Dr. R. K. SHUKLA.
Department of Physics.
University of Lucknow.

Numericals on optical Communication

(d) 2013 2006, 2007 Q:- A laser operating at 1550 nm has 4 nm spectral width. Find the frequency spread.

Ans.

$\Delta\lambda = 4nm = 4\times10^{-9} m$

$\lambda = 1550 nm = 1550\times10^{-9} m$

$c = 3\times10^{8} m$

Imp

$$\boxed{\Delta\nu = \frac{c}{\lambda^2}\Delta\lambda}$$

$$= \frac{3\times10^{8}}{(1550\times10^{-9})^2}\times4\times10^{-9}$$

$$= 500\times10^{9} Hz$$

$$= 500\ GHz \quad \text{Ans.}$$

$\nu = c/\lambda$

$\Delta\nu = c\frac{\Delta\lambda}{\lambda^2}$

Q1 (iii)/2009

Q:- Calculate the channel spacing in nm if the frequency spacing is 500 GHz and network operates at 1550 nm.

Ans:- Using eqn

$$\Delta\nu = \frac{c}{\lambda^2}\Delta\lambda$$

$\Delta\nu = 500 GHz = 500\times10^{9} Hz = 5\times10^{11} Hz$

$\lambda = 1550 nm = 1550\times10^{-9} m$

$$\Delta\lambda = \Delta\nu \cdot \frac{\lambda^2}{c}$$

$$= \frac{5\times10^{11}\times(1550\times10^{-9})^2}{3\times10^{8}}$$

$$= 4\times10^{-9} m$$

$$= 4 nm$$

$\boxed{\Delta\lambda = 4nm}$ Ans

Q1(b)/2011, 2009 (5KHz) → Q2(a)/2008

Q3/2012, Q2(b)/2010. If a voice channel of bandwidth 4kHz is sampled and each sample is represented by 8 bit, Calculate the bit rate. If there are 24 such voice channels and one extra bit is added in a frame, calculate bit rate if all channels are transmitted simultaneously by TDM.

Ans:- Given

Bandwidth = 4 kHz = 4×1000 Hz = 4000 Hz

Number of samples per sec = 2 × Bandwidth
= 2 × 4000
= 8000 sample/sec.

as we know that each sample is represented by 8 bits.

So, number of bits = 8000 × 8
= 64000 bits/sec = 64 kb/sec.

one voice channel - **bit rate = 64 kb/sec**

In the above question, only suppose that each sample has 8 bit, and number of channels = 24

Thus, total number of bits = 24×8 = 192 bits (2)

This is known as 'one frame'.

Imp → Further one extra bit is added which is known as frame ~~synchronising~~ synchronising bit. It is added at the front of each frame to mark its beginning.

Thus, total number of bits = 192+1 = 193 bits.

Bandwidth of voice channel is 4000Hz then total no. of samples will be
= 4000×2 = 8000 samples.

Thus, the total no. of bits of 8000 samples (in one frame) will be = 193 × 8000
= 1544000 bits/sec

∴ **bit rate = 1.544 Mb/sec**

Thus it may be concluded that in voice channel (B.W. = 4000Hz), if 1 sample is represented by 8 bits so data rate is 1.544 Mb/sec (one extra bit is added a frame)

and in absence of multiplexing data rate (of one voice channel) will be = 64 kb/sec.

⇒ According to Nyquist theorem,

Total no. of samples = 2 × Bandwidth.

Q 4(b) / 2011 A signal of 6 MHz Bandwidth has to be transmitted. If the photodiode has junction capacitance 5 pf, what is the value of maximum load resistance.

Ans :- A detector is used with $C_j = 5\,pf = 5 \times 10^{-12}\,f$

$$\text{Bandwidth} = \frac{1}{2\pi R_L C_j}$$

or

$$R_L = \frac{1}{2\pi C_j \,\text{Bandwidth}}$$

$$= \frac{1}{2\pi \times 5 \times 10^{-12} \times 6 \times 10^{6}}$$

$$= 5305\ \Omega$$

$$\simeq 5.3\ K\Omega \quad \underline{\text{Ans}}$$

(3)

Q 5(b) / 2006 Calculate system rise time if bandwidth to be transmitted is 6 MHz.

Ans :- The rise time is related to bandwidth as

$$t_r = \frac{0.35}{\text{Bandwidth}}$$

$$= \frac{0.35}{6 \times 10^{6}}$$

$$= 58.3\ \text{nsec} \quad \underline{\text{Ans}}$$

Q:- In a link, the source is emitting 0dBm and receiver power requirement is −57 dBm. It is required to leave 5dBm power margin. The losses at transmitter and receiver ports are 6dB each. Two connectors with 1 dB loss each and 5 splices with −5dB loss each are used. Fiber has 2 dB/km attenuation loss. Calculate the link length.

