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A Procedure for Measurement of Electromagnetic Radiation in the Presence of Multiple Base Stations

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Abstract

This document describes the measurement procedure adopted by the **monIT** Project for monitoring electromagnetic radiation originated by multiple base stations from mobile communication systems. It specifies techniques for the measurement of electromagnetic fields in order to assess compliance with thresholds for human exposure.

The overall procedure is based on the recommendation ECC/REC (02)04 from CEPT, which specifies a measurement method to assess electromagnetic radiation levels on the frequency band from 9 kHz to 300 GHz.

A simple method for the selection of measurement points is also proposed. It was developed by the **monIT** Project team and consists in a several steps procedure, depending on the topology type of the surrounding antennas and on the number of transmitters.

The proposed approach aims to be as practical as possible, allowing a systematic use of the method.

1. Introduction

The **monIT** Project (<http://www.lx.it.pt/monit>), developed at Instituto de Telecomunicações/Instituto Superior Técnico/Technical University of Lisbon, aims at providing the general public with relevant information on electromagnetic radiation produced by mobile communication systems, namely:

- Basic concepts related with electromagnetic waves, human exposure thresholds, bibliography, relevant references, etc..
- Results from systematic measurement campaigns carried out by the project team, near base station antennas in public sites.

One of the measurement types addressed within the project is the localised monitoring, which is performed by technicians that travel around the country. This type of measurements intends to evaluate compliance of public places around base station antennas with exposure to radiation thresholds.

At this moment, as a result of the localised monitoring process, 166 locations were already analysed. In order to guarantee a meaningful analysis of the results from each location, it is important to follow well-defined procedures for the selection of measurement points and for the tasks to perform on each point.

The measurement procedure described herein summarises all the tasks performed in the **monIT** Project localised monitoring process. Section 2 describes the procedure to follow on each measurement point, which is based on the recommendation ECC/REC (02)04 from

CEPT¹ [1]. The necessary steps for the selection of measurement points are described in Section 3. Finally, Section 4 draws the most important conclusions.

2. General procedure for electromagnetic field measurement

This section describes the general procedure adopted by the **monIT** Project team for electromagnetic field measurement. A portable field monitor, [2], is used on a first stage, providing the total radiation level within the frequency band of 0.1 to 3 000 MHz for the analysed environment. The basic assumptions taken by the project are summarised in Table 1.

All mobile communications systems base stations antennas on a given location are considered as reference for the definition of the measurement environment.

Figure 1 shows the main stages of the measurement procedure.

Table 1 – Fundamental concepts.

Measurable Quantities	Measurable Quantities are Electric Field, E , Magnetic Field, H , and Power Density, S . The equipment in use measures E directly, thus, this is the quantity adopted by the monIT Project.
Calculated Quantities	The quantities E , H and S are related by well-known expressions within the analysed frequency band. Once one of these quantities is measured, it is possible to calculate the other two. The measured quantity is E and the calculated ones are H and S .
Reference Level	The most restrictive value of the considered measurable quantity within the analysed frequency band. This value is the one adopted by the European Union Council, [3], and for E it is equal to 28 V/m.
Decision Level	Value xx^2 times below the reference level adopted for the considered measurable quantity. For Portugal, it is established by ANACOM ³ and for E it is equal to yy^2 V/m.
Critical Point	Measurement point (place) where decision level for the considered quantity is exceeded.
Total Exposure Coefficient	Summation of all the individual frequency exposure quotients in the measured frequency band at a single location.

After the definition of the measurement environment, the most representative points are selected for a compliance evaluation with exposure to radiation thresholds. The criteria used by the **monIT** team for the selection of measurement points are described in Section 3. Figure 2 shows the measurement procedure on each selected point, using the portable field monitor.

If there is a point where the decision level is exceeded, it is necessary to perform a detailed frequency investigation. The measurement equipment used is a spectrum analyser, [4], allowing the identification of individual contributions from each transmission source for the total field level. The field level of each transmission source, that is to say, of each

¹ CEPT – European Conference of Postal and Telecommunications Administrations.

² Waiting for publication from national competent entity (ANACOM).

³ ANACOM – Portuguese National Communications Authority.

transmitted frequency, is compared with the respective exposure thresholds (frequency dependent), [3]. The total exposure coefficients are also calculated.

