ATTACHMENT A

FM-5

TECHNICAL DESCRIPTION

A.1 GENERAL DESCRIPTION

The Sirius FM-5 satellite was launched in June 2009 and is currently in service at an orbit location of 96.0 degrees West Longitude. As discussed in previous filings,[1] when the three Sirius NGO satellites (all launched in 2000) are retired, Sirius XM will transition to a two geostationary satellite constellation by relocating FM-5 from its current orbital location of 96.0 degrees West Longitude to a location close to 85.0 degrees West Longitude. In order to optimize our network, we now plan to locate FM-5 at 86.15 degrees West Longitude rather than 85.0 degrees West Longitude. Along with the Sirius FM-6 satellite at 116.15 degrees West Longitude, FM-5 creates the constellation that will allow Sirius XM to continue providing Sirius-network subscribers with the best practical service availability. This GEO constellation configuration matches the commonly-owned legacy XM Radio constellation, which will facilitate the continued integration of the legacy companies under the Sirius XM umbrella. Under this scenario, and assuming grant of the instant application, the FM-5 satellite would then operate at the 86.15 degrees West Longitude orbital location to serve Sirius XM subscribers in the continental United States (CONUS - including its offshore waters) and Sirius XM Canada's subscribers in Canada using a single transponder at either of two selectable frequencies. These satellite transmissions will be compatible with the current and next generation of Sirius XM radios.

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[1] *See* Sirius XM Radio Inc., Request for Special Temporary Authority for FM-6 Satellite, File No. SAT-STA-20130701-00091 (stamp grant Sept. 19, 2013); Satellite CD Radio, Inc., Application for Authority to Launch and Operate the FM-6 Satellite, File No. SAT-LOA-20100409-00072 (stamp grant Feb. 4, 2011).

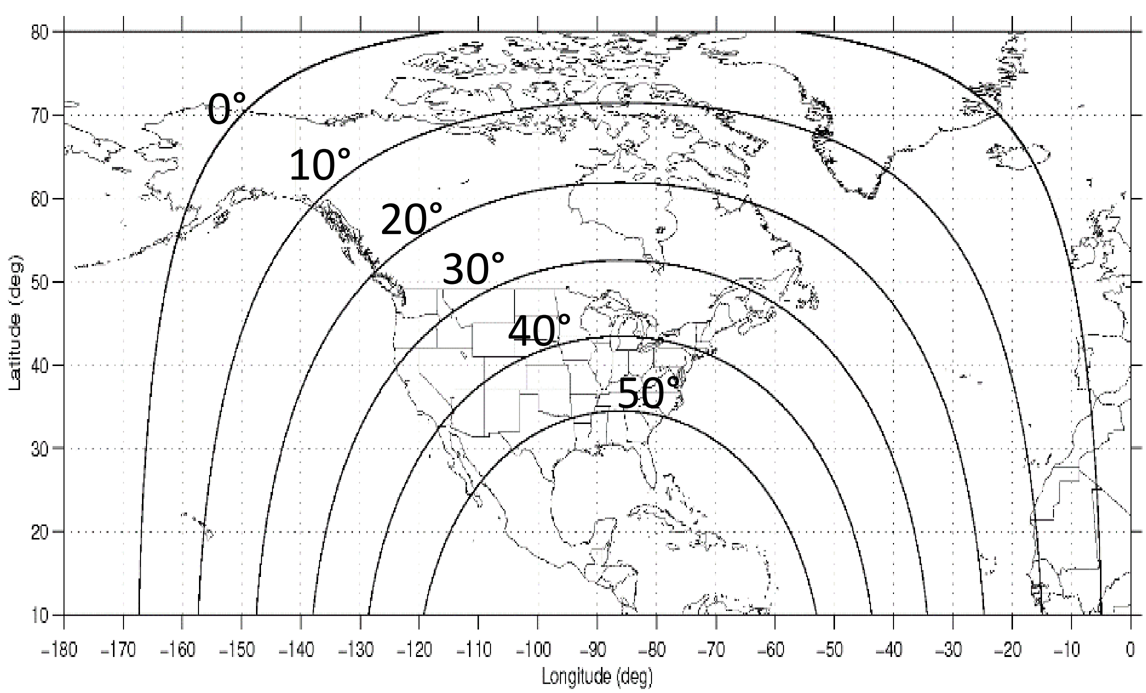
The FM-5 satellite will use the 2320.0-2332.5 MHz DARS radio frequency band, which Sirius XM currently uses for downlink operation of its hybrid constellation. The uplink broadcast transmissions will use X-band frequencies in the 7050.5-7072.5 MHz band.

A.2 ORBITAL LOCATION

Sirius XM requests Commission authority to use the 86.15° W.L. geostationary orbital location for the FM-5 satellite. This orbital location will facilitate implementation of Sirius's two satellite GEO constellation, since it provides both excellent satellite spatial diversity, interference free operation with the XM-3 and XM-5 satellites (collocated at 85.15° W.L.) and good elevation angles to subscribers within the service area. High elevation angles minimize the risk of mobile subscriber receiver signal blockage due to buildings and foliage.

Figure A.2-1 shows the elevation angles from the 86.15° W.L. orbital location to the service area of the proposed FM-5 satellite. The majority of CONUS is above 30° elevation angle.

Figure A.2-1 – Elevation Angles from the 86.15° W.L. Orbital Location



A.3 SATELLITE COVERAGE

The FM-5 satellite will provide DARS broadcast service to receiving terminals located in the broadcast service area. The DARS service beam coverage is provided by a single 9m diameter unfurlable mesh satellite antenna fed by a shaped subreflector. Section A.5 provides further details of the DARS broadcast antenna beam.

The FM-5 X-band feeder link coverage can originate in a portion of central and eastern CONUS between New York, Denver, Northern Texas and Northern Florida. A single feeder link spot beam is created by a 1.2m diameter shaped receive antenna on the satellite. Section A.6 provides further details of the feeder link antenna beam.

A.4 FREQUENCY AND POLARIZATION PLANS FOR COMMUNICATIONS LINKS

For the broadcast service in the DARS band, the FM-5 satellite will be capable of transmitting on either of three carriers in the 2320-2332.5 MHz band. Operational transmissions will take place over a 4.50 MHz bandwidth centered at either 2322.29 MHz (Chan. 1) or 2330.21 MHz (Chan. 2) as allowed under current authorizations for operations on the Sirius network. A 4.50 MHz bandwidth channel centered at 2326.25 MHz (Channel 3) is also available. Left Hand Circular (LHC) polarization will be used on the broadcast downlink.

The FM-5 satellite can receive the X-band feeder link on any of three carriers in the 7060.5-7072.5 MHz band. Uplink operational signal reception will be a single carrier over a 4.50 MHz bandwidth centered at either 7062.29 MHz (Chan. 1) or 7070.21 MHz (Chan. 2) or, if subsequently requested and authorized, within Channel 3 (7066.25 MHz). The feeder link uses Right Hand Circular (RHC) polarization.

TT&C operations will take place below the feeder link frequencies and in the broadcast link frequency ranges, as discussed in detail in Section A.19.

