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NATO AGARD Conference on "Propagation Effects
on ECM-Resistant Systems in Communication and
Navigation

J.M. Goodman*

15 October 1982

*Naval Research Laboratory
Washington, DC

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The 30th symposium of the Electromagnetic Wave Propagation Panel of NATO-AGARD was held from 24 to 28 May 1982 in Copenhagen, Denmark. A discussion of the proceedings is contained herein along with appropriate clarifications and personal reflections. The conference dealt with various issues related to the ECM-resistant systems in communications and navigation with special emphasis upon propagation influences. Contributed and review papers covered		

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propagation effects and limitations, system adaptation, and the interaction of specified systems with the environment. The report also describes a concluding round table discussion in general terms.

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NATO AGARD CONFERENCE ON PROPAGATION EFFECTS ON ECM-RESISTANT
SYSTEMS IN COMMUNICATION AND NAVIGATION

The NATO AGARD Conference on Propagation Effects on ECM-Resistant Systems in Communication and Navigation was held in Copenhagen, Denmark, from 24 to 28 May 1982. As is typical of NATO-AGARD meetings, particularly those sponsored by the Electromagnetic Wave Propagation Panel (EPP), the conference was attended by technical experts in the field through official invitation. There was a restriction on invitations to observers although special allowances were made on a case-by-case basis. In general, invitations are obtained from the national delegates through appropriate channels. In the US case, requests for invitations pass from the originator to the US Government technical point of contact on the EPP Panel (the US enrollment coordinator) and then to the US national delegate to AGARD with copies to pertinent officials of NATO/AGARD including (for the Navy) the US Navy liaison officer to AGARD.

As part of standard NATO/AGARD practice, an unclassified preprint document was provided to all registrants; it carried an AGARD-CPP-331 designation. As a rule this document is an invaluable reference for workers in the field. In some cases the preprints are abstracts of papers that were not made available by the publication deadline. Thirty-one papers were originally scheduled, 28 were presented, 13 were published in full form, and 15 were published in abstracted form. Nevertheless, most authors provided preprints of their papers to the registrants to complete the set of papers actually presented. A final document including all the unclassified versions of the papers will be designated AGARD-CP-331, and will have the same title as the conference. A NATO-SECRET classified annex is also planned; it will include discussions following each paper, as well as a synopsis of the round-table discussion held on the final day.

As noted in the appendix there were four principal sessions, two of which were bifurcated. The chairmen are identified below:

:Session I	Dr. W. Utlaut, US
:Session II	Dr. H. Soicher, US
:Session IIIA	Mr. V. Coyne, US
:Session IIIB	Dr. J. Goodman, US
:Session IVA	Dr. J. Belrose, Canada
:Session IVB	Dr. E. Lampert, FRG

The program chairman was Dr. H. Albrecht of FRG.

There were five review papers presented at the conference. They were:

"HF Radar Ionospheric Clutter," by Dr. G. Millman; "VHF, UHF, SHF Propagation Limitations in the Marine Atmosphere," by Dr. K.E. Fischer; "The Atmospheric Propagation Medium between 45 and 75 GHz," by Dr. H.J. Liebe; "HF Propagation Factors Limiting Real-time Channel Evaluation Adaptive Systems," by Dr. J. Aarons; and "The Role of the Propagation Environment in HF Electronic Warfare," by Dr. J. Goodman.

A brief synopsis of the technical program follows.

Major technical issues relating to the topics associated with the subject of the conference were at least identified. A frequency range between HF and K-band was covered and disciplines included HF communication (radio), radar, and navigation systems with special emphasis on radio. As in many typical conferences in the past, the issue of the role of predictions, forecasting, and assessment of the radio channel was a major topic. The consensus was that median statistical models are useful to provide the basis for planning or for design of robust adaptive systems, but the efficacy of such models for use in prediction of the real-time ECM environment was questioned. Nevertheless continuing research in model development was expected to remain useful. Several papers by Dr. J.P. Murray of the Institute of Telecommunications Sciences (ITS) Boulder, CO, together with colleagues, reviewed propagation models from several viewpoints. Murray produced an atlas of propagation curves based upon his research; curves were tailored for use by the EW community.

