High-resolution channel impulse response measurements for "Radio in the Local Loop"

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Abstract: *"Radio in the Local Loop" for ATM transmission is expected to become economically important if transmission channels prove to be sufficiently well behaved. Using a PRBS channel sounder we have measured channel impulse responses at 29.940 GHz with a 5 ns temporal resolution for distances up to 3.8 km. Results obtained so far suggest "Radio in the Local Loop" should support ATM transmission.*

Motivation

"Radio in the Local Loop" is eagerly expected because it will enable new operators to compete against subscriber line owners in deregulated telecommunication markets, and generally will slash last km, inner city, and subscriber premises cabling cost. Bandwidth for 155.52 Mb/s ATM transmission or higher is available only above 20 GHz. On the other hand it is desirable to operate below 40 GHz for minimum path attenuation and remote terminal equipment cost. While appropriate electronics is clearly feasible this potentially widespread, economically important service critically depends on the prevalence of acceptable channel properties.

Cost per subscriber is influenced by a number of issues: Movements of cars make impulse responses time-variant and may mandate adaptive equalizers. If pronounced zeros appear in the channel frequency response OFDM rather than simple TDM must be adopted. The longer the permitted transmission distances are, the higher is the central office sharing factor. If non-line-of-sight paths are acceptable the receiver antenna mounting expenses may drop considerably for many customers.

A few broadband channels have been assessed [1]-[4]. Doppler spectra have been investigated both at lower frequencies and quasi-statically for an indoor channel [3]-[5]. However, there are no conclusive results concerning above-mentioned issues. We have recently measured initial impulse responses and Doppler spectra of broadband channels [6]. Here we report on the benign nature of some channels that might have been considered unsuitable beforehand, making use of increased temporal resolution in our channel sounder.

Channel sounder

Correlation of pseudo-random (PRBS) or similar bit sequences is routinely used for channel sounding [3]-[7]. In contrast, signal sampling and subsequent correlation via FFT is practical only at moderate data rates and updating rates [3], [4], [8].

We have realized an 800 Mb/s PRBS channel sounder [6] using a correlation technique that differs from the classical "sliding correlator" concept and allows for high data rate and high updating rate, e.g., 100 Mb/s and 205 μ s, respectively. Measured impulse response appears convolved with the triangular autocorrelation function of the PRBS.

Experimental data rates are presently limited to 200 Mb/s by available radio transmission permissions. Technical data for two operation modes of the channel sounder are given in Table 1. ‘Doppler mode’ is chosen if a fast updating rate is desired for alias-free detection of $\leq$ 2.5 kHz Doppler shifts [6]. ‘High-resolution mode’ mode with 1.25 ns impulse response sampling time allows to view details, and has been used to obtain the following results. In both modes correlation of one sampling point takes ~ 20 μ s which corresponds to a detected, though aliased, Doppler bandwidth of ~ 25 kHz.

Measurements

We have investigated two scenarios:

A: 6 different streets that are more or less straight to enable line-of-sight (LOS) condition, except for three measurements. Distance varied from 120 m to 3.8 km in rural, residential and business areas. Remarkably, postcursors were quite weak, even for the longest distance (Fig. 1a). For a 230 m long non-LOS path in a curved street lined with buildings we have measured good transmission (only 3 dB weaker than in free space) and again only moderate postcursors (Fig. 1b). Two further non-LOS scenarios yielded similar measurement results.

B: Transmitter antenna was mounted at a wall of a building in a height of ~ 25 m. Receiver was placed at different locations within surrounding residential area. LOS path was not obstructed, but there were buildings beneath the LOS. Distances varied from 400 to 650 m. Postcursors were found to be insignificant (Fig. 1c).

In Figs. 1a and 1c the delay spread is ≤ 1.25 ns; otherwise the triangular PRBS autocorrelation function would appear broadened in the measured impulse responses. In Fig. 1b some broadening is visible, and this is believed to be due to the channel topology which permitted several non-LOS paths.

Destructive interference of multiple paths as well as partial obstruction of the first Fresnel ellipsoid cause fading. In Fig. 1a the impulse responses suffer from fading during the 655 ms recording time, probably due to moving cars which act as reflectors in secondary paths. At 3 locations along this street, average received power and error bars ($\pm\sigma$) have been extracted from 10 measurements that were taken every 50 s (Fig. 2). Calculated propagation loss in free space is also shown for comparison.

Doppler frequency shifts are rare and do not contribute significantly to the total received power. In more than 100 impulse responses taken at 4 different places, the strongest Doppler path was ~ 40 dB weaker than the LOS path. 75 % of all measurements did not show any Doppler components above -65 dB.

Conclusions

We have measured time-variant outdoor channel impulse responses at 29.940 GHz with a temporal resolution of 5 ns for distances up to 3,8 km. Delay spread does not seem to increase with increasing distance, but path attenuation may be higher than in free space. Doppler effects were negligible in the scenarios investigated so far. These results suggest "Radio in the Local Loop" should support ATM transmission up to substantial distances, and in some cases not even a LOS connection may be needed. However, further measurements and subsequent simulations are required to assess feasibility more clearly.

