		NGSO Earth Station Collocated with the NGSO MSS Feeder Link Earth Station				NGSO Earth Station at 160 km separation from the NGSO MSS Feeder Link Earth Station			
		Probability of Interference (%)	Mean Interference Event Duration (sec)	Maximum Interference Event Duration (sec)	Mean Time Between Events (hr)	Probability of Interference (%)	Mean Interference Event Duration (sec)	Maximum Interference Event Duration (sec)	Mean Time Between Events (hr)
Standard Earth Station	Case 1	4.3	52.7	205	0.33	1.1	42.0	105	1.1
	Case 2	1.5	46.6	160	0.86	1.0	41.2	110	1.1
	Case 3	0.004	[B]	[B]	[B]	[A]	[A]	[A]	[A]
	Case 4	0.	0.	0.	NA	0.	0.	0.	NA
Mobile Earth Station	Case 1	20.0	67.4	295	0.072	3.4	59.7	195	0.47
	Case 2	1.5	46.6	160	0.86	1.0	41.2	110	1.1
	Case 3	0.004	[B]	[B]	[B]	[A]	[A]	[A]	[A]
	Case 4	0.	0.	0.	NA	0.	0.	0.	NA
High Rate Earth Station	Case 1	0.14	[B]	[B]	[B]	[A]	[A]	[A]	[A]
	Case 2	0.005	[B]	[B]	[B]	[A]	[A]	[A]	[A]
	Case 3	0.00007	[B]	[B]	[B]	[A]	[A]	[A]	[A]
	Case 4	0.	0.	0.	NA	0.	0.	0.	NA

Table 4.1

Note [A] : Interference event is theoretically possible for this case, but there was no such events detected during the simulation period

Note [B] : The number of interference events occurred during the simulation period is too small such that no significantly reliable statistics can be obtained from the data.

5. Conclusion

This paper presents statistical results that are useful in evaluating the potential for frequency sharing. However, the exact criteria for frequency sharing between the feeder links of a NGSO MSS system, and the FSS and MSS, Service and Feeder links of another NGSO Satellite System have not been defined.

The simulation results indicate a positive potential for sharing between the NGSO MSS Feeder Links and the NGSO Satellite System High Rate Links (FSS Service Links and FSS and MSS Feeder Links) with site separation between the respective Earth Stations. Additional work is required to determine the minimum separation requirement based on the acceptable interference levels.

The interference levels between the NGSO MSS Feeder Links and the NGSO Satellite Systems Standard and Mobile Links is higher. Earth station site separation reduces the interference problem but does not eliminate it. Additional work is required to determine the effect of other mitigation techniques in improving the sharing potential.

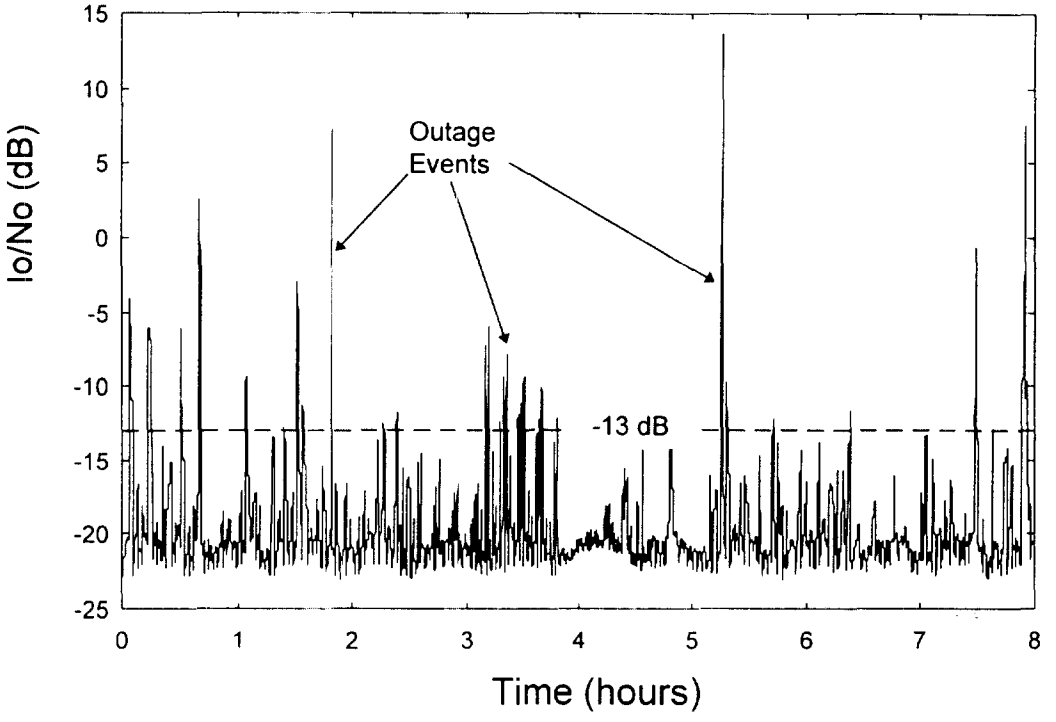

Figure 4.1 CASE 1, I_0/N_0 Time History, Collocated Standard Earth Station.

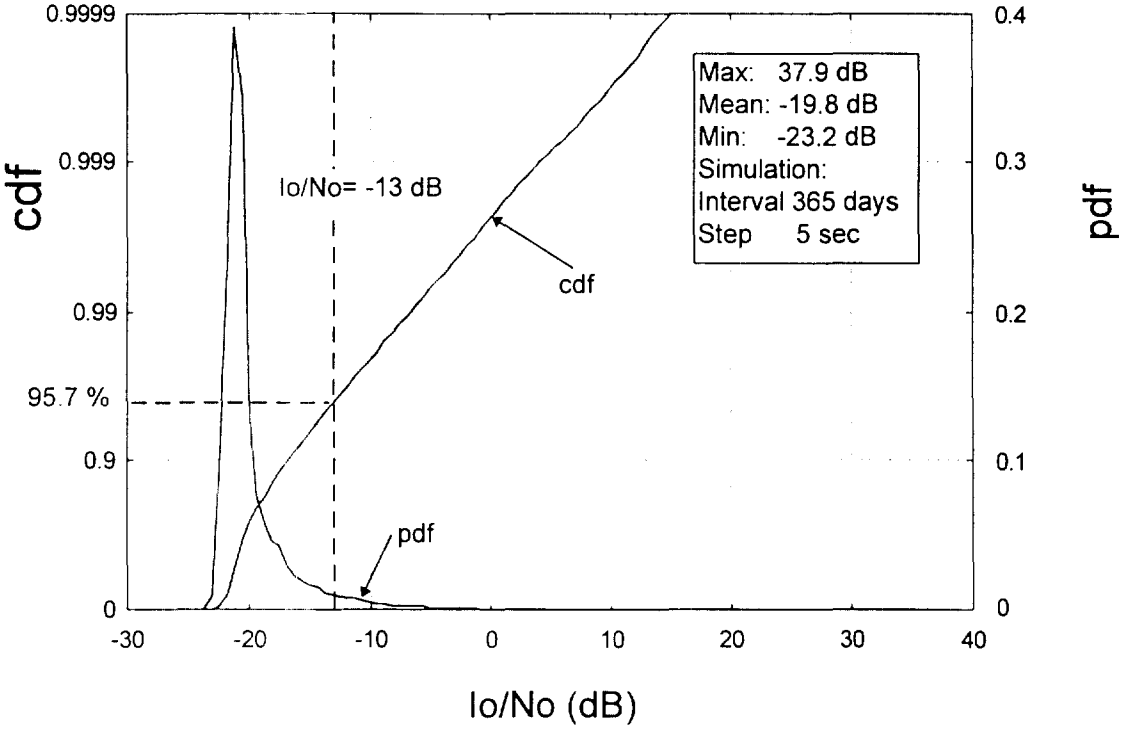

Figure 4.2 CASE 1, I_0/N_0 Probability, Collocated Standard Earth Station.

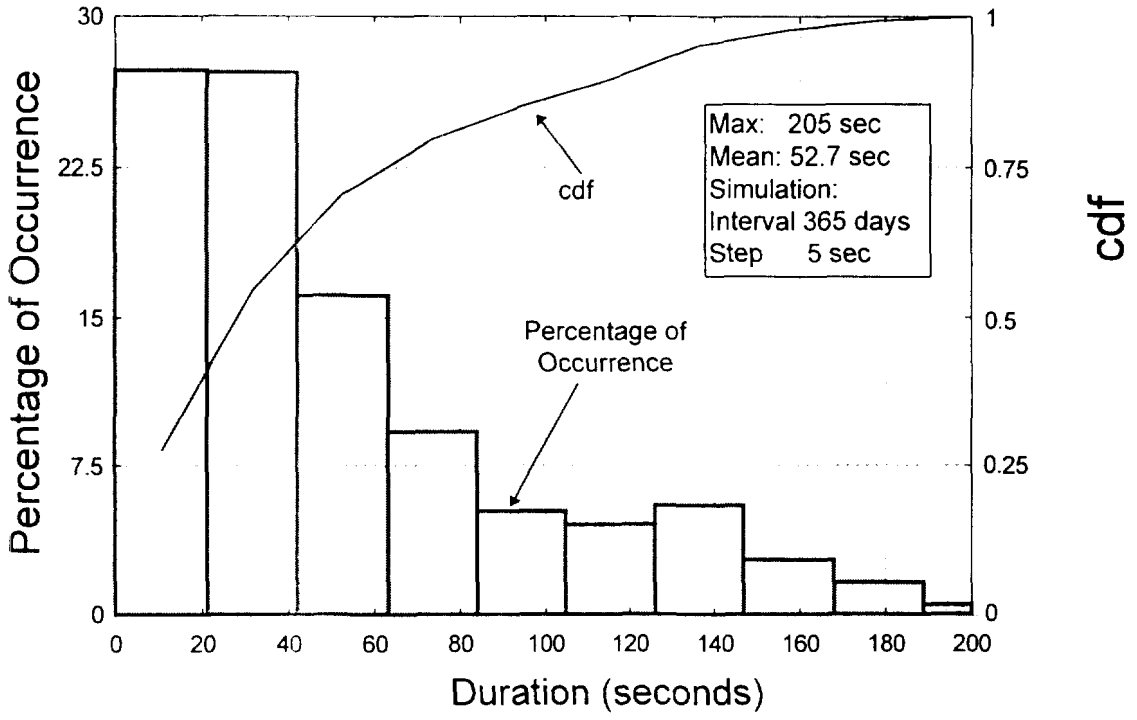

Figure 4.3 CASE 1, Interference Event Duration, Collocated Standard Earth Station.

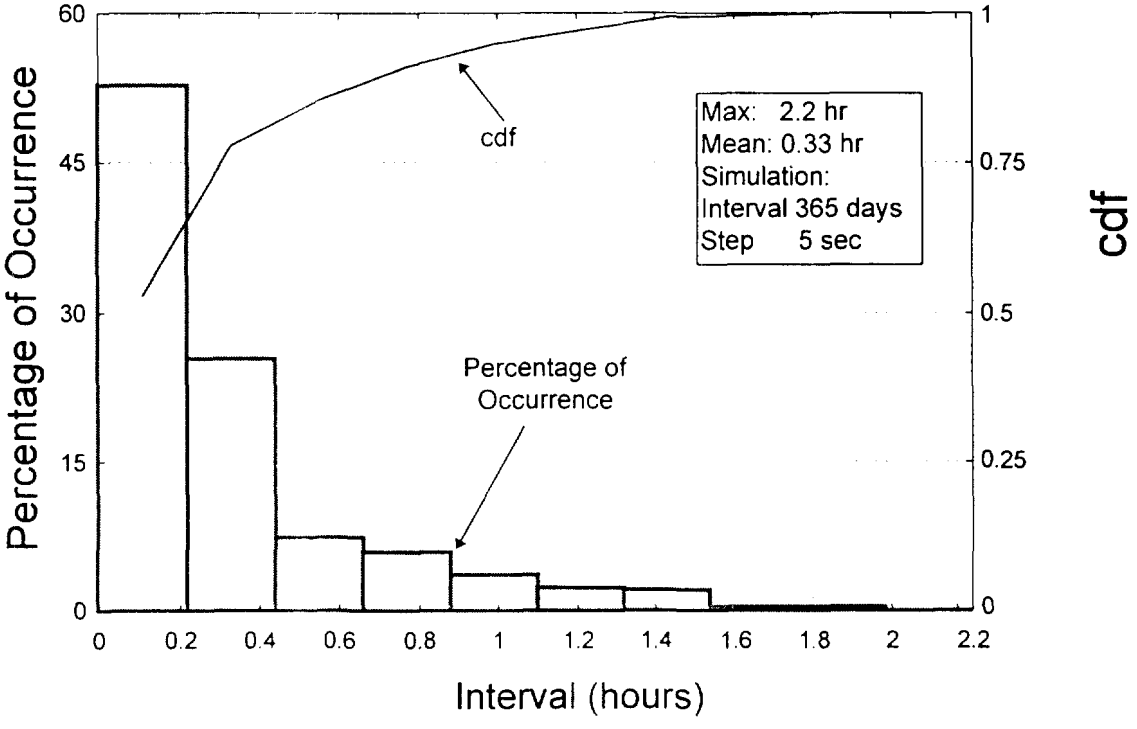

Figure 4.4 CASE 1, Interval Between Interference Events, Collocated Standard Earth Station

