EEE6430 2013 Solutions

Q1

a. The Random Access (RA) burst is only used on the uplink and carries the RA logical channel. It is so called because a mobile station (MS) handset transmits this type of burst at random times, and only when it is trying to gain initial access to the system. There are 88 bits ($= 324.7\mu s$) of data in the burst and the long guard period of 68.25 bits ($= 251.8\mu s$) allows for propagation delay between the MS and base transceiver station (BTS). Such an allowance is important because of the synchronous nature of the time division multiple access (TDMA) protocol, in which propagation delay must be accounted for. The MS will be synchronised to the data stream from the BTS when it is idling on standby. It will know the timing of the random access time slot, and when required the MS will start transmitting when it thinks this time slot starts. However, in reality the time slot has already started (i.e. the BTS has started listening for random access bursts) d/c seconds ago, where d is the distance between the BTS and MS, and c is the propagation velocity of radio waves ($c = 3 \times 10^8 ms^{-1}$). It will also take d/c seconds for the MS transmission to reach the BTS, meaning that the access request will be received at the BTS 2d/c seconds after the listening period starts. For a successful access attempt, all the 88 bits must be received at the BTS, and to compensate for the propagation delay, the BTS actually listens for a time longer than is required to receive these, i.e. for an extra guard period corresponding to *68.25* bits. This therefore defines a maximum distance from which an MS can successfully access a BTS, i.e.:

$$\frac{2d_{max}}{c} = 3.69 \times 68.25 \times 10^{-6} \text{sec, so } d_{max} = 37.8\text{km} \quad (1)$$

Once a successful access attempt has been made, the BTS then instructs the phone to time advance (TA) its transmissions by

$$n \times 3.69 \times 10^{-6} \approx \frac{2d}{c} \text{ sec} \qquad (2)$$

(n = 0 to 63) so that the BTS actually receives data at the beginning of the time slot allocated to the MS. The maximum TA allowed is therefore 63, which corresponds to a propagation delay of $3.69 \times 63 = 232.47\mu s$, just inside the guard period. The TA cannot exceed this guard period since this would imply lost RA data. 6

b.

Since all bits are set equal in the burst, the spectrum is given by

$$\left[F(f) \times \delta_f(\frac{1}{T})\right] * \delta(f - f_c) \qquad (3)$$

where

$$F(f) = A \int_{-\frac{\tau}{2}}^{\frac{\tau}{2}} e^{-j2\pi ft} dt = A\tau \operatorname{sinc}(\pi f\tau) \quad (4).$$

F(f) defines the sinc function spectral envelope and $\delta_f(\frac{1}{T})$ the location of actual frequency components or harmonics.

Since all RA bits are set to '1' then $\tau = 324.7\mu s$.

$\delta_f(\frac{1}{T})$ is a series of delta functions in frequency separated by the reciprocal of the burst repetition period $T = 8 \times (324.7 + 251.8) = 4.612\text{ms}$.

The carrier frequency $f_c = 900\text{MHz}$.

Thus we can calibrate various features of the spectral sinc envelope therefore:

(i) From the given relation, sinc(1.895)=0.5 which defines the –6dB points since $20\log_{10} 0.5 = -6\text{dB}$, so from (4) $\pi f \tau = 1.895$ and therefore $f = \dfrac{1.895}{\pi\tau} = 1857.7\text{Hz}$.

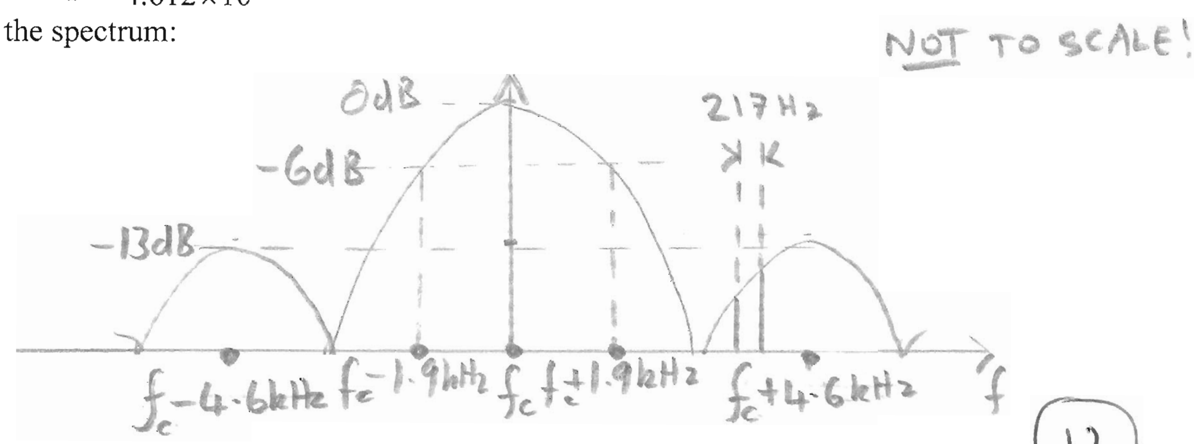
Thus actual frequencies are $f_c \pm f$ and the bandwidth is $2f = 3715.4\text{Hz}$.