Acknowledgements

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References

[1] LØVNES, G., REIS, J.J., RÆKKEN, R.H.: ‘Channel Sounding Measurements at 59 GHz in City Streets’, Wireless Networks – Catching the Mobile Future – 5th IEEE International Symposium on Personal, Indoor and Mobile Communications (PIMRC ´94), and ICCC Regional Meeting on Wireless Computer Networks (WCN), 1994, pp. 496-500

[2] VIOLETTE, E.J., ESPELAND, R.H., DeBOLT, R.O., SCHWERING, F.: ‘Millimeter Wave Propagation at Street Level in an Urban Environment’, IEEE Transactions on Geoscience and Remote Sensing, 1988, 26, (3), pp. 368-380

[3] MOHAMED, S.A., LØVNES, G., ANTONSEN, E., RÆKKEN, R.H., NIGEON, B., REIS, J.J.: ‘Mobile Broadband Systems’, CEC Deliverable R2067/BTL/2.2.2/DS/P/035.a1 , RACE project R2067 - MBS

[4] KADEL, G., CZYLWIK, A., DROSTE, H.: ‘Kanal- und Systemaspekte für mobile Breitband-Funksysteme’, ITG-Fachbericht 141, "Auf dem Weg zur modernen Informationsinfrastruktur", 18.-19. Feb. 1997, Stuttgart, Germany, pp. 229-234

[5] HERMANN, S., MARTIN, U., RENG, R. SCHUESSLER, H.W., SCHWARZ, K.: ’High Resolution Channel Measurement for Mobile Radio’, Signal Processing V: Theory and Applications, (Torres, L., Masgrau, E., Lagunas, M.A. (eds.), Elsevier Science Publishers B.V., 1990), pp.1903-1906

[6] KARTHAUS, U., NOÉ, R., ´High resolution Channel impulse response measurements for radio in the local loop’, MMMCOM , Dresden, May 12-13, 1997, pp. 84-88

[7] WALES, S.W., RICHARD, D.C.: ‘Wideband Propagation Measurements of Short Range Millimetric Radio Channels’, Electronics & Communication Engineering Journal, 1993, 5, (4), pp. 249-254

[8] FELHAUER, T., BAIER, P.W., KÖNIG, W., MOHR, W.: ‘Ein optimiertes System zur breitbandigen Vermessung des Mobilfunkkanals’, Kleinheubacher Berichte, U.R.S.I. and ITG meeting, Telekom, 1992, 36, pp. 411-422

Table 1: Technical data of channel sounding experiments

	Doppler mode [6]	High-resolution mode
Bit rate; τ -resolution	100 Mb/s; 10 ns	200 Mb/s; 5 ns
τ -sampling period	10 ns	1.25 ns
PRBS length	1023	2047
Detectable, though aliased, Doppler bandwidth	~ 25 kHz	
Modulation	2-PSK	
TX frequency	29.940 GHz	
TX power	20 dBm	
TX antenna	sector horn, 12 dB gain, mounting height 3 ... 20 m	
transmission distances	120 m ... 3.8 km	
RX antenna	horn, 25 dB gain, mounting height 2.7 ... 5 m	
RX noise figure	8 ... 9 dB	
IF	2.4 GHz	
Correlators	4 each for I & Q	1 each for I & Q
Impulse response length investigated (τ)	200 ns	112.5 ns
Updating period (t), alias-free Doppler bandwidth	204.8 us 2.5 kHz	5.12 ms 200 Hz
Number of sampling points (t)	512	90
Measurement time (t)	105 ms	655 ms

