东南大学

2021 年国际暑期学校

项目主题：无线通信原理与关键技术国际暑期学校

开课院系：信息科学与工程学院

开设课程：无线通信系统概论

移动衰落信道建模

微波、毫米波与太赫兹前沿技术

开课时间：2021 年 7 月 18 日-2021 年 8 月 29 日

目录

1. 项目介绍

1.1. 项目主题：无线通信原理与关键技术国际暑期学校

International Summer School of Wireless Communication Principles and Key Technologies

1.2. 开课院系：信息科学与工程学院

School of Information Science and Engineering, Southeast University

1.3. 项目简介：

项目立足于东南大学信息学科综合优势，坚持学术导向，强化拓展培养，将通识教育、专业教育、学术交流和创新创业教育有机结合，全面提升学生综合素质。围绕无线通信系统的基本原理与前沿技术这一主题，开设《无线通信系统概论》、《移动衰落信道建模》、《微波、毫米波与太赫兹前沿技术》3 门全英文课程，由 4 名校内专任教师、8 名外籍教师、3 名企业教师共同参与，每门课程均包含理论授课、实验实践、国际大师讲座、企业教师讲座及参观座谈 5 部分内容。通过本项目的建设，学生将体验国内外专家学者的授课，接轨国际高校授课方式，紧密结合理论和应用，激发创新思维和学习积极性，为从事相关领域的工作和研究建立坚实基础。每门课程可获得 2 学分,共 32 学时，该课程面向所有电类专业的同学，课程考核方式是提交报告，对外校学生：三门课程成绩合格后，会获得学院开具的课程证明（或者是其他的上课证明）等相关说明。

This project is based on the overall advantages of information subject of Southeast University (SEU). It adheres to academic-oriented and strengthens expanding training by integrating general education, professional education, academic exchange, and innovation and entrepreneurship, thus enabling overall improvements of students’ comprehensive quality. By focusing our theme on the basic principles and technology frontiers of wireless communication systems, we set up three English courses, i.e., Introduction to Wireless Communication System, Mobile Fading Channel Modeling, and Frontiers of Microwave, Millimeter-wave and

Terahertz Technologies. Four SEU teachers, eight foreign teachers, and three company teachers will participate in this project. Each course has five parts, including theoretical teaching, experiments, talks given by international masters, talks given by company experts, and visit and discussion. From the construction of this project, students will experience classes by experts at home and abroad, be geared to international university teaching styles, closely combine theory and applications, inspire innovative thinking and learning activity, laying a solid foundation for work and research in related areas. Each course has 2 credits and 32 teaching hours. The assessment method for each course is to submit a report. The undergraduate applicants are preferred to major in electronics and information, automation, computer science or related area, and has excellent language ability. The foreign school students will get the course certificate (or other certificate of attendance) and other related instructions issued by the college after passing the three courses.

2. 课程介绍

2.1. Introduction to Wireless Communication System (无线通信系统概论)

本课程重点介绍无线通信系统的基础理论和关键技术，以及数字信号调制、传输、接收和均衡技术的过程。 将讨论各种调制技术以及性能分析方法。我们还将介绍数字通信中的一些进阶课题，例如信道均衡、信道编码和脉冲整形、多址接入和 OFDM。还将举办关于绿色智能通信、无人机毫米波通信、无线未来的三个有前途的范式和 5G 无线通信技术的四场特邀讲座。

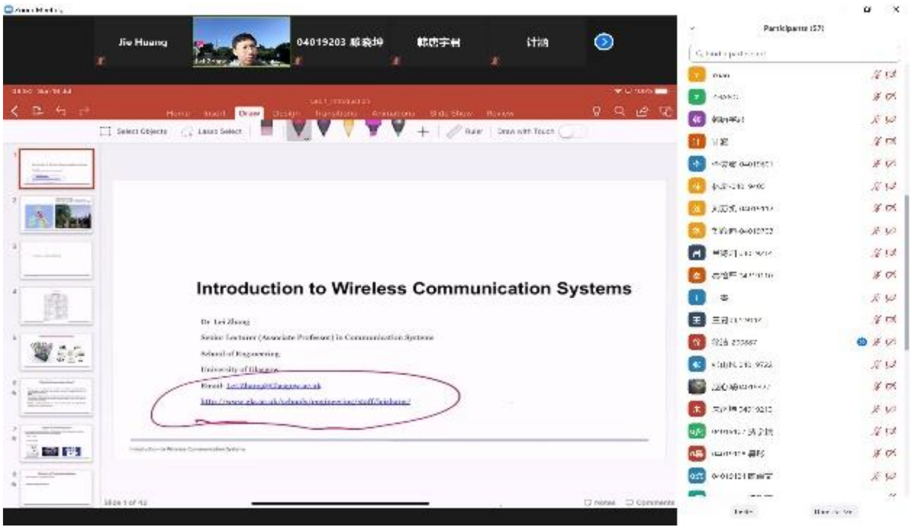
This course focuses on the fundamental theories and key technologies of wireless communication system, along with process of digital signal modulation, transmission, reception, and equalization techniques. Various modulation techniques will be discussed, as well as the performance analysis methods. We will also introduce some advanced topics in digital communications, such as channel equalization, channel coding and pulse shaping, multiple access, and OFDM. Four invited lectures on green and intelligent communications, millimeter wave communications for UAV, three promising paradigms for wireless future, and 5G wireless communication technologies will also be given.

