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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***Abstract*—Measurements of the Electro Magnetic Fields (EMF) emitted by 3 UMTS base stations have been correlated with network counters related to traffic variation and radiated power, in order to obtain a more realistic yet conservative calculation of the EMF emitted from a UMTS base station.**

Keywords-component; radio base station; radiated power; EMF calculation; UMTS

I. INTRODUCTION

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 [1]. 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 paper, EMF field measurements have been correlated with the network counters measuring the traffic variation and the radiated power from a UMTS radio base station, in order to define a more realistic yet still conservative evaluation of the power emitted by a UMTS radio base station.

II. 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. 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, a spectrum analyzer provided by ARPA Valle d'Aosta and managed by a remote control through dedicated software. Radiated power values have been stored directly from the radio base stations by the vendor of the radio equipment, through a dedicated procedure.
In order to identify only the EMF associated to a specific cell whose network counters were under tracking, digital narrowband measurements have been performed on the UMTS control channel, then the global wideband signal's integral has been calculated over the entire 5 MHz frequency band. As network counters were available for radiated power and traffic with an interval of 3-5 seconds, the sampling rate for the EMF measurements has been defined at 10 seconds.

Figure 1. Radio Base Station monitored in Saint Vincent, Valle D'Aosta

At the beginning, three sites with different signal operating modes and urban type have been monitored by ARPA Valle d'Aosta, two in the Region Valle d'Aosta (Quart and Saint Vincent, Figure 1) and one in the Region Piemonte (Ivrea). After that, a new site in Turin has been monitored by ARPA

Piemonte, with the same instrument used in the first measures but with a sampling rate of 5 seconds, in order to replicate the findings. Every site is in front of a radio base station working with UMTS signal.

III. 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 of the three locations. The correlations have been done both with instantaneous values and with mean value on several time intervals.

Differences found in the post processing analysis can be associated with the type of traffic handled by the antenna, the week of the day considered, the atmospheric conditions, etc. However, good correlations between the measured EMF and the network counters associated to the radiated power has been found in all the situations characterized by a high number of data, stored in many continuous hours of sampling.

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 [2], therefore it was identified the possibility to define a percentage threshold with respect to the maximum theoretical radiated power, to be applied for a more realistic assessment of the human exposure close to UMTS base stations.

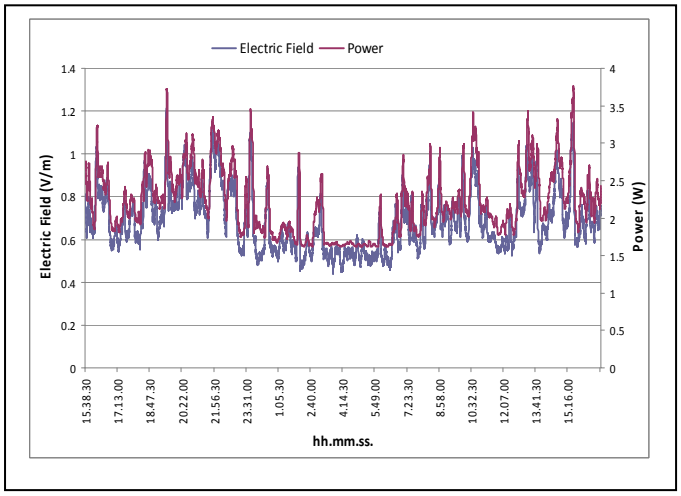

Figure 2. Quart, correlation between EMF and radiated power counters, 6 minutes average

Figure 2 shows a 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.

Figure 3 shows the same analysis 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.

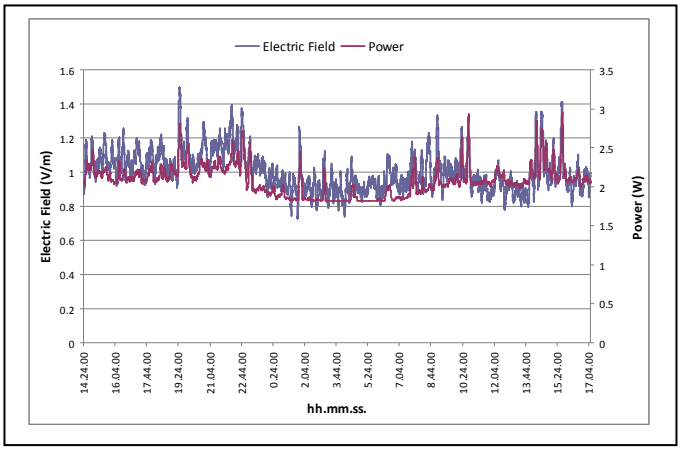

Figure 3. Saint Vincent, correlation between EMF and radiated power counters, 6 minutes average

EMF measurements in environment and the associated network counters related to the radiated power from the radio base station, therefore, have been used to verify the accuracy of the calculation models used to assess EMF from radio base stations, which are usually based on the maximum theoretical power that a radio base station can transmit.

