Adaptive Mitigation of Jammer & Clutter in an Airborne GMTI scenario using Sample Matrix Inversion Processing

Debasish Bhaskar, Mousumi Gupta, Rabindranath Bera

Abstract*— *In this paper, we propose an adaptive jammer & clutter suppression scheme using digital beam formation (DBF) technology in RADAR with uniform rectangular phased-array antennas. Digital Beam Forming (DBF) algorithm is employed to cover a detection area of long range (2000 m) and angular orientation of [900, -35.260] w.r.t the RADAR platform flying in an Airplane under the airborne scenario. The airplane is actually a carrying a spaceborne radar with its baseband source using linear frequency modulated (LFM) waveform. The RF carrier is used as a single 3 GHz oscillator. The simulation of the flying radar is done with consideration of a ground clutter being generated near to the target zone and also the existence of a wideband Gaussian-distributed barrage-jammer is encountered. The back-end processing uses Sample Matrix Inversion (SMI) of Clutter & Jammer Covariance matrix with subspace-based DBF algorithm [1]. The proposed 3 GHz Adaptive Beamforming and Jammer Suppression (ABJS) in Airborne RADAR can be used for mitigating the Jammers and Clutters in a Ground Moving Target Indicator (GMTI) system prevailing under the war-field condition.

Index Terms*— *Digital beam formation, GMTI, Jammer suppression, Airborne RADAR, Gaussian distributed barrage-jammer.

I. INTRODUCTION

The proposed ABJS radar uses an LFM waveform as the signal source, which has a simple architecture and requires low computing power compared to a pulse waveform. The LFM waveform is used to obtain the range and velocity simultaneously. Also, the radar adopts subspace based DBF technology using a 10 x 10 Uniform Rectangular Array (URA) structure with multi-channel transmitter and receiver to implement digital beam synthesis and multi-range function. This URA structure can lower the system cost by reducing the number of receiver channels, as well as lessen the system size. The DBF technology is used to detect the azimuth/elevation angle with high resolution and accuracy.

In a ground moving target indicator (GMTI) system, an airborne radar collects the returned echo from the moving target on the ground. However, the received signal contains not only the reflected echo from the target, but also the returns from the illuminated ground surface. The return from the ground is generally referred to as clutter.

The clutter return comes from all the areas illuminated by the radar beam, so it occupies all range bins and all directions. The total clutter return is often much stronger than the returned signal echo, which poses a great challenge to target detection. Hence, the clutter filtering is a critical part of a GMTI system. In a traditional GMTI system, it is considered that the ground is stationary and hence, the clutter due to ground bounce does also occupy the zero Doppler bin in the Doppler spectrum. So, pulse canceller can easily filter out this type of zero doppler clutter [2]. But when the radar platform itself is moving, such as in a airborne scenario, the Doppler component from the ground return is no longer zero. In addition, the Doppler components of clutter returns are angle dependent. In this case, the clutter return is likely to have energy across the Doppler spectrum. Hence, the clutter cannot be filtered only with respect to Doppler frequency.

Jamming is another significant interference source that is often present in the received signal. The jammers may be carried by special aircraft flying on holding patterns in a stand-off mode or may be installed on the ground. In these cases they are generally received by the sidelobes of our antenna. In special worst-case situations the jammers are received within the width of our mainbeam. This situation may occur especially in Air-Defence applications if attacking hostile aircraft are accompanied by escorting aircraft carrying the jammers. The complete jammer scenario may be encompassed by stand-off, escorting and ground-based jammers. Certain jammer scenarios have been generated by military planning authorities but the real possible future scenario is unknown. Jammers are inexpensive compared with radar systems and it may be worthwhile for our counterpart to apply a larger number of jammers to make our radar ineffective.

The simplest form of jamming is a barrage jammer, which is strong, continuous white noise directed toward the radar receiver so that the receiver cannot easily detect the target return. The jammer is usually at a specific location, and the jamming signal is therefore associated with a specific direction. However, because of the white noise nature of the jammer, the received jamming signal occupies the entire Doppler band.

The URA, having dimension of [10 x 10], is mounted on the radiator/collector platform of the airborne radar. DPCA Technique: In the Displaced Phase Centered Array (DPCA) technique, the airborne radar is flying along the y-axis of the URA at a speed such that it travels a half element spacing of the array during one pulse interval. Such a setting of velocity is provided in the DPCA technique. The DPCA technique cannot suppress the jammer interference. To suppress the clutter and jammer simultaneously, we need a more

Manuscript received February, 2014.

Debasish Bhaskar, Department of Electronics and Communication Engineering, Sikkim Manipal Institute of Technology, Majitar, Sikkim, India.

Mousumi Gupta, 2Department of Computer Science and Engineering, Sikkim Manipal Institute of Technology,Majitar, Sikkim, India,.

Dr. Rabindranath Bera, Department of Electronics and Communication Engineering, Sikkim Manipal Institute of Technology, Majitar, Sikkim, India.

sophisticated algorithm. This technique is based on clutter/jammer covariance matrix generation from the raw data cube and then followed by the inversion of the covariance matrix to obtain the adaptive weights for jammer/clutter suppression [2, 3].

This leads to SMI beamformer and it is applied to the collected data cube within the seeker receiver. In addition to the information needed in DPCA, the SMI beamformer needs to know the number of guard cells and the number of training cells. The algorithm uses the samples in the training cells to estimate the interference. Thus, we should not use the cells that are close to the target cell for the estimates because they may contain some target information, i.e., we should define guard cells. The number of guard cells must be an even number to be split equally in front of and behind the target cell. The number of training cells also must be an even number and split equally in front of and behind the target. Normally, the larger the number of training cells, the better the interference estimate.