(ii) Again from (4) at 1st sinc sidelobe $\pi f \tau = \dfrac{3\pi}{2}$, so $f = \dfrac{3}{2\tau} = 4619.6\text{Hz}$, so position of sidelobes is at $f_c \pm f$. Height of 1st sidelobe wrt main lobe is

$$A\tau \frac{\sin\left(\frac{3\pi}{2}\right)}{\frac{3\pi}{2}} / A\tau = \frac{2}{3\pi} = -13.5\text{dB} .$$

(iii) Frequency separation of spectral frequency components from (3) is given by $\delta_f(\frac{1}{T})$, so $\dfrac{1}{T} = \dfrac{1}{4.612 \times 10^{-3}} = 216.8\text{Hz}$.

Hence the spectrum:



12

c.

Buzzing interference may be heard due to the $f_c \pm n \times 216.8\text{Hz}$ frequency components mixing in the audio equipment to produce intermodulation products $n \times 216.8\text{Hz}$ within the audio frequency spectrum e.g. for two frequency components:

$$2\cos(2\pi f_c t) \times \cos(2\pi f_c t + 2\pi \times 216.8t) = \cos(2\pi \times 2f_c t + 2\pi \times 216.8t) + \cos(2\pi \times 216.8t) \quad (5)$$

The second term on the right of (5) causes the buzzing interference.

2

Q2

a.

Fast power control is required in WCDMA systems, since without it a single overpowered mobile could block an entire cell, or a mobile close to the base station could block those further away. The optimum strategy for maximising capacity therefore is to equalize the received power per bit from all mobile stations. Whereas open loop power control can be used to provide a coarse initial power setting for a mobile, the only effective solution is fast closed loop power control. Here the base station performs frequent estimates of the signal to interference ratio (SIR) on the uplink pilot bits on every slot of the DPCCH, and instructs the mobile to adjust its power to achieve a target SIR on the downlink TPC bits. This measure-command-react cycle is executed at a rate of 1500Hz for each mobile station and thus operates faster than any path loss change. The basic step size is 1dB. The near-far problem of one strong signal blocking weaker ones is not so important in the downlink direction since there is usually only one base station transmitting to a mobile. However closed loop power control is still used to provide additional signal power to mobiles on the edge of cells.

5

b.

Mobile transmit power P = 0.05W = 17dBm

Additional parameter: Dipole antenna directivity $D_d \approx 2\text{dBi}$

Additional parameter: Body Loss $L_b \approx 3\text{dB}$

So equivalent isotropic radiated power $\text{EIRP} = P + D_d - L_b = 16\text{dBm}$ (1)

Base station receiver noise density $\eta_t = -174\text{dBm/Hz}$

Receiver noise figure $N_f = 5\text{dB}$

Additional parameter: Receiver bandwidth $B \approx 3.84\text{MHz}$

10

So receiver noise power $N_o = \eta_t + 10\log_{10} B + N_f = -103.2\text{dBm}$

Interference margin $I \approx 3\text{dB}$

Chip rate $R_c = 3.84\text{Mcps}$

Data rate $R_d = 120\text{kbps}$

Additional parameter: processing gain $G_p = 10\log\left(\frac{R_c}{R_d}\right) = 15\text{dB}$

Required bit/noise power ratio $\frac{E_b}{N_o} = 5\text{dB}$

Minimum receiver signal power therefore is $S = N_o + I + \frac{E_b}{N_o} - G_p = -110.2\text{dBm}$ (2)

Base station antenna directivity $D_b = 14\text{dBi}$ (3)

Fading margin F = 7dB (4)

Additional parameter: cable/connector loss $L_c \approx 2\text{dB}$ (5)

Soft handover gain $G_h \approx 3\text{dB}$ (6)

Thus the *minimum* received signal power must equal the (system signal power) – *maximum* or allowed propagation loss L, thus from (1)-(6)

i.e. $S = (EIRP + D_b + G_h - L_c - F) - L$, hence

$$L = (EIRP + D_b + G_h - L_c - F) - S = 134.2\text{dB} \qquad (7)$$

c.

The range of the cell is therefore

$$R = 10^{\frac{L-137.4}{35.2}} = 0.81\text{km} \qquad (8)$$

(i) Indoors the signal would be partially screened or attenuated, and therefore this range would decrease

(ii) Away from the main beam of the antenna, the signal strength would decrease, and therefore the range would reduce 5

(iii) On high ground, obstacles that block the signal such as buildings would be avoided and therefore the range would increase

Q3

a.

