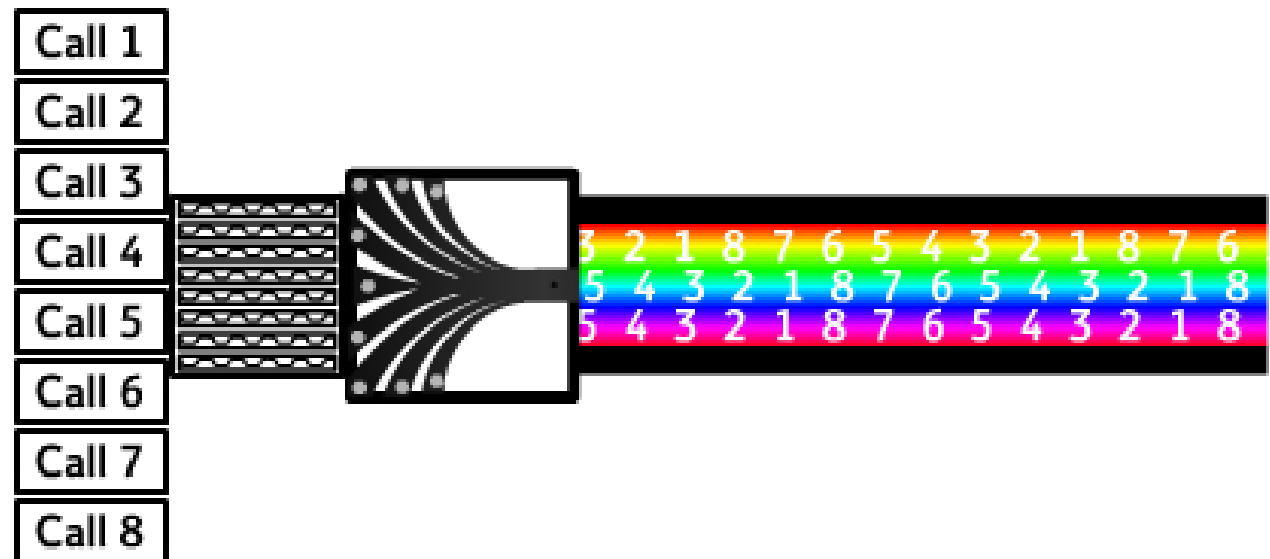


Chapter 7

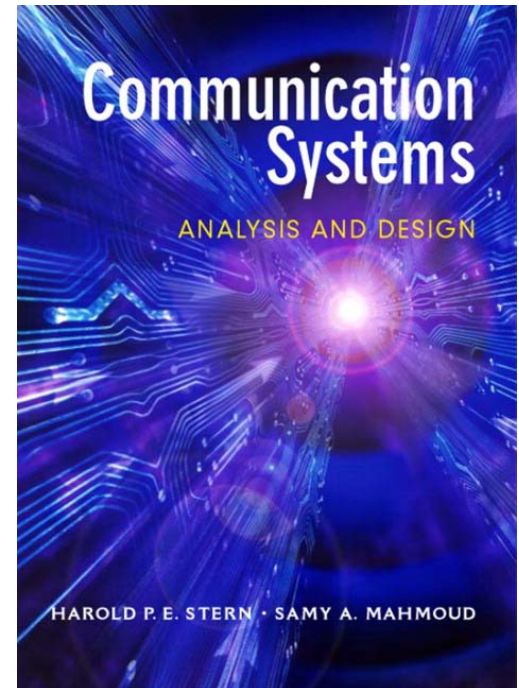
Multiplexing Techniques



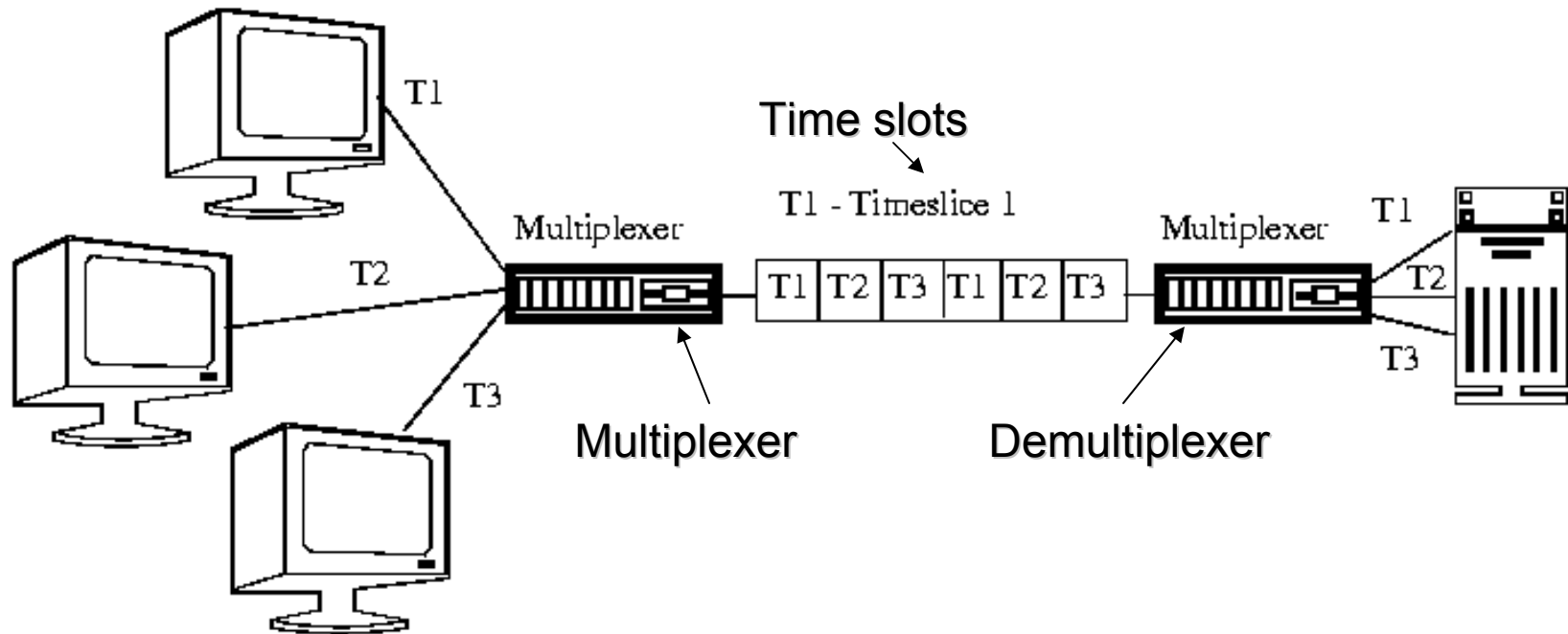
Chapter 7

Multiplexing Techniques

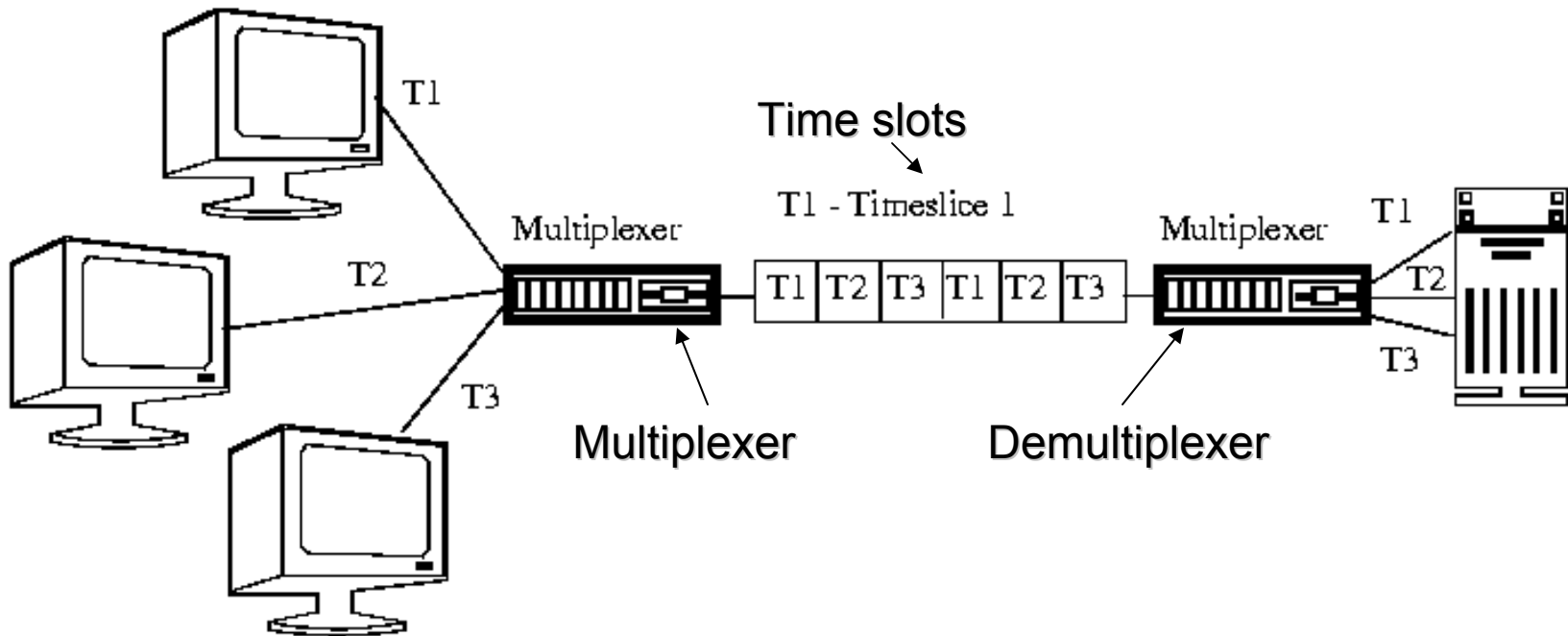
- *Time Division Multiplexing*
- Pages 364-368



