SOLUTIONS TO EEE443/6430 2012

Q1)

(a)

(i) **F**requency **C**orrection **CH**annel (FCCH) is a downlink channel and maps onto the *frequency correction burst*. It is used by the MS as a frequency reference.

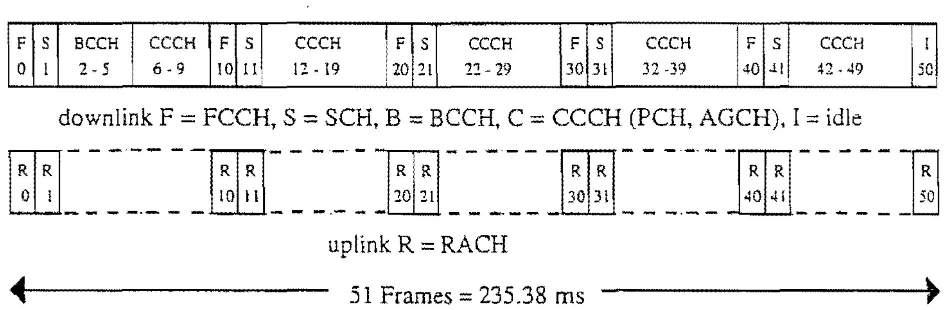
(ii) **S**ynchronisation **CH**annel (SCH) is a downlink channel and maps onto the *synchronisation burst*. This channel is used by the MS to learn the **B**ase **S**tation **I**nfo **C**ode (BSIC), and for frame synchronisation.

(iii) **B**roadcast **C**ontrol **CH**annel (BCCH) is a downlink channel and informs the MS about specific system parameters such as Cell Id (identifies the cell), **L**ocal **A**rea **C**ode (LAC) (identifies the area or cell group to which the cell belongs), **M**obile **N**etwork **C**ode (MNC) identifies the system operator (e.g. Cellnet, Orange etc.). It also gives the frequencies of neighbouring cells and maps onto a *normal burst*.

(iv) The **C**ommon **C**ontrol **CH**annels (CCCH) support the establishment of a dedicated link between the MS and BTS. There are three types of CCCH:

a) **R**andom **A**ccess **CH**annel (RACH) (uplink) is used by the MS to request a dedicated channel from the network. The BTS never transmits on the RACH. The RACH is essentially the *random access burst*.
b) **A**ccess **G**rant **CH**annel (**AGCH**) (downlink) is used to inform the MS which dedicated channel it should use, and is a response by the BTS to the mobile's RACH message. The BTS also informs the MS what timing advance it should use on the AGCH, based on the time of arrival of the *random access burst*.
c) **P**aging **CH**annel (PCH) (downlink) is used by the BTS to inform the MS about incoming traffic.

(b)



(c)

Each frame is

$$\tau = 4.615ms$$

and a timeslot is

$$\tau s = \frac{4.615}{8} ms.$$

in duration, and there are *51* frames in a multiframe. If there are *4* BCCH frames, then the elapsed time between the end of the last BCCH burst of multiframe *n* and the beginning of the first BCCH burst of the next *(n+1)* is

$$51\tau - (3\tau + \tau s) = 220.943ms.$$

If timeslot *5* were used in frame *n+1* then the epoch would change to

$$51\tau - (3\tau + \tau s) + 5\tau s = 223.827ms$$

(d)

The **C**ell **B**roadcast **CH**annel (CBCH) is not really a logical channel, rather it is carried on an SDCCH. It is used on the downlink for point to multipoint or broadcast type messages and the MS does not acknowledge any of the messages. Typical messages could be local STD codes to inform the user of preferential tariffs, traffic information, advertisements etc. CBCH messages are never sent from the MS.

The SMS however is a point to point service, it exists on both the uplink and downlink, and messages are acknowledged. SMS messages generally originate and terminate at the MS, and are carried on the SDCCH or SACCH.

