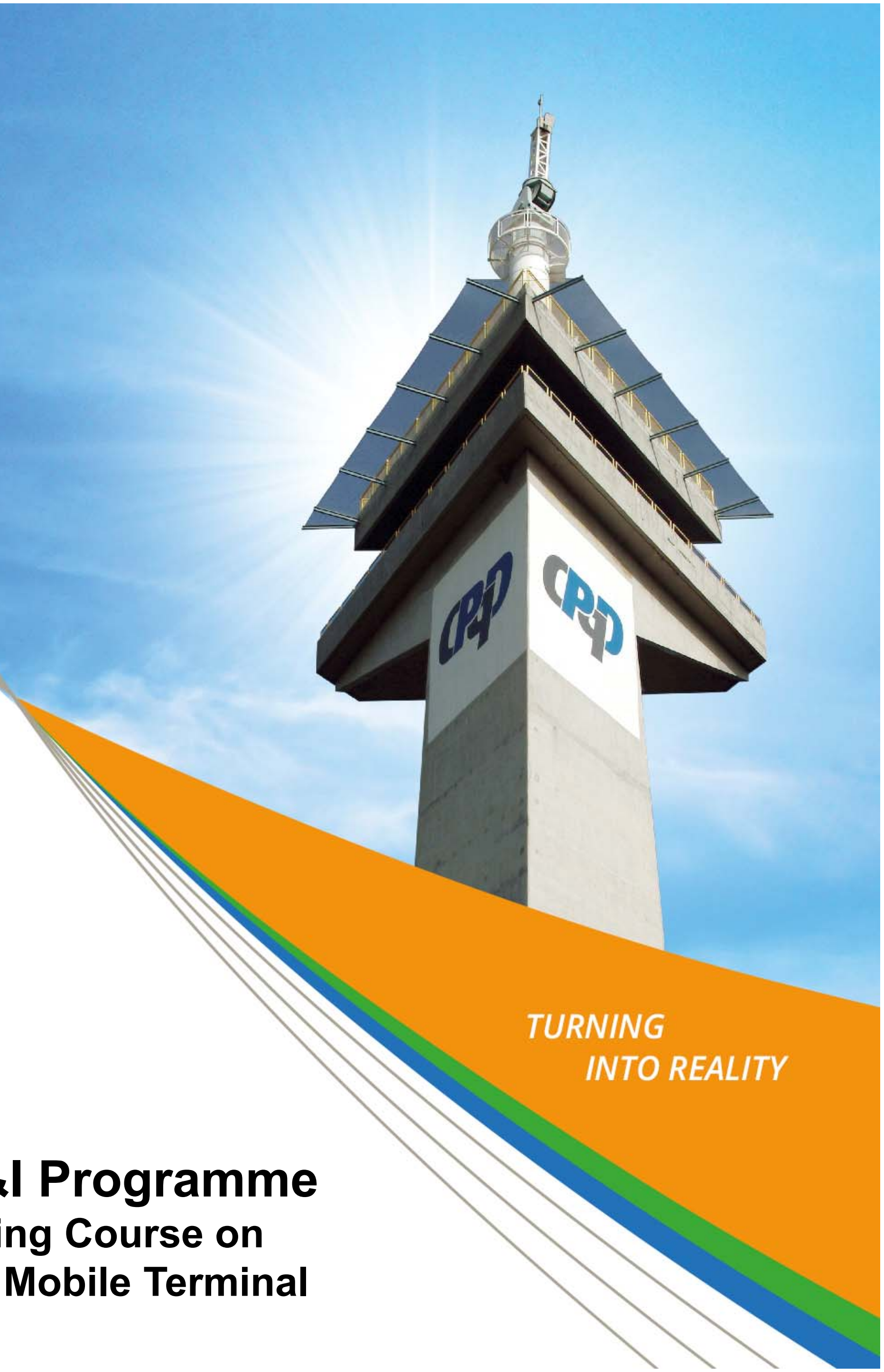
Conformity and Interoperability Training

Homologation Procedures and Type Approval Testing for Mobile Terminals



ITU C&I Programme

Training Course on Testing Mobile Terminal

Schedule

- Basic concepts on IMT technologies and other mobile radiocommunication technologies
- Standards and test specifications for mobile terminals
- Aspects regarding Specific Absorption Rate (SAR) Testing
- Aspects regarding EMC Testing
- Aspects regarding Safety Testing
- ISO/IEC 17025 accreditation - measurement uncertainty - calibration

Schedule

- **Basic concepts on IMT technologies and other mobile radiocommunication technologies**
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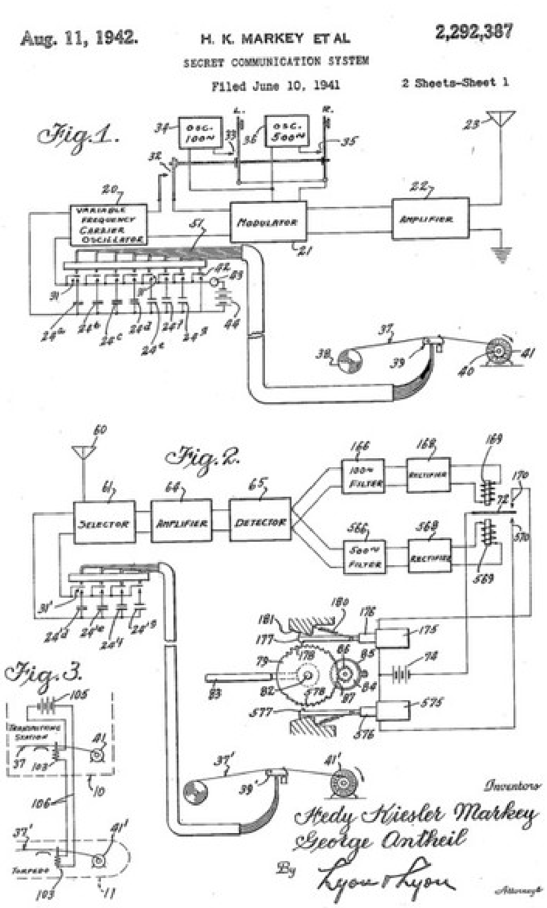
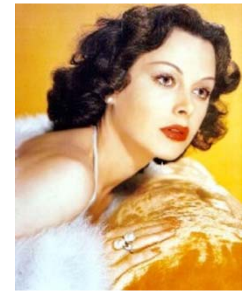
- **Aspects regarding Specific Absorption Rate (SAR) Testing**
- **Aspects regarding EMC Testing**
- **Aspects regarding Safety Testing**
- **ISO/IEC 17025 accreditation - measurement uncertainty - calibration**

Cell Phone Timeline History

- **20th Century**



Hedwig Eva Maria Kiesler [Hedy Lamarr]



1941 Patent denied

Radio Communication Secret System

1942 Patent granted – Markey e Antheil

Patented Aug. 11, 1942 **2,292,387**

UNITED STATES PATENT OFFICE

2,292,387

SECRET COMMUNICATION SYSTEM

Hedy Kiesler Markey, Los Angeles, and George Antheil, Manhattan Beach, Calif.

Application June 10, 1941, Serial No. 397,412

6 Claims. (Cl. 250—2)

This invention relates broadly to secret communication systems involving the use of carrier waves of different frequencies, and is especially useful in the remote control of dirigible craft, such as torpedoes.

An object of the invention is to provide a method of secret communication which is relatively simple and reliable in operation, but at the same time is difficult to discover or decipher.

Briefly, our system as adapted for radio control of a remote craft, employs a pair of synchronous records, one at the transmitting station and one at the receiving station, which change the tuning of the transmitting and receiving apparatus from time to time, so that without knowledge of the records an enemy would be unable to determine at what frequency a controlling impulse would be sent. Furthermore, we contemplate

Fig. 2 is a schematic diagram of the apparatus at a receiving station;

Fig. 3 is a schematic diagram illustrating a starting circuit for starting the motors at the transmitting and receiving stations simultaneously;

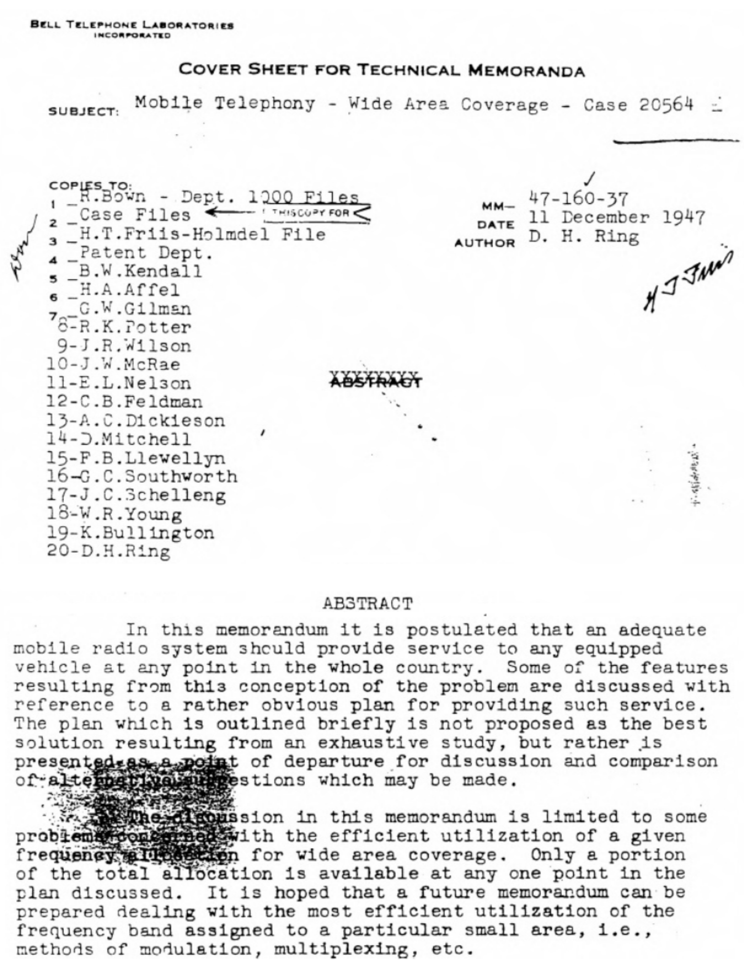
Fig. 4 is a plan view of a section of a record strip that may be employed;

Fig. 5 is a detail cross section through a record-responsive switching mechanism employed in the invention;

Fig. 6 is a sectional view at right angles to the view of Fig. 5 and taken substantially in the plane VI—VI of Fig. 5, but showing the record strip in a different longitudinal position; and

Fig. 7 is a diagram in plan illustrating how the course of a torpedo may be changed in accordance with the invention.

Cell Phone Timeline History



BELL TELEPHONE LABORATORIES
INCORPORATED

COVER SHEET FOR TECHNICAL MEMORANDA

SUBJECT: Mobile Telephony - Wide Area Coverage - Case 20564

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17-J.C.Schelleng
18-W.R.Young
19-K.Bullington
20-D.H.Ring

MM– 47-160-37
DATE 11 December 1947
AUTHOR D. H. Ring

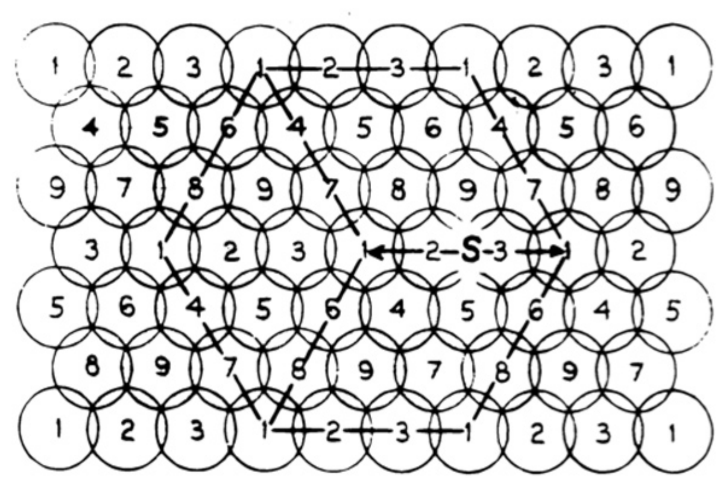
ABSTRACT

In this memorandum it is postulated that an adequate mobile radio system should provide service to any equipped vehicle at any point in the whole country. Some of the features resulting from this conception of the problem are discussed with reference to a rather obvious plan for providing such service. The plan which is outlined briefly is not proposed as the best solution resulting from an exhaustive study, but rather is presented as a point of departure for discussion and comparison of alternative suggestions which may be made.

The discussion in this memorandum is limited to some problems concerned with the efficient utilization of a given frequency allocation for wide area coverage. Only a portion of the total allocation is available at any one point in the plan discussed. It is hoped that a future memorandum can be prepared dealing with the most efficient utilization of the frequency band assigned to a particular small area, i.e., methods of modulation, multiplexing, etc.

1947 Bell Labs

- First memorandum
-
- High capacity telephone system
- Antennas



Cell Phone Timeline History

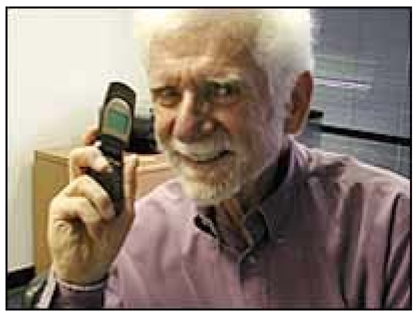
1956 MTA – Mobile Telephone A – Ericsson

- First mobile system – Ericsson
- Pulsed signaling system
- 160 MHz frequency range
- 40 kg weight
- 100 users / MTA

Cell Phone Timeline History

1973 First call from a cellular device – Motorola

DynaTAC 8000X Model
(7 x 25 cm – 1 kg – 20´ battery)



> “I never really started to carry a cellular phone until it was small enough so I could put it on my belt and not even feel it was there”
>
> Martin Cooper

Beginning of the commercial operations

- 1979 – Japan and Sweden
- 1983 – United States

Mobile Service Evolution

1989 subscriptions ➡ **4 million**
2019 subscriptions ➡ **> 9 billion**

Galaxy S5

2014

iPhone 5s

US$ 600

Technology

Evolution

1973

DynaTAC
US$ 8,000

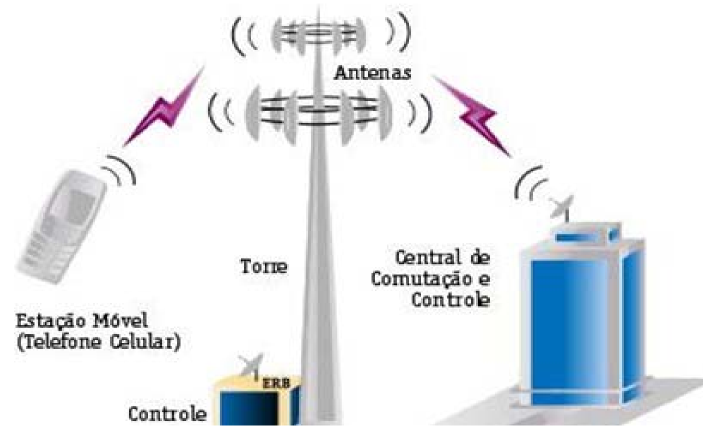
"ITU considers cellular communications the fastest technology adopted throughout the history"

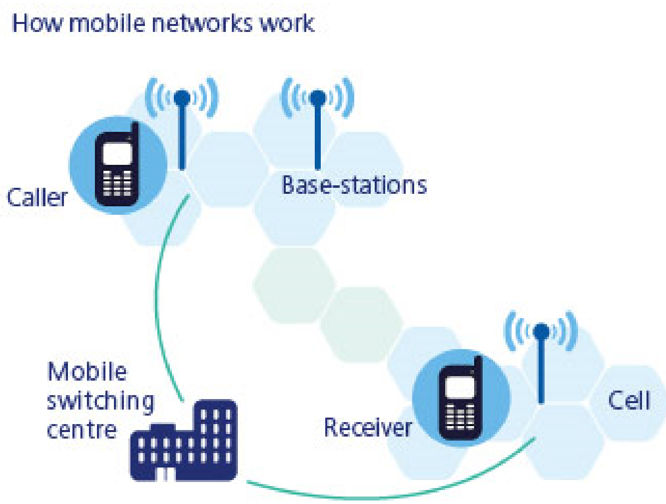
Basic Concepts in Cellular Communication Technology

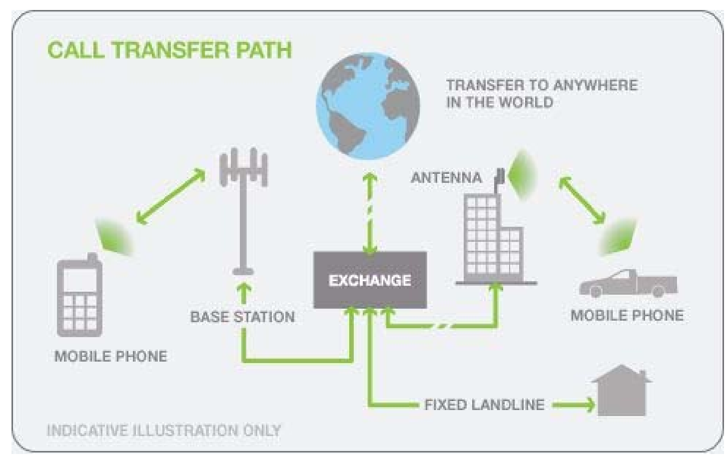
RBS Radio Base Station

MSC Mobile Switching Center

MT Mobile Terminal







Basic Concepts in Cellular Communication Technology

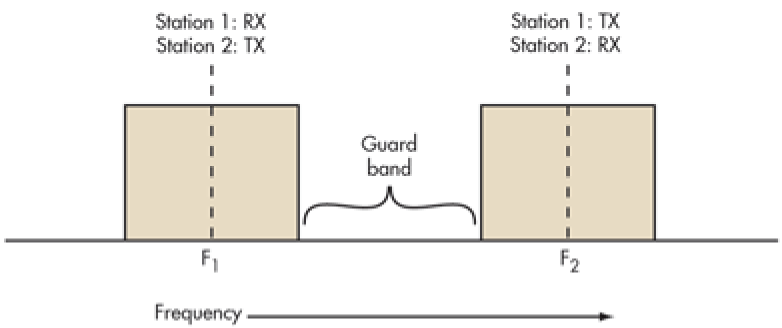
Mobile Communication Systems Goal: High Capacity