II. RADAR SYSTEM DESIGN

For jammer suppression and to develop an improved insight the derivation of the weighting coefficients for a receiving URA, is the first step. The main goal is to generate notches into given jammer directions. Let's consider an URA with N antenna elements at a regular spacing with $d = \lambda/2$. The direction of the main beam is given by $u_0 = (\sin \Phi_0)$ and the directions of the K jammers by u_k with $k = 1, \ldots, K$.

The received signals from these sources impinging on the array with normalized amplitudes equal to 1 are given by the columns a_k in matrix A with elements $n = 1, \ldots, N$ (Fig.1):

$a_{kn} = \exp(j\Pi u_{kn})$ [1]

$$A = \begin{bmatrix} a_{01} & a_{11} & a_{21} & \ldots\ldots a_{K1} \\ \vdots & \vdots & \vdots & \ldots\ldots \vdots \\ a_{0N} & a_{1N} & a_{2N} & \ldots\ldots a_{KN} \end{bmatrix} \qquad [2]$$

This matrix 'A' is containing the Antenna vectors where, each column of A, is mutually orthogonal

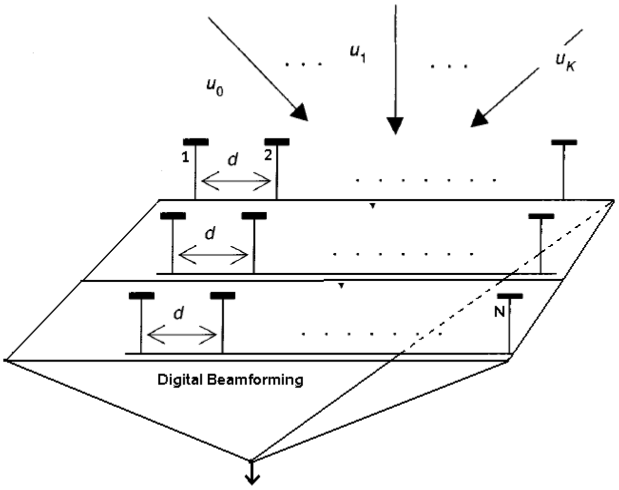


Fig.-1: Jamming signals incident on N elements of the [10 x 10] URA

The MATLAB object 'phased.IsotropicAntennaElement' the antenna elements are designed. Each antenna element has its operating frequency range [0.3GHz to 5GHz]. But the proposed spaceborne radar is operating at RF=3GHz. The radar platform is situated at a height of 1000m above the battle ground.

Another object 'phased. LinearFMWaveform' is used to design the baseband source of the airborne radar. The baseband waveform is having following attributes:

Sample Rate=20MSa/s, Sweep Bandwidth=10MHz, Sweep Direction=Down, Sweep Interval=Symmetric, PRF=10KHz, Pulse Width=5 microsec, Total Samples in one Pulse Repetition Interval=2000.

MATLAB object 'phased.URA' is used to construct the uniform rectangular array of [10 x 10] dimension having the element spacing of 0.05m. Now, the 'phased.Radiator' object implements a narrowband signal radiator which upconvert the baseband signal to the RF of 3GHz, similarly, the 'phased.Collector' object implements a narrowband signal collector which collects the RF stimuli from each of the 100 elements of the URA and finally downconverts them to baseband waveform. The input signals to the radar collector are multiple plane waves impinging on the entire array. Each plane wave is received by all collecting elements.

Target is designed to be operating at 3GHz and its type is non-fluctuating having mean radar cross section (RCS) of 1m2. The target platform is located at co-ordinate [1000, 1000, 0] in the ground plane. The target is moving with a velocity 30m/sec. .

Presence of Gaussian distributed jammer is considered in this scenario and the location of the jammer is taken in the 1st case at [Azimuth=900, Elevation=00], in the 2nd case [Azimuth=1200, Elevation=00] & in the 3rd case [Azimuth=600, Elevation=00].

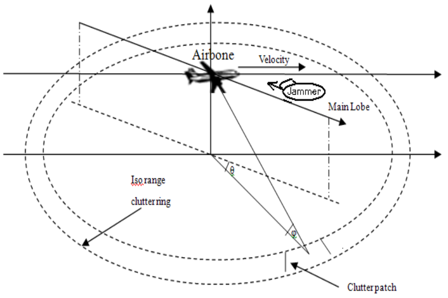


Fig.-2: The Clutter & Jammer conditions in airborne or spaceborne MTI systems

Target returns the desired signal; however, this interference is also present in the received signal. This section focuses on the jammer with an effective radiated power (ERP) of 100 Watts.

Using the constant gamma model of Matlab with a gamma value of -15 dB, the ground clutter has been modelled. Azimuth span of each clutter patch is taken 100 and the clutter is formulated near to the target.

In the receiver side, the sample matrix inversion processor operates on a cube of data as illustrated in Fig.-3.

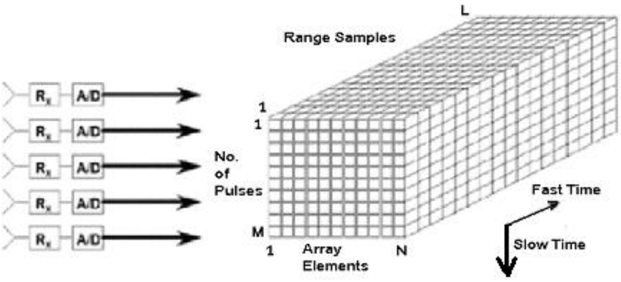


Fig.-3: Received data cube in Sample Matrix Inversion based Airborne RADAR receiver

Extra dimension, N, comes from the N distinct inputs from the array antenna (for both elevation and azimuth). This will produce a radar data cube of dimensions N (number of array antenna inputs) by L (number of range bins in fast time) by M (number of pulse in CPI in slow time). Doppler processing occurred over the data slice across the L and M dimensions. In Sample Matrix Inversion method, the slices of data across the N and M dimensions are processed.