EMF calculations carried on using the maximum theoretical power have been compared with calculations performed using the highest value of power obtained from the data averaged over 6 minutes, and also with the EMF measurements averaged over a 6 minutes period.

Two different behaviors are possible. For those sites where the correlation between the measured EMF and the network counters associated to the radiated power is good (higher than 0.9), 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.

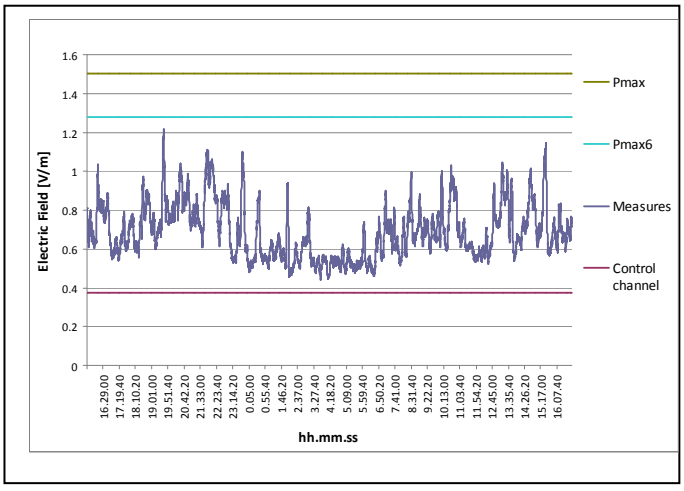

Figure 4. Quart, comparison of EMF calculations using the maximum theoretical power (Pmax), using the highest value of power obtained from the data averaged over 6 minutes (Pmax6), and the EMF measurements

In these cases, the highest value of power obtained from the data averaged over 6 minutes on our site is approximately the 75% of the maximum theoretical power that a radio base station can transmit; this new value seems to be more realistic, yet still conservative to provide an accurate EMF calculation for UMTS base stations.

Figure 4 shows the result of these theoretical elaborations for the site of Quart, while Figure 5 shows a subset of the network counters power data, used for the simulation, stored in a specific interval of 6 min in which the values are highest, which is the highest value of power obtained from the data averaged over 6 minutes (probably a HSPA burst).

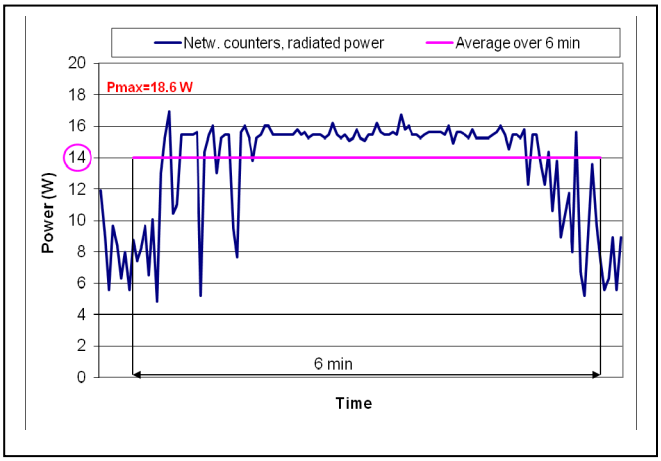

Figure 5. Quart, highest value of power obtained from the data averaged over 6 minutes vs. instantaneous radiated power from network counters

In the other sites, 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.

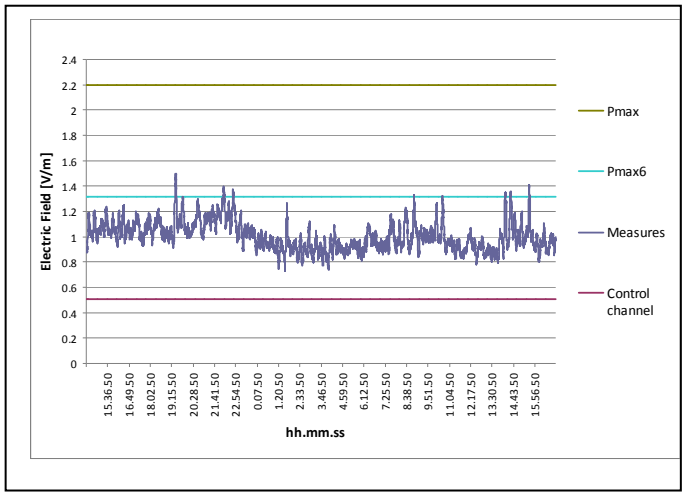

Figure 6. Saint Vincent, comparison of EMF calculations using the maximum theoretical power (Pmax), using the highest value of power obtained from the data averaged over 6 minutes (Pmax6), and the EMF measurements

Figure 6 shows the result of these theoretical elaborations for the site of Saint Vincent, while Figure 7 shows the power data, used for the simulation, stored in the interval of 6 min in which the values are highest.

