CEPT/ERC RECOMMENDATION 74-02 E (Bucharest 1999)

METHOD OF MEASURING THE FIELD STRENGTH AT FIXED POINTS IN THE FREQUENCY RANGE 29.7 – 960 MHz

Recommendation adopted by the Working Group "Frequency Management" (WGFM):

INTRODUCTION

The purpose of this Recommendation is to provide a common method, which will enable CEPT Administrations to recognise measurement results relating to the field strength measurements at fixed points on a mutual basis.

”The European Conference of Postal and Telecommunications Administrations,

considering

a) that field strength measurements at fixed points have to be carried out in cases of harmful interference, for frequency planning and frequency co-ordination purposes;

b) that field strength measurements over long periods of time have to be carried out e.g. to verify propagation models and other theoretical considerations;

c) that there is a need for common measurement methods to achieve mutual acceptance of the measurement results, especially in border regions;

recognising

a) that the methods described in the annex are in accordance with the requirements of the Vienna Agreement 93;

b) that there are more CEPT members than participants in the Vienna Agreement 93;

recommends

that the method described in the annex is used for performing field strength measurements in the frequency range 29.7 - 960 MHz.”

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ANNEX

1 General

In order to achieve mutually acceptable results administrations shall apply the following procedures in all fixed point field strength measurements in the frequency range 29.7-960 MHz with the exception of special cases in which administrations may deviate by mutual agreement.

2 Quantities and units of measurement

a_c	cable loss (dB)
a_f	attenuation caused by attenuators, filters and amplifiers (dB)
E	electric field strength component (μV/m)
e	electric field strength component (dBμV/m)
G_d	antenna gain relative to a half-wave dipole
G_i	antenna gain relative to an isotropic antenna
g	g = 10 logG (dB)
g_d	g relative to a half-wave dipole (dB)
g_i	g relative to an isotropic antenna (dB)
K	antenna factor (1/m)
k	k = 20 logK (dB)
V_0	output voltage of the antenna at its nominal load (μV)
v_0	v_0=20 log V_0 (dB(μV))
R_N	nominal load resistance of the antenna (Ω)

3 Basic theoretical principles

The electric field strength E to be measured induces a voltage V_0 at the antenna base. The relationship between the electric field strength and the voltage induced at the receiving antenna is a function of the frequency. The antenna factor K of the receiving antenna is equal to the electric field strength E divided by the output voltage V_0 of the antenna at its nominal load resistance R_N.

$$K = E/V_0.$$

The gain of an antenna relative to an isotropic antenna G_i or relative to a half wave dipole is frequently given instead of the antenna factor K. The relationship between the antenna gain and the antenna factor K is:

for R_N = 50 Ω	for R_N = 75 Ω
$K = \dfrac{f\ /\ MHz}{30.81 * \sqrt{G_i}}$	$K = \dfrac{f\ /\ MHz}{37.75 * \sqrt{G_i}}$
$K = \dfrac{f\ /\ MHz}{39.47 * \sqrt{G_d}}$	$K = \dfrac{f\ /\ MHz}{48.34 * \sqrt{G_d}}$

The formulas can be given in logarithmic form:

for $R_N = 50\ \Omega$	for $R_N = 75\ \Omega$
$k = -29.77dB - g_i$ / dB + 20 log(f/MHz)	$k = -31.54dB - g_i$ / dB + 20 log(f/MHz)
$k = -31.93dB - g_d$ / dB + 20 log(f/MHz)	$k = -33.69dB - g_d$ / dB + 20 log(f/MHz)

Taking also a_c and a_f into account the field strength can be given in logarithmic form:

$$e/dB(\mu V/m) = v_0/dB(\mu V) + k/dB(m^{-1}) + a_c/dB + a_f/dB$$

The vectorial sum of the direct wave and the wave reflected from the ground can result in an increase in the measured value of up to 6 dB depending on the antenna height. The anti phase sum of the waves can result in a practical decrease in the measured value of up to around 50 dB. The measuring antenna height shall therefore be varied in order to determine the maximum field strength.

4 Requirements

4.1 Measurement sites

Measurement sites should be selected so that there are no reflecting objects and as few overhead conductors (power and telephone lines, antennas, buildings with metal roofs or gutters) as possible within ten times the wavelength.

4.2 Antennas

Dipole antennas should be preferred as measuring antennas. However, directional antennas can be used and may even be more appropriate depending on the measurement task, for example, in order to reduce reflections and to significantly improve the signal-to-noise ratio.

Active antennas could be used. Owing to the presence of active circuits and in order to avoid susceptibility to intermodulation and cross-modulation, the second-order intercept point should be higher than 55 dBm and the third-order intercept point higher than 30 dBm.

Since the majority of modern measuring receivers have an input impedance of 50 Ω and in order to avoid the use of additional matching transformers, 50 Ω antennas should be used.

