इरिसेट IRISET

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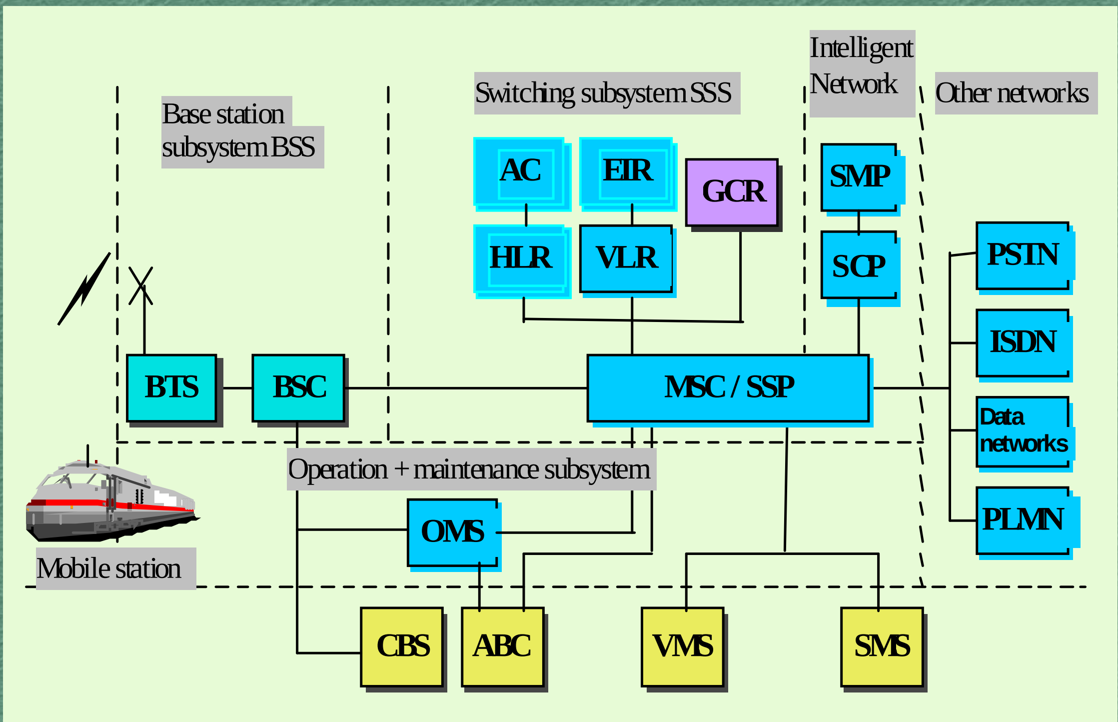
MOBILE COMMUNICATION



Indian Railways Institute of
Signal Engineering and Telecommunications
SECUNDERABAD - 500 017

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INDIAN RAILWAYS INSTITUTE OF SIGNAL ENGINEERING & TELECOMMUNICATIONS, SECUNDERABAD - 500 017

Issued in August 2014

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No. of Pages	121
No.of Sheets	62

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CHAPTER-1

SCENARIO OF MOBILE TRAIN RADIO COMMUNICATION ON INDIAN RAILWAYS

1.0. INTRODUCTION

The growth of Mobile Train Radio Communication (MTRC) system on Indian Railways including the existing mode of communication with the moving train in the present scenario and future planning of Mobile Train Radio Communication are discussed in this chapter.

1.1. EMERGENCY COMMUNICATION - PRESENT STATUS

Emergency Communication is provided by portable control phones (PCPs) using following means:

a) Hooking on the overhead control alignment in non-RE area;
b) Provision of emergency sockets in RE area.

The disadvantages of the above mode of Emergency Communication are:

(a) The Driver/Guard have to carry the cumbersome telescopic masts and the PCP sets;
(b) Hooking up of the telescopic mast on the overhead alignment is a difficult procedure;
(c) In some cases, overhead alignment may be far away from the track.
(d) In RE area, Driver and Guard have to walk about 500 meters for establishing emergency communication.
(e) The emergency sockets and posts are prone to vandalism
(f) Emergency communication is initiated only from the site of emergency by driver / guard of the affected train.
(g) The Section Controller/Emergency Controller is not able to contact the train crew in moving conditions.
(h) The emergency communication is initiated only in static condition after the trains come to a halt and not in mobile conditions.
(i) All emergency calls are directed to the Control office and not the nearest Station Master.
(j) SOS facility is not available.
(k) The weight of the Emergency Control phones is fairly heavy.

1.2. WHY TRAIN RADIO COMMUNICATION

Absence of mobile communication, in the present circumstances, due to the above limitations of the existing system, has the potential of conversion of the following situations into accidents or cause avoidable detention to trains:

a) Accidents/unusual situation due to landslides, floods, obstructions on track causing unsafe conditions;
b) Robbery / thefts in trains;
c) Carriage & wagon problems due to train parting, hanging parts;
d) Locomotives failure;
e) Chain pulling etc.

1.3. NEED FOR MOBILE COMMUNICATION

Providing Mobile Train Radio Communication (MTRC) solves all the problems/short comings of the existing mode of communication. MTRC provides capability to provide/establish the following modes of communication:

a) Driver to Control;
b) Guard to Control;
c) Driver to Station Master;
d) Driver to Guard;
e) Guard to train crew.

In addition to the above, the system also provides communication from:

a) Maintenance staff to Control;
b) Maintenance staff to Station Master.
c) Maintenance staff to Driver.
d) Maintenance staff to Guard.
e) SOS signal to all in vicinity.

Provision of above communication between the various functionaries involved in train running results in continuous monitoring of train running with the possibility of taking corrective action, even on run, whenever required. This increases safety and operational efficiency of trains.

1.4. INTRODUCTION OF MOBILE COMMUNICATION ON IR

1.4.1. Mughalsarai - Howrah Section

A Radio based solution for both Block working and Emergency communication was planned for the first time on IR, as a solution to thefts/vandalism of cables and emergency sockets. In 1980 a decision was taken to introduce 18 GHz communications between Mughalsarai - Howrah Section to provide Block working and Emergency communication.

Train Radio Communication was provided for the first time on Indian Railways on MGS-HWH section in 1980 as a means to provide emergency communication in the new arrangement. The system provides simplex communication from the Driver/Guard to the Controller. The system operates in VHF band (147.975MHz.) with 18 GHz microwave system acting as communication backbone.

1.4.2. Nagpur — Itarsi Section

With the introduction of Optical Fibre cable, OFC Communication was planned in Nagpur - Durg - Itarsi Section during the year l985-86. The planning of the project was on the same lines as 18 GHz project on HWH-MGS section. OFC communication system was planned to provide control communication & block working. However as a solution to provide emergency control communication, in this section, Mobile Train Radio system was installed.

The system caters for full Duplex Communication System between the Driver/Guard and Control. However, due to technical problems of frequency switching, the system could provide communication only between Driver/Guard to Control and not between Driver and Guard. The mobile Train Radio system works on 314-322 MHz band with OFC communication system acting as a backbone. The mobile sets were also provided to maintenance staff for communication to control.

The above two sections symbolise, beginning of Train Radio Communication era on Indian Railways. However, it can be seen that Train Radio Communication on IR got a false start, as the initial systems were provided only as an alternative to emergency communication and not as Mobile Train Radio Communication in real sense.

1.4.3. Delhi - Mughalsarai Section

The first Mobile Train Radio Communication on Indian Railways in real sense was provided in Delhi-MGS section. The system catered for full duplex communication between Driver/Guard and Controller. The mobile system operates in 314-322 MHz band and the communication backbone works in 2.1-2.5 GHz UHF band. The backbone has since been shifted to digital microwave in 7 GHz band.

The system is similar to the one provided in Nagpur - Itarsi Section and provides similar communication facilities. However in this section mobile sets were not provided either to Guards or to maintenance staff.

1.5. SHORTCOMINGS/LIMITATIONS OF THE EXISTING MOBILE COMMUNICATION SYSTEMS

The system installed in Howrah-Mughalsarai section operates in VHF band and as such there were problems and complaints of noise due to electrical interference. The system also had the deficiency of non-availability of selective calling, and channel blocking due to shortage of channels.

The full potential of the system in Nagpur - Itarsi Section & Delhi - Mughalsarai section also could not be exploited due to the following drawbacks:

a) All locos running in the above section were not provided with the Mobile Communication equipment;
b) The Guards were not provided with the communication equipment because of shortage of equipment and lack of power supply arrangements in the Brake Van.
c) Special indigenous arrangements for wiring of loco, had to be made for installation of the equipment in the loco resulting in failures;
d) There were some blank zones due to inadequate coverage;
e) The system was not provided on the entire run of the train and the loco equipment was to be loaded/removed in mid run.
f) Communication between driver and guard was not implemented.
g) Direct communication to the nearest SM was not possible.
h) SOS Emergency call from Driver to all the mobile sets was not possible.
i) Provision of using the system for communication to passengers on train was not planned.

1.6. UNIVERSAL EMERGENCY COMMUNICATION (UEC)

Subsequent to the experiences of Train Radio Communication and considering the deficiencies & costing of the existing systems, it was decided to provide a low cost UEC system on Indian Railways. The system was indigenously developed and was designed to provide emergency communication between:

i) Driver and Guard of the Train and vice versa;
ii) Driver and station master of the nearest station and vice versa;
iii) Guard and station master of the nearest station and vice versa;
iv) Driver/Guard of a train to another Driver/Guard in vicinity of 5Km.
v) Driver/Guard of a train to section controller through manual switching at base station.
vi) SOS signal to all trains/stations equipped with mobile sets in vicinity of 5.0 Km/7.5 Km of distress signal.

The UEC system consists of suitable VHF base stations installed at all Railway stations with suitable mobile & handled sets provided to the drivers and guards respectively. The mode of communication is Simplex and is feasible in both static as well as running conditions of the train, except in case of guards in which case the communication is feasible when the radio is outside or antenna is projected out from the cabin. The system operates in VHF frequency range i.e. 146.2-151.45 MHz or 159.6-162.45 MHz band with minimum of two channels in either of these two bands. The base station consists of 40W VHF equipment along with Omni-directional antenna (Ground plane) fixed at a suitable height. Feature for manual patching with the Control circuit is also available

Initially, works for Universal Emergency Communication were taken on three sections for trials:

a) Vadodara - Ahmedabad section - Western Rly.
b) Delhi - Ambala Section - Northern Rly.
c) Chennai - Arkkonam Section - Southern Rly.

The trials on only Ahmedabad - Vadodara section has been taken up.

1.6.1. SALIENT DETAILS OF THE SYSTEM INSTALLED ON WESTERN RAILWAY

1. All along the route are provided with base station equipment along with 10 meter OHE mast is used for fixing of ground plane antenna and lightening arrestor with proper earthing arrangement.

2. On this route there are three Loco sheds:
   - Valsad for AC/DC Loco (72Locos)
   - Vadodara for AC Locos (140 Locos)
   - Vatva for Diesel Locos (66 Locos)

It was decided that permanent Loco fixtures will be provided on AC/DC Locos only for conducting trials. In addition, DMU/MEMU operating on the section will be covered.

3. The salient details of the installation and project are as under:

• Section	Mumbai-Ahmedabad
• Route Kms	492
• No. of Stations	91
No. of Locos equipped	
• AC/DC Electric Loco	72
• DMU	02
• MEMU	13
• Sets for Guards	220
• Cost of Contract	Rs.201 lakhs
• Date of Award of contract	1.10.1997
• Completion period	One year
• Installation completed	31.1.1999
• Users trial started	1.3.1999

PROJECT IMPLEMENTATION

1. The work was divided into following –

- VHF Radio Survey on the entire section
- Trials for one month on VR - Dhanu Road section with Loco fixtures in one DMU and two AC/DC Locos.

Incorporating the deficiencies noticed during trial in the system to be supplied for final installation.

- Supply of equipment with RDSO' inspection.
- Installation of station and Loco equipment.
- Training to technical staff, repair center personnel's and users.
- Commissioning of the equipment and final testing.
- Users trials and commissioning of the system.

2. During the VHF Radio survey, base station equipment were installed on every station or alternative station in case the stations were closer and signal strength and quality of speech was monitored in the running train and at stations. The actual results were compared with theoretical calculations. The result indicated the following
   - Signal strength was satisfactory and very close to theoretical values.
   - Continuous coverage was available through out the section with 10 to 12 Kms coverage from each base station to train.

3. After the Radio survey, base station equipments were installed at four stations on Virar - Dhanu Road section and Loco fixtures were installed in one DMU and two Locos for conducting actual trial of the system before giving clearance to contractor for manufacture and supply of equipment. The users Deptts. i.e. Electrical, Mechanical and Safety were involved during the trials. The trials were also witnessed by ED/Tele from Railway Board and Director (Tele) RDSO also. The following design changes and improvements were implemented after the trials:
   - The Audio output in electric Loco was not adequate. It was decided to install an external horn in the electric locomotive.
   - It *was* noticed that main VHF channel was resulting into locking of *set* to SOS channel when the received signal strength was high. The CTCSS frequency which was same for main and SOS channel was changed as under in consultation with RDSO.
     - Main channel 93Hz
     - SOS Channel 98 Hz
   - LED indications provided on the set were not visible and as such these were replaced with 5 mm bright LEDs.

4 The installation details for electric locomotives were finalised in consultation with Sr.DEE/TRS BL and program was drawn up for installation of equipment in both the cabs while the Loco comes to the shed for monthly schedule. No extra detention was caused to the Loco on this account.

5. The training classes were organised at the factory as well as in the fields for technical staff, repair center personnel and users i.e. drivers, guards, Loco supervisors etc.

6. After the installation of the system, joint testing and detailed measurements were carried out before the system was put on actual users trial.

7. Joint procedure order for the operation and maintenance of UEC system was issued from HQ duly signed by HODs of S&T, Electrical and Safety Deptts. The joint procedure order included the following details:

Description of the system

Training to users
Procedure of handing/taking over of the VHF set of Loco.
Procedure of handing/taking over of the VHF set for Guard of passenger and goods trains.
Charging of VHF sets.
Use of system
Facility of SOS.
Patching of Control by ASM.
Maintenance and repair of equipment.

EXPERIENCES OF THE PAST

From the Train Radio Communication Systems installed till date, the following can be concluded

a) Train Radio Communication on Indian Railways was initially taken up only as a means of an alternative to existing mode of emergency communication;
b) All trains were not equipped with the equipment;
c) The system was provided only in patches not on a complete route;
d) All the four systems installed till date had different technology;
e) The loco equipment was not integral part of the locos but was provided after making alterations in the loco cab as also in the mobile cab unit.

1.7. PRESENT STATUS

After the GAISAL Accident in 1999, Board have taken a decision to provide full duplex Mobile Train Radio Communication on A, B & C routes on Indian Railways. It has also been decided to provide Universal Emergency Communication on D, D (Spl.), E & E (Spl.) routes.

Mobile Train Radio Communication systems have been sanctioned in Works Program 2000-2001 on a total of 2225 Route Kms. This includes complete Northern belt of Jammu Tawi / Amritsar-Delhi-HWH section and Katihar — Guwahati section on NF Railway.

