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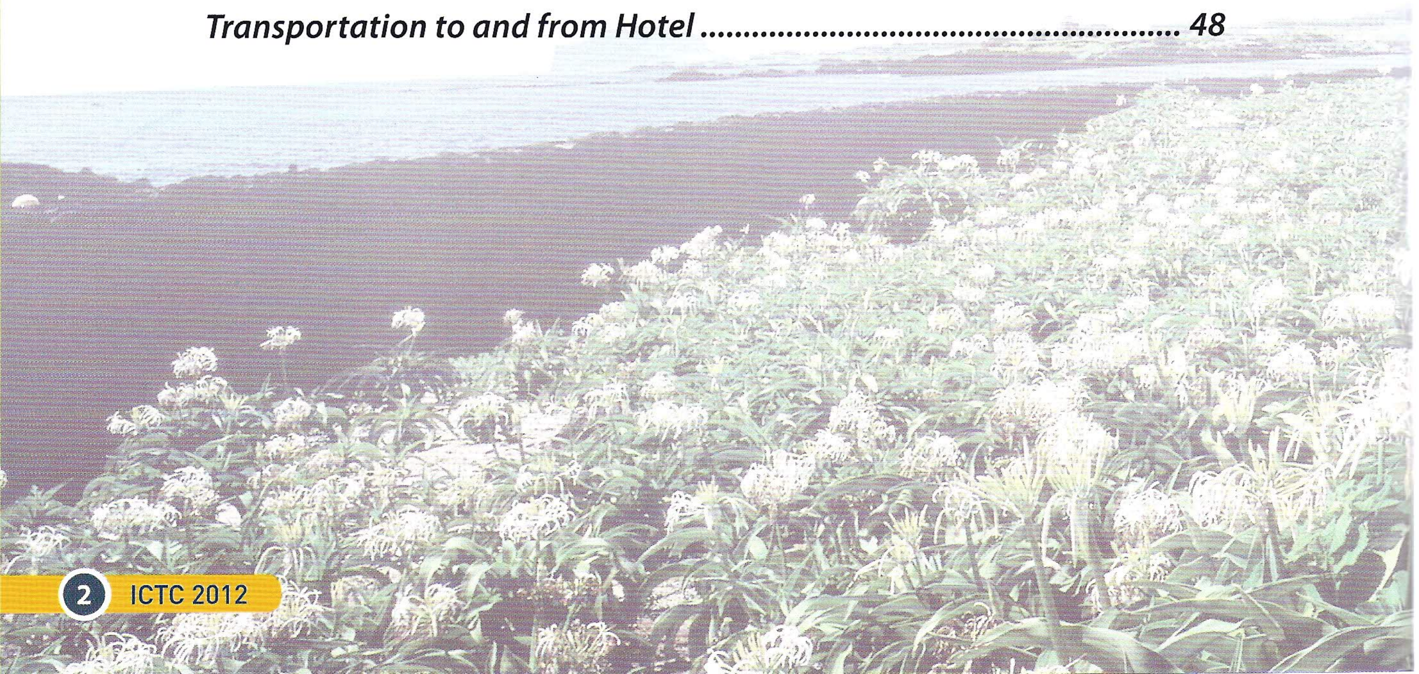

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With great pleasure, we'd like to welcome you to the International Conference on Information and Communication Technology Convergence 2012 (ICTC 2012) being held in Jeju Island, Korea.

ICTC 2012 is one of the major international conferences on the topic of ICT convergence in Asia hosted by the Korea Communications Commission(KCC), organized by The Korean Institute of Communications and Information Sciences(KICS) and Electronics and Telecommunications Research Institute(ETRI) with technical co-sponsorship of IEEE Communications Society, and patronized by major companies, including Samsung Electronics, KT, SKT, LG Electronics, Samsung Fiber Optics, Qualcomm Korea, Ericsson LG, SkyCross, Multi Screen Service Forum of Korea, and so on.

