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ElectroMagnetic Compatibility and Radio Spectrum Matters (ERM); Improvement of radiated methods of measurement (using test sites) and evaluation of the corresponding measurement uncertainties; Part 5: Striplines

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Foreword

This ETSI Technical Report (ETR) has been produced by the Electromagnetic compatibility and Radio spectrum Matters (ERM) Technical Committee of the European Telecommunications Standards Institute (ETSI).

ETRs are informative documents resulting from ETSI studies which are not appropriate for European Telecommunication Standard (ETS) or Interim European Telecommunication Standard (I-ETS) status. An ETR may be used to publish material which is either of an informative nature, relating to the use or the application of ETSs or I-ETSs, or which is immature and not yet suitable for formal adoption as an ETS or an I-ETS.

The present document is part 5 of a multi-part Technical Report (ETR) covering Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement of radiated methods of measurement (using test sites) and evaluation of the corresponding measurement uncertainties, as identified below:

Part 1-1:   "Uncertainties in the measurement of mobile radio equipment characteristics; Sub-part 1: Introduction";

Part 1-2:   "Uncertainties in the measurement of mobile radio equipment characteristics; Sub-part 2: Examples and annexes";

Part 2:   "Anechoic chamber";

Part 3:   "Anechoic chamber with a ground plane";

Part 4:   "Open area test site";

Part 5:   "Striplines";

Part 6:   "Test fixtures";

Part 7:   "Artificial human beings".

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1 Scope

This ETR covers the methods of radiated measurements on mobile radio equipment in Stripline test facilities and applies to the assessment of the associated measurement uncertainties.

This ETR also provides the methods of evaluation and calculation of the measurement uncertainties for each of the measured parameters.

2 References

Within this ETR the following references apply:

[1]   CCITT Recommendation O.41: "Psophometer for use on telephone-type circuits".

[2]   CCITT Recommendation O.153: "Basic parameters for the measurement of error performance at bit rates below the primary rate".

[3]   IEC 489-3 Appendix J 1988: "Methods of measurement for radio equipment used in the mobile services. Part 3: Receivers for A3E or F3E emissions".

[4]   EN 55020 (1994): "Electromagnetic immunity of broadcast receivers and associated equipment".

[5]   ETR 273-1-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement of radiated methods of measurement (using test sites) and evaluation of the corresponding measurement uncertainties; Part 1: Uncertainties in the measurement of mobile radio equipment characteristics; Subpart 1: Introduction".

[6]   ETR 273-1-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement of radiated methods of measurement (using test sites) and evaluation of the corresponding measurement uncertainties; Part 1: Uncertainties in the measurement of mobile radio equipment characteristics; Sub-part 2: Examples and annexes".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of this ETR, the following definitions apply:

Audio Frequency (**AF) load**: Normally a resistor of sufficient power rating to accept the maximum audio output power from the EUT. The value of the resistor is normally that stated by the manufacturer and is normally the impedance of the audio transducer at 1 000 Hz.

> NOTE 1:   In some cases it may be necessary to place an isolating transformer between the output terminals of the receiver under test and the load.

A-M1: A test modulation consisting of a 1 000 Hz tone at a level which produces a deviation of 12 % of the channel separation.

A-M2: A test modulation consisting of a 1 250 Hz tone at a level which produces a deviation of 12 % of the channel separation.

A-M3: A test modulation consisting of a 400 Hz tone at a level which produces a deviation of 12 % of the channel separation. This signal is used as an unwanted signal for analogue and digital measurements.

AF termination: Any connection other than the audio frequency load which may be required for the purpose of testing the receiver. (i.e. in a case where it is required that the bit stream be measured, the connection may be made, via a suitable interface, to the discriminator of the receiver under test).

> NOTE 2: The termination device is normally agreed between the manufacturer and the testing authority and details included in the test report. If special equipment is required then it is normally provided by the manufacturer.

antenna: That part of a transmitting or receiving system that is designed to radiate or to receive electromagnetic waves.

antenna factor: Quantity relating the strength of the field in which the antenna is immersed to the output voltage across the load connected to the antenna. When properly applied to the meter reading of the measuring instrument, yields the electric field strength in V/m or the magnetic field strength in A/m.

antenna gain: The ratio of the maximum radiation intensity from an (assumed lossless) antenna to the radiation intensity that would be obtained if the same power were radiated isotropically by a similarly lossless antenna.

bit error ratio: The ratio of the number of bits in error to the total number of bits.

combining network: A multipole network allowing the addition of two or more test signals produced by different sources for connection to a receiver input.

