AVERAGE POWER – DELAY PROFILES IN SHORT-RANGE UWB TRANSMISSIONS

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The ultra wideband (UWB) communication system proved to be a new and reliable system for wireless communications due it capacity to provide low power, short range high date rate, fade free, relatively shadow-free communications in a dense multipath propagation environment. Ultra wideband systems with the multi-band orthogonal frequency division multiplexing techniques (ODFM) represent a promising technology for future high-speed networks.

Keywords: ultra wideband, orthogonal frequency division multiplexing, average power delay

1. INTRODUCTION

In our days is a great demand for low cost, high-rate transmission, low-power consume communication systems. One of the most effective and attractive technology is using the ultra wideband systems (UWB). UWB is defined as any radio technology having a spectrum that occupies a bandwidth greater than 20 percent of the center frequency, or a bandwidth of at least 500 MHz There are many types of UWB systems which are using the 3.1 – 10.6 GHz unlicensed spectrum: time-hopping spread spectrum impulse radio, direct sequence spread spectrum impulse radio and the last and the most interesting is ultra wideband systems with the multi-band orthogonal frequency division multiplexing techniques (UWB ODFM). The standardization group IEEE 802.15.3a developed a standard for orthogonal frequency division multiplexing (OFDM), combined with time-frequency interleaving. In that way it is covered UWB communication systems for wireless personal network area (WPAN).

The standardization group IEEE 802.15.3a developed a standard for such systems. The target bit rates of this new standard are data rates of up to 110 Mbit/s at 10m distance, 200Mbit/s at 6m distance, and optional up to 480 Mbit/s at 2m distance.

2. THEORETICAL APPROACH

The IEEE 802.15 Task Group 3a proposed system uses 128 sub-carriers that are modulated using quadrature phase shift keying (QPSK). System uses a convolutional encoder. The system operates in the 3.1 – 10.6 GHz frequency range. The spectrum is divided into 13 sub-bands, each subband being 528 MHz wide. The relationship between center frequency and band number is given by equation (1):

$$f_{center} = 2904 + 528 * n_b \text{ (MHZ)}, \; n_b = 1,\ldots,14 \quad (1)$$

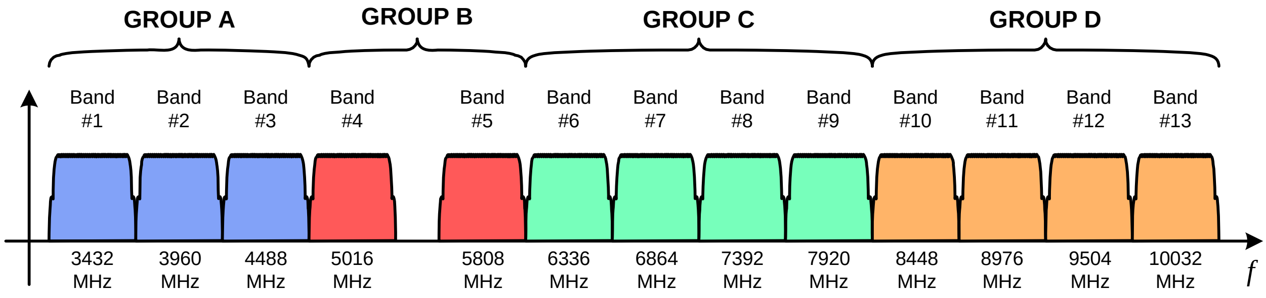

Figure 1. Band allocation for OFDM UWB

With these 13 bans are defined five band groups: four groups of three bands and one group of two bands. Band groups 1, meaning bands 1 – 3, is used for Mode 1 devices (mandatory mode),(fig. 2) while the remaining band groups are reserved for future use.

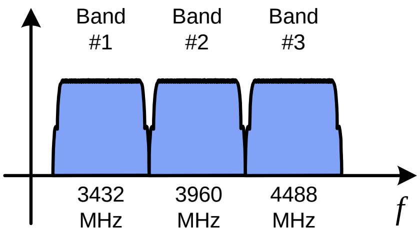

Figure 2. Frequency of operation for a Mode 1 device.

Users share these bands according to assigned time-frequency codes. Each subband has 128 sub-carriers among which there are 100 data tones for information transmission, 12 pilot tones, 10 guard tones and 6 reserved null tones for peak-to-average power ratio reduction.

