Solutions EEE6420 2012/13 RJ Langley

Q1

a.

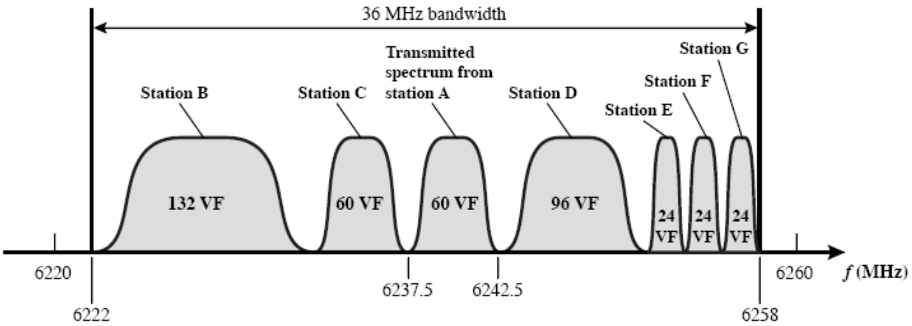
i. Coverage footprint; beam pattern laid down on ground from satellite, known as contour it can be shaped for optimum coverage **2 marks**

ii. Orthogonally polarised beams; to obtain frequency reuse signals transmitted on orthogonal polarizations- circular or linear **2 marks**

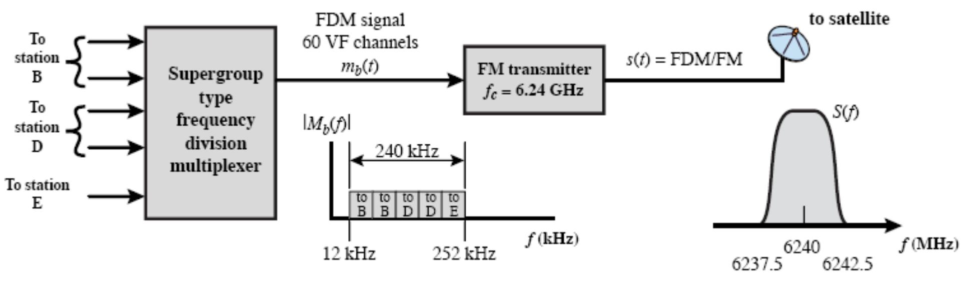
iii. Antenna noise temperature – noise introduced into receiver by antenna and consists of thermal, cosmic and other noise existing . **2 marks**

b. FDMA uses multi-destination carriers, each earth station pre-assigned carrier and bandwidth according to traffic requirements.

Channels transmitted regardless of destination.
Distant earth stations receive all carriers and select only those wanted by filtering.
Smaller channel assignments need proportionally more bandwidth. FDM/FM signals.



(a) Transponder uplink frequency allocation



(b) Station A ground transmitting equipment

3 marks

TDMA - Different stations assigned different time slots – digital – uses entire transponder bandwidth – operation and control complex – global clocks needed for synchronisation – only 1 carrier at transponder at any time – no IM products – TWT operates at saturation maximising C/N and efficiency.

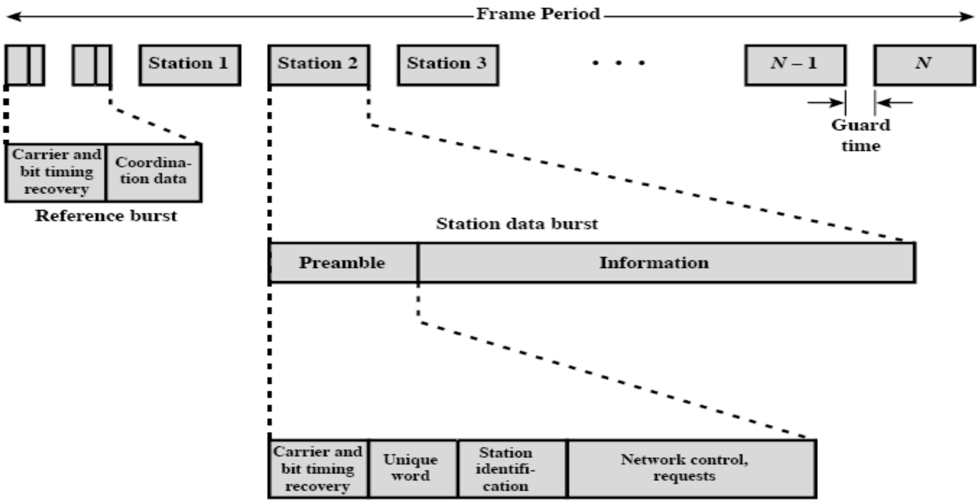


Figure 9.13 Example of TDMA Frame Format

3 marks

c. Given the following information about a satellite communications link, determine the earth station receiver noise temperature.

