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Performance Analysis of Smart Antenna for Wireless Network

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Abstract— The Smart Antenna are the key solution to enhance the performance of Mobile Communication. It allows energy to be transmitted and received in a particular direction rather than dissipating it in all the directions. Smart antenna System (SAS) combines an antenna array with digital signal processor (DSP) to transmit and receive in adaptive manner. The most important and crucial problem in Smart Antenna is DOA (Direction of Arrival) finding. The performance of Smart Antenna depends upon the resolution of Direction of Arrival. The two classic algorithms for DOA finding is MUSIC (Multiple Signal Classification) and ESPRIT (Estimation of Signal Parameters via Rotational Invariance Technique). However, these two algorithms are unable to work on coherent signals directly as happens in multiple path propagation. For handling such coherent signals both ESPRIT and MUSIC algorithm requires pre-processing method like spatial smoothing which degrades the performance of the Smart Antenna. However, WSF (Weighted Subspace Fitting) is the most superior algorithm which can handle such coherent signals directly without any pre-processing. But this conventional WSF algorithm requires number of signals to be known in advance. The proposed algorithm is the modified WSF which can automatically detect the number of signals and calculate the DOA with better resolution than conventional algorithms like ESPRIT and WSF.

Keywords— Smart Antenna (SA), Direction of Arrival (DOA), MUSIC. ESPRIT, WSF.

I. INTRODUCTION

A Smart Antenna (SA) is an array of antenna elements or sensor elements which provided by signal processing algorithms improves the transmission and reception of the signal [1] [2][3]. It is an array of antenna elements which are placed either in linear, circular or rectangular pattern [4][5][6]. There is nothing smart in antenna, it is the antenna system which is smart and work intelligently for adaptive beamforming [7] [8]. Much of the research on smart antenna [10] has been focused on Direction of Arrival (DOA) calculation using MUSIC algorithm and its family [9]. Little work has been done on calculating DOA using ESPRIT algorithm. Yet opinions and results are so important that whenever anyone have to make a decision then these opinions matter a lot. This is true for individuals as well as for the whole organizations.

In this paper, the proposed work comprises ESPRIT algorithm working with WSF algorithm to calculate direction of arrival, so that resolution should be better than other algorithms and this proposed algorithm for DOA calculation is suitable for coherent and non-coherent signals both. As the cost of the WSF algorithm is quite high due to which it cannot be used in real life. But the cost of the proposed algorithm is quite less than that of the WSF algorithm. WSF requires number of signals to be known in advance to calculate DOA but the proposed algorithm will work automatically without knowing the number of signals in advance. The resolution of DOA calculation using proposed algorithm is quite better than the conventional algorithms like ESPRIT and WSF and the performance of the smart antenna depends on the resolution of DOA.

Rest of the paper is organised as follows, Section I contain the introduction of Smart Antenna and the overview of existing and the proposed work on Direction of Arrival of Smart Antenna, Section II contain the problem related to existing algorithms like MUSIC and ESPRIT, Section III contain the Proposed work for direction of arrival and explaination of the algorithms which forms the basis of the proposed work, Section IV contain the proposed algorithm i.e. EWSF which stands for Enhanced Weighted Subspace Fitting algorithm, section V explain the DOA calculation methodology, Section VI explain the benefits of the proposed algorithm, Section VII shows the implementation and results of the proposed work. Section VIII concludes research work with future directions.

II. DIRECTION OF ARRIVAL CALCULATION: PROPOSED WORK

To increase the accuracy and resolution of the DOA estimation is one of the most important research work in the field of Smart Antenna. Estimating the DOA is a significant problem in array signal processing [9] [10].

Angle estimation is used for source tracking or for source localization by determining the desired signal location or may be used to reduce the unwanted effects of the noise and the interference [11] [12] [13].

