Progressive Transmission of JPEG encoded Line Drawings over GSM

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Abstract:
After an introduction of mobile telecommunication, with GSM in particular, the JPEG coding technique is discussed, with respect to progressive transmission of line drawings. Practical results are compared to a theoretical model about the number of transmitted bits, when the line drawings are represented by an x-y representation that is JPEG encoded, and are transmitted progressively over GSM. Also the coverage of this GSM network is tested by using the data-communication facility.

Indexing terms:
Mobile data-communication, GSM, JPEG, Progressive Transmission, Line Drawings, x-y representation.

Contents

Summary

With the coming of mobile data-communication, especially with the new GSM network, new applications in this field are offered to the mobile user. One of these applications is the transmission of line-drawings. But mobile data-telecommunication is still rather expensive if compared to the public telephone network, so special care must be taken in compression of the drawings. Another way to reduce the transmission time is to use progressive transmission. In this way the transmission can be stopped if the receiver finds the drawings clear enough.

One coding scheme that consist of both good compression and progressive transmission is called JPEG. But this compression method is not suitable for coding line drawings. In this report it will be shown that if the line-drawing is represented by a representation method like the x-y representation, the JPEG coding scheme will give good results.

To be able to test the transmission of JPEG encoded Line Drawings over GSM, the GSM network had to be tested first about the coverage in the Netherlands, with respect to the main rivers. In this way it becomes possible to transmit the drawings at both good and worse places and retrieve mean results. The outcome of these coverage tests for the tested ereas was, that only between Nijmegen and the German border it was difficult to get a good connection.

When transmitting the different parts of progressive transmission a number of errors will occur due to the mobile environment. Because of this phenomenon a number of re-transmission will occur. In the tests performed in this report, the number of transmitted bits, due to re-transmissions, did not exceed the number of bits of the original drawing and there was still a good reduction factor in these images. So for transmitting line drawings progressively over a mobile communication channel, JPEG is a good compression method.

List of Abbriviations

BS	Base Station
DCT	Discrete Cosine Transformation
DPCM	Differential Pulse Code Modulation
E-Mail	Electronic Mail
FEC	Forward Error Correction
GSM	Groupe de travail Spécial pour les service Mobiles / Global System for Mobile communicatiojn
IDCT	Inverse Discrete Cosine Transformation
ISDN	Integrated Services Digital Networks
IWF	Interworking function
JBIG	Joint Bi-level Image Group
JPEG	Joint Photographic Experts Group
MHS	Message Handling Systems
MPEG	Motion Pictures Expert Group
MS	Mobile Station
MSC	Mobile Switching Centre
MSE	Mean Squared Error
MT	Mobile Terminator
PSTN	Public Switched Telephone Network
RLP	Radio Link Protocol
SC	Service Centre
SMS	Short Message Service
VLC	Variable Length Codes
VLI	Variable Length Integers

Introduction 1

A business example :

Suppose someone is traveling in an area to which he is not known. He receives an order on his data terminal. In this order he is asked to pick up a package at point A and deliver it at point B within a certain time. Because he is not familiar with the environment, he needs some kind of description about the route he has to travel. Now he can call with a device, that is capable of performing data communication, to an address where the route information is stored. This information is now sent progressively to the applicant. Very quick he can have an impression about the route he needs to follow.. As time passes, more detail is sent. The transmission can be aborted if the applicant finds the detailed information sufficient. With the information about the route, the traveling time can be estimated. With this estimation the mobile user can send a message to point A with the expected time of arrival. In this way they can have the package ready for transport by the time he arrives. Such forms of route information described above are investigated by the Dutch government (V&W, project MRI: Multimodale reizigersinformatie) and the European Union (Eurotriangle, ACCEPT, Rhine Corridor).

1.1 Mobile data-communication.

With reference to the former example, mobile data communication offers new applications in the field of exchanging information in a mobile environment. It becomes possible to transmit plain text, images and drawings, or even structured forms. All these kinds of data communication need a data-terminal at both ends of the transmission path.

One of the applications for mobile data communication can be the transmission of line drawings, especially in the field of route information. Also a problem can be clarified by means of a sketch. Advantages of this kind of transmission above existing devices, like fax, are:

- colors can be used to indicate different lines,
- lines can be transmitted progressively,
- drawings can be adjusted,
- drawings can be re-transmitted without quality loss.

Because transmission of line drawings can find its application in the field of route information, this form of data communication certainly is an interesting subject to investigate in a mobile environment.

1.2 Mobile data networks.

For mobile communication nowadays a few networks can be used. First there are the somewhat longer existing, first generation, analogue networks. Some names known in the Netherlands for these systems are:

- NMT-900 (Nordic Mobile Telephone system), for example ATF3, standard for analogue (first generation) mobile telephone,
- MPT1327, for example Traxys, trunked communication protocol primarily developed for speech communication.

Most of these systems are developed for speech communication, although data communication is also possible on a very small scale.

The newer generation of mobile telephone networks is based on digital transmission. A few names in this context are:

- GSM (Global System for Mobile communication), primarily developed for speech transmission, but also very suitable for data communication,
- Mobitex, primarily developed for data-transmission.

Because the analogue networks are not really suitable for data communication, only the digital networks remain for further investigation. In this report the GSM network is chosen instead of Mobitex for the following reasons:

- The coverage in the Netherlands is much better than that of Mobitex,
- It will cover all of Europe by the end of 1995,
- It will be cheaper if the volume of transmitted data is large (10 kBytes or above) [4]. Drawings are mostly represented by many bytes.
- The data-facility is rather new in the Netherlands (July 1995) and is worth investigating.

1.3 Progressive Transmission.

Progressive transmission of a drawing is a way of sending an image gradually to a receiver instead of all at once. In other words, first a low resolution approximation of the drawing will be sent first, followed by higher resolution information to refine the drawing as time passes. This special way of transmitting an image has a few advantages:

- a global impression of the drawing is obtained fast,
- the costs can be reduced by stopping the transmission on demand.

A quick impression of the drawing is especially useful when there is limited time to decide on the basis of the drawing. The receiving mobile user can stop the transmission when he finds the drawing clear enough, thus saving costs.

Certainly in the field of mobile communication the cost saving aspect is an important motivation to use progressive transmission. Mobile communication is a rather expensive medium (90 cents per minute in the top hours for GSM), so much can be saved by minimizing transmission time. That is why this way of transmitting an image certainly is worth investigating.

1.4 Coding Line Drawings.

Nowadays many different possibilities are known to effectively code a line drawing. But most of these coding techniques do not have an option for progressive transmission. One coding technique that does possess this, is called JPEG (Joint Photographic Experts Group). But JPEG only performs well with real life images, and not with black-and-white (one bit per pixel) drawings and motion pictures. Derived techniques for these kinds of images are JBIG (Joint Bi-level Image Group) and MPEG (Motion Pictures Expert Group).

The JBIG coding scheme seems to be the most obvious and perhaps the best coding technique for line drawings. But a part of the JBIG coding scheme is patented by IBM, so the source code and detailed information is difficult to obtain. Another problem with JBIG shows if a line drawing is coded progressively. The low resolution approximation shows as big blocks on the screen. So another coding scheme, which will keep the characteristics of a line drawing, must be used. For these reasons the Line Drawings are discribed in such a way, that they can be coded with JPEG.

1.5 Scope of this report.

The purpose of this report is to investigate in what way line drawings are effected when they are coded with JPEG and progressively transmitted over the mobile network, GSM. To reach this, first the GSM network is tested on coverage and quality. Next, the line drawings are described in such a way that it will give good results after JPEG coding. The effect of errors in different steps of the progressive transmission and how they will work through the image are investigated as well.

In Chapter 2 the overall model of mobile telecommunication will be discussed.

Chapter 3 will handle GSM with all the facilities and especially the data facility.

Chapter 4 focusses on the JPEG coding scheme. In this chapter it will also be shown that if a line drawing is looked at in another way than a bit-plain, the JPEG coding scheme might actually work.

Chapter 5 will handle the JPEG coding scheme with respect to Line Drawings.

Chapter 6 will give a theoretical review about an estimation of the transmitted number of bits if the Line Drawings is encoded with JPEG and transmitted over GSM.

In Chapter 7 the results of the tests to retrieve the information about the quality and coverage of the GSM network are discussed. This is followed by the results of the progressive transmission of the line drawings, coded with JPEG and transmitted over GSM.

In Chapter 8 conclusions will be drawn about the quality of GSM and the suitability of JPEG with line-drawings.

Mobile Telecommunication 2

The growth in the use of mobile telecommunications nowadays is the result of the fast developments in the field of micro electronics. These developments made it possible to reduce the weight and size of both transmitter and receiver. Also the availability of smaller batteries, which last longer, and the development of systems like cellular network with micro and pico cells have contributed to a miniaturisation of terminals.

2.1 Cellular Networks

A cellular mobile communication system is made of a number of cells with in every cell one or more Base Stations [2]. These Base Stations dispose of several radio channels. With the use of two radio channels a mobile user can make a duplex connection with the nearest Base Station. The Base Station is connected to a Mobile Switching Centre and this one is connected to the local telephone network (see Figure 2.1).

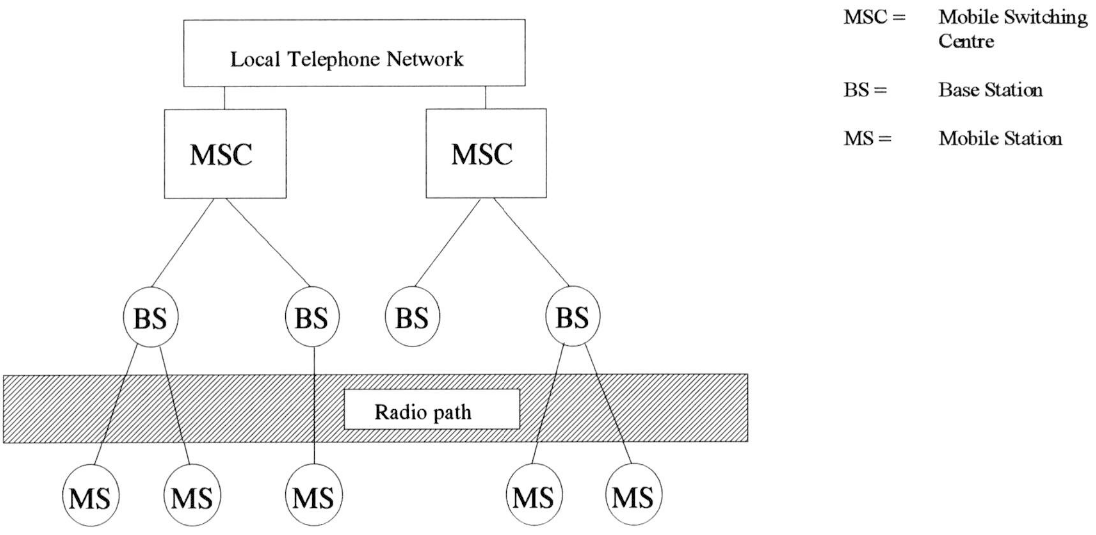


Figure 2.1: Mobile Communication System

To be able to move through the mobile network without any problems, two roaming facilities have been made.

1. **Hand over**
   In the receiver of the Base Station the power of the signal is constantly measured. When this power drops beneath a certain level the Mobile Switching Centre is notified. The Switching Centre then orders the surrounding Base Stations to measure the power of the mobile station. The Base Station that measures the highest power must take over the mobile connection in a free radio channel. The switching between base stations may take some hundreds of a millisecond.
2. **Location Registration**
   To make a connection with the mobile user one has to know the location in which the user remains. The location of a user is defined by the nearest Mobile Switching Centre. Every subscriber of the mobile network is registered in the location register of the MSC closest to the subscribers home address (Home MSC). All relevant data about the subscriber are situated in this HMSC, like his registration number, net number, services that can be used, conversation costs and the Visiting MSC in which the user is situated. Location registration goes as follows. If the subscribers Mobile Station is stand-by, it is sending its registration number. This is received by the nearest Base Station, that will pass this message on to the VMSC. The VMSC registrates the message of the visiting user and tells the HMSC that the subscriber is in the area of the VMSC. In this way a call from a subscriber can be passed via the HMSC to the VMSC.

The advantage of cellular networks is situated in the fact that a frequency channel can be re-used over a certain distance. This distance is defined by the strength of the mutual interference of the cells. The lesser the interference must be, the further the cell must be apart. Creating the distance between the cells is accomplished by making clusters of these cells. The total available frequency band is now divided over the cells of one cluster. An example of a cluster with seven cells is shown in Figure 2.2. Cells with the same numbers use the same frequency.

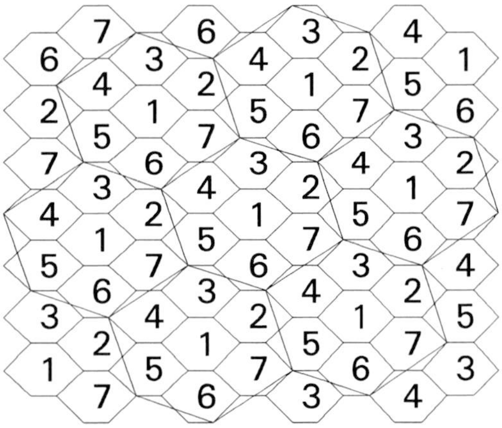


Figure 2.2: a cluster with 7 cells

One of the major problems of mobile communication is the effect of fading. There are two different kind of fading phenomena: the slow variation in mean signal power that is called shadow fading and the fast fluctuations that are called multi-path fading. Shadow fading is caused by the presence of obstacles between transmitter and receiver. The multi path fading is caused by the many ways in which the transmitted signal can travel. At the input of the receiver all the signal components are added and in this way may exclude each other (for further detail see paragraph 6.2.1).
Another problem of radio communication is the interference of other not wanted signals. These signals can be coming of neighbour cells or cells from another cluster. Fact is that this interference should be kept as small as possible.

2.2 Ordering the channel

When several communication channels are needed between the same points, significant economies may be realised by sending all messages on one transmission facility. This process is called multiplexing. There are three basic multiplexing techniques: Frequency Division multiplexing, Time Division multiplexing and Code Division multiplexing. These three forms of multiplexing are pictured in Figure 2.3.

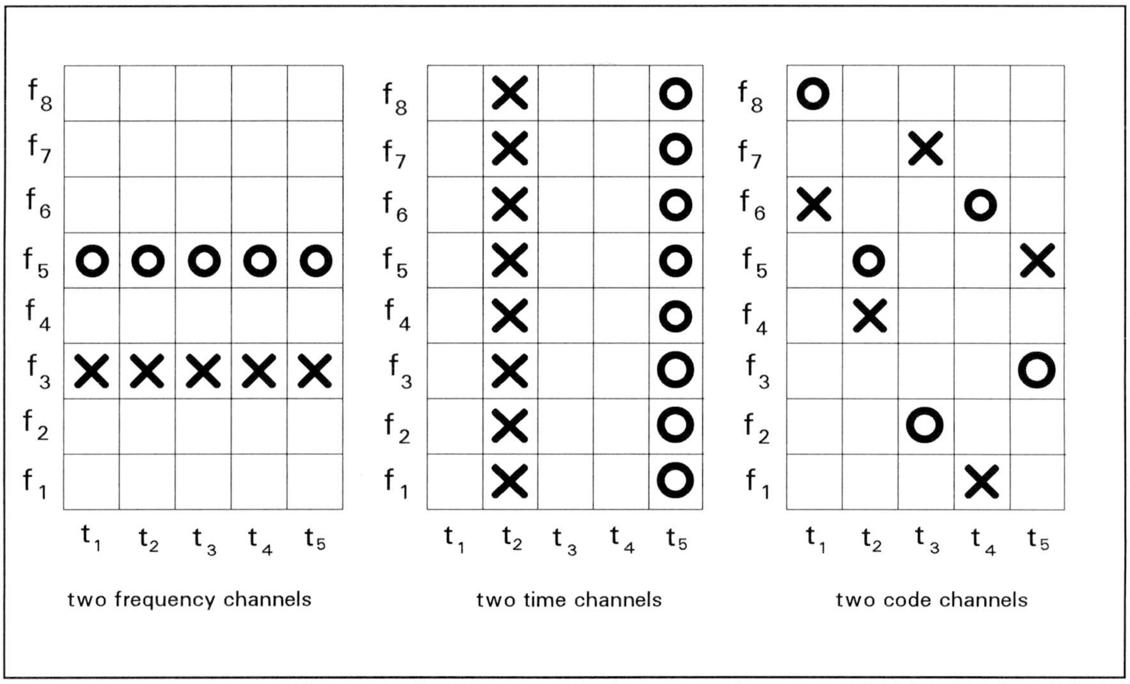


Figure 2.3: Three multiplexing techniques, FDM, TDM and CDM

2.2.1 Frequency division multiplexing (FDM)

The principle of FDM is illustrated by Figure 2.4, where several input messages individually modulate the sub-carier f1, f2, etc., after passing through the low pass filters to limit the message bandwidths. The frequency spectrum of the FDM signal is shown in Figure 2.5. These stacked frequency channels are then modulated to get them in the desired frequency band (carrier modulation).

Message recovery or demodulating of FDM is accomplished in three steps. First the carrier demodulation reproduces the base-band signal. Then the modulated sub-carriers are separated by a bank of bandpass filters in parallel. At last the messages are individually detected.

The major practical problem of FDM is cross talk, the unwanted coupling of one message into another. Intelligible cross talk (cross modulation) arises primarily because of nonlinearities in the system. This causes one message signal to appear as modulation on another sub-carrier. Another cause of intelligible cross talk is imperfection of the different filters. To reduce this phenomenon, guard bands are introduced between the frequency channels.

