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FRQUENCY OFFSET ESTIMATION FOR MB-OFDM USING UWB

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Abstract- We address low-complexity; highly-accurate frequency offset estimation for multi-band orthogonal frequency division multiplexing (MB-OFDM) based ultra-wide band systems in time-invariant as well as time-variant channels. We investigate the unique characteristics of MB-OFDM systems, namely, different frequency offsets, channel responses, received energies, and preamble structures in different frequency bands. Utilizing them, we develop frequency offset estimators based on the best linear unbiased estimation principle. If compared to the reference estimators, our proposed methods achieve significantly better estimation performance (4 to 6.4 dB (5 to 20 dB) estimation mean-square error advantage in the time-invariant (time-variant) channels) for all preamble patterns of the MB-OFDM system. ULTRA-WIDE band (UWB) systems (e.g., impulse radios and transmitted reference schemes to name a few) offer improved ranging precision, better penetration through obstacles, higher data rate, and increased multipath or frequency diversity. Due to ultra-wide bandwidth, UWB systems can operate at low power spectral density which allows overlay with other narrow-band systems. The coexistence issue and the spectral analysis of UWB systems have been investigated. Another approach to realize UWB systems is multi-band orthogonal frequency division multiplexing (MB-OFDM) which has been proposed for the IEEE 802.15.3a standard and adopted in European Computer Manufacturers Association (ECMA) standard. The very high data rate (480 Mbps and beyond) capability of the UWB technology would provide a compelling cable-replacement wireless technology. OFDM is a relatively mature technology and has been adopted in digital broadcasting, wireless LAN and MAN standards. OFDM has several advantages such as low complexity equalization in dispersive channels and the spectral density scalability/adaptability (e.g., adaptive bit loading).

Index Terms- ULTRA-WIDE band , OFDM , estimators

I. INTRODUCTION

THE TERM wideband, as applied to communication systems, can have different meanings. In conventional systems, "wideband" implies a large modulation bandwidth and thus a high data transmission rate. In this paper, a spread-spectrum (SS) system is described in which the transmitted signal occupies an extremely large bandwidth even in the absence of data modulation. In this case, a signal is transmitted with a bandwidth much larger than the data modulation bandwidth and thus with a reduced power spectral density. This approach has the potential to produce a signal that is more covert, has higher immunity to interference effects, and has improved time-of-arrival resolution.

The SS radio system described here is unique in another regard: it does not use a sinusoidal carrier to raise the signal to a frequency band in which signals propagate well, but instead communicates with a time-hopping (TH) baseband signal composed of sub nanosecond pulses (referred to as monocycles). Since the bandwidth ranges from near dc to several gigahertz, this impulse radio signal undergoes distortions in the propagation process even in benign propagation environments. On the other hand, the fact that an impulse radio system operates in the lowest possible frequency band that supports its wide transmission bandwidth means that this radio has the best chance of penetrating materials that tend to be more opaque at higher frequencies. Finally, it should be noted that the use of signals with gigahertz bandwidths means that multipath is resolvable down to path differential delays on the order of a nanosecond or less, i.e., down to path length differentials on the order of a foot or less. This significantly reduces fading effects even in indoor environments. The capability to highly resolve multipath combined with the ability to penetrate through materials makes impulse technology viable for high-quality, fully mobile short-range indoor radio systems. Lack of significant multipath fading may considerably reduce fading margins in link budgets and allow low transmission- power operation. Low transmission-power and short-range operation with ultra-wide bandwidth (UWB) results in an extremely low transmitted power spectral density, which insures that impulse radios do not interfere with narrow-band radio systems operating in dedicated bands. Modulation of TH-SS impulse radio is accomplished through the time shifting of pulses. Antipodal modulation cannot be achieved by this means because pulse inversion is not an option in this signaling format. Comparison with direct-sequence code-division multiple-access (DS-CDMA) systems over comparable bandwidths indicates that comparable numbers of users could also be supported by DS-CDMA signals although the spectral shapes of these systems are quite different. However, the authors are not aware of any DS-CDMA systems that operate with gigahertz bandwidths. On the other hand, impulse radios with gigahertz bandwidths have been implemented and demonstrated in single-user links with data rates up to 150 kb/s, and hence the basic principles of operation have been validated. The key motivations for using TH-SS impulse radio are the ability to highly resolve multipath and the availability of the technology to implement and generate UWB signals with relatively low complexity. The techniques for generating UWB signals have existed for more than three decades. Perhaps it is more readily known to the radar community under its time domain description as “baseband carrierless short pulse” techniques.

