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毫米波國家重點實驗室
State Key Laboratory of Millimeter Waves
(香港城市大學夥伴實驗室)
(Partner Laboratory in City University of Hong Kong)

Workshop on Millimeter-Wave Antenna Technologies for 5G and Beyond

30 – 31 March 2017
City University of Hong Kong

About the workshop

The world-first standard for the 5th generation (5G) wireless communications was unveiled when the US Federal Communications Commission's (FCC) passed unanimously the Spectrum Frontiers vote on July 14, 2016, opening up a total of 3.85 GHz licensed spectrum in 28, 37 and 39 GHz bands and a new unlicensed band at 64–71 GHz. Further notice for future FCC ruling includes bands above 95 GHz. The addition of the 64–71 GHz band to the existing 57–64 GHz WiGig makes available 14 GHz of contiguous unlicensed spectrum, which paves the runway in launching new and exciting enabling technologies that cannot be even conceived today.

Advancing millimeter-wave (MMW) antenna technologies to provide fiber-like wireless connectivity has been one of our main research goals. The research team boosts 5 antenna experts including 4 Fellows of IEEE, the Lead Guest Editor of the Special Issue of Proceedings of the IEEE on Antennas in Wireless Communications and the Immediate Past Editor-in-Chief of the IEEE Transactions on Antennas and Propagation. The team was also conferred a second-class honor in the 2011 State Technological Invention Award. In addition, the laboratory has near-field, far-field and compact range antenna measurement facilities, covering from 700 MHz to 1.1 THz.

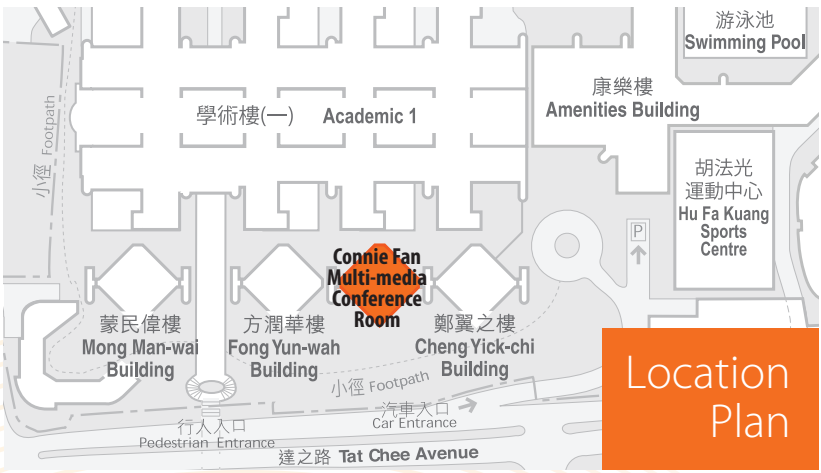
The workshop targets antenna practitioners who have general knowledge in antenna designs for mobile devices and base-station antennas at microwave frequencies and would like to learn the latest developments in MMW antennas to prepare for the coming of the 5G era. MMW antennas and arrays fabricated by PCB, 3D printing, LTCC and antenna in package (AIP) technologies will be covered in the 1 day workshop and followed by a half day optional MMW antenna measurement demonstration.

Venue

Connie Fan Multi-media Conference Room
Floor 4, Cheng Yick-chi Building, City University of Hong Kong,
Tat Chee Avenue, Kowloon, Hong Kong SAR

Directions from MTR

1. When you get off the MTR look for Festival Walk exit.
2. In Festival Walk, on Level LG1, there is a Pedestrian Subway which will lead you to CityU campus.
3. After walking through the Pedestrian Subway, go down the staircase on your right and follow the directional signs, you will find yourself walking under a covered corridor alongside the garden which will lead you to the University Circle.
4. From the University Circle, you will see Cheng Yick-chi Building on your right.
5. Go inside Cheng Yick-chi Building, you will find Connie Fan Multi-media Conference Room there.



Program

	30 March 2017 (Thur)	31 March 2017 (Fri)
0930–1030	3D Printed Millimeter-Wave Antennas ***by Dr Hang Wong***	Tutorial at SKLMW
1030–1050	Tea Break	
1050–1150	Beam Shaping of Millimeter-Wave Antennas ***by Prof Chi Hou Chan***	
1200–1400	No program	No program
1400–1500	A 60GHz CMOS Transceiver Chip with Antenna in Package ***by Prof Quan Xue***	
1500–1520	Tea Break	
1520–1620	Designs of Millimeter-Wave Dielectric Resonator Antennas ***by Prof Kwok Wa Leung***	
1620–1720	Design Techniques for 60 GHz Microstrip Antennas and Magneto-Electric Dipoles ***by Prof Kwai Man Luk***	

