A Comparative Study & Analysis of Angle of Arrival Methods for UWB Phased Linear Antenna Array Applications

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Abstract. The proposed work offers Phased Arrays operating in the Ultra-Wideband Range and integrates with various Angle of Arrival Methods i.e. MUSIC, Root-MUSIC, RWSF, MVDR and ESPRIT. A Uniform Linear Array of 4~30 antenna (antenna elements) with half-the-wavelength (inter-element spacing). Random noise is added to the Signal and then received by the Uniform Linear Array. Afterwards, the above-mentioned Angle of Arrival Methods have been applied to obtain the estimated value of the target in terms of angle. In the end, the RMSE of the estimated value is computed for validation purposes.

Keywords: UWB, AoA, Multiple Signal Classification (MUSIC), Root-MUSIC, Root Weighted Subspace Fitting (RWSF), Minimum Variance Distortion-less Response (MVDR) and Estimation of Parameters via Rotational Invariance (ESPRIT)

1. Introduction

There are multifarious applications of Phased Arrays in the field of radar, Sonars, Satellite Systems, Communications Systems and cutting-edge defence technologies. Phased Arrays help to achieve electronic steering of the beam which result enhances the efficiency of the system in terms of scanning speed, agility, lesser thermal requirement, lesser power consumption, and higher efficiency. Phased arrays working in a wide range of frequencies and wide coverage make Ultra-Wideband (UWB) Phased Arrays. They offer multitudinous advantages over conventional antenna arrays i.e., swift angle scanning, high gain, active return loss, and apt radiation pattern. On the other hand, there are countless Angles of Arrival Methods for estimation. The widely employed algorithms are Multiple Signal Classification (MUSIC), Root-MUSIC, Root Weighted Subspace Fitting (RWSF), Minimum Variance Distortion-less Response (MVDR) and Estimation of Parameters via Rotational Invariance (ESPRIT) etc. There is limited literature available exploiting UWB Phased Arrays integrated with Angle of Arrival Methods. The proposed work takes advantage of the UWB Phased Arrays and integrates them with Angle of Arrival techniques for enhanced efficacy and accuracy of estimation.

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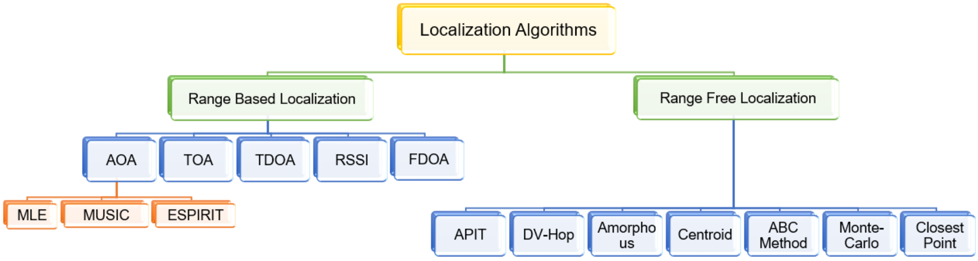


Fig. 1 Classification of Localisation Algorithms

2. Evaluation

The experiment introduced a hybrid digital-analog technique to overcome the challenges faced in UWB direction finding due to the wide bandwidth and low signal-to-noise ratio (SNR) of the signals. The technique involves using a broadband analog beam former to perform initial beamforming on the received signals, while the digital processing involves using a two-stage algorithm to refine the direction-of-arrival (DOA) estimates obtained from the analog beamformer. The simulation results show that the proposed hybrid digital-analog technique achieves better accuracy and resolution in direction finding, especially in low SNR scenarios. However, there are some limitations, such as the need for hardware capable of both analog and digital signal processing, the dependence on the sparsity of the UWB signal, and the accuracy of the coarse direction estimate obtained from the analog component [1].