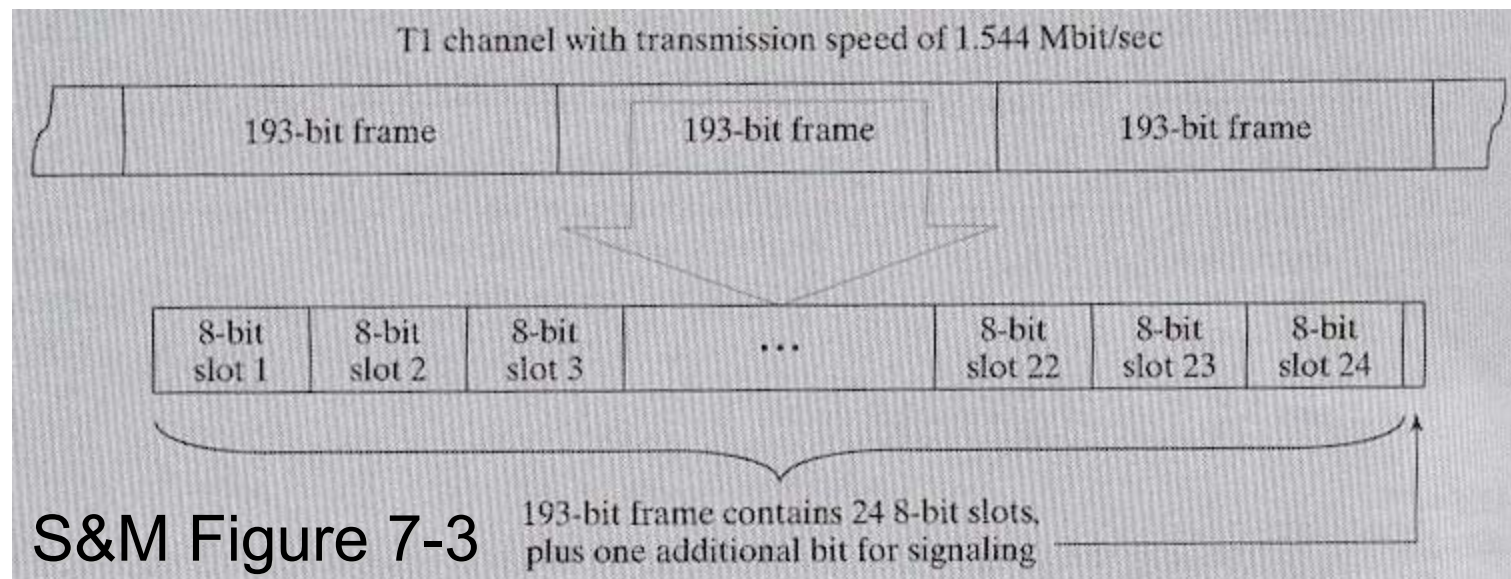
- *Time division multiplexing (TDM)* combines several low, fixed and predefined bit rate sources into a single high speed bit stream for transmission over a single digital communication channel:



- The TDM time slots have to be chosen properly. If the time slots are too small (for example, 1 bit) then the multiplexer and demultiplexer must switch rapidly. If the time slots are too large (for example, 64 Kb) then the data must be *buffered* and *delay* would be produced. TDM is used for baseband (*not* bandpass) data transmission.

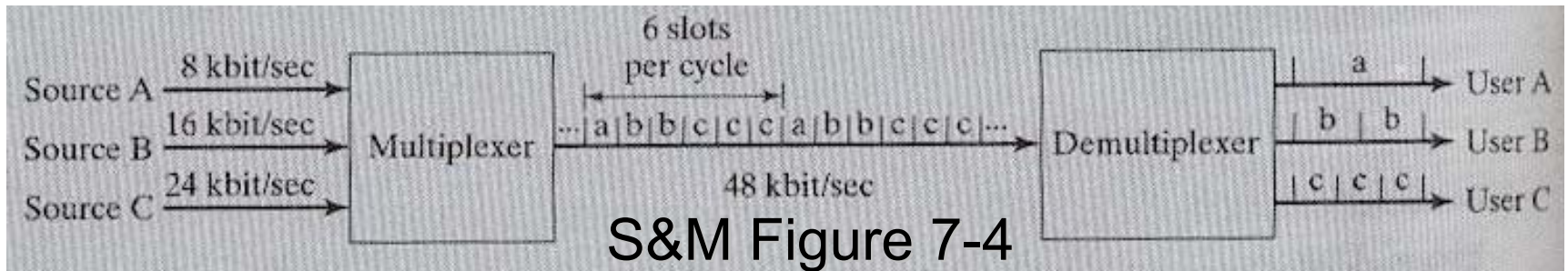


- The T1 TDM system for telephone networks uses a 193 bit *frame* where each frame has 24 8-bit *slots* and 1-bit in each frame for signaling. The T1 bit rate $r_b = 1.544$ Mb/sec.



The duration of each frame $T_f = 193 \text{ b} / 1.544 \text{ Mb/sec} = 125 \mu\text{sec}$ or 8 k samples/sec. Here all the data sources have the same data rate.

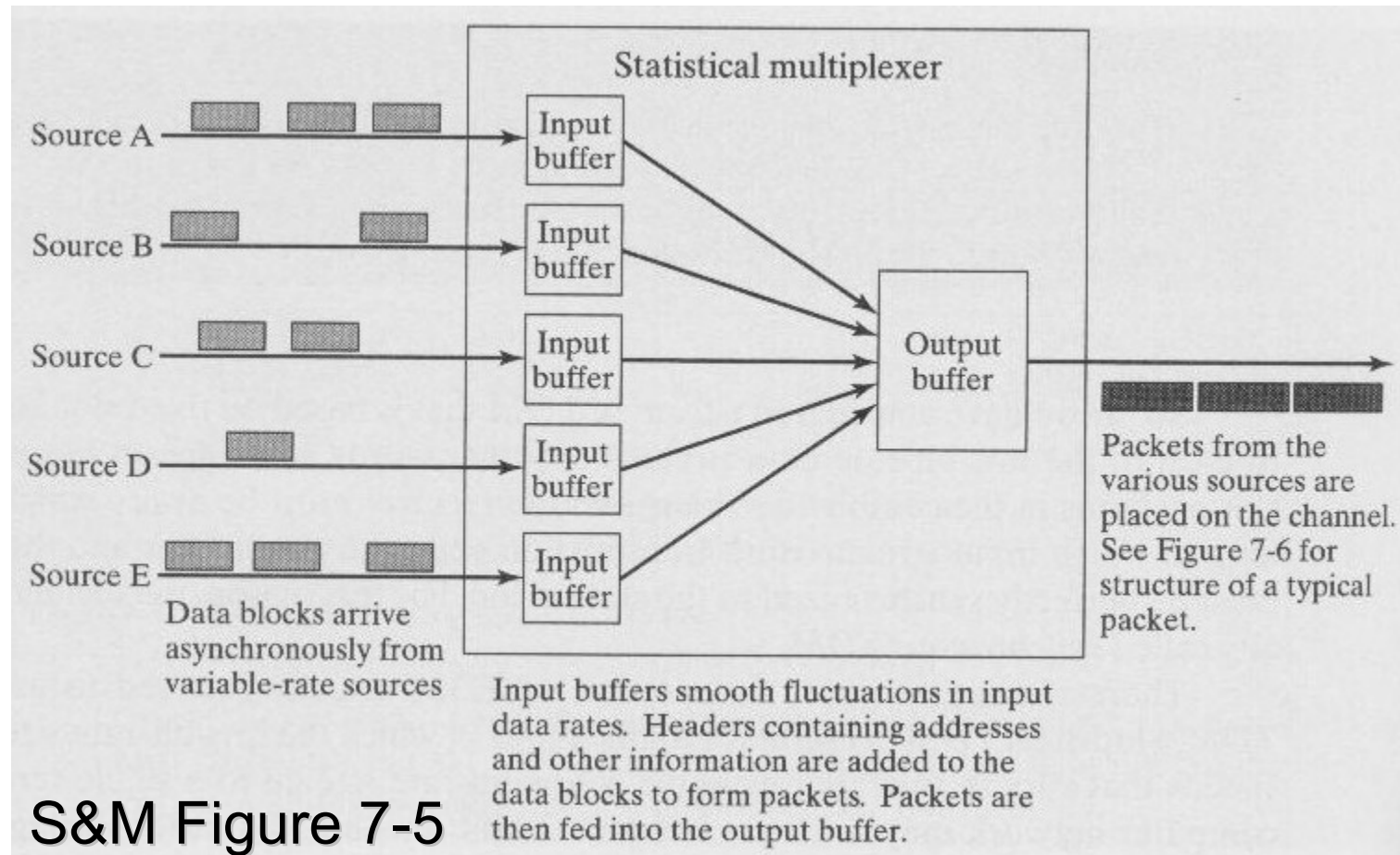
- If the data sources have different rates a *multiplexer scheme* must reconcile the disparate rates.



The data rates are in the lowest possible ratio of 8:16:24 or 1:2:3 for a total of $1 + 2 + 3 = 6$ slots. The slots are apportioned to the channels as: $a\ b\ b\ c\ c\ c$ and the channel data rate is 48 kb/sec.