A comprehensive reference of early work in this area can be found. Transmitted-reference (TR) signaling, in conjunction with an autocorrelation receiver (AcR), offers a low-complexity alternative to Rake reception. Due to its simplicity, there is renewed interest in TR signaling for ultrawide bandwidth (UWB) systems. To assess the performance of these systems, we develop an analytical framework based on the sampling expansion approach. In particular, we derive closed-form expression for the bit-error probability (BEP) of TR signaling with AcR that can be used to exploit multipath diversity inherent in wideband channels. We further extend our analysis to the BEP derivation of modified AcR with noise averaging. Our methodology does not require the Gaussian approximation and is applicable for any fading scenario, provided that the correlator output signal-to-noise ratio (SNR) can be characterized in terms of a characteristic function. We show that the validity of the conventional Gaussian approximation depends on the time-bandwidth product and the number of transmitted pulses per symbol. Our results enable the derivation of a computationally simple lower bound on the BEP of TR signaling with AcR. This lower bound allows us to obtain the SNR penalty associated with an AcR, as compared with All-Rake and Partial-Rake receivers.

II. EXISTING WORK

Recent advances in consumer electronics (camcorders, DVD players, wireless USB’s etc.) have created a great need for wireless communications at very high data rates over short distances. Ultra-wide-Band (UWB) systems have shown their ability to satisfy such needs by providing data rates of several hundred Mbps. In 2002, the Federal Communications Commission (FCC) allocated a large spectral mask from 3.1 GHz to 10.6 GHz for unlicensed use of commercial UWB communication devices. Since then, UWB systems have gained high interest in both academic and industrial research community. UWB was first used to directly modulate an impulse-like waveform with very short duration occupying several GHz of bandwidth. Two examples of such systems are Time-Hopping Pulse Position Modulation (TH-PPM) introduced in and Direct-Sequence UWB (DS-UWB). Employing these traditional UWB techniques over the whole allocated band has many disadvantages including need for high complexity Rake receivers to capture multipath energy, high speed analog to digital converters (ADC) and high power consumptions. These considerations motivated a shift in UWB system design from initial ‘single-band’ radio that occupies the whole allocated spectrum in favor of ‘multi-band’ design approach. ‘Multi-banding’ consists in dividing the available UWB spectrum into several sub-bands, each one occupying approximately 500 MHz (minimum bandwidth for a UWB system according to FCC definition). By interleaving symbols across different sub-bands, UWB system can still maintain the same transmit power as if it was using the entire bandwidth. Narrower sub-band bandwidth also relaxes the requirement on sampling rates of ADCs consequently enhancing digital processing capability. Multiband-OFDM (MB-OFDM) is one of the promising candidates for PHY layer of short-range high data-rate UWB communications. It combines Orthogonal Frequency Division Multiplexing (OFDM) with the above multi-band approach enabling UWB transmission to inherit all the strength of OFDM technique.

III. PROPOSED WORK

A multi-band OFDM system divides the available bandwidth into smaller non-overlapping subbands such that the bandwidth of a single sub-band is still greater than 500MHz (FCC requirement for a UWB system). The system is denoted as an ‘UWB-OFDM’ system because OFDM operates over a very wide bandwidth, much larger than the bandwidth of conventional OFDM systems. OFDM symbols are transmitted using one of the sub-bands in a particular time-slot. The sub-band selection at each time-slot is determined by a Time-Frequency Code (TFC). The TFC is used not only to provide frequency diversity in the system but also to distinguish between multiple users. The proposed UWB system utilizes five sub-band groups formed with 3 frequency bands (called a band group) and TFC to interleave and spread coded data over 3 frequency bands. Four such band groups with 3 bands each and one band group with 2 bands are defined within the UWB spectrum mask (Fig. 2). There are also four 3-band TFCs and two 2-band TFCs, which, when combined with the appropriate band groups provide the capability to define eighteen separate logical channels or independent piconets. Devices operating in band group #1 (the three lowest frequency bands) are selected for the mandatory mode (mode #1) to limit RF phase noise degradations under low-cost implementations.