Pawel presents a method for localizing wireless sensor nodes based on the angle of arrival (AoA) of the received signal. The proposed method uses an antenna array to estimate the AoA of the incoming signal and then employs triangulation techniques to determine the location of the node. The method is evaluated through simulations and compared with other localization techniques, showing high accuracy and precision, especially in non-line-of-sight scenarios. However, the method requires the deployment of antenna arrays, which may not be feasible in some environments, and its accuracy is affected by factors such as the number and arrangement of antennas, signal propagation effects, and signal-to-noise ratio. A real-time hardware-implemented system using TDoA technique for the localization of CDMA2000 cell phones for both line-of-sight and non-line-of-sight signals is presented [3]. The proposed system combines two different types of UWB signals, a direct sequence (DS) signal and a pulse position modulation (PPM) signal, to improve the accuracy of the TDoA measurement. The paper provides a promising solution for various applications, such as indoor and outdoor localization, asset tracking, and surveillance. However, the system also has some limitations, such as the need for UWB transceivers and antennas and the impact of signal propagation effects and clock drift. The paper also includes a calibration procedure to account for the clock offset between the UWB transceivers.

A hardware implementation of two popular spectral analysis techniques, MUSIC and ESPRIT, using the National Instruments (NI) PXI platform and a Field Programmable Gate Array (FPGA) for real-time processing of signals is demonstrated in [4]. The authors proposed a hardware architecture for the system and provide details of the implementation of the MUSIC and ESPRIT algorithms on the FPGA. They also present performance results and compare the results with simulations, demonstrating the effectiveness of the hardware implementation. [5] Discusses the application of time of arrival (TOA) and time difference of arrival (TDOA) measurements for source localization. The paper provides a comparison of TOA and TDOA-based localization, highlighting the advantages and disadvantages of each method. It also discusses the importance of selecting appropriate sensors, such as microphones or GPS receivers, for accurate localization. The paper presents an overview of various localization algorithms, including MLE, WLS, and NLS, and discusses the importance of signal processing techniques, such as synchronization and filtering, for improving the accuracy of source localization. It also highlights the challenges associated with localization, such as multipath and non-line-of-sight (NLOS) propagation, and potential solutions to address these issues.

The FPGA is used to estimate Direction of Arrival (DOA) in real time [6]. The system's hardware design includes an FPGA board, microphone array, and host computer for control and data visualisation. Its software implementation utilising Xilinx System Generator and MATLAB is also described. Simulations and real-world trials show that the LDL decomposition-based DOA estimate method works well. The FPGA board's real-time implementation processes numerous signals simultaneously with minimal latency and great precision. The suggested LDL decomposition-based technique is ideal for resource-constrained contexts due to its computational complexity and memory needs. The downside is Phase Synchronisation greatly reduces estimate accuracy. Using Wi-Fi radio with RSSI and Trilateration, a locating system is suggested [7]. The study suggested a LabVIEW-based RSS-based indoor localization and tracking system for Wi-Fi applications. Using a wireless access point and various Wi-Fi-enabled devices, the system estimates the position of a target device by evaluating RSS values of received signals. LabVIEW is used to construct and test the suggested system inside. With an average inaccuracy of less than 1 metre, the suggested system can localise and track inside. In [8], the authors build computationally efficient multi-source direction-of-arrival (DOA) estimate methods using FPGAs. Based on the matrix pencil and propagator approach, the suggested methods may estimate the DOAs of many narrowband sources without eigen- or singular value decomposition. A hardware description language is used to implement on a Xilinx Virtex-7 FPGA and process data from eight antenna elements in real time. The FPGA-based technology outperforms a desktop computer software implementation in speed and accuracy. The suggested implementation may be used in radar, sonar, and wireless communications. Hardware implementation of DOA estimating techniques benefits from the study. Low processing power and cost-efficiency are advantages of this technology. This technique has phase-time synchronisation and scalability issues. Labview is used to create a local positioning system (LPS) GUI [9]. The system estimates mobile device location using wireless communication with anchor nodes. The GUI makes system calibration, configuration, and mobile device position visualisation easy. Indoor testing shows that the technology can accurately estimate mobile device location. Triangulation utilising UWB technology estimates position. The low-cost, basic design is easily implemented on hardware but has low precision.

