Q1

FM

Advantages:

- Constant amplitude means that power efficient non-linear power amplifiers can be used.
- Better signal to noise ratio can be achieved (compared with AM) if bandwidth is sufficiently high.

Disadvantages:

- Usually occupy more bandwidth than AM.
- More complicated hardware.

AM

Advantages

- Low bandwidth
- Easy to modulate, demodulate signal

Disadvantages

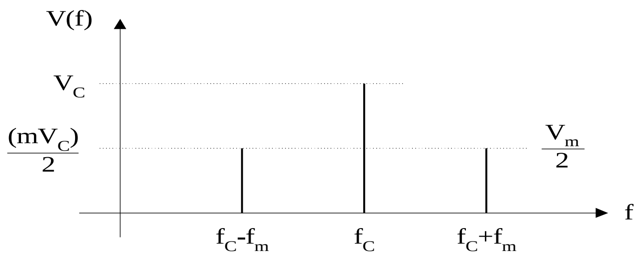
- Fading
- Interfering signals received additively and must be discriminated during demodulation
- Noise greatly affects amplitude of received signal
- Hard to lock frequency of receiver local oscillator to carrier frequency (esp. in S.C. systems)

6 marks

(b) $$V_{AM} = V_c(1 + m\sin\omega_s t)\sin\omega_c t$$

This is a wave of frequency ω_c whose amplitude varies sinusoidally at the modulating signal frequency ω_s. It is amplitude modulated. The expanded expression is given below

2 marks



4 marks

(c)

(i) Carrier power = 2x 10^3 = V_C^2/ 50 . V_C = 316.2 V rms

Then lower sideband amplitude = $mV_C/2$ = 0.8 x 316.2/2 = 126.4 V rms = **<u>178V pk</u>** since m=0.8 when V_{in} = 8V.

(ii) Total sideband power = 2 x $(mV_c/2)^2$/ 50 = 0.64x316^2/100 = 640 W

Ratio of SB to carrier power = 640 / 2000 = **<u>0.32</u>** (also from $m^2/2$= 0.64/2)

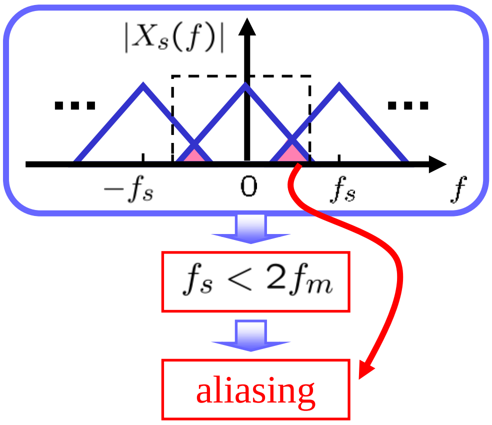
(iii) Since the transfer characteristic of the modulator is linear, if input amplitude reduced from 8V to 6V then m decreases from 0.8 to 0.6

Output power is now $P_c(1+m^2/2)$ $2000(1+0.6^2/2)$ = **2360 W**

8 marks

Q2

(a) Sampling theorem – min 2 samples at highest signal frequency



Aliasing

4 marks

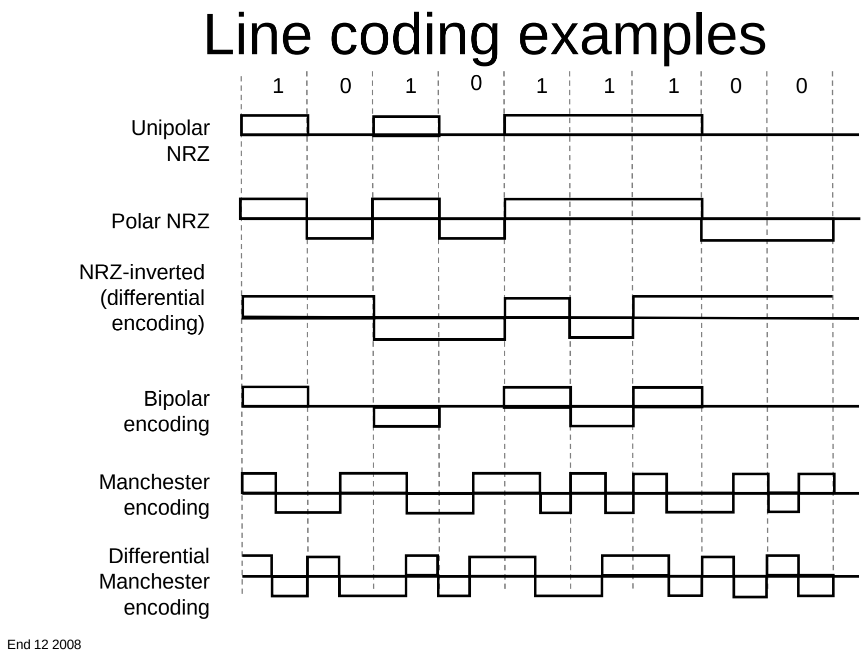
(b)

