

# WLAN evolution from HIPERLAN type 2 to MEDIAN

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**Abstract:** HIPERLAN type 2 system being currently in the final standardisation process in ETSI BRAN is expected to operate in the 5.15 - 5.35 GHz or 5.470 - 5.725 GHz or 5.725 - 5.925 GHz frequency range while the MEDIAN system to be standardised in the near future is expected to work at least in frequency band from 61.0 to 61.5 GHz allocated to Industrial, Scientific and Medical applications (ISM). Both systems are based on orthogonal frequency division modulation (OFDM) physical layer scheme and will support quality of service requests for ATM as well as for IP based networks. Cost efficient terminal development and broad market acceptance can be supported by designing systems in a compatible and evolutionary way. A renewed MEDIAN system design is presented here, based on experience made in the ACTS project AC006 MEDIAN considering the evolutionary approach regarding recent HIPERLAN type 2 / IEEE 802.11a harmonised standardisation actions.

## 1. INTRODUCTION

Recent changes in the HIPERLAN type 2 standardisation due to harmonisation with the IEEE 802.11a show the need of world wide harmonisation in system design and development in order to ensure mass market production for component manufacturer. Decreasing production costs due to high volumes enable fast market introduction because of cost dependent higher customer acceptance.

MEDIAN demonstrator has been designed and build and experience shows, that the technical approach of the MEDIAN project to transmit wireless gross data rates of more than 200 Mbit/s at 60 GHz radio has been realised successfully. The demonstrator consists of one base station and two mobile stations each consisting of physical layer, media access control and interworking units. User data up to 150 Mbit/s can be transmitted. MEDIAN demonstrator has been designed and built using market place available technology. For this reason many choices in demonstrator system design had to be far from optimal. After finishing the demonstrator design a future MEDIAN system design has started. This design incorporates more

optimal solutions but trying to keep a certain compatibility to the latest HIPERLAN type 2 development. Performance of the HIPERLAN/2 and new MEDIAN system is determined by computer simulations incorporating measured local oscillator phase noise and radio channel data.

## 2. HIPERLAN/2 TO MEDIAN DESIGN

Current HIPERLAN type 2 physical layer parameters are 20 MHz channel spacing and sample rate, COFDM modulation scheme, 64 point complex FFT, 48 subcarrier used for data transmission, 800 ns guard time, BPSK, QPSK, 16 QAM and 64 QAM subcarrier modulation using coherent demodulation. Forward error correction is applied using standard convolutional code with constraint length 7 and code rate 0.5. According to map one PDU onto integer numbers of OFDM symbols the mother code will be punctured to required code rates of  $\frac{9}{16}$  and  $\frac{3}{4}$ . The DLC-PDU length is 54 bytes. The ideas presented here base on use as much as possible components of the HIPERLAN/2 system for the future MEDIAN system. There are physical layer parts like FFT, subcarrier modulation, coding and digital filters, the PDU length of 54 bytes and upper layer protocols to be re-useable for MEDIAN. Two new MEDIAN design discussions shall consider what is possible and what is convenient.

## 3. First MEDIAN Design Discussion

The first approach is to use the HIPERLAN/2 design with a sampling rate of 100 Msamples/s instead of 20 Msamples/s. Thus a guard time of 160 ns would be achieved. Due to the less dispersive radio channel at 60 GHz a guard time of 160 ns is presumed to be sufficient [3]. Using HIPERLAN/2 equipment in 16 QAM mode with 5 times the original sample rate can provide a physical layer fulfilling MEDIAN data rate requirement. This provides a gross data rate of 240 Mbit/s. Applying a forward error correction with code rate 0.625 enables to carry one DLC-PDU in four OFDM symbols (768 bit). Thus the net bit rate is 150 Mbps for 16QAM. That subcarrier modulation for normal and QPSK for bad channels is foreseen. The forward error correction to be applied in the future

MEDIAN system needs to be more sophisticated than the standard scheme proposed for HIPERLAN type 2 due to the minimum code rate 0.625. Thus the TURBO coding scheme is foreseen, which is not compatible to the current HIPERLAN/2. This point is under investigation in order to identify as much as possible decoder elements to be used in both systems.

