CableLabs®

Digital Transmission Characterization of Cable Television Systems

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DISCLAIMER

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TABLES

ACRONYMS

ADC	Analog-to-Digital Conversion
ASCII	American Standard Code for Information Interchange
CDF	Cumulative Distribution Function
CNR	Carrier-to-Noise Ratio
CTB	Composite Triple Beats
DFT	Discrete Fourier Transform
FM	Frequency Modulation
FT	Fourier Transform
GPIB	General Purpose Interface Board
IDFT	Inverse Discrete Fourier Transform
IF	Intermediate Frequency
IFT	Inverse Fourier Transform
MS-DOS	Microsoft Disk Operating System
NTSC	National Television Standard Committee
PDF	Probability Distribution Function
RF	Radio Frequency
TDR	Time Domain Reflection

SYMBOLS

dB	Decibel
dBm	Decibel milliwatt
dBmV	Decibel millivolt

f_s	Sampling frequency for converting analog signal to digital
GHz	Giga Hertz
$h_d[n]$	Ideal impulse response of the channel
$h[n]$	non-ideal impulse response of channel using spectral shaping windows
n	Time index for discrete signals
k	Frequency index for discrete signals
kHz	Kilohertz
L	Window length for median filters
MHz	Megahertz
N	Number of points for a discrete Fourier transform pair
r	Integer for selecting a period of periodic signals (r =0,1,2,...)
t	Time symbol for analog signals
T_s	Sampling period for converting analog signal to digital
$w[n]$	Time domain response of spectral shaping window
$W(e^{j\omega})$	Frequency domain response of spectral shaping window
$x(t)$	Continuous time domain signal
$x[n]$	Discrete time domain signal
$x_{ap}[n]$	Aperiodic discrete time domain signal
$x_p[n]$	Periodic discrete time domain signal
$X_p[k]$	Periodic discrete Fourier series
$X_{ap}[k]$	Discrete Fourier transform for discrete time domain signals
$X(\Omega)$	Fourier transform for continuous time domain signals
$X(e^{j\omega})$	Fourier transform for discrete time domain signals

π	Transcendental constant $\cong$ 3.1415926...
ω	Continuous frequency for discrete time domain signals
Ω	Continuous frequency for continuous time domain signals

Digital Transmission Characterization of Cable Television Systems

Abstract

Cable Television Laboratories (CableLabs®) has performed an evaluation of cable channel characteristics to statistically quantify the cable environment for high-speed, band-limited transmission of digital information in a study conducted in cooperation with several of our member cable system operators. Approximately three hundred subscriber home sites in twenty cable systems were measured and analyzed over a wide range of channel frequencies.

The range of channel characteristics, degree of impairments, and relative frequency of occurrence in a statistical distribution of both the cable plant and the subscriber home wiring is presented. These results provide the purveyors of digital cable modem equipment with valuable design information that can be used to determine the receiver interference mitigation techniques required, the complexity and performance characteristics of a demodulator design, and the relative percentage of cable subscribers who can satisfactorily receive a digital transmission using a specific demodulator implementation.

Various measurements of relevant channel characteristics provide useful information needed for both cost and performance optimization of the digital demodulator, as well as the cable system transmission equipment.

1. INTRODUCTION

The range of channel characteristics, degree of impairments, and relative frequency of occurrence of several impairments in a statistical distribution of both the cable plant and the subscriber home wiring are needed to determine the receiver interference mitigation techniques required, the complexity and performance characteristics of a demodulator design, and the relative percentage of cable subscribers who can satisfactorily receive a digital transmission using a specific demodulator implementation. Thermal noise level, carrier power level, channel frequency response (or, alternatively, impulse response), and interference due to ingress characterized by a statistical distribution of stationary disturbances in the cable environment provide useful information needed for both cost and performance optimization of the digital demodulator, as well as the cable system transmission equipment.

For a communication system designer, prior knowledge of the propagation characteristics of a signal through the transmission medium is beneficial in reducing cost, development time, and hardware complexity. This study provides basic channel characteristics that can be utilized to determine the capability of existing cable systems to carry digital signals in various modulation formats. The results of cable channel measurements show that the most severe problems are encountered in the subscriber home. For example, a comparison of the channel response at the tap with the channel response at the home outlet demonstrates this difference.

CableLabs has completed a digital channel characterization project that quantifies these stationary impairments on a multiplicity of cable systems across the U.S. and Canada. A number of geographically separated cable systems of varying size, age, and technology were investigated. Within each cable system, multiple distribution tap and home locations on as diverse a set of system branches as possible were measured. These data are available to provide the purveyors of digital cable modem equipment with valuable design information.

The digital transmission characterization project conducted field measurements of both cable television transmission channel and subscriber home distribution characteristics. The field measurements were performed using computer-automated instrumentation installed in a vehicle configured into a self-powered mobile laboratory. The data acquired at each location within each cable system were compiled into a database for generation of a statistical distribution of cable plant and subscriber home wiring transmission characteristics including frequency response, shielding effectiveness, ingress, thermal noise level, carrier power level, time domain reflection response, and composite triple beat intermodulation distortion level. These measured data can be linked to a description of relevant cable system design parameters obtained and catalogued for each cable system prior to measurement.

These measurements were performed in unoccupied bandwidth provided by each cable system tested. Up to 100 MHz of unused spectrum above the last active cable channel was considered if available. This is the most likely spectrum where new downstream digital signals will transmit high-speed data for digital video, digital audio, and other services.

The requirements for transmission of digital signals differ significantly from those for their analog counterparts. For example, analog signals tolerate phase noise far more than digital signals, while forward error corrected digital signals are totally immune to noise above threshold rather than exhibiting continuously degraded reception in analog signals. Thus, virtually error-free transmission is possible with a digital system.

This report describes in detail the various steps taken in accomplishing the digital transmission characterization project. In Section 2, complete descriptions of each measurement, instruments used for measuring, and initial set-up procedures are given. Section 3 covers preliminary analysis of measurement data, as well as utilization of various signal processing algorithms to extract useful parameters. Section 4 contains a statistical analysis of the measurement data in the form of histograms and cumulative histograms. A review of some important signal processing algorithms used to analyze the measurement data is given in A.1. A.2 contains the digital transmission characterization test procedure manual, describing the steps required to perform individual measurements at each cable site. Appendices B through U present complete results for the individual cable systems tested.

2. MEASURING CABLE SYSTEM CHARACTERISTICS

Numerous measurements were performed to characterize a cable subscriber receiving site, giving a comprehensive knowledge of signal transmission characteristics at that location in the cable system. Due to the variations in sizes and available frequency spectrum for testing from one cable system to another, a flexible testing procedure was needed. This task was accomplished by designing a menu-driven software instrument control program that reads cable system parameters for the measurement procedures from an input script file. The script files are in editable American Standard Code for Information Interchange (ASCII) format that can be easily modified for a given test. Measurement data files are stored in binary format with an additional ASCII header for later conversion to appropriate absolute measurements. Binary transfer and storage is used for efficiency and ease of detection of instrument transmission errors.

The following sections describe the procedures used in measuring cable system impairments. A brief description of the architecture of the cable networks is given. Instruments used both at the cable headend site as well as at the remote site are described. The menu-driven software program for instrument control and data acquisition is explained. Finally, the approaches taken for performing each measurement are discussed.

2.1 Architecture of Cable Networks

Conventional cable networks consist of a tree-branch architecture. A signal originates at a cable headend and is sent to the cable subscriber through several bifurcations and a number of amplifiers spaced at pre-determined distances. Each amplifier receives a broadband signal and inserts enough gain and equalization such that a cascade of amplifiers have unity gain throughout the system.

A variety of cable systems ranging from a few hundred subscribers to several hundred thousand subscribers were selected for testing. Equipment manufacturers for trunk amplifiers, distribution amplifiers, line extenders, passives, coaxial cables, lasers, etc., varied from one cable system to another. Some cable systems consisted solely of coaxial cable plants, while others had hybrid coaxial with fiber optic nodes, and some had analog microwave links (AML). In some systems, a mixture of aerial and underground cable was used. Cable plant bandwidth ranged from as low as 230 MHz to cable systems designed for 550 MHz. Some systems tested had other services available such as cable in the classroom, signals for addressable converters, digital cable radio, data channels, and status monitoring. Single family units as well as multiple dwelling units were tested.

2.2 Description of Instruments

The instruments used for the digital transmission characterization study were a network analyzer and a spectrum analyzer with a group delay measurement option. A pair of Hewlett-Packard HP8593E spectrum analyzers with a group delay measurement option was used for standard spectrum measurements as well as amplitude flatness and group delay responses. An HP8752B network analyzer was used for measuring amplitude flatness and group delay of home wiring.

The HP8752B network analyzer measures the reflection and transmission characteristics of two port devices by applying a known sweep signal and measuring the responses of the network. The signal transmitted through the device at the output or reflected back from the input is compared with the incident signal generated by a swept RF sinusoidal source. The swept RF signal is produced by a built-in synthesized source in the range of 300 kHz to 3.0 GHz. At the receiver input, the high frequency RF signal is translated to a low frequency IF signal and digitized for further signal processing. The frequency response is calculated and displayed.

The HP8593E in link transmitter-receiver mode was used for measuring the frequency response at the remote site. The link transmitter generates a frequency modulated tone which periodically sweeps the frequency band of interest. This signal is combined at the headend with other cable signals in a spectrally unoccupied band. The sweep signal level is chosen to be equal to the other carrier levels for the system under test. The FM frequency deviation determines the accuracy of the group delay response measurement. A narrowband FM deviation is desired to give better accuracy for the group delay response. The link receiver is properly configured with parameters matching the link transmitter. When the link receiver is locked to the transmitter signal, both amplitude flatness and group delay can be measured. For the link receiver to give accurate results, the received sweep signal must be relatively free of all interferences. In addition, the received signal amplitude is limited to 16 dB of dynamic range. The receiver design limits the measured amplitude response to a maximum reflection delay range of 4 microseconds and the group delay response to a maximum range of 2 microseconds. Therefore, care must be taken when a micro-reflection of greater than 2 microseconds is present in the cable system. In addition, amplitude flatness depends on the frequency span. For a span of 100 MHz and 401 points, the frequency spacing is 250 kHz. If one takes the measured frequency response and performs an inverse discrete Fourier transform (IDFT), a time domain waveform known as the channel impulse response is obtained. This time waveform has a time span of 4 microseconds.

2.3 Instrument Control Software at the Test Site

The automatic measurement software used for data acquisition was a menu-driven instrument control program written in the "C" programming language which works under the MS-DOS operating system. A test measurement can be selected from a pull-down menu. Each test requires an ASCII script file containing commands to be sent to the instrument for proper set up and measurement. Results of each test were retrieved from the instrument and stored on computer disk for later analysis. The initial set up for each test can be altered according to local cable system parameters. Measurements are retrieved and stored in binary file format for both simplicity and reduced storage size. In addition, each file has a header in ASCII format containing valuable information about location, time, date, external attenuator value, and other measurement and instrument setup parameters required to convert binary data into their absolute measurement values.

The control program is further enhanced with unique features to recover from any communication errors over the general purpose interface bus (GPIB) board for instrument automated control. The software is designed such that all communications over the bus are monitored to detect any errors. If an error occurs, the control program automatically terminates the test and returns to the main menu for the test operator to correct the problem and repeat the test. Another useful feature provides the operator with the ability to manually change instrument settings after initiating a given test. Any changes made would be immediately noticed and reflected into the measurement files. Hence, the test operator has the ability to manually override and repeat a measurement until satisfactory results are obtained.

Figure 2-1 shows a flow diagram of a sample measurement selected from the Measure SubMenu of the control program. Upon selecting a particular measurement, a dialog window will appear requiring the user to enter an input script file name (e.g., **test4.scr**) and output data file name (e.g., **a3.4**). At this point, the user can select the **Continue** button to branch to the next step or **Quit** button to abort the measurement. If the **Continue** button is selected, another dialog box will be displayed requiring a value for the external attenuator. After entering the external attenuator value, the user has the option to use **Quit** button or **Measure** button. By choosing the **Measure** button, a dialog box with external attenuator and three buttons **ReMeasure, Continue** and **Quit** will appear. In this dialog box, the user has the option of remeasuring by changing the external attenuator value or even changing the instrument setting such as center frequency, frequency span, etc., from the instrument front panel and selecting the **ReMeasure** button to remeasure. This process can continue until a satisfactory result is obtained. Any changes made in the instrument setting will be stored with each measurement file. At the end of a measurement, data are saved by selecting the **Continue** button to go to the last dialog box, with **Save** and **Quit** buttons, and using the **Save** button to permanently store measurement traces on the internal hard disk drive of the DOS PC.

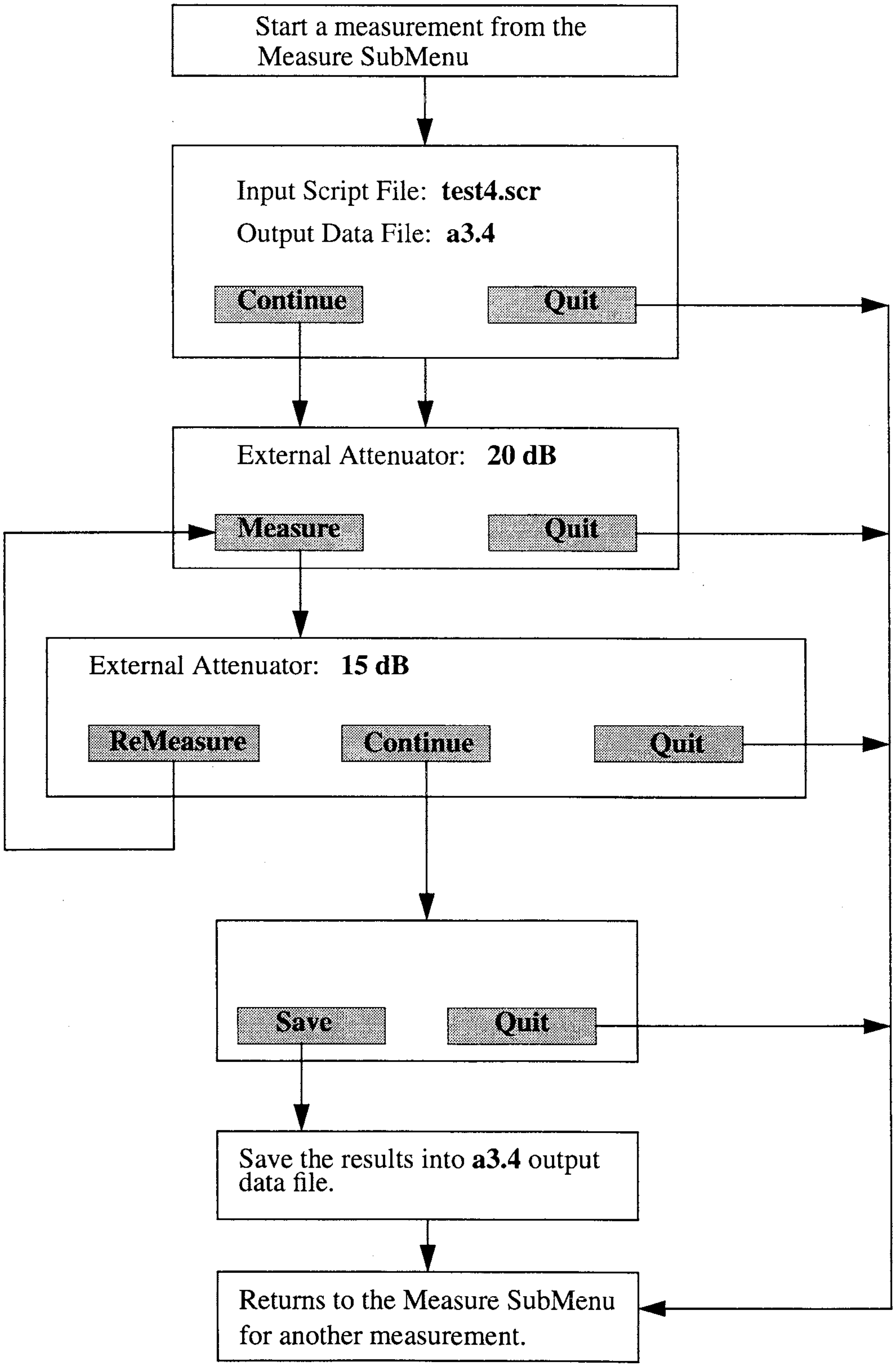


Figure 2-1: A flow diagram for performing a test from the Measure SubMenu.

An example of a script file used for instrument control and data acquisition is shown in Figure 2-2. This file is in ASCII format and can be easily modified. A line with a # character in the first column is considered to be a comment line. In addition, comments can be used on the same line with instrument commands by inserting a # after these commands.

```
#============================ A Sample Script File=======================
# File: test4.scr
# Testing for the cable Spectrum using the HP 8593E Link Analyzer,
# in spectrum mode.
# Created by Majid Chelehmal.
# Date Created:  2/11/1993.
# Last Modified: 4/27/1993

# Beginning of the measurement
Begin(3)

# Perform these commands only once
Send(MOV _TX_MODE,1;)
Send(BWR _PRIMADRS,10;)
Send(BWR _SECADRS,0;)
Send(BWR _PRIMADRS,4;)
Send(BWR _SECADRS,0;)
Send(IP;)
Send(MODE,0;)
Send(CLRW TRA;)
Send(FA,50.00MZ;)
Send(FB,462.00MZ;) # <-------------||
Send(RL -10DM;)
Send(AT,10DB;)
Send(RB,300KZ;)
Send(VB,300KZ;)
Send(ST,10SC;)

# Repeat the following commands:
Repeat()
Send(CLRW TRA;)
Send(SNGLS;TS;)
Send(MXMH,TRA;)
Delay(25)

# Save the instrument settings
Send(FA?;)
Receive(24, ASCII, CONTINUE, ONOD)
Send(FB?;)
Receive(24, ASCII, CONTINUE, ONOD)
Send(RL?;)
Receive(24, ASCII, CONTINUE, ONOD)
Send(AT?;)
Receive(24, ASCII, CONTINUE, ONOD)
Send(ST?;)
Receive(24, ASCII, CONTINUE, ONOD)
Send(RB?;)
Receive(24, ASCII, CONTINUE, ONOD)
Send(VB?;)
Receive(24, ASCII, CONTINUE, ONOD)

# Process data internally
Send(MOV TRC,TRA;)
Send(SUB TRC,TRC,8000;)
Send(DIV TRC,TRC,100;)
Send(DONE;)

WriteToFile(SHORT)
WriteToFile(401)

Send(TDF,A;)
Send(TRC?;)
Receive(806, BINARY, CONTINUE, OFFHEADER)

# End of measurement
End(3)
#========================== End of Sample Script File ===============
```

Figure 2-2: A sample input scripts file.

2.4 Instrument Remote Control at the Cable Headend

Remote control of instrumentation placed in a headend is facilitated with a cellular phone connected to a remote answer/tone decoder interfaced to a computer. The phone will answer, and the tone decoder will interpret touch tone commands (e.g., * or #) for the computer. Software residing on a DOS PC will interpret the decoded tones and control instrumentation via a GPIB interface.

2.5 Site Measurements

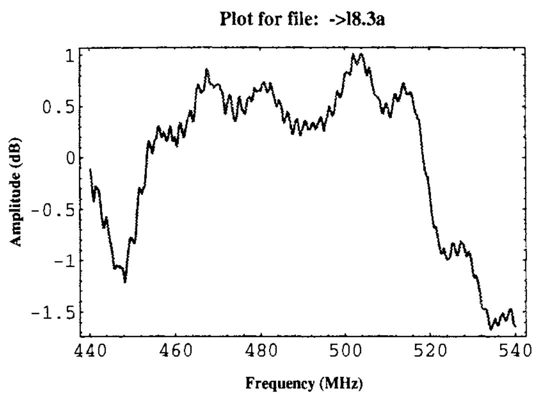
Each test was selected to measure a particular type of impairment that may exist in the cable system. After a careful study, a series of tests were chosen to account for a multiplicity of impairments present in cable systems. The tests performed at each cable site are as follows:

1. Amplitude flatness and group delay from the headend to the home outlet
2. Amplitude flatness and group delay from the headend to the tap
3. Amplitude flatness and group delay of the home wiring
4. Carrier spectrum from the headend to the tap
5. Noise spectrum from the headend to the tap
6. Spurious spectrum from the headend to the tap
7. Composite triple beat from the headend to the tap
8. Spectrum of the off air FM radio band
9. Spectrum of the home wiring in the FM radio band.

In the following sections, the purpose and methodology of each test is discussed.

2.5.1 Tap Frequency Response

Measurement of the frequency response at the tap provides knowledge of signal characteristics in the cable plant excluding the subscriber home. Any impairment measured at this point is due to the equipment deployed in the cable system. Amplitude flatness and group delay are measured for the cable system at the tap location. Usually, a well-conditioned signal exists at the tap. Measuring both in-home frequency response and response at the tap will give complete knowledge of the characteristics of the channel at the cable subscriber site. One can use these measurements to isolate problems in the subscriber home wiring from those that exist in the cable plant. A 100-ft coaxial cable equalized at the input of a broadband amplifier was used in the signal path. An external attenuator was used to ensure an input signal level of -20 dBmV ±5 dBmV into the HP8593E spectrum analyzer in the link receiver mode. The attenuator value was recorded along with the measurement data into the file for later correction. Two traces were saved along with the header information for each measurement. The first trace is the amplitude flatness response and the second trace is for the group delay response. Both traces contain 401 points of sampled data with 16-bit resolution. Figure 2-3 depicts example plots for the amplitude flatness and group delay responses measured at the subscriber tap site.



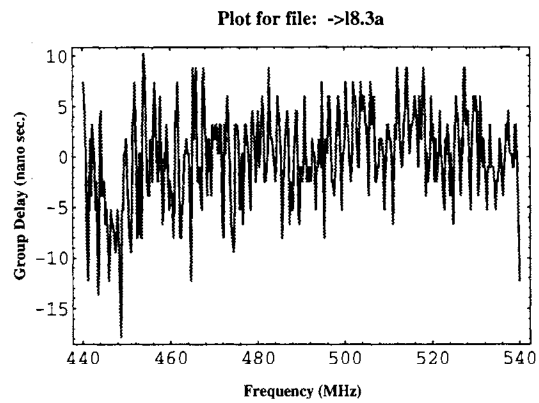
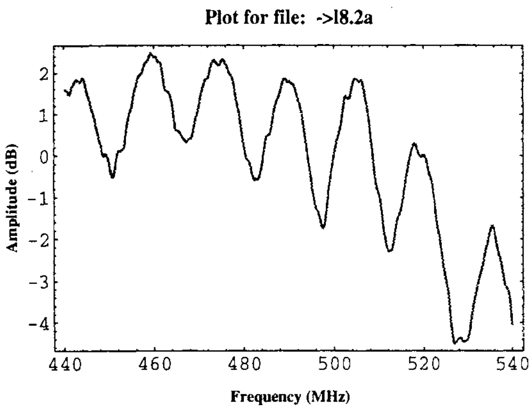


Figure 2-3: Measured frequency responses at the tap.

2.5.2 Home Outlet Frequency Response

This test measures the frequency response of the cable system at the subscriber home television outlet. A comparison of this measurement with the cable frequency response at the tap will reveal any impairments caused inside the subscriber premises wiring. A 100-ft coaxial cable equalized at the input of a broadband amplifier was used in the signal path to connect the subscriber home outlet signal to the input of the HP8593E spectrum analyzer in the link receiver mode. In addition, a signal level of -20 dBmV ±5 dBmV was maintained by using an external attenuator at the input of the broadband amplifier. Figure 2-4 depicts sample plots for amplitude flatness and group delay responses measured at the subscriber home outlet. Note the presence of an echo in this figure, seen from the sinusoidal variation in the amplitude flatness response. Later, in Section 3.3.1, the data from these graphs will be analyzed to calculate an impulse response for each 6 MHz cable channel.



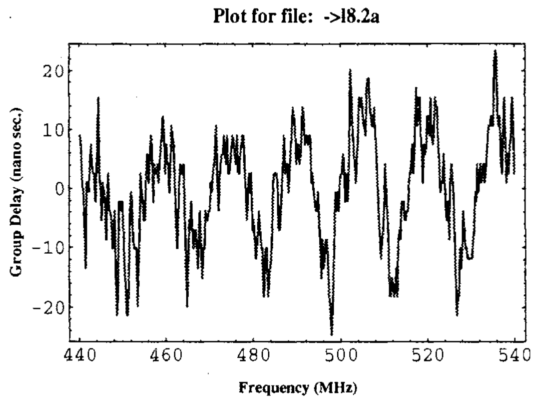


Figure 2-4: Measured frequency responses at the home outlet.

2.5.3 Home Wiring Frequency Response

Amplitude flatness and group delay responses of the home wiring are useful for determining levels of linear channel impairments cable signals experience as they travel through cables in the home. An HP8752B network analyzer was used to measure the home wiring frequency response in the 50 to 560 MHz frequency range. A 100-ft coaxial cable was used in the signal path to make this measurement. The effect of this length of cable was recorded by the HP8752B network analyzer and automatically corrected with each measurement. Amplitude flatness response and group delay response were measured. Using these responses, the impulse response of home wiring can be calculated. The impulse response shows any micro-reflection present in the home wiring. To maintain a good signal quality, a flat amplitude response and a constant group delay response is desirable for the home wiring, which yields a single non-zero-valued impulse response. Figure 2-5 depicts measured amplitude flatness and group delay responses at the subscriber home wiring site. Note the notch in the amplitude response indicating the response of a trap filter. Also, note the increasing amplitude ripple at higher frequencies, indicating impedance mismatching at higher frequencies.

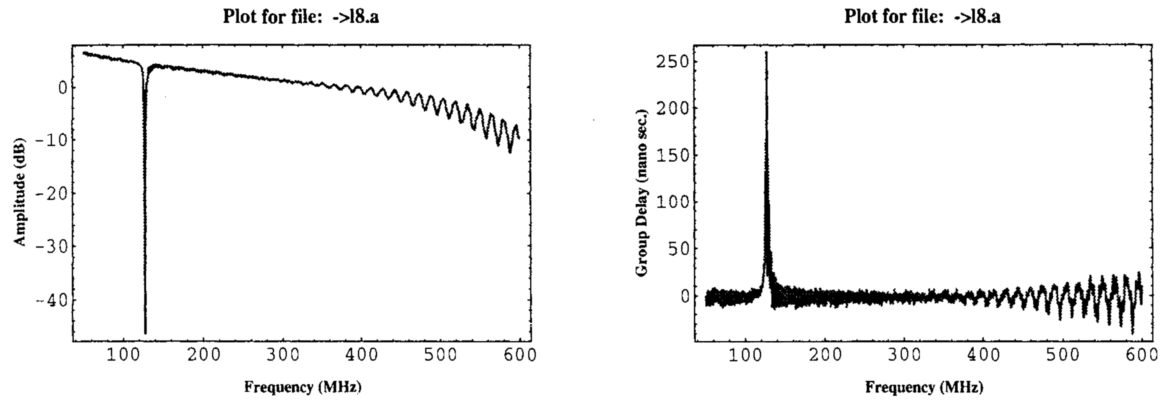


Figure 2-5: Measured frequency responses of home wiring.

2.5.4 Tap Carrier Spectrum

Carrier spectrum was measured at the tap at each test site with the HP8593E spectrum analyzer. The signal path from the tap to the spectrum analyzer also included a 100-ft coaxial cable equalized at the input of a broadband amplifier and an external attenuator to adjust the input level. The frequency range for measuring the carrier spectrum covers all available system bandwidth. Carrier spectrum measurement contains maximum carrier power levels for the measured frequency range. Carrier spectrum was measured by setting the spectrum analyzer in max hold mode and sweeping long enough to let all carriers reach their maximum levels. Knowing carrier levels and impairment levels one can easily determine any carrier-to-impairment ratio in the frequency band of interest. Carrier spectrum measurement also shows variation of each carrier level in different frequency bands. A cable system designed for unity gain should have equal carrier levels throughout the system. However, variations in the carrier levels do exist due to non-ideal performance of the cable system. Figure 2-6 shows a plot of the carrier spectrum measurement performed at the subscriber tap site.

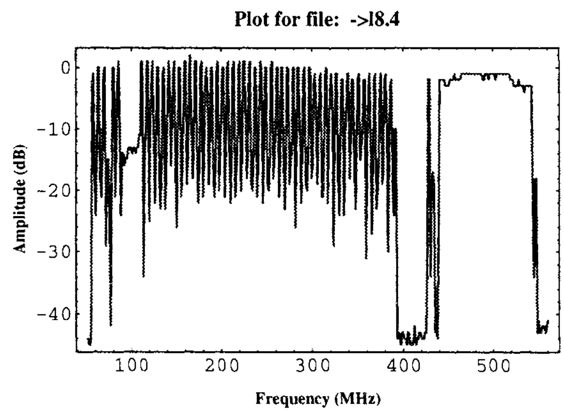


Figure 2-6: Measured carrier spectrum at the tap.

2.5.5 Tap Noise Spectrum

Noise spectrum was measured at the tap for each test site with the HP8593E spectrum analyzer. Included in the signal path were 100-ft of coaxial cable equalized at the input of a broadband amplifier, an external attenuator (normally set for 0 dB), and a highpass filter to reject active cable channel energy. An unoccupied frequency band located above the normal National Television Standard Committee (NTSC) video carriers was chosen for the noise test. A suitable highpass filter is inserted in the signal path to reject the effects of system carriers in the measurement. The noise measurement can be compared with the system carrier spectrum to compute the carrier-to-noise ratio (CNR) at the tap. In Figure 2-7, an example of noise spectrum measured at the subscriber tap site is depicted.

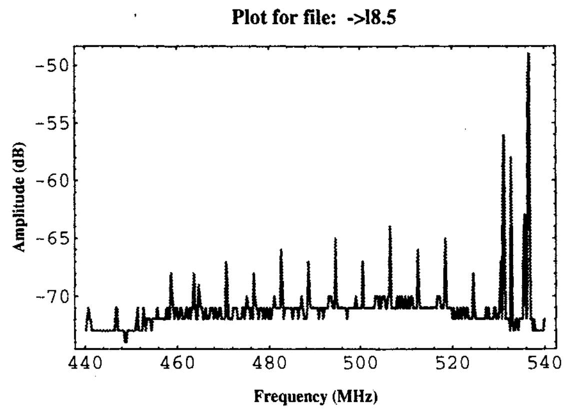


Figure 2-7: Measured noise spectrum at the tap.

2.5.6 Tap Spurious Components

Spurious components were measured at the tap for each site with the HP8593E spectrum analyzer. The same signal path used in measuring the noise spectrum was repeated in the frequency band where the noise spectrum was measured. In measuring spurious components, the spectrum analyzer was kept in peak mode for a period of two minutes to capture peak transient spurious energy. Spurious components measured at subscriber tap site are shown in Figure 2-8.

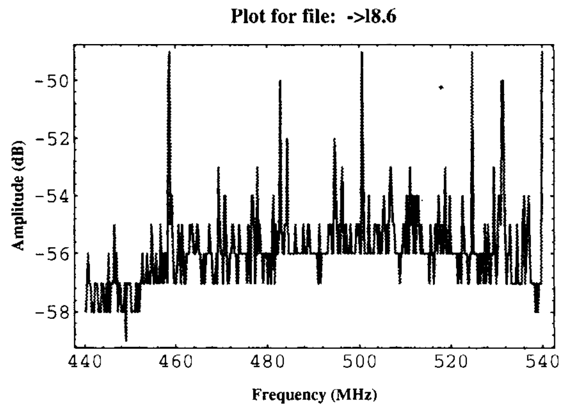


Figure 2-8: Measured spurious components at the tap.

2.5.7 Tap Composite Triple Beat

Composite triple beat (CTB) is an intermodulation product resulting from amplifier non-linearities in a multiple-carrier cable system cascade. CTB was measured at the tap at each site using the HP8593E spectrum analyzer. The signal came from the tap through a 100-ft coaxial cable equalized at the input of a broadband amplifier, and an external attenuator to control the level to the input of the spectrum analyzer. In addition, a narrowband bandpass filter was employed to pass only the existing CTB frequency component. A frequency 12 MHz above the highest NTSC video carrier in use was selected for the measurements of any CTB component in the system at that frequency. Video averaging was used for measuring the CTB power.

2.5.8 FM Radio Band Spectrum

Susceptibility to ingress can result from poor shielding of the cable wiring and connectors. An external reference field is needed to measure a relative shielding effectiveness. The FM radio band (88 to 108 MHz frequency band) is a widely available external RF field source which can be used to determine home wiring shielding effectiveness. A reference field was measured by connecting the output of an FM dipole antenna to the input of the HP8593E spectrum analyzer. This spectrum shows carrier levels for all the FM radio stations available at that site. Figure 2-9 depicts FM radio band spectrum measured at the subscriber site.

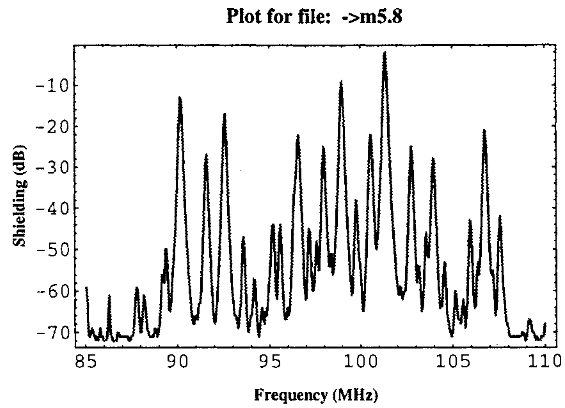


Figure 2-9: Measured FM radio band spectrum.

2.5.9 Home Wiring Isolation in the FM Radio Band

A shielding effectiveness measurement shows the ability of the home wiring to reject any external field from ingressing into the cable system. For this test, the drop cable to the home was disconnected from the cable system and terminated at the drop. Next, the home wiring was connected to the input of the HP8593E spectrum analyzer and the frequency spectrum in the FM radio band was measured. This is compared with the FM dipole antenna measurement described in the previous section, and a relative shielding effectiveness is determined as described in a subsequent section. Properly shielded home wiring limits any external field from entering the cable system. Figure 2-10 depicts the spectrum of home wiring shielding in the FM radio band measured at the subscriber site.

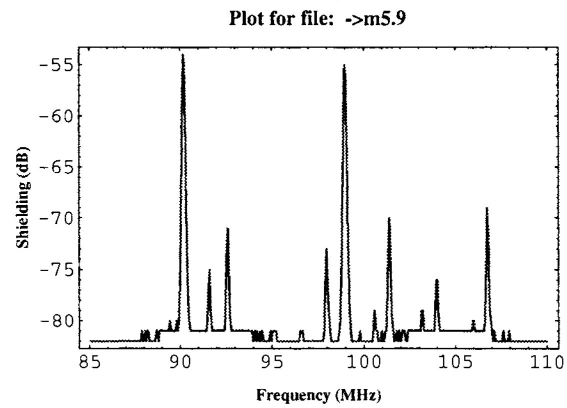


Figure 2-10: Measured home wiring shielding in the FM radio band.

3. ANALYSIS OF THE CABLE SYSTEM MEASUREMENTS

Analysis of the digital transmission characterization field measurements requires processing of the collected data to calculate various cable system channel characteristics and impairment levels. The complexity of analyzing each type of measurement depends on the kind of test performed at each cable site. A file containing a field measurement must be preprocessed into a proper format for further analysis. Extra care must be taken when analyzing a measurement file for a particular test performed. This involves considering the insertion loss of filters, amplifier responses, attenuators used for each measurement, as well as the nature of the impairment being measured. For example, when processing a file belonging to the noise spectrum, one must consider noise contributed by the measurement instrument and subtract that from the measured value to obtain an actual noise spectrum.

The following sections discuss the software tools used for data processing, the digital signal processing algorithms employed for data analysis, and a detailed analysis description of each measurement type.

3.1 Software Tools Used for the Measurements Analysis

Processing of the digital transmission characterization field data requires various signal processing routines. Furthermore, an interactive environment is needed to read a large number of data files and perform comparative analysis. The Mathematica® software package was used for data processing. Measurement files were read and stored into Mathematica "list" formats which are easily sorted, manipulated, processed, and compared. One limitation of the Mathematica program is the slow speed of reading external measurement files. To overcome the speed problem, a library of customized external "C" programs was written and linked to a Mathematica session using the MathLink functions protocol. This approach greatly reduced the amount of time required to read a measurement file and return the results into "list" formats.

3.2 Digital Signal Processing Techniques

Digital signal processing techniques are employed to process field data and compute cable system performance parameters. Techniques used include: data windowing, spectral shaping windows, median filtering, peak detection, averaging, data smoothing and discrete Fourier transform (DFT) operation. A particular technique employed depends mainly on the type of measurement file and the particular performance parameter desired. Some results can be presented by a single number, while others are in functional forms. In addition, statistical analyses are performed to create histograms and cumulative distributions.

3.3 Processing of the Cable Site Measurements

Several channel characteristics are computed from the measurement data, such as impulse response, carrier power, noise power, CNR, spurious components, CTB, and home wiring shielding effectiveness. In the following sections, analysis techniques for processing each type of measurement data are discussed.

3.3.1 Impulse Response

Impulse response is calculated by performing an inverse DFT operation on the complex (real and imaginary) parts of the cable frequency response obtained from the amplitude flatness and phase response data. Field measurement are available as amplitude flatness and group delay response data. Phase response is calculated from integration of the group delay data over the frequency span. For an ideal case with flat amplitude and linear phase responses, the impulse response has only a main pulse at time zero. Any frequency deviation from this ideal case will result in other pulses in addition to the main pulse. For example, a frequency response containing an echo (signal reflection) will result in an impulse response having a main pulse and a time-delayed and attenuated pulse that is called an echo. If this echo occurs before the main pulse this delay would be negative (i.e., a pre-echo), and for echoes that happen after the main pulse (post-echoes), delays are positive.

To emphasize the effect of micro-reflections for each cable channel, a frequency domain spectral shaping window is utilized before computing the impulse response. Basically, a window is used as a frequency selective filter to select a desired frequency region representing a particular 6 MHz cable channel. A simple window for this purpose is a rectangular window where the frequency points inside the window are left unchanged (or scaled by a constant) and the data points outside the window are set to zero. However, a rectangular window will give rise to Gibbs' phenomenon. To reduce this problem, some other suitable spectral shaping windows are available; the well-known Blackman window function is used in this study. See Appendix A.1 for a brief description of spectral shaping windows. With the Blackman windowing technique, the frequency domain response is centered at a desired cable channel in the measured frequency span. Then an inverse DFT operation is applied to the windowed frequency response, and an impulse response is computed for each 6 MHz channel. This windowing procedure is repeated for the entire frequency span. Figure 3-1 is an example of an impulse response calculated from measured frequency responses using an inverse DFT operation. Note the presence of an echo 20 dB down from the main pulse and approximately 100 nanoseconds long. This is also evident from the frequency response plot shown in Figure 2-4, from which this impulse response is computed.

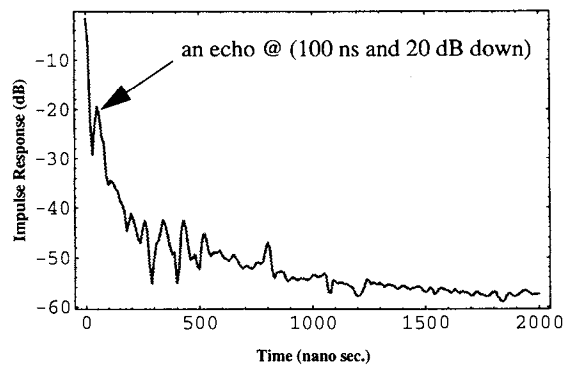


Figure 3-1: Computed impulse response.

3.3.2 Carrier Power

Carrier power in a 6-MHz cable channel is computed by processing the carrier spectrum measurement. This measurement contains carrier power levels for 401 equally spaced frequencies in measurement range. In particular, carrier levels in the frequency range where the link transmitter sweep signal was measured is of interest. The entire frequency span of the carrier spectrum measurement is divided into 6-MHz intervals centered at each cable channel center frequency. A sliding rectangular window of 6-MHz bandwidth centered at each channel is used to select carrier spectrum points for that channel. Within this window, a maximum value was selected to represent the received carrier power in that channel. The reason for choosing a maximum level in this manner was that in measuring the carrier spectrum, the procedure was to max-hold the spectrum analyzer. Hence, each point in a given cable channel would have reached this maximum value. In calculating the carrier power for the normal NTSC signal, the carrier level during the sync pulse in the blanking interval is measured. Therefore, the procedure just described approximates the NTSC sync pulse measurement for the carrier power using the link transmitter sweep signal.

3.3.3 Noise Power

Calculating system noise power requires processing of noise spectrum measurement data to remove any non-Gaussian spurious components such as CTB. This is accomplished by applying an appropriate non-linear smoothing filter (e.g., a median filter as explained in Appendix A.1) to detect and remove these components. Noise is calculated for the frequency range where the link transmitter sweep signal was utilized. Noise power density is integrated for each 6-MHz cable channel measured to compute the total noise power in that channel. A rectangular window is used to select points of the noise spectrum in each 6-MHz cable channel and numerically integrate these points to compute the total noise power in a 6-MHz bandwidth. To ensure that the noise just calculated is the actual noise of the system, and is not influenced by the spectrum analyzer noise floor, the noise density measured is reduced by the spectrum analyzer noise floor. In addition, other instrument noise correction factors such as the spectrum analyzer log detected noise (≈2.5 dB added to measured noise) and filter noise-equivalent bandwidth (≈0.52 dB subtracted from measured noise) are taken into account when calculating the noise power.

3.3.4 Carrier-to-Noise Ratio

The carrier-to-noise ratio (CNR) is calculated as the ratio of the carrier power to the noise power for each 6-MHz cable channel. The process involves calculating for each measured cable site a carrier power in a particular cable channel and comparing it with the noise power in the same cable channel. The ratio of these two measurements yields the CNR for each 6-MHz cable channel.

3.3.5 Spurious Components

The measurement data for spurious components is divided into 6-MHz bands. A rectangular window centered at each cable channel is applied to the spurious measurement data to select spurious components (i.e., spikes in the peak held power spectrum) for that channel. For each measured channel, spurious components are added to give total spurious power. A suitable median filter was utilized to select only those components of the spurious measurement data which were above the system noise threshold level. The approach taken ensures a valid result, since the flat system noise will not be considered as spurious components.

3.3.6 Composite Triple Beat

Composite triple beat (CTB) was recorded at each test site 12 MHz above the last channel in service, giving the power of any interfering intermodulation present. This number is compared with the noise power density measured in the same cable channel. If CTB power is above the noise power, a valid CTB component exists, otherwise no CTB is reported.

3.3.7 Home Wiring Shielding Effectiveness

This test determines how effective a shield the house wiring presents against an external radiating field. To obtain the house wiring shielding effectiveness, an antenna measurement of the FM field in the 88-108 MHz frequency band is compared with the house wiring field for the same frequency range of interest. The ratio of these two measurements gives the effective shielding of the home wiring, averaged over all FM radio stations received at the measurement site. Figure 3-2 compares FM radio band spectra with home wiring shielding from which the home wiring shielding effectiveness plot is determined. Note that poorly shielded home wiring will allow stronger FM radio carriers to penetrate inside the home cable.

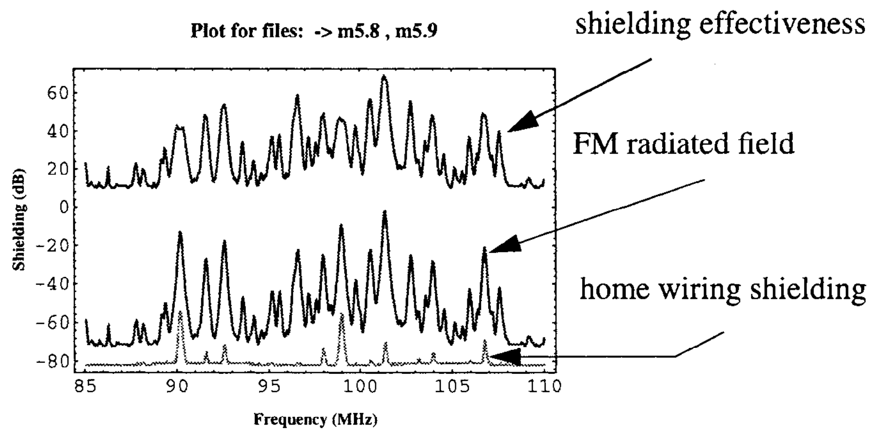


Figure 3-2: Comparing FM antenna with home wiring shielding.

4. DIGITAL TRANSMISSION CHARACTERIZATION RESULTS

After a careful analysis of cable system measurements of various types of channel impairments, one can tabulate channel characteristics in a statistical model in the form of histograms and cumulative histograms. A histogram is a count of the relative frequency of occurrence of a particular measurement for all possible measured values. This approximates the probability distribution function (PDF) of the measured observations. The cumulative histogram is the count of the total relative number of all observed values below a given value. This approximates the cumulative distribution function (CDF) of the measured observations. The cumulative histogram is useful for obtaining the percentage of measured cable sites that exceeded a particular level of a given channel impairment.

Statistical analysis is helpful in quantifying cable channel impairments to determine requirements for digital modem performance. This analysis can easily be accomplished by computing the histogram and the cumulative histogram for each type of cable impairment. In particular, the cumulative histogram shows the proportion of all cable systems tested below a given level of impairment. As an example, suppose one wants to design a modem which works above some nominal CNR ratio. By inspection of Table 4-2, better than 35 dB CNR is available for 90% of measured sites. Adding spurious power reduces effective CNR by an additional 5 to 7 dB.

Further analysis of the measured data is required to calculate a histogram. The amount of processing necessary depends on the type of impairment being considered. The basic approach in gathering statistical information is to use a table with a specified number of rows and columns. For instance, each column may be a specific impairment level and each row designates a particular frequency range. Therefore, a cell in the table represents a histogram count value for a given level of impairment in a particular frequency range.

In the following sections, a complete statistical analysis of measured cable system impairments is given. In Section 4.1, the results of the statistical analysis are summarized in two tables. In subsequent sections, individual cable impairments are discussed using histogram and cumulative histogram plots, providing detailed impairment characteristics.

4.1 Summary of Digital Transmission Characterization Results

Results of the digital transmission characterization are summarized into two tables. Table 4-1 describes micro-reflection delay and amplitude statistics averaged over all the cable systems measured. This table is arranged into four different impairment categories: (1) micro-reflections from the headend to the tap, (2) micro-reflections from the headend to the subscriber home outlet, (3) micro-reflections for the home wiring in the 50-200 MHz frequency band, and (4) micro-reflections for the home wiring in the 222-558 MHz frequency band. The home wiring micro-reflection statistics are divided into two different frequency bands to determine any difference in behavior of echoes at lower frequencies compared to higher frequencies. The higher frequency band was selected to be the link transmitter sweep signal frequency band for each cable system tested. Note that numbers in parentheses in Table 4-1 are for the roll-off regions extending 12 MHz above the specified bandwidth for each cable system.

Table 4-1: Micro-Reflection Impairments Summary for all Systems.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 222 - 558 MHz				
Delay (nanosecond)	230 (350)[1]	640 (790)	860 (920)	1520 (1470)
Amplitude (dB)	-37 (-37)	-29 (-28)	-26 (-26)	-19 (-20)
Headend Thru Home Outlet:				
Frequency: 222 - 558 MHz				
Delay (nanosecond)	230 (360)	570 (770)	730 (920)	1280 (1420)
Amplitude (dB)	-37 (-37)	-27 (-27)	-24 (-23)	-19 (-20)
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	140	350	430	640
Amplitude (dB)	-37	-26	-22	-16
Home Wiring:				
Frequency: 222 - 558 MHz				
Delay (nanosecond)	130	330	440	1250
Amplitude (dB)	-37	-28	-25	-19

1. Numbers in parenthesis are for the roll-off regions.

Table 4-2 provides the remaining cable system impairments summary. Carrier spectrum, noise spectrum, CNR, spurious components, CTB, and home wiring shielding effectiveness are noted. As was the case in Table 4-1, these impairments were calculated over all the cable systems characterized. An important point to mention from this table is that the average CNR drops by 6 dB in the roll-off regions because of signal quality degradation in this region.

Table 4-2: Noise/Interference Impairments Summary for all Systems.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 222 - 558 MHz					
Carrier/Noise (dB)	48 (42)[1]	43 (38)	35 (30)	33 (27)	25 (19)
Carrier Power (dBm)	-32 (-35)	-37 (-42)	-48 (-53)	-53 (-55)	-60 (-60)
Noise Power (dBm) in 6 MHz Bandwidth	-72 (-68)	-82 (-83)	-72 (-73)	-68 (-71)	-60 (-51)
Spurious Power (dBm) in 6 MHz Bandwidth	-68	-78	-66	-62	-56
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-67 (-65)	-77 (-77)	-65 (-65)	-61 (-61)	-55 (-50)
CTB Power (dBm) 12 MHz above the last active channel	-93	-107	-90	-86	-80
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	67	58	42	36	27

1. Numbers in parenthesis are for the roll-off regions.

4.2 Micro-Reflections

Impulse responses were analyzed for echoes within a desired magnitude range and delay time range. A table was created giving a count of a given echo amplitude at a given delay time. Echo amplitudes and delays were tabulated into two-dimensional histogram tables with rows representing the relative number of echo delay times within a given amplitude range, and columns representing the relative number of echo amplitudes within a particular echo delay time range. The distribution itself can be described as a table with a number of rows and columns, where a value in a table cell represents a total count of echoes with a given amplitude in dB at a specified delay time in nanoseconds.

After calculating impulse responses and tabulating results into histograms, one can determine other parameters easily. For instance, if it is desired to know the delay time distribution of all echoes regardless of their amplitude, simply add all elements of each column of the two-dimensional histogram table array to obtain a single row vector where each column element is a count for an echo delay time value. Similarly, echo amplitude characteristics are determined by reducing a two-dimensional histogram table array into a single column vector with a number of rows. In this case, each row element represents a count for a particular amplitude value.

A statistical model of the cable channel for micro-reflections is derived from the two-dimensional histogram distribution of amplitude versus delay time of echoes. A column in this histogram represents a PDF of an echo amplitude for a specific delay time. A CDF is calculated by a column-wise integration of the PDF. Each data point in the CDF denotes the number of measurements below an echo amplitude in dB as a relative percentage of the total at a specific delay time. This approach is repeated for the remaining PDFs for each echo delay time by taking each column from the histogram table and computing a corresponding CDF.

A cable channel model can be easily determined from these CDFs for a desired percentage of echo amplitude values, such as the amplitude for 99% of all echoes with specified echo delay time. In this case, the echo amplitude below which 99% of all measurements fall is determined for each CDF and the result is stored into an element of an array of size equal to the number of echo delay time values. This array represents the worst-case impulse response of a cable channel for echoes which are below a desired relative percentage of measurements.

Figures 4-1 to 4-4 show statistical histogram analyses of both amplitude and delay time of echoes for all measurements made at the tap. Figure 4-1 shows micro-reflection statistics where the axis labeled "time (nano sec.)" denotes the delay time of echoes and the axis labeled "amplitude division (dB)" denotes the amplitude of echoes in dB weaker than the main signal level. The relative frequency axis denotes a relative number of counts for an echo with a particular delay time and amplitude below the main signal level. This figure can be simplified into Figures 4-2 and 4-3 by projection into the time and amplitude axes respectively. Hence, Figure 4-2 is a histogram of echoes for different delay time regardless of amplitude. Similarly, Figure 4-3 represents the amplitude distribution of echoes regardless of delay time. By inspecting the graph on the left side of Figure 4-2, one can see that in the majority of cases, delay times are less than 500 nanoseconds. In addition, one can better understand the statistics of echoes by generating a cumulative distribution as shown in the right hand side graph in Figure 4-2. This shows a percentage below a given delay range from 0% to 100%. For example, if it is desired to find a maximum echo delay time below 95% of systems, it is found to be approximately 640 nanoseconds.

Figure 4-4 illustrates possible cable channel micro-reflection models (impulse responses) for 50%, 90%, 95% and 99% of all measured sites. The plot for 99% can be considered to be a worst-case channel model.

Similarly, Figures 4-5 to 4-8 show the statistical histogram analyses for both amplitude and delay time of echoes at the home outlet, which includes home wiring. Figures 4-9 to 4-16 show the statistical histogram analyses of the home wiring only. Note that the home wiring analyses were performed in two frequency bands to determine if there are any significant changes in the micro-reflection behavior in the frequency band of 50 to 200 MHz, and in the frequency band of 222 to 558 MHz.

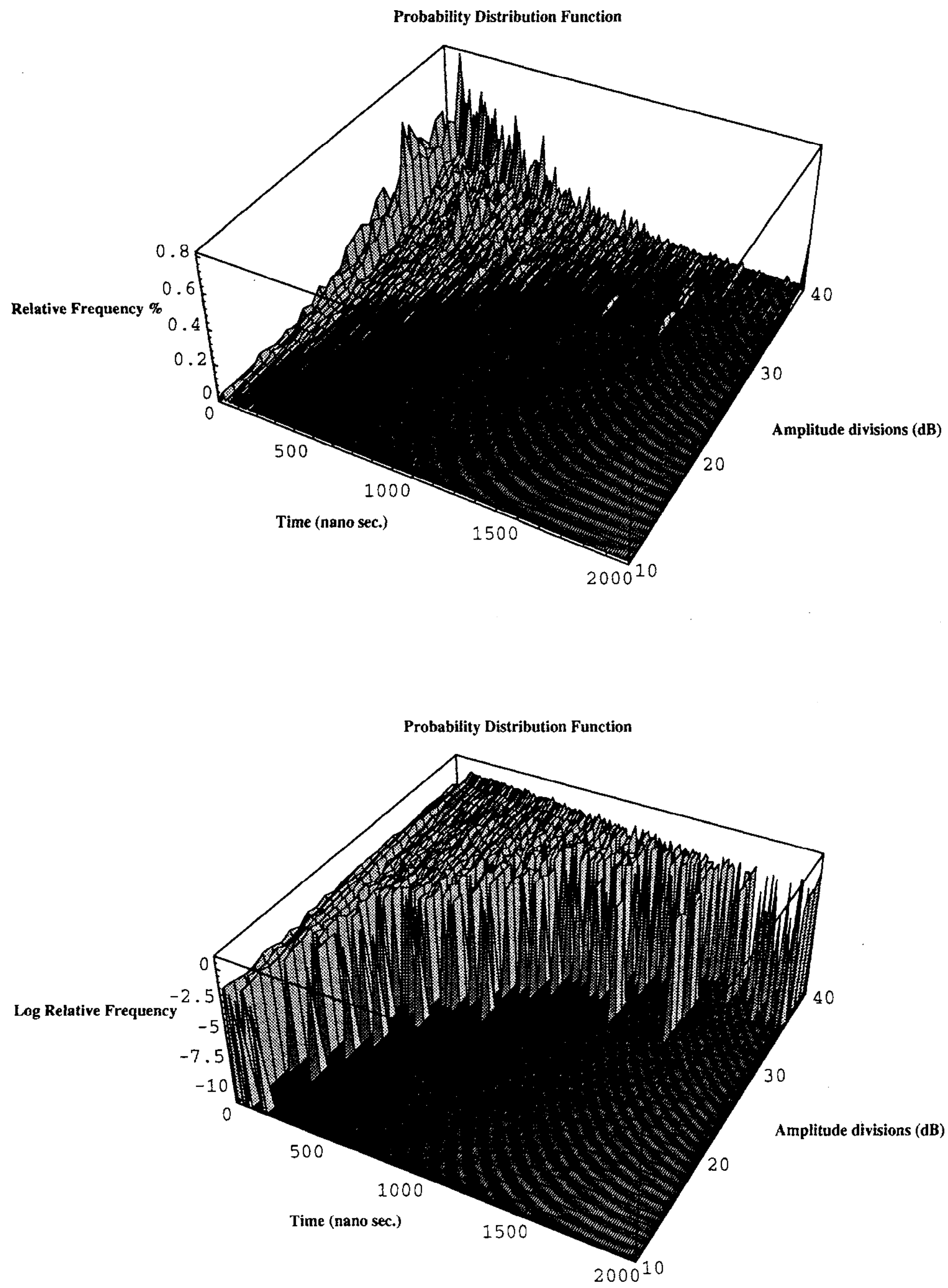


Figure 4-1: Tap distribution of echoes (222 - 558 MHz).

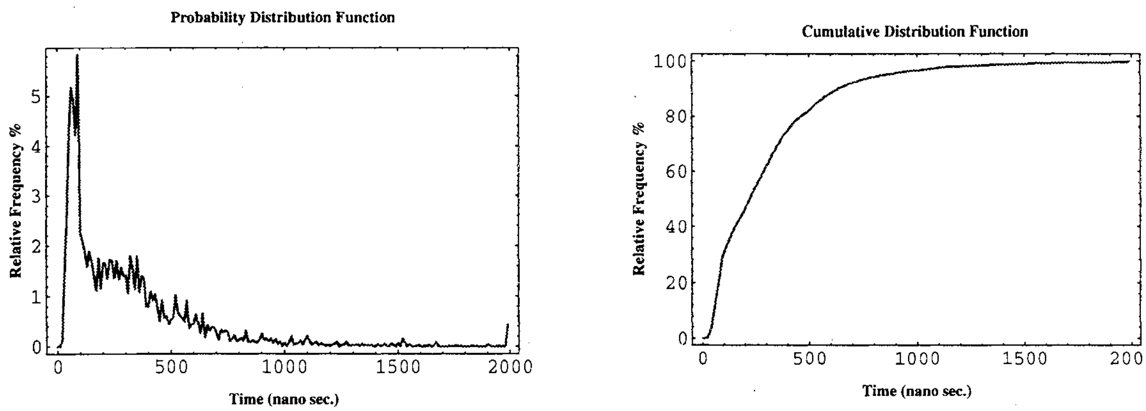


Figure 4-2: Tap histogram of echo delays (222 - 558 MHz).

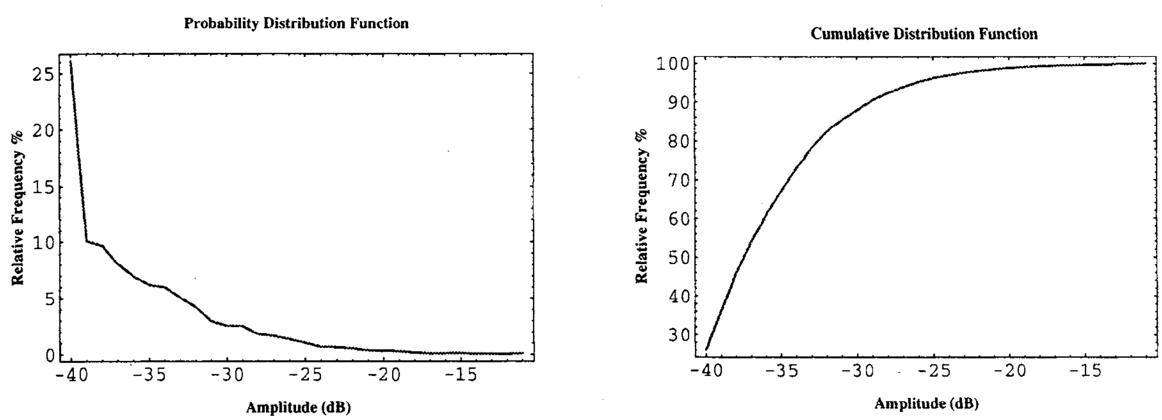


Figure 4-3: Tap histogram of echo amplitudes (222 - 558 MHz).

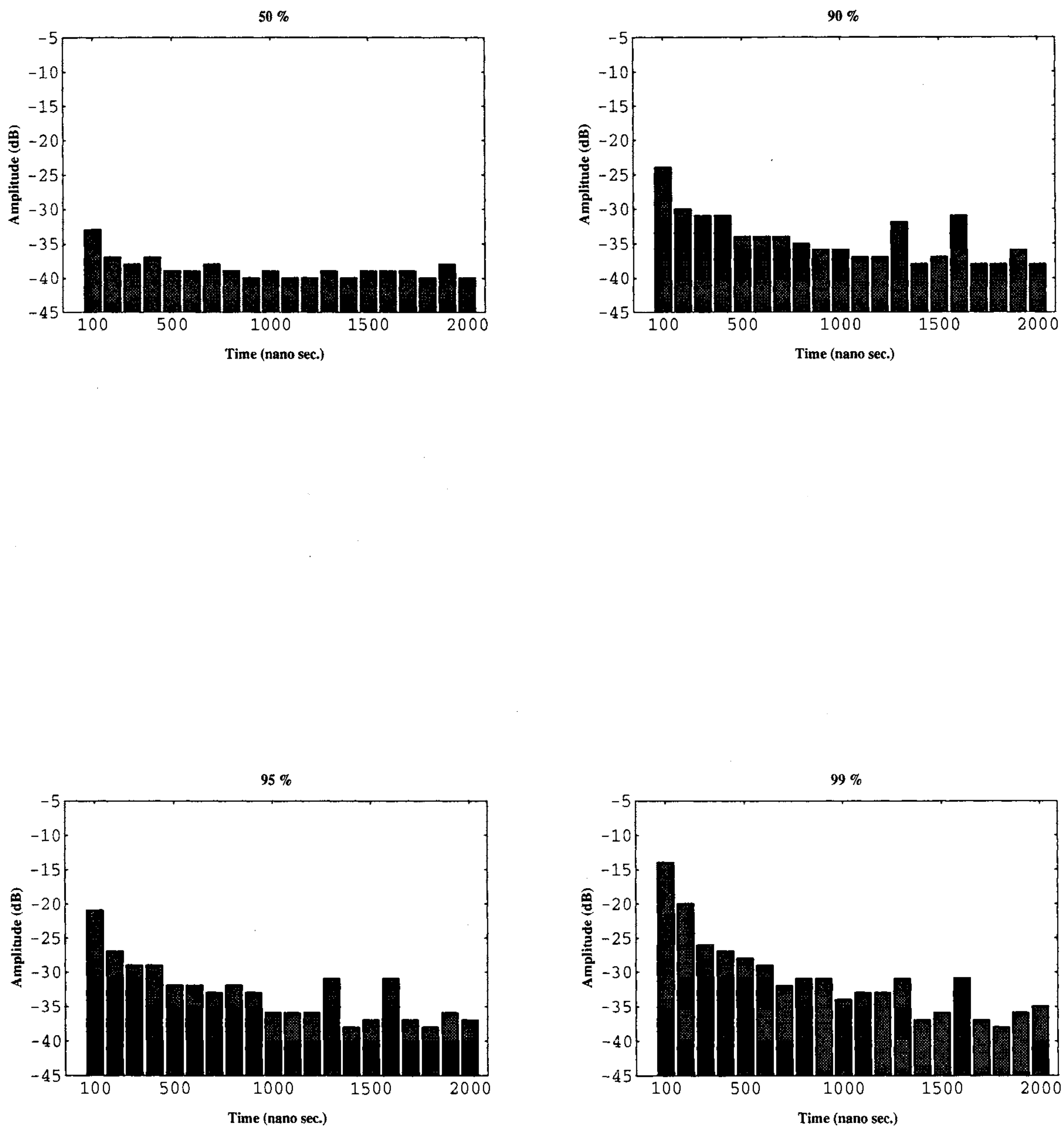
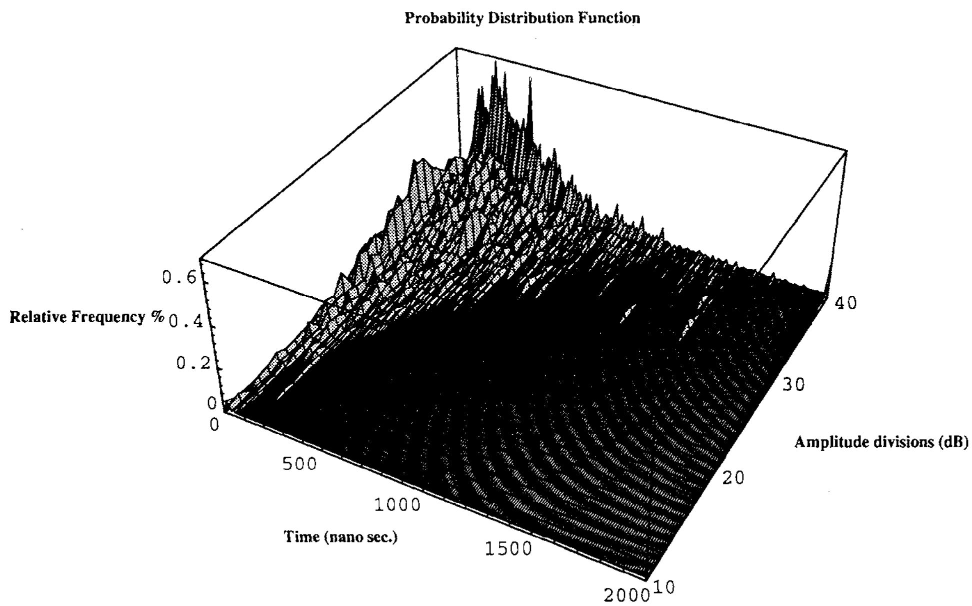


Figure 4-4: Tap echo amplitude vs. echo delay: (222 - 558 MHz)



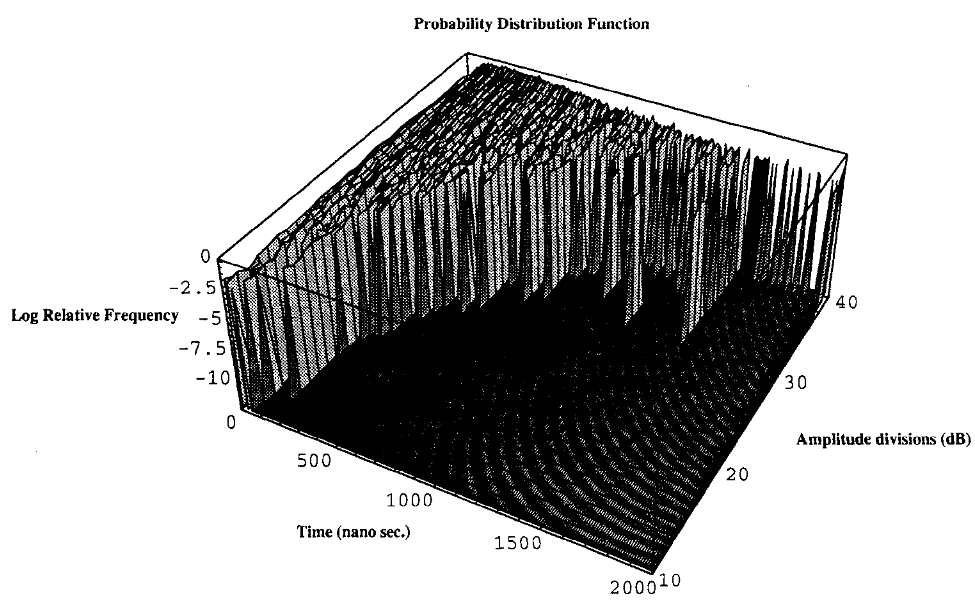


Figure 4-5: Home outlet distribution of echoes (222 - 558 MHz).

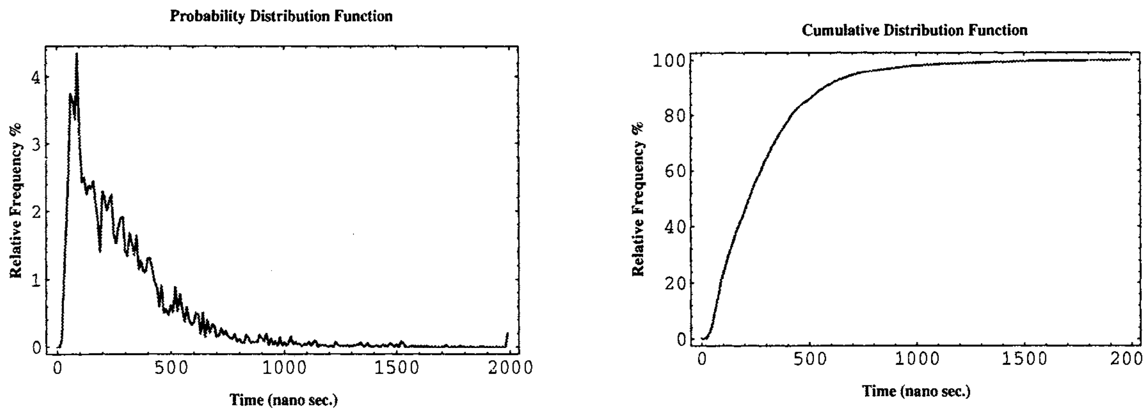


Figure 4-6: Home outlet histogram of echo delays (222 - 558 MHz).

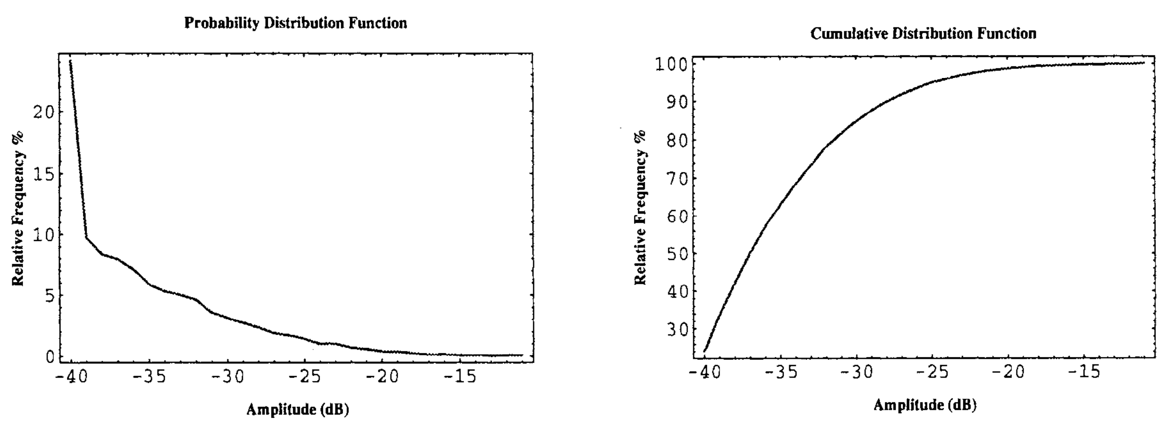


Figure 4-7: Home outlet histogram of echo amplitudes (222 - 558 MHz).

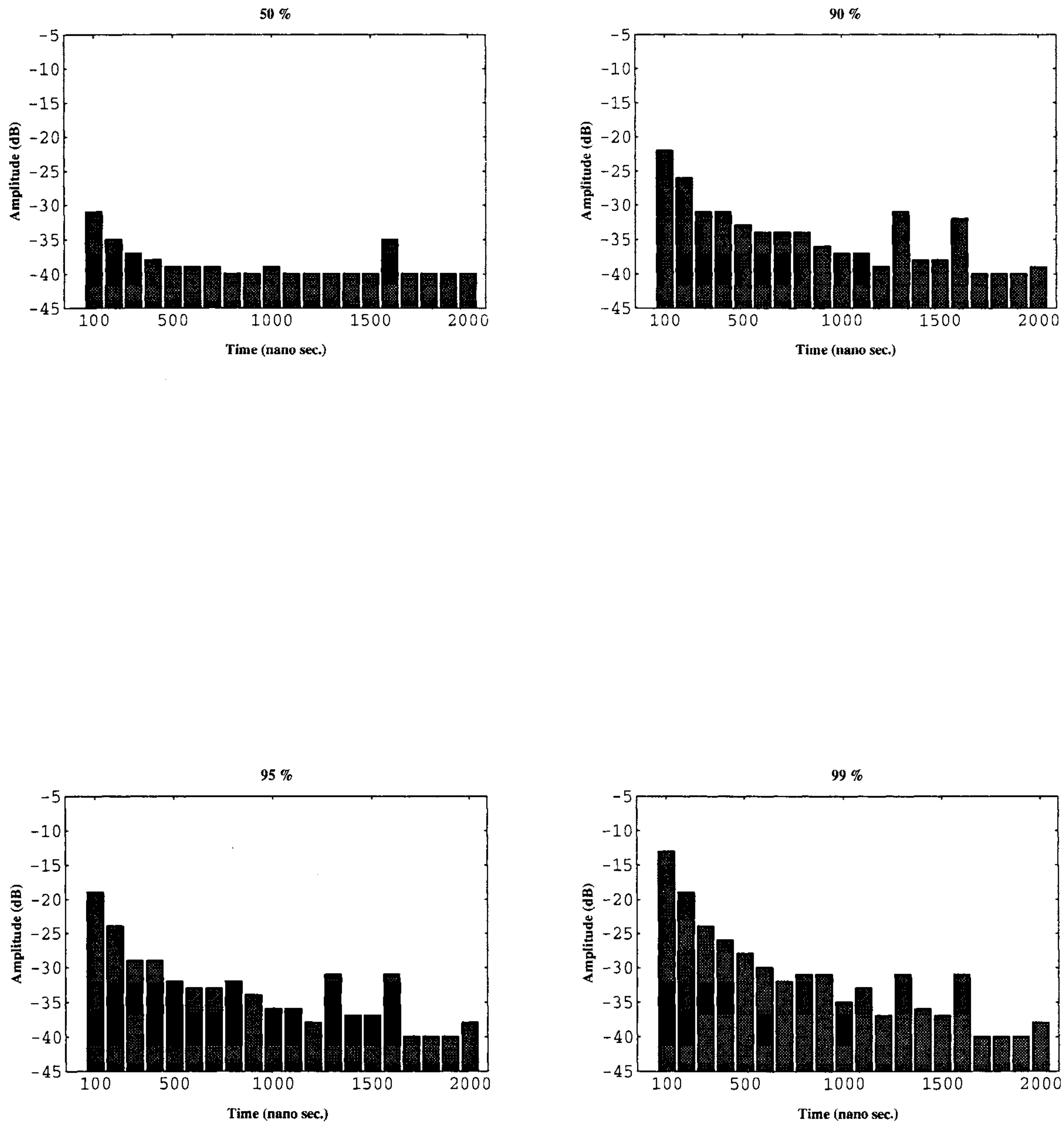


Figure 4-8: Home outlet echo amplitude vs. echo delay: (222 - 558 MHz)

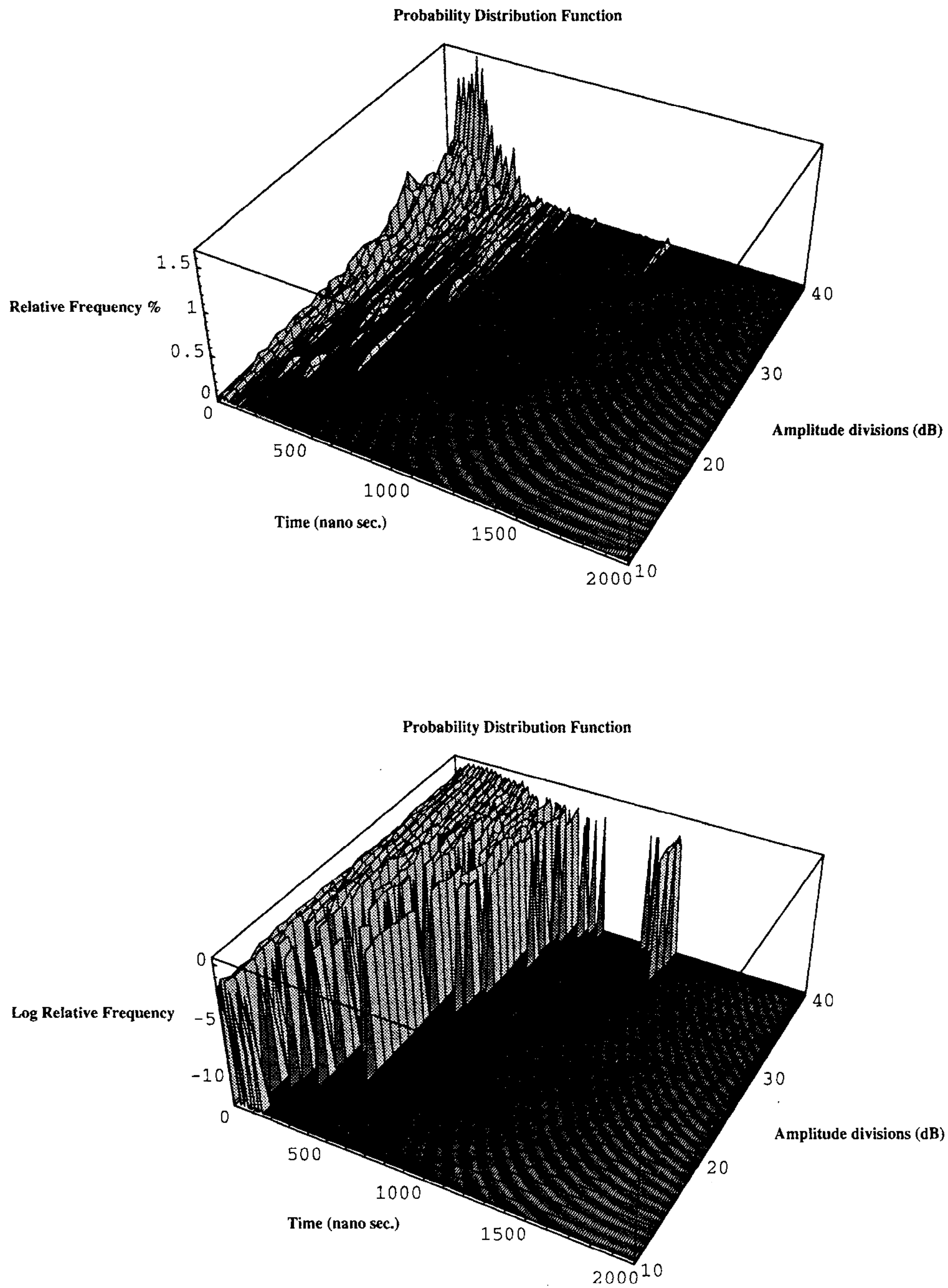


Figure 4-9: Home wiring distribution of echoes (50 - 200 MHz).

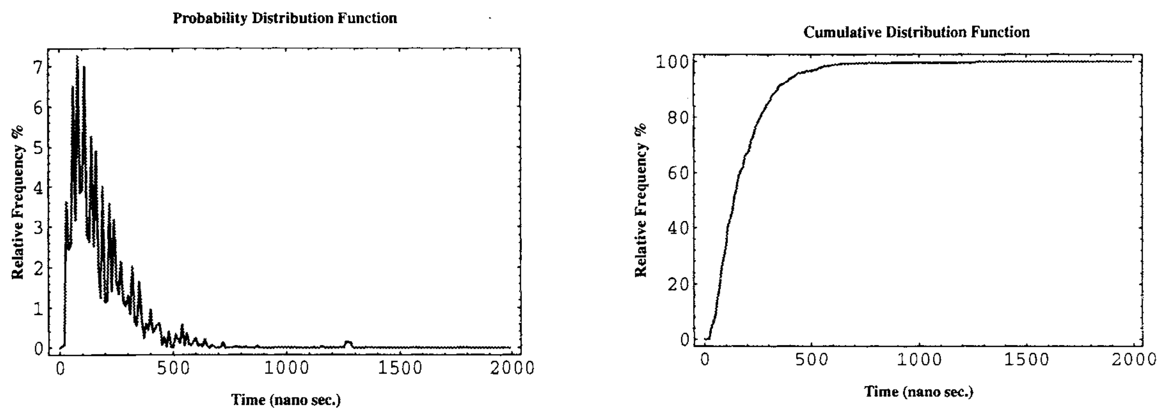


Figure 4-10: Home wiring histogram of echo delays (50 - 200 MHz).

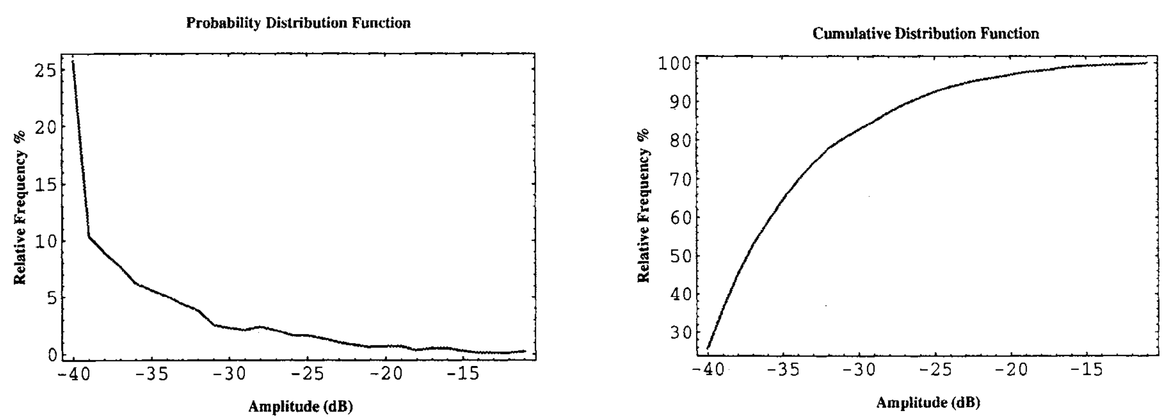


Figure 4-11: Home wiring histogram of echo amplitudes (50 - 200 MHz).

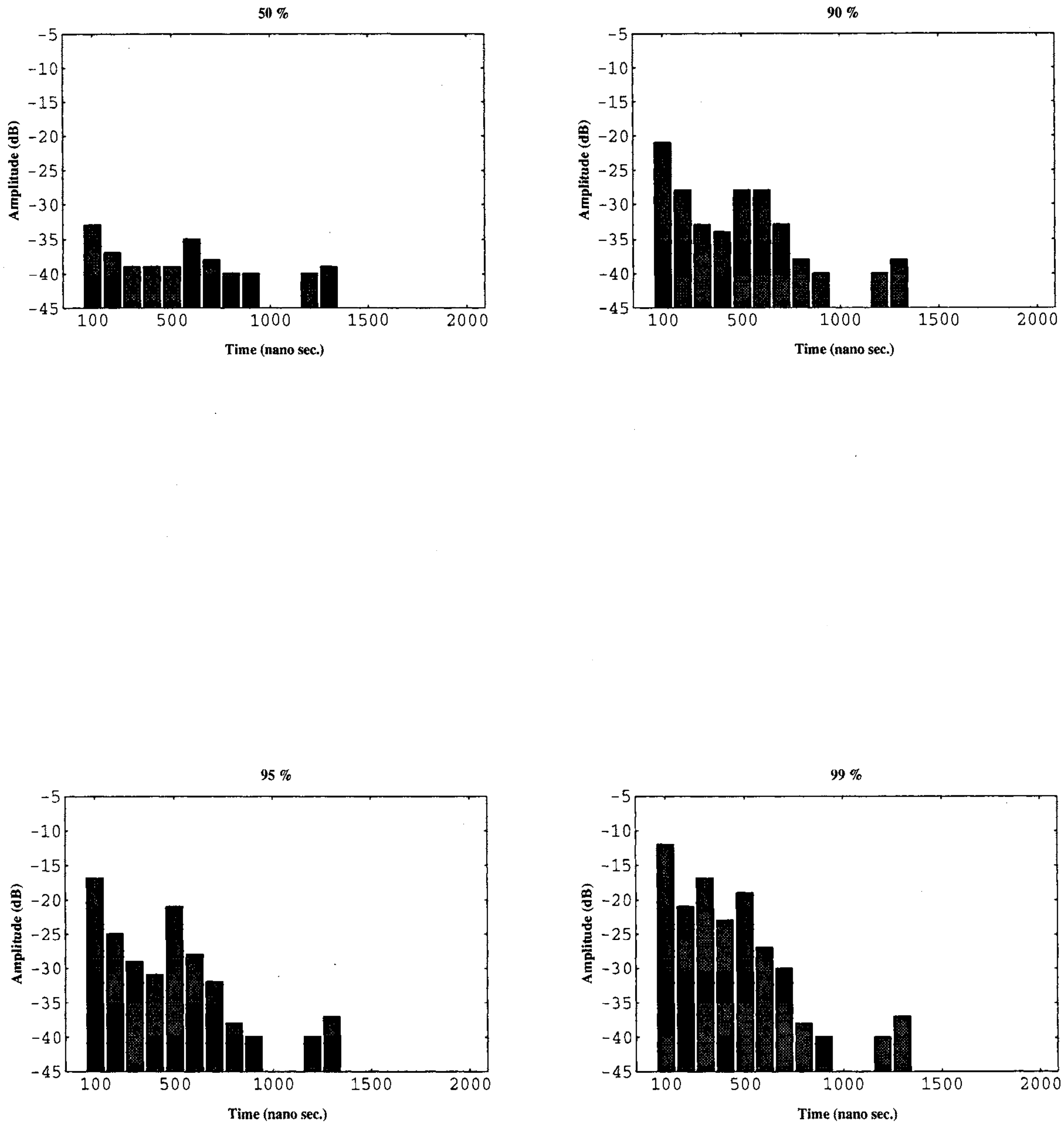


Figure 4-12: Home wiring echo amplitude vs. echo delay: (50 - 200 MHz)

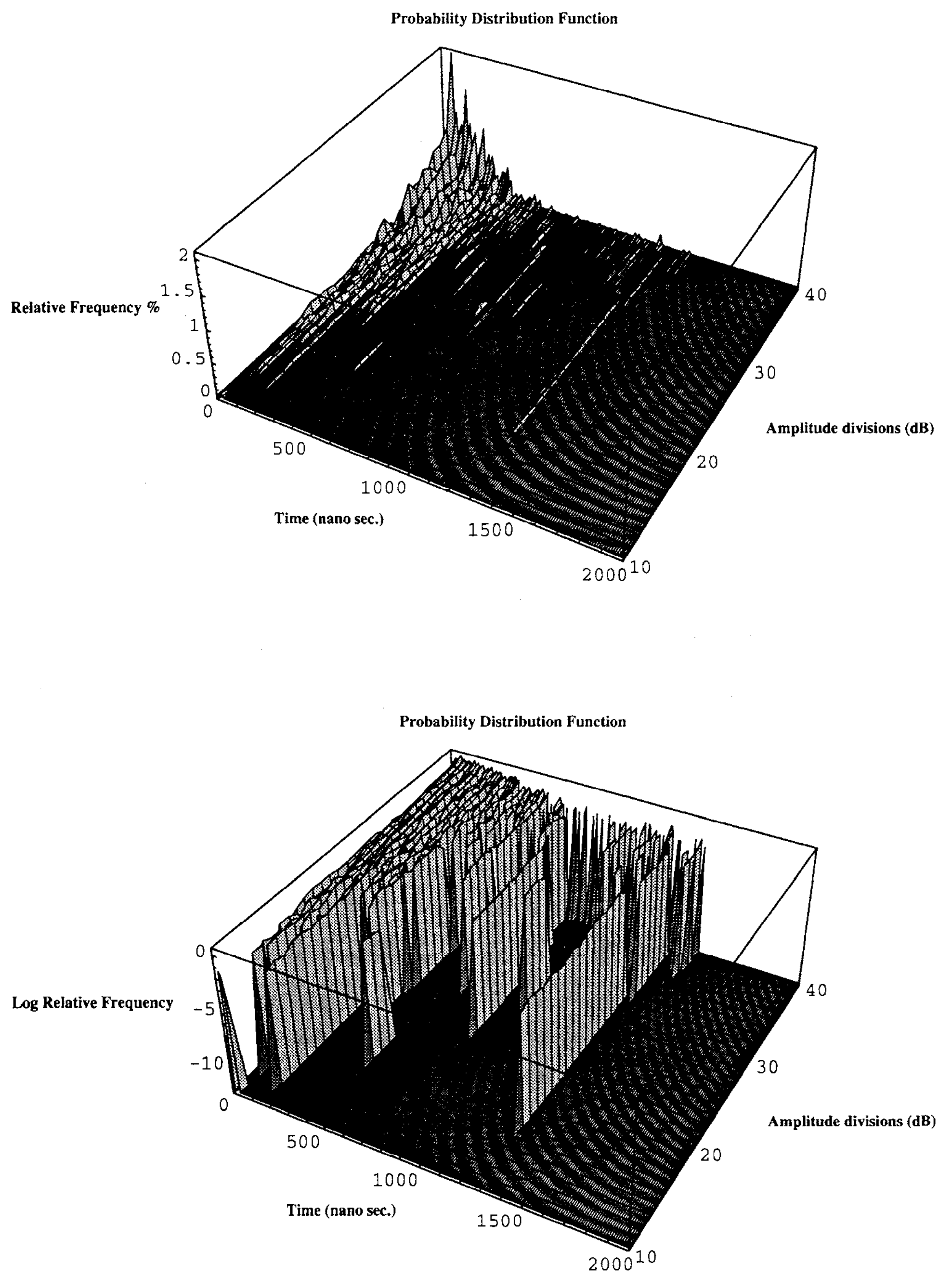


Figure 4-13: Home wiring distribution of echoes (222 - 558 MHz).

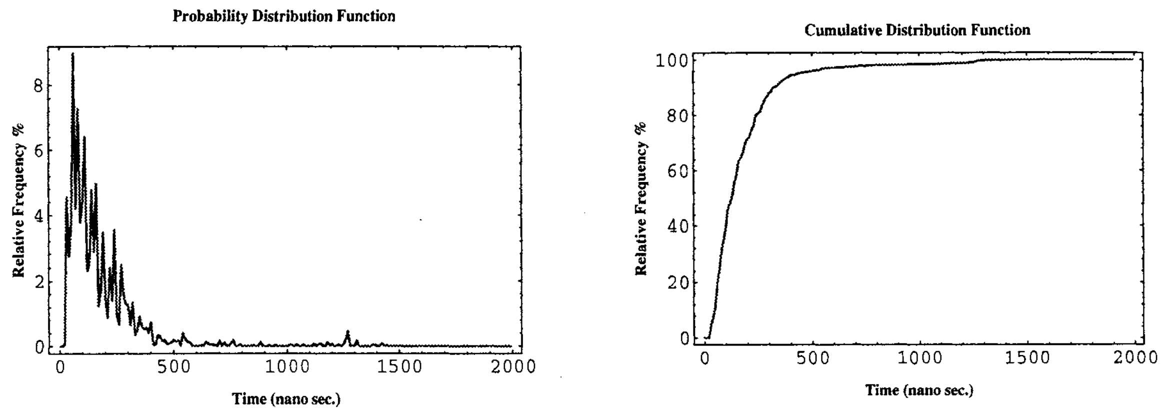


Figure 4-14: Home wiring histogram of echo delays (222 - 558 MHz).

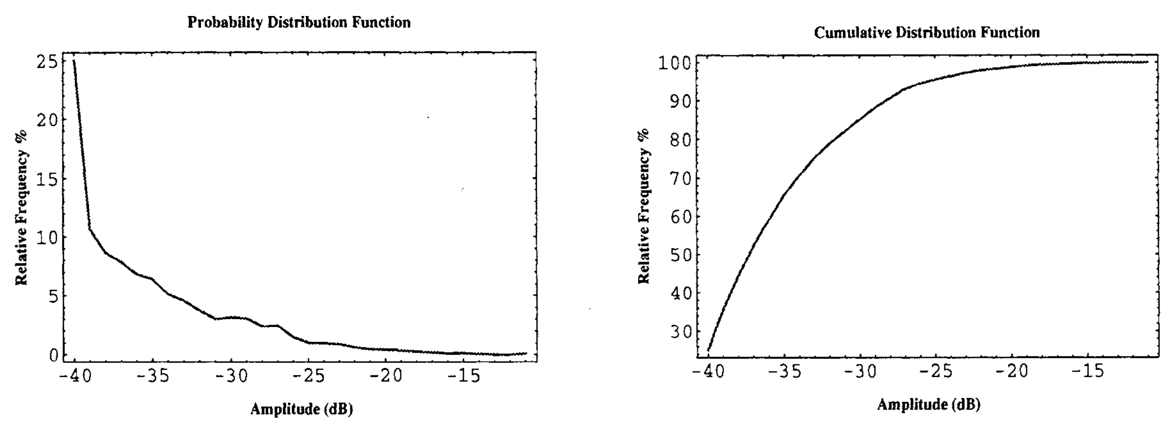


Figure 4-15: Home wiring histogram of echo amplitudes (222 - 558 MHz).

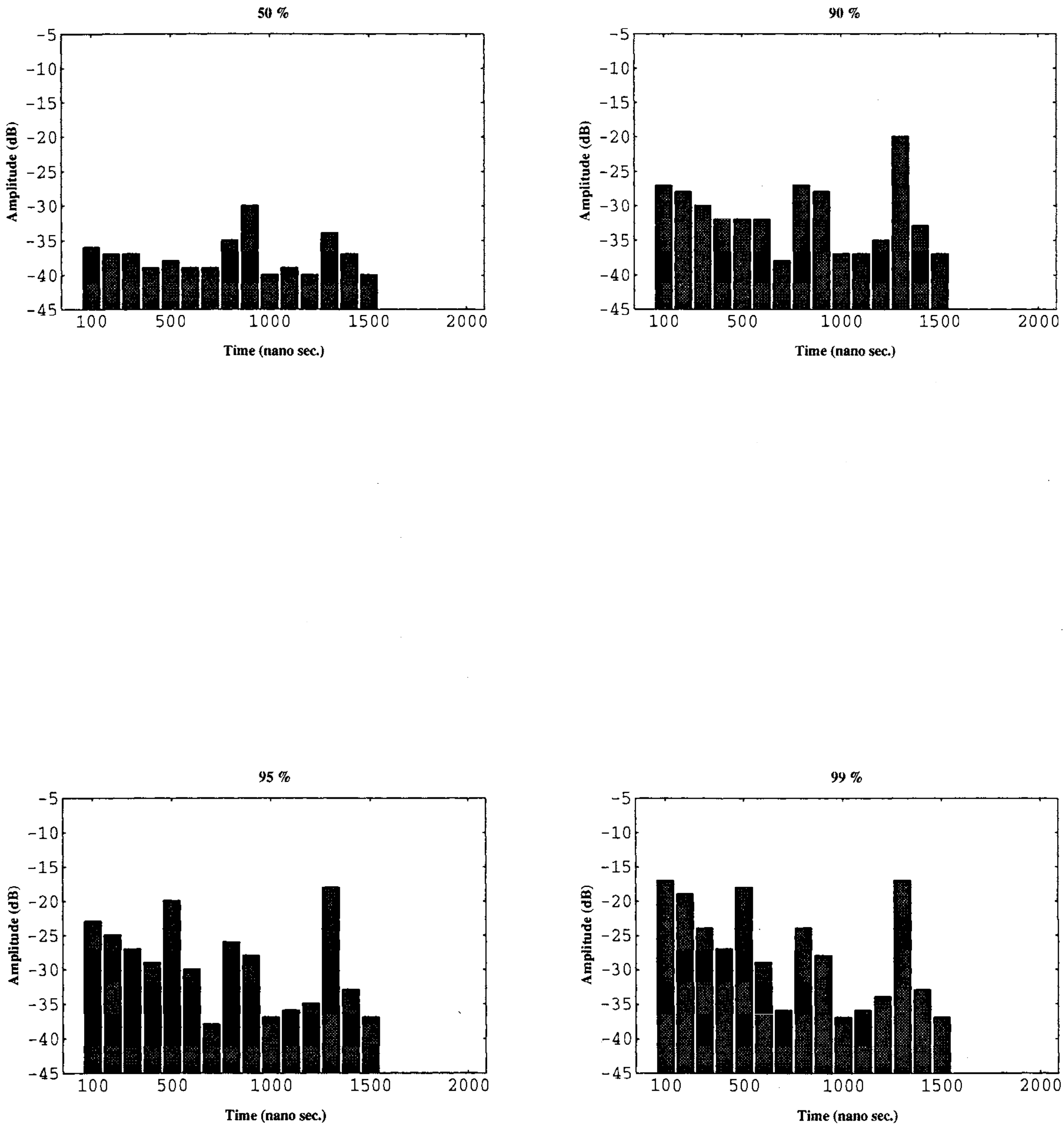


Figure 4-16: Home wiring echo amplitude vs. echo delay: (222 - 558 MHz)

4.3 Carrier Spectrum

Carrier spectrum statistics were generated for each 6-MHz cable channel where the carrier spectrum was measured. An amplitude range was determined to cover all the possible carrier levels. These statistics were collected as a histogram distribution into a table. Each row designates a particular amplitude of the carrier, and each column denotes a cable channel frequency. Therefore, a cell in the table stores a count for a given carrier level at a particular cable channel frequency (i.e., cable channel, carrier level).

The histogram for the carrier power is simplified by adding the column elements of this table to obtain a single column table with each row element representing the relative number of measurements at a given carrier power level, independent of channel frequency.

Figure 4-17 shows a statistical histogram analysis for measured carrier spectrum power at the tap. Note that an average carrier level of -32 dBm is obtained across all cable systems tested. In addition, the carrier level varies from -20 dBm to -60 dBm in this distribution.

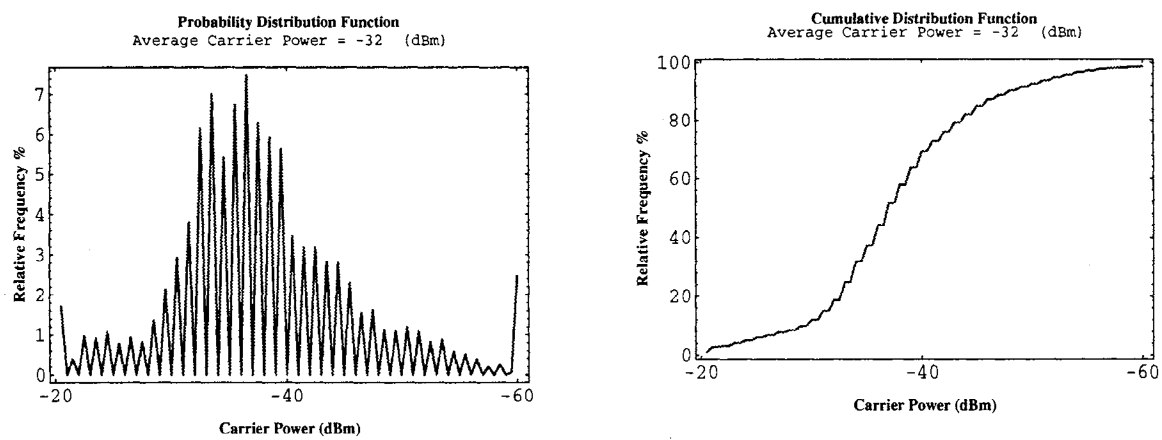


Figure 4-17: Tap histogram of the carrier spectrum power.

4.4 Noise Spectrum

The same approach is taken to calculate a histogram for the noise spectrum distribution as applied to the carrier spectrum. Recall from Section 3.3.4 that for each noise spectrum measurement, the entire frequency span was divided into 6-MHz cable channels. For each channel, noise power (dBm) is calculated by integrating a noise density over the entire 6-MHz channel. A suitable noise power range (-100 to -50 dBm) is selected. A histogram distribution for these levels was created from the calculation of noise power for all the measurements. The cells in this table represent a count for each noise power level in a given 6-MHz cable channel. The frequency range where the noise was measured is 222 to 558 MHz. The histogram table for the noise power is simplified by adding the column elements of this table to obtain a single column table with each row element representing the relative number of measurements at a given noise power level, independent of channel frequency.

Figure 4-18 shows a statistical histogram analysis for measured noise spectrum power at the tap. The graph on the left side of the figure shows the histogram for the noise power level with an average noise power of -72 dBm. The graph on the right-hand side shows the cumulative distribution of the noise power.

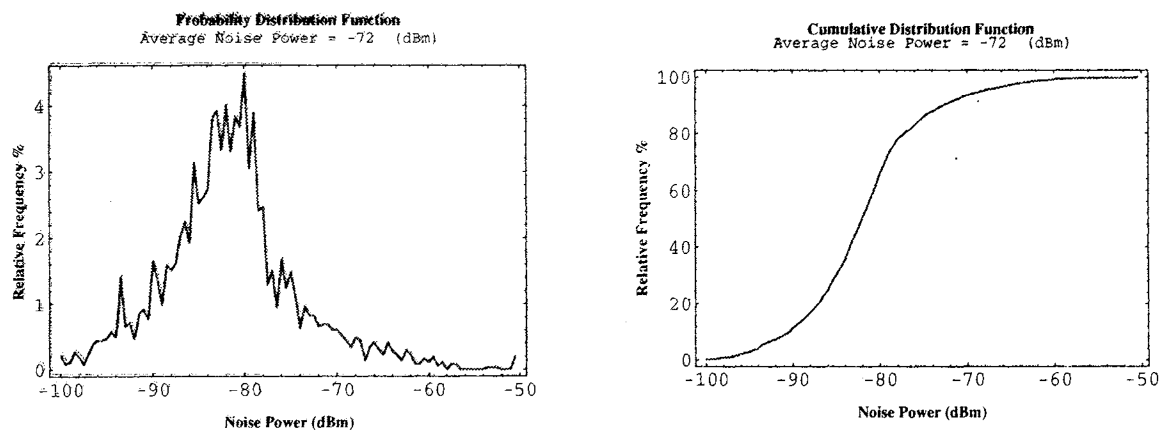


Figure 4-18: Tap histogram of the noise spectrum power.

4.5 Carrier-to-Noise Ratio

Figure 4-19 shows the CNR statistical histogram analysis calculated at the tap. An average CNR of 48 dB is obtained for all systems tested. Note that some sites also have close to 60 dB of CNR which was verified to be close to the headend site or the headend itself, where a smaller cascade of amplifiers were encountered in the transmission path.

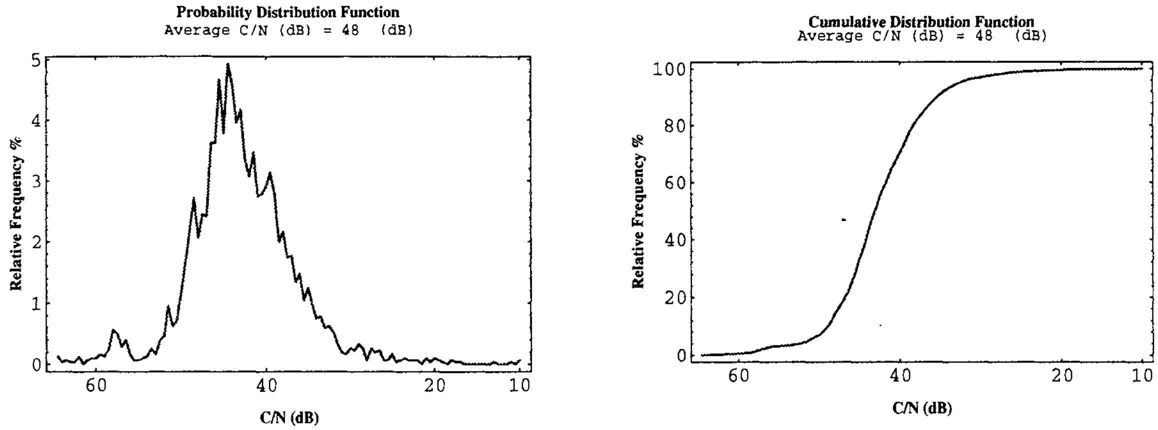


Figure 4-19: Tap histogram of the CNR.

4.6 Spurious Components

A two-dimensional histogram distribution is also used to determine spurious component statistics at the tap, where the first dimension is the spurious amplitude and the second dimension is a 6-MHz cable channel. Figure 4-20 shows the statistical histogram analysis for the spurious components, independent of channel frequency. An average spurious power of -68 dBm is obtained for all cable systems measured.

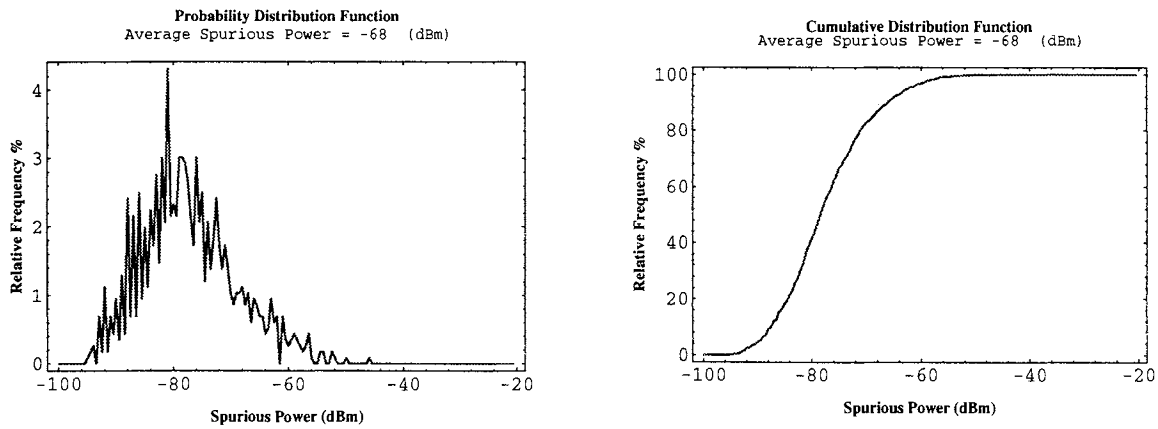


Figure 4-20: Tap histogram for the spurious components.

4.7 Composite Triple Beat

Figure 4-21 shows a statistical histogram analysis for the CTB level 12 MHz above the last active NTSC channel, measured at the tap. The average CTB level was found to be -93 dBm.

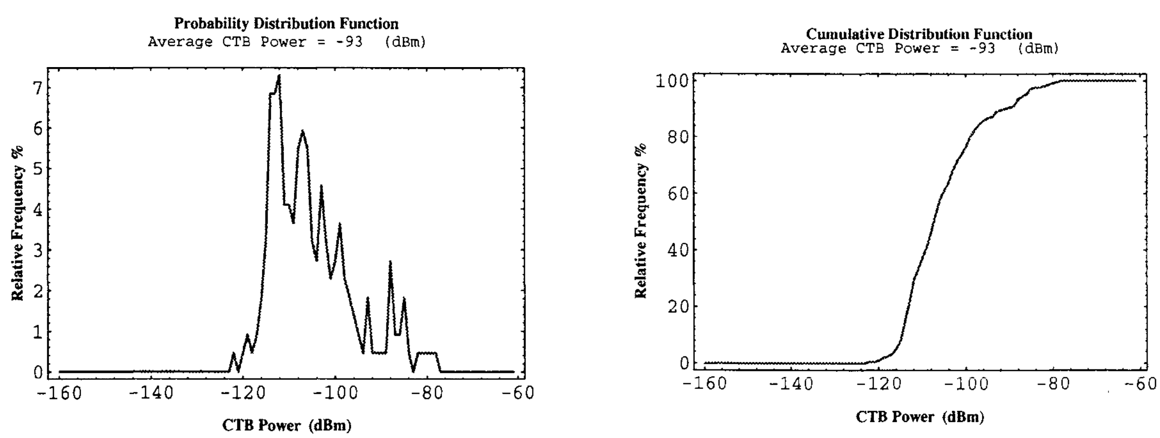


Figure 4-21: Tap histogram of the CTB.

4.8 Home Wiring Shielding Effectiveness

Figure 4-22 shows a statistical histogram analysis of the home wiring shielding effectiveness. The results of this study show that while most cable system home wiring shielding effectiveness is satisfactory, a significant portion is not. There is a variation of home shielding effectiveness both within a particular cable system and across all the systems. Across all measured cable systems, the shielding range is from the lowest of 16 dB of isolation to the highest of 83 dB. Average shielding was found to be 67 dB. Note in Table 4-2 that about 95% of homes provided more than 36 dB of shielding to external RF fields, hence 5% of homes have less than 36 dB shielding effectiveness.

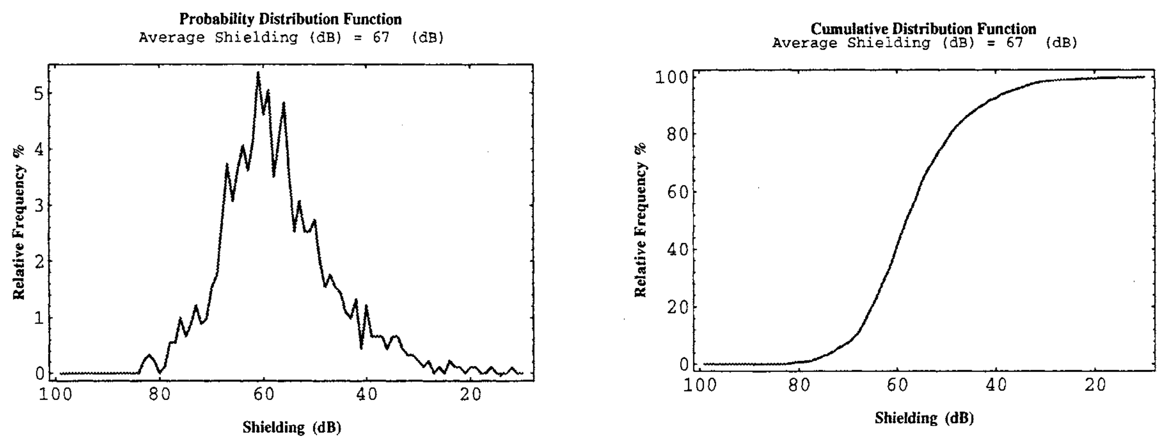


Figure 4-22: Histogram of the home wiring shielding effectiveness.

APPENDIX A.1 SIGNAL PROCESSING ALGORITHMS

In this appendix, a brief mathematical description of some of the signal processing algorithms used in the analysis of the digital characterization measurements are presented. In particular, the basic theory for the Fourier transform, spectral shaping windows, and median filters are described.

A.1.1 Fourier Transform

The Fourier transform is a mathematical operation applied to a continuous time domain signal x(t) to obtain a frequency domain signal representing spectral content of x(t). The time signal x(t) may represent a voltage waveform across or a current waveform through a circuit element. x(t) is called an analog signal because it is defined for all values of the time variable t. The Fourier transform of x(t) is denoted by X(Ω) and is also a continuous function of the frequency variable Ω (i.e., $-\infty \le \Omega \le +\infty$). x(t) and X(Ω) are related by:

$$X(\Omega) = \int_{-\infty}^{\infty} x(t)\, e^{-j\Omega t} dt \tag{A.1.1}$$

$$x(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} X(\Omega)\, e^{j\Omega t} d\Omega \tag{A.1.2}$$

The above equations represent a Fourier transform pair for continuous time signals. An example is given to clarify the meaning of A1.1 and A.1.2.

Example 1 - x(t) is defined as a rectangular pulse of duration 2T:

$$x(t) = \begin{cases} 0 & (|t| > T) \\ 1 & (|t| < T) \end{cases}$$

Hence, Fourier transform of x(t) is calculated using (A1.1) as follow:

$$X(\Omega) = \int_{-\infty}^{\infty} x(t)\, e^{-j\Omega t} dt = \int_{-T}^{T} e^{-j\Omega t} dt = \frac{2\sin(\Omega T)}{\Omega}$$

The result of Fourier transform is shown in Figure A1-1. Figure A1-1(a) shows the time signal x(t) and Figure A1-1(b) depict its Fourier transform $X(\Omega)$. It is worthwhile to note that even though x(t) is finite in duration (i.e., $x(t) = 0$ for $|t| > T$), its Fourier transform $X(\Omega)$ exists for all values of Ω (i.e., for $-\infty \leq \Omega \leq +\infty$).

