Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**PHY for WirelessHUMAN™**
Date Submitted	**2001-01-13**
Source(s)	Mika Kasslin Nokia Research Center Itamerenkatu 11-13 FIN-00180 Helsinki, Finland Voice: +358-9-4376 6294 Fax: +358-9-4376 6856 mailto:mika.kasslin@nokia.com Nico van Waes Nokia Networks 313 Fairchild Dr. Mountain View, CA, USA Voice: +1-650-625 2201 Fax: +1-650-625 2058 mailto:nico.vanwaes@nokia.com
Re:	Call for Contributions for Proposed Modification of Specified MAC/PHY standards for WirelessHUMAN™ (TG4); issued 2000-11-17.
Abstract	This document describes shortly a PHY based on IEEE 802.11a PHY to be used in WirelessHUMAN™ specification. Additionally, link level simulations are given to show the performance in noise and interference limited cases.
Purpose	The PHY described should be considered as the basic PHY mode of the TG4 standard.
Notice	
Release	
Patent Policy and Procedures	

PHY for WirelessHUMAN™

Mika Kasslin, Nico van Waes

This paper proposes a physical (PHY) layer for WirelessHUMAN™ standard. Proposal is to use the IEEE 802.11a PHY [1] as such without modifications. We describe only the basic parameters of the PHY and the main purpose of the document is present the performance of the given PHY. For that a set of simulations have been run and a set of results are given in the document.

1 The OFDM PHY

The proposal is to use the IEEE 802.11a PHY as such without any modifications, at least as one of the basic PHY modes. The PHY would then be based on OFDM and would use 64-point FFT with 52 active carriers, 20 MHz basic clock rate, convolutional coding with various puncturing patterns and BPSK/QPSK/16QAM/64QAM modulation in sub-carriers. All the relevant parameters are given in Table 1. With these parameters and given modulation, coding schemes and puncturing patterns the PHY will provide for 6, 9, 12, 18, 24, 36, 48 and 54 Mbit/s as shown in Table 2.

The two main reasons for proposing the 802.11a PHY as such are that it provides good performance (as shown later) in the given environment and required system features, and cost-effectiveness due to the re-use of an existing PHY standard and COTS chip sets. The current proposal should be considered together with some specific system and MAC level functionalities described in the separate proposal [2]. It is envisioned that when the WirelessHUMAN™ standard contains all the basic interference mitigation techniques on the system level on top of MAC and PHY (DFS, link adaptation control, antenna selection, etc.), a relatively simple PHY that provides for reliable operation in unlicensed bands, is enough and most suitable one. Should the larger delay spreads be tolerated in the system one should incorporate additional PHY modes with higher number of subcarriers allowing longer cycic prefixes. For mass markets, densely populated areas and high market penetration (i.e. relatively short links and small delay spreads) there should however be a PHY mode that provides for reliable and cost-effective solution like the 802.11a PHY does.

Parameter	Value
Basic rate f_s=1/T	20 MHz
Useful symbol part duration T_U	64*T 3.2 µs
Cyclic prefix duration T_{CP}	16*T 0.8 µs
Symbol interval T_S	80*T 4.0 µs (T_U+T_{CP})
Number of data sub-carriers N_{SD}	48
Number of pilot sub-carriers N_{SP}	4
Total number of sub-carriers N_{ST}	52 (N_{SD}+ N_{SP})
Sub-carrier spacing Δ_f	0.3125 MHz (1/T_U)
Spacing between the two outmost sub-carriers	16.25 MHz (N_{ST}*Δ_f)

Table 1. Basic PHY parameters

Data rate (Mbit/s)	Modulation	Coding rate	Coded bits per subcarrier	Coded bits per OFDM symbol	Data bits per OFDM symbol
6	BPSK	_	1	48	24

9	BPSK	_	1	48	36
12	QPSK	_	2	96	48
18	QPSK	_	2	96	72
24	16QAM	_	4	192	96
36	16QAM	_	4	192	144
48	64QAM	2/3	6	288	192
54	64QAM	_	6	288	216

Table 2. Rate-dependent parameters

2 Simulation results

Simulation of the physical layer was performed with different modes. For every mode Packet Error Ratio (PER) was computed as a function of signal-to-noise ratio either E_b/N_0 or C/I, where E_b, N_0, C, and I are energy per bit, noise energy, signal power, and interference power, respectively.

