GNSS Jamming Nulling Scheme using Jamming-Free Subspaces

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***Abstract*—In this paper, Global Navigation Satellite System (GNSS) jamming nulling scheme using jamming-free subspaces is presented to overcome the jamming attack. It is based on the adaptive beamforming using array antennas. The eigenvalue decomposition (EVD) of the covariance matrix is used for separation between the jamming subspaces and the others. The proposed scheme determines the array weights by the jamming-free subspaces, which are composed of all subspaces except all jamming subspaces. The simulation results demonstrate that the proposed scheme nulls the jamming signal and receives all Global Position System (GPS) signal under the jamming environment.**

Keywords- GNSS; GPS; Jamming; Nulling; beamforming; subspaces.

I. INTRODUCTION

Even though GNSS is most widely used in many applications for position, velocity, and precise time (PNT), it is easily vulnerable to the jamming. As GPS jammers are purchased for about $30 over the online, GPS jamming events could be more often happened. It is known that a 1 watt jammer can disturb GPS coarse/acquisition (C/A) code acquisition up to 63 km and C/A code tracking up to 32 km [1]. North Korea has repeatedly jammed GPS signals in South Korea during 6 days from March 31, 2016 to April 5. It was reported that 1,786 base stations for mobile telecommunication, 962 airplanes and 694 ships in South Korea experienced GPS disruptions. As many critical applications are still being dependent on absolute and accurate position or time by GNSS receiver, the GNSS jamming making the GNSS receiver malfunctioned is very critical threat to those applications using GNSS system. In order to overcome the jamming attack, the anti-jamming technique is needed. The spatial nulling scheme using array antennas has been considered as an effective technique. So, in this paper, the GNSS jamming nulling scheme based on array antennas is presented using jamming-free subspaces, which are composed of all subspaces except all jamming subspaces. The eigenvalue decomposition (EVD) of covariance matrix is used for separation between the jamming subspaces and the others. The simulation results demonstrate that the proposed scheme nulls the jamming signal and receives GPS signal under the jamming environment. Sect. II describes the proposed scheme based on the signal model. In Sect. III, we present the simulation results of GNSS jamming nulling scheme. Finally, the conclusion is drawn in Sect. IV.

II. GNSS JAMMING NULLING SCHEME

A. Signal model

Firstly, we consider the signal model including GNSS signals, jamming signals, and noise. Assuming that M-element array antenna with half-wavelength spacing, the samples vector **x**(n) after down-conversion and analog-to-digital conversion can be expressed as

$$\mathbf{x}(n) = \mathbf{s}(n) + \mathbf{J}(n) + \mathbf{v}(n) \tag{1}$$

where **s**(n) and **J**(n) denotes the GNSS signal vector and the jamming signal vector respectively and **v**(n) is the additive white Gaussian noise vector.

Let z(n) = $\mathbf{w}^H\mathbf{x}(n)$ be the output data of the beamformer where **w** is beamforming weight vector. Then, covariance is given by

$$E\{z(n)z^H(n)\} = \mathbf{w}^H E\{\mathbf{x}(n)\mathbf{x}^H(n)\}\mathbf{w} \tag{2}$$

where $\mathbf{R} = E\{\mathbf{x}(n)\mathbf{x}^H(n)\}$ denotes the covariance matrix.

B. Proposed scheme

Fig. 1 shows the block diagram of the proposed scheme. As GNSS signals use the spread spectrum scheme, they have a spreading gain against jamming. Therefore, the power of jamming, which is vulnerable to GNSS signals is considerably higher than that of GNSS signal. Accordingly, after performing the EVD of the covariance matrix **R**, we can collect the jammer-free subspaces. The EVD of the covariance matrix **R** yields

$$\mathbf{R} \cong [\mathbf{U_J}\ \mathbf{U_{JF}}]\begin{bmatrix}\Lambda_\mathbf{J} & 0 \\ 0 & \Lambda_\mathbf{JF}\end{bmatrix}\begin{bmatrix}\mathbf{U_J^H} \\ \mathbf{U_{JF}^H}\end{bmatrix} \tag{3}$$

where $\mathbf{U_J}$ and $\mathbf{U_{JF}}$ denotes the eigenvector of the jamming subspaces with equivalent power of $\Lambda_\mathbf{J}$ and the jamming-free subspaces with equivalent power of $\Lambda_\mathbf{JF}$

The number of the jamming subspaces is determined by the minimum description length (MDL) or Akaike Information Criterion (AIC) [2]. Lastly, the beamforming array weighting vector **w** is calculated by the Linearly Constrained Minimum Variance (LCMV) beamformer [3]

$$\mathbf{w} = \mathbf{R}^{-1}\mathbf{C}(\mathbf{C}^H\mathbf{R}^{-1}\mathbf{C})^{-1}\mathbf{f} \tag{4}$$

where **C** is the constraint matrix composed of the jamming-free subspaces and $\mathbf{f} = [1 \quad \ldots \quad 1]^T$

