EEE6430 2014

SOLUTION TO Q1.

Speech Coding in GSM

(a)

i) The audio signal is sampled at a rate of 8kHz and quantized by 13 bits giving 8192 quantization levels. The output of the ADC is $8000 \times 13\text{bps} = 104\text{kbs}$. (3)

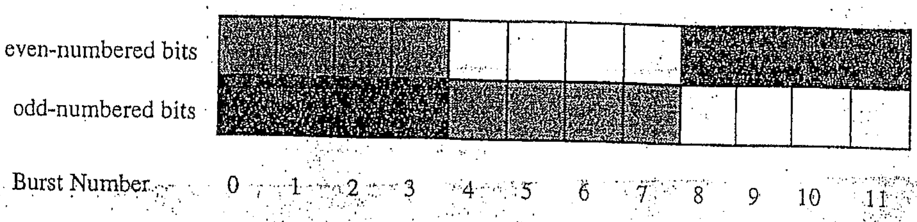
ii) The speech encoder then uses Linear Predictive Coding, Regular Pulse Excitation and Long Term Prediction analysis to convert an input of 20ms worth of speech (160 samples) representing 2080 bits to an output of just 260 bits. The speech data rate is therefore 13kbs. (2)

iii) These 260 bits are then sorted into three different classes according to their importance. The most important are the 50 Class 1a bits, then the 132 Class 1b bits, and finally the 78 Class 2 bits. (3)

iv) The Class 1a bits are block coded which uses a cyclic code for error detection. It adds three parity bits to the speech data. If there is an error detected upon reception in these first 50 bits, then the entire 260 bits in the block are abandoned. Convolution coding is then used for both the Class 1a and 1b bits, including the three parity bits. Four bits are added before encoding so that 189 bits enter the encoder and 378 bits are output. The class 2 bits are not protected. The speech data rate has therefore been increased from 13kbs to 22.8kbs. (2)

v) The 20ms speech block is therefore coded onto the traffic channel as 456 bits. They are spread out over eight traffic channel time slot bursts with bit numbers 0,8…..448 comprising the even bits of burst N, bit numbers 1,9……449 even bits of burst N+1 etc. up to burst N+3, and then the odd burst bits are used up to N+7. In this way 57 bits of a particular speech block appear in each burst, and these are interleaved with 57 bits from another speech block in each burst. (1)

Bit Number of the Coded Bits	Position Within the 26-Frame Structure	
0 8 448	Even bits of burst N	(No. 0, 4, 8, 13, 17, 21)
1 9 449	Even bits of burst $N + 1$	(No. 1, 5, 9, 14, 18, 22)
2 10 450	Even bits of burst $N + 2$	(No. 2, 6, 10, 15, 19, 23)
3 11 451	Event bits of burst $N + 3$	(No. 3, 7, 11, 16, 20, 24)
4 12 452	Odd bits of burst $N + 4$	(No. 4, 8, 13, 17, 21, 0)
5 13 453	Odd bits of burst $N + 5$	(No. 5, 9, 14, 18, 22, 1)
6 14 454	Odd bits of burst $N + 6$	(No. 6, 10, 15, 19, 23, 2)
7 15 455	Odd bits of burst $N + 7$	(No. 7, 11, 16, 20, 24, 3)



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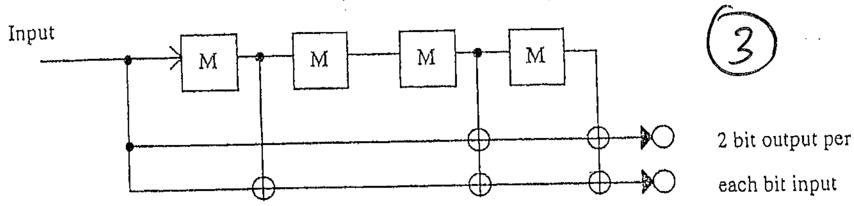
(b)



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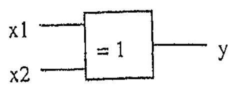
M Memory

⊕ XOR connection:



(schematic display)

logical table for a XOR (=1) connection:

x1	x2	y
0	0	0
0	1	1
1	0	1
1	1	0

1

(c)

Convolutional coding.