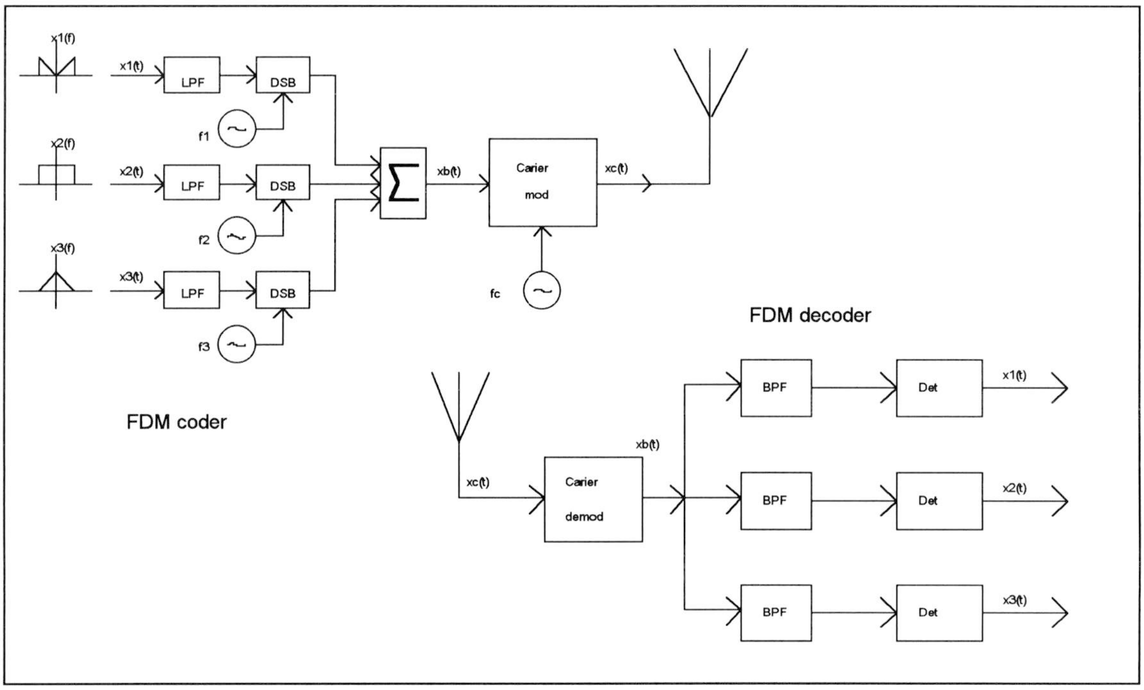


Figure 2.4: FDM Principe

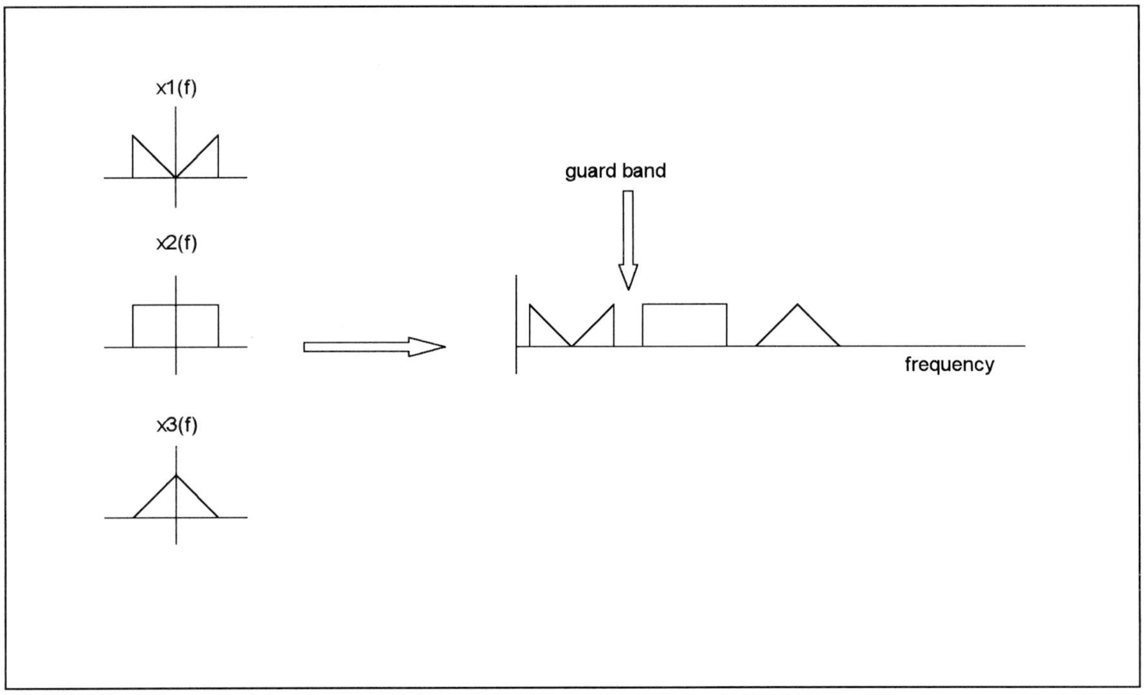


Figure 2.5: frequency spectrum of FDM

2.2.2 Time division multiplexing (TDM)

A TDM system can be pictured as in Figure 2.6. In this figure the pulse-modulation gates process the individual inputs to form the TDM output. The gate control signals come from a flip-flop chain (a broken ring counter) driven by a digital clock. For radio transmission of the TDM signal the additional step of modulation is necessary. The demodulator of TDM would have similar structure.

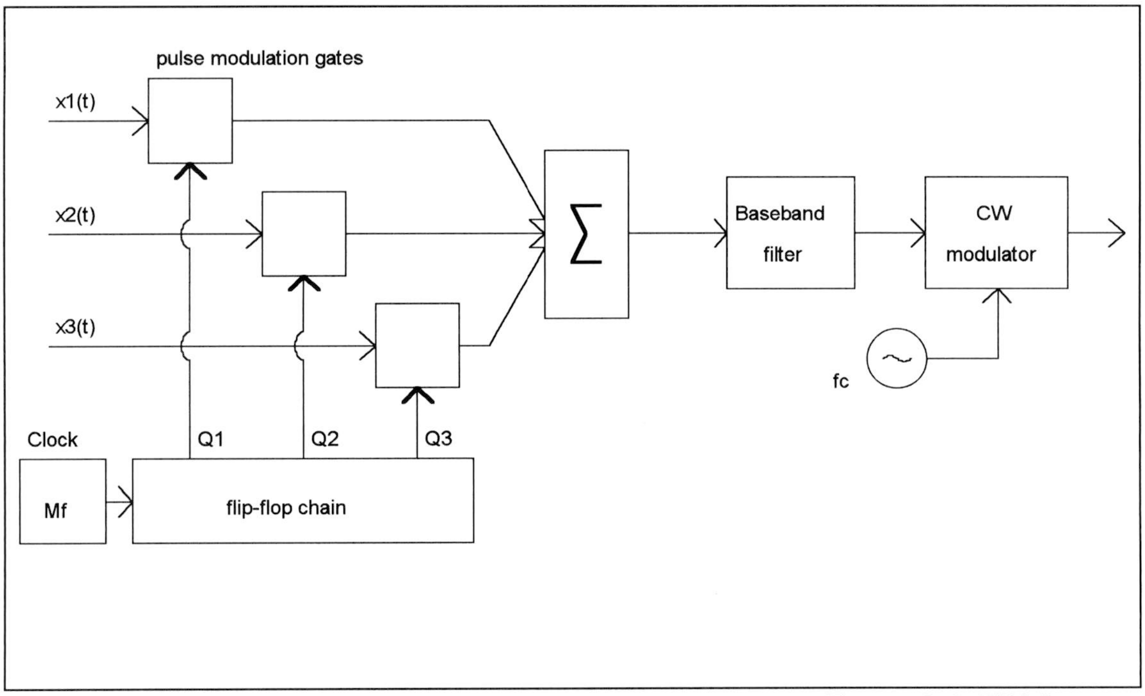


Figure 2.6: TDM system

Regardless to the type of pulse modulation, TDM systems require careful synchronisation between transmitter and receiver. Synchronisation is a critical consideration in TDM, because each pulse must be distributed to the correct output line at the appropriate time. A TDM signal also has cross talk if the transmission channel results in pulses whose tails or postcursors overlap into the next time slot of the frame. Pulse overlap is controlled by establishing guard times between pulse, analogous to guard bands between channels in a FDM system. Practical TDM systems have both guard time and guard bands, the former to suppress cross talk, the latter to facilitate message reconstruction with non-ideal filters.

2.2.3 Code division multiplexing (CDM)

With CDM the channel is created by using different codes. This code represents the selection means and the carrier of the transmitted information. The taken radio frequency band is mostly much broader than the base-band. This is why this technique is also called spread spectrum technique. The principle of the coding will be explained on the basis of the direct sequence method.

Direct sequence method.
The direct sequence method uses pseudo random series. Every user gets one of these series, which is sufficiently different from the others. It is necessary that there are enough series of a certain length that consists of a sufficiently low cross correlation. Interesting in this field are the so called 'Gold Codes'. These codes are made from a combination of maximum length series. The resulting series do not consist of the maximum length properties, but do have an efficient correlation behaviour. The code generator is built from two shift registers of n sections. These registers each generate a different maximum length series. By summing the outputs modulo-2 one Gold Code is created (see Figure 2.7). In his way 2^n-1 Gold codes can be made.

The autocorrelation function of a Gold code has one peak and this is when the codes are the exactly same. With the use of this property the different users can be detected and separated. The transmitter and receiver are pictured in Figure 2.8.

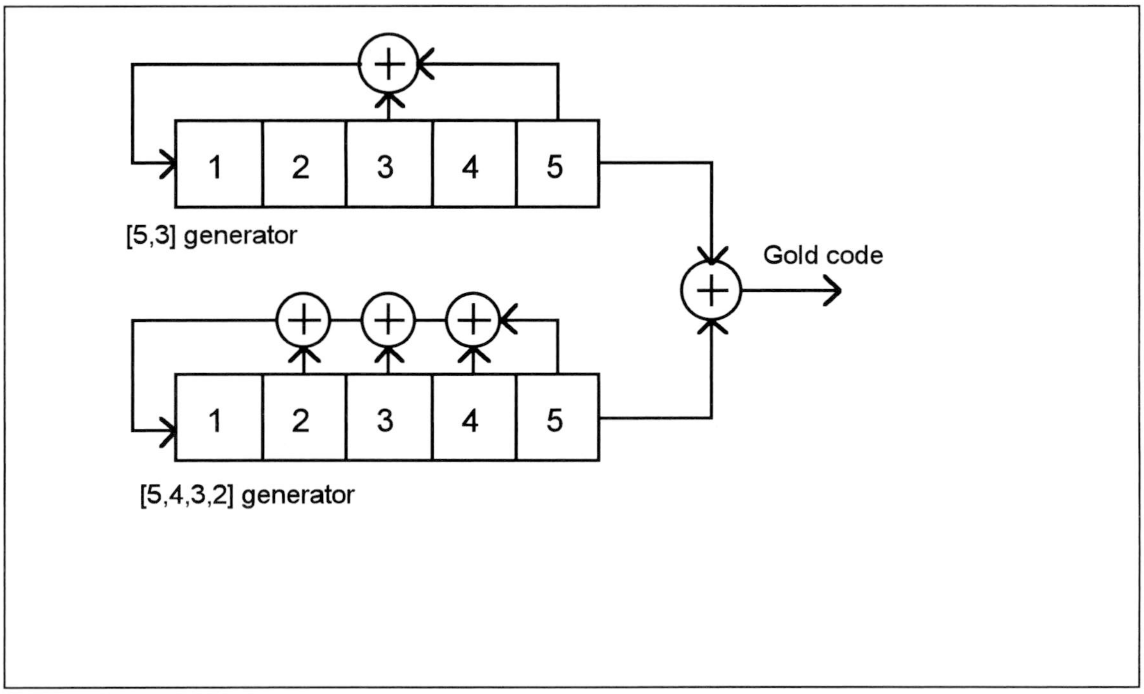


Figure 2.7: gold code generator

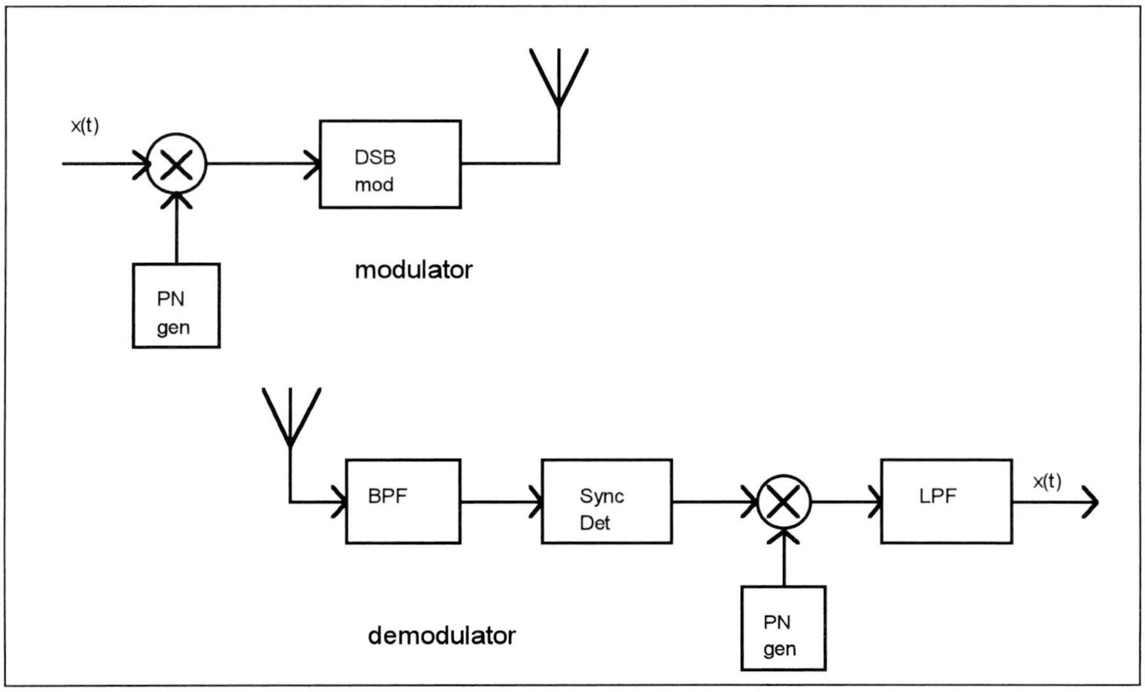


Figure 2.8: modulator and demodulator with code multiplexing

2.2.4 Random Access

Except a central ordered allocation of time slots in a TDM system, it is also possible to let the allocation be done by the users. One step further even the time slots can be released. An example of a system with no time slots is the ALOHA system, developed in the university of Hawaii. The system is developed to have data transmission in packets. Every user sends its packets whether the channel is already being used or not. It is necessary for the receiver to transmit an acknowledgement. If this message is not received then there must have been a collision between other packets.The user sends the packet again and again until it is properly received. Between every re-transmission of a packet there is some pause, which is different for every user, so there will not be a constant repetition of collisions.

There are some adjustments about this ALOHA system, like slotted ALOHA. More information about the ALOHA system can be found in [3].

GSM 3

From the first of July 1994 a new carphone network is operational in a number of European countries.This network is called GSM. The abbreviation GSM comes from 'Groupe de travail Spécial pour les services Mobiles', and is called nowadays 'Global System for Mobile communication'. This workgroup was founded within the CEPT, Conférence Eurpéenne des administrations des Postes et des Télécommunications, an institute of 22 PTT telecom operators. The workgroup GSM has been working intensively since 1985 on the specifications of GSM. The most important demands about the system are:

- it must work in all of Europe;
- it must be able to co-operate with ISDN;
- it must offer a great deal of datacommunication services;
- it must be suitable for phones and handheld phones;
- the quality of speech must be at least equal to the existing systems;
- access to the network must be secured and the information must be able to be encoded;
- the available frequency spectrum must be used as efficiently as possible;
- it must use the frequency band from 890 to 915 and from 935 to 960 MHz;
- it may not interfere with other systems;
- the total costs may not exceed the costs of the existing systems.

The capacity of the GSM network was determined as 25 conversation per square kilometre at one time. At the beginning the GSM network was not determined to be a digital network. Later during the work of the workgroup it became obvious that GSM had to be digital in order to meet the requirements.

3.1 Services and facilities

The telecommunication services in GSM are, just like in ISDN, divided into three categories:

1. bearer services, the transmission services offered by the network access;
2. teleservices, the services offered to the user by using the available bearer services;
3. supplementary services.

It is tried to offer as much similarity of services as in ISDN. The difference with ISDN services comes from the limitation of the capacity of the mobile channel. ISDN offers two 64 kbit/s channels for data and one 16 kbit/s channel for signalling. GSM offers only one 22.8 kbit/s channel for data and one 1.9 kbit/s channel for signalling.

3.1.1 Services

Bearer services:

Seven GSM bearer services can be described:
1. digital circuit switched connection, meant for interworking with the 3.1 kHz audio-ISDN-service;
2. circuit switched asynchronous duplex dataconnection at a speed of 300, 1200, 1200/75, 2400, 4800 and 9600 bit/s;
3. circuit switched synchronous duplex data connection at a speed of 1200, 2400, 4800 and 9600 bit/s;
4. packet switched synchronous duplex connection at a speed of 2400, 4800, 9600 bit/s;
5. alternate speech and data;
6. speech followed by data;
7. digital 12 kbit/s data connection.