Q2)
(a)

(i) Dipole array antenna gain for $N = 5$ is

$$G = 10\log_{10}(N) + 2.15\,dBi = 9.1dBi$$

(ii) The positions of the first sidelobes are approximately at the first sidelobes of the array factor which occur at

$$\frac{kNd}{2}\cos(\theta) = \pm\frac{3\pi}{2}$$

so that

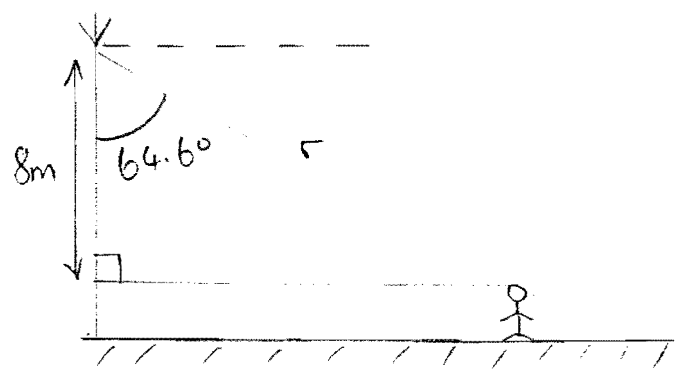
$$\theta = \cos^{-1}\left(\pm\frac{3\lambda}{2Nd}\right) = \cos^{-1}\left(\frac{3}{2\times 5\times 0.7}\right) = 64.6^{o} \text{ and } 115.4^{o}.$$

(iii) The height of these sidelobe with respect to the main lobe is

$$20\log_{10}\left(\frac{\dfrac{1}{\sin(3\pi/2N)}}{N}\right) = -12.1dB.$$

(iv)

With respect to the right angled triangle:



$$r = \frac{8}{\cos(64.6^{o})} = 18.7m$$

Isotropic power density is

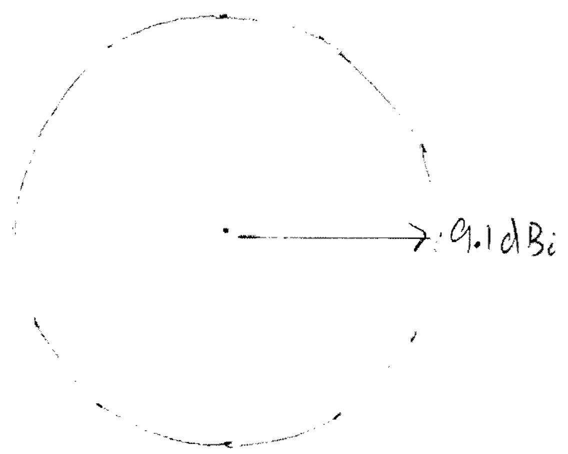
$$P_d = \frac{20}{4\pi r^2}\,dBi$$

but antenna gain is $9.1dBi$ and 1st sidelobe is $9.1 - 12.1dBi = -3dBi$.

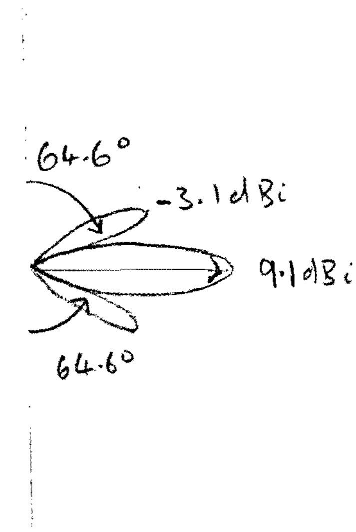
Thus power density hitting the head is

$$\frac{P_d}{2} = \frac{20}{8\pi \times 18.7^2} = 2.3mW/m^2$$

(b)



Az



Elev

(c)

(i) Considering the first sidelobe, the power density incident on a person's head is orders of magnitude below ICNIRP safety guidelines.

