ISSN (O): 2320-5407
ISSN (P): 3107-4928

Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/23337
DOI URL: http://dx.doi.org/10.21474/IJAR01/23337

CONFERENCE PAPER

STUDY OF PULSE WAVEFORMS FOR UWB BASED INDOOR LOCALIZATION

Sujata Mohanty

1. Faculty in Department of ITM, Ravenshaw University, Cuttack, Odisha.

Manuscript Info

Manuscript History
Received: 8 February 2026
Final Accepted: 10 March 2026
Published: April 2026

Key words:-
UWB, Indoor, Localization, ISI

Abstract

Ultra-Wideband (UWB) technology has gained significant attention for indoor localization due to its high temporal resolution and robustness in multipath environments. A critical factor influencing the performance of UWB systems is the choice of pulse waveform used for signal transmission. This work focuses on the analysis of Gaussian pulses and Hermite pulses for UWB-based indoor localization. Gaussian pulses are widely used due to their simple structure, smooth time domain characteristics, and efficient spectral confinement, which help in minimizing interference with other wireless systems. However, their limited flexibility in spectral shaping may restrict optimal performance under varying channel conditions. In contrast,Hermite pulses,generated using Hermite polynomials applied to Gaussian functions, provide enhanced adaptability, better spectral efficiency, and orthogonally properties that can improve multipath resolution and reduce inter-symbol interference (ISI). This study analyses these pulse shapes for UWB indoor localization. The results demonstrate that while Gaussian pulses offer simplicity and ease of implementation, Hermite pulses provide superior performance in complex indoor scenarios due to their enhanced waveform characteristics. The findings of this work contribute to the design and optimization of UWB pulse shaping techniques for improved indoor positioning accuracy and reliability.

Introduction:-

Indoor localization has become essential for applications such as smart buildings, healthcare monitoring, robotics, and asset tracking [1]. Traditional systems like Wi-Fi and Bluetooth suffer from poor accuracy due to multipath interference. Ultra-Wideband (UWB) overcomes these limitations by transmitting ultra-short pulses over a wide bandwidth, enabling centimetre-level accuracy. UWB technology has emerged as a promising solution for high-precision indoor localization due to its ability to transmit extremely short-duration pulses over a wide frequency spectrum.

Corresponding Author:- Sujata Mohanty
Address:-Faculty in Department of ITM, Ravenshaw University, Cuttack, Odisha.

Unlike narrowband systems, UWB signals offer fine time resolution, making them highly suitable for accurate distance estimation and positioning in complex indoor environments affected by multipath propagation and signal attenuation [2-3]. A key aspect of UWB systems is the design of the transmitted pulse waveform, as it directly impacts localization accuracy, spectral efficiency, and regulatory compliance. Among various pulse shapes, the Gaussian pulse and its derivatives, particularly the Hermite pulse, are widely studied and utilized. The Gaussian pulse is favored for its simple mathematical form, smooth time-domain characteristics, and compact spectral properties. It minimizes side lobes and reduces interference with other wireless systems, making it suitable for UWB communication and ranging applications. However, its basic form may not fully exploit the available spectrum or optimize performance under all channel conditions.

To address these limitations, Hermite pulses, derived from Gaussian functions using Hermite polynomials, provide greater flexibility in pulse shaping [4]. These pulses exhibit orthogonally and improved spectral control, which can enhance system performance in terms of multipath resolution and interference mitigation. Additionally, Hermite pulses allow better adaptation to regulatory spectral masks imposed on UWB systems [5]. The choice between Gaussian and Hermite pulses significantly affects positioning accuracy. Therefore, analyzing and comparing these pulse shapes is essential for optimizing UWB-based localization systems.The performance of UWB localization systems is strongly influenced by the choice of pulse waveform. While Gaussian pulses are widely used due to simplicity, Hermite pulses offer advanced features like orthogonally and spectral efficiency. However, their impact on localization accuracy in indoor environments requires detailed investigation.

