Conformity and Interoperability Training

Homologation Procedures and Type Approval Testing for Mobile Terminals

TURNING
INTO REALITY

ITU C&I Programme

Training Course on
Testing Mobile Terminal

Schedule

- Overview on Cellular Communications and Mobile Terminals Embedded RF Technologies
- Test Standards and Requirements for Mobile Cellular Terminal Certification in Brazil and other Large Global Urban Centers
- Description, Purpose and Importance of each RF Test Required for the ANATEL Certification and Approval Process
- Description, Purpose and Importance of each SAR Test Required for the ANATEL Certification and Approval Process
- Basic Concepts for Calculating Measurement Uncertainty
- Good Practices and Important Aspects for IEC/ISO 17025 Accreditation

Schedule

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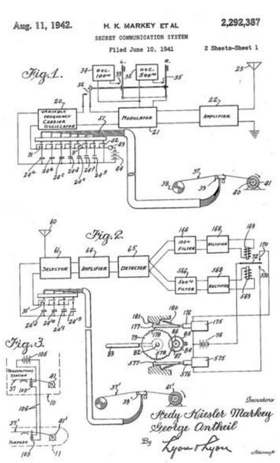
Good Practices and Important Aspects for IEC/ISO 17025 Accreditation

Cell Phone Timeline History

- **20th Century**

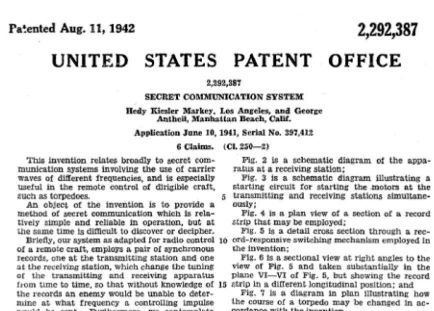


Hedwig Eva Maria Kiesler [Hedy Lamarr]

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;

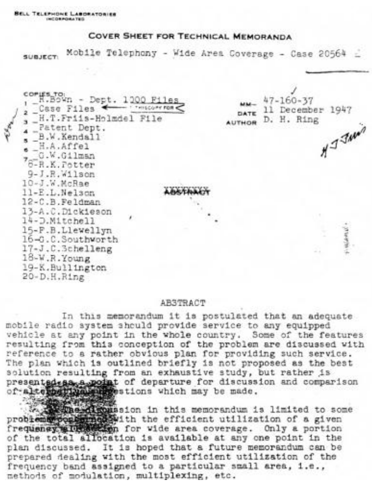
Fig. 4 is a plan view of a section of a record strip that may be employed;

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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15-F.B.Llewellyn
16-G.C.Southworth
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~~

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.

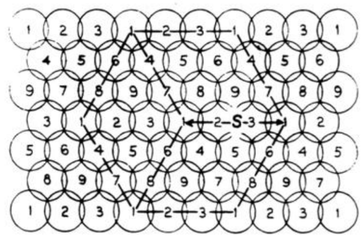
The discussion in this memorandum is limited to some problems concerned with the efficient utilization of a given frequency allocation for wide area coverage. Only a portion of the total allocation is available at any one point in the plan discussed. It is hoped that a future memorandum can be prepared 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



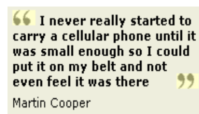
Cell Phone Timeline History

- **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)



- 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

1973

Technology

Evolution

DynaTAC
US$ 8,000

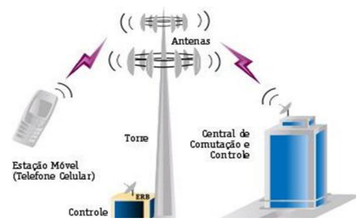
“ITU considers cellular communications the fastest technology adopted throughout the history”

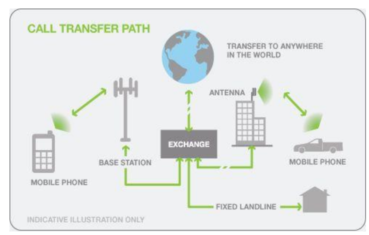
Basic Concepts in Cellular Communication Technology

RBS **Radio Base Station**

MSC **Mobile Switching Center**

MT **Mobile Terminal**



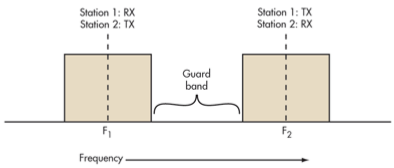


Basic Concepts in Cellular Communication Technology

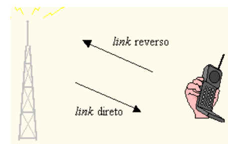
- Mobile Communication Systems Goal: High Capacity
- Technological Tools:
  - Resource sharing for multiple users scarcity
  - Bandwidth Growth x Spectrum
  - Duplexing Techniques
  - Access Techniques
  - Multiplexing Techniques
  - Modulation Schemes
  - Advanced Technique:
    - Carrier Aggregation
    - MIMO and Antenna Beamforming

Duplexing Systems

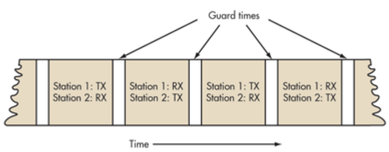
Full Duplex FDD Frequency Division Duplex



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



Half Duplex TDD Time Division Duplex



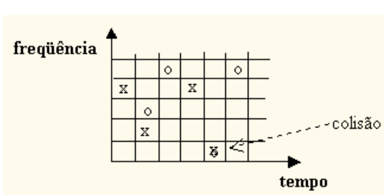
Single frequency band
Shares band assigning time slots
Symmetrical or asymmetrical
Guard Times

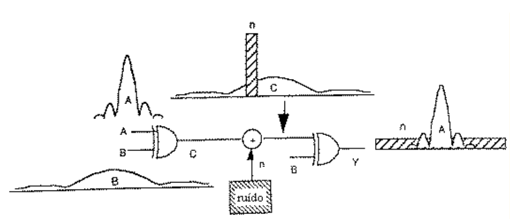
Spread Spectrum Transmission Technique

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

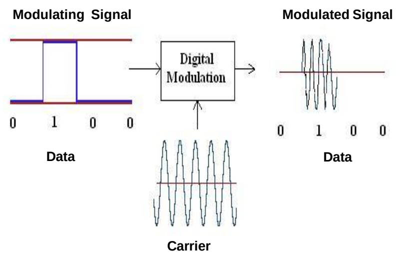
FHSS – Frequency Hopping
- Different carrier frequency at different time

DSSS – Direct Sequence
- Fixed carrier frequency
- Information is spread out into a larger bandwidth

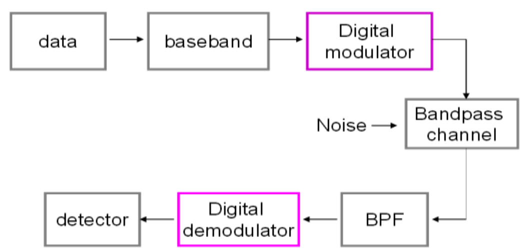




Digital Modulation Technique



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

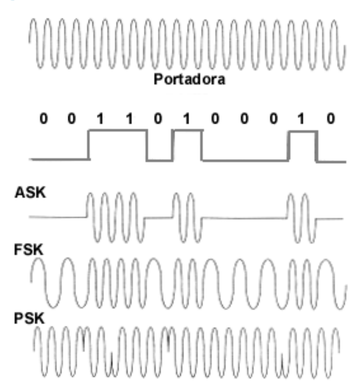
FSK (Phase Shift Keying)
Carrier frequency alterations as a function of the transmitted information

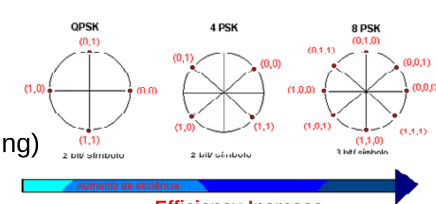
PSK (Phase Shift Keying)
Carrier phase alterations as a function of the transmitted information

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





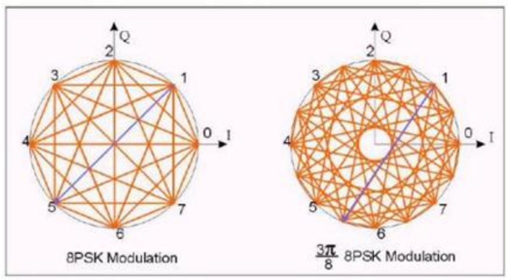
Digital Modulation Schemes

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)

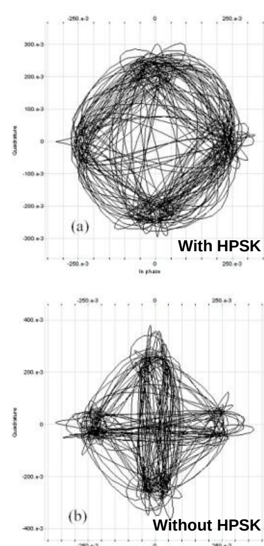
- 3π/8 rotation in addition to the symbol transition
- Prevents the carrier passing through the origin and falling to zero amplitude
- Decreases the dynamic range



Digital Modulation Schemes

HPSK Hybrid Phase Shift Keying

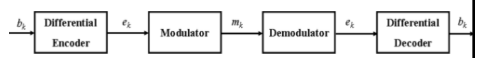
- Eliminates zero crossings
- Reduces peak-to-average power ratio (PAR) before amplification
- Increases amplifier efficiency
- Improves bit error rate (BER)



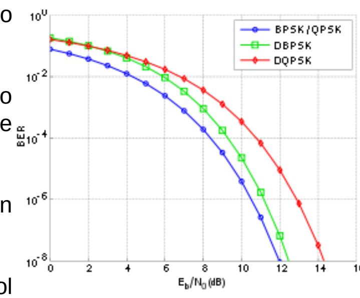
Digital Modulation Schemes

Differential Phase Shift Keying

- DBPSK
- DQPSK

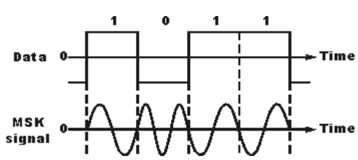


- Simpler to implement than ordinary PSK
- Avoids complex carrier-recovery schemes to provide an accurate phase
- Non-coherent – no need for the demodulator to have a copy of the reference signal to determine the exact phase of the received signal
- This scheme depends on the difference between successive 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

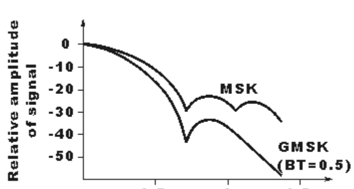
MSK Minimum Shift Keying



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

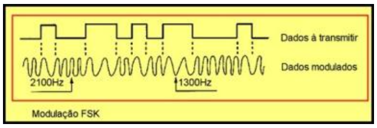
GMSK Gaussian filtered MSK



Spectral density of MSK and GMSK signals

Digital Modulation Schemes

GFSK Gaussian frequency-shift keying



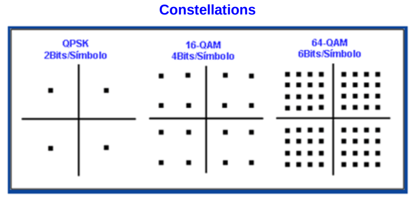
- Modulator similar to FSK
- A Gaussian filter is used before FSK modulator:
  - Making transitions smoother
  - Decreasing spectral width

Digital Modulation Schemes

QAM Quadrature Amplitude Modulation

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

Constellations



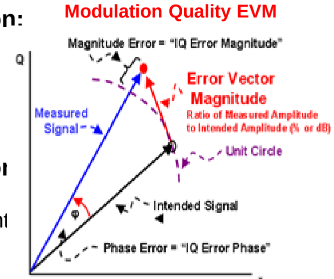
16QAM Constellation:

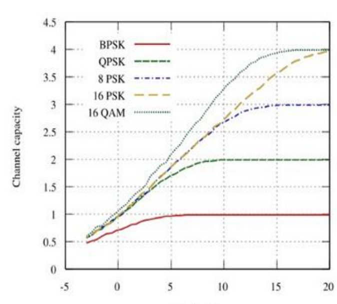
- ❑ 16 symbols
- ❑ 4 symbols/quadrant
- ❑ 4 bits/symbol

64QAM Constellation:

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

Modulation Quality EVM

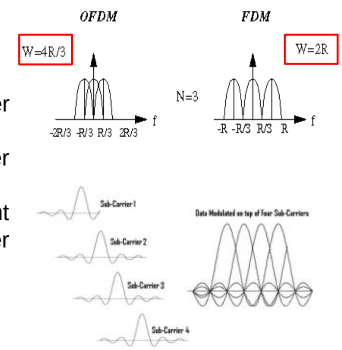


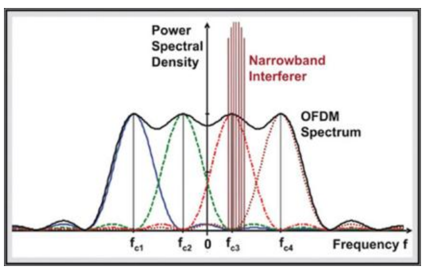


Digital Modulation Schemes

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





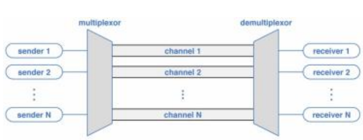
Some OFDM advantages

- ✓ 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)

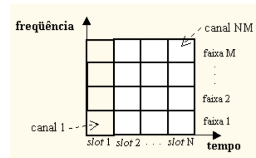
Time Division Multiplexing – TDM ➡ TDMA

- 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

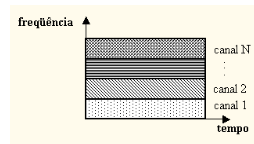
TDMA Time Division Multiple Access

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



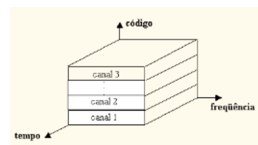
FDMA Frequency Division Multiple Access

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



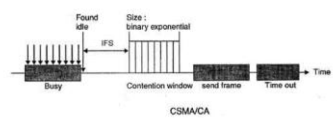
CDMA Code Division Multiple Access

- 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

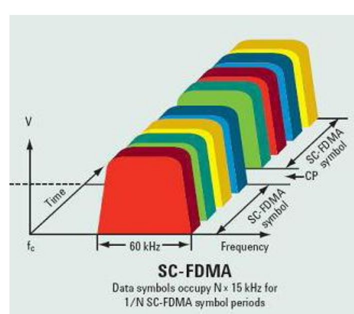
- Nodes attempt to avoid collisions by transmitting only when the channel is sensed to be idle



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

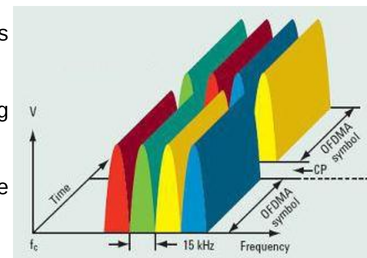


Multiple Access Methods

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)

