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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

Basic concepts on IMT technologies and other mobile radiocommunication technologies

Standards and test specifications for mobile terminals

Aspects regarding Specific Absorption Rate (SAR) Testing

Aspects regarding EMC Testing

Aspects regarding Safety Testing

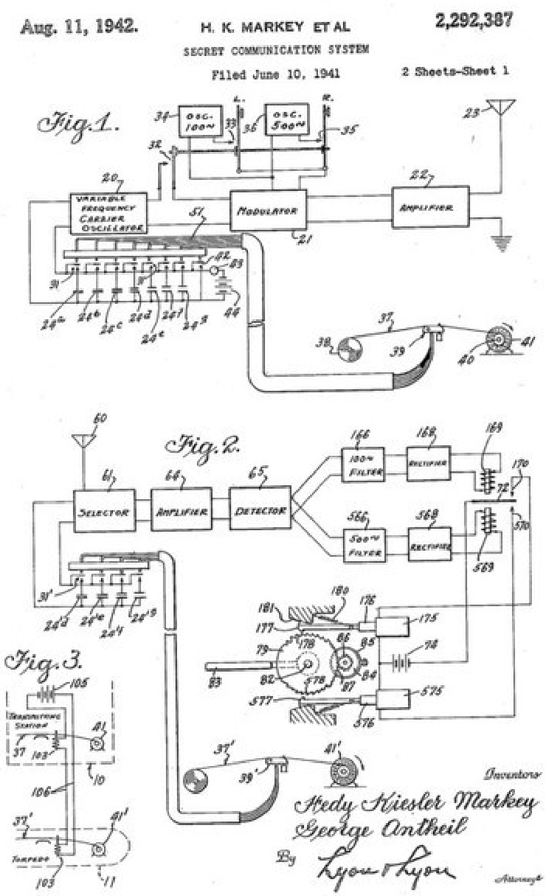
ISO/IEC 17025 accreditation - measurement uncertainty - calibration

Schedule

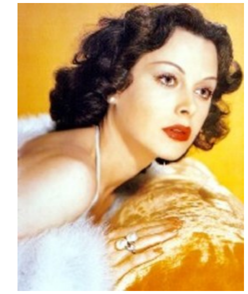
- Basic concepts on IMT technologies and other mobile radiocommunication technologies
- Standards and test specifications for mobile terminals
- Aspects regarding Specific Absorption Rate (SAR) Testing
- Aspects regarding EMC Testing
- Aspects regarding Safety Testing
- ISO/IEC 17025 accreditation -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

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;

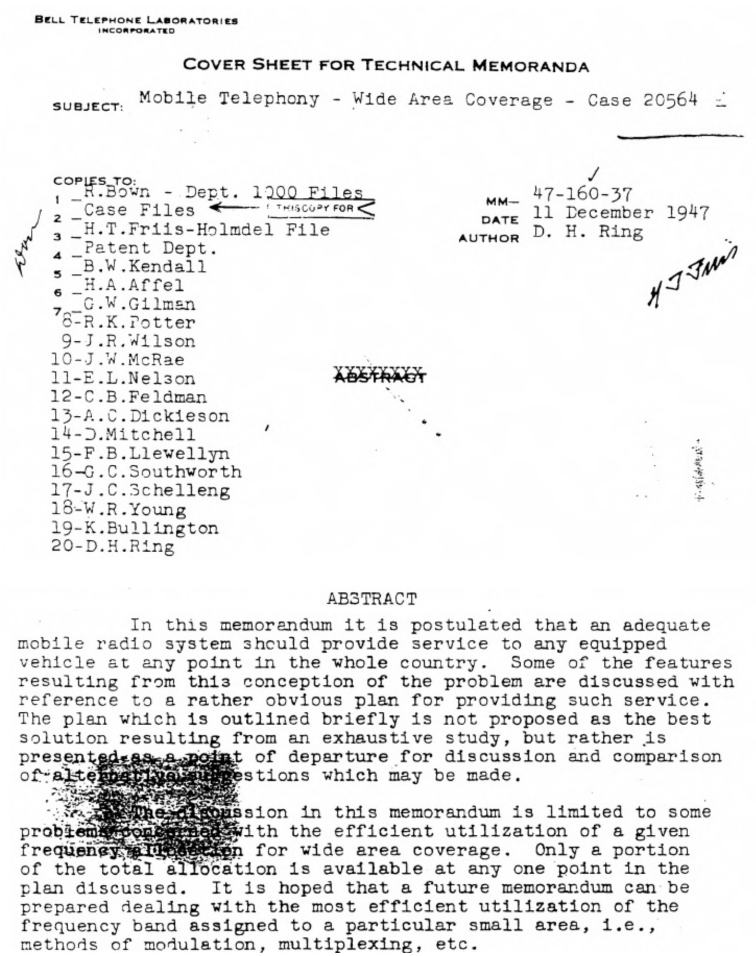
Fig. 6 is a sectional view at right angles to the view of Fig. 5 and taken substantially in the plane VI—VI of Fig. 5, but showing the record strip in a different longitudinal position; and

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

1947 Bell Labs

- First memorandum
-
- High capacity telephone system
- Antennas



BELL TELEPHONE LABORATORIES
INCORPORATED

COVER SHEET FOR TECHNICAL MEMORANDA

SUBJECT: Mobile Telephony - Wide Area Coverage - Case 20564

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

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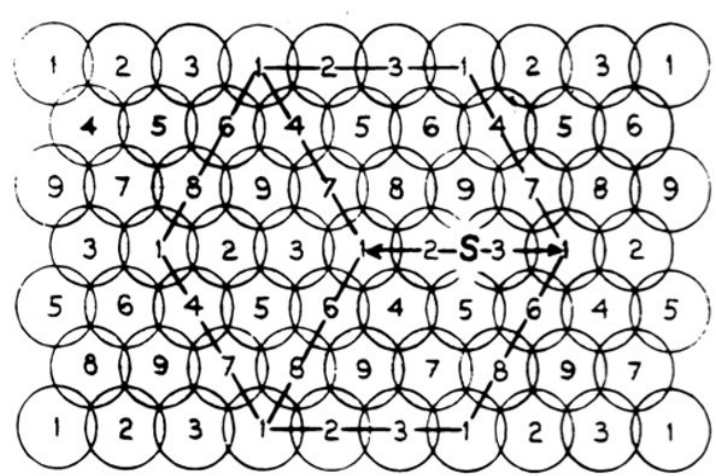
~~ABSTRACT~~

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.



Cell Phone Timeline History

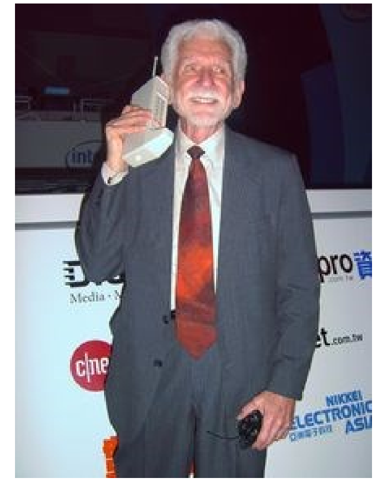
1956 MTA – Mobile Telephone A – Ericsson

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

Cell Phone Timeline History

1973 First call from a cellular device – Motorola

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



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

Martin Cooper

Beginning of the commercial operations

- 1979 – Japan and Sweden
- 1983 – United States

Mobile Service Evolution

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

Galaxy S5

2014

iPhone 5s

US$ 600

1973

Technology

Evolution

DynaTAC
US$ 8,000

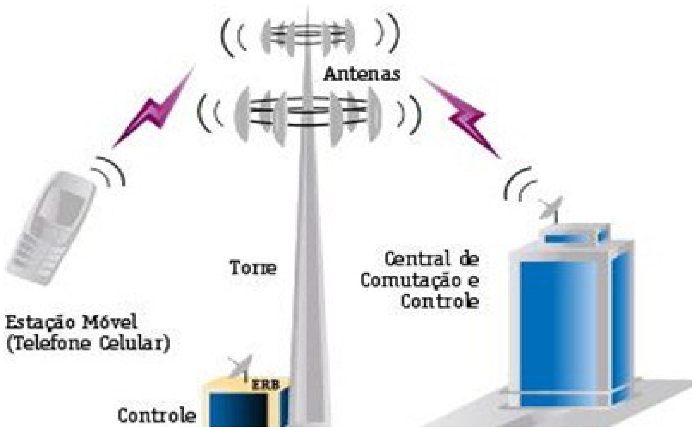
"ITU considers cellular communications the fastest technology adopted throughout the history"

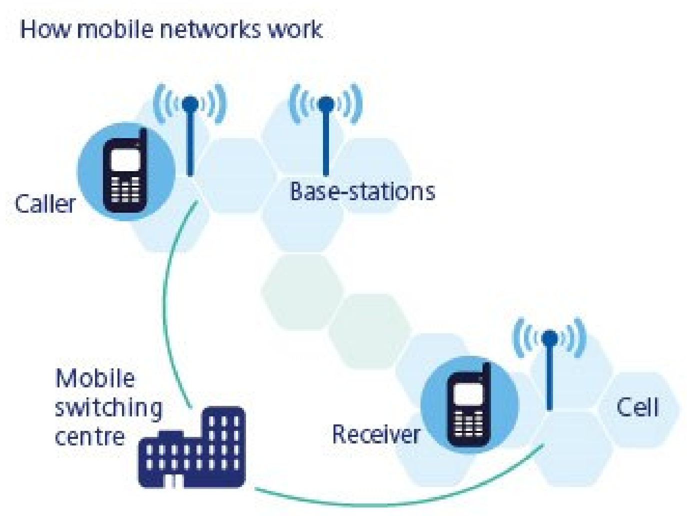
Basic Concepts in Cellular Communication Technology

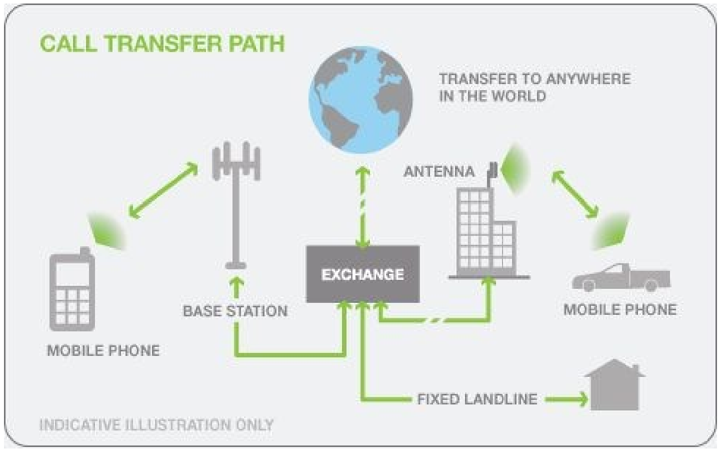
RBS **Radio Base Station**

MSC **Mobile Switching Center**

MT **Mobile Terminal**







Basic Concepts in Cellular Communication Technology

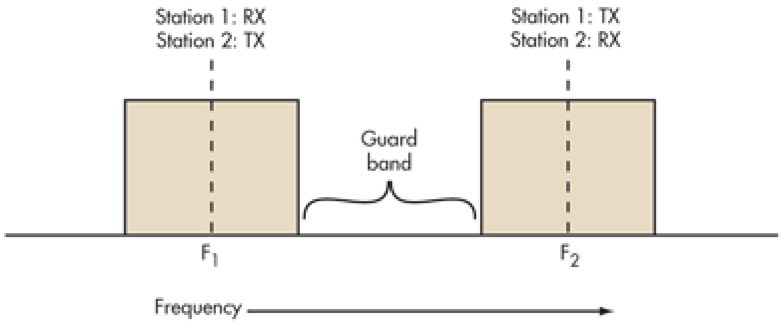
Mobile Communication Systems Goal: High Capacity

Technological Tools:

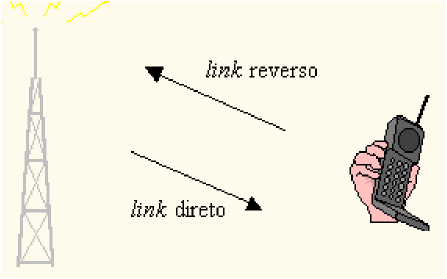
- Resource sharing for multiple users scarcity
- Bandwidth Growth x Spectrum
- Duplexing Techniques
- Access Techniques
- Multiplexing Techniques
- Modulation Schemes
- Advanced Technique:
  - Carrier Aggregation
  - MIMO and Antenna Beamforming

Duplexing Systems

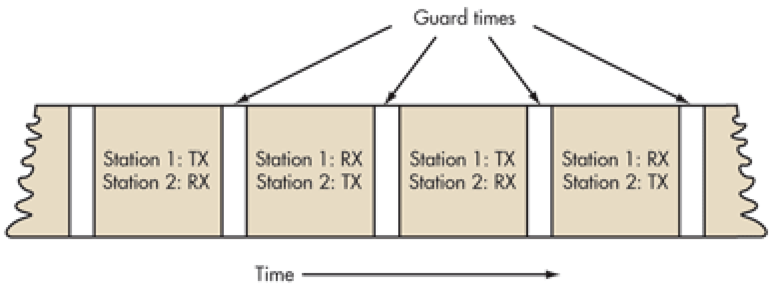
Full Duplex FDD Frequency Division Duplex



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



Half Duplex TDD Time Division Duplex



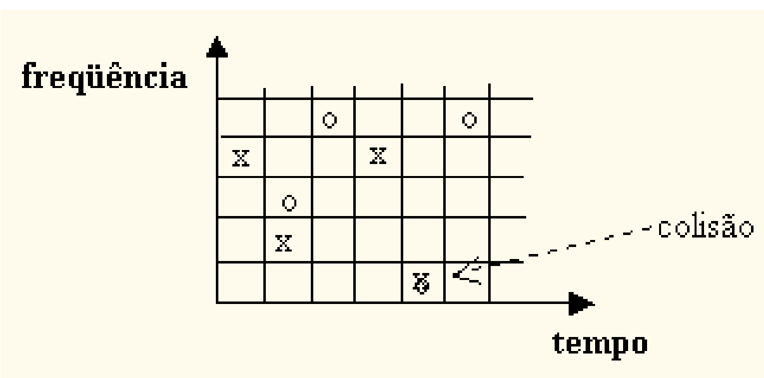
Single frequency band
Shares band assigning time slots
Symmetrical or asymmetrical
Guard Times

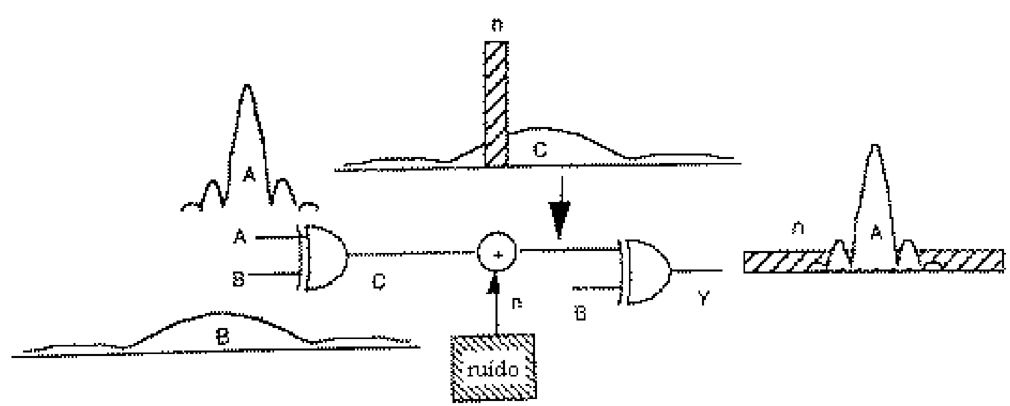
Spread Spectrum Transmission Technique

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

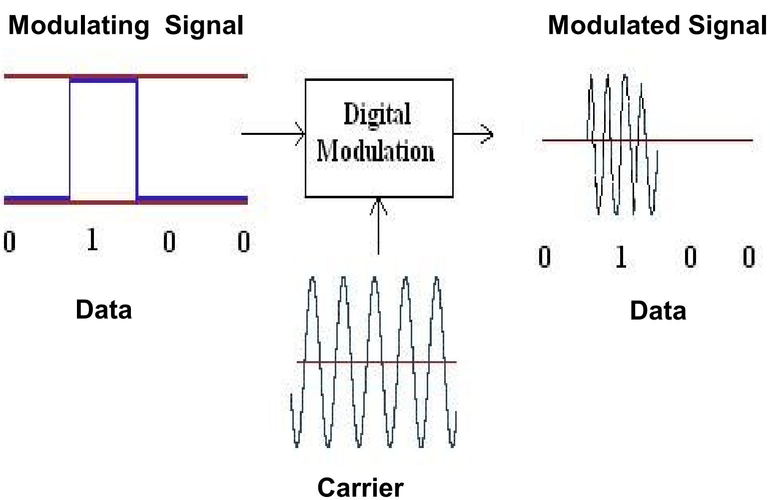
FHSS – Frequency Hopping
- Different carrier frequency at different time

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

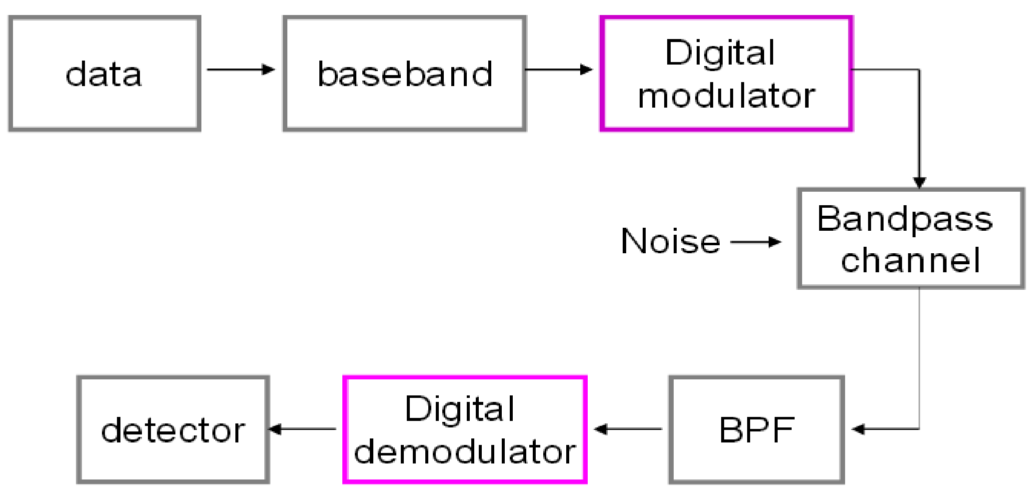




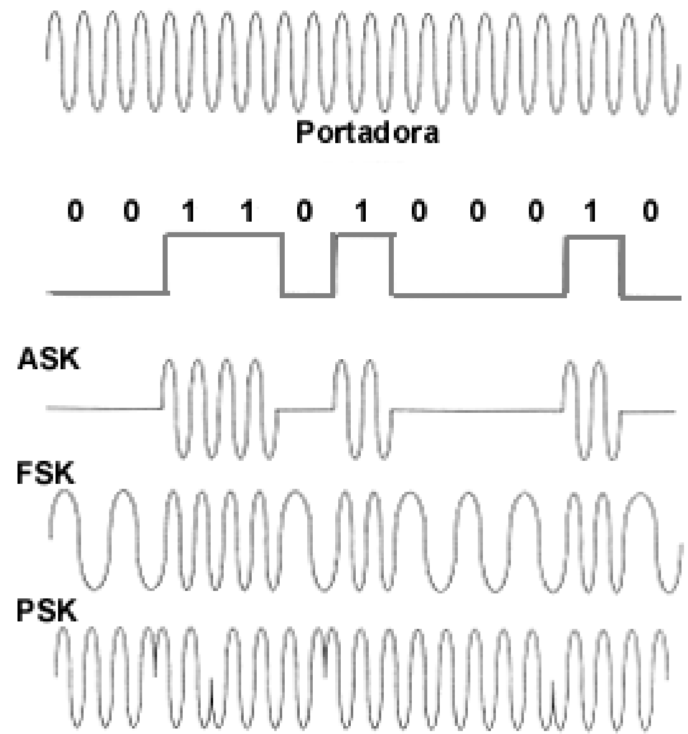
Digital Modulation Technique



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)

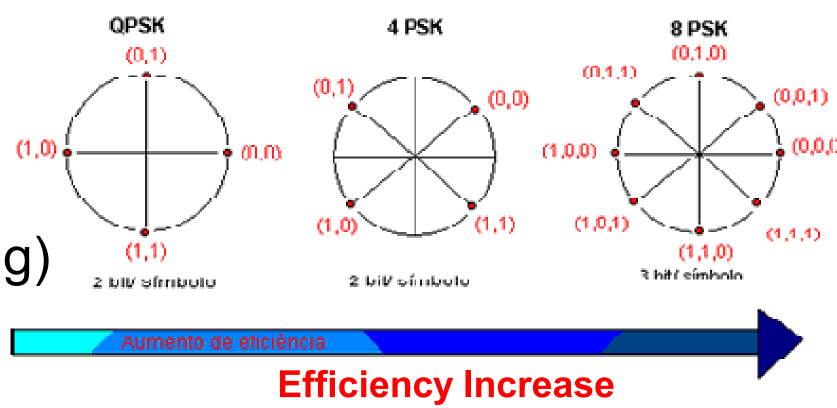
PSK level #2

nPSK (Binary Phase Shift Keying)

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

QPSK (Quadrature Phase Shift Keying)

PSK level #4



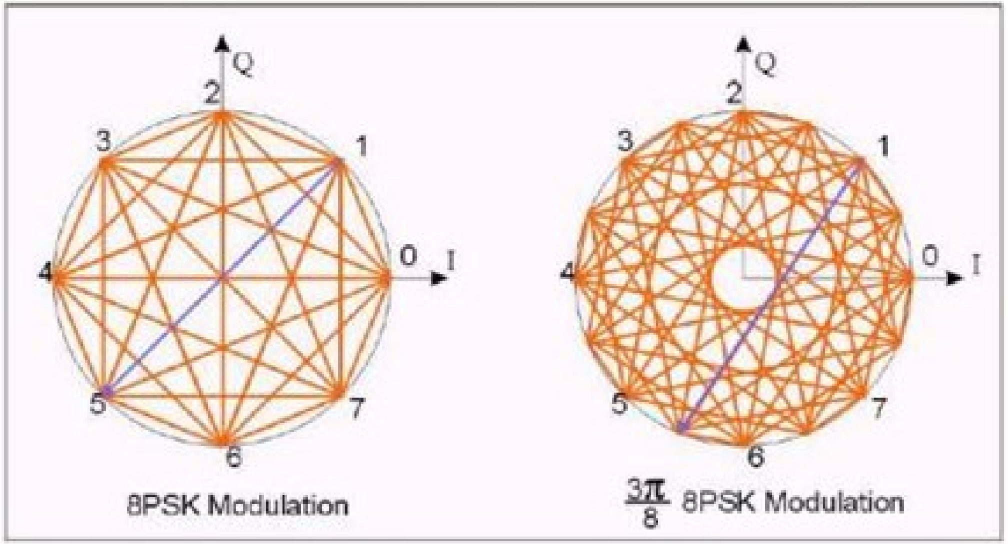
Digital Modulation Schemes

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)

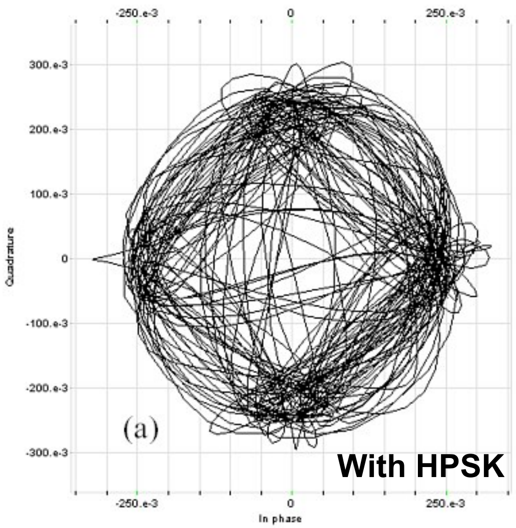
- 3π/8 rotation in addition to the symbol transition
- Prevents the carrier passing through the origin and falling to zero amplitude
- Decreases the dynamic range

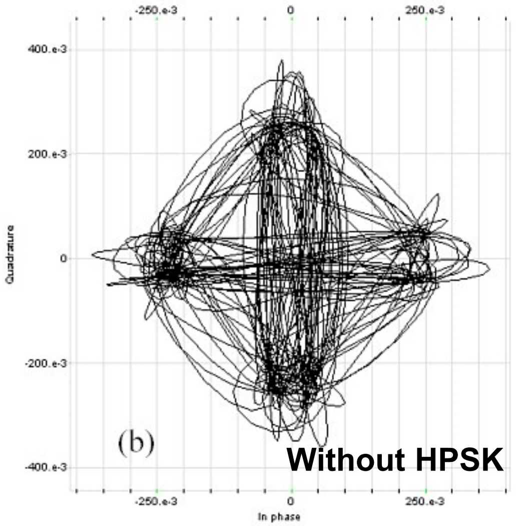


Digital Modulation Schemes

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)

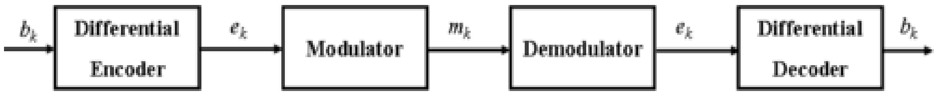




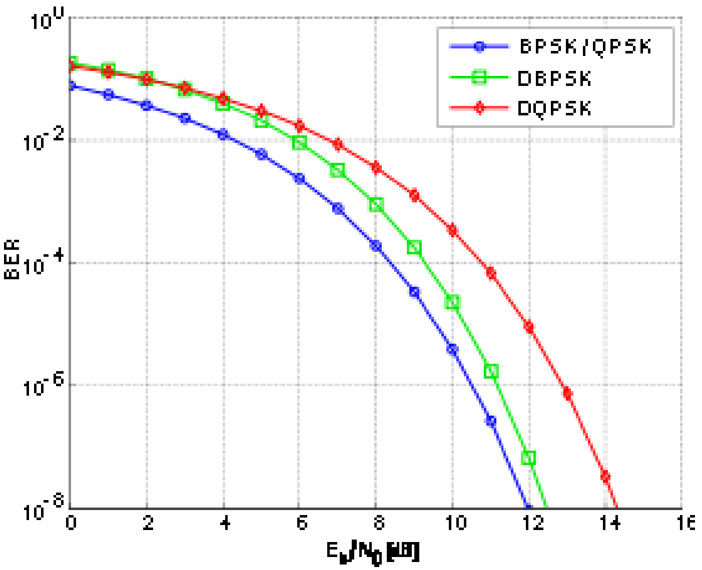
Digital Modulation Schemes

Differential Phase Shift Keying

- DBPSK
- DQPSK

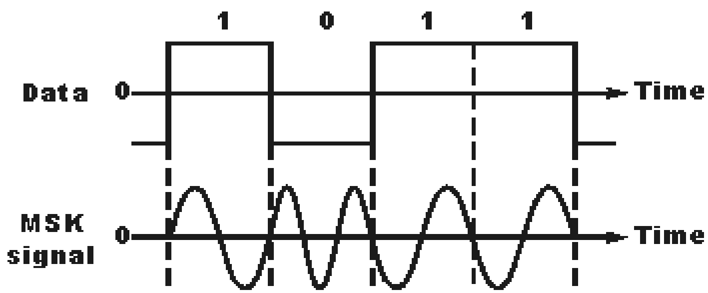


- Simpler to implement than ordinary PSK
- Avoids complex carrier-recovery schemes to provide an accurate phase
- Non-coherent – no need for the demodulator to have a copy of the reference signal to determine the exact phase of the received signal
- This scheme depends on the difference between successive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

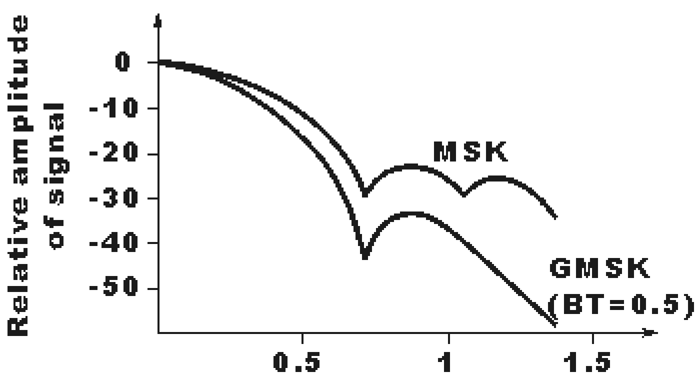
MSK Minimum Shift Keying



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

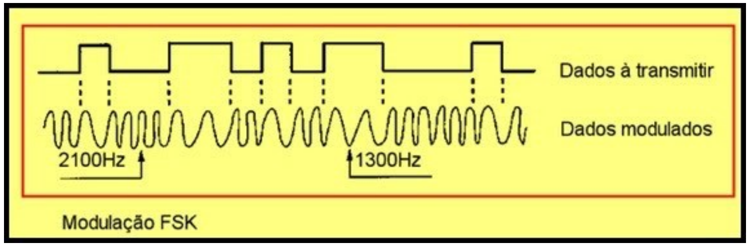
GMSK Gaussian filtered MSK



Spectral density of MSK and GMSK signals

Digital Modulation Schemes

GFSK Gaussian frequency-shift keying

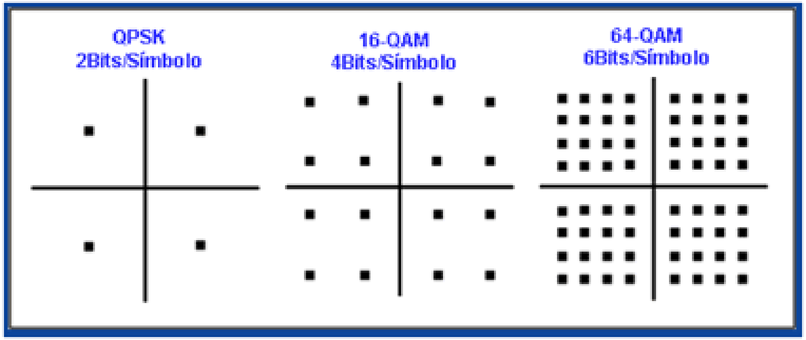


- Modulator similar to FSK
- A Gaussian filter is used before FSK modulator:
  - Making transitions smoother
  - Decreasing spectral width

