JSC-PR-04-044

DEPARTMENT OF DEFENSE
JOINT SPECTRUM CENTER
ANNAPOLIS, MARYLAND 21402-5064

COMMON DATA LINK EMC ANALYSIS

Prepared for

AERONAUTICAL SYSTEMS CENTER
RECONNAISSANCE SYSTEMS PROGRAM OFFICE,
SENSORS AND DATA LINKS
Common Data Link Program Office
2640 Loop Road West, Room 213,
Wright-Patterson AFB, OH 45433-7106

JSC Project Engineer
Captain Heather Bragg, USAF

SEPTEMBER 2004

PROJECT REPORT

Prepared by
Adekunle Adegorusi, Jonathan Timko, and Ron Mendolera

Alion Science and Technology
Under Contract to
Department of Defense

This report was prepared by Alion Science and Technology under Contract DCA100-00-C-4012 in support of the DoD Joint Spectrum Center (JSC) in Annapolis, Maryland.

This report has been reviewed by the following personnel:

JOSHUA J. GLEASON
Project Manager, SENTEL

A. HENRY BEARD
Division Manager, Alion

This report is approved for publication.

DAVID A. GAINES
Lt Col, USAF
Chief, Acquisition Support Division
Joint Spectrum Center

RICHARD B. LARSON
Technical Director
Joint Spectrum Center

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
09-2004

2. REPORT TYPE
Project Report

3. DATES COVERED *(From – To)*

4. TITLE AND SUBTITLE
Common Data Link EMC Analysis

5a. CONTRACT NUMBER
DCA100-00-C-4012

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Adegorusi, Adekunle; Timko, Jonathan; and Mendolera, Ron

5d. PROJECT NUMBER
P 1562

5e. TASK NUMBER
Task 1

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)

Joint Spectrum Center
Acquisition Support Division (JSC/J8)
2004 Turbot Landing
Annapolis, MD 21402-5064

8. PERFORMING ORGANIZATION REPORT NUMBER

JSC-PR-04-044

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Aeronautical Systems Center, Reconnaissance Systems Program Office, Sensors and Data Links
Common Data Link Program Office
2640 Loop Road West, Room 213,
Wright-Patterson AFB, OH 45433-7106

10. SPONSOR/MONITOR'S ACRONYM(S)
ASC/RAJD

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Distribution authorized to the Department of Defense and US DoD contractors only; Operational Use; September 2004. Other requests shall be referred to JSC/J8.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The Aeronautical Systems Center Common Data Link (CDL) Program Office requested that the Joint Spectrum Center (JSC) conduct an electromagnetic compatibility analysis between the CDL communications-electronics equipment and Fixed Satellite Service (FSS) systems. The JSC identified FSS systems that operate in the 13.75 – 15.63-GHz frequency range. Two analyses were performed to determine the potential for electromagnetic Interference (EMI) between the CDL and the various FSS systems due to in-band and adjacent-band interference. For the CDL interfering with FSS systems, an analysis considering the CDL interfering with a -20-dB and -8.5-dB I/N criteria were conducted. For FSS systems interfering with the CDL, a qualitative analysis was performed for the FSS system interfering with a -12-dB I/N criterion. An initial cull analysis was performed using mainbeam antenna gains. The initial cull analysis interactions were placed into one of two categories: "EMI not Predicted" or "EMI Predicted." Interactions in the EMI predicted group were analyzed further by taking into consideration mainbeam-to-sidelobe, sidelobe-to-mainbeam, and sidelobe-to-sidelobe antenna coupling.

Data in this report is current as of July 2004.

15. SUBJECT TERMS
CDL, Common Data Link, EMC Analysis, Space-based communications-electronics equipment, Fixed Satellite Service, FSS.

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Captain Heather Bragg, USAF
U	U	U	SAR	71	19b. TELEPHONE NUMBER *(include area code)* (410) 293-2681, DSN 281-2681

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

PREFACE

The Joint Spectrum Center (JSC), a field activity of the Defense Information Systems Agency (DISA), was established to provide advice and assistance on all matters regarding the electromagnetic battlespace. Support is provided to the Secretary of Defense, the Joint Staff, the military departments, combatant commands, defense agencies, and other agencies of the US Government. The JSC works closely with the Joint Staff, Director for Command, Control, Communications, and Computer Systems, and the Assistant Secretary of Defense for Network and Information Integration on spectrum matters. Direct support is provided to the Unified Commands and Joint Task Force Commanders on electromagnetic battlespace issues, including spectrum management and electronic warfare deconfliction. Support to DoD components and the US Government is provided through a sponsor-reimbursed electromagnetic compatibility (EMC) program that provides EMC analyses for specific projects.

Comments regarding this report should be submitted to the Commander, JSC, 2004 Turbot Landing, Annapolis, MD 21402-5064.

EXECUTIVE SUMMARY

The Aeronautical Systems Center Common Data Link (CDL) Program Office requested that the Joint Spectrum Center (JSC) conduct an electromagnetic compatibility (EMC) analysis between the K_u-band CDL and the Fixed-Satellite Service (FSS) systems. The objective of this analysis was to determine whether there is a potential for electromagnetic interference (EMI) between the K_u-band CDL and the FSS systems.

The JSC identified worldwide FSS systems that operate in the 13.75 – 15.63-GHz frequency range from the International Telecommunication Union-Radiocommunication Bureau (ITU-BR) Space Radiocommunication Stations database. A search of the database identified 740 FSS system segment-pairs forming 134 FSS systems, which were considered in this EMC analysis. To determine if EMI is predicted from the CDL transmitters to the FSS receivers, an initial cull analysis was performed based on mainbeam-to-mainbeam antenna coupling using International Telecommunication Union-Radiocommunication Sector (ITU-R) Recommendations S.738 and S.1432. To bound the range of the CDL transmitter interference to FSS receivers, two scenarios were analyzed: interference that causes an increase in the victim receiver noise temperature by 1% [corresponding to a -20 dB interference-to-noise power ratio (I/N)] and interference that causes an increase in the victim receiver noise temperature by 14% (corresponding to a -8.5-dB I/N). For interactions where the I/N criteria were not exceeded, no further analysis was required. For interactions where the I/N criteria were exceeded, further analysis was conducted, taking into consideration combinations of mainbeam and sidelobe antenna coupling.

For the CDL waveform interfering with the -20-dB I/N criterion, the CDL is predicted to cause interference to 118 FSS systems when considering mainbeam-to-mainbeam antenna coupling. When considering sidelobe-to-sidelobe antenna coupling, the CDL is predicted to cause interference to 20 FSS systems. For the CDL interfering with the -8.5-dB I/N criterion, the CDL is predicted to cause interference to 117 FSS systems when considering mainbeam-to-mainbeam antenna coupling. When considering the best-case spatial coupling scenario (sidelobe-to-sidelobe antenna coupling), the CDL waveform is predicted to cause interference to 14 FSS systems.

The JSC conducted qualitative EMC analyses involving FSS transmitters interfering with the CDL receivers. The results indicated that the CDL receivers will experience interference from FSS transmitters. However, frequency mitigation techniques of off-tuning the CDL receivers from the most significant sources of interference and spatial mitigation techniques, such as ensuring that the CDL receiver antenna is not directly pointed at an interfering FSS transmitter antenna, will reduce or eliminate interference.

The JSC recommends that the CDL Program Office consider migrating this data link to a different frequency band so that the CDL can operate on a primary allocated status. While this may not eliminate potential for EMI; with a primary allocation however, other co-primary or secondary allocated systems will have to grant greater interference tolerance to CDL emissions. In addition, it will afford the CDL receiver protection from interference from secondary allocated transmitters. If the CDL Program Office does not migrate the data link to another band, the JSC recommends that the CDL Program Office consider frequency mitigation and spatial mitigation techniques. Frequency mitigation techniques involve slightly off-tuning the CDL transmitter from victim FSS system receivers and off-tuning the CDL receiver from FSS system transmitters. Spatial mitigation techniques involve achieving mainbeam-to-sidelobe and sidelobe-to-sidelobe antenna coupling rather than mainbeam-to-mainbeam coupling. Both of these mitigation techniques would reduce the amount of EMI from an interfering transmitter to a victim receiver.

TABLE OF CONTENTS

Figures

Tables

GLOSSARY

BW	Bandwidth
CDL	Common Data Link
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FCC	Federal Communications Commission
FDR	Frequency-Dependent Rejection
FL	Forward Link
FSS	Fixed Satellite Service
GEO	Geostationary
I/N	Interference-to-Noise Power Ratio
ISR	Intelligence, Surveillance, and Reconnaissance
ITU-BR	International Telecommunication Union-Radiocommunication Bureau
ITU-R	International Telecommunication Union-Radiocommunication Sector
JSC	Joint Spectrum Center
NGEO	Non-Geostationary
RL	Return Link
S/N	Signal-to-Noise Power Ratio
SEM	Spherical Earth Model
STATGN	Statistical Antenna Gain

SECTION 1 – INTRODUCTION

1.1 BACKGROUND

The Common Data Link (CDL) system is a family of full-duplex communication links used in intelligence, surveillance, and reconnaissance (ISR) missions. The CDL system provides real-time connectivity and interoperability between multiple ISR collection platforms and surface terminals, and operates in two frequency ranges on a secondary allocation status [X-band (9.75 – 10.425 GHz) and K_u-band (14.4 – 15.35 GHz)]. Secondary allocation status requires that the CDL operate on a non-interference basis with primary allocated systems, which includes fixed satellite service (FSS) systems. In addition, the CDL must accept interference from primary allocated systems. The Aeronautical Systems Center CDL Program Office requested that the Joint Spectrum Center (JSC) conduct an electromagnetic compatibility (EMC) analysis between the K_u-band CDL and the FSS systems. The CDL Class I links, which are ground-to-air and air-to-ground communication links, with airborne platforms operating at speeds up to Mach 2.3 and altitudes up to 80,000 ft, were used for this analysis.

1.2 OBJECTIVE

The objective of this analysis was to determine the potential for electromagnetic interference (EMI) between the K_u-band CDL and the FSS systems.

1.3 APPROACH

1.3.1 General

The JSC identified worldwide FSS systems that operate in the 13.75 – 15.63-GHz frequency range from the International Telecommunication Union-Radiocommunication Bureau (ITU-BR) Space Radiocommunication Stations database.[1-1] FSS system sources or victims of interference operating in the frequency bands below 13.75 GHz and above 15.63 GHz were not considered in this analysis because satellite communications systems have multiple-pole bandpass filters and waveguides that will significantly reduce out-of-band emissions and the associated EMI risk.

[1-1] "*ITU-BR Space Radiocommunication Stations Database*," [SRS Database], Geneva, Switzerland: OTI-R, [Cited 8 March 2004]. Available from http://www.itu.int.

An initial search of the ITU-BR database identified over 144,000 frequency assignments within the desired frequency range. These 144,000 frequency assignments correspond to 2,075 waveforms. For the EMC analysis, the JSC selected one frequency assignment for each waveform used for satellite to earth communications. The frequency assignment that was selected was either in band to the CDL operating frequency band or the closest to the CDL operating frequency band if there was no overlap.

The 2,075 waveforms analyzed correspond to 740 FSS system segment-pairs. An FSS system segment-pair is composed of a ground-segment and a corresponding space-segment. The 740 FSS system segment-pairs formed the 134 FSS systems considered in this analysis.

1.3.2 CDL Transmitters to FSS Receivers

To determine the EMI predicted between the CDL transmitters (surface and airborne) and the FSS receivers, an initial cull analysis using mainbeam-to-mainbeam antenna coupling was performed using International Telecommunication Union-Radiocommunication Sector (ITU-R) Recommendations S.738 and S.1432.[1-2, 1-3] These recommendations were used as guidelines for EMI since there are no generally accepted standards to address interference between FSS systems and mobile service systems. Based on the results of the initial cull analysis, the interactions were placed into one of two categories: "*EMI not Predicted* " or "*EMI Predicted*." Interactions where the calculated additional loss necessary to preclude EMI between the CDL transmitters and the FSS receivers was less than or equal to a threshold value were characterized "*EMI not Predicted* " and no further analysis was conducted. Interactions where the calculated additional loss necessary to preclude EMI between the CDL transmitters and the FSS receivers was greater than the threshold value were characterized "*EMI Predicted*."

For the interactions deemed "*EMI Predicted*," further analysis was conducted by taking into consideration the various combinations of mainbeam and sidelobe antenna coupling, which is a spatial mitigation technique. A final list of FSS systems that the CDL Program Office must coordinate with, regardless of the antenna pointing angle, was compiled for those cases where EMI was predicted for sidelobe-to-sidelobe coupling.

