The Future for Mobile Phones

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Overview

The emphasis of the seminar and this presentation will be on the aspects of mobile communications that might impact human health, in this case the transmission characteristics. Though the transmit power from a mobile can be small compared to that of a base station, the distance to the body to a mobile phone is only 10's of millimeters, whereas, it is rarely possible to get closer than 10's of meters to a base station. As a result the highest exposures to radio frequency energy comes about from the use of a mobile phone close to the body rather than the larger power more distance base station. For this reason this talk will further restrict its scope to consideration of the characteristics of the mobile phone only.

The talk will briefly cover the types of devices and how their modes of usage might impact the amount of absorbed power (SAR). The focus will then move to current mobile phones and their characteristics and how the evolution of mobile phones form 2nd generation through 3rd and forward towards 4th generation will impact the transmitted signals and the characteristics pertinent to research into human health effects. The talk will be rounded off with a discussion of technologies that are not specific to any one mobile telephone standard but are likely to be significant.

Mobile Phone Generations

The main drive in the evolution of mobile phones from 2G to 2.5G and 3G has been an increase in the available data rate. There are different methods of classifying what constitutes a particular generation. One is chronological, based on the time of introduction with ½ generations introduced for advances based on a particular technology, and the second is based on the data rate. One classification puts the boundaries between generations as follows: 2G 7 – 28.8kbit/s, 2½G 50 – 144kbit/s and 3G 384kbit/s – 2Mbit/s.

Whatever the basis the following classification is generally agreed:

2G	GSM, TETRA
2½G	GPRS, HSCSD, EDGE
3G	UMTS, (EGDE)
4G	Multi-carrier Advanced TDMA ?????

Note: the EDGE extension to GSM falls into 2½G in terms of its technology but can achieve data rates commensurate with 3G.

Important to the signals transmitted is the type of access method employed by a mobile phone. Most systems use time division multiple access, which in simple terms means that a number of simultaneous users can be facilitated by sharing the time between the users. In reality what this means is that the transmission is will be pulsed, each phone transmitting on its allocated time slot. The repetition rate of the pulses depends on the particular system, but is in the range of 10's to 100's of pulses per second. Additionally the ratio between the transmitter being on and off is also system dependent.

Speech Encoding

One irony of the advance in mobile phone technology is that while potential data rates are increasing the data rate required for speech transmission is reducing due to advances in speech coding. To digitally represent speech without coding techniques a digital bit stream of 64kbit/s is required; this gives good dynamic range and adequate bandwidth. This is rather a high bit rate, therefore all mobile phones use techniques such as linear predictive coding with regular pulse or algebraic code excitation to reduce the data rate required to between 9.6kbit/s and 4.567kbit/s.

It is this lower rate digital data that is encoded onto the radio frequency (RF) signal through a process called modulation. Two modulation methods you are probably familiar with are amplitude modulation AM and frequency modulation FM. The modulation schemes used for digital radios are more complex exploiting mathematical properties of the signals in ways that are not possible with normal broadcast radio. Once modulated the RF signal is then amplified and transmitted.

Current Mobile Phones

Digital mobile phones in the UK are based on GSM (Global System for Mobile Communications); this is a second generation (2G) mobile system, based on time division and frequency division multiple access. The system employs a cellular architecture where a geographical area is divided into smaller areas called cells. A cell is the area of coverage from a single base station, and can vary from as little as 500m across for inner cities to as much as 30km for rural locations. The key influences on cell size are terrain and population density. As a user travels within a cellular infrastructure there is a requirement to hand over from one base station to another as you leave one geographical area and enter another. At this point your phone retunes to transmit and receive on different frequency channels. As the mobile moves towards or away from a base station the power transmitted from the phone is altered to maintain a smaller range of received power levels at the base station receiver. The transmitted power from the mobile phone can be varied by up to 30dB in 2dB steps (by up to a factor of 1000 in steps of ~1.5). The closer the mobile phone is to the base station the lower the transmit power.

