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The comparison of time division multiple access (TDMA) (global system for mobile communication, GSM) and wideband-code division multiple access (W-CDMA) (third generation, 3G) system based on their modulation techniques

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Mobile network communication system offers the users with seamless communication and this has caused wireless communication to increasingly become the preferred method of carrying multimedia traffic or messages such as voice, video, images, and data files. Time division multiple access (TDMA) is the multiple access scheme used in global system for mobile communication (GSM), while third generation (3G) system uses wideband-code division multiple access (W-CDMA). The former is designed majorly for voice and a little of data. Due to the increase in number of phone users and the services enjoyed by the users, there is higher demand for non-voice services, mobile extensions to fixed-line services and richer mobile content. This has caused the network operators to develop 3G system with the goal of providing a network infrastructure that can support a much broader range of services than existing systems in which its penetration level has reached market saturation. This paper presents a comparison of the two wireless systems performance based on their modulation techniques. From the constellation gotten, the two systems were analyzed and the analysis shows that W-CDMA (that is, 3G) provides a network infrastructure that can support a much broader range of services than existing systems (GSM) because the main forces behind development of the 3G have been driven by the second generation systems' low performance data services, incompatible service in different parts of the world, and lack of capacity.

Key words: Time division multiple access (TDMA), wideband-code division multiple access (W-CDMA), call drop rate, call set-up success rate (CSSR), handover rate, constellation.

INTRODUCTION

In recent years, cellular communication has experienced exponential growth, and the growth continues unabated worldwide, with cell phone users numbering billions. It presents the users with seamless communication where

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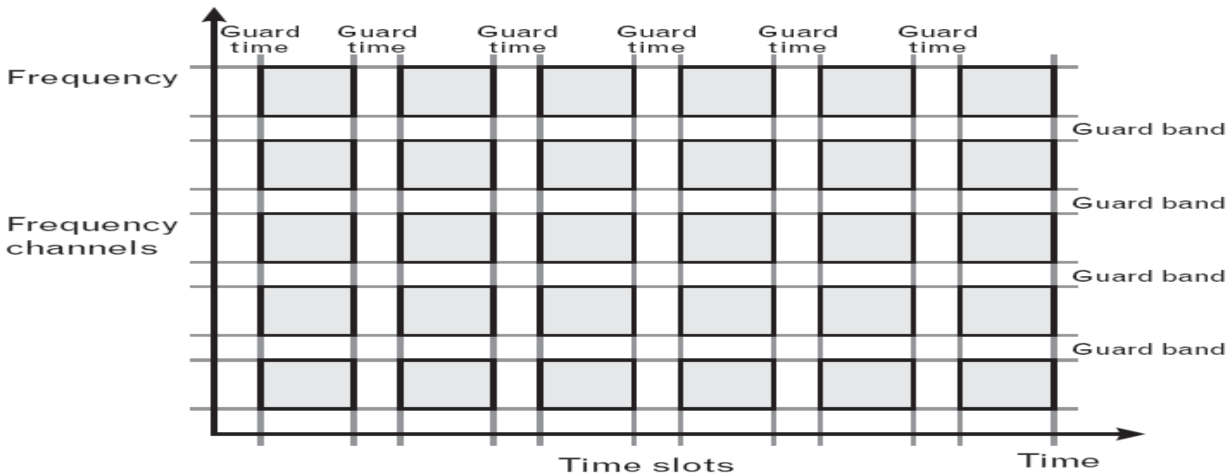

Figure 1. Hybrid frequency division multiple access/ time division multiple access (FDMA/TDMA) system. Korhonen (2003).

possible end-to-end. As more wireless solutions become available, it becomes more important to understand the strength and capabilities of each technology.

The third generation (3G) system is now the generally accepted term used to describe the latest wave of mobile networks and services. The previous wave, 2G system, arrived in the late 1980s and moved towards a digital solution which gave the added benefit of allowing the transfer of data and provision of other non-voice services.

Of these, the global system for mobile communication (GSM) has been the most successful, with its global roaming model (Jeffrey et al., 2004). 3G leverages on the developments in cellular to date, and combines them with complementary developments in both the fixed-line telecom networks and the world of the internet.

The result is the development of a more general purpose network, which offers the flexibility to provide and support access to any service, regardless of location. These services can be voice, video or data and combinations thereof, but, as already stated, the emphasis is on the service provision as opposed to the previous technology.

