A Comparison of energy efficiency for UWB Modulations

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Outline

- Objectives
- UWB modulations descriptive
- The system model
- UWB modulations comparative
- Conclusions and perspectives

Objectives (1/2)

Green Communication:

- The growing demand of data from mobile networks users ➡ greater energy consumption and greater CO_2 rejections.
- Researchers presented a concept called "Green communications".
- The key techniques of Green Communication are:
  - Cognitive Radio: improve the spectrum utilization efficiency and the network transmission performance.
  - Network coding: remove the redundant routes ➡ optimize the throughput ➡ the effect of energy and bandwidth saving.
  - Smart Grid: the combination of new communication techniques, hardware and software optimization to save energy.

Objectives (2/2)

- This work is a part of the third category of green communications techniques.
- The UWB system is chosen:
  - low energy consumption
  - low complexity.
- Using an Analytical model to compare the energy consumption of modulation techniques.
- Comparing the energy efficiency of some commonly used UWB modulations in a multi-path environment.

efficient modulation for future applications.

UWB modulations descriptive (1/3)

PPM (Pulse Position Modulation):

- Transmitting a short pulse with a delay in time if the transmitted bit is 1.
- The PPM signal:

$$s = \sqrt{\frac{E_t}{N_s}} \sum_{j=-\infty}^{+\infty} p(t - jT_f - c_j T_c - d[j/N_s]\delta)$$

- The duration of a pulse: T_p and the bandwidth: B= $\frac{1}{T_p}$.
- T_f=βT_p $(\beta > 100)$, the symbol duration: $T_s = N_s T_f$

UWB modulations descriptive(2/3)

PAM (Pulse Amplitude Modulation)

- Transmitting a short pulse with different level of Amplitude for 0 and 1.
- The PAM signal:

$s = \sqrt{\frac{E_t}{N_s}} \sum_{j=-\infty}^{+\infty} A_{d[j/N_s]} p(t - jT_f - c_j T_c)$, $\sqrt{\frac{E_t}{N_s}} A_{d[j/N_s]}$ is one of the possible amplitude, $A_{d[j/N_s]} = 2\mathrm{d}[j/N_s] - 3$ and $E_t = {E_{av}}/{3}$

- Parameters are defined like the PPM case.

UWB modulations descriptive (3/3)

PSM (Pulse Shape Modulation):

- Transmitting a short pulse with two different waveforms for 0 and 1.
- The PSM signal:

$s = \sqrt{\frac{E_t}{N_s}} \sum_{j=-\infty}^{+\infty} P_{d[j/N_s]}(t - jT_f - c_j T_c)$ with $P_{d[j/N_s]}$ is one of the possible waveforms.

- Parameters are similar to the PPM's ones.

The system Model (1/2)

- The time duration to transmit N bit: $T = T_{ac} + T_{sl} + T_{tr}$
- The energy needed to transmit N bit:

$$E = P_{ac}T_{ac} + P_{sl}T_{sl} + P_{tr}T_{tr} \quad (P_{ac} \gg P_{sl} \Rightarrow P_{sl} = 0)$$

- The total energy consumed to transmit 1 bit :

$$E_a = \frac{(P_t+P_c)T_{ac}+P_{tr}T_{tr}}{N}$$

P_t: the transmission power, P_c=P_{ct}+P_{cr} : the power of the transceiver circuitry.

The system Model (2/2)

- For transmission: $P_{ct} = P_{pg} + P_{amp} + P_{filt}$

$$P_{amp} = \alpha P_t \qquad (\alpha = \frac{\xi}{\eta} - 1)$$

- For PAM and PPM:

$$P_{cr} = P_{LNA} + P_{mix} + P_{int} + P_{pg} + P_{filr} + P_{ADC}$$

- For PSM:

$$P_{cr} = P_{LNA} + 2(P_{mix} + P_{int}) + P_{pg} + P_{filr} + P_{ADC}$$

UWB modulations comparative (1/10)

The average BER in a UWB channel for PPM and PSM: $P_e = \int_0^{+\infty} Q(\sqrt{SNR.x}) f_h(x) dx$

