MO&DS DIRECTORATE

CODE 500

An RF Interference Mitigation Methodology with Potential Applications in Scheduling

GSFC
Code 531.1

Yen F. Wong
James L. Rash

December 12, 1990

MO&DS DIRECTORATE

CODE 500

An RF Interference Mitigation Methodology with Potential Applications in Scheduling

Agenda

An RF Interference Mitigation Methodology with Potential Applications in Scheduling

GSFC

- Communications Link Analysis and Simulation System (CLASS)
- Space Network RF Mutual Interference and Scheduling
- RF Interference Mitigation Methodology
- Interference Mitigation Aid for Scheduling
- Numerical Examples
- Conclusions and Future Work

G-3

An RF Interference Mitigation Methodology with Potential Applications in Scheduling

GSFC

CLASS

G-4

MO&DS DIRECTORATE | CODE 500

Communications Link Analysis & Simulation System (CLASS)

GSFC

- Unique software tool for the prediction and evaluation of TDRSS/user spacecraft communications link performance.
- End-to-end modeling of Space and Ground Networks, channel environment, and user spacecraft communications systems.
- All communications channel parameters that affect link performance, including interference, are maintained in CLASS data bases.
- Developed by NASA Goddard Space Flight Center (GSFC) Code 531.

G-5

MO&DS DIRECTORATE | CODE 500

CLASS Interference Analysis and Mitigation Tools

GSFC

- Interference analysis and mitigation tools have been developed in the CLASS environment for use in:
  - -- communications performance evaluation
  - -- mission planning
- Potential applications in:
  - -- analysis, evaluation, and optimization of user schedules

G-6

MO&DS DIRECTORATE	An RF Interference Mitigation Methodology with Potential Applications in Scheduling
CODE 500	

GSFC

Space Network RF Mutual Interference and Scheduling

G-7

MO&DS DIRECTORATE	Space Network RF Mutual Interference and Scheduling
CODE 500	

GSFC

- Increasingly competitive climate for scheduling of Space Network resources in the Space Station era.
- Potential RF mutual interference warrants increasing concern in terms of efficiency in network resource allocation and scheduling.
- Scheduling efficiency of current network operations system could be enhanced through consideration of communications performance in mutual interference mitigation.
- CLASS interference analysis tools can be used in efforts to enhance network scheduling efficiency.

G-8

Interference Mitigation Methodology

G-9

Interference Mitigation Methodology

- STEP 1

For every given pair of desired and interfering signals, determine the discrimination required to guarantee nonnegative BER link margin.

G-10

MO&DS DIRECTORATE
CODE 500

Interference Mitigation Methodology

- **Required discrimination**

$$\delta = \left(\frac{S}{I}\right)_{required} - \left(\frac{S}{I}\right)_{worst}$$

"Required S/I" is the value of S/I such that the degradation of the desired user's signal equals its worst case channel margin. The worst case channel margin is a parameter that characterizes the desired user's link performance.

"Worst S/I" is determined by formulating S/I as a function of the separation angle between interferer and desired user. "Worst S/I" designates the global minimum of this function.

G-11

MO&DS DIRECTORATE
CODE 500

Interference Mitigation Methodology

- **The signal to interference level ratio S/I in dB at TDRS is defined as a function of the separation angle α between the desired user and the interferer as seen from TDRS:**

$$\frac{S}{I}(\alpha) = (P_d + G(0)) - (P_i + G(\alpha) + R(\alpha)) + G_p + A_p + L_{fs}$$

G-12

Interference Mitigation Methodology

Pd = the worst case (maximum range) TDRS received power at unity antenna gain for the desired user (dB) including the loss due to the nonperfect polarization match between the TDRS and desired user antennas. It is assumed that the desired user is on the TDRS antenna boresight and that the desired user antenna is pointing toward TDRS. Pd includes contributions from stochastic sources such as multipath (vehicle, earth, and atmospheric) and RFI.

Pi = the best case (minimum range) TDRS received power at unity antenna gain for the interferer (dB).

G = the TDRS antenna gain (dB) as a function of the angle alpha.

R = the polarization rejection of the interferer signal at the oppositely polarized TDRS antenna (dB) as a function of the angle alpha. The value of R is always negative when rejection is present.

Interference Mitigation Methodology

Gp = 10 * ALOG10 (Desired user PN chip rate/Desired channel symbol rate) is the processing gain (in dB) of the PN spread signal

Ap = 10 * ALOG10 (Interferer channel PN chip rate/Desired channel symbol rate) is the reduction factor (in dB) if the interferer is PN spread when the desired channel is not PN spread.

Lfs = reduction of interferer power due to frequency separation.