The following factors should be considered so that deficiencies/short-comings brought out in the planning/execution of the earlier works are taken care of during execution of works in future:

a) Technology based on open/standard architecture should be selected so that the system can be seamlessly extended and multi vendor sources are available;
b) Loco equipment should be made an integral part of the loco at the time of manufacturing itself.
c) The practice of loading and removal of loco equipment should be stopped.
d) Adequate number of mobile equipment should be catered for so that all the communication requirements are catered for.
e) The backbone communication whether Radio or Optical Fibre based should be reliable and cover the entire run with no dark zones.
f) With the introduction of Radio based Signaling, the system should have the capability of integrating both the Signaling and Telecommunication applications.
g) The system should be based on digital technology.
h) The project should be implemented on a complete route instead on piece meal basis.
i) Communication to passengers on the trains should also be catered in the system.

1.8. FUTURE OPTIONS AVAILABLE

As on date, there are mainly two technologies of Radio Communication systems available which broadly meet the railway requirements:

1. TETRA based systems

Terrestrial Trunk Radio (TETRA) works on an international open standard architecture that improves performance heightens reliability and increases efficiency. It provides an infrastructure that is able to support both voice and data traffic. The system consists of only two basic elements in the Network Architecture i.e.

a. Radio Access; b. Network Transport Layers.

Because there is no hierarchy within the switching network, capacity of the network can be matched effectively to the traffic demand.

It *is* seen that the network transport layer consists of private network exchange, which is in turn connected to the Radio Access network. Depending upon the amount of traffic to be handled by the various Radio site equipment's a decision can be taken to include more number of switches in the system

The main features of the TETRA based systems are:

a) Frequencies for Tetra based systems in 380-400 MHz & 410-430 MHz bands are - available.
b) The system does not support railway-signalling applications like AWS, ATS -etc.

2. GSM-R based systems

The other Mobile Radio Communication Systems presently in vogue on European Railways are GSM-R based. The International Union for Railways (UIC) has developed a GSM based system modified for the Railways viz. GSM-R. The GSM-R based system works on the most popular platform for Mobile Communication GSM and gives the advantages of ISDN-like services and guarantees a future proof and cost optimized solution. While the system has the capability of working in the complete GSM band, in Europe 876-880 MHz for the up-link and 921-925 MHz for the down-link have been reserved for GSM-R based railway applications.

Objective:

1. The mobile Train Radio system in NGP-ITR section works on 314-322 MHz band. (T/F)
2. The mobile Train Radio system in NGP-ITR section works on full duplex mode of operation (T/F)
3. The back bone communication system for mobile Train Radio system in NGP-ITR section is on OFC system (T/F)
4. The back bone communication system for mobile Train Radio system in NGP-ITR section is on MW system (T/F)
5. The UEC system operates in VHF frequency range (T/F)

Subjective:

1. What are the disadvantages of present state of emergency communication systems?
2. What is the need for mobile train radio communication?
3. What are the modes of communication provided by MTRC?
4. What are the short shortcomings/limitations of the existing mobile communication systems?

CHAPTER-2

VERY HIGH FREQUENCY (VHF) MOBILE RADIO COMMUNICATION

2.0. INTRODUCTION:

The frequency band of VHF Communication is 30 to 300 MHz. The frequency allotted by WPC (Wireless Planning and Coordination wing of ministry of communication) in VHF for Indian Railways are in the band 146 -174 MHz.

Communication in this range of frequencies is mainly due to line of sight, reflection and scattering of waves.

2.1. Application of VHF Communication on IR are

1. Communication during Maintenance and Constructional Blocks
2. Yard communication
3. Communication in the train between Guard & Driver
4. Mobile Communication between moving train/vehicle with fixed location (Station) or another moving train/ vehicle.
5. Emergency Communication:
6. ART equipped with hand held and base station VHF sets.

2.2. Modes of operation:

Simplex
Half-duplex
Duplex

Simplex: One way radio communication i.e, either trans or receive

Half-duplex: Both way radio communication, ie we can trans and receive but one at a time (because the same frequency is used for both trans and receive)

Full duplex: Both way radio communication simultaneously. (Trans and receive frequencies are different)

Simplex VHF sets are used as walkie-talkie sets

Duplex VHF Sets are utilized for Extension of exchange number to distant place, Control working (Train Traffic Control) /Patching.

Universal Emergency Communication for communication between driver, guard, station master & Cabin.

2.3. VHF RADIO SPECIFICATION (General)

1. Frequency Band allotted for Railways 146 MHz to 174 MHz. One spot frequency is used for each channel
2. Mode of Propagation: Line of sight waves, Reflection & scattering of waves
3. Type of operation: Simplex/Duplex
4. Channel capacity: Single channel/Four channel/Sixteen channel for Voice or Low speed

Data or both. [Sets are equipped for more than one channel i.e. upto 16 channels or so. Crystal controlled or synthesized version, out of them one channel can be used at a time.]

5. Type of Equipment:
   i) Walkie -Talkie (Hand Held) Set- 1W/2W to 5W switchable output power operated on in-built NI- CD/ NiMH/LiO batteries.
   ii) Mobile Sets – Mobile Sets can be carried in a case or bag or can be fitted in a vehicle, the Output power is 25 Watt, Operated on 12V car battery
   iii) Base Station – Installed at desired location, Operating on AC Mains or by 12V battery. External antenna with feeder cable connector mounted on a mast (Roof top) needed.
6. Antennas used are Whip Antenna for portable sets, Ground Plane (GP) Antenna for base radio equipment, Low Profile for engine.
7. Feeder cable: 50 Ohms Unbalanced Coaxial cable
8. Communication Range: Depends upon terrain. The average range of a Walkie -Talkie (Hand Held set) - 1 to 2 km. , Mobile Set- Upto 15 km. And Base Station – upto 50 Kms. When antenna used is directional & fixed at the height of 15 to 20 metres.
9. License: Mandatory, License is to be obtained through Railway Board from WPC, Ministry of communication. Such license shall be applied on prescribed form
10. Frequencies allotment: Wireless planning and Coordination wing of Ministry of Communication (WPC) allots different band of frequencies and spot frequencies in the band for different department, according to National Frequency Allocation Plan.

2.4 Guidelines for utilization of Walkie-Talkie/VHF sets on Indian Railways.

VHF sets of 25W and walkie-talkie sets of 5W are being used for different operation and maintenance functions including Driver & Guard communication and station to station communication. Since all these sets can be tuned in entire VHF band and operated in multiple channel mode, there is a need to streamline and standardize the system of working. Therefore, the following guidelines are issued:-

2.4.1. Frequency allocation for Departments:

Henceforth, frequency programming of 25W VHF sets and walkie-talkie sets for department-wise applications should be done as per Frequency Allocation given in Annexure-1

2.4.2. Frequency Allocation of VHF sets with the SM:

Normally one 25W simplex VHF set will be provided to SMs at the Railways stations. This set will be provided with DTMF signaling for selective calling facility and CTCSS/DCS signaling to ensure one to one secured and secret communication for block communication channel. There should be display of called and calling party ID on each VHF set. This can be done either by programming and displaying a code or the name of the station of calling party on called party set and vice a versa. This set will have priority channel scan (Guard Driver communication channel with station master at frequency 161.15 MHz) to ensure automatic switch over of VHF sets to Driver Guard communication channel in case of calling station master failed to switch over the channel manually within 5 secs. after the talk is over.

2.4.3. Frequency allocation for block communication by using VHF sets during failure of Block Instrument and Electrical Communication Instrument:

For exchanging paper line clear, VHF sets should be used as per the directive issued by Board's letter No.2005/Safety(A&R)/19/7 dated 01.07.2005. From the consideration of safety, three (3) frequencies are allotted for straight route for taking 'Line Clear' and programmed as channel-5, 6 and 7. These channels should be programmed with CTCSS/MF coding using alternate frequencies for adjacent sections as detailed below:-

Channel-5 for 1st section (150.100 Mhz)
Channel-6 for 2nd adjoining section (150.150 Mhz)
Channel-7 for adjoining 3rd section (159.600 Mhz).
Channel-5 for next 4th section.
Channel-6 for next 5th section and so on

For the junction stations the more number of frequencies will be required to maintain alternate frequency plan for adjacent sections. Six additional frequencies are kept reserved for this purpose as shown in Annex.-I. Railways may prepare their own frequency plan for Junction Stations using these frequencies.

2.4.4. VHF sets provided to Operating and Maintenance Staff:

i) 25W Simplex VHF sets provided to SMs at Railway Station will be on Driver Guard frequency with priority scan and will have single knob control for setting to frequencies for:
    a) Taking line clear at the time of block failure;
    b) Coordination with maintenance staff;
    c) Coordination with other station staff for shunting & yard movements.

ii) The walkie-talkie sets provided to various departments shall be tuned to two (2) frequencies/channels only i.e. one common channel-10 (160.400 MHz) and second to that allocated to the respective departments.

iii) The departmental staff should keep their walkie-talkie sets tuned to the frequency/channels allotted to them as per Annexure-I.

iv) A common frequency (160.400 MHz) for inter-departmental use is provided so that users of different department with mutual consent can communicate among themselves when they switch over to this channel. This channel can also be used for direct dialing the exchange subscribers where this facility is provided.

v) Staff of Operating department such as SMs and shunting staff should use VHF sets in channel-14 (162.100 MHz) for shunting and yard communication.

vi) All activities as detailed above should be carried out through secured communication on MTRC phones on the sections where Mobile Train Radio Communication is commissioned.

2.4.5. VHF sets provided in ARTs:

ART frequency (147.975 MHz) should be used for communication at disaster sites. This should normally be restricted to 30 sets in the ART which should be distributed only among the officers/supervisors directly connected with relief and restoration arrangements at site, as decided by the senior most officer-in-charge. Other users having separate walkie-talkie sets should not come on this frequency.

2.4.6. Communication with Level Crossing Gate:

When needed, a separate 25W simplex VHF set shall be provided at level crossing gate and nearest station. Only channel-9 (159.700 MHz) should be programmed in this 25W VHF set with CTCSS/MF coding.

These guidelines are issued in consultation with the Safety and Traffic Directorates of Ministry of Railways.

