

Applicaton Note

UMTS measurements with the Selective Radiation Meter SRM-3000

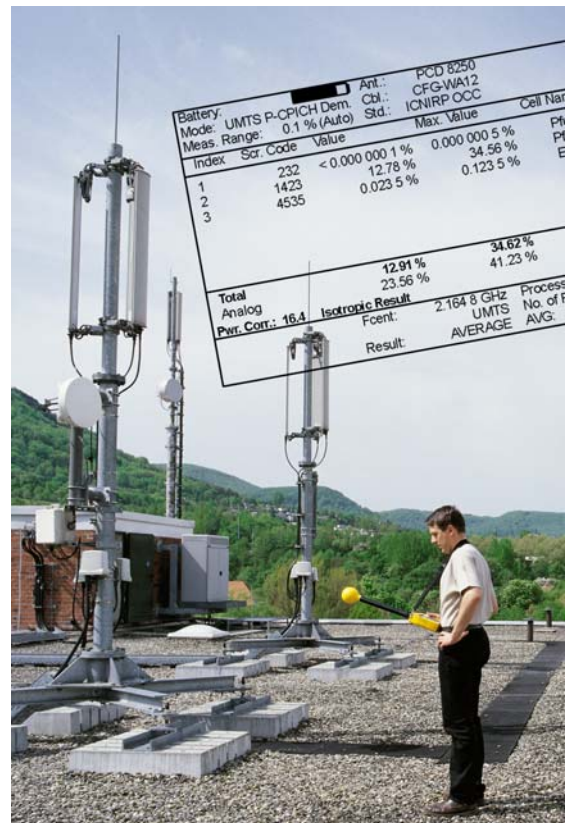
Determining field exposure levels in the vicinity of UMTS transmitting equipment

UMTS, the Universal Mobile Telecommunications System, is a third-generation mobile phone standard (3G). UMTS is widely used in Europe. Compared with GSM (2G), UMTS allows variable and much higher data transmission rates. Since a higher data rate is coupled with a shorter range, a higher density of transmitting stations is required. Other wireless services as well as UMTS and GSM often share the same antenna location, so the proportion of the total field exposure level due to UMTS can only be determined by selective measurement.

This Application Note describes an example field emission measurement on UMTS transmitting equipment using the SRM-3000 and its evaluation from the point of view of human safety.

Contents

1	Background	Page 2
2	Standards and regulations	Page 3
3	Preparation for measurement	Page 3
4	Fundamental measurement settings	Page 4
5	UMTS frequency channel measurement using Safety Evaluation mode	Page 5
6	UMTS frequency channel measurement using Spectrum Analysis mode	Page 6
7	Measuring a UMTS channel using Spectrum Analysis mode	Page 6
8	Measuring UMTS cells using UMTS P-CPICH Demodulation mode	Page 7
9	Determining maximum field exposure level by extrapolation	Page 7
10	Evaluating the results and generating a report	Page 8
	Annex: Calculating the center frequency; Abbreviations	Page 10
	References	Page 11



Typical multiple antenna array for GSM 900, GSM 1800 and UMTS

1 Background

UMTS utilizes a wide-band code-division multiple access procedure (W-CDMA) for transmitting voice and data signals. The transmitted voice and data channels differ in the way they are coded, but not necessarily in their frequencies.

UMTS frequency channels

Each provider has obtained a license to use one or more frequency channels, each having a bandwidth of 5 MHz. Each UMTS base station (Node-B) operates on one of these frequency channels. Thus, many cells utilize one and the same frequency. There are two variants: UMTS-FDD occupies separate pairs of frequency channels for the uplink and downlink, while UMTS-TDD uses a common frequency channel for both directions (see table). As TDD is seldom used, this Application Note only looks at **FDD**. Normally, only the **downlink** (from the base station to the mobile device) is of interest when considering human safety because its field strength predominates in close proximity to the transmitter location.

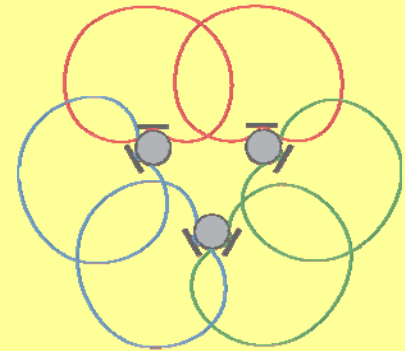
Code channels

The information in the separate voice and data channels is encoded individually by a Channelization Code and simultaneously spread over the entire width of a frequency channel. The complete information stream in the downlink for a cell is again scrambled using a Scrambling Code. There are 512 sets of scrambling codes which are used to distinguish the individual cells from one another.