The characteristics of the transmitted signal are governed by the type of modulation, in this case GMSK, which results in a signal of constant amplitude being transmitted within each time slot.

However, the mobile phone transmits in only one time slot in eight so the overall transmission is pulsed with a repetition rate of 217Hz and has a 8:1 ratio between peak and average power. In the case when discontinuous transmission (DTX) is enabled, if the user is listening and not speaking, then the mobile only transmits one slot every 120ms for 3 frames then a sample of the back ground noise in the 4^{th} frame. This results in a lower average transmit power, extending the life of mobile phone batteries.

The other second generation mobile phone system is TETRA which is a European digital radio system for public services and private mobile radio. Unlike GSM it has two modes of operation. Firstly, mobile to base station in a cellular type structure the same as GSM and also a mobile to mobile mode that does not require a connection to the network. Again this is based on time division and frequency division multiple access. A $\pi/4$DQPSK modulation is used which is not constant envelope and each pulse has an amplitude variation at the symbol rate of 18ksymbols/s. Greater than this is the amplitude variation due to the fact that each base station can support up to 4 simultaneous users per channel; the resource is shared by allowing each user to transmit for 1/4 of the time.

TETRA also implements adaptive power control, in this case the transmit power is varied in 5dB steps (a ~3 fold power change) from +15dBm up to the nominal power level of the particular class of mobile. For a 1W handset a total power control range of 15dB (30 fold change in power) is available.

2½G Systems

High speed circuit switched data (HSCSD) offers the following key features:

smooth integration into GSM infrastructure by software update and a boost in net bit rate per time slot from 9.6 to 14. 4kbps. HSCSD offers both symmetrical and asymmetrical data rates with uplink rates up to 28.8kbit/s and downlink rates up to 43.2kbit/s. A HSCSD link is equivalent to a normal phone call, in that once set up you have use of the capacity whether or not you require it at that instant, this is so called connection orientation.

The General Packet Radio Service GPRS also offers enhanced data rates over GSM systems, however, this service is ‘always on’ and you use capacity as and when it is required paying on a per packet transported basis. Data rates up to 172.2kbit/s are possible if one user has all the capacity, though more typical rates are 28.8kbit/s.

Both HSCSD and GPRS use essentially the same hardware as a normal GSM handset but there may be transmission for more than $1/8^{th}$ of the time. However, it is likely that when used in these modes the handset will not be placed next to the head.

Enhanced Data rates for GSM Evolution EDGE is another extension to the GSM standard, but this differs from HSCSD and GPRS in that the extension utilises new as well as existing modulation formats. The data rates are between 8.8kbit/s and 59.2kbit/s per time slot, however, there are limits on when the highest data rates can be used as a higher quality signal is required for higher rates. The

higher EDGE data rates use an 8PSK modulation format. The 8PSK gives an amplitude variation within time slot as well as pulsed output, where within a slot the peak to average power ratio is approximately 1.67.

UMTS - IMT2000

UMTS is a 3G system that uses a fundamentally different multiple access scheme compared to previous systems. All the users in a given cell can use the same (5MHz) channel simultaneously using a technique called wideband code division multiple access (WBCDMA). In this case each base station and mobile have a unique code which enables the signal to be encoded such that each user does not interfere with other users. These codes operate at the high speed of 3.84Mc/s. For UMTS there are two possible modes frequency division or time division duplex (FDD or TDD) which results either in continuous transmission or pulsed transmission. The data rate from the mobile can be in the range 15kbit/s - 960kbit/s. WBCDMA uses a modulation format termed dual channel QPSK, which gives rise to an amplitude variation with a time period equal to the code rate (very fast). The peak to average power varies between 4.1 and 4.6dB. In the TDD mode the transmission is pulsed at 100Hz and each mobile transmits for $1/15^{th}$ of the time or potentially multiples of that when higher data rates are required.

In the UMTS standard various power classes are defined; the ones shaded in grey are ones that could be used in a handset and comply with the guidelines on SAR.