3D Printed Millimeter-Wave Antennas

Abstract This talk will introduce a new antenna technology for high frequency antenna development and realization for recent fast-speed communication systems in millimeter-wave spectrum. The content of this talk includes linearly-polarized and circularly-polarized antenna designs with the help of 3D printing technology to develop low-cost, wideband, and high-gain directional beam antennas. Thanks to the conventional printed-circuit-board PCB fabrication, the proposed antennas can find an ease of integration with the current 3D printing technology. This talk exhibits how to combine the conventional and the newly-developed fabrication technologies into the antenna designs. One of examples, a 3D printed polarizer is placed above a radiating aperture operating at the centre frequency of 60 GHz. An electric field, E, radiated from the aperture generates two components of electric fields, Ex and Ey. After passing through the polarizer, both Ex and Ey fields can be degenerated with an orthogonal phase difference which results in having a wide axial ratio bandwidth. The proposed antenna with the polarizer achieves a wide impedance bandwidth of 50% from 45 to 75 GHz for the reflection coefficient ≤ -10 dB, and yields an overlapped axial ratio bandwidth of 30% from 49 to 67 GHz for the axial ratio ≤ 3 dB. The maximum gain of the antenna reaches to 15 dBic. The proposed methodology of this design can apply to applications related to millimeter-wave wireless communication systems.

Biography **Hang Wong** received the B.Eng., M.Phil., and Ph.D. degrees in electronic engineering from City University of Hong Kong in 1999, 2002 and 2006, respectively. He joined the State Key Laboratory (SKL) of Millimeter Waves, in Hong Kong SAR, China, in 2008 as a senior engineer. He was an acting assistant professor in the Department of Electrical Engineering, Stanford University, in 2011. He joined the Department of Electronic Engineering as an assistant professor at City University of Hong Kong in 2012. He had several visiting professorships at University of Waterloo; Canada, University of College London, UK; and University of Limoges, France in the years of 2013, 2014, and 2015 respectively. His research interests include design of broadband antennas, small antennas, millimeter wave antennas, 3D printed antenna and related applications. He has published more than 90 international journals and conference papers. He was awarded 17 US and China patents. He was the co-author of two antenna research book chapters. He was the chair of the IEEE Hong Kong Section of the Antennas and Propagation (AP)/Microwave Theory and Techniques (MTT) Chapter from 2011 to 2014. He is recently appointed as the IEEE APS Region-10 Representative. He is an associate editor of IEEE AWPL, Antennas and Wireless Propagation Letters, since 2012. Dr. Wong received 2011 State Technology Invention Award 國家科學技術發明獎 presented by the Ministry of Science and Technology of the P.R. China with Professors Kwai-Man Luk, Chi-Hou Chan, and Quan Xue for their contributions of wideband patch antenna developments and applications.

Beam Shaping of Millimeter-Wave Antennas

Abstract In this tutorial, we will discuss the modification of the radiation pattern of a single antenna element and beam shaping of array antennas. When compared to its microwave counterparts, the fabrication of millimeter-wave antennas using printed-circuit-board technology requires a higher precision accuracy due to their small size. To address the fabrication cost and tolerance issues, we have investigated the use of higher-order mode patch that is physically larger and less susceptible to fabrication errors. Due to its geometrical structure, the radiation pattern of a single patch element is asymmetric which is then eradicated with the use of a mirrored pair of patches fed by a differential feed. At 60 GHz, the array antennas can be designed without serious physical constraints. The radiation patterns of the array antenna can be manipulated with proper amplitude and phase control of the signal fed to each of the array elements. We will demonstrate beam tilting and beam scanning with lens antennas and leaky-wave antennas and sidelobe suppression with microstrip array antennas, all working at millimeter-wave band.

Biography **Chi Hou Chan** (S'86–M'86–SM'00–F'02) received the B.S. and M.S. degrees in electrical engineering from the Ohio State University, Columbus, OH, USA, in 1981 and 1982, respectively, and the Ph.D. degree in electrical engineering from the University of Illinois, Urbana, IL, USA, in 1987.

From 1987 to 1989, Dr. Chan was a Visiting Assistant Professor in the Department of Electrical and Computer Engineering at the University of Illinois. From 1989 to 1998, he was a faculty member in the Department of Electrical Engineering at the University of Washington, Seattle, WA, USA. In 1996, he joined the Department of Electronic Engineering, City University of Hong Kong, and was promoted to Chair Professor of Electronic Engineering in 1998. From 1998 to 2009, he was first Associate Dean and then Dean of College of Science and Engineering. He also served as Acting Provost of the university from July 2009 to September 2010. He is currently the Director of State Key Laboratory of Millimeter Waves, Partner Laboratory in the City University of Hong Kong. His current research interests include computational electromagnetics, millimeter-wave circuits and antennas, and terahertz science and technology.

