SECTION 4

CHARACTERISTICS OF REPRESENTATIVE EQUIPMENT IN THE 2025-2300 MHz FREQUENCY RANGE

INTRODUCTION

The technical characteristics of the operational and planned equipment in the 2025-2300 MHz frequency range were given in Part 1 of this report (Farrar, 1982). A summary of the typical data for terrestrial systems using line-of-sight transmission will be duplicated here for easy reference. The characteristics of the U.S. and non-U.S. satellites given in Part 1 were updated and additional information on the operation of these satellites, which was pertinent to the analysis given here, was obtained. The updated characteristics of satellites are discussed here and typical data representative of systems in space services in the 2025-2300 MHz frequency range are given in this section. The typical data representing the systems in both terrestrial and space services were used in the analysis section to prepare the input parameters for the computer programs used in the calculation of pfd limits.

SYSTEMS IN TERRESTRIAL SERVICES

Some of the recommended technical characteristics of the HRC defined by the CCIR cannot be applied readily to a majority of the communication trendlines operating in the 2025-2300 MHz frequency range in the United States. For example, long-haul communications, noise criteria for international connections, and intercontinental telephony are not applicable to most of the systems operating in this frequency range in the United States. On the other hand, it will be futile to determine pfd limits based on unique usage of the spectrum for any specific system. For example, a mobile telemetry system used in a Government test range temporarily pointing its antenna toward geostationary orbit describes a specific and limited use of the spectrum. Also, a single hop communication by an Auxiliary Broadcast system cannot be accepted as representative for pfd limits calculations. However, since the majority of the systems in the 2200-2290 MHz frequency range are in Mobile Service, the effect of the pfd limits on these systems should be treated in the analysis.

Basic premises of communication requirements such as direction of antennas, noise criteria due to interference from satellites, hop length, and number of hops in a trendline, should be selected carefully in the determination of pfd limits. The limits should protect the terrestrial users now and in the forseable future, and yet, not restrict unnecessarily the operation of satellites.

Fixed and Mobile Services constitute the terrestrial services in the 2025-2300 MHz frequency range. Of particular interest to this analysis are the characteristics of commercial equipment used in auxiliary broadcast station in the 2025-2300 MHz frequency range, systems in telemetry mobile, and fixed point-to-point communication in the 2200-2300 MHz frequency range. Technical characteristics typical of representative systems for the three categories of equipment listed above are as follows:

Auxiliary Broadcast Stations

Typical characteristics of systems for this category are as follows:

Number of hops......................	1-5
Transmitter Power...................	2-12 Watts
Antenna Gain........................	20 dBi
Receiver Noise Figure...............	4-8 dB
IF Bandwidth........................	8-30 MHz
Frequency Range.....................	1.99-2.11 GHz
Receiver Threshold (33dB S/N).......	-88 dBm

The above data for equipment in Auxiliary Broadcast Station were obtained through interview and published literature received from the U.S. manufacturers.

In addition to the frequency range used by the Auxiliary Broadcast Station, the space services also share the 2200-2300 MHz frequency range with the Fixed and Mobile Services allocated to the Government users. The functions of the Government systems are primarily for telemetry mobile and fixed point-to-point communications. Characteristics of these systems appropriate to the analysis are summarized below.

Telemetry Mobile

In this category, technical characteristics for the systems in aeronautical telemetry systems are most sensitive to potential interference from spacecraft in the 2200-2300 MHz frequency range. Of particular interest to the analysis are the equipment associated with station class MOEB defined by the NTIA Manual.

Function............................	Air-to-Ground Telemetry
Area of Operation...................	Government test ranges
Transmitter Power	0.4-20 watts
Transmitter Antenna Gain	0.0-10 dBi
Receiver Antenna Gain...............	1-45 dBi
Signal-to-Noise Ratio	28 dB

Systems in MOEB class are used for telemetering from a ballon; from a booster or rocket, excluding a booster or rocket in orbit about the Earth or in deep space; or from an aircraft, excluding a station used in the flight testing of aircraft. The systems in this class are located at specific military test ranges. The tests conducted by such systems can be scheduled and persist for a relatively short time.

Fixed Point-to-Point Communication

Typical characteristics identified here are representative of the U.S. systems and the band usage in the United States. The analysis data for the determination of pfd limits which are applicable to equipment in the Fixed Service is given in Table 4.

