PERFORMANCE OF THE OVERALL MEDIAN DEMONSTRATOR PHYSICAL LAYER

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ABSTRACT

This paper deals with the physical layer concept of the pilot system AC006-MEDIAN, which is developed in the framework of ACTS program under the European Commission. After a brief discussion about the applied OFDM principle, the use of time invariant modelled 60 GHz indoor wireless LAN channel and the synchronisation algorithm are enlightened. Finally performance of synchronisation and mean bit error rates versus bit energy-to-noise ratios are presented for coded and uncoded DQPSK modulation scheme using the simplified multipath and AWGN channels.

INTRODUCTION

The main objective of MEDIAN [1] is to implement a high speed wireless customer premises local area network (WCLAN) system for multimedia applications. The pilot system relies on a multicarrier modulated scheme, Orthogonal Frequency Division Multiplexing OFDM [2] and supports wireless ATM network. The demonstrator will provide proof of the overall MEDIAN concept. Unlike the presently existing standards, like GSM, DECT and HIPERLAN, the MEDIAN concept extends the wireless means through high data rates (up to 150 MBits/s) over a 60 GHz RF link in an indoor environment and enables the expansion of services of the fixed B-ISDN. With the application of Adaptive Time Division Duplex (ATDD) access technique, an optimised use of bandwidth is ensured. This paper deals only with the physical layer. In the following sections we give an overview of the system. The 60 GHz channel considered for the demonstrator is explained briefly in the subsection 1.2. The subsequent section presents an overview of the implementation of synchronisation algorithm which was basically proposed by P. Mandarini et. al. from University of Rome for MEDIAN demonstrator. Finally, the achieved COSSAP simulation results regarding the overall performance of the physical layer are presented.

1. SYSTEM DESCRIPTION

The transmission system considered here consists of an extended ATM data packet source, a channel encoder, modulator, discrete IFFT processor and guard time insertion, High Power Amplifier (HPA) [3]. The causes of signal distortion are the phase noise of transmitter and receiver, multipath signal reception, AWGN and local oscillator frequency offset addition. The receiver assembly has the complementary structure to the transmitter (see figure 1).

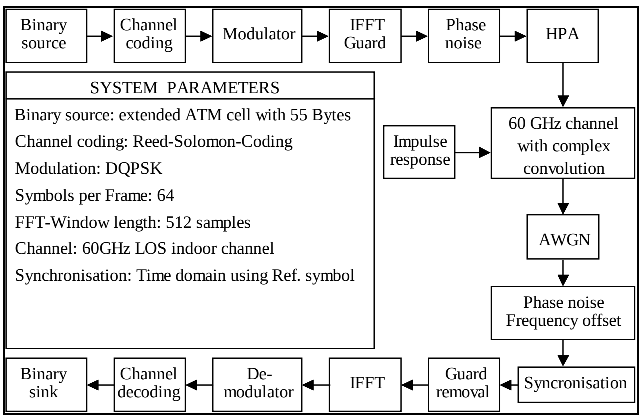


Figure 1: *Considered Transreceiver.*

1.1 FRAME GENERATION

MEDIAN implies frame oriented transmission techniques. Each frame consists of 62 data symbols, one broadcast symbol which contains control information relevant to the future frame and a reference symbol for synchronisation purpose.

Each data symbol consists of preamble (guard), postamble samples and FFT samples. The binary data which is to be transmitted (one ATM frame) is at first modulated with DQPSK principle. After the IFFT processing pre- and postamble samples are added to form one OFDM symbol. The preamble samples are more than sufficient to fight multipath (typical multipath delays of maximum 60 ns). The postamble samples are needed to compensate the propagation delay and remaining synchronisation offsets. In this paper the broadcast symbol is considered to be one of the data symbols. The distribution of the information signal carrying subcarriers in a symbol are depicted in figure 2.

