WIDEBAND PROPAGATION MEASUREMENTS AT 900 MHz AND 1.7 GHz IN MACROCELLS

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ABSTRACT. Multipath measurements at 953 and 1718 MHz have been performed in macrocells in urban and rural terrain, using a frequency sweep technique and correlation in the receiver. Statistical distributions of instantaneous mean delay, delay spread, delay window and delay interval have been calculated. No significant difference between the two frequencies was observed, even though there sometimes seemed to be slightly worse multipath conditions at 1718 MHz. When line of sight, intersymbol interference caused by multipath generally represents no problem in macrocells. When no line of sight, multipath profiles of length more than 100 µs were observed.

I. INTRODUCTION

Norwegian Telecom Research has performed impulse response measurements at 953 and 1718 MHz in different macrocell environments in Norway.

The measurements were part of narrow- and wideband propagation measurements carried out within the European RACE-programme.

An earlier paper [3] presented the results obtained during measurements in 1990. In this paper a summary of results from measurements carried out in 1990 and 1991 is presented.

II. THE CHANNEL SOUNDER

The channel sounder is described in [3]. A brief description will be given in the following.

A frequency sweep technique was used, because it was then possible to achieve a sufficient coverage area to measure impulse responses in large cells by use of moderate output power. In addition this method is resistant against interference from other services.

Table 1 shows how the parameters of the channel sounder varied depending on the sweep length:

Sweep length, µs	128	64	32	16
Sweep BW, MHz	1.0	2.0	4.0	8.0
IR length, µs	100	50	25	12.5
IR resolution, µs	1	0.5	0.25	0.125

Table 1. Channel sounder parameters

When it was possible, existing base station sites for the analogue NMT-system were used as transmitter sites. TX power was 25 W for both carrier frequencies. Vertically polarized omnidirectional and directional transmitting antennas with 5 - 15 dBi gain were used.

The receiver was placed in a van with antenna height 2 m. The RX antennas had approximately 5 dBi gain.

We performed instantaneous impulse response (IR) measurements, and assumed the channel to be constant if the receiver moved less than $\lambda/12$ during recording of one impulse response. 15 impulse responses were estimated every second.

Instantaneous and total dynamic range of the receiver was more than 30 and 80 dB respectively.

III. PROCESSING OF MEASUREMENT DATA

Sampled impulse responses were stored on the disk of a PC, and channel statistics were calculated afterwards.

Every sample in an IR below a certain limit (Noise Spurious Threshold - NST) was skipped from the calculations to avoid false channel statistics calculations due to noise. When receiving weak signals, complete IRs were rejected from channel statistics calculations.

The theoretical noise threshold for this channel sounder equals -133 dBm for a receiver bandwidth (BW) of 0.5 MHz (assuming noise temperature 300 K and receiver noise factor 4 dB), and is increased by 3 dB each time the BW is doubled. Averaging of up to 31 received sweeps before channel estimation improves this figure by up to 15 dB. Adding a safety margin of 15 dB to these theoretical values, one false measurement per hour might be accepted.

Cumulative distributions have been calculated for instantaneous values of the following parameters [1,2]:
- Mean delay: The first order moment of the IR; the power-weighted average of excess delays
- Delay spread: The second order moment of the IR; the power-weighted standard deviation of the excess delay
- Delay interval: The interval from first time the power of the impulse response exceeds a given threshold to the last time it falls below this threshold, which here

was 3 or 6 dB below peak

- Delay window: Length of middle portion of the IR containing 50 and 90% of the total energy found in that impulse response.

IV. RESULTS

Our main interest was to explore propagation conditions in macrocells, and we have conducted measurements in different landscape types: Forest/farmland, valley, mountain, fjord, coast, suburban and urban. In this paper a small extract of the results will be presented. Further results are presented in [4].

In table 2 parameter values for both 953 and 1718 MHz are presented. For each measurement we tabulate values for median and 90% quantile of mean delay (MD), delay spread (DS), 3 and 6 dB down delay interval (3DI, 6DI) and 50 and 90% delay window (50DW and 90DW). We also present some cumulative distributions of delay spread.

IV.1 Measurements in rural farmland and forest

Measurements were conducted in different rural areas with varying degree of open farmland and forest.

Frm_1A: An open rural area with gently sloped farmland. Scattered residential houses and trees along the measurement route. Antenna height 8 m above ground level. The distance between TX and RX varied between 0.6 and 5 km. The direct line of sight (LOS) path was often obstructed by the smoothly rolling terrain. During non LOS (NLOS) conditions, the longest IRs were found closest to the transmitter. The parameter values were slightly larger at 1718 than at 953 MHz.