Dr. Chan received the U.S. National Science Foundation Presidential Young Investigator Award in 1991 and the Joint Research Fund for Hong Kong and Macao Young Scholars, National Science Fund for Distinguished Young Scholars, China, in 2004. He received outstanding teacher awards from the Department of Electronic Engineering, CityU in 1998, 1999, 2000, and 2008. He is the General Co-Chair of ISAP 2010, iWAT2011, iWEM 2013, iCCEM 2015, iCCEM 2016 and GSMM2017.

A 60GHz CMOS Transceiver Chip with Antenna in Package

Abstract The techniques of a 60GHz CMOS transceiver chip with antenna in package (AiP) will be presented. Contents include: 1) Systematic consideration of the design of a millimeter wave module with CMOS chip and LTCC antenna as package in the same design; 2) Key components (amplifiers, oscillators, mixers, etc.) with innovative designs and improved performances used in the chip; 3) Novel planar aperture antennas with linear, dual, and circular polarizations for the application of AiP. These new techniques are expected to find wide applications in the coming 5G wireless communications.

Biography **Quan Xue** received the B.S., M.S., and Ph.D. degrees in electronic engineering from University of Electronic Science and Technology of China (UESTC), Chengdu, China, in 1988, 1991, and 1993, respectively. In 1993, he joined the UESTC, as a Lecturer. He became a Professor in 1997. From October 1997 to October 1998, he was a Research Associate and then a Research Fellow with the Chinese University of Hong Kong.

In 1999, he joined City University of Hong Kong where he is currently a Chair Professor of Microwave Engineering. He also served the University as the Associate Vice President (Innovation Advancement and China Office) (June 2011-Jan 2015), and is now the Director of Information and Communication Technology Center (ICTC center), and the Deputy Director of the State Key Lab of Millimeter Waves (Hong Kong).

He has authored or co-authored over 300 internationally referred journal papers and over 140 international conference papers. He is co-inventors of 5 granted Chinese patents and 17 granted US patents, in addition with 26 filed patents. His research interests include microwave/millimeter-wave/THz passive components, active components, antenna, microwave monolithic integrated circuits (MMIC, and radio frequency integrated circuits (RFIC) etc. Professor Xue is a Fellow of IEEE. He served the IEEE as an AdCom member of MTT-S (2011-2013) and the Associate Editor of IEEE Transactions on Microwave Theory and Techniques (2010-2013), the Editor of International Journal of Antennas and Propagation (2010-2013), the Associate Editor of IEEE Transactions on Industrial Electronics (2010-2015). He is now an Associate Editor of IEEE Transactions on Antennas and Propagation (2016-present).

Designs of Millimeter-Wave Dielectric Resonator Antennas

Abstract This talk will begin with the basic designs of 60-GHz dielectric resonator antennas (DRAs). Both linearly polarized (LP) and circularly polarized (CP) DRAs will be covered. Also, their 2´2 LP and CP DRA arrays will be presented. Next, two dual-frequency DRAs that simultaneously work at microwave and millimeter-wave bands will be given. A hollow DR working as 2.4-GHz DRA and 24-GHz Fabry-Perot resonator antenna (FPRA) will be presented first. It will be followed by a substrate-integrated DRA (SIDRA) that simultaneously operates at 5.2 GHz and 24 GHz. Finally, advantages of designing millimeter-wave DRAs with higher-order modes are discussed. By using higher-order modes, a simple cylindrical DRA that provides a wide bandwidth of 25.1 % (22.6–29.1 GHz) can be obtained easily. Both measured and simulated results will be presented in this talk.

Biography **Kwok Wa Leung** was born in Hong Kong. He received the B.Sc. degree in electronics and the Ph.D. degree in electronics engineering from the Chinese University of Hong Kong, Hong Kong, in 1990 and 1993, respectively. In 1994, he joined the Department of Electronic Engineering, City University of Hong Kong (CityU), where he was an Assistant Department Head from 2009 to 2013 and is currently a Chair Professor. From January to June, 2006, he was a Visiting Professor at the Department of Electrical Engineering, The Pennsylvania State University, State College, PA, USA. His research interests include antenna designs, guided wave theory, computational electromagnetics, and mobile communications.