Clustered OFDM is a promising technique for high-rate OFDM systems where adjacent OFDM tones in each subband are further grouped into non-overlap clusters. The clustered OFDM has some additional advantages beside those offered by the classical OFDM, such as in-band diversity gain, reduced peak-to-average power ratio, hardware simplicity.

A clustered multiband OFDM system is a particular type of a multi-carrier system where the transmitted bandwidth is divided into some marrow subchannels that are transmitted in parallel. A block diagram for a clustered multiband OFDM based UWB system in presented in figure 3.

The transmitted signal is:

$$r_{RF}(t) = \mathrm{Re}\left\{ \sum_{k=0}^{N-1} r_k (1 - kT_{sym}) \exp(j2\pi f_k t) \right\} \quad (2)$$

where *Re(*)* represent the real part of a complex variable, $r_k(t)$ is the complex baseband signal of the *k*-th OFDM symbol and is nonzero over the interval from 0 to T_{sym}, N is the number of OFDM symbols, T_{sym} is the symbol interval and f_k is the center frequency of the *k*-th band.

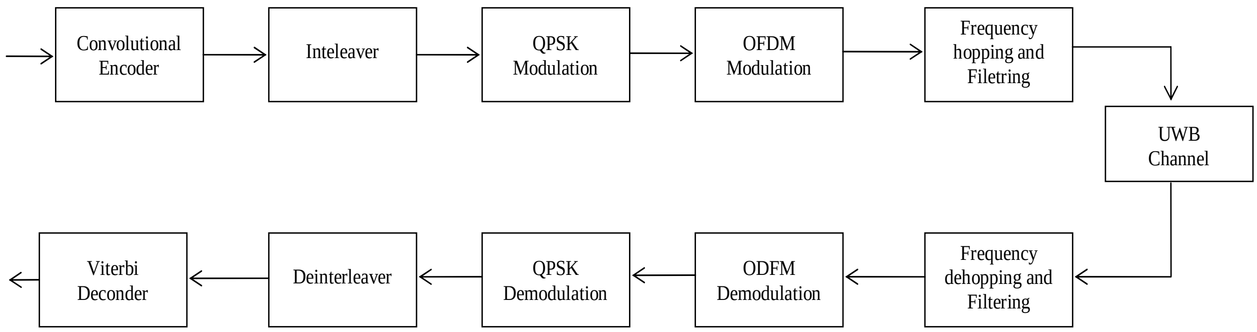

Figure3. Block diagram for a OFDM UWB system

The multipath model is a Saleh-Valenzuela model, modified so that multipath gains have a lognormal distribution rather than a Rayleigh distribution. The standard propose four channel models for different propagation environments. So we have:

- CM1: channel model 1, used for line of sight (LOS) scenario with a distance between the transmitter and the receiver smaller than 4 meters.
- CM2 : channel model 2, used for a non line of sight (NLOS) scenario with a distance between the transmitter and receiver smaller than 4 meters.
- CM3 : channel model 3, used for a non line of sight (NLOS) scenario with a distance between the transmitter and receiver between 4 and 10 meters.
- CM4 : channel model 4, used for an extreme non line of sight (NLOS) scenario with 25 ns RMS delay spread.

Tabel 1 contain the channel target characteristic, model parameters and model characteristic for these channels.

Table 1
Multipath target characteristic model parameters and model characteristic

	CM1	**CM2**	**CM3**	**CM4**
τ_m [ns[(means excess delay)	5.05	10.38	14.18	
τ_{rms} [ns] (rms delay spread)	5.28	8.03	14.28	25
NP (85%) (number of paths that capture 85% of channel energy)	24	36.1	61.54	
MODEL PARAMETERS				
Λ [1/nsec] (cluster arrival rate)	0.02 33	0.4	0.0067	0.0067
λ [1/nsec] (ray arrival rate)	2.5	0.5	2.1	2.1