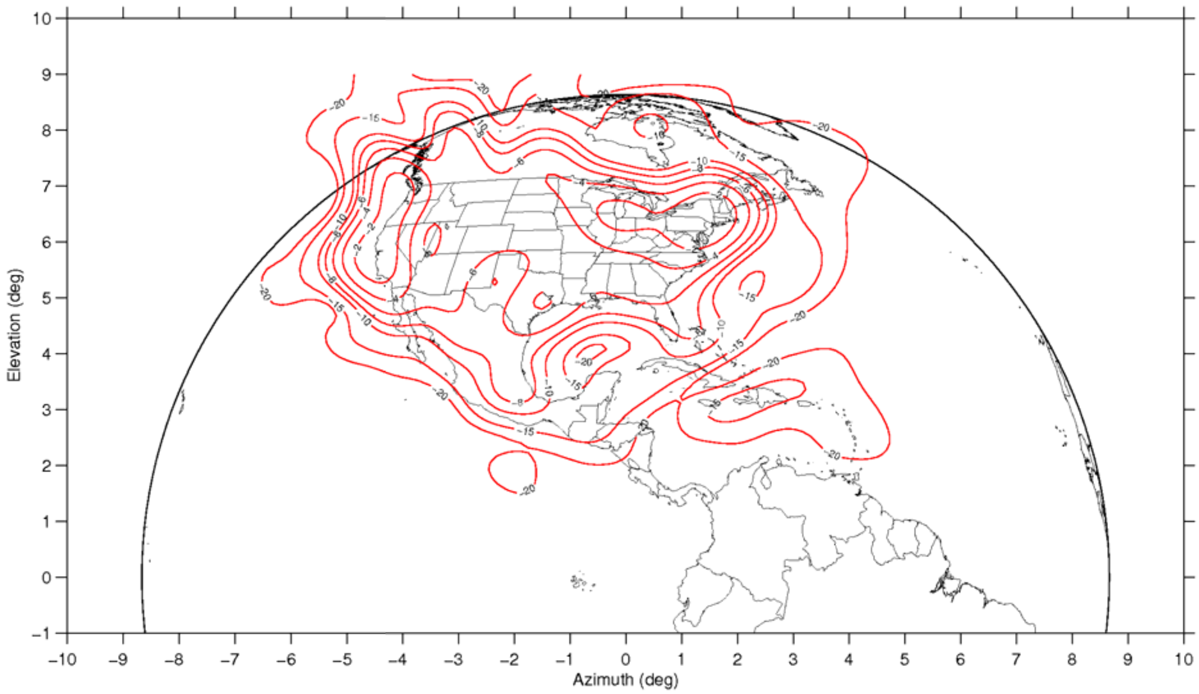
A.5 SATELLITE TRANSMIT CAPABILITY

The detailed gain contours for the DARS broadcast beam are shown in Figure A.5-1. FM-5 will provide a single carrier downlink signal in this coverage area. The downlink coverage pattern is generated by using a shaped 2.4m diameter subreflector in a Gregorian configuration with a 9m diameter unfurlable antenna system. The RF output section is a channel amplifier that feeds a high power TWTA array consisting of a 44:32 array of 245-W, conduction cooled, TWTAs. Each of four 11:8 rings of TWTAs feeds one arm of a four port Ortho Mode Transducer (OMT) combiner. The combiner output launches into an S-band feed horn which illuminates the shaped subreflector.

The cross-polarization isolation of the satellite broadcast transmit antenna will exceed 30 dB within the receive coverage area shown in Figure A.6-1 and throughout CONUS. The receive antenna cross-polarization isolation also exceeds 30 dB within the CONUS coverage area.

Figure A.5-1 – DARS Downlink Beam Gain Contours

(Contours shown are -2, -4, -6, -8, -10, -15, and -20 dB relative to the beam peak of 35.7 dBi)

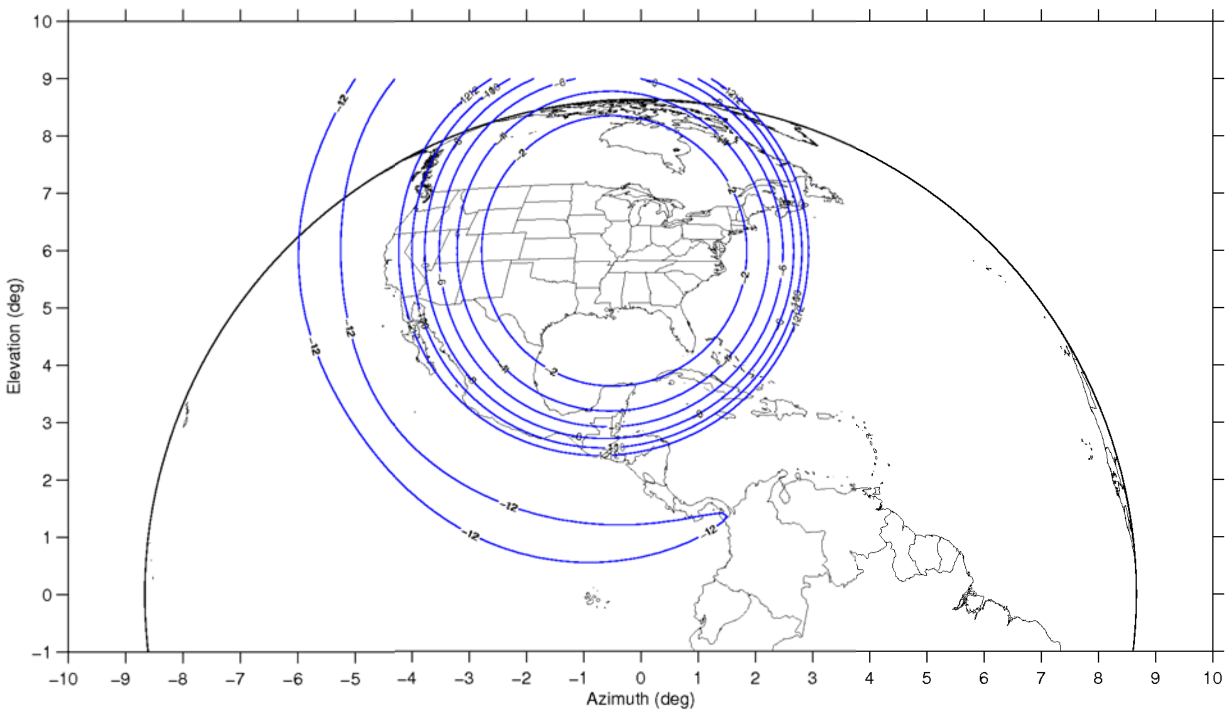


A.6 SATELLITE RECEIVE CAPABILITY

The FM-5 satellite will receive the X-band feeder link by a 1.2m diameter receive shaped antenna from the CONUS feeder link coverage area shown in Figure A.6-1. The detailed gain contours are shown with pointing error added to the basic coverage area. A highly redundant input section on the satellite provides the X to S band radio frequency conversion, filters the signal and provides the S-band signal to the output section of the repeater.