The major "channels" discussed in the conference included line-of-sight-terrestrial, troposcatter and ionoscatter links, ionospheric-reflected propagation, and earth-space propagation. Limitations of the propagation modes were discussed in the first session.

To the author the highlight of the program was the round-table discussion held following the last technical session on the final day. The discussion was led by Dr. Hans Albrecht (FRG) and included V. Coyne (US), Dr. J. Aarons (US), Mr. L. Bothias (FR), Dr. E. Lampert (FRG) and Dr. Wm. Utlaut (US). Each major topic was briefly summarized by the panel and this was followed by open discussion.

It was interesting to note that models for HF propagation were not generally espoused. Rather, the development of adaptive HF systems in their various forms was to be encouraged to provide the required robustness to improve reliability as well as availability and resistance in the ECM environment (i.e., jamming and intercept). The HF approaches were reviewed by Aarons earlier in the conference, and Session II covered system adaptation in general, including troposcatter applications. Approaches of HF, of course, include not only adaptive equalization and kindred techniques but also adaptive antennas (say adaptive null steering), spread-spectrum techniques, and ionospheric sounding.

Several authors discussed the use of sounders to assist in the efficient use of the HF band. Goodman (the author) discussed the use of ionospheric sounders of the oblique type for update of simple modes of the HF channel and indicated that conditions often exist for extrapolation of channel assessments to future times over cooperative links as well as over uncooperative disjoint paths. Aarons suggested that sounders or similar remote sensing devices should be used to update models rather than simply using predictive models alone. He stressed the need for real-time assessment and for utilization of adaptive approaches. He further suggested that channel sounding should be organic to the system if possible. A concern was raised by Dr. Soicher (US) that with the proliferation of sounders for channel assessment

there might be a problem with interference. Goodman expressed a similar concern, noting that the necessity for procurement of a huge number of (nonorganic) chirp sounder transmitters is unclear owing to the nonvanishing spatial correlation of channel evaluations. He suggested that sharing of transmitter assets by the various services be considered and further suggested that additional efficiencies could be effected by intelligent use of simple models for spatial and temporal extrapolation. Utlaut stressed system approaches (i.e., adaptive approaches) to ECM resistance as opposed to models.

In the areas of ionoscatter, Albrecht asked Utlaut to review the possibilities of artificial modification to open up new links that would not ordinarily be available. (Utlaut, of ITS-Boulder, conducted the original landmark experiments during which the Platteville HF vertically firing "heater" was used to produce an artificial scatter path by which various communication modes could be opened. This was in the early 1970s.) A vigorous discussion followed, not detailed herein.

It was pointed out by Belrose, referring to the paper by Unkauf (Raytheon, US), that multipath is helpful in a spread spectrum approach for circumventing problems over the troposcatter channel. Indeed multipath does provide an intrinsic diversity provided it is exploited properly.

The US Navy plans to use the same property in its strategic upgrade of the HF Improvement Program (HFIP), although the latter application is based upon the ionospheric channel multipath and requisite data rates are considerably lower than in Unkauf's tropospheric case. A well-known strategy used in the ionospheric case to minimize multipath is to operate at the maximum usable frequency (MUF) or slightly below it (i.e., the FOT) to increase channel availability. However, it may be advantageous to operate at frequencies well below the FOT in the ECM environment. Furthermore in the strategic environment for which jamming is also a factor, all possible modes must be exploited and this dictates an architecture that accesses multipath modes, side-scatter and possible bomb modes, as well as the normally efficient modes near the benign MUF.)

A number of adaptive systems were alluded to in the conference including equalization with adaptive feedback (mentioned above), RADE technology, ionospheric sounding, and diversity. Diversity may take a number of forms including space, path, frequency, angle, polarization, and time. Many of the schemes that have a degree of robustness in the nuclear environment may also be useful in the ECM environment and vice-versa. There are a number of systems that use time diversity to avoid or reduce the vulnerability to fading; the simplest is of the ARQ type, another involves coding and interleaving. In ECM environment, as pointed out by the author in his review paper, one finds that space, path, and angle diversity schemes may be the most useful.

