector, in the first quarter of 2010, is US$ 26 billion, an

increase of 4,8% from the last quarter of 2009. The number of telecommunication access, in the first quarter of 2011, was 277.4 million, which includes fixed and mobile telephony, wired and wireless broadband, and cable television. This is an increase of 15.5% compared to the same period of 2010. Wireless broadband increased 77%, from 13.8 to 24.4 million Internet accesses. Telephony grew from 179.1 to 210.5 million devices with a 17.5% increase. Fixed broadband evolved 20.5% in the period, from 11.7 to 14 million. Overall, the number of wide band connections, wired and wireless, reached 40.9 million in April, 2011. The growth in television subscribers was 31.6%, in 12 months. The total number of clients increase from 7.9 to 10.4 million.

The Brazilian Telecommunications Society (SBrT) sponsored the XXV Brazilian Telecommunications Symposium (SBrT07), which was held in Recife, between days 3 and 6 of September, 2007, with general coordination of Rafael Dueire Lins and with Valdemar Cardoso da Rocha Jr as technical coordinator. There were four short courses related to the books from the Series SBrT-Brasport. Three tutorials were presented together with 184 technical articles and 14 scientific Initiation posters. The technical program also had three invited talks by Bahram Honary (U. Lancaster-UK), Jose Luis Santos (INESC Porto-Portugal) and Garik Markarian (U. Lancaster-UK).

Rio de Janeiro hosted the XXVI Brazilian Telecommunications Symposium (SBrT08) during the period between the 2nd and 5th of September, 2008. The 2008 symposium was a special edition, in which the 25th SBrT anniversary was celebrated. The XXVII Brazilian Telecommunications Symposium (SBrT 2009) was organized by FURB and UFSC (LINSE), held in Blumenau between the 29th of September and the 2nd of October, in 2009. In charge of the event, general coordination was Orlando Jose Tobias. Paulo Roberto Brandt, Bartolomeu Uchoa Filho, and Rui Seara were the technical chairs.

The International Telecommunications Symposium (ITS), the most important international forum on all areas of telecommunications in Latin America, was held in Manaus, chaired by Prof. Rafael Lins. The ITS, which occurs every four years, was organized by the Brazilian Telecommunications Society (SBrT) and was supported by the IEEE Communications Society (COMSOC).

The 13th International Symposium on Wireless Personal Multimedia Communications (WPMC 2010) was held in Recife, Brazil for four days, from October 11 to 14, 2010, under the sponsorship of NICT and YRP. It also received collaboration and support from Institute for Advanced Studies in Communications (Brazil), Recife Conventions and Visitors Bureau (Brazil), Federal University of Campina Grande (Brazil), University of Sao Paulo (Brazil), University of Toronto (Canada), Federal University of Pernambuco (Brazil), The Brazilian Council for Research and Development, and the Brazilian Telecommunications. The series of the symposium was inaugurated in 1998 in Yokosuka, Japan, and had taken place in Asia, Europe, and North America. This was the first WPMC took place in the South American Continent. The theme for the symposium was Towards Autonomous Network Infrastructure, which highlighted the current dynamism in the area of network infrastructure development and the emerging interest on autonomous networks as a means to realize the high capacity of large networks required for the provision of cost effective broadband wireless multimedia services in large wireless markets such as that of Brazil. In addition to high-level technical sessions, the Symposium featured six keynote presentations, special technical sessions, panel discussions and four tutorials. The scope

of the symposium was set in five categories: Network Deployment and Management Technologies, Air-Interface Technologies, Wireless Network Technologies, Applications and Services, and Systems and Regulation. The number of submissions was 98 and, out of them, 90 papers were accepted for presentations in 24 sessions. At the opening ceremony, on October 11th, the organizers had the honor to have the presence of Prof. Sergio Machado Rezende, Minister of Science and Technology of Brazil, Dr. Hiroshi Kumagai, Vice-President, National Institute of Information and Communications, Japan, Mr. Kazushige Fujita, Director for Technology Policy Planning, Technology Policy Division, Global ICT Strategy Bureau, Ministry of Internal Affairs and Communications, Japan, and other distinguished guests. Among the submitted papers, six papers were selected by the Award Committee members and were given citations, a certificate and honorarium. A total of 202 participants from 18 countries registered for the event, which ended up in a huge success.

The SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference is a traditional event promoted by the Brazilian Microwave and Optoelectronics Society (SBMO) since 1985. The 2009 edition of the event was held in Belm, on November 3 to 6. The general chair was Gervasio Cavalcante, the general co-chair was Joao Tavares Pinho, the technical program chair was Joa Crisstomo Weyl Costa and the technical program co-chair was Maria Thereza Rocco Giraldi. The Brazilian Microwave and Optoelectronics Society (SBMO) sponsored, in 2009, the International Conference on Electromagnetic Fields, Health and Environment (EHE), conceived to become a global forum to discuss the latest developments and studies about the influence of electromagnetic fields on health and the environment. The conference was held in Sao Paulo, on September 25, 2009.

The Brazilian Electromagnetics Society (SBMag) organized the Compumag Conference of 2009. Compumag 2009 was held in Florianopolis, Brazil on November 22 to 26, 2009. Joa Pedro Assumpco Bastos was the chair and Nelson Sadowski was the vice-chair of the event. The Editorial Board was lead by Nathan Ida. The 14th Brazilian Symposium on Microwaves and Optoelectronics and the 9th Brazilian Congress on Electromagnetism (MOMAG 2010) occured in Vila Velha, Espirito Santo, in 2010. The event was organized by the Laboratorio de Telecomunicaces (LabTel), Federal University of Esprito Santo (UFES) and by the Laboratorio de Eletromagnetismo Aplicado (LMAG), Escola Politcnica, University of Sao Paulo (USP). The event was supported by the Brazilian Microwave and Optoelectronics Society (SBMO) and by the Brazilian Electromagnetics Society (SBMag). The 2011 SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference (IMOC 2011) is a biennial international forum of telecommunication technologies organized by the Brazilian Microwave and Optoelectronics Society (SBMO) and co-sponsored by IEEE Microwave Theory and Techniques Society (IEEE MTT-S). In its fourteenth edition, this conference will be held at the amazing city of Natal, Brazil. The conference venue is the Imir Plaza Hotel, a beach hotel with 166 apartments, located at Via Costeira. IMOC 2011 will provide a major international forum for exchanging information on research and development in the theoretical and experimental fields of Microwaves and Optoelectronics including Millimeter and Nanometer Waves, Antennas, Propagation, Wireless Communication, Fiber Optics, and Photonic Networks. The general chair is Prof. Adaildo G. Dessunco (UFRN, Brazil), and the technical program chairs are Prof. Gervsio P. S. Cavalcante (UFPA, Brazil) and Prof. Evandro Conforti (Unicamp, Brazil).

The Journal of the Brazilian Telecommunications Society (JBTS) was created in 1986 by the

SBrT as a way to document and disseminate the results produced by Brazilian researchers. Effective December, 2005, the Board of the SBrT approved a new title for its publication, which became known as Journal of Communication and Information Systems (JCIS). The JCIS is aimed at the international audience, with special emphasis towards the Ibero American environment. The JCIS is managed by two Editors-in-Chief (EIC) and 16 Associate Editors, composed of distinguished scholars from the international and Brazilian community. The Editors-in-Chief, for the past three years, were Marcelo S. Alencar and Elvino S. Sousa. Joa Marcos Romano is the new Editor-in-Chief. The Journal of Microwaves, Optoelectronics and Electromagnetic Applications (JMOe) is published by the Brazilian Microwave and Optoelectronics Society (SBMO) and Brazilian Society of Electromagnetism (SBMag). It is a refereed publication devoted to disseminating technical information in the areas of Microwaves, Optoelectronics, Photonics, and Electromagnetic Applications. The journal is published in electronic format since 1997. The editors, until 2009, were Murilo Arauo Romero and Joa Pedro Asumpco Bastos. The new editors are Maria Thereza Miranda Rocco Giraldi and Joa Pedro Asumpco Bastos.

Considering the economy, one interesting point to comment is the amount of taxes the companies pay. The fixed and mobile companies together paid US$ 22.34 billion in taxes, in 2007, which represented 42.0% of the net operational revenue, and was the largest percentage in the world. In 2008, the percentage increased to 42.7%, and, in 2009, to 43.3% of the net operational revenue. The market value of the telecom service providers in Brazil, in 2007, was US$ 105.33 billion. Because of the world economic crisis of 2008, the market value of the telecom service providers decreased to US$ 74.5 billion, in 2009. As a recommendation, it is important that the International Union of Radio Science (URSI), Commission C, begin to sponsor the conferences organized by the Brazilian Telecommunications Society (SBrT) and by the Brazilian Microwave and Optoelectronics Society (SBMO).