REVIEW OF PREVIOUS WORKS

The concept of multiple access

According to Miceli (2003), cellular system would not be very practical if it only allows one call per system at a time. Thus, cellular designers need to implement methods of multiple accesses (that is, allowing multiple conversations simultaneously).

Today's digital systems use a combination of frequency division multiple access (FDMA) with another multiple access technique, time division multiple access (TDMA). TDMA involves separating users into different timeslots and then adding at different frequencies these "time-divided".

In a TDMA system, the used system bandwidth is usually divided into smaller frequency channels. So in that sense GSM is actually a hybrid FDMA/TDMA system (Figure 1), as are most other 2G systems. In a TDMA system, all users can use the entire channel bandwidth and are distinguished by allocating short and distinct time slots to each user. In this system, a physical channel is defined as a time slot with a time slot number in a sequence of TDMA frame (Poonam et al., 2007)

In code divisional multiple access (CDMA), all users are allowed to use the entire system bandwidth all the time. The signals of users are distinguished by assigning different spreading codes (Poonam et al., 2007). Figure 2 shows how the signals are separated from each other by means of special codes.

Radio-channel access schemes

The usage of radio spectrum must be carefully controlled because it is a scarce resource. Mobile cellular systems use various techniques to allow multiple users to access the same radio spectrum at the same time. In fact, many systems employ several techniques simultaneously (Korhonen, 2003).

Modulation techniques

Freeman (2005) defined modulation as the process of putting useful information on a carrier that can be transmitted from one point to another. This information can be voice, data or signaling data. Data modulation is

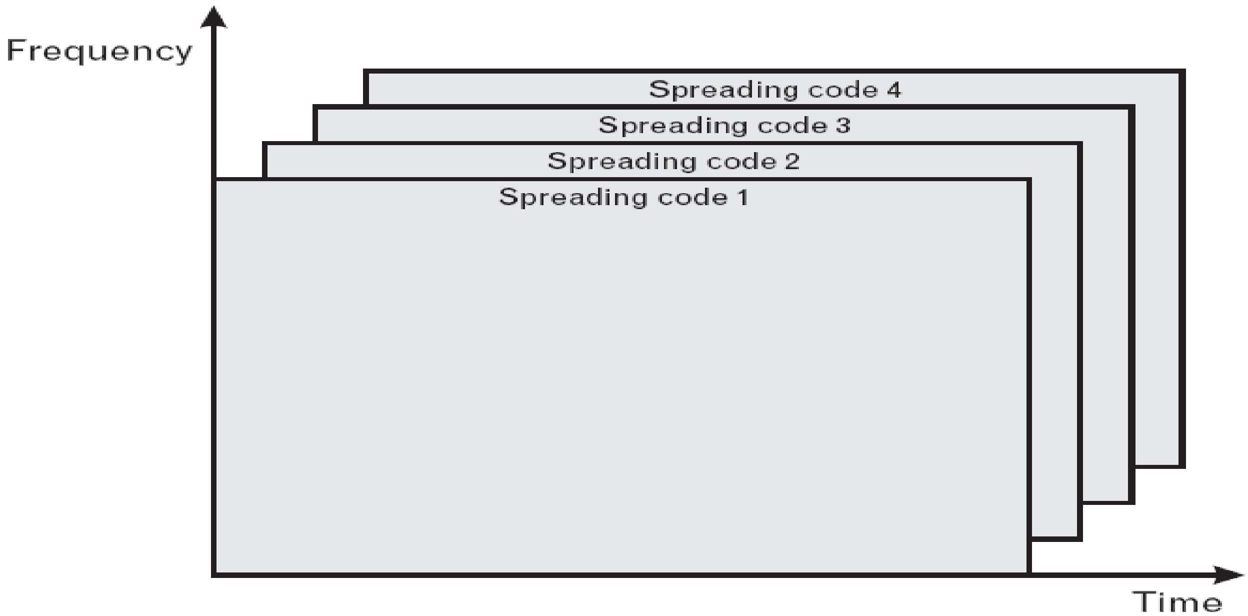

Figure 2. CDMA system: all users occupy the same frequency at the same time, but their signals are separated from each other by means of special codes. Korhonen (2003).

always in digital sense. Modulation techniques used in GSM and 3G were reviewed.

Digital modulation consists of mapping bit sequences into waveforms for transmission over the channel. The main considerations in choosing a particular digital modulation technique are:

1) High data rate
2) High spectral efficiency (minimum bandwidth occupancy)
3) High power efficiency (minimum required transmit power)
4) Robustness to channel impairments (minimum probability of bit error)
5) Low power/cost implementation.