Figure A.6-1 – Feeder Uplink Beam Gain Contours

(Contours shown are -2, -4, -6, -8, -10, and -12 dB relative to the beam peak of 32.6 dBi)



The effective system noise temperature of the satellite feeder link receiver is 830 K (equivalent to 29.2 dB-K). Therefore the beam peak G/T performance is 3.4 dB/K (*i.e.*, 32.6 dBi -29.2 dB-K) and the minimum edge of coverage G/T is 0.8 dB/K.

The cross polarization isolation of the satellite feeder link receive antenna will exceed 30 dB within the -3 dB gain contour at the receive frequency.

A.7 **TRANSMISSION SCHEMES**

The broadcast transmission for the FM-5 satellite is a digital signal stream. It will include the same legacy digital transmission currently used for FM-1/2/3/6 satellite constellation which has a throughput of 4.5 Mb/s containing the audio programming (music and voice channels which have been compressed and multiplexed into this stream as well as several low speed data and service channels). Most of the channel programming is generated at the Sirius XM programming center in New York City with the remaining programming coming from the Sirius XM programming center in Washington DC, remote Sirius XM studios, provider facilities or points of origination (*e.g.*, sports events) for compression and multiplexing. Appropriate encoding (inner coding is convolutional/outer coding is Reed Solomon) and encryption are then performed.

The multiplexed encoded digital stream is sent from the New York facility to the Sirius XM uplink earth station complex in Vernon, NJ where it is split into two streams. One stream is delayed 3-4 seconds relative to the other to achieve time diversity. Both streams are then 4-phase PSK modulated (QPSK) and transmitted at X-band to the two satellites in the Sirius constellation. The satellites are bent pipe repeaters and, after power amplification and frequency translation, relay the digital stream from the satellites at S-band for reception by subscriber mobile and fixed receivers. The FM-5 satellite will relay one of the two digital signal streams to system users.

In addition to this legacy modulation, the Sirius satellites, when active, also transmit an additional digital stream, embedded in the legacy signal, called "overlay modulation." The legacy modulation whose symbols carry two information bits had been modified to carry a third information bit. This modulation was done by shifting the phase of the legacy QPSK symbols from their original locations by a certain angle (+/-ten to fifteen degrees). This additional data stream is encoded with a low density parity check code concatenated with a BCH code. The digital stream throughput can be up to 1.35 Mb/s. The additional transmission capacity is used for providing subscribers with more audio channel programming, data and other ancillary purposes. The FM-5 satellite will transmit the legacy and overlay modulated signal to system receivers.

A.8 TRANSPONDER GAIN CONTROL AND SATURATION FLUX DENSITY

The communications payload can be operated in either automatic level control (ALC) or in a fixed gain mode. The actual gain is programmable by ground command, over a 20 dB range in 1 dB steps. It is also possible to cease all transmission by ground command. Because the system broadcasts a single carrier, it is normally operated near transmitter output saturation. The receive flux density at the satellite for saturated operation will be between -88 dBW/m^2 and -108 dBW/m^2.

The range of gain for the transponder, measured from the output of the X-band receive antenna to each of four inputs to the S-band transmit antenna feed, is from 126 dB to 146 dB, depending on the gain setting.

A.9 SATELLITE FILTER RESPONSE

The following considerations dictate the specification for the overall in-band filter response and out-of-band attenuation:

1. The in-band gain and group delay response must be flat enough so as not to degrade significantly the bit error rate performance of the digital carrier transmitted.
2. The out-of-band attenuation must be high enough to meet the out-of-band emission limits of §25.202(f) (1), (2) and (3).

The FM-5 satellite is being designed to comply fully with these requirements. The linear response of any transmission over the usable bandwidth of channels 1 or 2 will not vary by more than the following values:

Transponder Bandwidth (MHz)	Offset From Center Frequency (MHz)	Gain Flatness (dBp-p) *	Maximum Gain Slope (dB/MHz) *
4.5	±1.60	0.8/0.7	0.65/0.6
	±1.95	1.3/1.2	0.85/0.75
	±2.25	1.8/1.7	1.1/1.0

* The first number is for the total payload, the second number for the receive portion.

The group delay and stability for channels 1 or 2 will not exceed the following values:

Transponder Bandwidth (MHz)	Offset From Center Frequency (MHz)	Group Delay Variation (nsec p-p) *	Group Delay Stability (nsec p-p)
4.5	±1.6	45 / 40	10
	±1.95	65 / 55	12
	±2.25	70 / 65	15

* The first number is for the total payload, the second number for the receive portion.

The response relative to that at the center frequency of each channel for channels 1 and 2 will meet the limits defined below:

Offset from channel center frequency (MHz)	±4.5	±6.75	±9.0
Response, dB	-2	-20	-30

A.10 UNWANTED EMISSIONS

The out-of-band emissions will not exceed the limits of §25.202(f) (1), (2) and (3).

The mean power of emissions will be attenuated below the mean output power of the transmitter in accordance with the following schedule:

(1) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 50 percent up to and including 100 percent of the authorized bandwidth: 25 dB;

(2) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 100 percent up to and including 250 percent of the authorized bandwidth: 35 dB;

(3) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 250 percent of the authorized bandwidth: An amount equal to 43 dB plus 10 times the logarithm (to the base 10) of the transmitter power in watts.

A.11 EMISSION DESIGNATORS AND ALLOCATED BANDWIDTH OF EMISSION

The communications and TT&C signals will utilize carriers of varying bandwidths and different modulation schemes. All communications carriers will be digitally modulated. The following table lists the emission designators for these signals. During performance testing such as the In-Orbit testing following launch, an unmodulated carrier is employed during certain measurements.

Signal Types	Emission Designators
Communications Telemetry, Command	4M50G7E 300KG1D , 1M00F1D

A.12 **EARTH STATIONS**

A.12.1 User Terminals

Many millions of Sirius legacy subscriber receivers are currently in operation. Most receivers are installed in vehicles (automobiles, trucks, boats, etc.) but appreciable numbers are installed in homes or are portable. Many are transportable or re-locatable (*e.g.*, plug and play).

Each receiver generally has a radio frequency unit (*i.e.*, antenna and associated amplifier) which feeds an electronics unit, the latter providing frequency translation, demodulation, channel selection and decompression. All receivers are functionally similar with the main radio frequency unit variation being the antenna size and consequent gain. The electronics unit is based on a standard chipset so basic functionality is also nearly identical. The chipset provides a three-channel radio so signals from both satellites of the Sirius XM constellation and, in many urban markets, a local rebroadcast terrestrial transmitter can simultaneously be received when available with good strength.

Each receiver has a unique digital identification in the chipset. This allows Sirius XM to address individual receivers through the subscriber service channel (*i.e.*, a command channel originated at the Sirius XM National Broadcast Center and multiplexed with the audio program channels) for purposes such as radio activation/deactivation, channel realignments, etc.

Further details are provided in the link budget section of this technical annex (Section A.13).