[1-2] Recommendation ITU-R S.738, "*Procedure for determining if coordination is required between geostationary-satellite networks sharing the same frequency bands*," Geneva, Switzerland: ITU-R 1992. Available from http://www.itu.int; INTERNET.
[1-3] Recommendation ITU-R S.1432, "*Apportionment of the allowable error performance degradations to fixed-satellite service (FSS) hypothetical reference digital paths arising from time invariant interference for systems operating below 15 GHz*," Geneva, Switzerland: ITU-R 1992. Available from http://www.itu.int; INTERNET.

For FSS receivers that operate in the same band with the CDL transmitters, frequency dependent rejection (FDR) was assumed to be zero. For FSS receivers that operate out-of-band with the CDL transmitters, FDR was determined by using the CDL emission spectrum mask (described in Section 2.1). The CDL emission spectrum mask limits the maximum permissible out-of-band emissions from the CDL transmitters for various CDL data rates.

1.3.3 FSS Transmitters to CDL Receivers

Interference from the FSS transmitters to the CDL receivers (surface and airborne) was expected. However, since the CDL system is a secondary allocated system in the bands analyzed, it must tolerate interference from the transmitting FSS systems. The JSC conducted a quick-look EMI analysis (first using mainbeam-to-mainbeam and then combinations of mainbeam and sidelobe antenna coupling) to determine which transmitting FSS system segments were the most significant sources of interference to the CDL receivers. The JSC qualitatively considered the mitigation techniques of off-tuning the CDL receivers from the most significant sources of interference and ensuring that the CDL antenna was not pointed directly at an interfering FSS system segment.

SECTION 2 – SYSTEM DESCRIPTION

2.1 CDL

The CDL system is designed to provide real-time connectivity and interoperability between multiple ISR collection platforms operated by the DoD and US Government agencies. The CDL has five link classes:

- Class I – Ground-based applications with airborne platforms operating at speeds up to Mach 2.3 and altitudes up to 80,000 ft
- Class II – Airborne applications operating at speeds up to Mach 5 and altitudes up to 150,000 ft
- Class III – Airborne applications operating at speeds up to Mach 5 and altitudes up to 500,000 ft
- Class IV – Terminals in satellites orbiting at 750 nmi
- Class V – Terminals in relay satellites operating at altitudes greater than 750 nmi

This analysis considered the Class I K_u-band link only. The CDL is a full-duplex communication link which includes a forward link (FL) and a return link (RL). The FL is used to communicate command and control functions from the processing (surface) terminal to the gathering (airborne) terminal. The RL transfers sensor data from the airborne terminal back to the surface terminal. The CDL is currently designed to operate in the X-band and K_u-band, shown in Table 2-1.

Table 2-1. CDL X-band and K_u-band Frequency Ranges

	X-band Frequency Ranges, GHz	K_u-band Frequency Ranges, GHz
FL	9.75 – 9.95	15.15 – 15.35
RL	10.15 – 10.425	14.40 – 14.83

The CDL has several standard data rates and waveform-types, as specified in the CDL waveform specification standard, for operations in the K_u-band.[2-1] The data rates for the FL can range from 200 kbps to 45 Mbps. The data rates for the RL link can vary between 200 kbps and 274 Mbps. In addition, data rates of 548 Mbps and 1096 Mbps have been proposed and may be supported in the future. However, the bandwidth for these data rates will be comparable to the 274-Mbps data rate. The bandwidths for the different CDL data rates operating in the K_u-band are listed in Table 2-2.

[2-1] *Waveform Specification for the Standard Common Data Link (CDL) – Revision F (U),* Common Data Link Working Integrated Product Team, 22 November 2002 (SECRET) (Declassify on: X3).

Table 2-2. CDL Waveforms

CDL Waveform Name	Data Rate, Mbps	Bandwidth, MHz
BR-0.2	0.2	0.8
BR-0.4	0.4	1.6
BR-2.0	2	8
BR-10.71A	10.71	21.4
BR-10.71B	10.71	21.4
BR-21.42	21.42	42.8
BR-44.73	44.7368	89.5
BR-137A	137.088	137.1
BR-137B	137.088	146.3
BR-137C	137.088	137.1
BR-137D	137.088	146.3
BR-274A	274.176	274.2
BR-274B	274.176	292.6
BR-274C	274.176	274.2
BR-274D	274.176	292.6

For FSS systems that operate in the same band with the CDL, FDR was assumed to be zero. Because the receiver selectivity data for the FSS system waveforms is not provided in the ITU-BR database, for FSS systems that operate out-of-band with the CDL, the FDR was determined by using the CDL emission spectrum mask. The CDL K_u-band emission spectrum mask (shown in Figure 2-1) limits the maximum permissible out-of-band emissions from the CDL for all of the K_u-band CDL data rates listed in Table 2-2.

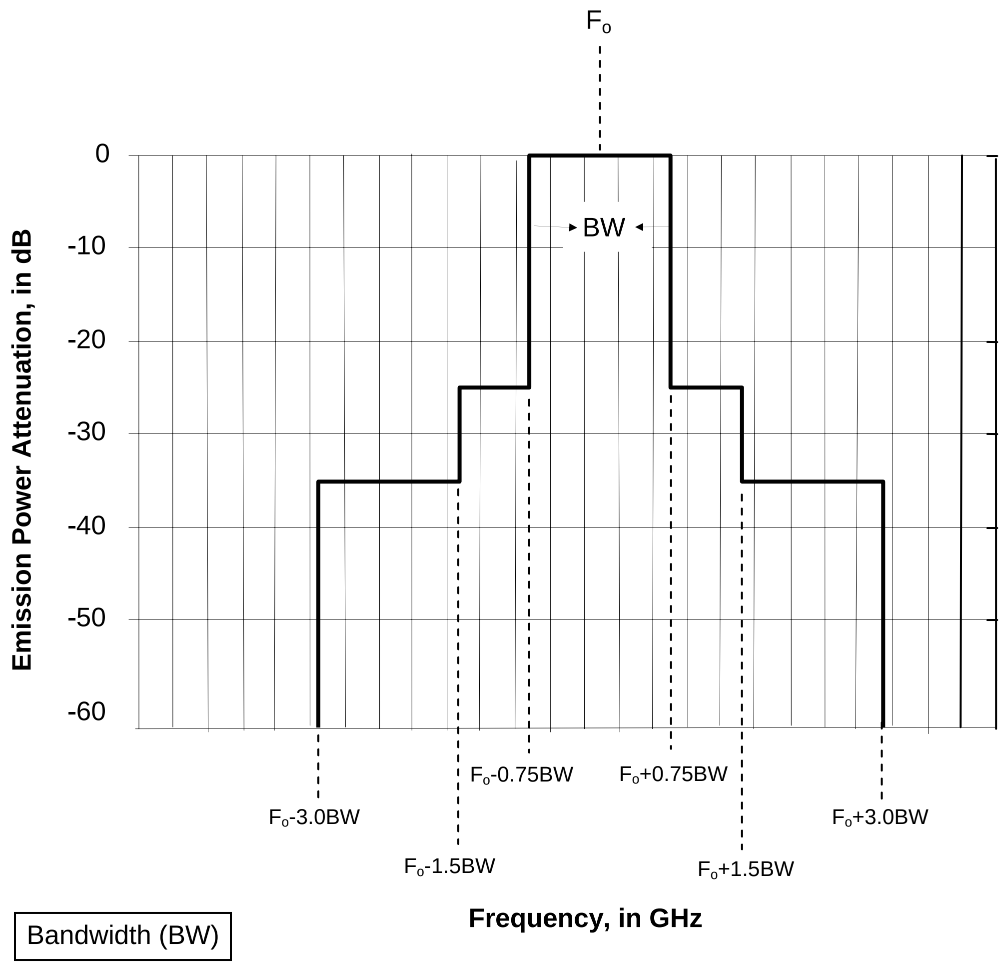

Figure 2-1. CDL Emission Spectrum Mask

The CDL transmitter and receiver characteristics used in this analysis were derived from the Application for Equipment Frequency Allocation (DD Form 1494) J/F 12/7426.[2-2] The surface terminal and airborne terminal K_u-band characteristics are listed in Tables 2-3 and 2-4, respectively.

[2-2] *Application for Equipment Frequency Allocation (DD Form 1494) for the Common Data Link (CDL)*, J/F 12/7426, Washington, DC: MCEB, 07 July 1997.

Table 2-3. CDL Surface Terminal Characteristics

Characteristic	Specification
Transmitter	
Tuning Range, GHz	15.15 – 15.35
Power, dBW	18.45
Spurious Emission Attenuation, dB	52
Receiver	
Tuning Range, GHz	14.40 – 14.83
Sensitivity, dBm	-99 to -120
Antenna	
Mainbeam Gain, dBi	44

Table 2-4. CDL Airborne Terminal Characteristics

Characteristic	Specification
Transmitter	
Tuning Range, GHz	14.40 – 14.83
Power, dBW	18.45
Spurious Emission Attenuation, dB	52
Receiver	
Tuning Range, GHz	15.15 – 15.35
Sensitivity, dBm	-108 to -111
Antenna	
Mainbeam Gain, dBi	24

2.2 IDENTIFIED FSS SYSTEMS AND WAVEFORMS

The FSS systems analyzed operate in the frequency range of 13.75 – 15.63 GHz. This frequency range encompasses the nearest FSS allocated bands above and below the CDL tuning limits. Since FSS systems have multiple-pole bandpass filters and waveguides that will significantly attenuate out-of-band signals, the CDL should not pose an EMI risk to out-of-band FSS systems.

An initial search of the ITU-BR database for the 13.75 – 15.63-GHz band identified over 144,000 frequency assignments within the desired frequency range. These 144,000 frequency assignments correspond to 2,075 waveforms. For the EMC analysis, the JSC selected one frequency assignment for each waveform used for satellite-to-earth communications. The selected frequency assignment was either in-band to the CDL operating frequency band or, if there was no overlap, the closest to the CDL operating frequency band.

For interference interactions from the CDL to the FSS systems, the 2,075 waveforms and associated FSS system segment-pairs were grouped into one of the following four categories:

- **Processing geostationary (GEO) FSS Systems**: Processing GEO FSS system space segments are located in a geostationary orbit. GEO space segments operate at a minimum altitude of approximately 36,000 km above the surface of the earth.[2-3] The processing GEO space segment demodulates a desired K_u-band received signal from a ground segment, then performs a set of functions on the demodulated information, re-modulates, and transmits the modified information to another space or ground segment at a frequency other than K_u-band. Therefore, only the interference from the CDL to the space segment was considered in this analysis. Twenty-seven processing GEO FSS systems were identified and are listed in Table 2-5.

Table 2-5. Identified Processing GEO FSS System Space Segments

AGRANI	F-SAT	NAHUEL	TAIKI
ANIK	GDL	N-SAT	TDRS
BIFROST	INTELSAT	NSS	TONGASAT
BS-3	JCSAT	N-STAR	URUSAT
CANSAT	KYPROS	RASCOM	USASAT
EGYPTSAT	LUXSAT	SEYSAT	VIDEOSAT
EUROPE*STAR	MALTASAT	SKYSAT	
USASAT is a generic name used by the Federal Communications Commission (FCC). USASAT has multiple FSS systems that operate independently. For a complete list of USASAT FSS systems, see the processing GEO and the non-processing GEO worksheets listed in the FSS_Segment.xls file included in the attached CD-ROM.			

- **Non-processing GEO FSS Systems**: Non-processing GEO FSS system space segments are located in a geostationary orbit and are equivalent to a "bent pipe;" in that the space segment receives a desired signal in K_u-band from a ground segment, then, without demodulating the signal, it amplifies and re-transmits the original signal at a frequency other than K_u-band to another space or ground segment (end-user). Since the CDL operates out-of-band from the non-processing GEO end-user, only the interference from the CDL to the end-user via the space segment was considered in this analysis. Ninety non-processing GEO FSS systems were identified and are listed in Table 2-6.

[2-3] Timothy Pratt, Charles Bostian, and Jeremy Allnutt, *Satellite Communications*, Valerie Vargas, 2nd Edition, Hoboken, NJ: John Wiley & Sons, 2003.