Jammer is transmitted continuously; its energy is present in all the range bins. And, as shown in Fig.-4, the jammer cuts across the all Doppler frequency bins due to its wideband, noise-like nature. It does appear at a distinct angle of arrival however. Fig.-4 also depicts the ground degree of clutter in a side-looking airborne radar due to the Doppler of the ground relative to the aircraft motion. A slow moving target return can easily blend into the background clutter.

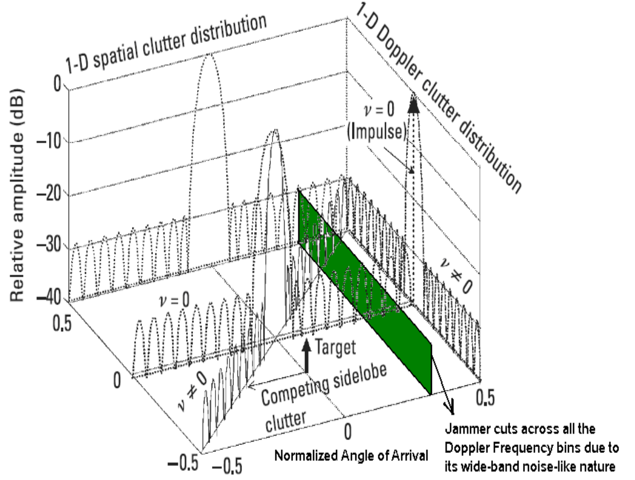


Fig.-4: Clutter & Jammer orientation in Doppler space

III. ADAPTIVE DIGITAL BEAMFORMING WITH JAMMER & CLUTTER PROCESSING ALGORITHM.

As mentioned in equation (2), the matrix A contains the columns which are mutually orthogonal. In other way it means that the corresponding patterns have a zero in the respective other beam directions, only if the directions u_k are on a directional raster u:

-1: 2/N : 1, or uk = 2k/N. Then from equation (1), it can be written as:

$$\begin{aligned} a_k^*.a_l &= \sum_{n=1}^{N} \exp\left(-\frac{j2\pi}{N}(k-l).n \right) \\ &= 0 \quad for\ k \neq l \qquad (3) \\ &= N \ \ for\ k = l \end{aligned}$$

Each beam would have zeros in the pattern for all other beam directions. But for arbitrary directions u_k this is not the case [4]. Under this condition, the computation of the weighting vector in order to form a receive beamformer is needed for the adaptive suppression of the jammer. Let's assume a signal vector containing the unknown signal amplitudes of the sources (target and jammers) in the column matrix 's':

$$s = \begin{bmatrix} s_0 \\ s_1 \\ \vdots \\ s_K \end{bmatrix}$$

(4) and the noise vector at the receiver is given by

$$n = \begin{bmatrix} n_1 \\ n_2 \\ \vdots \\ n_N \end{bmatrix} \qquad (5)$$

Due to the superposition of all signal components k = 0 , . . . , K, including the main beam signal for k = 0, and the noise vector 'n', the collected signal vector 'z' at the radar receiver will be given by: **z = As + n** (6)

Now, from the received signal vector z, an estimate $\hat{s}$ of the source signal s is evaluated with a least-mean-square error between s & $\hat{s}$. The weighting matrix W is needed to get the estimate. The resulting expression is given by:

$$\hat{\boldsymbol{s}} = \boldsymbol{W}^* \boldsymbol{x} \qquad (7)$$

If the covariance of s is given by P and Q being the covariance matrix of the noise n, the weight matrix is related with P & Q as:

$$\boldsymbol{W} = \left(\boldsymbol{APA}^* + \boldsymbol{Q} \right)^{-1} \boldsymbol{AP} \qquad (8)$$

Matrix W* has (K + 1) rows and each row (with index k) is the beamforming vector in the direction uk with minimum output signal from all other directions ul and $k \neq l$. It does mean that each beamforming vector gives rise to a beam having notches in the other beam directions. Hence, a set of mutually decoupled beams has developed. As a result, the notches in all other jammer directions u1, . . . , uK are achieved for the main beam direction u0 [5]. The main beam is selected by the row matrix e*[l, (K + I)] given by:

$$\boldsymbol{e}^* = [1 \ \ 0 \cdots \ 0] \qquad (9)$$

and the weighting vector for the main beam direction becomes

$$\boldsymbol{w}_0^* = \boldsymbol{e}^* \boldsymbol{W}^*$$

(10)

The resultant weight vector for the main beam is comprised of the individual array element weights as:

$$\boldsymbol{w}_0^* = [\boldsymbol{w}_{01}^* \ \boldsymbol{w}_{02}^* \cdots \boldsymbol{w}_{0N}^*] = \boldsymbol{e}^* \boldsymbol{A}^* \left(\boldsymbol{AA}^* + \boldsymbol{Q} \right)^{-1} \qquad (11)$$

From this equation (11), the term e*A* is the beamforming vector for the direction u0. The noise covariance matrix Q may be expressed as Q = qI[K + 1, K + 1] giving:

$$\boldsymbol{w}_0^* = \boldsymbol{a}_0^* \left(\boldsymbol{AA}^* + \boldsymbol{qI} \right)^{-1} \qquad (12)$$

I[K+1, K+1] is the identity matrix because the jammer signals are mutually uncorrelated & depending upon the receiver noise to jammer power ratio, the noise level 'q' is selected.

