EEE 224/227

Solutions to Tutorial Sheet 4

1. Sampling frequency = 8 kHz.

$\therefore$ Time between adjacent samples of same channel = 125 μs.

Each channel requires 2 + 3 + 3 + 2 = 10 μs

$\therefore$ Number of 10 μs slots in 125 μs = 12.

i.e. <u>12 channels can be transmitted</u>.

2. (a) All channels sampled equally, therefore number of samples per second = 2 x 8 x 10,000 = <u>160,000</u>

(b) Hence, according to Nyquist, with this number of samples we can recover a composite waveform with a maximum bandwidth of 80 kHz.
Hence LPF bandwidth = <u>80 kHz</u>

(c) Total SSB bandwidth

= 2 x 10 + 6 x 3.3 = <u>39.8 kHz</u>.

(d) New sampling scheme

Use 1 pole, 12 way rotary switch with contacts 1 and 2 connected to 10 kHz signals and contacts 3 to 8 connected to 3.3 kHz signals.

Now max frequency of input data is essentially
10/3 = 3.33 kHz.

$\therefore$ Sampling frequency for 1 channel = 2 x 3.33 = 6.66 kHz.

$\therefore$ For 12 channels = 12 x 6.66 = <u>80 kHz</u>.

$\therefore$ Again from Nyquist, LPF bandwidth = <u>40 kHz</u>.

SSB bandwidth = <u>40 kHz</u>.

3. Number of quantisation levels $= 2^N$

where N = number of bits/sample.

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

$\therefore$ Need at least 50 levels

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

4. $f_c = 1.5 + (2{\cdot}8 - 1{\cdot}5)/2 = 2.15$ kHz.

$\Delta f = (2{\cdot}8 - 1{\cdot}5)/2 = 0{\cdot}65$ kHz.

Bandwidth required = 2 x data signal bw + 2 x Δf

= 2 x 100 + 2 x 650 = $\underline{1{\cdot}5 \text{ kHz}}$.

If data rate now 1000 bits/sec

LF = $2{\cdot}15 - 0{\cdot}65 - 1 = \underline{500 \text{ Hz}}$.

HF = $2{\cdot}15 + 0{\cdot}65 + 1 = \underline{3{\cdot}8 \text{ kHz}}$.

5. (a) $f_{IF} = f_{LO}$ - fsig $= 2{\cdot}86 - 2{\cdot}8 = 0.06$ GHz $= \underline{60 \text{ MHz}}$.

(b) Mutual interference between the receivers could occur if the local oscillator radiation from one receiver was picked up by the other. For example, the first receiver has an image frequency of 2.92 GHz. Hence, if the local oscillator in the second receiver was set to 2.92 GHz then this could cause intereference to the first receiver. In this case the second receiver is tuned to 2.92 – 0.06 = 2.86 GHz.
Alternatively, if the local oscillator of the second receiver was set to 2.80 GHz, its input signal frequency would be 2.80 – 0.06 = 2.74 GHz.

(c) Either receiver can be tuned to receive a signal over the range 2.8 to 3.0 GHz. Hence neither receiver will interfere with the other if the IF is increased to at least 200 MHz.

6. $f_{LO} = 136 - 30 = 106$ MHz.

$\therefore$ f image $= 106 - 30 =$ 76 MHz. (1st IF image)

2nd IF $= 10$ MHz and 2nd LO > 30

i.e. $- \underset{\substack{\uparrow \\ 30}}{\text{f sig}} + \text{LO} = 10$ $\therefore$ f 2nd LO $= 40$ MHz.

Then would have f 2nd image $= 30 + 20 = 50$ MHz.

6cont $\therefore$ $f_2 - 106 = 50$ $\underline{f_2 = 156 \text{ MHz}}$

$106 - f_3 = 50$ $\underline{f_3 = 56 \text{ MHz}}$

Input signals causing 2nd IF image problems

7. $f_{LO} > f$ sig

$\therefore$ $f_{LO} - f\text{ sig} = f_{IF}$

$f_{IF} = 1010 - 555 = 455$ kHz

$\therefore$ f image $= f\text{ sig} + 2\, f_{IF}$

$= 555 + 2 \times 455 =$ 1465 kHz.

$$\rho = \frac{\text{f image}}{\text{f signal}} - \frac{\text{f signal}}{\text{f image}}$$

$$= \frac{1465}{555} - \frac{555}{1465} = 2{\cdot}640 - 0{\cdot}379$$

$$= 2{\cdot}261$$

$$\therefore \quad \alpha = \sqrt{1 + Q^2\rho^2}$$

$$= \sqrt{1 + 40^2 \times 2.261^2} = 90.4$$

$$\alpha_{dB} = 20 \log_{10}(\alpha) = \underline{39.1 \text{ dB}}$$

8. $\alpha = \alpha_1 \alpha_2$ and $\alpha_1 = \alpha_2$

$$\therefore \alpha = 120 = \sqrt{1 + Q^2\rho^2}^{\,2}$$

$$\therefore Q^2 = \frac{120 - 1}{\rho^2} \qquad \text{i.e. } Q = \frac{\sqrt{119}}{\rho}$$

$f\ signal = 15\ MHz$

$IF = 450\ kHz$ $\therefore\ f_{LO} = 14.55\ MHz.$

$\therefore\ f\ image = f\ sig - 2 \times f_{IF}$

$= 15 - 0.9 = 14.1\ MHz.$

$$\rho = \frac{f\ image}{f\ signal} - \frac{f\ signal}{f\ image} = \frac{14.1}{15} - \frac{15}{14.1}$$

$$= 0.94 - 1.064$$

$\therefore\ |\rho| = 0.124$

$$\therefore Q = \frac{\sqrt{119}}{0.124} = \underline{88}$$

9. $S/N = 32\ dB \equiv 1585$

Then from Hartley Shannon Law

$C = B \log_2 (1 + S/N)$

$= 3100 \log_2 (1 + 1585)$

$= 3100 \times 10.63 = \underline{32953\ bits/sec}$

10. $S/N = 28\ dB \equiv 631$

$C = 4000 \log_2 (1 + 631)$

$= 4000 \times 9.305 = \underline{37219\ bits/sec}$

If the S/N in a 4 kHz bandwidth is 631 this is equivalent to a noise power of 1 mW when the signal power is 631 mW. The signal power is unchanged when the bandwidth is doubled but when the bandwidth is doubled, so is the noise power.

$\therefore\ C = 8000 \log_2 (1 + 631/2)$

$= 8000 \log_2 (316.5) = \underline{66455\ bits/sec}$