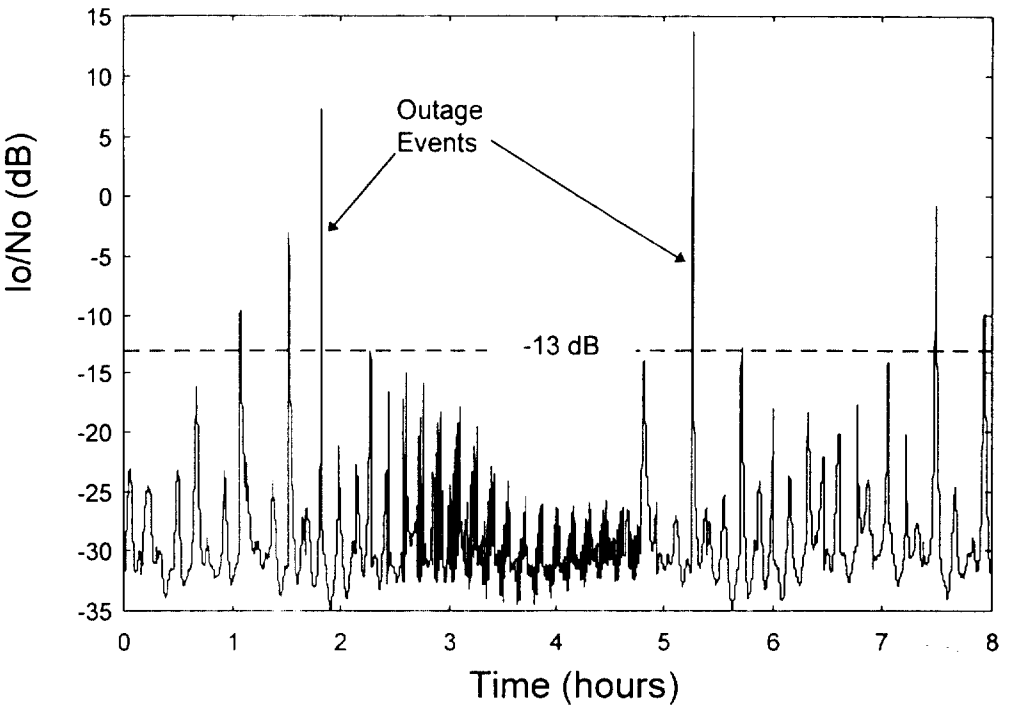

Figure 4.5 CASE 1, I_0/N_0 Time History, Standard Earth Station at 160 km Separation.

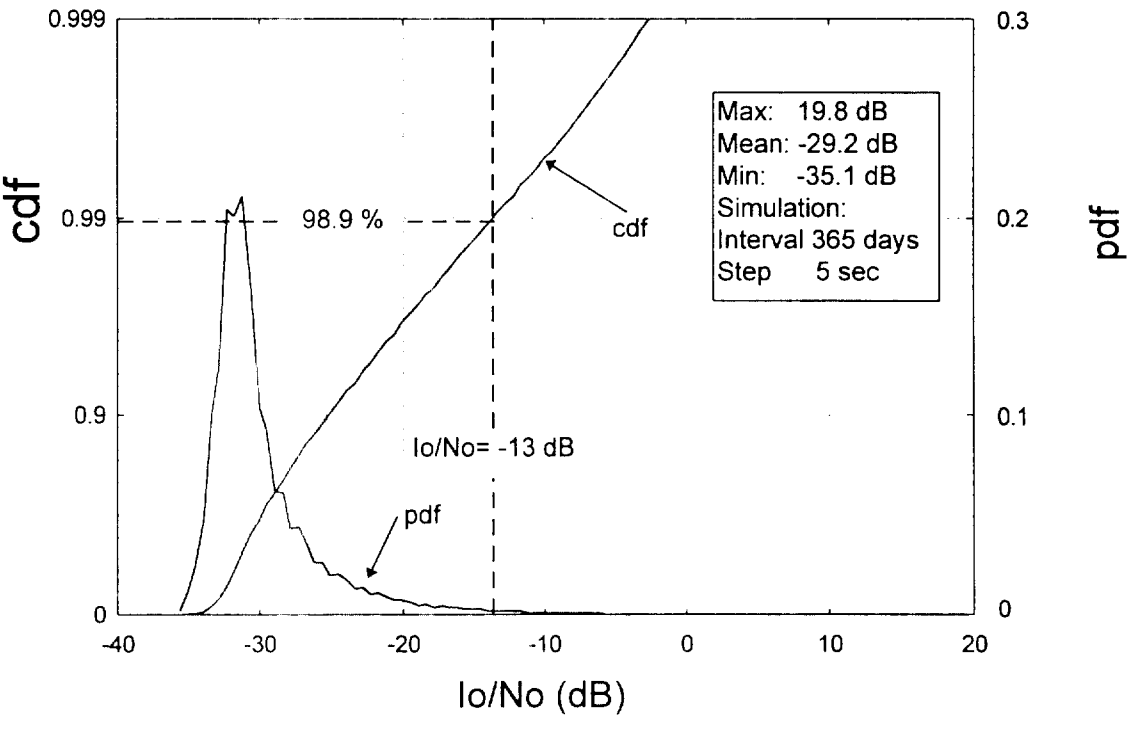

Figure 4.6 CASE 1, I_0/N_0 Probability, Standard Earth Station at 160 km Separation.

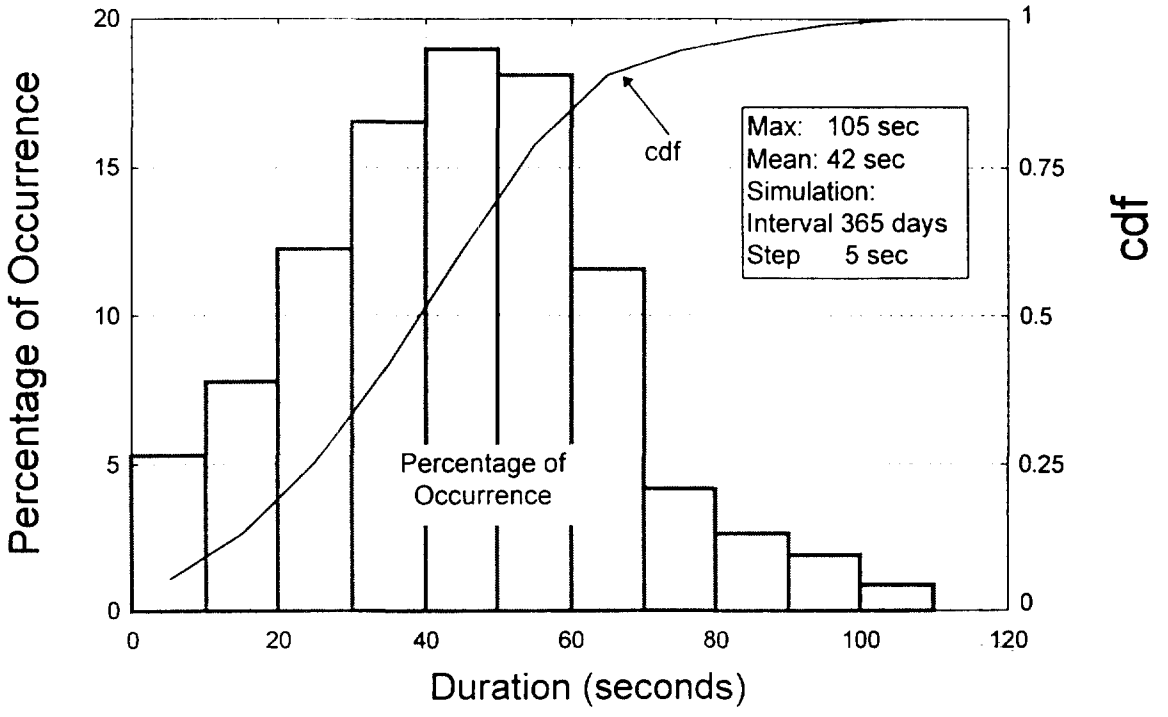

Figure 4.7 CASE 1, Interference Event Duration, Standard Earth Station at 160 km Separation.

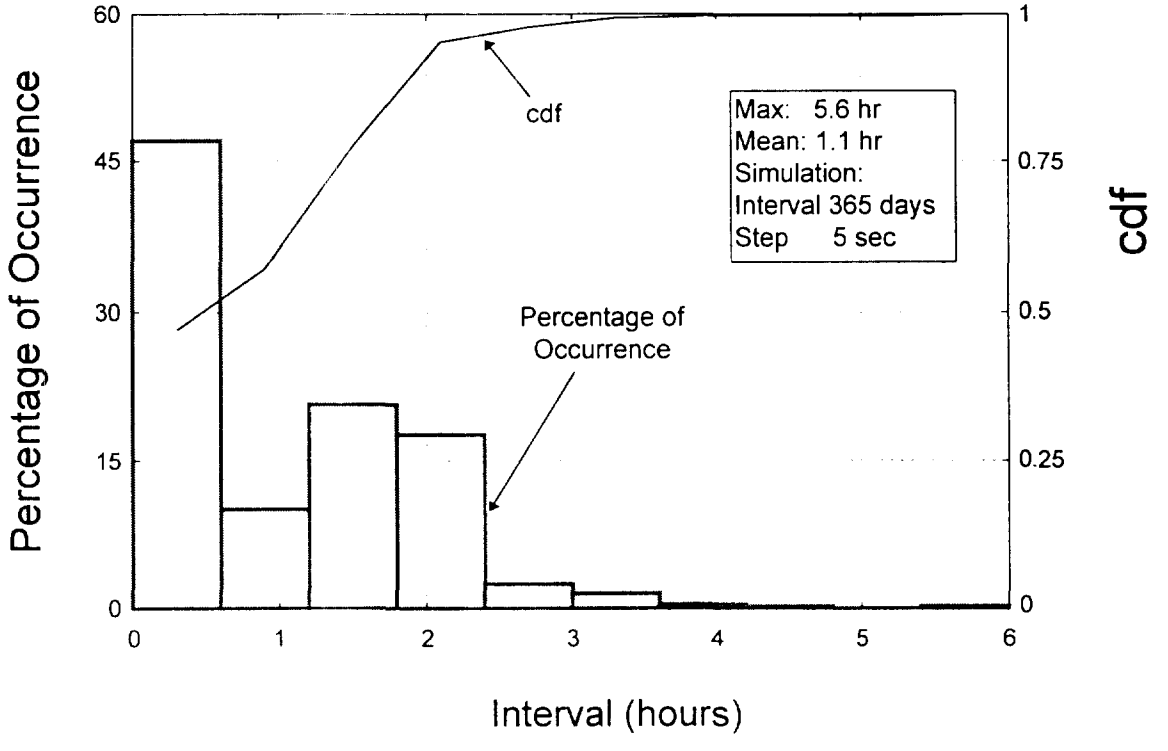

Figure 4.8 CASE 1, Interval Between Interference Events, Standard Earth Station at 160 km Separation.

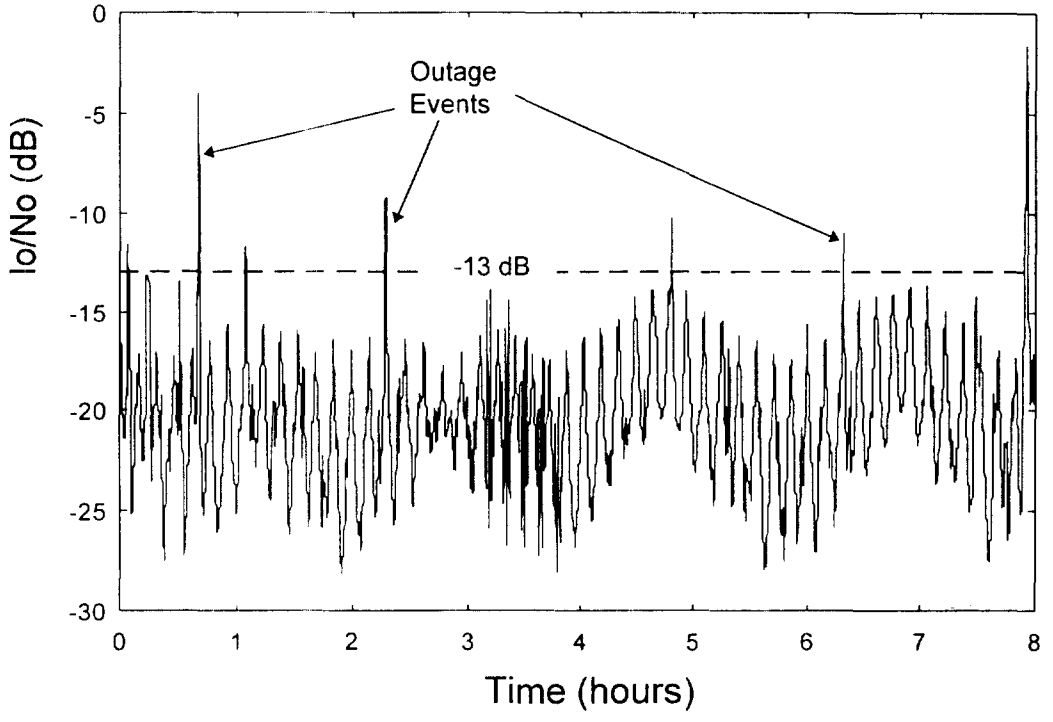

Figure 4.9 CASE 2, I_0/N_0 Time History, Collocated Standard Earth Station.