Teleservices:

The following teleservices are defined within GSM:
1. speech communication, telephone and emergency calls;
2. Short Message Services (SMS), point-to-point and cell broadcast;
3. access to Message Handling Systems (MHS);
4. videotex;
5. teletex;
6. facsimile, automatic fax and alternate speech and fax;

Emergency call and SMS are not defined in ISDN. The first service offers everyone with a GSM set to place an emergency call, even when the person doesn't have a GSM subscription. In SMS two versions are defined, point-to-point and cell broadcast. With the former the user has the possibility to send at the most 160 characters to a Service Centre (SC). This SC acts as a store-forward-centre and sends the message to the addressee if he is available. The sender receives a confirmation if the message is delivered.

Supplementary services:

The supplementary services are based on the similar services in ISDN. In some cases the services are adjusted or added because of the mobile environment. A survey of the most important services is given below.

Number Identification Services
This group of services shows to the caller the number of the one he is calling and to the one who is called the number of the caller before the phone is picked up. These services do not work if the callers' number is a secret number. Also the subscriber can prevent that his number will be shown.

Switch Through Services
These services offer the subscriber the possibility to switch incoming calls under certain circumstances to another subscriber, without excepting the call. The circumstances of switching are:

- allways;
- if the line is taken;
- if there is nobody to answer;
- if the mobile station is disconnected or there is another reason why radio contact can not be made.

Call hold
With this service the subscriber is told if any new calls are in a que when he is calling. The person who is called, can decide wether to accept the call or neglect it. If the call is accepted, one can choose to end the existing conversation or to temporarily interrupt it.

Call back when busy
In case the line is busy, the caller can give the network an order to call again when the line is free. With mobile communication this only works when the caller stays in the same mobile switching centre.

Cost indication
With this service the mobile station can calculate the costs of the conversation. At the beginning of the conversation the mobile station is told how much the charge rates are. The mobile station uses then an internal clock to measure the length of the conversation and computes an estimation of the costs.

3.1.2 Facilities

The most important facilities on GSM are given below.

Smart card.
In GSM many security measures are taken, such as safeguarding users against abusing the network and protecting the privacy of the users. If a subscriber wishes access, the network checks his or her identity with the help of cryptographic techniques. This access procedure is based on a unique subscribers identity number and a secret key, that is given to each subscriber by the network manager. To secure the privacy of the user, this identity is replaced by a temporary identity. This makes it very hard for anyone to track the user. Also the signals of the users are scrambled.

The security function of the mobile stations are placed on the smart card. This is a removable, small and easy to take plastic card with a micro processor build in. It does not belong to the communication set, but is given to the user by the network manager as a part of the subscription. This admits the user to call at his own account, regardless of the GSM set that is used.

Set identity
Because there is no direct relation between the user and his set, special efforts were made to trace malfunctioning sets or stolen sets. To make tracing possible, each set has its own unique set identity, a kind of serial number. The network can check this number any time. If it turns out to be a malfunctioning or stolen set, the network can deny access of this set to the network. With this identity, statistical information can be gathered

Emergency call.
Every GSM set can easily place an emergency call. To limit the abuse of this facility a little, it is possible to deny permission of a certain GSM set if the emergency call is repeatedly placed.

Other facilities.
Other features of a GSM set are:
- presentation of the dialed number;
- indication of the proceeding of the build-up of the conversation;
- presentation of the country and GSM network where the user is situated;
- indication of the power of the transmitter.

3.2 The GSM radio system

With GSM the signals are transmitted digitally. That is why it is necessary to digitise the analogue speech. In the next part speech coding will be discussed followed by the digital transmission.

3.2.1 Speech coding.

To transmit a speech signal in the frequency band of 300 to 3400 Hz with good quality a bit rate of 64 kbit/s is need when a conventional method like Pulse Code Modulation (PCM) is used. Channels with a capacity of 64 kbit/s take to much radio bandwidth, so the speech signal has to be coded. This coding technique makes it possible to reduce the bit rate to 13 kbits/s and the frequency channel is then reduced to 25 kHz.

3.2.2 The speech codec.

The speech codec reduces the bit rate to the amount of 13 kbits/s. To reach this reduction several techniques are used:
- Discontinuous Transmission System,
- Long Term Prediction
- Linear Predictive Coding,
- Frequency discrimination.

First the GSM system uses the so called Discontinuous Transmission System (DTX-systems). This system takes care that the radio channel is only used when there is speech information. During the pauses between speech the radio transmitter is shut down. In a normal conversation both parties use approximately 50 percent of the speech time. To make DTX possible the GSM codec is supplied with a Voice Activity Detector. By using the DTX system, the system capacity is almost doubled. Another advantage of DTX is the saving of energy of the batteries. In this way smaller batteries can be used, which makes the mobile telephone smaller and lighter.

The second technique for data-reduction that is used, is based on the fact that both users are human. The human speech production gives certain properties to the speech signal, which the codec can use. A speech signal has a regular pattern. The repeat frequency of this are conform to the frequency of the vocal chords. In other words: sampled signals at time t are strongly correlated with sampled signals at time $t-T$, with T the repeat period. In the speech codec this is called 'long-term-dependency'. By using this correlation in the signal, a prediction can be made of how the signal will be in the next time period of length T. This way of prediction is called *Long term Prediction.*

The sampled signal values also have a short term dependency. On basis of for example eight successive signal samples, a following signal can be predicted. This technique is called *Linear Predictive Coding.*

Apart from prediction of the speech signal the codec also uses the properties of the human hearing. A signal can become inaudible if a louder second signal is present with a frequency close to the first signal, thus the first signal can be neglegted. In this way a minimal number of bits is needed to subscribe the signal.

3.3 Frequencies.

A Mobile Station (MS) communicates through a radio path with the Base Station (BS). To make this possible, there are two frequency bands reserved for GSM around the 900 MHz. One frequency band is used for transmission from the Mobile Stations to the Base Station (also called 'uplink'). The other frequency band is used for transmission from the Base Station to the Mobile Stations ('downlink'). In the Netherlands two frequency bands are available in the GSM frequency part since the first of January 1991 (see Figure 3.1) with a bandwidth of 9 MHz. In 2001 it should reach the amount of 25 MHz per band. Per BS about 50 channels must be made. Because it is very hard to transmit 50 different frequencies with one antenna without interfering other systems, there is chosen to multilpex several channels to one frequency by TDM (see Paragraph 2.2.2)

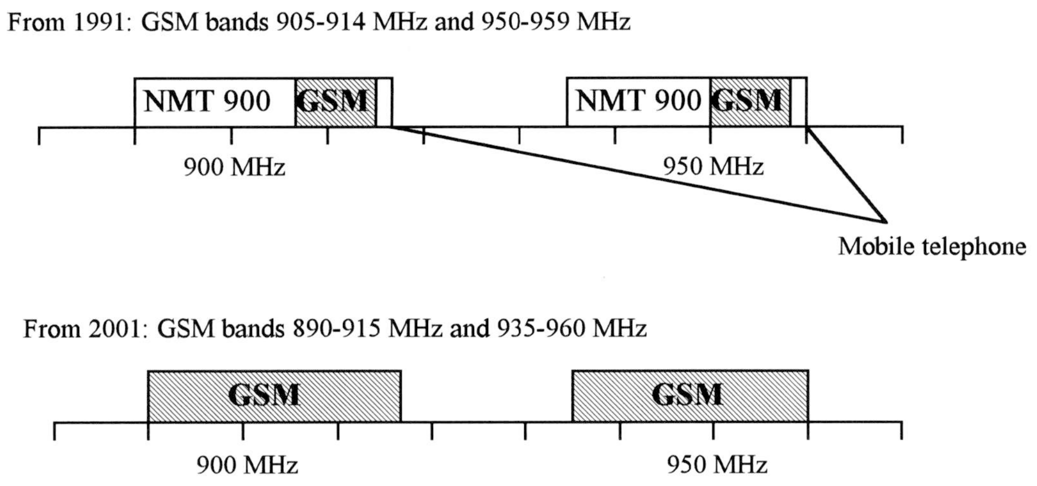


Figure 3.1: Frequency bands in the GSM system.

3.4 The Cellular Net of GSM.

Just like other conventional systems of land mobile communication, the GSM system is built in a cellular structure. The total area in which the GSM system is working, is divided into smaller parts called cells. In the centre of each cell there is a Base Station which handles the radio traffic with all the mobile stations situated in the cell. For further information on Cellular networks see Chapter 2.

3.5 Data transmission in GSM.

Data transfer is commonly used in fixed networks. This so called asynchronous data transfer is done by means of modems in PSTN networks or by means of terminal adapters in ISDN networks.The bandwidth of a traffic channel in the GSM network is considerably smaller, when compared to fixed networks. This is realised by maximising the use of the available radio resources. So the GSM system works with a special codec (described in 3.2) to reduce voice signals to the small band width. But this codec is not suitable for signals generated by a modem.

The GSM system uses a special interworking function (IWF) to support the data transfer [10]. In case of a data transfer between a mobile station and a data terminal in PSTN, the IWF terminates the connection to the fixed network modem with an own modem and performs the conversion between the dataformat used in the fixed network and the GSM network. The user data are transferred over the radio link in a bit stream of a special GSM-format. A mobile termination (MT) converts the GSM-data format to the user format and provides the user data at a standard interface (see Figure 3.2). The different user data rates of the asynchronous data services from 300 to 9600 bit/s are supported by the GSM bearer services. The GSM-network decides on the chosen bearer service which type of IWF is needed.

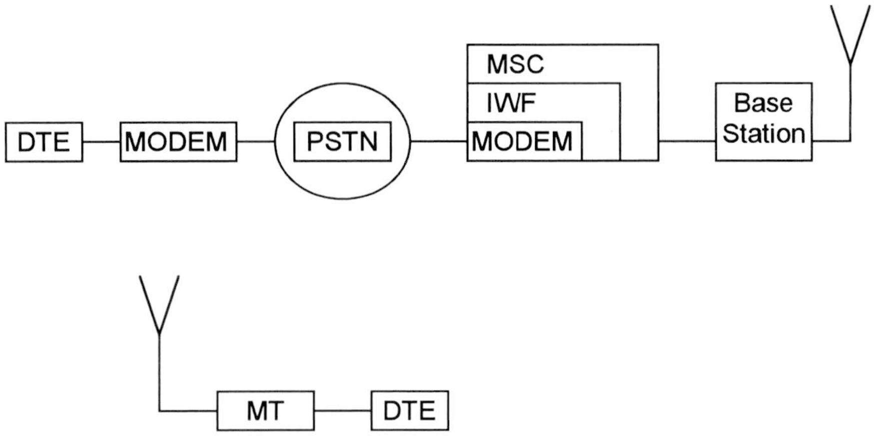


Figure 3.2: GSM data service interworking with PSTN

The GSM system employs sophisticated forward error correction (FEC) to reduce the influence of the radio conditions on the information transfer. Blocks of user data are coded to increase the redundancy. Further the coded data are spread in time by interleaving for an uniform distribution of bursty radio disturbances over the coded data blocks. But all these procedures lead to a permanent transmission delay depending on the chosen bearer service.

The transparent mode of the GSM data service uses the above mentioned mechanism only. These mechanism can not guarantee an error free data transmission over the radio link. For this reason the GSM system offers a non-transparent mode. In this case an additional Radio Link Protocol (RLP) performs the correction of the disturbed data blocks by re-transmission. This re-transmission causes an additional delay increasing with the extension of the disturbance on the radio link.

Generally asynchronous data transfer in the GSM networks and in the fixed networks are distinguished by the following:

- a constant transmission delay for GSM data services caused by FEC,transmission errors depending on the radio disturbances in transparent mode of the GSM data service;
- an additional delay and a decreasing throughput depending on the radio disturbances in non-transparent mode of the GSM data service.

It is in the responsibility of the user to choose a suitable application for mobile data communication over GSM and to take the GSM data service with the necessary parameters which support the application in the best way.

3.6 GSM Data Pilot.

In November 1994 the Dutch Telecom company PTT started a project pilot for data communication with GSM. A few companies were able to participate in this test, before this service was accessible for all GSM-users. The transmission rate for the test was 2400 baud and the GSM creditcard could only be used for data communication purposes and not for speech or fax messages. The tests with GSM were limited to the Netherlands due to lack of international roaming.

One of the participants of the data pilot was the company Joanknecht B.V.. This company provides E-mail services for inland shipping. In inland shipping the contact with the shore must be made by means of mobile services. For the use of the E-mail facilities the mobile networks ATF1, ATF2, and ATF3 are used. With these networks a transmission rate of 1200 baud is common. Joanknecht BV was selected to participate in the pilot due to the fact that they already had experience in mobile datacommunication..

5 GSM devices are used by Joanknecht BV for testing the network. These five devices were distributed among barges. With this GSM E-mail is sent and received. After they used the GSM-datafacility the users have to fill in a form, which is automatically sent the next time they use the E-Mail facility. The questions of this questionnaire can be read in Appendix A. With the help of this test a good picture can be drawn of the coverage of GSM limited to the rivers in the Netherlands. Also an overall performance of the data-facility of GSM can be concluded. The results of the tests can be seen in Chapter 7.

JPEG 4

JPEG is a standardised image compression mechanism [7]. It stands for Joint Photographic Experts Group (the original name of the committee that wrote the standard). JPEG is designed for compressing either full-colour or grey-scale digital images of 'natural' (i.e. real world) scenes. It does not handle black-and-white (1-bit per pixel) images, nor does it handle motion picture compression. For these purposes there are the related committees, JBIG and MPEG respectively, working on standards for compressing that type of images [12].

JPEG is "lossy" that means that the retrieved image from the decompression differs from the original image. The algorithm achieves much of its compression by exploiting known limitations of the human eye; notably, the fact that small colour details are not perceived as well as small details of light-and dark. So JPEG is intended for compression of images that will be looked at by humans.

A useful property of the JPEG algorithm is that the degree of lossiness can be varied by adjusting compression parameters. This means that the image maker can trade off file size against output image quality. He can make extremely small files with poor quality that can be very useful for indexing image archives, making thumbnail views or icons, etc. Conversely if he is not happy with the output quality, he can improve the quality and accepting lesser compression.

4.1 JPEG Overall structure.

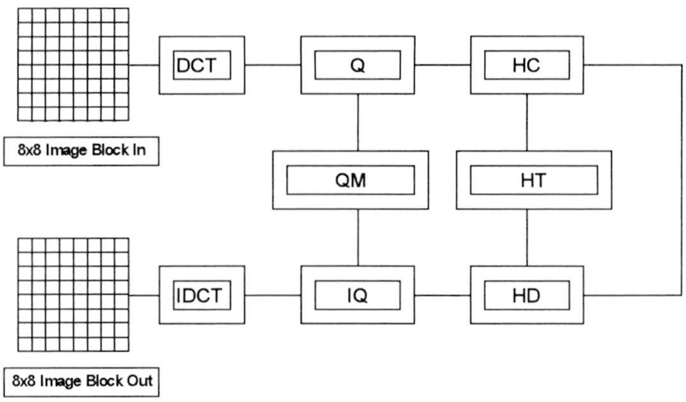
The JPEG algorithm structure is composed of three main parts[7]:

1. a Baseline System;
2. a set of optional Extended System capabilities;
3. an Independent Lossless coding capability;

4.1.1 The Baseline System.

The Baseline System is the name given to the simplest image coding/decoding capability proposed for the JPEG standard. It consists of a 8x8 DCT, Uniform quantization and Huffman Coding. This system is pictured in Figure 4.1 [15].

Together this algorithm provides a non-lossless, high-compression image coding capability, which preserves image fidelity at compression rates competitive with or superior to any technique, regardless of their complexity. The Baseline System only provides in sequential build-up. For further information about the Baseline System see paragraph 4.2



DCT	Discrete Cosine transformation
IDCT	Inverse DCT
Q	Quantization
IQ	Inverse Quantization
QM	Quantization Matrix
HC	Huffman Coder
HD	Huffman Decoder
HT	Huffman Table

Figure 4.1 : Blockdiagram of Baseline JPEG.

4.1.2 Extended System.

Extended System is the name given to a set of additional capabilities not provided by the Baseline System. Each set is intended to work in conjunction with, and to build upon, all (or most) of the components internal to the Baseline System, in order to extend its mode of operation. These optional capabilities may be implemented single or in appropriate combinations. Some of the extensions to the Baseline System are :

- Arithmetic coding,
- Progressive Build-up,
- Progressive lossless,

The Arithmetic Coding is an optional alternative to Huffman Coding. Because this coding method adapts to image statistics as it encodes, it generally provides 5-10% better compression than the Huffman method. This benefit is balanced by some increase in complexity.

Progressive Build-up is especially useful for human interaction with picture databases over low-bandwidth channels. It may be regarded as a way of re-ordering the coded data prior to transmission.

Progressive Lossless refers to a lossless compression method that operates in conjunction with progressive build-up. In this mode of operation, the final stage of progressive build-up results in a received image, which is bit-for-bit identical to the original.

For further detail on the Extended System see paragraph 4.3.

4.1.3 Lossless coding capability.

This capability is a simple DPCM based, stand alone method of lossless compression. An independent Lossless codec is not compatible with Baseline or Extended Systems, in the sense of having data interchange capabilities with either. It has been developed in addition to Extended System's progressive lossless option for the following reason. Progressive lossless operates as a final pass added to one or more DCT-based, non lossless progressive passes. The DCT, plus the required buffers and control logic needed in a progressive lossless implementation, are relatively complex in comparison with the DPCM-based Independent Lossless algorithm. Applications that require lossless coding only, with no need for any non-lossless capability, are likely to find the progressive lossless method burdensome.

4.2 Baseline System in detail.

The following is a brief description of the JPEG baseline system [7].

