

ME1130

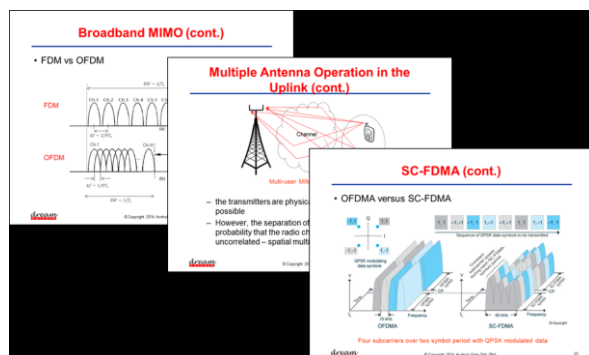
Essentials of LTE and LTE-Advanced

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Teaching Slides

- Editable Microsoft® PowerPoint® slides
- Covers 45 hours of teaching



Training Kit

- LTE Radio-Access Node (eNodeB) and Core Network Nodes (EPC) hardware set
- LTE UE
- GNU Radio with SDR
- Lab sheets and model answers
- Problem-based assignments



Target university subject	Target year of study	Prerequisite(s)
Advanced Mobile Communications	Third or Fourth-year undergraduate	Digital Communications Digital Modulations

The ME1130 serves as a ready-to-teach package for in-depth understanding and hands-on experience on LTE and LTE-Advanced technologies. The PC-based implementation of LTE's eNodeB and EPC is a powerful platform for students to explore LTE protocols and learn how to build a standalone LTE network. This set up is useful both for teaching and research. The complete teaching resources include teaching slides, training kits, lab sheets, and problem-based assignments.

Learning Outcomes

Students would be able to:

- Describe the main features of LTE and LTE-A
- Describe the overall system architecture of the radio access network and the core network
- Analyze the LTE protocols (e.g., PHY, MAC, etc)
- Configure and set up an end-to-end experimental LTE network
- Analyze OFDM/SC-FDMA signals in time and frequency domains
- Measure and analyze LTE signals

Benefits of the ME1130 courseware

- The hardware kit is a standard-compliant implementation of a subset of 3GPP Release 10 LTE for UE, eNodeB, MME, HSS, SGW and PGW on standard Linux-based computer. A software-defined radio is used as the RF front-end of the LTE eNodeB. This powerful and flexible platform is useful for both teaching and research.
- The training kit can be used for both simulation and real-time implementation of the LTE network. Students will learn how to configure and connect a commercial off-the-shelf (COTS) UE (e.g., smartphone) to the LTE network (the soft eNodeB and EPC) and gain further insight on the real-time signal processing and protocols of LTE.
- GNU radio with another SDR is configured to be a signal analyzer to provide LTE spectrum analysis capabilities.



Teaching Slides

More than 400 editable Microsoft PowerPoint teaching slides, covering 45 hours of teaching for one full semester are provided. The slides cover the following topics:

- Introduction to LTE
- OFDMA, SC-FDMA, and MIMO Techniques
- LTE System Architecture
- LTE Protocols
- Spectrum and RF Aspects of LTE
- LTE-A and Beyond



Training Kit

LTE Hardware Kit

1. LTE eNodeB & EPC

The ME1130 uses a software-based approach to implement a standard-compliant LTE for UE, eNodeB, MME, HSS, SGw, and PGw on standard Linux-based computer (software preinstalled on an Intel i7 mini PC). It incorporates a software-defined radio (SDR) as the RF front-end with continuous spectrum coverage from 100 kHz to 3.8 GHz and support full-duplex, 2x2 MIMO operation with up to 60 MHz of bandwidth.

The ME1130 training kit is a versatile system that can be configured to work as an offline system for simulation or as a real-time system for over-the-air transmission and testing. One of its special features is the system can be configured as a standalone LTE network and commercial off-the-shelf (COTS) UE (e.g., modem or smartphone) can be used for accessing the network. This allows for greater insight into the real-time signals and protocols of an LTE network.

Open-source software-based implementation of the LTE Core (EPC) and Radio-Access Network (eNodeB) is pre-installed on a provided mini PC. The 3GPP standard-compliant software ensures interoperability with other closed-source commercial equipment in either part of the network. For example, standard COTS LTE device can connect to the LTE software for rapid proof-of-concept demonstration of real-time LTE protocols.



2. LTE UE

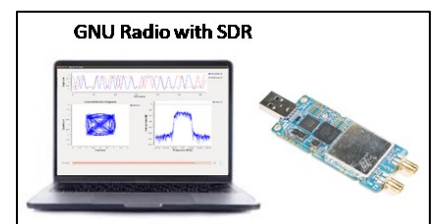
A 4G LTE 150Mbps USB Modem with test SIM is used as user equipment to provide an end-to-end LTE connection.



3. GNU Radio with SDR

GNU Radio is a software development framework that enables users to design, simulate, and deploy highly capable real-world software defined radios. The framework offers a graphical design approach in addition to supporting development in Python and C++. It's configured here with a SDR mini to provide LTE spectrum analysis.

