DIGITAL COMMUNICATIONS

Fundamentals and Applications

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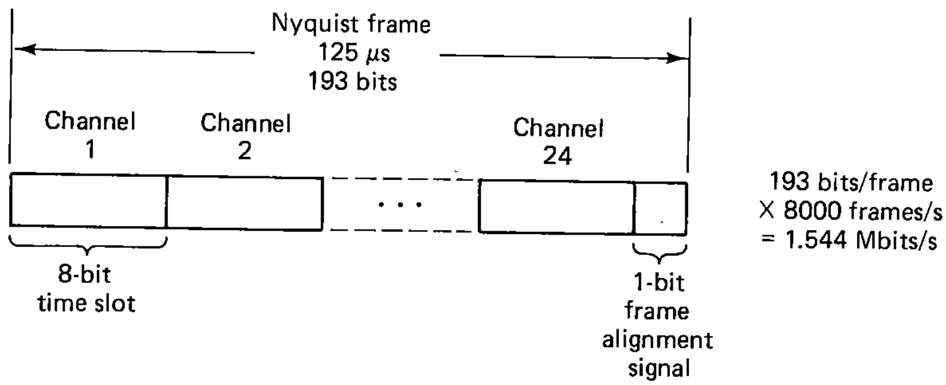
Within this 2-ms frame are contained

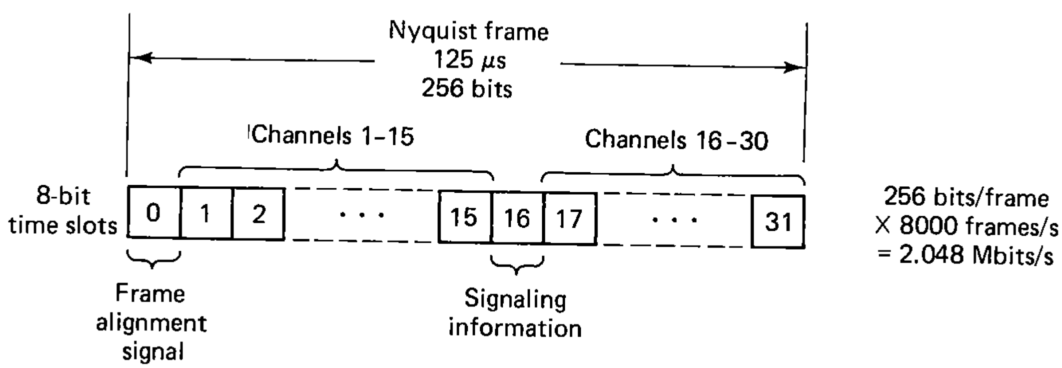
$$16 \text{ Nyquist frames} \times 256 \text{ bits/Nyquist frame} = 4096 \text{ bits}$$

The basic idea behind TDMA is that a user's low-rate data stream can share the CR with similar streams from other users by *bursting* the transmission at a much faster rate than the rate at which it is generated. Figure 9.35b illustrates a 2-ms high-rate TDMA frame. The frame begins with a reference burst, RB1, emitted by a reference station. The burst contains information necessary to enable other stations to precisely position their message traffic bursts in the frame. There may be a second burst, RB2, for reliability, followed by a sequence of traffic slots. The traffic slots may be preassigned, or they may be assigned according to a DAMA protocol [20].

The PCM multiplex signal with a bit rate of $R_0 = 2.048$ Mbits/s and a frame duration of $T = 2$ ms is compressed (by a factor of 59) and transmitted using QPSK modulation at a burst rate of $R_T = 120.832$ Mbits/s (symbol rate of 60.416 megasymbols/s). The duration of the traffic data field T_{tr} in the high rate TDMA



(a)



(b)

Figure 9.34 PCM multiplex frame structure. (a) Frame structure for T-Carrier (North American) PCM multiplex. (b) Frame structure for the European PCM multiplex.