TABLE 4
SOME TECHNICAL CHARACTERISTICS OF REPRESENTATIVE
RECEIVERS IN FIXED SERVICE (2200-2300 MHz)

DESCRIPTION	U.S. DATA	CCIR DATA
Receiver Noise Temperature (K)	1200	750
Number of Stations in a Trendline	40	50
Maximum Antenna Gain (dBi)	36	42
Receiver Interference Threshold (dBrnco)	14	14
Feeder Loss (dB)	3	3
Branching Loss (dB)	0	0
Antenna Pattern	CCIR Rpt. 614-2	Rpt. 614-2
Receiver Signal Modulation	FDM/FM	FDM/FM

The rationale for the selected values given in Table 4 will now be discussed. The future needs for the systems in the Fixed Service were a factor in the selection of the typical antenna gain and the receiver noise temperature for these systems. In the pfd analysis given in CCIR Reports Nos. 387-1 and 387-3 receiver noise temperatures were 750 and 1750 Kelvin depending upon the type of receiver and the operating frequency for which it was designed. The analysis in CCIR Report 387-3 assumed the receiver noise temperature to be 750 Kelvins for a high sensitive type receiver operating at 2500 MHz. The noise temperatures for the system discussed in Part 1 varied from 440 to 2000 Kelvins. Data received from the manufacturers indicated that for the majority of the equipment the noise temperature is in the range of 880 to 2000 Kelvins. Hence, 1200 Kelvins for the noise temperature of a typical receiver in the 2200-2300 MHz frequency range is representative for the systems in this frequency range.

The receiver interference threshold level equal to 14 dBrnco corresponds to 25 pw thermal noise (psophometrically weighted) which has been used in CCIR Report No. 387-1. The separation distance of 30 km between stations in a trendline and 40 stations in a trendline for the operational system were typical for this frequency range. The assumption of 40 hops in a trendline is conservative. In the 2025-2110 MHz frequency range which the Space Research, Space Operation, and Earth Exploration satellites may operate, the usage of the frequency range is limited to television pickup and television intercity relay operations. The trendlines for such operations generally consist of a few hops (well below 40). Discussions with U.S. manufacturers indicate that estimated number of hops in the frequency range of interest will not be greater than 40. Three dB feeder loss listed above includes the loss for 40 meters of rigid waveguide and 0.5 dB connector loss. Branching loss was assumed to be equal to zero and space diversity was not considered in the analysis.

SYSTEMS IN SPACE SERVICES

There are three space services which have allocations in parts of the 2025-2300 MHz frequency range. These services are: Space Research, Space

Operations, and Earth Exploration Satellite. It will not be accurate to define typical characteristics based on the typical parameters associated with these services. Despite definitions and attempts by the CCIR to characterize these services, it is very difficult to relate the functions of satellites to these services. Hence, it is more meaningful to consider the characteristics of the operational satellites regardless of the services in which they operate. Typical characteristics for the satellites were derived using the information given in Table 5. Table 5 describes the appropriate parameters for U.S. satellites and Table 6 lists the parameters for non-U.S. satellites. Note that there are 42 satellites in Table 5 as compared to 23 satellites in Table 6. The characteristics of the U.S. satellites given in Table 5 were used in the preparation of the typical parameters for space services employed in the analysis given here.

The proliferation of U.S. satellites in the 2025-2300 MHz frequency range is related to the unique requirements of the Manned Space Program and the development of a space communication system in the 2 GHz band. The signal structure of spacecraft in the 2025-2300 MHz frequency range is complex and diversified. A careful study is necessary to determine the effective bandwidth for the emissions from these satellites. The term "effective bandwidth" is intended only for the analysis given here and it implies the bandwidth where the energy concentration is highest. For all practical purposes, in systems with smooth spectrum density, bandwidth at 3-15 dB is all that is necessary for the determination of the pfd limits. When spectrum density looks like a series of disconnected peaks it is difficult to define an effective bandwidth for that spectrum. In estimating an effective bandwidth for a satellite transmitter, it is important not to include in this bandwidth portions of spectrum between high peaks where negligible amount of energy exists as compared to the energy under the peaks. An appreciation of effective bandwidth is important for the analysis given in Section 5.

In a strict sense, signal structure and spectrum density of any satellite system is one of a kind. Yet for a tractable analysis it is desirable to categorize the spectrum densities of satellites in 2025-2300 MHz frequency range. The analysis results, as shown later, are not sensitive to the detailed signal structure of satellites. The envelope of a signal spectrum density, to a greater extent, and the positions of nulls around the main peaks of the spectrum, to a lesser extent, are all that is necessary for the analysis given here.