The *primary* **C**ommon **C**ontrol **P**hysical **CH**annel (**CCPCH**) carries the higher layer downlink **B**roadcast (transport) **CH**annel (**BCH**). It needs to be demodulated by all terminals in a cell, and provides network and cell information and random access codes and access slots etc. The spreading factor is 256, giving a channel bit rate of 30kbps due to the rate doubling caused by QPSK modulation. The channel is time multiplexed with the **S**ynchronisation **CH**annel (**SCH**) and there are 2304 CCPCH chips and 256 SCH chips per time slot, and a 10ms multiplexed frame has 15 timeslots, as shown in the figure.

The **S**ynchronisation **CH**annel (**SCH**) is needed for cell search, and there are *primary* and *secondary* channels. The primary SCH uses a 256 chip spreading sequence identical in every cell. The secondary SCH uses sequences representing 64 code groups, and once the terminal has identified this channel it has obtained frame and slot synchronisation as well as information on the group the cell belongs to. No transport channel is mapped onto the SCH, and it is time multiplexed with the primary CCPCH as mentioned previously. The primary and secondary channels are sent in parallel.

The *secondary* CCPCH carries two downlink transport channels, the **F**orward **A**ccess **CH**annel (**FACH**) and the **P**aging **CH**annel (**PCH**). The FACH carries control information to terminals, and sometimes packet data as well. There can be more than one FACH in a cell. The PCH carries data relevant to initiating communication with a terminal. The spreading factor is fixed and determined according to the maximum data rate. The FACH and PCH may be multiplexed onto a single secondary CCPCH or they may use different CCPCH's, hence there may be additional secondary CCPCH's in a cell. 10

b.

This transport channel should have previously been identified in part 'a' as the BCH.
(i) The BCH symbol rate is given by

$$R_S = \frac{R_C}{S}$$

where the chip rate $R_C = 3.84 \times 10^6$ and spreading factor $S = 256$, so

$$R_S = \frac{3.84 \times 10^6}{256} = 15\text{kbps}$$ 6

(ii) The BCH instantaneous bit rate is then $2R_S = 30\text{kbps}$ due to QPSK.

(iii) The BCH average data rate R_D is reduced by the 90% occupancy of each time slot, since 256 chips are used by the SCH, and further by the two third rate coding, thus