P-CPICH

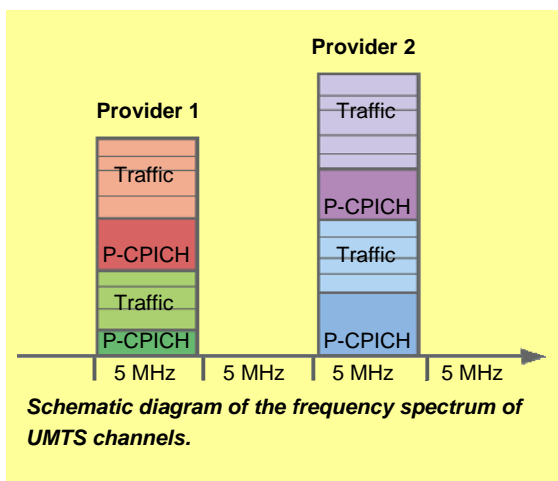
One P-CPICH (Primary Common Pilot Channel) per cell is embedded in the multiplex signal. This channel is transmitted continuously at a constant power level. The field strength of this channel can be measured by decoding it, and assigned to the particular cell by means of the scrambling code. The value can be used to extrapolate the “worst case” scenario, i.e. the maximum field strength when the cell capacity is fully utilized.

Universal Mobile Telecommunications System	
Frequency range for FDD uplink	1920 – 1980 MHz (12 frequency channels of 5 MHz)
Frequency range for FDD downlink	2110 – 2170 MHz (12 frequency channels of 5 MHz)
Frequency ranges for TDD	1900 – 1920 MHz (4 frequency channels of 5 MHz) 2010 – 2025 MHz (3 frequency channels of 5 MHz)
Carrier frequency (center frequency)	Can be freely chosen by the provider within a frequency channel, but must be an integer multiple of 100 kHz
Number of channels per carrier	Variable, depends on the data transmission rates of the individual channels
Modulation	QPSK; 6-QAM also used for HSDPA
Access type	CDMA



Typical arrangement of UMTS antennas, viewed from above.

The antennas are so-called sector antennas, each covering an angle of 120°. Two antennas on adjacent masts radiate in each direction (space diversity). Thus, a total of three cells is installed and fed from just three Node B base stations, which are differentiated by three scrambling codes. Several such arrays may be installed at one and the same location. The external appearance of UMTS antennas is very similar to that of GSM antennas.



Schematic diagram of the frequency spectrum of UMTS channels.

Left: Overview of commonly used UMTS frequencies and other UMTS properties.

Uplink: from the mobile device (phone) to the base station (Node B).

Downlink: from the base station to the mobile device – this is usually the subject of measurements.

Many service providers give a channel number to the exact center frequency of a UMTS frequency channel they are using. The calculation of the associated frequency is described in the Annex.

2 Standards and regulations

In 1998 the International Commission for Non-Ionizing Radiation Protection (ICNIRP) published its “Guidelines on Limiting Exposure to Non-Ionizing Radiation” [1, 2]. These guidelines include frequency-dependent limit values in the form of two different limit value curves: a higher one for protection in the work environment (occupational) and a lower one for the general public. The higher values apply in controlled areas where safety measures have been taken and which are only accessible to specially trained personnel. This applies, for example, to mobile phone antenna sites, for which operators have to define safe distances.

The limit values, as well as their division into two parts, are reflected in the European guidelines. Occupational safety is governed by Guideline 2004/40/EC of 29 April 2004 [3], whereas Recommendation 1999/519/EC [4] for protecting the general public was published much earlier, on 12 July 1999. In addition, many countries have their own national standards, most of which are based on the ICNIRP limit values, although some specify lower levels for the limit values.

3 Preparation for measurement

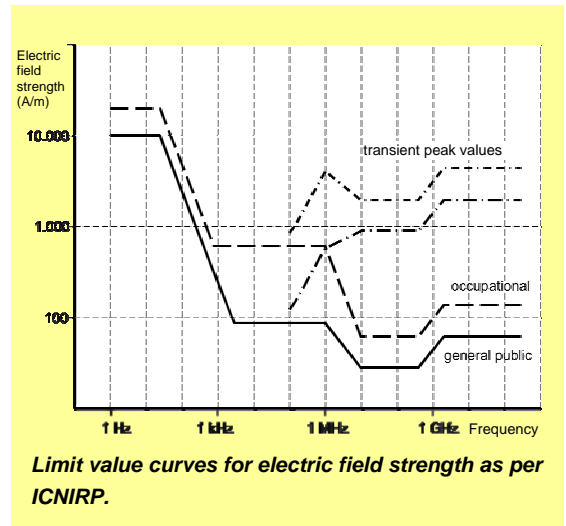
UMTS measurements can generally be made “on the move”. The measuring antenna can be mounted directly on the SRM basic unit or connected to it by the 1.5 m long RF cable for this purpose.

The three-axis (isotropic) E-field antenna is recommended for making measurements using the **dot matrix method**, where specific points in the space are measured according to a fixed pattern. The SRM basic unit then determines the isotropic (non-directional) result for each measured point automatically.