A.12.2 Feeder Link Earth Stations

The primary feeder link Earth station is located at Vernon, NJ and uses a 7.2m diameter antenna as noted in the following budget. A backup feeder link earth station is located at Ellenwood, GA and uses a 7.2m antenna. The transmission characteristics are shown in the link budgets below. The antennas have sidelobe characteristics that meet or exceed ITU-R recommendations.

In addition to the primary and backup feeder link earth stations used during on station operations, an 8.0m full motion antenna in Ellenwood, GA and a 4.6m full motion antenna located in Vernon, NJ will be used as feeder link earth stations to maintain service continuity while the FM-5 satellite is being moved from its current location at 96ºW.L. to the new location at 86.15ºW.L.

Applications for licenses for these stations will include frequency coordination data regarding terrestrial sharing service users. The Sirius XM satellite fleet currently uses the X-band uplink broadcast frequency and the command frequency transmissions. Therefore, the uplink transmissions out-of-band flux densities will not interfere with any other operators' on-orbit satellites.

A.13 **LINK BUDGETS**

A.13.1 Communications Links

The FM-5 satellite will support digital communications traffic. The communications payload on the FM-5 satellite is a transparent transponder type ("bent-pipe"). Tables A.13-1a-e show representative link budgets with X-band uplink and S-band broadcast downlink.

Table A.13-1a –Link Budget FM-5 DARS Broadcast from Vernon, NJ (7.2m Antenna)

Parameter	**Uplink**	**Units**
Antenna size	7.2	meters
Transmitted Frequencies	7062.293, 7070.207	MHz
Antenna Efficiency	60.0	**%**
Nominal HPA Power at Flange	30.0	dBW
HPA Backoff	3.0	dB
HPA to Antenna Loss	2.5	dB
Power at Feed Flange	24.5	dBW
Antenna Gain	50.5	dBi
Nominal Transmitted EIRP	75.0	dBW
Isotropic Area	38.4	dBW/m^2
Range Distance	37688	km
Range Loss	200.9	dB
Rain Fade	2.4	dB
Pointing Loss	0.5	dB
Received EIRP at Spacecraft	-128.8	dBW
Received Flux Density	-90.4	dBW/m^2
Required Flux Density	-100.0	dBW/m^2
SFD Margin	**9.6**	**dB**

Table A.13-1b –Link Budget FM-5 DARS Broadcast from Vernon, NJ (4.6m Antenna)

Parameter	**Uplink**	**Units**
Antenna size	4.6	meters
Transmitted Frequencies	7062.293, 7070.207	MHz
Antenna Efficiency	60.0	**%**
Nominal HPA Power at Flange	34.3	dBw
HPA Backoff	6.3	dB
HPA to Antenna Loss	2.0	dB
Power at Feed Flange	26.0	dBw
Antenna Gain	46.5	dB
Nominal Transmitted EIRP	72.5	dBw
Isotropic Area	38.4	dBw/M^2
Range Distance	37688.0	km
Range Loss	200.9	dB
Rain Loss	2.4	dB
Pointing Loss	0.5	dB
Received EIRP at Spacecraft	-131.3	dBw
Received Flux Density	-92.9	dBw/M^2
Required Flux Density	-100.0	dBw/M^2
SFD Margin	**7.1**	**dB**

Table A.13-1c – Link Budget FM-5 DARS Broadcast from Ellenwood, GA (8.0m Antenna)

Parameter	**Uplink**	**Units**
Antenna size	8.0	meters
Transmitted Frequencies	7062.293, 7070.207	MHz
Antenna Efficiency	60.0	**%**
Nominal HPA Power at Flange	30.4	dBW
HPA Backoff	8.7	dB
HPA to Antenna Loss	2.0	dB
Power at Feed Flange	19.7	dBW
Antenna Gain	52.8	dB
Nominal Transmitted EIRP	72.5	dBW
Isotropic Area	38.4	dBW/M^2
Range Distance	37020.0	km
Range Loss	200.8	dB
Rain Loss	2.4	dB
Pointing Loss	0.5	dB
Received EIRP at Spacecraft	-131.2	dBW/M^2
Received Flux Density	-92.7	dBW/M^2
Required Flux Density	-100.0	dBW/M^2
SFD Margin	**7.3**	**dB**

Table A.13-1d – Link Budget FM-5 DARS Broadcast from Ellenwood, GA (7.2m Antenna)

Parameter	**Uplink**	**Units**
Antenna size	7.2	meters
Transmitted Frequencies	7062.293, 7070.207	MHz
Antenna Efficiency	60.0	**%**
Nominal HPA Power at Flange	30.0	dBw
HPA Backoff	3.0	dB
HPA to Antenna Loss	2.5	dB
Power at Feed Flange	24.5	dBw
Antenna Gain	50.5	dB
Nominal Transmitted EIRP	75.0	dBw
Isotropic Area	38.4	dBw/M^2
Range Distance	37020.0	km
Range Loss	200.8	dB
Rain Loss	2.4	dB
Pointing Loss	0.5	dB
Received EIRP at Spacecraft	-128.7	dBw
Received Flux Density	-90.2	dBw/M^2
Required Flux Density	-100.0	dBw/M^2
SFD Margin	**9.8**	**dB**

Table A.13-1e - FM-5 Satellite Payload Transmission

Link Budget (New York City Area)

Parameters	**Downlink**	**Units**
Spacecraft Saturated EIRP	71.0	dBW
Transmitted Frequencies	2322.293, 2330.207	MHz
Range Loss	191.1	dB
Rain Fade	0.5	dB
Car Antenna Gain (40° Elevation Angle)	3.7	dBi
EIRP Received at Car	-117.1	dBW
Flux Density Received at Car	-88.3	dBW/M^2
Total Noise Temperature	158.0	°K
Receiver Noise Bandwidth	66.5	dB-Hz
Boltzmann Constant	-228.6	
Receiver Noise Power	-140.1	dBW
C/N Received at the Car	23.0	dB
Required C/N	4.0	dB
Implementation Loss	1.0	dB
Link Margin*	18.0	dB

* The minimum Link Margin in the service area is 10.7 dB to achieve the required service availability. Additional margin is necessary for many requirements, particularly heavy foliage attenuation which can be many decibels.

A.13.2 TT&C Links

Tables A.13-2a-c and A.13-3a-c provide the command and telemetry link budgets for on-station operations.