Bit stream (input)	1 0 1 1 0 0 0 1 1 0 1 0 1
Adding of four 0 bits (M)	1 0 1 1 0 0 0 1 1 0 1 0 1 0 0 0 0
Delay of one bit (M2)	0 1 0 1 1 0 0 0 1 1 0 1 0 1 0 0 0 0
Delay of two bit (M3)	0 0 1 0 1 1 0 0 0 1 1 0 1 0 1 0 0 0 0
Delay of three bit (M4)	0 0 0 1 0 1 1 0 0 0 1 1 0 1 0 1 0 0 0 0
Delay of four bit (M5)	0 0 0 0 1 0 1 1 0 0 0 1 1 0 1 0 1 0 0 0 0
1st stage (M + M4 + M5)	1 0 1 0 1 1 0 0 1 0 0 0 0 1 0 0 0
2nd stage (M + M2 + M4 + M5)	1 1 1 1 0 1 0 0 0 1 0 1 0 0 0 1 1
Output of the convolutional code	1110111001110000011000100001001010

2

2

Solution to Question 2

2(a)

Both the *Dedicated Physical Data CHannel* (*DPDCH*) and the *Dedicated Physical Control CHannel* (*DPCCH*) 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, to minimise the generation of audio frequency intermodulation products caused by pulsed transmission, as is evident when a *GSM* handset is placed near audio equipment for example. Since this is not an issue for *BTS* transmissions, the downlink uses normal *QPSK* where the control and data streams are time-multiplexed. The scrambling codes are used to differentiate between terminals in the uplink, and cells in the downlink, whereas the channelisation codes differentiate data and control channels in the uplink and terminals in the downlink. Variable spreading factors are used for the *DPDCH* channelisation codes between *4 - 256* (*512* in downlink), dependent on the data channel bit rate (*960 – 15kbps*), whereas the *DPCCH* uses a fixed spreading factor of *256*. When higher data rates are needed, up to *6* parallel code channels are used, raising the channel bit rate up to a maximum of *5740kbps* on the uplink. The two channels are transmitted with a 4-bit power difference on the uplink as shown in Fig 2.1.

The uplink dedicated channel structure is shown in Fig.2.2. The physical layer control information is carried by the *DPCCH*, and the higher layer information, including user data, 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 *Transport Format Combination Indicator* (*TFCI*). The *Pilot* bits are used for channel estimation in the receiver, the *Transmission Power Control* (*TPC*) bits carry control commands for the downlink power control and the *FeedBack Information* (FBI) bits are used for closed loop transmission diversity. The downlink dedicated channel structure is shown in Fig.2.3, where time multiplexing is now used for physical control information and higher layer data. If *TFCI* is not present, then lower data rates are implemented with *Discontinuous Transmission* (*DTX*), by gating slots at a rate of *1500Hz* (1/slot period)

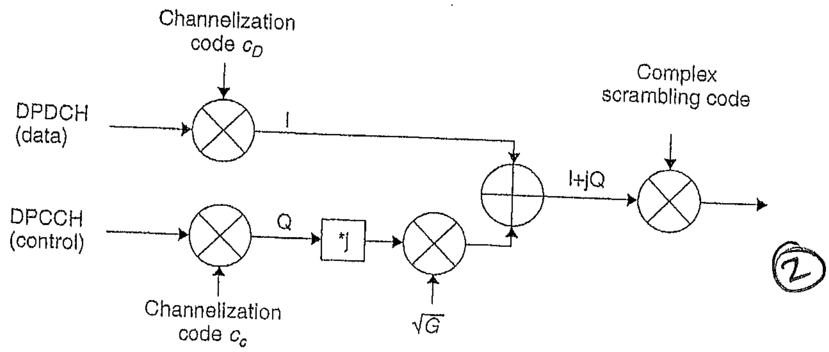


Fig 2.1 I-Q/code multiplexing with complex scrambling (UPLINK)