Literature Review:-

Ultra-Wideband (UWB) technology has been extensively studied for high-accuracy indoor localization due to its capability of transmitting ultra-short pulses with high time resolution [6]. Early studies highlighted that UWB signals enable precise position estimation using time-based techniques. A significant body of research has focused on pulse waveform design, as it directly influences system performance, spectral efficiency, and localization accuracy. Among various pulse shapes, Gaussian pulses and their derivatives are widely used due to their simplicity and favorable time-frequency characteristics. Gaussian pulses provide good time resolution and are easy to generate using practical hardware, making them suitable for low-complexity UWB systems. The transceiver for Multi band (MB) Pulsed Orthogonal Frequency division multiplexing (OFDM) UWB system is shown in Fig.1. Additionally, higher-order derivatives of Gaussian pulses have been explored to improve spectral efficiency and meet regulatory requirements such as the FCC spectral mask [7]. Several studies have also investigated the use of Gaussian derivative pulses in modulation schemes. For instance, research on energy detection-based UWB systems demonstrated that different-order Gaussian pulses can be used to represent binary information while achieving good bit error rate (BER) performance, particularly in multipath environments.

These pulses exhibit distinct spectral characteristics, allowing efficient signal separation and improved robustness to synchronization errors. On the other hand, Hermite pulses, derived from Gaussian functions using Hermite polynomials, have attracted attention due to their orthogonally properties. Orthogonal pulse sets are particularly useful in multiuser and multi-dimensional UWB systems, as they minimize interference and enhance system capacity [8]. Research has shown that modified Hermite pulses (MHP) enable simultaneous transmission of multiple signals without mutual interference, thereby improving data rate and system efficiency. Further studies have emphasized the role of Hermite pulses in pulse shape modulation (PSM) techniques. These pulses provide near-zero cross-correlation, which is beneficial for reducing inter-symbol interference and improving detection performance. Additionally, orthogonal Hermite pulses have been designed to be robust against timing jitter, leading to improved performance in noisy and imperfect synchronization conditions [9].

In the context of indoor localization, orthogonal pulse design plays a crucial role in enhancing positioning accuracy. However, some studies also point out limitations of Hermite pulses, such as overlapping spectra between different pulse orders, which may reduce their effectiveness in certain receiver architectures like energy detection systems [10]. Recent research trends focus on optimizing pulse shapes to achieve a balance between spectral efficiency, orthogonally, and implementation complexity. Techniques such as optimization algorithms, hybrid pulse design, and alternative orthogonal basis functions have been proposed to improve UWB system performance while complying with regulatory constraints .Overall, the literature suggests that while Gaussian pulses are preferred for their simplicity and ease of implementation, Hermite pulses offer advantages in terms of orthogonally and multiuser capability. The choice between these pulse shapes depends on system requirements, particularly in terms of localization accuracy, interference mitigation, and hardware complexity.

Gaussian Pulse:-
The Gaussian pulse is smooth, symmetric and concentrated in both time and frequency domains. It is good in time resolution that is accurate ToA estimation. It has Low complexity generation and limited control over spectral shaping. It generates Smooth waveform with low complexity and good noise immunity [11].

The mathematical representation for Gaussian pulse is represented below:

$$p(t)=\frac{A}{\sqrt{2\pi\sigma^2}}\exp^{-\frac{t^2}{2\sigma^2}}$$

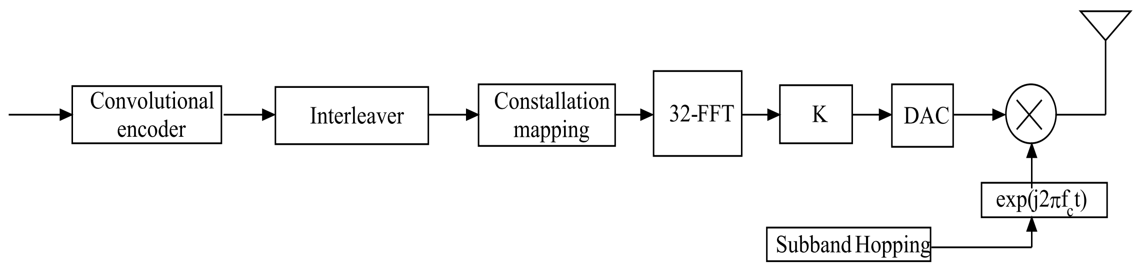
Where A represents amplitude,
σ is the pulse width parameter