$$R_D = 0.9 \times \frac{2}{3} \times R_S = 18\text{kbps}$$

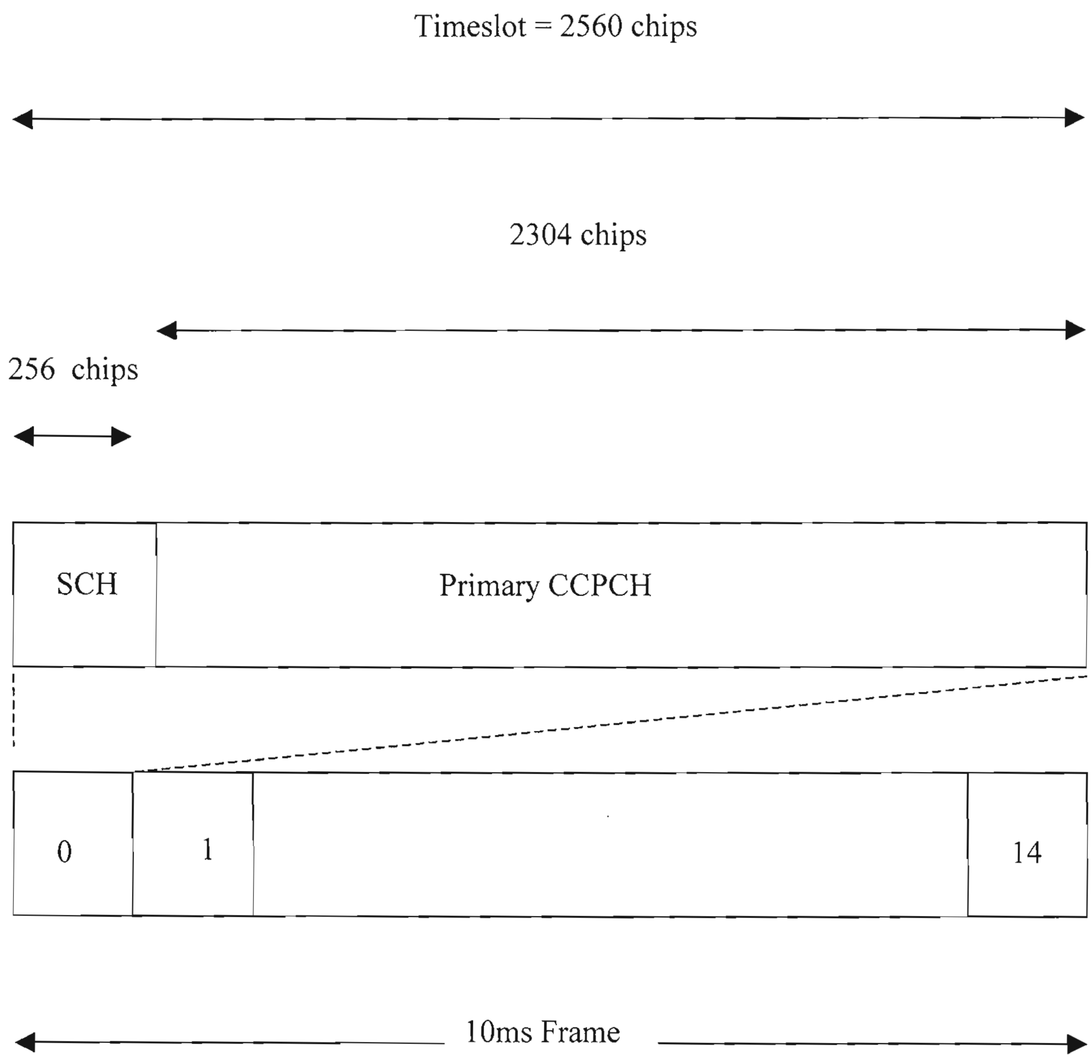


Fig 3.1

c.
These channels should have previously been identified in part 'a' as primary and secondary SCH. 4
(i) Their symbol rate is the same as for the CCPCH 15kbps.

(ii) The total SCH bit rate is 30kbps due to QPSK, but this is shared equally between primary and secondary channels, so the individual bit rates are 15kbps.

(iii) Their average bit rates are therefore $0.1 \times 15\text{kbps} = 1.5\text{kbps}$

Q4

a.

The various types of diversity gain are:

(i) Frequency diversity:

GSM: This is achieved by frequency hopping. The idea is that by transmitting consecutive frames on different frequencies, any wavelength dependent fading null will be ameliorated at the next frequency, and therefore the impact of this fading will be reduced. Typically 4 or 5 different frequencies are cyclically rotated.

3G: WCDMA has built in frequency diversity gain due to the wide signal bandwidth of ~5MHz compared to the 200kHz of GSM. Thus the wavelength changes sufficiently within the signal spectrum to reduce sharp fading nulls.

(ii) Polarization diversity:

Useful in both GSM and 3G networks. The signal from a mobile handset will have a constantly changing polarization ranging from vertical through slant to horizontal as the user moves. For maximum signal strength therefore the BTS needs to have orthogonally polarized antennas.

(iii) Space diversity:

GSM: Since a fading null is dependent on the receiver antenna location, then a second antenna separated by several wavelengths is unlikely to experience the same null. Hence by constantly comparing relative signal strengths and dynamically selecting the stronger antenna signal, the effects of fading can be ameliorated. Generally employed at the BTS since antenna separation distances are very limited at the handset.

3G: This can be achieved using Rake reception, in which antennas pointing in different directions and receiving direct and multipath reflected signals for instance are connected to different Rake fingers. The signal from each is then equalised and combined to give increased gain, thus making constructive use of multipath propagation.

(iv) Time diversity:

Not used in GSM, but in 3G Rake reception can again be employed but this time using a single antenna, and assigning delayed versions of the signal due to multipath propagation to different Rake fingers and then combining them for increased gain.

10

b.
At f = 1710.2MHz,

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{1710.2 \times 10^6} = 0.175418\text{m}$$

(i) If the path length difference is $\ell_r - \ell_d = 175.5057\text{m}$, then this corresponds to

$$\frac{175.5057}{0.175418} = 1000.5\lambda$$

Hence the direct and reflected path signals are in anti-phase, and will interfere destructively due to the odd number of half wavelengths between them. If their amplitudes were the same, then complete signal cancellation would occur, otherwise there will be partial cancellation.

(ii) At f = 1719.6MHz,

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{1719.6 \times 10^6} = 0.1744591\text{m}$$

corresponding to a path length difference of

6

$$\frac{175.5057}{0.1744591} = 1006\lambda$$

Thus the direct and reflected signals are now in phase due to the even number of half wavelengths, and will interfere constructively and enhance the signal.

c.

$$\ell_r = \ell_d + 175.5057\text{m} = 675.5057\text{m}$$

and

$$A = \cos^{-1}\left(\frac{\ell_d / 2}{\ell_r / 2}\right) = 42.3^{\text{o}}$$

The significance of this is with regard to the azimuth beamwidth of the BTS antenna, which may be less than $2 \times 42.3^{\text{o}}$, thus causing some attenuation of the reflected signal.

4