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
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<th>Topic</th>
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</tr>
</tbody>
</table>
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
Cell Phone Timeline History

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)

Beginning of the commercial operations

• 1979 – Japan and Sweden
• 1983 – United States
Mobile Service Evolution

1989 subscriptions ➔ 4 million
2019 subscriptions ➔ > 9 billion

“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
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

Efficiency Increase
Digital Modulation Schemes

8PSK
- Carrier amplitude drops to zero as it transitions between symbols
- Dynamic range causes problems to radio implementation

$3\pi/8$ 8PSK (modification to basic 8PSK)
- $3\pi/8$ 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

PSK problem: sidebands extend out from the carrier

- MSK and GMSK
  - Continuous-phase FSK
  - No phase discontinuities

- **GMSK** Gaussian filtered MSK

  - 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

**16QAM Constellation:**
- 16 symbols
- 4 symbols/quadrant
- 4 bits/symbol

**64QAM Constellation:**
- 64 symbols
- 16 symbols/quadrant
- 6 bits/symbol

![Modulation Quality EVM](image)
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
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

**STC** Space Time Coding

**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

Source: Radio Access Networks: Status and Evolution Perspectives, Roland Munzener e Hardy Halbauer, Alcatel, 2006
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.
Enhancing Communication Capacity – Advanced Techniques

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-Advanced and IEEE 802.16m Mobile WiMAX

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

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<td>Bandwidth</td>
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<td>Latency Time</td>
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<td>Theoretical Peak Data Rate</td>
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<td>Service</td>
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<td>Packet or Circuit Switched</td>
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<td></td>
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<tr>
<td>Conformance Testing Standard</td>
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</tbody>
</table>
**WCDMA** Wideband Code Division Multiple Access

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

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

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<td><strong>Modulation</strong></td>
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<tr>
<td><strong>Bandwidth</strong></td>
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<tr>
<td><strong>Latency Time</strong></td>
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<tr>
<td><strong>Theoretical Peak Data Rate</strong></td>
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<tr>
<td><strong>Service</strong></td>
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<tr>
<td><strong>Packet or Circuit Switched</strong></td>
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<tr>
<td><strong>Conformance Testing Standard</strong></td>
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</tbody>
</table>
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
  - MIMO operation (Release 7)
  - Dual carrier + MIMO + 64QAM (Release 9)
  - Multi-Carrier Aggregation + MIMO + 64QAM (Release 10)

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

**Table: HSPA+ Specifications**

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

**Graph: HSPA+ Throughput Chart**

- **HSPA+ Downlink**
  - Theoretical Peak Rate in Mbps
  - 3GPP Rel 7: 21 Mbps
  - 3GPP Rel 8: 42 Mbps
  - 3GPP Rel 9: 168 Mbps
  - 3GPP Rel 10: 336 Mbps
  - 3GPP Rel 11: 336 Mbps

**Legend:**

- **MIMO**
- Dual-Carrier Combinations
- 2x12 MHz 2x2 MIMO 64 QAM
- 2x10 MHz 2x2 MIMO 64 QAM
- 2x5 MHz 2x2 MIMO
- 2x20 MHz 2x2 MIMO 64 QAM

**Source:** www.4gamericas.org
Cellular Communication Technology Evolution

LTE
• High data rate, low-latency and packet-optimized system
• SC-FDMA UL
• OFDMA DL
• 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”

LTE
- Long Term Evolution – Release 8

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<tr>
<td>Technology</td>
<td>LTE</td>
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<tr>
<td>Radio Technology</td>
<td>LTE: OFDMA and SC-FDMA, TDD and FDD</td>
</tr>
<tr>
<td>Modulation</td>
<td>QPSK, 16QAM, 64QAM</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>LTE: 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz</td>
</tr>
<tr>
<td>Latency Time</td>
<td>LTE: 10 ms</td>
</tr>
<tr>
<td>Latency Time</td>
<td>LTE Advanced: &lt; 5 ms</td>
</tr>
<tr>
<td>Theoretical Peak Data Rate</td>
<td>LTE (DL): 300 Mbps (20 MHz, 64QAM, 4x4 MIMO)</td>
</tr>
<tr>
<td>Theoretical Peak Data Rate</td>
<td>LTE (UL): 75 Mbps (20 MHz, 64QAM)</td>
</tr>
<tr>
<td>Service</td>
<td>LTE: High data rate, High-mobility</td>
</tr>
<tr>
<td>Packet or Circuit Switched</td>
<td>Packet switched only</td>
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<tr>
<td>Conformance Testing Standard</td>
<td>3GPP TS 36.521-1 V9.5.0 (2011-06)</td>
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</table>
Adicionado definição de VoLTE

Separado LTE de LTE-A

RadioLab, 04/05/2015
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 (further 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.