Modulation in 3G

According to Jeffrey et al. (2004), Universal mobile telecommunication system (UMTS) defines the use of quadrature phase shift keying (QPSK) modulation for the air interface. With a QPSK modulation scheme, the complex signal that results from the spreading function is split by a serial to parallel converter into a real and an imaginary branch, each of which is multiplied with an oscillator signal. However, the imaginary branch is 90° out of phase with the real branch. When summed, the resulting signal can have four possible phase angles, each of which represents two data bits.

Figure 3 illustrates the general principle. QPSK modulation is specified for use in both the uplink and the downlink; however, the use of the QPSK modulation scheme does present some difficulties in the uplink. Consider that the amplifier is at a maximum output power and needs to change its signal by 180°. This consumes a considerable amount of power in the amplifier to retain the linearity of the signal, particularly across such a wide frequency band, and most of this power ends up wasted as heat. This is not so difficult a problem at the BTS, but is quite impractical at the UE, where cost, power consumption, battery life and heat dissipation are all significant issues. A common solution to this problem is to use offset QPSK in the uplink instead. With offset QPSK, there is a delay introduced into the imaginary branch to offset the phase shifting of this branch relative to the real branch. The result is that when 180° phase shift is required, the shift is performed in two steps of 90°. QPSK modulation provides a one-to-one relationship between the bit rate of an unmodulated signal and the symbol rate after modulation. In practice, this means that a 3.84 Mcps spread signal entering the modulator will emerge as a 3.84 MHz signal. In the course of the modulation process, pulse shaping is also performed. Wideband-code division multiple access (W-CDMA) uses a root-raised cosine filter with a roll-off of 0.22. A modulated signal with this roll off, plus the provision of a guard band between neighboring frequencies, equates to the 5 MHz of spectrum allocated per W-CDMA carrier. For frequencies licensed to the same operator, there can be less than 5 MHz spacing between carriers. However, the centre frequency must lie on a 200 kHz raster (Jeffrey et al., 2004).

Pulse shaping is a spectral processing technique by

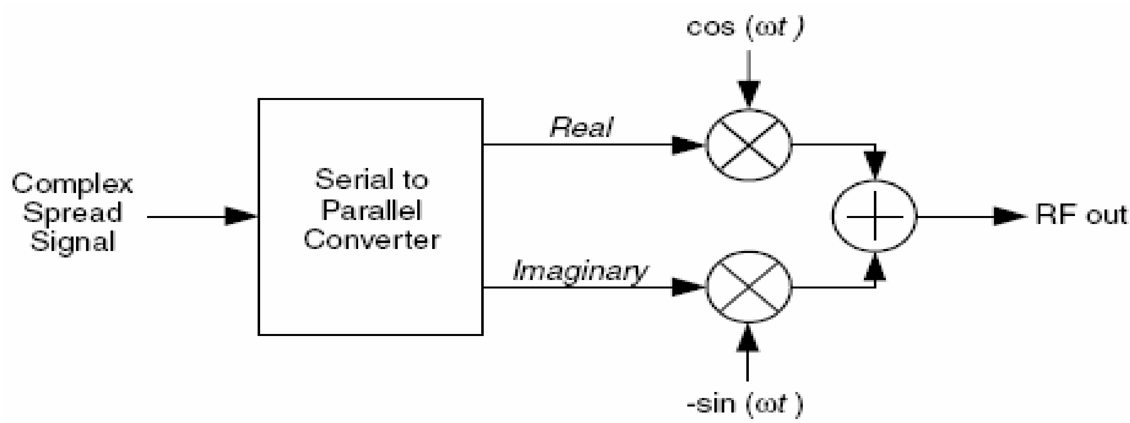

Figure 3. QPSK modulation principle. This modulation technique is used in 3G system. Jeffrey et al. (2004)