You can also use a single-axis antenna for the dot matrix method, but the procedure is more time-consuming. Refer to the SRM-3000 Operating Manual under “Isotropic measurements with a single-axis antenna” for more information.

Either the three-axis or the single-axis E-field antenna can be used for the **pendulum method**, where the spatial volume is swept continuously. If the antenna is connected to the SRM basic unit using the 1.5 m long RF cable, the instrument can be attached to a belt and the antenna panned through the space by hand. The single-axis antenna should be rotated during panning to take account of the polarization of the field. This is not necessary if the three-axis antenna is used.

Important: When using the pendulum method, the **panning rate** must be slow enough for the SRM to make two or three measurements for each position of the antenna.



The measuring equipment

depends on the measurement task.

A complete set of equipment comprises:

- SRM Mainframe with the latest firmware (download from www.narda-sts.de) as well as the UMTS P-CPICH Demodulation option,
- Three-axis (isotropic) E-field antenna for SRM-3000 up to 3 GHz
– or –
single-axis E-field antenna for the frequency range up to 3 GHz,
- RF cable, 1.5 m,
- AC Adapter / Charger or spare rechargeable battery if no power supply available on site,
- Writing materials for noting down measurement setups, local conditions, frequencies, measurement settings and possible sources of interference
– or –
Notebook PC with the latest SRM-TS PC software for controlling the SRM, saving measurement results and recording comments (download from www.narda-sts.de)

If you are using the dot matrix measurement method with a single-axis antenna, you will also need:

- Tripod
- Antenna holder for single- and three-axis measuring antennas
- RF cable, 5 m.

4 Fundamental measurement settings

Setting the measurement range (MR)

In most cases, the automatic “MR Search” function will be the quickest way to set the measurement range in all operating modes. The measurement range *must* be set manually only when field strengths from impulse type sources such as radar located nearby predominate (see Application Note AN_HF_1003 “Radar Measurements”). The setting *can* of course be made individually following the results of an overview measurement.

Overview measurement in Spectrum Analysis mode

An overview measurement of the entire available frequency range setting (Full Span) is always recommended if there are other dominant field sources in the vicinity of the UMTS transmitting equipment such as radio transmitters, which can affect control of the measuring instrument (figure 1).

Starting from a large measurement range MR (low sensitivity), the MR is progressively reduced (sensitivity increased) until the spectrum becomes clearly separated from the noise signal. Using the “Highest Peak” marker function, the field strength of the highest spectral line peak is read off and the measurement range set to approximately twice this value.

Setting the frequency range (Span)

It is sensible to restrict the frequency range to the frequencies of interest to achieve good screen resolution and fast measurement speeds. The upper and lower frequency limits can be selected using “Fmin / Fmax” or the zoom functions can be used for this (figures 2, 3; also refer to the Operating Manual).

Setting the resolution bandwidth (RBW)

Since UMTS uses a frequency channel spacing of 5 MHz, a resolution bandwidth of 5 MHz is also sufficient to resolve the spectrum into individual channels. The SRM uses a special algorithm to ensure that the real value is displayed when making evaluations with the Peak Table or using the Highest Peak marker function even if the selection filter is not exactly tuned to the channel center frequency. This does not apply if the marker is positioned using the rotary control.

Setting the result type (Result Type)

The Result Type depends on the purpose of the measurement and the standard or regulation used to assess the results.

Setting the display units (Display Unit)

The choice that needs to be made here is whether to measure in physical units (V/m, A/m, W/m², dBμV/m etc.) or as a percentage of the limit value (%), see section 10). Subsequent conversion from one set of physical units to another is possible.

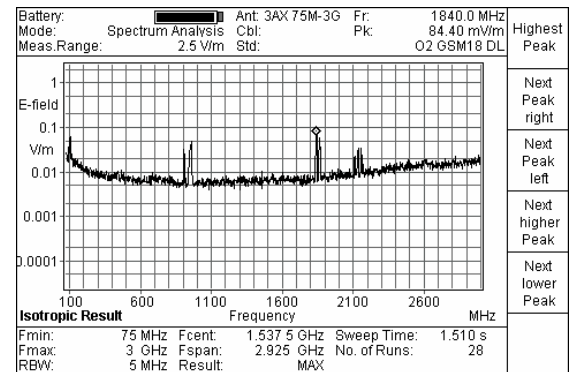


Figure 1: The overview measurement shows fields from GSM-900, GSM-1800, and UMTS at 2100 MHz.