### LTE Advanced – Release 10 and forward

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<td>LTE Advanced</td>
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<td>Radio Technology</td>
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<td>Modulation</td>
<td>QPSK, 16QAM, 64QAM</td>
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<td>Bandwidth</td>
<td>1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz</td>
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<tr>
<td>Latency Time</td>
<td>&lt; 5 ms</td>
</tr>
<tr>
<td>Theoretical Peak Data Rate</td>
<td>DL: 1 Gbps (4x4 MIMO, with BW&gt;70 MHz)</td>
</tr>
<tr>
<td></td>
<td>UL: 500 Mbps</td>
</tr>
<tr>
<td>Service</td>
<td>High data rates for advanced applications:</td>
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<tr>
<td></td>
<td>[100 Mbps for high mobility and 1 Gbps for low mobility]</td>
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<tr>
<td>Packet or Circuit Switched</td>
<td>Packet switched only</td>
</tr>
<tr>
<td>Conformance Testing Standard</td>
<td>3GPP TS 36.521-1</td>
</tr>
</tbody>
</table>

R5

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

Informações atualizadas

RadioLab, 04/05/2015
Wireless Connectivity Technologies

**Bluetooth** IEEE 802.15.1 Standard

- Wireless communication between electronic devices
- Short range technology
  - Class 1: 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

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

**Wireless Connectivity Technology**

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

<table>
<thead>
<tr>
<th>Technology</th>
<th>WiFi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio Technology</td>
<td>CSMA - CA (Carrier Sense Multiple Access - Collision Avoidance)</td>
</tr>
</tbody>
</table>
| 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

- 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

<table>
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<th>WIRELESS CONNECTIVITY</th>
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<tbody>
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<td>Modulation</td>
</tr>
<tr>
<td>Bandwidth</td>
</tr>
<tr>
<td>Theoretical Peak Data Rate</td>
</tr>
<tr>
<td>Service</td>
</tr>
<tr>
<td>Packet or Circuit Switched</td>
</tr>
<tr>
<td>Conformance Testing Standards</td>
</tr>
<tr>
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</tr>
</tbody>
</table>

Some NFC Applications:
- Contactless transactions
- Personal ID
- Data exchange:
  - Smart poster
  - Business cards
  - Digital photos
**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

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.
Global Mobile Technology Market Shares

Q4 2013

- GSM: 66% (4.4 Billion Subscriptions)
- HSPA: 21% (1.4 Billion Subscriptions)
- CDMA: 7% (0.3 Billion Subscriptions)
- LTE: 3% (0.2 Billion Subscriptions)
- TD-SCDMA: 5% (0.3 Billion Subscriptions)

Q4 2018

- GSM: 22% (1.8 Billion Subscriptions)
- HSPA: 51% (4.2 Billion Subscriptions)
- LTE: 16% (1.3 Billion Subscriptions)
- TD-SCDMA: 6% (0.5 Billion Subscriptions)
- CDMA: 5% (0.4 Billion Subscriptions)

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

Growth through 2019

- 9.3 Billion Mobile Subscriptions
- 2.6 Billion LTE Subscriptions

Source: Ericsson (Nov 2012)

www.4gamericas.org
LA&CA Mobile Technology Market Shares

**Latin America Mobile Market Shares**

- **712 Million Total Connections**
- **4Q 2013**
  - GSM: 497 Million (70%)
  - HSPA: 192 Million (27%)
  - CDMA: 10.6 Million (1.5%)
  - IDEN: 10.2 Million (1.4%)

**Forecast /Latin America & Caribbean**

- ** Millions of Connections**
- **Dec 14**
  - CDMA: 440
  - GSM: 258
  - HSPA: 6
- **Dec 15**
  - CDMA: 376
  - GSM: 345
  - HSPA: 13
- **Dec 16**
  - CDMA: 301
  - GSM: 435
  - HSPA: 25
- **Dec 17**
  - CDMA: 228
  - GSM: 512
  - HSPA: 47
- **Dec 18**
  - CDMA: 82
  - GSM: 564
  - HSPA: 164

*Source: Informa Telecoms & Media, WGS+ December 2013*
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)

Global Regulatory Scenario

ITU-T RECOMMENDATIONS ON EMC AND RESISTIBILITY

- ITU-T K38: Radiated emission test procedure for physically large systems
- ITU-T K43: Immunity requirements for telecommunication equipment

