



Commission for  
**Communications Regulation**

## Site Survey Methodology

### Programme of Measurement of Non-Ionising Radiation Emissions

Methodology for the Conduct of Surveys to Measure Non-Ionising Electromagnetic Radiation from Transmitter Sites

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## 1 Introduction

The Commission for Communications Regulation (ComReg) is the licensing authority for the use of the radio frequency spectrum in Ireland. It is a condition of various Wireless Telegraphy licences issued by ComReg that licensees must ensure that non-ionising radiation (NIR) emissions from each transmitter operated under the licence must be within the limits set down in the guidelines published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP)<sup>1</sup>. Levels of NIR emissions from a licensed transmitter must not exceed the ICNIRP limits in any part of the site or surrounding area to which the general public has access.

In order to assess compliance with conditions relating to NIR, ComReg currently arranges for NIR surveys to be conducted near a sample number of licensed transmitter sites nationwide. Each survey involves measurement and recording of NIR emission levels at the point of highest emissions (in a public area) associated with the transmitter and a subsequent comparison of the levels with the ICNIRP Limits. All measurements and analysis are then documented in a comprehensive technical report.

This document outlines the methodology employed by ComReg for the conduct of NIR surveys. The methodology incorporates many of the measurement methods and procedures outlined in ECC Recommendation (02)04<sup>2</sup>. In order to provide as accurate as possible a picture of the level of emissions present at each survey location, ComReg has added several enhancements to the basic ECC recommended methodology, most notably:

- Correction factors to compensate for limited spectrum analyser measurement bandwidths with respect to wideband signals.
- Frequency selective measurements to be conducted in all cases

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<sup>1</sup> “Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)”, International Commission on Non-Ionizing Radiation Protection, Published in ‘Health Physics’, April 1998, Volume 74, Number 4. [www.icnirp.de](http://www.icnirp.de)

<sup>2</sup> ECC REC (02)04 (revised Bratislava 2003, Helsinki 2007), “MEASURING NON-IONISING ELECTROMAGNETIC RADIATION (9 kHz – 300 GHz)”, published by the European Communications Committee on [www.ero.dk](http://www.ero.dk)

- Three-axis (“isotropic”) antennas to be used for most frequency selective measurements below 3 GHz.

ComReg reserves the right to amend and update this methodology from time to time in order to establish appropriate techniques for measuring emissions from new forms of wireless technology and to incorporate any relevant advances in measurement technology and survey methods.

## 2 Terms and Definitions

### **Reference Levels**

These are the Reference Levels for General Public Exposure<sup>3</sup> specified in the ICNIRP Guidelines and which have been derived from the ICNIRP basic limits of exposure of human beings to electromagnetic fields. Measurements below the reference level guarantee that the requirement that basic limits of exposure are not exceeded is satisfied. Measured and adjusted levels are compared against the reference levels.

### **Designated Transmitter Site**

The transmitter site which has been chosen for survey in order to assess compliance with the Reference Levels of NIR emissions from antennas located at the site.

### **Measurement Point**

The position, typically in the vicinity of the designated transmitter site, where the survey antennas and probes are mounted (i.e. on a suitable stand or tripod). This point represents the location of the maximum field strength, attributable to the antennas at the designated transmitter site, to which a member of the public might be subjected.

### **Measured Level**

The physical magnitude of an electromagnetic emission determined using measurement equipment. Expressed in Volts per metre (V/m) for electric field strength, and in Amperes per metre (A/m) for magnetic field strength.

### **Adjusted Level**

In the case of some emission types an adjusted level is calculated from the measured electric field level for any or all of the following reasons:

- (a) to correct for a spectrum analyser measurement bandwidth which is less than the signal bandwidth;
- (b) to extrapolate to an estimate of the level of emissions from a transmitter under maximum traffic conditions;

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<sup>3</sup> See Annex 1

- (c) to account for the characteristics of certain complex signal types.

### **Total Exposure Quotients**

The Total Exposure Quotients<sup>4</sup> are calculated in order assess simultaneous exposure to multiple frequency fields in respect of *electrical stimulation effects* and/or *thermal effects* as appropriate. The calculation of the quotient values is defined in the ICNIRP Guidelines.

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<sup>4</sup> See Annex 2

### 3 Survey Stages - General Procedure

Surveys must be conducted in three stages as follows:

#### 1 Initial Site Survey

At all sites surveyed, an initial investigation is to be carried out using a field strength meter with an isotropic field probe (appropriate to the frequency range of emissions from the site) to find the location of the maximum field strength. This will be the *measurement point* for the next two stages of the survey.

In the case of *designated transmitters sites* where emissions occur in bands for which isotropic field probes are not currently available, the *measurement point* may be selected by means of:

- (a) a sweep of the area using a spectrum analyser with appropriate antennas;
- or
- (b) calculation based on the theoretical propagation from the antennas on the designated transmitter.

#### 2 Broadband Measurements

Once the location of the maximum field strength has been identified, the field strength meter and isotropic field probe are to be mounted on a non-conductive stand (e.g. a tripod) at the *measurement point* with the probe at a height of 1.5 m above the ground / floor. The aggregate electric or magnetic field strength (in V/m or A/m as appropriate) is to be recorded over a period of at least six minutes. Survey personnel should retreat from the probe during measurements in order not to perturb the electromagnetic field.

In the case of *designated transmitter sites* where emissions occur in bands for which isotropic field probes are not currently available, this stage may be omitted.

