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Development of a Multilayer Interference Simulation Program for MSS Systems

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ABSTRACT

This paper discusses the development of a multilayer interference analysis and simulation program which is used to evaluate interference between non-geostationary and geostationary satellites. In addition to evaluating interference, this program can be used in the development of sharing criteria and coordination among various Mobile Satellite Services(MSS)systems. A C++/Windows implementation of this program, called Globalstar Interference Simulation Program (GISP), has been developed and will be demonstrated in the conference.

INTRODUCTION

Since the relative position and pointing of the Geo-Stationary Orbit(GSO) and Low Earth Orbit(LEO) satellites constantly change, the parameters affecting interference also change with time and satellite positioning. With these changing parameters, the interference situation cannot be evaluated fully using conventional techniques of interference analysis. To gain better understanding of the interference situation and to develop sharing criteria, this multilayer interference analysis and simulation program was developed.

In order to help visualize the complex interference environment of MSS systems, we use the analogy of utilization of a single spectrum analyzer to view the interference signals. This spectrum analyzer can be connected to a terminal of either a victim satellite or a victim user antenna.

INTERFERENCE TO A SATELLITE

The total interference signal received by a victim satellite antenna terminal measured by the fictitious spectrum analyzer can be represented by the following summations.

$$P_{i,k}(t,f) = \sum_{j=1}^{N_s(t)} \sum_{p=1}^{N_{b_j}}$$

$$\frac{G_{i,k}(\theta_{ij}(t),\varphi_{ij}(t))G_{j,p}(\theta_{ji}(t),\varphi_{ji}(t))Po_{j,p}}{L_{i,j}(t)}$$

$$+ \sum_{j=1}^{N_u(t)} \frac{G_j(\theta_{ji}(t),\varphi_{ji}(t))G_{i,k}(\theta_{ij}(t),\varphi_{ij}(t))Po_j}{L_{i,j}(t)}$$

Where

- $P_{i,k}(t,f)$ is the total power spectral density at the terminal of kth antenna beam of victim satellite i, at time t and frequency f. It is measured in dBW/Hz.

- $N_s(t)$ is the number of interfering satellites visible to victim satellite i at time t.

- N_{b_j} is the number of multiple beams of interfering satellite j.

- $G_{i,k}(\theta_{ij}(t),\varphi_{ij}(t))$ is the gain of the kth antenna beam of victim satellite i at the angle $\theta_{ij}(t)$ and $\varphi_{ij}(t)$, and $\theta_{ij}(t)$ and $\varphi_{ij}(t)$ are the corresponding victim satellite i's local spherical coordinate angles towards interfering satellite j at the time instant t.

- $G_{j,p}(\theta_{ji}(t),\varphi_{ji}(t))$ is the gain of the pth antenna beam of interfering satellite j at the angle $\theta_{ji}(t)$ and $\varphi_{ji}(t)$, and $\theta_{ji}(t)$ and $\varphi_{ji}(t)$ are the corresponding interfering satellite j's local spherical coordinate angles towards victim satellite i at the time instant t.

- Po_{jp} is the power spectral density into the terminal of the pth antenna beam of interfering satellite j.

- $L_{i,j}(t)$ is the path loss between victim satellite i and interfering satellite j at time t.

In the second summation,

- $N_u(t)$ is the number of interfering mobile user units visible to victim satellite i at time t.

- $G_{i,k}(\theta_{ij}(t),\varphi_{ij}(t))$ is the gain of the kth antenna beam of victim satellite i at the angle $\theta_{ij}(t)$ and $\varphi_{ij}(t)$, and $\theta_{ij}(t)$ and $\varphi_{ij}(t)$ are the corresponding victim satellite i's local spherical coordinate angles towards interfering user unit j at the time instant t.

- $G_j(\theta_{ji}(t),\varphi_{ji}(t))$ is the gain of the antenna beam of interfering mobile user j at the angle $\theta_{ji}(t)$ and $\varphi_{ji}(t)$, and $\theta_{ji}(t)$ and $\varphi_{ji}(t)$ are the corresponding interfering user j's local spherical coordinate angles towards victim satellite i at the time instant t.

- Po_j is the power spectral density into the terminal of the antenna beam of interfering mobil unit j.

- $L_{i,j}(t)$ is the path loss between victim satellite i and interfering mobile user unit j at time t.

In the above formula, the first summation corresponds to the interference from all other satellites, whereas the second summation corresponds to interference from all ground based mobile user units.