Hermite Pulse:-
Hermitepulse is derived from Gaussian and retains smoothness. It shows the orthogonally between different orders and better spectral control (FCC compliance). It has multiple pulse shapes available (multi-order design). It represents orthogonal pulse set, flexible spectral design and higher computational complexity. In general we can say Gaussian pulse is robust and simple whereasHermite pulse is flexible but complex [12].

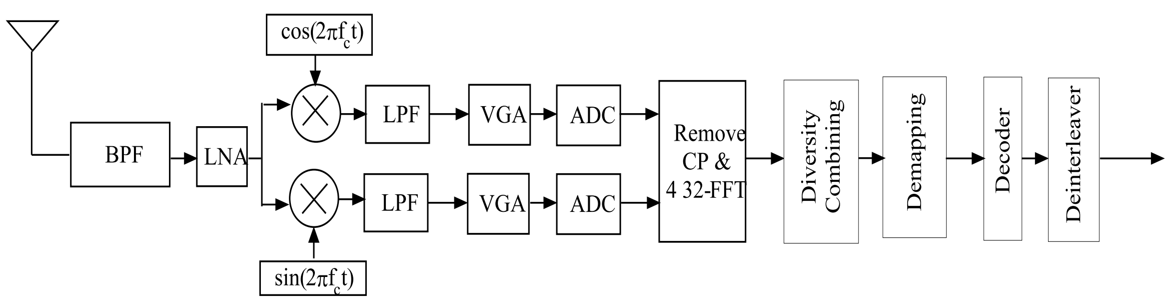
$$g_n(t)=\frac{d^n}{dt^n}g(t)=(-1)^n\frac{1}{a^n}H_n(t)g(t)$$

Where $H_n(t)$ represents the Hermite polynomial and n represents the order of the pulse.

System Model:-



(a)



(b)

Fig. 1 Transceiver for MB-Pulsed-OFDM-UWB System

Simulation Result and Discussion:-
Here Fig.2 represents the Gaussian pulse and Hermite pulse simulation. In Fig.3, the convolution operation is done in between the Gaussian signal and that of the channel. Similarly Fig. 4 represents the convolution of Hermite pulse with the channe. After that the transmitted signal is added with noise and the noisy signal is delayed to reach at receiver side. In Fig.5 and Fig. 6, it represents the Averaging operation at the Receiver side.