Technological Tools:

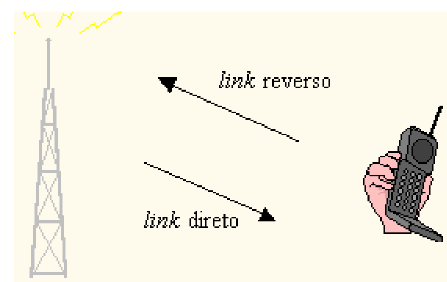
- Resource sharing for multiple users scarcity
- Bandwidth Growth x Spectrum
- Duplexing Techniques
- Access Techniques
- Multiplexing Techniques
- Modulation Schemes
- Advanced Technique:
  - Carrier Aggregation
  - MIMO and Antenna Beamforming

Duplexing Systems

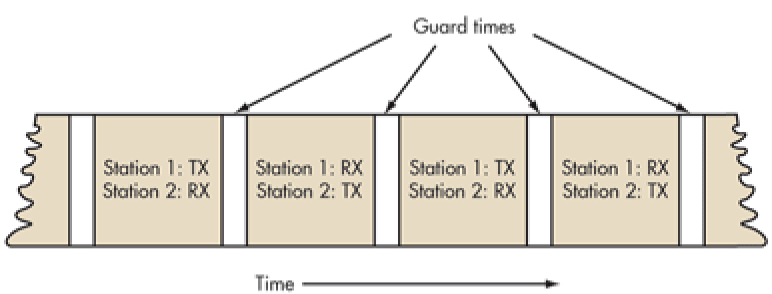
Full Duplex FDD Frequency Division Duplex



Different carrier frequencies
Up Link (reverse) and Down link (direct)
Simultaneous transmissions
More spectrum needed
Guard bands



Half Duplex TDD Time Division Duplex



Single frequency band
Shares band assigning time slots
Symmetrical or asymmetrical
Guard Times

Spread Spectrum Transmission Technique

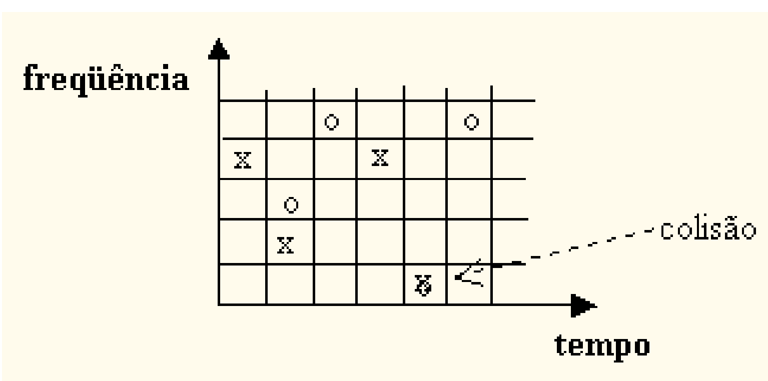
- Frequency diversity properties
- Reduced interference
- Ability to reject interference
- Hard to intercept
- Inherent security

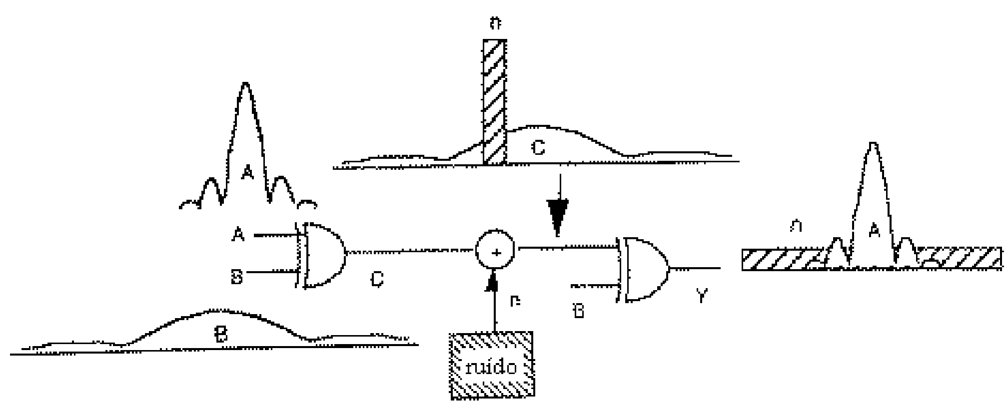
FHSS – Frequency Hopping

- Different carrier frequency at different time

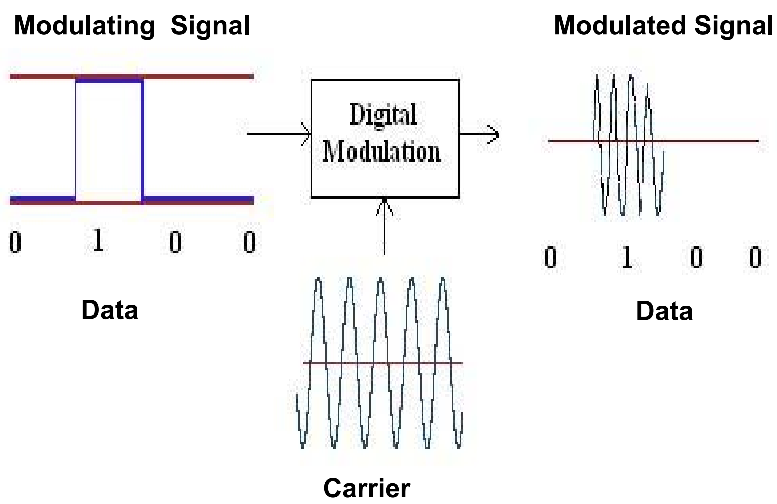
DSSS – Direct Sequence

- Fixed carrier frequency
- Information is spread out into a larger bandwidth

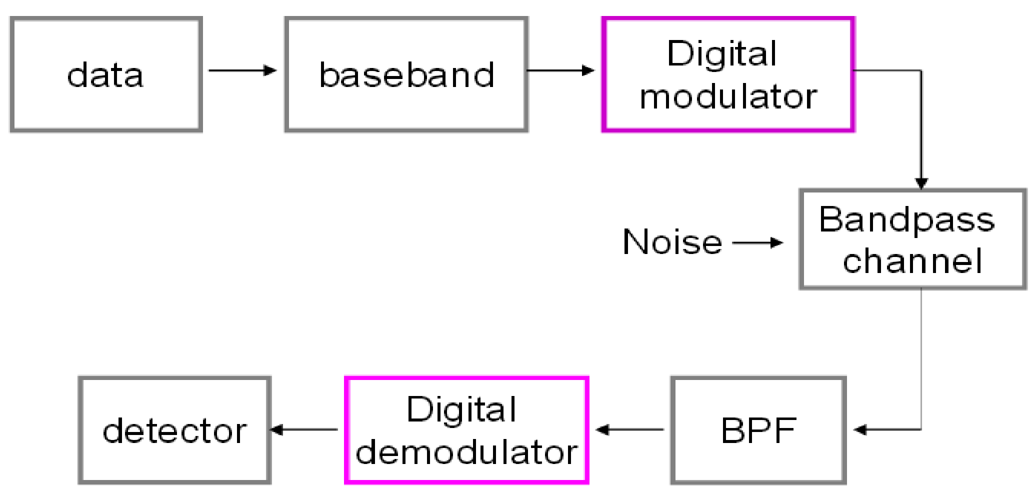




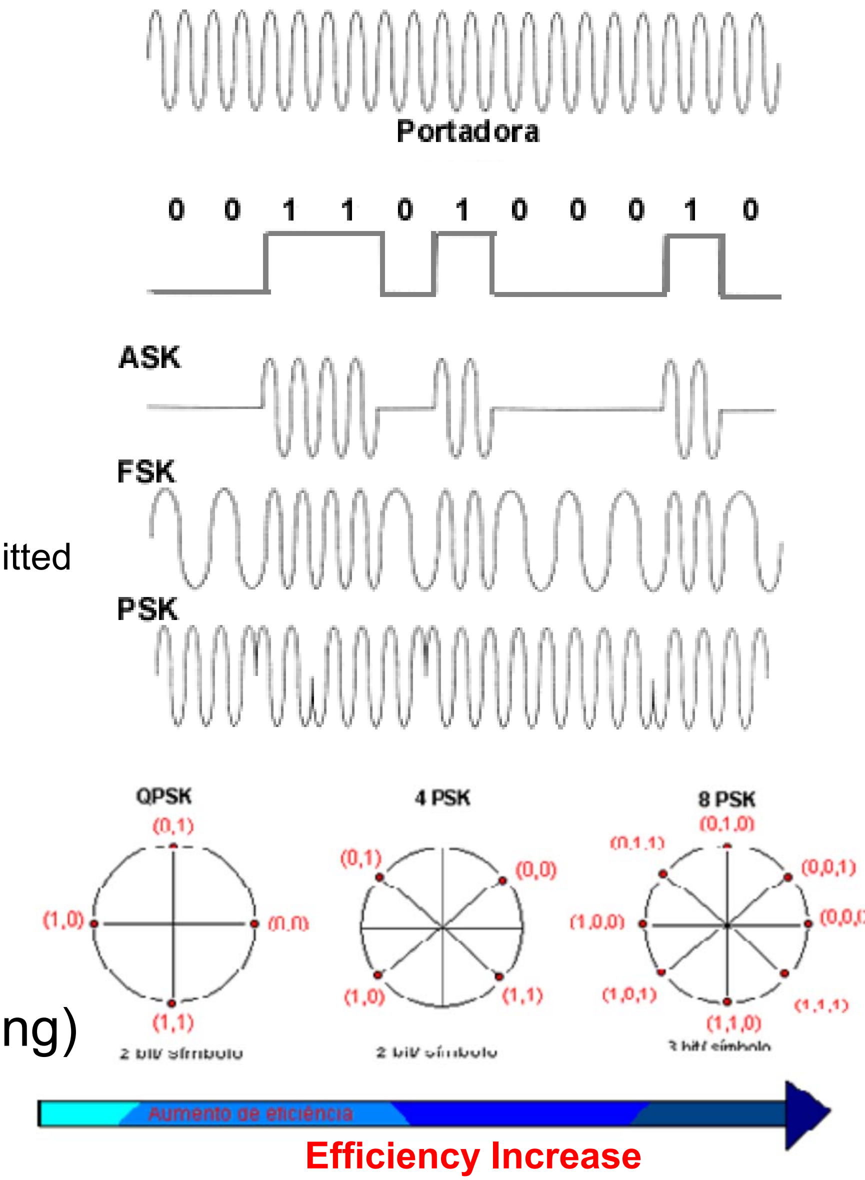
Digital Modulation Technique



Characteristics of a carrier (**amplitude, frequency, or phase**) may vary in accordance with a modulating signal



Digital Modulation Schemes



ASK (Amplitude Shift Keying)

Carrier amplitude alterations as a function of the transmitted information

FSK (Phase Shift Keying)

Carrier frequency alterations as a function of the transmitted information

PSK (Phase Shift Keying)

Carrier phase alterations as a function of the transmitted information

BPSK (Binary Phase Shift Keying)

PSK level #2

nPSK (Binary Phase Shift Keying)

PSK level #n (n=4, 8 etc)

QPSK (Quadrature Phase Shift Keying)

PSK level #4

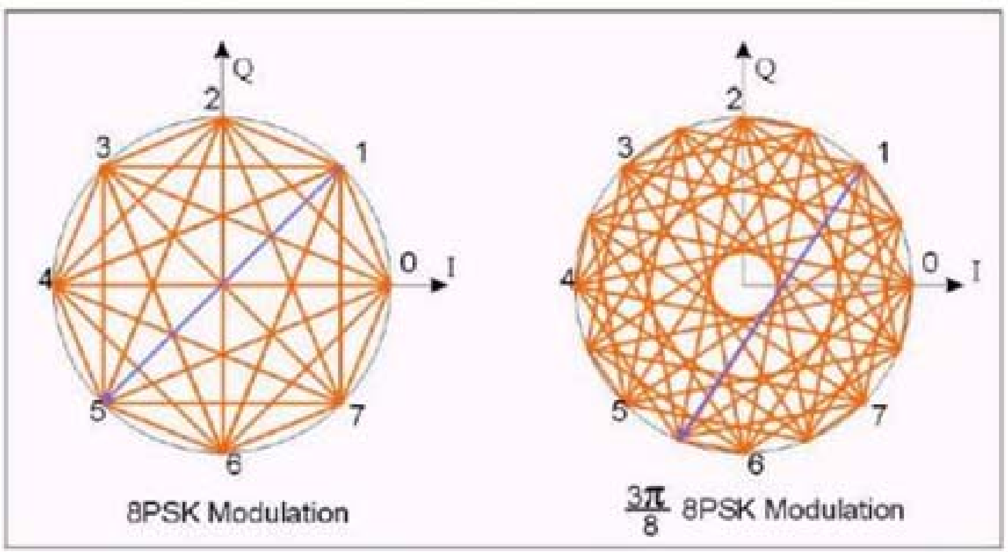
Digital Modulation Schemes

8PSK

- Carrier amplitude drops to zero as it transitions between symbols
- Dynamic range causes problems to radio implementation

3π/8 8PSK (modification to basic 8PSK)

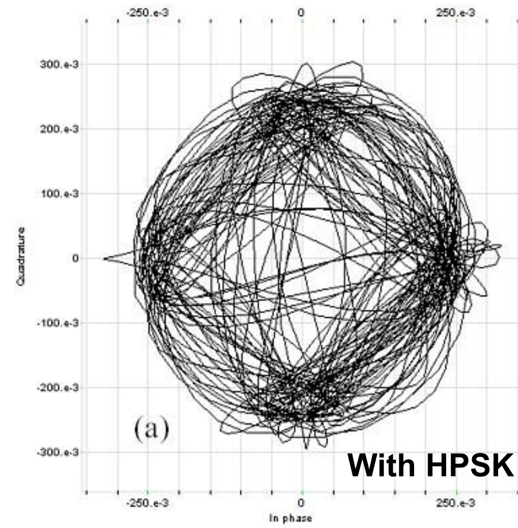
- 3π/8 rotation in addition to the symbol transition
- Prevents the carrier passing through the origin and falling to zero amplitude
- Decreases the dynamic range

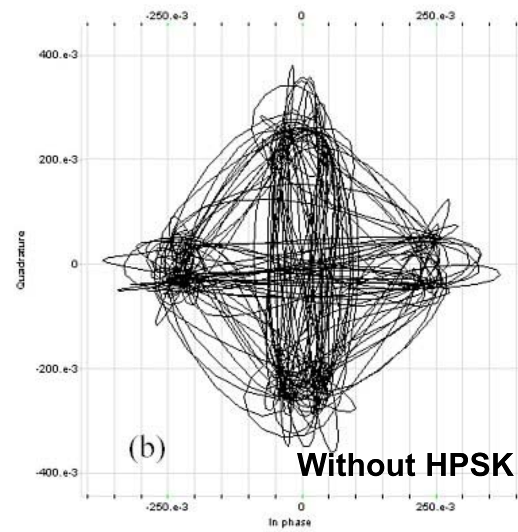


Digital Modulation Schemes

HPSK Hybrid Phase Shift Keying

- Eliminates zero crossings
- Reduces peak-to-average power ratio (PAR) before amplification
- Increases amplifier efficiency
- Improves bit error rate (BER)

