ULTRA WIDE BAND FOR SENSOR NETWORKS
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Fluid Coding in Time Hopping Ultra Wide Band Networks

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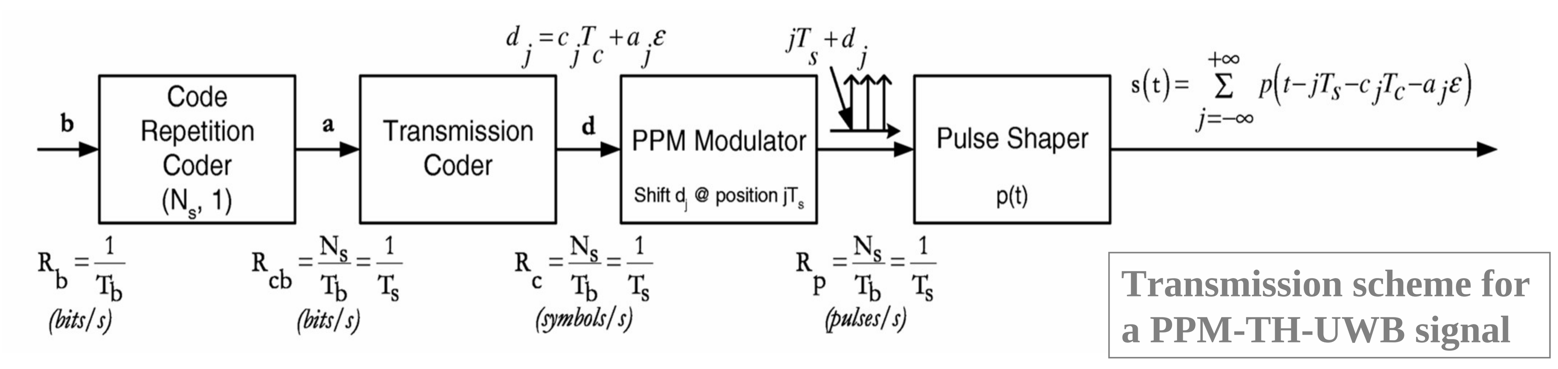
1-Introduction

➢One possible way of generating Ultra Wide Band (UWB) signals is by radiating pulses that are very short in time (Impulse Radio, IR)

➢PAM or PPM modulation schemes are commonly used to modulate the information data symbols

➢In order to shape the spectrum of the generated signal, the data symbols are encoded using pseudonoise (PN) sequences by the Transmission Coder



Transmission scheme for a PPM-TH-UWB signal

2-Time Hopping Code

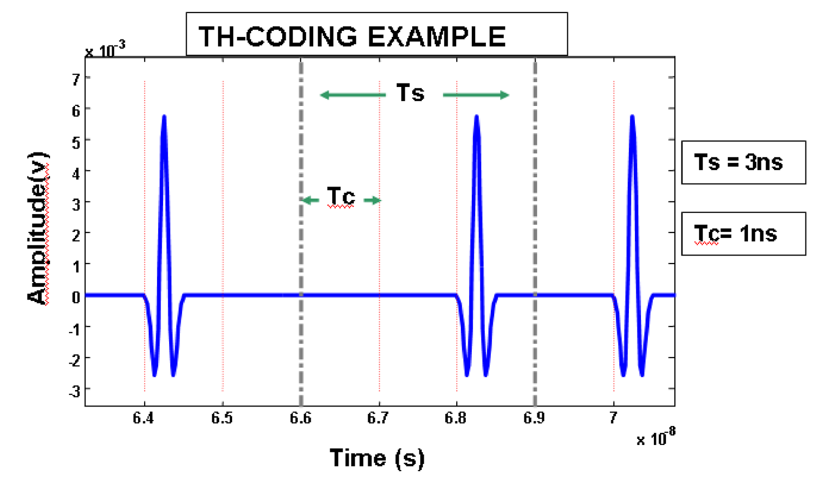
➢In a standard approach c is a pseudorandom code, its generic element c_j being an integer verifying $0 \le c_j \le N_h - 1$, where N_h is the cardinality of the code. The code might be periodic with period N_p

➢If N_s is the number of times each bit is repeated a common choice is $N_p = N_s$

The figure shows a standard TH-coding with N_h=3 and no PPM shift

$$s(t) = \sum_{j=-\infty}^{+\infty} p(t - jT_S - c_jT_C)$$

Ts is the Pulse Repetition Period, Tc is the Chip Time introduced by the code



3-PSD Peaks

➢In the common case of periodicity of the code coinciding with the bit repetition interval, the power of a TH-UWB signal concentrates at multiples of the bit repetition frequency

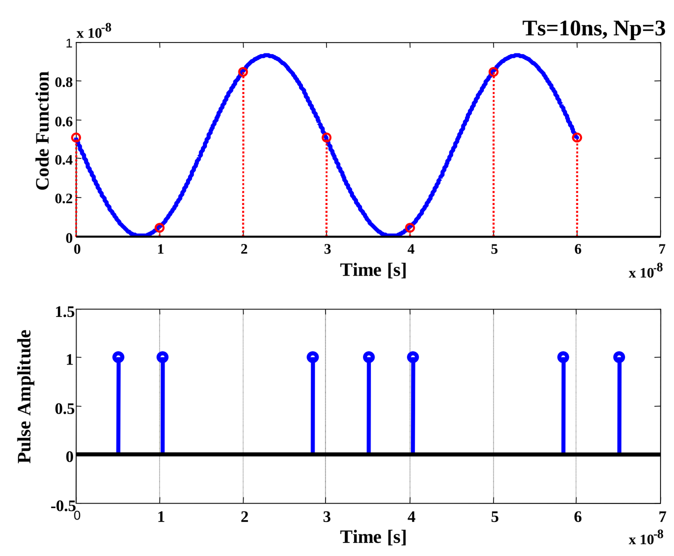
➢Spectral analysis of such signals show that it is not possible to remove all the peaks of the Power Spectral Density (PSD) by only increasing the periodicity of the TH code