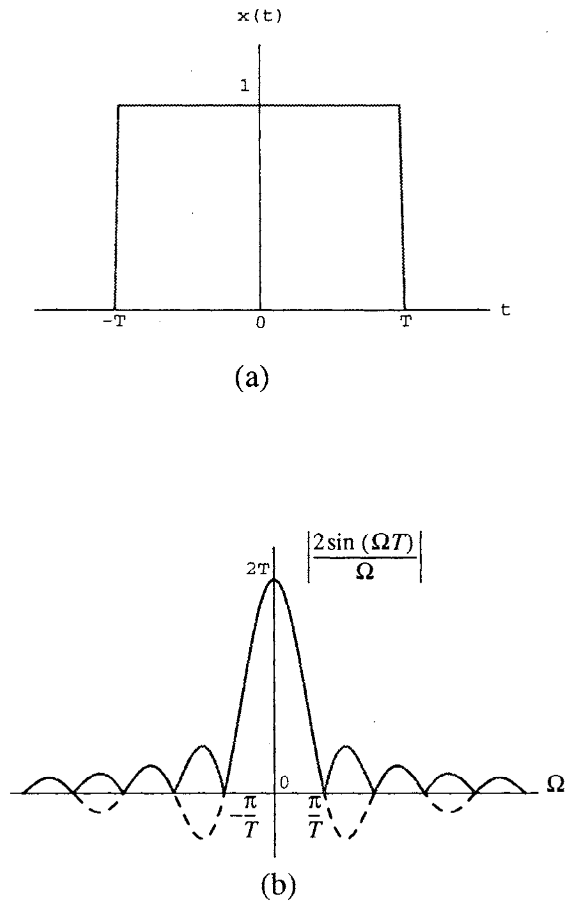


Figure A1-1: Fourier transform of a continuous time signal.

By sampling x(t) at equally spaced time intervals $t_n = nT_s$, (n an integer), a discrete time signal $x[nT_s]$ is obtained. If the sampling period T_s, or equivalently the sampling frequency f_s is selected appropriately, $x[nT_s]$ completely represents the original analog signal x(t). In this case x(t) is completely recovered from $x[nT_s]$ by using a low pass filter. For a discrete time signal $x[nT_s]$, the Fourier transform pair is given by the following equations:

$$X\left(e^{j\omega}\right) = \sum_{n=-\infty}^{\infty} x[n]\, e^{-j\omega n}$$

(A.1.3)

$$x[n] = \frac{1}{2\pi}\int_{-\pi}^{\pi} X\left(e^{j\omega}\right) e^{j\omega n}\, d\omega$$

(A.1.4)

where for simplicity $T_s = 1$. As can be seen, the Fourier transform of a discrete time signal is also a continuous function of the angular frequency ω. However, the angular frequency ω is only defined for $-\pi \le \omega \le +\pi$ compared with $-\infty \le \Omega \le +\infty$ case.

Example 2 - Suppose the signal x(t) from Example 1 is sampled to obtain x[n]. Let the number of non zero samples for x[n] be denoted by N, so that

$$x[n] = \begin{cases} 1 & (0 \le n \le N-1) \\ 0 & \text{elsewhere} \end{cases}$$

The Fourier transform of x[n] is calculated by using (A.1.3) as follows:

$$X\left(e^{j\omega}\right) = \sum_{n=0}^{N-1} x[n]\, e^{-j\omega n} = \sum_{n=0}^{N-1} e^{-j\omega n}$$
$$= \frac{\sin\left(\frac{N\omega}{2}\right)}{\sin\left(\frac{\omega}{2}\right)} e^{-j(N-1)\frac{\omega}{2}}$$

Both x(t) and $X(e^{j\omega})$ are depicted in Figure A1-2. It can be seen that the Fourier transform is a continuous function of the angular frequency ω. In addition, $X(e^{j\omega})$ is only defined for the frequency interval $-\pi \le \omega \le +\pi$.

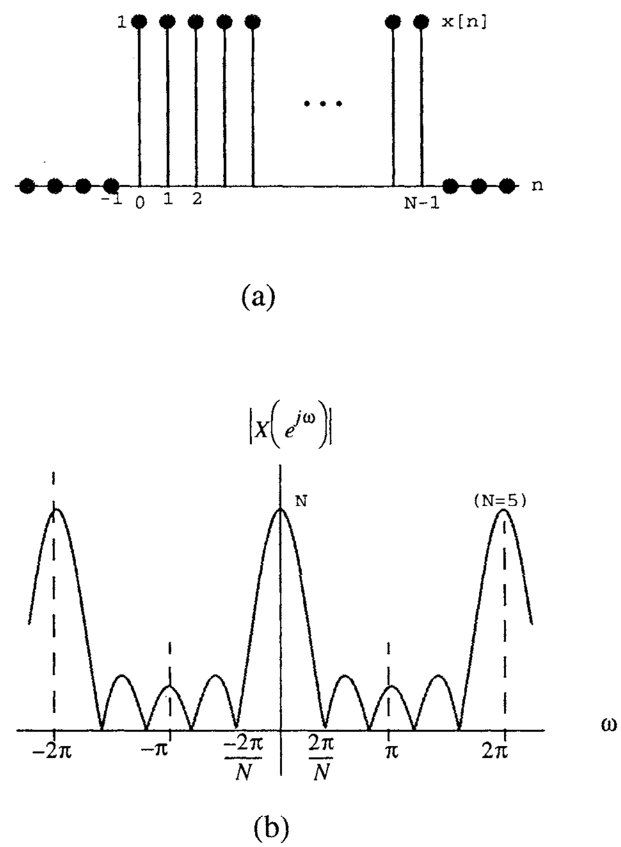


Figure A1-2: Fourier transform of a discrete time signal.

The concept of the Fourier transform can be further extended to represent discrete signals of finite duration by first defining the Fourier series for periodic signals. A periodic signal of period N is defined as $x_p[n] = x_p[n + rN]$ for integer r, $0 \le n \le N-1$. For periodic signals both forward and inverse transforms are discrete. Furthermore, the resulting forward Fourier series is also periodic with period N, that is, $X_p[k] = X_p[k+rN]$. A discrete Fourier transform (DFT) is obtained from the Fourier series by selecting a single period of $x_{ap}[n] = x_p[n + rN]$ for any given integer value of r. Therefore, the following pair of equations define the DFT relationship:

$$X_{ap}[k] = \sum_{n=0}^{N-1} x_{ap}[n] e^{-j2\pi n \frac{k}{N}}$$

(A.1.5)

$$x_{ap}[n] = \frac{1}{N}\sum_{k=0}^{N-1} X_{ap}[k]\, e^{j2\pi n\frac{k}{N}}$$

(A.1.6)

The DFT pair is a useful tool in analyzing sampled data waveforms. The above equations imply that a DFT is periodic both in the time and frequency domains.

A.1.2 Spectral Shaping Windows

Spectral shaping windows are useful as a frequency selective filtering process, where a particular range of frequency components is selected by emphasizing certain values over others. The simplest of these filters is a rectangular shaped window. When using this window, frequency components inside of the window are left unchanged (or simply scaled by a non-zero constant factor) and points outside are set to values of zero. A major disadvantage of this type of window function is the truncation of the resulting impulse response, which gives rise to Gibbs' phenomenon. Gibbs' phenomenon results from the approximation of an ideal filter specification (a rectangular window can be regarded as an ideal filter response) which requires an infinite number of coefficients for its impulse response (i.e., a requirement for the convergence of Fourier series). Thus, the resulting impulse response h[n] after applying a window function $W(e^{j\omega})$ is the periodic continuous convolution of the desired impulse response $h_d[n]$ with the inverse Fourier transform of the window $W(e^{j\omega})$, or w[n]. If the pulse shape of w[n] is narrow compared to variations in $h_d[n]$, then h[n] will "look like" $h_d[n]$. Thus the choice of window frequency response function $W(e^{j\omega})$ is governed by the desire to have w[n] as narrow a possible in time so as to faithfully reproduce the desired impulse response $h_d[n]$.

Another way of looking at the effect of a window is by investigation of its resulting shape in the time domain. This shape can be classified as a combination of a "main lobe" together with "side lobes." To maintain a good representation of the desired impulse response $h_d[n]$, "side lobes" of a chosen window should have amplitudes much lower than the "main lobe" and attenuated as time increases. If one examines the impulse response for a rectangular spectral shaping window, these "side lobes" are nearly as strong as the "main lobe" and their amplitudes do not decrease rapidly for increasing time. This problem can be reduced by using a less abrupt truncation of the Fourier series. By tapering the spectral shaping window smoothly to zero at each end, the height of the side lobe can be diminished at the expense of a wider main lobe. One example of such a spectral shaping window is the Blackman window. A function describing this window in the time domain is given below:

$$w[n] = 0.42 - 0.5\cos\left(\frac{2\pi n}{N-1}\right) + 0.08\cos\left(\frac{4\pi n}{N-1}\right), \qquad 0 \le n \le N-1$$

(A.1.7)

A.1.3 Median Filters

Median filtering is a nonlinear signal processing operation for removing impulse type noise from an input signal. A median filter is completely specified by a window size parameter. A window size of length L (L is odd) defines a median filter to span L samples of an input signal. A median filter operates by sliding a rectangular window of size L over the input signal one sample at a time. At each input sample instant n, L samples are selected from n - (L-1) / 2 to n + (L-1) / 2 assuming that n is the center of the median filter window. The median value of these samples is used to replace the sample located at the center of window for the original input signal.

There are both recursive and nonrecursive median filters. A recursive median filter is one that replaces original input signal samples with their median values and uses both the original input samples and previously computed median samples for successive median filtering. A nonrecursive median filter on the other hand uses only the original samples of the input signal. A root signal is invariant to the median filtering process since it has constant regions and transition regions and no impulses. In other words, a signal that is a root will not be changed if it is passed through the median filter. For a recursive median filter, a root signal is achieved through a single iteration. In a nonrecursive median filter, normally several median filtering operations are required to achieved a root signal. The length of a median filter effects the output of the filter. A large window size will remove wider impulses through a single iteration.

APPENDIX A.2 TEST PROCEDURE MANUAL

A.2.1 Headend Site Procedure

- Install remote-controlled equipment
- Warm up equipment, activate cell phone and check it
- Calibrate spectrum analyzers
- Program transmitter (first day)
- Calibrate link receiver
- Couple into combiner (with amp if necessary)
- Copy and modify script files
- Calibrate long and short cables
- Connect tap cable to launch test point
- Check sweep level
- Test 1 (save first day data only)
- Tests 3, 4 5, 6 (first day only)

A.2.2 Test Site Procedure

- Select cable length
- Check cable calibration (S11, S21)
- Connect house cable to outlet
- Copy and modify script files
- Tests 1, 2
- Connect tap cable to multitap and terminate drop cable
- Tests 1, 3, 4, 5, 6, 7, 8, 9 and fill out site form
- Remove termination from drop cable and move tap cable from multitap to drop cable
- Tests A, B
- Restore cable service

A.2.3 Remote Control Transmitter Installation Procedure

This procedure describes the installation and operation of the remote communication link between the digital communications test van and the HP 11402 Link Transmitter located in the headend at each test site.

The following figure shows a block diagram of the remote equipment.

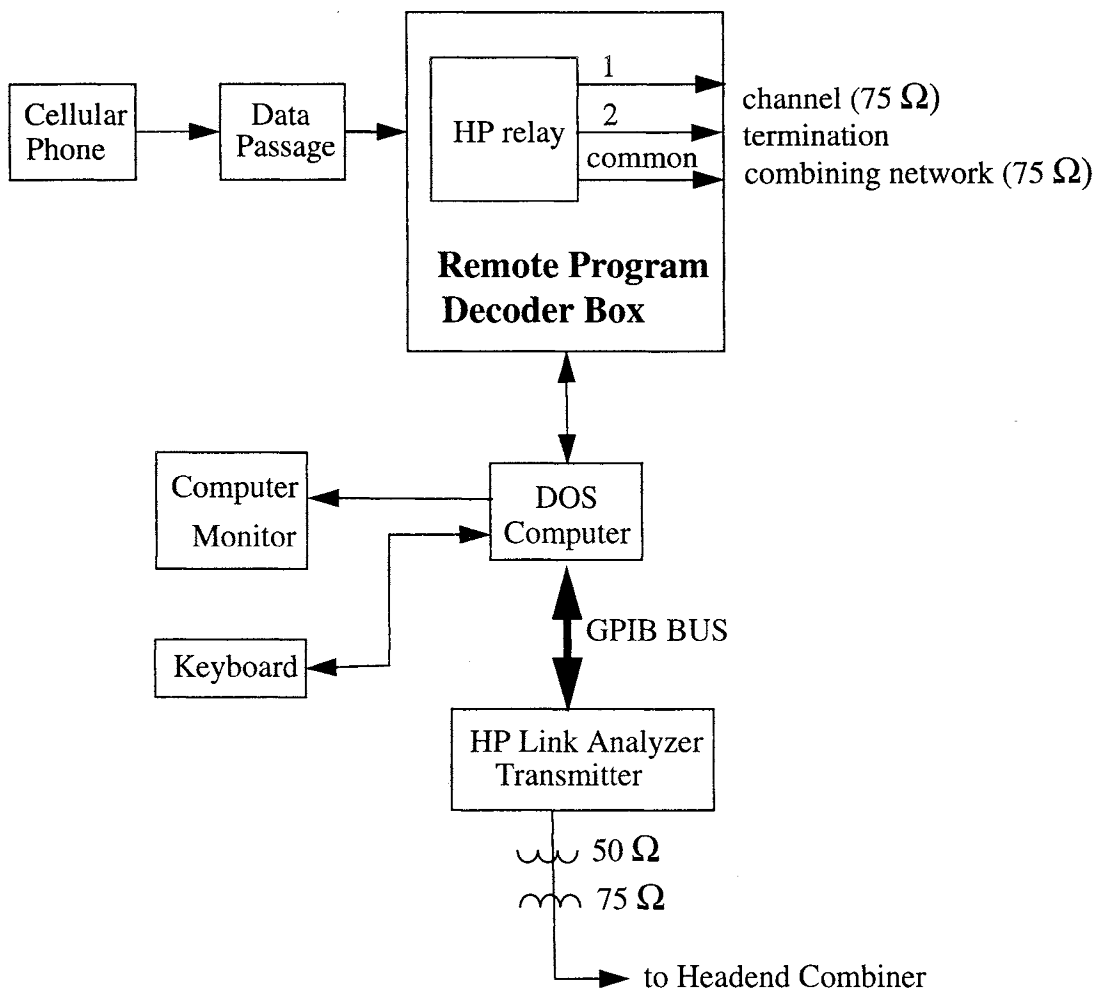


Figure A2-1: Remote Control Link Transmitter.

1. Turn on and warm up equipment. Turn on cellular phone and activate roaming (*18 SEND).

2. Install the equipment in accordance with the figure. Note that all connectors are labeled for their correct location. All equipment will be rack mounted so that the only connections that need to be made are the monitor, keyboard and the cellular phone system.

3. Start the remote control computer program. The remote program will automatically start when the computer is turned on. If the program needs to be terminated, then the CTRL C keys should be pressed. If the program is terminated and the computer returns to DOS, restart the program by typing REMOTE. The cellular phone must be turned on.

The remote program will allow the link transmitter to recall 4 stored memory locations. To access the locations dial 303-550-7814 (the headend cellular phone) or if a dedicated direct phone line in the headend can be used, dial that number. (The tone decoder instructions will be located in the van). The phone will ring twice and automatically be answered by the tone decoder. A five-second tone will tell the user that the connection has been made and the system is ready for use.

4. Check the remote control operation. At the headend, the link transmitter remote controller has already been preprogramming to recall memory states 1, 2, 3, and 4. Pressing the 1, 2, 3, or 4 on the van phone will load the instrument state stored in the respective memory location. The relays will stay in the selected position. A short tone in response indicates that the relay selected has been activated. A buzz indicates that your command was not completed and must be reentered.

In addition, relays 5 and 6 on the tone decoder can be activated to control an HP RF relay. Activating relays 5 or 6 will not affect the state of the link transmitter. If needed, this relay can cut off a channel that is in the test frequency band. This allows the channel to be turned off for a short amount of time while testing is being done. Activating relay 5 on the tone decoder via the cellular phone will allow the channel to be turned on and activating relay 6 will turn the channel off.

5. Observe the following cautions:

The cellular phone connection must be gracefully terminated prior to making a measurement. Prior to hanging up, the user must turn off the tone decoder or the user will have to wait four minutes for time out on the toned decoder. To turn off the tone decoder, press #8 or *8 on the phone, then hang up.

If problems occur with the remote connection, the status of what relay is selected will be displayed on the monitor in the headend.

If another number is selected (5, 6,... etc.) the tone decoder will activate that relay and the status will go to "No Relay selected Previous relay selected was...". The link transmitter will stay in the previous state (recall 1, 2, 3, or 4) that it was in and will not change until relay 1, 2, 3, or 4 is activated.

A.2.4 Headend Procedure

1. First calibrate both spectrum analyzers to be used as a link transmitter and receiver pair.

a. Allow the spectrum analyzers to warm up for 20 minutes.

b. Hit preset.

c. Select the spectrum analyzer mode.

d. Connect the short HP 50-ohm cal cable from cal to input.

e. Calibrate amplitude and frequency, wait about 8 minutes, and store the calibration each day.

2. Program the link transmitter.

a. Hit preset again.

b. Select the link transmitter mode.

c. Set center frequency, span, and baseband frequency. Use the maximum start and stop frequencies for the system under test, with a 2 MHz guard band from existing services, or 2 MHz from the top of the highest channel in use. The maximum frequency sweep width that should be used is 100 MHz. Use the 55 kHz baseband sweep frequency, and a modulation index of 1 (the default).

d. Turn on the power (aux. ctrl) and set the output level from the headend to video sync tip level. Store this state in register 2.

e. Repeat the setup from step a, going at least 12 MHz into the rolloff. Store this in register 3. This will be used for a rolloff test.

f. Recall 1, turn the RF power off, and store it in register 1. This register will be used to turn off the sweep signal.

Note: if there is more than 100 MHz of spectrum open in a system, then the sweep will need to be divided into two ranges.

3. Calibrate the link receiver.

a. Connect a cable from RF out to RF in.

b. Hit preset.

c. Select link receiver mode.

d. Set center frequency and span covering all sweep ranges.

e. Set baseband frequency to 55 kHz.

f. Hit cal.

g. Select cal frequency range for programmed frequency range.

4. Insert sweep signal into the cable system. Use a port on the combiner network if possible. If necessary, an amplifier may be inserted to boost the level. Keep cable lengths short to avoid long reflections. The sweep transmitter has been lab tested, and does not produce any spurious above -55 dB relative to the video carriers.

5. Fill out the system questionnaire on the specifics of the cable system's construction and operation.

6. Copy the measurement script files from the template directory c:\menu\scripts to the headend site directory by executing the command:

copysite \menu\scripts [headend directory]

7. Edit the script files for the start and stop sweep frequencies for the link receiver and spectrum analyzer. Edit the files for any parameter changes such as CTB measurement frequency.

8. Calibrate the network analyzer for both sets of test cables. Check the calibration of the test cables every day. This should be done at a time during the day when the temperature is near the mean (average) for the test day. Recalibrate if the previously saved cal is not accurate.

The 100-ft cables (RG-6) are calibrated first, and the transmission cal results (S21) and instrument state are stored in register 1. Next, the reflection cal results (S11) and instrument state are stored in register 2.

Calibration procedure for transmission:

1. Hit PRESET

2. START 50 MHz

3. STOP 600 MHz

4. MENU; NUMBER OF POINTS 1601

5. MEAS; TRANSMISSION

6. FORMAT; LOG MAG

7. CAL; CALIBRATE MENU; RESPONSE

8. SHORT (F)

9. OPEN (F)

10. THRU

11. DONE RESPONSE

12. Save in REG1 for transmission.

Calibration procedure for reflection:

1. Hit PRESET

2. START 180 MHz

3. STOP 480 MHz (these frequencies are chosen to avoid traps)

4. MENU; NUMBER OF POINTS 401

5. MEAS; REFLECTION

6. FORMAT; SMITH CHART

7. CAL; CALIBRATE MENU; REFLECTION 1 PORT

8. OPENS; OPEN (F)

9. SHORTS; SHORT (F)

9. LOAD

10. DONE 1 PORT CAL

11. Save in REG2 for reflection.

Next, the computer is used to extract the information from REG1 and REG2 and store it in a file for setup of tests A and B. Under the test CALIBRATION menu, select Save Calibrations. Select the appropriate cable length (100 feet). Hit return to enter the default cal output data file SHORTCAL.DAT. Select Continue to save the instrument setup plus cal data to the file.

Now repeat the whole calibration procedure for the 150-ft RG-11 cables. The file name used for the RG-11 cables is "LONGCAL.DAT".

WARNINGS:

1. Don't mix up the cables that go to the "tap" and "house"

2. Use Trompeter connectors for good return loss.

3. Calibrate out the effects of patch panels.

4. Always calibrate new cables.

9. Connect tap cable to headend launch amp test point.

10. Set transmitter sweep level to be equal to video carrier level.

11. Lock link receiver using test 1.

12. Characterize the signal leaving the headend using tests 3, 4, 5, and 6 (first day only).

A.2.5 Home Site Procedure

In addition to filling out the form, note anomalies in the notebook and use the tape recorder (dictating machine) as a verbal backup of any interesting relevant data or facts for the measurements.

1. Select the appropriate length cables for the distances between the truck and the test points.

2. Check the calibration for the selected cables. Use the computer to restore the information from the file to the network analyzer. The computer will put transmission cal results in REG3, and reflection cal results in REG4. Registers 1 and 2 are not re-written.

Under the test CALIBRATION menu, select Restore Calibrations. Select the appropriate cable length. Enter any temporary output data file (e.g., temp). Select Continue to restore the instrument setup plus cal data from the previously saved cal file.

Check that the cal in REG3 and REG4 is good for the cables.

3. Connect the house cable to the outlet inside the house.

4. Copy measurement script files from a previous site to the new site directory by executing the command:

copysite [old site directory] [new site directory]

Edit the files for any parameter changes such as frequency sweep range if necessary.

5. Perform tests 1 and 2.

6. Disconnect and terminate the drop cable from the multitap and connect the tap cable to the multitap.

7. Perform tests 1, 3, 4, 5, 6, 7, 8, 9, and fill out site form.

8. Remove the termination from the drop cable. Remove the tap cable from the multitap and connect it to the drop cable.

9. Perform tests A and B.

10. Restore cable service.

A.2.6 Test Procedures

A.2.6.1 Output Data Files

All test procedures place the measurement data into an output data file. The file naming convention is as follows:

Output Data File: AZ.nYX

where: A = System(A, B,...); Z = location number (1, 2,... where Z = 1 denotes the headend location); n = test n; Y = sweep range of link transmitter in test 1 (A, B,...); and X = next test (2 or 3) to be run after locking link receiver in test 1.

A.2.6.2 Summary of Tests

1. Setup: Lock Link Receiver
2. AF and GD: Headend through House
3. AF and GD: Headend through Tap
4. Spectrum: Headend through Tap
5. Noise: Headend through Tap
6. Spurious: Headend through Tap
7. CTB: Headend through Tap
8. Field: FM Antenna

9. Shielding: House Wiring

A. AF and GD (S21): Tap through House

B. AF and GD (S11): Tap through House

At the Headend, a Tap Only, an AML Hub or a Fiber Hub:

Do only tests 1,3,4,5,6, and 7.

A.2.6.3 Test 1 - Setup: Lock Link Receiver

This test sets up the link receiver for data capture in tests 2 and 3.

Use the HP8593E in link receiver mode. See wiring diagram for test 1. The outlet that the main TV is connected to is the input test point. Make sure that no devices in the home are putting out local oscillator radiation. Turn on the link transmitter by phone. Load the register for a normal sweep or for a rolloff sweep. (Caution, only do a rolloff sweep if you determine less than 12 dB rolloff at the band edge using a manual spectrum analyzer sweep). Make very sure that the link receiver start and stop frequencies are the same ones that the link transmitter is using. Connect the input signal and run the measurement script from measure sub menu. This will lock the link receiver and help determine the correct external attenuator setting. Check on the link receiver that the input sweep level is -20 dBm, +/-0.5 dB.

external attenuator: Value needed to give -20 dBm to link analyzer.

(If -20 dBm is not achievable, set the external attenuator to 0)

input test script: TEST1A.scr, TEST1B.scr,... (one per sweep range)

output data file: AZ.1YX

A.2.6.4 Test 2 - AF and GD: Headend through House

See wiring diagram for test 2. Capture the amplitude flatness and group delay (AF & GD). Enter the external attenuator setting.

The averaged amplitude flatness is stored in internal trace 1, and the averaged GD is stored in internal trace 2.

Plot the amplitude flatness and group delay. Write the external attenuator setting on the plot.

external attenuator: TBD (value needed for -20 dBm input level)

input test script: TEST2.scr

output data file: AZ.2Y

Note that less than 50 nsec for peak-to-peak group delay is normal.

A.2.6.5 Test 3 - AF and GD: Headend through Tap

See wiring diagram for test 3. Repeat test 1 to lock the link receiver prior to starting this test. The attenuator will probably need to be adjusted. Make sure the disconnected drop is not touching the cable system or tap. Terminate the end of the drop cable. Capture the amplitude flatness and group delay (AF & GD).

external attenuator: TBD (value needed for -20 dBm input level)

Input test script: TEST3.scr

Output data file: AZ.3Y

Plot the amplitude flatness and group delay. Write the external attenuator setting on the plot.

A.2.6.6 Test 4 - Spectrum: Headend through Tap

See wiring diagram for test 4. Sweep at least to the top of the bandwidth capability of the test site. Be careful not to overload the spectrum analyzer input. The purpose of this test is to record the spectrum flatness and carrier level. Use the attenuator setting found in test 3. Leave the link transmitter sweep on for a reference carrier level. Note the sweep carrier level at the CTB measurement frequency.

resolution bandwidth: 300 kHz

video bandwidth: 300 kHz

sweep time: 10 sec.

internal attenuator: 10 dB

max hold on

external attenuator: same as test 3

scale per division: 5 dB

input test script: TEST4.scr

output data file: AZ.4

Plot the spectrum. Write the external attenuator setting on the plot.

A.2.6.7 Test 5 - Noise: Headend through Tap

See wiring diagram for test 5. Call the headend and turn off the sweep using the previously described remote communication procedure. Put an appropriate fixed high pass filter ahead of the spectrum analyzer to avoid overload. Set the external attenuator to 0 if this can be done without incurring CTB effects. Pull the cable off of the attenuator and measure noise floor of the system above the noise floor of the analyzer. This number is the "rise," and should be at least several dB. This level may be difficult to obtain if the tap level is low or if the system has a very low noise floor. Verify that the noise floor is stable from sweep to sweep. Note the external attenuator setting and the rise above the noise floor. Also note the noise power at the CTB measurement frequency.

resolution bandwidth: 100 kHz

video bandwidth: 1 kHz

sweep time: auto

internal attenuator: 0 dB

external attenuator: 0 dB if possible without CTB problems

input test script: TEST5.scr

output data file: AZ.5

Plot the noise spectrum. Write the external attenuator setting on the plot. Also write the "rise" that was obtained on the plot.

A.2.6.8 Test 6 - Spurious: Headend through Tap

See wiring diagram for test 6. This test uses the same wiring as test 5, except the spectrum analyzer sweep is optimized to detect ingress that may be transient. The start and stop frequencies are the same as test 5.

resolution bandwidth: 300 kHz

video bandwidth: 300 kHz

sweep time: auto

acquisition time: 60 sec

max. hold on

internal attenuator: 10 dB

external attenuator: 0 dB if possible without CTB problems input test script: TEST6.scr

output data file: AZ.6

Plot the spurious results. Write the external attenuator setting on the plot.

A.2.6.9 Test 7 - CTB: Headend through Tap

See wiring diagram for test 7. Using the Calan tunable filter, measure the CTB on a vacant channel near the top of the occupied spectrum (approximately 12 MHz above the highest channel). Position the marker manually at the top of the beat peak if necessary. If no beat can be found, measure the noise floor and note that the beat is less than the noise level. Make sure that the CTB being measured is not being generated by the analyzer or external amplifier by verifying that the CTB drops dB-for-dB with the attenuator increase.

resolution bandwidth: 30 kHz

video bandwidth: 100 Hz

sweep time: auto

averaging: 16

external attenuator: 0 dB

internal attenuator: 0 dB (10 dB if the analyzer is generating beats)

input test script: TEST7.scr

output data file: AZ.7

A.2.6.10 Test 8 - Field: FM Antenna

See wiring diagram for test 8. Connect the antenna on top of the truck to the spectrum analyzer through the FM bandpass filter. Set the analyzer frequency from 85 to 110 MHz. Set the external attenuator as low as possible, while avoiding generating beats in the analyzer. Record the spectrum and the attenuator setting.

Plot the received FM spectrum from the antenna. Write the external attenuator setting on the plot.

resolution bandwidth: 100 kHz

video bandwidth: 1 kHz

sweep time: auto

frequency range: 85 - 110 MHz

averaging: 16

internal attenuator: 10 dB (0 dB for weak FM signals)

external attenuator: TBD (to avoid display clipping)

input test script: TEST8.scr

output data file: AZ.8

A.2.6.11 Test 9 - Shielding: House Wiring

See wiring diagram for test 9. Connect the house wiring to the spectrum analyzer through the FM bandpass filter. Terminate the drop at the tap. Set the attenuator as low as possible, while avoiding generating beats in the analyzer (normally 0 dB.). Record the spectrum and the external attenuator setting.

resolution bandwidth: 100 kHz

video bandwidth: 1 kHz

sweep time: auto

frequency range: 85 - 110 MHz

averaging: 16

external attenuator: 0 dB

internal attenuator: 0 dB

input test script: TEST9.scr

output data file: AZ.9

Plot the spectrum from the house wiring. Write the external attenuator setting on the plot.

A.2.6.12 Test A - AF and GD (S21): Tap through House

The network analyzer calibration should have been checked to insure that the saved cal is still valid. The object of this test is to characterize the house wiring. Note on the form whose house it is, and their job (i.e. tech, CSR, installer, manager, etc.)

See wiring diagram for test A. The output from the node used to drive the main TV set is returned to the truck. If the homeowner has a description of the house wiring, record it on the site form and note if any amplifiers or traps are in use. Note which cables (RG-6 or RG-11) are used at this location. Use high return loss connectors (Trompeter brand). Sweep from 50 MHz to 600 MHz (set during calibration).

Record the frequency response data. Note that traps in the line will skew the data. Center and rescale the displays for 2 dB/division amplitude flatness and 10 nsec/division group delay if necessary. Note that if there is an amplifier in the house, the network analyzer's input may be saturated. If this happens, use the external attenuator and record the value.

input test script: TESTA.scr

output data file: AZ.A

Plot the frequency response from the house wiring.

A.2.6.13 Test B - GD and AF (S11): Drop Reflection

The purpose of this test is to perform a time domain reflection (TDR) to determine house wiring topology, and measure distances electrically. The network analyzer calibration should have been checked to ensure that the saved cal is still valid.

See wiring diagram for test B. The setup is identical to test A. Sweep from 180 to 480 MHz (set during calibration). Record the transformed data.

input test script: TESTB.scr

output data file: AZ.B

Plot the log magnitude time domain reflection response.

A.2.7 Measurement Data Verification

Record these results manually in the notebook:

1. Signal level at tap

2. Frequency response at tap

3. Carrier to noise at the tap

4. CTB ratio at the tap

5. House shielding effectiveness (test 8, test 9)

6. First few transmission echoes and amplitudes.

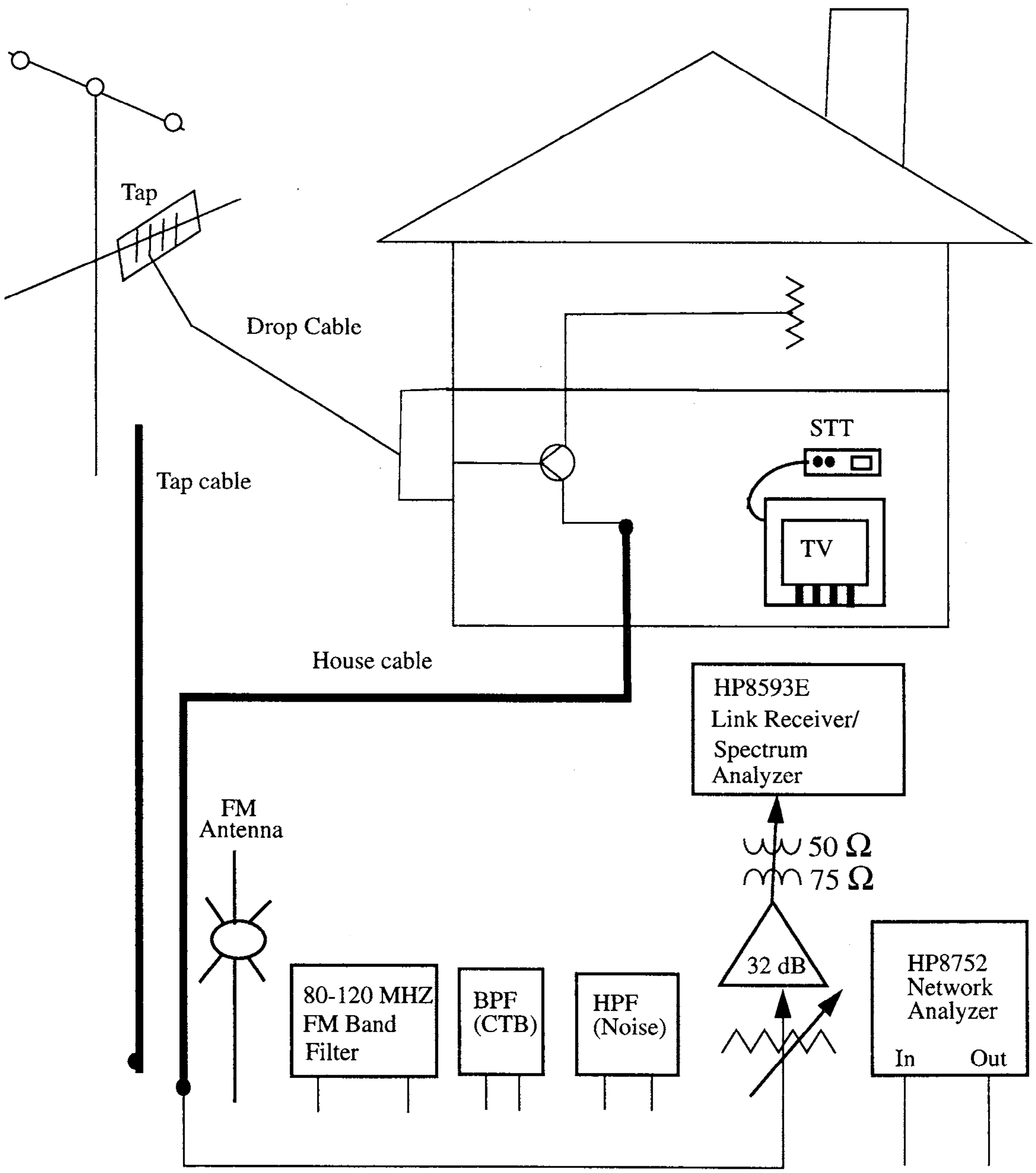


Figure A2-2: Test 1 and test 2: AF and GD - Headend Through House.

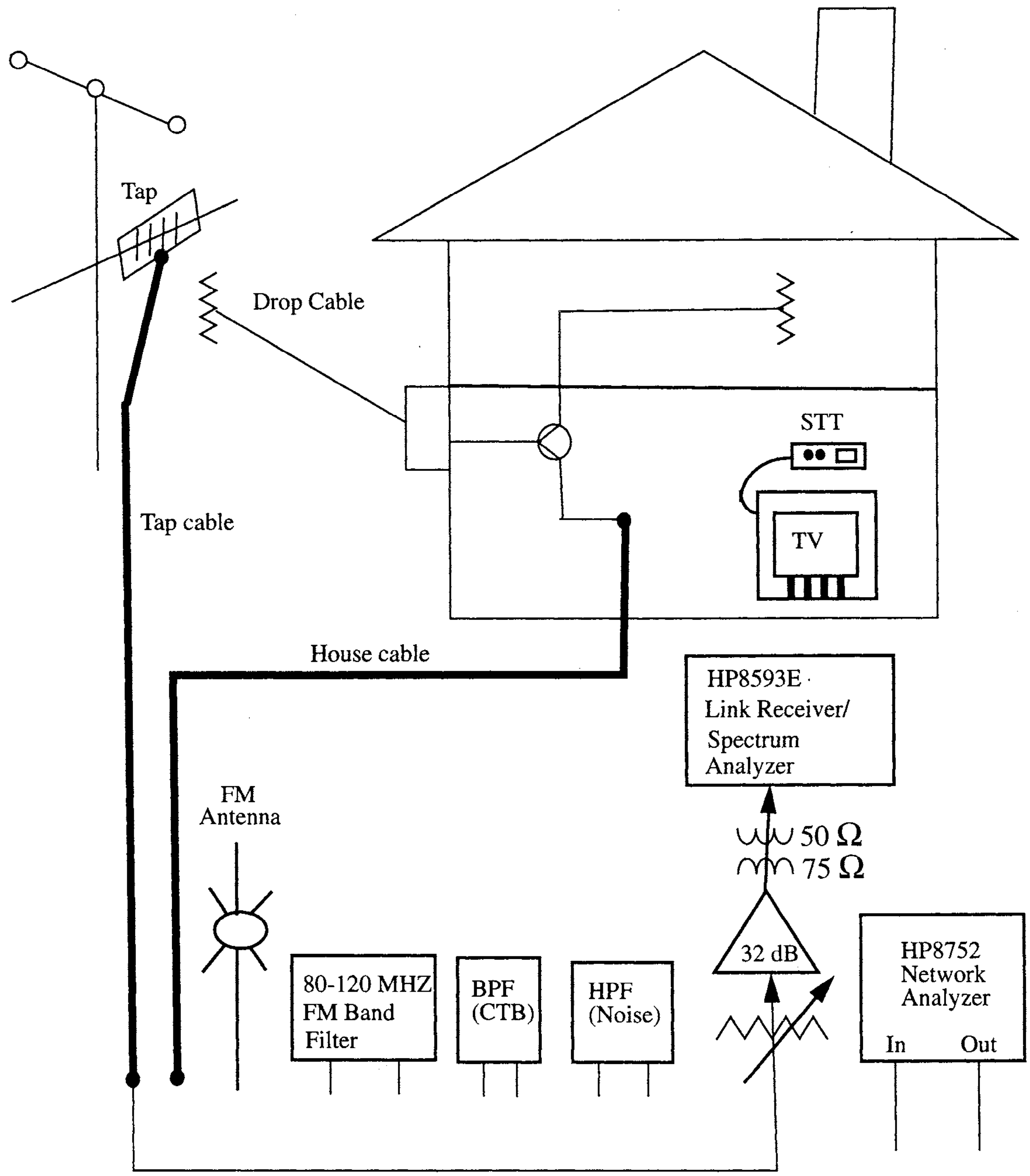


Figure A2-3: Test 1 and test 3: Af and GD - Headend Through Tap. Test4: Spectrum - Headend Through Tap.

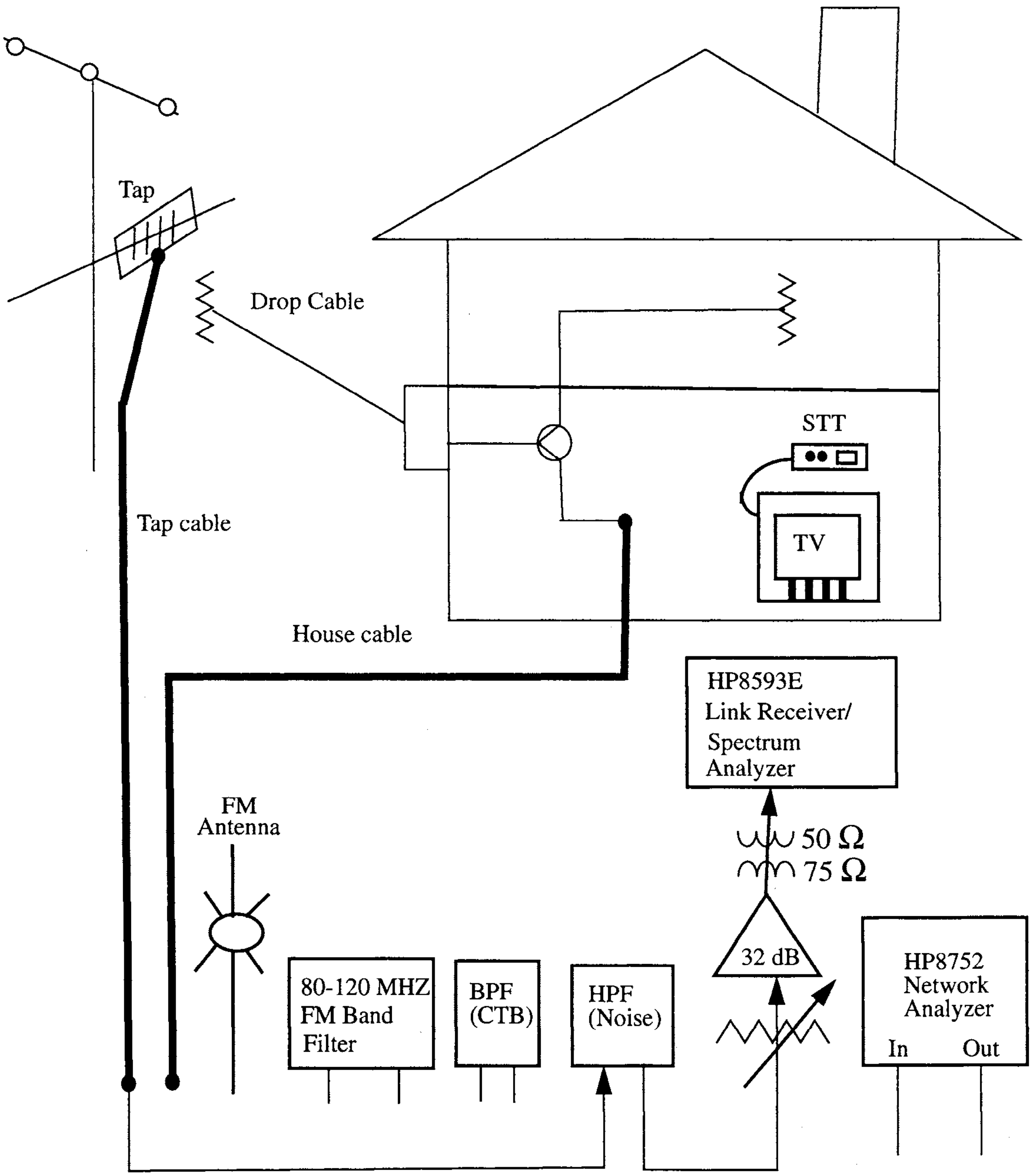


Figure A2-4: Test 5: Noise - Headend Through Tap. Test 6: Spurious - Headend Through Tap.

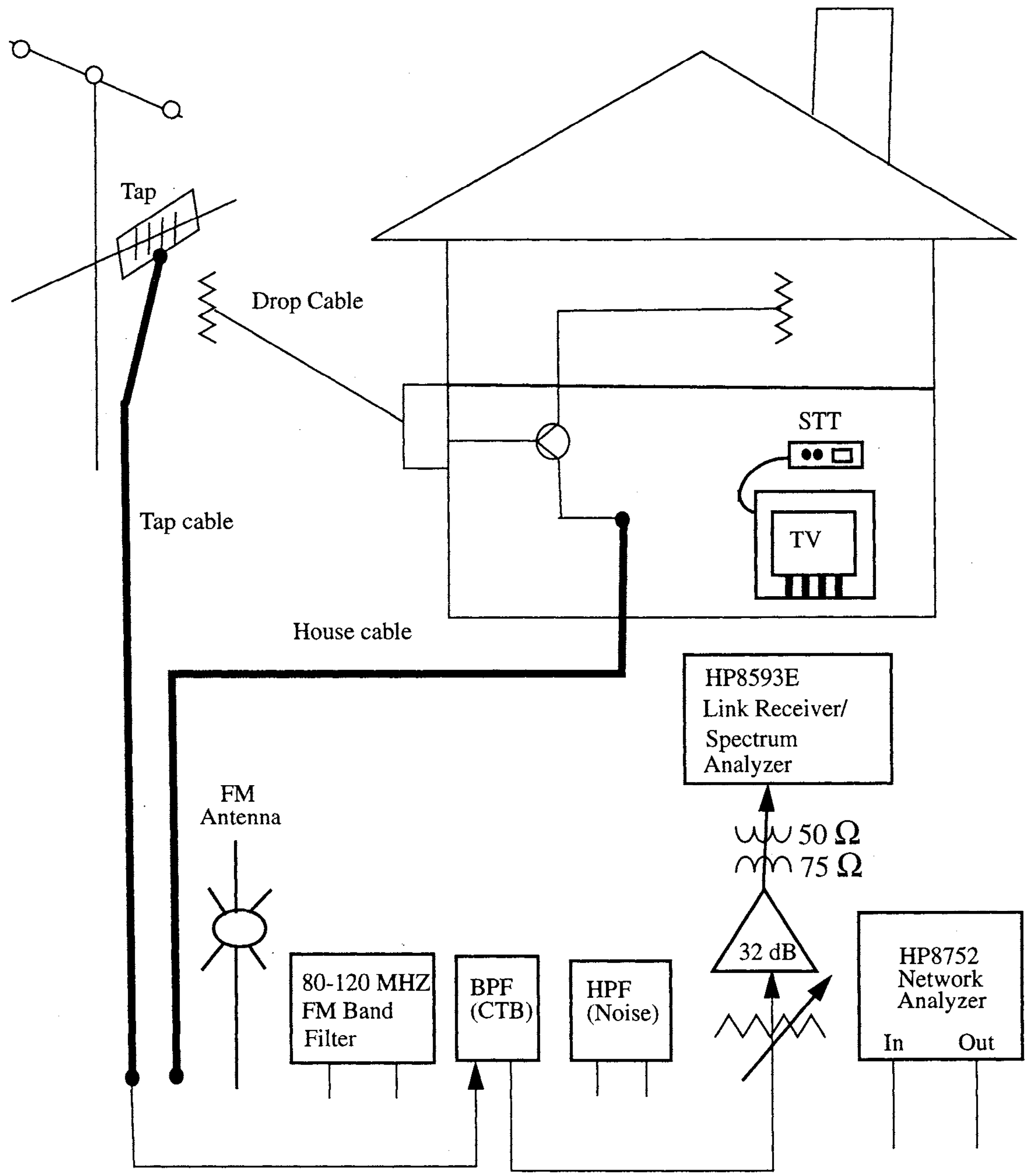


Figure A2-5: CTB - Headend Through Tap.

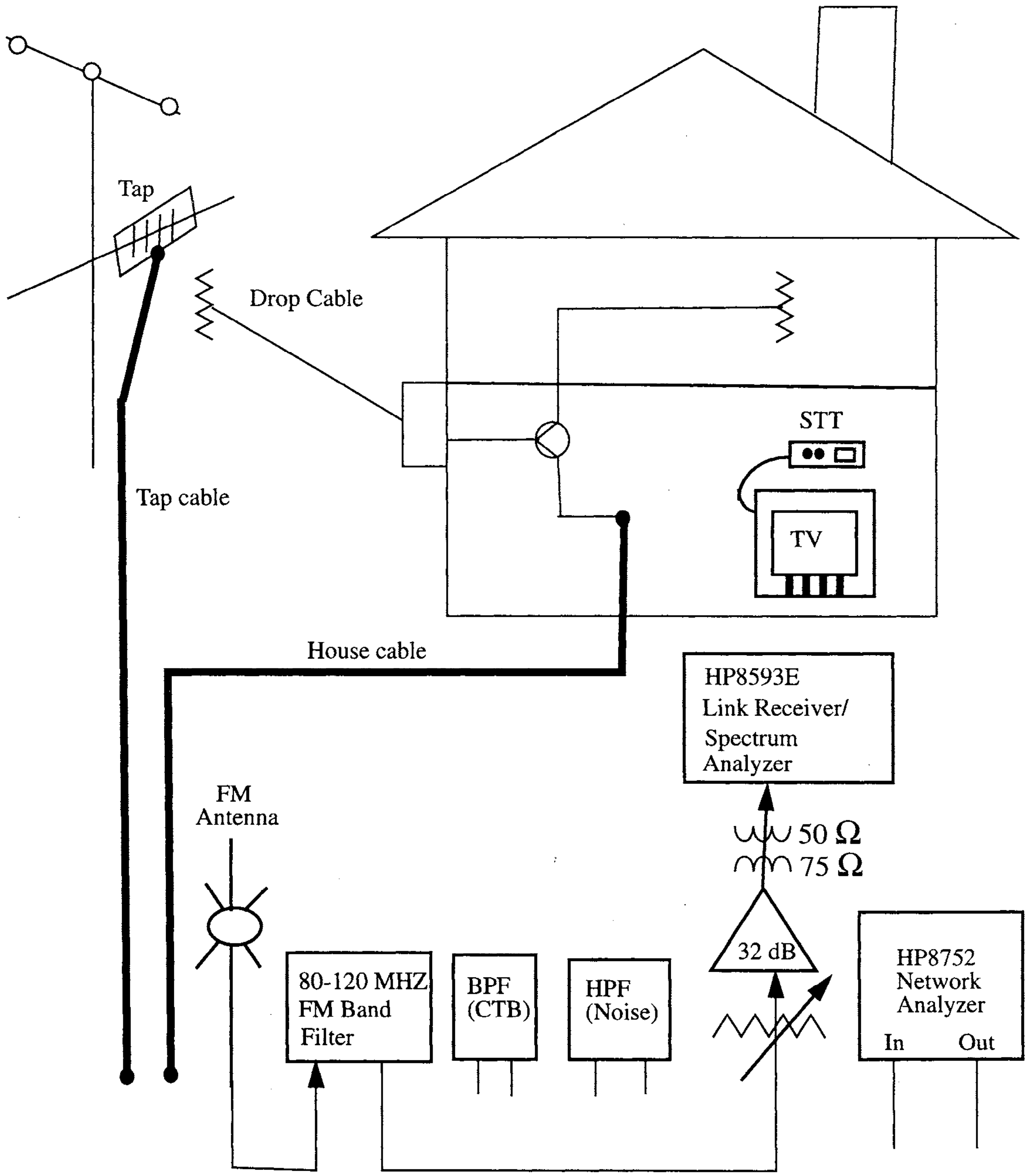


Figure A2-6: Test 8: Field - FM Antenna.

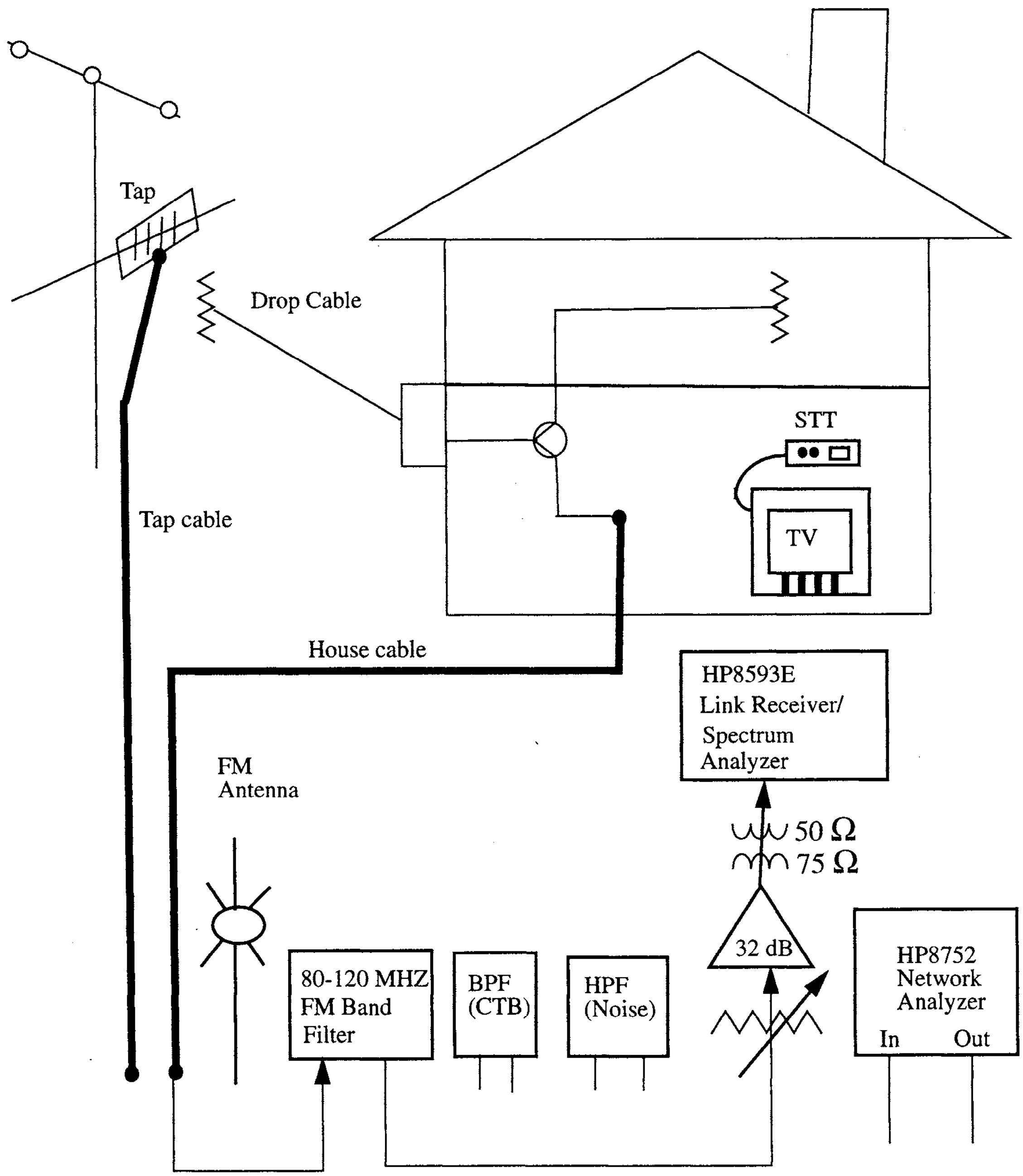


Figure A2-7: Test 9: Shielding - House Wiring.

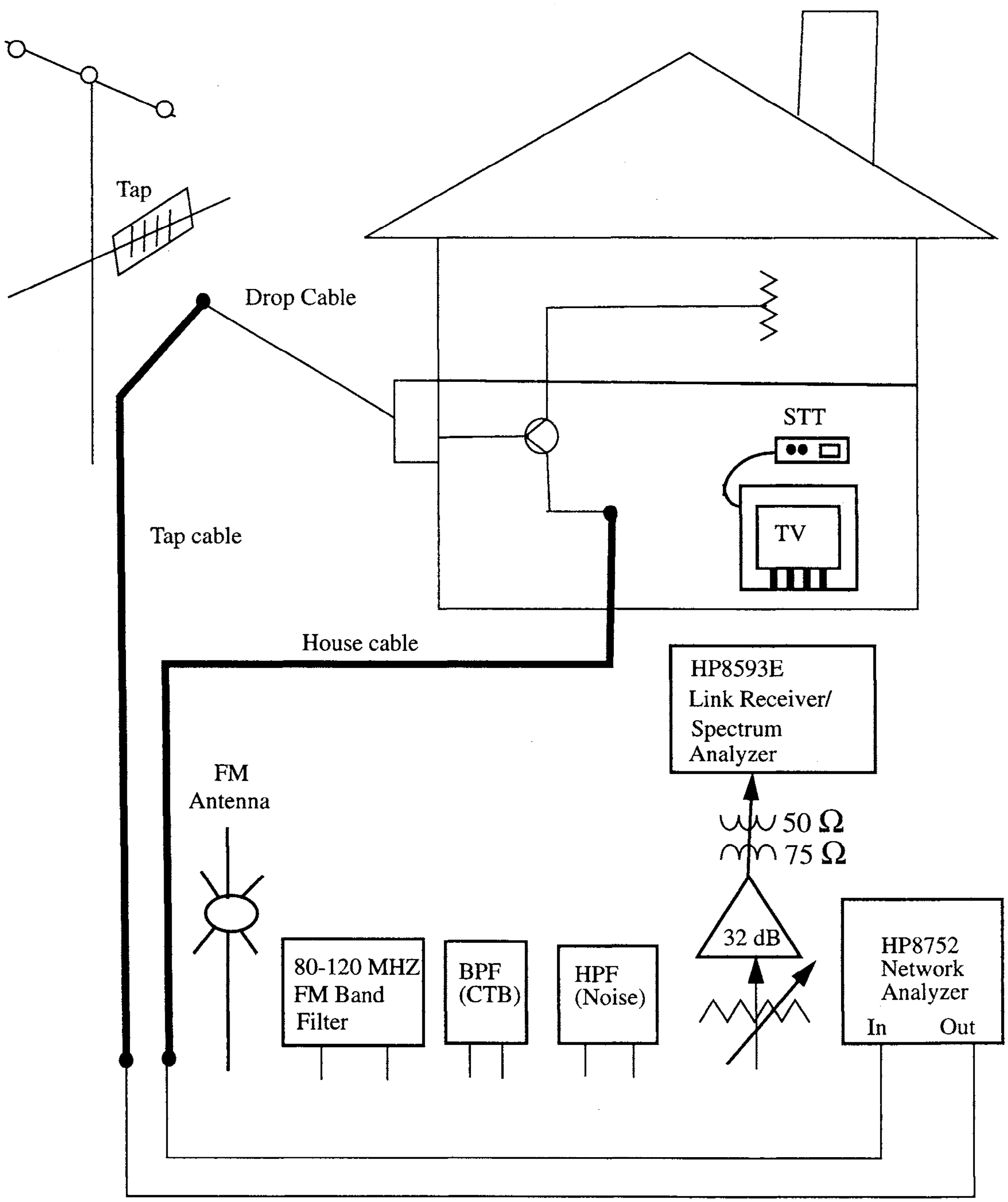


Figure A2-8: Test A: AF and GD (S21) - Transmission Through House.

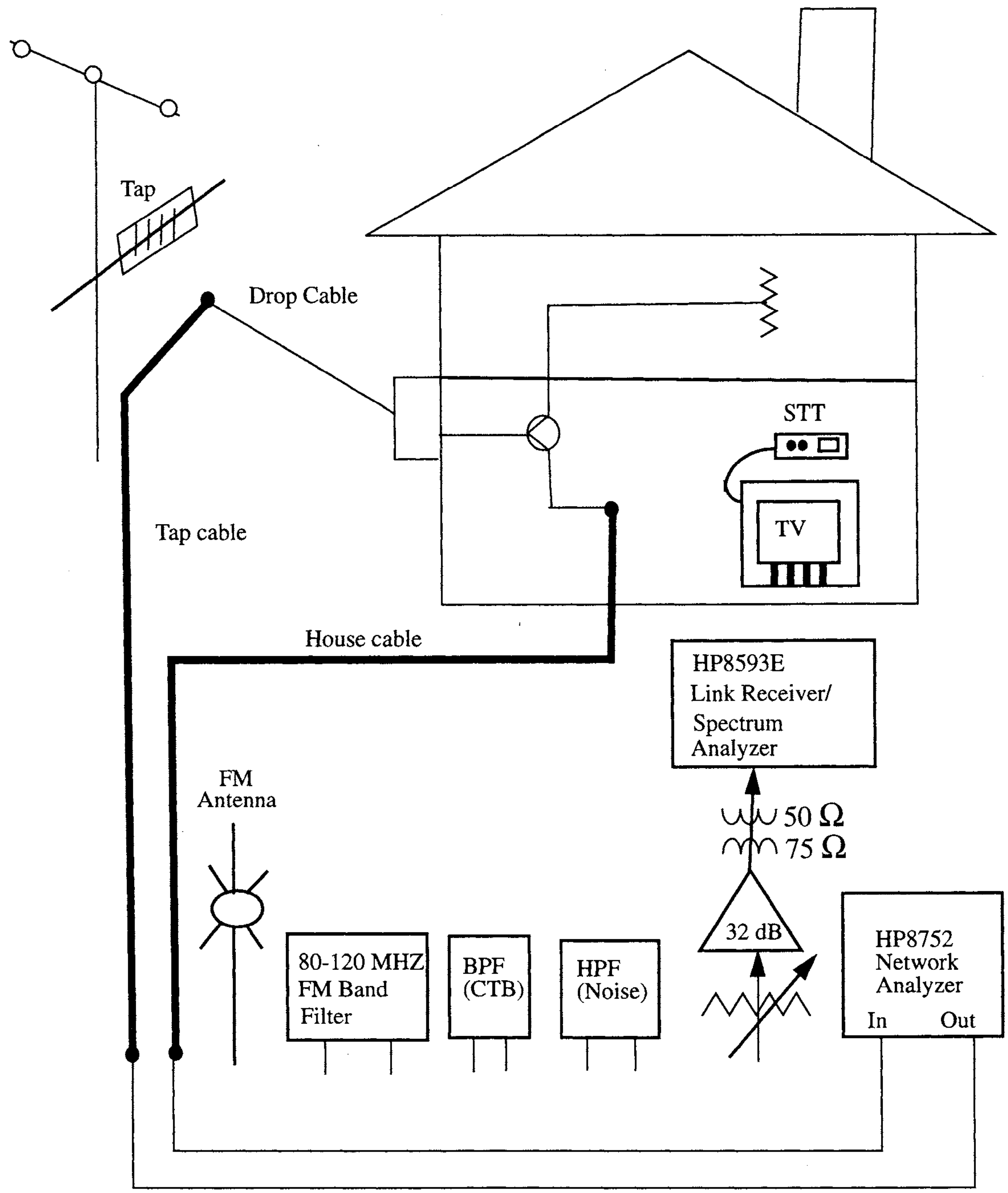


Figure A2-9: Test B: AF and GD (S11) - Reflection Through House.

APPENDIX B. RESULTS FOR CABLE SYSTEM B

Table B-1: Micro-Reflection Impairments Summary for Cable System B.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 390 - 456 MHz				
Delay (nanosecond)	130	300	330	390
Amplitude (dB)	-39	-31	-29	-28
Headend Thru Home Outlet:				
Frequency: 390 - 456 MHz				
Delay (nanosecond)	140	290	330	430
Amplitude (dB)	-37	-28	-27	-25
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	350	780	980	1220
Amplitude (dB)	-36	-29	-25	-23
Home Wiring:				
Frequency: 390 - 456 MHz				
Delay (nanosecond)	320	730	980	1220
Amplitude (dB)	-36	-29	-27	-23

Table B-2: Noise/Interference Impairments Summary for Cable System B.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 390 - 456 MHz					
Carrier/Noise (dB)	49	44	33	32	31
Carrier Power (dBm)	-40	-42	-51	-52	-53
Noise Power (dBm) in 6 MHz Bandwidth	-83	-84	-80	-80	-79
Spurious Power (dBm) in 6 MHz Bandwidth	-85	-86	-83	-81	-81
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-81	-82	-78	-77	-77
CTB Power (dBm) 12 MHz above the last active channel	NA	NA	NA	NA	NA
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	73	66	55	52	49

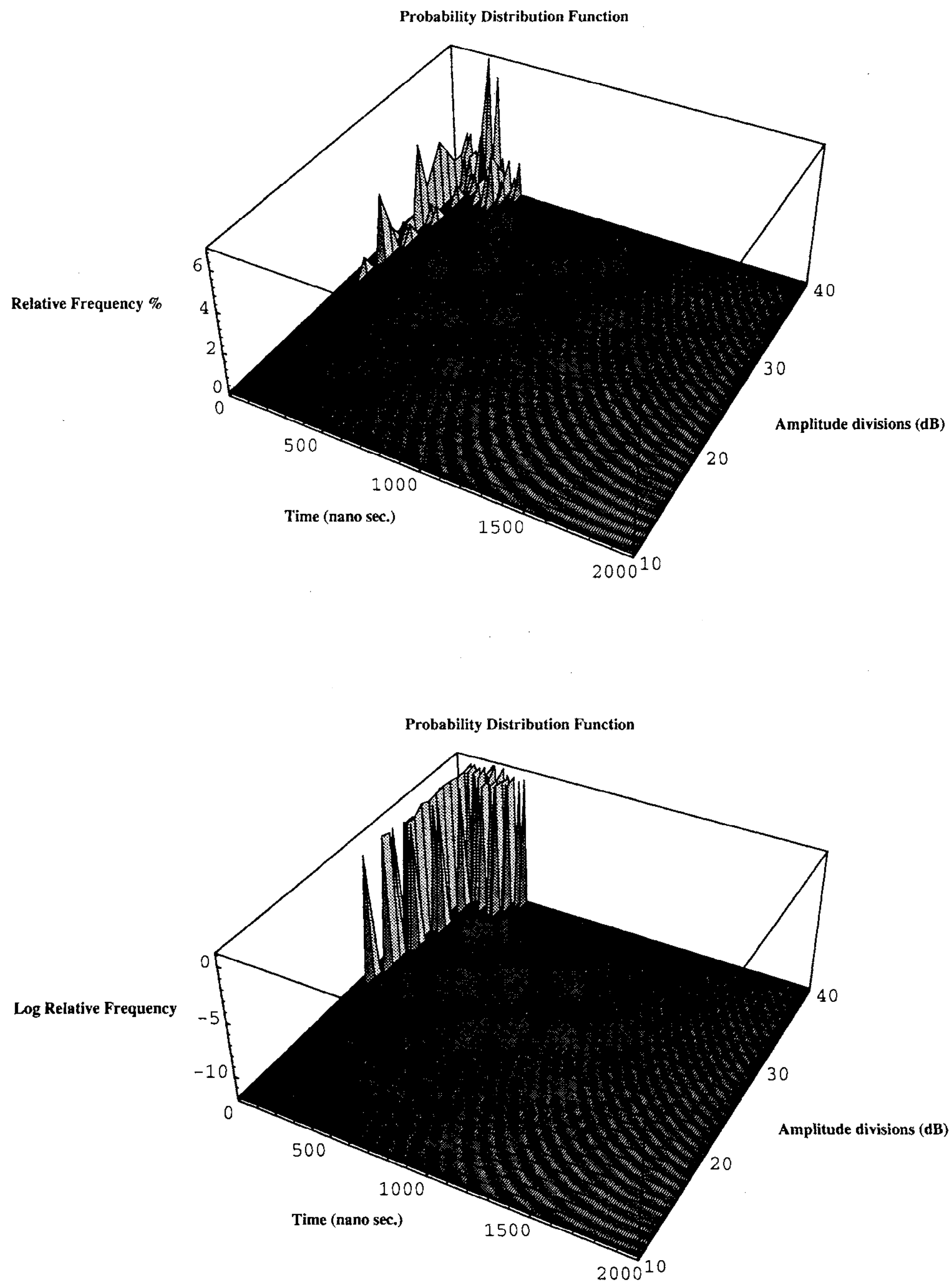


Figure B-1: Tap distribution of echoes (390 - 456 MHz).

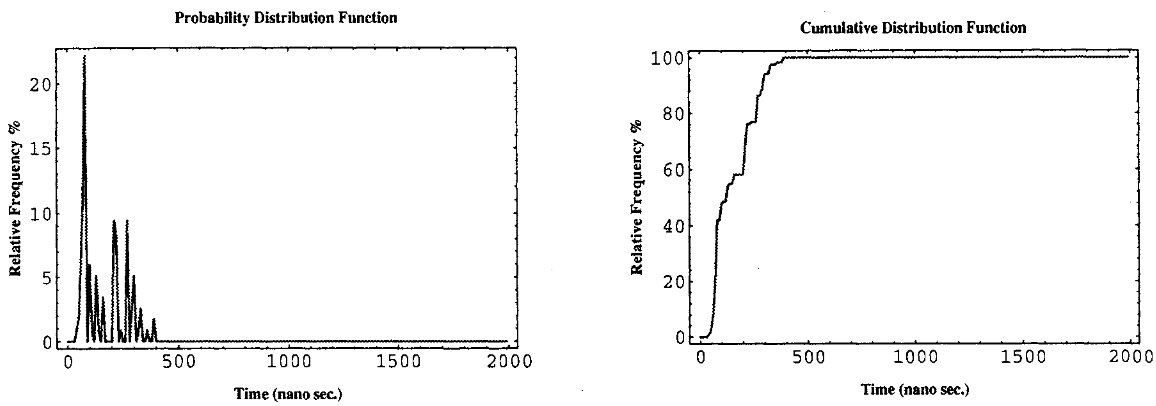


Figure B-2: Tap histogram of echo delays (390 - 456 MHz).

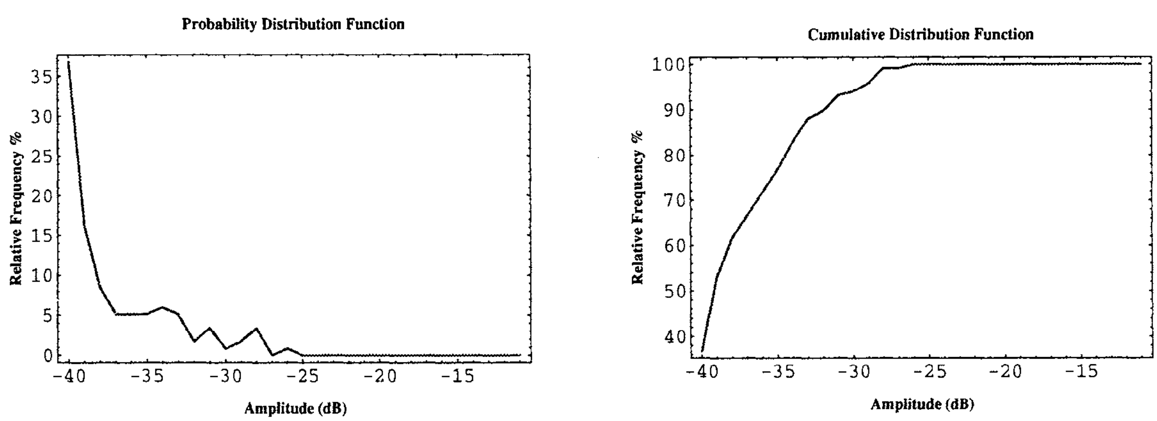
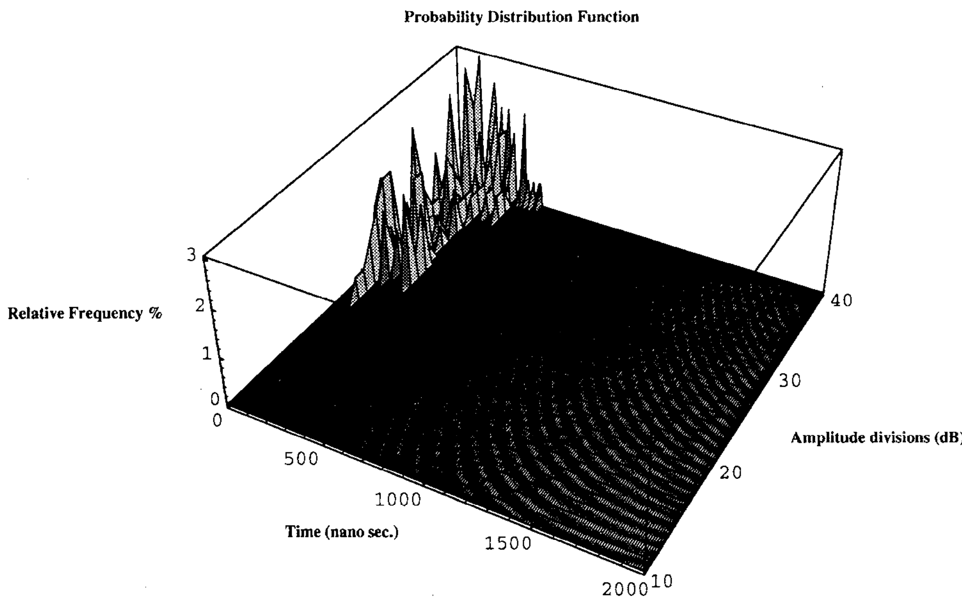


Figure B-3: Tap histogram of echo amplitudes (390 - 456 MHz).



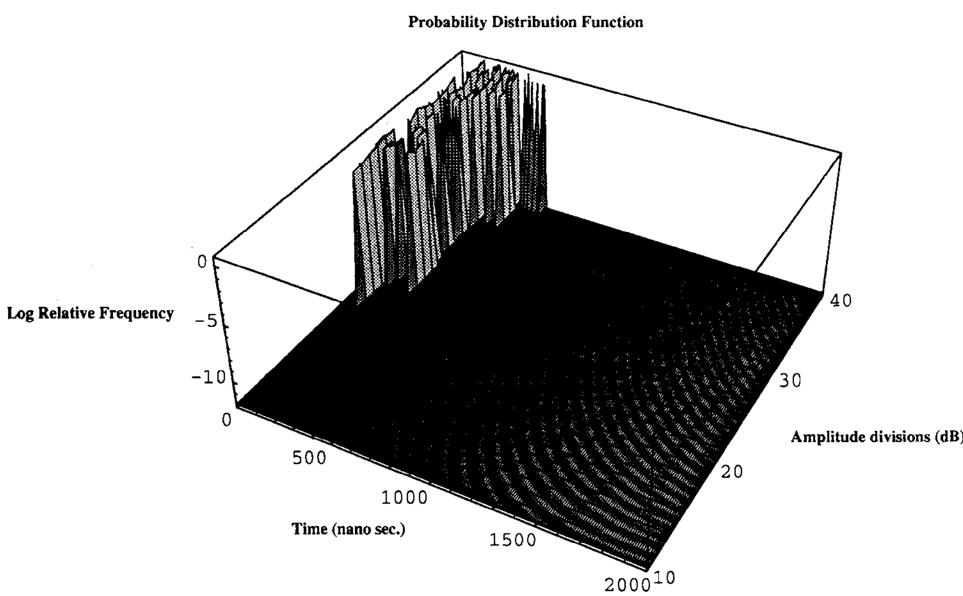


Figure B-4: Home outlet distribution of echoes (390 - 456 MHz).

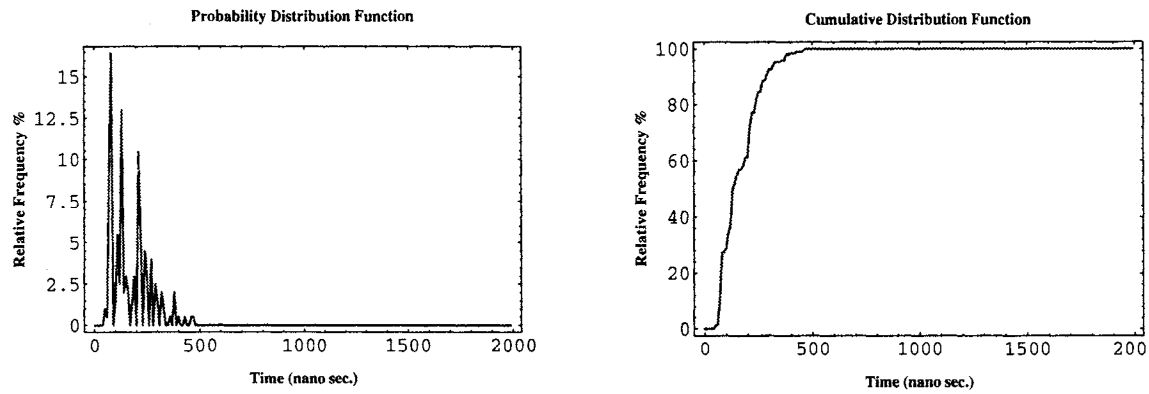


Figure B-5: Home outlet histogram of echo delays (390 - 456 MHz).

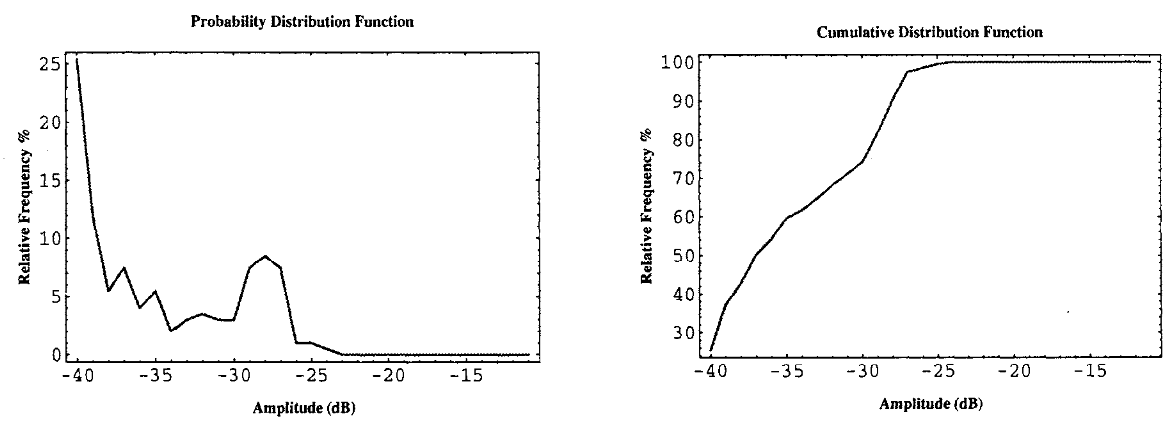
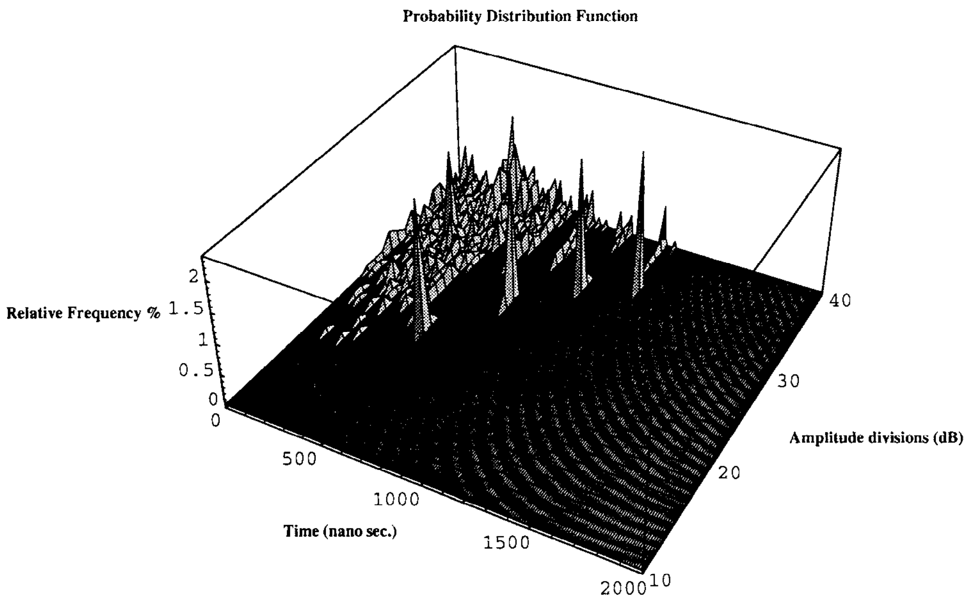


Figure B-6: Home outlet histogram of echo amplitudes (390 - 456 MHz).



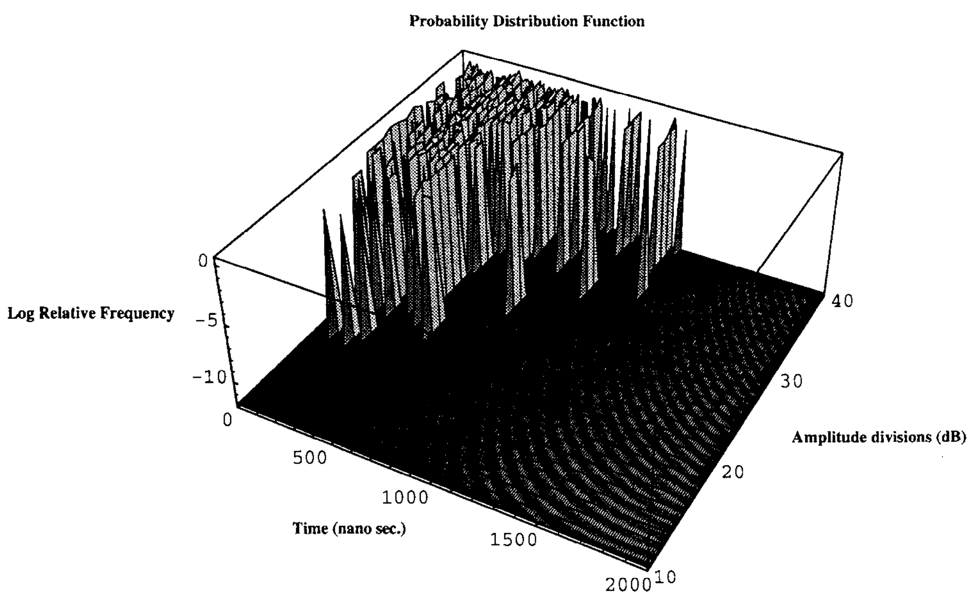


Figure B-7: Home wiring distribution of echoes (50 - 200 MHz).

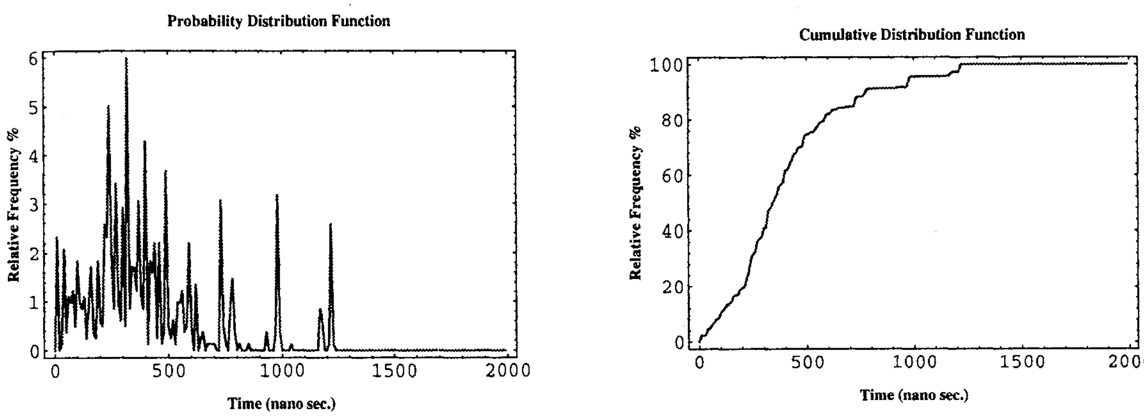


Figure B-8: Home wiring histogram of echo delays (50 - 200 MHz).

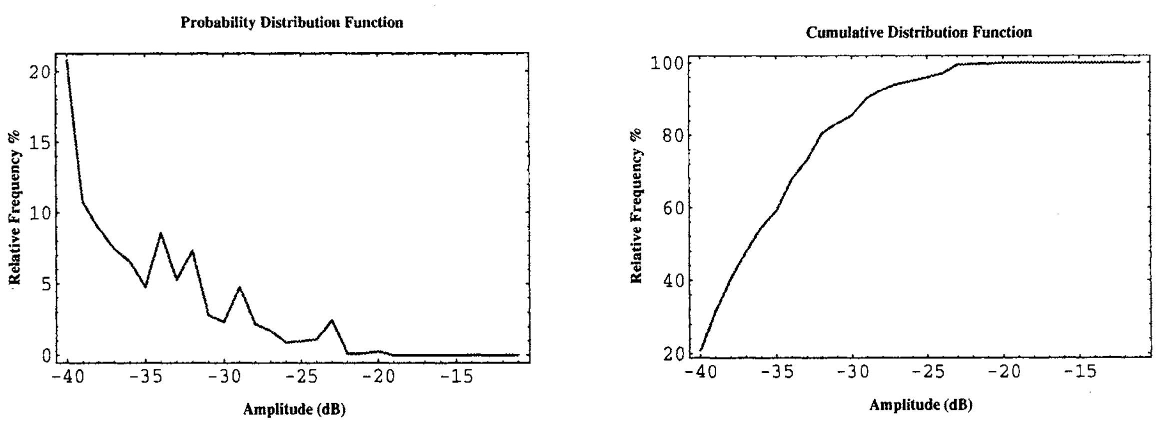
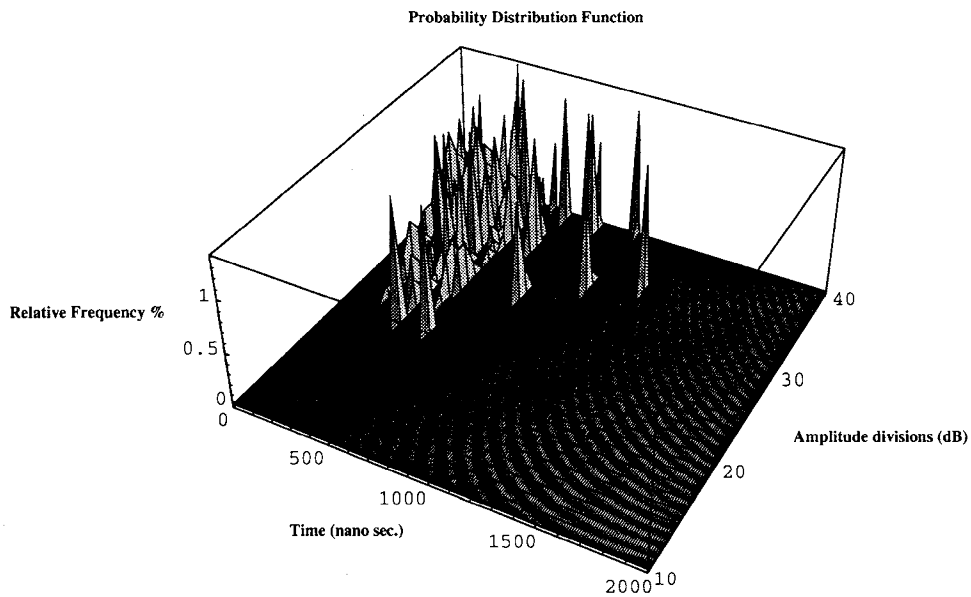


Figure B-9: Home wiring histogram of echo amplitudes (50 - 200 MHz).



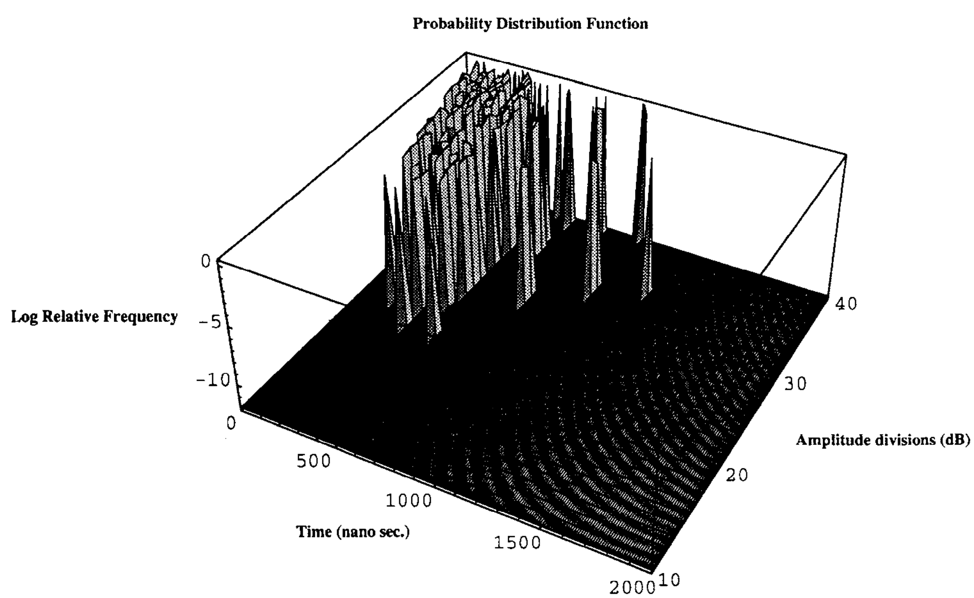


Figure B-10: Home wiring distribution of echoes (390 - 456 MHz).

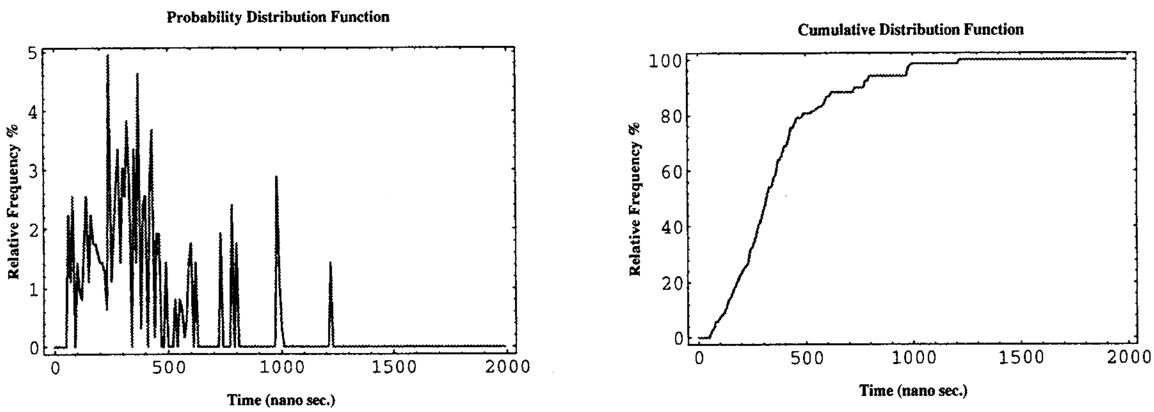


Figure B-11: Home wiring histogram of echo delays (390 - 456 MHz).

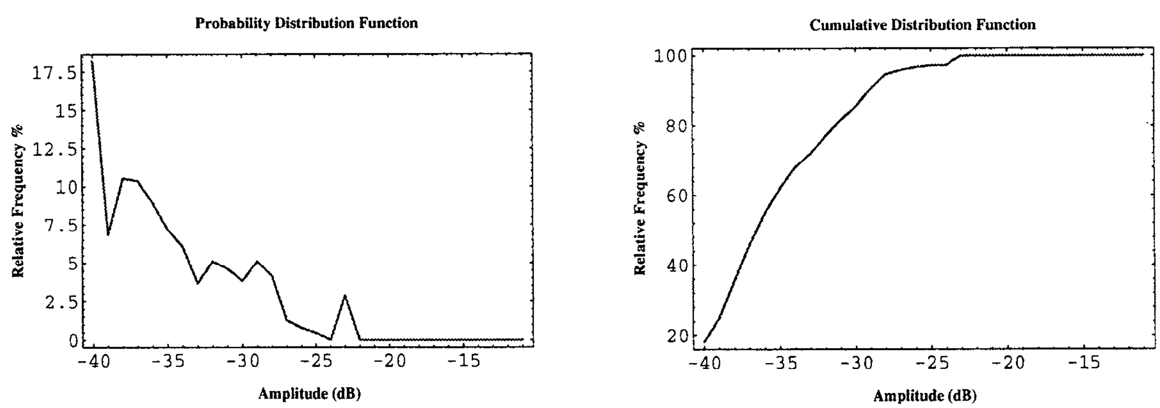


Figure B-12: Home wiring histogram of echo amplitudes (390 - 456 MHz).

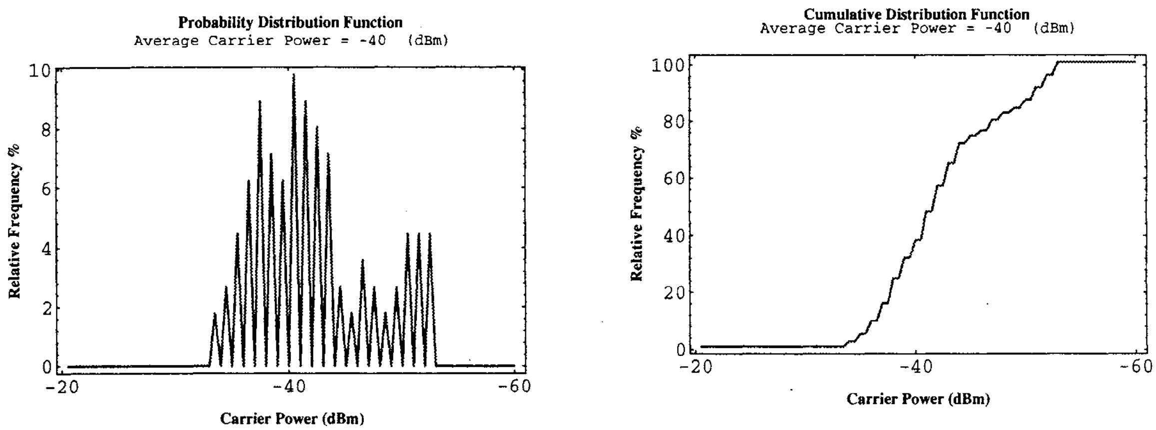


Figure B-13: Tap histogram of carrier power (390 - 456 MHz).

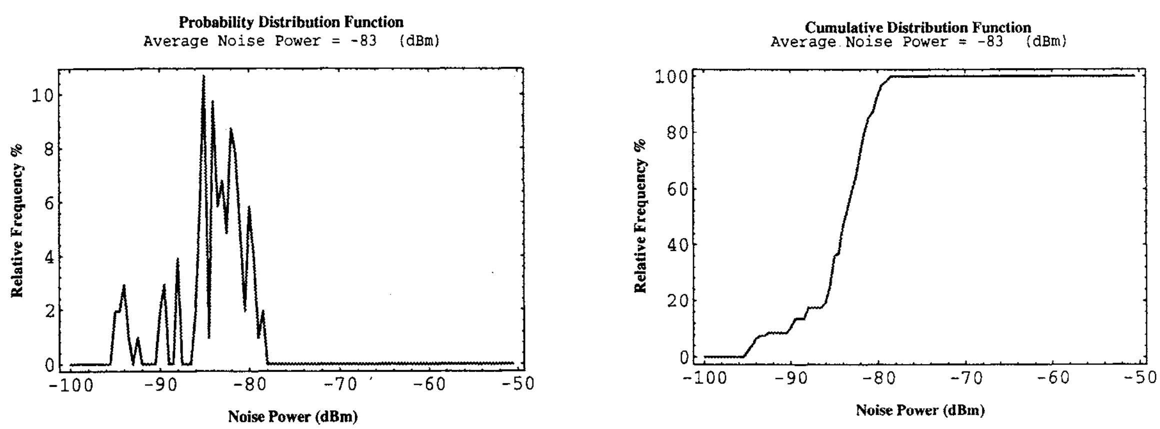


Figure B-14: Tap histogram of noise power (390 - 456 MHz).

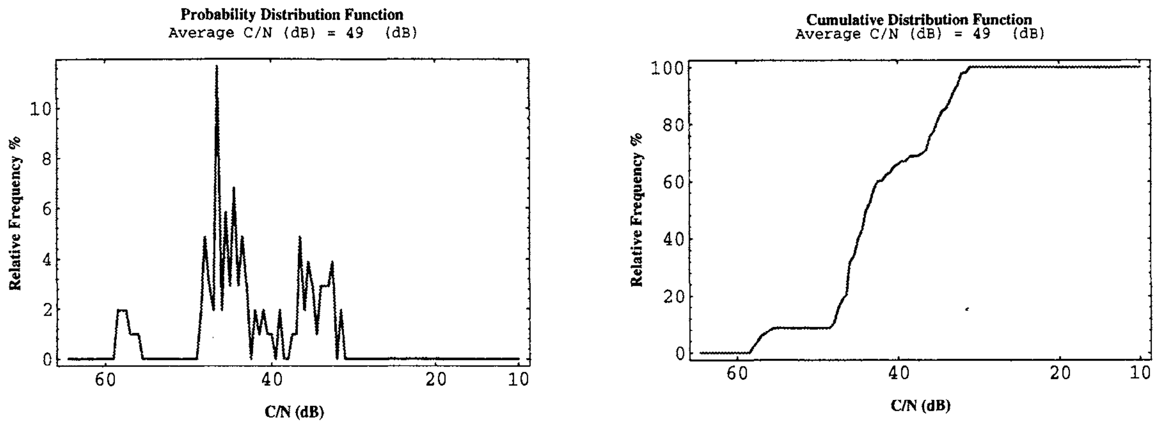


Figure B-15: Tap histogram of carrier-to-noise ratio (390 - 456 MHz).

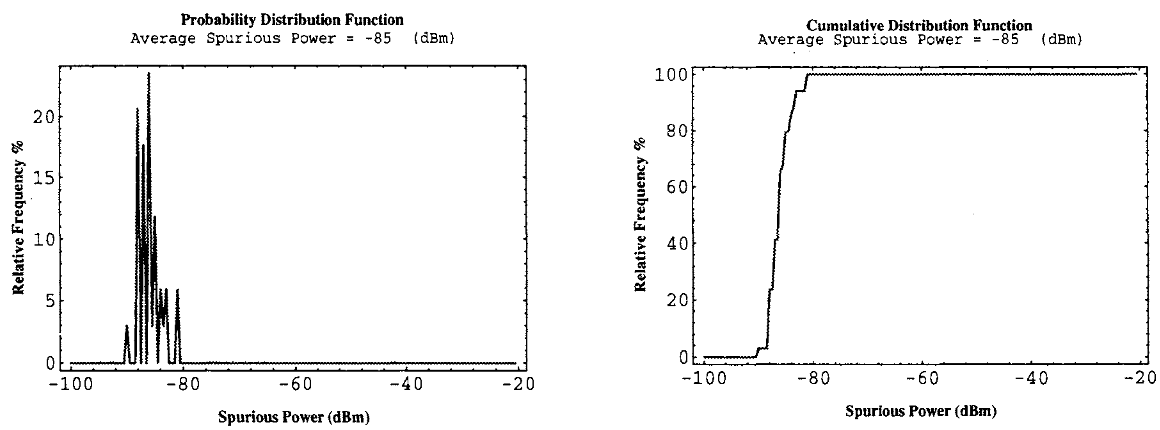


Figure B-16: Tap histogram of spurious components (390 - 456 MHz).

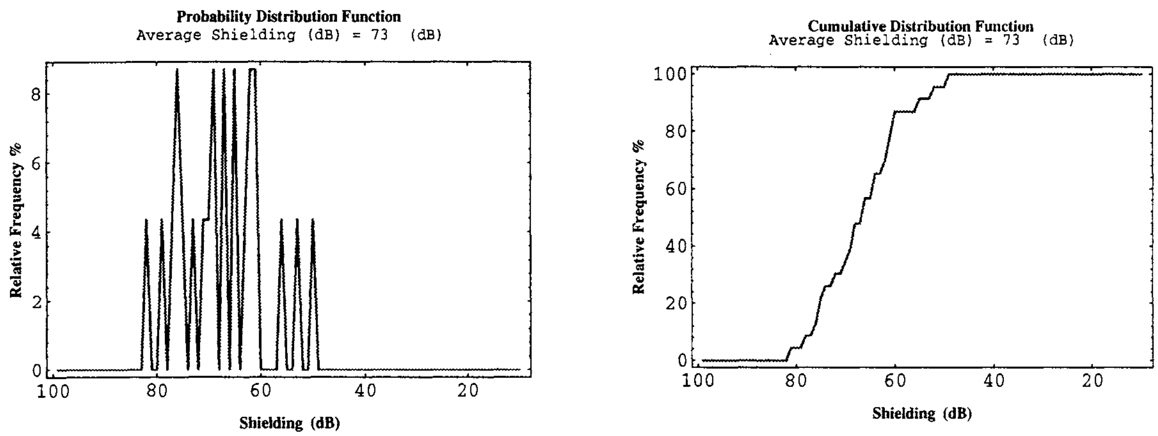


Figure B-17: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

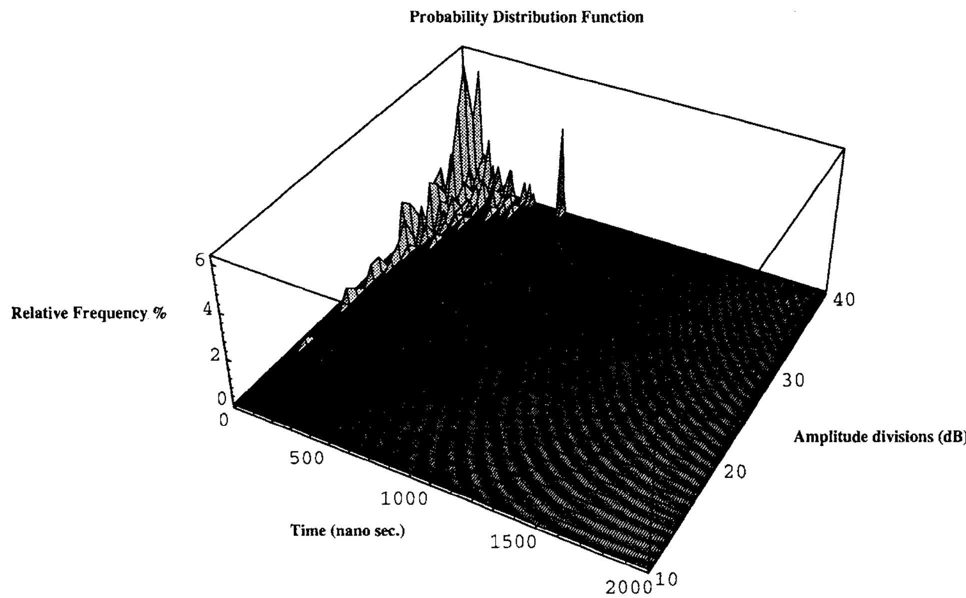
APPENDIX C. RESULTS FOR CABLE SYSTEM C

Table C-1: Micro-Reflection Impairments Summary for Cable System C.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 222 - 306 MHz				
Delay (nanosecond)	90	270	560	570
Amplitude (dB)	-38	-31	-30	-23
Headend Thru Home Outlet:				
Frequency: 222 - 306 MHz				
Delay (nanosecond)	120	330	450	570
Amplitude (dB)	-37	-30	-27	-23
Home Wiring:				
Frequency: 50 - 150 MHz				
Delay (nanosecond)	90	300	330	380
Amplitude (dB)	-37	-28	-26	-24
Home Wiring:				
Frequency: 222 - 306 MHz				
Delay (nanosecond)	70	330	340	340
Amplitude (dB)	-36	-27	-27	-27

Table C-2: Noise/Interference Impairments Summary for Cable System C

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 222 - 306 MHz					
Carrier/Noise (dB)	47	43	30	25	17
Carrier Power (dBm)	-34	-36	-42	-48	-51
Noise Power (dBm) in 6 MHz Bandwidth	-73	-80	-69	-66	-62
Spurious Power (dBm) in 6 MHz Bandwidth	-79	-82	-75	-73	-72
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-72	-78	-68	-65	-62
CTB Power (dBm) 12 MHz above the last active channel	-119	-119	-119	-119	-119
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	66	62	40	40	40



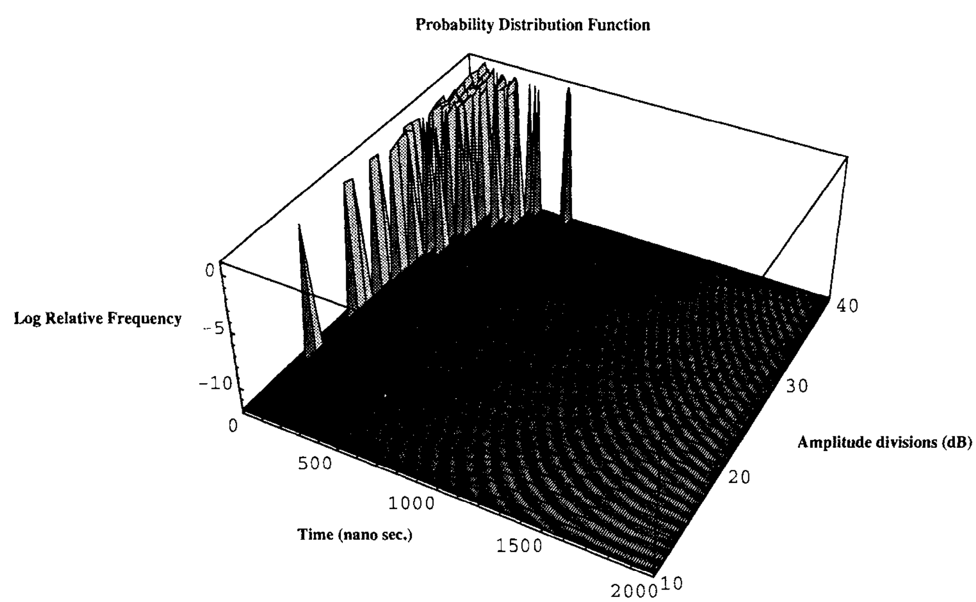


Figure C-1: Tap distribution of echoes (222 - 306 MHz).

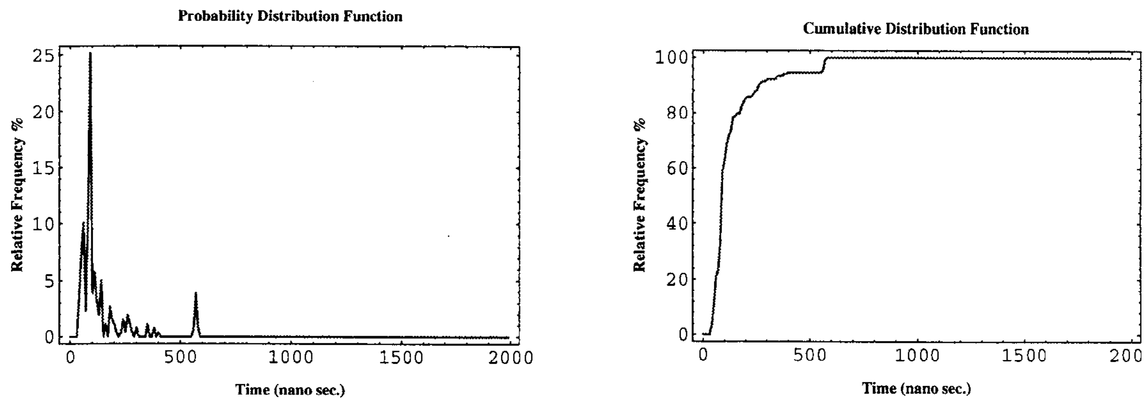


Figure C-2: Tap histogram of echo delays (222 - 306 MHz).

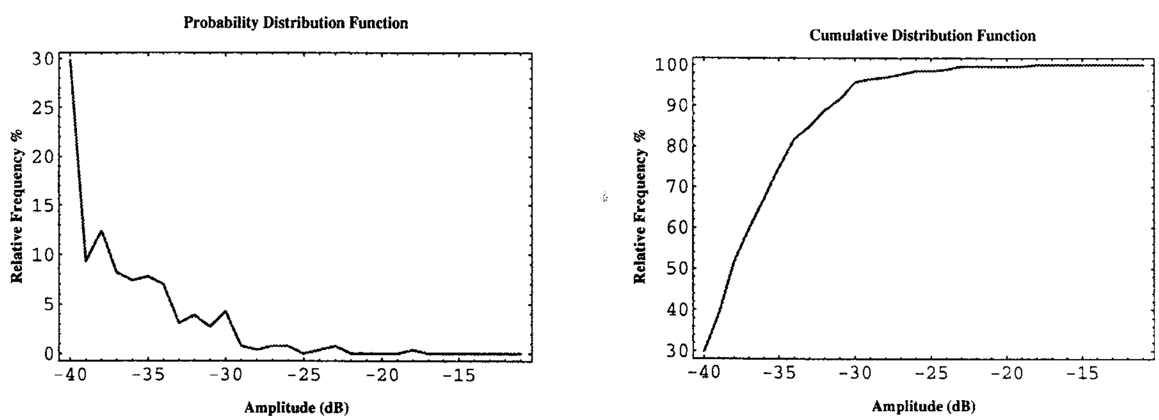
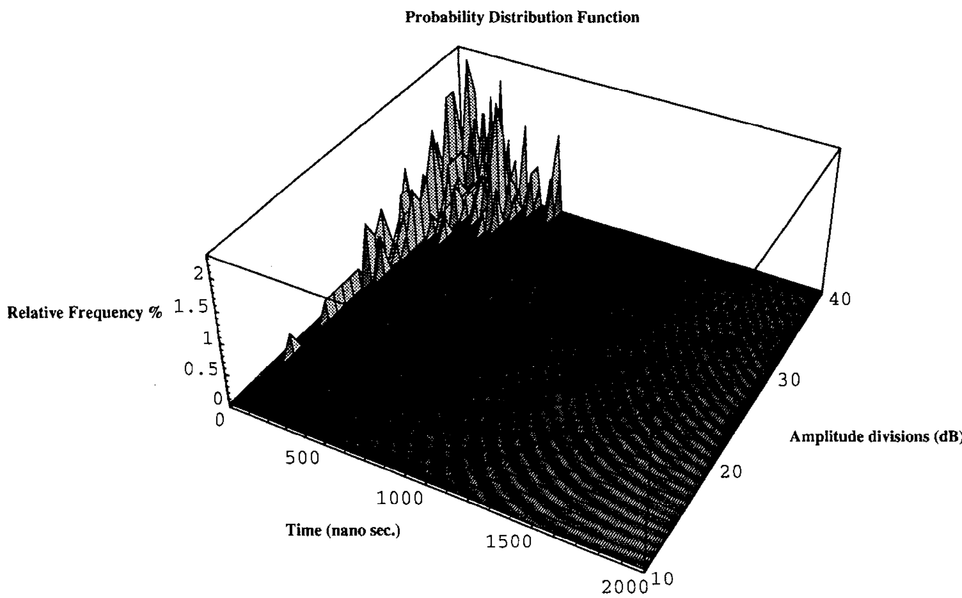


Figure C-3: Tap histogram of echo amplitudes (222 - 306 MHz).



