

A SATELLITE LINK ANALYSIS TOOL
FOR A PORTABLE GROUND STATION

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The product of this research effort is a comprehensive and integrated software package for the analysis of digital satellite links. The system is designed to run on the IBM PC, and would be a useful addition to any portable ground station based on a compatible personal computer.

The system performs three basic classes of functions: satellite orbital analysis, antenna gain pattern plotting, and link analysis. The first class of functions includes the computation of such quantities as velocity, orbital period, and coverage area for satellites in circular and elliptical orbits. The second class of functions is concerned with plotting the gain patterns for horns, helixes, parabolic reflectors, and phased arrays of dipoles. The last class of functions represents the major thrust of the system, and entails computing such items as the G/T figure of merit, received useful power, carrier-to-noise ratio, bit error rate, maximum data rate, and power margin. Inherent within this class are mathematical models for computing the attenuation due to rainfall and atmospheric absorption.

The link budget itself appears as a color-coded display with two columns: one for the uplink path, and one for the downlink path. The user also has the capability to change certain key inputs, and then have the system automatically recompute the entire link budget with the modified data.

INTRODUCTION

The satellite communication path itself can best be described as the total transmission path from the first ground station transmitter, through the channel, to the receiver at the second ground station. This includes all the modulators, transmitters, receivers, demodulators, and antennas both on the ground and onboard the satellite. The channel is the total electromagnetic path connecting a given transmitter-receiver pair, and includes atmosphere as well as free space.

Since most communications satellites perform a frequency translation from uplink downlink, the block diagram in Fig. 1 shows only one half of the path for a full satellite link. This figure can represent either the uplink or the downlink for the purposes of understanding the system description.

In a typical satellite link, the received signal may degrade in one of two ways: through a loss in desired waveform power, or through the addition of noise to the signal. Losses occur when a portion of the signal is diverted or reflected from its intended route, or is attenuated along its intended route. Noise arises from unwanted signal energy being injected into the link, or from thermal noise generated within the link. In a typical link, free space propagation loss accounts for the single largest loss in signal power. Prominent sources of noise include the internal noise of receiver amplifiers and feed lines, as well as the noise introduced by the receiving antennas.

One of the most important tools available to the satellite communications engineer is link budget analysis. A system link budget is essentially a balance sheet of gains and losses. It is comprised of a detailed listing of transmission and reception sources, noise sources, and signal attenuators as measured along the entirety of the link. Many of the items appearing in the link budget are derived from the calculation of received useful power. Link budget analysis is basically an estimation technique for evaluating communications system performance. Link budgets are especially useful for predicting system performance under established constraints, and for experimenting with various system design tradeoffs (Ref. 1,2).

Because portable ground stations are typically set up in trailers or other small structures, size and power constraints may be considerable. In fact, these constraints may well prohibit any processing capability beyond that of a personal computer. Therefore it is the purpose of this research effort to develop a comprehensive set of software

routines for performing link budget analysis, and to integrate them into a transportable package for use on a personal computer. This software in effect turns a personal computer into a dedicated satellite link analysis workstation.

Assumptions

It is assumed that the user has at least a cursory knowledge of digital satellite communications, and is familiar with link budgets. No particular knowledge of the software is required to successfully run it, since it is entirely menu driven.

The host computer must be an IBM PC or equivalent compatible with at least one floppy disk drive. A dot matrix printer is also suggested for obtaining a hardcopy of plots or other displays. The system disk contains 63 kilobytes of object code, plus an additional 2 kilobytes of system overhead software. Since DOS requires an additional 27 kilobytes, it is recommended that the host computer be equipped with at least 128 kilobytes of memory. Also, the displays will only be readable on a color monitor.

Several other technical assumptions are made regarding the link:

1. All noise is thermal additive white gaussian noise, with a flat power spectral density for all frequencies of interest.
2. The noise bandwidth is taken to be equal to the transmission bandwidth.
3. The mathematical models for computing atmospheric and rain attenuation take into account only absorptive losses.
4. No provision is made for error-correcting codes.
5. Pulse shaping techniques are not taken into account, so information transmission is subject to the constraints dictated by the Shannon/Nyquist criteria.
6. The complications of satellite-to-satellite crosslinks and multiple-point accesses are not considered.

SYSTEM DESCRIPTION

The behavior of a satellite link is best understood by analyzing each of its components. Here the term "component" is taken to mean a source of gain, loss, or noise. Each component therefore belongs to one of three sections of the link: the transmitter, channel, or receiver.

System Components

The transmitter section consists of a microwave

transmitter and an antenna, with some type of cable or waveguide between the two. The circuit losses include the effects due to both the lossy line and imperfectly matched couplings. The efficiency of the antenna takes into account the losses due to reradiation, scattering, and spillover.

The channel section consists of free-space path losses, atmospheric losses, and rainfall losses. Path loss is due to the decrease in electric field strength with distance, and is unavoidable. Atmospheric losses are due to absorption of the signal by atmospheric oxygen and water vapor. Rainfall losses are due to the attenuation of the signal by rain in the uplink and/or downlink paths. The effects of atmospheric and rainfall losses can be minimized by an appropriate choice of frequency (Ref. 3).

The receiver section consists of the receiving antenna, a low-noise receiver, and some type of coupling between the two. This side of the link is similar to the transmitter side, with some additional complications. The receiving antenna now contributes to system noise via the antenna noise temperature. Sources of antenna noise include galactic noise, man-made noise, as well as atmospheric and rainfall absorptive losses. Internal receiver noise is also a prominent source of system noise (Ref. 4).