3.3 Russia Section: Alexander Shmelev

Members of Russian Commission C took part in organization and execution of the following scientific events: (1) XV, XVI and XVII annual sci-tech conferences “Radiolocation, navigation, communication” held in Voronez (Russia), April 2009-2011. Every conference gathered nearly 200-300 participants mainly from Community of Independent States (former USSR). Proceedings of these conferences were published in Russian. (2) Workshop “Information technologies in radar science” held on the basis of Bauman Moscow State University, June, November 2009. (3) Second International Symposium on Radio Systems and Space Plasma held in Sofia (Bulgaria), August 25-27, 2010. (4) III all-Russian sci-tech conference “Radiolocation & Radio Communication” held in Kotelnikov Institute of Radio-engineering and Electronics, Russian Academy of Science, Moscow, October 26-30, 2009. (5) The seminar dedicated to centenary of eminent scientist – radio physicist Prof. S.M. Rytov held in Institute of the History of Science and Technology, Russian Academy of Science, Moscow, March 2009. (6) Commission C, together with Russian Committee of URSI, took part in activities related to XXX General Assembly of URSI in Istanbul.

3.4 Spain Section: Manuel Sierra

The main activity in the Spain URSI and particularly the Commission C is the Spain URSI

Symposium that is celebrated each September in a Spanish city. The meetings of this triennium occurred in Bibao as URSI 2010 (http://ursi2010.org), Santander 2009 (http://ursi2009.org) and Madrid 2008. This Symposium meets more than 300 papers and 400 people, mainly coming from Spain but some of the people come from the Spanish America and from Portugal. Although the National Symposium covers all the commissions, commissions B and C are largely represented. Two prizes are organized to the best student paper. This meeting usually groups other activities like National Research Office project evaluation or Commissions social and organization meetings. More information and the full publication of papers from the National URSI Symposium, celebrated since 1980, can be obtained in the Spain URSI web page http://w3.iec.csic.es/ursi/. In 2011 the Symposium will be celebrated in Leganes, a town near Madrid (http://ursi2011.org).

3.5 United Kingdom Section: Sana Salous

Since the GA in Chicago, the UK URSI panel has agreed to run a one day event to encourage young engineers and scientists to participate in radio science. This one day event is named Festival of Radio Science, FRS. So far the FRS was held in 2009 in Birmingham and in January 2011 in Leicester. The 2011 FRS was chaired by Commission C and it is planned that the next FRS will be organized by the Chair of Commission C and that it will be held in Durham University. Looking at the programs of the FRS events in 2009 and 2011 http://www.ursi.org.uk/Meetings/tabid/91/language/en-US/Default.aspx there were 22 papers in both events with 7 papers and 6 papers contributed by Commission C, respectively.

3.6 Japan Section: Kenji Itoh

In this triennial we had remarkable achievements in the seven scientific fields as follows.

(1) Wireless Power Transmission

Wireless power transmission (WPT) via microwave has long history especially in Japan. In 80's, point-to-point WPT via microwave experiments were carried out in Japan. In 2000's, new WPT applications were proposed in Japan, for example, Ubiquitous Power Source (UPS), wireless charging for electric vehicles, wireless buildings, and etc.. After proposal of resonant coupling power transmission by MIT in U.S. in 2006, various WPT systems which include the WPT via microwave and resonant coupling power transmission are studied in Japan in recent three years. Professor Shinohara and his group carried out some WPT experiments via microwave. They carried out the field experiment of the UPS for emergency in 2009, in which the microwave power was transmitted from airship above 50 meter high and the mobile phones were charged only with microwave power from the airship. They have another WPT researches. They revised wireless charging for electric vehicles in which the rectennas, receiving antennas, received 76.0 % of the transmitted microwave power. They were succeeded in wireless power supply for ZigBee wireless sensors via microwave power. They used 2.45GHz continuous wave for all experiments.

