Simple Channel Model for 60 GHz Indoor Wireless LAN Design Based on Complex Wideband Measurements

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Abstract – *Based on practical complex wideband measurements, a simple model for the 60GHz indoor wireless radio channel is presented in this paper. The multipath channel is modeled by a conventional time invariant FIR filter structure. Two sets of filter coefficients are provided for typical indoor wireless LAN application scenarios with an RF bandwidth of 200MHz and 62GHz center frequency. The scenarios represent the line of sight (LOS) and non line of sight (NLOS) case where omni-directional antennas are used for both transmit and receive side.*

The present channel model is used for system design simulations in the European wireless ATM project MEDIAN [1] and can easily be adopted for similar simulation purposes. So, a new pragmatic system design tool for the 60GHz indoor radio environment is given with this paper.

I. Introduction

Reliability of performance simulations of wireless communications systems (WCS) depends on the channel model used. One important part of transmission among filtering, amplification, and clipping effects is the radio channel (including antenna). There are two basic channel modeling approaches to evaluate the influence of the radio channel on the transmission system performance. Statistical channel models are described by distribution functions. If the environment becomes easily describable, deterministic channel models can be used. Sufficient propagation measurements are needed in both modeling cases for a proof of the selected model.

The mm-wave indoor radio channel may be described with a countable number of rays arriving at the receiver. Therefore a deterministic description and modeling of the radio channel is possible. A joint deterministic and statistic modeling yields a good trade-off between simplicity and reliability [KAT95]. It is shown that certain parameters of the indoor radio channel like amplitude and phase fit good into known statistical distribution functions, but other parameters like arrival time and correlation between different wave rays do not fit in general. They strongly depend on the specific environment. In contrast to cm-wave radio channels, the attenuation for mm-wave is very high. Thus, only direct or scattered rays within one room contribute to the channel impulse response. These can be calculated by means of ray tracing [SMU95, FAL96].

During a system and standard creation process, the specific environment of the final product is not exactly known, but certain edge parameters are estimated from operational requirements. A compromise solution for appropriate radio channel modeling at this development stage is to fit parameters of a common channel model according to the results of some measurement campaigns covering most likely application environments. The number of campaigns is a trade off between costs and correctness of the model data. In case of mm-wave indoor channel modeling interesting results can be found in [SMU95].

Environments differ in main parameters for very flexible WCS applications, thus several typical environments should be defined. For each of them a separate channel model data set has to be provided. This was done for some major WCS such as GSM or HIPERLAN, and the European ACTS project MEDIAN follows a similar approach.

With the present paper, typical wireless LAN application environments are discussed. 60GHz propagation measurements are presented and typical results are evaluated as a basis for the proposed channel model. The described generic 60GHz channel model is based on a conventional FIR-filter structure with the filter coefficients taken from typical channel measurements. While measurements with antennas at different heights (ceiling vs. table) were done within our work as well [HÜBb97, HÜBa97], only results for both Tx and Rx antenna placed in the same horizontal plane are taken for modeling here. This was also done in [BOCH96] and represents a bad case scenario with respect to multipath propagation.

The model is easy to use for quick simulations on system behavior in a 60GHz multipath environment. However, a restriction of the proposed model is the time invariance. This

[1] European Research Project AC006 MEDIAN in the framework of the ACTS program of the 4th Research program of the European Commission.

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assumes, the Tx/Rx parts of the system are not moved during operation and the environment is not changing during operation either.

Finally, a practical simulation example using the proposed channel model is presented in this paper.

II. 60GHz Channel Measurements

In an empty room at Dresden University of Technology which is illustrated in Fig. 1 measurements of mm-wave indoor radio channels were accomplished for several configurations. Two of them are presented in the following.

To measure the channel characteristics a vector network analyzer (Wiltron 360 B) with an antenna measurement system was used. Frequencies up to 67 GHz can be explored. All measurements were performed with a center frequency of 62GHz and a bandwidth of 2GHz for LOS and NLOS. Impulse responses were calculated from the measured frequency transfer functions using the inverse Fourier transformation.

For the here presented omni-omni called environment, the transmitter antenna is a biconical horn antenna (gain 6dB) and the receiving antenna is a shaped monopol (gain 4dB), respectively. Both antennas have an omni-directional antenna characteristic in horizontal plane and both were placed in a height of 1,50 m above the floor. The receiver was moved step by step from position 1 to position 3 (see configuration 1 in Fig. 1.). So 3000 impulse responses in equal distances of 1 mm were measured.