Measurement settings:

Minimum Frequency	75 MHz
Maximum Frequency	3 GHz
Resolution Bandwidth	5 MHz
MR	depends on field situation
Unit	V/m
Result Type	MAX

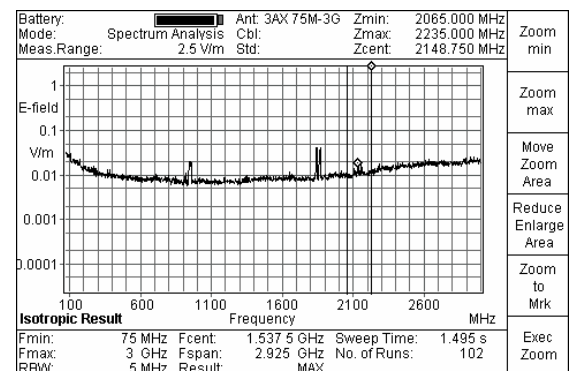


Figure 2: The frequency range can also be set using Zoom min / Zoom max.

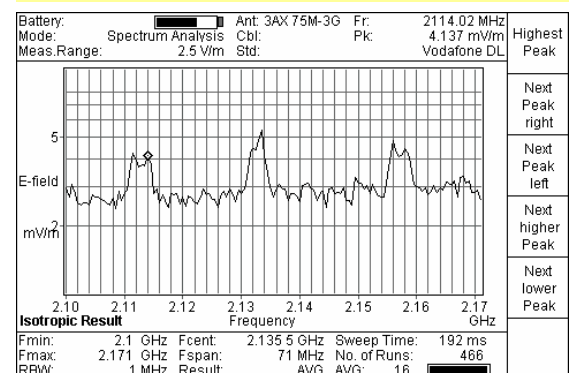


Figure 3: UMTS downlink spectrum.

Measurement settings differing from those above:

Resolution Bandwidth	1 MHz
Unit	mV/m
Result Type	AVG

5 UMTS frequency channel measurement using Safety Evaluation mode

The SRM 3000 “Safety Evaluation” mode is useful if a quick assessment of the overall field situation is required, since it is the easiest way to display the results. It does however require that corresponding Service Tables defining the frequency ranges of the UMTS frequency channels of interest (e.g. according to service providers) are stored in the instrument.

Recommended settings:

- Resolution bandwidth RBW: **50 kHz**
- Measurement Range MR: as described in section 4
- Result Type: As defined by the standard or regulation to be used for evaluating the results.

Example: Client-specific Service Table “UMTS_D” and ACT evaluation mode (figure 4). The SRM displays the instantaneous downlink field strength values here, broken down according to providers, together with the Total value. “Others” represents the field strengths that lie between the defined frequency channels. Results below a pre-settable threshold value are shown by the SRM as “less than” (e.g. <7.261 mV/m). These values can in any case be ignored when calculating the overall field exposure level. The environmental impact at the measurement location can be read off directly.

Example: Measured values displayed as a percentage of the permitted limit value, again broken down according to providers (figure 5). This automatically provides evaluation from the point of view of human safety.


Battery: 		Ant: 3AX 75M-3G UMTS 8 Kanäle		Sel. first service
Mode: Safety Evaluation Cbl:		Std:		
Meas.Range: 2.5 V/m		Std:		
Service	Value	Frequency		
Vodafone DL	9.961 mV/m	2110.400 MHz to 2115.200 MHz		Sel. last service
Vodafone DL	<7.528 mV/m	2115.200 MHz to 2120.000 MHz		
E-Plus DL	12.66 mV/m	2130.200 MHz to 2135.000 MHz		
E-Plus DL	<7.631 mV/m	2135.000 MHz to 2139.800 MHz		
O2 DL	<7.724 mV/m	2150.000 MHz to 2154.800 MHz		Sel. all service
O2 DL	7.824 mV/m	2154.800 MHz to 2159.600 MHz		
T-Mobile DL	<7.806 mV/m	2160.000 MHz to 2164.800 MHz		
T-Mobile DL	<7.820 mV/m	2164.800 MHz to 2169.600 MHz		Meas. Range
Others	<15.90 mV/m			
Total		<26.91 mV/m 2110.400 MHz to 2169.600 MHz		Result type
Isotropic Result				
Fmin:	2.110 4 GHz	Process Time:	397 ms	RBW
Fmax:	2.169 6 GHz	No. of Runs:	9187	
RBW:	50 kHz	Result:	ACT	

Figure 4: Safety Evaluation using a service table specially created for German UMTS service providers and ACT evaluation mode. Results are displayed in units of field strength.