After approximations:

- In case of non-severe fading: $P_e \leq \frac{2^{n-1} n!}{SNR^n} \exp(n^2 \frac{\sigma^2}{2} - n\mu) \quad \forall\, n \in N$ (Lognormal approximation)
- In case of severe fading: $P_e \approx \frac{p\lambda_1 + (1-p)\lambda_2}{SNR}$ (coxian approximation)

UWB modulations comparative (2/10)

- $T_s = N_s T_f$, so $T_s = \frac{\beta}{B}$. $T_{ac} = NT_s$ thus $T_{ac} = \frac{N\beta}{B}$ $(N_s = 1)$
- In case of non-severe fading for n=1:

$$P_e = \frac{1}{SNR}\exp(\frac{\sigma^2}{2} - \mu) \text{ so SNR=}\frac{1}{P_e}\exp(\frac{\sigma^2}{2} - \mu)$$

$$\text{SNR=}\frac{E_s}{N_0} = \frac{E_t}{G_d N_0} = \frac{P_t T_s}{G_d N_0} \text{ then } P_t T_s = N_0 \frac{1}{P_e}\exp(\frac{\sigma^2}{2} - \mu) G_d \quad (G_d = M_l d^k G_1)$$

$$\Rightarrow P_t T_{ac} = N_0 \frac{1}{P_e}\exp(\frac{\sigma^2}{2} - \mu) G_d \mathrm{N}$$

- Total energy consumption:

> $E_{a,PPM} = (1 + \alpha) N_0 \frac{1}{P_e}\exp(\frac{\sigma^2}{2} - \mu) G_d + \frac{(P_{c,PPM} - P_{amp}) T_{ac}}{N}$

> $E_{a,PSM} = (1 + \alpha) N_0 \frac{1}{P_e}\exp(\frac{\sigma^2}{2} - \mu) G_d + \frac{(P_{c,PSM} - P_{amp}) T_{ac}}{N}$

UWB modulations comparative (3/10)

- In case of severe fading:

$P_e \approx \frac{p\lambda_1+(1-p)\lambda_2}{SNR}$ so $SNR = \frac{p\lambda_1+(1-p)\lambda_2}{P_e}$

SNR= $\frac{E_s}{N_0} = \frac{E_t}{G_d N_0} = \frac{P_t T_s}{G_d N_0}$ then $P_t T_s = N_0 \frac{p\lambda_1+(1-p)\lambda_2}{P_e} G_d$

$$\Rightarrow \quad P_t T_{ac} = N_0 \frac{p\lambda_1+(1-p)\lambda_2}{P_e} G_d N$$

- Total energy consumption:
  - $E_{a,PPM} = (1+\alpha)N_0 \frac{p\lambda_1+(1-p)\lambda_2}{P_e} G_d + \frac{(P_{c,PPM}-P_{amp})T_{ac}}{N}$
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UWB modulations comparative (4/10)

The average BER in a UWB channel for PAM:

$$P_e = \int_0^{+\infty} Q\left(\sqrt{2SNR.x}\right) f_h(x)dx$$

After approximations :

- In case of non-severe fading: $P_e \leq \frac{2^{n-1}n!}{(2SNR)^n} \exp(n^2 \frac{\sigma^2}{2} - n\mu)$ $\forall\, n \in N$ (Lognormal approximation)
- In case of severe fading: $P_e \approx \frac{p\lambda_1+(1-p)\lambda_2}{2SNR}$ (coxian approximation)

UWB modulations comparative (5/10)

- we have $T_s = N_s T_f$, so $T_s = \frac{\beta}{B}$. $T_{ac} = NT_s$ thus $T_{ac} = \frac{N\beta}{B}$
- In case of non-severe fading for n=1:

$$P_e = \frac{1}{2SNR}\exp(\frac{\sigma^2}{2} - \mu) \text{ Alors SNR}=\frac{1}{2P_e}\exp(\frac{\sigma^2}{2} - \mu)$$

$$\text{SNR}=\frac{E_s}{N_0} = \frac{E_t}{G_d N_0} = \frac{P_t T_s}{G_d N_0} \text{ donc } P_t T_s = N_0 \frac{1}{2P_e}\exp\left(\frac{\sigma^2}{2} - \mu\right) G_d$$

$$\Rightarrow \quad P_t T_{ac} = N_0 \frac{1}{2P_e}\exp(\frac{\sigma^2}{2} - \mu) G_d \mathrm{N}$$