### **3 Frequency Selective Measurements**

Measurements of emissions at specific frequencies are then to be carried out at the *measurement point* using a spectrum analyser and a range of antennas matched to the frequencies of the emissions being measured. The spectrum analyser must be set to sweep each frequency range continuously for a period of up to six minutes and the results must be recorded in the spectrum analyser for later analysis and documentation in the site survey report.

Survey personnel should retreat from the antenna during measurements in order not to perturb the electromagnetic field.

This procedure is to be repeated at different frequency ranges until the emission levels in all relevant frequency bands have been recorded.

The approach to frequency selective measurements is outlined in greater detail in the next section.

## 4 Frequency Selective Measurements

Detailed frequency selective measurements must be conducted at the selected measurement point, in order to identify the individual transmit frequencies and field strengths of each emission present. The results of the measurements are used to calculate Total Exposure Quotients for simultaneous exposure to multiple frequency fields. Measurements may be conducted by means of scans of the relevant frequency bands with a spectrum analyser.

### 4.1 Measurement Equipment

#### 4.1.1 Receivers

These measurements are best carried out using a lightweight battery powered spectrum analyser which should be capable of software control. Software control is essential due to the vast amount of frequency and amplitude data to be collected during the survey and to maintain consistent results over several sets of survey equipment being operated by several different survey officers. This software should also make provision for the programming of antenna factors and feeder cable insertion loss. This will allow the survey system to use a variety of antennas and cables allowing for a degree of customisation for specific band surveys. In this way human error can be kept to a minimum. The spectrum analysers will occasionally be required to operate in hostile RF environments and good dynamic range and inter-modulation performance will be essential for reliable and repeatable results.

Additionally it should be noted that for a reactive near-field situation both electric and magnetic measurement are required (use of E and H sensors). In the case of some types of emissions, especially pulsed or Ultra Wide Band, the use of a time domain receiver / analyser is strongly recommended to pre-analyse signals (for example detection and characterisation of bursts) and ensure that measurement settings are adapted accordingly.

#### 4.1.2 Antennas

For the frequency selective measurements, antennas should be lightweight and robust, and good quality feeder cables should be used. Preferred types of antennas to be used are:

- Magnetic loop for HF
- Broadband dipole antenna or (encapsulated) log-periodic antenna
- Bi-conical antenna
- Directional antenna such as horn, dish, lens, log-periodic (for emissions above 3 GHz)
- Three-axis (“isotropic”)

**In the case of emissions in the range 75 MHz to 3 GHz, three-axis (“isotropic”) antennas only must be used.** These antennas are readily available commercially and will capture most commonly occurring emissions (GSM, UMTS, PMR etc.) from all directions simultaneously, thus giving a fuller picture of the various emissions contributing to the overall electromagnetic field at the measurement point.

For lower frequencies, taking into account the significant wavelength, electrically small antennas should be chosen. Using passive electric antennas, the minimum distance between the antenna and any obstacle (e. g. wall or ground for example) must be at least  $1 \lambda$ .

## 4.2 Measurement Bands and Analyser Settings

At every site, scans of **all** the bands shown in *table 1* below must be performed in order to determine the presence of emissions. If emissions are present in a band, full frequency selective measurements must be conducted and recorded in the band. The table lists the spectrum analyser settings to be used for each band. ComReg reserves the right to specify measurement of emissions in additional bands at any designated transmitter site.

Emission Type	Band MHz			RBW <sup>5</sup>	VBW	Detector	Sweep Time <sup>6</sup>
	from	-	to				
<b>PMR VHF Low</b>	68	-	74.8	30 kHz	>=RBW	RMS	100 ms
<b>PMR VHF Low</b>	75.2	-	87.5	30 kHz	>=RBW	RMS	100 ms
<b>FM Radio</b>	87.5	-	108	200 kHz	>=RBW	RMS	100 ms
<b>PMR VHF Mid</b>	138	-	156.8	30 kHz	>=RBW	RMS	100 ms
<b>PMR VHF High</b>	156.8	-	174	30 kHz	>=RBW	RMS	100 ms
<b>TV VHF</b> (analogue PAL)	174		222	3 MHz	>=RBW	<b>Peak</b>	100 ms
<b>T-DAB</b>	222		230	1.6 (2) MHz	>=RBW	RMS	100 ms
<b>TETRA</b>	390	-	400	30 kHz	>=RBW	<b>Peak</b>	700 ms – 1 sec
<b>PMR UHF High</b>	450	-	470	30 kHz	>=RBW	<b>Peak</b>	700 ms – 1 sec
<b>TV UHF</b> (analogue PAL)	470	-	862	3 MHz	>=RBW	<b>Peak</b>	700 ms – 1 sec
<b>TV UHF</b> (DVB-T)	470	-	862	8 MHz	>=RBW	RMS	700 ms – 1 sec
<b>GSM 900</b>	925	-	960	200 (300) kHz	>=RBW	<b>Peak</b>	700 ms – 1 sec
<b>GSM 1800</b>	1805	-	1880	200 (300) kHz	>=RBW	<b>Peak</b>	700 ms – 1 sec
<b>UMTS TDD</b>	1900	-	1920	4.6 (5) MHz	>=RBW	RMS	700 ms – 1 sec
<b>UMTS FDD</b>	2110	-	2170	4.6 (5) MHz	>=RBW	RMS	700 ms – 1 sec
<b>WiFi 2.4GHz</b>	2400	-	2483.5	variable	>=RBW	RMS	700 ms – 1 sec
<b>MMDS</b> (analogue PAL)	2500	-	2686	3 MHz	>=RBW	<b>Peak</b>	700 ms – 1 sec
<b>MMDS</b> (DVB-T)	2500	-	2686	8 MHz	>=RBW	RMS	700 ms – 1 sec
<b>FWALA 3 GHz<sup>7</sup></b>	3510	-	3600	variable	>=RBW	RMS	700 ms – 1 sec
<b>FWALA 3 GHz</b>	3710	-	3800	variable	>=RBW	RMS	700 ms – 1 sec
<b>WiFi</b>	5470	-	5725	variable	>=RBW	RMS	700 ms – 1 sec
<b>FWA</b> (Licence-exempt)	5725	-	5875	variable	>=RBW	RMS	700 ms – 1 sec
<b>FWALA 10 GHz</b>	10154	-	10287	variable	>=RBW	RMS	700 ms – 1 sec

**Table 1**

<sup>5</sup> See Important Note 2.