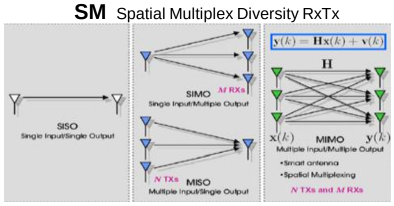


OFDMA
Data symbols occupy 15 kHz for one OFDMA symbol period

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

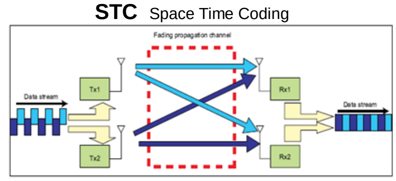
MISO x SISO
- Provides transmit antenna redundancy
- Transmit diversity techniques
- Improves receiver SINR and performance under fading

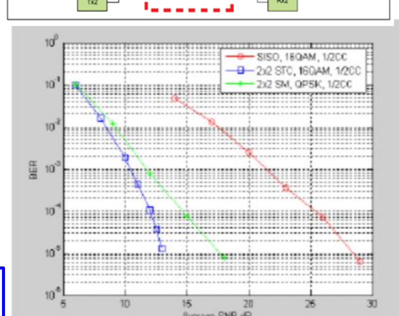
MIMO
- Provides both additional transmit and receive
- Improves SINR, data throughput and spectrum efficiency

MIMO-SM
- Improves robustness and cell coverage

MIMO-STC
- Improves data throughput, and reduces BER

STC Space Time Coding

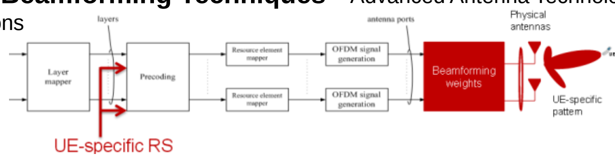


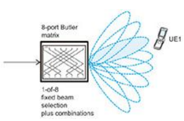


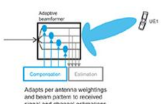
Souce: Radio Access Networks: Status and Evolution Perspectives,Roland Munzener e Hardy Halbauer, Alcatel, 2006

Enhancing Communication Capacity – Advanced Techniques

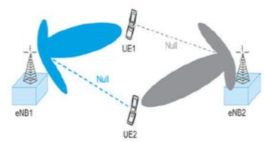
Antenna Beamforming Techniques – Advanced Antenna Technology Configurations



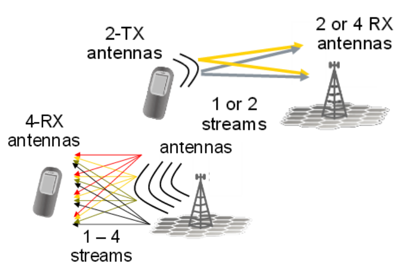


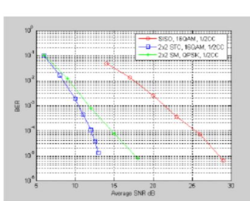


- Multi-antenna configurations focus transmission or reception in a particular direction
- Phased array antenna techniques
  - Switched beamforming (predefined patterns)
  - Adaptive beamforming (real-time adaptive patterns)
- Channel estimation technique (open loop)
- Channel feedback technique (closed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

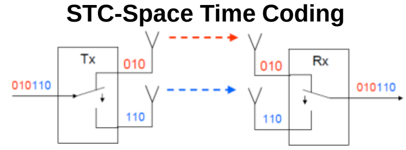


Enhancing Communication Capacity – Advanced Techniques





STC-Space Time Coding



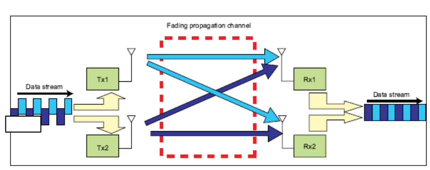
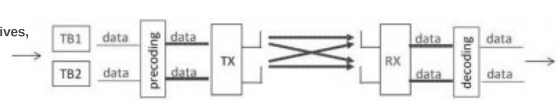
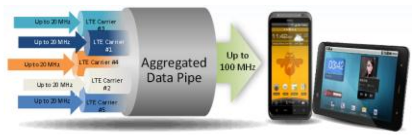


Figure 1: Sequential multiplexing of packet data is routed from baseband to the multiple antenna.

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



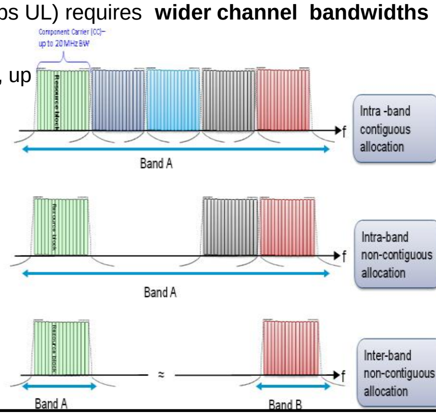
Enhancing Communication Capacity – Advanced Techniques



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



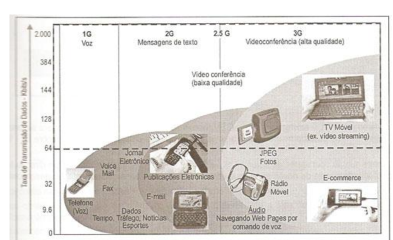
Mobile Phone Standards and Technology Generations

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

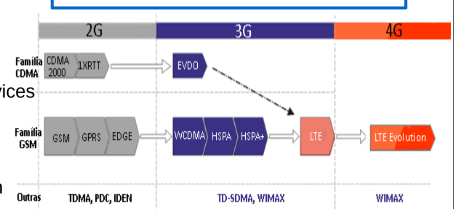
3G Third Generation
- Established through ITU's project on International Mobile Telecommunications 2000 (IMT-2000)
- Enabled faster data transmission speeds, greater network capacity and more advanced network services
- Packet data services (videostreaming)
- WCDMA, HSPA, HSPA+

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

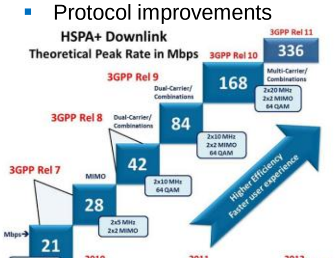
HSPA
- Combination of high speed downlink packet access (HSDPA) and high speed uplink packet access (HSUPA)
- TTI (Transmission Time Interval) reduction

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 **/ LTE Advanced**

LTE

- High data rate, low-latency and packet-optimized system
- SC-FDMA UL
- OFDMA DL
- VoLTE
- Scalable bandwidth up to 20 MHz
- Dynamic adaptive modulation
- Supports MIMO antenna technology
- Low latency and high data rate

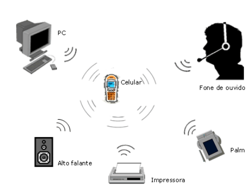
LTE Advanced

- 4G technology meet IMT-Advanced
- Higher data rates
- 100 Mbps minimum UL high mobility
- 1 Gbps DL low mobility
- Carrier aggregation
- MIMO extension (DL: 8x8; UL: 4x4)

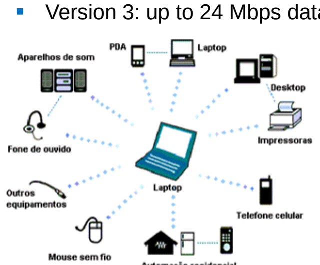
CELLULAR COMMUNICATION	
Technology	LTE / LTE Advanced
Radio Technology	LTE: OFDMA and SC-FDMA, TDD and FDD
Modulation	QPSK, 16QAM, 64QAM
Bandwidth	LTE: 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz LTE Advanced: up to 100 MHz with Carrier Aggregation
Latency Time	LTE: 10 ms LTE Advanced: < 5 ms
Theoretical Peak Data Rate	LTE (DL): 300 Mbps (20 MHz, 64QAM, 4x4 MIMO) LTE (UL): 75 Mbps (20 MHz, 64QAM) LTE Advanced (DL): 1 Gbps (4x4 MIMO, with BW>70 MHz) LTE Advanced (UL): 500 Mbps
Service	LTE: High data rate, High-mobility LTE Advanced: 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 V9.5.0 (2011-06)

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

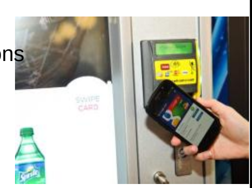
NFC Near Field Communication

ISO/IEC 18092 / ECMA-340 Near Field Communication Interface and Protocol-1
ISO/IEC 21481 / ECMA-352 Near Field Communication Interface and Protocol-2

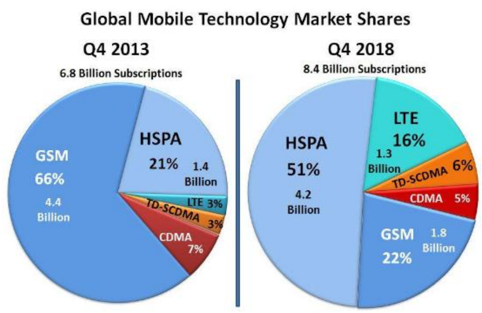
- Very short-range wireless connectivity technology (a few cm)
- Point-to-point interactions between electronic devices
- Low power consumption
- Based on inductive coupling between two loop antennas
- Unlicensed ISM band of 13.56 MHz
- Active NFC initiator/reader
- Active or passive NFC target/tag modes

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

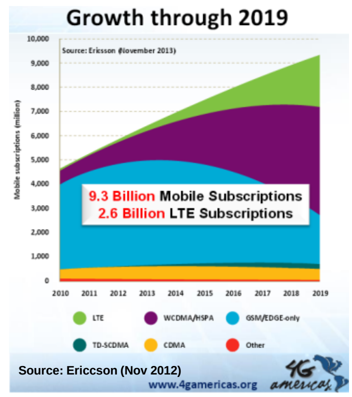
Some NFC Applications:
- Contactless transactions
- Personal ID
- Data exchange:
  - smart poster
  - business cards
  - digital photos



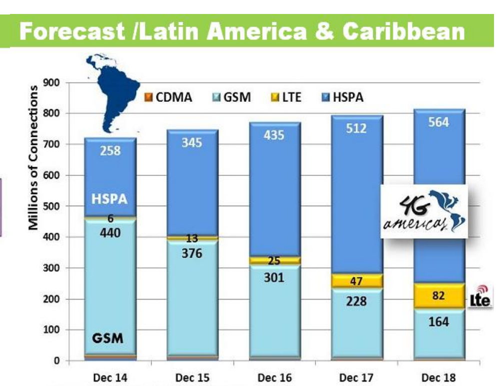
Global Mobile Technology Market Shares



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



LA&CA Mobile Technology Market Shares



Schedule

- Overview on Cellular Communications and Mobile Terminals Embedded RF Technologies
- **Test Standards and Requirements for Mobile Cellular Terminal Certification in Brazil and other Large Global Urban Centers**
- Description, Purpose and Importance of each RF Test Required for the ANATEL Certification and Approval Process
- Description, Purpose and Importance of each SAR Test Required for the ANATEL Certification and Approval Process
- Basic Concepts for Calculating Measurement Uncertainty
- Good Practices and Important Aspects for IEC/ISO 17025 Accreditation

Brazilian Certification Test Requirements

The purpose of lab tests executed during the certification and approval process of telecommunication products is to verify which equipment meet 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

In Brazil, the National Telecommunications Agency (**ANATEL**) is the competent 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

Technical requirements for the approval of mobile terminals in Brazil are presented in the document published by ANATEL namely:

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

In English:

TECHNICAL REQUIREMENTS AND TEST PROCEDURES FOR THE CERTIFICATION OF TELECOMMUNICATION PRODUCTS CATEGORY I

www.anatel.gov.br → Informações Técnicas→Certificação de Produto

Brazilian Certification Test Requirements

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
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	- Título 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.	- Título III – Capítulo II - Dos Procedimentos de Avaliação de Estações Terminais Portáteis
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 – GSM 850, GSM 900, DCS 1800 e PCS 1900:	12.1.1 -Emissão de espúrios conduzidos - terminal em comunicação;	- Os procedimentos de ensaio se encontram no próprio documento normativo;

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)

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.

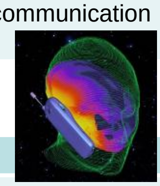
<u>Section IX</u>
Maximum Transmitter Output Power
Maximum Width of Occupied Hop Channel Range at 6 dB
Peak Power Density in any 3 kHz Range
Spurious Emissions

<u>Section X</u>
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

SAR Tests

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



EMC Tests

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

Electrical Safety Tests

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

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

3GPP – 3rd Generation Partnership Project

A GLOBAL INITIATIVE

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

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 (PCS)

- 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

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 **2**011/65/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

Applicable EMC standards for cellular terminals use possible international IEC and CISPR references, such as:

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

IEC/CISPR 22 – Radio Interference from ITE

As for SAR measurements and measurement method requirements, in Europe EN50360 is the harmonized standard of choice, but the theme is still under intense international discussion.

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

Global Regulatory Scenario

International Specific Absorption Rate (SAR) documents are adopted as the worldwide reference.

- 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 – DRAFT. 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, 2008.
- AUSTRALIAN COMMUNICATIONS AUTHORITY, Radiocommunications (Electromagnetic Radiation — Human Exposure) Standard, 2003.

Global Regulatory Scenario

- FCC OET65 Supplement C. Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields -Additional Information for Evaluating Compliance of Mobile and Portable Devices with FCC Limits for Human Exposure to Radiofrequency Emissions - Supplement C.
- UNITED STATES ARMY, Gordon, C. C., Churchill, T., Clauser, C. E., Bradtmiller, B., McConville, J. T., Tebbetts, I., and Walker, R. A. “1988 Anthropometric Survey of U.S. Army Personnel: Methods and Summary Statistics” Technical Report NATICK/TR-89/044, U.S. Army Natick Research, Development and Engineering Center, Natick, Massachusetts, Set. 1989.
- Kuster N., Kästle, R., and Schmid, T. “Dosimetric evaluation of mobile communications equipment with known precision” IEICE Transactions on Communications, May 1997, vol. E80-B, no. 5, pp. 645-652.

Standards and limits adopted in some regions of the world:

Region / Country	-Reference to – SAR measurement protocol	Reference to SAR limit	Limit
Europe / Brazil	European Specification ES 59005 (1998)	ICNIRP Guidelines 1998 (ICNIRP 1998)	2.0 W/kg in 10g of tissue
Australia	Australian Communications Authority (ACA) Standard (ACA RS 1999)	Australian Standard AS/NZS 2772.1	1.6 W/kg in 1g of tissue
US	Federal Communications Commission (FCC) Guidelines (FCC 1997)	American Standard ANSI C95.1 (ANSI 1992)	1.6 W/kg in 1g of tissue

Schedule

- Overview on Cellular Communications and Mobile Terminals Embedded RF Technologies
- Test Standards and Requirements for Mobile Cellular Terminal Certification in Brazil and other Large Global Urban Centers
- **Description, Purpose and Importance of each RF Test Required for the ANATEL Certification and Approval Process**
- Description, Purpose and Importance of each SAR Test Required for the ANATEL Certification and Approval Process
- Basic Concepts for Calculating Measurement Uncertainty
- Good Practices and Important Aspects for IEC/ISO 17025 Accreditation

RF Tests (Functional) – 2G Technology

GSM®

GLOBAL SYSTEM FOR
MOBILE COMMUNICATIONS

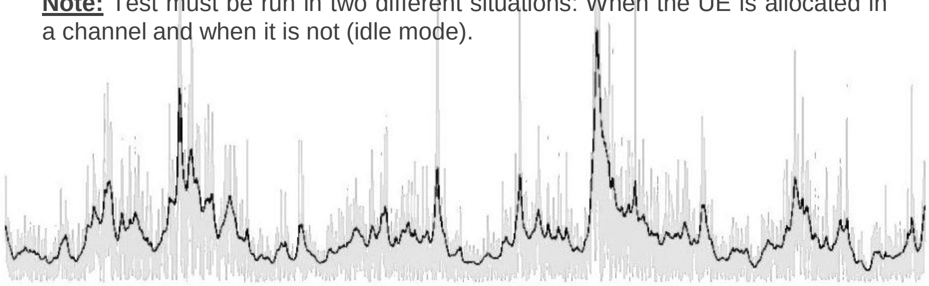
RF Tests (Functional) – 2G Technology

12.1 Conducted Spurious Emissions

Definition: Conducted spurious emissions, when the MS has been allocated a channel, are emissions from the antenna connector at frequencies other than those of the carrier and sidebands associated with normal modulation.

