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NIR MEASUREMENTS. Principles and practices of
EMF characterization and measurements

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Summary

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1. Introduction

The concern about non-ionizing radiation (NIR) and its study started in the 1950's. It was established a very comprehensive research that continues until now. According to the WHO- EMF-Project database there are more than 3000 studies.

Within the frame of the WHO International EMF Project it have been developed a huge research effort in order to conduct the risk assessment of non-ionizing radiation as a basic step to establish policies and actions to enhance levels of people's radio protection.

One important task to the risk assessment is the evaluation of exposure levels coming from diverse sources from NIR. This is why this short course is aimed to give the basic Principles and practices of EMF measurement.

2. Standards for limiting exposure to electromagnetic fields

TABLE I. ICNIRP reference levels -occupational exposure- rms values)

Frequency range	E- field strength (Vm ⁻¹)	H- field strength (Am ⁻¹)	B- field (μT)	Equivalent plane wave power density S _{eq} (Wm ⁻²)
Hasta 1 Hz	–	1.63 x 10 ⁵	2 x 10 ⁵	–
1 – 8 Hz	20 000	1.63 x 10 ⁵ /f ²	2 x 10 ⁵ /f ²	–
8 – 25 Hz	20 000	2 x 10 ⁴ /f	2.5 x 10 ⁴ /f	–
0.025 – 0.82 kHz	500 / f	20 / f	25 / f	–
0.82 – 65 kHz	610	24.4	30.7	–
0.065 – 1 MHz	610	1.6 / f	2 / f	–
1 – 10 MHz	610 / f	1.6 / f	2 / f	–
10 – 400 MHz	61	0.16	0.2	10
400 – 2000 MHz	3 f ^{0.5}	0.008 f ^{0.5}	0.01 f ^{0.5}	f / 40
2 – 300 GHz	137	0.36	0.45	50

TABLE II. ICNIRP reference levels –general public exposure- rms values)

Frequency range	E- field strength (Vm ⁻¹)	H- field strength (Am ⁻¹)	B- field (μT)	Equivalent plane wave power density S _{eq} (Wm ⁻²)
Hasta 1 Hz	–	3.2 x 10 ⁴	4 x 10 ⁴	–
1 – 8 Hz	10 000	3.2 x 10 ⁴ /f ²	4 x 10 ⁴ /f ²	–
8 – 25 Hz	10 000	4000/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	0.92 / f	–
1 – 10 MHz	87/ f ^{0.5}	0.73/ f	0.92/ f	–
10 – 400 MHz	28	0.073	0.092	2
400 – 2000 MHz	1.375 f ^{0.5}	0.0037 f ^{0.5}	0.0046 f ^{0.5}	f/ 200
2 – 300 GHz	61	0.16	0.20	10

TABLE III. ICNIRP reference levels for telecommunication services –
 general public exposure- rms values)

Services	Frequency range (MHz)	E- field strength (Vm⁻¹)	B- field (μT)	Equivalent plane wave power density S_{eq} (Wm⁻²)
FM broadcast	88- 108 MHz	28.0	0.092	2.0
VHF TV	54- 88 MHz 174- 216 MHz	28.0	0.092	2.0
UHF TV	407- 806 MHz	29.8	0.099	2.0
Trunking 800 MHz	806-869 MHz	40.0	0.13	4.3
Mobile Telephony 800 MHz	824-894MHz	40.6	0.14	4.4
Mobile Telephony 900 MHz	890-960 MHz	41.0	0.14	4.5
PCS 1800	1710- 1880 MHz	56.9	0.19	8.6
PCS 1900	1850- 1900 MHz	60.5	0.20	9.7

3. Field regions

3.1 Reactive near field

It is the region that is immediately surrounding the antenna and where the reactive field predominates. The limit of region is considered to be at a distance of λ from the antenna]. The attenuation of electric field and magnetic field is an inverse function of the square and cube of distance respectively: For mobile telephony systems the reactive near field limits is very limited (some dozens of cm). The evaluation of these fields are only important for occupational exposure.

3.2. Reactive-radiating near field

This region is a transition zone wherein radiating field gets an increasing importance compared with the reactive one. The limit of this sub-region is considered to be at 3λ from the antenna.

3.3. Radiating near field

This region only exists if the maximum dimension L of the antenna is large compared with λ . In this region the radiating field predominates. The field is not considered to propagate as plane waves but the electric and magnetic components of the field can be considered locally normal and related by the intrinsic impedance of the medium $Z_0=377$ ohms. The limit of this region is considered to be $R_{ff} = 2L^2 / \lambda$

Where:

R is the distance between the evaluation location and the antenna

L is the greatest linear dimension of the radiating part of the antenna

λ is the wavelength of the electromagnetic field transmitted

3.4. Far field (*Franhoufer region*)

According to the theory of electromagnetic fields the limit between near field and far field is located at

$$R_{ff} \geq \frac{2L^2}{\lambda}$$

The field is considered to propagate as plane waves and the electric and magnetic components of the field are perpendicular and related by the intrinsic impedance of the medium Z_0

The boundary curve between the far field and radiating near field is given by.

$$R_{ff}(\alpha) = \frac{2L^2 \cos^2 \alpha}{\lambda}$$

where:

α : angle between the horizontal axis and the propagation direction

$R_{ff}(\alpha)$: Franhoufer distance in the direction forming an angle α with the horizontal axis

In Table IV it is summarized the main features of the field regions, in Table V. it is shown the far field distance for mobile services and in Fig. 1. it is presented a scheme of fields regions

TABLE IV. Main features of electromagnetic fields depending on field region

	Distance range	Power density	Relation between E and H	
Reactive near- field	0- λ	$S < EH$	Not normal	$\frac{E}{H} \neq Z_0$
Reactive- radiating near-field	0- 3λ	$S < EH$	Not normal	$\frac{E}{H} \neq Z_0$
Radiating near-field	$3 \lambda - 2L^2/\lambda$	$S \approx EH$	Locally	$\frac{E}{H} \approx Z_0$
Radiating far-field	$2L^2/\lambda - \infty$	$S = EH$	Normal	$\frac{E}{H} = Z_0$