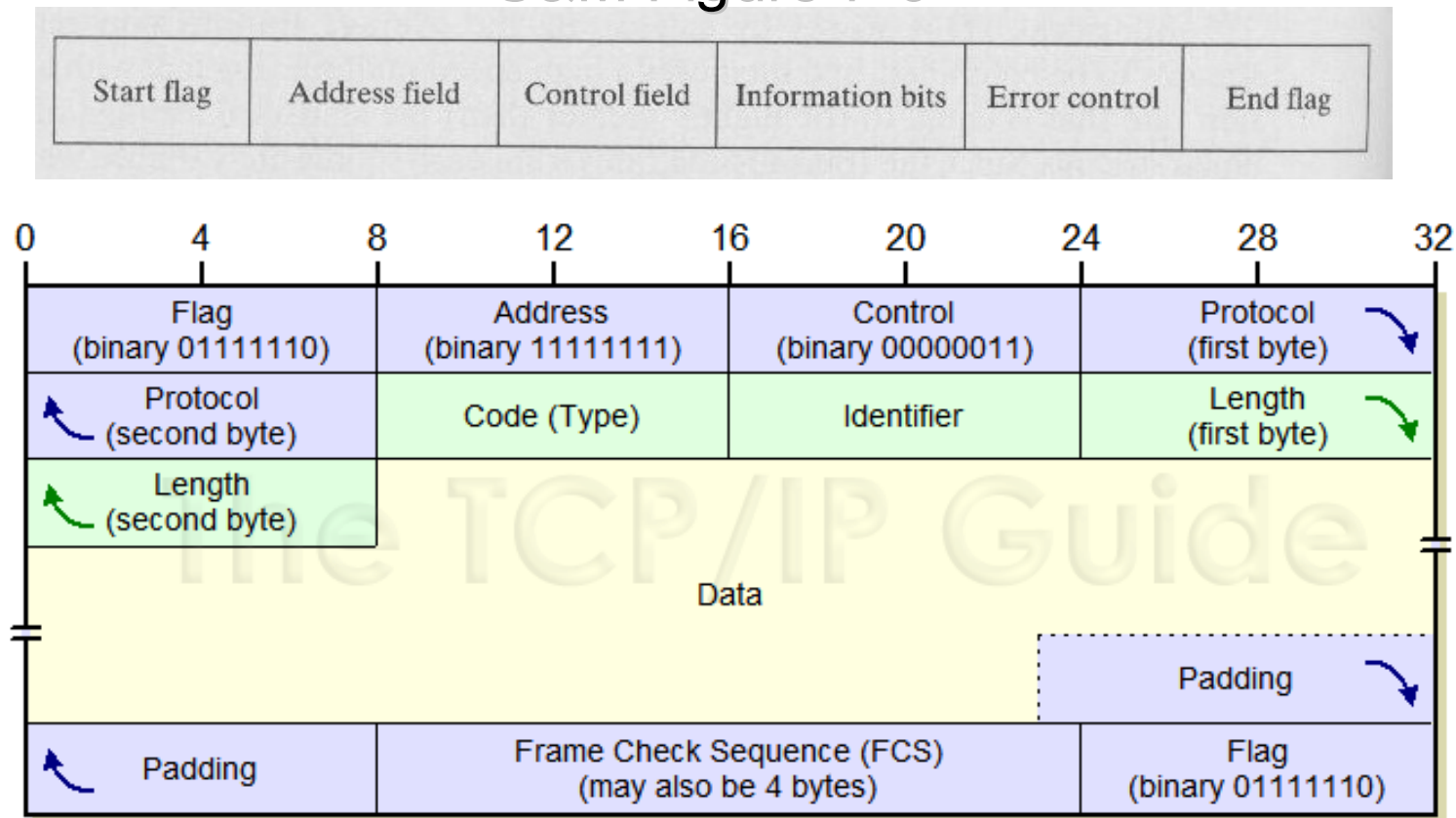
Another example is data rates of 10, 15, 20, and 30 Kb/sec which reduces to 2:3:4:6 (the LCD is 5) for $2 + 3 + 4 + 6 = 15$ slots and the channel data rate is 45 kb/sec.

- If data arrives *asynchronously* from variable rate sources, a *statistical multiplexer* with input buffers is used. The design is performed by observation and tested in simulation.



- The statistical TDM packet consists of a *start flag*, *address field*, *control field*, *information bits*, *error control*, and an *end flag*.