Digital Modulation Schemes

QAM Quadrature Amplitude Modulation
- Symbols with different amplitudes
- Phase and amplitude modulation
- Phase and quadrature mapping

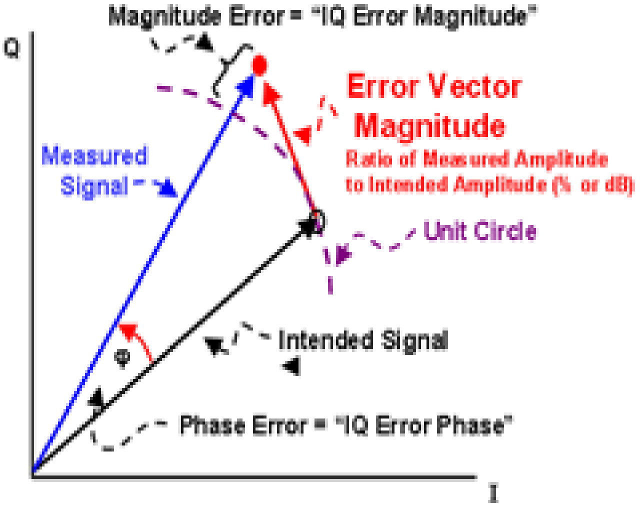
Constellations

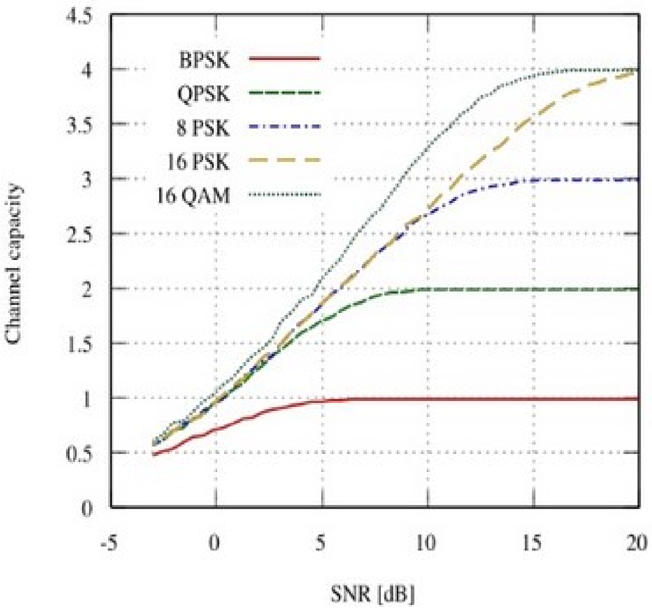


16QAM Constellation:
- 16 symbols
- 4 symbols/quadrant
- 4 bits/symbol

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

Modulation Quality EVM

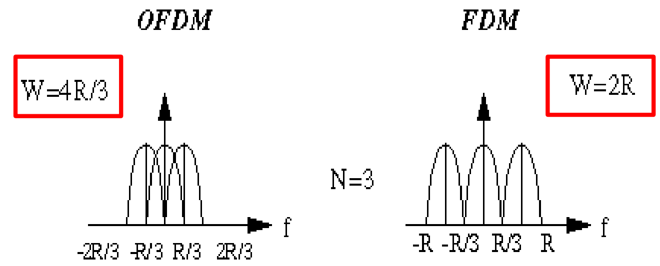


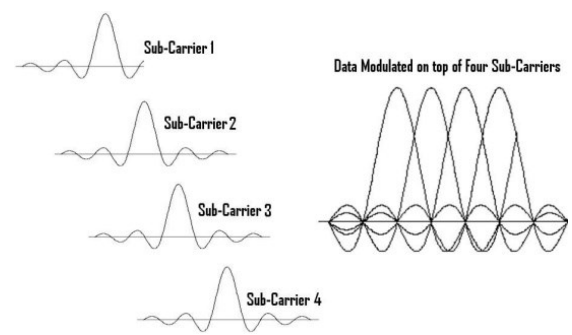


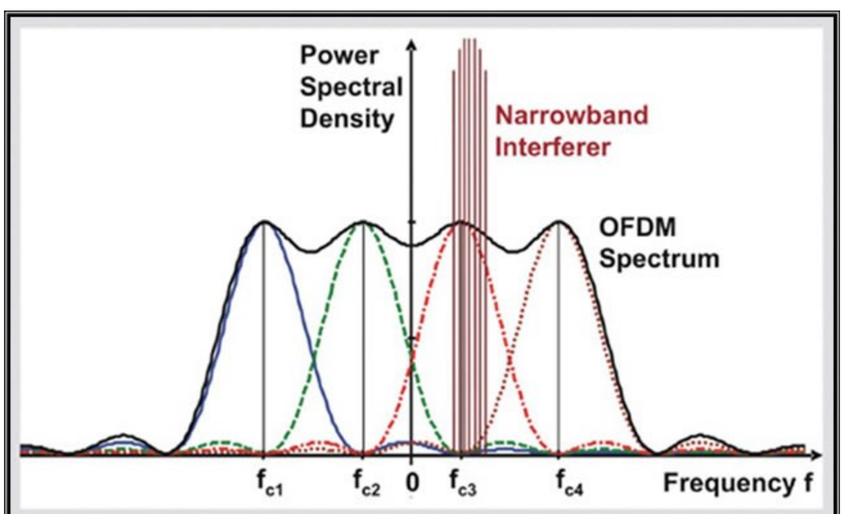
Digital Modulation Schemes

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







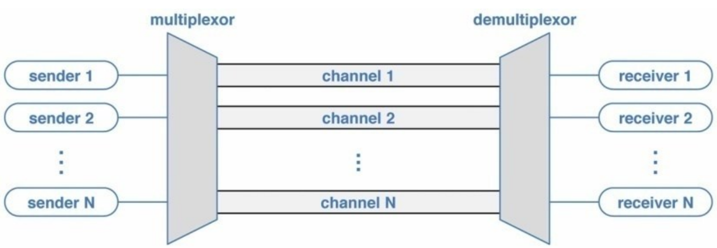
Some OFDM advantages

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

Multiplexing Techniques

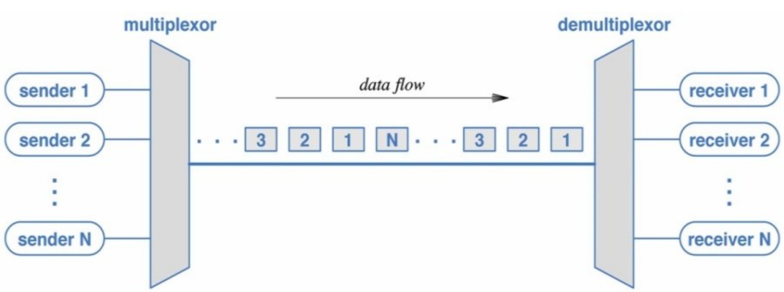
Multiplexing is a technique in which multiple data signals are combined for simultaneous transmission via a shared communication medium.

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

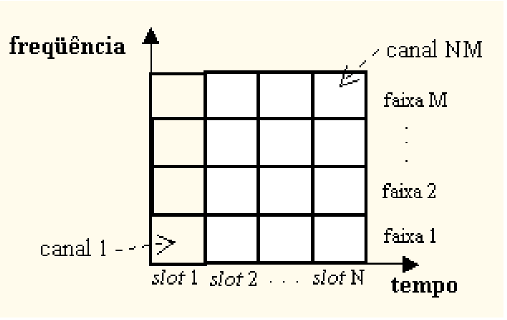


- Transmits two or more streaming digital signals over a common channel
- Signals are divided into time slots
- When TDM is used to allow multiple users to a common channel, the technology is called time division multiple access (TDMA)

Multiple Access Methods

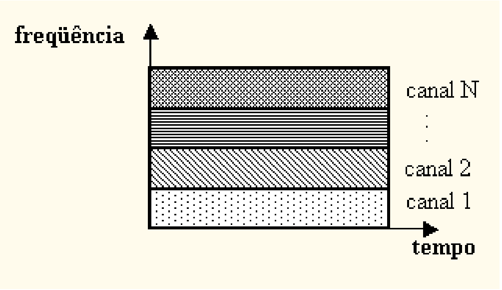
TDMA Time Division Multiple Access

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



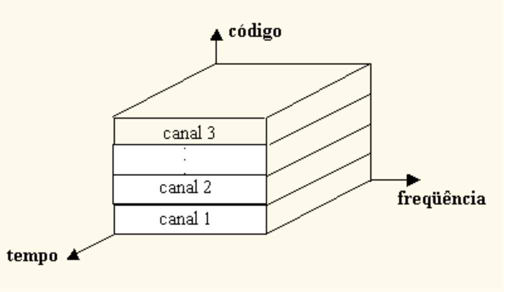
FDMA Frequency Division Multiple Access

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



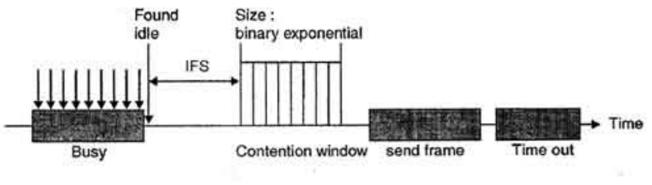
CDMA Code Division Multiple Access

- 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

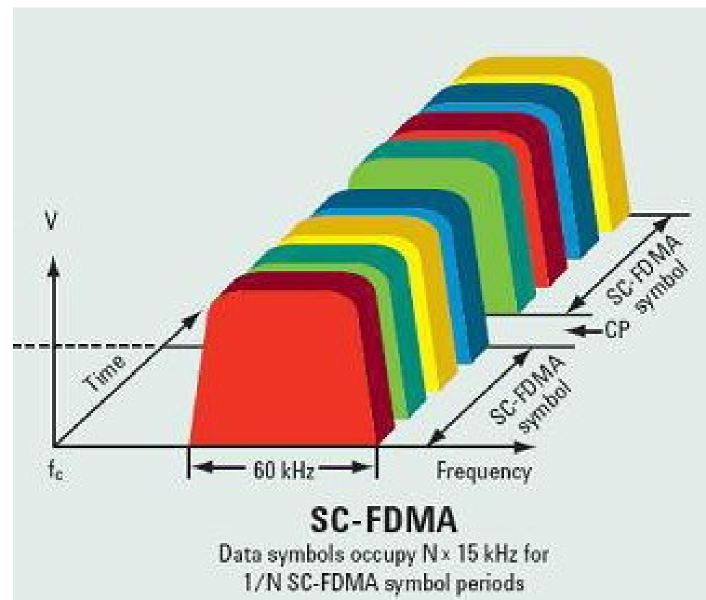


CSMA/CA

Multiple Access Methods

SC-FDMA Single Carrier – Frequency Division Multiplexing Access

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



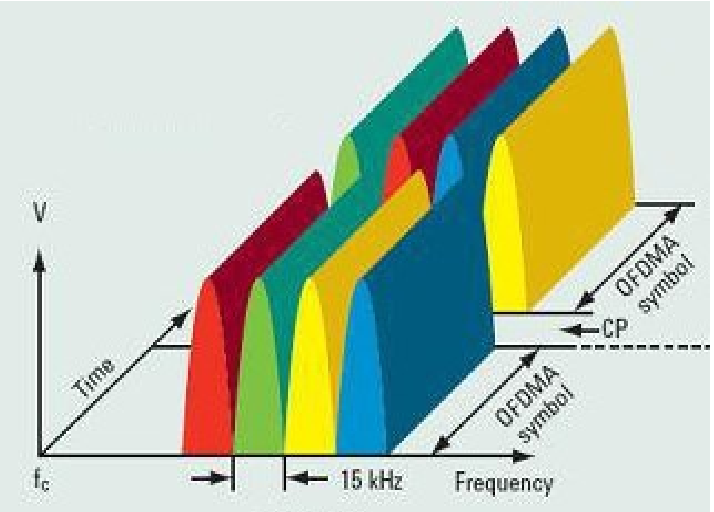
Multiple Access Methods

OFDMA

Orthogonal Frequency Division Multiplexing Access

- OFDMA transmits the data (four QPSK symbols) in parallel, one per subcarrier

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

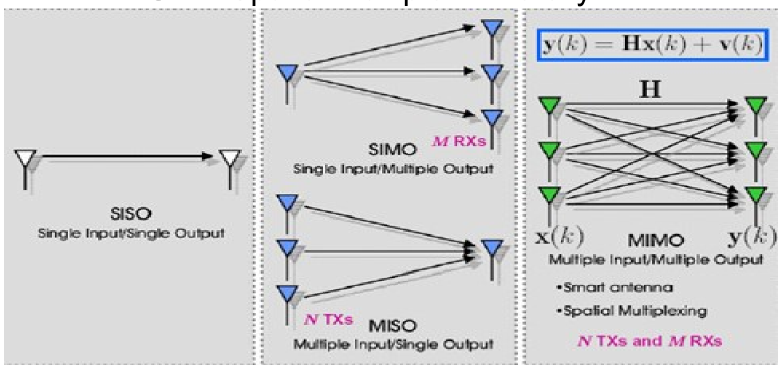


OFDMA
Data symbols occupy 15 kHz for one OFDMA symbol period

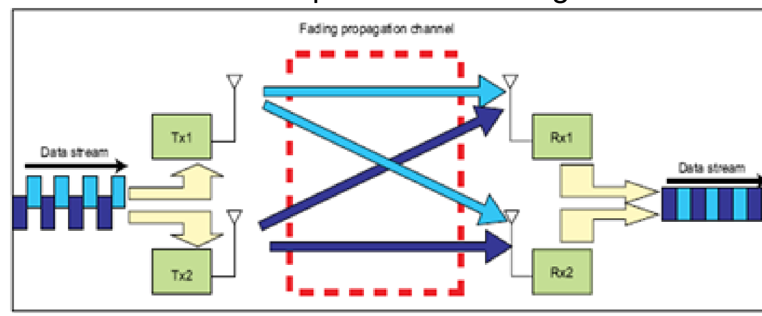
Enhancing Communication Capacity – Advanced Techniques

MIMO Advanced Antenna Technology Configurations

SM Spatial Multiplex Diversity RxTx



STC Space Time Coding



SIMO x SISO

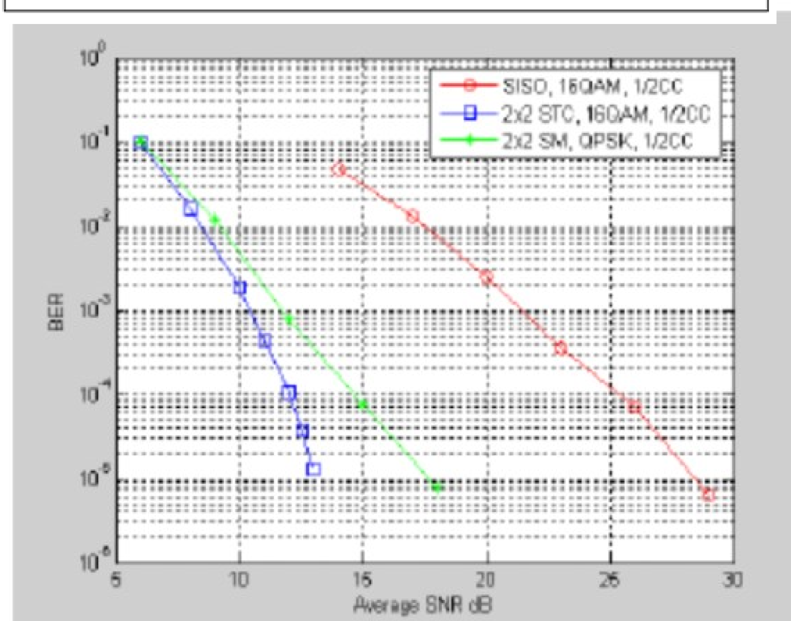
- Provides receive antenna redundancy
- Receive diversity techniques
- Improves receiver SINR and performance under fading

MISO x SISO

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

MIMO

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



MIMO-SM

- Improves robustness and cell coverage

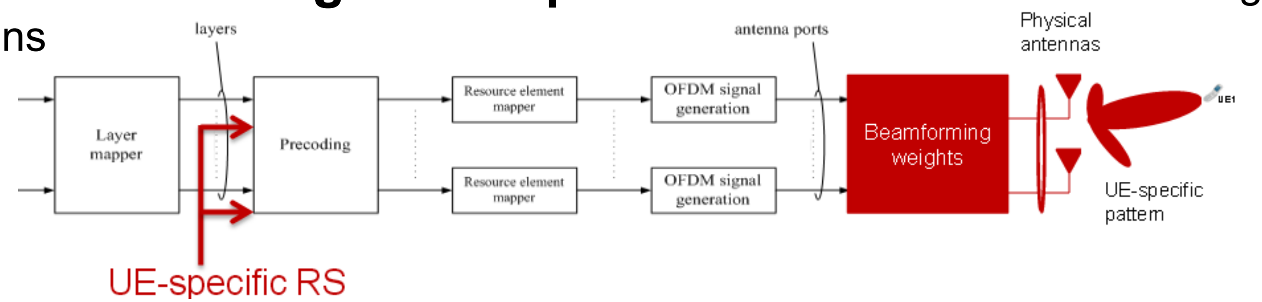
MIMO-STC

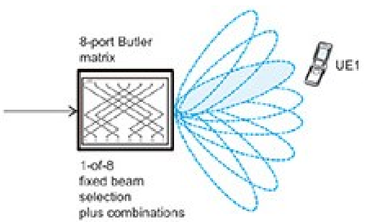
- Improves data throughput, and reduces BER

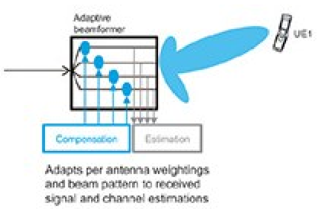
Souce: Radio Access Networks: Status and Evolution Perspectives,Roland Munzener e Hardy Halbauer, Alcatel, 2006

Enhancing Communication Capacity – Advanced Techniques

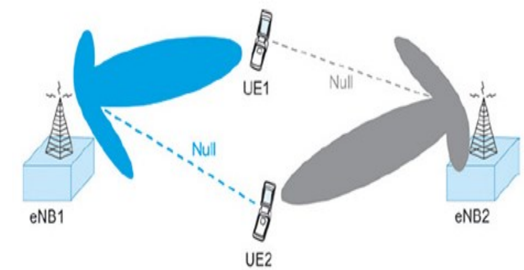
Antenna Beamforming Techniques – Advanced Antenna Technology Configurations

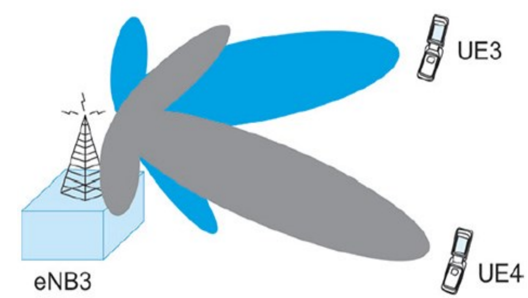




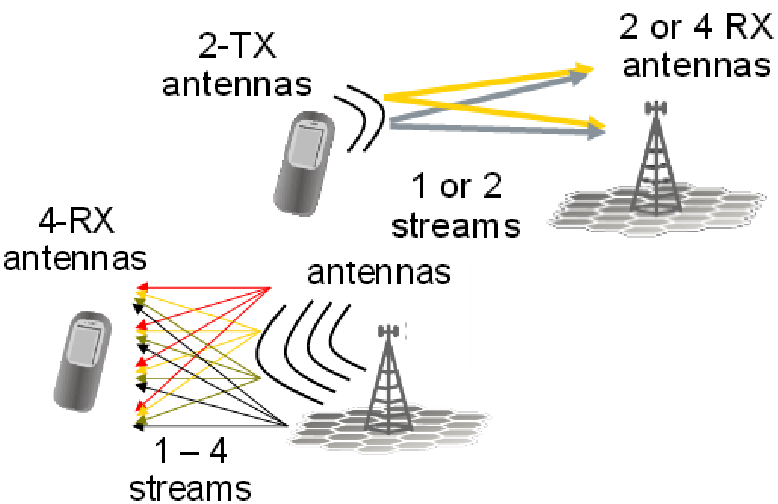


- Multi-antenna configurations focus transmission or reception in a particular direction
- Phased array antenna techniques
  - Switched beamforming (predefined patterns)
  - Adaptive beamforming (real-time adaptive patterns)
- Channel estimation technique (open loop)
- Channel feedback technique (closed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

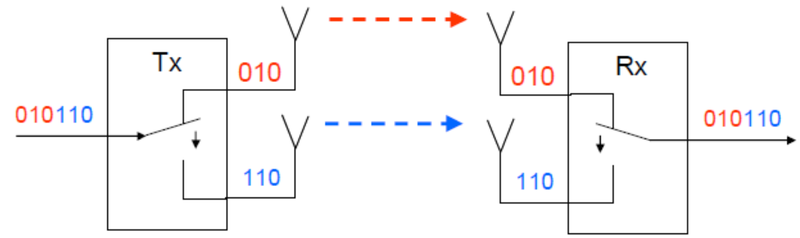




Enhancing Communication Capacity – Advanced Techniques



STC-Space Time Coding



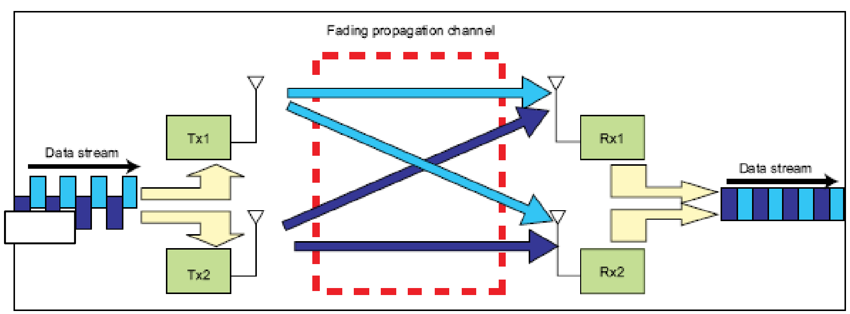
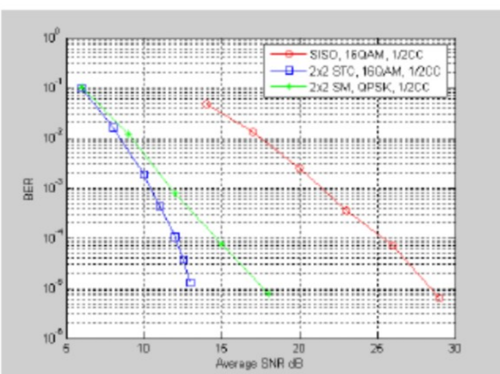
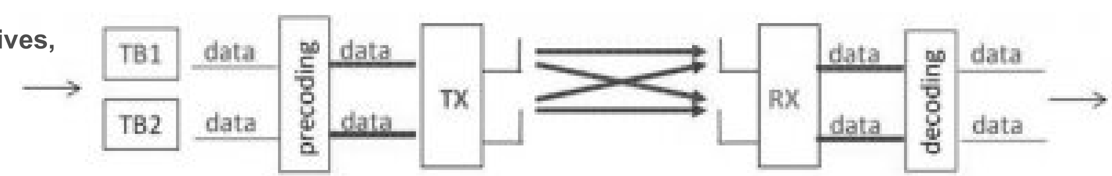


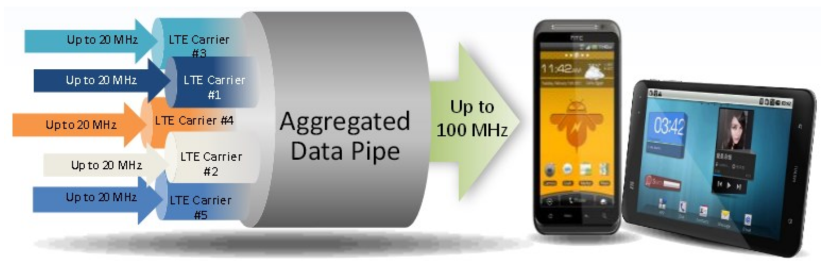
Figure 1: Sequential multiplexing of packet data is routed from baseband to the multiple antenna.



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



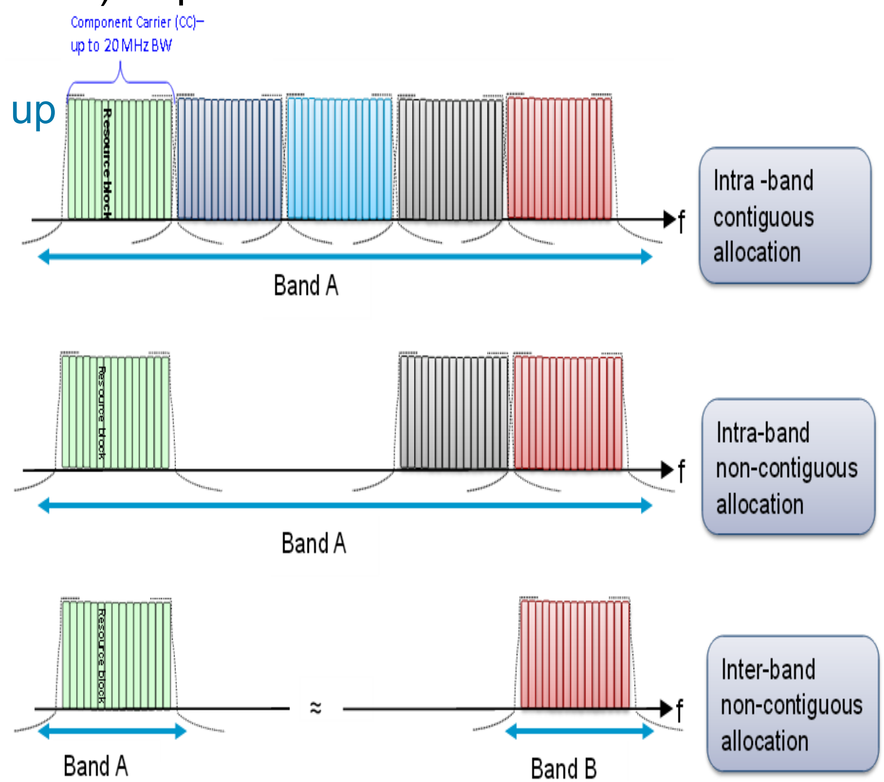
Enhancing Communication Capacity – Advanced Techniques



CA – Carrier Aggregation

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

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



Mobile Phone Standards and Technology Generations

1G First Generation Advanced Mobile Phone Service

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

2G Second Generation

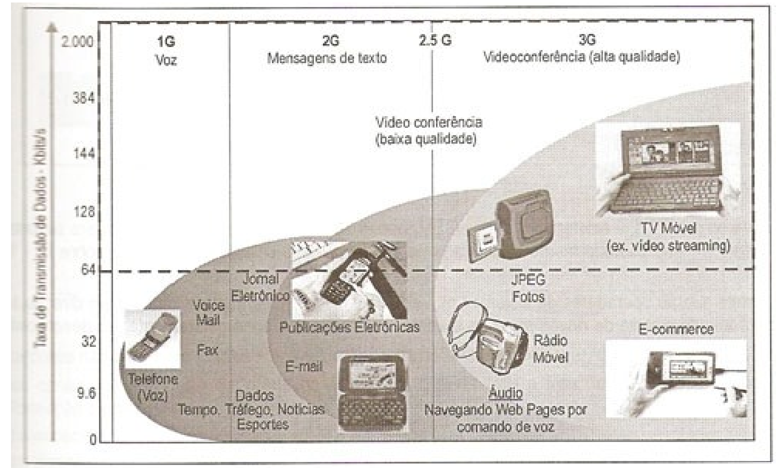
- Refers to wireless digital communication networks
- Variable areas Cells
- Voice and data services
- TDMA, CDMA, GSM, GPRS, EDGE technologies

3G Third Generation

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

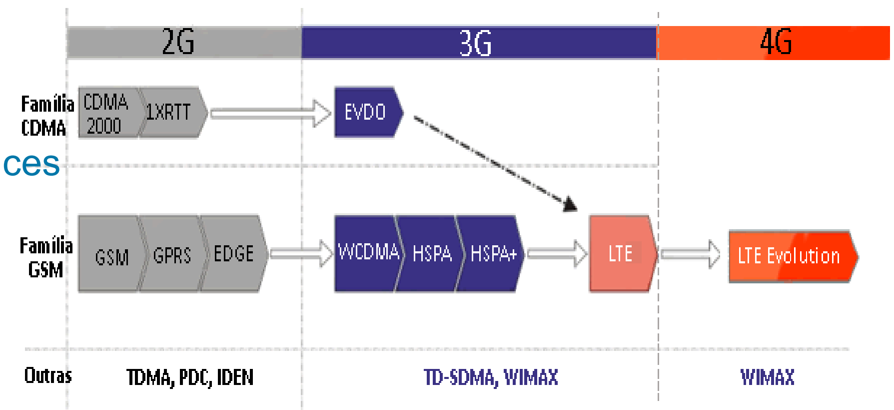
4G Fourth Generation

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



Evolução dos sistemas móveis celulares.