- The original image is partitioned into 8x8 pixel blocks and each block is independently transformed using DCT.
- All transform coefficients are normalised (weighted) by applying a user defined normalisation array that is fixed for all blocks. Each component of the normalisation array is an 8-bit integer and is passed to the receiver as part of the header information that is required for every image. Up to four different normalisation arrays may be used for the different colour components of a colour image. The normalised coefficients are then uniformly quantized by rounding to the nearest integer. The normalisation array can be viewed as scaling the quantizer so as to control the amount of quantization error introduced in each coefficient.
- The top-left coefficient in the 2-D DCT array is referred to as the DC coefficient and is proportional to the average brightness of the spatial block. After quantization, this coefficient is encoded with a lossless DPCM scheme using the quantized DC coefficient from the previous block as a 1-D predictor.
- After the DPCM encoding of the DC term, this term is encoded with a Huffman coding scheme. For the baseline system, up to two separate Huffman tables for encoding the resulting differential signal can be specified in the header information.
- The quantization of the AC coefficient produces many zeros, especially at higher frequencies. To take advantage of these zeros, the 2-D array of the DCT coefficients is formatted into a 1-D vector using a zigzag recording. This re-arranges the coefficients in approximately decreasing order of their average energy (as well as in order of increasing spatial frequency) with the aim of creating large runs of zeros.
- Each non-zero AC coefficient is encoded or 'modelled' in combination with the runlength of zero-valued AC coefficients preceding it in the zigzag sequence. Each runlength/non-zero-coefficient combination is represented by two codes (see paragraph 4.2.4).
- Each component of a colour (or multi-spectral) image is encoded independently.
- At the decoder, after the encoded bit stream is Huffman decoded and the 2-D array of quantized DCT coefficients is recovered, each coefficient is de-normalised by

multiplying it by the corresponding component of the normalisation matrix. The result array is inverse DCT transformed to yield an approximation to the original image block. The resulting reconstruction error depends on the amount of quantization, which is controlled by the normalisation matrix.

In the next paragraph these different topics will be further discussed. In that discussion an example will be drawn to make things even more clear.

4.2.1 DCT transformation.

After the image has been divided into parts of 8x8 pixels, these blocks are transformed by means of the Discrete Cosine Transformation [16]. Consider the following 8x8 block of pixel values:

$$f(x,y) = \begin{bmatrix} 139 & 144 & 149 & 153 & 155 & 155 & 155 & 155 \\ 144 & 151 & 153 & 156 & 159 & 156 & 156 & 156 \\ 150 & 155 & 160 & 163 & 158 & 156 & 156 & 156 \\ 159 & 161 & 162 & 160 & 160 & 159 & 159 & 159 \\ 159 & 160 & 161 & 162 & 162 & 155 & 155 & 155 \\ 161 & 161 & 161 & 161 & 160 & 157 & 157 & 157 \\ 162 & 162 & 161 & 163 & 162 & 157 & 157 & 157 \\ 162 & 162 & 161 & 161 & 163 & 158 & 158 & 158 \end{bmatrix}$$

Prior to the Forward DCT (FDCT), the pixels are shifted about zero (-128 to +127). The FDCT and the Inverse DCT used in JPEG are described by Equation (4.1) and (4.2).

$$F(u,v) = \frac{1}{4} C(u)C(v) \sum_{x=0}^{7} \sum_{y=0}^{7} f(x,y) \cos\frac{(2x+1)u\pi}{16} \cos\frac{(2y+1)v\pi}{16} \qquad (4.1)$$

$$f(x,y) = \frac{1}{4} \sum_{u=0}^{7} \sum_{v=0}^{7} C(u)C(v)F(u,v) \cos\frac{(2x+1)u\pi}{16} \cos\frac{(2y+1)v\pi}{16} \qquad (4.2)$$

$$where: \quad C(u),C(v) = 1/\sqrt{2} \quad for\ u,v = 0; \quad C(u),C(v) = 1\ otherwise$$

These equations define the idealised, infinite-precision DCT. To reduce the hardware and software complexity, several implementations of the Equations (4.1) and (4.2) have been developed with the aim of minimising the number of multiplications and additions. These practical DCT algorithms all use fixed-precision integer arithmetic.

The DCT of the example block is given by:

$$F(u,v) = \begin{bmatrix} 1260 & -1 & -12 & -5 & 2 & -2 & -3 & 1 \\ -23 & -17 & -6 & -3 & -3 & 0 & 0 & -1 \\ -11 & -9 & -2 & 2 & 0 & -1 & -1 & 0 \\ -7 & -2 & 0 & 1 & 1 & 0 & 0 & 0 \\ -1 & -1 & 1 & 2 & 0 & -1 & 1 & 1 \\ 2 & 0 & 2 & 0 & -1 & 1 & 1 & -1 \\ -1 & 0 & 0 & -1 & 0 & 2 & 1 & -1 \\ -3 & 2 & -4 & -2 & 2 & 1 & -1 & 0 \end{bmatrix}$$

The top-left transform coefficient is 8 times the DC-value of the block, and it can be seen that the energy of the block is concentrated in only a few low-frequency coefficients.

4.2.2 Normalization and quantization.

Next, each of the 64 DCT output coefficients $F(u,v)$ is quantized by a uniform quantizer. Quantization is accomplished by using an 8x8 quantization matrix of 64 numbers $Q(u,v)$. Each $Q(u,v)$ is the quantizer step-size for its respective quantized coefficient $F^*(u,v)$, and may take any integer value from 1 to 255. Larger values correspond to larger quantization steps. Thus the quantization function is defined as [7]:

$$F^*(u,v) = IntegerRound\left(\frac{F(u,v)}{Q(u,v)}\right) \tag{4.3}$$

A typical normalisation array that has been used by JPEG in their studies is:

$$Q(u,v) = \begin{bmatrix} 16 & 11 & 10 & 16 & 24 & 40 & 51 & 61 \\ 12 & 12 & 14 & 19 & 26 & 58 & 60 & 55 \\ 14 & 13 & 16 & 24 & 40 & 57 & 69 & 56 \\ 14 & 17 & 22 & 29 & 51 & 87 & 80 & 62 \\ 18 & 22 & 37 & 56 & 68 & 109 & 103 & 77 \\ 24 & 35 & 55 & 64 & 81 & 104 & 113 & 92 \\ 49 & 64 & 78 & 87 & 103 & 121 & 120 & 101 \\ 72 & 92 & 95 & 98 & 112 & 100 & 103 & 99 \end{bmatrix}$$

If we apply Equation (4.3) to the DCT coefficients this will result in:

$$F^*(u,v) = \begin{bmatrix} 79 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ -2 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

4.2.3 DPCM encoding of DC coefficient.

Prior to Huffman coding, the quantized 'DC' coefficient, $F^*(0,0)$, is treated separately from the 63 other $F^*(u,v)$, the quantized 'AC' coefficients. The quantized DC term from block i is differentially encoded with respect to the DC term from the previous block $i\text{-}1$:

$$DiffDC(i) = DC(i) - DC(i-1) \tag{4.4}$$

4.2.4 Zigzag-scan ordering of AC coefficients.

Before the 63 AC coefficients are encoding by Huffman coding, they are ordered from their 2-dimensional matrix into a 1-dimensional sequence, according to the 'zigzag scan'. This zigzag scan looks like:

$$\begin{bmatrix} 0 & 1 & 5 & 6 & 14 & 15 & 27 & 28 \\ 2 & 4 & 7 & 13 & 16 & 26 & 29 & 42 \\ 3 & 8 & 12 & 17 & 25 & 30 & 41 & 43 \\ 9 & 11 & 18 & 24 & 31 & 40 & 44 & 53 \\ 10 & 19 & 23 & 32 & 39 & 45 & 52 & 54 \\ 20 & 22 & 33 & 38 & 46 & 51 & 55 & 60 \\ 21 & 34 & 37 & 47 & 50 & 56 & 59 & 61 \\ 35 & 36 & 48 & 49 & 57 & 58 & 62 & 63 \end{bmatrix}$$

For the example the result will be:

79 0 -2 -1 -1 -1 0 0 -1 EOB

4.2.5 Huffman encoding.

As Figure 4.2 shows, the Huffman encoder can be considered as a 2-step process. The first step is the modeling step followed by the second step, the coding step.

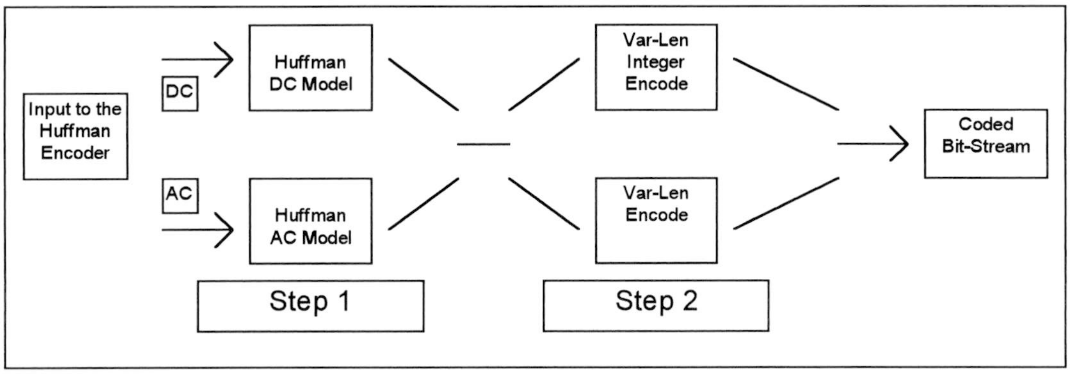


Figure 4.2: Huffman encoder Block Diagram

Modelling is the name given to an intermediate encoding prior to Variable-Length Coding.

4.2.6 Huffman DC modeling.

The differential-DC coefficient is encoded (modelled) as two separate codes. Code1, the SIZE code, gives the number of bits needed to represent Code2, the AMPLITUDE code, as a signed integer. The code will look like :

Code1	Code2
SIZE,	AMPLITUDE

4.2.7 Huffman AC modeling.

Each non-zero AC coefficient is encoded or 'modelled' in combination with the runlength of zero-valued AC coefficients proceeding in the zigzag sequence. Each runlength/non-zero-coefficient combination is represented also by two codes. The zigzag sequence of 63 AC coefficients for each pixel-block is modelled by a sequence of these code-pairs (with End-Of-Block (EOB) as the final code):

Code1	Code2
RUNLENGTH,SIZE,	AMPLITUDE

RUNLENGTH is the number of consecutive zero-valued AC coefficients that precedes the non-zero AC coefficient. SIZE is the number of bits needed to represent AMPLITUDE as a signed integer. The two are combined into Code1, a single 'two-dimensional' code. Code2 is the AMPLITUDE code. Its length in bits is specified by SIZE from Code1, and its value is the amplitude of the non-zero coefficient.

RUNLENGTH encodes zero-runs of length 0 to 15. If the actual runlength is 16 or greater, then the code 15,0 is interpreted as an extension code of runlength=16, to be followed by a RUNLENGTH,SIZE code that finishes the run, and is followed by an AMPLITUDE code. When the run of zeros includes the last AC coefficient (number 63), then the EOB code (0,0) is sent.

4.2.8 VLC and VLI encoding.

After modelling, both DC and AC terms are encoded as a combination of Variable-Length Codes (VLC) and Variable-Length-Integers (VLI), for practical reasons. VLCs are Huffman codes, and VLIs are codes of varying lengths, but are not Huffman codes.

For AC coefficients, each RUNLENGTH,SIZE code is VLC-encoded, and each AMPLITUDE code is VLI-encoded. These two codes are alternately inserted in the coded output bit stream. In Table 4.1 [11] an example is given of an Huffman table that can be used to encode the AC coefficient.

Zero Run	SIZE	Code Length	Codeword
0	1	2	00
0	2	2	01
0	3	3	100
0	4	4	1011
0	5	5	11010
0	6	6	111000
0	7	7	1111000
.	.	.	.
.	.	.	.
1	1	4	1100
1	2	6	111001
1	3	7	1111001
1	4	9	111110110
.	.	.	.
.	.	.	.
2	1	5	11011
2	2	8	11111000
.	.	.	.
.	.	.	.
3	1	6	111010
3	2	9	111110111
.	.	.	.
.	.	.	.
4	1	6	111011
5	1	7	1111010
6	1	7	1111011
7	1	8	11111001
8	1	8	11111010
9	1	9	111111000
10	1	9	11111001
11	1	9	11111010
.	.	.	.
.	.	.	.
End Of Block (EOB)		4	1010

Table 4.1: Example of JPEG AC Huffman code table.

With the help of this table RUNLENGTH,SIZE can be coded according to a Huffman coding scheme. The AMPLITUDE code of the AC term is coded according to Table 4.2:

AC coefficient AMPLITUDE	SIZE
-1,1	1
-3,-2,2,3	2
-7..-4,4..7	3
-15..-8,8..15	4
-31..-16,16..31	5
-63..-32,32..63	6
-127..-64,64..127	7
-255..-128,128..255	8
-511..-256,256..511	9
-1023..-512,512..1023	10
-2047..-1024,1024..2047	11

The differential DC coefficient for the pixel-block is encoded similarly. SIZE and AMPLITUDE are VLC encoded and VLI encoded, respectively. In our example the output sequence was: 79,0,-2,-1,-1,-1,0 ,0,-1,EOB. The first non-zero AC coefficient in this sequence is the term -2. This term is proceeded by one zero value. This term is a member of the SIZE equal to 2, so the VLC code word will be : 111001, according to table 4.1. This code word is then followed by a sign bit (0 for negative coefficients) and additional *k-1* bits to identify the AMPLITUDE of the coefficient. So the complete code for -2 will be in this sequence : 11100101. The total sequence will become:

DC difference Huffman Code word/11100101/000/000/000/110110/1010

4.2.9 Decoding at receivers end.

At the receiver, the quantized coefficients are reconstructed by a Huffman decoding procedure. After that the outcome will be de-normalised according to

$$\hat{F}(u,v) = F^*(u,v)Q(u,v) \tag{4.5}$$

The de-normalised block is then inverse transformed using the Inverse Discrete Cosine Transformation like equation 4.2.

If this computation is done with the example, the outcome will be:

$$f'(j,k)=\begin{bmatrix} 144 & 146 & 149 & 152 & 154 & 156 & 156 & 156 \\ 148 & 150 & 152 & 154 & 156 & 156 & 156 & 156 \\ 155 & 156 & 157 & 158 & 158 & 157 & 156 & 155 \\ 160 & 161 & 161 & 162 & 161 & 159 & 157 & 155 \\ 163 & 163 & 164 & 163 & 162 & 160 & 158 & 156 \\ 163 & 163 & 164 & 164 & 162 & 160 & 158 & 157 \\ 160 & 161 & 162 & 162 & 162 & 161 & 159 & 158 \\ 158 & 159 & 161 & 161 & 162 & 161 & 159 & 158 \end{bmatrix}$$

The errors introduced in the code values of the original image block due to compression are :

$$e(j,k)=\begin{bmatrix} -5 & -2 & 0 & 1 & 1 & -1 & -1 & -1 \\ -4 & 1 & 1 & 2 & 3 & 0 & 0 & 0 \\ -5 & -1 & 3 & 5 & 0 & -1 & 0 & 1 \\ -1 & 0 & 1 & -2 & -1 & 0 & 2 & 4 \\ -4 & -3 & -3 & -1 & 0 & -5 & -3 & -1 \\ -2 & -2 & -3 & -3 & -2 & -3 & -1 & 0 \\ 2 & 1 & -1 & 1 & 0 & -4 & -2 & -1 \\ 4 & 3 & 0 & 0 & 1 & -3 & -1 & 0 \end{bmatrix}$$

where $e(j,k)=f(j,k)-f'(j,k)$. The *MSE* [1]resulting from the encoding of this block is:

$$MSE = \sqrt{\frac{1}{64}\sum_{j=0}^{7}\sum_{k=0}^{7} e^2(j,k)} = 2.26 \qquad (4.6)$$

4.3 Extended System.

An Extended System includes all of the Baseline System, and then adds to it one or more of the capabilities described in this section.

4.3.1 Entropy coding option.

'Entropy coding' is the functional component of compression systems that compact the data by reducing static redundancy. Either Arithmetic or Huffman coding may be used as the entropy coding method for the JPEG Extended System implementation. Both coding methods have been designed by the committee so that transcoding from one to the other may be implemented straightforwardly.

4.3.1.1 Arithmetic coding

The basic principal of Arithmetic coding [13] will place the codes with probability p_1, p_2,.., p_n of the source signal as parts of an interval from 0 to 1 according to their probability. The coding can be seen as a recursive process. With every step a new source symbol will be added to the stream. At every step the left border of the interval will be C and the length of the interval will be A. If a new symbol is added the new left border will be:

$$C_{new} = C_{old} + A_{old} . P_i \quad (3.7)$$

with C_{old} the left border of the former step, A_{old} the length of the interval of the former step, P_i the cumulative probability of the symbol p_i. The length of the new interval will be calculated by:

$$A_{new} = A_{old} \cdot p_i \quad (3.8)$$

To find the final code word, the final left border C will be written in a binary form. The decoding scheme is in fact the inverse way by finding out which symbol has created the interval. With this result the former interval can be computed.

4.3.1.2 Extended Huffman Coding.

Huffman coding used in conjunction with any of the Extended System capabilities is referred to as 'Extended' Huffman Coding, to distinguish it from the specific set of Huffman codes used in the Baseline System. However, the Baseline Huffman codes form a subset of the Extended Huffman codes. With the Huffman coding algorithm the two least probable source symbols are joined together, to create a new code alphabet with one symbol less. This new alphabet is reordered according to the probability of all the symbols. After that, again the two symbols with least probability are joined together. This will repeat until only two symbols are left. These two symbols are assigned with a 1 or a 0. Then with every step back, when two symbols were joined, a 0 or 1 is added to the code word.

