Electromagnetic Propagation

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LONG TERM GOALS

Develop electromagnetic propagation models for use in operational or engineering propagation assessment systems.

OBJECTIVES

Develop an advanced unified hybrid radio propagation model based on parabolic equation and ray-optics methods for both surface-based and airborne applications. This model is named the Advanced Propagation Model (APM) and is the model used in the Advanced Refractive Effects Prediction System (AREPS). Resolve differences between current techniques used to model propagation effects under rough surface and strong ducting conditions.

APPROACH

We develop parabolic equation, ray optics, waveguide, and other models as necessary to produce both accurate and efficient models to be used in propagation assessment systems. In many cases we can use variations of existing models to achieve this goal, but sometimes completely new models are necessary. Once developed, these models are compared to other models and to experimentally collected propagation data for verification of accuracy. We stay abreast of other researchers' newest models by reading current literature, participating in propagation workshops, and attending conferences as appropriate. There is a strong international exchange of ideas and techniques in this area, as some

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important work is performed outside of the USA. This project is divided into two tasks: (1) Propagation over Terrain, and (2) Rough Surface Effects.

WORK COMPLETED

PROPAGATION OVER TERRAIN

We have included a sea clutter model in which the reflectivity, or clutter cross section per unit area, is based on the model developed by the Georgia Institute of Technology (GIT). We introduced a modification to this model in the determination of grazing angle for the computation of reflectivity. Initial modeling of land clutter has also been undertaken in a collaborative effort with the Refractivity From Clutter (RFC) task (P.I. Ted Rogers). In conjunction with the RFC task, a method has been developed to infer refractivity from land clutter. This method is based on computing the correlation between surface ray density, via ray trace, with measured surface clutter. This method is simpler and more efficient than the conventional "least squares" technique, which uses the parabolic equation (PE).

Refractive analysis on infrared transmission data collected during the Nov. '96 EOPACE IOP is ongoing. Both ray optics and PE techniques are being used to model refractive effects along the transmission paths.

ROUGH SURFACE EFFECTS

A mission plan was prepared for the Rough Evaporation Duct (RED) experiment, which is planned for 20 August to 18 September 2001. *R/P FLIP*, moored some 10 km offshore of Oahu, will serve as the primary meteorological data collection platform and will also serve as a terminal for both RF and EO propagation paths. Figure 1 shows the expected position of *R/P FLIP* and the propagation paths. Approval to use receiver sites at both the Marine Corps Base Hawaii (RF path) and at the Malaekahana State Park (EO path) has been obtained. RF components, EO components, and meteorological sensors were ordered and have either been received or are expected shortly.

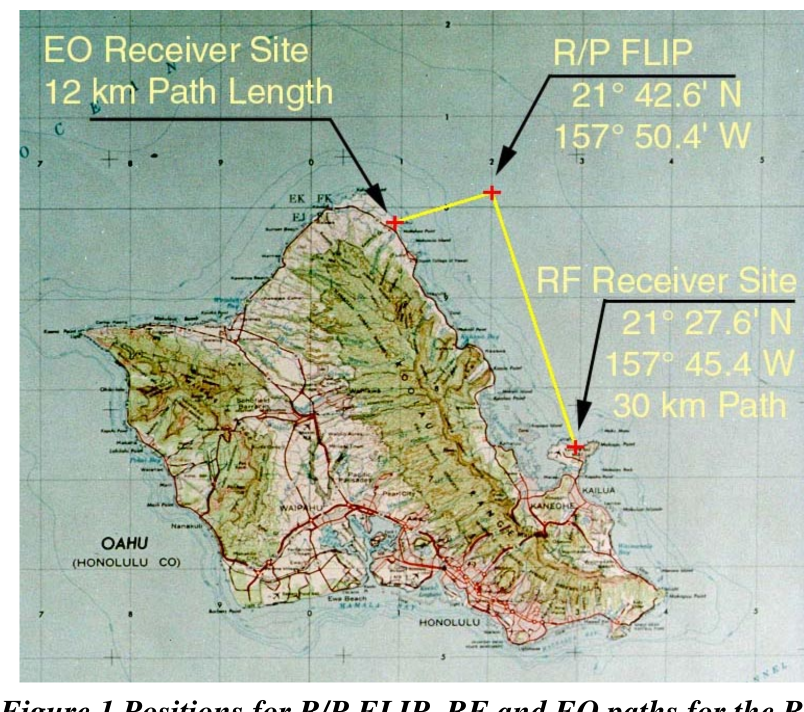

Figure 1.Positions for R/P FLIP, RF and EO paths for the RED

The equivalent impedance of a rough surface for horizontal polarization, valid insofar as the specular component of field at low grazing angles is concerned, was obtained at 3 GHz up to wind speeds of 20 m/s, at 10 GHz up to wind speeds of 15 m/s, and at 17 GHz up to wind speeds of 10 m/s. The impedance is complex valued as opposed to a real value predicted by the Miller Brown expression. A new formulation of propagation over a spatially non-constant impedance was developed, which is capable of handling any reasonable roughness induced impedance within the framework of parabolic equation without having to estimate the grazing angles of propagation. The impedance data derived in earlier work is now being integrated into this new formulation to make predictions of forward propagation over a rough surface.

