Um Interface

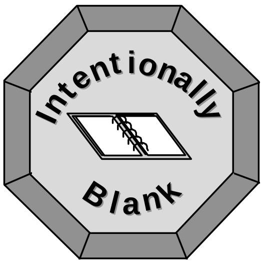
Chapter 6

This chapter is designed to provide the student with an overview of the Um (Radio) interface and the layer 2 protocol, LAPDm.

OBJECTIVES:

Upon completion of this chapter the student will be able to describe:

- layer 3 functions.
- the different protocols: RR, MM, and CM.
- the data link layer protocol (LAPDm).
- what functions are implemented in layer 1.
- idle mode behavior by MS, cell selection and reselection.
- measurements performed by MS in busy mode and the measurement report.


Intentionally
Blank

6 Um Interface

Table of Contents

Topic	Page

GENERAL **105**

SIGNALING LAYER 3 .... **107**
CONNECTION MANAGEMENT 108
MOBILITY MANAGEMENT 112
RADIO RESOURCE MANAGEMENT 113
L3 MESSAGE FORMAT 117

SIGNALING LAYER 2 .... **120**
UNACKNOWLEDGED OPERATION 122
ACKNOWLEDGED (MULTIPLE FRAME) OPERATION 122
SEGMENTATION 122
LAYER 2 INFORMATION 123
SERVICE ACCESS POINTS 128
SYSTEM PARAMETERS 131
TRAFFIC CASE - FROM THE LAPDM VIEW POINT 133
ANNEX A - RANDOM ACCESS PROCEDURE 134

SIGNALING LAYER 1 .... **135**
CHANNEL CODING 136
INTERLEAVING 138
CHANNEL CODING AND INTERLEAVING OF SPEECH (FULL RATE) 139
CODING AND INTERLEAVING OF CONTROL CHANNELS 141
CODING AND BURST FORMATTING OF SCH 143
CODING AND BURST FORMATTING OF ACCESS INFORMATION 144
SUMMARY OF CHANNEL CODING 146
MODULATION 146
OTHER LAYER 1 FUNCTIONS 148

Intentionally Blank

GENERAL

The Um interface is the interface between the MS and the RBS.

The layered structure of protocols can be used as a basis for describing signaling on the Um interface.

As explained in the signaling introduction chapter, layering is the basic structuring technique in the OSI model. Logically, the communication between user application processes is viewed as being partitioned into an ordered set of layers, organized in a vertical sequence. For signaling on the MS-RBS interface, three layers are required as shown in Figure 6-1.

Figure 6-1 Layering.

In each layer, there are entities responsible for specific signaling procedures. “Peer entities” are entities belonging to the same layer in different nodes. These peer entities communicate with each other by sending and receiving messages according to a specific protocol.

For communication between entities in adjacent layers of the same node, service primitives are used. The primitive carries the information over the common boundary of adjacent layers at a Service Access Point (SAP). A SAP is a logical concept defined in the OSI model as:

“a gate through which a lower layer provides service to an upper layer”

The SAP is identified by its Service Access Point Identifier (SAPI) value. Primitives are also used to describe information exchange between layers and the user application. The concept is described on Figure 6-2.

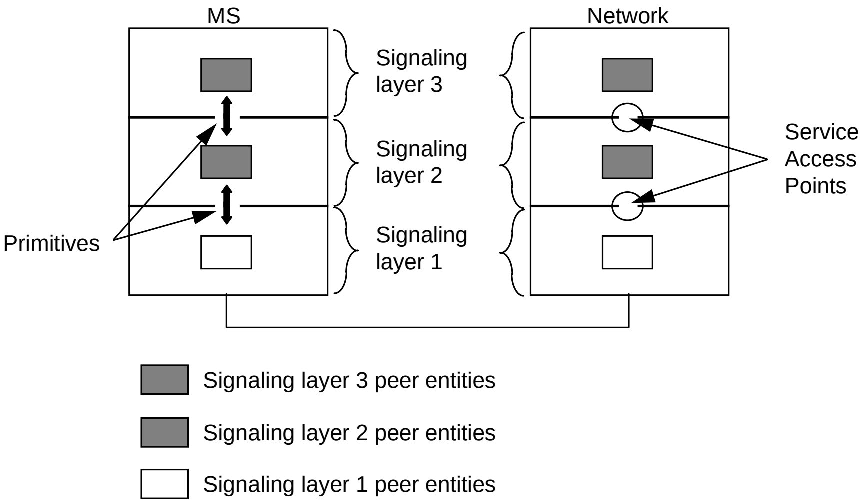


Figure 6-2 Layering on Um.

SIGNALING LAYER 3

Layer 3 provides the Mobile Network Signaling (MNS) service to the user application. An overview of layer 3 is shown in Figure 6-11. MNS includes:

- functions to establish, maintain and terminate circuit switched connections across a GSM PLMN and other networks to which the PLMN is connected.
- supporting functions for supplementary services and short message service control.
- functions for mobility management and radio resource management.

To realize these functions in layer 3, separate protocol control entities exist in the three sublayers:

- Connection Management (CM)
- Mobility Management (MM)
- Radio Resource management (RR)

In the MS, entities from all three sublayers are present. On the network side there is a distribution of the signaling functions between different network equipment. The RR functions reside mainly in the BSC, although some RR functions may reside in the MSC. In the BTS, most of the RR messages are handled as transparent messages. However, some of them must be interpreted by the BTS. For example, messages concerning random access, start ciphering and paging. The MM and CM functions on the network side are located in the MSC. See Figure 6-3.

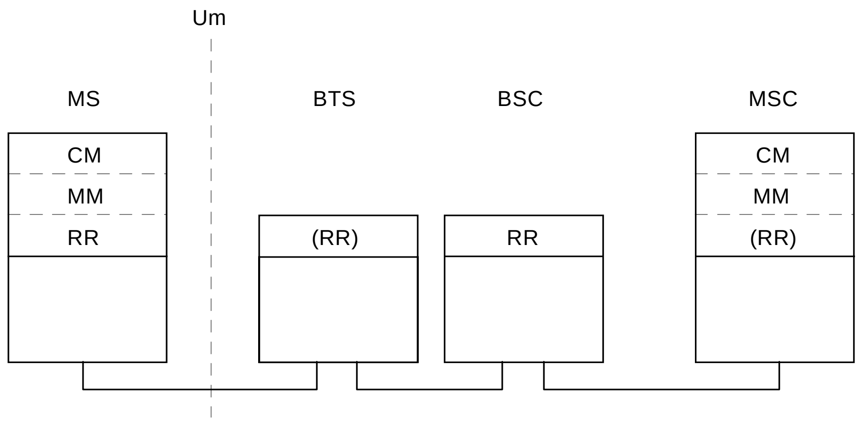


Figure 6-3 Um layer 3, distribution of signaling functions.

CONNECTION MANAGEMENT

The CM sublayer contains functions for:

- Call Control and call related supplementary services management (CC).
- Short Message Service (SMS).
- Non call related Supplementary Services management (SS).

Call Control

The CC protocol must be supported by all MSs. It provides functions and procedures for ISDN call control, although modified for adaptation to the radio environment. It also includes call re-establishment and in-call modification of bearer services during a call. For example, changing from speech to data, are two specific procedures included in the CC protocol. CC also contains functions for call specific supplementary services such as user to user signaling.

In the GSM specifications, the CC signaling procedures are described under *four* headings:

- call establishment procedures
- procedures during the active state
- call clearing
- miscellaneous procedures

However, the messages are grouped into *five* groups as can be seen in Figure 6-6.

Call Establishment Procedures

In the case of a mobile originating call, the mobile subscriber initiates call establishment by dialing a number and pressing the send button. This is known as a Man Machine Interface (MMI) procedure. These procedures are mapped onto call control procedures via an exchange of primitives over the Mobile Network CC Service Access Point (MNCCSAP). See Figure 6-11.

In the case of a mobile terminating call, information about call establishment procedures performed by a user is mapped onto the CC procedures when it reaches the MSC. The user in this case can be in an ISDN network, for example.

In all cases when the upper layers request to establish a call, a free (in state “null”) CC entity is selected to establish a CC connection between the MS and the network. This CC entity initiates the establishment by asking the MM sublayer to establish an MM connection. When the MM sublayer confirms the establishment of a MM connection, the CC entity sends a Setup message to its peer entity. Other CC messages such as Call Proceeding and Alert are then exchanged. When Connect/Connect Acknowledgment has finally been exchanged, the two peers enter the active state and the call establishment phase is complete.

Procedures During the Active State

During the active state, a CC entity may inform its peer entity of a call related event or call rearrangement (for example, change of user equipment connected to MS) by means of a Notify message.

The Modify message is used to change the call mode in support of dual services like alternate speech/data.

Call Clearing Procedures

The CC entity initiating clearing sends a Disconnect message to its peer. Then there is an exchange of Release/Release Complete messages after which the MM connection is released and the CC entities return to null state.

Miscellaneous Procedures

The DTMF protocol control procedure is one example of this procedure class. Another example is the status procedure which can be initiated by a CC entity that needs to know the call state of its peer.

Parallel CC transactions are possible through the existence of more than one CC entity. In Figure 6-4 four CM layer 3 entities are shown:

- two call control entities
- one short message service entity
- one supplementary service entity

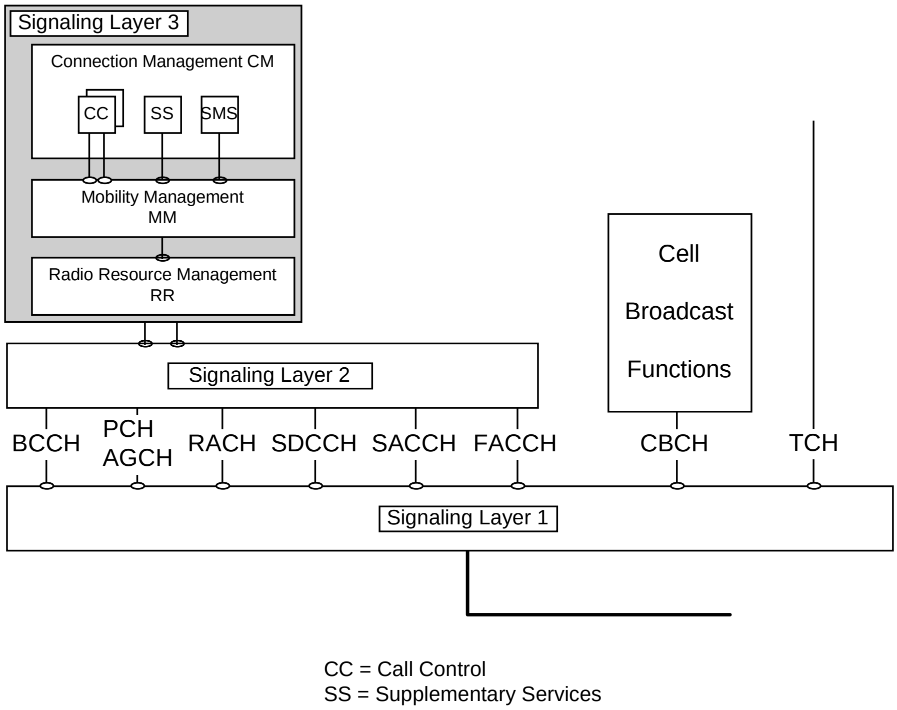


Figure 6-4 Radio interface protocol structure.

The CC entities are independent of each other and communicate with corresponding peer entities using separate MM connections. Different CC entities use different transaction identifiers. See Figure 6-9 and Figure 6-11.

Figure 6-5 shows the messages sent between CC entities.

Call establishment messages:
Alerting
Call confirmed 1)
Call proceeding
Connect
Connect acknowledge
Emergency setup 1)
Progress
Setup

Call information phase messages:
Modify 1)
Modify complete 1)
Modify reject 1)
User information

Call clearing messages:
Disconnect
Release
Release complete

Messages for supplementary service control:
Facility
Hold 1)
Hold acknowledge 1)
Hold reject 1)
Retrieve 1)
Retrieve acknowledge 1)
Retrieve reject 1)

Miscellaneous messages:
Congestion control
Notify
Start DTMF 1)
Start DTMF acknowledge 1)
Start DTMF reject 1)
Status
Status enquiry
Stop DTMF 1)
Stop DTMF acknowledge 1)

Figure 6-5 Messages for circuit mode connections call control and call related supplementary services management.

Note 1) Not supported by Blue Book CCITT Rec. Q 931 (network side).

Short Message Service Support (SMS)

SMS comprises entities called Short Message Control (SMC) using the peer protocol Short Message Control Protocol (SM-CP) to transfer short messages between MS and MSC. The SMC entities provide service to the SMS application via the Mobile Network SMS Service Access Point (MNSMS-SAP). See Figure 6-11 to examine the MS side. Figure 6-6 shows the protocol hierarchy for SMS. See also chapter 3 “Traffic Cases” .

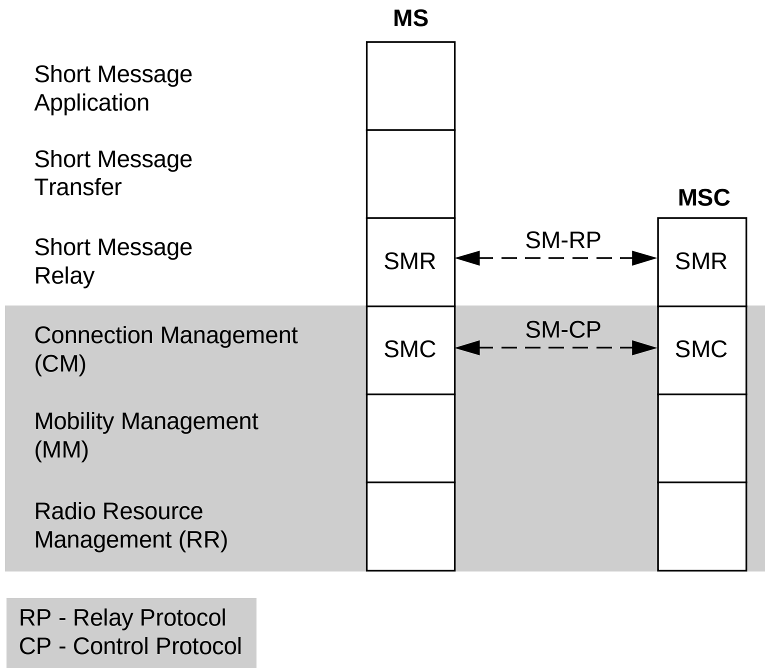


Figure 6-6 Layer structure, SMS point to point.

Supplementary Services support (SS)

SS handles services not related to a specific call. For example, registration of call forwarding on no reply or call waiting. This information is transferred to the HLR. The signaling procedures and the protocols used for supplementary services are described in chapter 14.

MOBILITY MANAGEMENT

Three types of procedures are performed by the MM sublayer. They are:

1. Procedures to support the mobility of the MS, such as informing the network about the MS's present location. These are known as MM specific procedures and include location updating type normal, location updating type periodic registration and location updating type IMSI attach.
2. MM common procedures provide user identity confidentiality. These procedures handle for example, authentication, TMSI reallocation, IMSI detach and identification of the MS by requesting either IMSI or IMEI.
3. The MM connection management procedures provide service to the different entities in the upper connection management sublayer. They provide the CM entity with the

ability to use an MM connection for communication with its peer entity. At reception of a request for a MM connection from a CM entity, the MM sublayer sends a request for the establishment of an RR connection to the RR sublayer. When the RR connection is established, the network may initiate MM common procedures like authentication and TMSI reallocation. It may also ask the RR sublayer to perform RR procedures such as ciphering mode setting. When all of these MM and RR procedures are successfully complete, the MM connection establishment is finished and the CM entity requesting the MM connection is informed.

Figure 6-7 shows messages used by MM.

