A Coding Technique for Spectral Shaping Ultra-Wideband Time Hopping Modulated Signals

UC San Diego

Center *for* Wireless COMMUNICATIONS

J. Jamp and L. Larson, University of California, at San Diego

Motivation

- *Ultra-Wideband*
  - Bandwidth: > 500MHz, or fractional BW > 20%
  - Frequency allocation: 3.1GHz-10.6GHz
  - Power spectrum density limited: -41.25 dBm/MHz
  - Many narrow-band interferers
    - 5GHz UNII band (802.11a, cordless telephones)
    - Airport and Marine Radars
    - WiMAX
  - Signal generation: Impulse (Gaussian Monopulse), DSSS, Spectral Encoding, etc.

1

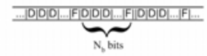
Motivation for Interference Mitigation

- *Narrowband interference (NBI)*
  - Receiver: Spectral notch at the NBI frequencies
  - Transmitter Shape signal spectrum to avoid transmitting in NBI bands
    - Reduced power consumption
- *Possible Solutions:*
  - Filters with desired spectral shape
    - Filters with narrow notches (<5% of BW) difficult and expensive to build
  - Techniques for spectral shaping
    - Coding
    - Spectral Encoding

2

Look Ahead Block Inversion

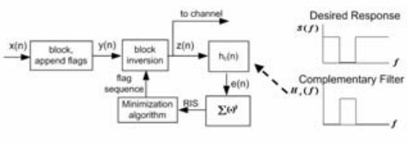
- *Described by Cavers and Marchetto (1991, Trans. Comm.)*
- *Allows for arbitrary shaping of a digital signal's spectrum through data block inversion*



- *Insert Flag bits to indicate polarity of the block*
- *Issues:*
  - Overhead
  - Achievable Spectral Shaping

3

Look Ahead Block Inversion



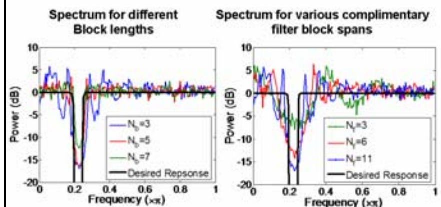
__Goal__: Determine the set of flag bit polarities that minimizes the power out of the complementary filter

- Minimizes total power transmitted in the notch

$$J(r) = \sum_{i=-\infty}^{r} RIS(i)$$

4

LABI Simulation Results



__Smaller__ block lengths improve spectral shaping

__Larger__ filters improve spectral shaping

5

UWB Time Hopping Signals

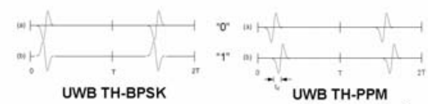
- *UWB TH Signal defined as:*

$$s(t) = \sum_n a(n) p(t - nT - t_{pn}(n) - t_d d(n))$$

T - frame length $\quad p(t)$ - pulse

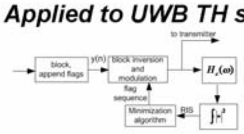
t_d - time offset $\quad a(n), d(n)$ - data bits

t_{pn} - pseudo-random time offset



6

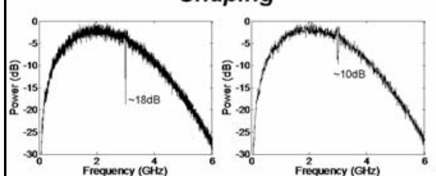
LABI Applied to UWB TH signals



- *RIS is a measure of the power out of the complementary filter.*
- *Change the RIS calculation to take into account TH offsets*
- *LABI calculates the RIS in the time domain. With UWB TH signals, it is preferable to calculate the RIS in the frequency domain*
  - Parseval's Theorem

7

Example of LABI PI Spectral Shaping



10MHz notch at 3GHz

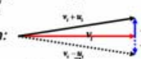
50MHz notch at 3GHz

Smaller blocks lengths and longer filters improve performance. Similar notches can be obtained with LABI TO