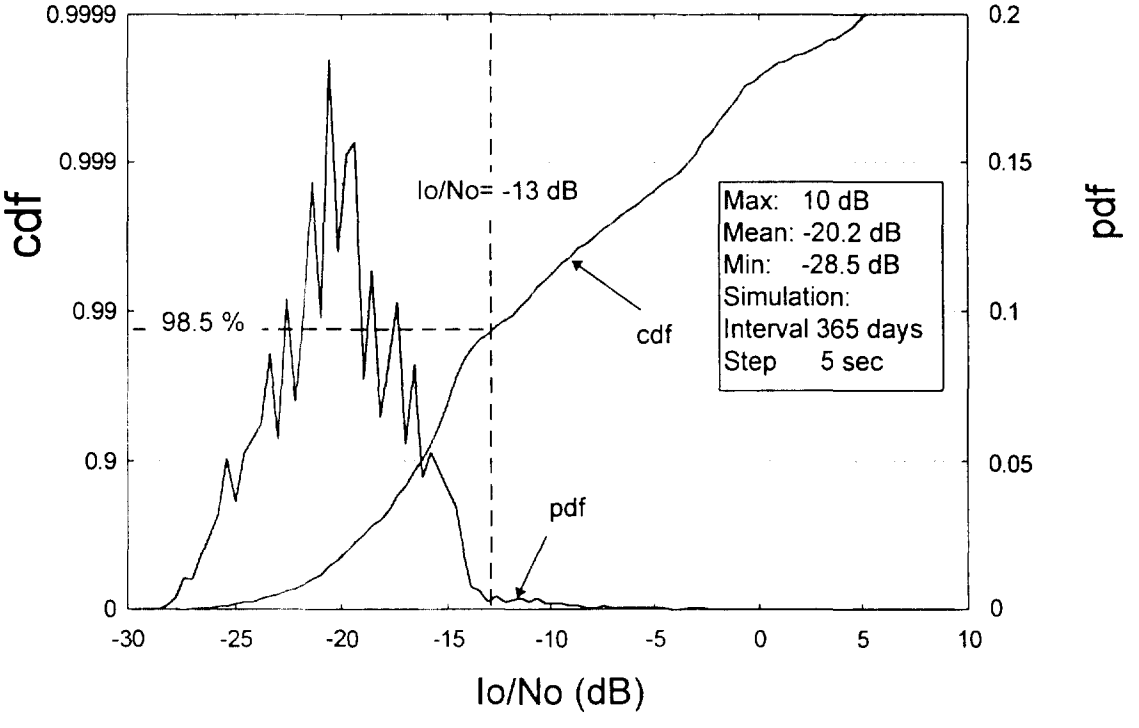

Figure 4.10 CASE 2, I_0/N_0 Probability, Collocated Standard Earth Station.

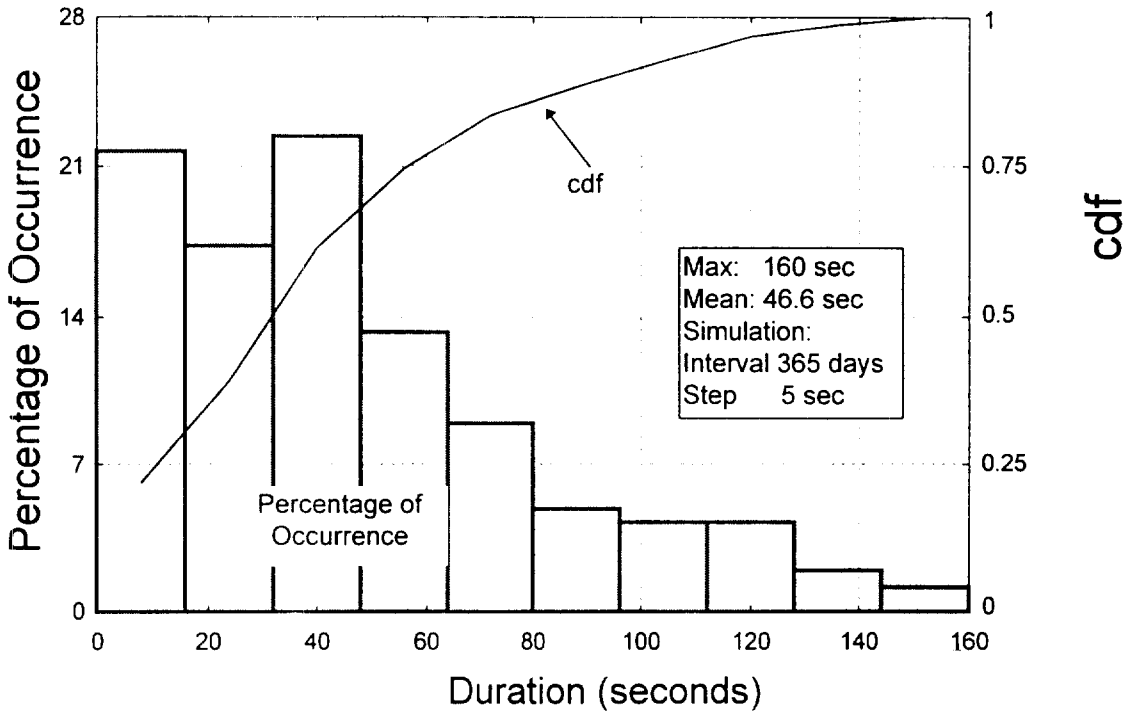

Figure 4.11 CASE 2, Interference Event Duration, Collocated Standard Earth Station.

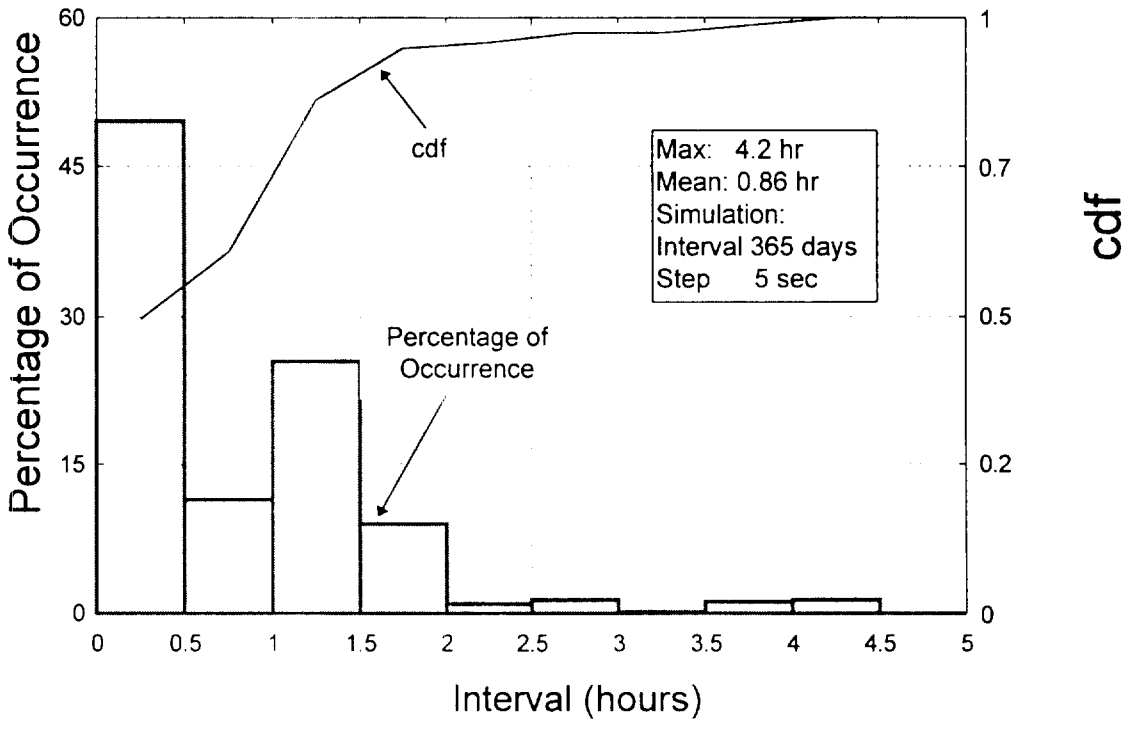

Figure 4.12 CASE 2, Interval Between Interference Events, Collocated Standard Earth Station.

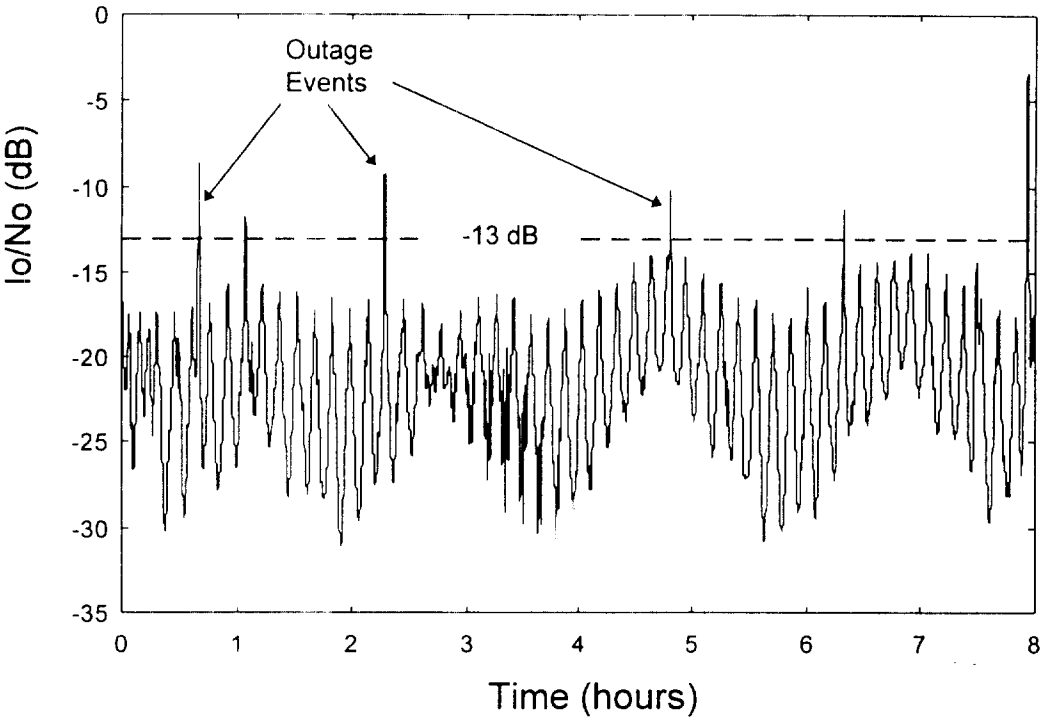

Figure 4.13 CASE 2, I_0/N_0 Time History, Standard Earth Station at 160 km Separation.

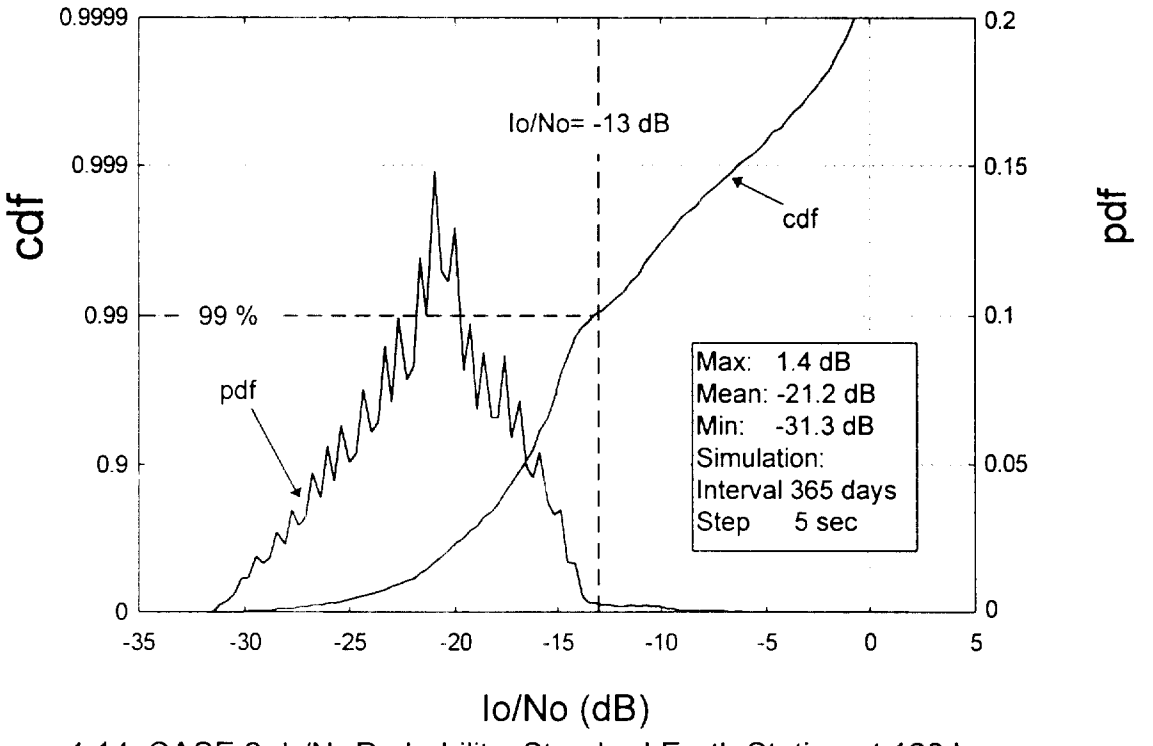

Figure 4.14 CASE 2, I_0/N_0 Probability, Standard Earth Station at 160 km Separation.

