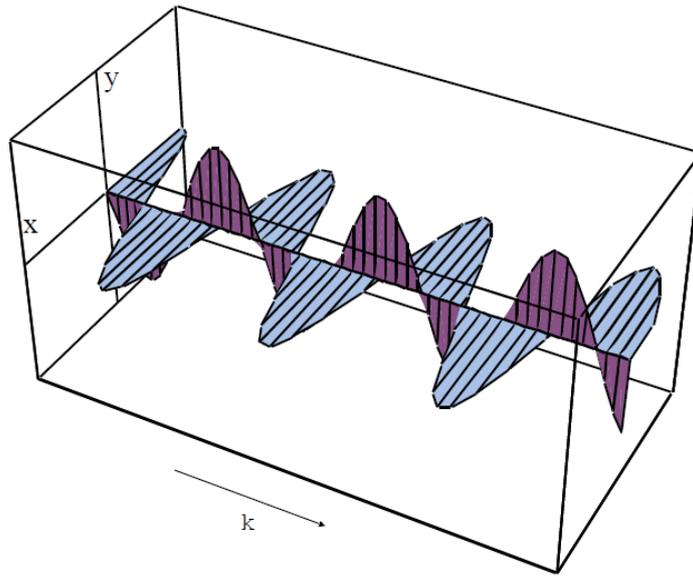


➤ Polarization Effects



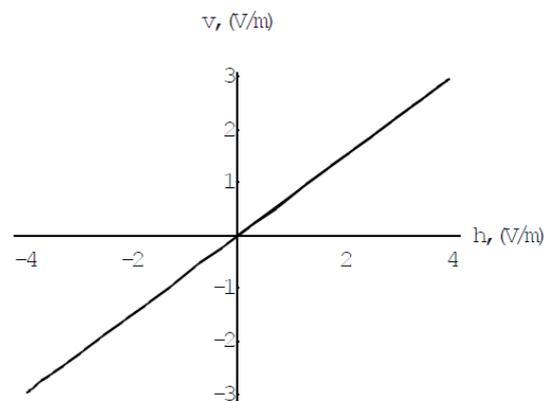
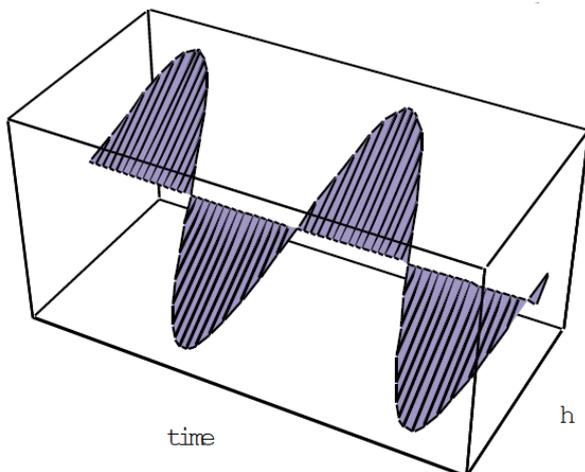
$$\vec{E}_x = \vec{e}_x E_{0x} \cos(\omega t - \beta z + \phi_x)$$