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INTERFERENCE TO A MOBILE UNIT

There are essentially two types of interference to a mobile user unit; the interference from all satellites who transmit in the same band as the user receiver, and other mobile users. This program currently simulates the first kind and the future plans include the implementation of second kind. To measure the total satellite interference to a mobile user unit, the fictitious spectrum analyzer is connected to terminal of antenna of the victim mobile user unit. The interference that the spectrum analyzer measures can be represented by the following formula.

$$P_j(t,f) = \sum_{i=1}^{N_s(t)} \sum_{k=1}^{N_{b_i}} \frac{G_{i,k}(\theta_{ij}(t),\varphi_{ij}(t))G_j(\theta_{ji}(t),\varphi_{ji}(t))Po_{i,k}}{L_{i,j}(t)}$$

Where

- $P_j(t,f)$ is the total power spectral density at the terminal of antenna of victim user j at time t and frequency f. It is measured in dBW/Hz.

- $N_s(t)$ is the number of interfering satellites visible to victim mobile user unit j at time t.

- N_{b_i} is the number of multiple beams of interfering satellite i.

- $G_{i,k}(\theta_{ij}(t),\varphi_{ij}(t))$ is the gain of the kth antenna beam of interfering satellite i at the angle $\theta_{ij}(t)$ and $\varphi_{ij}(t)$, and $\theta_{ij}(t)$ and $\varphi_{ij}(t)$ are the corresponding interfering satellites i's local spherical coordinate angles towards victim mobile user j at the time instant t.

- $G_j(\theta_{ji}(t),\varphi_{ji}(t))$ is the gain of antenna beam of victim mobile user j at the angle $\theta_{ji}(t)$ and $\varphi_{ji}(t)$, and $\theta_{ji}(t)$ and $\varphi_{ji}(t)$ are the corresponding victim mobile user j's local spherical coordinate angles towards interfering satellite i at the time instant t.

- Po_{ik} is the power spectral density into the terminal of the kth antenna beam of interfering satellite i.

- $L_{i,j}(t)$ is the path loss between victim user unit j and interfering satellite i at time t.

MULTILAYER MODELING OF INTERFERENCE

A systematic approach to partition the complex interference situation among multiple MSS satellite systems (both GSO and non-GSO) is to develop a multilayer interference model such that a computer analysis and simulation program can be developed around each layer. The formulas just presented are at the heart of GISP. In the following sections, major layers of the program are discussed.

GEOMETRIC LAYER

Since the relative position and pointing of GSO and LEO satellites constantly change, it is necessary to develop some

common reference systems for all satellite systems such that all satellites and user terminals can have a specific coordinate with respect to the same reference point. In this layer, the center of the earth has been identified as the center of this reference system as shown in Figure 1. Each interference source (i.e., a transmitter) and victim (i.e., a receiver) is identified by its own coordinate with respect to the center of the earth. The z-axis of the local coordinate system of a satellite or a user positioned at any point is defined as the vector from this particular point to the center of the earth. The y axis is defined in the negative direction of the normal to the plane of the orbit. A right hand coordinate system dictates that the x axis be in the plane of the satellite velocity .

The main purpose of this geometric layer is to determine whether an interference source is visible by the victim or otherwise shadowed by earth. Further processing is carried out to determine the level of interference if and only if the victim is in the line of sight of the interferer. Scattering reflection and refraction effects are considered secondary effects and are not included in the program at this stage. Major parameters to be input into this geometric layer include:satellite altitude, inclination angle, orbit phasing, orbit location or sub-satellite point (for GSO), orbit eccentricity, apogee and perigee, and others.

The computer program simulates orbits and constellations of different GSO or LEO systems, calculates the relative positions of each point (either an interference source or victim) and determines whether two points (i.e.

source and victim) are in line-of-sight or are blocked by the earth at any time of the simulation period.

ANTENNA LAYER

Once the line-of-sight between the interferer and the victim is established, the interaction between the source antenna and the victim antenna has to be modeled. Figure 2 illustrates the interaction among a single interference source and multiple victims. At this point, the local coordinate system of the satellite or user is defined and the pattern angle s θ and φ are calculated relative to these local coordinate systems. These angles are then used to determine the antenna gain levels of interferer toward the victim and the antenna gain of victim toward the interfering source. The relative distance and spatial loss between the source and victim is calculated by the geometric layer processor of the program. Thus the relative gain between the source and victim along the line-of-sight direction can be determined.

MOBILE USER UNITS

For simplicity, a uniform model of user distribution is used in this program. The earth is divided into cell regions bounded by certain latitudes and longitudes. Several mobile user units are then lumped at the center of each cell. This includes users of various MSS systems. In the uniform distribution model, it is assumed that users of different MSS systems are distributed evenly and uniformly over the same geographic area. This situation is illustrated in Figure 3.

By combining the traffic distribution profile of a MSS satellite system and the user distribution, interference between users and satellites, and between satellite and satellite can be simulated for a long period of time. To reduce the complexity of the problem, user-to-user interference is not currently considered.

PROGRAM OUTPUT

The program "measures" the total interference Power Spectral Density (PSD) at the terminal of the victim's antenna. The scope of the spectram analyzer is displayed graphically by the prgram. As the program steps in time, the location of the victim is also displayed graphically on a flat earth. The interference power information and orbital dynamics information are captured into separate files for further analysis. This information can be examined directly from the program or from any text editor.

