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RTO LECTURE SERIES 228

Military Application of Space-Time Adaptive Processing

(Les applications militaires du traitement adaptatif espace-temps)

The material in this publication was assembled to support a Lecture Series under the sponsorship of the Sensors and Electronics Technology Panel (SET) and the Consultant and Exchange Programme of RTO presented on 16-17 September 2002 in Istanbul, Turkey, on 19-20 September 2002 in Wachtberg, Germany and on 23-24 September 2002 in Moscow, Russia.

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RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote cooperative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective coordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also coordinates RTO's cooperation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of initial cooperation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS Studies, Analysis and Simulation Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier cooperation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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Military Application of Space-Time Adaptive Processing

(RTO EN-027 / SET-057)

Executive Summary

Surveillance of the ground by air- and spaceborne sensors has proven to be an essential part of modern warfare. Recent conflicts (Gulf, Bosnia, Afghanistan) have demonstrated the value of information gathered by air- and spaceborne sensors. Among the available sensors, radar has important advantages over optical sensors (IR, Visible), such as day and night/all-weather operation, penetration of foliage, obscurants, smoke and dust. Detection of moving targets on the ground is a primary goal of remote earth observation. However, radar echoes from targets have to compete with strong ground clutter returns. The target detection performance of conventional MTI radar (moving target indication) is strongly degraded by the Doppler spread of the clutter returns induced by the radar platform motion. Therefore, slow targets may not be detectable. For example, for a satellite, a space shuttle or even a fast aircraft most moving targets are 'slow'. Space-time adaptive processing (STAP) is capable of compensating for the platform motion induced Doppler spread of the clutter echoes so that optimum detection of slow moving targets is possible. Prerequisite for STAP is a coherent radar with a multichannel array antenna. There will be no future air- or spaceborne military radar without STAP capability.

This lecture series gives a comprehensive overview of the broad field of space-time adaptive processing. The series starts with a lecture by Dr. Melvin in which the basics and the theoretical background are expanded. The lecture 'Doppler properties of airborne clutter' by Dr. Klemm gives an introduction to the principles of STAP. The impact of the platform motion on the nature of clutter returns is discussed in some detail. Optimum STAP processing is addressed as well. In the second lecture Dr. Farina gives an introduction to the problems of using STAP with synthetic aperture radar which is used for ground and ground target imaging at high resolution. Both papers by Dr. Abramovich deal with theory and application of STAP techniques to Over-The-Horizon (OTH) radar which is used to monitor potential intruders moving towards the borders of the friendly country. This application appears in a new light since the terrorist attacks on the 11 September 2001. The lecture 'STAP architectures and limiting effects' by Dr. Klemm deals with suboptimum processor architectures with the capability of clutter rejection in real-time as well as an overview of degrading effects and remedies against them. Dr. Farina's second paper is focused on STAP processor architectures for real-time processing which is of predominant importance for practical implementation of STAP. In his second lecture Dr. Melvin explains the various radar configurations (airborne, spaceborne, bistatic) and expands on STAP techniques against terrain scattered jamming. In summary, this Lecture Series presents a unique overview of the state of the art in STAP research and offers a variety of material for all those being involved in this magic scientific area, e.g., students, university teachers, researchers, industrial system designers, and military users.

The material in this publication was assembled to support a Lecture Series under the sponsorship of the Sensors and Electronics Technology Panel (SET) and the Consultant and Exchange Programme of RTO presented on 16-17 September 2002 in Istanbul, Turkey, on 19-20 September 2002 in Wachtberg, Germany and on 23-24 September 2002 in Moscow, Russia.