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

Global Regulatory Scenario

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

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

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

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

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

2012-2015

2016-2017

2018-2019

2019-2020

Setting the stage for the future: vision, spectrum, and technology views

Defining the technology
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)

### Global Regulatory Scenario


<table>
<thead>
<tr>
<th>ITEM R&amp;TTE</th>
<th>Standard</th>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1.a</td>
<td>EN60950-1:2006 EN 50360:2001</td>
<td>Safety Requirement regarding RF human exposure</td>
</tr>
<tr>
<td>3.1.b</td>
<td>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</td>
<td>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)</td>
</tr>
<tr>
<td>3.2</td>
<td>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</td>
<td>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</td>
</tr>
</tbody>
</table>

Global Regulatory Scenario

USA

Federal Communication Commission rules


- § 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

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

**Producto:** Telephone móvel celular

<table>
<thead>
<tr>
<th>Documento normativo</th>
<th>Requisitos aplicáveis (vide nota II)</th>
<th>Procedimentos de ensaios</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>REQUISITOS APLICÁVEIS A TODAS AS TECNOLOGIAS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Anexo à Resolução Nº 442 de 21 de julho de 2006 - Regulamento para Certificação de Equipamentos de Telecomunicações quanto aos Aspectos de Compatibilidade Electromagnética</td>
<td>- Na integra, no que for aplicável, exceto Título II – Dos requisitos de emissão de perturbações eletromagnéticas radiadas, artigo 6º parágrafo 2</td>
<td>- vide notas III, IV e V.</td>
</tr>
<tr>
<td>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.</td>
<td>- Na integra, no que for aplicável.</td>
<td>- vide notas III, IV e IX.</td>
</tr>
<tr>
<td>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 Radiofrequências entre 9 KHz e 300 GHz</td>
<td>- Título II – Capítulo II - Dos Limites de Exposição – Tabela V- Restrições Básicas para exposição a CEMRF, na faixa de radiofrequências entre 9 kHz e 10 GHz e Art. 11</td>
<td>- Título III – Capítulo II - Dos Procedimentos de Avaliação de Estações Terminais Portáteis</td>
</tr>
</tbody>
</table>

**Scope:** EMC requirements, safety, SAR and functional requirements
Technical Requirements and Test Procedures for the Certification of Telecommunication Products Category I

<table>
<thead>
<tr>
<th>REQUISITOS APLICÁVEIS AO SERVIÇO MÓVEL PESSOAL – SMP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tecnologia CDMA:</strong></td>
</tr>
<tr>
<td>a) TIA/EIA-98-C - Recommended Minimum Performance Standards for Dual-Mode Spread Spectrum Mobile Stations</td>
</tr>
<tr>
<td>3.5.2 - Emissão de espúrios radiados (receptor);</td>
</tr>
<tr>
<td>4.1.1 - Exatidão de frequência;</td>
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<tr>
<td>4.4.1 - Faixa de potência de saída em loop aberto;</td>
</tr>
<tr>
<td>4.4.5 - Potência de saída de RF máxima;</td>
</tr>
<tr>
<td>4.4.6 - Potência de saída mínima controlada;</td>
</tr>
<tr>
<td>4.5.1 - Emissão de espúrios conduzidos;</td>
</tr>
<tr>
<td>4.5.2 - Emissão de espúrios radiados (transmissor).</td>
</tr>
<tr>
<td>- Os procedimentos de ensaio se encontram no próprio documento normativo;</td>
</tr>
<tr>
<td>- Os ensaios não deverão levar em consideração variações de temperatura e tensão de alimentação.</td>
</tr>
<tr>
<td>- vide nota IV;</td>
</tr>
</tbody>
</table>

| **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 frequência 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.

Section IX

• 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

Electrical Safety Tests

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
- \( \rho = \) Density

\[ SAR = \frac{c \Delta T}{\Delta t} \bigg| _{t=0} \]

- \( c = \) Specific Heat
- \( \Delta T = \) Temperature variation
- \( \Delta t = \) Duration (time) of exposure

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

- \( \sigma = \) Electrical conductivity
- \( E = \) RMS value of the electrical field vector
- \( \rho = \) 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
- Data Acquisition Electronics (DAE)
- Validation dipole
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:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE</td>
<td>Right Ear Reference Point (ERP)</td>
</tr>
<tr>
<td>LE</td>
<td>Left Ear Reference Point (ERP)</td>
</tr>
<tr>
<td>M</td>
<td>Mouth Reference Point</td>
</tr>
</tbody>
</table>

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 (15° 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

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<td>2W/kg</td>
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<td>Head / Body</td>
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<td>Body only / Other members</td>
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<td>Facing the mouth</td>
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Electromagnetic Environment