$$\vec{E}_y = \vec{e}_y E_{0y} \cos(\omega t - \beta z + \phi_y)$$

$$\beta = kn = \frac{2\pi}{\lambda} n$$

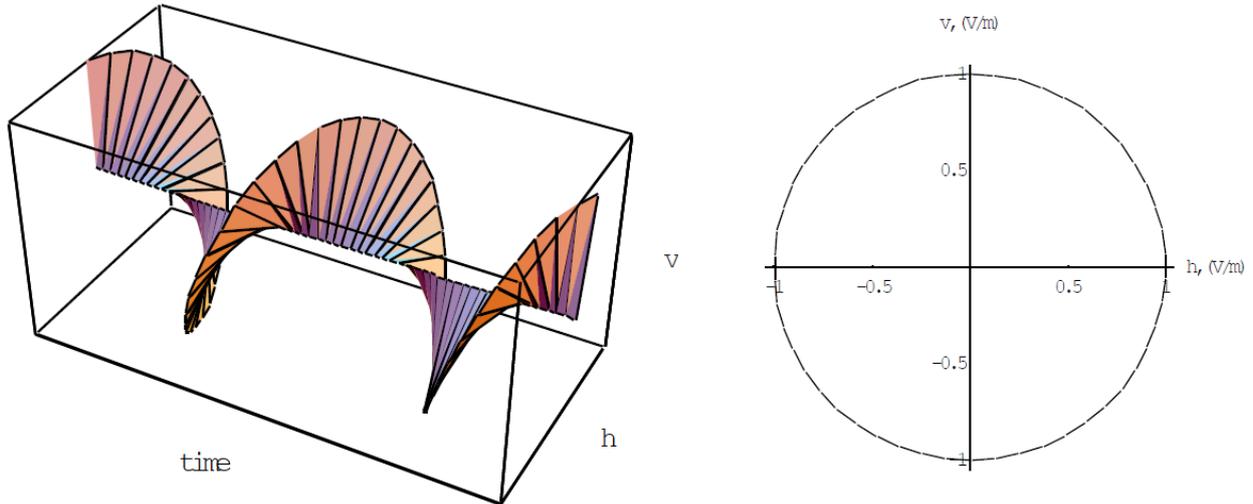
$$\vec{E}_{TOTAL} = \vec{E}_x + \vec{E}_y$$

Linear Polarization



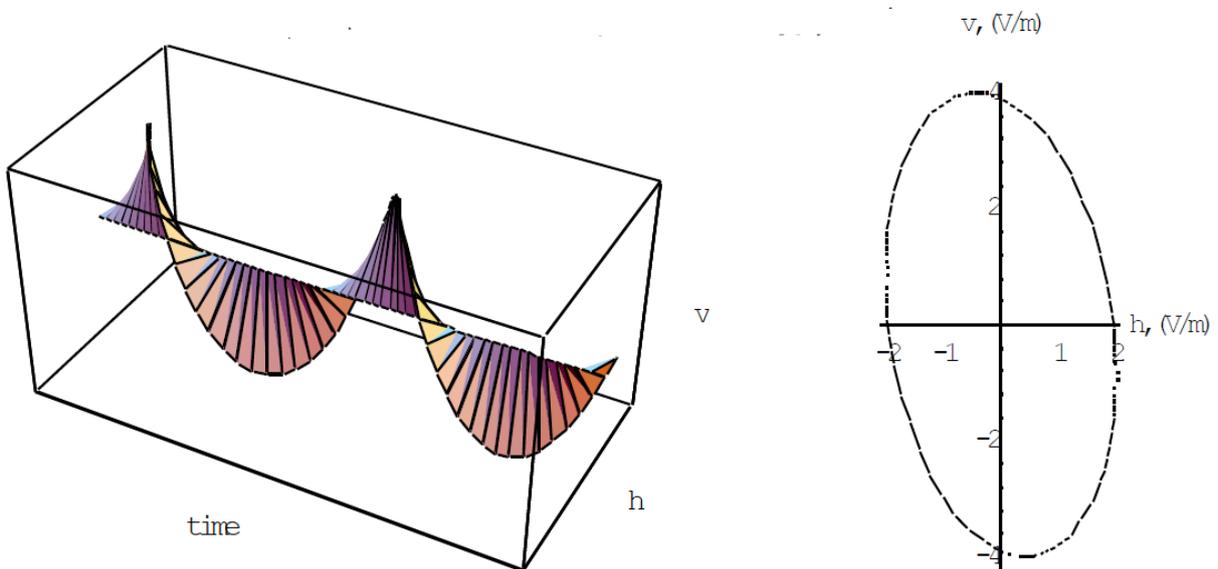
$$\vec{E}_{TOTAL} = \vec{e}_x E_{0x} \cos(\omega t - \beta z) + \vec{e}_y E_{0y} \cos(\omega t - \beta z + \pi)$$