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



Cellular Communication Technology Evolution

GSM Family

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

GSM

•Originally voice and
•9.6 kbps UL DL data rate

GPRS

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

EDGE

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

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

Cellular Communication Technology Evolution

WCDMA Wideband Code Division Multiple Access

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

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

Cellular Communication Technology Evolution

HSPA - High Speed Packet Access (HSDPA / HSUPA)

HSDPA

- Downlink speed optimization

HSUPA

- Uplink speed optimization

HSPA

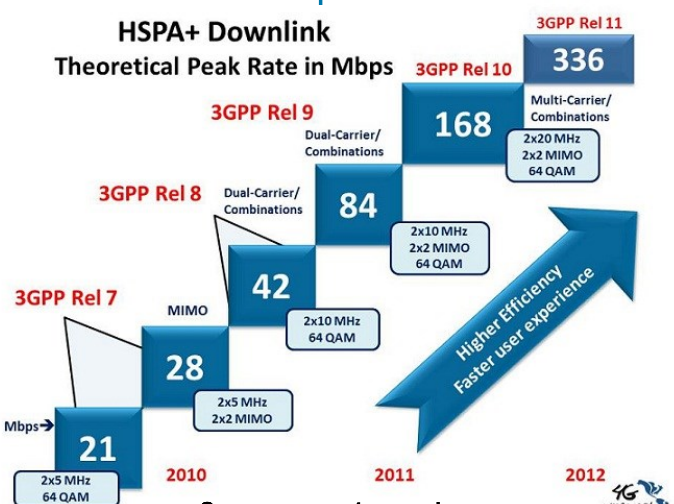
- Combination of high speed downlink packet access (HSDPA) and high speed uplink packet access (HSUPA)
- TTI (Transmission Time Interval) reduction

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

Cellular Communication Technology Evolution

HSPA+ Evolved High Speed Packet Access

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



Souce: www.4gamericas.org

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

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

Cellular Communication Technology Evolution

LTE Long Term Evolution – Release 8

LTE

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

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

Cellular Communication Technology Evolution

LTE Advanced – Release 10 and forward

LTE Advanced

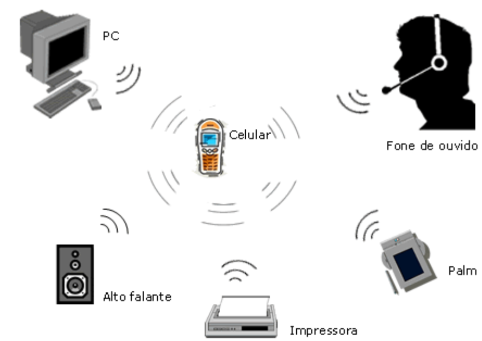
- 4G technology meet IMT-Advanced
- Up to 40 MHz with Carrier Aggregation (2 Component Carrier) – based on Release 11
- Carrier aggregation with up to 5 Component Carriers (CC) – future releases
- Higher data rates
- 100 Mbps minimum UL high mobility
- 1 Gbps DL low mobility
- MIMO extension (DL: 8x8;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

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

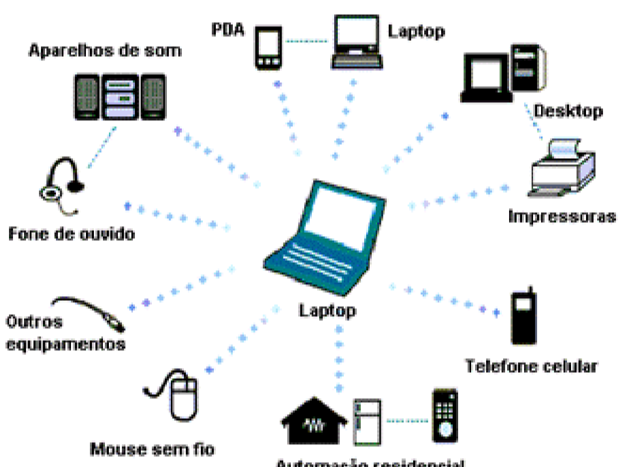
Wireless Connectivity Technologies

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

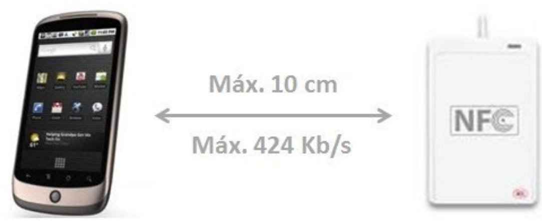
NFC Near Field Communication

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

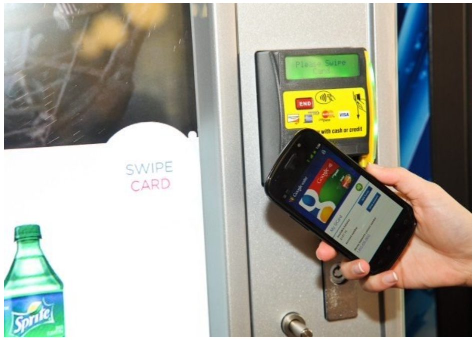
ISO/IEC 21481 / ECMA-352 Near Field Communication Interface and Protocol-2

- 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



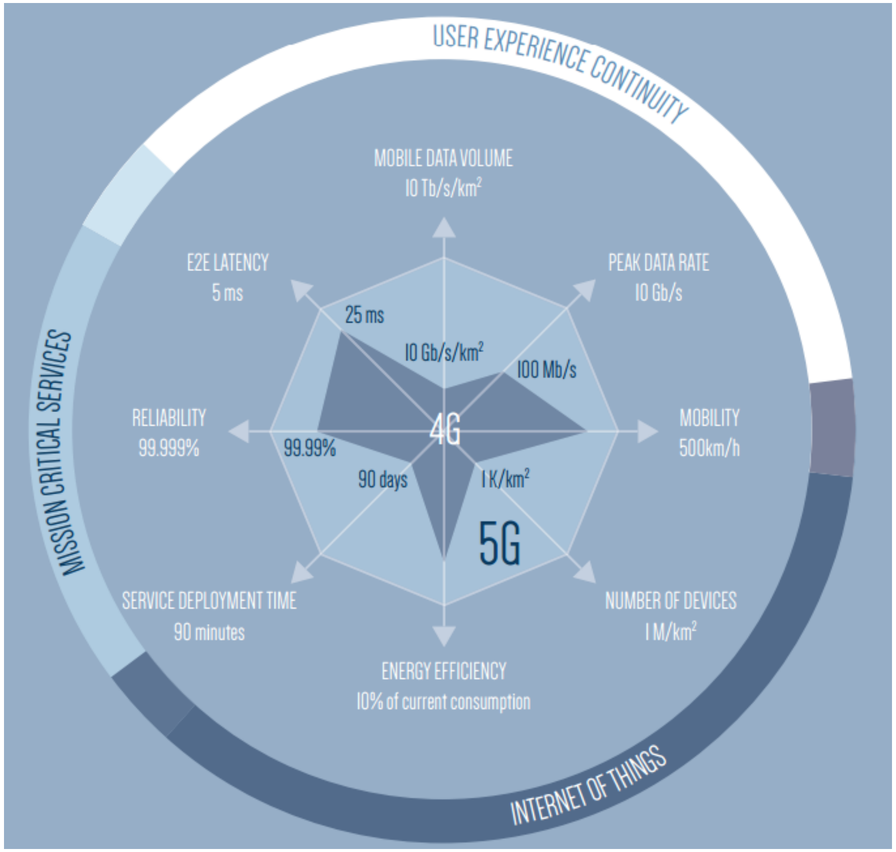
Cellular Communication Technology Evolution

5G

5G - Demands

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

Objectives



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

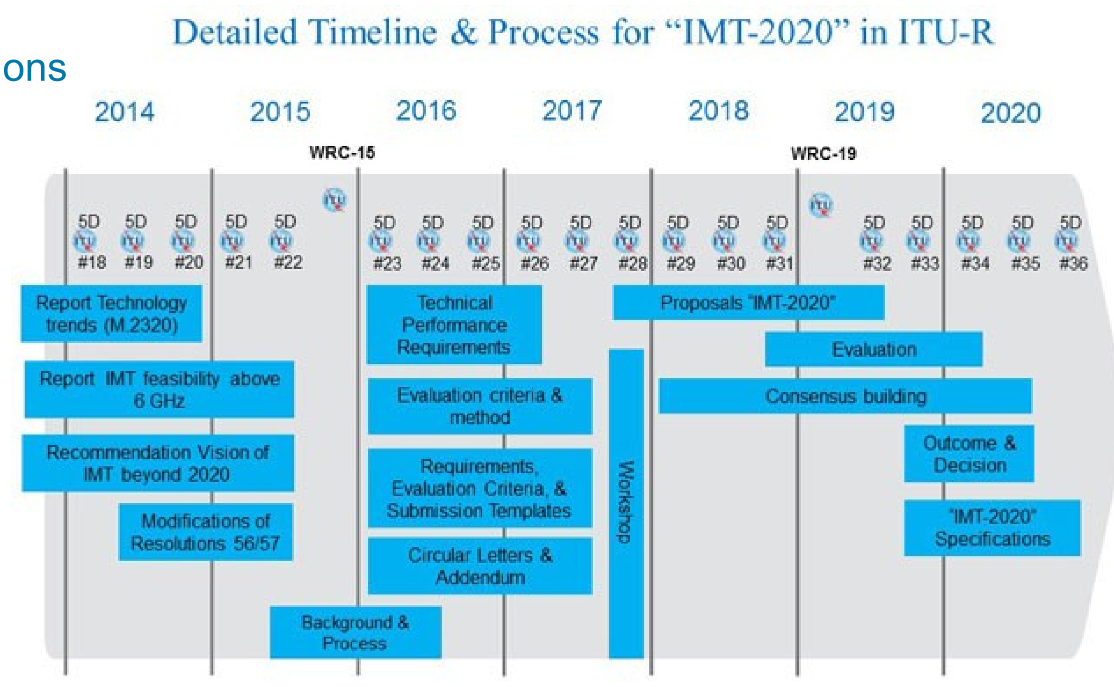
Cellular Communication Technology Evolution

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

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

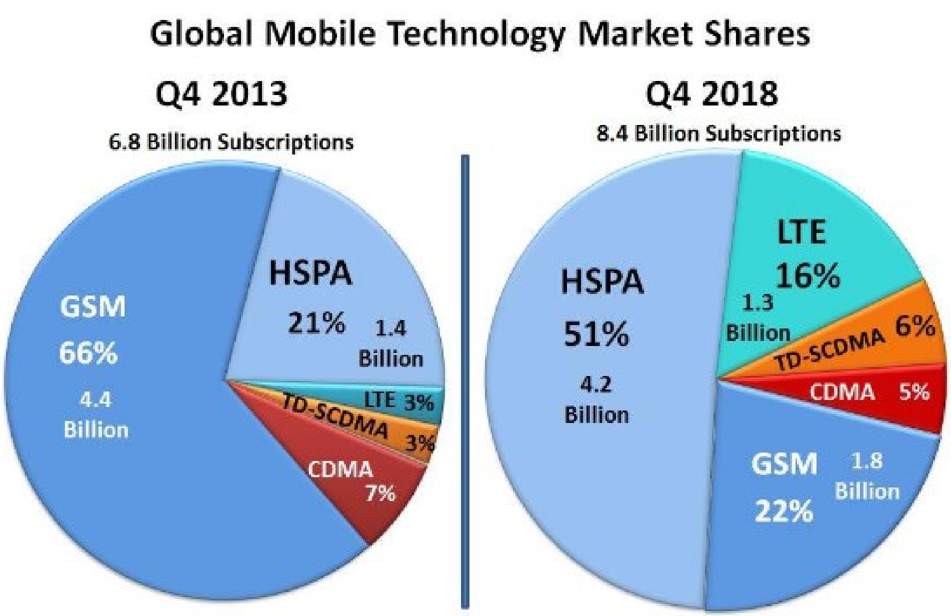
- In early 2012, ITU-R started to develop "IMT for 2020 and beyond", setting the stage for "5G" research activities that are emerging around the world

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

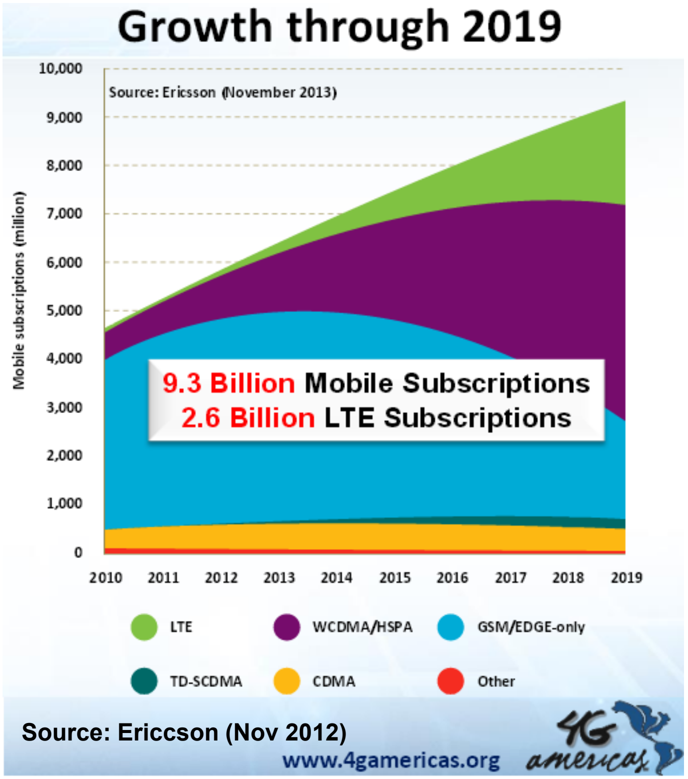


Note: While not expected to change, details may be adjusted if warranted.

Global Mobile Technology Market Shares

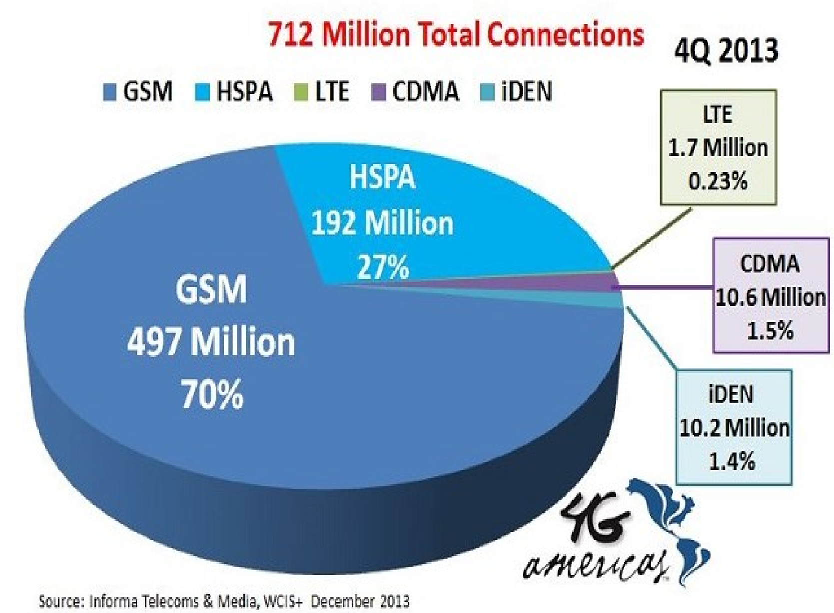


Souce: 4G Americas / 4G Mobile Broadband Evolution / February 2014

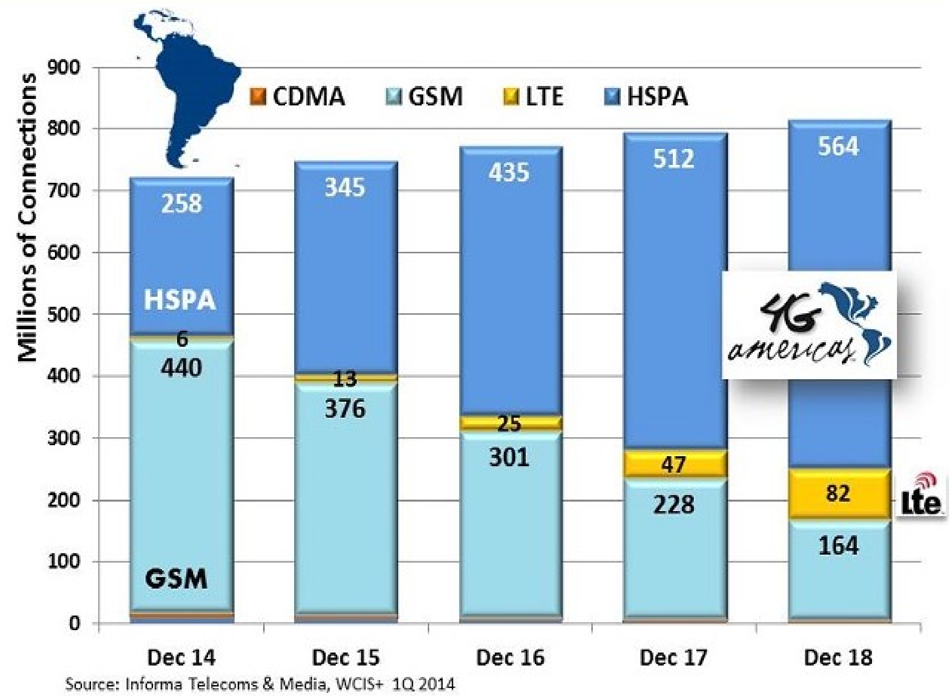


LA&CA Mobile Technology Market Shares

Latin America Mobile Market Shares



Forecast /Latin America & Caribbean



Schedule

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

Global Regulatory Scenario

International Standardization Bodies

IEC – International Eletrotechnical Commission

CISPR – Comité International Spécial des Perturbations Radioélectriques

ITU – International Telecommunication Union

ITU-R – Radiocommunication Sector

ITU-T – Telecommunication Standardization Sector

Global Regulatory Scenario

IEC / CISPR

Applicable EMC international standards from IEC and CISPR :

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

IEC/CISPR 22 – Radio Interference from ITE

(Basic and family standards)

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

Global Regulatory Scenario

ITU-T RECOMMENDATIONS ON EMC AND RESISTIBILITY

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

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

Global Regulatory Scenario

ITU-T RECOMMENDATIONS ON EMC AND RESISTIBILITY

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

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

Global Regulatory Scenario

3GPP – 3rd Generation Partnership Project

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

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

Global Regulatory Scenario

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

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

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

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

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

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

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

IMT-2020 Standardization Process

2012-2015

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

2016-2017

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

2018-2019

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

2019-2020

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

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

Defining the technology (2018-2020)

Global Regulatory Scenario

European Union

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

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

Global Regulatory Scenario

European Union

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

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

EN 50581:2012

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

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

Global Regulatory Scenario

European Union

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

Article 3 – Essential Requirements

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

Global Regulatory Scenario

European Union

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

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

Bodies responsible for drawing up such standards are:

European Telecommunication Standard Institute (ETSI)

European Committee for Electrotechnical Standardization (CENELEC)

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

Global Regulatory Scenario

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

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

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

Global Regulatory Scenario

USA

Federal Communication Commission rules

47 CFR Part 15 – Radio Frequency Devices

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

Global Regulatory Scenario

USA

Federal Communication Commission rules

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

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

Global Regulatory Scenario

USA

Federal Communication Commission rules

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

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

Global Regulatory Scenario

USA

Federal Communication Commission rules

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

Global Regulatory Scenario

Regarding Specific Absorption Rate (SAR)

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

Brazilian Regulation

Brazilian Certification Test Requirements

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

Brazilian Certification Test Requirements

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

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

Brazilian Certification Test Requirements

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

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

www.anatel.gov.br → Certificação de Produto → Requisitos Técnicos para Certificação → Lista de Requisitos Técnicos para Produtos de Telecomunicações Categoria I

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

Produto:	Telefone móvel celular

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

Scope: EMC requirements, safety, SAR and functional requirements

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

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

EMC requirements, safety, SAR and functional requirements

Brazilian Certification Test Requirements – Functional Tests

2G Technology (GSM, GPRS and EDGE)

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

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

Brazilian Certification Test Requirements – Functional Tests

3G Technology (WCDMA)

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

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

Brazilian Certification Test Requirements – Functional Tests

3G Technology (HSDPA and HSUPA)

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

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

Brazilian Certification Test Requirements – Functional Tests

LTE Technology

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

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

Brazilian Certification Test Requirements – Functional Tests

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

<u>Section IX</u>

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

Brazilian Certification Test Requirements – Functional Tests

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

Section IX

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

Section X

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

Brazilian Certification Test Requirements

EMC Tests

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

Electrical Safety Tests

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

SAR and BS Non Ionizing Radiation Protection Evaluation

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

SAR Tests

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

Schedule

Basic concepts on IMT technologies and other mobile radiocommunication technologies

Standards and test specifications for mobile terminals

Aspects regarding Specific Absorption Rate (SAR) Testing

Aspects regarding EMC Testing

Aspects regarding Safety Testing

ISO/IEC 17025 accreditation - measurement uncertainty - calibration

SAR Tests – Definitions

SAR – Specific Absorption Rate

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

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

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

SAR Tests – Definitions

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

dW **= Electromagnetic Energy**

dm **= Mass**

dV **= Volume**

ρ **= Density**

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

c = Specific Heat

ΔT = Temperature variation

Δt = Duration (time) of exposure

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

σ **= Electrical conductibility**

E **= RMS value of the electrical field vector**

ρ **= Middle density**

SAR Tests – Measurement Techniques

Temperature Alterations

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

Electrical Field Measurements

- Probes with dipoles and diodes
- Probes with optical sensors

Technology adopted by all standards

- Probes with dipoles and diodes

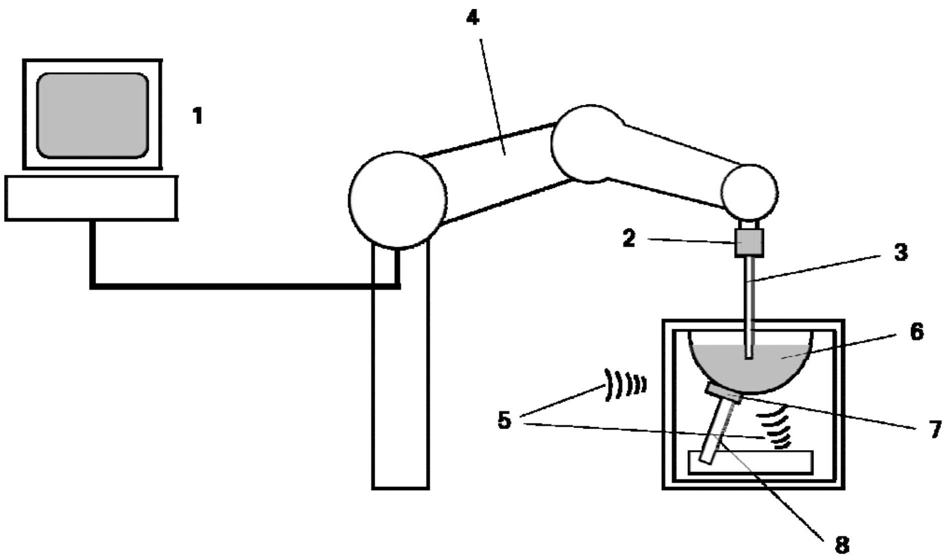
SAR Tests – Device Under Test

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

Examples of portable telecommunication terminals:

<u>Cell phones</u> <u>Tablets</u> <u>Radios</u> <u>Modems</u> <u>PTT</u>

SAR Tests – Basic Test Setup



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

SAR Tests – Environment Requirements

Reference Standards:

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

Room temperature: 18 to 25 °C

Maximum variation of liquid temperature: ± 2 °C

- Regarding temperature during characterization

EUT cannot connect to local network

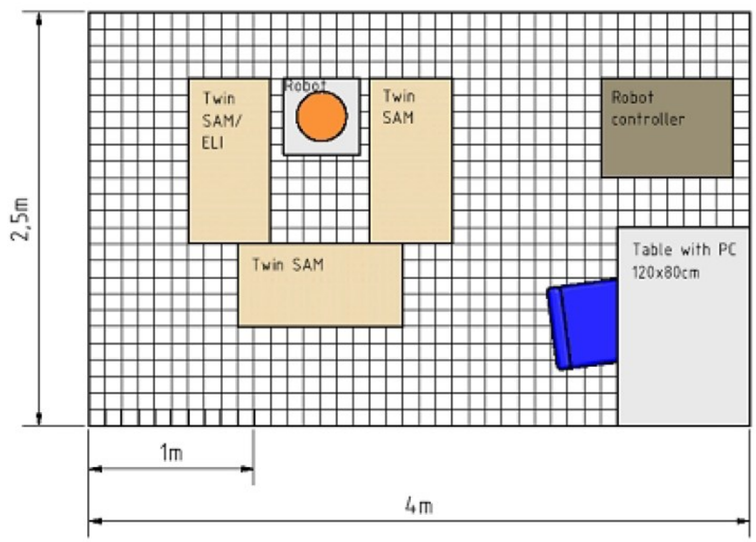
- RF Noise < 0.012 W/kg
  - External noise
  - Internal noise (reflections, internal RF transmitters, etc.)