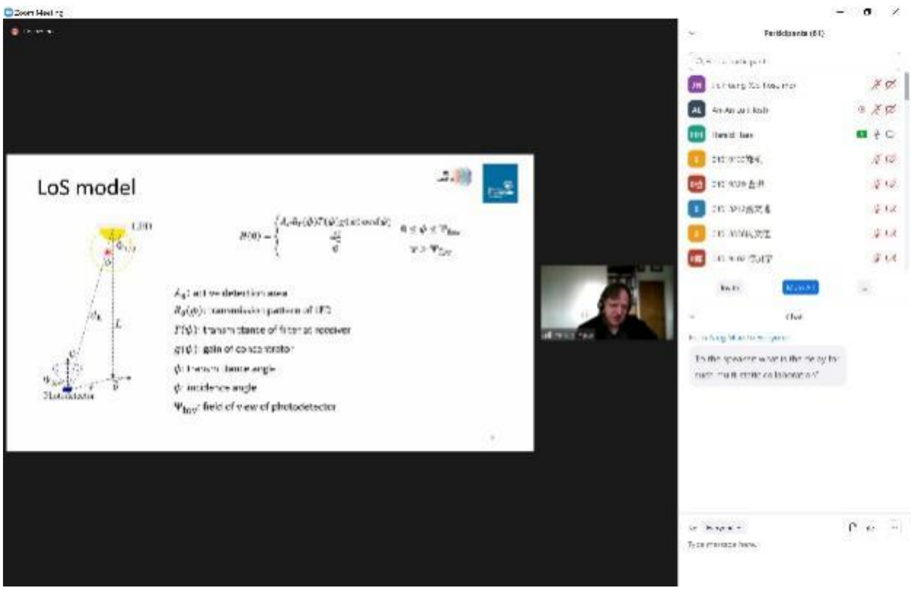
2.1.1. 教学日历

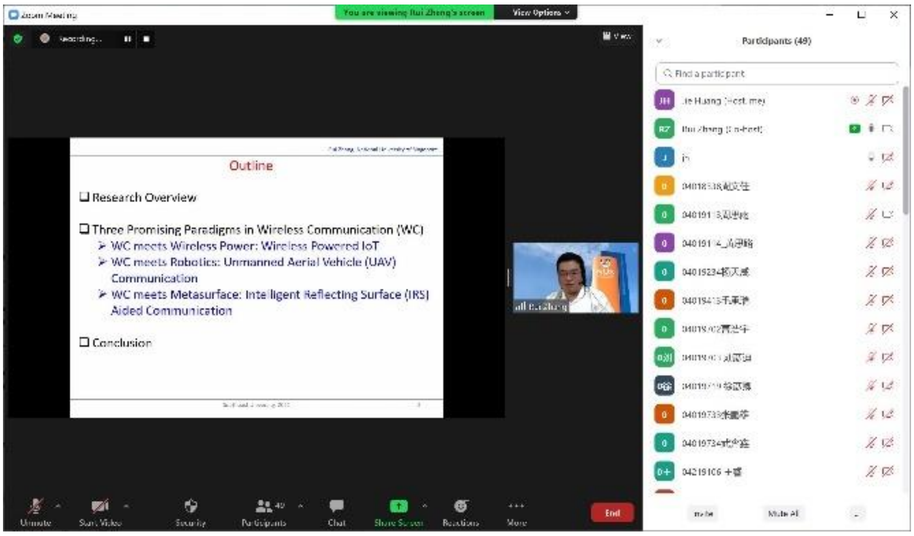
时间 Time	节数 Class	课程内容 Content	授课教师 Lecturer	授课平台 Platform
18-Jul 15:45-17:20	C1-C2	Introduction to wireless communication system	Lei Zhang	Zoom ID: 516 395 1064 Passcode: 2021
19-Jul 18:30-20:05	C3-C4	Digital signal modulation and demodulation	Lei Zhang	Zoom ID: 516 395 1064 Passcode: 2021
20-Jul 18:30-20:05	C5-C6	Digital signal modulation and demodulation	Lei Zhang	Zoom ID: 516 395 1064 Passcode: 2021
21-Jul 18:30-20:55	C7-C9	Signal detection theory and BER performance analysis	Lei Zhang	Zoom ID: 516 395 1064 Passcode: 2021
22-Jul 18:30-20:55	C10-C12	Channel equalization	Lei Zhang	Zoom ID: 516 395 1064 Passcode: 2021
23-Jul 18:30-20:55	C13-C15	Channel coding and pulse shaping	Lei Zhang	Zoom ID: 516 395 1064 Passcode: 2021
25-Jul 14:00-16:30	C16-C18	Experiments	Jie Huang	Zoom ID: 516 395 1064 Passcode: 2021
25-Jul 18:30-20:55	C19-C21	Multiple access and wireless channel	Lei Zhang	Zoom ID: 516 395 1064 Passcode: 2021
26-Jul 14:00-14:45	C22	Rui Zhang’s lecture	Rui Zhang	Zoom ID: 922 3747 7079 Passcode: 284763
27-Jul 10:00-10:45	C23	Wei Zhang’s lecture	Wei Zhang	Zoom ID: 940 6604 2648 Passcode: 966178
27-Jul 18:30-20:55	C24-C26	Multiple access and wireless channel	Lei Zhang	Zoom ID: 516 395 1064 Passcode: 2021
29-Jul 16:00-16:45	C27	John Thompson’s lecture	John Thompson	Zoom ID: 516 395 1064 Passcode: 2021
29-Jul	C28-C30	OFDM	Lei Zhang	Zoom ID: 516

