Statistical Analysis of Field Strength Location Variability for UHF Multimedia Broadband Services

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This letter investigates the location variability for dimensioning broadcast networks for mobile receivers. A statistical analysis of empirical data from three European cities is performed for services in UHF band. This work demonstrates that currently used values are too pessimistic and lead to inefficient network dimensioning.

Introduction: The location variability is a term referring to the standard deviation of the field strength, due to small-scale fading, over a small area inside the service area, typically represented by a square of $100 \times 100 \text{ m}^2$. The location variability is a key parameter in dimensioning broadcast infrastructures, specifically for portable and mobile services. The network architecture and radiating power need to be adjusted as a function of the possible variations of the received field strength level.

From the link budget point of view, the location variability effect is usually considered in the form of a log-normal location correction factor targeting a desired (required) coverage [1]. The value of the location correction factor can be obtained theoretically from the log-normal function of the field strength distribution provided the location variability is known.

Most recommendations consider a value for the location variability of 5.5 dB for wideband signals in Very High Frequency (VHF), Ultra High Frequency (UHF) and S Bands. This value is exclusively based on a cell size resolution of $100 \times 100 \text{ m}^2$, which is

the typical terrain grid resolution for planning broadcast networks [2]. Previous studies from the authors suggested that this value was pessimistic [3], [4]. In addition, the value of the cell size resolution of $100 \times 100 \text{ m}^2$ has been inherited from analogue planning and it was mainly conditioned by digital terrain base data available in the 90s. However, this consideration is no longer valid for network deployment in urban areas for mobile and portable receivers where a resolution of $25 \times 25 \text{ m}^2$ in suburban environments and $5 \times 5 \text{ m}^2$ in urban areas is the current practice.

Currently, experimental developments are ongoing for different mobile broadcast systems: Digital Video Broadcasting-Terrestrial 2 (DVB-T2) [5], Advanced Television System Committee-Mobile/Handheld (ATSC-M/H) [6] and the future system DVB-Next Generation Handheld (DVB-NGH).

In this context, this work presents the results of an empirical analysis of the location variability for cell sizes between $5 \times 5 \text{ m}^2$ and $500 \times 500 \text{ m}^2$ and proposes a more accurate value. The results can be used in future digital broadcast network planning. The study is based on extensive DVB-T measurement campaigns carried out in the UHF band in three cities.

Measurement campaigns: The present study is based on three measurement campaigns carried out in metropolitan areas of different cities: Madrid and Bilbao in Spain and Ghent in Belgium. The received power level was measured along different planned routes with variable longitude. The samples were measured by a spectrum signal analyzer using a receiving antenna with an omnidirectional horizontal pattern placed on top of the measurement vehicle at a height of 2 meters above the ground level.

One set of measurements was carried out in Bilbao and Madrid [3], Spain, using signals on channel 68 (850 MHz) of the UHF Band [3]. The network consisted of three transmitters (a main transmitter with two auxiliary gap fillers) providing coverage in the city center and its surrounding areas. This set up corresponds theoretically to single frequency network (SFN) features but in practice, there is a low overlapping between coverage areas of the transmitter and gap fillers so it can be considered as Low Dense SFN. The second group of data was obtained in the city of Ghent [4], where measurements were recorded at 602 MHz using a single transmitter, so it can be considered a multiple frequency network (MFN) environment.

Analysis methodology: The theoretical value of the location correction factor, $M(\text{dB})$, can be derived from the location variability assuming a log-normal distribution for the electric field variability [1].

$$M_{\text{theoretical}}(q) = Q_i(q/100) \cdot \sigma_L$$

This factor depends on the accumulative inverse function $Q_i(x)$ of the normal field distribution probability, the coverage target (q) and the mean value of the location variability (σ_L) for the considered cell size. The coverage target (q) represents the percentage of receiving locations inside the cell size where the electric field strength level will be higher than its median value.