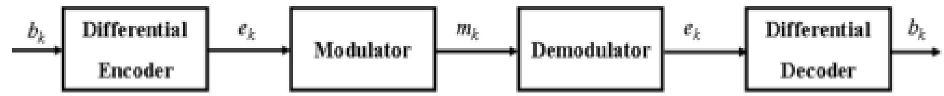




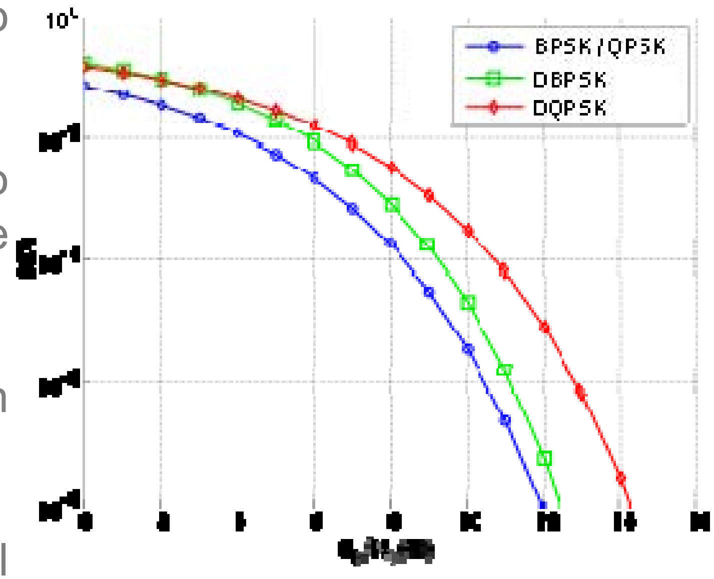
Digital Modulation Schemes

Differential Phase Shift Keying

- DBPSK
- DQPSK

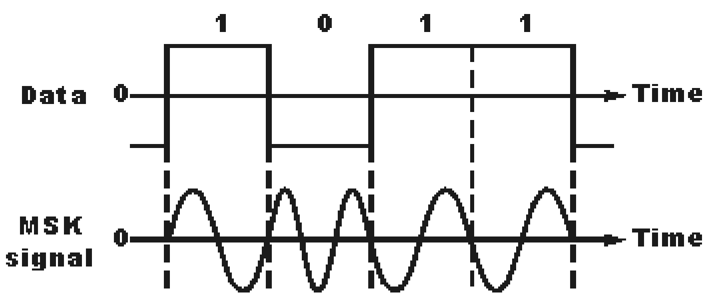


- Simpler to implement than ordinary PSK
- Avoids complex carrier-recovery schemes to provide an accurate phase
- Non-coherent – no need for the demodulator to have a copy of the reference signal to determine the exact phase of the received signal
- This scheme depends on the difference between successive phases
- Precoder maps the input symbol to a new symbol phase difference carrier in the table symbol phase correlations
- Produces more erroneous demodulation [BER]

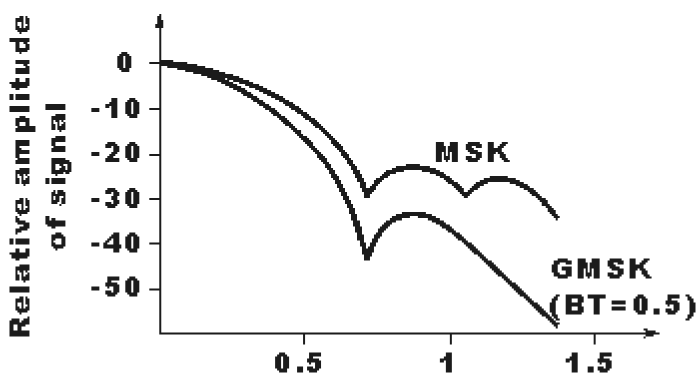


Digital Modulation Schemes

MSK Minimum Shift Keying



GMSK Gaussian filtered MSK



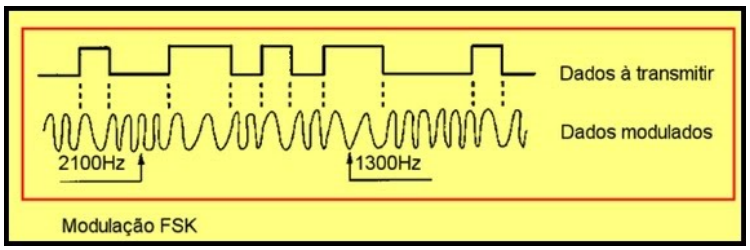
Spectral density of MSK and GMSK signals

PSK problem:
sidebands extend out from the carrier

- MSK and GMSK
  - Continuous-phase FSK
  - No phase discontinuities
- MSK ⟹ GMSK
  - MSK signal extends sidebands
  - Can be reduced with a Gaussian shaped response filter

Digital Modulation Schemes

GFSK Gaussian frequency-shift keying



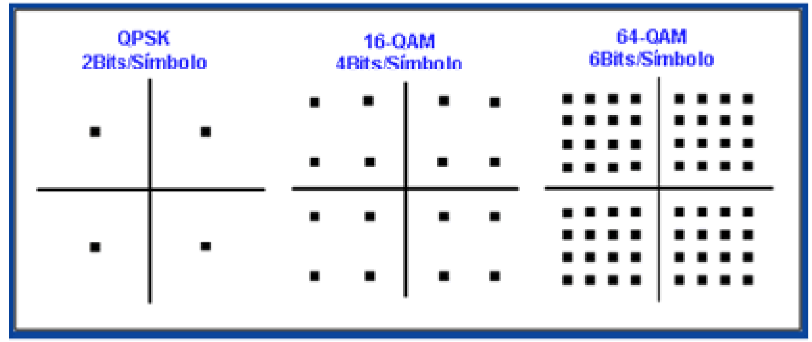
- Modulator similar to FSK
- A Gaussian filter is used before FSK modulator:
  - Making transitions smoother
  - Decreasing spectral width

Digital Modulation Schemes

QAM Quadrature Amplitude Modulation

- Symbols with different amplitudes
- Phase and amplitude modulation
- Phase and quadrature mapping

Constellations



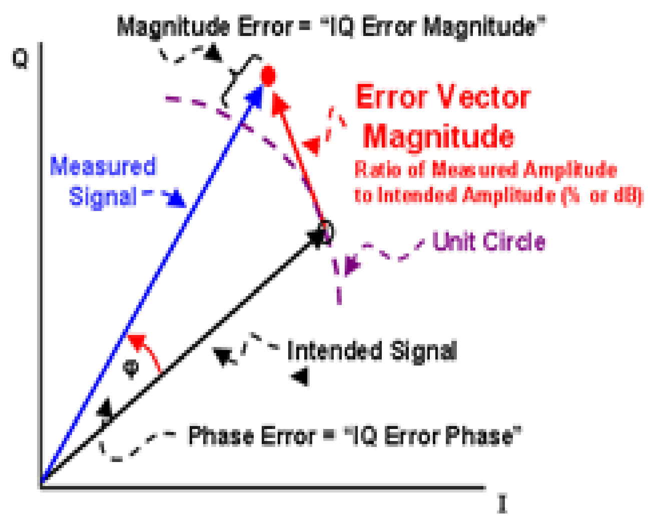
16QAM Constellation:

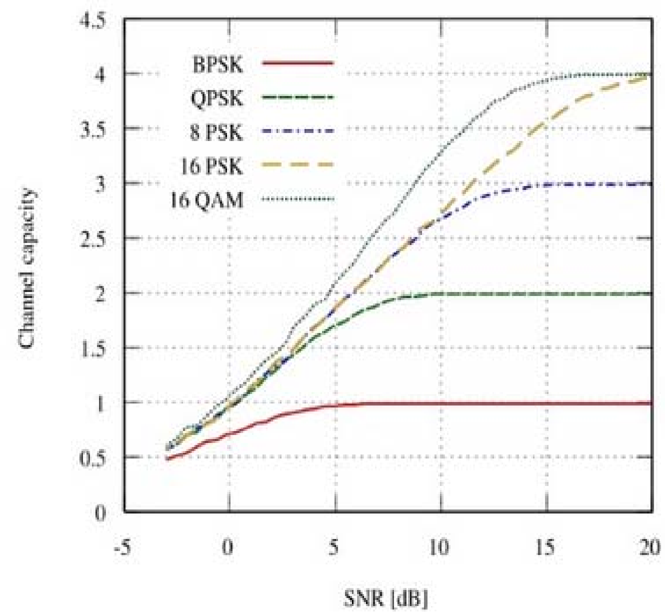
- 16 symbols
- 4 symbols/quadrant
- 4 bits/symbol

64QAM Constellatio

- 64 symbols
- 16 symbols/quadrant
- 6 bits/symbol

Modulation Quality EVM

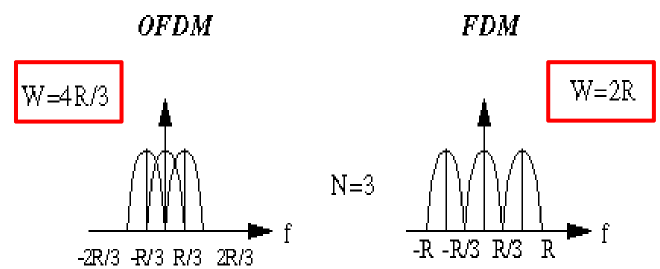


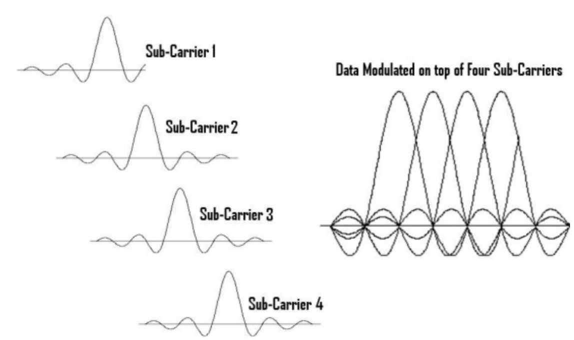


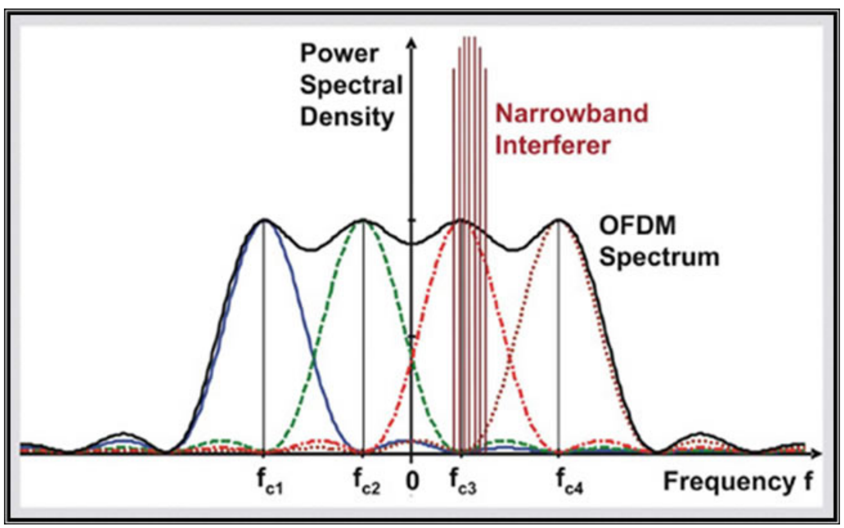
Digital Modulation Schemes

OFDM Orthogonal Frequency Division Multiplex

- A FDM scheme used as a digital multi-carrier modulation method
- Each subcarrier is sampled precisely at its center frequency (peak)
- The peak of any given subcarrier is the point corresponding to the zero-crossings of all the other subcarriers and hence there is no ICI
- Widely used in wireless communication nowadays







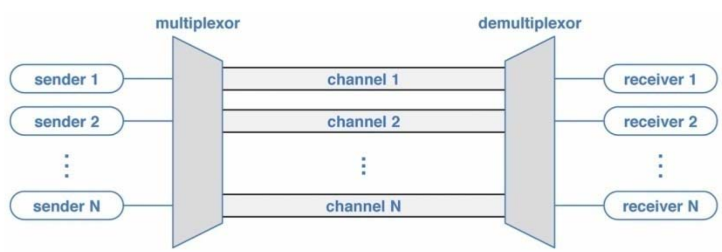
Some OFDM advantages

- ✓ High-speed data transmission
- ✓ Combating the frequency selective fading channel
- ✓ Immunity to delay spread and multipath
- ✓ Resistance to frequency selective fading

Multiplexing Techniques

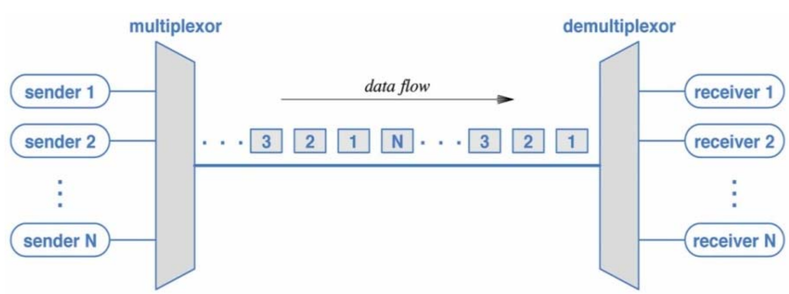
Multiplexing is a technique in which multiple data signals are combined for simultaneous transmission via a shared communication medium.

Frequency Division Multiplexing – FDM ➡ **FDMA** (multiple users/subcarriers)



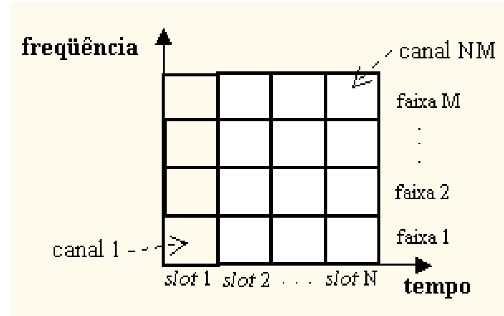
- Uses a carrier signal frequency for each data stream and then combines many modulated signals
- When FDM is used to allow multiple users to share a single physical communications medium (i.e. not broadcast through the air), the technology is called frequency-division multiple access (FDMA)

Time Division Multiplexing – TDM ➡ **TDMA**



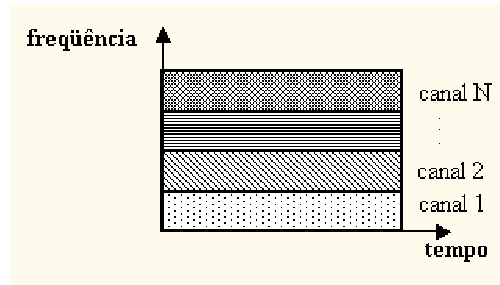
- Transmits two or more streaming digital signals over a common channel
- Signals are divided into time slots
- When TDM is used to allow multiple users to a common channel, the technology is called time division multiple access (TDMA)

Multiple Access Methods



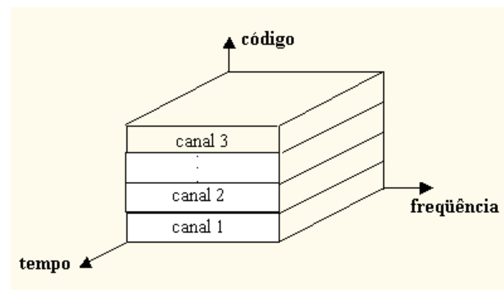
TDMA Time Division Multiple Access

- Several users share the same frequency channel by dividing the signal into different time slots



FDMA Frequency Division Multiple Access

- Gives users an individual allocation of one or several frequency bands, or channels

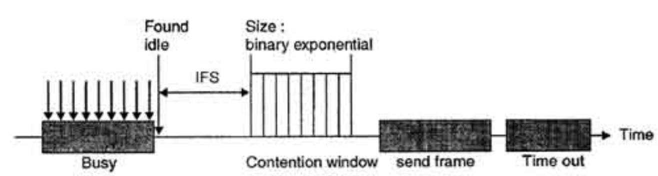


CDMA Code Division Multiple Access

- Several users can send information simultaneously over a single communication channel
- Employs spread-spectrum and a special coding scheme (where each transmitter is assigned a code)

CSMA-CA
Carrier Sense Multiple Access – Collision Avoidance

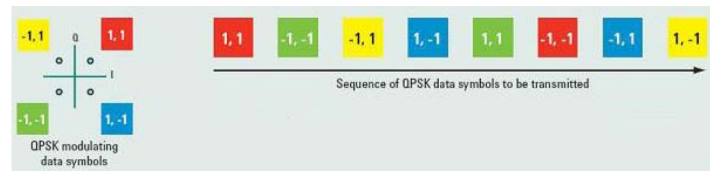
- Nodes attempt to avoid collisions by transmitting only when the channel is sensed to be idle



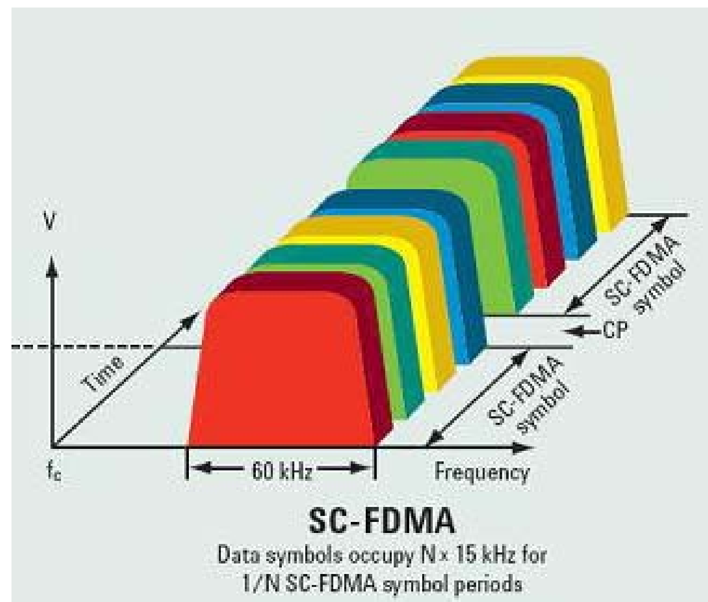
CSMA/CA

Multiple Access Methods

SC-FDMA Single Carrier – Frequency Division Multiplexing Access



- SC-FDMA transmits the data (four QPSK symbols) in time slots, with each data symbol occupying N x 15 kHz bandwidth
- One single carrier / time slot (multi-carrier transmission technique

