**EEE443/6430 2010 Solutions**

**Question 1**

**(a)**

(i) In rural areas with low population densities, a single *macro cell* could cover a relatively large area, since demand for channel allocations is small generally. Thus the BTS may be sited on an existing TV mast on a hill top for example. The antennas could be omni-directional, or sectored to increase capacity so that three cells are sited at one BTS for example.

(ii) In city centres with high population densities, many cells would be required to provide increased capacity. Further, since the number of rf channels available to a network is limited, it is desirable to re-use frequencies as often as possible to minimize limitations on capacity due to finite bandwidth allocations. Thus, cells are made small using low power BTS's which allows enhanced capacity by re-using frequencies through space diversity. The low power allows such *micro cells* using the same channels to be placed closer together without interfering with each other, especially if the cells are sectored. BTS's may be deliberately sited so as to limit their coverage to a few streets, using the shielding effects of buildings.

(iii) Motorways will require high capacity coverage due to the large potential population, but having many small cells for increased capacity may cause problems with fast moving vehicles requiring frequent hand-overs between cells. An *umbrella cell* can therefore be used which covers the same area as many smaller cells, and the network can then hand-over to this umbrella cell when it detects significant Doppler shift on the MS signal, indicating high speed.

(iv) In building coverage could be provided by *pico cells*. These have ranges comparable to WLAN transceivers, and would be connected to the mobile network via the internet, rather than using dedicated lines or microwave trunking.

**(b)**

The bit rate of a GSM signal is $1/\tau = 270kbps$, whereas the chip rate of a 3G WCDMA transmission is $1/\tau = 3.84Mbps$, where $\tau$ denotes the bit period. Therefore a delay of $\sim\tau$ in the reflected path (with respect to the direct path) from handset to BTS will potentially cause bit cancellation if the two signals are of comparable strengths. This delay corresponds to an extra reflected path length difference of $c\tau$ where $c = 3\times10^8 m/s$. Thus $c\tau|_{GSM} = 1.1km$ and $c\tau|_{3G} = 78m$, and in a city centre reflection off nearby buildings etc. will most probably cause path length differences of the order of the latter.

Rake reception could be used to compensate for this delay so that both direct and reflected path signals could be added coherently with correct time synchronization. The direct and reflected path signals would each be assigned a Rake finger, and delays and phase discrepancies between the two equalized before combining.

**(c)**

Typical mobile transmit power is

$$P_t = 20dBm \qquad (1.1)$$

Typical mobile antenna directivity is

$$D_m = 2dBi \qquad (1.2)$$

Typical body loss is

$$\eta_b = 2dB \qquad (1.3)$$

Equivalent Isotropic Radiated Power is

$$EIRP = P_t + D_m - \eta_b = 20dBm \qquad (1.4)$$

Typical receiver sensitivity

$$S - 120dBm \qquad (1.5)$$

Typical base station antenna directivity is

$$D_{BTS} = 18dBi \qquad (1.6)$$

Typical feeder loss

$$\eta_f = 2dB \qquad (1.7)$$

The maximum allowed propagation loss $L$ which must therefore define the cell boundary is when the received power reduces to *–120dBm* from an initial effective power of $EIRP + D_{BTS} - \eta_f$, so

$$EIRP + D_{BTS} - \eta_f - L = S \qquad (1.8)$$

or

$$L = EIRP + D_{BTS} - \eta_f - S = 156dB \quad (1.9)$$

From the given formula therefore, the typical range $R$ of the cell is

$$R = 10^{\frac{156-137.4}{35.2}} = 3.4km \qquad (1.10)$$

## Question 2

**(a)**

(i) The Common PIlot CHannel (CPICH) is an unmodulated code channel which is scrambled with the cell specific scrambling code. Its function is to aid the channel estimation at the mobile terminal. There are two types, *primary* and *secondary.* An important use for the primary channel is in measurements for handovers and cell selection/reselection, and by adjusting the CPICH power level the cell loading can be balanced between different cells. For instance, reducing the power causes some terminals to handover to other cells, while increasing it invites more terminals to handover to the cell, as well as to make their initial access to the network in that cell. The channel does not carry any higher layer information and no transport channel is mapped to it. The CPICH uses a spreading factor of *256*, and may be sent from two antennas if *transmission diversity* is used, in which case a simple modulation pattern is transmitted from the second antenna on the *secondary* CPICH for differentiation.

(ii) The Synchronisation CHannel (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, using the first *256* chips out of each *2560* chips of a timeslot. The primary and secondary channels are sent in parallel.