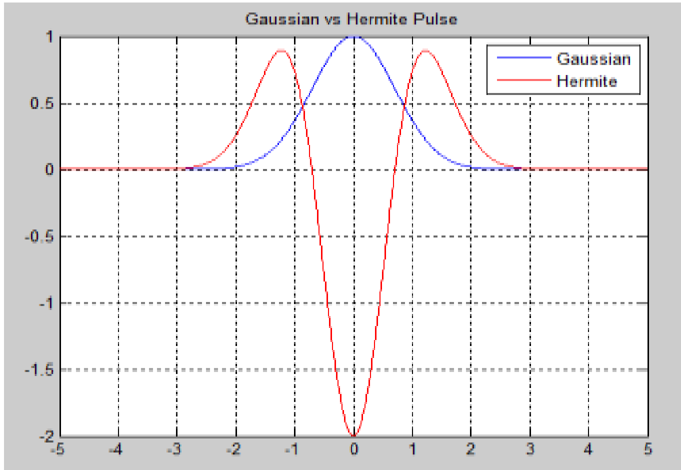


Fig. 2 Gaussian and Hermite pulse

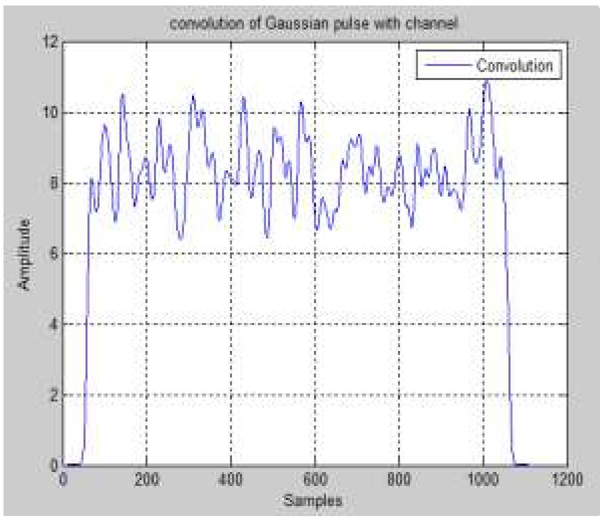


Fig. 3 Convolution with Gaussian pulse

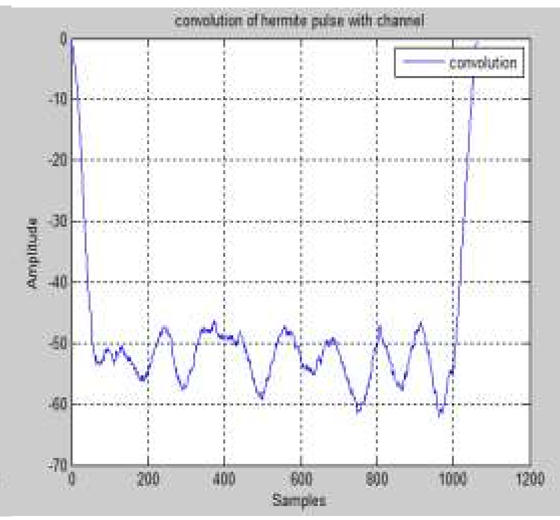


Fig. 4 Convolution with Hermite pulse

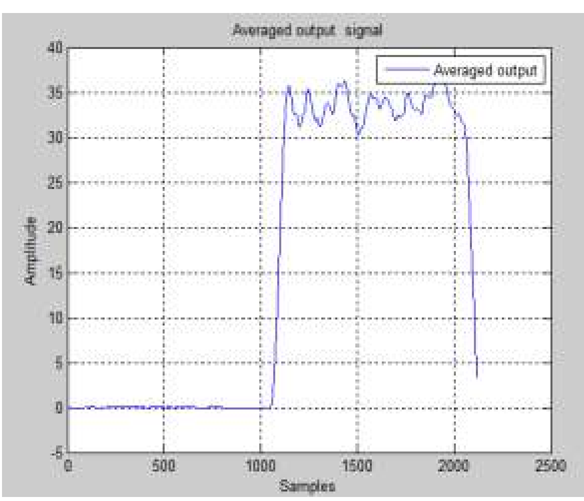


Fig. 5 Averaged output for Gaussian pulse

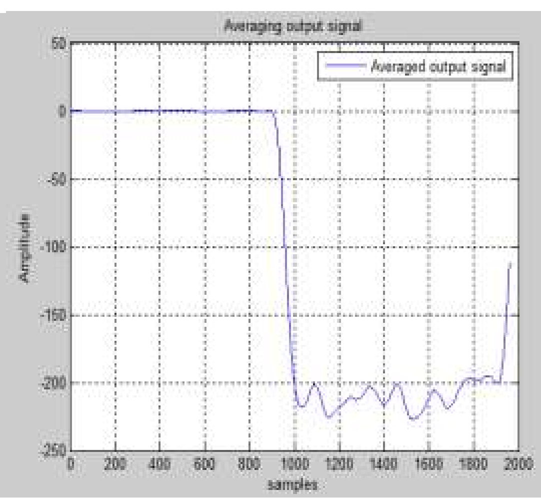


Fig. 6 Averaged output for Hermite pulse

Conclusion and Future Work:-

Ultra-Wideband (UWB) technology proves to be highly effective for indoor localization due to its ability to provide precise distance estimation and strong resistance to multipath interference.The Gaussian pulse offers simplicity in generation and maintains a smooth time-domain profile, making it suitable for basic UWB transmission. However, its spectral efficiency and orthogonality are relatively limited. On the other hand, Hermitian pulses demonstrate superior performance due to their orthogonal properties and better time-frequency localization. This leads to improved signal detection, reduced inter-symbol interference, and enhanced accuracy in distance estimation. Both pulses are effective for UWB localization. Gaussian pulse is preferred for real-world deployment. Hermite pulse is useful for high-precision or multi-user scenarios. The future work is to generate hybrid Gaussian-Hermite pulses, Real hardware implementation, and Machine learning-based pulse selection for UWB indoor localization.

Reference:-

1. F. Wang, H. Tang, J. Chen, “ Survey on NLOS identification and Error mitigation for UWB Indoor positioning,”Journal of Electronics, Vol. 12(7), 2023.
2. F. Che, Q. Z. Ahmed, P. I. Lazaridis, P. Sureephog, T. Alade, “Indoor positioning system using Ultrawide bandwidth for Industrial Internet of things,” Journal of Sensors, Vol. 23(12), 2023.