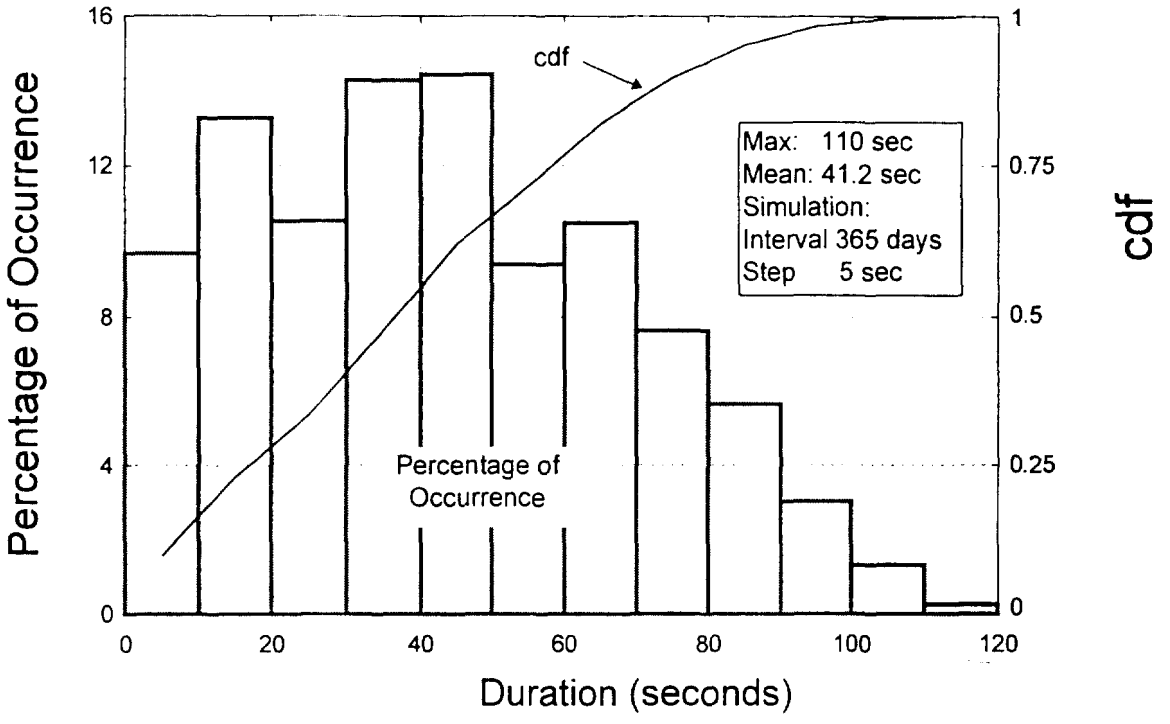

Figure 4.15 CASE 2, Interference Event Duration, Standard Earth Station at 160 km Separation.

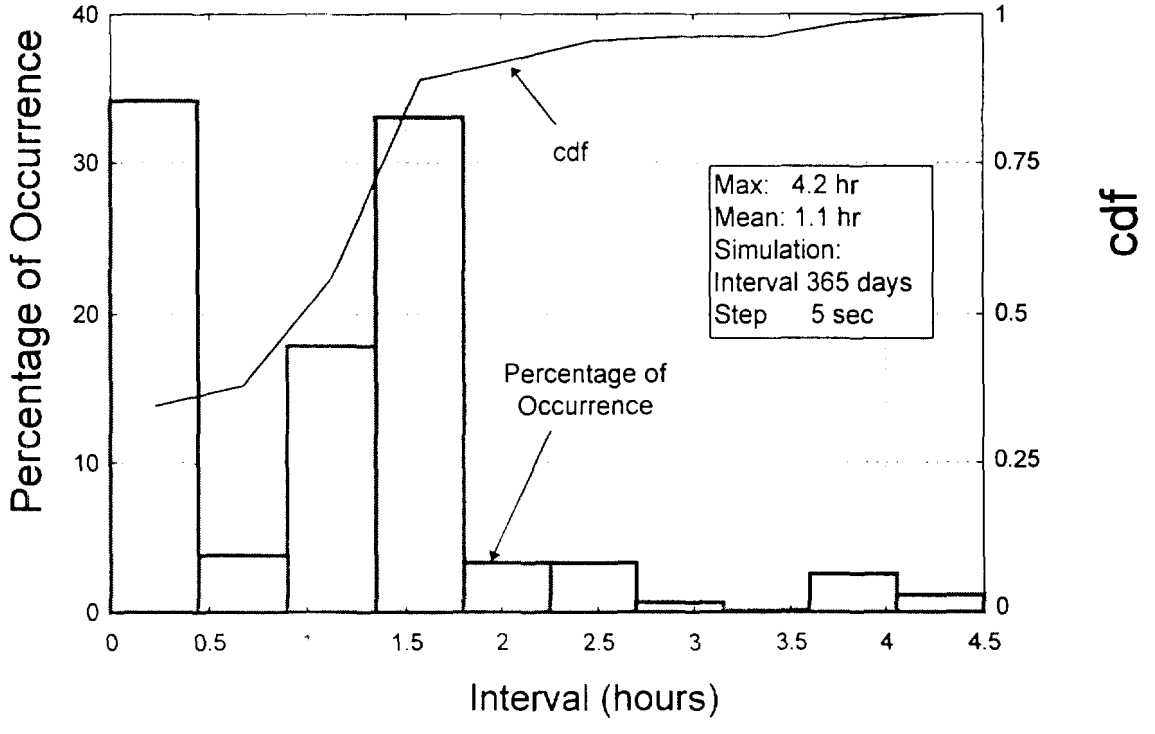

Figure 4.16 CASE 2, Interval Between Interference Events, Standard Earth Station at 160 km Separation.

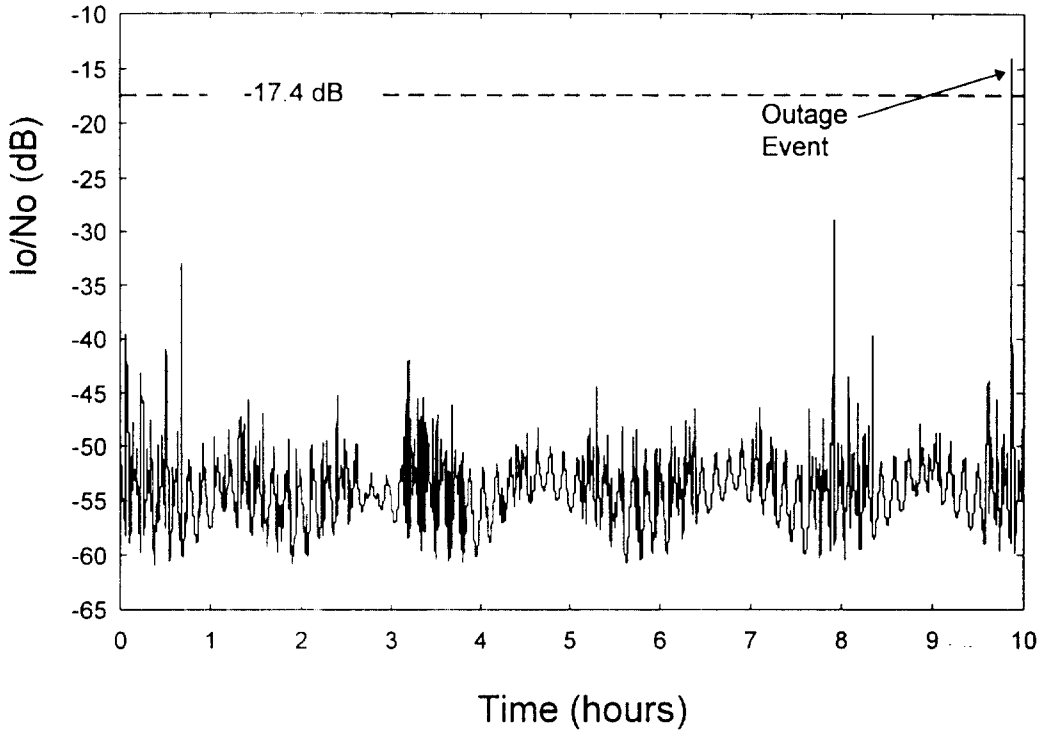

Figure 4.17 CASE 3, I_0/N_0 Time History, Collocated Standard Earth Station.

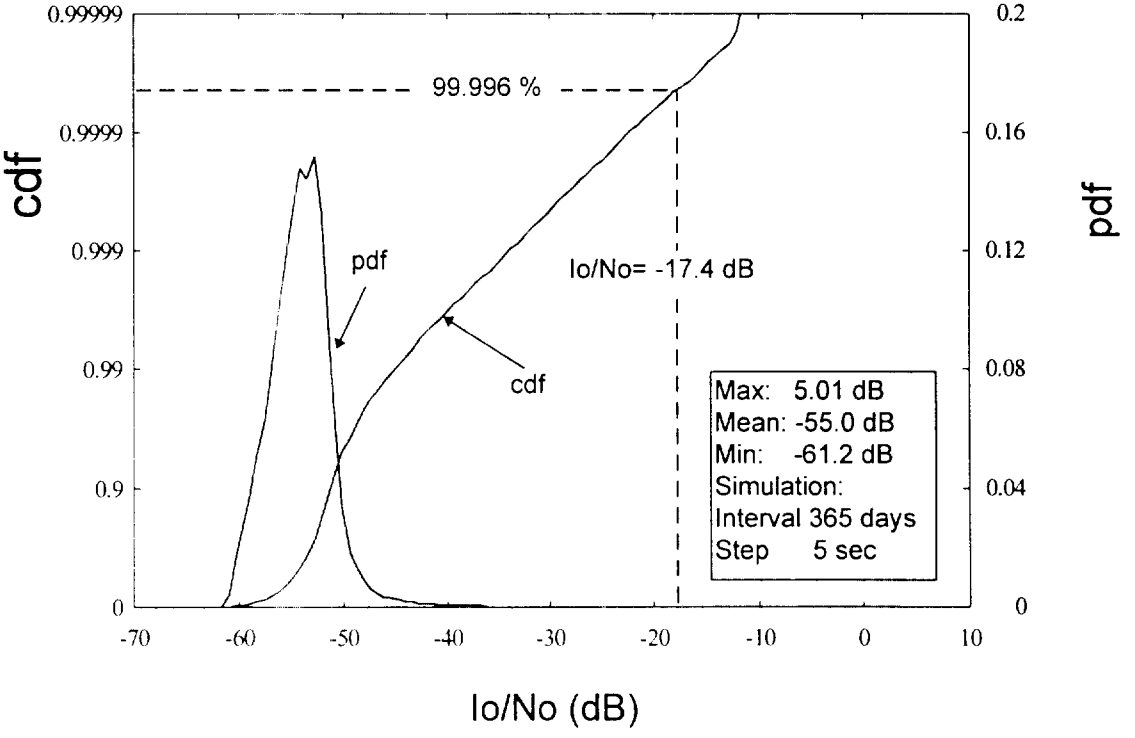

Figure 4.18 CASE 3, I_0/N_0 Probability, Collocated Standard Earth Station.

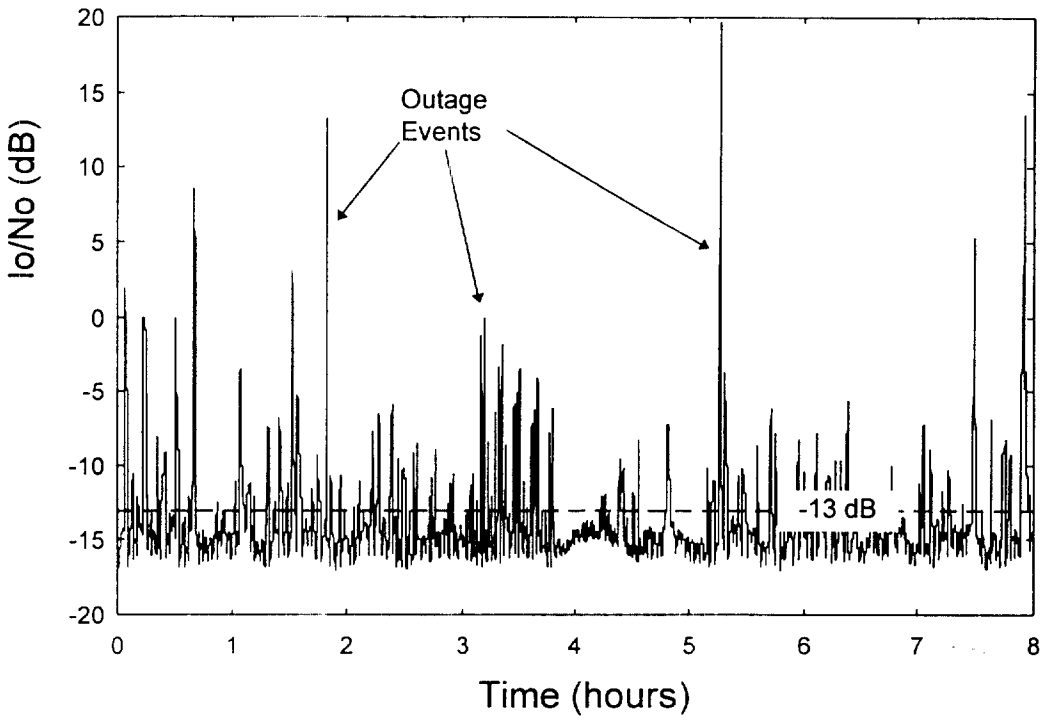

Figure 4.19 CASE 1, I_0/N_0 Time History, Collocated Mobile Earth Station.