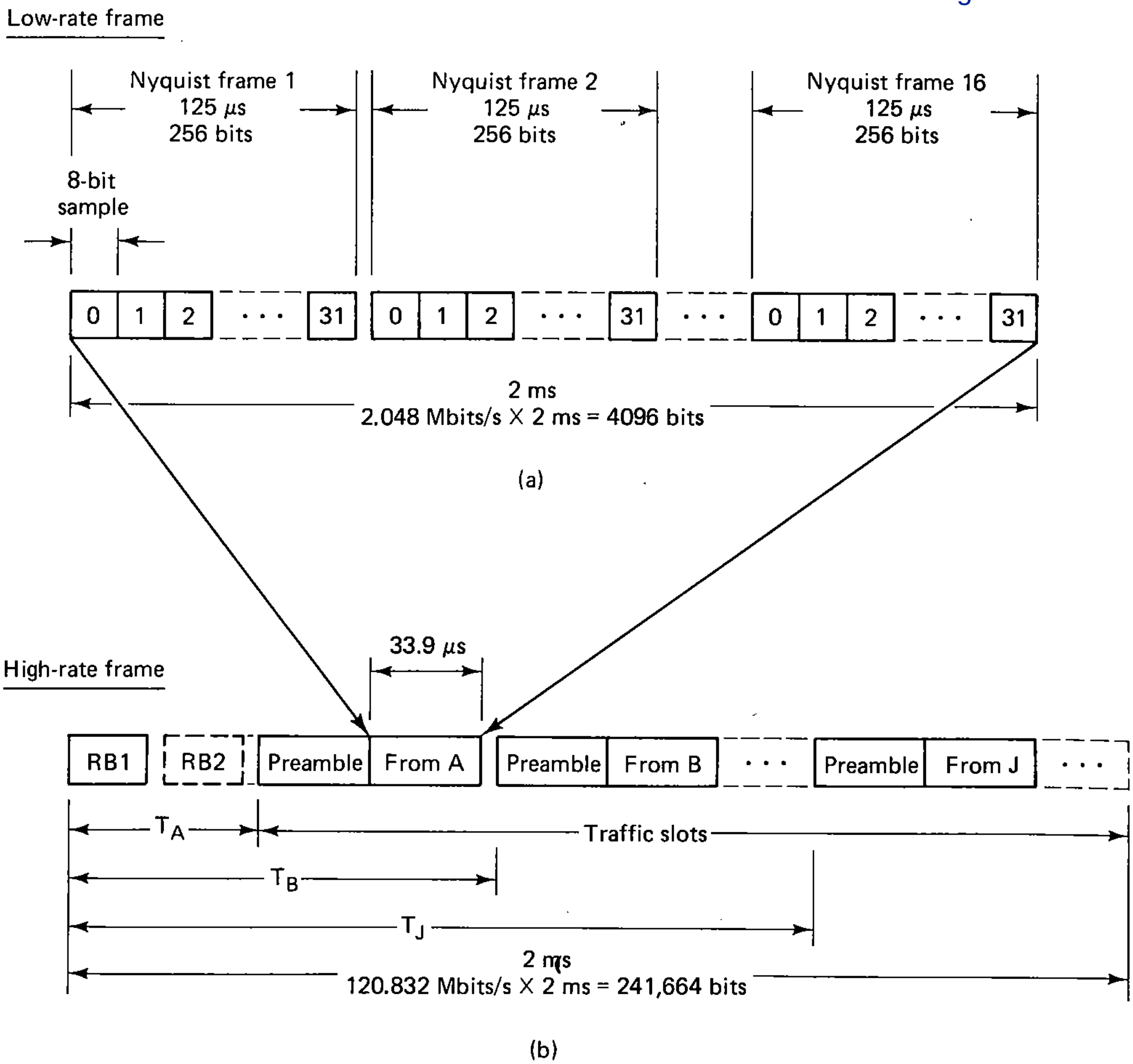


Figure 9.35 INTELSAT digital transmission standards for Europe. (a) Terrestrial PCM multiplex. (b) High-rate frame.