4.3.2 Progressive build-up (non hierarchical).

The operation of an Extended System with progressive build-up is in many ways similar to that of a Baseline System. The difference begins after quantization of the DCT coefficients. At this point the quantized coefficients are stored in an image buffer, rather than being entropy encoded and transmitted immediately. After initial quantization and storage, the encoder makes two or more passes through the image, encoding only a portion of each 8x8 block's quantized coefficient data during each pass.

There are two basic modes by which the quantized coefficients may be progressively encoded, known as 'Spectral Selection' and 'Successive Approximation'. In spectral selection, non-zero coefficients from a different, and successively higher, band of frequency from within the 8x8 block are encoded at each pass. Thus, in early passes the low-frequency, or rough-detail, information is sent, and in later passes the high-frequency, or fine-detail, information is sent. In successive approximation, the most-significant bits of non-zero coefficients within a band are transmitted in the first pass for that band. At each successive pass for that band, another 1-bit 'slice' of information is transmitted, until the full precision of the quantized coefficients for that band has been transmitted.

For non-hierarchical progressive build-up, there are two modes of operation. Mode 1 is the capability for spectral selection only. Mode 2 is the capability for both spectral selection and successive approximation, which makes Mode 1 a subset of Mode 2. A decoder with Mode 1 progressive capability is required to be able to decode only the first pass of a mode 2 encoder. However, a Mode 2 decoder can by definition decode any image sent by a Mode 1 progressive encoder, as Mode 2 is a superset of Mode 1.

4.3.3 Progressive Lossless.

This feature provides reversible compression by sending a difference image, the per-pixel difference between the non-reversible and the original images, as a final 'stage'. This feature requires that the encoder contains an inverse DCT and an inverse quantizer. At press time, the possibility of revising this feature to a 'near lossless' capability was under discussion in JPEG. This is because, unless JPEG specifies that the inverse DCT implementations in both the transmitter and receiver must be identical, pixels in the reconstructed image will occasionally differ from the original by one pixel level. This is a result of inevitable rounding differences resulting from the finite arithmetic of non-identical implementations.

4.3.4 Hierarchical progressive build-up.

This feature provides in hierarchical encoding of an image, obtained via following procedure:

1. Filter and down-sample the original image by a factor of 2^N in both dimensions,
2. Encode this reduced-size image either sequentially or progressively by the methods already discussed,
3. Use this reduced-size image as a prediction for the next (2^{N-1}) stage,
4. Encode the 2^{N-1} difference image.

This procedure is repeated until the final stage is reached. This capability is useful in applications where it is desirable to access a significantly reduced size version of a large image.

JPEG with Line-Drawings 5

According to [12] coding Line Drawings with JPEG will not perform very well. In the next example it will be shown that indeed if the line-drawing image is looked at as a bit-plane, JPEG will not perform well. Next another representation of a Line-drawing will be shown, which will give good results with the JPEG coding scheme.

5.1 JPEG with bit-plane of line drawings

If a line drawing is looked at as a bit-plane, this plane will only consist of many equal values value and only a few different values. If for example the value of white is equal to 255 (maximal intensity) and the value of black will be zero, 8x8 block of such a drawing may look like :

$$f(x,y)=\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 255 & 255 \\ 0 & 0 & 0 & 0 & 0 & 255 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 255 & 0 & 0 \\ 0 & 0 & 0 & 0 & 255 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 255 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 255 & 255 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 255 \end{bmatrix}$$

(This block is a white on black line. You can easily change the values to make it a black on white drawing. The choice for white on black is because you can see the line more easily.)

If this matrix is transformed with a DCT as in (4.1), the transformed matrix will look like:

$$F(u,v)=\begin{bmatrix} 287 & -256 & -17 & 125 & -32 & -63 & 42 & 8 \\ -44 & 22 & 37 & -24 & -37 & 46 & 10 & -40 \\ -7 & -73 & 195 & -164 & 7 & 82 & -36 & -22 \\ -37 & 93 & -118 & 25 & 83 & -28 & -142 & 180 \\ -96 & 100 & -17 & -62 & 96 & -80 & 42 & -13 \\ -25 & 38 & -79 & 171 & 206 & 84 & 106 & -151 \\ -101 & 139 & -99 & 1 & 100 & -120 & 60 & -5 \\ -8 & 31 & -63 & 71 & -46 & 14 & 2 & -3 \end{bmatrix}$$

A close look at this matrix will show that there are many high frequencies in a Line drawing. This is not surprising because a change in intensity from black to white is the largest step that the intensity can make. This sudden step results in high frequency components.

Now this matrix will be quantized and normalised by the same quantization matrix used in the example of the former chapter. The outcome of this step is:

$$F^*(u,v) = \begin{bmatrix} 17 & -23 & -1 & 7 & -1 & -1 & 0 & 0 \\ -3 & 1 & 2 & -1 & -1 & 0 & 0 & 0 \\ 0 & -5 & 12 & -6 & 0 & 1 & 0 & 0 \\ -2 & 5 & -5 & 0 & 1 & 0 & -1 & 2 \\ -5 & 4 & 0 & -1 & 1 & 0 & 0 & 0 \\ -1 & 1 & -1 & 2 & 2 & 0 & 0 & -1 \\ -2 & 2 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

This matrix will be encoded in the same way and then multiplied with the same quantization matrix to result in :

$$F'(u,v) = \begin{bmatrix} 272 & -253 & -10 & 112 & -24 & -40 & 0 & 0 \\ -36 & 12 & 28 & -19 & -26 & 0 & 0 & 0 \\ 0 & -65 & 192 & -144 & 0 & 57 & 0 & 0 \\ -28 & 85 & -110 & 0 & 51 & 0 & -80 & 124 \\ -90 & 88 & 0 & -56 & 68 & 0 & 0 & 0 \\ -24 & 35 & -55 & 128 & 162 & 0 & 0 & -92 \\ -98 & 128 & -78 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

As can be seen, the highest frequencies are completely disappeared from the matrix. This matrix will be transformed with an Inverse DCT to result in a representation of the original image $f(x,y)$. The IDCT of $F'(u,v)$ will look like:

$$f'(x,y) = \begin{bmatrix} 23 & -18 & -22 & 20 & 27 & -60 & 15 & 41 \\ -46 & 33 & 61 & -68 & -13 & 114 & \mathbf{218} & \mathbf{190} \\ -5 & 13 & -32 & 4 & 25 & \mathbf{170} & 37 & 26 \\ 33 & -17 & -91 & 52 & 103 & \mathbf{146} & -20 & 15 \\ -37 & 15 & 47 & -3 & \mathbf{130} & 54 & 60 & -14 \\ -20 & 6 & 25 & 23 & \mathbf{160} & 58 & 48 & -72 \\ 45 & -24 & -80 & 46 & 106 & \mathbf{144} & \mathbf{117} & 137 \\ -10 & 10 & 29 & -18 & -72 & 40 & 89 & \mathbf{162} \end{bmatrix}$$

In this matrix, the original line-drawing is pictured with the bold numbers. As can be seen in this matrix, the original picture is still noticeable but very vague. All kinds of other components have formed around the original drawing and the with line is not completely white anymore.

Also the total MSE of this matrix, calculated with Equation (4.6), will result in 59.9, which is very high.

5.2 x-y representation with JPEG.

As shown in paragraph 5.1 the JPEG algorithm will not work properly with line drawings as they are represented by a bitmap. But if we represent a line drawing by its x-y representation [14] the outcome is quite different. With this representation there are no abrupt changes like the change from white to black in a bitmap.

With a xy-representation every pixel of the line-drawing is represented by its x- and y-coordinate. Compared to other representation methods for line drawings, this is a very poor representation if we look at the correlation between succeeding coordinates. For this reason, the representation has to be transformed by some kind of transformation method. This transformation method has the function of reducing the correlation between succeeding coordinates. One of the known methods to transform bitmap images is the JPEG standard, that uses the Discrete Cosine Transformation to reduce the correlation and uses a Huffman or Arithmatic coding scheme to represent these tranformed images.

The JPEG standard will only work well if the changes in intensity of the image are very smooth. This is the reason that a bitmap in black and white (rough changes) will not give good results when it is transformed with a JPEG transformation. But the x-y represenation is a rather smooth representation. As will be shown in the next example the JPEG coding scheme will give some error, but the picture will remain recognizable. This is necessary for progressive transmission.

An example of a part of a line drawing is given in table 5.1:

x	24	25	26	27	29	31	33	36	38	40	42
y	4	5	6	8	9	10	11	12	13	14	15

Table 5.1 part of a used Line Drawing.

5.2.1 Suitability of line-drawings with JPEG.

Two things are important to make a line drawing, discribed with a x-y representation, suitable for coding with a JPEG coding scheme:

1. The JPEG coding scheme demands that the input will be devided into blocks of 8 by 8 samples. In this way the number of coordinates must be a multiple of 64.
2. The coordinates must be re-organized in such a way that the steps between the following coordinates is as small as possible, so that the difference becomes as smooth as possible.

In this report the coordinates are re-organized by first giving all the x-coordinates to the JPEG coder, followed by all the y-coordinates. This will introduce an error in the first coordinates of the line drawing, because there is a big step in coordinate difference. In the former example of the line drawing this will be from 24 to 4. Other ways of organizing (sending for example: x-coordinate, y-coordinate, x-coordinate...) are bound to give more errors, because there will be more steps in coordinate difference. Also the re-organization must be known at the receivers end. So it must be send with the drawing or must be the same for all the line-drawings sent.

If we look at the example of a part of a line drawing and we code and decode it with the JPEG-coding scheme, the result will be:

x	23	24	25	27	29	32	34	34	38	39	40
y	5	5	6	7	9	10	11	12	13	13	14

table 5.2: Part of the Line Drawing after JPEG coding and decoding.

In this small example it can be seen, that very few errors are introduced by the coding scheme. The whole picture will look like figure 5.1, and the MSE (Equation (4.6)) of this picture is:

MSE = 1.41

a *b*

Figure 5.1: Example of used Line Drawing
a: original drawing
b:drawing after coding and decoding with JPEG

In this drawing you can see that there are some small errors. These are also due to the fact that only the 8-bit facility of the JPEG coding scheme has been used. As a result of this the pictures are limited to coordinates from 0 to 255 in both x and y coordinates. So if there is a small error in a coordinate, this will result in a dot at the wrong place. This is clearly seen in Figure 5.1. Nevertheless the small error, the picture is still recognizable.

5.3 Progressive transmission of line drawings with JPEG.

Progressive transmission is a method of sending drawings or pictures in such a way that first a low detailed part is sent, refined with more detail as time passes. In this way a fast recognition of the drawing or picture becomes possible.

The JPEG coding scheme has a built-in option for progressive transmission (see paragraph 4.3.2) In this report the spectral selection method is used. This means that first the low frequency part of the drawing is transmitted, followed by higher frequency parts.

This selection method is done in 4 steps

1. First the line-drawing is divided into segments containing 8x8 coordinates (see 5.2.1)
2. Next these parts are transformed with a Discete Cosine Transformation.
3. For progressive transmission the first components of this DCT are sent first. At the receivers-end, these components are inverse DCT transformed. So now the received drawing consists of parts of low frequency appriximations of the original drawing.
4. These approximations are refined with higher frequency parts with next transmission steps.

With every transmission step, a better approximation of the original drawing can be shown, with as final step the 'original' drawing.

5.4 Results of Transmission Errors in JPEG.

Because the line drawing is transmitted in a mobile environment, it is very likely that transmission errors occur. Due to the fact that JPEG removes almost all the redundancy in the drawing, the drawing is very vulnerable to errors. Before transmitting drawings over GSM, all possible transmission errors must be examined. In this way it can be concluded what kind of error has appeared during the transmission.

5.4.1 Kind of errors.

A JPEG coded drawing consists of a header and a data part (see Figure 5.2).

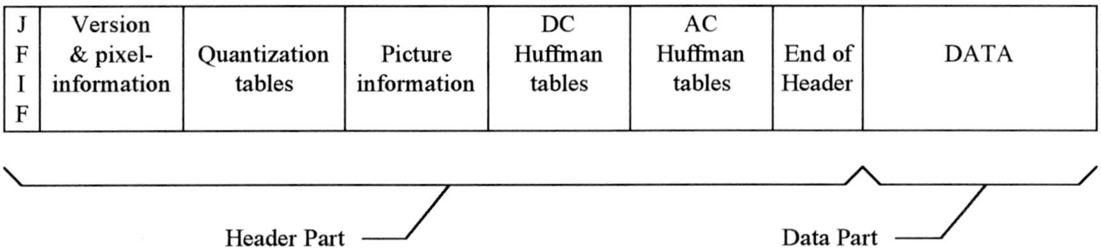


Figure 5.2: JPEG file format

The part 'JFIF' in the header stands for a marker at the beginnig of the file and the ASCII sequence 'JFIF'. The 'Version & pixelinformation'-part consists of a marker, the version of the used software and information about the pixel size and density. The next part in the header contains the information about the Quantization Tables. The part about the 'Picture information' handles the heighth and width of the drawing and the number of color-components. After that, the DC Huffman and AC Huffman tables are situated and followed by a small end of header, that contains information about spectral selection and successive approximation.

According to this JPEG coding scheme two different kind of errors may appear. These are:

1. Errors in the header,
2. Errors in the data.

Some of the errors will result in an error report by the software and others will distort the image to some amount. The kind of error is decribed in Table 5.3 for the different items in the header and data part.

	Error report	Image distortion
Header	JFIF Version & Pixel information Picture Information Header Tail	Quantization Table DC Huffman Table AC Huffman Table
Data	Size bits	Amplitude bits

Table 5.3 Kind of error

5.4.2 Errors in header.

The header of a JPEG file consists of several parts which are needed to decode the file. Errors in some parts will result in an error message by the used software, while others will result in a deformed drawing. For example errors in the information about the size of the drawing will be detected by the software and will result in an error message. Other errors like distortion in the quantization table, will result in a direct deformation of the drawing itself. This will also count for errors within the Huffman tables (see Figure 5.3 with an error in the quantization table).

a *b*

Figure 5.3: a: Original Line Drawing
b: Deformed Line Drawing by error in quantization table

5.4.3 Errors in data.

The data in the JPEG coding scheme is represented by a (zero run) size and amplitude (see 4.2.6 and 4.2.7). So a transmission error may appear in the size bits or in the amplitude bits. If the errors appear in the size bits, the image is totally lost. For example a bit stream like 11001 is transmitted. This bit stream represents 1 zero run, size 1 and amplitude 1. If an error appears in the amplitude part, the bit stream will look like 11000 which is 1 zero run, size 1 and amplitude -1 (see Table 4.1).This will cause an error in the picture, but can be very small. If an error occurs in the part of zero run and size, the error will be much bigger. For example the outcome will be 11011. This will result in a zero run of 2 and a size of 1 and the next bit followed by this stream will be seen as the amplitude. All bits followed next to the error are interpreted false so the picture will be totally destroyed. An error within the zero run and size bits are not allowed in the used software. If these kind of errors appear, the software detects that the data is distorted and it will give a mention that an error has occurred.

5.4.4 Error correction.

Many error correction methods are known. In this report a simple error correction method, plain retransmission, is used. This method can easily be implemented in this situation, because many transmission errors will result in an error message of the software. Just little files are transmitted because progressive transmission is used. Despite the retransmissions of blocks, the delay will not be very large before the drawing can be shown. For errors in the quantization tables and Huffman tables, no special error correction method is used. Mostly because these errors will not always result in a deformation of the drawing. For example if a quantization coefficient which corresponds to a zero coefficient of the DCT, is deformed, this will not result in an error in the drawing. So in one transmission step of progressive transmission only 1 of the 64 quantization coefficients (except for the last transmission step) will be sensible to transmission errors, because all the other DCT coefficients are zero. This also counts for the Huffman Tables in a same way.

No error corrections will be made for errors in the bits, that represent the amplitude. These error will only result in a deformation in just a small part of the drawing. Errors in the size bits of the Huffman coding scheme will result in an error message, thus in a retransmission of the block.

Estimation of Retransmissions 6

With the test of transmitting line drawings over GSM, a number of retransmissions will occur according to the number of transmission errors. These transmission errors will depend on the block length of the transmitted blocks and the error probability and characteristics of the mobile channel. For this reason this retransmission occurrence is investigated in this chapter, with respect to the block length and error probability of the channel.

6.1 Block length.

When we look at the original drawing represented by the x-y representation, the total number of bits to represent a line drawing will be:

$$B_o = N \cdot n_c \tag{6.1}$$

with n_c the number coordinate pairs of the representation and N the number of bits required per coordinate pair.

The JPEG coded file will consist of two different parts: a part which will contain the header information, and a part which will contain the data information. So for block i which will be sent, the total number of representation bits will be:

$$b_i = H + d_i \tag{6.2}$$

with H the number of header bits and d_i the number of data bits.