This very simple approach to implement a new MEDIAN system would save a lot of development time and costs but there are some disadvantages that should be considered. Thus the use of only 64 subcarrier in a frequency band of 100 MHz seems to be a waste of this precious resource. Because of the slowly changing MEDIAN indoor radio channel the orthogonality of the subcarriers is not greatly disturbed by Doppler shifts and this allows a closer subcarrier spacing.

Another point is the 16QAM used to reach the target net bit rate of 150 Mbps for wireless ATM. This modulation method is very sensitive in fading and frequency selective channel environment and needs a channel estimation before demodulation. To get sufficient results a relative high SNR is required. If differential encoded QPSK or 8PSK modulation is used there is no need for channel estimation. Additionally this modulation methods are more robust in radio channel environment and need a lower SNR to reach comparable error rates.

Since the nonlinearities of the RF front end high power amplifier (HPA) are more critical in 60 GHz region the crest factor (CF) reduction requires more effort than in HIPERLAN/2. Here a system with only 64 subcarriers shows a CF distribution that more often reaches higher values than the Rayleigh pdf valid for infinity number of subcarriers. A CF reduction coding is not applied due to the relatively high number of used subcarriers. In a system with even more subcarriers the amplitudes of the inphase (I) and quadrature (Q) signal components in time domain reaches nearly a Gaussian distribution. That results in a reduced probability of higher CFs.

Because of the above mentioned problems with the simple transformation of the HIPERLAN/2 system into a MEDIAN system it is not favoured for a new MEDIAN design. But it is maybe an interesting alternative until a standard is adopted.

#### 4. SECOND MEDIAN DESIGN DISCUSSION

A more sophisticated design needs to change number of subcarriers in one OFDM-symbol. Other parameters like PDU length and upper layer protocols are assumed still similar to HIPERLAN/2

system concept. With a number of four times the number of subcarriers of the HIPERLAN/2 system the efficient radix 4 algorithm to get a 256 point FFT can be used. Due to the increased number of subcarriers the magnitude of the signal in time domain fits better a Rayleigh distribution. By this reason the average Crest Factor is lower in comparison to the system with the 64 point FFT. On the other hand the system gets more sensitive for phase noise and Doppler shifts. The influence of the noise introduced by the local oscillators is investigated by simulations with the given phase noise mask in Figure 3a.

For subcarrier modulation differentially encoded PSK is chosen because of the robustness in fading environment and the possibility of simple non-coherent demodulation. The coding scheme is changed to a code with minimum code rate of 1/3. A detailed description of the new MEDIAN system is given in the following sections.

#### Physical Layer Description:

The basic functions of the new MEDIAN physical layer are scrambling / descrambling, coding / decoding, interleaving / deinterleaving, subcarrier modulation / demodulation with differential encoding, OFDM modulation / demodulation and time and frequency synchronisation.

**Scrambling / Descrambling and Interleaving / Deinterleaving:** is used as proposed for the HIPERLAN/2 system [5]

**Coding / Decoding:** In this section a coder with the coding rate  $R=1/3$  is foreseen. All needed code rates in the different physical layer modes are obtained by puncturing the mother code. For decoding soft decision decoding is foreseen with the technical progress in mind providing the ability for iterative decoding.

**Subcarrier Modulation / Demodulation:** The OFDM subcarriers are modulated by differential encoded QPSK (DQPSK) or D8PSK between adjacent subcarriers in the same OFDM symbol. For this reason two phase reference subcarriers are introduced per OFDM symbol.