S&M Figure 7-6

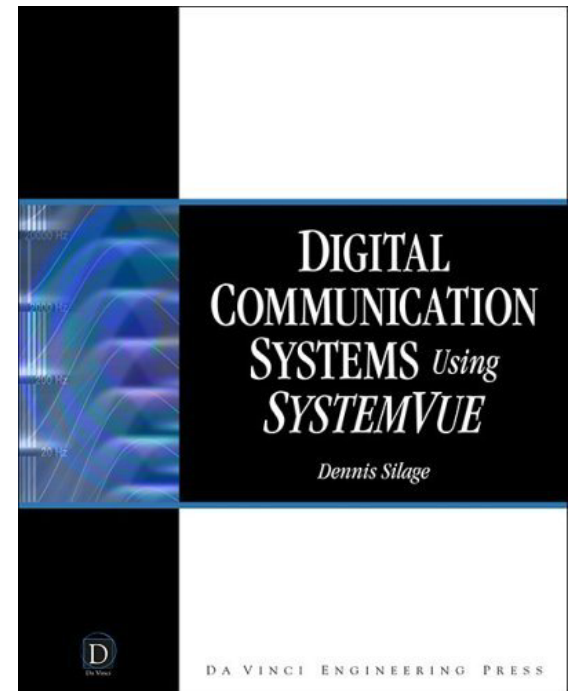


TCP/IP data packet

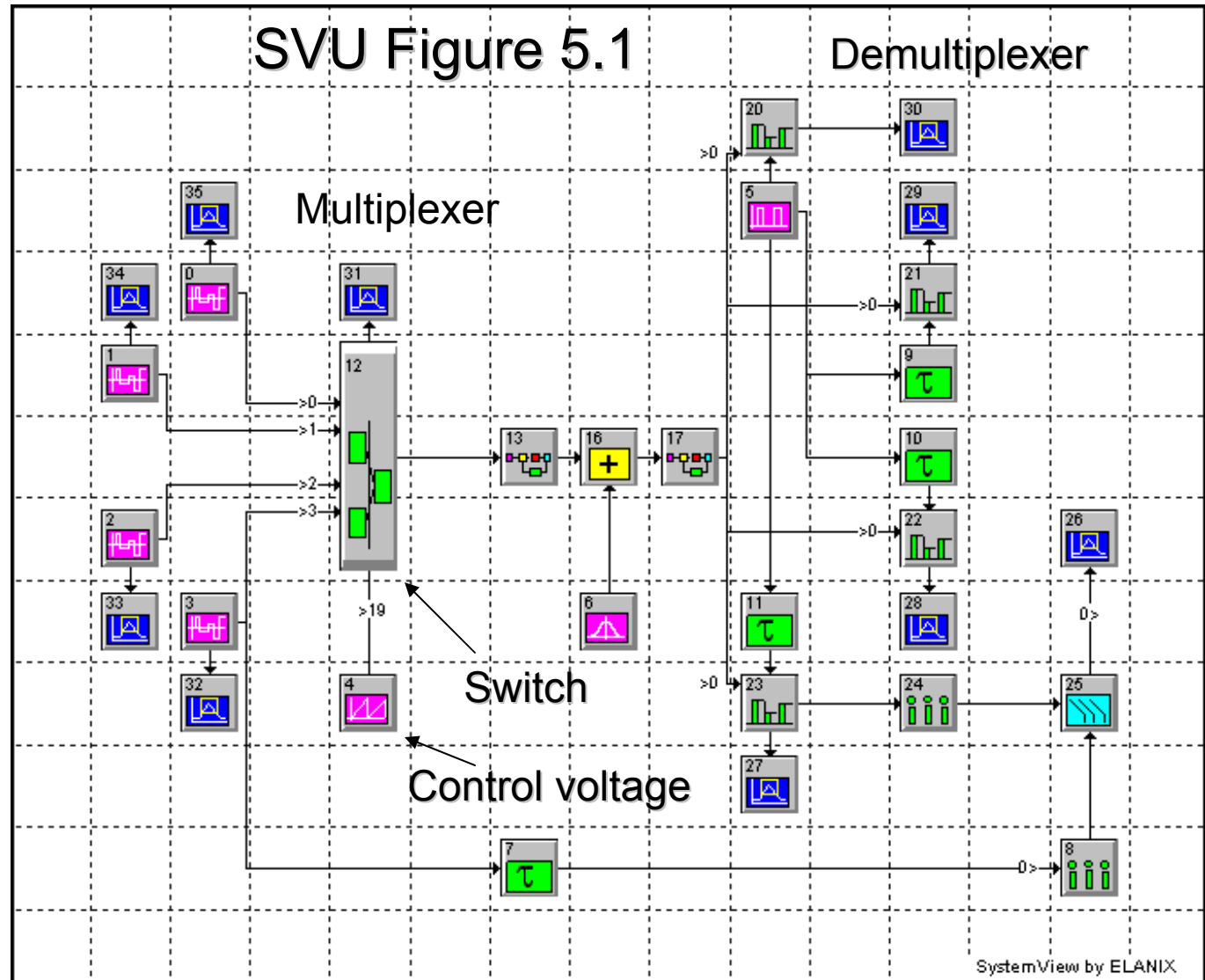
Chapter 7

Multiplexing Techniques

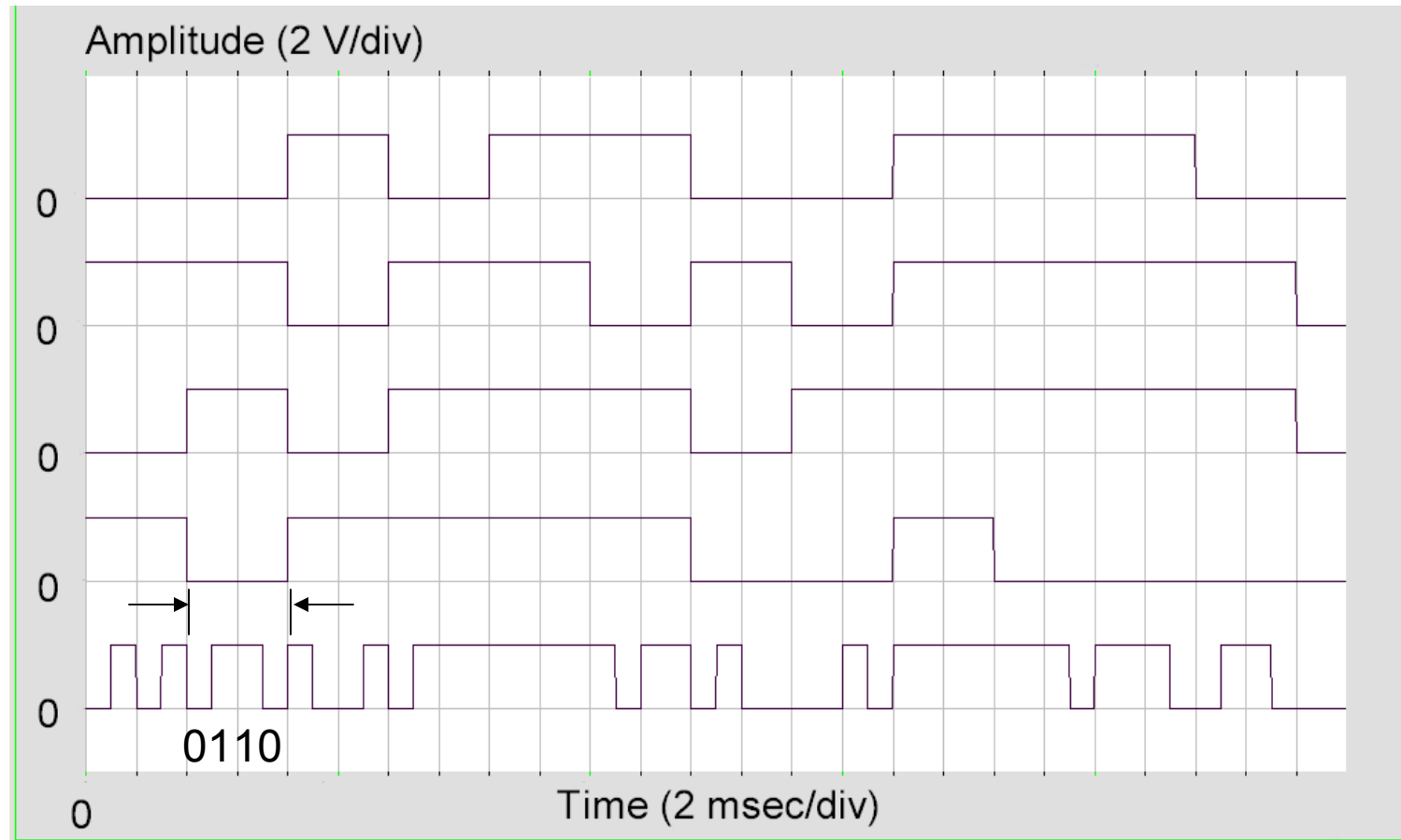
- *Time Division Multiplexing*
- Pages 254-258



- TDM with four equal data rate sources
- $r_b = 250 \text{ b/sec}$

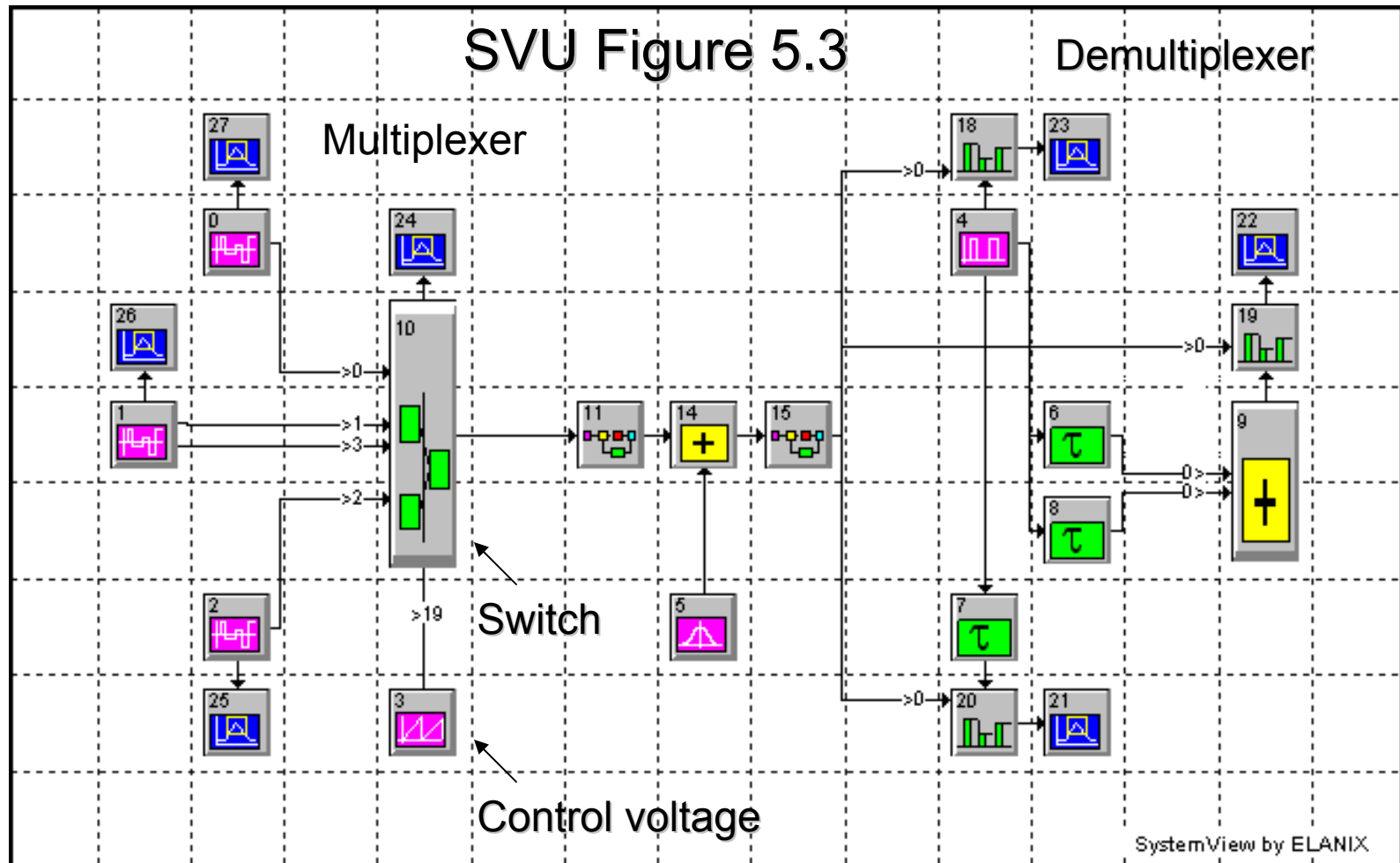


- TDM with four equal data rate sources $r_b = 250$ b/sec and a transmission rate $r_{\text{TDM}} = 1$ kb/sec

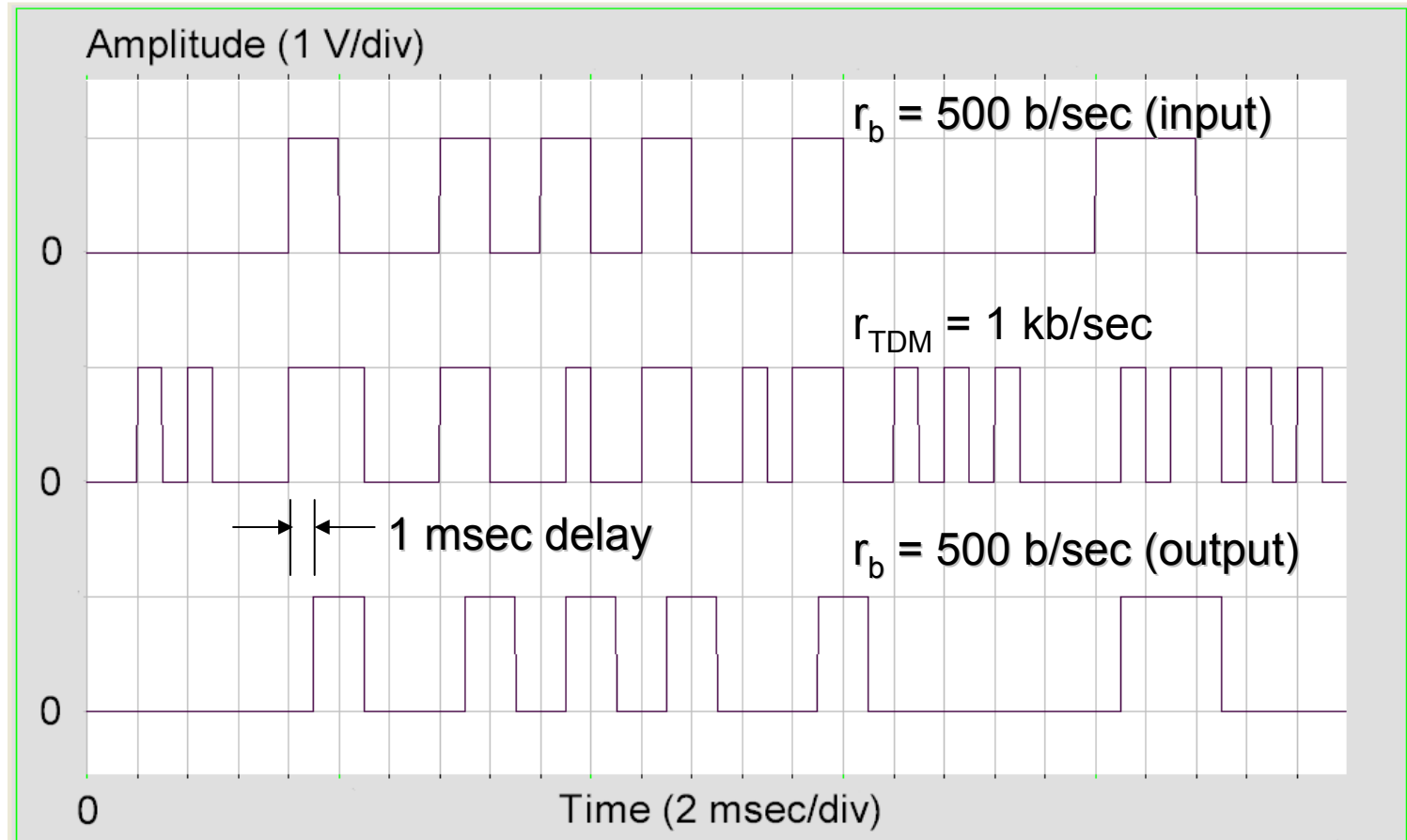


SVU Figure 5.2

- TDM with unequal data rate sources $r_b = 250, 250$ and 500 b/sec.