Table 2-6. Identified Non-Processing GEO FSS Systems Space Segments

AGILA	D-STAR	LATAMSAT	ST
AGRANI	EAST	LOUTCH	STATSIONAR
AMIT	EASTSAT	L-STAR	SUPERBIRD
AMOS	EMARSAT	LUX	TDRS
AM-SAT	ESDRN	MEASAT	TELECOM
ANIK	EUROPE*STAR	MELITASAT	TELE-X
APSTAR	EUTELSAT	MORELOS	THAICOM
ARABSAT	EXPRESS	MTSAT	TONGASAT
ARTEMIS	F-SAT	NAHUEL	TURKSAT
ASIASAT	GDL	NIR	UKRSAT
AUSSAT	GIBSAT	N-SAT	USASAT
BABYLONSAT	GSTAR	N-STAR	VIDEOSAT
BIFROST	HELLAS-SAT	ORION	VINASAT
BRUSAT	HISPASAT	PACSTAR	VSSRD
B-SAT	HUN-STAR	PAKSAT	WSDRN
BUMERANG	HYUNDAI	PALAPA	YAMAL
CESASAT	IFAT	RASCOM	ZOHREH
CHINASAT	INSAT	ROSCOM	ZSSRD
COLOMBIA	INTELSAT	SBTS	
CSDRN	INTERSPUTNIK	SEYSAT	
CSSRD	ITALSAT	SIMON BOLIVAR	
DB-SAT	JCSAT	SJC	
DFH	KOREASAT	SOLIDARIDAD	
DFS	KUPON	SPACENET	
USASAT is a generic name used by the FCC. USASAT has multiple FSS systems that operate independently. For a complete list of USASAT FSS systems, see the processing GEO and the non-processing GEO worksheets listed in the FSS_Segment.xls file included in the attached CD-ROM.			

- **Non-processing non-geostationary (NGEO) FSS Systems**: There are no non-processing NGEO FSS systems in the band of interest.

- **Processing NGEO FSS Systems**: Processing NGEO FSS system space segments are located in NGEO orbit, operating at an altitude between 500 and 15,000 km above the surface of the Earth (Reference 2-3). The altitude used in the analysis was 500 km. The processing NGEO space segment functions by demodulating a K_u-band desired received signal from a ground segment, then performs a set of functions on the demodulated information, re-modulates, and transmits the modified information to another space or ground segment using K_u-band or a different frequency band. Therefore, interference from the CDL to the space and ground segments were considered in the analysis. Twelve processing NGEO FSS system space segments were identified and are listed in Table 2-7. Five processing NGEO FSS system ground segments were identified and are listed in Table 2-8.

Table 2-7. Identified Processing NGEO FSS System Space Segments

F-SATMULTI	MSSLEO	RSNG	TANYA
HIBLEO	MUSES	SIGNAL	TONQUASI
LUX	QUASIGEO	SURFSAT	USAKU

Table 2-8. Identified Processing NGEO FSS System Ground Segments

FL15-1	ROBLEDO MAD DSS-53	USUDA
FL15-2	TYPICAL BS-15/19	

There can be multiple FSS system segment-pairs per FSS system. The correlation between the 740 FSS system segment-pairs and the 134 FSS systems analyzed is provided in Microsoft Excel XP file "FSS_Segment.xls" included in the CD-ROM for this report. The characteristics for the 2,075 waveforms analyzed are also provided on the CD-ROM (Microsoft Excel XP file "FSS_Waveform_Data.xls"). These files were included to effectively show the data that was used for the analyses, which is contained in four worksheets. The first worksheet in the FSS_Waveform_Data.xls file details the waveform characteristics for the processing GEO FSS systems. The second worksheet details the waveform characteristics for the non-processing GEO FSS systems. The third worksheet details the waveform characteristics for the processing NGEO FSS system space segments. The fourth worksheet details the waveform characteristics for the processing NGEO FSS system ground segments. Tables 2-9 through 2-11 provide a sample of the waveform characteristics collected.

Table 2-9. Sample Waveform Characteristics for a Processing GEO FSS System

Characteristic	Specification
FSS System Name	BS-3
Operating Frequency, GHz	14.37
Power Density, dBW/Hz	-36.9
System Losses, dB	3
Space Segment Noise Temperature, K	1210
Space Segment Mainbeam Antenna Gain, dBi	41.4
Space Segment Sidelobe Antenna Gain, dBi	11.4
Space Segment Name	BS-3
Ground Segment Noise Temperature, K	290
Ground Segment Mainbeam Antenna Gain, dBi	41.4
Ground Segment Sidelobe Antenna Gain, dBi	27.3
Ground Segment Name	OSAKA

Table 2-10. Sample Waveform Characteristics for a Non-Processing GEO FSS System

Characteristic	Specification
FSS System Name	AGILA
Operating Frequency, GHz	14.45
Power Density, dBW/Hz	-33.3
System Losses, dB	3
Transmission Gain Factor, dB	2
Space Segment Noise Temperature, K	1250
Space Segment Mainbeam Antenna Gain, dBi	40.9
Space Segment Sidelobe Antenna Gain, dBi	10.9
Space Segment Name	AGILA-A1
Ground Segment Noise Temperature, K	4317
Ground Segment Mainbeam Antenna Gain, dBi	40.9
Ground Segment Sidelobe Antenna Gain, dBi	26.9
Ground Segment Name	TYPICAL 4.5M

Table 2-11. Sample Waveform Characteristics for a Processing NGEO FSS System

Characteristic	Specification
FSS System Name	F-SATMULTI
Operating Frequency, GHz	14.4966
Power Density, dBW/Hz	-61
System Losses, dB	3
Space Segment Noise Temperature, K	580
Space Segment Mainbeam Antenna Gain, dBi	19.5
Space Segment Sidelobe Antenna Gain, dBi	-10.5
Space Segment Name	F-SATMULTI-1B
Ground Segment Noise Temperature, K	140
Ground Segment Mainbeam Antenna Gain, dBi	33
Ground Segment Sidelobe Antenna Gain, dBi	20.98
Ground Segment Name	MULTISERV1

SECTION 3 – ANALYSIS METHODOLOGY

3.1 GENERAL

3.1.1 CDL Transmitters to FSS Receivers

An initial cull analysis using mainbeam-to-mainbeam antenna coupling and free-space wave-spreading loss was performed using ITU-R Recommendations S.738 and S.1432 (Reference 1-2 and 1-3) to determine if EMI is predicted from the CDL transmitters (surface and airborne) to the FSS receivers.

ITU-R S.738 outlines the procedure for determining if coordination is required between GEO-satellite networks that share the same frequency bands. It provides the equations required to calculate the change in noise temperatures for FSS systems and explains the method of using the ratio of the change in noise temperature to the noise temperature of the receiver as the criterion for calculating EMI.

ITU-R S.1432 apportions the allowable error performance degradation to an FSS system, arising from time-invariant interference, among various sources. For potential interfering systems such as the CDL, which must operate on a non-interference basis, ITU-R S.1432 only permits a 1% increase in the FSS system noise temperature, which is equivalent to a -20-dB interference-to-noise power ratio (I/N) for 100% of a month. Since the CDL transmitter does not operate continuously and is used on mobile platforms, the interference from the CDL transmitter to any particular satellite system receiver will be present much less than 100% of a month. Using the procedures described in ITU-R S.1432 to convert between bit error rate for a percentage of total interference in a month and I/N, Figure 3-1 was developed to show the allowable I/N for various percentages of a month.

To bound the range of the CDL transmitter interference to FSS receivers, two scenarios were analyzed: interference causing a 1% increase in the victim receiver noise temperature (corresponding to a -20-dB I/N) and interference causing a 14% increase in the victim receiver noise temperature, which is equivalent to a -8.5-dB I/N. -8.5-dB I/N corresponds to the 0.005% of a month interference scenario from Figure 3-1.

Based on the results of the initial cull analysis, the interactions were placed into one of two categories: "*EMI not Predicted* " or "*EMI Predicted.*" For interactions where the -20-dB I/N criterion was not exceeded, no further analysis was deemed necessary and those interactions were characterized "*EMI not Predicted*." Interactions where the -20-dB I/N criterion was exceeded were characterized "*EMI*

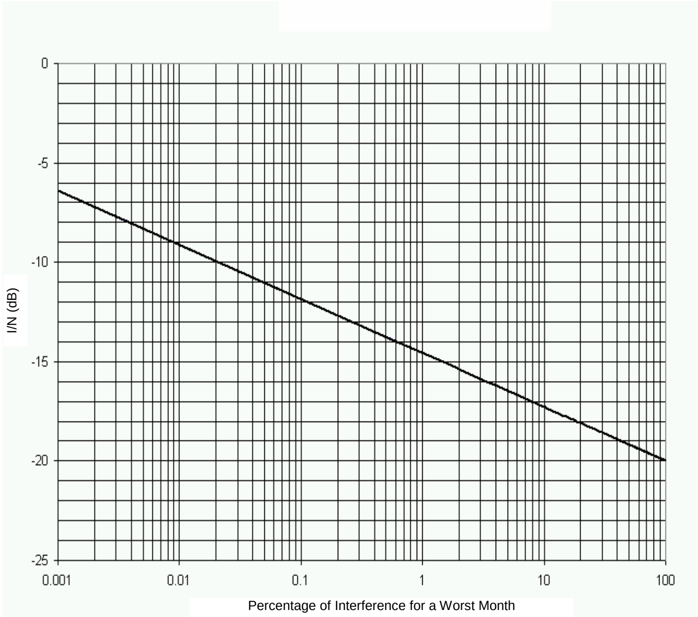

Figure 3-1. Digital Satellite Allowable I/N Versus Duration of Interference

Predicted," and additional analyses were completed to account for spatial configurations (e.g., sidelobe-to-mainbeam, mainbeam-to-sidelobe, and sidelobe-to-sidelobe antenna coupling). The CDL to FSS system initial cull analysis was repeated using the -8.5-dB I/N criterion.

For the interactions deemed "*EMI Predicted*," further analyses were conducted, taking into consideration the various combinations of mainbeam and sidelobe antenna gain coupling. This included the CDL mainbeam-to-FSS system sidelob e, the CDL sidelobe-to-FSS system mainbeam, and the CDL sidelobe-to-FSS system sidelobe antenna coupling. These analyses used the same criterion as the mainbeam-to-mainbeam antenna coupling case.

3.1.2 FSS Transmitters to CDL Receivers

Interference from FSS transmitters to CDL receivers is expected. However, since the CDL is a secondary allocated system in the frequency bands analyzed, the CDL receivers must tolerate interference from the FSS transmitters. The JSC conducted a quick-look EMI analysis using the initial cull analysis methodology, except that the CDL was the victim and the FSS systems were the interferer. A qualitative analysis approach was applied to determine if the interference could be mitigated by off-tuning the CDL receiver from the significant sources of interference and implementing prudent CDL antenna-pointing geometry.

For FSS transmitter to CDL receiver interference, the JSC used a conservative threshold of 6% as the permissible increase in the CDL receiver noise temperature because there is no ITU-R recommendation for tolerable interference to non-primary allocated systems from primary allocated systems. A CDL I/N was used as an estimate of permissible receiver noise temperature increase. As the CDL I/N was not provided in the Application for Equipment Frequency Allocation, it was assumed to be 12 dB based on the CDL signal-to-noise power ratio (S/N), which corresponds to a 6% increase in the CDL system noise temperature 100% of a month.

3.2 CDL TRANSMITTERS TO FSS RECEIVERS ANALYSIS

3.2.1 Analysis Assumptions

The analysis was completed using the following assumptions:

- Processing and non-processing GEO space segments operate at a minimum altitude of 36,000 km
- Processing NGEO space segments operate at a minimum altitude of 500 km
- The minimum distance separation between the CDL surface terminal and the FSS system ground segment is 100 km
- For free-space wave-spreading loss propagation modeling, atmospheric and polarization losses are 0 dB
- For Spherical Earth Model (SEM) propagation modeling, polarization losses are 0 dB

3.2.2 Initial Cull Analysis

An initial cull analysis was performed using mainbeam antenna gains. For interactions involving the CDL surface terminal transmitters and the FSS system ground segments receivers, the JSC SEM was used to calculate the propagation loss necessary to preclude EMI. SEM provides a more realistic propagation loss estimate than free-space wave-spreading loss for terrestrial links since SEM includes environmental factors such as atmospheric refractivity, humidity, ground reflectivity, ground conductivity, and the curvature of the earth. SEM does not account for loss due to vegetation, rough terrain (including hills and valleys) and man-made obstructions. For all other interactions, free-space wave-spreading propagation loss was used to calculate propagation loss.

Additional rejection due to the frequency separation between the CDL transmitters and various FSS receivers was derived from the CDL emission spectrum mask illustrated in Figure 2-1. For FSS receivers that operate in the same band with the CDL transmitters, FDR was assumed to be zero. For FSS receivers that operate out-of-band with the CDL transmitters, FDR was determined by using the

CDL emission spectrum mask which limits the maximum permissible out-of-band emissions from the CDL transmitters for various CDL data rates.

The additional loss necessary to preclude EMI from the CDL transmitters to the FSS receivers was calculated using the waveform characteristics obtained from the ITU-BR database (Reference 1-1). Based on the ITU-R recommendations (References 1-2 and 1-3), an increase in the noise temperature of a FSS receiver signifies that there is interference from an external source. To determine the additional loss necessary to preclude EMI, the propagation loss for the minimum distance separation between the various the CDL terminals and the FSS system segments was first determined. The minimum path loss required to preclude a 1% victim receiver noise temperature increase (corresponding to the -20-dB I/N criterion) was then calculated using the modified ITU-R recommendations. Finally, the propagation loss for the minimum distance separation was subtracted from the minimum path loss that precludes a 1% change in noise temperature resulting in the additional loss necessary to preclude EMI.