A rather coarse categorization of satellite spectrum density may be achieved by considering two types of spectrum used by satellites. These two types of spectrum are those used by TDRSS and Landsat-4. The power density spectrum for satellites in this frequency range generally is similar to these two types. Sometimes a satellite may be capable of transmitting both types. Examination of these two types of signal structure and their respective power density spectrum are as follows:

<u>Landsat-4 Type Power Spectrum Density</u>

This type of spectrum was originally used in the design of Unified S-Band (USB) system (as designed for Apollo) used subcarriers and a PN signal. The PN signal for this system was later modified to distribute the power more evenly over a wider band for use in TDRSS design. The USB signal consisted of

TABLE 5

U.S. SATELLITES PLANNED OR OPERATIONAL IN 2025-2300 MHz FREQUENCY RANGE

ORBIT	SPACE SYSTEM	NATIONAL STATUS	IFRB STATUS	OPERATIONAL STATUS	ORBIT ALTITUDE (KM)	INCLINATION ANGLE (DEG.)	FREQUENCY (MHz)	SPECTRUM TYPE
HE	AMPTE	SR(3)	AP(Prep)	Planned	Elliptical	28.5	2271.	1
LO	COBE (TDRSS)			Planned	900 x 900	99	2287.5	3
HE	DE-A	SR(3)	AP	Active	Elliptical	89.7	2214.	1
LO	ERBS(TDRSS)	SR(Prep)	AP(Prep	Planned	610 x 610	46	2287.5	3
LO	EUVE(TDRSS)			Planned	550 x 550	28.5	2287.5	3
DS	Galileo	SR(3)	AP(Prep)	Planned	Deep Space		2295,2296.4815	1
G	GOES-3			Active	Synch	0.0	2031.1, 2034.2	1
G	GOES-4 (D)			Active	Synch	0.0	2034.9, 2209.086	1
G	GOES E,F			Planned	Synch	0.0	2214,2033	3
LO	GRO(TDRSS)	SR(3)	AP(Prep)	Planned	400 x 400	28.5	2287.5	1
LO	IRAS	SR(3)	AP(Prep)	Planned	900 x 900	99	2253	1
HE	ISEE-1 (A)	SR(3)	AP	Active	Elliptical	27.5		1
HALO	ISEE-3(C)	SR(3)		Active	Elliptical	24.3	2215.5, 2264.8	
RE	IUE		AP	Active	Elliptical	28.7	2249.8	1
LO	LANDSAT-D(TDRSS)	SR(3)	AP	Active	705 x 705	98.2	2287.5, 2265.5	3
LO	NIMBUS-7 (G)		AP(Prep)	Active	960 x 945	99	2211,2273.5	1
DS	OPEN			Planned				1
DS	PIONEER 6-11		REG	Active	Deep Space		2294.26, 2293.89	3
LO	SME(TDRSS)	SR	AP	Planned	530 x 530	97.5	2287.5	3
LO	SMM(TDRSS)	SR(3)	AP REG(Prep)	Active	574 x 574	33	2287.5	3
LO	ST	SR	AP	Planned			2255.5, 2287.5	3
LO	STS(TDRSS)	SR(2)	AP(Prep)	Planned	Variable		2217.5,2250,2287.5	3
G	TDRSS-E,W,C	SR(3)	AP,REG(Prep)	Planned	Synch		2211,2106.4	3
LO	UARS-A+B			Planned	600 x 600	57		3
DS	Viking 1 Land	SR(4)	AP(REG)	Active	Deep Space		2293.15,2294.63	
DS	Voyager 1	SR(3)	REG	Active	Deepspace		2295, 2296.48	
DS	Voyager 2	SR(3)	REG	Active	Deepspace		2113.31, 2295	
G	GSP/NAVSTAR	SR(4)	AP REG	Active	Synch	0.0	2227.5	1
G	IRV	SR(2)		UNKNOWN	Synch	0.0		1
G	LES 8	GMF		Active	Synch	0.0		1
LO	P78-1	SR(4)	AP COORD*REG*	Active	593 x 593	97.7	2247.5, 2252.5	1
LO	P78-2	SR(4)	AP COORD REG	Active	43 x 28	8.3	2222.5	1
LO	P80-1	SR(3)	AP COORD	Planned 11/82	740 x 740	72.5	2212.5-2207.5	1
	SAMS026-70			UNKNOWN				1
G	DSCS II IND OCN			Active	Synch	0.0	2272.5, 2277.5	1
G	DSCS II ATL			Active	Synch	0.0	2272.5, 2277.5	1
G	DSCS II EPAC			Active	Synch	0.0	2272.5, 2277.5	1
G	DSCS II WPAC			Active	Synch	0.0	2272.5, 2277.5	1
G	DSCS III INDOCN	SR(4)		Planned	Synch	0.0	2257.5, 2277.5	1
G	DSCSIII ATL/MID	SR(4)		Planned	Synch	0.0	2257.5, 2277.5	1
G	DSCS III EPAC	SR(4)		Planned	Synch	0.0	2257.5, 2277.5	1
G	DSCSIII WPAC	SR(4)		Planned	Synch.	0.0	2257.5, 2277.5	1
G	FLTSATCOM INDOCN			Active	Synch	0.0		
G	FLTSATCOM ATL			Active	Synch	0.0		
G	FLTSATCOM EPAC			Active	Synch	0.0		
G	FLTSATCOM WPAC			Active	Synch	0.0		
G	FLTSATCOM INDOCN	SR(4)		Planned	Synch	0.0		
G	FLTSATCOM ATL	SR(4)		Planned	Synch	0.0		
G	FLTSATCOM EPAC	SR(4)		Planned	Synch	0.0		
G	FLTSATCOM WPAC	SR(4)		Planned	Synch	0.0		
LO	BLOCK-5D(DMSP)	SR(4)	AP	Active	752 x 724	98	2207.5, 2252.5 2237.5, 2267.5	1