Battery: 		Ant: 3AX 75M-3G UMTS_D		Sel. first service
Mode: Safety Evaluation Cbl:		Std: ICNIRP GP		
Meas.Range: 1 250 %		Std:		
Service	Value	Frequency		
Vodafone DL	0.0057592 %	2110.400 MHz to 2115.200 MHz		Sel. last service
Vodafone DL	0.0052349 %	2115.200 MHz to 2120.000 MHz		
E-Plus DL	0.0055437 %	2130.200 MHz to 2135.000 MHz		
E-Plus DL	0.0063916 %	2135.000 MHz to 2139.800 MHz		
O2 DL	0.0066106 %	2150.000 MHz to 2154.800 MHz		Sel. all service
O2 DL	0.0065969 %	2154.800 MHz to 2159.600 MHz		
T-Mobile DL	0.0067690 %	2160.000 MHz to 2164.800 MHz		
T-Mobile DL	0.0061718 %	2164.800 MHz to 2169.600 MHz		Meas. Range
Others	0.0258076 %			
Total		0.0748854 % 2110.400 MHz to 2169.600 MHz		Result type
Isotropic Result				
Fmin:	2.110 4 GHz	Process Time:	168 ms	RBW
Fmax:	2.169 6 GHz	No. of Runs:	140	
RBW:	1 MHz(Auto)	Result:	AVG AVG: 64 	

Figure 5: Safety Evaluation as in figure 4 but using AVG evaluation mode with direct display of results as a percentage of the permitted limit value (referred here to the ICNIRP general public standard).

6 UMTS frequency channel measurement using Spectrum Analysis mode

“Spectrum Analysis” mode allows measurement of field strengths over the entire UMTS frequency channel, just like “Safety Evaluation” mode. The evaluation is a bit more complex, but the measurement gives additional information about the type of spectrum.

Recommended settings:

- **Frequency range (Span):**
Fmin, Fmax corresponding to the downlink frequency range
- **Resolution bandwidth (RBW):**
1 MHz or less
- **Result Type:**
ACT to view the instantaneous value
MAX to view the maximum value during the measurement period
AVG to determine the average over e.g. a period of 6 minutes

Spatial averaging: Refer to the Application Note “GSM Measurements with the Selective Radiation Meter SRM-3000” (AN_HF_1005).

The Integration over Frequency Band function can be used to determine the field strength of the entire UMTS frequency channel (see section 10).

7 Measuring a UMTS channel using Spectrum Analysis mode

The spectrum analysis measurement described above can be used to determine the field strength of a UMTS frequency channel by setting the integration limits accordingly. More exact information about the channel spectrum can be obtained by restricting the frequency range to the apparent channel width using the Zoom function (figure 7) or by entering the exact frequencies numerically (figure 8):

- **Frequency range (Span):**
Fcent corresponding to the center frequency used by the UMTS service provider. If the provider specifies a channel number, the frequency can be calculated using a simple formula (see Annex).
Fspan = 10 MHz
- **Resolution bandwidth (RBW):**
20 kHz, maximum 1/10 Fspan
- **Result Type:**
ACT to view the instantaneous value
MAX to view the maximum value during the measurement period
AVG to determine the average over e.g. a period of 6 minutes

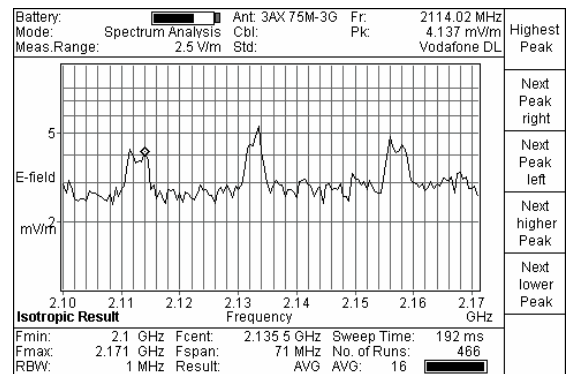


Figure 6: Field strength spectrum in the UMTS frequency band (FDD downlink).

Measurement settings:

Minimum Frequency 2.1 GHz
Maximum Frequency 2.171 GHz
Resolution Bandwidth 1 MHz

The values at the marker position are displayed top right. As a service table has been recorded, the name of the service provider is also shown in each case.

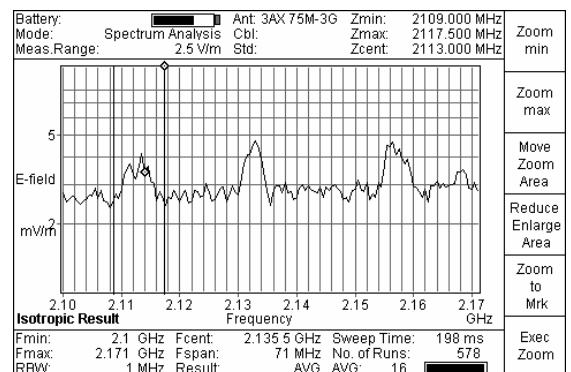


Figure 7: Using the Zoom function to manually restrict the frequency range to a single UMTS frequency band.

