NON-COOPERATIVE AIR TARGET IDENTIFICATION BY RADAR

Research Activities of the Panel 10, RSG.12 (DRG)
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Background

In 1984 RSG.12 started its first working phase. In the first TOR you can read the following sentences:

" Probably the most serious defficiency in NATO's air defence capability... is the lack of a rapid and reliable means of identifiying all objects at max;mum weapon and surveillance system range. To improve identification capabilities and to ensure high confidence in positive air target identification, more advanced techniques and additional sources have been proposed (STANAG 4162 on the "Technical Characteristics of the NATO Identification System (NIS)). These include Non-Cooperative Target Identification (NCTI) by radar."

By that the focus of the RSG.12 activities was defined. What has been achieved in the meantime?

Overview on the different phases of work of RSG.12

Since 1984 RSG.12 has completed three phases of work:

Phase I 1984-1988

- The first phase was dedicated to elaboration of a survey and detailed discussion on candidate techniques applicable to Non-Co-operative Target Identification (NCTI) of air targets by radar.

Phase II 1988-1992

- As Jet Engine Modulation (JEM) was found to be the most promising and easiest implementable technique, the second phase focused on investigation of JEM-techniques for NCTI of aircraft.

Phase III 1992 - 1996

- While JEM-techniques were found to provide a powerful NCTI capability under certain prerequisites they showed some drawbacks as far as detection ranges and all aspect capabilities were concerned. For this reason the capabilities of Radar Imaging Techniques in the context of NCTI were investigated within this phase.

Paper presented at the RTO SCI Symposium on "Non-Cooperative Air Target Identification Using Radar", held in Mannheim, Germany, 22-24 April 1998, and published in RTO MP-6.

Phase IV 1997 - 1999

- Radar Imaging Techniques showed to be a very promising approach for non-cooperative air target identification. These techniques have the potential of overcoming at least some of the shortcomings of the JEM-techniques but the establishment of reference data bases is a challenging and still unsolved problem. So the present working phase focusses on investigations on the quality of reference data generated via modelling techniques. Besides that the improvement in identification performance using fully polarimetric data will be investigated.

More detailed description of the different working phases

Phase I: Survey of candidate techniques for NCTI of aircraft using radar

- Participating nations: Denmark, France, Germany, The Netherlands, Norway, United Kingdom, United States of America, SHAPE Technical Centre

- The following candidate techniques were discussed:

  High Range Resolution (HRR)
  High Cross Range Resolution by Inverse Synthetic Aperture Radar (ISAR)
  Combination of HRR and ISAR
  Jet Engine Modulation (JEM)
  Helicopter Rotor Modulation (HERM)
  Backscatter Modulation by Aircraft Vibration
  Target Backscatter Fluctuation
  Polarimetric Techniques
  Resonance Region Techniques
  Non-Linear Scattering Effect .

Most promising technique

As most promising technique applicable to NCTI of air targets JEM (or HERM) were identified.

- Extractable target (turbine) features should be independent of target aspect
- Relatively simple target data base

Promising techniques

Radar Imaging Techniques (HRR and 2-D-ISAR) were anticipated as promising techniques.

Problems:

- Features will be sensitive to target aspect changes
- Features will be sensitive to changes in external load configurations
- High demands on radar bandwith
- No simple reference data base

Beneficial to NCTI techniques

Adding polarimetric capabilities to other NCTI techniques

In principle useful

- Aircraft Vibrations. Restricted to mmW or shorter wavelengths

Hard to estimate

- NCTI techniques in the resonant region

Limited NCTI capability

- Target Backscatter Fluctuation

Most probably will only allow for discrimination between rather broad target classes (e.g. jet aircraft and propeller aircraft)

No NCTI capability

- Non-linear scattering techniques

Most probably only allows for discrimination between metallic objects and non-metallic objects

System considerations

- All techniques require relatively long dwell times and /or high prf modes

  $\Rightarrow$ Severe problems for surveillance radar modes

- Candidates most suited to the incorporation of NCTI techniques will be tracking radars and multifunctional active phased array radar systems

Phase II 1988 - 1992: Radar Signal Modulation Techniques for NCTI

Participating nations: Canada, Denmark, France, Germany, The Netherlands, Norway, United Kingdom, United States of America, SHAPE Technical Centre