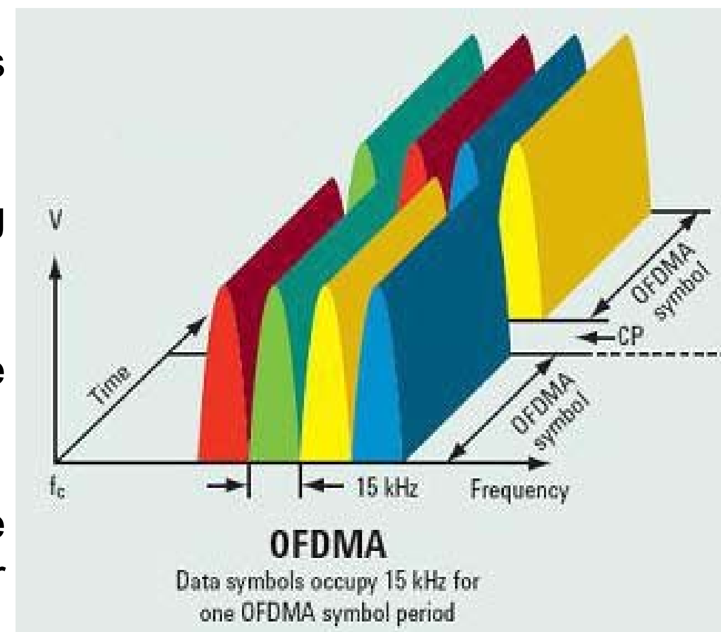


Multiple Access Methods

OFDMA

Orthogonal Frequency Division Multiplexing Access

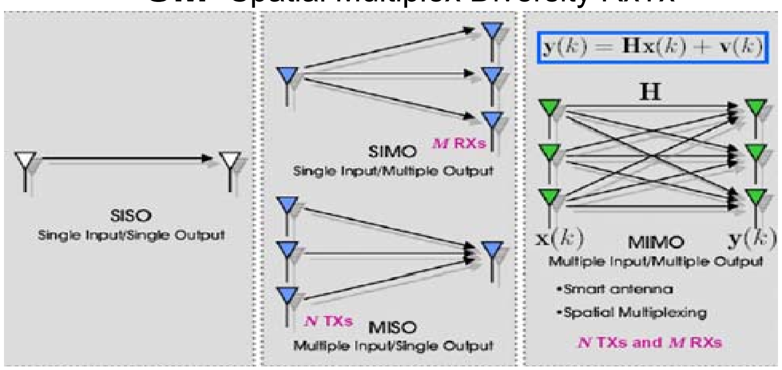
- OFDMA transmits the data (four QPSK symbols) in parallel, one per subcarrier
- Multi-user version of the popular OFDM
- A multi-carrier transmission technique, which divides the available spectrum into many subcarriers
- Multiple access is achieved in OFDMA by assigning subsets of subcarriers to individual users
- A combination of frequency domain (OFDM) and time domain (TDMA) multiple access
- OFDMA refers to simultaneously supporting multiple users by assigning them specific sub channels for intervals of time (slots)



Enhancing Communication Capacity – Advanced Techniques

MIMO Advanced Antenna Technology Configurations

SM Spatial Multiplex Diversity RxTx



SIMO x SISO
- Provides receive antenna redundancy
- Receive diversity techniques
- Improves receiver SINR and performance under fading

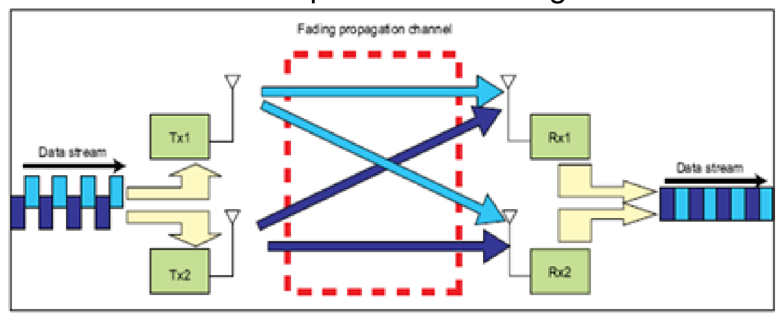
MISO x SISO
- Provides transmit antenna redundancy
- Transmit diversity techniques
- Improves receiver SINR and performance under fading

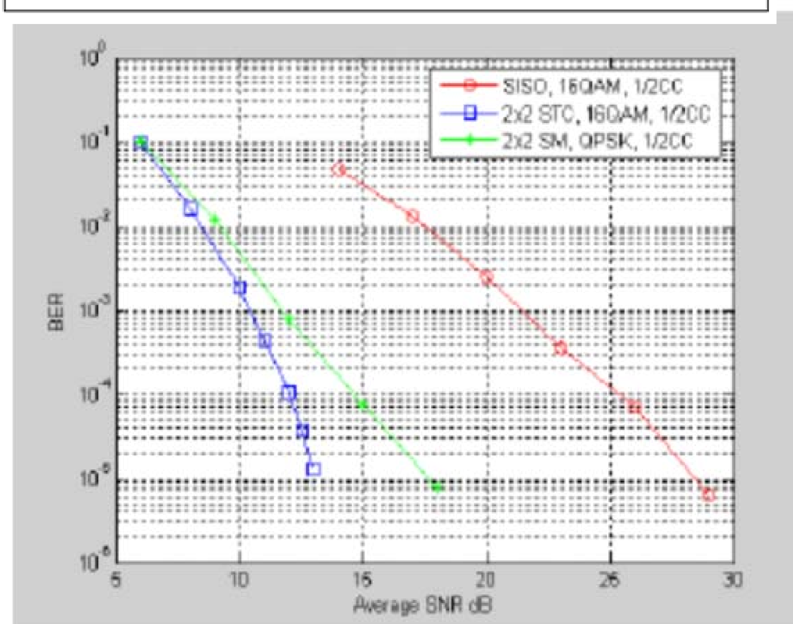
MIMO
- Provides both additional transmit and receive
- Improves SINR, data throughput and spectrum efficiency

MIMO-SM
- Improves robustness and cell coverage

MIMO-STC
- Improves data throughput, and reduces BER

STC Space Time Coding

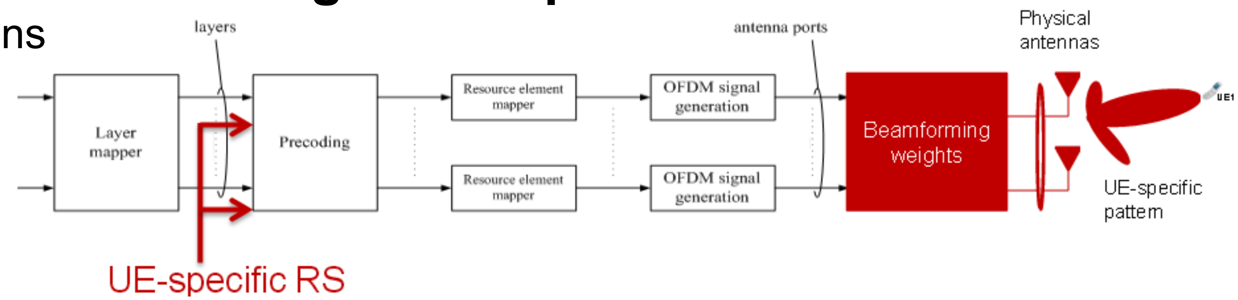


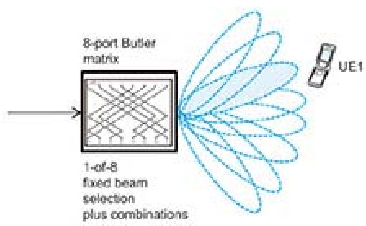


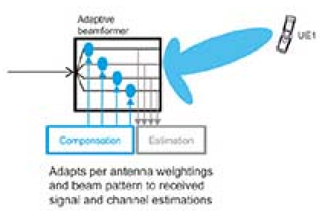
Souce: Radio Access Networks: Status and Evolution Perspectives,Roland Munzener e Hardy Halbauer, Alcatel, 2006

Enhancing Communication Capacity – Advanced Techniques

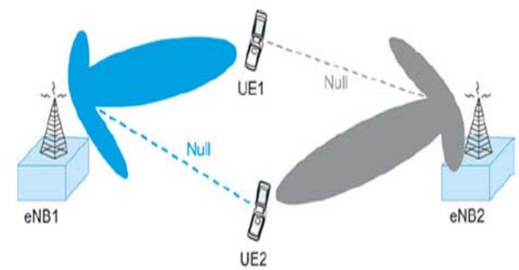
Antenna Beamforming Techniques – Advanced Antenna Technology Configurations

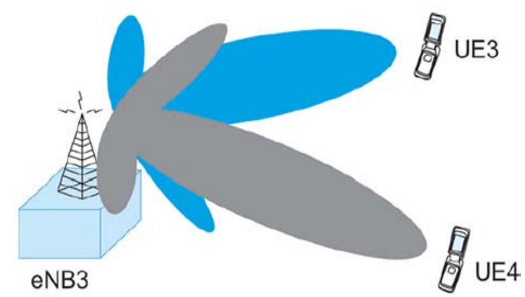




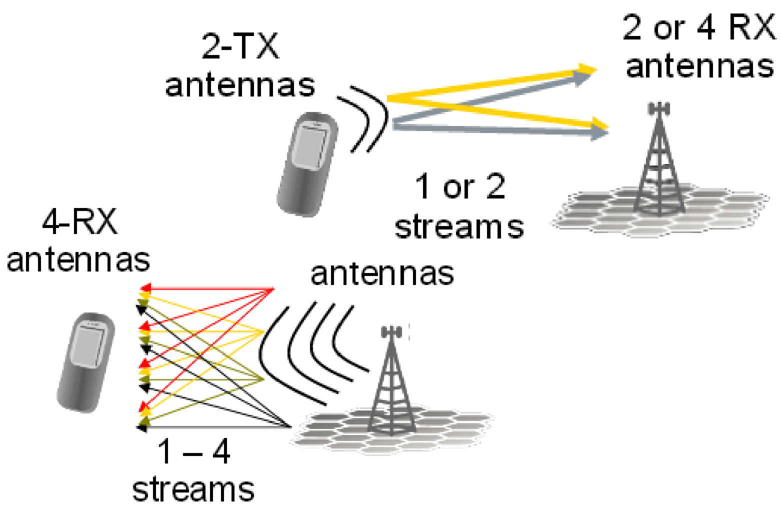


- Multi-antenna configurations focus transmission or reception in a particular direction
- Phased array antenna techniques
    - Switched beamforming (predefined patterns)
    - Adaptive beamforming (real-time adaptive patterns)
- Channel estimation technique (open loop)
- Channel feedback technique (closed loop – OFDMA channel sounding)

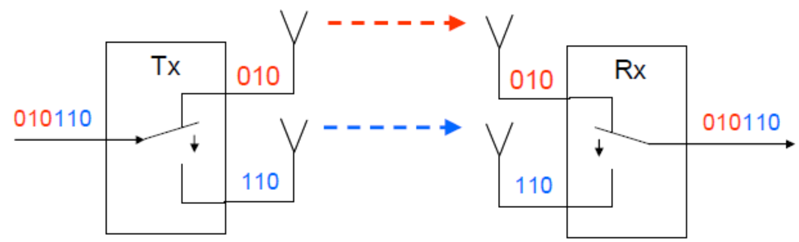




Enhancing Communication Capacity – Advanced Techniques



STC-Space Time Coding



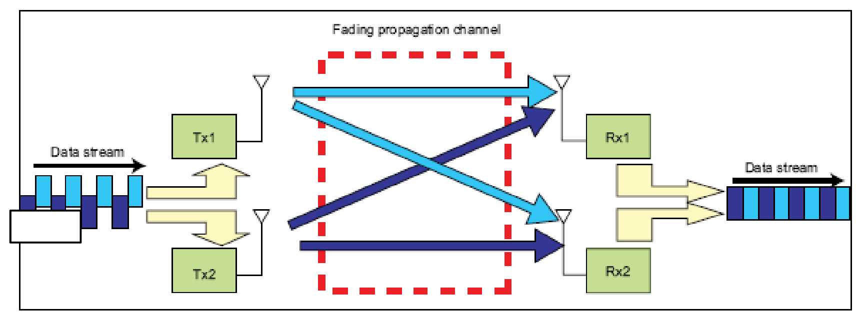
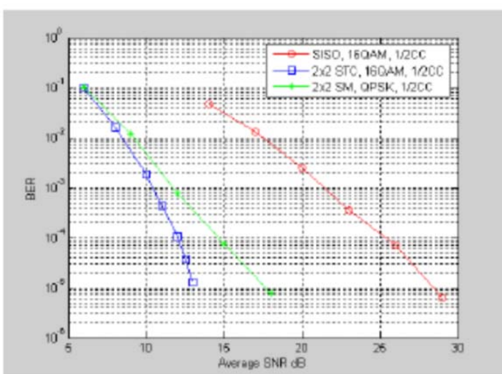
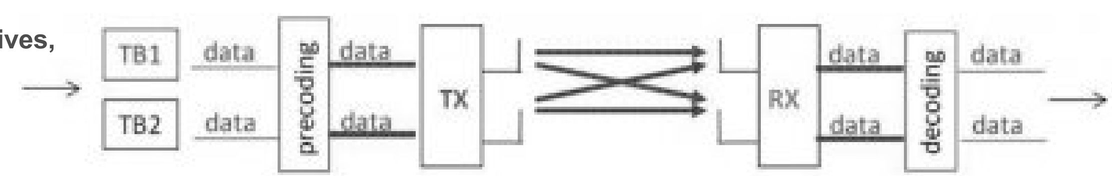


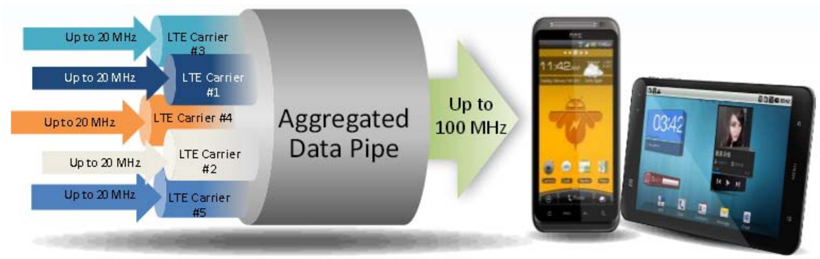
Figure 1: Sequential multiplexing of packet data is routed from baseband to the multiple antenna.



Radio Access Networks: Status and Evolution Perspectives, Roland Munzener e Hardy Halbauer, Alcatel, 2006



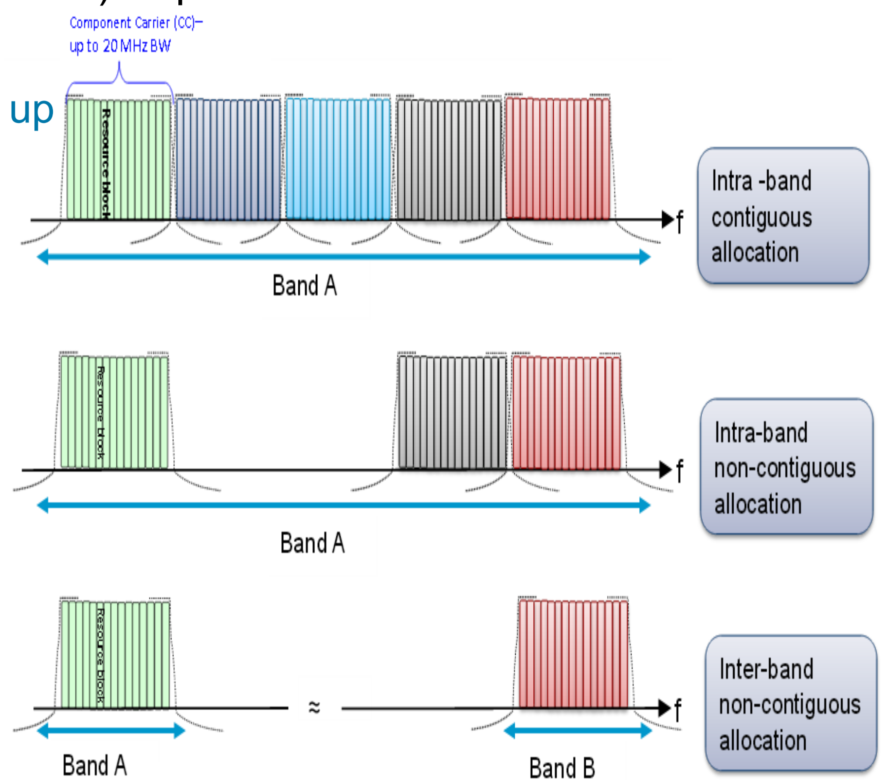
Enhancing Communication Capacity – Advanced Techniques



CA – Carrier Aggregation

IMT-Advanced 4G target (1Gbps DL / 500 Mbps UL) requires **wider channel bandwidths**

- LTE-Advanced supports CA
- Extends maximum transmission bandwidth, up to 100 MHz, aggregating up to five LTE carriers (5 x Component Carriers - CC)
- Efficient use of fragmented spectrum
- Three different CA allocation modes:
  - Intra-band contiguous
  - Intra-band non-contiguous
  - Inter-band
- 3GPP initially limits aggregation to 2 CC only
- Majors design challenges
  - Enhance multi-antenna transmission
  - UE multiple simultaneous Rx/Tx chains
  - reduce harmonics and other IP
- Less impact to eNB



Mobile Phone Standards and Technology Generations

1G First Generation Advanced Mobile Phone Service

- Refers to analog communication networks
- Introduced mobile cellular technology
- First analog “brick phones”
- Basically analog voice service
- AMPS, TACS, NTT technologies

