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 objective is to assess the fidelity of using radar reflectivity (Z) recorded from tactical scans of a Hazardous Weather Detection and Display Capability (HWDDC) system for estimating attenuation (k) on earth-to-satellite paths [1, 2].

APPROACH

Rain rate (R), radar reflectivity (Z), and attenuation (k) can be related to one another by integrating over the drop size (D) where the integrand contains the drop-size distribution $N(D)$ and additional terms which are also functions of D [3]. When observing Z using radar, it is only the integrated effect of $N(D)$ and the additional terms that is known, not the $N(D)$ itself. In practice, $N(D)$ – or its effect -- has been approximated using empirically adjusted exponential distribution with a power-law dependency on R. ; i.e., the model of $N(.)$ has several arguments, including R and the empirically determined parameters. Differences between the true and modeled $N(D)$ are believed to be a significant component of the reason differences between rain gage and radar-retrieved values of R are in the range of 15% to 30% [4]. Uncertainty in estimating k directly from Z at X-band (nominally 10 GHz) for the purpose of improving rain rate estimates continues to drive research in this area [e.g. 4].

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Our application inherently involves measuring Z at one frequency (typically 3 GHz) and utilizing that information to estimate *k* across frequencies from 3 to 20 GHz. When the difference between the frequencies of the *Z* measurement and the computation of *k* differ significantly, we expect a need to understand the effect of error and uncertainty arising from: (a) the values of parameters used (i.e., what are commonly referred to as "a" and "b" parameters or "Λ_1" and "Λ_2" parameters [3] in the literature), (b) the sensitivity of *k* to variations in those parameters, and (c) the *N*(*D*) formulation being too simple to adequately span the frequency range considered. Considering the uncertainty in the problem, it is likely that the correct "answer" to the question of "What is *k* given *Z* for the frequency difference in question?" is the probability of *k* conditioned on *Z* and the respective frequencies for sensing and use. This year's effort was designed to collect data to support this investigation.

A data collection had originally been planned the summer of 2011 at Dam Neck, VA that would utilize a shore-based SPS-48. Due to scheduling conflicts, the location and time of the experiment was changed to Wallops Island, VA, for the summer of 2012, where another shore-based SPS-48 system was located. We obtained site and frequency authorization to locate a horn antenna transmitting an 8.45 GHz continuous wave (CW) signal on the roof of Bldg. V-3 at the Navy Surface Combat Systems Center (SCSC) at Wallops Island. The receiving system using a parabolic dish antenna was located on the rooftop of a garage at the United States Coast Guard (USCG) Station in Chincoteague, Virginia.

A block diagram of the system is shown in Figure 1, the geographic setup in Figure 2, and the system link budget in Figure 3. Post-installation checks indicated received received signals level (RSL) on the link during clear (i.e., sunny day) conditions agreed within 3 dB of the values in the link-budget for the system. [Note: The expected RSL is found by removing the 45 dB rain attenuation from the design basis received signal level (RSL) of -97.8 dBm; i.e., the design basis clear day RSL is 52.8 dBm.]

RESULTS

Only a single rain event occurred during a time when a local radar system was available and even its availability only touched but did not fully overlap the rain event. SCSC's SPS-48 system had problems with its output amplifiers for which SCSC could not effect repairs during the experimental period. As a back-up plan for another experiment using SCSC's SPS-48, we had also secured a limited amount of use (2 hrs / day) of GSFC's SPANDAR (Space Range Radar). The SPANDAR, also an S-band radar, offers comparable data. However, the availability of the SPANDAR (which had to be scheduled a day in advance) was during a period of time when the rain was so intense as to drop the received signal below the noise floor of the receiving system (see Figure 4). The data collected does not support our objectives.

We will complete development (as stated above) of an expression for the probability of *k* conditioned on *Z* and the respective frequencies for sensing and use. We might consider a variety of opportunistic methods for validation and calibration of the method using rank-histogram or other techniques suitable for ascertaining the goodness of predictions of distributions.

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.

