Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Experimental Test of UWB Signaling for BANs]

Date Submitted: [15 July 2008]

Source: [Marco Hernandez, Ryuji Kohno] **Company:** [NICT]

Address: [3-4 Hikarino-oka, Yokosuka, 239-0847, Japan]

Voice: [+81 468475439] **Fax:** [+81 468475431] **Email:** [Marco@nict.go.jp]

Re: []

Abstract: [The presentation shows some preliminary tests of UWB techniques in a test bed.]

Purpose: [Identifying trade-offs among performance, feasibility of implementation , scalability and safety for BAN applications.]

Experimental Test of UWB Signaling for BANs

NICT, Japan

Motivation

UWB as a potential candidate for on-body communications

- UWB implemented with simple transceivers can offer
  - Low implementation complexity (critical for low power consumption)
  - Low transmitting power (body safety and interference)
  - It might give bit rate scalability from LDR (medical) to HDR (non-medical)
- Caveat: no every UWB solution offers those simultaneously.

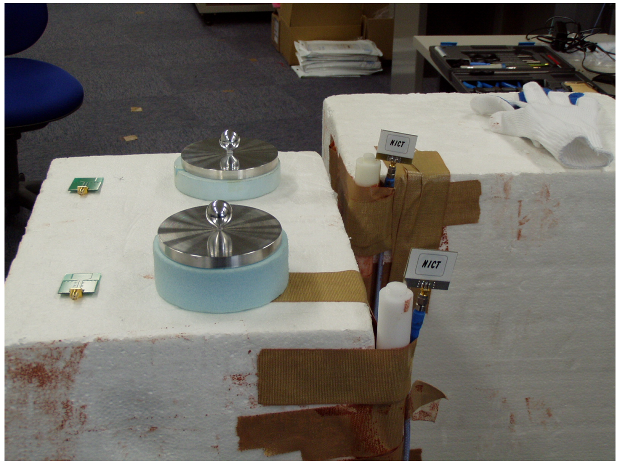
Motivation

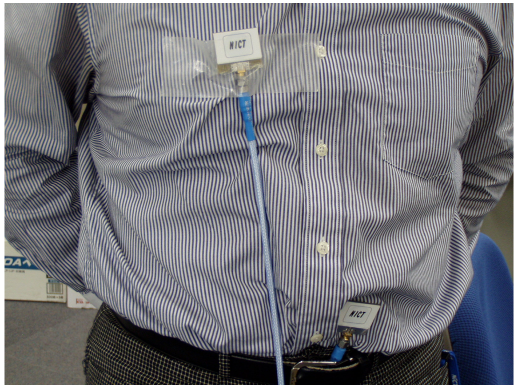
From a signal design perspective we study some UWB implementations in a test bed, so we can have useful insights for design.

- It allows to implement arbitrary discrete UWB signals with a minimum sampling time of 0.1 nsec and 4 bits of resolution.

Motivation

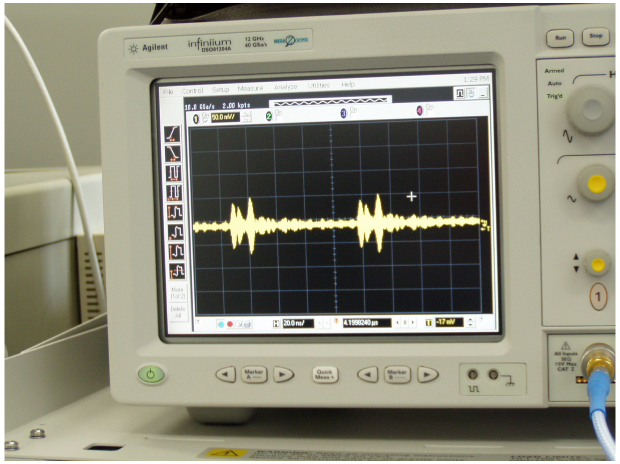
Set of available UWB antennas and set up