2G Second Generation

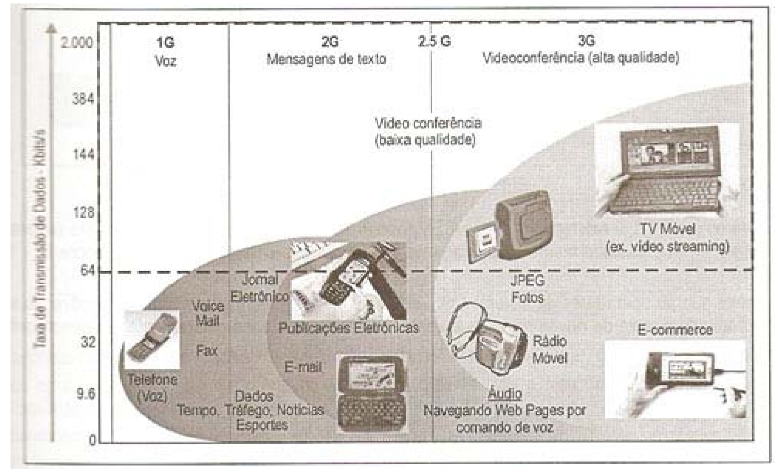
- Refers to wireless digital communication networks
- Variable areas Cells
- Voice and data services
- TDMA, CDMA, GSM, GPRS, EDGE technologies

3G Third Generation

- Established through ITU’s project on International Mobile Telecommunications 2000 (IMT-2000)
- Enabled faster data transmission speeds, greater network capacity and more advanced network services
- Packet data services (videostreaming)
- WCDMA, HSPA, HSPA+

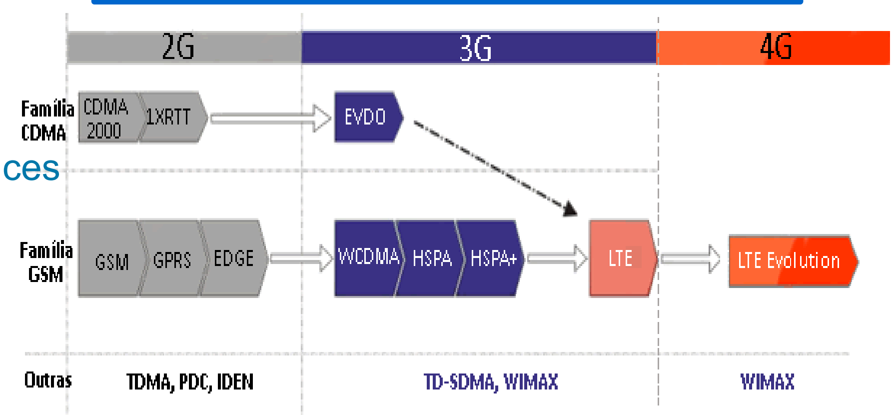
4G Fourth Generation

- Defined by ITU and established as an agreed upon definition in IMT-Advanced
- Integration services (voice data image video)
- LTE-Adanced and IEEE 802.16m Mobile WiMAX



Evolução dos sistemas móveis celulares.

the reference to 2.5G and 3.5G is not an officially recognized standard by the ITU



Cellular Communication Technology Evolution

GSM Family

- **GSM** Global System for Mobile Communications
- **GPRS** General Packet Radio Services
- **EDGE** Enhanced Data for GSM Evolution

GSM
•Originally voice and
•9.6 kbps UL DL data rate

GPRS
•Internet browsing, WAP, SMS, MMS
•Supported multislot class mobiles
•8 slots (UL or DL)

EDGE
•New modulation scheme
•Enhances effective data rate
•Commercial average DL 300 kbps

CELLULAR COMMUNICATION	
Technology	GSM / GPRS / EDGE
Radio Technology	TDMA and FDMA with FDD
Modulation	GSM/GPRS: GMSK EDGE: 3π/8 shift 8PSK or 8PSK
Bandwidth	200 kHz
Latency Time	GSM/GPRS: 500 ms EDGE: 300 ms
Theoretical Peak Data Rate	GSM: 43.2 kbps (DL) and 14.4 kbps (UL) GPRS: 171.2 kbps (DL) and 128.4 kbps (UL) EDGE: 473.6 kbps (DL) and 355.2 kbps (UL)
Service	GSM : voice, SMS, circuit switched data GPRS and EDGE: packet switched data
Packet or Circuit Switched	GSM: circuit switched GPRS and EDGE: adding packet switched data
Conformance Testing Standard	3GPP TS 51.010 -1 V6.5.0 (2005-11)

Cellular Communication Technology Evolution

WCDMA Wideband Code Division Multiple Access

- CDMA communication concepts
- Increases bandwidth
- Broadband communication initiation
- TDD – increases efficiency
- Web service asymmetrical applications

CELLULAR COMMUNICATION	
Technology	WCDMA
Radio Technology	CDMA with FDD and TDD
Modulation	HPSK (UL) QPSK (DL)
Bandwidth	5 MHz
Latency Time	250 ms
Theoretical Peak Data Rate	384 kbps
Service	High-mobility cellular, voice, SMS circuit and packet switched data
Packet or Circuit Switched	Circuit switched and packet switched
Conformance Testing Standard	ETSI TS 134 121-1 V9.1.0 (2010-07)

Cellular Communication Technology Evolution

HSPA - High Speed Packet Access (HSDPA / HSUPA)

HSDPA
- Downlink speed optimization

HSUPA
- Uplink speed optimization

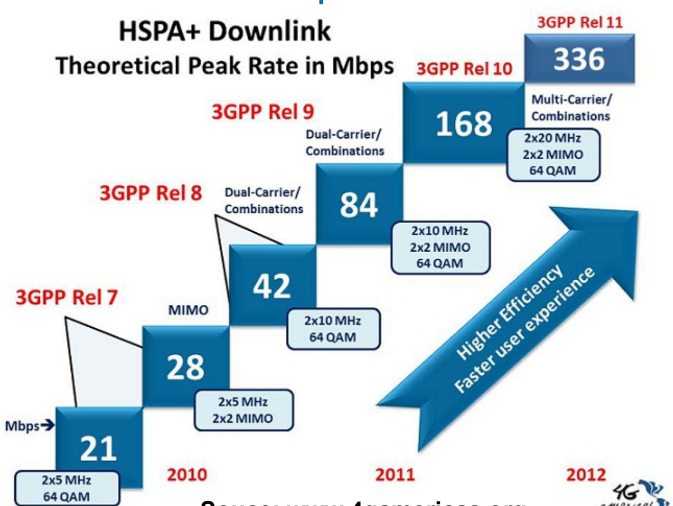
HSPA
- Combination of high speed downlink packet access (HSDPA) and high speed uplink packet access (HSUPA)
- TTI (Transmission Time Interval) reduction

CELLULAR COMMUNICATION	
Technology	HSPA (HSDPA and HSUPA)
Radio Technology	CDMA with FDD and TDD
Modulation	DL: QPSK, 16QAM (Rel6) adding 64QAM (Rel7,8) UL: HPSK (Rel6) adding 16QAM (Rel 7,8)
Bandwidth	5 MHz
Latency Time	70 ms
Theoretical Peak Data Rate	HSDPA (DL): 14.4 Mbps (16QAM)
	HSUPA (UL): 5.76 Mbps
Service	High-mobility cellular, high speed packet data
Packet or Circuit Switched	Circuit switched and packet switched
Conformance Testing Standard	ETSI TS 134 121-1 V9.1.0 (2010-07)

Cellular Communication Technology Evolution

HSPA+ Evolved High Speed Packet Access

- Enhances HSPA capacity
- Higher-order modulation schemes
- Circuit-switched voice over HSPA provides optimized support of voice services
- Protocol improvements



Souce: www.4gamericas.org

CELLULAR COMMUNICATION	
Technology	HSPA +
Radio Technology	CDMA with FDD and TDD
Modulation	DL: QPSK, 16QAM (Rel6) adding 64QAM (Rel7,8) UL: HPSK (Rel6) adding 16QAM (Rel 7,8)
Bandwidth	5 MHz
Latency Time	30 ms
Theoretical Peak Data Rate	HSPA + (DL): 84.4 Mbps (64QAM, 2x2 MIMO) HSPA + (UL): 23.0 Mbps (16QAM)
Service	High-mobility cellular, high speed packet data
Packet or Circuit Switched	Circuit switched and packet switched
Conformance Testing Standard	ETSI TS 134 121-1 V9.4.0 (2011-03)

- MIMO operation (Release 7)
- Dual carrier + MIMO + 64QAM (Release 9)
- Multi-Carrier Aggregation + MIMO + 64QAM (Release 10)

Cellular Communication Technology Evolution

LTE Long Term Evolution – Release 8

LTE

- High data rate, low-latency and packet-optimized system
- SC-FDMA UL
- OFDMA DL
- R1 Scalable bandwidth up to 20 MHz
- Dynamic adaptive modulation
- Supports MIMO antenna technology
- Voice service supported by:
  - VoLTE (Voice Over LTE)
  - SRVCC (Single Radio Voice Call Continuity)
  - CSFB (Circuit Switched Fall-Back)
- Release 9 included the support for MBMS (Multimedia Broadcast Multicast Service)
- Home eNB (HeNB) – "Femtocell"

CELLULAR COMMUNICATION	
Technology	LTE
Radio Technology	LTE: OFDMA and SC-FDMA, TDD and FDD
Modulation	QPSK, 16QAM, 64QAM
Bandwidth	LTE: 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz
	LTE Advanced: up to 100 MHz with Carrier Aggregation
Latency Time	LTE: 10 ms
	LTE Advanced: < 5 ms
Theoretical Peak Data Rate	LTE (DL): 300 Mbps (20 MHz, 64QAM, 4x4 MIMO)
	LTE (UL): 75 Mbps (20 MHz, 64QAM)
Service	LTE: High data rate, High-mobility
Packet or Circuit Switched	Packet switched only
Conformance Testing Standard	3GPP TS 36.521-1 V9.5.0 (2011-06)

Slide 35

R1 Adicionado definição de VoLTE

Separado LTE de LTE-A

RadioLab, 04/05/2015

Cellular Communication Technology Evolution

LTE Advanced – Release 10 and forward

R5

LTE Advanced

- 4G technology meet IMT-Advanced
- Up to 40 MHz with Carrier Aggregation (2 Component Carrier) – based on Release 11
- Carrier aggregation with up to 5 Component Carriers (CC) – future releases
- Higher data rates
- 100 Mbps minimum UL high mobility
- 1 Gbps DL low mobility
- MIMO extension (DL: 8x8; UL: 4x4)
- Support for eICIC (enhanced Inter-cell Interference Coordination) and feICIC (futher enhanced Inter-cell Interference Coordination)
- CoMP (Coordination MultiPoint) – allows to UE to receive and transmit data from and to several points ensuring optimum performance even at cell edges.

CELLULAR COMMUNICATION	
Technology	LTE Advanced
Radio Technology	OFDMA and SC-FDMA, TDD and FDD
Modulation	QPSK, 16QAM, 64QAM
Bandwidth	1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz
	Up to 100 MHz with Carrier Aggregation (CA) using 5 Component Carrier (CC)
Latency Time	< 5 ms
Theoretical Peak Data Rate	DL: 1 Gbps (4x4 MIMO, with BW>70 MHz) UL: 500 Mbps
Service	High data rates for advanced applicatons: [100 Mbps for high mobility and 1 Gbps for low mobility]
Packet or Circuit Switched	Packet switched only
Conformance Testing Standard	3GPP TS 36.521-1 R6

Slide 36

R6 Retirei a versão pois o LTE-A deveria ser A PARTIR da REL 10.

Não sabia se devia inserir REL10 ou se inseria a mais atualizada (12.4)

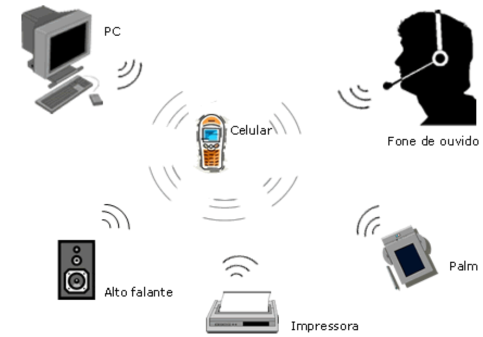
RadioLab, 04/05/2015

R5 Informações atualizadas

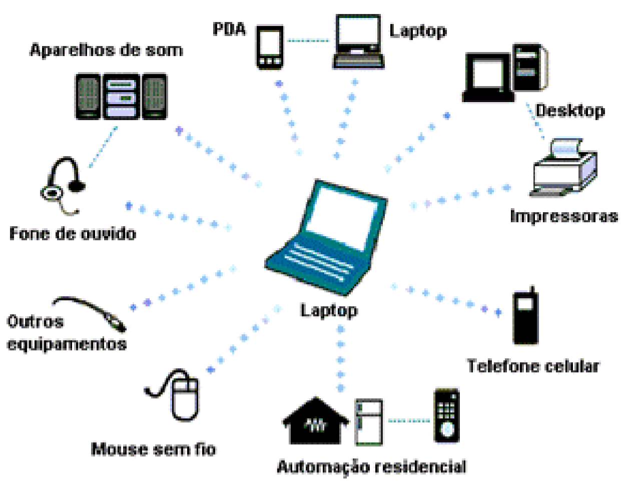
RadioLab, 04/05/2015

Wireless Connectivity Technologies

Bluetooth IEEE 802.15.1 Standard



- Wireless communication between electronic devices
- Short range technology
  - Class1: 100 m @100 mW)
  - Class 2: 10 m @ 2.5 mW)
  - Class 3:1 m @ 1 mW
- Simultaneously handle data and voice
- Very low power consumption
- Low cost solution
- Version 2: 3 Mbps data rate
- Version 3: up to 24 Mbps data rate



WIRELESS CONNECTIVITY	
Technology	BLUETOOTH + EDR
Radio Technology	TDMA
Modulation	GFSK (1.2 and low energy), 8DPSK (Differential PSK) and π/4 DQPSK
Bandwidth	1 MHz (Frequency Hopping)
Theoretical Peak Data Rate	1 Mbps
Service	Low mobility data and voice
Packet or Circuit Switched	Packet switched
Conformance Testing Standards	Anatel Resolution Nº 506, July 1st 2008 Anatel Resolution Nº 442, July 21 2006 Anatel Resolution Nº 529, June 3 2009

Some Applications: hands-free headsets for voice calls, printing and fax capabilities, synchronization for PCs and mobile phones

Wireless Connectivity Technologies

WiFi Wireless Fidelity – IEEE 802.11 Standard

- Wireless LAN technology (up to 400 m)
- Unlicensed ISM bands (2.4/5 GHz)
- Highly optimized for IP and Ethernet
- Ideally suited for wireless Internet access
- Short range technology (~100 m)
- 802.11n includes MIMO technologies
- 802.11p C2C, V2V, V2I communications
- 802.11ac – higher data rates – 6 Gbps
  - Higher channel bandwidths
  - 256QAM subcarrier modulation
- 802.11ad – higher frequency range – 60 GHz

WIRELESS CONNECTIVITY	
Technology	WiFi
Radio Technology	CSMA - CA (Carrier Sense Multiple Access - Collision Avoidance)
Modulation	b: DBPSK/DQPSK (1 and 2 Mbps) b: CCK with DQPSK (5.5 and 11 Mbps) a,g,h,j: up to 64QAM on 52 OFDM subcarrires n: up to 64QAM on 114 OFDM subcarrires ac: up to 256QAM on 484 OFDM subcarrires
Bandwidth	b: 25/10 MHz (non-overlapping/overlapping) g: 25 MHz, a/h: 20 MHz j: 20 MHz n: 20 MHz ac: 20, 40, 80, 160 MHz
Theoretical Peak Data Rate	b: 11 Mbps a/g/h/j: 54 Mbps n: 72.2Mbps (20MHz-1Tx), 600Mbps (40MHz-4Tx) ac: 86.7Mbps (20MHz-1Tx), 6.9Gbps (160MHz-8Tx)
Service	Low mobility data
Packet or Circuit Switched	Packet switched
Conformance Testing Standards	Anatel Resolution Nº 506, July 1st 2008 Anatel Resolution Nº 442, July 21 2006 Anatel Resolution Nº 529, June 3 2009

Wireless Connectivity Technologies

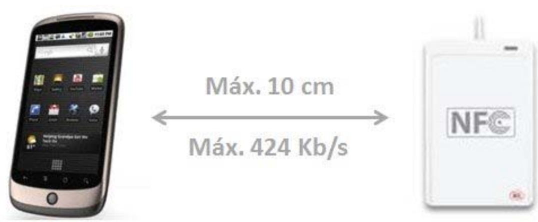
NFC Near Field Communication

ISO/IEC 18092 / ECMA-340 Near Field Communication Interface and Protocol-1

ISO/IEC 21481 / ECMA-352 Near Field Communication Interface and Protocol-2

- Very short-range wireless connectivity technology (a few cm)
- Point-to-point interactions between electronic devices
- Low power consumption
- Based on inductive coupling between two loop antennas
- Unlicensed ISM band of 13.56 MHz
- Active NFC initiator/reader
- Active or passive NFC target/tag modes

WIRELESS CONNECTIVITY	
Technology	NFC
Modulation	ASK
Bandwidth	ISO 18092: n/a
Theoretical Peak Data Rate	106 kbps up to 848 kbps
Service	Contactless identification, interconnection and data transmission between electronic devices
Packet or Circuit Switched	Packet based
Conformance Testing Standards	Anatel Resolution Nº 506, July 1st 2008 Anatel Resolution Nº 442, July 21 2006 Anatel Resolution Nº 529, June 3 2009



Some NFC Applications:

- Contactless transactions
- Personal ID
- Data exchange:
  - Smart poster
  - Business cards
  - Digital photos