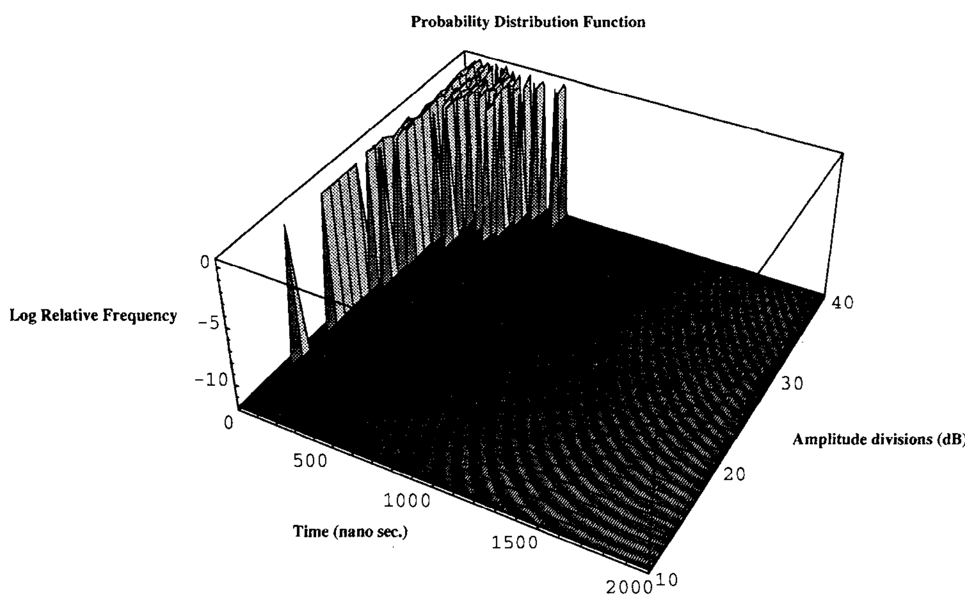


Figure C-4: Home outlet distribution of echoes (222 - 306 MHz).

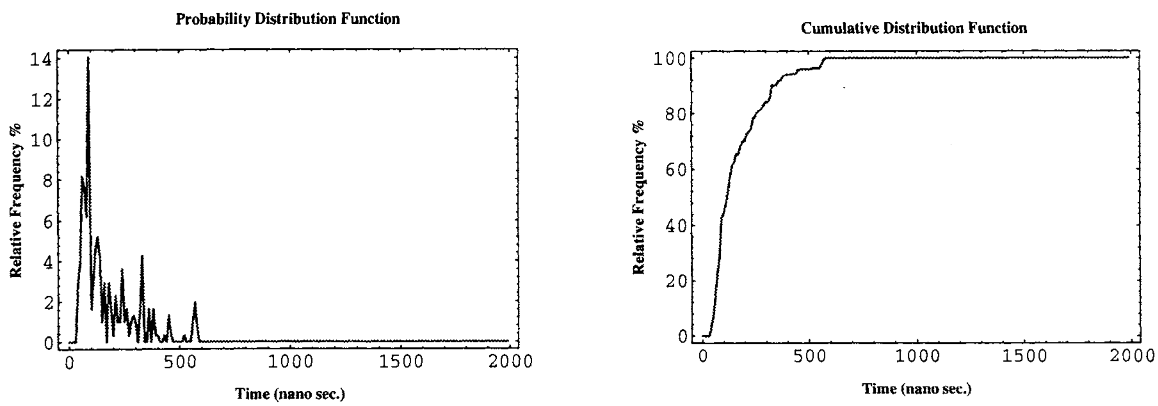


Figure C-5: Home outlet histogram of echo delays (222 - 306 MHz).

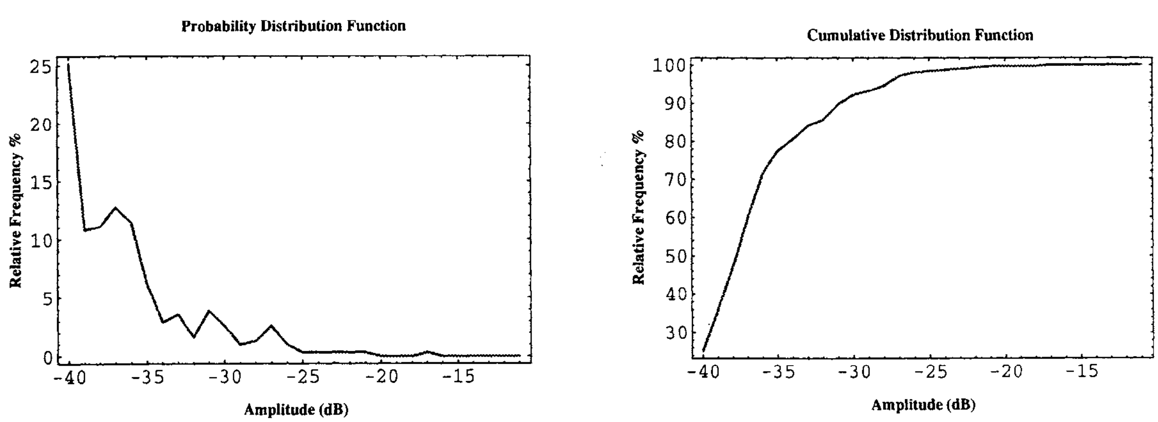


Figure C-6: Home outlet histogram of echo amplitudes (222 - 306 MHz).

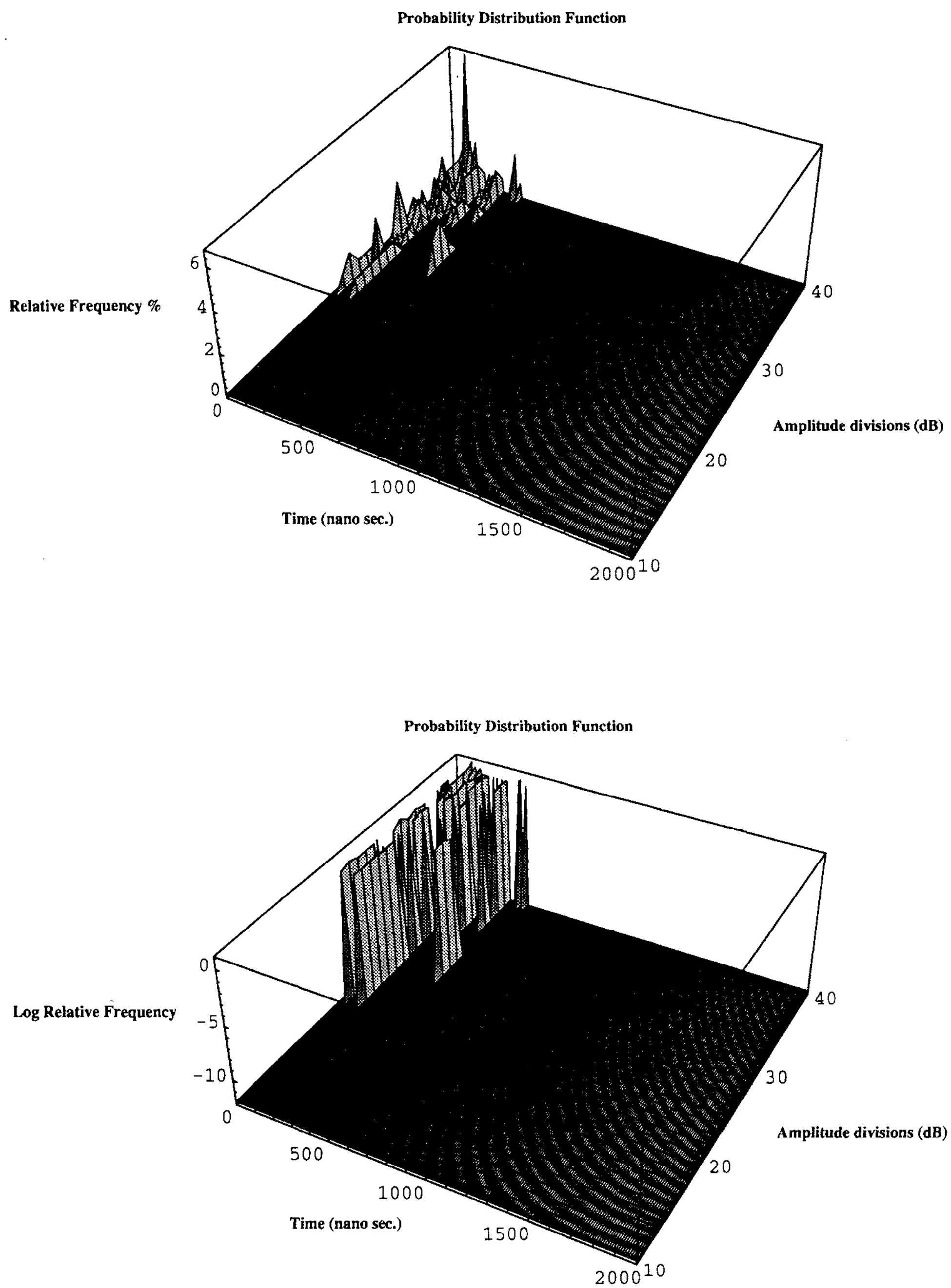


Figure C-7: Home wiring distribution of echoes (50 - 150 MHz).

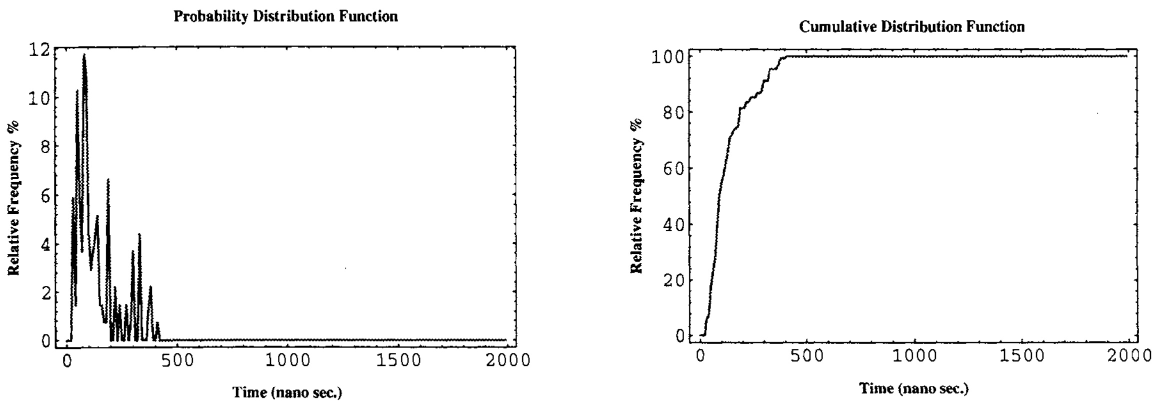


Figure C-8: Home wiring histogram of echo delays (50 - 150 MHz).

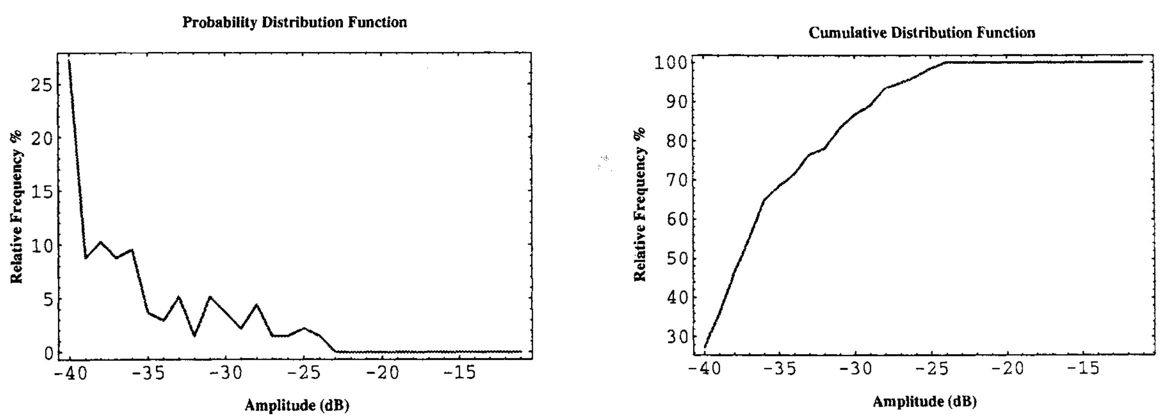
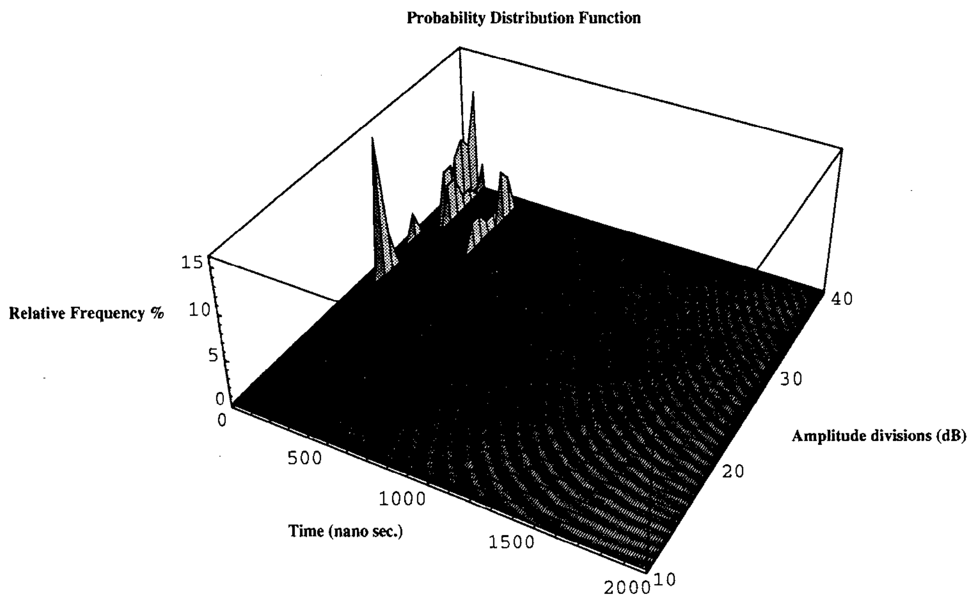


Figure C-9: Home wiring histogram of echo amplitudes (50 - 150 MHz).



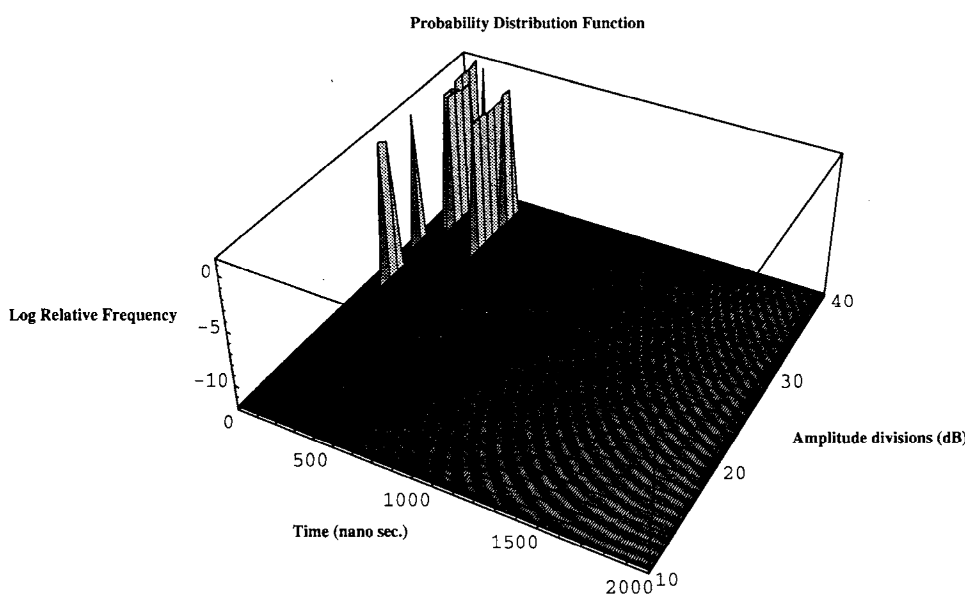


Figure C-10: Home wiring distribution of echoes (222 - 306 MHz).

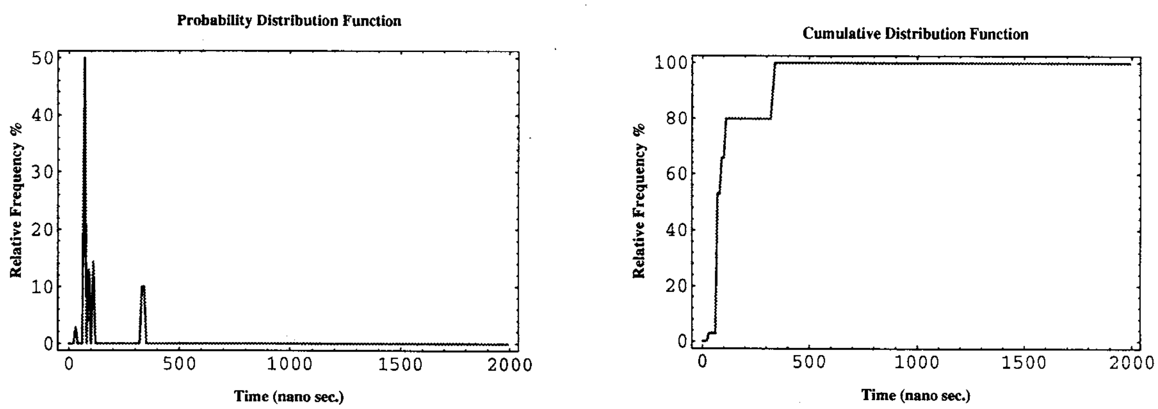


Figure C-11: Home wiring histogram of echo delays (222 - 306 MHz).

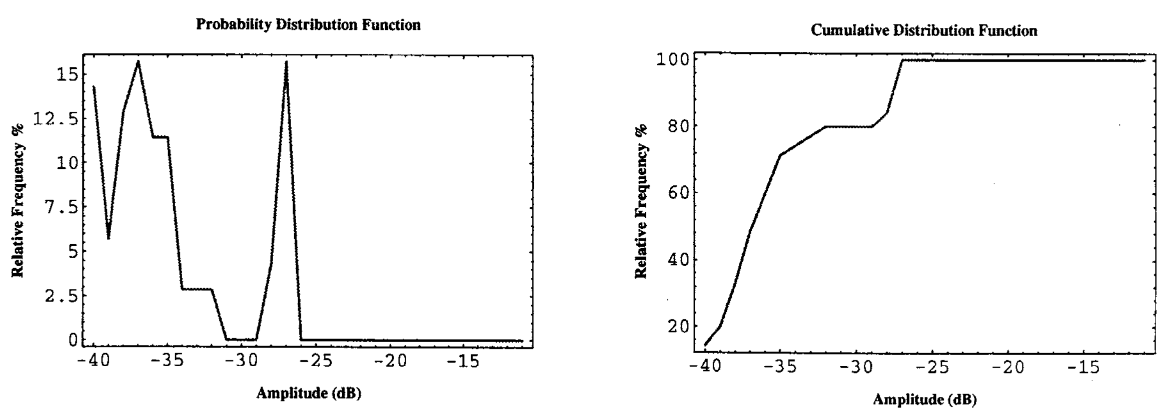
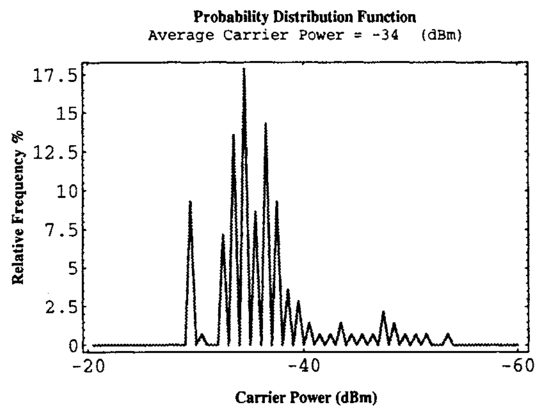


Figure C-12: Home wiring histogram of echo amplitudes (222 - 306 MHz).



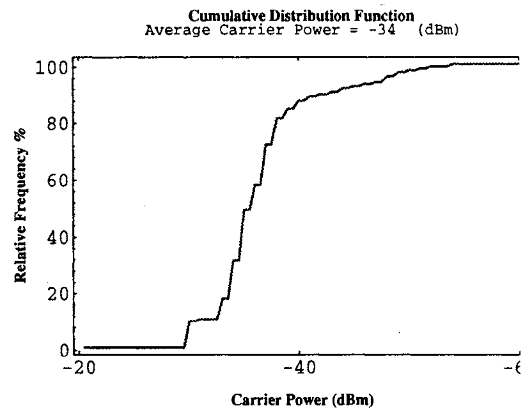
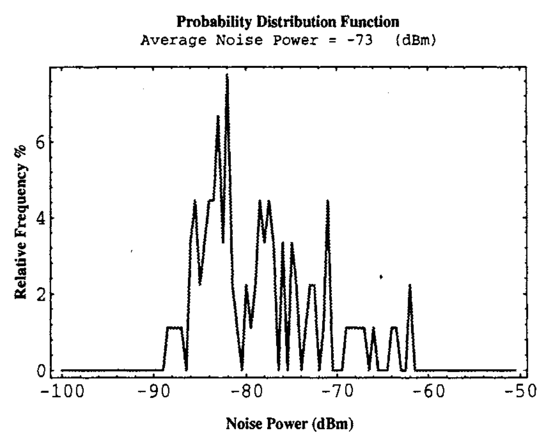


Figure C-13: Tap histogram of carrier power (222 - 306 MHz).



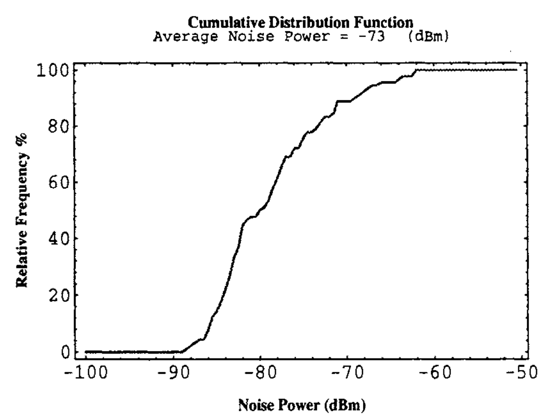


Figure C-14: Tap histogram of noise power (222 - 306 MHz).

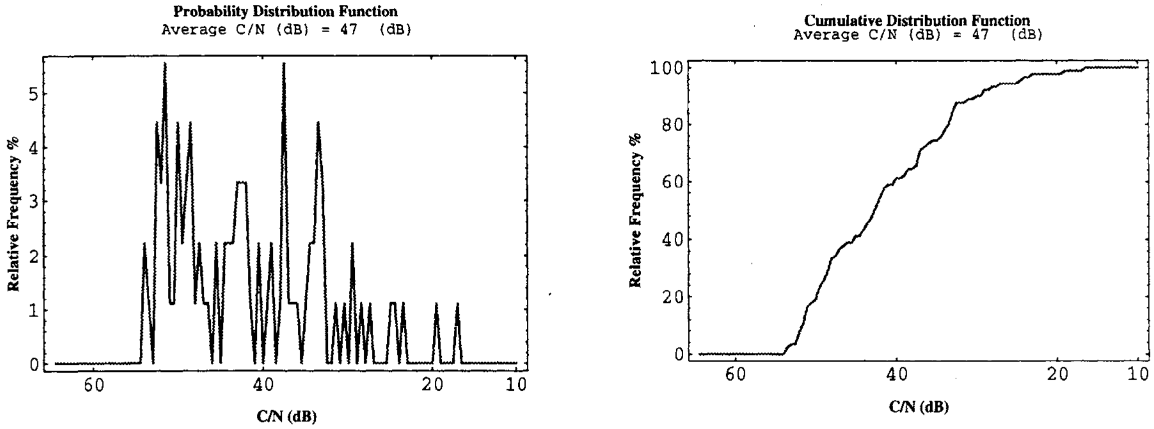


Figure C-15: Tap histogram of carrier-to-noise ratio (222 - 306 MHz).

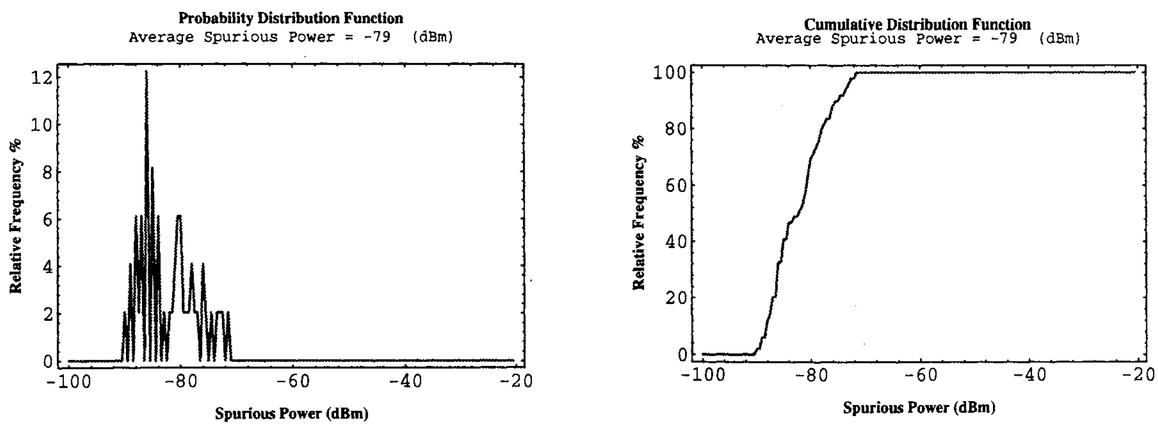


Figure C-16: Tap histogram of spurious components (222 - 306 MHz).

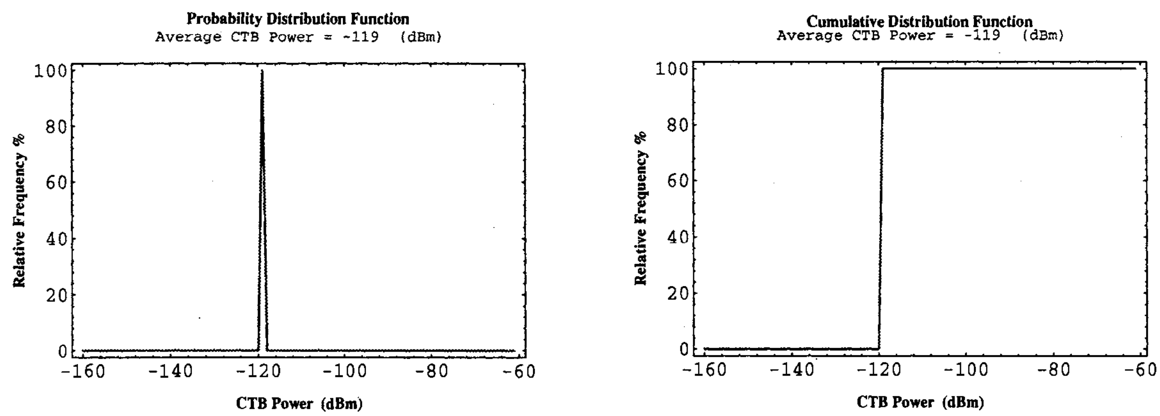


Figure C-17: Tap histogram of composite triple beats (222 - 306 MHz).

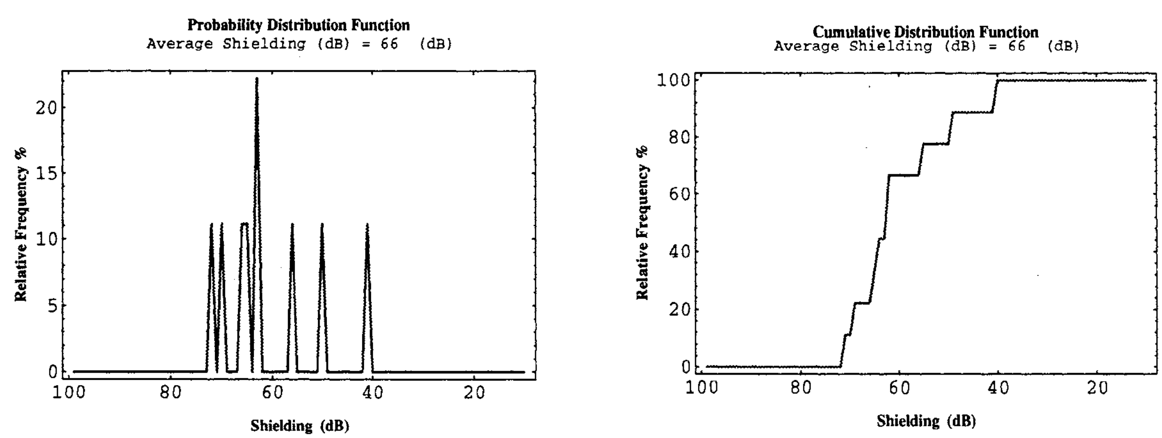


Figure C-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

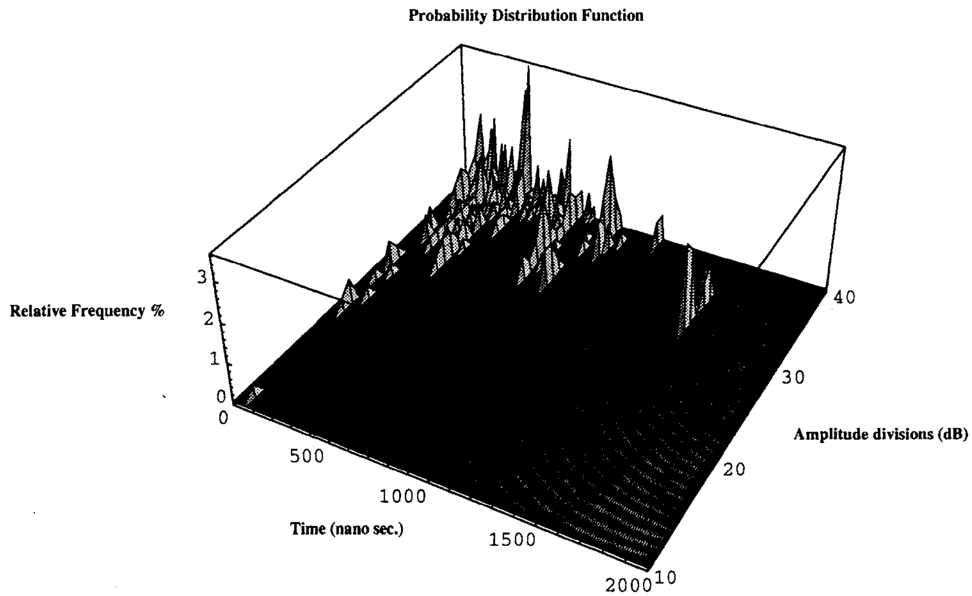
APPENDIX D. RESULTS FOR CABLE SYSTEM D

Table D-1: Micro-Reflection Impairments Summary for Cable System D.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 242 - 342 MHz				
Delay (nanosecond)	360	910	1520	1530
Amplitude (dB)	-38	-32	-31	-23
Headend Thru Home Outlet:				
Frequency: 242 - 342 MHz				
Delay (nanosecond)	340	900	1500	1520
Amplitude (dB)	-37	-31	-25	-20
Home Wiring:				
Frequency: 50 - 110 MHz				
Delay (nanosecond)	140	440	570	630
Amplitude (dB)	-36	-26	-19	-17
Home Wiring:				
Frequency: 242 - 342 MHz				
Delay (nanosecond)	160	440	520	570
Amplitude (dB)	-38	-27	-20	-19

Table D-2: Noise/Interference Impairments Summary for Cable System D.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 242 - 342 MHz					
Carrier/Noise (dB)	43	39	27	25	20.5
Carrier Power (dBm)	-39	-40	-51	-52	-53
Noise Power (dBm) in 6 MHz Bandwidth	-78	-80	-76	-75	-68
Spurious Power (dBm) in 6 MHz Bandwidth	-77	-79	-73	-73	-69
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-74	-76	-71	-71	-65
CTB Power (dBm) 12 MHz above the last active channel	-109	-112	-107	-103	-103
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	70	51	32	28	19



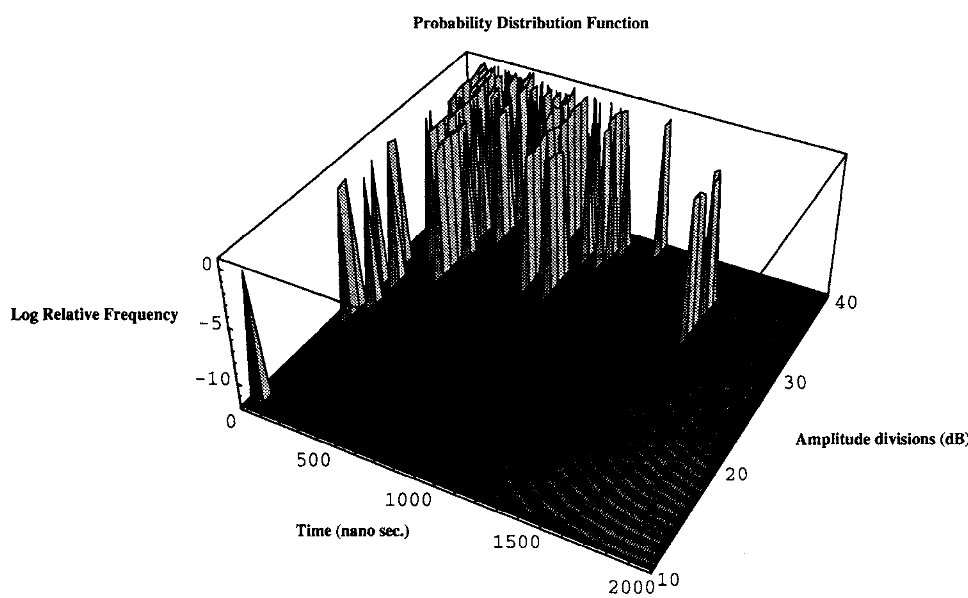


Figure D-1: Tap distribution of echoes (242 - 342 MHz).

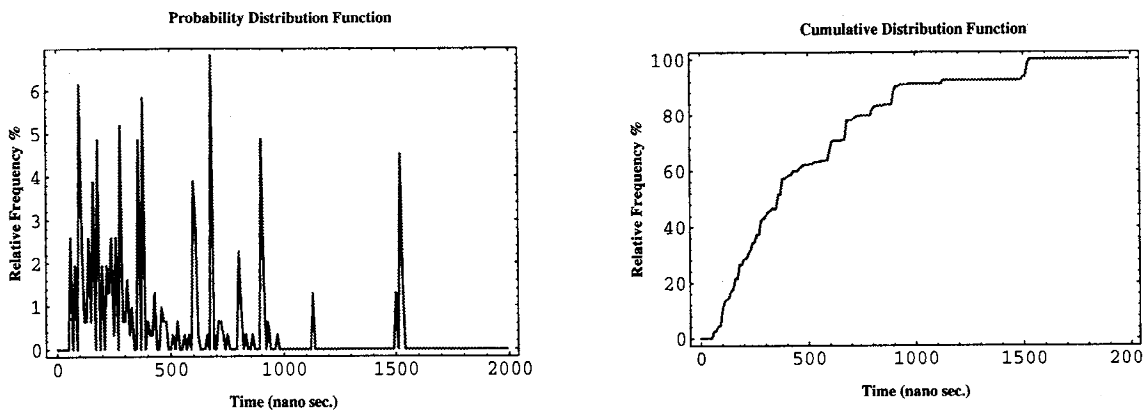


Figure D-2: Tap histogram of echo delays (242 - 342 MHz).

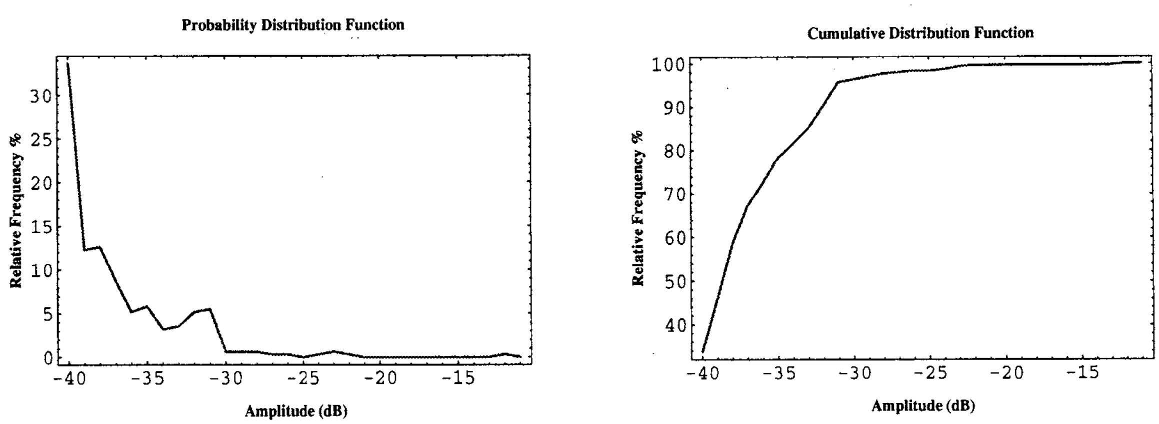
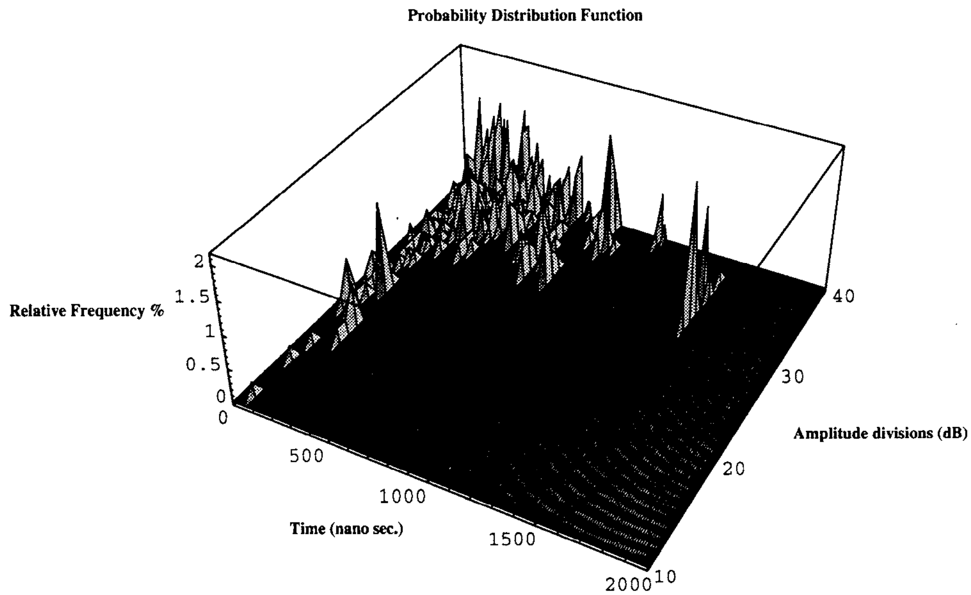


Figure D-3: Tap histogram of echo amplitudes (242 - 342 MHz).



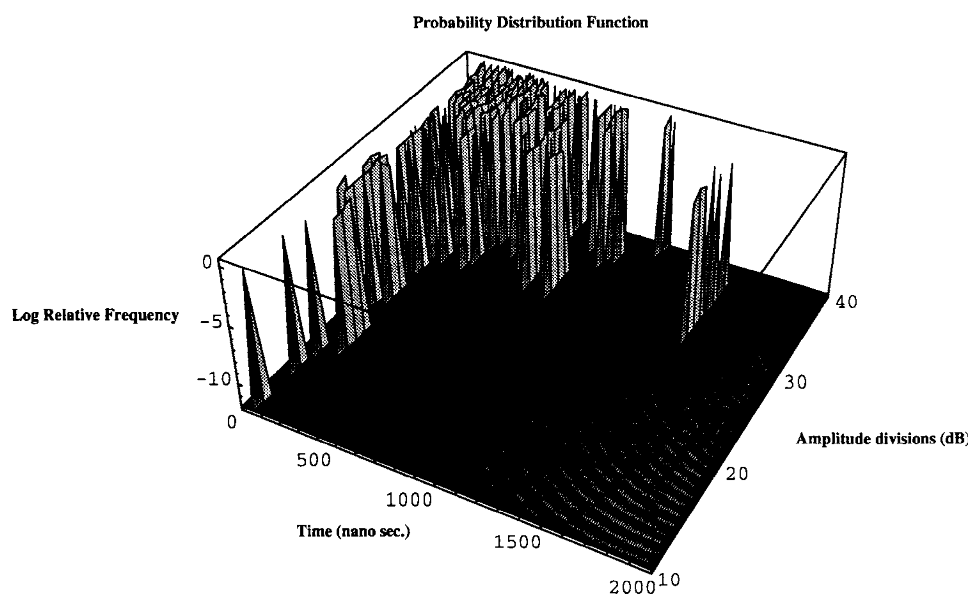


Figure D-4: Home outlet distribution of echoes (242 - 342 MHz).

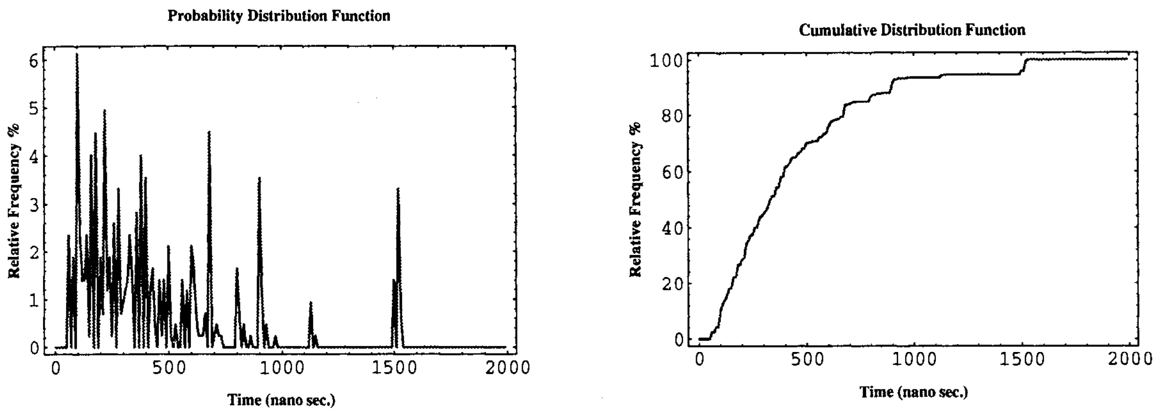


Figure D-5: Home outlet histogram of echo delays (242 - 342 MHz).

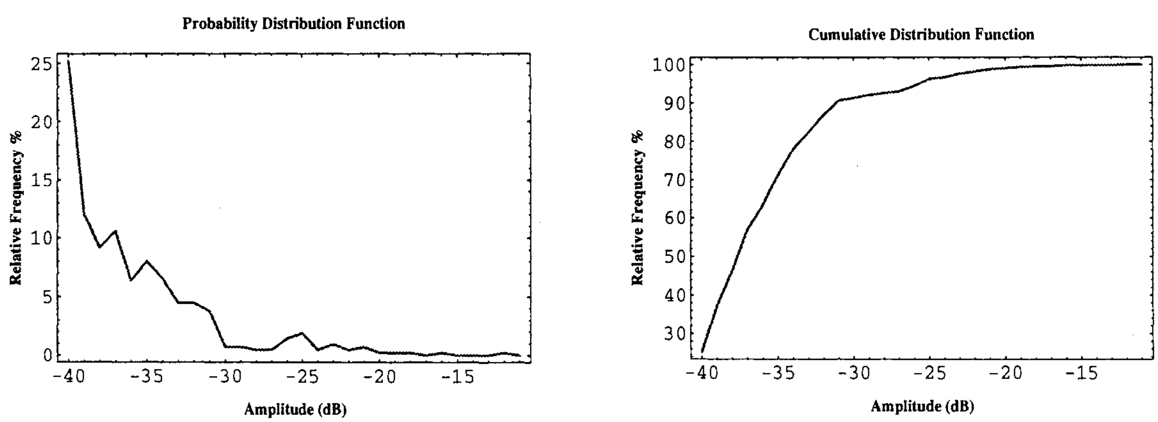
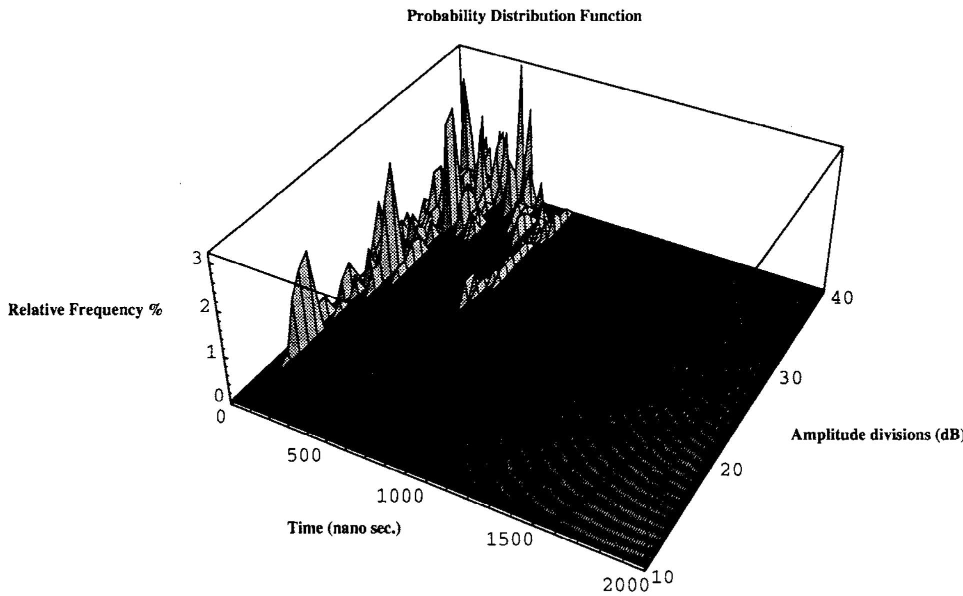


Figure D-6: Home outlet histogram of echo amplitudes (242 - 342 MHz).



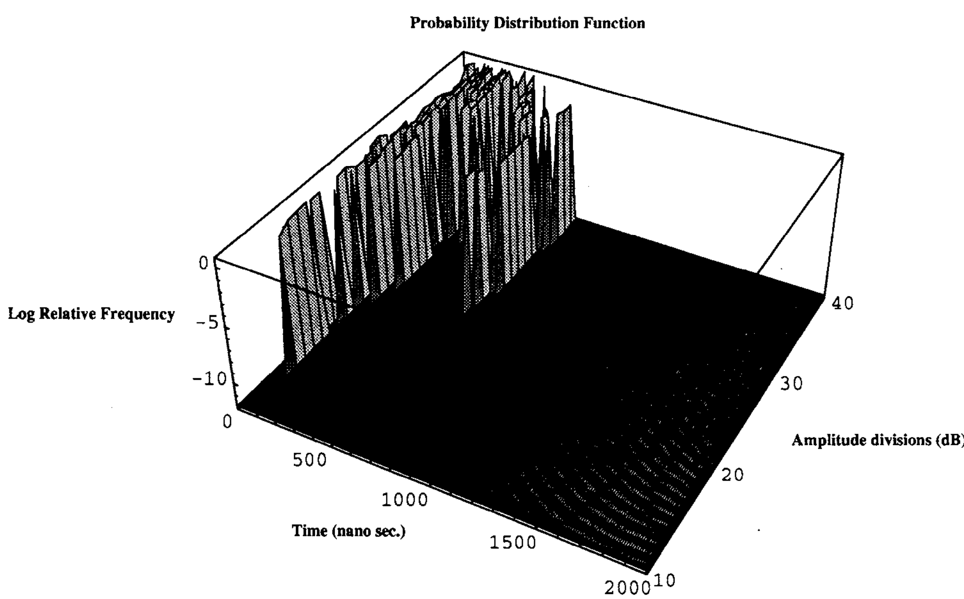


Figure D-7: Home wiring distribution of echoes (50 - 110 MHz).

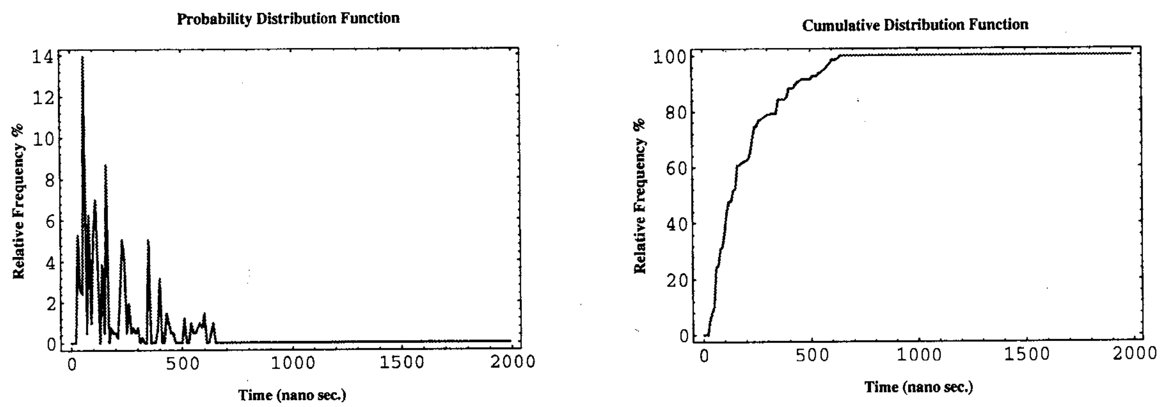


Figure D-8: Home wiring histogram of echo delays (50 - 110 MHz).

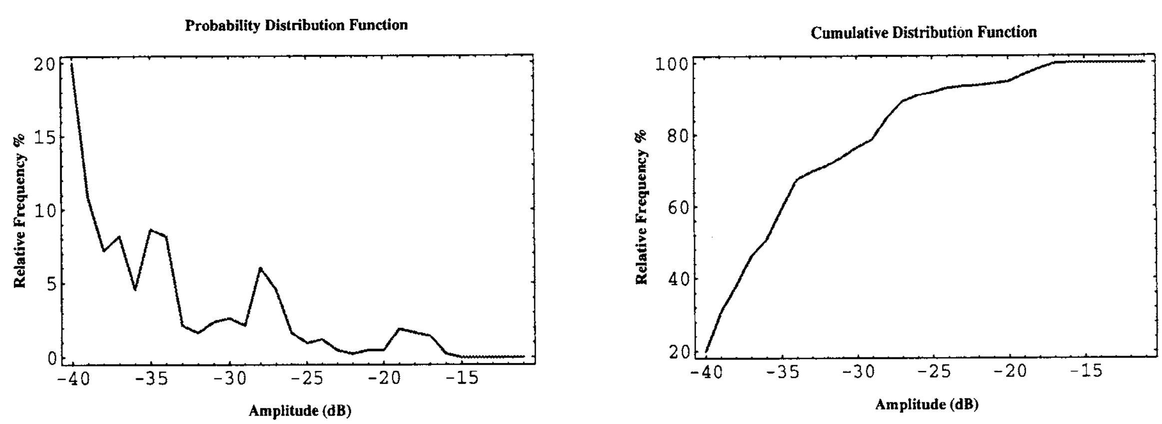


Figure D-9: Home wiring histogram of echo amplitudes (50 - 110 MHz).

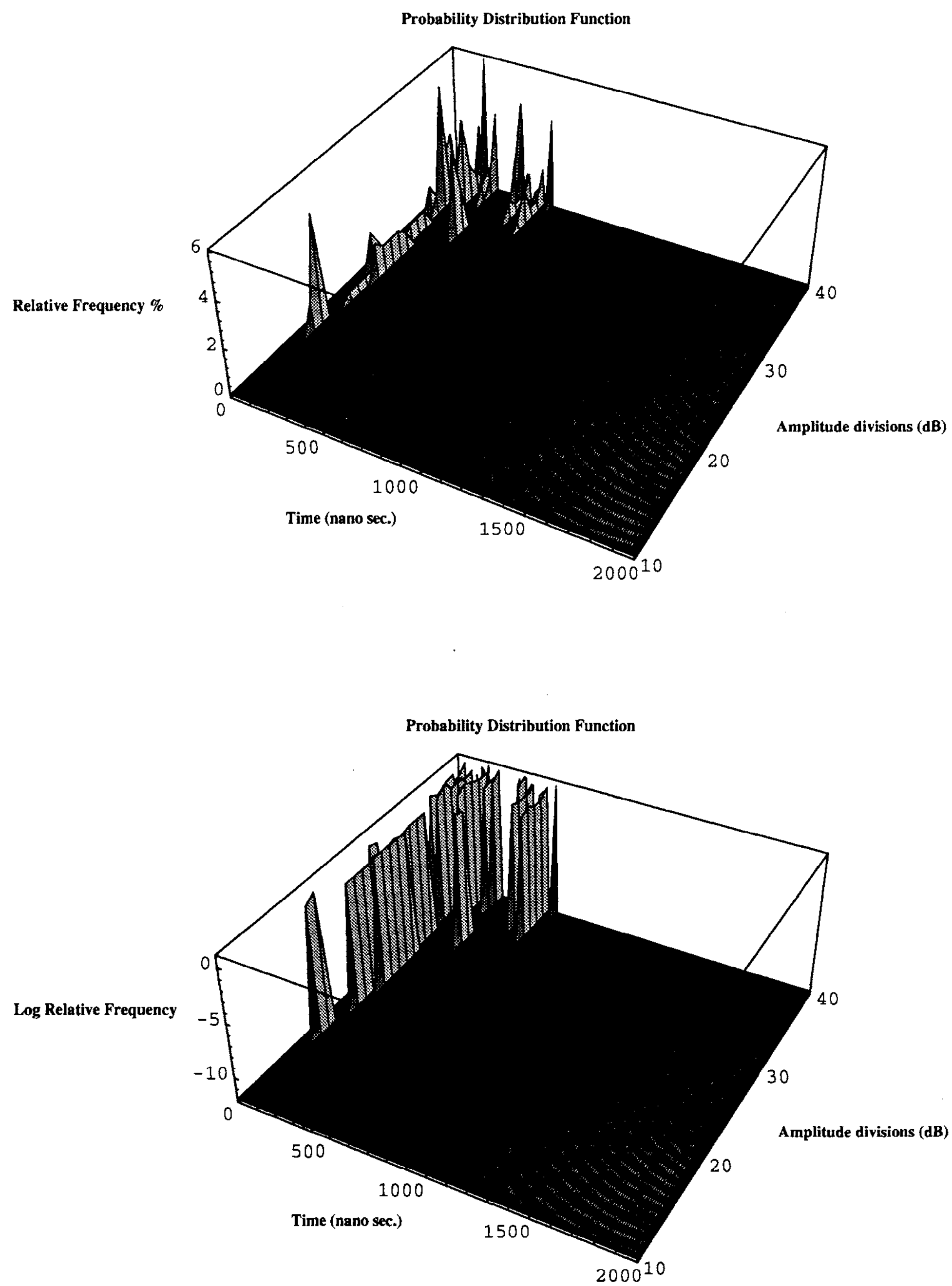


Figure D-10: Home wiring ditribution of echoes (242 - 342 MHz).

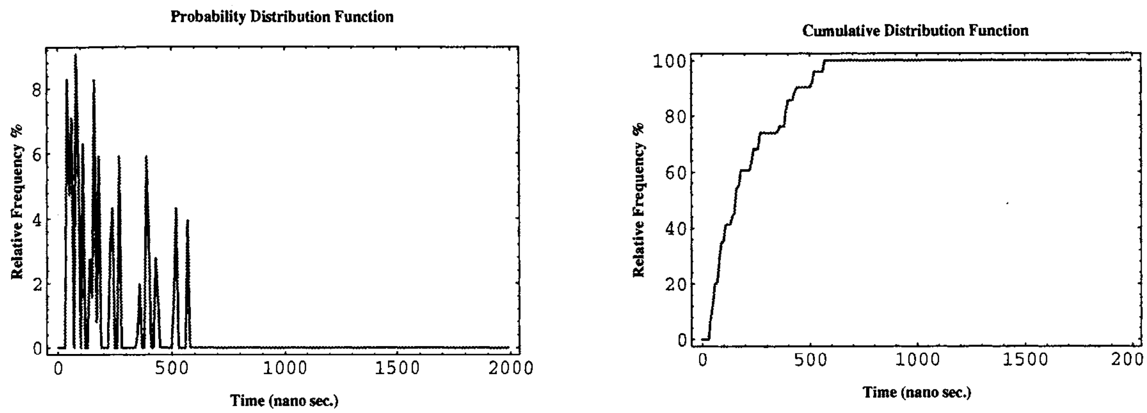


Figure D-11: Home wiring histogram of echo delays (242 - 342 MHz).

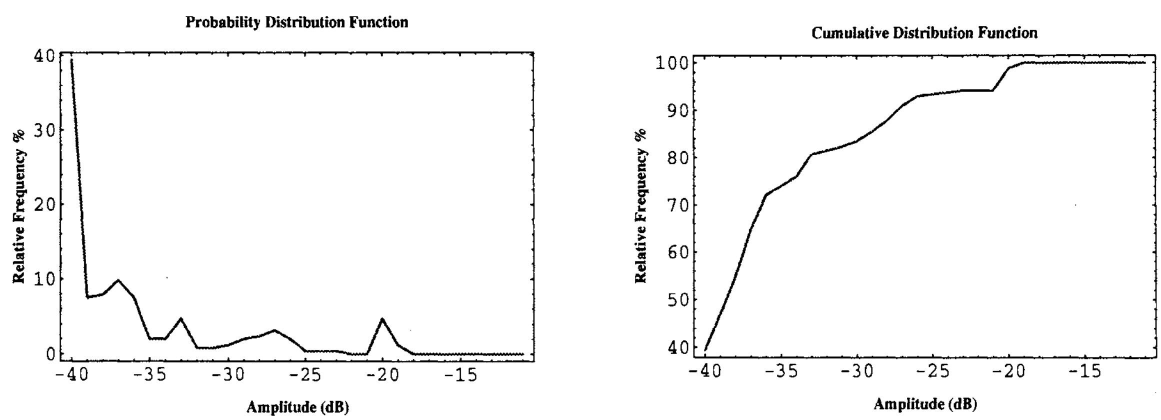


Figure D-12: Home wiring histogram of echo amplitudes (242 - 342 MHz).

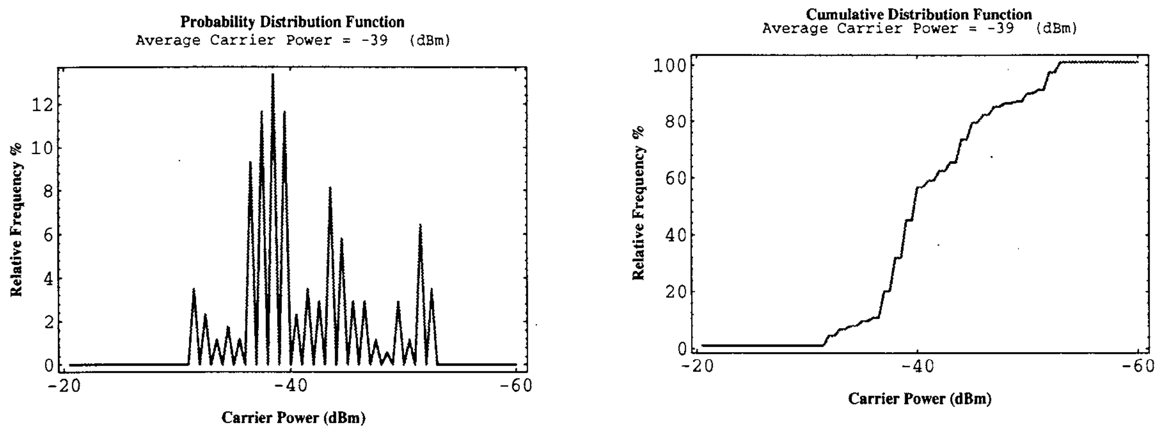


Figure D-13: Tap histogram of carrier power (242 - 342 MHz).

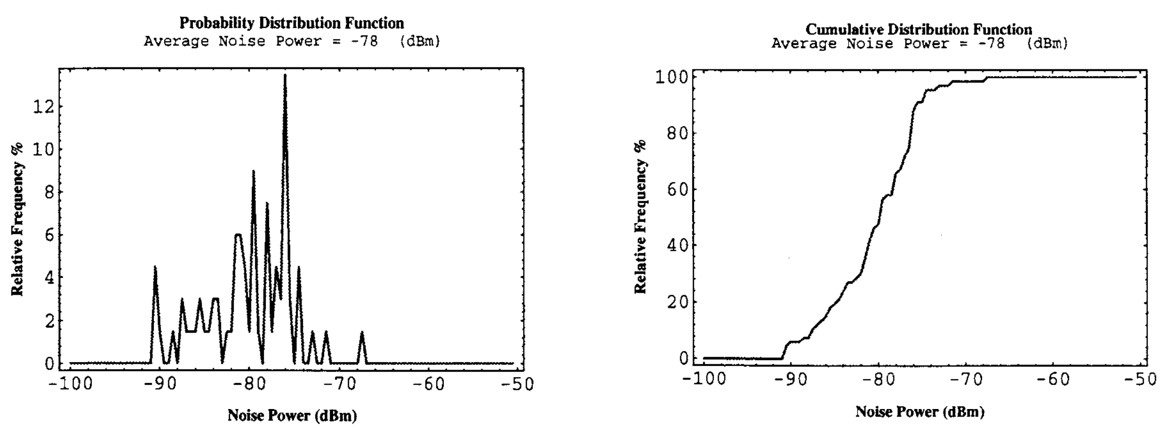


Figure D-14: Tap histogram of noise power (242 - 342 MHz).

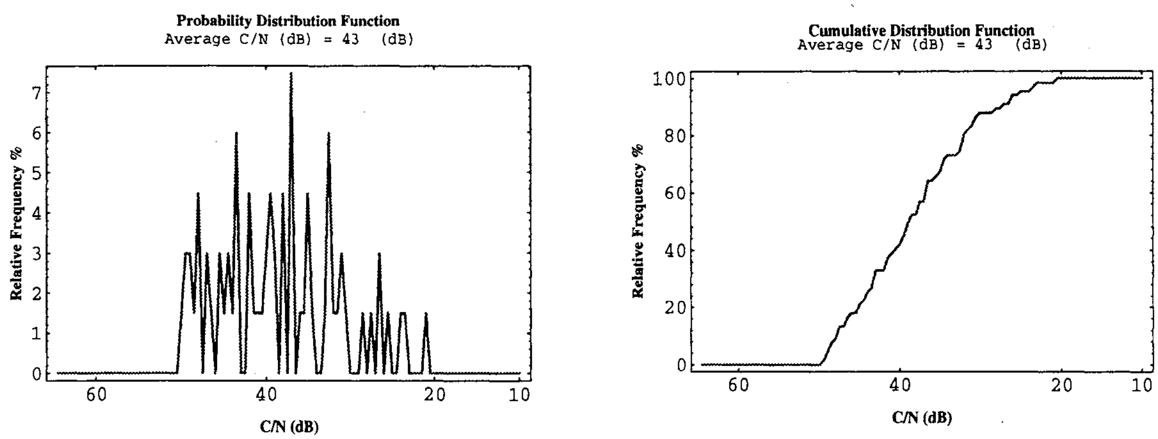


Figure D-15: Tap histogram of carrier-to-noise ratio (242 - 342 MHz).

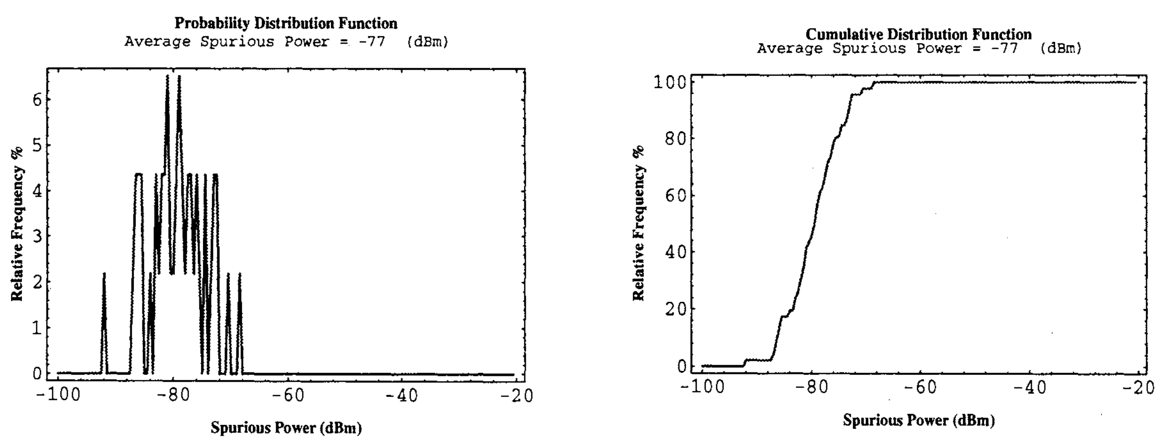


Figure D-16: Tap histogram of spurious components (242 - 342 MHz).

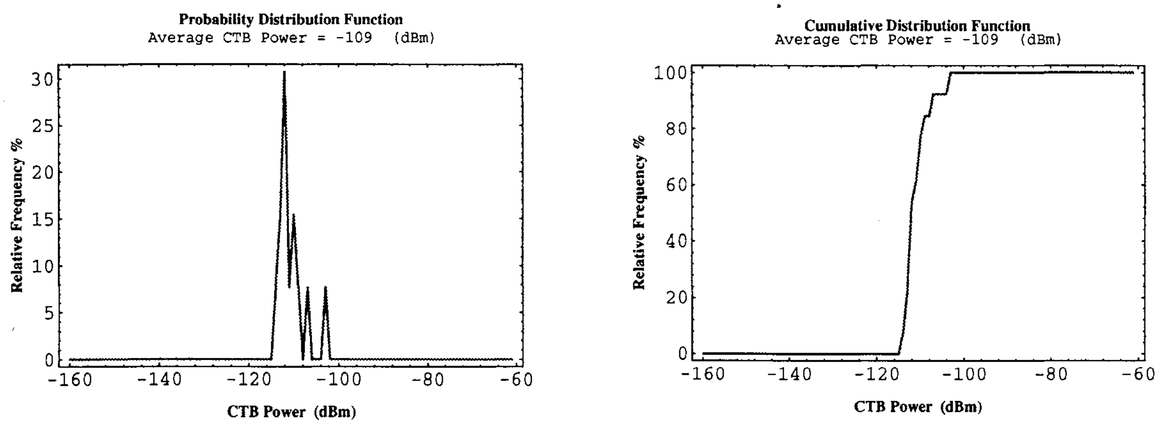


Figure D-17: Tap histogram of composite triple beats (242 - 343 MHz).

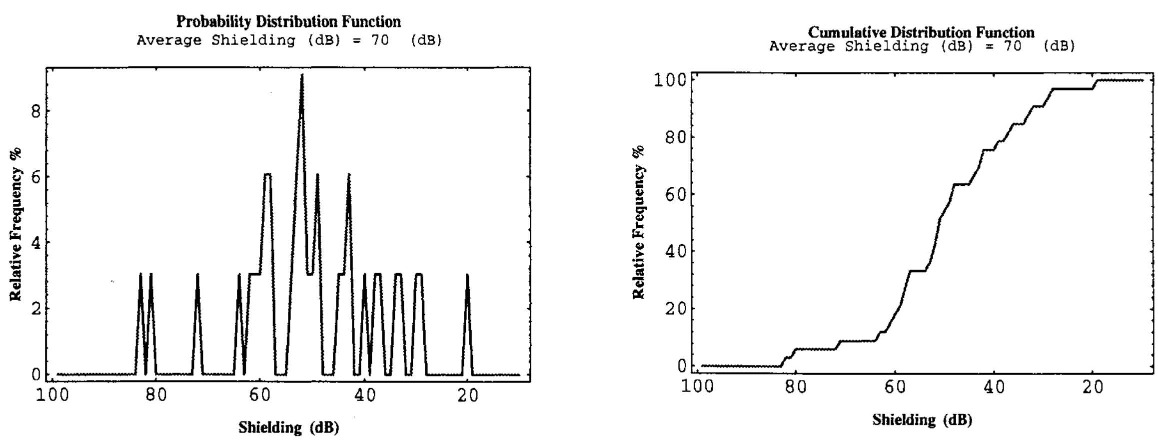


Figure D-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

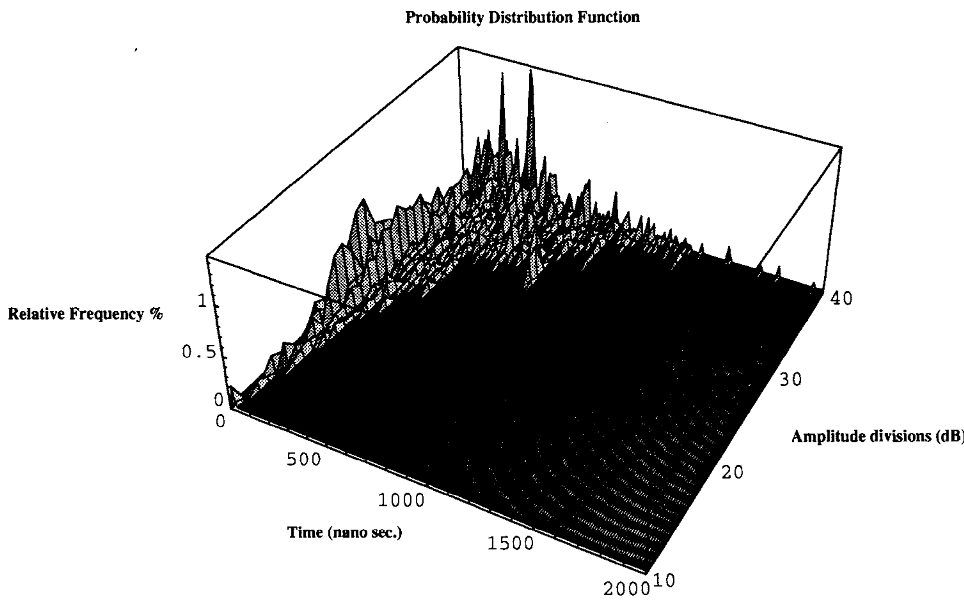
APPENDIX E. RESULTS FOR CABLE SYSTEM E

Table E-1: Micro-Reflection Impairments Summary for Cable System E.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 306 - 396 MHz				
Delay (nanosecond)	240	700	890	1260
Amplitude (dB)	-37	-25	-22	-16
Headend Thru Home Outlet:				
Frequency: 306 - 396 MHz				
Delay (nanosecond)	250	680	850	1240
Amplitude (dB)	-37	-24	-21	-16
Home Wiring:				
Frequency: 50 - 110 MHz				
Delay (nanosecond)	140	420	520	540
Amplitude (dB)	-35	-25	-20	-16
Home Wiring:				
Frequency: 306 - 396 MHz				
Delay (nanosecond)	100	180	270	550
Amplitude (dB)	-37	-29	-24	-20

Table E-2: Noise/Interference Impairments Summary for Cable System E.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 306 - 396 MHz					
Carrier/Noise (dB)	44	42	33	31	23
Carrier Power (dBm)	-32	-44	-55	-57	-59
Noise Power (dBm) in 6 MHz Bandwidth	-78	-88	-74	-69	-67
Spurious Power (dBm) in 6 MHz Bandwidth	-79	-90	-78	-72	-66
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-75	-86	-73	-67	-63
CTB Power (dBm) 12 MHz above the last active channel	-111	-113	-107	-106	-106
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	71	53	21	18	15



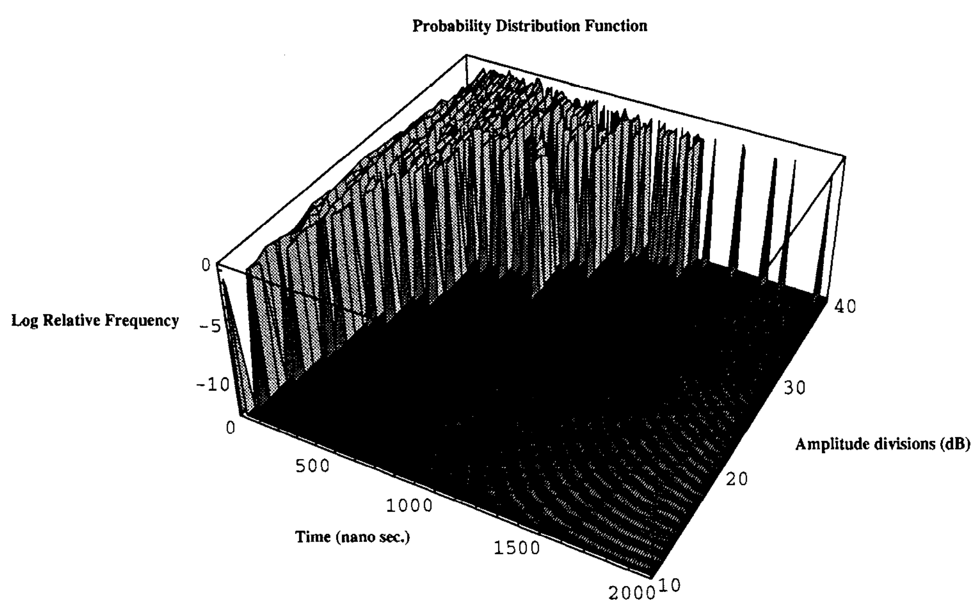


Figure E-1: Tap distribution of echoes (306 - 396 MHz).

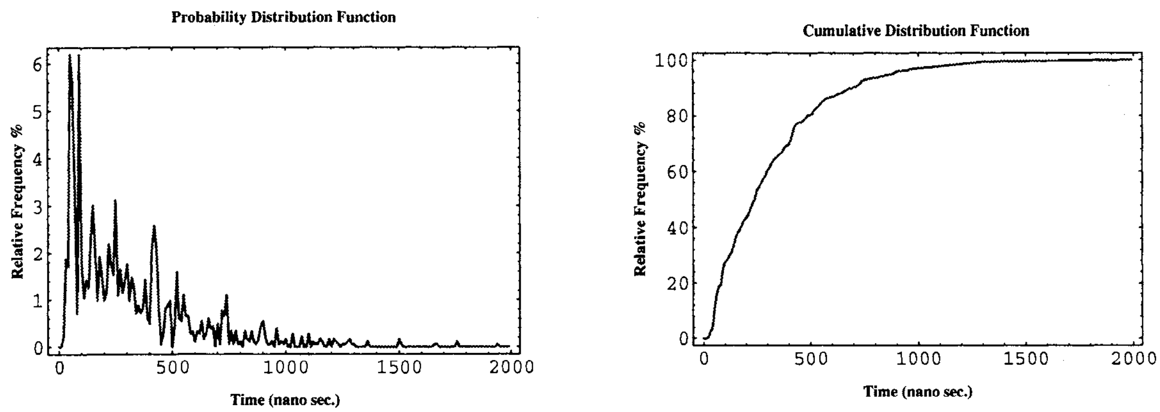


Figure E-2: Tap histogram of echo delays (306 - 396 MHz).

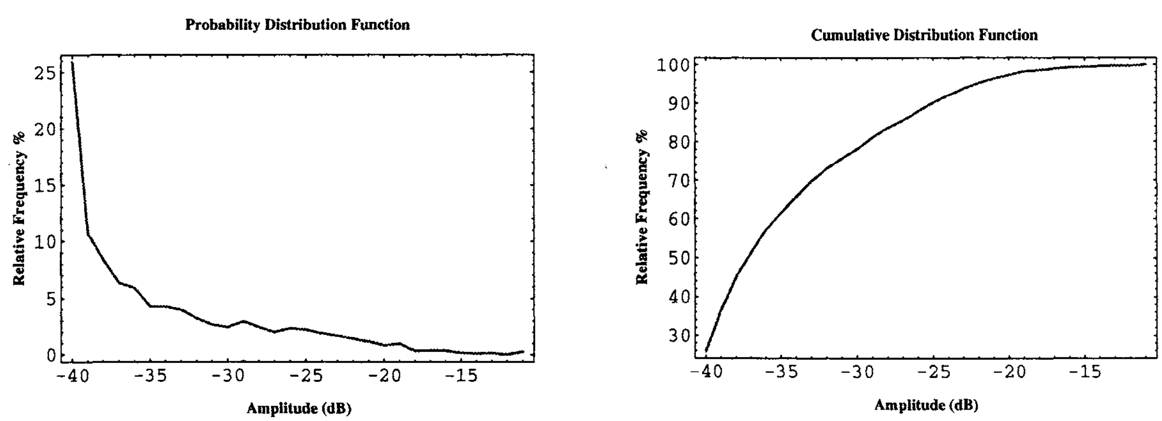
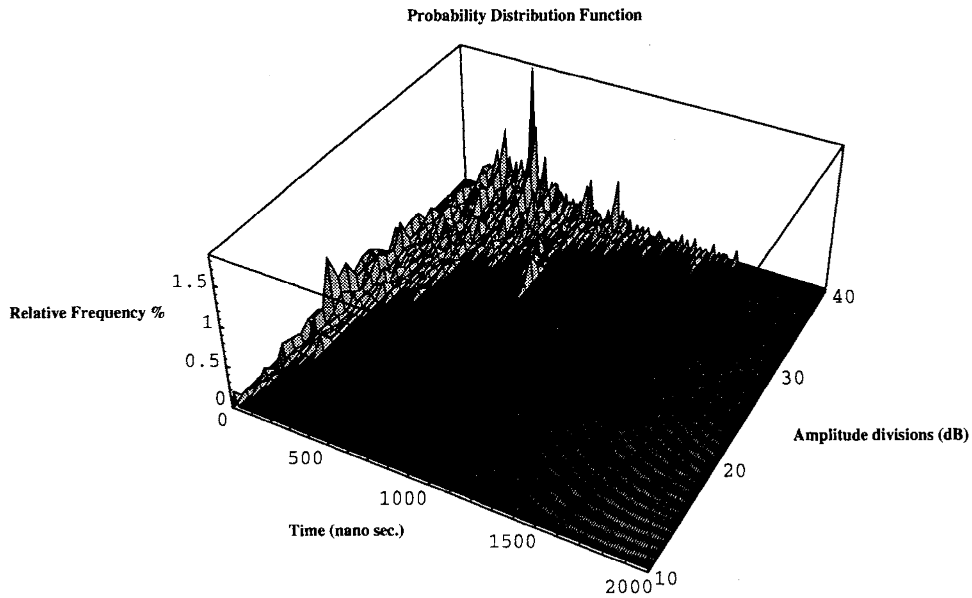


Figure E-3: Tap histogram of echo amplitudes (306 - 396 MHz).



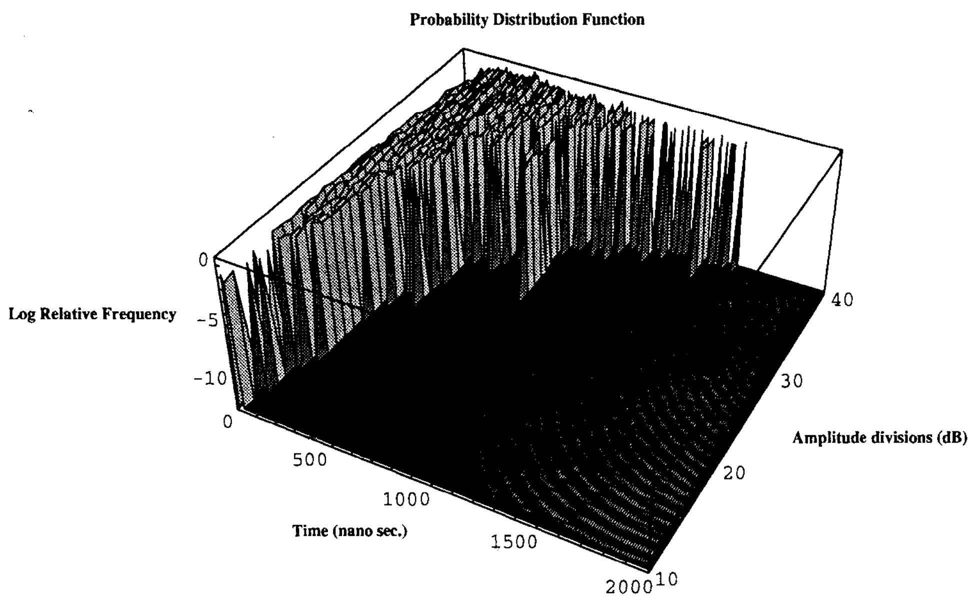


Figure E-4: Home outlet distribution of echoes (306 - 396 MHz).

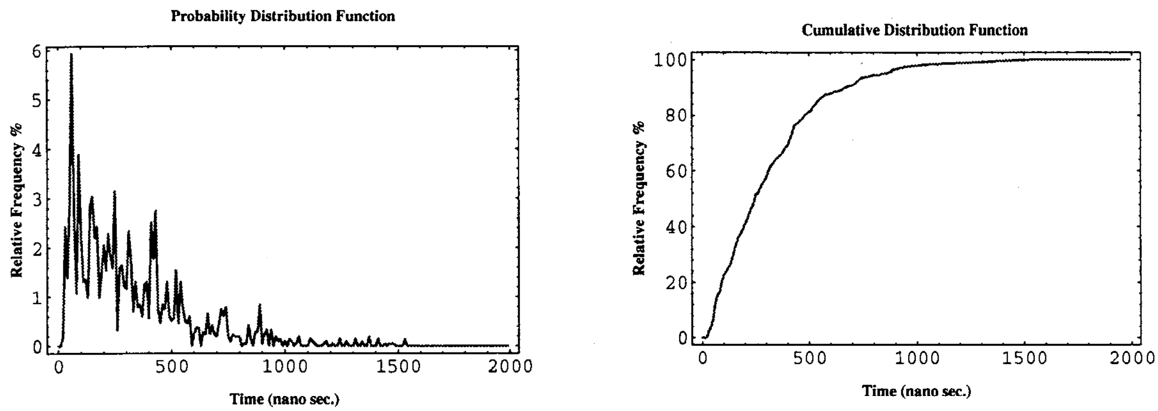


Figure E-5: Home outlet histogram of echo delays (306 - 396 MHz).

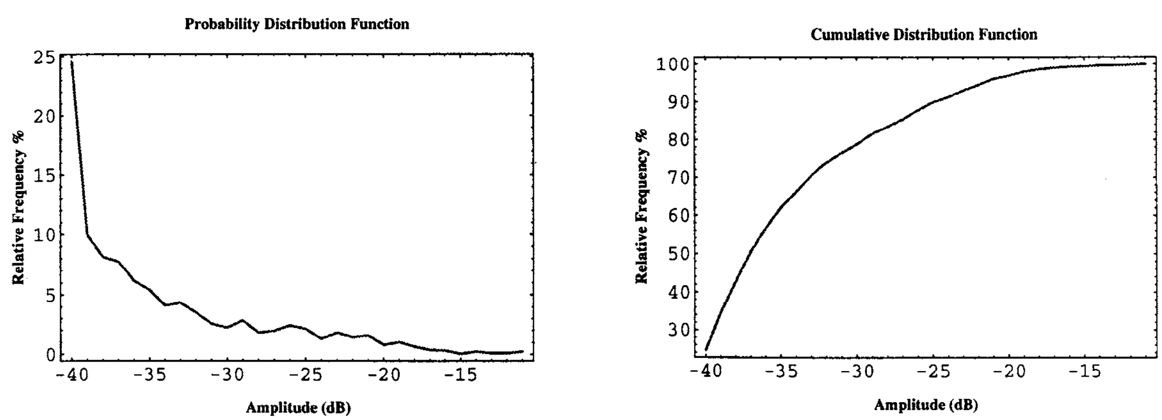
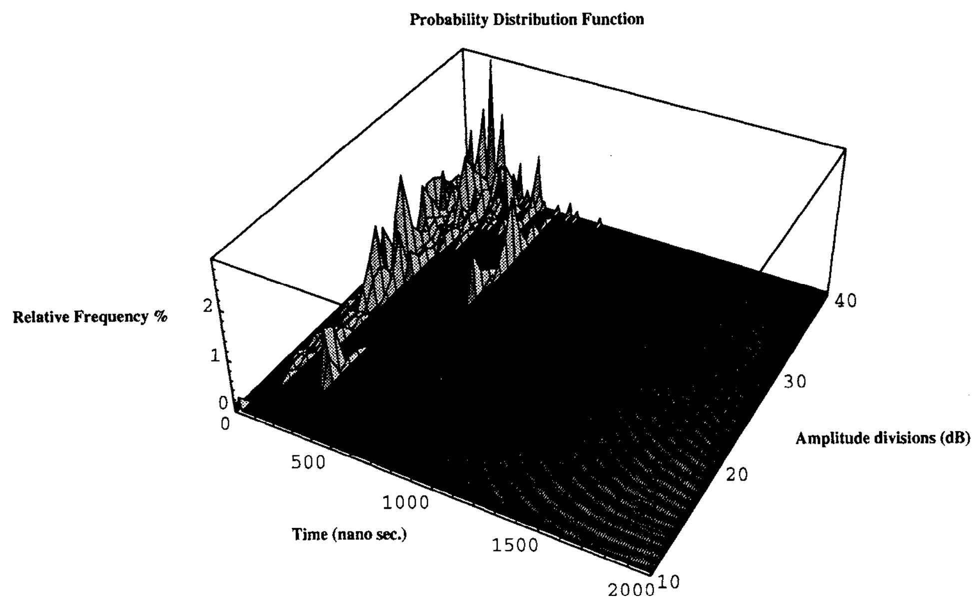


Figure E-6: Home outlet histogram of echo amplitudes (306 - 396 MHz).



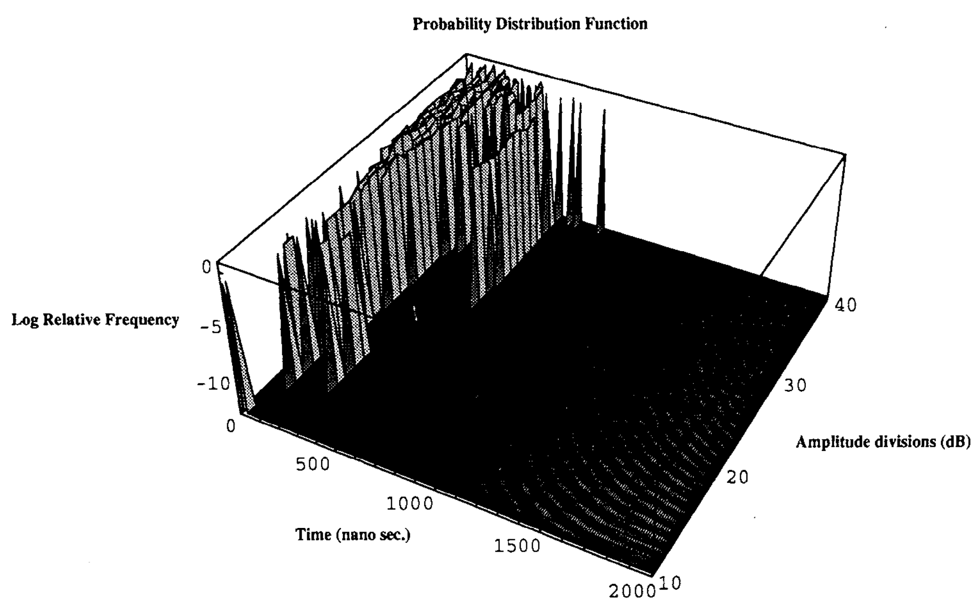


Figure E-7: Home wiring distribution of echoes (50 - 110 MHz).

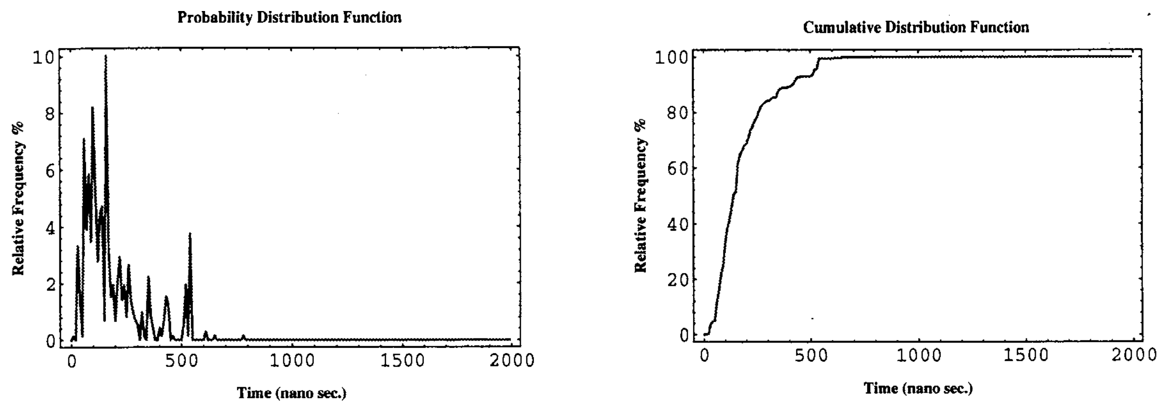


Figure E-8: Home wiring histogram of echo delays (50 - 110 MHz).

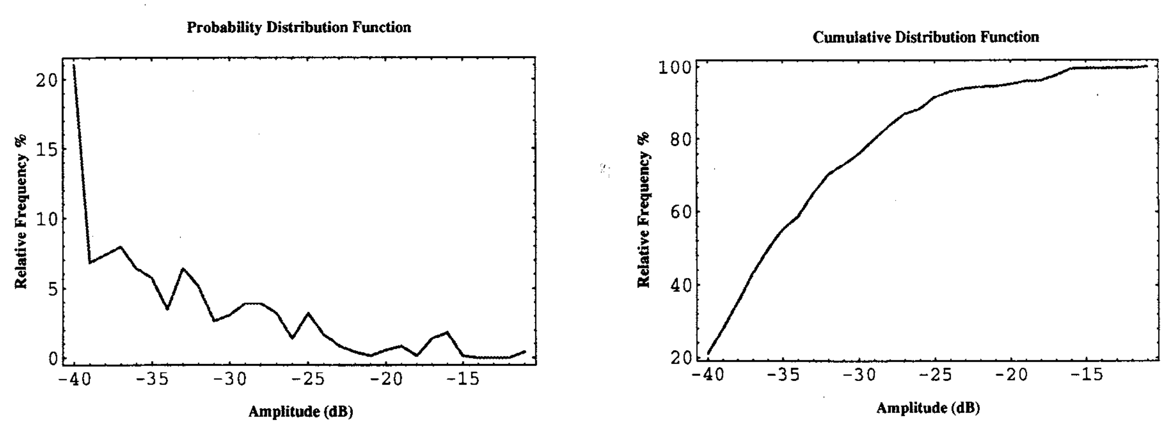


Figure E-9: Home wiring histogram of echo amplitudes (50 - 110 MHz).

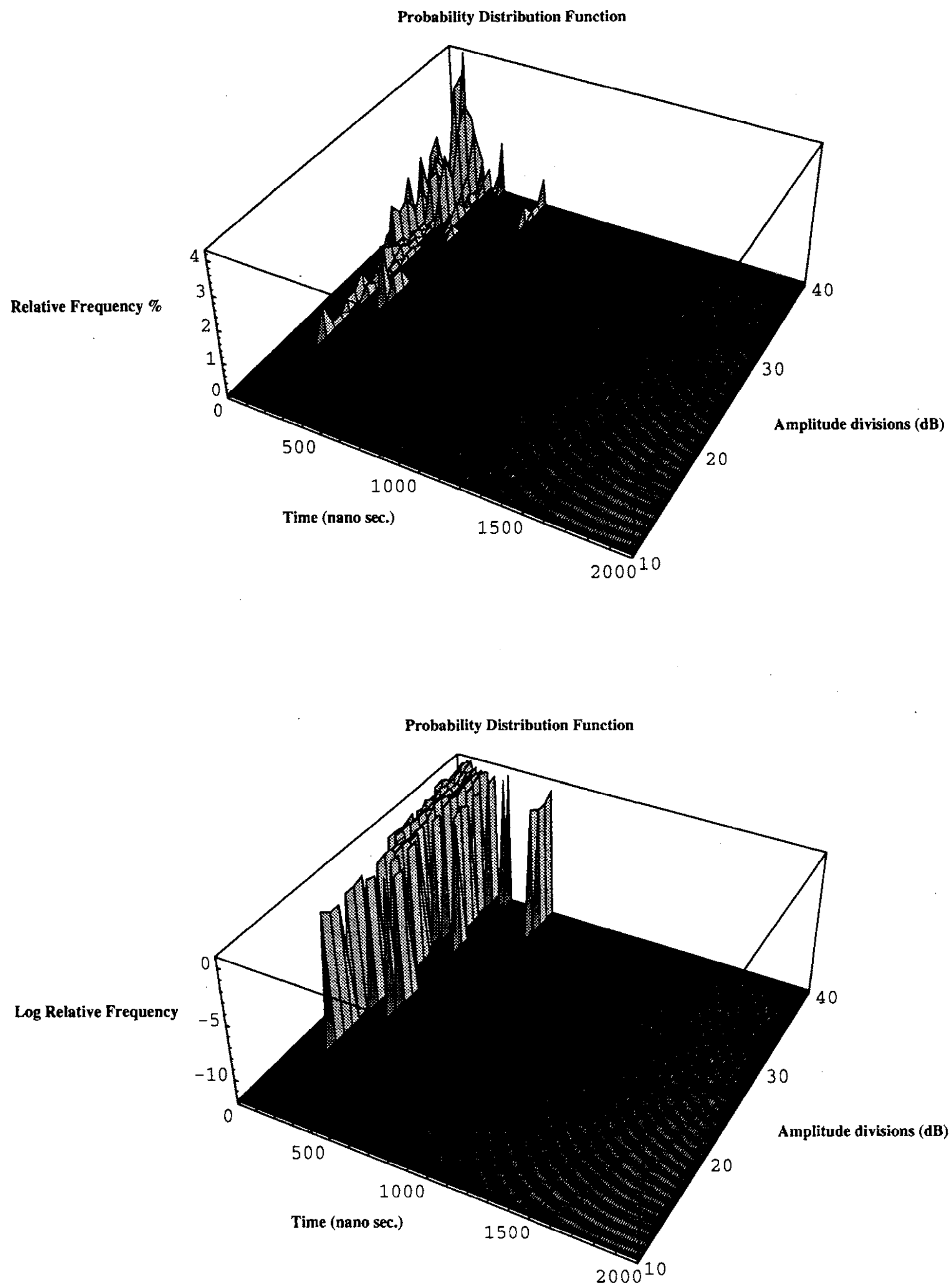


Figure E-10: Home wiring distribution of echoes (306 - 396 MHz).

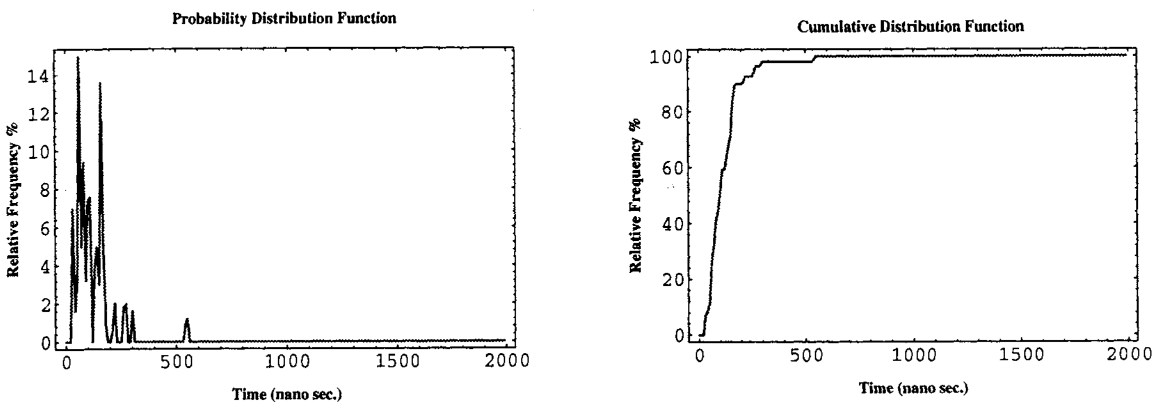


Figure E-11: Home wiring histogram of echo delays (306 - 396 MHz).

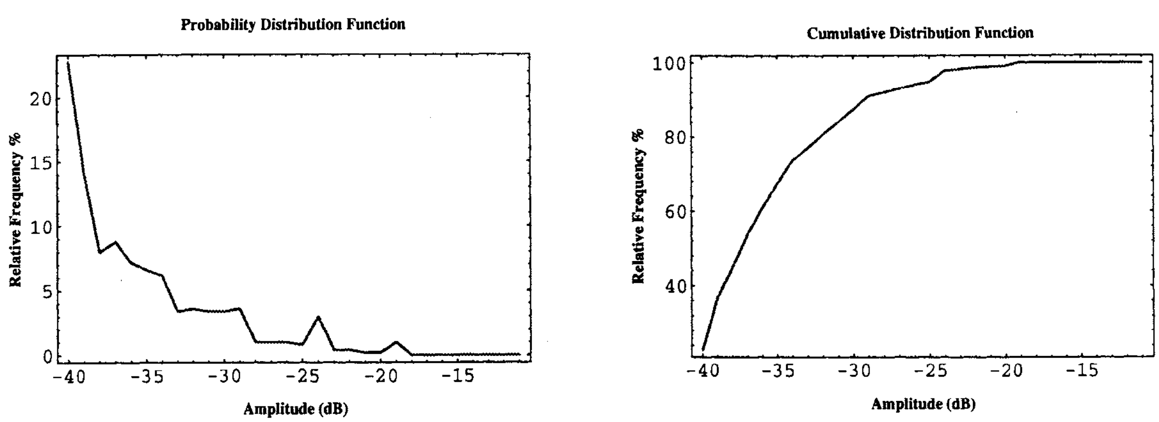


Figure E-12: Home wiring histogram of echo amplitudes (306 - 396 MHz).

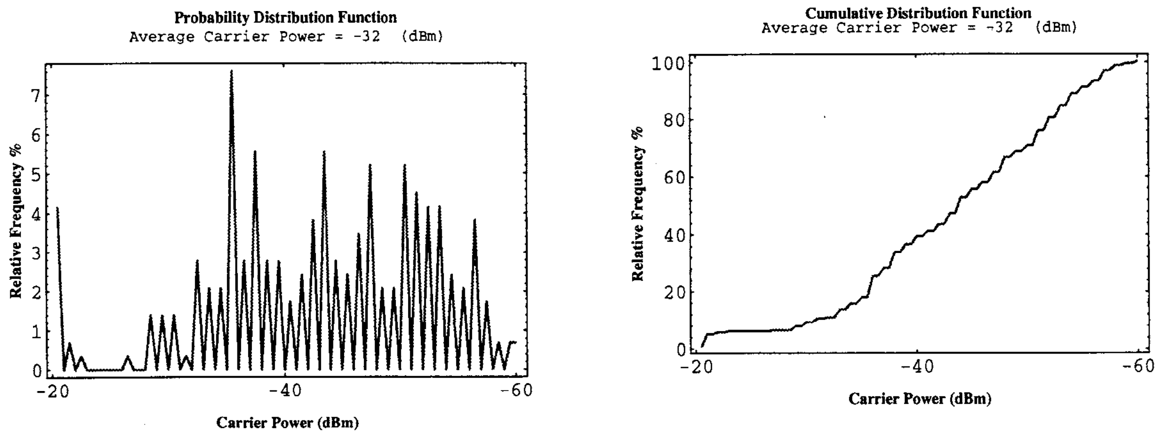


Figure E-13: Tap histogram of carrier power (306 - 396 MHz).

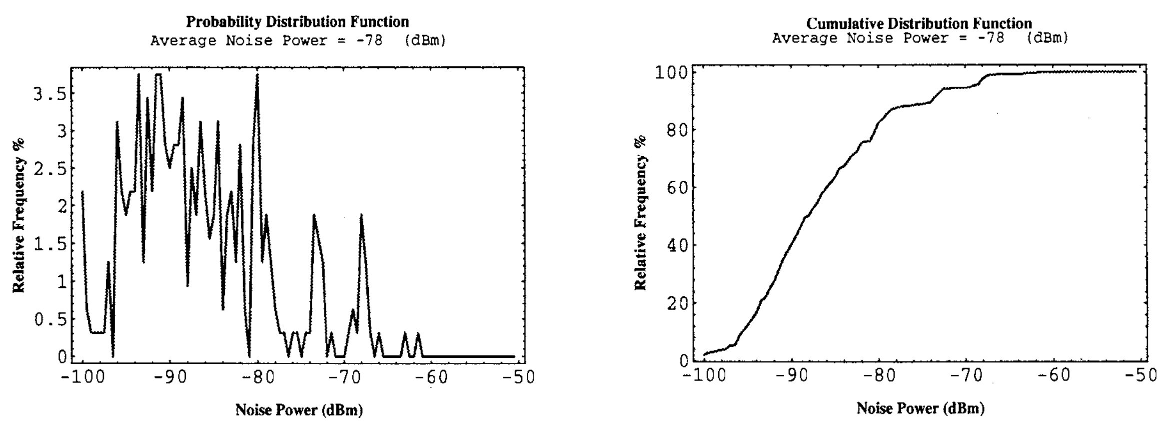


Figure E-14: Tap histogram of noise power (306 - 396 MHz).

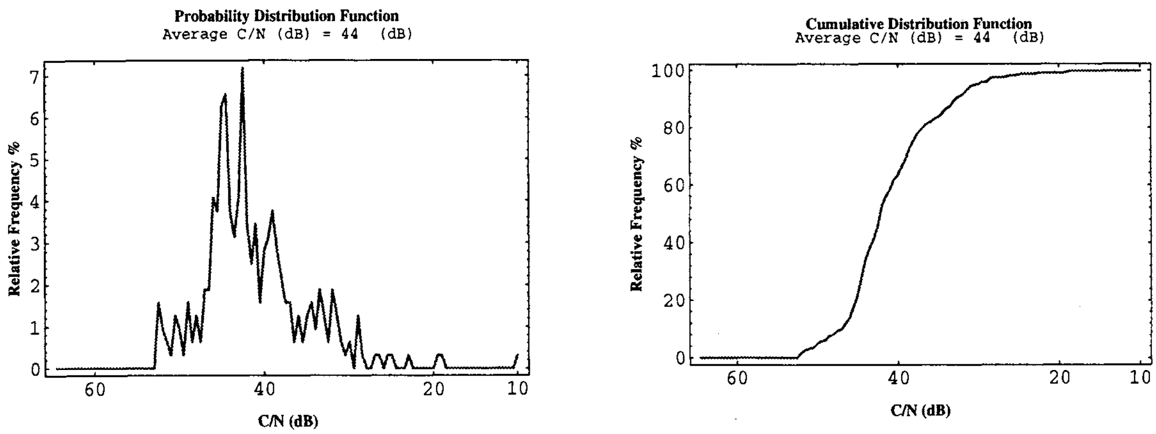


Figure E-15: Tap histogram of carrier-to-noise ratio (306 - 396 MHz).

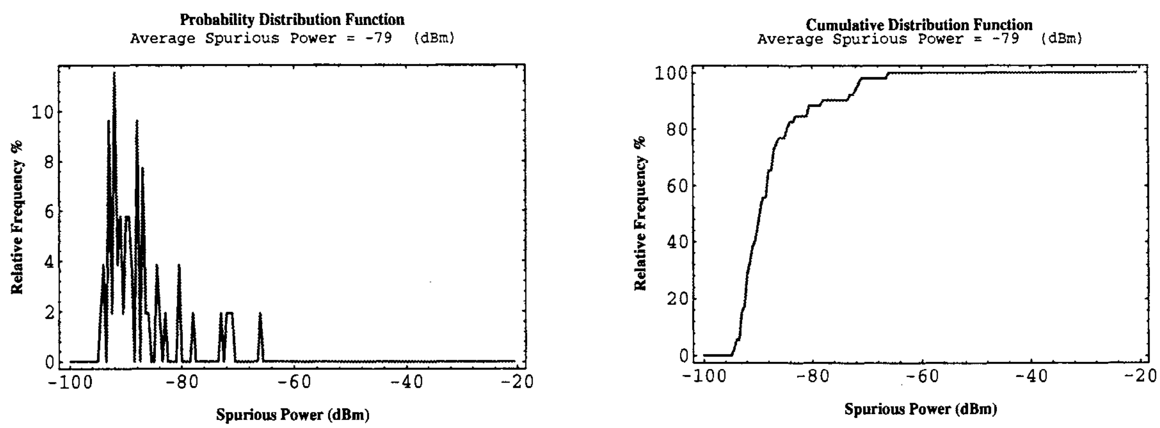


Figure E-16: Tap histogram of spurious components (306 - 396 MHz).

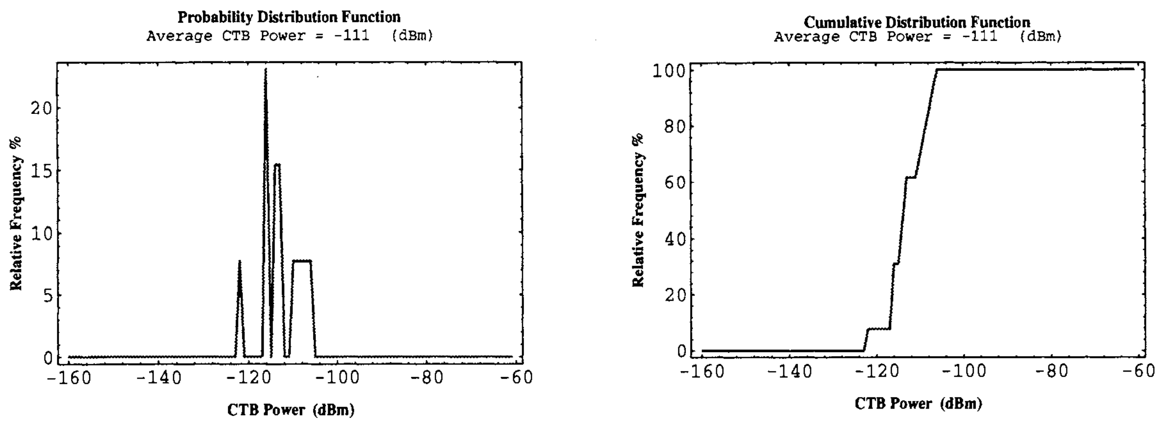


Figure E-17: Tap histogram of composite triple beats (306 - 396 MHz).

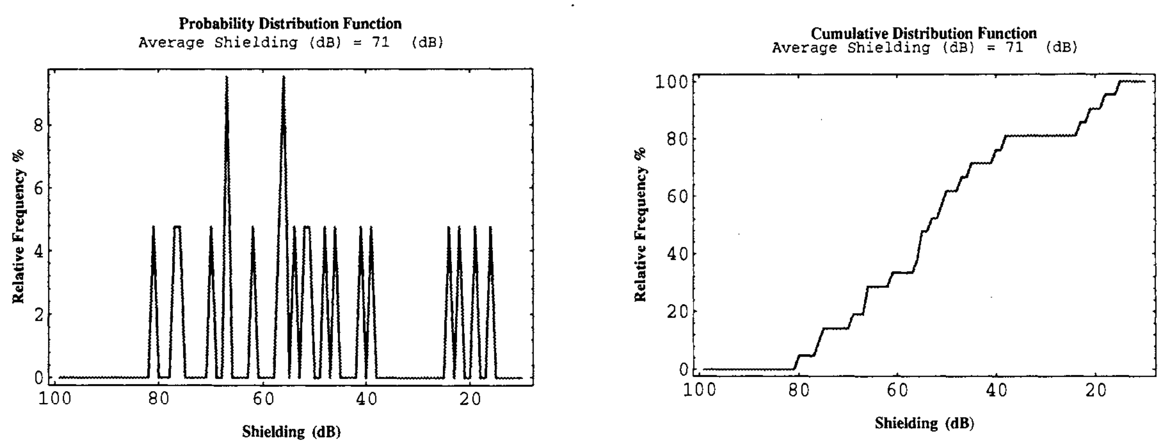


Figure E-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

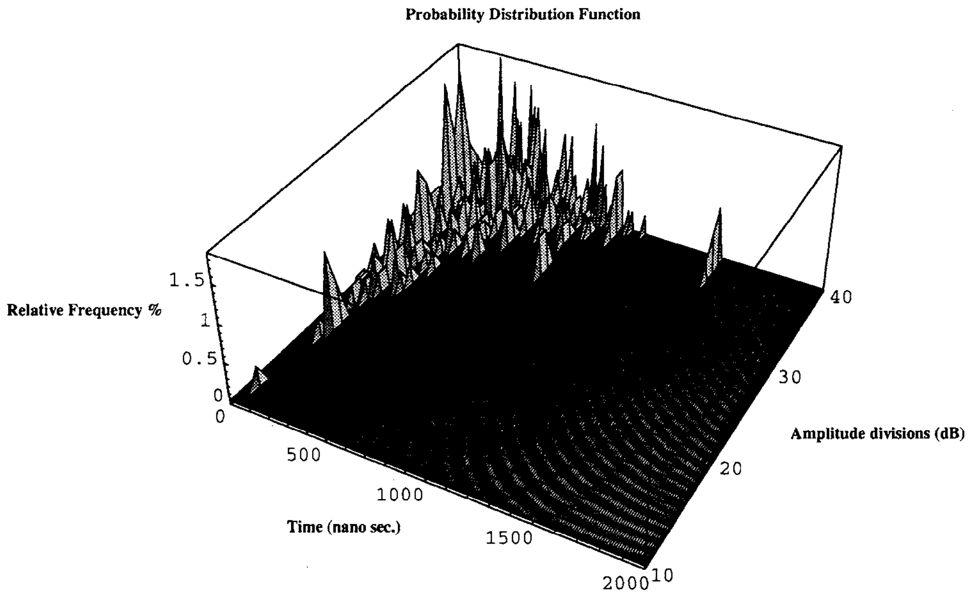
APPENDIX F. RESULTS FOR CABLE SYSTEM F

Table F-1: Micro-Reflection Impairments Summary for Cable System F.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 420 - 456 MHz				
Delay (nanosecond)	320	750	830	1470
Amplitude (dB)	-37	-27	-25	-20
Headend Thru Home Outlet:				
Frequency: 420 - 456 MHz				
Delay (nanosecond)	320	750	860	1470
Amplitude (dB)	-37	-27	-24	-20
Home Wiring:				
Frequency: 50 - 110 MHz				
Delay (nanosecond)	150	340	390	430
Amplitude (dB)	-38	-31	-29	-27
Home Wiring:				
Frequency: 420 - 456 MHz				
Delay (nanosecond)	150	340	350	670
Amplitude (dB)	-36	-27	-27	-23

Table F-2: Noise/Interference Impairments Summary for Cable System F.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 420 - 456 MHz					
Carrier/Noise (dB)	43	39	27	25	21
Carrier Power (dBm)	-39	-40	-51	-52	-53
Noise Power (dBm) in 6 MHz Bandwidth	-78	-80	-76	-75	-68
Spurious Power (dBm) in 6 MHz Bandwidth	-77	-79	-73	-73	-69
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-74	-76	-71	-71	-65
CTB Power (dBm) 12 MHz above the last active channel	-109	-112	-107	-103	-103
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	70	51	32	28	19



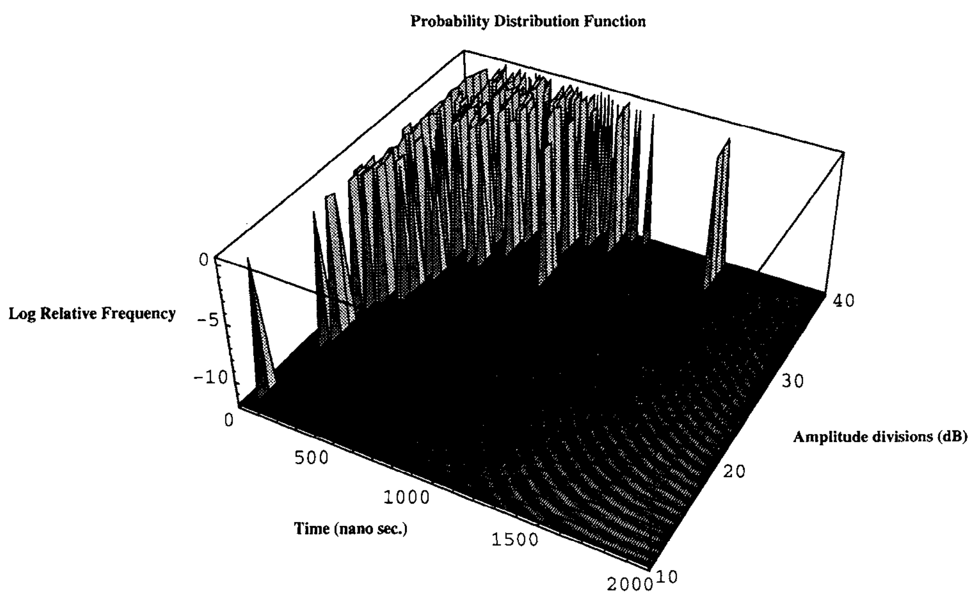


Figure F-1: Tap distribution of echoes (420 - 456 MHz).