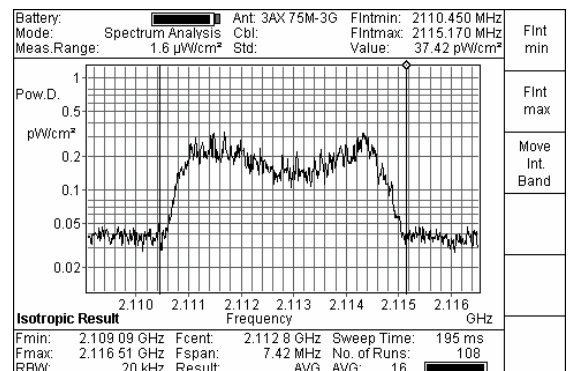


Figure 8: Field strength of a UMTS frequency band.

Measurement settings:

Center Frequency 2.1128 GHz
Frequency Span 7.42 MHz
Resolution Bandwidth 20 kHz

8 Measuring a UMTS cell using UMTS P-CPICH Demodulation mode

In “UMTS P-CPICH Demodulation” mode (option), the SRM decodes all the scrambling codes that are present in a selected UMTS frequency channel. In his way, the instrument can separately determine and list the contribution of each individual cell to the overall field strength of a UMTS frequency channel. It also calculates the total of all these contributions. In addition to this, the SRM displays the analog measurement value. This corresponds to the actual field exposure level integrated over the complete UMTS frequency channel of 5 MHz.

Recommended settings:

- **Frequency:**
Fcent corresponding to the center frequency used by the UMTS service provider, **to the exact 100 kHz**. It is easier to enter the UMTS channel number (setting made using the CONF menu).
- **Demodulation algorithm:**
FAST if a high measurement speed is needed, e.g. when using the pendulum method
SENSITIVE if weak signals from distant cells are also to be detected and decoded
- **Result Type:**
ACT to view the instantaneous value
AVG to determine the average over e.g. a period of 6 minutes

Save the result(s) and evaluate as described in section 10.

9 Determining maximum field exposure level by extrapolation

By means of a settable extrapolation factor, the SRM can calculate the worst case situation which would occur if all cells were operating at full capacity. The ratio of the total possible transmitted power level to the power level of the P-CPICH is known and can therefore be requested from the service provider.

The extrapolation factor applies to all cells equally, i.e. the SRM multiplies all the individual results (Value, Max. Value) and the total result (Total) by this extrapolation factor, but not the result of the analog measurement.

Battery:		Ext. Power:		Ant: 3AX 75M-3G		Full Screen
Mode: UMTS P-CPICH Dem.		Cbl:				
Meas. Range:		2.5 V/m		Std:		
Ind.	Scr.	Value	Max. Value	Value/Analog		
1	34	0.000 $\mu\text{V}/\text{m}$	1.551 mV/m	-999.00 dB		
2	339	1.236 mV/m	6.306 mV/m	-17.35 dB		
3	501	4.752 mV/m	20.35 mV/m	-5.65 dB		
Total		4.910 mV/m	21.30 mV/m			Bar Graph
Analog		9.111 mV/m	30.96 mV/m			
Isotropic Result						
SENSITIVE		Fcent: 2.112 8 GHz	Process Time: 1.807 s			
Full Table		Result: ACT	No. of Runs: 341			

Figure 9: Field strengths of individual UMTS cells within a UMTS frequency band.

Measurement settings:

Center frequency Fcent 2.1128 GHz
Result Type ACT

Results:

Scr. Identity of the UMTS cell given by the decoded scrambling code number

Value Measured instantaneous P-CPICH field strength in mV/m

Max. Value Maximum P-CPICH field strength that has occurred since the start of the measurement

Value/Analog Ratio of the instantaneous P-CPICH value of one UMTS cell to the analog field strength measurement value for the entire UMTS frequency band in dB

Total Total field strength of all decoded P-CPICHs (power sum)

Analog Analog field strength measurement value for the entire UMTS frequency band.

Battery:		Ext. Power:		Ant: 3AX 75M-3G		Select Menu
Mode: UMTS P-CPICH Dem.		Cbl:				
Meas. Range:		128 $\text{dB}\mu\text{V}/\text{m}$		Std:		
Ind.	Scr.	Value	Max. Value	Cell Name		
1	34	-999.00 $\text{dB}\mu\text{V}/\text{m}$	69.00 $\text{dB}\mu\text{V}/\text{m}$			Select All
2	339	69.70 $\text{dB}\mu\text{V}/\text{m}$	81.18 $\text{dB}\mu\text{V}/\text{m}$			
3	501	80.12 $\text{dB}\mu\text{V}/\text{m}$	91.36 $\text{dB}\mu\text{V}/\text{m}$			Extr. Pol OFF
Total		80.49 $\text{dB}\mu\text{V}/\text{m}$	91.75 $\text{dB}\mu\text{V}/\text{m}$			Extr. Pol Factor
Analog		80.22 $\text{dB}\mu\text{V}/\text{m}$	89.82 $\text{dB}\mu\text{V}/\text{m}$			
Isotropic Result						
SENSITIVE		Fcent: 2.112 8 GHz	Process Time: 1.876 s			Sort Table
Full Table		Result: ACT	No. of Runs: 286			

Figure 10: Field strengths of individual UMTS cells within a UMTS frequency band with extrapolation to give the possible maximum value.