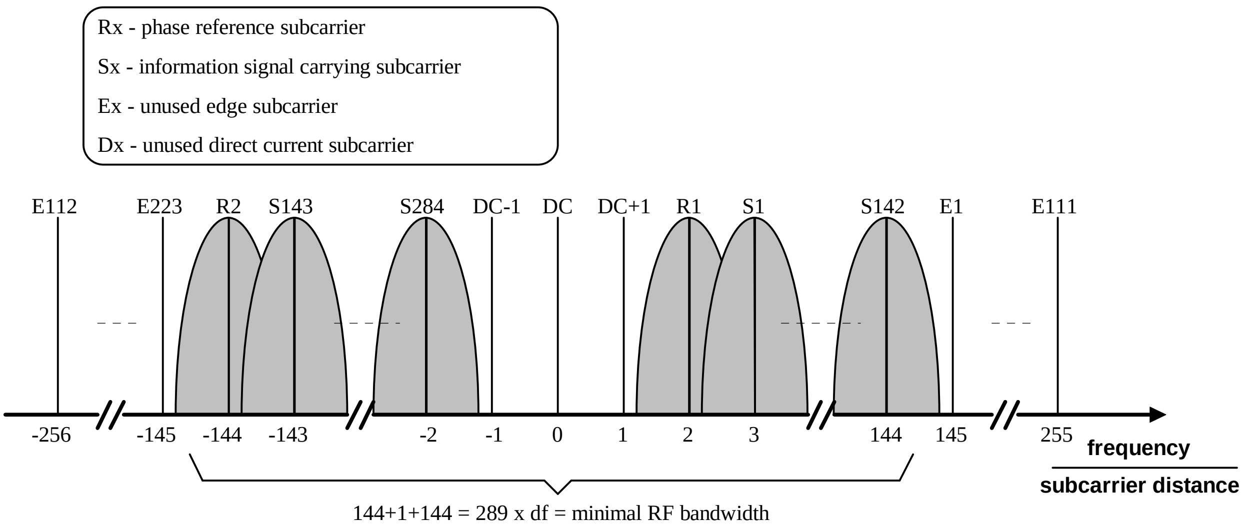


Figure 2: *Demonstrator Frequency Spectrum in the Equivalent Lowpass Domain* .

The construction of Reference symbol can be achieved either in frequency domain [4] or in time domain. In case of frequency domain reference symbol, it consists of M pilot tones spaced by ΔN OFDM subcarriers. The reference symbol in time domain consists of periodic signal pattern. Similar to data symbols, reference symbol is also protected against Inter Symbol Interference (ISI). Since the frequency domain processing of reference symbol requires much hardware and delivers the similar results like the time domain processing, only the time domain reference symbol is considered in this paper.

1.2 60 GHz CHANNEL MODEL

Among all non-linearity influences the main physical layer degradation is generally expected from the radio channel. As part of it, the radio antennas determine the channel behaviour significantly.

Static impulse responses for the 60-62GHz indoor channel were newly measured in a MEDIAN demonstrator typical environment with real demonstrator antennas [5]. As the major outcome of this measurement campaign it is shown that the demonstrator channel behaves practically Gaussian like and is even better than a typical Line of Sight (LOS) multipath mobile radio indoor channel. This is due to the strong directivity of the proposed antenna combination lens-horn. With correct adjustment of the horn antenna, there were no reflections stronger than 35dB below the signal of the direct path in the whole room. The channel measurements were taken to derive a simple static model to be used in physical layer system performance simulations and predictions.

1.3 SYNCHRONISITION IN MEDIAN SYSTEM

In MEDIAN system there is a need of synchronisation not only in the time but also in frequency domain. This is because, the MEDIAN base station (BS) and the portable stations (PS) are physically separated, with BS being the master. No synchronisation is done in the base station due to the insufficient time between consecutive symbols. Since this system is a TDD/TDMA, it requires frame, frequency and symbol synchronisation. In the considered system it is done in time domain with the use of a reference symbol in each frame. Finally the estimation of the local frequency offset error is done. The acquisition and tracking process are performed offline on the received samples in three phases. In all three phases auto correlation products are computed.

Phase 1 of acquisition is called coarse frame timing. This phase delivers a rough estimation of the reference symbol starting position in the received data. The achieved starting position from this phase has an accuracy of 73.3%.