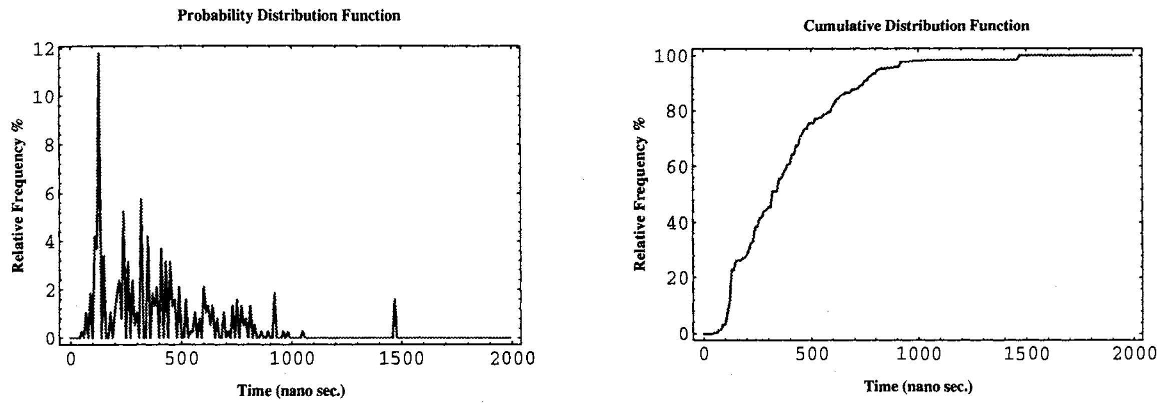


Figure F-2: Tap histogram of echo delays (420 - 456 MHz).

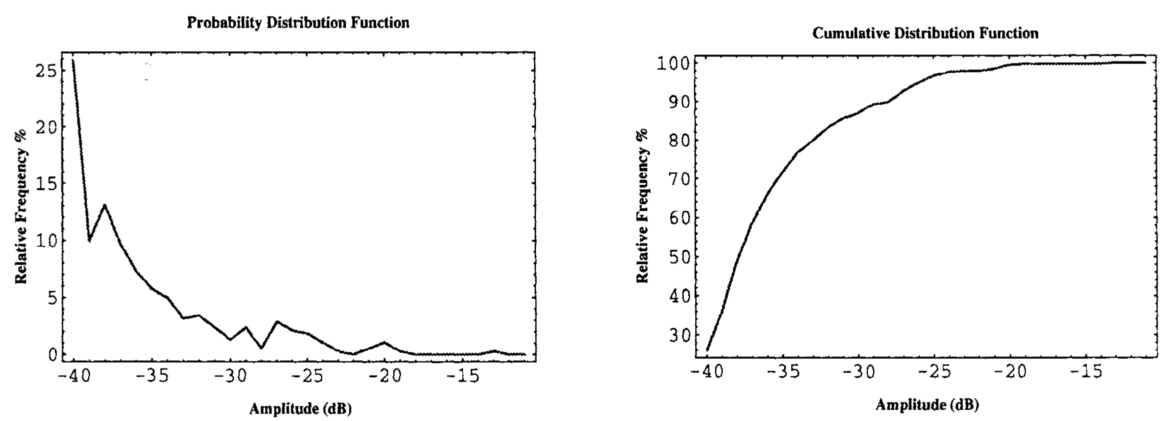
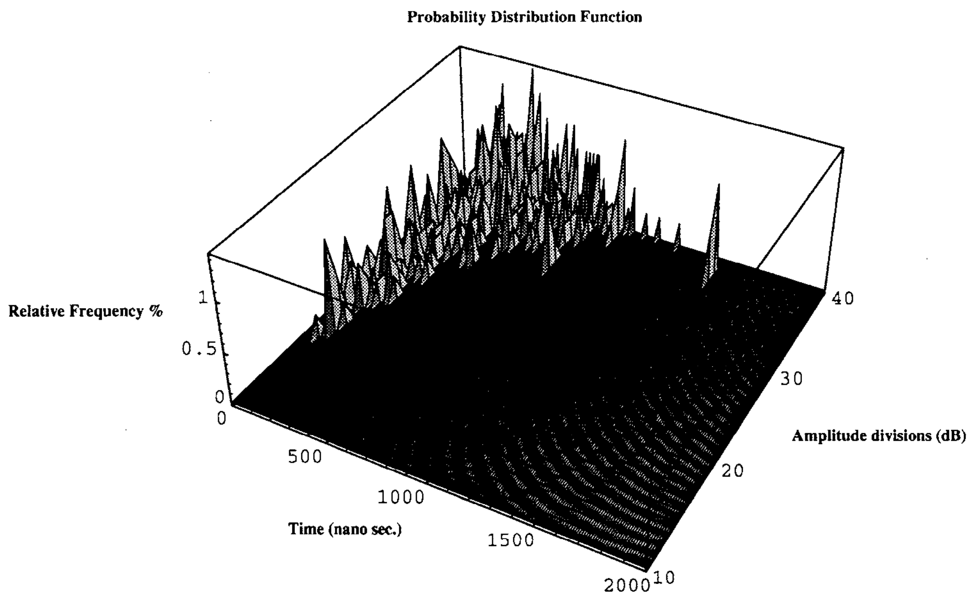


Figure F-3: Tap histogram of echo amplitudes (420 - 456 MHz).



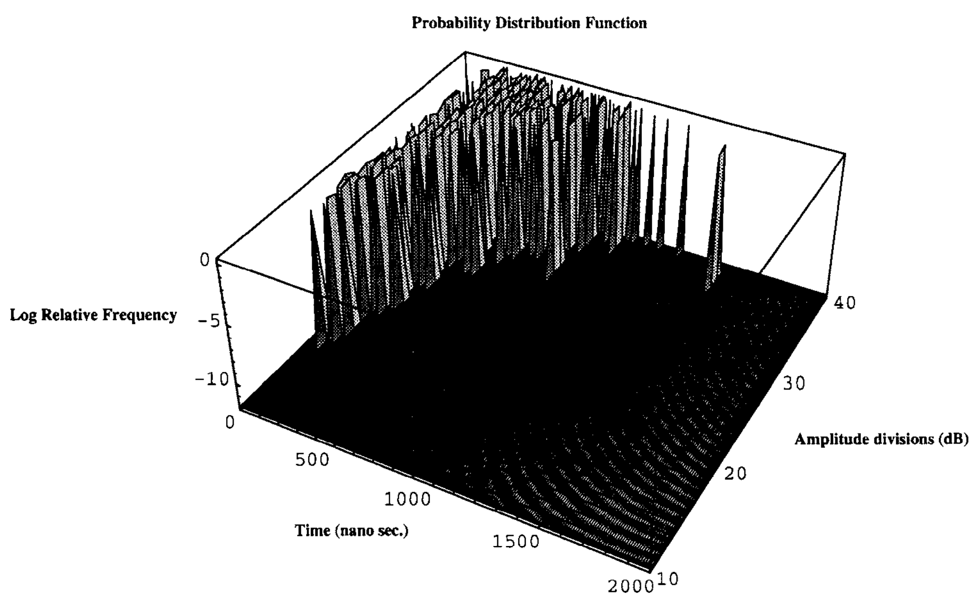
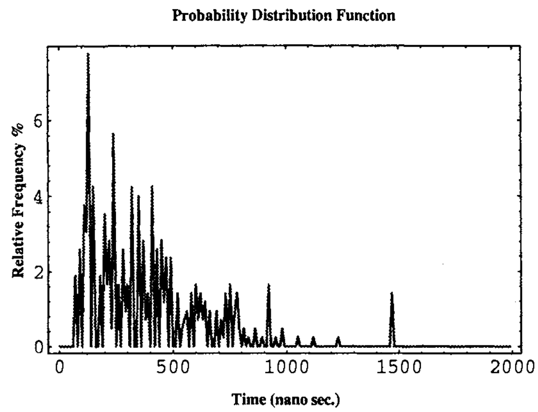


Figure F-4: Home outlet distribution of echoes (420 - 456 MHz).



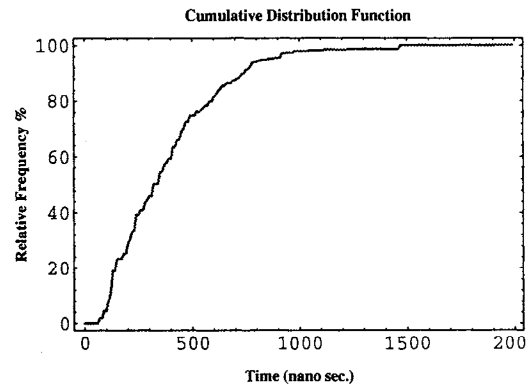
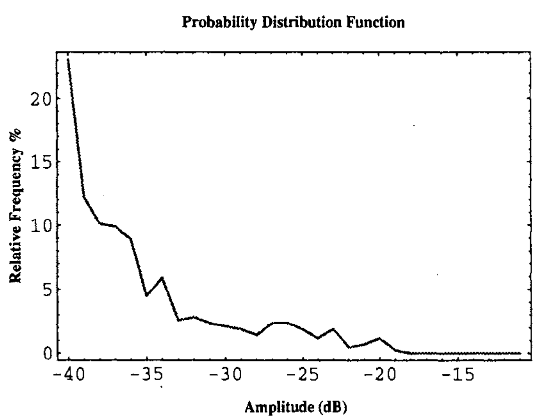


Figure F-5: Home outlet histogram of echo delays (420 - 456 MHz).



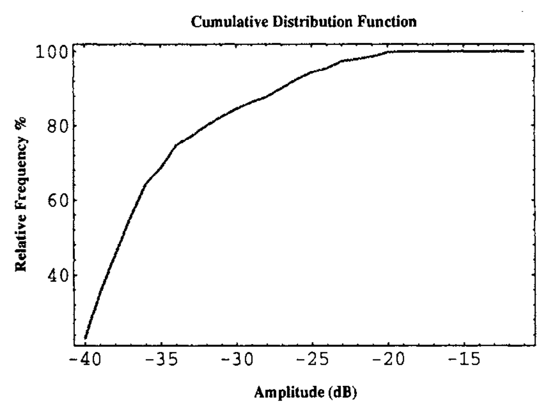
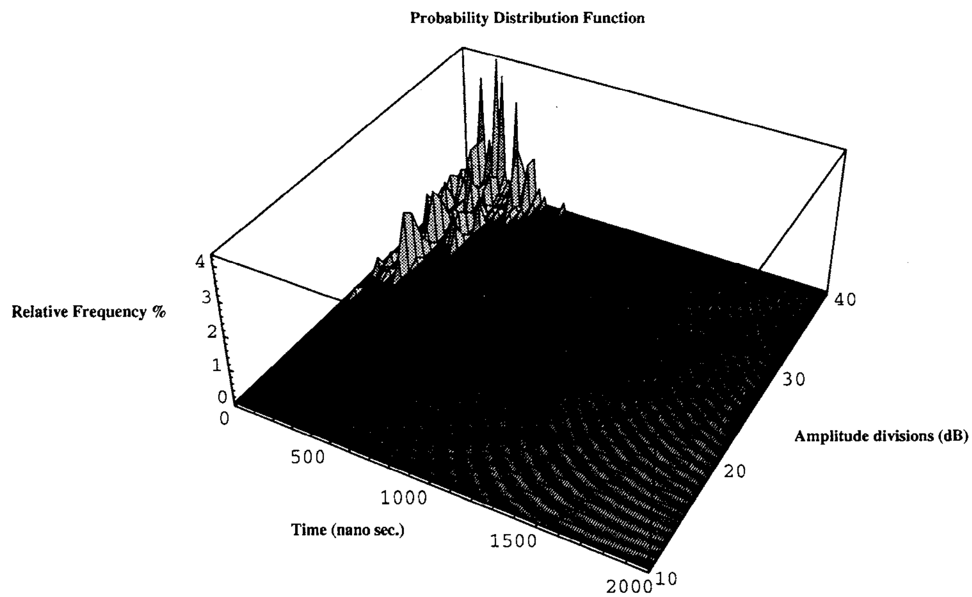


Figure F-6: Home outlet histogram of echo amplitudes (420 - 456 MHz).



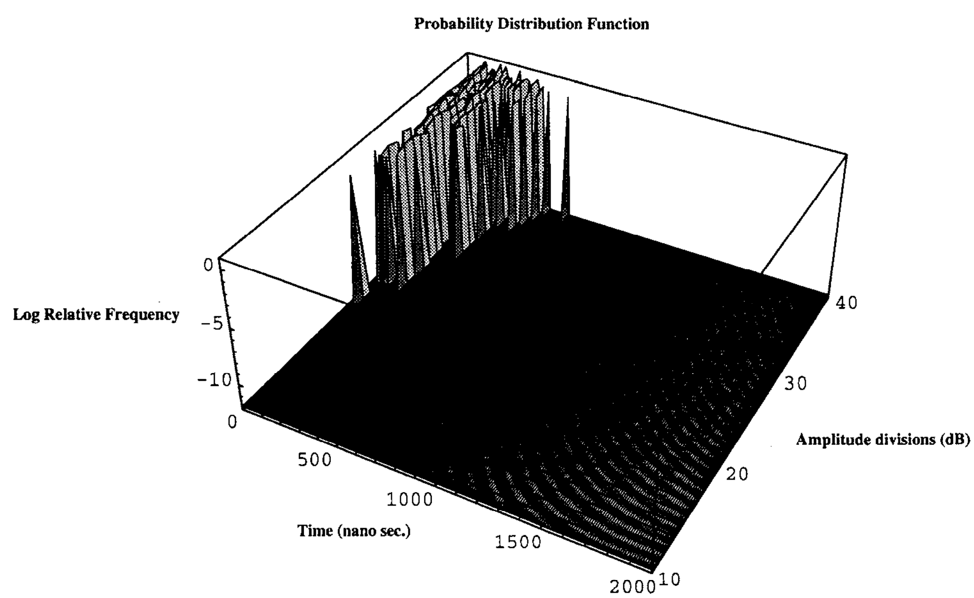


Figure F-7: Home wiring distribution of echoes (50 - 110 MHz).

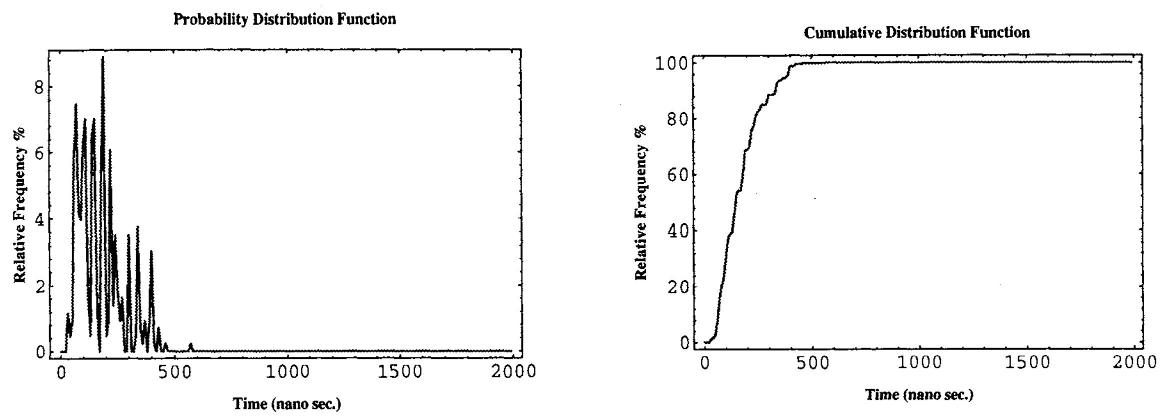


Figure F-8: Home wiring histogram of echo delays (50 - 110 MHz).

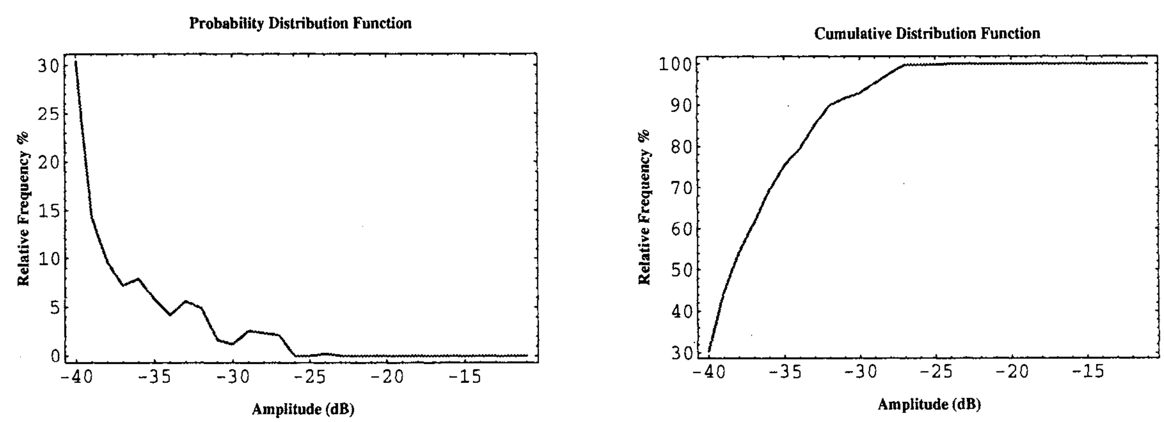
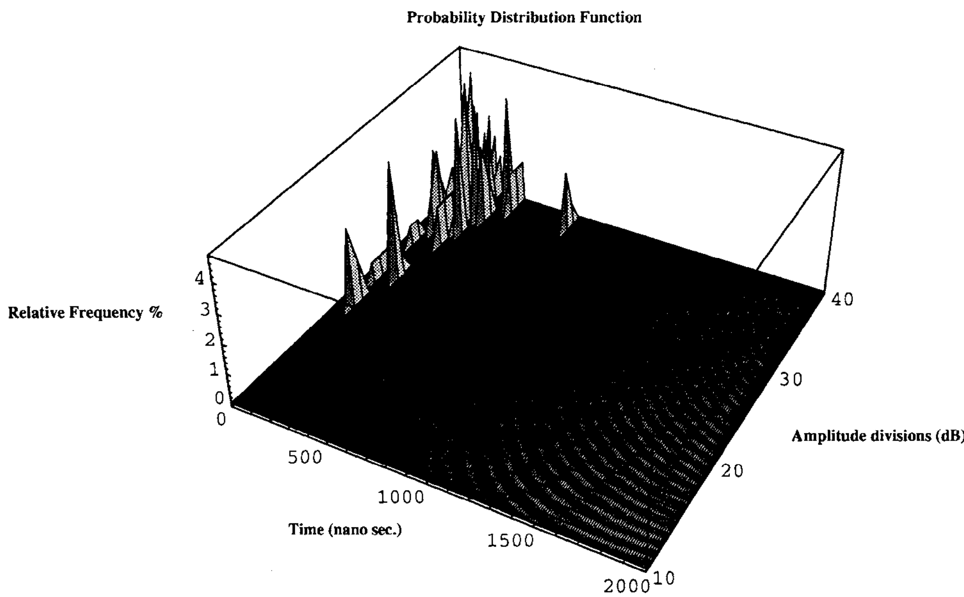


Figure F-9: Home wiring histogram of echo amplitudes (50 - 110 MHz).



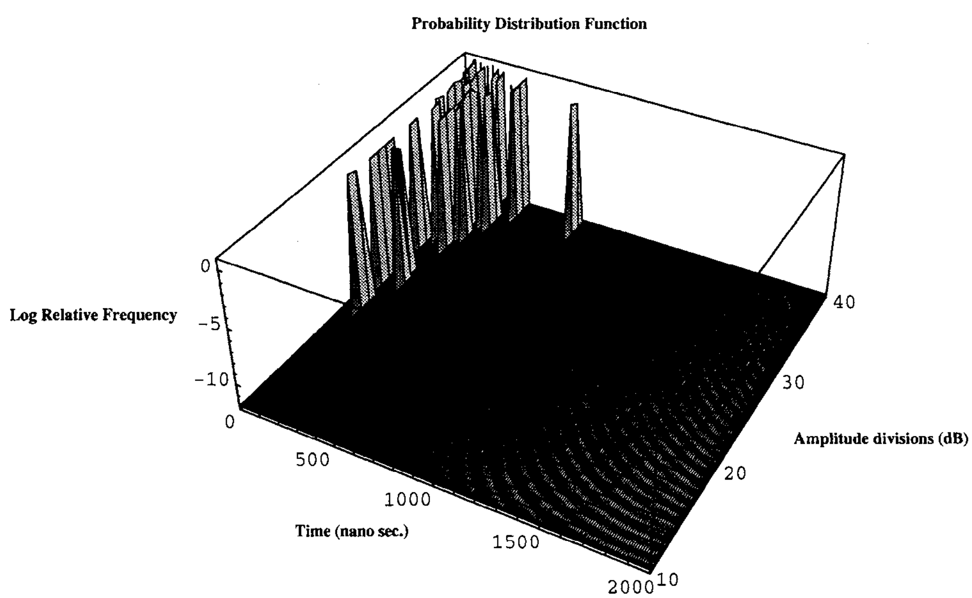


Figure F-10: Home wiring distribution of echoes (420 - 456 MHz).

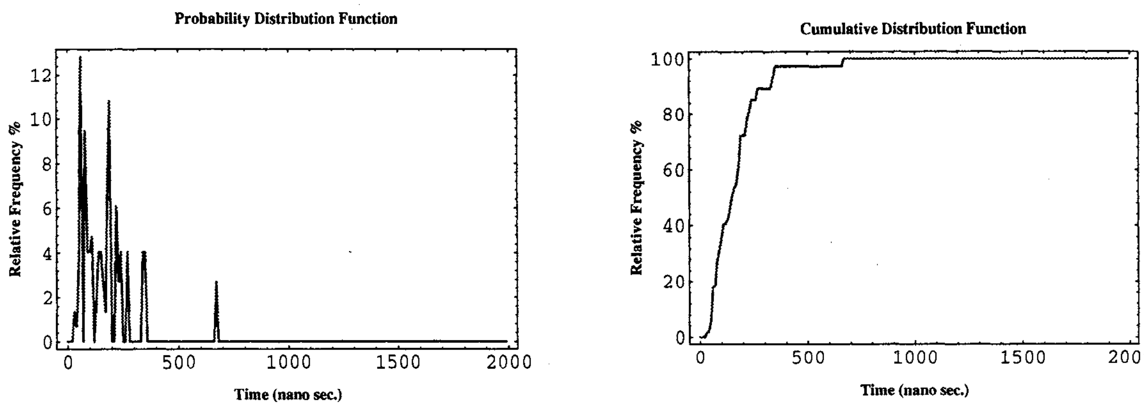


Figure F-11: Home wiring histogram of echo delays (420 - 456 MHz).

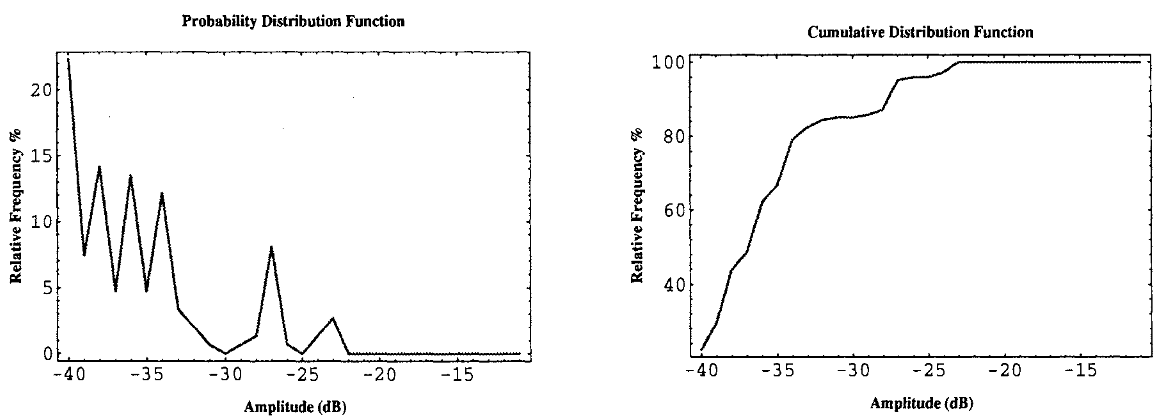


Figure F-12: Home wiring histogram of echo amplitudes (420 - 456 MHz).

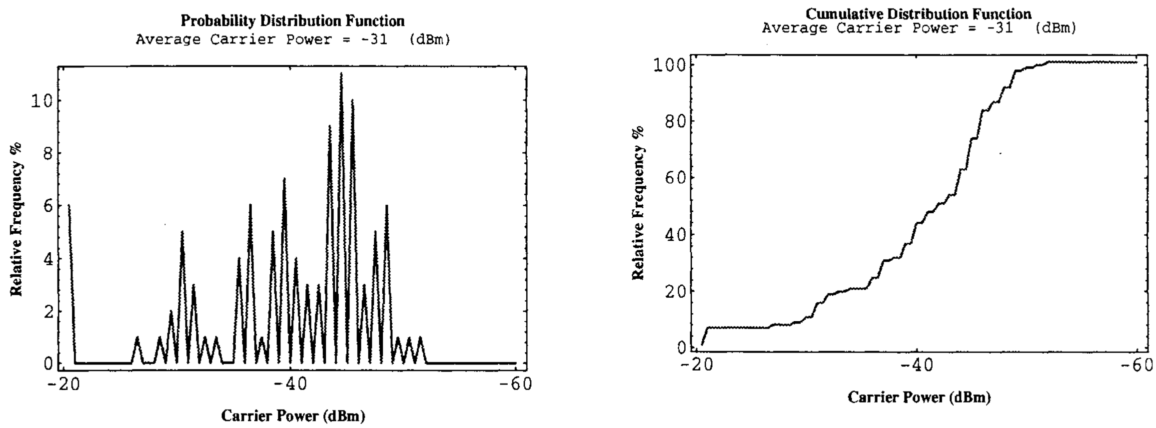


Figure F-13: Tap histogram of carrier power (420 - 456 MHz).

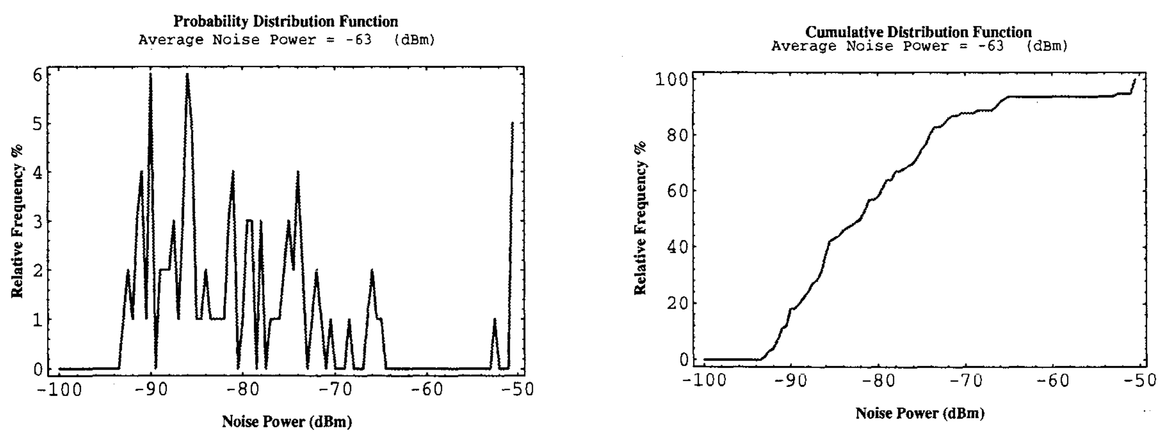


Figure F-14: Tap histogram of noise power (420 - 456 MHz).

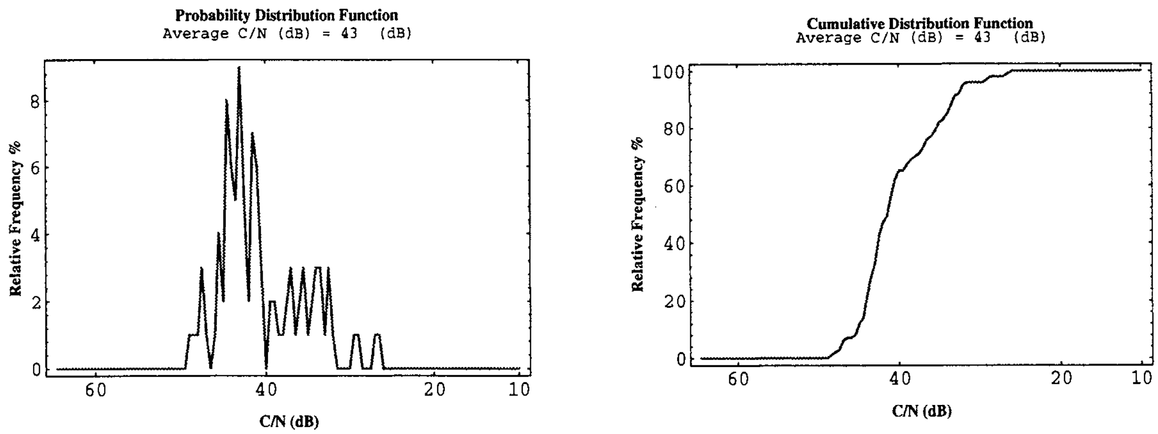


Figure F-15: Tap histogram of carrier-to-noise ratio (420 - 456 MHz).

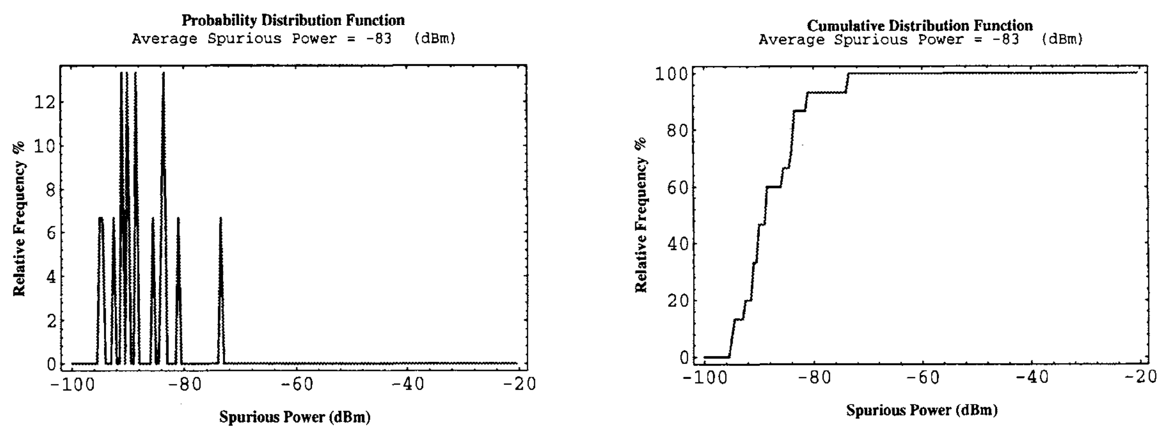


Figure F-16: Tap histogram of spurious components (420 - 456 MHz).

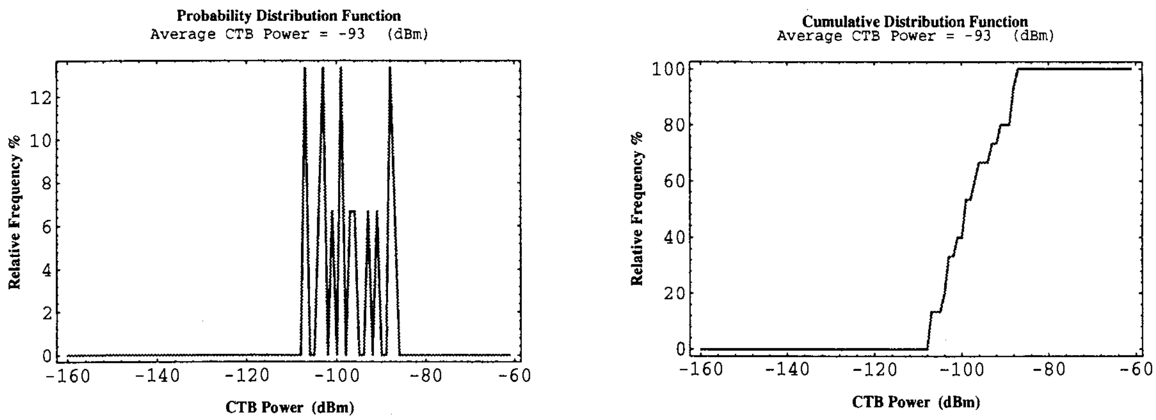


Figure F-17: Tap histogram of composite triple beats (420 - 456 MHz).

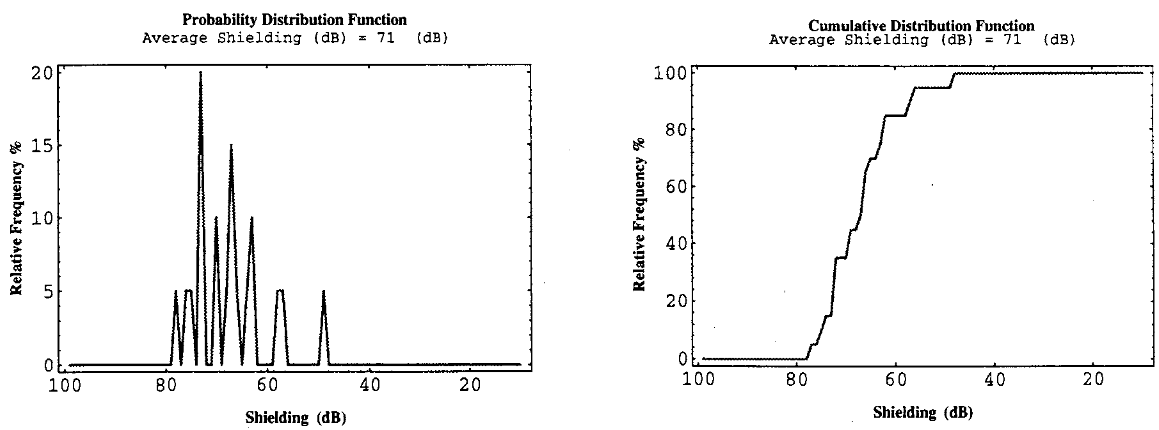


Figure F-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

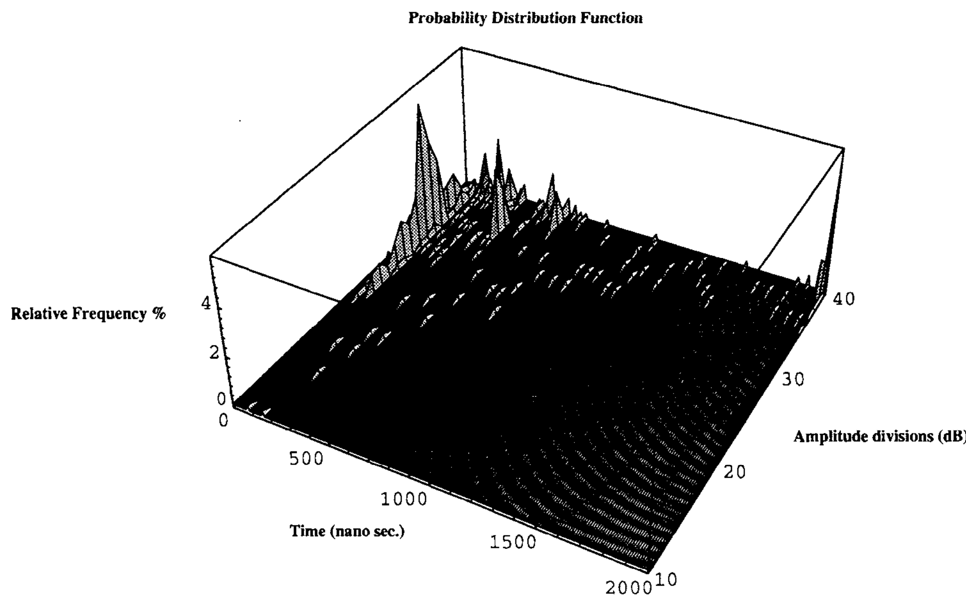
APPENDIX G. RESULTS FOR CABLE SYSTEM G

Table G-1: Micro-Reflection Impairments Summary for Cable System G..

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 456 - 534 MHz				
Delay (nanosecond)	190	1950	1990	1990
Amplitude (dB)	-36	-29	-26	-19
Headend Thru Home Outlet:				
Frequency: 456 - 534 MHz				
Delay (nanosecond)	170	460	520	640
Amplitude (dB)	-35	-29	-28	-25
Home Wiring:				
Frequency: 50 - 110 MHz				
Delay (nanosecond)	190	350	380	450
Amplitude (dB)	-36	-22	-18	-12
Home Wiring:				
Frequency: 456 - 534 MHz				
Delay (nanosecond)	140	370	550	700
Amplitude (dB)	-36	-29	-26	-21

Table G-2: Noise/Interference Impairments Summary for Cable System G.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 456 - 534 MHz					
Carrier/Noise (dB)	41	39	35	33	26
Carrier Power (dBm)	-26	-28	-34	-45	-46
Noise Power (dBm) in 6 MHz Bandwidth	-65	-68	-61	-60	-58
Spurious Power (dBm) in 6 MHz Bandwidth	-62	-65	-58	-57	-54
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-60	-63	-56	-55	-53
CTB Power (dBm) 12 MHz above the last active channel	-82	-85	-79	-78	-78
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	60	56	51	49	38



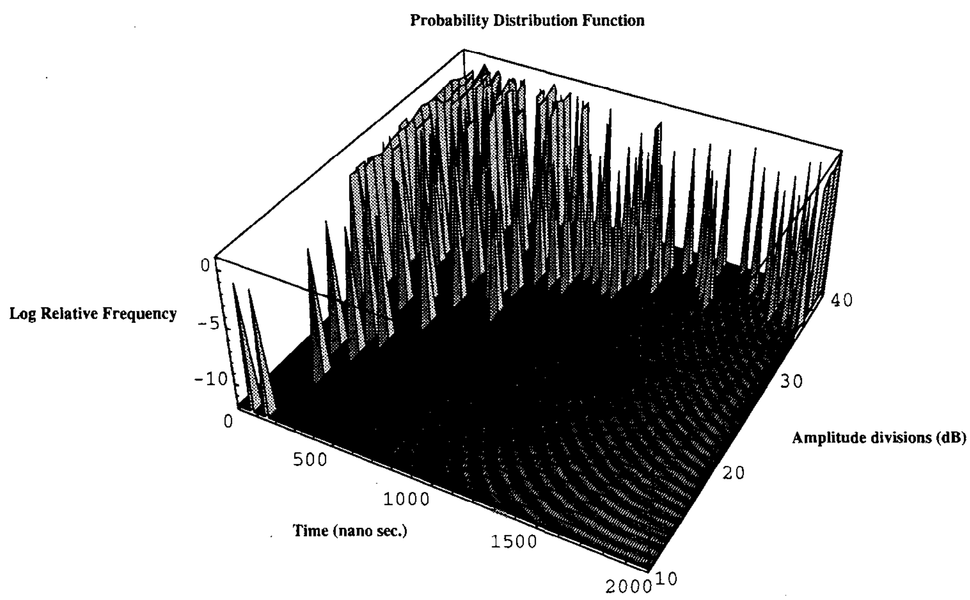


Figure G-1: Tap distribution of echoes (456 - 534 MHz).

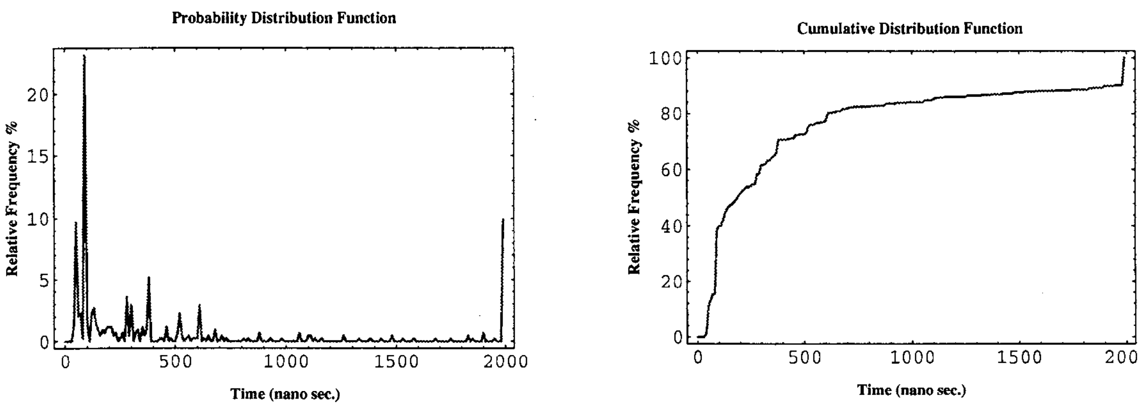


Figure G-2: Tap histogram of echo delays (456 - 534 MHz).

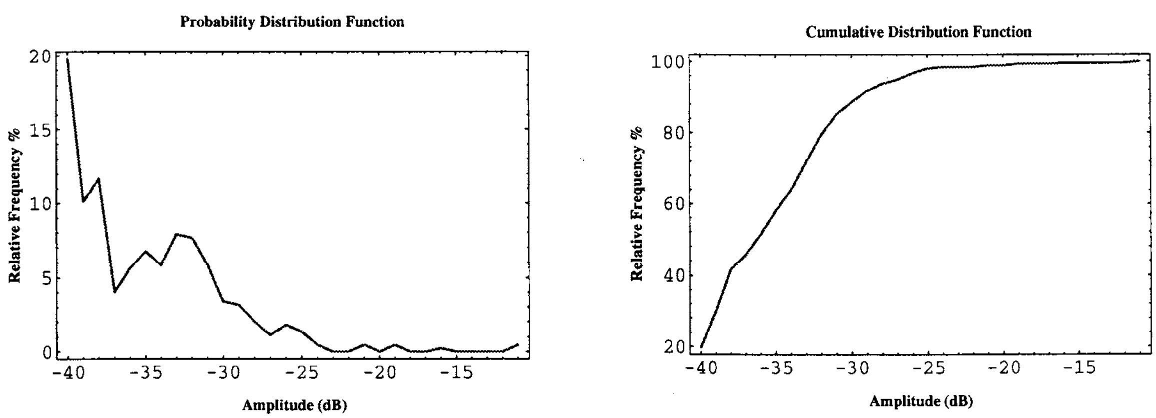
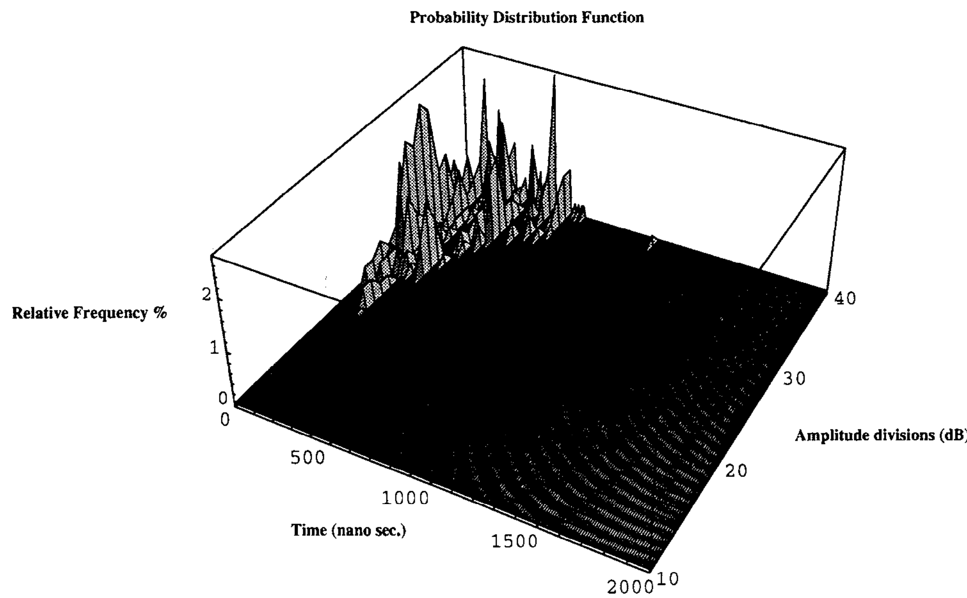


Figure G-3: Tap histogram of echo amplitudes (456 - 534 MHz).



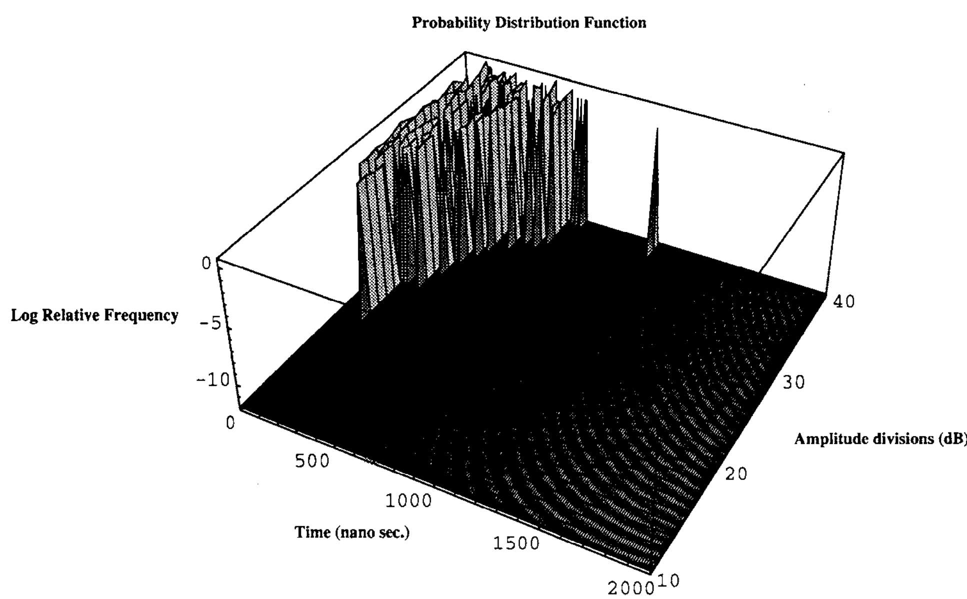


Figure G-4: Home outlet distribution of echoes (456 - 534 MHz).

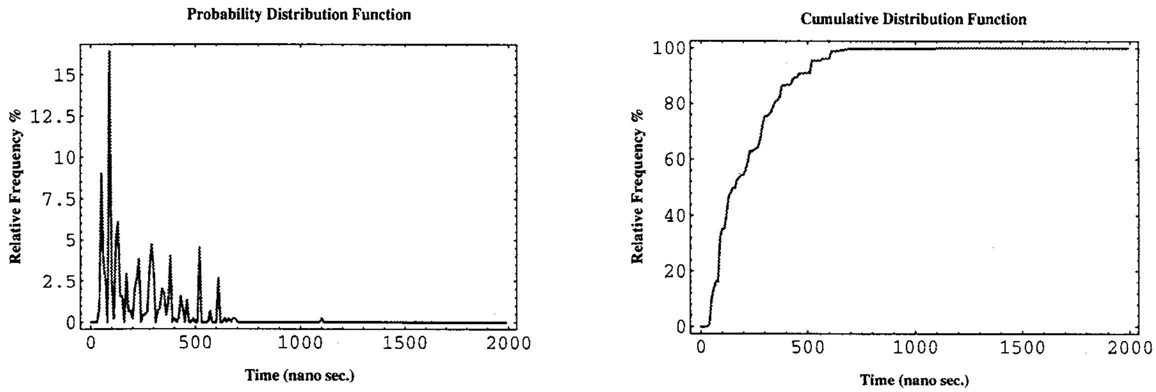


Figure G-5: Home outlet histogram of echo delays (2456 - 534 MHz).

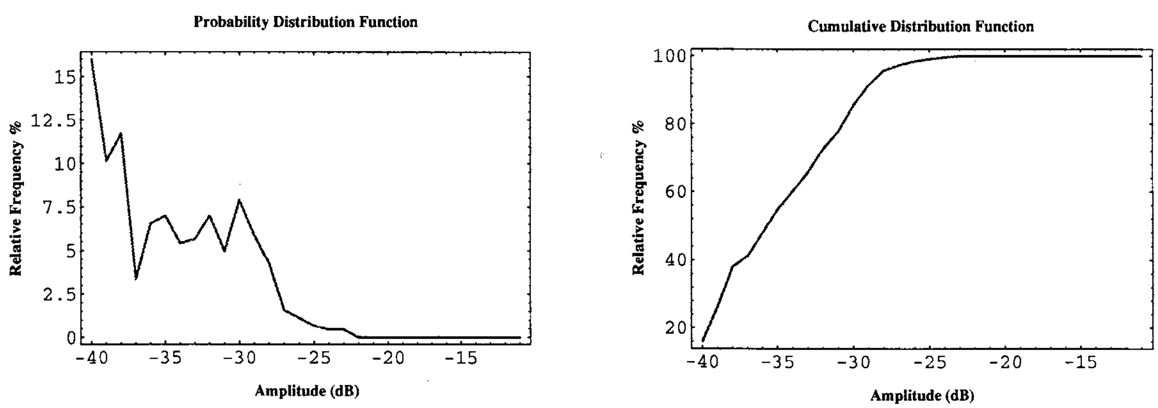
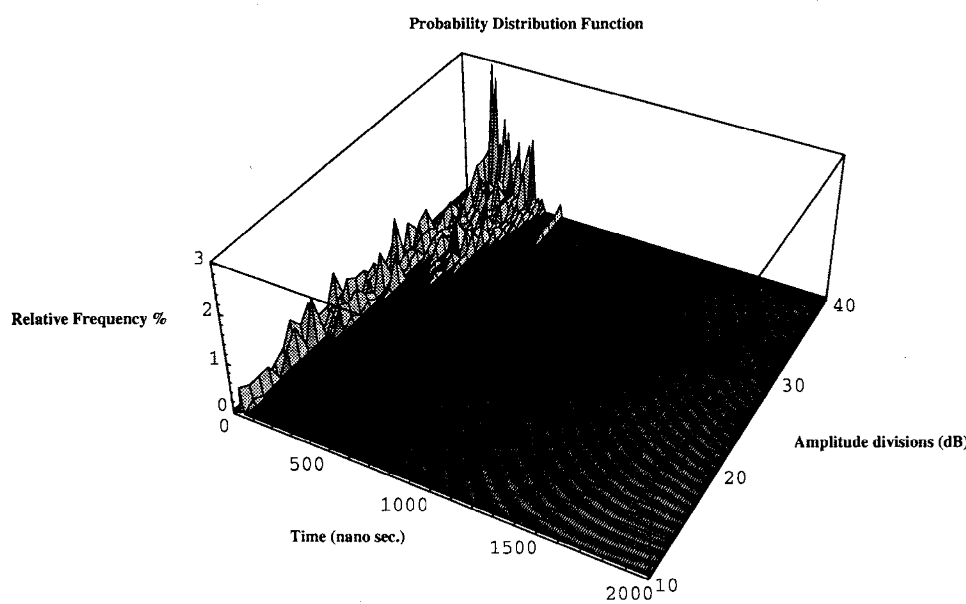


Figure G-6: Home outlet histogram of echo amplitudes (456 - 534 MHz).



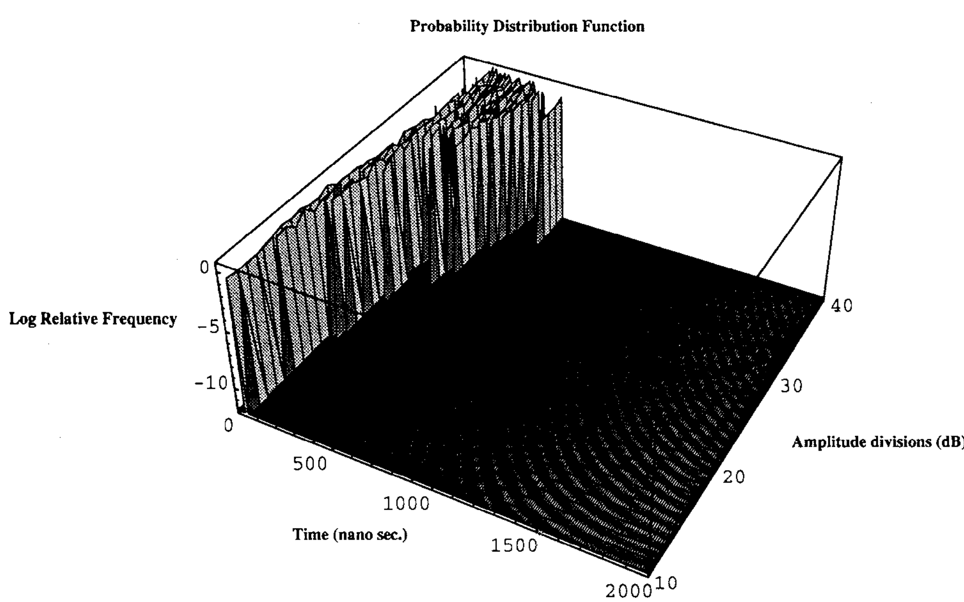


Figure G-7: Home wiring distribution of echoes (50 - 110 MHz).

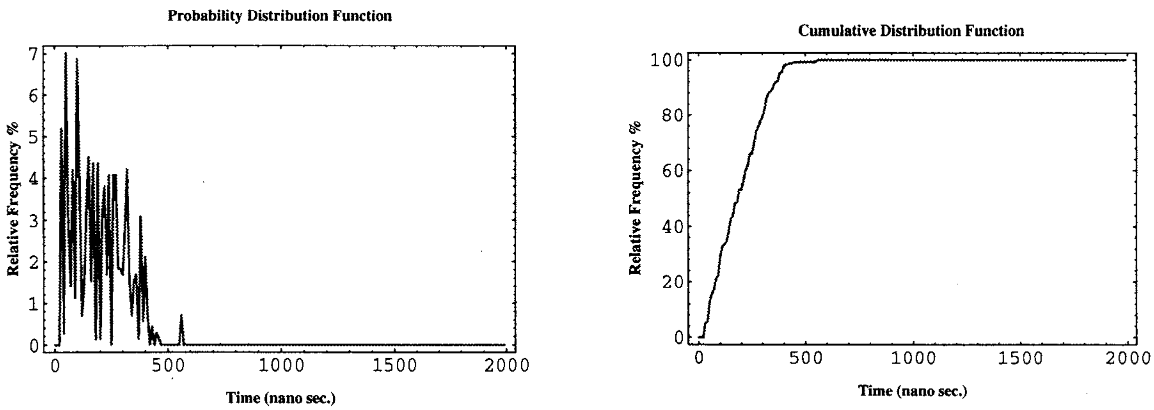


Figure G-8: Home wiring histogram of echo delays (50 - 110 MHz).

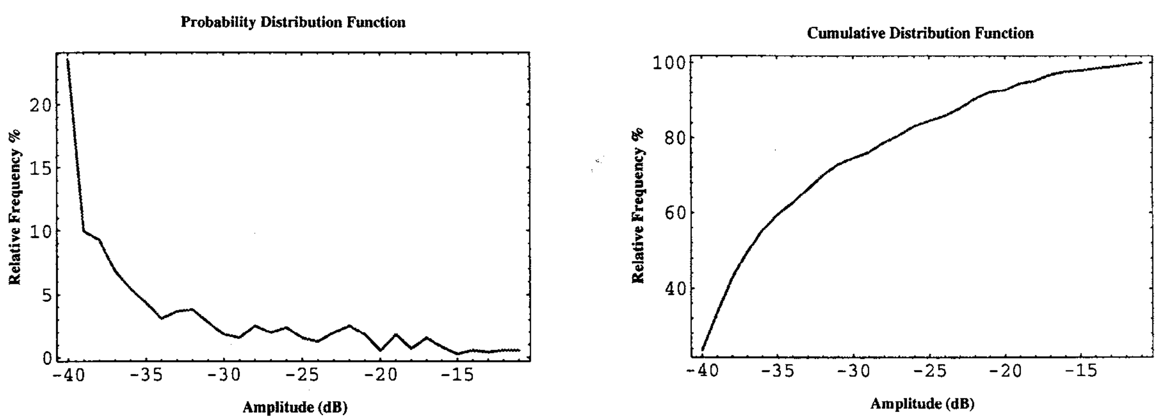
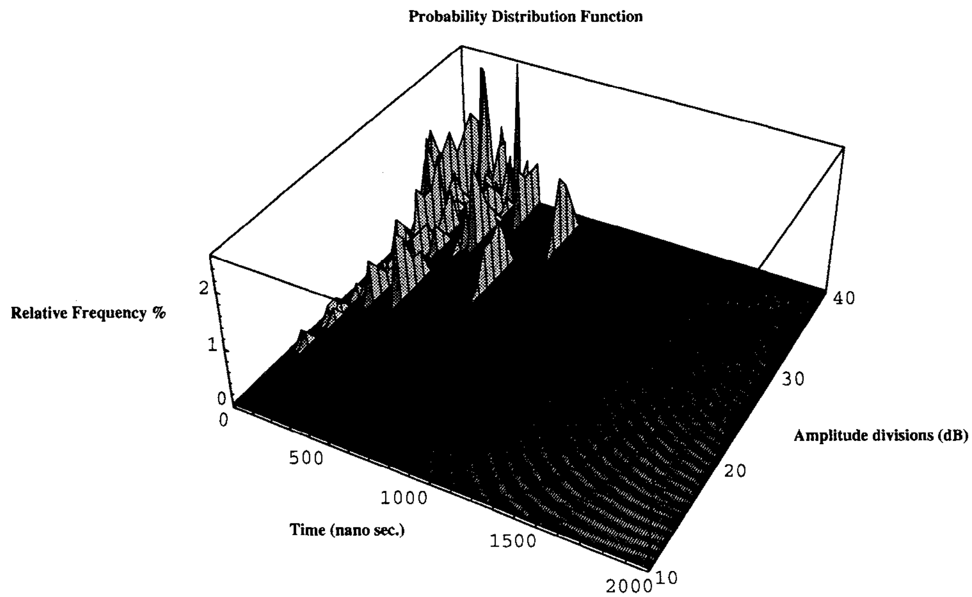


Figure G-9: Home wiring histogram of echo amplitudes (50 - 110 MHz).



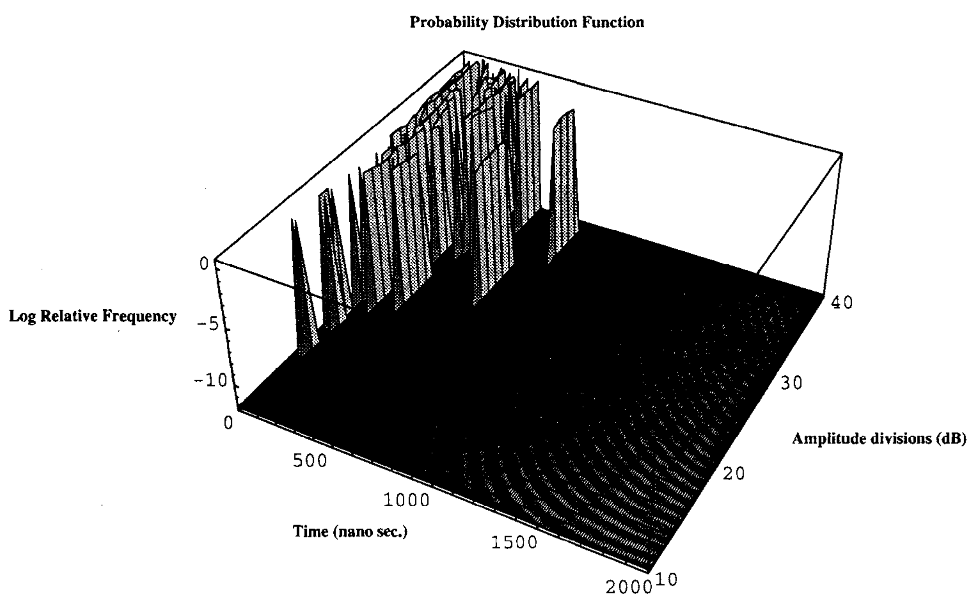


Figure G-10: Home wiring distribution of echoes (456 - 534 MHz).

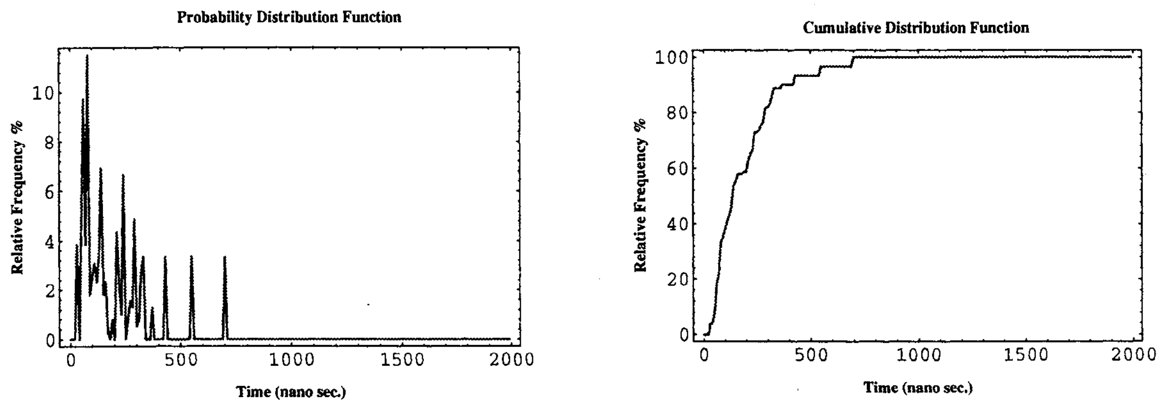


Figure G-11: Home wiring histogram of echo delays (456 - 534 MHz).

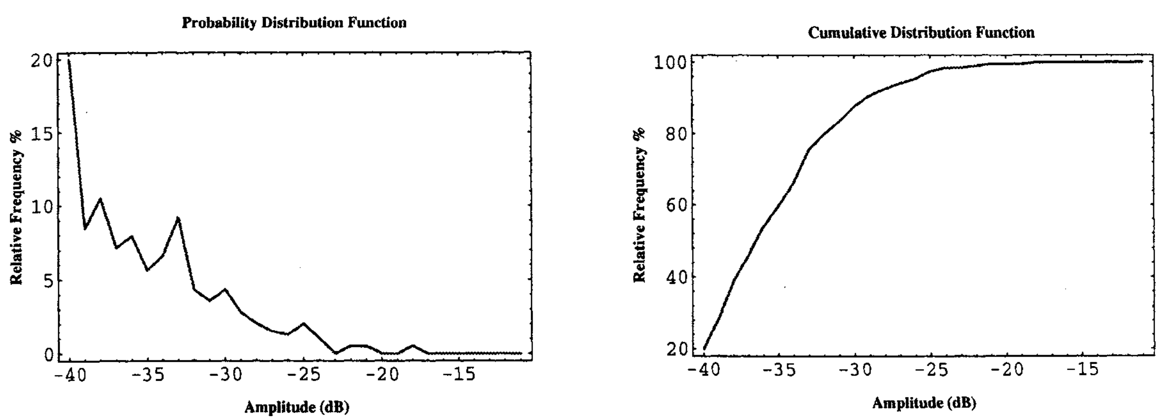


Figure G-12: Home wiring histogram of echo amplitudes (456 - 534 MHz).

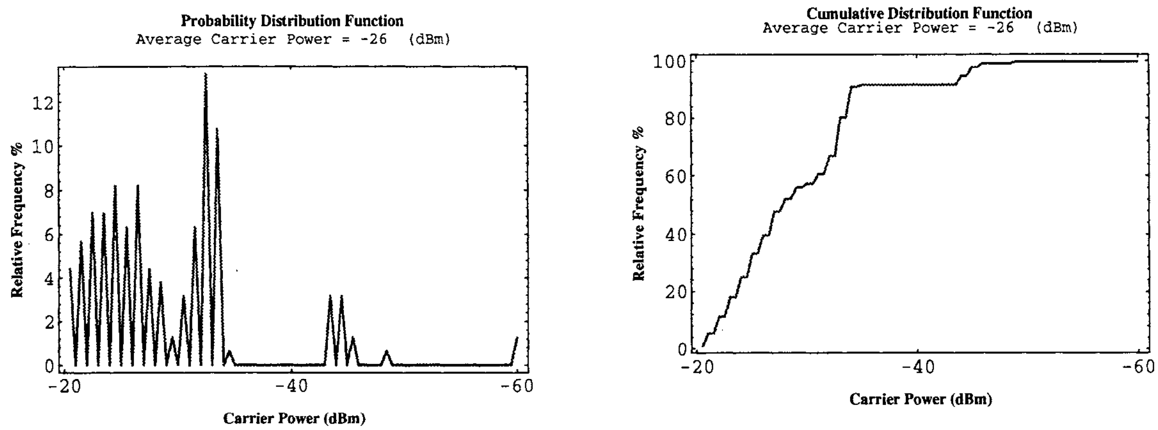


Figure G-13: Tap histogram of carrier power (456 - 534 MHz).

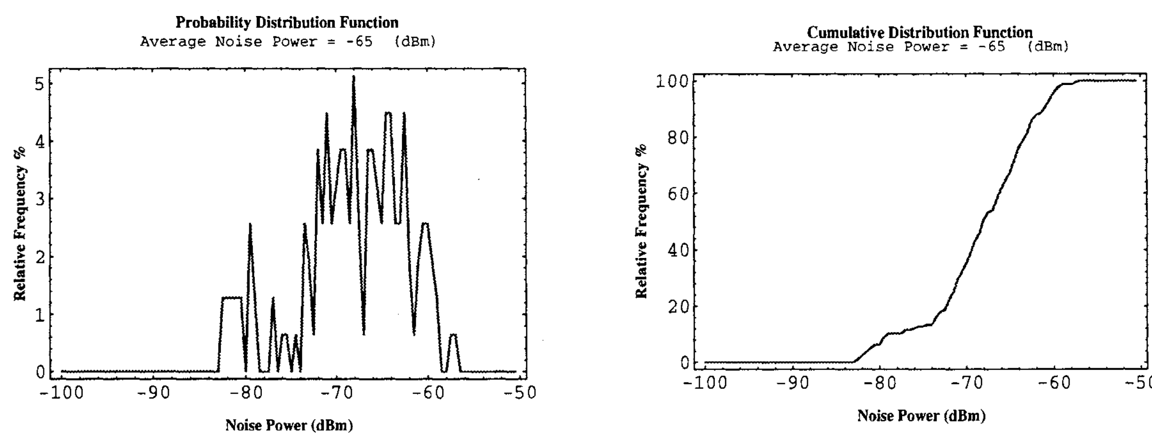


Figure G-14: Tap histogram of noise power (456 - 534 MHz).

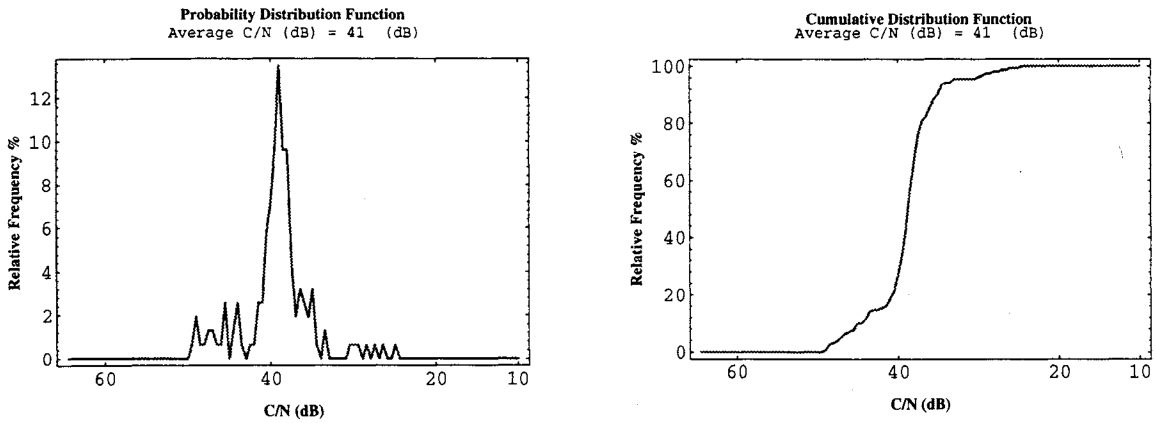


Figure G-15: Tap histogram of carrier-to-noise ratio (456 - 534 MHz).

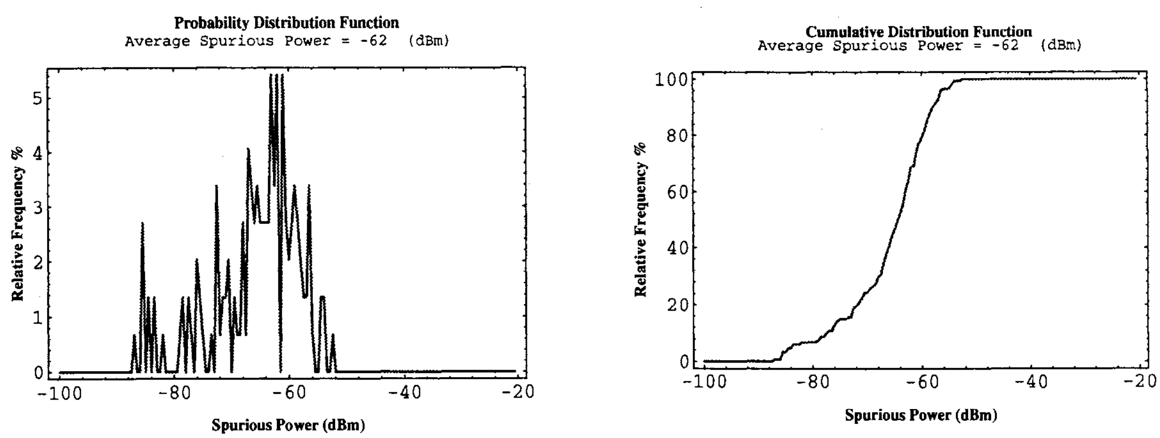


Figure G-16: Tap histogram of spurious components (456 - 534 MHz).

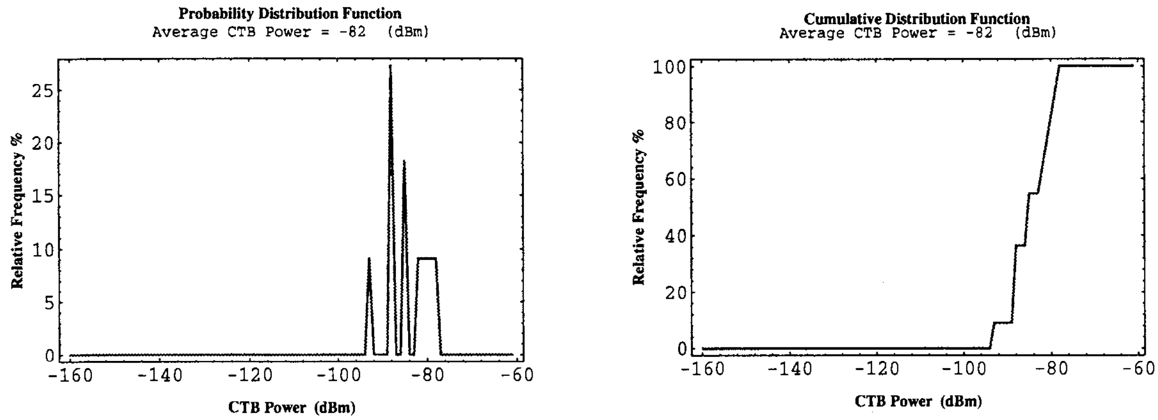


Figure G-17: Tap histogram of composite triple beats (456 -534 MHz).

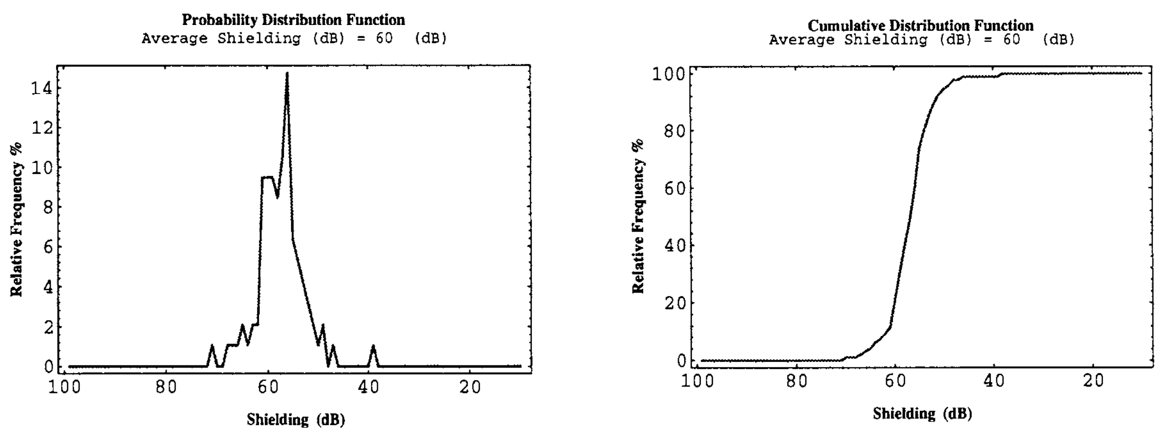


Figure G-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

APPENDIX H. RESULTS FOR CABLE SYSTEM H

Table H-1: Micro-Reflection Impairments Summary for Cable System H.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 408 - 492 MHz				
Delay (nanosecond)	250	770	1040	1450
Amplitude (dB)	-37	-29	-25	-15
Headend Thru Home Outlet:				
Frequency: 408 - 492 MHz				
Delay (nanosecond)	290	940	1140	1570
Amplitude (dB)	-37	-27	-23	-13
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	140	250	300	330
Amplitude (dB)	-39	-32	-31	-31
Home Wiring:				
Frequency: 408 - 492 MHz				
Delay (nanosecond)	200	500	500	500
Amplitude (dB)	-39	-25	-24	-23

Table H-2: Noise/Interference Impairments Summary for Cable System h.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 408 - 492 MHz					
Carrier/Noise (dB)	40	38	30	27	11
Carrier Power (dBm)	-43	-47	-55	-56	-59
Noise Power (dBm) in 6 MHz Bandwidth	-79	-84	-75	-73	-69
Spurious Power (dBm) in 6 MHz Bandwidth	-70	-100	-88	-76	-52
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-69	-84	-75	-71	-52
CTB Power (dBm) 12 MHz above the last active channel	-101	-101	-98	-98	-98
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	57	49	44	42	42

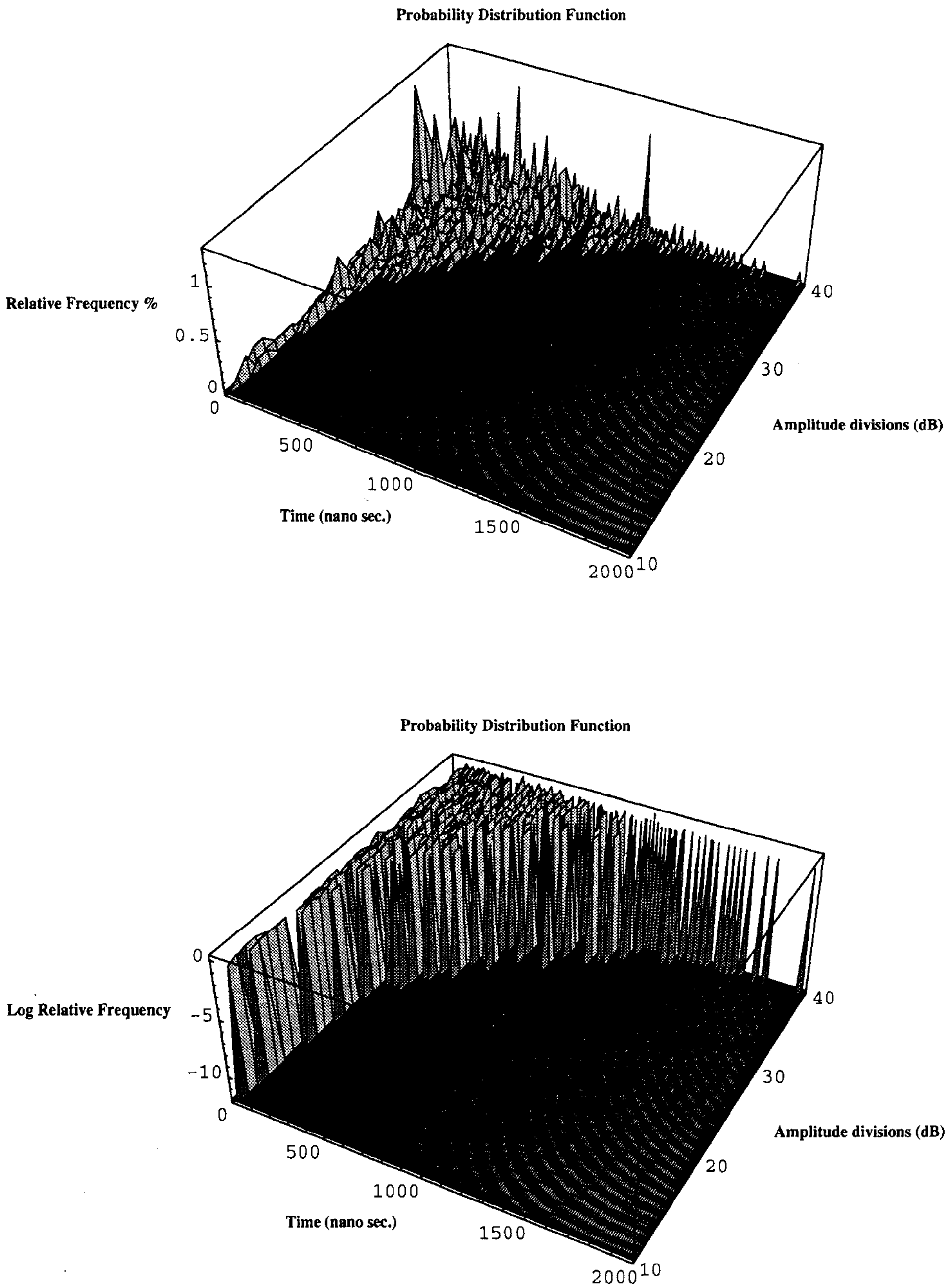


Figure H-1: Tap distribution of echoes (408 - 492 MHz).

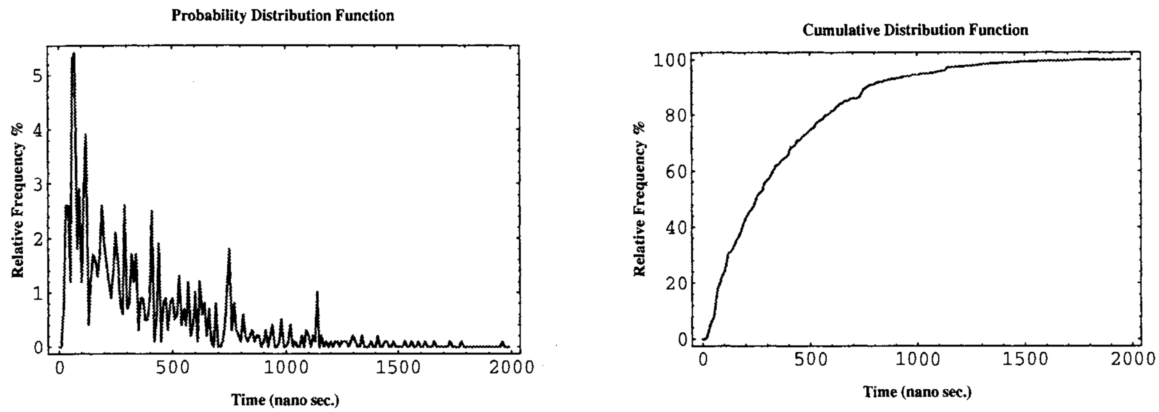


Figure H-2: Tap histogram of echo delays (408 - 492 MHz).

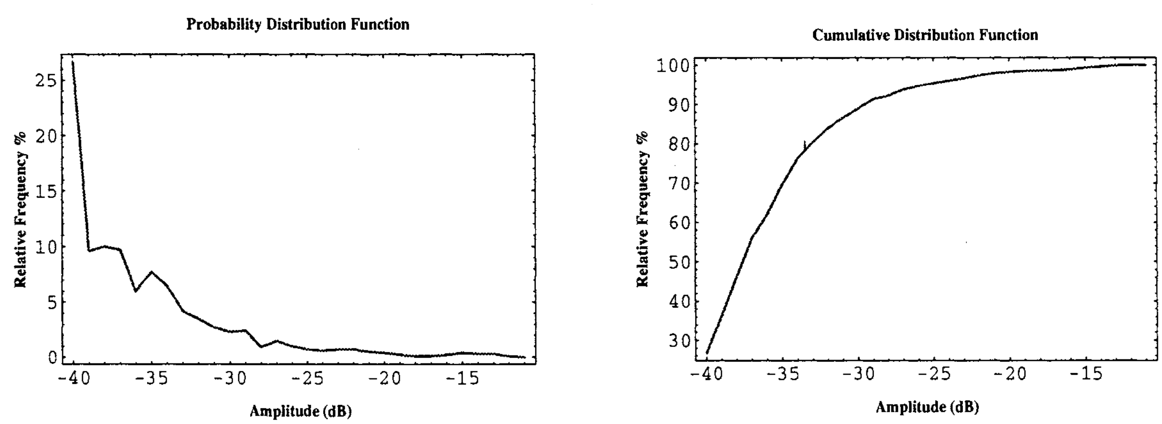
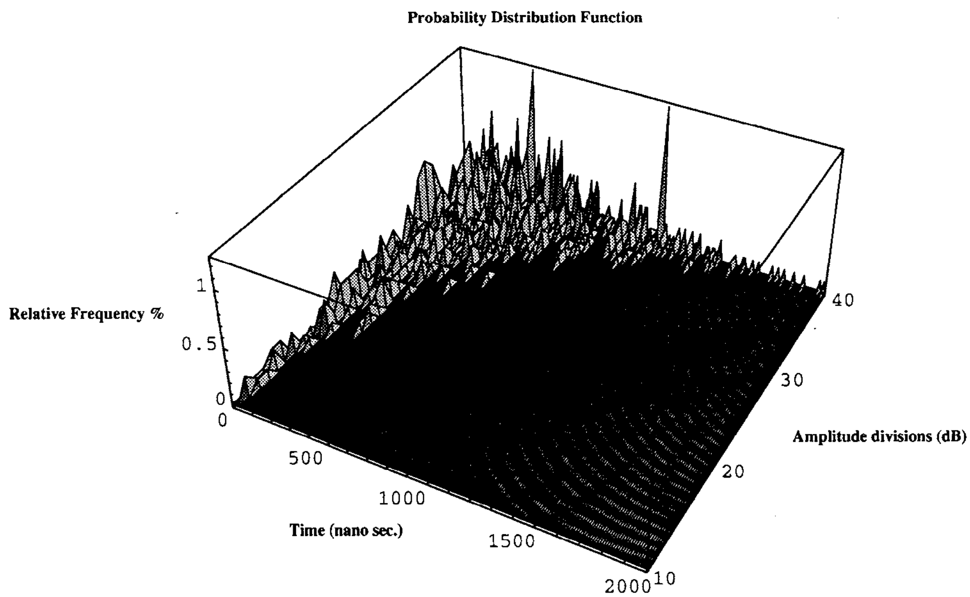


Figure H-3: Tap histogram of echo amplitudes (408 - 492MHz).



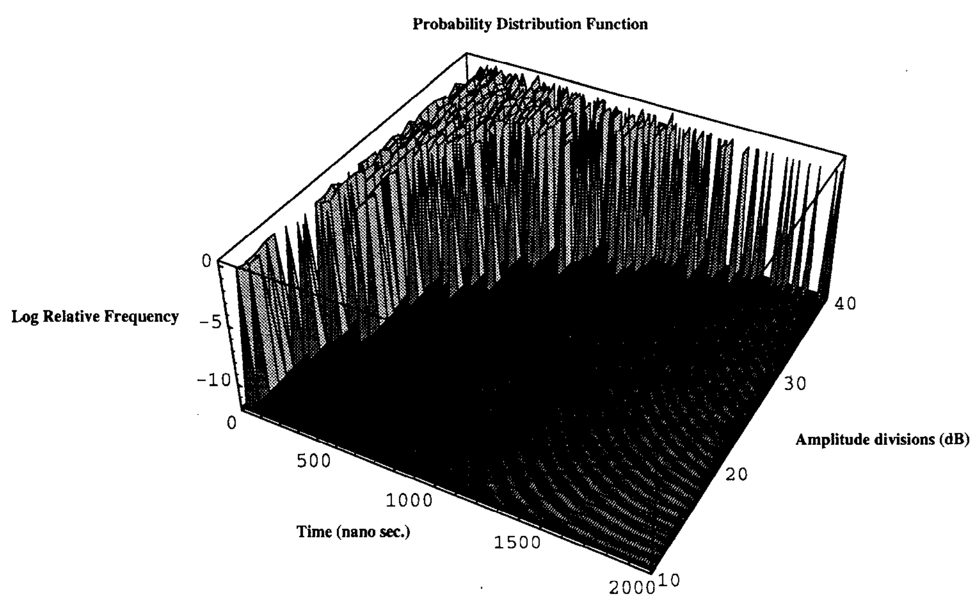


Figure H-4: Home outlet distribution of echoes (408 - 492MHz).

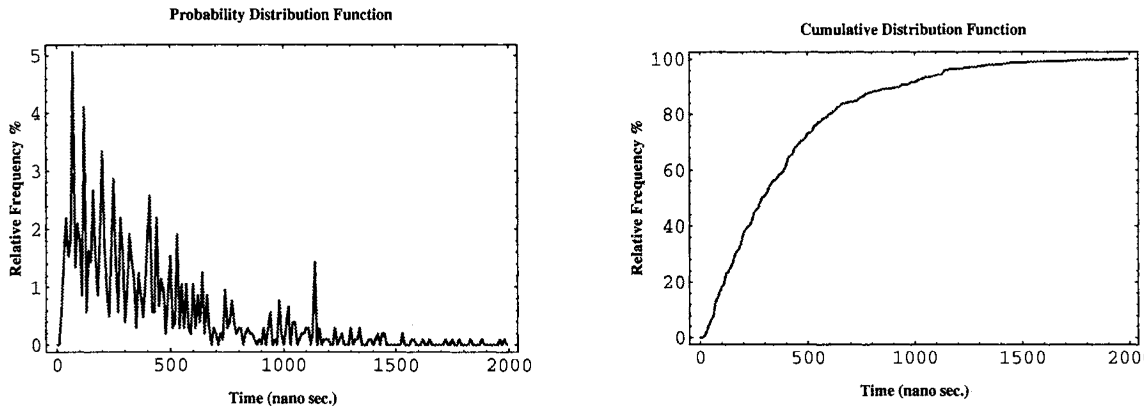


Figure H-5: Home outlet histogram of echo delays (408 - 492MHz).

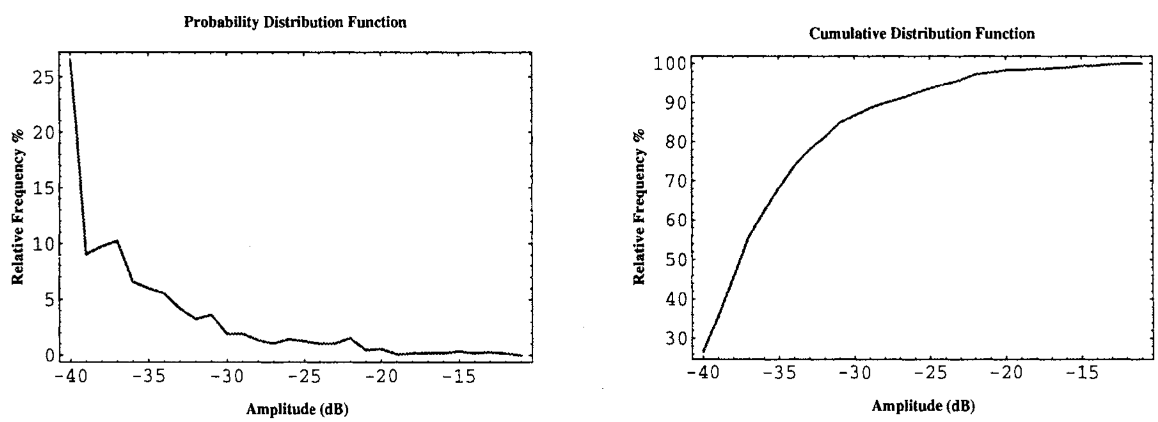
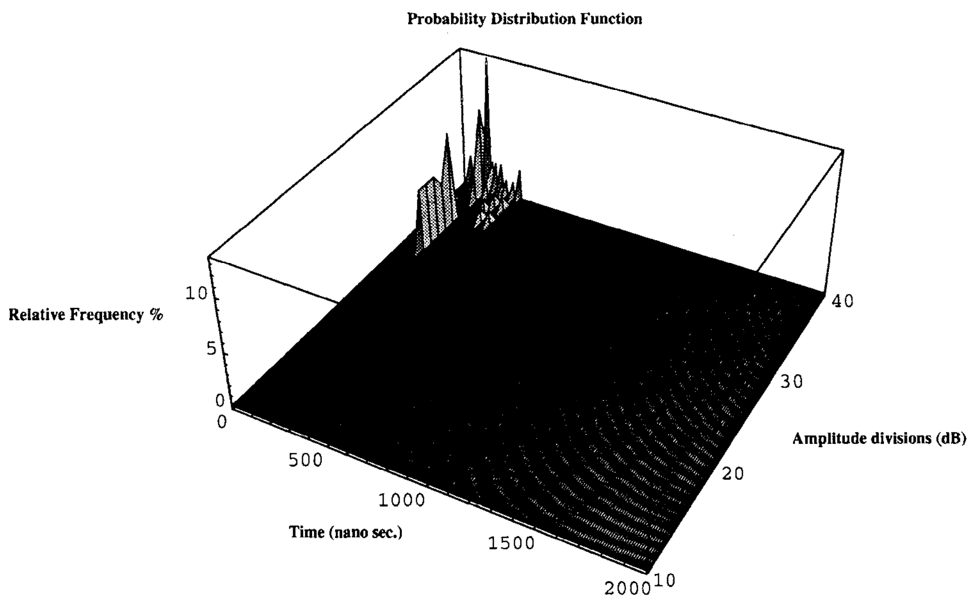


Figure H-6: Home outlet histogram of echo amplitudes (408- 492MHz).



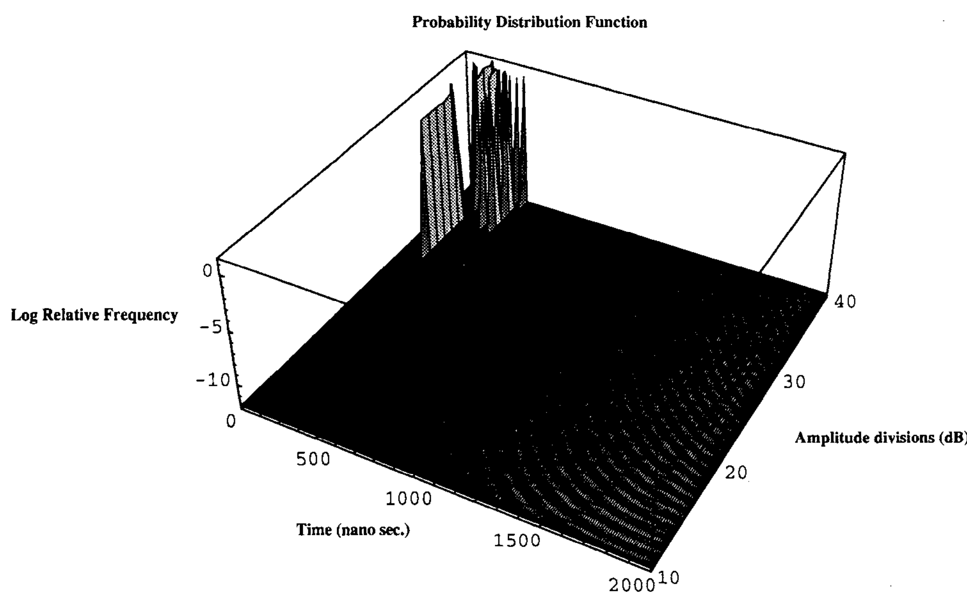


Figure H-7: Home wiring distribution of echoes (50 - 200 MHz).

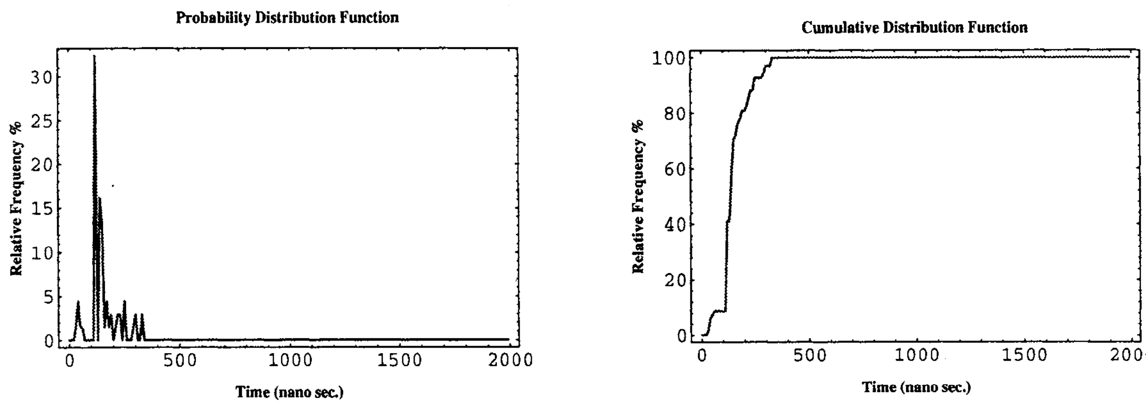


Figure H-8: Home wiring histogram of echo delays (50 - 200 MHz).

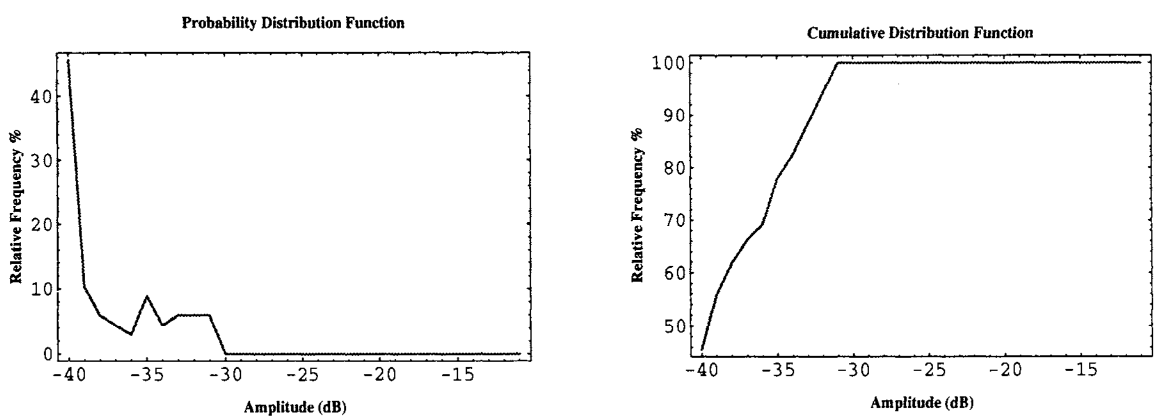
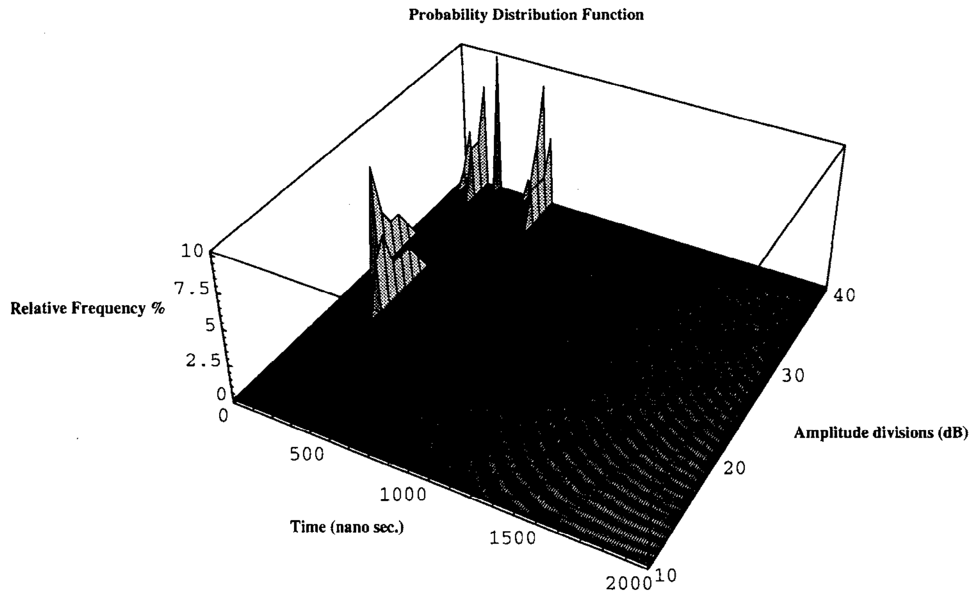


Figure H-9: Home wiring histogram of echo amplitudes (50 - 200 MHz).



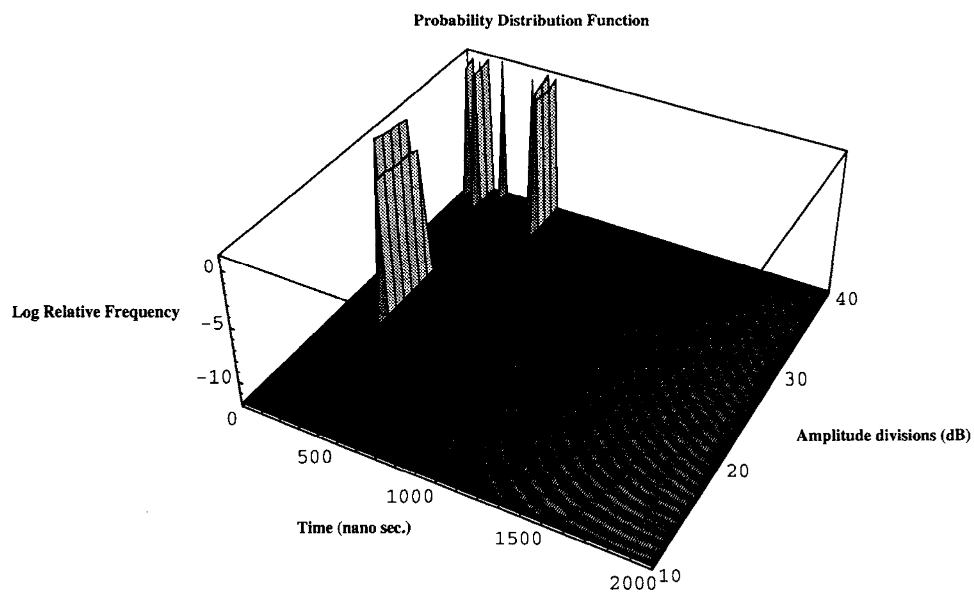


Figure H-10: Home wiring distribution of echoes (408 - 492 MHz).

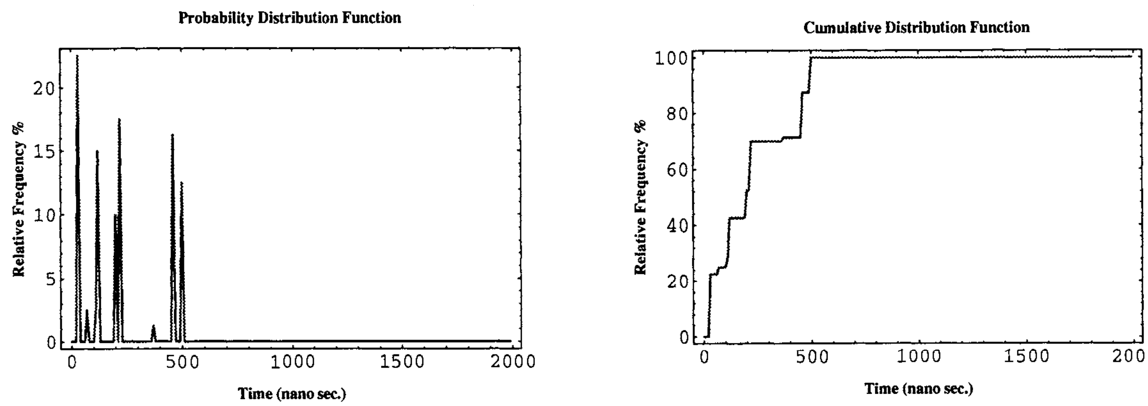


Figure H-11: Home wiring histogram of echo delays (408 - 492 MHz).

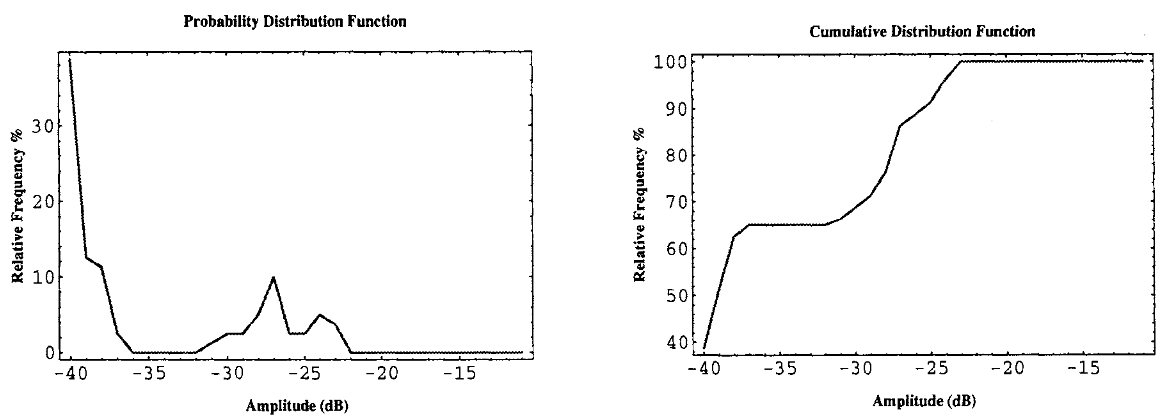


Figure H-12: Home wiring histogram of echo amplitudes (408 - 492 MHz).

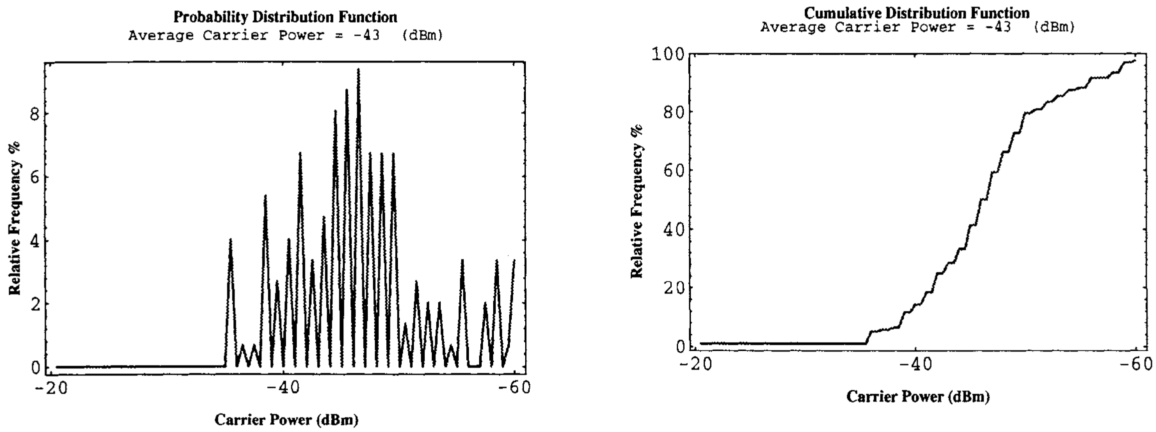


Figure H-13: Tap histogram of carrier power (408 - 492 MHz).

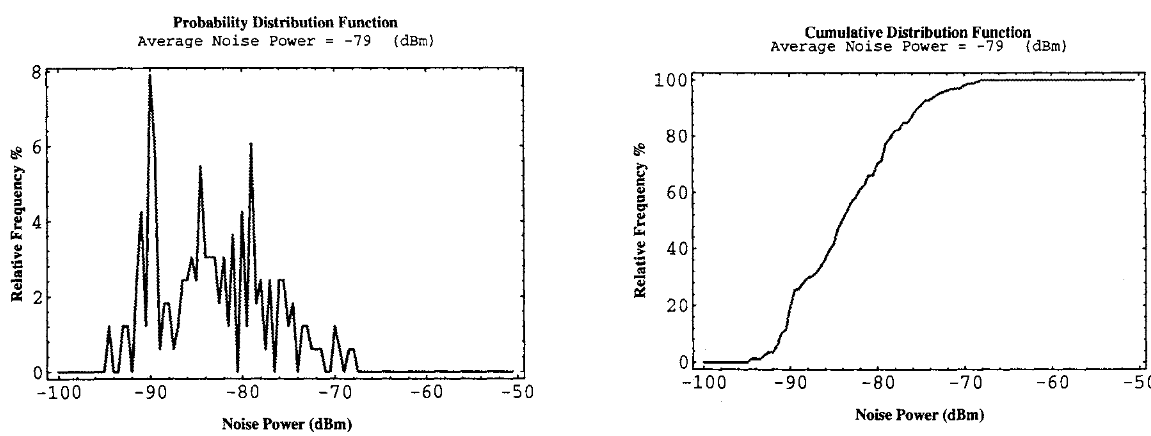


Figure H-14: Tap histogram of noise power (408 - 492MHz).

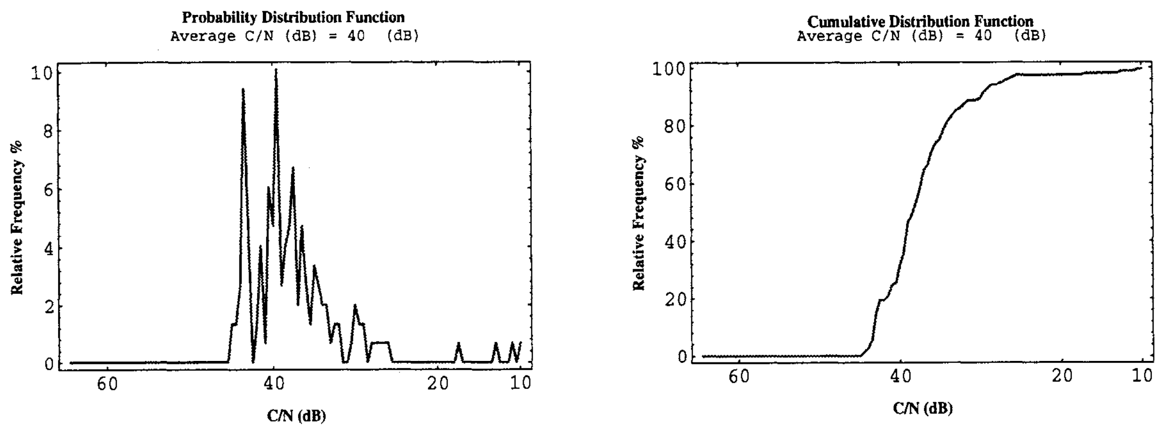


Figure H-15: Tap histogram of carrier-to-noise ratio (408 - 492 MHz).

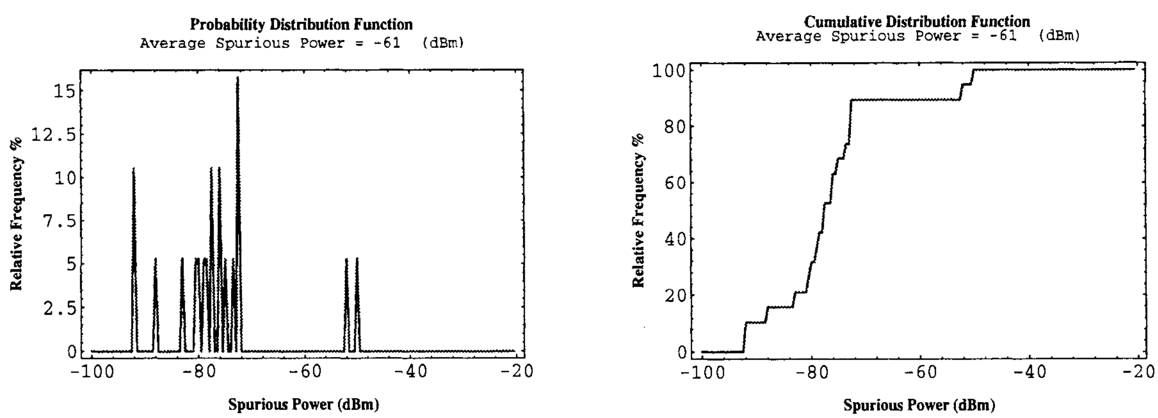


Figure H-16: Tap histogram of spurious components (408 - 492 MHz).