Test purpose: To verify that conducted spurious emissions from the UE do not exceed the conformance requirements. These conducted spurious emissions will be measured in the frequency band 100 kHz to 12,5 GHz.

Note: Test must be run in two different situations: When the UE is allocated in a channel and when it is not (idle mode).



RF Tests (Functional) – 2G Technology

12.2 Radiated Spurious Emissions

Definition: Radiated emissions from the entire UE structure.

Test purpose: Verify if the spurious emissions radiated from the UE exceed conformity requirements in normal voltage conditions.

Note: Test must be run in two different situations: When the UE is allocated in a channel and when it is not (idle mode).

RF Tests (Functional) – 2G Technology

13.1 Frequency Error and Phase Error

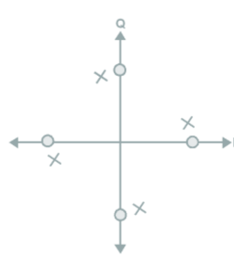
13.16.1 Frequency Error and Phase Error in GPRS Multislot Configuration

Definition: The frequency error is the difference in frequency between the RF transmission from the UE and the nominal frequency for the channel used.

The phase error is the difference in phase between the RF transmission from the UE and the theoretical transmission according to the intended modulation.

Test purpose: To verify that:

- The UE carrier frequency error does not exceed 0.1 ppm
- The phase error does not exceed 5 degrees



RF Tests (Functional) – 2G Technology

13.17.1 Frequency Error and Modulation Accuracy in EGPRS Configuration

Definition: The frequency error is the difference in frequency between the RF transmission from the UE and the nominal frequency for the channel used.

The phase error is the difference in phase between the RF transmission from the UE and the theoretical transmission according to the intended modulation.

The magnitude of the error vector is called Error Vector Magnitude (EVM). The error vector between the vector representing the transmitted signal and the vector representing the error-free modulated signal defines modulation accuracy.

RF Tests (Functional) – 2G Technology

13.17.1 Frequency Error and Modulation Accuracy in EGPRS Configuration

Test purpose: To verify that:

- The EU carrier frequency error does not exceed 0,1 ppm
- The phase error does not exceed 5 degrees
- The RMS EVM over the useful part of any burst of the 8-PSK modulated signal does not exceed 9,0% under normal conditions
- The peak EVM values of at least 200 bursts of the 8-PSK modulated signal are ≤ 30%
- The 95:th-percentile value of any burst of the 8-PSK modulated signal is ≤ 15 %
- The Origin Offset Suppression for any 8PSK modulated signal does not exceed 30 dB

RF Tests (Functional) – 2G Technology

13.3 Transmitter Output Power and Burst Timing

Definition: The transmitter output power is the average value of the power delivered to an artificial antenna, over the time that the useful information bits of one burst are transmitted.

The transmit burst timing is the envelope of the RF power transmitted with respect to time.

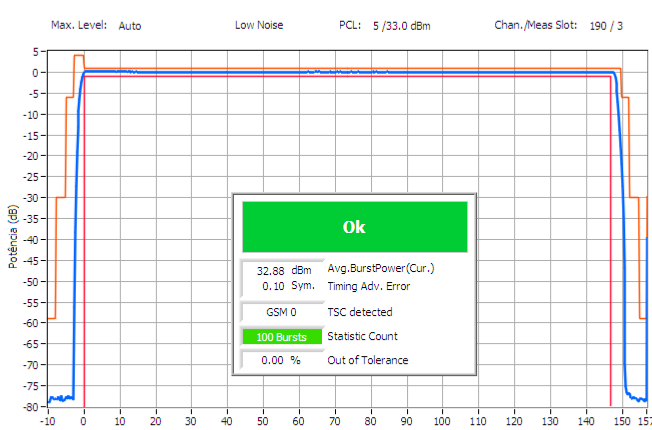
Power control is the capacity the UE has to adjust output power in response to Node B commands.

Test purpose: To verify that:

- The maximum output power is within conformance requirements
- All power control levels, relevant to the class of UE, are implemented within conformance requirements
- The difference between consecutive PCLs is within limits
- The output power relative to time, when sending a normal burst, is within conformance requirements
- The output power relative to time, when sending an access burst, is within conformance requirements

RF Tests (Functional) – 2G Technology

13.3 Transmitter Output Power and Burst Timing



RF Tests (Functional) – 2G Technology

13.16.2 Transmitter Output Power in GPRS Multislot Configuration

13.17.3 EGPRS Transmitter Output Power

Definition: The transmitter output power is the average value of the power delivered to an artificial antenna, over the time that the useful information bits of one burst are transmitted.

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Power control is the capacity the UE has to adjust output power in response to Node B commands.

Test purpose: To verify that:

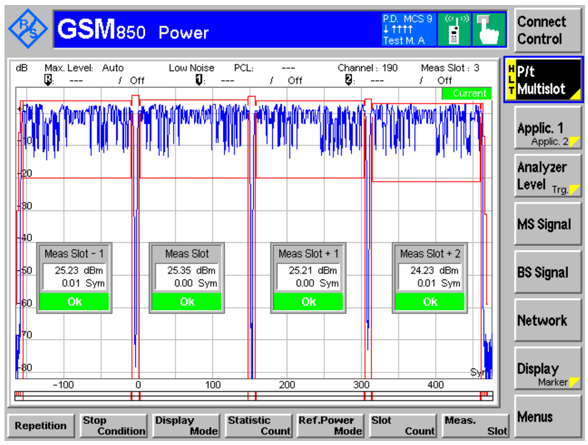
- The maximum output power is within conformance requirements
- All power control levels, relevant to the class of UE, are implemented within conformance requirements
- The difference between consecutive PCLs is within limits
- The output power relative to time, when sending a normal burst, is within conformance requirements

RF Tests (Functional) – 2G Technology

13.16.2 Transmitter Output Power in GPRS Multislot Configuration

RF Tests (Functional) – 2G Technology

13.17.3 EGPRS Transmitter Output Power



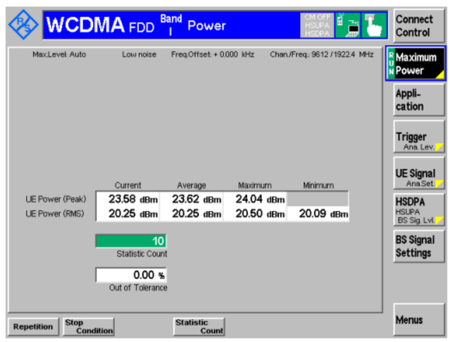
RF Tests (Functional) – 3G Technology

RF Tests (Functional) – 3G Technology

5.2 Maximum Output Power

Definition: The maximum output power is a measure of the maximum power the UE can transmit. The nominal maximum output power and its tolerance are defined according to the Power Class of the UE.

Test purpose: To verify that the error of the UE maximum output power does not exceed the range prescribed by the nominal maximum output power and tolerance.



RF Tests (Functional) – 3G Technology

5.2AA Maximum Output Power with HS-DPCCH

5.2B Maximum Output Power with HS-DPCCH and E-DCH

Definition: The maximum output power with HS-DPCCH (HSDPA) and HS-DPCCH and E-DCH (HSUPA) and its tolerance are defined according to the Maximum Power Reduction (MPR) for the nominal maximum output power.

The maximum output power with HS-DPCCH / HS-DPCCH and E-DCH is a measure of the maximum power the UE can transmit when HS-DPCCH / HS-DPCCH and E-DCH is fully or partially transmitted during a DPCCH timeslot. The measurement period shall be at least one timeslot.

Test purpose: To verify that the error of the UE maximum output power with HS-DPCCH (HSDPA) and with HS-DPCCH and E-DCH (HSUPA) does not exceed the range prescribed by the maximum output power and tolerance in table 5.2AA.2 and table 5.2B.5, respectively, from the ETSI TS 34 121-1 standard.

An excess maximum output power may interfere with other channels or other systems. A small maximum output power decreases the coverage area.

RF Tests (Functional) – 3G Technology

5.2C UE Relative Code Domain Power Accuracy

5.2D UE Relative Code Domain Power Accuracy for HS-DPCCH and E-DCH

Definition: The UE Relative code domain power accuracy is a measure of the ability of the UE to correctly set the level of individual code powers relative to the total power of all active codes. The measure of accuracy is the difference between two dB ratios:

UE Relative CDP accuracy = (Measured CDP ratio) – (Nominal CDP ratio)

where:

Measured CDP ratio = 10*log((Measured code power) / (Measured total power of all active codes))

Nominal CDP ratio = 10*log((Nominal CDP) / (Sum of all nominal CDPs))

The nominal CDP of a code is relative to the total of all codes and is derived from beta factors.

RF Tests (Functional) – 3G Technology

5.2C UE Relative Code Domain Power Accuracy

Test purpose: To verify that the UE relative code domain power accuracy meets the requirements given in table 5.2C.4 (HSDPA) and table 5.2D.8 (HSUPA).

Table 5.2C.4: UE relative code domain power accuracy test requirements

Nominal CDP ratio	Accuracy (dB)
≥ -10 dB	±1.7
-10 dB to ≥ -15 dB	±2.3
-15 dB to ≥ -20 dB	±2.9

Table 5.2D.8: UE relative code domain power accuracy test requirements

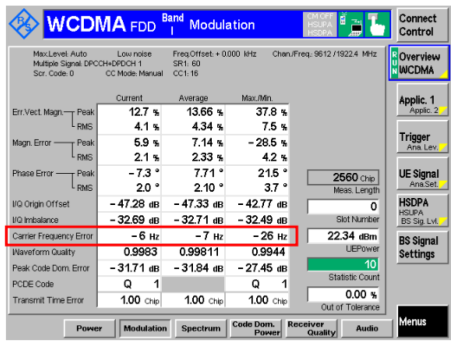
Nominal CDP ratio	Accuracy (dB)
≥ -10 dB	±1.7
-10 dB to ≥ -15 dB	±2.3
-15 dB to ≥ -20 dB	±2.9

RF Tests (Functional) – 3G Technology

5.3 Frequency Error

Definition: The frequency error is the difference between the RF modulated carrier frequency transmitted from the UE and the assigned frequency.

Test purpose: To verify that the UE carrier frequency error does not exceed ±0,1 ppm.



RF Tests (Functional) – 3G Technology

5.4.1 Open Loop Power Control in the Uplink

Definition: Open loop power control in the uplink is the ability of the UE transmitter to set its output power to a specific value. This function is used for PRACH transmission and based on the information from Node B using BCCH and the downlink received signal power level of the CPICH. The information from Node B includes transmission power of CPICH and uplink interference power level.

The power measured by the UE of the received signal and the signalled BCCH information are used by the UE to control the power of the UE transmitted signal with the target to transmit at the lowest power acceptable for proper communication.

The test stresses the ability of the receiver to measure the received power correctly over the receiver dynamic range.

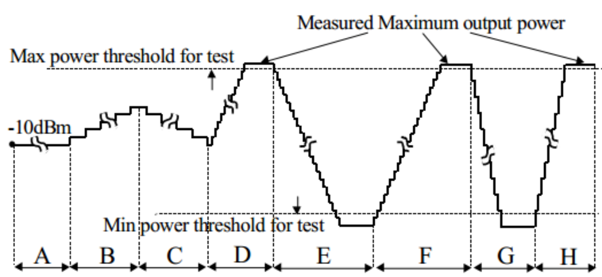
Test purpose: The test purpose is to verify that the UE open loop power control tolerance does not exceed ±9 dB (normal conditions) or ±12 dB (extreme conditions).

RF Tests (Functional) – 3G Technology

5.4.2 Inner Loop Power Control in the Uplink

Definition: Inner loop power control in the uplink is the ability of the UE transmitter to adjust its output power in accordance with one or more TPC commands received in the downlink.

The power control step is the change in the UE transmitter output power in response to a single TPC command, TPC_cmd, derived at the UE. An excess error of the inner loop power control decreases the system capacity.



RF Tests (Functional) – 3G Technology

5.4.2 Inner Loop Power Control in the Uplink

Test purpose: To verify that the UE inner loop power control size and response is meet to the described value shown in clause 5.4.2.2.

To verify that TPC_cmd is correctly derived from received TPC commands.

Table 5.4.2.2: Transmitter aggregate power control tolerance

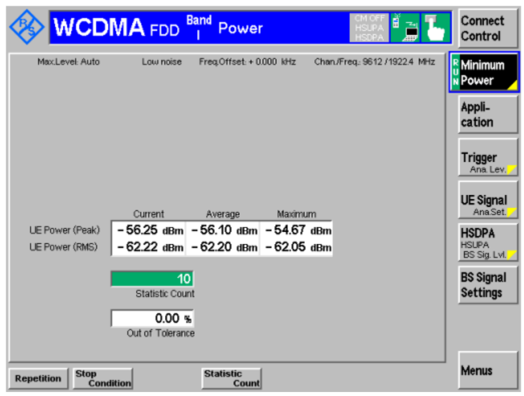
TPC_cmd group	Transmitter power control range after 10 equal TPC_cmd group (all units are in dB)				Transmitter power control range after 7 equal TPC_cmd groups (all units are in dB)	
	1 dB step size		2 dB step size		3 dB step size	
	Lower	Upper	Lower	Upper	Lower	Upper
+1	+8	+12	+16	+24	+16	+26
0	-1	+1	-1	+1	-1	+1
-1	-8	-12	-16	-24	-16	-26
0,0,0,0,+1	+6	+14	N/A	N/A	N/A	N/A
0,0,0,0,-1	-6	-14	N/A	N/A	N/A	N/A

RF Tests (Functional) – 3G Technology

5.4.3 Minimum Output Power

Definition: The minimum controlled output power of the UE is when the power control setting is set to a minimum value.

Test purpose: To verify that the UE minimum transmit power is less than -50 dBm.



RF Tests (Functional) – 3G Technology

5.5.1 Transmit OFF Power

5.5.2 Transmit ON/OFF Time Mask

Definition: Transmit OFF power is defined as the RRC filtered mean power when the transmitter is off. The transmit OFF power state is when the UE does not transmit or during periods when the UE is not transmitting DPCCH due to discontinuous uplink DPCCH transmission.

The time mask for transmit ON/OFF defines the ramping time allowed for the UE between transmit OFF power and transmit ON power.

Test purpose: To verify that the transmit OFF power is less than –56 dBm.