ICTC 2012 features an extremely rich program with the main theme of "Global Open Innovation Summit for Smart ICT Convergence". The attendees will have the opportunity to associate with the world's most distinguished industry leaders, researchers, government officials, and academia professionals in areas of advanced multi-screen services, future smart TV, future wireless communications and networking technologies.

Furthermore, ICTC 2012 will provide three day presentations of invited and regular papers from diverse groups from all around the world on topics of wireless & mobile communications, future internet, smart media & broadcasting, smart grid, encryption, security, u-health & bio-informatics, green communication technologies and solutions, and much more towards smart ICT Convergence.

We urge you to join us in Jeju Island from October 15th to 17th for this great event and enjoy Jeju, which is known as the "Island of the Gods," and one of the top vacation spots in Korea.

We look forward to seeing you at ICTC 2012 soon.

Jinwoo Park
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Generalized Receiver with Non-blind Beamforming Based on LMS Algorithm

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Abstract— **This paper deals with applying the adaptive non-blind beamforming (NB-BF) based on the least mean square (LMS) algorithm employed by the generalized receiver (GR) that is constructed according to the generalized approach to signal processing (GASP) in noise. The simulation results show good ability to cancel the interference at the GR output using the proposed combination.**

Keywords— **Non-blind beamforming, Least mean square algorithm (LMS) , Generalized receiver (GR).**

I. INTRODUCTION

The main problem in any radar sensor and wireless communication system is to detect with high quality the desired signal and define its parameters under stimulus of noise and interference. One way to cancel the interference action is an adaptive beamforming that defines dynamically the optimal weight vectors of array antenna elements.

Filtering procedures are not able to distinguish the signal if the desired signal and interference occupy the same frequency bandwidth. The desired signal and interference are usually caused by difference spatial locations. The spatial separation can be exploited to separate signal from interference using beamforming as a spatial filtering approach. Beamforming is a versatile approach to spatial filtering to separate signals having overlapping frequency content but originated from different spatial locations [1]. Adaptive beamforming is implemented in the case when the signal spatial locations are variable. In wireless communications, beamforming is used to point an antenna at the signal source and, consequently, to reduce interference and improve quality. If we need to define a signal direction, the beamforming can be used to steer an antenna to define a direction of the signal source [2]. Beamforming technique is usually applied to array systems. Spatial filtering can be implemented under the use of different algorithms to change the weight vectors of each array antenna element. Adaptive beamforming algorithms can be categorized as non-blind algorithms (NB-BF) and blind algorithms depending on whether the reference signal is used or not. NB-BF algorithms update the weight vectors of array antenna to form a desired direction vector based on information about the received signal and reference signal. Least mean square (LMS), Sample Matrix Inverse (SMI), and Recursive Least Squares (RLS) algorithms are categorized as NB-BF algorithms. Constant Modulus algorithm (CMA), Spectral self-Coherence Restoral (SCORE), and Decision Directed (DD) algorithms are the examples of blind beamforming algorithms [3].

The generalized receiver (GR) constructed based on the generalized approach to signal processing (GASP) in noise has the better detection performance in comparison with other detectors designed based on the classical and modern signal detection and signal processing theories [4]-[7]. The GR is a combination of the Neyman-Pearson detector that is optimal for detection of signals with known parameters, and the energy detector that is optimal for detection of signals with unknown parameters. This combination allows us, firstly, to take into consideration such a very important statistical parameter as a variance of the likelihood function, and, secondly, to formulate a decision-making rule about the presence or absence of the target return signal based on a definition of the jointly sufficient statistic of the mean and variance of likelihood function.

This paper deals with interference cancellation using the beamforming technique. The interference cancellation by GR is achieved applying the NB-BF based on the LMS algorithm. The LMS adaptive beamforming algorithm incorporates an iterative procedure that makes successive corrections to the array antenna weight vector in the direction of negative gradient vector [8]. The simulation results demonstrate good interference cancellation performance at the GR output. The rest of the paper is arranged as follows. Section 2 introduces the GR structure. The beamforming technique and LMS algorithm are presented in section 3. Section 4 introduces the combination of GR and LMS beamformer. Section 5 presents the simulation results. The conclusions remarks are discussed in section 6.