For progressive transmission, a number of these successive JPEG coded files must be transmitted to obtain an impression of the total drawing. If this number is set to k successive coded blocks, the total number of bits to be transmitted will be:

$$B_c = \sum_{i=1}^{k} b_i = kH + \sum_{i=1}^{k} d_i \tag{6.3}$$

The total number of bits (B_c) can also be written as a function of the number of bits of the original drawing (B_o) and a reduction factor λ like:

$$B_c = \lambda \cdot B_o \tag{6.4}$$

If $0<\lambda<1$ a data reduction is accomplished, otherwise a data expansion will appear. If the Equations (6.1), (6.3) and (6.4) are combined, the reduction factor λ can be written as:

$$\lambda = \frac{B_c}{B_o} = \frac{kH + \sum_{i=1}^{k} d_i}{N \cdot n_c} \tag{6.5}$$

In this study the number of bits, representing the original drawing (B_o), is kept constant for all drawings. Keeping this in mind, Equation (6.5) can be reduced to a constant part C and a varying part m like:

$$\lambda = C + m \tag{6.6}$$

$$\text{with} \quad C = \frac{kH}{N \cdot n_c}, \quad \text{and} \quad m = \frac{\sum_{i=1}^{k} d_i}{N \cdot n_c}$$

Now assume that the varying factor m can be described with a normal density function [1] with mean ζ and variance σ^2. Then the reduction factor λ_x for a certain drawing containing $x/N.n_c$ (normalised) data-bits can be written as:

$$\lambda_{x'} = C + \frac{2\varsigma}{2\delta} \int_{x-\delta}^{x+\delta} t \cdot p(t)dt \tag{6.7}$$

$$C + \frac{\varsigma}{\delta} \int_{x-\delta}^{x+\delta} t \cdot \frac{1}{\sigma\sqrt{2\pi}} e^{-\left(\frac{t-\varsigma}{\sigma\sqrt{2}}\right)^2} dt$$

$$\text{with } \delta = \frac{1}{2N \cdot n_c}$$

The δ is chosen in this way because it agrees with a difference in length of the datablock of 1 bit.

With the help of Taylor expansion [15] this formula can be written as:

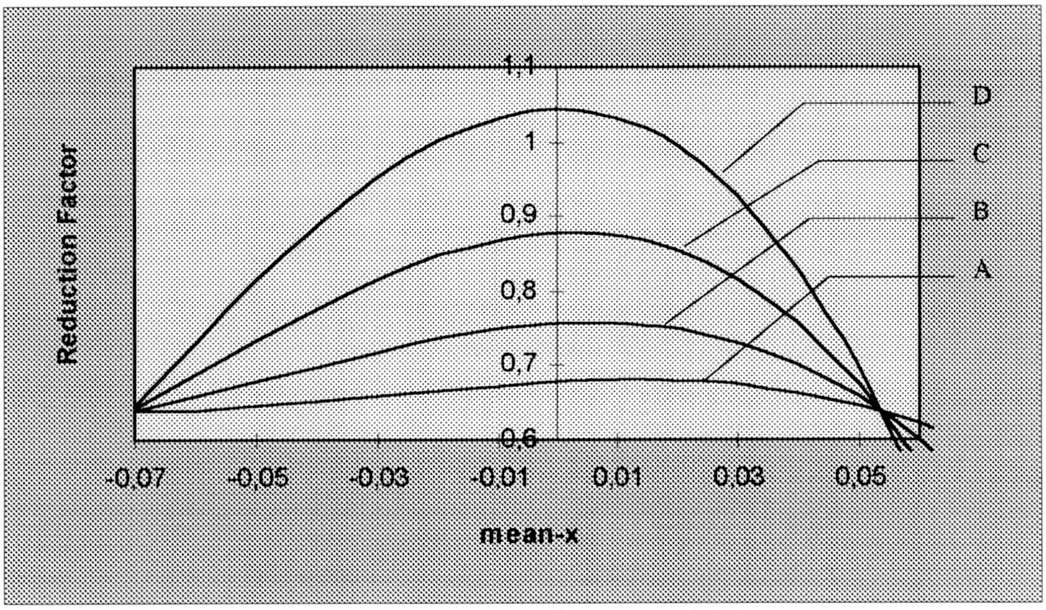
$$\lambda_x = C + \frac{\varsigma}{\delta\sigma\sqrt{2\pi}} \int_{x-\delta}^{x+\delta} t \sum_{n=0}^{\infty} \frac{(-1)^n \left(\frac{t-\varsigma}{\sigma}\right)^{2n}}{n!\, 2^n} dt \tag{6.8}$$

If the order coefficients above 1 are neglected, this will reduce Equation (6.8) to:

$$\lambda_x \approx C + \frac{\varsigma}{\delta\sigma\sqrt{2\pi}} \int_{x-\delta}^{x+\delta} t - t \frac{\left(\frac{t-\varsigma}{\sigma}\right)^2}{2} dt \tag{6.9}$$

$$= C + \frac{\varsigma}{\delta\sigma\sqrt{2\pi}} \left(\left[\frac{t^2}{2} \right]_{x-\delta}^{x+\delta} - \frac{1}{2\sigma^2} \left[\frac{t^4}{4} - \frac{2\varsigma t^3}{3} + \frac{\varsigma^2 t^2}{2} \right]_{x-\delta}^{x+\delta} \right)$$

This function for different size in mean and a constant value of variance will look like:



A: mean = 0.06
B: mean = 0.11
C: mean = 0.16
D: mean = 0.21

Figure 6.1 : reduction factor as a function of a different number of normalised databits

The functions with different mean values are shifted on to eachother so that all the different mean values are placed onto each other. In this way better comparison for the different values in λ can be achieved. For the drawing used in this report the values for mean and variance are equal to respectively 0.18 and 0.002.

An important point in these graphs is the point where λ exceeds the value of 1. At this point the drawing will not reduce in size, when decoded with the JPEG coding scheme and transmitted progressively, but will consist of more bits than the original drawing.

6.2 Number of transmissions.

Due to transmission errors, some blocks have to be retransmitted. These number of retransmissions depend upon the error probability of the channel in which they are transmitted. In a mobile channel two sources of interference can be indicated:

1. interference of the desired signal to itself,
2. interference of another carrier with the same frequency (co-channel interference).

6.2.1 Own channel interference.

The own channel interference of the desired signal consist of two sources:
1. Multipath Fading,
2. Shadow Fading.

6.2.1.1 Multipath Fading.

The Multipath fading is caused by the numerous ways for the signal to reach the receiver. This fading will cause a fast fluctuation of the signal power. the probability density function of the envelope of the total signal can be described with a Rayleigh-distribution [3]:

$$f_r(r) = \frac{r}{P_o} e^{-r^2/2P_o} \tag{6.10}$$

with r the envelope of the total signal and P_o the mean signal power.

6.2.1.2 Shadow Fading.

Shadow fading is mainly caused by large obstacles between the transmitter and receiver. This kind of fading will cause slow fluctuations in the mean signal power. The slow fluctuation can be described static in a logarithmic form by a normal distribution function like[3]:

$$f_s\{\ln(P_o)\} = \frac{1}{\sigma\sqrt{2\pi}} e^{-\{\ln(P_o)-m\}^2/2\sigma^2} \tag{6.11}$$

with variance σ^2, mean value m and mean power P_o. By transforming this distribution function, the log normal distribution function $f(P_o)$ can be derived. This function will look like:

$$f(P_o) = \frac{1}{\sigma P_o\sqrt{2\pi}} e^{-\{\ln(P_o)-m\}^2/2\sigma^2} \tag{6.12}$$

6.2.2 co-channel interference.

Because of the cellular structure of the mobile radio system, same carrier frequencies are re-used at a certain distance. This method will cause these signals to interfere at a certain level. This level of interference depends on the so called re-use distance and the signal powers.

This signal with the same carrier also suffers from multipath and shadow fading as described in paragraph 6.2.1.

6.3 Total error probability.

The total picture of disturbances on the transmission path can be seen as:

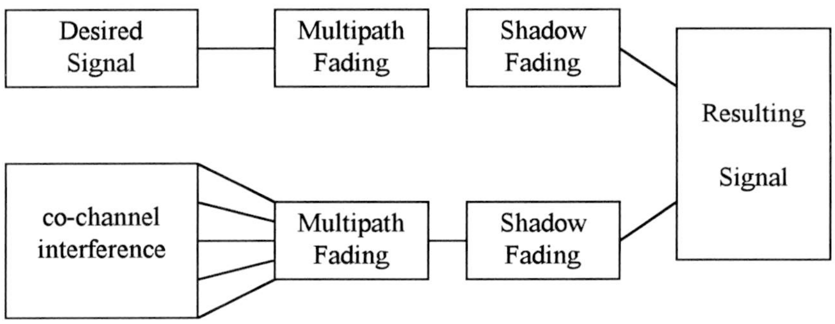


Figure 6.2 : Total picture of interference in a mobile channel

Due to the assumption that the own channel interference will exceed other interfering sources like disturbing Electro-Magnetic fields, thermal noise etcetera, these interfering sources will not be taken into account.

If the total of co-channel interfering sources is limited to 1, an error probability function can be derived [3]. This function will look like:

$$P(\frac{p_d}{p_u} < \alpha) = \frac{1}{\sqrt{\pi}} \int_{-\infty}^{\infty} \frac{e^{-u^2}}{1 + \frac{\xi_d}{\alpha \xi_e} e^{-u\sqrt{2(\sigma_d^2 + \sigma_u^2)}}} du \qquad (6.13)$$

with $\xi_d = exp(m_d)$ = median of P_{od},
and $\xi_u = exp(m_u)$ = median of P_{ou}

In this function, p_d is the power of the desired signal, p_u is the power of the undesired signal, m_x (with $x = d$ or u) is the mean value of the log-normal distribution and σ^2_x (with $x = d$ or u) the variance of the log-normal distribution. For city space a much used value for σ [dB] is between 6 and 12 dB, and for digital modulation techniques the value used for $10\log(\alpha)$ is between 8 and 12 dB.

Equation (6.13) can be estimated by a Hermite Integration [1]. This approximation has the form of:

$$\int_{-\infty}^{\infty} e^{-x^2} f(x)dx = \sum_{i=1}^{n} w_i f(x_i) + R_{n1} \qquad (6.14)$$

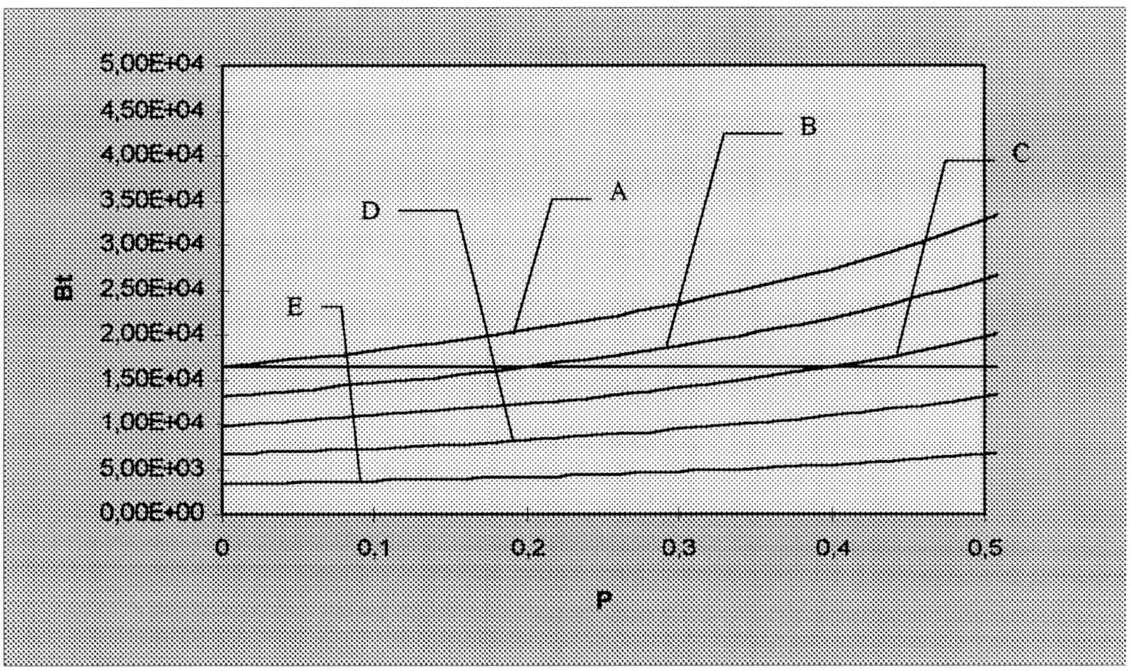
In this function, w_i is a special weigh factor for hermite integration and x_i the zeros of Hermite polynomals and R the rest factor.

6.4 Estimation of number of transmitted bits.

The total number of bits to be transmitted, can be estimated by the reduction factor λ and the error probability function. This estimation can be described as:

$$\begin{aligned} B_t &= \lambda \cdot B_o(1 + P(\alpha) + P^2(\alpha) + P^3(\alpha) + \ldots) \\ &= \lambda \cdot B_o\left(\frac{1}{1 - P(\alpha)}\right) \end{aligned} \qquad (6.15)$$

with B_o the number of bits of the original drawing, λ the reduction factor, and *P(α)* the error probability function described in Equation (6.13). The number of transmitted bits will at some error probability exceed the number of bits of the original drawing. This effect is drawn in figure 6.3 for a certain mean value of reduction factor. The mean reduction factor for the used drawings in this report is almost 0.8 so at an error probability of 0.2 the number of transmitted bits will outgrow the number of bits of the original drawing.



A = λ of 1,
B = λ of 0.8,
C = λ of 0.6,
D = λ of 0.4,
E = λ of 0.2

Figure 6.3 : Number of transmitted bits (B_t) to Error Probabillity P

The second aspect that to investigate is the effect of the total number of transmitted bits with respect to the number of data-bits at different values of Error probability.

Some practical values (see paragraph 6.3) for this error function will be for different value of variance (in dB), and errorlevel R = 10log(α) are:

D = 256

	R = 12	R = 8
σ = 12	0.259795 (A)	0.181164 (B)
σ = 6	0.077246 (C)	0.034774 (E)

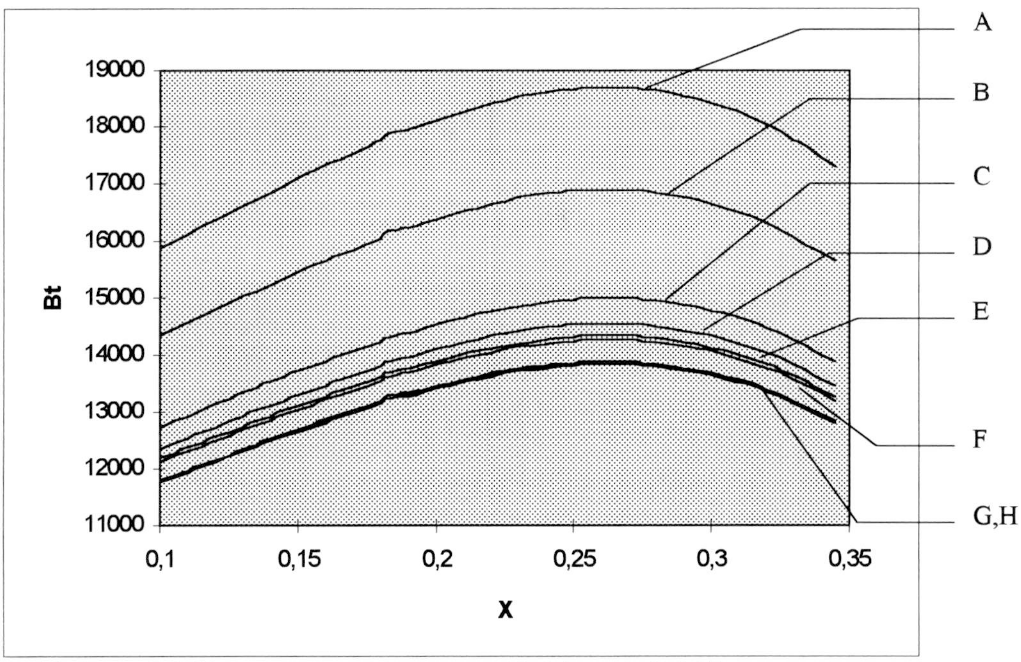
D = 10000

	R = 12	R = 8
σ = 12	0.048514 (D)	0.029852 (F)
σ = 6	0.003079 (G)	0.001164 (H)

Table 6.1: some practical values of transmission errors

with D = quotient of ξ_d and ξ_e. (for more detail see [3]).

For these different kind of error probability value, the the total number of transmitted bits (B_t) can be drawn as a function of x. This will look like:



A: Error = 0.260
B: Error = 0.181
C: Error = 0.077
D: Error = 0.049
E: Error = 0.035
F: Error = 0.030
G: Error = 0.003
H: Error = 0.001

Figure 6.4: Transmitted bits against number of normalised data-bits for different transmission errors

In this figure the mean value of x is equal to 0.18 and the standard deviation is set at a value of 0.025. It can easily be seen, that if the the error probability grows, the number of transmitted bits will grow.

Now we have retrieved a good model to place the results of the tests of the error probability of the GSM channel if JPEG encoded line-drawings are transmitted

Results 7

Two kinds of tests are performed with the GSM data-netork.
1. Coverage of the large rivers in Holland
2. Transmitting JPEG encoded Line-Drawings.

In this chapter the results of these two tests are summened.

7.1 Tested Coverage in the Netherlands.

First the GSM network is put to the test about the coverage on the main rivers in the Netherlands. This is done by means of an E-Mail service called 'Waternet'. After using this service, the user had to fill in a small questionnaire about the communication with GSM (see Appendix A). In total 5 GSM sets were used in this test. With the help of several inland-shipmen, a global impression of the coverage of the GSM data network of some large rivers in the Netherlands can be made. All the results of the questionnaire are listed in Appendix B. In this chapter only the highlights are covered.