<sup>6</sup> See Important Note 3.

<sup>7</sup> FWALA: Fixed Wireless Access Local Area – refers mainly to wireless broadband systems.

**Important Note 1: Sub-bands**

In order to ensure that narrowband signals are not lost in the band scan, the frequency bands to be measured must be split into sub-bands if the following condition is not fulfilled by the spectrum analyser:

$$\text{Span} / \text{RBW} < \text{number of horizontal pixels on analyser display}$$

**Important Note 2: Resolution Bandwidth**

The resolution bandwidth (RBW) of the spectrum analyser should be set to the values listed in *table 1* for each band and emission type. For some emission types (e.g. WiFi and FWALA) the signal bandwidth<sup>8</sup> may vary and as such no RBW has been specified in the table. In such cases the RBW of the spectrum analyser should be set to a value equal to (if possible, otherwise larger than) the signal bandwidth of the emission.

In the case of wideband emissions, such as DVB-T and FWALA, it may not be possible to set an RBW as prescribed in the table as the signal bandwidth may exceed the maximum RBW of the spectrum analyser. In such cases, the analyser should be set to the maximum RBW and an appropriate correction factor<sup>9</sup> should be applied to the measured level to calculate the level for the full signal bandwidth as part of the measurement analysis.

In rare instances it may be apparent that the bandwidth of an emission exceeds its regular stated bandwidth, e.g. due to inadequate filtering at the transmitter end. In such cases the RBW should be adjusted to match the actual bandwidth of the signal.

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<sup>8</sup> See Annex 3 for a list of possible signal bandwidths for various emission types.

<sup>9</sup> See Annex 4: Correcting for Spectrum Analyser RBW Limitations.

**Important Note 3: Sweep Time**

Many spectrum analyser settings such as span, RBW, sweep time etc. are interdependent and most modern analysers couple these parameters in normal operating mode in order to optimise the parameters and to avoid measurement errors. If one setting is varied all other dependent parameters will be adapted automatically.

Table 1 above shows sweep times as recommended in ECC/REC/(02)04. However, where analysers offer the automatic parameter coupling facility, it is acceptable to measure emissions using the resulting sweep time setting as long as the following condition<sup>10</sup> is met:

$$T_{\text{SWEEP}} = k \times \frac{\Delta f}{\text{RBW}^2}$$

where

- $T_{\text{SWEEP}}$  = minimum sweep time
- RBW = resolution bandwidth
- $\Delta f$  = span
- $k$  = proportionality factor

The proportionality factor  $k$  depends on the type of IF filter used. For analogue filters (consisting of four or five individual circuits)  $k = 2.5$ . For digital Gaussian filters  $k = 1$  can be attained.

**Important Note 4: Measurement Duration**

Frequency Range	Duration
100 kHz to 10 GHz	6 minutes
> 10 GHz	$68/f^{1.05}$ minute period ( $f$ in GHz)

<sup>10</sup> Rauscher, C et al., "Fundamentals of Spectrum Analysis", Rohde & Schwarz GmbH, 2005, pp76-79.

#### 4.3 Emissions from Distant Transmitters - Important Note

It is important to make an accurate assessment of the overall electromagnetic field present at the point of highest emissions near the designated transmitter site in order to assess simultaneous exposure to multiple frequency fields (as per the ICNIRP Guidelines).

Therefore it is necessary to take into account the main field strength contributions of emissions from the designated transmitter site and also secondary contributions from distant transmitters (e.g. adjacent cell GSM base stations, TV transmitters serving the area etc.). To that end, it is necessary to measure bands in which the transmitters at the designated site emit no signals, as signals in those bands from distant transmitters may be apparent at the measurement point. It is important to measure and record those emissions and document them in the site survey report in order to factor them in to the calculation of the Total Exposure Quotients.

## 4.4 Measurement Procedure

### 4.4.1 Equipment pre-Check

All measurement equipment should be calibrated (according to the manufacturer's recommendations) to traceable standards. RF cables, waveguides and connectors should be individually marked and checked prior to use for mechanical damage and checked regularly for insertion and return loss characteristics. Any changes in antenna factors and cable loss should be programmed into the measurement receiver.

It is the responsibility of the survey team to confirm the calibration factors are correct and updated as necessary prior to each task. A record in the survey notebook should show that the check/update has been made. A check should be made to verify that the correct cable and antenna parameters are loaded and activated in the receiver.

### 4.4.2 Measurement with Isotropic Antennas

When using isotropic antennas, the following measurement procedure must be followed in respect of each measurement band:

- (1) Mount the antenna on a non-conductive stand (e.g. a tripod) at the *measurement point* at a height of 1.5 m above the ground or floor.
- (2) Determine if the emission type to be measured is a special case<sup>11</sup> as listed in Section 7. If so implement any additional or alternative procedures outlined in Section 7.
- (3) Set the analyser to **Max Hold**.
- (4) Program the spectrum analyser with the appropriate settings (RBW, VBW, Detector, Sweep Time) for the band to be measured.