If the additional loss necessary was less than zero, the interaction was characterized as "*EMI not Predicted* " and no further analysis was deemed necessary. For the "*EMI Predicted* " cases, the CDL mainbeam-to-FSS system sidelobe, the CDL sidelobe-to-FSS system mainbeam, and the CDL sidelobe-to-FSS system sidelobe antenna coupling scenarios were considered, as detailed in Sections 3.2.3, 3.2.4, and 3.2.5.

Figures 3-2 through 3-9 show multiple scenarios in which the CDL can interact with GEO and NGEO FSS systems.

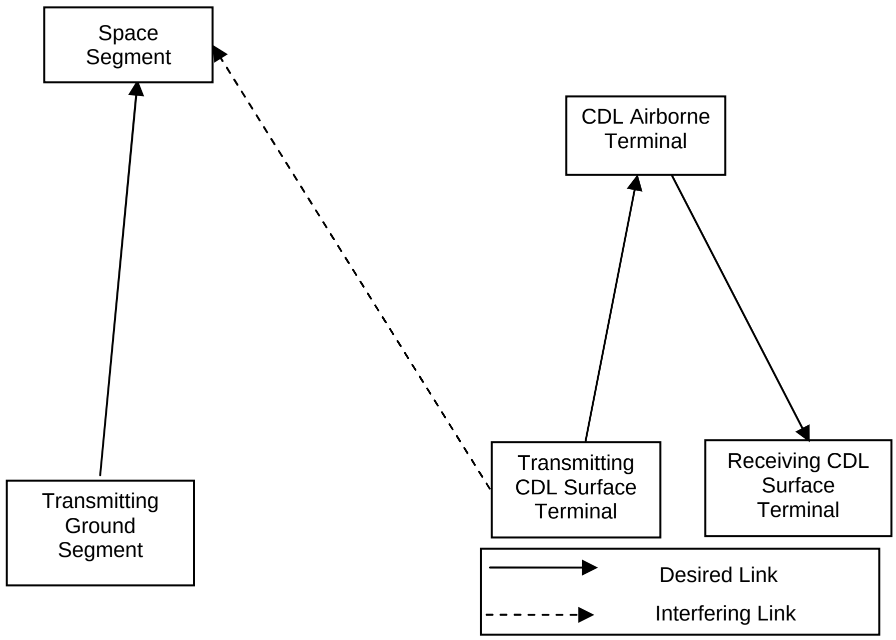

Figure 3-2. CDL Surface Terminal Interfering with the Processing GEO FSS System Space Segment

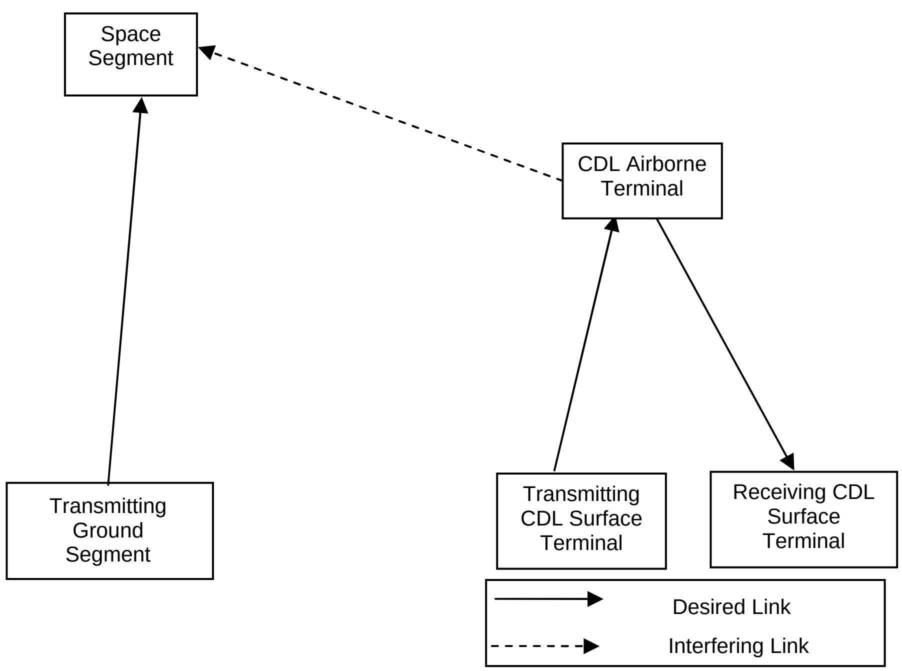

Figure 3-3. CDL Airborne Terminal Interfering with the Processing GEO FSS System Space Segment

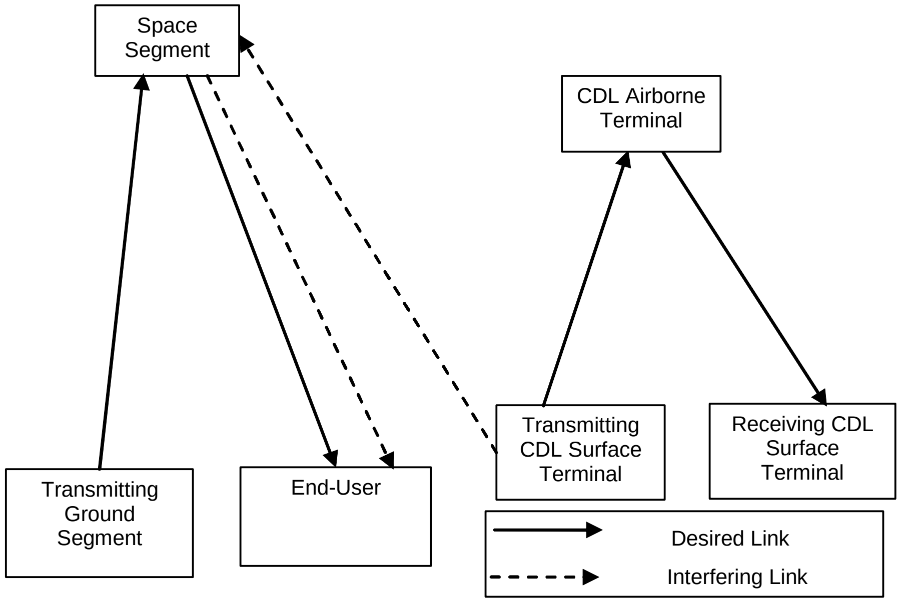

Figure 3-4. CDL Surface Terminal Interfering with the Non-Processing GEO FSS System Ground Segment, via the Space Segment

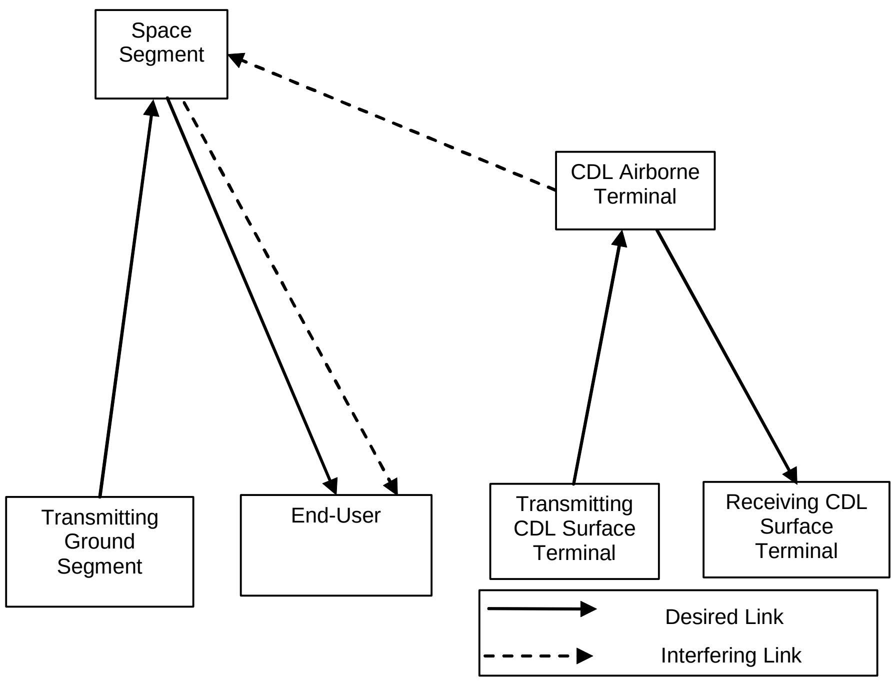

Figure 3-5. CDL Airborne Terminal Interfering with the Non-Processing GEO FSS System Ground Segment, via the Space Segment

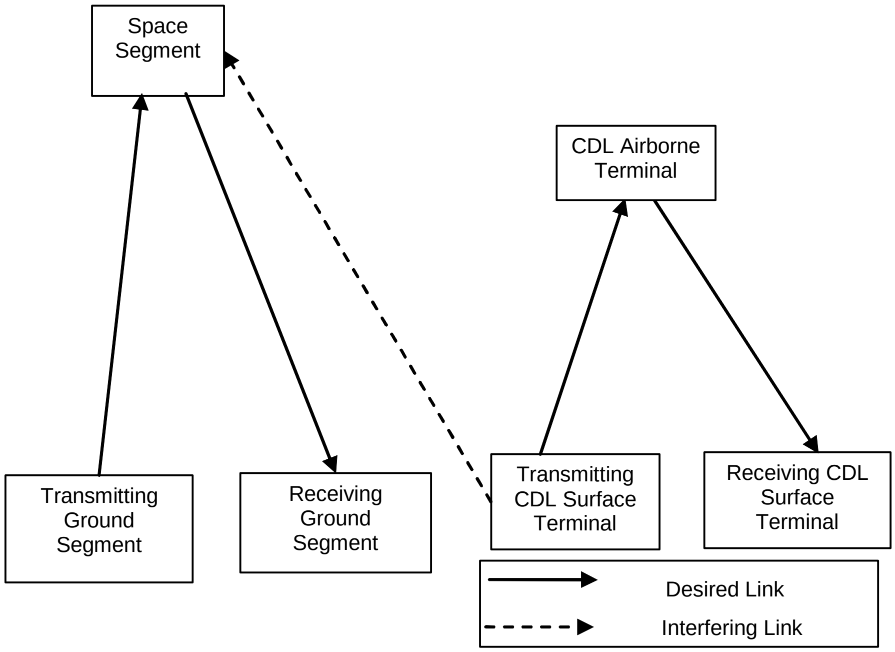

Figure 3-6. CDL Surface Terminal Interfering with the Processing NGEO FSS System Space Segment

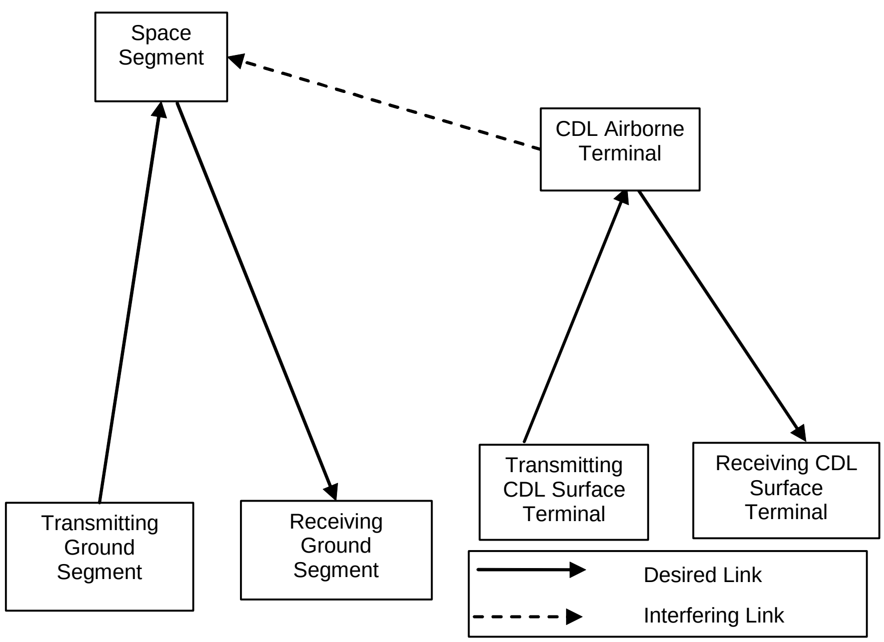

Figure 3-7. CDL Airborne Terminal Interfering with the Processing NGEO FSS System Space Segment