(ii) Residents of nearby buildings may be in the line of the main lobe on the 1st floor for instance. Taking the most stringent ICNIRP safety restriction of $4.6W/m^2$, and using the multiplicative gain of the antenna ($9.1dBi \equiv 8.1$)

$$\frac{20}{4\pi r^2} \times 8.1 < 4.6W/m^2$$

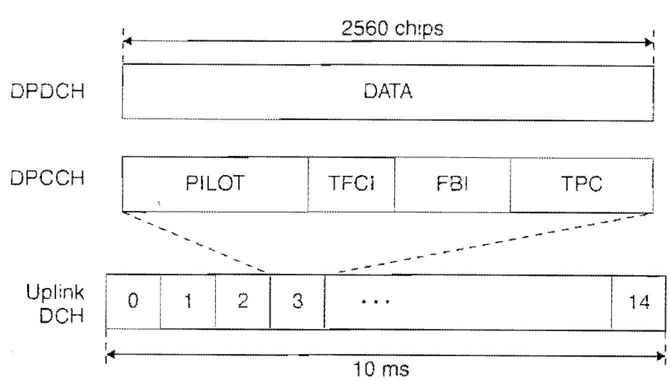
so

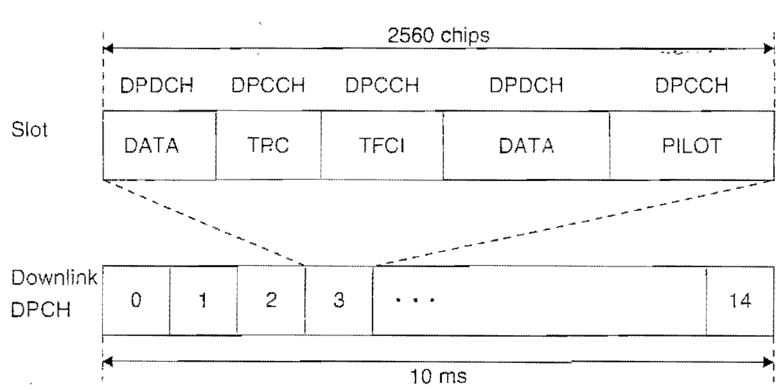
$$r < 1.7m$$

to exceed safety limits. A BTS antenna should never be this close to an upstairs window.

Q3)
(a)

Both the **D**edicated **P**hysical **D**ata **CH**annel (DPDCH) and the **D**edicated **P**hysical **C**ontrol **CH**annel (DPCCH) are dedicated *physical* channels carrying the **D**edicated **CH**annel (**DCH**) which is a type of *transport* channel (similar to *logical* channel in GSM). They are spread using channelisation codes running at 3.84Mcps, and are subsequently scrambled at the same rate. In the uplink direction, the handset transmits using dual channel QPSK modulation, also called I-Q Code/multiplexing, where the control and data channels are transmitted as orthogonal (IQ) data streams. This is to maintain a more even signal level during DTX periods. The downlink uses normal QPSK where the control and data streams are time-multiplexed. Variable spreading factors are used for the DPDCH channelisation codes between 4 - 256 (512 in downlink), dependent on the data channel bit rate. When higher data rates are needed, up to 6 parallel code channels are used, raising the channel bit rate up to a maximum of 5760kbps. The physical layer control information is carried by the DPCCH, and the higher layer information, including user data (e.g. speech), is carried on one or more DPDCHs. The DPDCH data rate may vary on a frame by frame basis, which is informed on the DPCCH via the **T**ransport **F**ormat **C**ombination **I**ndicator (TFCI). The *Pilot* bits are used for channel estimation in the receiver, the **T**ransmission **P**ower **C**ontrol (TPC) bits carry control commands for the downlink power control and the **F**eed**B**ack **I**nformation (FBI) bits are used for closed loop transmission diversity.





(b)

The chip rate is 3.84Mcps, and therefore a spreading factor of 16 means a symbol rate of

$$\frac{3.84 \times 10^6}{16} = 240kbps$$

(i) Uplink DPDCH symbol rate = $240kbps$

(ii) Uplink DPDCH bit rate = symbol rate = $240kbps$ because modulation is effectively BPSK

(iii) Uplink DPDCH user data rate is $\frac{240}{2} = 120kbps$ because half of the bits are used for FEC

(iv) Downlink DPCH symbol rate = $240kbps$

(v) Downlink DPCH bit rate = $2 \times 240kbps = 480kbps$ because of QPSK modulation