frame is calculated as follows:

$$T_{tr} = \frac{R_0 T}{R_T} \tag{9.31}$$

$$= \frac{2.048 \times 10^6 \times 2 \times 10^{-3}}{120.832 \times 10^6}$$

$$= 33.9 \ \mu s$$

To obtain the total duration of a traffic burst, the time used for the preamble must be added. If the preamble contains S_P symbols, then assuming QPSK modulation, the total length of the traffic burst measured in number of symbols, S_T, is

$$S_T = \frac{R_0 T}{2} + S_P \tag{9.32}$$

and the burst-time duration is

$$T_T = \frac{2S_T}{R_T} \tag{9.33}$$

If the preamble contains 300 symbols, then

$$S_T = \frac{2.048 \times 10^6 \times 2 \times 10^{-3}}{2} + 300$$

$$= 2348 \text{ symbols}$$

Using this in Equation (9.33), we obtain

$$T_T = \frac{2 \times 2348}{120.832 \times 10^6} = 38.9\ \mu\text{s}$$

9.4.4.3 The High-Rate TDMA Frame for North America

The INTELSAT TDMA burst (bit) rate of $R_T = 120.832$ Mbits/s was chosen to be compatible with both the European and North American standards. Figure 9.36 is similar to Figure 9.35 except that the PCM multiplex signal is the 24-channel T-Carrier instead of the 30-channel European standard. The essential T-Carrier features that are different from the European standard are listed below and are shown on the figure.

1. Each Nyquist frame is comprised of 24 channels or samples × 8 bits + 1 frame alignment bit = 193 bits.
2. The 16 Nyquist frames contain 16 × 193 = 3088 bits.
3. The T-Carrier data rate is 1.544 Mbits/s.
4. The duration of the traffic data field in the high-rate TDMA frame is calculated from Equation (9.31).

$$T_{tr} = \frac{1.544 \times 10^6 \times 2 \times 10^{-3}}{120.832 \times 10^6}$$

$$= 25.6\ \mu\text{s}$$

9.4.4.4 INTELSAT TDMA Operation

At the transmitting earth station, the continuous low-rate data stream enters one of a pair of buffers illustrated in Figure 9.37a. When one buffer is filling at the low rate (1.544 Mbits/s or 2.048 Mbits/s), the other is emptying at the burst rate (120.832 Mbits/s). The buffers alternate functions at each TDMA frame. The time of application of the high-rate clock is controlled so that the traffic burst is transmitted in the proper interval to arrive at the satellite in its assigned position in the TDMA frame.

At the receiving station, the received traffic burst is routed to one of a pair of expansion buffers, shown in Figure 9.37b, that have the inverse function of

