# RECOMMENDATION ITU-R SM.1708

## Field-strength measurements along a route with geographical coordinate registrations

(Questions ITU-R 214/1 and ITU-R 215/1)

(2005)

The ITU Radiocommunication Assembly,

*considering*

a) that the number of mobile networks using different modulation types and accesses techniques is increasing;

b) that in order to ensure efficient use of the spectrum administrations have a need to know the radio coverage of networks;

c) that field-strength prediction needs support by practical measurements performed by monitoring;

d) that mobile field-strength measurements are sometimes the only solution for determining the radio coverage of a large area;

e) that regulators may need to check the coverage deployment of a network according to licence;

f) different methods of mobile field-strength measurement are used by administrations,

*recognizing*

a) that common measurement procedures are necessary in order to achieve mutual acceptance of measurement results by the parties concerned,

*recommends*

**1** that the method described in Annex 1 should be used for field-strength measurements of vertically polarized signals along a route.

# Annex 1

## 1 General

Influenced by the local receiving conditions, the real values of the field strength can significantly differ from their predicted values, therefore they must be checked by measurements for establishing the radio field-strength coverage of a large area.

Registration of test results must be recorded along with their geographical coordinate data for locating the scenes of measurements and for mapping the results were gathered on the most accessible roads of the area in question.

Instead of measuring the actual field strength, there is sometimes the necessity for measuring the output voltage of a user antenna (the typical antenna for the service under investigation) for radio coverage evaluation.

Digital network systems (such as GSM, DCS1800, and UMTS or DAB, DVB-T) are sensitive to the effects of reflected reception. In this case, besides measuring the signal level, the reception quality measurement, made by the measurement of the bit-error ratio (BER) or channel impulse response measurement, is also necessary to determine the system performance evaluation. Using automatically made calls, these measurements can be made on operational digital networks without any adverse effect.

For measurement purposes along a route a continuous transmission is necessary.

## 2 The results of mobile field-strength measurement

Due to the effect of reflected signals, the field strength along a route shows severe fluctuation. The result of a single measurement can coincide with the minimum or maximum value of reflection and is also influenced by the chosen height of the receiver antenna, the season, the weather, the vegetation and the wetness of surroundings, making that false.

Considering the factors mentioned above, reproducible field-strength test results can be calculated from a large number of raw data readings, by means of statistical processing of them.

## 3 Calculation of field strength

With knowledge of the output voltage of the antenna (usually measured in dB(μV)), the antenna factor and the attenuation of antenna signal path, the field-strength value can be calculated by the following equation:

$$e = v_o + k + a_c$$

where:

- $e$: electric field-strength component (dB(μV/m))
- $v_o$: output voltage of the antenna (dB(μV))
- $k$: antenna factor (dB($m^{-1}$))
- $a_c$: attenuation of antenna signal path (dB).

Using certain test receivers it is possible to read the field-strength result directly in dB(μV/m), by previously writing the summarized antenna factor and signal path attenuation into the memory of the receiver.

## 4 Measuring antennas

During the measurement the chosen height of the test antenna is 1.5 ... 3 m. The result will be considered as being carried out at a height of 3 m.

## 5 Test receiver settings

### 5.1 Dynamic range

The operating dynamic range of the measuring receiver should be ≥60 dB.

### 5.2 Detector functions and bandwidths for the respective types of signal

The receiver bandwidth should be wide enough to receive the signal including the essential parts of the modulation spectrum. The detector type should be set depending on the characteristics and modulation mode of the tested signal.

<table>
<tr><th>Example of signal types</th><th>Minimum bandwidth<br>(kHz)</th><th>Detector function</th></tr>
<tr><td>AM double sideband</td><td>9 or 10</td><td>Linear average</td></tr>
<tr><td>AM single sideband</td><td>2.4</td><td>Peak</td></tr>
<tr><td>FM broadcast signal</td><td>170 or greater</td><td>Linear (or log) average</td></tr>
<tr><td>TV carrier</td><td>200 or greater</td><td>Peak</td></tr>
<tr><td>GSM signal</td><td>300</td><td rowspan="5">r.m.s.</td></tr>
<tr><td>DAB signal</td><td>1 500</td></tr>
<tr><td>DVB-T signal<br>Systems: 6 MHz<br>7 MHz<br>8 MHz</td><td><br>6 000<br>7 000<br>8 000</td></tr>
<tr><td>TETRA signal</td><td>30</td></tr>
<tr><td>UMTS signal</td><td>3 840</td></tr>
<tr><td>Narrow-band FM radio<br>Channel spacing: 12.5 kHz<br>20 kHz<br>25 kHz</td><td><br>7.5<br>12<br>12</td><td><br>Linear (or log) average<br>Linear (or log) average<br>Linear (or log) average</td></tr>
</table>

GSM: Global System for Mobile Communications
DAB: digital audio broadcasting
DVB-T: digital video broadcasting terrestrial
TETRA: terrestrial trunked radio
UMTS: Universal Mobile Telecommunication System, a specific technology within the IMT-2000 family

## 6 The vehicle speed

The vehicle speed ($V$) must be appropriate for the wavelength the simultaneously measured number of the tested signals with different frequencies and the applicable shortest measuring time of the test receiver:

$$V\,(\text{km/h}) \leq \frac{864}{f\,(\text{MHz}) \times t_r\,(\text{s})}$$

Where $t_r$ is the minimum time given by the receiver specifications to revisit a single frequency.