- TDM with unequal data rate sources $r_b = 250, 250$ and 500 b/sec and a transmission rate $r_{\text{TDM}} = 1$ kb/sec

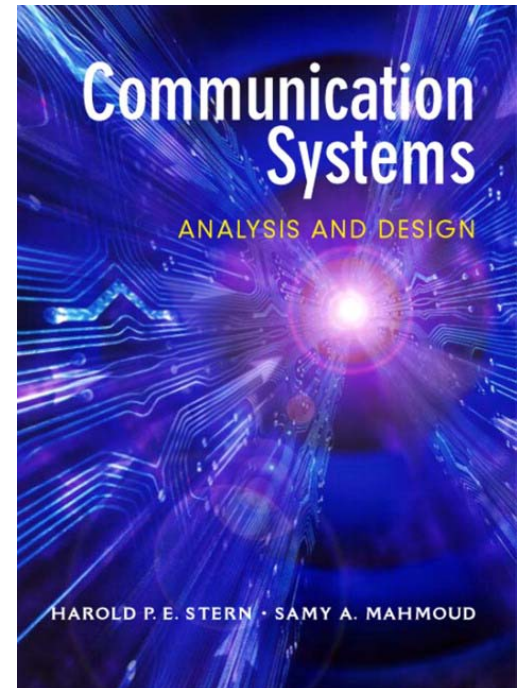


SVU Figure 5.4

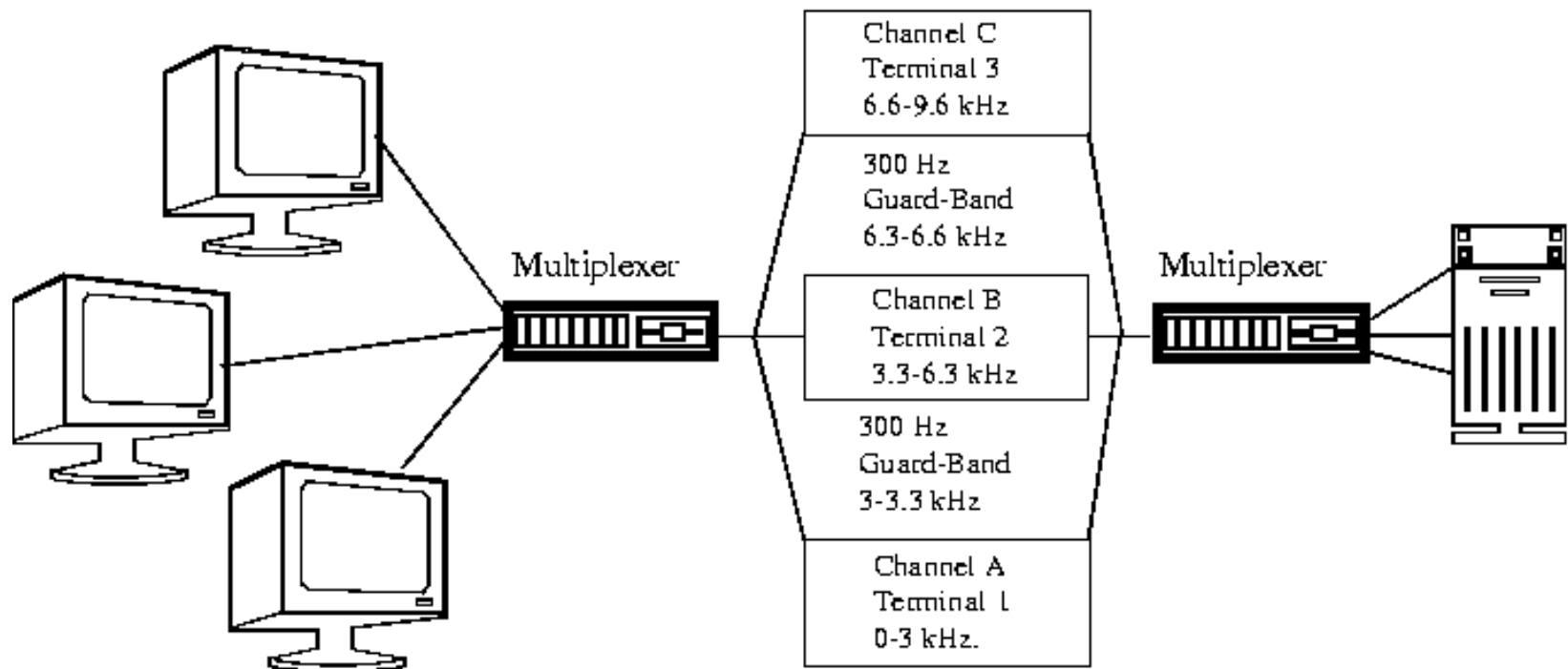
Chapter 7

Multiplexing Techniques

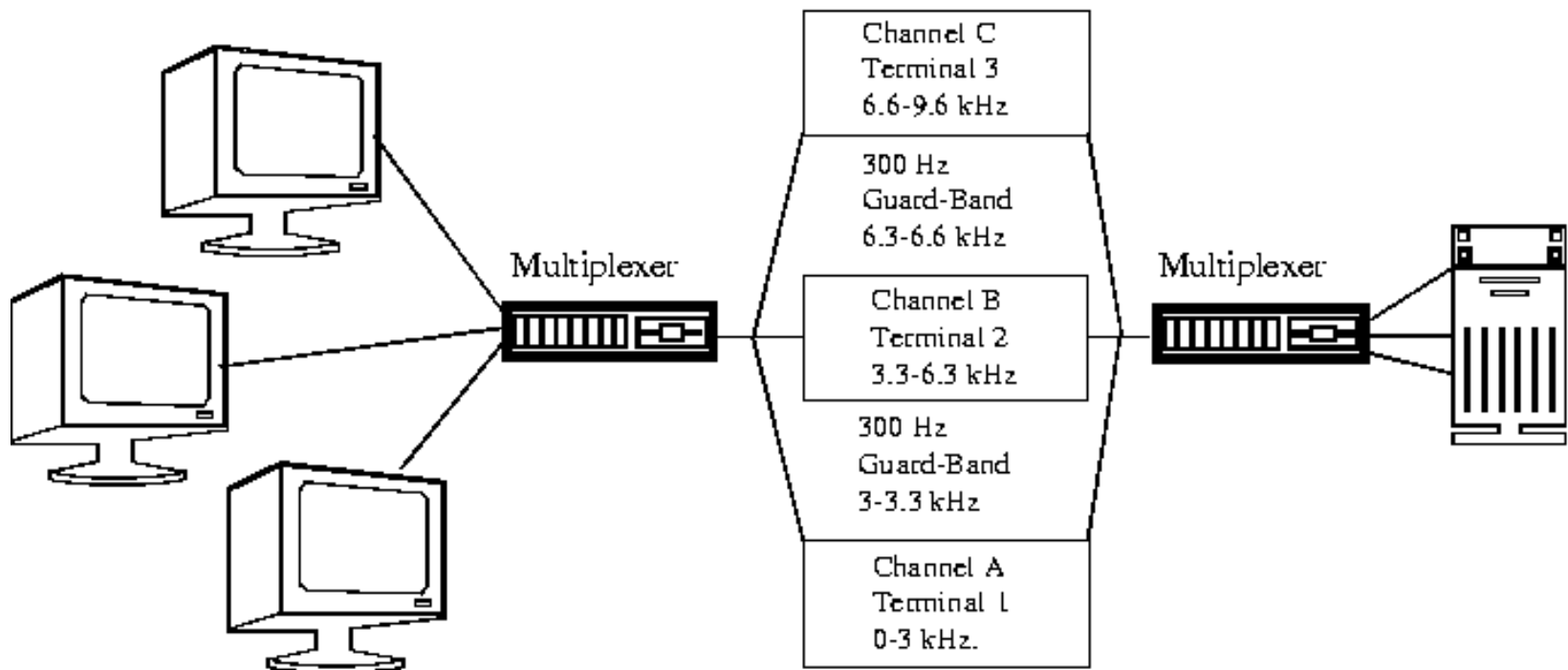
- *Frequency Division Multiplexing*
- Pages 368-370