SAR Tests – Environment Requirements

Using shielded room

Assumptions:

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

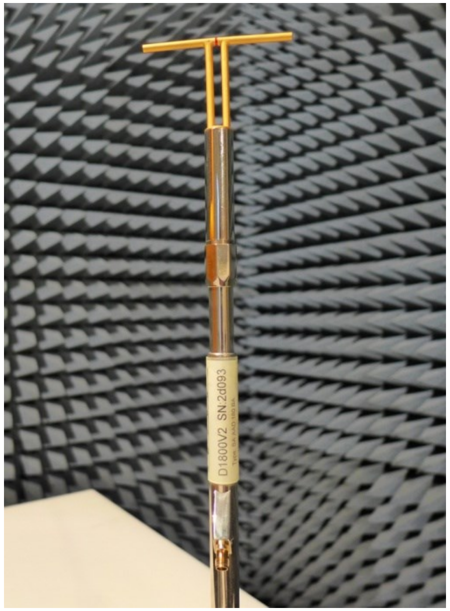


SAR Tests – Basic Instrument Set

Measuring probe

Data Acquisition
Electronics (DAE)

Validation dipole



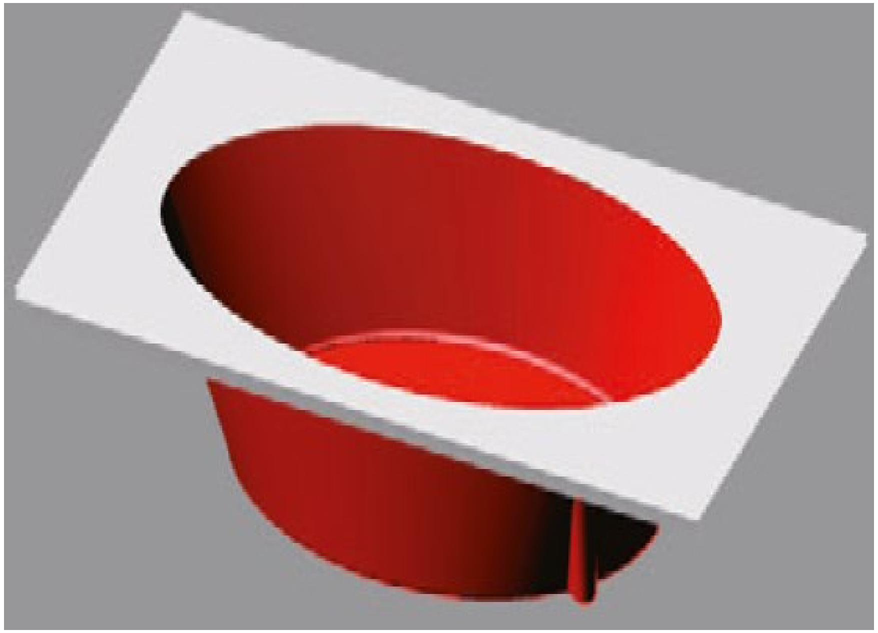
SAR Tests – Basic Instrument Set

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

Shell Thickness	2.0 ± 0.2 mm

SAR Tests – Basic Instrument Set

Flat phantom (ELI)



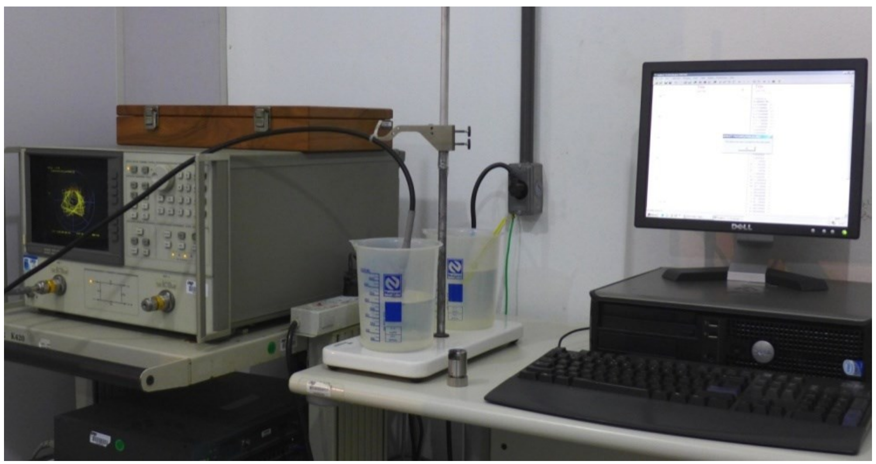
Shell Thickness

2.0 ± 0.2 mm (Only the ELI is approved)

SAR Tests – Basic Instrument Set

Validation setup

Dielectric Setup



SAR Tests – Basic Instrument Set

Simulating Liquid

Reference Standards:

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

Liquid with dielectric properties

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

SAR Tests – Basic Instrument Set

Liquid simulator – Ingredients

Saccharine (sugar) (purity > 98%)

Sodium Chloride (salt) (purity > 99%)

Hydrolysis of cellulose (HEC)

Bactericide

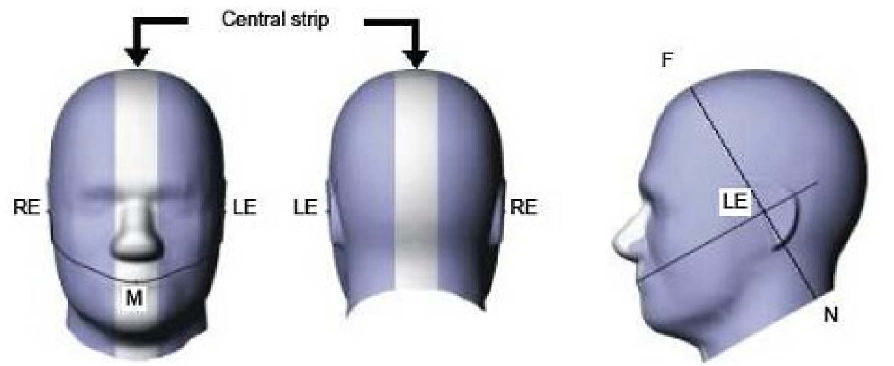
Deionized water (Minimum resistivity) 16 MΩ.cm)

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

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

SAR Tests – Test Scenarios

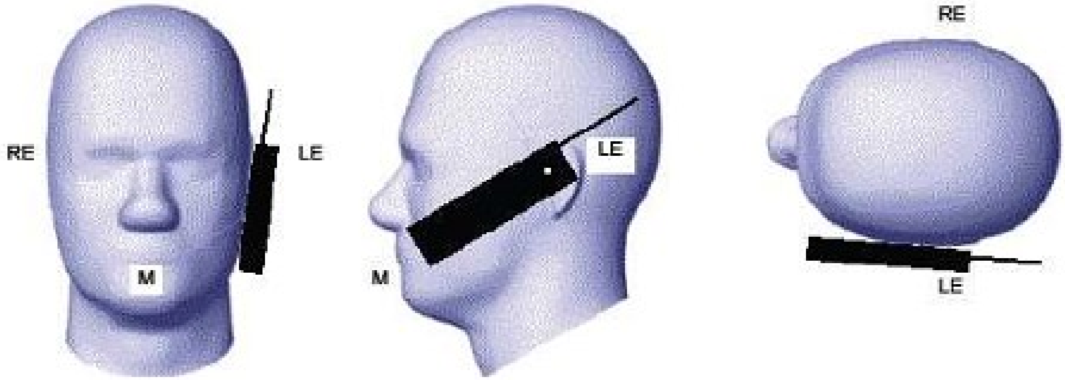
The following is an illustration of the head phantom.



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

SAR Tests – Test Scenarios

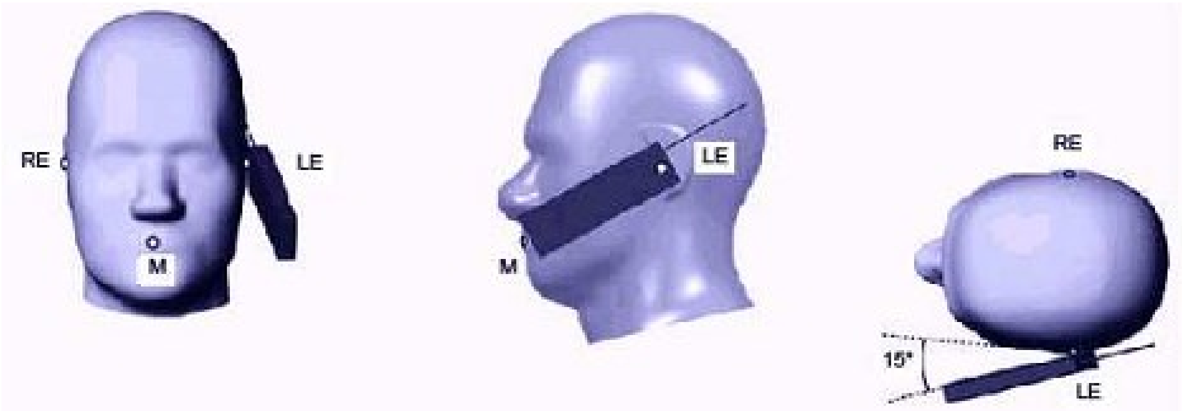
How the terminals are placed touching the bi-sectioned phantom head:



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

SAR Tests – Test Scenarios

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



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

SAR Tests – Test Scenarios

Examples of phantom head placement:

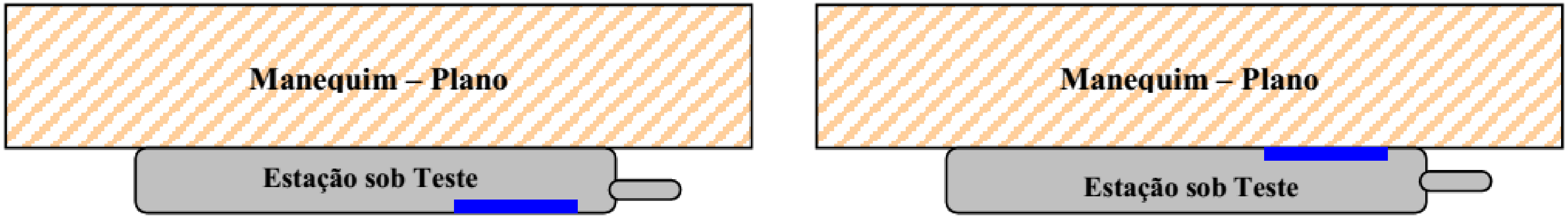
Cheek (Touching)

Tilt (15º angle)

SAR Tests – Test Scenarios

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

Touching the phantom flat



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

SAR Tests – Test Scenarios

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

Examples of Accessories:

Leather case with belt clip.

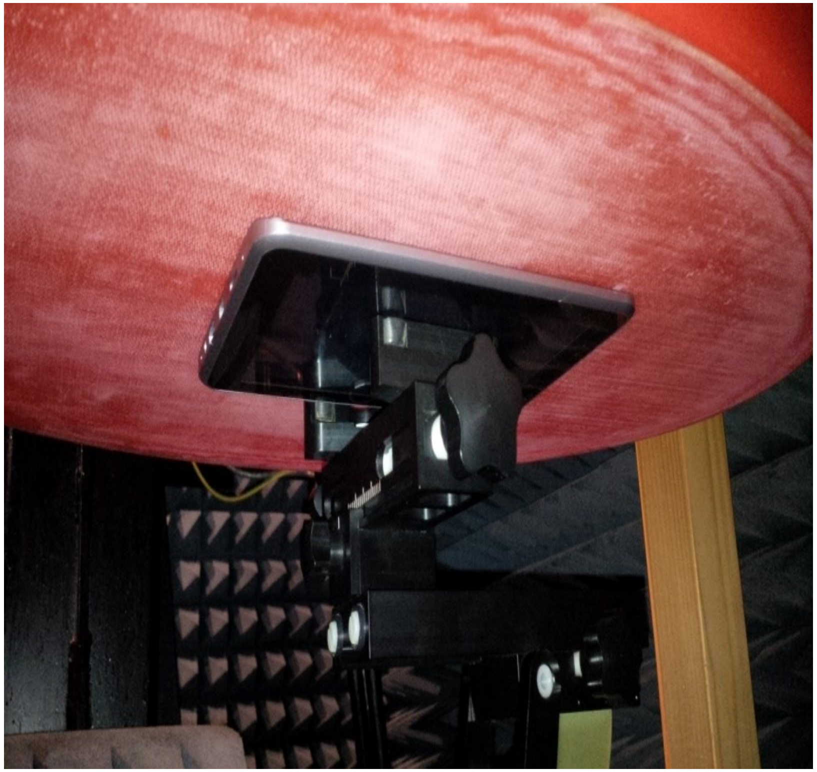
Wired headphones.

SAR Tests – Test Scenarios

Examples of terminal placement on flat phantom

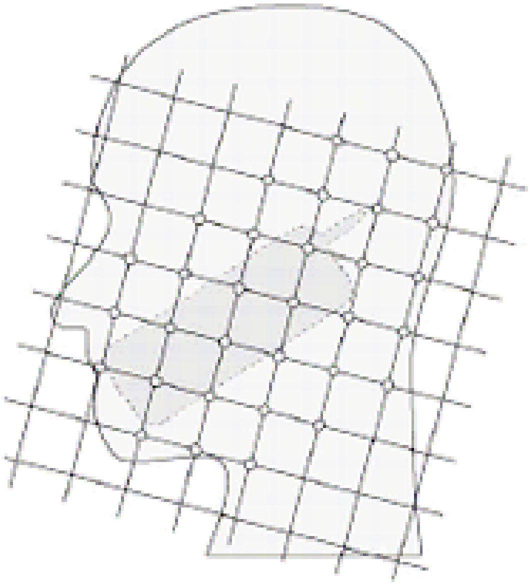
Body with accessories

Body without accessories

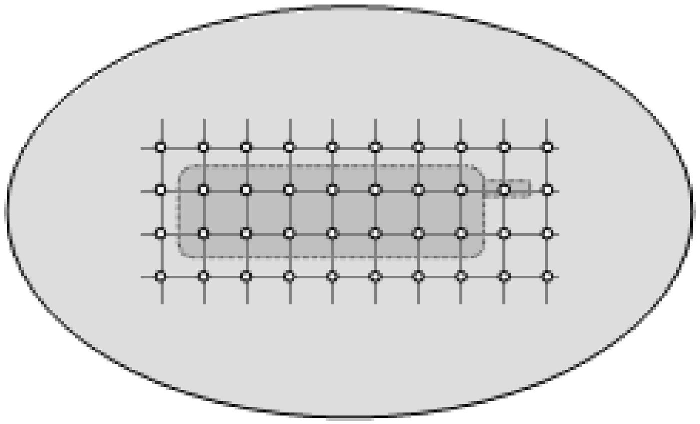


SAR Tests – Test Scenarios

Defining the test scan area around the terminal



Head area

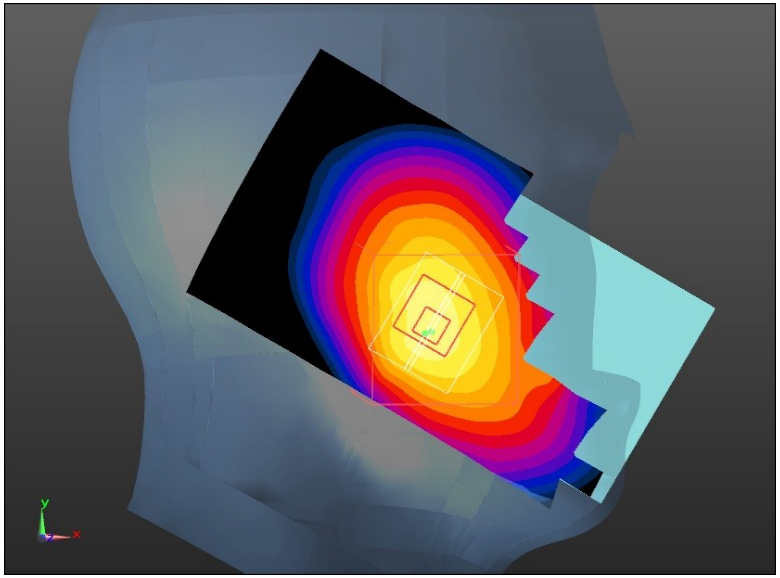


Body area

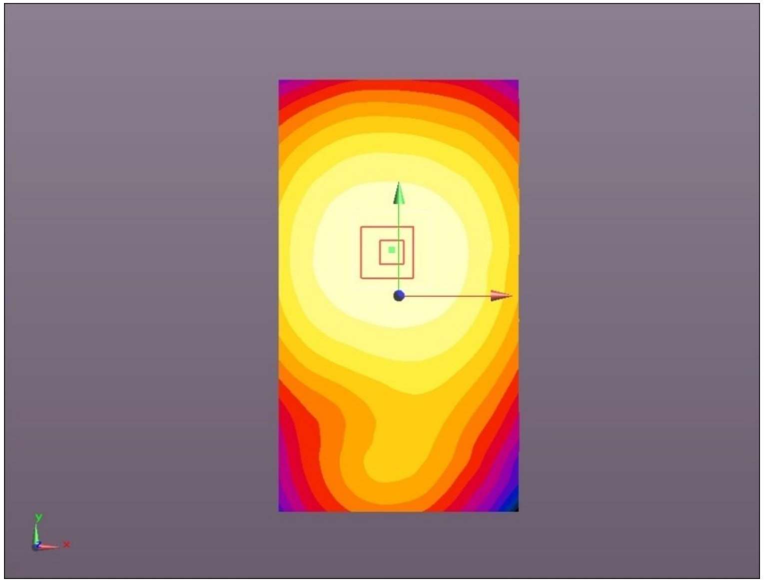
SAR Tests – Test Results

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

Head



Body



SAR Tests – Normative Limit for SAR Tests in Brazil

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

Schedule

Basic concepts on IMT technologies and other mobile radiocommunication technologies

Standards and test specifications for mobile terminals

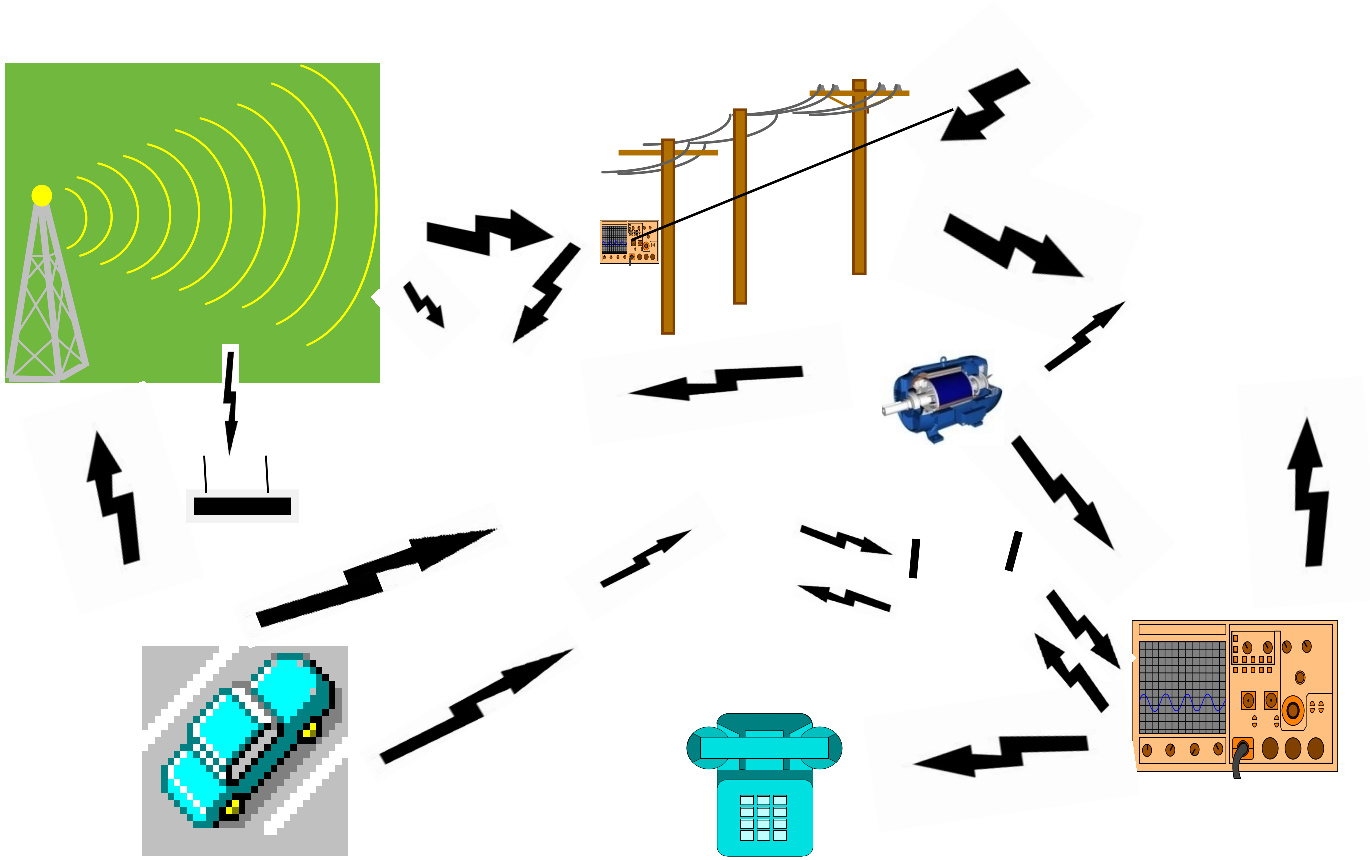
Aspects regarding Specific Absorption Rate (SAR) Testing

Aspects regarding EMC Testing

Aspects regarding Safety Testing

ISO/IEC 17025 accreditation - measurement uncertainty - calibration

Electromagnetic Environment



Introduction

EMC standard objective

- Guarantee the protection of radiofrequency spectrun
- Guarantee the normal operation of equipment at the installation site

Introduction

Terminology

Electromagnetic compatibility – ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

IEV161-01-07

International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility

Introduction

Terminology

Electromagnetic interference (EMI) – degradation of the performance of an equipment, transmission channel system caused by an electromagnetic disturbance

IEV161-01-06

International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility

Introduction

Terminology

Electromagnetic disturbance – any electromagnetic phenomenon which may degrade the performance of device, equipment or system, or adversely affect living or inert matter

IEV161-01-05

International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility

Introduction

Terminology

Immunity (to a disturbance) – ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

IEV161-01-20

International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility

Introduction

Terminology

Radio frequency interference – degradation of the reception of a wanted signal caused by radio frequency disturbance

IEV161-01-14

International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility

Introduction

Some standards are elaborated by

ISO – International Organization for Standardization

ITU – International Telecommunication Union

IEC – International Electrotechnical Commission

CISPR – Comité International Spécial des Perturbations Radioélectriques

CENELEC – Comité Européen de Normalisation Electrotechnique

And others

International Standards on EMC

International Telecommunication Union – Standards (ITU)

International Electrotechnical Commission (IEC)

Comité International Spécial des Perturbations Radioelectriquès (CISPR)

International Standards on EMC

Some Relevant IEC/CISPR Recommendations

- **IEC 61000-4-2** - Electromagnetic Compatibility (EMC) - Part 4: Testing and Measurement Techniques. Section 2 Electrostatic discharge immunity test.
- **IEC 61000-4-3** - Electromagnetic Compatibility (EMC) - Part 4: Testing and Measurement Techniques. Section 3 Radiated electromagnetic field requirements.
- **IEC 61000-4-4** - Electromagnetic Compatibility (EMC) - Part 4: Testing and Measurement Techniques. Section 4 Electrical fast transient.
- **IEC 61000-4-5** - Electromagnetic Compatibility (EMC) - Part 4: Test and Measurement Techniques - Section 5: Surge Immunity Test.
- **IEC 61000-4-6** - Electromagnetic Compatibility (EMC) - Part 4: Testing and Measurement Techniques. Section 6 Immunity to conducted disturbances induced by radio-frequency fields.
- **IEC 61000-4-11** - Electromagnetic Compatibility (EMC): Part 4: Testing and Measurement Techniques; Section 11: Voltage dips, short interruptions and voltage variations; Immunity tests

International Standards on EMC

Some Relevant IEC/CISPR Recommendations

- **CISPR 11** - Industrial, scientific and medical (ISM) radio-frequency equipment Electromagnetic disturbance characteristic - Limits and methods of measurement.

- **CISPR 22** - Limits and methods of measurement of radio disturbance characteristics of information technology equipment.

- **CISPR 24** - Information technology equipment - Immunity characteristics - Limits and methods of measurement

International Standards on EMC

Some Relevant ITU –T Recommendations

- ITU-T K21 – Resistibility of Telecommunication equipment installed in custmore premises to overvoltages and overcurrents
- ITU-T K38: Radiated emission test procedure for physically large systems
- ITU-T K42: Preparation of emission and immunity requirements for telecommunication equipment – General principles
- ITU-T K43: Immunity requirements for telecommunication equipment
- ITU-T K.44: Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents - Basic recommendation.

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

International Standards on EMC

Some Relevant ITU –T Recommendations

- **ITU-T K48: Product family EMC requirements for each telecommunication network equipment**
- ITU-T K49: Test condition and performance criteria for voice terminal subject to interference from digital mobile phone
- ITU-T K60: Emission levels and test methods for wireline telecommunication networks to minimize electromagnetic disturbance of radio services
- ITU-T K74: EMC, resistibility and safety requirements for home network devices
- ITU-T K76: EMC requirements for telecommunication network equipment (9 kHz – 150 kHz)

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

International Standards on EMC

Some Relevant ITU –T Recommendations

- ITU-T K80: EMC requirements for telecommunication network equipment (1 GHz – 6 GHz)
- ITU-T K81: High power electromagnetic immunity guide for telecommunication systems
- ITU-T K88: EMC requirements for next generation network equipment
- ITU-T K92: Conducted and radiated electromagnetic environment in home networking
- ITU-T K93: Immunity of home networking devices to electromagnetic disturbances

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

ITU-T K48

Used as reference in Annex to Resolution 442 - ANATEL

ITU-T K48 – Product family EMC requirements for each telecommunication network equipment

This Recommendation specifies the emission and immunity requirements for switching, transmission, power, digital mobile base station, wireless LAN, digital radio relay system, digital subscriber line (xDSL) and supervisory equipment. It also describes operational conditions for emission and immunity testing. Performance criteria for immunity tests are also specified.

ITU-T K48

Emission requirements

- Test methods and their limits are in accordance with CISPR 22. The limit depends on the place of installation: telecommunications center or outside.
- Radio communication equipment excluding digital mobile base stations are classified as:
  - Category 1 equipment with integrated antenna
    - Category 1.1 equipment whose frequency is below 1 GHz
    - Category 1.2 equipment whose frequency is above 1 GHz
  - Category 2 devices with integrated antenna
- For categories 1.2 and 2 apply CISPR 22. Consider exclusion band
- For categories 1.1 and digital mobile base stations apply

ITU-R SM 329-10 emissions limits in the spurious domain

(ITU-R Recommendation SM.329-10 (2003), *Unwanted emissions in the spurious domain. At present SM 329-12 – 2012)*

ITU-T K48

Immunity Requirements

- Apply the methods and general test levels specified in ITU-T K43.
- The conductive immunity test shall be made in the input and output ports power and signal ports.
- Test shall be applied to one port at a time.
- If the specified maximum length connected line is less than 3 m, it is not necessary to test.
- It is not required to test lines which the specified maximum length is less than 10 m.
- Shall be tested signal port of each type found in the equipment.
- Multi-pair cables and / or compounds shall be tested as a single cable, but wires grouped into bundles for aesthetic reasons must be tested individually.
- For the shielded cables, the voltage is applied directly to the screen.

ITU-T K48

SCOPE

- Transmission Equipment
- Power Supply Equipment
- Supervisory Equipment.
- Wireless LAN
- Digital Mobile Base Station
- Digital Radio Relay System
- xDSL equipment

Table 4/K.48 – Wireless LAN performance criteria

Criteria	During test	After test
A	Shall operate as intended May show degradation of performance (Note 1) Shall be no loss of function Shall be no unintentional transmissions	Shall operate as intended Shall be no degradation of performance (Note 2) Shall be no loss of function Shall be no loss of stored data or user programmable functions
B	May show loss of function (one or more) May show degradation of performance (Note 1) No unintentional transmissions	Functions shall be self-recoverable Shall operate as intended after recovering Shall be no degradation of performance (Note 2) Shall be no loss of stored data or user programmable functions
C	May be loss of function (one or more)	Functions shall be recoverable by the operator Shall operate as intended after recovering Shall be no degradation of performance (Note 2)

NOTE 1 – Degradation of performance during the test is understood as a degradation to a level not below a minimum performance level specified by the manufacturer for the use of the apparatus as intended. In some cases, the specified minimum performance level may be replaced by a permissible degradation of performance.

If the minimum performance level or the permissible performance degradation is not specified by the manufacturer, then either of these may be derived from the product description and documentation (including leaflets and advertising), and what the user may reasonably expect from the apparatus, if used as intended.

NOTE 2 – No degradation of performance after the test is understood as no degradation below a minimum performance level specified by the manufacturer for the use of the apparatus as intended. In some cases, the specified minimum performance level may be replaced by a permissible degradation of performance. After the test, no change of actual operating data or user retrievable data is allowed.

If the minimum performance level or the permissible performance degradation is not specified by the manufacturer, then either of these may be derived from the product description and documentation (including leaflets and advertising), and what the user may reasonably expect from the apparatus if used as intended.

Immunity test levels

Table A.1/K.48 – Equipment for telecommunication centre

Environmental phenomena	Test levels	Units	Basic standard	Performance criteria	Remarks
Enclosure port					
Radio-frequency electro-magnetic field	3 10 3 10	V/m	IEC 61000-4-3 [36]	A	80-800 MHz 800-960 MHz 960-1000 MHz 1400-2000 MHz (Note 1)
Electrostatic discharge	4	kV	IEC 61000-4-2 [35]	B	Contact and air discharge
Outdoor telecommunication ports					
Radio-frequency conducted continuous	3	V	IEC 61000-4-6 [39]	A	0.15-80 MHz (Notes 2, 3 and 5)
Surges	0.5 (line to line) 1 (line to ground)	kV	IEC 61000-4-5 [38]	B	10/700 μs (Notes 4 and 13)
Fast transients	0.5	kV	IEC 61000-4-4 [37]	B	(Note 12)
Indoor telecommunication ports					
Radio-frequency conducted continuous	3	V	IEC 61000-4-6 [39]	A	0.15-80 MHz (Notes 2, 3 and 5)
Surges	0.5 (line to ground)	kV	IEC 61000-4-5 [38]	B	1.2/50 (8/20) μs (Note 4)
Fast transients	0.5	kV	IEC 61000-4-4 [37]	B	(Note 12)
DC power ports					
Radio-frequency conducted continuous	3	V	IEC 61000-4-6 [39]	A	0.15-80 MHz (Notes 2, 3 and 5)
Fast transients	0.5	kV	IEC 61000-4-4 [37]	B	(Note 12)

Table A.1/K.48 – Equipment for telecommunication centre

Environmental phenomena	Test levels	Units	Basic standard	Performance criteria	Remarks
Voltage dips	>95 0.5	% reduction period	IEC 61000-4-11 [40]	B	(Note 6)
	30 25	% reduction period	IEC 61000-4-11 [40]	C	(Note 6)
Voltage interruption	95 250	% reduction period	IEC 61000-4-11 [40]	C	(Note 6)

NOTE 1 – The test may be performed with a start frequency lower than 80 MHz, but not less than 27 MHz.

NOTE 2 – A lower test level above 10 MHz can be applied. The specific level is under study.

NOTE 3 – The test level can be defined as equivalent current into 150 Ω.

NOTE 4 – This test may not be applied for unscreened cable when appropriate CDN does not exist.

NOTE 5 – It is recognized that radio-frequency electromagnetic fields and conducted continuous voltages are 1 V/m and 1 V respectively in major telecommunication centres.

NOTE 6 – This test applies to equipment having a rated input current not exceeding 16 A per phase.