R4

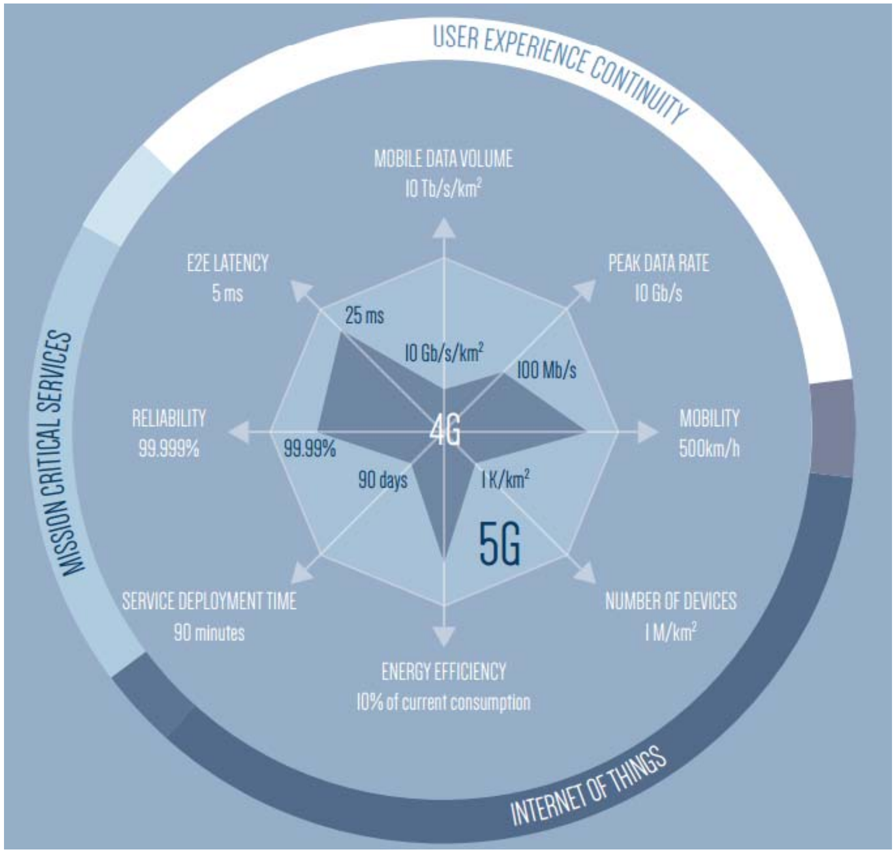
Cellular Communication Technology Evolution

5G

5G - Demands

- Higher data rates than 4G
- Lower latency
- New PHY layer
- New Access Technologies
- New Digital Modulations
- No standards are defined for 5G yet
- Multiple organizations working on standardization
    - IMT for 2020 and beyond
    - 5G-ppp
    - 3GPP – TSG
    - 5GNOW

Objectives



Source: http://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf

Slide 40

R4 Novo Slide
RadioLab, 04/05/2015

R7

Cellular Communication Technology Evolution

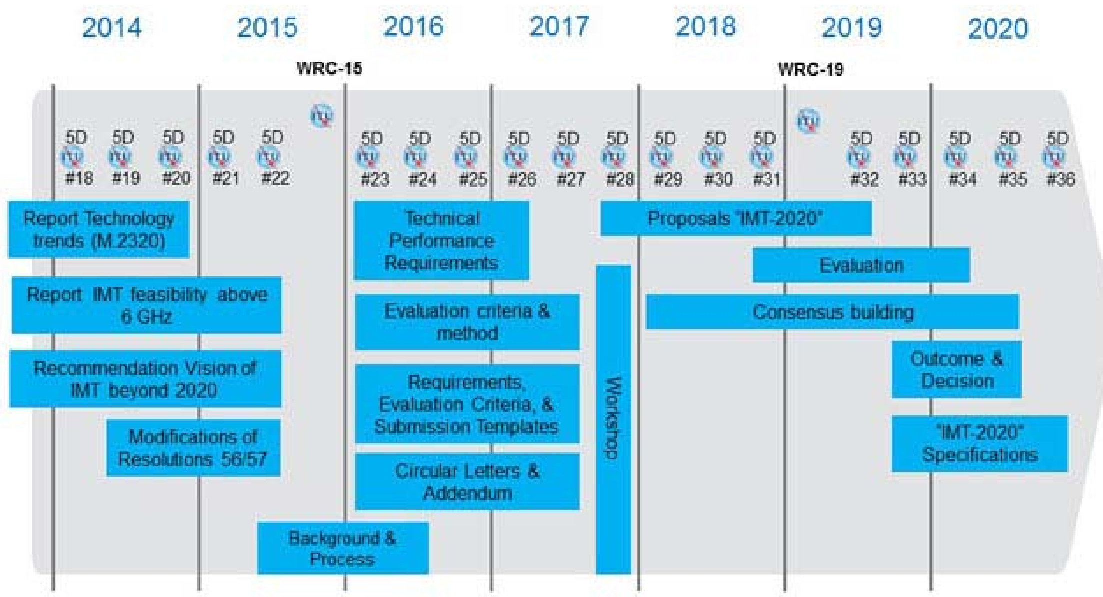
- The International Mobile Telecommunications (IMT) framework encompasses both IMT-2000 and IMT-Advanced systems. All of today's 3G and 4G mobile broadband systems are based on the ITU's IMT standards.

- IMT provides the global platform on which to build the next generations of mobile broadband services

- In early 2012, ITU-R started to develop "IMT for 2020 and beyond", setting the stage for "5G" research activities that are emerging around the world

- The workplan and timeline for the future development of IMT have been defined

Detailed Timeline & Process for "IMT-2020" in ITU-R

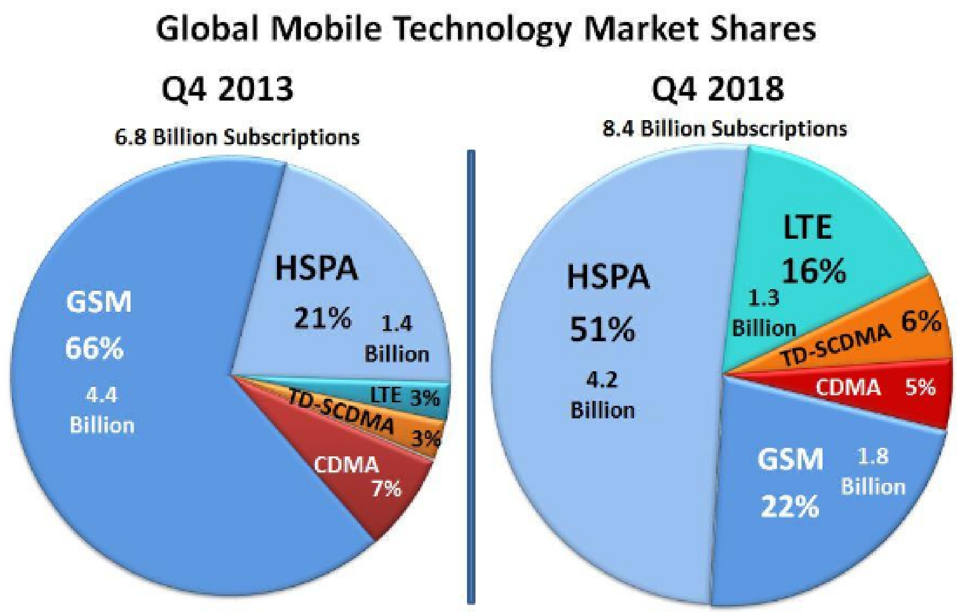


Note: While not expected to change, details may be adjusted if warranted.

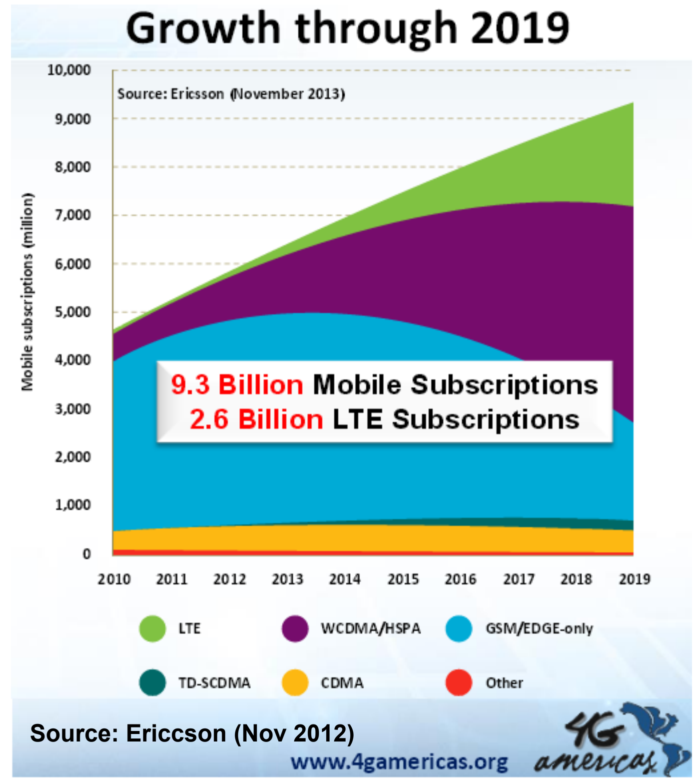
Slide 41

R7 Novo Slide
RadioLab, 04/05/2015

Global Mobile Technology Market Shares

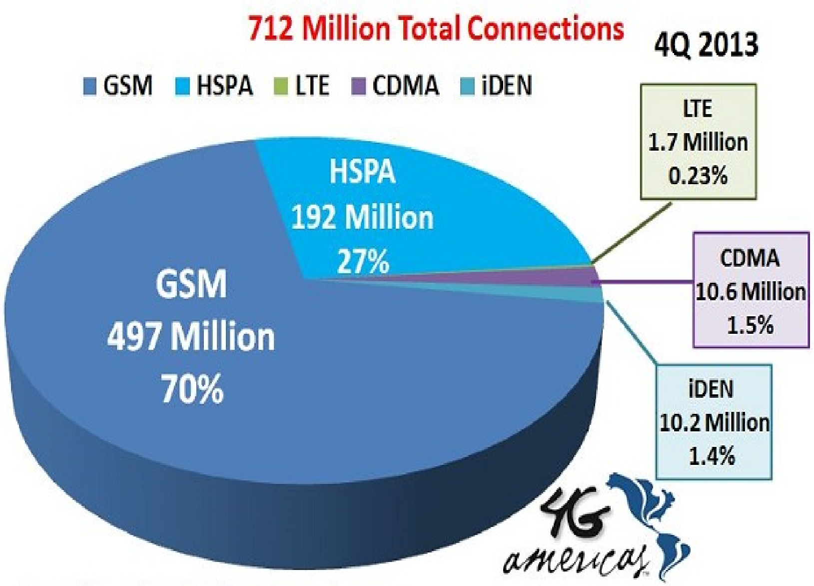


Souce: 4G Americas / 4G Mobile Broadband Evolution / February 2014



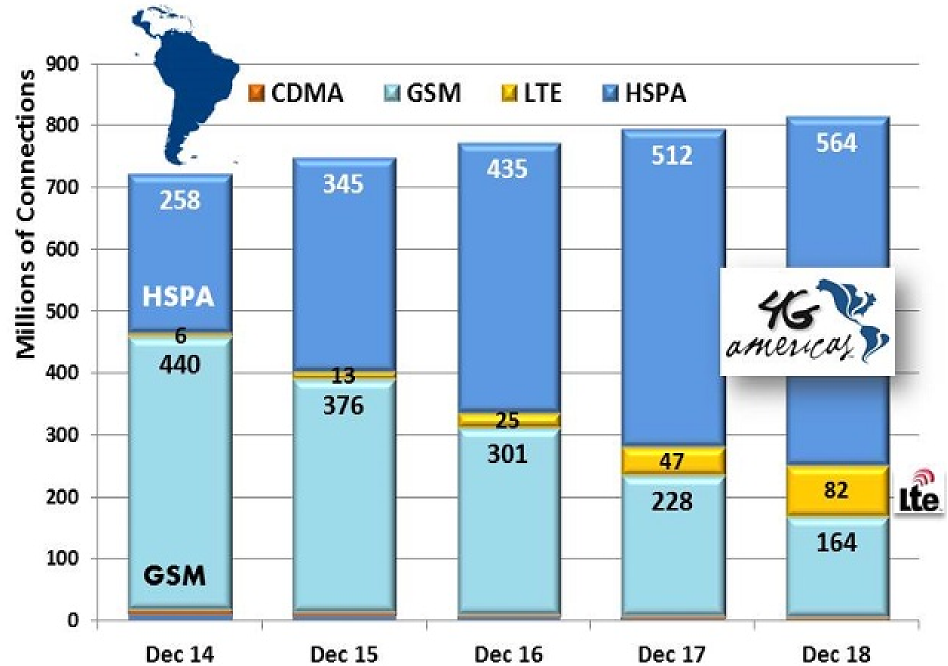
LA&CA Mobile Technology Market Shares

Latin America Mobile Market Shares



Source: Informa Telecoms & Media, WCIS+ December 2013

Forecast /Latin America & Caribbean



Source: Informa Telecoms & Media, WCIS+ 1Q 2014

Schedule

Basic concepts on IMT technologies and other mobile radiocommunication technologies

Standards and test specifications for mobile terminals

Aspects regarding Specific Absorption Rate (SAR) Testing

Aspects regarding EMC Testing

Aspects regarding Safety Testing

ISO/IEC 17025 accreditation - measurement uncertainty - calibration

Global Regulatory Scenario

International Standardization Bodies

IEC – International Eletrotechnical Commission

CISPR – Comité International Spécial des Perturbations Radioélectriques

ITU – International Telecommunication Union

ITU-R – Radiocommunication Sector

ITU-T – Telecommunication Standardization Sector

Global Regulatory Scenario

IEC / CISPR

Applicable EMC international standards from IEC and CISPR :

IEC 61000-4-2, 3, 4, 5, 6, 11 – Immunity

IEC/CISPR 22 – Radio Interference from ITE

(Basic and family standards)

http://ec.europa.eu/enterprise/policies/european-standards/harmonised-standards/rtte/index_en.htm

Global Regulatory Scenario

ITU-T RECOMMENDATIONS ON EMC AND RESISTIBILITY

- ITU-T Rec. K.21 (2003) - Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents.
- ITU-T Rec. K.44 (2003) - Resistibility tests for telecommunication equipment exposed toovervoltages and overcurrents - Basic recommendation.
- ITU-T K38: Radiated emission test procedure for physically large systems
- ITU-T K43: Immunity requirements for telecommunication equipment

http://www.itu.int/ITU-T/recommendations/index_sg.aspx?sg=5

Global Regulatory Scenario

ITU-T RECOMMENDATIONS ON EMC AND RESISTIBILITY

- ITU-T K48: Product family EMC requirements for each telecommunication network equipment
- ITU-T K49: Test condition and performance criteria for voice terminal subject to interference from digital mobile phone
- ITU-T K60: Emission levels and test methods for wireline telecommunication networks to minimize electromagnetic disturbance of radio services

http://www.itu.int/ITU-T/recommendations/index_sg.aspx?sg=5

Global Regulatory Scenario

A GLOBAL INITIATIVE

3GPP – 3rd Generation Partnership Project

This was created within the scope of the **project** called "**International Mobile Telecommunications ITU 2000**, to deal with 3rd generation mobile systems. Its scope was then broadened to include the development and maintenance of radio access technologies. Several major standardization bodies, known as "Organizational Partners," participate in this project.

ETSI was one of the founding organizational **3GPP** partners and plays an active role in the evolution of 3G and other technologies.

Global Regulatory Scenario

"3GPP Organizationals Partners" is formed by six members from Asia, Europe and North America. The objective of each one of these bodies is to define general 3GPP policy and strategy.

Association of Radio Industries and Businesses (**ARIB**) – Japan

Aliance for Telecommunications Industry Solutions (**ATIS**) – USA

China Communications Standards Association (**CCSA**) – China

European Telecommunications Standards Institute (**ETSI**) – Europe

Telecommunications Technology Association (**TTA**) – Korea

Telecommunication Technology Committee (**TTC**) – Japan

IMT-2020 Standardization Process

2012-2015

- Development Plan
- Market/Services View
- Technology/ Research Kick Off
- Vision - IMT for 2020
- Name
- < 6 GHz Spectrum View
- Process Optimization

2016-2017

- Spectrum/Band Arrangements
- Technical Performance Requirements
- Evaluation Criteria
- Invitation for Proposals

2018-2019

- > 6 GHz Spectrum View
- Proposals
- Evaluation
- Consensus Building

2019-2020

- Spectrum/Band Arrangements
- Decision & Radio Framework
- Detailed IMT-2020 Radio Specifications
- Future Enhancement/ Update Plan & Process

Setting the stage for the future: vision, spectrum, and technology views (2012-2017)

Defining the technology (2018-2020)

Global Regulatory Scenario

European Union

Cellular terminals sold in European Union countries need to be in compliance with the applicable European Directives that define the essential requirements that these products must meet.

- **Directive 2011/65/EU** – RoHS
  (restricting the use of certain hazardous substances)
- **Directive 2012/19/EC** – WEEE
  (on electrical and electronic equipment waste and disposal)
- **Directive 2006/66/EC** – Battery and accumulator
  (minimize environmental impact of battery use)
- **Directive 1999/5/EC** – R&TTE
  (on radio and telecommunication terminal equipment)

Global Regulatory Scenario

European Union

Directive 2012/19/EU on waste electrical and electronic equipment (WEEE)

Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)

EN 50581:2012

Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators

The Directive aims at minimizing the negative impacts of batteries and accumulators on the environment.