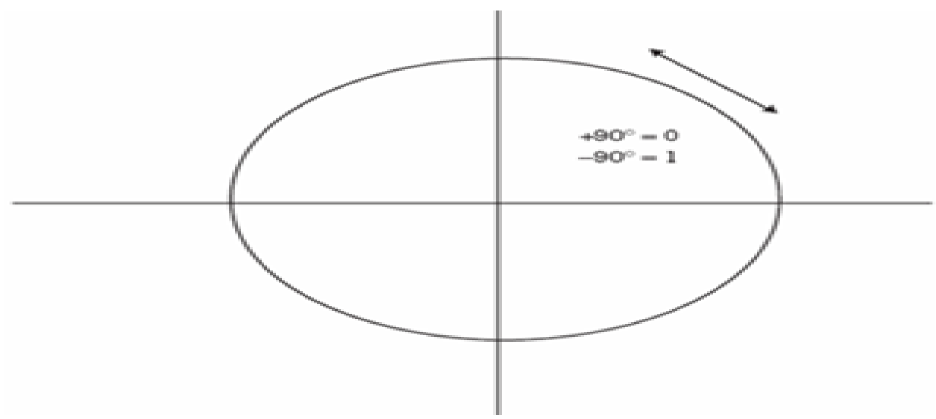

Figure 4. GSM uses GMSK modulation. Amplitude remains constant during phase shifts of ±90. The constellation of a GSM signal thus resembles a circle. Andrew (2003).

which fractional out of band power is reduced for low cost, reliable, power and spectrally efficient mobile radio communication systems. It is clear that the pulse shaping filter not only reduces inter-symbol interference (ISI), but it also reduces adjacent channel interference (Kang and Sharma, 2011).

Modulation in GSM

Masud et al. (2010) stated that GSM uses a modulation format called Gaussian minimum shift Keying (GMSK) (Figure 4). The transmit rate of the GSM system is 270.833 Kbps, while the bandwidth of the signal is 200 kHz. Thus, the modulation efficiency of GSM (data rate divided by bandwidth) is 1.35 bps/Hz. This is a lower efficiency than North American (NA)-TDMA (1.6 bps/Hz).

One of the trade-offs for the lower modulation efficiency is that GSM uses a constant signal envelope, which means less battery drain and more robustness in the presence of interfering signals. In having a constant signal envelope, the constellation diagram of a GSM signal is a circle, and, thus, unlike NA-TDMA and CDMA, constellation analysis will not tell a technician very much about the quality of modulation.

Another important difference between GSM and NA-TDMA pertains to the downlink transmission. In NA-TDMA, the base station transmitted all slots.

This GMSK modulation can only transmit data rate of 1 bit per symbol. So it is quite sure that this kind of modulation scheme is not suitable for the 3G communication system (Masud et al., 2010). So, there is a need to study the performance of new modulation technique that could deliver higher data rate effectively in a multipath fading channel.

However, the implementation of high data rate modulation techniques that have good bandwidth efficiency in W-CDMA cellular communication requires perfect modulators, demodulators, filter and transmission path that are difficult to achieve in practical radio environment. Modulation schemes which are capable of delivering more bits per symbol are more immune to

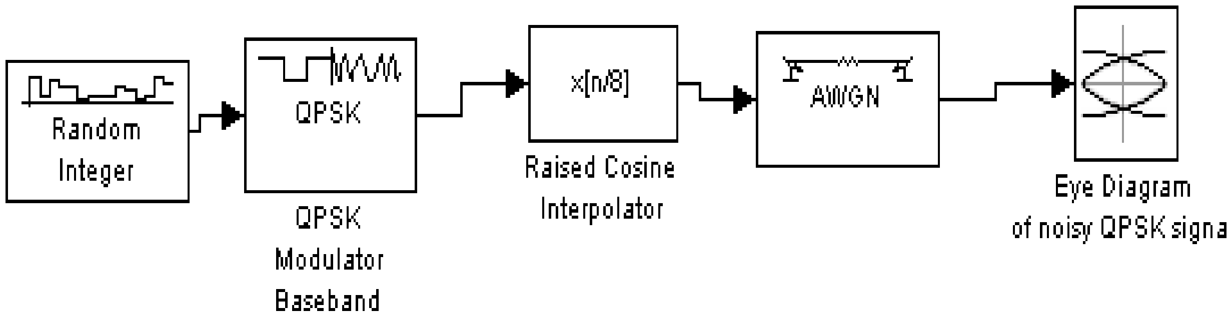

Figure 5. Block diagram of QPSK transmitter. The quadrature form of modulating using I and Q channel.