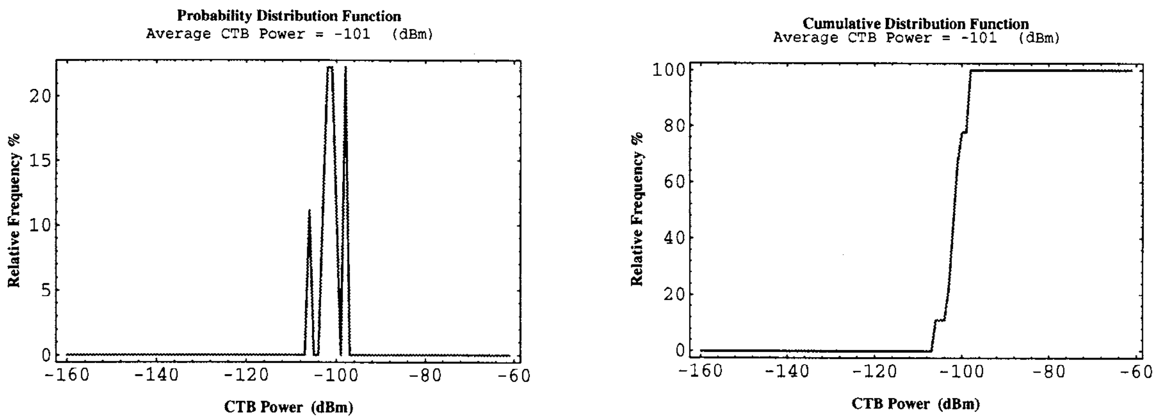


Figure H-17: Tap histogram of composite triple beats (408 - 492 MHz).

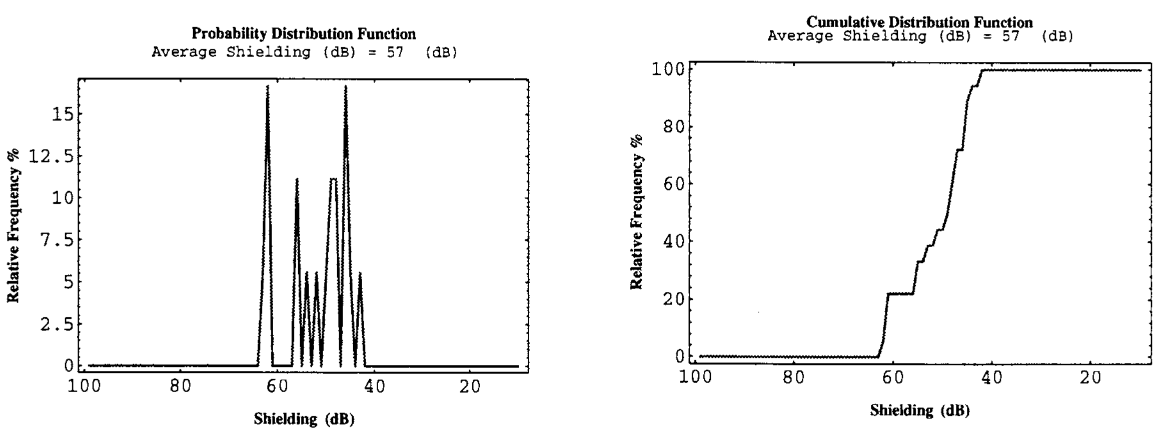


Figure H-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

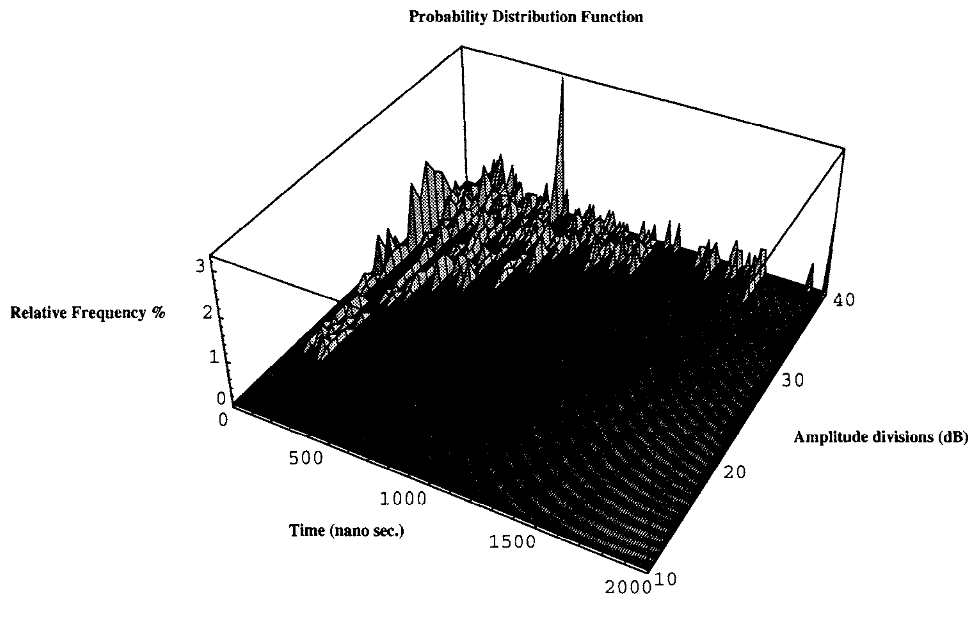
APPENDIX I. RESULTS FOR CABLE SYSTEM I

Table I-1: Micro-Reflection Impairments Summary for Cable System I.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 480 - 546 MHz				
Delay (nanosecond)	330	1410	1640	1990
Amplitude (dB)	-37	-28	-25	-18
Headend Thru Home Outlet:				
Frequency: 480 - 546 MHz				
Delay (nanosecond)	330	1340	1990	1990
Amplitude (dB)	-37	-27	-25	-18
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	170	270	270	280
Amplitude (dB)	-37	-32	-31	-30
Home Wiring:				
Frequency: 480 - 546 MHz				
Delay (nanosecond)	140	220	290	290
Amplitude (dB)	-36	-32	-28	-27

Table I-2: Noise/Interference Impairments Summary for Cable System I.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 480 - 546 MHz					
Carrier/Noise (dB)	44	42	39	37	35
Carrier Power (dBm)	-33	-35	-49	-51	-55
Noise Power (dBm) in 6 MHz Bandwidth	-76	-80	-71	-71	-70
Spurious Power (dBm) in 6 MHz Bandwidth	-58	-80	-63	-53	-46
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-58	-77	-62	-53	-46
CTB Power (dBm) 12 MHz above the last active channel	-109	-111	-106	-106	-106
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	66	59	39	33	30



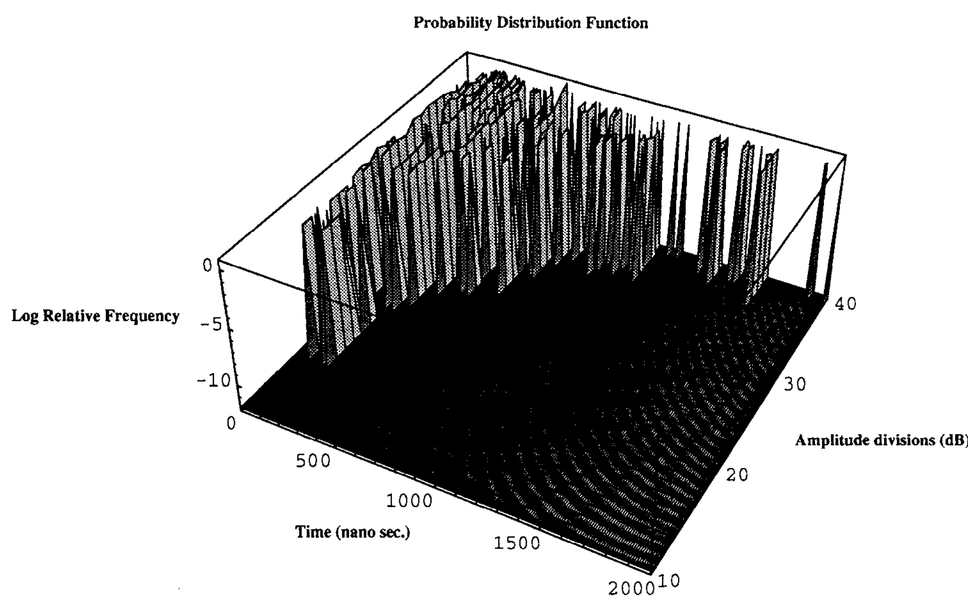


Figure I-1: Tapdistribution of echoes (480 - 546 MHz).

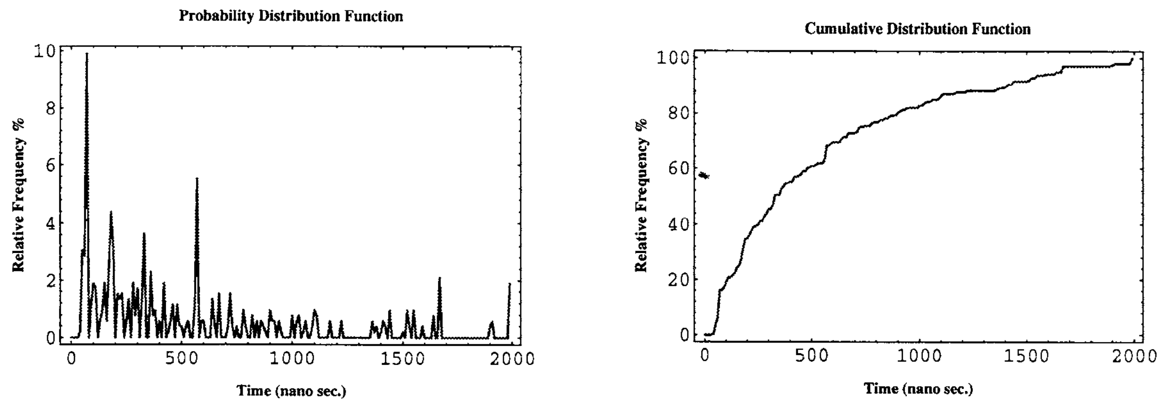


Figure I-2: Tap histogram of echo delays (480 - 546 MHz).

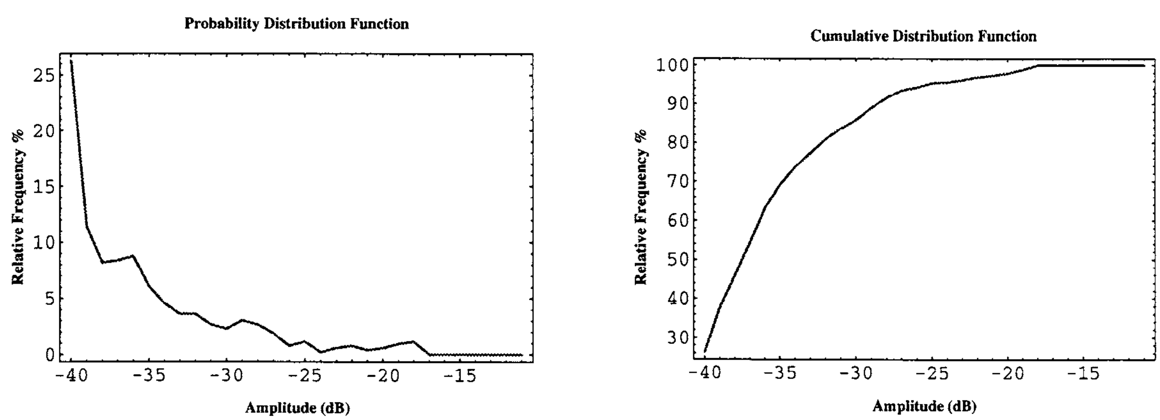


Figure I-3: Tap histogram of echo amplitudes (480 - 546 MHz).

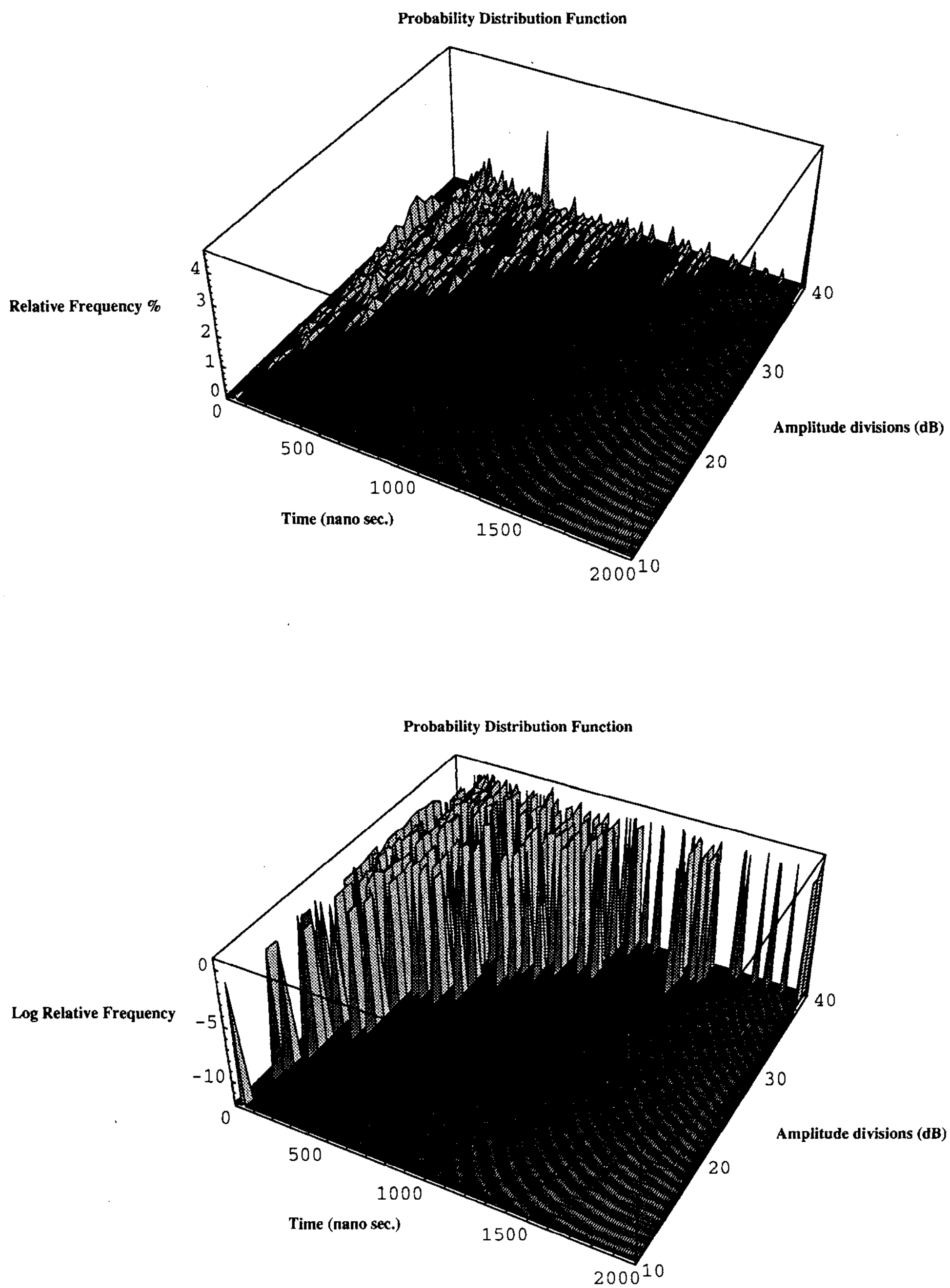


Figure I-4: Home outlet distribution of echoes (480 - 546 MHz).

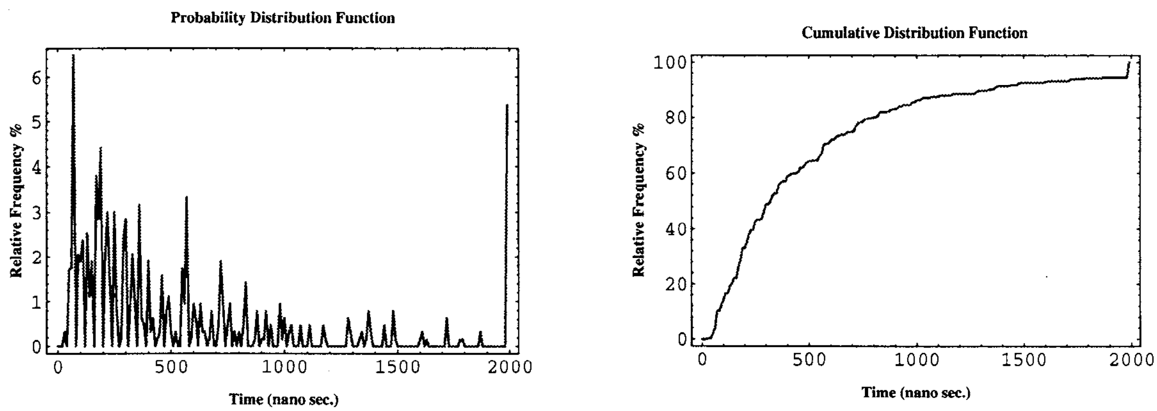


Figure I-5: Home outlet histogram of echo delays (480 - 546 MHz).

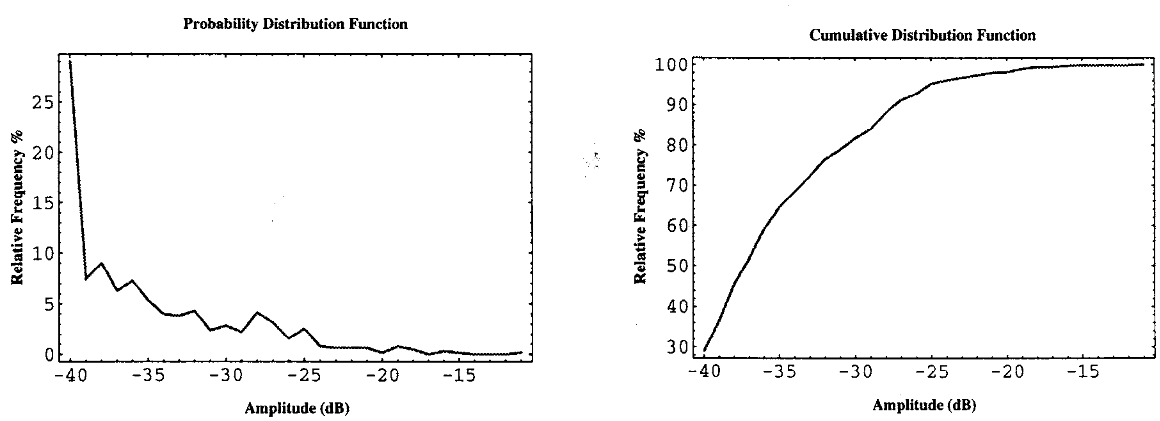


Figure I-6: Home outlet histogram of echo amplitudes (480 - 546 MHz).

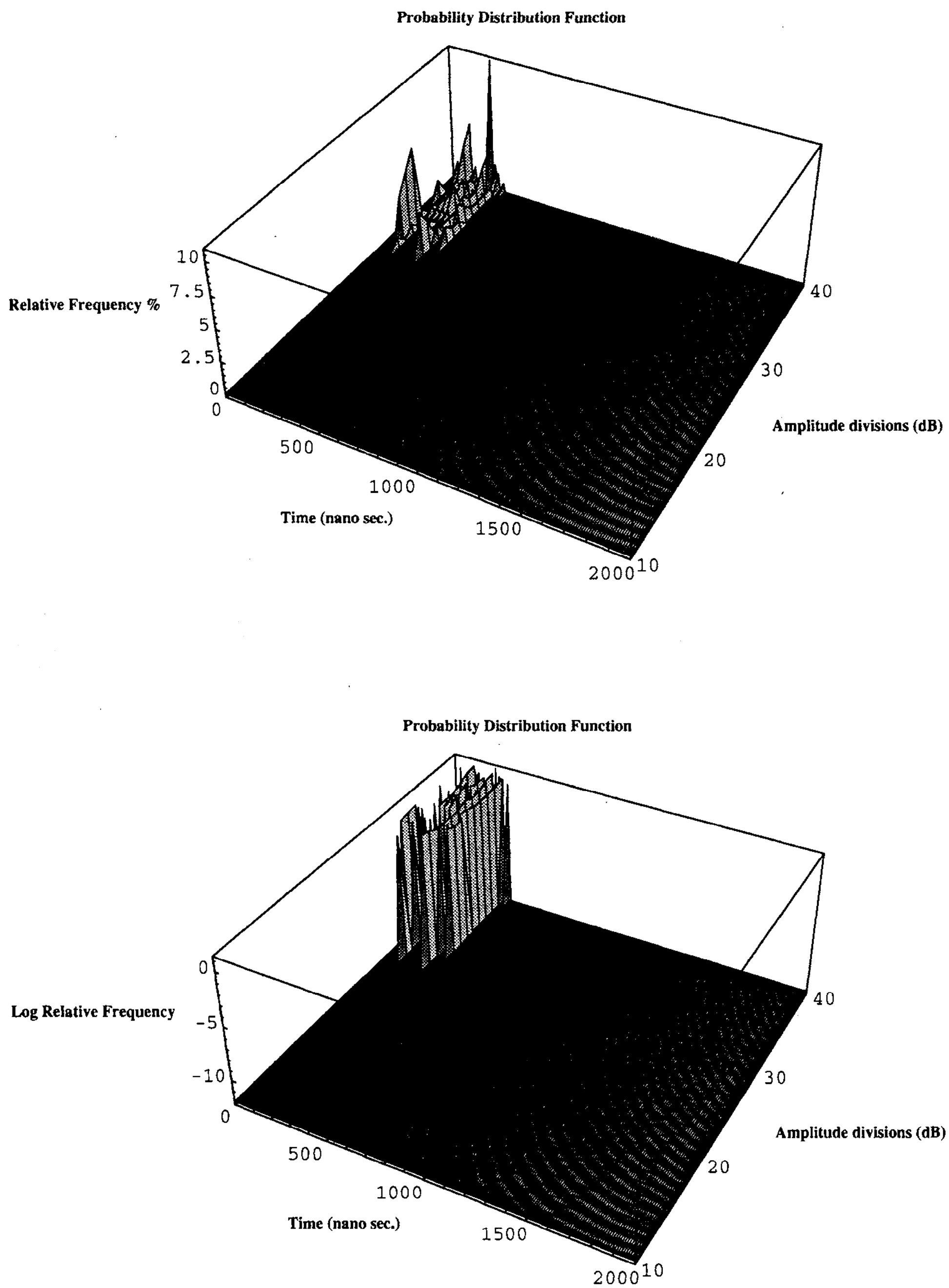


Figure I-7: Home wiring distribution of echoes (50 - 200 MHz).

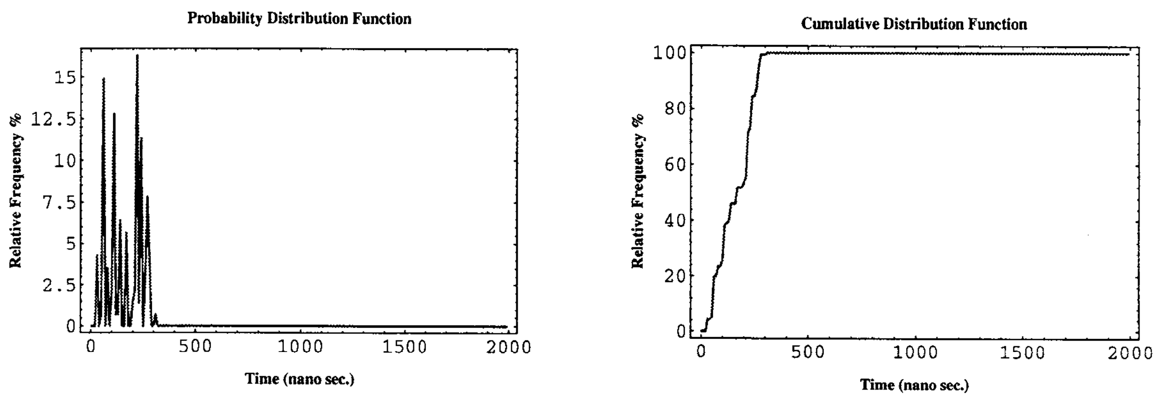


Figure I-8: Home wiring histogram of echo delays (50 - 200 MHz).

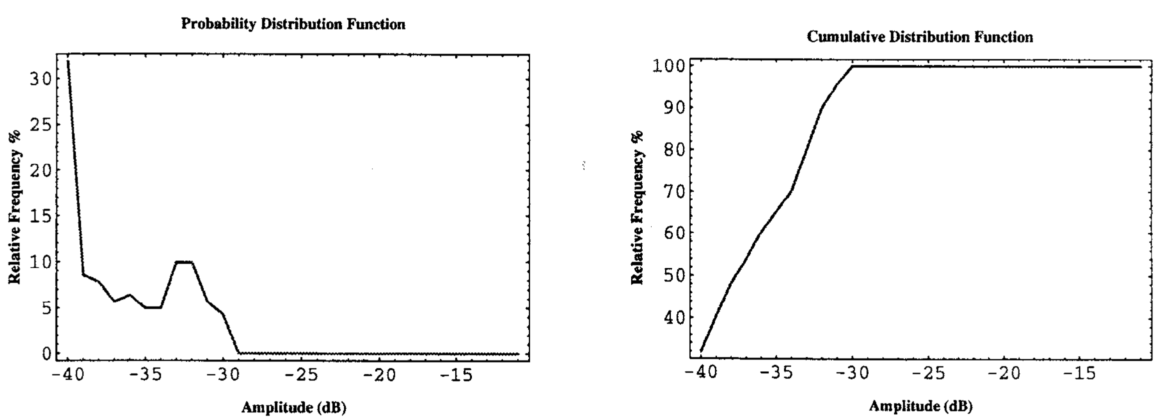


Figure I-9: Home wiring histogram of echo amplitudes (50 - 200 MHz).

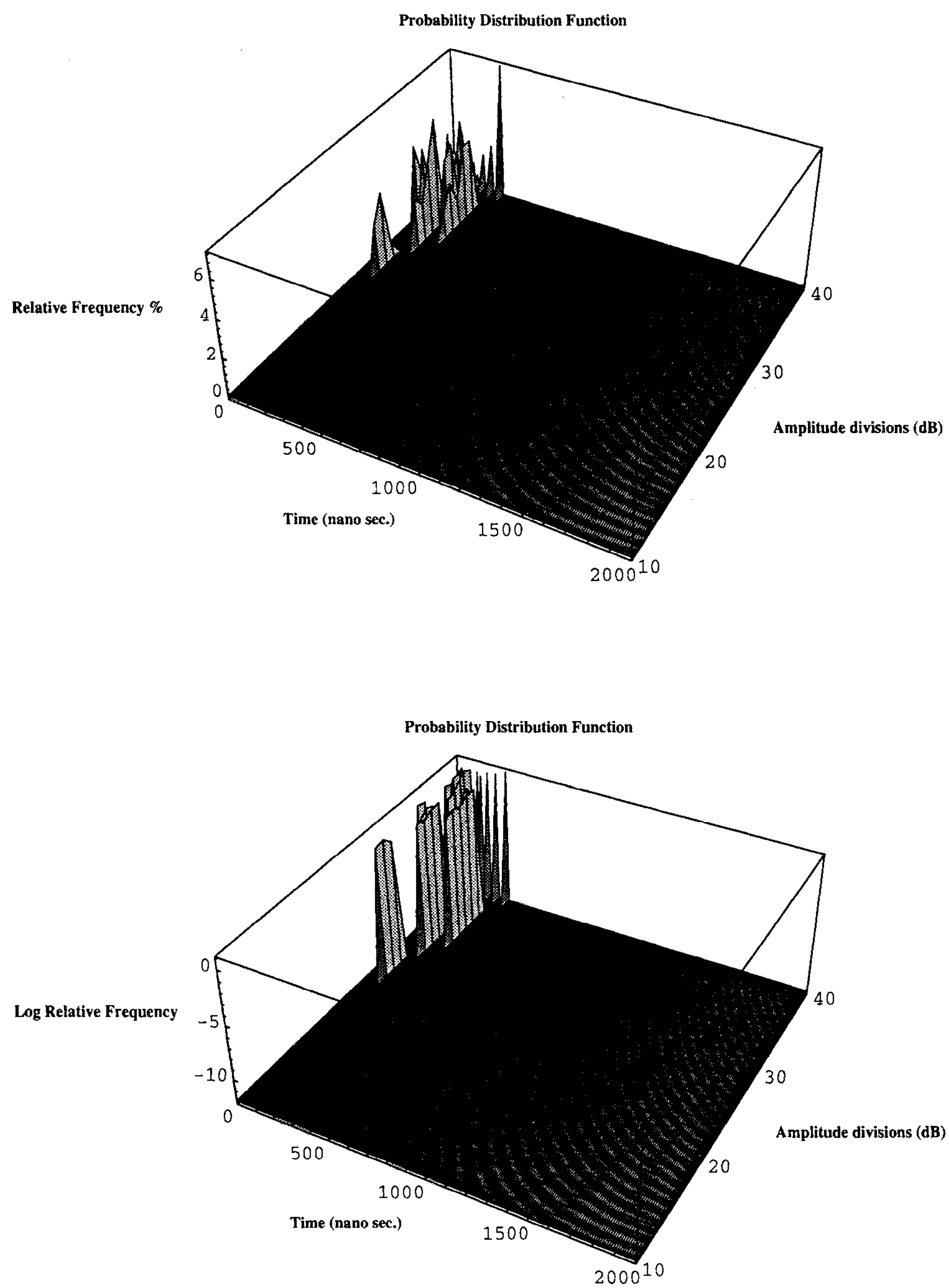


Figure I-10: Home wiring distribution of echoes (480 - 546 MHz).

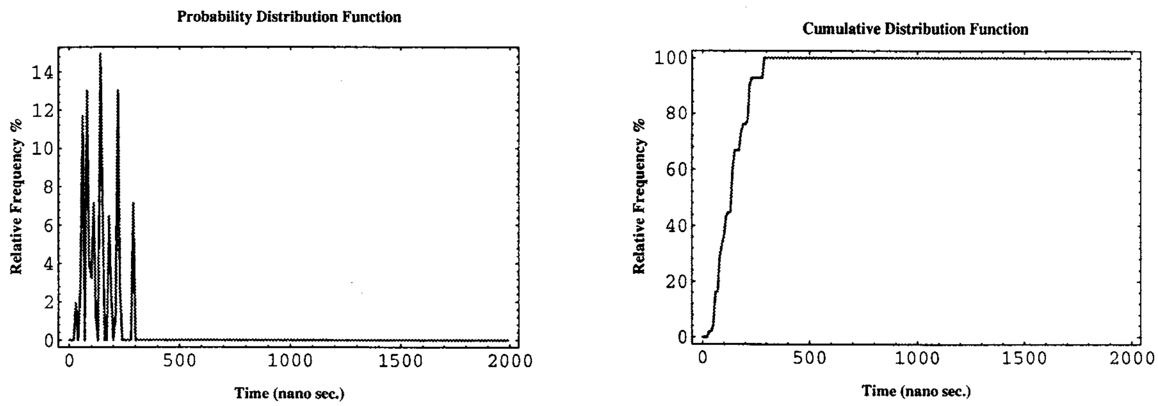


Figure I-11: Home wiring histogram of echo delays (480 - 546 MHz).

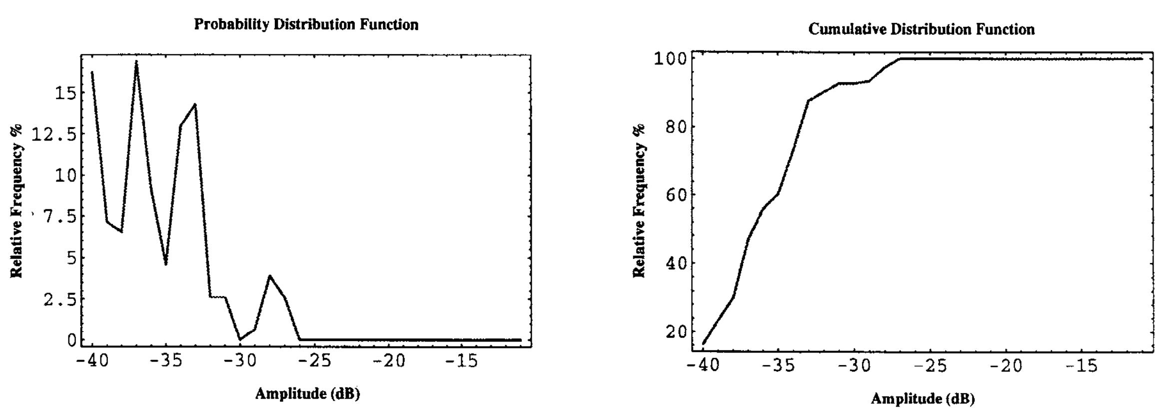


Figure I-12: Home wiring histogram of echo amplitudes (480 - 546 MHz).

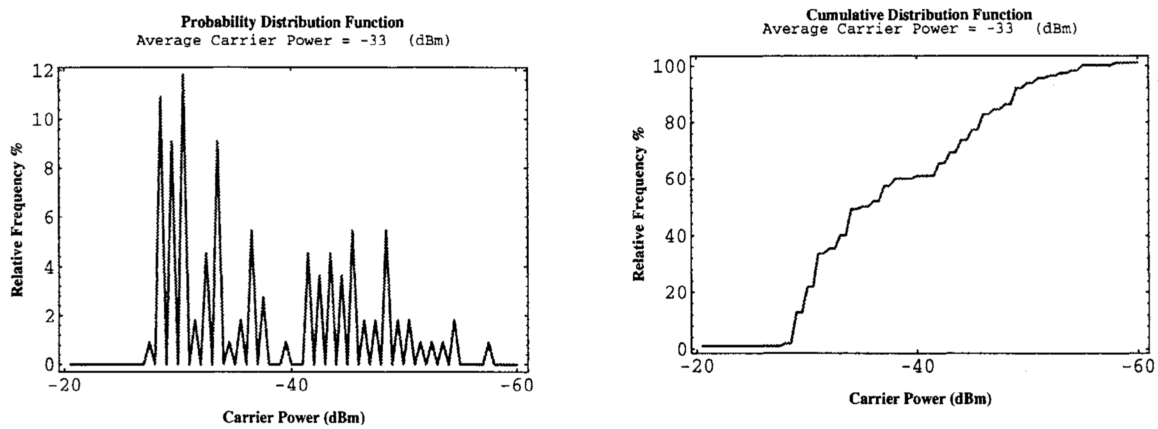


Figure I-13: Tap histogram of carrier power (480 - 546 MHz).

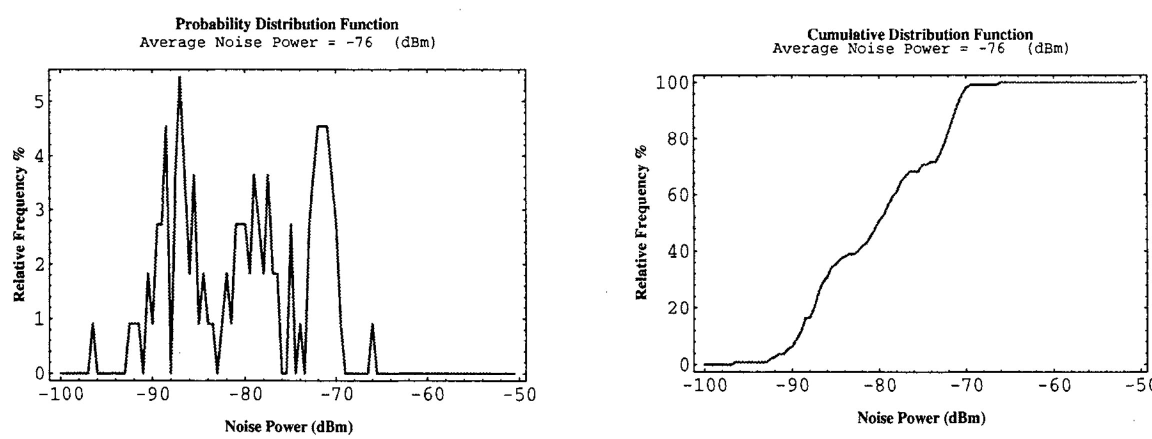


Figure I-14: Tap histogram of noise power (480 - 546 MHz).

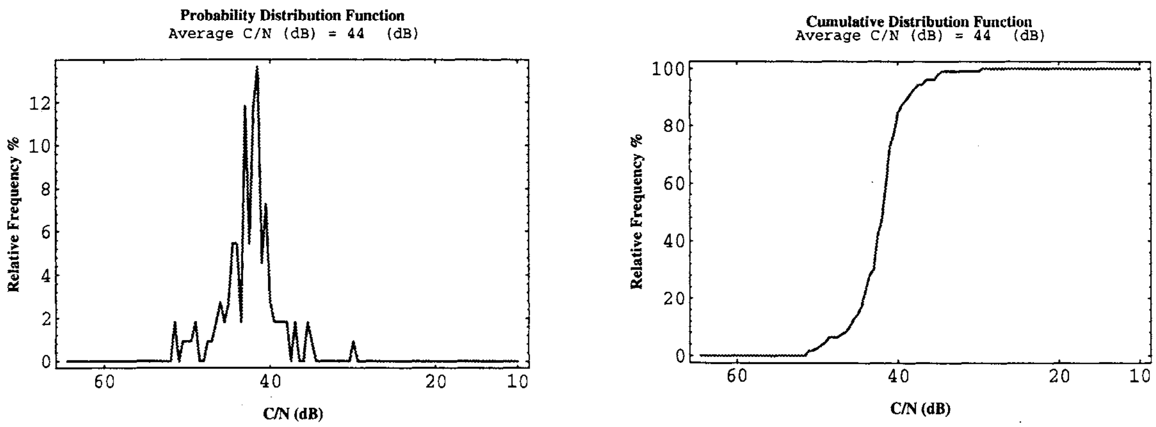


Figure I-15: Tap histogram of carrier-to-noise ratio (480 - 546 MHz).

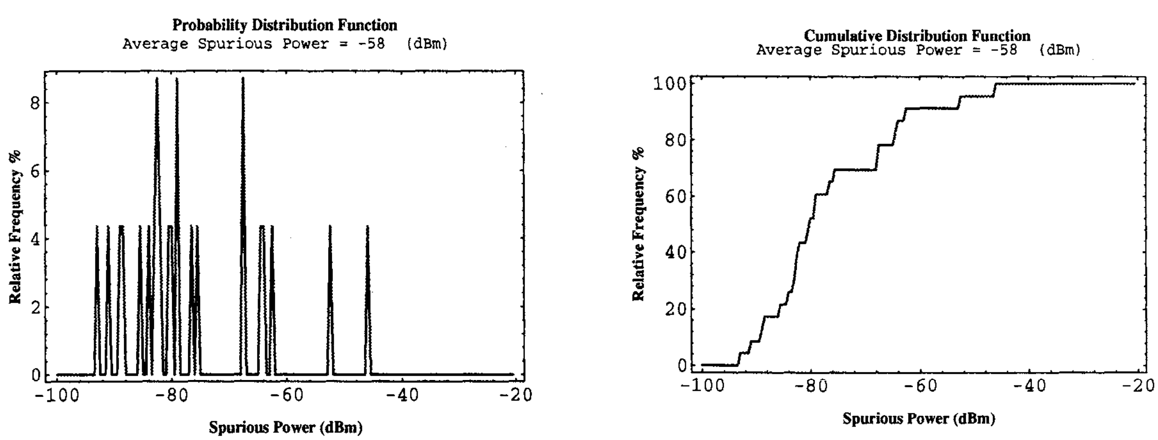


Figure I-16: Tap histogram of spurious components (480 - 546 MHz).

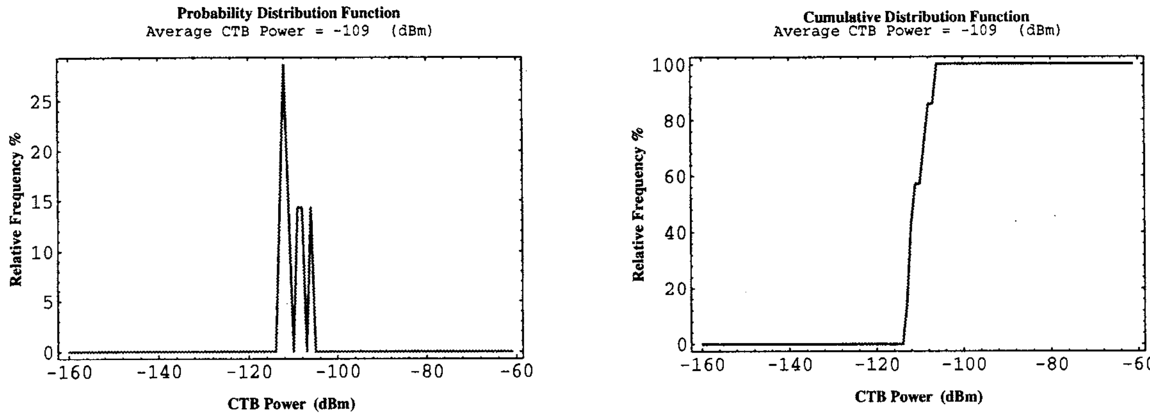


Figure I-17: Tap histogram of composite triple beats (480 - 546 MHz).

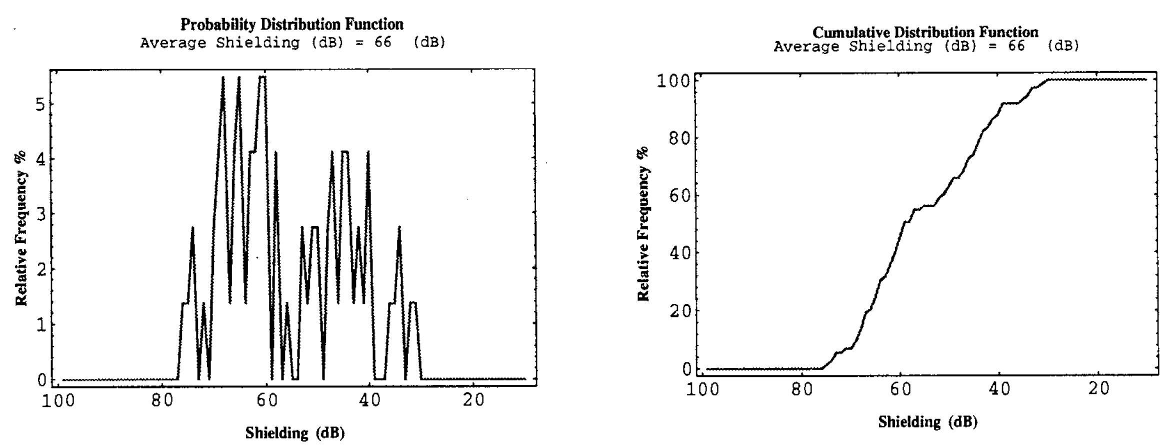


Figure I-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

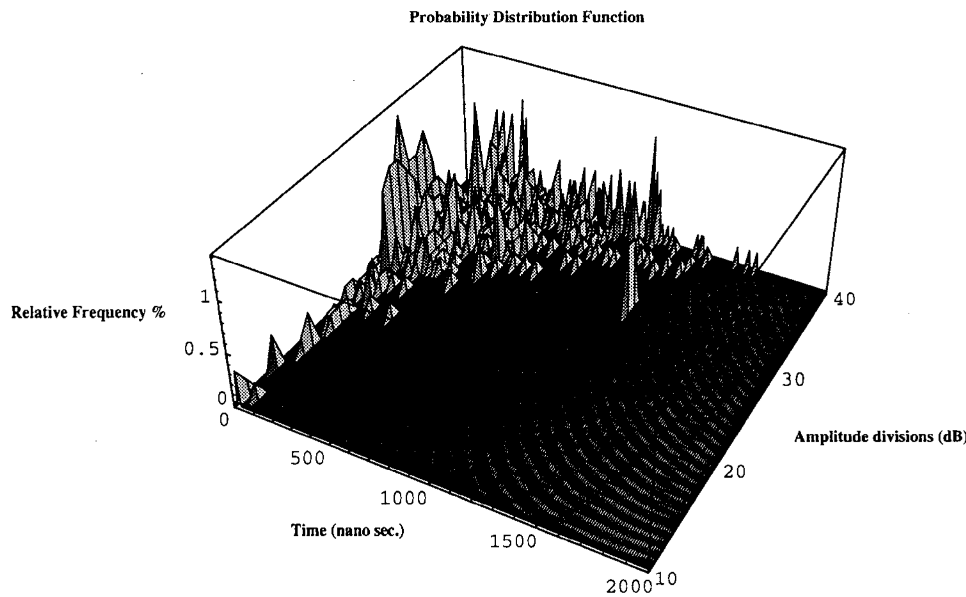
APPENDIX J. RESULTS FOR CABLE SYSTEM J

Table J-1: Micro-Reflection Impairments Summary for Cable System J.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 456 - 546 MHz				
Delay (nanosecond)	280	950	1110	1340
Amplitude (dB)	-36	-28	-26	-15
Headend Thru Home Outlet:				
Frequency: 456 - 546 MHz				
Delay (nanosecond)	300	920	1110	1400
Amplitude (dB)	-36	-28	-25	-18
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	110	250	250	380
Amplitude (dB)	-39	-32	-29	-26
Home Wiring:				
Frequency: 456 - 546 MHz				
Delay (nanosecond)	90	240	250	480
Amplitude (dB)	-38	-31	-30	-28

Table J-2: Noise/Interference Impairments Summary for Cable System J.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 456 - 546 MHz					
Carrier/Noise (dB)	45	43	29	27	22
Carrier Power (dBm)	-32	-38	-51	-53	-57
Noise Power (dBm) in 6 MHz Bandwidth	-67	-81	-67	-64	-54
Spurious Power (dBm) in 6 MHz Bandwidth	-78	-81	-75	-74	-69
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-67	-78	-66	-64	-54
CTB Power (dBm) 12 MHz above the last active channel	-95	-99	-89	-89	-89
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	64	60	53	53	49



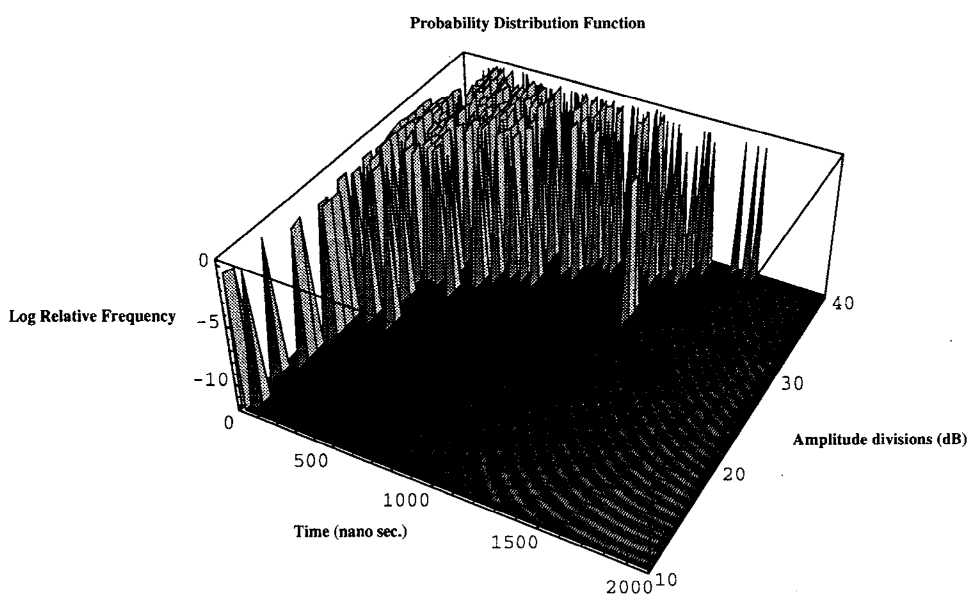


Figure J-1: Tap distribution of echoes (456 - 546 MHz).

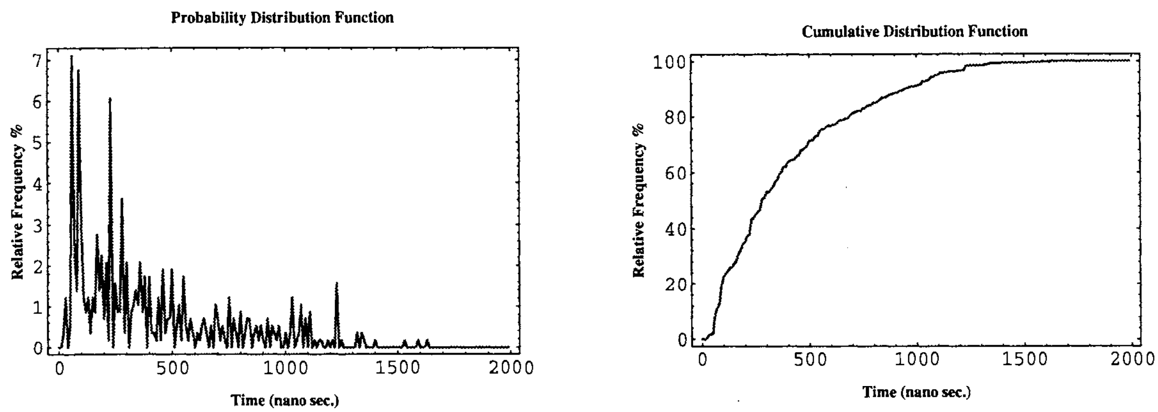


Figure J-2: Tap histogram of echo delays (456 - 546 MHz).

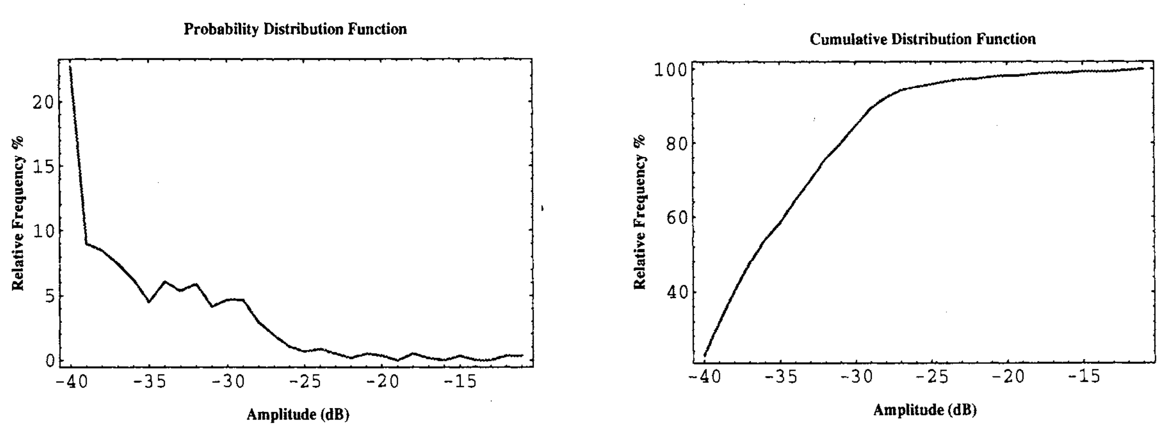
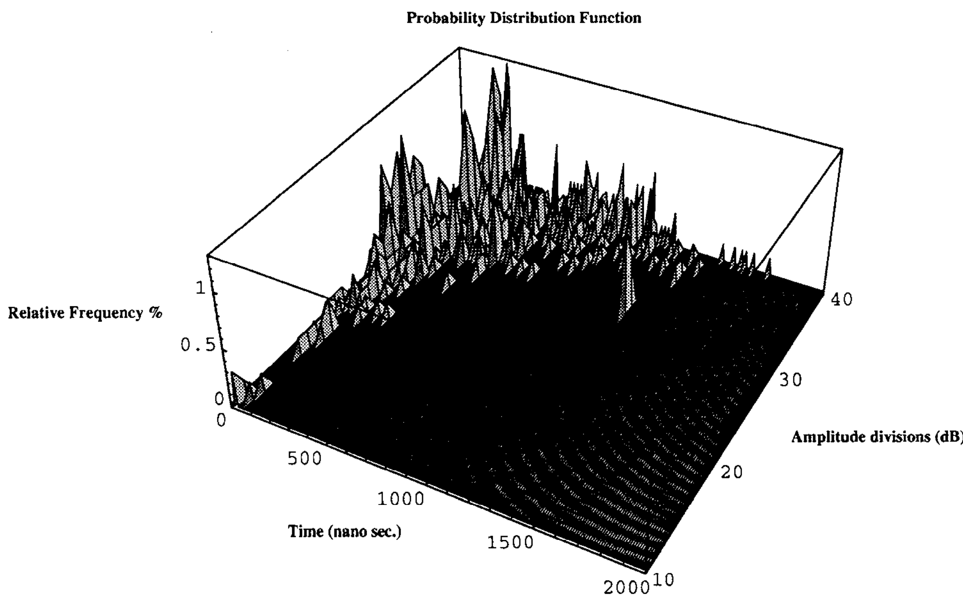


Figure J-3: Tap histogram of echo amplitudes (456 - 546 MHz).



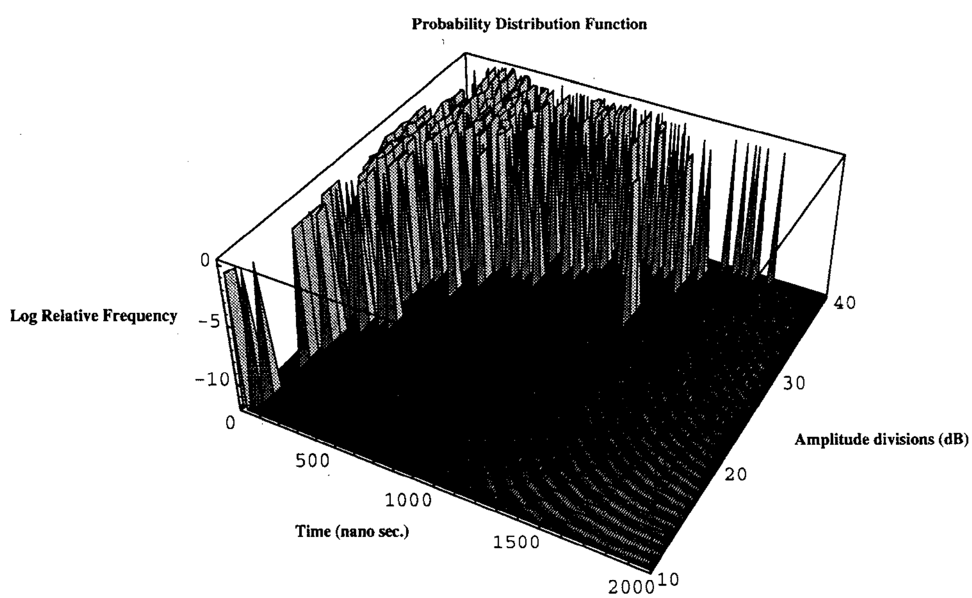


Figure J-4: Home outlet distribution of echoes (456 - 546 MHz).

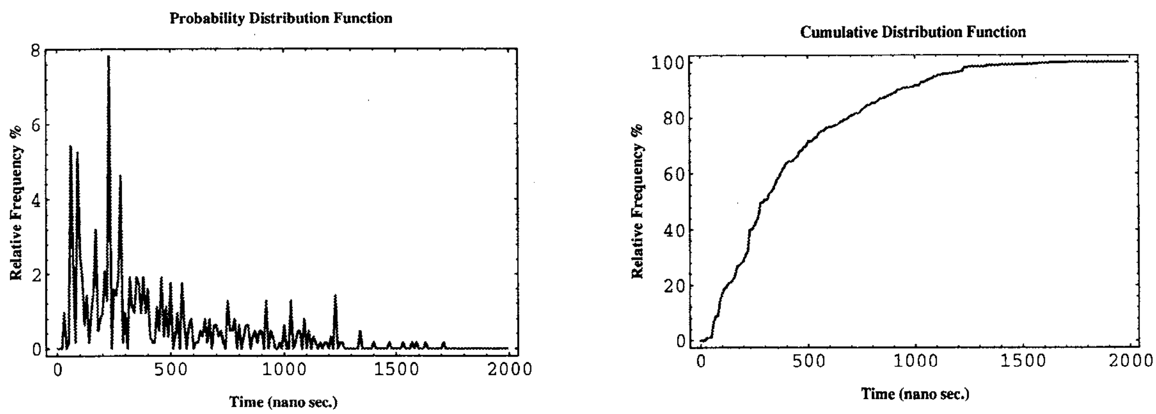


Figure J-5: Home outlet histogram of echo delays (456 - 546 MHz).

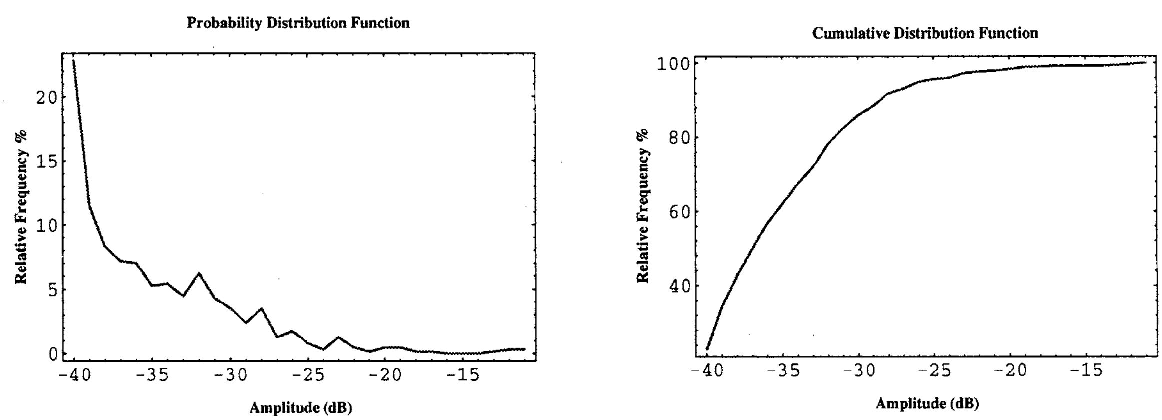
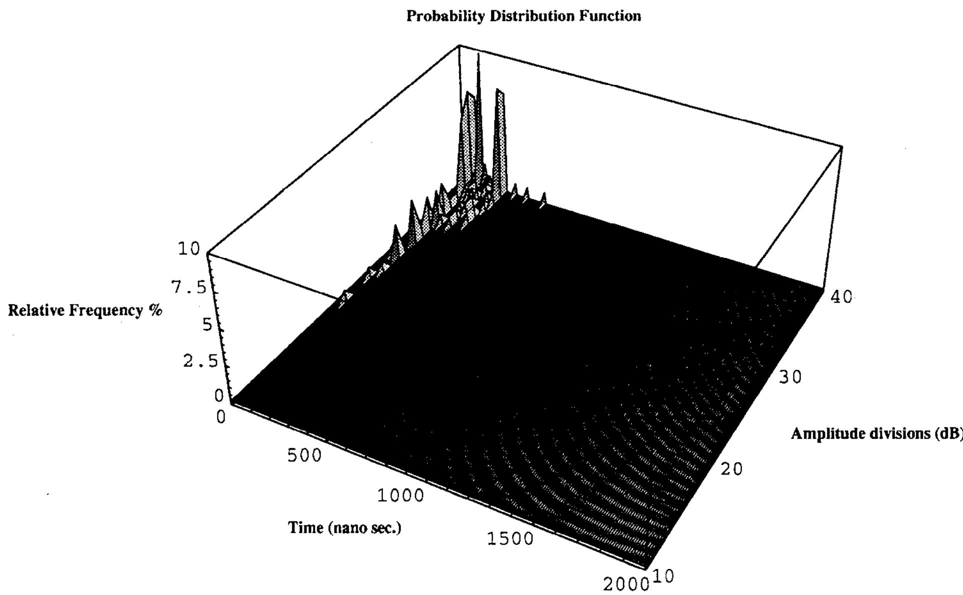


Figure J-6: Home outlet histogram of echo amplitudes (456 - 546 MHz).



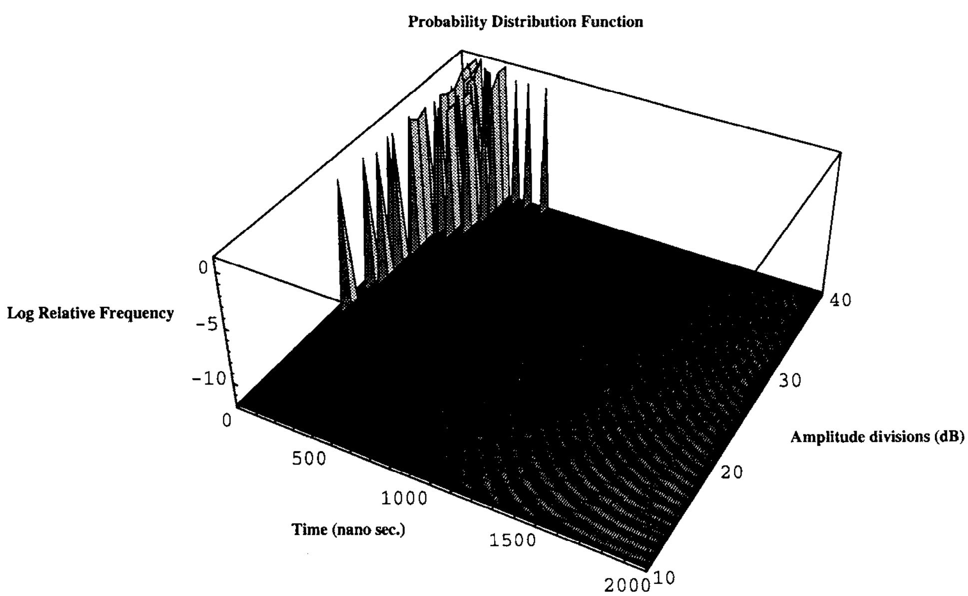


Figure J-7: Home wiring distribution of echoes (50 - 200 MHz).

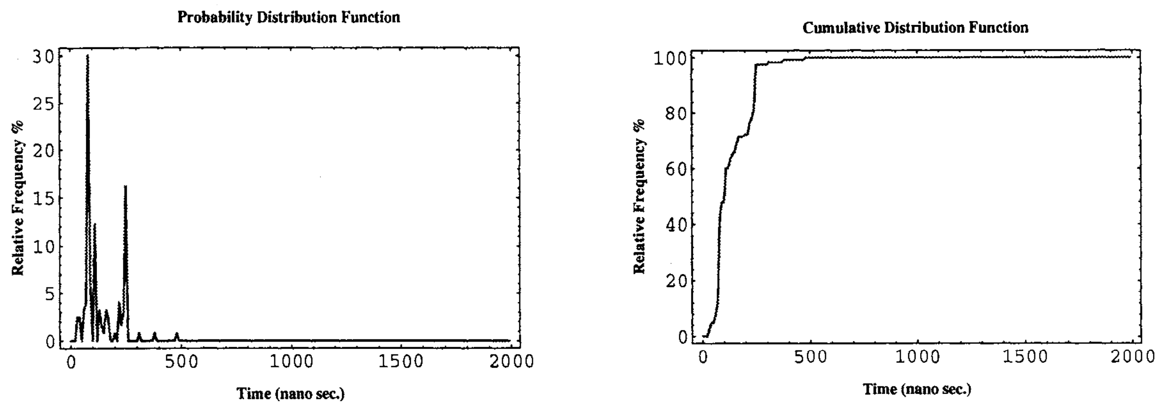


Figure J-8: Home wiring histogram of echo delays (50 - 200 MHz).

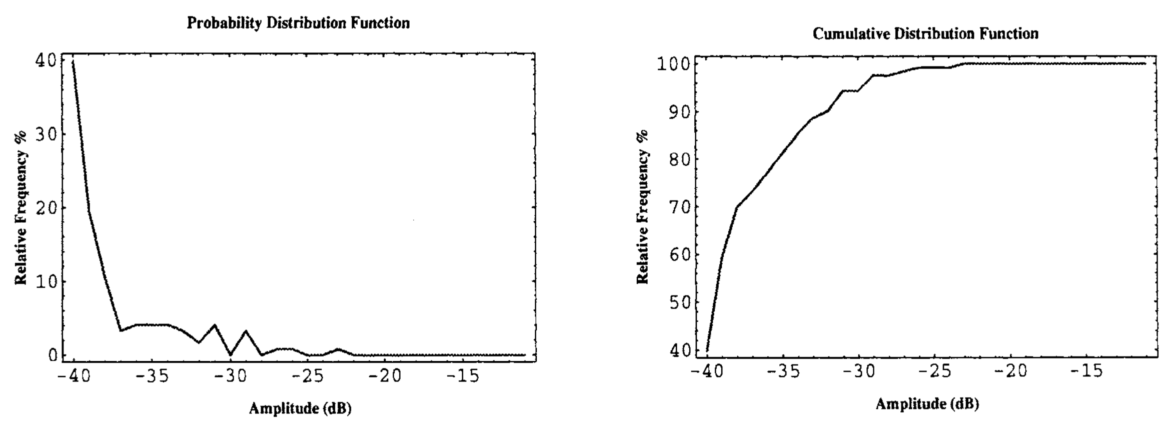
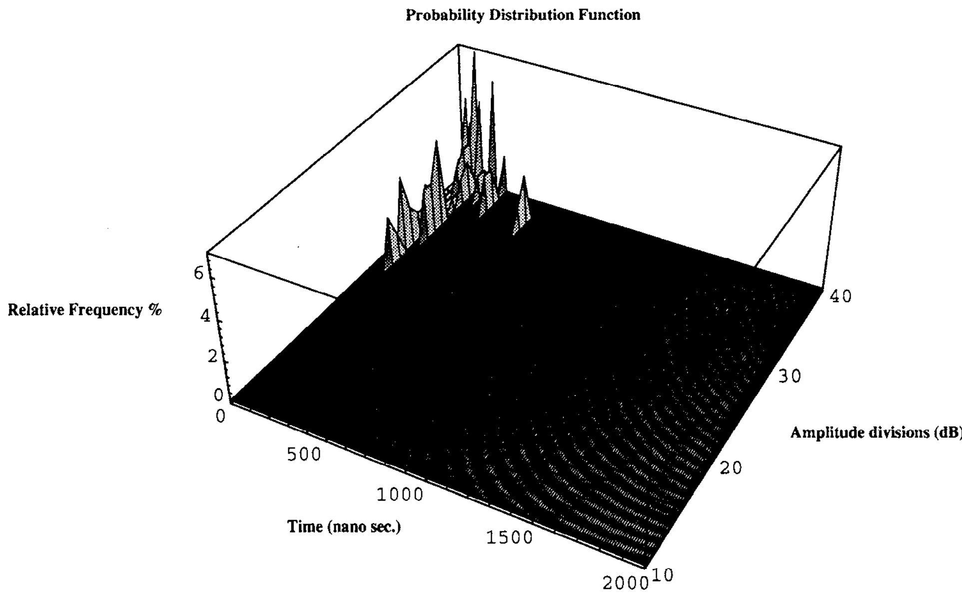


Figure J-9: Home wiring histogram of echo amplitudes (50 - 200 MHz)



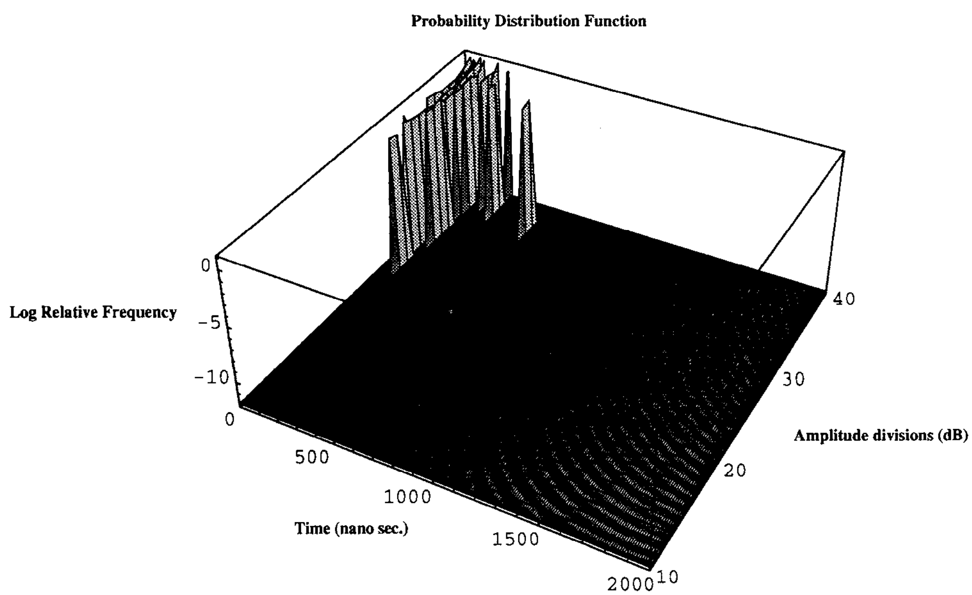


Figure J-10: Home wiring distribution of echoes (456 - 546 MHz).

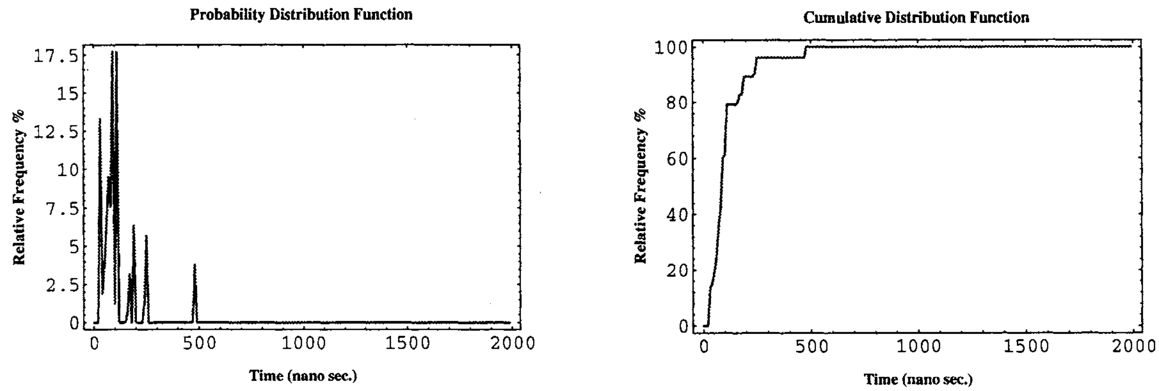


Figure J-11: Home wiring histogram of echo delays (456 - 546 MHz).

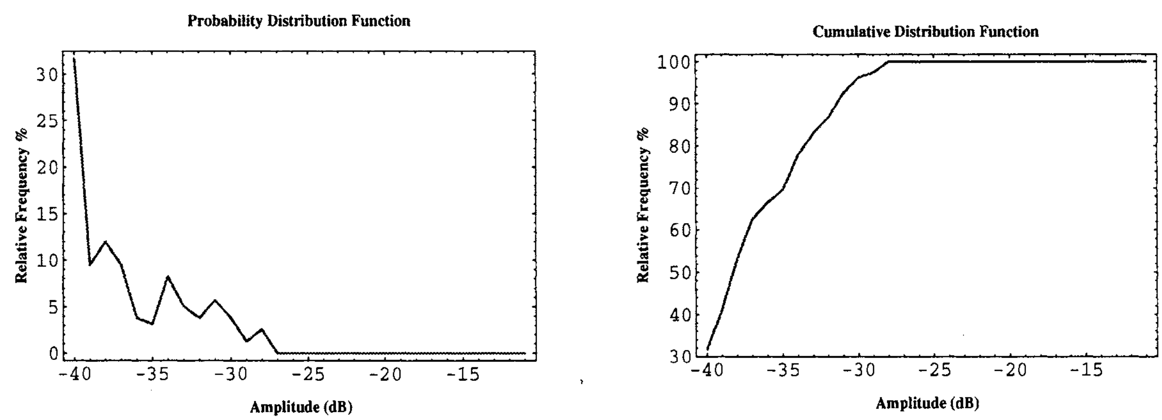


Figure J-12: Home wiring histogram of echo amplitudes (456 - 546 MHz).

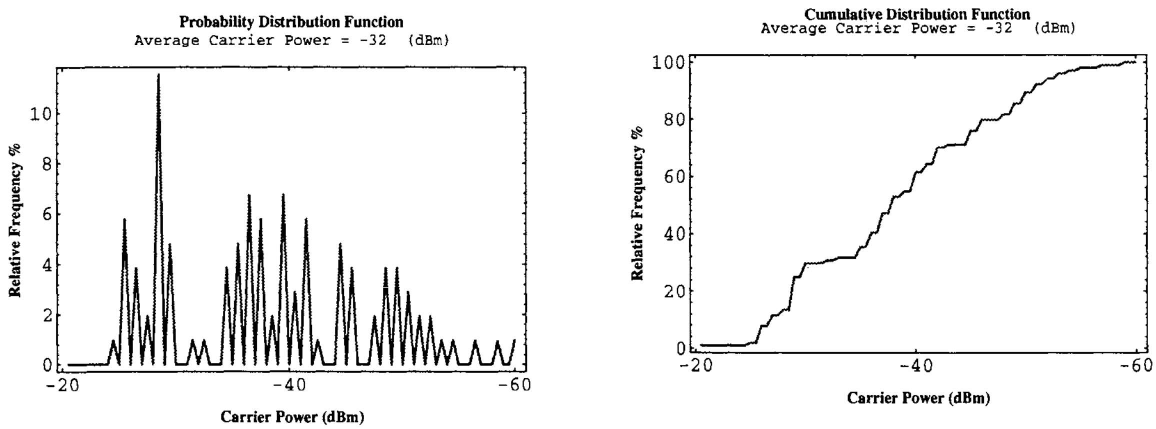


Figure J-13: Tap histogram of carrier power (456 - 546 MHz).

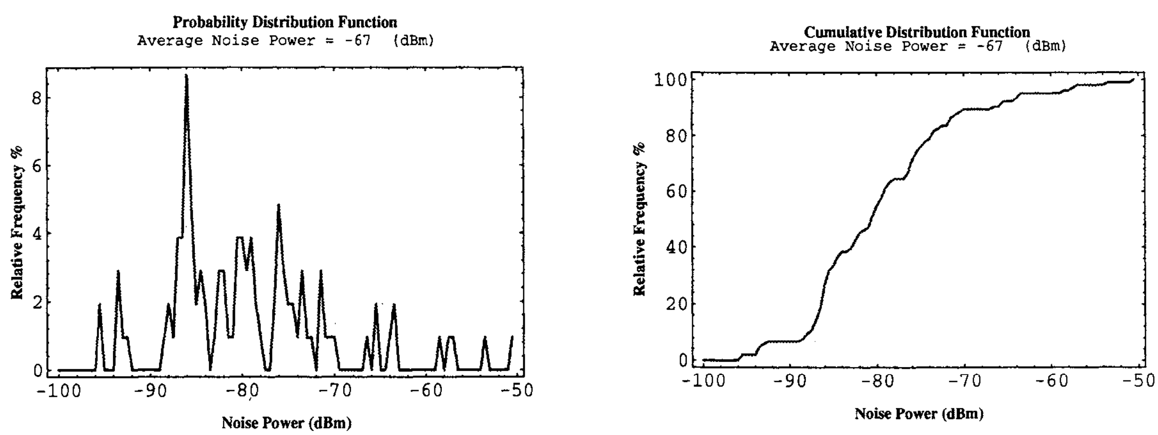


Figure J-14: Tap histogram of noise power (456 - 546 MHz).

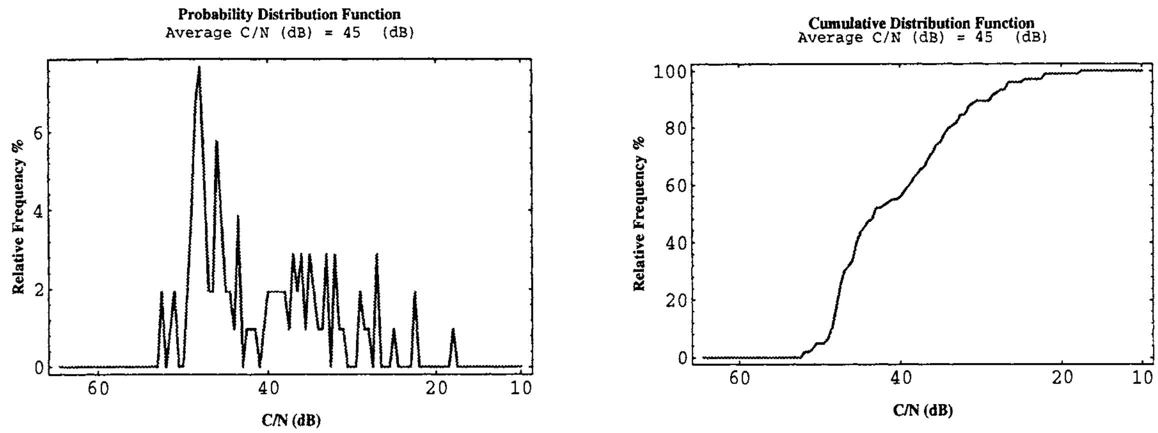


Figure J-15: Tap histogram of carrier-to-noise ratio (456 - 546 MHz).

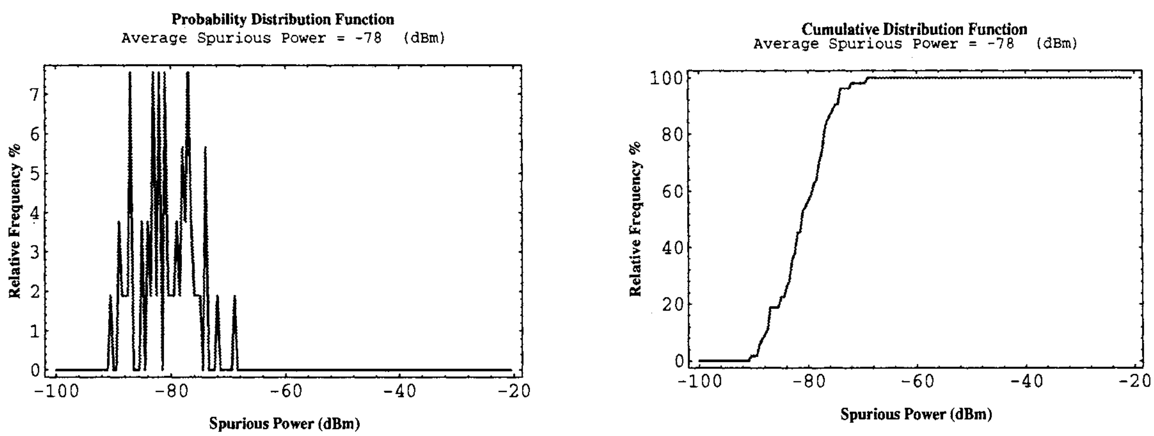


Figure J-16: Tap histogram of spurious components (456 - 546 MHz).

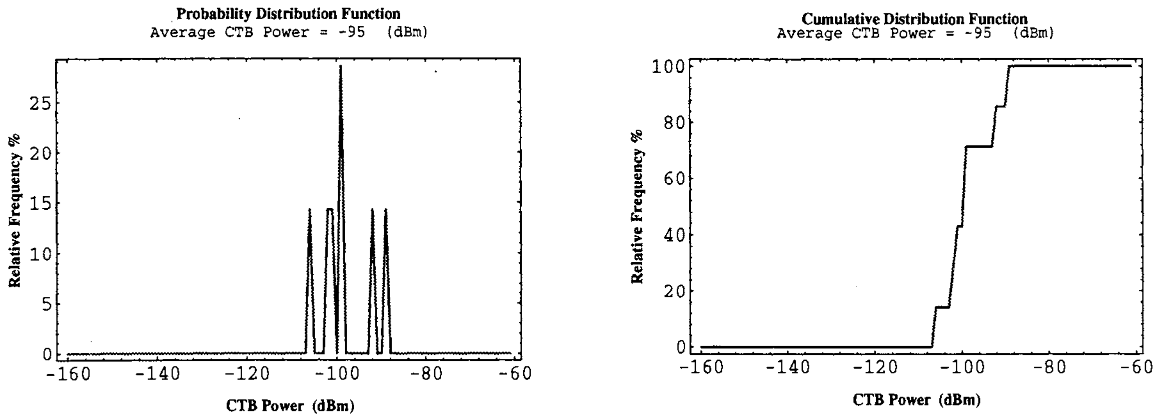


Figure J-17: Tap histogram of composite triple beats (456 - 546 MHz).

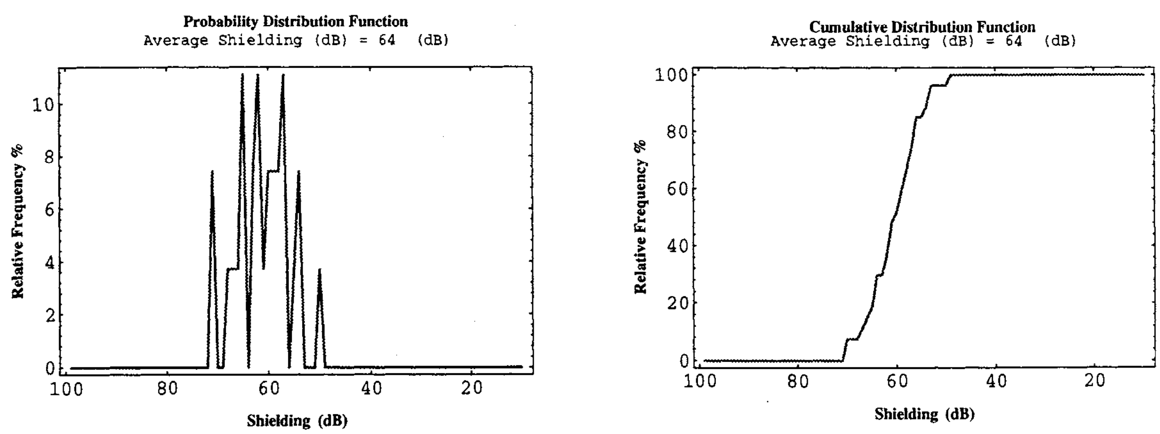


Figure J-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

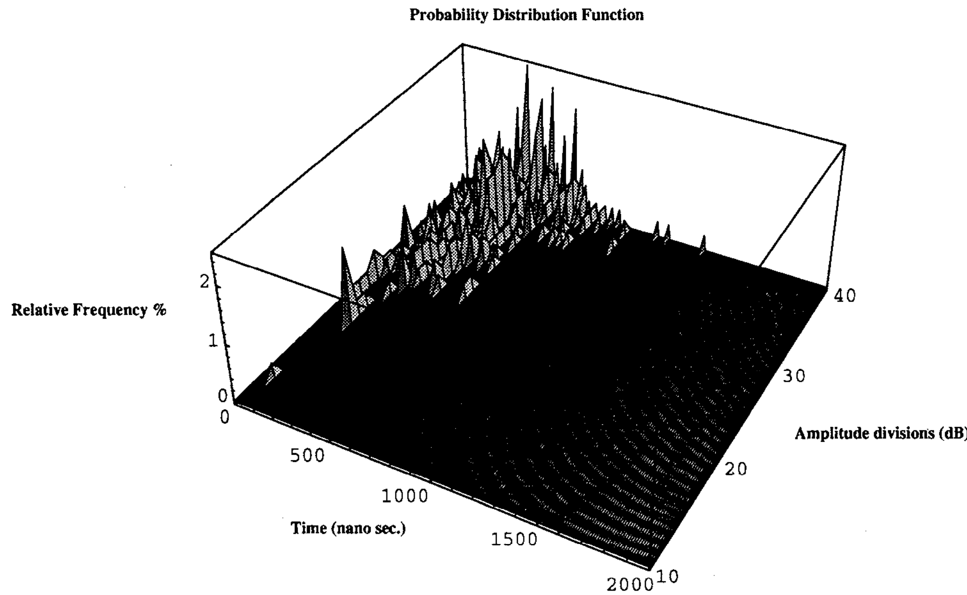
APPENDIX K. RESULTS FOR CABLE SYSTEM K

Table K-1: Micro-Reflection Impairments Summary for Cable System K.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 414 - 456 MHz				
Delay (nanosecond)	350	640	680	950
Amplitude (dB)	-37	-28	-27	-21
Headend Thru Home Outlet:				
Frequency: 414 - 456 MHz				
Delay (nanosecond)	350	660	720	1100
Amplitude (dB)	-37	-27	-25	-21
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	80	140	140	140
Amplitude (dB)	-39	-32	-32	-31
Home Wiring:				
Frequency: 414 - 456 MHz				
Delay (nanosecond)	80	140	140	180
Amplitude (dB)	-36	-29	-29	-29

Table K-2: Noise/Interference Impairments Summary for Cable System K.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 414 - 456 MHz					
Carrier/Noise (dB)	43	39	35	27	26
Carrier Power (dBm)	-42	-47	-56	-59	-59
Noise Power (dBm) in 6 MHz Bandwidth	-87	-88	-84	-83	-81
Spurious Power (dBm) in 6 MHz Bandwidth	-86	-87	-86	-86	-86
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-83	-84	-82	-81	-80
CTB Power (dBm) 12 MHz above the last active channel	-111	-112	-108	-108	-108
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	66	60	51	50	48



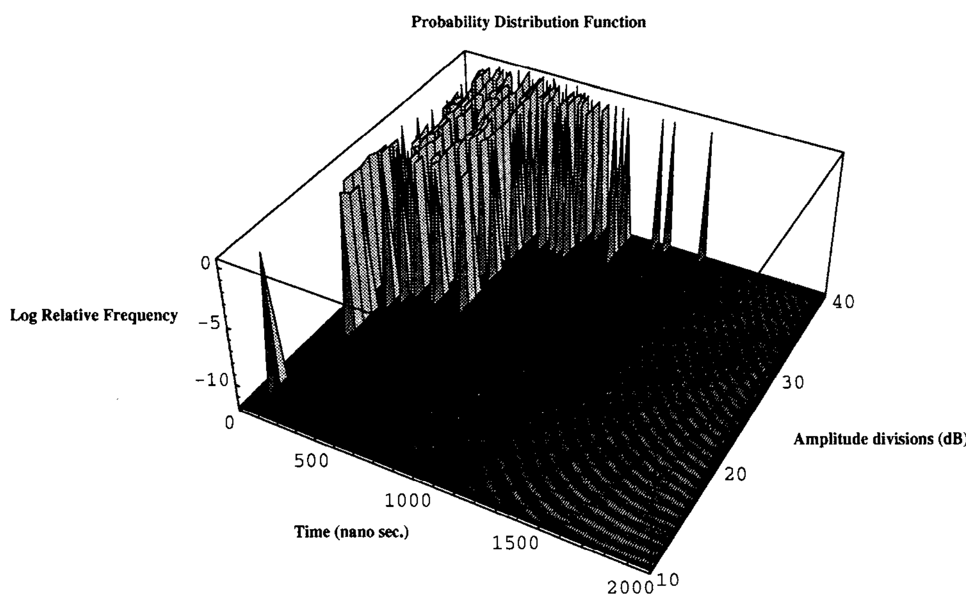


Figure K-1: Tap distribution of echoes (414 - 456 MHz).

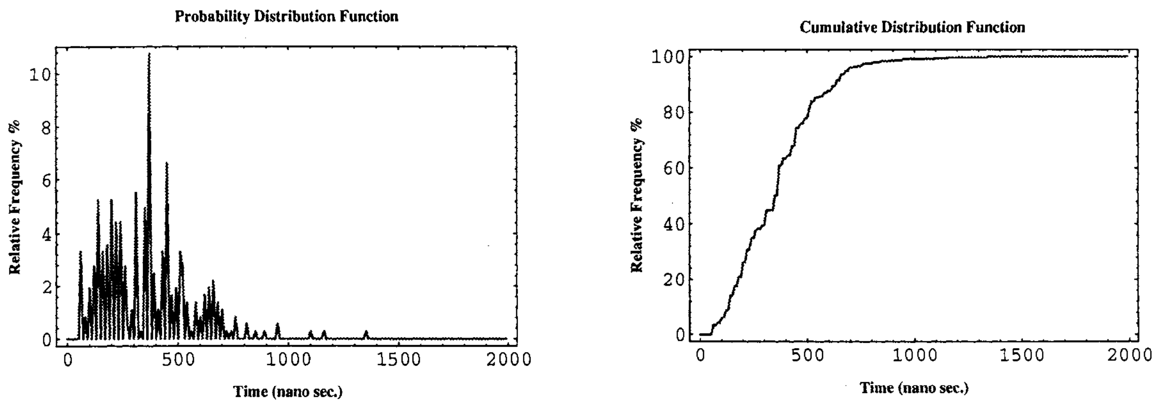


Figure K-2: Tap histogram of echo delays (414 - 456 MHz).

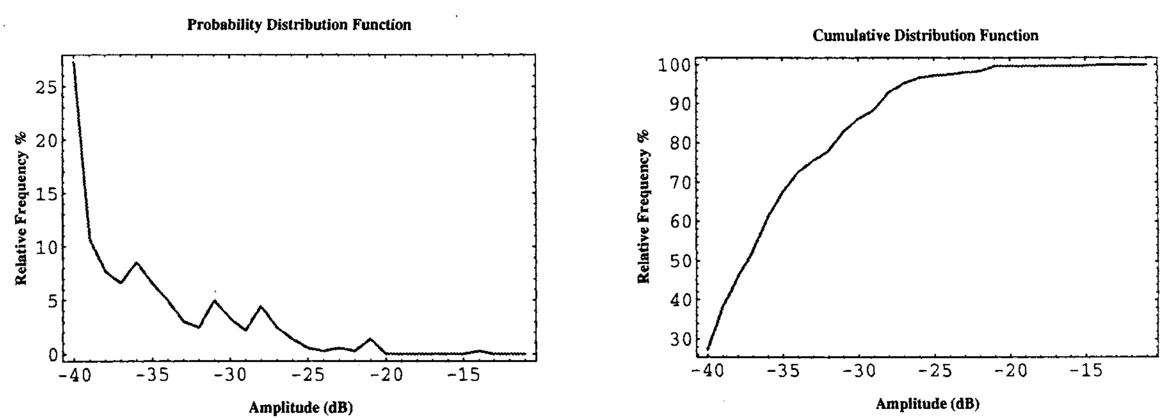
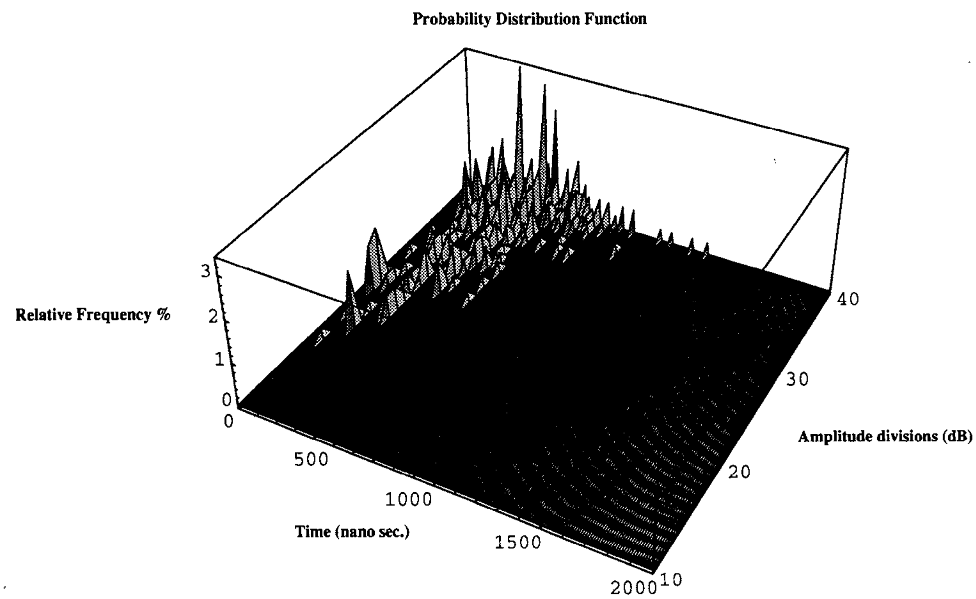


Figure K-3: Tap histogram of echo amplitudes (414 - 456 MHz).



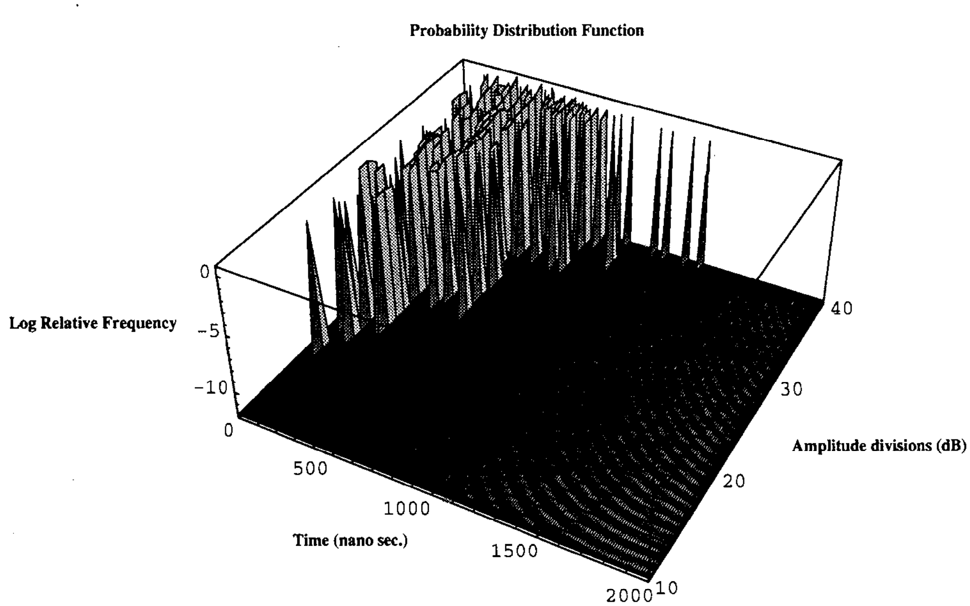


Figure K-4: Home outlet distribution of echoes (414 - 456 MHz).

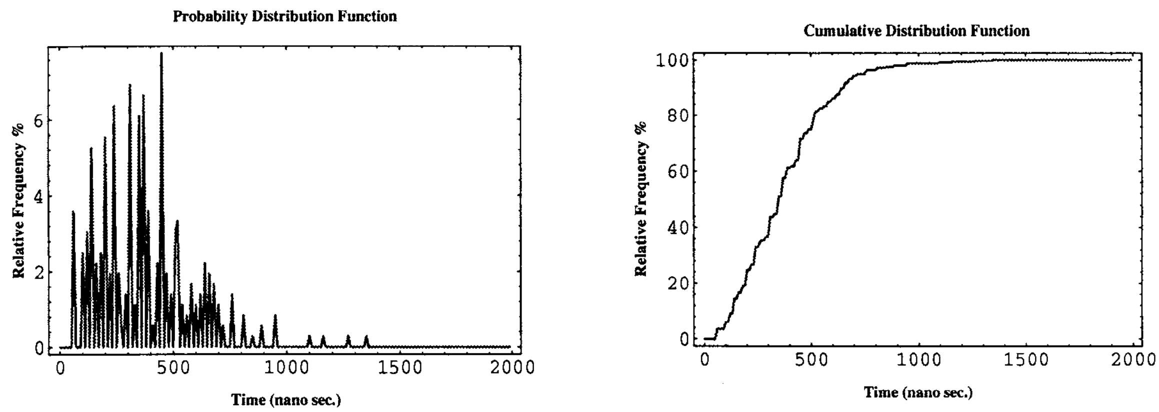


Figure K-5: Home outlet histogram of echo delays (414 - 456 MHz).

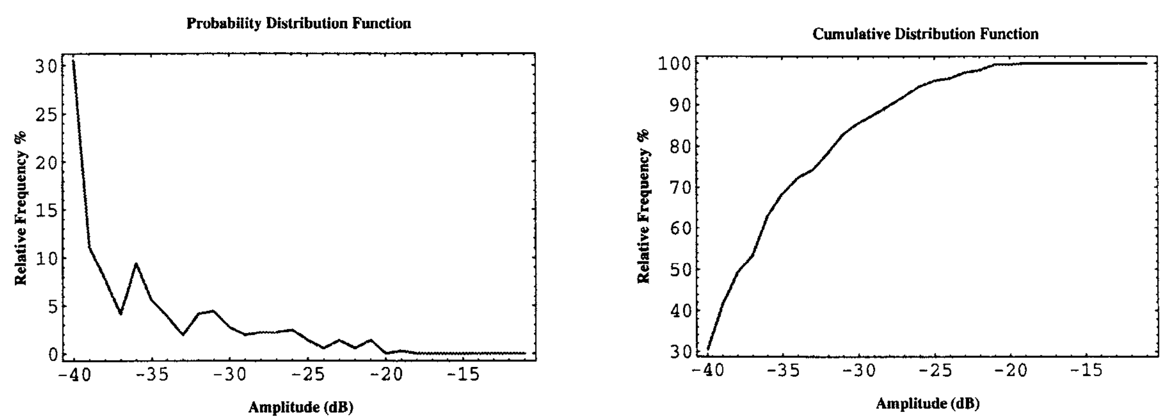
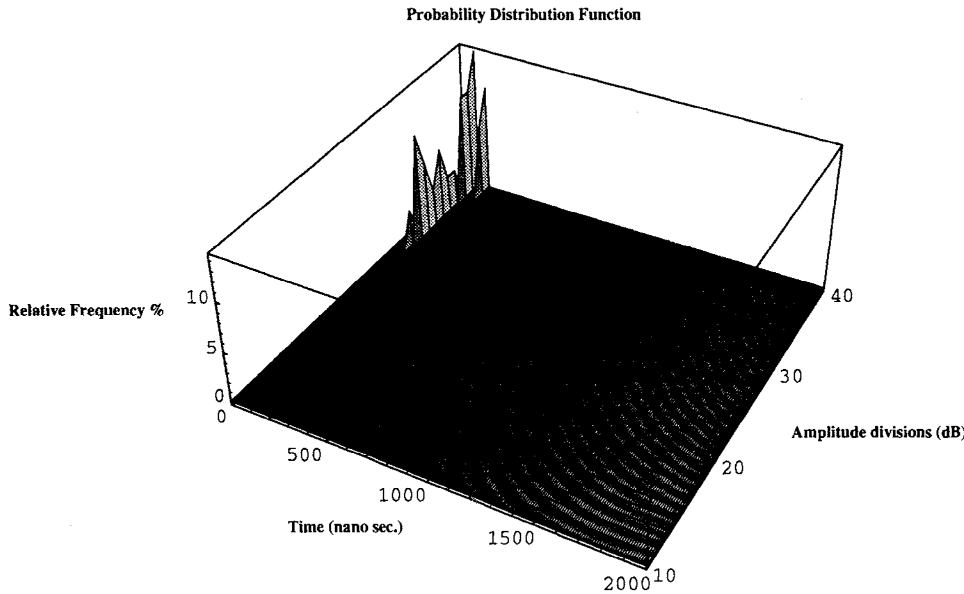


Figure K-6: Home outlet histogram of echo amplitudes (414 - 456 MHz).



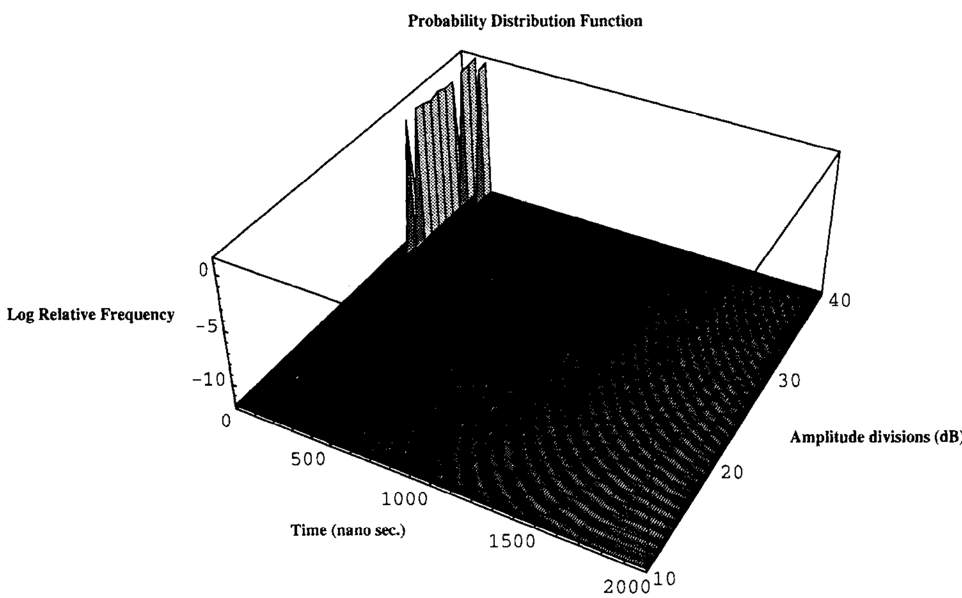


Figure K-7: Home wiring distribution of echoes (50 - 200 MHz).

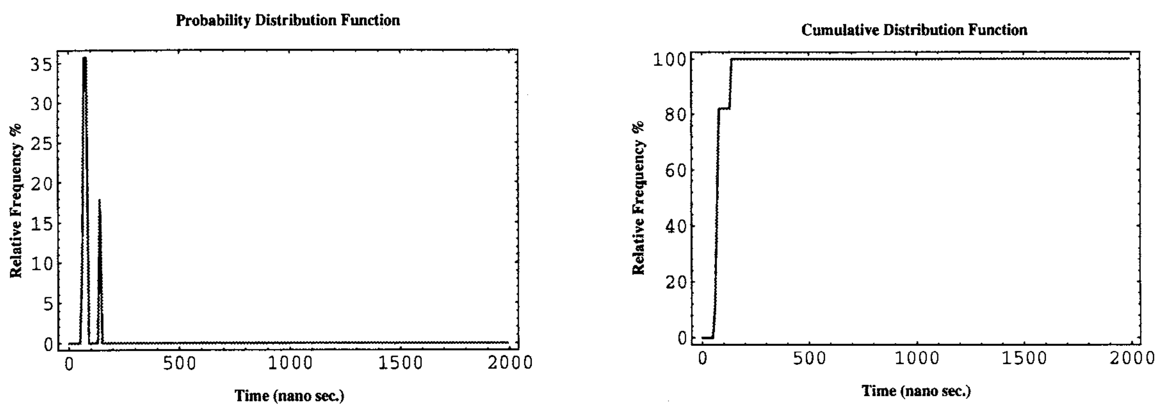


Figure K-8: Home wiring histogram of echo delays (50 - 200 MHz).

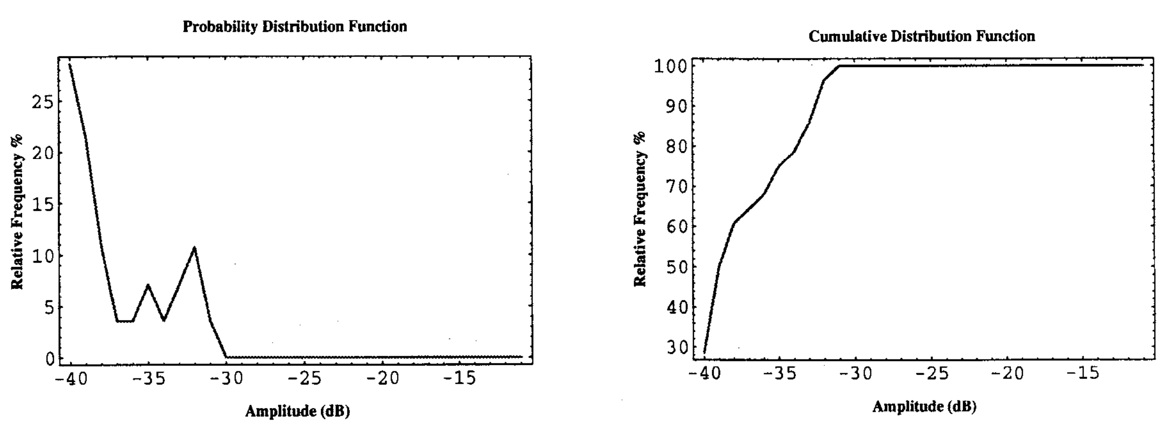


Figure K-9: Home wiring histogram of echo amplitudes (50 - 200 MHz).

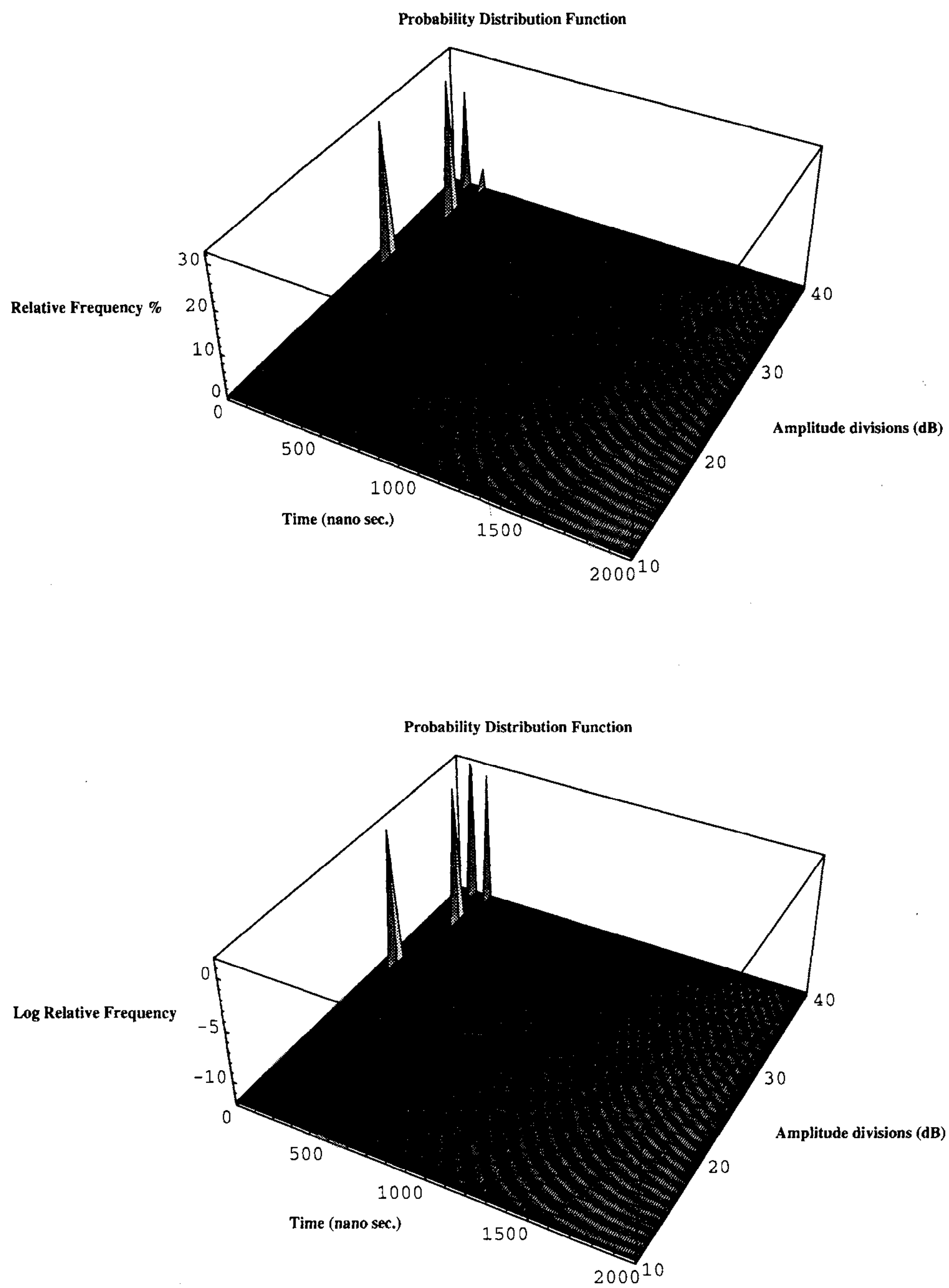


Figure K-10: Home wiring distribution of echoes (414 - 456 MHz).

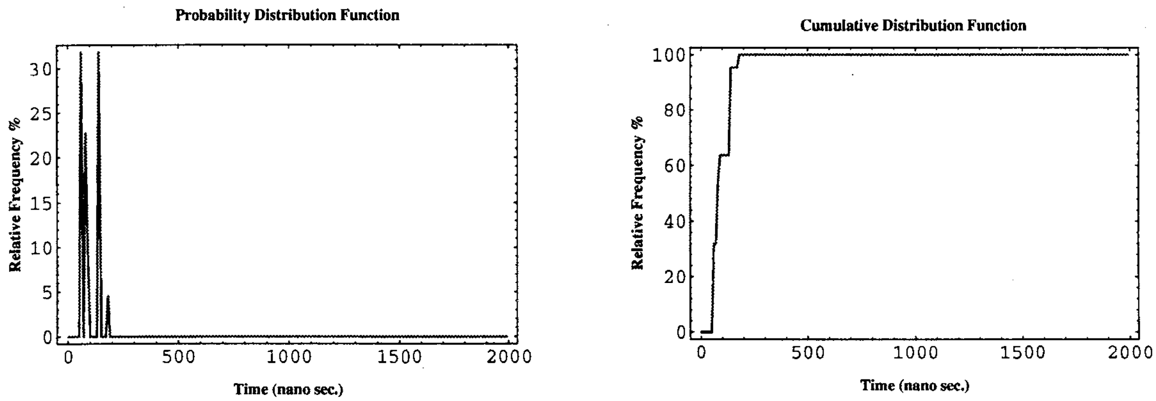


Figure K-11: Home wiring histogram of echo delays (414 - 456 MHz).