Note: The influence of matching transformers on the antenna factor or the antenna gain must be taken into account.

In order to achieve proper results the antenna should be calibrated so that antenna factor or antenna gain at the measured frequency is known.

4.3 Cables

The antenna cables should be coax-cables, which are matched to the receiver input impedance as well as to the antenna load impedance. The load impedance is usually 50 Ω.

The cable loss a_c which depends on the type and the length of the cable and on the frequency must be known in order to produce correct results. Cables are often moved and may therefore become split or kinked which alters their characteristics. Hence, cables should be checked regularly to see if the cable loss has changed.

4.4 Receivers

Typical measuring receivers designed for field strength measurements should include the required IF bandwidth and detector functions (peak, linear average, quasi-peak, r.m.s.).

The bandwidth should be wide enough to receive the signal, including the essential parts of the modulation spectrum, while excessive bandwidth should be minimised to avoid adjacent channel interference.

If the bandwidth is less than that of the signal under measurement, a correction factor should be applied to the measured values. However, the correction factor can only usually be determined accurately if the signal's amplitude is constant over the whole bandwidth (e.g. DAB signals).

The type of detector should ensure that the signal carrier is measured.

Detector function and bandwidth for some signal type		
Signal type	Min. bandwidth (kHz)	Detector function
AM double sideband	9 or 10	linear average
AM single sideband	2.4	peak
FM broadcast	120	linear (or log.) average
Narrow Band FM,		linear (or log.) average
channel spacing 12.5 kHz	7.5	
20 kHz	12	
25 kHz	12	
Analogue TV carrier	200	peak
GSM	300	peak
T-DAB	1500	r.m.s.
DVB-T	8 MHz (7 MHz)	r.m.s.
TETRA	30	peak

4.5 Attenuators, selective filters, pre-amplifiers

These components should also be calibrated and their influence taken into account in calculating the field strength.

5 Measurements

A differentiation is made between two types of measurements: cluster measurements and measurements over longer time periods.

The following preparations should be made before both types of measurements:

- determination and documentation of the test point(s);
- selection of the antenna, filter(s) and attenuator(s) taking account of the direction, polarisation and level of interfering signals and of the signal to be measured;
- examination of the measurement set-up: attention shall be paid to the fact that no damaged cables are used and there are no sharp bends in the cable;
- any integrated measuring receiver calibration and self-test programmes should be run;
- setting of the correct bandwidth and selection of a suitable detector;
- monitoring of the emission by using a panoramic display and/or an appropriate demodulator to confirm identification;
- verification that the correct antenna factor curve is selected (if storage is available).

5.1 Cluster measurements

During the measurement period the height of the measuring antenna should be varied from 3 m to 10 m in order to read or record the maximum field strength at every test point. The maximum field strength shall be recorded together with the actual antenna height at which this value was measured. The result shall be regarded as the field strength at 10 m.

This measurement can be simplified by using computer-controlled measuring equipment and an electronically controlled antenna mast.

The required number of test points depends on the required reliability and the difference e_{max} - e_{min} between the measured values, where:

e_{max} = field strength at the best reception point,
e_{min} = field strength at the worst reception point.

Confidence		$\Delta e = e_{max} - e_{min}$ (dB)			
level %	interval ±dB	0-5	5-10	10-15	15-20
		number of points needed			
90	1	3	11	24	43
90	1.5	2	5	11	19
95	1	4	15	35	61
95	1.5	2	7	15	27

Table: Required number of locations as a function of e_{max} - e_{min} and the required reliability.

The minimum number of locations shall be 5, regardless of the number given in the table. The field strength is the average of the measured values.

Each monitoring location should be clustered around the chosen area and should be as representative as possible but should also be dictated by practical positioning limitations.

5.2 Measurements over longer time periods

This is the performance of a measurement over a longer period of time, which should be carried out as realistically as possible. It is useful for the registration of field strengths between fixed stations for distances exceeding 50 km. This can be done by using a special bilaterally agreed test frequency, with either a permanent or an intervalled signal over a period of at least 24 hours. The measurements shall be made over an appropriate period of time if the influence of the seasons on the time distribution of the field strength is to be determined. A suitable method to identify the transmitting station has to be agreed upon by the Monitoring Services concerned. The results of the measurements shall include data concerning the field strength value for 10%, 50% and 90% of the time probability. However, other time percentages may also be required.

6 Achievable accuracy

The achievable accuracy depends on numerous factors (noise level, atmospheric noise, external interference, class of emission, required type of detector, level and frequency stability of the signal, characteristics of the measurement site). Some degree of improvement can be obtained by making continuous field strength recordings. An accuracy of 3 dB could be reached under optimum measurement conditions and with high-quality instruments.