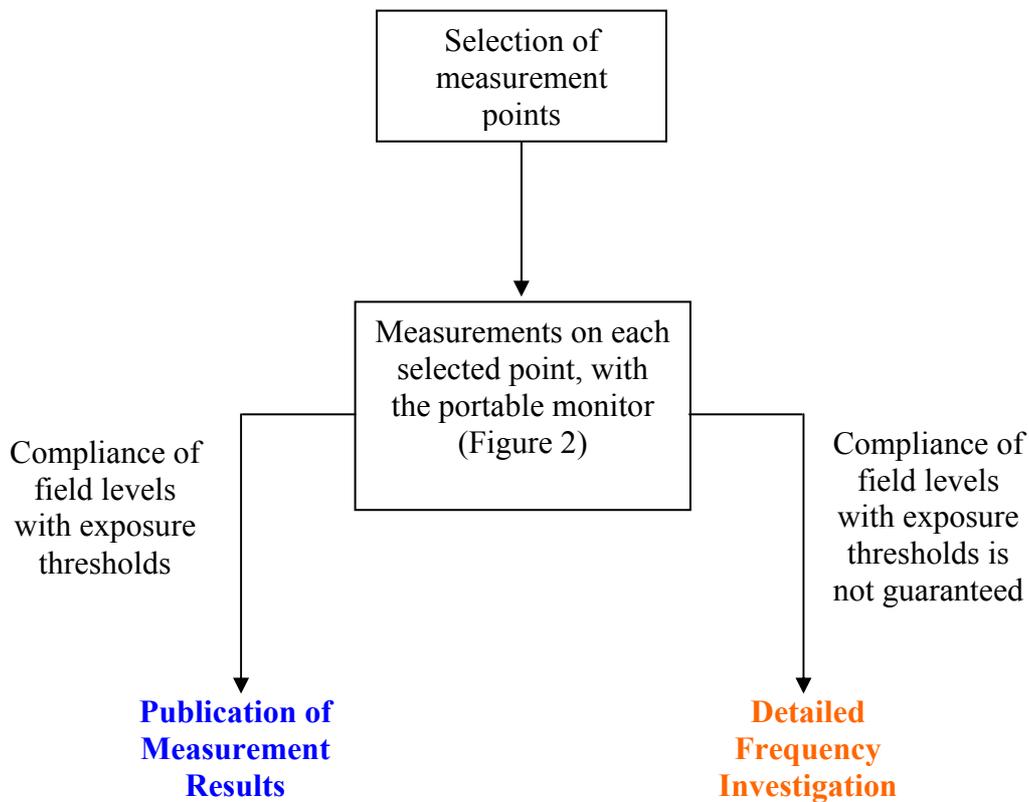


Figure 1 – Main stages of the measurement procedure.

Figure 3 represents the detailed frequency investigation procedure.

Figure 4 represents the procedure to be followed in each chosen point, using the spectrum analyser.

3. Selection of measurement points

3.1 Initial stages

The European recommendations do not establish any strict criteria for the selection of measurement points. This way, there was a need to establish adequate procedures based on the experience and investigation conducted by the **monIT** team on this matter.

The present section describes the set of tasks to select the points where electromagnetic fields measurements must be carried out. These procedures must be followed whenever there are adequate physical and logistical conditions. Otherwise, the alternative procedure must be as close as possible from the ones indicated herein.

Figure 5 shows the initial stages that set the procedure for selection of measurement points.

Since the selection of points has the base station antennas present at a given location as reference, there are two main factors that rule the procedure choice: the installation topology and the number of base station antennas.

Table 2 identifies the seven installation topology types for each base station.