Notes for Table 5 are given on the next page.

NOTE 1: The abbreviations used in this table are as follows:

SR( )	=	System review (stage of review)
GMF	=	Frequency Assignment in GMF
AP	=	Advanced Publication
COORD	=	Frequency assignments coordinated with other administrations
REG	=	Frequency assignments in the Master Register of IFRB
(Prep)	=	Documents in question prepared but not submitted or action not completed.
*	=	Only some of the necessary actions with the IFRB have bee completed.
LO	=	Low Orbiting
HE	=	Highly Elliptical
G	=	Geostationary
DS	=	Deep Space

NOTE 2: TDRS and Landsat represent two types of spectrum used in this frequency range. Type 1 in Table 5 represent a spectrum similar to that used by Landsat Satellite and Type 3 represents a satellite transmitter that is capable of producing Landsat and TDRS types signals.

NOTE 3: Frequencies shown in Table 5 are satellite transmit and receive frequencies. All the frequencies in the 2025-2120 MHz frequency range are satellite receive frequencies with the exception of those for TDRS which may transmit on any frequency in the 2025 to 2120 MHz frequency range.

TABLE 6

SOME OF THE NON-U.S. SATELLITES IN 2025-2300 MHz FREQUENCY RANGE

ORBIT	SPACE SYSTEM	COUNTRY	IFRB STATUS	DATE OF USE	ORBIT ALTITUDE (KM)	INCLINATION ANGLE (DEG.)	FREQUENCY (MHz)	
							UPLINK	DOWNLINK
HE	EXOS	FRANCE	AP	Dec, 1981		72	2260.8	
G	L-SAT	FRANCE	AP	1985			2201	
LO	SPOT	FRANCE	AP	June, 1984	822 x 822	98.7	2205.93	
LO	SPOT-2	FRANCE	AP	June, 1985	829 x 813	98.7	2206.53	
G	TDF-1	FRANCE	AP	1984			2204.73	
G	TELECOMM 1C	FRANCE	AP				2203.5-2208.5	
HE	IC2	FRANCE	AP	1977			Unknown	
LO	[illegible]	FRANCE		Planned	700 x 900	Polar	Unknown	
G	TV-SAT	GERMANY	AP	1984			2200.24	
LO	ASTRO-A	JAPAN	AP	1981	640 x 480	31	2280.5	
LO	ASTRO-B	JAPAN	AP	1983	650 x 550	31	2280.5	
G	BS-2	JAPAN	COORD	Feb, 1984			2276.99,2280.7	
G	CSE	JAPAN	AP	Feb, 1977			2110-2120	2200-2290
G	CS-2A	JAPAN	COORD	Feb, 1983			2286.5	
G	CS-2B	JAPAN	COORD	Nov, 1983			2286.5	
HE(1)	ETS-IV	JAPAN	AP	1981			2208.706	
G	TELE-X	SWEDEN	AP	1986			2027-2035	2202-2210
G(2)	PROGNOZ 1	USSR	COORD	1982				
G(2)	PROGNOZ 2	USSR	COORD	1982				
G(2)	PROGNOZ 3	USSR	COORD	1982				