A novel indoor ranging algorithm based on the Received Signal Strength Indicator (RSSI) and Channel State Information (CSI) using an Extended Kalman Filter (EKF) is demonstrated in [10]. The proposed algorithm combines the advantages of both RSSI and CSI to improve the accuracy and reliability of indoor ranging. The EKF is used to estimate the distance between the transmitter and receiver by exploiting the correlation between the RSSI and CSI. The performance of the proposed algorithm is evaluated through simulations and experimental tests, showing promising results in terms of accuracy and robustness. The algorithm has potential applications in various fields, such as indoor localization, tracking, and navigation. [11] Proposes a novel approach for indoor localization using ultra-wideband (UWB) radios. The proposed technique, called AnguLoc, is based on concurrent angle of arrival (AoA) estimation using a distributed antenna array. The authors have developed a prototype implementation of the proposed technique using off-the-shelf UWB radios and demonstrated its effectiveness through experiments conducted in a realistic indoor environment. The results indicate that AnguLoc can achieve an average localization error of less than 10 cm, making it a promising solution for indoor localization applications.

Localization of sensor nodes in wireless sensor networks for monitoring and control operations in many applications is very important. A survey and comparative study of range-free localization of these sensor nodes is presented [12]. The authors compared three popular algorithms, namely Centroid, DV-hop, and APIT, under different scenarios with varying node densities, network sizes, and anchor placements. The evaluation metrics used include the mean localization error and the percentage of localized nodes. The authors also proposed a novel. l hybrid algorithm that combines the strengths of Centroid and APIT algorithms. The results show that the hybrid algorithm outperforms the other algorithms in terms of localization accuracy and percentage of localized nodes. The study provides useful insights into the selection of range-free localization algorithms for wireless sensor networks. A wifi-based, real-time implemented indoor localization approach is proposed in [13]. This proposed localization system has improved localization accuracy and lower computational complexity than MUSIC and 2D MUSIC algorithms and validated through AoA error, time cost and location error. Moreover, time consumption is lesser than 2D MUSIC and greater than MUSIC. The performance of this system is dependent on the number of antennas, their selection and the spacing between the antennas. An introduction to Time of Arrival (TOA) measurement for Ultra-Wideband (UWB) indoor localization systems is presented in [14]. The authors provide an overview of the principles of UWB technology, discuss the concept of TOA measurement, and explain the challenges associated with it. They also describe the UWB indoor localization system architecture and the steps involved in the TOA measurement process. The paper concludes by discussing the limitations and future directions of TOA measurement for UWB indoor localization systems. Overall, the paper provides a comprehensive introduction to the TOA measurement technique for UWB indoor localization systems. TDOA measurement independent of drift and relative clock offset can be realized in two ways but it requires accuracy of distance measurement which demands time synchronization eventually limiting its scalability to the localization of passive tags relative to static, synchronized anchors. This work is supported by mathematical evaluation, enabling TDOA measurements without the need for static or synchronized anchors [15]. However the credibility of the solution is questionable due to lack of simulation or hardware demonstration and in hardware, it is quite difficult to maintain clock drift deviation at various frequencies and phases. Phase long-baseline Interferometer based direction finding method is presented in [16] which resolved the phase difference ambiguity problem in MLBI systems by using actual phase shift of the longest baseline and validated by RMSE. The authors recommended the most appropriate array configuration to improve angular accuracy and ambiguity resolution. The estimation accuracy increases by increasing the number.

Table 1: List of interested previous work.