Table A.13-2a: Command Link Budget from Vernon, NJ (7.2m Antenna)

Parameters	
Command Frequency (GHz)	7.052, 7.056
Nominal HPA Output (including W/G Losses), dBW	24.5
Antenna size (meters)	7.2
Antenna Efficiency	0.6
Antenna Gain (dB)	50.5
Nominal Transmitted EIRP (dBW)	**75.0**
Isotropic Area (dBW/m^2)	38.4
Range Distance (Km)	37688.0
Range Loss (dB)	200.9
Rain Fade (dB)	2.4
Nominal Flux Density CMD Omni Antenna (dBW/m^2)	**-89.9**
Command Omni Antenna Gain (dB)	-4.0
Command System Noise Temperature (ºK)	630.0
Command System G/T (dB/ºK)	-32.0
Boltzmann Constant	-228.6
Available C/No (dB-Hz)	68.8
Data Bandwidth (250 b/s)	24.0
Available C/N (dB-Hz)	**44.8**
Transmitted Noise BW (250 b/s)	24.0
CMD SNR Required for BER=10^-6 (dB)	10.7
Implementation Loss (dB)	1.5
Net C/No Required (dB-Hz)	**36.2**
Nominal EIRP at Omni Antenna (dBm)	-98.3
Losses to CMD Receiver (dB)	5.20
Power Available at CMD Receiver (including Omni Gain), dBm	**-107.5**
Spec Requirement for CMD Receiver Sensitivity (dBm)	**-112.0**
CMD Receiver Sensitivity Margin (dB)	**4.5**

Table A.13-2b: Command Link Budget from Ellenwood GA (8.0m Antenna)

Parameters	
Command Frequency (GHz)	7.056
Nominal HPA Output (including W/G Losses), dBw	26.6
Antenna size (Meters)	8.0
Antenna Efficiency	0.6
Antenna Gain (dB)	52.8
Nominal Transmitted EIRP (dBw)	**79.4**
Isotropic Area (dBw/M^2)	38.4
Range Distance (Km)	37020.0
Range Loss (dB)	200.8
Rain Loss (dB)	2.4
Nominal Flux Density CMD Omni Antenna (dBw/M^2)	**-85.4**
Command Omni Antenna Gain (dB)	-3.0
Command System Noise Temperature (ºK)	630.0
Command System G/T (dB/ºK)	-31.0
Boltzmann Constant	-228.6
Available C/No (dB-Hz)	74.4
Data Bandwidth (250 b/s)	24.0
Available C/N	**50.4**
Transmitted Noise BW (250 b/s)	24.0
CMD SNR Required (BER=10^-6)	10.7
Implementation Loss (dB)	1.5
Net C/N Required (dB-Hz)	**36.2**
C/N Margin (dB)	**14.2**
Nominal EIRP at Omni Antenna (dBm)	-93.8
Losses to CMD Receiver (dB)	5.20
Power Available at CMD Receiver , dBm	**-102.0**
Spec Requirement for CMD Receiver Sensitivity (dBm)	**-112.0**
CMD Receiver Sensitivity Margin (dB)	**10.0**

Table A.13-2c: Command Link Budget from Ellenwood GA (7.2m Antenna)

Parameters	
Command Frequency (GHz)	7.052, 7.056
Nominal HPA Output (including W/G Losses & Backoff), dBw	24.5
Antenna size (Meters)	7.2
Antenna Efficiency	0.6
Antenna Gain (dB)	50.5
Nominal Transmitted EIRP (dBw)	**75.0**
Isotropic Area (dBw/M^2)	38.4
Range Distance (Km)	37020.0
Range Loss (dB)	200.7
Rain Loss (dB)	2.4
Nominal Flux Density CMD Omni Antenna (dBw/M^2)	**-89.7**
Command Omni Antenna Gain (dB)	-3.0
Command System Noise Temperature (ºK)	630.0
Command System G/T (dB/ºK)	-31.0
Boltzmann Constant	-228.6
Available C/No (dB-Hz)	69.5
Data Bandwidth (250 b/s)	24.0
Available C/N	**45.5**
Transmitted Noise BW (250 b/s)	24.0
CMD SNR Required (BER=10^-6)	10.7
Implementation Loss (dB)	1.5
Net C/N Required (dB-Hz)	**36.2**
C/N Margin (dB)	**9.3**
Nominal EIRP at Omni Antenna (dBm)	-98.1
Losses to CMD Receiver (dB)	5.20
Power Available at CMD Receiver (including Omni Gain), dBm	**-106.3**
Spec Requirement for CMD Receiver Sensitivity (dBm)	**-112.0**
CMD Receiver Sensitivity Margin (dB)	**5.7**

Table A.13-3a: Telemetry Link Budget at Vernon, NJ (7.2m Antenna)

Vernon, NJ	S-Band TLM
Downlink carrier freq (MHz)	2321.0
Reference Bandwidth	(BW=200 kHz)
Downlink e.i.r.p. (dBW)	**19.4**
Modulation loss (dB)	-8.9
Range (km)	37688.0
Path loss (through equator=35551 km) (dB)	--191.3
Rain fade (dB)	0.5
Earth Station Antenna Gain (dBi) 7.2m diameter	42.2
System Noise Temp (K)	192.5
System Noise Temperature (dB-K)	22.8
Earth Station G/T (dB/K)	19.4
Rec power @Earth surface dBW/200 kHz	-181.3
Received C/N (dB-Hz)	66.8
Received C/No and I/No* (dB-Hz)	**66.0**
Data Bandwidth (4800 bps, BPSK) (dB-Hz)	37.6
Required C/No for BER=10^-6 (dB)	11.5
Implementation Loss (dB)	1.0
Required C/No (dB-Hz)	**50.1**
Telemetry Margin for BER=10^-6 (dB)	**15.9**

*** The Payload Co-pol =56.6 and cross-pol =54.6 transmissions act as additional noise to the telemetry reception**

Table A.13-3b: Telemetry Link Budget at Ellenwood, GA (8.0m Antenna)

Ellenwood, GA	**S-Band TLM**
	RHCP
Downlink carrier freq (MHz)	2321.0
Reference Bandwidth	(BW=300 kHz)
Downlink e.i.r.p. (dBW), On-Station	**19.4**
Modulation loss (per SS/LORAL) (dB)	-8.9
Payload Sidelobe Impact	
Range (km)	37020
Path loss (through equator=34643 km) (dB)	-191.1
Typical fade (dB)	0.5
Earth Station Antenna Gain (dBi) **8.0m**	43.0
System Noise Temp (K)	122.0
System Noise Temperature (dB-K)	20.9
Earth Station G/T (dB/K)	22.1
Rec power @Earth surface dBW/300 kHz	-181.1
Received C/N and I/N* (dB)	69.7
Available C/(N-I1-I2) (dB-Hz)	**69.3**
Data Bandwidth (4800 bps, BPSK) (dB-Hz)	37.6
Required Eb/No for BER=10^-6 (dB)	11.5
Implementation Loss (dB)	1.0
Required C/N (dB-Hz)	**50.1**
Telemetry Margin for BER=10^-6 (dB)	**19.2**

*** The Payload Co-pol (I1=57.9) and cross-pol (I2=50.9) transmissions act as interferers to the Telemetry transmission**

Table A.13-3c: Telemetry Link Budget at Ellenwood, GA (7.2m Antenna)

Ellenwood, GA	S-Band TLM
	RHCP
Downlink carrier freq (MHz)	2321.0
Reference Bandwidth	(BW=300 kHz)
Downlink e.i.r.p. (dBW), On-Station	**19.4**
Modulation loss (per SS/LORAL) (dB)	-8.9
Payload Sidelobe Impact	
Range (km)	37020
Path loss (through equator=34643 km) (dB)	-191.1
Typical fade (dB)	0.5
Earth Station Antenna Gain (dBi) **8.0m**	42.2
System Noise Temp (K)	192.5
System Noise Temperature (dB-K)	22.8
Earth Station G/T (dB/K)	19.4
Rec power @Earth surface dBW/300 kHz	-181.1
Received C/N and I/N* (dB)	66.8
Available C/(N-I1-I2) (dB-Hz)	**66.7**
Data Bandwidth (4800 bps, BPSK) (dB-Hz)	37.6
Required Eb/No for BER=10^-6 (dB)	11.5
Implementation Loss (dB)	1.0
Required C/N (dB-Hz)	**50.1**
Telemetry Margin for BER=10^-6 (dB)	**16.6**

*** The Payload Co-pol (I1=56.6) and cross-pol (I2=54.6) transmissions act as interferers to the Telemetry transmission**

A.14 **STATION-KEEPING AND ANTENNA POINTING ACCURACY**

The FM-5 satellite will be maintained in longitude within ±0.05° of its nominal orbital location and in latitude within ±0.05° of the equator. The antenna axis pointing will be maintained within ±0.16° of nominal.

