**Solutions to EEE206 Communication Systems May/June 2010**
**Set by Richard Langley**

## 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**

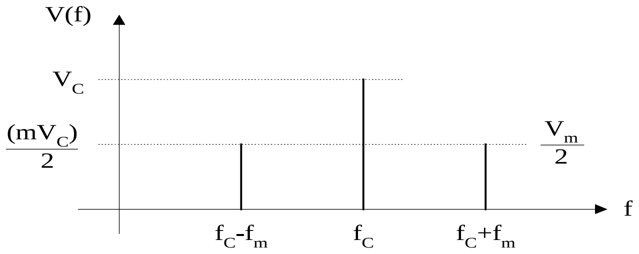
- Fading
- Interfering signals received additively and must be discriminated during demodulation
- Noise greatly affects amplitude of received signal
- Hard to lock frequency of receiver local oscillator to carrier frequency (esp. in S.C. systems)

6 marks

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

This is a wave of frequency $\omega_c$ whose amplitude varies sinusoidally at the modulating signal frequency $\omega_s$. 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 = $2 \times (mV_c/2)^2 / 50 = 0.64 \times 316^2/100 = 640$ 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 $P_c(1+m^2/2)$ $2000(1+0.6^2/2)$ = **<u>2360 W</u>**

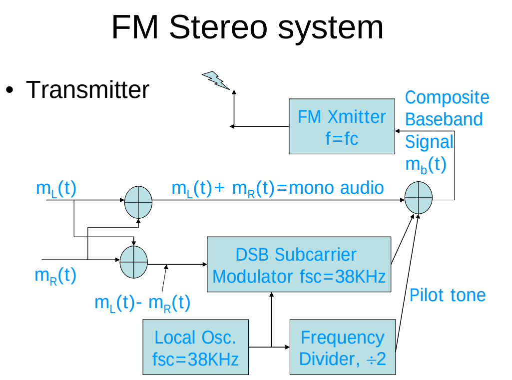
8 marks

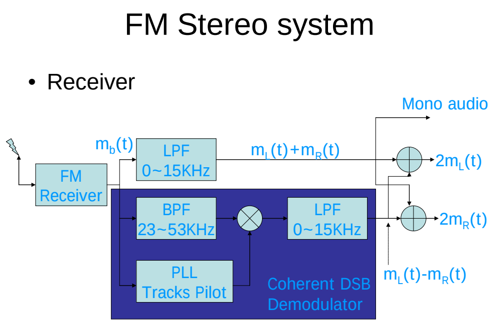
## <u>Q2</u>

(a) Many radio stations are simultaneously transmitting signals containing the same band of frequencies, e.g. audio/music. If everyone sent those signals as directly transmitted radio waves, interference would cause them to be inefficient and incomprehensible.
These signals can be received separately if a different <u>carrier</u> frequency is used for each station.
Improvement of signal-to-noise ratio
Ease of radiation in radio systems - to overcome hardware limitations -
Efficient radiation from antenna requires length to be $\geq \lambda/4$
e.g. at 10kHz: $\lambda/4$ = 750 km, at 100MHz: $\lambda/4$ = 75 cm
Enables multiplexing

**<u>4 marks</u>**

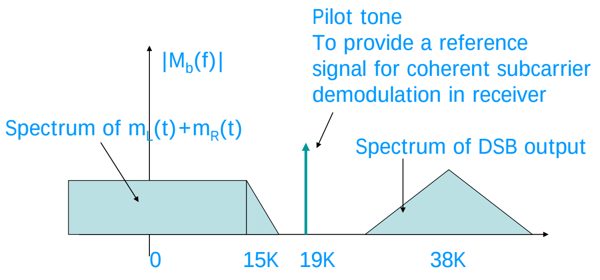
(b)



## FM Stereo system

- Spectrum of composite signal




**8 marks**

(c)

1st sidebands disappear when $J_1(\beta) = 0$

i.e. $\beta = 3.832$.

