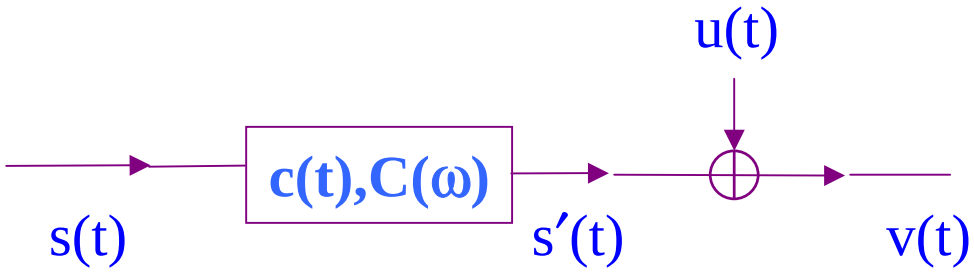
1.6 Fundamentals for Digital Communications

A Communication System

- **Major Components**
  - source of information, user of information
  - channel: the physical medium
  - transmitter and receiver

  See Fig. 1, p. 2 of Haykin

- **Possible Channels**
  - wired: coaxial cable, fiber, etc.
  - wireless: radio, satellite, mobile, etc.
  - simplified model



c(t), C(ω) : channel distortion

u(t) : undesired components : noise, interference, etc.

$v(t) = s(t) * c(t) + u(t) = s'(t) + u(t)$

A Communication System

- Ideal Channel :

  $C(\omega) = A\, e^{-j\omega a}$ in signal band

  $S'(\omega) = AS(\omega)e^{-j\omega a}$

  $s'(t) = As(t-a)$

  distortionless : constant amplitude, linear phase in signal band

  (A = 1, a = 0 for simplicity)

  n(t) : white, Gaussian, zero-mean noise

- Time shifting Property of Fourier Transform

  $s(t) \overset{F}{\longleftrightarrow} S(\omega)$

  $s(t-a) \longleftrightarrow S(\omega)e^{-j\omega a}$

- **Modulation :**
  - varying some parameters of a carrier signal according to the information to be transmitted
  - the carrier signal can be transmitted through the channel
  - purposes of modulation :

    matching the channel characteristics

    reducing the effect of channel impairments

    multiplexing : simultaneous transmission of many signals over the same channel

A Digital Communication System

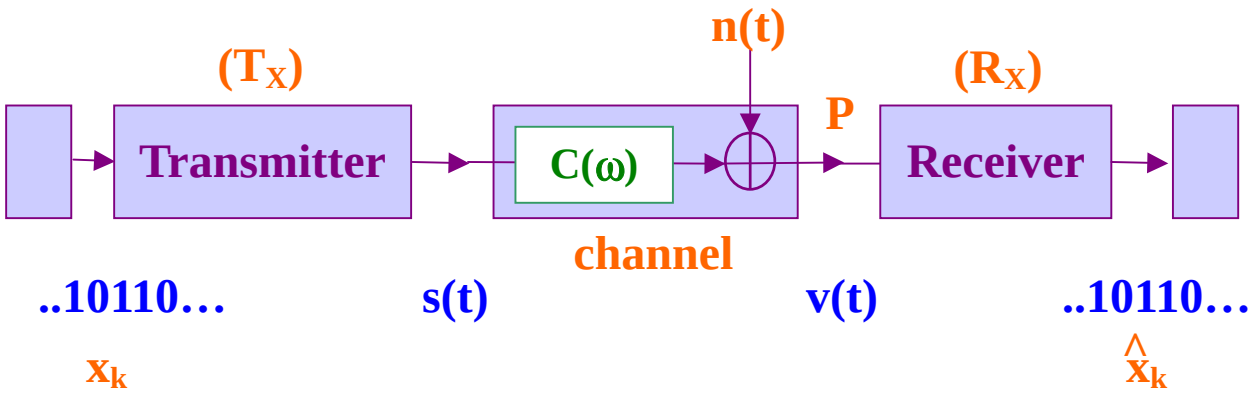
- **Source Encoder**
  - removing redundant information
  - producing minimum number of bits to be transmitted
  - data compression for efficient use of channel

- **Channel Encoder**
  - reducing error probability by introducing controlled redundancy
  - error control coding

See Fig. 9, p. 22 of Haykin

A Digital Communication System

- **A Simplified Model**



- Ideal channel

  $C(\omega) = 1$

  n(t) : white Gaussian noise (WGN)

  $S_n(\omega) = \frac{N_0}{2}$, all ω

- Basic Parameters

  bit duration = T

  bit rate = $r = \frac{1}{T}$ (bits/sec, bps): transmission speed

  received power = P (at the receiver front end)

  energy per bit = $E_b = PT = \frac{P}{r}$

  E_b / N_0: describing signal quality at receiver

  bit error rate = P_e = Prob[$\hat{x}_k \neq x_k$]

  = P_e (E_b / N_0) a decreasing function

  transmission bandwidth = B (α r)

  bandwidth efficiency = $\eta = \frac{r}{B}$ (bps/Hz)

A Digital Communication System

- **Digital Communication Problem**

  - Given Resources :

    1. transmission power
    2. transmission bandwidth

  - Goals :

    1. low P_e (E_b / N_0) to save power
    2. high $\eta = r / B$ to save bandwidth
    3. resistance to channel impairments
    4. practical feasibility, e.g. small size of handsets

Ref : 0.1, 0.2, 0.3, 0.5, 0.6, 0.7 of Haykin