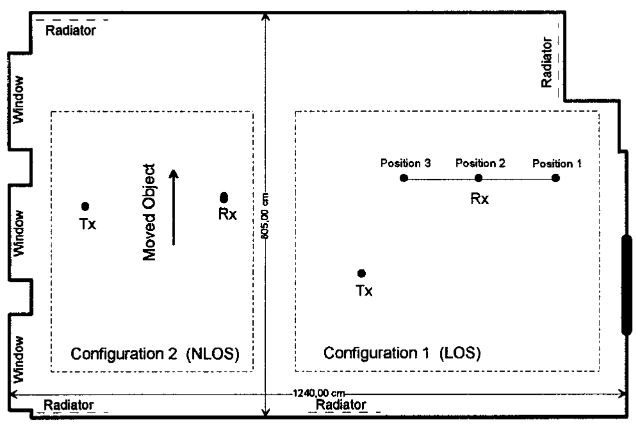


Fig. 1. Measurement environment at Dresden University of Technology facilities. All antennas are located in the same horizontal plane. Tx-antenna: biconical horn (gain 6dB), Rx-antenna: shaped monopol (gain 4dB).

In order to obtain below presented impulse responses Fig. 3 a, b and c, measurements were done at indicated positions 1, 2 and 3, respectively.

It is shown that one impulse response (IR) with selected parameters represents a typical case better than an average impulse response. Thus, it is useful to use a selected and not an average complex impulse response for simulations. Nevertheless, Fig. 2 presents the average of all 3000 calculated impulse responses.

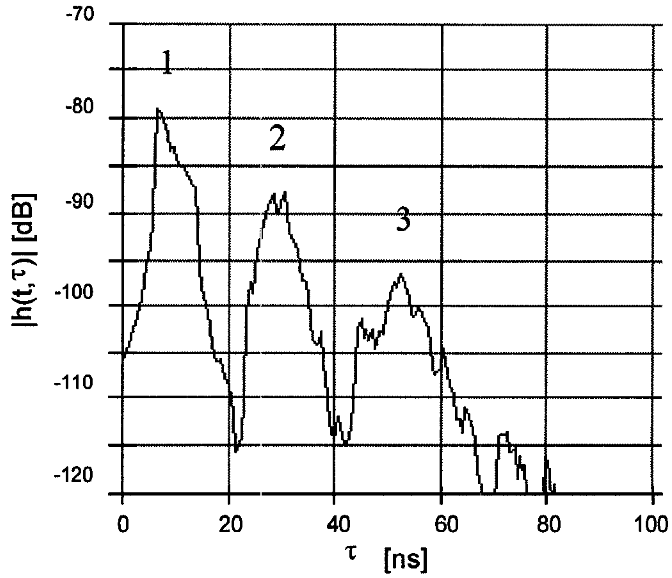


Fig. 2. Average of impulse response magnitudes. Averaging was done over 3000single impulse responses. 62GHz carrier frequency, 2GHz measurement bandwidth.

The average impulse response can be described with three clusters:

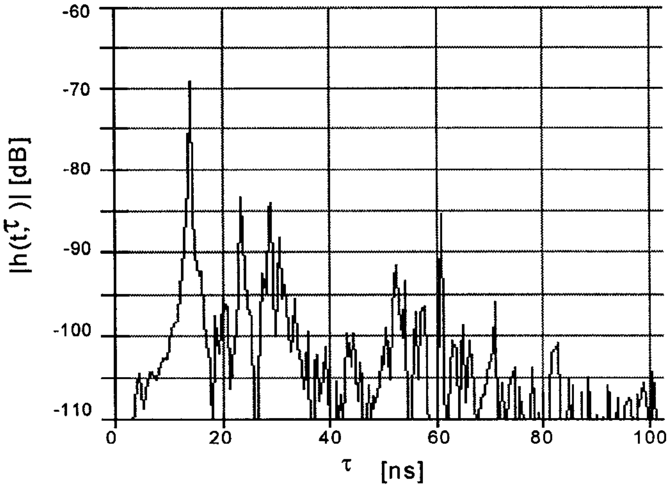
1. direct path
2. first order reflected paths from side walls
3. second order reflected paths from side walls and first order reflected path from window front.

Since the receiver is moved towards the transmitter, the arrival time of the direct path is decreased for each new measurement. So, the cluster of the direct component looks broad but is actually small for each separate impulse response. This effect occurs for each wave ray arriving at the receiver.

