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FIELD STRENGTH MEASUREMENTS ALONG A ROUTE

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FIELD STRENGTH MESUREMENTS ALONG A ROUTE

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.

Field strength measurement along a route with co-ordinate registration by mobile means is the most time and cost-effective solution for establishing the radio field strength coverage of a large area for radio surveillance, or when the task is to find and eliminate radio interference radiation.

Registration of test results must be recorded along with their geographical co-ordinate data for locating the scenes of measurements and for mapping the results. Different colours on the final radio coverage map can indicate the measured field strength levels, which were gathered on the most accessible roads of the area in question. It can be easily determined on the basis of the coloured map, whether that particular area is covered by the required field strength.

Instead of measuring the actual field strength, there is sometimes a requirement to measure the output voltage of a user antenna (the typical antenna for the service under investigation) in order to determine to what extent its output voltage exceeds the threshold value of a receiver used by that service, for radio coverage evaluation.

Furthermore measuring only the carrier wave is not sufficient when testing a digital network system (such as GSM, DCS1800 or DAB) which is sensitive to the effects of reflected reception. In this case, besides measuring the signal level, a reception quality measurement made by the measurement of the bit-error ratio (BER) or channel impulse response (CIR) measurement is also necessary to determine the performance evaluation of digital systems. Using automatically made calls; these measurements can be made on operational GSM networks without any adverse effect.

2 THE RESULTS OF MOBILE FIELD STRENGTH MEASUREMENT

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

The field strength level, at a given point, not only depends on its distance from the transmitter, the frequency of transmission and the antenna heights but also on the long-term and short-term interferences caused by reflections of the natural environment (terrain configuration, vegetation) and the man-made environment. The received signal must be considered as the vector sum of the wanted signal and many reflected signals. Due to the effect of reflected signals, the field strength along a route shows severe fluctuation. The rate of fluctuation increases at higher speed and at higher transmission frequencies.

Since, the measurements are made on public roads the reflected signals coming from other vehicles cannot be foreseen. The field strength test results therefore very rarely match the results of measurements obtained at the same place, at a different time.

If the measurement is performed by a single short time measurement using a peak or an average detector, it can coincide with the minimum or maximum value of reflection making the result false. Test results are also influenced by the chosen height of the receiver antenna since its height probably differs from the antenna height of a subscriber or user. Other factors include the season, the weather, the vegetation and the wetness of surroundings.

The difference between the maximum and minimum field strengths can reach some tens of decibels.

Considering the factors mentioned above, ***the results of mobile field strength measurements must be regarded as statistic-like results.***

3 CALCULATION OF FIELD STRENGTH

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

$$\mathbf{e = v_o + k + a_c}$$

where;

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

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

4 THE NECESSARY NUMBER OF MEASURING POINTS AND THE AVERAGING INTERVAL. (Lee Method)

For statistical evaluation a large number of measurement data points are necessary. Increasing the number of measuring points improves the reliability of the averaging, however beyond a certain confidence interval, it does not return a significant improvement.

For statistical evaluation 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 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.

According to calculations, 40λ are considered to be the proper averaging length of raw data. For obtaining 1 dB confidence interval around the real mean value, the samples of test points should be chosen at each 0.8λ (wavelength), over 40λ averaging interval. (50 measured values within 40 wavelength.). For a low frequency operation, an interval of 20λ can be taken.

5 THE VEHICLE SPEED

The vehicle speed should be appropriate for the wavelength, the simultaneously measured number of the tested signals and the applicable shortest measuring time of the test receiver.

Some examples:

frequency (MHz)	radio service	distance of adjacent samples (0.8λ) (m)	repetition time of samples at speed of 100 km/h (msec)
80	VHF radio	3	108
100	FM broadcasting	2.4	86
160	VHF radio	1.5	54
450	NMT 450	0.53	19
900	GSM 900	0.27	9.7
1800	GSM 1800/DECT	0.13	4.7

Simultaneous measurement at different frequencies takes longer time. (Practically, it takes approx. 0.2 sec for each measurement at three different frequencies.)

6 MEASURING ANTENNAS

Following the curves of the road by the measuring vehicle, the received signal comes from different angles to the test antenna, therefore the effect of the antenna diagram should be known on field strength test result.

