GLOBAL MARKETS, GLOBAL TECHNOLOGY, AND GLOBAL STUDENTS?

A COMMUNICATIONS CONTRIBUTION TO THE WORKSHOP, “THE FUTURE OF & TECHNOLOGY” UNIVERSITY OF FLORIDA @ GAINESVILLE

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THE

DEPARTMENT OF ELECTRICAL ENGINEERING

With the approval of the Faculty
hereby recognizes the permanent appointment of

ULRICH L. ROHDE

as

Professor of Electrical Engineering

March 15, 1977
THE GEORGE WASHINGTON UNIVERSITY

THE

DEPARTMENT OF ELECTRICAL ENGINEERING

With the approval of the Faculty
hereby recognizes the permanent appointment of

Ulrich L. Rohde

as

Adjunct Professor of Electrical Engineering

Arthur D. Friedman
Chairman, Department of Electrical Engineering

May 4, 1982
GLOBAL MARKETS, GLOBAL TECHNOLOGY, GLOBAL STUDENTS

Using the example of the cell phone industry
International communications market

- The technologies involved are a combination of analog and digital applications as well as passive and active components.
- The globally/universally useful RF engineering additionally understands:
  - A/D converters
  - DSP, digital signal processing (DSP),
  - Micro processor coding in C++
  - Business education (MBA)
  - Innovative design with an eye for quality and reliability of the product.
RF front ends consists of:
- Analog low noise preamplifiers
- “Linear mixers”
- PLL based synthesizers with low power consumption

Design parameters may be:
- Noise figure, i.e.: < 1dB
- Intermodulation distortion IP3>1dBm
- Input selectivity,
- Phase noise (-145dBc/Hz @ 200KHz)
- Settling speed, less than 1mS
Digital Technology Example

- Analog to digital converters (A/D)
  - Optimized IF frequencies
  - Impedance matching
  - Overload vs. noise figure
- Design decisions may be:
  - IF selectivity
  - Coding scheme
  - Composite filters implementation in DSP
  - Automatic gain routines
  - Computational delay time
ANALOG AND DIGITAL TECHNIQUES
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Using the example of the cell phone industry
Evolution of the cellular technologies

- **1G**: Voice
- **2G**: Voice, SMS
- **3G**: Voice, SMS, Web
- **4G**: Voice, Audio, Video, Apps
- **5G**: Audio, Video, Apps, AR/VR (eMBB), Sensors (mMTC), Sensors/Actuators (URLLC)
EVOLUTION OF DIGITAL CELLULAR TECHNOLOGIES

2G
- Mainly GSM
  - Narrowband 270 kHz
- Few frequencies
  - 900/1800/1900 MHz
- No global frequencies
- Low data rates
  - Initially 9.6 kbps
  - Evolving up to 384 kbps
- Very high latency

3G
- Mainly WCDMA
  - Bandwidth 5 MHz
- Initially 2.1 GHz
  - Almost global availability
  - Evolved to a global standard
- Data rates
  - 384 kBit/s evolving to 42 Mbit/s
- Medium latency
  - Suffered from IPR fights

4G
- LTE
  - Flexible bandwidth up to 20 MHz
  - Deployed from 400 MHz to 3.7 GHz
- Data rates
  - From 40 Mbit/s to today's 1.2 Gbit/s
- Low latency

5G
- 5G NR
  - Scalable bandwidth up to 400 MHz
  - Frequencies up to 53 GHz
- Very high data rates
  - Ultra low latency possible
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Winners and others: Some examples
Winners

• Apple
  • Entered the mobile world 2007
  • Most profitable since manufacturer 2009

• Samsung
  • Scale of economy
  • In house touch screen expertise
  • Worlds largest manufacturer

• Google
  • Android has 85% market share as mobile OS
  • 38% of all devices connected to the internet are using Android
  • 2021 – 3 billion active devices
Nokia
- 2009 the largest cellphone maker in the world
- Too proud to adopt Android
- Strong innovation culture – failed to bring innovations to the market – sold to Microsoft – Name sold to HMD

Motorola
- Sold to Google – sold to Lenovo

Ericsson
- Cellphones was a mean to sell infrastructure - when 3G matured – not capable to compete.
- Sold to Sony

Blackberry
- Focused on messaging
- Missed the touch screen revolution

Huawei
- First cellphones 2003
- 2019 worlds second largest supplier of smartphones
- "Killed" by US trade sanctions
CELLPHONE SHIPMENTS UNTIL 2021

SOURCE: WWW.STATISTA.COM
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Looking Forward: What will drive the technological development?
The number of mobile subscriptions exceeds the population in many countries, which is largely due to inactive subscriptions, multiple device ownership or optimization of subscriptions for different types of calls.

Today, there are around 5.6 billion subscribers globally compared to 7.9 billion subscriptions.

Global subscription penetration is at 104 percent in Q3 2018.

There were 120 million new mobile subscriptions globally in Q3 2018.

Top countries by net additions Q3 2018:
1. China (+37 million)
2. India (+31 million)
3. Indonesia (+13 million)

New mobile subscriptions Q3 2018 (million):
- North America: 2
- Middle East: 2
- Western Europe: 4
- Central and Eastern Europe: 14
- Africa: 27
- APAC (excluding China and India): 37
- China: 31
- India: 26
- Latin America: 25

Subscription penetration Q3 2018 (percent of population) *excluding China and India:
- Western Europe: 123%
- China: 142%
- Central and Eastern Europe: 82%
- Africa: 104%
- Latin America: 104%
- North America: 111%
- Middle East: 87%
- India: 117%
- APAC: 117%
THE FUTURE OF WIRELESS TECHNOLOGIES

SOURCE: ERICSSON MOBILITY REPORT

Figure 1: Mobile subscriptions by technology (billion)

- **3.5bn**
  - In 2026, 3.5 billion 5G subscriptions are forecast.