Table A.2/K.48 – Equipment for outdoor locations

Environmental phenomena	Test levels	Units	Basic standard	Performance criteria	Remarks
Enclosure port					
Radio-frequency electro-magnetic field	3 10 3 10	V/m	IEC 61000-4-3 [36]	A	80-800 MHz 800-960 MHz 960-1000 MHz 1400-2000 MHz (Notes 1 and 5)
Electrostatic discharge	4	kV	IEC 61000-4-2 [35]	B	Contact and air discharge
Telecommunication ports					
Radio-frequency conducted continuous	3	V	IEC 61000-4-6 [39]	A	0.15-80 MHz (Notes 2 and 3)
Surges	0.5 (line to line) 1 (line to ground)	kV	IEC 61000-4-5 [38]	B	10/700 µs (Notes 4 and 13)
Fast transients	0.5	kV	IEC 61000-4-4 [37]	B	(Note 12)
DC power ports					
Radio-frequency conducted continuous	3	V	IEC 61000-4-6 [39]	A	0.15-80 MHz (Notes 2 and 3)

Table A.2 continued except voltage variation on DC power supply ref. IEC 61000-4-29

Fast transients	0.5	kV	IEC 61000-4-4 [37]	B	(Note 12)
AC power ports					
Radio-frequency conducted continuous	3	V	IEC 61000-4-6 [39]	A	0.15-80 MHz (Notes 2 and 3)
Surges	0.5 (line to line) 1 (line to ground)	kV	IEC 61000-4-5 [38]	B	1.2/50 (8/20) µs
Fast transients	1.0	kV	IEC 61000-4-4 [37]	B	(Note 12)
Voltage dips	>95 0.5	% reduction period	IEC 61000-4-11 [40]	B	(Note 6)
	30 25	% reduction period	IEC 61000-4-11 [40]	C	(Note 6)
Voltage interruption	95 250	% reduction period	IEC 61000-4-11 [40]	C	(Note 6)
	30 25	% reduction period	IEC 61000-4-11 [40]	C	(Note 6)

NOTE 1 – The test may be performed with a start frequency lower than 80 MHz, but not less than 27 MHz.

NOTE 2 – A lower test level above 10 MHz can be applied. The specific level is under study.

NOTE 3 – The test level can be defined as equivalent current into 150 Ω.

NOTE 4 – This test may not be applied for unscreened cable when appropriate CDN does not exist.

NOTE 5 – In cases where mobile communications are permitted, radio field immunity higher than 10 V/m may be requested at communication frequencies.

NOTE 6 – This test applies to equipment having a rated input current not exceeding 16 A per phase.

Table A.3/K.48 – Equipment for telecommunication centre (Emission)

	Frequency	Quasi-peak limit	Average limit	Basic standard	Remarks
Enclosure port					
Radiated electromagnetic field	30 to 230 MHz	40 dB(μV/m)	N/A	CISPR 22 [30]	Physically large systems should be tested according to ITU-T Rec. K.38 [15] (Note 3)
	230 to 1000 MHz	47 dB(μV/m)			
Telecommunication ports (outdoor and indoor)					
Conducted disturbance voltage	0.15 to 0.5 MHz	97 to 87 dB(μV)	84 to 74 dB(μV)	CISPR 22 [30]	(Notes 1 and 2)
	0.5 to 30 MHz	87 dB(μV)	74 dB(μV)		
AC power ports					
Conducted disturbance voltage	0.15 to 0.5 MHz	79 dB(μV)	66 dB(μV)	CISPR 22 [30]	(Note 2)
	0.5 to 30 MHz	73 dB(μV)	60 dB(μV)		
DC power ports					
Conducted disturbance voltage	0.15 to 0.5 MHz	79 dB(μV)	66 dB(μV)	CISPR 22 [30]	(Note 2)
	0.5 to 30 MHz	73 dB(μV)	60 dB(μV)		

NOTE 1 – The limits decrease linearly with the logarithm of the frequency.

NOTE 2 – Equivalent current limit can be applied.

NOTE 3 – The limits are given for 10 metres measurement distance.

Table A.4/K.48 – Equipment for outdoor location (Emission)

	Frequency	Quasi-peak limit	Average limit	Basic standard	Remarks
Enclosure port					
Radiated electro-magnetic field	30 to 230 MHz	30 dB(µV/m)	N/A	CISPR 22 [30]	Physically large systems should be tested according to ITU-T Rec. K.38 (Note 3)
	230 to 1000 MHz	37 dB(µV/m)			
Telecommunication ports (outdoor and indoor)					
Conducted disturbance voltage	0.15 to 0.5 MHz	84 to 74 dB(µV)	74 to 64 dB(µV)	CISPR 22 [30]	(Notes 1 and 2)
	0.5 to 30 MHz	74 dB(µV)	64 dB(µV)		
AC power ports					
Conducted disturbance voltage	0.15 to 0.5 MHz	66 to 56 dB(µV)	56 to 46 dB(µV)	CISPR 22 [30]	(Notes 1 and 2)
	0.5 to 5 MHz	56 dB(µV)	46 dB(µV)		
	5 to 30 MHz	60 dB(mV)	50 dB(µV)		
DC power ports					
Conducted disturbance voltage	0.15 to 0.5 MHz	66 to 56 dB(µV)	56 to 46 dB(µV)	CISPR 22 [30]	(Notes 1 and 2)
	0.5 to 5 MHz	56 dB(µV)	46 dB(µV)		
	5 to 30 MHz	60 dB(µV)	50 dB(µV)		

NOTE 1 – The limits decrease linearly with the logarithm of the frequency.

NOTE 2 – Equivalent current limit can be applied.

NOTE 3 – The limits are given for 10 metres measurement distance.

Resolution 442 – ANATEL - 2006

REFERENCES

- I - Anatel - Regulamento para Certificação e Homologação de Produtos para Telecomunicações.
- II - IEC 61000-4-2(2001) - Electromagnetic Compatibility (EMC) - Part 4: Testing and Measurement Techniques. Section 2 Electrostatic discharge immunity test.
- III - IEC 61000-4-3 (2002) - Electromagnetic Compatibility (EMC) - Part 4: Testing and Measurement Techniques. Section 3 Radiated electromagnetic field requirements.
- IV - IEC 61000-4-4 (2004) - Electromagnetic Compatibility (EMC) - Part 4: Testing and Measurement Techniques. Section 4 Electrical fast transient.
- V - IEC 61000-4-5 (2001) - Electromagnetic Compatibility (EMC) - Part 4: Test and Measurement Techniques - Section 5: Surge Immunity Test.
- VI - IEC 61000-4-6 (2004) - Electromagnetic Compatibility (EMC) - Part 4: Testing and Measurement Techniques. Section 6 Immunity to conducted disturbances induced by radio-frequency fields.

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- VII - IEC 61000-4-11 (2004) - Electromagnetic Compatibility (EMC): Part 4: Testing and Measurement Techniques; Section 11: Voltage dips, short interruptions and voltage variations; Immunity tests.
- VIII - CISPR 11 (2003) - Industrial, scientific and medical (ISM) radio-frequency equipment - Electromagnetic disturbance characteristic - Limits and methods of measurement.
- IX - CISPR 22 (2005) - Limits and methods of measurement of radio disturbance characteristics of information technology equipment.
- X - CISPR 24 (1997), Amend 1 (2001) e Amend 2 (2002) - Information technology equipment - Immunity characteristics - Limits and methods of measurement

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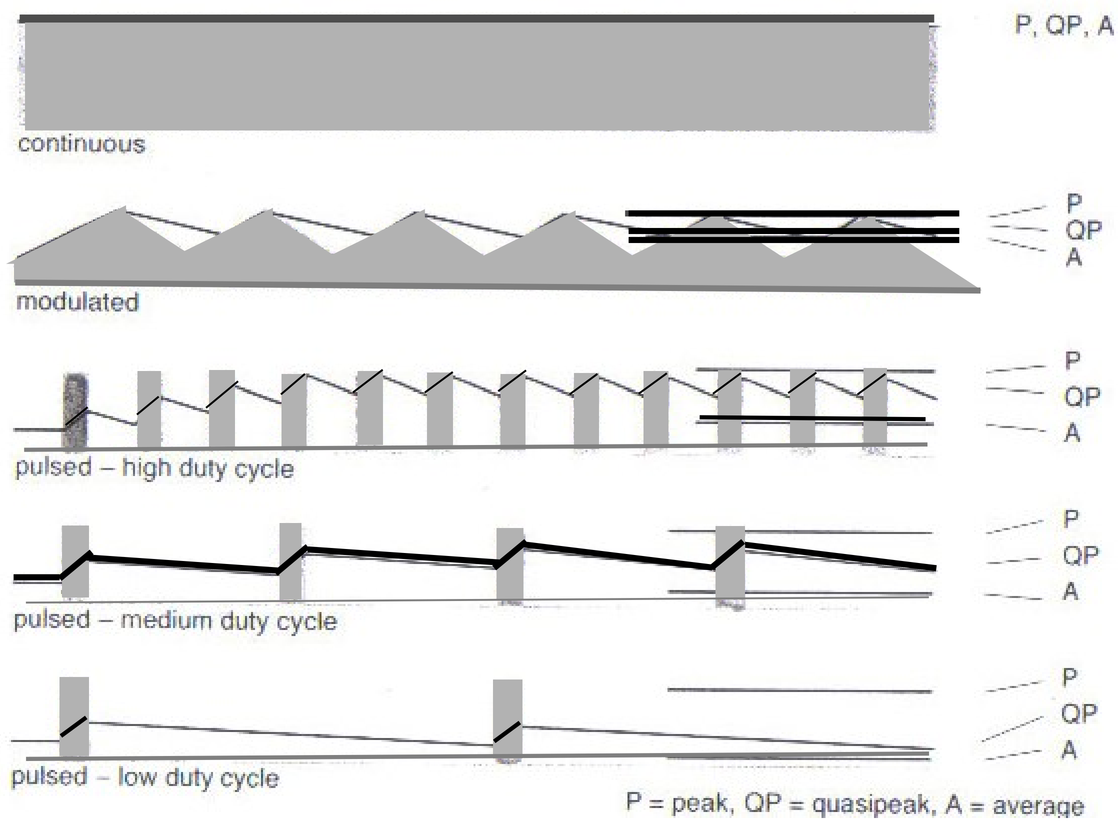
- XI - ITU-T Rec. K.21 (2003) - Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents.
- XII - ITU-T Rec. K.44 (2003) - Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents - Basic recommendation.
- XIII - ITU-T Rec. K.38 (1996) - Radiated emission testing of physically large telecommunication systems.
- XIV - ITU-T Rec. K.48 (2003) - EMC Requirements for each telecommunication equipment – product family recommendation

Basic Concepts

Peak, Quase-peak and Average values

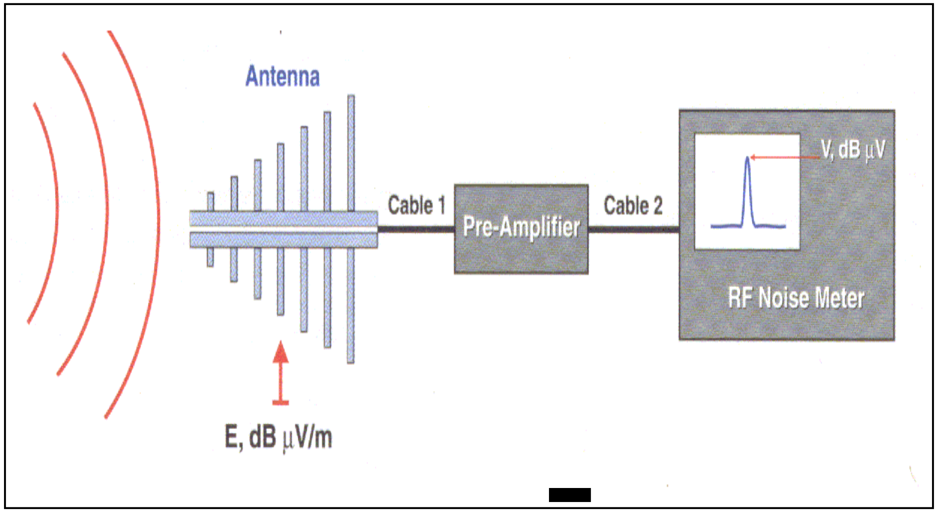


Basic Concepts

Electric field strength measurement

Measuring equipment

- Antenna
- Transmission line
- Attenuator or amplifier
- Receiver



Basic Concepts

EMC measuring antennas

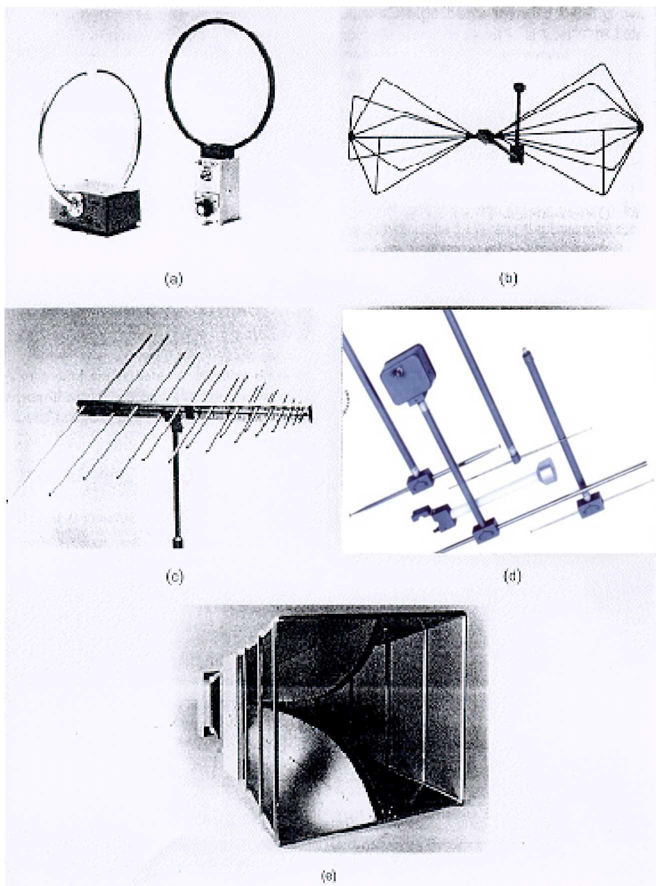


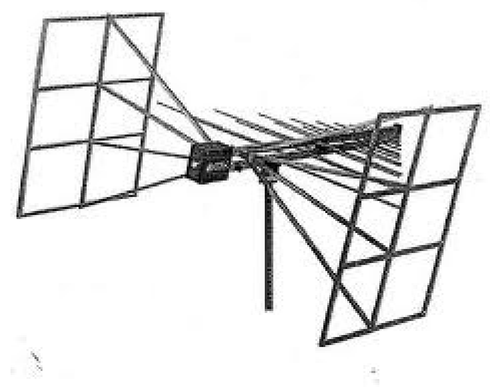
Figure 5-3 Examples of test antennas (a) loop antenna, (b) biconical antenna, (c) log periodic antenna, (d) conical log spiral, (e) double ridged waveguide (photographs courtesy of The Electromechanics Company)

- **Loop antenna**
  - 9 kHz – 30 MHz
- **Biconical antenna**
  - 30 MHz – 200 MHz
- **Log periodic antenna**
  - 200 MHz – 1000 MHz
- **Dipolo**
  - 30 MHz – 1000 MHz
- ***DOBLE RIDGE antenna***
  - 1 GHz – 18 GHz

Basic Concepts

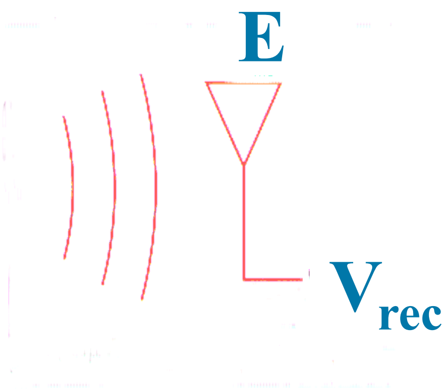
MEASURING ANTENNAS

- BICONILOG ANTENNA
  - 30 MHz – 2000 MHz



Basic Concepts

ANTENNA FACTOR (AF) - Ratio of the electric field strength to the voltage V induced across the terminals of a antenna



$$AF\ (1/\mathrm{m}) = \frac{E\ (\mathrm{V/m})}{V_{\mathrm{rec}}\ (\mathrm{V})}$$

ASPECTS REGARDING EMC TEST

Publication CISPR 22

CISPR 22 – Information Technology Equipment – Radio Disturbance Characteristics – Limits and Methods of Measurement

This publication establishes requirements for the radio disturbance emission and methods of measurement in order to prevent radio interference.

Publication CISPR 22

Information Technology Equipment (ITE)

any equipment:

- **which has a primary function of (or a combination of) entry, storage, display, retrieval, transmission, processing, switching, or control, of data and of telecommunication messages and which may be equipped with one or more terminal ports typically operated for information transfer;**
- **It includes, for example, data processing equipment, office machines, electronic business equipment and telecommunication equipment.**

Publication CISPR 22

Classification of ITE

Class B ITE is intended primarily for use in the domestic environment and may include:

- Equipment with no fixed place of use; portable equipment and telecommunication terminal, personal computers and auxiliary connected equipment.

NOTE: The domestic environment is an environment where the use of broadcast radio and television receivers may be expected within a distance of 10 m of the apparatus concerned.

Class A ITE is a category of all other ITE which satisfies the class A ITE limits but not the class B ITE limits. Such equipment should not be restricted in its sale but the following warning shall be included in the instructions for use.

Warning: This is a class A product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

Publication CISPR 22

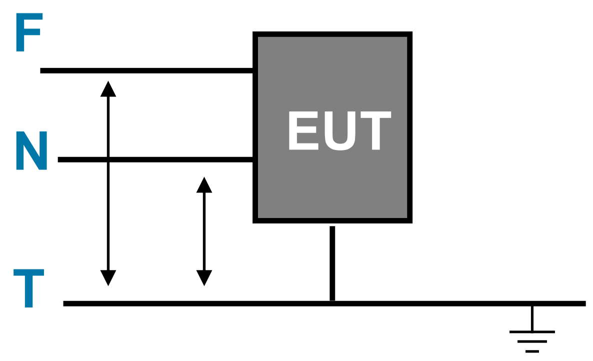
Important aspect of CISPR 22 to be mentioned is the use average peak and quasi-peak detectors

- Use of average and quasi-peak detectors
- Radiated emission up to 1 GHz – use of quasi-peak detector
- Radiated emission higher than 1 GHz – use of average and peak detectors

Publication CISPR 22

Conducted emission from mains terminals and telecom lines

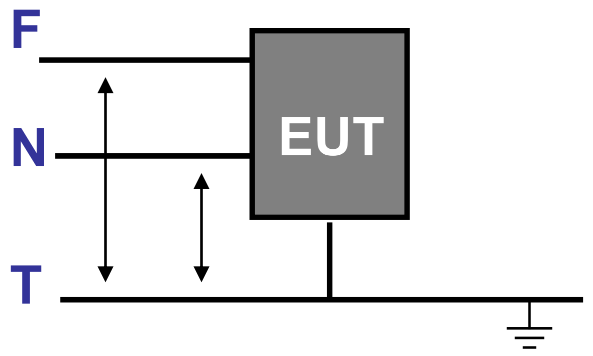
- Usage of average and quasi peak detectors
- AMN – Artificial mains network
- ISN – Impedance Stabilization Network
- Frequency range of 150 kHz to 30 MHz
- Ambient disturbances 6 dB below the limit (usage of shielded chamber)



Publication CISPR 22

Emission limits for Class B Equipment

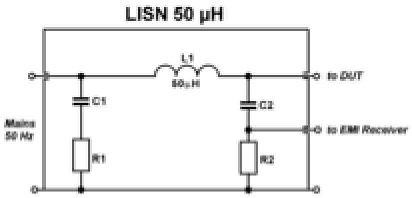
FREQUENCY MHz	LIMITS IN dB (μV) CLASS B	
	Quasi-peak	Average
0,15 - 0,50	66 a 56	56 a 46
0,5 - 5	56	46
5 - 30	60	50



Publication CISPR 22

Artificial mains network – AMN

Line impedance stabilization network - LISN



Simplified circuit

Ensures normalized impedance at the input of EUT (50 Ω) regardless the actual value of the local mains impedance

Publication CISPR 22

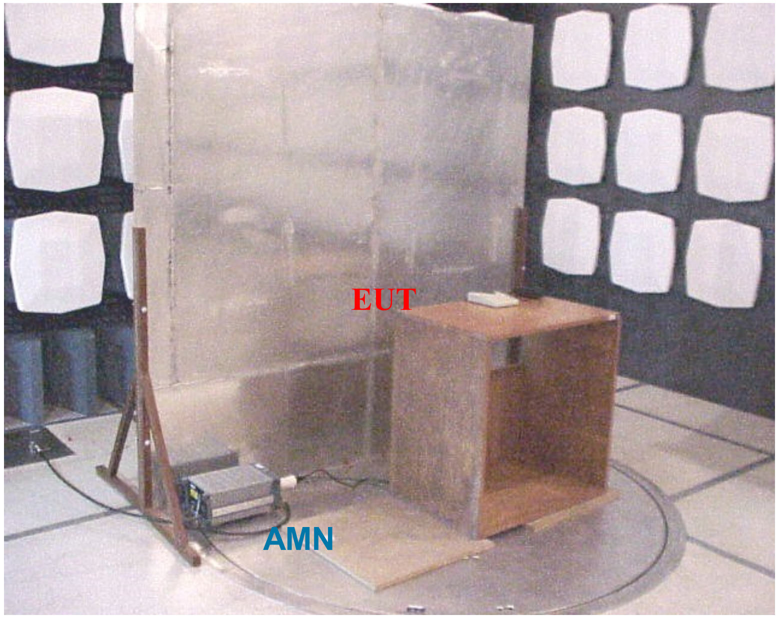
Artificial mains network – AMN

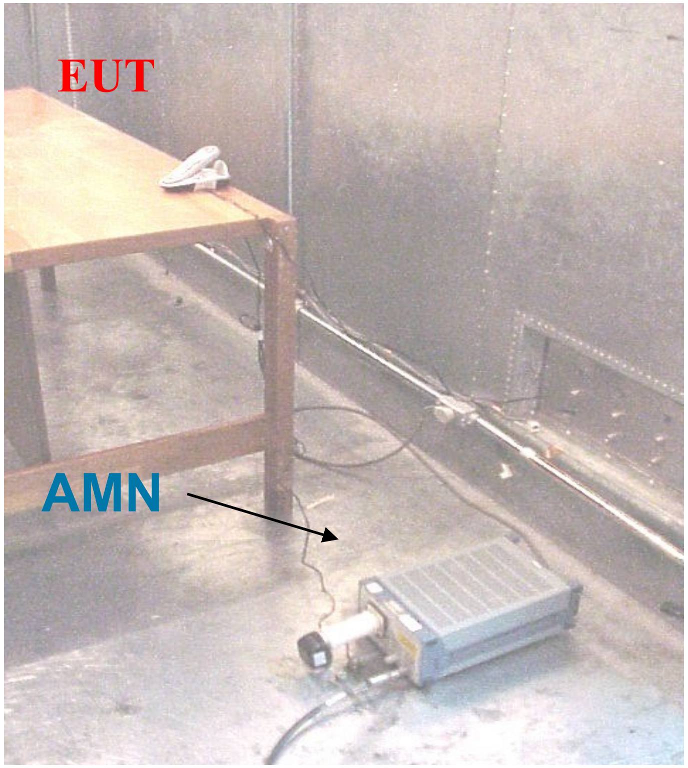
Line impedance stabilization network - LISN

Reduce the presence of disturbance of the environment on the emission levels to be measured

Publication CISPR 22

Conducted Emission Measurement – Test setup





Publication CISPR 22

Limites de emisión de las líneas de telecomunicaciones

Frecuencia MHz	LIMITS IN dB (μV) CLASS B		LIMITS IN dB (μA) CLASS B	
	Quasi-pico	Average	Quasi-peak	Average
0,15 - 0,50	84 a 74	74 a 64	40 a 30	30 a 20
0,5 - 30	74	64	30	20

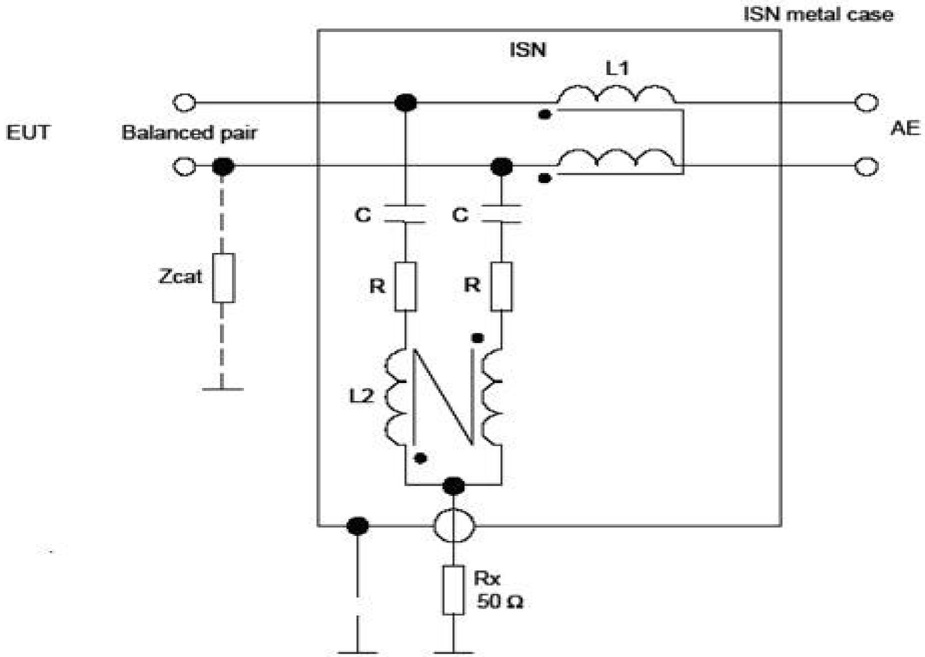
Nota:

the limits increase with the logarithm of the frequency in the range 0,15 MHz to 0,5 MHz

Current and voltage are derived from the usage of ISN (150 Ω)

Impedance Stabilization Network – ISN

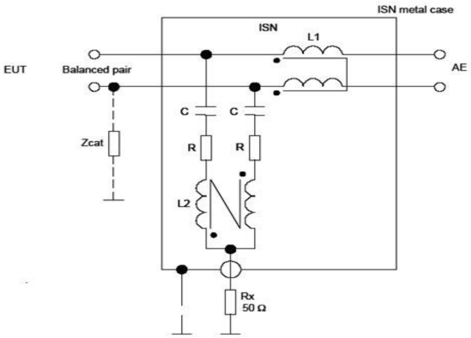
For telecom line conducted emission test



Publication CISPR 22

Impedance stabilization network – ISN

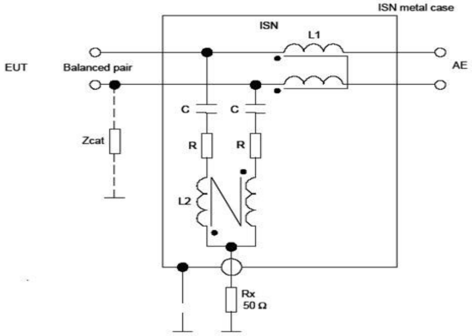
Ensures a normalized asymmetric impedance to the telecom line of the EUT (150 Ω)



Publication CISPR 22

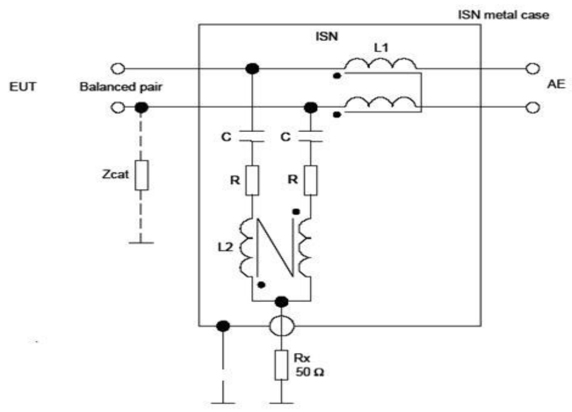
Impedance stabilization network – ISN

Reduce the presence of environment disturbance on the emission levels to be measured