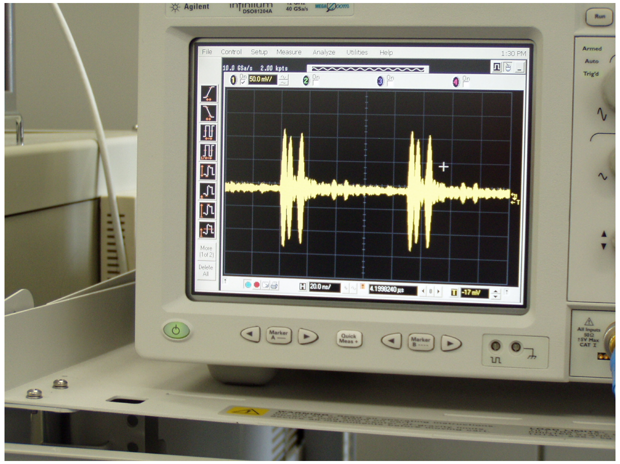




Preliminary Results

- Moving the antennas around the body trying to identify a creeping wave around the HB was not observed (UWB).
- If antennas are placed on my trunk, moving the body around the lab the reception changes dramatically.





Preliminary Conclusions

- The reception strength depends if the Rx antenna is catching refections from the environment.
- So, the ideal environment is indoors (UWB).
- If BAN is desired to be used outdoors, antennas should be in LOS. Otherwise, significant drop in performance.

UWB Signaling for BAN

A realistic implementation of UWB systems in BAN devices, those must be low complex, low power consumption and so feasible to integrate in a chip, and to power with a long lasting battery.

UWB is a "relative" new field (communications).

From a system design perspective it is well understood, but from a feasibility of implementation perspective (chip), it is still a topic of research.

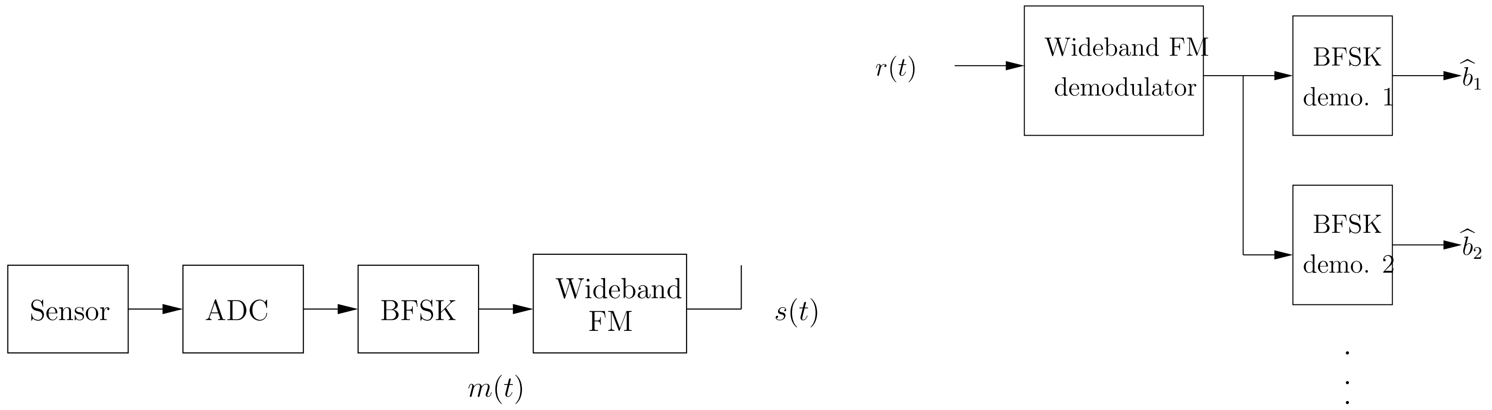
It is important to choose UWB candidate systems that are not only good in performance, complexity, etc., but that those can be implementable in a relative short time to hit markets.

We started studying three potential candidates.

FM-UWB

It is a hybrid system that concatenates BFSK and wideband FM.

- Several LDR BFSK signals might be allocated in the wideband FM modulator.



- Transmitted signal

$$s(t) = A\,\cos\left(2\pi f_c t + 2\pi k_f \int_{-\infty}^{t} m(t)\,dt\right)$$

- peak frequency deviation $\Delta f = k_f A_m$ and modulation index $\beta = \Delta f / f_m$.