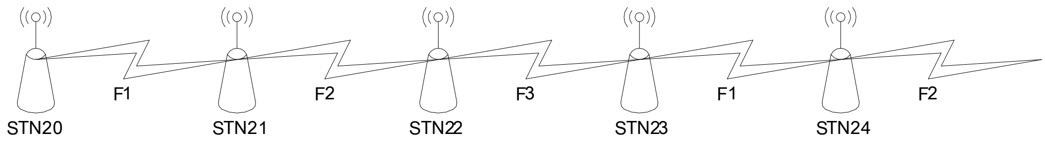


Diagram 1: Frequency Scheme for Straight Section

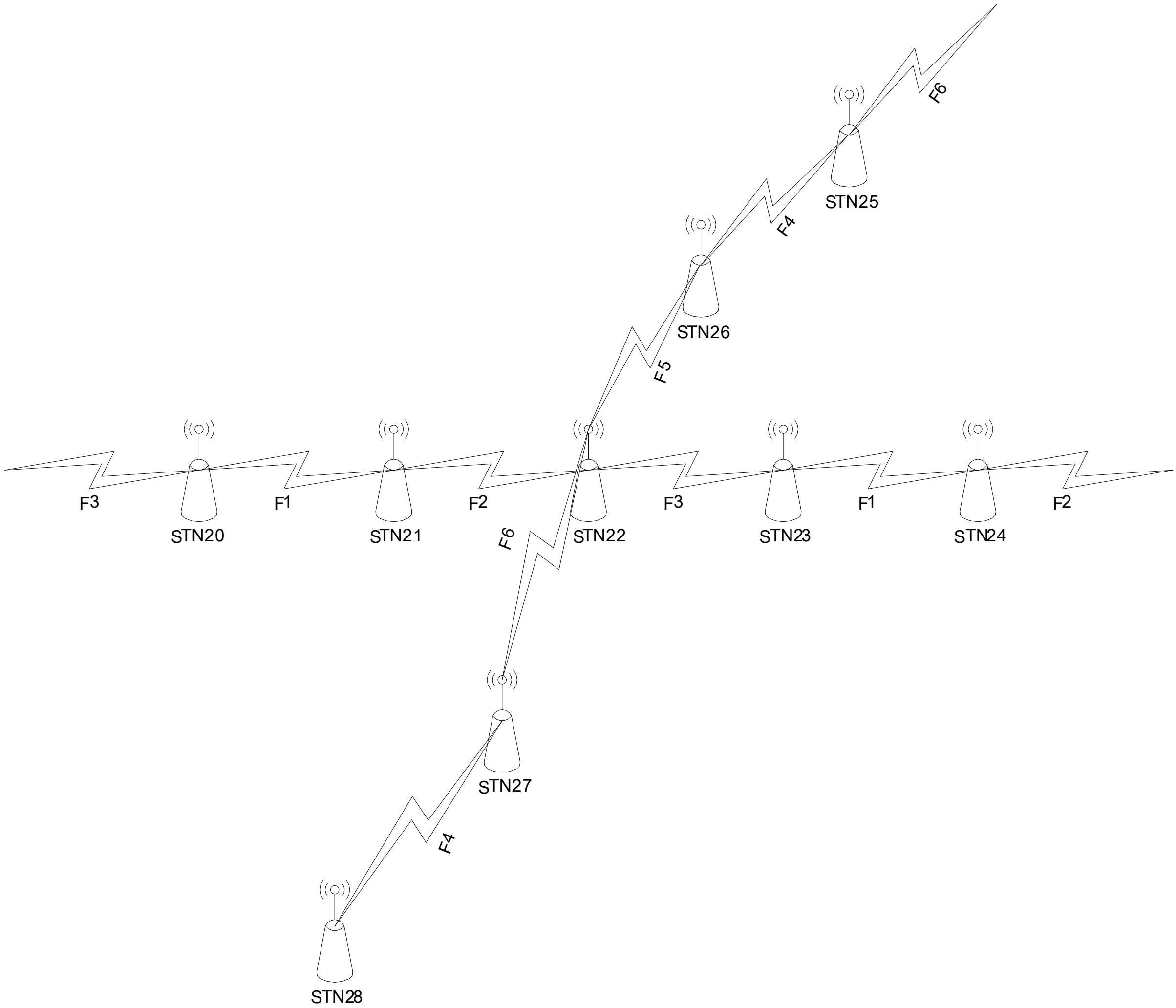


Diagram 2: Frequency Scheme for 4 Direction Junction Station

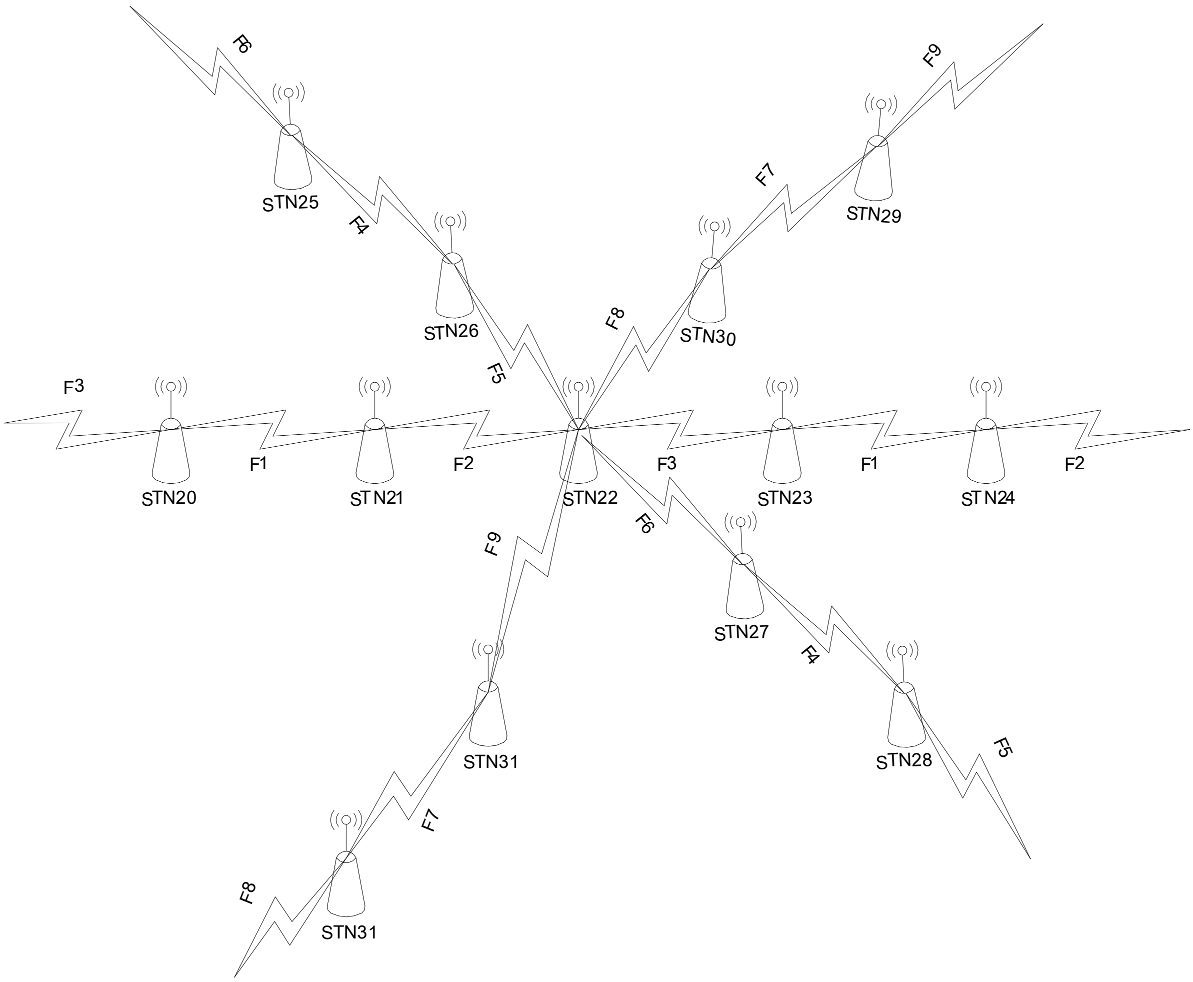


Diagram 3: Frequency Scheme for 6 Direction Junction Station

Annexure-1 Standardisation of VHF – Frequencies on Indian Railways

S.No.	Frequency in MHz	SM at all stns.	Station to LC gate	Driver & Guard	Shunting/Operating	Engineering deptt.	Electrical deptt.	S&T deptt.	Commercial deptt.	RPF	Mechanical deptt.	To be used for	
1	146.400									X		Security Department	
2	147.975	ART Frequency										Accident Site Communication	
3	148.100										X	Mechanical Department	
4	149.750					X						Engineering Department	
5	150.100	XC										F1 – for PLC; 1st section of Straight Section	
6	150.150	XC										F2 – for PLC; 2nd section of Straight Section	
7	159.600	XC										F3 – for PLC; 3rd section of Straight Section	
8	159.650							X				S&T Department	
9	159.700	XC	XC									Communication with LC gate	
10	160.400	X			X	X	X	X	X	X	X	Common Frequency	
11	160.550								XE	XE		Train Escorting Purpose	
12	161.150	X		X								Driver & Guard communication	
13	161.425						X					Electrical Department	
14	162.100	X			X							Shunting & Yard Communication	
15	146.200	XC										F4 – for PLC; 1st section	For Junction Station (Direction 1)
16	148.050	XC										F5 – for PLC; 2nd section	
17	149.500	XC										F6 – for PLC; 3rd section	
18	149.550	XC										F7 – for PLC; 1st section	For Junction Station (Direction 2)
19	151.400	XC										F8 – for PLC; 2nd section	
20	151.450	XC										F9 – for PLC; 3rd section	
	Note:												
	X -	Channel programmed											
	XC -	Channel programmed with CTC SS/MF coding.											
	XE -	For Train duties only.											

2.5. Driver/guard/ASM communication system:

Walkie-talkie sets provided for driver/guard will be operated on simplex mode. As per railway board's instructions all the sets are tuned to a fixed frequency of 161.15 MHz irrespective any model or any manufacturing and it cannot be changed by driver or guard. With this sets the driver /guard of the same train can have the communication, the driver/guard of one train to driver guard of another train can have the communication and the driver/guard of the train to the station master can have the communication.

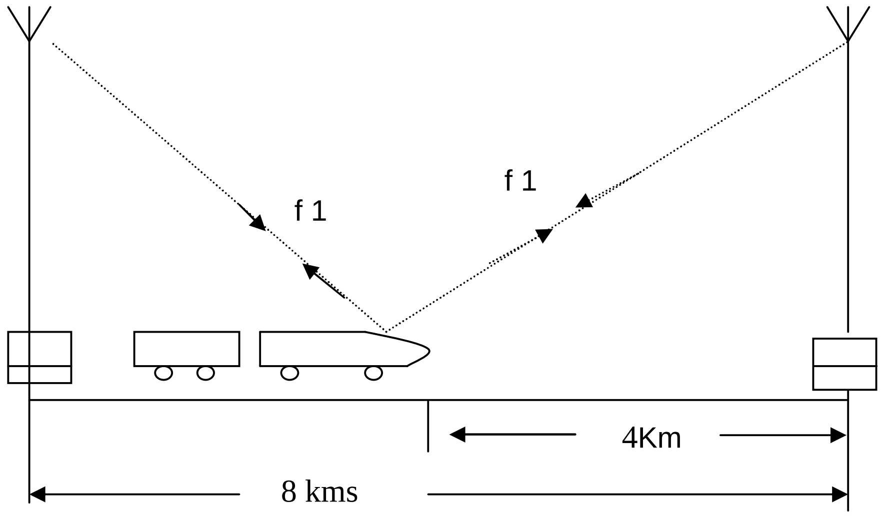


FIG 2.1. Driver ASM communication in normal coverage

The range of coverage area with 5W sets will be 3-5 Kms. So the communication can be established between any two sets will be within this range. Various methods of connectivity are being followed in different zones according to their requirements. When the block section is more than 8 kms, repeater becomes necessary.

The repeater can be located at the mid section If the driver guard frequency be f1, the repeater will receive f1 and transmits f2 to the station. The station receives f2 and transmits SM's speech towards the repeater at f3. This f3 is transmitted back to the driver at f1 by repeater. At the station there is separate equipment for communication with the repeater in addition to the one tuned to f1. When the driver comes closure to the station his transmission is directly picked up by the set tuned to f1. The SM need not know whether the driver's speech is coming through repeater or directly since both speakers are kept closure. He can use the same microphone and its output is connected to both transmitters in parallel through a coupling Thus the SM can speak to driver at a distance of 12 kms easily. When the driver is close to other station is beyond 12kms the other station will respond to driver. Thus a block section of 16 kms can be covered with a walkie talkie.. Use of semi duplex mode with f2, f3 will ensure that there is no feedback from any adjacent section repeater.

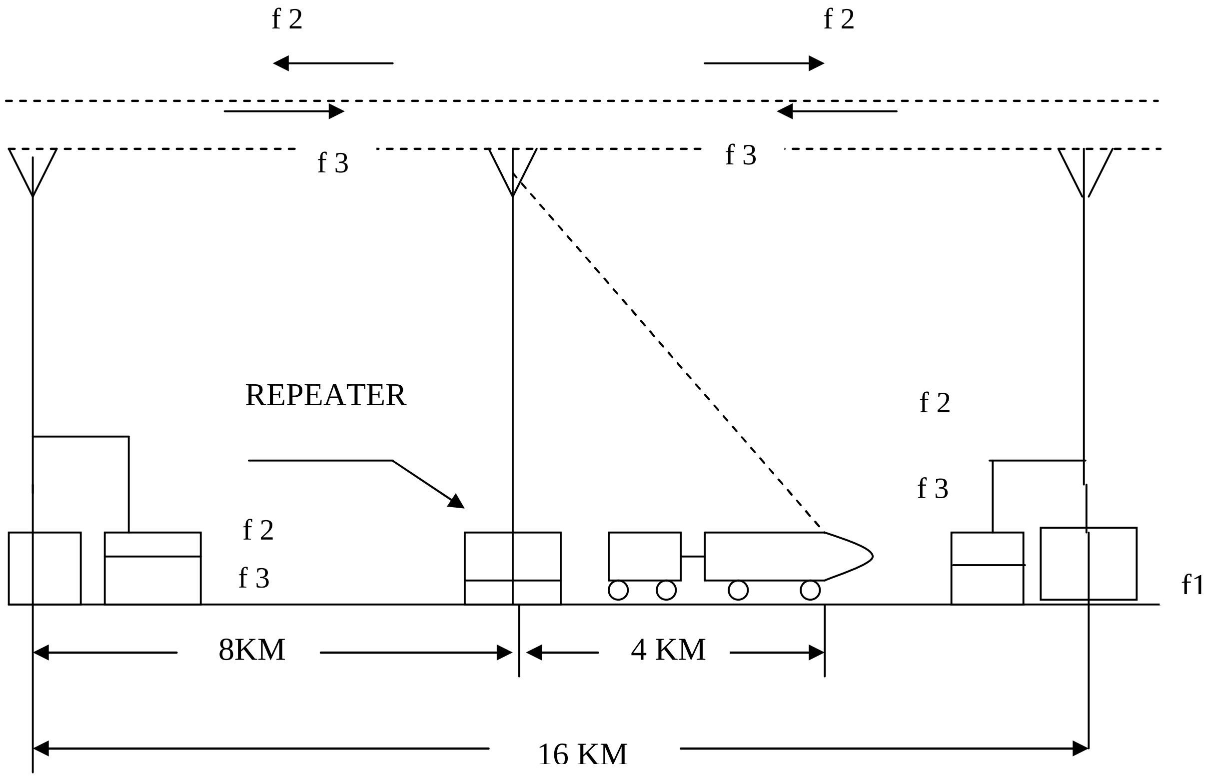


Fig.2.2.Driver station master communication with repeater

2.6. Communication with control

The arrangement provides facility to connect to the control when the driver desires to speaks to controller or controller desires to speak to driver, SM presses a button at his equipment which connects the input and output of the VHF set to the control circuit through a voice operated transmission (VOX) switch. Since the communication mode is simplex, whenever the controller speaks, the VOX activates the transmitter at the particular station simulating the PTT button and otherwise the set goes to the receive mode. This system is suitable wherever 4-wire control communication is available. When the system is considerable and desirable to retain both the control communication through VHF as well as mobile communication to driver with the SM independently a system of scanning with the same equipment is to be adopted. The scanning mode has to be programmed to the desired VHF sets. The set is normally set to the preferred frequency but it can also scan the other prescribed frequencies for any incoming signals. If incoming signal is detected on the scanned frequency it is received full and the SM switches to that frequency for responding. SM can also initiate the conversation on any of the frequencies. Thus the set can be used for control communication through VHF as well as communication with driver guard.

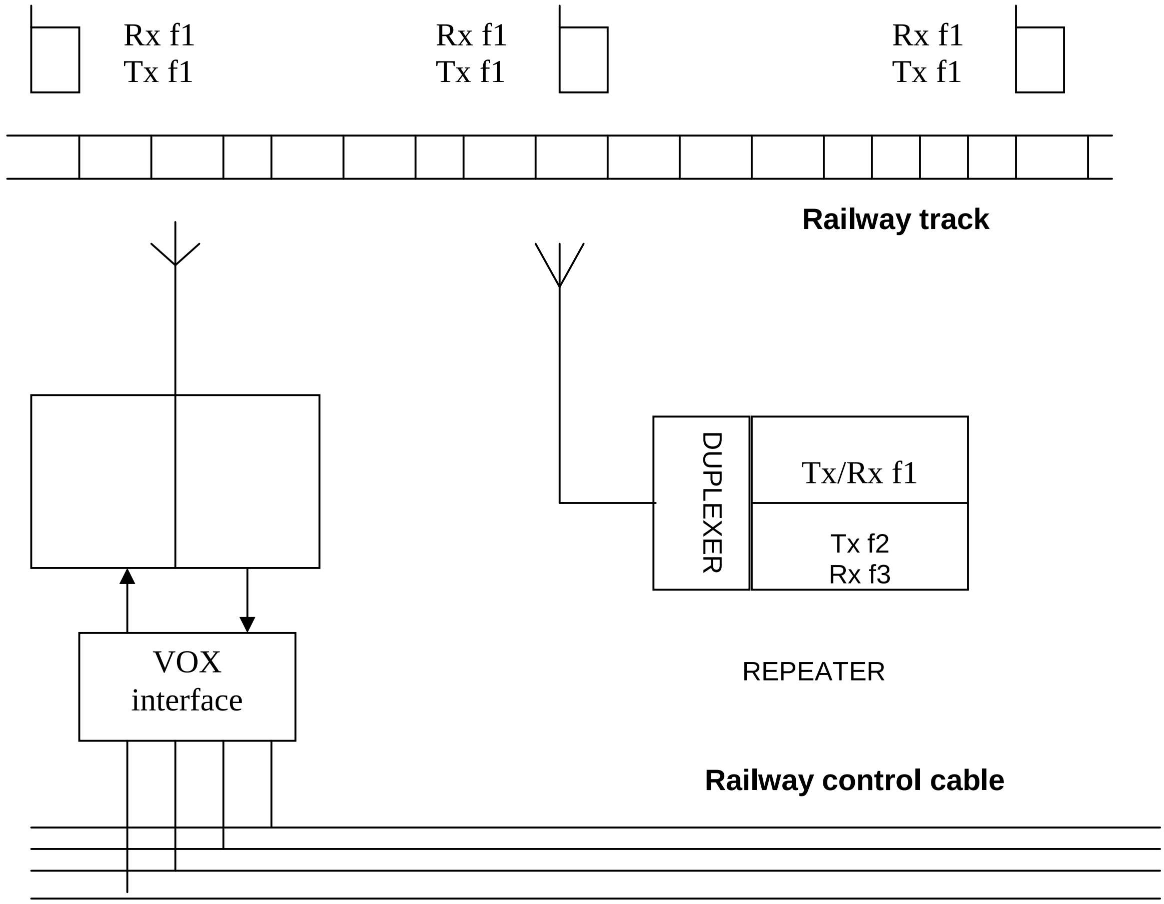


FIG.2.3. Driver to controller communication with and without repeater

2.6.1. Repeater interface card (RIC):

The repeater consists of two Tx/Rx equipment in bi-directional mode. The receiver of one set is connected to the transmitter of the other set and vice-versa. To activate the PTT feature of the transmitter the incoming carrier in the receiver is sensed and is used to switch on the transmitter circuit. The transmitter and receiver of a set cannot be actuated at the same time. Thus bi-directional simplex working is achieved. The RIC is supplied as standard equipment as part of the repeater set.