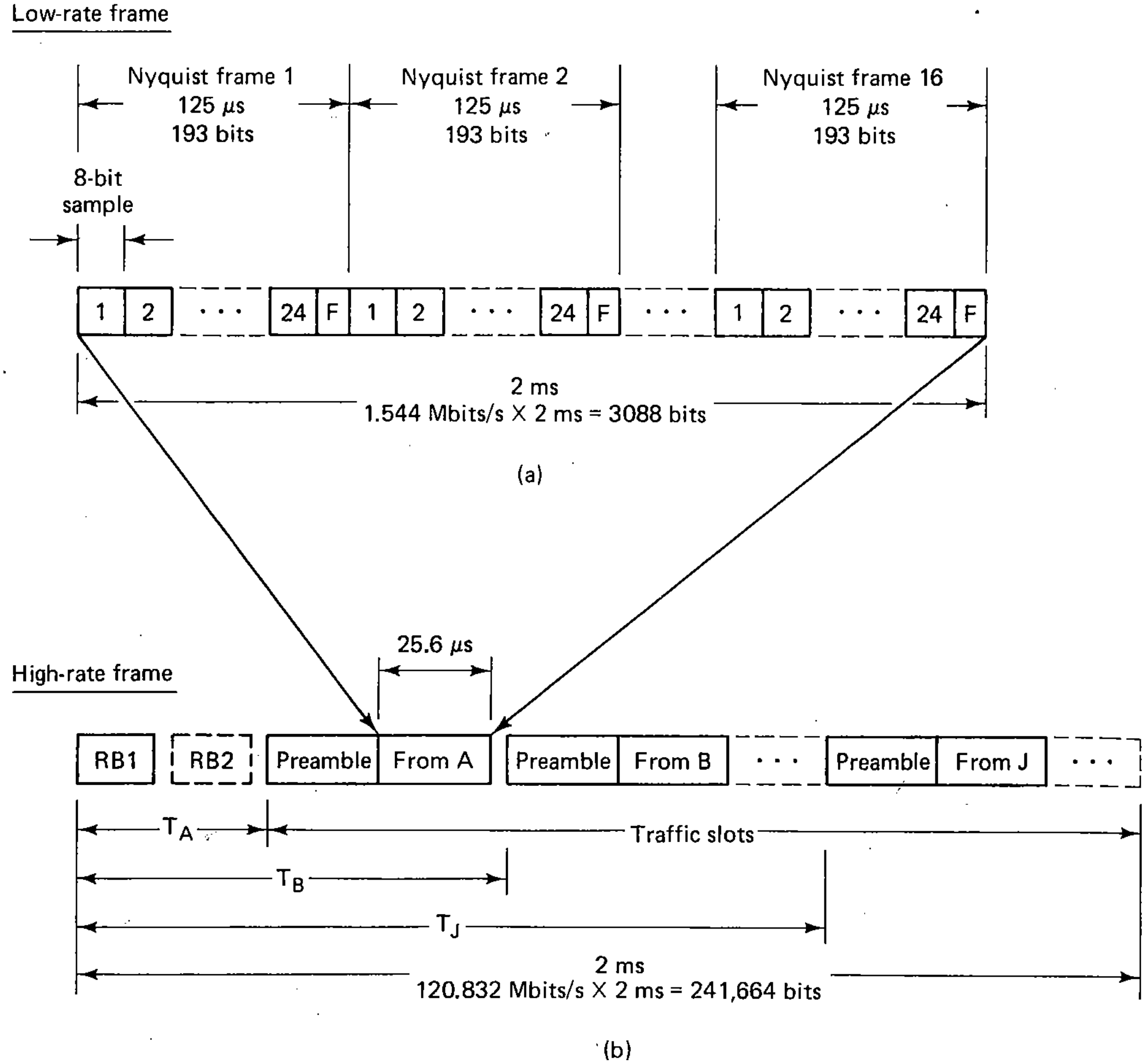


Figure 9.36 INTELSAT digital transmissions standards for T-Carrier. (a) Terrestrial PCM multiplex. (b) High-rate frame.

the compression buffers in Figure 9.37a. When one buffer is filling at the high rate, the other is emptying at the desired output rate.

The most critical aspect of TDMA operation is the precise synchronization needed to assure orthogonality of the time slots [20]. Figure 9.38 illustrates the general idea behind most commercial satellite synchronization schemes. One station is designated as the master or control station. This station transmits periodic bursts of reference timing pulses. User stations also transmit their timing pulses, designated as slave pulses in Figure 9.38. On the downlink, the using station receives the master or reference pulses in addition to its own slave pulses. The time difference between the master and slave pulses corresponds to the timing error. The station adjusts its clock so as to reduce this timing error.