TABLE V. Far field inner limit for mobile telecommunication services

Fabricante	Model	Frequency range (MHz)	fc (MHz)	L(m)	$R_{ff} \geq \frac{2L^2}{\lambda} \text{ (m)}$
Allgon	7273.03	806 - 896	851	2.580	37.76
Decibel	DB848H90E-XY	806 - 896	851	2.438	33.72
Kathrein	739 495	1710 - 1990	1850	1.302	20.91

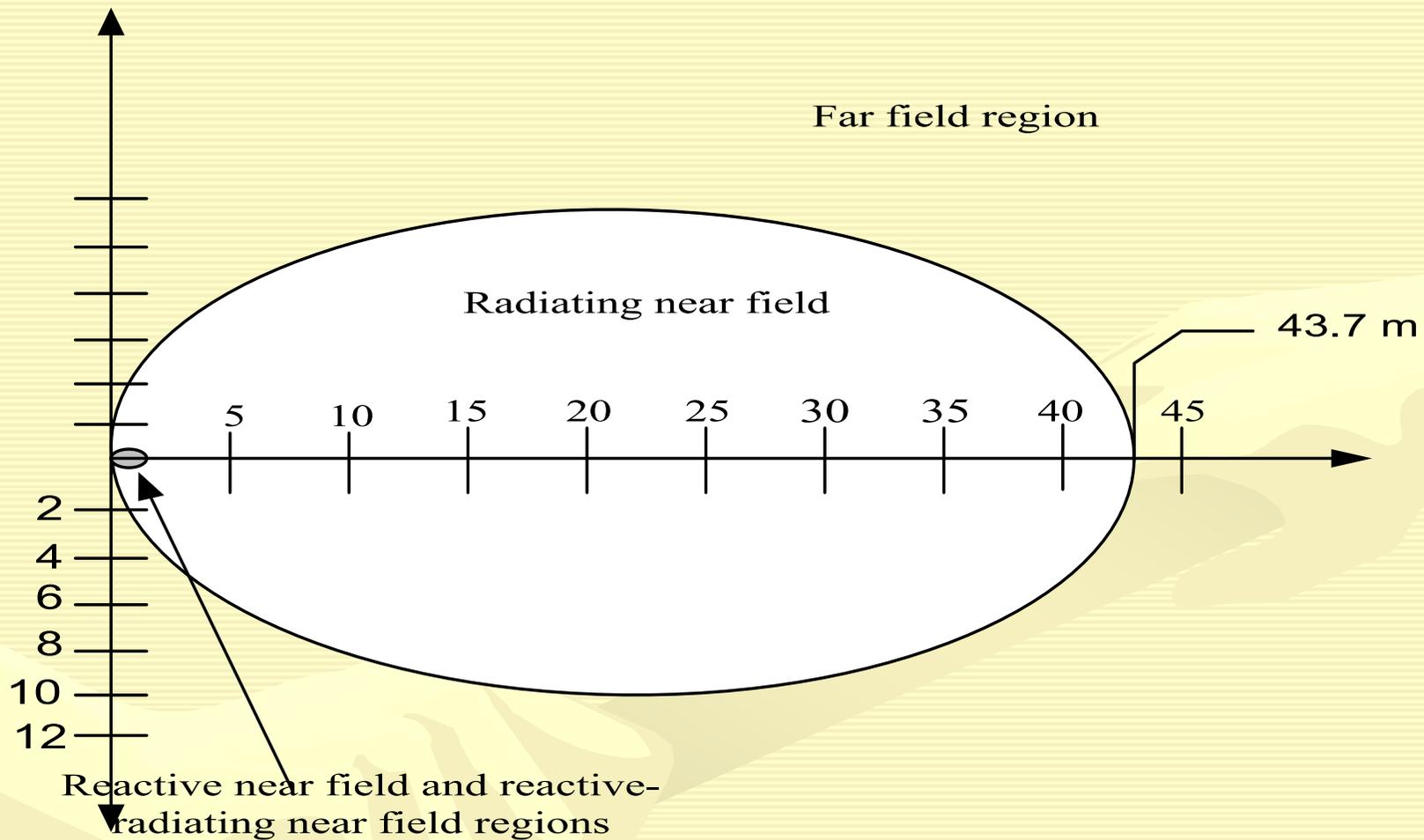


FIG. 1. Cross-sectional view of field regions for an antenna of 2.7 m high working at 900 MHz band

It is important to point out some remarks about the field regions

- (a) The boundaries of the regions only depend on antenna dimensions and wavelength, they do not depend on any case on the emitted power.
- (b) In the reactive near field and reactive –radiating near field regions are not applicable the formulas for far field, but it does not necessarily imply that the field strengths levels are important.
- (c) The electric and magnetic fields for the reactive near field and reactive – radiating near field regions could be calculated with relatively complex methods and they can be measured with a spectrum analyzer and the appropriate antennas for every component.

4. EMF Exposure assessment

4.1 Purpose

The main objective is to provide information in order to implement a plan for protecting people from exposure levels above recommended international or national standards.

The assessment of exposure could be done by calculation or by measurements but normally both evaluations are performed being the calculation the first step before measurements.