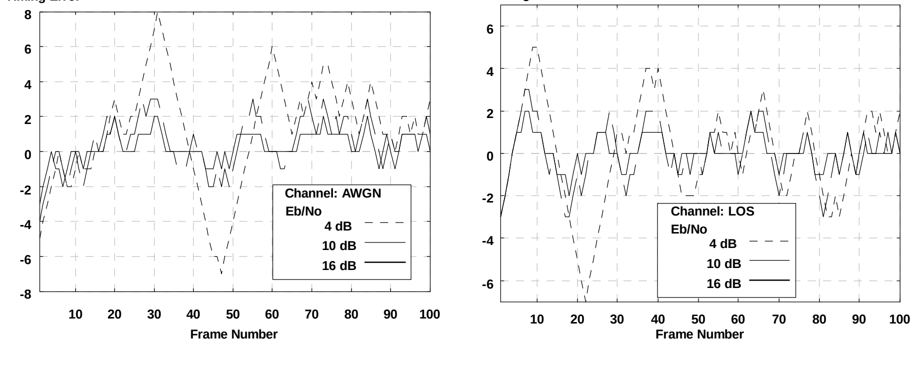
Phase 2 of the acquisition process (symbol timing) is analogue to the phase 1, but the starting index of the search is computed from the results of first phase. The resolution of the search step size is improved such that the result of this phase has an accuracy of 99.3%. An estimation of the frequency offset is also done with the help of the correlation result at the maximum value index. Phase 1 and 2 of the synchronisation are done once per out of synchronisation signal.

The acquisition results are given to the tracking process which is done in the third and final phase. Tracking is performed on every frame and the results are used to correct the time and frequency offset errors continuously. To reduce the calculation power of this phase, two correlations are performed parallel on the received reference symbols, early and late correlations. The results are filtered to compensate the sudden changes like a person passing through the LOS signal path. The computed time and frequency error estimations have an accuracy of 99.67%. Since these results lie inside the maximum allowed residual estimation error, an exact synchronisation is performed.

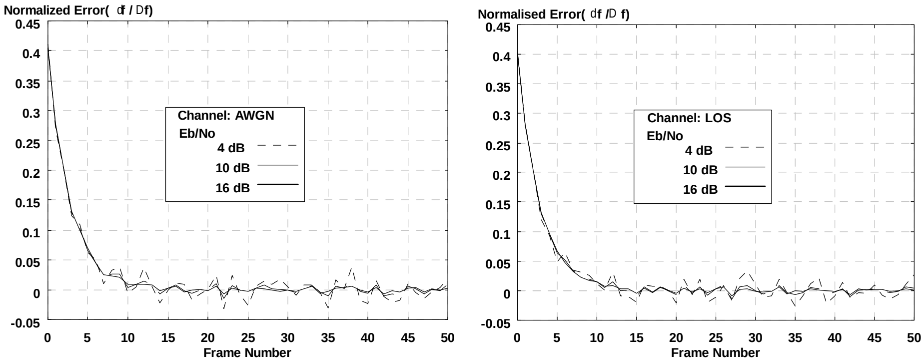
2. SIMULATIONRESULTS

To test the performance of above mentioned synchronisation algorithm, the Implementation of complete physical layer is done using the COSSAP simulation tool. As binary source an extended ATM cell is considered. This source also includes MAC informations. For channel coding a Reed-Solomon code with 30% of redundancy is chosen. Prior to the OFDM modulation the output of the encoder is mapped into gray coded symbols and DQPSK-modulation is performed. Successive symbols are placed on the adjacent subcarriers, whereby the edge subcarrier transmits a reference phase. After the modulation an additional guard time is inserted in order to avoid ISI in the presence of a time-dispersive channel. The sources of distortion are the transmitter and receiver phase noise, multipath channel, AWGN and the local oscillator frequency offset. For the simulations the floating point calculations are considered. For the correction of the frequency and time offset errors a closed loop of synchronisation is selected.

Figure 3 presents the correction time required in terms of frames by the tracking unit if the initial time and frequency offsets are -4 samples and 0.4 ¶$f/\Delta f$ respectively at the starting of tracking and for bit energy-to-noise ratios 4, 10 and 16dB. The effect of HPA is not considered.



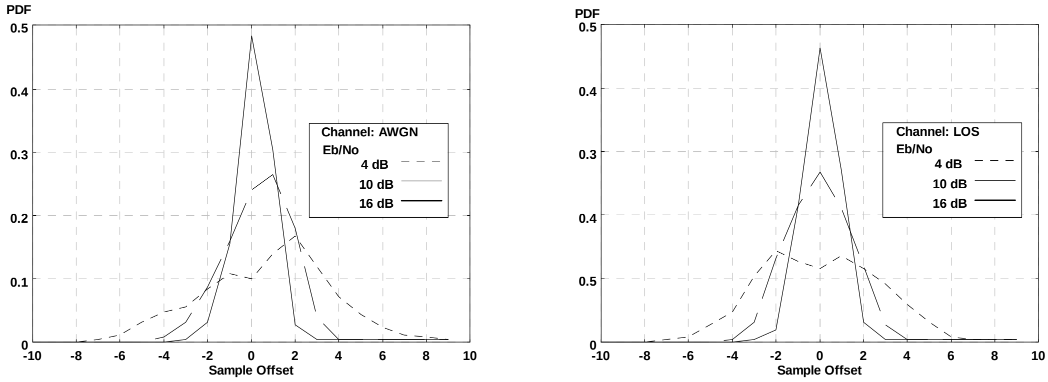
(a) (b)