Registration messages:
IMSI detach indication
Location updating accept
Location updating reject
Location updating request

Security messages:
Authentication reject
Authentication request
Authentication response
Identity request
Identity response
TMSI reallocation command
TMSI reallocation complete

Connection management messages:
CM service accept
CM service reject
CM service abort
CM service request
CM reestablishment request
Abort

Miscellaneous message:
MM status

Figure 6-7 Messages for mobility management.

RADIO RESOURCE MANAGEMENT

The RR sublayer receives service from layer 2 and gives service to the MM sublayer. In addition, RR communicates directly with layer 1 for exchange of information related to measurement control and channel management.

The general purpose of the RR procedures is to establish, maintain and release a dedicated connection between the MS and the network. This includes handover procedures, cell selection at power on and cell re-selection in idle mode, recovery from lack of coverage in idle mode.

The cell selection and re-selection is carried out in close cooperation with layer 1, fulfilling the requirements for PLMN selection as specified in GSM recommendations (phase 2). In addition, in the MS RR there are functions for reception of the uni-directional BCCH and CCCH (paging sub-channel) when no RR connection is established. On the network side, RR handles the broadcasting of system information described in chapter 5 “System information”, and continuos transmission on all paging sub-channels to MSs in idle mode.

Establishment of an RR connection initiated by the MS is triggered by request from the MM sublayer. Establishment of a RR connection can also be initiated by an RR entity on the network side. For example, through transmission of a paging message. In both cases, the first thing the RR entity does in the MS is transmission of a channel request message asking for a signaling channel. The network allocates a dedicated channel to the MS by sending an immediate assignment message. After exchange of the layer 2 frames SABM and UA (refer to the “Signaling Layer 2” section of this chapter), the RR connection is established and the MM sublayer in MS and in the network are informed that an RR connection exists.

When in RR connected mode:

- on the downlink, the RR sublayer sends system information to the busy MS.
- on the uplink, the MS transmits measurement reports.
- the network may use the RR ciphering mode setting procedure for setting the ciphering mode.
- entities in upper layers can send messages to their peer entities.
- upper layers on the network side can request the RR sublayer to set the channel mode, by running the channel mode modify procedure. The channel mode covers coding, decoding and transcoding mode.
- an inter cell change of channel can be requested by the network RR sublayer.
- the classmark change procedure is used by the MS to provide the system with additional MS classmark information. It is also used to indicate to the network a

change in classmark. For example, when the power capabilities of a hand held MS are changed because the MS is connected to external power in a vehicle.

- the classmark interrogation procedure can be used by the network to request information about MS classmark.

The release of a RR connection can be performed by the normal release procedure or the radio link time-out procedure described in chapter 5 “System Information”.

Only one RR connection can be established for one MS at one time.

More information about cell selection/reselection procedures and measurements in idle/busy mode, can be found in the “signaling layer 1” part of this chapter.

In Figure 6-8 the messages sent between RR entities are shown.

Channel establishment messages:
Additional assignment
Immediate assignment
Immediate assignment extended
Immediate assignment REJECT

Ciphering messages:
Ciphering mode command
Ciphering mode complete

Handover messages:
Assignment command
Assignment complete
Assignment failure
Handover access
Handover command
Handover complete
Handover failure
Physical information

Channel release messages:
Channel release
Partial release
Partial release complete

Paging messages:
Paging request type 1
Paging request type 2
Paging request type 3
Paging response

System information messages:
System information type 1
System information type 2
System information type 2bis
System information type 2ter
System information type 3
System information type 4
System information type 5
System information type 5bis
System information type 5ter
System information type 6
System information type 7
System information type 8

Miscellaneous messages:
Channel mode modify
Channel mode modify acknowledge
Channel request
Classmark change
Classmark enquiry
Frequency redefinition
Measurement report
Synchronization channel information
RR status

Figure 6-8 Messages for radio resources management.

L3 MESSAGE FORMAT

The messages listed in Figure 6-5, Figure 6-7 and Figure 6-8 are exchanged between peer entities over the Um interface. The messages are, with a few exceptions, standard L3 messages. This means that the form of the L3 message is a sequence of octets, consisting of the following parts:

- protocol discriminator
- transaction identifier or skip indicator
- message type
- other information elements as required

8 7 6 5	4 3 2 1	
Transaction identifier or Skip Indicator	Protocol discriminator	octet 1
Message type		octet 2
Other information elements as required		etc...

Figure 6-9 Organization of a standard L3 message.

Every message starts with a message header containing:

Protocol Discriminator (PD):
Bits 1 to 4 of the first octet is the protocol discriminator. See Figure 6-9. The PD identifies the L3 protocol to which the message belongs. There is a one to one correspondence between L3 protocol and PDs. This is shown in Figure 6-10.

bits 4 3 2 1	
0 0 1 1	call control; call related SS messages
0 1 0 1	mobility management messages
0 1 1 0	radio resources management messages
1 0 0 1	SMS messages
1 0 1 1	non call related SS messages
1 1 1 1	reserved for tests procedures

Figure 6-10 Protocol discriminator values.

Transaction Identifier (TI) and Skip Indicator:
Bits 5 to 8 of every CM message contain the transaction identifier. See Figure 6-9. The TI makes it possible to decide

which one out of several parallel transactions, handled by the same CM protocol, a message belongs to. For RR and MM messages this field is called skip indicator and is coded as 0000.

Message Type:
The message type information element determines the function of a message within a protocol and in a given direction. See Figure 6-9. The meaning of the message type is therefore dependent on the protocol and direction. Thus, the same value can have different meanings in different protocols and the same value can have different meanings in the same protocol depending on the direction the message is being sent.

In the RR and MM sublayers, functions related to the transport of messages are defined. Their task is to examine the message header and route the message to or from the correct protocol entity according to the PD and the TI. See Figure 6-11. In the case of parallel transactions, multiplexing and splitting are performed by these functions.

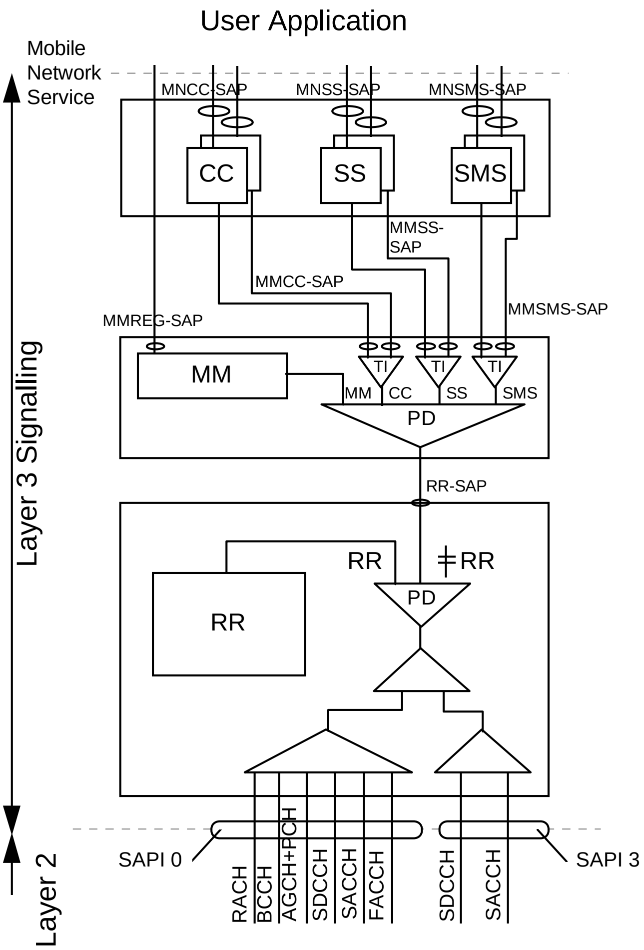


Figure 6-11 Protocol architecture of layer 3-MS side.

SIGNALING LAYER 2

Link Access Procedures on the Dm channel (LAPDm) is the layer 2 protocol used to convey signaling information between layer 3 entities across the radio interface, using the Dm channel. Dm channel refers to the control channels, independent of the type. This includes broadcast, common or dedicated control channels. Each logical control channel is allocated a separate protocol entity. The RACH is treated in a special way and does not utilize LAPDm. For RACH, LAPDm acts as an interface between layer 3 entities and the physical layer. The random access procedure is described in Annex A.

LAPDm is a protocol that operates at the data link layer of the OSI structure. The purpose of that layer is to provide a reliable signaling link. It receives services from the physical layer and provides services to layer 3.

In Ericsson's GSM system, LAPDm is controlled by software located in the TRXC. The function block that handles the functionality for BCCH and CCCH is named the Common Channel Handler (CCH). The function block that handles the functionality for the dedicated channels SACCH, FACCH and SDCCH is called the Air Link Handler (ALH).

LAPDm is based on the ISDN protocol LAPD, which is used on the Abis interface. However, due to the radio environment, the LAPD protocol can not be used in its original form. Some modifications have been made to adapt the protocol and make it more efficient. For example, no check sum is used because the channel coding on layer 1 already provides these functions. Another modification is that some layer 2 control frames, such as SABM and UA, may carry layer 3 information. This procedure is called piggybacking.

A LAPD message is too long to be sent over the radio interface using a narrow bandwidth TDMA. Over LAPD, the total number of octets that can be sent in one frame is 260. These 260 octets include a header and a layer 3 message which are handled by the BTS. For a downlink transparent message, the header is removed by the BTS and the remaining 249 octets are sent as data to the MS. This set of 249 octets is still too long for one frame on the air interface. Therefore, LAPDm segments the message into a number of shorter messages. Data exchanged between the data link layer and the physical layer is 23 octets for BCCH, CCCH, SDCCH and FACCH. For SACCH only, 21 octets are sent from layer 2 to layer 1.

Figure 6-12 shows what happens with a layer 3 message from layer 3 down to layer 1.

Examples of LAPDm functions include:

- LAPDm provides one or more data link connections on a Dm channel. Data Link Connection Identifier (DLCI) is used for discriminating between data link connections.
- LAPDm allows for the recognition of frame types.
- It allows layer 3 message units be delivered transparently between layer 3 entities.
- It provides sequence control to maintain the sequential order of frames across the data link connections.

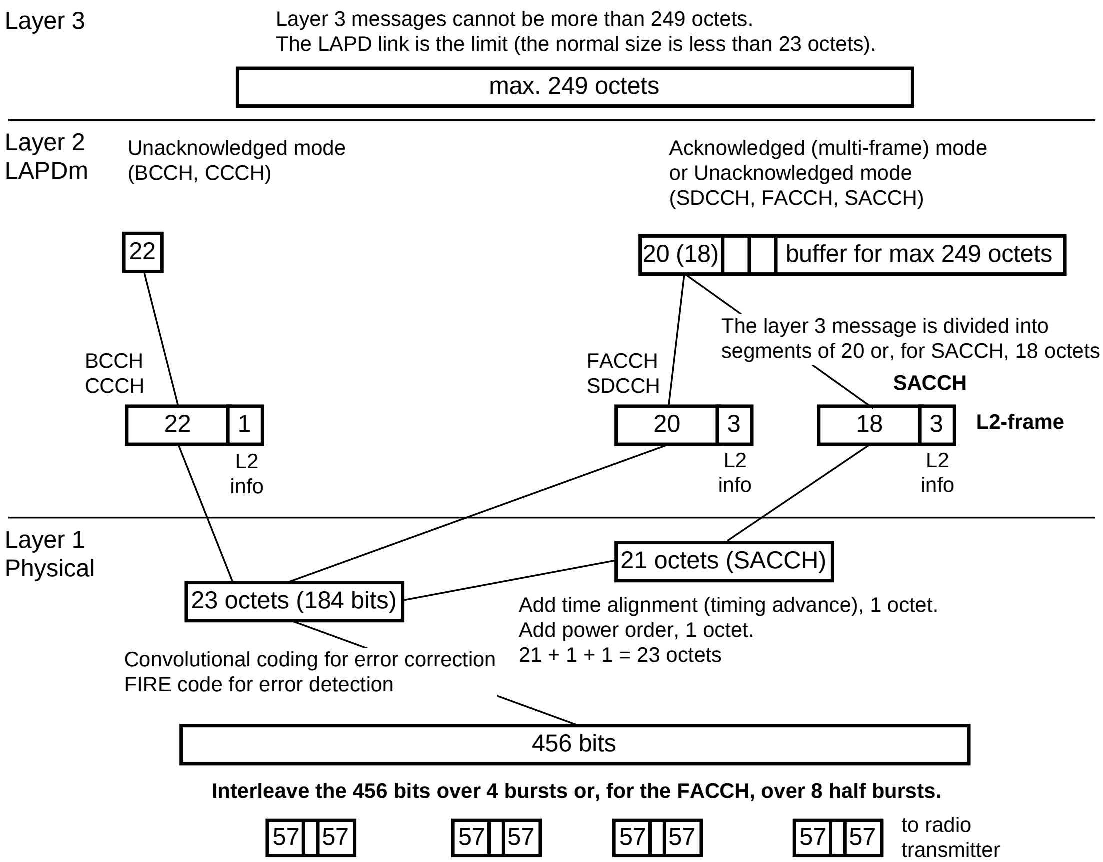


Figure 6-12 Signaling over the radio interface.

Two types of operation on the data link are supported by LAPDm. They are:

- unacknowledged operation
- acknowledged (or multiple frame) operation

These can co-exist on a signaling channel. This means that even if signaling messages are exchanged in acknowledged mode, messages which need not be acknowledged may be exchanged as well. BCCH and downlink CCCH, that is PCH and AGCH; only support unacknowledged mode. SDCCH, SACCH and FACCH support acknowledged and unacknowledged mode, depending on the information content. This is shown in Figure 6-18.

UNACKNOWLEDGED OPERATION

Messages that need not be acknowledged are sent in Unnumbered Information (UI) frames. This means that there is no flow control or error recovery mechanism defined.

ACKNOWLEDGED (MULTIPLE FRAME) OPERATION

When an answer or acceptance is required, operation in acknowledged mode is applied. Acknowledged mode is applicable on dedicated control channels only.

Multiple frame operation is the only form of acknowledged operation that is defined.

Layer 3 messages are sent in numbered I frames. In this case, a number of consecutive I frames (a window) can be sent before an acknowledgment is required. However, for LAPDm the size of the window is one, which means that each frame must be acknowledged before the next one is sent.

The multiple frame mode is initiated with the Set Asynchronous Balanced Mode (SABM) command. The counters for send and receive sequence control are then reset to the value “0”.

SEGMENTATION

In the acknowledged mode, the data link layer segments messages longer than 20 or 18 octets on the transmitting side. On the receiving side, the message units are joined again.

In the unacknowledged mode, the data link layer does not provide the segmentation service. No layer 3 message sent on BCCH and CCCH exceeds 22 octets of layer 3 information.

The signaling over the radio interface, including segmentation, is illustrated in Figure 6-12.

LAYER 2 INFORMATION

LAPDm adds overhead information depending on the frame type used. For BCCH and CCCH information frames, a length indicator field of one octet is added. This means that there is a maximum of 22 octets of layer 3 information, as the maximum number of information octets on the radio interface is 23. For the frame type used by FACCH, SACCH and SDCCH an address field and a control field are included in addition to the length indicator. Messages to be sent on FACCH or SDCCH can therefore contain a maximum of 20 octets of layer 3 information. On SACCH, only 18 octets of information are allowed because layer 1 adds two octets. One octet for time alignment and one for power order. The format types are shown in Figure 6-13.

Fill bits	L3 information	Length indicator field	
23...	...4, 3, 2,	1	Octet no

a) Frame type used by BCCH and CCCH

Fill bits	L3 information	Length indicator field	Control field	Address field	
23...	...5, 4,	3,	2,	1	Octet no

b) Frame type used by FACCH and SDCCH

Fill bits	L3 information	Length indicator field	Control field	Address field	L1	L1	
23...	...7, 6,	5,	4,	3,	2,	1	Octet no

c) Frame type used by SACCH

Figure 6-13 Frame formats for unacknowledged and acknowledged information transfer.