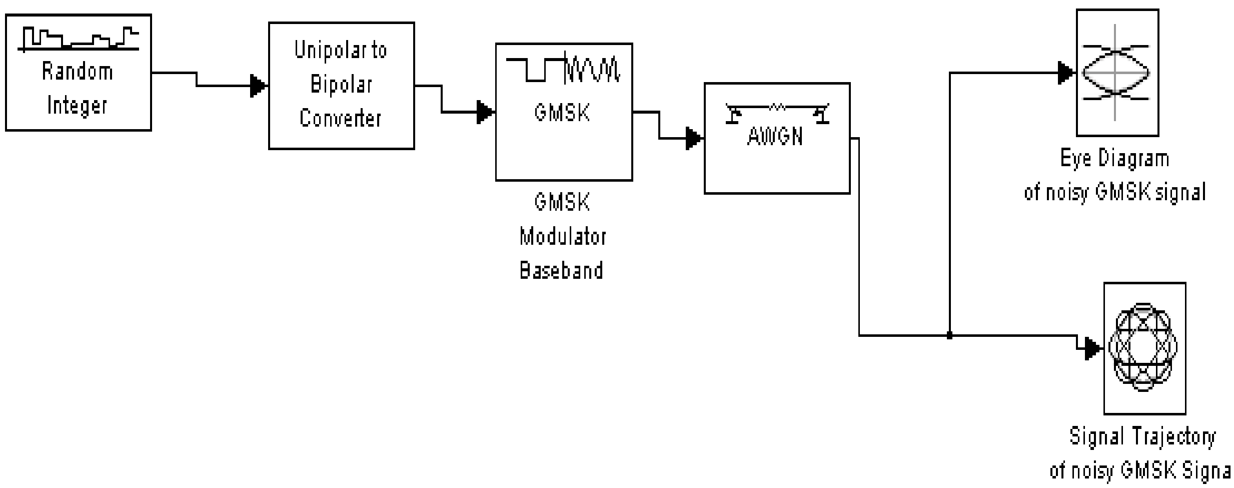

Figure 6. A GMSK modulator implemented.

errors caused by noise and interference in the channel. Moreover, errors can be easily produced as the number of users is increased and the mobile terminal is subjected to mobility (Masud et al., 2010).

Tomislav et al. (2009) emphasized the fact that it is important for base-band signals to be heavily band limited before modulation and that can be achieved by pulse shaping of rectangular bits.

National Instruments RF Projects (2013) also presents these two important requirements: generation of band limited channels, and reduction of ISI from multi-path signal reflections as pulse shaping filter fundamentals on wireless communication system

METHODOLOGY

Simulation of modulation techniques

Simulation of their modulation techniques using MATLAB was carried out. Simulation is programs often quite complex that mimic the dynamic behavior of the model system over time. This method was chosen because simulation is of particular interest during system design, when real life hardware is not available for measurement and in situations where a reasonable accurate analytical model of a system is not mathematically tractable. W-CDMA uses QPSK modulation, while GSM uses GMSK as its own modulation technique.

The circuit diagram for W-CDMA modulation is shown in Figure 5. In the simulation environment, the following outlines were followed:

1) Random number generation (1000).
2) Those numbers were shaped using a square root raised cosine filter.
3) Modulation of the output in ii above was done using QPSK.
4) Constellation plot was carried out.

The circuit diagram for TDMA modulation is also shown in Figure 6. In the simulation environment, the following outlines were also followed for GMSK modulation:

1) Random number generation (1000).
2) Those numbers were shaped using a Guassian low pass filter.
3) Modulation of the output in ii above was done using FSK.
4) Constellation plot was carried out.

SIMULATION RESULTS AND DISCUSSION

Figure 7 shows the Gaussian pulse-shaping filter used in GMSK modulation technique. It is used to smooth the