Techniques for exploiting the maritime ducting environment were discussed in several papers including those by Dr. K.E. Fischer (FRG) and R.M. Wright (UK). Techniques involve ray tracing, and the

atmospheric refractivity models are updated through use of radiosondes and microwave refractometers. Some concern was expressed about the accuracy of radiosonde, and Utlaut indicated that Dr. Dutton of his organization is working on the problem. The US Navy IREPS program, although not presented at the conference, was referred to on several occasions.

Earth-space considerations vis-a-vis ECM were discussed by A. Johnson (Air Force Avionics Lab, US). He reviewed the EHF, UHF, and SHF scintillation introduced by the ionosphere and presented a useful graph describing the worst-case conditions.

The technical agenda for the conference is attached as Appendix A; for the most part, the schedule was maintained as advertised. The conference was classified NATO secret, and many technical details viewed to be sensitive have been omitted from this unclassified summary. It has been informally cleared by the Electromagnetic Wave Propagation Panel Executive EPP after examination by EPP members; nevertheless it should not be cited as an official record of the conference. The official conference proceedings will be published by NATO-AGARD.

APPENDIX A - TECHNICAL PROGRAM

Monday, 24 May 1982

SESSION I - PROPAGATION LIMITATIONS TO MODERN SYSTEMS

HF RADAR IONOSPHERIC CLUTTER

Dr. G.H. Millam, General Electric Company, US

FAST FADING CHARACTERISTICS OF MEDIUM RANGE H.F. SIGNALS

Dr. V.B. Mitchell, University of Exeter, UK

VHF-, UHF, AND SHF-PROPAGATION LIMITATIONS IN THE MARINE ATMOSPHERE

Dr. K.E. Fischer, Amt fur Wehrgeophysik, Germany

THE ATMOSPHERIC PROPAGATION MEDIUM BETWEEN 45 AND 75 GHZ

Dr. H.J. Liebe, Institute for Telecommunications Sciences, Boulder, CO, US

MM-WAVE PROPAGATION IN SURFACE VICINITY

Dr. W. Schuck, Mr. J. Detlefsen, Messerschmitt-Bolkow-Blohm, Germany

RELATIVE COST BENEFITS TO BE ASSOCIATED WITH ALTERNATIVE TERRAIN REPRESENTATIONS IN ELECTRONIC WARFARE SIMULATION

Dr. J.P. Murray, Dr. G. Hufford, Institute for Telecommunications Sciences, Boulder, CO, US

PREDICTIONS OF MULTIPATH LEVELS FOR AIR TO AIR ECM RESISTANT COMMUNICATION SYSTEMS

Dr. P. Loester, Mitre Corp., US

Tuesday, 25 May 1982

SESSION II - SYSTEM ADAPTATION TO PROPAGATION FEATURES

HF PROPAGATION FACTORS LIMITING REAL TIME CHANNEL EVALUATION ADAPTIVE SYSTEMS

Dr. J. Aarons, Dept. of Astronomy, University of Boston, and Dr. M. Grossi, Raytheon Company, US

NEW RESULTS ON ECM RESISTANT COMMUNICATION IN HF CHANNELS

Dipl. Ing. R. Espreseter, Mr. H. Scholler, Mr. H. Humann, AEG-Telefunken, Germany

IMPLICATIONS OF THE TIME-VARIANT PROPERTIES OF THE HF SKYWAVE CHANNEL FOR THE DESIGN AND PERFORMANCE OF SMALL ADAPTIVE ANTENNA SYSTEMS

