DELAY-BASED BPSK FOR PULSED-UWB COMMUNICATION

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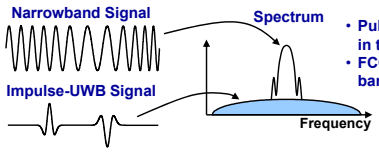
Background

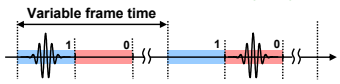
What is Pulsed-UWB Signaling?

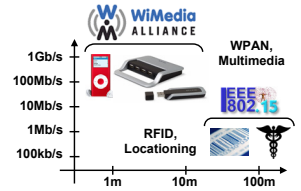


- Pulsed-UWB narrow in time, wide in freq.
- FCC defines UWB as bandwidth >500MHz

- Most common pulse-based modulations: BPSK, PPM
- PPM encodes data in pulse position in time

Pulse Position Modulation (PPM)



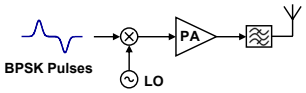


- UWB has a wide range of applications
- Optimal architecture depends on data rate
- High data rate – coherent (BPSK, OFDM)
- Low data rate – non-coherent (PPM)

Motivation

- BPSK is the most commonly used modulation
  - Used as primary modulation, or for scrambling spectrum
- Signal inversion for BPSK costly to implement in hardware (increased power and die area)

BPSK Transmitter Architecture



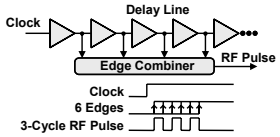
- Eliminating signal inversion enables digital architecture

All-digital transmitter ➡ Reduced power and area
Benefits from process scaling

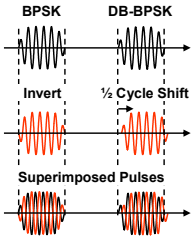
Delay-Based BPSK Modulation Technique

- Instead of inverting pulses (BPSK), delay by ½ of an RF period
- Suitable for delay line based class of pulse generators
  - Synthesize pulses from series of edges
  - Delay/stage is equal to ½ RF period

Delay Line Based Pulse Generator



Comparison of DB-BPSK to BPSK



- Signal spectrum can generally be described by continuous and discrete parts
- BPSK has only a continuous part

BPSK: $P(f)=\frac{1}{T_s}|S(f)|^2$

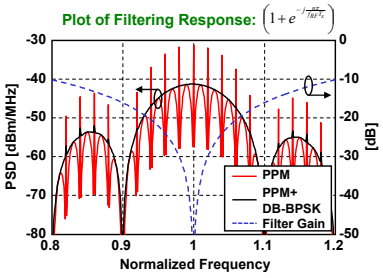
- DB-BPSK has continuous and discrete parts with additional filter term

DB-BPSK: (Filter term)

$$P(f)=\frac{1}{T_s}|S(f)|^2-\frac{1}{4T_s}\left|S(f)\left(1+e^{-j\frac{\pi f}{2f_s}}\right)\right|^2+\frac{1}{4T_s^2}\cdot\sum_{n=-\infty}^{\infty}\left|S\left(\frac{n}{T_s}\right)\left(1+e^{-j\frac{\pi n}{2f_sT_s}}\right)\right|^2\delta\left(f-\frac{n}{T_s}\right)$$

- At f=f_{RF}, the filter term = 0 and the equations collapse to only a continuous part

Plot of Filtering Response: $\left(1+e^{-j\frac{\pi f}{2f_s}}\right)$

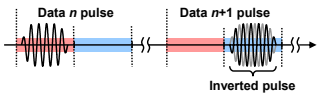


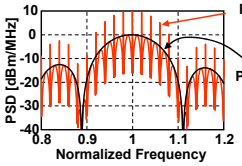
Pulsed-UWB Applications

Scrambling 2-PPM Signals

- PPM is known to produce a line spectrum
- Scrambling used to eliminate tones

Conventional PPM+BPSK



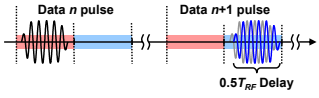


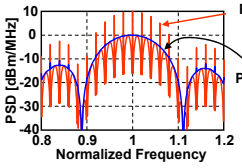
Randomly modulated PPM signal

PPM+BPSK scrambling eliminates tones

- BPSK is costly to implement in hardware
- DB-BPSK eliminates tones in main lobe

Proposed PPM+DB-BPSK





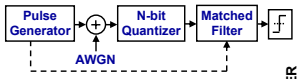
Randomly modulated PPM signal

PPM+Delay-Based BPSK scrambling eliminates tones in the main lobe

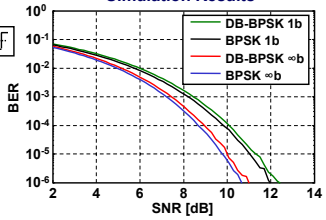
Replacement for BPSK modulation

- DB-BPSK can replace BPSK in a coherent receiver
- Simulated performance with a matched filter receiver architecture

Coherent Receiver



Simulation Results



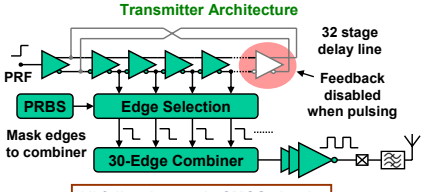
- Performance loss is function of number of cycles/pulse
- Loss is independent of ADC resolution in receiver

DB-BPSK can replace BPSK in a coherent receiver with 0.2dB loss

Experimental Verification

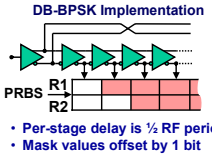
- Fabricated delay-line based transmitter RFIC
- All-digital architecture for greatest energy efficiency
- Generates PPM+DB-BPSK pulses in 3.1-5GHz band
- Supports three channels

Transmitter Architecture



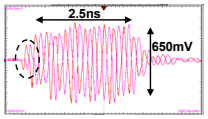
All full-swing static CMOS circuits

DB-BPSK Implementation

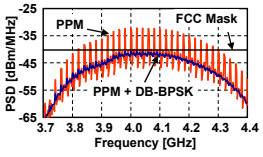


- Per-stage delay is ½ RF period
- Mask values offset by 1 bit

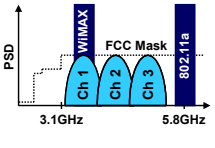
Measured DB-BPSK Pulses



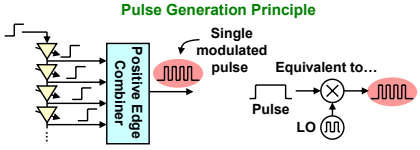
PPM + DB-BPSK Spectrum



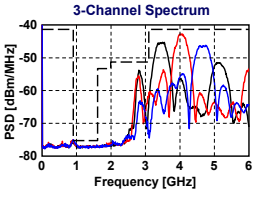
Three-Channel Frequency Plan



Pulse Generation Principle



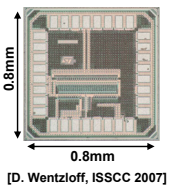
3-Channel Spectrum



Results Summary

Technology	90nm CMOS
Active Area	0.2x0.4mm²
Modulation	PPM
Scrambling	DB-BPSK
Supply	1V
Leakage Power	96µW
Active E/pulse	37pJ/pulse
PRF Range	10kHz to 16.7MHz
Total E/bit	9.6nJ/bit to 43pJ/bit

Die Photo



[D. Wentzloff, ISSCC 2007]

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