Γ (cluster delay factor)	7.1	5.5	14	24
γ (ray delay factor)	4.3	6.7	7.9	12
σ_1 [dB] (stand dev. of cluster lognormal fading term in dB)	3.4	3.4	3.4	3.4
σ_2 [dB] (stand dev. of ray lognormal fading term in dB)	3.4	3.4	3.4	3.4
σ_x [dB] (stand dev. of lognormal fading term for total multipath realization in dB)	3	3	3	3
MODEL CHARACTERISTIC				
τ_m	5.0	9.9	15.9	30.1
τ_{rms}	5	8	15	25
NP_{10dB} (number of paths within 10 dB of the strongest paths)	12.5	15.3	24.9	41.2
NP (85%)	20.8	33.9	64.7	123.3
Channel energy mean [dB]	-0.4	-0.4	0.0	0.3
Channel energy std dev. [dB]	2.9	3.1	3.1	2.7

Because of the very short distance between the transmitter and the receiver, the terminal mobility in very limited and thus the model assumes the channel to be time-invariant within the transmission of each packet.

Impulse response is modeled by the following equation:

$$h_i(t) = X_i \sum_{l=0}^{L} \sum_{k=0}^{K} \alpha_{k,l}^{i} \delta(\tau - T_l^i - \tau_{k,l}^i) \qquad (3)$$

where :

$\alpha_{k,l}^i$ - are the multipath gain coefficients, T_l^i is the delay of the *l*-th cluster, $\tau_{k,l}^i$ is the delay of the *k*-th multipath component relative to the *l*-th arrival time (T_l^i), X_i represents the log-normal shadowing , and *i* refers to the *i*-th realization .

We use the following definition for the proposed model:

T_l = the arrival of the first path of the *l*-th cluster

$\tau_{k,l}$ = the delay of the *k*-th cluster path within the *l*-tj cluster relative to the first path arrival time, T_l. By definition, $\tau_{0,l} = 0$.

Λ = cluster arrival rate

λ = ray arrival rate, meaning the arrival rate of path within each cluster.

The distribution of cluster arrival time and the ray arrival time are given by the equations (4):

$$p\left(T_l \middle| T_{l-1}\right) = \Lambda \exp[-\Lambda(T_l - T_{l-1})], \quad \mathrm{l} > 0$$
$$p\left(\tau_{k,l} \middle| \tau_{(k-1),l}\right) = \lambda \exp[-\lambda(\tau_{k,l} - \tau_{(k-1),l})], \quad \mathrm{k} > 0 \tag{4}$$

The channel coefficients are defined as a product of *l-th* cluster fading coefficient ξ_l and the fading coefficient $\beta_{k,l}$, associated with the *k*-th ray of the *l*-th cluster.

$$\alpha_{k,l} = p_{k,l}\xi_l\beta_{k,l}, \tag{5}$$

where $p_{k,l}$ is equiprobable ± 1 to account for signal inversion due to reflections.

The fading is log-normal distributed:

$$20\lg(\xi_l\beta_{k,l}) \approx \mathcal{N}(\mu_{k,l}, \sigma_1^2 + \sigma_2^2) \tag{6}$$

and

$$\left|\xi_l\beta_{k,l}\right| = 10^{\frac{\mu_{k,l}+n_1+n_2}{20}} \tag{7}$$

where

$$n_1 \approx \mathcal{N}(0, \sigma_1^2) \quad \text{and} \quad n_2 \approx \mathcal{N}(0, \sigma_2^2) \tag{8}$$

are independent and correspond to the cluster fading (n_1) and ray fading (n_2).
The behavior of the averaged power delay profile is:

$$E\left[\left|\xi_l\beta_{k,l}\right|^2\right] = \Omega_0 e^{-\frac{T_l}{\Gamma}} e^{-\frac{\tau_{k,l}}{\gamma}} \tag{9}$$

which reflects the exponential delay of each cluster, as well as the decay of the total cluster power delay.

The $\mu_{k,l}$ is given by:

$$\mu_{k,l} = \frac{10\ln(\Omega_0) - 10\frac{T_l}{\Gamma} - 10\frac{\tau_{k,l}}{\gamma}}{\ln(10)} - \frac{\left(\sigma_1^2 + \sigma_2^2\right)\ln(10)}{20} \tag{10}$$

This model contains a number of simplification. We considered that the cluster and rat arrival rates are delay-invariant. The model assumes that the variance of the lognormal fading is independent of the delay.

3. Simulations and Conclusions

For each channel model a Monte Carlo simulation has been developed. The average power delay profiles were simulated and the results plotted in figure 4.