LINE CODING _ baseband transmission

To transmit information through physical channels, binary 0s and 1s such as PCM sequences (codewords) for example have no timing information - can be transformed to pulses (waveforms) called Line Codes which can be more efficient in transmitting data.

There are two major categories: return to zero (RZ) (returns to zero at end of bit - timing information) and non return to zero (NRZ) which has no timing information.

- Mapping of binary information sequence into the digital signal that enters the channel
  - Ex. “1” maps to +A square pulse; “0” to –A pulse **4 marks**



2 marks

(c)

$$C = B\log_2(1+\frac{S}{N})$$

C = information carrying capacity of the channel in bits / sec
B = bandwidth in Hz
S = signal power in watts
N = noise power in watts **4 marks**

S/N = 30 dB ≡ 1000

C = 20000 $\log_2$ (1 + 1000) [$\log_2(x) = \log_{10}(x)/\log_{10}(2)$]

= 20000 x 9.968 = <u>199360 bits/sec</u> **2 marks**

If the S/N in a 40 kHz bandwidth is 1000 this is equivalent to a noise power of 1 mW when the signal power is 1000 mW. The signal power is unchanged when the bandwidth is doubled but when the bandwidth is doubled, so is the noise power.

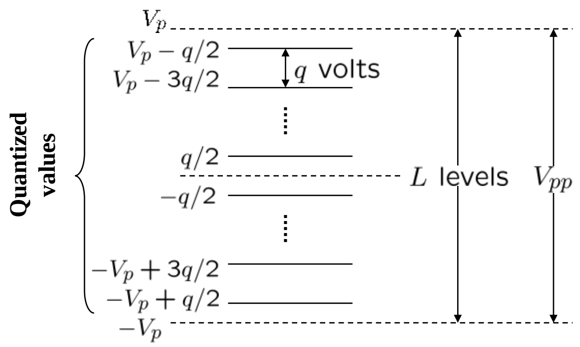
∴ C = 40000 $\log_2$ (1 + 1000/2)

= 40000 $\log_2$ (501) = <u>358780 bits/sec</u> **4 marks**

Q3

(a)

Quantization errors



- Average quantization noise power $\sigma^2 = \frac{q^2}{12}$
- Signal peak power $V_p^2 = \frac{L^2 q^2}{4}$
- Signal power to average quantization noise power $\left(\frac{S}{N}\right)_q = \frac{V_p^2}{\sigma^2} = 3L^2$

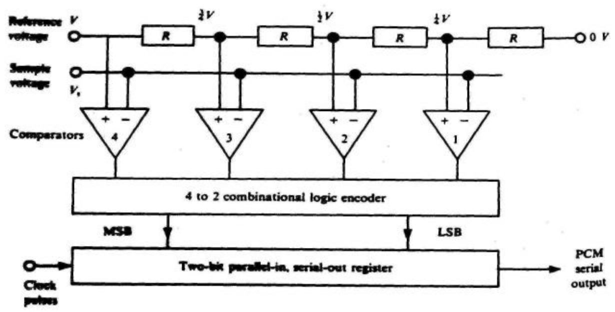
6 marks

(b)

PCM generation - outline

- Analog signal is sampled.
- Converted to discrete-time continuous-amplitude signal (Pulse Amplitude Modulation)
- Pulses are ***quantized*** and assigned a digital value.
  - A 7-bit sample allows 128 quantizing levels.