If complex received signal after the Digital Beam Synthesis at radar receiver, is represented as:

$$\boldsymbol{z} = \boldsymbol{x} + \boldsymbol{jy} = \begin{bmatrix} \boldsymbol{x}_1 + \boldsymbol{jy}_1 \\ \vdots \\ \boldsymbol{x}_N + \boldsymbol{jy}_N \end{bmatrix} \qquad (13)$$

The equation is transformed into the important form for the Gaussian distribution, now with Q = E{zz*}:

$$\boldsymbol{p}(\boldsymbol{z}) = \frac{1}{\pi^N \det \boldsymbol{Q}} \exp\left(-\boldsymbol{z}^* \boldsymbol{Q}^{-1} \boldsymbol{z} \right) \qquad (14)$$

Target signal vector s may be known and the noise is assumed to be Gaussian distributed. Then we have from equation (14), with s as the mean vector:

$$p(\boldsymbol{z},\boldsymbol{s}) = \frac{1}{\pi^N \det \boldsymbol{Q}} \exp\left(-(\boldsymbol{z}-\boldsymbol{s})^* \boldsymbol{Q}^{-1}(\boldsymbol{z}-\boldsymbol{s})\right) \quad (15)$$

From the Likelihood Ratio Test (LRT) Function;

$$\begin{aligned}\lambda(\boldsymbol{z}) &= \frac{p(\boldsymbol{z},\boldsymbol{s})}{p(\boldsymbol{z},0)} \\ &= \exp\left(-(\boldsymbol{z}-\boldsymbol{s})^*\boldsymbol{Q}^{-1}(\boldsymbol{z}-\boldsymbol{s}) + \boldsymbol{z}^*\boldsymbol{Q}^{-1}\boldsymbol{z}\right) \quad (16) \\ &= \exp\left(\boldsymbol{s}^*\boldsymbol{Q}^{-1}\boldsymbol{z} + \boldsymbol{z}^*\boldsymbol{Q}^{-1}\boldsymbol{s}\right)\exp\left(-\boldsymbol{s}^*\boldsymbol{Q}^{-1}\boldsymbol{s}\right)\end{aligned}$$

The second exp factor does not depend on '**z**', it is only a factor for the decision threshold, and we can write for λ:

$$\lambda(\boldsymbol{z}) = \exp\left(2\mathrm{Re}\{\boldsymbol{z}^*\boldsymbol{Q}^{-1}\boldsymbol{s}\}\right) \quad (17)$$

Re{z} means real part of '**z**'.
This equation guides to compute the expression:

$$\boldsymbol{y} = \mathrm{Re}\{\boldsymbol{z}^*\boldsymbol{Q}^{-1}\boldsymbol{s}\} = \mathrm{Re}\{\boldsymbol{s}^*\boldsymbol{Q}^{-1}\boldsymbol{z}\} \quad (18)$$

or for uncorrelated receiver noise with Q = I:

$$\boldsymbol{y} = \mathrm{Re}\{\boldsymbol{s}^*\boldsymbol{z}\} = \mathrm{Re}\left\{\sum_{n=1}^{N} \boldsymbol{s}_n^*\boldsymbol{z}_n\right\} \quad (19)$$

All these components s_n of '**s**' are vectors with a certain known phase, while the noise components have a random phase. By a back rotation of the received signal components z_n according to the phases of s_n by forming the products $\mathbf{z_n s_n}^*$ all the signal components are aligned before the final summation and the sum results in a maximum signal value.
If the expected signal vector components differ in amplitude then an amplitude weighting is performed using the LRT according to the products $\mathbf{z_n s_n}^*$
In real radar operation the directions of the jammers are unknown or at least not precisely known. There are some effects which influence the received jammer signals to be different from a model: mutual coupling between the antenna elements, unbalanced receiver channels and multipath effects. Hence, only an adaptive solution can be efficient in practice.
We may apply the basic equation (17) for our task of Beamforming with interference suppression: the Beamforming vector a(u) for a selected direction '*u'* has to be multiplied by the inverse covariance matrix $\mathbf{Q}^{-1}$ and then by the received signal vector '**z**':

$$\boldsymbol{v} = \boldsymbol{a}^*\boldsymbol{Q}^{-1}\boldsymbol{z} \quad (20)$$

'v' is the Beamforming output and may be used for further signal processing such as pulse compression, Doppler filtering and sequential detection.
Two interpretations or realizations are possible for equation (20):

- The received signal vector '**z**' is first multiplied by the inverse of the covariance matrix 'Q' resulting in a vector y with minimized jammer signals, then follows Beamforming with '**a**':

$$\boldsymbol{y} = \boldsymbol{Q}^{-1}\boldsymbol{z} \;\; \textit{and} \;\; \boldsymbol{v} = \boldsymbol{a}^*\boldsymbol{y} \quad (21)$$

for each signal component $\mathbf{z_n}$ the most likely interference part $\hat{\boldsymbol{z}}_n$ is estimated from all other signal components $\mathbf{z_m}$ (m ≠ n). By using $\boldsymbol{y}_n = \boldsymbol{z}_n - \hat{\boldsymbol{z}}_n\,(\boldsymbol{n} = 1, \ldots, \boldsymbol{N})$ the interference is optimally cancelled from the signal vector '**y**'. Q has to be estimated from the received interference signal and noise from time segments without target echoes. For interference suppression by this matrix multiplication, N^2 complex multiplications are necessary for each received data sample '**z**'.

Beamforming is performed afterwards by the weighting vector **a*** applied to '**y**'.

Multiple beams may be formed from '**y**', that is after interference suppression, by applying a set of Beamforming vectors.

- An adapted Beamforming weight vector **w** is first computed by:

$$\boldsymbol{w}^* = \boldsymbol{a}^*\boldsymbol{Q}^{-1} \quad (22)$$

and then follows:

$$\boldsymbol{v} = \boldsymbol{w}^*\boldsymbol{z} \quad (23)$$

The N^2 multiplications with $\mathbf{Q}^{-1}$ have to be performed only for each new Beamforming vector or beam position [6]. For each data sample '**z**' the beam is formed by multiplication with w by N multiplications. Generally, this concept is much more economical.