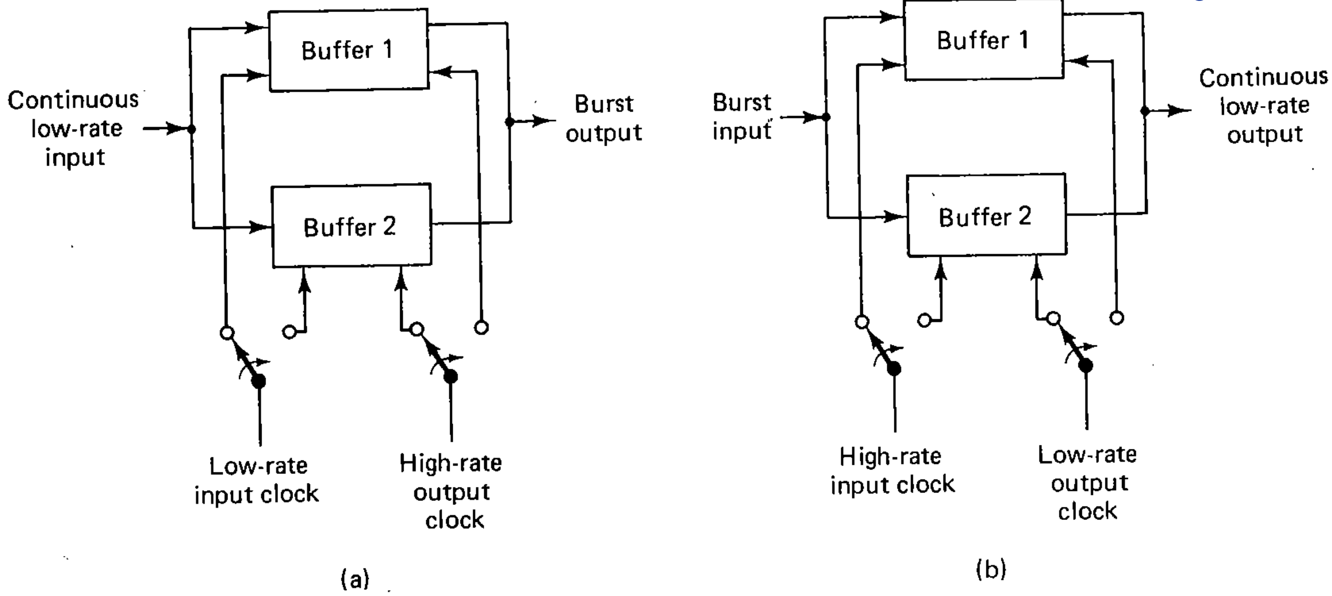


Figure 9.37 Burst compression and expansion buffers. (a) Compression buffers at transmitter. (b) Expansion buffers at receiver.

9.4.5 Satellite-Switched TDMA in INTELSAT

Modern communication satellites often employ several regional antenna beams. For a satellite based over the Atlantic Ocean, separate beams might be aimed at North America, Europe, South America, and Africa. Switches are used to allow the interconnection of stations in one region to communicate with stations in another region. The basic goal of a satellite-switched TDMA (SS/TDMA) scheme is to provide an efficient way of cyclically providing interconnection of TDMA data among various coverage regions.

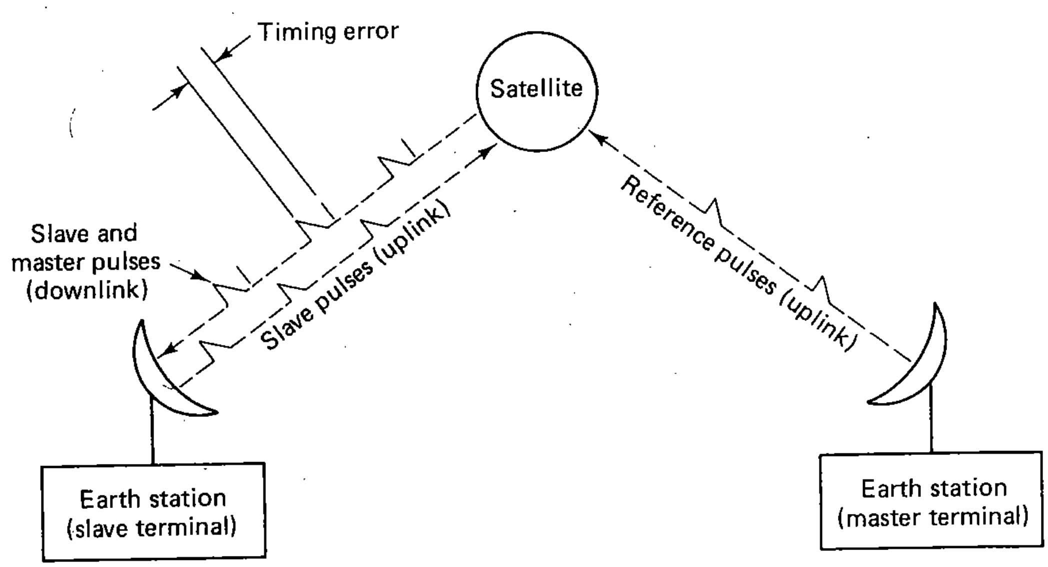


Figure 9.38 TDMA synchronization concept.