STUDY OF PROPAGATION EFFECTS APPLICABLE TO L-BAND SHIP-EARTH STATIONS

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This review has two explicit objectives:

I. To review and assess propagation and superstructure blockage effects, including theory and measurement data, and determine specific areas for which the data are inadequate for L-band maritime communications.

II. To formulate a propagation measurement program that will provide additional data necessary for future maritime communications applications.

A measurement program takes time to implement, and additional time is required to incorporate the findings into a data base in a form useful for practical application. Therefore, the significance of a third, implicit, objective of the review must be stressed, i.e., the establishment of a working assumption model based on an existing data base, for use in applications in the immediate future.

To fulfill objective I, a propagation literature review was performed in three general areas:

a. modeling of the sea for microwave transmission applications,

b. theoretical studies of wave propagation over the sea, and

c. assessment of multipath fading data from various shipboard L-band experiments. In addition, the superstructure blocking effect was thoroughly investigated.

In terms of item (a), it was noted that communications engineers habitually view the sea intuitively, and hence their analyses characterize the sea in loosely defined terms. The steepness parameter β, which has been designated as the prime factor in the current empirical model, is ambiguous. The literature surveyed suggests that the β factor cannot be uniquely defined, even if a known sea state can be established. Further, the sea state classification is itself rather arbitrary.

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In terms of item (b), a classical problem remains: electromagnetic wave physicists must resolve the scattering properties of the waves incident upon a random rough surface. The key theoretical difficulty lies in the fact that, at L-band, the wave length is comparable to the roughness scale. Consequently, neither the perturbation approach nor the geometric optics approach is applicable.

Assessment of multipath fading data from various shipboard L-band experiments has proven to be the only reliable approach for obtaining a useful engineering model. More than a dozen data sets from INMARSAT, ESTEC, DFVLR, KDD, COMSAT, GEC-Marconi, FAA, NASA, CCIR, and other literature sources have been collected and reviewed. Based on the review, the following conclusions were reached:

a. Sufficient data exist for conventional narrow-beam antennas with gains of 10 dB or more, although most of the data consist of amplitude fading statistics gathered at moderate to high elevation angles.

b. Only limited data exist for low-gain (0 to 6 dB) antennas, in particular for the hemispheric-coverage unpointed antennas. Nevertheless, it has been possible to derive working assumptions for fade margins vs antenna gain and elevation angle for low-gain antenna configurations. These working assumptions should be refined as more data become available.

c. Data on superstructure effects are extremely scanty. The effects of superstructure blockage, and in particular the possible effects of superstructure reflections on the performance of low-gain broad-beam antennas, are important topics which require further study.

d. More data may be needed on the performance of polarization shaping and other fading reduction techniques, even for higher gain antennas.

e. Some uncertainty exists regarding the assessment of multipath fading during high sea states (5-m wave height or more). The limited data at hand suggest that under high sea state conditions the severity of multipath fading is independent of sea state; however, this deserves verification. In addition, direct wave blockage in high sea states at low elevation angles may further affect the multipath fading statistics. Measurements along these lines are definitely needed.

f. Among many existing theoretical models for L-band applications, the KDD model is regarded as the most promising. Further study is needed to develop it into a viable model for maritime application.

g. It would be most useful to correlate multipath fading measurements with direct measurements of sea state, e.g., by radar measurement.

These conclusions formed the basis for the work related to objective II. Since the superstructure blockage problem was judged to be the most significant, a measurement program was defined. Such a program would have three phases: analysis, experiment, and assessment. Physical optics methods could be used for the analysis phase. The experimental phase is aimed first at obtaining superstructure blockage data of a sufficiently general nature to establish an empirical model for application to shipboard obstruction configuration. An antenna-range measurement may be sufficient to obtain the data. The next goal would be to perform verification tests on selected ships to confirm and refine the empirical model. This could be accomplished by requesting that ships equipped with maritime communications terminals make several 360° turns at low elevation angles while recording L-band signal variations. In the assessment phase, the results of the analysis and experimental phases would be used to develop SES installation guidelines.

Another proposed measurement program is the Standard C ship earth station measurement program, which would use small shipboard antennas (0 to 6 dBi antenna gain) to collect propagation data under high sea state conditions. Such tests, performed under these extreme conditions, would provide further information on multipath fading, as well as assisting in the development of Standard C antenna specifications and installation guidelines.

It would be highly desirable if the measurement could surpass the baseline configuration of measuring only amplitude fading statistics at different elevation angles under various sea conditions. The next level of sophistication would be the incorporation of polarization shaping and BER tests. For polarization shaping, the adjustment and control procedures necessary to achieve optimum polarization under various fading configurations and using various fading reduction techniques will be the most important areas for investigation.

To fulfill the third requirement, working assumption models for fading amplitude statistics, worst-case specular reflections under smooth sea conditions, the multipath fading spectrum, fade duration, delay spread, and coherent bandwidth are proposed. The key element for the amplitude statistics model (assuming a Ricean probability distribution) is the C/M factor for various elevation angles and antenna gain configurations.

For the purpose of systems planning, it can be concluded that the 3-dB fading spectrum bandwidth is generally less than 1 Hz, while the 20-dB fading spectrum bandwidth is generally less than 10 Hz. The coherent bandwidth on the other hand, is believed to be significantly larger than the signaling bandwidths for current maritime allocations. However, the coherent bandwidth is probably much smaller than the 101.5-MHz frequency separation between the up- and down-link allocations.

A working assumption model for polarization shaping and fading reduction has yet to be derived. However, the KDD technique of fading reduction by polarization shaping demonstrates a definite advantage. Because existing data on polarization shaping are limited, more testing is required to demonstrate repeatable results and to provide a reliable estimate of performance improvement. An optimum methodology can conceivably be derived for fading reduction that involves a technique of polarization shaping control, together with other schemes such as FEC coding and/or multi-element antenna combinations. This can only be determined by a well-planned experiment.