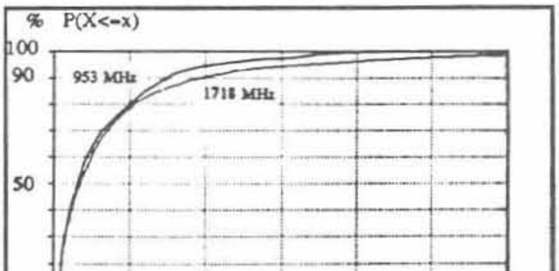

Figure 1. Cumulative distribution of delay spread, measurement Frm_1A

Frm_5: The transmitter placed in an open, rural environment with farmland and some wooded areas. The antenna was placed 8 m above ground level. The distance to the measurement route was 0.3 - 7 km. The forest and small, smooth hills caused a NLOS situation along the route. No significant difference between 953 and 1718 MHz was observed.

In general, for all measurements performed in farmland and forests, typical lengths of IRs under NLOS conditions were 10 µs, sometimes increasing to 20 - 40 µs.

IV.2 Measurements in valleys

Measurements were performed in several valleys.

Val_2: A rural area in a smooth "U"-shaped valley, 3 km wide with 350 m high wooded hillsides and a 2 km wide lake in the middle. The TX was placed in the hillside 230 m above the measurement route. The route followed the lake at a distance 1.3 - 12 km from the TX. The direct LOS path was generally obstructed by the hillside. The length of the IRs were 20 - 40 µs, even right below the transmitter. The larger parameter values at 953 MHz are probably due to the larger number of rejected impulse responses at 1718 MHz.

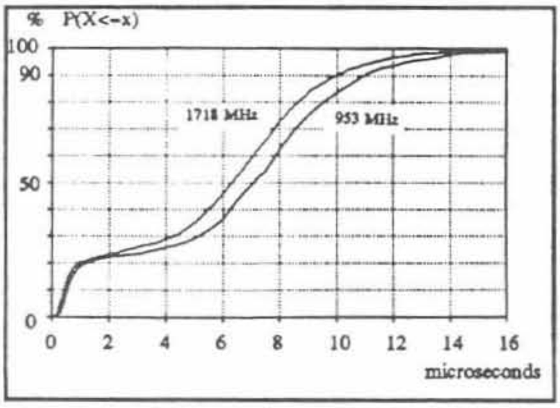

Figure 2. Cumulative distribution of delay spread, measurement Val_2

Val_4: A rural area in a quite steep valley, 0.3 - 1 km wide with 700 m high mountain chains surrounding it. Some forest in the more gentle hillsides. The TX was placed in the bottom of the valley at road level with an 8 m high omnidirectional antenna. The measurement route followed the valley at a distance of 0.7 - 10 km from the TX. Half way down the route the valley made a 60° turn, giving a NLOS condition further down the route. The upper part of the route had partly NLOS conditions due to obstacles close to the road. In general we found the longest IRs in the NLOS area closest to the transmitter, and as we drove away from the transmitter, the IRs became shorter. We observed slightly longer IRs at 1718 than at 953 MHz.

We also performed measurements in a 0.7 - 1.5 km wide canyon-like valley where naked mountain sides gave good reflection conditions. This was a "worst case environment", and parameters were two to four times as large as the parameters from measurement Val_4.

IV.3 Measurements in coastal districts

Measurements were conducted in a coastal district with scattered islands.

Cst_1A: The TX was placed on top of a 270 m high mountain. Most of the islands in the area had 200 - 300 m high hills or mountains. The measurement route was on the same island as the transmitter, but almost at sea level. The distance to the TX was 0.7 - 2 km. Due to shadowing from the mountain ridge, many parts of the route had NLOS conditions. The distance to the neighbouring islands was 2 - 5 km. Parameters were slightly larger at 953 MHz.

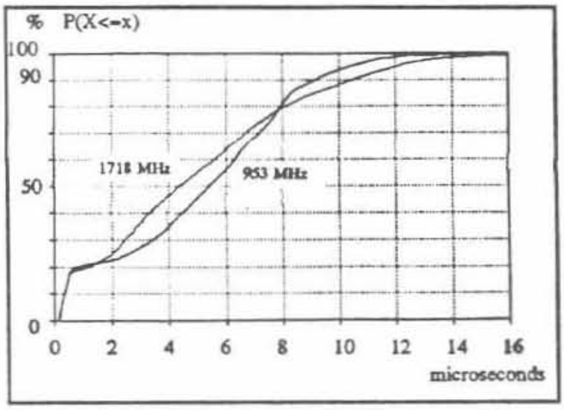

Figure 3. Cumulative distribution of delay spread, measurement Cst_1A.