THEORETICAL FRAMEWORK							
Year	Author	Title	Path	Method	Pros	Cons	Validation

2006	Joni Polili Lie, Boon Poh Ng, and Chong Meng See	Hybrid Digital-Analog Technique for UWB Direction Finding	Line of Sight + Non Line of Sight	UWB + DAC	Compact Solution Both with and without multipath effects have been considered for simulation	Direction of Arrival is sensitive to Inter-element spacing and number of elements Though high-speed DAC is not required yet it requires high-speed analog hardware i.e. tunnel diode, envelope detector and comparator	Root Mean Square Error (RMSE)
2010	Paweł Kułakowski, Javier Vales-Alonso et al.	Angle-of-arrival localization based on antenna arrays for wireless sensor networks	Line of Sight	Smart Antennas + Angle of Arrival	Influence of SNR on AOA localization accuracy has been taken into account Location errors have been reduced Realistic propagation model has been employed Suitable for outdoor WSNs	Large number of sensors are required, with each sensor being equipped with antenna array of 04 elements Specific MAC protocol that organizes the anchor transmissions have been assumed Cost Ineffective	Root Mean Square Error (RMSE)
2013	Benjamin Lonske, Eric van Do et al.	UWB Enhanced Time Difference of Arrival System	Line of Sight + Non Line of Sight	UWB + Time Difference of Arrival	Conceptualizations Hardware Implementation	Fingerprint calibration is required Limited to CDMA2000	Power Spectral Density
2014	Ahmed A. Hussain, Nizar Tayem et al.	Hardware Implementation of MUSIC and ESPRIT on NI-PXI Platform	Line of Sight	MUSIC + ESPIRIT	Hardware Implementation Online Measurement Lower Computation Time Scalability	Conventional Methods have been demonstrated on Hardware Estimation Accuracy is dependent upon Phase Calibration	Root Mean Square Error (RMSE)
2016	Xinya Li, Zhiqun Daniel Deng,a) Lynn, Rauchenstein, & Thomas J. Carlson	Source-localization algorithms and applications using time of arrival and time difference of arrival measurements	Line of Sight + Non Line of Sight	Time of Arrival + Time Difference of Arrival	Comparison of TOA and TDOA have been presented in terms of Accuracy, Time Synchronization, and Computational Cost Applications of Source localization were briefed	No Performance Analysis was presented in terms of Simulation results, rather only theoretical performance analysis is given	Accuracy Time Synchronization Computational Cost
2018	Ahmed A Hussain, Nizar Tayem and Abdel-Hamid Soliman	LDL-Decomposition Based FPGA Real-time Implementation of DOA Estimation	Line of Sight	LDL Decomposition	Faster execution Low resource utilization Hardware implementation	Phase Synchronization heavily affects the estimation accuracy	Estimation Accuracy

2018	Jayabharathy.R, shanmuga priya .R, prithiviraj.V	Received signal strength based indoor localization and tracking using LabVIEW for Wi-Fi applications	Line of Sight	RSSI + Trilateration	Low Cost Position estimation of stationary and non-stationary targets Target Tracking	High MSE Low Accuracy	Mean Square Error (MSE)
2019	Ahmed A. Hussain, Nizar Tayem et al.	FPGA-Based Hardware Implementation of Computationally Efficient Multi-Source DOA Estimation Algorithms	Line of Sight	LDL + Cholesky Based Angle of Arrival	Real Time Hardware Implementation Low Cost Lower Computation Time	Phase & Time Synchronization Limited Scalability	Root Mean Square Error (RMSE)
2019	Hameedah Sahib Hasan, Mohamed Hussein et al.	Graphical User Interface (GUI) for Local Positioning System Based on LabVIEW	Line of Sight	UWB + Triangulation	Simple Architecture Low Cost Hardware Implementation	Low Accuracy	Position Error
2020	Jingjing Wang and Joon Goo Park	A Novel Indoor Ranging Algorithm Based on a Received Signal Strength Indicator and Channel State Information Using an Extended Kalman Filter	Line of Sight	Received Signal Strength Indicator + Channel State Information + Kalman Filter	Extended Kalman Filter has been used to fuse non-linear RSSI & CSI ranging values to obtain distance with minimum error	Specific to WiFi applications Increased Computational Complexity	Mean Ranging Error Standard Deviation
2020	Milad Heydariaan, Hossein Dabirian, Omprakash Gnawali	Concurrent Angle of Arrival Estimation for Indoor Localization with UWB Radios	Line of Sight	Concurrent Angle of Arrival	Reduced air-time due to Concurrency Low power consumption Accuracy is independent of TX timestamping	Requires two UWB radios per anchor Larger AOA Error due to weaker reception on the sides of dipole antennas Limited Scalability	AOA Error
2020	Ibrahim Nemer, Tarek Sheltami et al.	Performance evaluation of range-free localization algorithms for wireless sensor networks	-	Centroid + DV Hop + APIT	No additional hardware is required Low power consumption Easy deployment	Low Level of Accuracy Low robustness	Location Error Average Energy Assumption
2021	Zengshan Tian,Ya Wang, Ze Li	Indoor Real-Time Localization by Mitigating Multipath Signals	Line of Sight	Angle of Arrival	Improved Localization Accuracy Low Computational Complexity than MUSIC and 2D MUSIC	Performance is dependent upon Antennas (selection, spacing, number etc.)	AOA Error Time Cost Location Error