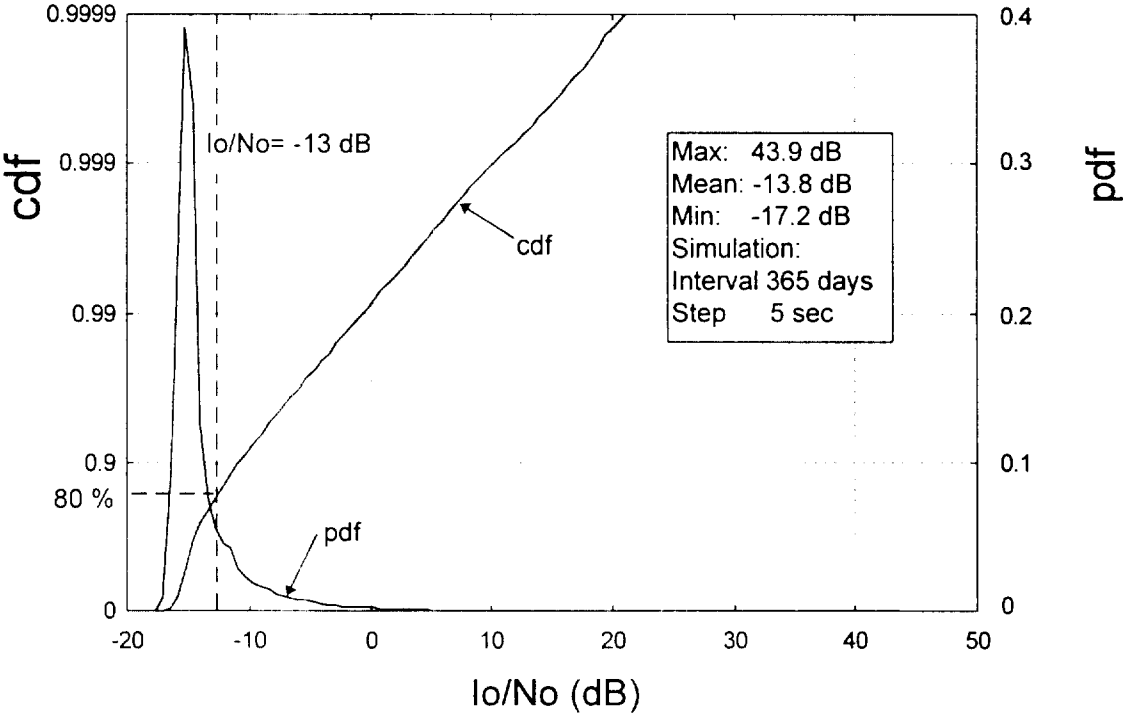

Figure 4.20 CASE 1, I_0/N_0 Probability, Collocated Mobile Earth Station.

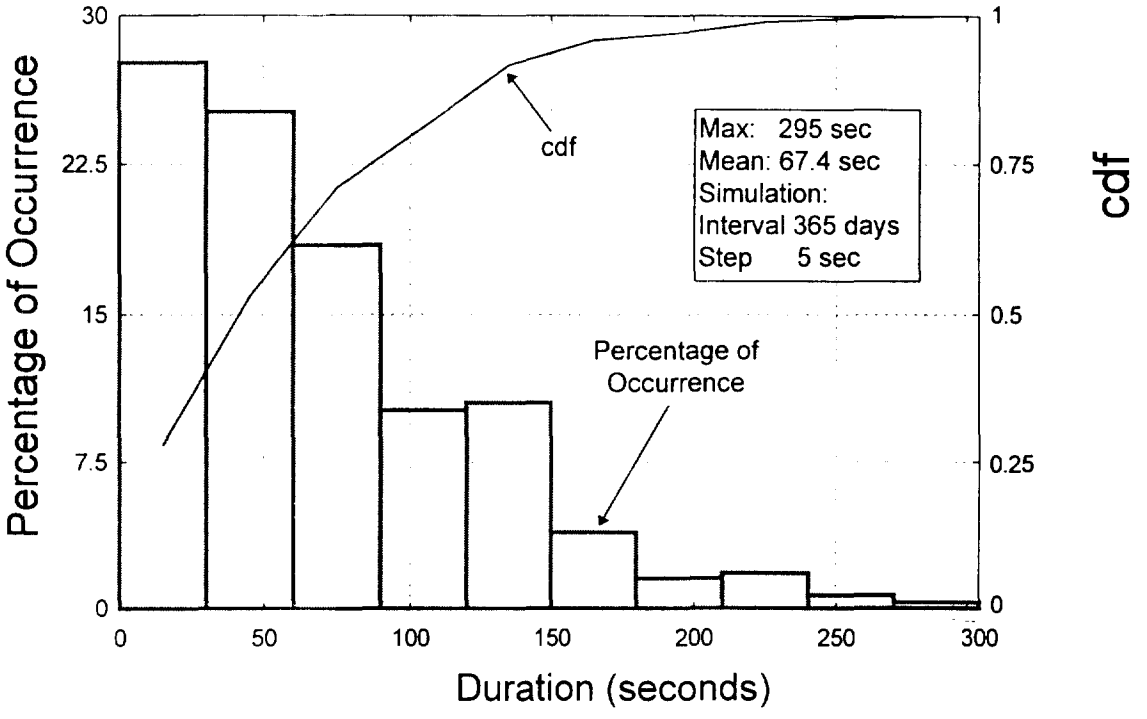

Figure 4.21 CASE 1, Interference Event Duration, Collocated Mobile Earth Station.

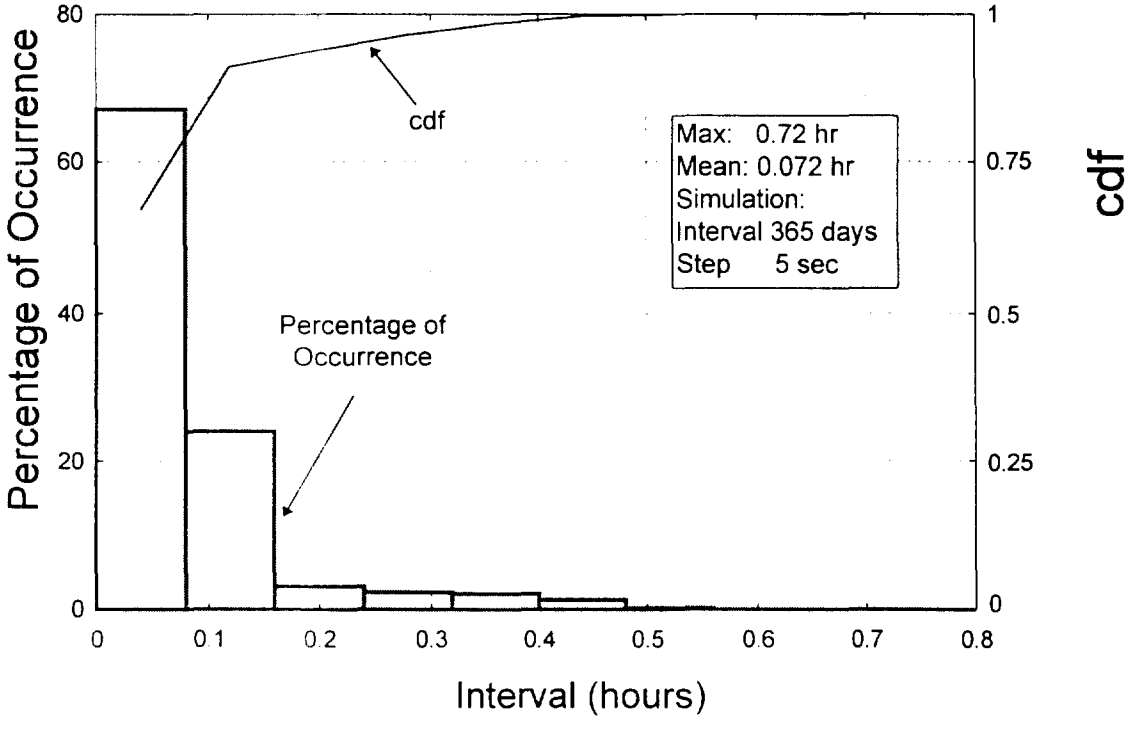

Figure 4.22 CASE 1, Interval Between Interference Events, Collocated Mobile Earth Station.

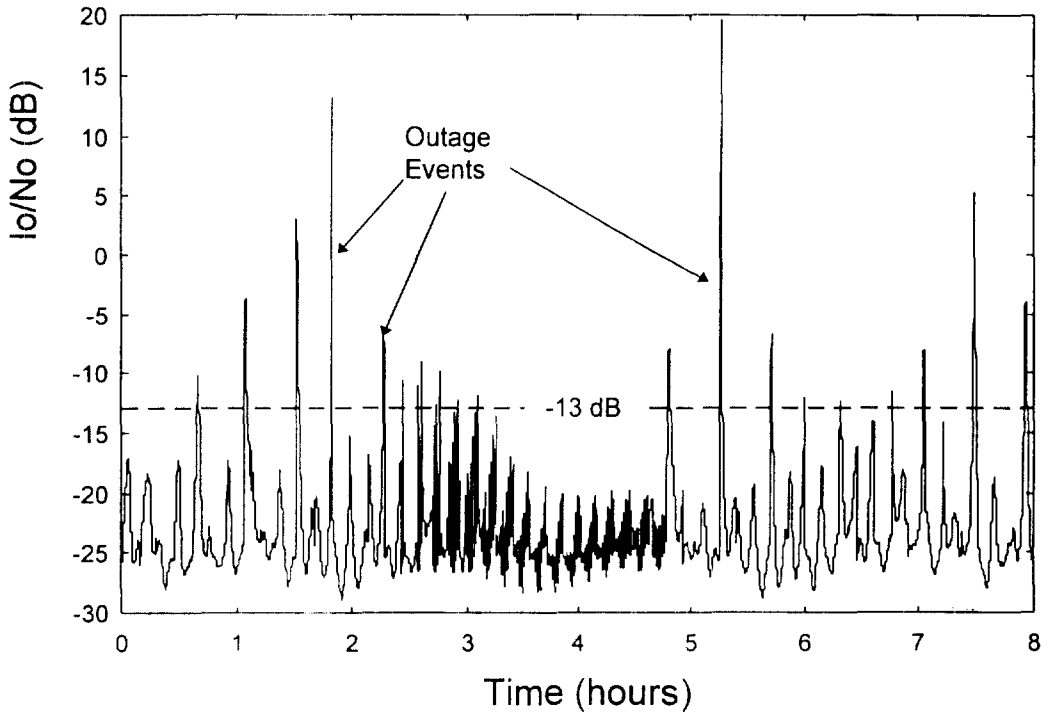

Figure 4.23 CASE 1, I_0/N_0 Time History, Mobile Earth Station at 160 km Separation

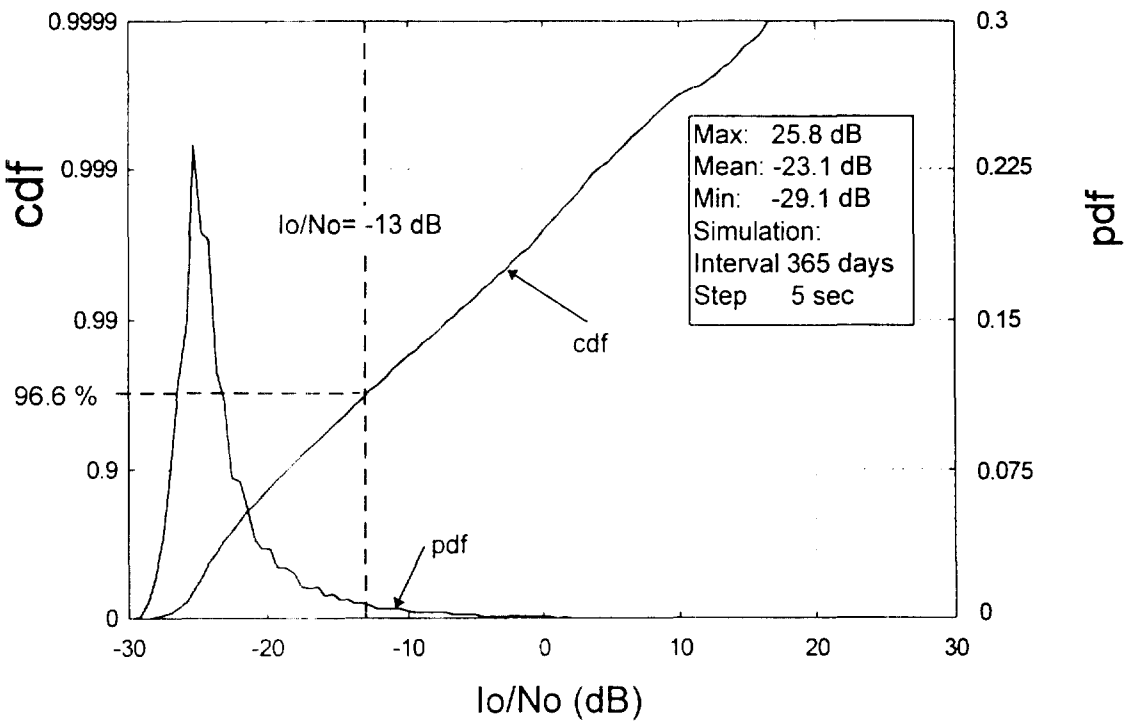

Figure 4.24 CASE 1, I_0/N_0 Probability, Mobile Earth Station at 160 km Separation