The antenna factor (“k”) accuracy should be within 1 dB. (Can be calibrated using the substitution method.)

If the vehicle is equipped with a digital compass, the software directly provides the angular position of the antenna with respect to magnetic North.

When measuring a vertically polarised signal, a vertical non-directional antenna can be used.

For automatic horizontal measurement some kind of directional antenna is used. (This could be a dipole or at lower frequencies an active dipole with rotor which should be controlled via an RS-232 interface by the process controller. Alternatively, an antenna where the reception pattern can be electrically rotated could be used. The operating software should automatically determine the best direction for the antenna.

The deviation of the horizontal radiation diagram of the measuring antenna from a non-directional diagram should not exceed 3 dB.

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

For reducing the falsification effects of reflections it is possible to use space diversity arrangement. In such a case the distance between the antennas is 1/2 λ. This is more reasonable at higher frequencies where the two antennas can be easily placed close to each other.

7 TEST RECEIVER SETTINGS

7.1 Dynamic range:

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

7.2 Detector functions and bandwidths for the respective types of signal:

When mobile field strength measurements are carried out, the instrument settings (e.g. measurement bandwidth, detector type and measuring time) should be set depending on the characteristics and modulation mode of the tested signal.

The bandwidth should be wide enough to receive the signal including the essential parts of the modulation spectrum. The table below gives a representative sample of signal types in order to demonstrate the minimum bandwidths needed, together with the detector functions.

Signal type	**Minimum bandwidth** (kHz)	**Detector function**
AM double side band	9 or 10	linear average
AM single side band	2.4	peak
FM broadcast signal	120 or greater	linear (or log) average
TV carrier	200 or greater	peak
GSM signal	300	peak
DAB signal	1500	r.m.s.
Narrow band FM radio		
channel spacing 12.5 kHz	7.5	linear (or log) average
20 kHz	12	linear (or log) average
25 kHz	12	linear (or log) average

8 NAVIGATION AND POSITIONING SYSTEMS

8.1 Dead Reckoning System

Using only a ”traditional” positioning system operated *with gyroscope*, mobile field strength measurements are more difficult because the starting point of the mobile measurement has to be registered manually, by using accurate maps during the test the position data occasionally has to be corrected. At other locations the determination of 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. Using software, the mobile measured results along with position data are stored on a computer disk. The location accuracy depends on the accuracy of the starting point registration and the distance covered by the test vehicle.

8.2 GPS System

The previous positioning system supplemented with *GPS (or GLONASS)* equipment, has allowed mobile field strength measurements to become simpler, automatic and significantly more efficient. A commercialised (SPS) GPS in itself can only give accurate position data from a few 10 to 100 metres and does not operate accurately in tunnels, narrow streets or valleys.

The required positioning accuracy of the measurements depends on the type of system being tested. An accuracy of 100 or 200 metres is 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. In such a case differential GPS should be used in the positioning system.

8.3 Complex Navigation System

Taking into account that the GPS system does not work in certain environmental circumstances, recent navigation systems have therefore used GPS along with a newly developed fibre optic gyroscope (with no moving parts; therefore it does not require any run-up time) for occasionally making those corrections. Without the need for manual operator intervention, these navigation systems continuously provide; position and time data, heading and waypoint information, pitch and roll data (by using a 3-axis gyro sensor cluster). The standard version contains a single axis, fibre optic gyroscope.

The positions of measurements, localised by using any type of co-ordinate systems, combined with the additional time and data information should be transferred to the process controller of the measuring system via a standard RS-232 computer interface.

9 REQUIRED ACCURACY OF FIELD-STRENGTH MEASUREMENTS (Rec. ITU-R SM.378)

Below 30 MHz	± 2 dB
30 to 2700 MHz	± 3 dB

10 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 different measuring and evaluation methods.

10.1 Measurement result collecting without data reduction (Raw field strength data):

All digitised field-strength results in relation to distance should be held in the processor’s RAM and stored when the test vehicle is stopped.

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.

10.2 Measurement result collecting with data reduction:

Taking into account that reproducible field strength test results can only be calculated from a large number of raw data readings, the aim is to convert the raw data into reproducible results, by means of statistical processing. Furthermore, this efficient method also allows the amount of data to be reduced considerably. Some of the test receivers are able to perform internal classification of test results over predefined user intervals.