Ans:- source power = 0 dBm
receiver required = −57 dBm
Power margin = 5dBm

Losses at transmitter and receiver end = 6dB each
Connector loss = 2 × 1 dB = 2dB
Splice loss = 5 × (−5) dB = −25 dB
Attenuation loss (α) = 2 dB/km

The combined component losses must not be more than
0 − (−57 dBm) = 57dBm,
other losses also needs to be considered, so

Power left = 57 − [2 × 6 + 2 − 25]
= 57 − [12 + 2 − 25]
= 57 − [14 − 25]
= 57 − [−11]
= 57 + 11
= 68 dB

Power margin to be left = 5 dB
Power left = 68 − 5 = 63dB
Attenuation = 2dB/km
i.e. loss in making 1 km link = 2dB

∴ link length = $\frac{63}{2}$
= 31.5 km

Ans

(4)

Q:- Consider a source emitting 0dBm and receiver requires 6µW i.e. −22.2 dBm. 0.2 dB is the reflection loss at both ends and 1dB connector loss each at transmitter and receiver. Also coupling loss at step index fiber is 12.4 dB and for GRIN fiber is 15.4 dB. Calculate the link length for SI fiber and GRIN fiber if attenuation loss is 5 dB/km.

Ans:- Power budget suggest that power will be given as

$$0-(-22.2) = 22.2 \text{ dBm}$$

Power left in SI fiber will be

$$= 22.2 - 0.2\times 2 - 2\times 1 - 12.4$$
$$= 7.4 \text{ dBm}$$

Power left in GRIN fiber

$$= 22.2 - 0.2\times 2 - 2\times 1 - 15.4$$
$$= 4.4 \text{ dBm}$$

(5)

Attenuation ⇒ loss in making 1 km link = 5dB

Now, link length for SI fiber $= \frac{7.4}{5} = 1.48$ km

link length for GRIN fiber $= \frac{4.4}{5} = 0.88$ km   Ans.

Q:- Rise time of LED (source) = 12 nsec and length Bandwidth of SI fiber = 33 MHz.km length. Bandwidth of GRIN fiber = 500 MHz.km and Bandwidth of signal = 6 MHz, Calculate t_{fiber} i.e. rise time of fiber

using emperical formula

$$t_s^2 = t_{LS}^2 + t_{fiber}^2 + t_{PD}^2$$

$$\Rightarrow \quad t_{fiber}^2 = t_s^2 - (t_{LS}^2 + t_{PD}^2)$$

$$t_s = \frac{0.35}{\text{Bandwidth}} = \frac{0.35}{6\times 10^6} = 58.3 \text{ nsec}$$

$$t_{PD} = 2.19 R_L C_j = 2.19 \times 5100 \times 5 \times 10^{-12}$$
$$= 55.8 \text{ nanosec}$$

$$t_{LS\,(\text{light source})} = 12 \text{ nsec} \quad (\text{given})$$

$$t_{fiber}^2 = (58.3)^2 - (55.8)^2 - (12)^2$$
$$= 141 (\text{nsec})^2$$

$$t_{fiber} = \sqrt{141} \text{ nsec} \approx 11.9 \text{ nsec}$$
$$= 11.9$$

$$\boxed{f_{ele} = 0.71\, f_{3dB}(\text{optical})}$$

P.T.O.

Q:- The information in an analog waveform with maximum frequency $f_m = 3\,kHz$ is to be transmitted over an M-level PCM system where the number of quantization level is $M = 16$. The quantization distortion is specified not to exceed 1% of peak to peak analog signal.

(i) what would be the maximum number of bits per sample that should be used in this PCM system.

(ii) what is the minimum sampling rate and what is the resulting bit transmission rate.

Ans:- (i) Since the number of quantization levels given here are $M = 16$

$$q = M = 16$$

we know that the bits and levels in binary PCM are related as.

$$q = 2^{\nu}$$

Here ν = number of bits in a codeword.

Thus

$$16 = 2^{\nu}$$

$$\boxed{\nu = 4 \text{ bit}}$$

7

(ii) Since $f_m = 3\,kHz$

By sampling theorem, we know that

$$f_s \geq 2 f_m$$

$$\geq 2 \times 3\,kHz$$

$$\geq 6\,kHz$$

Hence, the minimum sampling rate is 6 kHz

Also, bit transmission rate or signaling rate is given as.

$$r \geq \nu f_s$$

$$\geq 4 \times 6 \times 10^3$$

$$r \geq 24 \times 10^3 \text{ bits per second}$$ Ans.