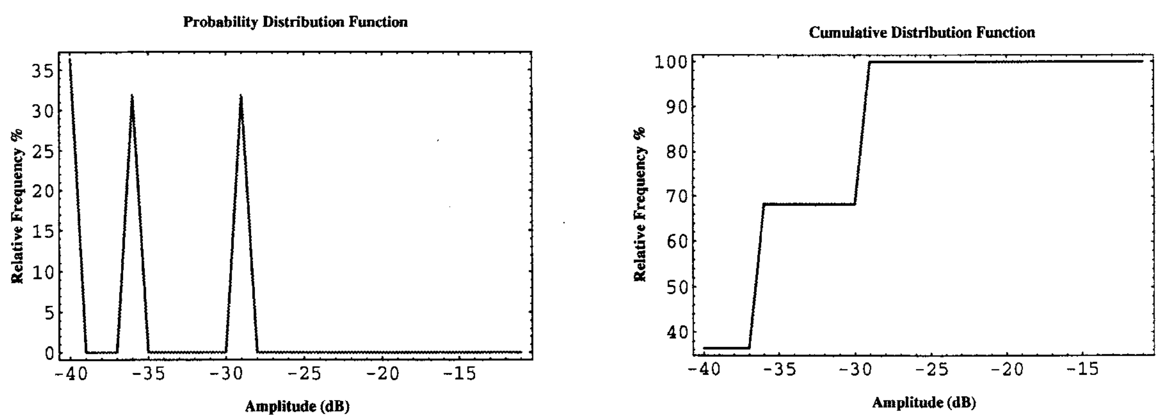


Figure K-12: Home wiring histogram of echo amplitudes (414 - 456 MHz)

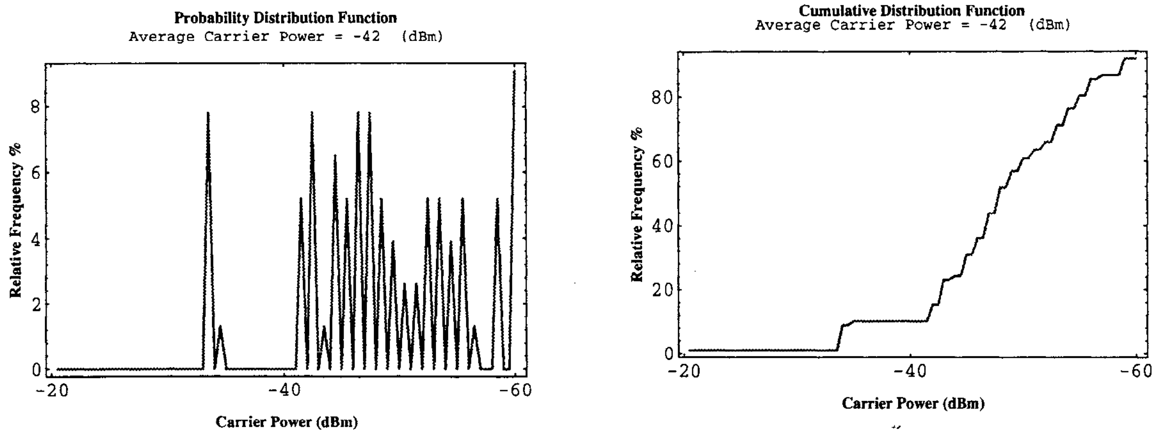


Figure K-13: Tap histogram of carrier power (414 - 456 MHz).

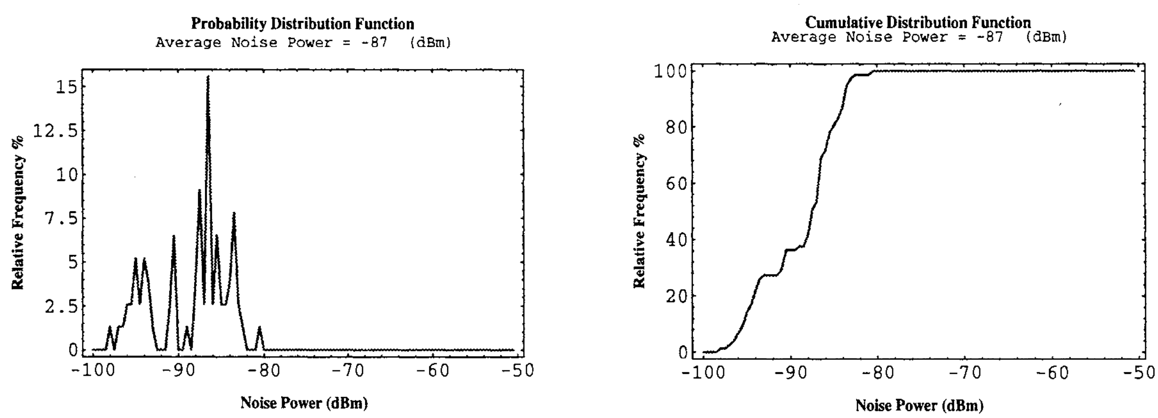


Figure K-14: Tap histogram of noise power (414 - 456 MHz).

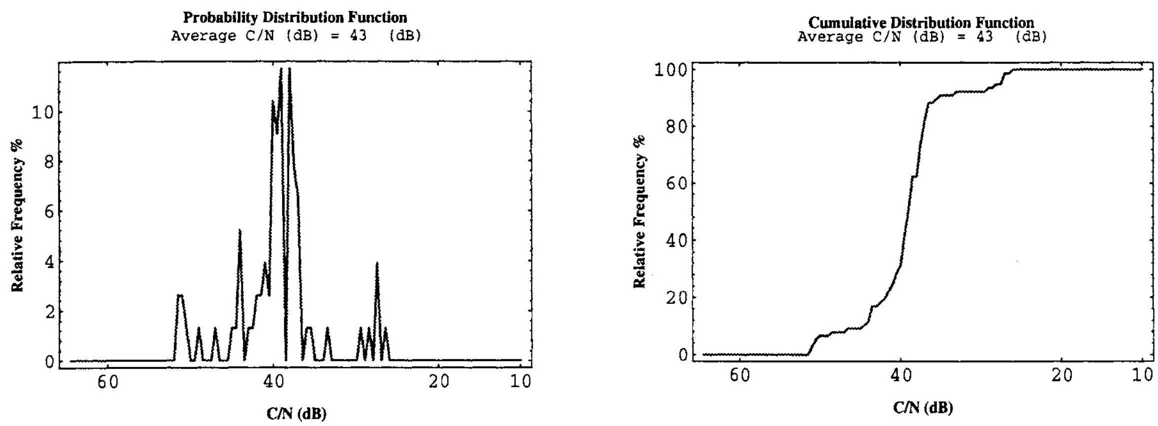


Figure K-15: Tap histogram of carrier-to-noise ratio (414 - 456 MHz).

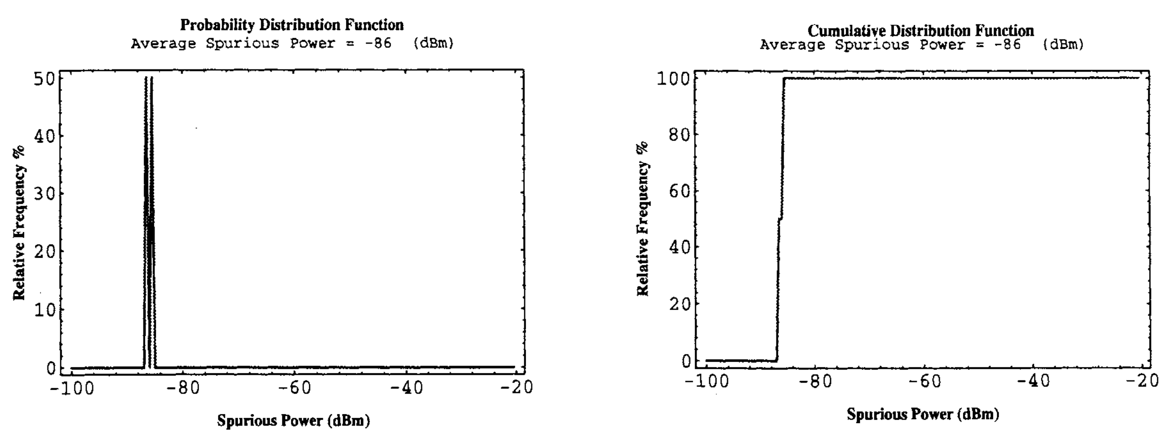


Figure K-16: Tap histogram of spurious components (414 - 456 MHz).

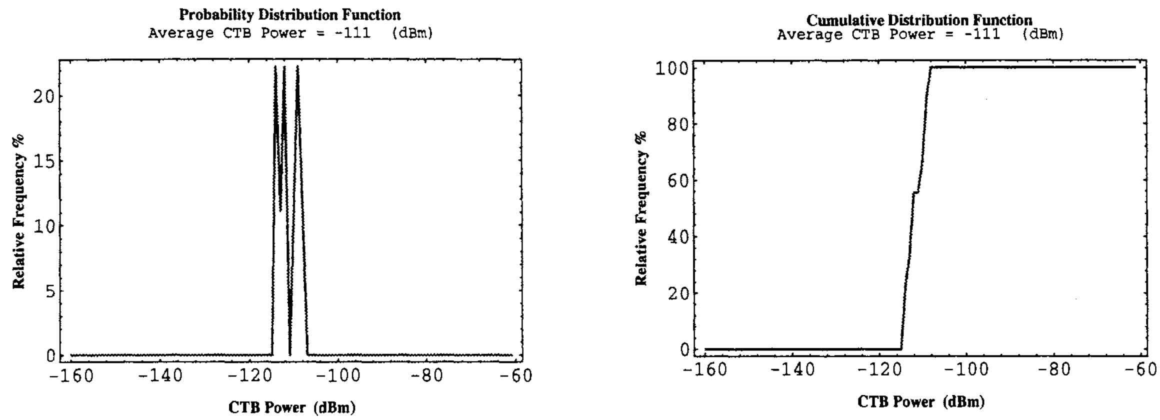


Figure K-17: Tap histogram of composite triple beats (414 - 456 MHz).

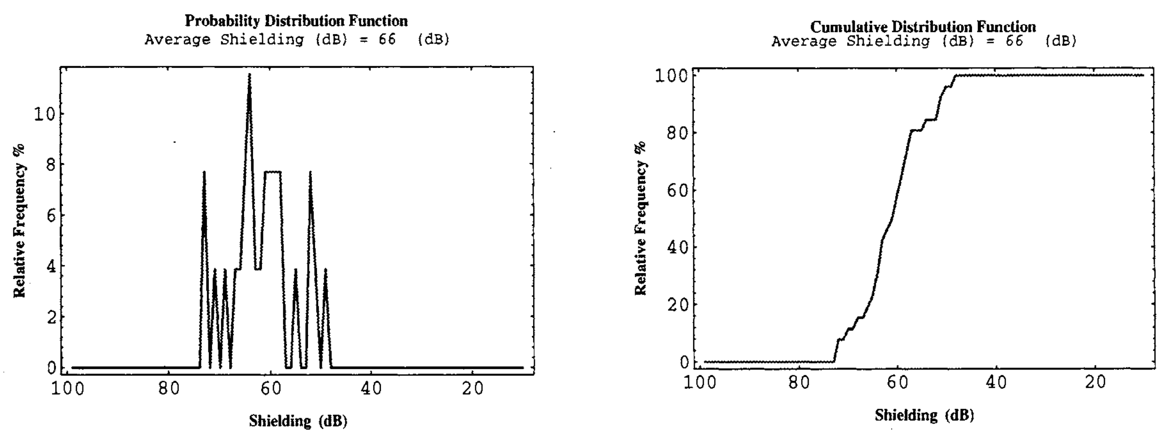


Figure K-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

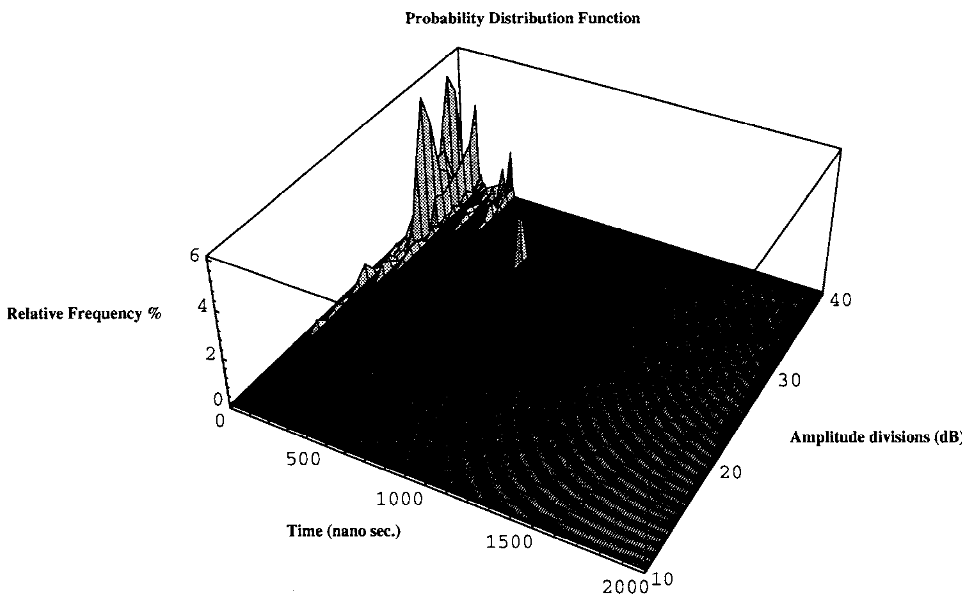
APPENDIX L. RESULTS FOR CABLE SYSTEM L

Table L-1: Micro-Reflection Impairments Summary for Cable System L.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 444 - 546 MHz				
Delay (nanosecond)	80	220	290	610
Amplitude (dB)	-36	-32	-30	-25
Headend Thru Home Outlet:				
Frequency: 444 - 546 MHz				
Delay (nanosecond)	90	290	330	620
Amplitude (dB)	-36	-27	-25	-18
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	130	270	320	400
Amplitude (dB)	-37	-29	-26	-21
Home Wiring:				
Frequency: 444 - 546 MHz				
Delay (nanosecond)	120	290	290	320
Amplitude (dB)	-37	-28	-22	-16

Table L-2: Noise/Interference Impairments Summary for Cable System L.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 444 - 546 MHz					
Carrier/Noise (dB)	49	47	39	36	21
Carrier Power (dBm)	-33	-34	-39	-40	-41
Noise Power (dBm) in 6 MHz Bandwidth	-73	-80	-75	-70	-60
Spurious Power (dBm) in 6 MHz Bandwidth	-74	-79	-71	-69	-64
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-70	-76	-70	-66	-59
CTB Power (dBm) 12 MHz above the last active channel	-98	-113	-103	-87	-87
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	66	63	52	44	36



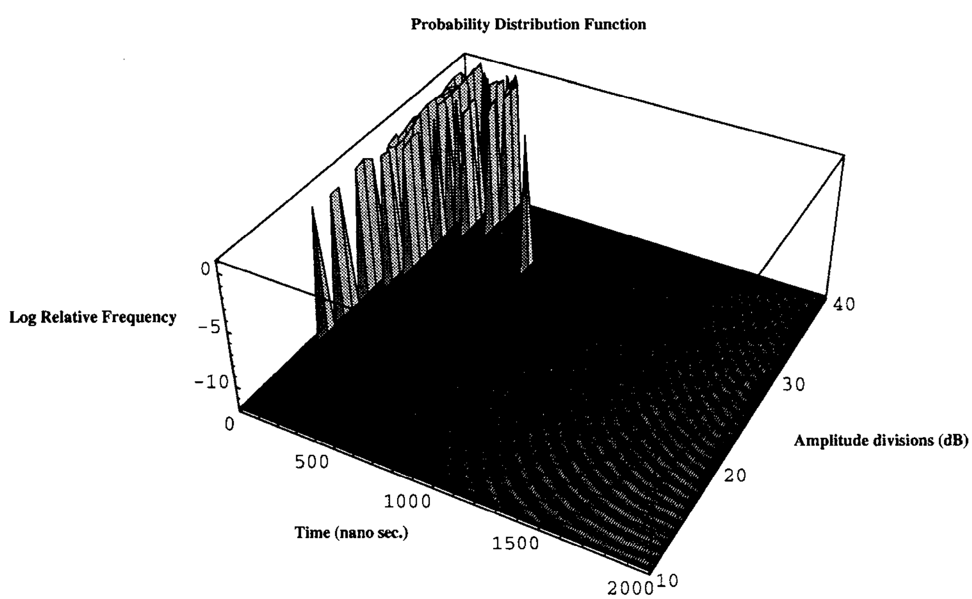


Figure L-1: Tap distribution of echoes (444 - 546 MHz).

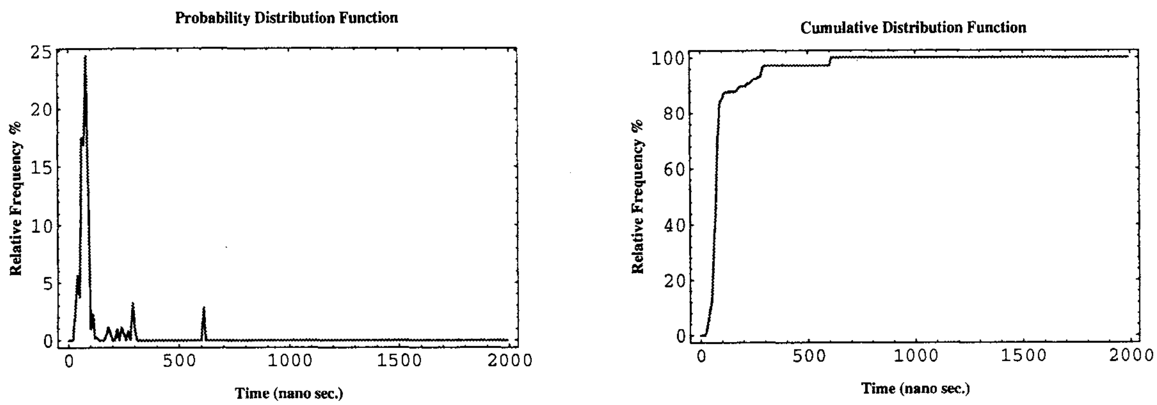


Figure L-2: Tap histogram of echo delays (444 - 546 MHz).

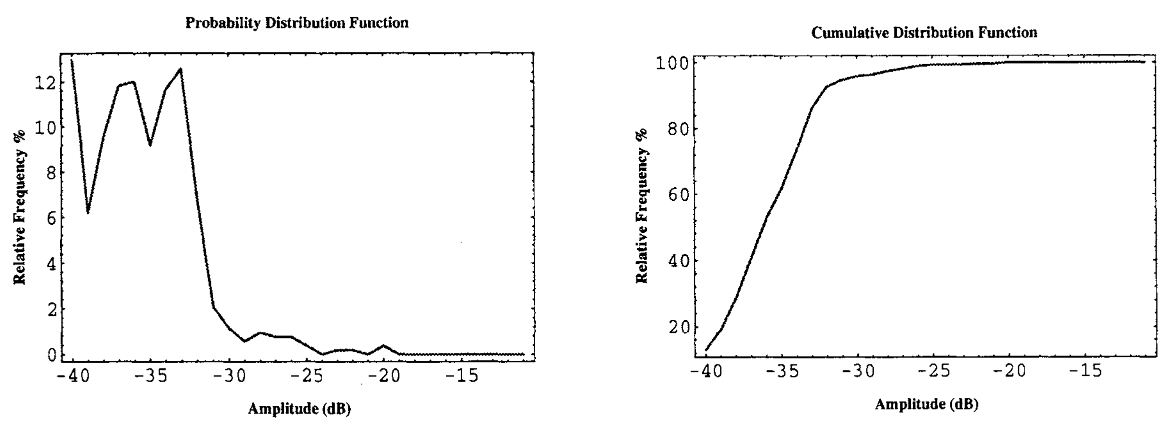
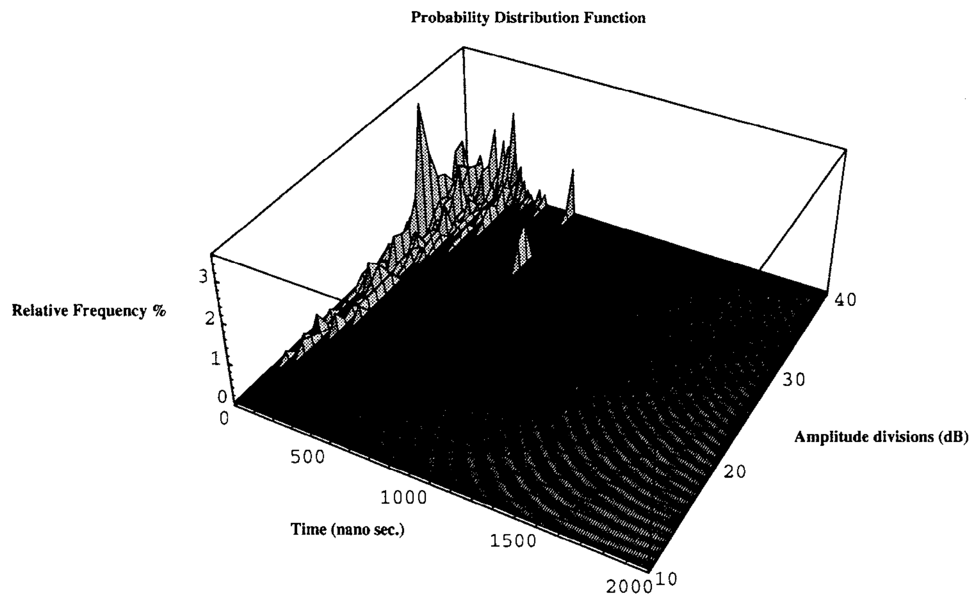


Figure L-3: Tap histogram of echo amplitudes (444 - 546 MHz).



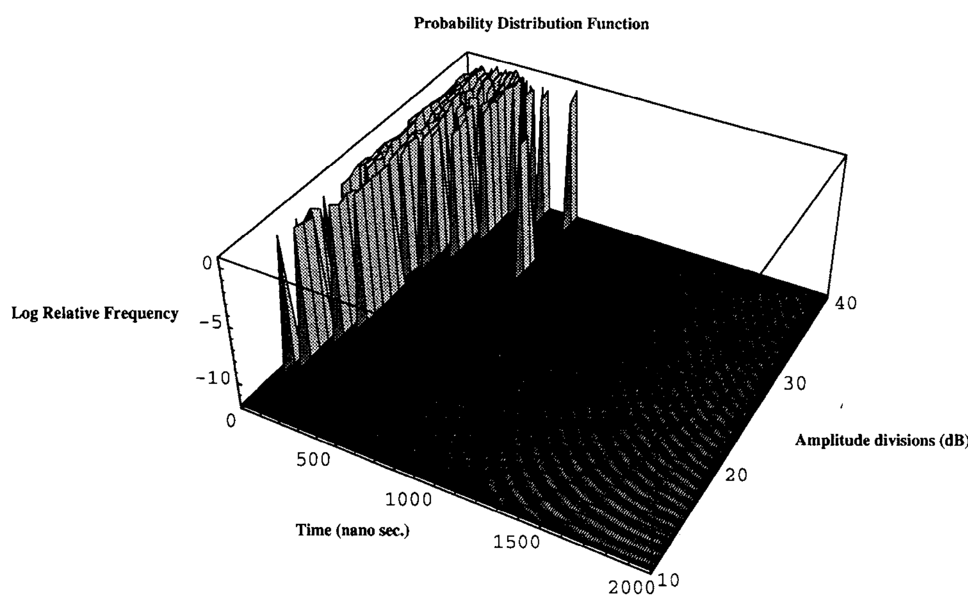


Figure L-4: Home outlet distribution of echoes (444 - 546 MHz).

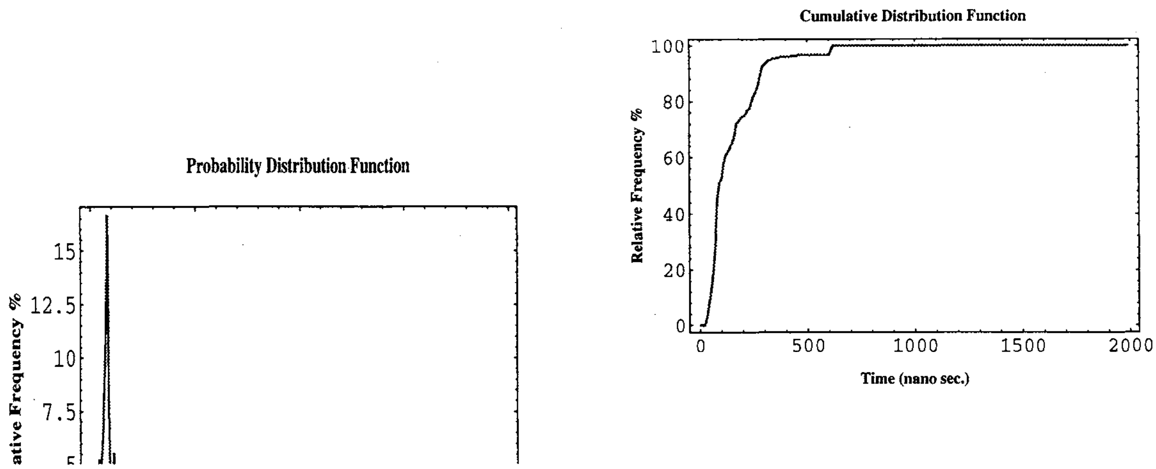


Figure L-5: Home outlet histogram of echo delays (444 - 546 MHz).

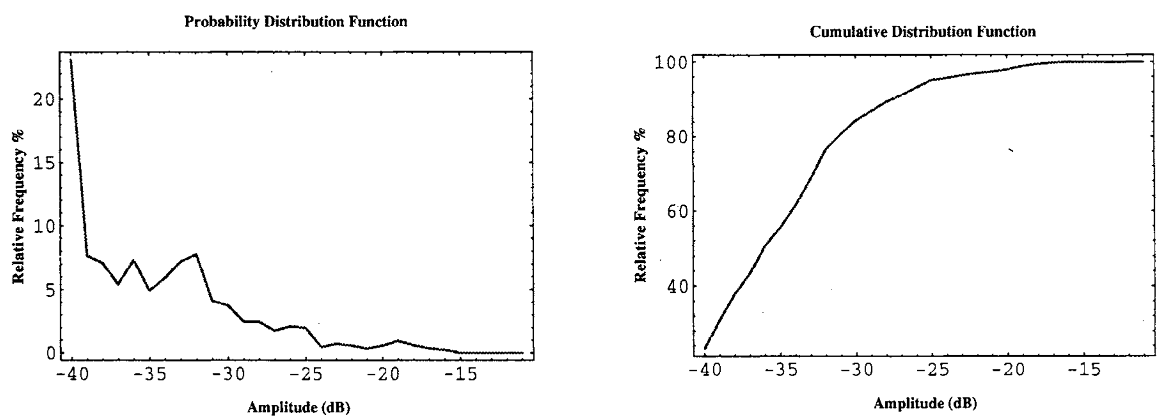


Figure L-6: Home outlet histogram of echo amplitudes (444 - 546 MHz).

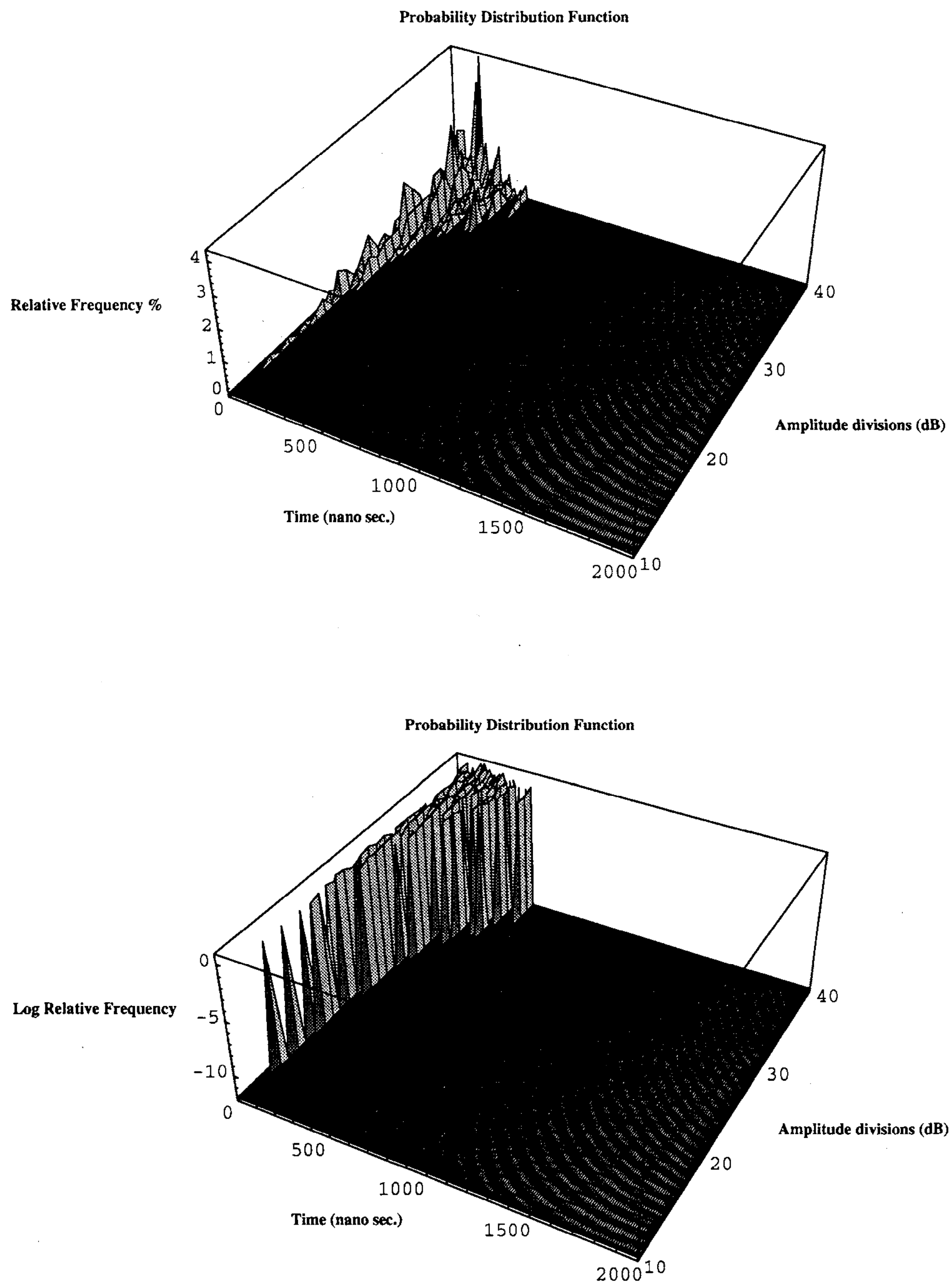


Figure L-7: Home wiring distribution of echoes (50 - 200 MHz).

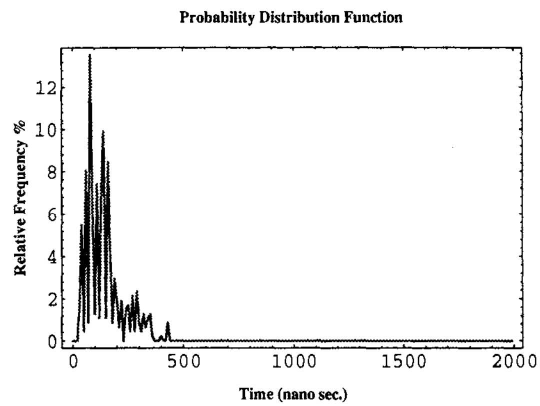


Figure L-8: Home wiring histogram of echo delays (50 - 200 MHz).

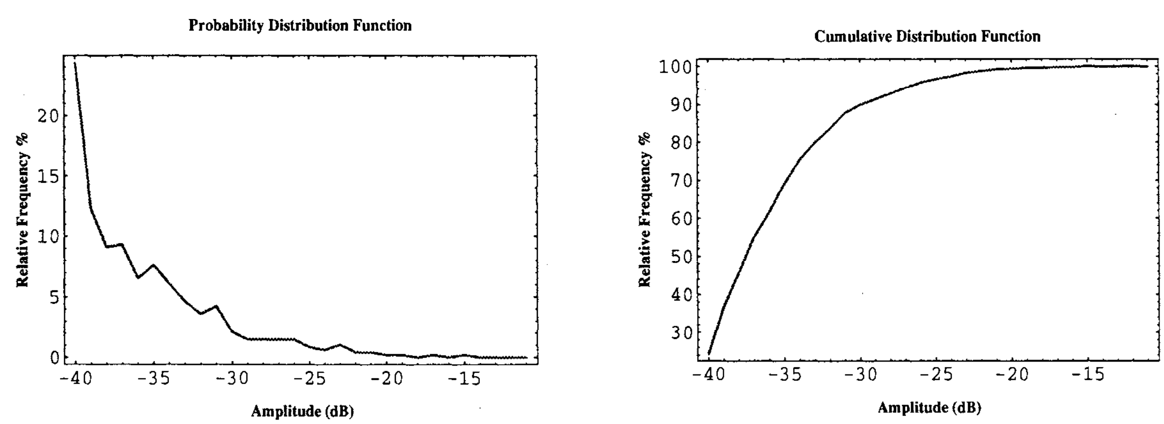
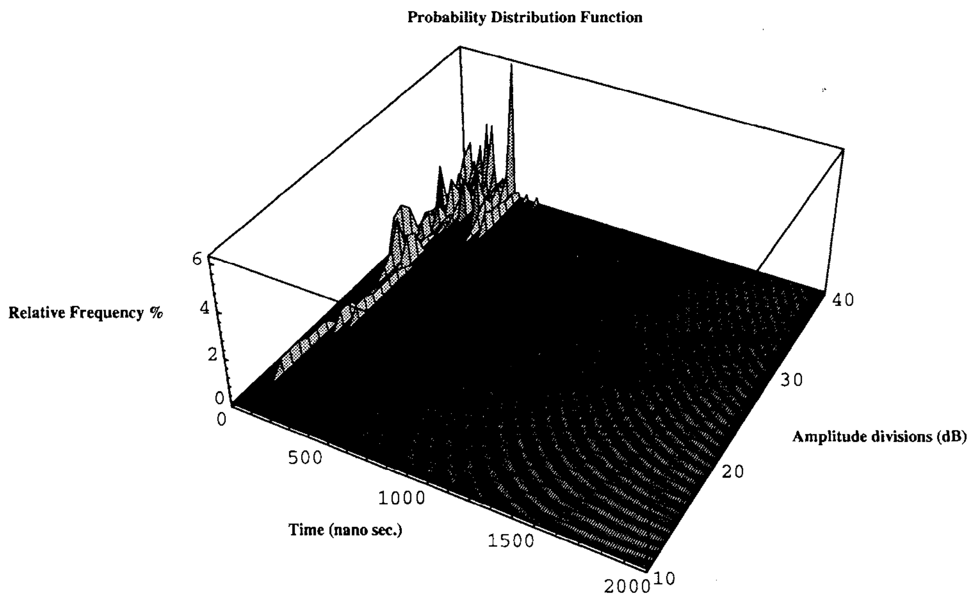


Figure L-9: Home wiring histogram of echo amplitudes (50 - 200 MHz)



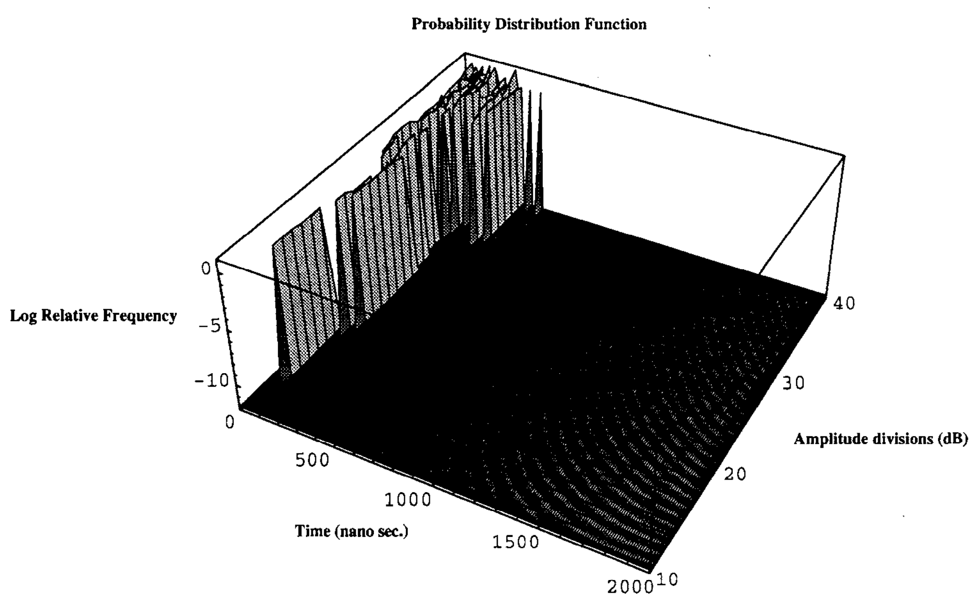


Figure L-10: Home wiring distribution of echoes (444 - 546 MHz).

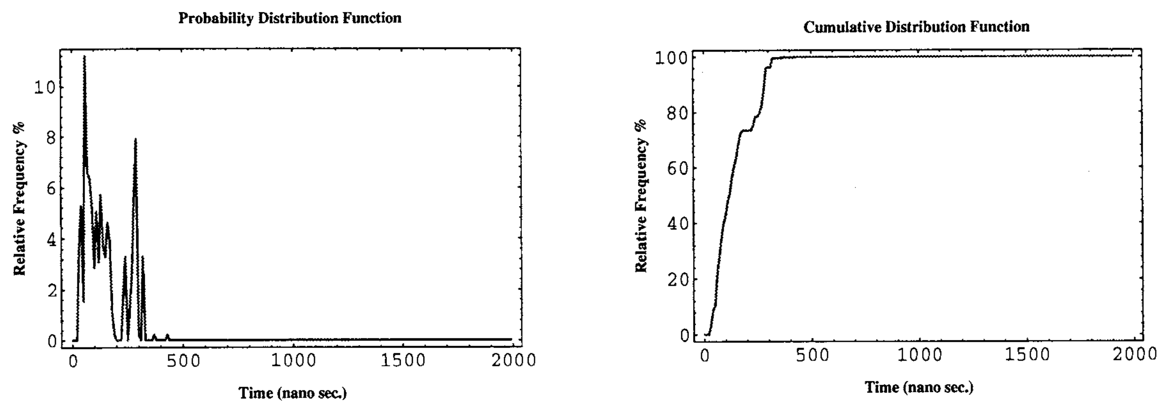


Figure L-11: Home wiring histogram of echo delays (444 - 546 MHz).

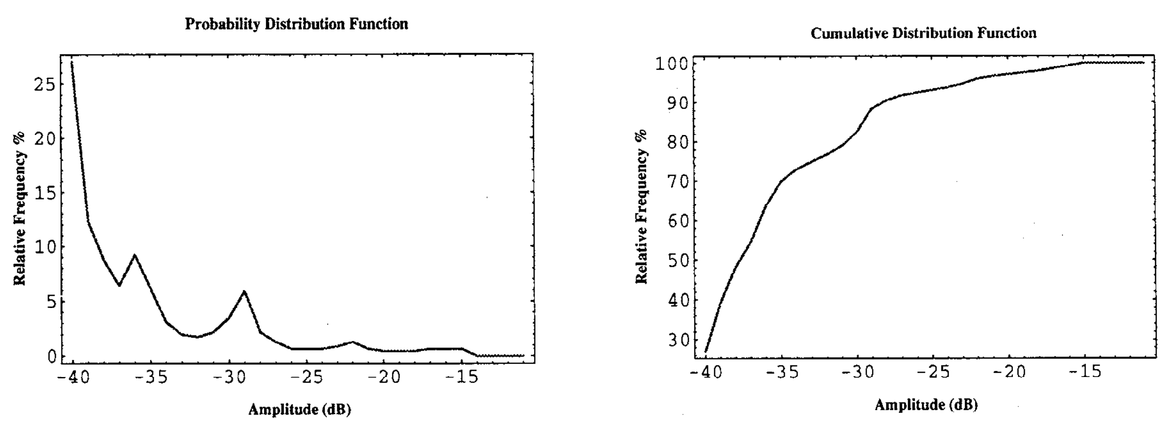


Figure L-12: Home wiring histogram of echo amplitudes (444 - 546 MHz).

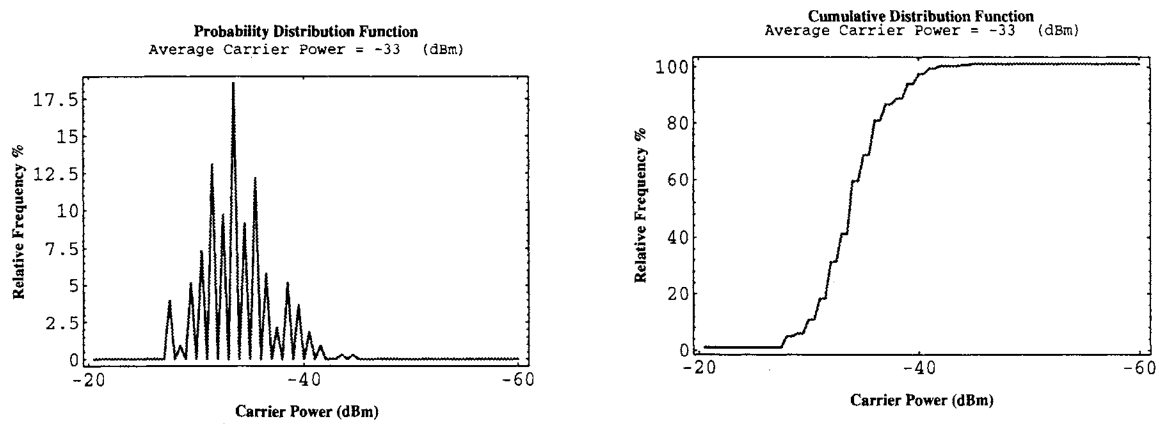


Figure L-13: Tap histogram of carrier power (444 - 546 MHz).

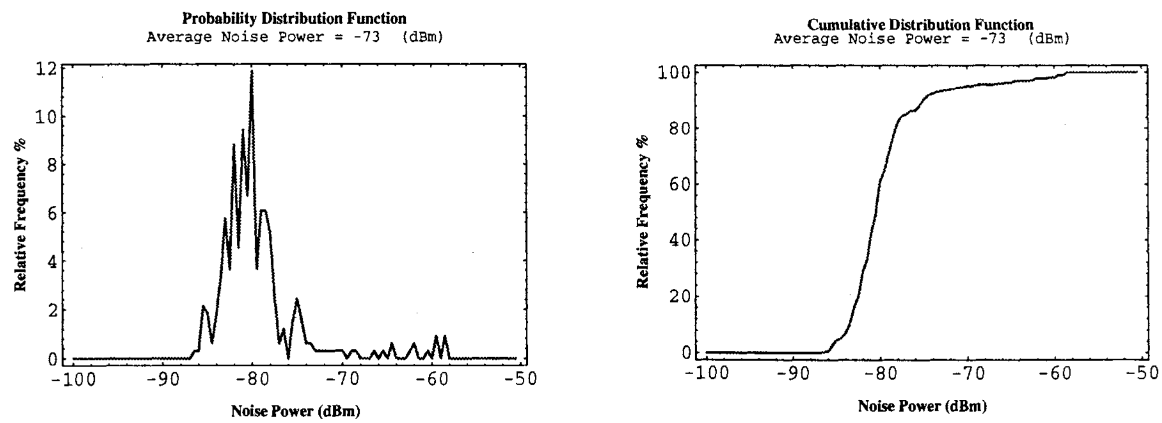


Figure L-14: Tap histogram of noise power (444 - 546 MHz).

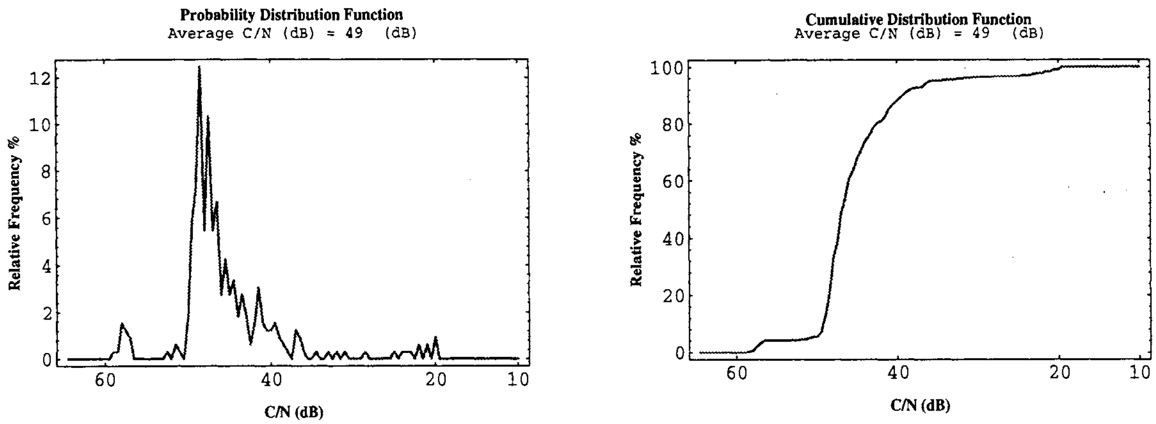


Figure L-15: Tap histogram of carrier-to-noise ratio (444 - 546 MHz).

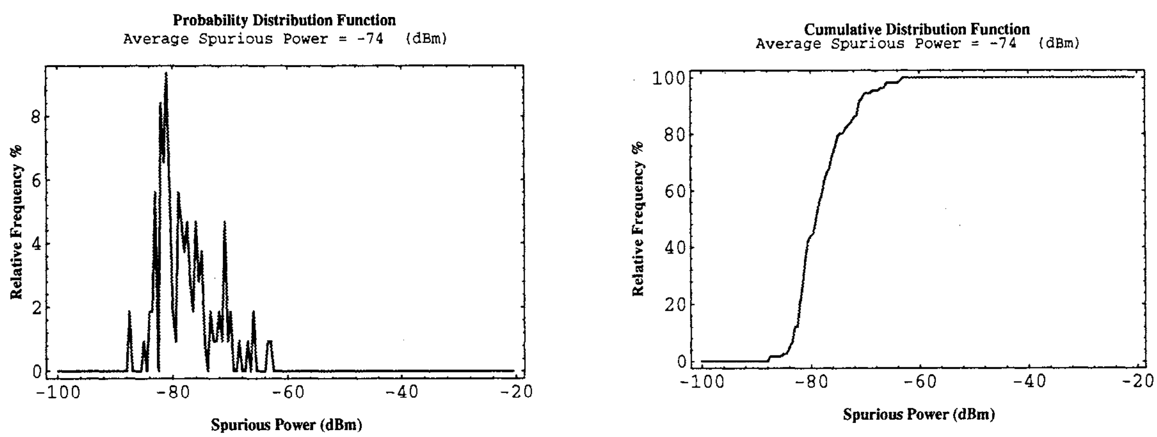


Figure L-16: Tap histogram of spurious components (444 -546 MHz).

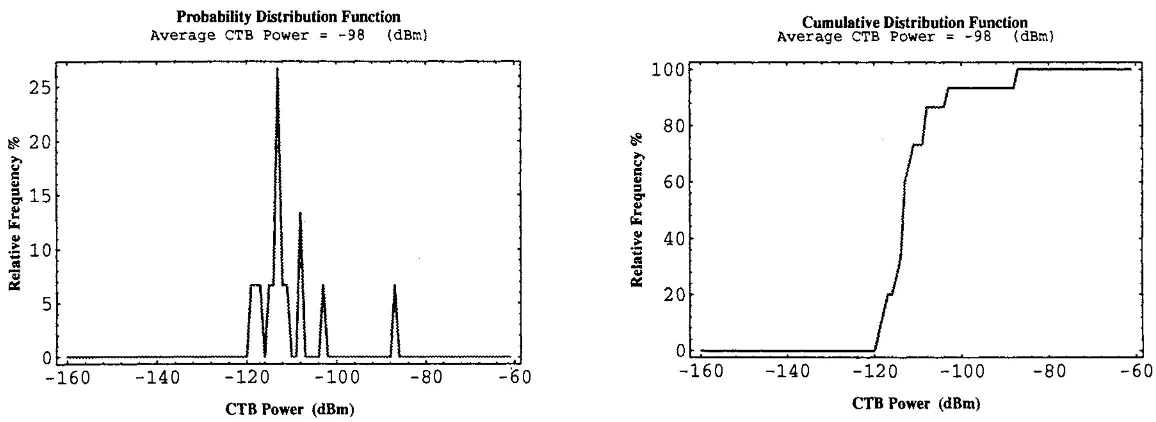


Figure L-17: Tap histogram of composite triple beats (444 - 546 MHz).

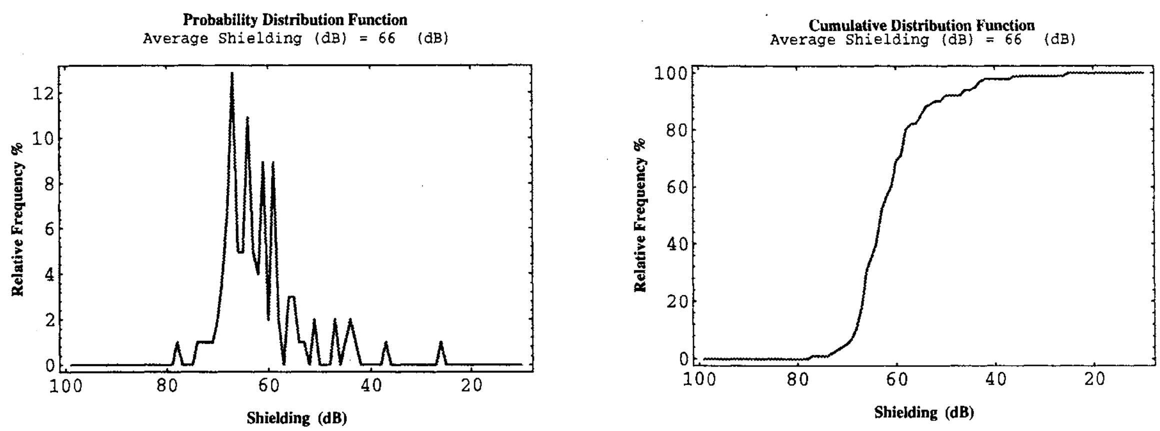


Figure L-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

APPENDIX M. RESULTS FOR CABLE SYSTEM M

Table M-1: Micro-Reflection Impairments Summary for Cable System M.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 343 - 534 MHz				
Delay (nanosecond)	100	350	510	560
Amplitude (dB)	-37	-28	-25	-18
Headend Thru Home Outlet:				
Frequency: 343 - 534 MHz				
Delay (nanosecond)	160	400	510	580
Amplitude (dB)	-36	-29	-25	-16
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	150	410	610	1280
Amplitude (dB)	-37	-28	-23	-17
Home Wiring:				
Frequency: 343 - 534 MHz				
Delay (nanosecond)	150	430	1180	1380
Amplitude (dB)	-37	-29	-27	-20

Table M-2: Noise/Interference Impairments Summary for Cable System M.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 343 - 534 MHz					
Carrier/Noise (dB)	46	42	38	37	35
Carrier Power (dBm)	-34	-40	-47	-54	-56
Noise Power (dBm) in 6 MHz Bandwidth	-80	-84	-78	-77	-72
Spurious Power (dBm) in 6 MHz Bandwidth	-73	-77	-69	-67	-64
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-72	-76	-68	-67	-63
CTB Power (dBm) 12 MHz above the last active channel	-107	-113	-100	-99	-99
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	65	58	33	27	22

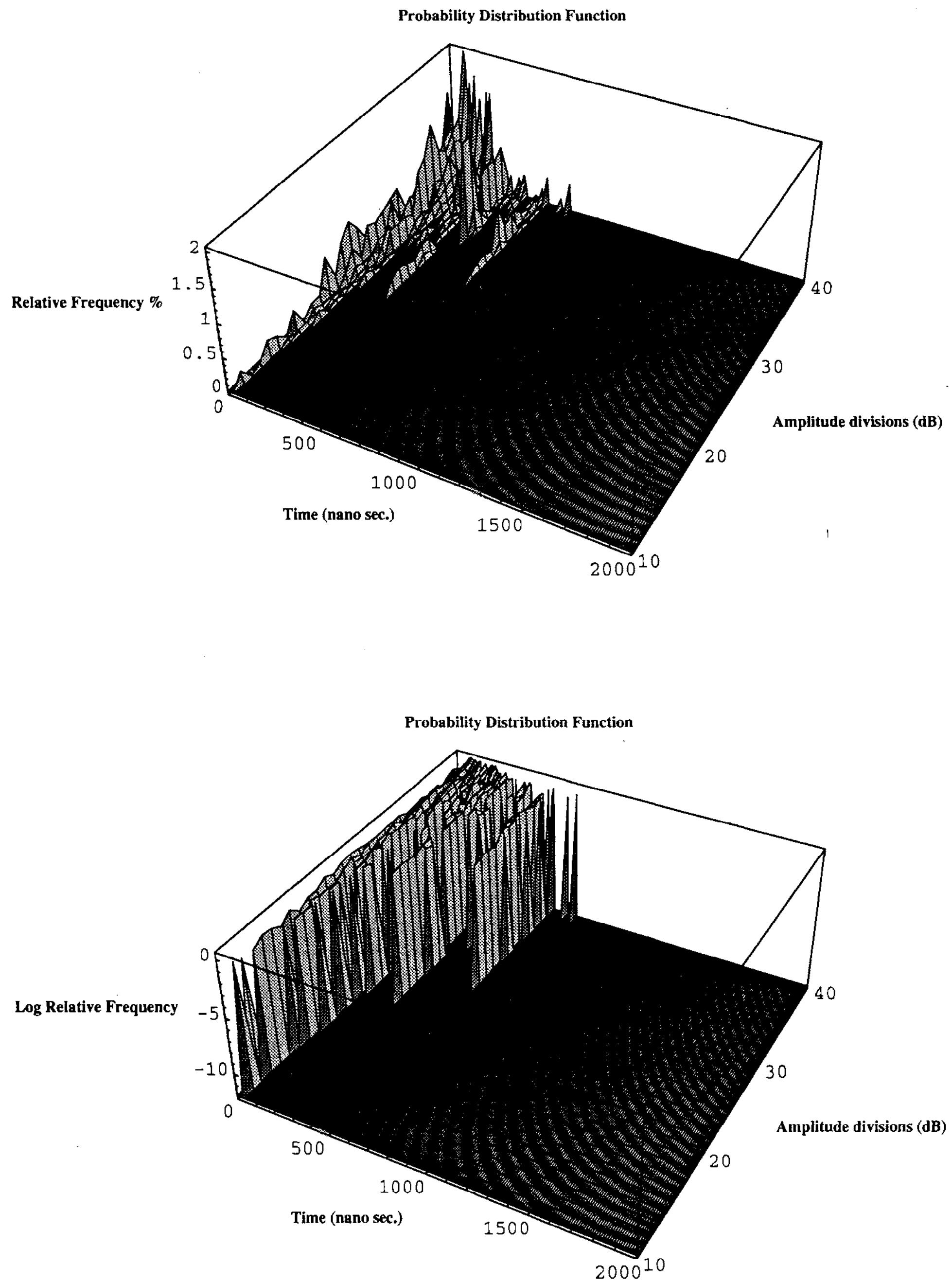


Figure M-1: Tap distribution of echoes (343 - 534 MHz).

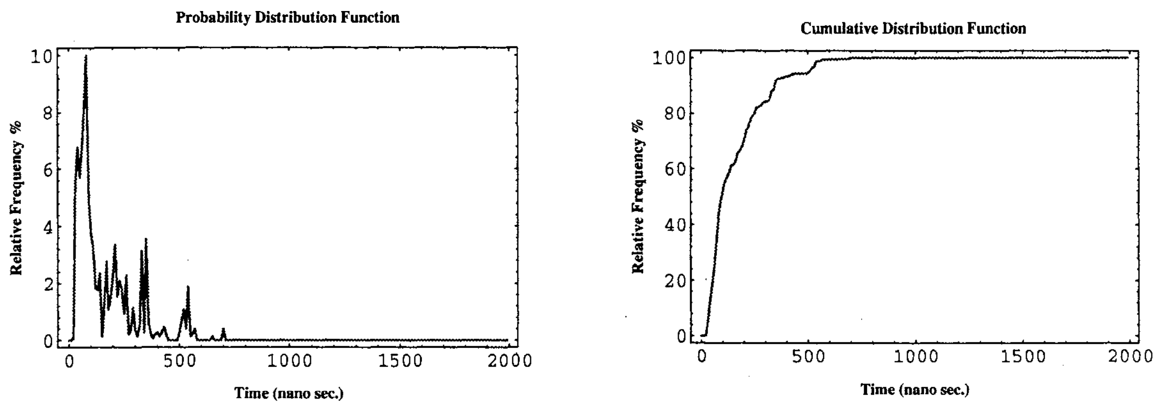


Figure M-2: Tap histogram of echo delays (343 - 534 MHz).

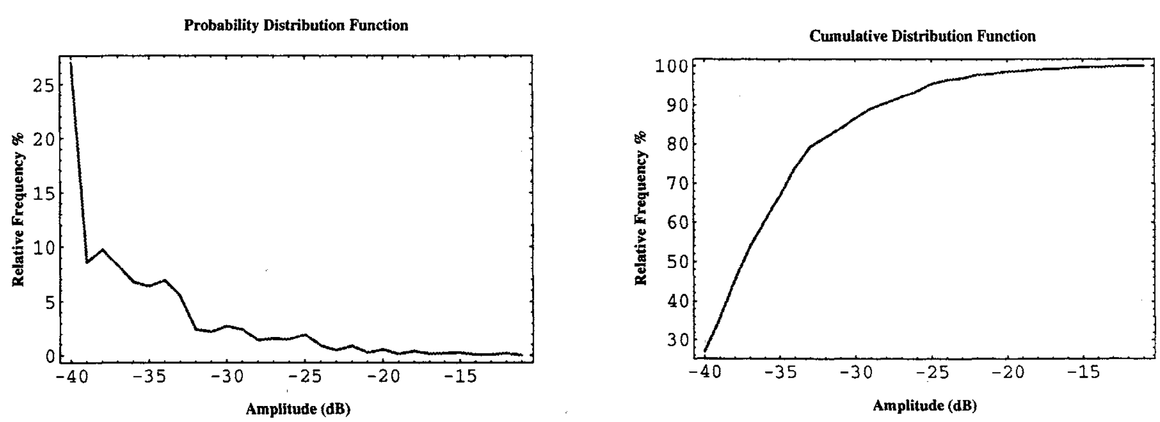
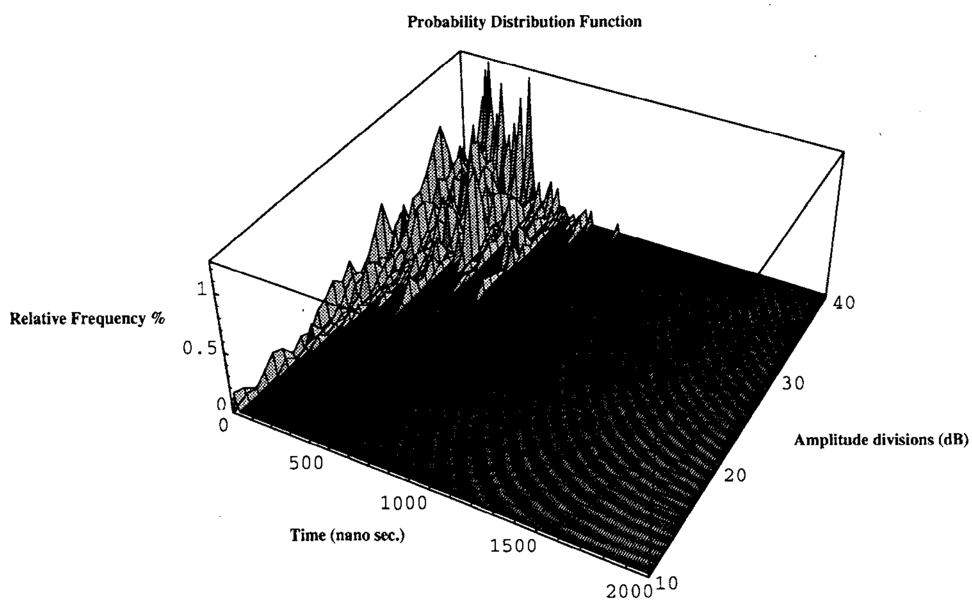


Figure M-3: Tap histogram of echo amplitudes (343 - 534 MHz).



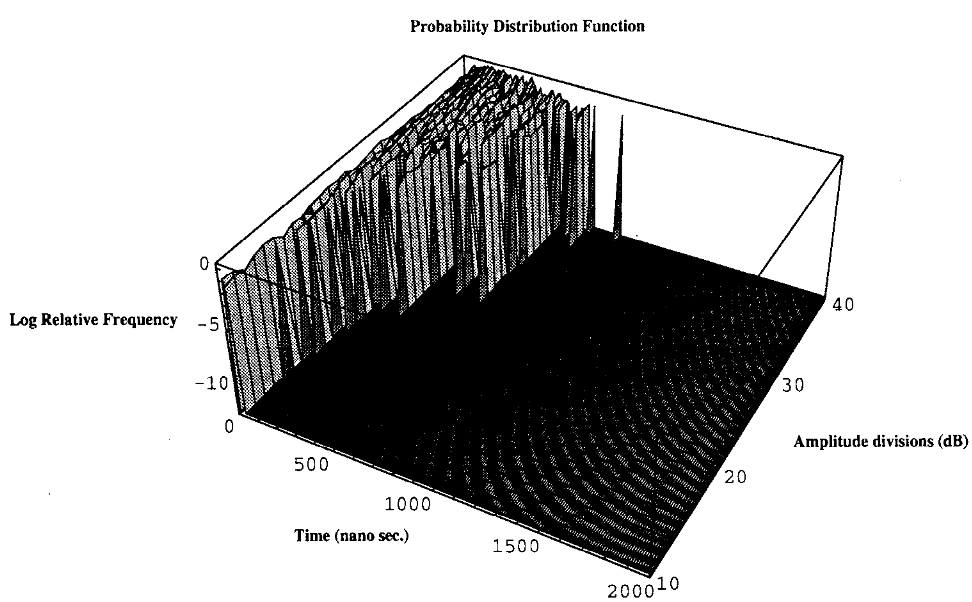


Figure M-4: Home outlet distribution of echoes (444 - 534 MHz).

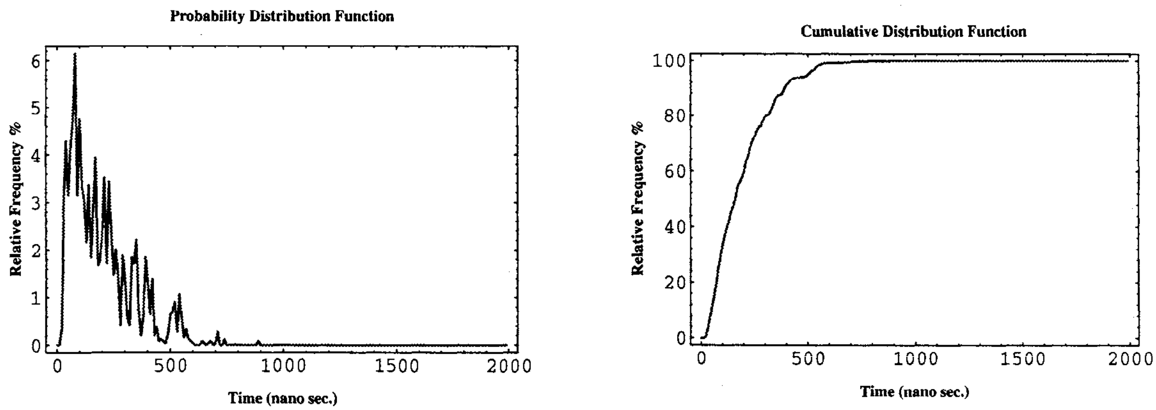


Figure M-5: Home outlet histogram of echo delays (343 - 534 MHz).

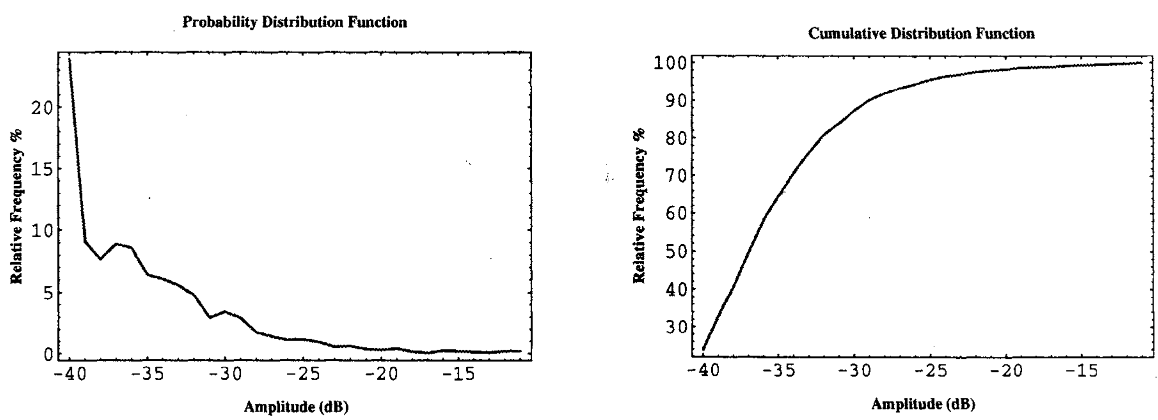


Figure M-6: Home outlet histogram of echo amplitudes (343 - 534 MHz).

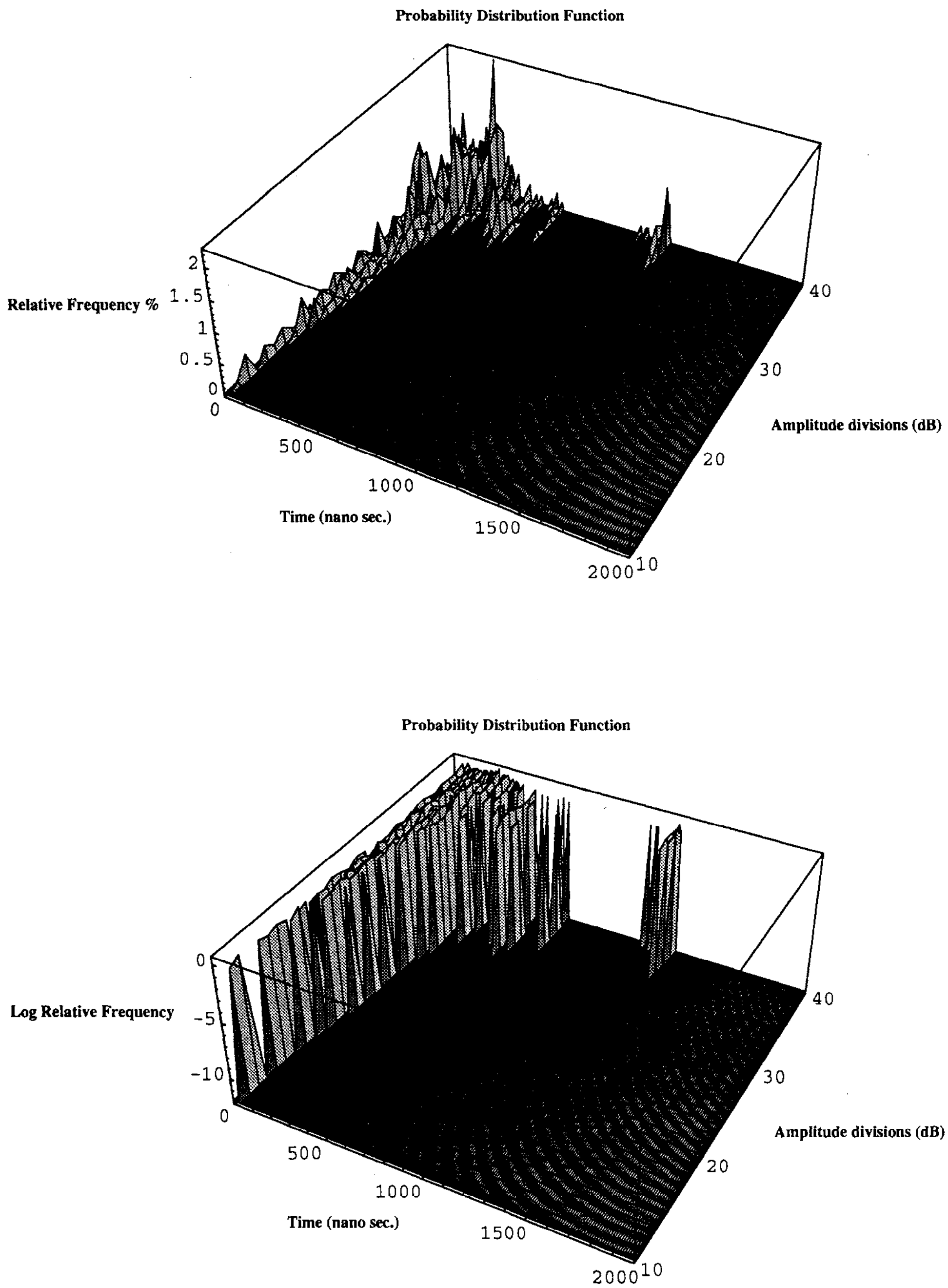


Figure M-7: Home wiring distribution of echoes (50 - 200 MHz).

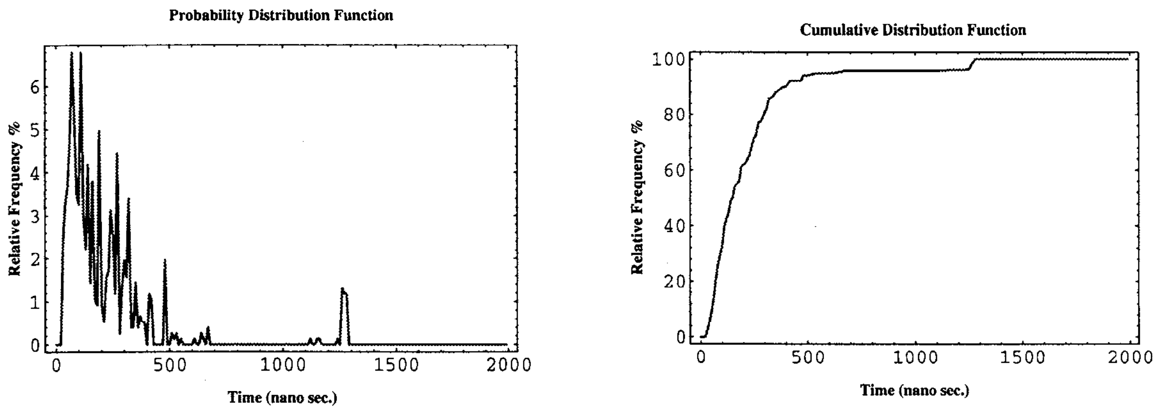


Figure M-8: Home wiring histogram of echo delays (50 - 200 MHz).

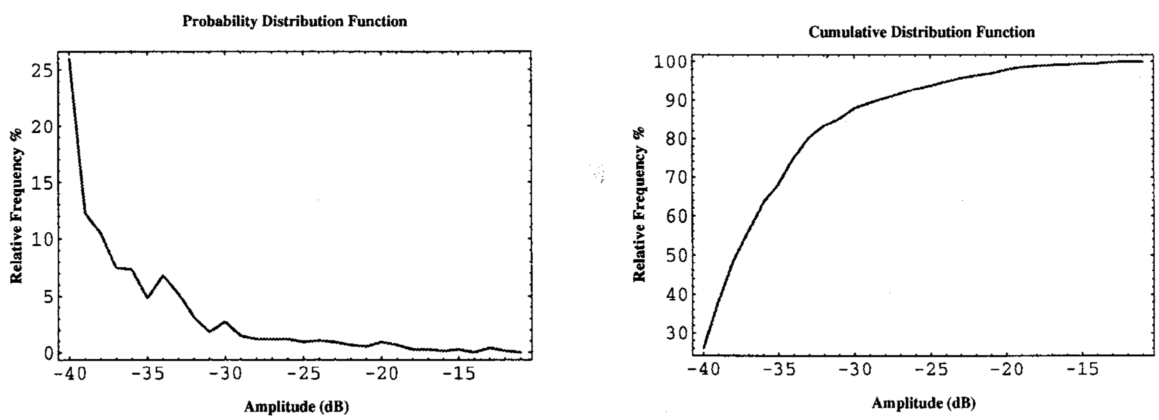
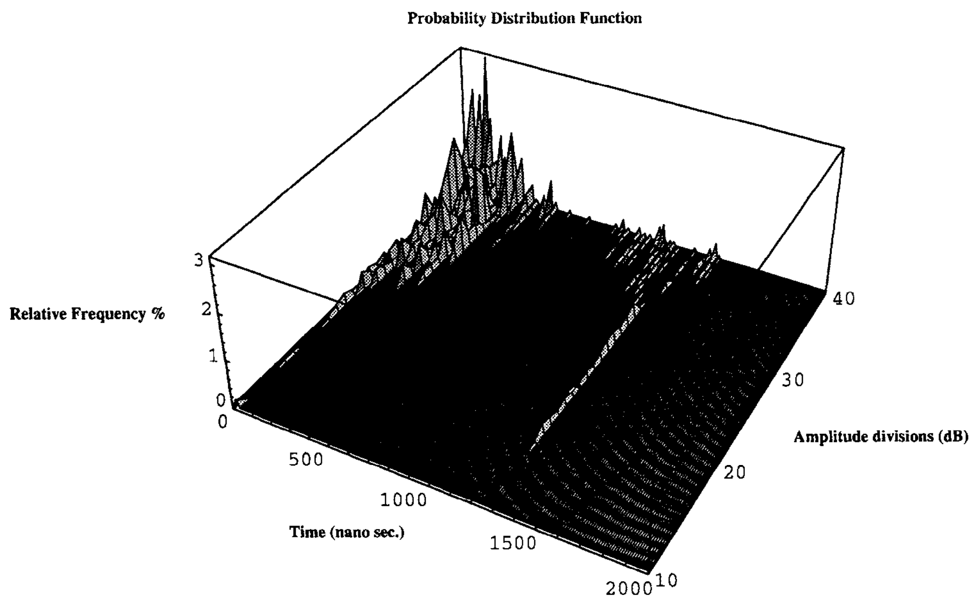


Figure M-9: Home wiring histogram of echo amplitudes (50 - 200 MHz).



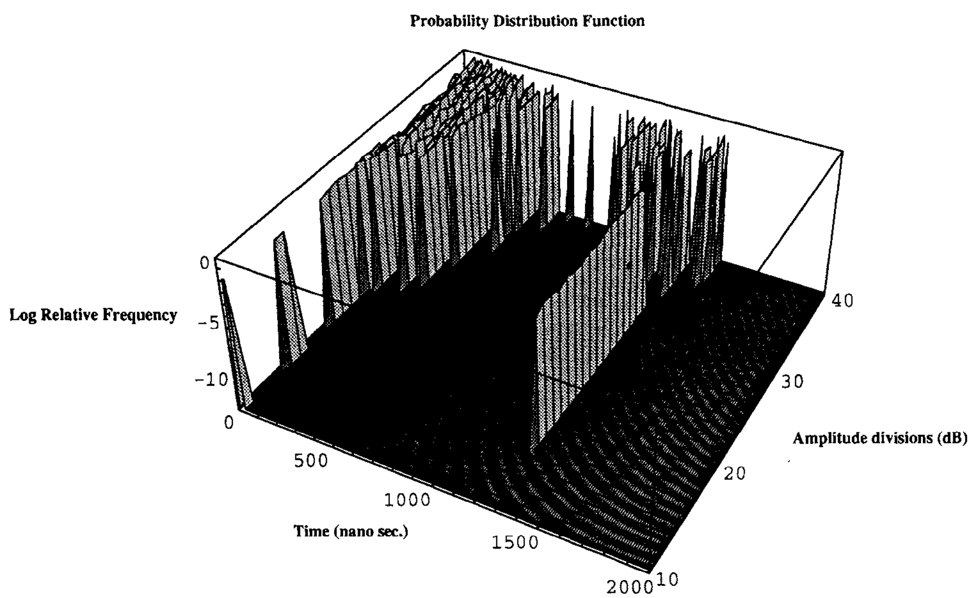


Figure M-10: Home wiring distribution of echoes (343 - 534 MHz).

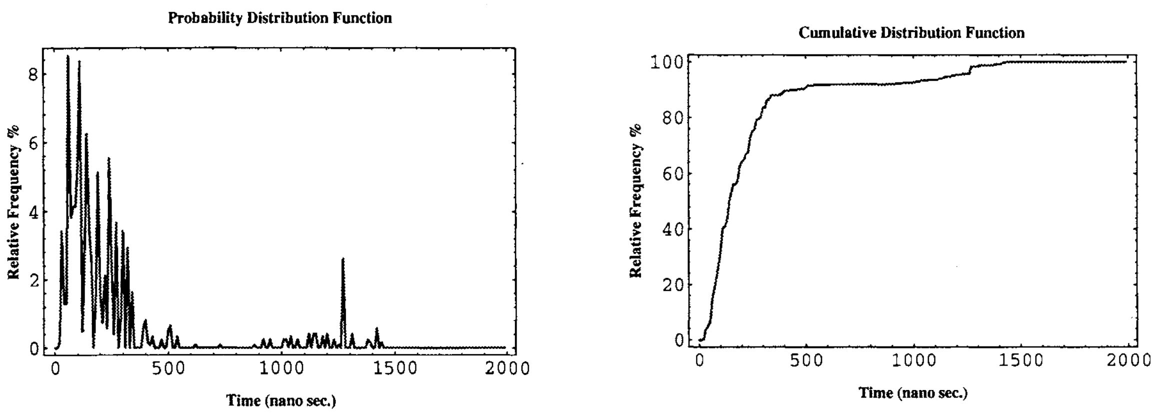


Figure M-11: Home wiring histogram of echo delays (343 - 534 MHz).

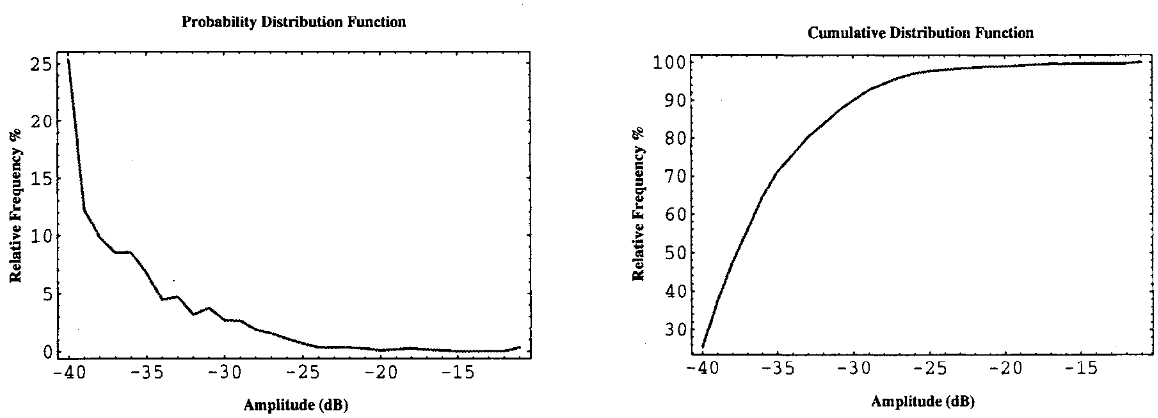


Figure M-12: Home wiring histogram of echo amplitudes (343 - 534 MHz).

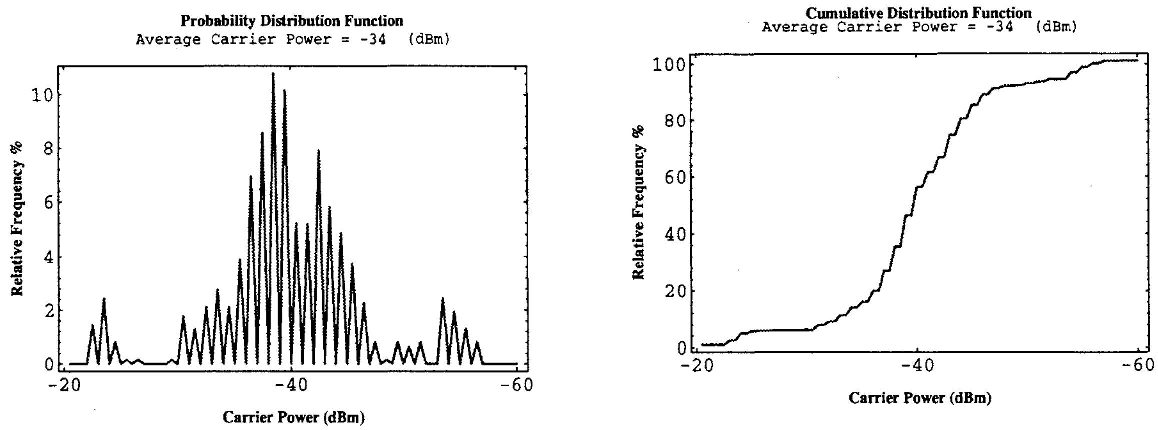


Figure M-13: Tap histogram of carrier power (343 - 534 MHz).

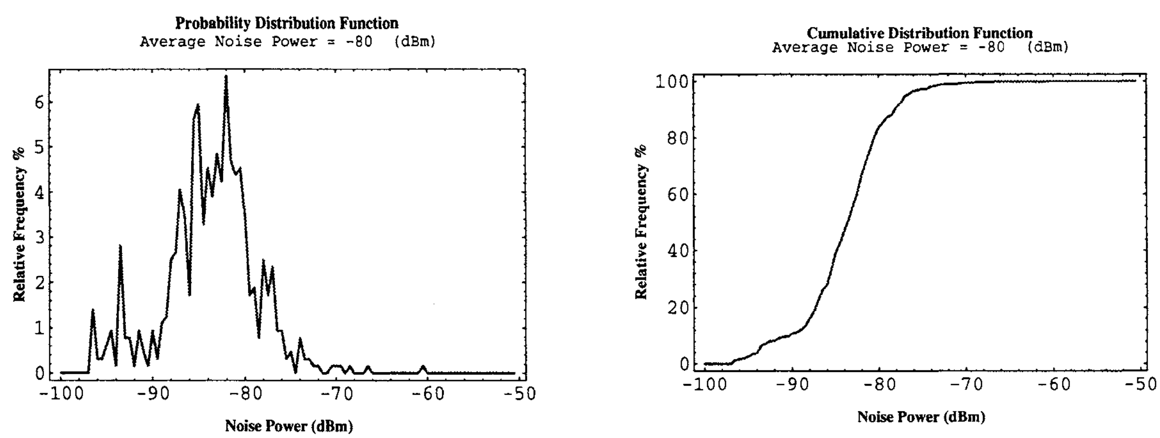


Figure M-14: Tap histogram of noise power (343 - 534 MHz).

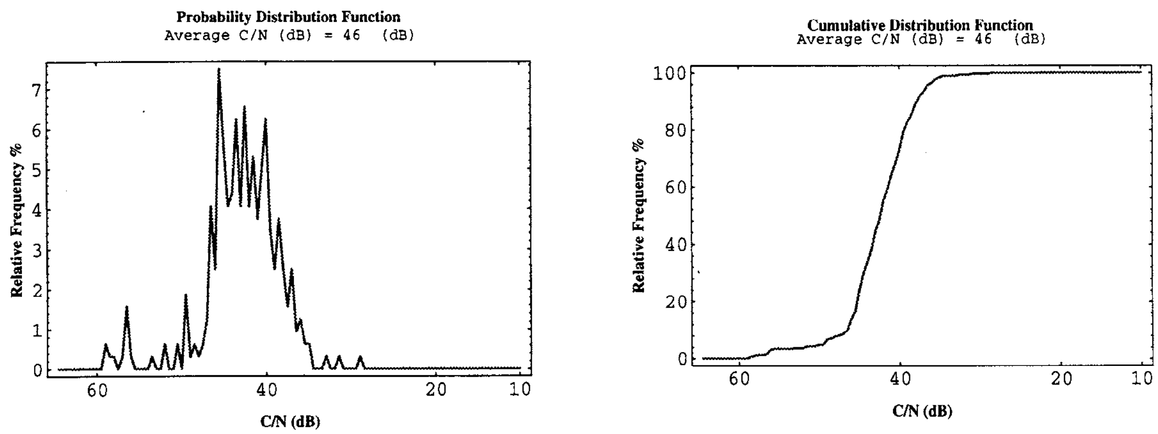


Figure M-15: Tap histogram of carrier-to-noise ratio (343 - 534 MHz).

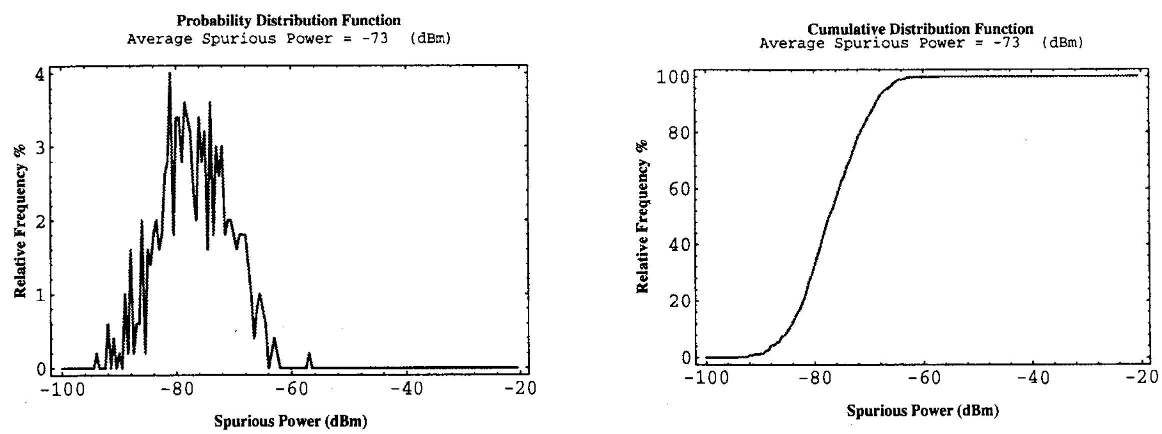


Figure M-16: Tap histogram of spurious components (343 - 534 MHz).

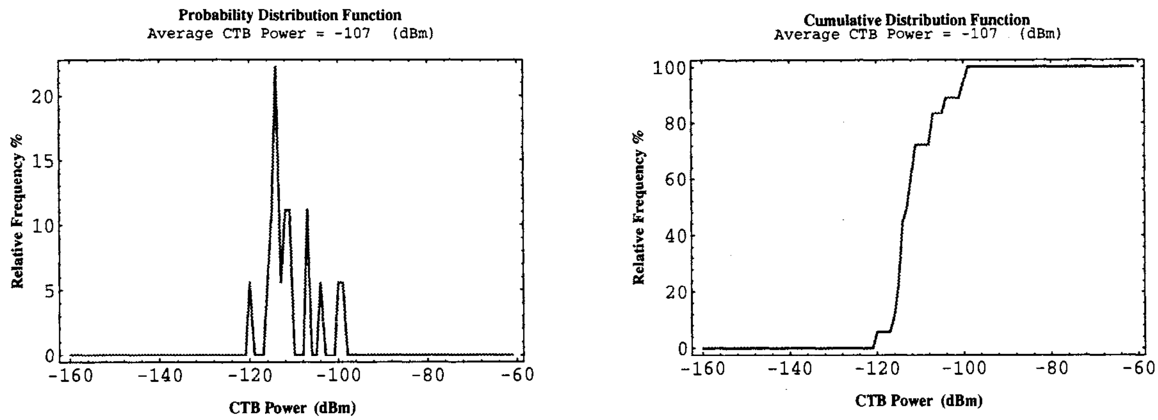


Figure M-17: Tap histogram of composite triple beats (343 - 534 MHz).

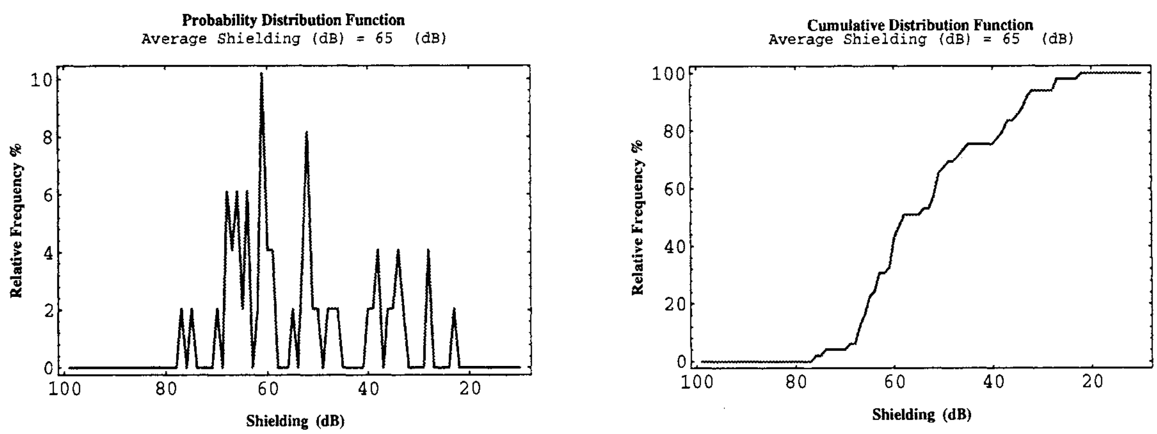


Figure M-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

APPENDIX N. RESULTS FOR CABLE SYSTEM N

Table N-1: Micro-Reflection Impairments Summary for Cable System N.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 378 - 546 MHz				
Delay (nanosecond)	280	610	690	830
Amplitude (dB)	-37	-30	-28	-26
Headend Thru Home Outlet:				
Frequency: 378 - 546 MHz				
Delay (nanosecond)	260	580	670	820
Amplitude (dB)	-37	-29	-27	-24
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	100	220	220	240
Amplitude (dB)	-40	-36	-35	-32
Home Wiring:				
Frequency: 378 - 546 MHz				
Delay (nanosecond)	90	190	220	220
Amplitude (dB)	-39	-33	-29	-25

Table N-2: Noise/Interference Impairments Summary for Cable System N.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 378 - 546 MHz					
Carrier/Noise (dB)	49	44	41	40	38
Carrier Power (dBm)	-30	-37	-42	-44	-46
Noise Power (dBm) in 6 MHz Bandwidth	-79	-83	-78	-76	-66
Spurious Power (dBm) in 6 MHz Bandwidth	-87	-87	-86	-86	-86
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-78	-82	-77	-76	-66
CTB Power (dBm) 12 MHz above the last active channel	-109	-111	-106	-106	-106
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	65	42	36	34	32

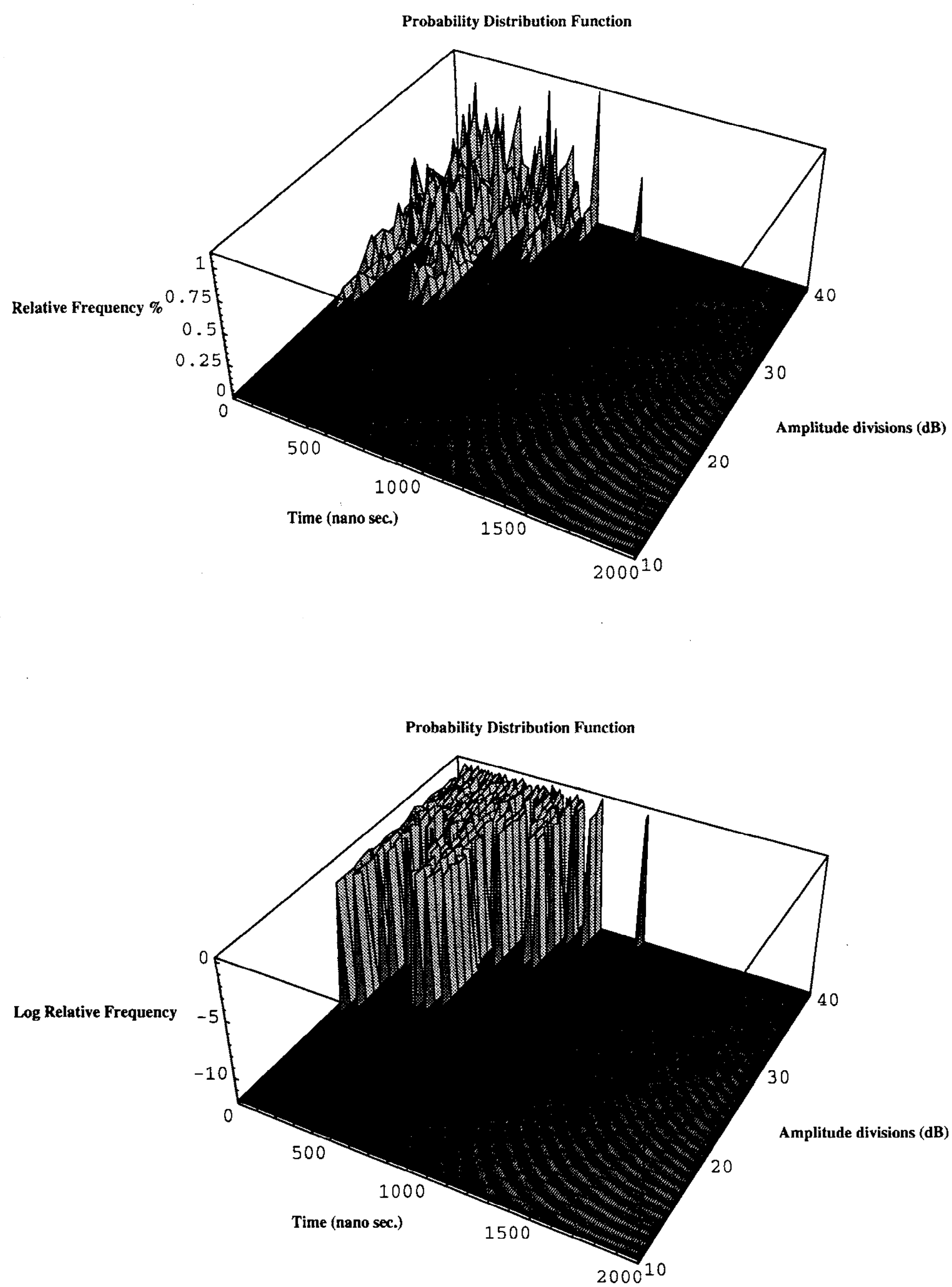


Figure N-1: Tap distribution of echoes (378 - 546 MHz).

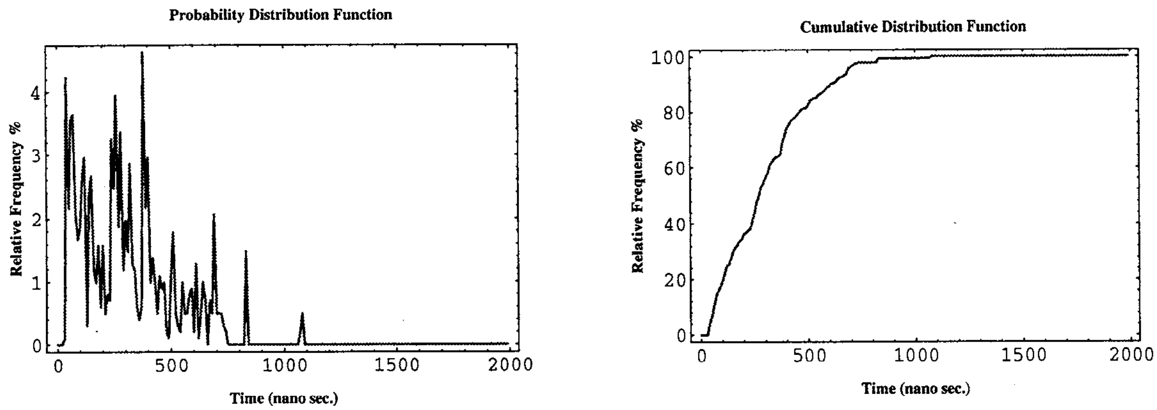


Figure N-2: Tap histogram of echo delays (378 - 546 MHz).

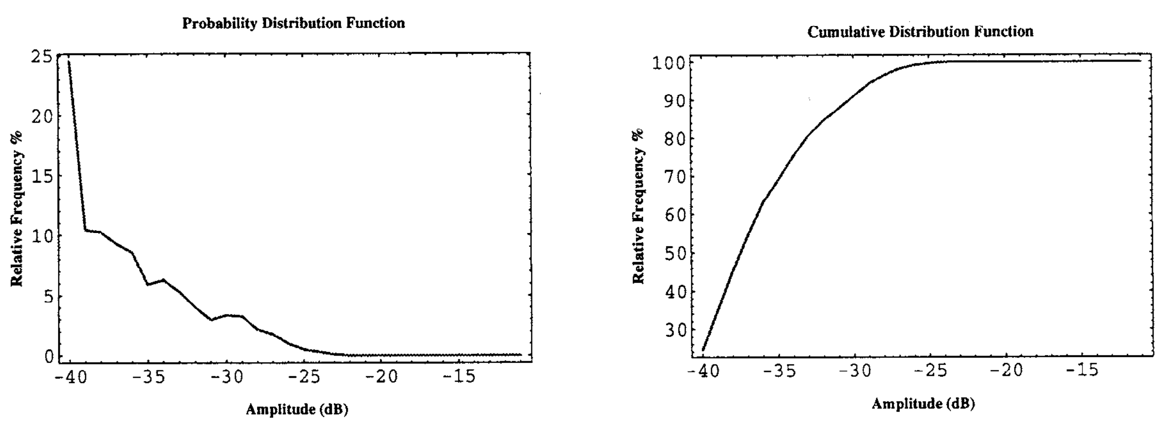
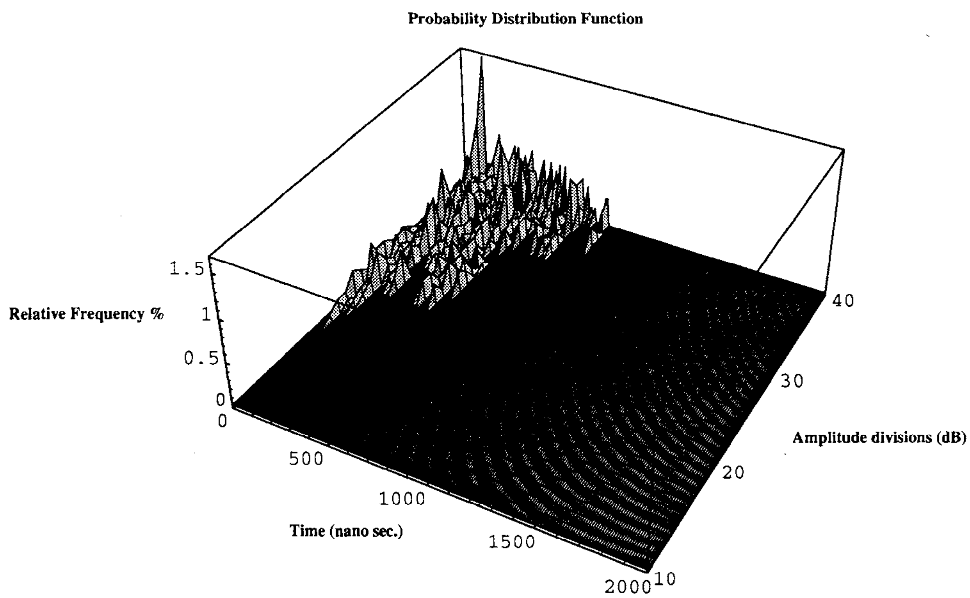


Figure N-3: Tap histogram of echo amplitudes (378 - 546 MHz).



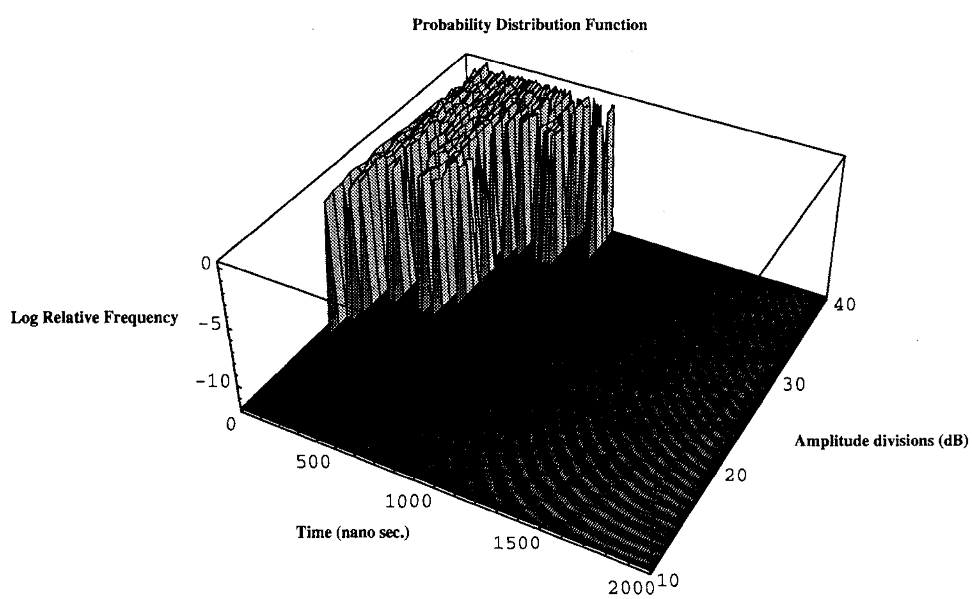


Figure N-4: Home outlet distribution of echoes (378 - 546 MHz).

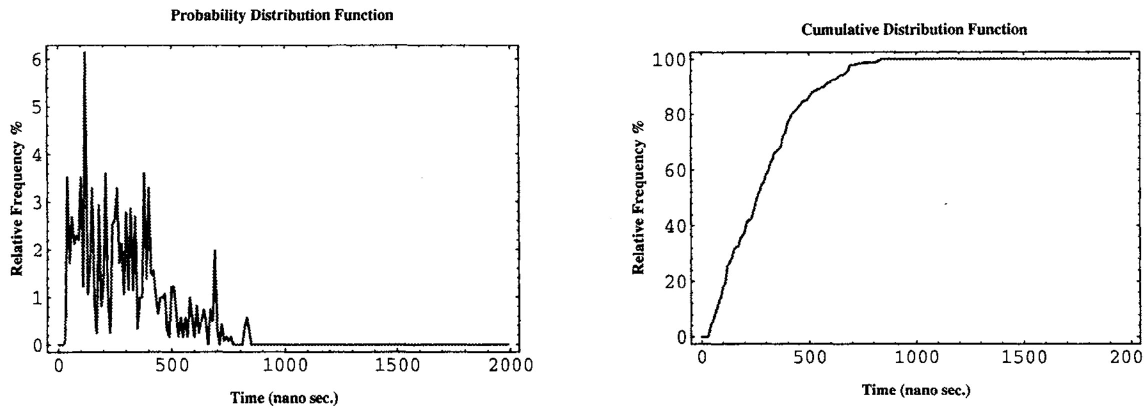


Figure N-5: Home outlet histogram of echo delays (378 - 546 MHz).

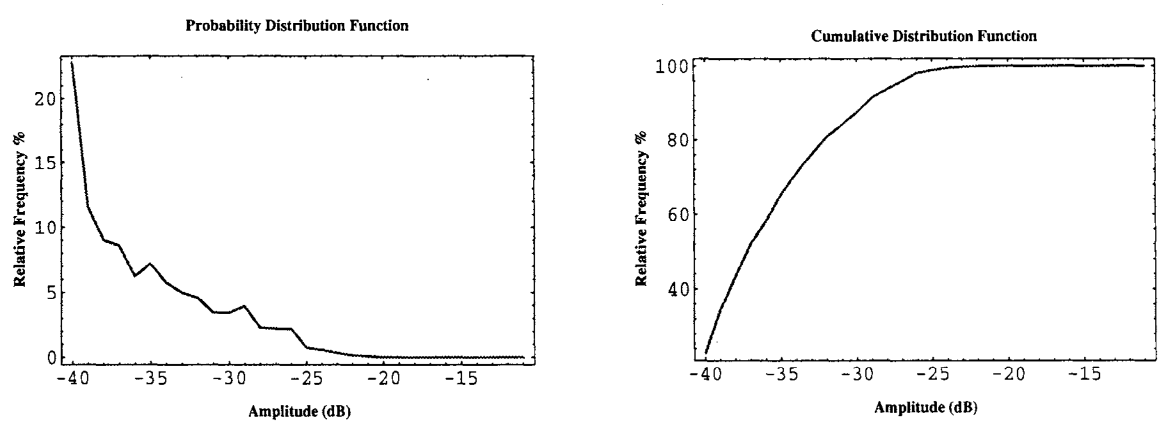
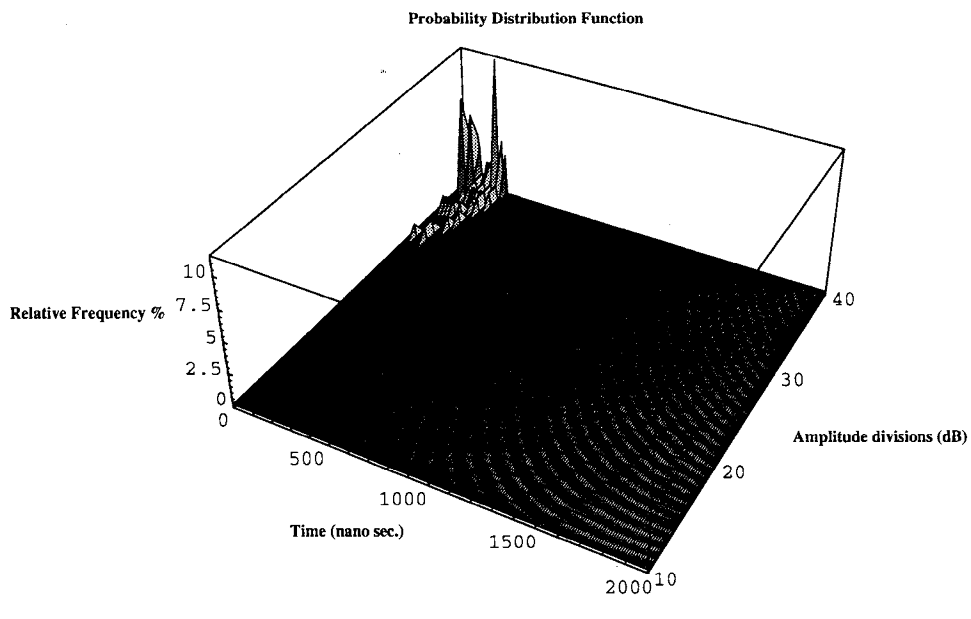


Figure N-6: Home outlet histogram of echo amplitudes (378 - 546 MHz).



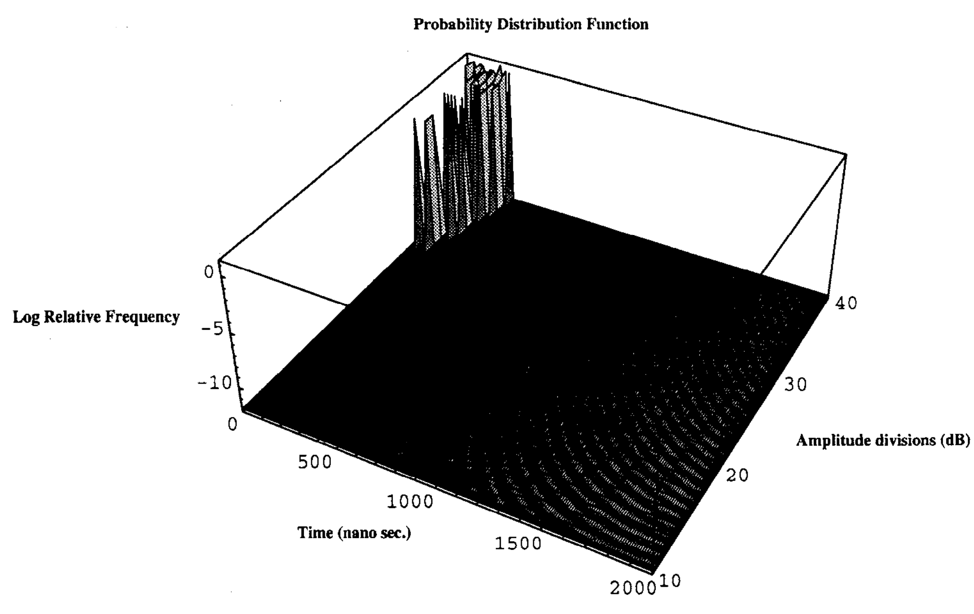


Figure N-7: Home wiring distribution of echoes (50 - 200 MHz).

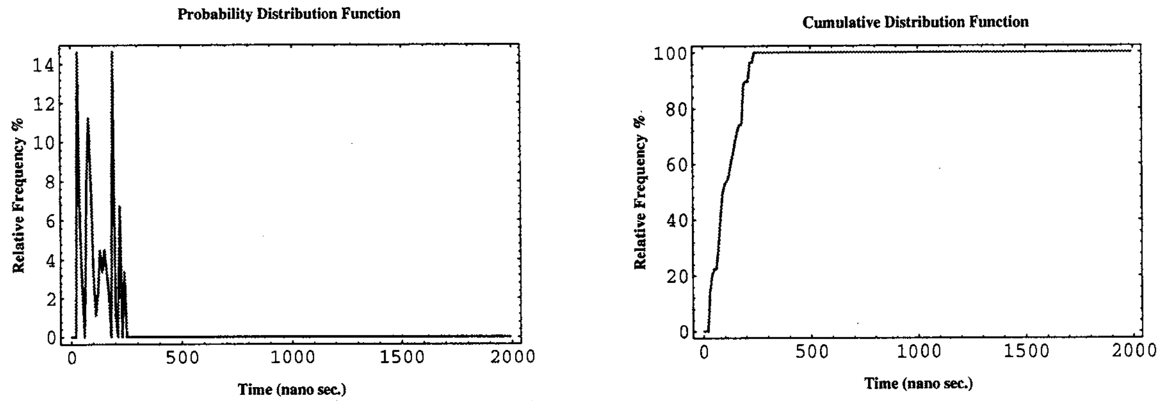


Figure N-8: Home wiring histogram of echo delays (50 - 200 MHz).

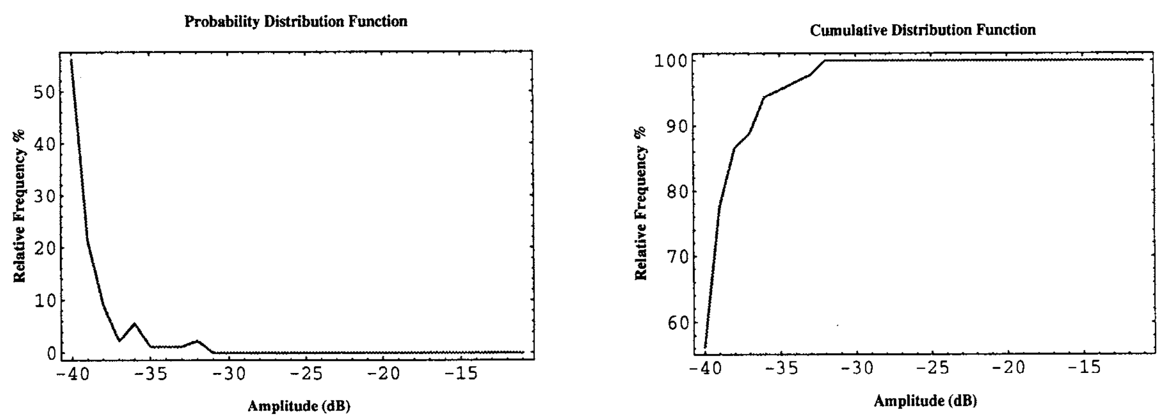


Figure N-9: Home wiring histogram of echo amplitudes (50 - 200 MHz).