## 7 The necessary number of measuring points and the averaging interval

For statistical evaluation (Lee method)* the number of sample points should be chosen in such a way that the results should display the process of slow changing in the field strength (effect of

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* Mr William C.Y. Lee, *Mobile communications design fundamentals*, ISBN number: 0-471-57446-5

long-term fading), and more or less, they should also reflect the local (instantaneous) individuality (effect of short-term fading) of the field-strength distribution.

For obtaining 1 dB confidence interval around the real mean value, the samples of test points should be chosen at each 0.8 λ (wavelength), over 40 λ averaging interval (50 measured values within 40 wavelength).

## 8 Navigation and positioning systems

### 8.1 Dead reckoning system

The distance from the starting point is reckoned with the help of a distance-to-pulse transducer attached to a non-motor driven wheel of the test vehicle, while the mechanical gyroscope provides the heading information. The location accuracy depends on the accuracy of the starting point registration and the distance covered by the test vehicle.

### 8.2 Global positioning systems (GPS)

Commercialized GPS in themselves can only give accurate position data from a few metres but do not operate accurately in tunnels, narrow streets or valleys. Nevertheless GPSs are the preferred method for positioning for field-strength measurements.

The accuracy of standard GPS are quite sufficient when testing broadcasting coverage of a TV or radio station.

Testing a digital micro-cell system in an urban area requires an accuracy of positioning information within several metres.

### 8.3 Complex navigation system

This system is the combination of the above-mentioned systems. Without the need for manual operator intervention, these navigation systems continuously provide; position and time data, heading and waypoint information.

## 9 Data collection and processing

Either the average, maximum/minimum peak values, statistical evaluation or level exceeding probability of the results can be obtained by the following measuring and evaluation methods.

### 9.1 Measurement result collecting without data reduction (raw field-strength data)

Due to the varying fading and reflection effects, a single test result is not reproducible, therefore can not represent directly the field-strength value of a test point. The raw data can be further processed as desired (see § 9.2.1 and § 9.2.2).

### 9.2 Measurement result collecting with data reduction

By means of statistical processing, this method allows the amount of registered raw data to be reduced considerably.

### 9.2.1 Averaged values

Some of the test receivers are able to perform internal classification of test results over predefined user intervals. The user can select the evaluation intervals of up to some 10 000 measured samples, but each interval must contain at least 100 values.

Only the arithmetic averaged values of the predefined number of test results are stored onto the hard disk and are indicated on the final map of radio coverage.

### 9.2.2 Classification of results according to level exceeding probability

During measurements the results are classified according to exceeding probability, between 1-99%. These percentage values represent the probability of overstepping for the applicable field-strength level. Their typical values are 1, 10, 50, 90 and 99%. The median value, 50% is preferred for propagation studies.

It deserves attention that receivers require some milliseconds for the evaluation of the classification, so during this time the trigger pulses are ignored, therefore no new measurements are obtained.

## 10 Data presentation

Using the process controller's built-in monitor, colour monitor of an external PC, printer or plotter the following representations should be possible:

### 10.1 Representation of raw data in tabular form

Advantage: Gives detailed information about local fading effects. The results can be converted into any kind of easy to view results by mathematical or statistical process.

Disadvantage: Too much volume of data. The individual results are unrepeatable.

### 10.2 Plotting in Cartesian coordinates

Graphical representation of processed field-strength data is plotted in Cartesian coordinates versus distance with indications of these calculated median values.

Advantage: It gives a fast, easy to view result about distribution and locations below a given threshold level of the field strength.

Disadvantage: It is difficult to relate the results to the exact places of the measurements.

### 10.3 Mapping

A multicoloured line is displayed to represent the processed field-strength levels (e.g. with 10 dB(μV/m) scale) or the level exceeding probabilities (between 1 and 99%) on the road map.

The scale of the selected map should correspond to the size of the area covered by the radio signal under investigation and the required resolution of processed field-strength results. Due to the scale of the map, the represented intervals can include the multiples of the averaged intervals. The resolution of the presented result should be chosen in such a way that it can plot local peculiarities without the coloured line being too colourful.

If there is a need to represent the averaged intervals with higher resolution (e.g. when representing results in microcells), the system should be able to zoom the map at disposal.

If during the measurements two data series are registered simultaneously (e.g. field strength and BER) it is expedient to represent them together, by two parallel coloured lines along the plotted roads of the map.

Advantage: The test results can be joined to exact spot of measurements. It gives fast, easy to view results about distribution and getting to below a given threshold level of the field strength.

Disadvantage: The resolution of the plotted interval can be greater than the processed interval. Therefore it can gloss over the local characteristics of field strength.