

CHAPTER 3

FREQUENCY DIVISION MULTIPLEXING TELEMETRY STANDARDS

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CHAPTER 3

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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 RF carrier. Two types of frequency modulation (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 (FM) or phase modulate (PM) 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.

3.2.1 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 (PCM).

3.2.2 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 [3-1A](#), Table [3-1B](#), and Table [3-1C](#) 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 3-1A. PROPORTIONAL-BANDWIDTH FM SUBCARRIER CHANNELS ±7.5% 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) |
| 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 | .864 |
| 11 | 7350 | 6799 | 7901 | 110 | 3.2 | 551 | .635 |
| 12 | 10 500 | 9712 | 11 288 | 160 | 2.2 | 788 | .444 |
| 13 | 14 500 | 13 412 | 15 588 | 220 | 1.6 | 1088 | .322 |
| 14 | 22 000 | 20 350 | 23 650 | 330 | 1.1 | 1650 | .212 |
| 15 | 30 000 | 27 750 | 32 250 | 450 | .78 | 2250 | .156 |
| 16 | 40 000 | 37 000 | 43 000 | 600 | .58 | 3000 | .117 |
| 17 | 52 500 | 48 562 | 56 438 | 788 | .44 | 3938 | .089 |
| 18 | 70 000 | 64 750 | 75 250 | 1050 | .33 | 5250 | .06 |
| 19 | 93 000 | 86 025 | 99 975 | 1395 | .25 | 6975 | .050 |
| 20 | 124 000 | 114 700 | 133 300 | 1860 | .19 | 9300 | .038 |
| 21 | 165 000 | 152 625 | 177 375 | 2475 | .14 | 12 375 | .029 |
| 22 | 225 000 | 208 125 | 241 875 | 3375 | .10 | 16 875 | .021 |
| 23 | 300 000 | 277 500 | 322 500 | 4500 | .08 | 22 500 | .016 |
| 24 | 400 000 | 370 000 | 430 000 | 6000 | .06 | 30 000 | .012 |
| 25 | 560 000 | 518 000 | 602 000 | 8400 | .04 | 42 000 | .008 |

See notes at end of Table 3-1C.

| TABLE 3-1B. PROPORTIONAL-BANDWIDTH FM SUBCARRIER CHANNELS ±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 | .53 | 3300 | .106 |
| B | 30 000 | 25 500 | 34 500 | 900 | .39 | 4500 | .078 |
| C | 40 000 | 34 000 | 46 000 | 1200 | .29 | 6000 | .058 |
| D | 52 500 | 44 625 | 60 375 | 1575 | .22 | 7875 | .044 |
| E | 70 000 | 59 500 | 80 500 | 2100 | .17 | 10 500 | .033 |
| F | 93 000 | 79 050 | 106 950 | 2790 | .13 | 13 950 | .025 |
| G | 124 000 | 105 400 | 142 600 | 3720 | .09 | 18 600 | .018 |
| H | 165 000 | 140 250 | 189 750 | 4950 | .07 | 24 750 | .014 |
| I | 225 000 | 191 250 | 258 750 | 6750 | .05 | 33 750 | .010 |
| J | 300 000 | 255 000 | 345 000 | 9000 | .04 | 45 000 | .008 |
| K | 400 000 | 340 000 | 460 000 | 12 000 | .03 | 60 000 | .006 |
| L | 560 000 | 476 000 | 644 000 | 16 800 | .02 | 84 000 | .004 |

See notes at end of Table 3-1C.

**TABLE 3-1C. 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 00 | 15 400 | 28 600 | 1320 | .265 | 6600 | .053 |
| BB | 30 000 | 21 000 | 39 000 | 1800 | .194 | 9000 | .038 |
| CC | 40 000 | 28 000 | 52 000 | 2400 | .146 | 12 000 | .029 |
| DD | 52 500 | 36 750 | 68 250 | 3150 | .111 | 15 750 | .022 |
| EE | 70 000 | 49 000 | 91 000 | 4200 | .083 | 21 000 | .016 |
| FF | 93 000 | 65 100 | 120 900 | 5580 | .063 | 27 900 | .012 |
| GG | 124 000 | 86 800 | 161 200 | 7440 | .047 | 37 200 | .009 |
| HH | 165 000 | 115 500 | 214 500 | 9900 | .035 | 49 500 | .007 |
| II | 225 000 | 157 500 | 292 500 | 13 500 | .026 | 67 500 | .005 |
| JJ | 300 000 | 210 000 | 390 000 | 18 000 | .019 | 90 000 | .004 |
| KK | 400 000 | 280 000 | 520 000 | 24 000 | .015 | 120 000 | .003 |
| LL | 560 000 | 392 000 | 728 000 | 33 600 | .010 | 168 000 | .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 [3-2](#) 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 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, subparagraph 17.4 (Tape Speed and Flutter Compensation). The standard reference frequency used shall be in accordance with the criteria in Table [3-3](#) when the reference signal is mixed with data.

TABLE 3-2. 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 |
| <p>Notes:</p> <p>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.</p> <p>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 trade offs.</p> <p>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 MHz.</p> | 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 | | | | |

TABLE 3-3. REFERENCE SIGNAL USAGE

| Reference Frequency (kHz $\pm 0.01\%$) |
|--|
| 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 CHAPTER 3 ******