G(2)	PROGNOZ 4	USSR	COORD	1982				
HE	VIKING	SWEDEN	AP	2nd half 1984	822 x 15,000	98.7	2033.35	2208.1629
G	MSAT	CANADA	AP	1987			2090.15	2269.85
G	DFS-1	FRG	AP	1987			2028	2202.35
G	DFS-2	FRG	AP	1988			2028	2202.35
HE	AMPTE-UKS	BRITIAN	AP	Aug, 1984	547 x 112,891	28.5	2093.75	2273.76
HE	AMPTE-IRM	FRG	AP	Aug, 1984	500 x 121,000	85	2103.6	2284.5
G	APEX	FRANCE	AP	1986			2029-2033.6	2203.5-2208.5
G	F-SAT 1	FRANCE	AP	1987			2025-2110	2200-2290
G	F-SAT 2	FRANCE	AP	1986			2025-2110	2200-2290
(3)	GIOTTO	FRANCE	AP	July, 1985			2116.723	2298.704
G	HIPPARCOS	FRANCE	AP	1988			2063.59	2241.00
(4)	ISPM	FRANCE	AP	May, 1986			2111.607	2293.148
G	VIDEOSAT-1	FRANCE	AP	1987			2025-2110	2200-2290
G	VIDEOSAT-2	FRANCE	AP	1987			2025-2110	2200-2290
LO	EXOS-C	JAPAN	COORD	Feb, 1984	320 x 1,000	73	2108.557	2280.5
G	GMS-3	JAPAN	AP	Aug, 1984			2025-2110	2200-2290
(5)	MS-T5	JAPAN	AP	Jan, 1985			2111.607	2293.148
(3)	PLANET-A	JAPAN	AP	Aug, 1985			2112.289	2293.8889
G	HELVESAT-I	SWITZERLAND	AP	1986			2025-2110	NONE
G	UNISAT I	BRITIAN	AP	1986			2025-2110	2200-2290

1 - Earth-so-Space -- 2116.6 MHz. Space-to-Earth -- 1705. MHz
2 - All PROGNOZ Type satellite Operation on These Bands: 2131, 2151, 2191, 2211, 2231, 2251 MHz, (all ± 10 MHz) 2277, 2289 MHz (both ± 6 MHz).
3 - Will observe Halley's Comet.
4 - Earth-to-Jupiter mission
5 - Interplanetary mission

a carrier and standard subcarriers which were 1.024 MHz and 1.25 MHz (used for telemetry and voice) away from carrier frequency. This, of course, resulted in energy concentrations in certain segments of the spectrum, depending upon the number of subcarriers used. The USB as used today (May, 1983) operates in very much the same way as it did for Apollo.

Landsat-4 has a power spectrum density similar to that used by USB. A variety of Landsat-4 type signals have been used by satellites other than TDRSS. A detailed description of Landsat-4 type spectrum given below is of interest.

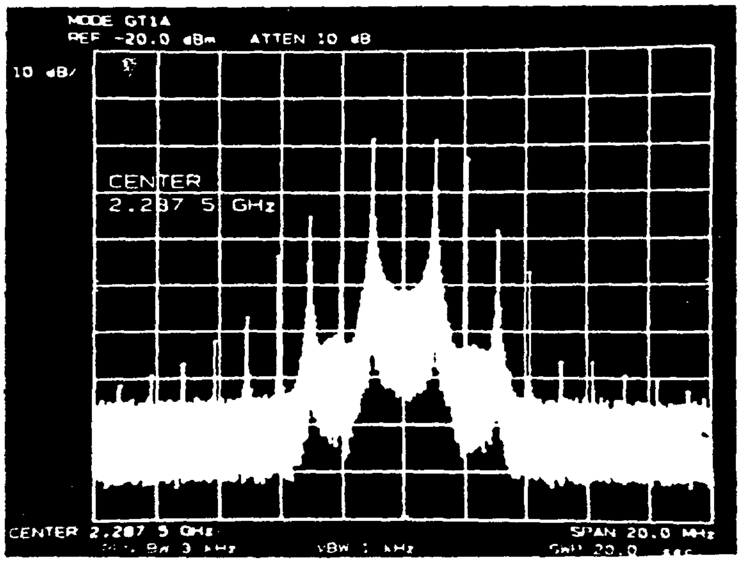
Landsat-4 has an S-band transponder that is capable of working in either the TDRSS or USB (Unified S-band) mode. In the USB mode, it is capable of operating in four different "sub-modes" as follows:

Mode	Modulation	Data Rate (Bio-S)	Mod Index
1 (GT1A)	PCM/PSK/PM	8 kpbs	1.6 rad
2 (GT2A)	PCM/PSK	8 kbps	0.8 rad
	PCM/PM	32 kbps	1 rad
3 (GT3A)	PCM/PSK	8 kbps	0.8 rad
	PCM/PM	256 kbps	1 rad
4 (GT4A)	PCM/PSK	8 kbps	0.8 rad
	Tone PM		0.39 rad

These modes all use the basic 5 watt transmitter and subcarriers are detuned by 1.024 MHz from the carrier. Note that the relatively low modulation indices imply most of the energy is in the close-in sidebands. These modes will now be examined in greater detail.

The first mode, GT1A, is a mode with an 8 kbps, bi-phase signal modulated (PSK) on the 1.024 MHz subcarrier which is in turn phase modulated on the carrier (2287.5 MHz). The carrier level is down about 6.9 dB from total power (5 watts or 7 dBW) or about 1 watt. Note that the peaks in Figure 3 are well separated and that their amplitudes decrease rapidly.

Now consider the GT2A mode in Figure 4. The power level of the carrier is about the same because of a change in the modulation index (see tabulation above). The oscillogram in Figure 4 shows the effect of modulating a 32 kbps bi-phase random wave on the carrier. Significant energy is located at plus or minus 32 kHz from the carrier, about 8 dB below the carrier (160 mw). There is a null at 64 kHz from the carrier but, again, significant energy at about 100 kHz (3 x 32 kHz). This is about -15 dB below the carrier (30 mw). Clearly, except for the carrier, the energy is "bunched" every 64 kHz. An expansion of Figure 4 is shown in Figure 5 which shows a 2 MHz portion of the same spectrum. Note that the 1.024 MHz carrier is down about 8 dB from total carrier power (-8 dBW or about 160 mw). This is lower than that for mode GT1A because of the lower modulation index (1 radian vs 1.6 radian). Modes GT3A and GT4A are similar to mode GT2A.



LANDSAT-4

H 2 MHz/div

V 10 dB/div

BW 3 KHz

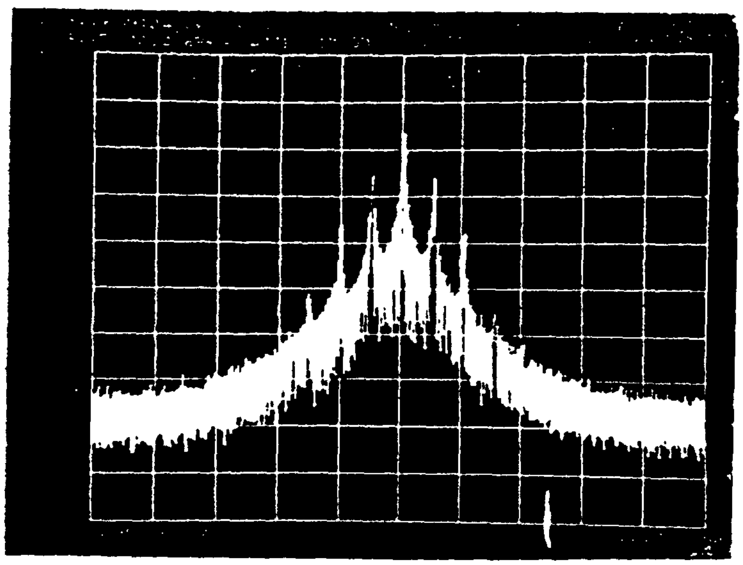
SWP 20 sec

CF 2287.5 MHz

Photo 1

Mode GT1A

Figure 3 Mode GT1A emission from LANDSAT-D



LANDSAT-4

H 2 MHz/div

V 10 dB/div

BW 10 kHz

SWP 6.0 sec

CF 2287.5 MHz

Photo 2

Mode GT2A

Figure 4 Mode GT2A emission from LANDSAT-D.

