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14. ABSTRACT

At the conclusion of this project, we can say that we have accomplished our final objective, that is to extend the theory of spectral estimation to non-stationary signals. Of course there are already existing approaches such as the Wigner-Ville Transform, the rihazeck Transform, the Choi-Williams Transform, and many more, deakling with this problem, but we see our approach as a natural extension of the Wiener-Kintchine theorem. Moreover, we have the flexibility to replace the wavelets with any time-frequency atoms such as local trigonometric functions or any lapped orthogonal transform (LOT). The potential application for Air Force is the use of this concept in the communication system to improve fratricide avoidance. On the civilian side, this approach can find its application in biomedical signal processing.

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FINAL PERFORMANCE REPORT

Fratricide Avoidance Using Transform Domain Techniques: A New Spectral Estimation Method Based on the Evolutionary Wavelet Spectrum Concept

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Agreement number: FA9550-05-0174

Report submitted to: Dr. Jon Sjogren

Program Manager

1. Objective

The objective of this work is to investigate and develop a tool that would help the jammer avoid self- interference. In combat situations, the jammer should be able to recognize enemy communications from friendly ones at every instant in order to avoid fratricide. This is only possible if he has a clear representation of the electromagnetic spectrum when he decides to send his interference signals. A time-frequency map of the local electromagnetic environment will help him have that clear representation. The Transform Domain Communication System (TDCS) is one system that has demonstrated interference avoidance capability. However it fails to correctly estimate the spectral content of non-stationary signals such as swept-tone interference. A wavelet-based spectral estimation referred to as Wavelet Domain Communication System (WDCS) was developed and was found to better estimate and mitigate swept-tone interference effects than the original TDCS. Even though spectral estimation is statistical by nature, none of the previously mentioned approaches addressed that aspect.

We propose a spectral estimation based on the concept of the evolutionary wavelet spectrum (EWS). This concept addresses both the statistical and non-stationary nature of the problem. The idea is to extend the Wiener-Kintchine theorem, which relates the variance of a stationary random signal to its power spectral density (PSD), to the non-stationary case. The evolutionary wavelet spectrum (EWS) is related to the local auto-covariance (LACV) through the auto-correlation wavelet. Unlike the power spectral density (PSD), which is only frequency dependent, the evolutionary wavelet spectrum

(EWS) is both time and scale dependent and this scale dependence can be easily transformed into frequency dependence via the Wigner-Ville Transformation. This spectral estimation technique is perfect for the implementation of the time-frequency map mentioned above.

2. Status of effort

We have firmly established the theoretical foundations of the Evolutionary Wavelet Spectrum (EWS) concept. Furthermore, we have tested it on some artificial waveforms. We have also performed the periodogram smoothing. We have inserted this new spectral estimation technique in a communication system and we have compared its performance to that of WDCS. Our finding is that this new spectral estimation technique is superior to the WDCS when one has to deal with non-stationary interferences. The results of the finding are described in our paper titled " An Enhanced Wavelet Domain Communication System (EWDCS) with Nonstationary Interference Avoidance Capability" accepted for presentation at the IEEE Vehicular Technology Conference in Fall 2006.

3. Accomplishments/New Findings

At the conclusion of this project, we can say that we have accomplished our final objective, that is, to extend the theory of spectral estimation to non-stationary signals. Of course there are already existing approaches such as the Wigner-Ville Transform, the Rihazeck Transform, the Choi-Williams Transform, and many more, dealing with this problem, but we see our approach as a natural extension of the Wiener-Kintchine theorem. Moreover, we have the flexibility to replace the wavelets with any time-frequency atoms such as local trigonometric functions or any lapped orthogonal transforms (LOT). The potential application for Air Force is the use of this concept in the communication system

to improve fratricide avoidance. On the civilian side, this approach can find its application in biomedical signal processing.

4. Personnel Supported

Jean Andrian: principal investigator, one month salary for Summer 2005

Frank Candocia: co-principal investigator, one month salary for Summer 2005

Kefeng Tan: graduate student, tuition and stipend for Summer and Fall 2005 semesters.

5. Publications

We have two conference presentations from this grant:

1) "An Enhanced Wavelet Domain Communication System (EWDCS) with Nonstationary Interference Avoidance Capability" to be presented at the IEEE Vehicular Technology Conference Fall 2006 in Montreal
2) "An Improved V-BLAST with Narrowband Interference Avoidance Capability" submitted for presentation at IEEE MILCOM in Washington DC.

6. Interactions/Transitions

a) Participation/ presentations at meetings, conferences, seminars, etc. We expect to present the two papers mentioned above at the respective conferences

b) Consultative and advisory functions to other laboratories and agencies, especially Air Force and other DoD laboratories. We have been in contact with Mr. James Stephens at Wright-Patterson Air Force Research Laboratory. Mr. Stephens was the contact person who suggested this research subject to us. As a result of this work, we submitted a white paper to Mr. James Stephens and he agreed to fund our idea through a sub contract with a private company namely, Universal Technology Corporation of Dayton Ohio.

c) Transitions. We are in the final stage of contract negotiation of a project titled " Design

and Development of Cognitive Jamming" with Wright- Patterson Air Force Research Laboratory. The contact person is Mr. James Stephens, tel: (937) 255-5579 ext: 4239. This contract will be handled by Universal Technology Corporation in Dayton Ohio. The contact person is Dr. Douglas Hutchens, tel: (937) 426-8530.

7. New discoveries, inventions, or patent disclosures.

None.

8. Honors/Awards

None

This report covers the period from March 2005 to February 2006.