RF Performance Predictions for Real Time Shipboard Applications

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LONG TERM GOALS

Develop electromagnetic propagation models, that perform equally well over land and sea and in the presence of anomalous propagation conditions for both surface and airborne emitters, for use in operational or engineering propagation assessment systems.

OBJECTIVES

The specific technical objectives are to 1) develop a method to extract rainfall data from the tactical scans of the SPS-48 radar and provide the rain data in a form suitable for propagation models such as the Earth-to-Satellite Propagation Model with METOC (ESPM2) and the Advanced Propagation Model (APM); and 2) modify the current statistics-based rain attenuation model within the ESPM2 and the APM to ingest real time rainfall rate data obtained from shipboard radar (SPS-48 initially).

APPROACH

The problem of obtaining accurate rain rates from radar returns is an old one and has been studied by the weather radar community for many years. In the usual application, the problem is the prediction of rain rates at the ground from measurements made aloft by the radar. In our case, the rain rate is an

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intermediate parameter used to specify the attenuation rate for RF propagation. So our approach has been to use the results from the work that has been done as it applies to our particular application but some modifications are required. We also retain parts of the ITU rain attenuation model as they apply to the current effort.

A common problem one faces in developing shipboard applications is that of obtaining verification and validation data in open ocean areas. Specifically, the relationship between reflectivity factor (Z) and rain rate (R) is highly dependent on geographic location and rain type [1]. While many attempts have been made to develop a general relationship that is suitably accurate in all situations, it remains true that this relationship is highly variable. The lack of open ocean data and the mobility of the shipboard radar make it even more difficult to obtain a single parametric relationship that is accurate in all situations. However, before these difficult questions can be researched, an estimate of the accuracy of the model as it exists needs to be obtained. So our plans for this year included the collection of data suitable for an end-to-end assessment of the accuracy of the model that was developed earlier under this effort. An end-to-end assessment requires basic refractivity data from a SPS-48 shipboard weapons radar from which our conversion to rain rates can be verified. From the rain rates we obtain rain attenuation estimates which can only be verified by comparison to measured attenuation rates during the same rain events. The availability of the SPS-48 radar gives us an opportunity to collect the required data set at a fixed, land based site.

RESULTS

The rain attenuation model developed in previous years has been described in previous reports and mid-year reviews and will not be repeated here [2,3]. The effort this year was to be centered on the collection of data suitable for assessing the accuracy of the model for a 'simple' application of a fixed radar site. The data set must be capable of assessing the complete model, from estimating rain rates from radar data to estimating attenuation on RF propagation paths.

Our initial intent was to conduct our data collection at Dam Neck, Virginia, for which we had obtained the necessary permissions. The data collection campaign was scheduled to be executed during the summer of 2011. However, the completion date for the upgrade of the Dam Neck SPS-48E to the SPS-48G radar was changed from April 2011 to January 2012. Thus, we would be unable to conduct our test in 2011, and were forced to push the measurements to the summer of 2012. We were able to find another site that has the SPS-48E radar, Wallops Island, Virginia which, according to our models offers improved propagation conditions relative to the Dam Neck site. A NATO group was preparing to conduct a field campaign at that location in June 2012, and for the purposes of having additional resources and collecting more data, we joined their effort. Unfortunately, that group had to disband due to foreign financial issues. For our effort, though, we decided to move forward with the Wallops Island, Virginia measurement location.

For this new location, we conducted two site visits to determine suitable locations for our equipment. Our plan is to set up one end of our system at the Navy Surface Combat Systems Center (SCSC), Wallops Island, Virginia, and the other end at the garage of the United States Coast Guard (USCG) Station in Chincoteague, Virginia. While we have permission from the USCG Station Chincoteague to use their site, we are in the process of obtaining formal approval from the USCG. To gain the necessary permissions from SCSC, documents were written, including the Facility Requirement Document, and the Frequency User Request. Currently, we have our permissions from SCSC, and are working with both their frequency coordinator and our own to obtain Department of Defense (DoD) certification for our system.

Due to the new site, we are examining the possibility of using higher gain antennas, and hope to borrow them, as we did the current antennas. The precise building at SCSC which we will use has not yet been determined, but there are multiple options ranging from 8-12 km paths over-water. We have run simulations on each of these paths to assess propagation conditions for the area. We are continuing to analyze the path options to determine which meet our requirements while also being of good value. Once the path has been selected we can proceed with other details such as obtaining the necessary cables at the appropriate lengths. An analysis of the losses of the different cables under consideration has already been performed.

The software for controlling the system is complete and runs successfully. It includes a graphical user interface (GUI) for each end of the system. The GUIs take inputs of frequency, transmit times, cycling time, start and end times. For the transmit side of the system it also takes in the power to transmit, and for the receive side the sampling rate and file name for the data. The data will be stored in an Excel file, with each frequency's information on a separate worksheet. There will also be a backup file generated for each system run. This code has been tested with the other system equipment and performs as expected.