Prof. Leung received the International Union of Radio Science (USRI) Young Scientists Awards in Japan and Russia, in 1993 and 1995, respectively. He also received the CityU Research Excellence Award in 2013, and Departmental Outstanding Teacher Awards in 2005, 2010, and 2011. His students received the 2015 iWEM Student Best Paper Award, 2015 IEEE AP-S Eugene F. Knott Memorial Pre-Doctoral Research Award, and 2014 IEEE MTT-S Undergraduate/Pre-graduate Scholarship. He was Chair of the IEEE AP/MTT Hong Kong Joint Chapter for 2006 and 2007. He was the Technical Program Chair, 2008 Asia-Pacific Microwave Conference, Hong Kong, the Technical Program Co-Chair, 2006 IEEE TENCON, Hong Kong, and the Finance Chair of PIERS 1997, Hong Kong. He was an Editor for HKIE Transactions and a Guest Editor of IET Microwaves, Antennas and Propagation. He served as Associate Editor for the IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS. Prof. Leung was also an Associate Editor of the IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION (TAP) and received Transactions Commendation Certificates twice, in 2009 and 2010, for his exceptional performance. He has been the Editor-in-Chief of TAP from August 2013 to July 2016, being the first Chinese and also the first appointed from Asia since the journal was founded in 1952. He was a Distinguished Lecturer of the IEEE Antennas and Propagation Society from 2012 to 2014 and is currently a member of the AP-S Distinguished Lecturer Program Committee. He is a Fellow of IEEE.

Design Techniques for 60 GHz Microstrip Antennas and Magneto-Electric Dipoles

Abstract Basic design techniques for microstrip antennas are reviewed. Technical issues on realization of 60 GHz microstrip antennas and arrays are discussed, including feeding structures, material used and fabrication technologies. Bandwidth enhancement techniques are described. The advantages of using magneto-electric dipoles over microstrip antennas are discussed. Techniques for generating circularly polarized antennas and dual polarized magneto-electric dipoles operating at millimeter-waves are presented. Efficient feeding networks for high-gain and multi-beam planar antenna designs are studied.

Biography **Kwai Man Luk** (M'79–SM'94–F'03) was born and educated in Hong Kong. He received the B.Sc.(Eng.) and Ph.D. degrees in electrical engineering from The University of Hong Kong in 1981 and 1985, respectively. He joined the Department of Electronic Engineering at City University of Hong Kong in 1985 as a Lecturer. Two years later, he moved to the Department of Electronic Engineering at The Chinese University of Hong Kong where he spent four years. In 1992, Professor Luk returned to the City University of Hong Kong, where he served as Head of Department of Electronic Engineering from 2004 – 2010 and Director of State Key Laboratory of Millimeter Waves from 2008 – 2013, and is currently Chair Professor of Electronic Engineering. His recent research interests include design of patch antennas, magneto-electric dipole antennas and dense dielectric patch antennas for various wireless applications. He is the author of 3 books, 10 research book chapters, over 333 journal papers and 250 conference papers. He was awarded 5 US and more than 10 PRC patents on the design of a wideband patch antenna with an L-shaped probe feed. He was Technical Program Chairperson of the 1997 Progress in Electromagnetics Research Symposium (PIERS), General Vice-Chairperson of the 1997 and 2008 Asia-Pacific Microwave Conference (APMC), General Chairman of the 2006 IEEE Region Ten Conference (TENCON), Technical Program Co-Chairperson of 2008 International Symposium on Antennas and Propagation (ISAP), and General Co-Chairperson of 2011 IEEE International Workshop on Antenna Technology (IWAT), General Co-Chair of 2014 IEEE International Conference on Antenna Measurements and Applications (CAMA), and General Co-Chair of 2015 International Conference on Infrared, millimeter, and Terahertz Waves (IRMMW-THz 2015) . Professor Luk received the Japan Microwave Prize, at the 1994 Asia Pacific Microwave Conference held in Chiba in December 1994, the Best Paper Award at the 2008 International Symposium on Antennas and Propagation held in Taipei in October 2008 and the Best Paper Award at the 2015 Asia-Pacific Conference on Antennas and Propagation held in Bali in July 2015. He was awarded the very competitive 2000 Croucher Foundation Senior Research Fellow in Hong Kong. He received the 2011 State Technological Invention Award (2nd Honor) of China. He was a Chief Guest Editor for a special issue on "Antennas in Wireless Communications" published in the Proceedings of the IEEE in July 2012. He is a Deputy Editor-in-Chief of PIERS journals and an Associate Editor of IET Microwaves, Antennas and Propagation. Professor Luk is a Fellow of the Chinese Institute of Electronics, PRC, a Fellow of the Institution of Engineering and Technology, UK, a Fellow of the Institute of Electrical and Electronics Engineers, USA and a Fellow of the Electromagnetics Academy, USA.