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<sup>11</sup> e.g. GSM, TETRA, UMTS

- (5) Scan the band for emissions. If no emissions whatsoever have been detected in the band, do not proceed with the full measurement recording. Instead save a brief scan of the band. The scan should be included in the subsequent report, in order to document the absence of any signal in the band from the designated transmitter site.
- (6) Set the spectrum analyser to record measurements over the specified duration and retreat from the antenna.

#### 4.4.3 Measurement with Directional Antennas

In instances where directional antennas (horn, dish, log-periodic etc.) are used, it is still important to account for any significant emissions from distant transmitters in addition to those from the nearby designated transmitter site. In such cases, the following measurement procedure must be followed for each frequency band to be measured:

- (1) Mount the antenna on a non-conductive stand (e.g. a tripod) at the *measurement point* at a height of 1.5 m above the ground or floor.
- (2) Determine if the emission type to be measured is a special case<sup>12</sup> as listed in Section 7. If so implement any additional or alternative procedures outlined in Section 7.
- (3) Mount the antenna on a non-conductive stand (e.g. a tripod) at the *measurement point* at a height of 1.5 m above the ground or floor.
- (4) Set the analyser to **Max Hold**.
- (5) Program the spectrum analyser with the appropriate settings (RBW, VBW, Detector, Sweep Time) for the band to be measured.

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<sup>12</sup> e.g. GSM, TETRA, UMTS

**Measure emissions from the designated transmitter site**

- (6) Orient the antenna in the direction of the transmitter.
- (7) Vary the polarisation and tilt of the antenna until a maximum signal level has been detected.
- (8) With the polarisation and upward tilt corresponding to the maximum signal level, set the spectrum analyser to record measurements over the specified duration and retreat from the antenna.
- (9) If no emissions have been detected from the designated transmitter site, do not proceed with the full measurement recording. Instead save a brief scan of the band. The scan should be included in the subsequent report, in order to document the absence of any emissions in the band from the designated transmitter.

**Measure Emissions from distant transmitters**

- (10) It is also necessary to determine if emissions in the band from distant transmitters are present at the location.
- (11) Rotate the antenna 360° horizontally while varying the polarisation and tilt. When a maximum signal level has been detected, orient the antenna in the appropriate direction, with the appropriate polarisation and tilt. Then, set the spectrum analyser to record measurements over the specified duration and retreat from the antenna.
- (12) If no emissions have been detected from distant transmitters, do not proceed with the full measurement recording. Instead save a brief scan of the band. The scan should be included in the subsequent report, in order to document the absence of any emissions in the band from distant transmitters.

## 5 Measurement Analysis

Once the survey has been completed and all measurements have been recorded, the measurements must be analysed in order to assess compliance of the emissions from the site with the reference levels.

### 5.1 Broadband Measurements

The purpose of the broadband measurements is to get an overview of the intensity of the electromagnetic field present at the point of measurement. The average and maximum levels recorded are to be compared to the lowest maximum reference level which is 28 V/m.

If a broadband measurement is higher than 28 V/m, it does not necessarily follow that the reference levels have been exceeded, as the reference levels are frequency dependent. Analysis of the frequency selective measurements is necessary to assess compliance with the reference levels.

### 5.2 Frequency Selective Measurements

Analysis of the frequency selective measurements should proceed in four stages as follows:

#### **(1) Selection of Measurements for Analysis**

For each frequency band for which frequency selective measurements were conducted, all emissions with field strengths greater than *the threshold level*<sup>13</sup> must be included in the analysis. If no emission exceeds the threshold level within a frequency band the two highest emissions must be included

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<sup>13</sup> The threshold level is 40 dB below the relevant Reference Level for a particular frequency. For E-Field measurements, this corresponds to a factor of 100 times below the Reference Level.

## **(2) Calculation of Adjusted Levels**

Where applicable an adjusted level is to be calculated from the measured level for any or all of the following reasons:

- To compensate for when emission bandwidth exceeds spectrum analyser RBW (RBW Correction Factor)<sup>14</sup>
- To extrapolate to a Maximum Traffic Level (e.g. for GSM, TETRA & UMTS)<sup>15</sup>
- To apply a Correction Factor for emissions with complex signal structures (e.g. PAL TV)<sup>16</sup>

## **(3) Assessment of ICNIRP Compliance of Individual Emissions**

The level for each emission, which has been adjusted where applicable, is compared to the reference level which applies at the particular frequency of the emission in order to determine their compliance with the reference levels.

## **(4) Assessment of ICNIRP Compliance of Cumulative Emissions**

The levels (adjusted where applicable) for all the emissions are used to calculate two Total Exposure Quotients<sup>17</sup> in order to assess simultaneous exposure to multiple frequency fields (i.e. emissions on different frequencies from multiple transmitters). The calculated values of the quotients must be  $< 1$  in order for the aggregate of NIR emissions to satisfy the criteria of the ICNIRP Guidelines.