The system operation schedule calls for transmitting each of three frequencies sequentially for 20 seconds each as the basic transmission block (BTB). We are looking at frequency ranges 10-10.55, 13.4-14.3, and 15.7-17.3 GHz, and are planning for 10.1, 14.1, and 17.1 GHz. The transmit frequencies can not be finalized until we are granted approval from both SCSC and NASA at Wallops Island, Virginia. During dry periods, no rain, the BTB will be repeated every 30 minutes and the data stored to an external drive. During rain events the BTB will be repeated as often as every five minutes. Both the transmit times and the sampling rates can easily be changed individually for each frequency, as they are both user-entered values in the system GUIs. We expect to determine from our measured data what the sampling rate should be. While collecting the power received data, the system will be simultaneously collecting rain amount data from the rain gauge, prevailing wind data and UF files from the SPS-48 radar on a similar schedule. The data collected during non-rain periods will be averaged to give background estimates of received signal strength for comparison to data taken during rain events.

IMPACT/APPLICATIONS

The primary payoff of this task is to allow a shipboard user of the ESPM2 and the APM to use real time weather data, which will become available in the near future, to provide more accurate assessment of expected system performance and allow tuning of system parameters (i.e. transmitter power levels) to meet performance criteria while, perhaps, conserving shipboard assets.

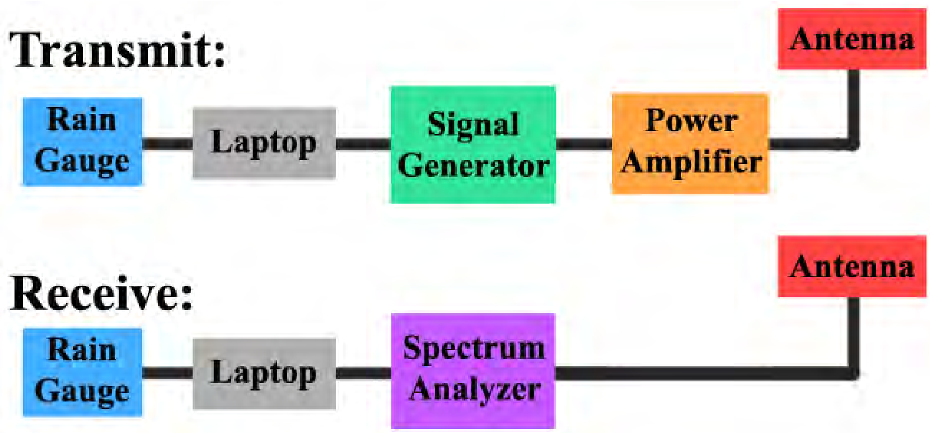

Figure 1. Measurement System Diagram

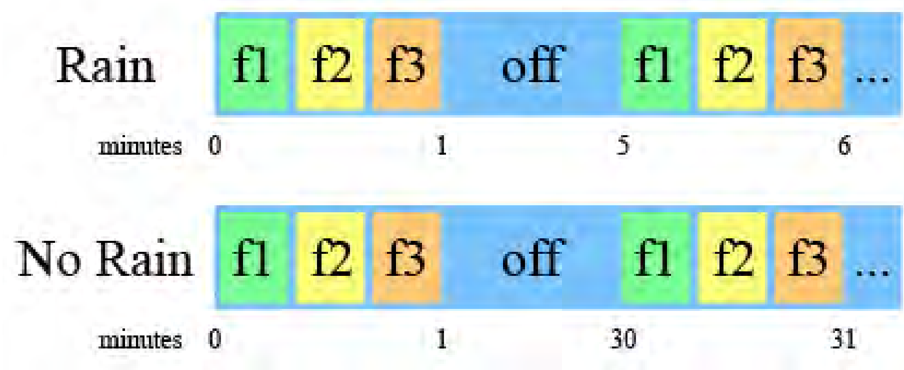

Figure 2. Frequency Transmission Cycling Schedule

TRANSITIONS

Propagation models and applications developed under this task and intended for operational use transition into the Naval Integrated Tactical Environmental Subsystem (NITES) EM module, PE 0603207N, and could also transition into any other propagation assessment system. Models will transition into the Oceanographic and Atmospheric Master Library (OAML), from which they will be available for transition or incorporation into any assessment, simulation, or engineering-support system that needs them. Propagation models and algorithms under this task and intended for operational use may also transition to the Littoral Battlespace Sensing, Fusion, and Integration (LBSF&I) program (PE 0603207N). The propagation models and algorithms developed under this task will significantly aid in the overarching capability under the LBSF&I program to provide a completely integrated end-to-end "system of systems".

RELATED PROJECTS

Efforts under this task are related to the Joint Tactical Radio System (JTRS) program and any related program requiring SATCOM performance assessment. Under the tri-service Battlespace

Environments Technology Area Plan, our propagation models are also available to both Air Force and Army.

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3. Sprague, R. A., P. Babu, N. Fuhrer, "RF Rain Attenuation from Shipboard Radar Clutter", *Battlespace Atmospheric and Cloud Impacts on Military Operations* (BACIMO) Conference, Omaha, NE, April 2010.

PUBLICATIONS

1. Sprague, R. A., P. Babu, N. Fuhrer, "RF Rain Attenuation from Shipboard Radar Clutter", *Battlespace Atmospheric and Cloud Impacts on Military Operations* (BACIMO) Conference, Omaha, NE, April 2010.