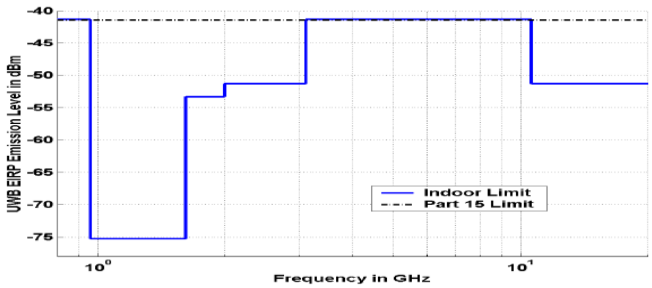


Figure 1: UWB ESTIMATION

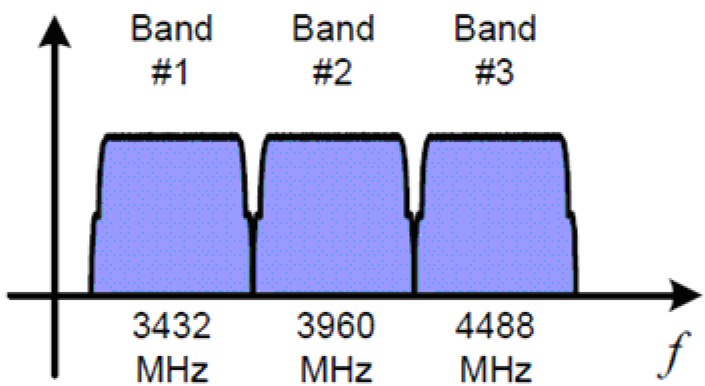


Figure 2: UWB Spectrum Division in to Sub – bands

Fig. 2 gives an example of a TFC, where the available bandwidth of 1.584GHz (3.168-4.752 GHz) is divided into 3 sub-bands of 528MHz each.

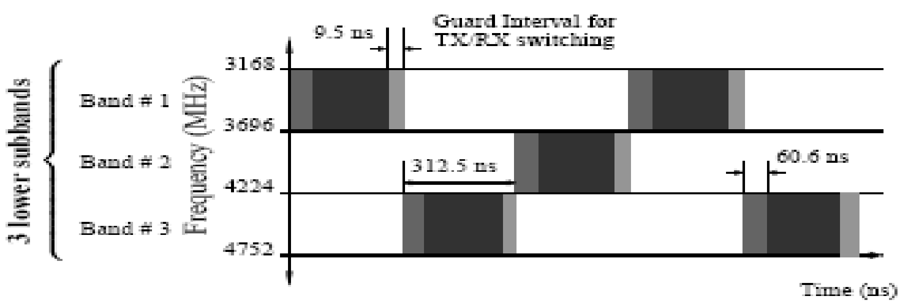


Figure 3: UWB divided into three sub bands

There are many advantages associated with using the 'MB-OFDM' approach. This includes the ability to efficiently capture multi-path energy, simplified transceiver architecture, enhanced frequency diversity, increased interference mitigation capability and spectral flexibility to avoid low quality sub-bands and to cope with local regulations. The TX and RX architecture of an MB-OFDM system is very similar to that of a conventional wireless OFDM system. The main difference is that MB-OFDM system uses a time-frequency kernel which provides TX with a different carrier frequency at each time-slot, corresponding to one of the center frequencies of different sub-bands. Fig. 3 shows the presence of a time frequency kernel in a typical OFDM TX architecture. In case of figure 3, time-frequency kernel produces carriers with frequencies of 3.432MHz, 3.960MHz and 4.488MHz, corresponding to center frequency of subband 1, 2 and 3. The MB-OFDM based UWB PHY layer proposal [9] submitted to IEEE 802.15.3a working sub-committee for WPANs specifies parameters for different modules of PHY layer.