IV. DESIGN & SIMULATION RESULTS

A. Creating the Jammer very close to Main Beam of the RADAR:

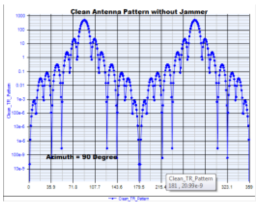


Fig.-5: Antenna pattern Without jammer

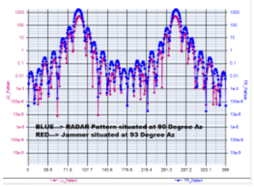


Fig.-6: Jammer arises at 93˚azimuth (very close to RADAR Beam)

The jammer beam almost enters the main beam direction and as a result the radar target detection is disturbed by the false alarms as shown in Fig.-7. The proper identification of the target gets difficult under this condition. [7, 8]. The target may be visible but at the same time, there are other false detections, so the ambiguity remains to correctly recognize the desired target.

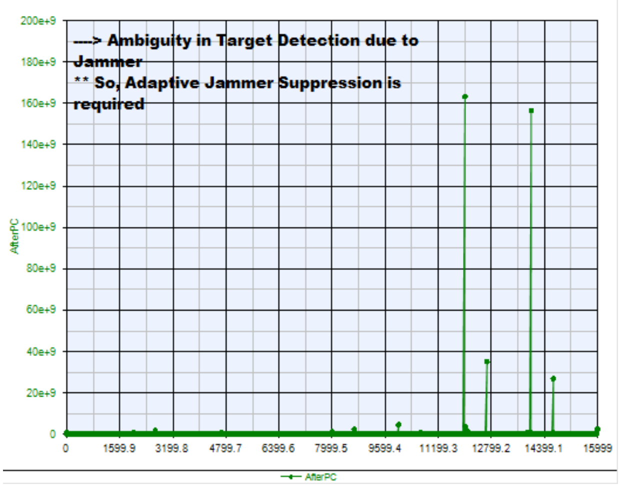
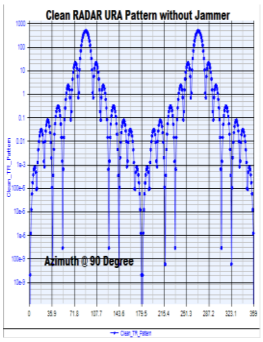


Fig. -7: Jammer effects the target detection; ambiguous detection occurs

B. Manually filtering Jammer by setting Theta (Elevation), Phi (Azimuth)



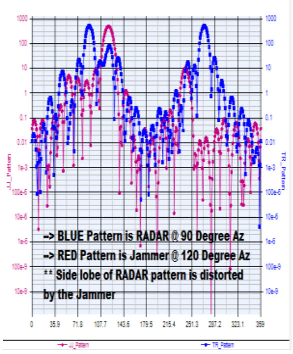


Fig.-8: Clean antenna pattern Fig-9 Jammer is oriented at 120^0 azimuth

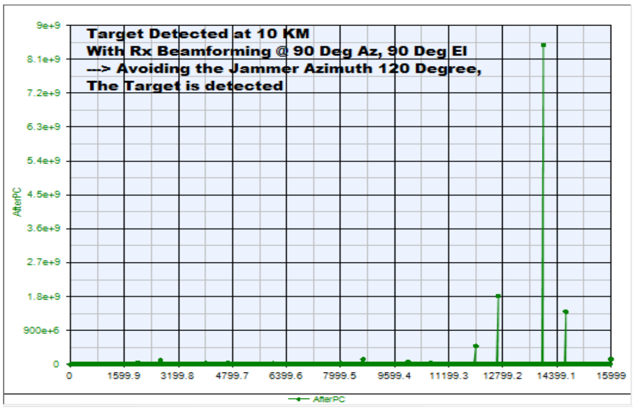


Fig.-10: After manual direction filtering (Az, El) Jammer effects get nullified; Target is unambiguously detected

In the simulation model, the radar receiver Digital Beam Synthesis is oriented manually to form a receiver beamformer pointing towards the target direction. As the Jammer orientation (Azimuth = 120^0) is far apart from the broadside view angle of the target (i.e., Jammer is azimuthally far apart from the target azimuth 90^0), the jammer can not distort the target detection at the output of the radar receiver as shown in Fig.-10. Rather, the ambiguity in target detection becomes much less in this case w.r.t the previous case (Fig.-7).

C. Adaptive Clutter & Jammer Suppression: Tx/Rx Digital Beam formation Sample Covariance Matrix Inversion Method: Cognitive Approach-1

- Target + Clutter Condition:

RADAR: 10 x 10 URA, Phased Array Gain 32 dB, Rmax=15 KM, Baseband B.W = 10MHz, Baseband waveform LFM, RF=3 GHz, RADAR Beam formed direction = [45^0, -35.26^0]

CLUTTER: Clutter Rmax=1.5 KM, Clutter signal Bandwidth = 10MHz, Clutter RF=3 GHz, Clutter orientation = [450, -35.260], Clutter Azimuth Coverage = 1800, Clutter Velocity = 0 m/sec.

RADAR TARGET: Target Rmax=1.5 KM, Target orientation = [45^0, -35.26^0], Target Velocity = 0 m/sec.