Address field

The address field may consist of a variable number of octets. However, for applications on control channels the field consists of only one octet. See Figure 6-14. The address field identifies the SAP for which a command frame is intended. Below is a description of the address fields:

EA The address field extension bit, enables the field to be extended to span more than one octet (EA=0). For this implementation, EA is always “1”, indicating that it is the final octet of the address field.

C/R The Command/Response bit identifies a frame as either a command or a response. The MS side sends commands with the C/R bit set to “0” and responds with C/R set to “1”. The BTS sends commands with the C/R bit set to “1” and responds with C/R set to “0”.

SAPI The Service Access Point Identifier identifies whether the message is a CM (CC or SS), a MM or a RR message or short message service.

LPD The Link Protocol Discriminator is coded as “0” except for Short Message Service Cell Broadcast (SMSCB) information. In the case of SMSCB the first octet is called “block type” instead of address field. With SMSCB bit 8 is spare and the LPD equals 1 while bits 1-5 indicate the sequence number of the SMSCB block. Instead of LAPDm the cell broadcast functions take care of such messages.

BIT	8	7	6	5	4	3	2	1
	0	LPD		SAPI			C/R	EA

LPD = Link Protocol Discriminator
SAPI = Service Access Point Identifier
C/R = Command / Response bit
EA = Extended Address field indicator

Figure 6-14 Address field.

Control field

The control field consists of one octet and identifies the type of frame, which is either a command or a response. Three types of control field formats are specified. They are:

- numbered information frames (I format)
- supervisory functions (S format)
- unnumbered information and control functions (U format)

These are shown in Figure 6-15.

Format	Commands	Responses	8	7	6	5	4	3	2	1
Information transfer	I		N(R)			P	N(S)			0
Supervisory	RR	RR	N(R)			P/F	0	0	0	1
	RNR	RNR	N(R)			P/F	0	1	0	1
	REJ	REJ	N(R)			P/F	1	0	0	1
Unnumbered	SABM		0	0	1	P	1	1	1	1
		DM	0	0	0	F	1	1	1	1
	UI		0	0	0	P	0	0	1	1
	DISC		0	1	0	P	0	0	1	1
		UA	0	1	1	F	0	0	1	1

SABM = Set Asynchronous Balanced Mode
UA = Unnumbered Acknowledgment
I = Information
RR = Receiver Ready
RNR = Receiver Not Ready
REJ = REJect

DISC = DISConnect
DM = Disconnected Mode
UI = Unnumbered Information
P/F = Poll/Final bit
N(S) = Send sequence number
N(R) = Receive sequence number

Figure 6-15 Control field.

P/F All frames contain the Poll/Final bit. In command frames, the P/F bit is referred to as the P bit. In response frames, the P/F bit is referred to as the F bit. The P bit set to "1" is used by the data link layer entity to force (poll) an immediate response frame from the peer data link layer entity. The F bit set to "1" is used by the data link layer entity to indicate that the response frame is transmitted as a result of a poll command. For unacknowledged information transfer, the P/F bit is not used and is set to "0".

Sequence numbers Send sequence number, N(S), of the transmitted frame is contained in I frames only. The number may have the value 0 through 7. Receive sequence number, N(R), is included in I frames as well as in supervisory frames. N(R) is the expected send sequence number of the next I frame to be received.

Information Transfer Format: I

The I format is used to transfer sequentially numbered frames containing information fields provided by layer 3. See Figure 6-16.

Supervisory Format: S

The S format is used to perform data link supervisory control functions such as acknowledging or requesting re-transmission of I frames. Examples of S frames are Receive Ready (RR), Receive Not Ready (RNR) and REJect (REJ). In Ericsson’s GSM system, only RR frames are used. RNR is, for example, used to tell the transmitting side not to send more messages because the buffer is full. REJ is sent from the receiver side in cases when a message is lost. A lost message is detected when the received message is out of order. As the window size for LAPDm is one (each message unit is acknowledged), RNR and REJ do not improve the performance of the system and therefore are not used.

Unnumbered Format: U

The U format is used to provide additional data link control functions and unacknowledged information transfer. See Figure 6-16. Examples of U frames are:

Commands:

SABM
Set Asynchronous Balanced Mode is used as a command frame to request the establishment of multiple frame operation. An information field is permitted with the SABM command (piggybacking).

DISC
Disconnect is a command transmitted in order to terminate a multiple frame operation.

UI
Unnumbered Information is used when a layer 3 entity requests unacknowledged information transfer to a peer entity.

Responses:

UA
Unnumbered Acknowledgment is used to acknowledge the receipt and indicate the acceptance of the mode setting commands SABM or DISC. An information field is permitted with the UA response. That is, if SABM is to be acknowledged, the UA response to that command must contain the same information field as received in the SABM command. (The SABM message is looped back.)

DM
Disconnect Mode is used as a response to report to a peer entity that multiple frame operation cannot be performed.

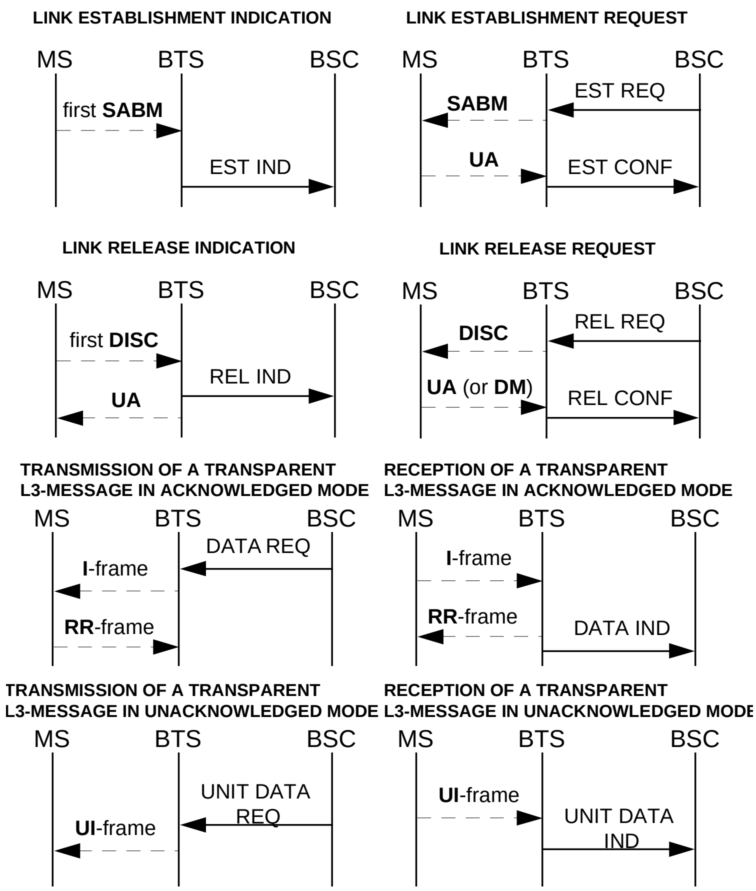


Figure 6-16 Use of layer 2 messages.

Length Indicator Field

The length indicator field, shown in Figure 6-17, consists of the length indicator field extension bit (EL), the More data bit (M) and a Length indicator (L).

BIT	8	7	6	5	4	3	2	1
	L						M	EL

L = Length indicator
M = More data bit
EL = Extended Length field indicator

Figure 6-17 Length indicator field.

EL The length indicator field extension bit will make it possible in the future to expand the length indicator field by setting EL=0. However, in this implementation of Ericsson's GSM system, EL is always coded as "1".

M The more data bit is used to indicate segmentation of layer 3 message units on data link layer frames. M=1 indicates that the information field contains only a segment of the layer 3 message unit. M=0 indicates that the information field contains the last segment of a layer 3 message unit.

L The length indicator consists of 6 bits which are used to indicate the number of octets contained in the information field of UI, SABM, UA or I frames. L=0 is used in frames that do not contain an information field. If the length indicator has a value less than N201, which is the maximum allowed number of information octets, the frame contains fill bits. See paragraph System Parameters. Octets containing fill bits take the binary value "00101011" on the downlink. This is due to the modulation and interleaving schedules used in GSM. On the uplink, the MS may use "11111111".

SERVICE ACCESS POINTS

Service Access Points (SAPs) of a layer are defined as gates through which services are offered to an adjacent higher layer. SAP is identified with the Service Access Point Identifier (SAPI). The SAPI between layer 3 and layer 2 has a specific value for each of the following functions on the Dm channel. See Figure 6-11.

SAPI = 0 for CC, SS, MM and RR signaling

SAPI = 3 for short message services

Between layer 2 and the physical layer there are SAPs defined for each control channel. See Figure 6-19.

In GSM, the RR sublayer of layer 3 controls the SAPs between layer one and layer 2. That is, establishment and release of channels. The procedure differs from the OSI reference model, where it is the data link layer that controls the establishment and release of channels.

Mode of Operation and Allowed SAPIs

The operation mode used on a specific channel is dependent on SAPI as shown in Figure 6-18 where SACCH/T is associated to a TCH and SACCH/C is associated to a control channel.

Type of channel	SAPI=0	SAPI=3
BCCH	Unacknowledged	Not supported
CCCH	Unacknowledged	Not supported
SDCCH	Unacknowledged and acknowledged	Acknowledged
SACCH/C	Unacknowledged	Not supported
SACCH/T	Unacknowledged	Acknowledged
FACCH	Unacknowledged and acknowledged	Not supported

Figure 6-18 Mode of operation, depending on channel and SAPI.

Procedural Types

Figure 6-19 shows a functional block diagram of the data link layer in the MS. The data link connections for all physical channels have terminating points at the SAP identified by SAPI=0, but only the data link connections for SACCH and SDCCH can terminate at the SAP identified by SAPI=3. Three procedural types are shown in Figure 6-19:

- the data link procedure
- the data link distribution procedure
- the random access procedure

These are described below.

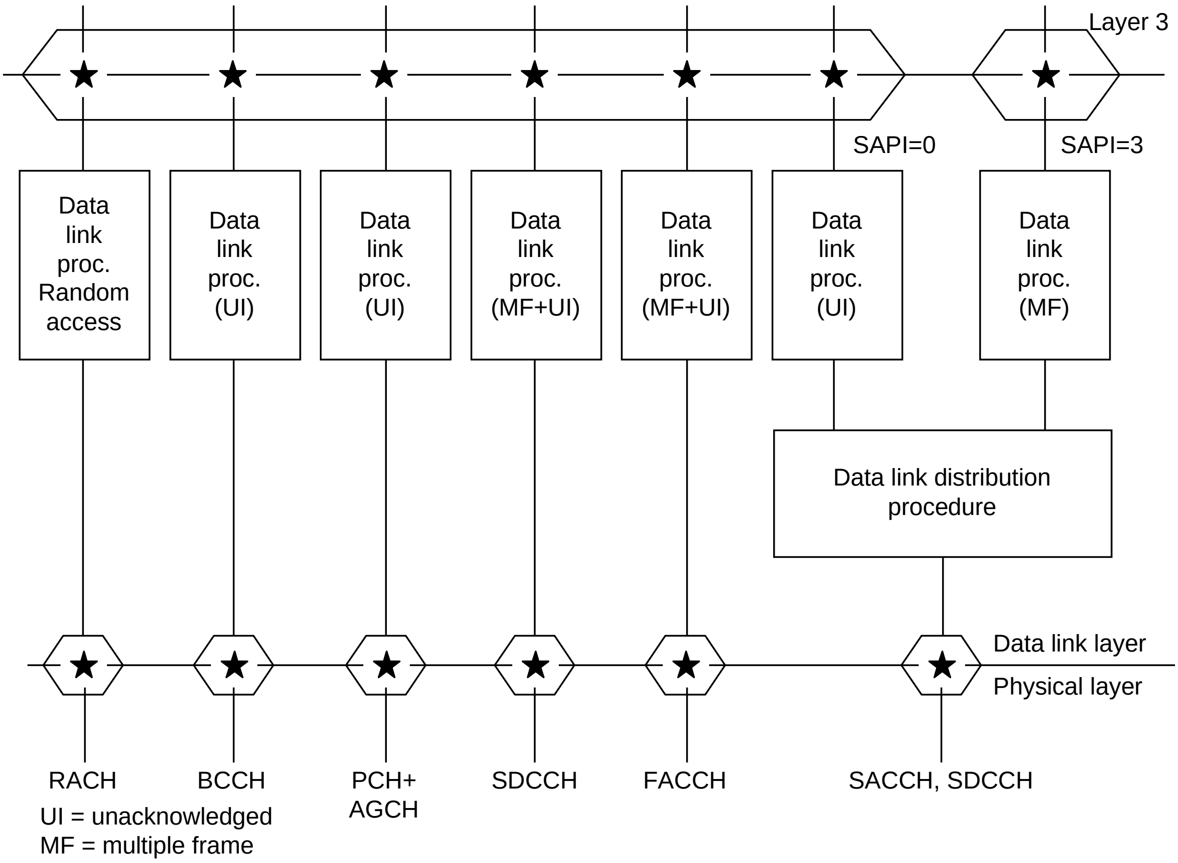


Figure 6-19 Data link layer connections in MS.

Data Link Procedure

The data link layer procedure is performed once for each SAPI, on each type of physical channel that is supported on that SAPI. The procedure analyses the control field and the length indicator field of the received frame. The procedure segments and rejoins the layer 3 message units.

Data Link Distribution Procedure

When there is more than one SAPI on a physical channel, the distribution procedure is required. On frame reception, the procedure analyses the address field and the type of physical channel in order to distribute the message unit to the appropriate data link procedure block. On frame transmission, the procedure delivers frames to the required physical channel. The procedure also provides contention resolution between the various data links procedure blocks on the same physical channel. The contention resolution is based on the SAPI and on the priority requested by layer 3.

Random Access Procedures

The random access procedures are used for data links on the random access channel. The procedure in the MS formats the random access frames and initiates transmission of them. The procedure in the BTS receives the random access frames and provides the appropriate indication to layer 3.

Services Required from the Physical Layer

The data link layer requires the following services from the physical layer:

- Physical layer connection where the bits of a frame and the message signal units are delivered to the peer entity in the same order as they were submitted to the physical layer on the transmitting side.
- Frame synchronization
- Provision of error protection to ensure a low residual bit error rate in the data link layer.
- Transmission (in MS) and reception (in BTS) of random access bursts.

SYSTEM PARAMETERS

There are a number of system parameters specified which are used in the different procedures of the protocol handling. These include:

- Timer T200
- N200: Maximum number of re-transmissions
- N201: Maximum number of octets in an information field
- k: Maximum number of unacknowledged I frames

These system parameters are described below.

Timer T200

T200 indicates the maximum waiting time for an acknowledgment of an earlier transmitted I, SABM or DISC command frame. The value of timer T200 for data links is chosen so that re-transmission of a frame can take place at the earliest opportunity. It does not time out before the next frame in the other direction is received and processed. If it times out, the repeated frame is sent in the next block.

The value of T200 depends on which DCCH is used. Figure 6-20 shows the values of timer T200.

SAPI	Type of channel	Repetition delay [ms]	T200, indicative timer value [ms]
0	SDCCH	235.4	220
0	FACCH/Full rate	120 to 220	155
0	FACCH/Half rate	240 to 280	155
0	SACCH (with TCH)	960	900
0	SACCH (with SDCCH)	941.6	900
3	SDCCH	470.8	450
3	SACCH (with TCH)	1440	1350

Figure 6-20 Indicative values for timer T200 and repetition delay.

N200: Maximum Number of Re-transmissions

The maximum number of re-transmissions depends on the state and channel used. For establishment and release of a layer 2 link, the value of N200 is 5.

SDCCH	N200=23
FACCH/F	N200=34
SACCH	N200=5

A rule of thumb is that after 5 seconds the channel should be released independent of which channel is used. T200 times N200 equals approximately 5 seconds.