MUSIC and ESPRIT are the most classic two algorithms for DOA because the resolution is acceptable and the computation complexity is much lower than some other algorithms [14] [15]. However, MUSIC and ESPRIT cannot deal with coherent signal (which occurs for e.g. in case of multipath propagation) directly [16-21]. In this case, MUSIC and ESPRIT need the pre-processing techniques such as spatial smoothing [22]. However, the resolution of DOA would be greatly degraded if the pre-processing technique is used. And the resolution of MUSIC and ESPRIT is not good enough when SNR is low [23] [24].

III. PROPOSED WORK FOR DOA

As there are certain disadvantages of MUSIC algorithm like

- If two sources are very close then music algorithm unable to resolve the source.
- In MUSIC first of all peaks are to be drawn to calculate the DOA due to which it is somewhat complex [22].

But ESPRIT algorithm overcomes all such problems by directly calculating the DOA instead of showing peaks and complexity of ESPRIT is quite simple than MUSIC algorithm. It requires less storage space than MUSIC algorithm [22]. So because of these advantages of ESPRIT algorithm our work is proceeded using ESPRIT algorithm.

ESPRIT: ESPRIT stands for Estimation of Signal Parameters via Rotational Invariance Techniques and it was first proposed by Roy and Kailath. The goal of the ESPRIT technique is to make the productive use of the rotational invariance in the signal subspace which is created by two arrays with a translational invariance structure ESPRIT assumes narrowband signals so that the translational phase relationship between the multiple arrays should be known [17].

ESPRIT provides better solution than MUSIC algorithm and complexity is less but it is not applicable on Coherent Signals. For handling coherent signals one have to depend on some other algorithm.
So for handling coherent signals WSF algorithm have to be considered.

WSF: WSF (Weighted Subspace Fitting) algorithm is a high-caliber technique which has much higher resolution and can handle coherent signals without any pre-processing. The WSF DOA block estimates the direction of arrival of a specified number of narrowband signals incident on a uniform linear array using the Root weighted subspace fitting (WSF) algorithm [20].

WSF does not require any pre-processing technique to calculate DOA like required in ESPRIT and MUSIC algorithm.

However conventional WSF requires number of signals to be known initially to calculate DOA which deteriorates its performance. That's why in this research paper we proposed a modified WSF algorithm called EWSF which can calculate DOA automatically without externally knowing the number of signals and provides much better resolution than any other algorithm like WSF and ESPRIT.

IV. PROPOSED ALGORITHM FOR DOA CALCULATION

Scheduler EWSF algorithm is proposed which adapts the advantages of both WSF and ESPRIT. As ESPRIT algorithm do not work on coherent signals and for handling such signals they have to depend on some preprocessing technique. These pre-processing methods deteriorates the performance. Whereas the WSF works on coherent signals but it requires number of sources to be known initially for calculating DOA and it is not effective.

The proposed algorithm EWSF will work on both coherent and non-coherent signals without requiring the number of signals to be known in advance and provides better resolution than any other algorithms like ESPRIT and WSF.
Following steps are to be followed to calculate the DOA in proposed algorithm:-

1. Calculate the number of signals using MDL test.
2. Covariance matrix is calculated using WSF algorithm as number of signals are obtained.
3. With the help of this covariance matrix diagonal matrix is obtained using ESPRIT algorithm.

Finally, DOA is calculated

V. PROPOSED METHODOLOGY

First Step: Minimum Description Length (MDL) is used to calculate number of signals along with the forward backward averaging. With the help of this MDL one gets to know the number of signals impinging on the antenna array i.e. N.
Second Step: Use WSF algorithm for calculating the relation between the two signal matrix. This relational matrix is called the Covariance Matrix.

Third step: ESPRIT works on the doublets it is assumed that two signals are correlated, there is a phase shift between two signals.

$$x1\ \varphi = x2$$

where,
x1, x2 are the two signal matrix.
This φ(chi) is calculated which is the diagonal matrix
Fourth step: DOA calculated from this diagonal matrix.