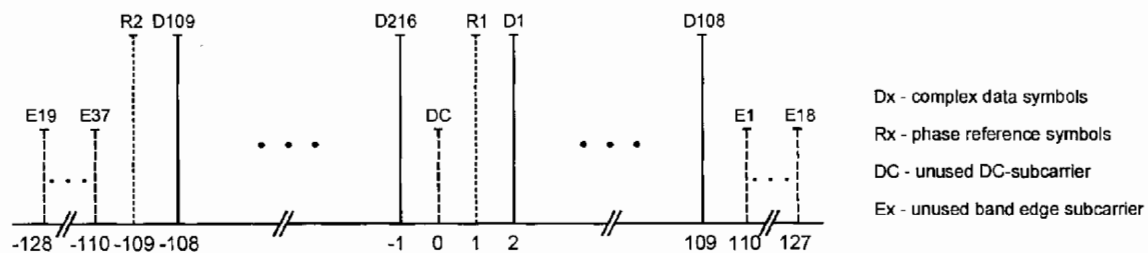
Due to differential modulation with noncoherent demodulation no channel estimation is used. Coherent demodulation will be investigated further for its advantage in SNR requirement. Decoding with channel state information (CSI) is foreseen. The subcarrier modulation dependent parameters of the potential future MEDIAN basic modes are listed in the following table.

Modulation	Coding rate R	Coded bits per OFDM symbol	Data bits per OFDM symbol	OFDM symbols per PDU	Net bit rate
DQPSK	1/2	216 x 2 = 432	216	2	75 Mbps
D8PSK	1/3	216 x 3 = 648	216	2	75 Mbps
D8PSK	2/3	216 x 3 = 648	432	1	150 Mbps

**Table 1: Physical layer modes of potential future MEDIAN system.**

**OFDM Modulation / Demodulation:** After subcarrier modulation the complex symbols are mapped to an OFDM symbol. The general structure is shown in Figure 1. For the data there are 216 subcarriers and for reference symbols two subcarriers in each OFDM symbol. The DC carrier and the band edge carriers are not used and set to zero. These carriers are used to cope with adjacent

channel interference (ACI) and out of band emissions. In the time domain, a cyclic prefix with 32 samples is added to the actual OFDM samples to compensate for the intersymbol interference (ISI) introduced by the multipath channel. The length of the guard interval is equal to 320 ns. To reach a slightly higher throughput rate a shorter guard interval is possible.



**Figure 1: Subcarrier frequency allocation**

The band of 500 MHz in the range 61.0 – 61.5 GHz which is currently foreseen for MEDIAN could be divided in five channels with 100 MHz bandwidth. Then the distance between the outmost carriers of two adjacent channels is 30.469 MHz. The distance to the edges of the MEDIAN frequency band is only a half this value. Depending on power

amplifier output backoff requirements, the absolute transmission power and decisions about spurious power emission limits outside the range 61.0 – 61.5 GHz this value can be increased.

The values for mean OFDM parameters of the created new MEDIAN system are given in the following table.

Parameter	Value
Sampling rate $f_s=1/T$	100 MHz
FFT complex points	256
Symbol part duration $T_U$	$256 \cdot T = 2.56 \mu s$
Guard interval duration $T_G$	$32 \cdot T = 0.32 \mu s$
OFDM symbol interval $T_S$	$288 \cdot T = 2.88 \mu s$
Number of data subcarriers	216
Number of reference symbol subcarrier	2
Subcarrier spacing	390.625 kHz
Spacing between the two outmost subcarriers	85.15625 MHz

**Table 2: Second MEDIAN OFDM parameter set.**

## 5. PERFORMANCE SIMULATIONS

At this point of investigation several HIPERLAN/2 simulations and some MEDIAN simulations with the second MEDIAN design draft have been carried out. The PDU (54 byte) error rate for (D)QPSK and 16QAM is depicted in Figure 2. The channel model used for both simulations (HIPERLAN/2 and MEDIAN) is Model A according to document [2]. In this time and frequency selective channel model the doppler shifts are introduced according to a velocity of 3 m/s and the carrier frequencies 5.2 GHz or 61 GHz. In Figure 2a HIPERLAN/2 and MEDIAN results for (D)QPSK are shown in one diagram. 16QAM is only foreseen in HIPERLAN/2 and is depicted in the diagram of Figure 2b. The different code rates are the result of mapping one PDU in an integer number of OFDM symbols.