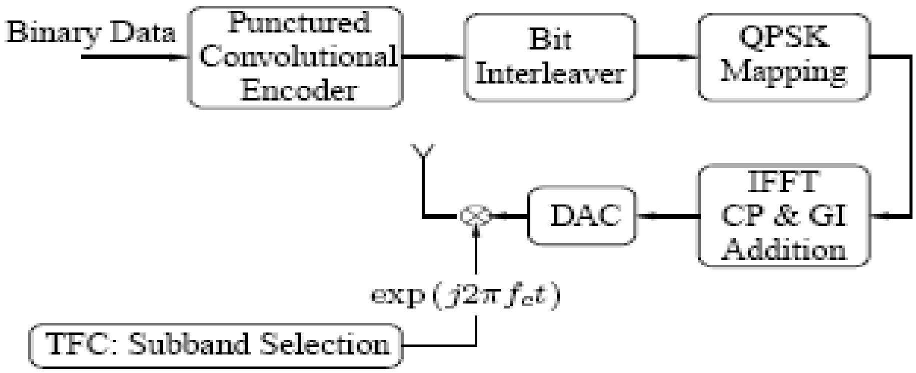
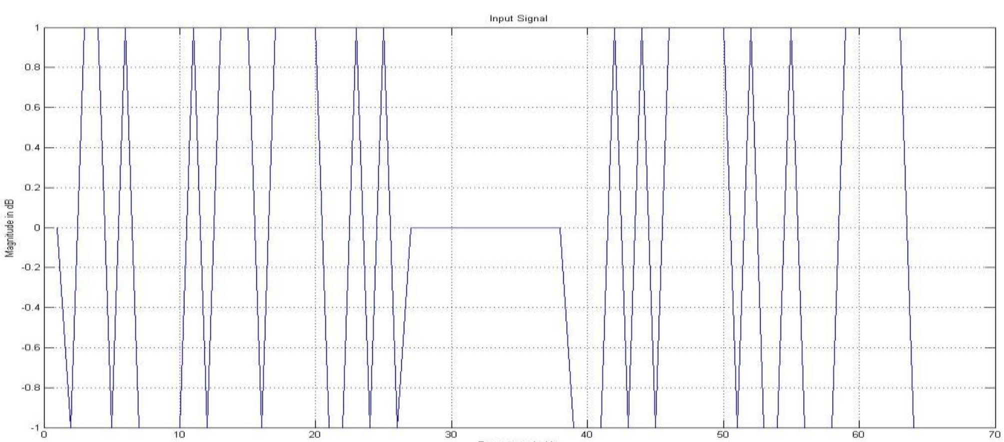


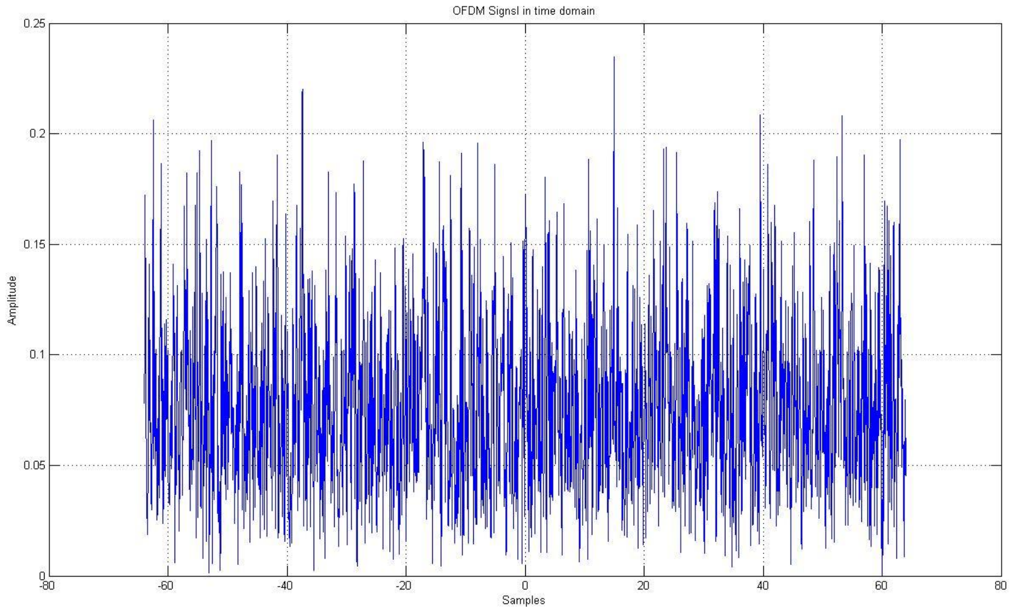
Figure 4 :TX architecture of an mb-ofdm system

