Ulrich L. Rohde, Ph.D.
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Synergy Microwave Corp.
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Germany
Partner Rohde & Schwarz

Global Markets, Global Technology, and Global Students?

UF | UNIVERSITY of FLORIDA

A contribution to the workshop,
"The Future of Communications & Technology"
University of Florida @ Gainesville
Updated February 2017

SYNERGY® MICROWAVE CORPORATION

University of Florida

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

Wayne H. Chen
Dean, College of Engineering

Donald L. Childers
Chairman, Department of Electrical Engineering

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

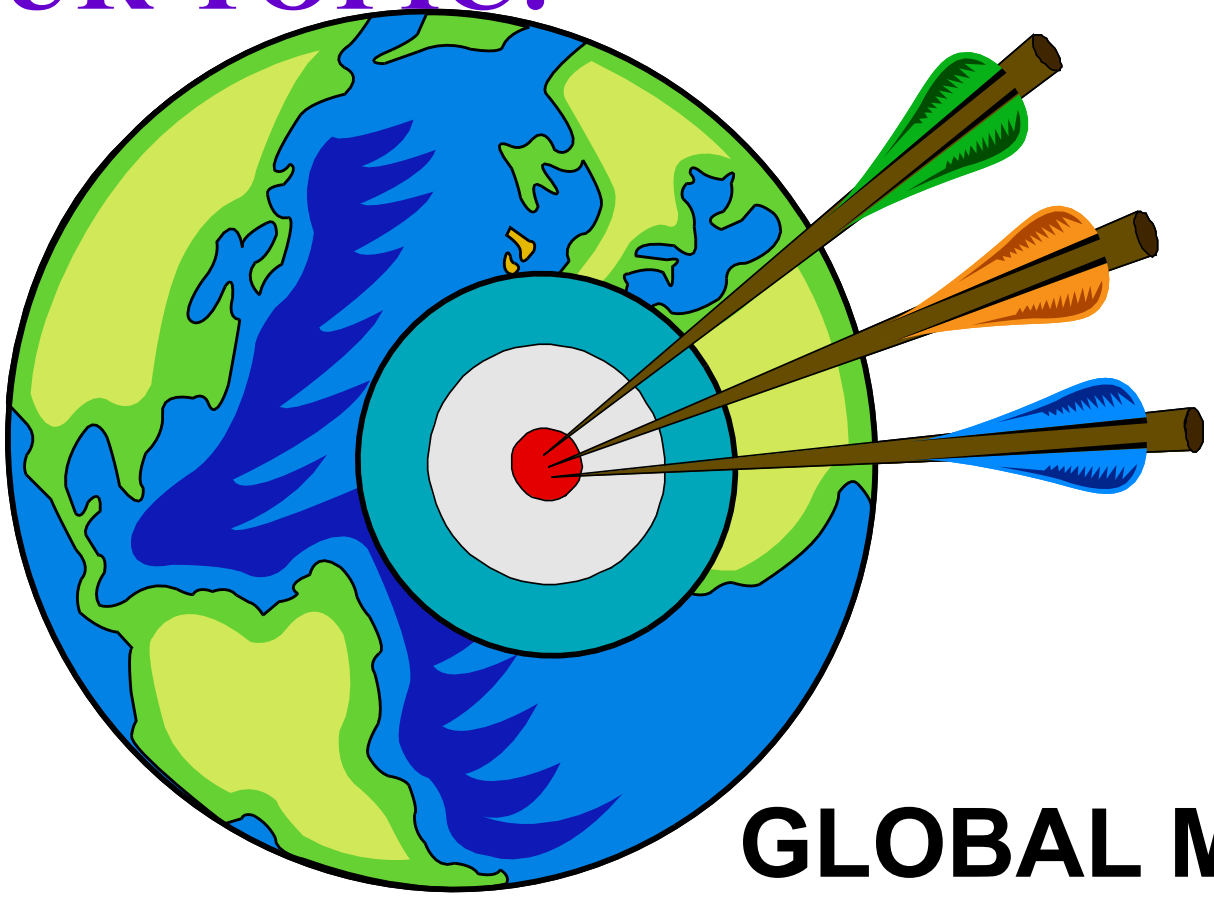
Adjunct Professor of Electrical Engineering

Arthur D. Friedman

May 4, 1982

Arthur D. Friedman
Chairman, Department of Electrical
Engineering and Computer Science

OUR TOPIC:



GLOBAL MARKETS,
GLOBAL TECHNOLOGY,
GLOBAL STUDENTS ?

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OUR TOPIC:

- In engineering we address the 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 student in RF engineering additionally understands A/D converters DSP, digital signal processing (DSP), micro processor coding in C++ programming language and has some business education (MBA) and relates to innovative design with an eye for quality and reliability of the product.

GLOBAL MARKETS

It mixes analog and digital techniques.

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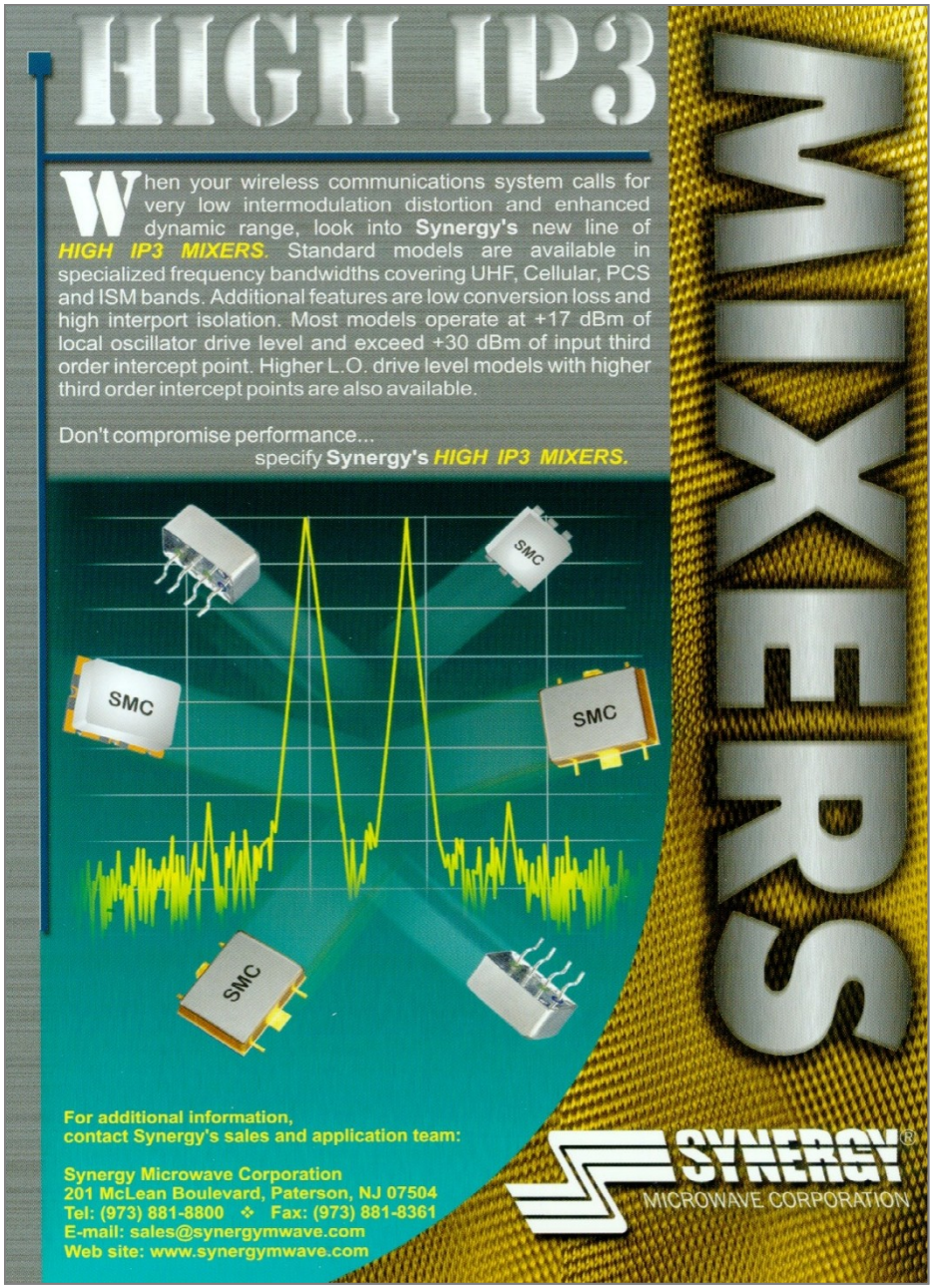
GLOBAL MARKETS