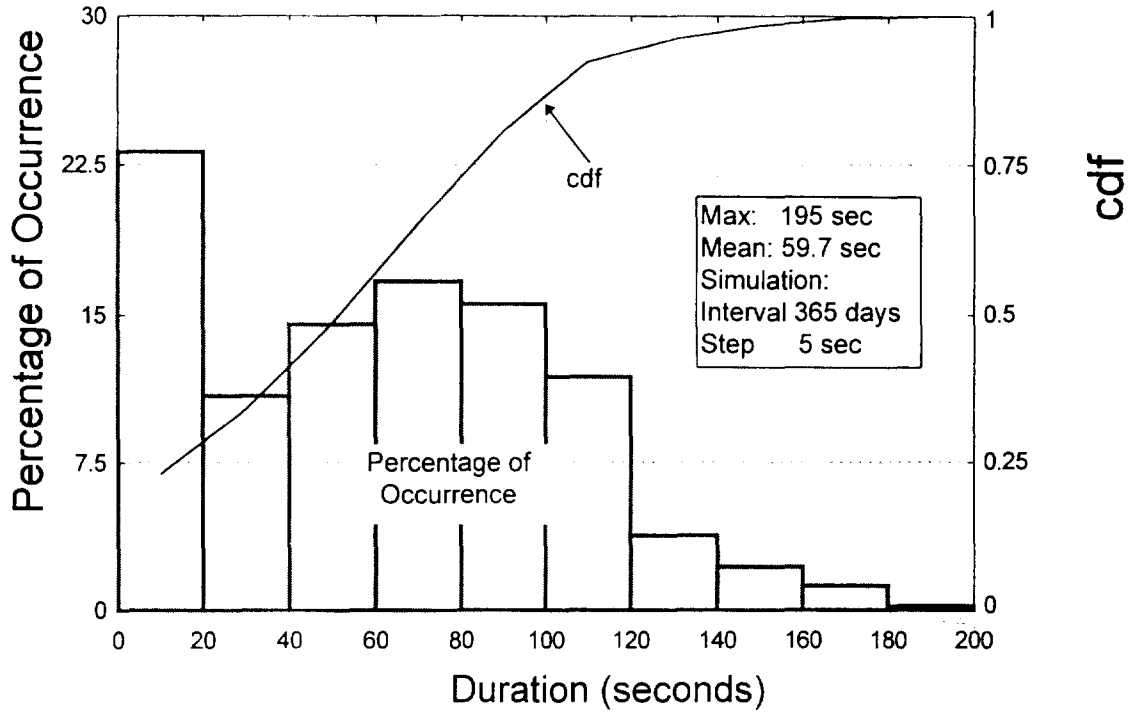

Figure 4.25 CASE 1, Interference Event Duration, Mobile Earth Station at 160 km Separation

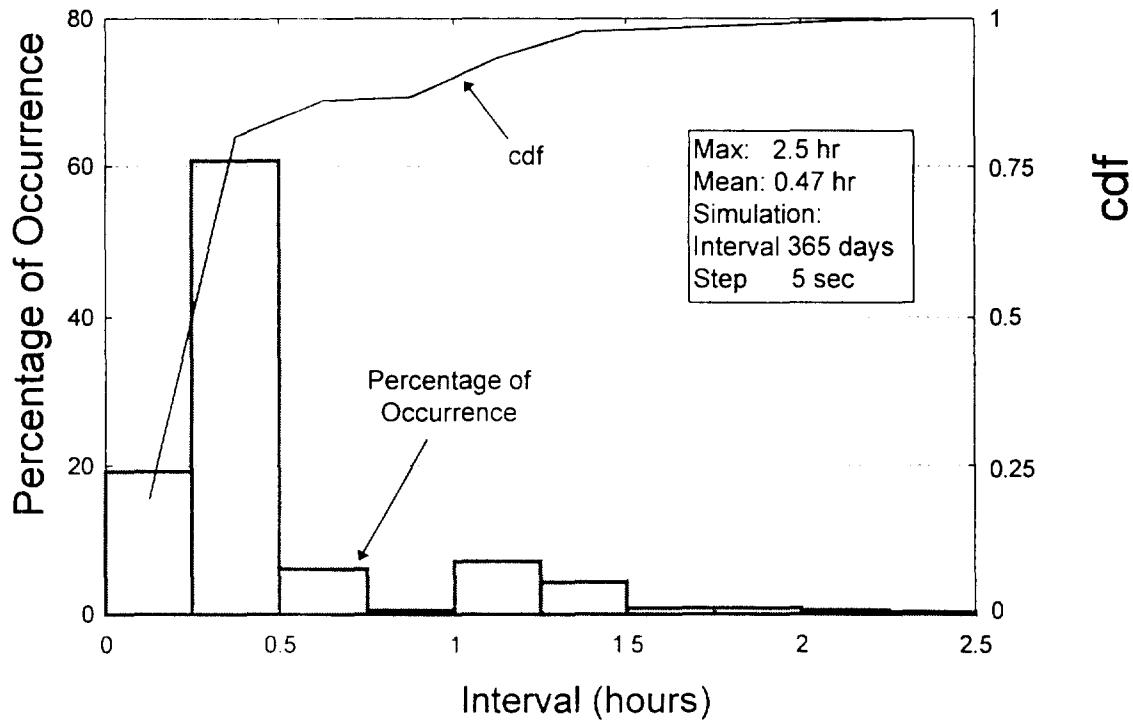

Figure 4.26 CASE 1, Interval Between Interference Events, Mobile Earth Station at 160 km Separation

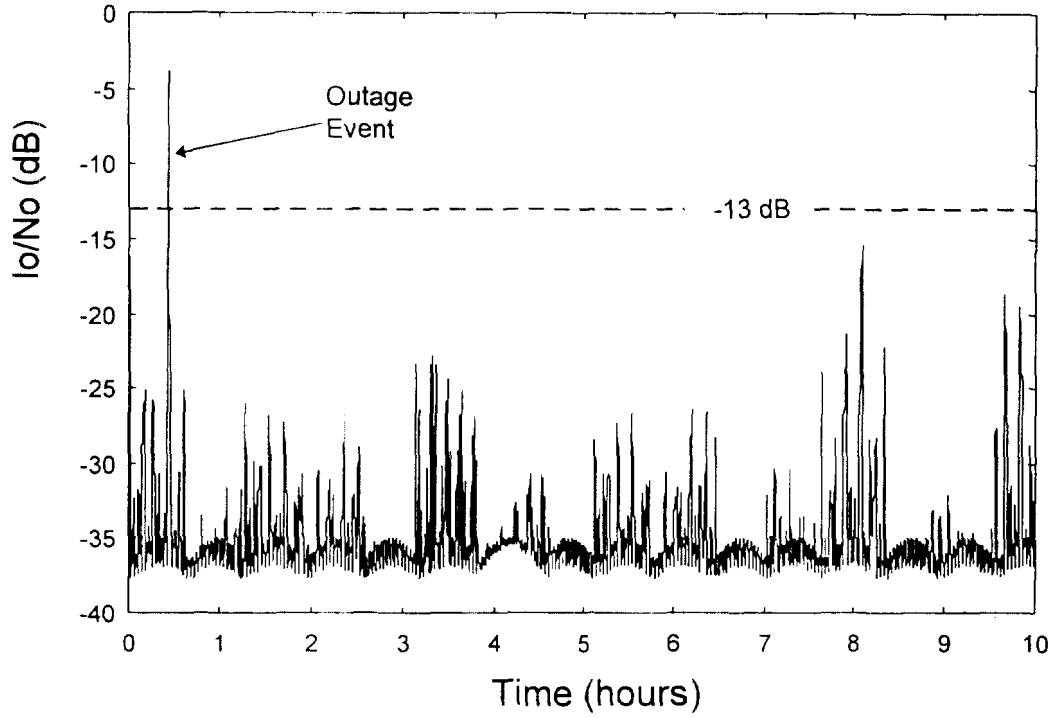

Figure 4.27 CASE 1, I_0/N_0 Time History, Collocated High Rate Earth Station.

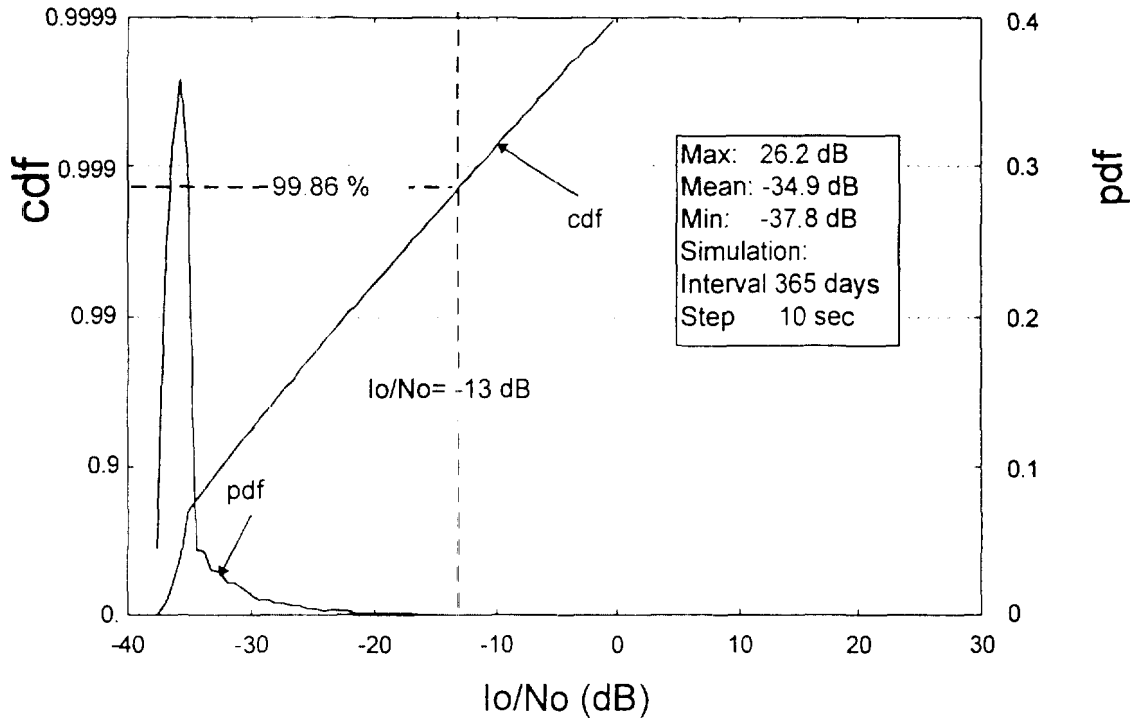

Figure 4.28 CASE 1, I_0/N_0 Probability, Collocated High Rate Earth Station.

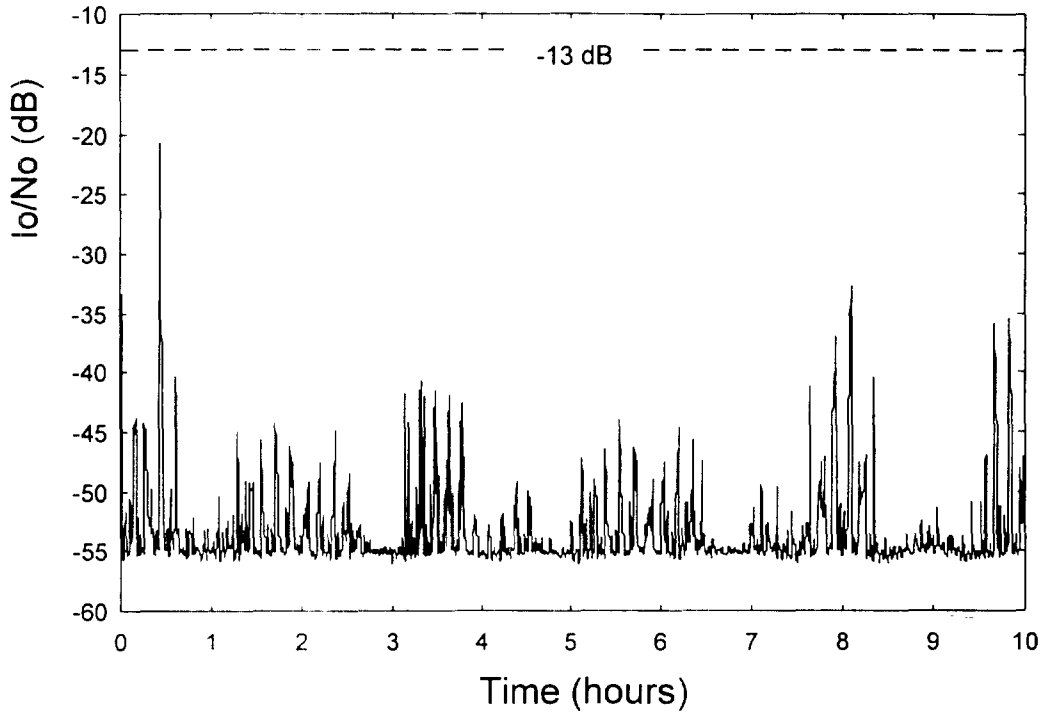

Figure 4.29 CASE 2, I_0/N_0 Time History, Collocated High Rate Earth Station.

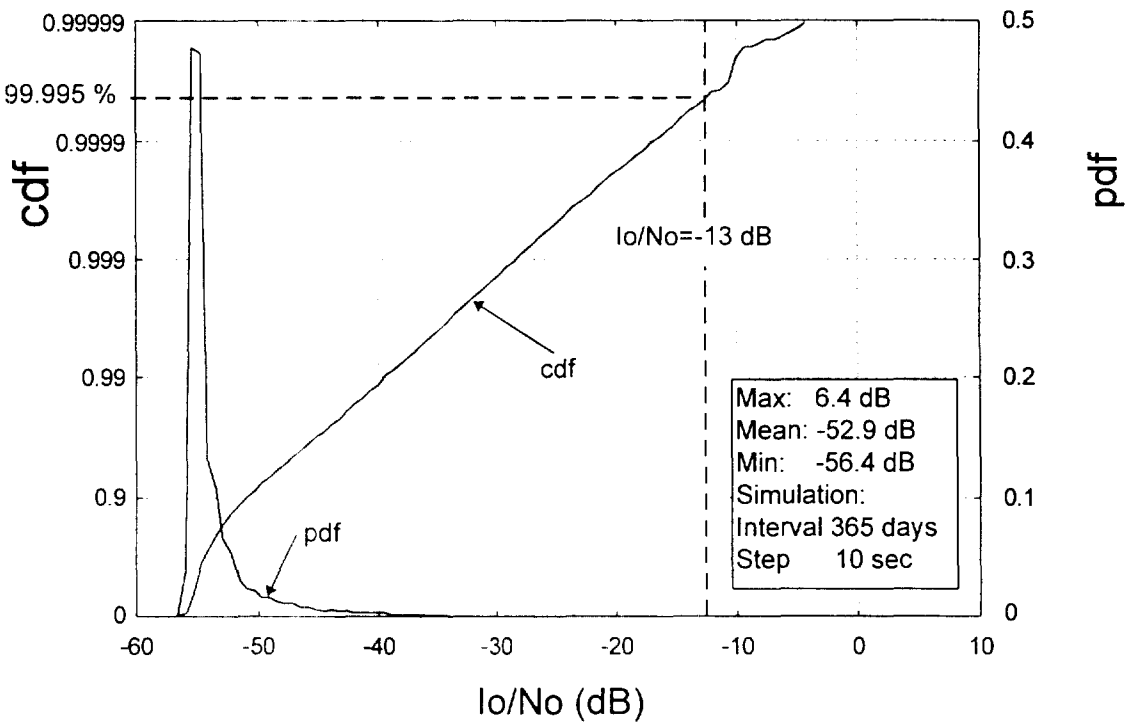

Figure 4.30 CASE 2, I_0/N_0 Probability, Collocated High Rate Earth Station.