For QPSK channel model A is the worst case in performed HIPERLAN/2 simulations. That is due to the bad frequency selective behaviour of this model. There are large and deep fades in the frequency domain that can hardly corrected with the implemented code. The influence of the channel state information (CSI) is clearly visible. Soft

Decision with CSI gives the best results but the technical burden should be taken in consideration.

The DQPSK curve of the MEDIAN simulations is degraded in comparison to coherent QPSK, but in addition to the noncoherent differential demodulation the time selective fading is strongly increased. That is due to the fact of the increased subcarrier number. At a PDU error rate equal to  $10^{-3}$  the difference between the soft decision curves is 1.3 dB. That is a rather good result. The better frequency selective behaviour in the case of more used subcarriers is one point that should be mentioned here. In the case of a channel model especially designed for the 60 GHz channel and even with a strong direct path the PDU error rate can be improved further. Only such a channel model allows expressive statements about real transmission error rates. With the given Model A only the HIPERLAN/2 and the new MEDIAN draft can be compared.

For 16QAM the increased  $E_b/N_0$  ratio should be pointed out. That is combined with the disadvantage of a needed amplitude correction of the received signal. By this reasons that modulation method is not foreseen in the new MEDIAN design.

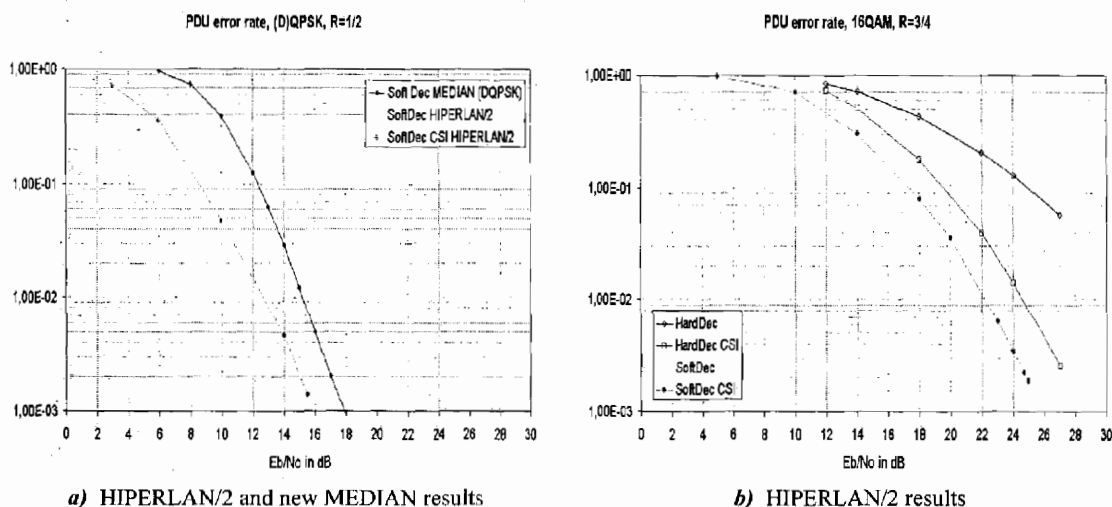


Figure 2: PER for a transmission over HIPERLAN/2 channel A [2]

Using the 60 GHz channel models, the local oscillator model, and the high power amplifier

model derived in the MEDIAN AC006 project error rate performance simulations are performed.

