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A New Blind DOA Estimation Using Two Uniform Linear Array for Low Side Lobe Adaptive Array

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Suitably designed Adaptive algorithm can collect the main signals' multipath and add them constructively with main signal with very low side lobe level in all other directions, hence eliminating the jamming signal from other directions. A new technique for DOA estimation of signals impinging on Two Uniform Linear Array (ULA) offset with each other by a known angle also has been proposed for further analysis and discussions.

Keywords: DOA, Uniform Linear Array (ULA), Adaptive algorithm

Introduction

For an adaptive antenna system, if p users transmit signals from different locations, and each user's signal arrives at the array through multiple paths. Suitably designed Adaptive algorithm can collect the main signals' multipath (Fig. 1) and add them constructively with main signal with very low side lobe level in all other directions, hence eliminating the jamming signal from other directions.

Low Side Lobe Adaptive Array Processing

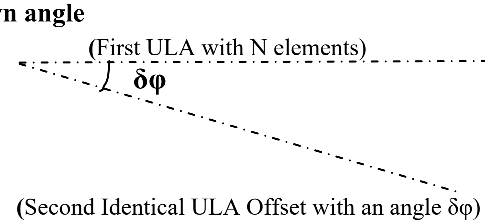
Let L_{Mi} denote the number of multipath components of i-th user. We have $\sum_{i=1}^{p} LM_i = p$

Let's further assume that all of the multi path components for a particular user arrive within a time window which is much less than the channel symbol period for that user, then the input data vector could be expressed as[1–3]

$$x(t) = \sum_{i=1}^{p} \sum_{k=1}^{LM_i} \alpha_{i,k} a(\theta_{i,k}) s_i(t) + n(t) \qquad \dots (1)$$

where $\theta_{i;k}$ is the DOA of the k-th multi path component for the i-th user, $a(\theta_{i;k})$ is the steering vector corresponding to $\theta_{i;k}$, $\alpha_{i;k}$ is the complex amplitude of the k-th multipath component for the i-th user.

Direction of Arrival Estimation by Two ULA offset with a known angle



The signal component arriving on *n*th antenna element of First ULA at a particular instance of time is given by Sarkar *et al.*[1]

$$X_{n1} = A \exp(j2\pi nd \cos\varphi/\lambda) \qquad \dots (2)$$

Where A = complex amplitude of the signal, φ = Direction of Arrival (DOA) of the signal (unknown), d = spacing between antenna elements and λ = wavelength.

Now, one can view (2) as and the signal component arriving on *n*th antenna element of Second ULA i.e X_{n2} at a particular instance of time is given by modifying (3) as below –

$$X_{n1} = A \exp[j2\pi f (nd \cos\varphi/c)] \ \& \ X_{n2} = A \exp[j2\pi f (nd \cos(\varphi + \delta\varphi)/c)] \qquad \dots (3)$$

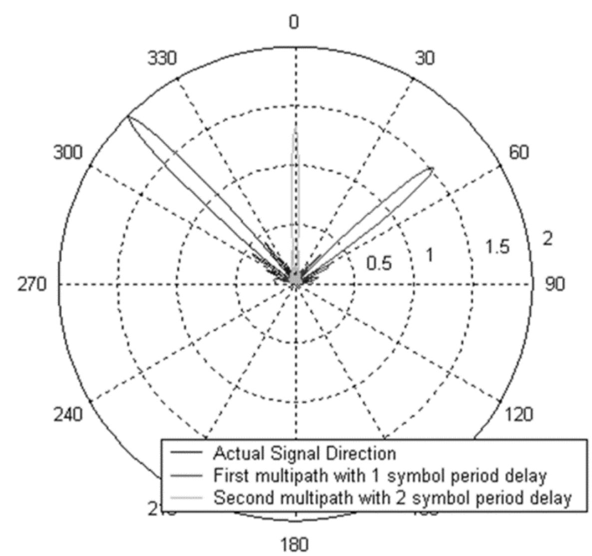


Fig. 1 — Very Low side lobe Adaptive Array response where signal is coming form -45º and two multipath are coming from 0º and 45º respectively