Before Inversion of Clutter Covariance Matrix:

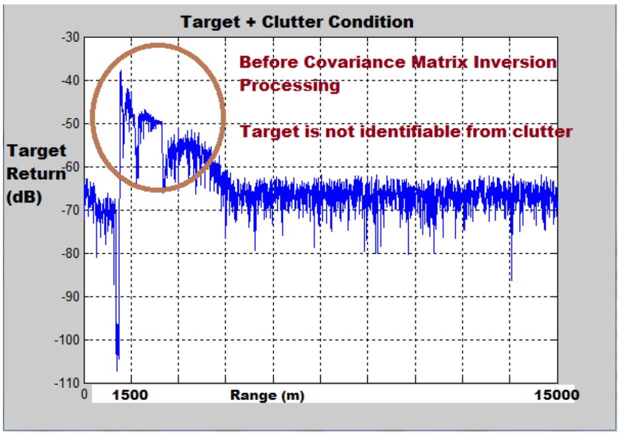


Fig.-11: Target is hidden in clutter

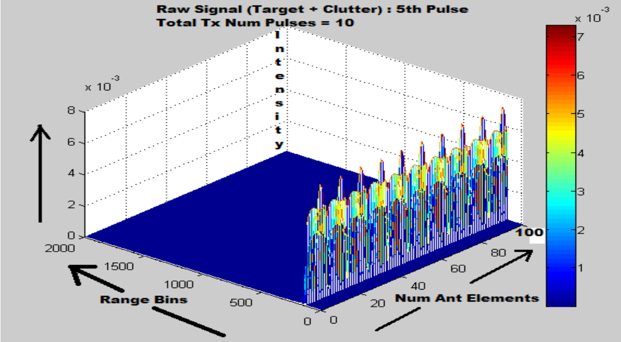


Fig.-12: 3D Plot for the received 5th Pulse containing return from Target + Clutter

The following plot is generated after the Clutter Covariance Matrix Estimation. The clutter is falling under the diagonal of the covariance matrix as shown in Fig.-13

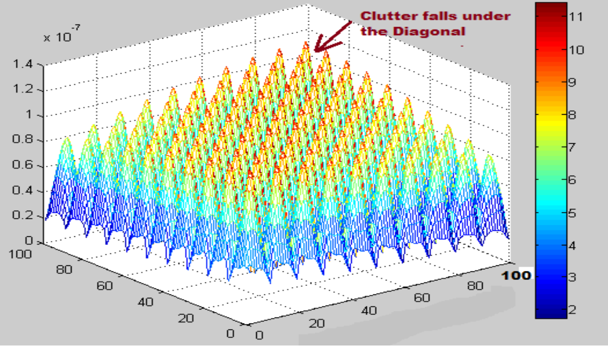


Fig.-13: Plot for the clutter covariance matrix at 3 GHz RF

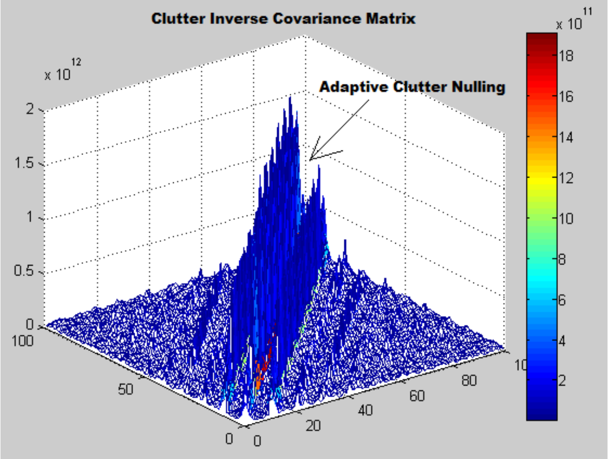


Fig.-14: Adaptive clutter nulling after inversion of clutter covariance matrix

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

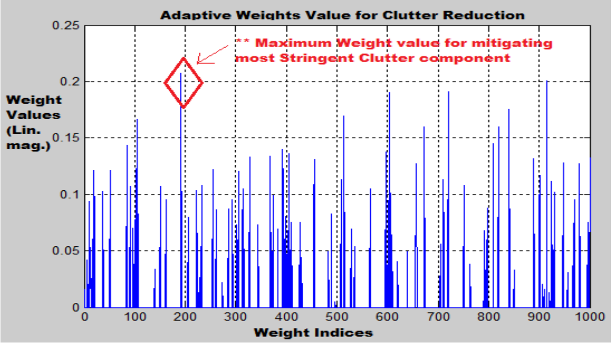


Fig.-15: Adaptive weights value for clutter reduction

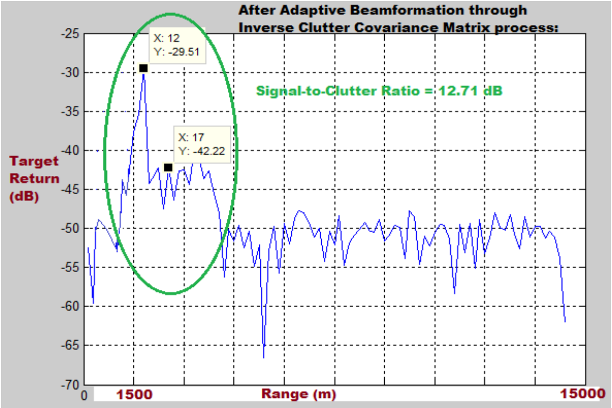


Fig.-16: After inversion of clutter covariance matrix, target is detected with adaptive DBF

Adaptive weights (w) are formulated to downweight the existing clutter, the plot is given in Fig.-15 for the linear magnitudes of Adaptive Weights.From Fig.-16, it is noticed that the Signal-to-Clutter ratio is obtained as 12.71dB with the target range detected at 1500m.

- <u>Target + Jammer Condition:</u>

RADAR: 10 x 10 URA, Phased Array Gain=32 dB, Rmax=15 KM, Baseband B.W = 10MHz, Baseband waveform is LFM, RF=3 GHz, RADAR Beam formed direction = $[45^0, -35.26^0]$

JAMMER: Jammer signal = Wideband Gaussian Jammer, Jammer orientation = $[60^0,$ $0^0]$, Jammer Velocity = 0 m/sec.