II. GR STRUCTURE

The GASP is a special signal processing approach that has a significant ability to compensate the noise in the radar sensor and wireless communication systems. The GR flowchart is presented in Fig. 1. The additional filter (AF) is used to generate the reference noise. The AF resonance frequency is detuned relatively to that of the preliminary filter (PF) that can be considered as a band pass filter matched with the desired signal by bandwidth. The value of detuning in resonance frequency between AF and PF should be more than 4~5 times the signal bandwidth. Under this condition, the processes at the AF and PF outputs can be considered as independent and uncorrelated. If we satisfy this condition, in practice, the correlation coefficient is not more than 0.05.

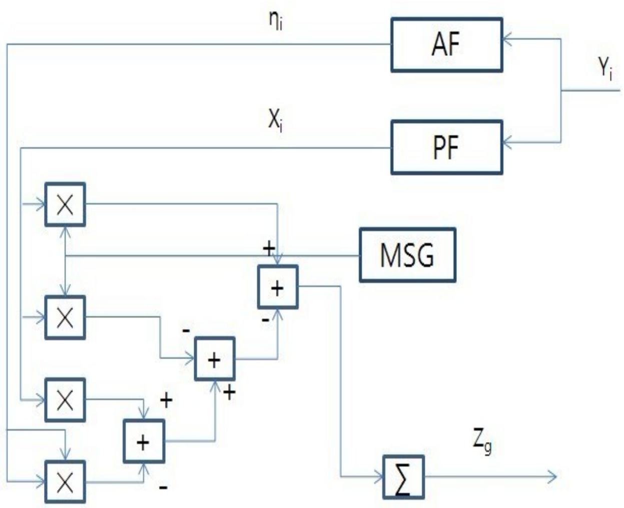

Figure 1. The main structure of GR.

The model signal generator (MSG) is a local oscillator generating the reference signal or model signal a_i^M in the GR. Y_i denotes the signal at the GR input. As follows from Fig. 1, the GR output can be presented in the following form

$$Z_g = \sum_{i=1}^{N} (2X_i a_i^M - X_i^2 + \eta_i^2), \tag{1}$$

where X_i is the PF output, η_i is the reference noise generated by AF, and i =1,…,N, N is the sample size. Thus, the received signal and noise can be appeared at the PF output and only the reference noise is appeared at the AF output. In the case of a yes signal in the input process, X_i can be defined as

$$X_i = a_i + \xi_i, \tag{2}$$

where ξ_i is the noise at PF output, and a_i is the desired signal at the PF output. The model signal a_i^M is defined as

$$a_i^M = \gamma a_i, \tag{3}$$

where γ is the coefficient of proportionality. Substituting (2) and (3) into (1) and satisfying the main GR functioning condition γ =1, we can write

$$Z_g = \sum_{i=1}^{N} (a_i^2 + \eta_i^2 - \xi_i^2). \tag{4}$$

In (4), a_i^2 is the signal energy, and $\eta_i^2 - \xi_i^2$ is defined as the background noise formed by AF and PF. However, when there is an interfering signal at the GR output, this interference will generate some multiplicative components that cause deterioration in the GR performance. Assuming that the interference signal is I_i, the equation (4) becomes as

$$Z_g = \sum_{i=1}^{N} (a_i^2 - 2I_i\xi_i - I_i^2 + \eta_i^2 - \xi_i^2). \tag{5}$$

In (5), the new term $-2I_i\xi_i - I_i^2$ is generated due to the interference and noise interactions that deteriorate the GR performance.