➢To decrease the energy concentration at peaks, one should allow each pulse to assume random positions inside each pulse interval

➢We relax the hypothesis of considering discrete values for the time shift introduced by the TH code, by considering the possibility of generating real-valued codes that introduce time hopping in a "fluid" way

4-Fluid Time Hopping

➢There are many possibilities in choosing the analog waveform that generates the fluid code. A possible way is to sample a sinewave *c(t)* expressed as:



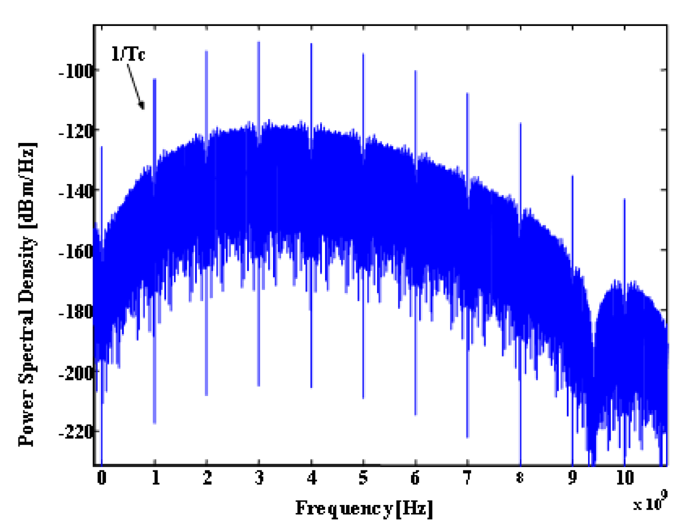
$$c(t) = \frac{(T_s - T_m - \varepsilon)}{2} \cdot \left[1 + \sin(2\pi f_0 t + \varphi)\right]$$

c_jT_c is now substituted by a real value c_j in the interval $[0, Ts - Tm - \varepsilon]$, where Tm is the duration of the pulse and ε is the PPM shift. The sampling instants at multiple of T_s and the corresponding pulses positions are highlighted.

5-Standard TH code Example

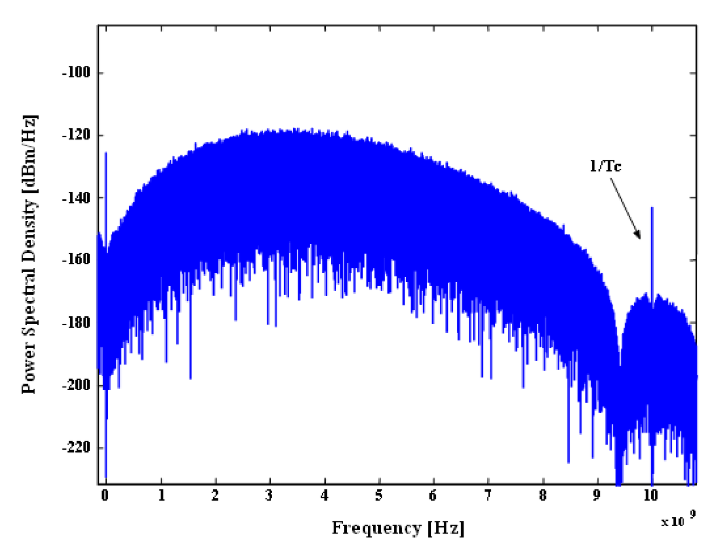
➢Let us consider the PSD of a signal adopting a discrete pseudorandom TH code with average pulse repetition period *Ts* = 10 ns, chip time *Tc* = 1 ns, and code period *Np* = 5000.

As expected, the transmitted power is concentrated at spectral peaks located at multiples of the repetition frequency of the TH sequence, which is here 1 GHz. Note that to remove all the peaks of the PSD, increasing the periodicity of the TH code is not sufficient.



6-Towards Fluid Time Hopping

Improvement obtained by using a quasi-fluid TH code



➢We now reduce the value of *Tc* to 0.1ns. As expected, the introduction of a quasi-fluid TH code has the effect of eliminating peaks in the PSD of the transmitted signal

➢The peak values of this second PSD are now about two orders of magnitude smaller than peak values of the first PSD considered

➢In the proposed example, the gain in transmission power allowed by fluid TH ranges in the order of 20 dB

7-Applications (1/2)

➢A possible application of fluid TH coding is to multi-user UWB communications

➢For example a network of asynchronous binary PPM-TH UWB devices adopting discrete pseudorandom TH codes can be strongly affected by multi-user interference

➢Fluid coding, based for example on the sinusoidal code function described before, can represent a possible way of improving spectral separation among different transmission

➢Multiple access might be implemented by random selection of a different period or phase of the sine wave for each active link of the network: in this way, spectral peaks of different signals are located at different frequencies

8-Applications (2/2)

➢In clustered MAC networks, nodes are organized in different subgroups, named *clusters*

➢In an uncoordinated and asynchronous network, clustering could be easily achieved by separating different clusters with different periods of the sinusoidal fluid TH code: in this way, interference among different subgroups would be better controlled

➢In the same way, fluid TH coding could be also introduced with the aim of allowing multiple UWB networks to coexist over the same geographical area: the basic idea, in this case, is to reduce mutual interference among different networks by adopting a different set of fluid TH codes for each network

➢The advantage of network separation by fluid coding resides in the possibility of avoiding partitioning the available bandwidth among different networks