There are some kinds of the WPT via microwave researches in Japan. New rectenna for weak power receiving and rectifying was developed in Okayama University. They also proposed and developed ultrasonic WPT system. Scientists in Tokyo University carried out a micro aerial vehicle flight experiment whose power was transmitted wirelessly from phased array on the ground. The same group started researches of mid range WPT with resonant coupling

technology. Some Japanese makers start rectenna products for the WPT receivers.

We can transmit the wireless power via microwave, however, present radio wave regulation does not allow the WPT as commercial use. On the contrary, we can use the resonant coupling because there is no radiation from resonators. The efficiency of resonant coupling is higher than that of microwave power transmission. Therefore, it is easy to make products of WPT. There are many researches and commercial products in Japan in recent three years. New design theory based on BPF theory was formulated by Professor Ikuo Awai in Ryukoku University. Equivalent circuit approach of magnetic resonant WPT was calculated in Nagoya Institute of Technology. Tohoku University focused on impedance matching of magnetic resonant WPT in equivalent circuit.

Tokyo University carried out some experiments of the resonant coupling WPT application for an electric vehicle. A coil-free WPT scheme for a running electric vehicle was invented by Professor Takashi Ohira, Toyohashi University of Technology and Dr. Masahiro Hanazawa, Toyota Central R&D Lab. Famous Japanese companies, for example, Panasonic, Sony, Toshiba, Toyota, Nagano Nihon Musen, etc., made new resonant coupling WPT applications public.

Based on the Japanese WPT activities, WPT working group was established in Broadband Wireless Forum (BWF) in 2009. Radio regulations, consideration of electromagnetic limits for human body, and other equipments are discussed in the working group of BWF. On May 12-13, 2011, IEEE MTT-S International Microwave Workshop Series (IMWS) on Innovative Wireless Power Transmission: Technologies, Systems, and Applications2011 (IMWS-IWPT2011) was organized in Japan. This was the first international workshop in which we focused on the WPT. Many researchers attended the workshop and discuss the technologies and applications of the WPT.

(2) Satellite Communication Systems

Research and development projects in the field of satellite communication systems, such as wideband internetworking satellite communication, mobile satellite communication, integrated mobile communication and improvement of ground station technology were conducted in Japan during these three years. Wideband Internetworking engineering test and Demonstration Satellite (WINDS) is an experimental satellite aiming at research and development of broadband satellite communications system which takes part in construction of worldwide broadband networks and it was launched into geostationary orbit at 23, Feb., 2008. After launching the satellite, fundamental and application experiment is now undergoing. In these experiments, health check of onboard Ka-Band Active Phased Array Antenna (APAA) was confirmed in orbit, and shown a good result. Moreover, data communication of 1.244 Gbit/s (world record) was succeeded combining two 622 Mbit/s waves with the bent-pipe mode using Satellite-Switched Time Division Multiple Access (SS-TDMA) system.

The Engineering Test Satellite VIII (ETS-VIII, Japanese name “KIKU-8”) was developed by the JAXA, NICT, and Nippon Telegraph and Telephone Corporation (NTT) and was launched into geostationary orbit at 146 degrees east longitude on 18 Dec. 2006. The aim of this project is to develop the following new technologies; in-orbit experiments such as Large-scale satellite-mounted Deployable Reflector(LDR) (19 m x 17 m), mobile satellite communications using small ground stations such as handheld terminals (about 300 g). The LDR and beam forming network designed by Takashi Ohira and his team were evaluated in orbit and the expected beam

spot was successfully achieved with an excellent pointing accuracy even against the thermal distortion of the large reflector. Experimental result of portable terminal was reported and shows good characteristics such as the degradation of BER around 1 dB compared to the identical in the case of without error correction.

For the purpose of communications at the disaster and digital divide measures in the local area, satellite/terrestrial integrated mobile communication system (STICS) is now under research. In this system, dual mode handheld terminal with satellite and terrestrial communication function should be used. In the satellite, 30 meter class reflector antenna is assumed to enable satellite communications with a handheld terminal. The frequency is shared for both satellite and terrestrial uses. Several frequency shearing methods were proposed and a measurement experiment of interference wave such as terrestrial communication was carried out.