Les applications militaires du traitement adaptatif espace-temps

(RTO EN-027 / SET-057)

Synthèse

La surveillance de la terre par des capteurs aéroportés et spatiaux est devenu un facteur essentiel de la guerre moderne. Des opérations récentes (la guerre du Golfe, la Bosnie, l'Afghanistan), ont démontré l'intérêt des informations fournies par les capteurs aéroportés et spatiaux. Comparé aux autres capteurs (optiques et infrarouges, visibles), le radar offre des performances complémentaires telles qu'un fonctionnement tous temps, jour et nuit, une longue portée et la capacité de voir au travers du feuillage, de la fumée, du brouillard et de la poussière. La détection de cibles mobiles terrestres est l'un des objectifs primaires de la télédétection depuis la terre. Cependant, les retours de cible sont souvent mélangés avec de forts retours de fouillis de sol. Les performances en détection de cibles des radars MTI classiques se trouvent fortement dégradées par l'étalement Doppler des retours de fouillis induits par les mouvements de la plate-forme radar. Les cibles évoluant à basse vitesse peuvent, par conséquent, rester indétectables. Par exemple, depuis un satellite, une navette spatiale ou un avion supersonique, la plupart des cibles mobiles apparaissent comme « lentes ». Le traitement adaptatif espace-temps (STAP) peut compenser l'étalement Doppler des retours de fouillis pour permettre la détection optimale des cibles évoluant à basse vitesse. Le STAP nécessite un radar cohérent associé à une antenne réseau multivoies. Tous les radars aéroportés et spatiaux militaires futurs seront équipés de STAPs.

Ce cycle de conférences présente un tour d'horizon complet du vaste domaine du traitement adaptatif espace-temps. Le programme débute par une communication présentée par le Dr. Melvin, qui expose les principes de base et la théorie fondamentale. La conférence sur « Les caractéristiques Doppler du fouillis aérien » présentée par le Dr. Klemm propose une introduction aux principes du STAP. L'impact des mouvements de la plate-forme sur la nature du fouillis est examiné dans le détail. L'optimisation du traitement STAPSQ est également couvert. La deuxième communication, présentée par le Dr. Farina, fournit une introduction aux problèmes de la mise en œuvre de STAP pour les radars à ouverture synthétique utilisés pour l'imagerie de la terre et d'objectifs au sol à haute résolution. Les deux communications du Dr. Abramovich traitent de la théorie et de l'application de techniques STAP aux radars transhorizon (OTH) utilisés pour suivre la trajectoire d'intrus potentiels se dirigeant vers les frontières d'un pays ami. Cette application revêt une importance particulière depuis les attaques terroristes du 11 septembre 2001. La communication « Architectures STAPS et effets restrictifs » par le Dr. Klemm traite d'architectures sous-optimales de processeur en vue de l'élimination de fouillis, et donne un aperçu de leurs effets dégradants ainsi que des remèdes éventuels. La deuxième communication du Dr. Farina est axée sur des architectures de processeur STAPS pour le traitement en temps réel, qui est d'une importance capitale pour la mise en œuvre effective du STAP. La deuxième communication du Dr. Melvin explique les différentes configurations radar (aéroporté, spatial, bistatique) et développe les techniques STAP contre le brouillage diffusé. En résumé, ce cycle de conférences présente un tour d'horizon unique de l'état actuel de la recherche en matière de STAP et propose divers éléments d'information destinés à tous ceux qui travaillent dans ce domaine technique fort intéressant, par exemple les étudiants, les chercheurs, les concepteurs de systèmes industriels, et les militaires.

Cette publication a été rédigée pour servir de support de cours pour le Cycle de conférences 228, organisé par la Commission de la technologie des capteurs et des dispositifs électroniques (SET) dans le cadre du programme des consultants et des échanges de la RTO du 16-17 septembre 2002, à Istanbul, Turquie, du 19-20 septembre 2002 à Wachtberg, Allemagne et 23-24 septembre 2002 à Moscou, Russie.

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Spaceborne radar
STAP (Space Time Adaptive Processing)
Surface targets
Synthetic aperture radar
Target acquisition

14. Abstract

Space-time adaptive processing (STAP) is a signal processing technique for detection of moving targets buried in ground clutter by means of a moving (air- or spaceborne) radar. No future military air- or spaceborne radar will be designed without this feature. This Lecture Series gives a comprehensive overview of the broad field of STAP, starting with fundamentals, clutter characteristics, application to synthetic aperture radar (SAR), and issues in over-the-horizon radar (OTH). Beside the principles and underlying fundamentals special aspect are covered, such as economic STAP architectures, limiting effects, algorithms for real-time processing, and special applications such as bistatic radar configurations and terrain scattered jamming.

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