High Performance analog techniques

An Example



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GLOBAL TECHNOLOGY

Analog Technology, Examples

- All RF front ends consists of analog low noise preamplifiers, “linear mixers” and PLL based high performance synthesizers and low power consumption
- Important parameters are spot noise figure, i.e.< 1dB intermodulation distortion IP3>1dBm, (3dB per dB for 3rd order products), input selectivity, low phase noise (-145dBc/Hz @ 200KHz off carrier synthesizers with fast settling speed, less than 1mS

GLOBAL TECHNOLOGY

Digital Technology, Example

- Optimized IF frequencies for the analog to digital converters (A/D), understand the A/D impedance matching, overload vs. noise figures.
- Choose proper IF selectivity coding, DSP implementation of composite filters using Bessel/Cauer and elliptic filters, choose appropriate DSP derived automatic gain, control minimize computational delay time and optimize other important parameters

GLOBAL TECHNOLOGY

Leaders & Losers

1. Samsung– World Leader in Volume
2. Nokia– Big on “dumb phones”, Went from #1 to #7 in “Smartphones” in two years.
3. 2014 #11 with <3% market share, In 2015 down to 2%. Re-launch 2017 with Android
4. Apple– iPhone Most Appealing
5. ZTE- Chinese low cost manufacturer
6. LG- South Korean electronics company
7. In the top 10 smartphone companies, 5 are Chinese: Lenovo, Huawei, ZTE, Xiaomi, Coolpad/Yulin

- Sony Ericsson – Now Sony –Struggling to survive
- Motorola – Sold to Google for their IP rights – sold to Lenovo.
- Blackberry- Once in every business persons pocket, today <1% market share
- Siemens & Ericsson – Left the cell phone business

CELL PHONE MANUFACTURER

Nokia

Changed from a technology innovative leadership with lower cost. (production cost) to a systems integrator.
Bought by Microsoft to rescue failing Windows OS under the name Microsoft.
Nokia reemerges 2017 with Android devices

CELL PHONE MANUFACTURER

- Changed the mobile world with the introduction of the iPhone 2007
- Became the most profitable manufacturer 2009
- Since 2012 until today (Q1 2017) the worlds highest valued company
- 2017 has 18 % of the world market with high end smart phones. Increasing volumes, regaining market shares
- Nokia went from 30% to <3% Market share from 2010 to 2014.
- Samsung went from 8% to 30% between 2010 and 2012. Loosing market share to 20% in 2017.
- Lost its #1 position in China to Xiaomi

CELLULAR PHONE market

- Android was introduced 2007
- Smart phone market share
  - 2009 2.8%
  - 2010 33%
  - 2012 75%
  - 2014 81%
- 1.5 Million device activations per day in 2015
- 2013 there were 3.5 times more active smartphones&tablets then Windows based PCs
- Today used in TVs, cars, watches etc.

CURRENT TECHNOLOGIES

- GSM (Simcards!) 80% Market Share, Used Internationally (3G/UMTS, > 4G) advantage is high capacity, system is upgradable, economy of scale
  - Shutdown started with Telstra (AUS) and AT&T (US)
- LTE (erroneously called 4G, Launched 2009)
  - Evolution of UMTS
  - 2014 only 170 million subscribers
  - 75 % in the US, South Korea and Japan
- cdma2000 (formerly IS-95 System)
  - 15% Market Share (Example Sprint)
  - Qualcomm Patent
  - Shutdown planned for 2017 in Canada & Taiwan

CELLULAR PHONE MARKET

PRICE DOWN

PROFIT DOWN

NUMBER OF MODEL UP

Nokia

Hugh volumes
Almost no profit

Ericsson

Merged with Sony
and then exit

Siemens

(Out of Business)

Motorola

Saved by Google, sold to Lenovo

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GLOBAL MARKETS

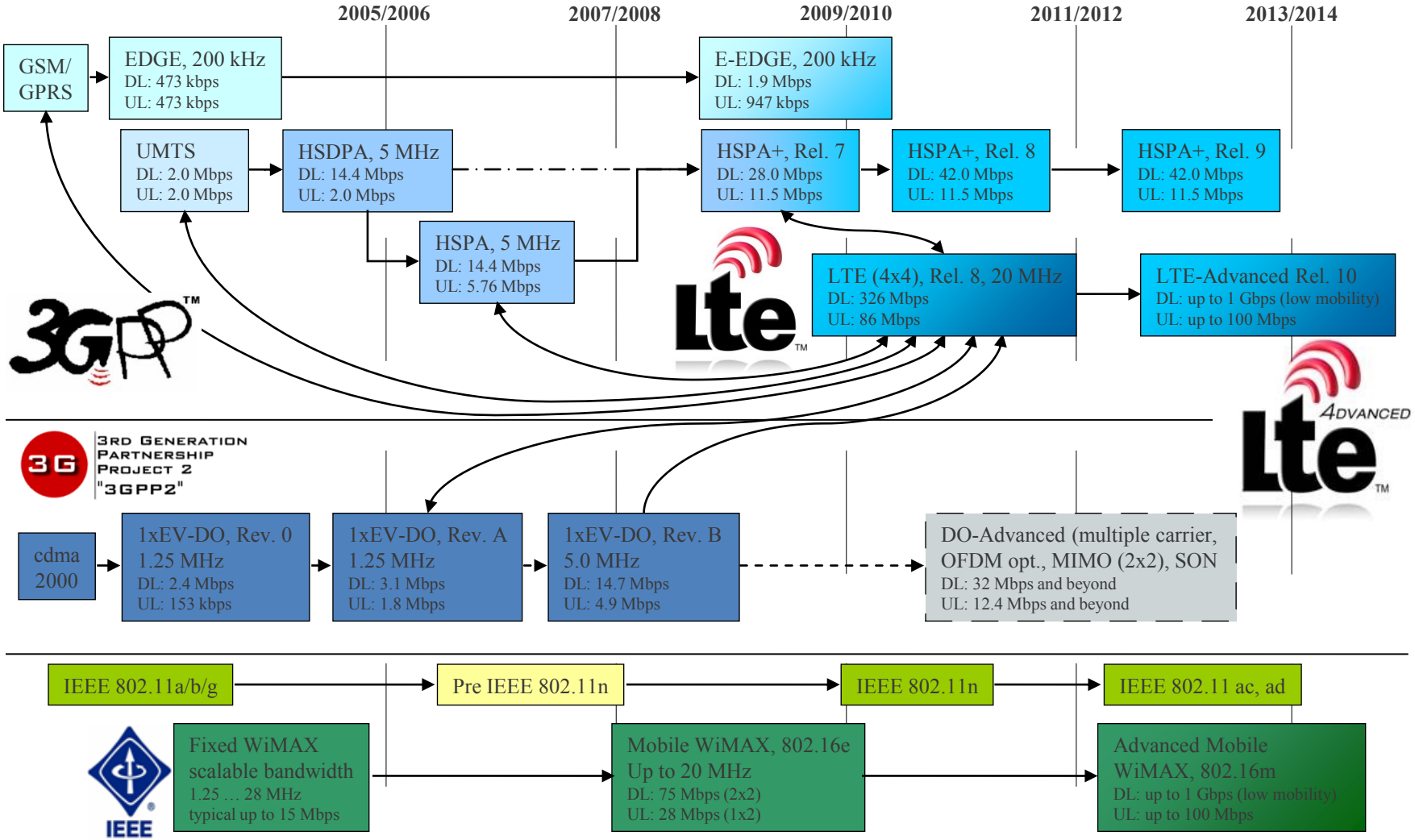
Most growth potential:

- Multimedia Communications (includes high quality video images)
  - Video is expected to increase by around 55 percent annually up until the end of 2019, Source Ericsson
  - It is forecasted to make up more than 50 percent of global mobile traffic
- Cloud based services, Facebook etc.
  - E.g. uploading pictures. The four most popular cameras on Flickr are Iphone 6 & 6s followed by Samsung S6 and Iphone 5 and 6 Plus
  - 4 billion camera phone owners 2014
- Hand held or pocket sized computers (phablets) using UMTS/
- Internet of Things (IOT)
- WiFi important assisting technology
  - Contrary to popular belief WiFi not reducing mobile data traffic smartphones

GLOBAL TECHNOLOGY

- **First Generation- Analog Cell phone System (1985)**
- **Second Generation - Digital System (1990)**
  - **Voice, Text Messaging, GSM, CDMA-ONE, TDMA**
- **Third Generation (3G) - UMTS-Digital System (2001)**
  - **High data rate, IP based (email, web, navigation etc.)**
  - **Multimedia Communications**
- **Fourth Generation(4G)- LTE advanced (2013)**
  - **Higher speed data communication**
  - **Voice communication is just one use case**
- **Fifth Generation (5G)**
  - Only data transmission

TECHNOLOGY EVOLUTION PATH



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WHAT IS UMTS?