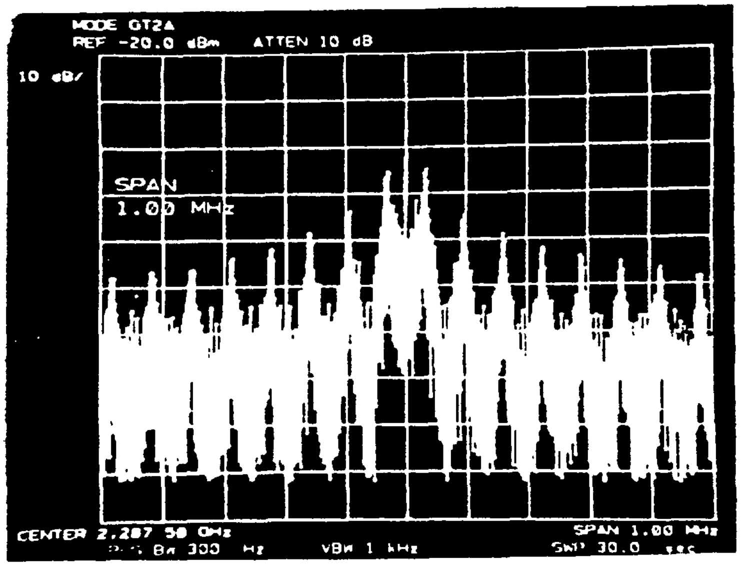
Landsat-4 has a second S-band transmitter (transmit frequency 2265.5 MHz) which is used to transmit wideband data at a power level of 10 watts (total transmit power). This signal is PCM/FM on the carrier at 15 Mbps. Examination of the power spectrum for this operation shows that the energy is distributed with some degree of uniformity (within 10 dB) over a bandwidth in excess of 15 MHz. It is reasonable to assume that most of the power (10 W) is in this bandwidth.

TDRSS Type Power Spectrum Density

An oscillogram of emission spectrum for Landsat-4 operating in the TDRSS mode is shown in Figure 6. The signal structure in Figure 6 is typical of both the TDRS forward link transmit signal (to the user) and the return link signal transmitted by the user to the TDRS. TDRS is a product of the latest technology developed by NASA. Briefly, TDRS, as envisioned by NASA, is a consolidated system which provides at once communication requirements for the near-earth unmanned systems (previously performed at VHF frequencies) and for the USB system which operated at S-band. The USB was used for Apollo and other manned spacecraft. Hence, TDRS is a satellite network which provides communication functions for both manned and unmanned space programs. Oscillogram of the emission spectrum for TDRS is shown in Figure 6. The data in Figure 6 shows a direct sequence spread spectrum signal in which the spreading chip rate is about 8 megabits per second. Note that power density spectrum shown in Figure 6 is of the $(\sin x/x)^2$, with nulls above and below the center frequency and with a null-to-null bandwidth of about 6 MHz. It is estimated that about 80% of the power is in the region defined by $\pm$ 1.6 MHz. Considering the spectrum shown in Figure 6 a bandwidth of $\pm$ 1.6 MHz is close to 8 dB points on the spectrum and at 20 dB below the peak where the first nulls appear are at $\pm$ 3 MHz points.

As noted, the spectrum in Figure 6 is typical of the TDRSS associated spectrum for most spacecraft. The spreading signal, a PN code, can also be used for ranging and/or data transmission purposes. In the past the satellite technology used by NASA was such that the spectrum for every satellite was generally custom designed based on the mission of satellite. This mode of operation also required a number of earth stations which NASA had to maintain overseas. However, it should be pointed out that with the advent of TDRS, the future satellites should be designed in conformity with the spectrum presently designed for TDRS. Most of the Earth stations overseas are being phased out and data transmission and collections by the satellites will be carried out through TDRS systems. Landsat-4 has a transmitter with a spectrum compatible to TDRS that may be activated by remote control. The changeover should take place when TDRS is fully operational.

The discussion on TDRSS pertains to plans envisioned by NASA which is a major user of the spectrum in space services in the 2025-2300 MHz frequency range. Other U.S. agencies such as Department of Defense may continue to design satellites with a spectrum similar to those used by LANDSAT-4 or a variety of other types. However, for the purpose of pfd analysis it is more desirable to use a typical spectrum rather than a variety or even the worse case one.