III. LMS BEAMFORMING ALGORITHM

LMS algorithm belongs to NB-BF algorithms based on the minimum mean square error (MMSE) criterion and is considered as the steepest descent method optimizing the weight vector. In the array antenna systems, the structure of LMS beamformer can be presented in Fig. 2. The main principle of LMS algorithm is based on definition of the error between the output and reference signals to update the weight vector that can make the output signal M_i close to the reference signal. Simply, the main form of the LMS algorithm is given by

$$W_{i+1} = W_i + \mu e_i^* S_i, \tag{6}$$

where W_i and W_{i+1} are the weight vectors, μ is the step size or convergence parameter, and S_i is the received signal or the beamformer input. The error e_i^* in (6) is given by

$$e_i^* = M_i - d_i, \tag{7}$$

where d_i is the reference signal or model signal in LMS beamformer, the complex conjugate is denoted for mathematical convenience.

The LMS algorithm is usually stable under the following condition of μ:

$$0 < \mu < \varphi, \tag{8}$$

where $\varphi = 1/\lambda_{\max}$, and $\lambda_{\max}$ is the largest eigenvalue of the correlation matrix R that can be given by

$$R = S_i S_i^H, \tag{9}$$

The convergence of the LMS algorithm is inversely proportional to the eigenvalue spread of the matrix R. A variable signal environment may lead to variable matrix R and unstable value of φ. To obtain a good convergence performance, we propose a simple approach that scales the φ by a coefficient ρ to realize the variable step size:

$$\mu = \rho\varphi, \tag{10}$$

ρ is defined based on a specific signal environment. It is an experimental or empirical value that needs to be defined accurately in different signal conditions. In addition to, it should be usually chosen between 0 and 1. By adjusting ρ appropriately, a good performance can be obtained.

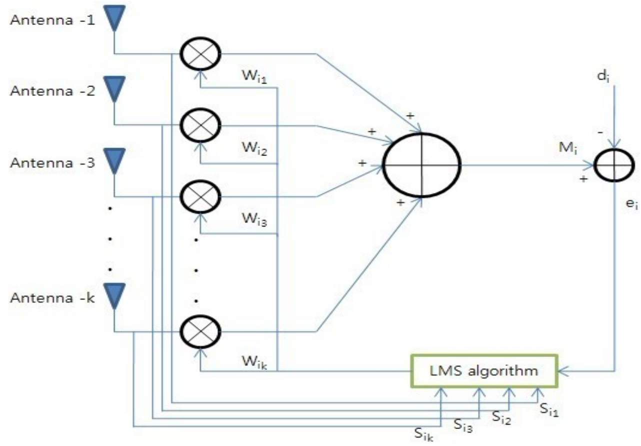

Figure 2. The main structure of LMS beamformer.

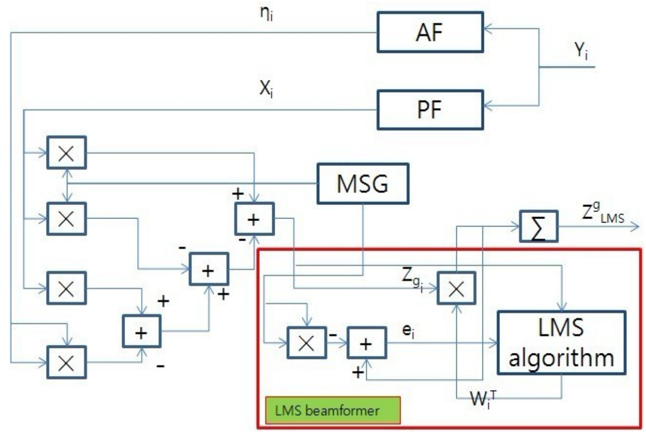

Figure 3. GR with LMS beamformer.

IV. THE COMBINATION OF GR AND LMS BEAMFORMER

The interference components at the GR output deteriorate the detection performance. Interference can be cancelled by beamforming technique adjusting adaptively the weight vector. We propose to use the LMS algorithm owing to its simplicity.

By applying the LMS algorithm in GR, the interference at the GR output can be canceled. GR with LMS beamformer is shown in Fig. 3. In this new structure, we apply the LMS beamformer behind the GR to process its output. By this way, the interference components at the output of GR will be cancelled. The model signal of LMS beamformer is the square of the signal a_i^M due to the fact that the output of the GR is the energy of the signal.