- UMTS stands for Universal Mobile Telecommunications System
- UMTS is a member of the ITU's IMT-2000 global family of "third-generation" (3G) mobile communications systems, 4G next
- UMTS played a key role in creating a mass market for high-quality wireless multimedia communications that
  - will approach 5 billion unique users worldwide by the year 2017
  - Exceeded 8 billion connections in 2016

WHY LTE?

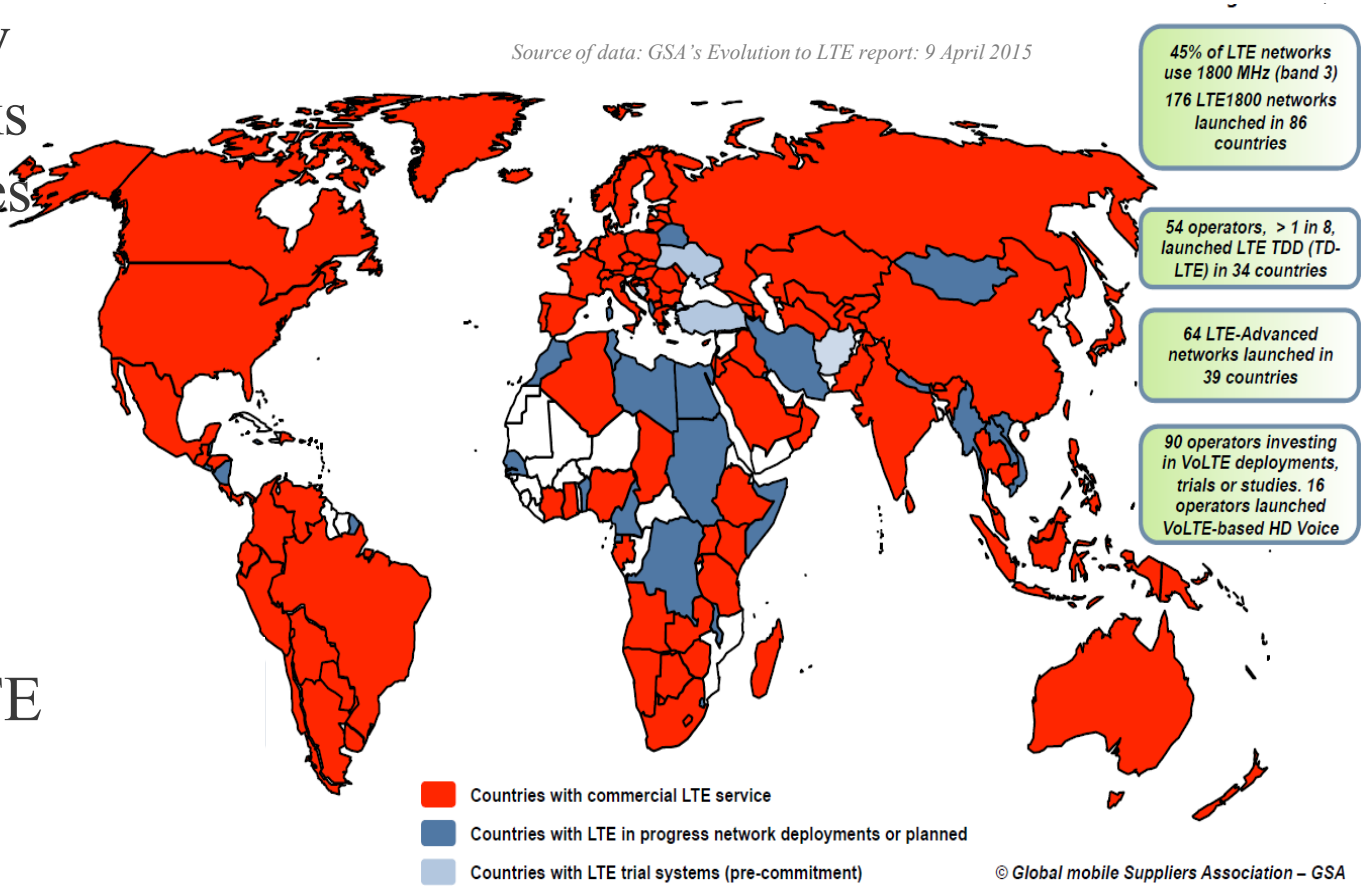
Ensuring Long Term Competitiveness of UMTS

- LTE is the next UMTS evolution step after HSDPA/HSUPA.
- Main targets of LTE:
  - Peak data rates of 299.6 Mbps (downlink) and 75.4 Mbps (uplink)
  - Scalable bandwidths up to 20 MHz
  - Cost efficiency
- Study was initiated in December 2004 (3GPP release 7).
- First commercial network 2009 (Telia, Sweden)

LTE Today

393 commercially launched networks

- in 138 countries
  - 2 in 2009
  - 14 in 2010
  - 30 in 2011
  - 100 in 2012
  - 118 in 2013
  - 100 in 2014
- 460 networks estimated by E2015
- 497 million LTE subscribers by Q4/14



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LTE advanced

- True 4G
- Backward compatible to LTE
- Theoretical up to 3.3 Gbps downlink transmission
- First network started June, 2013 in South Korea
- 1 Gbps/s shown in commercial network in 2016 (Ericsson, Qualcomm and Netgear)

5G has not been defined yet !

Discussed Scenarios & Requirements

- **Dense crowd of users:**
- High data rates. high capacity, limited area.

- **Internet of Things (emergency comms, robots, …):**
- Low latency, high reliability
- resilience and security;
- user case specific data rates/capacity.

- **Internet of Things (sensors; leisure applications, …):**
- The volume of devices and "things" will create new requirements.

Battery life time expectation → years

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The Triangle of 5G Use Cases

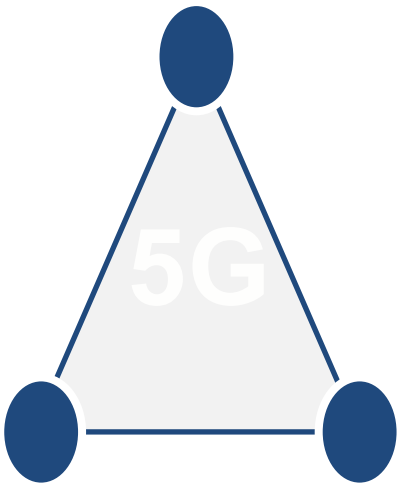
eMBB remains Priority 1

eMBB – the known playground

- Established ecosystem (operators, manufacturers, certification of devices)
- Evolution from existing technologies (LTE-A, 802.11 ad) and revolutionary additions (cm- / mm-wave)
- It's all about data (speed and capacity)

Massive IoT

- A diverse ecosystem (operators, manufacturers, local authorities, certification only for some technologies)
- Mix of technologies
- (GSM, Lora, Zigbee, WLAN, Bluetooth, Cat M, NB-IoT,…)
- It's all about cost efficiency and massive connectivity



URLLC

- A significantly enhanced and diverse ecosystem (operators (?), manufacturers, verticals, certification not existing (yet))
- Existing technologies do not provide sufficient performance
- It's all about reliability and security (data and capacity)

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New Frequencies are needed
Many new challenges coming