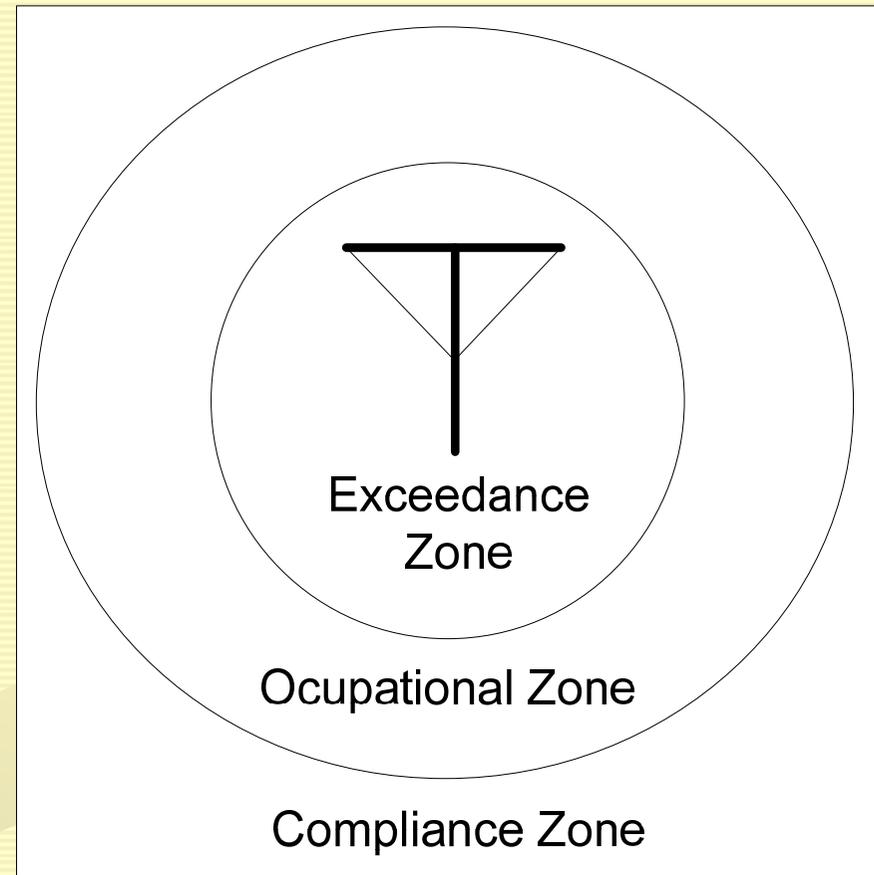


FIG.2. Exposure zones

4.2 Exposure level assessment procedure

The assessment of the exposure level shall consider as general criteria: the worst emission conditions and the simultaneous presence of several EMF sources, even at different frequencies.

The following parameters should be considered:

- (a) The maximum EIRP of the antenna system for mean transmitter power.
- (b) The antenna gain G including maximum gain and beam width;
- (c) The frequencies of operation; and
- (d) Various characteristics of the installation, such as the antenna location, antenna height, beam direction, beam tilt.

4.3. The installation classification schema:

Each emitter installation should be classified into the following three classes:

(a) Inherently compliant: These are sources that produce fields that comply with exposure limits at the operation frequencies a few centimeters away from the source. It is not necessary special precautions. (EIRP < 2W)

(b) Normally compliant: These are sources that produce EMF that can exceed exposure limits at the operation frequencies, but for normal installation practices and typical use the exceedance zone of these sources is not normally accessible to people but only to maintenance personnel. ITU states that normally compliant installations include antennas mounted on sufficiently tall towers or narrow-beam and only maintenance personnel who come into the close vicinity of emission antennae need to exercise precaution. (Mobile telephony base stations)

(c) Provisionally compliant: These are installations that require special measures to achieve compliance which involves determination of the exposure zones and measurements. (Broadcasting stations)

5. Prediction of Exposures from Base Stations

5.1 Simple Prediction Method to Evaluate Electromagnetic Field Exposure

The first step to calculate the exposure level is to compute the Maximum Equivalent Isotropically Radiated Power ($EIRP_{max}$) is given in Equation 1.

$$EIRP_{max} = P_{Tx} G_{Txm} L_{Tx} \quad (\text{Eq. 1})$$

P_{Tx} : Transmitter power

G_{Txm} : Maximum Gain of antenna system

L_{Tx} : Losses of antenna system

The EIRP will depend on the $EIRP_{max}$ and the antenna directivity factor $F(\theta)$.

Figures 3 and 4 show the parameters used in the calculation of the exposure at the ground level and on adjacent building.

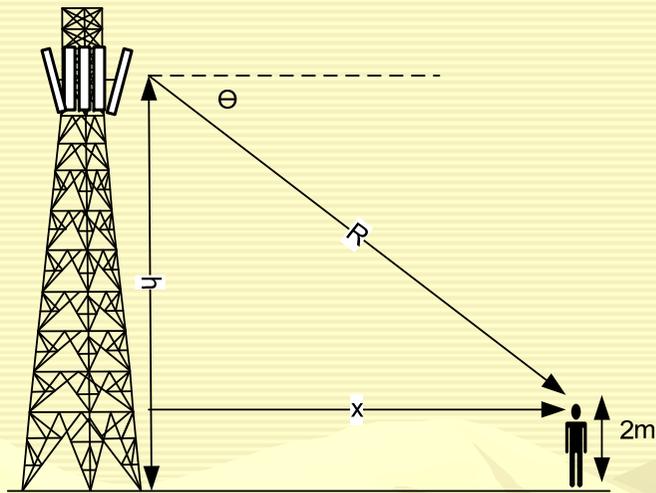


FIG.3. Exposure at ground level

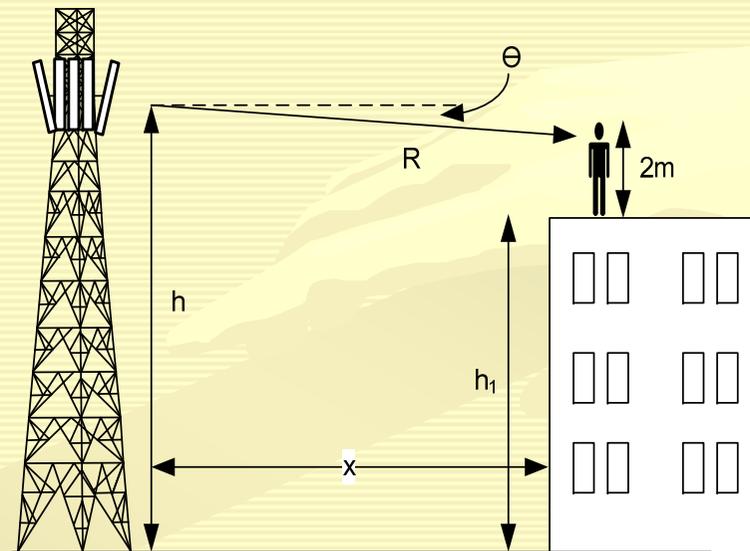


FIG. 4. Exposure at an adjacent building

(a) Exposure at ground level

According to ITU-T K.52 Recommendation the radiation centre of the antenna system is assumed to be at a height h and it is evaluated the power density at a point at a height of 2m above ground level at a distance x of the base of the tower. The main beam of the antenna is axially symmetrical and down-tilted an angle ϕ . If the main beam is parallel to ground $\phi = 0$

If $h' = h - 2\text{m}$, then:

$$R^2 = h'^2 + x^2, \quad \theta = \tan^{-1}\left(\frac{h'}{x}\right)$$

and

$$S = \frac{(1 + \rho)^2}{4\pi} F(\theta) \frac{\text{EIRP}_{\max}}{x^2 + h^2} = \frac{2.56}{4\pi} F(\theta - \phi) \frac{\text{EIRP}_{\max}}{x^2 + h^2} \quad (\text{Eq. 2})$$

where ρ is the reflection coefficient.

