Chapter 5

Analog Transmission
5-1 DIGITAL-TO-ANALOG CONVERSION
Figure 5.1  *Digital-to-analog conversion*
Figure 5.2  *Types of digital-to-analog conversion*
Bit rate is the number of bits per second. Baud rate is the number of signal elements per second. In the analog transmission of digital data, the baud rate is less than or equal to the bit rate.
An analog signal carries 4 bits per signal element. If 1000 signal elements are sent per second, find the bit rate.

Solution
In this case, $r = 4$, $S = 1000$, and $N$ is unknown. We can find the value of $N$ from

$$S = N \times \frac{1}{r} \quad \text{or} \quad N = S \times r = 1000 \times 4 = 4000 \text{ bps}$$
Example 5.2

An analog signal has a bit rate of 8000 bps and a baud rate of 1000 baud. How many data elements are carried by each signal element? How many signal elements do we need?

Solution

In this example, $S = 1000$, $N = 8000$, and $r$ and $L$ are unknown. We find first the value of $r$ and then the value of $L$.

\[ S = N \times \frac{1}{r} \]
\[ r = \frac{N}{S} = \frac{8000}{1000} = 8 \text{ bits/ baud} \]

\[ r = \log_2 L \]
\[ L = 2^r = 2^8 = 256 \]
Figure 5.3  Binary amplitude shift keying

Amplitude

1 signal element 1 signal element 1 signal element 1 signal element 1 signal element

Bit rate: 5

1 0 1 1 0

Time

1 s

Baud rate: 5

r = 1  S = N  B = (1 + d)S

Bandwidth

0

f_c
**Figure 5.6** Binary frequency shift keying

![Diagram of binary frequency shift keying](image)

- **Amplitude**
- **Bit rate: 5**
- **Time**
- **Baud rate: 5**

- **Equation:**
  
  \[ r = 1 \quad S = N \quad B = (1 + d)S + 2Df \]

- **Diagram Details:**
  - \[ B = S(1 + d) + 2Df \]
  - \[ S(1 + d) \]
  - \[ 2Df \]
  - \[ f_1, f_2 \]
Figure 5.9  *Binary phase shift keying*
Quadrature amplitude modulation is a combination of ASK and PSK.
Figure 5.14  Constellation diagrams for some QAMs

a. 4-QAM  
b. 4-QAM  
c. 4-QAM  
d. 16-QAM
Figure 5.15 *Types of analog-to-analog modulation*
Figure 5.16  *Amplitude modulation*
Figure 5.18 Frequency modulation

Amplitude

Modulating signal (audio)

Carrier frequency

FM signal

Time

Voltage-controlled oscillator

$B_{FM} = 2(1 + b)B$

0

$f_c$
Figure 5.20  Phase modulation

Amplitude

Modulating signal (audio)

Carrier frequency

PM signal

Time

VCO

d/dt

B_{PM} = 2(1 + b)B

0

f_c