A.15 **POWER FLUX DENSITY AT THE EARTH'S SURFACE**

There are no PFD limits in the 2310-2360 MHz downlink frequency band according to the FCC Rules or the ITU Radio Regulations. The PFD requirements of Canada and Mexico are met.

A.16 **FREQUENCY TOLERANCE**

The satellite local oscillator frequency stability will determine the accuracy of the frequency conversion between uplink and downlink transmissions. This frequency conversion error will not exceed ±1 in 10^6 under all circumstances.

All transmissions that originate from on-board frequency sources (*e.g.*, telemetry downlinks) will maintain a frequency accuracy of ±0.002% of the reference frequency.

A.17 **CESSATION OF EMISSIONS**

All communications link transmissions from the satellite can be turned on and off by ground command, thereby causing cessation of emissions from the satellite, as required.

A.18 **LAUNCH VEHICLE**

The FM-5 satellite was launched June 30, 2009 via a Proton M/Breeze M launch vehicle.

A.19 **TT&C**

The telemetry, tracking, and command (TT&C) subsystem provides the satellite communications links for pre-launch, orbit-raising, and on-station operations. FM-5 satellite operations are conducted by Intelsat. The TT&C system receives commands from the Satellite Operations Center in Tysons Corner, VA, authenticates the commands, and transmits the commands to the satellite. The TT&C system also receives satellite telemetry and ranging data which is forwarded to the Satellite Operations Center. A backup Satellite Operations Center is located in Long Beach, CA. The satellite TT&C system is a standard X/S-band system and incorporates redundant command receivers, telemetry transmitters, and power amplifiers. Orbit-raising and contingency operations use wide angle X-band antennas for command and S-band wide angle antennas for telemetry. On-station operations utilize the X-band wide angle antennas for on-station command operation and the S-band broadcast area coverage antenna for telemetry. This TT&C system is essentially the same as the standard design for the Space Systems/Loral 1300 product line. A summary of the TT&C subsystem parameters is given in Table A.19-1 below.

Table A.19-1: Summary of the TT&C Subsystem Parameters

Parameter	Transfer Orbit and Emergency	On-Station
Command/Ranging Frequencies/Polarization	7052.0 MHz (LHCP) 7056.0 MHz (LHCP)	7052.0 MHz (LHCP) 7056.0 MHz (LHCP)
Uplink Flux Density	Between -90 and -50 dBW/m^2	Between -90 and -84 dBW/m^2
Uplink Antenna Coverage (relative to the +Z axis of the spacecraft, antenna boresight)	+Z +10E ± 110° (E/W) x ± 55° (N/S) -Z -10E ± 50° (E/W) x ± 50° (N/S)	+Z +10E ± 110° (E/W) x ± 55° (N/S) -Z -10E ± 50° (E/W) x ± 50° (N/S)
Peak Deviation (Command/Ranging)	± 400 kHz	± 400 kHz
Telemetry/Ranging Frequencies	2320.5 MHz (RHCP) 2321.0 MHz (RHCP) 2331.5 MHz (RHCP) 2332.0 MHz (RHCP)	2320.5 MHz (RHCP) 2321.0 MHz (RHCP) 2331.5 MHz (RHCP) 2332.0 MHz (RHCP)
Downlink Antenna Coverage (relative to the +Z axis of the spacecraft, antenna boresight)	+Z +10E ± 110° (E/W) x ± 55° (N/S) -Z -10E ± 50° (E/W) x ± 50° (N/S)	+Z ± 17.5° (E/W) x ± 17.5° (N/S)
Maximum Downlink EIRP	0 dBW	24 dBW
Telemetry/Ranging Modulation Index 1 sub-carrier 2 sub-carriers 3 sub-carriers	 1.0 0.7 0.6	 1.0 0.7 0.6

TT&C is performed from a TT&C earth station located in Vernon, NJ using a 7.2m diameter antenna. The Vernon station is backed up by a TT&C station in Ellenwood, GA also equipped with a 7.2m diameter antenna. Frequency coordination data for sharing terrestrial service users will be provided with the license application to be filed for these earth stations. There are two

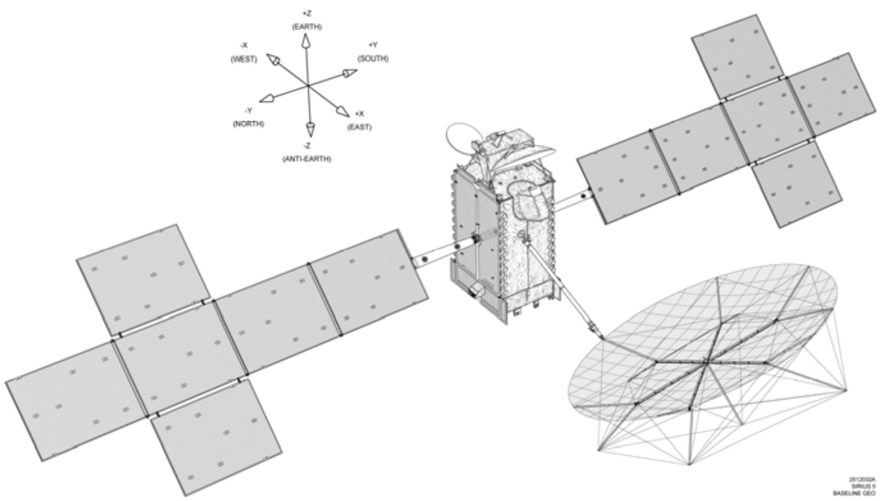
Satellite Operations Centers with the primary one located in Tysons Corner, VA and the secondary one located in Long Beach, CA. The network management center is located in New York, NY.

A.20 SPACECRAFT CHARACTERISTICS

The FM-5 satellite design is based on a Space Systems/Loral 1300 standard satellite platform that has been optimized for FM-5 broadcast requirements with a 15 year design life, 9 meter diameter deployable S-band mesh antenna for operation in a GEO positioned at 86.15^{o} WL.

An illustration of the satellite design is shown in Figure A.20-1 below.