Earth station: Pt = 250 W; Ge = 55 dB; Te = ?K
Satellite : Gs = 25 dB; Ps = 20 W; Ts = 1250K
Overall: Path losses – uplink = 204 dB, down link = 199 dB
Bandwidth = 16 MHz Operating margin = 4 dB
C/N = 21 dB k = 1.38 x 10-23 J/K

Answer

Ts = 1250K = 31 dBK k = -228.6, B=72 hence kB=-156.6
Ps = 13 dBW
Pt = 24 dBW

Down link: $$\left(\frac{C}{T}\right)_D = E_s - L_D - M + \frac{G_e}{T_e}$$

$C/T_D = 13 + 25 - 199 - 4 + 55 - T_e = -110 - T_e$

3 marks

Uplink: $$\left(\frac{C}{T}\right)_U = E_e - L_U - M + \frac{G_s}{T_s}$$

$C/T_U = 24 + 55 - 204 - 4 + 25 - 31 = -135$ dBW/K $= 3.16 \times 10^{-14}$ (C/N_U=21.6)

2 marks

Overall C/N = 21 dB, hence $C/T_T = -135.6$ dBW/K $= 1.38 \times 10^{-14}$

$$\left(\frac{C}{T}\right)_T = \frac{1}{\dfrac{1}{(C/T)_U} + \dfrac{1}{(C/T)_D}}$$

Hence C/T_D = 2.14 x 10-14 = -126.7 dBW/K = -110 - T_e

2 marks

Te = 16.7 dBK = 47K

1 mark

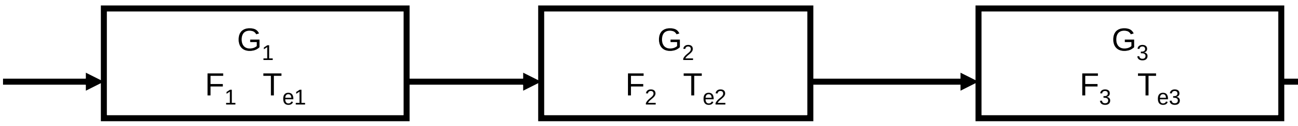
Q2

a. Hostile environment for satellites

Satellite components need to be specially “hardened”
Circuits which work on the ground will fail very rapidly in space
Temperature is also a problem – temperature gradient up to 200ºC across satellite - so satellites use electric heaters to keep circuits and other vital parts warmed up - they also need to control the temperature carefully: antennas need to be heat distortion resistant.
Corrosion
Withstand launch – vibration and G forces
Vacuum

6 marks

b.



Noise generated by each amplifier stage multiplied by gain of next stage and succeeding stages.
3 stage ampifier:
$C_{out} = C_{in}G_1G_2G_3$
$N_{in} = k\,T_0\,B$, $\quad T_0 = 290K$
$N_{out} = k\,T_0\,B\,G_1\,G_2\,G_3 + k\,T_{e1}\,B\,G_1\,G_2\,G_3 + k\,T_{e2}\,B\,G_2\,G_3 + k\,T_{e3}\,B\,G_3$
Now $F_n = 1 + T_{en} / T_0$
Then $N_{out} = N_{in}\,G_1\,G_2\,G_3 + N_{in}\,(F_1 - 1)\,G_1\,G_2\,G_3 + N_{in}\,(F_2 - 1)\,G_2\,G_3 + N_{in}\,(F_3 - 1)\,G_3$
$F = (C_{in}/N_{in})/(C_{out}/N_{out})$ =

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1G_2} + \ldots\ldots.\frac{F_n - 1}{G_1G_2..G_{n-1}}$$

The noise performance of the first amplifier is important as the noise carries through to the receiver and to large extent determines the receivers performance.

6 marks

c.

