

APPENDIX K

Pulse Amplitude Modulation Standards

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Acronyms

dB	decibel
FM	frequency modulation
IF	intermediate frequency
PAM	pulse amplitude modulation
NRZ	non-return-to-zero
RZ	return-to-zero

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APPENDIX K

Pulse Amplitude Modulation Standards

1.0 General

This standard defines the recommended pulse train structure and design characteristics for the implementation of pulse amplitude modulation (PAM) telemetry systems. The PAM data is transmitted as time division multiplexed analog pulses with the amplitude of the information channel pulse being the analog-variable parameter.

2.0 Frame and Pulse Structure

Each frame consists of a constant number of time-sequenced channel intervals. The maximum shall be 128-channel time intervals per frame, including the intervals devoted to synchronization and calibration. The pulse and frame structure shall conform to either [Figure K-1](#) or [Figure K-2](#).

2.1 Commutation Pattern

The information channels are allocated equal and constant time intervals within the PAM frame. Each interval ("T" in [Figure K-1](#) and [Figure K-2](#)) contains a sample pulse beginning at the start of the interval and having amplitude determined by the amplitude of the measurand of the corresponding information channel according to a fixed relationship (usually linear) between the minimum level (zero amplitude) and the maximum level (full-scale amplitude). For a 50-percent duty cycle (return-to-zero [RZ]-PAM), the zero level shall be 20 to 25 percent of the full amplitude level as shown in [Figure K-1](#). The pulse width shall be the same in all time intervals except for the intervals devoted to synchronization. The duration shall be either $0.5T \pm 0.05$, as shown in [Figure K-1](#), or $T \pm 0.05$, as shown in [Figure K-2](#).

2.2 In-Flight Calibration

It is recommended that in-flight calibration be used and channels 1 and 2, immediately following the frame synchronization interval, be used for zero and full-scale calibration. For RZ-PAM, channel 3 may be used for an optional half-scale calibration, and for non-return-to-zero (NRZ)-PAM, the channel interval preceding channel 1 may be used for half-scale calibration if set to 50 percent.

2.3 Frame Synchronization Interval

Each frame is identified by the presence within it of a synchronization interval.

2.3.1 Fifty Percent Duty Cycle (RZ-PAM)

The synchronization pattern interval shall have a duration equal to two information channel intervals (2T) and shall be full-scale amplitude for 1.5T followed by the reference level or zero baseline for 0.5T (see [Figure K-1](#)).