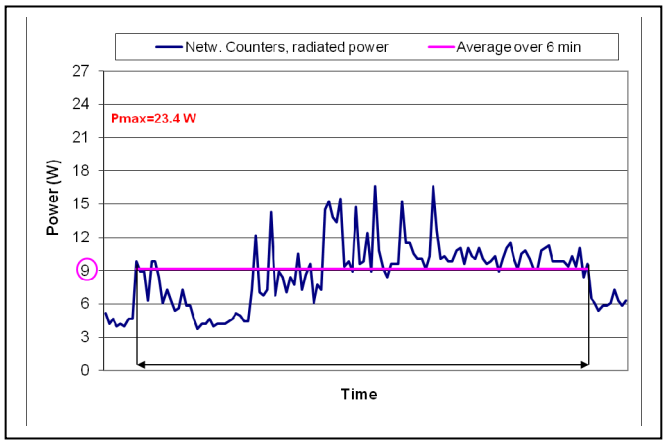

Figure 7. Saint Vincent, highest value of power obtained from the data averaged over 6 minutes vs. instantaneous radiated power from network counters

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.

Similar results have been replicated in a second measurement campaign, carried on by ARPA Piemonte in another high traffic site in Grugliasco, close to Turin. Even in this case, a good correlation between the measured EMF and the network counters associated to the radiated power was observed (0.94), 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.

IV. 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.
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.

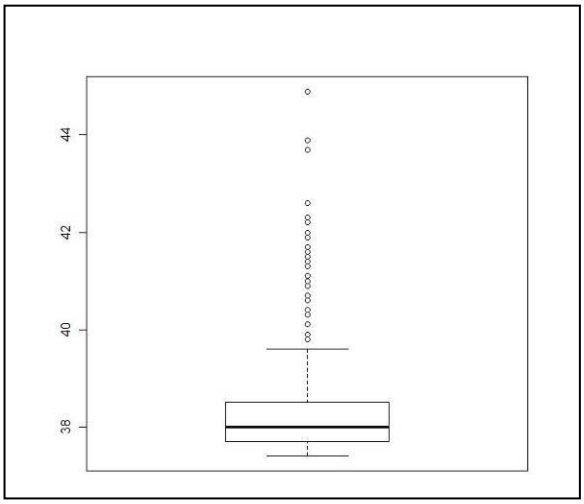

Figure 8. Boxplot for a data series related to a Northern Italy city,

High power conditions have been identified as the "outlayers" values in the boxplot, being higher than the limit (L_{out}) defined as the sum of 75th percentile and the inter-quartile range. The first step was to identify those cells where high power conditions were verified for a time interval grater than1 minute: 12 cells out of 30 were selected, and for these cells a rolling average over 6 minutes was considered as an effective estimation of the maximum radiated power. Among other cells, the following selection criteria were applied: (1) the instantaneous maximum value is higher than 95% of the theoretical maximum power, and (2) the outlayers percentage is higher than the 10% of the sum of all data, meaning that at least 30 minutes over 24 hours are in high power conditions. For these cells (7 out of 30), the estimation was done through the average of the outlayers, "reconstructing" a theoretical period of the worst 6 minutes. This value has been estimated also for the first 12 cells, resulting in line with the highest value of radiated power obtained from the data averaged over 6 minutes, thus confirming the validity of the approach.
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.

V. CONCLUSIONS

The analysis of measured EMF values and of the corresponding network counters related to the radiated power has shown a good correlation (higher than 0.9) when the measurement interval is at least 6 minutes.
As 6 minutes is the averaging period considered in the definition of the Italian and international EMF limits, a statistical analysis has been carried on network counters, identifying the highest value of radiated power 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. Then, 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 study has identified a correlation between EMF measured values and network counters related to the radiated power in UMTS technology, and a methodology which can be used to define a power offset (the highest value of radiated power obtained from the data averaged over 6 minutes) in order to perform more realistic, but still precautionary, EMF calculations.

ACKNOWLEDGMENT

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