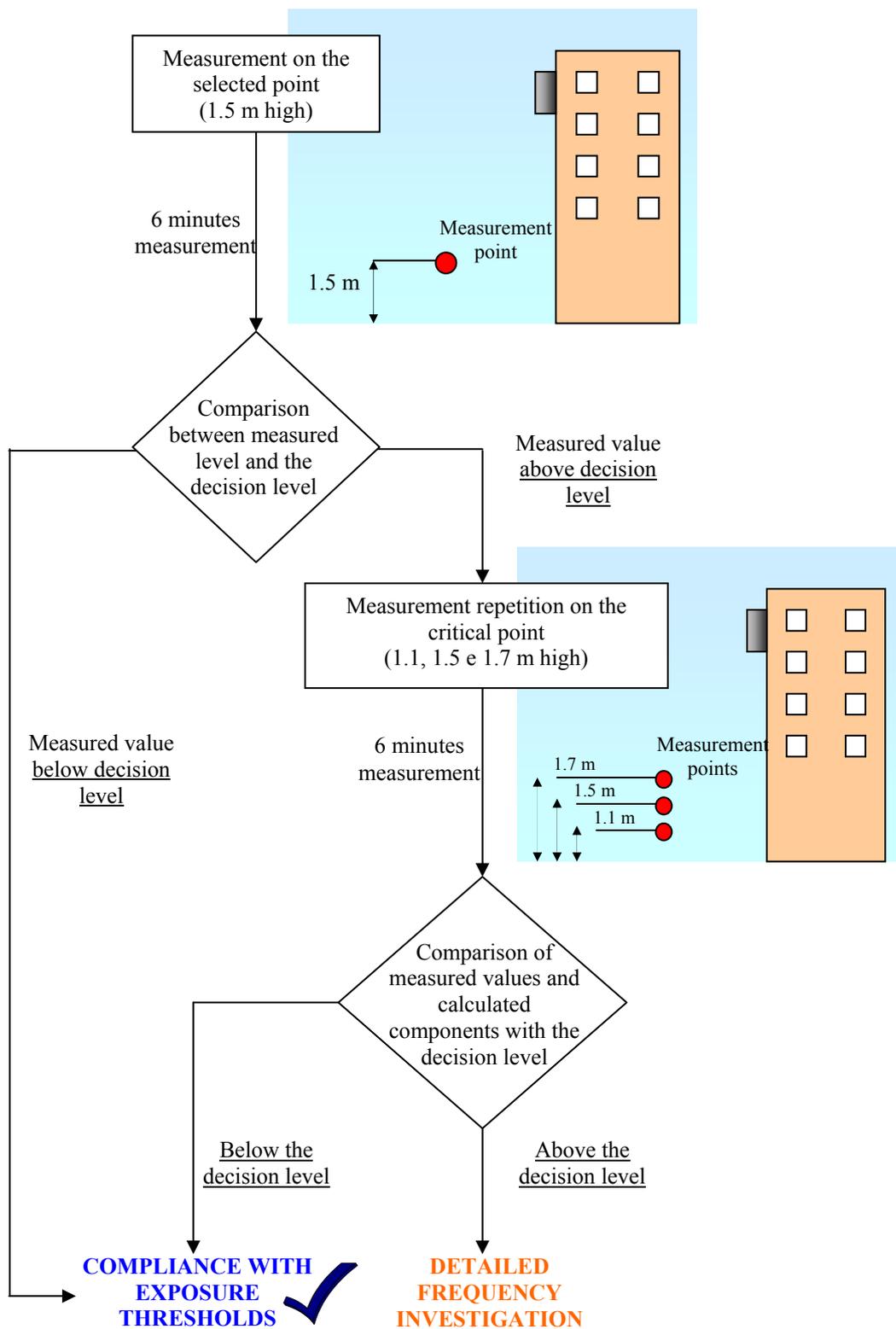


Figure 2 - Measurement on each selected point, with the portable field monitor.

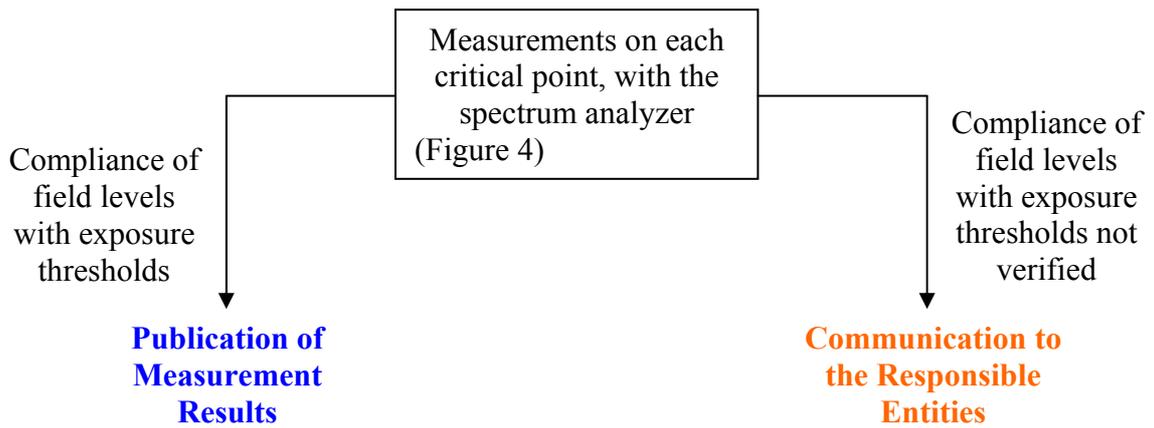


Figure 3 – Detailed frequency investigation stages.