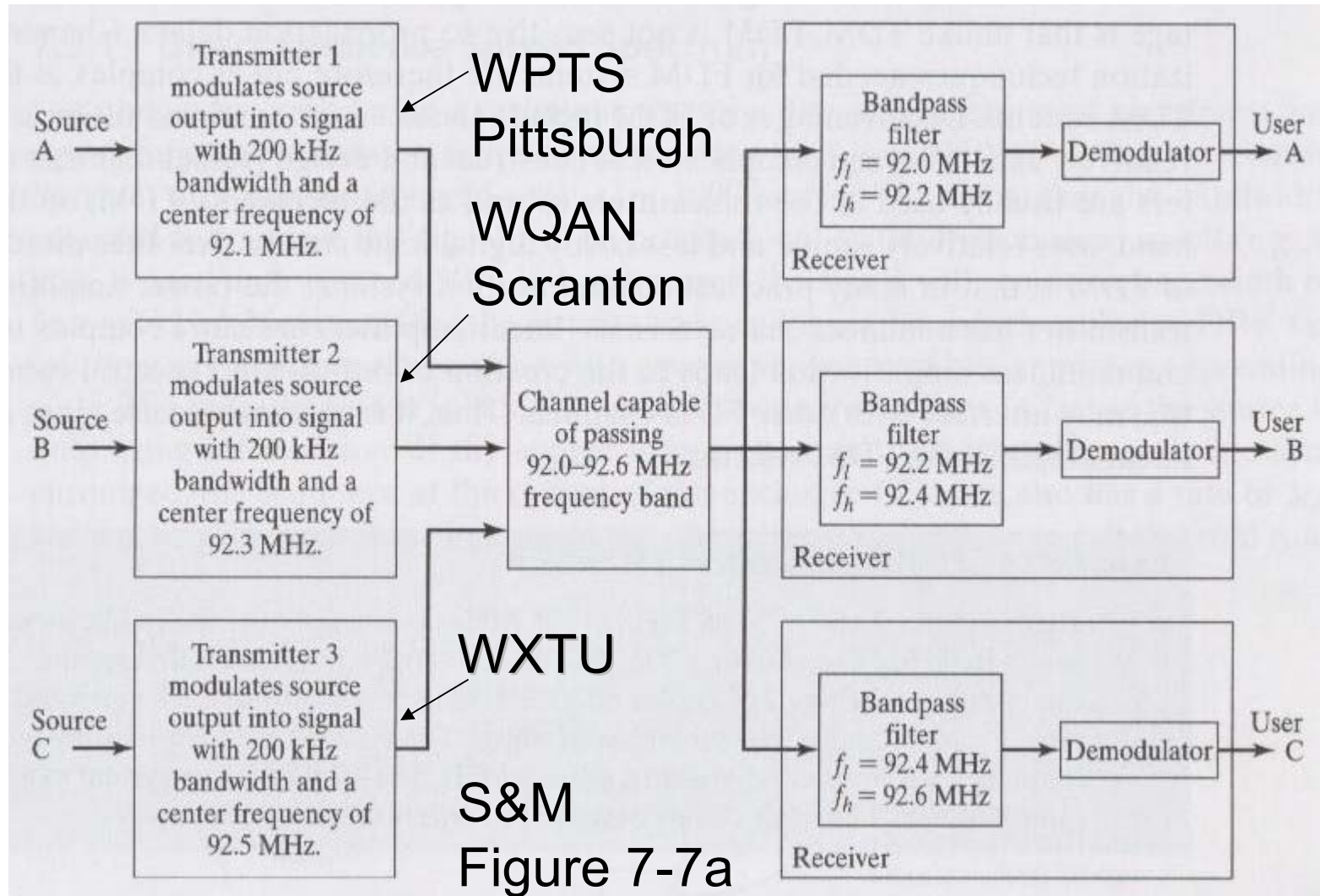
- *Frequency division multiplexing (FDM)* divides the total bandwidth available to the system into *non-overlapping* frequency sub-bands for transmission over a single digital communication channel.



- FDM usually utilizes *guard bands* to separate the digital data transmissions. FDM is used for bandpass (*not* baseband) data transmission

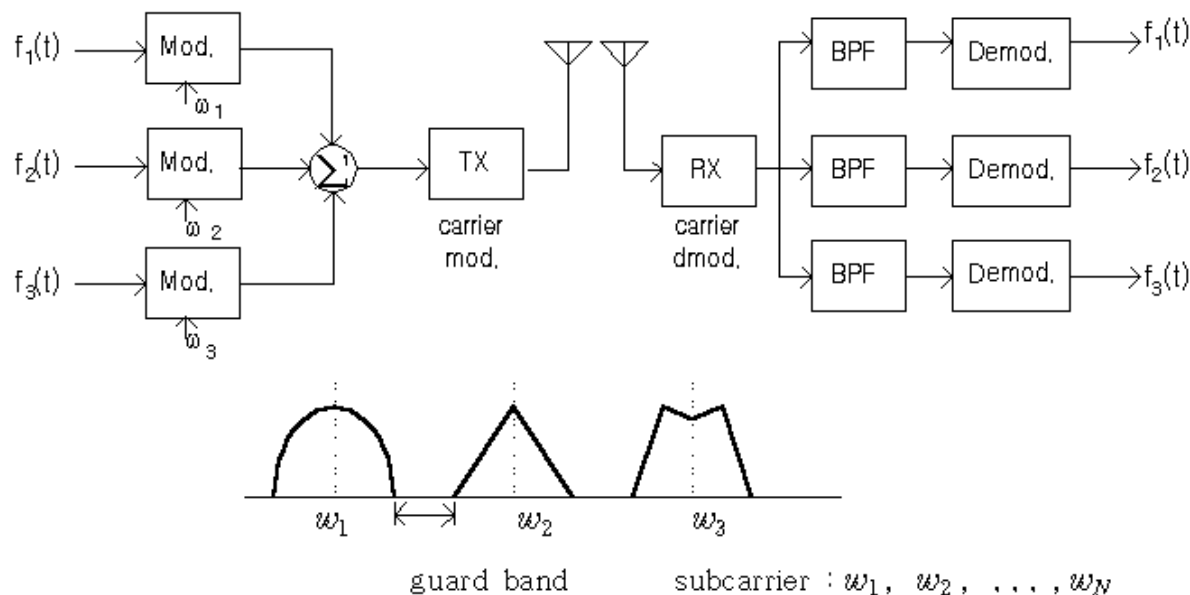
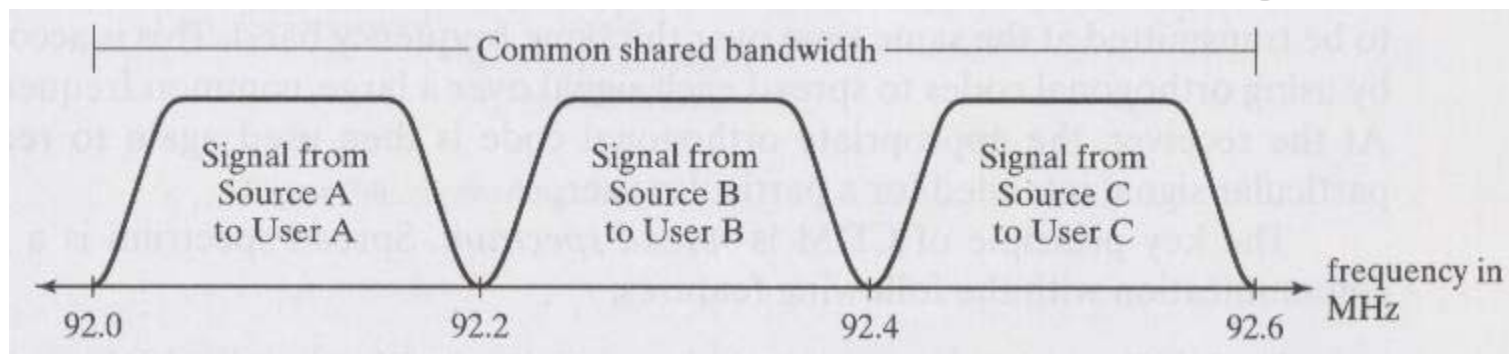


- FDM for *FM broadcasting* over a cable system:

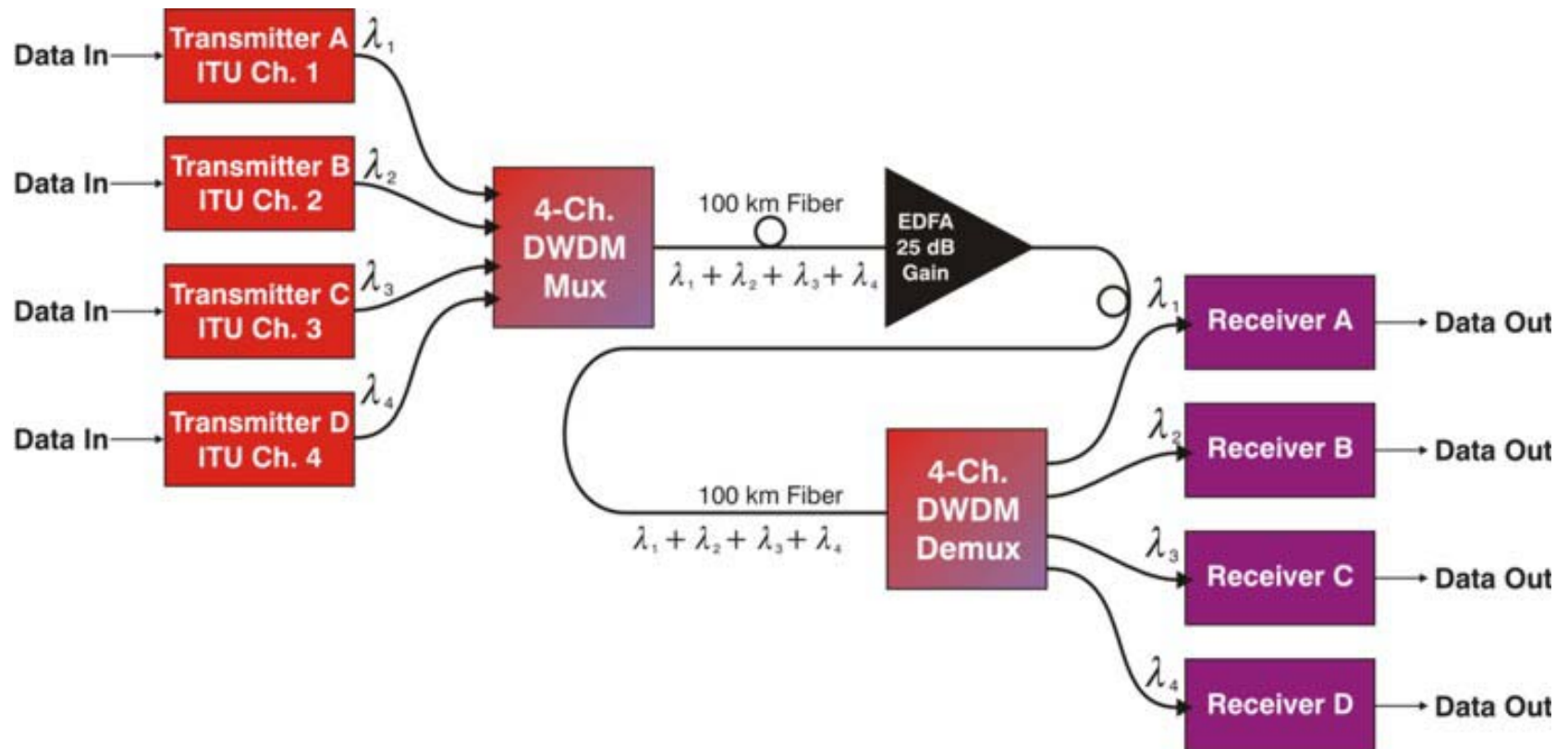


- FDM employs a common shared bandwidth but here with no apparent guard bands.