2.6.2. Duplexer:

It is important equipment in the repeater set up and ensures that same antenna can be used for trans and receives functions on both sides though the frequencies on the both sides of repeater may have a difference of 5MHz. The duplexer is a factory tuned to predetermined pair of frequencies with the antenna connection on the center and the two-equipment connection on either side. The duplexer can also be used with f1, f2 and f3 if the separation between f2 and f3 on the semi duplex side is not much. The performance of a repeater is better than having a separate antenna.

2.7. Communication between walkie-talkie/base radio and auto telephone vice versa

To establish the communication from a land line telephone (from EPABX) to walkie-talkie or to a base radio and vice-versa can be possible by providing a radio telephone interface unit. This facility is very useful for railway application, to provide a telephone connection to a remote location where telephone lines are inaccessible, and a person who is working at a remote site can have the communication with his walkie-talkie to a land line telephone. And at the site of accident we can extend landline communication through a VHF radio set. Since wireless is independent of the vagaries of nature of human intervention, the link is more reliable than traditional methods of connecting through cables/overhead lines.

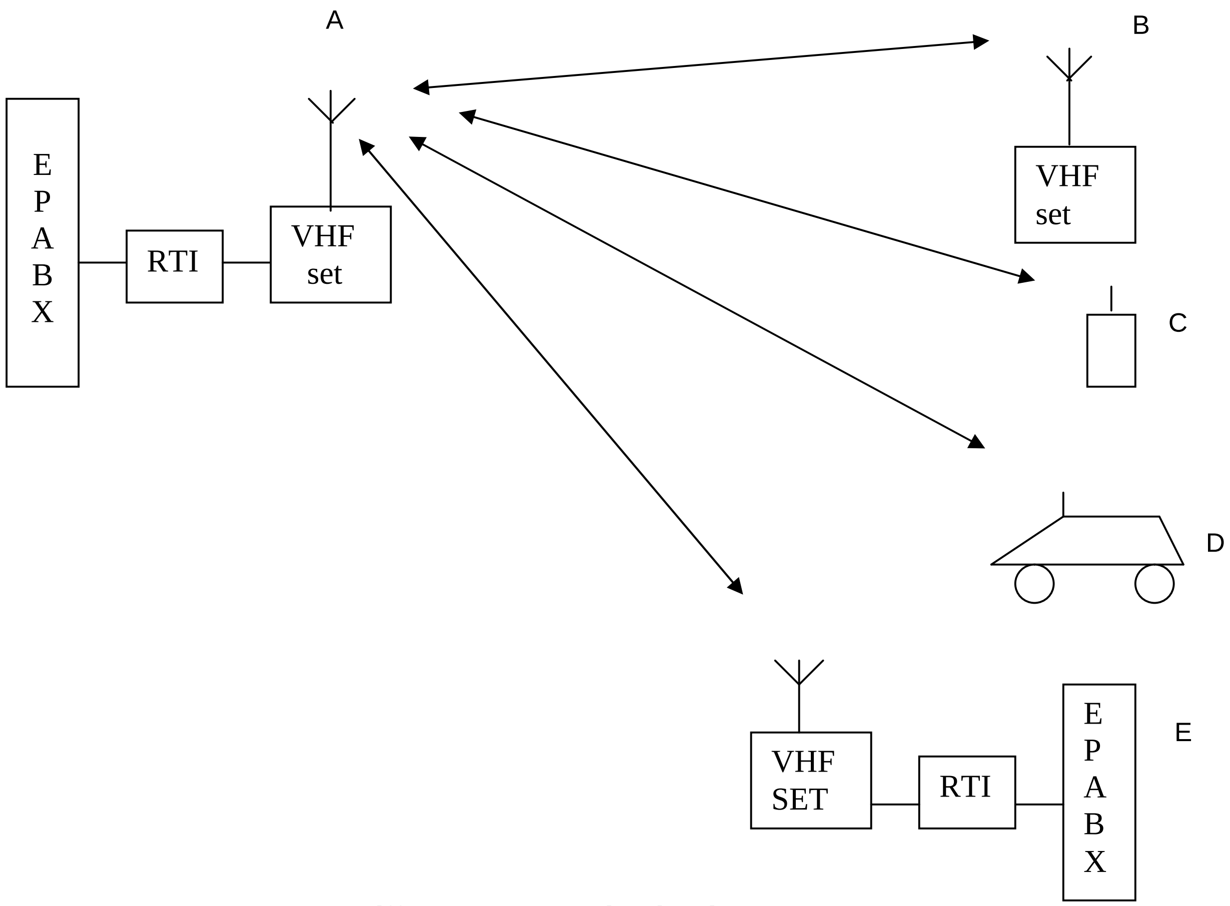


FIG.2.4.Different communication between VHF sets

2.8. System of application:

Any telephone at location A can talk to any wireless transceiver at B, C or D in the network or vice-versa. Any telephone extension at location A can talk to any desired telephone extension/direct telephone subscriber at location E using radio link. A remote location like B where telephone facility is not available can have access to any telephone subscriber in the location A.

2.8.1. Radio telephone interface unit (RTI):

Radiotelephone interface unit/phone patch unit between a wireless transceiver and telephone line of EPABX provides communication between VHF set and any exchange number by dialing directly from the VHF set.

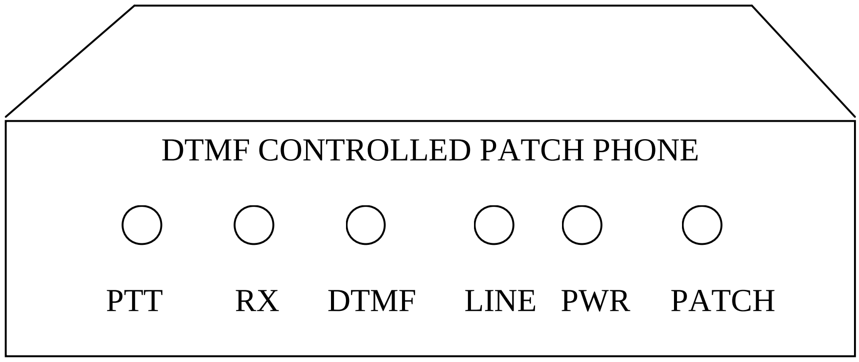


FIG.2.5. FRONT VEIW OF RTI

2.8.2. Features of the system:

1. Automatic call forward- If the base station is unattended, incoming calls can be automatically transferred to mobiles or portables in the field and constant communication is maintained. The ring out settings decide whether the call should be transferred on the first or other no. of rings. The system is smart enough to detect the busy tone and disconnect the line.
2. Timeout timer- Automatically shuts off the link after a predefined time intervals.
3. PTT timeout- Automatically shuts off the link if the PTT remains active for more than 60 sec., thus saves the equipment from burnout.
4. No activity timeout- automatically shuts off the link, if there is no activity for more than 45 secs.
5. Line impedance-Unit automatically balances the line impedance. No manual adjustments are required to maintain clear, consistent volume levels during communication.

2.9. Specifications:

Input voltage	10.5-13.5V DC
Input current	less than 500 ma
Telephone line connector	modular plug
Telephone line	Two wire
AF response	300-3000Hz
Audio distortion	3% max.

2.10. LIMITATIONS OF VHF COMMUNICATION:

- Short distance coverage
- Blank Zones occur due to terrain, high-rise buildings & other structures, so area must be surveyed for blank zones from where communication is not possible.
- Simplex mode of working
- Maintenance of rechargeable batteries
- AC power supply is required for charging of batteries, which may not be available at the sight of use. Charging also needs about 4 to 6 hours. Thus the set requires more than one battery set for continuous operation.
- Interference due to other user having adjacent frequencies.
- Effect of prevailing noise in the surrounding.

2.11. INSTALLATION OF VHF

1. For point-to-point communication availability of line of sight is essential
2. Antenna height must be decided at both locations by measuring minimum field strength needed for satisfactory communication. This can be measured by putting one transreceiver at one end and mounting antenna at a suitable height (of 15 to 20 metres) and measuring the field strength by field strength meter at other location. VHF set of the same power and frequency can also be installed to check the quality of communication. Antenna height and orientation can be adjusted to get a maximum signal strength or voice.
3. Antenna can be mounted on a tower/Mast of approved design or on a pipe on the roof of a building. Feeder cable must be of 50 Ohm. impedance unbalanced of approved design.
4. Connectors used must be also of good quality and supplied by approved supplier.
5. Power Supply System
   230V AC mains operated power supply of rated voltage & current is supplied by the supplier along with VHF set. A 12V/80-120 AH battery must be connected on float to the set to prevent communication failure during mains failure.
6. Spark Suppressors must be installed in the Vehicle in case of mobile set is installed in the vehicle and powered by its battery.

2.12. MAINTENANCE OF VHF

1. VHF set's transmitting frequency and power are to be measured once in a month.
2. Spurious emission squelch operation current drain frequency stability, frequency deviation, sensitivity of receiver & adjacent channel selectivity are to be checked once in a year in the centralised repair centre.
3. Power Supply System, Following measurements shall be taken
   Input and output voltage & currents – weekly
   Specific gravity of each cell - weekly
   Care must be taken while using such sets when low battery indication is appearing on the set, it must be charged as specified in the manual.
4. Antenna system along with feeder cable & connector
   Antenna system Physical and visual inspection once in a week. VSWR, Power-handling capacity, frequency band of operation, directivity, and radiation pattern must be checked annually.

2.13. TEST METERS REQUIRED AT CENTRALISED REPAIR CENTRE

i) Tools
ii) Test jigs & fixture
iii) Antistatic workstation
iv) Temperature Control soldering/de-soldering station
v) Digital Multi Meter
vi) Frequency Counter
vii) Power meter
viii) Oscilloscope
ix) Field strength meter
x) Insulation Tester
xi) Programmable frequency scanner
xii) Communication Radio Test set.

INSPECTION

VHF installation must be inspected every month by Section Engineer.
Sr.DSTE/DSTE/ASTE once in a year

2.14. FAILURE REPORT

1. VHF system's failure must be reported to controlling officer daily in the morning.
2. Monthly statement of a failure must be reported in the PCDO to Headquarter.
3. The VHF sets must not be opened at site as far as possible. Faulty sets must be sent to Repair Center to prevent further damage at site by Electro Static discharge.
4. Spare sets must be kept at site or at suitable location to replace the faulty sets.

Objective:

1. Simplex mode of operation means both way radio communication (T/F)
2. Full duplex mode of operation is both way radio communications simultaneously. (T/F)
3. Frequency Band allotted for Railways for walkie-talkie system are 85.5MHz to 86.5 MHz and 146 MHz to 174 MHz. (T/F)
4. The maximum no. of channels derived from the spectrum is 128 (T/F)
5. The channel spacing will be 12.5KHz in VHF spectrum (T/F)
6. In mobile radio systems the mode of Propagation will be line of sight waves, Reflection & scattering of waves (T/F)
7. Antenna used for walkie-talkie system is Whip Antenna (T/F)

Subjective:

1. What are the applications of VHF radio communication on IR?
2. What are the Specifications and performance parameters to be followed for VHF systems?
3. What are the limitations of VHF communication?

CHAPTER-3

CELLULAR MOBILE RADIO COMMUNICATION SYSTEMS

3.0. Introduction

What is a cellular radio, and how is it different from other forms of mobile radio communication systems?

The Federal Communication Commission (FCC) has defined a cellular system as:

A high capacity land mobile system in which assigned spectrum is divided into discrete channels which are assigned in groups to geographic cells covering a cellular geographic service area. The discrete channels are capable of being reused in different cells within the service area.

3.1. Objectives in the design of cellular systems:

Large subscriber capability:

The system should be capable of serving many thousands of mobile users within the local serving area with a fixed no. of channels.

Spectrum utilization:

The multiple use of the same channels in cells within geographical separation ensure that the radio spectrum is used efficiently.

Nationwide compatibility:

The mobile users should be able to use their equipment even though they have drifted from their home base to other areas that are served by different cellular systems. A mobile user in this situation is called as roamer.

Adaptability to traffic density:

Since the traffic density will differ from one point in a cellular coverage area to another, the capability to cope with different traffic must be designed as inherent feature of the cellular system.

Quality of service and affordability:

The service has to be comparable to regular telephone service. Since cost and economic considerations play a major role, it must be affordable for general public.

3.2. Cellular geometry:

Cells are defined as individual service areas, each of which has an assigned group of discrete channels assigned to it from the available spectrum. A system can grow geographically by adding new cells. The Cells are to be Space – separated to avoid Co-channel Interference. But, at the same time, there should be a minimum overlap to provide seamless Handoff for a Roaming Subscriber. This is achieved by using Geometrically Patterned structures for the Cells. Irregular Cell Structures would be very difficult to be configured initially and upgraded in future. Had the Cells been Circular in shape, some areas would have no Coverage at all, unless heavy overlapping is used.

So, regular Polygon shapes – Equilateral Triangle, Square, Rectangle and Hexagon were the main choices initially. If the Point of Transmission is at the centre of a Cell, the maximum Coverage Area is available from a Hexagonal Cell. The main advantage of using Hexagonal Cells is, this layout needs minimum number of Cells to cover a given area i.e., lesser number of Transmitting Sites are needed. This in turn, reduces Installation and Maintenance Costs. In fact, we can cover 30 % more area than a Square Cell and 100 % more than a Triangular Cell, if we use a Hexagonal Cell.

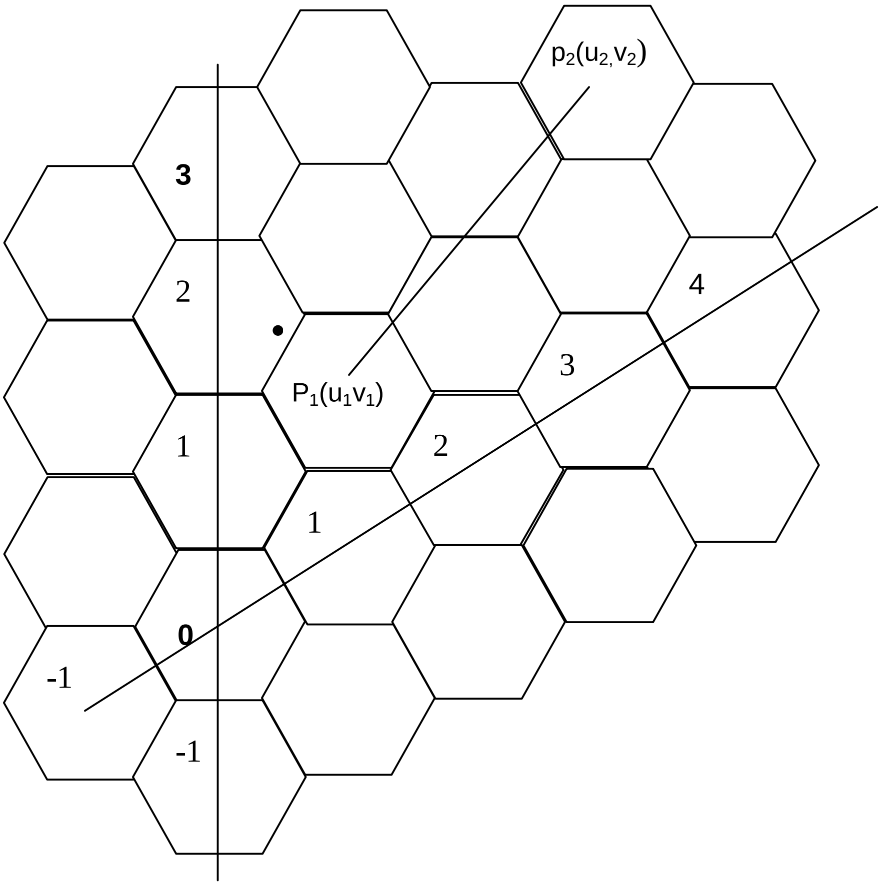


Fig.3.1. Cellular geometry

The most convenient coordinate system for hexagonal cellular structure are axes inclined at 60^0 angle, if two points have the coordinates (u_2, v_2) and (u_1, v_1) then the distance between them is

$$D=\sqrt{(u_2-u_1)^2 + (v_2-v_1)^2 + (u_2-u_1)(v_2-v_1)}$$

Assuming $(u_1, v_1) = (0,0)$, or the origin to be the center and restricting (u_2, v_2) to integer values (i, j), one obtains

$$D = \sqrt{(i + J)^2 - ij}$$

The normalized distance between two adjacent cells is unity (i = 1, j = 0) or (i = 0, j = 1).