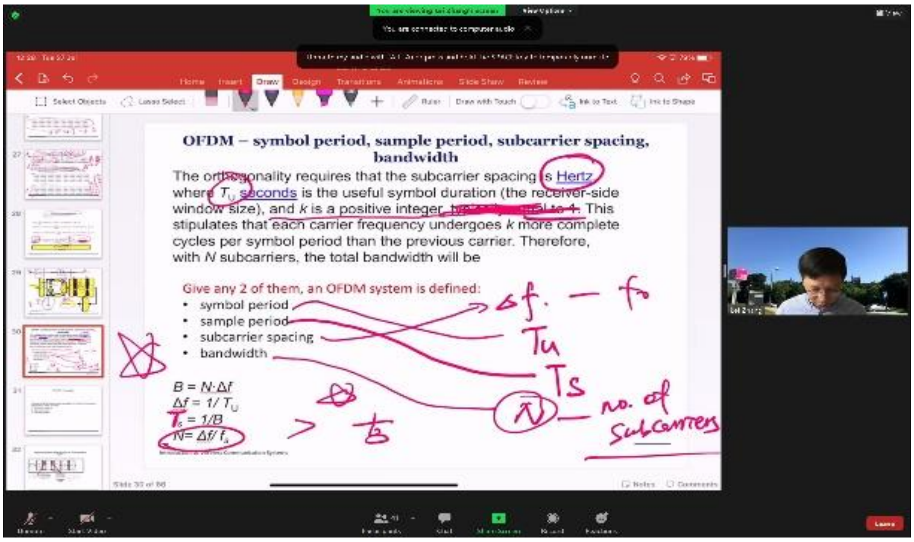
18:30-20:55				395 1064 Passcode: 2021
30-Jul 18:30-19:15	C31	Experiments and discussion	Jie Huang	Tencent ID: 574 138 285
4-Aug 19:00-19:45	C32	Jian Li’ s lecture	Jian Li	Tencent ID: 339 551 039

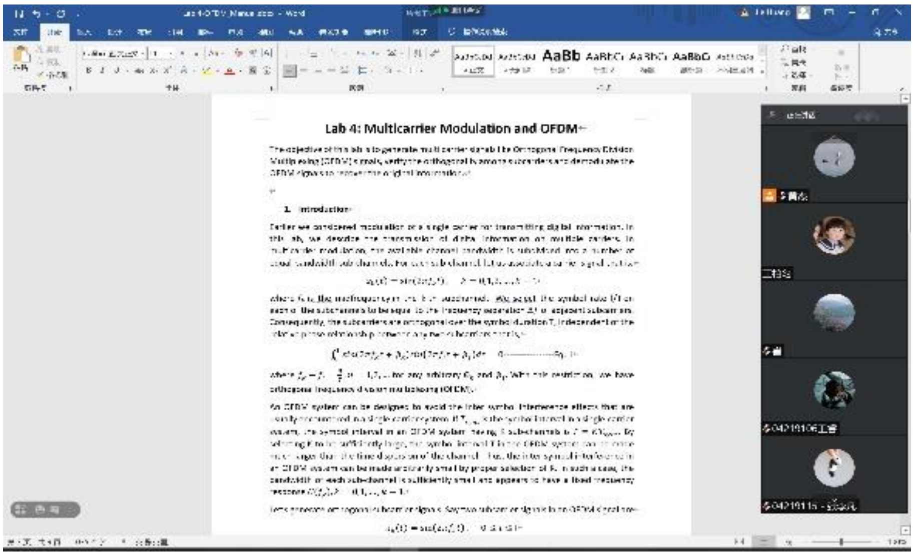
2.1.2. 课堂截图






Outline
Research Overview
Three Promising Paradigms in Wireless Communication (WC)
WC meets Wireless Power: Wireless Powered IoT
WC meets Robotics: Unmanned Aerial Vehicle (UAV) Communication
WC meets Metasurface: Intelligent Reflecting Surface (IRS) Aided Communication
Conclusion
Participants (49)