					Time consumption greater than 1 MUSIC and lesser than 2D MUSIC		
2021	B Venkata Krishnaveni, K Suresh Reddy, P Ramana Reddy	An Introduction to the TOA measurement for UWB indoor localization Systems	Line of Sight	UWB + TOA	Comparison among various TOA methods have been made i.e. correlation techniques, maximum likelihood, deconvolution methods and maximum probability detection and evaluated in terms of channel impulse response (CIR)	Simulations/Hardware validity has not been presented Limited techniques have been evaluated	Channel impulse response
2022	Patrick Rathje, Olaf Landsiedel	Time Difference on Arrival Extraction from Two-Way Ranging	Line of Sight	Two-Way Ranging	The work is supported by mathematical evaluation, enabling TDOA measurements without the need for static or synchronized anchors	The credibility of the solution is questionable due to lack of simulation or hardware demonstration In hardware, it is quite difficult to maintain clock drift deviation at various frequencies and phases	N/A
2022	Van-Sang Doan, Thien Huynh-The, Van-Phuc Hoang, Jiri Vesely	Phase-difference measurement-based angle of arrival estimation using long-baseline interferometer	Line of Sight + Non Line of Sight	Phase long-baseline Interferometer	Phase difference ambiguity problem in MLBI systems has been resolved by using the actual phase shift of longest baseline Recommendation of most appropriate array configuration has been made to improve angular accuracy and ambiguity resolution	Computational cost increases with increase in number of elements in antenna array Estimation accuracy is enhanced at the expense of increased antenna elements	RMSE
2023	Imran	A Comparative Study and Analysis of Angle of Arrival Methods For UWB Phased Array Applications	Line of Sight	Angle of Arrival + UWB + Phased Arrays	UWB Phased arrays have been integrated with Angle of Arrival Methods to determine the most effective method in various scenarios Performance evaluation has been done in various scenarios	The proposed work has been validated in Simulations	RMSE

					The proposed work is also extendable to 2D AOA Estimation		

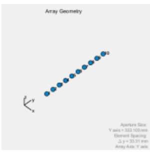
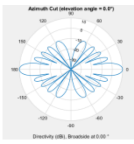
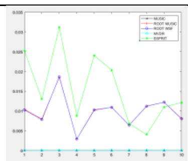
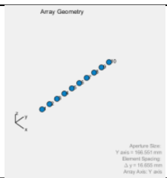
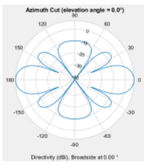
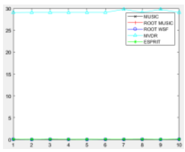
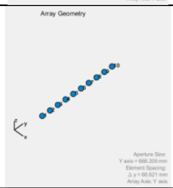
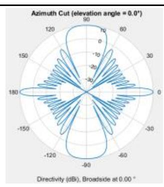
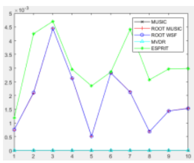
3. Simulation and Result