For the sensor network via a communication satellite system was proposed which is called "Hyper Multi-point SATCOM System", it can treat wide range data from several ten byte to several megabyte maximizing frequency efficiency. Variable polarization frequency division multiplexing (VPFDM) was proposed for the purpose of accurate polarization tracking using electrical steering antenna such as mechanical steered polarization tracking antenna. Because polarization multiplexing, technical standard of cross polarization level in Very Small Aperture Terminal (VSAT) was defined to be 27dB, and it had been difficult to establish such value in the electrical steered antenna. Validity of this system was confirmed by the experiment. The helicopter-satellite communication system (HELISAT) was proposed and developed. In the helicopter, satellite communication had been difficult by periodical interception by helicopter rotor blade. In this system spatial communication method was developed to synchronize with the rotating blade. Moving picture transmission of 1.5 Mbit/s was succeeded by using this system.

(3) Microwave Active Circuit

The frequency bands allocated to mobile communications are increasing with the growing demand for high-speed and high-capacity data transmission services. In particular, future mobile terminals are anticipated to work seamlessly in various mobile communication systems that have inherent specifications such as the operating bands, the bandwidths, or the modulation/demodulation schemes. In this sense, the following two topics are one of the most significant issues in recent microwave active circuits: One is to provide multi-band operation, and the other is to achieve highly-efficient operation. There have been reports on the architecture to provide multi-band/multi-mode operation for mobile terminals, which describe a quadrature mixer/modulator and multimode transceiver IC having a low spurious local oscillator configuration; and a reconfigurable architecture for configuring low-noise amplifier that incorporates integrated matching networks with MEMS switches. As a practical example of multi-band devices for mobile terminals, there have been proposals on a highly efficient multi-band power amplifier with a reconfigurable configuration comprising band-switchable matching networks and a biasing network, and a multi-band operation power amplifier integrated into a LTCC substrate. Aggressive R&D activities have given remarkable outcomes with regard to the highly-efficient operation. Typical topics during this period are divided into two regions: nonlinear distortion compensation techniques and harmonic tuning. With regard to the nonlinear distortion compensation techniques, a 3.5-GHz feed-forward power amplifier for mobile base stations has been proposed to demonstrate an experimental investigation on the wideband

intermodulation distortion compensation characteristics. In contrast to the feed-forward configuration, the digital predistortion (DPD) has also attracted much attention from the standpoint of the affinity with the digital signal processing in the modulation/demodulation circuits of the base stations. A fast calculation scheme has been presented for the coefficient values of a frequency characteristic compensator in the DPDL based on a quadratic function using the relationship between the coefficient values of the frequency characteristic compensator and the intermodulation distortion components. An adaptive DPDL has also been presented to improve the parameter convergence speed of the DPDL employing a series expansion technique with orthogonal polynomials. With regard to the harmonic tuning, highly-efficient power amplifiers have been demonstrated such as C-band GaN HEMT high power amplifier with a new circuit topology for simultaneous high efficiency matching at both fundamental and 2nd-harmonic frequencies, yielding the drain efficiency of over 57 % with 100 W output power; a new feed-forward amplifier employing a harmonic reaction amplifier as the main amplifier, yielding the efficiency of 19.3 % with 20 W output power; and 2-GHz band GaN HEMT, an inverse class-F amplifier, yielding the power added efficiency of over 70%. In addition to the above mentioned areas, high-performance active devices have been proposed to open up entirely-new areas of microwave applications such as a high integrated SiGe-MMIC transceiver for 5.8 GHz dedicated short range communications terminals, a Ka-band high-power protection switch utilizing new open/short-stub selectable circuit, and an octa-push VCO producing the eighth harmonic output.

(4) Wireless Interconnection for Microelectronics

Though signal speed and integration level continue to increase in LSI technology, interconnections from/to the LSIs become serious problems. Conventional wire bonding has speed limit and signal degradation due to inductance of metal wires. Traditional approach is mechanical connection, such as flip chip bonding using bumps or TSV (through silicon via) technology. Co-integration of optical devices has been long history of R&D, but material level heterogeneous integration is still far from practical uses. Recent approaches are wireless interconnection between IC chips. There are several approaches. One is by radio wave propagation with conventional antennas. An on-chip dipole antennas measures 6 mm in length and 5 mm in distance and exhibits S21 of -10 dB on high resistivity substrate. The transmission efficiency is so low that the system requires amplification of the received signal. However, the signals are transmitted to almost all directions, the system will be convenient for one to multi-port applications such as system clock delivery in digital circuits.