- Total energy consumption:

$$E_a = (1+\alpha) N_0 \frac{1}{2P_e}\exp(\frac{\sigma^2}{2} - \mu) G_d + \frac{(P_{c,PAM} - P_{amp}) T_{ac}}{N}$$

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UWB modulations comparative (6/10)

- In case of severe fading:

$P_e \approx \frac{p\lambda_1+(1-p)\lambda_2}{2SNR}$ so $SNR = \frac{p\lambda_1+(1-p)\lambda_2}{2P_e}$

SNR$= \frac{E_s}{N_0} = \frac{E_t}{G_d N_0} = \frac{P_t T_s}{G_d N_0}$ then $P_t T_s = N_0 \frac{p\lambda_1+(1-p)\lambda_2}{2P_e} G_d$

$$\Rightarrow \quad P_t T_{ac} = N_0 \frac{p\lambda_1+(1-p)\lambda_2}{2P_e} G_d N$$

- Total energy consumption:

➢ $E_{a,PAM} = (1+\alpha) N_0 \frac{p\lambda_1+(1-p)\lambda_2}{2P_e} G_d + \frac{(P_{c,PAM}-P_{amp})T_{ac}}{N}$

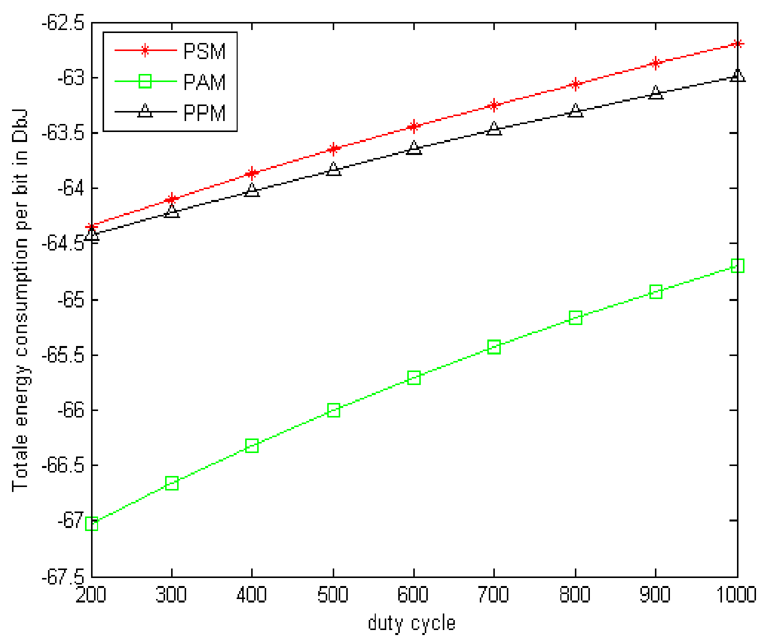
UWB modulations comparative (7/10)

Simulation parameters:

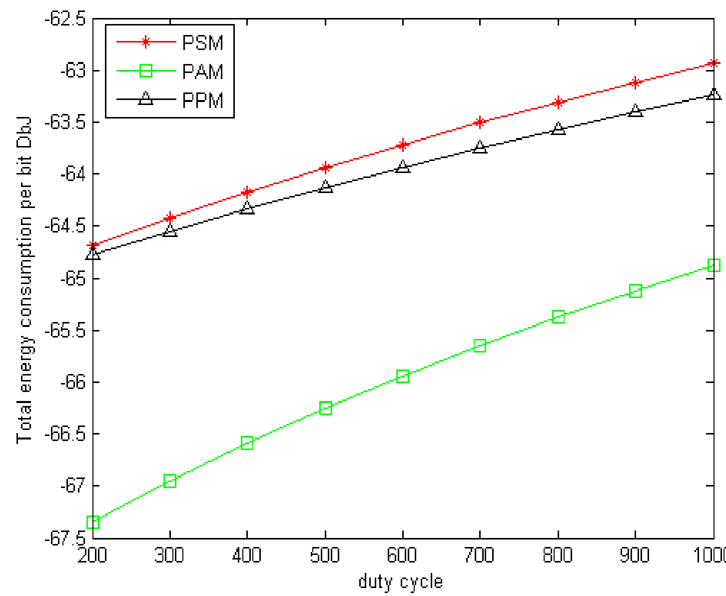
$f_c = 4\ GHZ$	$\eta = 0.6$	$k = 3.5$
$N_0 = -170$dBm/Hz	$B = 500\ MHZ$	$N = 10^6$
$P_{pg} = 25.2\ mW$	$P_{LNA} = 7.68\ mW$	$P_{mix} = 15\ mW$
$P_{int} = 2.5\ mW$	$P_{ADC} = 7.6\ mW$	$P_{VGA} = 12\ mW$
$P_{ED} = 10.8\ mW$	$P_{filt} = P_{filtr} = 2.5\ mW$	$M_l = 40\ dB$
$G_1 = 28\ dB$	$P_e = 10^{-3}$	β=500
$\mu = -0.0039$	$\sigma = 0.6883$	$\lambda_1 = 4.9$
$\lambda_2 = 65.44$	p=1.0617	d=10

UWB modulations comparative (8/10)

Non-severe fading

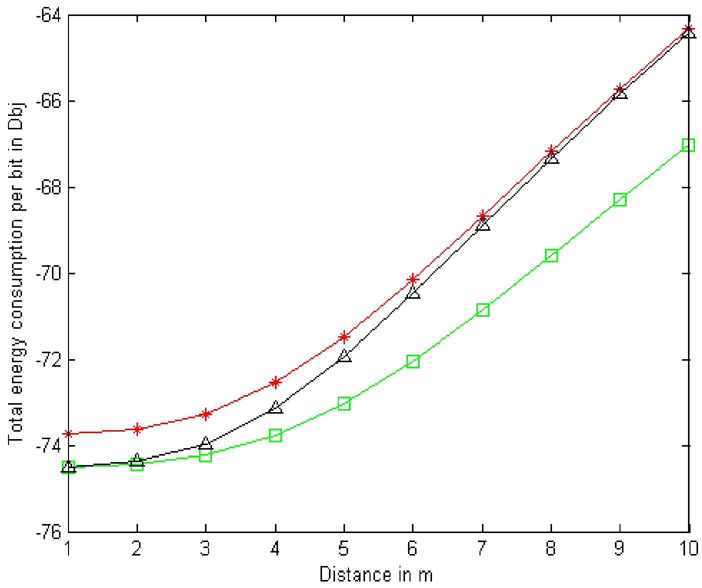


Severe fading

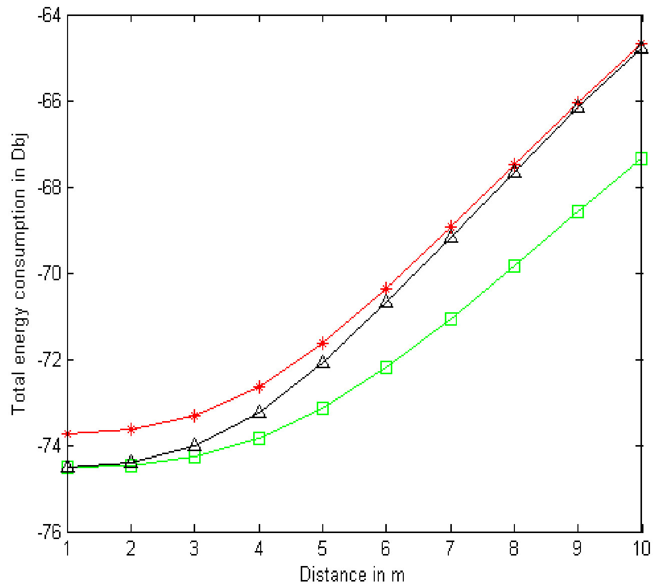


UWB modulations comparative (9/10)