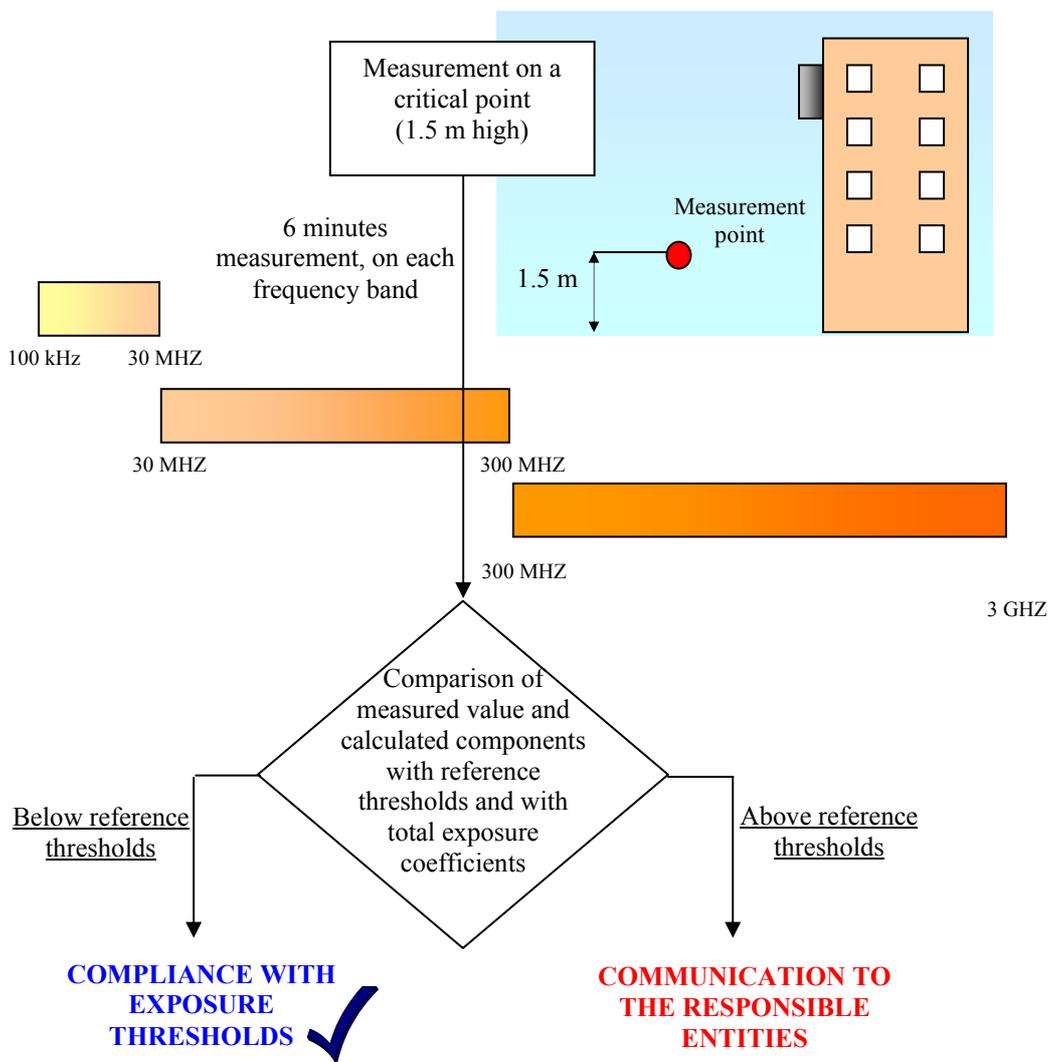


Figure 4 – Measurement on each critical point using the spectrum analyzer.