N201: Maximum Number of Octets in an Information Field

The maximum number of octets in an I, UI, SABM or UA frame information field is:

SDCCH and FACCH	N201=20 octets
SACCH	N201=18 octets
BCCH, AGCH and PCH	N201=22 octets

k: Maximum Number of Unacknowledged I Frames

For data links with SAPI=0 or SAPI=3, the maximum number (k) of sequentially numbered I frames that can be unacknowledged is one. That is, the window size of LAPDm is equal to one.

The maximum number of octets in an L3 message to be sent or received to or from layer 3 must not exceed 249.

TRAFFIC CASE - FROM THE LAPDM VIEW POINT

Figure 6-21 illustrates how re-transmission is performed by use of the numbering of frames and timers both in MS and on the network side.

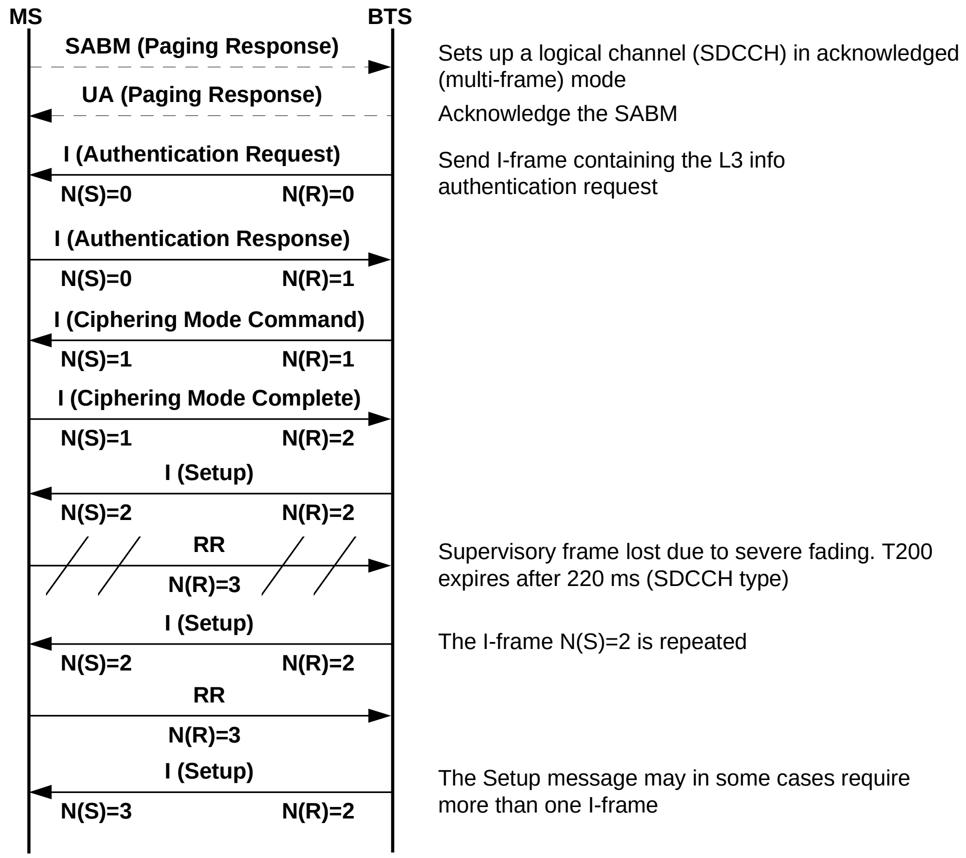


Figure 6-21 Part of call setup from the view of LAPDm.

ANNEX A - RANDOM ACCESS PROCEDURE

Procedure in MS

The random access procedure is initiated by layer 3. The data link layer receives the 8 bit information content of the random access burst. There will also be an indication of the type of channel to be used. The data link layer will then pass the information field to the indicated physical layer entity.

To the random access burst the physical layer will add the information indicating in which time slot and TDMA frame number the burst was transmitted. This information is then passed to layer 3.

Format

The random access burst contains a random reference number and an establish cause. The coding and burst formatting of the access burst is described in the signaling layer 1 part of this chapter.

Procedure in BTS

The physical layer will provide the random access information field and an indication of the time slot and TDMA frame number in which the random access burst was received, to the data link layer. There is also an indication of which type of channel the burst was received on. The data link layer passes this information to layer 3.

SIGNALING LAYER 1

The signaling layer 1, also called the physical layer, represents the functions required to transfer the bits over the physical channels on the radio medium.

In addition to signaling layer 2, layer 1 interfaces other functional units, such as speech coder and terminal adapters, for the support of traffic channels, see Figure 6-4.

The physical layer interfaces the radio resource management. On this interface, messages are sent which are related to the assignment of channels (random access) as well as to physical layer system information, including measurement results.

The physical layer consists of functions like channel coding for error detection Cyclic Redundancy Check (CRC) and error correction Forward Error Correction (FEC), interleaving, ciphering, burst formatting and modulation. Figure 6-22 describes the different parts, defined as layer 1 functions in the GSM recommendations. There are two interesting things to note in this figure. The first is that only the transmission part is described in the recommendations. The receiver is only specified via the overall performance requirements. Secondly, the speech coder is not considered as part of the layer 1 functions, instead it is part of the application.

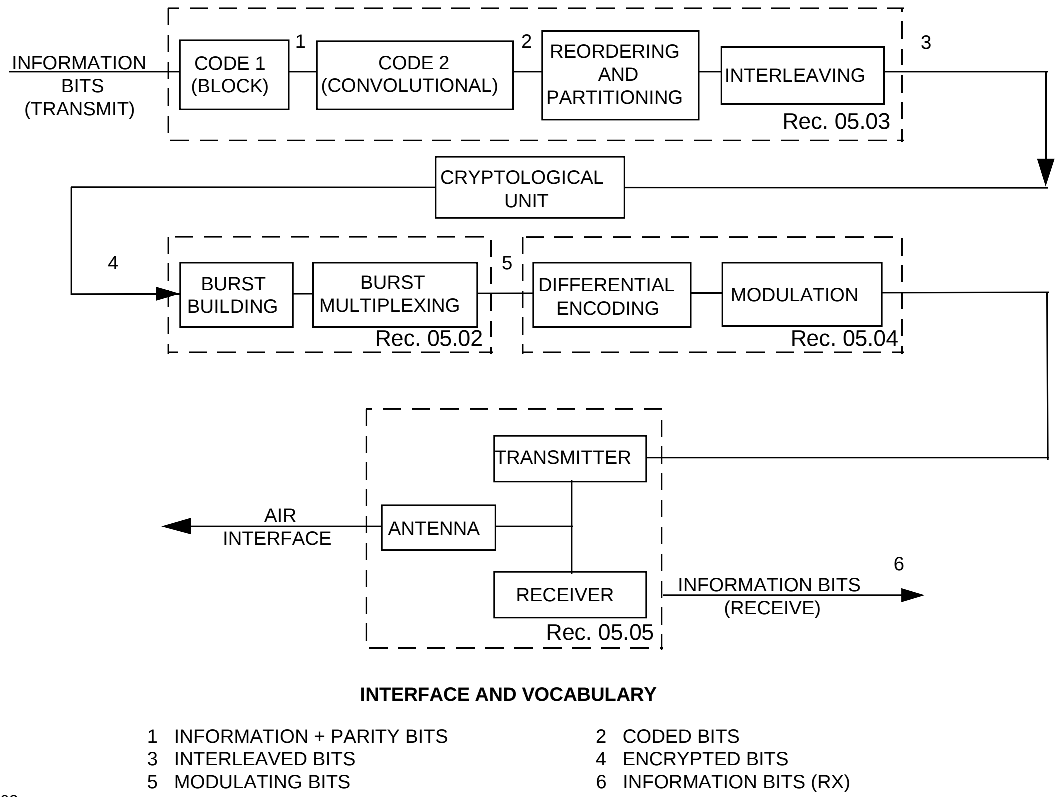


Figure 6-22 Reference configuration.

CHANNEL CODING

Channel coding is used to detect and correct bit errors in the received bit stream. That is, it reduces the Bit Error Rate (BER). In order to achieve this, redundancy is added to the information.

Two different forms of channel coding: block codes and convolution codes are used in GSM. These are described separately below.

Block Codes

For block codes, the information is divided into blocks of equal length. According to a specific algorithm a number of redundant bits are added to these blocks. See Figure 6-23.

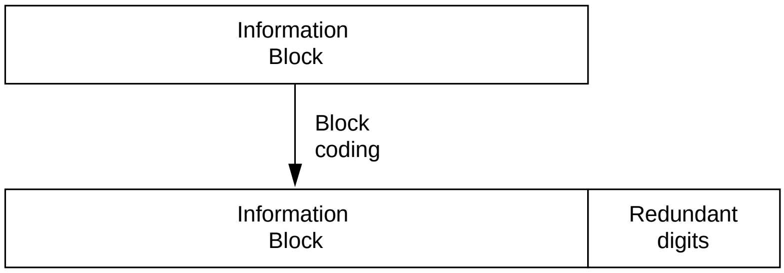


Figure 6-23 Block coding.

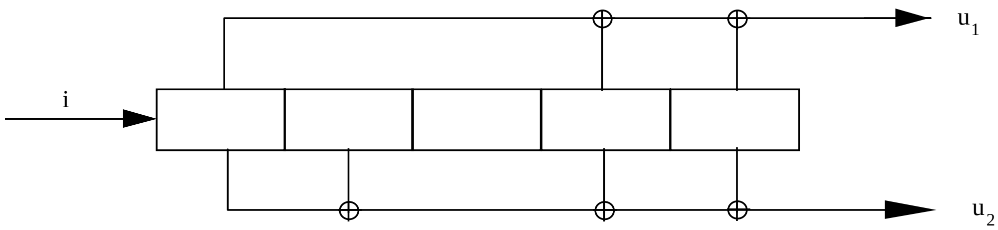
The block code used for full rate speech coding in the GSM systems uses 3 redundant bits and can detect any single bit error in each block of 50 information bits.

Convolution codes

This is an alternative to block code coding schemes which divides the data into much smaller blocks which are called information frames. The information frames typically contain no more than a few symbols which are encoded into code word frames.

Rather than coding a single information frame into a single code word frame, an information frame together with a number of previous information frames are encoded into a single code word frame. This procedure results in successive code word frames coupled together by the encoding procedure. The codes that are obtained in this way are called tree codes. The most important tree codes are known as convolution codes. Convolution codes are tree codes that satisfy certain additional linearity and time invariance properties.

The convolution codes can be illustrated by using the shift register in Figure 6-24. An information sequence is shifted through the register, and the output is formed as XOR operations of the bits in the register. Each information bit shifted in results in two coded bits. As long as the information bit is inside the shift register it affects the output code word. Each input bit in the diagram affects six output bits.



$u_1(j) = i(j) + i(j-3) + i(j-4)$

$u_2(j) = i(j) + i(j-1) + i(j-3) + i(j-4)$

Figure 6-24 A shift register encoder for a binary (19.27) convolution code.

Unlike block code, a convolution code does not detect and correct errors according to a certain number of bits. Rather, the distance between bit errors is the relevant parameter for the decoding capability of a convolution code.

A 2 error correcting block code can correct two errors per block, no matter where these two errors occur in the block.

A convolution code is sensitive to where the errors occur. The position in the sequence of coded bits is also relevant for a convolution code, as can be seen in Figure 6-25. The bit error correcting capability is higher in the beginning and end of the sequence.

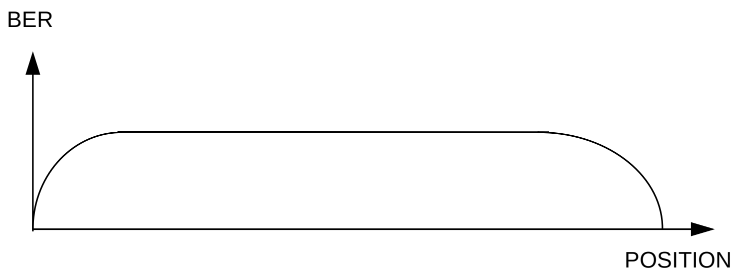


Figure 6-25 Bit error rate as a function of position, for a convolution code.

INTERLEAVING

Bit errors often occur in groups (burst errors). This is especially true in a mobile telephony system where long fading dips affect several consecutive bits. Unfortunately, channel coding and particularly convolution coding is most effective in detecting and correcting single random errors and bursts that are not too long. The interleaving method deals with this problem. It separates consecutive bits of a message, so that the bits can be sent in a non-consecutive way. If a burst of errors occurs in this non-consecutive sequence, it leads to separated single errors after the burst is reordered.

For example, take a message block consisting of four names each containing four letters. See Figure 6-26. This information is read into a matrix of four rows and four columns. When the information is read out, it is organized by columns so that the first letter in every name is transmitted first, the second letter is transmitted second, etc. During the transmission, frame 2 for example is lost. Without interleaving, the entire name would be lost. With interleaving, only one letter in each name is lost. This one error can then be corrected by the channel decoder.

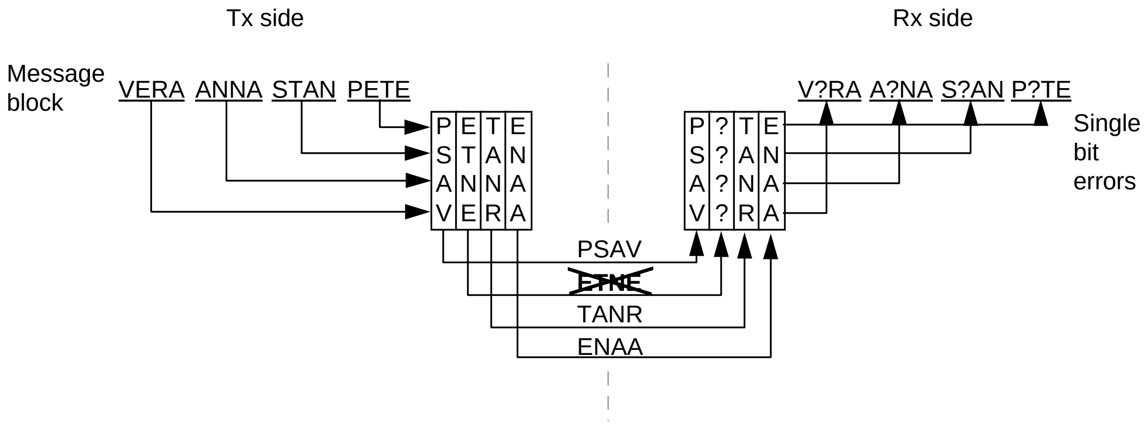


Figure 6-26 Interleaving.

CHANNEL CODING AND INTERLEAVING OF SPEECH (FULL RATE)

The full rate speech coder delivers a block of 260 bits every 20 ms to the channel coder. These bits are divided into 182 bits of class I (protected bits) and 78 bits of class II (non protected bits). This division is made according to the importance of the bits, which have been determined through listening tests. That is, subjective tests where a group of individuals have rated how seriously an error in a certain bit affects speech quality. The division is described in greater detail in the GSM recommendations.

The 50 most important bits of class I are protected by three parity bits used in error detection. These parity bits are calculated by using the shortened cyclic (53,50,2) code. The detection capability is equal to one per block of 50 bits. This means that *any* one bit error will be detected as well as most errors that are more than one bit.

The information and parity bits of class I are then convolution coded. Four tail bits (all zeroes) are added before coding to ensure that the initiating and terminating state is the all-zero state (0000). After convolution coding, the remaining bits from class II are added to the coded bits to form the output from the channel coder. The total channel coding for full rate speech is shown in Figure 6-27.