VI. BENEFITS OF THE PROPOSED ALGORITHM

- A Proposed Algorithm works on both coherent and non-coherent signals.
- No pre-processing is required to calculate DOA as in case of ESPRIT and MUSIC algorithm.
- As conventional WSF algorithm requires number of signals to be known in advance to calculate DOA. But this proposed algorithm works automatically without knowing the number of sources.
- Resolution of proposed algorithm is quite better than conventional algorithms like WSF and ESPRIT.

VII. IMPLEMENTATION AND RESULT

ESPRIT: (Estimation of Signal Parameters via a Rotational Invariance Technique) ESPRIT is a DOA estimation technique. ESPRIT is a vector subspace based methodology that, instead of identifying the spectral peaks, directly determines the DOAs.
In these 3 different directions of angles are considered. These broadside angles are 57, 31 and 25degree. Earlier work was done only by considering elements spacing as 0.5 but in this research paper work is focused by considering the spacing between the antenna elements as 0.4, 0.45 and 0.5. Now for these three different angles three cases are as:

CASE 1: N=8
Spacing between antenna elements are
a) d = 0.4
b) d = 0.45
c) d = 0.5

Table 1: ESPRIT N=8

No. of antenna Element = 8			
Spacing (mm)	Angles (degree)		
400	56.2447	31.1807	24.9456
450	56.4164	31.1389	24.8476
500	56.5387	31.1295	24.4871

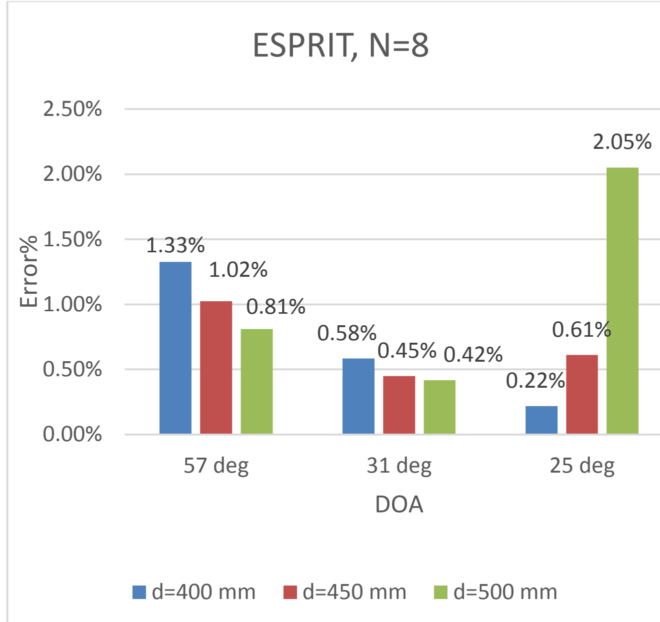

Figure 1: ESPRIT N=8

Results show that:

I. When d = 0.4 error rate is more in case of 57degree, then less in 31degree and least in case of 25degree.
II. When d = 0.45 again error rate is more in case of 57 degree, then for 25 degree and least in case of 31 degree.
III. When d = 0.5 error rate is more in case of 25degree, then for 57degree and least in case of 31degree.

CASE 2: N = 10
Results observed are as follows:

Table 2: ESPRIT N=10

No. of antenna Element = 10			
Spacing (in mm)	Angles (in degree)		
400	56.5681	30.2063	25.0472
450	56.6604	30.5109	24.7367
500	56.7346	30.7266	24.8315

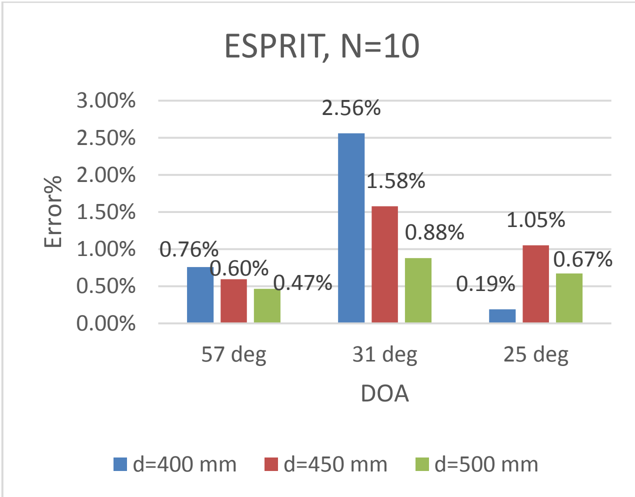

Figure 2: ESPRIT N=10

In this case error rate is more in case of DOA as 31degree in all the three cases of antenna spacing.