To verify that the power ON/OFF ratio of the PRACH shown in figure 5.5.1 meets the requirements given in table 5.5.2.2.

RF Tests (Functional) – 3G Technology

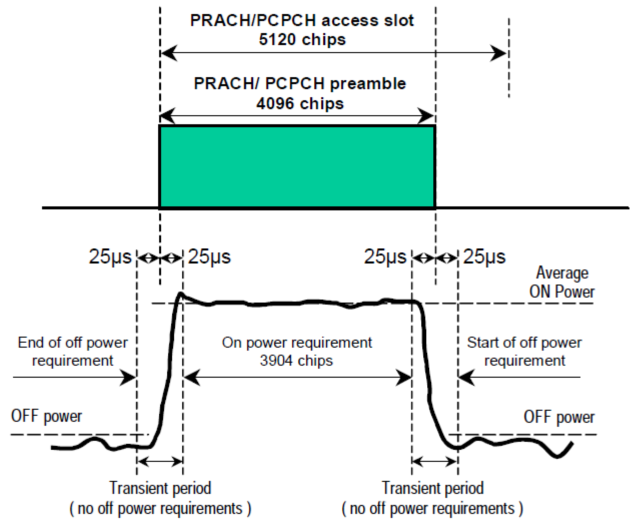


Figure 5.5.1: Transmit ON/OFF template for PRACH preambles

RF Tests (Functional) – 3G Technology

5.7 Power Setting in Uplink Compressed Mode

Definition: A change of output power is required during uplink compressed frames since the transmission of data is performed in a shorter interval.

Test purpose: To verify that the changes in uplink transmit power in compressed mode are within the prescribed tolerances.

Excess error in transmit power setting in compressed mode increases the interference to other channels, or increases transmission errors in the uplink.

RF Tests (Functional) – 3G Technology

5.7A HS-DPCCH power control

Definition: The transmission of ACK / NACK or CQI over the HS-DPCCH may cause transmission power in the uplink to vary.

The ratio of the amplitude between the DPCCH and the Ack/Nack and CQI respectively is signalled by higher layers.

Test purpose: To verify that the changes in uplink transmit power when transmitting the HS-DPCCH (Ack/Nack and CQI) and the power between HS-DPCCH transmissions are within the allowed power step tolerances as shown in table 5.7A.2 and 5.7A.3 of the ETSI TS 34121-1 standard.

RF Tests (Functional) – 3G Technology

5.7A HS-DPCCH power control

Table 5.7A.2: Transmitter power test requirements for TPC_cmd=0

Sub-test in table C.10.1.4	Power step	Nominal Power step size, ΔP [dB]	Rounded Power step size, ΔP [dB]	Transmitter power step Tolerance [dB]	Allowed Transmitter power step range [dB]
3	1	6.14	6	+/- 2.3	3.7 to 8.44
	2	-1.38	-1	+/- 0.6	-1.98 to -0.4
	3	-4.76	-5	+/- 2.3	-7.3 to -2.46
	4[1]	0	0	+/- 0.6	-0.6 to 0.6
	5	4.76	5	+/- 2.3	2.46 to 7.3
	6	1.38	1	+/- 0.6	0.4 to 1.98
	7	-6.14	-6	+/- 2.3	-8.44 to -3.7
	8[1]	0	0	+/- 0.6	-0.6 to 0.6
	9	4.76	5	+/- 2.3	2.46 to 7.3
	10	-4.76	-5	+/- 2.3	-7.3 to -2.46
	11[1]	0	0	+/- 0.6	-0.6 to 0.6
NOTE 1: Two test points.					

Ensaios de conformidade – Tecnologia 3G

5.7A HS-DPCCH power control

Table 5.7A.3: Transmitter power test requirements for TPC_cmd=1

Sub-test in table C.10.1.4	Power step	Nominal Power step size, ΔP [dB]	Rounded Power step size, ΔP [dB]	Transmitter power step Tolerance [dB]	Allowed Transmitter power step range [dB]
3	1	6.14	6	+/- 2.3	3.7 to 8.44
	2	-1.38	-1	+/- 0.6	-1.98 to -0.4
	3[3]	No requirements	No requirements	NA	No requirements
	4	-4.76	-5	+/- 2.3	-7.3 to -2.46
	5[1]	1	1	+/- 0.6	0.4 to 1.6
	6	4.76	5	+/- 2.3	2.46 to 7.3
	7[3]	No Requirements	No requirements	NA	No requirements
	8	1.38	1	+/- 0.6	0.40 to 1.98
	9	-6.14	-6	+/- 2.3	-8.44 to -3.7
	10[2]	1	1	+/- 0.6	0.4 to 1.6
	11	4.76	5	+/- 2.3	2.46 to 7.3
	12	-4.76	-5	+/- 2.3	-7.3 to -2.46
	13[2]	1	1	+/- 0.6	0.4 to 1.6

NOTE 1: Three test points.
NOTE 2: Two test points.
NOTE 3: In these test points rel-6 UE performs additional power scaling due to changes in allowed MPR, and therefore there are no requirements specified for transmitter power steps.

RF Tests (Functional) – 3G Technology

5.9 Spectrum Emission Mask

Definition: The spectrum emission mask of the UE applies to frequencies, which are between 2,5 MHz and 12,5 MHz away from the UE centre carrier frequency. The out of channel emission is specified relative to the RRC filtered mean power of the UE carrier.

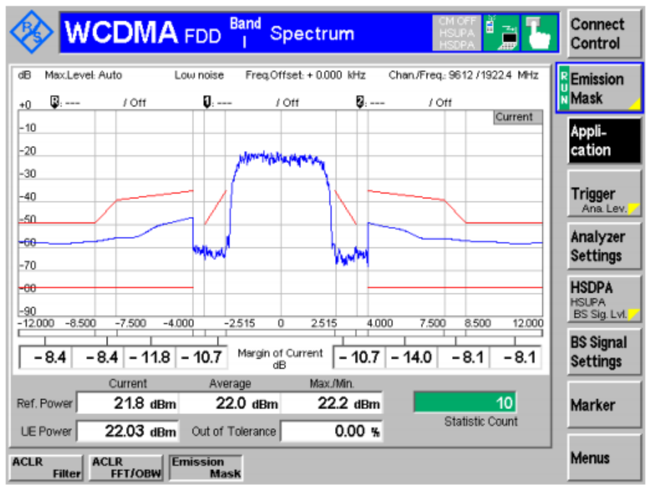
Test purpose: To verify that the power of UE emission does not exceed the prescribed limits shown in table 5.9.1.

Table 5.9.1: Spectrum Emission Mask Requirement

Δf in MHz (Note 1)	Minimum requirement (note 2) Relative requirement	Minimum requirement (note 2) Absolute requirement	Measurement bandwidth
2.5 - 3.5	$\left\{-35-15\cdot\left(\frac{\Delta f}{MHz}-2.5\right)\right\}dBc$	-71.1 dBm	30 kHz (note 3)
3.5 - 7.5	$\left\{-35-1\cdot\left(\frac{\Delta f}{MHz}-3.5\right)\right\}dBc$	-55.8 dBm	1 MHz (note 4)
7.5 - 8.5	$\left\{-39-10\cdot\left(\frac{\Delta f}{MHz}-7.5\right)\right\}dBc$	-55.8 dBm	1 MHz (note 4)
8.5 - 12.5 MHz	-49 dBc	-55.8 dBm	1 MHz (note 4)

RF Tests (Functional) – 3G Technology

5.9 Spectrum Emission Mask



RF Tests (Functional) – 3G Technology

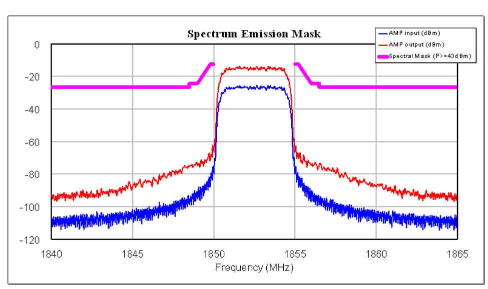
5.9A Spectrum Emission Mask with HS-DPCCH

5.9B Spectrum Emission Mask with E-DCH

Definition: The spectrum emission mask of the UE applies to frequencies, which are between 2,5 MHz and 12,5 MHz away from the UE centre carrier frequency. The out of channel emission is specified relative to the RRC filtered mean power of the UE carrier.

Test purpose: To verify that the power of UE emission does not exceed the prescribed limits shown in table 5.9A.1, even in the presence of the HS-DPCCH.

To verify that the power of UE emission does not exceed the prescribed limits shown in table 5.9B.1, even in the presence of the E-DCH.

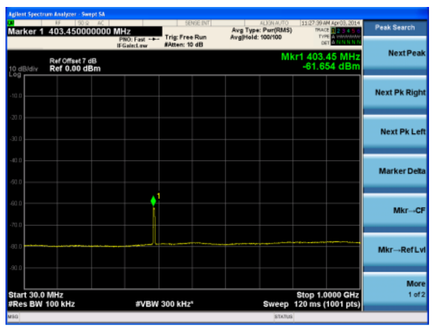


RF Tests (Functional) – 3G Technology

5.11 Spurious Emissions

Definition: Spurious emissions are emissions which are caused by unwanted transmitter effects such as harmonics emission, parasitic emission, intermodulation products and frequency conversion products, but exclude out of band emissions.

Test purpose: To verify that the UE spurious emissions do not exceed described value shown in table 5.11.1a and table 5.11.1b.



RF Tests (Functional) – 3G Technology

5.13.1 Error Vector Magnitude (EVM)

5.13.1A Error Vector Magnitude (EVM) with HS-DPCCH

5.13.1AA Error Vector Magnitude (EVM) and Phase Discontinuity with HS-DPCCH

Definition: The Error Vector Magnitude is a measure of the difference between the reference waveform and the measured waveform. This difference is called the error vector. The EVM result is defined as the square root of the ratio of the mean error vector power to the mean reference power expressed as a %.

Phase discontinuity for HS-DPCCH is the change in phase due to the transmission of the HS-DPCCH. In the case where the HS-DPCCH timeslot is offset from the DPCCH timeslot, the period of evaluation of the phase discontinuity shall be the DPCCH timeslot that contains the HS-DPCCH slot boundary.

Test purpose: To verify that the EVM does not exceed 17.5 %

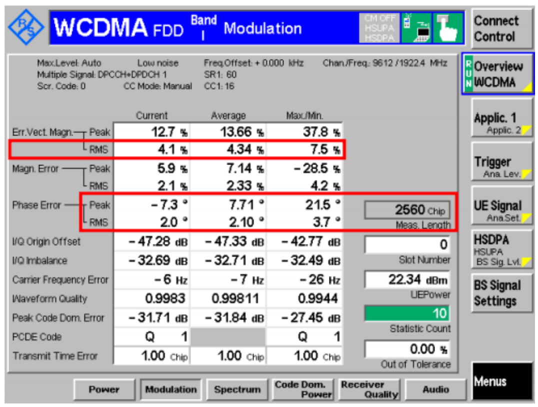
To verify that HSDPA phase discontinuity does not exceed 30 degrees.

RF Tests (Functional) – 3G Technology

5.13.1 Error Vector Magnitude (EVM)

5.13.1A Error Vector Magnitude (EVM) with HS-DPCCH

5.13.1AA Error Vector Magnitude (EVM) and Phase Discontinuity with HS-DPCCH



RF Tests (Functional) – 3G Technology

5.13.2A Relative Code Domain Error with HS-DPCCH

5.13.2B Relative Code Domain Error with HS-DPCCH and E-DCH

Definition: The Relative Code Domain Error is computed by projecting the error vector onto the code domain. Only the code channels with non-zero betas in the composite reference waveform are considered for this requirement.

Test purpose: To verify that the Relative Code Domain Error does not exceed the values in table 5.13.2B.9 for the beta values defined in table 5.13.2B.8.

Table 5.13.2B.9: Relative Code Domain Error test requirement

ECDP dB	Relative Code Domain Error dB
-21 < ECDP	≤ -15.5
-30 ≤ ECDP ≤ -21	≤ -36.5 – ECDP
ECDP < -30	No requirement

RF Tests (Functional) – LTE Technology

RF Tests (Functional) – LTE Technology

6.2.2 UE Maximum Output Power

Definition: Measure maximum power UE can transmit.

Test purpose: To verify that the error of the UE maximum output power does not exceed the range prescribed by the specified nominal maximum output power and tolerance.

RF Tests (Functional) – LTE Technology

6.2.3 Maximum Power Reduction (MPR)

Definition: The number of RB identified in Table 6.2.2.3-1 is based on meeting the requirements for adjacent channel leakage ratio and the maximum power reduction (MPR).

Test purpose: To verify that the maximum output power is within the range prescribed by the nominal maximum output power and tolerance in Table 6.2.3.5-1.

RF Tests (Functional) – LTE Technology

6.2.5 Configured UE Transmitted Output Power

Definition: Configured transmitted power is the capacity the UE transmitter has to adjust output power in response to Node B commands.

Test purpose: To make sure the UE does not exceed the minimum between the maximum allowed E-UTRAN *uplink* power and the maximum UE power, according to its power class. The maximum output power measured shall not exceed the values specified in table 6.2.5.5-1.

Table 6.2.5.5-1: P_{CMAX} configured UE output power

	Channel bandwidth / maximum output power					
	1.4 MHz	3.0 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Measured UE output power test point 1	-10 dBm ± 7.7					
Measured UE output power test point 2	10 dBm ± 6.7					
Measured UE output power test point 3	15 dBm ± 5.7					
Note: In addition note 2 in Table 6.2.2.3-1 shall apply to the tolerances.						

RF Tests (Functional) – LTE Technology

6.3.2 Minimum Output Power

Definition: The minimum output power is defined as the mean power in one sub-frame (1 ms).

Test purpose: Verify the UE's ability to transmit with output power below the value prescribed in test requirements, when value has been set for a minimum value. The minimum output power measured shall not exceed the values specified in table 6.3.2.5-1.

Table 6.3.2.5-1: Minimum output power

	Channel bandwidth / minimum output power / measurement bandwidth					
	1.4 MHz	**3.0 MHz**	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
Minimum output power	-39 dBm					
Measurement bandwidth (Note 1)	1.08 MHz	2.7 MHz	4.5 MHz	9.0 MHz	13.5 MHz	18 MHz
Note 1: Different implementations such as FFT or spectrum analyzer approach are allowed. For spectrum analyzer approach the measurement bandwidth is defined as an equivalent noise bandwidth.						

RF Tests (Functional) – LTE Technology

6.3.4.1 ON/OFF Time Mask

Definition: The time mask for transmit ON/OFF defines the ramping time allowed for the UE between transmit OFF power and transmit ON power.

Test purpose: To verify that the general ON/OFF time mask meets the requirements given in table 6.3.4.1.5-1.

Table 6.3.4.1.5-1: General ON/OFF time mask

	Channel bandwidth / minimum output power / measurement bandwidth					
	1.4 MHz	**3.0 MHz**	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
Transmit OFF power	-48.5 dBm					
Transmission OFF Measurement bandwidth	1.08 MHz	2.7 MHz	4.5 MHz	9.0 MHz	13.5 MHz	18 MHz
Expected Transmission ON Measured power	-14.8 ± 7.5	-10.8 ± 7.5	-8.6 ± 7.5	-5.6 ± 7.5	-3.9 ± 7.5	-2.6 ± 7.5

RF Tests (Functional) – LTE Technology

6.5.1 Frequency Error

Definition: This test verifies the ability of both the receiver and the transmitter to process frequency correctly.