7.1.1 Tested area

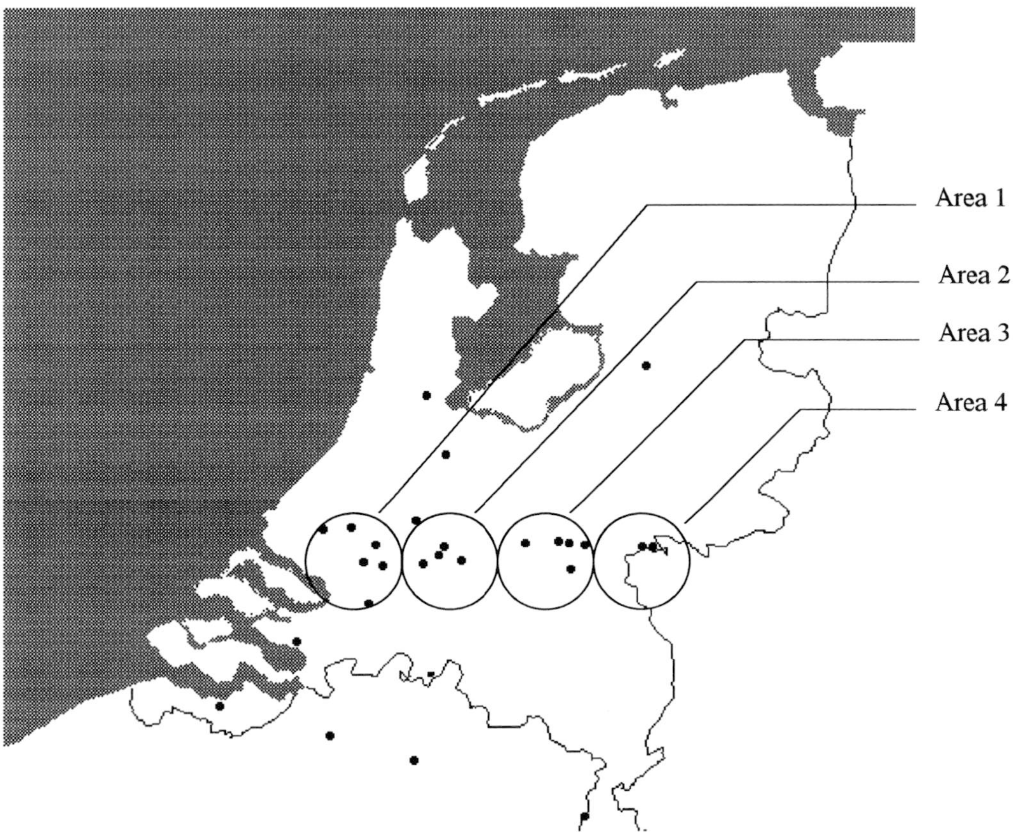


Figure 7.1: Invesigated areas in the Netherlands

In Figure 7.1 the tested areas in the Netherlands are drawn. As can be seen, most tests are performed on the river the Maas/Waal because most inland shipping uses this river to transport goods from the port (Rotterdam) the Germany. The most problem area on this route is between Nijmegen and Lobith. In that area it was hard to get a good connection by means of GSM.

In Table 7.1 the tested places are divided into 4 sub-groups around a large city from the west of the Netherlands to the east (see also Figure 7.1). Also the average of all the tests is given as a comparison. In this table it can be seen, that indeed nearby the city Nijmegen the total number of unsuccesful attemps is higher than in other parts of the country.

Area	# good attemps	total # attemps	mean # attemps
Area 1	14	22	1.57
Area 2	6	6	1
Area 3	6	6	1
Area 4	8	23	2.88
Area 5	88	120	1.36

Area 1 : Rotterdam, Ridderkerk, Dordrecht, Puttershoek, Vlaardingen
Area 2 : Gorinchem, Schoonhoven, Brakel, Arkel
Area 3 : Tiel, Druten, Deest
Area 4 : Nijmegen. Lobith, Niftrik
Area 5 : All tested places

Table 7.1: attemps in the tested areas in four different regions

Even in Rotterdam itself, the set could always make a connection to GSM despite of all the different interfering sources like industrial machinary, cranes etc. The analogue ATF-network has shown in the past to be much more sensitive to interference.

The rest of the tested areas were very successful in connecting via GSM. Almost every attempt was rewarded with a connection, or else the second try would suffice. Even in water-locks and under bridges the first time was almost allways a hit. Also at some places in Belgium it was possible to make a connection to the Dutch GSM network.

Some odd test results are the ones made in Germany and further on in Belgium. According to the Dutch PTT the sets could only make a connection to the Dutch GSM-Network, but one set could actually connect to the Belgian an German GSM Network. This set had one of the first data-cards handed by PTT to the company Joanknecht BV.

7.2 Testing GSM with Line-Drawings.

Second the GSM data network is tested by sending line-drawings without error correction of the used network. The only software error-correction used, is retransmission of damaged blocks of the drawing. The results of these tests are summened in Appendix C.

7.2.1 Used drawings.

In this chapter the used Line Drawings are shown. The JPEG encoded versions of the Line Drawings are placed next to them, so they can be compared. Also the mean squared error of the coded drawings are given.

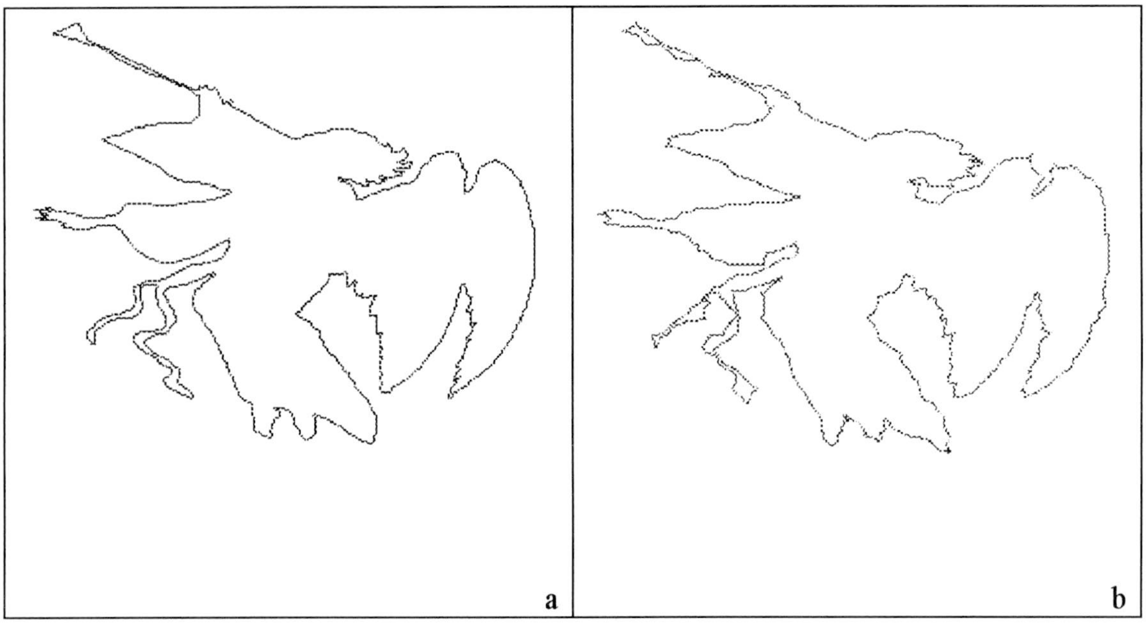


Figure 7.2: a - Original drawing engel1024
b - JPEG encoded drawing engel1024

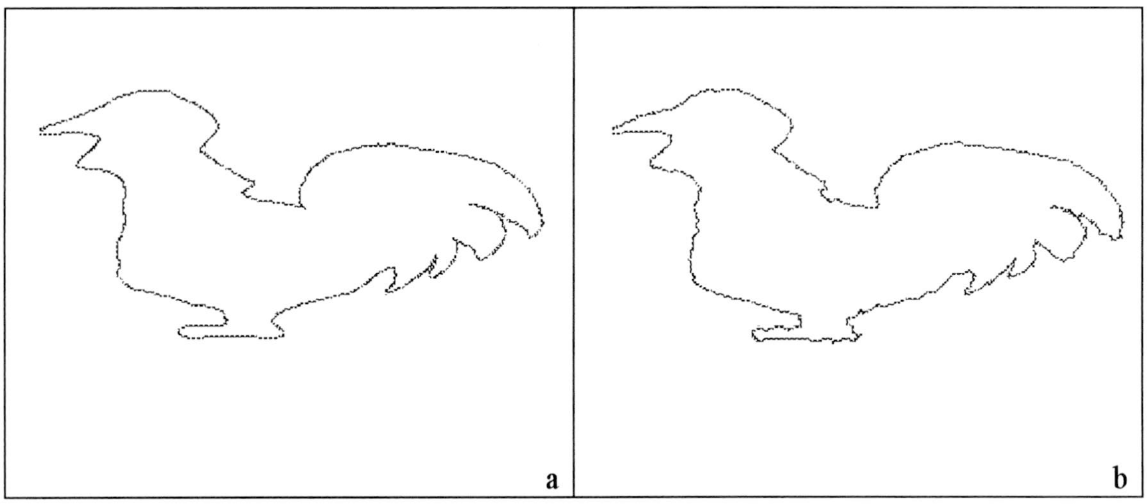


Figure 7.3: a - Original drawing Haan1024
b - JPEG encoded drawing Haan1024

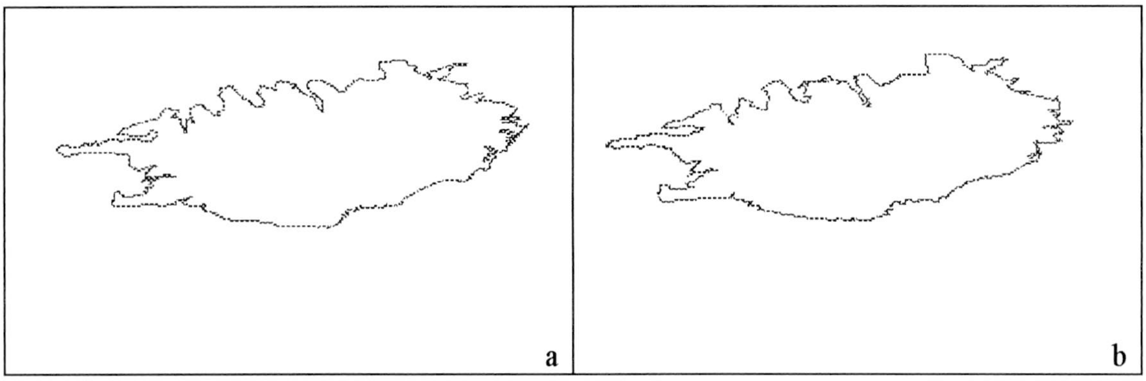


Figure 7.4: a - Original drawing ijs1024
b - JPEG encoded drawing ijs1024

Drawing	MSE
Engel1024	1.41
Haan1024	0.82
IJs1024	1.12

Table 7.2: Mean Squared Error of the used drawings when encoded with JPEG

7.2.2 Way of handling.

The written software handles the transmission of linedrawings as follows:

1. The caller (remote) calls a specific number of the host and sends a special id afterwards. This id gives a good insight in who is calling from the different users.
2. The host sends a menu of the different drawings that can be chosen.
3. The caller has to choose one of the drawings.
4. The first part of the choosen drawing is received.
5. The drawing is JPEG decoded and drawn on the screen.
6. The next part of the drawing is received.
7. This will continue until the last part is received. The the connection will be broken.

If an error occurs in any received part of the drawing, a re-transmission must take place of that part.

In the results in Appendix C, no re-transmissions are seen. This is due to the fact, that if a re-transmission should occur, the software was bound to hang the computer. Tested with just two modems, the computers did not suffer from this problem. But a good insight of the network can be reached with the obtained results. When an error occurs, the following blocks will not be transmitted, so a retransmission must be done. Only this retransmission will not show in the results.

7.2.3 Compilation of the results of appendix A:

# good blocks	# errors (re-transmissions)	# login errors	# choise errors
261	20	16	11

Table 7.3: Summed results of the tests with JPEG encoded Line Drawings

Good blocks:
These are the parts of the drawing which are received properly and showed good result of the drawing.

Errors (re-transmissions):
These are the blocks that obtained some distorted data. Normally this would give a retransmission of the distorted block, but as explained above it led to a hang of the remote computer.

Login errors:
These are the result of wrong received id's. This may be due to the fact that the host could also receive non-data calls (speech calls), which will automatically result in a wrong login.

Choise errors:
The host received a good id, but was not able to accept a number of a drawing. The number was or out of range (for example the choise could be made of three drawings, and a different number bigger than three has been chosen), or the remote could not receive the menu of the different drawings correctly so he could not make a choise, or the choise was made correctly but was not received correctly at the host end.

For getting the probability error of the GSM network compared to the retransmission of blocks, the login and choise errors will be left out. A mean error probability of the re-transmission can be calculated with the results of these tests by:

$$\overline{P} = \frac{\#error\ blocks}{total\ \#\ blocks} \qquad (7.1)$$

This will result in a mean error value of 0.08. The mean reduction factor λ can be calculated with the number of bits of the representation of the original drawings and the number of bits of the JPEG coded drawing. This will result in a value of the used drawings of 0.8.

With these calculated values of mean error and reduction factor a good comparison can be made with the theoretical calculated values in Paragraph 6.4. The practical values showed in Figure 6.3 will look like:

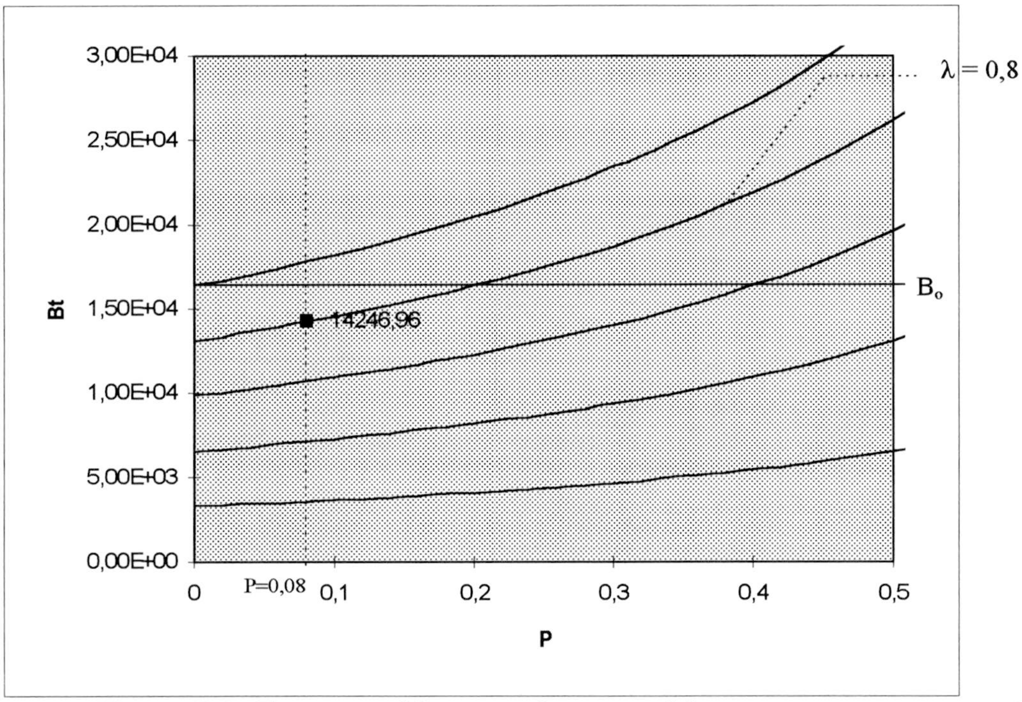


Figure 7.5: Transmitted bits as a function of the transmission error probability

In Figure 7.5 the total transmitted bits are drawn against the error probability function of the GSM channel. At the calculated mean error of 0,08 and a reduction factor of 0,8 the mean number of transmitted bits will be 14246,96. This value is below the value of the number of bits of the original drawing, B_o, so taken over a large number of transmissions, the number of bits transmitted will be smaller than the number of bits in the original drawing.

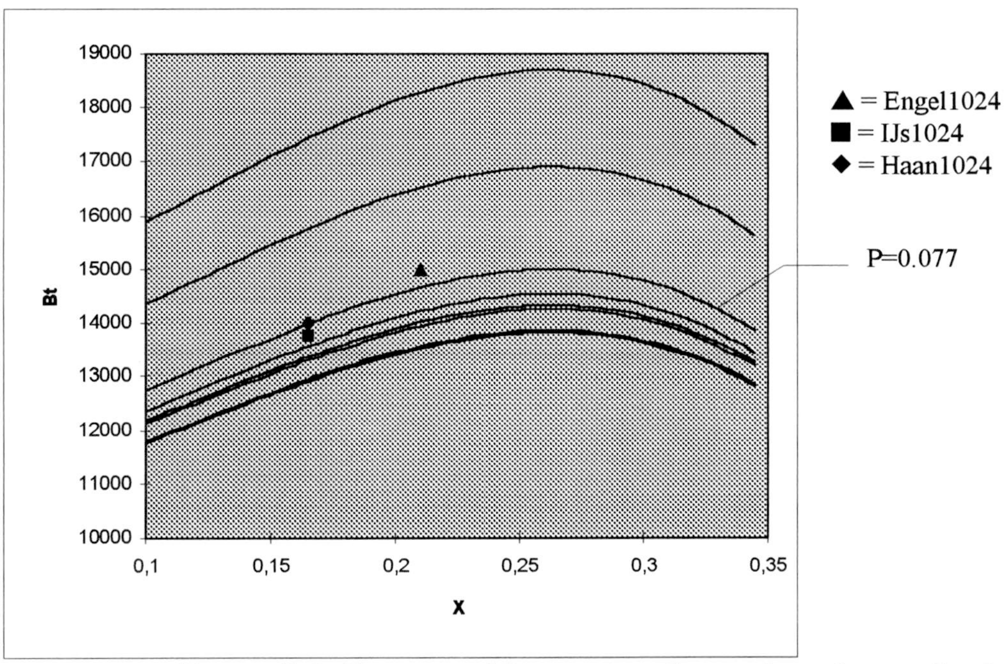


Figure 7.6: Transmitted bits against the number of normalized data-bits

In Figure 7.6 the used drawings are placed in Figure 6.4. Like the mean transmission error calculated with Equation (7.1) it shows that all the drawings are near the line with transmission error 0.077. So based with these three Line Drawings the retransmission estimation calculated in Chapter 6 is a good model with respect to transmission errors and block length.