In addition the simulations were performed with different channel models. Table 3 presents the channel models and the environments, which are represented by the different rms. delay spreads.

Channel model	rms delay spread [ns]	Environment description
A	50	Office NLOS
B	100	Open space/office NLOS
C	150	Large open space NLOS
D	150 (Rice)	Large open space LOS
E	250	Large open space NLOS

Table 3: Parameters of channel model

Definitions for the symbols in figures:

- ✿ BPSK code rate $1/2$
- ✿ BPSK code rate $3/4$
- X QPSK code rate $1/2$
- ✿ QPSK code rate $3/4$
- ✿ 16-QAM code rate $3/4$
- ✿ 16-QAM code rate $1/2$
- ✿ 64-QAM code rate $3/4$

The first two curves in Figure 1 show the performance with relatively small delay spreads. One can envision this kind of delay spreads occur also with directional antennas in outdoor environment.

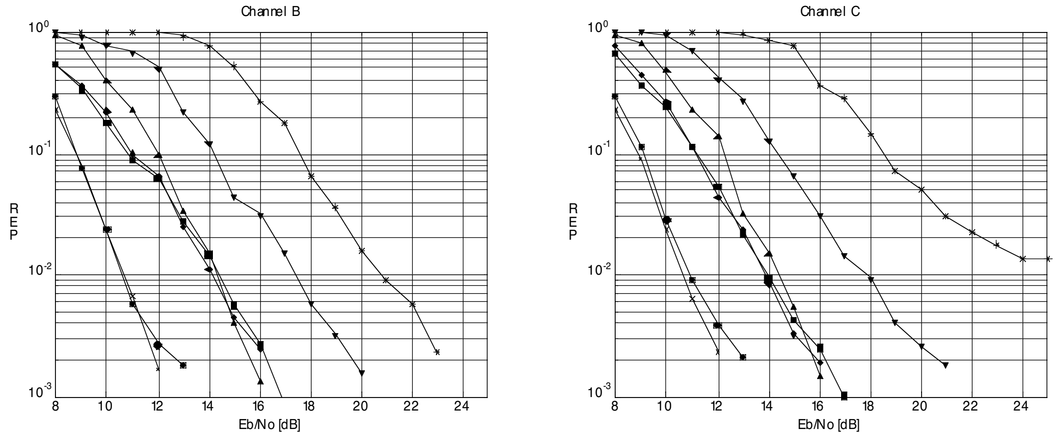

Figure 1: PER vs. Eb/No with channel models B and C.

Figure 2 presents PER as a function of C/I with channel models A, C, and E, respectively.