Circular Polarization



$$\vec{E}_{TOTAL} = E_{0x} [\vec{e}_x \sin(\omega t - \beta z) + \vec{e}_y \cos(\omega t - \beta z)]$$

Elliptical Polarization



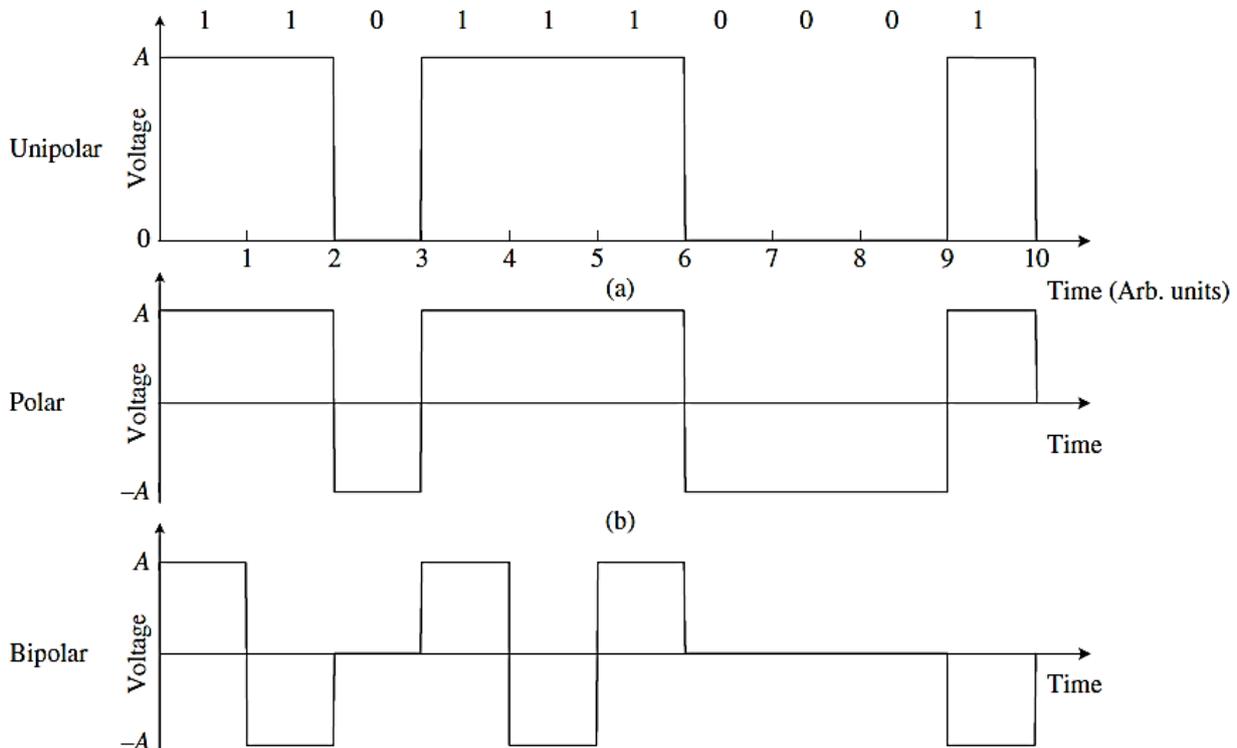
$$\vec{E}_{TOTAL} = \vec{e}_x E_{0x} \sin(\omega t - \beta z + \phi_1) + \vec{e}_y E_{0y} \cos(\omega t - \beta z + \phi_2)$$

➤ Optical Modulators and Modulation Schemes

To convey a message, the amplitude, frequency, and phase of an optical carrier are switched in accordance with the message data. For example, bits '1' and '0' can be transmitted by turning a laser diode on and off, respectively. Typically, the message signal is in the form of binary data in an electrical domain, and optical modulators are used to convert the data into an optical domain.

