Progress In Electromagnetics Research Letters, Vol. 29, 151–156, 2012

CORRELATION FOR MULTI-FREQUENCY PROPAGATION IN URBAN ENVIRONMENTS

B. Van Laethem[1], F. Quitin[1, 2], F. Bellens[1, 3], C. Oestges[2], and Ph. De Doncker[1, *]

[1]OPERA Department, Université Libre de Bruxelles, CP 165/81, 50 Avenue Roosevelt, Brussels 1050, Belgium

[2]ICTEAM Electrical Engineering, Université Catholique de Louvain, 3 Place du Levant, Louvain-la-Neuve 1348, Belgium

[3]L2E, UPMC University Paris 06, Paris, France

Abstract—The multi-frequency propagation in urban environment is investigated in this letter. An experimental measurement campaign is conducted to simultaneously measure the GSM-900, GSM-1800 and UMTS band of a cellular system in a suburban environment. The shadowing and small-scale fading parameters are extracted, and the correlation of these parameters across the different frequency bands is measured. It is shown that shadowing coefficients are highly correlated, while small-scale fading is completely uncorrelated between different frequency bands.

1. INTRODUCTION

The characterization of electromagnetic propagation for wireless systems has led to a wide variety of models for frequencies going from the GSM-900 band to the 5 GHz WiFi band. However, only little attention has been paid to the correlations and interactions that might exist between the different frequency bands. In [1], correlation between shadowing in the GSM-900 and the GSM-1800 band is investigated, but, to the best of the authors' knowledge, no other papers have addressed the problem of multi-band shadow fading and small-scale fading correlation. Exploring the multi-band propagation channel is led by two different motivations. The first one is the following: if shadowing and small-scale fading are found to be uncorrelated

Received 17 November 2011, Accepted 23 January 2012, Scheduled 27 January 2012
* Corresponding author: P. De Doncker (pdedonck@ulb.ac.be).

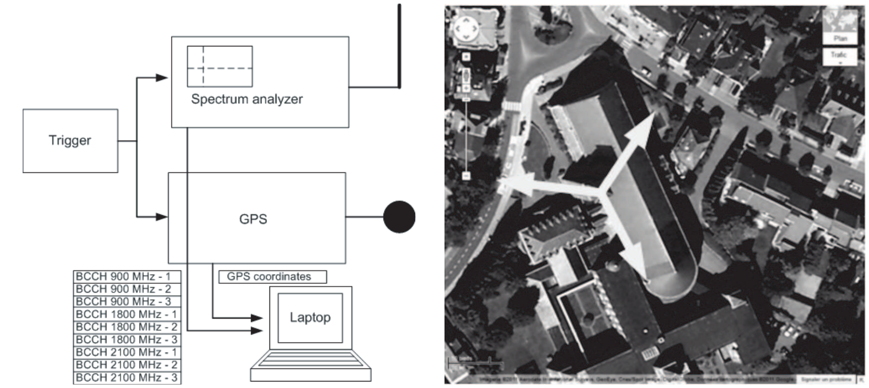
among different frequency bands, one might use *band diversity* to maintain a reliable communication link between the transmitter and the receiver [2]. The second motivation for investigating the multi-band propagation channel lies within government regulation. In order to prevent possible effects from electromagnetic radiation, the ICNIRP has recommended limiting the radiation levels of electromagnetic fields [3]. In order to account for the electromagnetic fields at different frequencies, most government regulators recommend adding up the electromagnetic fields in different frequency bands. In order to adjust these recommendations to real propagation channels, it is interesting for government regulators to determine whether propagation channels in different frequency bands are correlated or not, both for shadowing and for small-scale fading effects.

The aim of this paper is to experimentally evaluate the correlation between different frequency bands of shadowing and small-scale fading. The considered frequency bands are the GSM-900, GSM-1800 and UMTS (2100 MHz) bands. Despite not including the newer 4G-LTE frequency band, we expect that the findings in this paper can be generalized to any RF band. Measurements will be conducted in a urban environment to measure the power of the signals transmitted by a base station at different frequencies. The shadowing and small-scale fading parameters for each frequency band will be extracted, and correlation between the different bands will be investigated.