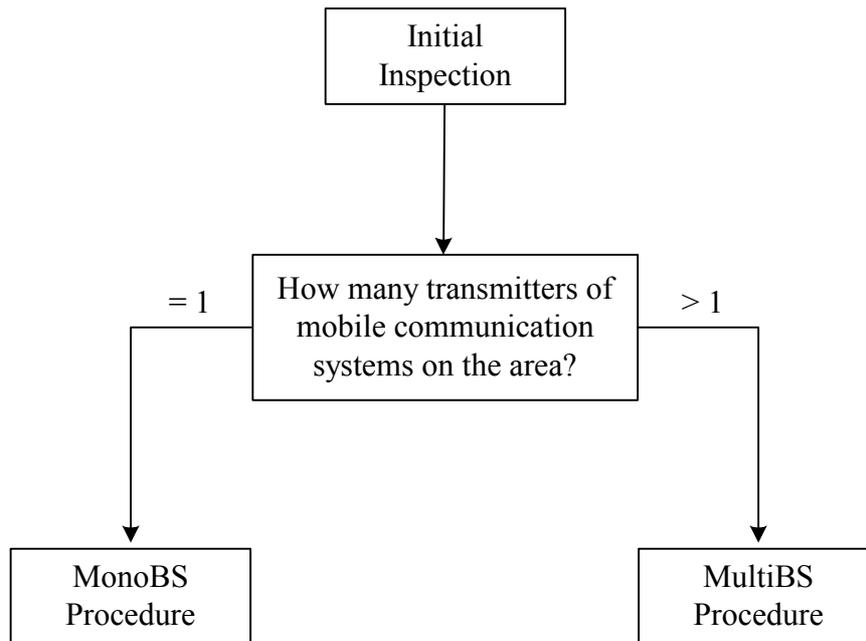


Figure 5 – Initial stages to set the procedure for selection of measurement points.

Table 2 – Typical installation topologies

Scenario	Installation Topology	Reference
Rural	Tower, Mast, Water sump, Tree	Rtower
Urban	Roof-top	Uroof
	Building façade	Ufaçade
	Light pole or other	Upole
	Tower	Utower
In-building	Roof	Iroof
	Walls	Iwall

3.2 MonoBS procedure

The MonoBS procedure is followed when there is only one mobile communication system transmitter at the local. The measurement points are selected regarding the transmitter installation topology.

For Rtower, Upole and Utower topologies:

- Identification of maximum field points along the radials represented in Figure 6. The radials extension must be defined regarding to the local geometry.
- Identification of maximum field points along the closed path represented in Figure 6. The paths extension must be defined regarding to the local geometry.
- Repetition of the previous procedures in order to avoid possible signal perturbations.
- Measurements on the identified maximum field points.
- Additionally, other relevant points can be chosen for compliance assessment with reference levels.

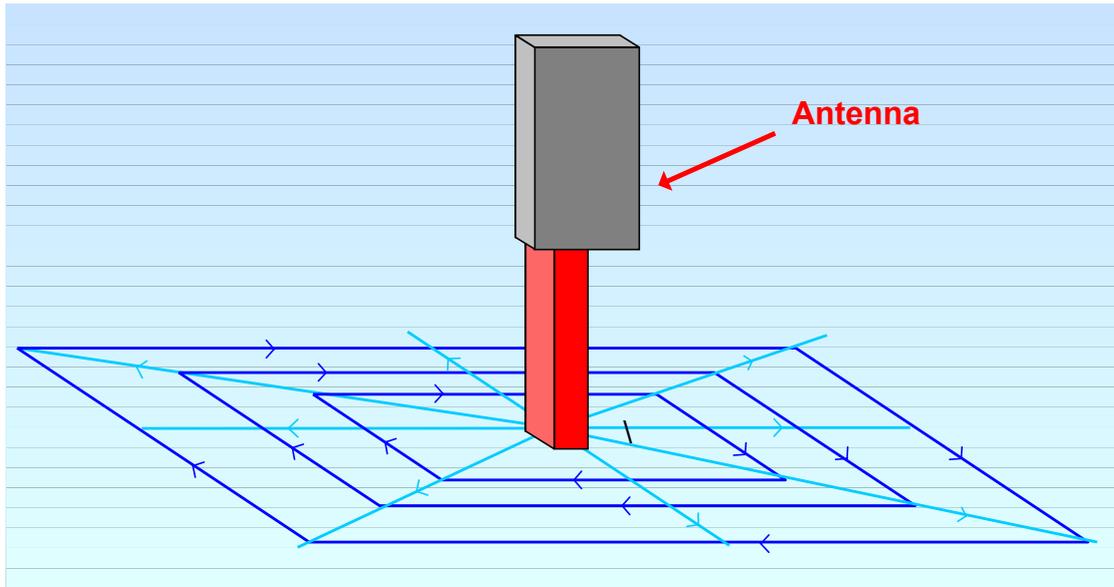


Figure 6 – Representation of paths for selection of measurement points (Rtower, Upole and Utower).

For Uroof and Ufaçade topologies:

- Identification of maximum field points along the radials represented in Figure 7. The radials extension must be defined regarding to the local geometry.
- Identification of maximum field points along the closed path represented in Figure 7. The paths extension must be defined regarding to the local geometry.
- Repetition of the previous procedures in order to avoid possible signal perturbations.
- Measurements on the identified maximum field points.
- Additionally, other relevant points can be chosen for compliance assessment with reference levels.

