Measurements of Electromagnetic Field strength in Urban Environment from UMTS Radio base Stations and Analysis of the Relation with the Radiated Power

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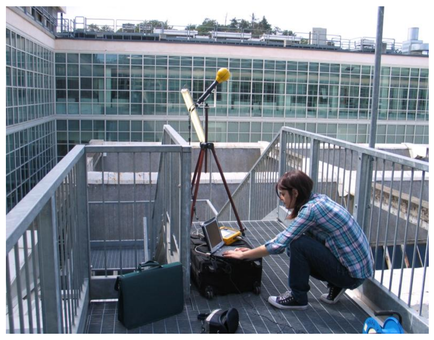
Executive summary

The Italian laws on Electro Magnetic Fields (EMF) requires a preliminary compliance assessment of the EMF emitted by a radio base station during the planning and authorization process, in order to verify that the base station will comply with the Italian limits, after the installation. The assessment is based on theoretical calculations, carried on starting from the radio electric parameters of the radio base station, including the expected power at the antenna connector. In order to provide a conservative assessment, calculations are carried on taking into account the theoretical maximum power that a radio base station can transmit; however, measurements shows radio base stations usually do not use the maximum power, due to the traffic variations and to the algorithms used to minimize interference.
In this document, EMF field measurements have been correlated with the network counters measuring the traffic variation and the radiated power from 3 UMTS radio base stations, in order to define a more realistic yet still conservative evaluation of the power emitted by a UMTS radio base station.

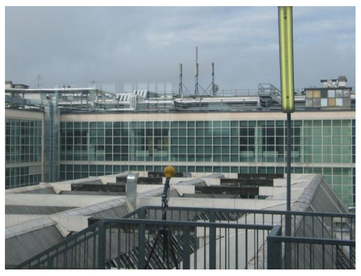
Measurement Setup



EMF generated by the UMTS radio base stations have been measured in the environment and, at the same time, the radio base station has been monitored in order to store the network counters related to radiated power and traffic variation. These values have been directly stored (3-5 seconds intervals) from the radio base stations by the vendor of the radio equipment, through a dedicated procedure.
Afterwards, the possible relationship between the different physical quantities at play has been evaluated. The instrument used for EMF measurement was a NARDA SRM 3000.

Monitored Sites

Quart and Saint Vincent in the Region Valle d'Aosta

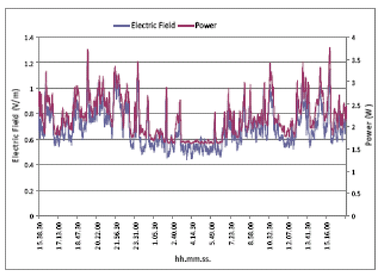


Ivrea and Grugliasco (Turin) in the Region Piemonte

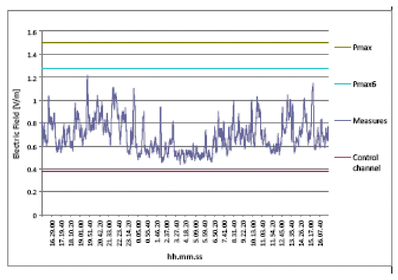
Correlation With Network Counters

Data processing was performed to correlate the measured electromagnetic field and the network counters related to the UMTS radiated power, in order to verify the correlation between the different sets of data in each locations. The correlations have been done both with instantaneous values and with mean value on several time intervals. It is worth noting that correlations are already good when measurement were carried on over an interval of 6 minutes: this is very important because 6 minutes is the average period defined by the Italian law setting the limits for EMF exposure.

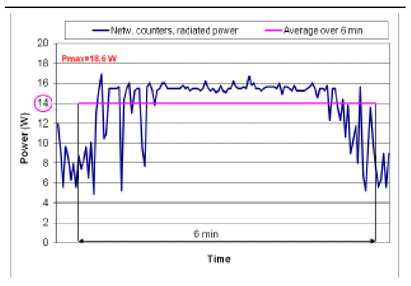
Graphic of comparison between measured EMF and the network counters related to the radiated power, averaged over 6 minutes for the site of Quart.
In this case the correlation is 0.91, an excellent result.



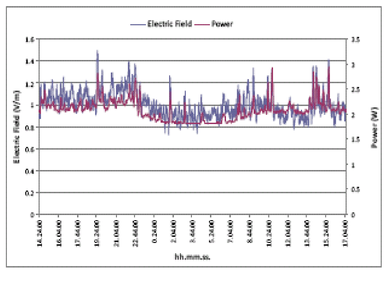
Quart's site: comparison of EMF calculations using the maximum theoretical power (Pmax), using the highest value of power obtained from the data averaged over 6 minutes (Pmax6), and the EMF measurements



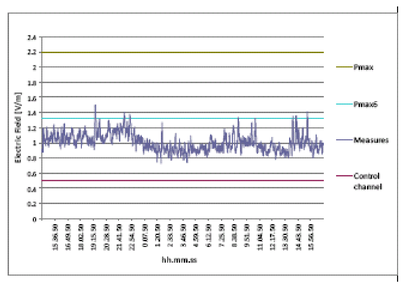
Quart: highest value of power obtained from the data averaged over 6 minutes vs. instantaneous radiated power from network counters



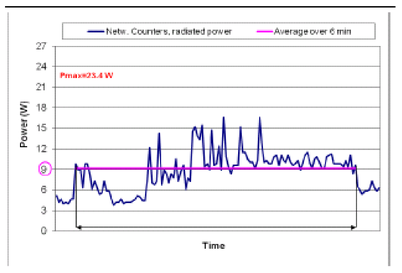
Graphic of comparison between measured EMF and the network counters related to the radiated power, averaged over 6 minutes for the site of Saint Vincent.
In this case the correlation is 0.75, a less positive result, probably due to the fact that measured EMF values were not only associated with the cell under analysis.