3.3. Determination of no. of cells per cluster:

The actual center to center distance of the adjacent hexagon is $\sqrt{3R} = (2R \cos 30^0)$, where R is the center to vertex distance. The concept of number of cells per cluster is important for locating co channel cell with in the cellular structure.

To define this, consider the cellular structure shown in fig.3.2 Cells designated by the letter A are the six nearest co channel cells of the center cell A. It can be seen that these cells are located at vertices of the larger hexagonal cell of radius D. Vectors from the center to different peripheral cells A subtend an angle of $n60^0$ with respect to each other, where n assumes the values of 1,2,3,….. 6. From the law of cosines, the radius of the large cell D given by

$$D^2 = 3R^2 (i^2 + j^2 + ij) \qquad \text{(i)}$$

Since the area of a hexagon is proportional to the square of its radius, the area of a large hexagon is

$$A_{large} = k (3R^2)(i^2+j^2+ij) \qquad \text{(ii)}$$

Similarly, the area of a small hexagon is

$$A_{Small} = k(R^2) \qquad \text{(iii)}$$

Therefore,

$$A_{large}/A_{Smal} = 3(i^2+j^2+ij) \qquad \text{(iv)}$$

From the symmetry of fig.3.2. shown below, we can see that the large hexagon encloses the center cluster of N cells (N= 7 cells, center cell surrounded by six other cells) plus one third the number of cells associated with six other peripheral hexagons. Thus the total number of cells enclosed is equal to 3N.Since the enclosed area is proportional to the number of cells, A_{large} = 3N, and A_{Small} = 1. Thus,

$$N = (i^2+j^2+ij) \qquad \text{(v)}$$

Combining (i) and (v) , we can obtain D/R = √ 3N

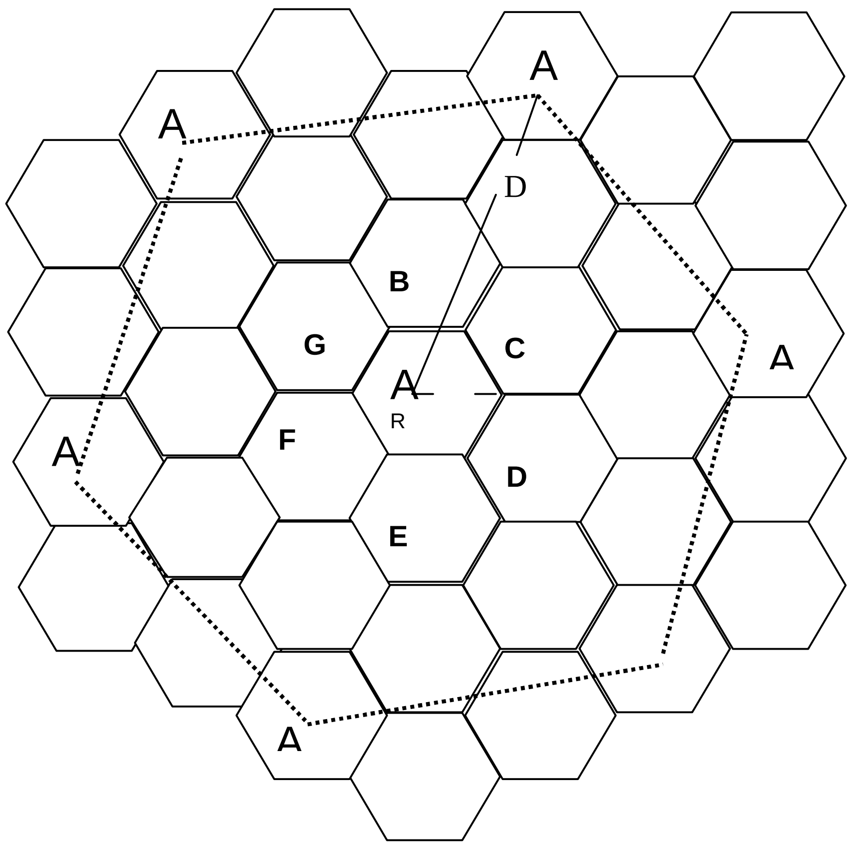


FIG. 3.2. Cell Clusters

The equation is important for estimating co channel interference. The above D/R ratio is known as co channel reuse ratio. The channel reuse ratio D/R is 4.6 for N=7.

3.4. Frequency re-use:

Frequency reuse allows the discrete channels assigned to a specific cell to be used again in any cell, which is separated from the assigned cell by enough distance to prevent co-channel interference. By using smaller Areas of Coverage and lower Power Output devices, Cellular technology has become much effective. The Channel Frequencies can be reused at least Two Cells away, thereby allowing a better Frequency Spectrum Management with minimum Interference. The Cells are generally grouped in 4, 7, 12 or 21 Cells. These groups are better known as Clusters.

The figure 3.3 shows cell structure using a Cluster of 7 Hexagonal Cells. The Frequency reuse concept is based on assigning a Group of radio channels to a Cell to cover a limited geographical area. Same Channels are not repeated in Adjacent Cells. That means a Channel is used only once in a Cluster. The coverage area of a Cell is called its Footprint. It should be noted that the Hexagonal Concept is only in Theory. In practice, it is more like a Distorted Circle

In this Cluster of Hexagonal Cells, the Centre-to-Centre Distance between Adjacent Cells is equal to 1.732 times the Distance between the Centre and Vertex of a Cell. The frequencies used in a Cell in a Cluster of 7 Cells each having the Distance R between the Centre and Vertex, can be reused at another Cell at a distance D, where, D = 4.6 R. The distance between the centres of two adjacent Cells is 1.732 R. The Ratio D / R is very important. If it is reduced, Co-channel Interference will increase and if it is increased, the Traffic Carrying Capacity will be reduced.

As long as all the Cells transmit equal amount of Power, Co-channel Interference will be independent of Transmitted Power of each Cell. In the diagram 3.2, Cells A to G at the centre form a Cluster. Around them a number of Hexagonal Cells are built to provide continuity of communication. Out of them, the six Cells marked A, are the Nearest Co-channel Cells (reuse of same frequency as in Cell A is possible) for the Cell A of central Cluster. There is a bigger Hexagon formed by the Cells having same Channel Frequencies.

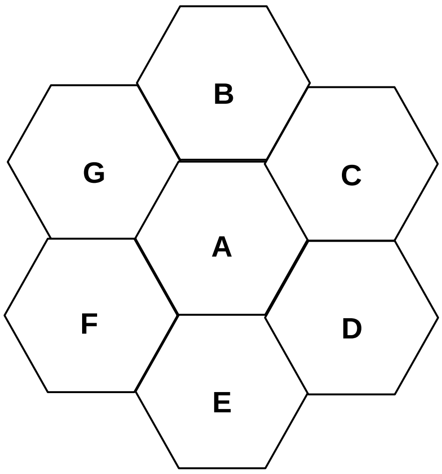


FIG.3.3. Channel distribution in a 7-cell cluster

Actual Frequency Reuse is implemented by dividing the total Frequency Spectrum into two or more groups of mutually exclusive Channels. A mobile handset with higher S/N Ratio is assigned a Channel with Lower Reuse factor group, while those with lower S/N Ratio gets a Channel from a Group having higher Reuse Factor. Typically Handsets nearer to the Cell-centre are allocated Channels from a Low Frequency Reuse factor.

In a Cluster of Cells, the Main Transmitter, Receiver and Antenna System (called Base Transceiver System or BTS) initially was located at the Centre of the Cell, the Antenna being Omni-directional.

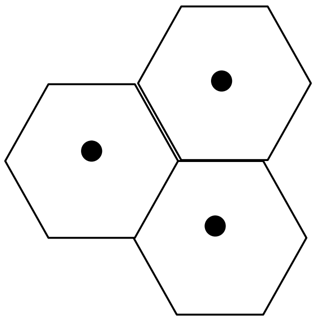


FIG.3.4. Location of BTS in a cell

In a Hexagonal Cell cluster, there is always interference from the six adjacent Cells. This Co-channel interference occurs at the Cell site as well as at the Mobile Handsets in the central Cell. A Mobile Set, at the edge of a Cell, receives weakest signal from its own Cell site. But it may be getting maximum Interference Signal from adjacent Cells. Thus, the S/I ratio may drop down from the required value of 18 dB. It would seem that the increase in D/R ratio is the solution. But this requires that the Cell Cluster size be increased to 9 or 12. Instead of increasing the number of Cells in the cluster, a Directional Antenna is a better solution for reducing the Co-channel Interference. Each Cell is now divided into 3 or 6 Sectors and uses 3 or 6 Directional Antennas at the Base Stations. In practice, Sectored Cells with 120° Beam Antennas are used as shown below.

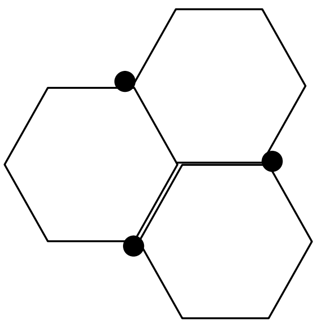


FIG.3.5.sectorised antenna

Sector Antennas reduce Co-channel Interference and improve the mean S/N ratio for a given Reuse Factor (from 18 dB to 24dB). But it reduces Trunking Efficiency, since each Sector gets less number of Channels. Practically, it does not create a problem, since less Interference can reduce the Reuse factor, thereby improving the Trunking Efficiency.

When the Traffic in a Cell increases to a situation where the Quality of Service (QoS) is affected, Cells can be divided in to smaller sizes. The Cell-splitting concept allows a Low Demand Area to be served by the Larger Cells and a High Demand Area to be Split in to Smaller Cells. The maximum Cell Radius is limited by the Transmitting Power generated by the Base Station as well as the Cellular Handsets, Antenna Gains and Topology of the Cell Area. Transmitting Power cannot be increased beyond a certain limit due to Interference from Noise and Power Consumption. When the Cells are split, the Cell Radius decreases.

A problem encountered in Cellular Communication is to provide continuation in Communication for a subscriber, who moves from one Cell to another Cell. No two adjacent Cells in a Cluster have the same Radio Channels. So, Re-allocation of Radio channels must be fast and smooth. This process is called Handoff.

Subscribers will cross Boundaries more often, causing frequent handoff of Calls between the Cells. This increases the Processing Load per Subscriber on the system. Practically, reduction of Cell Radius by 4 times increases Processing load approximately by a factor of 10.

Initially the Mobile Communication was based on Analog Technology and different countries were using different incompatible Radio Systems.

United States used a 50 MHz bandwidth in 824 to 849 MHz and 869 to 894 MHz, and the system had the provision of 832 Channels each of 30 KHz. The Channels were divided between two Service providers, each of which, handled 416 Channels, out of which, 21 Channels were used for Control and 395 Channels were for Voice Communications. The standard was called AMPS (Advanced Mobile Phone System). It used 8 KHz Frequency Modulation for Speech and binary Frequency Shift Keying at a rate of 10 Kb/s for Signalling. The system had the problems of Low calling capacity, Limited spectrum. Low Security and poor Data Communication facility.

Europe was having several standards like TACS (Total Access Communications System) in UK, Ireland, Italy, Spain and Austria, NMT (Nordic Mobile Telephone) in Scandinavia, C-450 in Germany and Portugal and RadioCom in France. All of these were using FM for Speech and FSK for Signalling.

Japan used a 56 MHz bandwidth – 925 to 940 MHz for Outgoing Calls from Mobile Stations and 870 to 885 MHz for Incoming Calls.

The various standards followed by different countries created a great problem for International Roaming Subscribers. This led to implementation of GSM Cellular Radio.

Objective:

1. The D/R ratio is known as co channel reuse ratio (T/F)
2. Frequency reuse allows the discrete channels assigned to a specific cell to be used again in any cell, (T/F)
3. The Channel Frequencies can be reused at least Two Cells away (T/F)
4. The groups of cells are known as Clusters (T/F)
5. If the Ratio of D / R is increased, the Traffic Carrying Capacity will be reduced. (T/F)
6. Co-channel Interference will be independent of Transmitted Power of each Cell (T/F)
7. Directional Antenna is used to increase the Co-channel Interference (T/F)
8. Sector Antennas reduce Co-channel Interference and improve the mean S/N ratio for a given Reuse Factor (T/F)

Subjective:

1. What is a cellular radio, and how is it different from other forms of mobile radio communication systems?
2. What is the objective of designing the cellular radio system?
3. Explain the frequency re use by 7-cell structure?

CHAPTER-4

GSM (GLOBAL SYSTEM FOR MOBILE COMMUNICATION)

4.0. Evolution of GSM:

The first mobile telephone service started in 1946, at St.Louis, USA.this was a manually operated service with restricted area for only few subscribers.

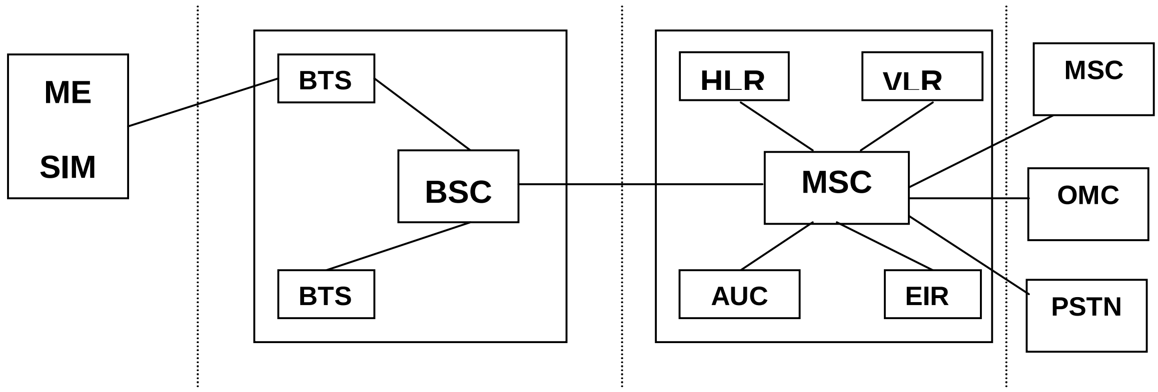
Between 1950 to 1970 mobile telephones evolved to be automatic. During 70s, Bell lab introduced a concept of cellular coverage. First cellular mobile system AMPS (Advanced Mobile Phone service) became a reality in US in 1979. Then a number of analog cellular systems such as NMT &TACS were introduced in 1980s. These systems were characterized by analog speech transmission, frequency modulation and nationwide coverage with hundreds of thousands of subscribers. These are known as 1G (first generation) systems.