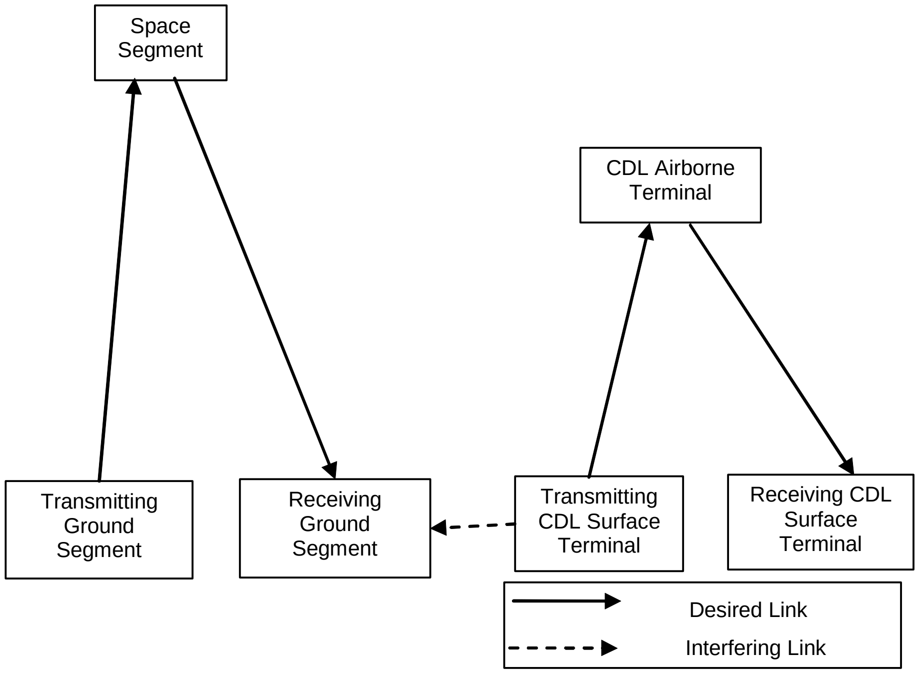

Figure 3-8. CDL Surface Terminal Interfering with the Processing NGEO FSS System Ground Segment

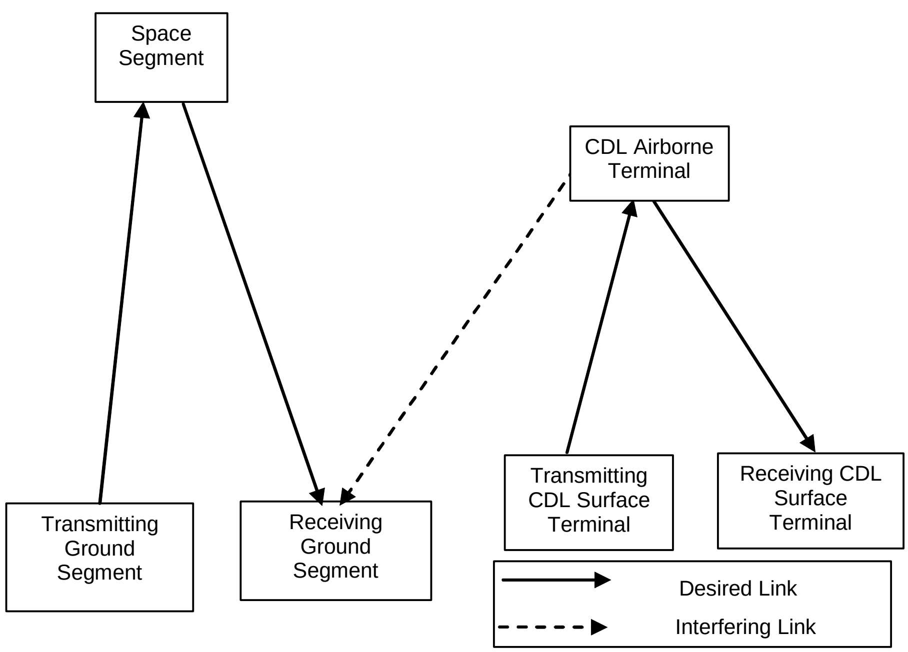

Figure 3-9. CDL Airborne Terminal Interfering with the Processing NGEO FSS System Ground Segment

Based on the ITU-R recommendations (References 1-2 and 1-3), in order to avoid EMI between the CDL and the FSS system, the increase in noise temperature needs to be less than or equal to 1% (corresponding to the -20-dB I/N criterion). The threshold increase in noise temperature due to interference to the FSS systems was calculated using Equation 3-1:

$$\frac{\Delta T}{T} = 0.01 \tag{3-1}$$

where ΔT = increase in victim receiver noise temperature, in degrees K
T = equivalent link noise temperature, in degrees K

Free-space wave-spreading propagation loss for the minimum distance separation between the CDL and a particular FSS system segment was calculated using Equation 3-2:

$$L_p = 20\log(F) + 20\log(D) + 92.45 \tag{3-2}$$

where L_p = free-space wave-spreading propagation loss for the minimum distance separation between the CDL and the FSS systems, in dB
F = frequency of the CDL terminal, in GHz
D = minimum distance separation between the CDL and the FSS system segment, in km

For the processing NGEO, the propagation loss for the minimum distance separation between the CDL surface terminal and the FSS system ground segments were calculated using SEM. The parameters used in SEM are listed in Table 3-1.

Table 3-1. SEM Parameters

Parameter	Value
Surface humidity, in g/m^3	20
Atmospheric refractivity, unitless	350
Ground permittivity, unitless	30
Ground conductivity, in S/m	0.002
FSS system ground segment antenna height, in m	20
CDL surface terminal antenna height, in m	3
Minimum distance separation, in km	100
Frequency, in GHz	15.35

The power spectral density for the CDL waveforms was calculated using Equation 3-3. Table 3-2 shows the calculated power spectral density for each CDL waveform:

$$PSD = 10\log(P_T) - L_s - 10\log(B) + 60 \tag{3-3}$$

where PSD = power spectral density, in dBW/Hz

P_T = the CDL transmit power, in dBW

L_s = cable and connector losses, 3 dB

B = the CDL bandwidth (from Table 2-2), in MHz.

Table 3-2. CDL Power Spectral Density for the Different Waveform Names

CDL Waveform Names	CDL Power Spectral Density, in dBW/Hz
BR-0.2	-43.6
BR-0.4	-46.6
BR-2.0	-53.6
BR-10.71A	-57.9
BR-10.71B	-57.9
BR-21.42	-60.9
BR-44.73	-64.1
BR-137A	-65.9
BR-137B	-66.2
BR-137C	-65.9
BR-137D	-66.2
BR-274A	-68.9
BR-274B	-69.2
BR-274C	-68.9
BR-274D	-69.2

Solving Equation 3-1 for T and including the power spectral density calculated in Equation 3-3, the path loss necessary to preclude EMI was calculated using Equation 3-4:

$$L_{P,Necessary} = \gamma + PSD + G_T + G_R - R - 10\log(k) - 10\log(100\Delta T) \tag{3-4}$$

where $L_{P,\ Necessary}$ = path loss necessary to preclude EMI, in dB

γ = FSS system transmission gain, in dB

G_T = the CDL transmitter antenna gain, in dBi

G_R = FSS system receiver antenna gain, in dBi

R = rejection due to the CDL emission spectrum mask, in dB

k = Boltzmann's constant, 1.38×10^{-23} J/K

ΔT = increase in victim receiver noise temperature, in degrees K

all other terms are as previously defined.

The additional loss necessary to preclude EMI was calculated using Equation 3-5:

$$P_{AL} = L_{P,\ Necessary} - L_p \tag{3-5}$$

where P_{AL} = additional loss necessary to preclude EMI, in dB

all other terms are as previously defined.

The parameters used for Equations 3-1, 3-2, and 3-4 are shown in Tables 3-3 through 3-5 for interference from the CDL transmitter to the three different FSS receiver categories.

Table 3-3. Parameters for the CDL to Processing GEO FSS System Interference Interactions

Parameter	Values for CDL Surface Terminal Case	Values for CDL Airborne Terminal Case
T, in K	Note 1	Note 1
f, in GHz	15.15	14.4
D, in km	36,000	36,000
γ, in dB	0	0
G_T, in dBi	44	24
G_R, in dBi	Note 1	Note 1
Note 1 – Varies for each FSS system analyzed.		

Table 3-4. Parameters for the CDL to Non-Processing GEO FSS System Interference Interactions

Parameter	Values for CDL Surface Terminal Case	Values for CDL Airborne Terminal Case
T, in K	Note 1	Note 1
f, in GHz	15.15	14.4
D, in km	36,000	36,000
γ, in dB	Note 1	Note 1
G_T, in dBi	44	24
G_R, in dBi	Note 1	Note 1
Note 1 – Varies for each FSS system analyzed.		

Table 3-5. Parameters for the CDL to Processing NGEO FSS System Interference Interactions

Parameter	FSS System Space Segment		FSS System Ground Segment	
	Values for CDL Surface Terminal Case	Values for CDL Airborne Terminal Case	Values for CDL Surface Terminal Case	Values for CDL Airborne Terminal Case
T, in K	Note 1	Note 1	Note 1	Note 1
f, in GHz	15.15	14.4	15.15	14.4
D, in km	500	475.6	Note 2	24.4
γ, in dB	0	0	0	0
G_T, in dBi	44	24	44	24
G_R, in dBi	Note 1	Note 1	Note 1	Note 1
Note 1 – Varies for each FSS system analyzed Note 2 – SEM was used to calculate propagation loss				

The entire analysis was repeated using the 14% increase in FSS receiver noise temperature (corresponds to the -8.5-dB I/N criterion), which represents an upper bound to allowable interference.

3.2.3 CDL Mainbeam-to-FSS System Sidelobe Antenna Coupling

Mainbeam-to-sidelobe coupling represents a spatial mitigation technique. This interaction provides 15 – 30 dB of additional attenuation compared to the mainbeam-to-mainbeam case analyzed in the initial cull. The FSS system receiver mainbeam antenna gain (G_R) presented in Equation 3-4 was replaced with the FSS system receiver sidelobe antenna gain to incorportate the additional loss associated with mainbeam-to-sidelobe coupling. The analysis methodology described in Section 3.2.2 was used for this antenna coupling scenario.

The FSS system space segment sidelobe gain was estimated by subtracting 30 dB from the mainbeam gain.[3-1, 3-2] The FSS system ground segment sidelobe gain was derived by using equations specified by the ITU-R[3-3] which were used to arrive at Equation 3-6:

$$G_s = 2 + [15(G - 7.7)]/20 \tag{3-6}$$

where G_s = FSS system ground segment sidelobe gain, in dBi
G = FSS system ground segment peak antenna gain, in dBi

A list of sidelobe gains for the FSS system waveforms used in this analysis are included on the report CD-ROM (file name “FSS_Waveform_Data.xls”).

3.2.4 CDL Sidelobe-to-FSS System Mainbeam Antenna Coupling

Sidelobe-to-mainbeam coupling represents a spatial mitigation technique. This interaction provides 10 – 20 dB of additional attenuation compared to the mainbeam-to-mainbeam case analyzed in the initial cull. The CDL transmitter mainbeam antenna gain (G_T) presented in Equation 3-4 was replaced with the CDL transmitter sidelobe antenna gain to incorporate the additional loss associated with mainbeam-to sidelobe coupling. The analysis methodology described in Section 3.2.2 was used for this antenna coupling scenario.

[3-1] Recommendation ITU-R S.672-4, “*Satellite antenna radiation pattern for use as a design objective in the fixed-satellite service employing geostationary satellites,*” [ITU-R website], Geneva, Switzerland: 1997. Available from http://www.itu.int; INTERNET.

[3-2] Recommendation ITU-R S.1528, “*Satellite antenna radiation patterns for non-geostationary orbit satellite antennas operating in the fixed-satellite service below 30 GHz,*” [ITU-R website], Geneva, Switzerland: 1997. Available from http://www.itu.int; INTERNET.

[3-3] Radio Regulations, 4 vols, Geneva: International Telecommunication Union, 2001.

The CDL sidelobe antenna gains were calculated using the JSC Statistical Antenna Gain (STATGN) model. STATGN is a collection of simple computer models that provide statistics-based estimates of antenna characteristics. STATGN is applicable to reflector antennas and other types of antennas having a mainbeam gain greater than about 10 dBi.