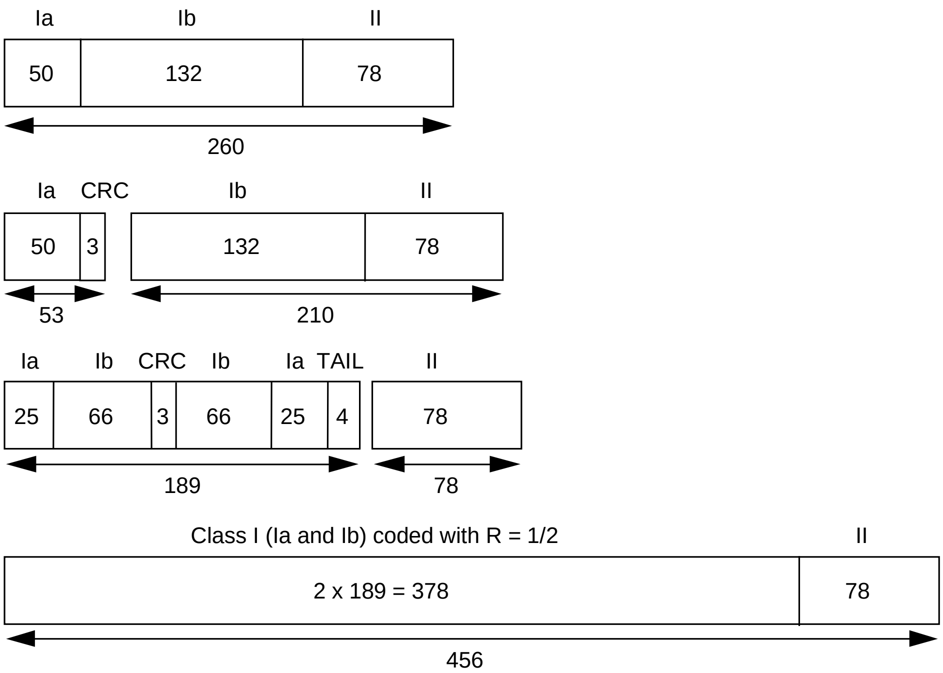


Figure 6-27 Channel coding for full rate speech.

The 456 coded bits are reordered and interleaved over 8 half bursts as can be seen in Figure 6-28. Each half burst consists of 57 coded bits. These half bursts are then block diagonal interleaved over 8 bursts. This procedure is referred to as "second level of interleaving".

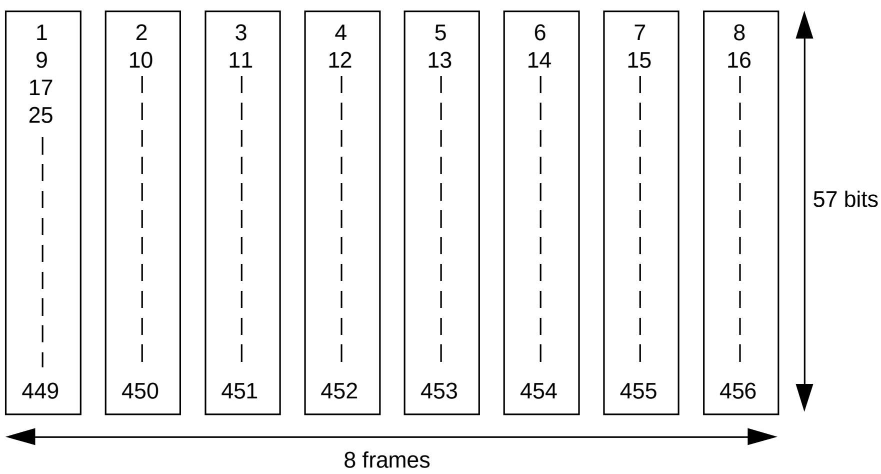


Figure 6-28 Interleaving for full rate speech.

The second level of interleaving refers to interleaving of two blocks of 20 ms of speech each. This interleaving is carried out according to a schedule which is shown in Figure 6-29.

Each 20 ms block yields 456 coded bits, ordered in 8 sub-blocks of 57 bits. The first sub-block from block B is then interleaved in the same burst as the fifth sub-block from block A. This interleaving is made on a per bit basis, which means that the bits from block B1 occupy all odd numbered positions in the two half bursts, and the bits from A5 occupy all even numbered positions. See Figure 6-29. Thus using the interleaving procedure, if a burst error of ten bits occurs within a TDMA burst for example, the errors are spread out in such a way that they appear 16 bits apart in the resulting, deinterleaved frame.

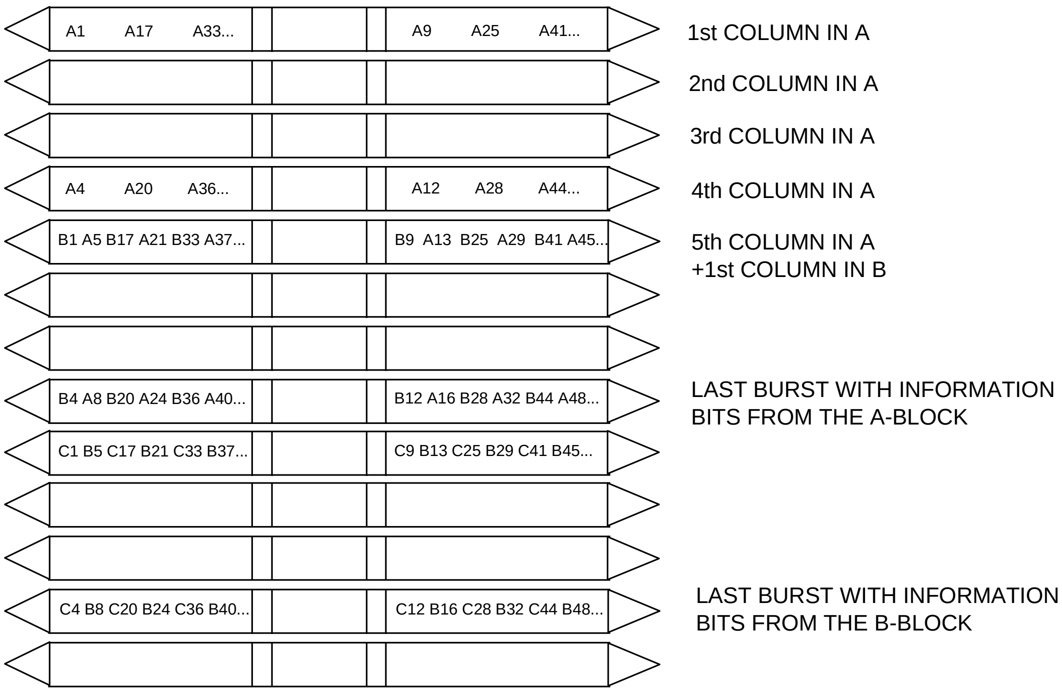


Figure 6-29 Second level of interleaving.

CODING AND INTERLEAVING OF CONTROL CHANNELS

The coding and interleaving procedures used for control channels are somewhat different from those used for speech. As signaling can be re-transmitted, there are more bits used for error detection for signaling than there are for speech.

Figure 6-30 shows the channel coding for BCCH, CCCH, SDCCH, FACCH and SACCH. The layer 2 information for BCCH, CCCH, SDCCH and FACCH contains 184 bits, but only 168 bits for SACCH. To the 168 bits, 16 bits describing timing advance and the power order are added by layer 1 functions. The resulting 184 bits are block coded with a 40 bits FIRE code for error detecting. Unlike the case for speech there are no unprotected bits on the control channels.

To the resulting 224 bits, 4 tail bits (zeroes) are added by the convolution coder. The resulting 228 bits are convolution coded. Due to different mapping on physical channels the interleaving used for control channels differs between the different channels.

BCCH, CCCH, SACCH and SDCCH are interleaved in a rectangular pattern occupying four entire bursts and using only the first level of interleaving. FACCH is interleaved over eight half bursts, just like speech. This is due to the fact that the FACCH is transmitted on bits which are stolen from a burst in the TCH. The stealing procedure used is organized so that even numbered bits in the first four bursts and the odd numbered bits in the following four bursts are stolen.

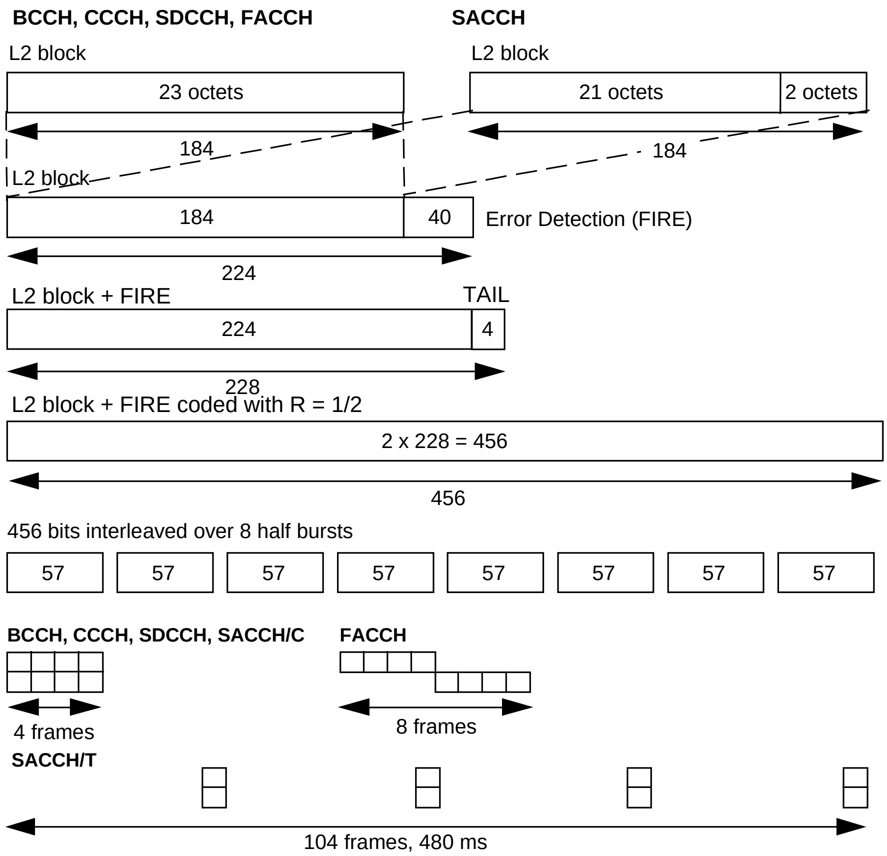
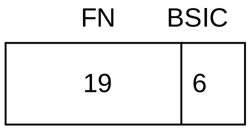


Figure 6-30 Channel coding and interleaving for control channels.

CODING AND BURST FORMATTING OF SCH

The information that the MS receives on the SCH is the BSIC and the TDMA Frame Number (FN). See Figure 6-31. There are six bits for the BSIC and 19 bits for the TDMA frame number.



FN = TDMA Frame Number
BSIC = Base Station Identity Code (NCC+BCC)

Figure 6-31 Information in synchronization burst.

Considering the fact that the hyperframe consists of 2,715,648 TDMA frames and since $2^{21} < 2{,}715{,}648 < 2^{22}$, 22 bits are needed to pinpoint one out of all TDMA frames in a hyperframe.

Since only 19 bits in the SCH burst for the FN are allowed, a procedure called reduced TDMA Frame No. is used. The procedure profits from the fact that the MS knows that there are only five synchronization bursts transmitted within each 51-multiframe and that they appear 10 TDMA frames apart.

First, 11 bits indicate what superframe is now transmitted. Second, five bits isolate which 51-multiframe they appear in. The reduced TDMA FN only informs the MS which of the five synchronization bursts are received, which requires only three bits, leaving to the MS to calculate the exact TDMA frame number. The reduced TDMA frame number is shown in Figure 6-32.

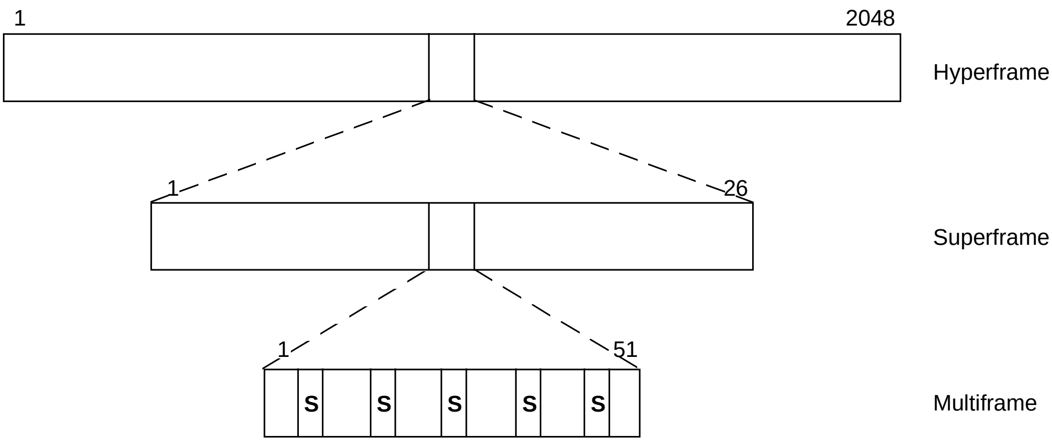


Figure 6-32 Reduced TDMA frame number.

Ten parity bits are added to the 25 bits of information. Furthermore, 4 tail bits consisting of zeroes are added to help the channel coder. (The BER close to a known bit pattern is low.) These 39 bits are convolution coded with the rate one bit in, two bits out. The output from the convolution coder contains 78 bits. To format the burst, the coded bits are placed on each side of an extended training sequence of 64 bits. Three tail bits on each side are also added. See Figure 6-33.

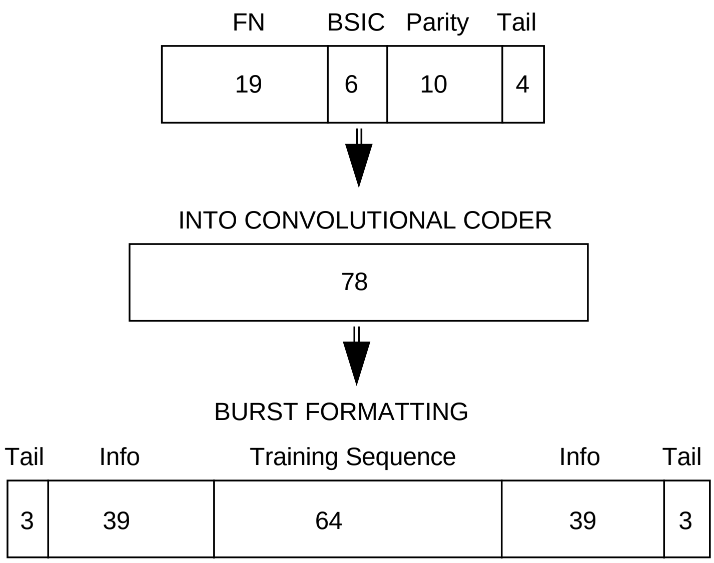


Figure 6-33 Coding and burst formatting of synchronization burst.

CODING AND BURST FORMATTING OF ACCESS INFORMATION

The access burst contains only eight information bits: 3-6 bits to establish cause and a random number of 5-2 bits for random access, or eight bits handover reference for handover access. As shown in Figure 6-34 six parity bits are added to these eight bits for error detection.

The six bits of the BSIC, taken from the BTS to which the random or handover access is intended, are added bit-wise modulo 2 to the six parity bits. This is done to ensure that the burst is received by the correct BTS, as all other BTSs will discard the request.

The convolution coder adds four tail bits to the resulting 14 bits and then encodes these 18 bits using the same coding polynomials as is used for all channels. See Figure 6-34.

When a BTS receives an access burst, it first convolution decodes the burst and then adds its own BSIC. If the BSIC is the same as the one that the MS added, and there are no errors, the burst passes through the error detection algorithm. If the BSIC is different, the resulting 14 bits are not the ones sent, and the error detection generates an alarm.