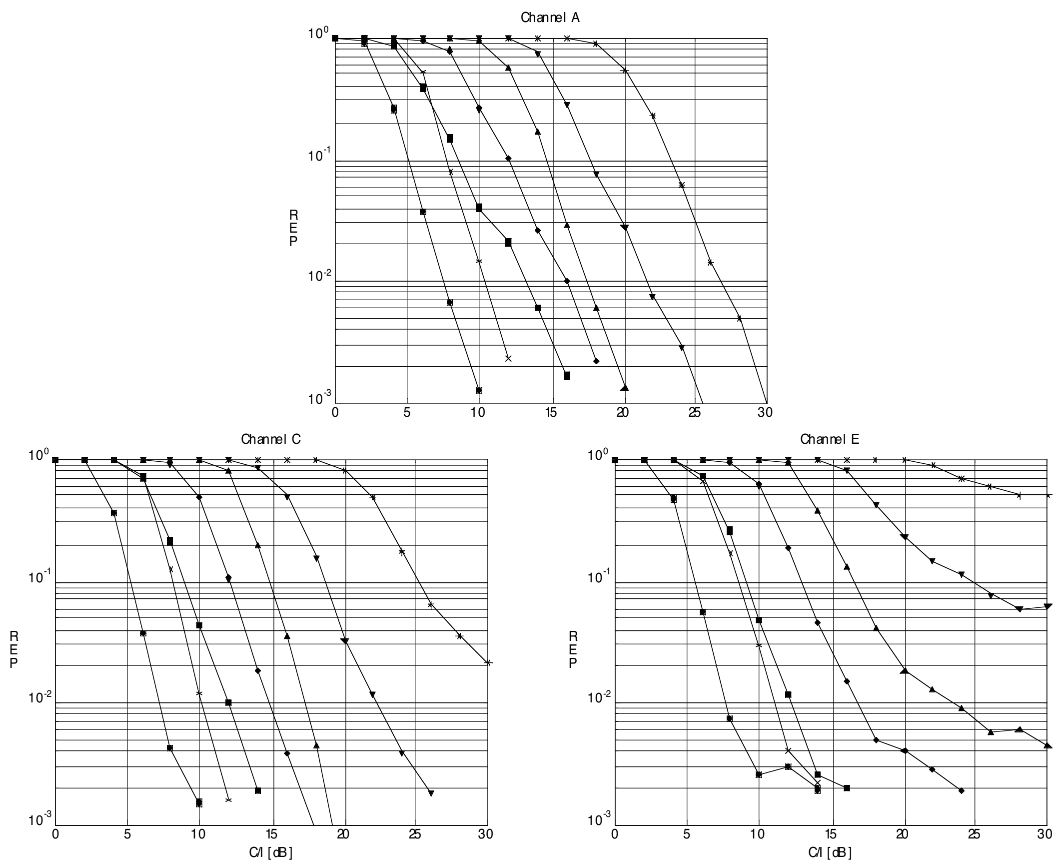

Figure 2: PER vs. C/I with channel models A, C, and E.

From these three curves one can easily see that the large delay spreads destroy entirely the highest bit-rate modes but have very little impact on the most robust modes. If one mandates use of the few lowest modes in control and schedule data transmission there is always a possibility to use any bit-rate suitable for unicast transmission in which directional antenna and transmission can be used.

Last we present some results of the simulations that were run to analyse the effect of the burst length. The two burst lengths used werer 54×8 bits and 9×8 bits. All simulations were run with BPSK code rate _ and _. Figure 3 presents PER vs. Eb/No for channel models B and C.

Definitions for the symbols in figures:

✿ BPSK code rate $1/2$ with burst length 54×8 bit

✿ BPSK code rate $1/2$ with burst length 9x8 bit

X BPSK code rate $3/4$ with burst length 54×8 bit

✿ BPSK code rate $3/4$ with burst length 9×8 bit

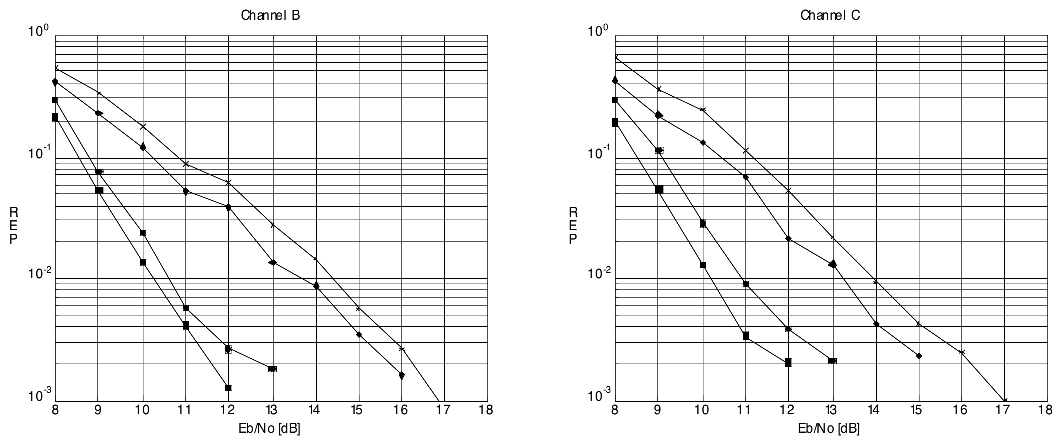

Figure 3: PER vs. Eb/No comparison between burst lengths of 9× 8 and 54× 8 bits with BPSK modulation with code rate _ and _ (channel models B and C).