During 1990s many digital mobile standards such as GSM, DAMPS, and CDMA were introduced in different countries. These are known as 2G (2nd generation) systems.

ETSI (European Telecommunication Standard Institute) is the body, which is primarily responsible for development of GSM.

4.1. GSM SYSTEM ARCHITECTURE:

The basic layout of GSM system architecture represents in terms of system entities. The GSM system entities represent groupings of specific wireless functionality. A reference model of GSM is shown below.



MS	BSS	NSS
MS-Mobile station	BSS-Base Station Subsystem	NSS-Network Switching Subsystem
ME-Mobile Equipment	BSC-Base station Controller	MSC-Mobile Switching Center
SIM-Subscriber Identity Module	BTS-Base Transceiver System	HLR-Home Location Register
		VLR-Visitor Location Register
		AUC-Authentication center
		OMC-Operation and Maintenance Center
		PSTN-Public Switched Telephone Network

FIG 4.1. GSM SYSTEM ARCHITECTURE

4.2. SYSTEM ENTITY FUNCTIONS:

4.2.1. Mobile station: The mobile station represents the terminal equipment used by cellular subscriber supported by GSM system. The MS consists of two entities

- Mobile Equipment (ME)
- Subscriber Identity Module (SIM)

Mobile Equipment normally called as Cell Phone Handset has a Transceiver, which is capable of tuning to all allocated Channels within the Traffic area. The major components of the Handset are – Transmitter, Receiver, Number Alignment Module, Logic Unit, Frequency Synthesizer, Antenna and the required software.

Subscriber Identity Module (SIM) is a smart card that holds information required to identify a particular subscription to a mobile service. The SIM card can be used with any approved GSM handset .The SIM card has the following components.

a. Central processing unit (CPU): The Central processing unit is the intelligence of the chip and performs all the mathematical functions and takes all the decisions required by the SIM.

b. Read Only Memory (ROM): Read Only Memory has sufficient memory to store the operating system, which is the set of commands that SIM understands. The contents of the ROM can be created as part of the manufacturing process. They are permanent and it will not possible to change them.

c. Random Access Memory (RAM): The Random Access Memory is an area of volatile memory and its contents are lost each time the power is turned off. The memory of the RAM can be at least 256 KB. It is used to store temporary system flags, buffer incoming data as a scratch pad for calculations.

d. Electrically Erasable programmable Read Only Memory (EEPROM):It stores all the application data such as the operator's specific parameters and the subscriber's data.

Functions of SIM card: The functions of SIM card are

- User authentication
- Authentication of the validity of the MS when accessing the network
- Storage of subscriber related information, which can be; data during administrative phase or temporary network data.

4.2.2. Functions of MS: The mobile station performs the following functions

- Radio transmission/reception
- Radio channel management
- Speech coding/decoding
- Radio link error protection
- Flow control of data
- Rate adaptation of user data to the radio link
- Mobility management
- Performance measurements of radio link.

4.3. Base Station Subsystem (BSS): Base Station Subsystem consists of two entities, Base Transceiver Station (BTS) and Base Station Controller (BSC).

4.3.1. Base Transceiver Station (BTS) is the equipment which facilitates the wireless communication between user equipments (UE) and the network.

BTS forms part of the Base Station Subsystem (BSS) developments for system management. It may also have equipments for encrypting and decrypting communications, spectrum filtering tools (band pass filters) etc. Antennas may also be considered as components of BTS in general sense as they facilitate the functioning of BTS. Typically a BTS will have several transceivers (TRXs) which allow it to serve several different frequencies and different sectors of the cell (in the case of sectorised base stations). The basic structure and functions of the BTS remains the same regardless of the wireless technologies.

A BTS in general has the following units*:*

- TRX : Transceiver ; - Quite widely referred to as DRX (Driver Receiver), Basically does transmission and reception of signals and Also does sending and reception of signals to/from higher network entities (like Base Station Controller)
- Power Amplifier : Amplifies the signal from DRX for transmission through antenna, May be integrated with DRX
- Combiner :- Combines feeds from several DRXs so that they could be sent out through a single antenna, For reduction of number of antenna used
- Duplexer : For separating sending and receiving signals to/from antenna, sending and receiving signals through the same antenna ports (cables to antenna)
- Antenna Antenna is considered as part of BTS
- Alarm Extension System : Collects working status alarms of various units in BTS and extends them to Operations and Maintenance (O&M) monitoring stations

The functions performed by the BTS are:

- ♦ Radio Transmission in GSM Format, employing Frequency Hopping techniques and Spatially diverse Antennas.
- ♦ Implementation of Equalization Algorithms, to counter the effects of Multiple Paths.
- ♦ Coding and Decoding of radio Channels.
- ♦ Encryption of transmission Data Streams.
- ♦ Control of the Protocols, governing Message Transmission in the Radio Data-link Layer.
- ♦ Transmission of Signaling Messages.
- ♦ Operations and Maintenance of the Base Transceiver station.

GSM specific Speech Encoding and decoding are done in the TRAU (Transcoder Rate Adapter Unit) in BTS.

4.3.2. Base Station Controller (BSC) controls the activities of all the BTS in a Cluster as shown below. Base Station Controller reserves the Radio Channel Frequencies, controls Call hand-over between Base Transceiver stations under its jurisdiction and pages the Mobile Stations for an incoming (Mobile Terminated Call).

A BTS is controlled by a parent Base Station Controller via the Base station Control Function (BCF). The BCF is implemented as a discrete unit or even incorporated in a TRX in compact base stations. The BCF provides an Operations and Maintenance (O&M) connection to the Network management system (NMS), and manages operational states of each TRX, as well as software handling and alarm collection.

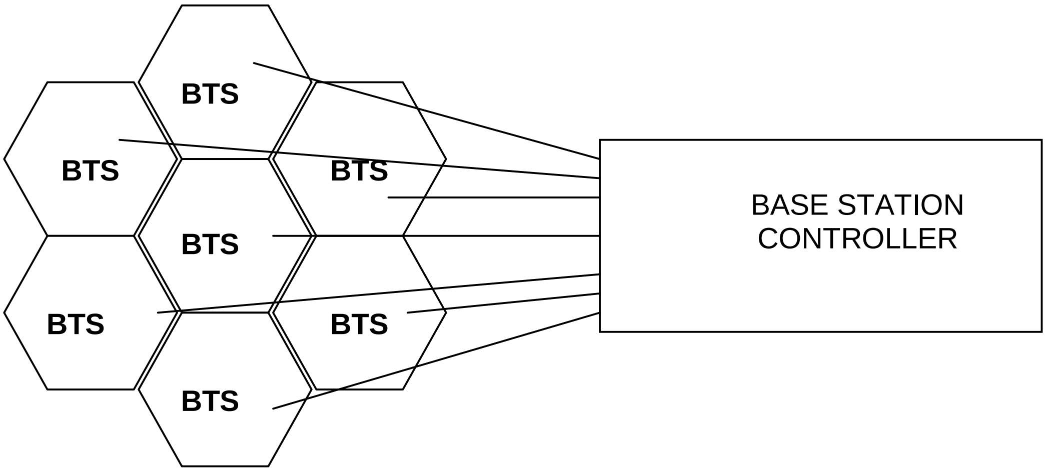


Fig.4.2. BASE STATION CONTROLLER

4.4. Network and Switching Subsystem (NSS):

It performs the Switching functions of GSM and consists of Databases needed for Subscriber and Mobility Management. Its main feature is to manage the communication between the Mobile Station and other users of the Cellular Network.

- Mobile Service Switching Centre (MSC): The Switching part, is controlled by the Mobile Service Switching Centre (MSC). It monitors Subscriber Mobility and manages Resources for handling and updating Location Information of the Subscribers. Seamless Hand-over of the established Calls is also controlled by MSC. Connections to external Networks like PSTN, PLMN and Intelligent Networks etc. are also controlled by MSC. An MSC, which provides connection to Networks outside the area under the MSC, is generally known as Gateway MSC.

- Home Location Register (HLR): Subscriber relevant data are kept in a Database called Home Location Register (HLR). It also contains information regarding real time location of the Roaming Subscriber, which is passed to the MSC for routing incoming Calls to the Mobile Station. Administrative updating of the Subscriber Data, by the Service Provider is kept in HLR. IMSI, ISDN Number and VLR Address are also kept in HLR. As soon as the Mobile Station crosses a Cell boundary (also known as Location Area), this information is updated in the HLR. Thus, HLR is the most important Database in the GSM structure.

- Visitor Location Register (VLR) dynamically stores Subscriber Information, when a Mobile Station is in the Location Area covered by the VLR Whenever a Roaming Subscriber enters in an area controlled by an MSC, the information is passed to the VLR, which recognizes the Subscriber as an outsider for the MSC. If the Subscriber is allowed to Roam, VLR finds the original HLR of the Subscriber and downloads all relevant information for the Subscriber from it.

- ♦ Equipment Identity Register (EIR), which stores Identifications of all Devices, registered in the particular MSC. Any Cell Phone can be used fraudulently by inserting an authentic SIM Card. but as soon as a report is registered that a handset is stolen or misplaced, EIR Database can be updated to render the handset useless. A list of all valid IMEI is kept in EIR along with the malfunctioning Mobile Stations.
- ♦ Authentication Centre (AUC), which protects User Identity and allows a Secured Transmission. Authentication Algorithm and Encryption Keys are contained in AUC and it generates Random Numbers for User Authentication in the HLR.
- ♦ Operation and Maintenance Centre (OMC), which monitors and controls all other components of GSM. Its main functions are – Traffic Monitoring, Subscriber as well as Security Management and Status report Generation.

4.5. GSM RADIO SPECTRUM

There are three main frequency bands used in GSM viz,

GSM-900
GSM-1800
GSM-1900

Depending upon the availability, the band of frequency spectrum will be allocated to different operators.

One of the frequency spectrum used in GSM is GSM-900 band in which, 890-915MHz for Up link (MS to BTS) and 935-960 MHz for Down link (BTS to MS) for full duplex communication. From the given frequency band the number of available RF channels will be 124 with a channel spacing of 200KHz. And the Duplex spacing will be 45MHz (between TX and RX).

4.6. Multiple Access techniques in GSM

The objective of the multiple access techniques is to combine signals from different sources into a common transmission medium in such a way that, at destinations, the different channels can be separated without mutual interference. In other words, multiple access systems permit many users to share a common medium in the most efficient manner. There are three basic types of multiple access techniques;

- Frequency division multiple access (FDMA)
- Time division multiple access (TDMA) and
- Code division multiple access (CDMA).

In FDMA, users share the radio spectrum in frequency domain. The user is allocated a part of the frequency band, which is used throughout conversation. Users are separated in frequency.

In TDMA, the users share the radio spectrum in time domain. An individual user is allocated a time slot during which he accesses a part of frequency. Users are separated in time.

In CDMA, each user is assigned a unique pseudorandom code and access the frequency time domain uniquely.

In GSM to achieve a high spectral efficiency in the network the combination of FDMA and TDMA is used.

In FDMA the bandwidth is divided into number of frequency channels with channel spacing of 200KHz and in TDMA each channel is assigned into eight timeslots.

The following figure shows the concept of FDMA and TDMA method.

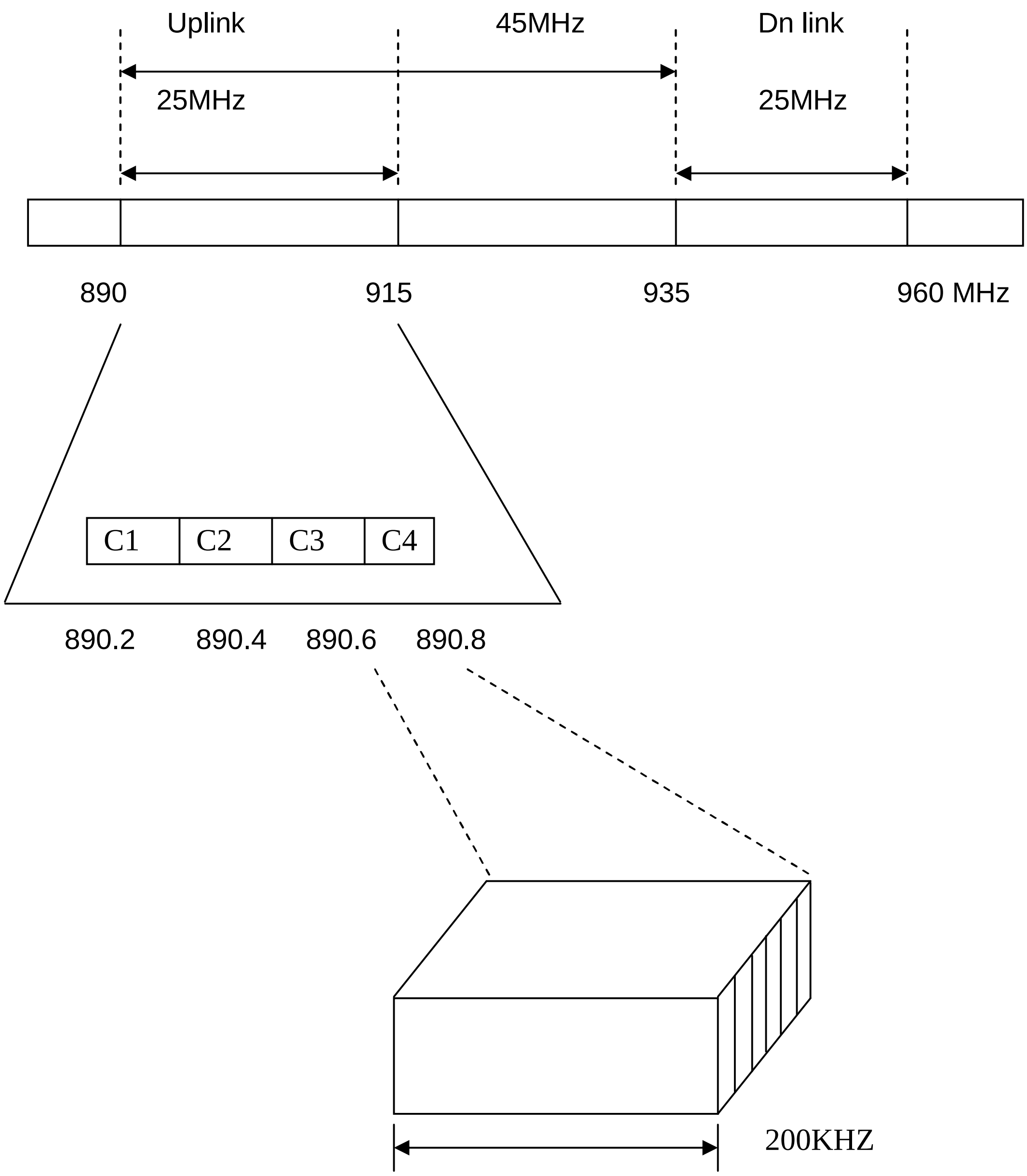


FIG.4.3. Concept of FDMA and TDMA

4.7. GSM RADIO INTERFACES

For the connection of the different nodes in the GSM network, different interfaces are defined in the GSM specifications

GSM has the following Radio Interfaces:

- U_m Interface,
- A_{bis} Interface,
- A Interface

U_m Interface

U $_m$ –interface is also called as Air interface. The Air Interface is the interface between the BTS (Base Transceiver Station) and the MS (Mobile Station). The air interface is required for supporting Universal use of any compatible mobile station in a GSM network.