From Fig. 3, we can obtain the following equations:

$$M_i = W_i^T Z_{g_i}, \quad (11)$$

$$d_i = (a_i^M)^2, \quad (12)$$

Then from (7), (11) and (12), we can write

$$e_i^* = W_i^T Z_{g_i} - (a_i^M)^2. \quad (13)$$

The weight is given by

$$W_{i+1} = W_i + \mu e_i^* Z_{g_i}. \quad (14)$$

In (14), μ satisfies to the condition (10). However, we have to note that φ in (10) should be related to the correlation matrix eigenvalue of the GR output signal Z_{g_i}.

The final output of GR with LMS beamformer can be presented in the following form:

$$Z_{LMS}^g = \sum_{i=1}^{N} (W_i^T Z_{g_i}) = \sum_{i=1}^{N} [W_i^T (a_i^2 - 2I_i\xi_i - I_i^2 + \eta_i^2 - \xi_i^2)]. \quad (15)$$

In (15), the component $-2I_i\xi_i - I_i^2$ formed by interference is cancelled by updating the weight vector W_i. The GR output after the cancellation of interference components can be approximated by

$$Z_{LMS}^g \approx \sum_{i=1}^{N} (a_i^2 + \eta_i^2 - \xi_i^2). \quad (16)$$

V. SIMULATION RESULT

In this section, we present the computer simulation examples to evaluate the performance of GR with LMS beamformer based on 4 uniform linear array (ULA) antennas with half wavelength distance. The desired signal arrives at 0^0 and two interference signals arrive at -40^0 and 40^0 respectively. The desired signal a_i and the interfering signals

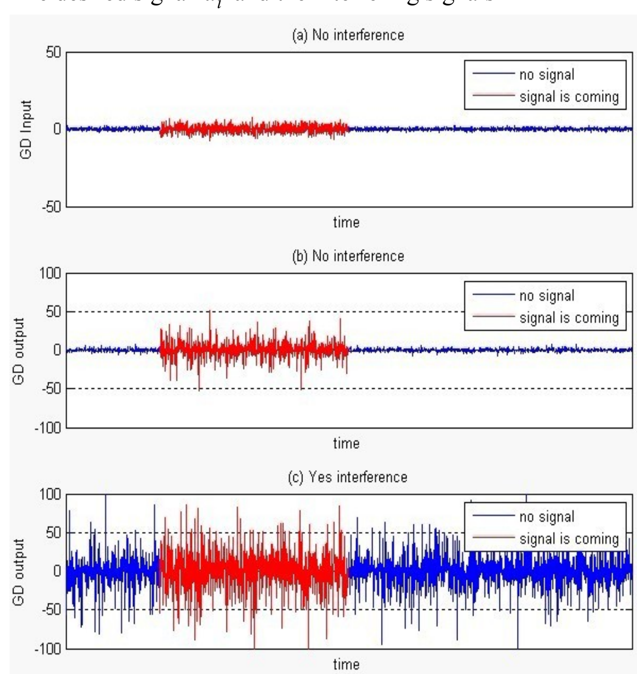

Figure 4. GR Input and output, with and without interference.

I_{1_i} , I_{2_i} are set as Gaussian random sequences with mean equals to 0 and signal-to-noise ratio (SNR) equals to 10 dB. For simplicity, the sample size is set to be 1.

Figure 4 presents the performance of GR with and without the interfering signals. The input signal is shown in Fig. 4a, GR output without interference is presented in Fig. 4b. As shown in Fig. 4c, the interference signals are within the limits of the observed interval.