Line Coder & Pulse Shaping:-

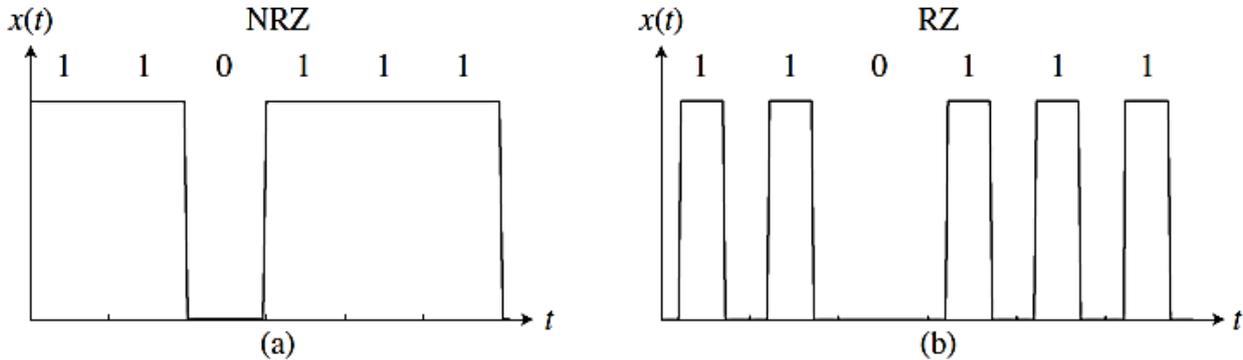
Digital data can be represented by electrical waveforms in a number of ways. This process is called line coding. In the binary case, bit '1' is sent by transmitting a pulse $p(t)$ and bit '0' is sent by transmitting no pulse. This line code is known as **unipolar or on-off**, as shown in Figure below. In other words, pulses representing consecutive bit '1's (no matter how many '0's are between the '1's) alternate in sign. Hence, this line code is also called **alternate mark inversion (AMI)**.



Various line codes: (a) unipolar, (b) polar, and (c) bipolar.

The message signal can be the internet data, voice data after **analog-to-digital conversion (ADC)**, or any other form of digital data in an electrical domain. The widely used pulse shapes ($p(t)$) are **non-return-to-zero (NRZ)**

and *return-to-zero* (RZ). In the case of NRZ, the signal does not return to a zero level if there are two consecutive '1's in a bit stream, whereas in the case of RZ, the signal returns to zero at the end of each bit slot, as shown in Figure below.



Pulse shapes: (a) NRZ, and (b) RZ.

The advantage of NRZ is that fewer transitions between '0' and '1' are required compared with RZ, since the signal amplitude remains the same if consecutive bits are '1' or '0'. Therefore, the bandwidth of a NRZ signal is less than that of a RZ signal. The wider spectral width of a RZ signal can also be understood from the fact that the pulse width of RZ pulse is shorter than that of a NRZ pulse. The message signal may be written as:

$$m(t) = A_0 \sum_{n=-\infty}^{\infty} a_n p(t - nT_b),$$

where a_n is the binary data in the bit slot, $p(t)$ represents the pulse shape, and A_0 is a real constant.