For Iroof and Iwall topologies:

- Identification of maximum field points along the radials represented in Figure 8. The radials extension must be defined regarding to the local geometry.
- Identification of maximum field points along the closed path represented in Figure 8. The paths extension must be defined regarding to the local geometry.
- Repetition of the previous procedures in order to avoid possible signal perturbations.
- Measurements on the identified maximum field points.
- Additionally, other relevant points can be chosen for compliance assessment with reference levels.

3.3 MultiBS procedure

The MultiBS procedure, described in this section, is applicable to the situations where there is more than one base station on the considered local. It is suitable for any configuration (base stations on line of sight situation, or not).

Initially, the selection of the temporary measurement points is performed, considering each base station separately. The procedures described in Section 3.2 are followed for each base station, Figure 9 and Figure 10.

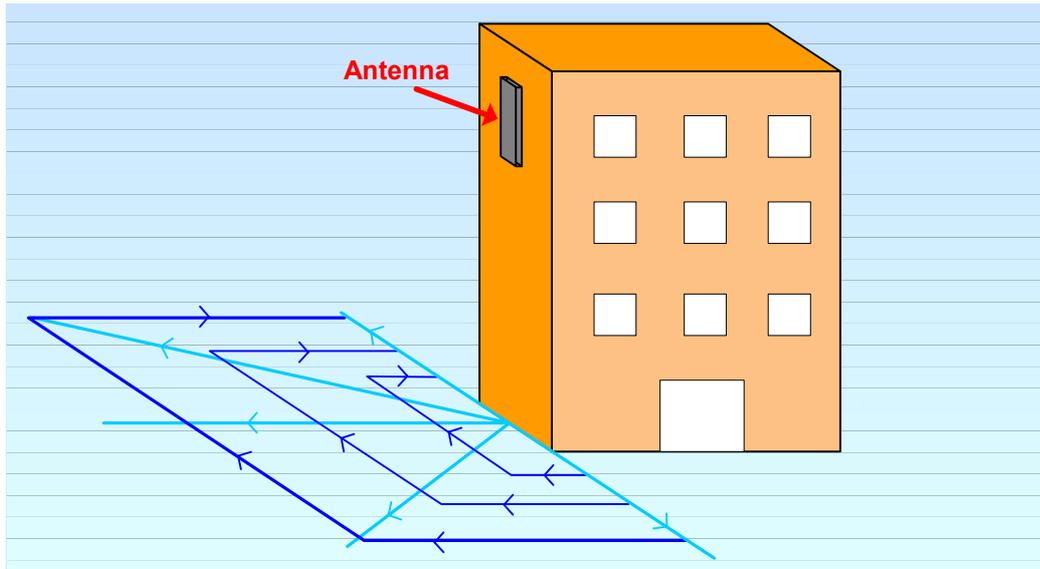


Figure 7 – Representation of paths for selection of measurement points (Uroof and Ufaçade).

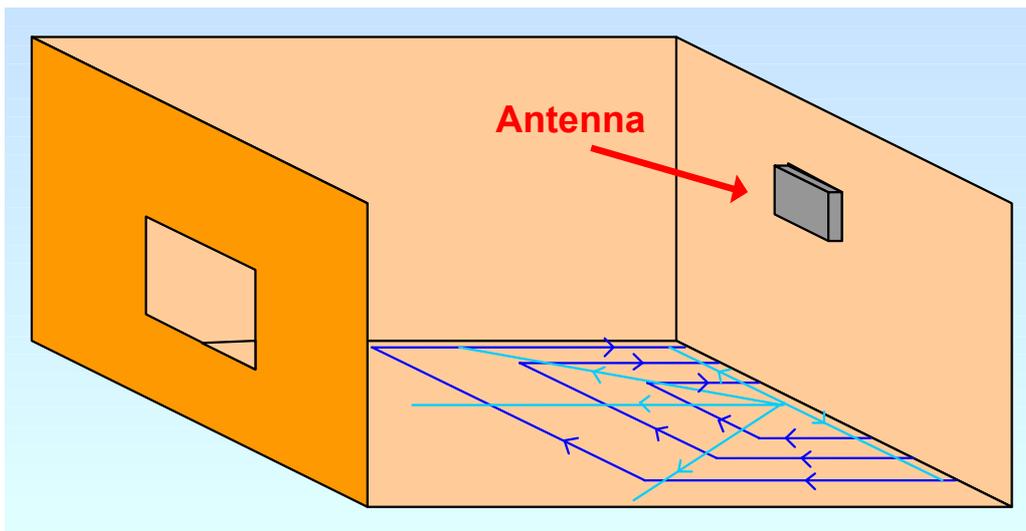
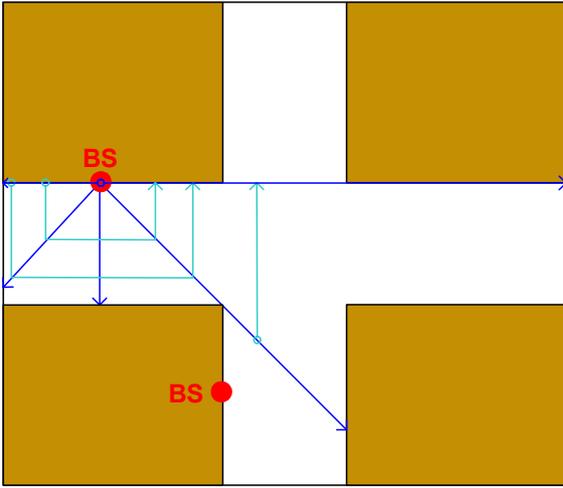