> NOTE 3: Sources of test signals are normally connected in such a way that the impedance presented to the receiver is 50 Ω. The combining networks are designed so that effects of any intermodulation products and noise produced in the signal generators are negligible.

correction factor: The numerical factor by which the uncorrected result of a measurement is multiplied to compensate for an assumed systematic error.

confidence level: The probability of the accumulated error of a measurement being within the stated range of uncertainty of measurement.

directivity: The ratio of the maximum radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions (i.e. directivity = antenna gain + losses).

DM-0: A test modulation consisting of a signal representing an infinite series of "0" bits.

DM-1: A test modulation consisting of a signal representing an infinite series of "1" bits.

DM-2: A test modulation consisting of a signal representing a pseudorandom bit sequence of at least 511 bits in accordance with CCITT Recommendation O.153 [2].

DM-3: A test signal agreed between the testing authority and the manufacturer in the cases where it is not possible to measure a bit stream or if selective messages are used and are generated or decoded within an equipment.

> NOTE 4: The agreed test signal may be formatted and may contain error detection and correction. Details of the test signal are be supplied in the test report.

duplex filter: A device fitted internally or externally to a transmitter/receiver combination to allow simultaneous transmission and reception with a single antenna connection.

error of measurement (absolute): The result of a measurement minus the true value of the measurand.

error (relative): The ratio of an error to the true value.

estimated standard deviation: From a sample of n results of a measurement the estimated standard deviation is given by the formula:

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

x_i being the ith result of measurement (i = 1,2,3, ...,n) and $\overline{x}$ the arithmetic mean of the n results considered.

A practical form of this formula is:

$$\sigma = \sqrt{\frac{Y - \frac{X^2}{n}}{n-1}}$$

Where X is the sum of the measured values and Y is the sum of the squares of the measured values.

extreme test conditions: Conditions defined in terms of temperature and supply voltage. Tests are normally made with the extremes of temperature and voltage applied simultaneously. The upper and lower temperature limits are specified in the relevant testing standard. The test report states the actual temperatures measured.

error (of a measuring instrument): The indication of a measuring instrument minus the (conventional) true value.

free field: A field (wave or potential) which has a constant ratio between the electric and magnetic field intensities.

free Space: A region free of obstructions and characterized by the constitutive parameters of a vacuum.

impedance: A measure of the complex resistive and reactive attributes of a component in an alternating current circuit.

impedance (wave): The complex factor relating the transverse component of the electric field to the transverse component of the magnetic field at every point in any specified plane, for a given mode.

influence quantity: A quantity which is not the subject of the measurement but which influences the value of the quantity to be measured or the indications of the measuring instrument.

intermittent operation: Operation where manufacturer states the maximum time that the equipment is intended to transmit and the necessary standby period before repeating a transmit period.

isotropic radiator: A hypothetical, lossless antenna having equal radiation intensity in all directions.

limited Frequency Range: The limited frequency range is a specified smaller frequency range within the full frequency range over which the measurement is made.

> NOTE 5: The details of the calculation of the limited frequency range are normally given in the relevant testing standard.

maximum permissible frequency deviation: The maximum value of frequency deviation stated for the relevant channel separation in the relevant testing standard.

measuring system: A complete set of measuring instruments and other equipment assembled to carry out a specified measurement task.

measurement repeatability: The closeness of the agreement between the results of successive measurements of the same measurand carried out subject to all the following conditions:

- the same method of measurement;
- the same observer;
- the same measuring instrument;
- the same location;
- the same conditions of use;
- repetition over a short period of time.

measurement reproducibility: The closeness of agreement between the results of measurements of the same measurand, where the individual measurements are carried out changing conditions such as:

- method of measurement;
- observer;
- measuring instrument;
- location;
- conditions of use;
- time.

measurand: A quantity subjected to measurement.

noise gradient of EUT: A function characterizing the relationship between the RF input signal level and the performance of the EUT, e.g., the SINAD of the AF output signal.