Publication CISPR 22

Impedance stabilization network – ISN

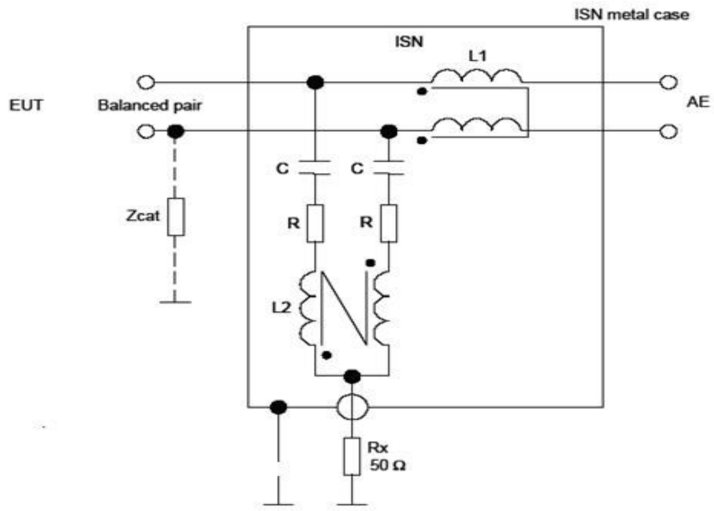


Impedance meter connection point should be 50 Ω

LCL must be compatible with the telecommunication network normally used with EUT

Publication CISPR 22

Impedance stabilization network – ISN



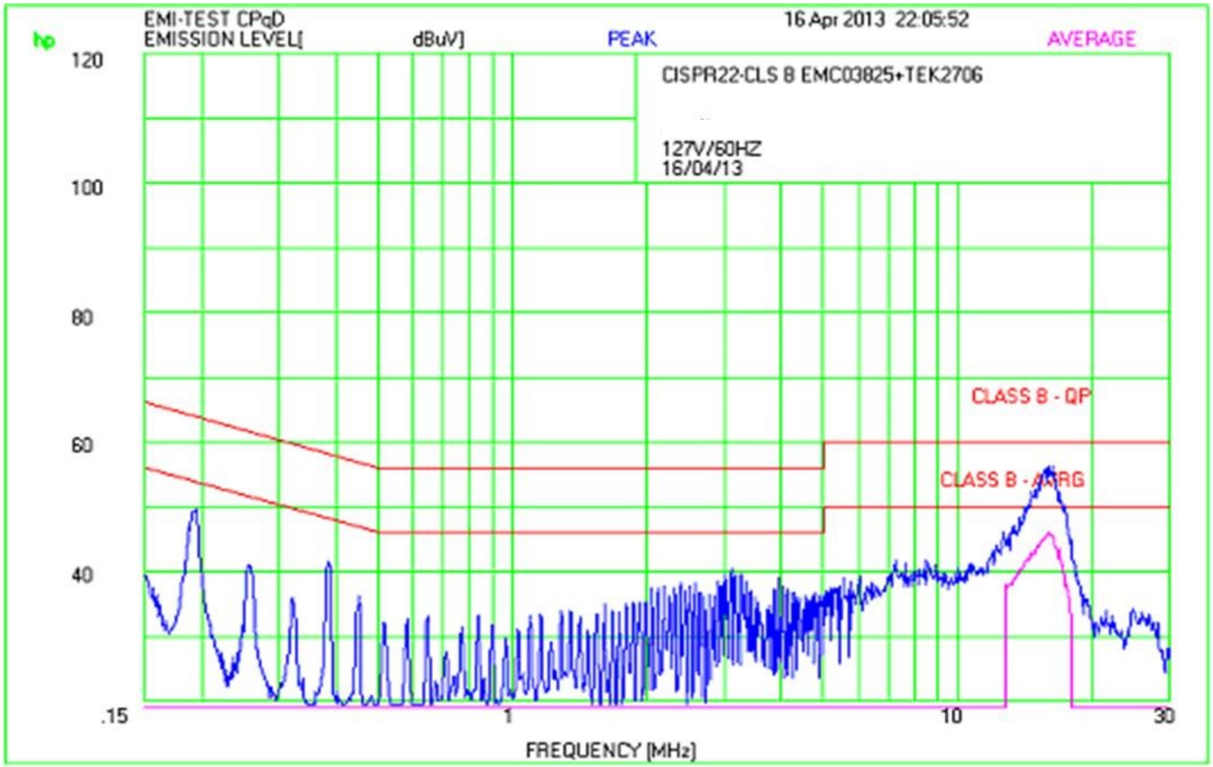
$$LCL = 20LOG\frac{U_C}{U_D}$$

U_C – common mode voltage

U_D – differential mode voltage

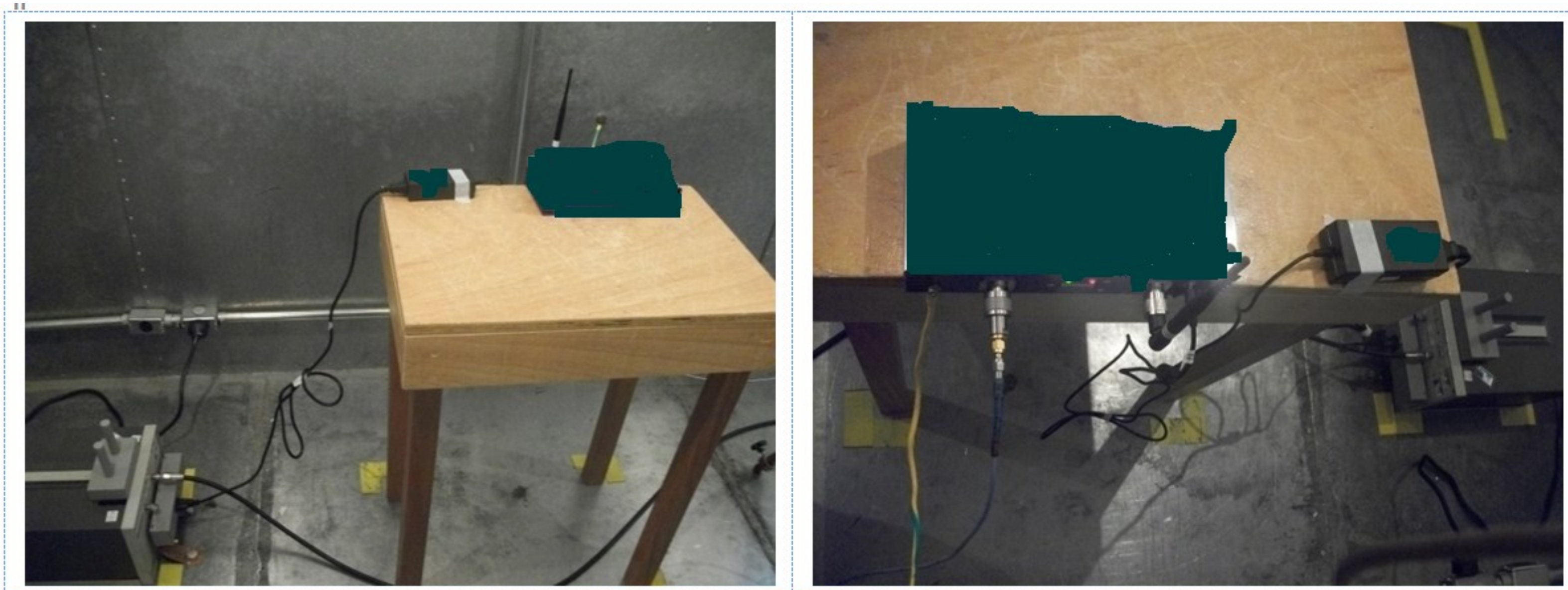
Publication CISPR 22

Example of conducted emission test result



Publication CISPR 22

Example of conducted emission test setup



Publication CISPR 22

RADIATED EMISSION TEST

- Quasi-peak detector for 30 MHz to 1000 MHz frequency range

- Average and peak detector for 1 GHz to 6 GHz frequency range

- Ambient disturbances at least 6 dB below the limit (usage of semianechoic chamber)

Publication CISPR 22

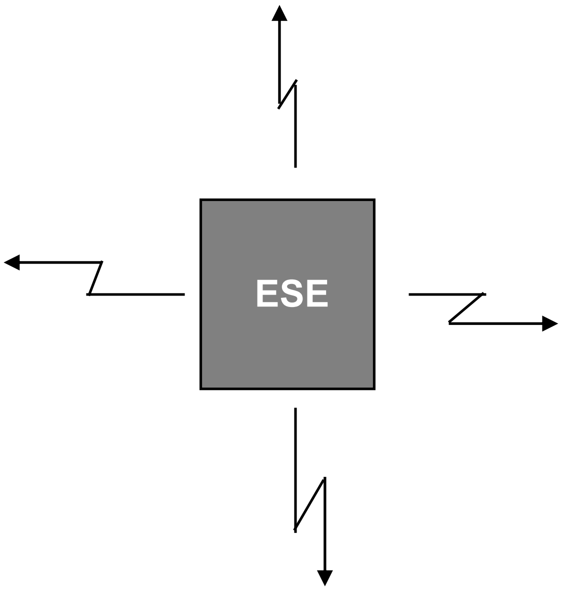
For frequencies above 1 GHz, the decision regarding the maximum frequency to be measured is given in the table below

Highest internal frequency (MHz)	Maximum frequency to measure (MHz)
< 108 $108 < f_{highest} < 500$ f >1 000	1000 5000 6000

Publication CISPR 22

Limits of radiated disturbance emission

Frequency range (MHz)	Class B limits quasi-peak value dB(uV/m)
30 - 230	30 (40)
230 - 1 000	37 (47)



OBS.: Limit levels for emissions measured at 10 (3) meters

Publication CISPR 22

Class B limits for frequencies higher than 1 GHz

Frequency range GHz	Average limit dB(μV/m)	Peak limit dB(μV/m)
1 to 3	56	76
3 to 6	60	80
NOTE: The lower limit applies at the transition frequency.		

OBS.: Limit levels for emission measured at 3 meters

Publication CISPR 22

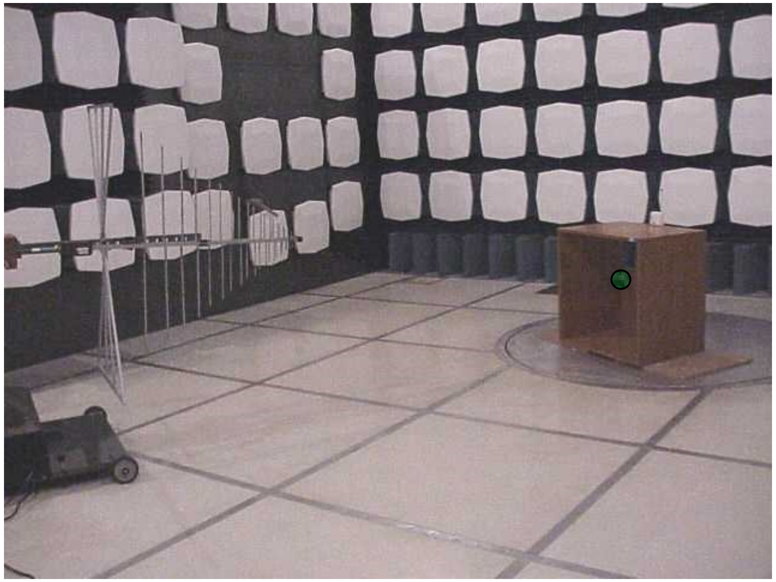
Class B limits for frequencies higher than 1 GHz

Frequency range GHz	Average limit dB(μV/m)	Peak limit dB(μV/m)
1 to 3	50	70
3 to 6	54	74
NOTE The lower limit applies at the transition frequency.		

OBS.: Limit levels for emission measured at 3 meters

Publication CISPR 22

Example of setup for radiated emission test



Electromagnetic disturbances immunity test

Electromagnetic immunity tests

Performance criteria (ITU-T K.43)

Criterion A – The equipment shall continue to operate as intended. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the equipment is used as intended. In some cases, the performance level may be replaced by a permissible loss of performance. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, then either of these may be derived from the product description and documentation and what the user may reasonably expect from the equipment if used as intended.

(for continuous phenomenon)

Electromagnetic immunity tests

Performance criteria (ITU-T K.43)

Criterion B – After the test, the equipment shall continue to operate as intended. No degradation of performance is allowed after the application of the phenomena below a performance level specified by the manufacturer, when the equipment is used as intended. In some cases, the performance level may be replaced by a permissible loss of performance. During the test, degradation of performance or loss of function is, however, allowed. No change of actual operating state or stored data is allowed. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, then either of these may be derived from the product description and documentation and what the user may reasonably expect from the equipment if used as intended.

(for no continuous phenomenon)

Electromagnetic immunity tests

Performance criteria (ITU-T K.43)

Criterion C – Loss of function is allowed, provided the function is automatically recoverable or can be restored by the operation of the controls by the user in accordance with the manufacturer's instructions.
Functions and information protected by a battery backup shall not be lost.

(for no continuous phenomenon)

Electromagnetic immunity tests

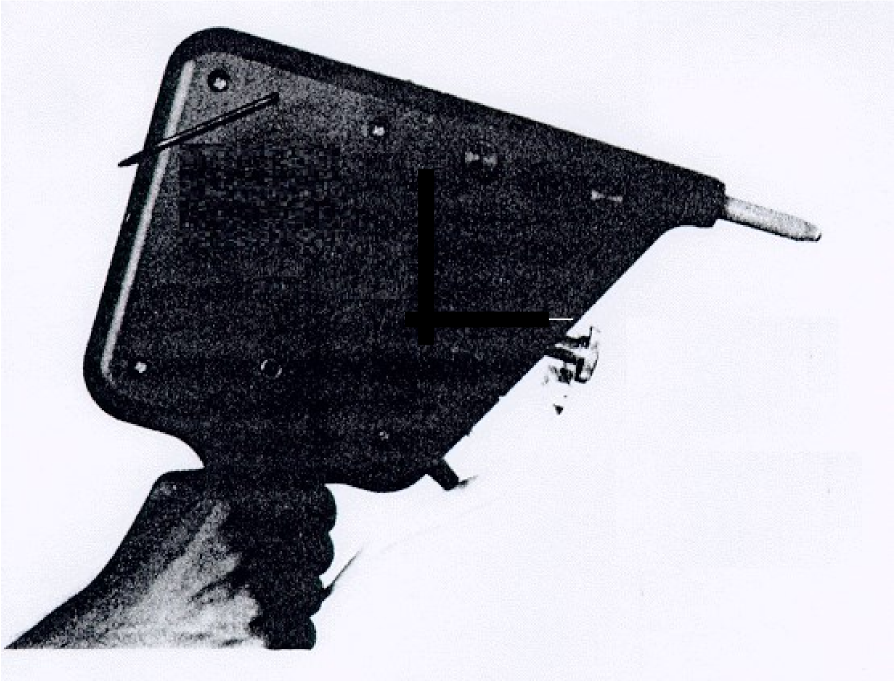
Electrostatic Discharge (ESD) immunity test according to IEC 61000-4-2

Severity level		
Test level		
Sev.	**Contact (kV)**	**Air (kV)**
1	2	2
2	4	4
3	6	8
4	8	15

Performance criterion B

Electromagnetic immunity tests

Example of test generator
(IEC 61000-4-2)

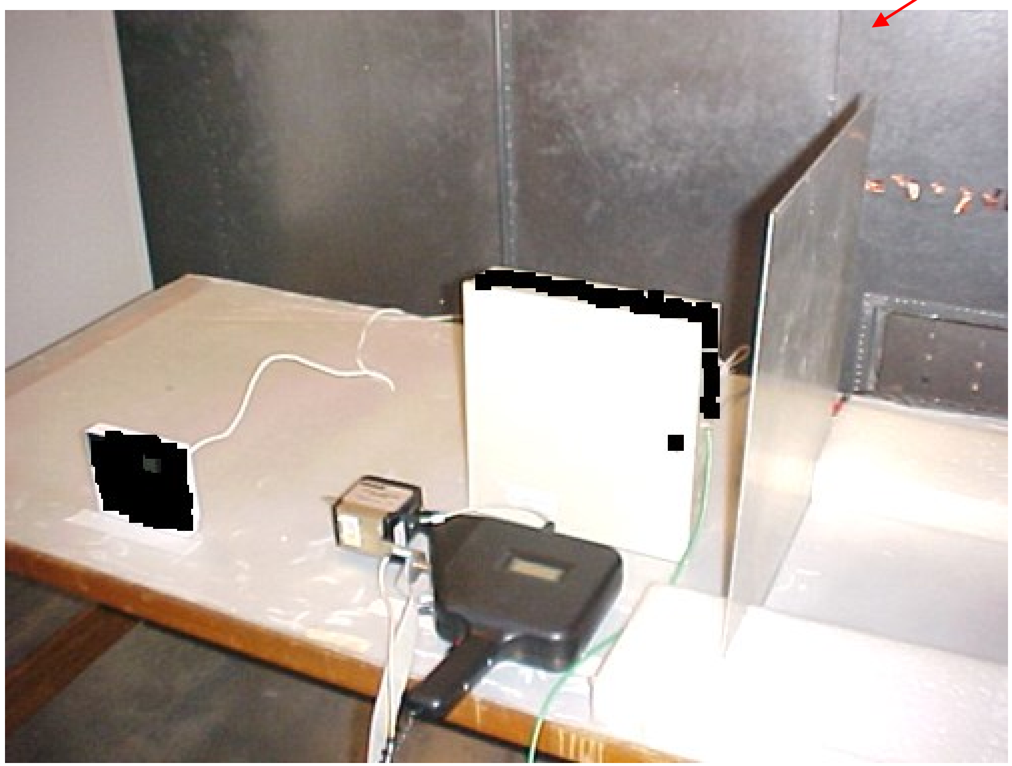


Electromagnetic immunity tests

Example of Test setup
(IEC 61000-4-2)

Vertical plane

Horizontal plane



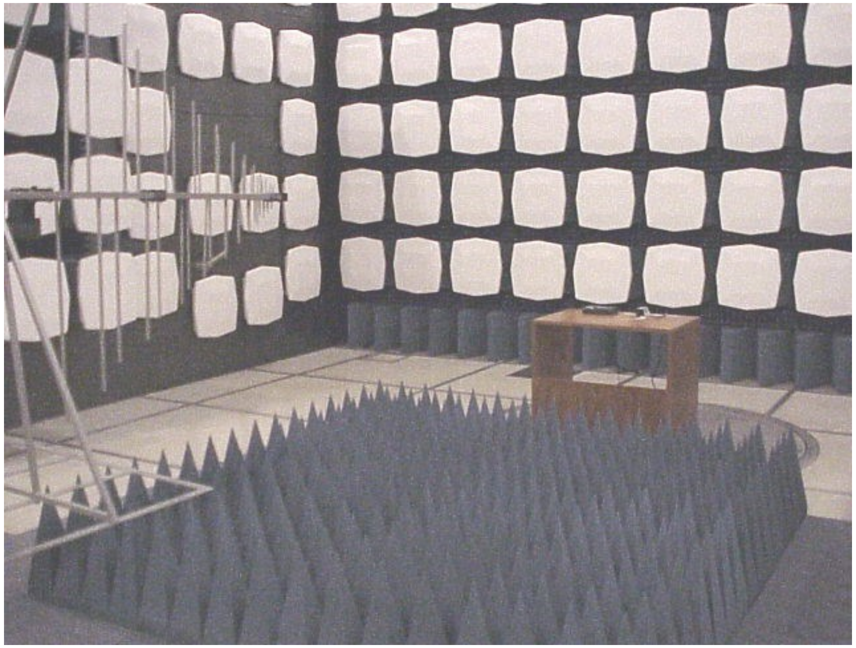
Electromagnetic immunity tests

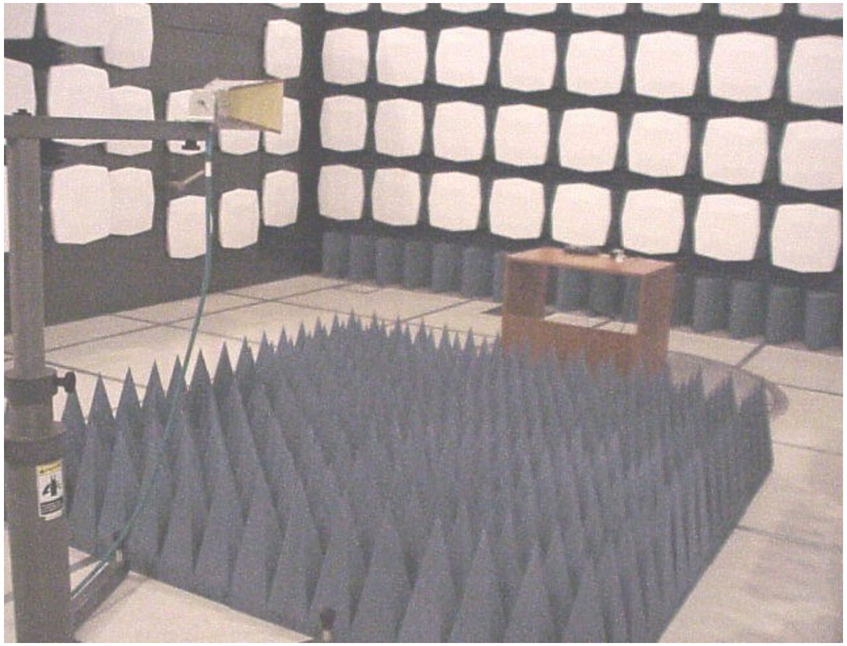
Radiated radio frequency immunity test according IEC 61000-4-3

Severity level	
Frequency range: 80 MHz - 1 GHz e 1,4 a 2 GHz Modulation *AM* 80% - 1 kHz	
Severity	**Field strength without modulation (V/m)**
1	1
2	**3**
3	10

Performance criterion A

Example of Test setup
(IEC 61000-4-3)





Electromagnetic immunity tests

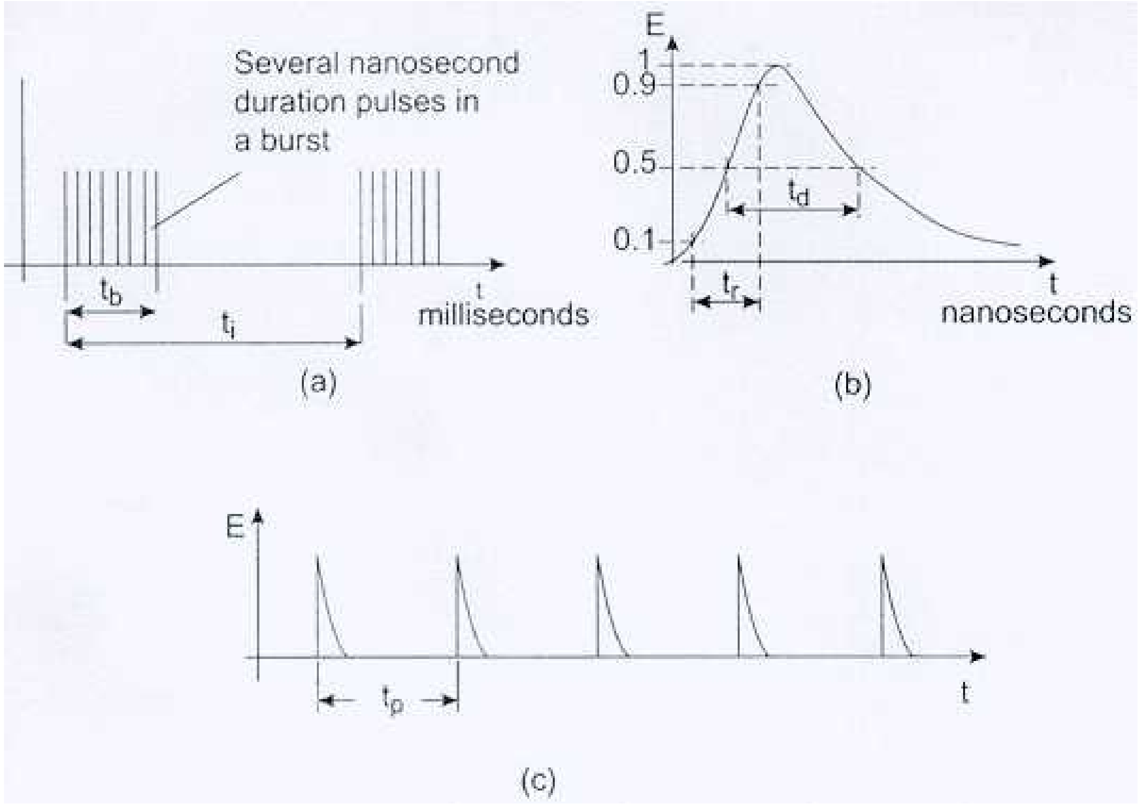
Electrical fast transient and burst immunity test
IEC 61000-4-4

Severity level		
tr/td: 5 ns/50 ns BURST: 15 ms/300 ms		
Open circuit output voltage		
Sev.	**Power supply lines (kV)**	**Signal lines (kV)**
1	0,5	0,25
2	**1**	**0,5**
3	2	1
4	4	2

Performance criterion B

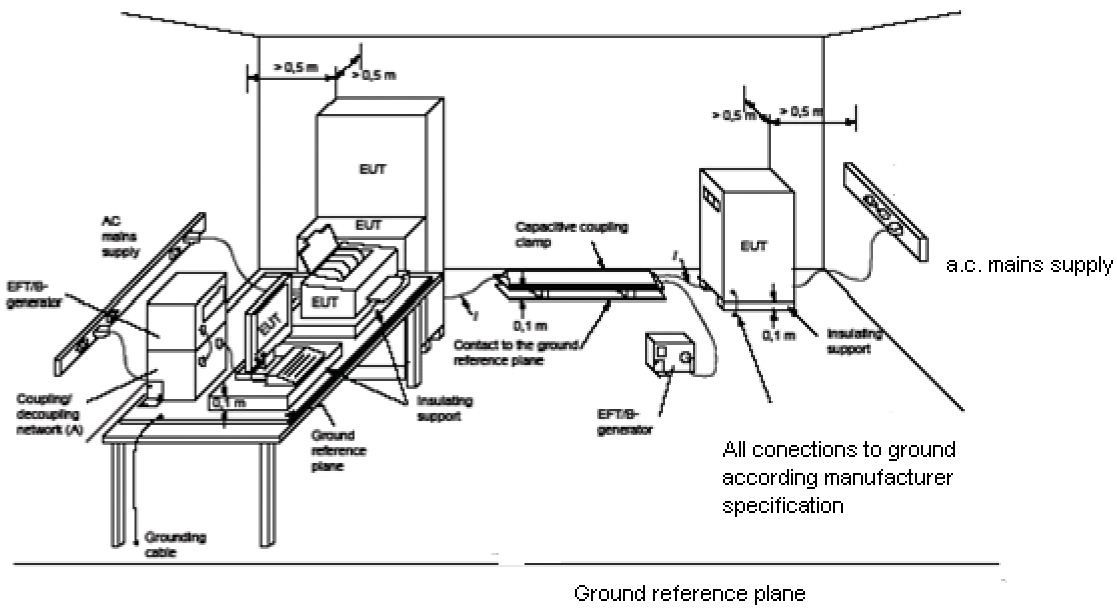
Electromagnetic immunity tests

Waveform according the IEC 61000-4-4



Electromagnetic immunity tests

Example of Test setup (IEC 61000-4-4)



Electromagnetic immunity tests

Example of Test setup (IEC 61000-4-4)

Electromagnetic immunity tests

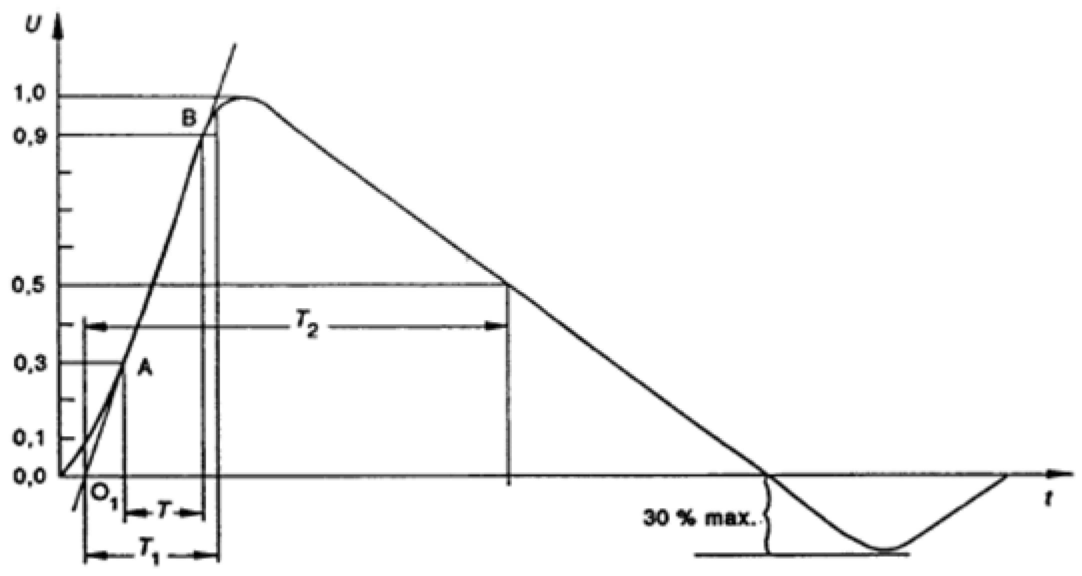
Surge immunity test
IEC61000-4-5

- Some combined wave generator characteristics
  - output voltage with open circuit and output current with short circuit shall be according the specification
  - test levels: **0.5; 1.0, 2.0, y 4 Kv**
  - polarity: positive and negative
  - line to line (differential mode) and line to ground

