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USER NEEDS FOR PROPAGATION DATA

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1. Introduction

New and refined models of radio signal propagation phenomena are needed to support studies of evolving satellite services and systems. Taking an engineering perspective, this paper reviews applications for propagation measurements and models in the context of various types of analyses that are of ongoing interest. Problems that have been encountered in the signal propagation aspects of these analyses are reviewed, and potential solutions to these problems are discussed.

The focus of this paper is on propagation measurements and models needed to support design and performance analyses of systems in the Mobile-Satellite Service (MSS) operating in the 1-3 GHz range.[1] These systems may use geostationary or non-geostationary satellites and Frequency Division Multiple Access (FDMA), Time Division Multiple Access Digital (TDMA), or Code Division Multiple Access (CDMA) techniques. Many of the propagation issues raised in relation to MSS are also pertinent to other services such as broadcasting-satellite (sound) at 2310-2360 MHz. In particular, services involving mobile terminals or terminals with low gain antennas are of concern.

2. Applications of Particular Concern

2.1 Form of Applied Propagation Factors

The engineering studies that require reliable predictions of signal propagation impairments include design and performance analyses that are described below. The analyses may be deterministic or use simulations, or may apply both simulation and deterministic techniques.[2] A deterministic approach is generally taken in cases where: baseband signal quality and availability are the dependent variables and simplicity is desired; initial estimates are sought; or accuracy sufficient for final results can be obtained. The more complex and costly simulation approach is taken when necessary for achieving the desired accuracy; performance in real time must be evaluated in detail; or it is desired to evaluate additional dependent variables such as loading on signaling channels. Consequently, suitable propagation models are needed for both analysis approaches.

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1 The 1992 World Administrative Radio Conference (WARC-92) allocated the following bands to MSS in North America and elsewhere: 1492-1559 MHz (space-to-Earth); 1610-1660.5 MHz (Earth-to-space); 1613.8-1626.5 MHz (space-to-Earth); 1675-1710 MHz (Earth-to-space); 1930-2010 MHz (Earth-to-space); 2120-2200 MHz (space-to-Earth); 2483.5-2520 MHz (space-to-Earth); and 2670-2690 MHz (Earth-to-space).

2 Deterministic analyses address propagation factors in the form of cumulative time distributions. Simulations encompass propagation factors using Markov or Finite State Models (FSM).

2.2 Design Analyses

In the process of designing new systems, channels, or networks, analyses may be conducted to: develop an initial set of system requirements or specifications; identify optimal tradeoffs among candidate system parameters; investigate "sizing and timing" requirements for various system elements; or establish theoretical compliance of a design with the applicable specifications . Signal propagation impairments can be very influential upon the results of these analyses. Initial specifications for channel performance must not be overly ambitious in order to prevent unnecessarily high implementation costs. Those costs would result from improperly motivated tradeoff decisions, and the tradeoff evaluation process could in itself be flawed through application of erroneous propagation factors. Additional costs can be incurred, unnecessarily, if sizing or speed requirements for hardware or software are over estimated. Theoretical verification of compliance with specifications is of little value if the system ultimately does not perform as desired or expected. Thus, errors committed in addressing propagation factors can have serious consequences in the system design process.

2.3 Performance Analyses

Apart from design processes, performance analyses are conducted to determine: achievable system capacity; signal quality or availability; permissible or acceptable levels of aggregate and individual interfering signals[3]; the potential for sharing frequencies among MSS systems and between the MSS and other services; and the design and operating constraints necessary to complete coordination of proposed frequency assignments (i.e., to prevent mutual interference). The propagation data used in these applications can have consequences that are as dire as those associated with the design process.

In deciding the potential merits of a proposed domestic MSS frequency allocation or commercial MSS system, the Federal Communications Commission (FCC) must determine whether granting an allocation or a license is in the public interest. This can involve consideration of performance analyses (i.e., the analysis results filed as part of a petition for allocations or license application as well as independent analyses that may corroborate or refute those analyses), particularly where several competing applications are filed or there may be impact on incumbent systems. For example, the FCC recently convened a "Negotiated Rule Making Committee" to develop recommended technical rules for use of proposed domestic MSS allocations at 1610-1626.5/2483.5-2500 MHz, in which one of the contentious issues was the temporal-spatial average level of fading on downlinks (ill-substantiated values near 2 dB were used). This factor, when applied to contemplated CDMA systems, directly affects the potential peak capacity of individual systems and several such systems, collectively. The results of these analyses were presented to the FCC with results of similar analyses for competing MSS TDMA/FDMA technologies, and these may be compared and used as the basis for forthcoming FCC technical rules and licensing decisions. Consequently, much is at stake for the companies proposing these technologies.

On both the national and international levels, propagation factors may greatly influence: the frequency allocations adopted for MSS; MSS design and operating standards; and the implementation of MSS systems on an interference-free basis. Several MSS systems are proposed for each of the MSS frequency bands, and these bands already are used by services other than MSS. Thus, in accommodating growth in MSS spectrum requirements through enactment and implementation of new allocations, important factors are the degree to which incumbent systems may be displaced and the amount of spectrum resource in a shared band that may ultimately be available to MSS systems.