Global Regulatory Scenario

European Union

Directive 1999/5/CE (R&TTE) on radio and telecommunication terminal equipment

Article 3 – Essential Requirements

- 3.1 (a) User protection and safety
- 3.1 (b) Electromagnetic Compatibility
- 3.2 Radio/RF aspects related with the efficient use of the allocated radio-electric spectrum, without causing radio-interference.

Global Regulatory Scenario

European Union

References of harmonized standards are published in the OJEU – **Official Journal of the European Union.**

Products that meet the Harmonized standards are considered compliant with the essential requirements defined by the Directives.

Bodies responsible for drawing up such standards are:

European Telecommunication Standard Institute (ETSI)

European Committee for Electrotechnical Standardization (CENELEC)

http://europa.eu/youreurope/business/profiting-from-eu-market/selling-goods/index_es.htm

Global Regulatory Scenario

Examples of harmonized standards related to Directive 1999/5/EC - R&TTE, applicable to cellular terminals.

ITEM R&TTE	Standard	Scope
3.1.a	EN60950-1:2006 EN 50360:2001	Safety Requirement regarding R F human exposure
3.1.b	EN 301 489-1 V1.9.2 EN 301 489-3 V1.6.1 EN 301 489-7 V1.3.1 EN 301 489-17 V2.1.1 EN 301 489-19 V1.2.1 EN 301 489-24 V1.5.1	EMC – Common technical requirements EMC – Short Range Devices – 9 kHz – 246 GHz EMC - Mobile and portable devices - GSM and DCS EMC - Broadband Data Transmission Systems EMC – ROMES operating in 1,5 GHz EMC - IMT-2000 CDMA (UTRA and E-UTRA)
3.2	EN 300 328 V1.7.1 EN 300 440-2 V1.4.1 EN 301 511 V9.0.2 EN 301 908-1 V5.2.1 EN 301 908-2 V5.2.1 EN 301 908-13 V5.2.1	Wide band transmission at 2,4 GHz ISM band Short Range Devices in the band 1 GHz – 40 GHz MS in GSM -900 MHz and GSM-1800 MHz bands IMT Cellular Network - common requirement IMT Cellular Network : 8j miiim– CDMA – UTRA - FDD IMT Cellular Network : E-ULTRA

http://ec.europa.eu/enterprise/policies/european-standards/harmonised-standards/rtte/index_en.htm

Global Regulatory Scenario

USA

Federal Communication Commission rules

47 CFR Part 15 – Radio Frequency Devices

- **§ 15.209** Radiated emission limits – general requirements
- **§ 15.245** Operation within the bands 902-928 MHz, 2435-2465 MHz, 5785-5815 MHz, 10500-10550 MHz and 24075-24175 MHz - Example: WiFi, RFID,Bluetooth
- **§ 15.407** General technical requirements for (U-NII) Unlicensed National Information Infrastructure. Devices operating in the 5,15-5,35 GHz, 5,47-5,725 GHz and 5,725-5,825 GHz bands. Ex.: LAN and WiFi.

Global Regulatory Scenario

USA

Federal Communication Commission rules

47 CFR Part 22 – Public Mobile Services
Subpart H – Cellular Radiotelephone Service

- **§ 22.900** Scope
- ......
- **§ 22.905** Channels for cellular service
- ….
- **§ 22.913** Effective radiated power limits
- **§ 22.917** Emission limitations for cellular equipment
- ……
- **§ 22.973** ....

Global Regulatory Scenario

USA

Federal Communication Commission rules

47 CFR Part 24 – Personal Communications Services
Subpart E – Broadband PCS

- **§ 24.200** Scope
- ……….
- **§ 24.236** Field strength limits
- ………..
- **§ 24.238** Emission limitations for Broadband PCS equipment

Global Regulatory Scenario

USA

Federal Communication Commission rules

- OET Bulletin 65, Edition 97-1
- SAR (Specific Absorption Ratio) Approach

Global Regulatory Scenario

Regarding Specific Absorption Rate (SAR)

- **IEEE STD 1528 (2003):** IEEE Recommended Practice for Determining the Peak Spatial – Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques.
- **EN50371 (2002) :**. Generic Standard to demonstrate the compliance of low power electronic and electrical apparatus with basic restrictions relate to human exposure to electromagnetic fields (10 MHz – 300 GHz) – General public, 2002.
- **IEC 62209 – 01 (2005):** Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz), 2005.
- **IEC 62209 – 02 (2010)**. Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures – Part 2: Procedure to determine the Specific Absorption Rate (SAR) in the head and body for 30 MHz to 6 GHz Handheld and Body-Mounted Devices used in close proximity to the Body, 2010.

Brazilian Regulation

Brazilian Certification Test Requirements

In Brazil, the National Telecommunications Agency (**ANATEL**) is the body responsible for defining the minimum technical requirements that telecommunication devices must meet. Such requirements reference normative documents drawn up by the agency itself and/or international standards.

Brazilian Certification Test Requirements

The purpose of lab tests during the certification and approval process of telecommunication products is to verify the equipment meets the minimum technical requirements to ensure adequate operation even when surrounded by several other kinds of communication systems. The certification and approval process also provides:

- Quality of services for users
- Equipment interoperability
- Electromagnetic compatibility
- User safety

Brazilian Certification Test Requirements

Technical requirements are based mainly on international standards and they are specified in the document published by ANATEL namely:

"*REQUISITOS TÉCNICOS E PROCEDIMENTOS DE ENSAIOS APLICÁVEIS À CERTIFICAÇÃO DE PRODUTOS PARA TELECOMUNICAÇÃO DE CATEGORIA I*"

www.anatel.gov.br → Certificação de Produto → Requisitos Técnicos para Certificação

⟶ Lista de Requisitos Técnicos para Produtos de Telecomunicações Categoria I

Technical Requirements and Test Procedures for the Certification of Telecommunication Products Category I

Produto:	Telefone móvel celular

Documento normativo	Requisitos aplicáveis (vide nota II)	Procedimentos de ensaios
REQUISITOS APLICÁVEIS A TODAS AS TECNOLOGIAS		
a) Anexo à Resolução Nº 442 de 21 de julho de 2006 - Regulamento para Certificação de Equipamentos de Telecomunicações quanto aos Aspectos de Compatibilidade Eletromagnética.	- Na íntegra, no que for aplicável, exceto Título II – Dos requisitos de emissão de perturbações eletromagnéticas radiadas, artigo 6º parágrafo 2	- vide notas III, IV e V.
b) Anexo à Resolução nº 529, de 03 de junho de 2009 - Regulamento para Certificação de Equipamentos de Telecomunicações quanto aos Aspectos de Segurança Elétrica.	- Na íntegra, no que for aplicável.	- vide notas III, IV e IX.
c) Anexo à Resolução nº 303 de 02 de julho de 2002 - Regulamento Sobre Limitação da Exposição a Campos Elétricos, Magnéticos e Eletromagnéticos na Faixa de Radiofreqüências entre 9 Khz e 300 GHz	- Titulo II – Capítulo II - Dos Limites de Exposição – Tabela V- Restrições Básicas para exposição a CEMRF, na faixa de radiofreqüências entre 9 kHz e 10 GHz e Art. 11.	- Titulo III – Capítulo II - Dos Procedimentos de Avaliação de Estações Terminais Portáteis

Scope: EMC requirements, safety, SAR and functional requirements

Technical Requirements and Test Procedures for the Certification of Telecommunication Products Category I

REQUISITOS APLICÁVEIS AO SERVIÇO MÓVEL PESSOAL – SMP		
Tecnologia CDMA: a) TIA/EIA-98-C - Recommended Minimum Performance Standards for Dual-Mode Spread Spectrum Mobile Stations	3.5.2 - Emissão de espúrios radiados (receptor); 4.1.1 - Exatidão de freqüência; 4.4.1 - Faixa de potência de saída em loop aberto; 4.4.5 - Potência de saída de RF máxima; 4.4.6 - Potência de saída mínima controlada; 4.5.1 - Emissão de espúrios conduzidos; 4.5.2 – Emissão de espúrios radiados (transmissor).	- Os procedimentos de ensaio se encontram no próprio documento normativo; - Os ensaios não deverão levar em consideração variações de temperatura e tensão de alimentação. - vide nota IV;
Tecnologia GSM: a) GSM – 3GPP TS 51.010-1 V6.5.0 (2005-11) 3rd Generation Partnership Project; Technical Specification Group GSM/EDGE Radio Access Network Digital cellular telecommunications system (Phase 2+); Mobile Station (MS) conformance specification; Part 1: Conformance specification (Release 6)	12.1.1 -Emissão de espúrios conduzidos - terminal em comunicação; 12.1.2 -Emissão de espúrios conduzidos - terminal inativo; 12.2 - Emissão de espúrios radiados; 13.1 - Erro de freqüência e fase; 13.3 - Potência de saída de transmissão, controle de potência e tempo de burst.	- Os procedimentos de ensaio se encontram no próprio documento normativo; - Os ensaios não deverão levar em consideração variações de temperatura e tensão de alimentação. - vide nota IV;

EMC requirements, safety, SAR and functional requirements

Brazilian Certification Test Requirements – Functional Tests

2G Technology (GSM, GPRS and EDGE)

Reference Standard: 3GPP TS 51.010-1 V6.5.0 (2005-11)

- 12.1 Conducted Spurious Emissions
- 12.2 Radiated Spurious Emissions
- 13.1 Frequency Error and Phase Error
- 13.16.1 Frequency Error and Phase Error in GPRS Multislot Configuration
- 13.17.1 Frequency Error and Modulation Accuracy in EGPRS Configuration
- 13.3 Transmitter Output Power and Burst Timing
- 13.16.2 Transmitter Output Power in GPRS Multislot Configuration
- 13.17.3 EGPRS Transmitter Output Power

Brazilian Certification Test Requirements – Functional Tests

3G Technology (WCDMA)

Reference Standard: : ETSI TS 134 121-1 V9.1.0 (2010-07)

- 5.2 Maximum Output Power
- 5.3 Frequency error
- 5.4.1 Open Loop Power Control in the Uplink
- 5.4.2 Inner Loop Power Control in the Uplink
- 5.4.3 Minimum Output Power
- 5.5.1 Transmit OFF Power
- 5.5.2 Transmit ON/OFF Time mask
- 5.7 Power Setting in Uplink Compressed Mode
- 5.9 Spectrum Emission Mask
- 5.11 Spurious Emissions
- 5.13.1 Error Vector Magnitude (EVM)

Brazilian Certification Test Requirements – Functional Tests

3G Technology (HSDPA and HSUPA)

Reference Standard: ETSI TS 134 121-1 V9.1.0 (2010-07)

- 5.2AA Maximum Output Power with HS-DPCCH
- 5.2B Maximum Output Power with HS-DPCCH and E-DCH
- 5.2C UE Relative Code Domain Power Accuracy
- 5.2D UE Relative Code Domain Power Accuracy for HS-DPCCH and E-DCH
- 5.7A HS-DPCCH Power Control
- 5.9A Spectrum Emission Mask with HS-DPCCH
- 5.9B Spectrum Emission Mask with E-DCH
- 5.13.1A Error Vector Magnitude (EVM) with HS-DPCCH
- 5.13.1AA Error Vector Magnitude (EVM) and Phase Discontinuity with HS-DPCCH
- 5.13.2A Relative Code Domain Error with HS-DPCCH
- 5.13.2B Relative Code Domain Error with HS-DPCCH and E-DCH

Brazilian Certification Test Requirements – Functional Tests

LTE Technology

Reference Standard: 3GPP TS 36.521-1 V9.5.0 (2011-06)

- 6.2.2 UE Maximum Output Power
- 6.2.3 Maximum Power Reduction (MPR)
- 6.2.5 Configured UE transmitted Output Power
- 6.3.2 Minimum Output Power
- 6.3.4.1 ON/OFF Time Mask
- 6.5.1 Frequency Error
- 6.5.2.1 Error Vector Magnitude (EVM)
- 6.5.2.2 Carrier Leakage
- 6.5.2.3 In-Band Emissions for Non Allocated RB
- 6.6.1 Occupied Bandwidth
- 6.6.2.1 Spectrum Emission Mask
- 6.6.2.3 Adjacent Channel Leakage Power Ratio
- 6.6.3.1 Transmitter Spurious Emissions

Brazilian Certification Test Requirements – Functional Tests

Bluetooth Technology
Addendum to ANATEL Resolution 506, dated July 1, 2008 – Standard for Restricted Radiation Radiocommunication Equipment.

<u>Section IX</u>

- Separating Carrier Frequencies in Hop Channels
- Maximum Transmitter Output Power Peak
- Hop Frequencies
- Maximum Width of Occupied Hop Channel Range at 20 dB
- Mean Occupancy Time of any Frequency
- Spurious Emissions

Brazilian Certification Test Requirements – Functional Tests

Wi-Fi Technology
Addendum to ANATEL Resolution 506, dated July 1, 2008 – Standard for Restricted Radiation Radiocommunication Equipment.

Section IX

- Maximum Transmitter Output Power
- Maximum Width of Occupied Hop Channel Range at 6 dB
- Peak Power Density in any 3 kHz Range
- Spurious Emissions

Section X

- Maximum Transmitter Output Power
- Mean EIRP
- EIRP Spectral Density Mean Value
- Spurious Emissions
- Transmit Power Control (TPC)
- Dynamic Frequency Selection (DFS)

Brazilian Certification Test Requirements

EMC Tests

Annex to Resolution 442, dated July 21, 2006 – Regulatory rules for electromagnetic compatibility certification of telecommunications equipment.

Electrical Safety Tests

Annex to Resolution 529, dated June 03, 2009 – Regulatory rules for electrical safety certification of telecommunications equipment.

SAR and BS Non Ionizing Radiation Protection Evaluation

Annex to Resolution 303, dated July 2, 2002– Regulation regarding limits of exposure to electric, magnetic and electromagnetic fields in the frequency range between 9 kHz and 300 GHz.

SAR Tests

Annex to Resolution 533, dated Sept 10, 2009 – Standard for specific absorption rates (SAR) certification and approval of telecommunication equipment.

Schedule

- Basic concepts on IMT technologies and other mobile radiocommunication technologies
- Standards and test specifications for mobile terminals
- **Aspects regarding Specific Absorption Rate (SAR) Testing**
- Aspects regarding EMC Testing
- Aspects regarding Safety Testing
- ISO/IEC 17025 accreditation - measurement uncertainty - calibration

SAR Tests – Definitions

SAR – Specific Absorption Rate

SAR is defined as the incremental electromagnetic power absorbed by an incremental mass contained in a volume element of given density, averaged over a certain period of time (ANSI,1982).

SAR is measured in W/kg, representing power absorbed by unit mass.

Normative limits for SAR tests are prescribed based on scientific studies regarding the effects of radiation to ensure that users' health will not be affected in the short term. Therefore, this test is fundamental from the aspect of user safety.

SAR Tests – Definitions

$$SAR = \frac{d}{dt}\left(\frac{dW}{dm}\right) = \frac{d}{dt}\left(\frac{dW}{\rho dV}\right)$$

***dW* = Electromagnetic Energy**

***dm* = Mass**

***dV* = Volume**

ρ = Density

$$SAR = \left.\frac{c\Delta T}{\Delta t}\right|_{t=0}$$

c = Specific Heat

ΔT = Temperature variation

Δt = Duration (time) of exposure

$$SAR = \frac{\sigma |E|^2}{\rho}$$

σ = Electrical conductibility

E = RMS value of the electrical field vector

ρ = Middle density

SAR Tests – Measurement Techniques

Temperature Alterations

- Temperature measurement probes
  - Optical or electrical technology
- Heat meters

Electrical Field Measurements

- Probes with dipoles and diodes
- Probes with optical sensors

Technology adopted by all standards

- Probes with dipoles and diodes

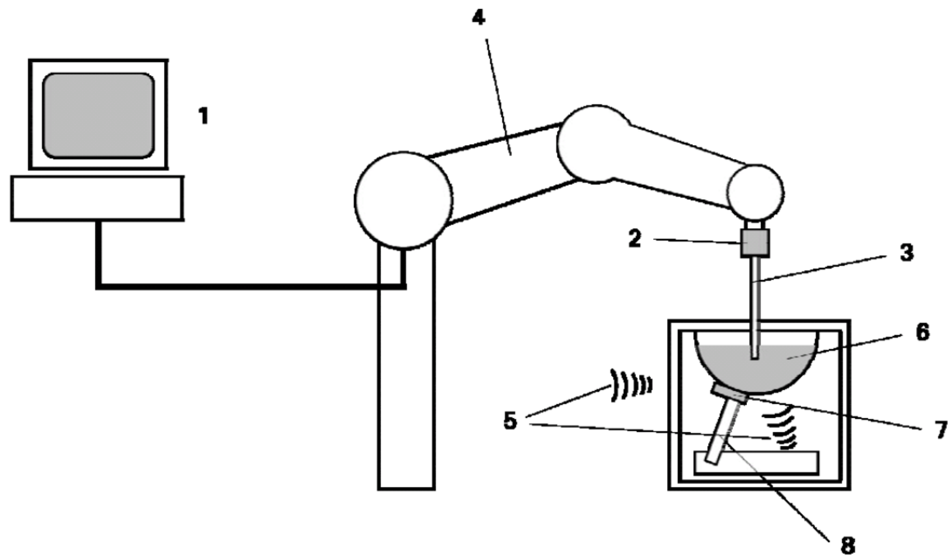
SAR Tests – Device Under Test

SAR tests must be run on portable radiofrequency telecommunication equipment that operate close to the human body. In Brazil, the Addendum to Resolution 533 defines that any portable terminal operating the range between 300 MHz and 6 GHz must be submitted to SAR tests.