FM-UWB

- **For** $\beta > 1$ **(wideband FM),** $s(t)$ **requires a transmission bandwidth of at least** $W_{\text{FM}} \simeq 2(f_m + \Delta f) = 2(\beta + 1) f_m$ **(Carson's rule).**

BFSK

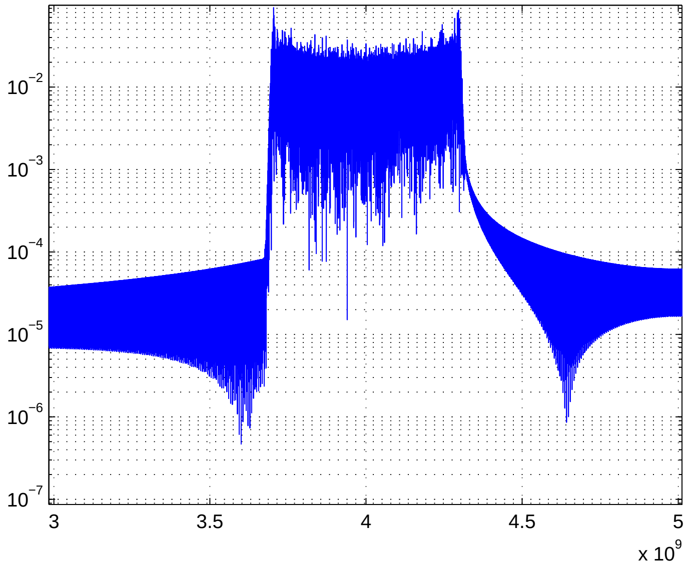
- $br = 250$ kbps, $f_1 = 800$ KHz, $f_2 = 1$ MHz $= f_m$
- $N_b = F_s/br = 10$ GHz/250 kbps $= 40,000$ **samples per bit**
- **Reason: signaling in passband.**
- **It does not mean it is bad. It is just difficult to implement/simulate with a digital front-end.**

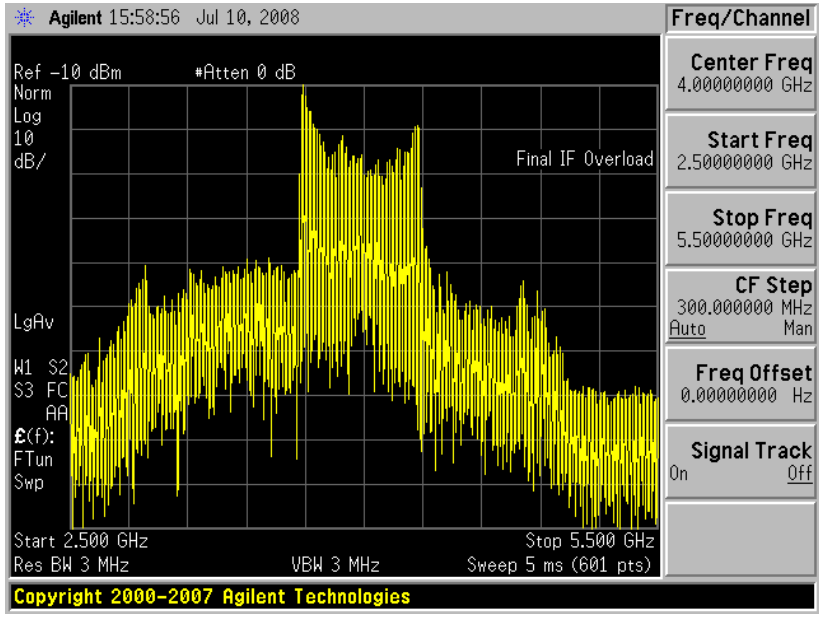
Wideband FM

- $f_c = 4$ GHz, $k_f = 300\text{x}10^6$, **so that** $\beta = k_f/f_m = 300$.
- $W_{\text{FM}} \simeq 2(300 + 1)1$ MHz $\simeq 602$MHz.

