Alternate bit reversal search for Acquisition of Ultra Wide-band Transmissions

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***Abstract*— Rapid acquisition of ultra wide-band(UWB) signals constitutes a major challenge because of the impulse-like short pulse at the sub-nanosecond scale, which results in a very wide uncertainty region of search.**

Recent studies have concluded that the process of acquiring the UWB signals can be expedited by the presence of multi-path. Acquisition analysis is done here using a generalized signal flow graph approach which allows for an arbitrary search pattern and a multiple detection scenario generated by the multi-path. It is shown in [1] that the bit reversal search leads to a near optimal search technique. The alternate bit reversal search proposed in this paper performs very closely to the bit reversal search.

I. INTRODUCTION

With the UWB spectral mask(in the range of 3.1 – 10.6 GHz) released by FCC in February 2002, the commercial interest of UWB technology is enormously increasing in the application area of short-range indoor wireless communications. This is followed by several interesting features of UWB technology: low cost, low power, impulse-like, baseband transmissions with improved penetration capability; rich multi-path diversity that can be collected with low-complexity RAKE receiver; a large number of users allowed access with Time Hopping(TH) codes; a narrow time resolution which allows for precise location tracking; and strikingly controversial features to overlay existing narrow-band systems, such as GPS, IEEE 802.11 and Bluetooth, with reduced interference (noise-like) characteristics; see [4] [5] [6] and references therein.

An UWB signal is one with a very wide fractional bandwidth, $B_f = 2(f_H - f_L)/(f_H + f_L)$, greater than 25 percent. Here f_L and f_H are the lower and upper end(3 dB or 10 dB) of the signal spectrum. The frequency spectrum of UWB signals yields an advantage over a more narrow-band signal. In Addition, systems required to operate in dense multi-path channels, such as indoor or urban environments, are well suited for UWB signals. This is because the individual multi-path components are resolvable and do not lead to a destructive interference, or nulls, as with narrow-band signals.

One of the important issues in exploiting the unique advantages of UWB transmissions, is the clock synchronization phase, the difficulty of which is remarkably revealed in UWB due to the fact that the information bearing waveforms are impulse-like, and have low amplitude. So, the threshold detection of the output of a sliding correlator between the received signal and the transmit-waveform template is not only sub-optimum in the presence of dense multi-path, but also results in unacceptably slow acquisition times, and has greatly time-consuming process when one has to perform exhaustive search, such as linear search, over thousands of bins(chips). Recent researches to reduce the acquisition time include a coarse bit reversal search considered in [1], and the design of a coded beacon sequence in conjunction with a bank of correlators in the context of data-aided localization [7].

The UWB system and multi-path channel are discussed in section II. The acquisition of time-hopped UWB signals in a dense multi-path channels is considered in this paper. The serial search in time is chosen here. A signal flow graph technique is used for analyzing the acquisition process. Fixed-dwell-time, serial search techniques can be modelled nicely using this approach. A general signal flow graph and the accompanying moment generating function are presented in section III. Other non-serial or non-fixed-dwell-time techniques exist and tend to offer slightly better performance when compared to fixed-dwell-time serial search techniques. The cost of increased performance, however, is increased with complexity in the receiver structure. A fully parallel search would be preferable but the associated complexity is often prohibitive. An alternate bit reversal search with a single correlator is discussed in section IV.

II. UWB SIGNAL MODEL AND CORRELATOR OUTPUT

To satisfy the spectrum mask requirement of the FCC, the shaping pulse, or also known as monocycle waveform in [6], is chosen to be the 5^{th} derivative of the Gaussian function and it can be expressed as,

$$g(t) = K_g\left(-15\left(\frac{t}{s}\right) + 10\left(\frac{t}{s}\right)^3 - \left(\frac{t}{s}\right)^5\right)\cdot \exp\left(-\frac{1}{2}\left(\frac{t}{s}\right)^2\right) \qquad (1)$$

This pulse has unit energy and the scale factor, s, determines the width of the pulse in time. Here, s is set equal to 0.0528 [nsec] according to the spectral mask requirement of the FCC.

The specular multi-path channel assumed here has the impulse response:

$$h(t) = \sum_{l=0}^{L-1} \alpha_l \delta\left(t - \tau_{l,0} - \tau_0\right) \qquad (2)$$