Receiver: to extract the correct frequency from the stimulus signal, offered by the System simulator, under ideal propagation conditions and low level.

Transmitter: to derive the correct modulated carrier frequency from the results, gained by the receiver.

Test purpose: The UE modulated carrier frequency shall be accurate to within ±0.1 PPM observed over a period of one time slot (0.5ms) compared to the carrier frequency received from the E-UTRA Node B.

RF Tests (Functional) – LTE Technology

6.5.2.1 Error Vector Magnitude (EVM)

Definition: The Error Vector Magnitude is a measure of the difference between the reference waveform and the measured waveform. This difference is called the error vector. The EVM result is defined as the square root of the ratio of the mean error vector power to the mean reference power expressed as a %.

The basic EVM measurement interval in the time domain is one preamble sequence for the PRACH and is one slot for the PUCCH and PUSCH in the time domain. When the PUSCH or PUCCH transmission slot is shortened due to multiplexing with SRS, the EVM measurement interval is reduced by one symbol, accordingly. The PUSCH or PUCCH EVM measurement interval is also reduced when the mean power, modulation or allocation between slots is expected to change.

Test purpose: The PUSCH EVM derived in E.4.2 shall not exceed 17.5% for QPSK and BPSK, 12,5% for 16 QAM.

The PUCCH EVM shall not exceed 17.5%.

The PRACH EVM shall not exceed 17.5%.

RF Tests (Functional) – LTE Technology

6.5.2.2 Carrier Leakage

Definition: Carrier leakage (the I/Q origin offset) is an interference caused by crosstalk or DC offset and expresses itself as unmodulated sine wave with the carrier frequency. It is an interference of approximately constant amplitude and independent of the amplitude of the wanted signal. I/Q origin offset interferes with the centre sub carriers of the UE under test (if allocated), especially, when their amplitude is small. The measurement interval is defined over one slot in the time domain.

Test purpose: The purpose of this test is to exercise the UE transmitter to verify its modulation quality in terms of carrier leakage, according to table 6.5.2.2.5-1.

Table 6.5.2.2.5-1: Test requirements for Relative Carrier Leakage Power

LO Leakage	Parameters	Relative Limit (dBc)
	3.2 dBm ±3.2dB	-24.2
	-26.8 dBm ±3.2dB	-19.2
	-36.8dBm±3.2dB	-9.2

RF Tests (Functional) – LTE Technology

6.5.2.3 In-Band Emissions for Non Allocated RB

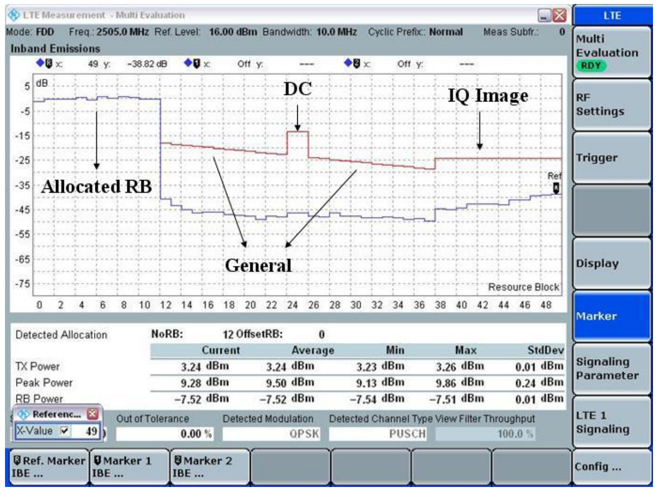
Definition: The in-band emissions are a measure of the interference falling into the non-allocated resources blocks.

The in-band emission is defined as the average across 12 sub-carrier and as a function of the RB offset from the edge of the allocated UL transmission bandwidth. The in-band emission is measured as the ratio of the UE output power in a non-allocated RB to the UE output power in an allocated RB. The basic in-band emissions measurement interval is defined over one slot in the time domain.

Test purpose: To verify that the relative in-band emissions do not exceed the values specified in table 6.5.2.3.5-1.

RF Tests (Functional) – LTE Technology

6.5.2.3 In-Band Emissions for Non Allocated RB



RF Tests (Functional) – LTE Technology

6.6.1 Occupied Bandwidth

Definition: Occupied bandwidth is a measure of the bandwidth containing 99 % of the total integrated mean power of the transmitted spectrum on the assigned channel.

Test purpose: To verify that the UE occupied bandwidth for all transmission bandwidth configurations supported by the UE are less than their specific limits.

Table 6.6.1.2-1: Occupied channel bandwidth

	Occupied channel bandwidth / channel bandwidth					
	1.4 MHz	3.0 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Channel bandwidth [MHz]	1.4	3	5	10	15	20

RF Tests (Functional) – LTE Technology

6.6.2.1 Spectrum Emission Mask

Definition: The spectrum emission mask of the UE applies to frequencies (ΔfOOB) starting from the edge of the assigned E-UTRA channel bandwidth. For frequencies greater than (ΔfOOB) as specified in Table 6.6.2.1.3-1 the spurious requirements in clause 6.6.3 are applicable.

Test purpose: To verify that the power of any UE emission shall not exceed specified lever for the specified channel bandwidth.

Table 6.6.2.1.3-1: General E-UTRA spectrum emission mask

Spectrum emission limit (dBm)/ Channel bandwidth							
Δf_{OOB} (MHz)	1.4 MHz	3.0 MHz	5 MHz	10 MHz	15 MHz	20 MHz	Measurement bandwidth
± 0-1	-10	-13	-15	-18	-20	-21	30 kHz
± 1-2.5	-10	-10	-10	-10	-10	-10	1 MHz
± 2.5-2.8	-25	-10	-10	-10	-10	-10	1 MHz
± 2.8-5		-10	-10	-10	-10	-10	1 MHz
± 5-6		-25	-13	-13	-13	-13	1 MHz
± 6-10			-25	-13	-13	-13	1 MHz
± 10-15				-25	-13	-13	1 MHz
± 15-20					-25	-13	1 MHz
± 20-25						-25	1 MHz

RF Tests (Functional) – LTE Technology

6.6.2.3 Adjacent Channel Leakage Power Ratio

Definition: ACLR is the ratio of the filtered mean power centred on the assigned channel frequency to the filtered mean power centred on an adjacent channel frequency at nominal channel spacing.

Test purpose: To verify that UE transmitter does not cause unacceptable interference to adjacent channels in terms of Adjacent Channel Leakage Power Ratio.

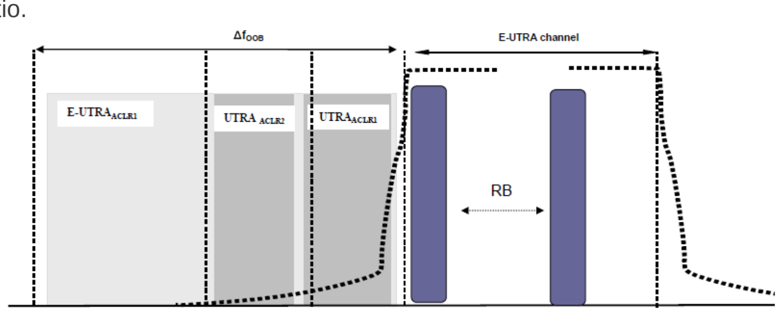


Figure 6.6.2.3.3-1: Adjacent Channel Leakage Power Ratio requirements

RF Tests (Functional) – LTE Technology

6.6.3.1 Transmitter Spurious Emissions

Definition: Spurious emissions are emissions which are caused by unwanted transmitter effects such as harmonics emission, parasitic emissions, intermodulation products and frequency conversion products, but exclude out of band emissions.

Test purpose: To verify that UE transmitter does not cause unacceptable interference to other channels or other systems in terms of transmitter spurious emissions, according to table 6.6.3.1.3-2.

Table 6.6.3.1.3-2: Spurious emissions limits

Frequency Range	Maximum Level	Measurement Bandwidth
9 kHz ≤ f < 150 kHz	-36 dBm	1 kHz
150 kHz ≤ f < 30 MHz	-36 dBm	10 kHz
30 MHz ≤ f < 1000 MHz	-36 dBm	100 kHz
1 GHz ≤ f < 12.75 GHz	-30 dBm	1 MHz

RF Tests (Functional) – 3G Technology

RF Tests (Functional) – Wi-Fi Technology 2.400-2.483,5 MHz and 5.725-5.850 MHz

Maximum Transmitter Output Power

Definition: Maximum transmitter output power is the measurement of the maximum power the UE can transmit.

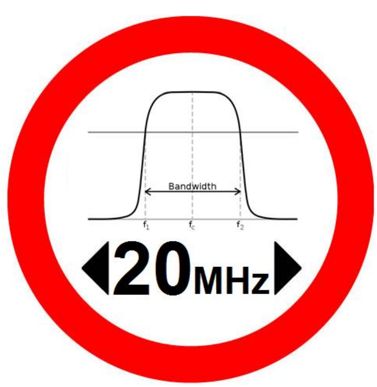
Test purpose: Verify, according to item II of article 41 in section IX, that maximum transmitter output power cannot exceed 1 Watt.

RF Tests (Functional) – Wi-Fi Technology 2.400-2.483,5 MHz and 5.725-5.850 MHz

Maximum Width of Occupied Hop Channel Range at 6 dB

Definition: Occupied bandwidth is a 6 db bandwidth measurement of the transmission peak signal in the assigned channel.

Test purpose: Verify, according to item I of article 41 in section IX that the bandwidth, at 6 db, must be at least 500 kHz.

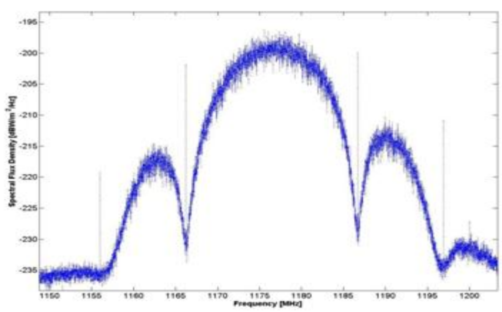


RF Tests (Functional) – Wi-Fi Technology 2.400-2.483,5 MHz and 5.725-5.850 MHz

Peak Power Density in any 3 kHz Range

Definition: Spectral power density describes how the energy of a signal or a time series shall be distributed with the frequency.

Test purpose: Verify, according to item II of article 41 in section IX that the spectral power density peak, in any 3 kHz range, during any continuous transmission time interval, shall never exceed 8 dBm.



RF Tests (Functional) – Wi-Fi Technology 2.400-2.483,5 MHz and 5.725-5.850 MHz

Spurious Emissions

Definition: Spurious emissions are emissions which are caused by unwanted transmitter effects such as harmonics emission, parasitic emissions, intermodulation products and frequency conversion products.

Test purpose: Verify, according to item III of article 41 in section IX, that produced radiofrequency power, in any 100 kHz bandwidth outside any one of the bands in which the system is operating, must be at least 20 dB below the maximum power produced in a 100 kHz interval, within the operating range.

RF Tests (Functional) – Wi-Fi Technology 5.470-5.725 MHz

Maximum Transmitter Output Power

Definition: Maximum transmitter output power is the measurement of the maximum power the UE can transmit.

Test purpose: Verify, according to item I of article 47 in section X, that maximum transmitter output power cannot exceed 250 mW.

RF Tests (Functional) – Wi-Fi Technology 5.150-5.350 MHz and 5.470-5.725 MHz

Mean EIRP

Definition: Equivalent radiated isotropic power mean is the average of the arithmetic product of the power suppled to the antenna and its gain.

Test purpose: Verify, according to item II of articles 46 and 47 of section X, that the EIRP mean value is limited to a maximum 200 mW (for an operating range of 5,150-5,350 MHz) and 1 W (for an operating range of 5,470-5,725 MHz).

RF Tests (Functional) – Wi-Fi Technology 5.150-5.350 MHz and 5.470-5.725 MHz

7 – EIRP Spectral Density Mean Value

Definition: The EIRP spectral density describes the power contributed to the wave by a frequency, considering the gain of the transmitting antenna.

Test purpose: Verify, according to item III of articles 46 and 47 of section X, that the EIRP spectral mean value is limited to a maximum of 10 mW/MHz (for an operating range of 5,150-5,350 MHz) and 50 mW/MHz (for an operating range of 5,470-5,725 MHz).

RF Tests (Functional) – Wi-Fi Technology 5.150-5.350 MHz and 5.470-5.725 MHz

Spurious Emissions

Definition: Spurious emissions are emissions which are caused by unwanted transmitter effects such as harmonics emission, parasitic emissions, intermodulation products and frequency conversion products.

Test purpose: Verify, according to article 48 in section X, that spurious emissions or those outside any of the operating ranges shall be inferior to the EIRP limit of -27dBm/MHz.

RF Tests (Functional) – Wi-Fi Technology 5.150-5.350 MHz and 5.470-5.725 MHz

Transmit Power Control (TPC)

Definition: Equipment without the TCP mechanism shall be exceptionally allowed. In this case, the EIRP mean value shall be limited to 100 mW for equipment operating in the 5,150-5,350 MHz band and limited to 500 mW range for equipment operating in the 5,470-5,725 MHz band.

Test purpose: Verify, according to article 49 in section X, that the UE allows dynamic selection of transmission power and assures a mitigating factor of at least 3dB.

RF Tests (Functional) – Wi-Fi Technology 5.150-5,350 MHz and 5,470-5,725 MHz

Dynamic Frequency Selection (DFS)

Definition: In the 5,250-5,725 MHz ranges, the Broadband Wireless Access System for Local Networks shall use the dynamic frequency selection mechanism. This frequency range is exclusively reserved for military radars, however, it can be used by Wi-Fi devices provided they have a device able to detect when a radar signal is operating in the same frequency.

Test purpose: Verify, according to article 50 in section X, that:

I - time taken to verify channel availability does not exceed 60 seconds and no transmission shall begin before channel availability has been verified;

II – one channel availability has been verified and its occupancy has been identified, this channel shall be subject to a 30-minute non-occupancy period;

III – for equipment operating at a maximum EIRP of less than 200 mW, the DFS mechanism shall be able to detect interfering signals below the –62 dBm threshold, calculated during an average interval of 1 microsecond;

RF Tests (Functional) – Wi-Fi Technology 5.150-5.350 MHz and 5.470-5.725 MHz

Dynamic Frequency Selection (DFS)

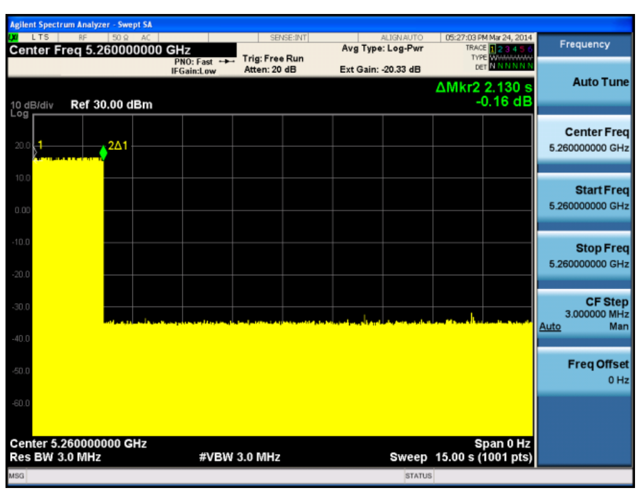
IV – for equipment operating at a maximum EIRP of between 200mW and 1 W, the DFS mechanism shall be able to detect interfering signals below the –64 dBm threshold, calculated during an average interval of 1 microsecond;

V – in case an interfering signal with a value above the DFS detection threshold, all transmissions on the channel in question shall stop within 10 seconds.