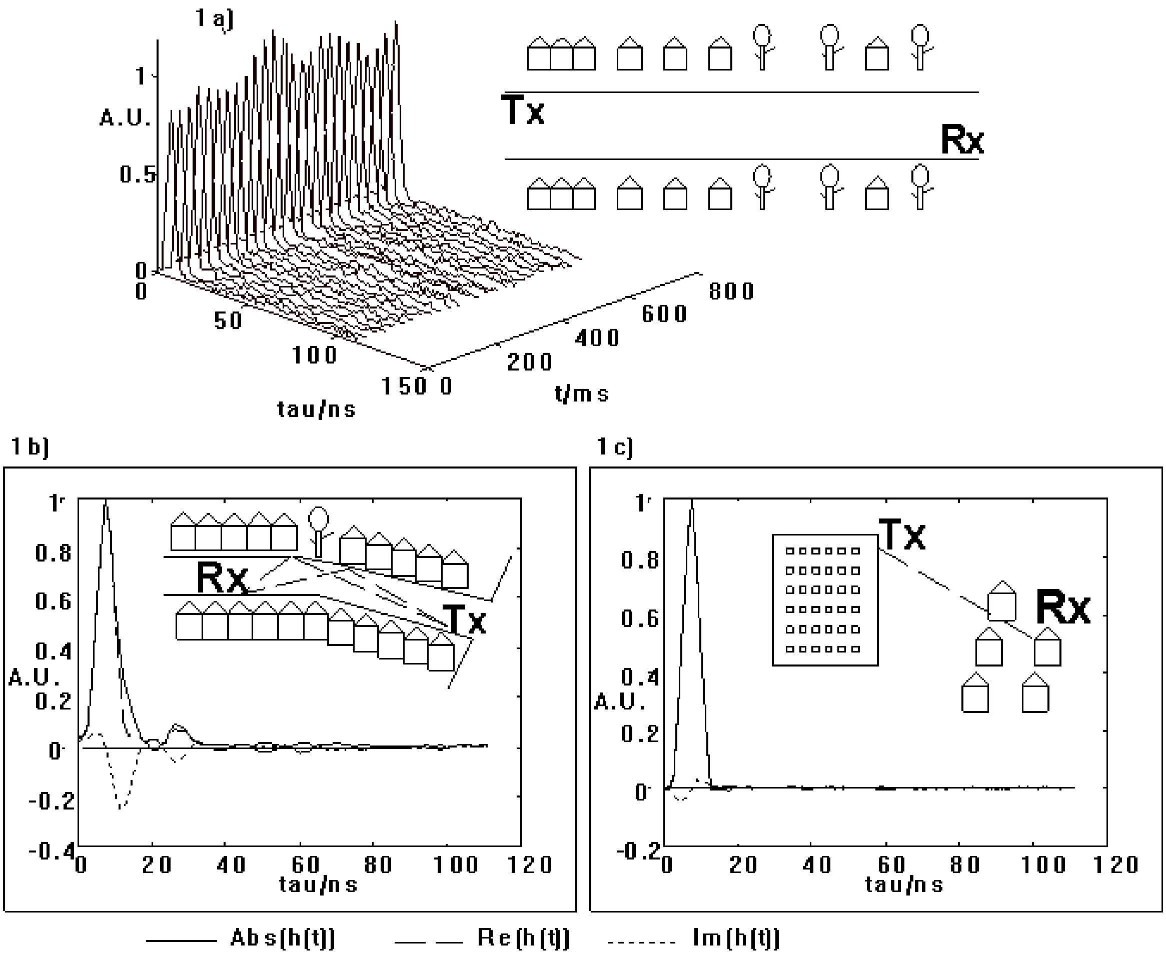

Fig. 1: Impulse responses h(τ ,t) (τ = delay (timescale of ns), t = observation time (timescale 20 μ s ... 1 s))
a) scenario A; straight street, total distance 3.8 km, 1 km buildings close to each other, 1 km some buildings, 1.8 km only a few buildings and trees
b) scenario A; slightly curved street, non-LOS, distance 230 m
c) scenario B; distance 650 m

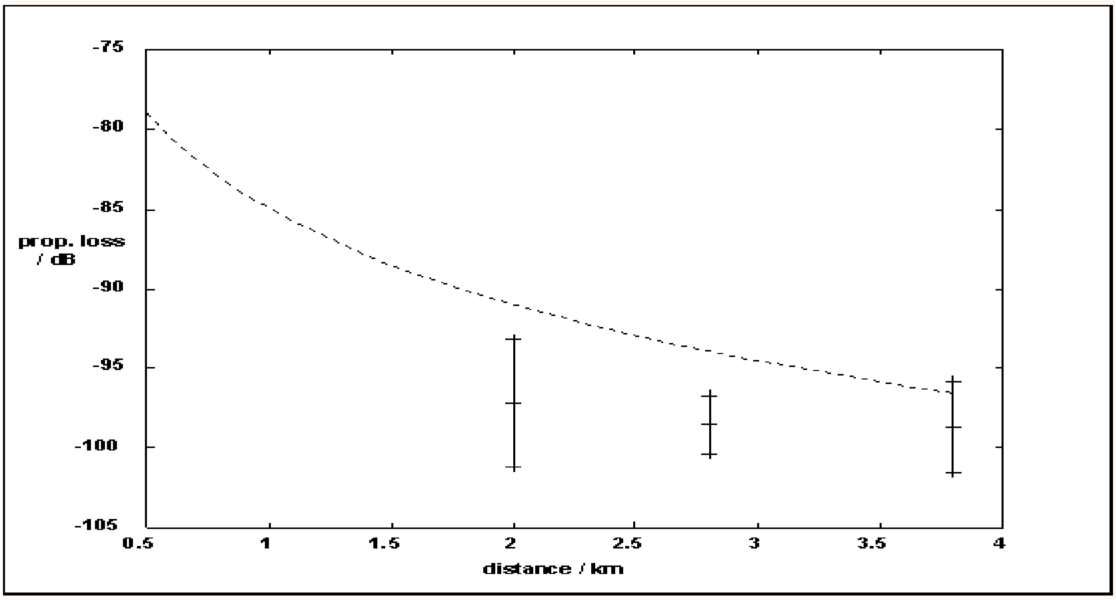

Fig. 2: scenario A; received power versus distance compared to calculated LOS path loss