3.2.5 CDL Sidelobe-to-FSS System Sidelobe Antenna Coupling

Sidelobe-to-sidelobe coupling represents a more restrictive spatial mitigation technique than the mainbeam-to-sidelobe or sidelobe-to-mainbeam cases. This interaction provides 25 – 50 dB of additional attenuation compared to the mainbeam-to-mainbeam case analyzed in the initial cull. The CDL transmitter mainbeam antenna gain (G_T) and the FSS system receiver mainbeam antenna gain (G_R) presented in Equation 3-4 were replaced with the CDL transmitter sidelobe antenna gain and the FSS system receiver sidelobe antenna gain to incorporate the additional loss associated with sidelobe-to-sidelobe coupling. The analysis methodology described in Section 3.2.2 was used for this antenna coupling scenario. If a potential for EMI still existed after implementing the CDL sidelobe-to-FSS system sidelobe antenna coupling, then no additional analysis was performed and the particular EMI interaction will require further mitigation.

The methodology for calculating the CDL sidelobe antenna gain and the FSS system sidelobe antenna gain is described in Sections 3.2.3 and 3.2.4.

3.3 FSS TRANSMITTERS TO CDL RECEIVERS ANALYSIS

The initial cull methodology detailed in Section 3.2 was used to perform a quick-look EMI analysis to identify potential sources of interference from the FSS transmitters to the CDL receivers for a 6% increase in noise temperature (corresponding to the -12-dB I/N criterion). The effect of CDL receiver selectivity was considered in this analysis. The JSC also performed a qualitative analysis to further examine possible mitigation techniques the CDL Program Office can implement to lessen the impact of EMI to the CDL.

SECTION 4 – RESULTS

4.1 FSS SYSTEM EMI MATRICES

There were 2,075 FSS system waveforms analyzed. The total dataset cannot be effectively presented in the body of this document. A CD-ROM is provided that contains several Microsoft Excel XP files detailing the analysis results.

As an example of the data included on the CD-ROM, Tables 4-1 through 4-4 list the FSS systems that the BR-0.2 CDL waveform is predicted to interfere with based on the -20-dB I/N criterion. Tables 4-5 through 4-8 list the FSS systems that the BR-0.2 CDL waveform is predicted to interfere with based on the -8.5-dB I/N criterion. An "X" in the table indicates interference conditions. Information on the FSS systems with which other CDL waveforms will interfere is provided on the CD-ROM.

Section 4.2 explains how the results are displayed on the CD-ROM. As noted in the tables, implementing spatial mitigation by limiting the CDL antenna pointing angle significantly reduces the number of interference cases. Section 4.3 presents the FSS receivers with which the CDL transmitter is predicted to interfere when maximum spatial mitigation is implemented (e.g., sidelobe-to-sidelobe antenna coupling).

Appendix A lists the FSS receivers with which the CDL transmitter will interfere based on the -20-dB and -8.5-dB I/N criterion.

Table 4-1. Matrix Showing the Processing GEO FSS Systems with EMI from CDL Predicted for the -20-dB I/N Criterion

FSS Systems	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
AGRANI					X		X	
ANIK					X	X	X	
BIFROST								
BS-3								
CANSAT					X		X	
EGYPTSAT					X		X	
EUROPE*STAR					X		X	
F-SAT								
GDL								
INTELSAT					X		X	
JCSAT					X	X	X	
KYPROS					X		X	
LUXSAT					X		X	
MALTASAT					X	X	X	
NAHUEL					X	X	X	
N-SAT					X	X	X	
NSS					X	X	X	
N-STAR					X	X	X	
RASCOM					X	X	X	
SEYSAT					X	X	X	
SKYSAT					X	X	X	
TAIKI								
TDRS	X	X	X	X	X	X	X	
TONGASAT					X	X	X	
URUSAT					X	X	X	
USASAT					X		X	
VIDEOSAT					X	X	X	

M-M = mainbeam-to-mainbeam
M-S = mainbeam-to-sidelobe
S-M = sidelobe-to-mainbeam
S-S = sidelobe-to-sidelobe

Table 4-2. Matrix Showing the Non-Processing GEO FSS Systems with EMI from CDL Predicted for the -20-dB I/N Criterion

FSS Systems	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
AGILA					X		X	
AGRANI					X		X	
AMIT					X		X	
AMOS					X	X	X	
AM-SAT					X	X	X	
ANIK					X		X	
APSTAR					X	X	X	
ARABSAT					X		X	
ARTEMIS								
ASIASAT					X	X	X	
AUSSAT					X	X	X	
BABYLONSAT					X		X	
BIFROST					X		X	
BRUSAT					X	X	X	
B-SAT					X		X	
BUMERANG								
CESASAT					X	X	X	
CHINASAT					X		X	
COLOMBIA					X		X	
CSDRN	X	X	X	X	X	X	X	
CSSRD	X	X	X	X	X	X	X	
DB-SAT					X		X	
DFH					X		X	
DFS					X	X	X	
D-STAR					X	X	X	
EAST								
EASTSAT					X	X	X	
EMARSAT					X		X	
ESDRN	X	X	X	X	X	X	X	
EUROPE*STAR					X	X	X	
EUTELSAT					X	X	X	
EXPRESS					X		X	
F-SAT					X	X	X	
GDL					X	X	X	
GIBSAT					X		X	
GSTAR					X		X	
HELLAS-SAT					X	X	X	
HISPASAT					X	X	X	
HUN-STAR					X		X	
HYUNDAI					X		X	
IFAT					X		X	
INSAT					X		X	
INTELSAT					X	X	X	
INTERSPUTNIK					X	X	X	
ITALSAT								
JCSAT					X	X	X	
KOREASAT	X				X	X	X	X
KUPON					X		X	

Table 4-2. Matrix Showing the Non-Processing GEO FSS Systems with EMI from CDL Predicted for the -20-dB I/N Criterion (continued)

FSS Systems	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
LATAMSAT					X	X	X	
LOUTCH					X		X	
L-STAR					X		X	
LUX					X		X	
MEASAT					X	X	X	
MELITASAT								
MORELOS					X		X	
MTSAT								
NAHUEL					X	X	X	
NIR					X		X	
N-SAT					X	X	X	
N-STAR					X	X	X	
ORION-					X	X	X	
PACSTAR					X	X	X	
PAKSAT					X	X	X	
PALAPA					X	X	X	
RASCOM					X	X	X	
ROSCOM					X		X	
SBTS					X		X	
SEYSAT					X		X	
SIMON BOLIVAR					X	X	X	
SJC					X	X	X	
SOLIDARIDAD					X		X	
SPACENET					X		X	
ST					X	X	X	
STATSIONAR					X		X	
SUPERBIRD					X	X	X	
TDRS	X	X	X	X	X	X	X	
TELECOM								
TELE-X								
THAICOM					X	X	X	
TONGASAT					X	X	X	
TURKSAT					X	X	X	
UKRSAT					X		X	
USASAT					X	X	X	
VIDEOSAT					X	X	X	
VINASAT					X		X	
VSSRD	X	X	X	X				
WSDRN	X	X	X	X	X	X	X	
YAMAL								
ZOHREH					X		X	
ZSSRD	X	X	X	X	X		X	

M-M = mainbeam-to-mainbeam
M-S = mainbeam-to-sidelobe
S-M = sidelobe-to-mainbeam
S-S = sidelobe-to-sidelobe

Table 4-3. Matrix Showing the Processing NGEO FSS System Space Segments with EMI from CDL Predicted for the -20-dB I/N Criterion

FSS Systems	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	**M-S**	**S-M**	**S-S**	**M-M**	**M-S**	**S-M**	**S-S**
F-SATMULTI	X				X	X	X	X
HIBLEO								
LUX	X	X	X		X		X	
MSSLEO								
MUSES	X	X	X	X	X			
QUASIGEO	X	X	X		X			
RSNG	X				X	X	X	X
SIGNAL	X							
SURFSAT	X	X	X	X				
TANYA	X	X	X		X	X	X	X
TONQUASI	X		X		X	X	X	X
USAKU	X	X	X		X	X	X	X
M-M = mainbeam-to-mainbeam M-S = mainbeam-to-sidelobe S-M = sidelobe-to-mainbeam S-S = sidelobe-to-sidelobe								

Table 4-4. Matrix Showing the Processing NGEO FSS System Ground Segments with EMI from CDL Predicted for the -20-dB I/N Criterion

FSS Systems	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	**M-S**	**S-M**	**S-S**	**M-M**	**M-S**	**S-M**	**S-S**
USUDA	X				X	X	X	X
FL15-1	X				X	X	X	X
FL15-2					X	X	X	X
TYPICAL BS-15/19					X	X	X	X
ROBLEDO MAD DSS-53	X				X	X	X	X
M-M = mainbeam-to-mainbeam M-S = mainbeam-to-sidelobe S-M = sidelobe-to-mainbeam S-S = sidelobe-to-sidelobe								

Table 4-5. Matrix Showing the Processing GEO FSS Systems with EMI from CDL Predicted for the -8.5-dB I/N Criterion

FSS Systems	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
AGRANI					X			
ANIK					X		X	
BIFROST								
BS-3								
CANSAT					X		X	
EGYPTSAT					X		X	
EUROPE*STAR					X			
F-SAT								
GDL								
INTELSAT					X		X	
JCSAT					X		X	
KYPROS					X			
LUXSAT					X			
MALTASAT					X		X	
NAHUEL					X		X	
N-SAT					X		X	
NSS					X		X	
N-STAR					X		X	
RASCOM					X		X	
SEYSAT					X		X	
SKYSAT					X		X	
TAIKI								
TDRS	X	X	X		X		X	
TONGASAT					X		X	
URUSAT					X		X	
USASAT					X		X	
VIDEOSAT					X		X	

M-M = mainbeam-to-mainbeam
M-S = mainbeam-to-sidelobe
S-M = sidelobe-to-mainbeam
S-S = sidelobe-to-sidelobe

Table 4-6. Matrix Showing the Non-Processing GEO FSS Systems with EMI from CDL Predicted for the -8.5-dB I/N Criterion

FSS Systems	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
AGILA					X		X	
AGRANI					X		X	
AMIT					X		X	
AMOS					X		X	
AM-SAT					X		X	
ANIK					X		X	
APSTAR					X		X	
ARABSAT					X		X	
ARTEMIS								
ASIASAT					X		X	
AUSSAT					X		X	
BABYLONSAT					X			
BIFROST					X		X	
BRUSAT					X		X	
B-SAT					X		X	
BUMERANG								
CESASAT					X		X	
CHINASAT					X		X	
COLOMBIA					X		X	
CSDRN	X	X	X	X	X	X	X	
CSSRD	X	X	X		X		X	
DB-SAT					X			
DFH					X		X	
DFS					X		X	
D-STAR					X		X	
EAST								
EASTSAT					X		X	
EMARSAT					X		X	
ESDRN	X	X	X	X	X	X	X	
EUROPE*STAR					X		X	
EUTELSAT					X		X	
EXPRESS					X			
F-SAT					X		X	
GDL					X		X	
GIBSAT					X			
GSTAR					X			
HELLAS-SAT					X		X	
HISPASAT					X		X	
HUN-STAR					X		X	
HYUNDAI					X		X	
IFAT					X			
INSAT					X		X	
INTELSAT					X		X	
INTERSPUTNIK					X		X	
ITALSAT								
JCSAT					X		X	
KOREASAT					X		X	
KUPON					X	X	X	

Table 4-6. Matrix Showing the Non-Processing GEO FSS Systems with EMI from CDL Predicted for the -8.5-dB I/N Criterion (continued)

FSS Systems	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
LATAMSAT					X		X	
LOUTCH					X			
L-STAR					X			
LUX					X		X	
MEASAT					X		X	
MELITASAT								
MORELOS					X			
MTSAT								
NAHUEL					X		X	
NIR					X			
N-SAT					X		X	
N-STAR					X		X	
ORION-					X		X	
PACSTAR					X		X	
PAKSAT					X		X	
PALAPA					X		X	
RASCOM					X		X	
ROSCOM					X			
SBTS					X		X	
SEYSAT					X		X	
SIMON BOLIVAR					X		X	
SJC					X		X	
SOLIDARIDAD					X		X	
SPACENET					X			
ST					X		X	
STATSIONAR					X		X	
SUPERBIRD					X		X	
TDRS	X	X	X	X	X		X	
TELECOM								
TELE-X								
THAICOM					X		X	
TONGASAT					X		X	
TURKSAT					X		X	
UKRSAT					X			
USASAT					X		X	
VIDEOSAT					X		X	
VINASAT					X		X	
VSSRD	X	X	X					
WSDRN	X	X	X	X	X		X	
YAMAL								
ZOHREH					X		X	
ZSSRD	X	X	X		X		X	

M-M = mainbeam-to-mainbeam
M-S = mainbeam-to-sidelobe
S-M = sidelobe-to-mainbeam
S-S = sidelobe-to-sidelobe

Table 4-7. Matrix Showing the Processing NGEO FSS System Space Segments with EMI from CDL Predicted for the -8.5-dB I/N Criterion

