Appendix C – GSM System and Modulation Description

C1. Parameters included in the modelling

In the modelling the number of mobiles and their positioning with respect to the wired device needs to be taken into account, along with carrier frequency and channel parameters as follows :

C1.1 The frequency of the transmitted signals - The bandwidth in the GSM is 25MHz. The frequency band used for the uplink path (mobile to base station) is 890 - 915 MHz and for the downlink path (base station to mobile) 935 - 960 MHz.

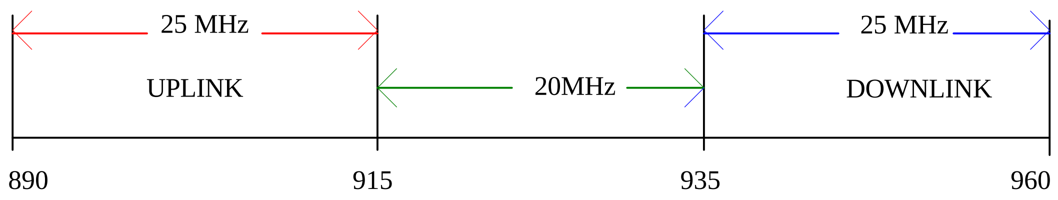

Figure C1: The Uplink and Downlink bandwidths for GSM.

In the GSM this frequency band is divided up into 124 channels (pairs of frequencies, one for the uplink and one for the downlink path) of width 200kHz centred around the carrier frequencies 890.2/935.2 MHz, 890.4/935.4 MHz , ..., 914.8/959.8 MHz

Each cell can normally have up to 15 carrier pairs (channels) and so, within a given region, an ensemble of mobiles will all be operating on different carrier frequencies. If we restrict ourselves to looking at the transmissions from mobiles within a single cell then we know there is a maximum of 15 different carrier frequencies being transmitted. We are looking at the overall effect of these (possible) 15 mobile signals, i.e. we look at the summation of these separate signals and treat it as a single signal. This information is used in Section 2 of the report where the effect of this combined signal on a nearby victim device is investigated.

Two extreme cases of channel spacing may be considered:

Case (1)

Here it is assumed that all 15 channels are grouped together. If for example, we take this to be channels 1 - 15 then we have uplink and downlink channels, of width 200kHz, centred around the carrier frequencies 890.2 /935.2, ..., 893.0/938.0. The spectrum is illustrated in Figure C2.

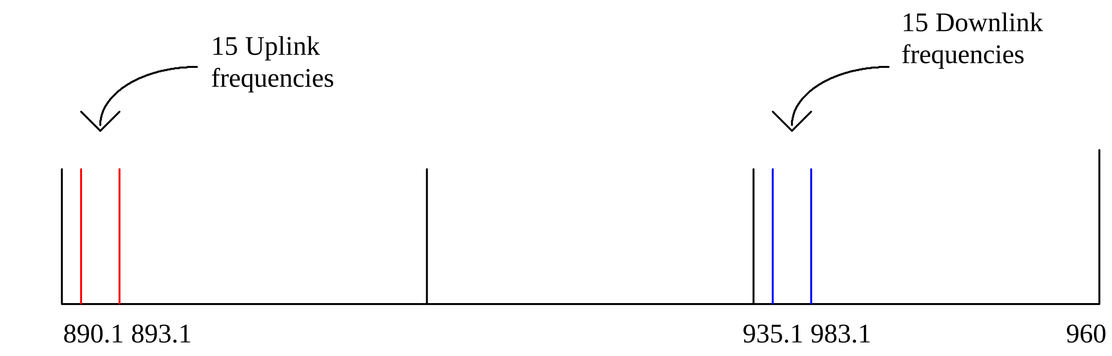

Figure C2: Selected Neighbouring GSM channels.

Since we are only considering signals from mobiles here, only the uplink frequencies are considered. This gives a band of 3MHz width and a space of 42 MHz as shown in Figure C3.