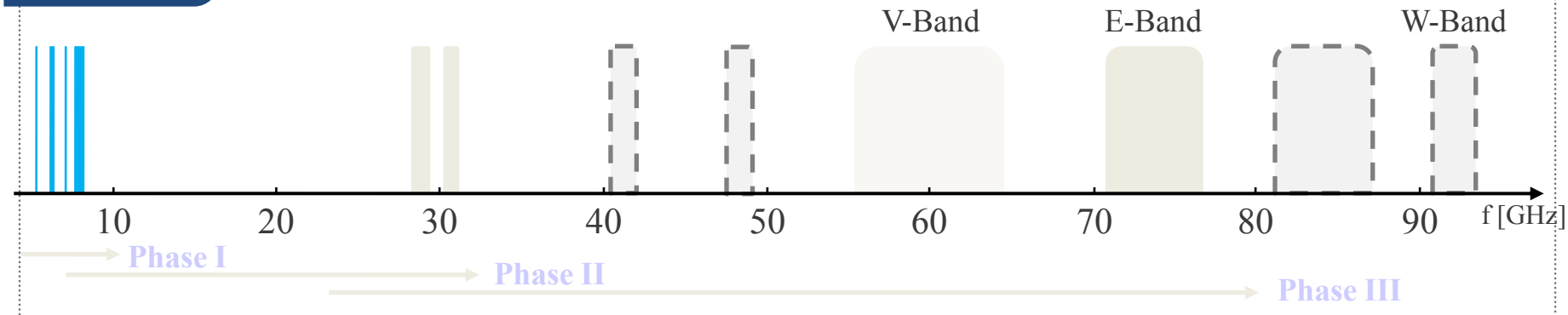
Known characteristics: LTE-A evolution possible

Different propagation; may require redesign

Significantly 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.**

Disruptive technology likely



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Extensive 5G trials activities are ongoing

27

China Mobile set to commence pre-5G trials in 100 cities

Nokia and Smart showcase 'live' 5G for the first time in the Philippines

Huawei and DOCOMO Conduct World's First 5G Large Scale Field Trial in the 4.5 GHz Band

Telecom Italia to pilot 5G network in Turin

AT&T Launches First 5G Business Customer Trial with Intel and Ericsson

Qualcomm, Ericsson, SKT Team on 5G NG Trials

Ericsson reveals separate 5G developments with Vodafone, Deutsche Telekom

ZTE Conducts High-Frequency 5G Field Tests

Deutsche Telekom and Huawei demonstrate world's first 5G E2E autonomous network slicing

Verizon to be first to field-test crazy-fast 5G wireless

It expects "some level of commercial deployment" to begin by 2017 for next-generation wireless. That's much earlier than the common industry belief that 2020 will mark the start.

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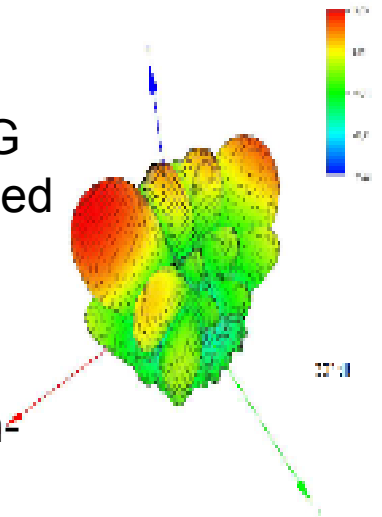
Is 5G just another generation? No its disruptive

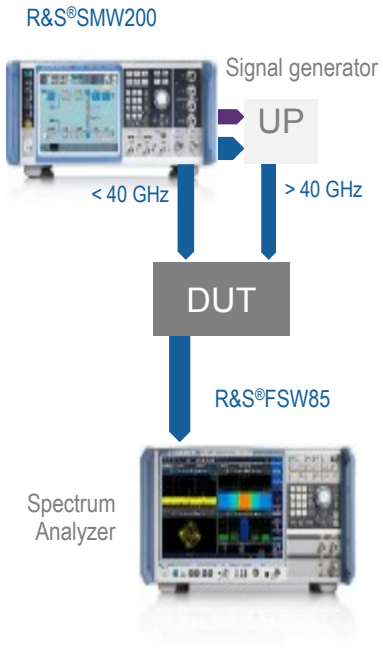
- **Approach in industry:**
  - 3G (3GPP: UTRA): 1: define a technology for data transmission, 2: “what is the killer app?”
  - 4G (3GPP: E-UTRA): define a better technology than 3G based on use case (mobile data)
  - 5G (3GPP: NR): 1: define use cases, 2: requirements, 3: elaborate technologies / solutions

- From cell-centric (2G - 4G) to user-centric / application-centric in 5G
- From link efficiency (2G - 4G) to system efficiency in 5G (RAT defined per app)
- From antenna connectors (2G - 4G) to Over-the-Air testing in 5G (antenna arrays, beamforming)
- Increasing demand for security / high reliability in 5G (up to mission- and safety-critical use cases)



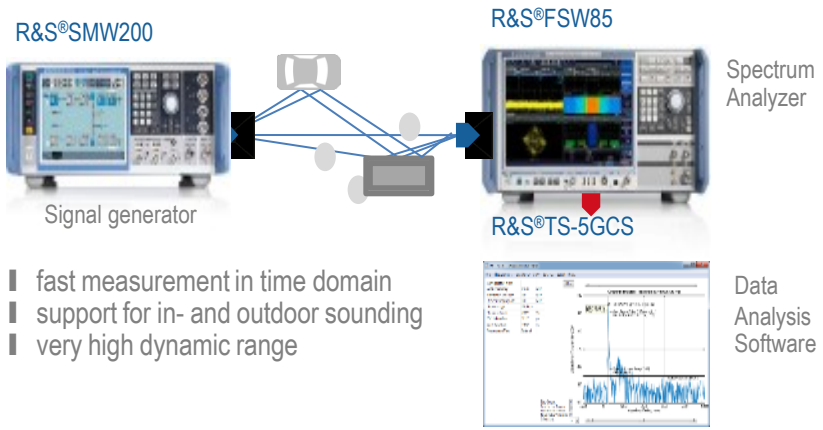
R&S test solutions to investigate, develop and standardize 5G

Wideband Signal Testing



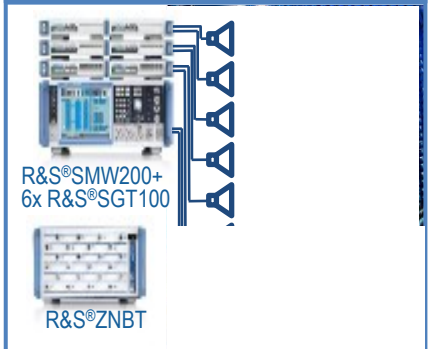
- 40 GHz signal generation
- 85 GHz signal analysis
- 2 GHz bandwidth support

Channel Sounding Solution



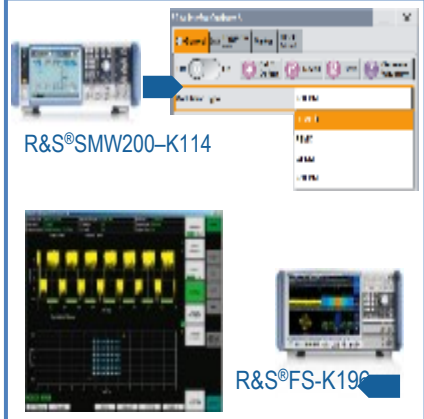
- fast measurement in time domain
- support for in- and outdoor sounding
- very high dynamic range

Massive MIMO - Beamforming



- Phase-coherent RF generation
- Multi-port VNA

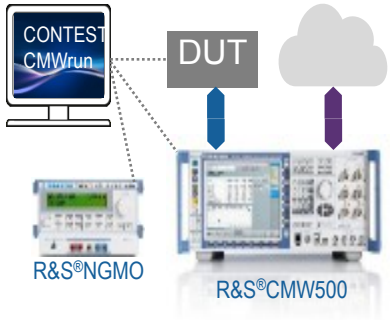
New 5G PHY Candidates



Component Characterization

Direct measurements up to 110 GHz

E2e Application Testing



Analyze application behavior like signaling load, delay, power etc.

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Rohde & Schwarz CMW500
The work horse for cellular devices

GSM/(E)GPRS
EDGEevo
WCDMA
HSPA
HSPA+
CDMA2000
1xEV-DO
LTE FDD
TD-LTE
TD-SCDMA
Mobile WiMAX
WLAN abgn
Bluetooth

Cellular/Non-Cellular Network-Emulation

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Internet of things

The next big thing?