It is important to point out that the factor 2.56 could be replaced by 4 (that is considering a reflection coefficient equal to 1)

(b) Exposure at an adjacent building

The radiation centre of the antenna system is assumed to be at a height h and it is evaluated the power density at a point at a height of $2m$ above the roof level of a building of height h_1 level and at a distance x of the base of the tower. The main beam of the antenna is axially symmetrical and down tilted an angle ϕ , so if the main beam is parallel to ground $\phi = 0$

To simplify $h' = h - h_1 - 2m$.

$$R^2 = h'^2 + x^2, \quad \theta = \tan^{-1}\left(\frac{h'}{x}\right) \quad (\text{Eq. 3})$$

then

In this situation it could be neglected the reflected wave because it could be attenuated by the same building, so the reflection coefficient tends to be zero and the resulting power density is as expressed in Equation 4

$$S = \frac{F(\theta - \phi) \text{EIRP}_{\max}}{4\pi (x^2 + h^2)} \quad (\text{Eq. 4})$$

(c) Calculation of the exposure quotient

For exposure to radiofrequencies waves composed of only one frequency the exposure quotient is an adimensional quantity and can be expressed as a function of power density or electric field strength, could be calculated using the formula in Equation 5:

$$\text{Exposure Quotient} = \frac{S_{\text{calculated}}}{S_{\text{lim}}} = \left(\frac{E_{\text{calculated}}}{E_{\text{lim}}} \right)^2 \quad (\text{Eq. 5})$$

where:

$S_{\text{calculated}}$: Calculated power density

S_{lim} : ICNIRP power density limit at the frequency of interest

It is important to point out that the formulas that are used for calculating the exposure quotient as a function of electric field strength (E) could be used in a similar way for magnetic field strength.

(d) Calculation of the total exposure quotient

It is used for the evaluation of the exposure to simultaneous diverse sources which generally implies various NIR sources . All of the signals contribute individually to the total exposure of a person and the Total Exposure Quotient is equivalent to the addition of all signals and is expressed by the equations 6 and 7.

$$\text{Total Exposure Quotient} = \frac{S_1^{\text{calculated}}}{S_1^{\text{lim}}} + \frac{S_2^{\text{calculated}}}{S_2^{\text{lim}}} + \dots + \frac{S_N^{\text{calculated}}}{S_N^{\text{lim}}} \quad (\text{Eq } 6).$$

$$\text{Total Exposure Quotient} = \sum_{i=1}^N \frac{S_i^{\text{calculated}}}{S_i^{\text{lim}}} \quad (\text{Eq. } 7)$$

This formula could also be expressed as a function of electric field and it is given in equations 8 and 9.

$$\text{Total Exposure Quotient} = \left(\frac{E_1^{\text{calculated}}}{E_1^{\text{lim}}} \right)^2 + \left(\frac{E_2^{\text{calculated}}}{E_2^{\text{lim}}} \right)^2 + \dots + \left(\frac{E_N^{\text{calculated}}}{E_N^{\text{lim}}} \right)^2 \quad (\text{Eq. 8})$$

$$\text{Total Exposure Quotient} = \sum_{i=1}^N \left(\frac{E_i^{\text{calculated}}}{E_i^{\text{lim}}} \right)^2 \quad (\text{Eq. 9})$$

Where N is the total number of signals. The Total Exposure Quotient must not exceed to 1 for complying with maximum exposure limit.

In general any point of the space near a base station receives a direct wave and one or more reflected waves, so the resultant field is a vectorial composition of several contributions. As a consequence there are an spatial variability of the EMF field strength. It is obvious that the Simple Prediction Method does not take into account such a phenomenon, although, the practical experience shows that the results calculated using this method provides the mean value of the field for short distances (some wavelengths).

Based on the results of predictive calculations could be obtained some graphics of the exposure quotient variation with distance for every base station and sector. Fig 5. shows an example of this kind of results.

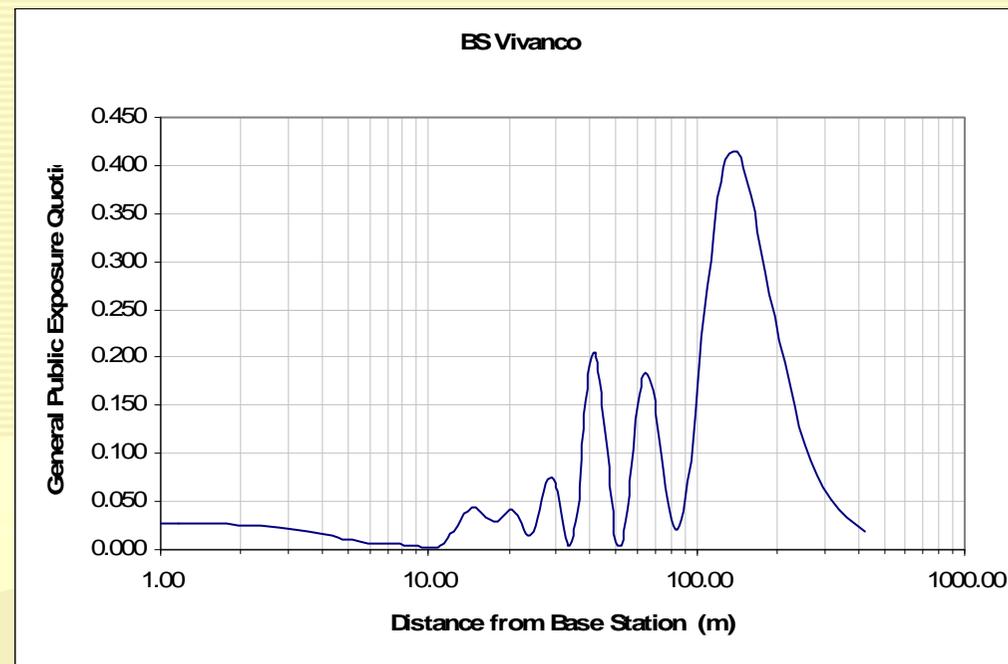


FIG. 5. Variation of the predicted general public exposure quotient as a function of distance

6. Exposure Measurement

6.1 Site Analysis

It is necessary to clearly identify the measurement regions in order to restrict the measurements to only one of the components electric (E) or magnetic (H). This objective can be met by assuring far field conditions otherwise it is necessary to measure both of the fields.