To make the program output more comprehensive, several data reduction and statistical programs were developed. The results of the statistical analysis is also captured into a file that can be accessed from the program. The statistical and power spectral density information can be used to estimate the aggregate Io and its impact on operation of various MSS systems. $Eb/(No + Io)$ for any scenarios and any MSS system can be calculated to evaluate the system operation and link integrity and circuit capacity. Furthermore, the information provided by GISP can be used to allocate expected interference noise from different MSS systems, and thus establish a criteria for frequency sharing among various MSS systems.
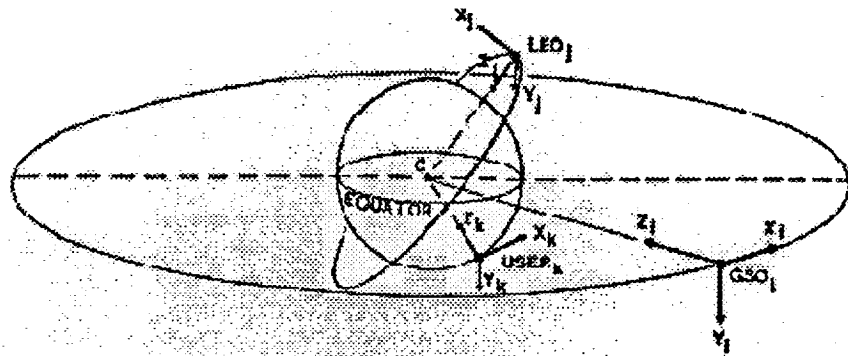
Figure 1. Illustration of various coordinate systems

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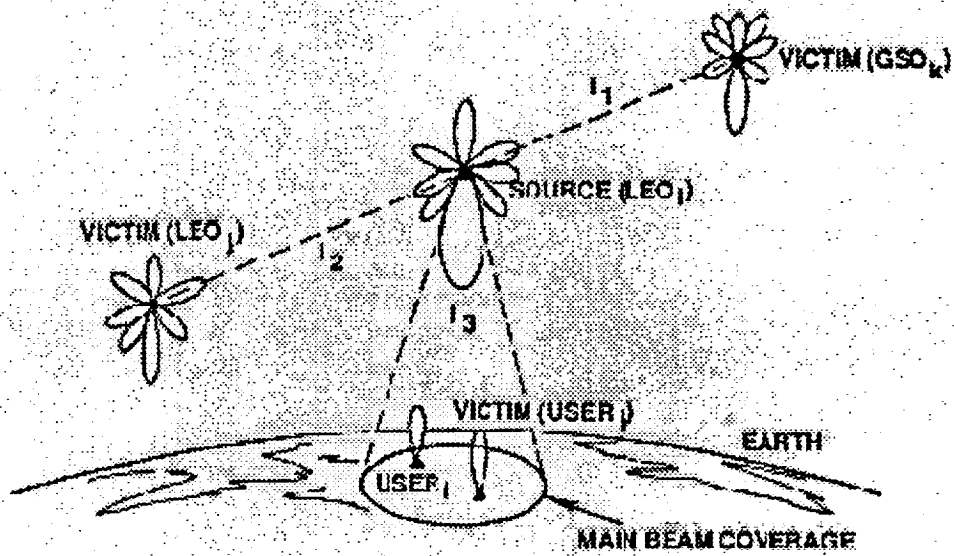
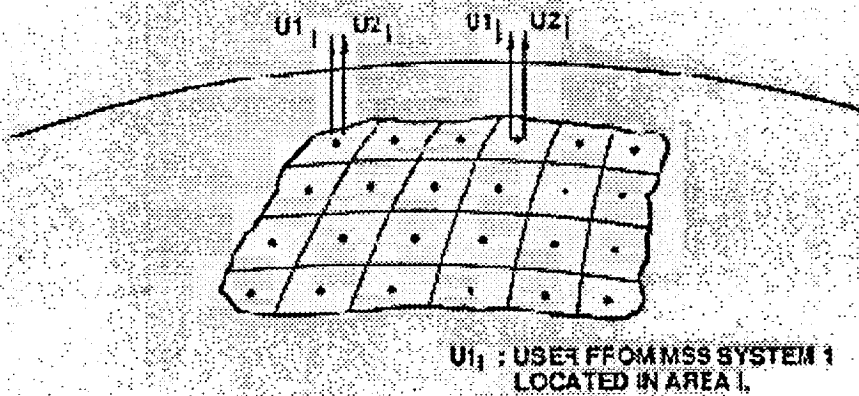Figure 2. Interference among various satellites

UI_i : USER FROM MSS SYSTEM 1
LOCATED IN AREA I.

Figure 3. Illustration of user distribution cells