- Most known example
  - Apple Watch

- Some examples
  - Car manufacturers, car2car communication for collision avoidance
  - Robots in factories
  - Farm animals
  - Healthcare

Internet of things

Just some examples from today WiFi:

Koubachi Plant Sensor

www.koubachi.com

Sengled Lightbulb

www.sengled.com

Amazon Dash Button

www.amazon.com

Bosch Rexroth

www.boschrexroth.com

Luna Mattress Cover

www.lunasleep.com

Masimo Patient Monito

www.masimo.com

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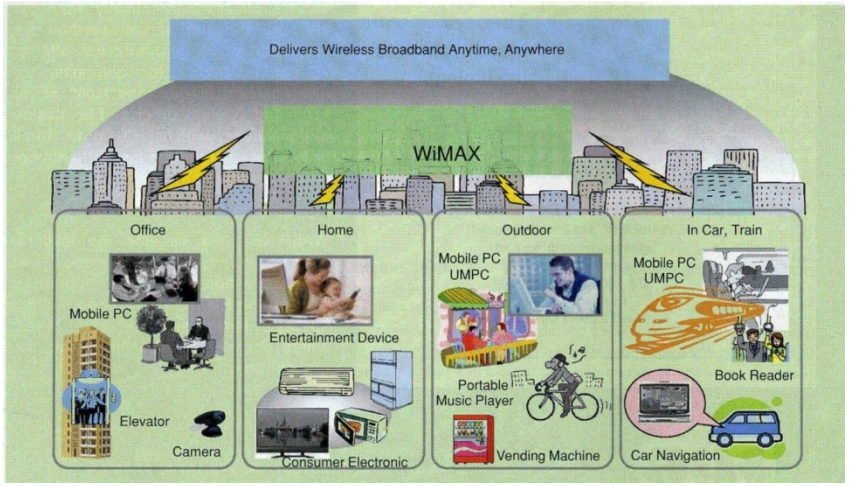
GLOBAL ACCESS

Worldwide interoperability for microwave access (WIMAX)

Lost the battle against LTE, due to limited operator backing

Sprint will phase out WIMAX 2015



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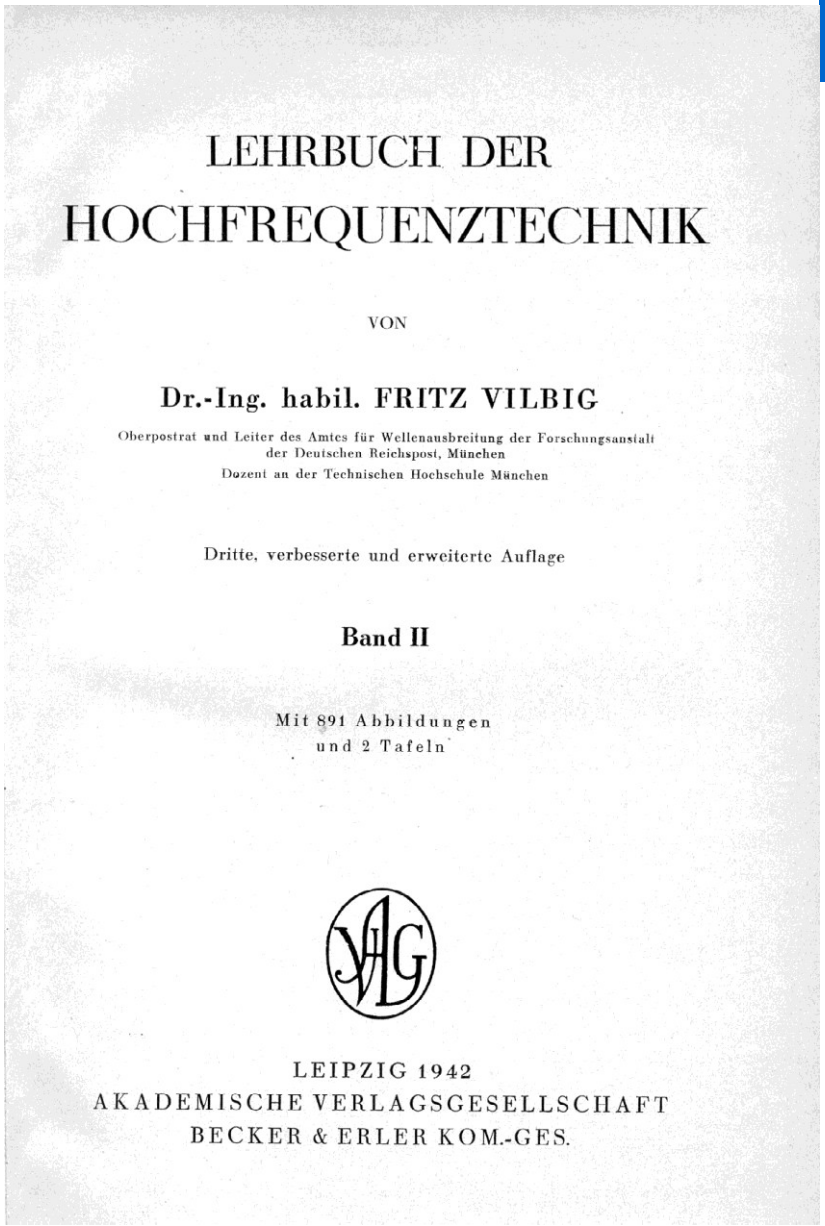
GLOBAL STUDENTS

- 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)



LEHRBUCH DER
HOCHFREQUENZTECHNIK

VON

Dr.-Ing. habil. FRITZ VILBIG

Oberpostrat und Leiter des Amtes für Wellenausbreitung der Forschungsanstalt der Deutschen Reichspost, München
Dozent an der Technischen Hochschule München

Dritte, verbesserte und erweiterte Auflage

Band II

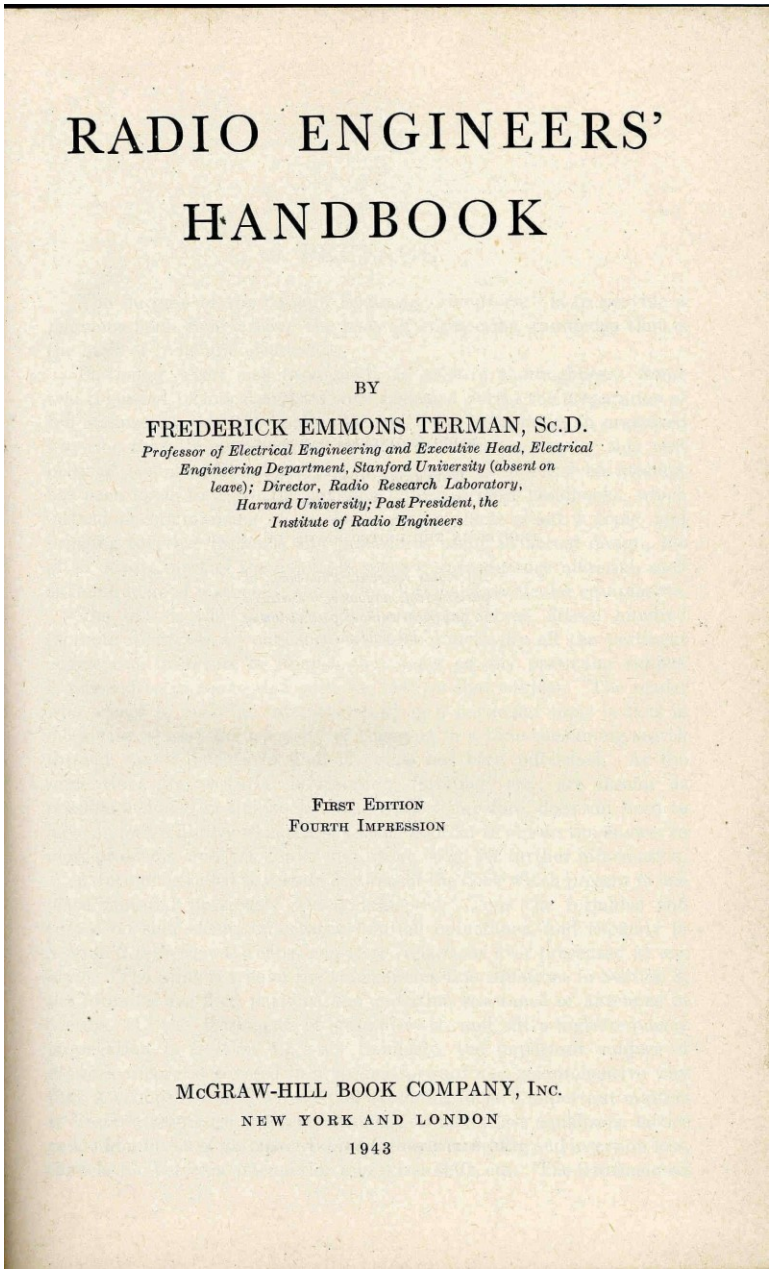
Mit 891 Abbildungen
und 2 Tafeln

LEIPZIG 1942
AKADEMISCHE VERLAGSGESELLSCHAFT
BECKER & ERLER KOM.-GES.