FSS Systems	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
F-SATMULTI	X				X	X	X	X
HIBLEO								
LUX	X		X		X			
MSSLEO								
MUSES	X	X	X	X				
QUASIGEO	X		X					
RSNG					X	X	X	
SIGNAL								
SURFSAT	X	X	X					
TANYA	X		X		X	X	X	X
TONQUASI	X		X		X	X	X	X
USAKU	X		X		X	X	X	X
M-M = mainbeam-to-mainbeam M-S = mainbeam-to-sidelobe S-M = sidelobe-to-mainbeam S-S = sidelobe-to-sidelobe								

Table 4-8. Matrix Showing the Processing NGEO FSS System Ground Segments with EMI from CDL Predicted for the -8.5-dB I/N Criterion

FSS Systems	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
USUDA					X	X	X	X
FL15-1					X	X	X	X
FL15-2					X	X	X	X
TYPICAL BS-15/19					X	X	X	X
ROBLEDO MAD DSS-53					X	X	X	X
M-M = mainbeam-to-mainbeam M-S = mainbeam-to-sidelobe S-M = sidelobe-to-mainbeam S-S = sidelobe-to-sidelobe								

4.2 OVERVIEW OF THE DETAILED RESULTS

The results of this analysis are included on the associated CD-ROM. There is a specific organization to the CD-ROM that will enable quick access to the results for a particular interaction. The CD-ROM contains eight Microsoft Excel XP files that include EMC analysis results. These files are divided into two groups: the results of using -20-dB I/N criterion as the basis for EMI and the results of using -8.5-dB I/N criterion as the basis for EMI. Each group has files that correspond to the four categories describing the FSS system waveforms (i.e., processing GEO, non-processing GEO, processing NGEO ground segments, and processing NGEO space segments. The file names are:

- Processing_GEO 20.xls
- Non_Processing_GEO 20.xls
- Processing_NGEO_Ground 20.xls
- Processing_NGEO_Space 20.xls
- Processing_GEO 8.5.xls
- Non_Processing_GEO 8.5.xls
- Processing_NGEO_Ground 8.5.xls
- Processing_NGEO_Space 8.5.xls

Within each Microsoft Excel XP file, there are 30 worksheets. Each worksheet corresponds to a particular CDL waveform (listed in Table 2-2 for the FL and RL). Microsoft Excel XP file "FSS_System_to_CDL_list.xls" provides the results of the FSS system to CDL interference analysis.

Within each worksheet, there is a large table which details the results of a particular interaction. Table 4-9 gives an example of the detailed output table of results included on the CD-ROM. From left to right, the columns indicate which FSS system is being analyzed, the FSS system segment pair (ground segment/space segment) for a particular FSS system, and the waveforms for a particular FSS system pair. The four right-most columns list the additional loss necessary to preclude EMI.

Table 4-9. Sample of the Detailed Table of Results (as shown on CD-ROM)

FSS System	Segment Pair Name	Waveform	M-M	M-S	S-M	S-S
INTELSAT	INTELSAT9 33E	S6BR	-11.6	*	*	*
		S5AR	-11.6	*	*	*
	INTELSAT9 340E	S5AR	-11.6	*	*	*
		S6BR	-11.6	*	*	*
USASAT	USASAT-14G	ARH	16.3	-13.7	3.4	-26.6
		ARV	20.7	-9.4	7.7	-22.3
	USASAT-14H	ARV	23.9	-6.1	11.0	-19.1
		ARH	23.6	-6.4	10.7	-19.4

M-M: CDL mainbeam-to-FSS system mainbeam antenna coupling
M-S: CDL mainbeam-to-FSS system sidelobe antenna coupling
S-M: CDL sidelobe-to-FSS system mainbeam antenna coupling
S-S: CDL sidelobe-to-FSS system sidelobe antenna coupling
* No further analysis required

4.3 SIGNIFICANT CDL EMI INTERACTIONS FOR THE -20-dB I/N CRITERION

Tables 4-10 through 4-14 list the additional loss required to preclude EMI after implementing maximum spatial mitigation (sidelobe-to-sidelobe coupling) if the BR-0.2 CDL waveform is interfering, for the -20-dB I/N criterion.

Based on Table 4-1, one processing GEO FSS receiver would experience EMI from the CDL transmitters even after implementing the maximum spatial mitigation technique. Table 4-10 lists the maximum additional coupling loss necessary to preclude EMI.

Table 4-10. Additional Loss to Preclude EMI from CDL Sidelobe to Processing GEO FSS System Sidelobe Antenna Coupling for the -20-dB I/N Criterion

FSS System	CDL Surface Terminal	CDL Airborne Terminal
TDRS	5.66	*
* No additional loss required to preclude EMI		

Based on Table 4-2, eight non-processing GEO FSS receivers would experience EMI from the CDL transmitters even after implementing maximum spatial mitigation (e.g., sidelobe-to-sidelobe antenna coupling). Table 4-11 lists the maximum additional coupling loss necessary to preclude EMI for each FSS system where EMI was predicted.

Table 4-11. Additional Loss to Preclude EMI from CDL Sidelobe to Non-Processing GEO FSS System Sidelobe Antenna Coupling for the -20-dB I/N Criterion

FSS System	CDL Surface Terminal	CDL Airborne Terminal
CSDRN	13.4	*
CSSRD	10.3	*
ESDRN	13.4	*
KOREASAT-2	*	5.5
TDRS	12.4	*
VSSRD	10.3	*
WSDRN	13.4	*
ZSSRD	10.3	*
* No additional loss required to preclude EMI		

Based on Tables 4-3 and 4-4, 12 processing NGEO FSS receivers would experience EMI from the CDL transmitters even after implementing maximum spatial mitigation (e.g., sidelobe-to-sidelobe antenna coupling). Table 4-12 lists the maximum additional coupling loss necessary to preclude EMI for each FSS system where EMI was predicted.

Table 4-12. Additional Loss to Preclude EMI from CDL Sidelobe to Processing NGEO FSS System Sidelobe Antenna Coupling for the -20-dB I/N Criterion

FSS System	Processing NGEO FSS System Ground Segment		Processing NGEO FSS System Space Segment	
	CDL Surface Terminal	CDL Airborne Terminal	CDL Surface Terminal	CDL Airborne Terminal
TANYA	*	*	*	33.7
TONQUASI	*	*	*	29.2
USAKU	*	*	*	28.9
MUSES	*	*	34.4	*
N-SAT	*	*	*	*
SIGNAL	*	*	*	*
SURFSAT-1	*	*	5.4	*
RSNG	*	*	*	8.5
F-SATMULTI	*	*	*	11.9
USUDA	*	34.2	*	*
FL15-1	*	27.4	*	*
FL15-2	*	17.4	*	*
TYPICAL BS-15/19	*	14.7	*	*
ROBLEDO MAD DSS-53	*	31.4	*	*
* No additional loss required to preclude EMI				

4.4 SIGNIFICANT CDL EMI INTERACTIONS FOR THE -8.5-dB I/N CRITERION

The following tables list the additional loss required to preclude EMI after implementing maximum spatial mitigation (sidelobe-to-sidelobe antenna coupling) if the BR-0.2 CDL waveform is interfering with the -8.5-dB I/N criterion.

Based on Table 4-5, no processing GEO FSS receivers would experience EMI from the CDL transmitters after implementing the maximum spatial mitigation technique.

Based on Table 4-6, four non-processing GEO FSS receivers would experience EMI from the CDL transmitters even after implementing maximum spatial mitigation (e.g., sidelobe-to-sidelobe antenna coupling). Table 4-13 lists the maximum additional coupling loss necessary to preclude EMI for each FSS system where EMI was predicted.

Table 4-13. Additional Loss to Preclude EMI from CDL Sidelobe to Non-Processing GEO FSS System Sidelobe Antenna Coupling for the -8.5-dB I/N Criterion

FSS System	CDL Surface Terminal	CDL Airborne Terminal
CSDRN	1.9	*
ESDRN	1.9	*
TDRS	0.97	*
WSDRN	1.9	*
* No additional loss required to preclude EMI		

Based on Tables 4-7 and 4-8, ten processing NGEO FSS receivers would experience EMI from the CDL transmitters even after implementing maximum spatial mitigation (e.g., sidelobe-to-sidelobe antenna coupling). Table 4-14 lists the maximum additional coupling loss necessary to preclude EMI for each FSS system where EMI was predicted.

Table 4-14. Additional Loss to Preclude EMI from CDL Sidelobe to Processing NGEO FSS System Sidelobe Antenna Coupling for the -8.5-dB I/N Criterion

FSS System	Processing NGEO FSS System Ground Segment		Processing NGEO FSS System Space Segment	
	CDL Surface Terminal	CDL Airborne Terminal	CDL Surface Terminal	CDL Airborne Terminal
F-SATMULTI	*	*	*	0.46
N-SAT	*	*	*	*
TANYA	*	*	*	22.27
TONQUASI	*	*	*	17.76
USAKU	*	*	*	17.47
MUSES-B	*	*	22.94	*
SIGNAL	*	*	*	*
SURFSAT-1	*	*	*	*
USUDA	*	22.7	*	*
FL15-1	*	15.9	*	*
FL15-2	*	5.9	*	*
TYPICAL BS-15/19	*	3.3	*	*
ROBLEDO MAD DSS-53	*	19.9	*	*
* No additional loss required to preclude EMI				

4.5 RESULTS FOR THE FSS TRANSMITTER TO CDL RECEIVERS INTERFERENCE INTERACTIONS

By implementing simple mitigation techniques, such as tuning the CDL above the lowest tunable frequency by at least one-half the necessary bandwidth for a particular CDL waveform and by pointing the CDL antenna away from the FSS systems, the EMI should be significantly reduced. Tables 4-15 through 4-17 list the number of FSS systems that are still significant sources of EMI to the CDL even after implementing the maximum spatial mitigation of FSS system sidelobe to the CDL sidelobe antenna coupling. The complete names of the FSS systems that interfere with the CDL are listed on the CD-ROM in Microsoft Excel XP file "FSS_System_to_CDL_list.xls."

Table 4-15. Processing GEO FSS Systems Results

Interaction	Number of Systems
FSS Ground Segment vs. CDL Airborne Terminal	19
FSS Ground Segment vs. CDL Surface Terminal	18

Table 4-16. Non-Processing GEO FSS Systems Results

Interaction	Number of Systems
FSS Ground Segment vs. CDL Airborne Terminal	75
FSS Ground Segment vs. CDL Surface Terminal	70

Table 4-17. Processing NGEO FSS Systems Results

Interaction	Number of Systems
FSS Ground Segment vs. CDL Airborne Terminal	11
FSS Ground Segment vs. CDL Surface Terminal	7
FSS Space Segment vs. CDL Airborne Terminal	0
FSS Space Segment vs. CDL Surface Terminal	0

SECTION 5 – CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The JSC conducted intersite analyses to determine the additional loss necessary to preclude EMI for interference from the CDL transmitters to the FSS receivers. By utilizing spatial mitigation techniques such as sidelobe-to-mainbeam, mainbeam-to-sidelobe, and sidelobe-to-sidelobe antenna coupling, fewer instances of predicted EMI were predicted. Also, by utilizing frequency separation between the CDL transmitters uplink and the FSS receivers, the amount of additional loss necessary to preclude EMI should be reduced. For FSS transmitter to CDL receiver interference, spatial mitigation did not have as significant of an impact on EMI as for the CDL transmitter to FSS receiver interference case because the distance separation between the CDL receiver ground stations and the FSS system transmitter ground segments was small, and FSS system transmitters have a much higher power spectral density.

5.2 RECOMMENDATIONS

The JSC recommends that the CDL Program Office consider migrating to a different frequency band so that the CDL can operate on a primary allocated status. While this may not eliminate the potential for EMI; with a primary allocation however, other co-primary or secondary allocated systems will have to grant greater interference tolerance to CDL emissions. It will also provide the CDL receiver increased protection from interference from secondary allocated transmitters. If the CDL Program Office does not migrate the data link to another band, the JSC recommends that the CDL Program Office consider frequency mitigation and spatial mitigation techniques. Frequency mitigation techniques involve slightly off-tuning the CDL transmitter from victim FSS system receivers and off-tuning the CDL receiver from FSS system transmitters. Spatial mitigation techniques involve mainbeam-to-sidelobe and sidelobe-to-sidelobe antenna coupling rather than mainbeam-to-mainbeam coupling. Both of these mitigation techniques would reduce the amount of EMI from an interfering transmitter to a victim receiver.

APPENDIX A – NUMBER OF INTERFERENCE INTERACTIONS

The JSC analyzed a total of 134 FSS systems: 27 Processing GEO FSS system space segments, 90 non-processing GEO FSS system space segments, 12 processing NGEO FSS system space segments, and 5 processing NGEO FSS system ground segments. The number of FSS systems where EMI was predicted from the CDL are shown in Tables A-1 through A-8.