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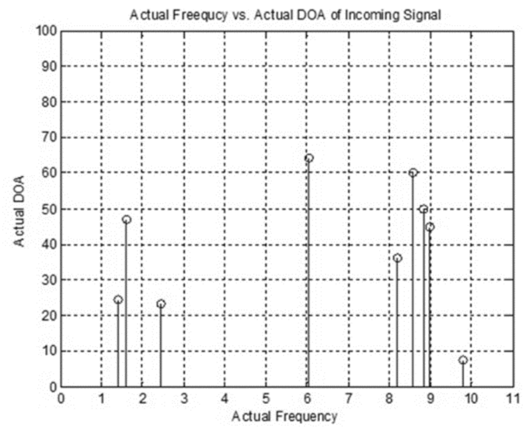
Where f= frequency of the signal and c= velocity of wave.

Now taking the frequencies (which can be known by seeing the spectra of the signal) of the signals form (3) namely X_{n1} and X_{n2}, and taking their ratio one could get-

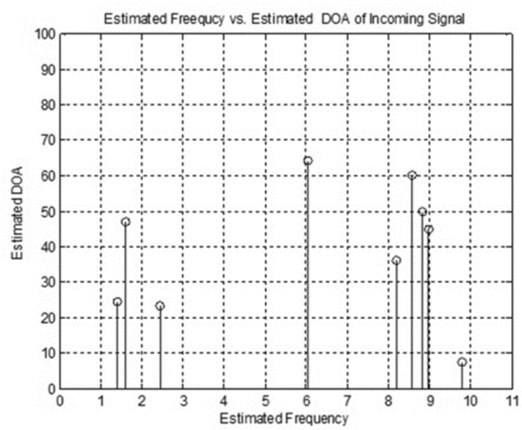
Frequency of X_{n1}/ Frequency of X_{n2} = $\cos\varphi/ \cos(\varphi+ \delta \varphi) = 1/K$

where, *K* is Known by the measurement of actual frequencies of the signals impinging on Two ULAs)

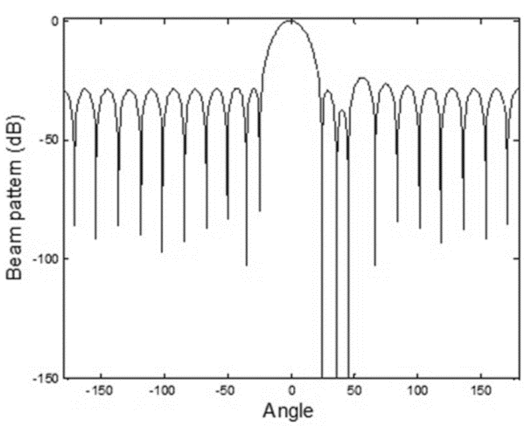
Hence, $\varphi = \tan^{-1}[(\cos(\delta \varphi) - K)/\sin(\delta \varphi)]$ … (4)