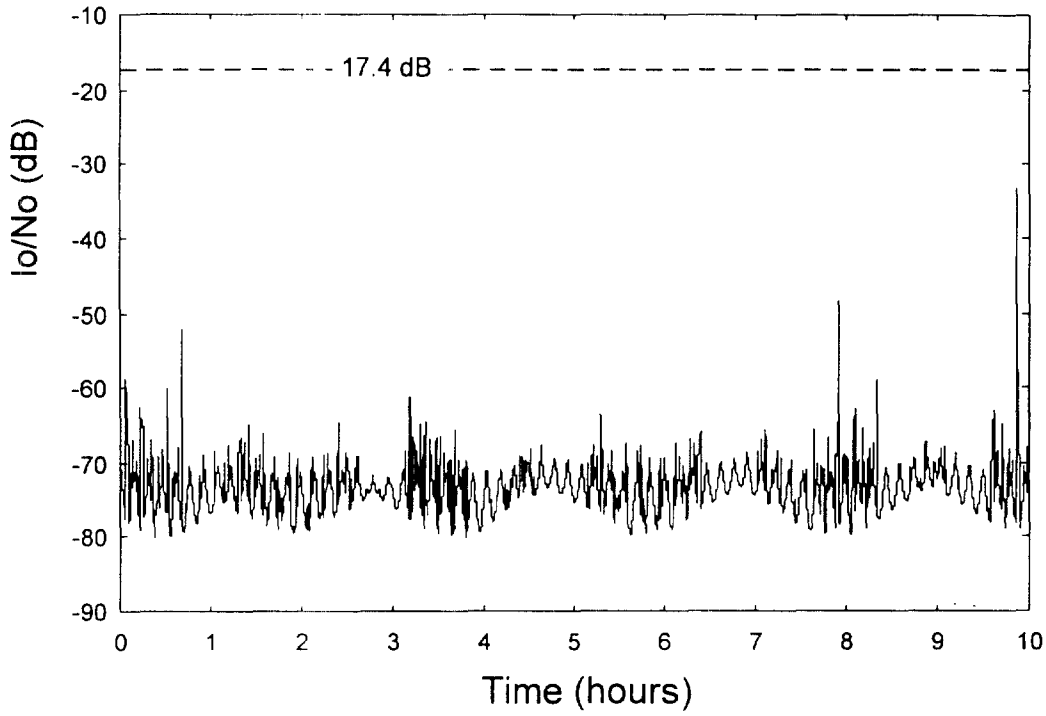

Figure 4.31 CASE 3, I_0/N_0 Time History, Collocated High Rate Earth Station.

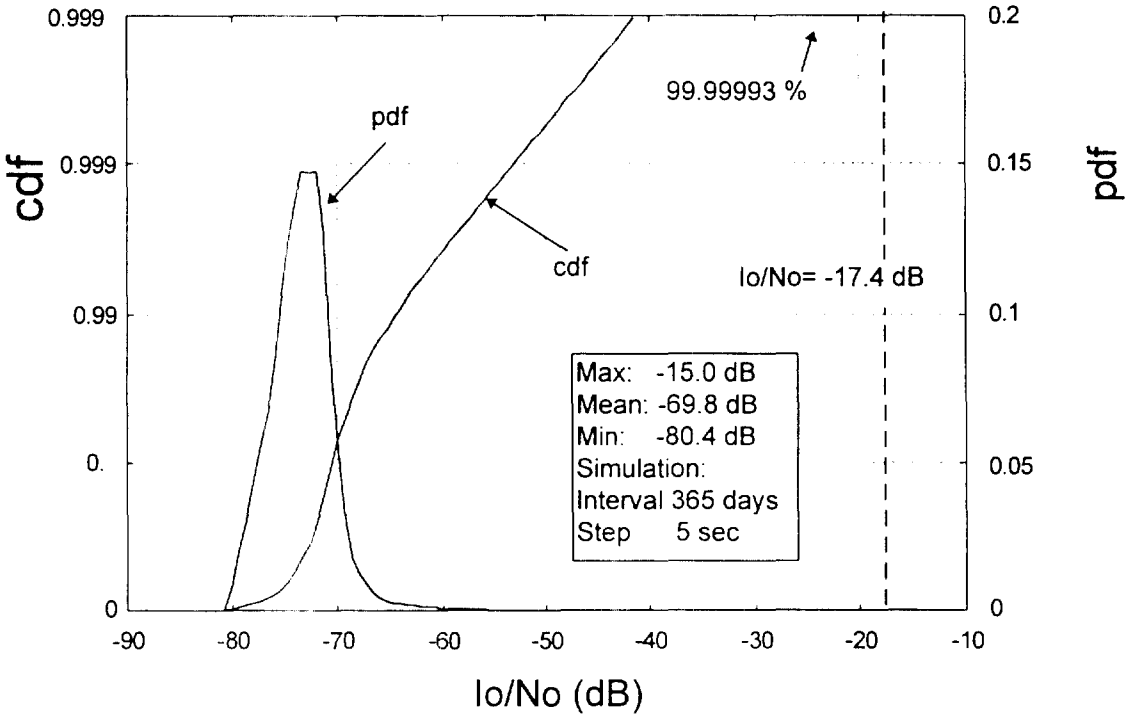

Figure 4.32 CASE 3, I_0/N_0 Probability, Collocated High Rate Earth Station.

APPENDIX C

February 16, 1995
Original: English

Co-Directional Frequency Sharing Between GSO FSS Systems and NGSO Satellite Systems (FSS and MSS, Service and Feeder Links) in the 30/20 GHz Band

1.0 Introduction:

Informal Working Group 4 (IWG-4) of the FCC Industry Advisory Committee for WRC-95 is tasked with developing a U.S. industry consensus position on proposals for preferred FSS frequency bands which could support MSS feeder link spectrum. As such, this paper presents extensive analysis and simulation results related to the feasibility of co-directional frequency sharing between GSO FSS, and FSS and MSS service links and feeder links of NGSO satellite systems. The feasibility of co-directional frequency sharing between GSO FSS systems and NGSO satellite systems is necessary in determining the optimum choice of frequency bands for these services.

The GEO 13 system is used as an example of a GSO FSS system operating in Ka-Band. The LEOSAT-1 system is used as a representative example of a NGSO satellite service operating in Ka-Band. It has both FSS and MSS service links, and FSS and MSS feeder-links. Extensive computer simulation runs are used to calculate the statistics of the interference between the links of the two systems. The two representative systems have proposed to operate at different Ka-band frequencies in some parts of the world and thus the analysis presented in this paper only examines the possibility of Co-frequency sharing.

2. Technical Characteristics of the Satellite Systems

Table 2.1 shows the orbital parameters of the NGSO Satellite system. The Technical characteristics of the communication systems of both systems are shown in Table 2.2. The antenna patterns are shown in Figures 2.2 to 2.11. The NGSO Satellite Service network uses a constellation of 840 operational interlinked low-Earth orbit (LEO) satellites. The Earth's surface is mapped into a fixed grid of approximately 20,000 supercells. Each supercell is a square with sides of 160 km in length. Each supercell is further divided into 9 square cells of area 53.3 km × 53.3 km each. The network uses a combination of space, time, and frequency division multiple access techniques. At any instant in time, each fixed supercell is served by 1 of the 64 transmit and 1 of the 64 receive beams

on one of the satellites. The scanning beam scans the 9 cells within the supercell with a 23.111 msec scan cycle, resulting in time division multiple access among the cells in a supercells. Physical separation and a checkerboard pattern of left and right circular polarization eliminate interference among cells scanned at the same time in adjacent supercells. Within each cell's time slot, terminals use Frequency Division Multiple Access (FDMA) on the uplink and Asynchronous Time Division Multiple Access (ATDMA) on the downlink.

	NGSO Satellite System
No. of Planes	21
No. of Satellites Per Plane	44
Altitude	700 km
Inclination	98.2°

Table 2.1 Orbital Parameters of the NGSO Satellite System

The GSO FSS system consists of 17 GSO satellites to cover the entire world however in this paper only the two GSO satellites covering North America are considered. These satellites are located at longitudes of 101° W and 99° W and each can provide a total of forty eight (24 in each polarization) 120 MHz spot beams for both the uplinks and the downlinks.

	NGSO Satellite System			**GSO FSS**
	Standard Links	Mobile Links	High Rate Links	
Uplink Polarization	LHC/RHC	LHC/RHC	LHC/RHC	LHC/RHC
Downlink Polarization	LHC/RHC	LHC/RHC	LHC/RHC	LHC/RHC
Satellite Transmit Power (dBW)	18.8	18.8	-5.5 to 6.6	13.0
Earth Station Transmit Power (dBW)	-20.3 to -1.9	-20.3 to -1.9	-3.8 to 16.9	-9.7 t0 -3.0
Satellite Receive Bandwidth (MHz)	0.275	0.275	800	0.5
Earth Station Receive Bandwidth (MHz)	396	99	800	120
Overall Eb/No per User (dB)	7.0	7.0	12.5	11.7
Required C/I Protection Ratio (dB)	25	25	25	18.2

Table 2.2 Communications Parameters

The NGSO Satellite Service network uses a wide variety of earth stations to support different kind of services and users. The Standard Earth Stations and the High Rate Earth Stations support FSS service and Feeder Links. The Mobile Earth Stations support MSS applications with the Standard Earth Stations and the High Rate Earth Stations providing the required feeder links. The three types

of Earth stations are described below. Figure 2.1 depicts the data flow between them.

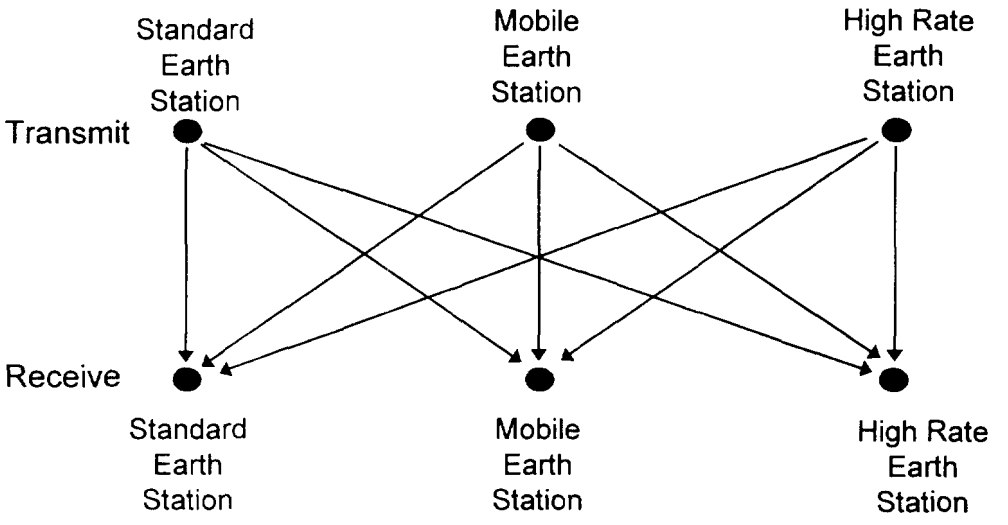

Figure 2.1 NGSO Satellite Service Network Data Flow

a. Standard Earth Stations

The Standard Earth Stations are designed to accommodate data rates from 16 kbps (Basic Channel) up to 2.048 Mbps (E1). Hundreds of these earth stations can be located within a single cell, but at any instant of time, only up to 1440 basic channel earth stations or 15 T1 rate (1.544 Mbps) earth stations or a combination of different data rate earth stations are allowed to operate simultaneously within a single cell.

Each cell within a supercell will be scanned by the satellite in a time division multiplexed manner, so the transmission is bursty with a duty cycle of about 10%. For uplinks within a cell, signals from different terminals are frequency multiplexed within the 400 MHz bandwidth available. The frequency band assigned to a certain terminal depends on the data rate the terminal requested. The downlinks operates in ATDMA manner. The satellite transmits a series of packets addressed to terminals within a cell. A terminal only selects those packets that are addressed to it. Figures 2.8 and 2.9 show the antenna patterns of the Standard Earth Station and Figure 2.6 shows the contour of the satellite antenna footprint for the Satellite Standard Link.

