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Overhead and Symbol Rate Calculations for the SLM-5650A

A description of the possible sources of overhead in the SLM-5650A Satellite Modem including numerical calculations of percent overhead and symbol rate given programmed bit rate.

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1. Abstract

The SLM-5650A Satellite Modem has several optional features and functions that can add overhead. This white paper discusses the processing flow where overhead can be added, the amount of overhead added by each feature when enabled, and provides a calculation of modem symbol rate and modem chip rate (when optional spreading is enabled) given the programmed modem bit rate.

2. SLM-5650A Processing Flow & Symbol Rate Calculation

The SLM-5650A supports both serial and Ethernet interface options, and has options for framing, modulation and spreading. The processing flow for these functions is illustrated below in Figure 1.

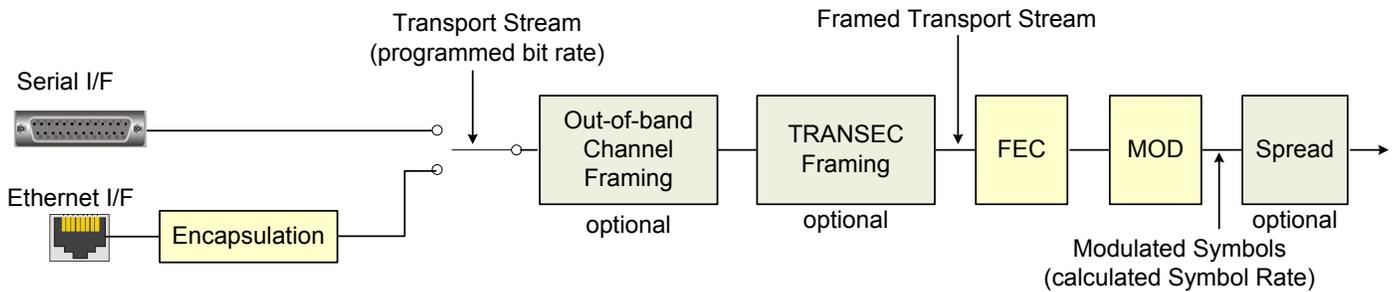


Figure 1: SLM-5650A Processing Flow

The symbol rate S_R is given in terms of the programmed bit rate B_R by the equation

$$S_R = \frac{B_R}{M_O C_R F_T F_C} \tag{1}$$

where

- M_O = Modulation Order
- = 1 if BPSK
- = 2 if QPSK
- = 3 if 8PSK
- = 4 if 16QAM

- C_R = Code rate of the forward error correction (FEC) (e.g. $C_R = 0.75$ if stated FEC code rate is “3/4”)¹

$$F_T = \text{TRANSEC Framing Factor} \tag{2}$$

$$= \frac{16N}{16N + 3} \quad \text{if TRANSEC enabled, } N = \text{the programmed TRANSEC frame length in AES blocks per frame}$$

$$= 1 \quad \text{if TRANSEC is disabled}$$

$$F_C = \text{Out-of-band Communication Channel Framing Factor} \tag{3}$$

$$= \frac{15}{16}, \quad \text{if AUPC/ASync framing enabled}$$

$$= \frac{32605}{32768}, \quad \text{if ACPC framing enabled}$$

$$= 1, \quad \text{if no framing enabled}$$

If the direct sequence spread spectrum (DSSS) feature is enabled, then the chip rate S_C of the spread symbols is equal to

$$S_C = K S_R$$

where K is the programmed spreading factor (e.g. $K = 2, 4, 8, 16, 32, 64$ or 128)

¹ Please note that LDPC code rates stated in the SLM-5650A data sheet available on our web site are approximate. See Tables in Sections B.2.13, B.2.14, and B.2.15 in the SLM-5650A User Manual available on our web site for exact values of the B_R to S_R multiplier with no framing overhead ($= 1/(M_O * C_R)$) for LDPC FEC.

3. Sources of Overhead

3.1. Framing Overhead

Two types of framing can be applied in the SLM-5650A, framing for out-of-band (OOB) communication channels, and TRANSEC framing. Either or both can be optionally enabled in the modem.