GLOBAL STUDENTS

- 1943 -

- Then 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



RADIO ENGINEERS' HANDBOOK

BY

FREDERICK EMMONS TERMAN, Sc.D.

Professor of Electrical Engineering and Executive Head, Electrical Engineering Department, Stanford University (absent on leave); Director, Radio Research Laboratory, Harvard University; Past President, the Institute of Radio Engineers

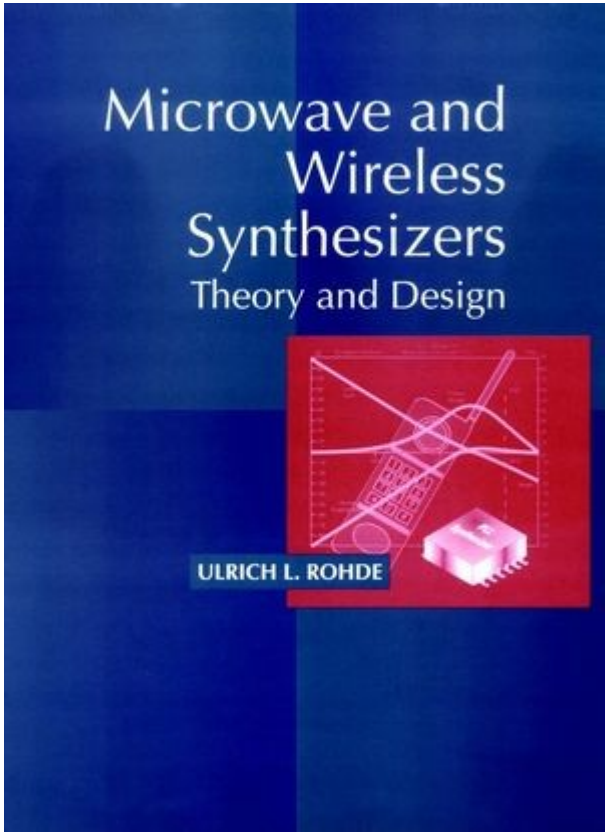
First Edition
Fourth Impression

McGRAW-HILL BOOK COMPANY, Inc.
NEW YORK AND LONDON
1943

GLOBAL STUDENTS

- 1997 -

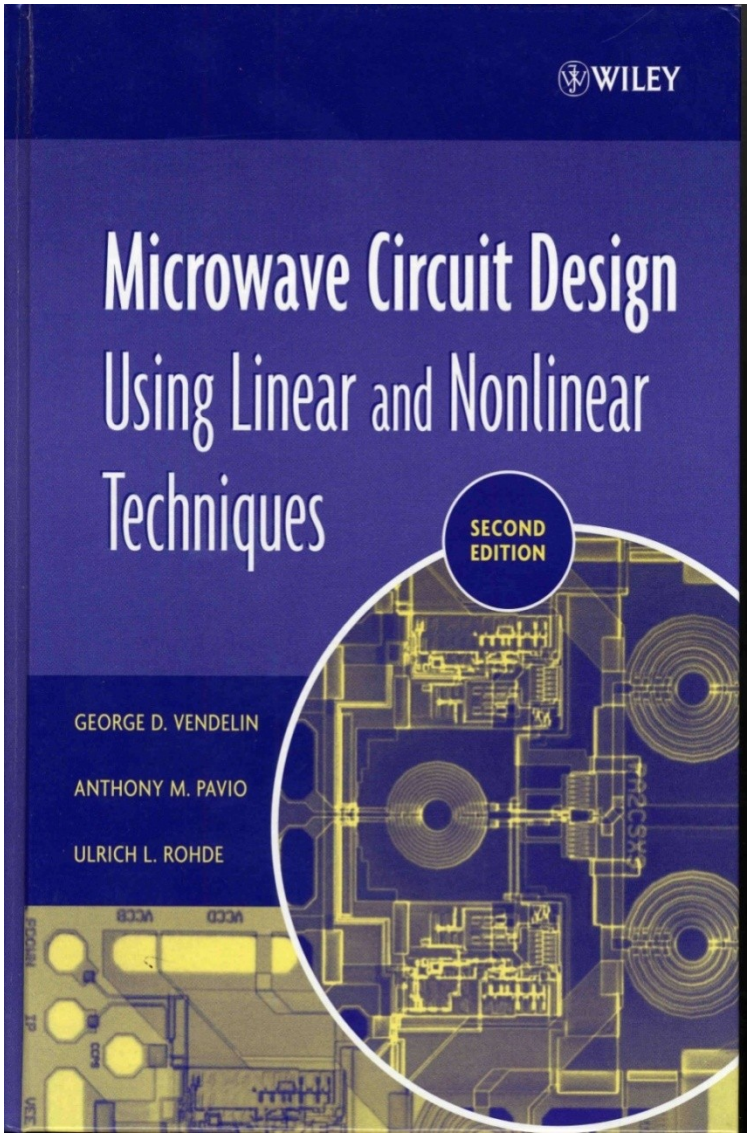
- Microwave and Wireless Synthesizers- the first book to emphasize both practical circuit information from RF to millimeter-wave frequencies and up-to-date theory.
- in-depth look at the practical side of the phase-lock loop (PLL) in synthesizers- including special loops, loop components, and practical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



GLOBAL STUDENTS

- 2005 -

- Linear and nonlinear circuit analysis treatment 2nd edition
- Best in class
- Covers all relevant material
- Ideal reference material
- 2018 update in preparation



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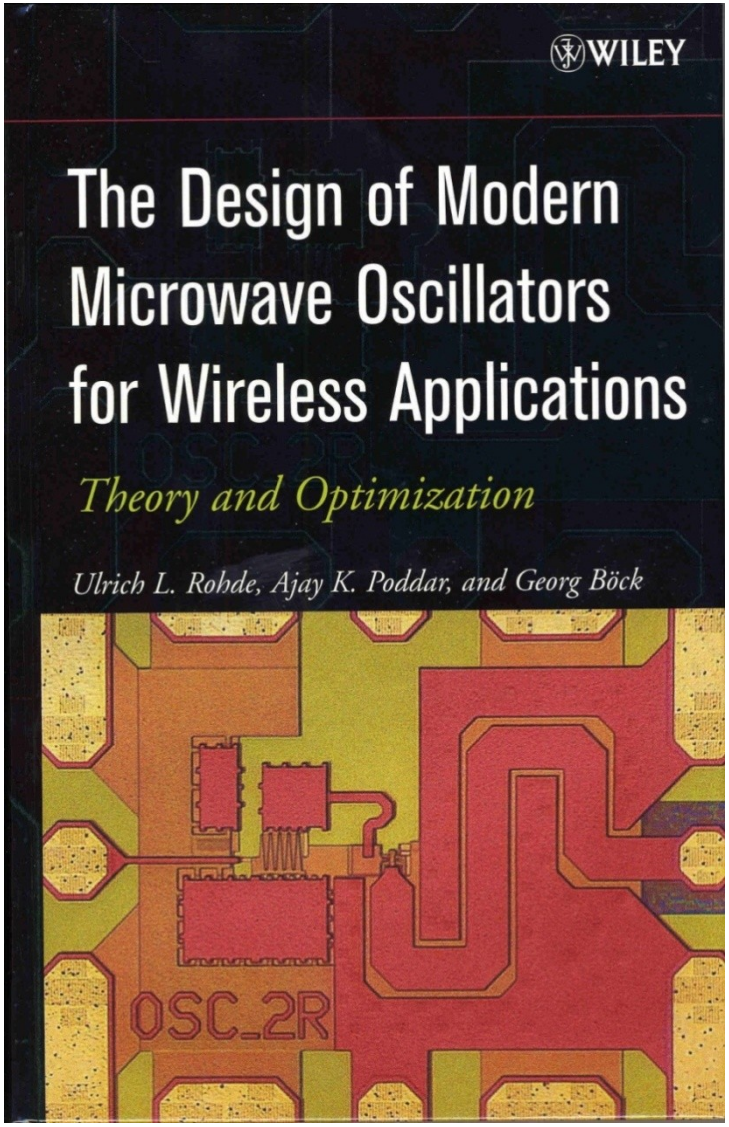
GLOBAL STUDENTS