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<sup>14</sup> See Annex 4

<sup>15</sup> See Section 7: Special Cases

<sup>16</sup> See Section 7: Special Cases

<sup>17</sup> See Annex 2

## 6 Reporting Measurement Results

The measurement results must be documented in the Site Survey Report<sup>18</sup> which must include the following:

- Address of designated transmitter site surveyed
- Date of survey
- Measurement point address and coordinates (latitude / longitude)
- Atmospheric temperature in °C at measurement point
- Photos of transmitter site and measurement equipment (as set up at the measurement point).
- Sketched map of the transmitter site and measurement location
- Outline of the conduct of the survey

In respect of broadband measurements, the report must fully document all measurements made in each band:

- Levels measured
- Field strength meter used: Manufacturer, Model, Serial no., Calibration Date
- Probe used: Manufacturer, Model, Serial no., Calibration Date, Frequency Range

The report must fully document all frequency selective measurements made in each band as follows:

- Frequency band measured
- Spectrum analyser trace
- Tabulation (example below) of measurements in each band including:
  - Centre frequency and level for each emission measured
  - Calculations of adjusted levels where applicable
  - Comparison of measured and adjusted levels to the relevant reference levels

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<sup>18</sup> The format of the report is specified by ComReg and may be revised from time to time.

- Spectrum analysers and antennas used: Manufacturer, Model, Serial no., Calibration Date, Frequency Range
- Spectrum analyser settings: Hold, RBW, VBW, Detector, Sweep time
- Measurement Uncertainty<sup>19</sup>

Frequency UMTS Channel (MHz)	ICNIRP Limit (V/m)	Measured E-Field		Adjusted E-Field			
		Level (V/m)	Times below limit	RBW Correction Factor	Max Traffic Extrapolation Factor	Adjusted Level (V/m)	Times below limit
2113.600	61.00	0.63090	96.7	2.0449	3.1623	4.07984	14.95
2128.600	61.00	0.20280	300.8	2.0449	3.1623	1.31145	46.51

**Figure 1:** Example table of frequency selective measurements in UMTS band

The report must contain a full analysis of the frequency selective measurements including the following:

- Tabulation of all frequency selective measurement results from all bands
- Assessment of ICNIRP compliance of individual emissions
- Calculation of total exposure quotients
- Overall conclusions

<sup>19</sup> For each band measured, the measurement uncertainty should be stated. Calculations of the uncertainty should be included in the report. Measurement uncertainty is to be estimated in accordance with the method outlined in Annex 5 - § 5 of ECC/REC/(02)04.

## 7 Special Cases

### 7.1 GSM and TETRA

In the cases of GSM and TETRA networks it is necessary to extrapolate to an estimate of the emission level under maximum traffic from the base station. The base stations of those networks produce emissions which vary according to the changing volume of calls and data traffic over the course of the day.

Transmissions by these systems consist of an always-on BCCH (pilot and control) channel. In addition, a base station may transmit one or more associated traffic channels. In order to take into account the maximum possible traffic, the following procedures must be followed:

#### **Frequency Selective Measurement Procedure**

- (1) Before commencing frequency selective measurements in the GSM and TETRA bands, firstly identify and note down the frequencies of all the BCCH channels present in the band. This may be done with the spectrum analyser in **Clear Write** mode.
- (2) Continue according to the standard procedure for Measurement with Isotropic Antennas.

#### **Measurement Analysis Procedure**

- (1) Identify the measured levels for the BCCH channels from the frequency selective scan.
- (2) Estimate the level for maximum traffic  $E_{MAX}$  associated with each BCCH as follows:

<p><b>V/m Calculation</b></p> $E_{MAX} = E_{BCCH} \times \sqrt{n_{channels}}$	<p><b>dB Calculation</b></p> $E_{MAX} = E_{BCCH} + 10\text{Log}_{10}(n_{channels})$
<p><math>n_{channels}</math> includes the BCCH plus the number of traffic channels.</p> <p>If the Number of traffic channels per BCCH is not known, <math>n_{channels}</math> is taken as:</p> <p><b>GSM: 4</b>                                      <b>TETRA (Emergency): 3</b>                                      <b>TETRA (Civil): 2</b></p>	

### **Reporting Measurement Results**

The following information must be documented in the site survey report:

- BCCH Channel in MHz
- Measured Level
- Adjusted Level .i.e. Estimated level for maximum traffic

The adjusted level is compared to the relevant Reference Level and is used in the calculation of the Total Exposure Quotients.

## 7.2 UMTS

In the cases of UMTS networks it is necessary to extrapolate to an estimate of the emission level under maximum traffic from the base station. The base stations of those networks produce emissions which vary according to the changing volume of calls and data traffic over the course of the day.

Transmissions by these systems consist of an always-on P-CPICH (pilot and control) channel. Any traffic channels are 'stacked' on top of the P-CPICH in the physical WCDMA UMTS channel. Therefore the level of each physical UMTS channel increases with traffic volume. In order to take into account the maximum possible traffic, the following procedures must be followed:

### **Frequency Selective Measurement Procedure**

- (1) If the spectrum analyser is capable of UMTS P-CPICH Demodulation, then follow the UMTS measurement procedure outlined in Annex 5 § 4.8 of ECC/REC/(02)04.
- (2) Otherwise, continue according to the standard procedure for Measurement with Isotropic Antennas, **except with the analyser set to MIN HOLD<sup>20</sup>**.

### **Measurement Analysis Procedure**

- (1) If the spectrum analyser is capable of UMTS P-CPICH Demodulation, then follow the UMTS analysis procedure outlined in Annex 5 § 4.8 of ECC/REC/(02)04. **Otherwise proceed as follows:**
- (2) Identify the measured levels for all UMTS channels from the frequency selective scan.
- (3) Estimate the level for maximum traffic  $E_{MAX}$  associated with each channel as follows:

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<sup>20</sup> The signal level measured for each UMTS channel is taken as an estimate of the P-CPICH level if the measurement receiver is unable to identify and measure any P-CPICH channels present. The level will tend towards the P-CPICH level with less traffic. The probability of capturing the actual P-CPICH level is increased when the analyser is set to MIN HOLD. The measured valued will serve as an estimate of the P-CPICH level.