Out-of-Band Communications Channel Framing:

Two different types of OOB communications channels are supported in the SLM-5650A². The first, the ASYNC overhead channel supports a RS-232 or RS-422 overhead channel that is asynchronous to the main traffic channel. This communications channel also supports modem-to-modem communications required when traditional automatic uplink power control (AUPC) is enabled. If the ASYNC/AUPC framing is enabled, 16 framed output bits are created for every 15 input bits of the transport stream. This leads directly to the ASYNC/AUPC case in Equation [3].

The second type of out-of-band communications channel supports automatic CnC power control (ACPC). The ACPC function requires modem-to-modem communications to implement the ACPC algorithm. When this type of framing is enabled, 32769 framed output bits are generated for every 32605 input bits of the transport stream. This leads directly to the ACPC case in Equation [3]. ASYNC/AUPC and ACPC communications framing are mutually exclusive (i.e. both cannot be applied).

TRANSEC Framing:

When TRANSEC is enabled, it adds 3 bytes of overhead for every “N” AES blocks. The parameter N is programmable from 1 to 16, and each AES block is 16 bytes in length. This leads directly to Equation [2] above. Larger values of N lead to lower overhead, at the expense of longer TRANSEC framing acquisition times.

Total Framing Overhead:

Sometimes the framing overhead is of interest, expressed as a percentage of framing overhead bits within the framed transport stream. This value can be expressed as:

$$\text{Framing Overhead [\%]} = [1 - F_T F_C] * 100 \quad [4]$$

As seen in Equation [1], since the factors F_T and F_C are less than unity, the framing overhead (when framing is present) increases the symbol rate. Framing overhead has no effect on the programmed modem bit rate, which is equivalent to the input bit rate of a serial data stream input to the modem.

3.2. Encapsulation Overhead

When an Ethernet interface is used, an additional source of overhead is necessary to encapsulate the packets into the transport stream. When the SLM-5650A operates in bridged mode, Ethernet packets received from the external interface are encapsulated. When the SLM-5650A operates in routed mode, the Ethernet header and CRC are removed from the input Ethernet packets, and IP packets are encapsulated.

In either bridged or routed mode, a form of the High-Level Data Link Control (HDLC) is used to encapsulate the Ethernet or IP packets. A start flag (0x7E) is prepended to each packet and a 2-byte CRC is attached at the end. In addition, in order to enable to receiver to recognize the start flag within the data stream a “0” is inserted wherever 5 “1”s occur in a row in the input data stream. Assuming random bits, the probability of bit stuffing using this technique is $1/62^3$. Considering both sources of HDLC overhead means that for a packet length L, ratio of input bits to encapsulated output bits is:

$$\begin{aligned} F_H &= \frac{L}{L + 3 + L/62} \\ &= \frac{L}{(63/62)L + 3} \end{aligned} \quad [5]$$

Unlike framing overhead, HDLC overhead reduces the effective throughput of packet bits relative to the programmed modem data rate. The packet throughput, in packet bits/second is

$$\text{Packet Throughput} = (\text{Programmed Modem Data Rate}) * F_H \quad [6]$$

Expressed as a percent overhead of the modem data rate, HDLC overhead is

$$\begin{aligned} \text{HDLC OH [\%]} &= (1 - F_H) * 100 \\ &= \frac{(1/62)L + 3}{(63/62)L + 3} * 100 \end{aligned} \quad [7]$$

HDLC overhead ranges from approximately 6% for L=64 to approximately 1.8% for L=1518.

² IBS and IDR framing are also technically supported in the SLM-5650A, in that these framing modes can be enabled. However, the overhead channel information associated with these framing modes is not available external to the modem in either transmit or receive directions. Hence these framing modes have limited utility in the SLM-5650A, and are not considered in this analysis.

³ See RFC4814 for a derivation of this probability

4. Conclusions

The SLM-5650A supports a variety of interfaces and framing options. The overhead associated with each option, as well as the relationship between programmed modem bit rate and the resulting modem symbol rate, has been provided for understanding and reference.

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