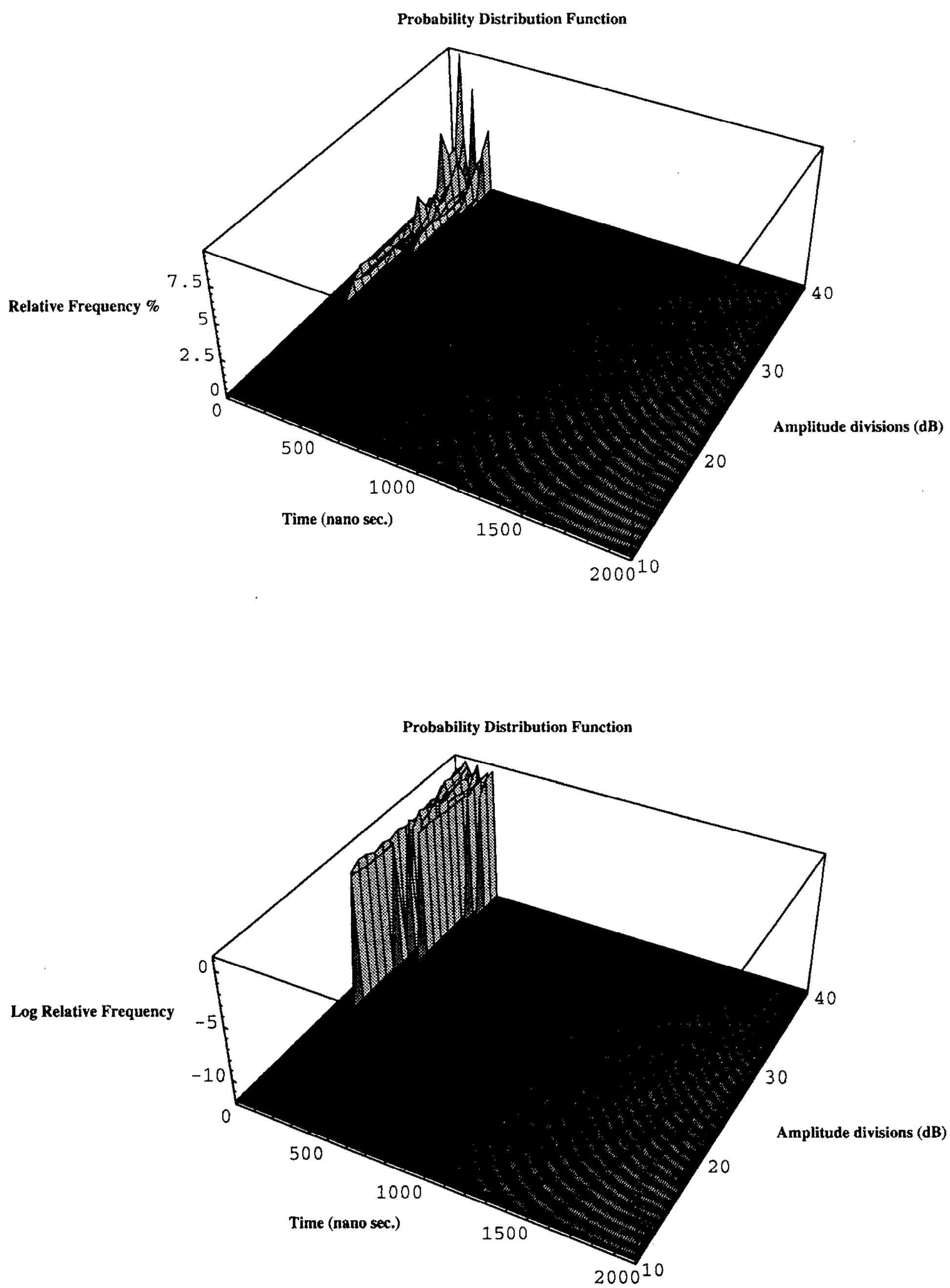


Figure N-10: Home wiring distribution of echoes (378 - 546 MHz).

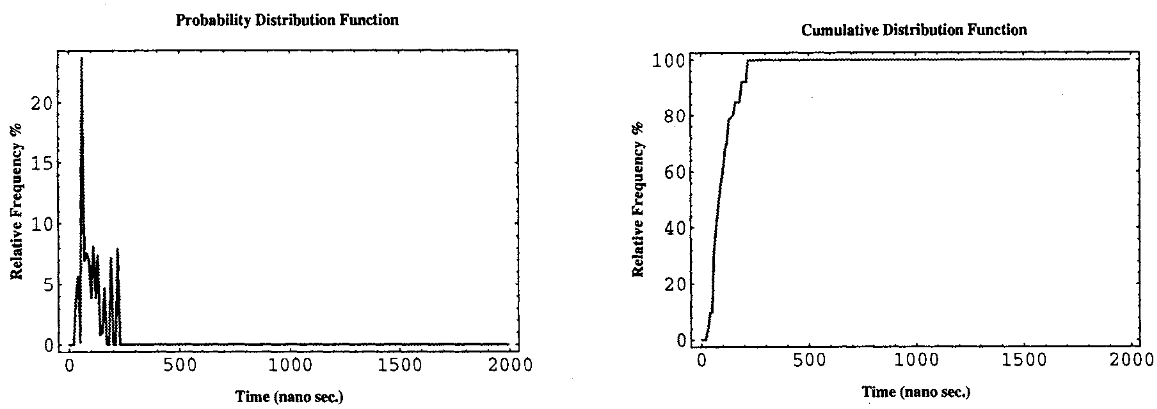


Figure N-11: Home wiring histogram of echo delays (378 - 546 MHz).

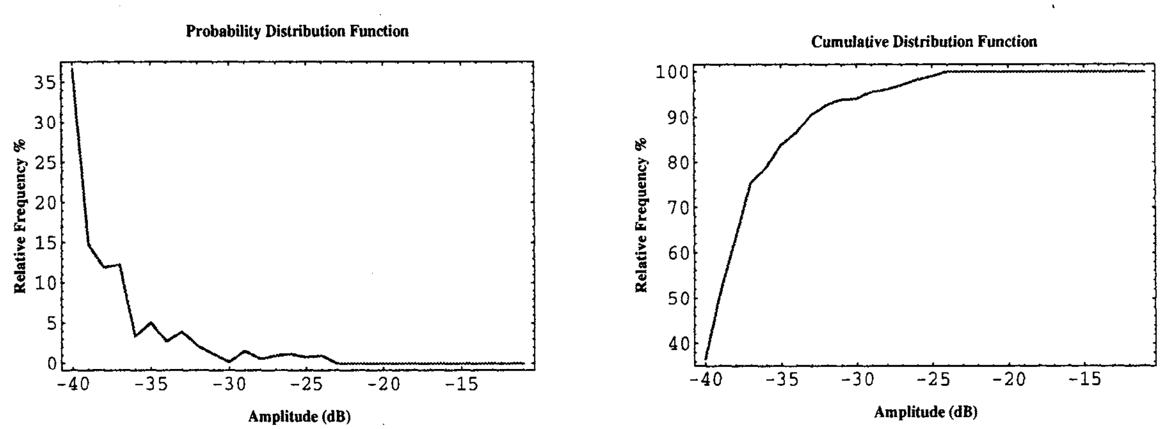


Figure N-12: Home wiring histogram of echo amplitudes (378 - 546 MHz).

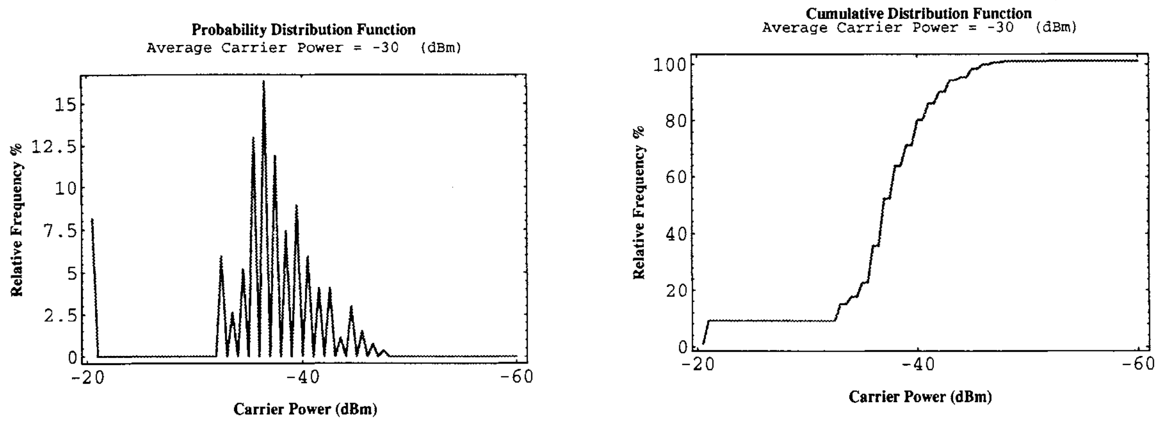


Figure N-13: Tap histogram of carrier power (378 - 546 MHz).

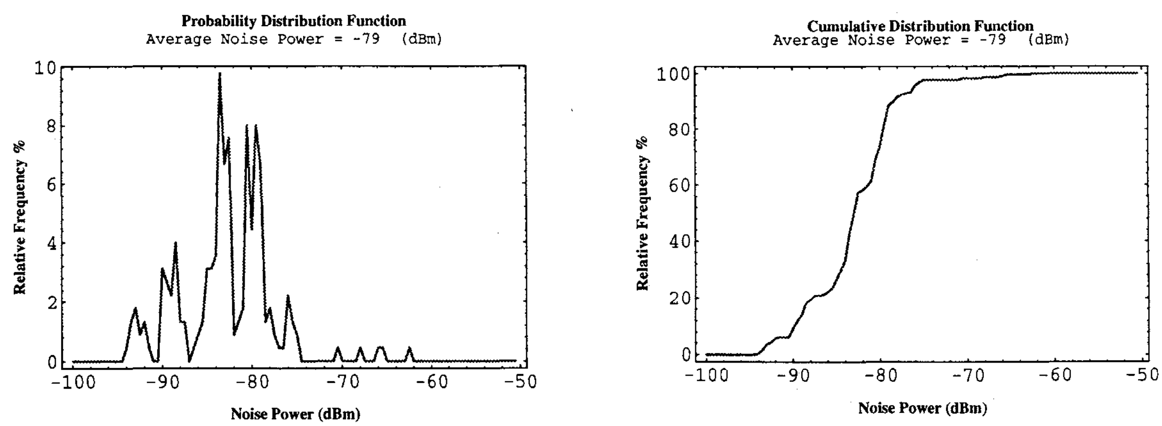


Figure N-14: Tap histogram of noise power (378 - 546 MHz).

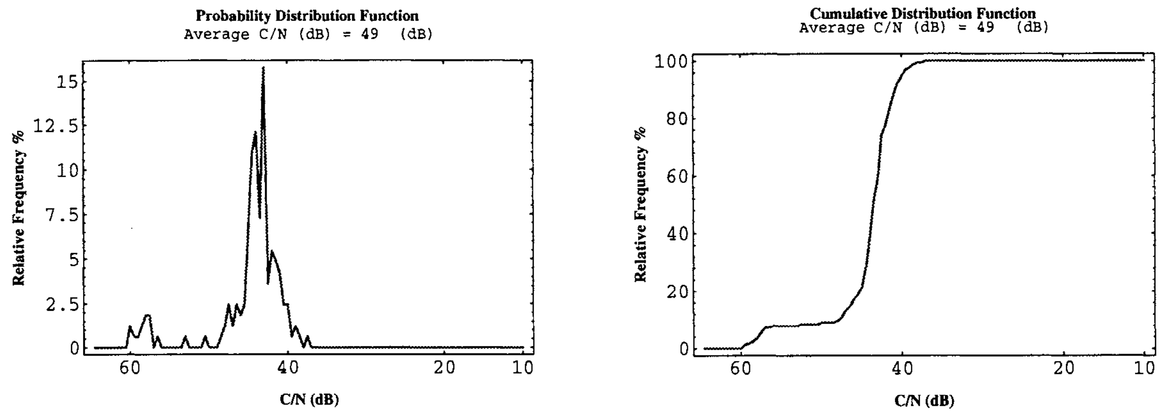


Figure N-15: Tap histogram of carrier-to-noise ratio (378 - 546 MHz).

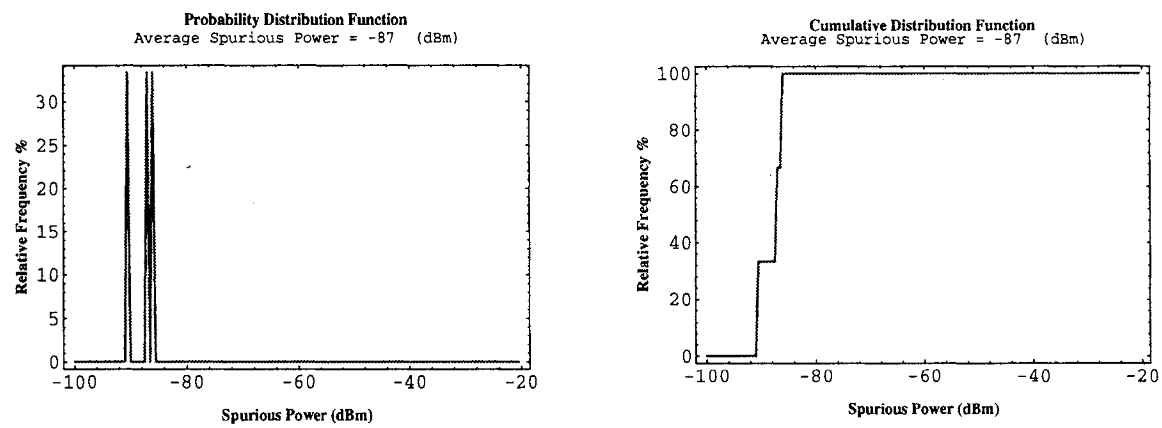


Figure N-16: Tap histogram of spurious components (378 - 546 MHz).

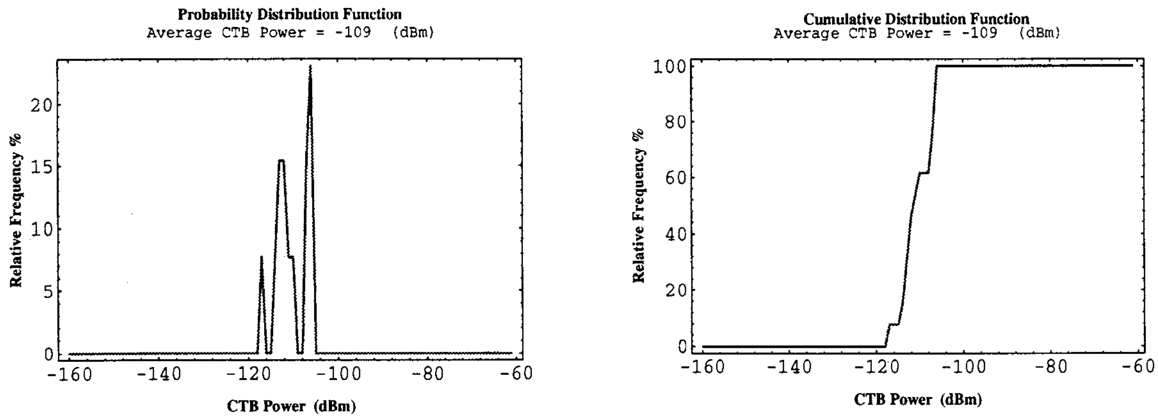


Figure N-17: Tap histogram of composite triple beats (378 - 546 MHz).

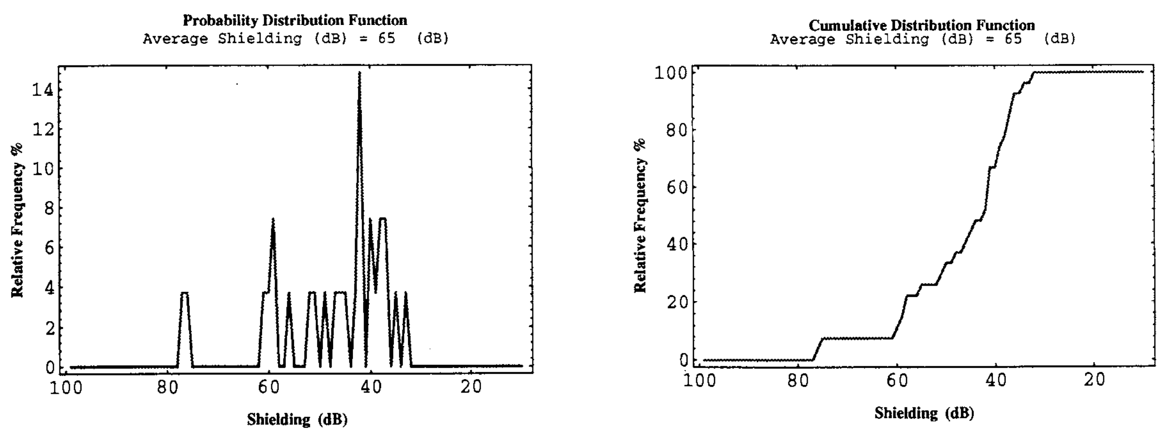


Figure N-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

APPENDIX Q. RESULTS FOR CABLE SYSTEM Q

Table Q-1: Micro-Reflection Impairments Summary for Cable System Q.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 324 - 384 MHz				
Delay (nanosecond)	230	480	590	640
Amplitude (dB)	-39	-29	-27	-24
Headend Thru Home Outlet:				
Frequency: 324 - 384 MHz				
Delay (nanosecond)	240	480	530	640
Amplitude (dB)	-37	-29	-27	-24
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	160	390	420	640
Amplitude (dB)	-36	-25	-22	-17
Home Wiring:				
Frequency: 324 - 384 MHz				
Delay (nanosecond)	120	320	350	400
Amplitude (dB)	-35	-28	-26	-22

Table Q-2: Noise/Interference Impairments Summary for Cable System Q.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 324 - 384 MHz					
Carrier/Noise (dB)	54	45	42	41	32
Carrier Power (dBm)	-35	-39	-45	-46	-48
Noise Power (dBm) in 6 MHz Bandwidth	-82	-86	-80	-75	-72
Spurious Power (dBm) in 6 MHz Bandwidth	-82	-83	-78	-78	-78
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-79	-81	-76	-73	-71
CTB Power (dBm) 12 MHz above the last active channel	-95	-101	-95	-88	-85
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	64	55	47	44	33

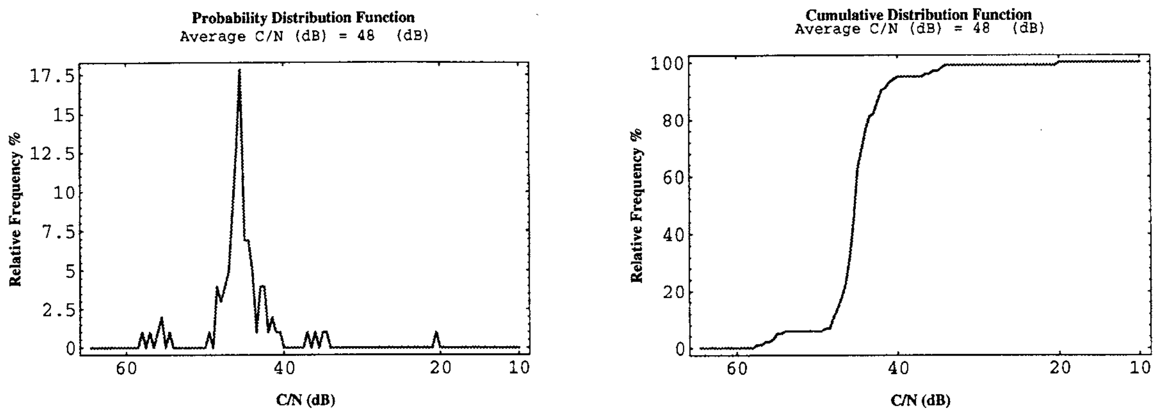


Figure P-15: Tap histogram of carrier-to-noise ratio (456 - 546 MHz).

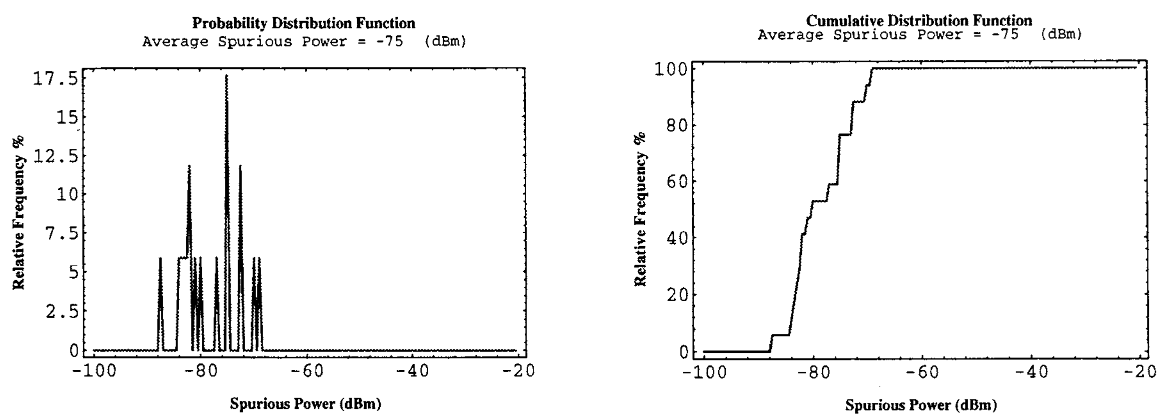


Figure P-16: Tap histogram of spurious components (456 - 546 MHz).

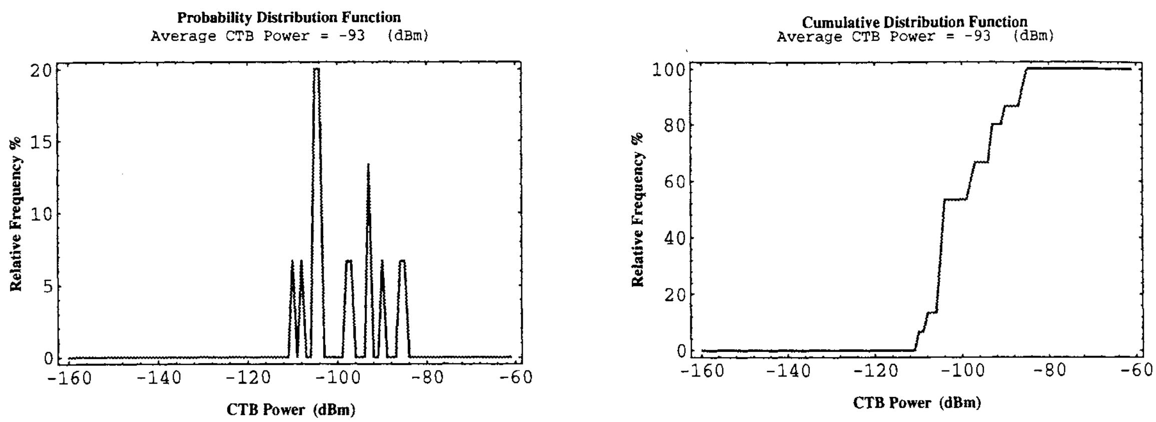


Figure P-17: Tap histogram of composite triple beats (456 - 546 MHz).

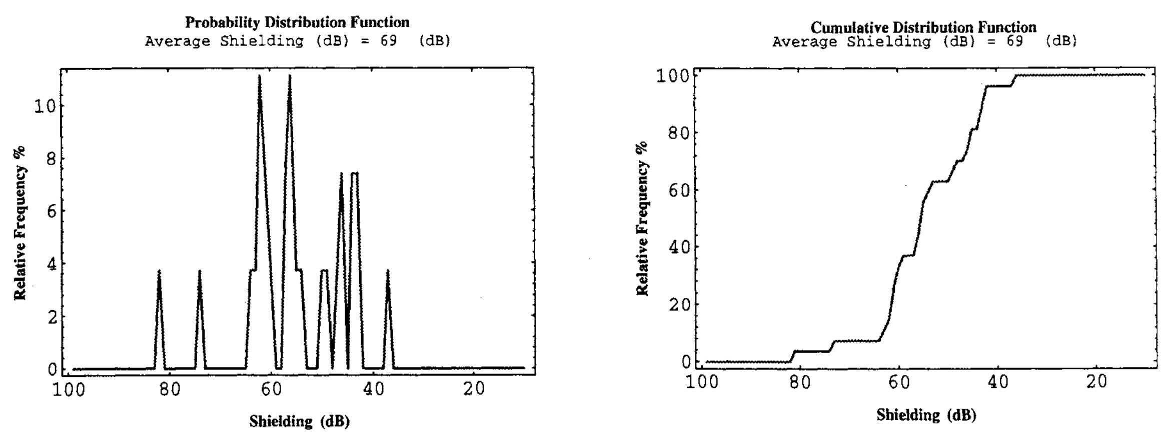


Figure P-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

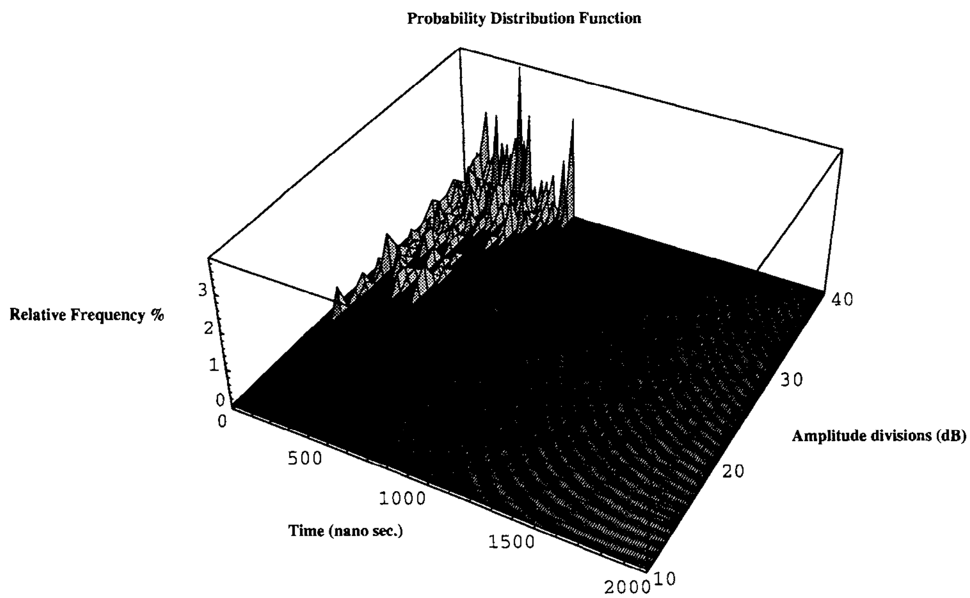
APPENDIX Q. RESULTS FOR CABLE SYSTEM Q

Table Q-1: Micro-Reflection Impairments Summary for Cable System Q.

Micro-Reflection Impairments	**50%**	**90%**	**95%**	**99%**
Headend Thru Tap:				
Frequency: 324 - 384 MHz				
Delay (nanosecond)	230	480	590	640
Amplitude (dB)	-39	-29	-27	-24
Headend Thru Home Outlet:				
Frequency: 324 - 384 MHz				
Delay (nanosecond)	240	480	530	640
Amplitude (dB)	-37	-29	-27	-24
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	160	390	420	640
Amplitude (dB)	-36	-25	-22	-17
Home Wiring:				
Frequency: 324 - 384 MHz				
Delay (nanosecond)	120	320	350	400
Amplitude (dB)	-35	-28	-26	-22

Table Q-2: Noise/Interference Impairments Summary for Cable System Q.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 324 - 384 MHz					
Carrier/Noise (dB)	54	45	42	41	32
Carrier Power (dBm)	-35	-39	-45	-46	-48
Noise Power (dBm) in 6 MHz Bandwidth	-82	-86	-80	-75	-72
Spurious Power (dBm) in 6 MHz Bandwidth	-82	-83	-78	-78	-78
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-79	-81	-76	-73	-71
CTB Power (dBm) 12 MHz above the last active channel	-95	-101	-95	-88	-85
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	64	55	47	44	33



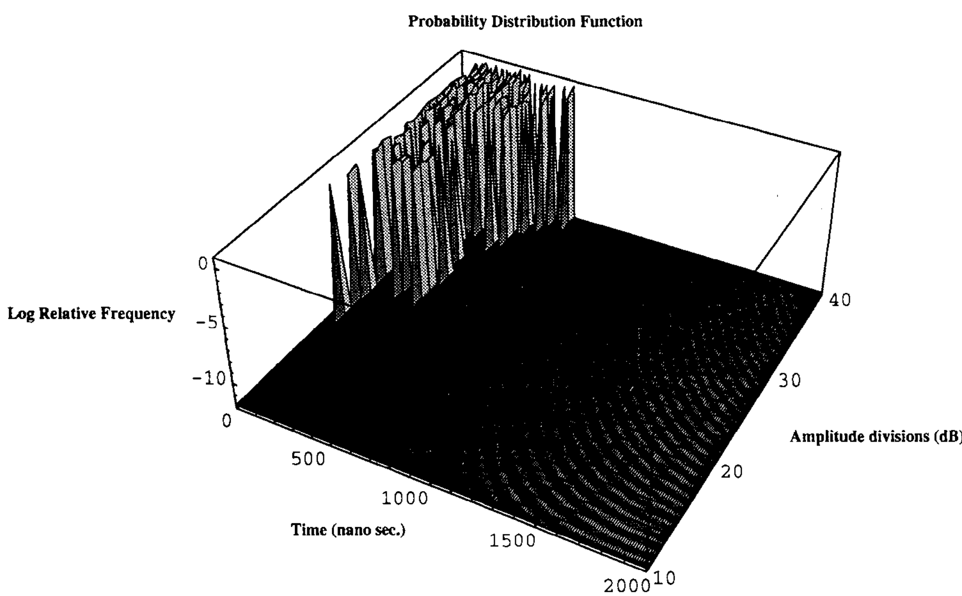


Figure Q-1: Tap distribution of echoes (324 - 384 MHz).

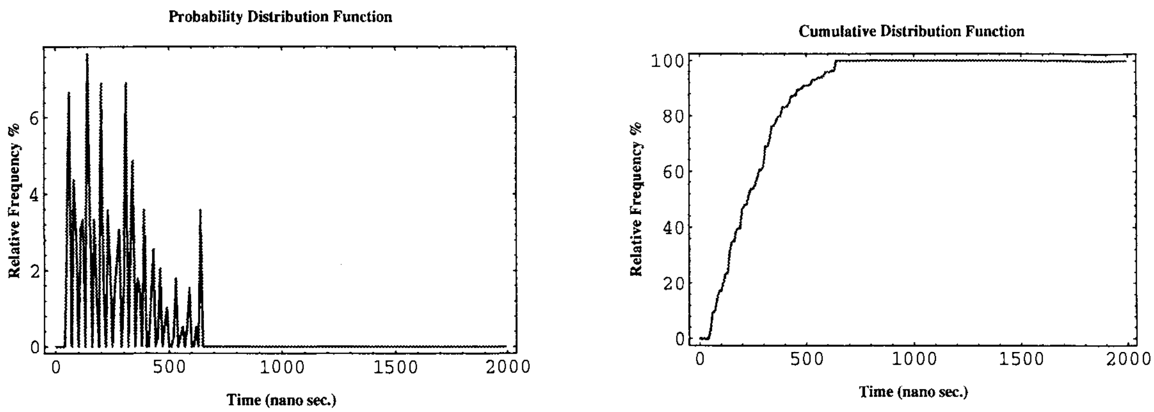


Figure Q-2: Tap histogram of echo delays (324 - 384 MHz).

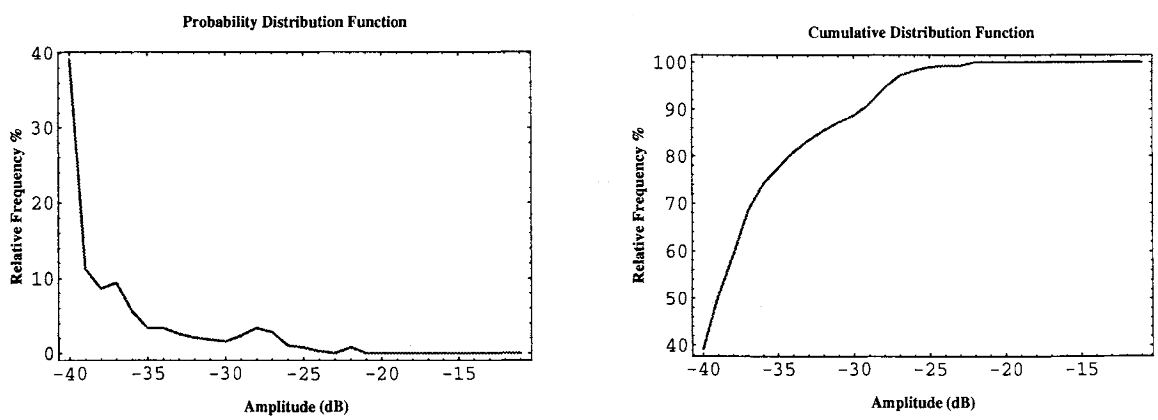


Figure Q-3: Tap histogram of echo amplitudes (324 - 384 MHz).

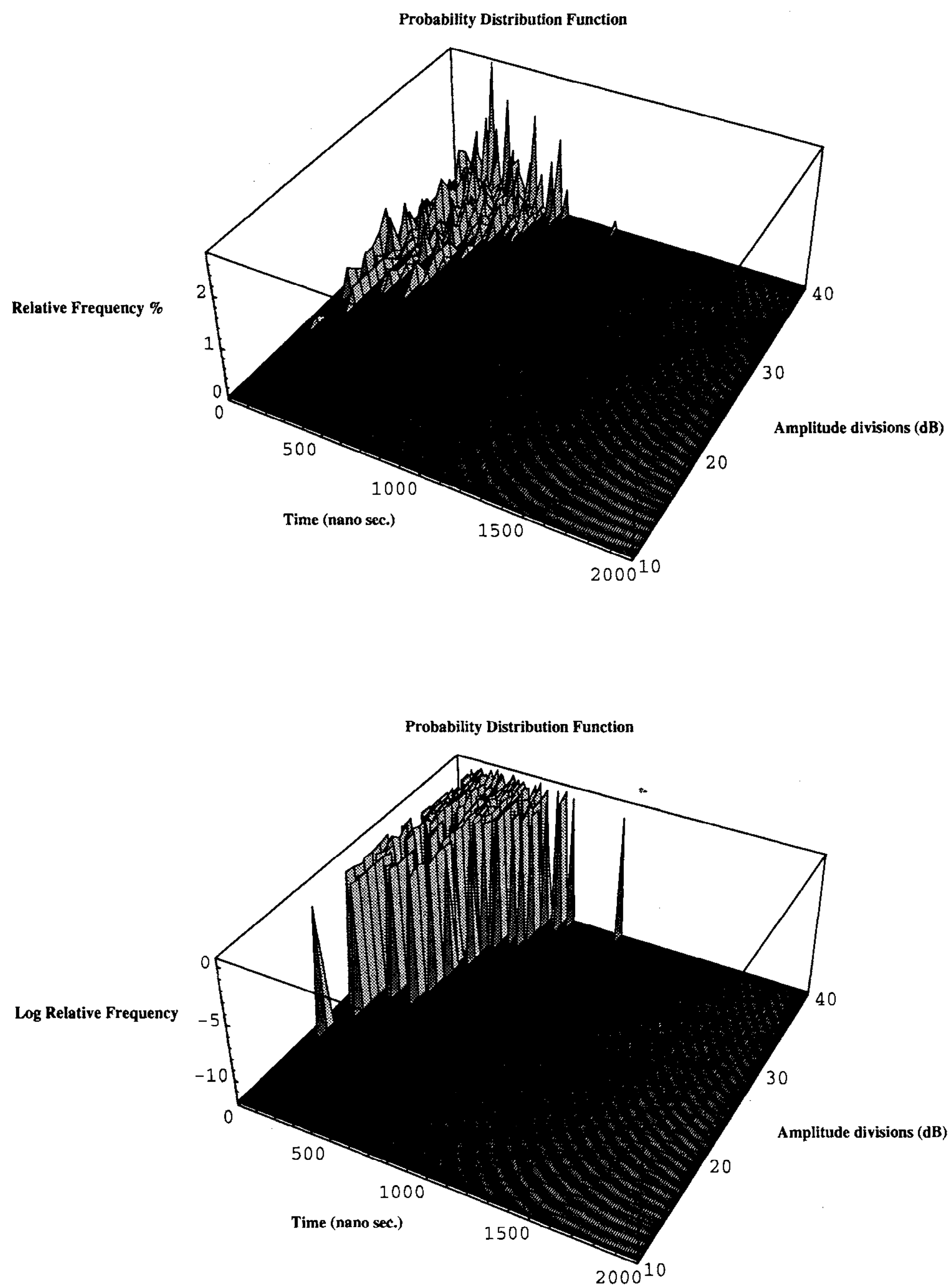


Figure Q-4: Home outlet distribution of echoes (324 - 384 MHz).

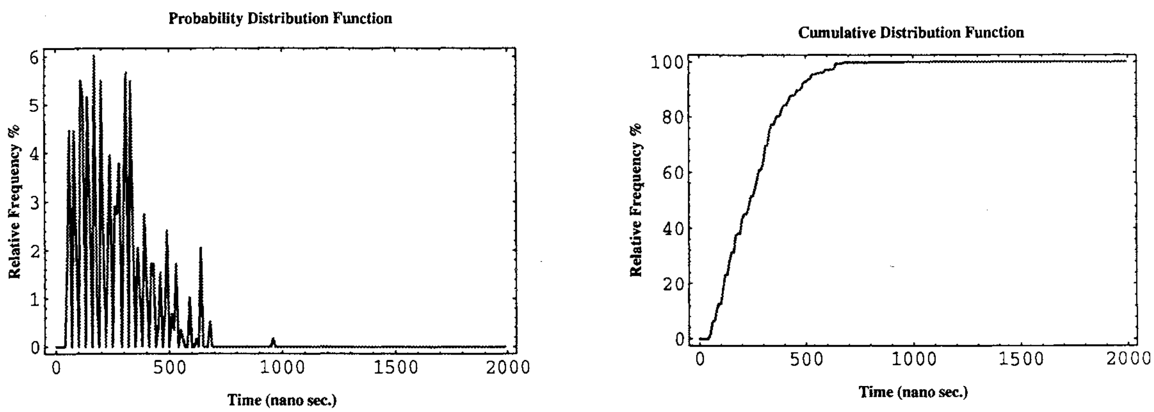


Figure Q-5: Home outlet histogram of echo delays (324 - 384 MHz).

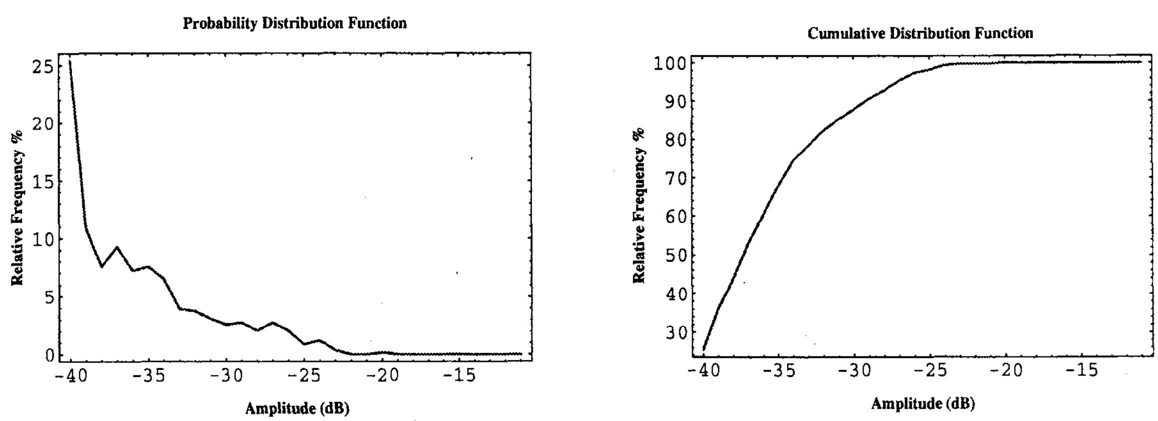
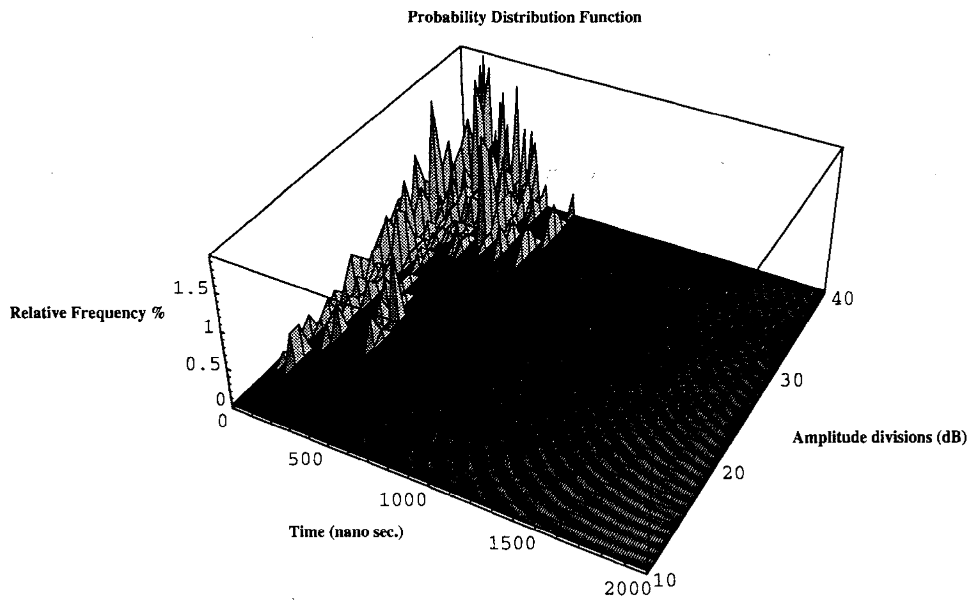


Figure Q-6: Home outlet histogram of echo amplitudes (324 - 384 MHz).



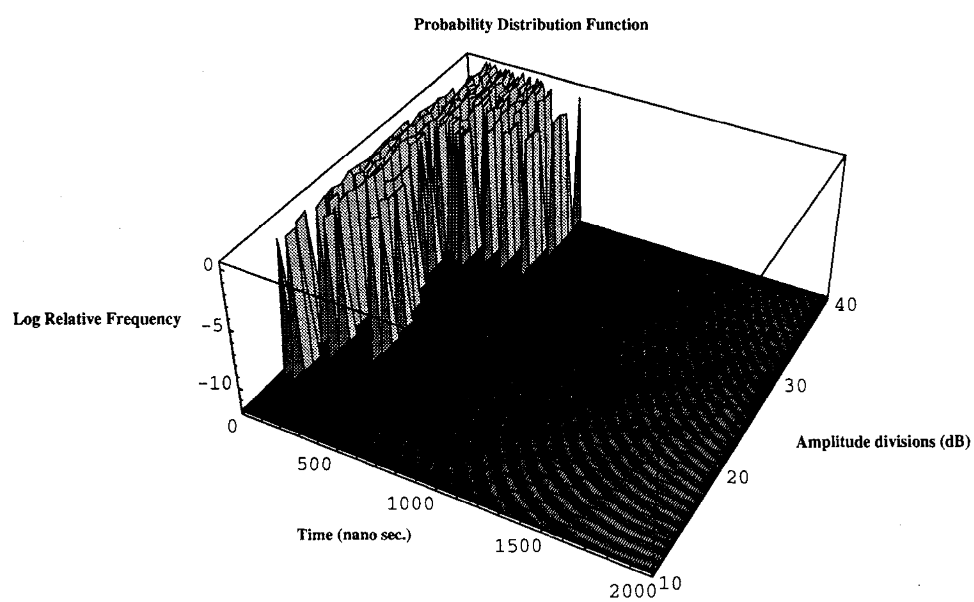


Figure Q-7: Home wiring distribution of echoes (50 - 200 MHz).

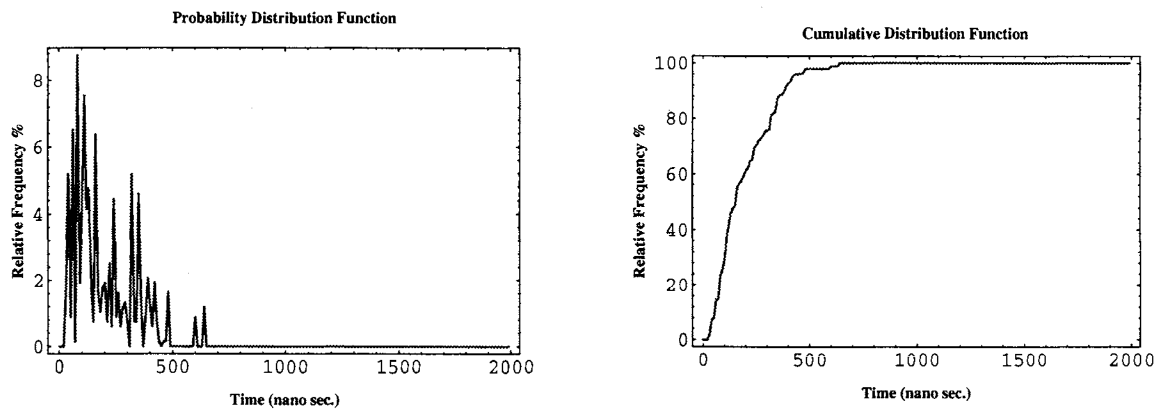


Figure Q-8: Home wiring histogram of echo delays (50 - 200 MHz).

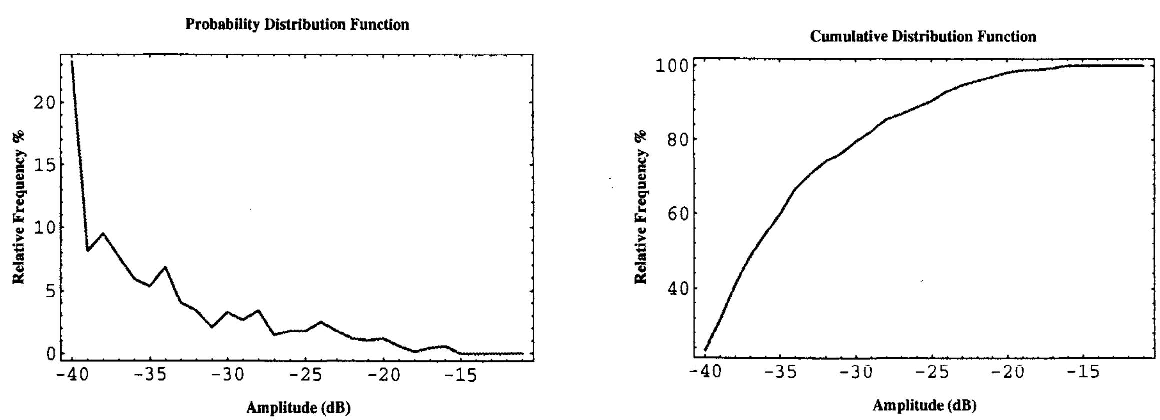


Figure Q-9: Home wiring histogram of echo amplitudes (50 - 200 MHz)

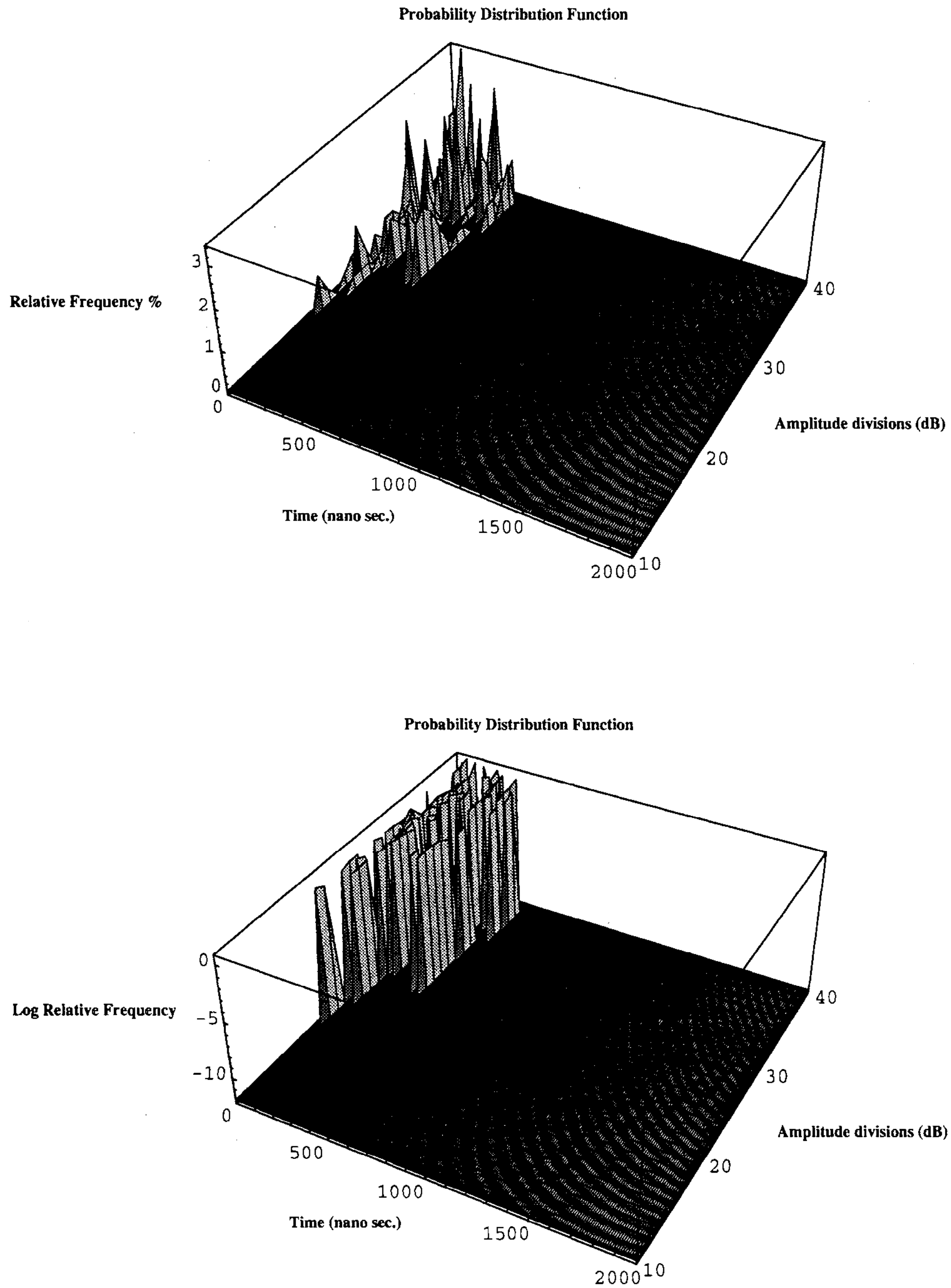


Figure Q-10: Home wiring distribution of echoes (324 - 384 MHz).

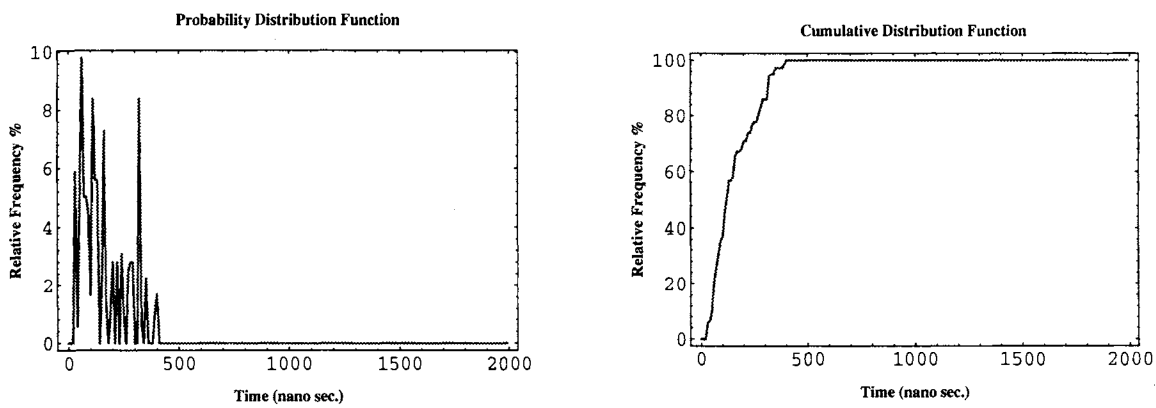


Figure Q-11: Home wiring histogram of echo delays (324 - 384 MHz).

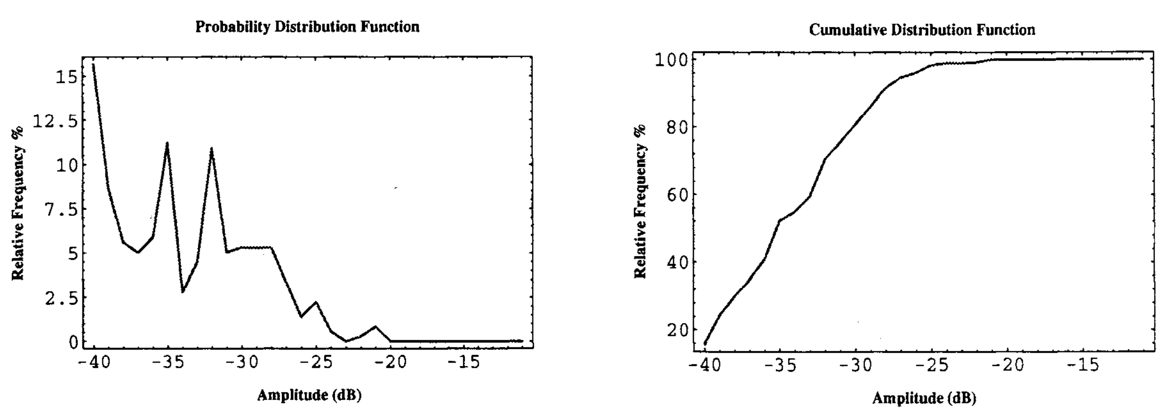


Figure Q-12: Home wiring histogram of echo amplitudes (324 - 384 MHz)

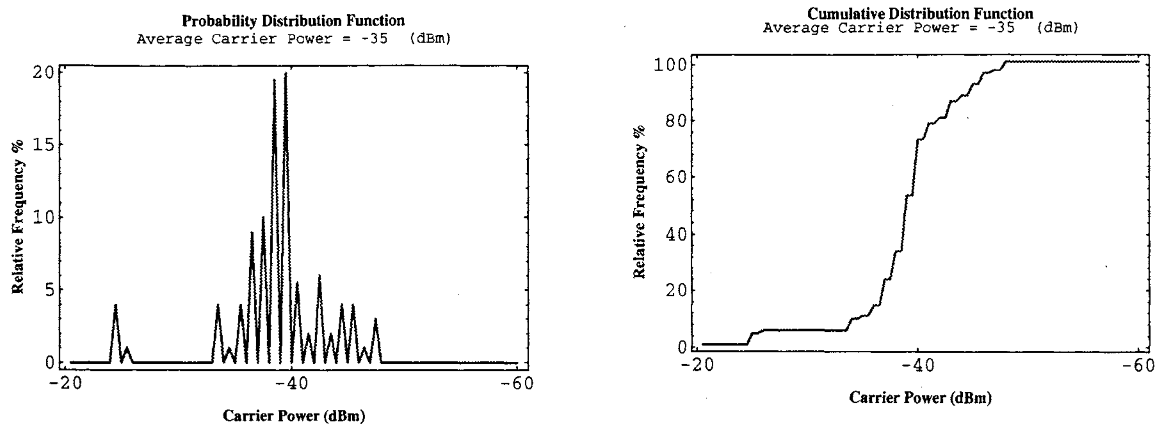


Figure Q-13: Tap histogram of carrier power (324 - 384 MHz).

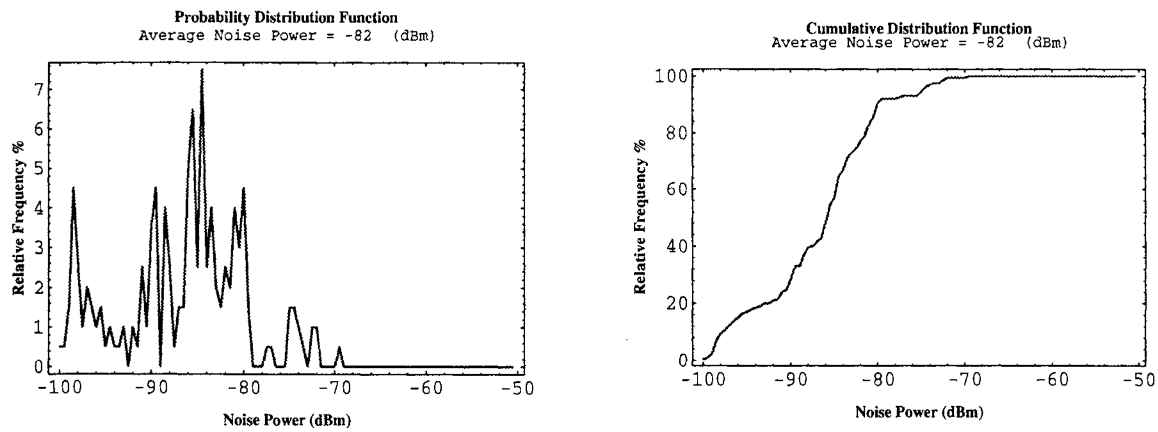


Figure Q-14: Tap histogram of noise power (324 - 384 MHz).

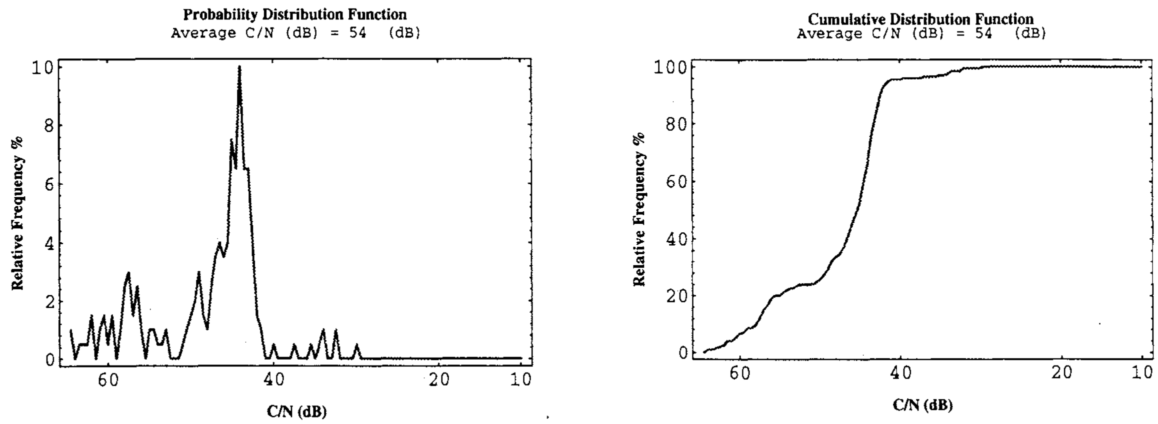


Figure Q-15: Tap histogram of carrier-to-noise ratio (342 - 384 MHz).

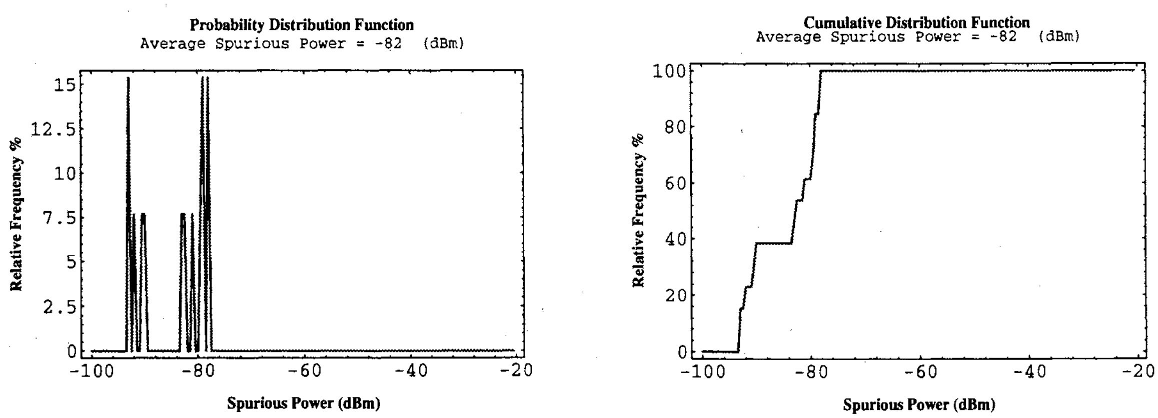


Figure Q-16: Tap histogram of spurious components (324 - 384 MHz).

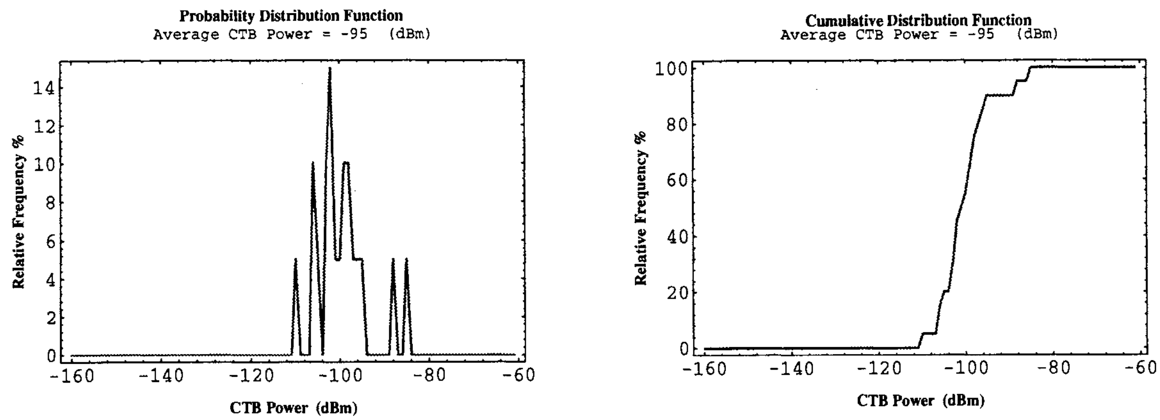


Figure Q-17: Tap histogram of composite triple beats (324 - 384 MHz).

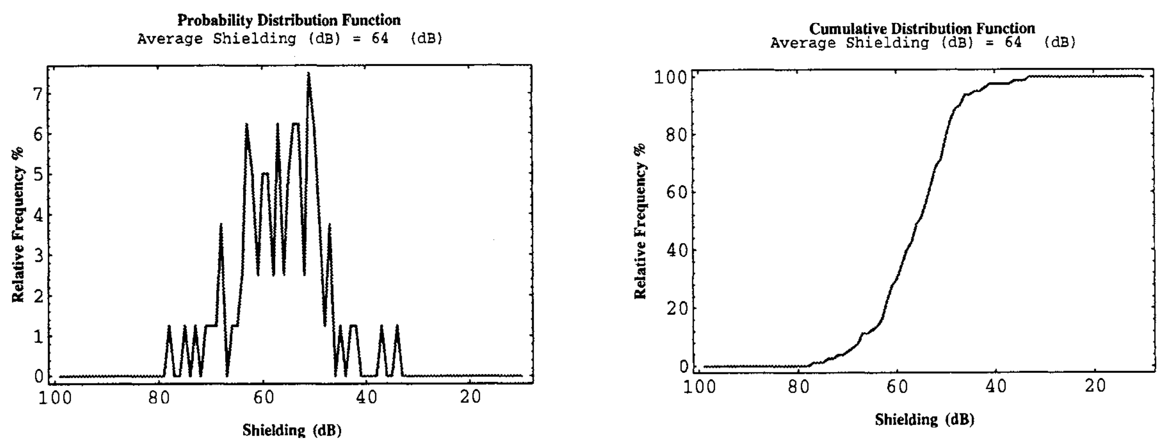


Figure Q-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

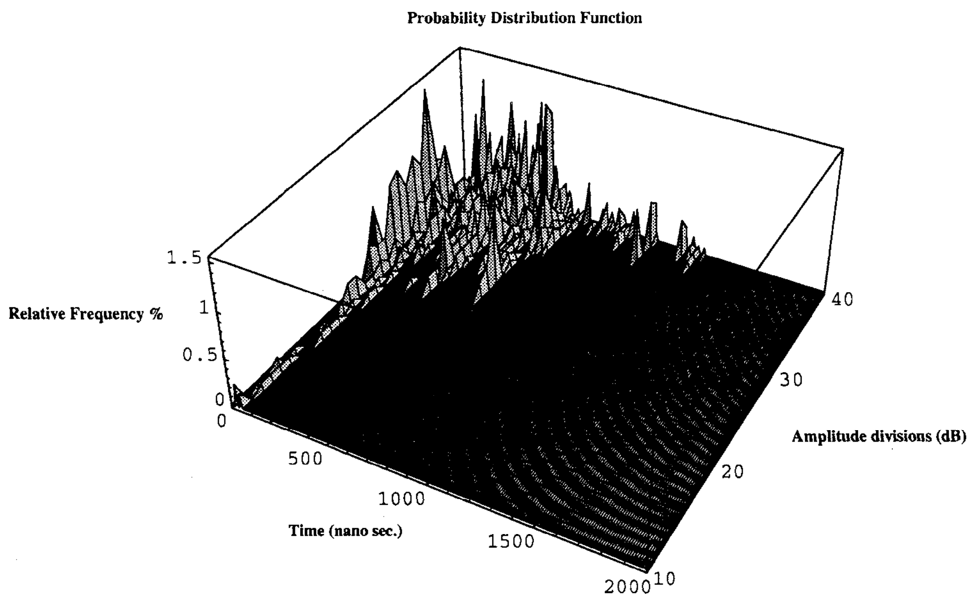
APPENDIX R. RESULTS FOR CABLE SYSTEM R

Table R-1: Micro-Reflection Impairments Summary for Cable System R.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 440 - 558 MHz				
Delay (nanosecond)	330	600	830	1270
Amplitude (dB)	-37	-30	-27	-15
Headend Thru Home Outlet:				
Frequency: 440 - 558 MHz				
Delay (nanosecond)	270	530	600	870
Amplitude (dB)	-36	-26	-23	-17
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	130	360	460	600
Amplitude (dB)	-37	-28	-25	-15
Home Wiring:				
Frequency: 440 - 558 MHz				
Delay (nanosecond)	140	360	450	1260
Amplitude (dB)	-36	-25	-22	-15

Table R-2: Noise/Interference Impairments Summary for Cable System R.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 440 - 558 MHz					
Carrier/Noise (dB)	41	37	34	34	33
Carrier Power (dBm)	-31	-37	-44	-46	-49
Noise Power (dBm) in 6 MHz Bandwidth	-73	-78	-71	-65	-65
Spurious Power (dBm) in 6 MHz Bandwidth	-75	-75	-72	-71	-71
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-71	-73	-68	-64	-64
CTB Power (dBm) 12 MHz above the last active channel	-92	-100	-86	-84	-84
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	68	55	39	30	11



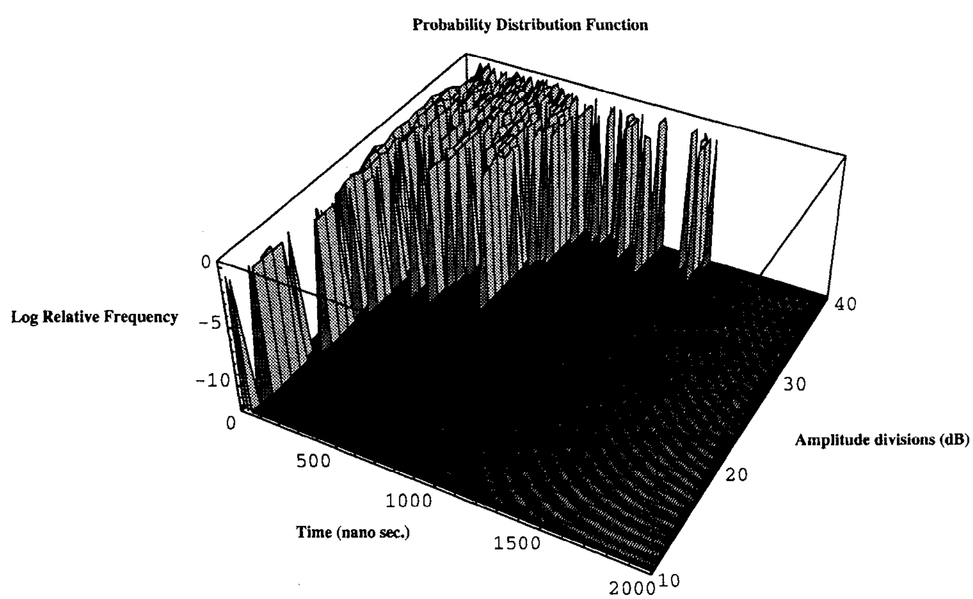


Figure R-1: Tap distribution of echoes (440 - 558 MHz).

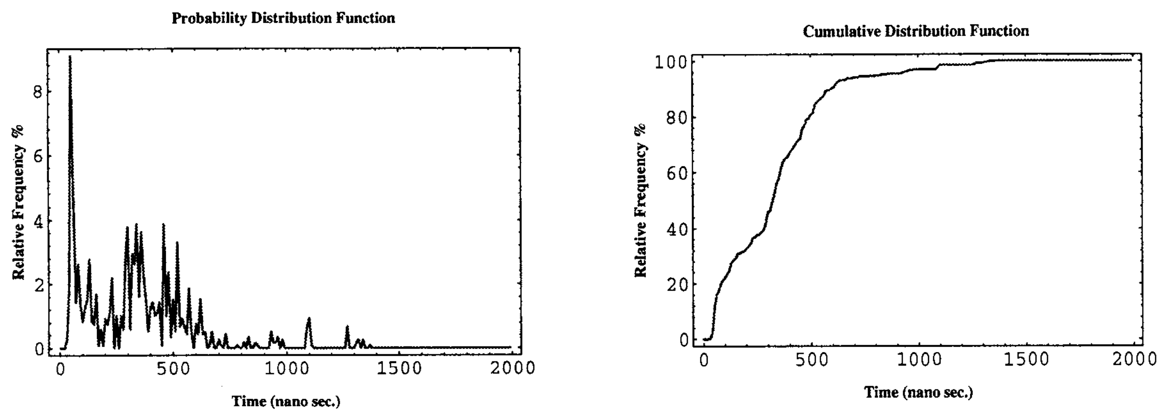


Figure R-2: Tap histogram of echo delays (440 - 558 MHz).

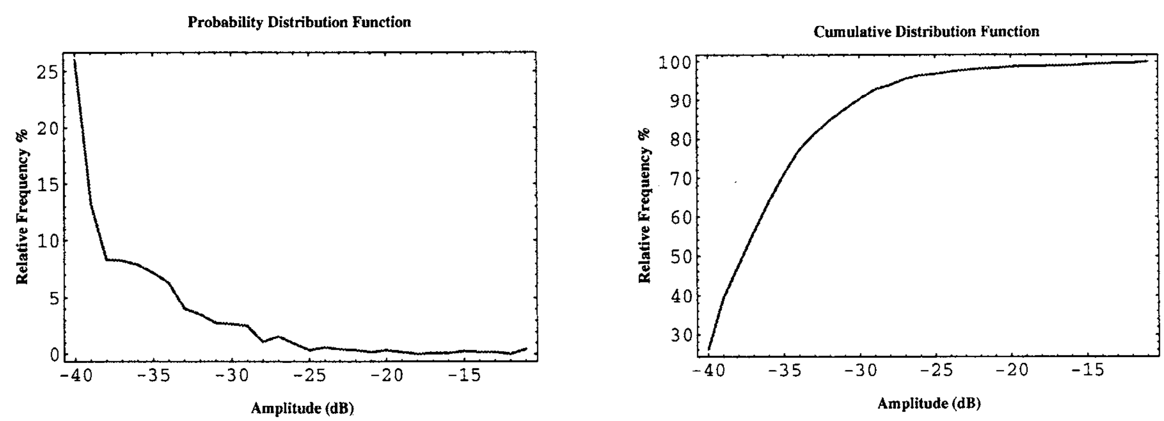
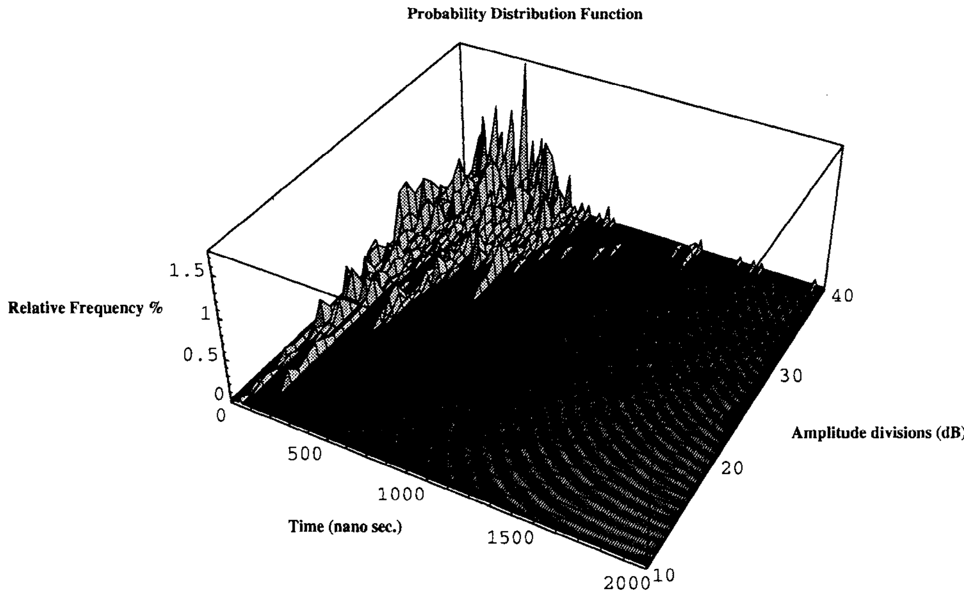


Figure R-3: Tap histogram of echo amplitudes (440 - 558 MHz).



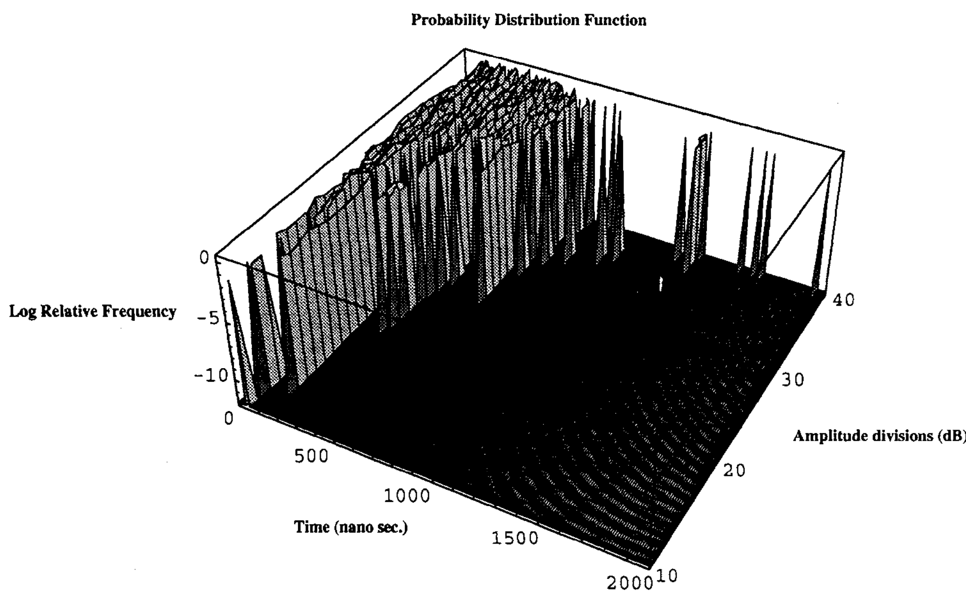


Figure R-4: Home outlet distribution of echoes (440 - 558 MHz).

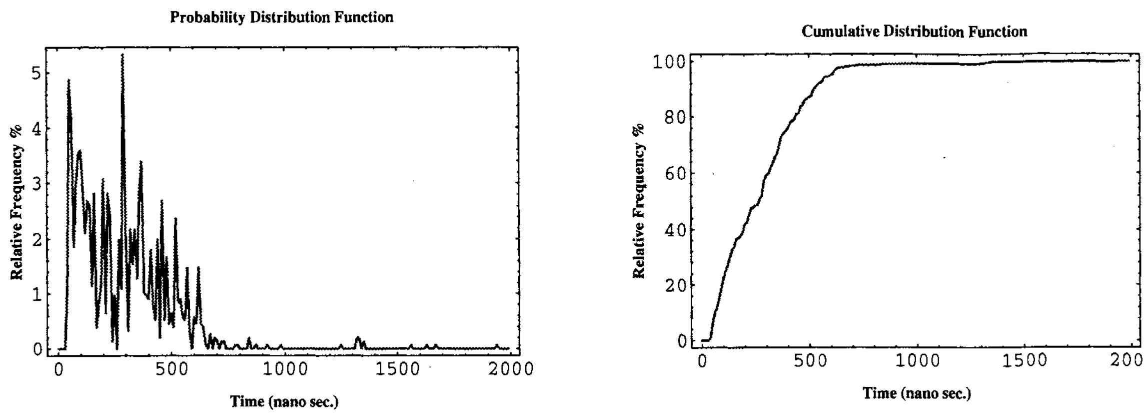


Figure R-5: Home outlet histogram of echo delays (440 - 558 MHz).

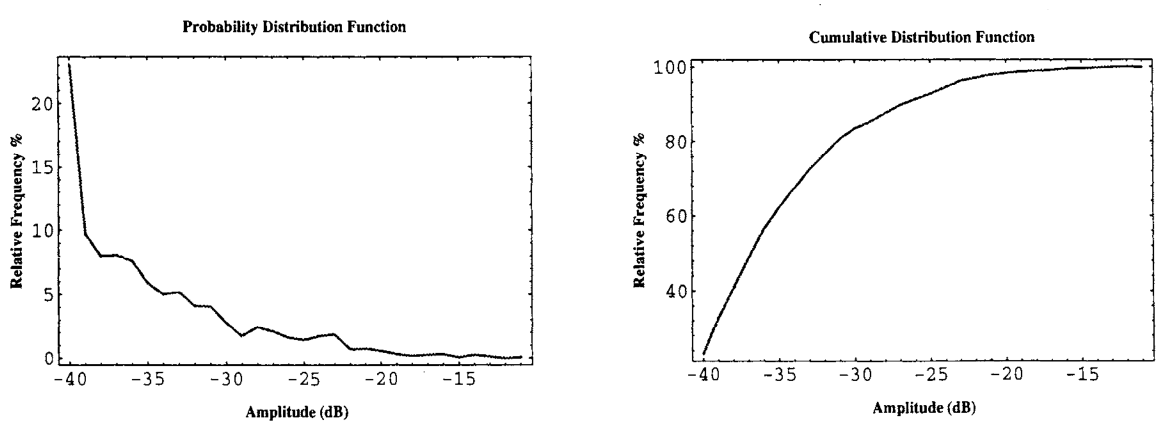
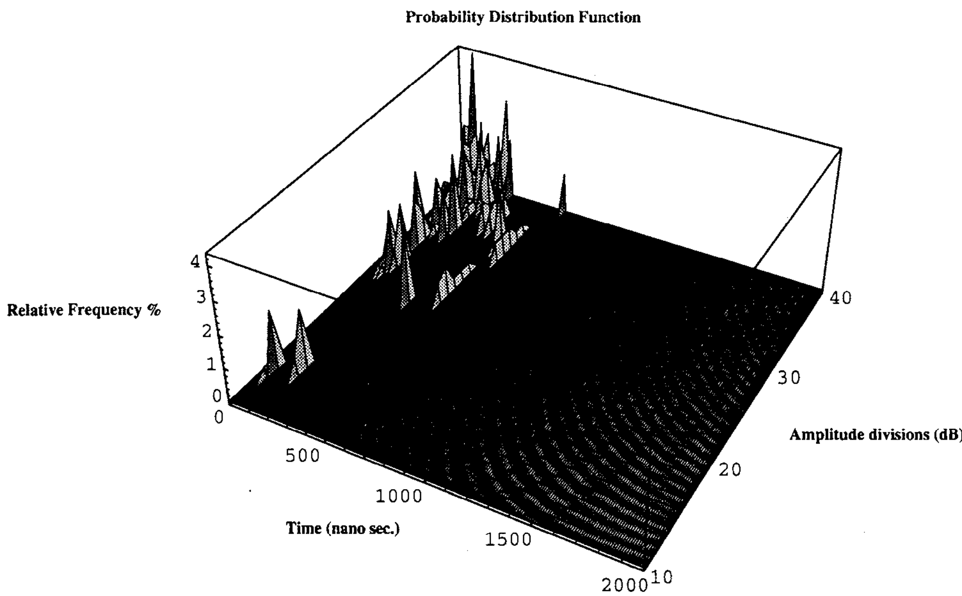


Figure R-6: Home outlet histogram of echo amplitudes (440 - 558 MHz).



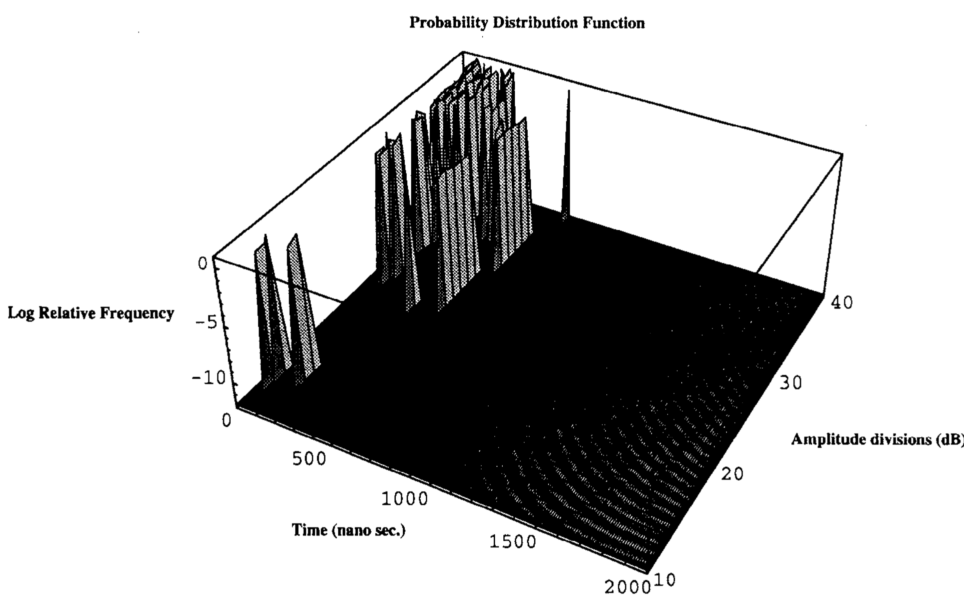


Figure R-7: Home wiring distribution of echoes (50 - 200 MHz).

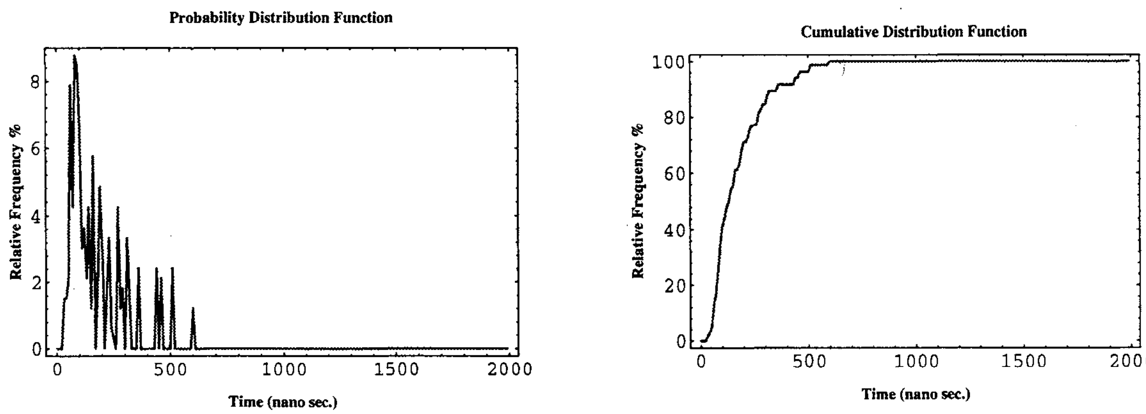


Figure R-8: Home wiring histogram of echo delays (50 - 200 MHz).

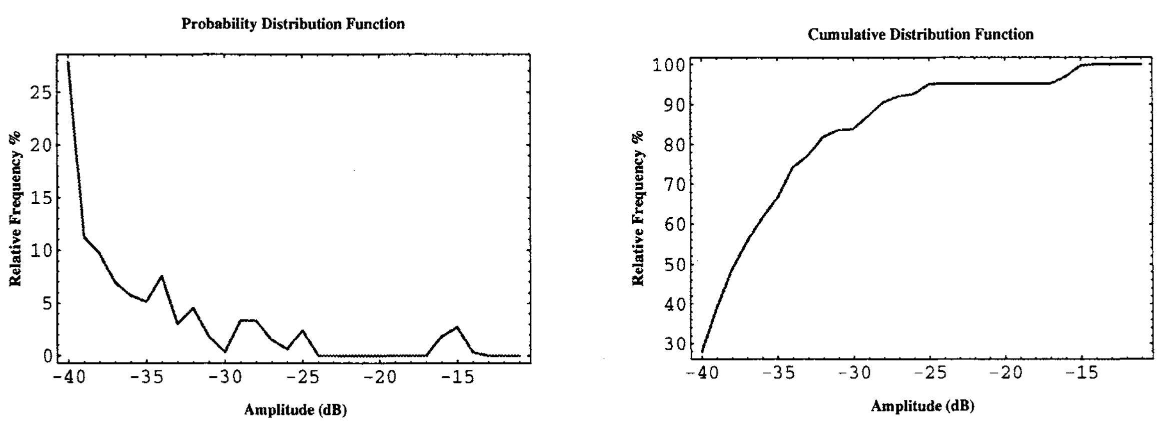
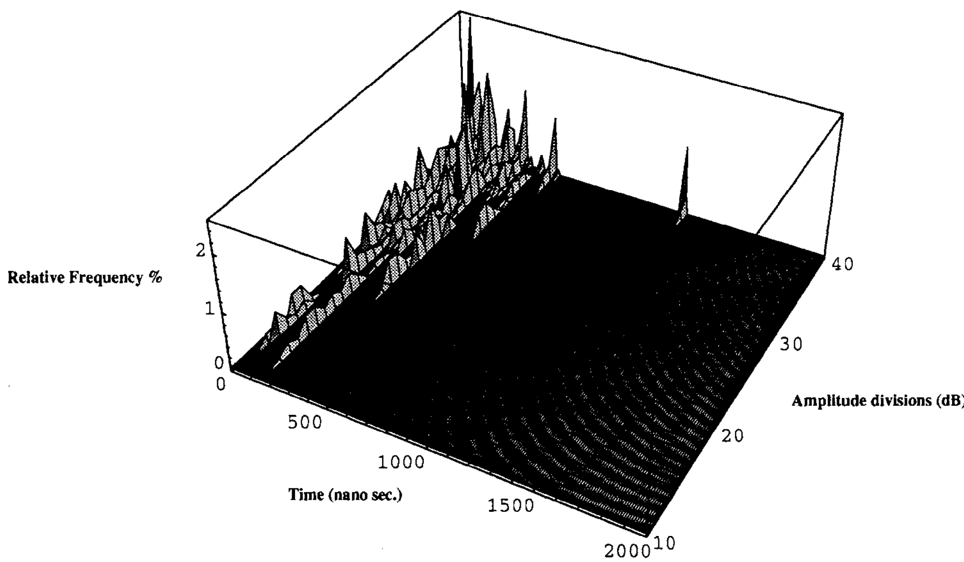


Figure R-9: Home wiring histogram of echo amplitudes (50 - 200 MHz)

Probability Distribution Function



Probability Distribution Function

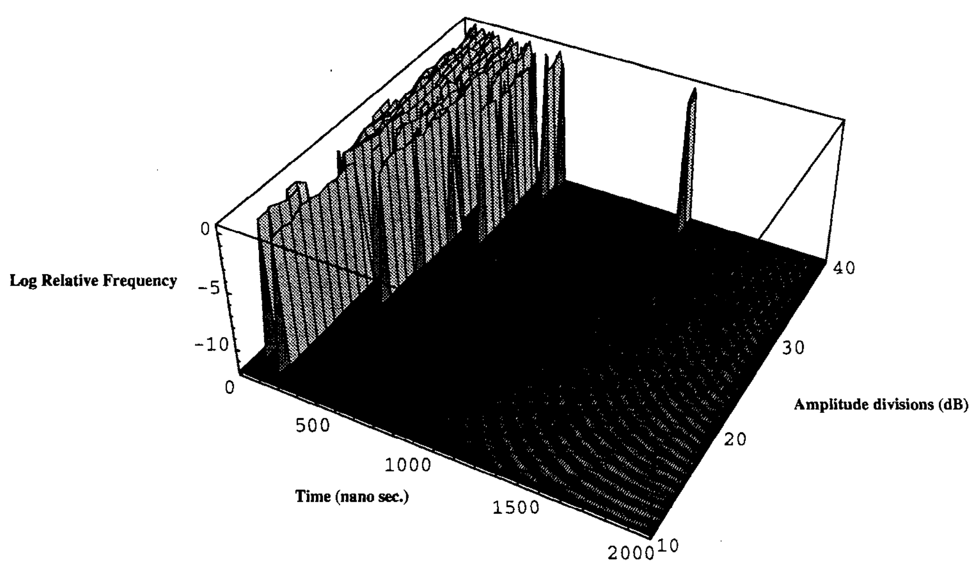


Figure R-10: Home wiring distribution of echoes (440 - 558 MHz).

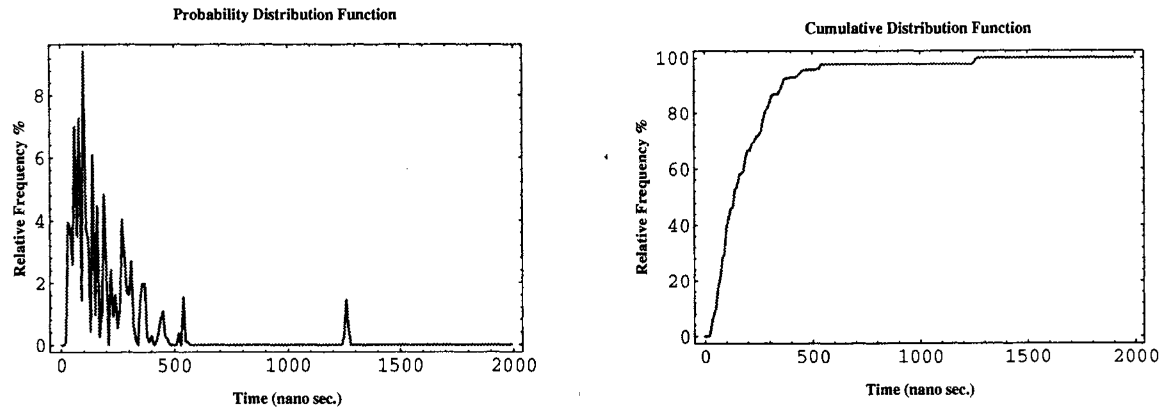


Figure R-11: Home wiring histogram of echo delays (440 - 558 MHz).

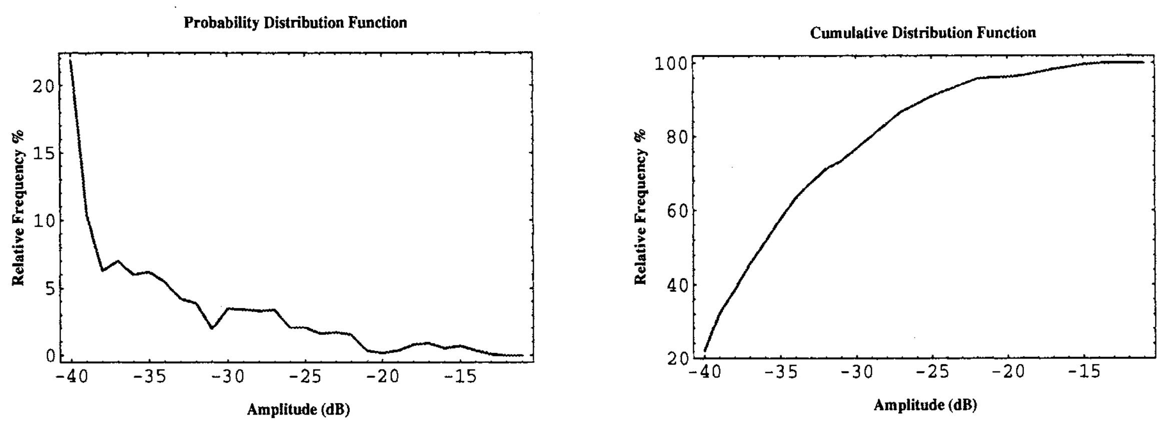


Figure R-12: Home wiring histogram of echo amplitudes (440 - 558 MHz).

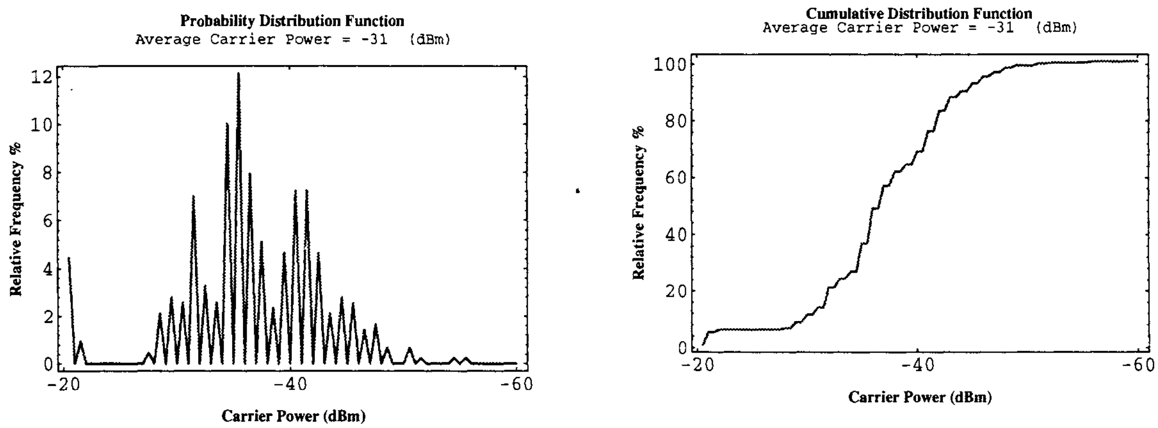


Figure R-13: Tap histogram of carrier power (440 - 558 MHz).

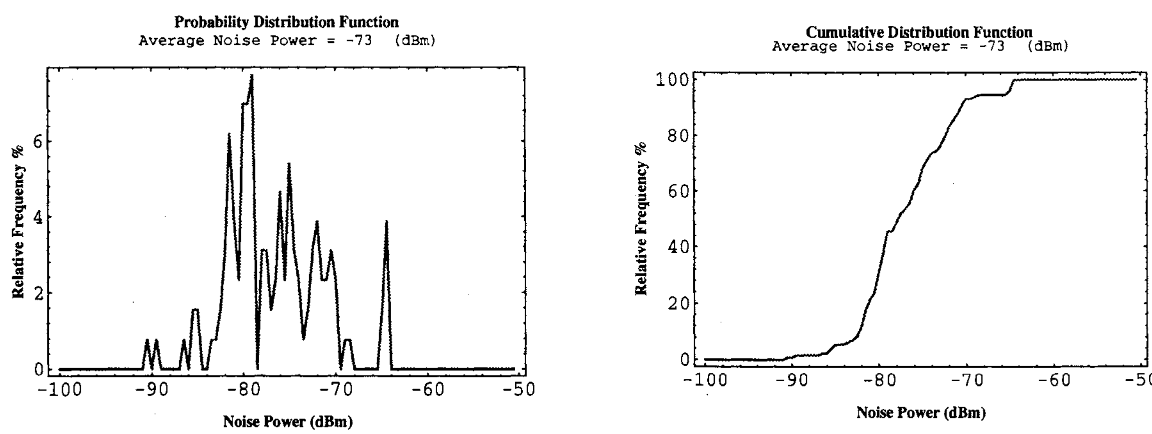


Figure R-14: Tap histogram of noise power (440 - 558 MHz).

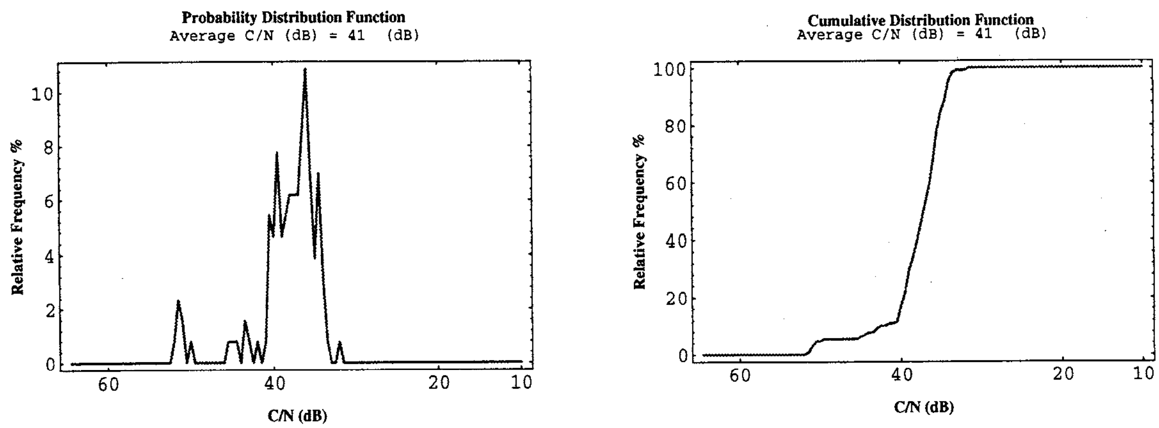


Figure R-15: Tap histogram of carrier-to-noise ratio (444 - 558 MHz).

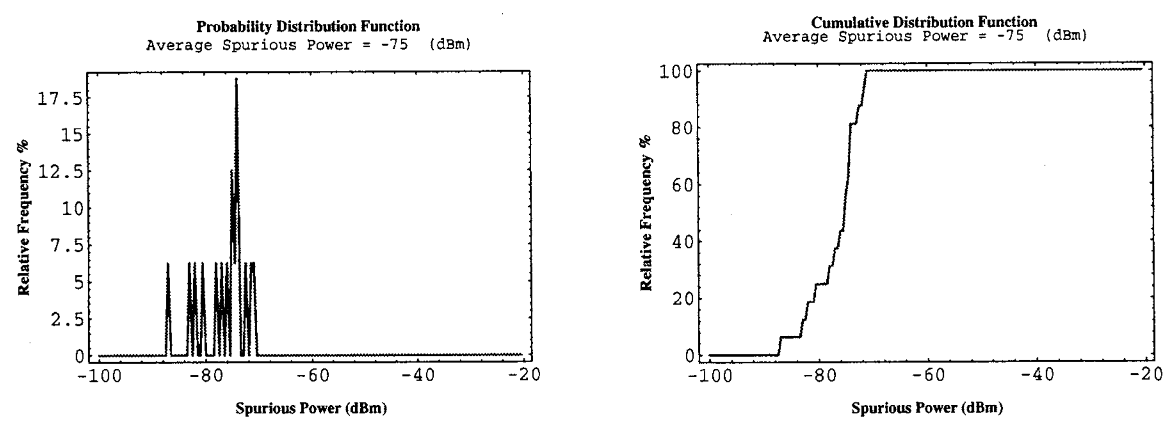
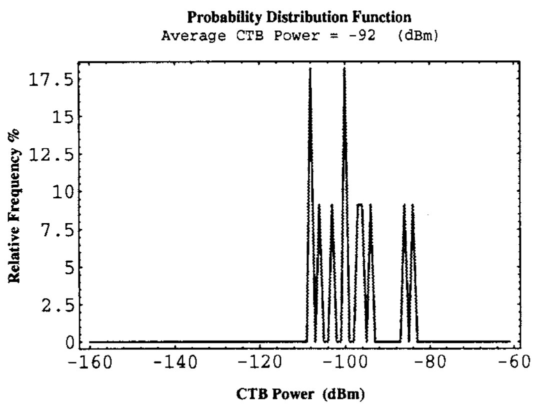


Figure R-16: Tap histogram of spurious components (440 - 558 MHz).



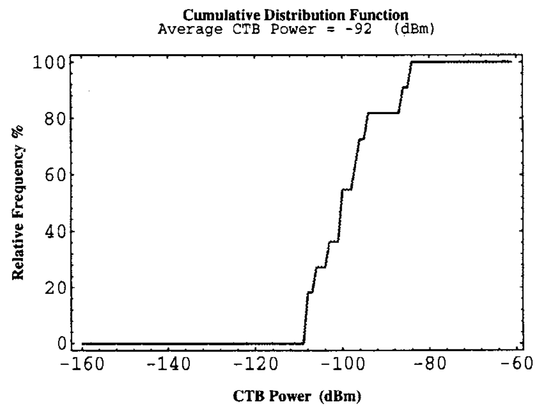
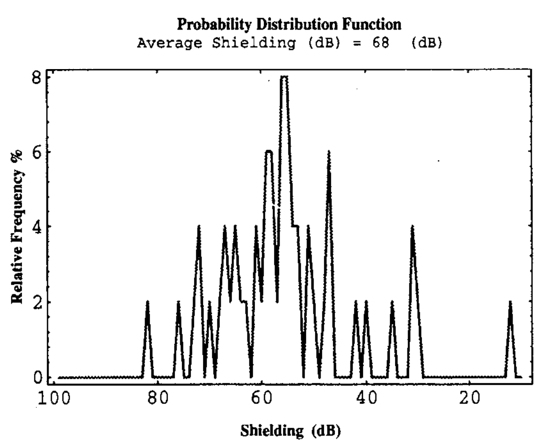


Figure R-17: Tap histogram of composite triple beats (440 - 558 MHz).



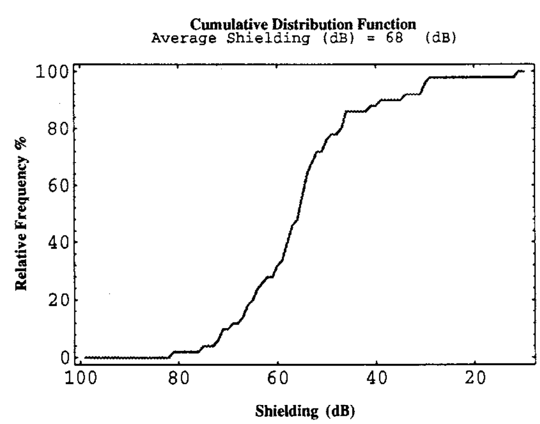


Figure R-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

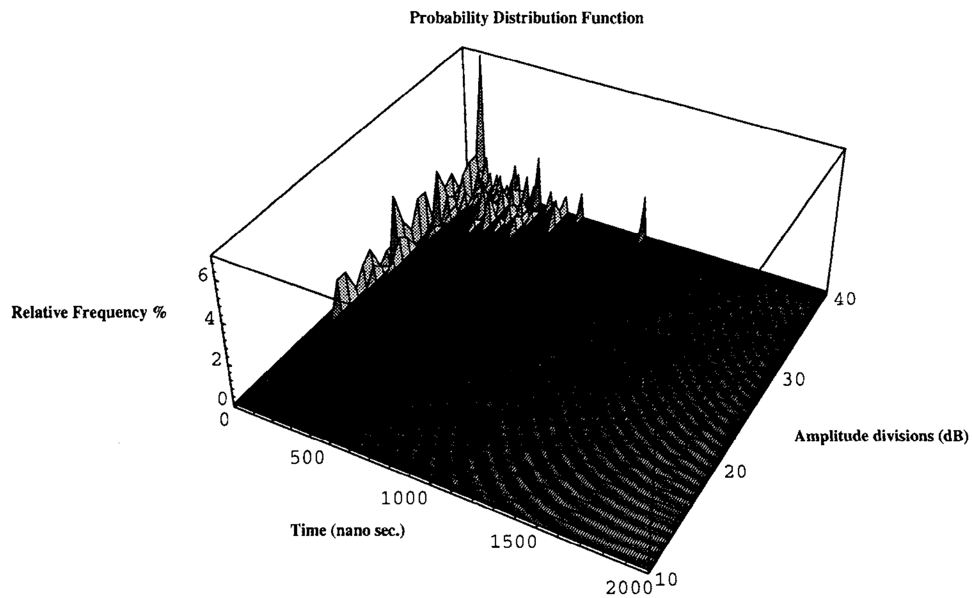
APPENDIX S. RESULTS FOR CABLE SYSTEM S

Table S-1: Micro-Reflection Impairments Summary for Cable System S.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 408 - 546 MHz				
Delay (nanosecond)	100	440	590	1030
Amplitude (dB)	-38	-29	-26	-22
Headend Thru Home Outlet:				
Frequency: 408 - 546 MHz				
Delay (nanosecond)	180	400	420	1030
Amplitude (dB)	-38	-28	-26	-23
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	130	330	420	590
Amplitude (dB)	-35	-24	-22	-19
Home Wiring:				
Frequency: 408 - 546 MHz				
Delay (nanosecond)	110	280	400	940
Amplitude (dB)	-35	-27	-24	-21

Table S-2: Noise/Interference Impairments Summary for Cable System S.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 408 - 546 MHz					
Carrier/Noise (dB)	44	42	39	35	28
Carrier Power (dBm)	-30	-34	-48	-50	-52
Noise Power (dBm) in 6 MHz Bandwidth	-70	-76	-73	-68	-57
Spurious Power (dBm) in 6 MHz Bandwidth	-77	-78	-75	-73	-73
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-69	-74	-71	-67	-57
CTB Power (dBm) 12 MHz above the last active channel	-115	-115	-115	-115	-115
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	65	55	38	32	23



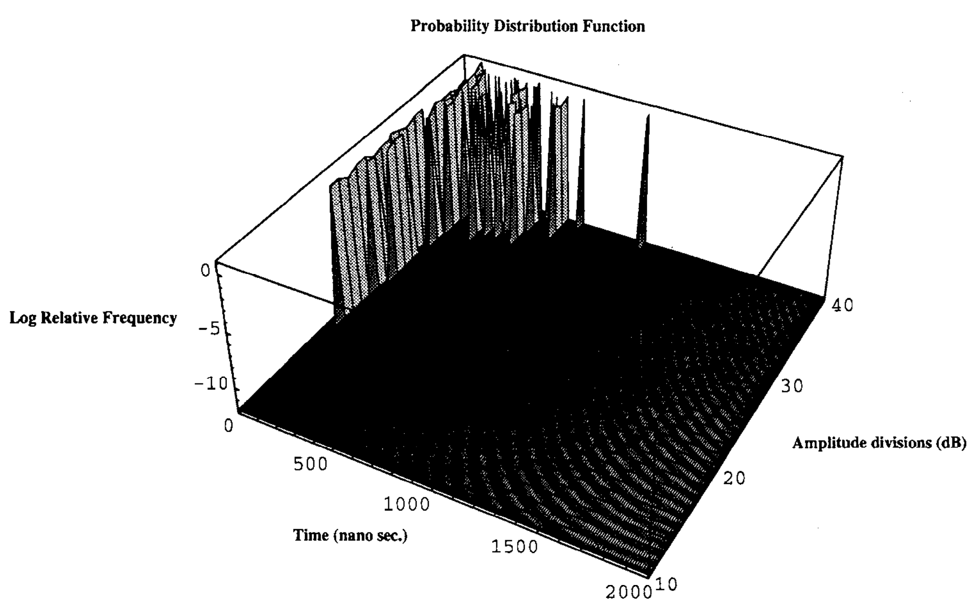


Figure S-1: Tap distribution of echoes (408 - 546 MHz).

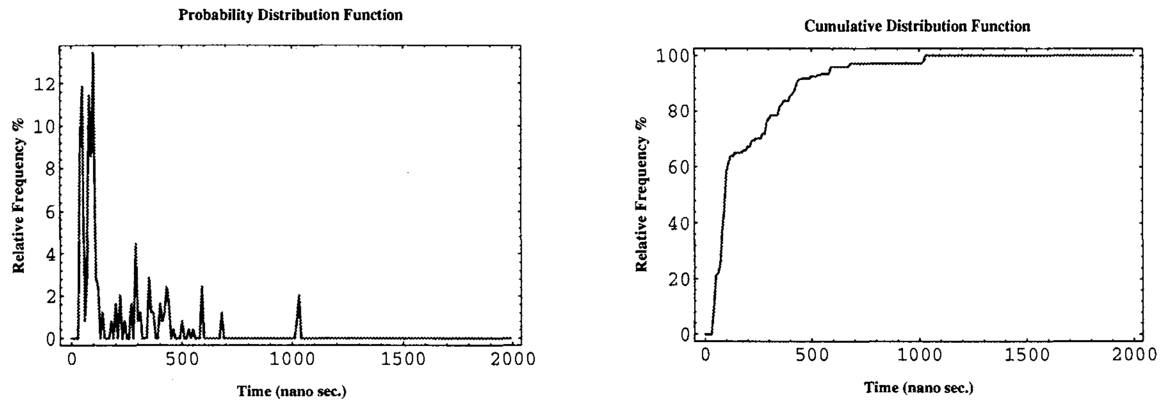


Figure S-2: Tap histogram of echo delays (408 - 546 MHz).