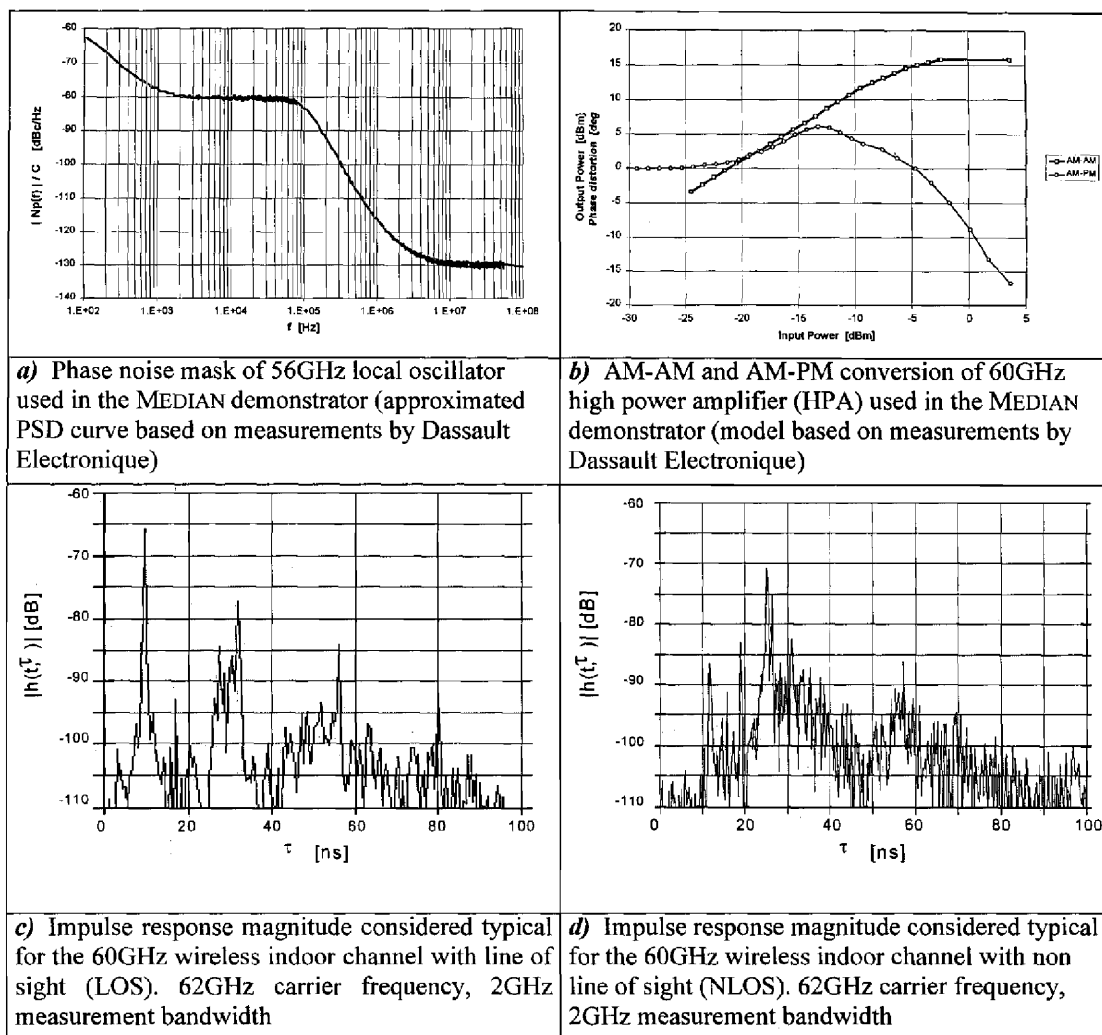


Figure 3: Models for 60 GHz Simulations

## 6. CONCLUSIONS

A future MEDIAN system design has been introduced. The simulation system models used for system error rate performance simulations have been provided. Compatibility with current HIPERLAN/2 standardisation process enables evolutionary introduction of the future MEDIAN system.

## 7. ACKNOWLEDGEMENT

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