OFDM – symbol period, sample period, subcarrier spacing, bandwidth
Give any 2 of them, an OFDM system is defined:
symbol period
sample period
subcarrier spacing
bandwidth
B = N·Δf
Δf = 1/ T_u
T_s = 1/B
N= Δf/ f_s
no. of subcarriers


Lab 4: Multicarrier Modulation and OFDM
1. Introduction

2.1.3. 课程总结

本课程为 2021 年无线通信原理与关键技术国际暑期学校项目中的一门全英文课程，给学生简要介绍无线通信系统的基本概念，以及数字信号调制、传输、接收、均衡技术。学生将学习多种调制技术及其性能分析，以及多载波调制、传输、差错检测与纠正、正交频分复用（OFDM）等先进数字通信技术。此课程对学生学习通信原理及后续的移动通信等相关课程起到重要的支撑作用。另外，在培养学生严谨认真的科学态度，提出问题、分析问题和解决问题的能力等方面起重要作用。

课程包含理论授课、实验实践、课外研学讲座（国际大师、企业专家）几部分，邀请英国格拉斯哥大学张磊教授、英国爱丁堡大学 John Thompson 教授、新加坡国立大学张瑞教授、澳大利亚新南威尔士大学张伟教授、华为技术有限公司李剑博士参与。因疫情影响，课程采用线上授课方式。

本课程的学生反馈意见普遍较好。由于选课学生包含大二、大三本科生，部分学生专业基础较薄弱，较难跟上英文授课进度，建议在部分重点内容辅以中文讲解，将在后续授课中采纳。

2.2. Mobile Fading Channel Modeling (移动衰落信道建模)

本课程重点介绍移动衰落信道建模方法，将简要介绍移动衰落信道，然后讨论信道统计特性、各种信道模型参数计算方法以及不同的信道建模方法，提供标准通道模型的概述。同时，将研究 5G 关键技术和信道建模中的挑战，还将举办三场关于毫米波和太赫兹信道测量与建模、光无线通信以及无线通信关键技术进展的特邀讲座。

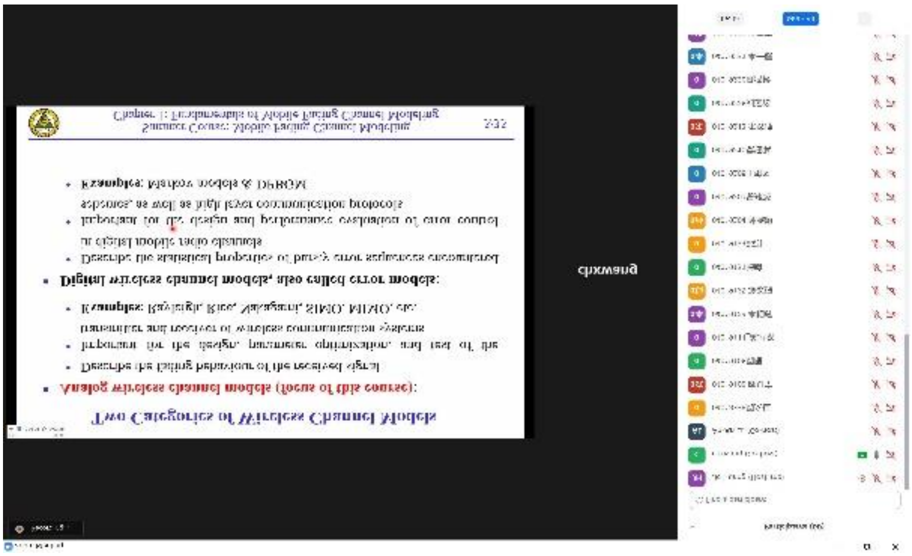
This course focuses on mobile fading channel modeling methods. A brief introduction of mobile fading channel will be given, followed by channel statistical properties, various channel model parameter computation methods, and different channel modeling methods will be discussed. An overview of standard channel models is then provided. Meanwhile, 5G key technologies and challenges in channel modeling will be investigated. Three invited lectures on millimeter wave and THz channel measurements and modeling, optical wireless communication, and advances in wireless communication key technologies will also be given.