FM-UWB

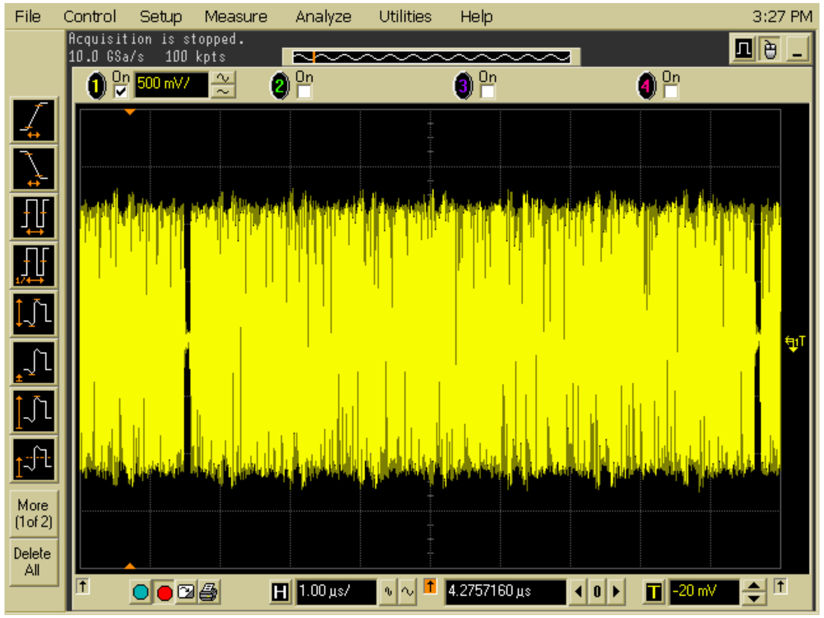
- Results in the frequency domain





FM-UWB

- Results in the digital sampling oscilloscope



- Due to finite memory of the DSO, it is possible to receive only few bits.
- Testing performance of FM-UWB would be easier with simulations with a very powerful computer or analog hardware.

DPSK

- Another interesting low complex UWB implementation is to employ a bandpass pulse shape with a carrier.
- In order to relax frequency carrier synchronization and channel estimation *differential* BPSK can be used.
- It does not require estimation of the carrier phase. Instead a phase estimate is derived from the previous symbol.
- The received signal of a non-coherent system is given by

$$r(t) = \sqrt{\frac{2E}{T}} \cos(\omega_0 t + \theta_i(t) + \alpha) + n(t)$$

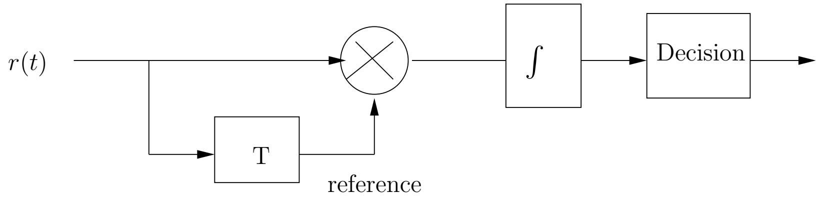
- where $\alpha \sim \mathcal{U}[0, 2\pi)$. If α varies slowly between two consecutive symbols:
- $(\theta_k(T_2) + \alpha) - (\theta_k(T_1) + \alpha) = \theta_k(T_2) - \theta_k(T_1) = \phi_i(T_2)$

DPSK

- It requires differential encoding of the message. If $a_n, b_n \in \{0,1\}$, $b_n = a_n \oplus b_{n-1}$
- Transmitted signal