NOTE: The use of the DFS mechanism in the 5,150-5,250 MHz band, however, the use of this mechanism is not mandatory in this band.

RF Tests (Functional) – Wi-Fi Technology 5.150-5.350 MHz and 5.470-5.725 MHz

Dynamic Frequency Selection (DFS)



RF Tests (Functional) – Bluetooth Technology

RF Tests (Functional) – Bluetooth Technology

Separating Carrier Frequencies in Hop Channels

Definition: Pseudo-random frequency hops separated by channels are used to minimize data transmission interference.

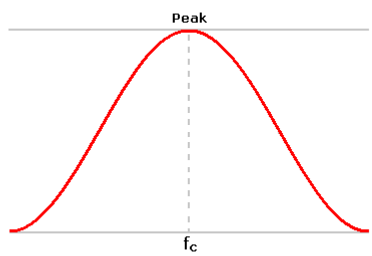
Test purpose: Verify, according to item I of article 40 in section IX, that the hop channel RF carriers are separated by a minimum 25 kHz or by the width of the hop channel at 20 dB, whichever value is greater.

RF Tests (Functional) – Bluetooth Technology

Maximum Transmitter Output Power Peak

Definition: Maximum transmitter output power is the measurement of the maximum power the UE can transmit.

Test purpose: Verify, according to item VII-d and VII-e of article 40 in section IX, that for systems utilizing less than 75 hop radiofrequencies, maximum transmitter output power peak is limited to 125 mW, and for systems using 75 or less radiofrequencies, maximum transmitter output power peak is limited to 1 Watt.

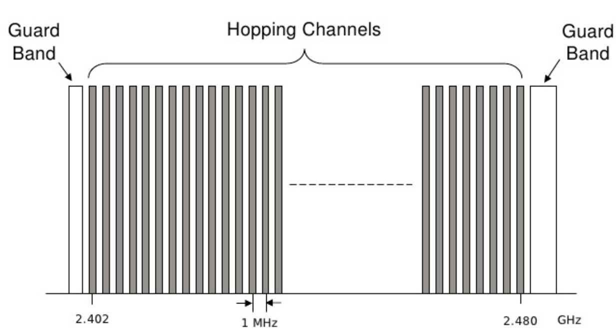


RF Tests (Functional) – Bluetooth Technology

Hop Frequencies

Definition: Count hop frequency channels within the specified range.

Test purpose: Verify, according to item VII-a of article 40 in section IX, that the system is using at least 15 non-coinciding hop frequencies.

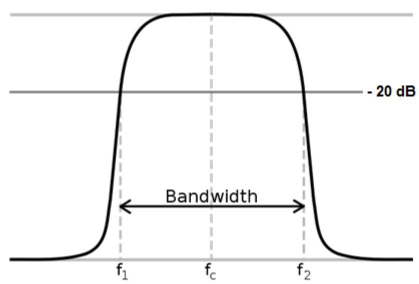


RF Tests (Functional) – Bluetooth Technology

Maximum Width of Occupied Hop Channel Range at 20 dB

Definition: Occupied hop channel bandwidth is a 20 dB bandwidth measurement of the transmission peak signal in the assigned channel.

Test purpose: Verify, according to item I of article 40 in section IX, the hop channel bandwidth at 20 dB.



RF Tests (Functional) – Bluetooth Technology

Mean Occupancy Time of Any Frequency

Definition: Measure hop channel mean occupancy time.

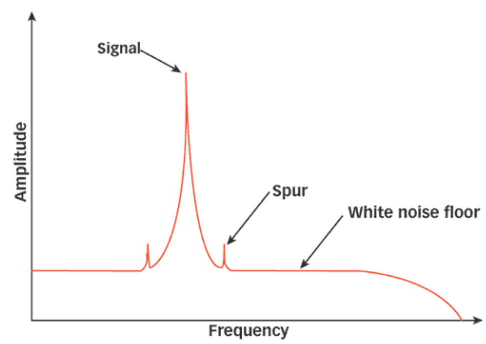
Test purpose: Verify, according to item VII-b of article 40 in section IX, that the mean occupancy time of any radiofrequency does not exceed 0.4 seconds in a 0.4 s interval multiplied by the number of hop channels utilized.

RF Tests (Functional) – Bluetooth Technology

Spurious Emissions

Definition: Spurious emissions are emissions which are caused by unwanted transmitter effects such as harmonics emission, parasitic emissions, intermodulation products and frequency conversion products.

Test purpose: Verify, according to article 44 in section IX, that produced radiofrequency power, in any 100 kHz bandwidth outside any one of the bands in which the system is operating, must be at least 20 dB below the maximum power produced in a 100 kHz interval, within the operating range.



Schedule

- Overview on Cellular Communications and Mobile Terminals Embedded RF Technologies
- Test Standards and Requirements for Mobile Cellular Terminal Certification in Brazil and other Large Global Urban Centers
- Description, Purpose and Importance of each RF Test Required for the ANATEL Certification and Approval Process
- **Description, Purpose and Importance of each SAR Test Required for the ANATEL Certification and Approval Process**
- Basic Concepts for Calculating Measurement Uncertainty
- Good Practices and Important Aspects for IEC/ISO 17025 Accreditation

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

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

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

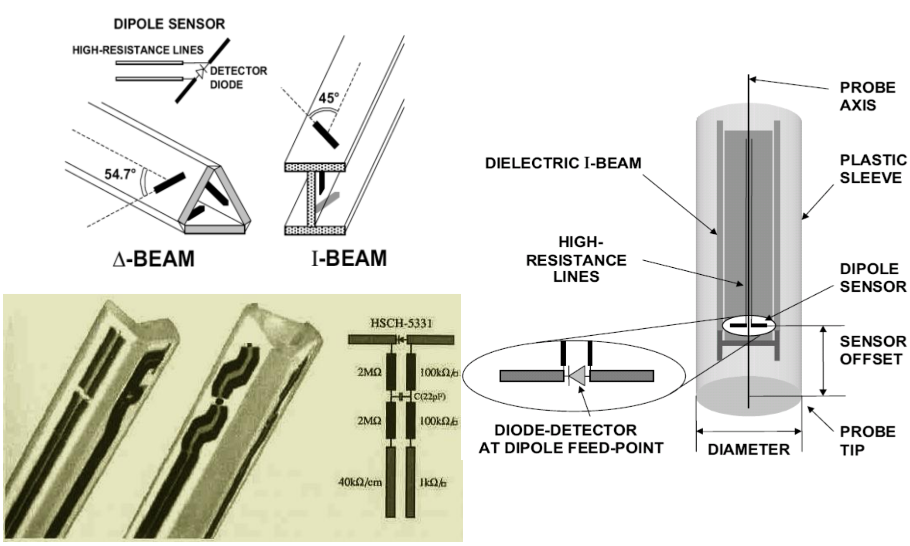
Electrical Field Measurements

- Probes with dipoles and diodes
- Probes with optical sensors

Technology adopted by all standards

- Probes with dipoles and diodes

SAR Tests – Measurement techniques



SAR Tests – Device Under Test

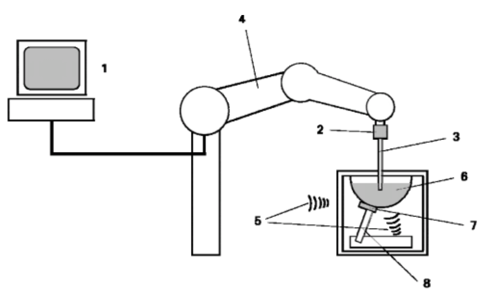
SAR tests must be run on portable radiofrequency telecommunication equipment that operate close to the human body. In Brazil, the Addendum to Resolution 533 defines that any portable terminal operating the range between 300 MHz and 6 GHz must be submitted to SAR tests.

Examples of portable telecommunication terminals:

Cell phones Tablets Modems PTT Radios




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

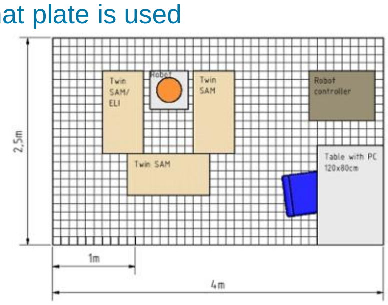
- External noise
- Internal noise (reflections, internal RF transmitters, etc.)
- 3% of the probe's minimum detection limit (0,4 W/kg)

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
- Above 10 MHz, losses by absorption predominate
- Top-quality shielding, no matter what plate is used
- Conductor and solid
- Very small thickness

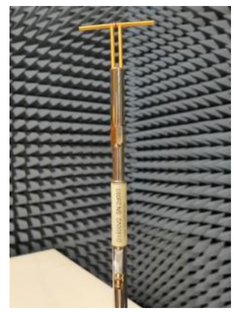


SAR Tests – Basic Instrument Set

Measuring probe

Data Acquisition Engine
(DAE)

Validation dipole

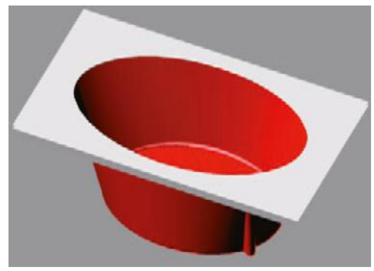


SAR Tests – Basic Instrument Set

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

SAR Tests – Basic Instrument Set

Flat phantom (ELI)



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 – Properties

IEEE 1528 and IEC 62.209 Part 1		
Frequency (MHz)	Relative Permissiveness (ε_r')	Conductivity(σ) (S/m)
300	45.30	0.87
450	43.50	0.87
835	41.50	0.90
900	41.50	0.97
1,450	40.50	1.20
1,800/-2,000	40.00	1.40
2,450	39.20	1.80
3,000	38.50	2.40

IEC 62.209 Part 2 – Additional Frequencies		
Frequency (MHz)	Relative Permissiveness (ε_r')	Conductivity(σ) (S/m)
30	[55.0]	[0.75]
150	[52.3]	[0.76]
4,000	38.00	3.50
5,000	36.20	4.40
5,200	36.00	4.70
5,400	35.80	4.90
6,000	35.30	5.30

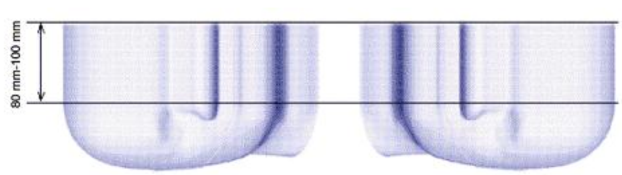
SAR Tests – Basic Instrument Set

Liquid simulator – Ingredients

Saccharine (sugar) (purity > 98%)
Sodium Chloride (salt) (purity > 99%)
Deionized water (Minimum resistivity) 16 MΩ.cm)
Hydrolysis of cellulose (HEC)
Bactericide
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

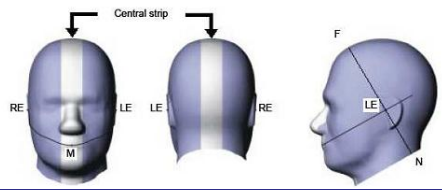
For running head SAR tests, we have: Bi-sectioned Twin SAM phantom



The bi-sectioned SAM phantom is used to run tests, simulating a user's head. Tests are run on the right and left side of the head in two different positions: touching the face and with a 15-degree inclination.

SAR Tests – Test Scenarios

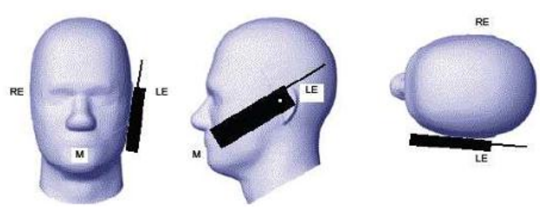
The following is an illustration of the head phantom.



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

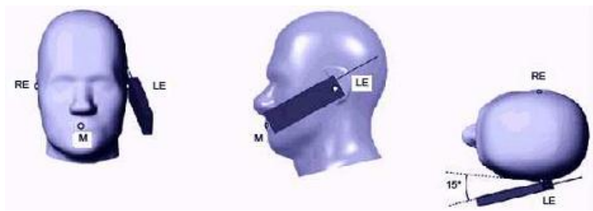
How the terminals are placed touching the bi-sectioned phantom head:



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:

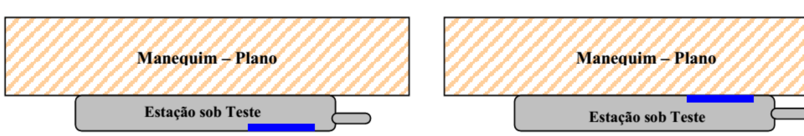


Legend:
RE: Right Ear Reference Point (ERP)
LE: Left Ear Reference Point (ERP)
M Mouth Reference Point
This complete head model is just for purposes of illustration and is directly derived from the phantom kit.

SAR Tests – Test Scenarios

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

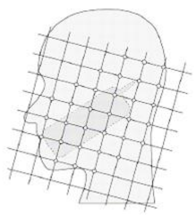
Touching the phantom flat

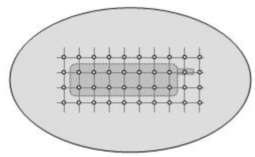


If the manufacturer should inform the recommended distance between the terminal and the phantom, body tests shall be performed at the informed distance.

SAR Tests – Test Scenarios

Defining the terminal under test scan area.