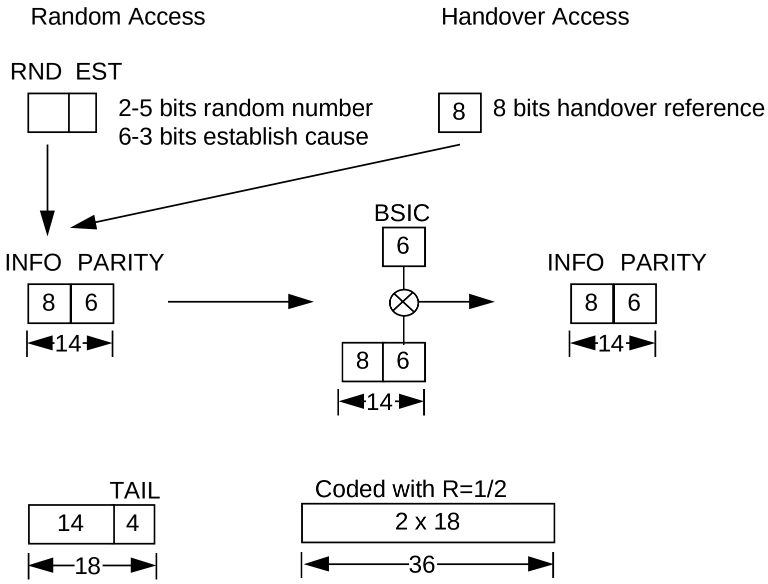


Figure 6-34 Coding of random and handover access burst.

The resulting 36 bits are burst formatted with 41 synchronization bits (an extended training sequence), eight tail bits in the beginning and three tail bits in the end of the burst. The resulting burst length is only 88 bits as seen in Figure 6-35, not 148 bits as for a normal burst. The random access burst is transmitted on RACH while the handover access burst is sent on FACCH in the new cell.

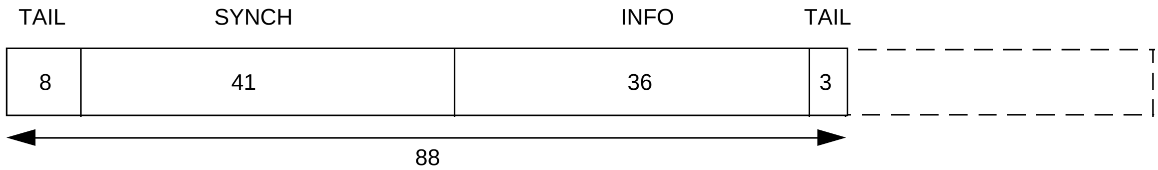


Figure 6-35 Burst formatting of random and handover access information.

SUMMARY OF CHANNEL CODING

Figure 6-36 shows a summary of channel coding for different types of channels.

Type of channel	Bits/block data+parity+tail[1]	Convol. code redundancy	Coded bits per block	Interleaving depth
TCH/FS			456	8
class I[2]	182 + 3 + 4	1/2	(378)	
class II	78 + 0 + 0	-	(78)	
TCH/F9.6	4x60 + 0 + 4	244/456	456	19
TCH/F4.8	60 + 0 + 16	1/3	228	19
TCH/H4.8	4x60 + 0 + 4	244/456	456	19
TCH/F2.4	72 + 0 + 4	1/6	456	8
TCH/H2.4	72 + 0 + 4	1/3	228	19
FACCHs	184 + 40 + 4	1/2	456	8
SDCCHs SACCHs	184 + 40 + 4	1/2	456	4
BCCH AGCH PCH	184 + 40 + 4	1/2	456	4
RACH	8 + 6 + 4	1/2	36	1
SCH	25 +10 + 4	1/2	78	1

Notes: 1) The tail bits mentioned here are the tail bits of the convolutional code.
2) The 3 parity bits for the TCH/FS detect an error on 50 bits of class Ia.

Figure 6-37 Summary of channel coding.

MODULATION

The modulation technique used in GSM is called Gaussian Minimum Shift Keying (GMSK). This is a narrow-band, digital modulation technique, which is based on phase shift keying. To explain GMSK, this section examines Minimum Shift Keying (MSK) and compares it to the Phase Shift Keying (PSK).

Figure 6-38 illustrates the difference between MSK and PSK. The diagram shows the phase variations, $\varphi(t)$, as a function of time, within each bit interval. The phase is a constant function for PSK, while it varies linearly for MSK. The modulated carrier can be expressed as:

$$s(t) = a\sin\left(\omega\, t + \varphi(t)\right)$$

which is also shown in Figure 6-38.

The phase for MSK changes continuously, avoiding the sharp discontinuities of the PSK signal. The result is that the spectrum for the MSK signal is more narrow than for the PSK signal.

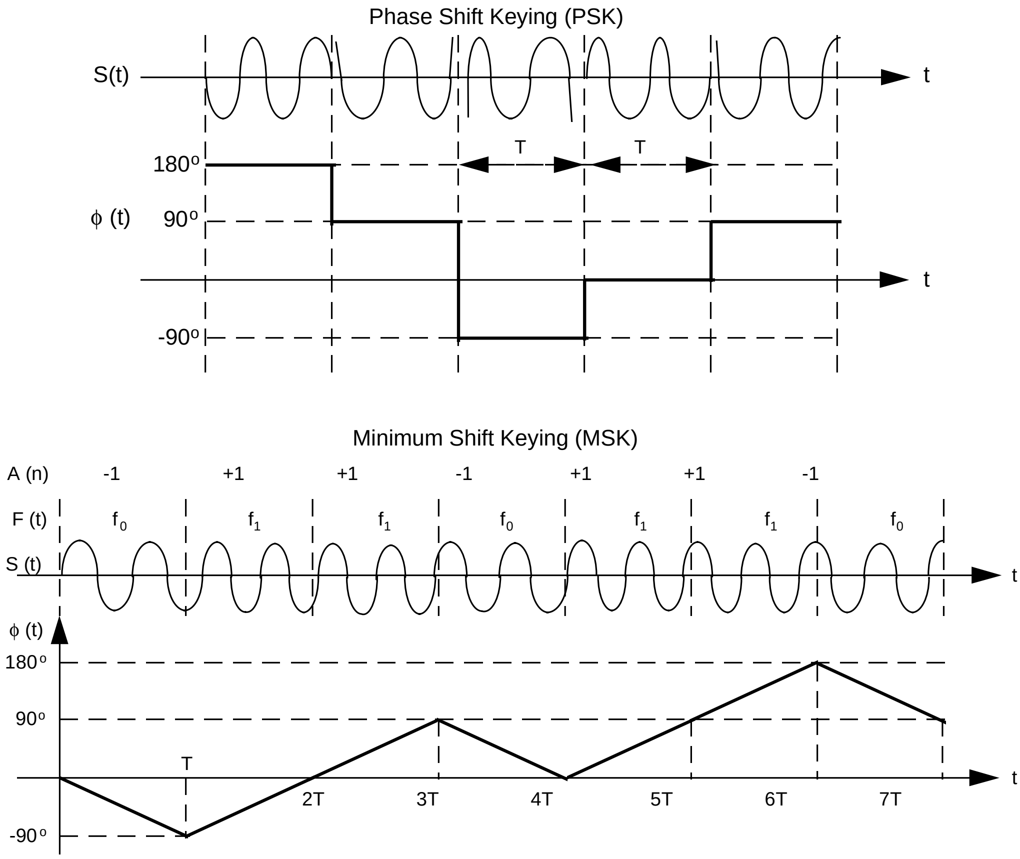


Figure 6-38 PSK and MSK.

The next step in the GMSK modulation is to filter the bit stream before modulation using a Gaussian filter. Different filter parameters result in different spectra. In GSM, a filter with a Time Bandwidth product (*TB*) equal to 0.3 is used. Remembering that $T = 48/13\,\mu\text{s} \approx (271\,000)^{-1}\,\text{s}$ provides the ability to find the 3 dB bandwidth as:

$$TB = 0.3 \Rightarrow B = \frac{0.3}{T} = \frac{0.3}{\left(271\cdot 10^{3}\right)^{-1}} = 81.25\ \text{kHz}$$

Figure 6-39 illustrates the influence that different Gaussian filters have on the spectrum. Looking at the figure below, note that the power level at 200 kHz from the nominal frequency is approximately -32 dB for GMSK with *TB*=0.3. The normalized frequency is 200/271=0.75.

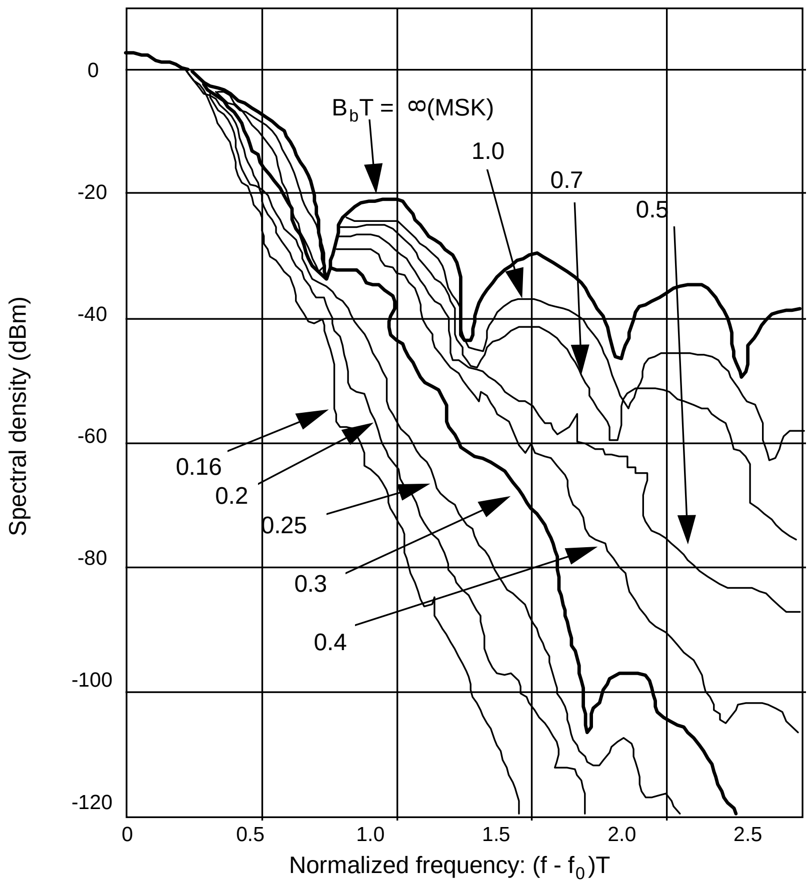


Figure 6-39 Spectrum for MSK and different GMSK modulations.

OTHER LAYER 1 FUNCTIONS

Transmission involves other layer 1 functions than those discussed earlier in this chapter. Some examples are:

- Mapping of logical channels on to physical channels, see chapter 2 “Channel Concept”.
- Setting of timing advance as commanded by the network.
- Power control mechanism, which adjusts the output level of the MS (and optionally of the base station). Power levels, with 2 dB steps, have been defined for this purpose.

- Synchronization of the mobile receiver with regard to frequency and time.
- Strategy of first selection or re-selection of a base station by an MS with the idle mode activity, such as listening to the CCCH paging groups.
- Handover and quality monitoring necessary to allow an MS to continue a call during a change of physical channel.

The remaining part of this chapter deals primarily with the last two points above.

MS in Idle Mode

In GSM recommendations phase 2, idle mode behavior of the phase 2 MS is described.

According to the recommendations, the tasks performed by an idle MS can be divided into three processes:

1. PLMN selection
2. Cell selection and re-selection
3. Location updating

PLMN Selection

There are two modes of PLMN selection, these are automatic and manual. At power on the MS selects the registered PLMN and attempts to perform location updating regardless of selection mode. The registered PLMN is the network used at power off and is given in the MCC+MNC part of LAI which is stored on the SIM card at the last successful location updating.

If the following circumstances exist, the MS acts according to the selection mode, which can be set by the mobile subscriber.

- the registered PLMN is not available any longer
- the location updating attempt is rejected by the registered PLMN for some reason
- there is no registered PLMN (no LAI stored on SIM)

Automatic selection mode
The MS selects the PLMN according to the following principles:

1. The home PLMN (if it was not the registered PLMN which was already tried).

2. In priority order - each PLMN in the “PLMN selector” data field stored on SIM.
3. In random order - other PLMNs with received signal strength level above -85 dBm.
4. All other PLMNs - taken in decreasing signal strength order.

A PLMN stored on the SIM card in the forbidden PLMN list will not be selected.

Manual selection mode
In manual selection mode the MS indicates available PLMNs to the subscriber. This includes networks in the list of forbidden PLMNs. The user may then select any PLMN. The available networks are presented to the subscriber in the same order as they are selected by the MS in automatic selection mode, as described above.

As soon as a PLMN is selected, the MS tries to find a “suitable cell” to camp on regardless of the selection mode (See cell selection). The MS then attempts location updating in that PLMN.

Cell selection - no BCCH Information Available

Figure 6-41 describes the MS procedures to find a suitable cell when switched on if the MS has no information on what BCCH carriers are used in the network. The MS searches all 124 (for GSM 900), 374 (for GSM 1800) or 299 (for GSM 1900) RF channels, measures received signal strength and calculates the received average level for each RF channel. The average is based on at least five samples for each RF channel spread over 3 to 5 seconds.

The MS then tunes to the carrier with the highest average level and determines whether this carrier is a BCCH carrier or not. This is determined by searching for the frequency correction burst, which is sent in time slot 0 on the BCCH carrier approximately every 10th TDMA frame. If it is a BCCH carrier, the MS attempts to synchronize to this carrier and read the BCCH data. That is, the system information messages. The MS camps on the cell if it can decode the BCCH data successfully and if this data indicates that the cell is suitable.

A cell is suitable if:

- The cell belongs to the selected PLMN.
- The cell is not barred for access.

- The path loss criterion parameter C1, as described below, is larger than 0.

Suitable cells can have two levels of priority, normal or low. During cell selection a cell with low priority indication is only selected if a suitable cell of normal priority can not be found. The priority for cell selection and re-selection depends on the parameters Cell Bar Qualify (CBQ) and Cell Barred (CB), found in the system information. Figure 6-40 shows how the settings of these two parameters affect cell priority.

CBQ	CB	Cell selection priority	Status for cell reselection
0	0	normal	normal
0	1	barred	barred
1	0	low	normal (see note 1)
1	1	low	normal (see note 1)

Note 1. The settings in the last two rows allows an operator to declare a cell as having low priority for a phase 2 MS. However, the operator can still decide whether a phase 1 MS is to be permitted to camp on a cell or not.

CBQ = Cell Bar Qualify
CB = Cell Barred

Figure 6-40 Parameters affecting cell priority.

In general, cell prioritization is a means of encouraging MSs to select suitable cells in preference to other cells. Since the priority comparison is only between suitable cells, prioritization does not affect coverage. Operators may prefer that a certain type of cell not be selected unless it is the only suitable type. A microcell may be an example of such a low prioritized cell since some MSs may be moving faster than what can be handled by microcells.

If the MS does not have any prior knowledge about what RF channels are used as BCCH carriers, it searches at least the 30 strongest in GSM 900 or 40 strongest in GSM 1800/GSM 1900 RF channels in descending order of received signal level to see which are BCCH carriers. If no BCCH carriers have yet been found, searching continues until at least one BCCH carrier is found. The first BCCH carrier found which is from a suitable cell and on which there is a normal priority indication is selected and that cell is camped on. If the only suitable cells found have low priority indication, the MS camps on the strongest of these cells.

If after searching all RF channels with strongest received signal level as described above, and at least one BCCH carrier is found but none of them belong to a suitable cell of the selected PLMN, then the MS can stop the attempt to find a suitable cell and choose a new PLMN in accordance with the PLMN selection rules. If the cell is part of the selected PLMN but still not suitable, the MS uses the BCCH allocation table obtained from this cell and subsequently searches only these BCCH carriers. Use of the list speeds up the procedure to some extent.