An important parameter that characterizes a RZ signal is the *duty cycle*. This is defined as the time for which the light is turned on in a bit interval divided by the bit interval, i.e., the fraction of time over which the light is on "duty" within a bit interval. In the above definition, we have assumed rectangular pulses. For pulses of arbitrary shape, the duty cycle x can be defined as the ratio of the Full width at half maximum (FWHM) of a pulse to the bit interval T_b ,

$$x = \frac{\text{FWHM}}{T_b}.$$

When rectangular pulses are used, a RZ pulse in a bit interval $[-T_b/2, T_b/2]$ may be written as:

$$\begin{aligned} p(t) &= 1 \quad \text{for } |t| < xT_b/2 \\ &= 0 \quad \text{otherwise.} \end{aligned}$$

➤ Digital Modulation Schemes

Amplitude-Shift Keying:-

A laser is an optical carrier whose amplitude and/or phase can be varied in accordance with a message signal by means of an optical modulator. Let the laser output be:

$$c(t) = A \cos(2\pi f_c t + \theta).$$

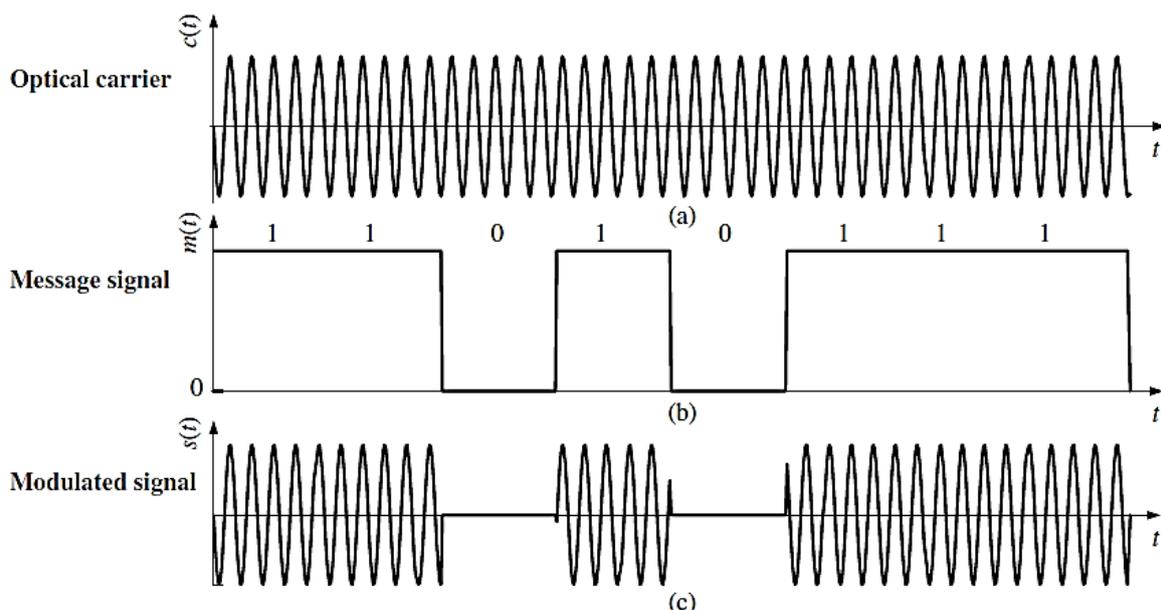
the amplitude A , frequency f_c , and phase factor θ are constants. When the amplitude A is varied in accordance with a message signal $m(t)$ while keeping f_c and θ constant, the resulting scheme is known as **amplitude modulation**. Suppose the amplitude is proportional to the message signal $m(t)$,

$$A(t) = k_a m(t),$$

where k_a is amplitude sensitivity. Now, the carrier is said to be amplitude modulated. The modulated signal can be written as:

$$s(t) = k_a m(t) \cos(2\pi f_c t + \theta).$$

When the message signal $m(t)$ is a digital signal, such as shown in Figure below, the modulation scheme is known as **amplitude-shift keying (ASK)** or **on-off keying (OOK)**. In general, to transmit bit '1', a sinusoid of certain amplitude A_1 is sent and to transmit bit '0', a sinusoid of amplitude A_2 is sent.



Modulation of the optical carrier by digital data: (a) carrier, (b) data, and (c) modulated signal.