(iii) The *primary* Common Control Physical CHannel (CCPCH) carries the higher layer downlink Broadcast (transport) CHannel (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 channel bit rate is *30kbps* with a spreading factor of *256*, and it is time multiplexed with the SCH as mentioned previously. A *10ms* CCPCH frame has *15* timeslots. The *secondary* CCPCH carries two downlink transport channels, the Forward Access CHannel (FACH) and the Paging CHannel (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.

(iv) The Paging Indicator CHannel (PICH) operates with the Paging (transport) CHannel (PCH) to provide terminals with efficient sleep mode operation. A channelisation code length of *256* is used, and the Paging Indicators (PI) occur once per slot on the PICH. There can be up to *144* paging indicators per *10ms* PICH frame. For detection of the PICH the terminal needs to obtain the phase reference from the CPICH. Once a PI has been detected, the terminal decodes the next PCH frame on the *secondary* CCPCH to see whether the paging message was intended for it.

**(b)**

(i) $Chip\ rate = 3.84Mc/s$ so baud rate is

$$\frac{3.84 \times 10^6}{256} = 15kb/s\,.$$

Since QPSK carrier modulation is used, the bit rate is therefore twice the baud rate at $30kb/s$.

(ii) Data is transmitted for $\frac{4096}{4096+1024}$ of the time, so average data bit rate is given by

$$0.8 \times 30 = 24kb/s\,.$$

However, with half rate coding average data rate is $12kb/s$.

**(c)**

If only timeslot 2 is used, then data is only transmitted for $0.8 \times \frac{1}{15}$ of the time, so the average data rate reduces to $\frac{12}{15} = 0.8kb/s$.

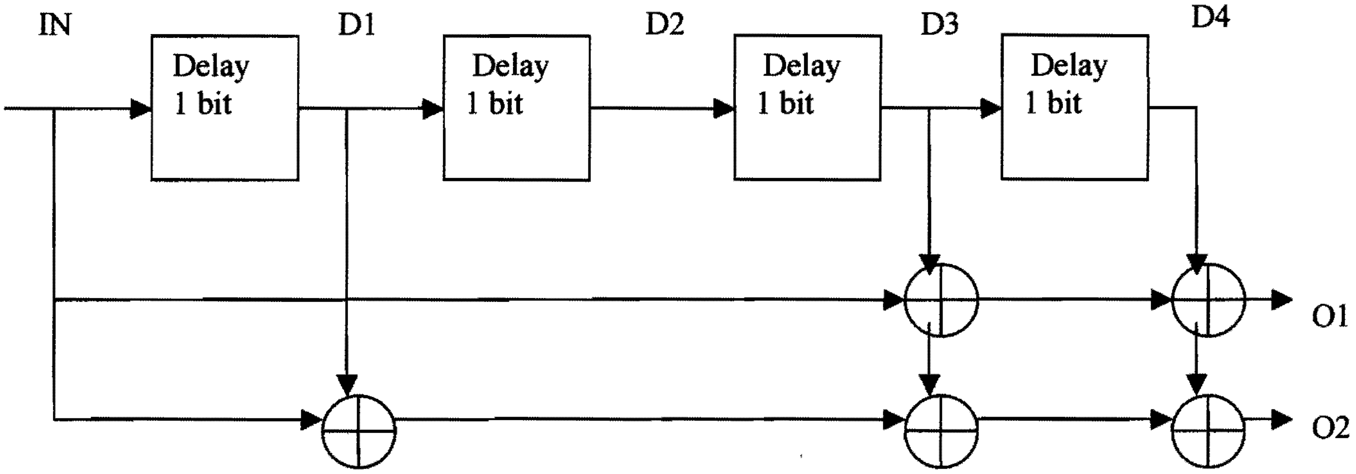
**(d)**

The remaining *1024* chips could be used to send data requiring fewer bits and hence a lower average data bit rate. They could alternatively be used as a guard period to aid synchronisation.

## Question 3

**(a)**

Convolution coding:




| | |
|---|---|
| **Bit stream** | **1 0 1 1 0** |
| **IN (add four 0 bits)** | **1 0 1 1 0 0 0 0 0** |
| **D1** | **0 1 0 1 1 0 0 0 0 0** |
| **D2** | **0 0 1 0 1 1 0 0 0 0 0** |
| **D3** | **0 0 0 1 0 1 1 0 0 0 0 0** |
| **D4** | **0 0 0 0 1 0 1 1 0 0 0 0 0** |
| **O1 = IN+D3+D4** | **1 0 1 0 1 1 0 1 0** |
| **O2 = IN+D1+D3+D4** | **1 1 1 1 1 1 0 1 0** |

**(b)**
The *20ms* speech block is coded onto the traffic channel as *456* bits.
The *456* bits are sent over eight traffic channel time slot bursts in the following manner:

Bits 0,8…448 comprise the even bits of burst N
Bits 1,9…449 comprise the even bits of burst N+1
Bits 2,10…450 comprise the even bits of burst N+2
Bits 3,11…451 comprise the even bits of burst N+3
Bits 4,12…452 comprise the odd bits of burst N+4
Bits 5,13…453 comprise the odd bits of burst N+5
Bits 6,14…454 comprise the odd bits of burst N+6
Bits 7,15…455 comprise the odd bits of burst N+7

Thus *57* bits of a particular speech block appear in each burst, and these are interleaved with *57* bits from another block. If the *456* bits were just sent in *4* consecutive frames, then if noise knocked out a frame *25%* of consecutive data would be lost, making recovery difficult. But this way, only *12.5%* of data from a particular speech block is lost, and additionally it is not consecutive data, so the chance of recovery is improved. For instance, speech blocks A,B,C map as follows

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Even Bits | B | B | B | B | C | C | C | C | | | |
| Odd Bits | A | A | A | A | B | B | B | B | C | C | |

Burst N N+1 N+2 ..

**(c)**

(i)

Channel bit rate is

$$R_b = \frac{1}{20 \times 10^{-3}} \times 228 = 11.4 kbps \qquad (3.1)$$

(ii)

Convolution coding will add $\sim 1.75$ times the bits to the speech payload. Hence the actual speech data rate is

$$R_d \approx \frac{11.4}{1.75} = 6.5 kbps \qquad (3.2).$$

## Question 4

**(a)**

$$\frac{P}{4\pi r^2}G = P_d \qquad (4.1)$$

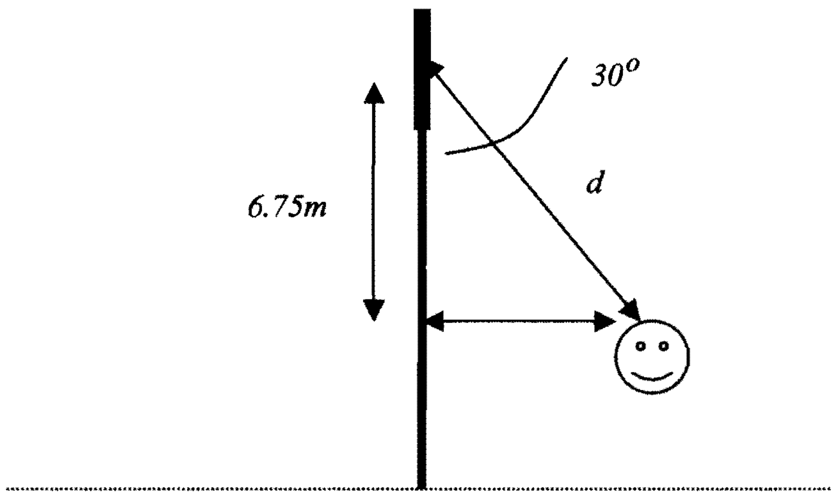
where

$G = 50$, $P_d = 100W/m^2$, P=10W.

Hence

$$r = \sqrt{\frac{PG}{4\pi P_d}} = \sqrt{\frac{10\times 50}{4\pi 10^2}} = 0.63m \qquad (4.2)$$

**(b)**




Distance to head from antenna,

$$d = \frac{6.75}{\cos 30^o} = 7.8m \quad (4.3)$$

If the sidelobe is *27dB* below the main lobe, there is effectively *10dB* of attenuation from isotropic, so from (4.1)

$$P_d = \frac{10}{4\pi\times 7.8^2}\times 0.1 = 1.3mW/m^2 \quad (4.4).$$

**(c)**

Assume for simplicity that we are in the far field of the antenna, and that there is no power absorption due to reactive near fields. Using (4.1), for the mobile handset $P = 0.1W$, $G = 2dBi$, so

$$P_d \approx \frac{P}{4\pi r^2}G \approx 1.3W/m^2 \qquad (4.5).$$

**(d)**

The incident power density on the head from a handset is ~*1000* times greater than that incident on a pedestrian from a BTS antenna, even when the handset is held quite far from the head, and both are well below safety limits. To exceed this limit one would have to climb the BTS antenna mast, and then the greatest threat to health would be from falling off.

There could be a bedroom window in line with the main lobe of the BTS antenna. Assuming this is *5m* away, then

$$P_d = \frac{10 \times 50}{4\pi \times 5^2} = 1.6W / m^2 \qquad (4.6).$$

We now have a power density of the same order of magnitude as when using a handset. One could argue however that this is more significant since the BTS is potentially transmitting *24/7*, whereas typical handset usage may be for only *30 mins* a day, and the recipient has no control over exposure time if he remains in the bedroom.