RESULTS

PROPAGATION OVER TERRAIN

The primary result of this task is the development of the Advanced Propagation Model. This model is now very robust and includes a very complete set of features. It is already being widely used by fleet operational personnel and others in the Advanced Refractive Effects Prediction System.

An update to the APM Computer Software Configuration Item Document (CSCI) was completed and delivered to the Oceanographic and Atmospheric Master Library (OAML), along with updated APM source code. In March 2000 a COMNAVMETOCCOM Independent Model Review Panel (CIMREP) was convened with participation by APM developers. Final decision by the CIMREP panel for possible submission of APM in the OAML is scheduled for Sep 2000.

Preliminary results in determining refractivity from land clutter based on ray trace methods are favorable. Figure 2 below shows the tri-linear refractivity profiles inferred from surface clutter over two-mixed land-sea paths, along with the measured profile. The inferred profiles were obtained from a least squares (LS) method, where clutter predictions were obtained from APM, and a new, more efficient ray trace and rank correlation (RC) scheme. Table 1 also provides numerical values of the inferred and measured profiles.

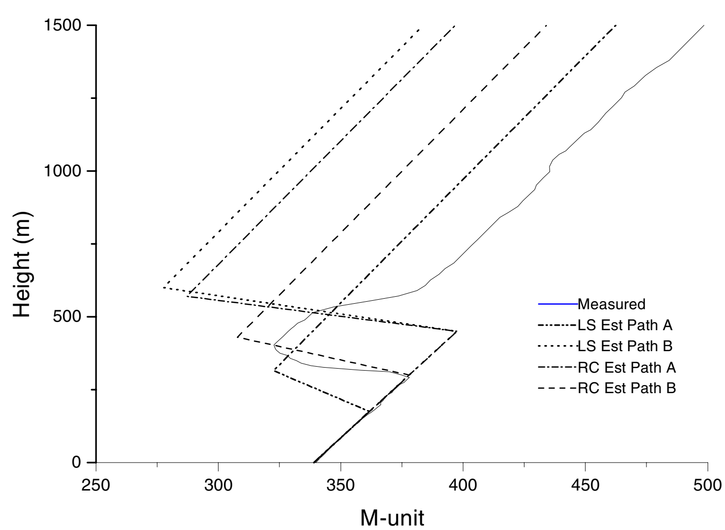

Figure 2. Inferred and measured refractivity profiles.

Table 1. Estimated tri-linear profile parameters from least squares and ray trace/rank correlation methods.

Parameter	**Least Squares** Path A 13.2 dB	**Least Squares** Path B 19.9 dB	**Ray Trace** Path A .75	**Ray Trace** Path B .84	**Actual**
Base ht. (m)	175	450	450	300	292
M-Deficit (M-Units)	40	120	110	70	55.4
Thickness (m)	140	150	120	130	111
Gradient (M-units / m)	-.28	-.8	-.92	-.54	-.5

ROUGH SURFACE EFFECTS

The major efforts for this year have been getting site use approvals, designing and ordering equipment, finalizing the RED mission plan, and coordination with Scripp's Marine Physical Laboratory for modifying and scheduling *R/P FLIP*. These efforts have been successful and the RED experiment is on-track for starting in August 2001.

IMPACT/APPLICATIONS

The goal of this work is to produce the best possible hybrid radio propagation model for incorporation into U.S. Navy assessment systems. Current plans call for APM to be the single model for all applications. As APM is developed it will be properly documented for delivery to OAML, from which it will be available for incorporation into Navy assessment systems. The extension of APM to model sea and land clutter will improve operational assessments and also provides modeling support for a related project pursuing the concept of extracting refractivity profile information from radar clutter returns.

TRANSITIONS

APM Version 1.3 now accounts for rough sea surface effects, sea clutter, and land clutter. APM was transitioned into the Tactical EM/EO Propagation Models Project (PE 0603207N) under PMW 185.

RELATED PROJECTS

This project is closely related to the synoptic and mesoscale numerical analysis and prediction projects pursued by NRL Monterey and the Coastal Variability Analysis, Measurement, and Prediction (COVAMP) project which pursue providing the refractivity inputs for APM. This project is also related to the Remote Refractivity Sensing project under ONR 321SI in providing fast-running, high-fidelity forward propagation modeling used in the RRS inference techniques. The transition target for this project is the Tactical EM/EO Propagation Models task under PMW 185 and the Oceanographic and Atmospheric Master Library. Tri service coordination is conducted under the Technology Area Review and Assessment.

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