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Title	**Channel and interference model for 802.16b Physical Layer**
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Abstract	A channel and interference model is proposed for 802.16b. The models may be used to evaluate the performance of the PHY proposal and to optimize relevant parameters.
Purpose	
Notice	
Release	
Patent Policy and Procedures	

Channel and Interference Models for 802.16b

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1. Introduction

The purpose of this document is to present channel and interference models for 802.16.4 OFDM PHY. The models are targeted towards parameter optimization rather then for establishing the actual performance of the proposed system.
The models include the following elements:

- A channel model, which captures effects of multipath.
- A Radio impairments models.
- An interference model, capturing the effects of typical interference, which exists at unlicensed bands.

The underlying guidelines for this work, are to try to define a mathematical framework for the elements under consideration, rather then to try to match the models to specific scenarios. This approach will result in an set of flexible models, which can tailored to specific situations and scenarios by a simple change of parameters.

The models proposed here are straightforward, simple to simulate and yet gives a realistic description of the system and the related impairments. The models are also mathematically tractable, and support a single parameter characterization.

The basic model is depicted in Figure 1. The specific blocks are described in subsequent sections.

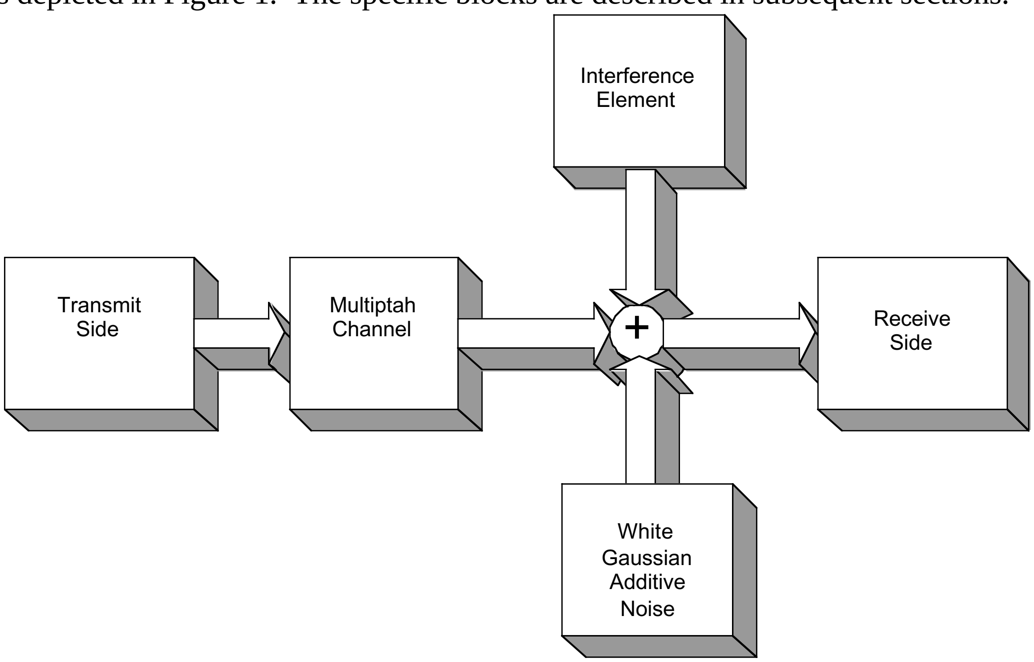

Figure 1 Basic model

2. Multipath channel

The multipath model is selected to be a Rayleigh fading model with an exponentially decaying power profile. The channel is specified by the RMS of the tap weights. This model is simple to analyze and simulate. With a proper choice of delay spread values it represents realistic conditions. For further discussion see [1] or [2].

The following, taken from [1], describes how to implement the multipath model in a discrete time simulation system.