Conclusions and Recommendations 8

8.1 Conclusions

One application that can be used in the field of mobile telecommunication is transmitting Line Drawings. But Line Drawings are represented by many bits and data transmission in a mobile environment is not very fast (now 2400 bits/s growing to 9600 bits/s in the future) and expensive. For these reasons progressive transmission and effective coding are used to reduce the number of transmitted bits. In this report the data facility of the mobile network GSM is investigated with respect to Line Drawings that are coded with the JPEG coding standard.

First the coverage of the GSM network in the Netherlands is tested to get an overview of the reachability of this network. This is done with the help of several inland shipmen, so only the main rivers are tested. On all the rivers they could obtain a good connection. Only between Nijmegen and the German border it was hard to get a proper connection with the GSM network.

With the help of the results about the coverage, the progressive transmission of JPEG encoded Line Drawings is performed at both good and rather bad connection places. In this way a mean number of transmission errors can be achieved. With this mean error an estimation of the total transmitted bits can be made for any drawing. The results show, that the total number of transmitted bits does not exceed the number of bits of the original drawing and still a good compression ratio is maintained. With the fast recognition possibility of progressive transmission, the way of coding Line Drawings with JPEG shows to be a good way to code these drawings in a mobile environment.

8.2 Recommendations.

Only the main rivers in the Netherlands are tested with the GSM data-facility. For a total picture of the coverage of the Netherlands also other parts must be investigated. This can be done by placing a data terminal on board of a truck and perform transmission with real route information.

More reduction can be achieved if the transmitted blocks of every progressive transmission step are re-organized. In this report with every step the header is transmitted. This header is the same for all the different steps of the transmission so only one transmission of this header will suffice.

The progressive transmission of JPEG encoded Line Drawings can be performed with other mobile networks like Mobitex. In this way a comparison of the different mobile data-communication networks can be drawn.

In this report only the 8-bit coding part of JPEG is used. This limited the size of the Line Drawings with coordinates not larger than 256. JPEG also has an option of 24 bit coding which will allow much larger drawings. Also this option can be worth investigating.

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Appendix A

Questions for the enquete about the GSM network tested with an E-Mail service for inland shipping.

1. Datum ? (Date ?)
2. Waar bevindt u zich? (Where are you travelling?)
3. Is er een storing geweest? (Has there been any kind of errors?)
4. Zo ja, welke ? (If yes, which?)
5. Hoeveel brieven heeft u verstuurd ? (How many letters did you send ?)
6. Hoeveel brieven heeft u ontvangen ? (How many letters did you receive ?)
7. Heeft u een binair bestand verstuurd of ontvangen ? (Did you send or receive a binary file ?)
8. Zo ja, hoe groot was deze dan ? (If yes, what was the size of this file ?)
9. Wat was ongeveer de tijd dat u verbinding met 'Waternet' had ? (How long where you approximately connected to 'Waternet' ?)
10. Regels commentaar ... (Lines of comment ...)

Appendix B

Results of the enquete about the GSM network and the E-Mail service 'Waternet' for Dutch inland shipping:

Datum	Plaats	Storing	# verstuurt	# ontvangen	Binair best.	tijd (min)	# pogingen	Opmerkingen
25-12-94	Hattem			1		3	1	
16-03-95	Nijmegen-Millingen	Weigering Bin-best	5	2	1243	5	5	Problemen met instelling modem
16-03-95	Deest		3	0		1	1	
21-03-95	Bolness		1			20 sec	1	
24-03-95	Sluiskil		1	3		1	1	
25-03-95	Rotterdam		1	1		17	4	
25-03-95	Hulhuizen		1	1	76890	5	1	
25-03-95	Nijmegen		1	0	1432	1,5	1	
26-03-95	Rotterdam	Uitval tel. 1 min	1	0		2	120	Server heeft eruit gelegen
26-03-95	Volkerak		0	0		20	8	Server heeft eruit gelegen
26-03-95	Nifterik	Geen aansluiting	0	0		2	4	Server heeft eruit gelegen
27-03-95	Nifterik		3	1		2	1	
27-03-95	Rotterdam	Uitval tel.	1	0		3	2	
27-03-95	Nifterik		3	3		2,5	1	
27-03-95	Rotterdam		0	2		1,5	2	
28-03-95	Nifterik		2	1		5	1	
29-03-95	Antwerpen		2	4	10*A4	2	1	
29-03-95	Krammersluis		3	4		2	1	
29-03-95	Krammersluis		1	0		1	1	
30-03-95	Terneuzen	Uitval terwijl online	1	2	210648	5	2	
30-03-95	Terneuzen		1	0		1	1	
31-03-95	Volkerak		4	4		3	1	
1-04-95	Werkendam		3	0		1	1	
2-04-95	Millingen		3	2		2*1	2	2 sessies
3-04-95	Stein		0	4		1	1	
6-04-95	Antwerpen (Schelde)		1	2	6*A4	2	2	
7-04-95	Rotterdam			4	7*A4	2+3	2	2 sessies (1 versturen 1 ophalen)
9-04-95	Rotterdam		4	1		2	1	
10-04-95	Rotterdam		1	1	1*A4	1,2	1	
11-04-95	Rotterdam		3	2		1	1	
11-04-96	Lobith		3	2		4	1	
12-04-95	Loevenstein		0	0		3	1	
12-04-95	Druten		2	4		2*3	1	2 sessies
13-04-95	afvarend Dodewaard		2	4		3	1	
14-04-95	Moerdijk (Shell)	1ste geen verbinding	1	0		1	2	

Datum	Plaats	Storing	# verstuurt	# ontvangen	Binair best.	tijd (min)	# pogingen	Opmerkingen
14-04-95	Marken (ijselmeer)		1	0		1	1	
18-04-95	IJmuiden		2	2		1,75	1	
19-04-95	Rotterdam		1	2		1	1	
20-04-95	Schoonhoven		1	3		3	1	
20-04-95	Dordrecht		3	5		3	1	
21-04-95	Antwerpen		1	4		2	1	
21-04-95	Antwerpen		2	2		1	1	
22-04-95	Olen (Belgie)		3	0		1,5	1	
23-04-95	Moerdijk		1	0		1	1	
23-04-95	Antwerpen		3	0		2	1	
23-04-95	Amsterdam		1	1		0,75	1	
24-04-95	Luik	moeite met verturen	4	2		5	5	
24-04-95	Amsterdam		2	0		1,2	1	
24-04-95	Luik		3	0		1,7	1	
24-04-95	IJselmeer		1	2		2	1	23-04 geen verbinding i.b.v. Grouw
25-04-95	Antwerpen		0	1		1	1	
25-04-95	Luik	2 x gehangen	2	2		4,5	3	2 x hangt netwerk, zelf afgebroken
25-04-95	Nifterik		5	3		3	2	
25-04-95	Tholen		1	2		2	1	
27-04-95	Puttershoek		2	2		1,5	1	
28-04-95	Oud Vossemeer		1	4		1,5	1	
28-04-95	Lobith		2	6		2,55	1	
28-04-95	Gorinchem		2	3		1	1	
29-04-95	Emmerich		3	0		1	1	Tssn Nijmegen & Dtslnd geen contact
29-04-95	Tiel		3	0		1	1	
29-04-95	Hulhuizen	contact BBS	0	0		2	5	bagger op scherm na contact BBS
29-04-95	Andernach		2	4		2,5	1	D2 net
30-04-95	Antwerpen		1	1		1	3	
1-05-95	Werkendam		2	1		1	1	
2-05-95	Freudenberg		5	14		5,1	1	D1 net
2-05-95	Bolnes	4x geen verbinding	0	0		0	4	
2-05-95	Faulbach	2x mislukt	2	1		3,5	3	
4-05-95	Wipfeld		2	6		2,2	1	
7-05-95	Brakel		3	2		3	1	

Datum	Plaats	Storing	# verstuurt	# ontvangen	Binair best.	tijd (min)	# pogingen	Opmerkingen
8-05-95	Tiel		2	5		5	2	2 sessies
8-05-95	Nurnberg		2	2		1,3	1	
8-05-95	Brakel		2	0	8000	2	1	
8-05-95	Moerdijk		1	3		3	1	
11-05-95	Arkel		1	4		1,5	1	
11-05-95	Antwerpen		2	1		0,5	1	
11-05-95	Faulbach		4	0		1,95	1	
13-05-95	Breukelen		2	5		2	2	
13-05-95	Dusseldorf		4	1		1,5	1	D1 net
15-05-95	Ewijk		2	0		1	1	
18-05-95	Schoonhoven	moeite vinden netwer	1	3		1,15	1	
21-05-95	Vlaardingen		1	1		2	1	
22-05-95	Kop v/h Land		3	3		3	1	
23-05-95	Antwerpen		2	1		1	2	
25-05-95	Frankfurt		5	0		2,5	2	2 sessies
30-05-95	Neuwied		2	1		1,2	1	
4-06-95	Brug Leeuwen		2	3		2	1	
7-06-95	Ijselmeer		2	5		2	1	

Appendix C

Results tests with GSM and JPEG encoded linedrawings.

These results are devided into 8 different parts per line. These are:

LOGIN-NAME, DATE, TIME, # Drawing, # part1, # part2, # part3, # part4

232, 08-06-95, 21:53:01, 0, 0, 0, 0, 0
210, 08-06-95, 22:36:16, 0, 0, 0, 0, 0
GSM01, 08-06-95, 22:37:21, 0, 0, 0, 0, 0
GSM01, 08-06-95, 22:38:38, 0, 0, 0, 0, 0
GSM01, 08-06-95, 22:41:26, 0, 0, 0, 0, 0
GSM01, 08-06-95, 22:45:38, 1, 1, 0, 0, 0
GSM01, 08-06-95, 22:47:55, 2, 1, 1, 0, 0
GSM01, 08-06-95, 22:49:02, 0, 0, 0, 0, 0
GSM01, 08-06-95, 22:51:39, 2, 1, 1, 1, 1
GSM01, 08-06-95, 22:54:12, 3, 1, 1, 1, 1
GSM02, 12-06-95, 08:42:49, 0, 0, 0, 0, 0
GSM02, 12-06-95, 08:48:54, 1, 1, 1, 0, 0
GSM02, 12-06-95, 08:53:43, 0, 0, 0, 0, 0
GSM02, 13-06-95, 12:15:14, 0, 0, 0, 0, 0
GSM02, 13-06-95, 12:21:55, 2, 1, 1, 1, 1
\¿cô□13-06-95, 12:24:19, 0, 0, 0, 0, 0
GSM02, 13-06-95, 12:27:10, 3, 1, 1, 1, 1
210, 13-06-95, 12:30:14, 0, 0, 0, 0, 0
210, 13-06-95, 12:37:54, 3, 0, 0, 0, 0
GSM02, 13-06-95, 12:40:05, 1, 1, 1, 1, 1
GSM02, 13-06-95, 12:48:37, 1, 1, 1, 1, 1
GSM02, 13-06-95, 12:52:52, 3, 1, 1, 1, 1
GSM02, 13-06-95, 12:55:32, 1, 1, 0, 0, 0
GSM02, 13-06-95, 12:58:21, 1, 1, 1, 1, 0
GSM02, 13-06-95, 13:02:41, 1, 1, 1, 1, 1
GSM02, 13-06-95, 13:16:57, 1, 1, 1, 0, 0
210, 13-06-95, 13:49:56, 0, 0, 0, 0, 0
GSM02, 13-06-95, 13:53:27, 1, 1, 1, 1, 1
GSM02, 13-06-95, 14:00:50, 1, 1, 1, 1, 1
210, 13-06-95, 14:17:48, 0, 0, 0, 0, 0
GSM02, 13-06-95, 14:27:07, 1, 1, 1, 1, 1
GSM02, 13-06-95, 14:48:31, 1, 1, 1, 1, 1
GSM02, 13-06-95, 14:51:40, 1, 1, 1, 1, 1
GSM02, 13-06-95, 14:55:53, 2, 1, 1, 1, 1
232, 13-06-95, 16:25:56, 0, 0, 0, 0, 0
GSM02, 14-06-95, 10:13:27, 1, 1, 1, 1, 1
GSM02, 14-06-95, 10:17:52, 2, 1, 1, 1, 1
GSM02, 14-06-95, 10:23:15, 3, 1, 1, 1, 1
GSM02, 14-06-95, 10:27:40, 3, 1, 1, 1, 1

GSM02, 14-06-95, 10:38:51, 3, 1, 1, 1, 1
GSM02, 14-06-95, 10:44:48, 3, 1, 1, 1, 0
232, 14-06-95, 12:46:05, 0, 0, 0, 0, 0
210, 14-06-95, 12:51:40, 0, 0, 0, 0, 0
GSM02, 14-06-95, 12:55:08, 1, 1, 1, 1, 1
øDeel, 14-06-95, 13:00:16, 1, 0, 0, 0, 0
GSM02, 14-06-95, 13:02:49, 2, 1, 1, 1, 1
GSM02, 14-06-95, 13:10:33, 1, 1, 1, 1, 1
GSM02, 14-06-95, 13:28:45, 1, 1, 1, 0, 0
232, 14-06-95, 15:23:55, 0, 0, 0, 0, 0
232, 14-06-95, 15:46:12, 0, 0, 0, 0, 0
232, 14-06-95, 15:48:52, 0, 0, 0, 0, 0
GSM00, 18-06-95, 14:55:42, 1, 1, 1, 1, 1
GSM00, 18-06-95, 14:57:29, 2, 1, 1, 1, 1
GSM00, 18-06-95, 14:59:07, 3, 1, 1, 1, 1
GSM00, 18-06-95, 15:00:43, 1, 1, 1, 1, 1
GSM00, 18-06-95, 15:02:23, 1, 1, 1, 1, 1
GSM00, 18-06-95, 15:03:58, 2, 1, 1, 1, 1
GSM00, 18-06-95, 15:05:43, 1, 1, 1, 1, 1
GSM00, 18-06-95, 15:07:24, 1, 1, 1, 1, 1
GSM02, 18-06-95, 15:13:22, 1, 1, 1, 0, 0
GSM02, 18-06-95, 15:19:19, 1, 1, 1, 1, 1
GSM02, 18-06-95, 15:21:58, 1, 1, 1, 1, 0
GSM02, 18-06-95, 15:26:27, 2, 1, 1, 1, 1
GSM02, 18-06-95, 15:28:46, 3, 1, 1, 1, 1
GSM02, 18-06-95, 15:31:15, 1, 1, 1, 1, 1
GSM02, 18-06-95, 15:33:10, 0, 0, 0, 0, 0
GSM02, 18-06-95, 15:36:27, 2, 1, 1, 1, 1
GSM02, 18-06-95, 15:38:46, 1, 1, 1, 1, 1
GSM02, 18-06-95, 15:40:43, 1, 1, 1, 1, 0
GSM02, 18-06-95, 15:46:15, 1, 1, 1, 1, 1
GSM02, 18-06-95, 15:51:55, 1, 1, 1, 1, 1
GSM02, 18-06-95, 15:54:21, 2, 1, 1, 1, 1
GSM02, 19-06-95, 10:13:18, 1, 1, 1, 0, 0
bû] 19-06-95, 10:14:23, 0, 0, 0, 0, 0
GSM02, 19-06-95, 10:18:25, 1, 1, 1, 1, 1
GSM02, 19-06-95, 10:21:25, 2, 1, 1, 1, 1
GSM02, 19-06-95, 10:24:33, 3, 1, 1, 1, 1
GSM01, 19-06-95, 10:26:39, 3, 1, 1, 1, 1
GSM02, 19-06-95, 10:49:15, 1, 1, 1, 1, 1
GSM02, 19-06-95, 10:52:15, 2, 1, 0, 0, 0
GSM02, 19-06-95, 10:57:16, 2, 0, 0, 0, 0
GSM02, 19-06-95, 11:00:30, 2, 1, 1, 1, 1
ÿûÿûî, 19-06-95, 11:02:33, 0, 0, 0, 0, 0
GSM02, 19-06-95, 11:07:59, 3, 1, 1, 1, 1
GSM02, 19-06-95, 11:13:08, 1, 1, 1, 1, 1
GSM02, 19-06-95, 11:17:49, 1, 1, 1, 0, 0
GSM02, 19-06-95, 11:21:16, 1, 1, 1, 1, 1
GSM02, 19-06-95, 11:23:45, 0, 0, 0, 0, 0

GSM02, 19-06-95, 11:30:22, 2, 1, 1, 1, 1
GSM02, 19-06-95, 11:32:45, 3, 1, 1, 0, 0
GSM02, 19-06-95, 11:39:06, 3, 1, 1, 1, 1
GSM02, 19-06-95, 11:42:12, 3, 1, 1, 1, 1
GSM02, 19-06-95, 11:48:16, 0, 0, 0, 0, 0
GSM02, 19-06-95, 11:51:52, 1, 1, 1, 1, 1
GSM02, 19-06-95, 19:15:57, 1, 1, 1, 1, 1
GSM02, 19-06-95, 19:17:34, 0, 0, 0, 0, 0
GSM02, 19-06-95, 19:20:04, 2, 1, 0, 0, 0
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GSM02, 19-06-95, 19:50:07, 2, 1, 1, 1, 0
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GSM02, 19-06-95, 19:59:11, 0, 0, 0, 0, 0
GSM02, 19-06-95, 20:05:24, 2, 1, 1, 1, 1