10.2.1 Averaged values

The volume of data can be reduced if the averaging happens during the data collection and 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. The user can select the evaluation intervals of up to some 10,000 measured samples, but each interval must contain at least 100 values.

10.2.2 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. (The applicable field strength level is overstepped by 50 % of the measured values.)

The results of the measurements are expressed in a value of field strength for the 50% of the locations.

Usually the receiver requires about 50 ms for the evaluation of the classification, so during this time the trigger pulses are ignored and therefore no new measurements are obtained.

11 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:

11.1 Representation of raw data in tabular form

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

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.

11.2 Plotting in Cartesian co-ordinates

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

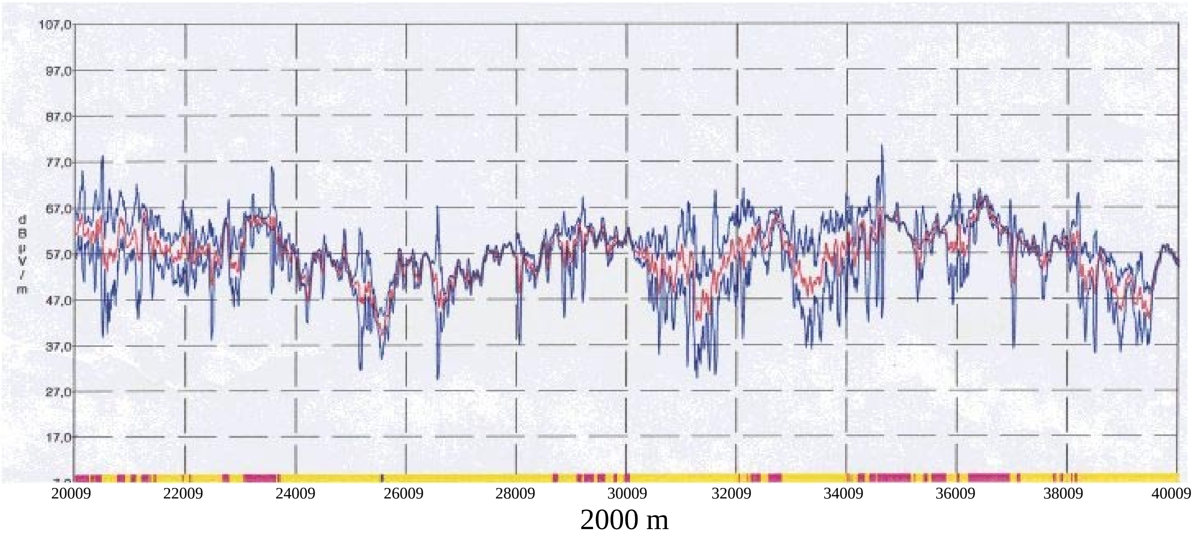

Figure 1

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

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

11.3 Mapping

The measured field-strength results are plotted on the road map with indications of the calculated median or level exceeding probability values. The scale of the selected map should correspond to the size of the area covered by the radio signal under investigation or the tested smaller area and the required resolution of processed field strength results.

A multicoloured line is displayed to represent the route. The different colours on the line represent different processed field-strength levels, e.g. with 10 dBμV/m scale. The user should define the colours representing the level thresholds.