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[3] "Permissible" levels of interference are developed by the ITU Bureau of Radiocommunications (formerly the CCIR) in order to support frequency sharing studies and to establish the minimum level of interference that must be accepted by all system operators. For the MSS, this process is still at an early stage.

2.4 Summary of Applications

Much more could be said about the nature and importance of various applications for propagation data. The critical point, however, is to recognize that the work of propagation experts is vital to MSS and other radiocommunication services -- the results of that work can greatly influence many decisions, including decisions affecting business, design, operations, standards, and policy. Moreover, by virtue of being of a statistical nature, and because there are numerous relevant independent variables involved, it appears implausible that one will ever be able to conclude that there is no need for additional propagation measurements and new or refined propagation models for MSS in the 1 - 3 GHz range.

3. Difficulties Encountered in Applying Measurements and Models

3.1 Overview

A substantial number of publications provide relevant measurements and models; however, there are certain deficiencies in these publications. These deficiencies fall into two categories: (1) the necessary propagation information appears to be available but important facets are not documented, and (2) the desired data or models simply are not available. In addition, based on first hand experience in applying propagation data (or models) and in reviewing how other engineers have applied these data, there are numerous ways to misapply the available information that must be blamed on the principle that "a little knowledge can be dangerous." The latter problem is best addressed to engineers who apply propagation data and models; however, be it known that documentation of propagation phenomena should strive to leave nothing to the imagination.

3.2 Inadequate Documentation

There is an engineering requirement for full descriptions of measurements and models that are suitable for use by engineers in design and analytical processes. Specifically, all significant independent variables must be addressed and dependent variables must be specified in a usable form. It is suspected that in cases where deficiencies arise in these areas, they are, more often than not, the result of limitations on funding, schedule, or scope, rather than simply poor quality of documentation.

As the pace of reporting of the results of MSS propagation measurements escalated in the mid 1980s, potentially useful data were available but key measurement or model parameters were missing. For example, although it would seem that the characteristics of the antennas and antenna installations used during measurements would have a significant bearing on results, quite often little or no information was supplied on these parameters. Thus, the opportunity to incorporate measured data in models was hampered insofar as antenna parameters are important independent variables. One effort that was made to eliminate such deficiencies was the establishment of a standard form for reporting the results of propagation measurements in CCIR Study Group 5. (Although the author contributed to the development of this form, he has not ascertained that the adopted form is comprehensive.)

In many cases, measurements or models are documented using undefined measurement calibrations or parameter reference points. The best (or worst) example of this problem may be cumulative time distributions of fading, where fading levels are specified relative to "line of sight" (LOS) or a mean measured value. What is line of sight? Engineering studies must deal with absolute total levels of transmission loss, and so, fading relative to mean or LOS values can be applied only if the relationships between those values and transmission loss are known. (Of course, to allow for different path lengths, fading could perhaps be specified relative to free space loss.)

3.3 Inadequate Measurements/Models

It is the authors opinion that insufficient propagation measurements and models are available to support evaluation of the following phenomena:

- Spatial availability throughout a satellite service area - to support more comprehensive specification and analysis of performance objectives (i.e., signal quality, temporal availability, and spatial availability).

- Time diversity - the "gain" (dB) or "advantage" (probability) stemming from use of forward error correction, interleaving, and TDMA, as well as the performance of system control and error-mitigating network protocols.

- Spatial diversity - the diversity "gain" or "advantage" stemming from use of two antennas on the mobile earth station under various switching or combining approaches.

- Angle diversity - the diversity "gain" or "advantage" stemming from use of two satellites to serve the same mobile earth station under various switching or combining approaches..

- Correlation of signals on different paths - to support of studies of interference within and among MSS systems, and between transmissions in the MSS and other services (similar to angle diversity).

- Depolarization - to support studies of isolation between orthogonally polarized transmissions, to guide antenna design, and to enable analyses of various multipath and interference cancellation techniques.

4. Potential Solutions to Deficiencies

The following points are raised as tentative conclusions of this paper and, specifically, as solutions to the perceived deficiencies in available propagation information.

- Deficiencies can be mitigated through joint design of models by applications-engineers and propagation specialists.

- More funding is needed to support propagation measurements, modeling, and documentation.

- Private industry should contribute much of the necessary funds, insofar as it stands to save considerable money through these efforts and to accrue great profits.

- In order to avoid duplication of effort and to converge on defined goals, measurement efforts should be coordinated and centrally organized to the extent practical.

- The above could be accomplished in a joint NASA-industry program, using NAPEX as the forum for discussing the approach and reporting results.

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Tentative Conclusions of Paper

- New/Refined Mesurements and Models are Needed
- Engineering Applications Must Be Considered
- There Are Deficiencies in Available Data
  - Inadequate Reporting
  - Missing Measurements and Models
- Deficiencies Can Be Avoided
- A Renewed Program of MSS Measurements and Modeling Can Be Established