Dr. R. Jenkins, C.R.C., Canada

ADAPTIVE EQUALIZATION OF TROPOSCATTER CHANNELS WITH FSK MODULATION. PART I - THEORY AND COMPUTER SIMULATIONS

Dr. E. Bitzer, AEG-Telefunken, Germany

ADAPTIVE EQUALIZATION OF TROPOSPHERIC CHANNELS WITH FSK MODULATION. PART II - HARDWARE STUDY & MEASUREMENTS

Dipl. Ing. U. Buse, AEG-Telefunken, Germany

PROPAGATION EFFECTS ON THE ECCM PERFORMANCE OF THE DIGITAL MICROWAVE RADIO

Mr. J.E. Bartow, CENCOMS, Fort Monmouth, NJ, US

SESSION III- PROPAGATION EFFECTS IN EW SCENARIOS

THE ROLE OF THE PROPAGATION ENVIRONMENT IN HF ELECTRONIC WARFARE
Dr. J.M. Goodman, Naval Research Laboratory, US
OPERATIONAL IMPLICATIONS OF PROPAGATION MODELS USED IN
COMMUNICATIONS EVALUATION IN TACTICAL ELECTRONIC WARFARE PLANNING
Dr. J.P. Murray, Dr. G. Hufford, Institute for
Telecommunications Sciences, Boulder, CO, US
AN ATLAS OF PROPAGATION CURVES FOR TACTICAL ELECTRONIC WARFARE
PLANNING IN GROUND-TO-GROUND SCENARIOS
Dr. J.P. Murray, Dr. G. Hufford, Institute for
Telecommunications Sciences, Boulder, CO, US

Wednesday, 26 May 1982

THE TACTICAL APPLICATIONS OF MICROWAVE PROPAGATION PREDICTION
Mr. R.M. Wright, Wg Cdr. P.J. Burton, Mr. J.S. Barr,
Ferranti Computer Systems Ltd., UK
CRITERIA FOR THE SELECTION OF PROPAGATION MODELS FOR ELECTRONIC
WARFARE PLANNING SIMULATION
Dr. J.P. Murray, Dr. G. Hufford, Institute for
Telecommunications Sciences, Boulder, CO, US
AN INTERFERENCE PROPAGATION MODEL FOR SYSTEM ASSESSMENT USE
Dr. P.R. Whittlestone, RSRE, UK
BROADBAND SIDELobe INTERFERENCE SUPPRESSION FOR TROPOSPHERIC
SCATTER COMMUNICATION
Dr. S.A. Parl, Signatron Inc., US
LIMITATIONS ON ECM EFFECTIVENESS IN HF COMMUNICATION
Dr. M.Darnell, University of York, UK

SESSION IV - GENERAL PROPAGATION/SYSTEM INTERACTION

THE EFFECT OF IONOSPHERIC SCINTILLATION ON EARTH-TO-SATELLITE ECM
RESISTANT LINKS
Mr. A.L. Johnson, Wright Patterson AFB, OH, US
TERRAIN MASKING WITH MONOSTATIC, MULTISTATIC, AND NETTED RADAR
Mr. E. Hanle, Forschungsinstitut fur Funk und Mathematik,
Germany
SIMPLIFIED INPUT DATA FOR PREDICTIONS OR RADAR CHARACTERISTICS AND
INTERCEPT SUSCEPTIBILITY (PROJECT GEOMAR)
Dr. K.E. Fischer, Amt fur Wehrgeophysik, Germany
THE PRACTICAL FREQUENCY HOPPING RADIO CHANNEL
Dr. D. Roth, SEL Pforzheim, Germany

Thursday, 28 May 1982

SPREAD SPECTRUM MODULATION TECHNIQUE FOR THE TROPOSPHERIC SCATTER
CHANNEL
Dr. M. Unkauf, Raytheon Co., and Mr. F. Zawislan, Griffis
AFB, US
FIELD TESTS OF AN ECM-RESISTANT DISTANCE MEASURING EQUIPMENT
UTILIZING A MODIFIED SECURE-K-BAND DATA LINK
Dr. I. Von Maydell, Mr. A. Blaha, Mr. J. Lauber,
Messerschmitt-Bolkow-Blohm, Germany

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**A COMPARISON OF ANALOG AND DIGITAL TRANSMISSION PERFORMANCE OVER
TROPOSCATTER LINKS**

Dr. P. Monsen, Signatron, US

ROUND TABLE DISCUSSION - Chairman: Dr. Albrecht

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