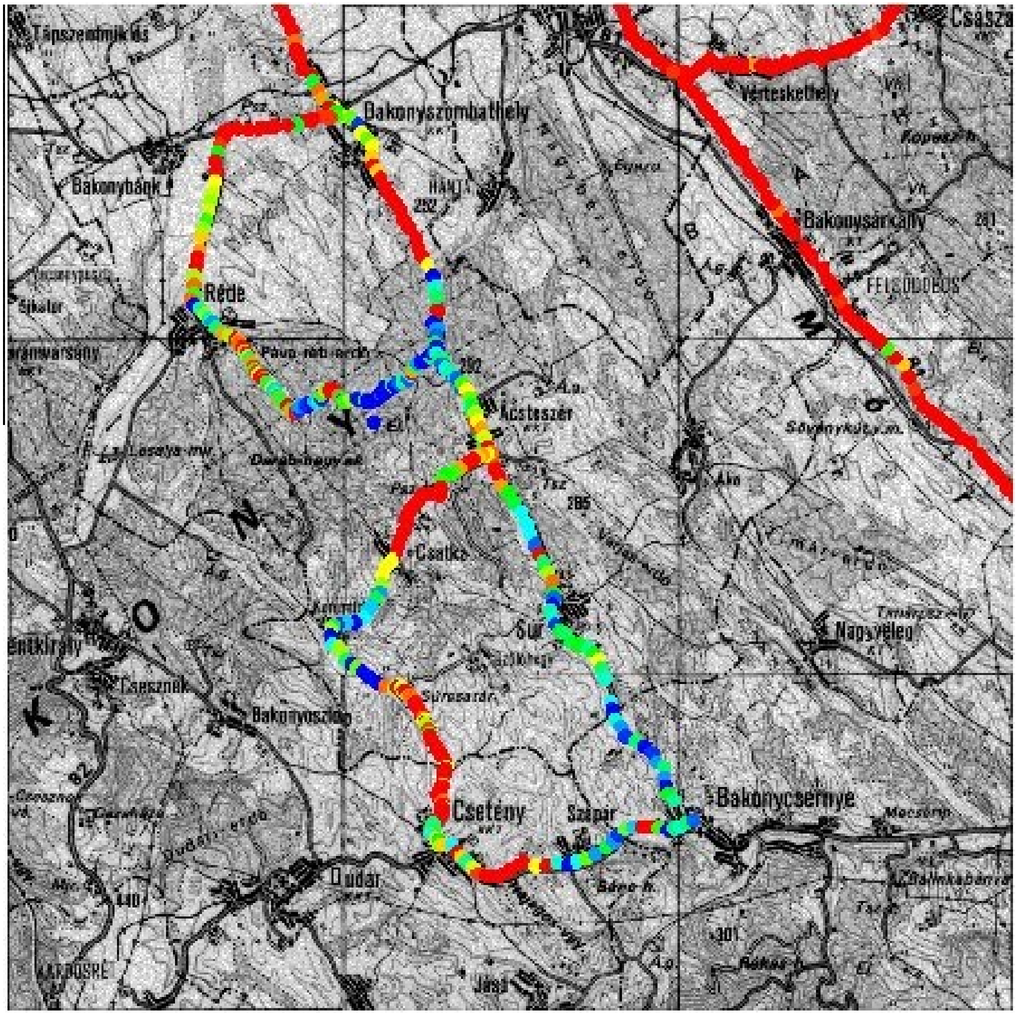

Figure 2

The level exceeding probability should be determined in percent by user selectable between 1 and 99 %, using XY co-ordinates. Each value selected is assigned a colour.

By presenting the results as coloured lines on the map, the aim is to make them easy to view and establish those places where the results fall below a threshold level.

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. Due to the scale of the map, the represented intervals can include the multiples of the averaged intervals. 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 as required.

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.

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.

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.

12 TEST SYSTEM REQUIREMENTS

- *Measuring receiver*

  <-10 dBμV sensitivity,
  Fast and accurate,
  IF bandwidths required for the frequency range,
  Built-in HF and IF attenuators,
  All required detector functions (peak, linear average, QP and rms.),
  Measurement of frequency,
  Measurement of modulation (AM, FM, PM),
  Demodulators for A0, A1, A3, A3J, F3 and a loudspeaker for aural monitoring,
  Built-in calibration generator,
  Provision for connection of an optional direction finder,
  I/Q demodulator outputs,
  IEEE, RS-232 etc. interface for computer control.

- *Computer configuration*

  Low radiation,
  Capability of mechanical resistance,
  486 processor or better,
  8 Mb or more RAM,
  Sufficient memory capacity to store all measured raw data without data reduction,
  Measuring software.

- *GPS and positioning system*

  Should be sufficiently accurate also in urban area,
  Data output.

- *Test system requirements*

  Fast; in order to fulfil and evaluate the field strength measurement (raw data),
  Statistical evaluation of results according to Lee's method,
  Classification of data according to levels of probability,
  Graphical representation of data,
  Provision for use in mobile field-strength measurements with simultaneous measurement on several frequencies.