For receiver alone

$C_o / N_o = C_i/(N_iF)$ $\qquad\qquad$ $F = (T_o + T_R)/T_o$

$N_i = kT_oB = k290B$ and $N_iF = kT_oB\,(T_o + T_R)/T_o = kB(T_o + T_R)$ **3 marks**

$C_o / N_o = Ci / \{k\,B\,(290 + TR)\} = 5$ dB = 3.16 ….**(1)**

1 mark

For receiver and pre-amplifier

Co / No = Ci / { k B (290 + Tsys) } = 21 dB = 125.9 ……**(2)**

1 mark

Pre-amplifier gain = 25 dB = 316

Hence

Tsys = Tpre-amp + TR / 316 $(T = T_1 + T_2/G_1)$

Pre-amplifier noise figure = 2 dB = 169.6 K

Tsys = 169.6 + TR / 316

Substitute for Tsys in equation 2 and solve equations 1 and 2 for TR

125.9(290+169.6 + TR/316) = 3.16(290+TR)

Hence TR = 20676 K

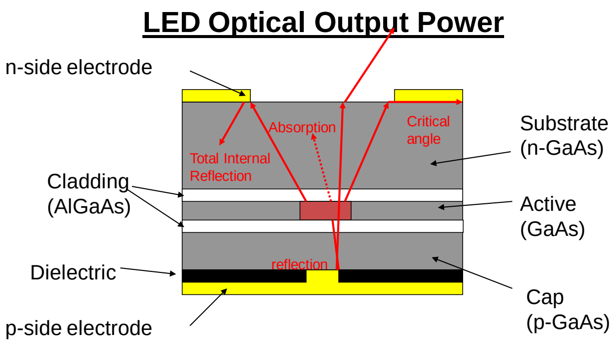
Receiver noise figure = 10 log10 (1 + 20676 / 290) = <u>18.59 dB</u>

3 marks

Q3

a.

LED – spontaneous emission – low current densities

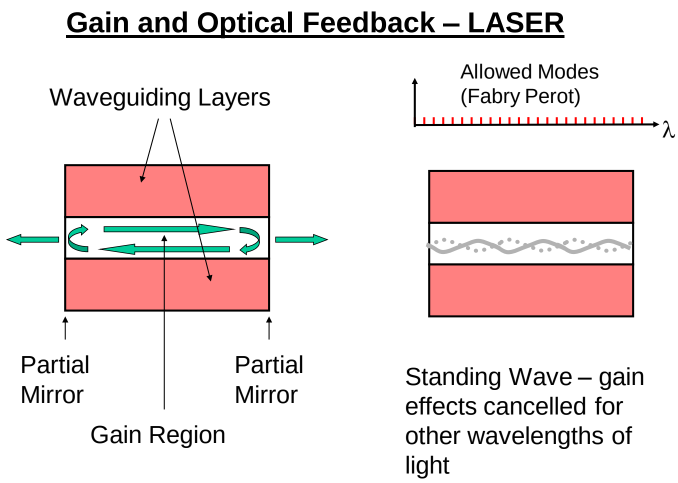


Typical external efficiencies of only ~1-3%

Surface and edge emitting types

3 marks

Laser – high current densities – stimulated emission – optical feedback

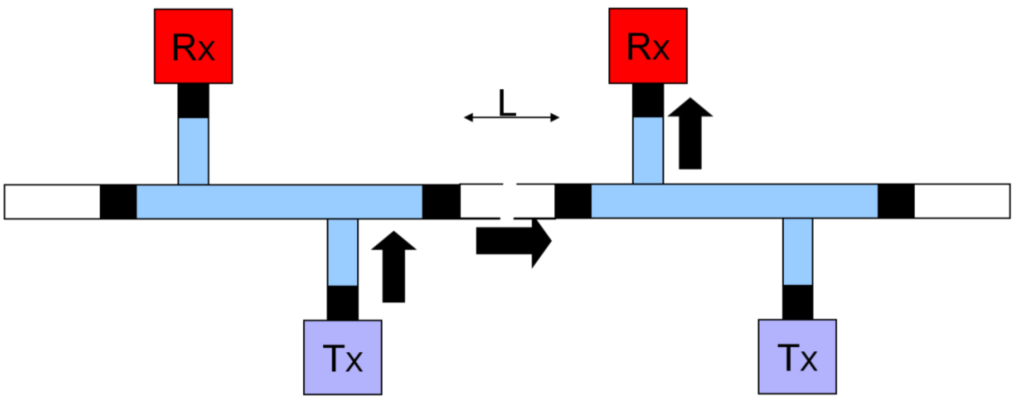


Fabry Perot cavity length = $n\lambda/2$ for transmission

3 marks

Choose laser for long distance system due to higher power and narrower line width **2 marks**

b.