(2A) Actual signals' DOAs and Frequencies

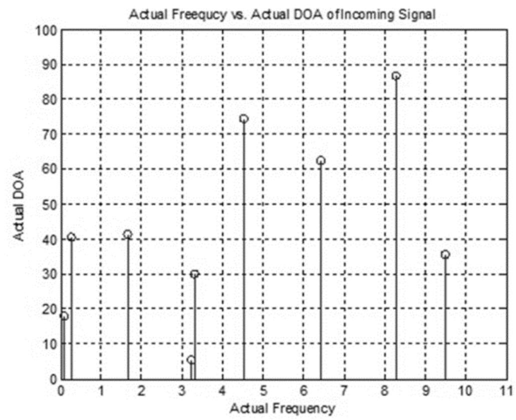


(2B) Estimated DOAs and Frequencies

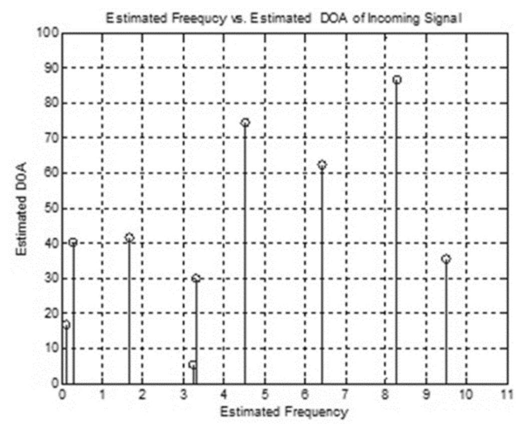


(2C) Creating NULL towards the undesired signals' directions

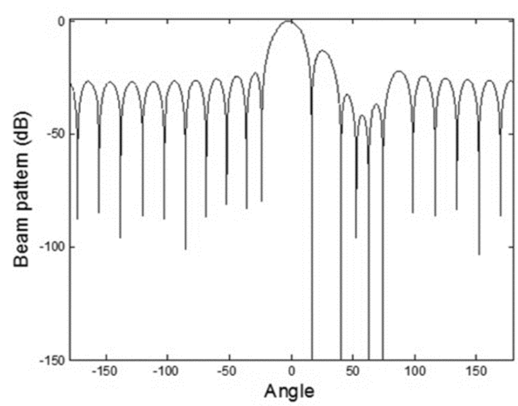
Fig. 2 — First MATLAB™ Simulation result shows Actual Signals, Estimated signals on the Array and Null creation towards the direction of three undesired signals



(3A) Actual signals' DOAs and Frequencies



(3B) Estimated DOAs and Frequencies



(3C) Creating NULL towards the undesired signals' direction

Fig. 3 — Second MATLAB™ Simulation result shows Actual Signals, Estimated signals on the Array and Null creation towards the direction of four undesired signals

Now using the simple relation given in (4) one can determine the unknown DOA (i.e. φ) of all incoming signal impinging on the array with suitable algorithm based on (3) and (4).

After determining the frequency and DOA of all impinging signals on the array by using Fourier transform and using (3) and (4) as shown in fig. 2A, 2B and fig. 3A, 3B and if desired signal directions are known to adaptive array (which is common for GPS receiver) as priori, then other signals' direction can be fed into a simple null creating algorithm[2] to produce nulls towards the undesired signals' directions[3] to reduce the jammer power. In the simulation data, jammers are indicated as with superscript (J1), (J2)...etc which stands for First Jammer Signal, Second Jammer Signal and so on. In these simulations $\delta\ \varphi = 1^{o}$. Estimated Frequencies and Estimated DOAs are not with the same order as signals are sensed by the array, but after estimating the entire signal space, their plots almost identical as exhibited between Fig. (2A) & (2B) and between Fig. (3A) & (3B). Maximum estimation error observed in DOA of second jammer signal of simulation 2, with an order of 1.5º only.

Simulation 1Results

Actual Frequency
(MHz) = 9.4850 4.5170^(J1) 3.3170 0.0780^(J2) 1.6580 8.2820 6.4340^(J3) 3.2230 0.2640^(J4)

Estimated FREQUENCY
(MHz) = 0.0774^(J2) 0.2633^(J4) 8.2833 4.5165^(J1) 1.6591 3.3177 6.4368^(J3) 3.2228 9.4849

Actual DOA
(Degree) = 35.5400 74.3900^(J1) 29.8700 18.1200^(J2) 41.5200 86.7300 62.4900^(J3) 5.5200 40.4100^(J4)

Estimated DOA
(Degree) = 16.7296^(J2) 40.2472^(J4) 86.7306 74.3877^(J1) 41.5637 29.8979 62.5029^(J3) 5.5211 35.5417

Simulation 2 Results

Actual Frequency
(MHz) = 9.4850 4.5170^(J1) 3.3170 0.0780^(J2) 1.6580 8.2820 6.4340^(J3) 3.2230 0.2640^(J4)

Estimated FREQUENCY
(MHz) =0.0774^(J2) 0.2633^(J4) 8.2833 4.5165^(J1) 1.6591 3.3177 6.4368^(J3) 3.2228 9.4849

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Conclusion

A new type of DOA estimation algorithm is proposed by rotating the radiation pattern of array using electronic steering by a small angle, MATLAB™ simulation shows estimations are very close both for DOA and frequencies. Combining this algorithm with conventional multipath constrained type of algorithm may produce very good results for low side lobe adaptive array. But before that, proposed DOA estimation algorithm needs more analysis and discussions.

References

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