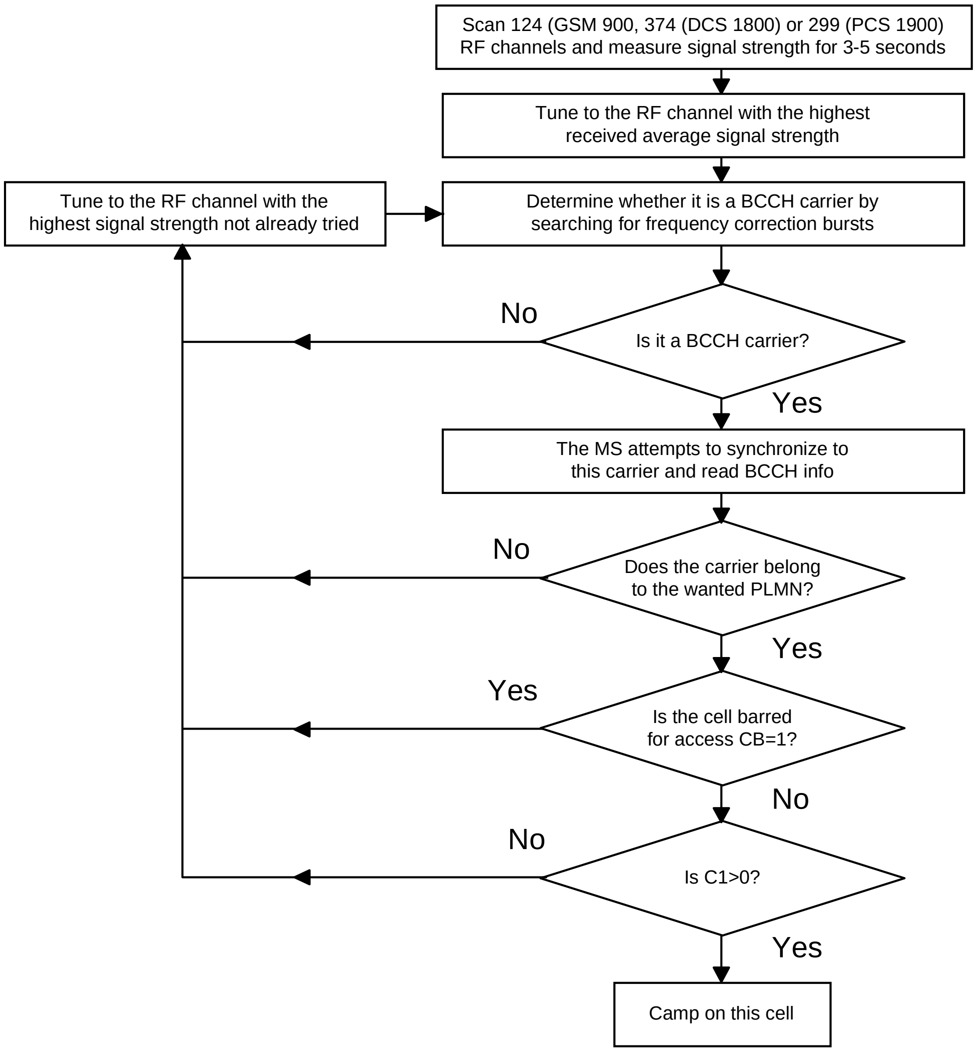


Figure 6-41 Cell selection - no BCCH information available.

Cell Selection - BCCH Information Available

The MS may include optional storage of BCCH carrier information when switched off. This information is stored in a non volatile store on the SIM card or in the mobile equipment, and therefore does not disappear when the SIM card is removed. For example, the MS may store the BCCH carriers in use by the PLMN selected when the MS was last active in the GSM network. An MS may also store BCCH carriers for more than one PLMN that it has selected previously. For example at a national border or when more than one PLMN serves a country.

If an MS has a stored BCCH carrier list of the selected PLMN, it performs the same procedure as described above with the exception that only the BCCH carriers in the list need to be scanned. The BCCH carrier list for a given PLMN stored in the MS is reset and updated whenever the MS retrieves new BCCH data from the PLMN.

Criteria for Cell Selection and Re-selection

The path loss criterion parameter is called C1 and is used for both cell selection and re-selection. It is defined by:

C1 = A – max (B,0)

where:

A = received level average – RXLEV_ACCESS_MIN
B = MS_TXPWR_MAX_CCH - P

RXLEV_ACCESS_MIN = minimum received signal strength required for access to the system

MS_TXPWR_MAX_CCH = maximum output power the MS may use when accessing the system until otherwise commanded

P = maximum output power of the MS

RXLEV_ACCESS_MIN and MS_TXPWR_MAX_CCH are parameters included in system information type 3. All values are expressed in dBm.

A large value on parameter A indicates a strong signal on the downlink. A large value on parameter B indicates a weak MS compared to the allowed power in the cell.

The re-selection criterion is called C2 and is used by phase 2 MSs for cell re-selection. C2 is calculated as:

C2 = C1 + CELL_RESELECT_OFFSET – TEMPORARY _OFFSET * *H*(PENALTY_TIME – T) for PENALTY TIME ≠11111

C2 = C1 – CELL_RESELECT_OFFSET for PENALTY TIME = 11111

where $H(x) = \begin{cases} 0 \text{ for } x < 0 \\ 1 \text{ for } x \geq 0 \end{cases}$

The timer T starts from zero when the cell is placed by the MS on the list of strongest carriers. When the cell is removed from the list, T is reset to 0.

CELL_RESELECT_OFFSET, TEMPORARY_OFFSET and PENALTY_TIME are the cell re-selection parameters described in chapter 5 “System Information”. These two parameters are found in system information type 3 and optionally in types 4, 7 and 8 in cells supporting phase 2 system information.

If these parameters are not found in the system information, they are set to 0 by the MS. This gives C1 = C2. In this case, the CBQ parameter is also set to 0.

The C1 and C2 parameters are used to ensure that the MS is camped on the cell with which it has the highest probability of successful communication for both uplink and downlink.

Cell Re-selection

The MS remains in sleep mode except when it listens to paging messages in its own paging group. To monitor changes in cell parameters, system information messages must be read at least once every 30 seconds.

The MS takes some measurement samples on neighboring cells when it is listening to its own paging group. See Figure 6-42. A running average value of received levels is calculated for each frequency in the BA list. The recommendations specify that at least five received level measurement samples are required for each average value.

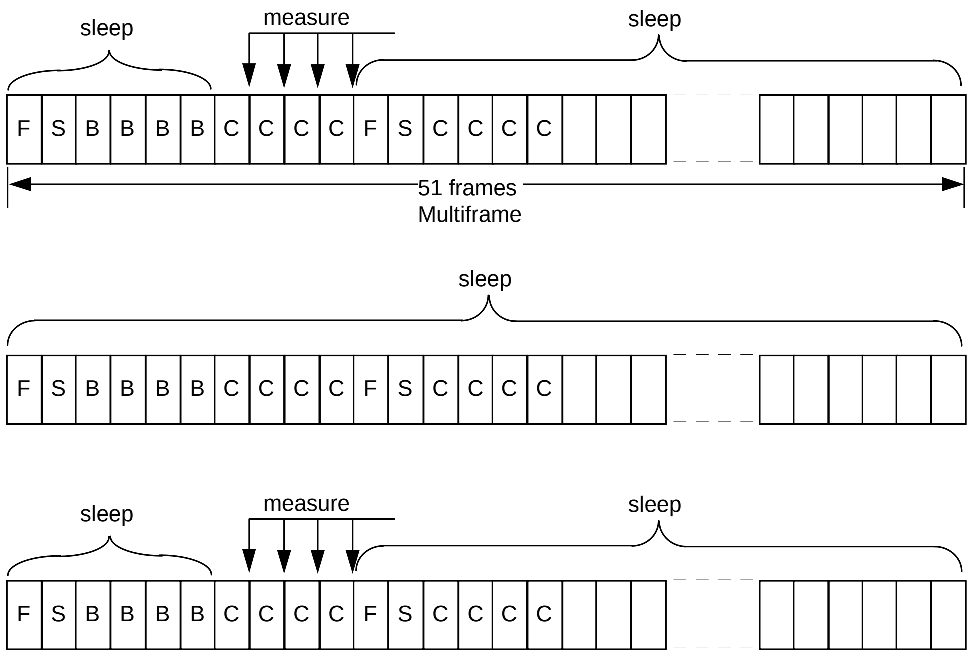


Figure 6-42 Measurements in idle mode.

The MS attempts to decode the BCCH data block that contains parameters affecting cell re-selection for each of the six strongest neighboring BCCH carriers at least every five minutes. When the MS recognizes that a new carrier has become one of the six strongest, then the BCCH data on that carrier is decoded within 30 seconds. The BCCH information is used to calculate the C1 and C2 values. The C1 and C2 values for serving and non serving cells, are regularly calculated by the MS. The system information is also used to determine if the cell belongs to a new location area. This implies that an idle MS hysteresis parameter must be used. The idle mode hysteresis parameter is used in the following way:

> If the chosen cell belongs to a different location area than the cell where the MS has performed location updating and there is a suitable cell in the old LA, the new cell is only selected if C2 of the new cell exceeds C2 of every suitable cell of the old LA by at least this hysteresis value. See Figure 6-43.

The hysteresis is introduced to avoid unnecessary location updating signaling.

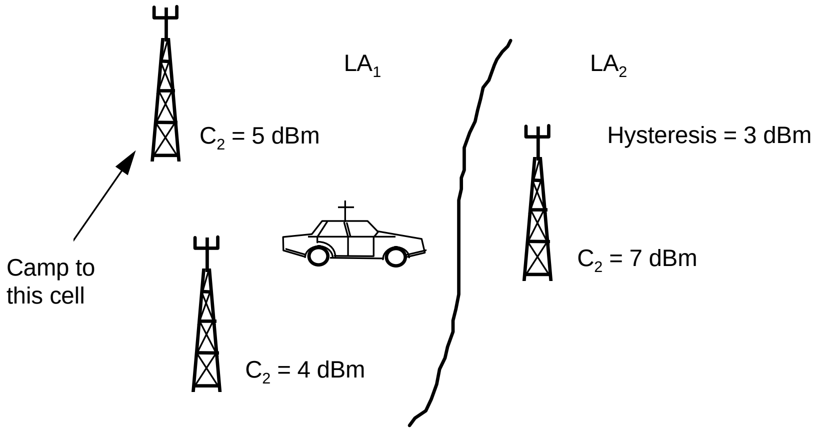


Figure 6-43 Hysteresis for location updating.

The MS also attempts to check BSIC for each of the six strongest surrounding cells at least every 30 seconds to confirm that it is still monitoring the same cell. If a change in BSIC is detected, then the carrier is treated as a new carrier and the BCCH data for this carrier is re-determined.

The MS tries to change cell if one of the following conditions occurs:

- The cell becomes barred.
- The MS has tried to access the cell the number of times permitted but has not succeeded.
- The MS detects a downlink signaling failure. That is, the MS can not decode the paging messages. The MS listens to the indicated paging block and tries to decode the paging or dummy paging messages. A counter in MS, the DCS, is set to 90/(BS_PA_MFRMS) and is decreased by four when the MS is not successful and increased by one when MS is successful in decoding the paging message. When DCS=0, a downlink signaling failure is indicated.
- C1 for the current serving cell falls below zero for a period of five seconds.
- C2 is better in a neighboring cell for at least five seconds. When the better cell is in a new location area, the hysteresis described above is used.

Measurements in Active Mode

During a call, the MS continuously reports (via SACCH) the signal strength from neighboring base stations to the BSC. The measurements on surrounding cells during a call take place when the MS does not do anything else. That is, between reception and transmission in the allocated time slot, interval 3 in Figure 6-44.

The signal strength and quality of the serving cell is monitored during the reception on the channel assigned to the MS. The MS is informed which BCCH carriers to monitor through system information type 5 on SACCH. To ensure that the measured values correspond to the proper BTS, the identity of the BTS must also be determined.

The identity of a neighboring BTS is given by its BSIC value. The BSIC is found on SCH on TS 0, c_0. During the idle frame on the TCH (one every 26 TDMA frames, interval 4 in Figure 6-44), BSICs for adjacent BTSs are checked. Only BSIC for the six strongest carriers are measured.

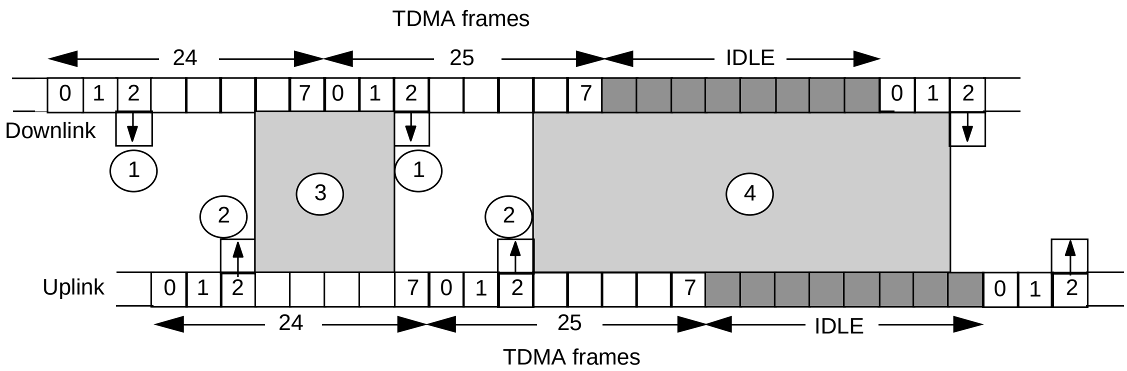


Figure 6-44 MS measurements principle.

The MS activities marked 1-4 in Figure 6-44 are:

1. MS receives and measures signal strength on serving cell, TS 2 downlink.
2. MS transmits, TS 2 uplink.
3. MS measures signal strength for at least one of the surrounding cells.
4. MS tries to read BSIC on SCH (TS 0, c_0) for one of the six strongest surrounding cells.

If the MS is not synchronized with an adjacent cell of which it is trying to determine the BSIC, the MS does not know when TS 0 occurs on the adjacent BCCH carrier. Therefore the MS measures over a period of time equal to at least one entire TDMA frame to ensure that TS 0 occurs during the measurement. This is achieved using the IDLE frame but still it is not certain that the SCH will be found.

Sliding Multiframes

The multiframe containing SCH is organized in such a way that the SCH only occurs once in 80 TSs. The probability that the MS picks the TS containing the BSIC is therefore only 15% (interval 4 in Figure 6-44).

To increase the hit probability, the multiframe carrying the TCH is sliding over the multiframe structure carrying the control information. The traffic multiframe is 26 TDMA frames long, while the control multiframe is 51 TDMA frames long. This implies that the IDLE frame slides over all different control channels on TS 0 and hits the SCH after less than or equal to 11 26 TDMA multiframes with 100% probability.

Figure 6-45 shows the procedure which is referred to as sliding multiframes. In the diagram, five instances are marked where the IDLE frame in the TCH frame structure overlaps the SCH in the control multiframe. Note that the SCH does not appear in every 10th frame in the end of the multiframe, as there is an IDLE frame inserted last. This means an extra delay in measuring the BSIC in the worst case scenario.

The MS must be able to decode the BSIC for the six best neighboring cells within ten seconds. Even if the worst case occurs for all six neighboring cells, the MS finds the six SCHs within ten seconds.