CASE 3: N=12

Table 3: ESPRIT N=12

No. of antenna Element = 12			
Spacing (mm)	Angles (degree)		
400	56.8865	31.5313	25.0922
450	56.9423	31.4206	25.05
500	56.979	31.3243	25.0164

For N=12 it is observed the above table

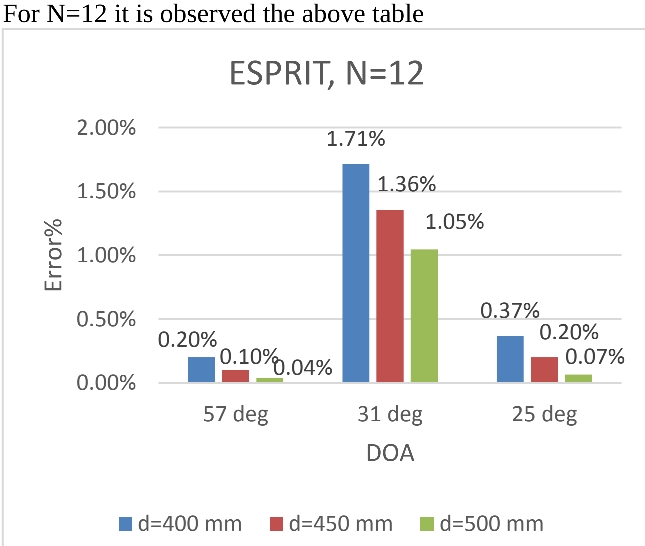

Figure 3: ESPRIT N=12

In this case also the error rate is more when DOA is as 31degree in all of these three cases of antenna spacing.

WSF: WSF stands for Weighted Subspace Fitting algorithm. This algorithm is better than ESPRIT because it works even on coherent signals also. But it is not cost effective algorithm and requires number of sources to be known to calculate DOA.
In this also three different cases are considered and results are observed as done in case of ESPRIT.

Table 4: WSF N=8

No. of antenna Element = 8			
Spacing (mm)	Angles (degree)		
400	56.9954	30.9387	25.0381
450	56.988	30.9342	25.0304
500	56.8805	30.9926	24.7616

This table shows the values which are calculated by this algorithm when number of elements are 8.

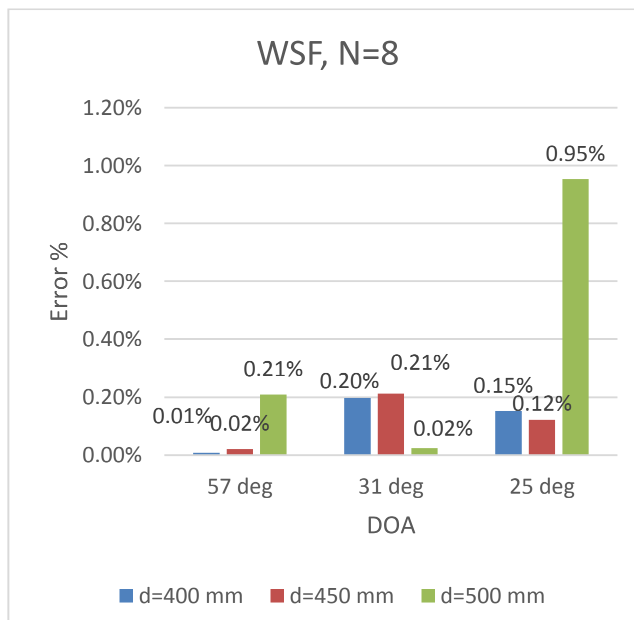

Figure 4: WSF N=8

This graph shows the error rate percent. It is noted that for n=8 error rate is more for 25degree.

