Radio Frequency Interference Between Spacecraft in Different Missions

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This article presents the results of a study to determine the possibility of separately receiving signals transmitted in a common frequency band from spacecraft in different missions. For the 18 mission pairs that were examined, co-channel operation without interference is generally possible. For some mission pairs, co-channel interference would occur during brief post-launch periods. Problems that may arise from simultaneous co-channel Earth-to-space transmissions from two stations at a single DSN complex were not considered.

I. Introduction

In a multimission environment, spacecraft in different missions may be simultaneously in view of a single deep space Earth station. The amount of radio frequency spectrum needed to allow separate reception of signals from these spacecraft is determined by the possibility of selecting each signal by means of the directivity of the Earth station antenna. When this can be done, the several spacecraft may transmit in a common frequency band. If the directivity of the Earth station is insufficient, the spacecraft must use different frequencies in order to avoid interference.

II. Method

Potential interference between signals from spacecraft in selected mission pairs was studied. The pairs were selected on the basis of a previous analysis whose purpose was to identify missions that would be simultaneously in view of DSN stations.

The interference calculation considered the relative signal strength from the nearer of the two spacecraft while the Earth station antenna was pointed at the more distant spacecraft. Equal radiated power from both spacecraft was assumed. The computation was:

$$I = (20 \log R_1 - 20 \log R_2) - (G_{max} - G_\theta)$$

where

I = interference level, dB

R_1 = range to most distant spacecraft, any length unit consistent with R_2

R_2 = range to nearer spacecraft, any length unit consistent with R_1

G_θ = antenna gain at θ degrees off the main beam axis

G_{max} = on-axis main beam gain

The value used for G_{max} was 67 dBi, assuming a 34-m antenna and 8400-MHz downlink frequency. The 8400-MHz frequency was selected for analysis purposes since it is expected to be used by many future spacecraft. It is recognized that several of the missions included in the analysis do not employ spacecraft with the capability for communication in that band.

Trajectories were computed using geocentric conic elements. The resulting spacecraft ranges and angular separation as a function of time were determined. Earth station antenna directivity was modeled by the expressions.

$$G_\theta = G_{max} - (G_{max} - 32) \cdot \theta \text{ dB} \qquad 0 \leqslant \theta < 1 \text{ deg}$$

$$= 32 - 25 \log_{10} \theta \text{ dB} \qquad 1 \leqslant \theta < 48 \text{ deg}$$

$$= -10 \text{ dB} \qquad \theta \geqslant 48 \text{ deg}$$

In consideration of the interference calculation, it must be kept in mind that equal radiated power from the two spacecraft has been assumed. Where this is not true, a correction must be applied. Similarly, the allowable ratio of interference power to desired signal power must be established: the calculation reported here compares the relative strength of the desired and interfering signals and does not include an additional margin of protection.

III. Results

Table 1 lists the mission pairs that were studied. As an example, a plot of calculated interference for the JOP/Voyager mission pair is shown in Fig. 1. For this case, the interference is always below the level of the desired signal. The desired signal was taken to be the relatively weaker signal from the more distant spacecraft. During the first 50 days of the period following launch of Jupiter Orbiter/Probe-82, the interference rapidly drops from 10 dB below to 30 dB below the Voyager 2 signal. During a 10-day period in July 1982 the interference to signals from the more distance spacecraft rises to −27 dB, an insignificant amount.

Interference calculations for the other mission pairs yield the results shown in Table 2.

IV. Conclusions

For the mission pairs that have been examined with the method and assumptions of this study, significant radio frequency interference occurs only in some cases and only during the immediate post-launch period. For the greater part of time, either of the signals from co-channel spacecraft in the mission pair could be selected by the Earth station. This is not to say that there would not be other problems connected with simultaneous co-channel operation of two stations at a particular deep space complex. For example, simultaneous transmission of two different but co-channel Earth-to-space signals from two stations at a single complex might create interstation interference not considered in this study.

Co-channel operation of two or more spacecraft in a single mission is usually considered not possible. This is evident for the case of simultaneous orbiters around a target planet. During the analysis of selected missions pairs, a question was raised regarding the possibility of co-channel operation of the two Voyager spacecraft. Of particular interest in this case is the circumstance that the spacecraft trajectories are such that the Voyager that was launched last will overtake the other spacecraft and be the first to arrive at Jupiter. The perhaps surprising result of interference analysis for the two Voyagers is that either downlink signal could be individually selected and received, with the potentially interfering signal from the other spacecraft at least 30 dB weaker, throughout the mission. From the standpoint of downlink interference, co-channel operation of the two spacecraft would be possible.

The study reported in this article assumed the use of a 34-m Earth station antenna. The 64-m antenna would provide additional directivity and thus extend the possibility of selecting individual co-channel signals. The angular resolving power of the deep space Earth station antennas is truly impressive and is a consequence of their very narrow beam width.