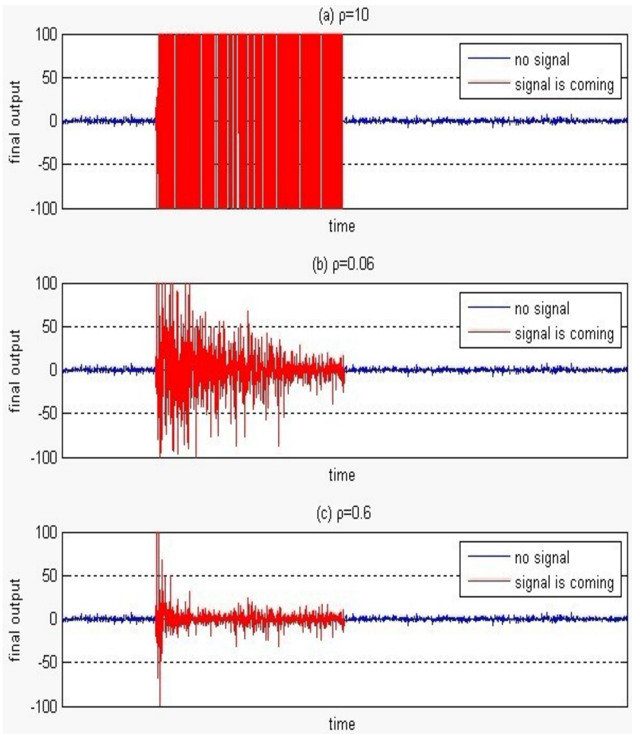

Figure 5. Output of GR with LMS beamformer at different values of the coefficient ρ .

Figure 5 presents the simulation results of GR with LMS beamformer. The coefficient ρ is chosen to have different values to evaluate the performance. The interfering signals come only coupled with the desired signal. As shown in Fig. 5a, when ρ equals to 10, this leads that the step size μ has a large value and LMS algorithm is not be stable. In Fig. 5b, ρ equals to 0.06, the value of μ is small and the convergence performance of the LMS beamformer is not so good. However, when ρ equals to 0.6, the performance of LMS beamformer becomes better as shown in Fig. 5c.

Figure 6 presents the array pattern for the GR with LMS beamformer. We assume that -40^0 and 40^0 are the angles of input interfering signals, and 0^0 is the angle of input desired signal. From this figure, we can find that the directions of the null points are approximately equal to -35^0 and 42^0, and at 0^0, there is a high gain. The reason is that the direction vectors of the interference have been shifted due to the processing by GR,

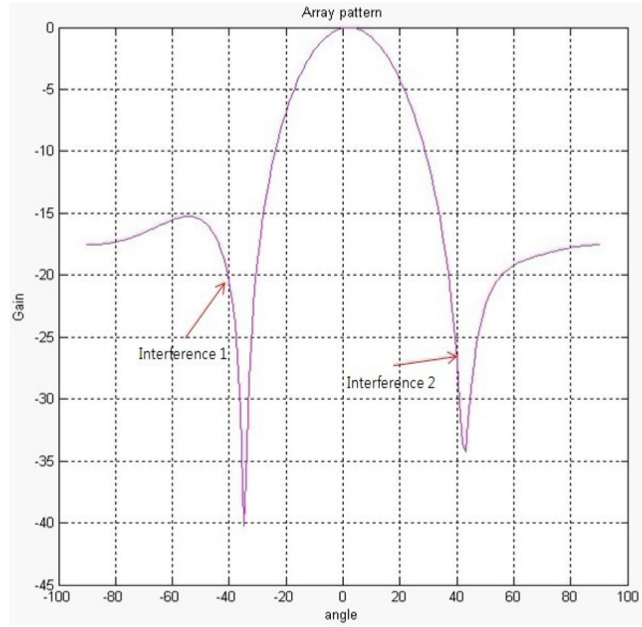

Figure 6. Array pattern of GR and LMS beamformer

and on the contrary, the direction vector of the desired signal is still the same.

VI. Conclusion

We propose a combination between the adaptive beamforming technique and GR in order to eliminate the interference effect that is an inevitable problem in wireless communication and radar sensor systems. LMS algorithm is a simple NB-BF algorithm and can be successfully applied to solve the interference cancellation employing GR. The simulation shows an ability of interference cancellation at the GR output by the proposed new structure in comparison with the conventional GR without LMS beamformer.

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