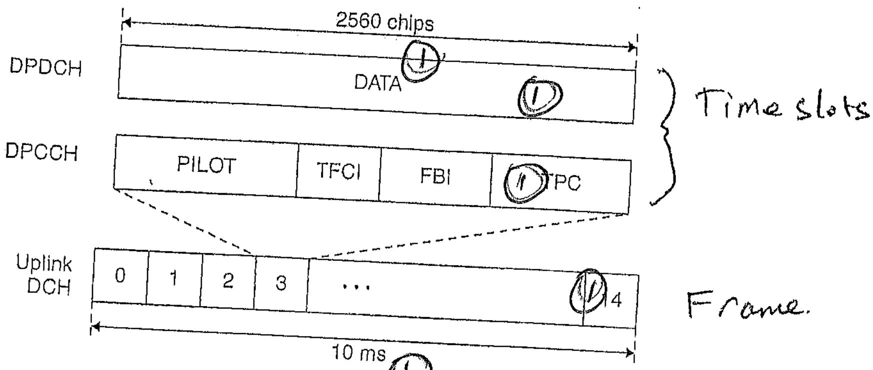


Fig 2.2 Uplink dedicated channel structure

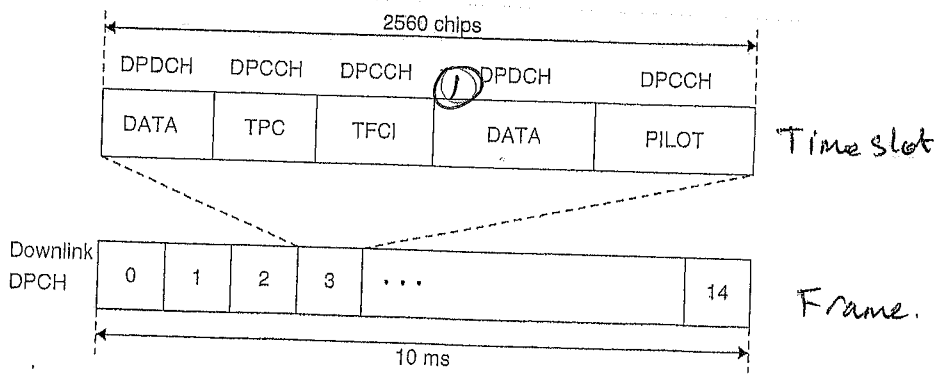


Fig 2.3 Downlink Dedicated Physical Channel (Downlink DPCH) control/data multiplexing

2(b)

The uplink *DPDCH* consists of *BPSK* symbols and so the symbol rate equals the bit rate. The chip rate is *3.84Mcps*, and so with a spreading factor of *64* the channel symbol or bit rate is 2

$$\frac{3.84}{64} \times 1000kbps = 60kbps \qquad (2.1)$$ 2

With half rate coding, the data rate is therefore $30kbps$. 2

The downlink *DPCH* is *QPSK* modulated so the bit rate is twice the symbol rate, and so the channel bit rate is

$$2 \times 60kbps = 120kbps \qquad (2.2)$$ 2

Solution to Question 3

3(a)

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

$$\frac{P}{4\pi R^2}G = P_d \qquad (3.1)$$

where

$G = 10^2$

$P_d = 100Wm^{-2}$

$P=10W$

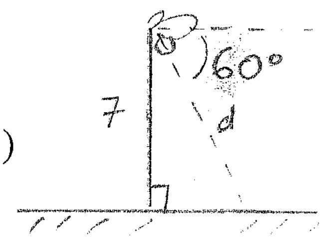
Hence 6

$$R = \sqrt{\frac{PG}{4\pi P_d}} = \sqrt{\frac{10^3}{4\pi 10^2}} = 0.89m \qquad (3.2)$$