Table A-1 lists the number of processing GEO FSS systems that require CDL coordination for each of the CDL waveforms based on the -20-dB I/N criterion.

Table A-1. Matrix Showing the Number of Processing GEO FSS Systems with EMI from CDL Predicted for the -20-dB I/N Criterion

CDL Waveform Name	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
BR-0.2	1	1	1	1	22	15	22	0
BR-0.4	1	1	1	1	22	8	21	0
BR-2.0	1	1	1	0	22	1	19	0
BR-10.71A	1	1	1	0	22	0	17	0
BR-10.71B	1	1	1	0	22	0	17	0
BR-21.42	1	1	1	0	22	0	16	0
BR-44.73	1	1	1	0	21	0	8	0
BR-137A	1	1	1	0	20	0	6	0
BR-137B	1	1	1	0	21	0	6	0
BR-137C	1	1	1	0	20	0	6	0
BR-137D	1	1	1	0	21	0	6	0
BR-274A	2	0	1	0	22	0	2	0
BR-274B	1	0	1	0	22	0	2	0
BR-274C	2	0	1	0	22	0	2	0
BR-274D	1	0	1	0	22	0	2	0

M-M: CDL mainbeam-to-FSS system mainbeam antenna coupling
M-S: CDL mainbeam-to-FSS system sidelobe antenna coupling
S-M: CDL sidelobe-to-FSS system mainbeam antenna coupling
S-S: CDL sidelobe-to-FSS system sidelobe antenna coupling

Table A-2 lists the number of non-processing GEO FSS systems that require CDL coordination for each of the CDL waveforms based on the -20-dB I/N criterion.

Table A-2. Matrix Showing the Number of Non-Processing GEO FSS Systems with EMI from CDL Predicted for the -20-dB I/N Criterion

CDL Waveform Name	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
BR-0.2	8	7	7	7	80	44	80	1
BR-0.4	8	7	7	7	80	26	78	1
BR-2.0	7	7	7	7	80	6	69	0
BR-10.71A	7	7	7	0	78	1	54	0
BR-10.71B	7	7	7	0	78	1	54	0
BR-21.42	7	7	7	0	80	1	44	0
BR-44.73	7	7	7	0	78	0	27	0
BR-137A	7	7	7	0	74	0	20	0
BR-137B	7	7	7	0	74	0	20	0
BR-137C	7	7	7	0	74	0	20	0
BR-137D	7	7	7	0	74	0	20	0
BR-274A	10	7	7	0	71	0	11	0
BR-274B	9	7	7	0	68	0	11	0
BR-274C	10	7	7	0	71	0	11	0
BR-274D	9	7	7	0	68	0	11	0

M-M: CDL mainbeam-to-FSS system mainbeam antenna coupling
M-S: CDL mainbeam-to-FSS system sidelobe antenna coupling
S-M: CDL sidelobe-to-FSS system mainbeam antenna coupling
S-S: CDL sidelobe-to-FSS system sidelobe antenna coupling

Table A-3 lists the number of processing NGEO FSS system space segments that require CDL coordination for each of the CDL waveforms based on the -20-dB I/N criterion.

Table A-3. Matrix Showing the Number of Processing NGEO FSS System Space Segments with EMI from CDL Predicted for the -20-dB I/N Criterion

CDL Waveform Name	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
BR-0.2	10	6	7	2	8	5	6	5
BR-0.4	10	5	7	2	7	5	6	5
BR-2.0	8	2	7	1	7	5	5	4
BR-10.71A	8	2	5	1	7	7	7	3
BR-10.71B	8	2	5	1	7	7	7	3
BR-21.42	9	2	4	1	7	7	7	5
BR-44.73	9	2	3	1	7	7	7	5
BR-137A	9	2	2	1	8	6	7	5
BR-137B	9	4	4	1	7	6	7	5
BR-137C	9	2	2	1	8	6	7	5
BR-137D	9	4	4	1	7	6	7	5
BR-274A	11	6	9	1	11	6	10	5
BR-274B	11	6	9	1	11	6	10	5
BR-274C	11	6	9	1	11	6	10	5
BR-274D	11	6	9	1	11	6	10	5

M-M: CDL mainbeam-to-FSS system mainbeam antenna coupling
M-S: CDL mainbeam-to-FSS system sidelobe antenna coupling
S-M: CDL sidelobe-to-FSS system mainbeam antenna coupling
S-S: CDL sidelobe-to-FSS system sidelobe antenna coupling

Table A-4 lists the number of processing NGEO FSS system ground segments that require CDL coordination for each of the CDL waveforms based on the -20-dB I/N criterion.

Table A-4. Matrix Showing the Number of Processing NGEO FSS System Ground Segments with EMI from CDL Predicted for the -20-dB I/N Criterion

CDL Waveform Name	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	**M-S**	**S-M**	**S-S**	**M-M**	**M-S**	**S-M**	**S-S**
BR-0.2	3	0	0	0	4	4	4	4
BR-0.4	3	0	0	0	4	4	4	4
BR-2.0	1	0	0	0	4	4	4	4
BR-10.71A	0	0	0	0	4	4	4	4
BR-10.71B	0	0	0	0	4	4	4	4
BR-21.42	1	0	0	0	4	4	4	3
BR-44.73	1	1	1	0	4	4	4	3
BR-137A	2	1	1	1	4	4	4	3
BR-137B	2	1	1	1	4	4	4	3
BR-137C	2	1	1	1	4	4	4	3
BR-137D	2	1	1	1	4	4	4	3
BR-274A	2	1	1	1	4	4	4	4
BR-274B	2	2	2	1	4	4	4	4
BR-274C	2	1	1	1	4	4	4	4
BR-274D	2	2	2	1	4	4	4	4

M-M: CDL mainbeam-to-FSS system mainbeam antenna coupling
M-S: CDL mainbeam-to-FSS system sidelobe antenna coupling
S-M: CDL sidelobe-to-FSS system mainbeam antenna coupling
S-S: CDL sidelobe-to-FSS system sidelobe antenna coupling

Table A-5 lists the number of processing GEO FSS systems that require CDL coordination for each of the CDL waveforms based on the -8.5-dB I/N criterion.

Table A-5. Matrix Showing the Number of Processing GEO FSS Systems with EMI from CDL Predicted for the -8.5-dB I/N Criterion

CDL Waveform Name	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
BR-0.2	1	1	1	0	22	0	18	0
BR-0.4	1	1	1	0	22	0	17	0
BR-2.0	1	1	1	0	20	0	7	0
BR-10.71A	1	0	1	0	18	0	2	0
BR-10.71B	1	0	1	0	18	0	2	0
BR-21.42	1	0	1	0	16	0	0	0
BR-44.73	1	0	1	0	12	0	0	0
BR-137A	1	0	1	0	8	0	0	0
BR-137B	1	0	1	0	10	0	0	0
BR-137C	1	0	1	0	8	0	0	0
BR-137D	1	0	1	0	10	0	0	0
BR-274A	1	0	0	0	5	0	0	0
BR-274B	1	0	0	0	5	0	0	0
BR-274C	1	0	0	0	5	0	0	0
BR-274D	1	0	0	0	5	0	0	0

M-M: CDL mainbeam-to-FSS system mainbeam antenna coupling
M-S: CDL mainbeam-to-FSS system sidelobe antenna coupling
S-M: CDL sidelobe-to-FSS system mainbeam antenna coupling
S-S: CDL sidelobe-to-FSS system sidelobe antenna coupling

Table A-6 lists the number of non-processing GEO FSS systems that require CDL coordination for each of the CDL waveforms based on the -8.5-dB I/N criterion.

Table A-6. Matrix Showing the Number of Non-Processing GEO FSS Systems with EMI from CDL Predicted for the -8.5-dB I/N Criterion

CDL Waveform Name	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
BR-0.2	7	7	7	4	80	3	67	0
BR-0.4	7	7	7	0	78	1	52	0
BR-2.0	7	7	7	0	71	0	23	0
BR-10.71A	7	7	7	0	58	0	10	0
BR-10.71B	7	7	7	0	58	0	10	0
BR-21.42	7	4	7	0	50	0	3	0
BR-44.73	7	0	7	0	34	0	1	0
BR-137A	7	0	7	0	27	0	1	0
BR-137B	7	0	7	0	26	0	1	0
BR-137C	7	0	7	0	27	0	1	0
BR-137D	7	0	7	0	26	0	1	0
BR-274A	7	0	7	0	13	0	0	0
BR-274B	7	0	7	0	13	0	0	0
BR-274C	7	0	7	0	13	0	0	0
BR-274D	7	0	7	0	13	0	0	0

M-M: CDL mainbeam-to-FSS system mainbeam antenna coupling
M-S: CDL mainbeam-to-FSS system sidelobe antenna coupling
S-M: CDL sidelobe-to-FSS system mainbeam antenna coupling
S-S: CDL sidelobe-to-FSS system sidelobe antenna coupling

Table A-7 lists the number of processing NGEO FSS system space segments that require CDL coordination for each of the CDL waveforms based on the -8.5-dB I/N criterion.

Table A-7. Matrix Showing the Number of Processing NGEO FSS System Space Segments with EMI from CDL Predicted for the -8.5-dB I/N Criterion

CDL Waveform Name	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
BR-0.2	8	2	7	1	6	5	5	4
BR-0.4	8	2	5	1	6	5	5	3
BR-2.0	7	2	2	1	5	4	5	3
BR-10.71A	7	1	2	1	7	3	7	3
BR-10.71B	7	1	2	1	7	3	7	3
BR-21.42	7	1	2	1	7	5	7	5
BR-44.73	5	1	2	1	7	5	7	3
BR-137A	5	1	2	1	7	5	7	1
BR-137B	7	1	4	1	7	5	7	1
BR-137C	5	1	2	1	7	5	7	1
BR-137D	7	1	4	1	7	5	7	1
BR-274A	10	1	6	0	8	5	7	1
BR-274B	10	1	6	0	8	5	7	1
BR-274C	10	1	6	0	8	5	7	1
BR-274D	10	1	6	0	8	5	7	1

M-M: CDL mainbeam-to-FSS system mainbeam antenna coupling
M-S: CDL mainbeam-to-FSS system sidelobe antenna coupling
S-M: CDL sidelobe-to-FSS system mainbeam antenna coupling
S-S: CDL sidelobe-to-FSS system sidelobe antenna coupling

Table A-8 lists the number of processing NGEO FSS system ground segments that require CDL coordination for each of the CDL waveforms based on the -8.5-dB I/N criterion.

Table A-8. Matrix Showing the Number of Processing NGEO FSS System Ground Segments with EMI from CDL Predicted for the -8.5-dB I/N Criterion

CDL Waveform Name	CDL Surface Terminal				CDL Airborne Terminal			
	M-M	M-S	S-M	S-S	M-M	M-S	S-M	S-S
BR-0.2	0	0	0	0	5	5	5	5
BR-0.4	0	0	0	0	5	5	5	5
BR-2.0	0	0	0	0	5	5	5	3
BR-10.71A	0	0	0	0	5	5	5	3
BR-10.71B	0	0	0	0	5	5	5	3
BR-21.42	1	0	0	0	5	4	5	2
BR-44.73	1	0	0	0	5	3	4	2
BR-137A	2	2	1	0	5	3	3	2
BR-137B	2	2	1	0	5	3	3	2
BR-137C	2	2	1	0	5	3	3	2
BR-137D	2	2	1	0	5	3	3	2
BR-274A	3	1	1	0	5	5	5	5
BR-274B	3	1	1	0	5	5	5	5
BR-274C	3	1	1	0	5	5	5	5
BR-274D	3	1	1	0	5	5	5	5

M-M: CDL mainbeam-to-FSS system mainbeam antenna coupling
M-S: CDL mainbeam-to-FSS system sidelobe antenna coupling
S-M: CDL sidelobe-to-FSS system mainbeam antenna coupling
S-S: CDL sidelobe-to-FSS system sidelobe antenna coupling

DISTRIBUTION LIST FOR
COMMON DATA LINK EMC ANALYSIS
JSC-PR-04-044

External	No. of Copies
Aeronautical Systems Center Reconnaissance Systems Program Office, Sensors and Data Links Common Data Link Program Office Attn: LtCol Nevraker, USAF 2640 Loop Road West Wright-Patterson AFB, OH 45433-7106	1
Aeronautical Systems Center Reconnaissance Systems Program Office, Sensors and Data Links Common Data Link Program Office Attn: Lloyd Cooper 2640 Loop Road West Wright-Patterson AFB, OH 45433-7106	4

Internal

J8/Capt. H. Bragg	1
DSH/H. Beard	1
SENTEL/J. Gleason	1
SENTEL /J. Timko	1
SENTEL /A. Adegorusi	1
SENTEL /R. Mendolera	1
DPS	5
DPS	Camera Ready and PDF