WIDEBAND HF NOISE/INTERFERENCE MODELING
PART I: FIRST-ORDER STATISTICS

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This report discusses the development of a wideband HF noise/interference model. The model is based on measured data and is suitable for implementation in a wideband HF channel simulator. The measured data are described and analyses performed on the data are discussed. Then the proposed noise/interference model is presented. Example results from the model are compared with measured data, and aspects of the model development which require further investigation are discussed.

Key words: channel simulator; noise/interference; wideband HF

1. INTRODUCTION

1.1 Background

There is currently widespread interest in HF communications over large bandwidths (on the order of 1 MHz or more), motivated by the application of spread spectrum technology to HF systems. The advantages of spread spectrum technology for communication systems are well known (Dixon, 1984), and include low-probability-of-intercept (LPI) communications, noise/interference rejection, and simultaneous operation of several transmitters in the same frequency band (code division multiple access). These advantages, which depend on the process gain inherent in spread spectrum systems, require use of the widest possible rf bandwidth.

On the other hand, there exist many uncertainties concerning the performance of HF systems over wide bandwidths. Channel simulation enables one to evaluate the performance of communication equipments without the cost of building hardware and running extensive field tests. Other advantages of channel simulation include accuracy, repeatability, stationarity, availability, and parameter variation (Hoffmeyer and Vogler, 1987). However,

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the design and implementation of a channel simulator requires a channel model which accurately describes the real-world conditions encountered on communication links.

Motivated by the possibility of constructing a wideband HF channel simulator, an investigation of channel models that represent the HF channel was conducted (Hoffmeyer and Nesenbergs, 1987). One conclusion of the study was that no validated channel model which accurately describes the wideband HF channel had been developed.

As a result, the Institute for Telecommunication Sciences has undertaken the development of a wideband HF channel model. The objective of the modeling effort is to develop a mathematical model of the HF channel which is accurate over wide bandwidths (on the order of 1 MHz or more), which can be validated with measured data, and which is suitable for implementation (in software and hardware) in a wideband HF channel simulator. The model is to include wideband HF noise and interference, as well as a model of the channel transfer function, describing the characteristics of ionospheric sky-wave propagation.

The wideband propagation model which has been developed has been discussed in detail elsewhere (Vogler et al., 1988; Vogler and Hoffmeyer, 1988 and 1990). The purpose of this report is to discuss the development of a wideband HF noise/interference model.

1.2 Objectives

The noise/interference model presented in this report differs in one important respect from previously developed models. In past developments noise/interference models have consisted of descriptions of the statistical characteristics of the received noise/interference at the output of a narrowband receiver. From this point of view noise/interference processes can be classified as Class A or Class B, depending on whether the bandwidth of the process is less than (Class A) or greater than (Class B) the bandwidth of the receiver front end. Numerous models have been developed for Class A and Class B processes, and can be grouped into two general categories: empirical models, which are designed to fit certain measured statistics of the noise/interference, and physical models, which attempt to take into account the physics of the noise/interference processes themselves. Summaries of existing noise/interference models have been provided by

Spaulding (1977 and 1982), Hall (1966), Giordano (1970), Ibukun (1966), and Spaulding and Middleton (1975). Such models are useful for the theoretical determination of communication system performance and for the design of systems with optimum performance in the real world noise/interference environment.

This is not the objective of the present work, however. Instead, what is required is a model which can be used to simulate the noise/interference over wide bandwidths in the propagation channel, rather than describing statistical characteristics of the noise/interference. Thus, the objective of the present work is to obtain a model of the noise/interference processes themselves.

It is necessary that such a model have the attributes of simplicity and flexibility, and that the model incorporate as many physical ideas as possible. The need for simplicity and flexibility seems obvious, because it is intended to implement the model in a noise/interference simulator with the capability to simulate any environment which could conceivably be encountered on HF communications links. However, the development and verification of any such model must be based on measured data, which is necessarily of limited scope. For example, the model discussed in this report is based on data obtained in Bedford, MA during March, 1989, whereas the model should have the capability to describe other environments as well. If the parameters of the model relate to the physical circumstances causing the noise/interference, it is possible to ascertain how to vary those parameters in order to describe environments other than those upon which the model development is based. To have this kind of predictive capability, the model must therefore be a physical model, as opposed to an empirical model which simply attempts to fit certain measured statistics of the noise/interference, and whose parameters do not relate to the physics of the noise/interference processes.

1.3 Scope

The model development discussed in this report has primarily involved generating probability distribution functions that describe various statistical characteristics of measured noise/interference and developing a model which exhibits those same characteristics. Clearly, many such characteristics could be examined. For example, noise models often specify distributions of the received instantaneous voltage, amplitude, phase, and the average level crossing rate of the noise envelope. Other quantities of interest include power spectra and distributions of power in the frequency domain (spectral occupancy).

These quantities are useful for characterizing the time-averaged behavior of the noise/interference. However, a complete description of the noise/interference process requires higher-order statistics as well. These statistics are necessary to specify the relationships between the noise/interference process at different instants in time. For example, given the average number of level crossings of the noise envelope per unit time, higher-order statistics are required to describe how the envelope crossings are distributed in time (pulse width and pulse spacing distributions). In addition, measured noise/interference is decidedly nonstationary, and knowledge of the time scales over which the characteristics of the noise/interference vary is necessary for a complete specification of the noise/interference process.

In this report, attention is restricted to the first-order statistics of the noise/interference. Investigation of higher-order statistics, including pulse width and pulse spacing distributions, as well as nonstationarity time scales, has been reserved for future work.