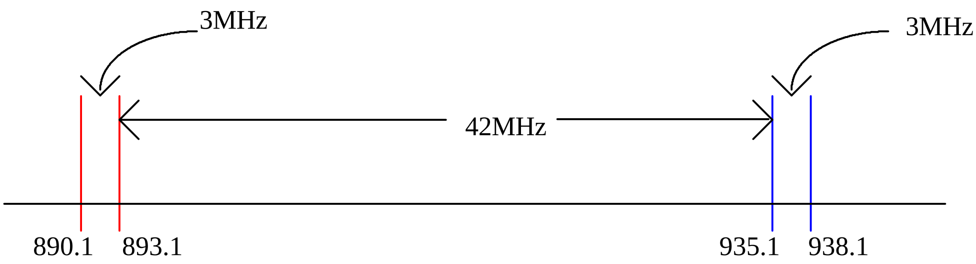

Figure C3: Selected neighbouring uplink channels.

Case (2)

In this case we assume that the 15 channels are spread throughout the whole of the 25 MHz uplink band.

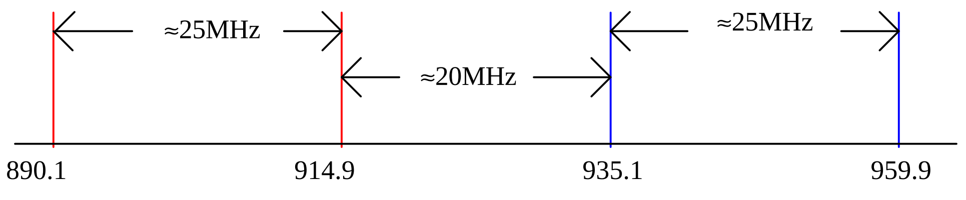

Figure C4: Selected channels spread over the bandwidth.

This gives a band of $\approx$ 25 MHz and a space of $\approx$ 20 MHz.

Obviously much more varied selections of frequencies will occur but for initial purposes we are concentrating on these two extreme cases.

C1.2 Modulation induced aspects such as envelope power. The modulation for the GSM is Gaussian Minimum Shift Keying (GMSK).

C1.3 The channel usage - The GSM transmits using Time Division Multiple Access (TDMA) with 8 time slots per carrier. Each user is allocated one of these time slots during which time he accesses part of the allocated spectrum for the system. Transmission takes place in bursts from the mobile to the base station (uplink path) with only one user transmitting to the base station at any given time. In the downlink path (base station to mobile), the base station usually transmits continuously with the mobile listening only at its allocated time slot.

We also need to take into account the error protection methods used by the system - The GSM uses interleaving, block and convolutional channel coding, frequency hopping and adaptive equalisation techniques. (For more details on this see Ref 2.)

C1.2 Antenna and propagation. Along with these various parameters we need to consider the model of propagation to be used from each emitter to the point on the wire.

Firstly we will consider the simplest, that is Line of Sight (LOS) where we have a loss of $1/d^2$. We will then bring in other factors such as ground reflection and diffraction (using simple geometry) if necessary, utilising previous work undertaken at the University of Hull. One possible approach is to use a statistical approach allowing each of the above parameters to take on one of a possible set of values e.g. varying the number of mobiles present, the frequencies of them, the power levels etc.. and using some form of expectation method. The antenna is assumed to radiate isotropically.

C2. GSM Specifications

Main specifications:

- Frequency Band 890 - 915 MHz (Uplink) - 960 MHz (Downlink)
- Carrier Spacing 200kHz
- Transmission Method TDMA with 8 timeslots per carrier

- Modulation Gaussian Minimum Shift Keying (GMSK) with normalised bandwidth 0.3

- Error Protection Methods
    - Interleaving
    - Channel Coding - Block and
    - Convolutional
    - Slow Frequency Hopping 217Hops/sec
    - Adaptive Equalisation 16μsec propagation time dispersion

- Speech coder 13kbs speech coder Regular Pulse Excited Long-Term Prediction

- Overall channel bit rate 22.8kbs

Transmission Method

The GSM uses narrowband Time Division Multiple Access (TDMA) with 8 channels per carrier. This means it splits the time into 8 slots and allocates one to each user over which time the user accesses part (since narrowband) of the allocated spectrum for the system.

Channels / Bandwidth

The bandwidth in the GSM is 25 MHz. The Frequency band used for uplink (mobile to base) is 890 - 915 MHz and for the downlink (base to mobile) 935 - 960 MHz. The GSM has 124 channels with 200kHz carrier spacing. For a given channel, the uplink frequency F_u and the downlink frequency F_d can be found by

$$F_u = 890.2 + 0.2\ (N-1)\ \text{MHz}$$
$$F_d = 935.2 + 0.2\ (N-1)\ \text{MHz}$$

N=1,2,...,124.