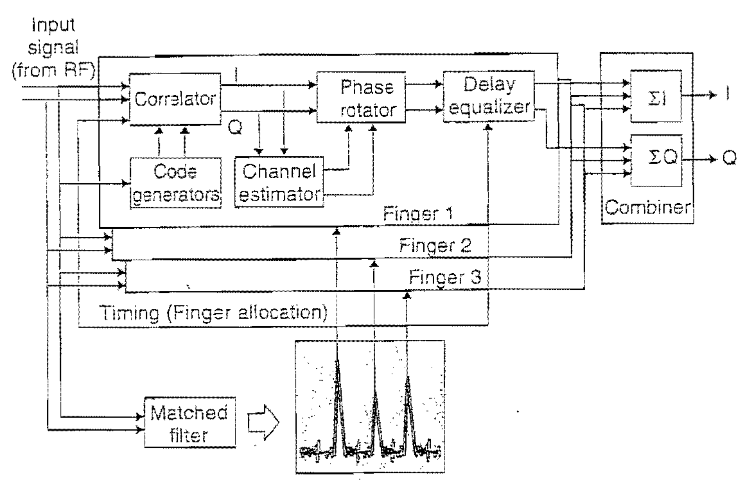
(vi) Downlink user data rate is $\frac{480}{2} = 240kbps$ because of half rate coding, which is further reduced by DPCCH occupancy of frame to $240 \times 0.9 = 216kbps$.

(c)

The frame length is 10ms, and thus DTX occupies 50% of available capacity, reducing the uplink user data rate to 60kbs.

Q4)
(a)

RAKE reception is employed both to obtain diversity gain from multipath propagation, and to combat the effects of Rayleigh type fading. Time delay positions of the order of multiples of the bit period are identified and correlation receivers, or RAKE fingers are then allocated to each delay path to compensate for it. Within each correlation receiver pilot symbols (similar to *Training Sequence* in GSM) transmitted as part of the WCDMA payload are used to sound the channel and provide an estimate of the momentary channel state for a particular finger. Phase compensation is then applied to minimise destructive interference caused by Rayleigh fading. The compensated, multiple-delayed versions of the same signal are then summed. Note that signals from multiple receive antennas can be combined in the same way as multiple paths received from a single antenna and RAKE fingers can be assigned to each antenna. Such additional antennas may be used where different propagation paths subtend an angular range at the BTS greater than the beamwidth of a single antenna for instance. The antennas could be electronically steered phased arrays that constantly scan their main beams searching for new paths. The ability to increase signal levels using multipath and spatial diversity gain in this way is one of the main advantages of a CDMA system over GSM.



(b)

During *softer handover*, a mobile station is in the overlapping cell coverage of two adjacent sectors of a single base station. The communications between the mobile station and base station take place concurrently via two air interface channels, one for each sector separately. This requires the use of two separate (channelisation) codes in the downlink direction, so that the mobile station can distinguish the signals. The two signals are received in the mobile handset using RAKE processing. In the uplink direction the (scrambling) code channel of the mobile is received in each sector, then routed to the same baseband RAKE receiver and the maximal ratio combined there in the usual way. During *soft handover*, a mobile station is in the overlapping cell coverage area of two sectors belonging to two different base stations. Communication takes place concurrently between the mobile and both base stations, and from the mobile's perspective there is little difference between *soft* and *softer* handover (except perhaps for the different scrambling codes differentiating the base stations). However in the uplink direction the received data from each base station is routed to the **R**adio **N**etwork **C**ontroller (**RNC**) for combining.

(c)

(i) Radio waves travel at $\sim 300m/\mu s$, and hence the difference between the two signal paths is

$$300 \times 2.6 = 780m\,.$$

(ii) Since $\phi_A - \phi_B = 180^o$ there could be a reflection from a hill or building $\sim 390m$ behind the BTS (wrt incident wave direction from the front).

(iii) By assigning each antenna to a RAKE finger.

(iv) It is also possible to assign more than one RAKE finger to a single antenna. Thus the back lobe reception of the ϕ_B signal could be assigned a separate finger of antenna A. It is worth noting however that the ϕ_B signal level would be significantly attenuated compared to that received by antenna B.

(v) If the ϕ_B signal were reflected off an aircraft, it could exhibit a Doppler frequency shift, which would vary as the velocity with respect to the signal direction changed. Thus dynamic equalisation may be required.