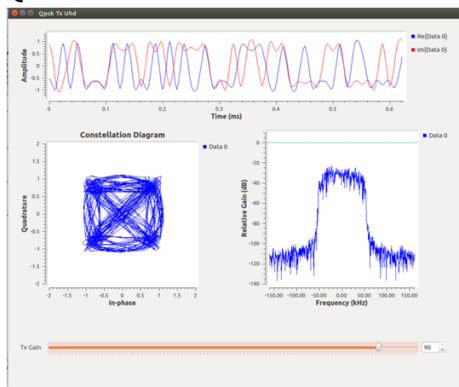
Note: PC not included



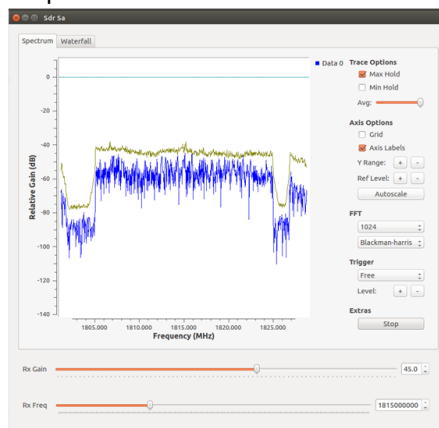
In order to comply with various countries' requirements for wireless devices and to avoid getting interfering signals from the public network while experimenting with the setup, this setup uses a direct RF cable connection instead of over the air transmission.

Example: Screenshots from the GNU Radio with the SDR

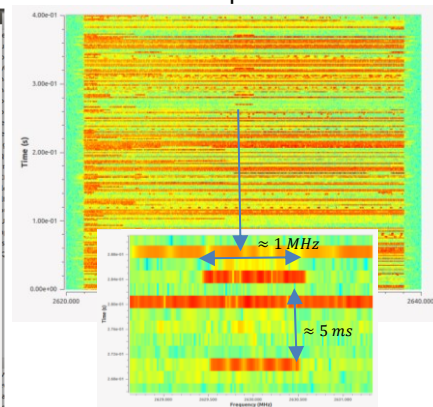
QPSK Modulated baseband



Spectrum scan in Band 3



Waterfall plot



Accessories

The following accessories are provided with the training kit.

Item	Quantity
RF attenuator: 1 x 10dB, 2 x 20dB, 2 x 60 dB	1 set
SMA RF cable: 2 x 1.0m	1 set
SMA to CRC9 RF cable	2 pcs
USB cable: 1 x 1.0m, 1 x 0.5m	1 set
Power adaptor for MiniPC	1 pc

Lab Sheets

The training kit includes six lab sheets in editable Microsoft® Word format. Each lab requires three hours to complete. Model answers are provided with all lab sheets. The required instruments for the labs are listed below.

Lab Sheet	Required Items (not provided)
	MATLAB
1. LTE Spectrum Analysis Using GNU Radio and SDR	
2. LTE Network Emulation: Configuration and implementation of eNodeB, EPC, and UE	
3. FDD-LTE Symbol Timing Recovery and Fractional Frequency Offset Compensation	✓
4. LTE Cell Search: Cell ID Detection Using PSS and SSS	✓
5. LTE Protocol Analysis	
6. LTE network Performance Evaluation	

Problem-Based Assignments

The problem-based assignments below allow students to enhance their problem-solving skills.

1. Set up a standalone LTE network that allows an off-the-shelf UE to access the network and perform testing and evaluation.
2. Implement and analyze standard MAC scheduler using the emulation environment of the LTE software
3. Configure the soft modem (LTE software + SDR) as UE to receive LTE signal from a commercial base station

Training Kit Hardware Specifications

LTE Training Kit	
Embedded PC	
Processor	Intel® Core™ i7
Operating System	Ubuntu 14.04.4 LTS
Memory	8 GB
Hard Drive	120 GB SSD
Software-Defined Radio For LTE	
Frequency Range	100 kHz - 3.8 GHz
Bandwidth	61.44 MHz
Sample Depth/Rate	12-bit / 61.44 MSPS
TX & RX Channels	2 x 2
Duplex	Full
Programmable Logic Gates	40k
Software-Defined Radio as LTE Analyzer	
Frequency Range	10 MHz - 3.5 GHz
Bandwidth	30.72 MHz
Sample Depth/Rate	12-bit / 30.72MSPS
TX & RX Channels	1 x 1
Duplex	Full
Programmable Logic Gates	16k
LTE UE USB Modem	
Speed	LTE FDD: Cat4 DL: 150Mbps / UL: 50 Mbps @20 M BW UMTS: DCHSPA+: 42 / 5.76 Mbps; 21 M / 5.76 Mbps; 14 M / 5.76 M HSUPA: 7.2 M / 5.76 M 2G: EDGE packet data service of up to 236.8 kbps
Hardware kit warranty	1 year

Ordering Information

Description	Package	Product Number
Teaching Slides	1 user license	ME1130-100
Training Kit	1 set	ME1130-200
Teaching Slides + Training Kit	1 user license + 1 set	ME1130-300

Training courses related to subject matter are available on request. Visit dreamcatcher.asia for details.

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