It is the most vital Radio Interface of the GSM System. The Physical Layer, consisting of a number of Physical Channels, accessible via FDMA and TDMA, is interfaced to Data Link Layer in both Mobile Station and base Stations. Each Physical Channel, in turn, supports a number of Logical Channels, used in Traffic and Signaling handling.

The Physical Layer is employed in Bit-Stream Transmission on the Radio Interface. The Data Link Layer performs Multiplexing, Error Control, Flow Control and Segmentation of Data. The Radio Resource Layer manages Radio Connection Establishment, Control, Release and Hand-over between Mobile Station and Base Transceiver Station.

A_{bis} Interface

The A $_{bis}$ -interface is the interface between the BSC (Base Station Controller) and the BTS. The interface comprises traffic and control channels. Functions implemented at the A bis -interface are Voice-data traffic exchange, Signaling exchange between the BSC and the BTS and transporting synchronization information from the BSC to the BTS

This Interface controls Traffic Channel Transmission and Radio Channel management. It supports 64 Kb/s Speech or Data for a full or Half-rate Radio Traffic Channel and 16 Kb/s Signaling Information between BTS and BSC. Traffic Management handles Transparent Messages, which need not be analysed by the BTS and Non-transparent Messages.

A Interface

The A-interface is the interface between the BSC and the MSC. The Physical Layer is a 2 Mb/s Digital Connection. The Signaling uses MTP (Message transfer Part) and SCCP (Signalling Connection Control Part) of Signaling System 7. BSS Management Application Part looks after Radio Resource handling in BSS and BSS Operation and Maintenance Application Part supports all Operation and Maintenance works of BSS.

4.8. GSM LOGICAL CHANNELS

A Cellular Radio system uses two types of Channels –

- ♦ Duplex Traffic Channels to carry Two-way Voice Communication.
- ♦ Duplex Control Channels to transfer Information for Call Setup and Call Breakdown.

One or more logical channels can be transmitted on a physical channel. There are different types of logical channels. The type of logical channel is determined by the function of the information transmitted over it.

The following are the logical channels:-

- Traffic channels
- Control channels (signaling channels)

Traffic channels:

The Traffic Channels carry Speech or User Data in both MS to BTS and BTS to MS directions. The Traffic Channels can work in Full Rate or Half Rate.

Traffic channel using full-rate transmission

A full-rate channel operates at 22.8 Kbit/s.

13 Kbit/s are used for speech transmission and the rest is basically used for error protection.

For data transmission, 12, 6 or 3.6 kbps is used. These are compatible respectively to the existing 9.6, 4.8 and 2.4 kbps PSTN and ISDN services.

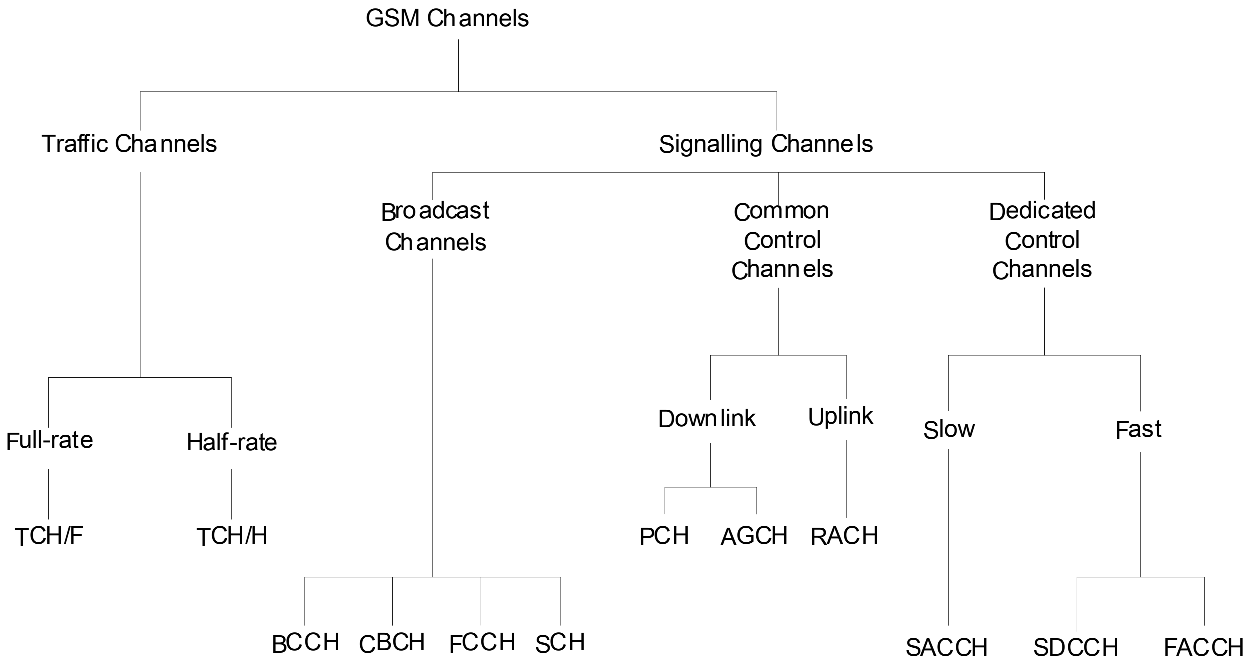
The following table may be referred:

	Useful data	Error Protection	Total
Traffic channel:			22.8 kbit/s
- Voice (full-rate)	13.0 kbit/s	9.8 kbit/s	
- Data	2.4 kbit/s	20.4 kbit/s	
	4.8 kbit/s	18.0 kbit/s	
	9.6 kbit/s	13.2 kbit/s	
	14.4 kbit/s	8.4 kbit/s	
Control channel:			0.95 kbit/s
Idle frame:			0.95 kbit/s
Total			24.7 kbit/s

Control Channels

The main function of the control channels is to transfer signaling information. They are sub divided into three categories

- Broadcast channels
- Common control channels
- Dedicated control channels



Broadcast Channels are point to multipoint channels, the information distributed over the broadcast channels helps the mobile stations to orient themselves in the mobile radio network. These are point to multipoint channels defined for down link direction i.e. BTS to MS. These are further classified into four.

Broadcast Control Channel (BCCH),
Frequency Correction Control Channel (FCCH)
Synchronization Channel (SCH).
Cell broadcast channel (CBCH)

BCCH: Through this channel, the mobile is informed about the system configuration parameters.

FCCH: To communicate with the BTS the mobile must tune to the BTS. The FCCH transmits a constant frequency shift of the radio frequency that can be used by mobile for frequency correction.

SCH is used to time synchronize the mobile stations. The data on this channel carries the TDMA frame number and the base station identity code.

CBCH: is used for the transmission of the general accessible information in a cell, which can be polled by MS.

Common Control Channels are Point to Multi-point Control Channels, which can be operated in one direction of transmission, either in uplink or in down link direction. They are used to carry Management Function Signalling Information. There are two CCCH between BTS to MS. They are Paging Channel (PCH) and Access Grant Channel (AGCH). The former is used for paging the Mobile stations during an Incoming Call. AGCH is used for assigning an MS to a Dedicated Control Channel. There is Random Access Channel (RACH) from MS to BTS for requesting access to DCCH.

Dedicated Control Channels are full duplex point-to-point channels used for Signalling and Control between BTS and certain MS. These are of three types

SACCH (slow associated control channel); is used for transmission of signaling data, radio link supervision measurements, transmit power control and timing advance data.

FACCH (Fast associated control channel) is used as a main signaling link for the transmission of signaling data (handover commands) It is also required for call setup and release.

SDCCH (Stand alone dedicated control channel) is used for signaling in higher layer. It is used for service requests, location updates, subscriber authentication etc.

Multiplexing Logical Channels into Physical Channels

Several of the above-mentioned types of logical channels can be transmitted over one single physical channel (timeslot). The GSM specifications 05.02 specify several combinations of channel types (the sequence of logical channels is fixed).The order of the logical channels depends on the channel combination.

The channel combinations are:

1. TCH/F + FACCH/F + SACCH/F
2. TCH/H + FACCH/H + SACCH/H
3. (TCH/F + FACCH/F + SACCH/F) or (TCH/H + FACCH/H + SACCH/H)
4. FCCH + SCH + CCCH + BCCH
5. FCCH + SCH + CCCH + BCCH + SDCCH/4 + SACCH/4
6. CCCH + BCCH
7. SDCCH/8 + SACCH/8

The CCCH is a channel that carries both the PCH and the AGCH on the downlink, and the RACH on the uplink.

The extensions “/4” and “/8” in the above-mentioned terms mean, respectively, that four and eight logical channels are mapped onto one physical channel (timeslot).

4.9. Digital transmission in GSM:

4.9.1. Speech coding process in MS: GSM mobile phone systems use digital techniques in various forms to transmit the voice signals of a phone call. This requires that the voice signals have to be converted into digital format. The conversion into a digital format is accomplished by using analog to digital converter (ADC). The ADC samples the waveform at fixed time intervals and generates a binary representation of the waveform. The actual voice quality is dependent upon two basic factors viz, the sampling rate and the number of bits in each sample. If we use normal PCM concept the output data rate will be 64Kbps. The amount of this data rate to send on a cellular channel is too high to accommodate. To overcome this problem, Vocoders will be used. These are able to analyze and compact the data representing the speech, so as, it requires lower data rates. To achieve this level of performance they use complex algorithms to analyze the speech. Vocoder is a digital hardware block, which will do the speech analysis and synthesis. It use a technique called linear prediction coding with regular pulse excitation (LPC RPE). The 64 kbps PCM is transcoded from the standard A-Law (quantized 8-bit/sample stream into a linearly quantized 13 bits/sample stream, giving rise to a 104 kbps bit rate)

The 104 kbps stream is fed into the RPE-LTP full-rate speech encoder, which takes the 13-bit samples in blocks of 260 samples (every 20ms).The RPE-LTP encoder produces 260 bits in every 20ms.

4.9.2. Channel coding:

The next step to speech coding is channel coding. In GSM it is recognized that some bits are more important than others. If some bits are missed or corrupted, as it is more important of voice quality than others. Accordingly the different bits are classified as

• Class 1a	50 bits	Most important and sensitive to bit errors.
• Class 1b	132 bits	Moderately sensitive to bit errors
• Class 11	78 bits	Least sensitive to bit errors.

Class 1a bits are given a 3-bit CRC so that errors can be detected. This makes a total length of 53 bits .If there are any errors; the frame will not be used and discarded. In its place a version of previous correctly received frame is used. These 53 bits together with the 132 bits with a 4-bit tail sequence are entered into a half rate convulsion encoder. The total length is 189 bits. The encoder encodes each of the bits that enter as two bits.

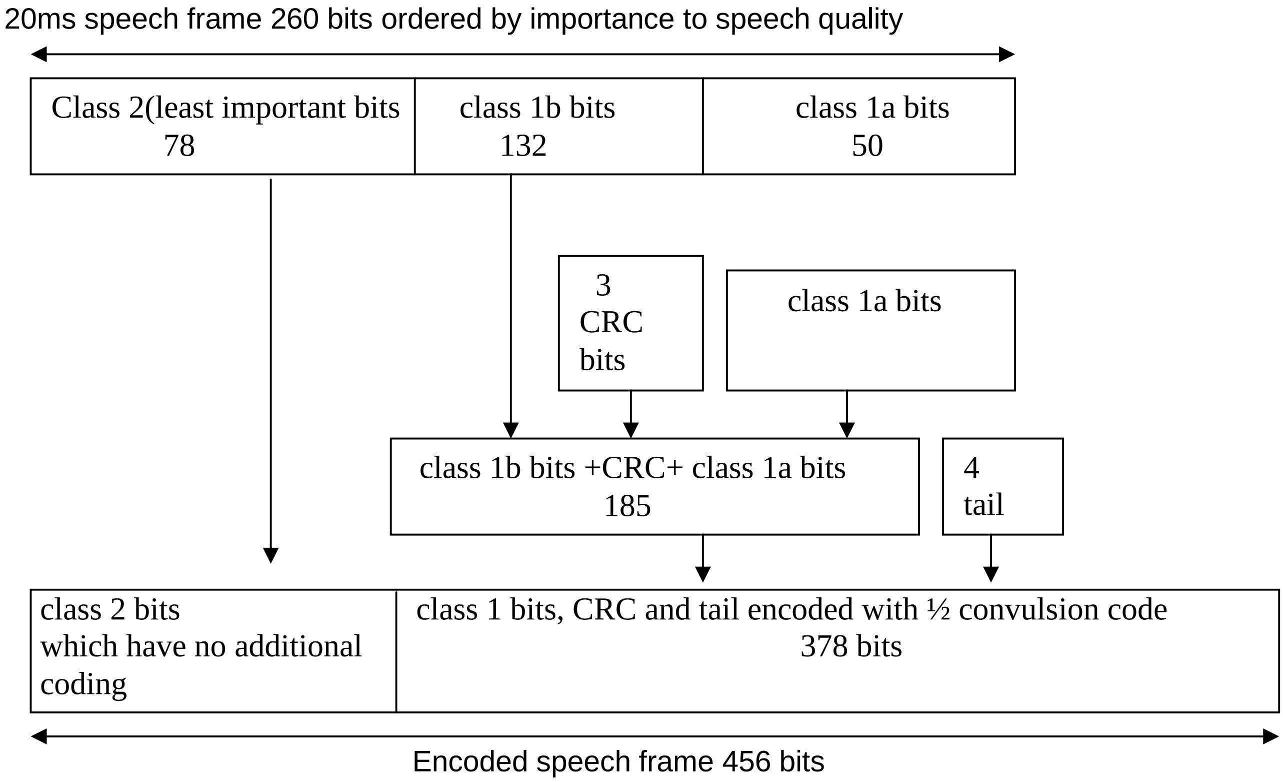


FIG.4.4.Channel coding for GSM speech coder

As a result, the output from the encoder is of 378 bits. The remaining 78 bits are considered as least sensitive to errors, so they are not protected and are simply added to data. (50+3+132+4=189, 189X2=378, 378+78=456 bits) In this way, every 20ms speech sample generates a total number of 456 bits. Accordingly the overall bit rate is 22.8Kbps.

4.9.3 Bit interleaving: The aim of interleaving is to distribute sub blocks of data obtained by channel coding in such a way that one data block is distributed over several TDMA frames. The sub blocks are rearranged for this purpose and transmitted in a different order.

- The 456 bit blocks from the channel encoder are fed to the bit interleaver where they are split into eight sub blocks of 57 bits.
- and these blocks are transmitted as eight consecutive bursts.