- 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



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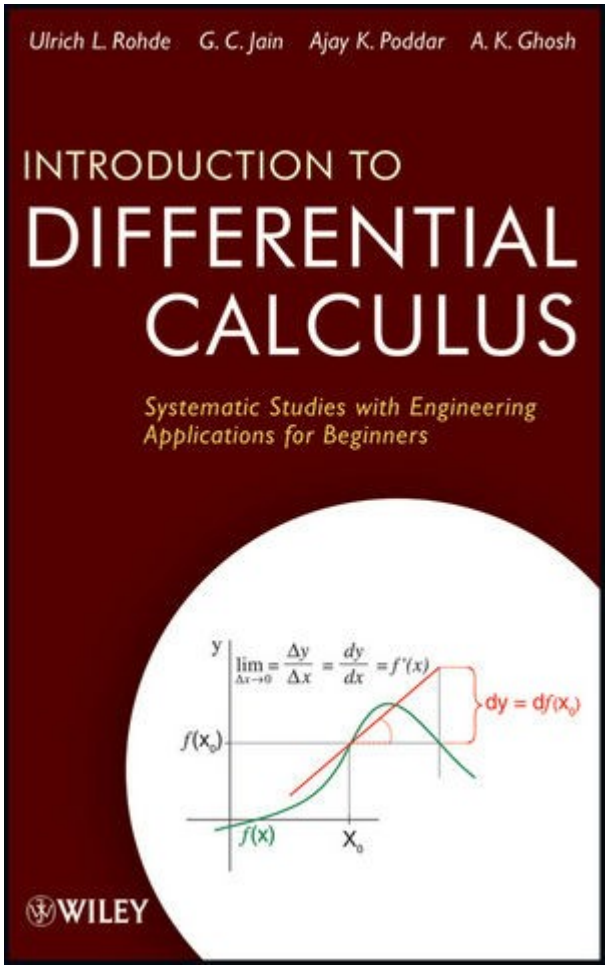
GLOBAL STUDENTS

- 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



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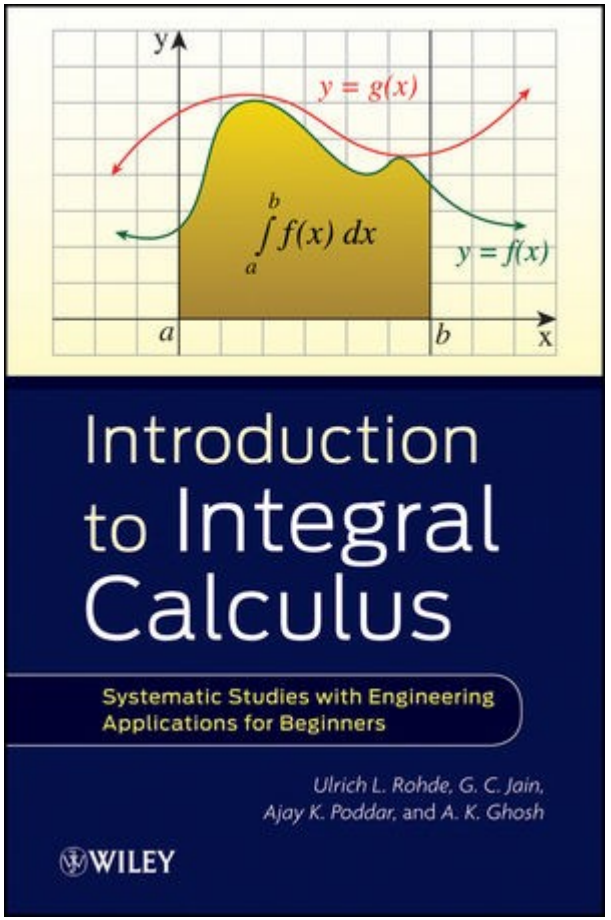
GLOBAL STUDENTS

- 2012 -

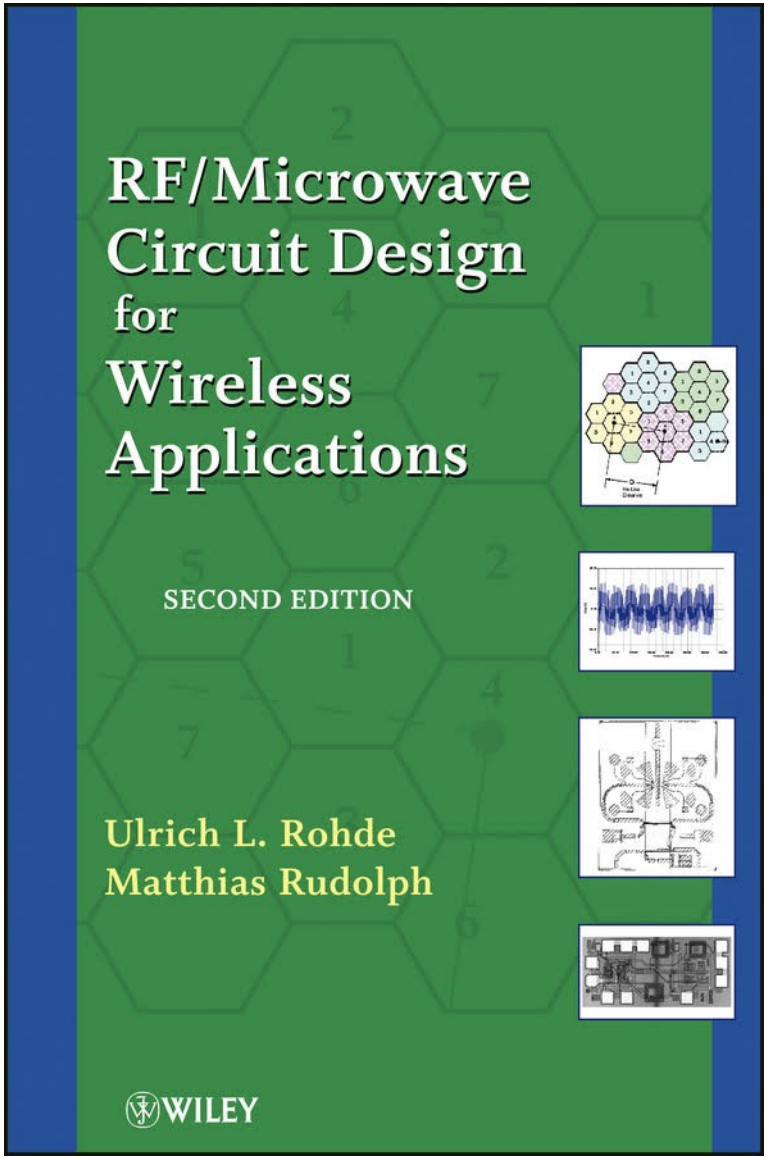
- Integration is an important function of calculus, and Introduction to Integral Calculus combines fundamental concepts with scientific problems to develop intuition and skills for solving mathematical problems related to engineering and the physical sciences
  - Mastering and applying the first and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