Various scenarios have been contemplated to validate the efficacy of the proposed method. There are numerous methods for estimating the angle of arrival for a one-dimensional array, out of which the mostly employed algorithms have been chosen for implementation simplicity and apt performance i.e. Multiple Signal Classification (MUSIC), Root-MUSIC, Root Weighted Subspace Fitting (RWSF), Minimum Variance Distortion-less Response (MVDR) and Estimation of Parameters via Rotational Invariance (ESPRIT). All these algorithms have been applied to the Ultra-Wideband Phased Arrays. After in-depth analysis, four parameters have been scrutinized to realize the effect on each algorithm i.e. Inter-Element Spacing, Number of Elements, Noise Level, and Snapshots. Root-mean square Error (RMSE) has been chosen as the validation parameter for performance evaluation.

3.1 Varied Inter-Element Spacing

A uniform linear array (ULA) has been placed along the y-axis. The array consists of 10 Elements with the spacing between antennae we can vary with 0.5 lambda, 0.25 lambda and lambda. For the simulation, we use 1 snapshot and 10 iterations. For the simulation, we also used a noise level of 0.1, and the signal source came from 2 different sources with the direction of the first source being 15 degrees in azimuth and 0 degrees in elevation, and for second source being 20 degrees in azimuth and 0 degrees in elevation. A summary of the simulation of the radiation changes is demonstrated in Table 2.

Table 2: The variations of radiation against the inter-element spacing.

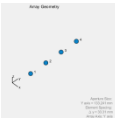
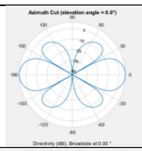
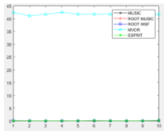
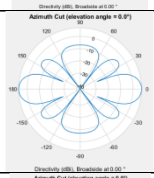
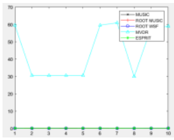
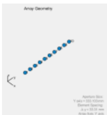
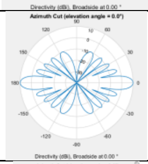
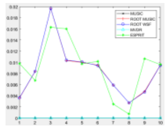
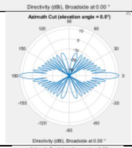
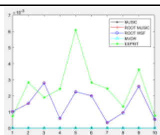
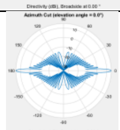
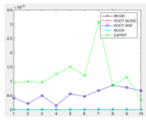
ELEMENT SPACING	ARRAY GEOMETRY	RADIATION PATTERN	RMSE DOA
0.5λ			
0.25λ			
λ			

The result shows us that different element spacing, it will affect the radiation pattern so that it will affect on RMSE of the direction-finding value. It has been found that MVDR is highly sensitive to spacing between elements and its value of RMSE was around 30 when the spacing between elements is 0.25λ. for better configuration, we use 0.5λ as inter-element spacing.

3.2 Varied Number Of Antenna Elements

For simulation, parameters are as follows: Spacing between elements: 0.5 λ, Noise level: 0.1, Snapshot: 1, Iterations: 10, Number of Sources: 2, Directions of source 1: 15 degrees in Azimuth 0 degrees in elevation, Directions of source 2: 20 degrees in Azimuth 0 degrees in elevation MVDR needs a smaller beamwidth to get a small Error between the true Direction of Arrival and the calculated DoA, which means that MVDR needs to have more antennas, because we can get a smaller beamwidth with more antennas in the array. The simulation result of Table 3 also shows us that the more antennas, we can get more accurate the calculation of the DoA.