I. RESULTS AND DISCUSSION

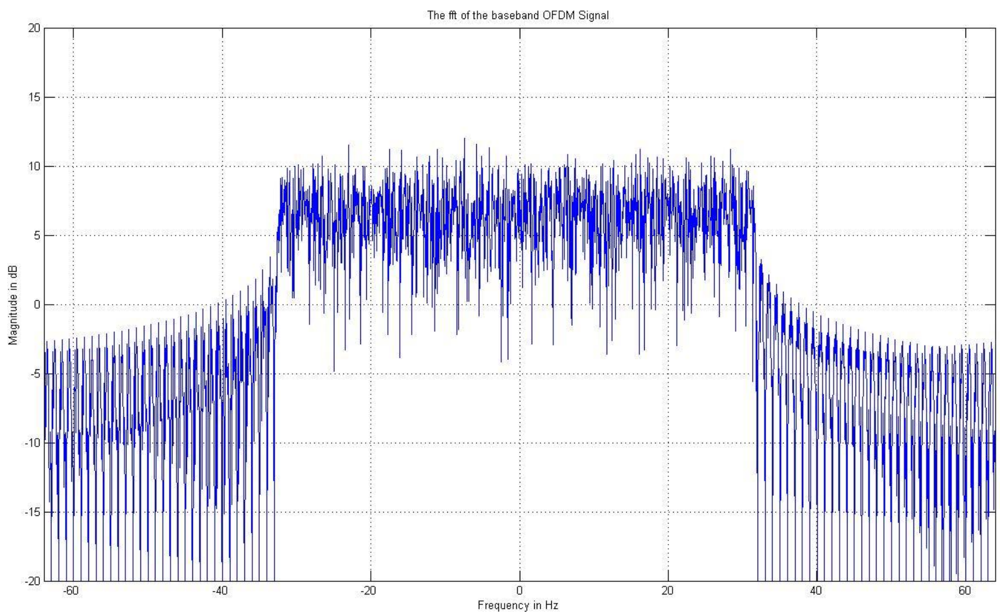
INPUT SIGNAL



OFDM SIGNAL IN TIME DOMAIN