- **Performance criterion B**

Electromagnetic immunity tests

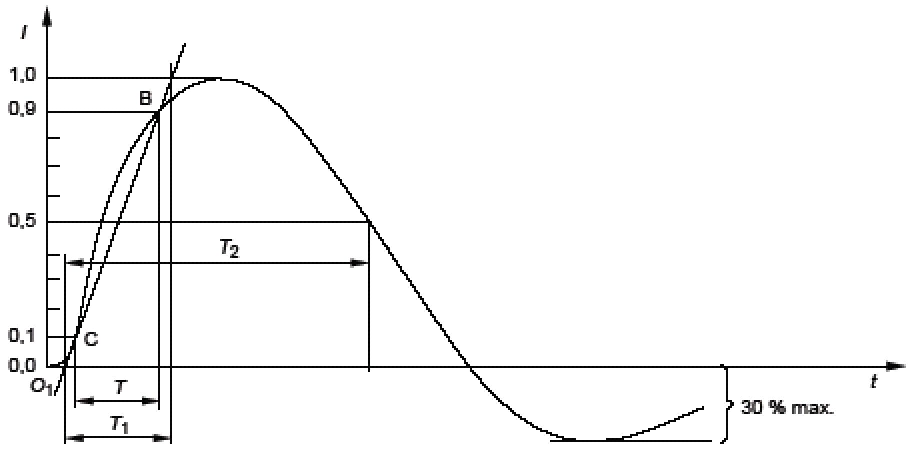
Waveform of open-circuit voltage (1,2/50 μs) (IEC 61000-4-5)



T_{1} = 1,2 μs ± 30 % and T_2=50 μs ± 20 %

Electromagnetic immunity tests

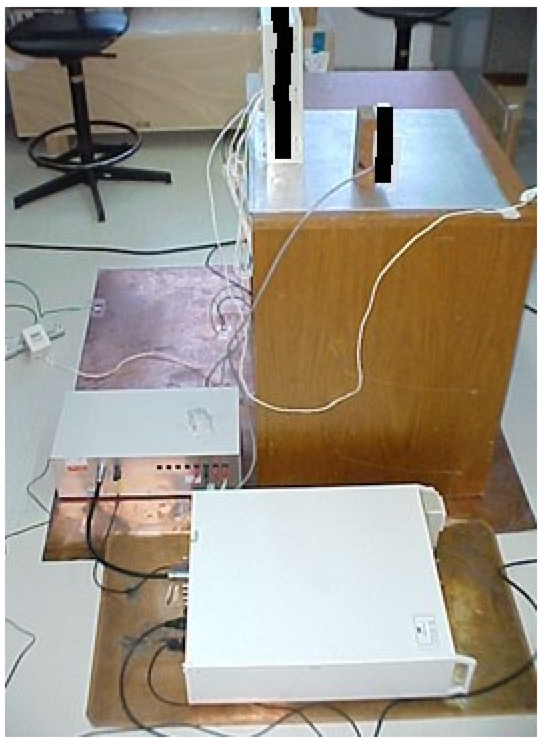
Waveform of short-circuit current (8/20 μs) (IEC 61000-4-5)



T_1 = 8 μs ± 30 % and T_2= 20 μs ± 20 %

Electromagnetic immunity tests

Example of Test setup
(IEC 61000-4-5)



Electromagnetic immunity tests

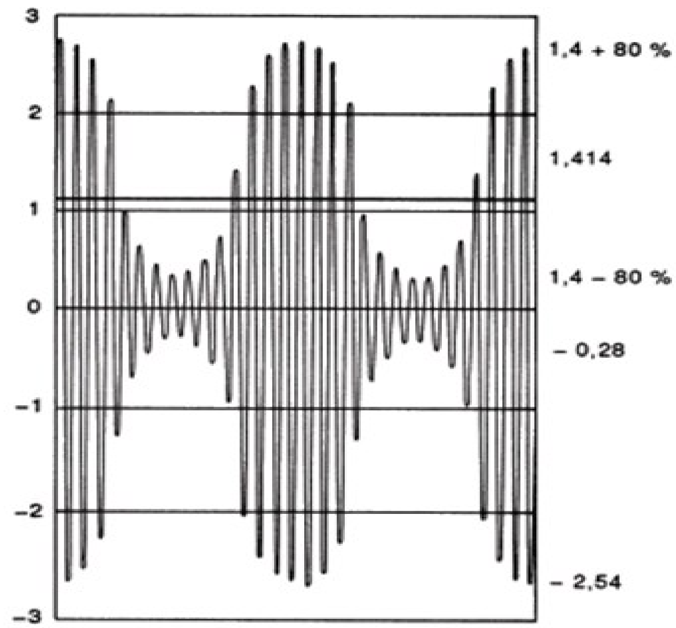
Immunity to conducted RF disturbances
IEC 61000-4-6

Test Levels
Frequency range: 0.15 - 80 MHz
RMS Value without Modulation (V)
1 **3** 10

Performance criterion A

Electromagnetic immunity tests

Waveform according to IEC 61000-4-6



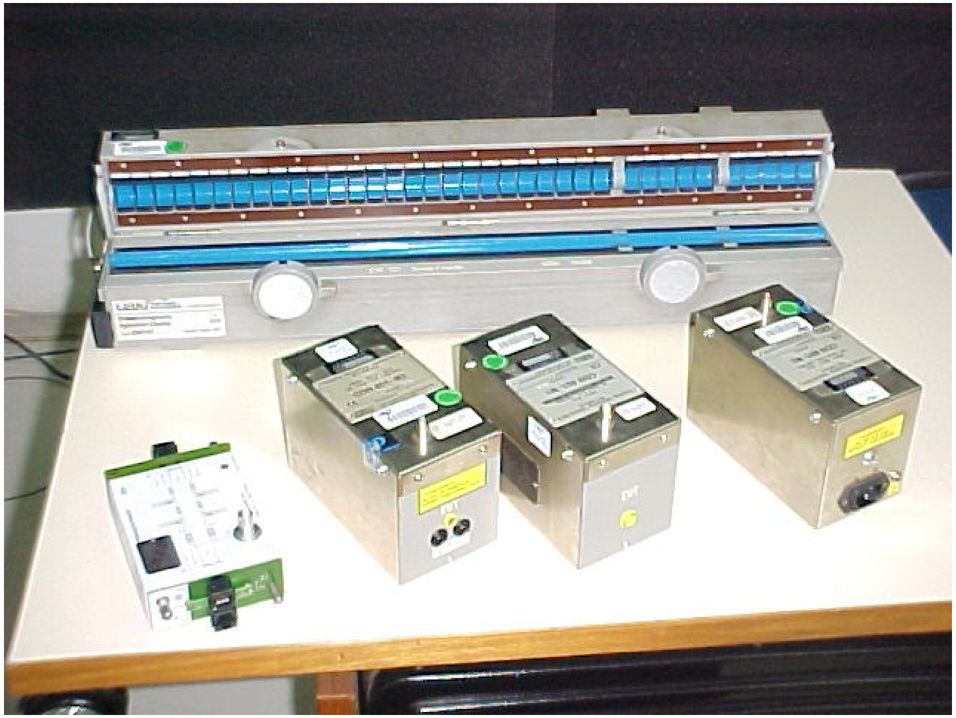
Tests are done with modulated RF signal 80% AM
Urms (s/mod) = 1 V Upp = 5,09 V Urms = 1,12 V

Electromagnetic immunity tests

Example of Test setup (IEC 61000-4-6)

Electromagnetic immunity tests

Coupling devices



Electromagnetic immunity tests

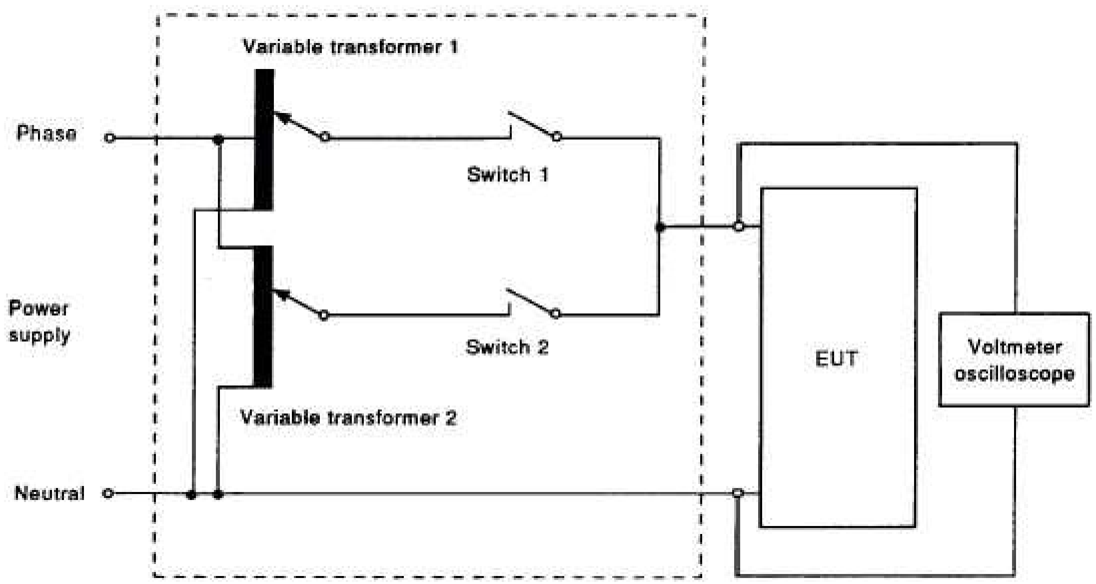
Voltage dips, short interruptions and voltage variations immunity on a.c. (IEC 61000-4-11)

Severity level	Reduction	Duration periods/cicles
1	> 95 %	0,5
2	30 %	25
3	> 95 %	250

Limits according to Resolution 442 ANATEL

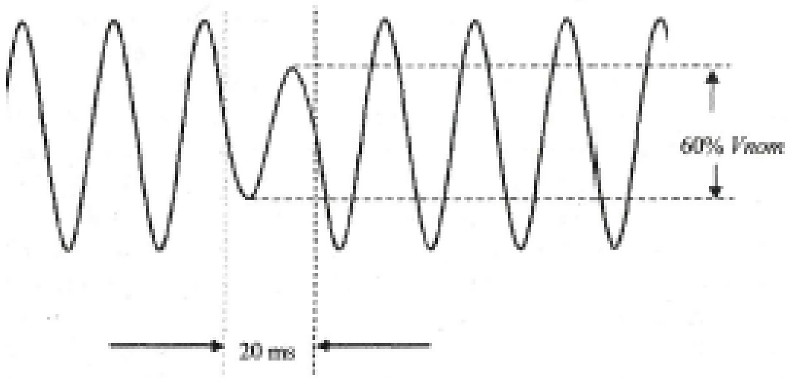
Electromagnetic immunity tests

Voltage dips, short interruptions and voltage variations immunity tests (IEC 61000-4-11)

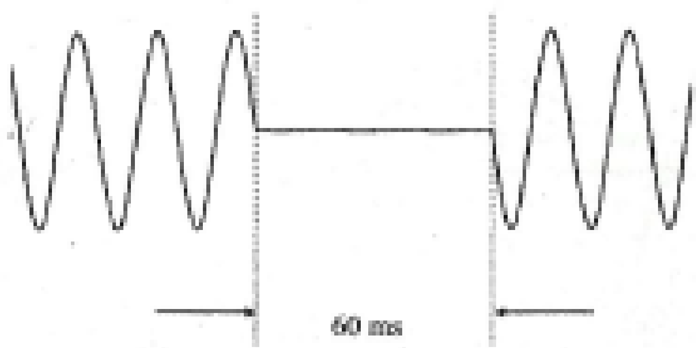


Electromagnetic immunity tests

Voltage dips, short interruptions and voltage variations immunity tests (IEC 61000-4-11)



Voltage Dip



Voltage Interruption

Electromagnetic immunity tests

Example of Test setup (IEC 61000-4-11)

Schedule

Basic concepts on IMT technologies and other mobile radiocommunication technologies

Standards and test specifications for mobile terminals

Aspects regarding Specific Absorption Rate (SAR) Testing

Aspects regarding EMC Testing

Aspects regarding Safety Testing

ISO/IEC 17025 accreditation - measurement uncertainty - calibration

Need of safety requirements for telecom equipment

In a rainy Christmas eve, a 19 years old boy took his mobile phone to make a call in a small rural Brazilian community.

As the telephone battery was flat, he plugged the charger into the wall mains outlet to proceed with the call.

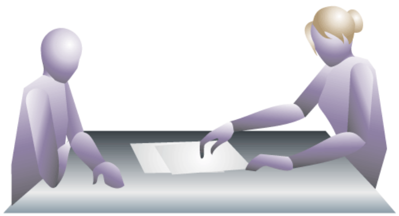
At this moment, he got an electric shock and was thrown away. He was taken to a hospital, but did not make it.

The legist reported death by electrocution and indicated burns from electricity in his ear and feet.

Need of safety requirements for telecom equipment

This event contributed to the reinforcement of a compulsory certification process for telecommunication equipment by the Brazilian Telecommunication Authority (Anatel):

- The safety requirements are based on ITU-T Recommendations and IEC Standards.
- Requirements other than safety are also included in the certification process (e.g., EMC and functional requirements).
- The certification process was successfully implemented several years ago and guarantees that unsafe and poorly-designed equipment will not have access to the Brazilian market.



Need of safety requirements for telecom equipment

Power supplies for ADSL modems that look alike from the outside,

but a surge protective component is missing in one of them ...

The black-box concept

Some standards give requirements for the devices and materials contained within the equipment.

- These standards are useful for the manufacturer in order to make a standard-complying product.

On the other hand, some standards give guidance on how to assess the equipment characteristics from tests carried out regardless of the equipment contents.

- These standards treat the equipment as a "black-box", as they are concerned only with its external interfaces.
- The black-box standards are useful for test houses in order to assess the conformity of a finished product with the standard.

Overview of international safety standards

The IEC 60950 series: Information technology equipment – Safety

In general, this standard is NOT a black-box standard.

Part 1 (2005): General Requirements

Although not being a black-box standard, it contains several important provisions that can be tested from outside the equipment. The most relevant are:

- Electric shock from mains under normal operating condition ("Touch current and protective conductor current")
- Electric shock from mains under overvoltage condition ("Electric strength")
- Electric shock from telecommunication lines ("Protection of equipment users from overvoltages on telecommunication networks")
- Equipment overheating

Overview of international safety standards

ITU-T K.21 (2015): Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents

This is a black-box standard. Although it addresses the resistibility of telecom equipment, it contains an important test for the prevention of fire from accidental contacts between power and telecom lines.

ITU-T K.20 (2015): Resistibility of telecommunication equipment installed in a telecommunications centre to overvoltages and overcurrents

This is a black-box standard. Similarly to K.21, it also contains an important test for the prevention of fire from accidental contacts between power and telecom lines.

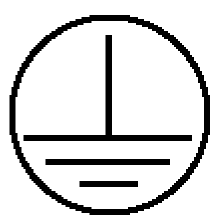
Electric shock from mains (normal operating condition)

A telecom equipment powered by the local mains must be tested for risk of electric shock under normal operating conditions (IEC 60950-1).

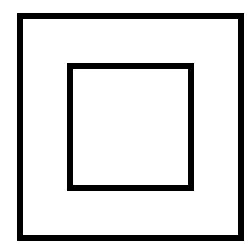
The test requirements depend on the class of equipment considered:

- Class I: Equipment for which the protection against electric shock relies on Basic Insulation and on the equipment grounding. This type of equipment must have a grounding terminal.
- Class II: Equipment for which the protection against electric shock relies on Double Insulation. This type of equipment does not have a grounding terminal.

Class I symbol



Class II symbol



Electric shock from mains (normal operating condition)

Typical Class I (left hand-side) and Class II (right hand-side) power supplies for ADSL modems.

In Class I power supplies, the ground pin (PE) is usually connected to the external conductor of the DC connector and the mains pins are single-insulated from the DC connector.

In Class II power supplies, the mains pins are double-isolated from the DC connector.

Electric shock from mains (normal operating condition)

When powered with its rated voltage, the RMS leakage current to ground must be within the limits of the table below:

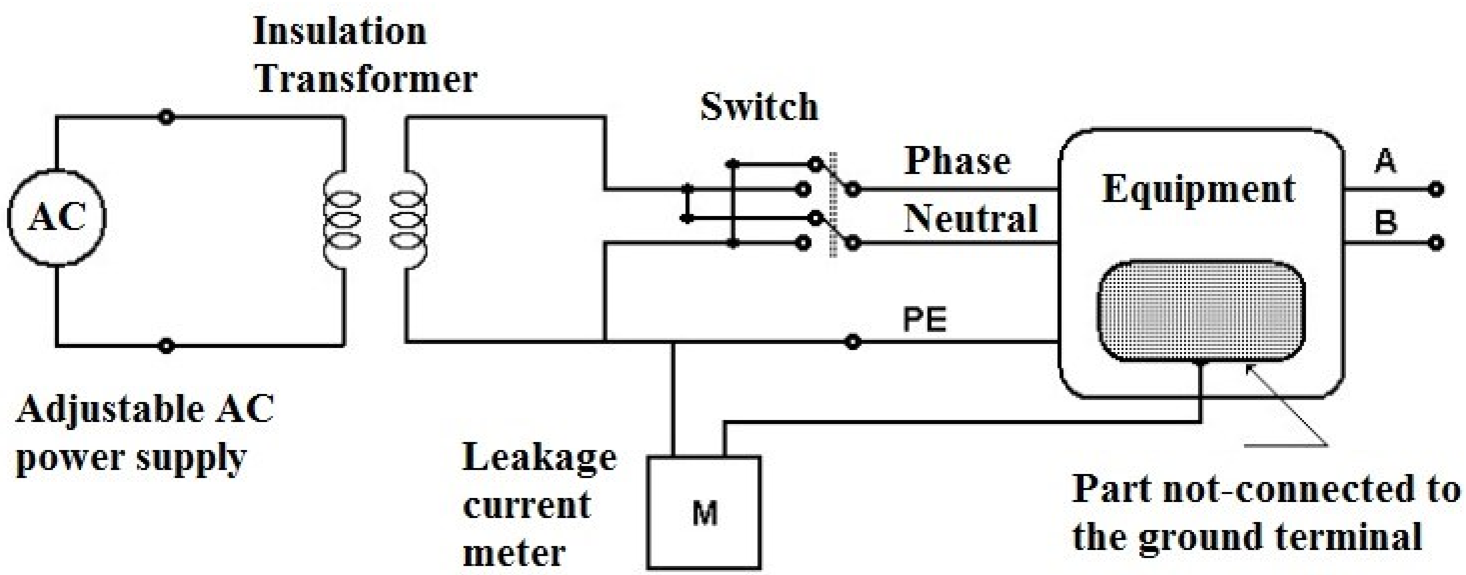
Class	Type of use	Parts not connected to the ground terminal	Parts connected to the ground terminal
I	Hand-held	0.25 mA	0.75 mA
	Non hand-held	0.25 mA	3.5 mA
II	All	0.25 mA	Not applicable

Typical hand-held equipment: mobile telephone when used with the charger

Typical non hand-held equipment: ADSL modem

Electric shock from mains (normal operating condition)

Class I and Class II equipment shall be tested according to the figure below, for the two positions of the switch.



The leakage current meter is the one shown in the previous slide.

Note: for Class II equipment, the PE conductor does not exist.

Electric shock from mains (normal operating condition)

In order to measure the leakage current from the non-grounded metallic parts, the test finger shown below shall be used:

The test finger shall search all exposed metallic parts of the equipment, including connectors and those parts that can be assessed by inserting the test finger into ventilation holes.

The test finger is intended to simulate the finger of a child that is touching the equipment.

Electric shock from mains (overvoltage condition)

A telecom equipment powered by the local mains must be tested for risk of electric shock under abnormal operating conditions. This condition is represented by the application of a relatively high-voltage at the equipment mains port without causing insulation breakdown. The test voltage can be AC or DC and depends on the equipment rated voltage and class (IEC 60950-1):

Rated Voltage (AC RMS)	Test Voltage (AC or DC)	Class I	Class II
Up to 148 V	AC	1000 V	2000 V
	DC	1414 V	2828 V
Above 148 V up to 297 V	AC	1500 V	3000 V
	DC	2121 V	4242 V

Note: This test is referred as Electric Strength in IEC 60950-1

Electric shock from mains (overvoltage condition)

The test voltage is raised gradually from zero up to its final value, and shall be maintained for 60s.

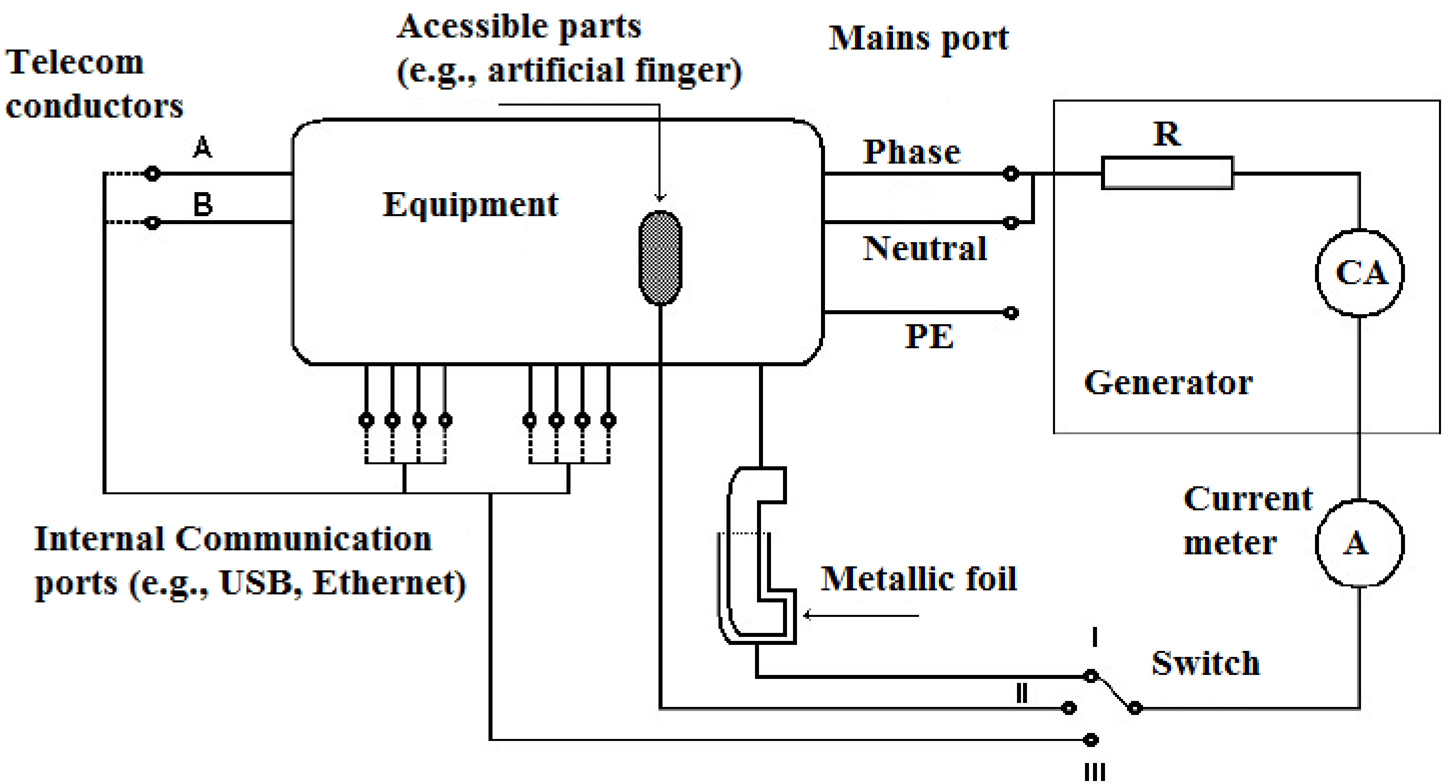
The equipment is approved in the test if there is no insulation breakdown.

Insulation breakdown is considered to have occurred when the current that flows as a result of the application of the test voltage rapidly increases in an uncontrolled manner, that is the insulation does not restrict the flow of the current. Corona discharge or a single momentary flashover is not regarded as insulation breakdown.

In order to avoid any subjectivity in the evaluation of the test outcome, Anatel Res.529 prescribes that the current through the equipment shall not be higher than 10mA RMS

Electric shock from mains (overvoltage condition)

The test shall be carried out with the wires of the equipment intended to be connected to the mains (e.g., phase and neutral) shorted together to form one terminal. The other terminal is related to the exposed parts of the equipment, as shown in the figure below.



Electric shock from mains (overvoltage condition)

Example of test using the artificial finger to inspect through the ventilation holes of a telecommunication equipment.

A small spark can be seen at the tip of the artificial finger, which indicates insulation breakdown and failure in the test.

In this case, energized parts were too close to the ventilation holes and led to a dangerous situation.

Electric shock from telecom lines

A telecom equipment powered by the local mains must be tested for risk of electric shock due to overvoltages coming from the telecom lines that run in the outside plant. The test voltages are given below (IEC 60950-1):

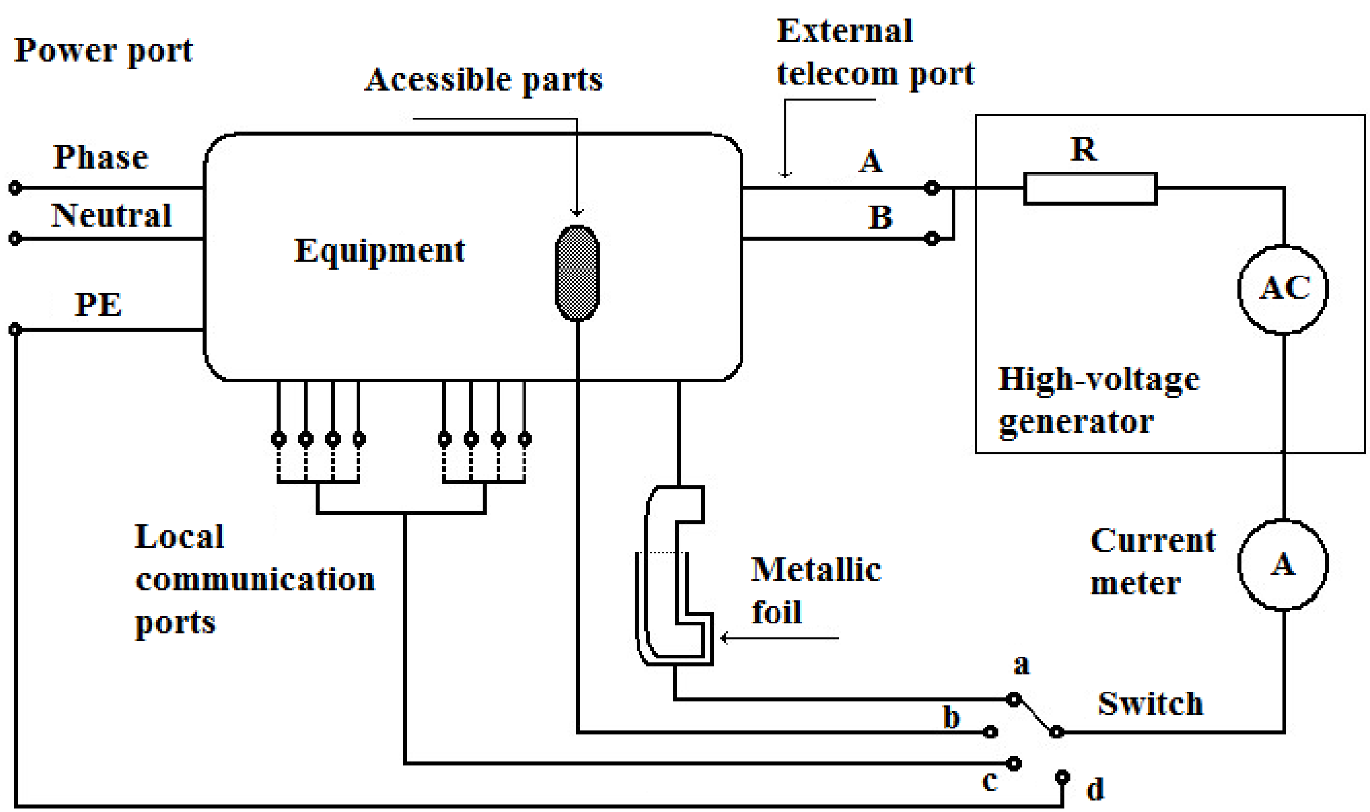
Test configuration	Test Voltage	
	AC (RMS)	DC
PE or ground terminal (if any)	1500 V	2121 V
Parts held or touched during use	1500 V	2121 V
Parts accessible by the test finger or hand	1000 V	1414 V
Parts connected to other equipment	1000 V	1414 V

If capacitors are bridging the insulation, the DC test is preferred.

Electric shock from telecom lines

The test diagram is shown below, where the switch positions mean:

- (a) Parts held or touched during normal use
- (b) Parts accessible by the test finger or test hand
- (c) Parts connected to other equipment
- (d) PE or ground terminal (if any)



Electric shock from telecom lines

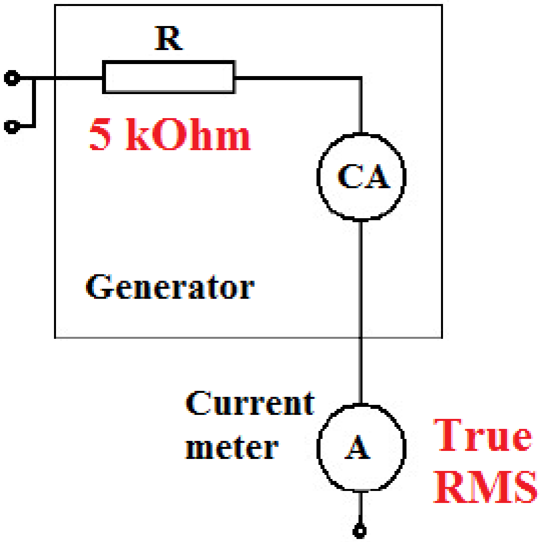
The test voltage is raised gradually from zero up to the specified voltage level.