2. EXPERIMENTAL SETUP

The power received from a base station, in different frequency bands, was measured by recording the broadcast control channels (BCCHs) transmitted from the base station. The powers of the BCCHs were measured simultaneously[†] in the GSM-900, GSM-1800 and UMTS band by using a Rohde & Schwarz TSM-Q spectrum analyzer while driving around. For each band, three BCCH were recorded, corresponding to the three antennas pointing in three different orientations around the base station. A built-in GPS was triggered at each measurement to simultaneously record the exact geographical position of the measurement. The orientations of the antennas of the different frequency bands were identical. The experimental setup, as well as a picture the base station with the antenna orientation, is given in Figure 1. The measurement campaign was performed in Brussels, Belgium. In total, over 25 km of measurements were taken,

[†] In this case ≪simultaneously≫ means that the spectrum was swept over the consider bands fast enough for the measurement time to be negligible compared to the movement of the vehicle.



(a) (b)

Figure 1. (a) Experimental setup and (b) picture of the base station. The arrows correspond to the orientation of the base station antennas.

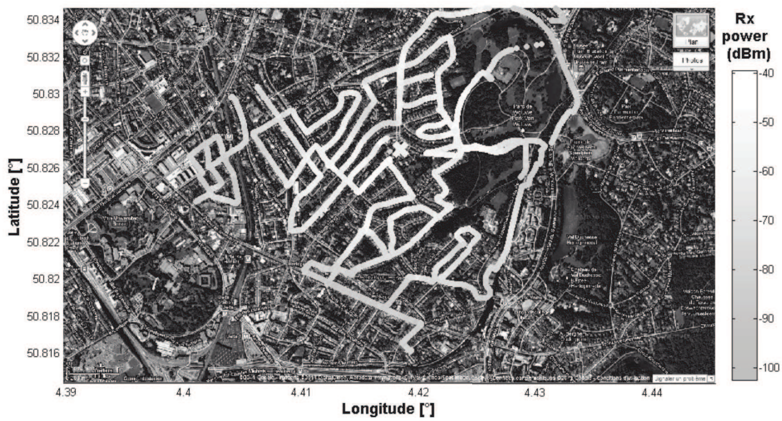


Figure 2. Measurement route and received power as a function of latitude and longitude for the 1800 MHz frequency band. The cross in the middle of the Figure indicates the position of the base station.

with one measurement taken at least every 2 m. The measurement route is shown in Figure 2. A preliminary data treatment was applied to suppress identical measurements (when the car was stopping or when driving twice through the same street). Since UMTS uses CDMA at the base station and the spectrum analyzer could not distinguish the signal of different base stations, measurements for the UMTS band were limited to 726 m around the base station to avoid interference from other base stations. Finally, the measurements were divided in three zones corresponding to the three orientations of the base station antennas. For each zone and each band, only the BCCH measurement corresponding to that zone was kept for further analysis. The gain of the transmitting antennas in each band was compensated for to de-embed the effect of the base station antennas at the different frequencies. In conclusion, for each measurement point, the following data are obtained: the path loss in the GSM-900 band, the path loss in the GSM-1800 band, the path loss in the UMTS band, and the geographical coordinates of the measurement. An example for the received power for the 1800 MHz band is shown in Figure 2.

3. SHADOWING CORRELATION

The received power was averaged over local areas of 4 m (12λ at 900 MHz, 24λ at 2100 MHz) to exclude small-scale fading effects. Figure 3 shows an example of instantaneous and averaged received power. It can be observed that the large-scale variations follow similar trends, while the small-scale variations (dotted curves) behave in a random manner. The path loss curve was estimated by linear regression of the received power versus distance. The variations of the received power around the path loss curve are considered to be solely due to shadowing. The shadow fading follows a log-normal distribution (or Gaussian in dB), as reported previously in literature [1]. The standard deviation of the shadow fading is 7.23 dB, 7.77 dB and 7.39 dB for the 900 MHz, 1800 MHz and 2100 MHz band respectively. Finally, the correlation of the shadow fading between the different frequency

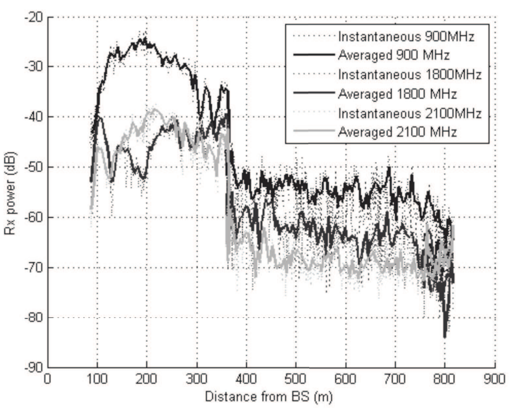


Figure 3. Received power as a function of distance from base station. The thick lines represent the averaged powers, the dotted lines represent the instantaneous received powers.