RADAR TARGET: Target Rmax=1.5 KM, Target orientation = $[45^0, -35.26^0]$,

Target Velocity = 0 m/sec.

Before Matrix Inversion Method: Target is Completely jammed by the Wideband Gaussian Jammer as shown in Fig.-17.

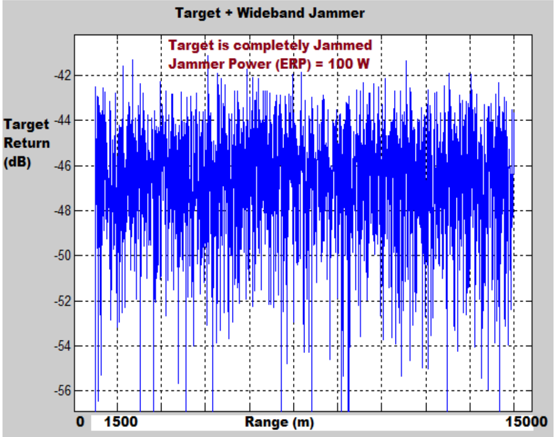


Fig.-17: Jammer makes the target invisible

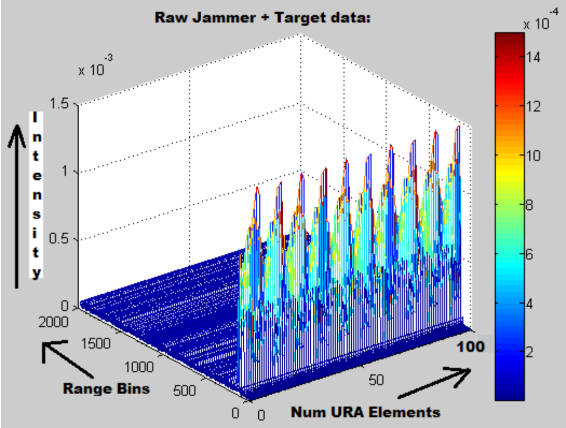


Fig.-18: 3D-Plot representing raw data including target with jammer signal

Formation of Jammer covariance matrix is done from the raw data cube as received by the 100 elements over 10 LFM pulses. The jammer covariance matrix is plotted below;

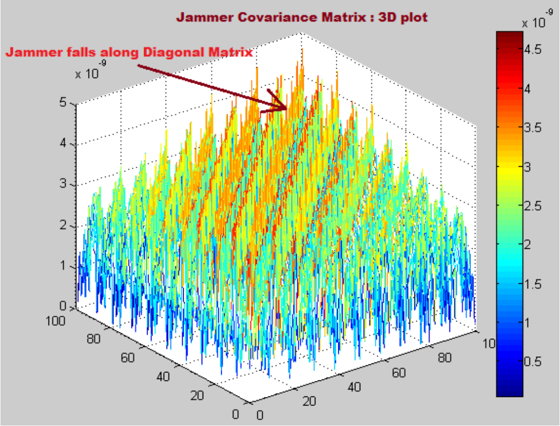


Fig.-19: Jammer covariance matrix

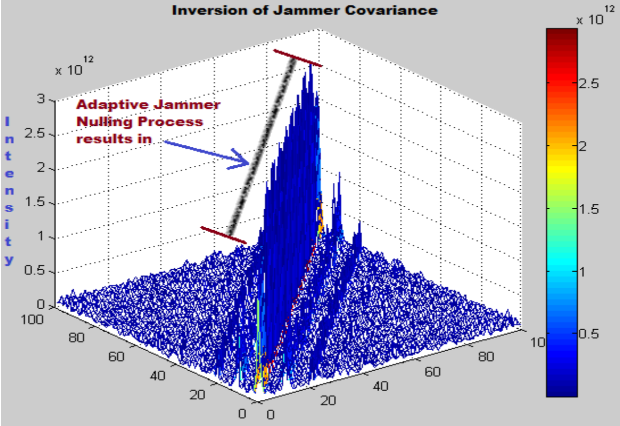


Fig.-20: Inversion of Jammer covariance matrix

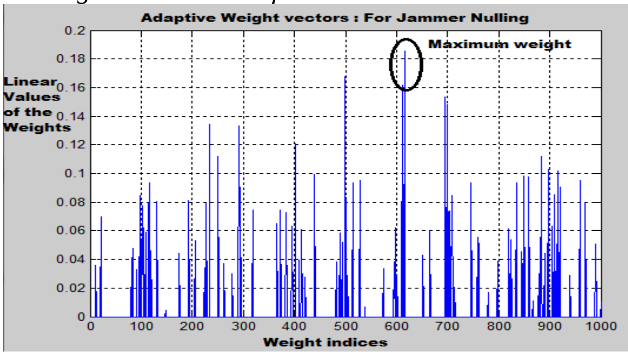


Fig.-21: Lin. magnitudes of Adaptive weight vectors w.r.t the weight indices

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

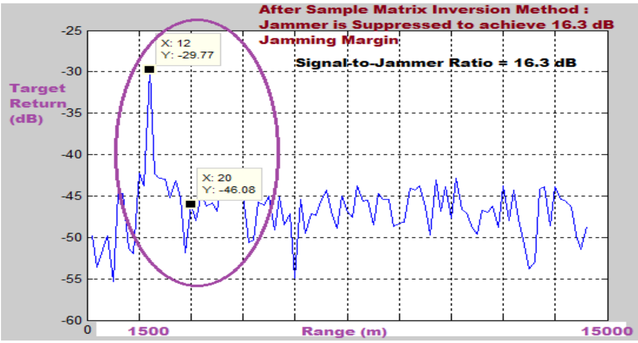


Fig.-22: Target is detected after adaptive jammer suppression, giving a signal-to-jammer ratio of 16.3 dB

Fig.-20 depicts that Inversion Matrix contains lowered intensity Jammer diagonal. The adaptive weights (w) are formulated to downweight the existing wideband jammer

- Target + Clutter + Jammer Condition:

RADAR: 10 x 10 URA, Phased Array Gain 32 dB, Rmax=15 KM, Baseband B.W = 10MHz, Baseband waveform LFM, RF=3 GHz, RADAR Beam formed direction = [45^0, -35.26^0] CLUTTER: Clutter Rmax=1.5 KM, Clutter signal B.W = 10MHz, Clutter RF=3 GHz,Clutter orientation = [45^0, -35.26^0], Clutter Azimuth Coverage = 180^0, Clutter Velocity = 0 m/sec.