<b>V/m Calculation</b>	<b>dB Calculation</b>
$E_{MAX} = E_{UMTS} \times \sqrt{R_{P-CPICH}}$	$E_{MAX} = E_{UMTS} + R_{P-CPICH}$
<p data-bbox="288 546 635 582"><math>R_{P-CPICH} = P_{MAX} / P_{P-CPICH}</math></p> <p data-bbox="288 613 1281 680">The P-CPICH transmits with a constant power typically 10 dB below the maximum possible power (<math>P_{MAX}</math>) for a UMTS signal.</p> <p data-bbox="288 714 624 750">Therefore <math>R_{P-CPICH} = 10</math> dB</p> <p data-bbox="288 779 644 831"><math>\sqrt{R_{P-CPICH}} = \sqrt{10} = 3.1623</math></p>	

### **Reporting Measurement Results**

The following information must be documented in the site survey report:

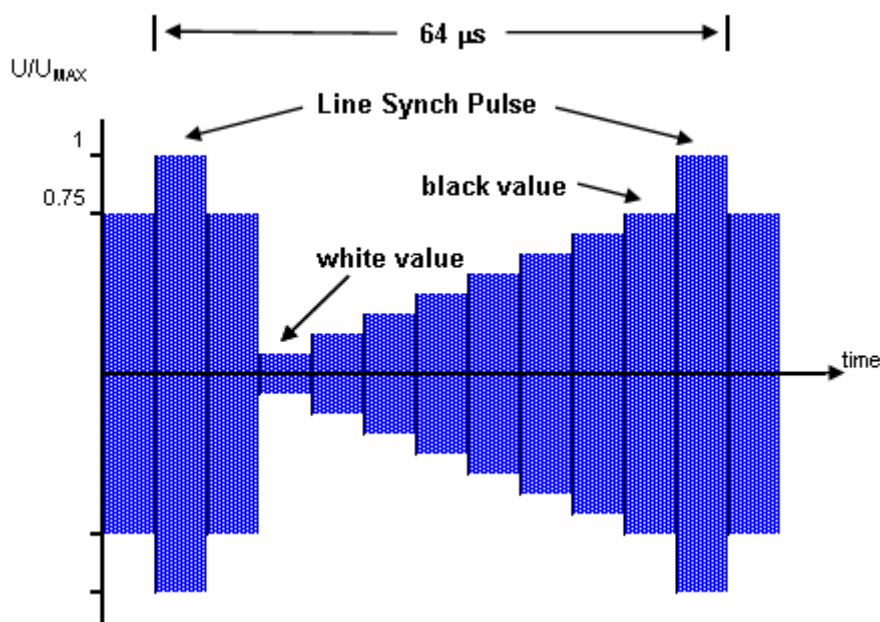
- UMTS Channel in MHz
- Measured Level (P-CPICH)
- Adjusted Level i.e. Estimated level for maximum traffic

The adjusted level is compared to the relevant Reference Level and is used in the calculation of the Total Exposure Quotients.

### 7.3 Analogue PAL TV

Given the complex structure of analogue PAL television signals, it is necessary to apply a correction factor to the measured level to derive a level indicative of the full signal. The characteristics of the signal shape make it difficult to measure an RMS level directly, which is indicative of worst case exposure.

The peak field strength caused by the synch pulses of the picture (luminance) carrier is measured. The field strength from the picture signal is at its highest when a synch pulse is being transmitted.



**Figure 2:** Luminance Signal in the Time Domain

For a black picture, the mean power is 2.5 dB below the peak power (i.e. for a synch pulse). It is assumed that 100% black picture is transmitted permanently for worst case exposure evaluation. The mean (RMS) level for a black picture is then calculated from the peak synch pulse level by applying a correction factor to the peak synch pulse level. The value of this **correction factor** is **-2.3 dB** rather than -2.5 dB, in order to take into consideration the small contributions of the FM and NICAM sound signal components.

**Frequency Selective Measurement Procedure**

- (1) An RBW of 3 MHz is used to capture the luminance signal.
- (2) Continue according to the standard procedure appropriate to the frequency band.

**Measurement Analysis Procedure**

- (1) Identify each PAL luminance signal measured from the frequency selective scan.
- (2) In each case, derive the level for the full PAL signal by applying the correction factor to the measurement for the peak luminance signal:

$$E_{\text{PAL}} = E_{\text{LUM}} \times k \quad \text{corr factor } k = -2.3 \text{ dB} = 0.767$$

**Reporting Measurement Results**

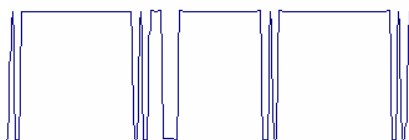
The following information must be documented in the site survey report:

- Luminance Channel in MHz
- Measured Level
- Adjusted Level .i.e. the level for the full PAL signal as calculated using the correction factor.

The adjusted level is compared to the relevant Reference Level and is used in the calculation of the Total Exposure Quotients.

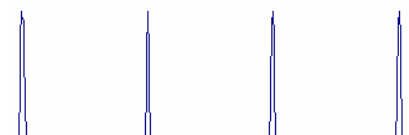
## 7.4 WiFi

In WiFi (IEEE 802.11) systems, data and signalling frames are multiplexed together on a signal physical channel. In addition the up- and downlinks are separated by TDD (Time Division Duplex).



**Figure 3:** data and beacon frames multiplexed (time domain)

If a WiFi access point (base station) is relaying no data traffic, only the regular beacon signal pulse will be transmitted.