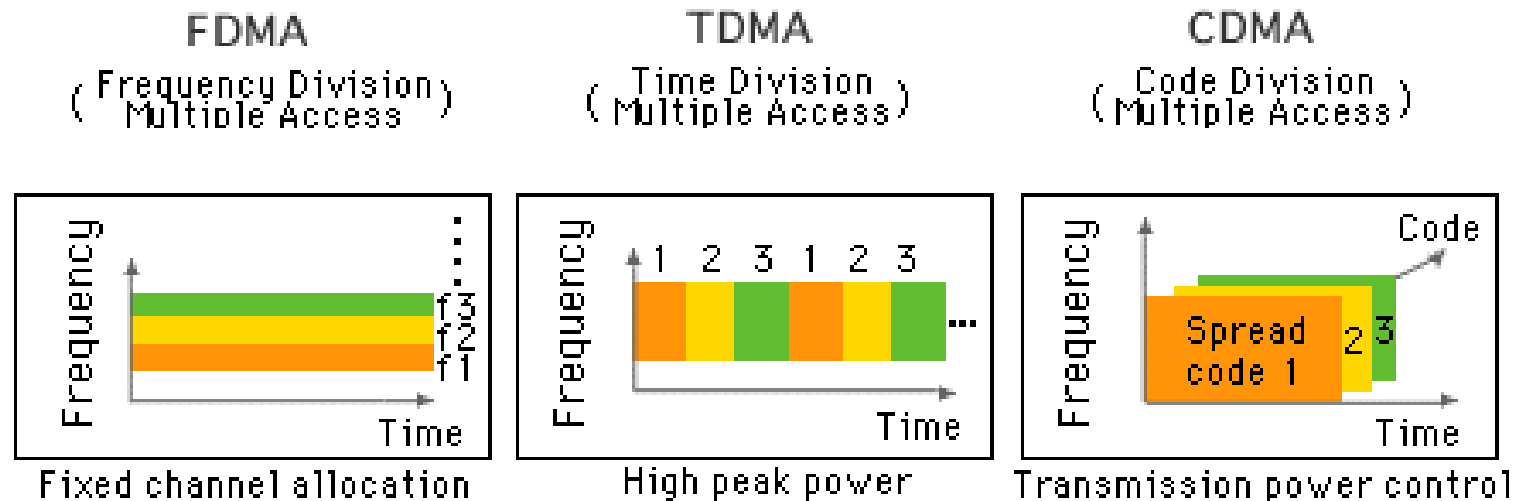
S&M Figure 7-7b



- Optical FDM is usually called *wavelength division multiplexing* (WDM) and utilizes separate wavelengths (λ) of light.



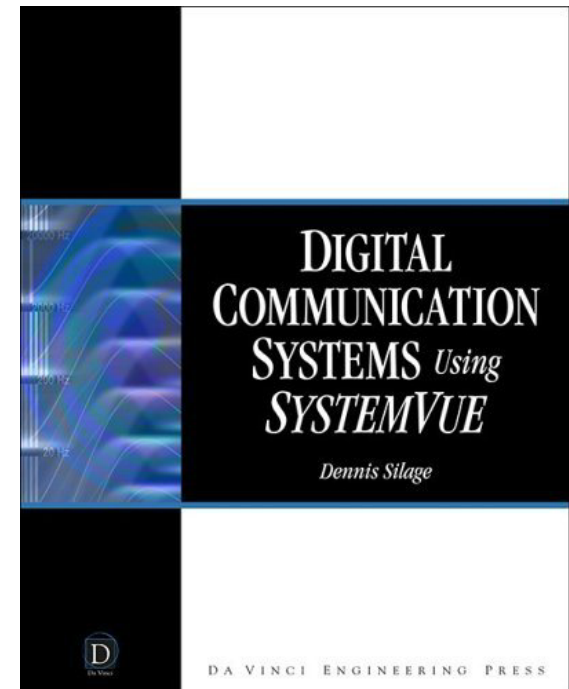
- TDM is used for baseband and FDM for bandpass data transmission. FDM requires the assignment and coordination of carrier frequencies which can be problematic. *Code division multiple access* (CDMA) utilizes spread spectrum modulation over the same frequency band. CDMA is considered in EE4542 Telecommunications Engineering.