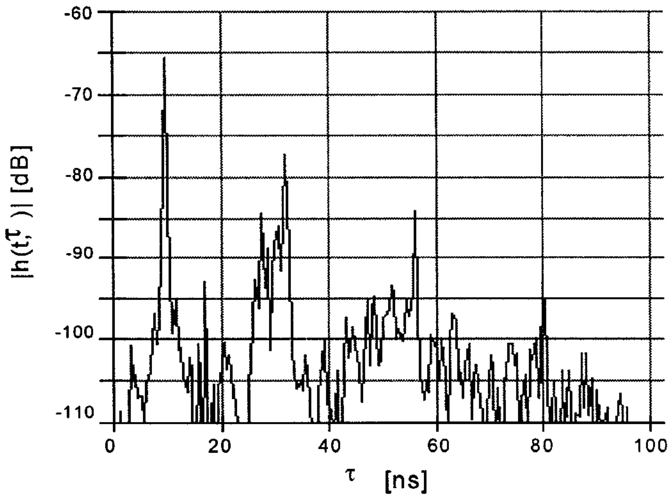
In Fig. 3 the clusters described above can be found again. Only the relative positions of the clusters with respect to each other and their power level differences are changed. These impulse responses are typical for line of sight conditions in the considered environment.

In some cases the direct component is blocked by an object, e.g. a person walking through the direct path. In this case non line of sight situations occur. The response for NLOS is shown in Fig. 4. The NLOS effect was explored by moving a human between transmitter and receiver (see Fig. 1. , configuration 2). More detailed measurement results with temporary shading of the direct path by a human at different antenna heights are shown in [HÜBb97].

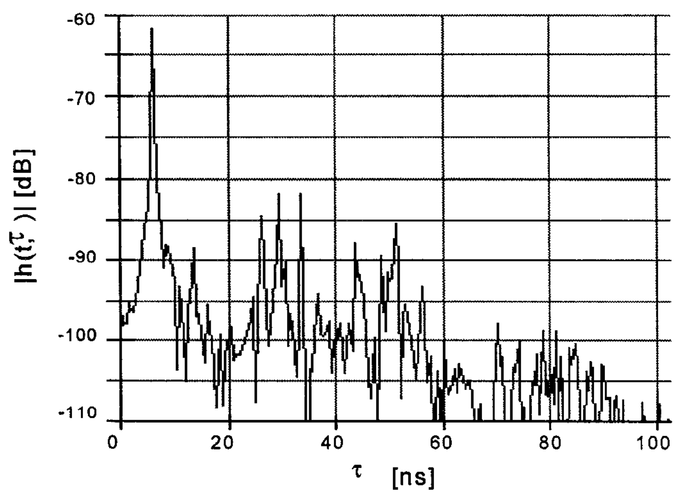
It is found, that the direct path is additionally attenuated. The exact value depends on the exact position of the disturbing object. A mean attenuation of 20dB is measured.



a) Impulse response magnitude at position 1.



b) Impulse response magnitude at position 2.



c) Impulse response magnitude at position 3.

Fig. 3. Impulse response magnitudes for Rx antenna positions 1 to 3 in measurement configuration 1. These plots are considered typical for the 60GHz wireless indoor channel with line of sight (LOS). 62GHz carrier frequency, 2GHz measurement bandwidth.

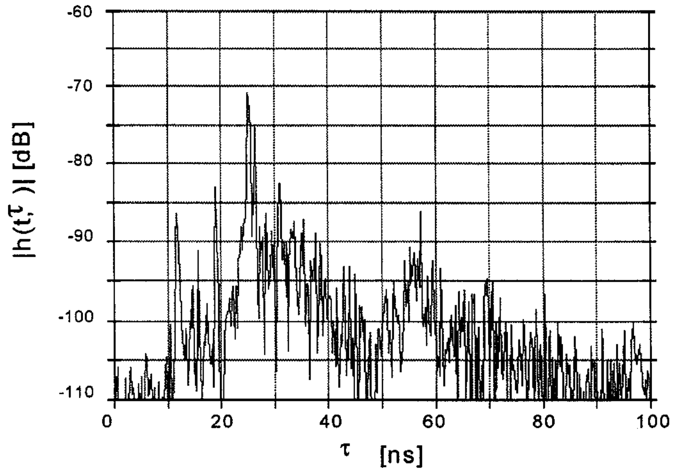


Fig. 4. Impulse response magnitude for measurement configuration 2. This plot is considered typical for the 60GHz wireless indoor channel with non line of sight (NLOS). 62GHz carrier frequency, 2GHz measurement bandwidth

III. Simplified Channel Model for Simulations

For quick simulations of multipath effects in the static 60GHz indoor radio environment, the channel was modeled by a conventional FIR-filter structure according to Fig. 5. The filter coefficients are determined based on the above measured impulse responses. In order to match bandwidth and sampling distance of the simulated systems, a resampling of the measured impulse responses is considered necessary.