Figure 8 – Representation of paths for selection of measurement points (Iroof and Iwall).

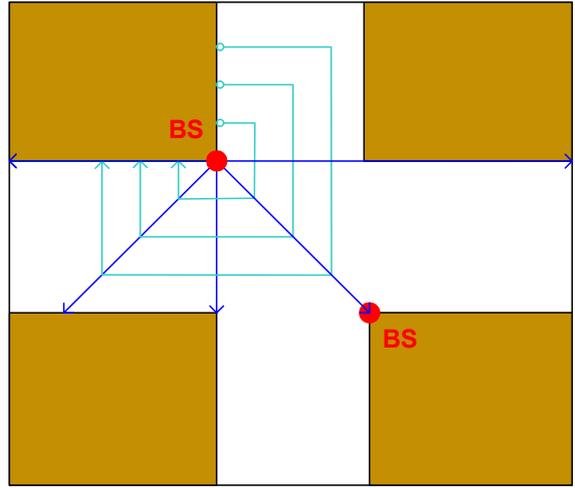
The temporary measurement points that are on line of sight situation with more than one base station are put under a more detailed analysis. On a general sense, this analysis is required in the area where there is superposition of the paths described on Section 3.2, for each base station. On this area, a new set of paths is defined, forming an analysis grid, Figure 11. It is important to note that the combination of the different topologies defined on Section 3.2 can origin a wide number of possibilities.

The selection of measurement points on the analysis grid involves the following procedure:

- Identification of maximum field points along the paths that form the analysis grid.
- Repetition of the previous procedure in order to avoid possible signal perturbations.
- Marking of the maximum field points on the analysis grid.

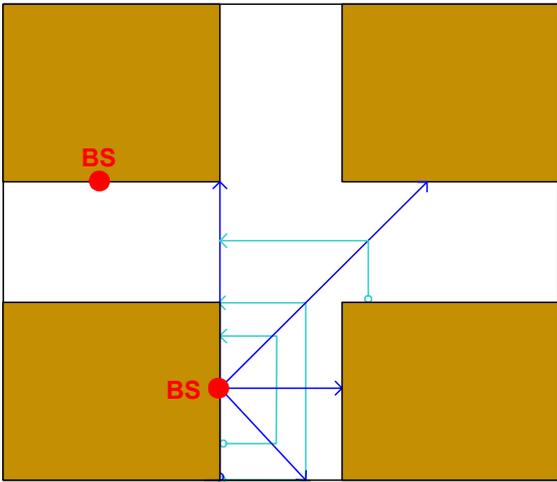


A – Non line of sight example

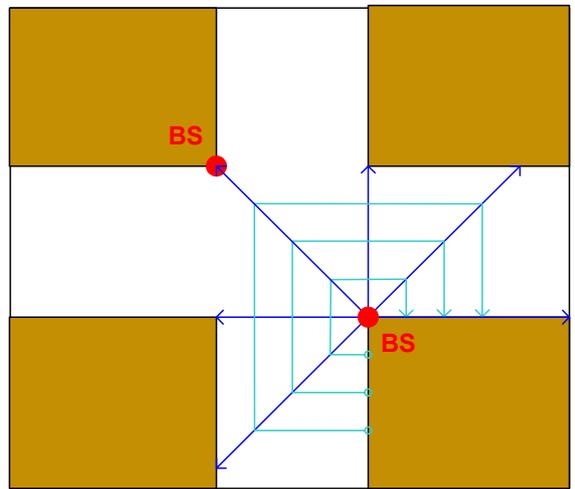


B – Line of sight example

Figure 9 – Paths for the first base station.