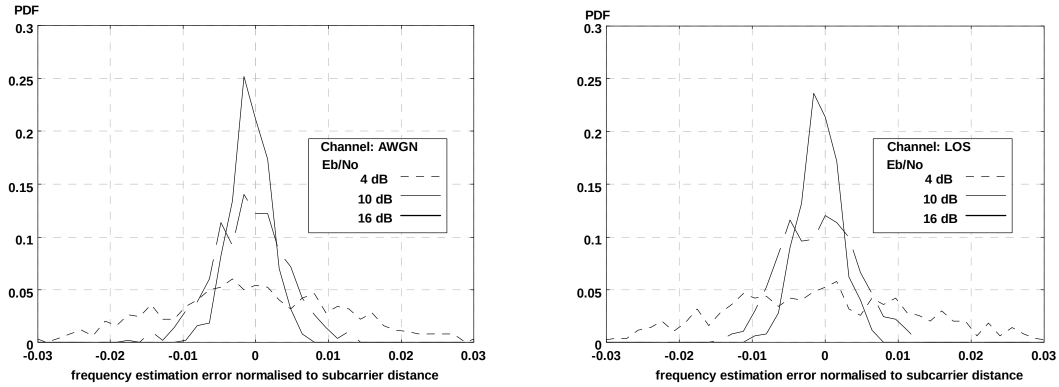
(c) (d)

Figure 3: *(a) and (b) represent the time offset corrections for AWGN and LOS channels for starting error of 4 samples where as (c) and (d) shows the normalised frequency error evolution starting from an error of 0.4 the carrier spacing.*

The next figure shows the histograms of the time and frequency offset error estimations.



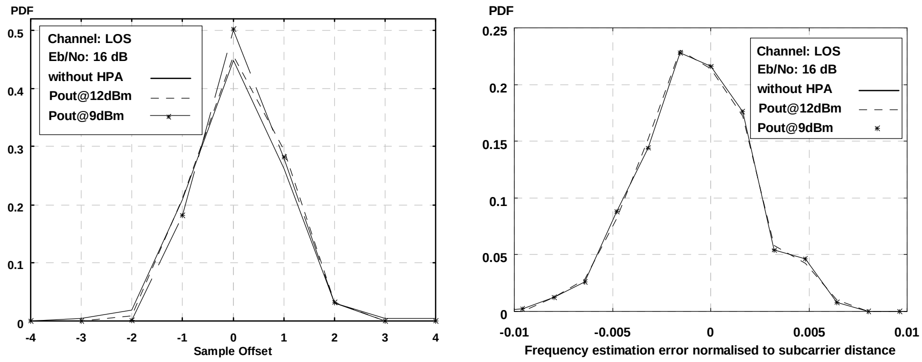
(a) (b)



(c) (d)

Figure 4: *(a) and (b) represent the histograms of normalised time offset error for AWGN and LOS channels where as (c) and (d) shows the histograms of the normalised frequency error estimation.*

It is noticed that the time correction requires about 5 frames to come into the tolerance range of +/- 2 samples. Whereas the frequency offset correction needs 15 frames to enter the tolerance range of $\P f / \Delta f$ = 1%. The acquisition phase requires 4 frames to deliver starting values for the tracking. Altogether, there is a need of 19-20 frames from the start synchronisation signal, i.e. a maximum latency of about 50 µs. Further, the simulations were carried out with a High Power Amplifier (HPA) model whose saturation point and 1 dB compression point were at 15dBm and 12dBm output power respectively. The following figures represent the histograms simulated in the LOS channel environment and at bit energy-to-noise ratio of 16 dB:



(a) (b)

Figure 5: *(a) represent the histograms of normalised time offset error where as (b) shows the histograms of the normalised frequency error estimation for LOS channel with HPA for Pout 9dBm and 12dBm.*

The above simulation results aver the functioning of synchronisation also in the presence of non-linear HPA.

The final proof of the above mentioned physical layer performance with synchronisation can be achieved with the bit error rates (BER) and cell loss rates (CLR). Figure 6 depicts the simulated curves.