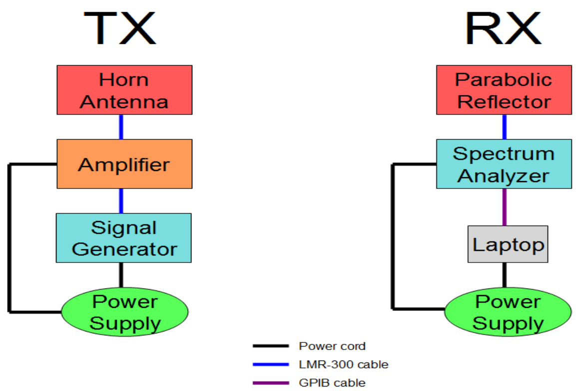

Figure 1. Measurement System Block Diagram

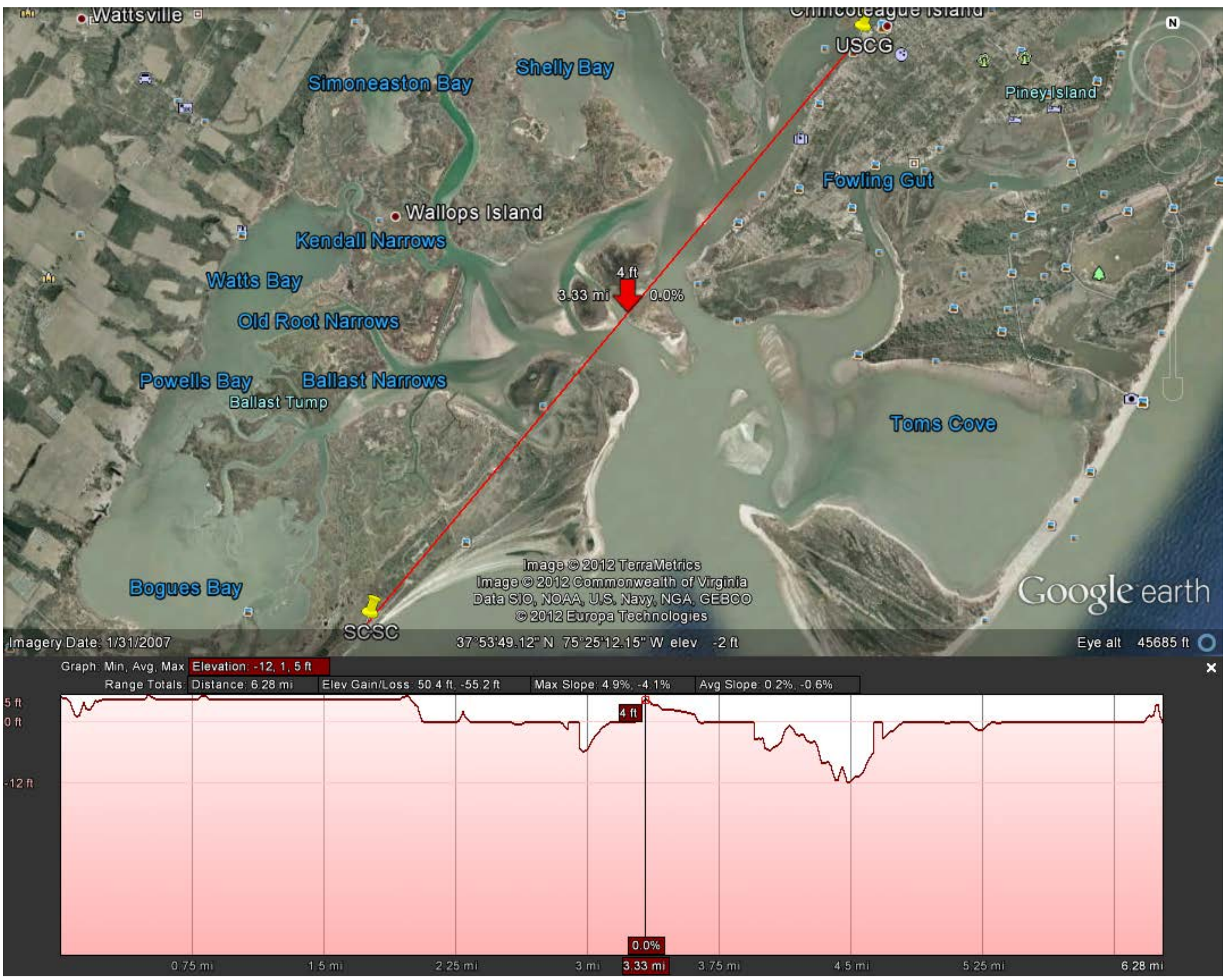

Figure 2. Line of Sight Transmit-Receive Path

ITEM	UNITS	8.45GHz	NOTES
SigGen	dBm	0.0	Neglegible power out
Cable (5ft)	dB	-1.0	Cable run between neighboring equipment
Amp	dBm	43.0	Fixed-power amplifier; to be placed next to SigGen
Cable (25ft)	dB	-5.1	Shorter run from platform
Horn	dBi	12.5	Mounted on roof of V-3
Path Loss	dB	-132.0	10km line of sight path
Rain	dB	-45.0	Scenario used assumes 55dBZ (99.8519mm/hr rain rate)
Reflector	dBi	37.0	Based on mid-band gain (spec sheet)
Cable (35ft)	dB	-7.2	Cable run from garage roof to storage closet
RX Power	dBm	-97.8	*LMR-300 cable type*
SpecAn	dBm	-147	

Figure 3. Estimated System Link Budget

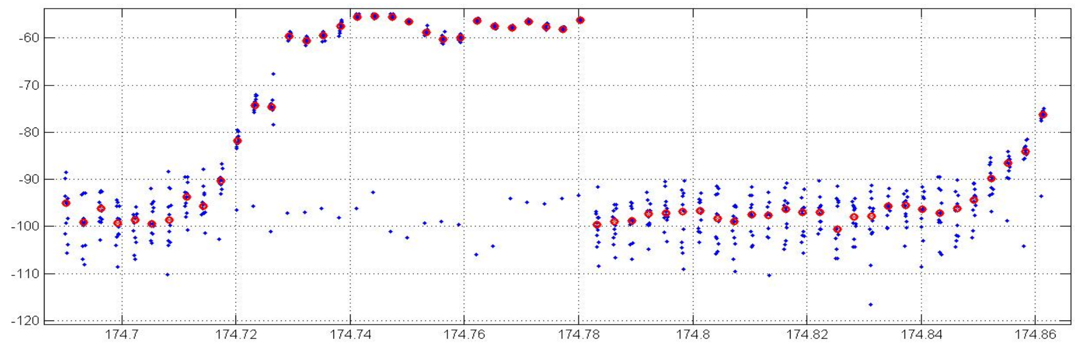

Figure 4. Received Power During First Rain Event

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

1. Refractivity-from-clutter Award Number, N0001412AF00002, conducted data collection in concert with the data collections described herein.

2. 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.

REFERENCES

1. Sprague, R. A., P. Babu, "RF Performance Prediction for Real Time Shipboard Applications", presented at the 2010 6.2 ONR Review, Monterey, CA, March 2010.

2. 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.

3. Delrieu, G., L. Hucke, J.D. Creutin, "Attenuation in Rain for X- and C- Band Weather Radar Systems: Sensitivity with respect to Drop Size Distribution," *Journal of Applied Meteorology*, Jan., 1999

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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.