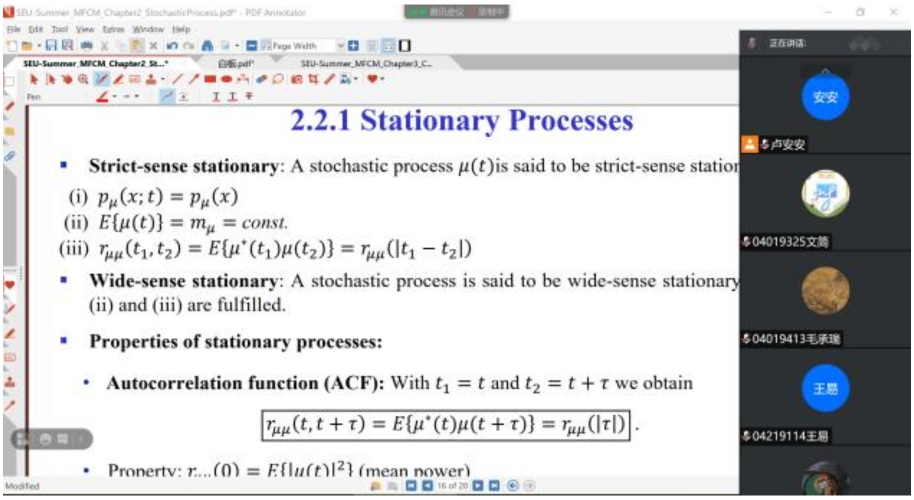
2.2.1. 教学日历

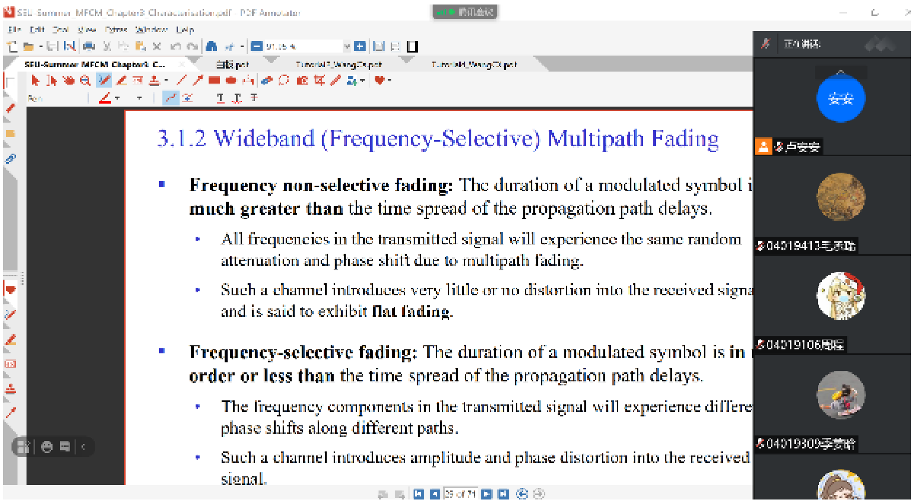
时间 Time	节数 Class	课程内容 Content	授课教师 Lecturer	授课平台 Platform
26-Jul 15:00-15:45	C1	Harald Haas’ s lecture	Harald Haas	Meeting ID: 336 157 0167 Passcode: G3sf22
26-Jul 18:30-20:05	C2-C3	Fundamentals of Mobile Fading Channel Modeling	Cheng-Xiang Wang	Zoom ID: 881 9214 6420 Passcode: G3sf22
28-Jul 18:30-20:05	C4-C5	Fundamentals of Mobile Fading Channel Modeling	An-An Lu	Zoom ID: 336 157 0167 Passcode: G3sf22
30-Jul 14:00-17:20	C6-C9	Random Variables, Stochastic Processes, and Deterministic Signals；Characterization and Modeling of Mobile Fading Channels	An-An Lu	Tencent ID: 465 571 554
30-Jul 20:10-20:55	C10	Experiments	An-An Lu	Tencent ID: 459 811 041
2-Aug 18:30-20:05	C11-C12	Characterization and Modeling of Mobile Fading Channels	An-An Lu	Tencent ID: 789 893 425
4-Aug 14:00-17:20	C13-C16	Characterization and Modeling of Mobile Fading Channels；Channel model parameter computation methods	Yang Miao	Zoom ID: 336 157 0167 Passcode: G3sf22
5-Aug 18:30-20:55	C17-C19	Experiments	An-An Lu	Tencent ID: 537 610 231
6-Aug 18:30-20:55	C20-C22	Comparison of Spatial Channel Model and KBSM；Non-Stationary High-Speed Train Wireless Channel Models	Jie Huang	Tencent ID: 727 112 273
9-Aug 18:30-20:55	C23-C25	Non-Stationary High-Speed Train Wireless Channel Models	Yang Miao	Zoom ID: 898 4053 4125 Passcode: G3sf22
11-Aug 18:30-20:05	C26-C27	Wireless Channel Models for 5G and Beyond	Jie Huang	Tencent ID: 966 930 183
12-Aug	C28	Zhimeng Zhong’ s Lecture	Zhimeng Zhong	Tencent ID: 137