**Figure 4:** beacon frames only transmitted (time domain)

Under such conditions, it is necessary to be able to measure the level of the beacon signal in order to determine mean exposure. With some spectrum analysers it may be difficult to capture the beacon signal pulse in the frequency domain due to its small pulse width (0.25 ms) and long period (100 ms). In such cases it is recommended to measure the beacon signal in the time domain rather than in the frequency domain (i.e. with a span “0” centred on the frequency of the emission).

### 7.5 Pulsed / Radar Emissions

These emissions should be measured according to the relevant procedure outlined in Annex 5 of ECC/REC/(02)04.

### 7.6 Discontinuous Signals

These emissions should be measured according to the relevant procedure outlined in Annex 5 of ECC/REC/(02)04.

### 7.7 Measurements in the Reactive Near-Field

In contrast to the radiating near-field and the far-field region, in the reactive near-field region, the H-field and E-field must be measured separately. In cases where emissions are to be measured inside the reactive near-field of a transmitter (e.g. when measuring emissions from a long wave transmitter) distinct sensors must be used for each field component.

The electric component (E) of the electromagnetic field can be easily measured using suitable antennas, e.g. dipole, bi-conical, log-periodic etc, and the magnetic component (H) of the electromagnetic field is usually measured with loop sensors (as the current induced in the loop is proportional to the magnetic field strength crossing the loop).

## ANNEX 1 ICNIRP Reference Levels - General Public Exposure

ICNIRP has defined basic restrictions and reference levels. Depending on frequency, the physical quantities used to specify the basic restrictions on exposure to electromagnetic fields (EMF) are current density, specific absorption rate (SAR), and power density. SAR is not easily measurable in living people therefore reference levels have been obtained from the basic restrictions by mathematical modelling and by extrapolation from the results of laboratory investigations at specific frequencies.

The reference levels are provided for comparison with measured values of physical quantities; compliance with all reference levels given in these guidelines will ensure compliance with basic restrictions. If measured values are higher than reference levels, it does not necessarily follow that the basic restrictions have been exceeded, but a more detailed analysis is necessary to assess compliance with the basic restrictions.

Frequency Range	E – Field Strength ( $\text{Vm}^{-1}$ )	H – Field ( $\text{Am}^{-1}$ )	B – Field ( $\mu\text{T}$ )	Equivalent plane wave power S ( $\text{Wm}^{-2}$ )
up to 1 Hz	-	$3.2 \times 10^4$	$4 \times 10^4$	-
1 – 8 Hz	10,000	$3.2 \times 10^4/f^2$	$4 \times 10^4/f^2$	-
8 – 25 Hz	10,000	$4,000/f$	$5000/f$	-
0.025 – 0.8 kHz	$250/f$	$4/f$	$5/f$	-
0.8 – 3 kHz	$250/f$	5	6.25	-
3 – 150 kHz	87	5	6.25	-
0.15 - 1 MHz	87	$0.73/f$	$0.092/f$	-
1 – 10 MHz	$87/f^2$	$0.73/f$	$0.092/f$	-
10 – 400 MHz	28	0.16	0.092	2
400 – 2000 MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	$0.0046f^{1/2}$	$f/200$
2 – 300 GHz	61	0.16	0.20	10

**Table 2:** Reference levels for general public exposure to time-varying electric and magnetic fields (unperturbed rms values). f in units as indicated in the Frequency Range column.

## ANNEX 2 Total Exposure Quotients

ICNIRP has specified a means of assessing additivity of exposures in situations of simultaneous exposure to fields of different frequencies. Additivity is examined separately for the effects of electrical and thermal stimulation, and ICNIRP has set out basic restrictions which should be met for both considerations.

For practical application of the basic restrictions, ICNIRP has advised that the following criteria<sup>21</sup> regarding reference levels of field strengths should be applied:

### **Induced Current Density and Electrical Stimulation**

For induced current density and electrical stimulation effects, relevant up to 10 MHz, the following two requirements should be applied to the field levels:

$$\sum_{i=1 \text{ Hz}}^{1 \text{ MHz}} \frac{E_i}{E_{L,i}} + \sum_{i>1 \text{ MHz}}^{10 \text{ MHz}} \frac{E_i}{a} \leq 1,$$

and

$$\sum_{j=1 \text{ Hz}}^{65 \text{ kHz}} \frac{H_j}{H_{L,j}} + \sum_{j>65 \text{ kHz}}^{10 \text{ MHz}} \frac{H_j}{b} \leq 1,$$

where

- $E_i$  = the electric field strength at frequency  $i$ ;
- $E_{L,i}$  = the electric field reference level from Tables 1 and 2;
- $H_j$  = the magnetic field strength at frequency  $j$ ;
- $H_{L,j}$  = the magnetic field reference level from Tables 1 and 2;
- $a$  = 610 V m<sup>-1</sup> for occupational exposure and 87 V m<sup>-1</sup> for general public exposure; and
- $b$  = 24.4 A m<sup>-1</sup> (30.7 μT) for occupational exposure and 5 A m<sup>-1</sup> (6.25 μT) for general public exposure.

