EEE6224 2016 Solutions

Q1)

a.

For a particular user *j*, the energy per user bit divided by the noise spectral density is given by

$$E_j = G_{p\,j} \frac{P_j}{P_t - P_j} \qquad (1)$$ **(1 mark)**

where P_j is the received signal power from user *j* and P_t the total received wideband power including thermal noise in the BTS, and the processing gain

$$G_{p\,j} = \frac{W}{R_j} \qquad (2)$$ **(2 marks)**

where *W* is the chip rate and R_j the data rate. Rearranging and factoring (1) yields

$$P_j = \frac{E_j}{E_j + G_{pj}} P_t = L_j P_t \qquad (3)$$ **(1 mark)**

where the load factor of one connection is

$$L_j = \frac{E_j}{E_j + G_{pj}} \qquad (4).$$ **(1 mark)**

The total received interference from *N* users, excluding the thermal noise P_n can then be written

$$P_t - P_n = \sum_{j=1}^{N} P_j = \sum_{j=1}^{N} L_j P_t \qquad (5).$$ **(1 mark)**

The noise rise due to user activity is then

$$\frac{P_t}{P_n} = \frac{1}{1 - \eta_{ul}} \qquad (6)$$ **(1 mark)**

where

$$\eta_{ul} = \sum_{j=1}^{N} L_j \qquad (7)$$ **(1 mark)**

is the *uplink load factor*.

If i = (interference from users of adjacent cells)/(interference from users of own cell)

(1 mark)

then the load factor of (7) is modified as

$$\eta_{ul} = (1+i) \sum_{j=1}^{N} L_j \qquad (8)$$ **(1 mark)**

Rewriting (8) using (4) for *N* users using uploading data at equal bit rate *R* gives

$$\eta_{ul} = (1+i)\frac{NE}{E+G_p} \quad (9).$$

At pole capacity

$\eta_{ul} = 1$ (10) **(1 mark)**

Substituting (2) into (9) and (10)

$(1+i)\frac{NRE}{RE+W} = 1$ (11) **(1 mark)**

and rearranging gives

$$NR = (R+\frac{W}{E})\frac{1}{(1+i)} \quad (12)$$

b.

(i) $N = 8$, $R = 200k$, $i = 0$, $E = 2$, so

$G_p = \frac{3840k}{200k} = 19.2$ **(1 mark)**

so from (9)

$\eta_{ul} = (1+0)\frac{8\times 2}{2+19.2} = 0.75$ **(2 marks)**

(ii)

$NR = (200k+\frac{3840k}{2})\frac{1}{(1+0)} = 2120kbps$ **(3 marks)**

c.

Total upload data rate = $NR = 8 \times 200k = 1600kbps$

Cell pole capacity is when $NR = 2120kbps$

So ratio is $\frac{1600}{2120} = 0.75$ **(1 mark)**

$= \eta_{ul}$. **(1 mark)**

Q2)

a.

If all timeslot bursts are active, then the average power is $P = 10W$. Now,

$$\frac{P}{4\pi R^2} G = P_d \quad (1)$$ **(2 marks)**

where

$G = 15.85$, $P_d = 35Wm^{-2}$

Hence minimum safe distance from (1) is

$$R = \sqrt{\frac{PG}{4\pi P_d}} = \sqrt{\frac{10 \times 15.85}{4\pi \times 35}} = 0.6m \quad (2)$$ **(2 marks)**

b.

Distance to ground from antenna,

$$d = \frac{10}{\cos 20^o} = 10.64m \quad (3)$$ **(1 mark)**

If the side lobe is 15dB below the main lobe, there is effectively 3dB of attenuation from isotropic, so from (1)

$$P_d = \frac{10}{4\pi \times 10.64^2} \times 0.5 = 3.5mW / m^2 \quad (4)$$ **(2 marks)**

c.

From (4) at a distance of 15m from antenna in direction of main lobe

$$P_d = \frac{10}{4\pi \times 15^2} \times 15.85 = 56.1mW / m^2 \quad (5)$$ **(2 marks)**

d.

The *Specific Absorption Rate* (*SAR*) is defined by

$$SAR = \frac{\sigma E^2}{D} W / Kg \quad (6)$$ **(2 marks)**

where σ denotes tissue conductivity, E is the electric field strength in the tissue and D is the tissue density. Recommended public safety limit is < 2W/kg. **(1 mark)**

e.

From (5)

$E^2 = 754 \times 56.1 \times 10^{-3} = 42.3(V/m)^2$ **(1 mark)**

so from (6)

$SAR = \frac{1.54 \times 42.3}{1000} = 0.065 W/kg$ (7) **(2 marks)**

f.