MO&DS DIRECTORATE

CODE 500

Interference Mitigation Methodology

GSFC

- **Step 2**

For every given pair of desired and interfering signals, calculate the required separation angle (the largest separation angle between the desired user and interferer that provides the required discrimination as determined in Step 1).

This calculation utilizes the TDRS antenna gain pattern, adjusted as necessary to reflect polarization rejection of the interferer signal.

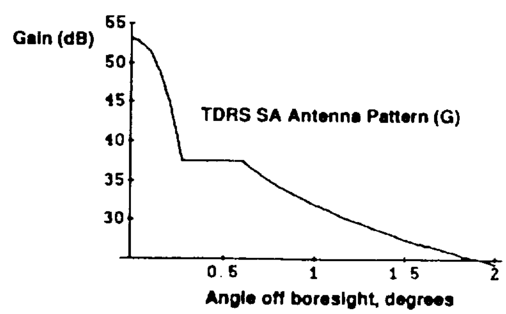
G-15

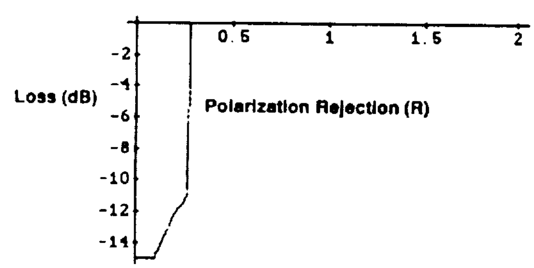
MO&DS DIRECTORATE

CODE 500

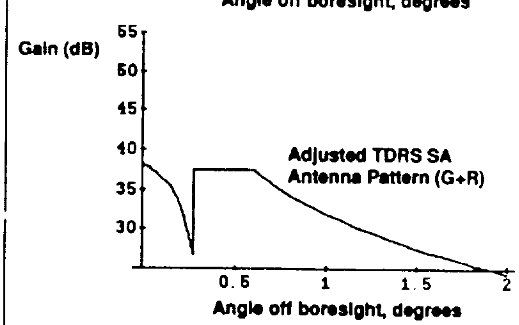
Adjusted Antenna Gain Pattern (Example)

GSFC





Polarization rejection modeled as a function of angle off boresight at the TDRS SA antenna when the transmitting antenna is that of the Space Station Manned Base.



$$\textit{required discrimination}\ \delta = -\Delta(G + R)$$

G-16

MO&DS DIRECTORATE

CODE 500

Interference Mitigation Methodology

GSFC

- **Step 3**

Based on the separation angles obtained in step (2), find all potential interference intervals.

A potential interference interval is defined as any time interval during which the separation angle between the two spacecraft is less than the required separation angle.

G-17

MO&DS DIRECTORATE

CODE 500

An RF Interference Mitigation Methodology with Potential Applications in Scheduling

GSFC

10

Interference Mitigation Aid for Scheduling

G-18

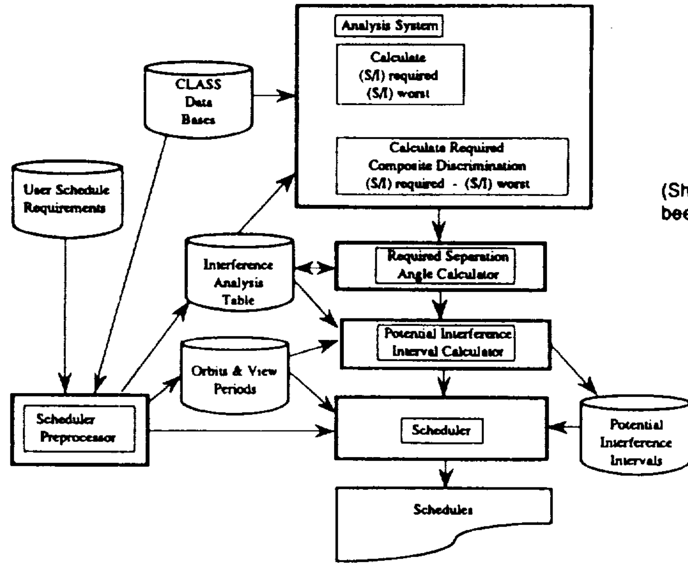
MO&DS DIRECTORATE

CODE 500

An Approach to Interference Mitigation Scheduling

GSFC

Block Diagram



(Shaded blocks have been implemented.)

G-19

MO&DS DIRECTORATE

CODE 500

An RF Interference Mitigation Methodology with Potential Applications in Scheduling

GSFC

Numerical Example

G-20

MO&DS DIRECTORATE

CODE 500

Numerical Example

- These missions operate at Ku band with carrier frequency equal to 15.0034 GHz, unspread.