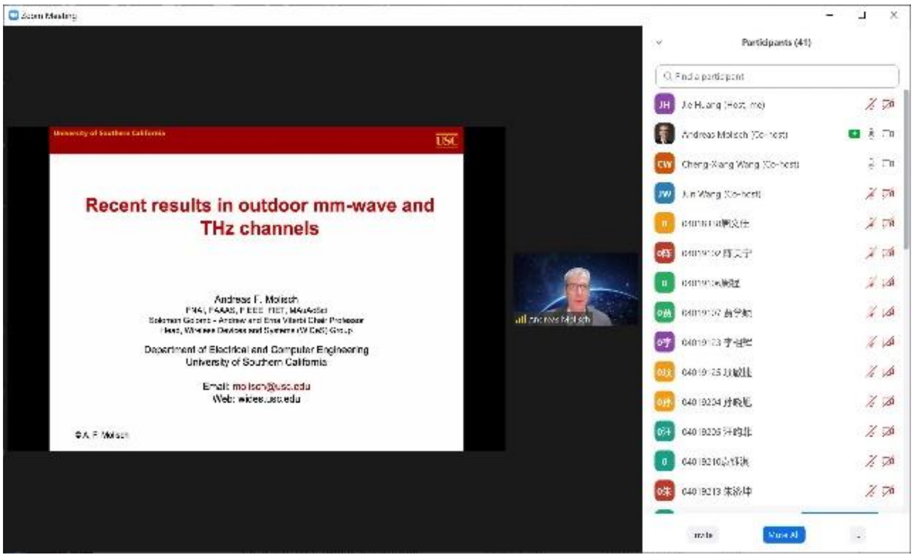
18:30-19:15				593 967
12-Aug 19:20-20:05	C29	Wireless Channel Models for 5G and Beyond	Jie Huang	Tencent ID: 137 593 967
13-Aug 12:00-12:45	C30	A. F. Molisch’ s Lecture	A. F. Molisch	Zoom ID: 336 157 0167 Passcode: G3sf22
13-Aug 18:30-20:05	C31-C32	Wireless Channel Models for 5G and Beyond	Jie Huang	Tencent ID: 314 706 203

2.2.2. 课堂截图




2.2.1 Stationary Processes
Strict-sense stationary: A stochastic process $\mu(t)$ is said to be strict-sense station
(i) $p_\mu(x;t) = p_\mu(x)$
(ii) $E\{\mu(t)\} = m_\mu = const.$
(iii) $r_{\mu\mu}(t_1,t_2) = E\{\mu^*(t_1)\mu(t_2)\} = r_{\mu\mu}(|t_1 - t_2|)$
Wide-sense stationary: A stochastic process is said to be wide-sense stationary
(ii) and (iii) are fulfilled.
Properties of stationary processes:
Autocorrelation function (ACF): With $t_1 = t$ and $t_2 = t + \tau$ we obtain
$r_{\mu\mu}(t,t+\tau) = E\{\mu^*(t)\mu(t+\tau)\} = r_{\mu\mu}(|\tau|)$.
卢安安
04019325文涛
04019413毛承瑞
王易
04219114王易


3.1.2 Wideband (Frequency-Selective) Multipath Fading
Frequency non-selective fading: The duration of a modulated symbol i
much greater than the time spread of the propagation path delays.
All frequencies in the transmitted signal will experience the same random attenuation and phase shift due to multipath fading.
Such a channel introduces very little or no distortion into the received signa and is said to exhibit flat fading.
Frequency-selective fading: The duration of a modulated symbol is in order or less than the time spread of the propagation path delays.
The frequency components in the transmitted signal will experience differe phase shifts along different paths.
Such a channel introduces amplitude and phase distortion into the received signal.
卢安安
04019413毛承瑞


Zoom Meeting
Participants (41)
Recent results in outdoor mm-wave and THz channels
Andreas F. Molisch
University of Southern California
Email: molisch@usc.edu

2.2.3. 课程总结

这门课程是全英文的研讨课， 学生刚开始听全英文的课程还是有些难度， 只能听懂60%-70%。 此外暑期学校的课程节奏比较快，学生听的有些吃力。在以后的授课中， 为了改进授课效果， 在刚开始的几节课可以适当放慢速度，还会结合暑期学校的特点改进 PPT 和课程顺序。

2.3. Frontiers of Microwave, Millimeter-wave and Terahertz Technologies (微波、毫米波与太赫兹前沿技术)

本课程介绍微波、毫米波和太赫兹技术的基础知识和应用，以及它们的最新发展。 具体详细介绍了以下内容： 微波、毫米波和太赫兹技术的发展历程； 电磁方程和电磁波的基础知识； 微波网络理论及其应用； 电磁导波理论及其应用，以及在先进滤波器设计中的应用； 下一代卫星和 5G/6G 无线通信系统中的微波和毫米波技术； 雷达系统基础知识； 先进相控阵雷达技术及其最新发展。本课程帮助学生掌握微波、毫米波和太赫兹技术的基础知识，了解它们的应用，建立微波技术的“场”概念。