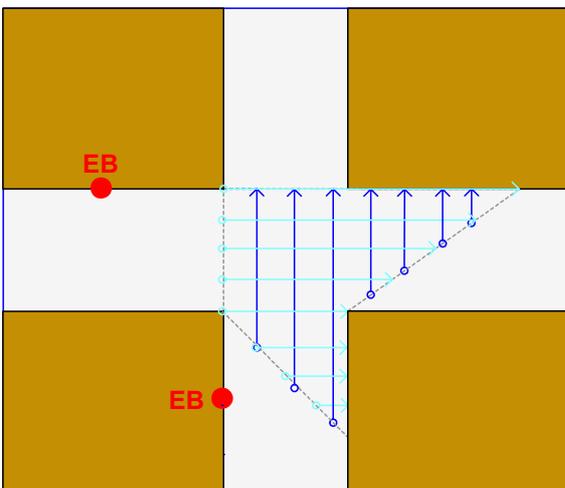


A – Non line of sight example

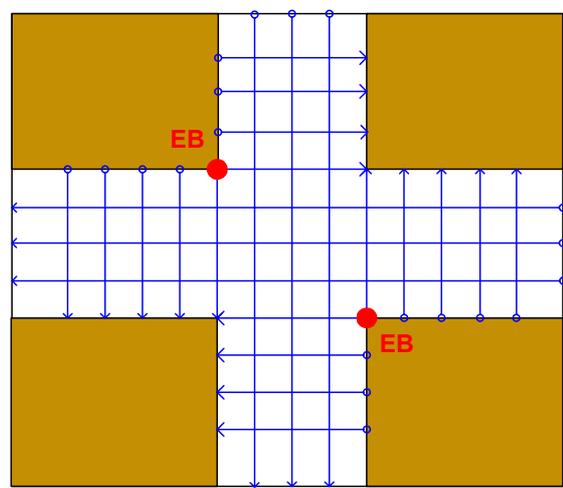


B – Line of sight example

Figure 10 – Paths for the second base station.



A – Non line of sight example



B – Line of sight example

Figure 11 – Analysis grid.

Finally, measurements are performed on the marked points on the analysis grid and on the points in situation of line of sight with only one base station, resulting from the previous individual analysis for each station.

4. Conclusions

This document describes the measurement procedure used by the **monIT** Project team within the localised monitoring process. It presents a practical method to assess compliance with exposure to electromagnetic radiation thresholds. The standard use of this well-defined procedure allows the direct comparison between results of every analysed location.

Two different issues are considered:

- The measurement procedure on a specific point is based on the recommendation ECC/REC (02)04 from CEPT, which specifies a method to assess electromagnetic radiation levels in the frequency band from 9 kHz to 300 GHz. A portable field monitor is used (wideband measurement, from 100 kHz to 3 GHz) and, whenever field levels are above a specific decision level, a spectrum analyser is used (selective measurement). If, by any reason, the measured levels are above the reference thresholds, a warning to the responsible entities is issued.
- The selection of measurement points is also addressed. A practical approach based on the **monIT** team experience and research is suggested, as there are no specific recommendations on this matter. The measurement environment (number of transmitters of mobile communication systems on the area and their installation topology) rules the procedure for the choice of measurement points.

The accuracy of the method for measurement of electromagnetic fields presented here may be improved with a previous theoretical analysis and simulation of the measurement environment. However, the complexity and the multiplicity of variables present in each environment will strongly restrict the practical approach, required for a systematic use of the method.

5. References

- [1] Electronic Communications Committee (ECC) European Conference of Postal and Telecommunications Administrations (CEPT), *Measuring Non-Ionizing Electromagnetic Radiation (9 kHz – 300 GHz)*, ECC Recommendation (02)04, Sep. 2002.
- [2] *PMM 8053A The Solutions for Every Electrosmog Problem*, Catalogue, PMM Safety Products, Segrate, Italy, 2003.
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- [3] Council of the European Union, "Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)", *Official Journal of the European Communities*, L 199/59, Brussels, Belgium, Jul., 1999.
- [4] MS2711B Handheld Spectrum Analyzer, Datasheet, Anritsu, EUA, Mar. 2002.
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