The current growth of the personal wireless communications market is pushing operators of mobile radio networks to explore capacity-increasing techniques such as the use of microcells. Whereas the base station (BS) antennas used in conventional macrocells are usually situated at high elevations, the idea of microcells is to place the BS antenna below the average height of the surrounding buildings to confine the radiated power within a small coverage area, such that the same frequency channels can be re-used at short distances without introducing an unacceptable degree of inter-user interference.

The efficient planning of microcells requires an accurate prediction of the electromagnetic field strength distribution. Various groups have been active in the development of so-called deterministic propagation models based on an accurate description of the buildings around the BS, and ray-tracing algorithms incorporating multiple reflection and diffraction [1 – 3]. Although considerably better than their statistical counterparts, these models have been found to provide an unsatisfactory prediction accuracy in some situations [5]. In particular, it was shown in [3] that deterministic models treating the buildings as being opaque at UHF frequencies can seriously underestimate the field strength behind the first buildings surrounding the BS. Since the shielding of the BS antenna from its nearby environment is essential in the microcellular concept, it is of special interest to obtain a better understanding of the propagation phenomena responsible for this discrepancy.

In the framework of a collaboration between EUT, KPN Research and Swisscom, an extensive measurement campaign was carried out in several urban microcell environments in Switzerland. In this Letter, we present the results of a high-resolution angle-of-arrival (AOA) measurement conducted behind a large building obstructing the line-of-sight to the BS antenna.

Experimental arrangement: The measurements reported in this Letter were conducted using a wideband radio channel sounding system previously described in [4]. In summary, a 50MHz pseudo-noise (PN) sequence is used as the sounding signal which modulates a 2000MHz carrier, and estimation of the complex impulse response (CIR) of the radio channel is performed at the mobile receiver through correlation of the demodulated received signal with a replica PN sequence. The resulting time delay resolution is equal to the chip period $T_c$ of the applied PN sequence, which is 20ns.

Transmission was from a 3dB BS antenna (5m above ground level, which was well below the average roof top level of the surrounding buildings) to a mobile station (MS) equipped with a rotatable 2dB omnidirectional antenna (2.2m above ground level). Impulse responses were measured along a horizontal circle with radius $r = 30cm$, thus effecting a synthetic uniform circular array (UCA) consisting of $M = 106$ elements.
For each propagation delay instant $\tau_i$ in the measured CIRs, the complex signals at the output of the $n$th array element (with azimuth $\gamma_n$) can be expressed as

$$y_n(\tau_i) = \sum_{n=1}^N s_n(\tau_i) e^{j2\pi \cos(\gamma_n - \theta_m)} + \eta_n(\tau_i)$$  \hspace{1cm} (1)$$

where the summation is over the $N$ multipath contributions to the considered delay bin, $s_n$ and $\eta_n$ are the complex amplitude and azimuth angle of the $n$th wave, $\mu_n = 2\pi \cos(\theta_m) \lambda$ includes the elevation angle $\theta$ (is the wavelength), and $\eta_n$ is an additive noise signal. Based on the estimated covariance matrix of the vector $[y_1(\tau_i), y_2(\tau_i), \ldots, y_N(\tau_i)]^T$ and an estimate of $N$, the UCA-MUSIC algorithm [4] provides high-resolution estimates of the AOA's, both in azimuth and elevation.

Fig. 1: Plan of urban microcell environment
Crosses indicate BS and MS locations

Fig. 2: Measured and predicted field strength along Rodtmatt Street
--- measured
--- predicted [3]

Fig. 3: Average measured power delay profile

Results: The measurement results shown here were obtained in an urban microcell environment in Bern, Switzerland (Fig. 1), which is characterised by 3 to 4 storey concrete buildings, scattered vegetation and moderate traffic density. Fig. 2 shows the measured field strength along the trajectory shown in Fig. 1, together with the field strength predicted by the ray-tracing model described in [3], which takes into account all combinations of multiple specular reflection and single diffraction. It is seen that the field strength behind building BR3 is considerably and consistently underestimated by the prediction model.

The average power delay profile measured at the MS location indicated in Fig. 1, which is shown in Fig. 3, is dominated by two peaks, which were determined to be 28 and 35dB below the freespace level. Fig. 4 shows the temporal and angular multipath distribution at the same location, and a panorama photograph taken from the receiver perspective. From this Figure it is clear that the propagation in the considered configuration is dominated by a series of strong contributions arriving from the direction of building BR3. The corresponding values of $\mu_n$ show that these waves are not the result of over-rooftop propagation (for which the elevation angle $\theta$ should be greater than 25°, or $\mu_n < 11.4$), but of transmission through BR3. The small angular spread of these multipath waves is probably the result of multiple scattering taking place inside the building. The weaker waves arriving from around $\varphi = 200^\circ$ are reflected from building BR5, which is on the other side of the MS.

The second peak of the measured delay profile displayed in Fig. 3 appears as a second cluster of points in Fig. 4. The time delay difference between both clusters suggests that the second contribution is due to reflection from building BB3 (with reflection coefficient -7dB) and subsequent transmission through BR3.

Fig. 4: Temporal and angular multipath distribution
Marker size indicates multipath wave amplitude relative to total power (down to -30dB); elevation angles are represented through $\mu_n = 2\pi \cos(\theta_m) \lambda$; BS antenna position is indicated by dashed vertical line

Conclusions: The presented result shows that propagation through buildings surrounding the BS antenna can be the dominant propagation mechanism in urban microcells at UHF frequencies. This mechanism is commonly not taken into account by propagation prediction models used for the planning of microcells. The associated loss over freespace loss is <30dB in the situation considered in this Letter. Disregarding such a small shielding of the BS antenna in the planning stage of urban microcells may lead to unacceptable levels of inter-user interference.

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References
Characterisation of rhenium Schottky contacts on n-type Al$_{x}$Ga$_{1-x}$N

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The electrical characteristics of Re Schottky contacts on Al$_{x}$Ga$_{1-x}$N ($x = 0.15, 0.22$ and 0.26) grown by MOCVD on sapphire substrates have been investigated. The effective barrier heights were obtained from current-voltage and capacitance-voltage measurements and were found to increase with aluminium concentration.

The study of Schottky barrier contacts on Al$_{x}$Ga$_{1-x}$N is of great importance for the fabrication of high power and high temperature heterostructure field effect transistors (HFETs). To make gate contacts for such devices, metals are needed which form high barrier heights and are metallurgically stable. Significant work has been done in characterising the Schottky barrier heights of a variety of metals (i.e. Ni, Au) to n-type GaN [1]. However, the majority of these metals are not stable under high temperature operation. Refractory metals or metal silicides are more desirable for high temperature applications [2]. Rhenium has been predicted to form thermodynamically stable contacts on GaN [3]. Rhenium is more promising than tungsten because of its higher metal work function and its demonstrated ability to withstand annealing temperatures up to 700°C for 10 minutes without performance degradation [4]. To date, no Schottky characteristics have been reported for Re on AlGaN. Such a study is necessary for exploring the possibility of using rhenium as the gate contact metal in Al$_{x}$Ga$_{1-x}$N HFETs. In this Letter, we report for the first time the Schottky characteristics of rhenium on Al$_{x}$Ga$_{1-x}$N ($x = 0.15, 0.22$ and 0.26).