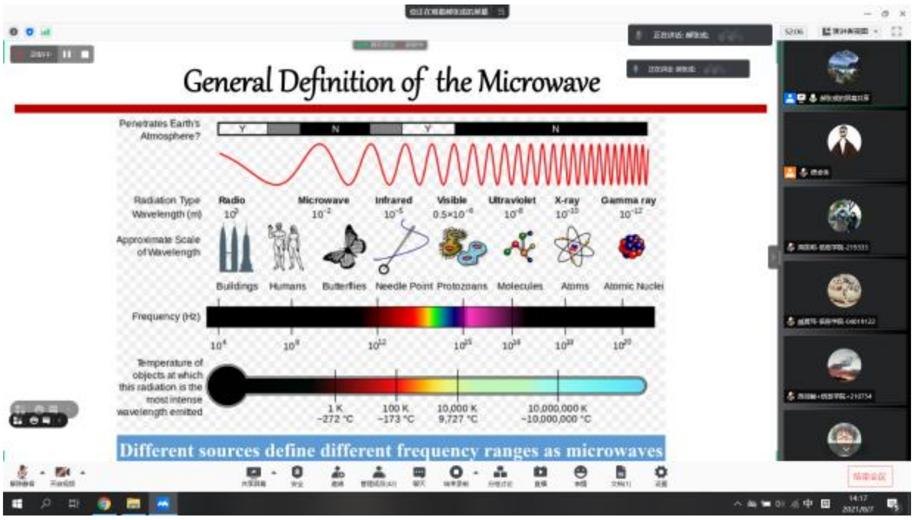
This course introduces the fundamental knowledge and application of microwave, millimeter-wave and terahertz techniques, as well as their recent developments. Specifically, following contents are introduced in detail: The development history of microwave, millimeter-wave and terahertz technology; The basic knowledge of electromagnetic equations and electromagnetic wave; Microwave network theory and its applications; Electromagnetic guided-wave theory and its applications, as well as its applications in the advanced filter design; Microwave and millimeter-wave technology in the next generation satellite and 5G/6G wireless communication systems; Basic knowledge of radar system; Advanced phased array radar technology and its recent development. This course helps students master the basic knowledge of microwave, millimeter-wave and terahertz technology, understand their applications, and establish the “field” concept of the microwave technology.