nominal frequency: One of the channel frequencies on which the equipment is designed to operate.

nominal mains voltage: The declared voltage or any of the declared voltages for which the equipment was designed.

normal test conditions: The conditions defined in terms of temperature, humidity and supply voltage stated in the relevant testing standard.

normal deviation: The frequency deviation for analogue signals which is equal to 12 % of the channel separation.

psophometric weighting network: As described in CCITT Recommendation O.41 [1].

polarization: For an electromagnetic wave, the figure traced as a function of time by the extremity of the electric vector at a fixed point in space.

quantity (measurable): An attribute of a phenomenon or a body which may be distinguished qualitatively and determined quantitatively.

rated audio output power: The maximum audio output power under normal test conditions, and at standard test modulations, as declared by the manufacturer.

rated radio frequency output power: The maximum carrier power under normal test conditions, as declared by the manufacturer.

shielded enclosure: A structure that protects its interior from the effects of an exterior electric or magnetic field, or conversely, protects the surrounding environment from the effect of an interior electric or magnetic field.

SINAD sensitivity: The minimum standard modulated carrier-signal input required to produce a specified SINAD ratio at the receiver output.

stochastic (random) variable: A variable whose value is not exactly known, but is characterized by a distribution or probability function, or a mean value and a standard deviation (e.g. a measurand and the related measurement uncertainty).

test load: The test load is a 50 Ω substantially non-reactive, non-radiating power attenuator which is capable of safely dissipating the power from the transmitter.

test modulation: The test modulating signal is a baseband signal which modulates a carrier and is dependent upon the type of EUT and also the measurement to be performed.

trigger device: A circuit or mechanism to trigger the oscilloscope timebase at the required instant. It may control the transmit function or inversely receive an appropriate command from the transmitter.

uncertainty (random): A component of the uncertainty of measurement which, in the course of a number of measurements of the same measurand, varies in an unpredictable way.

uncertainty (systematic): A component of the uncertainty of measurement which, in the course of a number of measurements of the same measurand remains constant or varies in a predictable way.

uncertainty (limits of uncertainty of a measuring instrument): The extreme values of uncertainty permitted by specifications, regulations etc. for a given measuring instrument.

> NOTE 6: This term is also known as "tolerance".

uncertainty (standard): The representation of each individual uncertainty component that contributes to the overall measurement uncertainty by an estimated standard deviation is termed the standard uncertainty.

uncertainty (combined standard): The combined standard uncertainty of a measurement is calculated by combining the standard uncertainties for each of the individual contributions identified.

> NOTE 7: This combination is carried out by applying the Root Sum of Squares (RSS) method under the assumption that all contributions are stochastic i.e. independent of each other.

uncertainty (expanded): The combined standard uncertainty is multiplied by a constant to give the expanded uncertainty limits.

upper specified AF limit: The maximum audio frequency of the audio pass-band. It is dependent on the channel separation.

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wanted signal level: For conducted measurements Pa level of +6 dBμV emf referred to the receiver input under normal test conditions. Under *extreme test conditions* the value is +12 dBμV emf.

> NOTE 8: For analogue measurements the wanted signal level has been chosen to be equal to the limit value of the measured usable sensitivity. For bit stream and message measurements the wanted signal has been chosen to be +3 dB above the limit value of measured usable sensitivity.

3.2   Symbols

For the purposes of this ETR, the following symbols apply:

β	$2\pi/\lambda$ (radians/m)
γ	incidence angle with ground plane (°)
λ	wavelength (m)
ϕ_H	phase angle of reflection coefficient (°)
η	120π Ohms - the intrinsic impedance of free space (Ω)
μ	permeability (H/m)
AF_R	antenna factor of the receive antenna (dB/m)
AF_T	antenna factor of the transmit antenna (dB/m)
AF_{TOT}	mutual coupling correction factor (dB)
c	calculated on the basis of given and measured data
C_{cross}	cross correlation coefficient
d	derived from a measuring equipment specification
$D(\theta,\phi)$	directivity of the source
d	distance between dipoles (m)
δ	skin depth (m)
d_1	an antenna or EUT aperture size (m)
d_2	an antenna or EUT aperture size (m)
d_{dir}	path length of the direct signal (m)
d_{refl}	path length of the reflected signal (m)
E	electric field intensity (V/m)
$E_{DH}{}^{max}$	calculated maximum electric field strength in the receiving antenna height scan from a half wavelength dipole with 1 pW of radiated power (for horizontal polarisation) (μV/m)
$E_{DV}{}^{max}$	calculated maximum electric field strength in the receiving antenna height scan from a half wavelength dipole with 1 pW of radiated power (for vertical polarization) (μV/m)
e_{ff}	antenna efficiency factor
ϕ	angle (°)
Δf	bandwidth (Hz)
f	frequency (Hz)
$G(\theta,\phi)$	gain of the source (which is the source directivity multiplied by the antenna efficiency factor)
H	magnetic field intensity (A/m)
I_0	the (assumed constant) current (A)
I_m	the maximum current amplitude
k	$2\pi/\lambda$
k	a factor from Student's t distribution
k	Boltzmann's constant (1,38 x 10-23 Joules/° Kelvin)
K	relative dielectric constant
l	the length of the infinitesimal dipole (m)
L	the overall length of the dipole (m)
l	the point on the dipole being considered (m)
m	measured
λ	wavelength (m)
p	power level value
$Pe_{(n)}$	probability of error n
$Pp_{(n)}$	probability of position n

P_r	antenna noise power (W)
P_{rec}	power received (W)
P_t	power transmitted (W)
θ	angle (°)
ρ	reflection coefficient
r	the distance to the field point (m)
ρ_g	reflection coefficient of the generator part of a connection
ρ_l	reflection coefficient of the load part of the connection
R_s	equivalent surface resistance (Ω)
σ	conductivity (S/m)
σ	standard deviation
r	indicates rectangular distribution
SNR_{b*}	Signal to noise ratio at a specific BER
SNR_b	Signal to noise ratio per bit
T_A	antenna temperature (° Kelvin)
u	indicates U-distribution
U	the expanded uncertainty corresponding to a confidence level of x %: $U = k \times u_c$
u_c	the combined standard uncertainty
u_i	general type A standard uncertainty
u_{i01}	random uncertainty
u_j	general type B uncertainty
u_{j01}	reflectivity of absorbing material: EUT to the test antenna
u_{j02}	reflectivity of absorbing material: substitution or measuring antenna to the test antenna
u_{j03}	reflectivity of absorbing material: transmitting antenna to the receiving antenna
u_{j04}	mutual coupling: EUT to its images in the absorbing material
u_{j05}	mutual coupling: de-tuning effect of the absorbing material on the EUT
u_{j06}	mutual coupling: substitution, measuring or test antenna to its image in the absorbing material
u_{j07}	mutual coupling: transmitting or receiving antenna to its image in the absorbing material
u_{j08}	mutual coupling: amplitude effect of the test antenna on the EUT
u_{j09}	mutual coupling: de-tuning effect of the test antenna on the EUT
u_{j10}	mutual coupling: transmitting antenna to the receiving antenna
u_{j11}	mutual coupling: substitution or measuring antenna to the test antenna
u_{j12}	mutual coupling: interpolation of mutual coupling and mismatch loss correction factors
u_{j13}	mutual coupling: EUT to its image in the ground plane
u_{j14}	mutual coupling: substitution, measuring or test antenna to its image in the ground plane
u_{j15}	mutual coupling: transmitting or receiving antenna to its image in the ground plane
u_{j16}	range length
u_{j17}	correction: off boresight angle in the elevation plane
u_{j18}	correction: measurement distance
u_{j19}	cable factor
u_{j20}	position of the phase centre: within the EUT volume
u_{j21}	positioning of the phase centre: within the EUT over the axis of rotation of the turntable
u_{j22}	position of the phase centre: measuring, substitution, receiving, transmitting or test antenna
u_{j23}	position of the phase centre: LPDA
u_{j24}	Stripline: mutual coupling of the EUT to its images in the plates
u_{j25}	Stripline: mutual coupling of the three-axis probe to its image in the plates
u_{j26}	Stripline: characteristic impedance
u_{j27}	Stripline: non-planar nature of the field distribution
u_{j28}	Stripline: field strength measurement as determined by the three-axis probe
u_{j29}	Stripline: transform factor