GLOBAL STUDENTS

- 2013 -

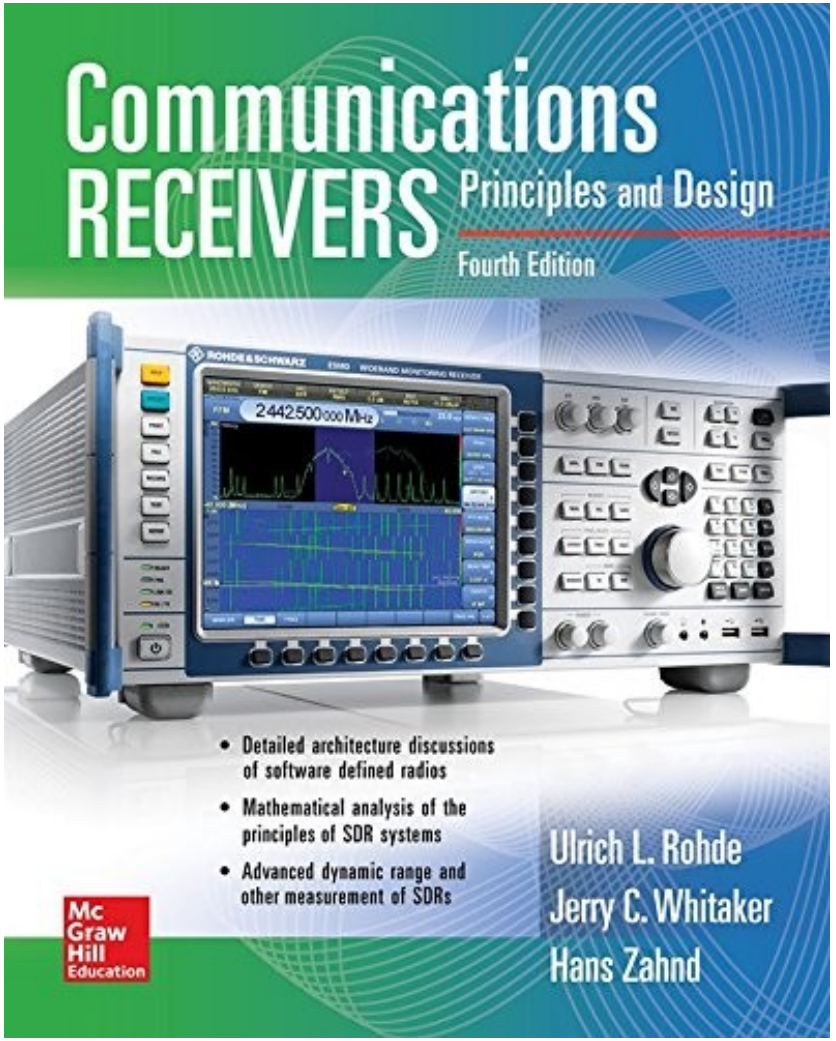
- Education in English international technology language
- Focus on theory and real life application
- Material presented at international conferences
- Result of technology exchange or transfer
- Covers modern cellular radio technology, analog and digital



GLOBAL STUDENTS

- 2017 -

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



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GLOBAL STUDENTS

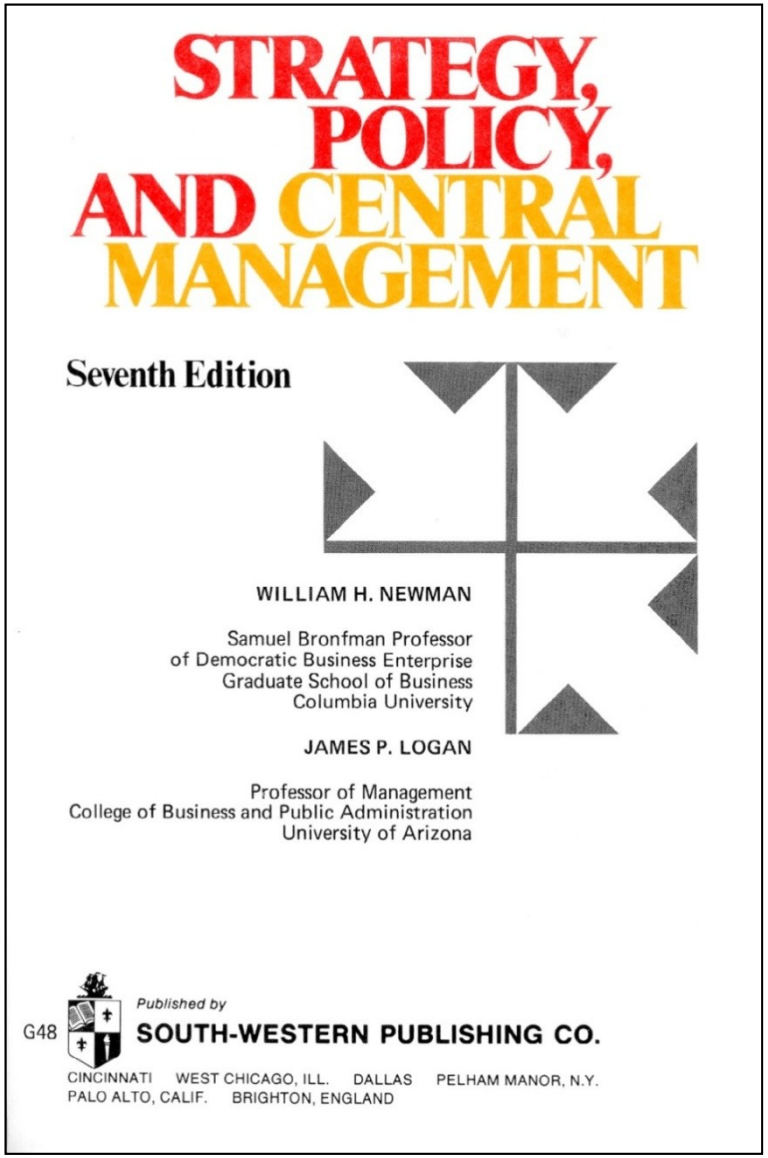
- This book by Christina Gessner of Rohde & Schwarz focuses on the radio access network and the radio aspects of LTE, i.e. the air interface from the mobile station and base station point of view.

- ISBN: 978-3-939837-11-4

GLOBAL STUDENTS

- 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



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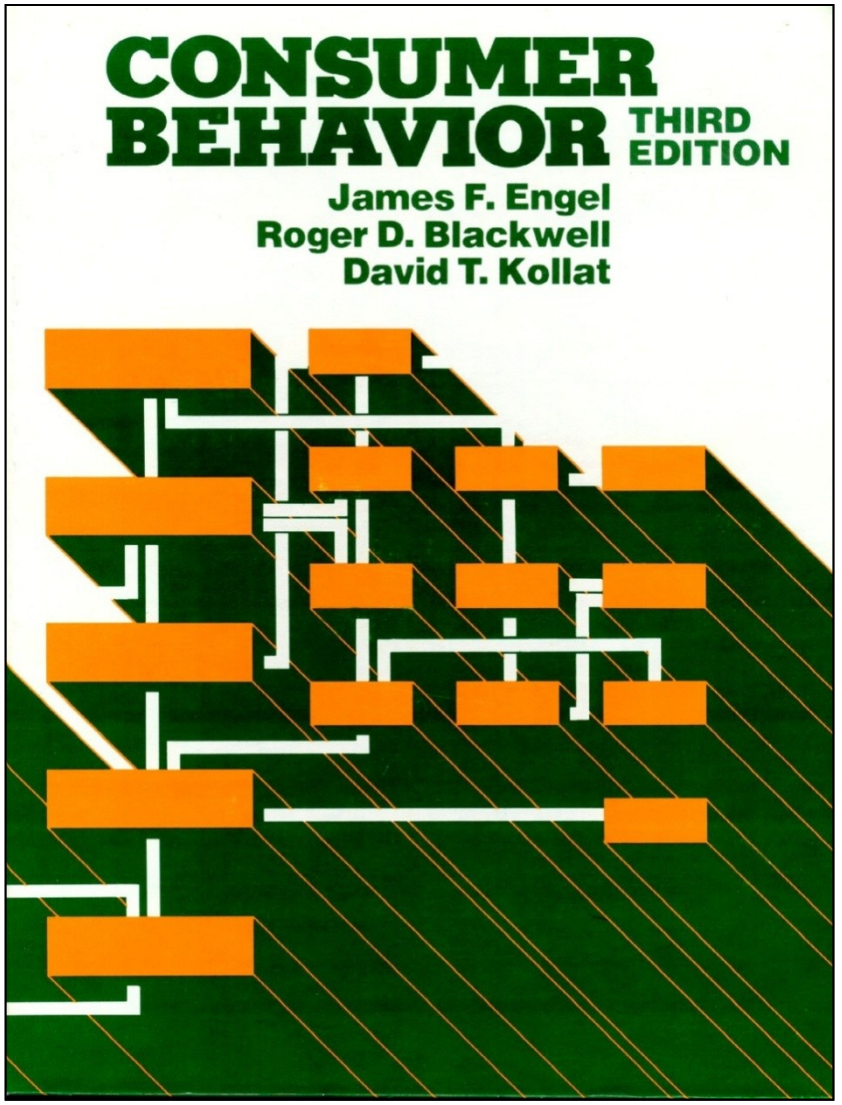
GLOBAL STUDENTS

- 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



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GLOBAL STUDENTS

Requirements For Modern Adaptive Students

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.

GLOBAL STUDENTS

Requirements For Modern Adaptive Students

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.

GLOBAL STUDENTS

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

http://www.b-tu.de/ag-hochfrequenztechnik/

GLOBAL STUDENTS

- The Professional -

- 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