Figure A.20-1: FM-5 Communications Satellite



The FM-5 satellite is designed to support the unique requirements of the mission while taking advantage of the Space Systems/Loral 1300 standard satellite platform modular design and integration techniques, standardized components and processes, and broad experience to deliver on-orbit performance, high reliability, and long life.

A summary of the satellite design is provided in Table A.20-1 below.

Table A.20-1: Satellite Summary

Satellite Manufacturer	Space Systems/Loral
Design Life	15 years
Satellite Platform	Space System/Loral 1300
Power Available (EOL)	19.8 kW
Batteries	Li-Ion
Solar Arrays	Sun tracking (GaAs panels)
Stationkeeping	±0.05º degrees N/S and E/W
Attitude Control	Three-axis stabilized
Communications Antenna	One 9m diameter S-band unfurlable mesh reflector One 1.2m diameter X-band reflector
Command and Telemetry	X-band Command (orbit-raising & on-station) S-band Telemetry (orbit-raising & on-station)

The satellite platform, structure, attitude control, propulsion, power, thermal, and telemetry, tracking, and command subsystems are described below.

A.20.1 Spacecraft Bus

The FM-5 spacecraft consists of a rectangular main structural body that houses the electronic equipment internally and supports the communications antennas on the satellite's faces. The satellite platform is designed to accommodate the 9 meter diameter deployable S-band mesh antenna, rigid X-band reflector, antenna feed element arrays, tracking solar arrays, and sufficient surface area for thermal control.

The satellite mass summary is provided in Table A.20-2 below.

Table A.20-2: Spacecraft Mass Summary

	Mass (kg)
Satellite Payload	560 kg
Satellite Bus	2,070 kg
Satellite Dry Mass	2,630 kg
Margin (7%)	170 kg
Fuel	3,050 kg
Launch Mass	5,850 kg

A.20.2 Attitude Control Subsystem

The momentum-biased attitude control subsystem (ACS) is composed of earth and sun sensors, star trackers, hemispheric resonator gyros, momentum wheels, thrusters, and the electronics equipment required to maintain control of the satellite at all times. This attitude control subsystem is essentially the same as the standard design for the Space Systems/Loral 1300 product line.

A.20.3 Propulsion Subsystem

The propulsion subsystem for FM-5 is a combination of chemical and plasma. This propulsion system is essentially the same as the standard design for the Space Systems/Loral 1300 product line that is currently being flown.

The liquid propulsion (chemical) subsystem is a bipropellant system. Propellant and helium pressurant are stored in tanks within the satellite platform body. One main satellite thruster is located along the satellite main body axis of thrust and is used for orbit raising. Twelve ACS thrusters are mounted around the satellite and are used for attitude control. The thrusters provide the impulse necessary for transfer orbit reorientation, 3-axis attitude control, East/West station keeping, station changes, and de-orbit maneuvers. The thrusters also provide a backup capability for North/South station keeping maneuvers. The satellite has been designed to use the bi-propellant system to de-orbit at end-of-life.

The stationary plasma thruster subsystem includes four ACS thrusters with Xenon tanks within the satellite platform. These thrusters provide the primary capability for North/South station keeping.

A.20.4 Electrical Power Subsystem

The electrical power subsystem is designed to provide approximately 19 kW of power at the end of life (equinox). Power generation is accomplished by two (2) x six (6) panel solar arrays populated with gallium arsenide (GaAs) solar cells. The solar arrays track the sun driven by two Solar Array Drive Assemblies (SADA). A rechargeable Lithium Ion battery is used to store power for eclipse operations when the solar array is shadowed. This power system is essentially the same as the standard design for the Space Systems/Loral 1300 product line.

The satellite power requirement summary (EOL, equinox) is provided in Table A.20-3 below.

Table A.20-3: Spacecraft Power Requirement Summary (EOL, Equinox)

	Power EOL (kW)
Satellite Payload	13.0 kW
Satellite Bus	4.3 kW
Satellite Total	17.3 kW

A.20.5 Thermal Control Subsystem

The thermal control subsystem provides a controlled thermal environment throughout the mission. The thermal control system consists of heat-pipes, surface treatments, radiators, blankets, insulators, and heaters to maintain all the equipment within the required operating environments. This thermal system is essentially the same as the standard design for the Space Systems/Loral 1300 product line.

A.20.6 Reliability

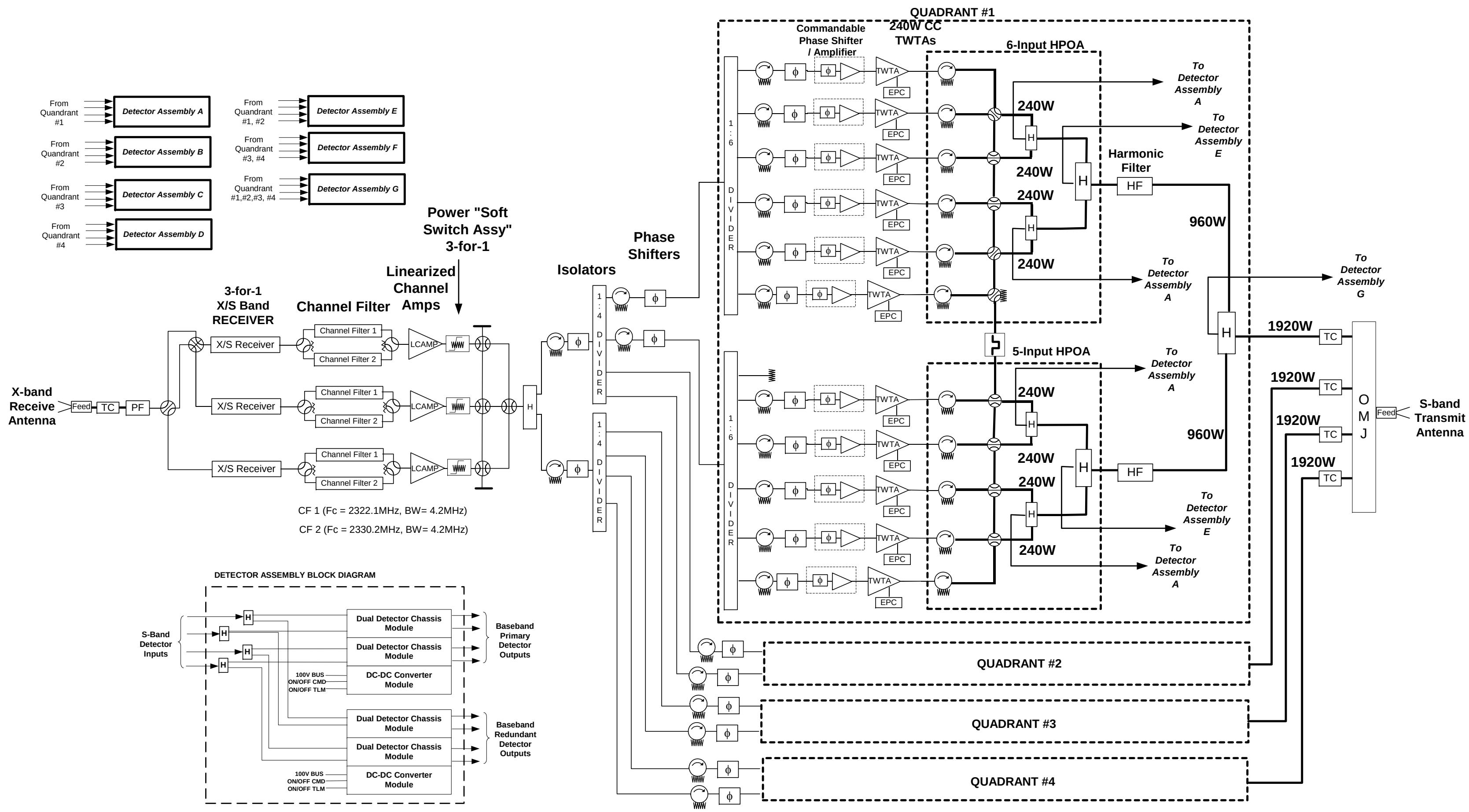
Spacecraft bus reliability will be greater than 0.85 with an overall spacecraft reliability at EOL of greater than 0.76.