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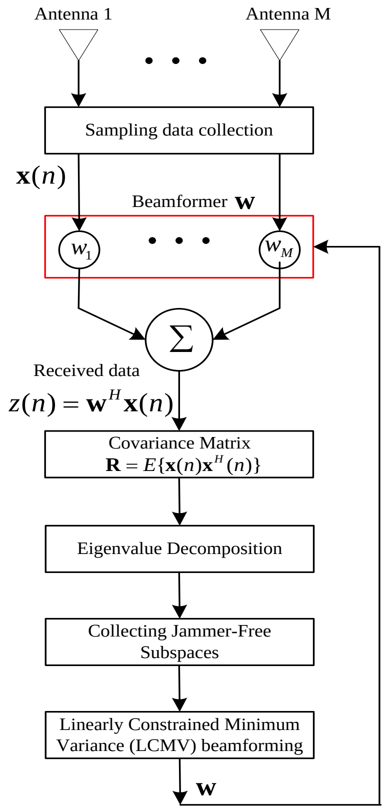

Figure 1. Block diagram of the proposed scheme.

III. SIMULATION RESULTS

The uniform circular array (UCA) consisting of M=10 sensors with half-wavelength spacing is used. A GPS satellite (PRN#12) and a jammer are located at (elevation 30°, azimuth 100°) and (elevation 50°, azimuth 200°). The 2046 samples are used in one millisecond. The signal type and the power of jamming are used as the continuous wave (CW) in GPS L1 frequency with JSR=30dB. Fig. 2 shows that the proposed scheme is able to null the jamming signals.

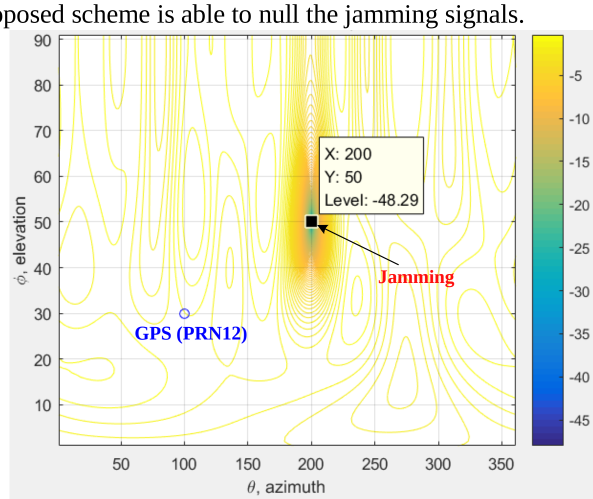

Figure 2. Block diagram of the proposed scheme.

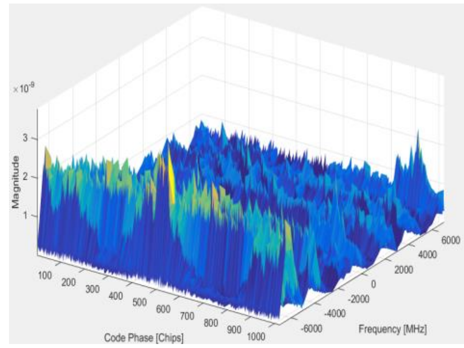

Figure 3. CAF using the received signal

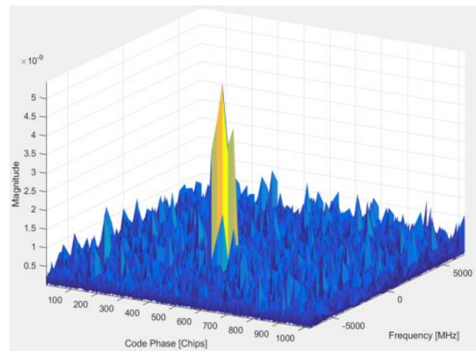

Figure 4. CAF after the proposed nulling scheme

Fig. 3 shows the cross ambiguity function (CAF) of GPS signal (PRN 12) using the received signal, which are incident on each element of array antenna. It is observed form Fig. 4 that GPS signal (PRN 12) is acquired successfully after the proposed nulling scheme.

IV. CONCLUSION

The GNSS jamming nulling scheme based on array antennas was proposed using jamming-free subspaces. The EVD of covariance matrix is used for separation between the jamming subspaces and the others. The simulation results showed that the proposed scheme nulls the jamming signal and receives GPS signal under the jamming environment (JSR=30dB). Also, it was demonstrated that GPS signal (PRN 12) was successfully acquired after the proposed nulling scheme.

ACKNOWLEDGMENT

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