Measurement of electromagnetic fields from telecommunications must be performed according to telecommunications service and the purpose of the evaluation. In most of the cases the measurement will be done in the far field region or in the worst case in the radiating near field, so it is only necessary to measure E field.

TABLE VI. Distances for radiating near field for telecommunication services

Telecommunication service	Approx. distance to radiating near field (3λ)
FM radiobroadcast	9 m
Low band VHF TV broadcasting	18 m
High band VHF TV broadcasting	4.5 m
UHF TV broadcasting	1.5 m
900 MHz GSM mobile communications	90 cm
1900 MHz GSM mobile communications	45 cm

6.2. Types of measurements

There are two types of measurements could be carried out:

6.2.1. Broadband measurement

In broadband measurements the total contribution over a large frequency range is obtained without distinction of the contribution of different sources operating at different frequencies.

Limited sensitivity, so the broadband meters are often used for compliance assessment. (Typical sensitivity of around 0.1 V/m)

It is recommended to use it for making measurements at locations where the exposure quotient is dominated by emissions from the base station of interest which has to be proven with narrow band measurements

The probe generally consists of short-electric dipoles (or loops) that detect the field.

Isotropic probes measure the field components in the three orthogonal directions in space and calculate the magnitude of the resultant field strength and thus facilitating the assessment procedure.

On the field meter, the value obtained is shown as rms or peak value, or as a percentage of a standard (ICNIRP or IEEE)



FIG. 6. Electromagnetic field analyzer and its electric field probe

(a) Advantages

- Broadband frequency range coverage which depends on the meter and the probe to be used
- Isotropic directivity
- Measurements are simple and less time –consuming than narrow-band measurements.
- Some meters are designed with frequency response shaped to meet the frequency variation of a particular international or national guideline (ICNIRP, IEEE) given the fields levels as a exposure quotient.

(b) Limitations

- These instruments are relatively insensitive, but they are getting better the typical sensitivity is around 0.1 V/m.
- General public exposures They are unable to responds to rapid signal changes due to modulation, access mode and for base stations are near or below the detection threshold difficulting reliable measurements.
- Lack of frequency selectivity so the results could be the addition of several signals.

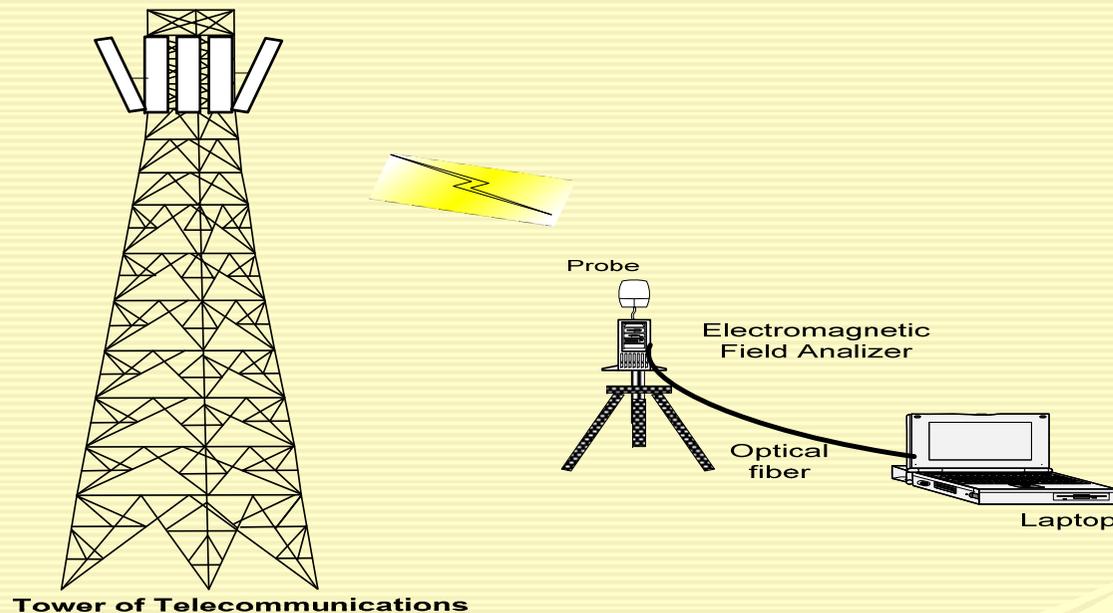


FIG. 7. Simplified schema of setup for broadband measurement

(c) Measurement uncertainty (accuracy) :

The main sources of uncertainty or broadband measurements are linked to:

- Electrical factors: Linked to the calibration of the field analyzer and its probe. The calibration certificate provides information on isotropic value and its uncertainty. The data sheet provides information on calibration factor, frequency response, linearity, drift and their uncertainties
- Factors coming from measurement practices: During measurement the electromagnetic field analyzer with its probe is mounted on a tripod and the measurement is performed without no contact with the operator, but there are additional uncertainty factor which depend on the coupling or positioning related to fixed structures or the use of the meter by hand rather than on tripod.

Total expanded uncertainty uncertainty for broadband measurement can be estimated as 3 dB.

6.2.2. Narrow band measurement

Narrow band measurements allow distinguishing between the specific contributions in the different frequency ranges. They are based on the use of a spectrum analyzer in conjunction with one or several different antennas according to the frequency range to evaluate: tuned dipoles, bi-conical dipoles (30-300 MHz, 20- 600 MHz, 250- 1000 MHz), log-periodic antennas (200-1000 MHz), horn antennas (1-18 GHz), double ridge waveguide horn antennas (1 -18 GHz) among others.