For phase II RSG.12 decided to investigate on the technique, that was identified as most promising technique for NCTI of aircraft using radar

Objective of the study

- To gain a better understanding of the capabilities and limitations of RSM/JEM techniques and to derive reliable estimates for achievable percentages of correct classification/identification and NCTI confidence factors in operational environment

Trials

- A prerequisit for further investigations was a common data base of real data
- RSG.12 initiated, organized and conducted a multinational cooperative field trial at WTD 81 Greding, Germany
- The name "TIME" (Target Identification by Modulation Exploitation) was assigned to this trial
- The trial TIME lasted from 3 - 28 April 1989
- Twenty-three aircraft from different member nations participated in the trial representing 16 different aircraft types
- Six different radar systems operating in the L, S, C, X and Ku bands were provided by the nations

The trial TIME turned out to be very effective in establishing a comprehensive common data base for the following investigations; data of trial TIME have been exchanged between the nations of RSG.12 and are still available

Main Conclusions of the study

- The Study showed that JEM techniques can provide a powerful tool for the non-cooperative identification of aircraft.
- Principal radar candidates for application of JEM techniques are lock-follow weapon system tracker/illuminator radars, multi-function phased array radars with high prf modes, and airborne interception radars.

Databases for JEM techniques are relatively simple but

- JEM techniques do not provide an all-aspect NCTI capability.
- They require a relatively high Signal-to-Noise ratio.

The Study ended with a Final Report on Radar Signal Modulation Techniques (NATO SECRET) (Technical Report AC/243 (Panel 10) TR/5.

Phase III 1992 - 1996: Radar Imaging Techniques for NCTI of Aircraft

Participating nations: Denmark, France, Germany, The Netherlands, Norway, United Kingdom, United States of America, NC3 A.

To overcome some of the shortcomings of the JEM techniques RSG.12 started in phase III the study on techniques having additional potential in NCTI of aircraft. The work focused on radar imaging techniques.

What do we understand by "radar imaging techniques" ?

The idea is having high resolved target RCS presentations in the slant-range and cross-range (2-DISAR techniques) dimensions.

Workshop

- In order to get a fast survey and a better understanding of the state of the art in the field of one- and two-dimensional radar imaging and data analysis RSG.12 organized a two days workshop on "Radar Imaging and Classification Techniques".

- The Workshop took place at FGAN, Werthhoven, Germany on 28-29 January 1993. Papers were published in the Technical Proceedings AC/243(Panel 10) TP/1.

- The Workshop was very succesful in giving an overview of the state of the art in radar imaging and in developing ideas on analysis of radar images with respect to target identification.

Trials

- Again a prerequisit for relevant investigations was a common data base of real, in-flight measured aircraft data. Because of the lack of any available data and to establish a common data base for the further investigations, RSG.12 conducted two multinational field trials in 1992 and 1993.

1992 Trials

- The trials of 1992 took place in autumn 1992 in the air spaces of the United Kingdom, of Germany and France.

- Two long-range radars participated,

  the BYSON radar of DERA, Great Malvern, UK and
  the TIRA radar of FGAN, Wachtberg-Werthhoven, GE.

BYSON-radar parameters:
- S-Band
- stepped frequency waveform
- 400 MHz bandwith

TIRA system parameters:
- Ku-Band
- chirp
- 800 MHz bandwith

- The BYSON radar collected HRR - profiles, the TIRA radar had the potential for both, HRR-profiles and 2-D-ISAR imagery.

- In the trials 9 different types of aircraft, provided by the RSG.12 member nations, participated.

- Total recording times were 9 hours for the BYSON and 8 hours for the TIRA system

1993 Trials

- In October 1993 the "AIDA" (Aircraft Imagery Data Acquisition) trials were conducted in the airspace of The Netherlands near Volkel.

- Its purpose was to build up a library of 2D-ISAR radar images of fighter aircraft.

- Four radar-systems participated in the measurements; two of these were long-range stationary systems (TIRA of FGAN, located at Werthhoven/GE and FELSTAR-radar of TNO/FEL, located at The Hague) and two were short-range mobile systems (MPR of DERA and RAMSES of ONERA).