Examples of portable telecommunication terminals:

Cell phones Tablets Radios Modems PTT

SAR Tests – Basic Test Setup



1) Unit for data acquisition/control
2) Electronic transducer test probe
3) Electrical field dosimetric test probe
4) Robotic test probe positioner
5) Present electromagnetic fields
6) Phantom filled with simulating liquid
7) Equipment Under Test (EUT)
8) EUT positioner

SAR Tests – Environment Requirements

Reference Standards:

- IEEE 1528 – Item 6.6.1.1
- IEC 62.209 – Item 5.1

Room temperature: 18 to 25 °C

Maximum variation of liquid temperature: ± 2 °C

- Regarding temperature during characterization

EUT cannot connect to local network

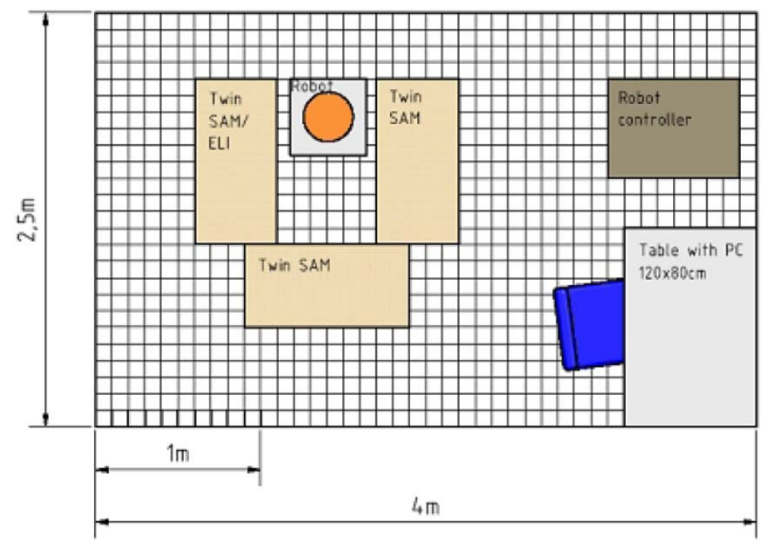
- RF Noise < 0.012 W/kg
  - External noise
  - Internal noise (reflections, internal RF transmitters, etc.)

SAR Tests – Environment Requirements

Using shielded room

Assumptions:

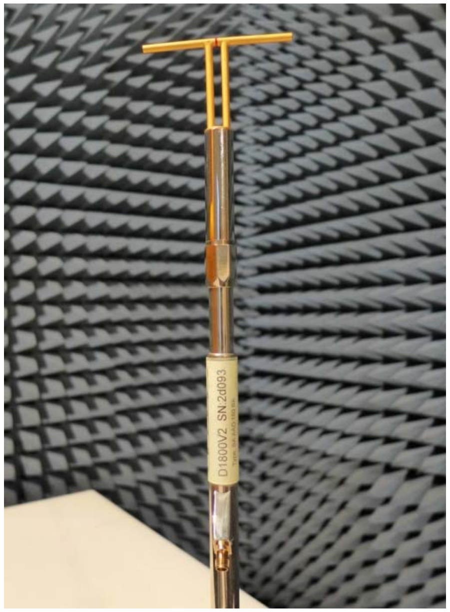
- Use of input filters for all cables
- To shield high frequency electromagnetic fields, use good conductor materials
- Top-quality shielding, no matter what plate is used
- Conductor and solid
- Very small thickness



SAR Tests – Basic Instrument Set

Measuring probe

Validation dipole



Data Acquisition
Electronics (DAE)

SAR Tests – Basic Instrument Set

Bi-sectioned phantom ("Twin Sam") and positioner

Shell Thickness	2.0 ± 0.2 mm

SAR Tests – Basic Instrument Set

Flat phantom (ELI)

Shell Thickness	2.0 ± 0.2 mm (Only the ELI is approved)

SAR Tests – Basic Instrument Set

Validation setup

Dielectric Setup

SAR Tests – Basic Instrument Set

Simulating Liquid

Reference Standards:

- IEEE 1528: Item 5.3.1 and Addendum C
- IEC 62.209: Item 5.2.4 and Addendum I

Liquid with dielectric properties

- Equivalent to human tissue
- Homogeneous: Mean value of several human tissues
- Transparent and low viscosity
- Frequency-dependent

SAR Tests – Basic Instrument Set

Liquid simulator – Ingredients

Saccharine (sugar) (purity > 98%)

Sodium Chloride (salt) (purity > 99%)

Hydrolysis of cellulose (HEC)

Bactericide

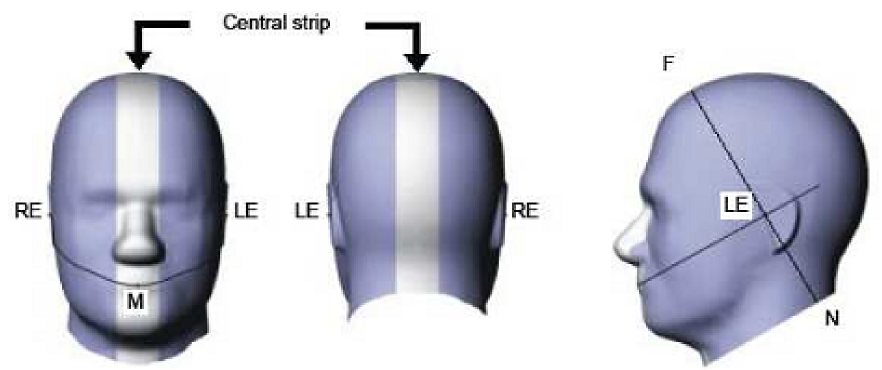
Deionized water (Minimum resistivity) 16 MΩ.cm)

Diethylene glycol butyl ether (DGBE) (purity > 99%)

Triton X-100 - Polyethylene glycol mono [4-(1,1,3,3-tetramethylbutyl) phenyl ether] Ultra pure

SAR Tests – Test Scenarios

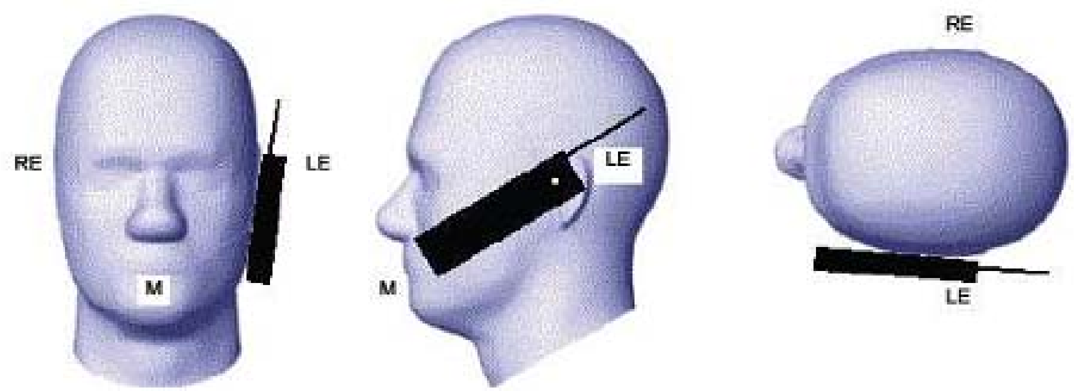
The following is an illustration of the head phantom.



Legend:
RE: Right Ear Reference Point (ERP)
LE: Left Ear Reference Point (ERP)
M Mouth Reference Point
F Line N – F: Last point on the face (this does not need to be marked on the SAM phantom).
N Line N – F: Last point on the neck (this does not need to be marked on the SAM phantom).
This complete head model is just for purposes of illustration and is directly derived from the phantom kit

SAR Tests – Test Scenarios

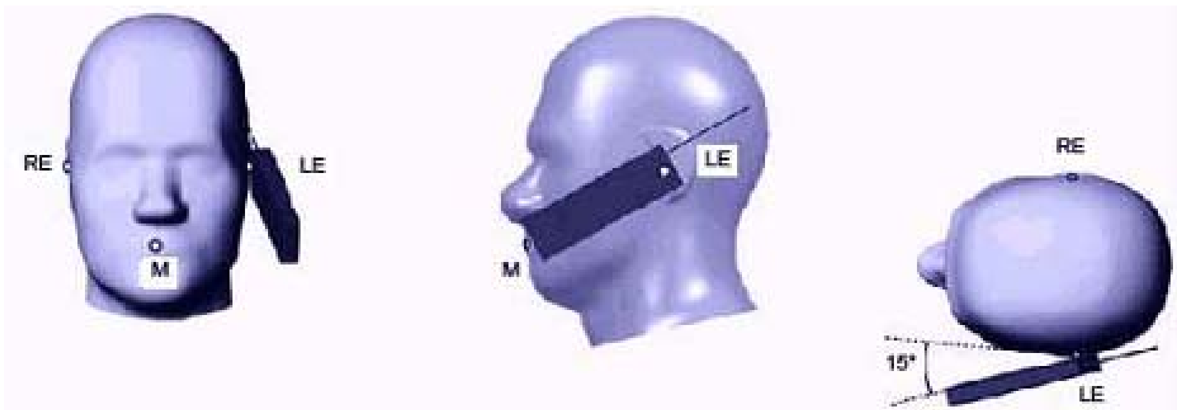
How the terminals are placed touching the bi-sectioned phantom head:



Legend:
RE: Right Ear Reference Point (ERP)
LE: Left Ear Reference Point (ERP)
M Mouth Reference Point
This complete head model is just for purposes of illustration and is directly derived from the phantom kit.

SAR Tests – Test Scenarios

How the terminals are placed at a 15-degree angle from the bi-sectioned phantom head:



Legend:
RE: Right Ear Reference Point (ERP)
LE: Left Ear Reference Point (ERP)
M Mouth Reference Point
This complete head model is just for purposes of illustration and is directly derived from the phantom kit.

SAR Tests – Test Scenarios

Examples of phantom head placement:

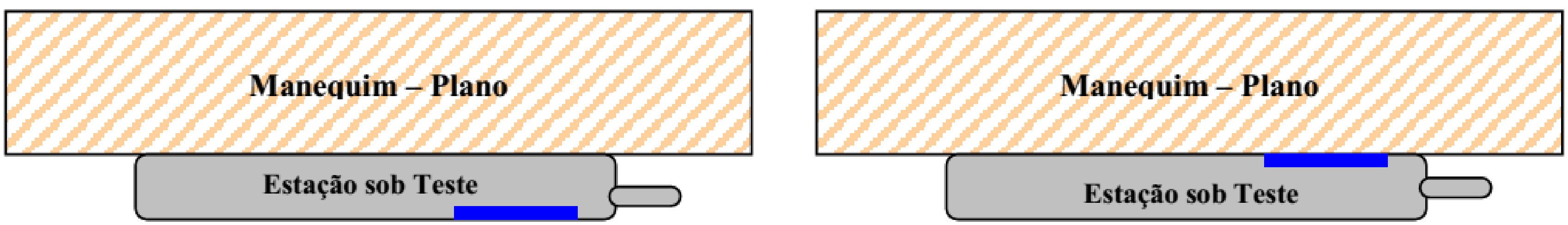
Cheek (Touching)

Tilt (15º angle)

SAR Tests – Test Scenarios

Body test must be run with the terminal facing frontwards and backwards, as shown in the image below:

Touching the phantom flat



If the manufacturer should inform the recommended distance between the terminal and the phantom, body tests shall be performed at the informed distance.

SAR Tests – Test Scenarios

If the terminal utilizes accessories such as wired headphones, cloth or leather cases, belt clips, and so forth, then body tests must be performed with and without these accessories.

Examples of Accessories:

Leather case with belt clip.

Wired headphones.

SAR Tests – Test Scenarios

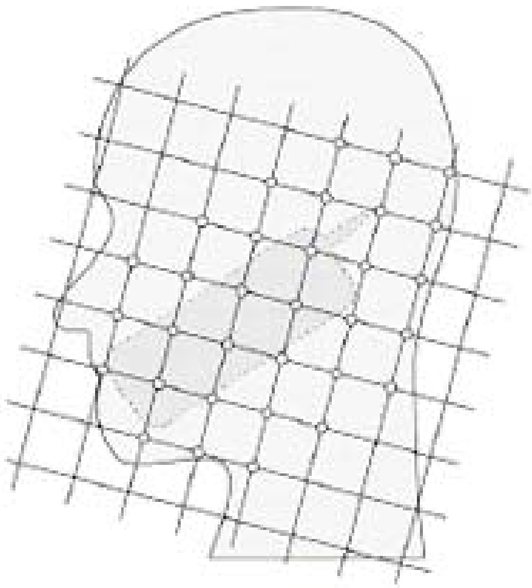
Examples of terminal placement on flat phantom

Body with accessories

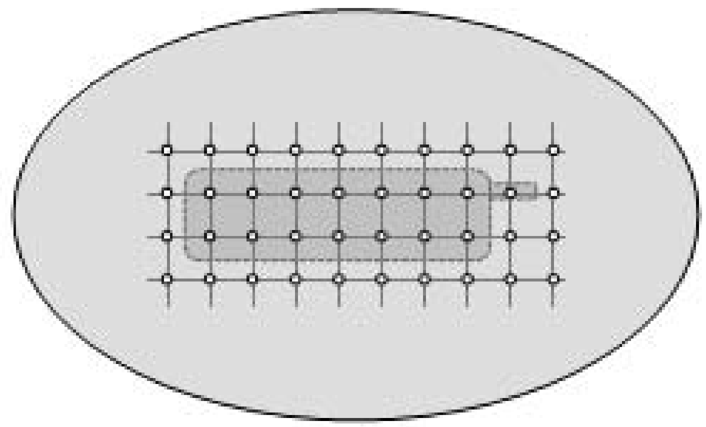
Body without accessories

SAR Tests – Test Scenarios

Defining the test scan area around the terminal



Head area

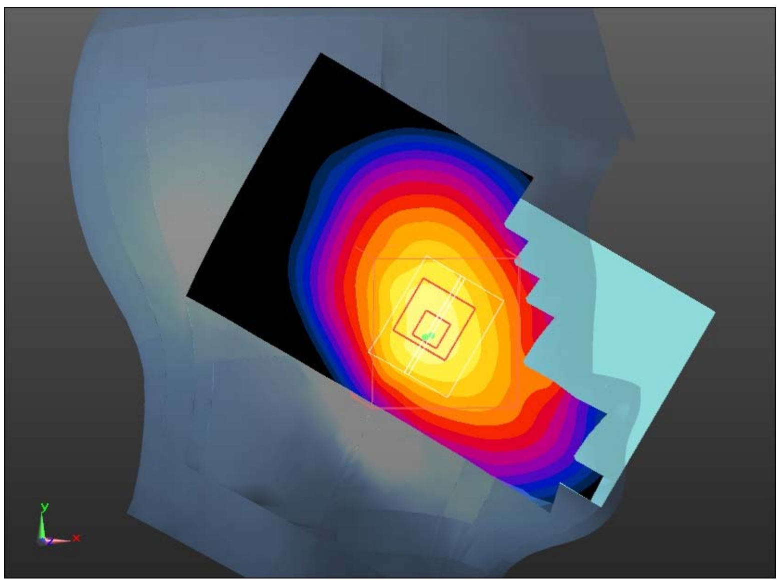


Body area

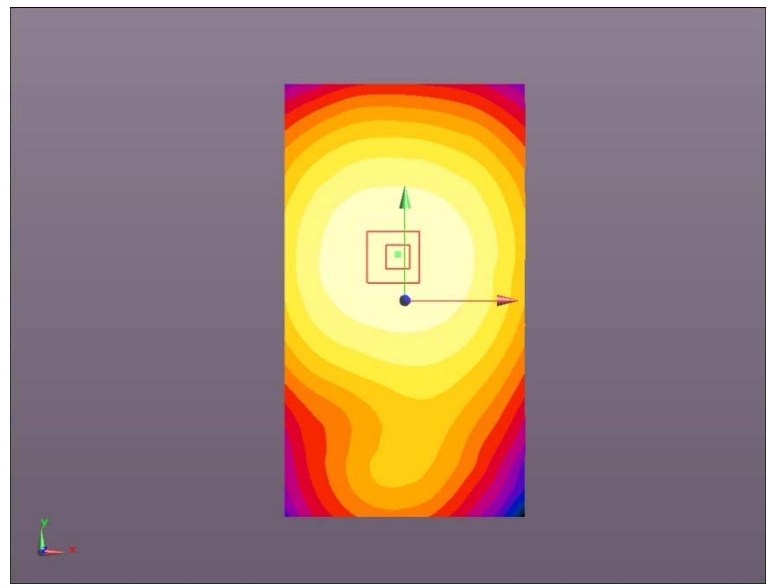
SAR Tests – Test Results

Example of the 10g cube on the head and body:

Head



Body



SAR Tests – Normative Limit for SAR Tests in Brazil

Usage Area	Limits – 10g Cube
Head	2W/kg
Head / Body	2W/kg
Body only / Other members	4W/kg
Facing the mouth	4W/kg

Schedule

Basic concepts on IMT technologies and other mobile radiocommunication technologies

Standards and test specifications for mobile terminals

Aspects regarding Specific Absorption Rate (SAR) Testing

Aspects regarding EMC Testing

Aspects regarding Safety Testing

ISO/IEC 17025 accreditation - measurement uncertainty - calibration

Electromagnetic Environment