CASE 2: N=10

Table 5: WSF N=10

No. of antenna Element = 10			
Spacing (mm)	Angles (degree)		
400	56.915	30.9983	24.9594
450	56.9551	31.0492	24.9859
500	56.9804	31.0605	25.0014

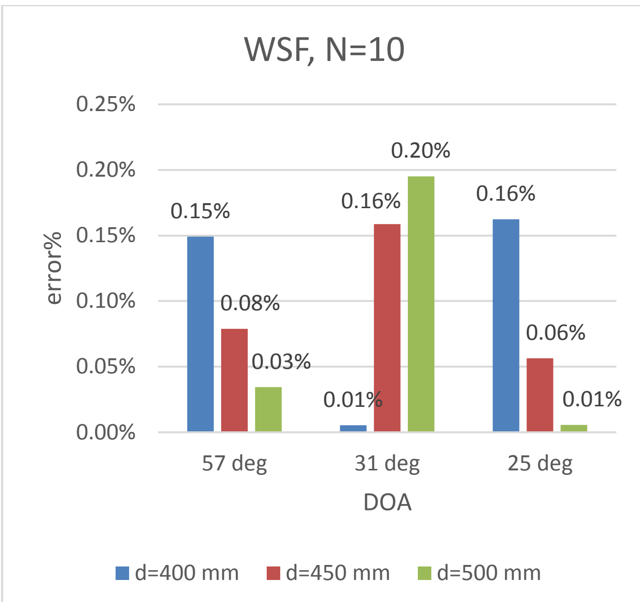

Figure 5: WSF N=10

<u>CASE 3</u>: When N=12
Calculated values are observed and shown in this table.

Table 6: WSF N=12

No. of antenna Element = 12			
Spacing (mm)	Angles (degree)		
400	57.0711	31.1732	24.9893
450	57.0647	31.1068	24.9834
500	57.05	31.0526	24.9818

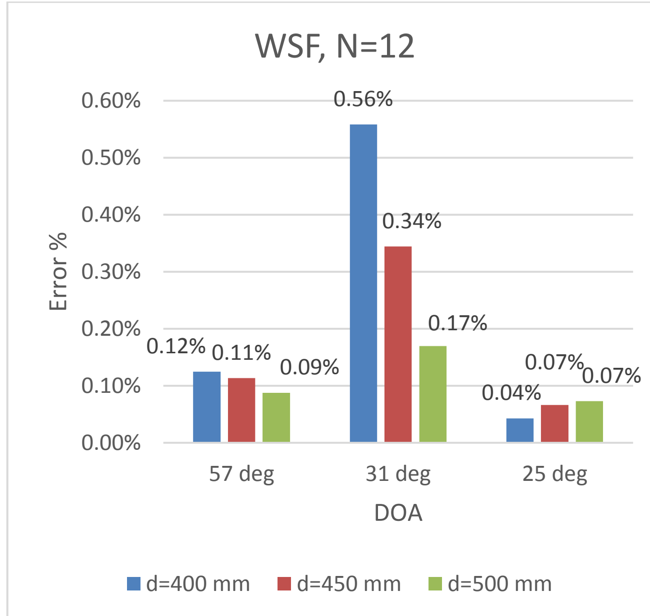

Figure 6: WSF N=12

This shows that for N=12 more error rate is observed in case of 31degree.

<u>Proposed Work:</u>
EWSF: EWSF stands for enhanced WSF which is the proposed work implementation. It will work on both coherent and non-coherent signals and do not require number of signals in advance to calculate DOA.