Software Description

The software is best described by discussing the users' view of the menus and the functions of the salient items in the menus. Once the software package is activated, the main menu appears (Fig. 2). From this menu, the user may select from 11 different program options.

Menu item 1, 'Satellite Orbital Parameters,' contains a submenu which permits the user to choose from computing escape velocity, satellite steady-state temperature, functional parameters for circular and elliptical orbits (such as velocity, period, and coverage area), or azimuth and elevation angles.

Menu item 2, 'Antenna Gain Patterns,' contains a submenu from which the user may choose to plot the gain patterns of horn, helical, parabolic reflector, or phased dipole array antennas.

Menu item 3, 'Link Analysis,' is used to perform link budget analysis, and represents the primary thrust of the entire program. The user is guided step-by-step through every calculation, and intermediate results are displayed along the way. Some of the items computed include antenna gains and beamwidths, effective isotropic radiated power,

atmospheric and rain attenuation, received useful power, G/T figure of merit, carrier-to-noise ratio, maximum data rate bit error rate, and link margin.

Of particular interest are the mathematical models for determining atmospheric and rainfall attenuation. Both models are principally concerned with estimating certain frequency-dependent quantities. This was accomplished by first plotting tabular data on the attenuation parameter of interest, and dividing the resultant curve into regions which were roughly monotonic. Quantitative data relationships were then developed by fitting various polynomials with known equations to each region of the curve. Once the proper polynomials were found, a program module was written to implement that piece of the model.

The final link budget can then be displayed by selecting menu item 4, 'Display Link Budget.' The link budget itself appears as a color-coded display with two columns: one for the uplink path and one for the downlink path. Situations which could adversely affect link closure, such as excessive data rate or negative link margin, are highlighted by flashing the appropriate display value.

Menu item 5, 'Recompute Link Budget,' allows the user to recompute all of the previous link calculations with new values of frequency, antenna design, transmitter power, receiver noise figure, bit error rate, or data rate. It also permits the user to perform the reverse process of computing bit error rate given the data rate.

The remaining menu items are concerned with database management. The user may store recently computed link budgets for subsequent review, recall previously computed link budgets, delete unwanted ones, list all currently stored link budgets, delete unwanted ones, change the default data disk drive, or exit to DOS (Ref. 5).

SUMMARY

The resultant end product of this research effort is a comprehensive, integrated, and transportable software package for the analysis of digital satellite links. While the primary objective of this software package is link budget analysis, the package also includes routines for computing satellite orbital parameters, as well as plotting antenna gain patterns.

System portability to other MS-DOS machines is facilitated by a removable graphics driver. Expandability is straightforward because each new function to be added is first written as a separate module and tested

independently. Once debugged, it may be included for compilation in the main program. In addition, the problem of tracing perceived errors is mitigated by the display of intermediate results following each major calculation.

The man-machine interface is designed to maximize the user's efficiency as well as to minimize confusion. Menus are used extensively to guide the user through the program, and the use of prompting and input validity checking insure the accuracy of all data entries. In addition, color displays are used to present the data in an organized, easy-to-read format.

This software package is currently being upgraded to take into account cloud and radome attenuation, atmospheric defocusing, frequency-selective fading, tropospheric scintillation, as well as modeling of antenna noise temperature.

This product should be a useful addition to any communication engineer's software library. In particular, because of its transportability and ease of use, it is ideally suited for use in a portable satellite ground station.

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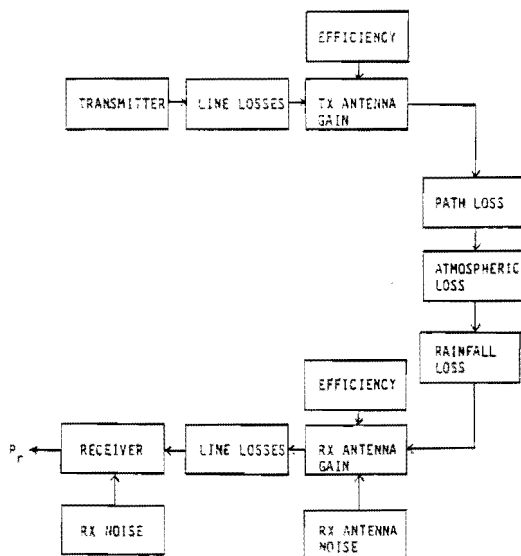


Fig. 1 Major Components of a Typical Satellite Link

MAIN MENU

1. Satellite Orbital Parameters
2. Antenna Gain Patterns
3. Link Analysis
4. Display Link Budget
5. Recompute Link Budget
6. Store Link File
7. Recall Link File
8. Delete Link File
9. List Link File Directory
10. Change Default Drive
11. EXIT

Fig. 2 Main Menu Display

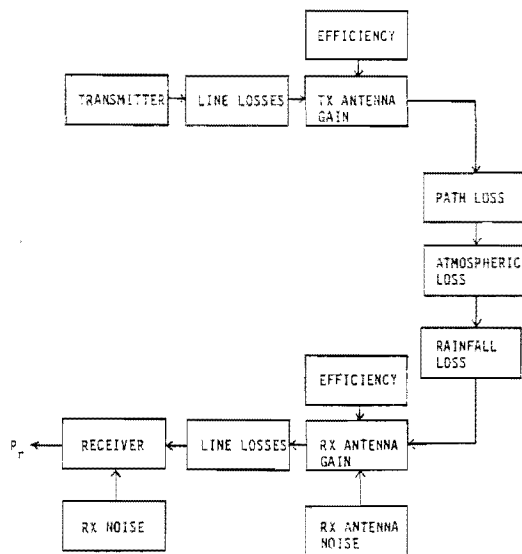


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