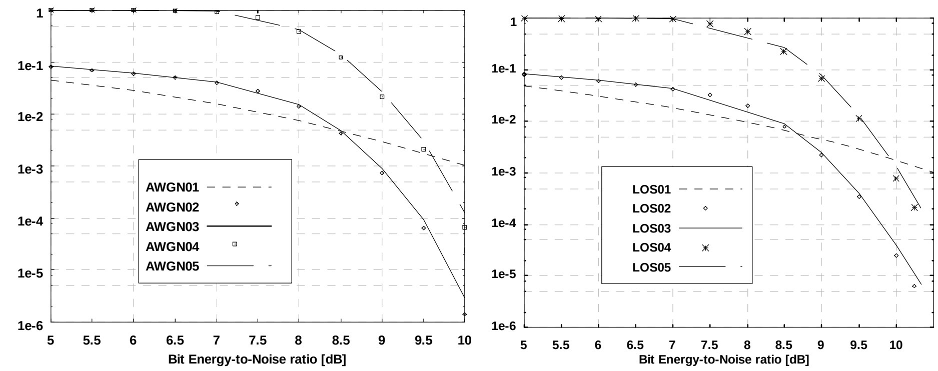


Figure 6: *Coded and uncoded BER and CLR of a 512 subcarrier DQPSK-OFDM system in AWGN/LOS with time and frequency corrections.*

The simulations are carried out with extended ATM cells as binary source neither considering CRC check nor ARQ. The curves AWGN01 and LOS01 represent the uncoded bit error rates in the respective channels. AWGN02 and LOS02 demonstrates the BER and AWGN04 and LOS04 stands for CLR in case of ideal synchronisation. In the same way AWGN03 and LOS03 represents the BER whereas AWGN05 and LOS05 stands for CLR where the synchronisation is done using the reference symbol. It is seen that there is a small deviation between ideal and normal synchronisation at small bit error rates. Due to the strong directivity of the proposed antenna combination, the LOS channel behaves almost like AWGN channel. Therefore there is a loss of 0.25 dB of bit energy at 2e-5 BER.

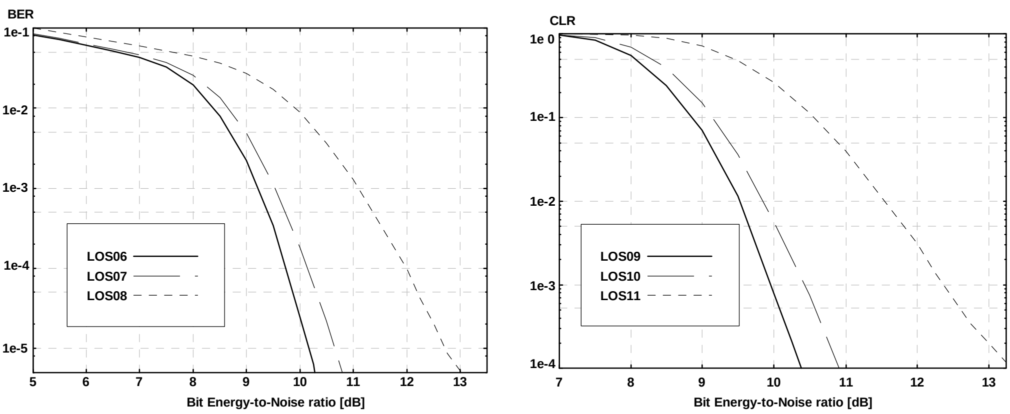


Figure 7: *Coded BER and CLR of a 512 subcarrier DQPSK-OFDM system using non linear HPA in LOS with time and frequency corrections.*

Finally, figure 7 evince the simulation results in the presence of a non linear HPA for the environment modelled by LOS channel. LOS06 and LOS09 stands for BER and CLR respectively for the simulations with the ideal synchronisation and without HPA. LOS07 and LOS10 represents BER and CLR for output power at 9dBm, whereas LOS08 and LOS11 shows the results for output power at 1dBm compression point.

CONCLUSIONS

In this paper we have presented the overall physical layer concept of the pilot system AC006-MEDIAN. The time and frequency synchronisation is done in time domain using a reference symbol. The simulation results give a proof of the concept of the considered system not only in AWGN but also in wireless 60 GHz indoor radio channels using non-linear HPA.

ACKNOWLEDGMENTS

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