Spectrum analyzers can detect signals being at least 8 to 10 orders of magnitude lower as the limits specified in the guidelines, standards or other documents.



FIG. 8. Spectrum analyzer

(a) Advantages

- Sensitivity of narrowband systems is higher than broadband systems'
- They are frequency selective so it is possible to identify the source of the non-compliance in case it is.

(b) Limitations

- The equipment is bulky, especially because of some antennas which are large and could be susceptible to wind load when mounted on a tripod.
- Most of the antennas are directional and have to be rotated or positioned at a number of orientations in order to ensure all of the signals to be detected properly which could deteriorate accuracy.
- The narrowband measurement process is more time-consuming than broadband measurement, but modern equipments are getting better performances.

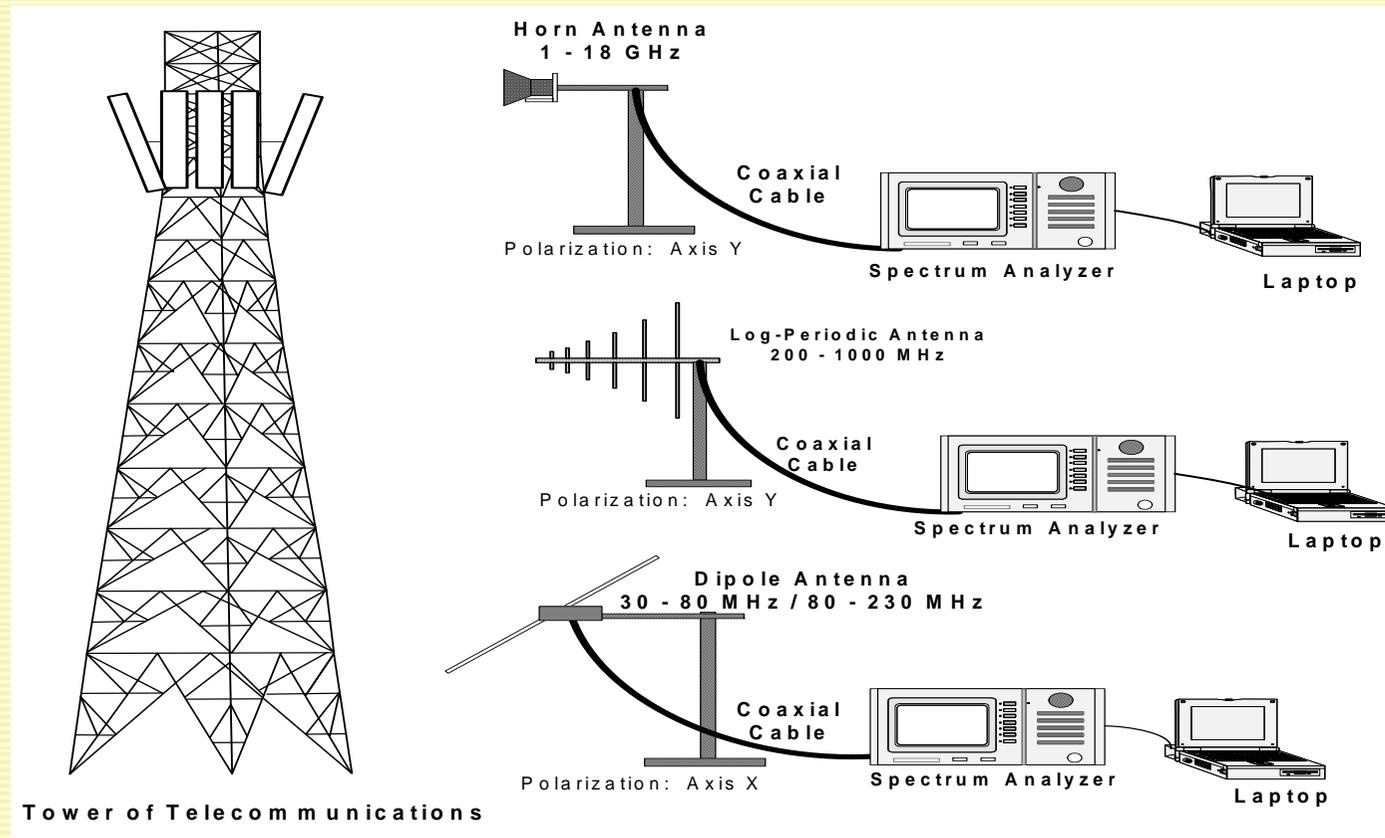


FIG. 9. Simplified schema of setup for narrowband measurement

(c) Measurement uncertainty

The main sources of uncertainty or narrow band measurements are linked to:

- Electrical factors: These factors are linked to the calibration of the field analyzer and antennas
- Factors coming from measurement practices: During measurement the antennas are on tripods and the measurement includes some rotations or positioning which could result in additional uncertainty because of the coupling or positioning related to fixed structures in the vicinity or the operator's body.

Total expanded uncertainty for narrowband measurements can be estimated as 2 dB

6.5 Measurement Protocol

6.3.1 General considerations

- (a) Taking into account the azimuths of antennas arrangement for each sector of the base stations (the measurements points are located at 2, 10, 20, 50 and 100 m from the base of the antenna in the direction of the main beam of the antennas arrangement, whenever the measurements locations at these distances be accessible).
- (b) The measurements shall be made for a single point at 1.5 m over the floor (temporal average).
In order to avoid interferences and/or errors in the field measurement, the operator maintained a minimum distance of 2.5 m from the probe.
- (c) The average time for temporal average will depend on the standard used to the assessment: for example for ICNIRP is 6 minutes and for IEEE is 6 and 30 minutes.