Power Class	FDD Mode Power (dBm)	TDD Mode Power (dBm)
1	33 (+1/-3)	30 (+1/-3)
2	27 (+1/-3)	24 (+1/-3)
3	24 (+1/-3)	21 (±2)
4	21 (±2)	10 (±4)

The maximum (average) power for a class 4 (lowest power) FDD mode terminal is therefore the same as a GSM1800 handset, however, the signal is continuous and not pulsed. In TDD mode the output power is defined as the power averaged over an active time slot multiplied by a factor of 1/15 for single time slot transmission. A class 1 (highest power) TDD mode terminal will have a lower average power than a GSM1800 handset when use in one time slot, In the latter case the transmission is pulsed.

UMTS implements fast power control as the maximum number of simultaneous users can only be accommodated if all the signals are received at approximately the same power at the base station. For this reason output power is controlled to maintain this small range of received power levels at the base station. The transmit power from the UMTS mobile phone can be varied by up to 77dB in 1-3dB steps

(by up to a factor of 50,000,000). The system allows the power to be changed up to 1500 times per second, so when moving quickly it is possible to get a further amplitude modulated component due to this power control.

4G (2010?)

With the fourth generation of mobile telephones not due roll out until 2010 or there abouts you might be thinking that there is little activity on this front, however, many groups are now formulating ideas. If it is possible to split them into groups the groups might be those looking towards a new standard and those that see 4G purely as a convergence of existing standards. The new standard is tipped by those who claim to know to be a multi-carrier standard known as OFDM (used for DAB and DVB) which is similar to high bit rate wireless LAN standards. Those in the convergence camp expect 2½ / 3G uplink technology to be used in conjunction with OFDM down link. Either way the transmissions could well be pulsed in nature as all the observers of the debate indicate that time division multiple access is the current favorite.

Associated Technologies

There are various technologies that are not specific to any single generation or standard of mobile phone that might impact the human health aspects of mobile phones, these include hands free kits and smart antennas. In addition, there are techniques such as software-defined radio and multiple input multiple output technologies that allow increased flexibility and capacity that are worth mentioning.

Hands Free Kit (HFK)

The key effect of a hands-free kit is to remove the major source of RF exposure, the antenna, away from the head and preferably other parts of the body. The exact location may be:
Trouser/skirt pocket;
Pocket of a jacket, shirt, blouse or other upper body garment;
Carried in the hand;
Attached to a belt around the waist;
On a table top away from the body.

There are two main types of hands free kit, wired and wireless. A wired HFK consists of:
an ear piece, microphone, lapel clip, interconnection cable and connector. Wireless HFK replaces the mobile phone transmitter close to the head with a smaller low power transmitter that itself communicates with the mobile phone. These use Bluetooth technology which acts as a so called personal area network. Bluetooth has a 2.45GHz radio interface with 1mW peak power and can operate over a 10m range.

Smart Antennas

Smart antennas are a part of the base station and enable the signals for a particular user to be directed in the optimum direction while reducing interference from other users. This enables lower transmit powers to be used for same received signal strength at both handset and base station, reducing the exposure to the user from their handset.

Software Defined Radio

Software defined radio or software radio for short is a key enabler for a flexible wireless architecture, providing adaptability to applications demands whilst offering a degree of future proofing, as the mobile station's protocols can be changed remotely.

MIMO

Multiple input multiple output transmission systems (space time coding) require multiple antennas at both ends of a link so it is not easy to implement this in a small handset and it may be of greater importance in devices such as laptop computers and personal digital assistants. Use of MIMO can increase data rate via spatial multiplexing and increase link quality through diversity. It should be noted that 2G and 3G standards do not allow for MIMO at this time.

Conclusion

There are aspects of mobile telephone transmissions that are common to most standards that could have implications for human health.

Multiple users are accommodated through the use of time division multiplexing (with the exception of the FDD mode of UMTS) that results in pulsed transmissions such that the peak power is greater than the average power. All systems employ some form of power control which results lower power transmissions close to base stations and higher power further away (up to the maximum defined in the standard) or where there is a highly built-up environment or large topographic features.