FELSTAR parameters:
- S-Band
- stepped frequency waveform
- 450 MHz bandwith

TIRA-system:
- Ku-Band
- chirp waveform
- 800 MHz bandwith

MPR-system:
- X-Band
- stepped frequency waveform
- 200 MHz bandwith

RAMSES system:
- Band
- chirp waveform
- 200 MHz bandwith

- In the trials 15 different aircraft participated, respresenting 13 different aircraft types

- Total flight time was about 30 hours

The trials in 1992 and 1993 again were very successful, the recorded data showed to be of high quality according to the requirements for the following investigations

Data distribution

- All the data were distributed among the member nations of RSG.12 and are still available

- Two approaches were investigated:

  i) one dimensional High-Range-Resolution (HRR)- techniques for NCTI

  ii) two dimensional ISAR imaging techniques for NCTI

- The different nations developed their own approaches for solving the identification problem based on the HRR or 2D-ISAR aircraft data.

- The results of the classification processes were distributed and discussed among the group members and the structures of the different classifiers were illustrated. Classifier codes were not exchanged.

Main Conclusions

- The study showed that target identification based on HRR is a highly promising NCTI technique for fighter size or larger aircraft. It has an all aspect capability and moderate demands on signal-to-noise ratio and shows real time capability.

- A definite answer on the capabilities of 2D-ISAR based identification could not be given. It turned out that the existing database still is not broad enough for statistically relevant conclusions. The performance is less satisfactory than expected. Reasons may be found in problems in imaging algorithms or features used. In any case this technique presently is not real time capable in a fighter aircraft.

- A necessary prerequisit for identification techniques based on radar images of the targets is a database of HRR resp. 2D-ISAR signatures form the different aircraft types.

The study ended with a Final report on Radar Imaging Techniques for NCTI of Aircraft (Technical Report AC/243 (Panel 10)TR/14; NATO SECRET).

Phase IV 1997-1999 : Present working phase

Participating nations : Canada, Denmark, France, Germany, Greece, Italy, The Netherlands, Norway, Spain, United Kingdom, United States of America, NC3A

The focus of the present working phase is on the following topics :

- Further research in the area of 2D-ISAR imagery (autofocus methods, problem of manoeuvering targets) before the background of still not satisfying identification results

- Investigate on the applicability of radar signature modelling techniques for establishing a reference data base of HHR or 2D-ISAR data including hostile targets.

- Investigate on the improvement in identification rates under all aspects and for all targets if data fusion techniques are applied, combining specifically JEM, HRR and 2D-ISAR techniques.

- Investigate on possible improvements in identification performance, if fully polarimetric signature data is used.

Trials

For the question of model validation, to find out about the benefit of fully polarimetric data and for a better understanding of problems in 2D-ISAR imagery a (limited) number of fully instrumented aircraft field trials was necessary.

The trials under the name CARMINA (Correlated Attitude Radar Measurements of Images of Non-cooperative Aircraft) were conducted in the time frame November to February 1997/1998.

Six aircraft performed test flights under observation of the

- TIRA - system of FGAN/GE
- BYSON-radar of DERA/UK
- MERIC-system of ONERA/FR
- HYPERBRAHMS-system of DGA/FR
- FELSTAR-system of TNO-FEL/NL

in the Dutch, the UK and the French airspace

Partly the aircraft were instrumented with INS-systems. Four aircraft were fitted with an external attitude measurement system (ARDS - pod) .

MERIC radar system:
- X-band
- stepped frequency waveform
- 300 MHz bandwith
- fully polarimetric system

HYPERBRAHMS:
- seven frequency bands from 500 MHz to 34 GHz
- high prf mode
- detection of JEM lines

The trials were succesfully finalized in February 1998. The radar data will be distributed in May/June.

In parallel the member nations started their work in scale-model measurements resp. computer modelling of those targets, that have participated in the CARMINA trials.

Expectations on this Symposium

This Symposium should act as a forum to bring together experts of the different disciplines that deal with problems related to the work in the fields of Automatic Target Recognition.

We hope that we will find a forum to discuss especially on the ideas of

- Target Characterization
- Target Classification
- Feature Extraction
- Modelling Techniques

in the area of air target identification and related areas.

At the end of this Symposium I hope we will leave with a lot of new, stimulating ideas, to go on in our different but related areas of research work for developing tools and methods for the Non-cooperative (air) target identification.