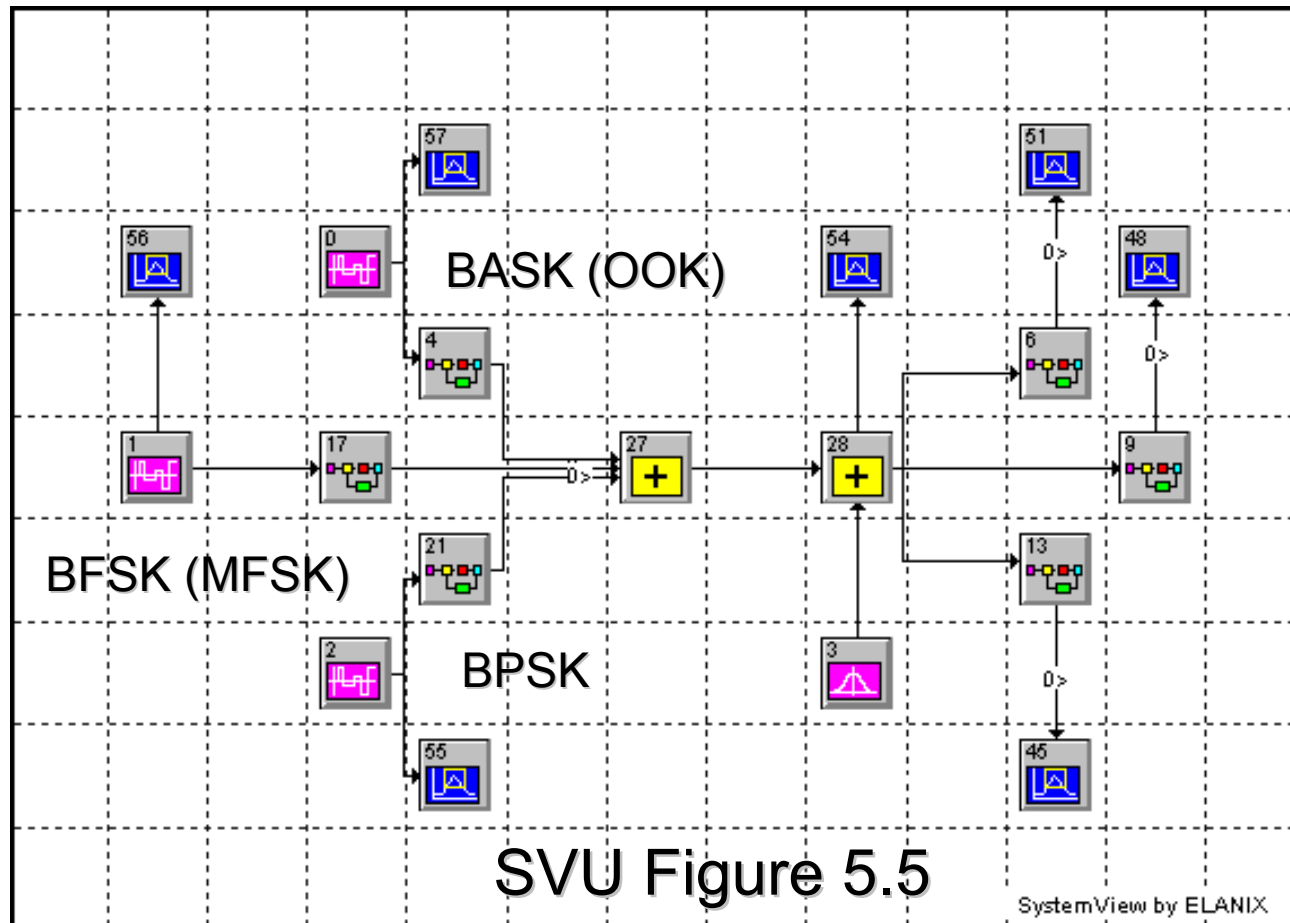
Chapter 7

Multiplexing Techniques

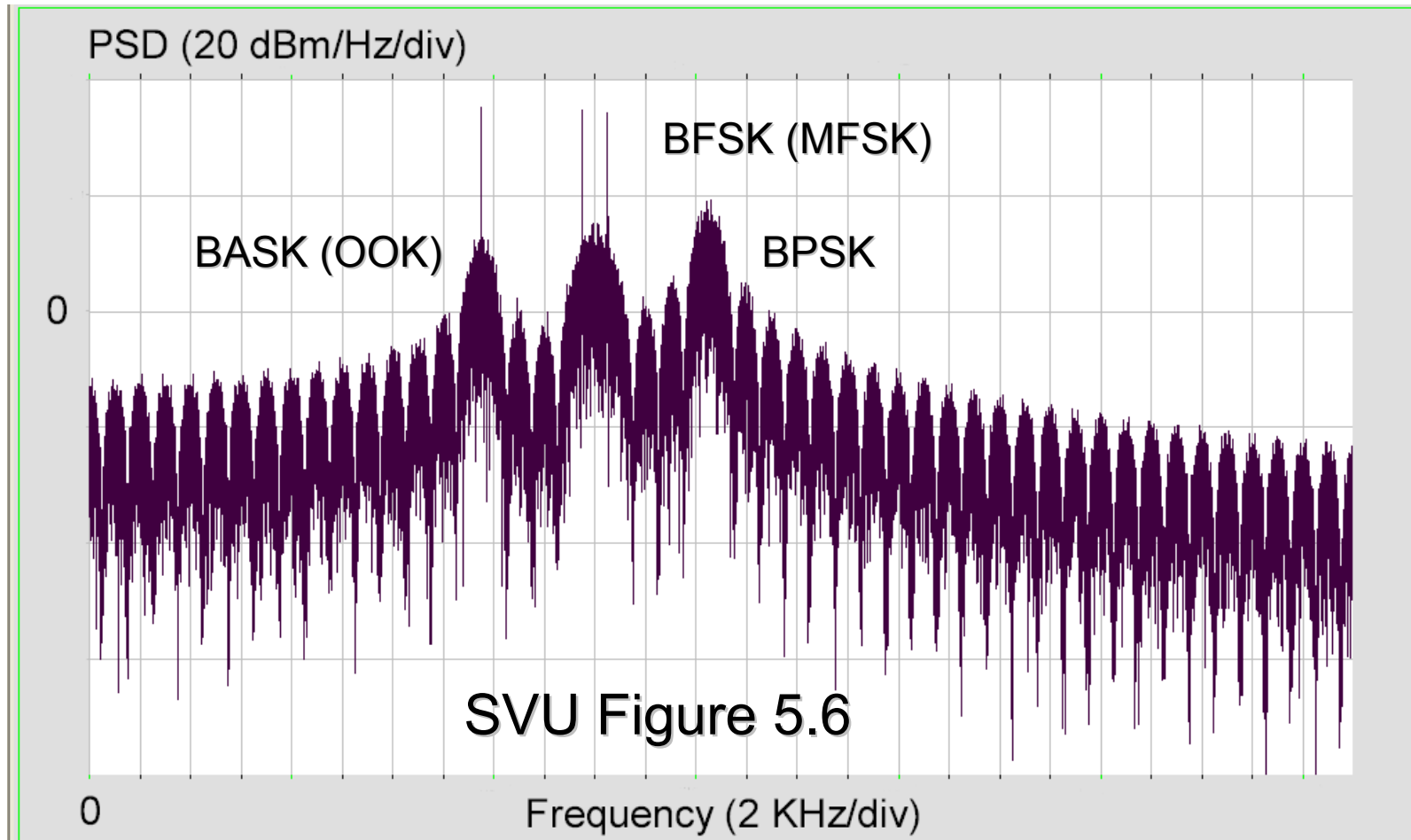
- *Frequency Division Multiplexing*
- Pages 258-264



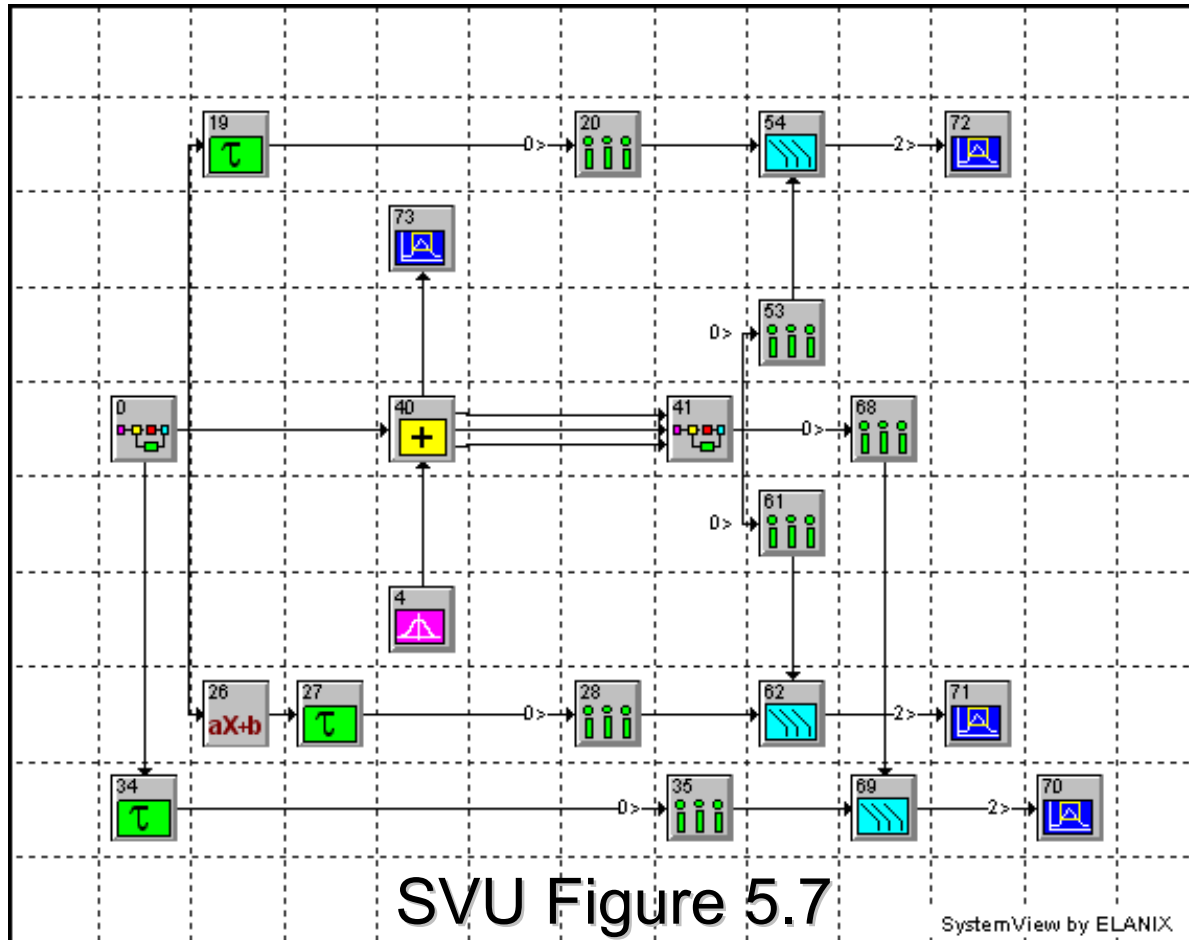
- FDM digital communication system with BASK (OOK), BFSK (MFSK) and BPSK modulators and demodulators with three equal data rate sources $r_b = 1$ kb/sec



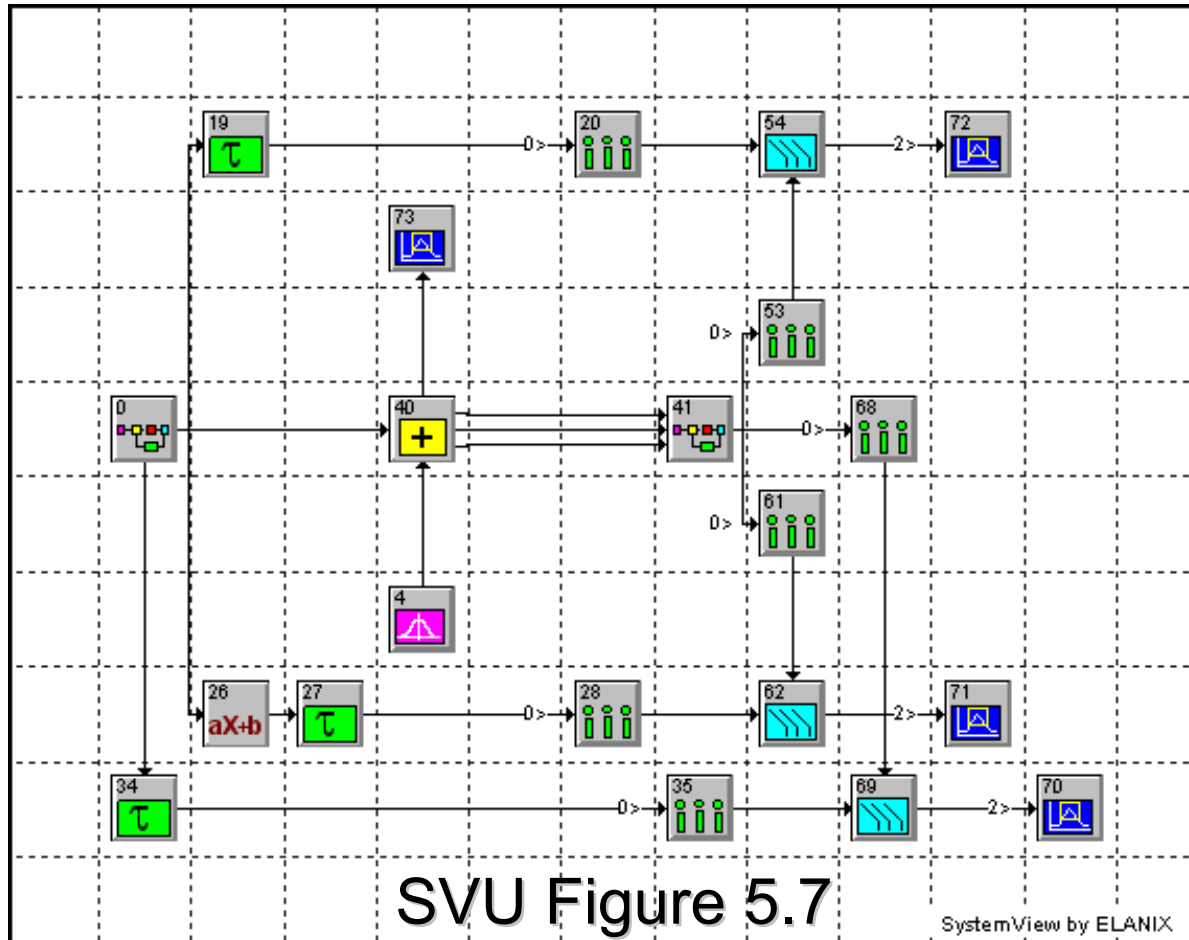
- FDM PSD with three equal data rate sources $r_b = 1$ kb/sec and three carrier frequencies of 15.5, 20 and 24.5 kHz.



- FDM digital communication system with BASK (OOK), BFSK (MFSK) and BPSK and BER analyses.



- The results of the FDM BER analyses show that the digital data transmissions are not affected (see SVU Table 5.1).



End of Chapter 7

Multiplexing Techniques