Let $h_k = h(t)\big|_{t=kT_s}$ denote the sampled impulse response of the channel, where T_s is the sampling rate of the simulation system. The coefficients h_k are complex random numbers with random uniformly distributed phase and Rayleigh distributed magnitude. The average power decays exponentially. The RMS power average of the taps is given by the parameter T_{rms}. The coefficients are selected according to:

$$h_k = N(0, \tfrac{1}{2}\sigma_k^2) + jN(0, \tfrac{1}{2}\sigma_k^2)$$
$$\sigma_k^2 = \sigma_0^2 e^{-kT_s/T_{RMS}}$$
$$\sigma_0^2 = 1 - e^{-T_s/T_{RMS}}$$

where $N(0, \tfrac{1}{2}\sigma_k^2)$ is a zero mean Gaussian random variable with variance $\tfrac{1}{2}\sigma_k^2$ (produced by generating a $N(0,1)$ r.v. and multiplying it by $\sigma_k / \sqrt{2}$), and $\sigma_0^2 = 1 - e^{-T_s/T_{RMS}}$ is chosen so that the condition $\sum \sigma_k^2 = 1$ is satisfied to ensure same average received power.

In Figure 2, the exponential power profile and a single realization of a channel are shown.

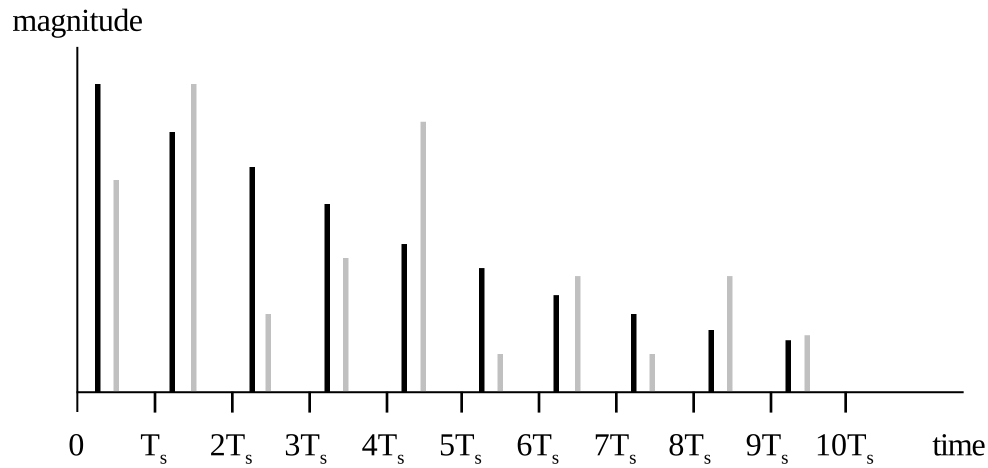

Figure 2 Power Profile (black) and a single realization (gray). the time positions are staggered for clarity only

The sampling time T_s in the simulation should not be longer than the smaller of 1/(signal bandwidth) or $T_{RMS}/2$. The number of samples to be taken in the impulse response should ensure sufficient decay of the impulse response tail, e.g. $k_{max}=10T_{RMS}/T_s$.

For each packet, a new channel response is generated. The channel is assumed to be static during a packet.

3. Interference models

Here the interference is assumed to be stemming from wide-band packetized transmissions (e.g. 802.11a HiperLAN/2). The model generates random interference bursts. For each burst the following parameters are selected at random:

1. Arrival time of burst.
2. Length of burst.
3. Center frequency of burst.
4. Power of burst relative to noise floor.

The focus in this section is to try to establish the mathematical framework for the interference model. Some crude assumptions are made with regard to the actual traffic parameters. These need to be refined.

The parameters are depicted schematically in Figure 3. Section 33.1 gives the underlying assumptions for the interference source. From those assumptions, the timing, power and signal descriptions are derived. They are described in section 3.2 and 3.3. Section 3.4 describes the procedure of generating the interference signal.