<u>CASE 1</u>: N=8

Table 7: EWSF N=8

No. of antenna Element = 8			
Spacing (mm)	Angles (degree)		
400	57.0009	30.9502	25.0497
450	57.0014	30.9507	25.049
500	56.9701	31.0136	25.0655

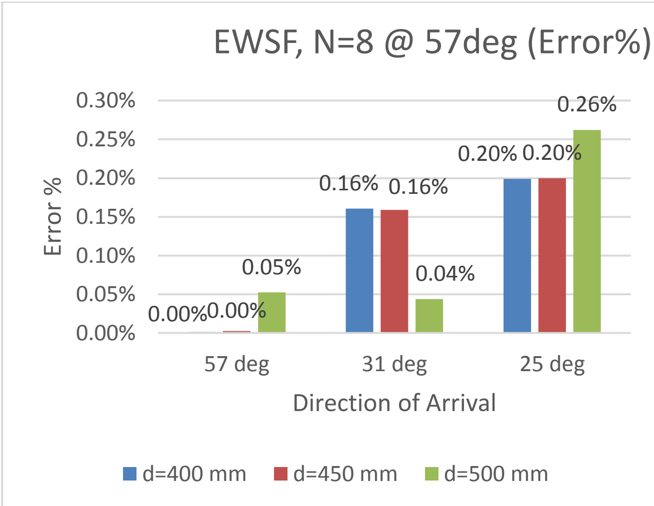

Figure 7: EWSF N=8

Error percent is almost equal in first two cases of d i.e. for 0.4 and 0.45.

CASE 2: When N=10

Table 8: EWSF N=10

No. of antenna Element = 10			
Spacing (mm)	Angles (degree)		
400	57.0013	31.0029	25.0043
450	57.0048	30.9948	25.0205
500	57.0096	30.9732	24.9859

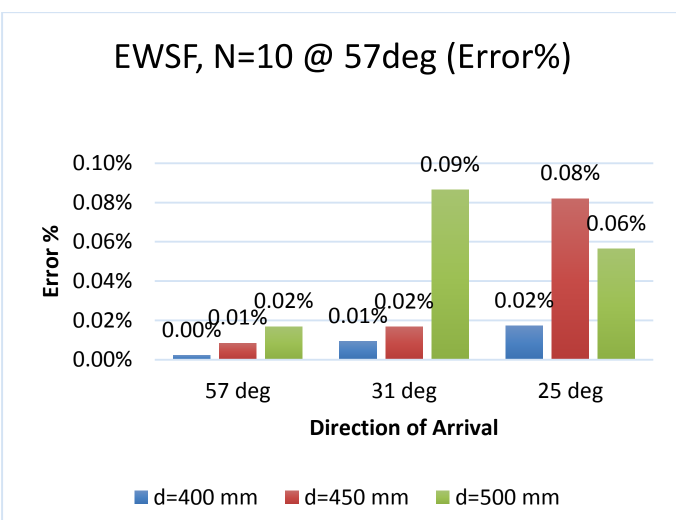

Figure 8: EWSF N=10

CASE 3: When N=2

Table 9: EWSF N=12

No. of antenna Element = 12			
Spacing (mm)	Angles (degree)		
400	57.0046	31.0011	24.995
450	56.9911	30.9955	25.0065
500	56.9985	31.0083	25.0231

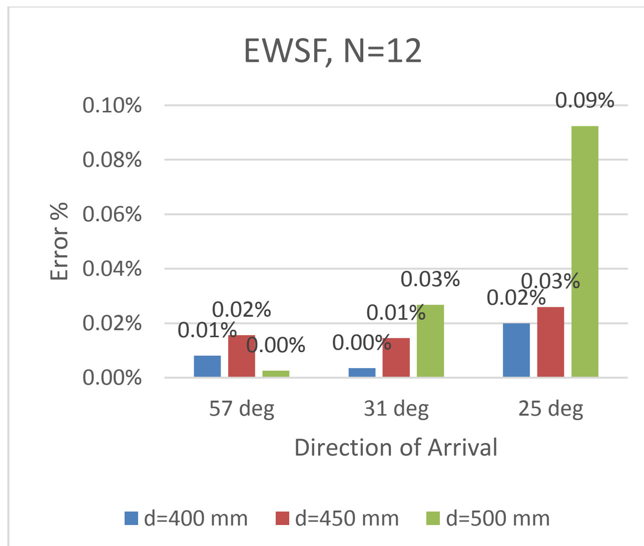

Figure 9: EWSF N=12

Error rate is less in case of N=12.