3. J. Dong, Z. Lian, J. Xu, Z. Yue, “UWB Localization based on improved robust Adaptive cubature kalman filter,” Journal of sensor, Vol. 23(5), 2023.
4. Q. Liu, Z. Yin, Y. Zhao, Z. Wu, M. Wu, “ UWB LOS/NLOS identification in multiple indoor environments using deep learning methods,” Journal of physical communication, Vol-52, 2022.
5. S. S Ghorpade, S. V Sankpal, “Performance Analysis of Multiband OFDM and Pulsed OFDM using MATLAB Simulation,” International Journal of Science and Research, Vol. 3(5), 2014.
6. L. Flueratoru, S. Wehrli, M. Magno, E. S. Lohan, “High Accuracy Ranging and Localization with Ultra wideband Communications for Energy-Constrained devices,” IEEE Internet of Things Journal, Vol. 9(10), pp. 7463-7480, 15th May,2022.
7. J. Wang, M. Wang, D. Yang, F. Liu, Z. Wen, “UWB Positioning Algorithm and accuracy evaluation for different Indoor scenes,” International Journal of Image and Data fusion, 12(3), pp. 203-225, 4th Jan., 2021.
8. Y. Shen, “Application of UWB Positioning technology in Smart home,” Proceedings of 2022 6th ISEMSS, pp. 874-883, 29th Dec. 2022.
9. T. Aziz, I. Koo, “A comprehensive Review of Indoor localization Techniques and applications in various sectors,” journal of applied science, 15, pp. 1-37, 3rd Feb. 2025.
10. N. Syazuani, N. H A. Wahab, K. Y Wong, “Indoor Positioning System: A Review,” International Journal of Computer science and Applications (IJACSA), Vol. 13, No-6, 2022.
11. L.Peilin, Z. Quingsong, Z. jianyun, L. Lei, “Pulsed design for UWB based on the combination of Gaussian deribatives,” 10th International Conference on Communication software and Networks, IEEE Xplore, 6th-9th July, 2018.
12. V. Chutchavong, T. Anuwongpinit, B. Purahong, K. Janchitrapongvej, “ Optimized Gauusian pulsed design for UWB system using particle sworm Optimization based on generalizedBessels Polynomial,” Journal of Mobile Multimedia, Vol.18(4), pp. 1231-1258, 17th March, 2022.