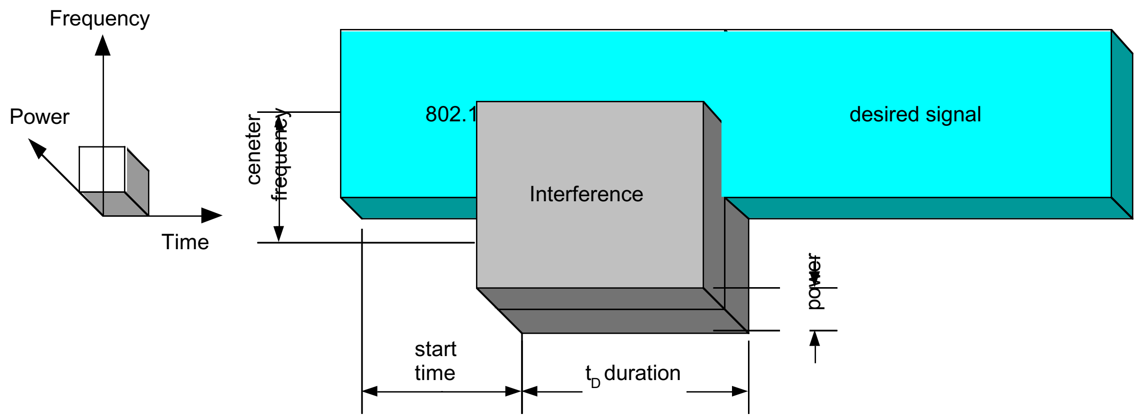

Figure 3 Interference parameters

3.1 Basic assumptions

Here we shall assume that the interferer is a 802.11a like signal (see [3]). The instantaneous transmission rate is 24Mb/s. The occupied bandwidth is about 17MHz. The PHY layer overhead per packet is assumed to be 20uSec.

For the interferer traffic, we shall use the results published in [4], where histograms of Ethernet packet sizes are shown. It is demonstrated that almost 75% of the packets are shorter than 522 bytes and nearly half the packets are 40-44bytes. In order to simplify and to reach round numbers, we shall assume that the packet size is uniformly distributed in the range 48 …480bytes. This is equivalent to a packet duration in the range of 36…180 uSec.

The time between consecutive interference bursts is can be computed as follows. From [4], we can assume that most traffic, in bytes, is concentrated in long packets, say in 500bytes packets. Let us assume a channel utilization of 25%. Thus the average idle channel time is (1-0.25)/0.25*500*8/24Mb/s= 500uSec.
Here we shall assume that the average time from end of interference burst to beginning of next burst is Poisson distribution with a mean of 500uSec.

It is assumed that the power spectral density (PSD) of the interference is in the same order of magnitude as the thermal noise floor. More specifically, the PSD is in the range of N_0 to N_0+20dB, where N_0 is the thermal noise floor.(–174dBm/Hz).
The frequency offset between the interferer and the desired signal is uniformly distributed in the range -10Mhz…+10MHz.

3.2 Signal Wave shape

The interference signal is generated by passing a white complex Gaussian process, through a raised cosine filter and amplifying it to the desired level. Then it is shifted in frequency in to a randomly selected center frequency. The motivation for using this wave shape is as follows:

- The proposed signal is easy to generate
- The spectral signature is similar to that of many communication systems.
- It has roughly the same peak to average power ratio as that of an OFDM signal.
- This signal, can be easily modified to represent other interfering signals.

The parameters of the raised cosine filter are rolloff factor of β=0.25 and 6dB corner of f_c=10MHz. The filter is given by:

$$H(f)=\begin{cases} 1 & |f|<(1-\beta)f_c \\ 1/2\left[1-\sin\frac{\pi}{2}\left(\frac{f}{f_c}-1\right)\Big/\beta\right] & (1-\beta)f_c \le |f| < (1+\beta)f_c \end{cases}$$

3.3 Generating Procedure

The signal generation is depicted in Figure 4. The procedure for generating the interference is given below.