Another approach is the use of inductive coupling with coils. On-chip coils are placed on two wafers, and they are coupled with magnetic flux. Since the flux extends towards both upper and lower directions of the coil, the signal can be delivered through several wafers. Thus, they are appropriate for stacked multi-chip systems. The confinement of the energy is a problem in regard to the transmission efficiency. Therefore, the amplification at receiving point is also required. The size of the coils are 100 to 200 μm square and the distances between the coils are limited to be 20 to 120 μm. Due to this short transmission distance, the wafers are placed face to face or thinned down to 20 to 50 μm. Using 65 nm CMOS technology, they have shown 1.1Gbps data transmission with 0.55 V power supply.

One more alternative is capacitive coupling. To reduce the capacitor area, the distance

between the electrodes should be as short as possible. Their target distance is 0.4 μm for 8 μm square electrodes. Since the technology requires face to face wafer stacks and precise chip-alignment, it will be used in limited areas such as 3-dimensional wafer stacks.

The final approach is resonator couplings. Recently, wireless power transmission between two LC resonators becomes popular in power electronics. Experiments are carried out with 10 MHz signal (λ = 30 m) where the coil diameter is about 30 cm and the transmission distance is around 1 m. If the frequency is increased up to 60 GHz, the resonator can be formed by small ring-type resonator (open-ring resonator) with the diameter of 240 μm on silicon or sapphire wafers. According to simulations, radiation loss is estimated to be less than 1 dB even through 200 μm wafers with a 3 dB bandwidth of 5 GHz. Experiments at 15 GHz signals showed S21 of -1.7dB. Due to this high transmission efficiency, the structure needs no amplification. Therefore, it will be used for assembling in microwave systems including passive components like antenna. Due to the use of resonance, the structure is tolerant to misalignment. To mitigate the loss due to the finite conductivity of silicon wafers, high resistivity silicon wafer is needed. A meta-material approache was proposed as a possible solution for this problem.

(5) Millimeter-wave and terahertz CMOS circuits

Recently, millimeter-wave and terahertz CMOS circuits are actively studied aiming for ultrahigh-speed wireless communication and noninvasive imaging. Although GaAs and InP circuits were conventionally used for millimeter-wave bands, CMOS circuits can operate in millimeter-wave region owing to device miniaturization using standard process. However, although standard CMOS process only offers process design kits (PDK) for relatively-low radio frequency (RF) including device models and layouts, they apply only below 30 GHz. As a result, even though current advanced CMOS process has potentials to operate millimeter-wave and terahertz frequencies, the dedicated PDK for them has to be established first. In 2008, Manzawa, et al, proposed bond-based design for millimeter-wave CMOS layout in order to overcome incomplete back annotation in millimeter-wave region, and proposed high-attenuation power line for millimeter-wave decoupling. Owing to these two techniques, reproducible CMOS design can be realized even in millimeter-wave bands. For low-power millimeter-wave wireless communication, Oncu et al. proposed 60 GHz pulse transmitter, pulse receiver, and wireless high-definition multimedia interface (HDMI) . Utilizing these technique, low-power communication technique was demonstrated even in millimeter-wave bands. Recently, terahertz CMOS circuits which operate over 100 GHz have attracted attentions. Fujimoto et al. proposed device modeling technique applicable to terahertz region and 120 GHz transceiver chip sets and demonstrated terahertz communication with 9 Gbps data rate and bit-error rates of below 10 to the power of negative 9. From now on, aiming at higher-speed communication and new sensing, CMOS circuits operating at higher frequency will be actively studied and will open up new applications.

(6) Silicon based RF integrated circuits

In this period, many RF integrated circuits which realized by compound semiconductor have been superseded with scaled CMOS and Si-Ge BiCMOS. The cut-off frequency of Si-Ge bipolar transistor was already achieved 400 GHz and that of scaled CMOS was 250-300 GHz in 40-32 nm process design rule. Especially, many RF integrated circuits designers and researchers

focused on cellular-phone, and millimeter-wave applications.