Comparisons: The comparisons are shown for one angle among the above three broadside angle. Let us consider it is 57degree.

CASE 1: When N=12

Table 10: N=12 @ 57deg

N=12 @ 57deg			
	EWSF	WSF	ESPRIT
d=400mm	57.0046	57.0711	56.8865

d=450mm	56.9911	57.0647	56.942 3
d=500mm	56.9985	57.05	56.979

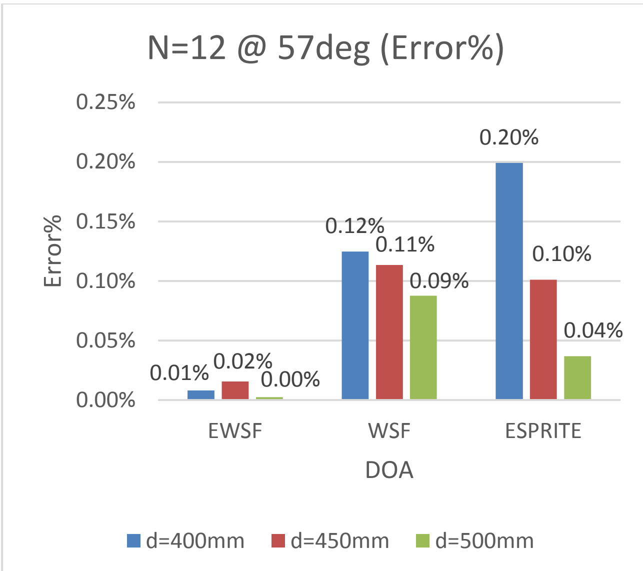

Figure 10: N=12 @ 57deg

Graph shows that EWSF (Enhanced Weighted Subspace Fitting) algorithm shows least error percentage than the above two algorithms.
It shows that resolution of EWSF is much better than the other two conventional algorithms.

<u>CASE 2</u>: When N=12

Table 11: N=8 @ 57deg

N= 8 @ 57deg			
	EWSF	WSF	ESPRIT
d=400mm	57.0009	56.9954	56.2447
d=450mm	57.0014	56.988	56.4164
d=500mm	56.9701	56.8805	56.5387

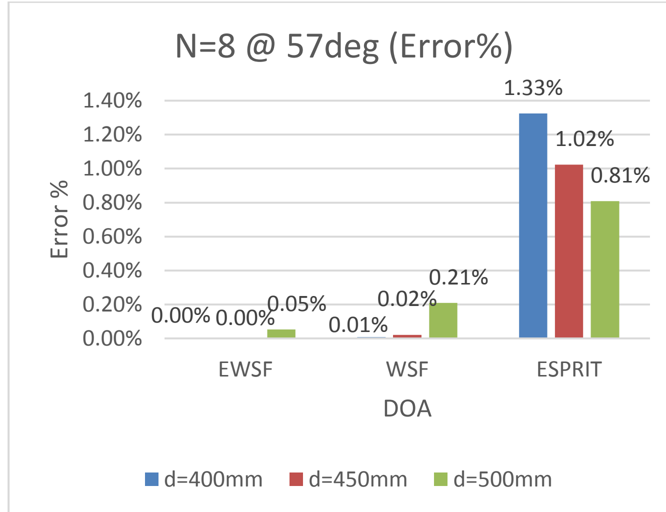

Figure 11: N=8 @ 57deg

<u>CASE 3</u>: For d=0.4

Table 12: d=400mm @ 57deg

d=400mm @ 57deg			
	EWSF	WSF	ESPRIT
N=8	57.0009	56.9954	56.2447
N=10	57.0013	56.915	56.5681
N=12	57.0046	57.0711	56.8865