All the power level measurement points along a route are grouped considering segments of a length corresponding to different small area sizes (from $5 \times 5 \text{ m}^2$ to $500 \times 500 \text{ m}^2$). For each segment, route and measurement area, mean, maximum and minimum statistical values of the location variability are determined. Also, the 50th, 70th, 95th and 99th percentiles of the received field strength level, $E(q)$, are calculated in order to determine empirically the location correction factor for different coverage targets.

$$M_{\text{empirical}}(q) = E(q) - E(50\%)$$

In order to ensure that the field strength samples were statistically representative, the recommended practice by the European Radiocommunication Committee (ERC) was followed [7]. A minimum distance between samples of 0.8λ was imposed to the database by re-sampling. In addition, oversampling was avoided by removing the measurements separated less than 0.2λ . In practice, the analysis of the results has shown that the sub-sampling condition did not have a significant impact on the final results.

Results: The accuracy of the log-normal approximation of the variation distribution is analyzed. In order to verify this assumption, Figure 1 compares the theoretical values (derived from the log-normal expression) and the empirical values (obtained from the measurement campaigns) of the location correction factors for different coverage targets (70%, 95% and 99%) and different cell sizes. These values represent the average for the three data sets. For increasing cell sizes, the location variability increases due to the higher variability of the electric field strength level. It can be observed that in all the considered cases the theoretical and empirical values fit well, that is, it can be assumed that the electric field variability is log-normally distributed with independence of the selected cell size. This means that the location correction factor needed to ensure a required coverage target (q) can be accurately derived from the location variability.

The results for the outdoor location variability are here summarized. Figure 2 shows the average, minimum and maximum of the location variability values as a function of the cell size for different cities. The mean value of the location variability for a cell size of $100 \times 100 \text{ m}^2$ is quite lower than the value of 5.5 dB recommended by the International Telecommunications Union – Radiocommunications sector (ITU-R) [2] and European

Telecommunications Standard Institute (ETSI) [8]. Considering a higher value for the location variability causes the location correction factors to be higher and this leads to broadcast network oversizing.

As expected, the smaller the cell size, the lower the location variability. However, the difference between cell sizes of $10 \times 10 \text{ m}^2$ and $100 \times 100 \text{ m}^2$ is lower than 1 dB. The results obtained for the cities in Spain are practically the same up to a cell size of $100 \times 100 \text{ m}^2$. Larger differences of 0.5 dB are obtained for cell sizes larger than $100 \times 100 \text{ m}^2$. This is due to the large-scale fading, which has a remarkable influence for distances larger than 40λ [1]. Its effect depends significantly on the topology of the city and causing the difference for cells higher than $100 \times 100 \text{ m}^2$.

Comparing measurements from Spain with those recorded in Ghent, it can be observed that when the cell size is smaller than $100 \times 100 \text{ m}^2$, location variability for Ghent is higher. This is due to the topology of the transmitting network, that is, SFN topology reduces the field strength variability in Madrid and Bilbao cases. If the cell size is higher than $100 \times 100 \text{ m}^2$, the location variability is lower in the case of Ghent. This is due to the large scale fading differences caused by the specific characteristics of the environment of the mentioned city (mainly suburban). For cell sizes of $5 \times 5 \text{ m}^2$ and $25 \times 25 \text{ m}^2$ (Figure 2) 1.5 dB and 2.2 dB are obtained on average for the three data sets, respectively.

The presented results are essential in order to improve coverage planning for new digital standards in UHF band such as DVB-T2, DVB-NGH or ATSC M/H.

Conclusion: The location correction factor to ensure a required coverage target can be derived accurately from value of the location variability. The recommended value for location variability is 1.5 dB for a cell size of $5 \times 5 \text{ m}^2$ and is 2.2 dB for a cell size $25 \times 25 \text{ m}^2$.

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Figure captions:

Fig. 1. Comparison between theoretical and empirical values of the location correction factor in the measurement campaigns for different cell sizes in the three cities under study

Fig. 2. Mean, maximum and minimum of the location variability (σ_L) obtained in Bilbao, Madrid and Ghent for different cell sizes.

Figure 1

Figure 2