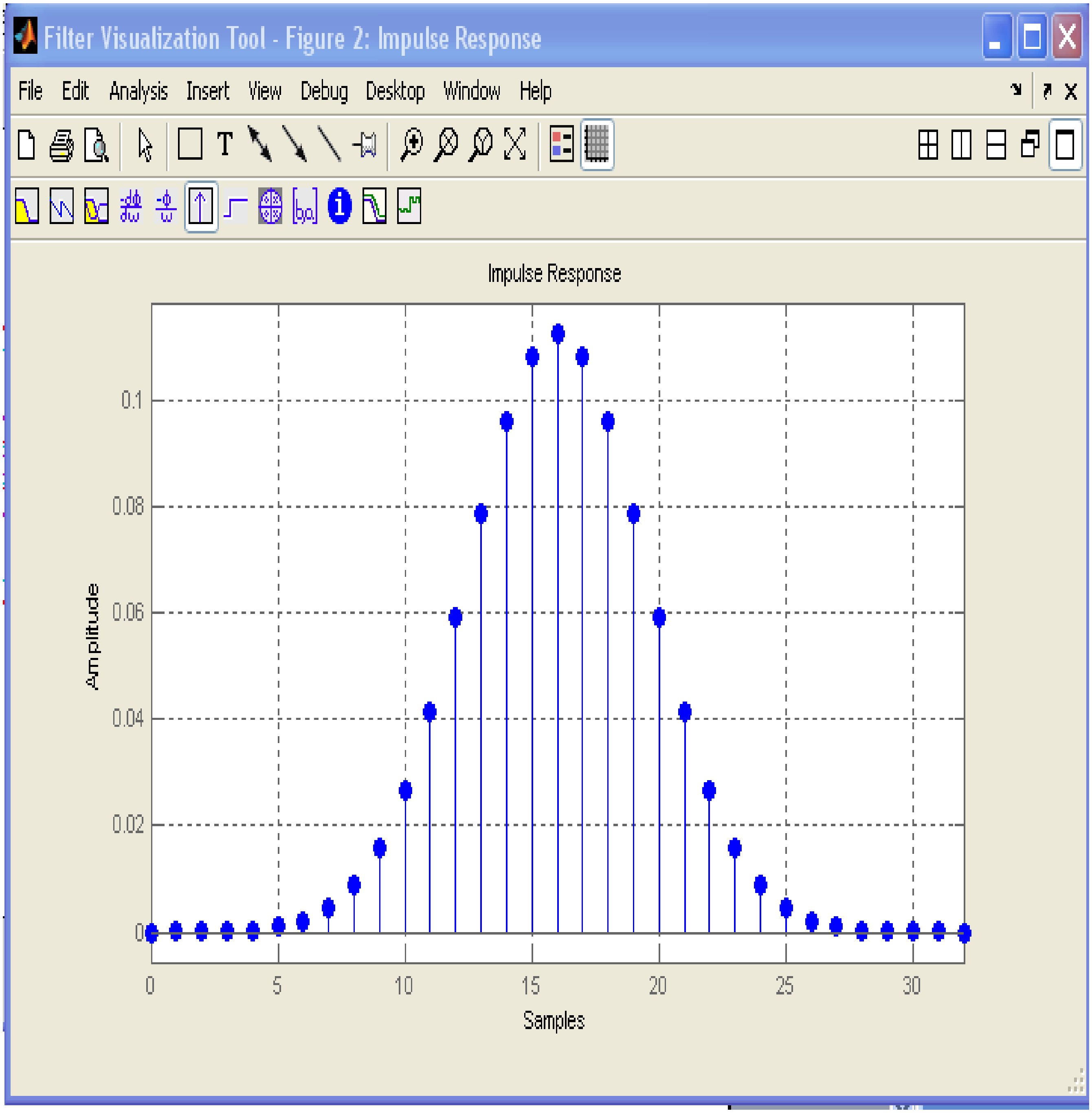

Figure 7. Gaussian pulse-shaping Filter used in GMSK modulation technique.

phase transitions of the modulated signal and also to effectively eliminate spectral leakage, reducing channel width, and reduction of interference from adjacent symbols (ISI) (Tomislav et al., 2009).

Figure 8 represents the GMSK constellation. From the figure it can be seen that the signals were separated among phase state by 45°. This causes the system not to be resilient to noise and this has caused it to be more exposed to interference. All these accounted to its high drop call rate, poor CSSR, poor handing over e.t.c. This kind of modulation scheme is not suitable for the 3G communication system and will not be able to deliver higher data rate effectively in a multipath fading channel.

From Figure 9, the type of filter used in QPSK modulation can be seen (square root raised cosine filter). The amplitude steps in a digital chip stream are the cause for high-frequency spectral components. Since the signal is transmitted on a bandwidth-limited channel,

