行政院國家科學委員會專題研究計畫　期中進度報告

應用信號週期穩態特性之強健式可適性陣列信號處理(1/2)

計畫類別：個別型計畫
計畫編號：NSC91-2219-E-002-037-
執行期間：91 年 08 月 01 日至 92 年 07 月 31 日
執行單位：國立臺灣大學電信工程學研究所

計畫主持人：李枝宏

計畫參與人員：計畫參與研究生：陳宏家, 鄭光鵬, 王智璋, 李勇漢

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中　華　民　國 92 年 5 月 13 日

行政院國家科學委員會補助專題研究計畫成果告

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應用信號週期穩態特性之強健式可適性陣列信號處理 (1/2)

Robust Adaptive Array Signal Processing Using Signal Cyclostationarity (1/2)

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計畫類別：■個別型計畫　　　整合型計畫

計畫編號：NSC91－2219－E－002－037－

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計畫主持人： 李枝宏

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一、中文摘要

本計劃已完成預期之研究工作一(1)研究發展分析應用信號週期穩態特性可適性陣列波束成型器對所欲信號之週期頻率誤差之敏感性，並藉此推導一新而有效之性能變差之數學理論公式。以期望能獲得具體之數學理論公式來表示可適性陣列波束成型器性能變差之現象，而且可明確的由實驗模擬來加以驗證。

(2) 研究發展分析應用信號週期穩態特性具有信號選擇能力的信號方位估測器對所欲信號之週期頻率誤差之敏感性，並藉此推導一新而有效之性能變差之數學理論公式。以期望能獲得具體之數學理論公式來表示具有信號選擇能力的信號方位估測器性能變差之現象，而且可明確的由實驗模擬來加以驗證。

電腦模擬實驗已驗證本計畫成果之有效性。

關鍵詞：週期穩態信號，波束成型，方位估測。

二、英文摘要

This project has accomplished research work for the development of the theory in evaluating the performance of (1) the conventional SCORE algorithms and (2) conjugate cyclic MUSIC in the presence of cycle frequency error (CFE) regarding the Signals Of Interest (SOI). Using the theory of Fourier transform, the problem formulation for the SCORE algorithms under CFE has been completed. This results in an analytical formula which demonstrates the behavior of the performance degradation for the SCORE algorithms. It is shown that the output SINR of an adaptive array beamformer using the SCORE algorithms deteriorates like a sinc function as the number of data snapshots increases. The similar problem for conjugate cyclic MUSIC has been also completed. From the theoretical analyses, we note that the performance of the conjugate cyclic MUSIC also degrades like a sinc function as the number of data snapshots increases. The validity of the obtained theoretical results is demonstrated by several simulation examples.

Keywords: Cyclostationary Signals, Beamforming, Bearing Estimation。

三、緣由與目的

Signal cyclostationarity has been widely considered for array signal processing because methods utilizing the cyclostationary properties generally outperform the conventional counterparts that ignore the cyclostationarity. By restoring these properties at a known value of frequency separation, it is possible to favor the desired signal and to discriminate against the interference and noise. Many cyclostationary-exploiting (CE) algorithms for adaptive beamforming and bearing estimation avoid the need for training signals, the knowledge of array manifold, and noise characteristics. The priori information that the CE algorithms require to work is only the cycle frequencies of the desired signal. Hence, the performance of the CE algorithms is very sensitive to the accuracy of the presumed cycle frequencies. However, the actual cycle frequencies may not be known very well in some applications due to for example the phenomenon of Doppler shift. In this two-year research project, we would like to conduct research for solving the problem of array signal processing in the presence of cycle frequency error (CFE). During the first year, we will evaluate the performance of CE algorithms when CFE regarding the desired signal exists. The problem formulations for each of adaptive array beamforming and bearing estimation using the CE algorithms will be investigated. This leads to analytical formulas demonstrating the performance degradation for the CE algorithms can be developed. During the second year, we will consider the problems of robust adaptive array beamforming and bearing estimation for cyclostationary signals. Based on the achievements obtained from the first-year research, efficient methods in conjunction with the CE algorithms will be developed. This leads to two robust techniques for adaptive array beamforming and bearing estimation with robust capabilities against the CFE, respectively. The research achievements of the one-year project are demonstrated by a lot of computer simulations and comparisons.

四、研究方法

First, the analytical formula for evaluating the performance of the SCORE algorithms in the presence of cycle frequency error (CFE) is developed。 Assume that the SOIs, SNOIs (signals of not interest), and noise are uncorrelated. Then, the cyclic conjugate correlation matrix at an arbitrary frequency f is computed. Due to the fact that the cyclic spectrum of a cyclostationary signal is discrete in the cycle frequency, we find the cyclic conjugate correlation functions of the SOI and the lth cyclostationary SNOI. Next, we compute the sample cross-correlation vector of the received array data vector and the reference signal. Using the property of Fourier transform, we can obtain the formula for expressing the sample cross-correlation vector. This formula shows that the effects of cycle leakage through a sinc window due to finite data samples. In the presence of CFE, we derived the formula for expressing the sample cross-correlation vector. This formula reveals that the performance degradation due to CFE. We observed that there exist periodic nulls in the curve of the output signal-to-interference plus noise ratio (SINR) versus the number of snapshots for adaptive beamforming. In the case of bearing estimation, we focus on the estimation of the required sample cyclic conjugate correlation matrix associated with the received array data vector. For simplicity, we consider the case where only one SOI is present. Following the procedure similar to the case of adaptive array beamforming, we can obtain the formula which shows that the dominant eigenvector is no longer proportional to the directional vector of the SOI. Therefore, a severe estimation error of bearing estimation will be induced.

五、研究成果與討論

In this project, we have developed a

new formula for theoretically showing the performance degradation for the adaptive array beamforming based on the SCORE algorithms in the presence of cycle frequency error. We observe that the SCORE algorithms provide similar array performance as the conventional approach based on maximum SINR criterion when the actual cycle frequency is used. However, the simulation results demonstrate that there are periodic nulls in the performance curve of the SCORE algorithms under the CFE. Next, we derived the theoretical formula to express the sample conjugate cyclic correlation matrix required for implementing bearing estimation in the presence of CFE. From the computer simulation results, we observe that conjugate cyclic MUSIC can successfully estimate the bearings of the SOIs using the actual cycle frequency and shows the capability of signal-selectivity as compared to the conventional MUSIC. However, conjugate cyclic MUSIC suffers from severe performance degradation when CFE exists. The validity of the derived theoretical formulas has been demonstrated by several computer simulation examples.

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