Table 1. Mission pairs

Venus Orbiter Imaging Radar (VOIR)	and	Pioneer 11
Pioneer 11 (PIO 11)		Jupiter Orbiter/Probe 82
Pioneer Venus Orbiter (PVO)		Jupiter Orbiter/Probe 82
Pioneer Venus Orbiter		Out-of-Ecliptic 83
Pioneer Venus Orbiter		Pioneer 10
Pioneer Venus Orbiter		Pioneer 11
Pioneer Venus Orbiter		Venus Orbiter Imaging Radar
Venus Orbiter Imaging Radar		Out-of-Ecliptic 83
Voyager 2 (JSX)		Pioneer Venus Orbiter
Pioneer 10 (PIO 10)		Pioneer 11
Voyager 2		Pioneer Venus Orbiter
Out-of-Ecliptic 83 (OOE)		Pioneer 11
Voyager 2		Venus Orbiter Imaging Radar
Jupiter Orbiter/Probe 82 (JOP 82)		Venus Orbiter Imaging Radar
Jupiter Orbiter/Probe 82		Out-of-Ecliptic 83
Voyager 2		Pioneer 10
Voyager 2		Out-of-Ecliptic 83
Voyager 2		Jupiter Orbiter/Probe 82

Table 2. Mission pairs with interference greater than -30dB

Pair	Time (month/ year)	Interference Maximum (dB)	Interference Duration Above -10 dB (days)	Remarks
JSX-JOP82	1/82-3/82	-9	1	JOP82 launch
	7/82			
PIO 11-JOP82	1/82	-20		JOP82 launch
JSX-PIO 10	8/77	+3	5	JSX launch
JSX-VOIR	6/83	-19		
JSX-PVO	5/78	-7	4	PVO launch
	11/80	-27		
	10/82	-22		
JSX-OOE	1/82	+13	10	OOE launch
	8/82	-24		
JSX-PIO 11	8/77	-10	1	JSX launch
VOIR-PIO 11	6/83	-18		VOIR launch
VOIR-OOE	6/83	-27		VOIR launch
PVO-PIO 10	5/78-6/78	+6	17	PVO launch
	3/80	-22		
	6/80	-28		
	4/81	-26		
PVO-PIO 11	5/78	-1	9	PVO launch
OOE-PIO 11	2/82			OOE launch

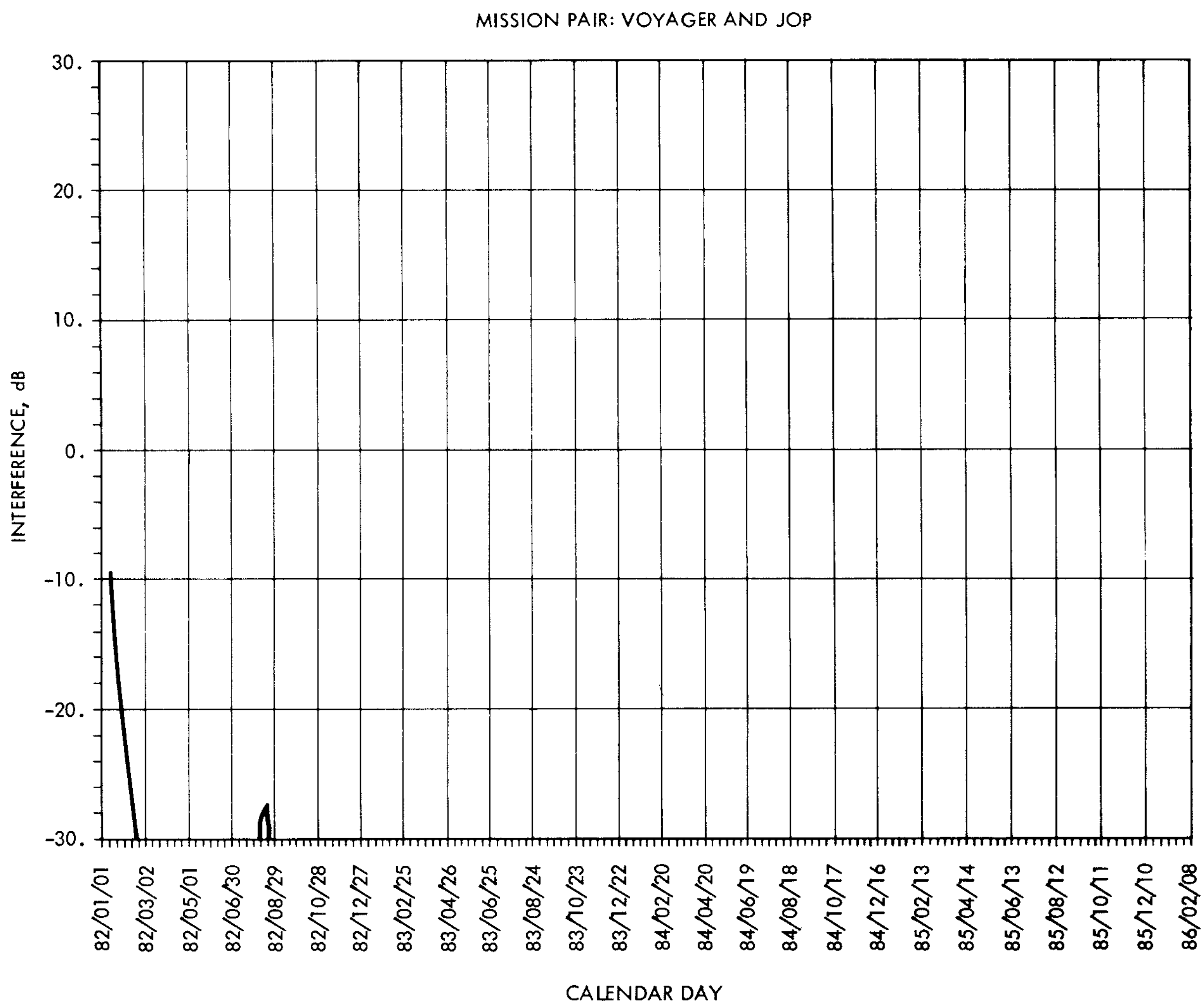

Fig. 1. Interference from nearest spacecraft while receiving signal from more distant spacecraft