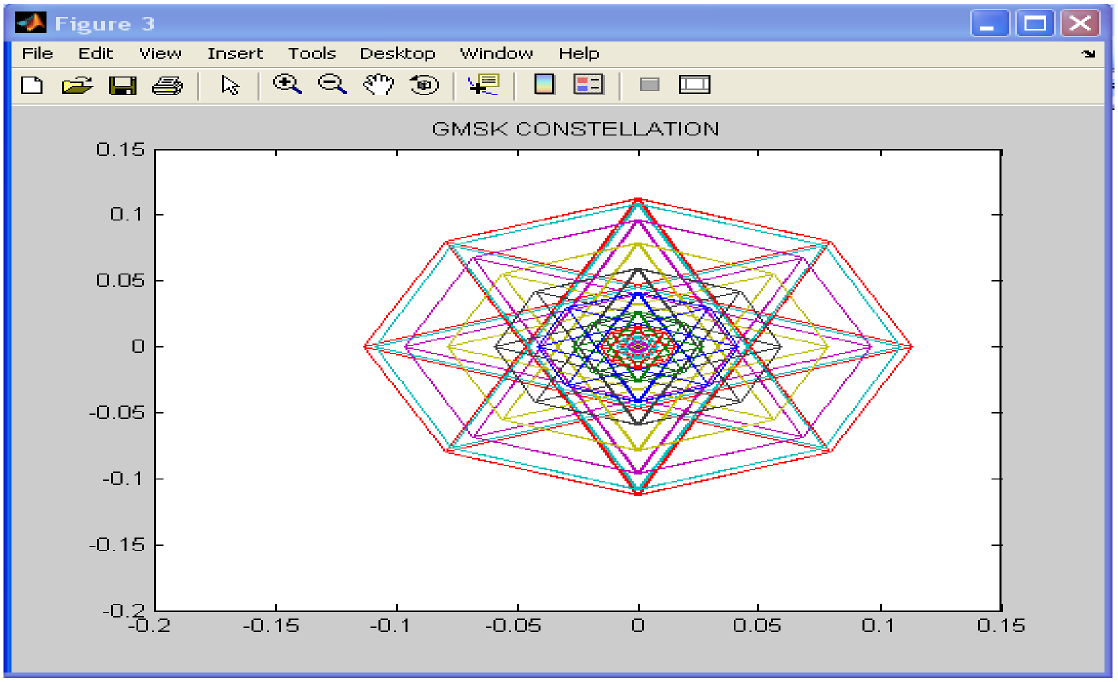

Figure 8. GMSK constellation plot.

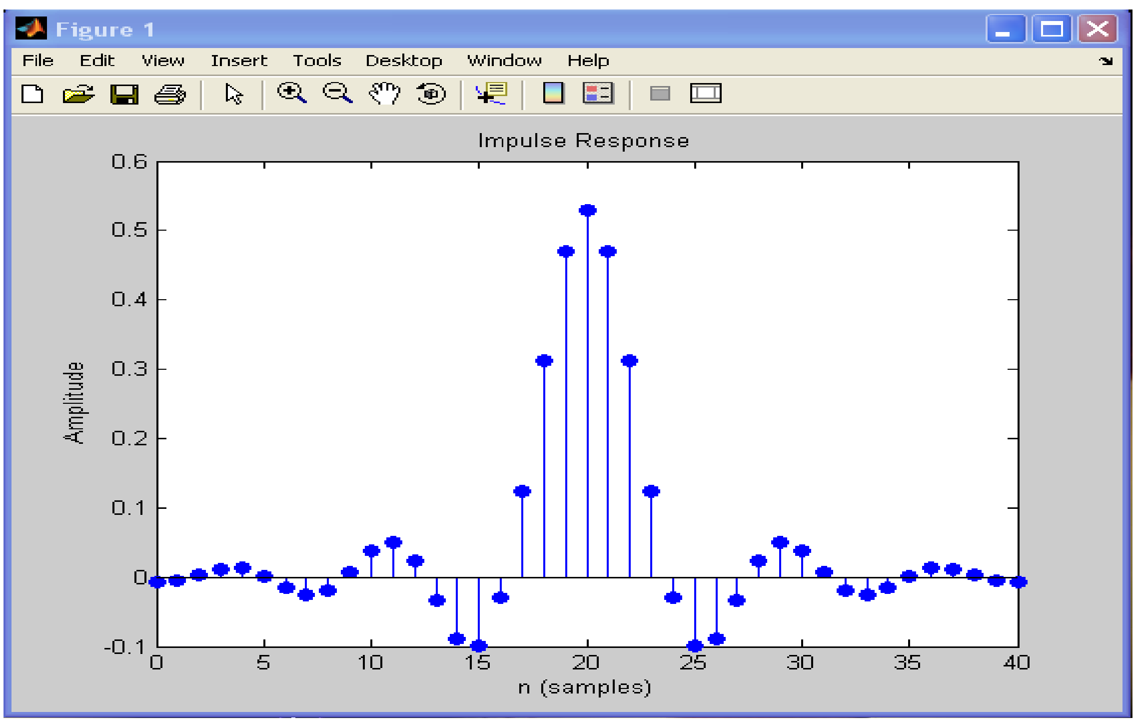

Figure 9. Square root raised cosine filter used in QPSK modulation technique.

smearing of adjacent symbols may happen, known as ISI. In order to avoid such interference, the signal is low-pass filtered using square root raised cosine filter and this accounts for its high performance (Joost, 2010).