(d) Depending on the measured value it could be done measurements for Spatial Average along a vertical line with three measurements points located to 1.1 m, 1.5 m and 1.7 m. over the reference surface as it is illustrated in the following figure:

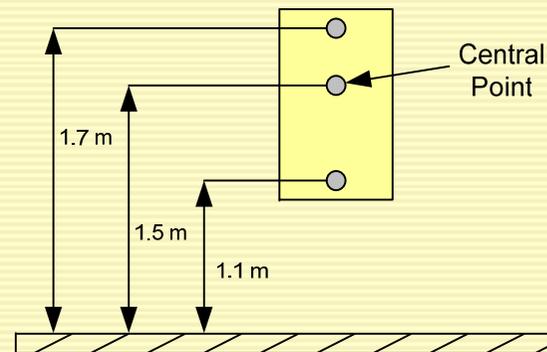


FIG. 10. Schema for spatial averaging

In this case the field strength value used for further calculations is the average of the three values obtained for each spatial point., as it is shown in equations 10 and 11.

$$E_{\text{spatial-average}} = \sqrt{\frac{\sum_{i=1}^3 E_i^2}{3}} \quad (\text{Eq. 10})$$

$$S_{\text{spatial-average}} = \frac{\sum_{i=1}^3 S_i}{3} \quad (\text{Eq. 11})$$

6.3.2 Measurement methods

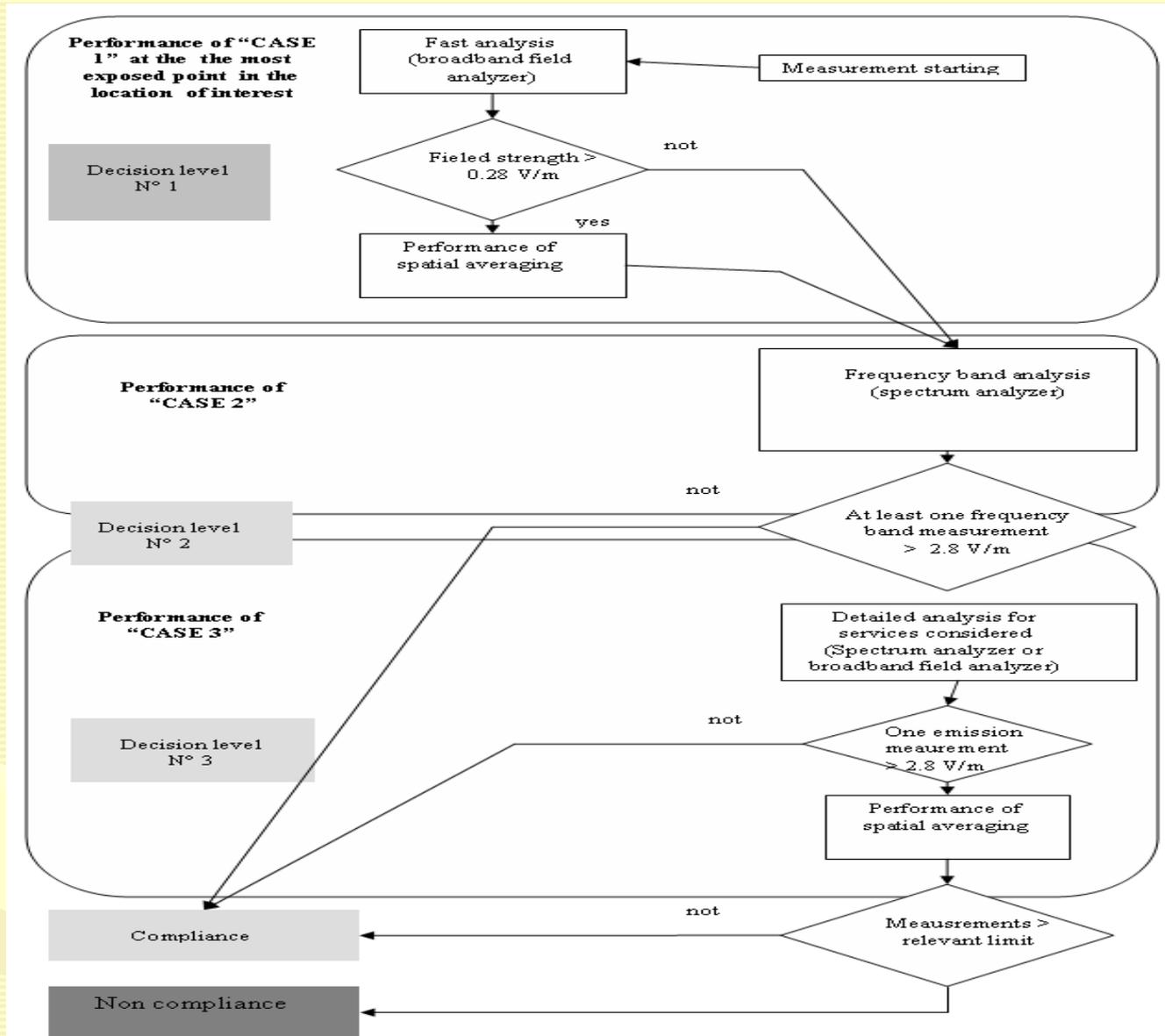


FIG. 11. Procedure for application of measurement methods

6.3.3 Quick overview method

This method is based on broadband measurement and basically is aimed to evaluate compliance with NIR standards, so it can not be applied in the following cases.

When it is necessary to know the contributions of different sources by frequency.

If the equipment threshold is of the same order of expected measurement values.

(a) Measurement procedure

The equipment that it is necessary to use is the same as expressed in ..

Choose of the most suitable probes for the frequencies of interest.

The choice of the points shall be according to general considerations

In some cases, it could be necessary two or more probes in this case the total values are given by the equations equations 12 and 13.

$$E_{\text{total}} = \sqrt{\sum_{i=1}^n E_i^2} \quad (\text{Eq. 12})$$

$$S_{\text{total}} = \sum_{i=1}^n S_i \quad (\text{Eq. 13})$$

where n is the number of probes covering the frequency band of interest and E_i y S_i are the values obtained for each probe.

(b) Post-processing

If the value is below the threshold sensitivity of the probe, the value has to be discarded.

A probe specific correction factor may be applied according to manufacturers' instructions.