JAMMER: Jammer signal = Wideband Gaussian Jammer, Jammer orientation = [60^0, 0^0], Jammer Velocity = 0 m/sec.

RADAR TARGET: Target Rmax=1.5 KM, Target orientation = [45^0, -35.26^0], Target Velocity = 0 m/sec.

Before Sample Matrix Inversion Method being adopted, the target detection is Completely failed by the Clutter + Wideband Gaussian Jammer as shown in Fig.-23.

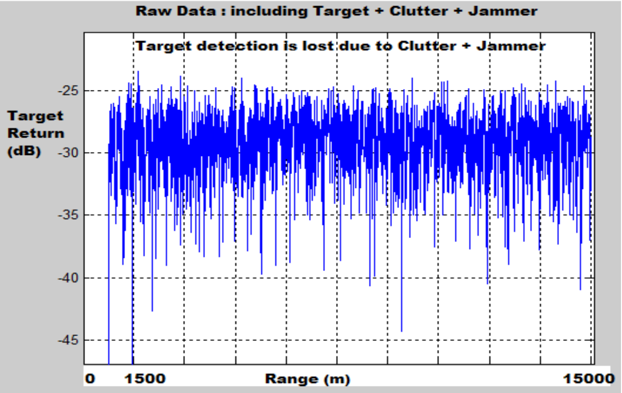


Fig.-23: Target detection is failed due to Jammer & Clutter

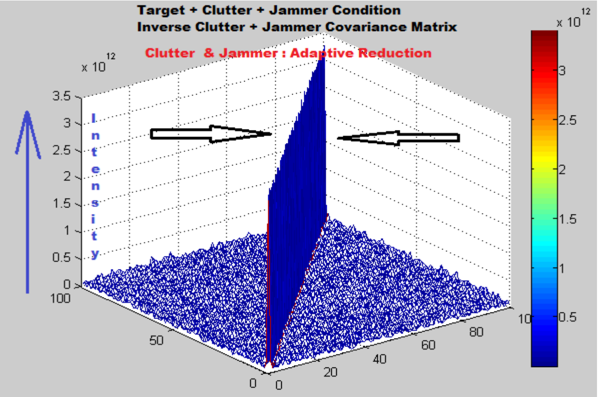


Fig.-24: Adaptive reduction of Clutter & Jammer after SMI of the Jammer + Clutter Covariance matrix

The Sample Matrix Inversion method under heavy Jammer & Clutter scenario gives rise to a Signal-to-Clutter + Jammer Ratio (SCJR) of 21.7 dB as depicted in Fig.-25.

V. CONCLUSION

In a war-field GMTI scenario, the airborne radar system should be efficiently capable of mitigating jammer & clutter. If so, there should be an economic and robust algorithm that can enhance the radar signal processing at the receiver in an adaptive manner. The sample matrix inversion method is an efficient way to electronically countermeasure against the threats belonging to the jammers or enemy radars. The algorithms, as discussed and simulated above for computations of the adaptive weights for generating the Beamformed output, help sufficiently to create notches in the antenna pattern for the suppression of the jammer signals adaptively. In an uniform rectangular phased array radar system, the technique of adaptive jammer suppression is well suited because, the elemental phase at transmitter can be accordingly adjusted/steered to avoid the jammer beam [8]. The model executes such an adaptive Beamformation within the digital signal processing block of the receiver beamformer and places the jammer beam at the null of the desired broadside beam looking to the target. So, better signal-to-jammer plus clutter ratio is achieved using the jammer/clutter covariance matrix inversion method.

REFERENCES

[1] J. R. Guerci, Space-Time Adaptive Processing for Radar, Artech House, 2003.

[2] S.-H. Jeong, H.-Y. Yu, J.-E. Lee, J.-N. Oh and K.-H. Lee: 'A Multi-Beam and Multi-Range Radar with FMCW and Digital Beam Forming for automotive applications', Progress In Electromagnetics Research, Vol. 124, 285-299, 2012.

[3] Van Trees, H., 'Optimum Array Processing'. New York: Wiley-Interscience, 2002.

[4] Wulf-Dieter Wirth, Radar techniques using array antennas, The Institution of Electrical Engineers, London, United Kingdom, 2001.

[5] WIRTH, W. D.: 'Omnidirectional low probability of intercept radar'. International conference on Radar, Paris, France, April 1984, pp. 27-30.

[6] C. K. Kim, S. Choi, and Y. S. Cho: 'Adaptive beamforming for an OFDM system'. In Proc. IEEE Vehicular Technology Conf., pages 484–488, Houston, TX, May 1999.

[7] Jonathan D. Fredrick, Yuanxun Wang and Tatsuo Itoh: 'A Smart Antenna Receiver Array Using a Single RF Channel and Digital Beamforming', IEEE Transactions On Microwave Theory And Techniques, Vol. 50, No. 12, December 2002.

[8] Nickel, U. (2006), 'Fundamentals of Signal Processing for Phased Array Radar', In Advanced Radar Signal and Data Processing (pp. 1-1 – 1-22). Educational Notes RTO-EN-SET-086, Paper 1. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp Abbreviations and Acronyms.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.