$$x(t) = \sum_n (-1)^{b_n} p(t - nT) \cos(\omega_c t + \theta)$$

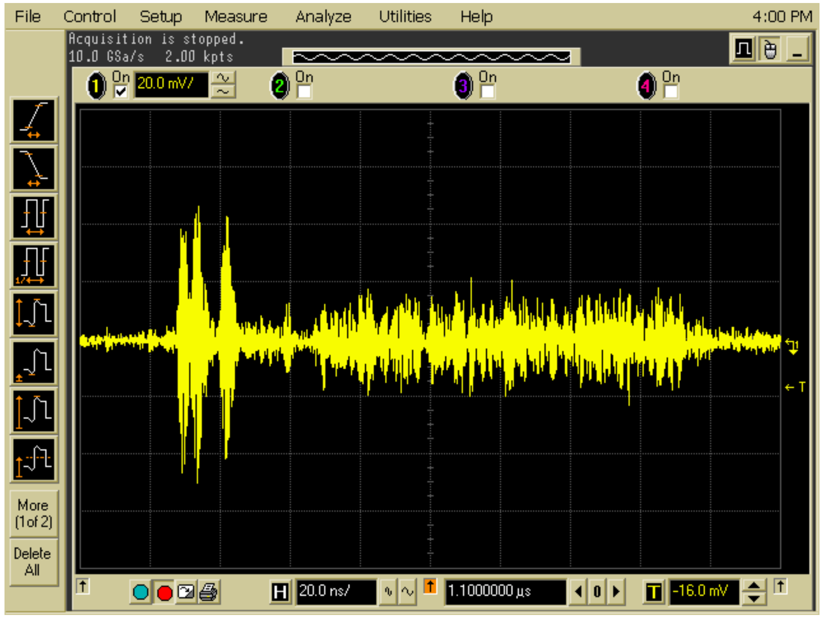
- Detection

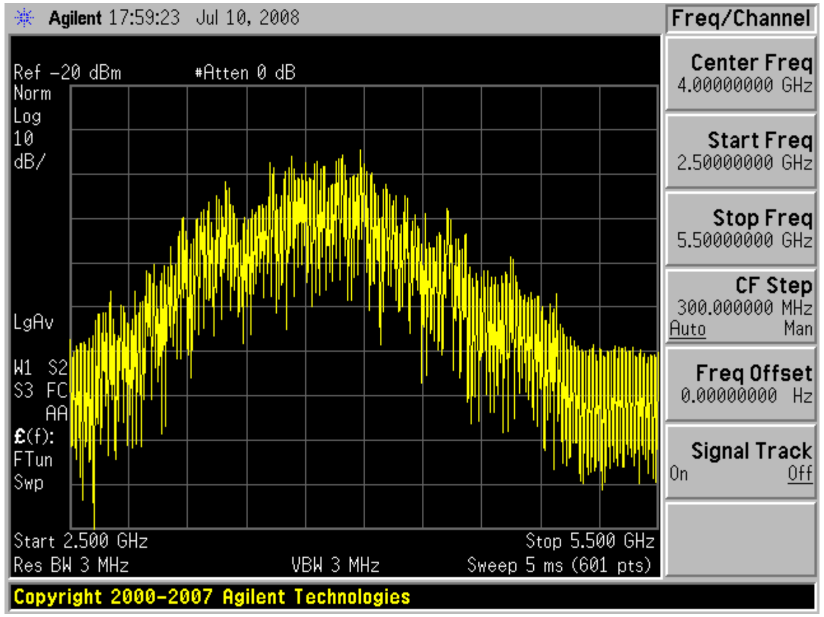


- Several pulse shapes are being tested.