A.21 COMMUNICATIONS PAYLOAD

The payload consists of a single high power transponder with a 1.2m diameter receive antenna, 3:1 redundant input section with each chain having an X-S receiver, channel filter assembly with selectable filters, and S-band channel amplifier. The channel amplifier feeds a high power TWTA array consisting of a 44:32 array of 245W, conduction cooled, TWTAs organized into four 11:8 sections. Each 11:8 section feeds one arm of a four port Ortho Mode Transducer (OMT) combiner. This combiner was qualified for the rated power levels early in the program. The combiner output launches into the S-band feed horn. A shaped 2.4m diameter subreflector is utilized in a Gregorian configuration with a 9m diameter unfurlable antenna system. The S-band transmit antenna optics are derived from heritage designs on previous Space Systems/Loral programs.

The block diagram for the communications payload is shown in Figure A.21-1.

Figure A.21-1: Block Diagram of the Communications Payload



A.22 **ORBITAL DEBRIS MITIGATION**

Sirius XM will utilize a satellite and launch vehicle design that minimizes the amount of debris released during normal operations. Sirius XM and its satellite contractor have performed a careful assessment and can confirm that no debris will be released by the space station during normal on-station operations. As noted below, Sirius XM has taken measures to ensure a safe operational configuration of its satellite system through hardware design and operational procedures. Each section below addresses specific measures taken by Sirius XM, as required under Section 25.114(d)(14) of the Commission's rules, to limit the possibility that its space station operations will generate orbital debris.

Collisions with small debris, meteoroids: Sirius XM has assessed the probability of the space station becoming a source of debris by collisions with small debris or meteoroids that could cause loss of control and prevent post-mission disposal. Collisions with the background environment, including meteoroids, are considered as part of the satellite design. These effects are considered on a statistical basis to determine collision risk. Sirius XM's satellite manufacturer, Space Systems/Loral, includes meteoroid environments as part of the satellite Environmental Requirement Specifications. Sirius XM has reviewed literature for large size space objects, particularly technical papers that present collision probability estimates for orbital conditions of interest. The satellite requirement was derived from these technical papers as well as NASA models to include debris and meteoroids of various sizes. Sirius XM has taken steps to limit the effects of such collisions through shielding, the placement of components, and the use of redundant systems.

Accidental explosions, energy sources on board: Sirius XM has assessed and limited the probability of accidental explosions during and after completion of mission operations. In designing the FM-5 satellite, the satellite manufacturer has taken steps to ensure that debris generation will not result from the conversion of energy sources on board the satellite into energy that fragments the satellite. In particular, the satellite manufacturer advises that no structural failures of pressurized volumes have occurred on its satellites to date. Burst tests are performed on all pressure vessels during qualification testing to demonstrate a margin of safety against burst. Bipropellant mixing is prevented by the use of valves that prevent backwards flow in propellant lines and pressurization lines. The Li Ion batteries do not contain any pressure vessels and procedures will be undertaken by Sirius XM to assure that each battery is discharged at the end of the mission. Pyrotechnics are nominally used only in the mission as part of the initial deployment process. After orbit raising to the disposal orbit, all unfired pyrotechnics will be fired as part of the final satellite decommissioning. Upon reaching the final disposal orbit, all fuel tanks will be close to empty. All remaining propellants and pressurants will be vented utilizing the on-board thrusters.

Collisions with large debris or operational space stations: Sirius XM has assessed and limited the probability of the space station becoming a source of debris by collisions with large debris or other operational space stations. Specifically, Sirius XM has assessed the possibility of collision with satellites located at, or reasonably expected to be located at, the requested orbital location, or assigned in the vicinity of that location.

As detailed below, Sirius XM has examined whether its station-keeping volume might overlap with that of other operational or planned satellites at the 86.15° W.L. orbital location. At this time, there are no other satellite operators with which Sirius XM must coordinate orbital positioning. Additionally, the XM-3 and XM-5 satellites, operated by Sirius XM's affiliate, XM Radio Inc., are collocated at 85.15° W.L. and will be internally coordinated by Sirius XM.

In considering operational and planned satellites that may have a station-keeping volume overlapping the FM-5 satellite, Sirius XM reviewed the lists of FCC licensed systems and systems currently under consideration by the FCC. In addition, Sirius XM has also reviewed networks for which a request for coordination has been submitted to the ITU in the vicinity of 86.15° W.L. The analysis has taken into account all networks that either operate, or are planned to operate, and can have an overlapping station-keeping volume with the FM-5 satellite.

In the event future satellites are authorized to operate at 86.15° W.L. by the U.S. or another administration, Sirius XM will coordinate the physical operation of its satellite with that satellite operator.

Post-mission disposal plans (disposal altitude and calculations, fuel reserves): At the end of the operational life of the FM-5 satellite, Sirius XM will maneuver the satellite into a disposal orbit with a minimum perigee of 350 km above the normal GSO operational orbit. This proposed disposal orbit altitude is based on the following calculation, as required in § 25.283:

Solar array area = 89 m^2
Satellite body area (oriented for max antenna exposure) = 5 m^2
X-band antenna area = 1 m^2
S-band antenna area = 22 m^2
Total Solar Pressure Area "A" = 117 m^2

"M" = Dry Mass of Satellite = 2812 kg
"C_R" = Solar Pressure Radiation Coefficient (worst case) = 2

Therefore the Minimum Disposal Orbit Perigee Altitude:

= 36,021 km + 1000 x C_R x A/M
= 36,021 km + 1000 x 2 x 117/2812
= 36,104 km
= 318 km above GSO (35,786 km)

To provide adequate margin, the nominal disposal orbit will be increased above this calculated value of 318 km to a value of 350 km.

The propulsion subsystem design and the FM-5 satellite fuel budget account for the post-mission disposal of the satellite and a sufficient amount of propellant will be allocated and reserved for the final orbit raising maneuvers.

CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this pleading, that I am familiar with Part 25 of the Commission's rules that I have either prepared or reviewed the engineering information submitted in this pleading, and that it is complete and accurate to the best of my knowledge and belief.

/s/ Bridget Neville

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