  -- Space Station Manned Base (SSMB) versus Space Shuttle Orbiter (SSO)

  -- Earth Observing System (EOS) versus Space Shuttle Orbiter (SSO)

G-21

MO&DS DIRECTORATE

CODE 500

Numerical Example (continued) -- SSO Link Characteristics

SSO operates with Right Circular Polarization (RCP). Link characteristics are as follows:

CHANNEL	DATA RATE (kbps)	EIRP (dBW)	LINK MARGIN (dB)
Channel 1: Subcarrier Q	192	39.4	19.0
Channel 2: Subcarrier I	2,000	43.6	13.5
Channel 3: Baseband	50,000	51.0	1.5

Channels 1 and 2 are rate 1/2 convolutional coded.
Channel 3 is uncoded.

G-22

MO&DS DIRECTORATE

CODE 500

Numerical Example (continued) -- SSMB Link Characteristics

SSMB operates with Left Circular Polarization (LCP) at data rates of 300 Mbps and 50 Mbps.

CHANNEL	DATA RATE (Mbps)	EIRP (dBW)	LINK MARGIN (dB)
I	150	57.1	3.0
Q	150	57.1	3.0
I	25	57.1	10.8
Q	25	57.1	10.8

The parameters given above for SSMB are preliminary and subject to change.

G-23

MO&DS DIRECTORATE

CODE 500

Numerical Example (continued) -- EOS Link Characteristics

EOS operates with RCP at a data rate of 300 Mbps.

CHANNEL	DATA RATE (Mbps)	EIRP (dBW)	LINK MARGIN (dB)
I	150	57.6	3.6
Q	150	57.6	3.6

G-24

MO&DS DIRECTORATE

CODE 500

Numerical Example (continued) --Interference Analysis Results

GSFC

There is no unacceptable interference between the EOS 300 Mbps link and the SSO channels 1 and 2.

There is no unacceptable interference between the SSMB 300 Mbps link and the SSO channels 1, 2, and 3.

		Case 1	Case 2
Desired User	User ID	SSO	SSO
	Channel	3	3
	Polarization	RHC	RHC
	Worst Case Margin (dB)	1.5	1.5
Interferer	User ID	EOS	SSMB
	Polarization	RHC	LHC
	Axial Ratio (dB)	1.5	2.1
S/I	Required (dB)	6.2 **	9.0**
	Boresight (dB)	-11.6	4.0
	Worst Case (dB)	-11.6	4.0
Required Discrimination (dB)		17.8	5.0
Required Separation Angle (deg)		0.74	0.92

** Note: CLASS simulation result.

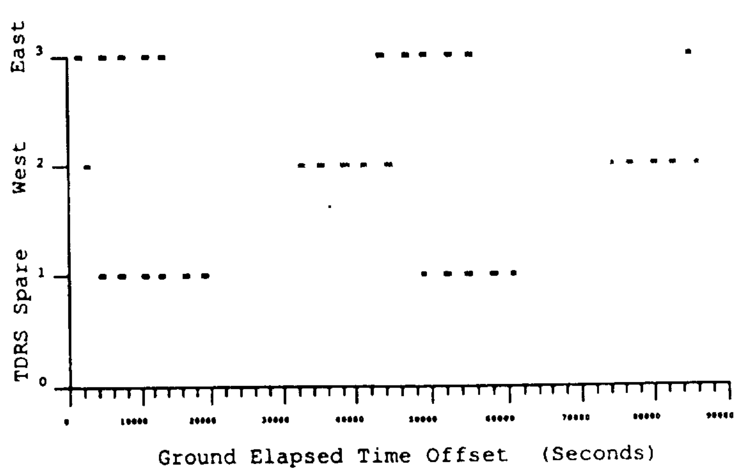
G-25

MO&DS DIRECTORATE

CODE 500

Numerical Example (continued) --Potential Interference Intervals

GSFC



Assumes the users (SSO and SSMB) have identical orbits except for a 20 degree difference in orbital phasing.

During the 24 hour period, potential interference exists for a total of approximately 20 minutes for each TDRS.

G-26

MO&DS DIRECTORATE

CODE 500

An RF Interference Mitigation Methodology with Potential Applications in Scheduling

GSFC

Conclusions and Future Work

G-27

MO&DS DIRECTORATE

CODE 500

Conclusions and Future Work

GSFC

- Tools for interference analysis and mitigation have been developed in the CLASS environment for:
  - -- communications performance evaluation
  - -- mission planning
- Potential applications are seen in:
  - -- analysis, evaluation, and optimization of user schedules
- Tools producing "required separation angles" and "potential interference intervals" can be used as an aid to mutual interference mitigation within a scheduling system.
- Possible future consideration of multiple interferers.

G-28