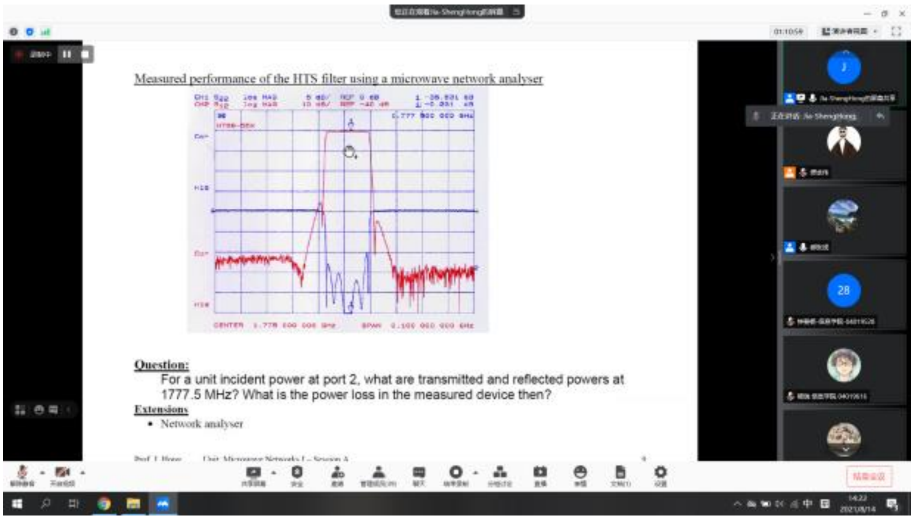
2.3.1. 教学日历

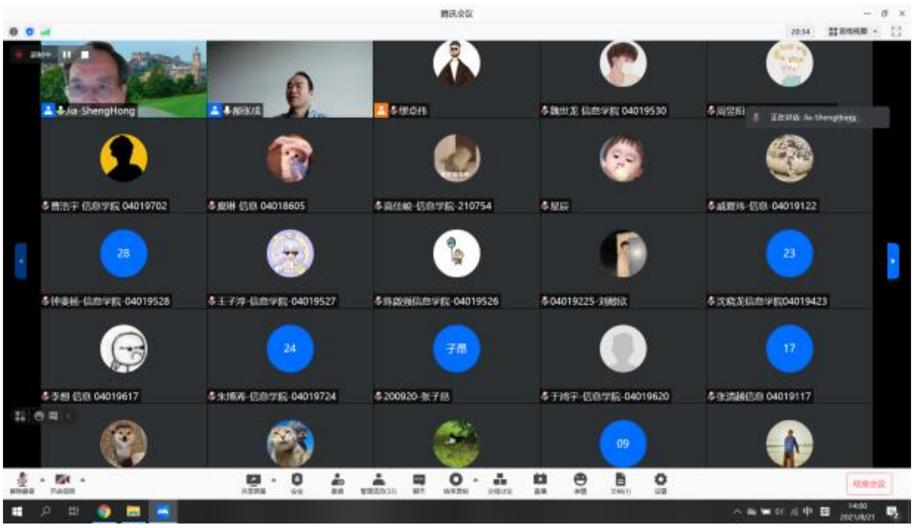
时间 Time	节数 Class	课程内容 Content	授课教师 Lecture	授课平台 Platform ID
7-Aug. 14:00-17:25 (Beijing Time)	C6-C9	Introduction and Overviewing of Microwave, Millimeter-wave and Terahertz	Prof. Zhang-Cheng Hao	466 1569 3791

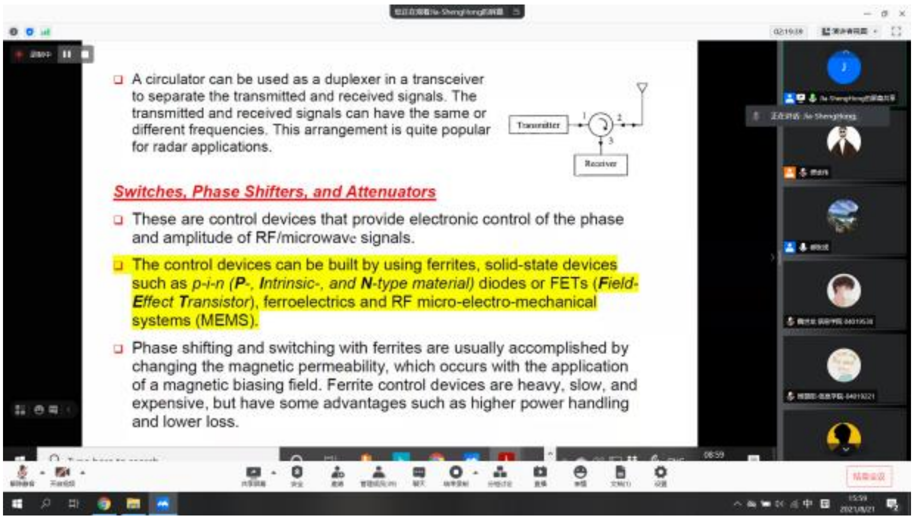
		Technologies		
8-Aug. 14:00-17:25 (Beijing Time)	C6-C9	Fundamental Equations of Electromagnetic Waves and Their Applications	Prof. Jia-Sheng Hong	980 4709 9431
14-Aug 14:00-17:25 (Beijing Time)	C6-C9	Microwave Network and Applications	Prof. Jia-Sheng Hong	466 1569 3791
15-Aug 14:00-17:25 (Beijing Time)	C6-C9	Guide-Wave Techniques and Fundamental Theories of Filters	Prof. Jia-Sheng Hong	980 4709 9431
21-Aug. 14:00-17:25 (Beijing Time)	C6-C9	Microwave and Miliimeter-wave Techniques in the Next Generation Satellite and 5G/6G Communication Systems	Prof. Jia-Sheng Hong	466 1569 3791
22-Aug 14:00-17:25 (Beijing Time)	C6-C9	Introduction of Radar Techniques and Relative Theory	Dr. Hong-Chao Wu	980 4709 9431
29-Aug 14:00-17:25 (Beijing Time)	C6-C9	The Modern Phase-Array Radar and its Key Techniques	Dr. Hong-Chao Wu	980 4709 9431

2.3.2. 课堂截图


General Definition of the Microwave
Penetrates Earth's Atmosphere?
Radiation Type
Wavelength (m)
Approximate Scale of Wavelength
Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma ray
Buildings
Humans
Butterflies
Needle Point
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (Hz)
Temperature of objects at which this radiation is the most intense wavelength emitted
Different sources define different frequency ranges as microwaves


Measured performance of the HTS filter using a microwave network analyser
Question:
For a unit incident power at port 2, what are transmitted and reflected powers at 1777.5 MHz? What is the power loss in the measured device then?
Extensions
• Network analyser


Jia-ShengHong



2.3.3. 课程总结

本课程介绍微波、毫米波和太赫兹技术的基础知识和应用，以及它们的最新发展。通过该课程有效扩展了学生视野，拓展了其兴趣。网课中由于师生不是面对面教学，师生互动效果仍需要进一步加强。