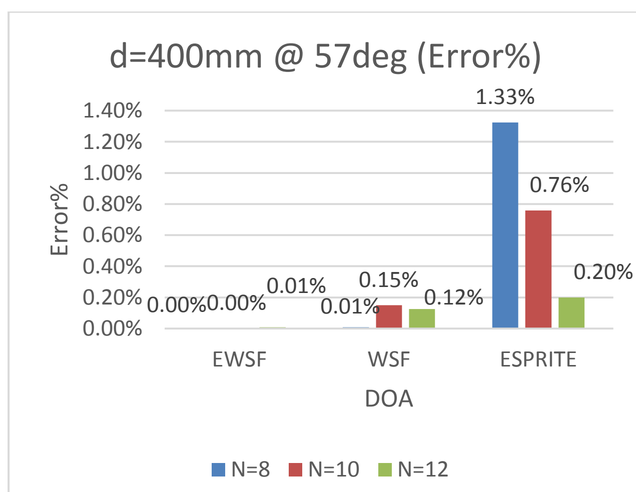

Figure 12: d=400mm @ 57deg

CASE 4: For d=0.5

Table 13: d=500mm @ 57deg

d=500mm @ 57deg			
	EWSF	WSF	ESPRIT
N=8	56.9701	56.8805	56.5387
N=10	57.0096	56.9804	56.7346
N=12	56.9985	57.05	56.979

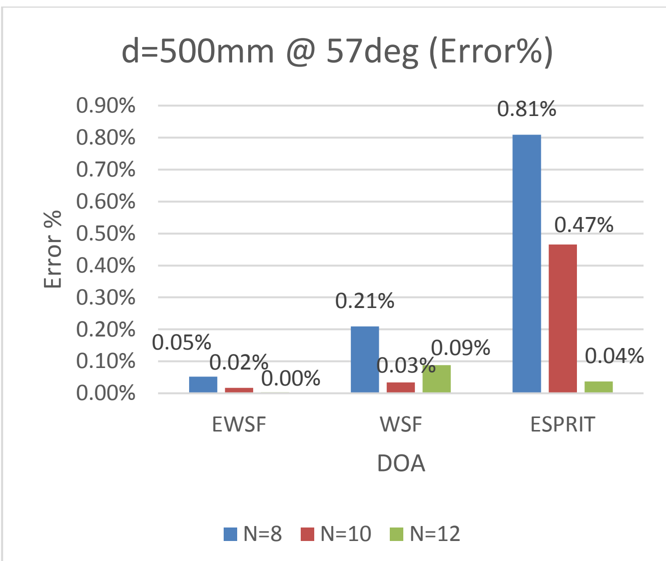

Figure 13: d=500mm @ 57deg

It is observed that EWSF shows almost negligible error rate by considering any number of elements for the above three cases.

Hence the results and comparisons shows that EWSF provides better resolution than the conventional algorithms.

VIII. CONCLUSION

A modified EWSF algorithm for calculating the DOA which will use the advantages of both ESPRIT and WSF algorithm. It will work on both coherent and non-coherent signals. The performance of Smart Antenna depends upon the resolution of Direction of Arrival. As the resolution of ESPRIT is better than the MUSIC algorithm, so we considered ESPRIT algorithm whose complexity is less and does not require peaks to calculate DOA unlike MUSIC algorithm. But due to shortcoming of this classic algorithm of not working on coherent signals we have to rely on WSF algorithm. Compared to conventional WSF which requires number of sources to be known in advance before calculating the DOA, EWSF works automatically and calculates the DOA without knowing the number of sources in advance. Whereas the ESPRIT algorithm works only on non-coherent signals. The experimental results show the performance of EWSF which is better than the conventional algorithms like WSF and ESPRIT.

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