3(b)

Distance to ground from antenna,

$$d = \frac{7}{\cos 30^o} = 8.1m \qquad (3.3)$$



If the sidelobe is $26dB$ below the main lobe, there is effectively $6dB$ of attenuation from isotropic, so
from (3.1)

$$P_d = \frac{10}{4\pi \times 8.1^2} \times 0.25 = 3mW/m^2 \qquad (3.4)$$

6

3(c)

From (3.1)

$$\frac{P}{4\pi R^2}G = P_d = \frac{10}{4\pi \times 100} \times 100 = 0.8Wm^{-2} \qquad (3.5)$$

3

However, there may be attenuation due to signal propagation through a window or wall, and so the signal could be weaker than this.

3(d)

Assuming plane wave propagation to the head and the phone of power *0.25W* held at a distance of *20cm*, with an antenna gain of *3dB* (factor of *2*) then

$$\frac{P}{4\pi R^2}G = P_d = \frac{0.25}{4\pi \times .04} \times 2 = 1Wm^{-2} \qquad (3.6)$$

which is similar to the power density in the bedroom.

Points to note:

(i) No power density is anywhere near the safety limit of $100Wm^{-2}$

(ii) To exceed this, you would have to climb the mast and get within a metre of the antenna, in which case falling off the mast would be the greater health concern

(iii) The power levels beneath the mast on the ground are negligible

(iv) If people are concerned about power levels within a close bedroom for instance, then they should also be concerned about using a mobile handset, since these are comparable.

(v) Screening by windows and walls would probably reduce the bedroom power levels by a further factor of *10*.

(vi) 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.

5

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

4(a)

Solution to Question 4

A *normal burst* in *GSM* is shown in Fig.4.1. It can be transmitted from the mobile to the BTS or vice-versa.
The *tail bits* are used as a guard time to cover the periods of uncertainty in power ramping, and are always set to zero.
The *guard period* allows for the ramping down of the current burst power, and simultaneously the next burst ramps its power up in this time. No data is transmitted in this period.
The *coded data* portions contain the actual information to be relayed, either signalling data used to allow the network and mobile to exchange link control information, or traffic data such as coded speech.
The type of data is indicated by the *stealing flags*, which allow the receiver to correctly route the information (e.g. to speech decoders or to frequency control circuits). 1
The *training sequence* is a fixed bit sequence known to both transmitter and receiver. It is used to compensate for signal distortion due to multi-path fading.
The *equaliser* in the receiver compares the received training sequence with what it knows it should be, and then adjusts its own filter characteristics to correct the received sequence. These filter characteristics will then also be effective in correcting the remaining unknown coded data. 1

The logical channels that are mapped onto the burst are
Traffic CHannels (TCH), carrying speech data
Broadcast Control CHannels (BCCH), carrying CellId's LAC's network id and info
Common Control CHannels (CCCH) and *Dedicated Control CHannels (SDCCH, SACCH, FACCH)* for establishing and maintaining a call. 4

Type	T	Coded Data	S	Training Sequence	S	Coded Data	T	GP
Number of Bits	3	57	1	26	1	57	3	8.25

148 Bit = 546.12 μs

Structure of a normal burst.

4(b)

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

$$\left[F(f)\times\delta_f\left(\frac{1}{T}\right)\right]*\delta(f-f_c) \qquad (4.1)$$

where

$$F(f)=A\int_{-\frac{\tau}{2}}^{\frac{\tau}{2}} e^{-j2\pi ft}\,dt = A\tau Sinc(\pi f\tau) \quad (4.2),$$ 2

τ is the burst duration, f_c the carrier frequency and $\delta_f(\frac{1}{T})$ is a series of delta functions in frequency separated by the reciprocal of the burst repetition period.