Table 1. Correlation of the shadow fading between the GSM900, GSM1800 and UMTS bands.

Bands for the correlation coefficient	Shadow fading correlation coefficient
GSM900–GSM1800	**0.84**
GSM900–UMTS	**0.79**
GSM1800–UMTS	**0.70**

Table 2. Correlation of the small-scale fading between the GSM900, GSM1800 and UMTS bands.

Bands for the correlation coefficient	Small-scale fading correlation coefficient
GSM900–GSM1800	**0.03**
GSM900–UMTS	**0.01**
GSM1800–UMTS	**0.05**

band is investigated. The shadow fading correlation between the 900 MHz, 1800 MHz and 2100 MHz bands is given in Table 1. It can be observed that there is a high correlation for the shadowing coefficients between all frequency bands. This shows that shadowing, which is mainly caused by blockage from obstacles, behaves in a very similar way for all frequency bands and causes very similar attenuation for all frequencies. Therefore, band diversity may not be considered as a suitable solution to combat shadow fading.

4. SMALL-SCALE FADING CORRELATION

The small-scale fading is obtained by removing the power averaged over the local area from each measurement point. These normalized measurements are grouped by sets of 150 m, as detailed in [4], to obtain data sets large enough to extract the small-scale fading statistics. The small-scale fading follows a Rice distribution in all cases with Ricean K-factors going from 7 dB in non-line-of-sight cases to 12 dB in line-of-sight cases. This indicates that propagation in suburban areas is usually dominated by a few constant rays which are diffracted over the rooftops, with only a fraction of scattered rays that induce small-scale fading. Similar values were reported in [5]. The correlation of the small-scale fading between different frequency bands is given in Table 2, averaged over all 150 m data sets. It can be observed that the correlation of the small-scale fading between different frequency bands is very low. This can be understood intuitively: small-scale fading is due to the constructive and destructive interferences between different multipath components. Multipath components at different frequencies have very different path lengths (in terms of wavelengths), and therefore have very different constructive and destructive interferences.

5. CONCLUSION

A measurement campaign has been conducted to measure the propagation channel in the GSM-900, GSM-1800 and UMTS bands of a cellular system simultaneously, in a suburban propagation environment. The shadowing and small-scale fading parameters have been extracted, and correlation of these parameters between different frequency bands has been investigated. It is observed that the shadow fading is highly correlated between different frequency bands, while the small-scale fading is completely uncorrelated between different frequency bands. This behaviour could be explained by the physical origins of shadowing and small-scale fading. Although the measurements were limited to GSM and UMTS bands, the findings in this paper are expected to be similar within other bands, such as the 3G-LTE frequency bands.

REFERENCES

1. Mogensen, P. E., P. Eggers, C. Jensen, and J. B. Andersen, "Urban area radio propagation measurements at 955 and 1845 MHz for small and micro cells," *Proceedings of Global Telecommunications Conference (GLOBECOM'91)*, 1991
2. Guturu, P. and A. Lachtar, "A class of call-fail-safe and distribution-effective multi-band multi-carrier traffic allocation methods for 3 GB wireless systems," *IEEE Transactions on Wireless Communications*, Vol. 5, 578, 2006.
3. ICNIRP Guidelines, "Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz)," *Health Physics*, 1998.
4. Parsons, J. D., *The Mobile Radio Propagation Channel*, John Wiley & Sons, 1992
5. Schneider, C., M. Narandzic, M. Käske, G. Sommerkorn, and R. S. Thomä, "Large scale parameters for the WINNER II channel model at 2.53 GHz in urban macro cell," *Proceedings of IEEE 71st Vehicular Technology Conference (VTC)*, 2010 (Spring).