Regarding in the cellular-phone, almost all RF integrated circuits were realized by silicon based integrated circuits due to Japanese WCDMA market extension. A quad-band WCDMA transceiver, which including low-noise amplifiers and direct conversion receiver and transmitter using 180 nm BiCMOS process achieved 3 % in EVM and -46 dBc in ACLR. On the other hand, using 130 nm CMOS process, eight-band WCDMA/GSM transceiver, including low-noise amplifiers and direct conversion receiver and transmitter was reported. The achieved performances of this transceiver were 2.4 % EVM and -49.7 dBc ACLR. The WiMAX is one of the candidates for next generation metropolitan area network application. The fully integrated WiMAX transceiver consisting of two receivers and one transmitter was also reported using 65 nm CMOS process.

Regarding in the millimeter-wave applications, 77 GHz automotive radar transceiver was realized by fully integrated circuits using CMOS and beyond 100 GHz RF circuits blocks were reported. Automotive 77 GHz FM-CW transceivers were reported using 90 nm CMOS with 520 mW power dissipation. This enabled to measure the distance approximately 8 m with 6 cm error. To realize of the demand of high data rate communication, higher carrier frequency is necessary. A 120 GHz ASK transmitter and receiver chipset with 9 Gbps communication rate was reported using 65 nm CMOS under 100 mW power dissipation. Many researches were reported on millimeter-wave circuit building blocks such as a wide-tuning range millimeter-wave oscillator.

(7) Microwave Active CircuitFrequency Conversion and Generation

In the RF region, evolution of the cell-phone system accelerated the RF system architecture including the frequency conversion and generation circuits, in past. For the third generation system based on CDMA, direct conversion transceivers and fractional-PLLs were technically improved under strong business competitions. Thus we could see important improvements on above topics in mid-2000s. However we are facing technical saturations on this area, although there are continuous research activities for mass-RF-IC markets. In the late-2010, the new cell-phone system named "LTE (Long Term Evolution)" was started in Japan for 37.5 Mbps down-link. To achieve high speed transmission, high resolution modulation like 64QAM is employed in LTE. So high accurate modulation mixer technique is key to realize the system. Also the digital pre-distortion system in transmitters need the same requirement on modulation circuits. Estimation and correction methodology by digital signal processing are proposed, and validation results are demonstrated for the practical LTE systems. For future wireless systems with high efficient frequency-use efficiency, cognitive radio systems are studied continuously. For the systems, RF-ICs are required to achieve ultra-wideband characteristics for frequency flexibility in radio communications. Also extreme dc current compensation is required for future hand-terminal utilizations.

Based on the rapid evolution of the silicon devices like deep sub-micron CMOS or SiGe BJT, research works for millimeter wave systems are very active. Also compound devices like InP HEMT or GaN HEMT are considered especially for power utilizations in millimeter wave. In parallel with above evolutions of semiconductor devices, HDTV systems are wider accepted in Japanese homes and wireless transmission requirements are becoming strong for Gbps data used in high vision TVs. Distribution of high definition TV programs is planned with future 10G-

Ethernet (10GE) on passive optical network. For the connection to above 10GE, 10 Gbit/s wireless link is studied at 120 GHz band. For the utilization, 120 GHz band digital modulator and demodulator were developed with 0.1 micron InP HEMT. In the Microwave/Millimeter wave region, we have two major evolutions of semiconductor devices: high frequency performance of submicron CMOS devoices and high breakdown voltage/high frequency performance of the wide band-gap devices. In addition to 120 GHz band utilization mentioned above, 77 GHz band utilization for high speed communications and short range radar were considered. Low phase noise oscillator techniques are inevitable to achieve high accurate digital modulation as 64QAM or high resolution radar equipments. For improvement of phase noise, harmonic oscillation and high Q resonance inside oscillator were proposed, and developed 77 GHz planer oscillators achieved phase noise around -110 dBc/Hz at 1 MHz offset was achieved without bulky resonators.

Phase noise of oscillators has been represented by well-known Leeson's formula with oscillators' Q factor. However, we had no clear definition of oscillators' Q. Professor Takashi Ohira defined a theoretical formula of oscillators' Q that enable us to estimate Q from circuit port impedance or S parameters. Based upon his fundamental theory, formulations for Q factors were done for practical oscillator configurations. Professor Kenji Itoh and his apprentice experimentally verified the relationship between resonator's Q and oscillator's Q for the first time.

Diode balanced mixers are very classical circuits from 1920s. However there are no formulas that indicates output power of the mixers in closed forms. Professor Kenji Itoh formulated the output power of the balanced diode mixers and even harmonic mixers by employing a switch model for diodes. The derived formulas well represented output power of the mixers.