These graphs show clearly the differences between the four channel types:

- CM1 is a channel model for short distance, line of sight communication: we don't have reflections of the received signal (for –10dB we have almost no delay) .
- CM2 – CM4 are channel models for non line of sight communication (the channel model with a bigger number, means worse conditions). For CM2, for example, we have few reflections, and for –10 dB we have a 20 ns delay, while for CM4 we have to wait about 80ns for a –10 dB reception.

As it was expected, the CM4 model gives the most difficult propagation conditions. The communication system must be designed according with these characteristics: it must accept a propagation delay of at least 250 ns and also 250 ns delay spread and the receiver have to equalize this delay spread.

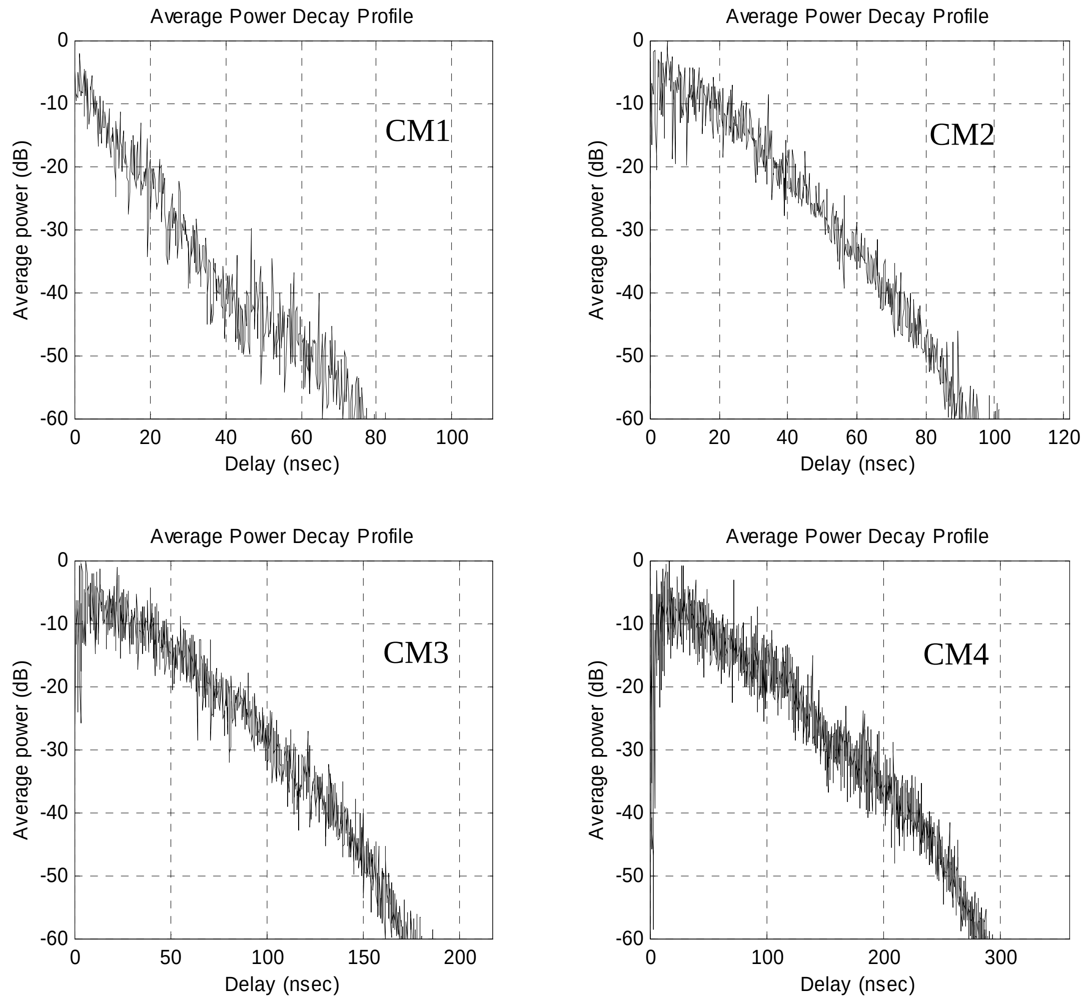

Figure 4. The block average power decay profile for CM1-4 channel models

The choose between one channel model or another depends on the conditions imposed by the conditions in the propagation area and the user requirements.

4. REFERENCES

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