CHAPTER 3

Frequency Division Multiplexing Telemetry Standards

List of Tables

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Acronyms

FM	frequency modulation
Hz	hertz
kHz	kilohertz
ms	millisecond
RF	radio frequency

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CHAPTER 3

Frequency Division Multiplexing Telemetry Standards

NOTE 	This chapter contains standards for analog frequency modulation (FM) data, specifically dealing with frequency division multiplexing and subcarrier channels. It is readily apparent that the use of analog data has been superseded by digital data to a large extent. Therefore, while the standards in this chapter are valid for any and all FM data still in use, further development pertaining to FM data is not supported or encouraged.

3.1 General

In frequency division multiplexing, each data channel makes use of a separate subcarrier that occupies a defined position and bandwidth in the modulation baseband of the radio frequency (RF) carrier. Two types of FM subcarrier formats may be used. The data bandwidth of one format type is proportional to the subcarrier center frequency, while the data bandwidth of the other type is constant, regardless of subcarrier frequency.

3.2 FM Subcarrier Characteristics

In these systems, one or more subcarrier signals, each at a different frequency, are employed to frequency-modulate or phase-modulate a transmitter in accordance with the RF conditions specified in Chapter 2. The following subparagraphs set forth the standards for utilization of FM frequency division multiplexing.

Each of the subcarriers conveys measurement data in FM form. The number of data channels may be increased by modulating one or more of the subcarriers with a time-division multiplex format such as pulse code modulation.

The selecting and grouping of subcarrier channels depend upon the data bandwidth requirements of the application at hand and upon the necessity to ensure adequate guard bands between channels. Combinations of both proportional-bandwidth channels and constant-bandwidth channels may be used.

3.3 FM Subcarrier Channel Characteristics

The following subparagraphs describe the characteristics of proportional-bandwidth and constant-bandwidth FM subcarrier channels.

3.3.1 Proportional-Bandwidth FM Subcarrier Channel Characteristics

Table 3-1, Table 3-2, and Table 3-3 list the standard proportional-bandwidth FM subcarrier channels. The channels identified with letters permit ±15 or ±30 percent subcarrier deviation rather than ±7.5 percent deviation but use the same frequencies as the 12 highest channels. The channels shall be used within the limits of maximum subcarrier deviation. See Appendix B for expected performance tradeoffs at selected combinations of deviation and modulating frequency.

Table 3-1. Proportional-Bandwidth FM Subcarrier Channels ±7.5% Channels

Channel	Center Frequencies (hertz [Hz])	Lower Deviation Limit (Hz)	Upper Deviation Limit (Hz)	Nominal Frequency Response (Hz)	Nominal Rise Time (millisecond [ms])	Maximum Frequency Response (Hz)	Minimum Rise Time (ms)
1	400	370	430	6	58	30	11.7
2	560	518	602	8	44	42	8.33
3	730	675	785	11	32	55	6.40
4	960	888	1032	14	25	72	4.86
5	1300	1202	1398	20	18	98	3.60
6	1700	1572	1828	25	14	128	2.74
7	2300	2127	2473	35	10	173	2.03
8	3000	2775	3225	45	7.8	225	1.56
9	3900	3607	4193	59	6.0	293	1.20
10	5400	4995	5805	81	4.3	405	0.864
11	7350	6799	7901	110	3.2	551	0.635
12	10,500	9712	11,288	160	2.2	788	0.444
13	14,500	13,412	15,588	220	1.6	1088	0.322
14	22,000	20,350	23, 650	330	1.1	1650	0.212
15	30,000	27,750	32,250	450	0.78	2250	0.156
16	40,000	37,000	43,000	600	0.58	3000	0.117
17	52,500	48,562	56,438	788	0.44	3938	0.089
18	70,000	64,750	75,250	1050	0.33	5250	0.06
19	93,000	86,025	99,975	1395	0.25	6975	0.050
20	124,000	114,700	133,300	1860	0.19	9300	0.038
21	165,000	152,625	177,375	2475	0.14	12,375	0.029
22	225,000	208,125	241,875	3375	0.10	16,875	0.021
23	300,000	277,500	322,500	4500	0.08	22,500	0.016
24	400,000	370,000	430,000	6000	0.06	30,000	0.012
25	560,000	518,000	602,000	8400	0.04	42,000	0.008

See notes at end of Table 3-3.

Table 3-2. Proportional-Bandwidth FM Subcarrier Channel ±15% Channels

Channel	Center Frequencies (Hz)	Lower Deviation Limit (Hz)	Upper Deviation Limit (Hz)	Nominal Frequency Response (Hz)	Nominal Rise Time (ms)	Maximum Frequency Response (Hz)	Minimum Rise Time (ms)
A	22,000	18,700	25,300	660	0.53	3300	0.106
B	30,000	25,500	34,500	900	0.39	4500	0.078
C	40,000	34,000	46,000	1200	0.29	6000	0.058

D	52,500	44,625	60,375	1575	0.22	7875	0.044
E	70,000	59,500	80,500	2100	0.17	10,500	0.033
F	93,000	79,050	106,950	2790	0.13	13,950	0.025
G	124,000	105,400	142,600	3720	0.09	18,600	0.018
H	165,000	140,250	189,750	4950	0.07	24,750	0.014
I	225,000	191,250	258,750	6750	0.05	33,750	0.010
J	300,000	255,000	345,000	9000	0.04	45,000	0.008
K	400,000	340,000	460,000	12,000	0.03	60,000	0.006
L	560,000	476,000	644,000	16,800	0.02	84,000	0.004

See notes at end of Table 3-3.