For the *normal burst*, $\tau = 577\times10^{-6}\,s$, and here we have four consecutive *normal bursts*, so $\tau = 2308\times10^{-6}\,s$. Noting that the zeros of the *Sinc* function occur when $\pi f\tau = n\pi$ (n integer and greater than zero) allows the spectra of Fig.4.2 to be drawn. Here, 2

$f_1 = 433Hz, f_2 = 866Hz, f_c = 900MHz$ and frequency components at $217Hz$ intervals in both cases.

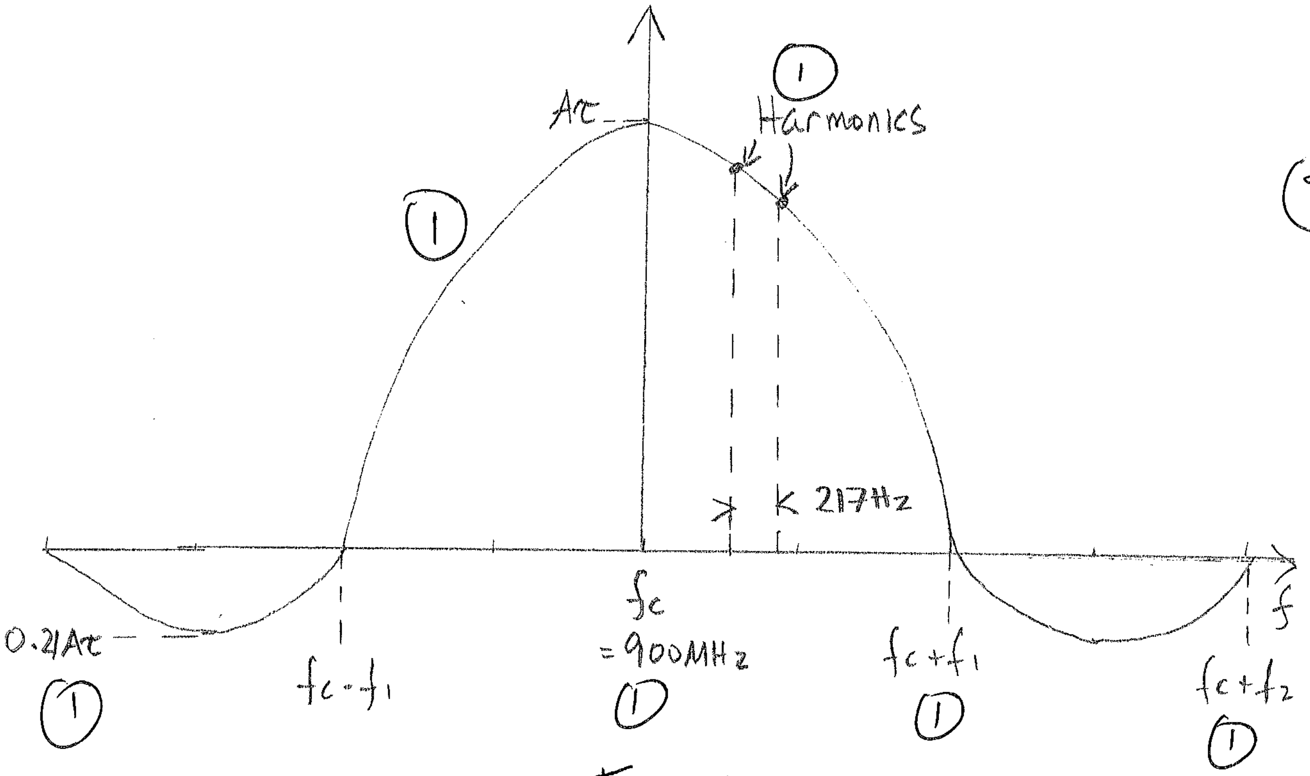


Fig 4.2