RF education & research

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Wireless content in a smart phone

Cellular modem:
LTE Cat4 (150Mb/s DL & 50Mb/s UL), HSPA+, EV-DO, TD-SCDMA

Application processor

RFIC: 2/3/4G TRx

RFIC: 4G CA TRx

PMIC WLS

PMIC other

16/64/128GB NAND Flash

NFC

BT LE

BT

WLAN

3G/2G PA

MB PA

HB PA

ANT SW

UHB PA

ET

LB PA

PA modules incl. Duplex filters

https://www.ifixit.com/Teardown/iPhone+6+Plus+Teardown/29206
2G/3G/4G RF transceiver
with 8 band support

Digital signal processing implementing wireless algorithms
Competences of a modern RF engineer

Fundamentals

• Understand various applications of radios
• Master very well basic principles of communications
• Master very well basics of electronics design
• Excel in fundamentals of RF from Smith chart and matching to noise and non-linearity
• Prototyping and measuring RF
• Computer tools for electronics design
Competences of a modern RF engineer

Advanced
- RF transceiver architectures
- RF system design and block level partitioning
- RF control algorithms
- IC design
- Communication circuits (LNA, PA, mixers, filters, amplifiers, ADCs, DAC’s, VCO’s, PLL’s, digital for RF, …)
- Antenna design
- Radio propagation
- Various implementation technologies: fundamentals and their boundaries (CMOS, BiCMOS, SiGe, HBT, GaN, SAW, BAW, PCB, …)
- Material physics in some cases when closely involved to electronics
- Digital signal processing for wireless
- Embedded programming
- …
Competences of a modern RF engineer

Capability to co-operate and learn new things
- With and from your close colleagues
- In cross-disciplinary topics
- On your own

Team work
Prerequisites for WCE-RF

Basic courses of electronics: Understanding small signal behavior of a transistor in addition to circuit theory as prerequisite for Electronics design II & III

Preferably basic course of radio technology/microwave engineering to support further studies in Radio Engineering I & II
# WCE–RF Schedule — 1st Year

## Autumn 2019
**Periods 1-2**

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
<th>Periods</th>
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<tbody>
<tr>
<td>Electronics Design II</td>
<td>6 cr, 1 p</td>
<td>Period 1-2</td>
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<tr>
<td>Electronics Design III</td>
<td>6 cr, 2 p</td>
<td>Period 1-2</td>
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<tr>
<td>Statistical Signal Processing</td>
<td>5 cr, 1 p</td>
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<tr>
<td>Radio Engineering I</td>
<td>5 cr, 2 p</td>
<td>Period 1-2</td>
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<tr>
<td>Broadband Communications Systems</td>
<td>5 cr, 1 p</td>
<td>Period 1-2</td>
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<tr>
<td>Wireless Communications I</td>
<td>5 cr, 2 p</td>
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<td>5 cr, 1 p</td>
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<tr>
<td>Radio Engineering II</td>
<td>6 cr, 3 p</td>
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<tr>
<td>Wireless Communications I</td>
<td>5 cr, 2 p</td>
<td>Period 1-2</td>
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<tr>
<td>Radio Channels</td>
<td>5 cr, 4 p</td>
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<tr>
<td>Advanced Practical Training (3 cr)</td>
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<td>Period 1-2</td>
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<tr>
<td>Optional Course</td>
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<td>Period 1-2</td>
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<tr>
<td>Finnish Language studies (2-10 cr)</td>
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<td>Period 1-2</td>
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## Spring 2020
**Periods 3-4**

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<tr>
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</thead>
<tbody>
<tr>
<td>Electronics Design III</td>
<td>6 cr, 2 p</td>
<td>Period 3-4</td>
</tr>
<tr>
<td>Commun. Signal Processing I</td>
<td>5 cr, 3 p</td>
<td>Period 3-4</td>
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<tr>
<td>RF Components and Measurements</td>
<td>5 cr, 4 p</td>
<td>Period 3-4</td>
</tr>
<tr>
<td>Radio Engineering II</td>
<td>6 cr, 3 p</td>
<td>Period 3-4</td>
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<td>Finnish Language studies (2-10 cr)</td>
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**Finnish Language studies (2-10 cr) and/or optional studies depending on personal study plan**

**Basic Studies**

**Advanced Studies**

**Optional Studies**
WCE–RF Schedule — 2nd Year

Autumn 2020
Periods 1-2

Electronic System Design (5 cr, 1 p)

Communications Circuit Design (6 cr, 1 p)

Optional Course

Optional Course

Spring 2021
Periods 3-4

Diploma (M.Sc.) Thesis Work (30 cr, 2-4 p)

Telecommunication Engineering Project (5 cr)

or

Electronics Design and Construction Exercise (6 cr, 1-2 p)

(one of these is mandatory)

Finnish Language studies (2-10 cr) and/or optional studies to fulfill PSP requirements

Basic Studies

Advanced Studies

Optional Studies
RF at University of Oulu

RF system analysis

RF and antenna lab

Complete platforms

RF related algorithms

IC design

Antennas
Facilities

- State-of-the-art design tools from RF system design (Agilent ADS and System Vue), RFIC design (Cadence flow), antenna design tools (CST,…) and PCB design
- Industrial and research ecosystem in Oulu region provides local facilities for all necessary electronics manufacturing (except IC that is done using MPW runs)
- Measurement capabilities for RF designs currently up to 67GHz and 2GHz bandwidth for modulated signals (antennas up to 18GHz)
- Measurement capability will be extended to 100GHz range and also to 300GHz region during 2020
5G mmW – platform

28GHz radio module done in CWC
Focus in HW is on key enabling technologies for 6G from materials to transceivers and sensing at THz range (0.1THz onwards)

Approach from systems to HW and back

Silicon based transceiver design from blocks to systems

Integration, scalability and performance of antenna arrays including challenge of wideband modulation

New technologies and materials beyond IC core

Build on the top of 5G experience, investing in THz to meet the goals