Table 3-3. Proportional-Bandwidth FM Subcarrier Channels ±30% Channels

Channel	Center Frequencies (Hz)	Lower Deviation Limit (Hz)	Upper Deviation Limit (Hz)	Nominal Frequency Response (Hz)	Nominal Rise Time (ms)	Maximum Frequency Response (Hz)	Minimum Rise Time (ms)
AA	22,000	15,400	28,600	1320	0.265	6600	0.053
BB	30,000	21,000	39,000	1800	0.194	9000	0.038
CC	40,000	28,000	52,000	2400	0.146	12,000	0.029
DD	52,500	36,750	68,250	3150	0.111	15,750	0.022
EE	70,000	49,000	91,000	4200	0.083	21,000	0.016
FF	93,000	65,100	120,900	5580	0.063	27,900	0.012
GG	124,000	86,800	161,200	7440	0.047	37,200	0.009
HH	165,000	115,500	214,500	9900	0.035	49,500	0.007
II	225,000	157,500	292,500	13,500	0.026	67,500	0.005
JJ	300,000	210,000	390,000	18,000	0.019	90,000	0.004
KK	400,000	280,000	520,000	24,000	0.015	120,000	0.003
LL	560,000	392,000	728,000	33,600	0.010	168,000	0.002

Notes:

1. Round off to nearest Hz.
2. The indicated maximum data frequency response and minimum rise time is based on the maximum theoretical response that can be obtained in a bandwidth between the upper and lower frequency limits specified for the channels. See Appendix B, Paragraph 3.0 for determining possible accuracy versus response tradeoffs.
3. Channels A through L may be used by omitting adjacent lettered and numbered channels. Channels 13 and A may be used together with some increase in adjacent channel interference.
4. Channels AA through LL may be used by omitting every four adjacent double lettered and lettered channels and every three adjacent numbered channels. Channels AA through LL may be used by omitting every three adjacent double lettered and lettered channels and every two adjacent numbered channels with some increase in adjacent channel interference.

3.3.2 Constant-Bandwidth FM Subcarrier Channel Characteristics

Table 3-4 lists the standard constant-bandwidth FM subcarrier channels. The letters A, B, C, D, E, F, G, and H identify the channels for use with maximum subcarrier deviations of ±2, ±4, ±8, ±16, ±32, ±64, ±128, and ±256 kilohertz (kHz), along with maximum frequency responses of 2, 4, 8, 16, 32, 64, 128, and 256 kHz. The channels shall be used within the limits of maximum subcarrier deviation. See Appendix B for expected performance tradeoffs at selected combinations of deviation and modulating frequencies.

3.4 Tape Speed Control and Flutter Compensation

Tape speed control and flutter compensation for FM/FM formats may be accomplished as indicated in Appendix D, Subsection 17.4. The standard reference frequency used shall be in accordance with the criteria in Table 3-5 when the reference signal is mixed with data.

Table 3-4. Constant-Bandwidth FM Subcarrier Channels

Frequency Criteria \ Channels:	A	B	C	D	E	F	G	H
Deviation Limits (kHz)	±2	±4	±8	±16	±32	±64	±128	±256
Nominal Frequency Response (kHz)	0.4	0.8	1.6	3.2	6.4	12.8	25.6	51.2
Maximum Frequency Response (kHz)	2	4	8	16	32	64	128	256
Notes:	Center Frequency (kHz)							
	8	16	32	64	128	256	512	1024
	16	32	64	128	256	512	1024	2048
	24	48	96	192	384	768	1536	3072
	32	64	128	256	512	1024	2048	
	40	80	160	320	640	1280	2560	
	48	96	192	384	768	1536	3072	
	56	112	224	448	896	1792	3584	
	64	128	256	512	1024	2048		
	72	144	288	576	1152	2304		
	80	160	320	640	1280	2560		
	88	176	352	704	1408	2816		
	96	192	384	768	1536	3072		
	104	208	416	832	1664	3328		
	112	224	448	896	1792	3584		
	120	240	480	960	1920	3840		
	128	256	512	1024	2048			
	136	272	544	1088	2176			
	144	288	576	1152	2304			
	152	304	608	1216	2432			
	160	320	640	1280	2560			
	168	336	672	1344	2688			
	176	352	704	1408	2816			

The constant-bandwidth channel designation shall be the channel center frequency in kilohertz and the channel letter indicating deviation limit; for example, 16A, indicating f_c = 16 kHz, deviation limit of ±2 kHz.

The indicated maximum frequency is based upon the maximum theoretical response that can be obtained in a bandwidth between deviation limits specified for the channel. See discussion in Appendix B for determining practical accuracy versus frequency response tradeoffs.

Prior to using a channel outside the shaded area, the user should verify the availability of range assets to support the demodulation of the channel selected. Very limited support is available above 2 megahertz.

Table 3-5. Reference Signal Usage

Reference Frequencies for Tape Speed and Flutter Compensation
Reference Frequency (kHz ±0.01%)
960[1]
480[1]
240[1]
200
100
50
25
12.5
6.25
3.125
Note: [1]These frequencies are for flutter compensation only and not for capstan servo speed control. In addition, the 240 kHz reference signal may be used as a detranslation frequency in a constant-bandwidth format.

If the reference signal is recorded on a separate tape track, any of the listed reference frequencies may be used provided the requirements for compensation rate of change are satisfied.

If the reference signal is mixed with the data signal, consideration must be given to possible problems with intermodulation sum and difference frequencies. Also, sufficient guard band must be allowed between the reference frequency and any adjacent data subcarrier.

****** END OF CHAPTER 3 ******