FFT OF BASE BAND OFDM SIGNAL



OFO PATTERNS

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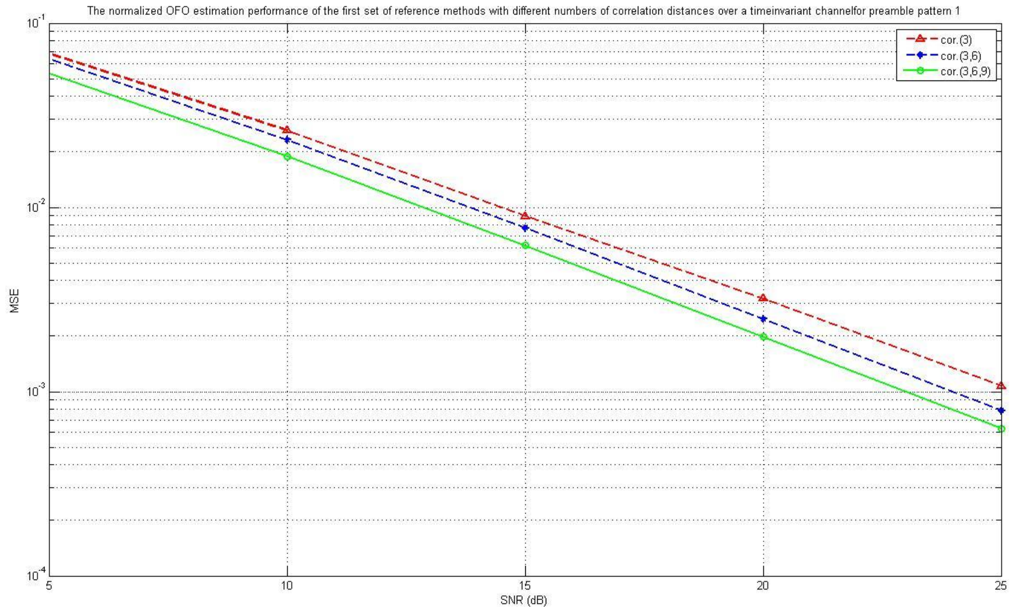