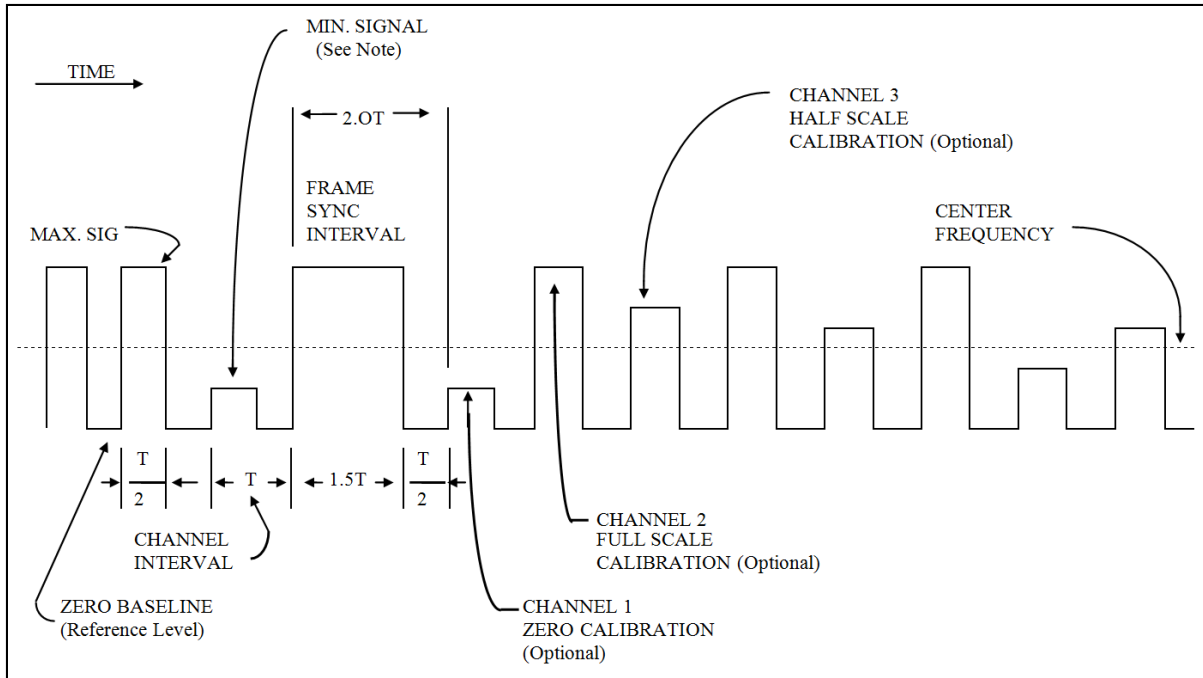



Figure K-1. 50 percent duty cycle PAM with amplitude synchronization

 <p>NOTE</p>	<p>A 20-25 percent deviation reserved for pulse synchronization is recommended.</p>
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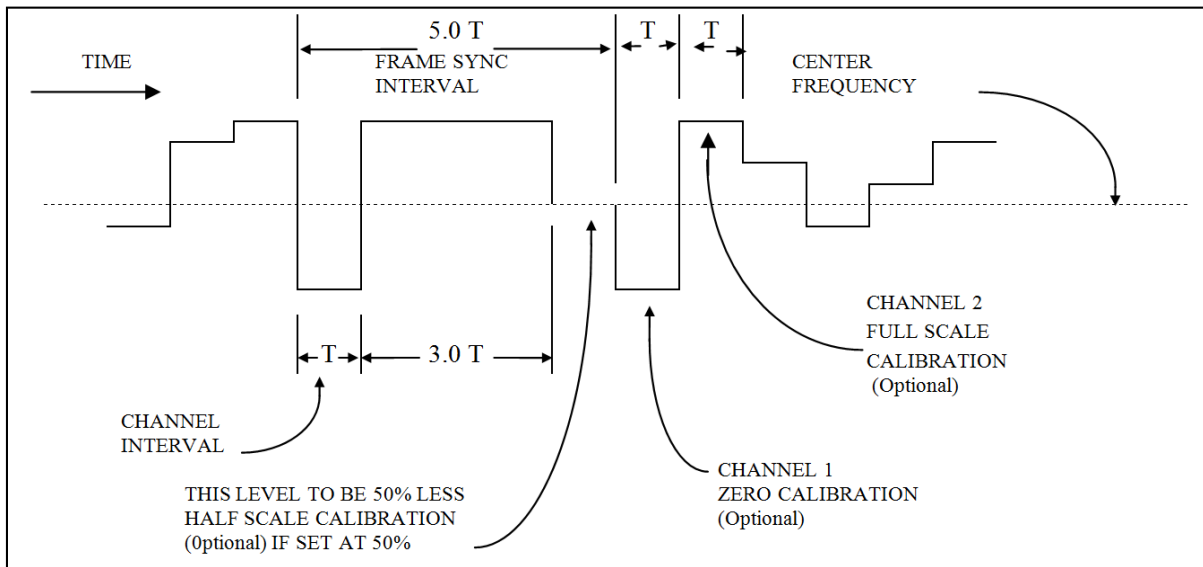


Figure K-2. 100 percent duty cycle PAM with amplitude synchronization

2.3.2 One Hundred Percent Duty Cycle (NRZ-PAM)

The synchronization pattern is in the order given: zero level for a period of T, full-scale amplitude for a period of 3T, and a level not exceeding 50-percent full-scale amplitude for a period T (see [Figure K-2](#)).

2.4 Maximum Pulse Rate

The maximum pulse rate should not be greater than that permitted by the following subparagraphs.

2.4.1 PAM/FM/FM

The reciprocal of the shortest interval between transitions in the PAM pulse train shall not be greater than one-fifth of the total (peak-to-peak) deviation specified in [Chapter 3](#) (Table 3-1, Table 3-2, and Table 3-3) for the FM subcarrier selected.

2.4.2 PAM/FM

The reciprocal of the shortest interval between transitions in the PAM pulse train shall be limited by whichever is the narrower of the following:

- a. One-half of the 3-dB frequency of the premodulation filter when employed.
- b. One-fifth of the intermediate frequency (IF) bandwidth (3 dB points) selected from the IF bandwidths listed in [Chapter 2](#), Table 2-7.

3.0 **Frame and Pulse Rate**

The frame and pulse parameters listed below may be used in any combination:

- a minimum rate of 0.125 frames per second, and
- a maximum pulse rate as specified in subparagraphs [2.4.1](#) and [2.4.2](#) above.

3.1 Long-Term Accuracy and Stability

During a measured period of desired data, the time between the occurrences of corresponding points in any two successive frame synchronization intervals should not differ from the reciprocal of the specified nominal frame rate by more than 5 percent of the nominal period.

3.2 Short-Term Stability

During a measured period (P), containing 1000-channel intervals, the time between the start of any two successive channel intervals (synchronization intervals excepted) should not differ from the average channel interval established by the formula

$$T_{avg} = \frac{P}{1000}$$

by more than 1 percent of the average interval.

3.3 Multiple and Submultiple Sampling Rates

Data multiplexing at sampling rates which are multiples and submultiples of the frame rate is permissible.

3.3.1 Submultiple Frame Synchronization

The beginning of the longest submultiple frame interval is identified by the transmission of a synchronization pattern. All other submultiple frames have a fixed and known relationship to the identified submultiple frames.

3.3.1.1 *Fifty Percent Duty Cycle (RZ)*

The synchronization pattern has a full-scale amplitude pulse in two successive occurrences of channel intervals allocated to data channels of the identified submultiple frame. The first such pulse has a duration equal to the channel interval; the second pulse immediately follows the first pulse and has a duration nominally one-half the channel interval. There is no return to zero between the two pulses.

3.3.1.2 *One Hundred Percent Duty Cycle (NRZ)*

The synchronization pattern has information in five successive occurrences of a channel interval allocated to data channels of the identified submultiple frame. The amplitude of the data channels assigned for synchronization is shown in the following items.

- a. First occurrence - zero amplitude.
- b. Second, third, and fourth occurrences - full-scale amplitude.
- c. Fifth occurrence - not more than 50 percent of full-scale amplitude.

3.3.2 Maximum Submultiple Frame Length

The interval of any submultiple frame, including the time devoted to synchronizing information, shall not exceed 128 times the interval of the frame in which it occupies a recurring position.

4.0 Frequency Modulation

The frequency deviation of an FM carrier or subcarrier, which represents the maximum and minimum amplitude of a PAM waveform, should be equal and opposite with respect to the assigned carrier or subcarrier frequency. The deviation should be the same for all occurrences of the same level.

5.0 Premodulation Filtering

A maximally linear phase response, premodulation filter, is recommended to restrict the radiated spectrum (see [Appendix A](#))

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