As we can conclude from Figure 5 the performance is slightly better when burst length 9×8 bits are used instead of 54×8 bits. The difference between system performances increases when rms. delay spread increases (channel models A, B, C, and E). This is also shown in the Figure 4.

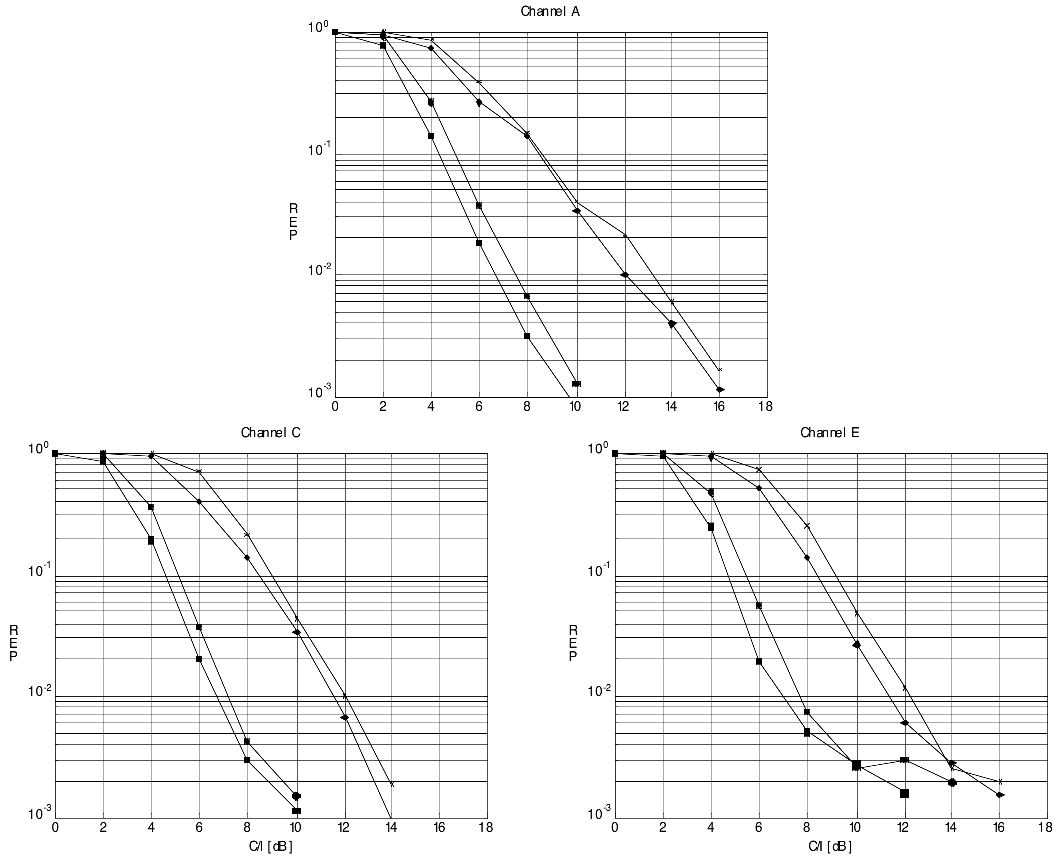

Figure 4: PER vs. C/I comparison between burst lengths of 9× 8 (■) and 54× 8 (●) bits with BPSK modulation and with code rates _ and _ (channel models A, C, and E).

References

[1] "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band", IEEE 802.11a-1999

[2] "A WirelessHUMAN™ System", M.Kasslin, N.van Waes, Contribution to TG4