The test voltage is maintained at the specified level for 60 seconds.

The equipment pass the test if no breakdown occur.

In order to detect the breakdown, it is recommended to monitor the test current and use the threshold value of 10 mA to indicate breakdown of insulation.

A true-RMS current meter is required for the test.



Fire hazard

A telecom equipment must withstand the application of 230 V (RMS) on its external telecom port without creating a fire hazard (ITU-T K.20, K.21, and K.45).

The test shall be carried out in common-mode (lines to ground) and differential-mode (between lines).

The test shall be repeated for 8 (eight) values of the generator short circuit current, as given below:

Sequence	Current (A)
1	0.23
2	0.38
3	0.72
4	1.40

Sequence	Current (A)
5	2.90
6	5.75
7	11.5
8	23.0

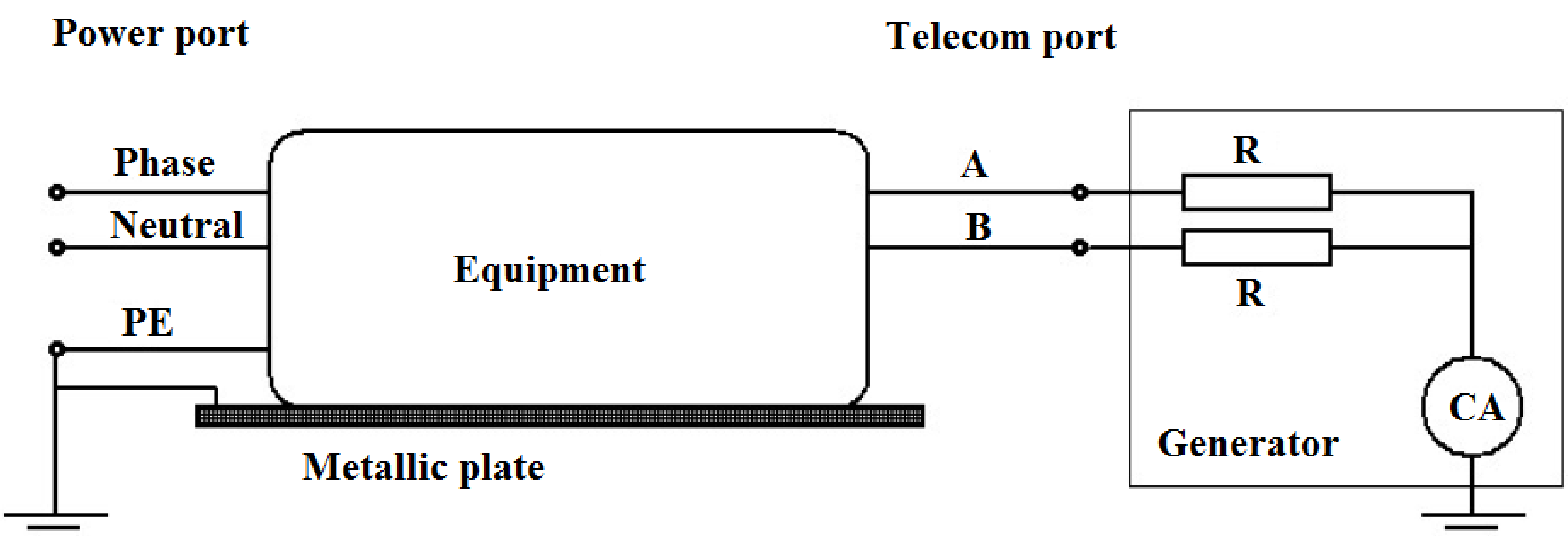
The current specified above is per each line of the equipment, i.e., for a common-mode test in a telecom twisted pair, the generator shall supply twice the values in the table.

Fire hazard

The equipment shall be placed above a metallic plate for the test, which shall be bonded to the PE conductor and grounded.

The generator short-circuit current shall be obtained by the use of series resistors. Series capacitors or inductors are not allowed.

The figure below illustrates the common-mode test configuration.

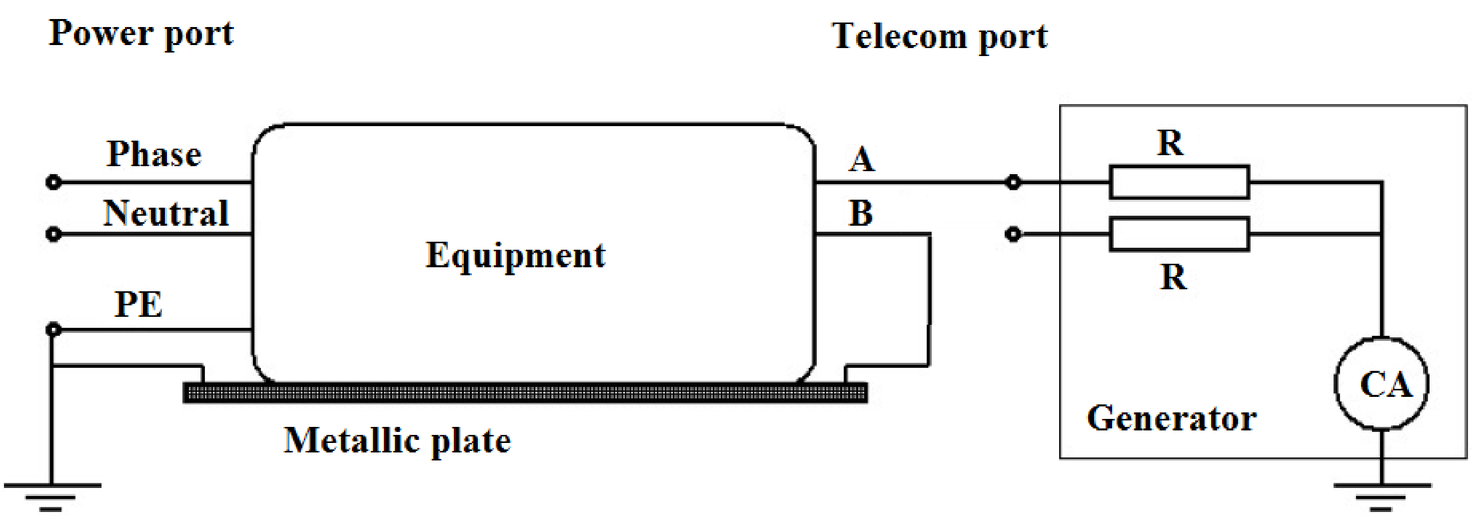


Fire hazard

The identification of fire hazard is made by visual inspection, based on the appearance of flames during the test.

The equipment is not expected to be operational during or after the test, i.e., it can be damaged but cannot catch fire.

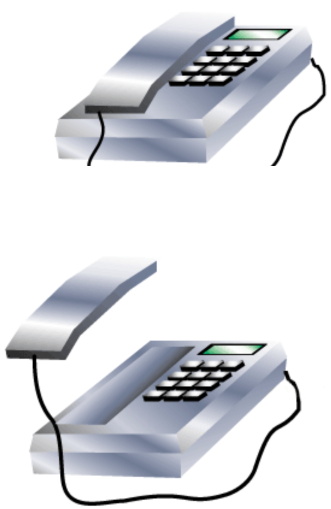
The figure below illustrates the differential-mode test configuration.



Fire hazard

The test duration shall be 15 minutes for each current level (sequence). The test shall be interrupted if the equipment catches fire during the test.

If the equipment has a switch in series with the telecom wires, the test shall be carried out for both switch positions (e.g., on-hook and off-hook conditions of a telephone set).



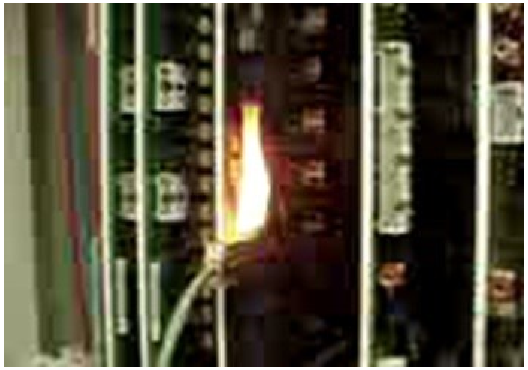
Equipment catching fire during the test.

Fire hazard

The reason of having 8 currents for the test is the possibility of blind-spots in the equipment, which means that the higher current test is not necessarily the worst case.

Currents up to 0.72 A: no effect

Current at 1.40 A: some smoke appears



Current at 2.90 A: flames come out

Current at 5.75 A and above: no effect

Acoustic shock

Telecommunication equipment that has an acoustic output and is connected to a wired line (e.g., plain-old telephone set – POTS) must limit the maximum acoustic pressure delivered by its output (ITU-T P.360 and IEC 61672-1).

The limits of the acoustic pressure are given below:

Type	Excitation	Level
Transient	1.5 kV impulses 10/700 μs waveshape	135 dBA
Steady state	10 V sinusoidal signal at 1000 Hz	125 dBA
Normal use	Dialing	125 dBA

Note: dBA is decibel related to 20 μPa and weighted by the acoustic pressure weighting curve A

Acoustic shock

The dB level is calculated as follows:

$$P(dB) = 10\log_{10}\frac{P_m}{P_r}$$

$P(dB)$ is the measured acoustic pressure in Decibels

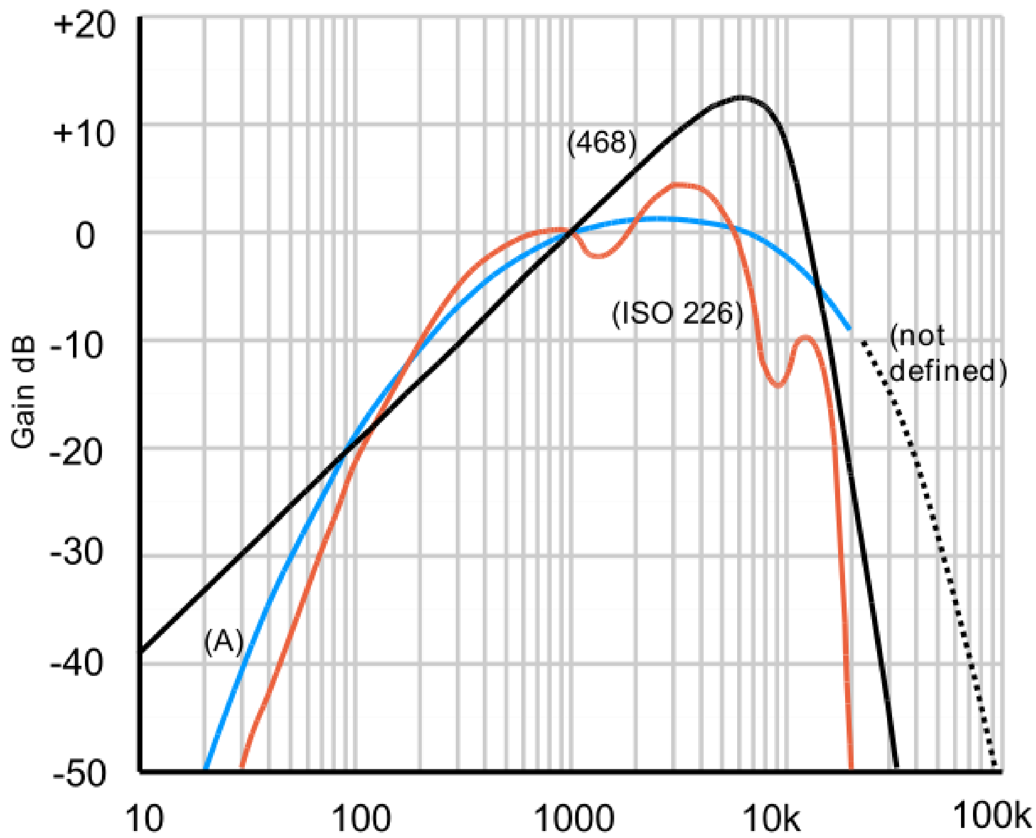
P_m is the measured acoustic pressure in micro-Pascal (µPa)

P_r is the reference acoustic pressure (e.g., 20 µPa)

The electrical excitations are applied to the wired telecommunication lines:

Acoustic shock

Comparison between sound-pressure weighting curves:



ITU- R 468 (blk), A-weighting (blue), and inverse ISO 226 (2003) (red)

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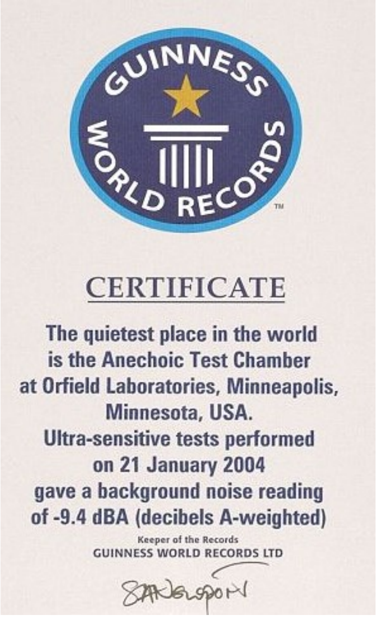
Acoustic shock

The evaluation of the acoustic sound produced by the ear set shall be carried out in a silent environment. However, a full-scale acoustic anechoic chamber (silence chamber) is not necessary. It is sufficient to have a box having its internal walls covered with sound-absorbing material.



Equipment overheating

The absolute equipment temperature shall not exceed the values of the table below (IEC 60950-1):

Accessible parts	**Maximum temperature (ºC)**		
	Metal	Glass, porcelain and vitreous material	Plastic and rubber
Parts held or touched for short periods of time	60	70	85
Parts continuously held or touched during normal use	55	65	75
External surfaces that may be touched	70	80	95
Parts inside the equipment that may be touched	70	80	95

9. Equipment overheating

The difference between the equipment temperature and the ambient temperature shall not exceed the values of the table below (Anatel Res. 529):

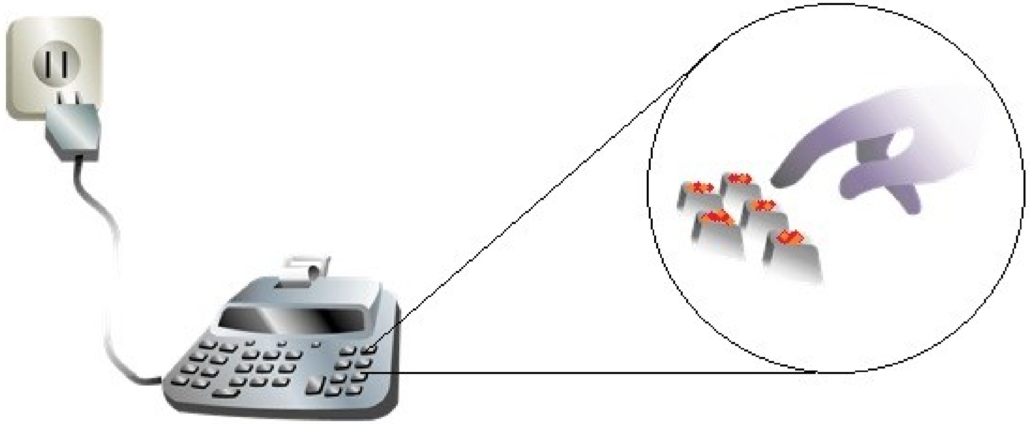
Equipment part	Metallic Surface	Non-metallic surface
Held or frequently touched during normal use	30 ºC	40 ºC
Not held but eventually touched during normal use	45 ºC	55 ºC

Note: The table above has been adapted by Anatel Res.529 from the previous one (from IEC 60950-1) by assuming a 25 ºC ambient temperature and unifying some conditions. It is more convenient for equipment testing, as the test result does not depend on the ambient temperature of the laboratory.

9. Equipment overheating

The equipment shall be turned on and put into operation until its temperature stabilizes:

- Equipment with a single rated voltage shall be powered with its rated voltage.
- Equipment with more than one rated voltage shall be tested at each one of its rated voltages.
- Equipment with a rated voltage range shall be tested at the lower and upper limits of its rated voltage range.



Conclusions

1. Telecommunication equipment must be designed in order to assure the safety of the users and its installations.

2. A certification program is necessary in order to assure that the manufacturer will implement into the equipment the needed protective procedures and devices.

3. In general, the most relevant safety tests are easily implemented in a test house, requiring low investment in testing equipment and personal training.

Schedule

Basic concepts on IMT technologies and other mobile radiocommunication technologies

Standards and test specifications for mobile terminals

Aspects regarding Specific Absorption Rate (SAR) Testing

Aspects regarding EMC Testing

Aspects regarding Safety Testing

ISO/IEC 17025 accreditation - measurement uncertainty - calibration

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.**

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

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.

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

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

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

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 shall 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 shall be identified and its calibration status fixed 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. ILAC members can be used.
- The laboratory shall have an established plan 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

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

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.**

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

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.**

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

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.

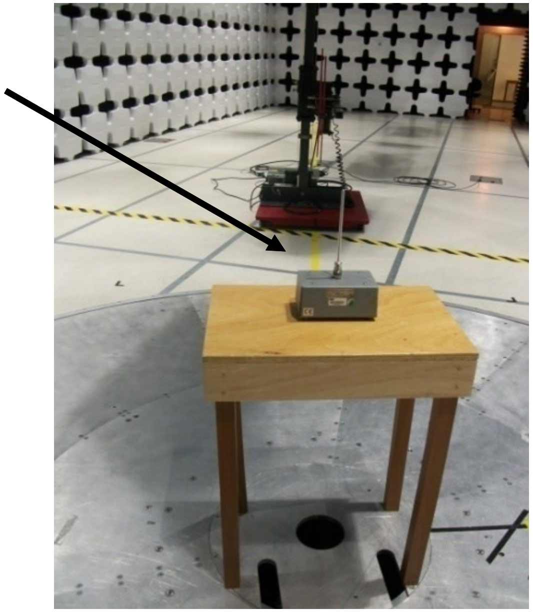
Quality control data shall be analyzed and, where they are found to be outside pre-defined criteria, a planned action shall be taken to correct the problem

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

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

Technical requirements

5.10 Reporting the results (cont.)

- 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

Basic Concepts for Calculating Measurement Uncertainty

Basic Concepts for Calculating Measurement Uncertainty

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

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

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

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.

- Value obtained by a perfect measurement
- 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.

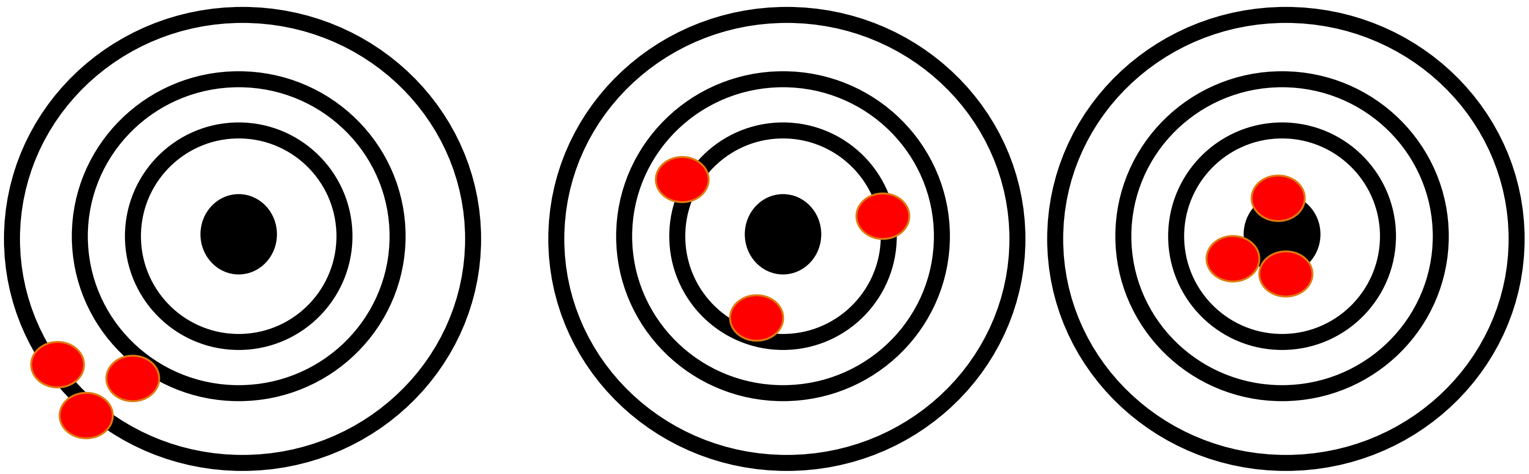
Note 1 – The concept 'measurement accuracy' is not a quantity and is not given a numerical quantity value. A measurement is said to be more accurate when it offers a smaller measurement error.

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

Accuracy x Precision



Good precision
Bad accuracy

Good accuracy
Bad precision

Good accuracy
Good precision

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

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.

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:

x_i

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

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

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.

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

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

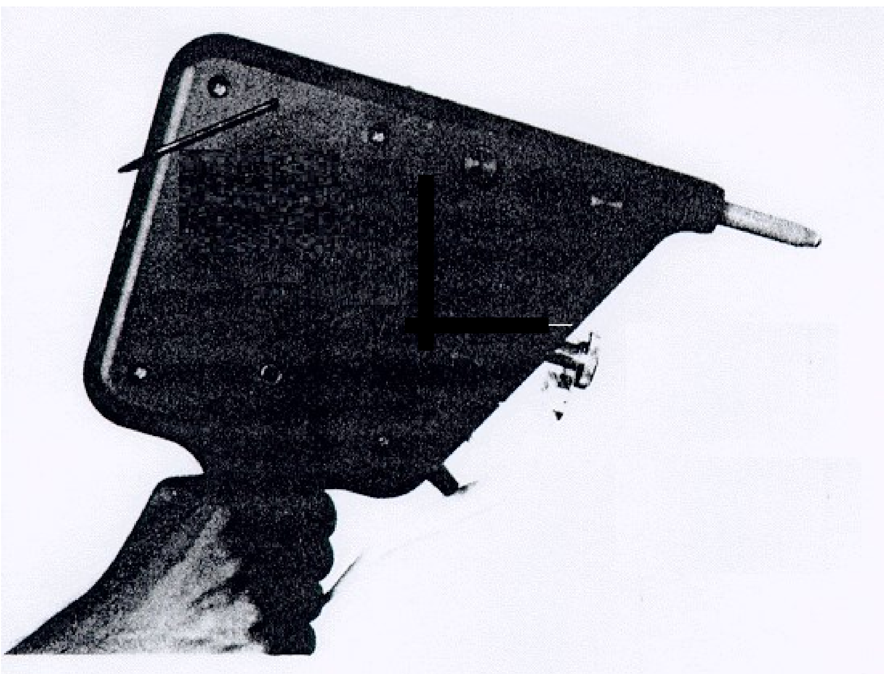
This is called type-A uncertainty standard, taking into consideration an adequate n number of observations.

For statistical reliability, n>10.

√2

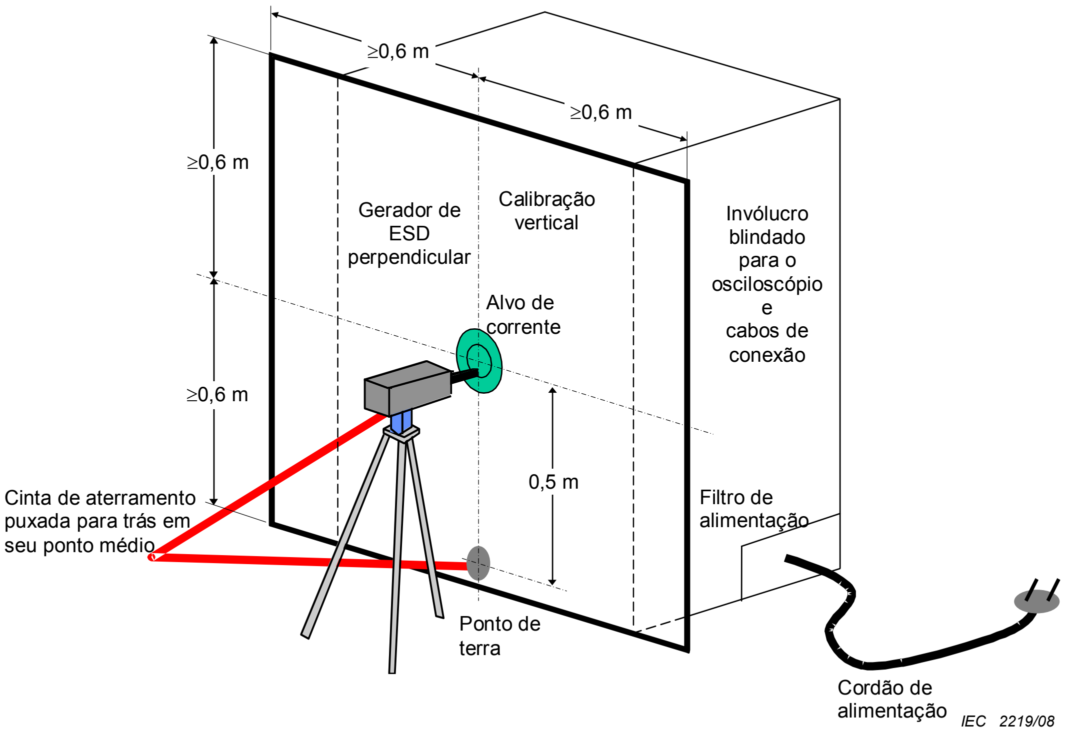
Peak ESD Current Calibration – Type-A Evaluation IEC 61000-4-2 Example

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



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

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



Peak ESD Current Calibration
Type-A Evaluation

Nominal Voltage	Adjusted Level	
	Corrected value	Reading
No of the discharge	**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
average	7989	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.

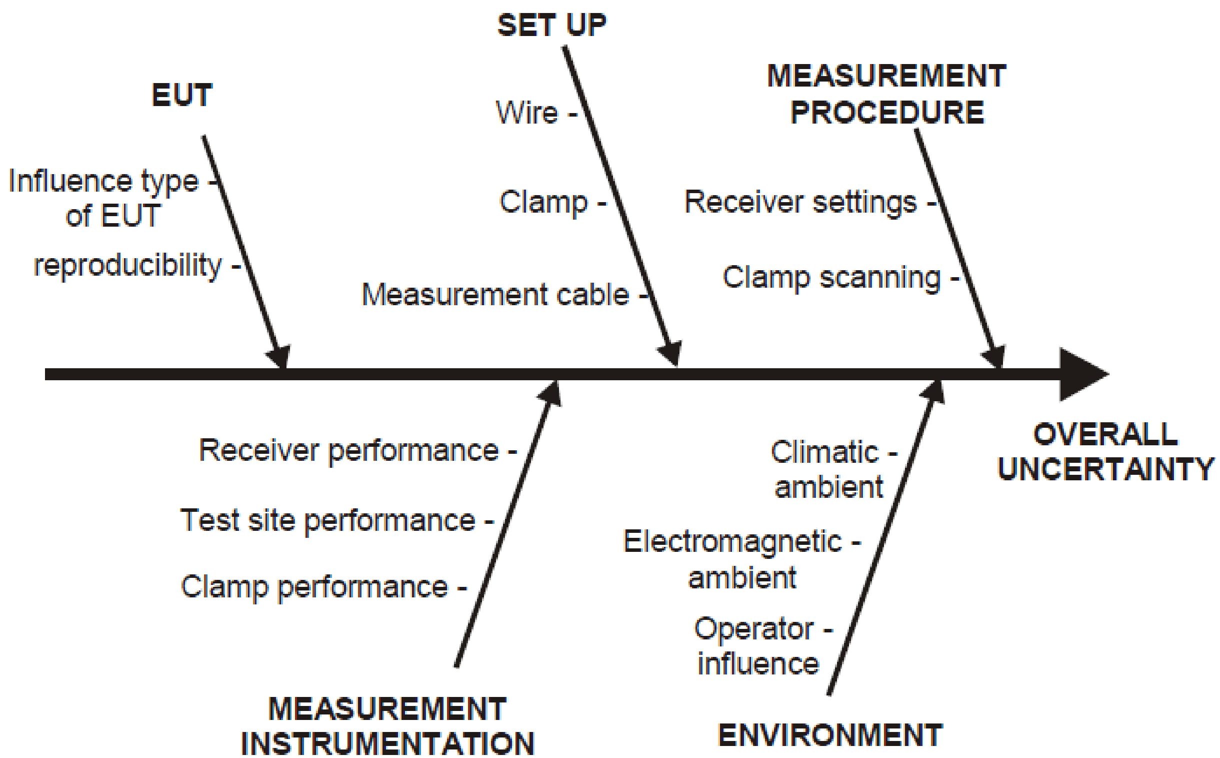
EXAMPLES: Evaluation based on information:

x_i

- 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

Measurement uncertainty components



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 shall 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

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**		**$u(x_i)$**	**c_i**	**$c_i\ u(x_i)$**
	dB	Probability distribution	dB	1	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**

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

$$u_c(x)=2{,}52 \quad dB$$

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

Basic Concepts for Calculating Measurement Uncertainty

PARTICULARLY IN THE CISPR (RADIO DISTURBANCE MEASUREMENT) APROACH

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:

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.*

Thank You!

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