Head area

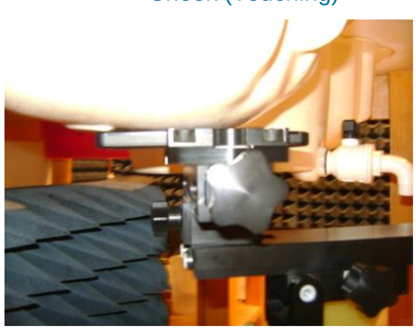
Body area

SAR Tests – Test Scenarios

Examples of phantom head placement:

Cheek (Touching)

Tilt (15º angle)



SAR Tests – Test Scenarios

Examples of terminal placement on flat phantom

Body with accessories

Body without accessories

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 – Head

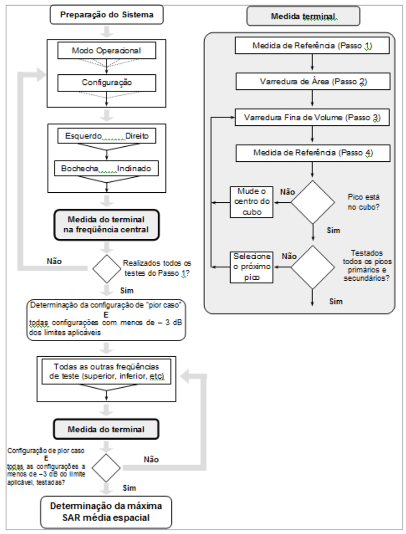


Diagrama de blocos dos testes a serem realizados – estação terminal portátil operando próxima à cabeça

SAR Tests – Test Scenarios – Body

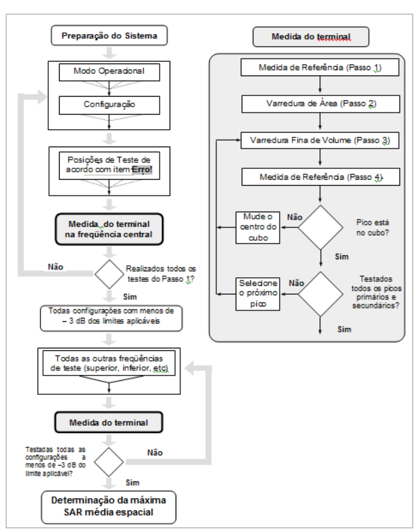
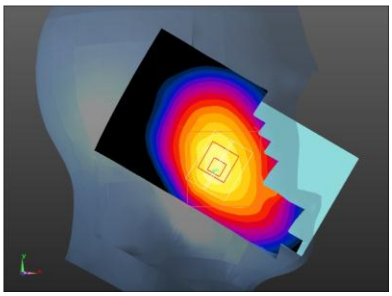


Diagrama de blocos dos testes a serem realizados – estação terminal portátil operando próxima ao corpo

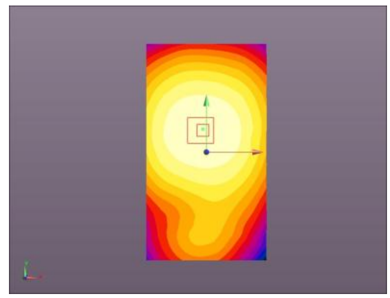
SAR Tests – Test Results

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 cheek	4W/kg

Schedule

- Overview on Cellular Communications and Mobile Terminals Embedded RF Technologies
- Test Standards and Requirements for Mobile Cellular Terminal Certification in Brazil and other Large Global Urban Centers
- Description, Purpose and Importance of each RF Test Required for the ANATEL Certification and Approval Process
- Description, Purpose and Importance of each SAR Test Required for the ANATEL Certification and Approval Process
- **Basic Concepts for Calculating Measurement Uncertainty**
- Good Practices and Important Aspects for IEC/ISO 17025 Accreditation

Basic Concepts for Calculating Measurement Uncertainty
Mandatory for ISO IEC 17025 Compliance
General Requirements for the Competence of Testing and Calibration Laboratories

Basic Concepts for Calculating Measurement Uncertainty

BASIC EXISTING REFERENCES

Evaluation of measurement data – Guide to the expression of uncertainty in measurement (GUM) JCGM 100:2008

Evaluation of measurement data – An introduction to the "Guide to the expression of uncertainty in measurement" and related documents JCGM 104:2009

Evaluation of measurement data – Supplement 1 to the "Guide to the expression of uncertainty in measurement" – Propagation of distributions using a Monte Carlo method JCGM 101:2008

Evaluation of measurement data – Supplement 2 to the "Guide to the expression of uncertainty in measurement" – Extension to any number of output quantities JCGM 102:2011

Evaluation of measurement data – The role of measurement uncertainty in conformity assessment JCGM 106:2012

http://www.bipm.org/en/publications/guides/gum.html

Basic Concepts for Calculating Measurement Uncertainty

EXISTING REFERENCES

International vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM) – 3rd edition

http://www.bipm.org/en/publications/guides/gum.html

Basic Concepts for Calculating Measurement Uncertainty

Several requirement standards and measurement methods today already include uncertainty concepts in tests. Ex.:

CISPR 16.4.2 – Uncertainty in Standardized EMC Tests

IEC 61000-4-2 – Testing Method for Immunity to Electrostatic Discharges

iEC 61000-4-3 – Testing method for immunity to radiated fields

IEC 61000-4-4 – Testing method for immunity to rapid transients

IEC 61000-4-6 – Testing method for immunity to conducted RF

IEC 62232 – Standard for measuring exposure to RF emitted by BTS

and others

Basic Concepts for Calculating Measurement Uncertainty

TERMINOLOGY

Measurement (VIM 2.1): process of experimentally obtaining one or more quantity values that can reasonably be attributed to a **quantity**.

Measurand (VIM 2.3): **quantity** intended to be measured

Measurement result (VIM 2.9): set of quantity values being attributed to a measurand together with any other available relevant information.

NOTE: A measurement result is generally expressed as a single measured quantity value and a measurement uncertainty.

Basic Concepts for Calculating Measurement Uncertainty

True quantity value (VIM 2.11): quantity value consistent with the definition of a quantity.

1. Value obtained by a perfect measurement
2. True values are, by nature, indeterminate

Conventional quantity value (VIM 2.12): quantity value attributed by agreement to a quantity for a given purpose.

Example: Standard acceleration of free fall (formerly called "standard acceleration due to gravity"), a=9,80665 m.s^2

Basic Concepts for Calculating Measurement Uncertainty

Measurement accuracy (VIM 2:13): closeness of agreement between a measured quantity value and a true quantity value of a measurand.

Note 1 – The concept 'measurement accuracy' is not a quantity and is not given a numerical quantity value. A measurement is said to be more accurate when it offers a smaller measurement error.

Note 2 – The term "measurement accuracy" should not be used for measurement trueness and the term "measurement precision" should not be used for 'measurement accuracy', which, however, is related to both these concepts.

Note 3 – Measurement accuracy' is sometimes understood as closeness of agreement between measured quantity values that are being attributed to the measurand.

Basic Concepts for Calculating Measurement Uncertainty

Measurement error (VIM 2.16): measured quantity value minus a reference quantity value.

Systematic measurement error (VIM 2.17): component of measurement error that in replicate measurements remains constant or varies in a predictable manner.

Basic Concepts for Calculating Measurement Uncertainty

Note 1 – A reference quantity value for a systematic measurements remains constant or varies in a predictable manner.

Note 2 – Systematic measurement error, and its causes, can be known or unknown. A correction can be applied to compensate for a known systematic measurement.

error.

Note 3 – Systematic measurement error equals measurement error minus random measurement error.

Basic Concepts for Calculating Measurement Uncertainty

Random measurement error (VIM 2.19): component of measurement error that in replicate measurements varies in an unpredictable manner.

Note 1 – A reference quantity value for a random measurement error is the average that would ensue from an infinite number of replicate measurements of the same measurand random measurement error.

Note 2 – Random measurement errors of a set of replicate measurements form a distribution that can be summarized by its expectation, which is generally assumed to be zero, and its variance.

Note 3 – Random measurement error equals measurement error minus systematic measurement error.

Basic Concepts for Calculating Measurement Uncertainty

Measurement uncertainty (VIM 2.26): non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used

Note 1 – Measurement uncertainty includes components arising from systematic effects, such as components associated with corrections and the assigned quantity values of measurement standards, as well as the definitional uncertainty. Sometimes estimated systematic effects are not corrected for but, instead, associated measurement uncertainty components are incorporated.

Note 2 – The parameter may be, for example, a standard deviation called standard measurement uncertainty (or a specified multiple of it), or the half-width of an interval, having a stated coverage probability.

Basic Concepts for Calculating Measurement Uncertainty

Note 3 – Measurement uncertainty comprises, in general, many components. Some of these may be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterized by standard deviations. The other components, which may be evaluated by Type B evaluation of measurement uncertainty, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information.

Note 4 – In general, for a given set of information, it is understood that the measurement uncertainty is associated with a stated quantity value attributed to the measurand. A modification of this value results in a modification of the associated uncertainty.

Basic Concepts for Calculating Measurement Uncertainty

Standard measurement uncertainty (VIM 2.30): measurement uncertainty expressed as a standard deviation.

Combined standard measurement uncertainty (VIM 2.31): standard measurement uncertainty that is obtained using the individual standard measurement uncertainties associated with the input quantities in a measurement model

Expanded measurement uncertainty (VIM 35): product of a combined standard measurement uncertainty and a factor larger than the number one.

(This factor refers to a coverage factor.)

Basic Concepts for Calculating Measurement Uncertainty

The combined standard uncertainty is calculated by the following expression where u(xi) is the standard uncertainty of a component and ci is the sensitivity coefficient.

$$u_c(y) = \sqrt{\sum_i c_i^2 \, u^2(x_i)}$$

Thus the expanded uncertainty can be calculated by the following expression where the factor kp is the coverage factor.

$$U(y) = k_p . u_c(y)$$

Basic Concepts for Calculating Measurement Uncertainty

Measurement repeatability: measurement precision under a set of repeatability conditions of measurement.

Condition of measurement, out of a set of conditions that includes:

- the same measurement procedure
- same operators, same measuring system, same operating conditions and same location
- and replicate measurements on the same or similar objects over a short period of time.

Basic Concepts for Calculating Measurement Uncertainty

Correction (VIM 2.53): compensation for an estimated systematic effect.

The compensation can take different forms, such as an addend or a factor, or can be deduced from a table.

Basic Concepts for Calculating Measurement Uncertainty

Components of measurement uncertainty should be grouped into two categories:

Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterized by standard deviations

Type B evaluation of measurement uncertainty, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information

Basic Concepts for Calculating Measurement Uncertainty

Instrumental measurement uncertainty (VIM 4.24): component of measurement uncertainty arising from a measuring instrument or measuring system in use.

Note 1 – Instrumental measurement uncertainty is obtained through calibration of a measuring instrument or measuring system, except for a primary measurement standard for which other means are used.

Note 2 – Instrumental measurement uncertainty is used in a Type B evaluation of measurement uncertainty.

Note 3 – Information relevant to instrumental measurement uncertainty may be given in the instrument specifications.

Basic Concepts for Calculating Measurement Uncertainty

Standard Deviation

For a series of n measurements of the same measurand, the magnitude "**s**", characterizing the dispersion of the results is given by the formula:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

x_i represents the result of the "umpteenth" measurement.

$\bar{x}$ represents the arithmetic mean of "n" results

Basic Concepts for Calculating Measurement Uncertainty

Type-A evaluation of measurement uncertainty (VIM 2.28): evaluation of a component of measurement uncertainty

by a statistical analysis of measured quantity values obtained under defined measurement conditions.

For various types of measurement conditions, see repeatability condition of measurement, intermediate precision condition of measurement, and reproducibility condition of measurement.

Basic Concepts for Calculating Measurement Uncertainty

Type-A evaluation of measurement uncertainty

For an input magnitude x_i determined by n repeated independent observations, we can say that the standard uncertainty of the mean is the standard experimental deviation of the mean.

$$u(x_i) = s\left(\bar{x}_i\right)$$

$$u(x) = s\left(\bar{x}_i\right) = \frac{S(x)}{\sqrt{n}}$$

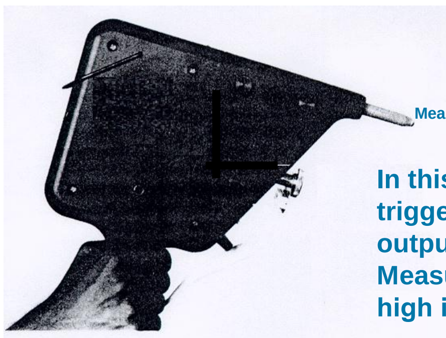
This is called type-A uncertainty standard, taking into consideration an adequate n number of observations.

For statistical reliability, n>10.

√2

Peak ESD Current Calibration – Type-A Evaluation
IEC 61000-4-2 Example

As an example, we shall consider the CC voltage calibration of the ESD generator



Measuring probe

In this situation, a discharge is triggered, and the generator's output capacitor is charged. Measurement is performed with a high impedance voltmeter: 20 GΩ

√2

Peak ESD Current Calibration
Type-A Evaluation

Nominal Voltage	8 kV	
	valor corrigido	coleta de dados
Aplicação	**Tensão DC [V]**	**Tensão DC [mV]**
1	7957	322,6
2	8015	324,9
3	8049	326,3
4	8009	324,7
5	8000	324,3
6	7911	320,7
7	7956	322,5
8	8021	325,2
9	7973	323,2
10	7996	324,2
média	7988,6	323,86
S(x) (%)	0,50	0,50
U(x) tipo A (%) 68%	0,16	0,16

Example: Type-A evaluation of uncertainty

$$u_A(x) = \frac{s(x)}{\sqrt{10}}$$

Basic Concepts for Calculating Measurement Uncertainty

Type-B evaluation of measurement uncertainty (VIM 2.29): evaluation of a component of measurement uncertainty determined by means other than a Type A evaluation of measurement uncertainty.

EXAMPLES: Evaluation based on information:

- associated with authoritative published quantity values
- associated with the quantity value of a certified reference material
- obtained from a calibration certificate
- about drift
- obtained from limits deduced through personal experience

Basic Concepts for Calculating Measurement Uncertainty

Components related to type B uncertainty are related to instruments and accessories which usually need to be calibrated.

The uncertainty value presented in calibration certificates usually are expanded measurement uncertainty. Thus, we must divide its value by the corresponding coverage factor in order to calculate the combined uncertainty of the measurand.

Basic Concepts for Calculating Measurement Uncertainty

All type B values used in the calculation of combined standard uncertainty shall match a standard deviation. Therefore the values of the components must be divided by factors corresponding to the probability distribution assigned to them:

Normal = 1

Normal (expanded) = 2

Rectangular = $\sqrt{3}$

Triangular = $\sqrt{6}$

U-format = $\sqrt{2}$

So all components of uncertainty will have a confidence level of 68%

Basic Concepts for Calculating Measurement Uncertainty

The standard uncertainty u(xi) in dB and the sensibility uncertainty must be taken into consideration when evaluating the standard combined uncertainties $u_c(y)$ of the estimated value of the measurand through the expression:

$$u_c(y) = \sqrt{\sum_{i}^{u=k} c_i^2 \, u^2(x_i)}$$

Based on the combined uncertainty value above, the expanded uncertainty value can be calculated by multiplying it by the k_p factor, which has to do with the degree of freedom of the variable.

$$U(y) = k_p . u_c(y)$$

Basic Concepts for Calculating Measurement Uncertainty

To calculate the coverage factor kp, the effective number of degrees of freedom is determined Veff

$$V_{eff} = \frac{u_c^4}{\sum_{i=1}^{n} \frac{u_i^4}{v_i}}$$

Through the obtained value of Veff and the degree of confidence desired, for example 95%, the coverage factor kp is determined in the distribution table-T (t-student) :

Veff	10	20	30	40	Infinito
T=kp	2,23	2,09	2,04	2,02	2

T = t-student coefficient

Basic Concepts for Calculating Measurement Uncertainty

RF disturbance emission tests usually only take instrumental uncertainties into consideration, which allows confrontation with the CISPR uncertainty**.**

Therefore, the *Ulab* evaluation corresponds to the type-B component uncertainty evaluation, taking into consideration the impact caused by test location and measurement setup components:

The following example corresponds to a radiated emission test in the 30 - 300 MHz range, with a biconical antenna in horizontal polarization.

