Results of Extensive 800 Mb/s, 30 GHz Channel Sounding Experiments

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Abstract

We have recorded more than 1000 channel CIRs (complex impulse responses) at ~30 GHz with temporal resolutions down to 1.25 ns and distances up to 3.8 km. Scenarios include 11 straight streets with different traffic loads, distances and building environments, some NLOS (non-line-of-sight) scenarios, residential areas fed from base stations with 25 m and 45 m antenna heights, and 3 squares. We have investigated the influences of polarization, antenna mounting position, traffic and antenna gain on fading and delay spread. Our results suggest that ATM transmission over distances of more than 200 m should be possible.

Introduction

„Radio in the Local Loop" based on ATM transmission in the lower mm wave region is expected to cut subscriber access cost. While appropriate electronics is clearly feasible this potentially widespread, economically important service critically depends on the prevalence of acceptable channel properties.

A few broadband channels have been characterized [1–7]. Doppler spectra have been recorded at lower frequencies and quasi-statically for an indoor channel [8, 9]. Recently, a first indoor Doppler measurement has been reported for 60 GHz channels [10]. However, to our knowledge, no broadband outdoor measurements have been reported at frequencies above a few GHz that included Doppler effects (except for our early results [11]) or had a temporal resolution below 2 ns [3].

We have recently measured a number of CIRs and Doppler spectra of broadband channels in Paderborn [11–13], but available radio permission limited the data rates to ≤200 Mb/s. Here we present for the first time results obtained with 800 Mb/s and a thereby greatly improved temporal resolution of 1.25 ns. Furthermore our data base has been substantially enlarged, including typical downtown scenarios measured in Munich.

Channel Sounder

We have chosen a concept that differs from the classical sliding correlator [4, 5]. Identical clock frequencies for RX and TX in combination with freely programmable pattern generators, an endless clock phase shifter and a number of correlators (presently 4×2) yield a high measurement speed, up to 5000 impulse responses per second. A more detailed hardware description including a block diagram can be found in [11–13].

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Measurement results

We have recorded a total of more than 1000 CIRs at various locations of different types:

- 11 straight streets bordered by buildings in different densities, with variable traffic conditions and distances ranging from 120 m to 3.8 km
- residential areas fed from base stations with 25 m or 45 m antenna heights
- 3 city squares
- several NLOS scenarios

Doppler effects

If reflectors such as cars in a multipath environment are moving, secondary paths are affected by Doppler shifts. We have therefore conducted Doppler measurements in Paderborn. Delays (up to 200 ns) and Doppler shifts (up to ±25 kHz, alias-free up to ±2.5 kHz) of secondary paths are determined simultaneously [11]. Less than 25% of all measurements showed any Doppler-affected paths above a -65 dB threshold. Since traffic load and building density and height were limited in Paderborn we also investigated propagation in a typical canyon-like street in Munich with heavy traffic on 4 lanes and 4-6 story buildings with very few spaces. We recorded a total of 50 CIRs in that street, using two different RX antennas (13 dBi, 26 CIRs; 25 dBi, 24 CIRs). Results were similar to those in Paderborn [11]. A figure showing a typical time-resolved Doppler spectrum will be presented at the Symposium.

Fading

Fading caused by superposition of time-variant paths with relative delays shorter than one bit duration has been measured along five streets. Here only the main peak of the CIR (essentially the LOS amplitude) was measured because it is more meaningful than the total received power. Polarization influence was investigated in three streets [13]. Different RX antennas were compared directly in two streets in Munich. In all cases the LOS-amplitude distribution yielded a good Rice fit (unless the LOS was temporarily obstructed). Polarization had a significant influence on fading, but for different channels different polarizations proved to be best. Different antennas (13 dBi or 25 dBi) did affect mean power, relative fading depth, and fading time percentage. A table and figures with statistical data on fading will be presented at the Symposium.