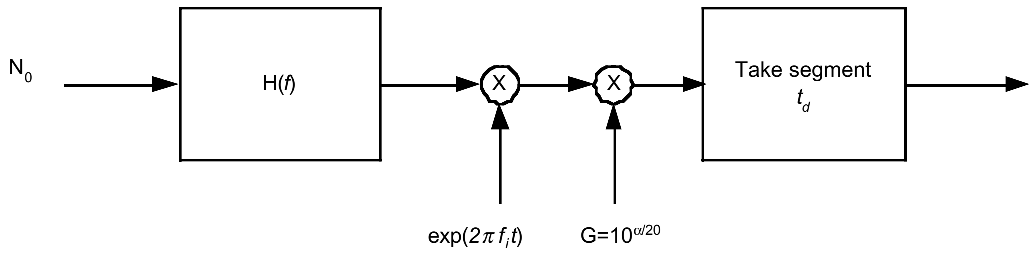

Figure 4 Generating the interference signal

1. Select the start time. Generate a poisson random variable t_0 with a mean of $1/\lambda$= 500uSec according to the probability distribution function given by :
$$f_t(t) = t\lambda e^{-\lambda t}\ .$$
2. Add t_0 to the end of the last interference Burst. If this is the first interference burst, t_0 signifies start time from beginning of transmission burst.
3. Select the duration. Generate a uniformly distributed random t_D variable in the range 36uSec...180uSec.
4. Generate a white gaussian noise process with double sided PSD of N_0.
5. Filter the noise process with *H(f)* given above.
6. Select center frequency, f_i in the range –10MHz…10MHz.
7. Shift the signal in frequency by multiplying it by $\exp(j2\pi f_i t)$.
8. Select amplification. Generate a random variable α, uniformly distributed in the range 0…20. Set the amplification to $G=10^{\alpha/20.}$
9. Take a segment of t_D of the generated signal. Add it to the desired signal at the start time selected in steps 1 and 2.
10. Repeat with step 1.

4. Radio Impairments

The radio impairments models consist of phase noise models and power amplifier non-linearties.

4.1 Power amplifier non-linearity

The power amplifier model is based on the well-known Rapp's model ([5]) with knee parameter P=2. Besides its simplicity, the model well represents typical power amplifiers at the sub 10GHz range.

Consider using a complex baseband notation. Denote by v_{IN} and v_{OUT} the input and output complex signals, respectively. Let $P_{SAT} = |v_{SAT}|^2$ denote let the saturated power of the amplifier be $P_{SAT} = |v_{SAT}|^2$. Then the relation between v_{IN} and v_{OUT} is given by:

$$v_{OUT} = v_{IN} \Big/ \left(1 + \left(|v_{IN}| / v_{SAT}\right)^{2P}\right)^{1/(2P)}, P = 2 \ .$$

4.2 Phase noise

For the phase noise simplified phase noise model is selected. While maintaining a simple description the model adequately represent the behavior of typical microwave phase-locked loop oscillator.

The phase noise is presented as white gaussian noise process for which is driven through a single pole low pass filter. The 3dB corner of the low-pass should be set at 10KHz, which is a typical value for large step oscillators. A typical PSD is shown in Figure 5.

The model ignores the contribution of the oscillator phase noise, which can be easily tracked and the effects of phase noise PSD flattening in high frequencies.

For simplicity it is recommended that the phase noise effects shall be simulated only on the transmitter side.

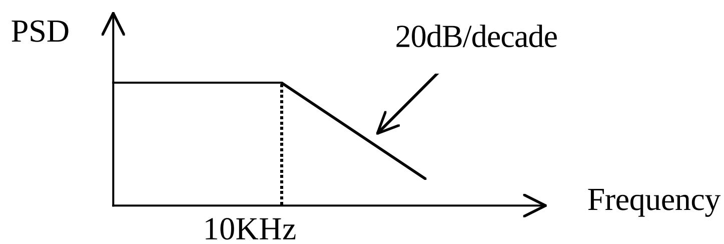

Figure 5 Phase noise PSD

5. Acknowledgements

It is a pleasure to acknowledge Dr. Vladimir Yanover for his assistance with the Caida database.

6. References

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[2] C. Tellambura, Y.J. Guo and S.K, Barton: Equalizer Performance for HiperLAN Indoor channels”, *Wireless Personal Comuunications vol.* 3, pp. 397-410 Feb. 1996.

[3] IEEE 802.11 Wireless LAN standard: high speed Physical layer in the 5Ghz Band.

[4] http://www.caida.org/outreach/papers/Inet98/

[5] Rapp, C. "Effects of HPA non-linearity on 4-DPSK/OFDM Signal for Digital Sound Broadcasting System" *Proceedings of the Second European Conference on Satellite Communications*, Liege Belgium pp.179-184, Oct 22-24 1991.