We also made measurements along a route on the other side of the island, using the same TX site. This route had only NLOS conditions due to the mountain ridge. Along this route the delay spread was more than twice that of route Cst_1A, and the multipath situation was slightly worse at 1718 MHz. Parameter values for this route are not tabulated in this paper.

In general, using this TX site, no significant difference between 953 and 1718 MHz was observed.

IV.4 Measurements in urban areas

Measurements were performed in two cities.

Urb_1: Urban environment with typically 4-7 storey buildings, mainly made of concrete. The antenna was placed in a small park below most roof tops, 13 m above street level. The distance between TX and RX was 0.1 - 1.3 km, mainly with NLOS conditions. The street width varied between 4 - 10 m. The street pattern was not regular. We were unable to perform measurements at 953 MHz, due to several GSM base stations transmitting in the frequency band used by our 900 MHz equipment.

Urb_2A: Urban environment with 5-6 storey buildings of concrete. Some 200 - 300 m high hills were located in the city surroundings, 1 - 2 km from the transmitter. The antenna was placed on the roof top of a 7 storey building in the middle of the city, giving partial LOS conditions to the route. The maximum distance between TX and RX was 700 m. The street width was 6 - 15 m. The 1718 MHz parameters were slightly larger than the 953 MHz parameters.

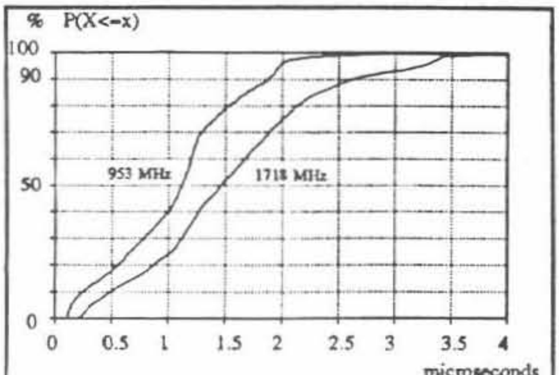

Figure 4. Cumulative distribution of delay spread, measurement Urb_2A.

Two other TX sites were also tested with the Urb_2A route. Using one TX site the resulting parameters were about the same size as the parameters in measurement Urb_1. Using the other TX site the parameters were more than twice as large as in measurement Urb_2A. With the former TX site the 953 MHz parameters seemed to be the larger, with the latter there was little difference between the two frequencies.

IV.5 General observations

Generally intersymbol interference caused by multipath propagation represents no severe problem when

Env.mt	Freq	BW	MD_{50}	MD_{90}	DS_{50}	DS_{90}	$3DI_{50}$	$3DI_{90}$	$6DI_{50}$	$6DI_{90}$	$50DW_{50}$	$50DW_{90}$	$90DW_{50}$	$90DW_{90}$
Frm_1A	953	4	0.3	1.1	0.3	1.5	0.25	0.50	0.50	1.25	0.50	1.25	1.00	4.00
Frm_1A	1718	4	0.3	1.4	0.4	1.9	0.25	0.75	0.50	1.50	0.50	1.25	1.00	4.75
Frm_5	953	2	0.8	3.1	1.0	4.3	0.5	2.0	1.0	3.0	1.0	3.0	3.0	11.5
Frm_5	1718	2	0.9	3.0	1.0	3.6	0.5	2.0	1.0	3.5	1.0	3.5	3.0	10
Val_2	953	1	8.0	15	7.0	11	2	13	5	23	7	16	23	35
Val_2	1718	1	7.6	14	6.3	10	2	12	4	20	6	14	20	32
Val_4	953	2	1.3	3.0	1.2	3.5	0.5	2.0	1.0	3.0	1.0	3.0	3.5	10.0
Val_4	1718	1	1.6	3.7	1.3	3.3	1.0	3.0	2.0	5.0	2.0	4.0	5.0	10.0
Cst_1A	953	1	8.5	19.5	5.5	9.2	2	13	4	20	4	13	15	29
Cst_1A	1718	1	5.7	15.3	4.3	10.5	2	11	4	19	4	13	13	34
Urb_1	1718	8	0.3	0.8	0.2	0.6	0.25	0.625	0.375	1.00	0.250	0.625	0.750	1.625
Urb_2A	953	4	1.1	2.4	1.1	1.9	0.5	2.75	1.25	4.25	1.25	3.25	3.50	5.75
Urb_2A	1718	2	2.2	3.8	1.5	2.7	1.0	4.0	1.5	5.5	1.5	4.0	4.5	7.0