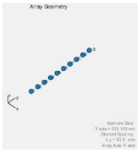
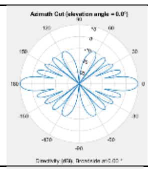
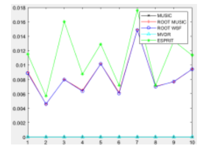
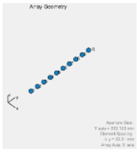
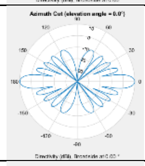
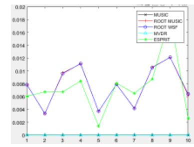
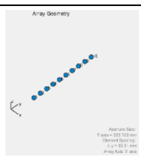
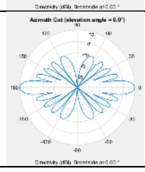
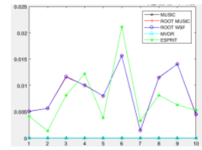
Table 3: Array elements against the radiation and EMSE DoA.

Number of Antenna	**ARRAY GEOMETRY**	**RADIATION PATTERN**	**RMSE DOA**
4			
5			
10			
20			
30			

3.3 Varied Number Of Snapshots

For simulation, parameters are: Spacing between elements: 0.5 λ, Noise level: 0.1, Number of Elements: 10, Iterations: 10, Number of Sources: 2, Directions of source 1: 15 degrees in Azimuth 0 degrees in elevation, Directions of source 2: 20 degrees in Azimuth 0 degrees in elevation For the result of the simulation of Table 4, we can conclude there is nothing different between any snapshots.

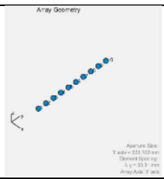
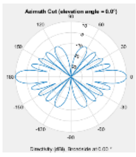
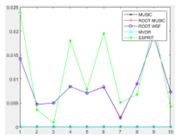
Table 4: Variations of radiation and DoA versus the number of snapshots.

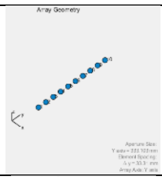
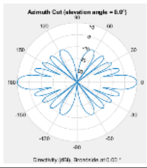
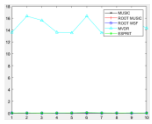
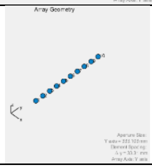
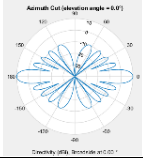
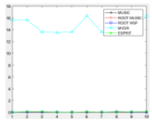
NUMBER OF SNAPSHOTS	ARRAY GEOMETRY	RADIATION PATTERN	RMSE DOA
1			
10			
20			

3.4 Varied Level Of Noise

For simulation of Table 5, parameters are: Spacing between elements: 0.5 λ, Number of Elements: 10, Snapshot: 1, Iterations: 10, Number of Sources: 2, Directions of source 1: 15 degrees in Azimuth, 0 degrees in elevation, Directions of source 2: 20 degrees in Azimuth, 0 degrees in elevation Result: MVDR needs the noise level to be small to get a better direction of arrival result, if the noise level is going bigger, the error also gets bigger. For other methods, it looks like have the same result with an error of less than 0.03 degrees.

Table 5: Variations of noise level against radiation and DoA.

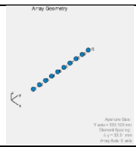
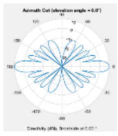
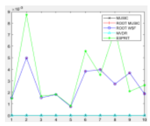
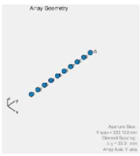
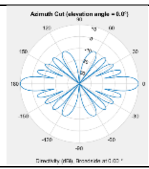
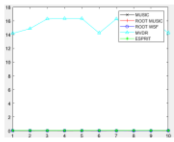
NOISE LEVEL	ARRAY GEOMETRY	RADIATION PATTERN	RMSE DOA
0.1			

0.25			
0.5			

3.5 Widely Spaced And Closely Spaced Targets (Azimuth)

For simulation of Table 6, parameters are: Spacing between elements: 0.5 λ, Number of Elements: 10, Snapshot: 1, Iterations: 10, Noise Level: 0.1, Number of Sources: 2, Directions of source 1: 15 degrees in Azimuth, 0 degrees in elevation, Directions of source 2: 0 degrees in elevation. Result in Table 6: MVDR just processes widely spaced targets. If the target space is less than 5 degrees, the calculation will be an error. Other methods can process whether it is a widely spaced or closely spaced target, with an error of less than 1 degree.