In order to relate the different quantities measured it could be used the formula in Equation 14.

$$S = EH = \frac{E^2}{Z_0} = H^2 Z_0 \quad (\text{Eq. 14})$$

In case of multiple-frequency exposure it is necessary to applied equations 15 and 16

$$E_{\text{total}} = \sqrt{\sum_{i=1}^n E_i^2} \quad (\text{Eq. 15})$$

$$S_{\text{total}} = \sum_{i=1}^n S_i \quad (\text{Eq. 16})$$

6.3.4. Variable frequency scan

This method is a kind of narrow band measurement and is applied when it is necessary to know non-ionizing radiation levels in a more detailed way, for example by telecommunication service band.

TABLE VII. Frequency bands considered for variable frequency scan

Frequency band	Telecommunication service	Minimum reference level	Detection Threshold
54- 88 MHz	Low band VHF TV	28 V/m	0.3 Vm
88- 108 MHz	FM Radio	28 V/m	0.3 Vm
174- 216 MHz	High band VHF TV	28 V/m	0.3 Vm
470- 806 MHz	UHF TV	28 V/m	0.3 Vm
851- 869 MHz	Trunking	40 V/m	0.4 V/m
869- 894 MHz	Mobile Telephony	40 V/m	0.4 V/m
1930-1945 MHz	PCS	60 V/m	0.6 V/m

(a) Measurement procedure

The equipment is the same as expressed in 5.2.2

The choice of the points shall be according to general considerations

It is recommended to use the following bandwidth combination settings for spectrum analyzers:

30 MHz -300 MHz Bw= 100 kHz with a sweep time of 50-100 ms

300 MHz – 3 GHz Bw = 100 kHz with a sweep time of 700 ms to 1 s

The threshold level has to be 40 dB below the reference level

It must be performed the electric field strength measurement for every frequency band of main telecommunications services.

It is necessary to carry out electric field strength measurement in 03 polarizations (x, y, z) at 2 m high over the floor.

Average time depending on the reference standard (6 minutes for ICNIRP) in each polarization

It should be used max-hold and peak mode detector.

(b) Post- processing

In order to relate the different quantities measured it could be used the formula in Equation 17.

$$S = EH = \frac{E^2}{Z_0} = H^2 Z_0 \quad (\text{Eq.17})$$

6.3.5. Detailed investigation

This method should be applied in the following situations:

- Where near field measurements are required.
- Where measurements of strong electric or magnetic fields are required.
- When it is necessary to measure pulsed, discontinuous or wide-band signals.
- If one of the total exposure quotients exceed the value “1”.

(a) Measurement procedure

- It could be use both types of equipment; broad band and narrow band meters.
- The choice of the points shall be according to general considerations.
- For spectrum analyzers it is recommended to use the following bandwidth combination settings:

30 MHz -300 MHz, Bw= 100 kHz with a sweep time of 50-100 ms

300 MHz – 3 GHz , Bw = 100 kHz with a sweep time of 700 ms to 1 s

The threshold level has to be 40 dB below the reference level

Reactive near –field measurement

- It could be done by broadband or narrow band measurements. In any case it is necessary to independently measure the E-field and the H-field.
- For broadband measurements it is necessary to use probes for electric and magnetic fields.
- For narrowband measurements of E field it could be used dipole, bi-conical, log-periodic and horn antennas among others and for measuring H-field it is usually used loop antennas.

Strong electric or magnetic field measurement

- For spectrum analyzers it is necessary to use passive antennas and appropriately protection features.
- Set the centre frequency on each channel of the emission with a resolution equal or larger than the bandwidth of the channel.
- Select average mode and “rms detector” during the time recommended in the applicable standard.
- If the antenna used has a single polarization it is necessary to perform the measurement for the three orthogonal directions to obtain the different components of the field. In this case the total field is given by Equation 18

$$E_{\text{total}} = \sqrt{E_x^2 + E_y^2 + E_z^2} \quad (\text{Eq. 18})$$

Pulsed emissions measurements

For this type of signals, the energy is carried in short bursts and the pulse is usually short compared to the signal period. The power peak usually ranges from 1 W to 50 MW and it is necessary to assess the peak and the rms level.

For the assessment of the peak value

- Choose a frequency band enough to cope with impulse bandwidth
- Select max-hold mode for 1 or several rotations of the radar (until stabilization of signal)
- Select “positive peak detection mode”
- The peak power should not exceed the reference by a 1000 factor for power density or 32 for field strength

For the evaluation of rms field strength

- Carried out the average of the instantaneous signal in the rms mode.
- Emission from mobile communications
- As these systems consist of a permanent control channel and traffic channels. A base station could be understood as n transmitters.
- In order to perform the measurement it could use the control channel (identified with a spectrum analyzer because of its features: permanence and stable level).
- Select centre frequency with resolution equal or larger to the bandwidth of the channel, max hold mode and peak detector
- If the antenna used has a single polarization it is necessary to perform the measurement for the three orthogonal directions to obtain the different components of the field. In this case the total field is given by the Equation 19

$$E_{\text{total}} = \sqrt{E_x^2 + E_y^2 + E_z^2} \quad (\text{Eq. 19})$$

Obtain the data of the number of transmitter for maximum load.

The maximum traffic field strength is calculated by the Equation 22:

$$E_{\max} = E_{\text{control-channel}} \sqrt{n_{\text{transmitters-max}}} \quad (\text{Eq. 20})$$

If the transmitters are using different power levels from control channel it has to be applied the Equation 23:

$$E_{\max} = E_{\text{control-channel}} \sqrt{\frac{P_{\text{total}}}{P_{\text{control-channel}}}} \quad (\text{Eq. 21})$$

7. Conclusions

There are two basic guidelines for non-ionizing radiations: ICNIRP guidelines and IEEE standards, being the ICNIRP guidelines the most accepted one.

There are two basic types of measurements for radiofrequency sources from telecommunications: broadband and narrowband

The broadband measurements are aimed to test compliance including all of the sources in the location which is tested. This type of measurements is not very sensitive so sometimes it is not very useful.

The narrowband measurements are aimed to know the sources of different emissions because is frequency selective. This type of measurement is very sensitive and could measure levels orders of magnitude below the international exposure limits.

There are three kind of measurement methods: Quick overview, Variable frequency scan and Detailed investigation.

Levels of exposure coming from base stations are very low typically 100 to 1000 times below international limits



THANK YOU VERY MUCH!