Note: IoT connections are not included in this graph. Fixed wireless access (FWA) connections are included.
DATA WILL BE DRIVING THE FUTURE OF THE CELLULAR INDUSTRY
Higher data rates require bandwidth only available at higher frequencies.

- Different propagation: may require redesign
  - Significant different propagation
    - Transmission through most objects is reduced but reflection is amplified.
    - Foliage loss is severe.
    - High pathloss component requires massive MIMO / beamforming technologies using active antennas.

- Known characteristics: LTE-A evolution possible

Disruptive technology likely

Phase I

Phase II

Phase III

- Frequency bands:
  - V-Band
  - E-Band
  - W-Band
FIRST 6G DEMOSTRATORS USING D-BAND
AIMING FOR COMMERCIALIZATION 2029

https://www.lgnewsroom.com/2021/08/lg-records-6g-thz-band-milestone/
How has the cellphone antenna developed over the years?
Antennas in a modern cellphone

Not just one antenna

- Up to 10 different frequency bands
- Multiple cellular technologies: GSM, UMTS, LTE, TD-SCDMA
- Non cellular technologies: WiFi, Bluetooth, GPS, Glonass, Galileo, Baidu, NFC
- Receive diversity antennas
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What tools are available for the RF engineers?
Wideband Signal Testing
- Signal generator
- DUT
- Spectrum Analyzer

Channel Sounding Solution
- Signal generator
- Fast measurement in time domain
- Support for in- and outdoor sounding
- Very high dynamic range
- Spectrum Analyzer
- Data Analysis Software

Massive MIMO - Beamforming
- Phase-coherent RF generation
- Multi-port VNA

New 5G PHY Candidates
- Network Analyzer
- Direct measurements up to 110 GHz

Component Characterization
- Network Analyzer
- Analyze application behavior like signaling load, delay, power etc.

E2e Application Testing
- DUT
Fewer young people nowadays choose engineering education, and what is even more worrisome is the fact that the most gifted students decide to study at the faculties of computer science and engineering, choosing zeros and ones over microwaves or curl and divergence. The said zeros and ones are significantly easier to comprehend than the area of curl and divergence.
Therefore, as a consequence, the computer students score higher than those who study the microwaves area, while putting, in fact, less effort into their learning. Difficult curriculum and fewer opportunities to obtain high grades cause the students to lose interest in microwaves.
Requirements For Modern Adaptive Students

“The only person who is educated is the one who has learned how to learn and change”

The general demand to master new skills results from constantly modernizing technologies.

“The world does not pay for what a person knows. But it pays for what a person does with what he knows.”

Reference: Josef W. Modelski, MTT-S Microwave Magazine, August 2008

https://www.b-tu.de/ag-hochfrequenztechnik/
https://www.unibw.de/universitaet/ehrensenatoren/prof-dr-ulrich-rohde
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Literature
From 1942

- RF/Microwave Education (in German)
- Focus mostly on theory
- No international conferences
- No technology exchange or transfer due to language problems
- No digital technology (did not exist at that time)
From 1943

• The State of the Art text book for radio engineering
• Probably the best comprehensive US radio electrical engineering book ever written. Used in all English speaking countries.
• Contains only analog circuitry
  (Digital technology did not exist at that time)
From 1997

- Microwave and Wireless Synthesizers—the first book to emphasize both practical circuit information from RF to millimeter-wave frequencies and up-to-date theory.
- In-depth look at the practical side of the phase-lock loop (PLL) in synthesizers—including special loops, loop components, and practical circuits-material
- Third edition 2021
From 2005

- Linear and nonlinear circuit analysis treatment
  3rd edition 2021
- Best in class
- Covers all relevant material
- Ideal reference material
From 2005

- Oscillator performance can make or break a system performance
- Covers RF to millimeter wave circuits
- Most advanced text book on this topic
- Ideal reference material
From 2012

Introduction to Differential Calculus fully engages readers by presenting the fundamental theories and methods of differential calculus and then showcasing how the discussed concepts can be applied to real-world problems in engineering and the physical sciences.

- Concepts of function, continuity, and derivative
- Properties of exponential and logarithmic function
- Inverse trigonometric functions and their properties
- Derivatives of higher order
- Methods to find maximum and minimum values of a function
- Hyperbolic functions and their properties
From 2012

Integration is an important function of calculus, and Introduction to Integral Calculus combines fundamental concepts with scientific problems to develop intuition and skills for solving mathematical problems related to engineering and the physical sciences

• Mastering and applying the first and second fundamental theorems of calculus to compute definite integrals
• Defining the natural logarithmic function using calculus
• Evaluating definite integrals
• Calculating plane areas bounded by curves
• Applying basic concepts of differential equations to solve ordinary differential equations
From 2013

• Education in English international technology language
• Focus on theory and real life application
• Material presented at international conferences
• Result of technology exchange or transfer
• Covers modern cellular radio technology, analog and digital
From 2017

- State of the art communication technology
- Covers high performance application
- Good reference for past and modern design
From 2009

- Success by implementing strategy, policies and central management
- Focus on market needs and cost effective manufacturing
- Watch your competitors at international conferences and adapt products
- Learn from technology exchange
From 2009

• Success by watching consumer behavior
• Listen to the customers needs
• Decisions are made on perceptions more often than reality
• Compatibility with existing technologies or products is key to success
Thank You

• You need a good mix between tradition and society demands
• Students come from all countries and become global professionals
• Country barriers are disappearing
• Success lies in education and commitment to excellency
• Good luck with all the Pomp and Circumstances!