Table 6: The variation of the source direction against the radiation and DoA.

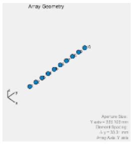
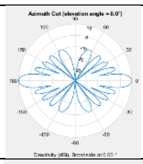
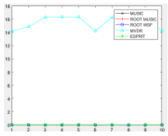
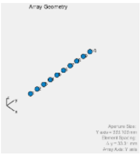
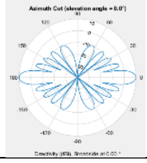
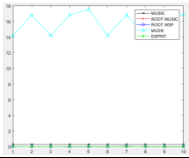
Direction of Source 2 in Az	ARRAY GEOMETRY	RADIATION PATTERN	RMSE DOA
-15			
18			

3.6 Widely Spaced and Closely Spaced Targets (Elevation)

For simulation of Table 7, parameters are Spacing between elements: 0.5 λ, Number of Elements: 10, Snapshot: 1, Iterations: 10, Noise Level: 0.1, Number of Sources: 2, Directions of source 1: 15 degrees in Azimuth, 0 degrees in elevation, Directions of source 2: 18 degrees in Azimuth, The calculation is still same with the azimuthally spaced target.

Table 7: The variation of source directions in EL against radiation and DoA.

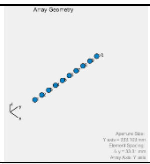
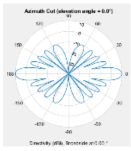
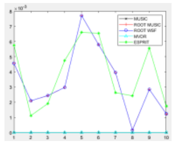
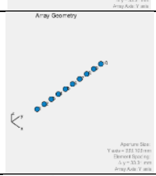
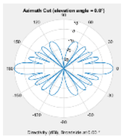
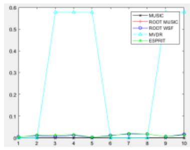
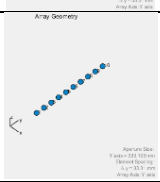
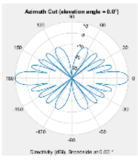
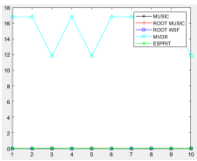
Direction of Source 2 in EL	ARRAY GEOMETRY	RADIATION PATTERN	RMSE DOA

0			
15			

3.7 Varied Number Of Target

For the simulation of Table 8, the parameters are: Spacing between elements: 0.5 λ, Number of Elements: 10, Snapshot: 1, Iterations: 10, Noise Level: 0.1, Number of Sources: 2, Directions of source 1: 5 degrees in Azimuth, 0 degrees in elevation, Directions of source 2: 20 degrees in Azimuth, 0 degrees in elevation, Directions of source 3: 25 degrees in Azimuth, 0 degrees in elevation, Directions of source 4: 35 degrees in Azimuth, 0 degrees in elevation. MVDR cannot process a signal rather than 3 signals at the same time, otherwise, the calculation will be an error. For other methods, it has the same performance for detecting multiple targets.

Table 8: The variation of target number against the radiation and DoA.

Number of Target	ARRAY GEOMETRY	RADIATION PATTERN	RMSE DOA
2			
3			
4			

4. Conclusion

After making several investigations and simulations on the performance of Direction of Arrival Methods: MVDR methods is highly sensitive methods, that need to have perfect parameters performance i.e., Element Spacing, number of antennas, target spacing, number of targets, noise level ROOT MUSIC and RWSF showed similar results in most of the Cases. ESPRIT have error +-0.2 degrees rather than ROOT MUSIC and RWSF in the system can use either Root MUSIC or RWSF to perform multiple target detection on UWB phased Array.

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