DPSK

- Received signal

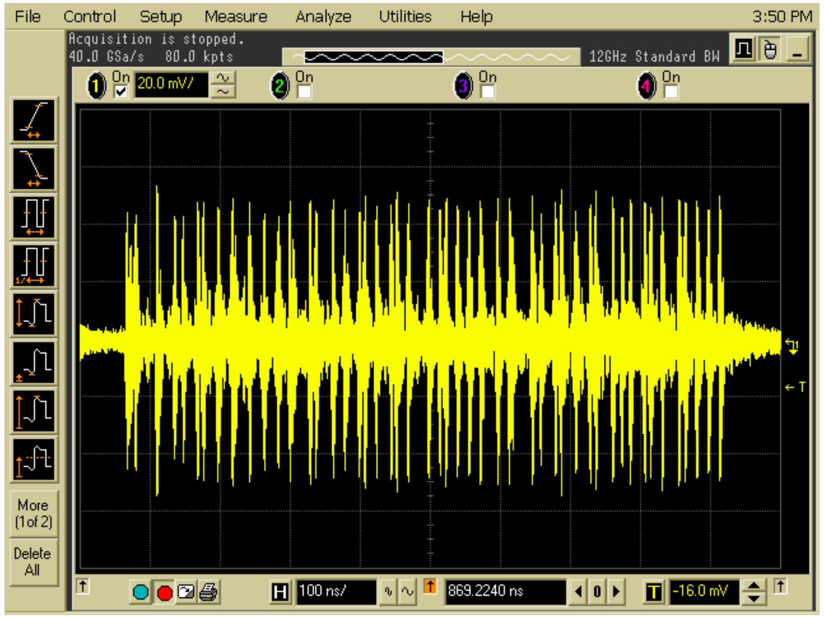


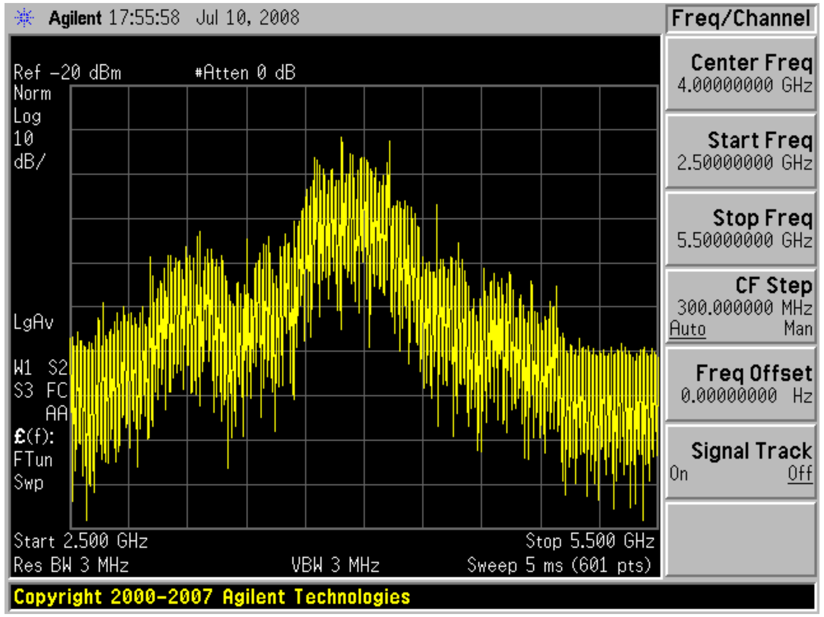


- We are processing the information for performance analysis.

On-off signaling

- Last but not least, another simple IR-UWB approach is to employ a pulse shape in passband (no carrier). Detection is performed by energy detection.
- Received signal





- By sending a probe signal, I can perform channel estimation and so to validate the proposed channel models for UWB.

Preliminary Conclusions

UWB PHY solution seems highly desirable for on-body BANs

- Although a realistic implementation in BAN devices, UWB systems must be low complex, low power consumption and so feasible to integrate in a chip, and to power with a long lasting battery.

So, a chip implementation of FM-UWB looks attractive.

- Still, we need to verify its performance and robustness in real BAN-UWB channels, as well as power consumption.
- It is limited to LDR.

Preliminary Conclusions

IR-UWB looks attractive as well.

- It can integrate potentially LDR and HDR applications.

But due to the high sampling rate, a digital implementation is difficult to achieve (too high power consumption).

State of the art on IR-UWB transceivers deals on how to decrease the power consumption and integration in a chip.

A transceiver architecture will be presented in September.

Multicarrier-Spread Spectrum structures are not considered yet.

References

[1] F.M. Gerrits, et.al., "Principles and Limitations of Ultra-Wideband FM Communications Systems", *EURASIP Journal on Applied Signal Processing*, Vol 2005 , Issue 1, January 2005, pp. 382 - 396.

[2] T. Norimatsu, et. al., "A UWB-IR Transmitter with Digitally Controlled Pulse Generator", *IEEE Journal of Solid Circuits*, Vol 42, No 6, June 2007.

[3] M. Hernandez, R. Kohno, "Ultra Low Power UWB Signal Design for Body Area Networks", *International Symposium on Medical Information and Communication Technology 2007*, December 2007, Oulu, Finland.