Basic Concepts for Calculating Measurement Uncertainty

Example: Measurement in Anechoic Chamber according to CISPR

Basic Concepts for Calculating Measurement Uncertainty

Example: Measurement uncertainty for radiated tests

Input quantity Xi	Uncertainty de x_i dB	Probability distribution	$u(x_i)$ dB	c_i 1	$c_i\ u(x_i)$ dB
Receiver reading	± 0,1	k =1	0,1	1	0,1
Attenuation antenna-receiver	± 0,2	k = 2	0,1	1	0,1
Fator de antena	± 2,0	k = 2	1,0	1	1,0
Receiver correction Sine wave voltagey	± 1,0	k = 2	0,5	1	0,5
Pulse amplitude response	**± 1,5**	**rectangular**	**0,87**	**1**	**0,87**
Pulse repetition rate response	**± 1,5**	**rectangular**	**0,87**	**1**	**0,87**
Noies floor proximity	**± 0,5**	**rectangular**	**0,29**	**1**	**0,29**
Mismatch antenna-receiver	**+0,9/-1,0**	U-shaped	**0,67**	**1**	**0,67**
Antenna corrections AF frequency interpolation	**± 0,3**	**rectangular**	**0,17**	**1**	**0,17**

Basic Concepts for Calculating Measurement Uncertainty

Example: Measurement uncertainty for radiated tests

AF variation with height		± 1,0	rectangular	0,58	1	0,58
Directivity difference – d = 3 m		± 0,0		0,0	1	0,0
Directivity difference – d = 10 m		± 0,0		0,0	1	0,0
Directivity difference – d = 30 m		± 0,0		0,0	1	0,0
Cross-polarization		± 0,0		0,0	1	0,0
Balance		± 0,3	rectangular	0,17	1	0,17
Site imperfections		± 4,0	triangular	1,63	1	1,63
Separation distance	d=10 m	± 0,1	rectangular	0,06	1	0,06
Table height	d=10 m	± 0,1	k = 2	0,05	1	0,05

$$u_c(x)=\sqrt{(0{,}1)^2+\left(\frac{0{,}2}{2}\right)^2+\left(\frac{2}{2}\right)^2+\left(\frac{1}{2}\right)^2+\frac{(1{,}5)^2}{3}+\frac{(1{,}5)^2}{3}+\frac{(0{,}5)^2}{3}+\frac{(0{,}95)^2}{2}+\frac{(0{,}3)^2}{3}+\frac{(1{,}0)^2}{3}+\frac{(0{,}3)^2}{3}+\frac{(4)^2}{6}+\frac{(0{,}1)^2}{3}+\left(\frac{0{,}1}{2}\right)^2}$$

$$u_c(x)=2{,}52 \quad dB \qquad\qquad U_E(x)=k_p\,u_c(x)=2\cdot 2{,}52=5{,}04 \ \mathbf{dB}$$

Normalized EMC Test Uncertainties CISPR 16-4-2

The CISPR 16-4-2 document takes instrumentation uncertainty and aspects of the setup into consideration when dealing with RF disturbance measurements. The estimated calculated value is called *Ucispr.*

Measurement		U_{cispr}
Conducted disturbance at mains port using AMN	(9 kHz to 150 kHz)	3,8 dB
	(150 kHz to 30 MHz)	3,4 dB
Conducted disturbance at mains port using voltage probe	(9 kHz to 30 MHz)	2,9 dB
Conducted disturbance at telecommunication port using AAN	(150 kHz to 30 MHz)	5,0 dB
Conducted disturbance at telecommunication port using CVP	(150 kHz to 30 MHz)	3,9 dB
Conducted disturbance at telecommunication port using CP	(150 kHz to 30 MHz)	2,9 dB
Disturbance power	(30 MHz to 300 MHz)	4,5 dB
Radiated disturbance (electric field strength at an OATS or in a SAC)	(30 MHz to 1 000 MHz)	6,3 dB

Normalized EMC Test Uncertainties
CISPR 16-4-2

A very unique CISPR test criterion prescribes that:

IF *Ulab is less than or equal to Ucispr, then the test report can state the Ulab value or state that Ulab is less than Ucispr.*

If *Ulab is greater than Ucispr, than the test report must state the actual lab Ulab value (em dB). In this case, the difference between Ulab and Ucispr must be subtracted from the limit in order to verify compliance with requirements.*

Schedule

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- **Good Practices and Important Aspects for IEC/ISO 17025 Accreditation**

GOOD LAB PRACTICES

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

Content

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

4.9 Control of nonconforming testing and/or calibration work

4.10 Improvement

4.11 Corrective action

4.12 Preventive action

4.13 Control of records

4.14 Internal audits

4.15 Management reviews

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

5 Technical requirements

5.1 General

5.2 Personnel

5.3 Accommodation and environmental conditions

5.4 Test and calibration methods and method validation

5.5 Equipment

5.6 Measurement traceability

5.7 Sampling

5.8 Handling of test and calibration items

5.9 Assuring the quality of test and calibration results

5.10 Reporting the results

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

4.2 Management system

- The laboratory shall establish, implement and maintain a management system appropriate to the scope of its activities.
- The laboratory shall document its policies, systems, programmes, procedures and instructions to the extent necessary to assure the quality of the test and/or calibration results.
- The lab shall document its policies, systems, programs, procedures and instructions.
- The laboratory's management system policies related to quality, including a quality policy statement, shall be defined in a quality manual.
- The quality policy statement shall be issued under the authority of top management. It shall include at least the following:
  - the laboratory management's commitment to good professional practice and to the quality of its testing and calibration in servicing its customers
  - the laboratory management's commitment to comply with this International Standard and to continually improve the effectiveness of the management system
  - a requirement that all personnel concerned with testing and calibration activities within the laboratory familiarize themselves with the quality documentation

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

4.2 Management system (cont.)

- The roles and responsibilities of technical management and the quality manager
- Top management shall ensure that the integrity of the management system is maintained when changes to the management system are planned and implemented.

4.3 Document control

- The laboratory shall establish and maintain procedures to control all documents that form part of its management system.
- Invalid or obsolete documents are promptly removed.
- Management system documents generated by the laboratory shall be uniquely identified. Such identification shall include the date of issue and/or revision identification, page numbering, the total number of pages, and the issuing authority(ies).
- Changes to documents shall be reviewed and approved by the same function that performed the original review unless specifically designated otherwise.
- Where practicable, the altered or new text shall be identified in the document.
- Procedures shall be established to describe how changes in documents maintained in computerized systems are made and controlled.

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

4.4 Review of requests, tenders and contracts

- The laboratory shall establish and maintain procedures for the review of requests, tenders and contracts.
- Records of reviews, including any significant changes, shall be maintained.
- The customer shall be informed of any deviation from the contract.
- If a contract needs to be amended after work has commenced, the same contract review process shall be repeated and any amendments shall be communicated to all affected personnel.

4.5 Subcontracting of tests and calibrations

- The laboratory is responsible to the customer for the subcontractor's work, except in the case where the customer or a regulatory authority specifies which subcontractor is to be used.
- The laboratory shall maintain a register of all subcontractors that it uses for tests and/or calibrations and a record of the evidence of compliance with this International Standard for the work in question.

4.6 Purchasing services and supplies

- The laboratory shall have a policy and procedure(s) for the selection and purchasing of services and supplies it uses that affect the quality of the tests and/or calibrations.

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

4.7 Service to the customer

- The laboratory shall be willing to cooperate with customers or their representatives in clarifying the customer's request and in monitoring the laboratory's performance in relation to the work performed, provided that the laboratory ensures confidentiality to other customers.
- The laboratory shall seek feedback, both positive and negative, from its customers.

4.8 Complaints

- The laboratory shall have a policy and procedure for the resolution of complaints received from customers or other parties.

4.9 Control of nonconforming testing and/or calibration work

- The laboratory shall have a policy and procedures that shall be implemented when any aspect of its testing and/or calibration work, or the results of this work, do not conform to its own procedures or the agreed requirements of the customer.

4.10 Improvement

- The laboratory shall continually improve the effectiveness of its management system.

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

4.11 Corrective action

- The laboratory shall establish a policy and a procedure and shall designate appropriate authorities for implementing corrective action when nonconforming work or departures from the policies and procedures in the management system or technical operations have been identified.
- The procedure for corrective action shall start with an investigation to determine the root cause(s) of the problem.
- Cause analysis is the key and sometimes the most difficult part in the corrective action procedure.
- The laboratory shall monitor the results to ensure that the corrective actions taken have been effective.

4.12 Preventive action

- Needed improvements and potential sources of nonconformities, either technical or concerning the management system, shall be identified.

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4.13 Control of records

- The laboratory shall establish and maintain procedures for identification, collection, indexing, access, filing, storage, maintenance and disposal of quality and technical records.
- All records shall be legible and shall be stored and retained in such a way that they are readily retrievable in facilities that provide a suitable environment to prevent damage or deterioration and to prevent loss. Retention times of records shall be established.
- The laboratory shall have procedures to protect and back-up records stored electronically and to prevent unauthorized access to or amendment of these records.

4.14 Internal audits

- The laboratory shall periodically, and in accordance with a predetermined schedule and procedure, conduct internal audits of its activities to verify that its operations continue to comply with the requirements of the management system and this International Standard.

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4.15 Management reviews

- In accordance with a predetermined schedule and procedure, the laboratory’s top management shall periodically conduct a review of the laboratory's management system and testing and/or calibration activities to ensure their continuing suitability and effectiveness, and to introduce necessary changes or improvements.

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

Technical requirements

5.1 General

Many factors determine the correctness and reliability of the tests and/or calibrations performed by a laboratory:

- Human factors
- Accommodation and environmental conditions
- Test and calibration methods and method validation
- Adjustment of measurement equipment
- Measurement traceability
- Sampling
- The handling of test and calibration items

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Technical requirements

5.2 Personnel

The management of the laboratory shall ensure the competence of all who:

- operate specific equipment;
- perform tests and/or calibrations;
- evaluate results;
- and sign test reports and calibration certificates.

The management of the laboratory shall formulate the goals with respect to the education, training and skills of the laboratory personnel.

The laboratory shall have a policy and procedures for identifying training needs and providing training of personnel.

The laboratory shall maintain current job descriptions for managerial, technical and key support personnel involved in tests and/or calibrations, including the responsibilities with respect to performing tests and/or calibrations, to the planning of tests and/or calibrations and evaluation of results, for reporting opinions and interpretations, and to method modification and development and validation of new methods.

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

Technical requirements

5.3 Accommodation and environmental conditions

- The laboratory shall ensure that the environmental conditions do not invalidate the results or adversely affect the required quality of any measurement.
- The laboratory shall monitor, control and record environmental conditions as required by the relevant specifications, methods and procedures or where they influence the quality of the results.
- Special care must be take to control and monitor environmental conditions.
- There shall be effective separation between neighboring areas in which there are incompatible activities.
- Access to and use of areas affecting the quality of the tests and/or calibrations shall be controlled.

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

Technical requirements

5.4 Test and calibration methods and method validation

- The laboratory shall use appropriate methods and procedures for all tests and/or calibrations within its scope, and, where appropriate, an estimation of the measurement uncertainty.
- The laboratory shall have instructions on the use and operation of all relevant equipment, and on the handling and preparation of items for testing and/or calibration, or both, where the absence of such instructions could jeopardize the results of tests and/or calibrations.
- Non-normalized methods shall be validated and agreed upon by the customer.
- Procedures are established and implemented for protecting the data; such procedures shall include, but not be limited to, integrity and confidentiality of data entry or collection, data storage, data transmission and data processing.
- Test data calculation and transfer must be submitted to due verification.
- Spreadsheets used for processing results must be validated.
- When data control involves the use of computers and automatic equipment, be sure to ensure integrity and reliability.

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

Technical requirements

5.5 Equipment

- Equipment and its software used for testing, calibration and sampling shall be capable of achieving the accuracy required and shall comply with specifications relevant to the tests and/or calibrations concerned.
- Equipment shall be operated by authorized personnel.
- Up-to-date instructions on the use, storage and maintenance of equipment shall be readily available for use by the appropriate laboratory personnel.
- Each item of equipment and its software used for testing and calibration and significant to the result shall, when practicable, be uniquely identified
- and present calibration status on their body.
- Records shall be maintained of each item of equipment: the manufacturer's name type identification, and serial number or other unique identification, results and copies of reports and certificates of all calibrations, adjustments, acceptance criteria, the due date of next calibration, the maintenance plan, where appropriate, and maintenance carried out to date.

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

Technical requirements

5.6 Measurement traceability

- All equipment used for tests and/or calibrations having a significant effect on the accuracy or validity of the result of the test shall be calibrated before being put into service.
- Calibrations must be performed by bodies that can provide traceability to the International System, using calibration labs accredited by a competent organism, for example, CGCRE in Brazil. In other countries, ILAC members can be used.
- The laboratory shall have an established programme and procedure for the calibration of its equipment.
- Certifications must have the information needed to verify traceability.
- Intermediary verifications must be performed.

Note: CGCRE – General INMETRO Accreditation Coordination
ILAC - International Laboratory Accreditation Cooperation

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Technical requirements

5.7 Sampling

The laboratory shall have a sampling plan and procedures for sampling when it carries out sampling of substances, materials or products for subsequent testing or calibration. The sampling plan as well as the sampling procedure shall be available at the location where sampling is undertaken. Sampling plans shall, whenever reasonable, be based on appropriate statistical methods. The sampling process shall address the factors to be controlled to ensure the validity of the test and calibration results.

Note: Not applicable for cellular terminals and EMC certification tests.

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Technical requirements

5.8 Handling of test and calibration items

The laboratory:

- Shall have procedures for the transportation, receipt, handling, protection, storage, retention and/or disposal of test and/or calibration items, including all provisions necessary to protect the integrity of the test or calibration item.
- Shall have a system for identifying test and/or calibration items.
- Shall record abnormalities or departures from normal or specified conditions.
- Shall register customer requests.
- When items have to be stored or conditioned under specified environmental conditions, these conditions shall be maintained, monitored and recorded.

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Technical requirements

5.9 Assuring the quality of test and calibration results

The laboratory shall have quality control procedures for monitoring the validity of tests and calibrations undertaken. This includes:

- Participation in proficiency-testing program.
- Replicate tests or calibrations using the same or different methods.
- Inter laboratory comparison.
- Regular use of certified reference materials.

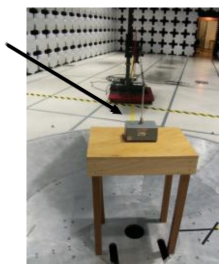
Quality control data shall be analyzed and, where they are found to be outside pre-defined criteria and planned action shall be taken to correct the problem

ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

Technical requirements

5.9 Assuring the quality of test and calibration results

For radiated emission tests: preliminary test with known field source.



ISO IEC 17025:2005 – General Requirements for the Competence of Testing and Calibration Laboratories

Technical requirements

5.10 Reporting the results

- The results of each test, calibration, or series of tests or calibrations carried out by the laboratory shall be reported accurately, clearly, unambiguously and objectively, and in accordance with any specific instructions in the test or calibration methods.
- Each test report shall include:
  - a title
  - the name and address of the laboratory
  - unique identification of the test report
  - on each page an identification in order to ensure that the page is recognized as a part of the test report
  - a clear identification of the end of the test report
  - the name and address of the customer
  - identification of the method used
  - a description of, the condition of, and unambiguous identification of the item(s) tested
  - the date of receipt of the test or calibration item(s)
  - all information needed for its analysis
  - the name(s), function(s) and signature(s) or equivalent identification of person(s) authorizing the test report

Thank You!