Quantiser + encoder = analog-to-digital converter (ADC)



The fastest ADC type is the parallel comparator ADC, essential for PCM, which uses a chain of resistors to quantise voltage sample – 2 bit version shown.

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6 marks

(c) Number of quantisation levels = 2^N

where N= number of bits/sample.

Need know sample amplitude to 1 part in 50 (± 1%)

∴ Need at least 50 levels

∴ <u>Choose N = 6</u> (2^6 = 64 levels)

Quantisation S/N = $20\log_{10}q$ where q = no of levels

hence <u>S/N = 20 log 64 = 36.1 dB</u>

Channel bandwidth

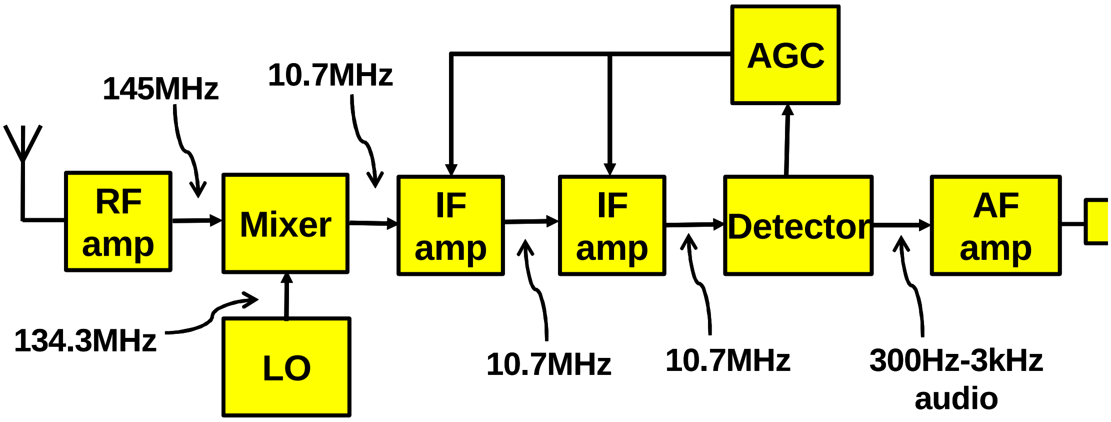
Bit rate = $2 x 20 x 10^3$ x 6 = 240 kbits/s

In receiver LPF bandwidth = 120 kHz minimum

8 marks

Q4

(a)



Tunable RF input frequency f_{RF} is converted to a single IF f_{IF} frequency by a tunable Local Oscillator (LO) f_{LO}

Mixer converts RF frequency to a lower frequency, the IF or intermediate frequency, that is easier to manipulate

IF frequency?

Standard frequencies are preferred 455kHz, 1.4MHz, 10.7MHz, 21.4MHz, 45MHz, 70MHz

Standard crystal and ceramic filters are low cost

Multiple tuned filter circuits are used to get selectivity in the IF

At high RF frequencies it is impossible to make sufficiently narrow filters for narrow band signals

…but we can do it at a lower IF

Amplifiers that work over wide frequency ranges (and with AGC) are difficult to make

But relatively simple for one fixed IF frequency

8 marks

(b) **Image is 2x IF away from the wanted frequency**

- Larger IF frequency makes suppression of image easier
- Too low an IF and the RF input filters are too difficult
- LO radiation is also a problem if it leaks up the antenna

4 marks

(c)

$f_{LO} = 900 - 70 = 830$ MHz.

$\therefore$ f image $= 830 - 70 =$ <u>760 MH</u>z. (1st IF image)

2nd IF $= 10$ MHz and 2nd LO > 70

i.e. $-\underset{\substack{\uparrow \\ 70}}{f_{sig}} + LO = 10$

$\therefore$ f 2nd LO $= 80$ MHz.

Then would have f 2nd image $= 70 + 20 =$ <u>90 MHz</u>.

Input signals causing 2nd IF image problems

$\therefore$ $f_2 - 830 = 90$ Hence $f_2 =$ <u>920 MHz</u>

$830 - f_3 = 90$ Hence f3 = <u>740 MHz</u>

8 marks