Also, Figure 10 shows the QPSK constellation plot. In it the signals were separated among phase states by 90° and this helps it to be:

i) Resilient to noise
ii) More efficient in bandwidth usage

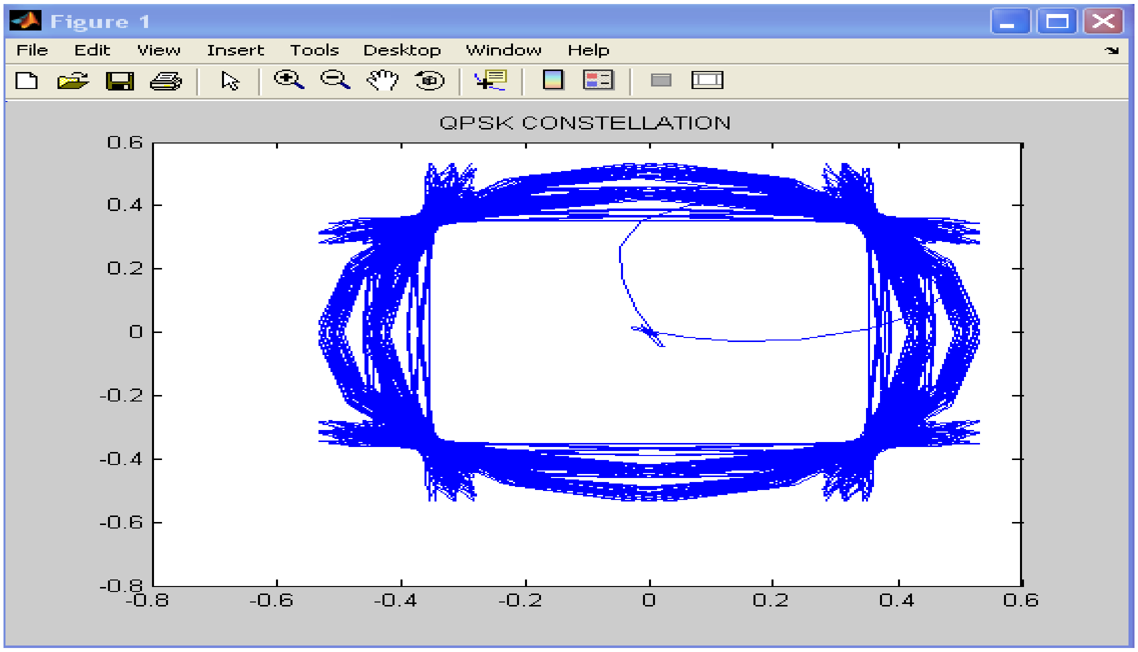

Figure 10. QPSK constellation plot.

iii) Better in data communication speed, because 3G system uses 3 of GSM E1 - is like a frame inside a Radio base station (RBS). RBS is responsible for all the call we make. Each E1 is 2 MBit/s and is divided into 32 time slots.

On the E1, after the slot in the location 0 and 15 have been allocated to framing and signaling, it remains 30 time slots. Each time slot is further divided into 8, which means in an E1, about 240 people can make use of it on time slot basis.

Therefore, in GSM system, about 240 people can use it on time slot basis, while in 3G system, about 720 people use it on time slot basis since it uses 3 of GSM E1 (6 MBit/s).

3G systems also have higher security compared to GSM system because all signals are separated from each other by means of special code since they all used the same frequency channel at the same time.

Conclusions

In this paper, we have evaluated the two systems (W-CDMA and TDMA) based on their modulation techniques. An examination of the two systems (W-CDMA and TDMA) revealed that W-CDMA system renders more general purpose network, which offers the flexibility to provide and support access to any service, regardless of location. These services can be voice, video or data and combinations thereof due to the characteristics and features embedded in it. The features include fast power control, soft handover, efficiency in bandwidth usage, resilient to noise, rake receiving and a lot more.

Conflict of Interest

The authors have not declared any conflict of interest.

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