Then carrier amplitude $\propto J_o(3.832) = -\cdot 4$

2nd sideband amplitude $\propto J_2(3.832) = \cdot 4$

When carrier is unmodulated

$$\frac{V_c^{\,2}}{2.50} = 10000\text{W} \therefore V_c = 1000\text{V}$$

When $\beta = 3.832$

carrier power $= \dfrac{V_c^{\,2}}{2R}\cdot\left[J_o(\beta)\right]^2 = 100\times 0.16 = 10000\text{x}0.16 = \underline{1600\text{ W}}$

$\therefore$ Power in remaining sidebands $= 10000 - 1600 = \underline{8400\text{ W}}$

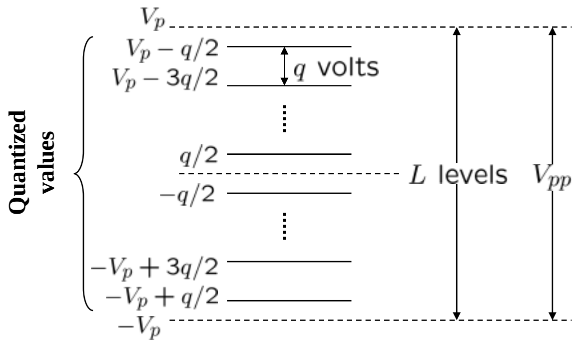
2nd sideband power

$= \dfrac{2V_c^{\,2}}{2R}\left[J_2(\beta)\right]^2 = 2.100.0\cdot 16 = 2\text{x}10000\text{x}0.16 = \underline{3200}\text{ W}$ **8 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 $\left(\frac{S}{N}\right)_q = \frac{V_p^2}{\sigma^2} = 3L^2$

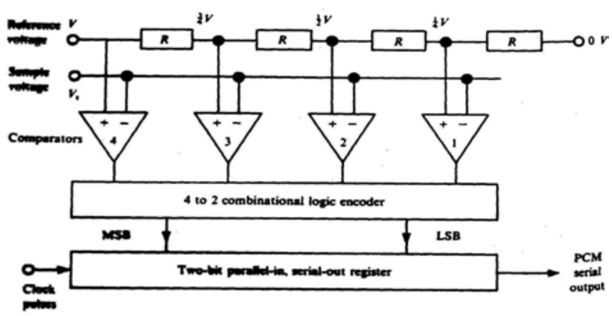
**<u>6 marks</u>**

(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.



**<u>6 marks</u>**

(c) Number of quantisation levels = $2^N$

where N= number of bits/sample.

Need know sample amplitude to 1 part in 50 ( $\pm$ 1%)

$\therefore$ Need at least 50 levels

$\therefore$ Choose N = 6 ( $2^6$ = 64 levels)

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

hence S/N = 20 log 64 = 36.1 dB

Channel bandwidth

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

In receiver LPF bandwidth = 120 kHz minimum

**8 marks**

## Q4

(a)

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

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**

(b)
(i) In this case, we do not know the actual value of the maximum frequency component in the message, but a sampling frequency of 44 kHz would suggest about 24 kHz, i.e. the message is slightly oversampled. Then for simplicity, estimate the minimum bandwidth = sampling frequency = ***44 kHz***

2 marks

(ii) Number of quantisation levels q = $2^{10}$. Hence S/N = $q^2 = 2^{20}$ = 1048576 2 marks

(iii) C = $44 \times 10^3 \times \log_2(1 + 2^{20}) = 44 \times 10^3 \times 6.02 / 0.301$
***= 880 K bits /sec*** 2 marks

(c) Multiplexing is a technique for sending many signals simultaneously over the same transmission medium, e.g. cable, optical fibre, radio link.

Most common forms of multiplexing are FDM, TDM, wavelength division multiplexing and code division multiplexing.
For FDM students should give a detailed description of the formation of a group of 12 channels, plus an outline of the higher combination hierachy.
For TDM, ditto and mention the 30 + 2 architecture - 2 channels for framing etc.

**5 marks**

(d)
Using SSB-SC, each channel occupies 20 + 4 = 24 kHz.
Hence number of channels = $45 \times 10^6 / 24 \times 10^3$ = **<u>1875</u>**

**3 marks**

(e) TDM with PCM will take up much more bandwidth but with a better quality signal (S/N).

2 marks