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<sup>21</sup> Here referred to as Total Exposure Quotients

### **Thermal Considerations**

For thermal considerations, relevant above 100 kHz, the following two requirements should be applied to the field levels:

$$\sum_{i=100 \text{ kHz}}^{1 \text{ MHz}} \left( \frac{E_i}{c} \right)^2 + \sum_{i>1 \text{ MHz}}^{300 \text{ GHz}} \left( \frac{E_i}{E_{L,i}} \right)^2 \leq 1,$$

and

$$\sum_{j=100 \text{ kHz}}^{1 \text{ MHz}} \left( \frac{H_j}{d} \right)^2 + \sum_{j>1 \text{ MHz}}^{300 \text{ GHz}} \left( \frac{H_j}{H_{L,j}} \right)^2 \leq 1,$$

where

- $E_i$  = the electric field strength at frequency  $i$ ;
- $E_{L,i}$  = the electric field reference level from Tables 1 and 2;
- $H_j$  = the magnetic field strength at frequency  $j$ ;
- $H_{L,j}$  = the magnetic field reference level from Tables 1 and 2;
- $c$  =  $610/f \text{ V m}^{-1}$  ( $f$  in MHz) for occupational exposure and  $87/f^{1/2} \text{ V m}^{-1}$  for general public exposure; and
- $d$  =  $1.6/f \text{ A m}^{-1}$  ( $f$  in MHz) for occupational exposure and  $0.73/f$  for general public exposure.

## ANNEX 3 Signal Bandwidths

Table 3 below lists typical signal bandwidths for common emission types. The table is presented as an aid to choosing appropriate RBWs for frequency selective measurements and to calculating RBW correction factors if it is necessary to compensate for limited spectrum analyser RBW when measuring wideband signals.

Emission Type	Band MHz			Signal Bandwidth
	from	-	to	
<b>PMR VHF Low</b>	68	-	74.8	12.5 / 25 kHz
<b>PMR VHF Low</b>	75.2	-	87.5	12.5 / 25 kHz
<b>FM Radio</b>	87.5	-	108	150 kHz
<b>PMR VHF Mid</b>	138	-	156.8	12.5 / 25 kHz
<b>PMR VHF High</b>	156.8	-	174	12.5 / 25 kHz
<b>TV VHF</b> (analogue PAL)	174		222	≈ 8 MHz
<b>T-DAB</b>	222		230	1.536 MHz
<b>TETRA</b>	390	-	400	25 kHz
<b>PMR UHF High</b>	450	-	470	12.5 / 25 kHz
<b>TV UHF</b> (analogue PAL)	470	-	862	≈ 8 MHz
<b>TV UHF</b> (DVB-T)	470	-	862	7.61 MHz
<b>GSM 900</b>	925	-	960	200 kHz
<b>GSM 1800</b>	1805	-	1880	200 kHz
<b>UMTS TDD</b>	1900	-	1920	4.6 MHz
<b>UMTS FDD</b>	2110	-	2170	4.6 MHz
<b>WiFi 2.4GHz</b>	2400	-	2483.5	16.56 / 22 MHz
<b>MMDS</b> (analogue PAL)	2500	-	2686	≈ 8 MHz
<b>MMDS</b> (DVB-T)	2500	-	2686	7.61 MHz
<b>FWALA 3.5 GHz</b>	3510	-	3600	wideband variable <sup>22</sup> 7/14/25/35 MHz
<b>FWALA 3.5 GHz</b>	3710	-	3800	wideband variable 7/14/25/35 MHz
<b>WiFi</b>	5470	-	5725	16.56 / 22 MHz
<b>FWA</b> (Licence-exempt)	5725	-	5875	wideband variable 7/14/25/35 MHz
<b>FWALA 10 GHz</b>	10154	-	10287	wideband variable 14/28 MHz

**Table 3:** Signal Bandwidths

<sup>22</sup> Wireless broadband (FWALA, FWA) signals can vary in bandwidth. The table shows indicative bandwidths for these emission types and actual signal bandwidths may differ in practice. If wireless broadband transmitters are employing WiMax, possible bandwidths are 20/25/28 MHz (WiMax Directional) and 1.5 to 20 MHz in steps of 1.5 MHz (WiMax Mobile).

## ANNEX 4 Correcting for Spectrum Analyser RBW Limitations

Where possible, the spectrum analyser should be set to a resolution bandwidth (RBW) equal to the bandwidth of the emission being measured. However, in the case of wideband emissions (e.g. DVB-T, WiFi, FWALA etc.) it may be not be possible to set the spectrum analyser to an RBW equal to the bandwidth of the emission. For example, a spectrum analyser with a maximum possible RBW of 5 MHz cannot directly measure a DVB-T signal across its full 7.61 MHz bandwidth.

In such cases it is necessary to compensate for the limited RBW of the spectrum analyser by applying an *RBW Correction Factor* to the measured emission level in order to calculate an adjusted level which accounts for all the energy present within the full bandwidth of the emission.

The *RBW correction factor* is to be derived as follows:

$$\text{Correction Factor}^{23}: \quad K_{\text{RBW}} = 10 \times \log_{10} (B_{\text{Signal}} / B_{\text{N}})$$

Where  $B_{\text{Signal}}$  is the signal/emission bandwidth

$B_{\text{N}}$  is the noise bandwidth of the analyser filter  
( for a Gaussian Filter:  $B_{\text{N}} \approx 1.1 \times B_{3\text{dB}}$  )

**Example:** Measuring a 7.61 MHz DVB-T signal with 5 MHz RBW:

$$B_{\text{Signal}} = 7.61 \text{ MHz}$$

$$B_{3\text{dB}} = \text{RBW} = 5 \text{ MHz} \quad \Rightarrow \quad B_{\text{N}} = 1.1 \times 5 = 5.1$$

$$K_{\text{RBW}} = 10 \times \log_{10} ( 7.61 / 5.1 ) = 1.74 \text{ dB}$$

<sup>23</sup> Alternatively, when calculating numerically in V/m for E-field measurements:

$$K_{\text{RBW}} = \sqrt{B_{\text{Signal}} / B_{\text{N}}}$$