LANDSAT- 4

H 100 kHz/div

V 10 dB/div

BW 300 Hz

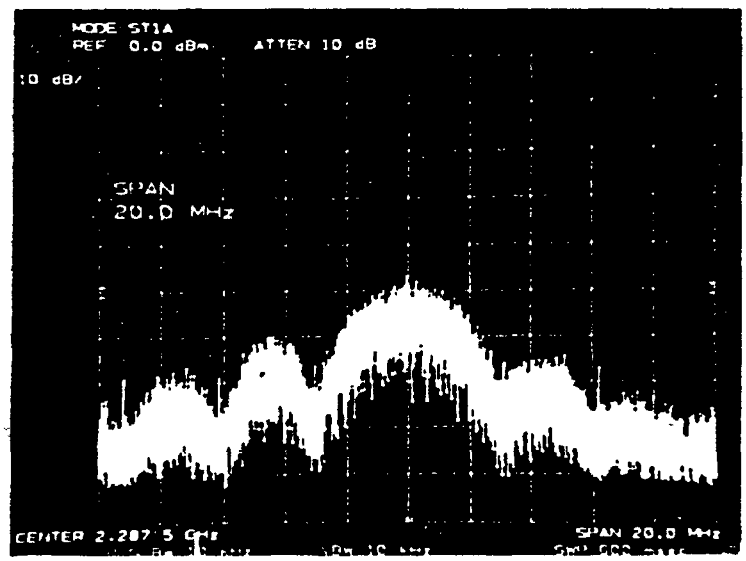
SWP 30.0 sec

CF 2287.5 MHz

Photo 3

Mode GT2A

Figure 5 Expanded data shown in Figure 4.



LANDSAT- 4

H 2 MHz/div

V 10 dB/div

BW 10 kHz

SWP 600 msec

CF 2287.5 MHz

Photo 45

Mode ST1A

Figure 6 Emission spectrum of TDRSS down path transmission $(\sin x/x)^2$.

A review of the available emission spectrums used often by the spacecraft in the 2025-2300 MHz frequency range indicate that the systems in the space services are relatively narrowband and that an effective bandwidth of 0.5 to 4 MHz is a reasonable range for the analysis. A bandwidth of 4 MHz accounts for nearly 90 percent of the power emitted from a wideband satellite in this frequency range. A bandwidth of 2 MHz was considered typical for emissions from spacecrafts in 2025-2300 MHz frequency range.

The types of power spectrum density described above are representative of the non-military spacecraft in the 2025-2300 MHz frequency range. However, military spacecraft such as those used in the Space Ground Link System (SGLS) generally have power density spectrums similar to that used by Landsat-4. SGLS has two carriers. Carrier 1 has 10 Mbps modulating code with modulation indices from 0.125 or 3 radians. Subcarriers for Carrier 1 are at 1.024 MHz and 1.7 MHz away from carrier. The modulating signal on the first subcarrier is 7.8 bps to 128 kbps and the modulating signal for the second subcarrier has a rate ranging from 125 bps to 512 kbps. Carrier 2 is PCM modulated with a 128 kbps to 1.024 Mbps signal. Note that the concept of carrier and subcarriers used in SGLA is not different from that used in Landsat-4. Frequency separation between carrier and subcarrier in addition to the rate of modulating signal varies among the satellites. These variations affect only position of peaks and nulls in the power spectrum density of a satellite. Such variations especially at sections of spectrum which are 10 dB or more below the peaks have little effect on the determination of pfd limits. Hence it was assumed that the two types of the spectrum density described above are sufficient for the analysis given here.

TYPICAL CHARACTERISTICS OF SATELLITES

The technical parameters used in the analysis of the satellites in low and geostationary orbits are as follows:

1. Geostationary orbit

   Separation between satellites (deg.)....................10-20

2. Non-Geostationary orbit

   Satellite orbit altitude (km)...........................300-1200
   Number of satellites visible to receivers...............8
   Satellite inclination angles (deg)......................10-99

The above data were extracted from the information obtained from the NASA, the GMF, and the system review files at NTIA. The input parameters for the computer models used in the analysis were extracted from the technical characteristics noted above.

A breakdown for the majority of the satellites in Table 5 is given below:

ORBIT	NUMBER OF SATELLITES	ACTIVE	PLANNED
Low Orbit	15	6	9
Geostationary	15	8	7
Deep Space	6	4	2
Highly Elliptical	4	3	1

The above data indicate that nearly 50 percent of the satellites in the frequency range 2025-2300 MHz are not yet active. The life expectancy of any of the active satellites in the frequency range is less than 10 years. The low orbit satellites in this frequency range operate at altitudes between 300 to 1200 km. The active low orbit satellites in the frequency range are launched in several orbits. In the computation, eight satellites were assumed to operate co-channel with radio-relays in a trendline and the satellites were distributed evenly in the orbits 300, 500, 800, and 1200 km. The inclination angles for approximately 50% of low orbit satellites range from 90 to 99 degrees. There are approximately eight U.S. satellites in the frequency range 2025-2300 MHz which may have inclination angles as low as 28 degrees. The majority of satellites in the frequency range 2025-2300 MHz use digital modulation each with the capability to operate with multiple modes.