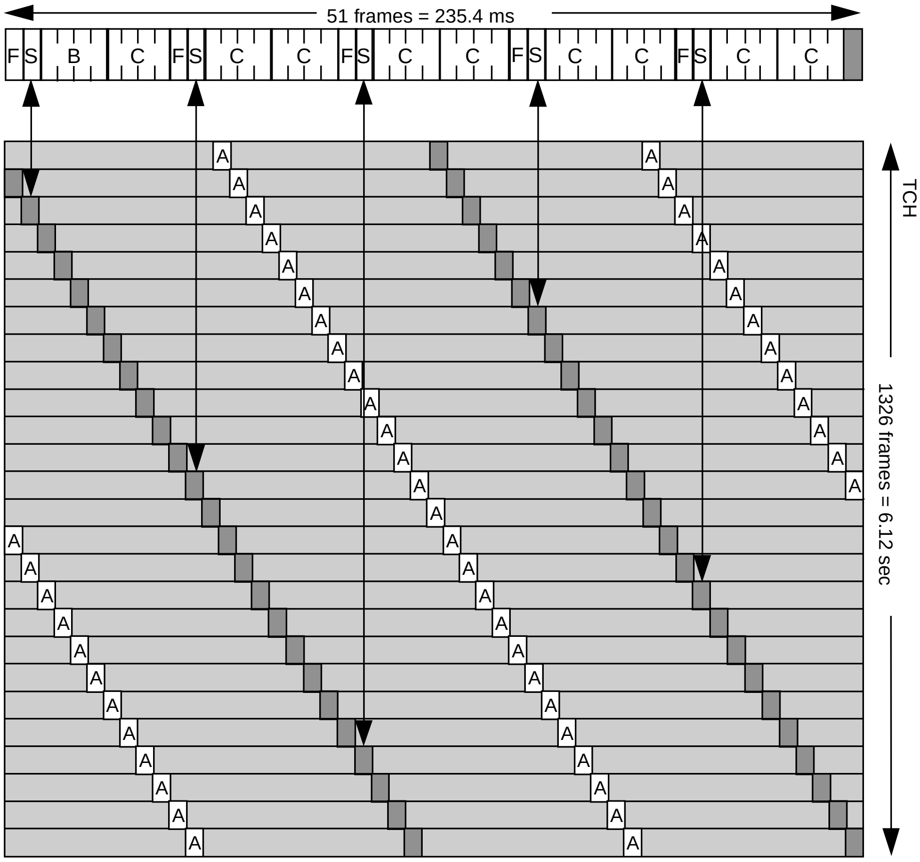


Figure 6-45 Sliding multiframes.

The MS makes signal strength measurements on up to 32 surrounding BCCH frequencies. The surrounding frequencies are defined in the neighbor cells description list, which is found in system information type 5 on SACCH. The MS takes at least one measurement sample in the period between sending a burst and receiving the next burst. (Interval 3 in Figure 6-44.)

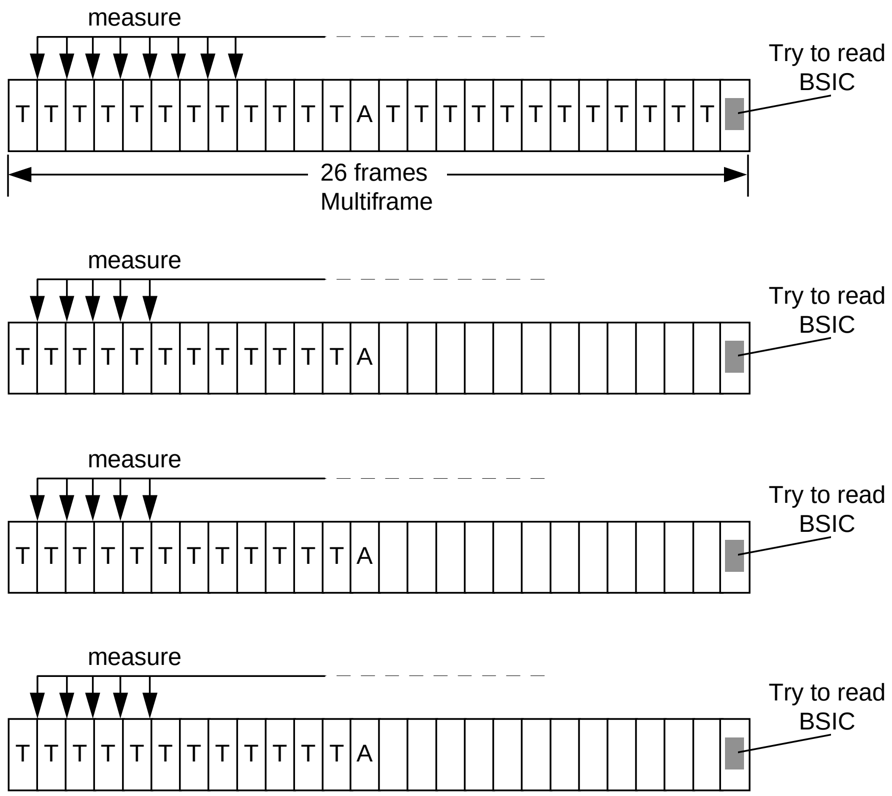


Figure 6-46 Measurements in active mode.

It takes four consecutive SACCH bursts to send a complete measurement report to the BTS. Which in a manner of time means $4 \cdot 26 \cdot 4.615 = 480$ ms. The MS takes at least $4 \cdot 25 = 100$ measurement samples during this period. Thus, if ten neighboring cells are defined then ten samples per cell are taken. No measurement samples are taken during the idle burst. Instead, the BSIC of one neighboring cell is searched for in this frame. See Figure 6-46.

The report that is sent to the BTS contains averaged values for the six best cells. The BSIC value of these six cells must be decoded at least every ten seconds, otherwise the measurement results for the cell are discarded. Figure 6-47 illustrates the requirements on the measurement results.

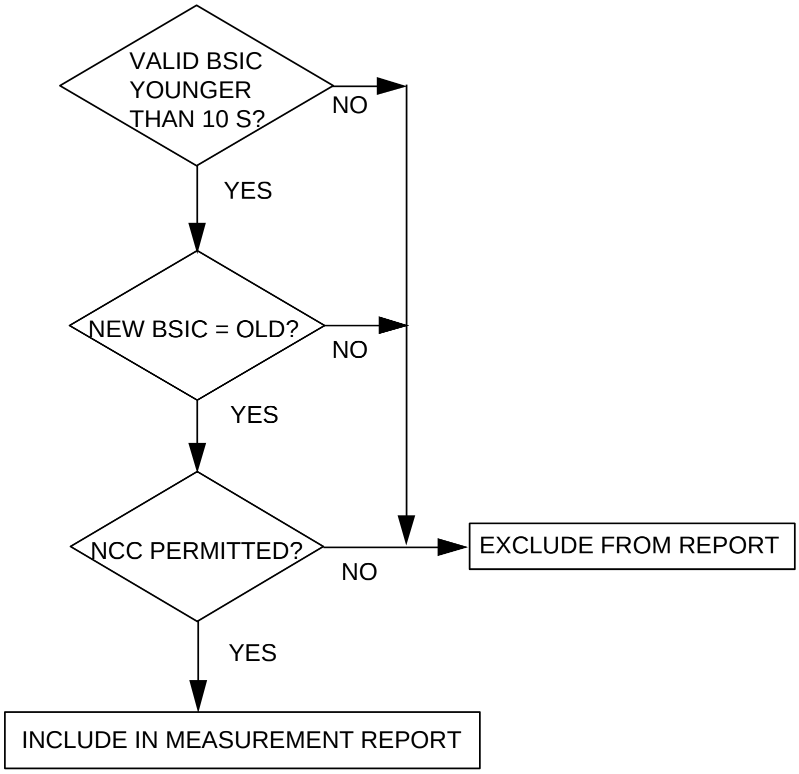


Figure 6-47 Requirements on measurements results.

Figure 6-48 summarizes how often the BSIC and the BCCH data must be decoded for the serving cell and for neighboring cells, both in idle and in active mode.

	Idle mode		Active mode	
	BSIC	BCCH	BSIC	BCCH
Serving cell	-	every 30 s	-	-
Six neighbors	every 30 s	every 5 min	every 10 s	-

Figure 6-48 Decoding of BSIC and BCCH.

When a BCCH carrier is no longer one of the six strongest, timing and BSIC information are retained for at least ten seconds. This is in case a handover is commanded to the cell just after the MS stops reporting measurement results for the cell. The timing information stored is the FN and the time slot offset. That is, where TS 0 is.

Measurement Report

In the message measurement report, the MS sends the result of the measurements made on its own cell as well as on neighboring cells. The contents of this message is shown in

Figure 6-49. One measurement report fits into four SACCH bursts.

The information elements in the measurement report are described below:

BA-USED
This bit indicates which one of the two BCCH allocation lists is used. It is related to the parameter BA-IND found in system information type 2 and type 5.

DTX-USED
This bit indicates if the MS used DTX on uplink during the previous SACCH period.

RXLEV-FULL-SERVING-CELL and
RXLEV-SUB-SERVING-CELL
These elements contain the average received signal strength of serving cell, measured on all time slots and on a subset of time slots. The full set of TCH and SACCH frames is either 100 (that is, 104 minus 4 idle) frames for full rate TCH or 52 frames for half rate. The subset consists of the 4 SACCH frames and the 8 SID frames. This subset is significant when DTX downlink is used.

The received signal strength is mapped to an RXLEV value between 0 and 63:

RXLEV 0 ⇔ RXLEV < -110 dBm
RXLEV 1 ⇔ -110 dBm < RXLEV < -109 dBm
.
.
.
RXLEV 63 ⇔ RXLEV>-48 dBm

MEAS-VALID
This bit indicates whether the measurement results for the dedicated channel are valid or not.

RXQUAL-FULL-SERVING-CELL and
RXQUAL-SUB-SERVING-CELL
These elements contain the average received signal quality on serving cell. Full serving cell refers to one measurement each TDMA frame while sub serving cell means measurements are made only on SACCH bursts and on SID frame bursts.

The received signal quality is mapped to the corresponding BER in a logarithmic way as described below:

RXQUAL 0 ⇔ BER < 0.2%
RXQUAL 1 ⇔ 0.2% < BER < 0.4%
.
.
.
RXQUAL 7 ⇔ BER > 12.8%

NO-NCELL-M
These three bits indicate the number of neighboring cells measurements.

<table>
<tr><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th></th></tr>
<tr><td colspan="4">SKIP INDICATOR</td><td colspan="4">PROTOCOL DISCRIMINATOR</td><td>octet 0</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td rowspan="2">octet 1</td></tr>
<tr><td colspan="8">Message type</td></tr>
<tr><td>BA-USED</td><td>DTX-USED</td><td colspan="6">RXLEV-FULL-SERVING-CELL</td><td>octet 2</td></tr>
<tr><td>0
spare</td><td>MEAS-
VALID</td><td colspan="6">RXLEV-SUB-SERVING-CELL</td><td>octet 3</td></tr>
<tr><td>0
spare</td><td colspan="3">RXQUAL-FULL-SERVING-CELL</td><td colspan="3">RXQUAL-SUB-SERVING-CELL</td><td>NO-NCELL-
M (high)</td><td>octet 4</td></tr>
<tr><td colspan="2">NO-CELL-M
(low part)</td><td colspan="6">RXLEV-NCELL1</td><td>octet 5</td></tr>
<tr><td colspan="5">BCCH-FREQ-NCELL1</td><td colspan="3">BSIC-NCELL1
(high part)</td><td>octet 6</td></tr>
<tr><td colspan="3">BSIC-NCELL1
(low part)</td><td colspan="5">RXLEV-NCELL2
(high part)</td><td>octet 7</td></tr>
<tr><td>RXLEV-N
CELL2 (low)</td><td colspan="5">BCCH-FREQ-NCELL2</td><td colspan="2">BSIC-NCELL2
(high part)</td><td>octet 8</td></tr>
<tr><td colspan="4">BSIC-NCELL2
(low part)</td><td colspan="4">RXLEV-NCELL3
(high part)</td><td>octet 9</td></tr>
<tr><td colspan="2">RXLEV-NCELL3
(low part)</td><td colspan="5">BCCH-FREQ-NCELL3</td><td>BSIC-N
CELL3(high)</td><td>octet 10</td></tr>
<tr><td colspan="5">BSIC-NCELL3
(low part)</td><td colspan="3">RXLEV-NCELL4
(high part)</td><td>octet 11</td></tr>
<tr><td colspan="3">BSIC-NCELL4
(low part)</td><td colspan="5">BCCH-FREQ-NCELL4</td><td>octet 12</td></tr>
<tr><td colspan="6">BSIC-NCELL4</td><td colspan="2">RXLEV-NCELL5
(high part)</td><td>octet 13</td></tr>
<tr><td colspan="4">RXLEV-NCELL5
(low part)</td><td colspan="4">BCCH-FREQ-NCELL5
(high part)</td><td>octet 14</td></tr>
<tr><td colspan="2">BCCH-FREQ-NCELL5
(low part)</td><td colspan="5">BSIC-NCELL5</td><td>RXLEV-N
CELL6(high)</td><td>octet 15</td></tr>
<tr><td colspan="5">RXLEV-NCELL6
(low part)</td><td colspan="3">BCCH-FREQ-NCELL6
(high part)</td><td>octet 16</td></tr>
<tr><td colspan="3">BCCH-FREQ-NCELL6
(low part)</td><td colspan="5">BSIC-NCELL6</td><td>octet 17</td></tr>
</table>

Figure 6-49 Measurement report.

RXLEV-NCELL
Received signal strength on the *i*th neighboring cell (*i*=1 to 6). This field is coded in the same way as the field for the serving cell.

BCCH-FREQ-NCELL
BCCH carrier of the *i*th neighboring cell. This field is coded as the binary representation of the position of the *i*th neighboring cell in the BCCH allocation list. The BCCH allocation list is the list of absolute RF channel numbers for which the bit is set to 1 in the neighbor cells description parameter. With 5 bits, range 0 to 31, one out of 32 neighboring cells can be pinpointed.

BSIC-NCELL
This element indicates the BSIC of the *i*th neighboring cell. BSIC consists of six bits.

Measurement Result on Abis Interface

Figure 6-50 illustrates the message format for the measurement report on Abis (the Reference field in the table indicates a section in GSM TS 08.58). The BTS adds measurement results for the uplink. That is, signal strength and quality, output power from BTS and the layer 1 information. The layer 1 information consists of the TA and the output power used by the MS. The L3 information field in the figure is the complete measurement report from the Um interface.

Information element	Reference	Direction	Type	Length
Message discriminator	9.1	BTS-BSC	M	1
Message type	9.2	BTS-BSC	M	1
Channel number	9.3.1	BTS-BSC	M	2
Measurement result number	9.3.27	BTS-BSC	M	2
Uplink measurements	9.3.25	BTS-BSC	M	V
BS power	9.3.4	BTS-BSC	M	2
L1 information	9.3.10	BTS-BSC	O	3
L3 information (MEAS REP)	9.3.11	BTS-BSC	O	V

M=mandatory, O=optional, V=variable

Figure 6-50 Measurement result on Abis.

Idle Channel Measurement

The interference level on idle TCHs and SDCCHs is continuously monitored by the BTS. The measurements are averaged over a time period and then placed into one out of five interference bands. See Figure 6-51.

Band	RXLEV	dBm
1	0-4	<-106
2	5-8	-106 to -102
3	9-15	-102 to -95
4	16-25	-95 to -85
5	26-63	-85 to >-48

Figure 6-51 Default interference bands.

The time period and limits for the interference bands can be altered on a per cell basis by command in the BSC.

The BTS reports to the BSC which interference band an idle channel belongs to with the message "RF RESource INDication". See Figure 6-52. At channel allocation this information can be used to choose the channel with the lowest possible interference level.

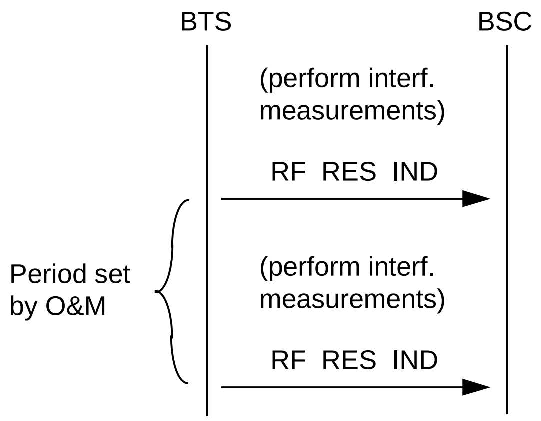


Figure 6-52 Idle channel measurement reporting.

This feature is activated on a per cell basis.