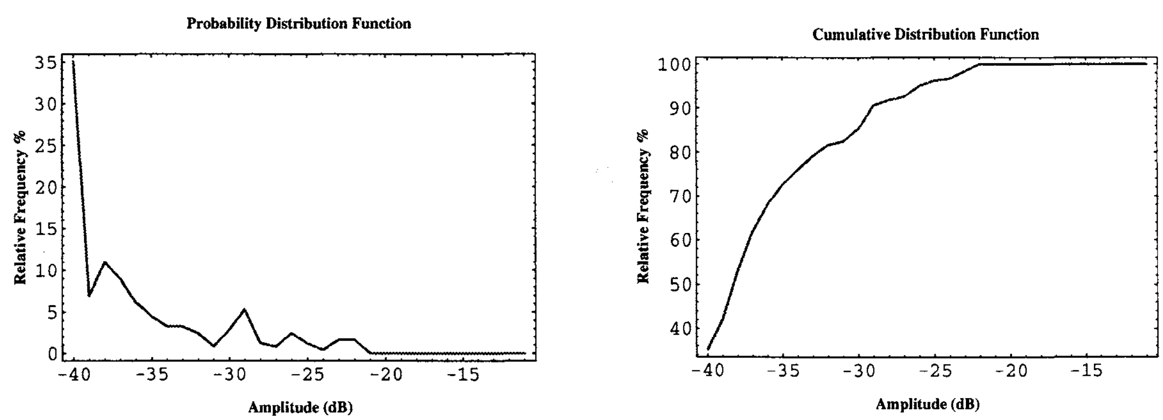
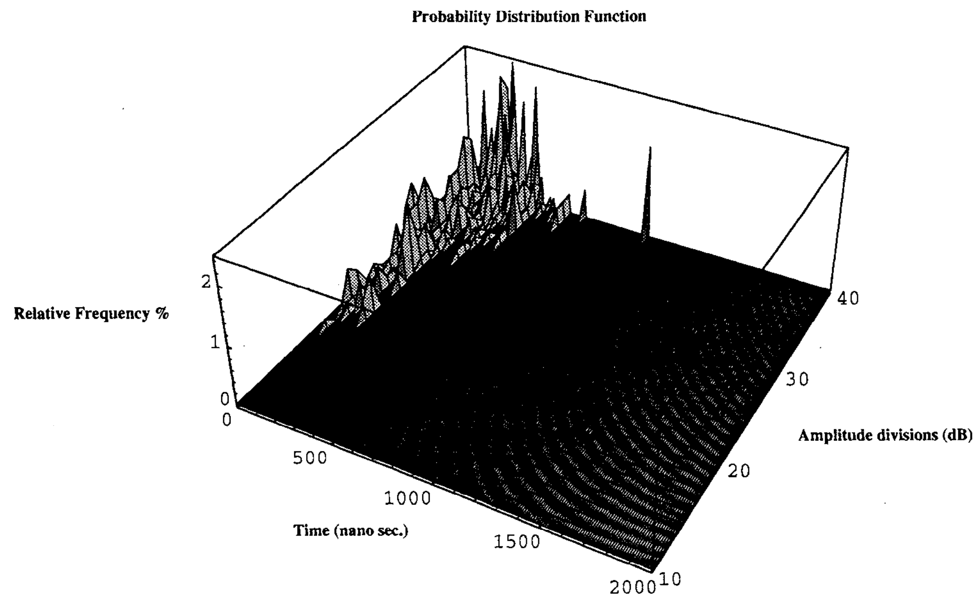


Figure S-3: Tap histogram of echo amplitudes (408 - 546 MHz).



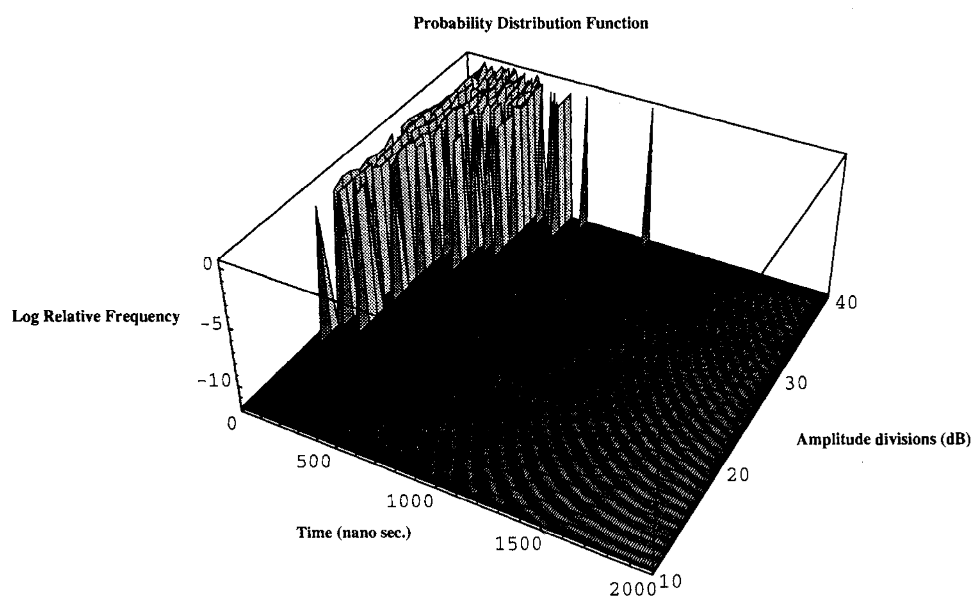


Figure S-4: Home outlet distribution of echoes (408 - 546 MHz).

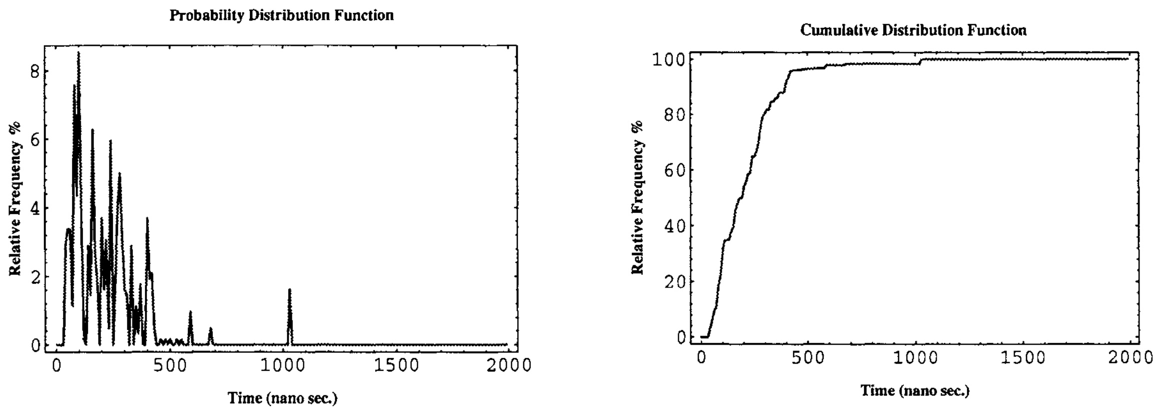


Figure S-5: Home outlet histogram of echo delays (408 - 546 MHz).

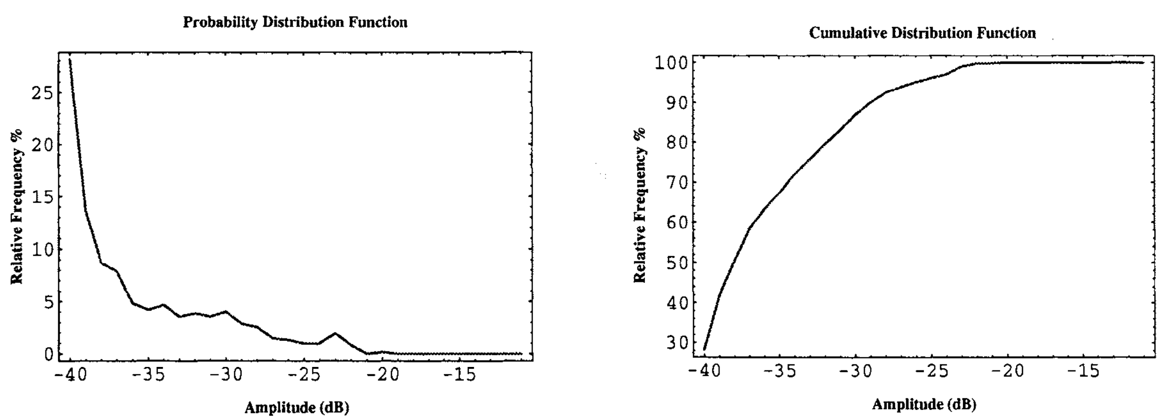


Figure S-6: Home outlet histogram of echo amplitudes (408 - 546 MHz).

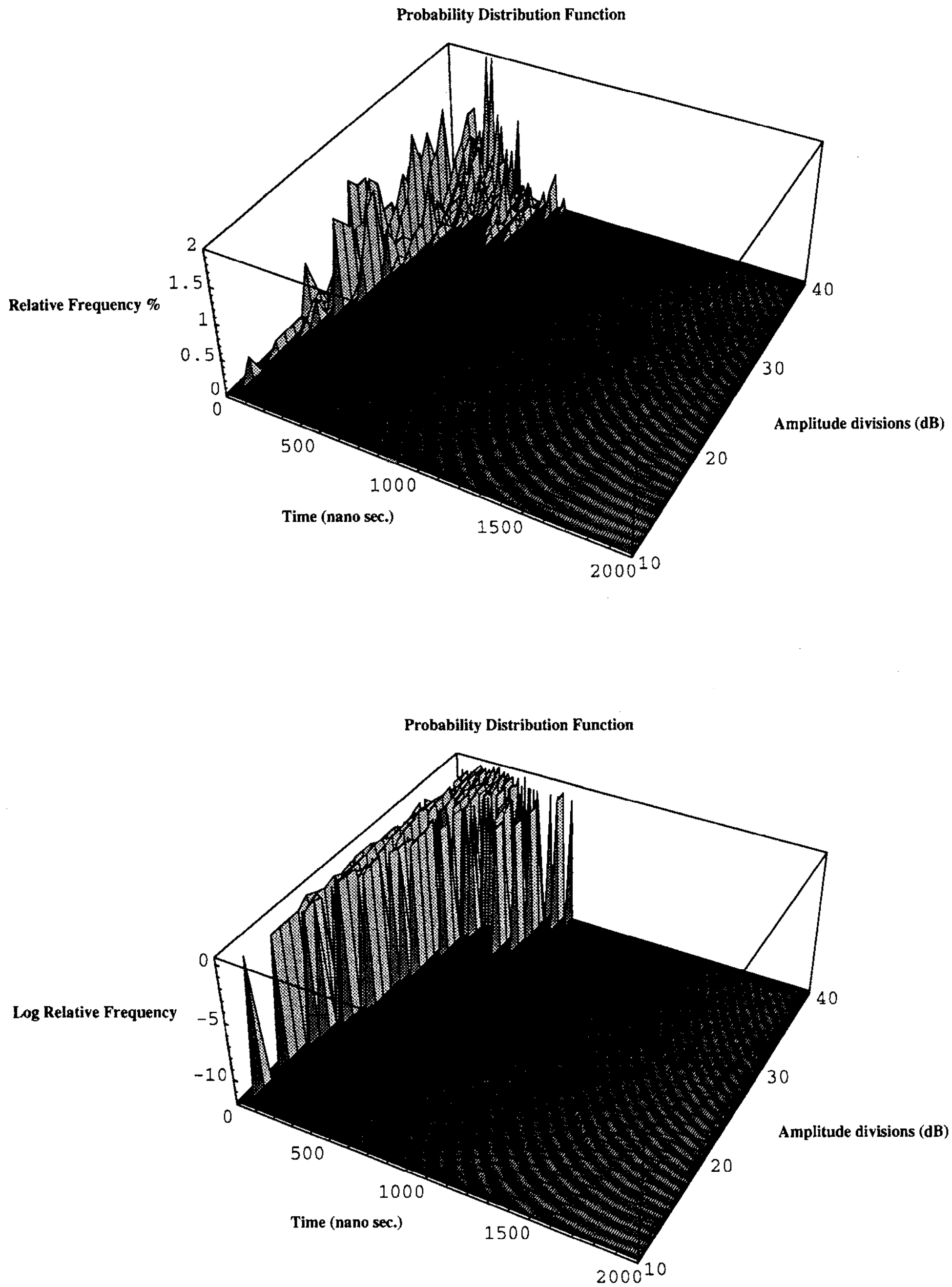


Figure S-7: Home wiring distribution of echoes (50 - 200 MHz).

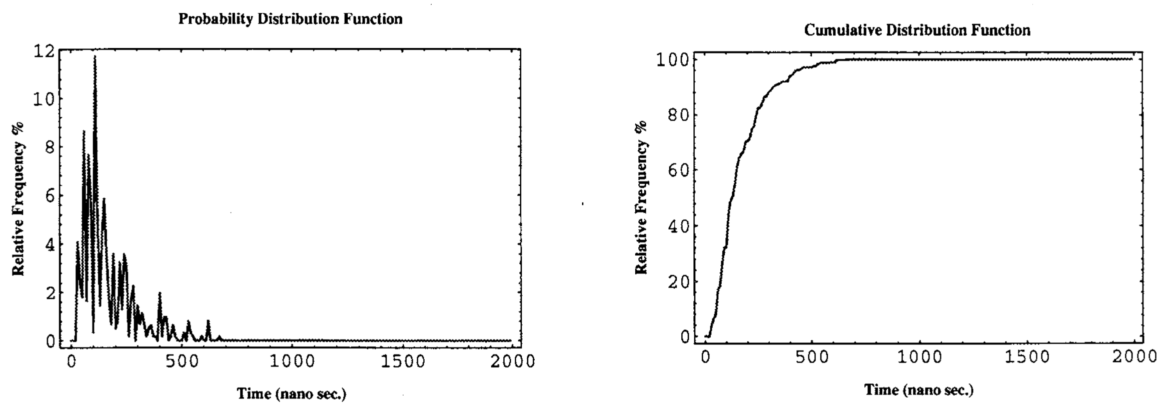


Figure S-8: Home wiring histogram of echo delays (50 - 200 MHz).

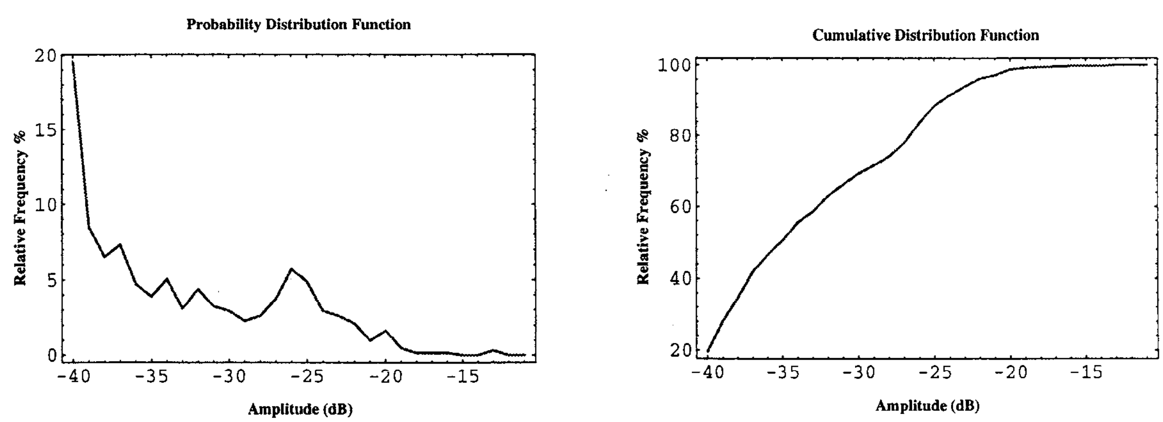
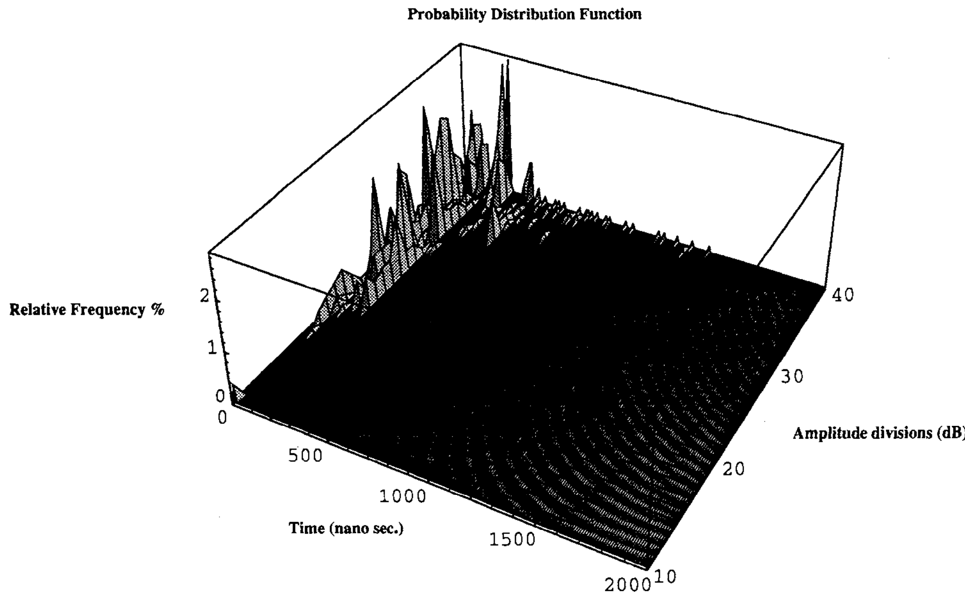


Figure S-9: Home wiring histogram of echo amplitudes (50 - 200 MHz)



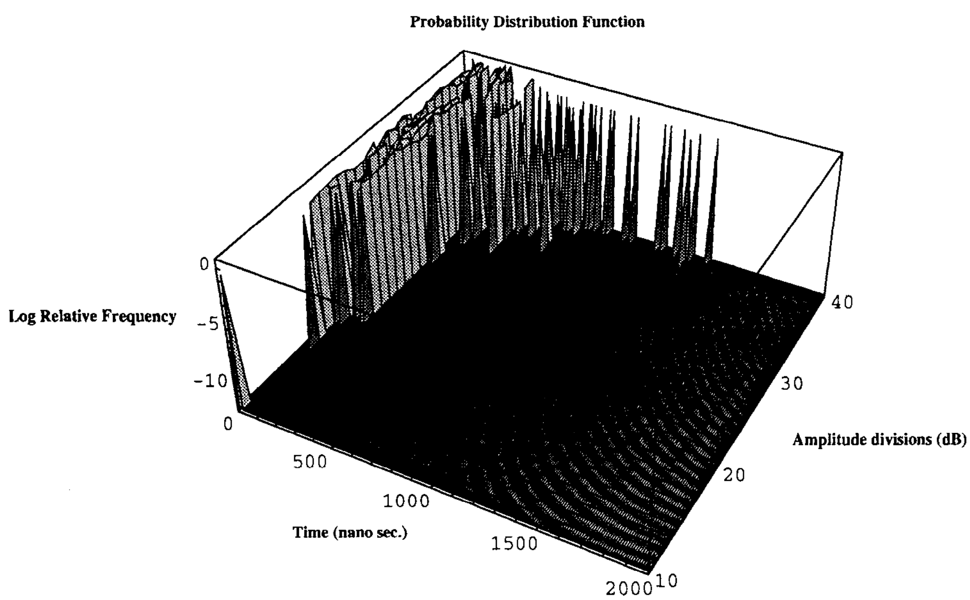


Figure S-10: Home wiring distribution of echoes (408 - 546 MHz).

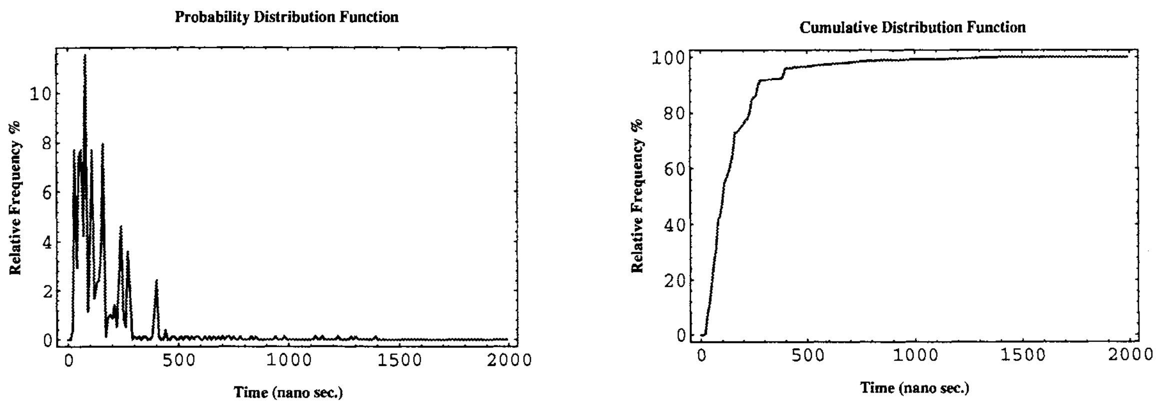


Figure S-11: Home wiring histogram of echo delays (408 - 546 MHz).

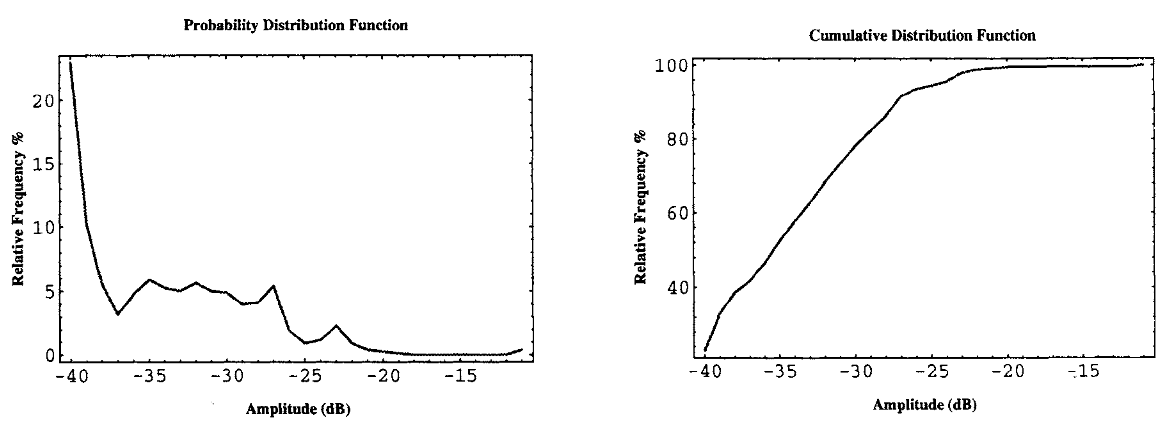


Figure S-12: Home wiring histogram of echo amplitudes (408 - 546 MHz).

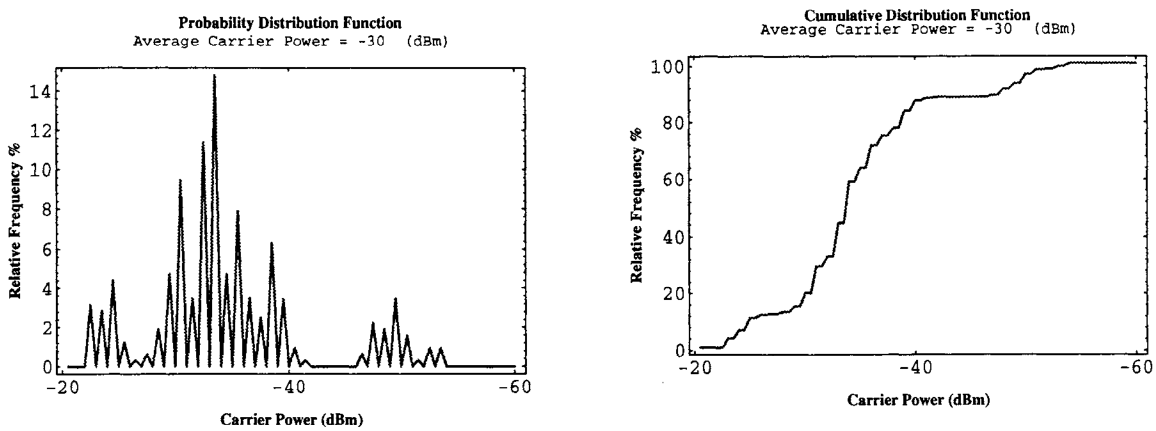


Figure S-13: Tap histogram of carrier power (408 - 546 MHz).

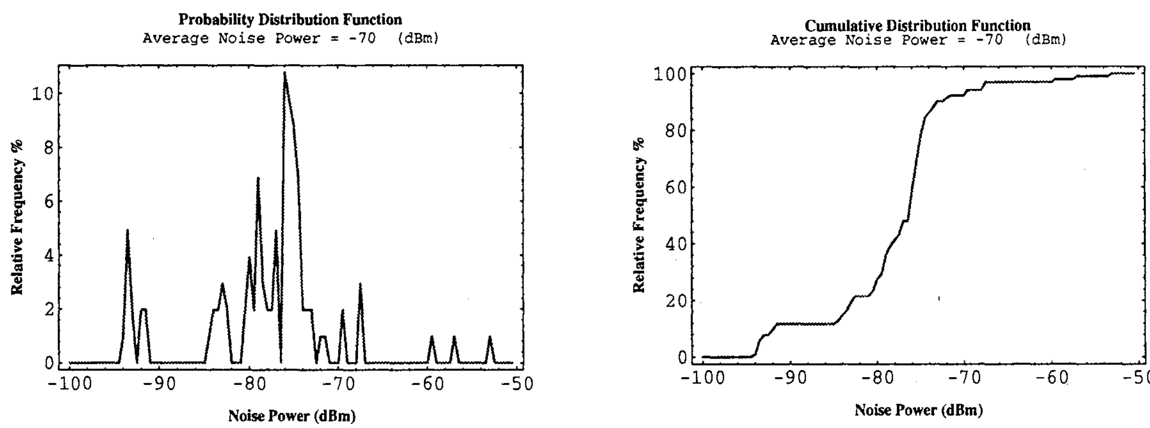


Figure S-14: Tap histogram of noise power (408 - 546 MHz).

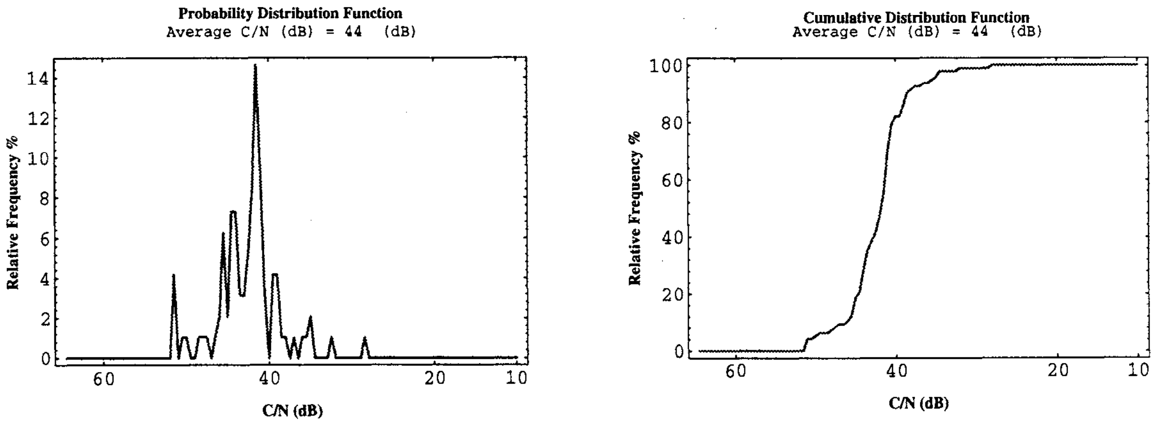


Figure S-15: Tap histogram of carrier-to-noise ratio (408 - 546 MHz).

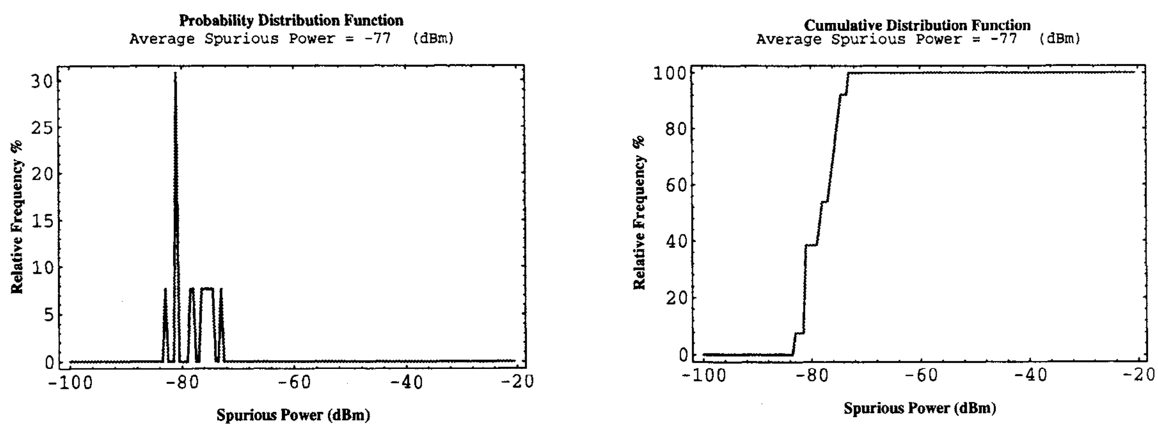


Figure S-16: Tap histogram of spurious components (408 - 546 MHz).

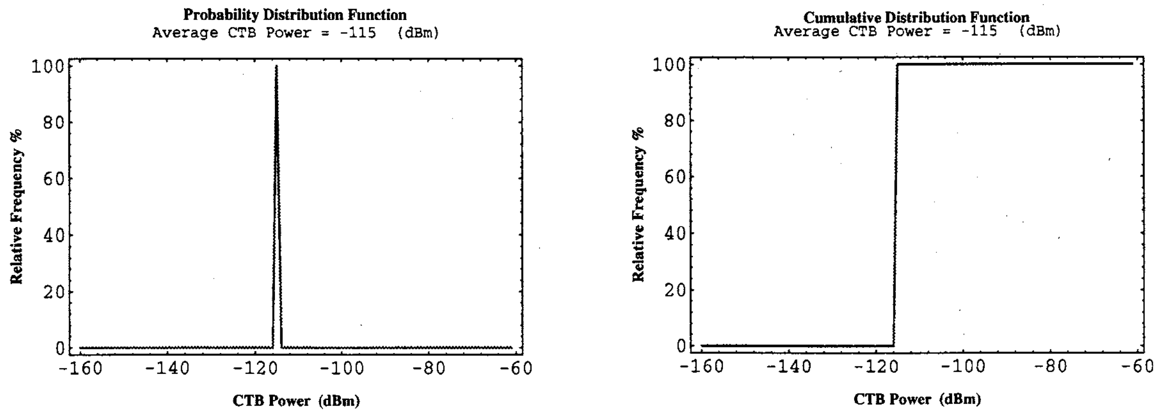


Figure S-17: Tap histogram of composite triple beats (408 - 546 MHz).

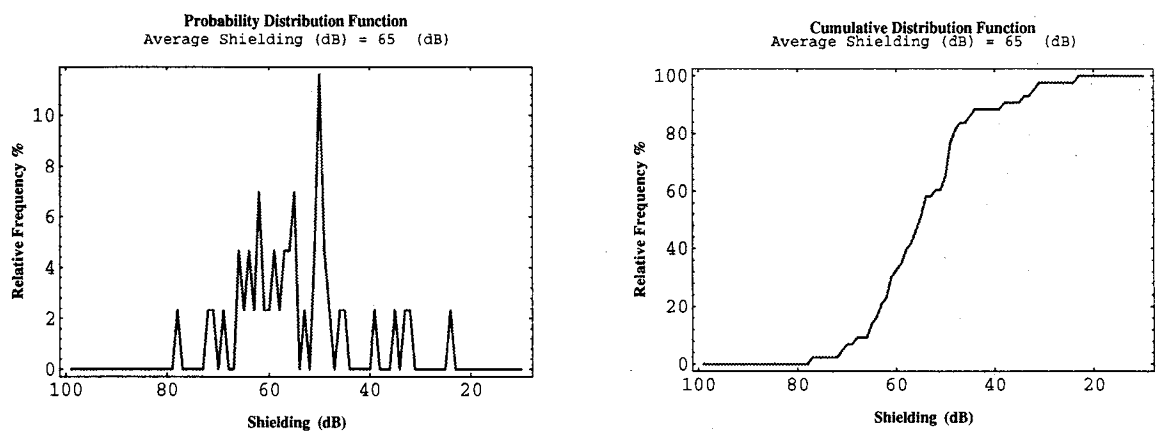


Figure S-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

APPENDIX T. RESULTS FOR CABLE SYSTEM T

Table T-1: Micro-Reflection Impairments Summary for Cable System T.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 462 - 516 MHz				
Delay (nanosecond)	290	640	740	1040
Amplitude (dB)	-37	-29	-26	-23
Headend Thru Home Outlet:				
Frequency: 462 - 516 MHz				
Delay (nanosecond)	260	640	690	1040
Amplitude (dB)	-36	-29	-26	-23
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	170	440	720	820
Amplitude (dB)	-39	-21	-19	-18
Home Wiring:				
Frequency: 462 - 516 MHz				
Delay (nanosecond)	190	660	880	1310
Amplitude (dB)	-38	-31	-27	-18

Table T-2: Noise/Interference Impairments Summary for Cable System T.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 462 - 516 MHz					
Carrier/Noise (dB)	44	43	39	36	27
Carrier Power (dBm)	-31	-36	-40	-41	-46
Noise Power (dBm) in 6 MHz Bandwidth	-73	-78	-70	-68	-62
Spurious Power (dBm) in 6 MHz Bandwidth	-76	-79	-71	-71	-71
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-71	-75	-67	-66	-61
CTB Power (dBm) 12 MHz above the last active channel	-108	-111	-103	-102	-102
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	68	58	47	43	37

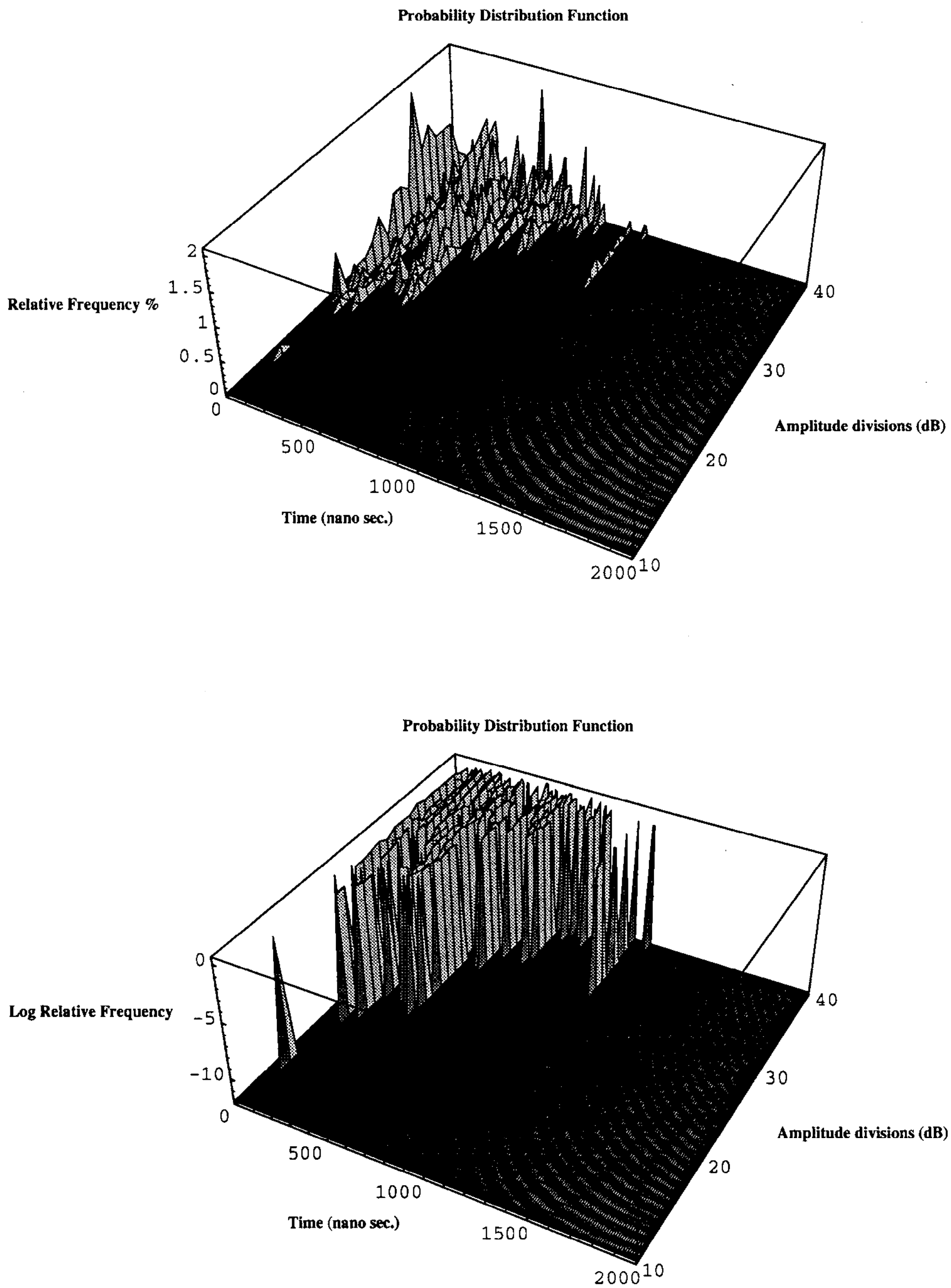


Figure T-1: Tap distribution of echoes (462 - 516 MHz).

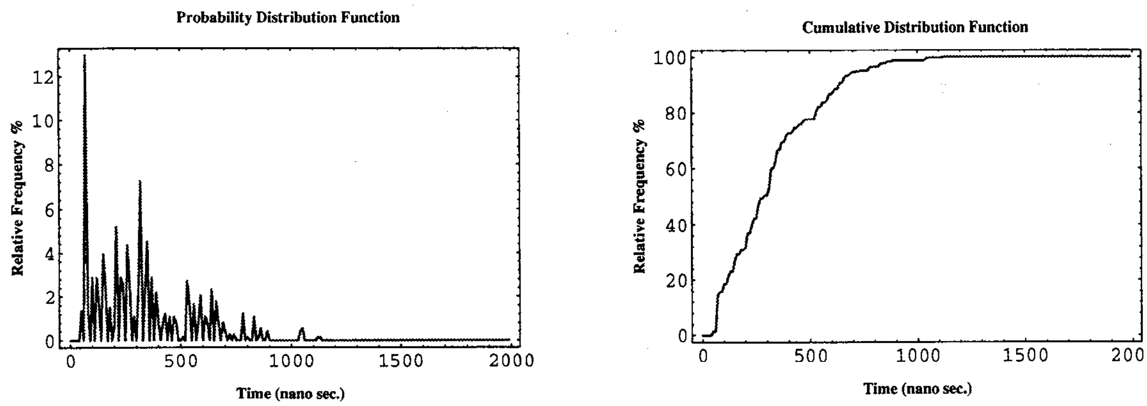


Figure T-2: Tap histogram of echo delays (462 - 516 MHz).

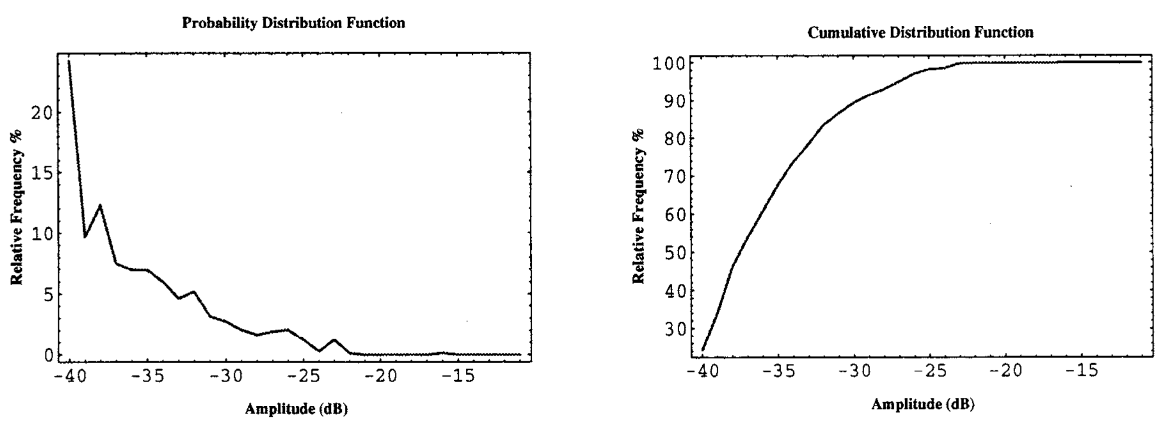
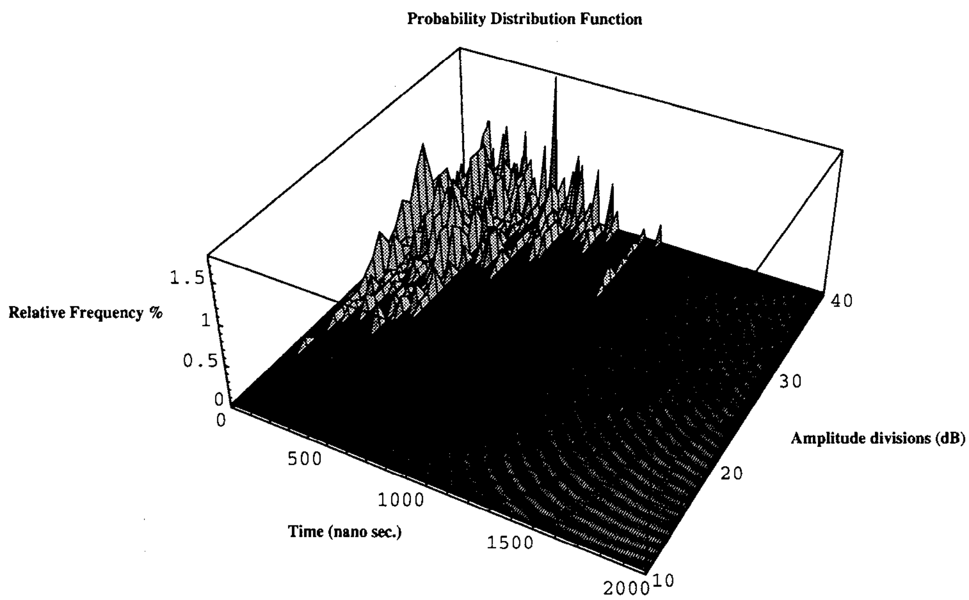


Figure T-3: Tap histogram of echo amplitudes (462 - 516 MHz)



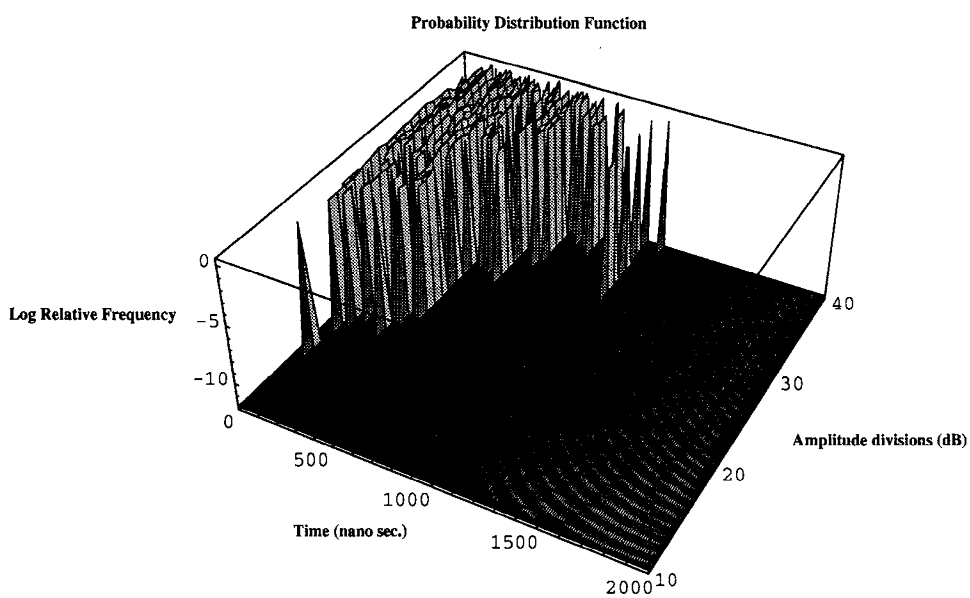


Figure T-4: Home outlet distribution of echoes (462 - 516 MHz).

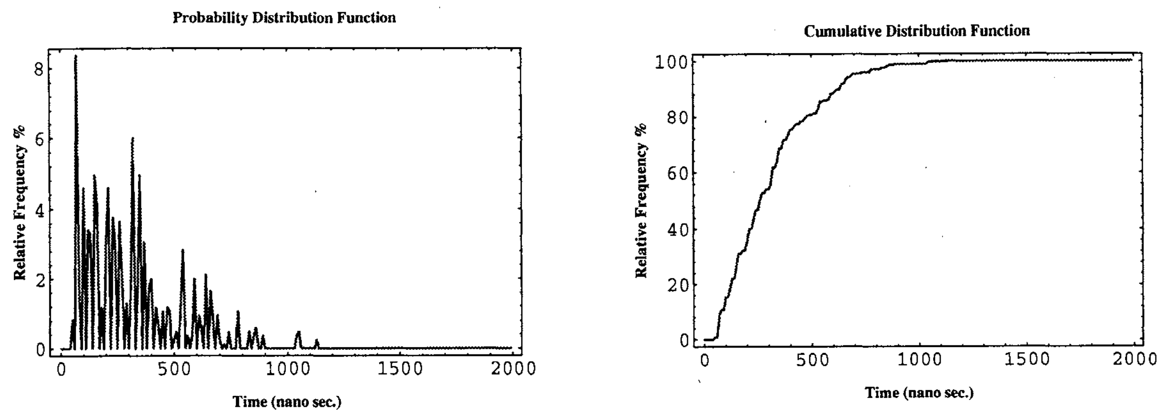


Figure T-5: Home outlet histogram of echo delays (462 - 516 MHz).

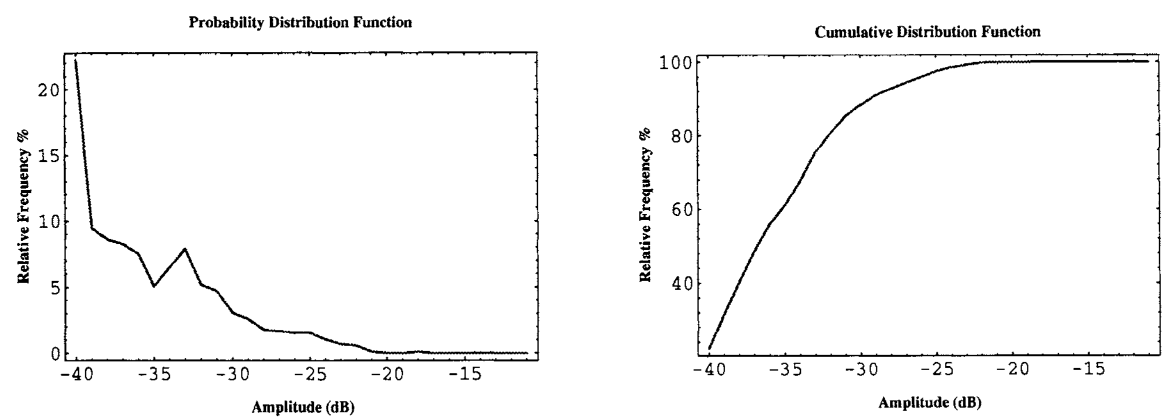
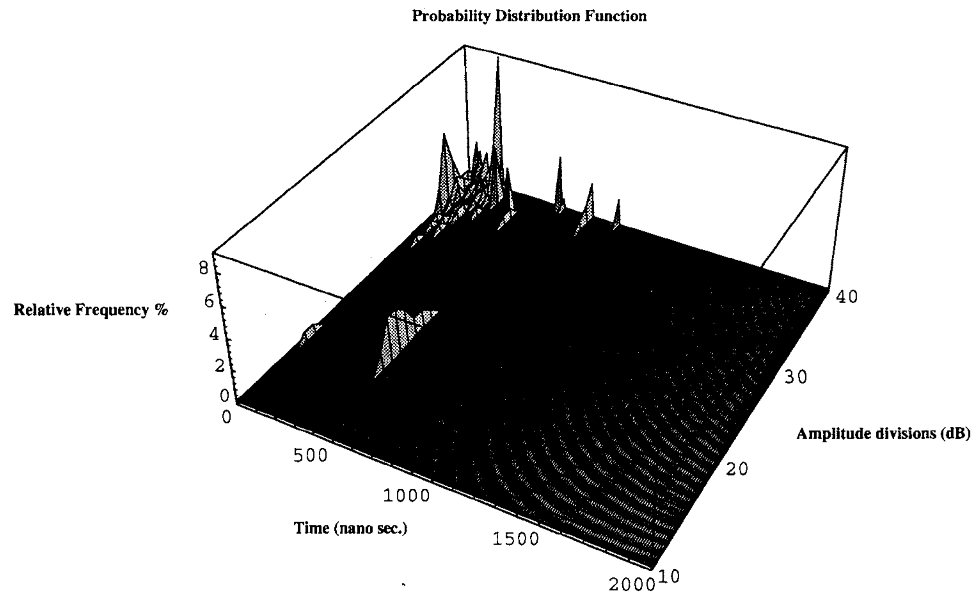


Figure T-6: Home outlet histogram of echo amplitudes (462 - 516 MHz).



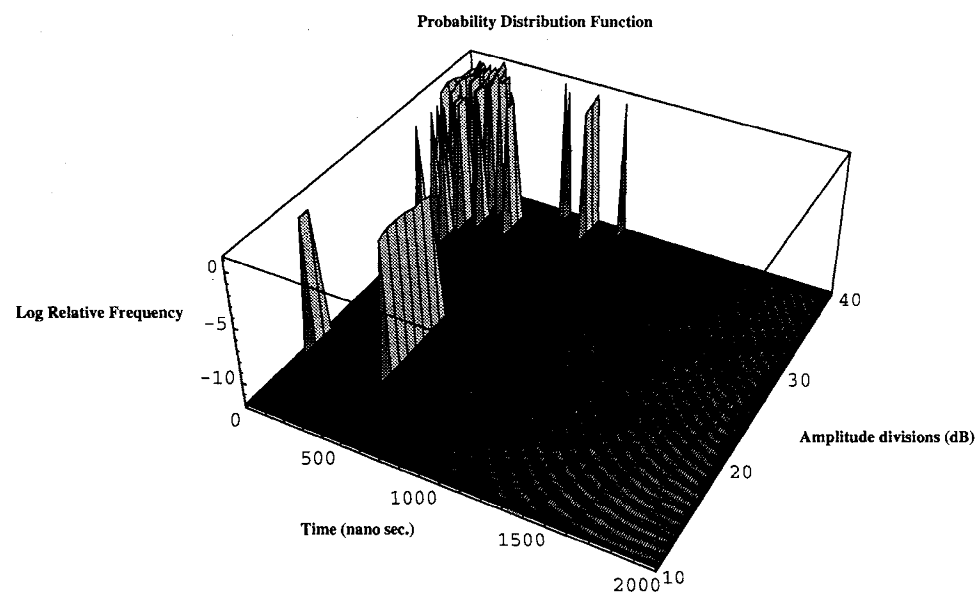


Figure T-7: Home wiring distribution of echoes (50 - 200 MHz).

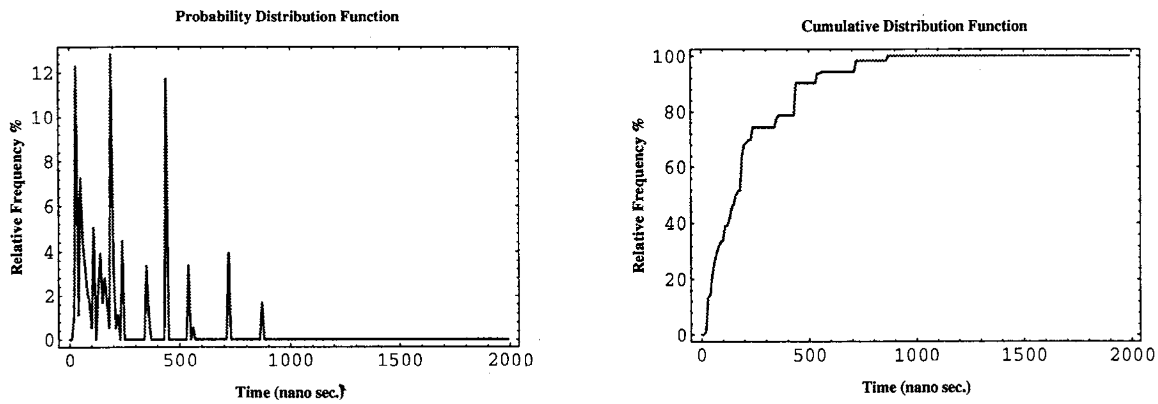


Figure T-8: Home wiring histogram of echo delays (50 - 200 MHz).

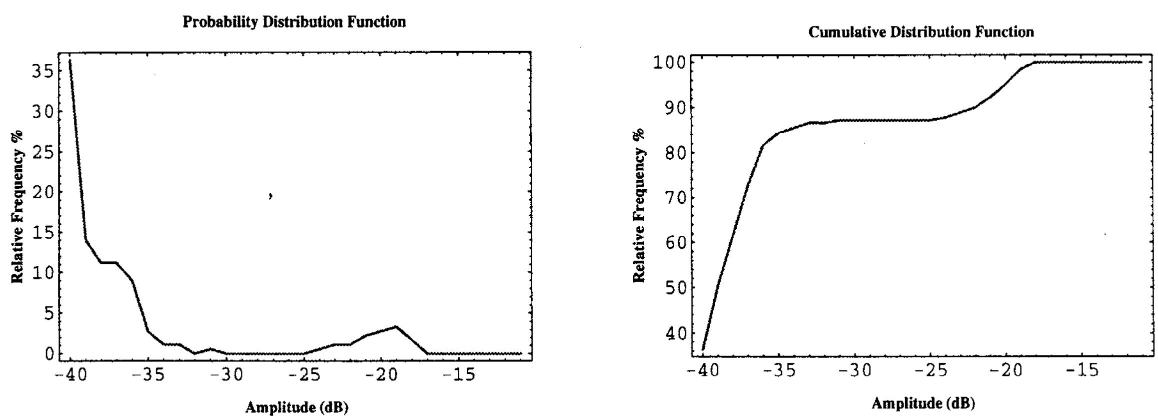


Figure T-9: Home wiring histogram of echo amplitudes (50 - 200 MHz).

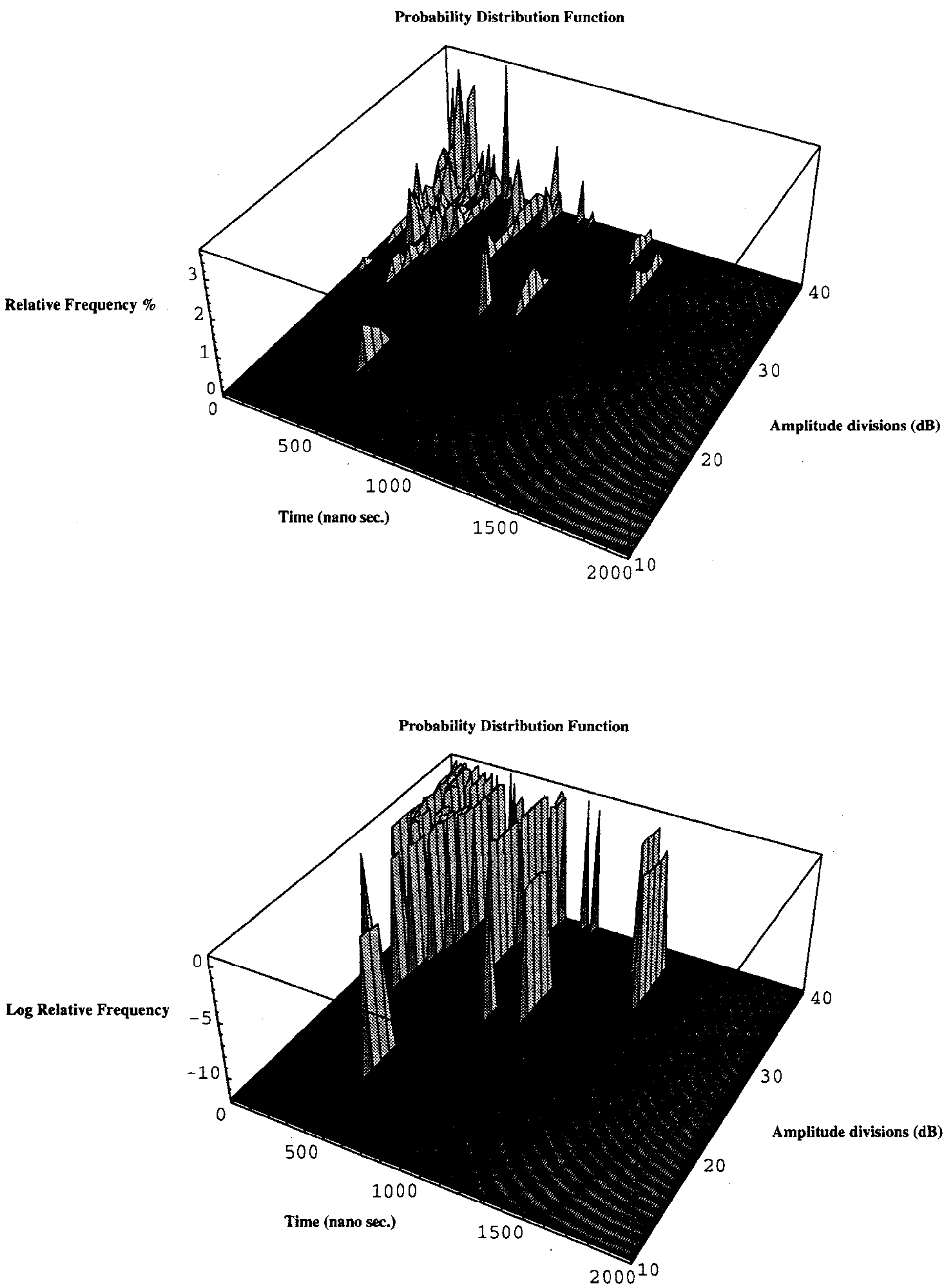


Figure T-10: Home wiring distribution of echoes (462 - 516 MHz).

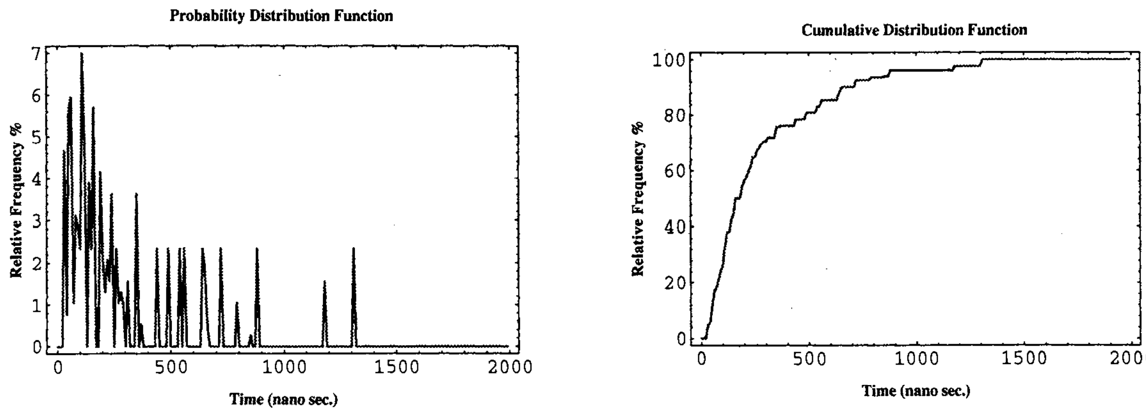


Figure T-11: Home wiring histogram of echo delays (462 - 516 MHz).

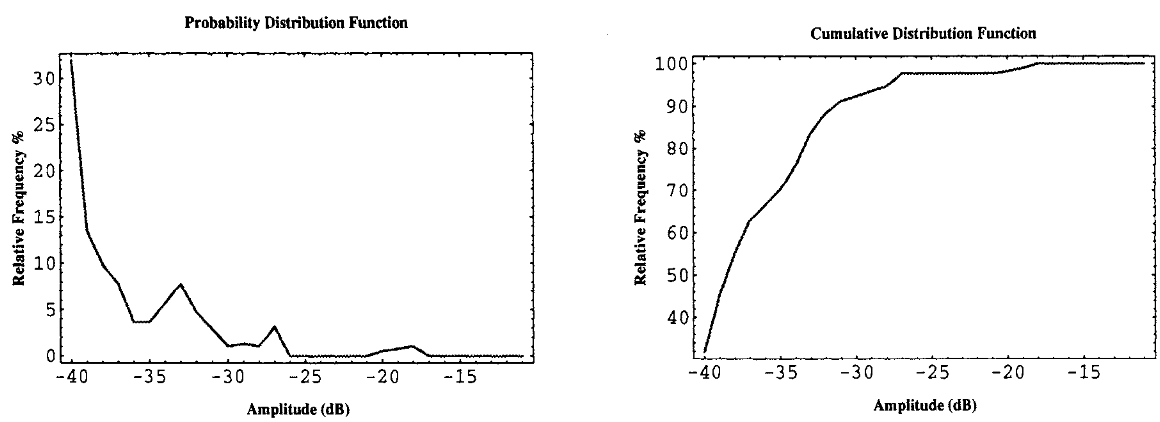


Figure T-12: Home wiring histogram of echo amplitudes (462 - 516 MHz).

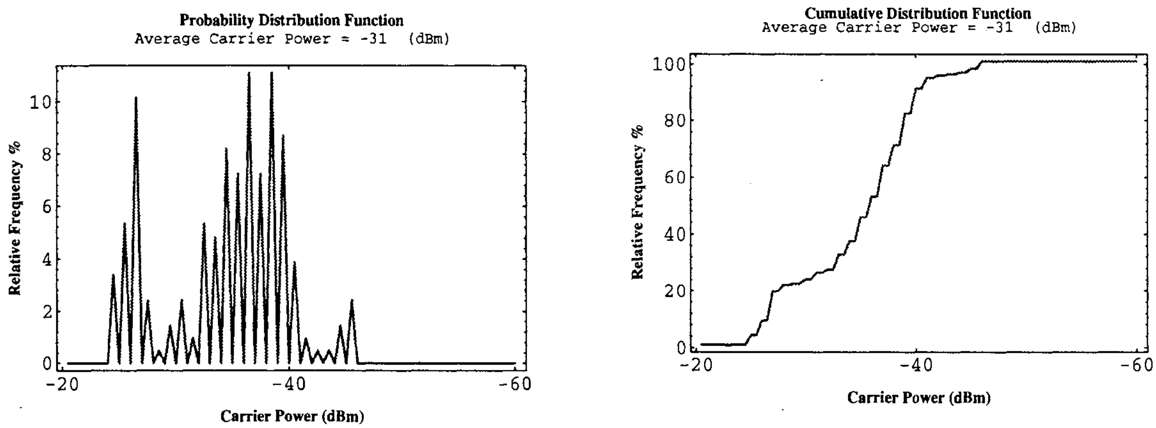


Figure T-13: Tap histogram of carrier power (462 - 516 MHz).

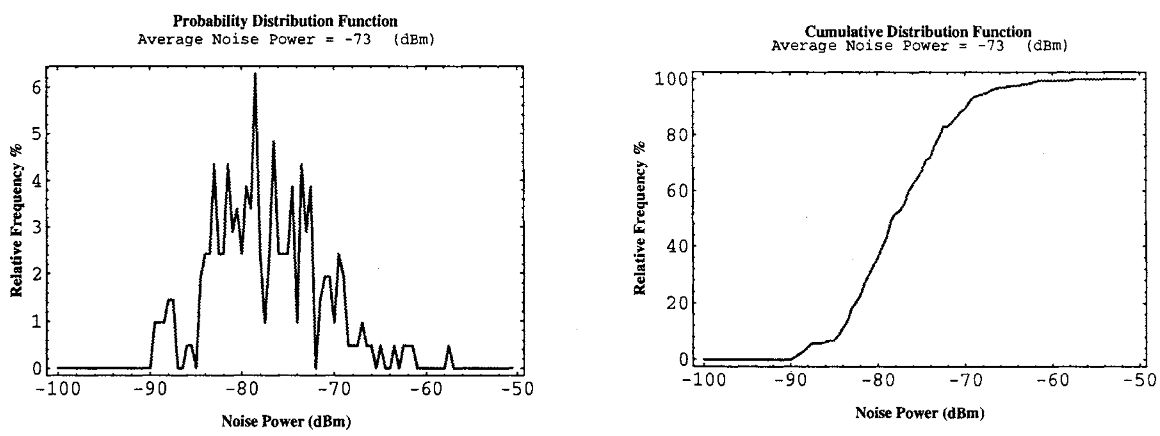


Figure T-14: Tap histogram of noise power (462 - 516 MHz).

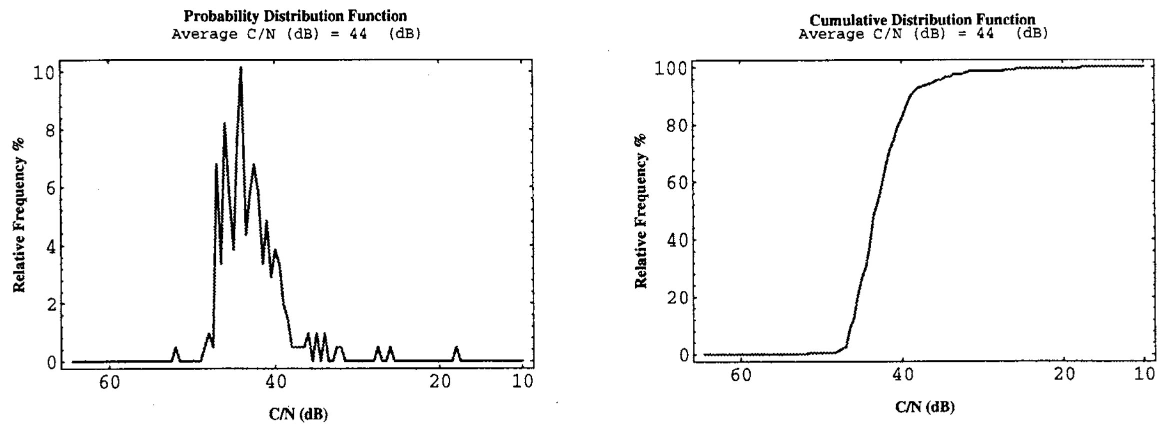


Figure T-15: Tap histogram of carrier-to-noise ratio (462 - 516 MHz).

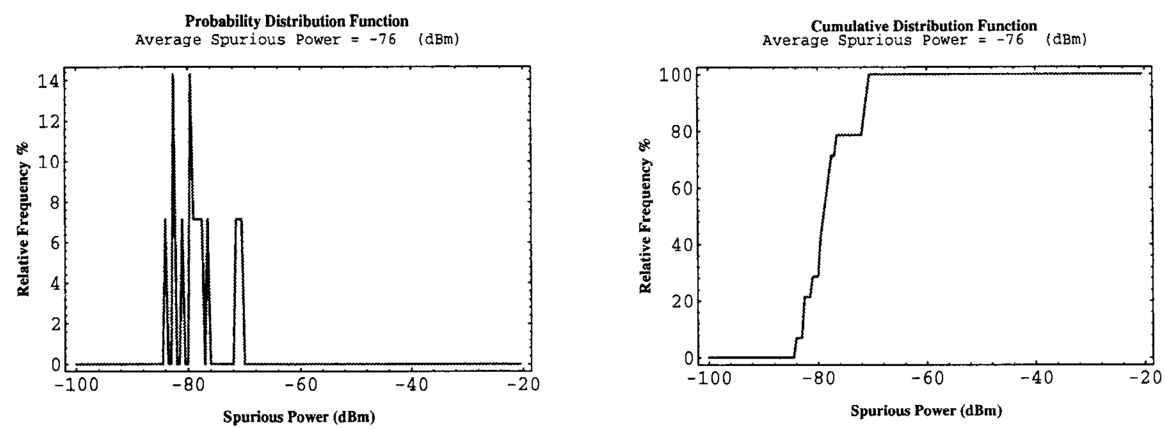


Figure T-16: Tap histogram of spurious components (462 - 516 MHz).

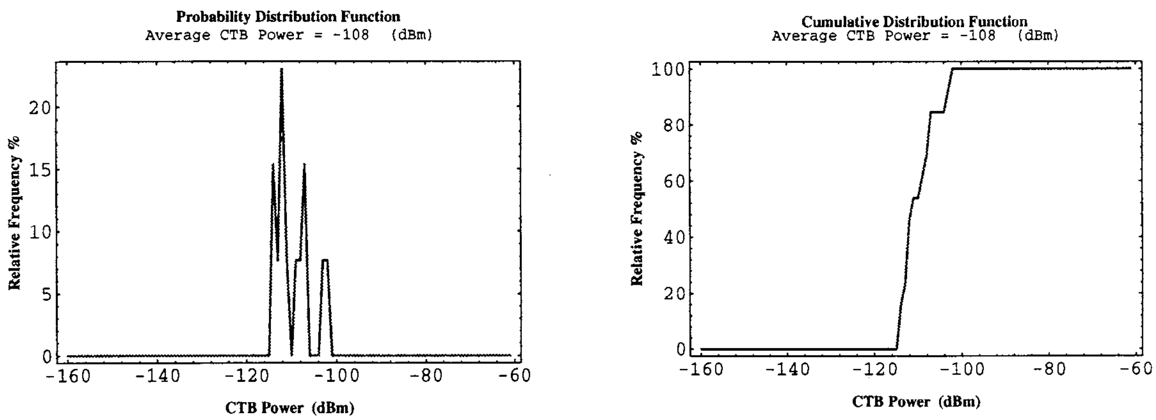


Figure T-17: Tap histogram of composite triple beats (462 - 516 MHz).

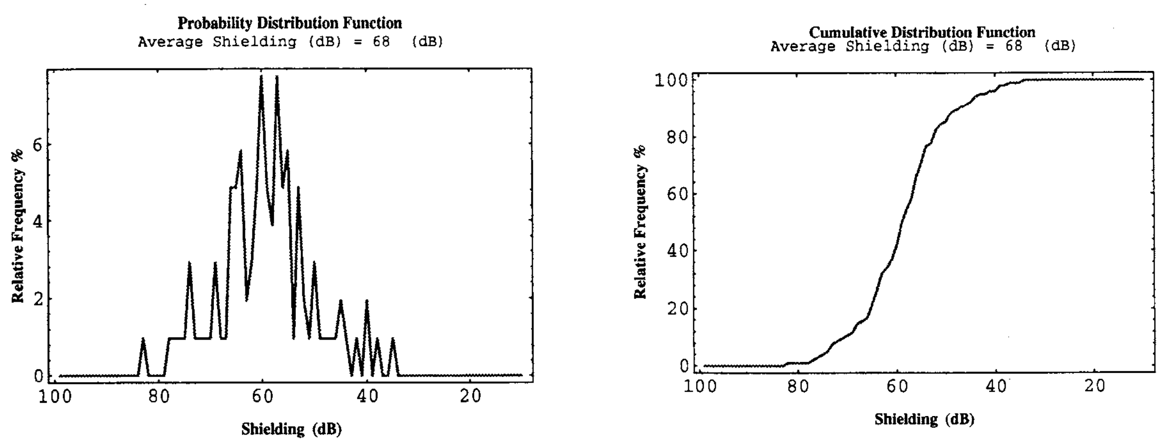


Figure T-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).

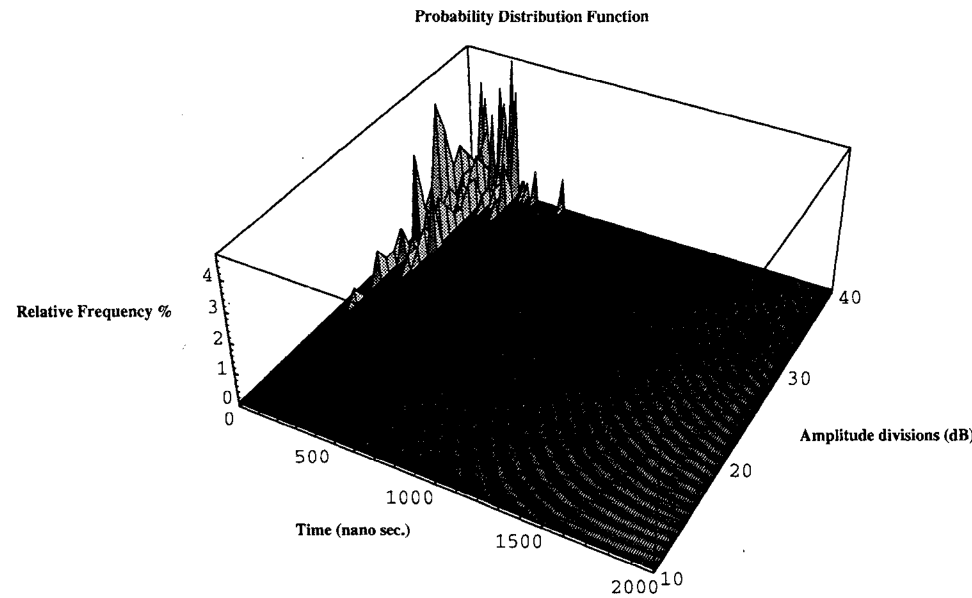
APPENDIX U. RESULTS FOR CABLE SYSTEM U

Table U-1: Micro-Reflection Impairments Summary for Cable System U.

Micro-Reflection Impairments	50%	90%	95%	99%
Headend Thru Tap:				
Frequency: 306 - 444 MHz				
Delay (nanosecond)	110	260	270	540
Amplitude (dB)	-38	-31	-29	-26
Headend Thru Home Outlet:				
Frequency: 306 - 444 MHz				
Delay (nanosecond)	200	430	540	630
Amplitude (dB)	-35	-25	-22	-18
Home Wiring:				
Frequency: 50 - 200 MHz				
Delay (nanosecond)	160	360	490	720
Amplitude (dB)	-34	-21	-16	-11
Home Wiring:				
Frequency: 306 - 444 MHz				
Delay (nanosecond)	150	350	380	760
Amplitude (dB)	-35	-25	-22	-19

Table U-2: Noise/Interference Impairments Summary for Cable System U.

Noise / Interference Impairments	Average	50%	90%	95%	99%
Frequency: 306 - 444 MHz					
Carrier/Noise (dB)	46	46	43	41	40
Carrier Power (dBm)	-35	-35	-43	-44	-59
Noise Power (dBm) in 6 MHz Bandwidth	-81	-82	-79	-78	-77
Spurious Power (dBm) in 6 MHz Bandwidth	-84	-84	-83	-83	-83
Noise + Spurious Power (dBm) in 6 MHz Bandwidth	-79	-80	-78	-77	-76
CTB Power (dBm) 12 MHz above the last active channel	-102	-107	-99	-95	-95
Frequency: 88 - 108 MHz					
Home Wiring Shielding (dB)	55	45	38	35	35



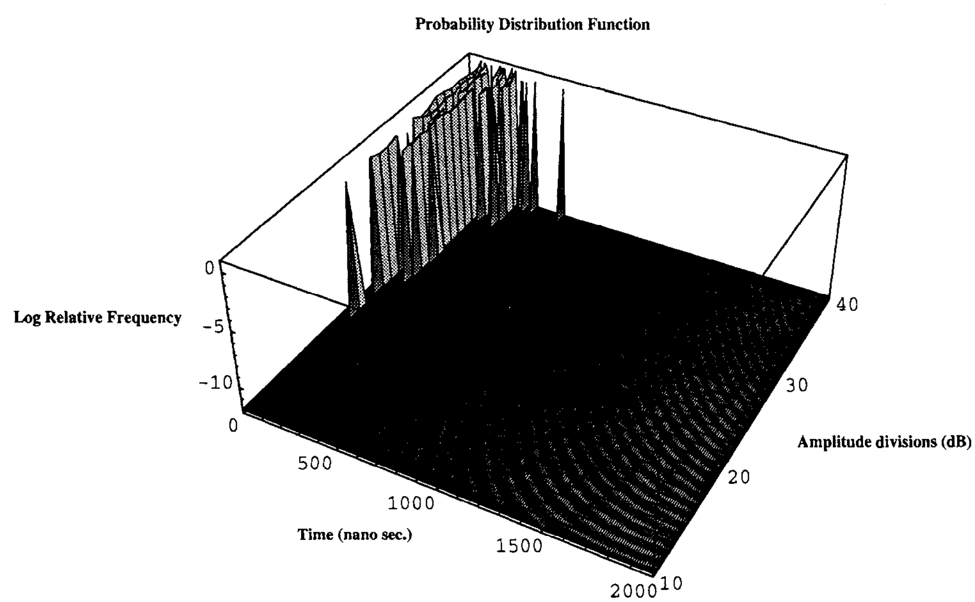


Figure U-1: Tap distibution of echoes (306 - 444 MHz).

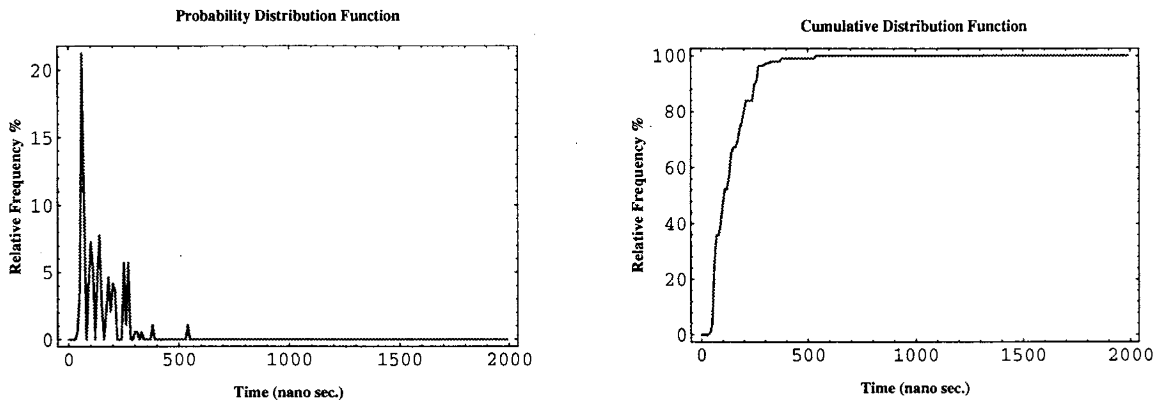


Figure U-2: Tap histogram of echo delays (306 - 444 MHz).

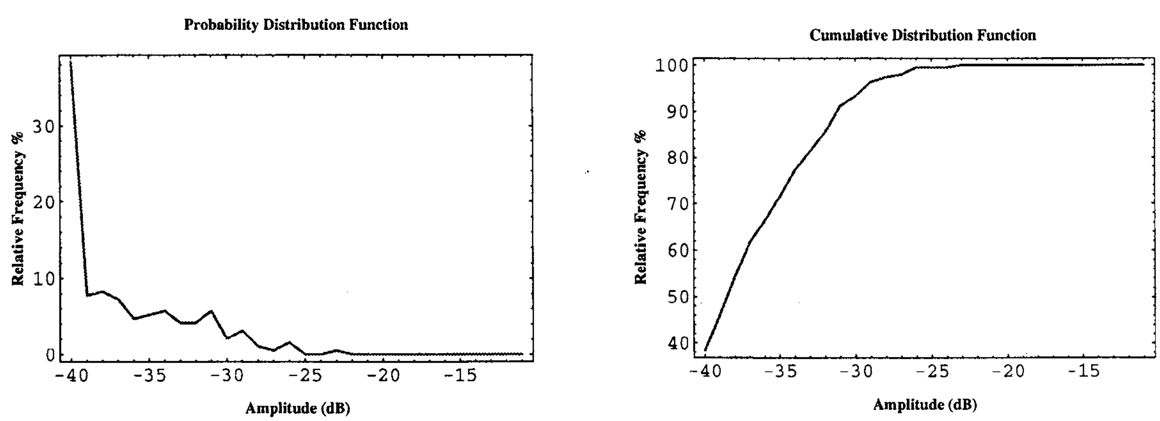
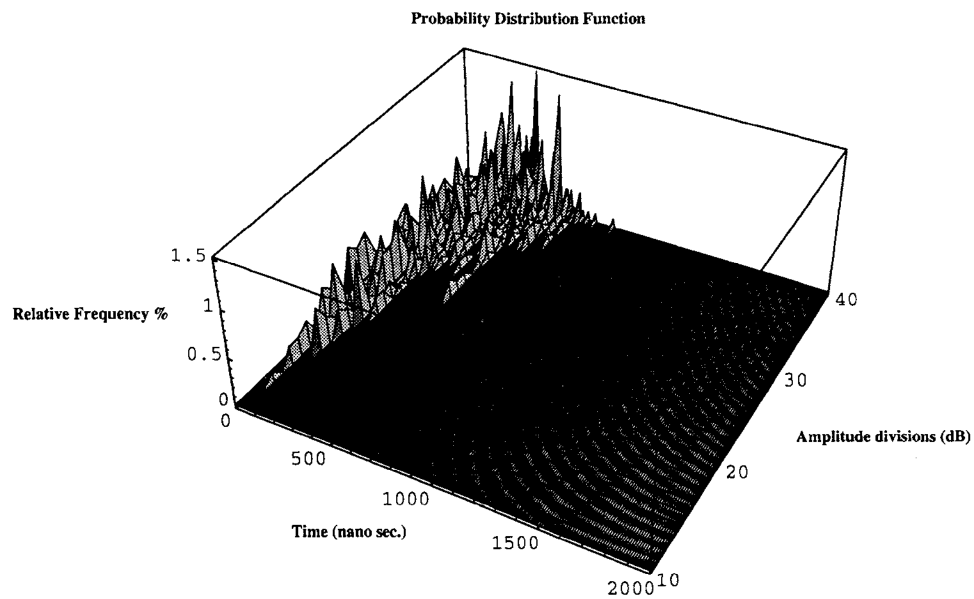


Figure U-3: Tap histogram of echo amplitudes (306 - 444 MHz).



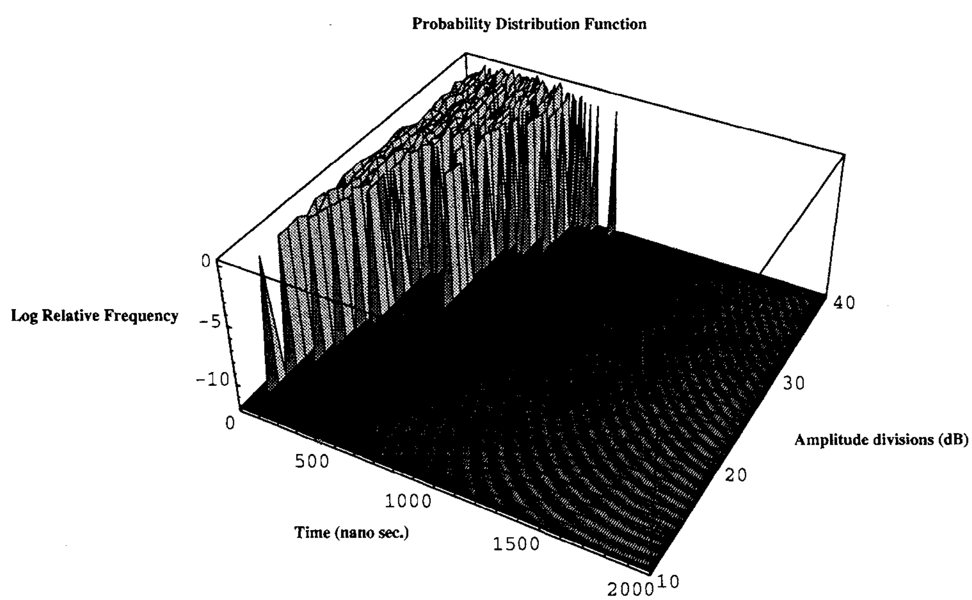


Figure U-4: Home outlet distribution of echoes (306 - 444 MHz).

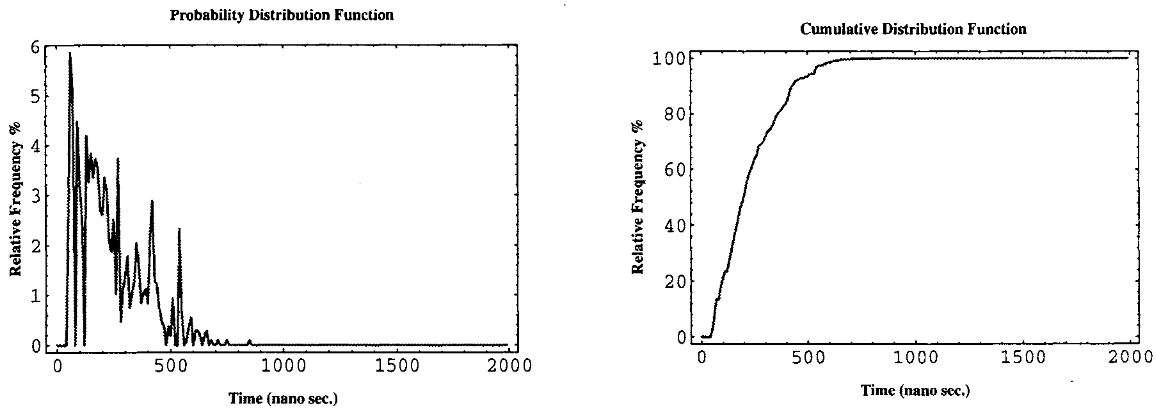


Figure U-5: Home outlet histogram of echo delays (306 - 444 MHz).

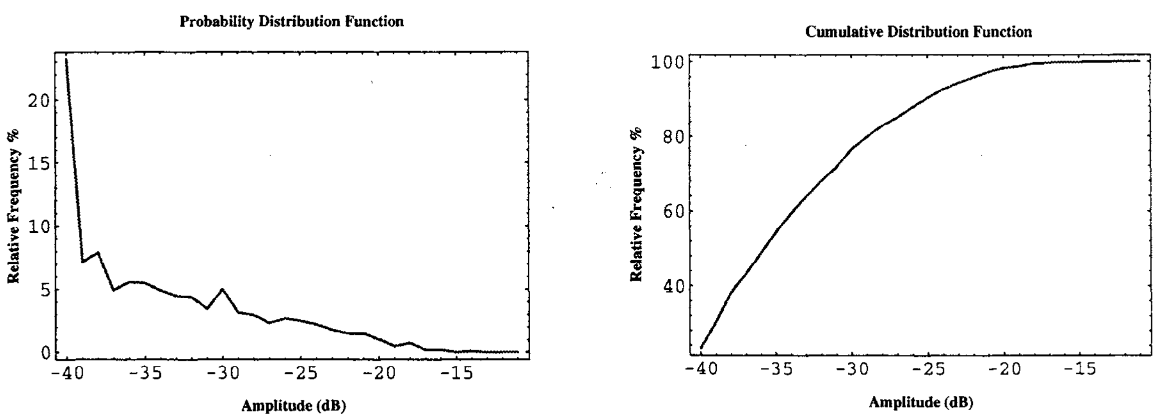
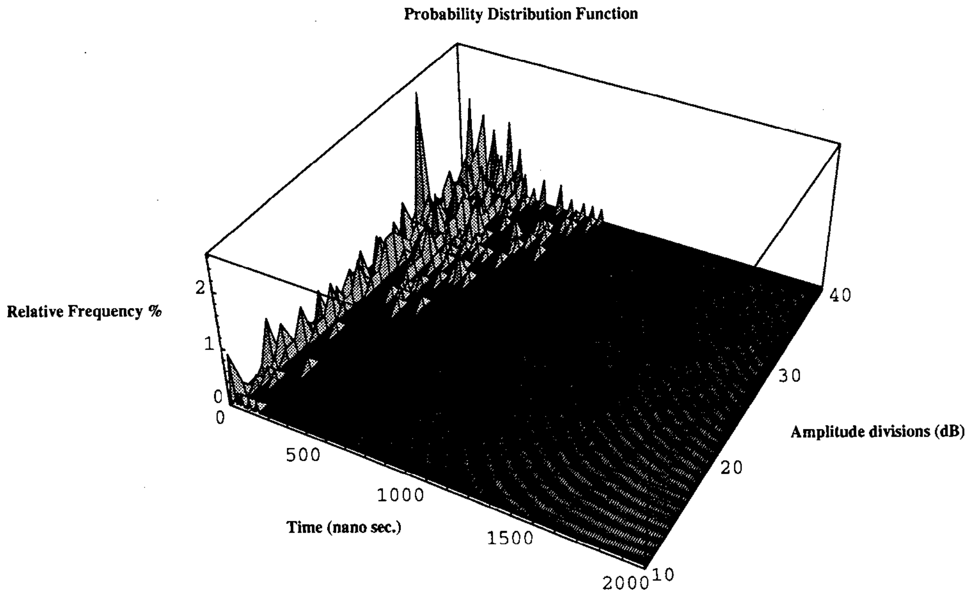


Figure U-6: Home outlet histogram of echo amplitudes (306 - 444 MHz).



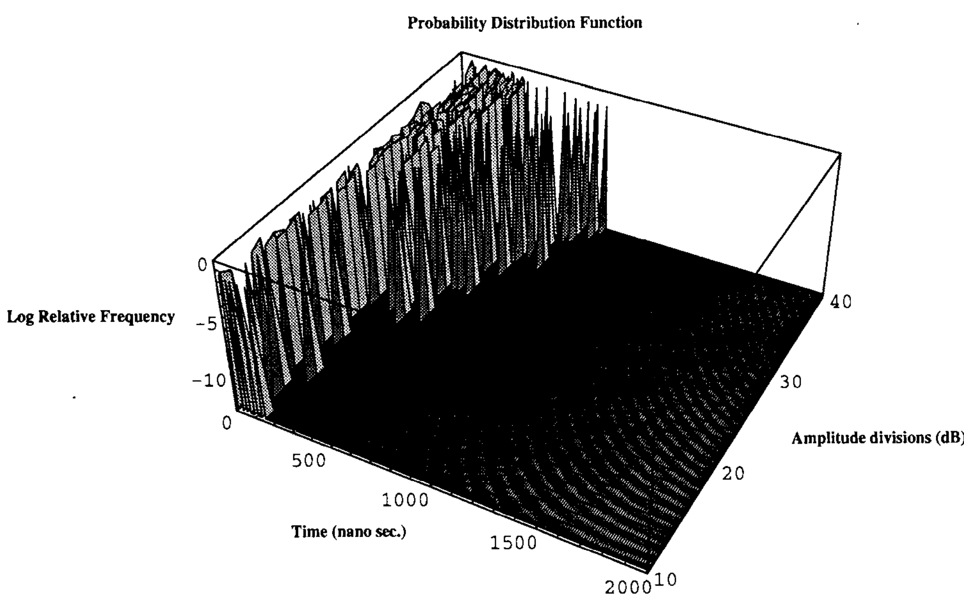


Figure U-7: Home wiring distribution of echoes (50 - 200 MHz).

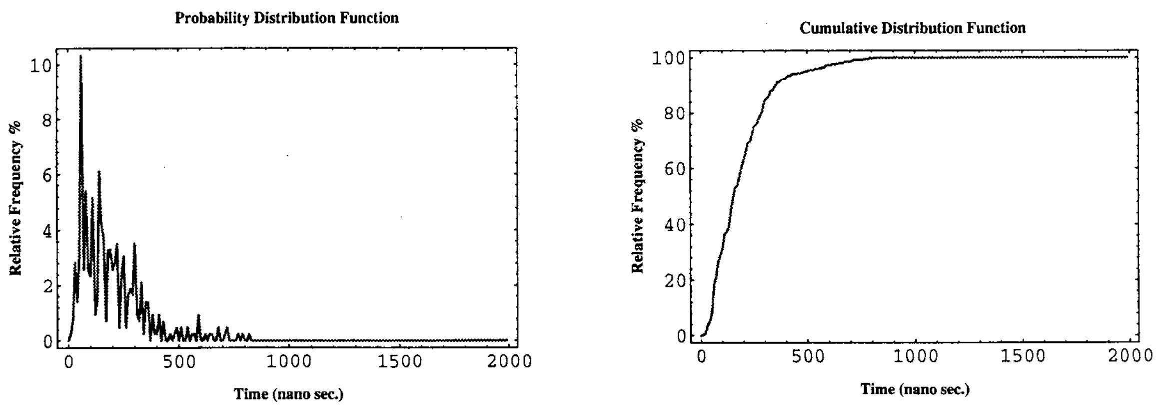


Figure U-8: Home wiring histogram of echo delays (50 - 200 MHz).

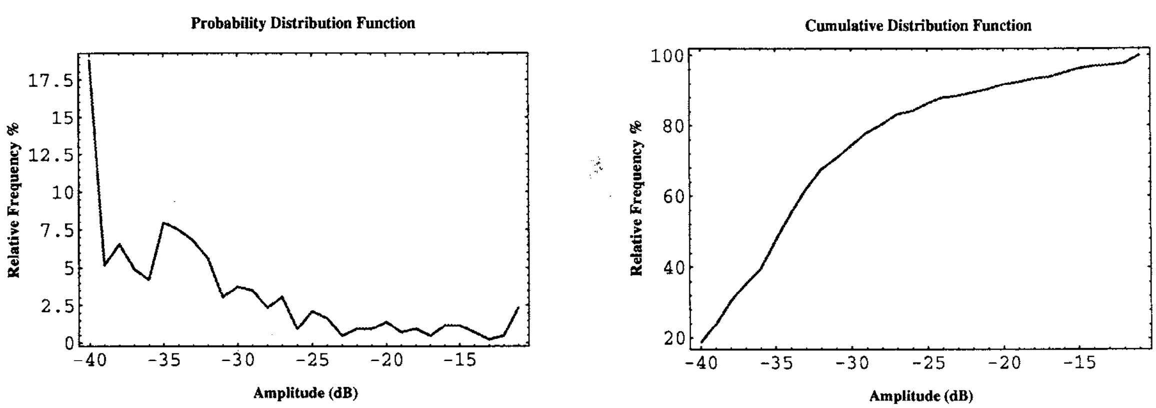
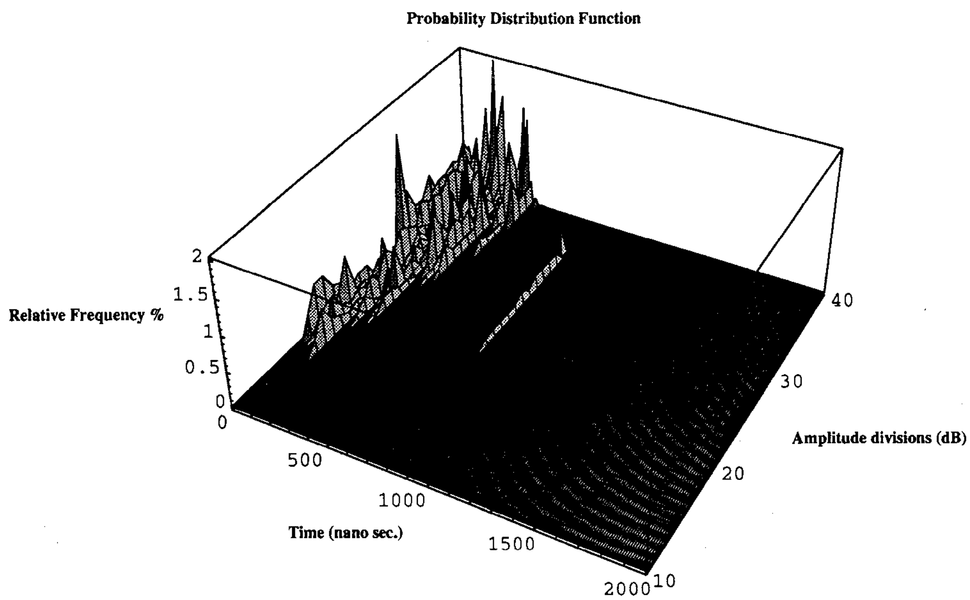


Figure U-9: Home wiring histogram of echo amplitudes (50 - 200 MHz).



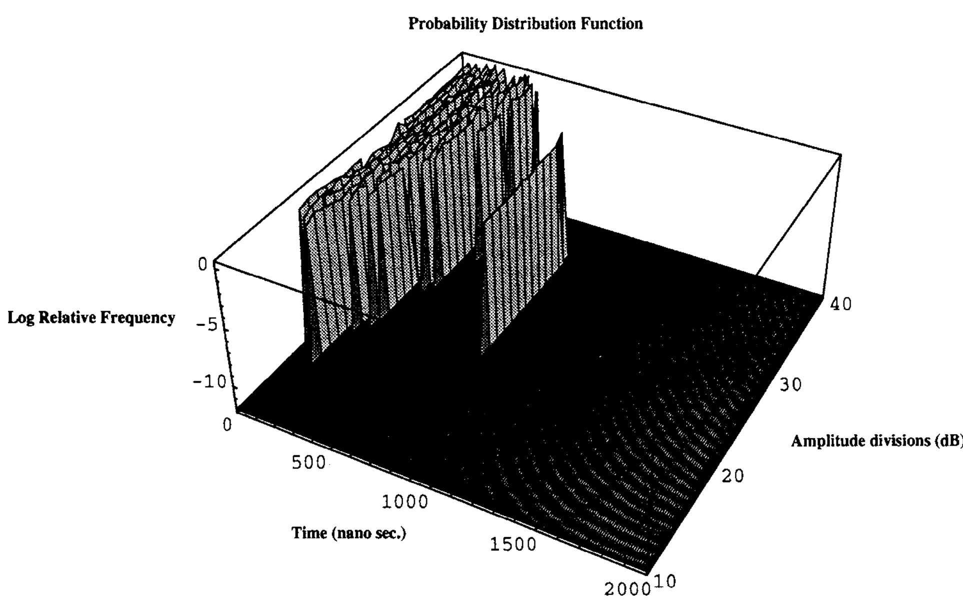


Figure U-10: Home wiring distribution of echoes (306 - 444 MHz).

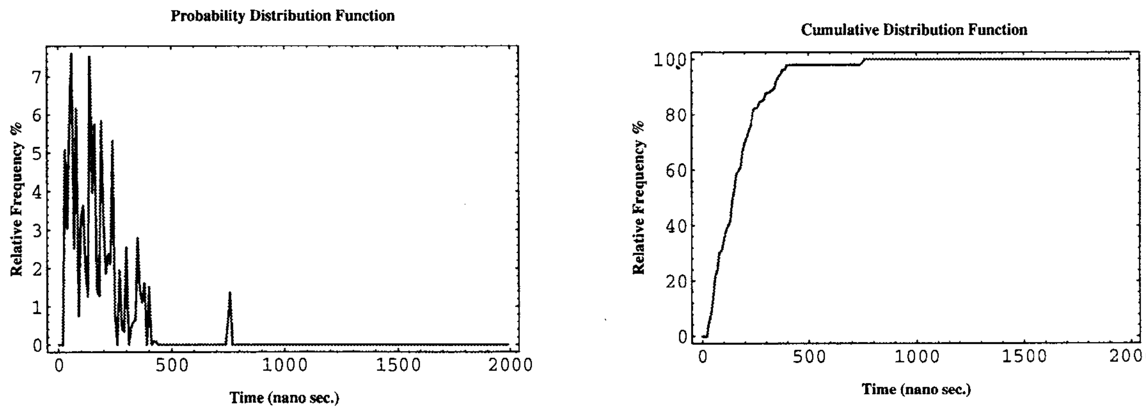


Figure U-11: Home wiring histogram of echo delays (306 - 444 MHz).

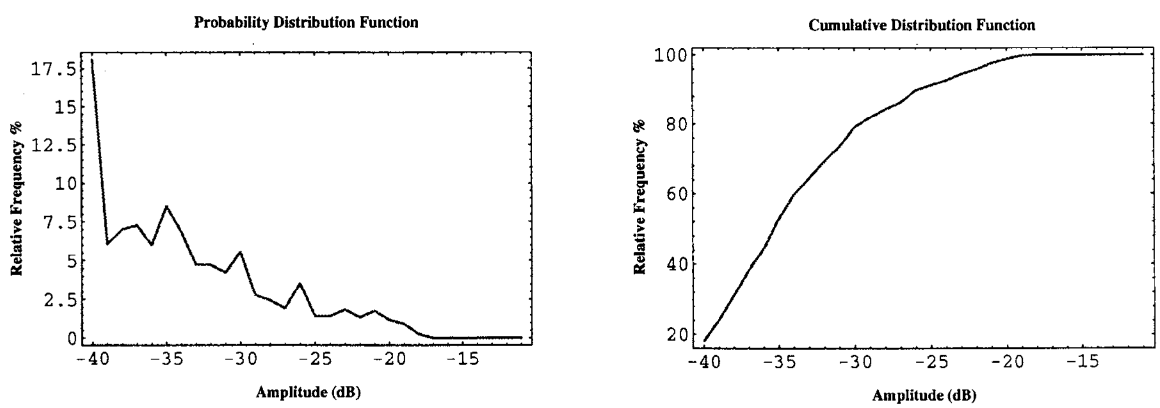


Figure U-12: Home wiring histogram of echo amplitudes (306 - 444 MHz).

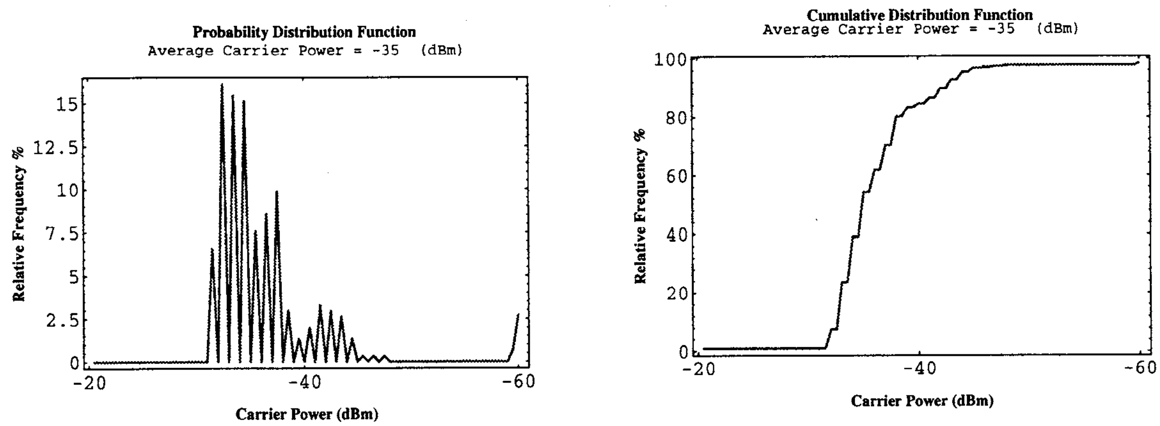


Figure U-13: Tap histogram of carrier power (306 - 444 MHz).

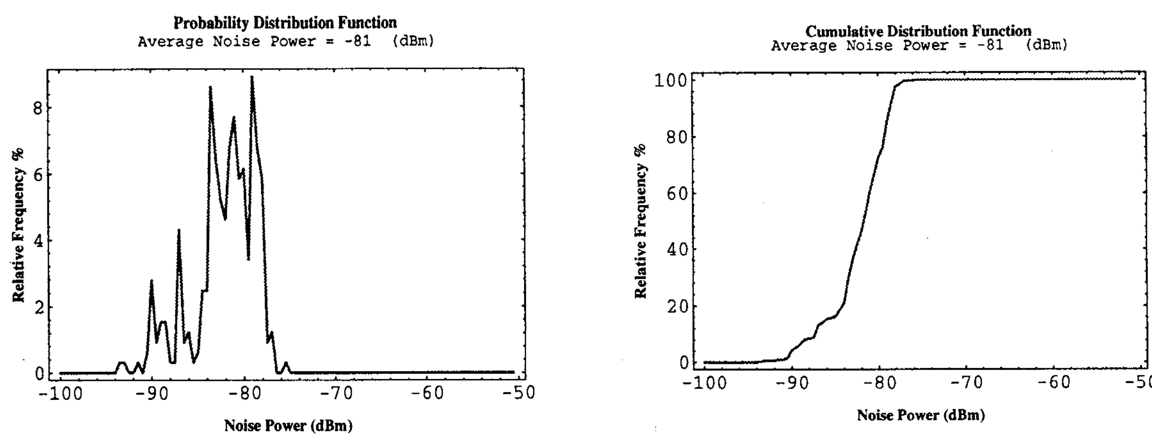


Figure U-14: Tap histogram of noise power (306 - 444 MHz).

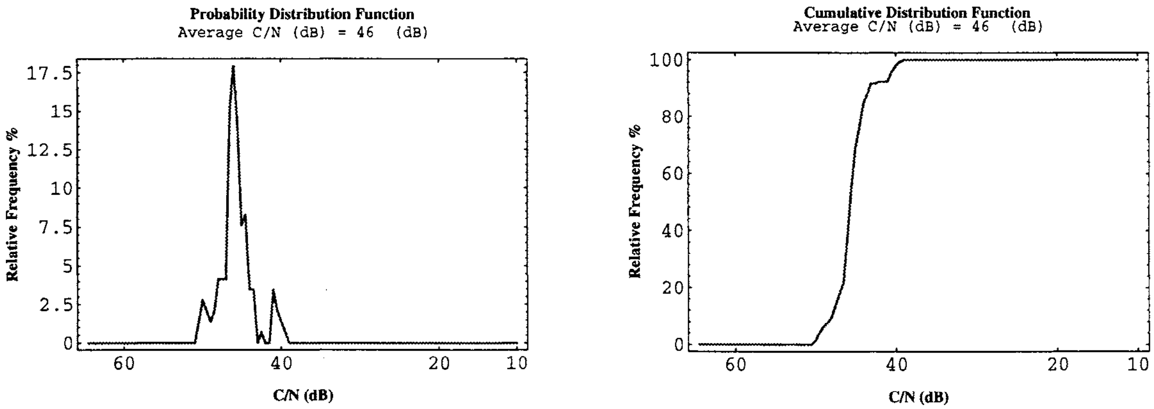


Figure U-15: Tap histogram of carrier-to-noise ratio (306 - 444 MHz).

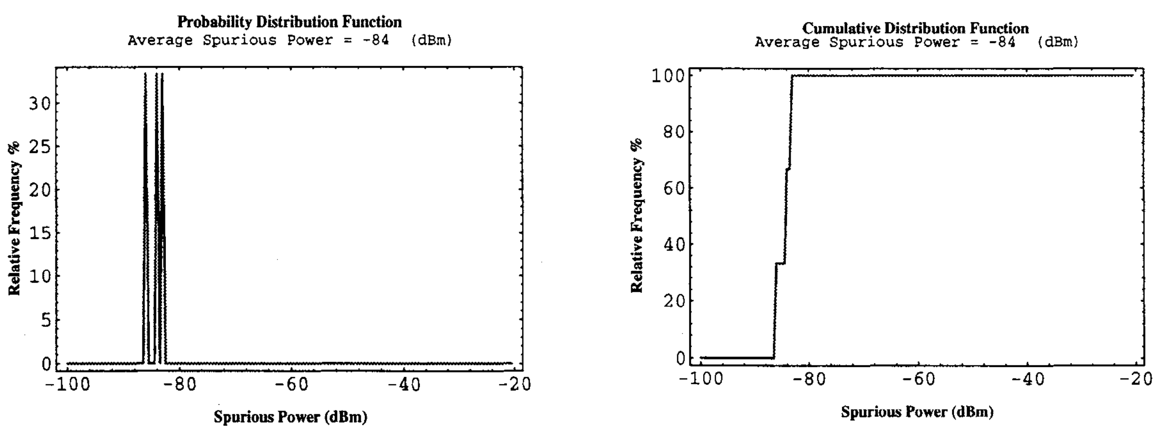


Figure U-16: Tap histogram of spurious components (306 - 444 MHz).

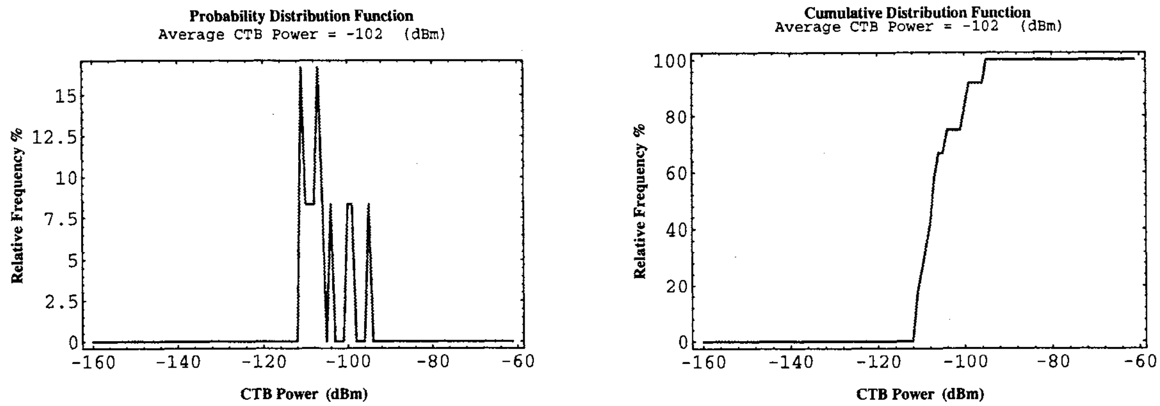


Figure U-17: Tap histogram of composite triple beats (306 - 444 MHz).

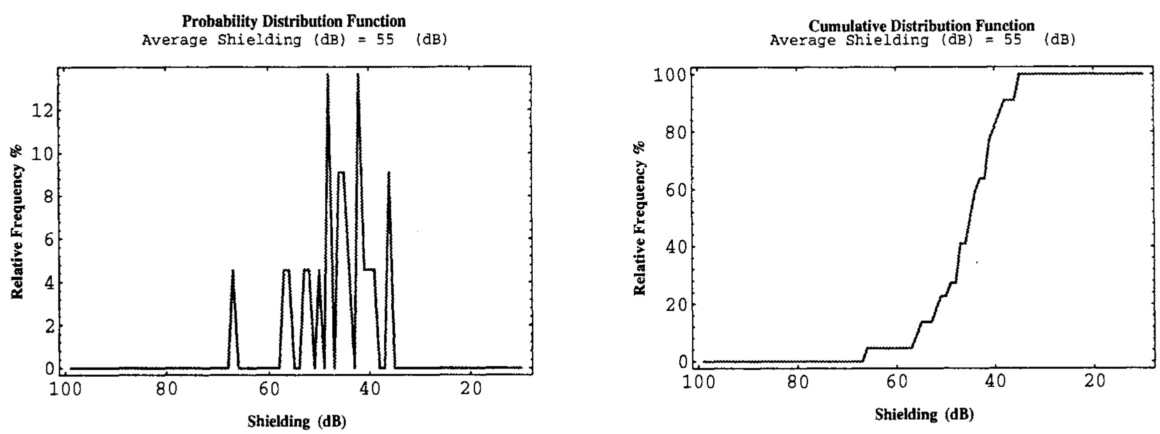


Figure U-18: Histogram of home wiring shielding effectiveness (88 - 108 MHz).