8

Intuition for LABI TO

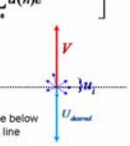
- *Original Equation:* $S(\omega) = P(\omega)\sum_{n=0}^{N-1} e^{-j\omega(nT + t_{pn}(n))} e^{-j\omega t_d d(n)}$
- *Using Taylor Series approximation:*



$$S(\omega) \approx P(\omega)\left[\sum_{n=0}^{N-1} e^{-j\omega(nT + t_{pn}(n))} - j\omega t_d \sum_{n=0}^{N-1} d(n) e^{-j\omega(nT + t_{pn}(n))}\right]$$

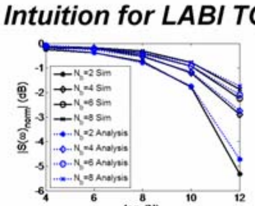
$$\approx P(\omega)\left[V + U\right]$$

- *Goal: Choose d(n) such that U ≈ -V.*



9

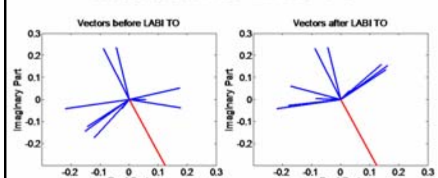
Intuition for LABI TO



$$|S(\omega_0)_{Norm}| \approx 1 - \omega t_d \frac{2}{\pi}\sqrt{\frac{N}{N_b}}$$

10

Intuition for LABI TO

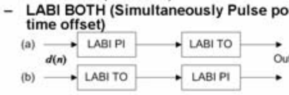


Vectors are inverted to such that the sum of the data modulated vectors best cancels the data independent vector.

11

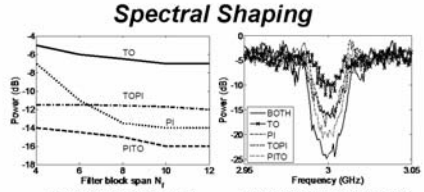
Improvements to LABI PI & TO

- *Only varies one aspect of a UWB TH signal:*
  - pulse polarity
  - timing position
  - Third aspect: Time hopping sequence
    - J. Bellorado et. al, "Time-Hopping Sequence Design for Narrowband Interference Suppression," VTC2004 Fall
- *Improved performance by varying both*
  - LABI TOPI (Cascade)
  - LABI PITO (Cascade)
  - LABI BOTH (Simultaneously Pulse polarity and time offset)



12

Spectral Shaping



Notch Power for various Nf

Notch depth for each technique

- *Example: -14dB Notch*
  - 2nd block in cascade has fixed Nf=6
  - LABI PI with Nf=10 (2^10 RIS calculations per trellis stage)
  - LABI PITO with Nf=4 & Nf=6 (2^4 & 2^6)
    - Same Performance with Lower Complexity

13

LABI for UWB TH: Timing Jitter Effects

- *Problem: Timing Jitter (i.e. noise) adds an additional time offset to the pulse*

$$s(t) = \sum_{n=0}^{N-1} p(t - \gamma_n - \delta_n)$$

where $\gamma_n = t_{pn}(n) + t_d d(n) + nT$

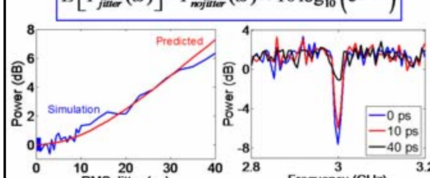
δ - jitter term, $N(0, \sigma^2)$

N - number of pulses

14

LABI for UWB TH: Timing Jitter Effects

$$E\left[P_{jitter}(\omega)\right] - P_{nojitter}(\omega) \approx 10\log_{10}\left(e^{\omega^2\sigma^2}\right)$$



Power in the notch increases due to jitter!

15