Candidates need to know how couplers work and losses associated with them

Connecting Loss L_c

Tap Loss (coupling) L_{tap} per tap,

Intrinsic Transmission Loss L_i

Loss Between Nearest Neighbours Tx-Rx

$= \alpha L + 2L_{tap} + 4L_c + 2L_i$ (α L=fibre loss/m)

Loss Between station 1 and N

2 Connectors per station – intrinsic loss at each station

@ transmitting and detector ends– one tap loss

@ intermediate stations – one L_{thru} losses

<u>Total Loss = $(N-1)\alpha L + 2NL_c + 2L_{tap} + (N-2)L_{thru} + NL_i$</u> **6 marks**

Detector used in Bus system will detect a large power at station 1 than at station N

The Detector must have a dynamic range equal to that of the Bus system = ratio of power levels received at station 1 and station N

In DB = difference between nearest neighbour and longest length power budget

Dynamic Range = $(N-2)(\alpha L + 2L_c + L_{thru} + L_i)$ **2 marks**

Now Tap loss L_{tap} = 10 dB = 10, hence CT = 0.1 and

$L_{thru} = -10 \log (1-C_T)^2 = -20 \log(1-C_T)$ dB = 0.9 dB

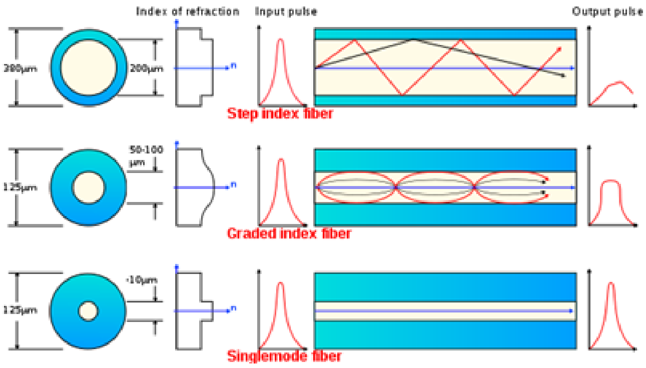
Connector loss L_c = 1 dB

Intrinsic transmission loss L_i = 0.5 dB

<u>Hence Dynamic range = 10 x (0.3x0.6 + 2x1 + 0.9 + 0.5) = 8 x 3.6 = 35.8 dB</u> **4 marks**

Q4

OPTICAL FIBRE TYPES



Step Index Fibre

- This cable has a specific index of refraction for the core and the cladding. It causes deformations due to the various paths lengths of the light ray. This is called modal distortion. It is the cheapest type of cabling. Within the cladding and the core, the refractive index is constant. Light propagates from reflections at the cladding.

Graded Index Fibre

- In graded index fibre, rays of light follow sinusoidal paths. Although the paths are different lengths, they all reach the end of the fibre at the same time. Multimode dispersion is eliminated and pulse spreading is reduced. Graded Index fibre can hold the same amount of energy as multimode fibre. The disadvantage is that this takes place at only one wavelength.

Single mode fibre

- Single mode propagates, low dispersion and loss.

6 marks

b. Dispersion

Dispersion Summary

Intermodal dispersion → **MODAL DISPERSION**
(ie between modes)

Multi-mode fibres only; minimised for graded-index fibres

Chromatic or → **MATERIAL DISPERSION**
Intramodal dispersion
(ie within a single mode) → **WAVEGUIDE DISPERSION**

Single or multi-mode fibres but only significant for single mode fibres.

Chromatic dispersions are wavelength dependent

Chromatic much less than modal dispersion. Choose a laser source with a narrow line width to reduce effects of chromatic dispersion.

6 marks

c. . $E = hv = hc/\lambda$

At 1300 nm Energy of 1 photon = $6.6 \times 10^{-34} \times 3\times10^{8}/1300\times10^{-9} = 1.53 \times 10^{-19}$ J

Need 1200 photons to detect 1 bit at 2 Gb/s

Need a peak received power of $1.53 \times 10^{-19} \times 1200 \times 2000 \times 10^{6} = 3.672 \times 10^{-7}$ W

Average power = peak power/2 = 1.83×10^{-7} = -67.4 dBW = -37.8 dBm

Launch power = 6 dBm

Assuming no margin have 43.8 dB available in power budget as a loss in fibre

Loss = 0.8dB/km, **hence fibre length = 43.8/.8 = 54 km.**

6 marks

To transmit a much higher data rate over the same distance –

- use narrower line width source
- use course wdm
- change wavelength to where D=0 **2 marks**