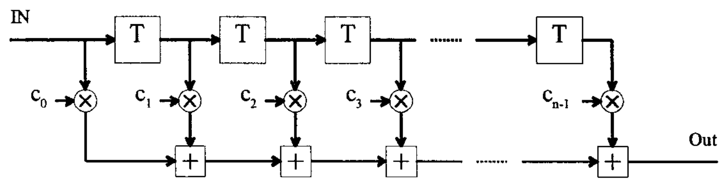


Fig. 5. Conventional FIR-filter structure as channel model. The n complex filter coefficients c_0.... c_{n-1} roughly determine the time-invariant behavior of the 60GHz multipath channel.

For LOS simulations, a selected impulse response like Fig. 3 b) for position 2 should be used (LOS condition). The noise floor can be set to -100dB. By calculation of the delay window with q=0.95 (95% of the received power is in the window, 5% outside) results don't exceed 70ns remarkably. So, arrival times exceeding 70ns relative to the direct wave ray, can be neglected.

Number of filter coefficient	relative delay time in ns	real part linear	imag part linear
0	0	0.45023402	0.86621991
1	5	0	0
2	10	0	0
3	15	-0.00118146	0.03175096
4	20	-0.11530161	-0.13648934
5	25	0	0
6	30	0	0
7	35	-0.0297353	-0.01119513
8	40	-0.01073347	0.02990505
9	45	0.10021063	0.00728164
10	50	0	0
11	55	-0.00792121	-0.01556035
12	60	0	0
13	65	0	0
14	70	0.02800481	-0.02856065

Table 1. Numerical values (filter coefficients) of the generic impulse response samples representing a typical line of sight (LOS) 62GHz indoor radio channel with 200MHz RF bandwidth and omni-directional antennas.

Number of filter coefficient	Relative delay time in ns	real part linear	imag part linear
0	0	0.194008	0.37325832
1	5	0	0
2	10	0	0
3	15	-0.00494651	0.13293465
4	20	-0.48274379	-0.57145242
5	25	0	0
6	30	0	0
7	35	-0.12449552	-0.04687168
8	40	-0.04493882	0.12520619
9	45	0.41956101	0.03048672
10	50	0	0
11	55	-0.03316445	-0.06514792
12	60	0	0
13	65	0	0
14	70	0.1172503	-0.11957749

Table 2. Numerical values (filter coefficients) of the generic impulse response samples representing a typical non line of sight (NLOS) 62GHz indoor radio channel with 200MHz RF bandwidth and omni-directional antennas.

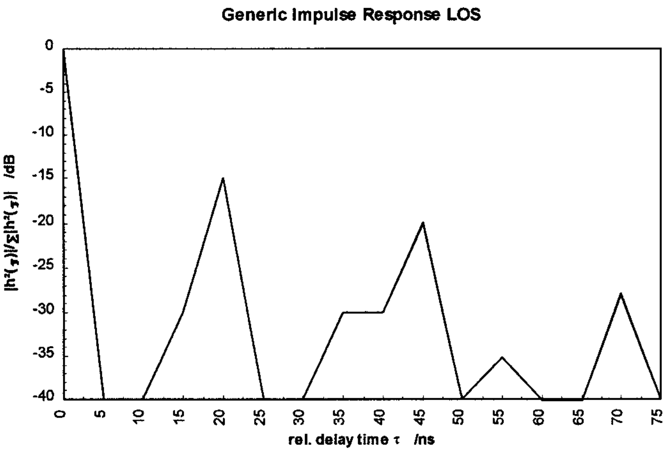


Fig. 6. Plot of the generic impulse response representing a typical line of sight (LOS) 62GHz indoor radio channel with 200MHz RF bandwidth and omni-directional antennas.