Impulse responses

Some 100 and 200 Mb/s CIRs have been presented in [11–13] but these were mostly performed in special scenarios that are not typical for „Radio in the local loop". All our new measurements performed at 800 Mb/s in typical scenarios such as the city of Munich show a number of secondary paths whose delays may sometimes exceed 100 ns and whose amplitudes may sometimes be of the same order of magnitude as the shortest path. Fig. 1 shows exemplary 800 Mb/s CIRs.

For CIR a) the measured channel consisted of attenuators and a short coaxial cable. If desired, this measurement could serve for calibration purposes.

CIR b) has been measured on a 100 m × 50 m square surrounded by 3-story houses. As expected, such a hostile scenario exhibits severe multipath propagation. In this example the rms delay spread (rds) was 72 ns.

CIRs c) and d) were obtained in NLOS scenarios with a 25 dBi horn at the RX. Transmission distances were 300 m and 150 m for c) and d), respectively. In plot c) received signals underwent multiple reflections. It can be seen that these NLOS CIRs are not usable with reasonable equalizers, but in three other NLOS scenarios we found better-behaved channels [12].

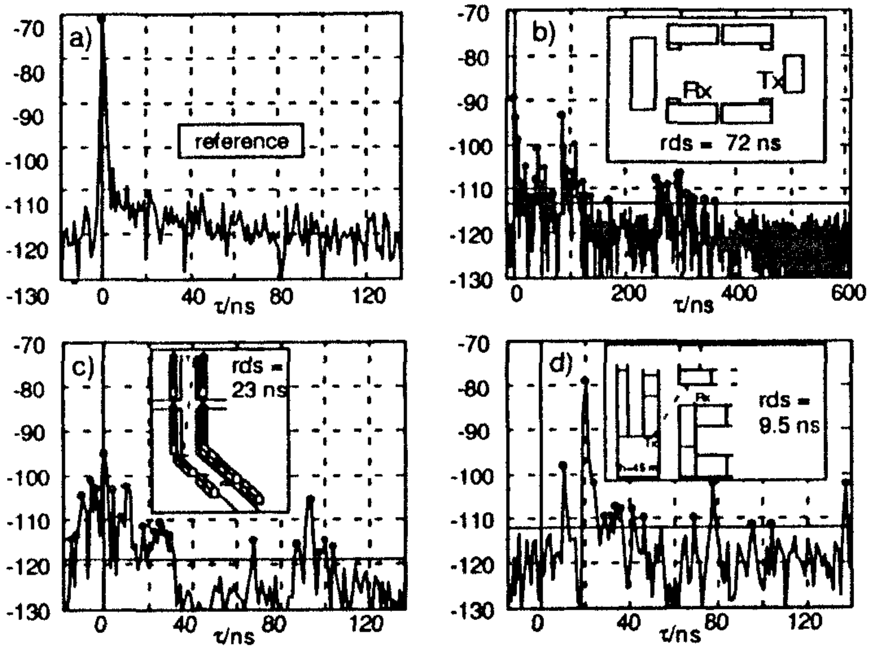

Fig. 1: Exemplary 800 Mb/s CIRs

Conclusions

We have measured more than 1000 time-variant outdoor channel CIRs at ~30 GHz with temporal resolutions down to 1.25 ns at sixteen locations, with distances up to 3.8 km. In contrast to our 100 and 200 Mb/s measurements [11–13] that were performed in special scenarios all our new measurements performed in typical scenarios at 800 Mb/s show a number of secondary paths that would also be of importance at lower data rates. Nevertheless, with Doppler effects, fading, and postcursors in impulse responses considered, we believe ATM transmission should be possible over distances of more than 200 m in scenarios typical for „Radio in the local loop". We even found some NLOS scenarios with acceptable CIRs and received powers only a few dB lower than for free space propagation. Further research needs to be done on transmission format and a sufficiently powerful channel equalizer.

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