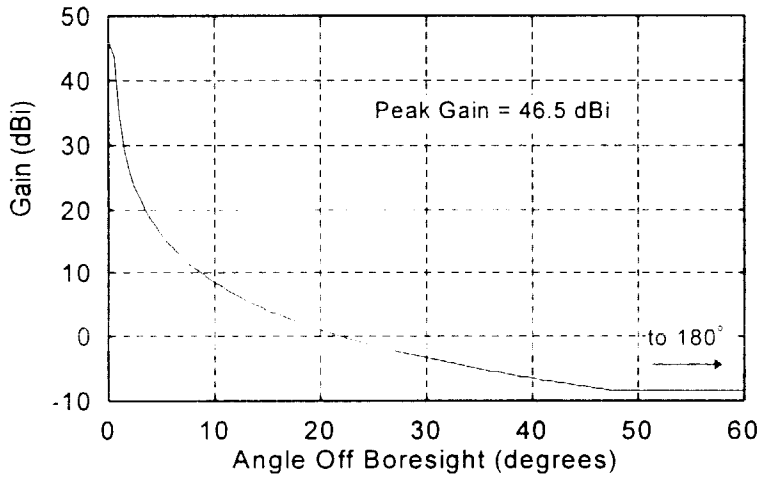

Figure 2.2 GSO FSS Satellite Transmit Antenna Pattern

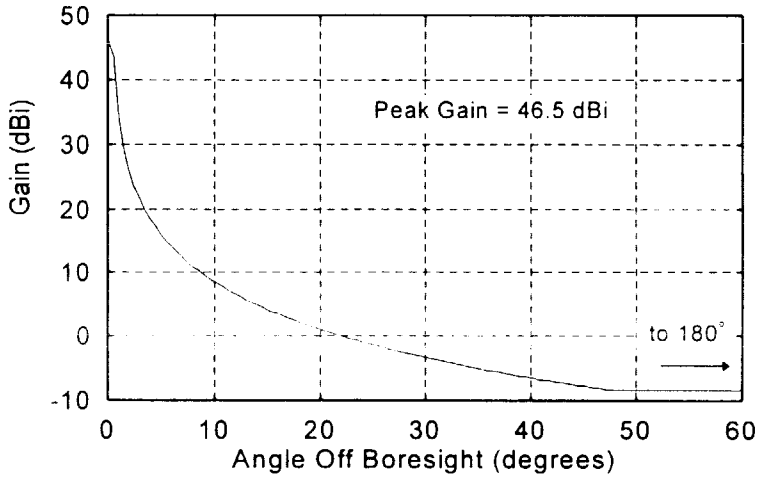

Figure 2.3 GSO FSS Satellite Receive Antenna Pattern

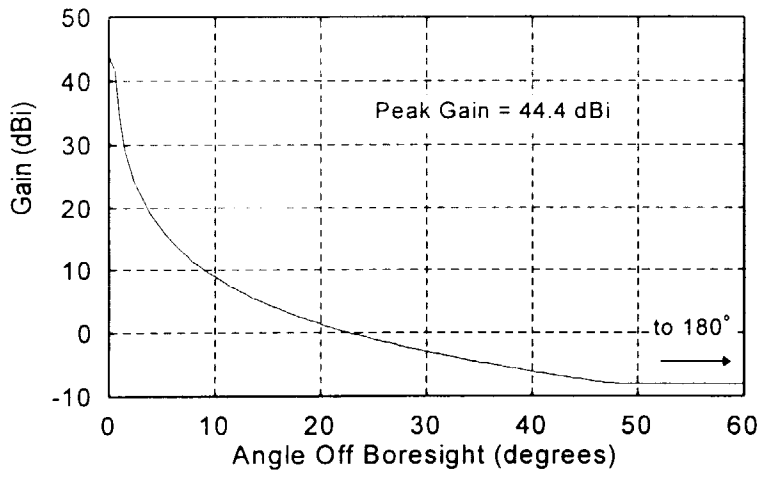

Figure 2.4 GSO FSS Earth Station Transmit Antenna Pattern

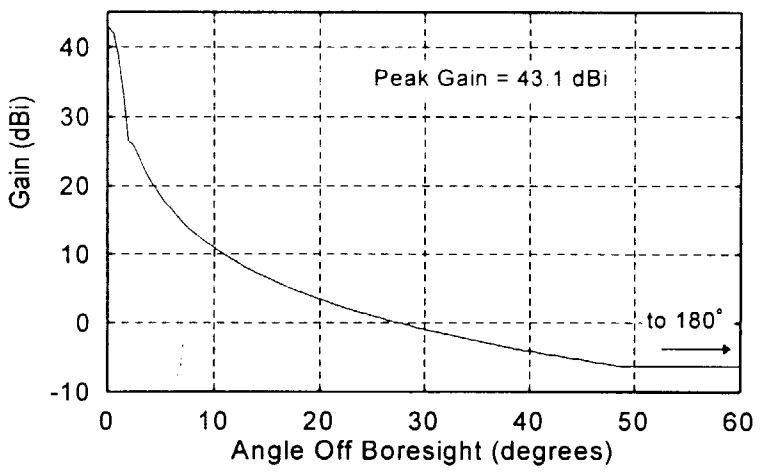

Figure 2.5 GSO FSS Earth Station Receive Antenna Pattern

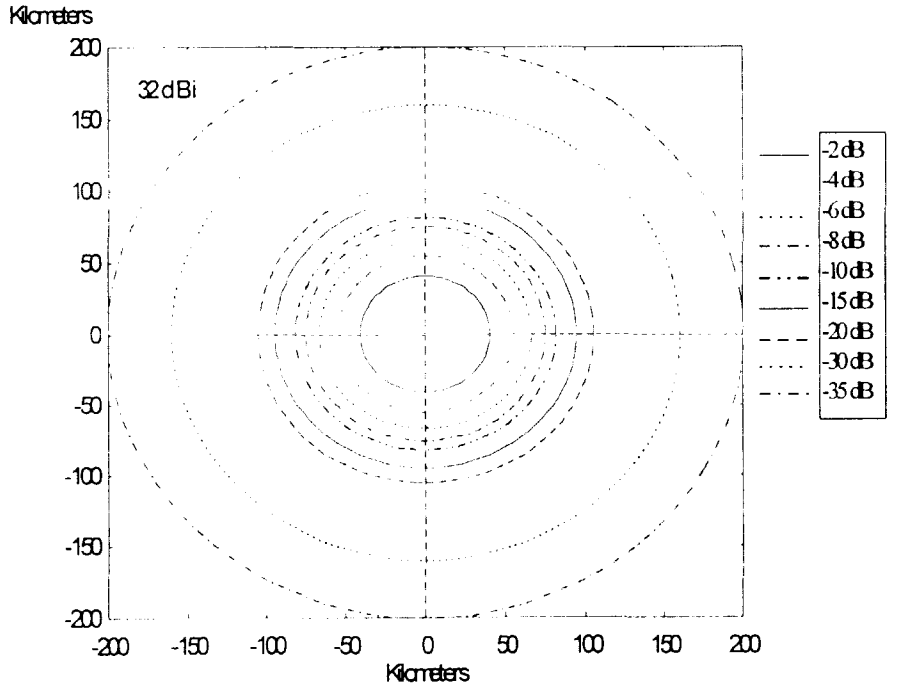

Figure 2.6 NGSO System Satellite Standard Link and Mobile Link Transmit and Receive Gain Contours

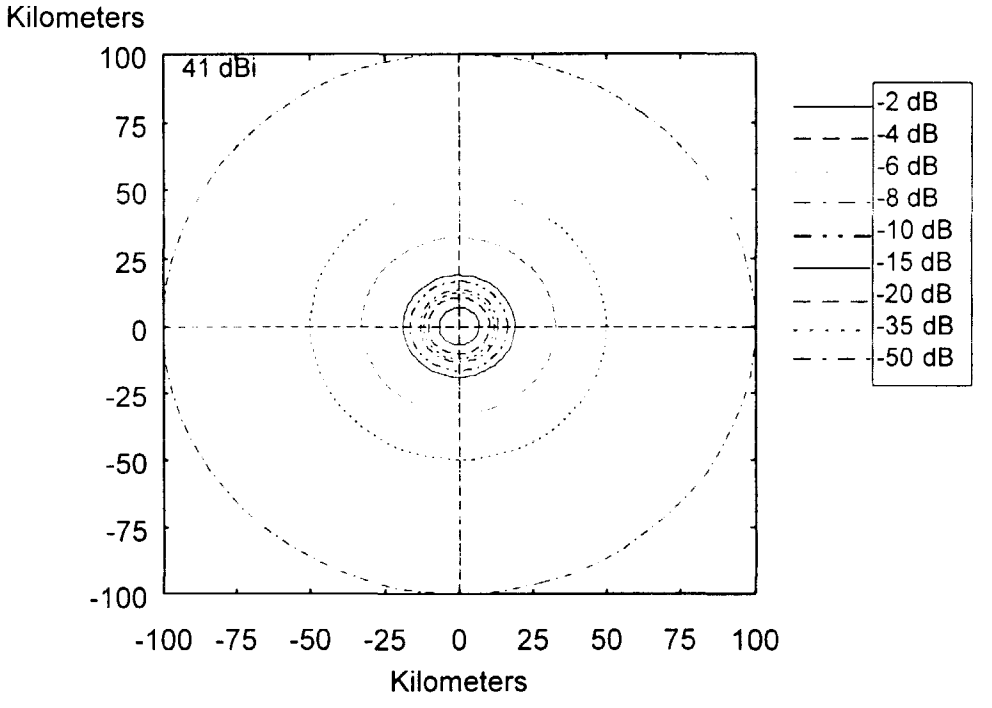

Figure 2.7 NGSO System Satellite High Rate Link Transmit and Receive Gain Pattern

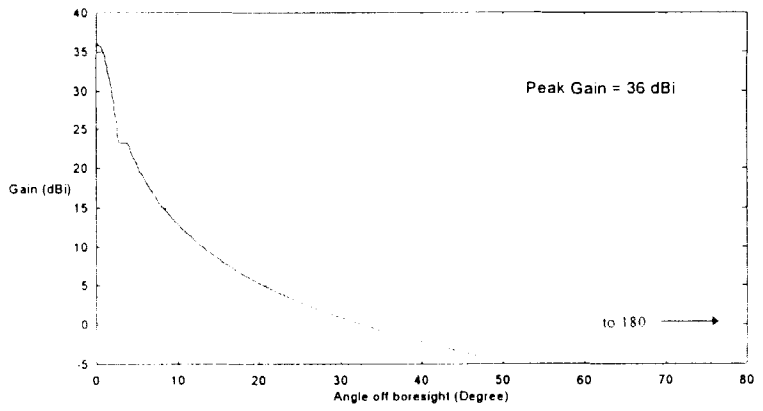

Figure 2.8 NGSO Satellite System Standard Earth Station and Mobile Earth Station Transmit Antenna Pattern

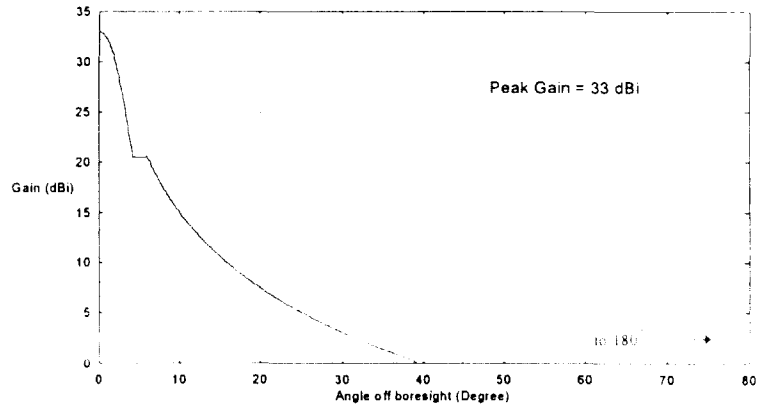

Figure 2.9 NGSO Satellite System Standard Earth Station and Mobile Earth Station Receive Antenna Pattern

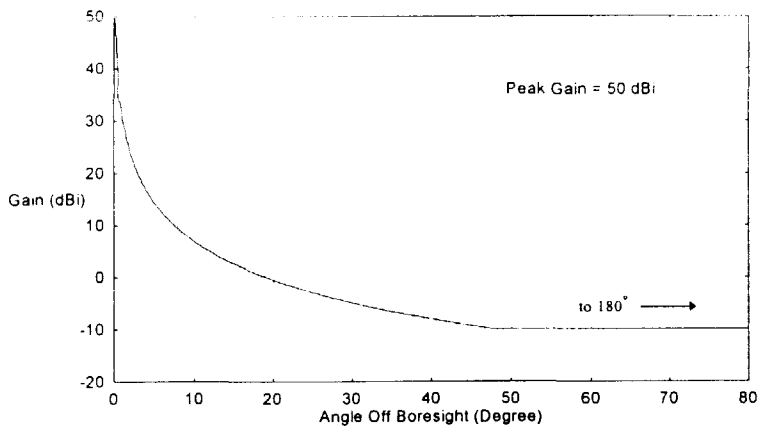

Figure 2.10 NGSO Satellite System High Rate Earth Station Transmit Antenna Pattern

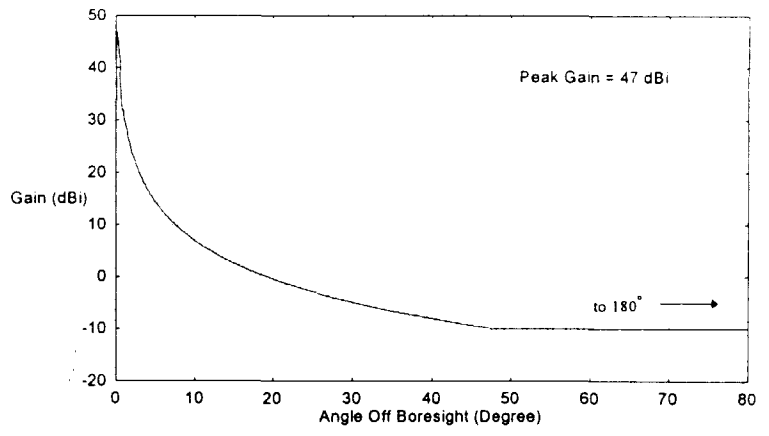

Figure 2.11 NGSO Satellite System High Rate Earth Station Receive Antenna Pattern