Setting:

Extrapolation factor 3.3
All the results except the analog value are now multiplied by the extrapolation factor, even though they are displayed here in $\text{dB}\mu\text{V}/\text{m}$.

10 Evaluating the results and generating a report

The client requesting measurements of field emissions is ultimately interested in knowing whether field strengths are within the permitted limit values, or which service provider is exceeding the limits (and by how much) and who therefore needs to reduce output power. Hence, an assessment of the results relative to the limit values is part of the evaluation. It is useful to have the results in terms of physical units when making environmental measurements so that they can be compared with the limit values prescribed for the measurement location, for example. Results expressed as a percentage of the permitted limit value are most convenient when making measurements in connection with human safety.

Safety Evaluation

This operating mode supplies the results for the UMTS frequency band and individual frequency channels or providers corresponding to the recorded Service Table (figure 11). Physical values only need to be compared with the permitted values. The results as a percentage of the permitted limit value are shown directly – a special feature of the SRM-3000.

Spectrum Analysis: Evaluation using Integration over Frequency Band

The result in this operating mode must be determined using the “Integration over Frequency Band” function. The SRM can perform this function directly (figure 8). It is more convenient to use the SRM-TS PC software (figure 12). For example, results can be integrated over precisely the frequency band occupied by a service provider. The field exposure caused by the antennas of this provider can then be read off directly in figures.

Integration over measured values obtained using the MAX result type tends to result in over-estimation of the field exposure level because the maximum values do not necessarily all occur at the same time.

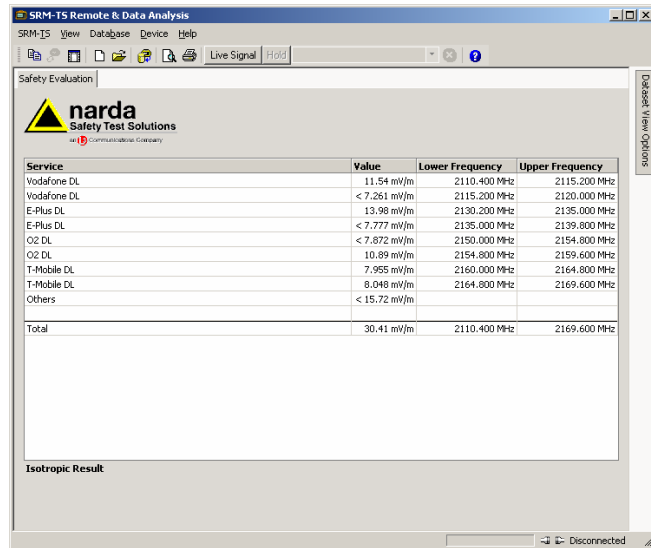


Figure 11: Results of a Safety Evaluation displayed using the SRM-TS PC software.

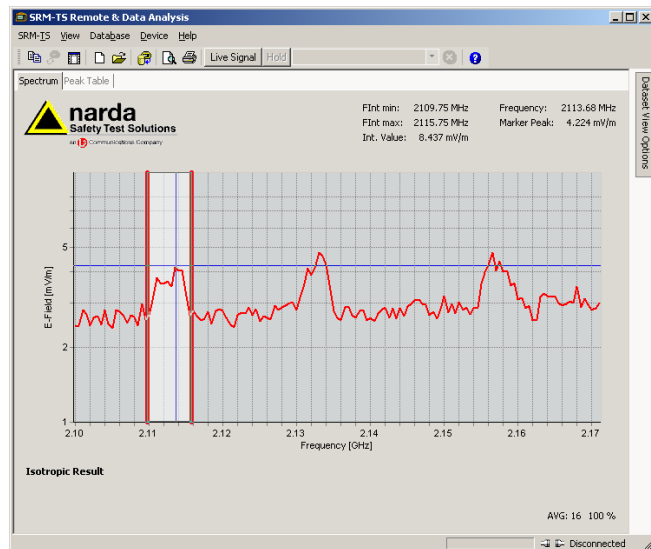


Figure 12: Spectrum evaluation using the SRM-TS PC software and the Integration over Frequency Band function.