Points to note:

(i) To exceed the exposure safety limit of $35Wm^{-2}$ you would have to climb the mast (2) and the most significant danger to health would then be falling off.
(ii) The power level beneath the mast at ground level due to side lobes is orders of magnitude less than the safety limit (4).
(iii) The power level in an adjacent bedroom still remains orders of magnitude below the safety limit (5).
(iv) The induced SAR in the adjacent bedroom is well below the safety limit (7).
(v) Screening by windows and walls would probably reduce the bedroom power levels by a further factor of *10*.
(vi) Using a mobile handset will cause significantly more local exposure to the head than a BTS, since as $R \rightarrow 0$ (1) the power density increases rapidly as inverse square law.
(vii) A mobile handset is only used for a few minutes per day on average, whereas a BTS will be on continuously, although not transmitting at maximum power 24/7.

(i)– (vi) = no worries, (vii) = possible concern.

(1 mark for each point, saturates at 5 marks)

Q3)

a.

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

Bits: $3\ tail\ \rightarrow 142\ fixed\ \rightarrow 3\ tail\ \rightarrow 8.25\ guard$ **(2 marks)**

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

Bits: $3\ tail\ \rightarrow 39\ coded\ \rightarrow 64\ sync\ \rightarrow 39\ coded\ \rightarrow 3\ tail \rightarrow 8.25\ guard$

(2 marks)

(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. Vodafone, EE etc.). It also gives the frequencies of neighbouring cells and maps onto a *normal burst*:

$$3\ tail \rightarrow 57\ coded \rightarrow 1\ steal \rightarrow 26\ train \rightarrow 1\ steal \rightarrow 57\ coded \rightarrow 3\ tail \rightarrow 8.25\ guard$$

(2 marks)

(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*:

Bits: $8\ tail \rightarrow 41\ sync \rightarrow 36\ coded \rightarrow 3\ tail \rightarrow 68.25\ guard$ **(2 marks)**

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*. **(1 marks)**

c) **P**aging **CH**annel (PCH) (downlink) is used by the BTS to inform the MS about incoming traffic. **(1 mark)**

b.

Downlink:

F0**S**1**B**2-5**C**6-9**F**10**S**11**C**12-19**F**20**S**21**C**22-29**F**30**S**31**C**32-39**F**40**S**41**C**42-49**I**50

F=FCCH, S=SCH, B=BCCH, C=CCCH, I=Idle, numbers refer to frames **(2 marks)**

Uplink:

RACH0 → **RACH**50 **(1 mark)**

c.

(i) The instantaneous bit rate is the same for all GSM bits. Since $\tau = 3.69\mu s$, then the bit rate is

$$\frac{1}{\tau} = \frac{1}{3.69\times10^{-6}} = 271kbps$$ **(2 marks)**

(ii) There are 88 bits in each RA burst, which repeat every frame, $\tau = 4.61ms,$ so the RACH average bit rate is

$$\frac{88}{4.61\times10^{-3}} = 19.1kbps$$ **(2 marks)**

d.

The cell broadcast service is transmitted on the **C**ell **B**roadcast **CH**annel (CBCH). This 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. **(2 marks)**

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. **(1 mark)**

Q4)

a.

(i) In the uplink direction, the handset transmits using dual channel QPSK modulation, also called I-Q Code/multiplexing, where the **D**edicated **P**hysical **C**ontrol **CH**annel (DPCCH) and **D**edicated **P**hysical **D**ata **CH**annel (DPDCH) 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. **(2 marks)**

(ii) They are spread using channelisation codes running at 3.84Mcps, and are subsequently scrambled at the same rate. 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.**(2mark)**

(iii) The DPDCH bits contain user data such as speech or ip traffic. The DPCCH bits comprise pilot bits for channel estimation, **T**ransport **F**ormat **C**ombination **I**ndicator (TFCI) bits for varying the DPDCH data rate, **T**ransmission **P**ower **C**ontrol (TPC) bits which carry control commands for the downlink power control and the **F**eed**B**ack **I**nformation (FBI) bits for closed loop transmission diversity. **(4 marks)**

(iv) Timeslot structure (15 timeslots in 10ms frame):
Bits in uplink timeslot:
I: DPDCH: 2560 data chips
Q: DPCCH: $Pilot \rightarrow TFCI \rightarrow FBI \rightarrow TPC = 2560\ chips$
Bits in downlink timeslot:
QPSK: $DPDCH \rightarrow TPC \rightarrow TFCI \rightarrow DPDCH \rightarrow Pilot = 2560\ chips$ **(4 marks)**

b.

(i) The uplink DPDCH symbol rate is

$\frac{3.84\times10^6}{128} = 30kbps$ **(2 marks)**

(ii) The uplink DPDCH bit rate is the same as (i) **(1 mark)**

(iii) The uplink DPDCH user data rate assuming half rate coding is

$\frac{30k}{2} = 15kbps$ **(1 mark)**

(iv) The downlink DPCH symbol rate is the same as (i) **(1 mark)**

(v) The downlink DPCH bit rate is

$30k \times 2 = 60kbps$ **(1 mark)**

(vi) The downlink average user data rate assuming half rate coding and that the DPCCH occupies 30% of the DPCH is

$\frac{60k}{2} \times 0.7 = 21kbps$ (**2 marks)**