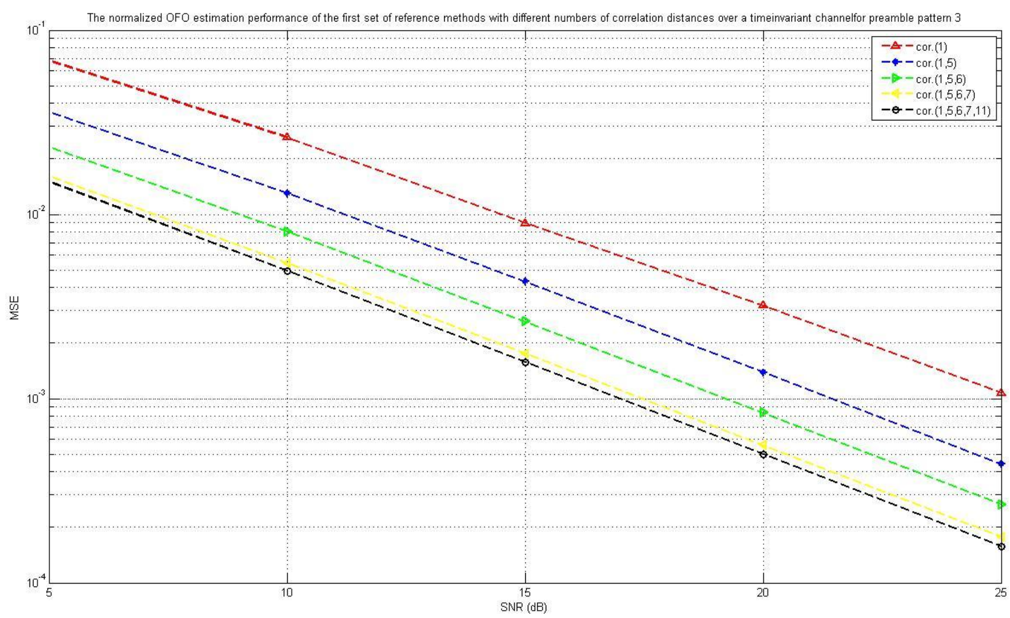
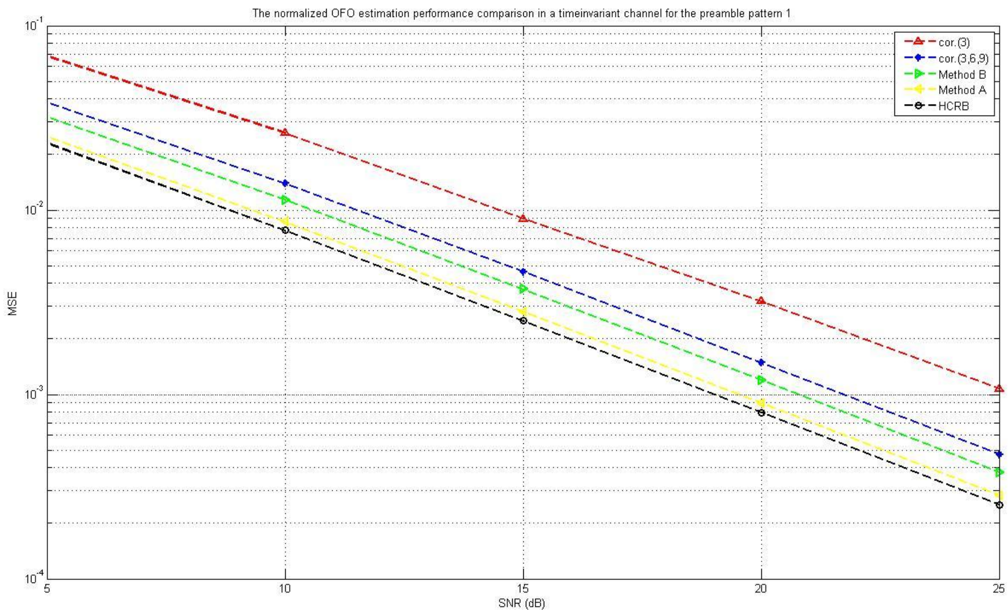
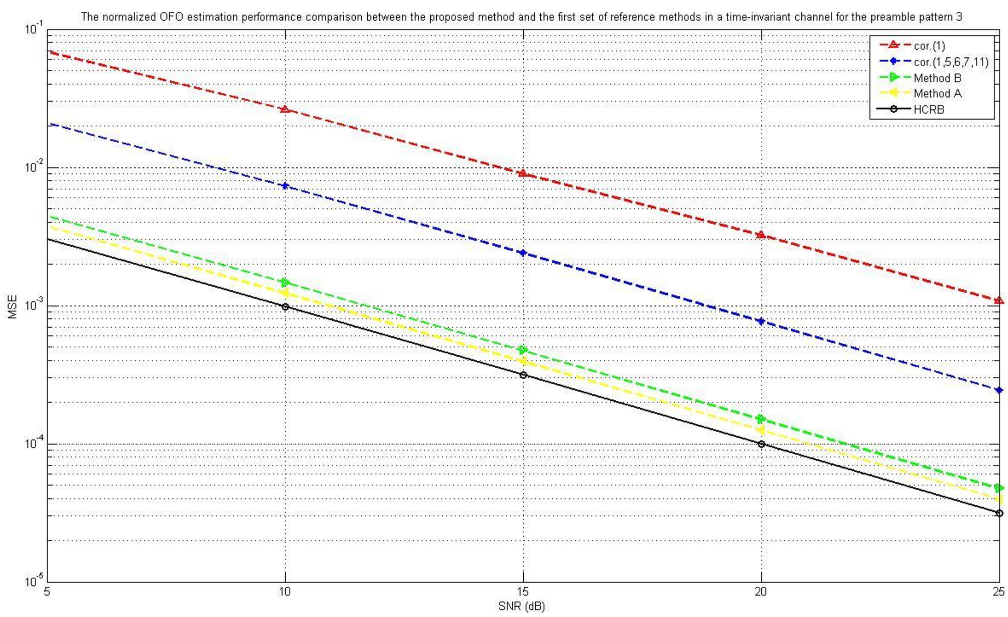





