Output power distributions of mobile radio base stations based on network measurements

D Colombi¹, B Thors¹, T Persson¹, N Wirén², L-E Larsson² and C Törnevik¹

¹Ericsson Research, SE-164 80 Stockholm, SWEDEN
²TeliaSonera, SE-123 43 Farsta, SWEDEN

E-mail: davide.colombi@ericsson.com

Abstract. In this work output power distributions of mobile radio base stations have been analyzed for 2G and 3G telecommunication systems. The approach is based on measurements in selected networks using performance surveillance tools part of the network Operational Support System (OSS). For the 3G network considered, direct measurements of output power levels were possible, while for the 2G networks, output power levels were estimated from measurements of traffic volumes. Both voice and data services were included in the investigation. Measurements were conducted for large geographical areas, to ensure good overall statistics, as well as for smaller areas to investigate the impact of different environments. For high traffic hours, the 90th percentile of the averaged output power was found to be below 65% and 45% of the available output power for the 2G and 3G systems, respectively.

1. Introduction
Human exposure to radio frequency (RF) electromagnetic fields (EMF) from base stations is directly proportional to the base station output power. In determining EMF limit compliance, the theoretical maximum output power is normally used. In reality, however, the transmitted power can be much lower than the maximum levels depending on factors such as power regulation, discontinuous transmission (DTX), traffic variations and radio access technology [1]. The objective of this study was to gather statistics on downlink output power in mobile networks to determine typical power levels and realistic distributions.

2. Method
In mobile communication networks it is possible to monitor many performance indicators to ensure that the networks meet expected quality requirements [2]. The performance surveillance is part of the Operational Support Systems (OSS) used by the network operators. Depending on access technology there are counters that either directly or indirectly can be employed to determine the downlink output power. Using these types of counters it was possible to simultaneously gather statistics for large sets of radio base stations (RBS) in the TeliaSonera 2G and 3G networks in Sweden. Effects of traffic variation and different environments such as urban and rural areas were analyzed for different radio access technologies.
The data monitored were sampled by the system with a relatively narrow time interval, about 100 ms for 3G and 10 s for 2G, and averaged over 15 minutes before being transmitted to the OSS. Thus, the analyzed figures correspond to RBS output power levels averaged over 15 minutes.

2.1. 2G network data
Traffic volume data were collected for both GSM 900 and GSM 1800 during 24 hours of a weekday. The dataset included a total of 12400 sectors (or GSM cells), covering 35% of the land area and potentially 70% of the population. Traffic volume data were also gathered during a full week for two different base station controllers corresponding to rural and urban environments, respectively.

Both voice and data (GPRS+EDGE) traffic were included in the analysis. The traffic volume data were translated to output power by calculating an average number of TRXs used during each 15 minute period. In this model, effects such as discontinuous transmission (DTX), frequency hopping, and number of traffic channels used for GPRS and EDGE were considered. The impact of DTX was taken into account by multiplying the obtained power levels related to voice traffic with a factor of 0.6 [3].

The distribution of the transmitted power compared to the maximum available power from the RBS was determined as function of the number of installed transceivers (TRXs). In GSM, TRXs are responsible for the transmission and reception of the signal over a pair of 200 kHz channels. Increasing the number of TRXs will increase the cell capacity.

2.2. 3G network data
Output power data were collected in the WCDMA 2100 MHz band during 24 hours of a weekday. Data for a total of three Radio Network Controllers (RNCs) were included, corresponding to about 220 radio base stations, covering urban, suburban, and rural areas.

3. Results
In the subsections below, results obtained for the 2G and 3G networks are presented.

3.1. 2G
In 99% of the analyzed GSM cells, the number of installed TRXs was less than seven, with cells containing two TRXs constituting the clear majority. The empirical probability density function (PDF) of the output power for the 2G network, including all collected data over 24 hours, is shown in Figure 1a. Figure 1b shows the corresponding cumulative distribution (CDF).

![Figure 1: Normalized RBS output power for different number of installed TRXs in the considered 2G network. (a) Empirical Probability Density Function (PDF). (b) Empirical Cumulative Distribution Function (CDF).](image-url)
The two first timeslots of the first TRX are normally used for signaling and this carrier is transmitted at constant power at all times. For those of the remaining six timeslots not used for traffic, dummy bursts are sent to ensure continuity in power levels [4]. As a consequence, at least one carrier is always transmitting at maximum power which, in combination with the employed normalization to maximum power levels, explains why the bars/curves in Figure 1 are shifted towards the left when more TRXs are added.

The CDFs in Figures 2a and 2b, show the differences in the output power distribution for low and high traffic hours (from 1 to 5 am and from 4 to 8 pm, respectively) and between urban and rural environments, respectively.

![Figure 2: CDFs of output power levels for different number of installed TRXs in the considered 2G network. (a) Variation between low and high traffic hours (all collected data). (b) Variation between different environments (one base station controller per environment).](image)

### 3.2. 3G

The overall 3G output power statistics are given in Figure 3.

![Figure 3: 3G output power statistics for all sites investigated. (a) PDF of RBS output power per cell. (b) CDF of normalized output power with respect to the maximum value.](image)

Figures 4a and 4b provide CDFs of the normalized output power for high versus low traffic hours (from 4 to 8 pm and from 1 to 5 am, respectively) and for different environments, respectively.
4. Discussion

4.1. 2G
For two TRxs and the dataset corresponding to the 24 hour measurements, the 90th percentile was found to be about 63% of the available output power. By restricting the measurements to high traffic hours, the corresponding figure increased to 65% as shown in Figure 2a. Similarly, in environments characterized primarily by suburban/rural areas (considering data for 24 hours), the 90th percentile output power was found to be 65%, see Figure 2b.

A characteristic of the investigated GSM network is that no power control technique is used. Therefore, the output power variation is mainly dependent on the traffic variation. In many other networks, however, power control algorithms are implemented to reduce interference and to save energy. With power control implemented, even lower RBS power levels would have been obtained.

4.2. 3G
The average output power per cell was 6 W, cf. Figure 3a. For 90% of the analyzed cells the maximum available output power was about 25 W. Including all collected power samples, the 90th percentile was found to be 35% of the available RBS output power. The corresponding figure considering high traffic hours only was 42%. By restricting the measurements to urban environments (all 24 hours included), the 90th percentile power level was 43% of the maximum output power.

5. Conclusion
In this work, large amount of network data were collected and the downlink output power distributions for 2G and 3G mobile communication networks were analyzed. Due to effects of power regulation, DTX, and traffic variations, the effective RBS power was found to be far below the maximum available power. For high traffic hours, the 90th percentile of the averaged output power was found to be 65% and 45% of the available RBS power for 2G and 3G, respectively.

References
[1] Mahfouz Z, Gati A, Lautru D, Wong M-F, Wiart J and V Hanna 2012 Influence of traffic variations on exposure to wireless signals in realistic environments Bioelectromagnetics 33 288-297
[2] Holm-Öste G and Norling M 2008 Ericsson’s user service performance framework, Ericsson Review 43-46
[3] 3GPP 2001 Technical specification group services and system aspects; full rate speech; voice activity detector (VAD) for full rate speech traffic channels 3GPP TS 46.032 4.0.0
[4] 3GPP 2009 Technical specification group GSM/EDGE radio access network; radio subsystem link control 3GPP TS 45.008 4.18.0