Non-severe fading

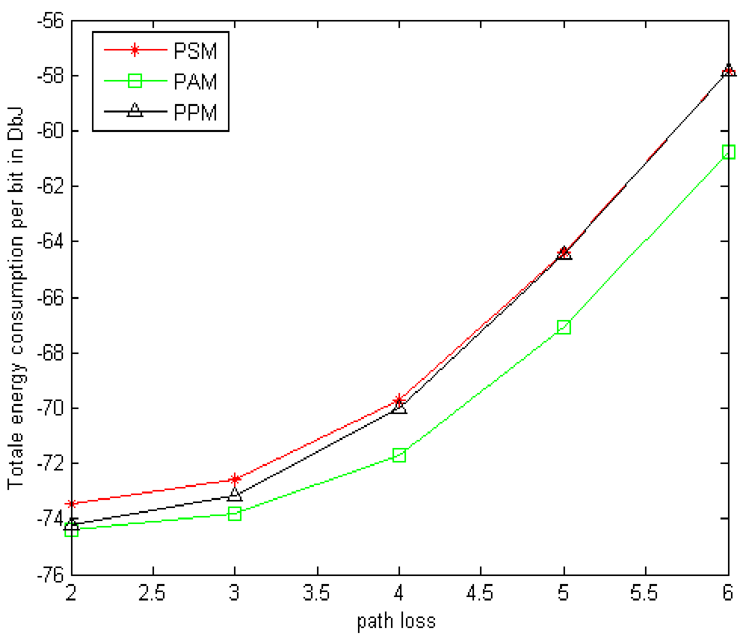


Severe fading

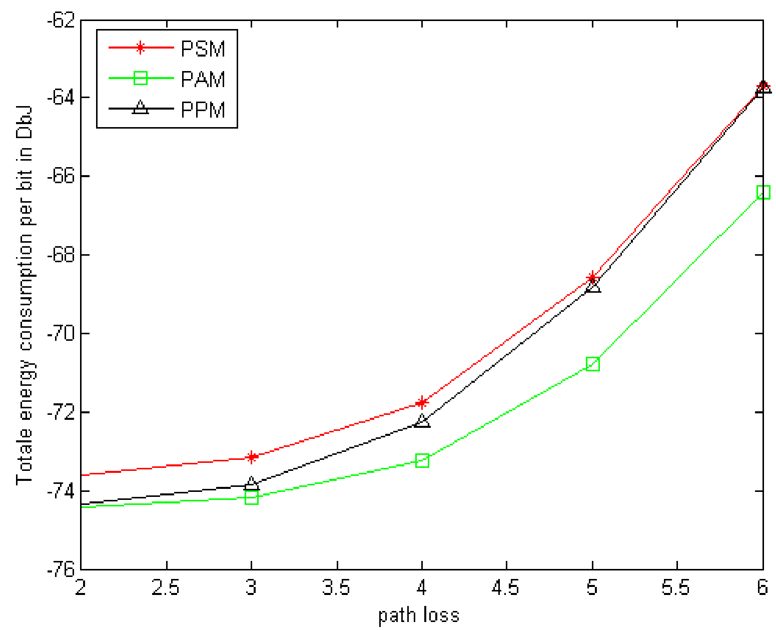


UWB modulations comparative (10/10)

Non-severe fading
$(G_d = M_l d^k G_1)$



Severe fading
$(G_d = M_l d^k G_1)$



Conclusion and perspectives

- PAM is a good candidate for green modulation:
  - Energy Effeciency.
  - Low hardware complexity.

Perspectives

- Short term:
  - Testing the model in multi-user environement
  - finding the energy efficient spreading sequences.
- Long term:
  - Using the results to design an energy efficient railway balise.

Aknowledgment

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Thank you for your attention