Saint Vincent's site: comparison of EMF calculations using the maximum theoretical power (Pmax), using the highest value of power obtained from the data averaged over 6 minutes (Pmax6), and the EMF measurements



Saint Vincent: highest value of power obtained from the data averaged over 6 minutes vs. instantaneous radiated power from network counters



Conclusions

The highest value of radiated power can be obtained from the data averaged over 6 minutes, which is a more realistic value than the theoretical maximum power, but still conservative as it is never exceeded by the EMF measured values. An extensive statistic analysis on a large number of base stations have been carried on, confirming that the calculated power offset (approximately 0.75) is also conservative for large clusters of sites: this value can be applied to the theoretical maximum power in order to perform more realistic, but still precautionary, EMF calculations.

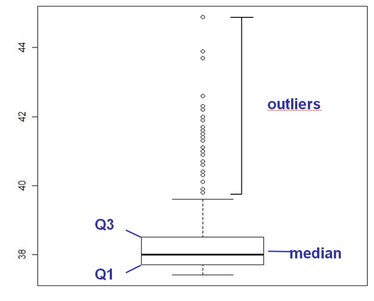
Where the highest value of power obtained from the data averaged over 6 minutes on is approximately the 75% of the maximum theoretical power that a radio base station can transmit, the calculated EMF values using the highest value of power obtained from the data averaged over 6 minutes is always greater than the instantaneous measured values, thus providing a conservative evaluation. In this case, a good correlation between the measured EMF and the network counters associated to the radiated power was observed (more that 0.9), and correspondingly the calculated EMF values using the highest value of power obtained from the data averaged over 6 minutes is again always greater than the instantaneous measured values.
Where the real power used by the radio base stations is much lower than the maximum theoretical power, some measured values exceed the highest value of power obtained from the data averaged over 6 minutes. However, these cases are less relevant for our analysis, because the calculated values are much lower if compared with the theoretical maximum, and the application of the highest value of power obtained from the data averaged over 6 minutes in the previous conditions (75%) would result in a large overestimation of the measured EMF values.

Statistical Analysis

Having validated the fact that the network counters related to the instantaneous radiated power reflect the real EMF measured values, a statistical analysis was carried on using a larger cluster of sites, concentrating on two large cities, one in Northern Italy, one in Southern Italy, in order to cover both the 3G radio equipment vendors currently used in Vodafone Italy's network. Within this clusters, the cells characterized by the highest radiated power have been selected.
The statistical analysis was intended to estimate a general power offset to be used in the calculation of the EMF emissions of a 3G base station, starting from the maximum theoretical power. As such, the analysis had to verify that the data clusters were really representative of sites with high traffic – radiated power, and to estimate a conservative power offset value.
The first analysis was the autocorrelation, to identify the more appropriate sample interval to work with: a sampling of 10 seconds was found to be enough to have significant data, being reciprocally independent.

High power conditions = "outliers" values in the boxplot.

After a new sampling, a second analysis was carried on to verify if data clusters were appropriate to represent sites with high traffic load (percentiles, boxplot), and to calculate a rolling average over 6 minutes.



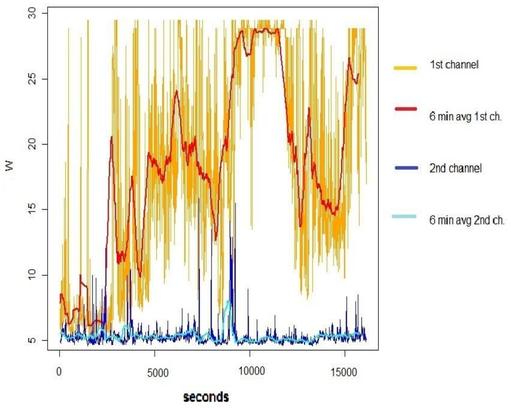
- **Group A**: cells with high power conditions verified for a time interval> 1 mim (12 cells out of 30)

- **Group B**: 2 selection criteria
  - istantaneous max value >95% of theoretical max power
  - Outliers % > 10% of the sum of all data (high power conditions for at least 30 min. over 24h)

(7 cells out of 30)

Estimation of conservative power offset value through:
Group A - highest value of radiated power obtained from the data averaged over 6 minutes
Group B - average of the outlayers, "reconstructing" a theoretical period of the worst 6 minutes

These parameters have been then expressed as a percentage of the theoretical maximum power: the higher percentage is lower than 80%, and looking at the cells with the highest radiated power the higher percentage is approximately 74%, resulting in a power offset which is approximately 0.75.



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