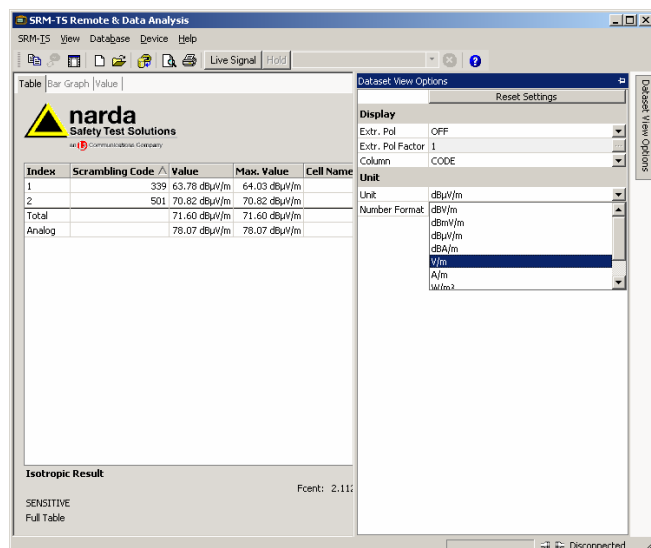


Figure 13: You can switch between different physical units in all operating modes in the SRM itself as well as in the PC software.

Spectrum Analysis: Evaluation using the Peak Table

The Peak Table gives a rapid overview during evaluation. It can be opened in the SRM-TS PC software and in the data memory of the SRM itself for each spectrum.

UMTS P-CPICH Demodulation

As described in section 9, the SRM uses the variable extrapolation factor to automatically extrapolate the instantaneous field strength to give the maximum possible field strengths. The extrapolation factor can also be set or adjusted subsequently (figure 14).

Accounting for measurement uncertainty

Measurement uncertainty must be taken into account in all results. Please refer to our Application Note "Accounting for Measurement Uncertainty in the SRM-3000" (AN_HF_1004).

A measurement report is usually prepared to record the evaluation and assessment. The SRM-TS PC software is very useful for this. The measurement data can be copied directly into the measurement report using simple copy and paste functions, or the measurement data sets can be exported to standard spreadsheet applications.

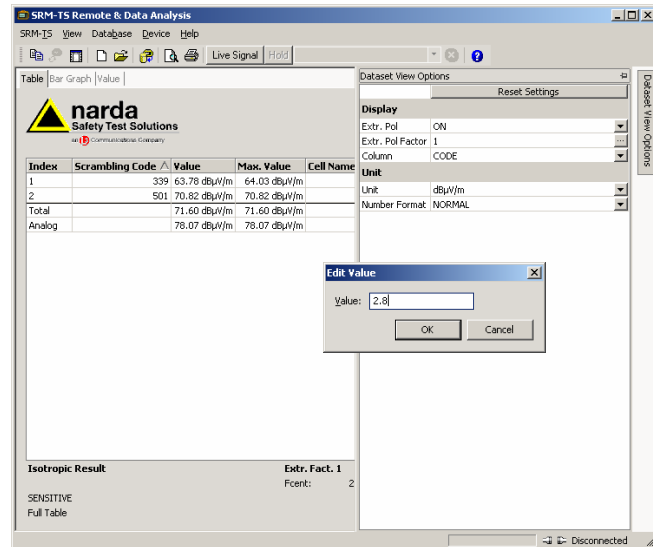


Figure 14:
 Extrapolation performed after measurement using the SRM-TS PC software.

Annex: Calculating the center frequency from the channel number

Service providers often specify a number denoting the exact center frequency of a UMTS frequency channel that they are using. This number is known as the UARFCN. The corresponding frequency is determined using the following equation:

$$f = \frac{UARFCN}{5} \text{ MHz}$$

Example: UARFCN = 10836
Center frequency = 2167.2 MHz

The SRM allows you to enter the channel number and calculates the corresponding center frequency automatically.

Abbreviations

16-QAM	16-stage quadrature amplitude modulation
E-field	Electric field
FDD	Frequency Division Duplex
HSDPA	High Speed Downlink Packet Access
ITU	International Telecommunication Union
MR	Measurement range
P-CPICH	Primary Common Pilot Channel
QPSK	Quadrature Phase Shift Keying
RBW	Resolution bandwidth
RMS	Root mean square
SRM	Selective Radiation Meter
TCH	Traffic channel
TDD	Time Division Duplex
UARFCN	UMTS Absolute Radio Frequency Channel Number
W-CDMA	Wideband Code Division Multiple Access

References

- [1] Guidelines on Limiting Exposure to Non-Ionizing Radiation. International Commission on Non-Ionizing Radiation Protection (ICNIRP), July 1999; ISBN 3-9804789-6-3.
- [2] Directive 2004/40/EC of the European Parliament and the Council of Europe on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th separate directive according to Article 16 Paragraph 1 of Directive 89/391/EEC) of 29 April 2004.
- [3] Council Recommendation of 12 July on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (1999/519/EC). Official Journal of the European Communities L 199/59, 30.7.1999.
- [4] BGV B11: Unfallverhütungsvorschrift Elektromagnetische Felder (Berufsgenossenschaftliche Vorschrift für Sicherheit und Gesundheit bei der Arbeit). 1st June 2001.
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