When the mobile is assigned to an information channel, a radio channel and a time slot are also assigned. Radio channels are assigned in frequency pairs - one for the uplink path and one for the downlink path (also called reverse and forward channels respectively). Each pair of radio channels supports upto 8 simultaneous calls. So the GSM can support upto 992 simultaneous users with the full-rate speech coder, this number will of course be doubled with the use of the half-rate speech coder.

The GSM Frame

The GSM multiframe is 120 ms. It consists of 26 frames of 8 time slots.

In a normal burst, two user information groups of 58 bits account for most of the transmission time in a time slot (57 bits carry data while the H bit is used to distinguish speech from other transmissions) 26 Training bits (T) are used in the middle of the time slot (these are used for equalisation purposes). The time slot begins and ends with 3 tail bits. The time slot also contains 8.25 Guard bits (G). So a time slot carries 156.25 bits.

3	57	1	26	1	57	3	8.25
Tail	Data	H	Training	H	Data	Tail	Guard

Table C1: The GSM Time Slot.

Equalisation

Each time slot contains 26 bits for equalisation purposes. The GSM recommendations do not specify a particular equaliser - it is up to the operators to do their own. BUT it does specify a maximum excess delay of 16μsec. This is equivalent to a path length difference of 4.8km.

GSM Speech Processing

In the GSM the transmitted bit period is approximately 37μsec and a delay spread of about 5μsec is not uncommon.

In the GSM the analogue speech from the mobile station is passed through a low-pass filter to remove the high-frequency content from the speech. The speech is sampled at a rate of 8000 samples per second, uniformly quantized to 2^{13} levels and coded using 13 bits per sample. This results in a digital information stream rate at 104 kbs.

At the base-station, the speech signal is digital (64 kbs) which is first transcoded into 13 bit samples corresponding to a linear representation of the amplitudes. This results in a digital information stream at a rate of 104 kbs. The 104 kbs digital stream is fed into the Regular Pulse Excited Long-Term Prediction speech encoder which then transcodes the speech into a 13 kbs stream. The full rate speech encoder takes a 2080 bit block from the 13 bit transcoder every 20 ms i.e. 160 samples and produces 36 “filter parameter” bits over the 20 ms period, 9 LTP bits every 5 ms and 47 RPE bits every 5 ms. Thus 260 bits are generated every 20 ms.

	Bits per 5 m	**Bits per 20 ms**
Linear Prediction Coding (LPC) filter		36
Long Term Prediction (LTP) filter	9	36
Excitation signal	47	188
Total		260
Class I		182 (class
Ia=50,class Ib=132)		
Class II		

Table C2: Details of Class I and Class II Bits.

Of these 260 bits 182 are classified as class I bits related to the excitation signal and the remaining 78 are class II bits related to the parameters of the Linear Prediction Coding (LPC) and LTP filters.

The Class I bits are further classified into Ia (50 bits) and class Ib (132 bits) .The class Ia bits are the most significant bits which are used to generate 3 Cyclic Redundancy Check (CRC) bits. The CRC bits along with 4 tail bits are added to 182 class I bits before they are passed through the half-rate convolutional coder to produce twice as many bits output as there are bits input (i.e. 2 X 189 = 378). The 78 class II bits remain uncoded and are bypassed. The total 456 bits (i.e.78 + 378) are fed to the bit interleaver. Since 456 bits are generated during 20 ms the user data rate is 456/0.02 = 22.8 kbs. This includes 13 kbs raw data and 9.8 kbs of parity, tail and channel coding.

Of the 456 bits 57 at a time are interleaved with 57 other bits from adjacent data block to form a data burst of 114 bits At this stage 42.25 overhead bits are added to the data burst to carry it into a time slot. Bit interleaving is used to reduce the adverse effects of Rayleigh fading by preventing entire blocks of bits from being destroyed by a signal fade. Interleaved data is passed through the GMSK modulator where it is filtered by a Gaussian filter before applying it to a modulator. The modulated data passes through a duplexer switch where filtering is provided between the transmitted and the received signal. On the receiving side the signal is demodulated and de-interleaved before the error correction is applied to the recovered bits.