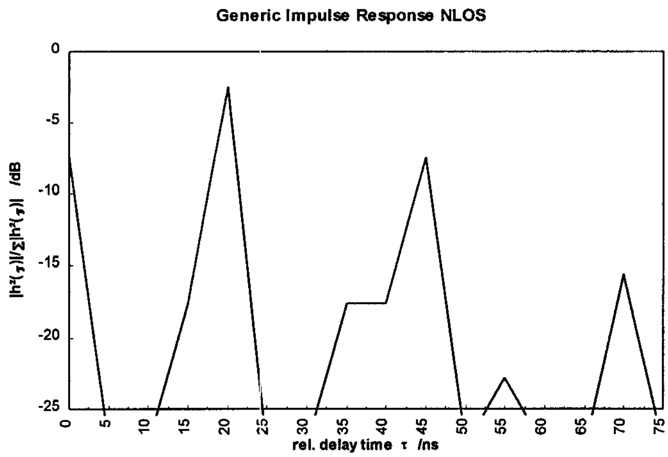


Fig. 7. Plot of the generic impulse response representing a typical non line of sight (NLOS) 62GHz indoor radio channel with 200MHz RF bandwidth and omni-directional antennas. Note that the direct path is attanuated and about 5dB below the 1st order reflected paths.

While the practical measurements were done with 2GHz bandwidth around 62GHz center frequency, a realistic system bandwidth for wireless LANs is about 200MHz or less. To get a channel impulse response with a bandwidth of 200MHz in frequency domain, only frequencies from 61.9 to 62.1GHz are used for transformation into the time domain by inverse Fourier transformation. This yields a resolution in time domain of 5 ns. The calculated impulse response is normalized, so that the arrival time of the direct path is zero and the total received power over the noise floor is 0dB. The coefficients of the FIR-filter according to Fig. 5 representing a typical LOS multipath scenario are summarized in Table 2 and plotted in Fig. 6 for 62GHz center frequency and 200MHz transmission bandwidth.

The behavior of non line of sight (NLOS) scenarios was studied and a typical impulse response is presented with Fig. 4. However, to generate an impulse response for NLOS conditions with similar channel characteristics, a typical LOS impulse response can be used by subtracting 20dB from the direct path. This is done for the NLOS case presented in Table 2. and Fig. 7., generating it from the LOS case. The received power of the IR is normalized again, so that the sum is 0dB.

The data are rescaled so, that the incoming mean power is equal to the outgoing mean power, using the whole bandwidth. If one is using just a part of the transmission bandwidth for signal transmission, e.g. not all subcarriers in a multicarrier modulated (MCM) system, the variance of the AWGN has to be adjusted for each different number of used subcarriers. In this case the outgoing power might be higher or lower than the incoming depending on the number of used subcarriers.

The described 60GHz indoor radio channel model is a complex finite impulse response (FIR) filter with specific coefficients. It can easily be used for simulations of multipath effects in system design under LOS and NLOS conditions.

IV. Simulation Example

The modeled impulse responses are used for physical layer system simulations within the MEDIAN project. Some examples of the simulation results are shown in Fig. 8. The AWGN case with ideal impulse response is shown for comparison to the NLOS and LOS case. The applied synchronization algorithm is able to stabilize the system at 3dB SNR for AWGN and LOS and 6dB for NLOS, respectively, in an uncoded transmission environment.

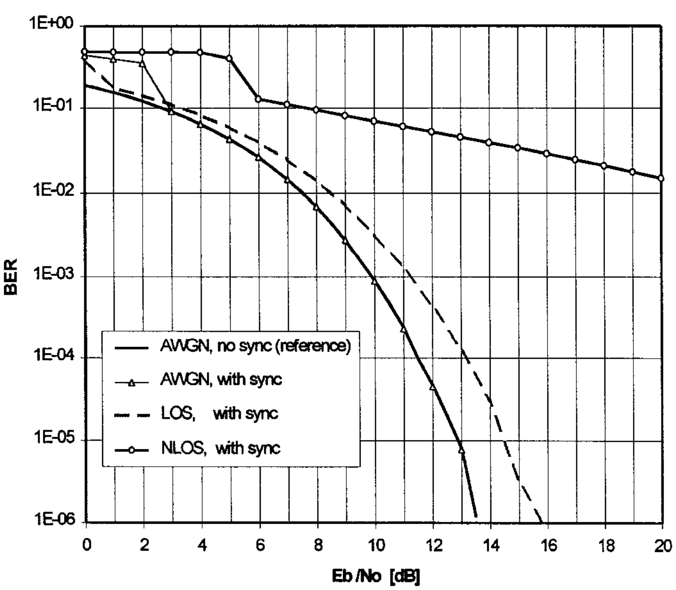


Fig. 8. Uncoded BER of a 512 subcarrier DQPSK-OFDM system in AWGN/LOS/NLOS with both time and frequency error correction working. The guard interval contains 50 samples.

Acknowledgments

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