Table 2. Statistical results for all measurements presented in this paper

there is line of sight, because the reflected signals are very much attenuated compared to the direct signal (typically 30-40 dB). However, with no line of sight, the power of the multipath components with very long excess delay can be comparable or even higher than the power of the first arriving component, and multipath profiles of length more than 100 μs have been observed.

Equal output power was used at the two frequencies, giving larger coverage area at 953 MHz due to larger effective receiver antenna area. Generally the received power was 10 dB higher at 953 MHz compared to 1718 MHz. Hence many of the IRs recorded close to the cell border at 1718 MHz were rejected from the statistics calculations due to noise, whereas the corresponding IRs recorded at 953 MHz were regarded as valid measurements. This makes it difficult to do fair comparisons between the two frequencies.

In cells where the coverage area was strictly limited by the surroundings (f. inst. a narrow valley), the reflected components were strong enough to be distinguished from the receiver noise. In such cases the multipath situation seemed to be slightly worse at 1718 MHz. This is because the semi-direct path - the diffracted ray - was of smaller magnitude at 1718 than at 953 MHz.

In more open terrain, many of the reflected components visible in the 953 MHz receiver were hidden in noise in the 1718 MHz receiver. Hence the tendency to slightly longer delay spread at 1718 MHz was not recognized in such cells.

In several measurements we found the worst multipath conditions quite close to the transmitter. Thus there is not always a negative correlation between delay spread and received power.

V. COMPARISON OF OBTAINED RESULTS WITH PREDICTED COVERAGE AREA

Measured coverage area was also compared with coverage area predicted by a network planning tool intended for analogue mobile communication systems. The planning tool takes height and land cover data from topographic data bases into account when predicting coverage.

Some times the coverage was excellent in areas where the planning tool predicted no coverage at all. This was when no direct path existed, but reflected signals perfectly well could be used for communicating.

Other times the planning tool predicted coverage in areas where large delay spread obviously would cause severe problems for digital radio communication. This occurs when there are strong reflections outside the equalizer window in the receiver. Such reflections will be regarded as co-channel interference by the receiver. Most planning tools for mobile infrastructure are basing coverage prediction only on field strength and interference level, but do not take reflections into account when they predict coverage area. This is a severe shortcoming for planning of network structure for digital mobile communication systems, and leads to unreliable coverage prediction.

VI. CONCLUSIONS

- When line of sight: Generally no problem with intersymbol interference caused by multipath in macrocells, because the direct component of the impulse response is much stronger than the reflected ones (typically 30-40 dB).

- Measurements were conducted with equal TX power at 953 and 1718 MHz, and the multipath situation was found to be equal or slightly worse at 1718 MHz.

- The Pan-European GSM-system, designed to cope with approximately 15 μs of multipath, will work satisfactory in most environments. However there are places where long delays will fall outside the equalizer-window the receiver is able to cope with, hence being regarded as co-channel interference, which may cause serious problems to the communication.

- To find the coverage area of digital mobile communication systems, multipath effects must be taken into account. And further: Carefully planning the base station sites may reduce the problems with multipath considerably, thus increasing the coverage area.

- Network planning tools developed for analogue mobile communication systems, basing coverage prediction only on field strength and interference level, do not give information about multipath effects. Hence they do not give reliable coverage prediction for digital mobile systems.

VII. REFERENCES

[1] E Gürdenli and P W Huish, "Propagation measurements and modelling for digital cellular radio systems", British Telecom Technical Journal, Vol. 8, No 1, January 1990.

[2] COST 231 TD(89)060, "A note on definitions of terms for impulse responses", Oct. 1989.

[3] R H Rækken, H Langaas, G Løvnes and S E Paulsen, "Wideband Impulse Response Measurements at 953 MHz and 1.7 GHz", Proc. of Globecom'91, pp. 1303-1307, Dec. 91.

[4] G Løvnes, S E Paulsen and R H Rækken, "UHF radio channel characteristics, part two: Wideband propagation measurements in large cells", Kjeller, Norwegian Telecom Research, March 1992.