The normalized OFO estimation performance comparison in a timeinvariant channel for the preamble pattern 1
cor.(3)
cor.(3,6,9)
Method B
Method A
HCRB
MSE
SNR (dB)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
5
10
15
20
25


The normalized OFO estimation performance comparison between the proposed method and the first set of reference methods in a time-invariant channel for the preamble pattern 3
cor.(1)
cor.(1,5,6,7,11)
Method B
Method A
HCRB
MSE
SNR (dB)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
5
10
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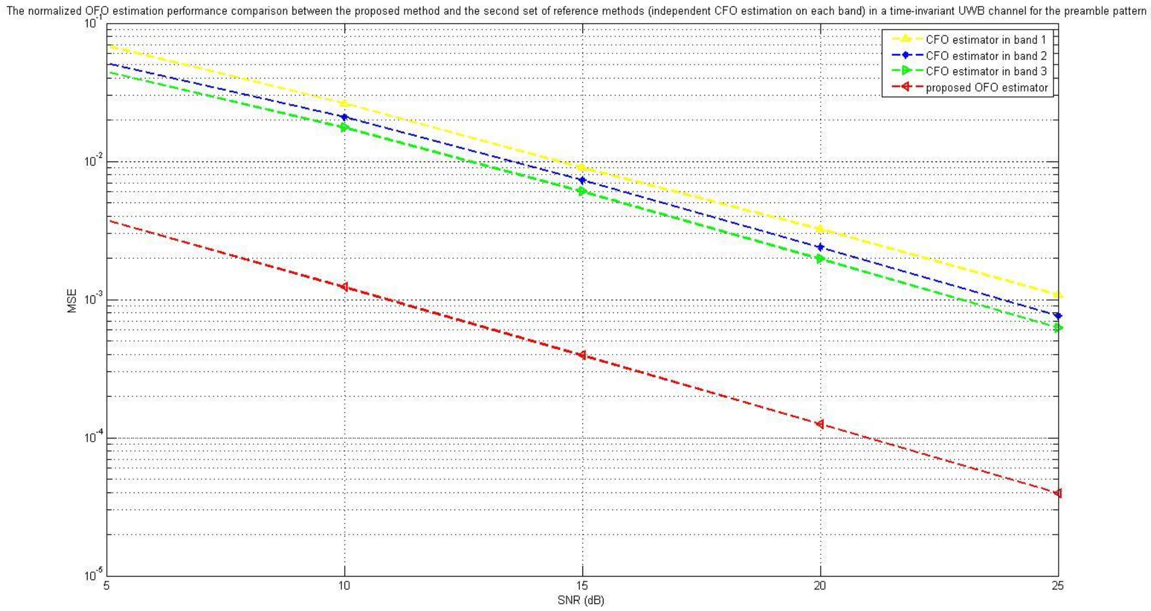

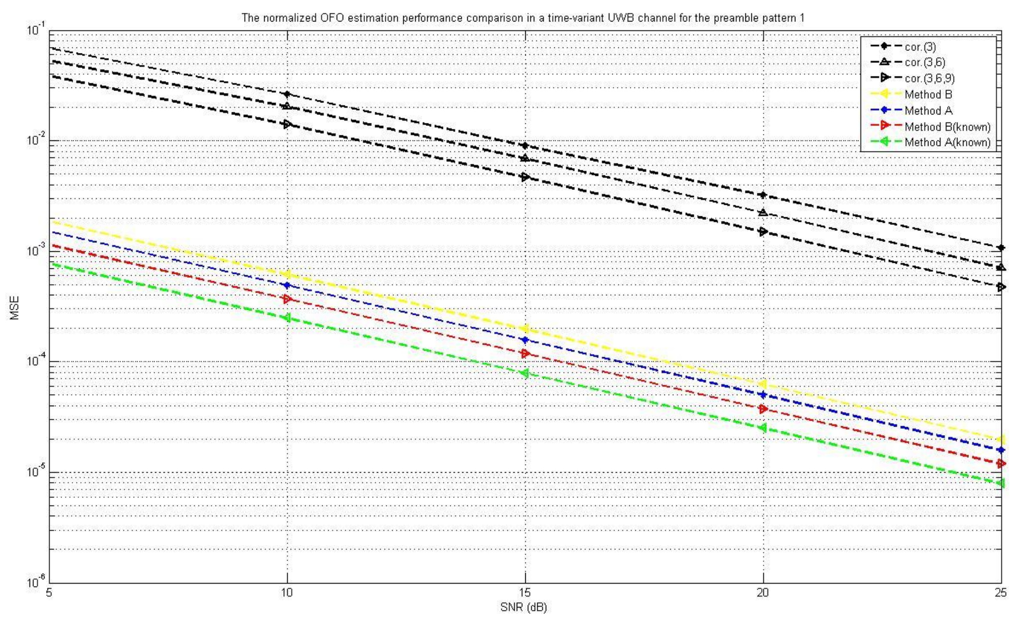

II. CONCLUSION

We have presented enhanced OFO estimators based on the BLUE principle for MB-OFDM based UWB systems by exploiting several characteristics of the MB-OFDM system –such as different CFOs, channel responses, received energies and preamble structures in different bands. We develop our estimators to be robust against sudden channel changes which can occur in some UWB systems with fast moving scatters. The proposed estimators are adaptive such that when a sudden channel change is detected during the preamble duration, the estimator designed for such a time-variant scenario is used, otherwise the estimator developed for the time-invariant channel is applied. For systems with no sudden channel changes, the latter estimator can be solely implemented for implementation simplicity. Our proposed approach can be applied to other multi-band systems or similar frequency hopped systems.

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