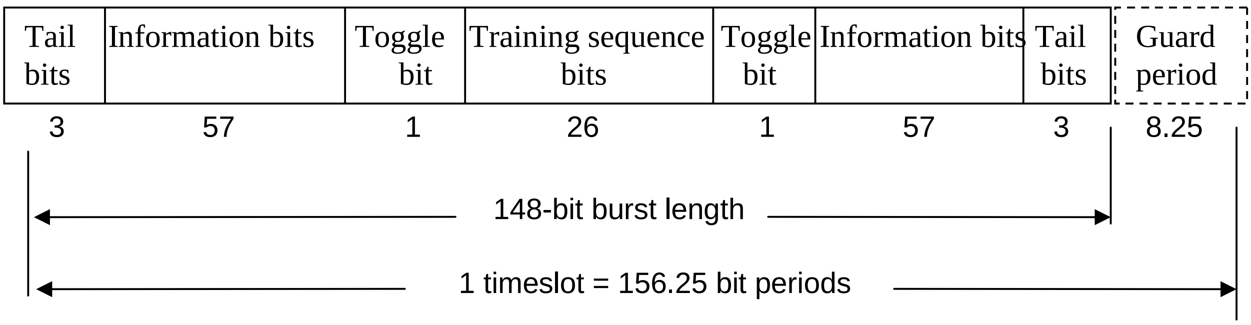


FIG.4.5.GSM normal burst

Definition of a burst: The burst is the physical content of as time slot. GSM radio transmission is accomplished by sending data in bursts.

A burst consists of sub parts viz, training sequence, encrypted, tail, guard period and stealing flag bits. A fixed bit pattern of 26 bits called training sequence is known by both MS and BTS. It is used to train the MS in predicting and correcting the signal distortions. Encrypted bits (information bits) represent the useful bits serving for speech, data transmission.

Tail bits (flag bits) define, the beginning and end of the burst. Guard period between two consecutive bursts is necessary for switching the transmitter ON and OFF, and timing advance.

The toggle/stealing flag bits: The network has the option to use the information bits in the normal burst to send signaling data as needed. By setting a flag, using the stealing flag bits, the receiver can distinguish between user data or signaling data.

Types of bursts:

- Normal burst
- Dummy burst
- Access burst
- Synchronization burst
- Frequency correction burst.

Normal burst is the most frequently used burst used for transmission of user data/signaling data (on TCH). The dummy burst has the same structure as that of normal burst. It is transmitted in idle time slots on the BCCH, Access burst is used for initial connection setup between MS and BTS. Synchronization bursts are used to synchronize MS with BTS in time. Frequency correction burst is used by MS to correct frequency.

4.10. GSM TDMA FRAME STRUCTURE:

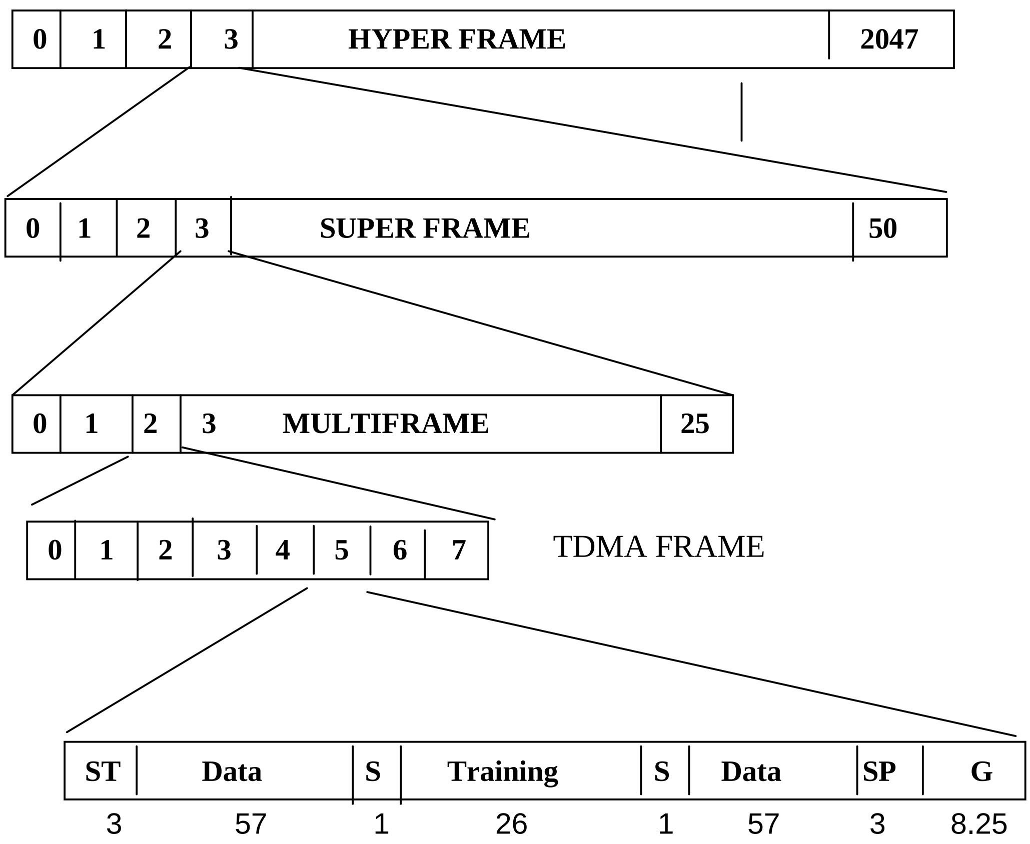


FIG.4.6. GSM TDMA FRAME STRUCTURE

The GSM specifications define several types of frames, which are:

TDMA frame: A TDMA frame consists of eight timeslots (physical channels). The length of a timeslot is 0.577 ms. The length of a TDMA frame is therefore 4.615 ms. The data on a timeslot is transmitted in bursts, the length of a timeslot is often expressed in BP (Burst Period); 1 BP represents the length of 1 timeslot.

26-TDMA multiframe: This multiframe is defined as a succession of 26 TDMA frames, and corresponds to the 26 x 8 BP or 120 ms cycle used in the definition of the TCH/F and TCH/H.

1-TDMA multiframe This multiframe is defined as a succession of 51 TDMA frames, and corresponds to the 51 x 8 BP cycle used in the definition of the TCH/F, TCH/H and of the common channels.

Super frame: The super frame is a succession of 51 x 26 TDMA frames (6.12 sec), and corresponds to the smallest cycle for which the organization of all channels is repeated.

Hyper frame: The hyper frame is the numbering period. It is 2048 x 51 x 26 x 8 BP long, or 3 hours, 28 minutes, 53 seconds and 760 milliseconds. It is a multiple of all previously cited cycles, and determines all the cycles in the transmission of the radio path. It is in particular the smallest cycle for frequency hopping and for ciphering.

1TDMA Frame	= 8 time slots = 4.615 ms 1 time slot= 0.577 ms
1 traffic multiframe	= 26 TDMA frames = 120 ms (26 x 4.615)
1 control multiframe	= 51 TDMA frames = 235.365 ms
1 super frame	= 51 traffic multiframes = 6.12 s
1 super frame	= 26 control multiframes = = 6.12 s
1 hyper frame	=2048 super frames 3 hours 28 minutes 53.76 s

4.11. GSM modulation:

GSM uses a form of phase modulation known as Gaussian filtered minimum shift keying (GMSK).

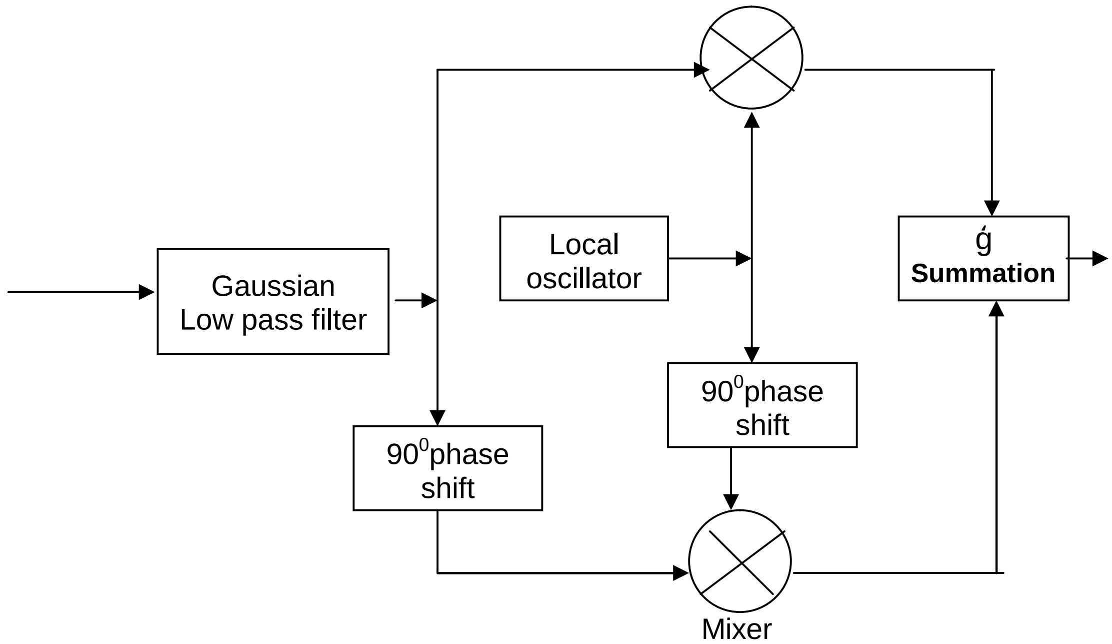


FIG.4.7. Block diagram of quadrature modulator for GMSK

The input data is differential encoded and is passed to a filter which has gaussian impulse response. Spectral efficient digital modulation requires prefiltering the digital data before modulation. By rounding off the sharp edges of the rectangular waves, the bandwidth is substantially reduced. After filtering the data will be applied to modulator circuit. There are different types of modulator circuits, in which one of the modulator called Quadrature modulator is used. The term quadrature means that the phase of the signal is in quadrature, or 90^0 to another one. This modulator uses one signal that is said to be in phase and another that is in quadratuer to this. In view of the quadrature and in phase elements, this type of modulator is often called as I-Q modulator. When using this type of modulator, the modulating index can be maintained exactly at 0.5 without the need of any settings or adjustments. This makes it much easier to use and capable of providing the required level of performance without need for the adjustments. A further advantage of GMSK is that it can be amplified by a nonlinear amplifier and remain undistorted. This is because there are no elements of signal that are carried as amplitude variations and it is therefore more resilient to noise than some other forms of modulation.

GMSK has the following features that make it suitable for radio applications.

- Constant envelope, which allows the utilization of efficient transmitters using power amplifiers in a saturation mode.
- Compact output power spectrum, which means narrower main lobe and lower side lobe peaks keep the adjacent channel interference at a low level.
- Good bit error performance.

The data corresponding to a call, flows between MSC and MS via A, M, Abis and U_m interfaces. A interface is used to carry the 64 Kbps speech data and signaling information between MSC and BSC. It shows the compression of four A links into one M link. Time slot 0 is used for synchronization purpose, time slots 1 to 15 and 17 to 31 are used to exchange 64 Kbps speech data and time slot 16 is used to transfer signaling information. In GSM network implementation of Lucent technologies, the BSC includes the Trans coder Rate Adaptor Unit (TRAU). The TRAU adapts the transmission bit rate of the A interface (64Kbps) to the A_{bis} interface (16Kbps). The interface between the physical BSC and TRAU is called as M interface. The M interface is multiplexed and transcoded A interface. The TRAU encodes the 64Kbps PCM signal to a 16Kbps signal, transcoding four channels of an A interface into one channel of M interface.

4.12. Mapping of data between different interfaces:

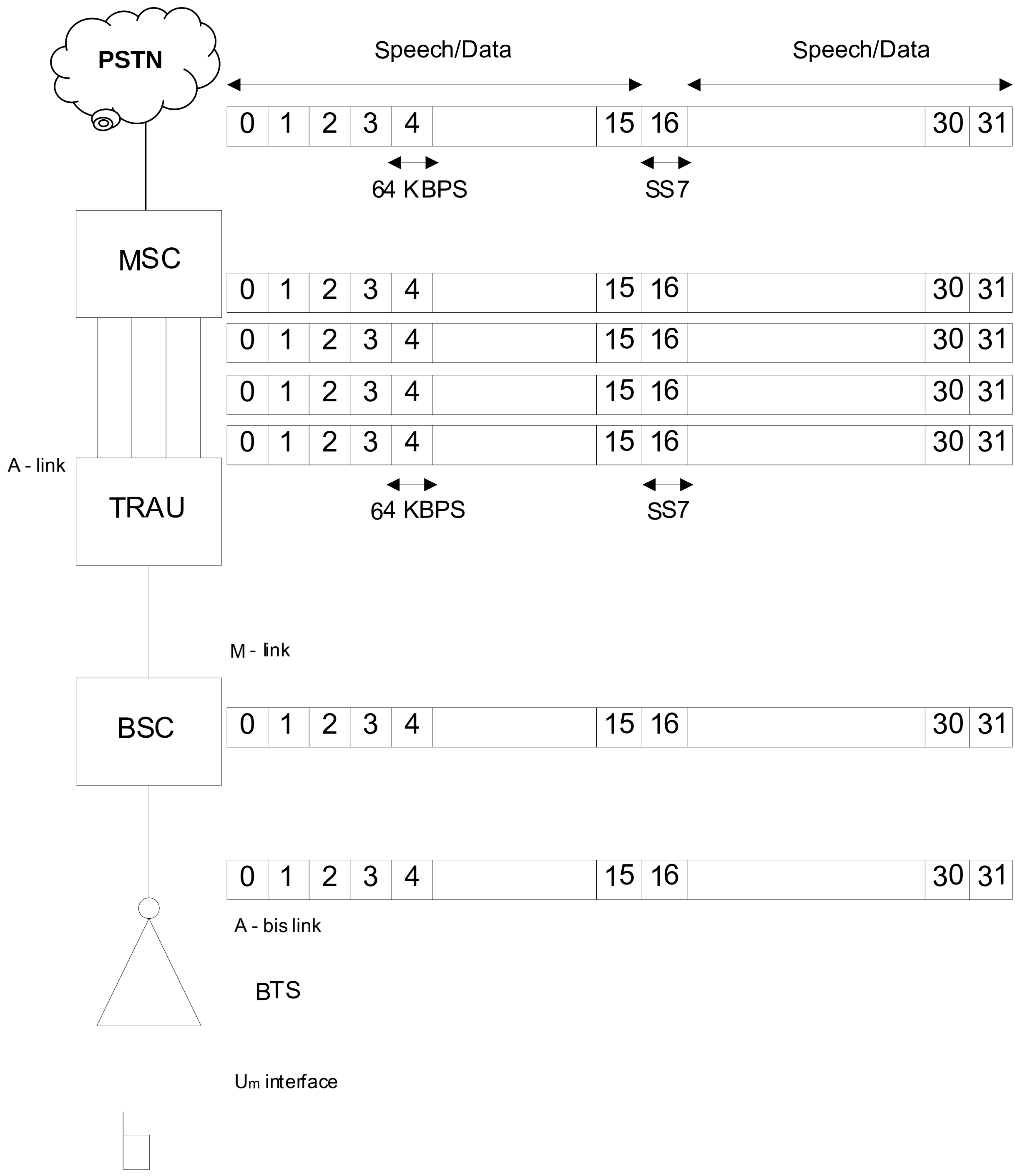


FIG.4.8. Mapping of data between different interfaces

4.13. GSM protocols on the interfaces:

Each interface between the GSM system entities is an open interface, which is defined in the GSM specifications. The signaling system SS7 is used in GSM. The following figure shows the scheme of GSM signaling architecture.

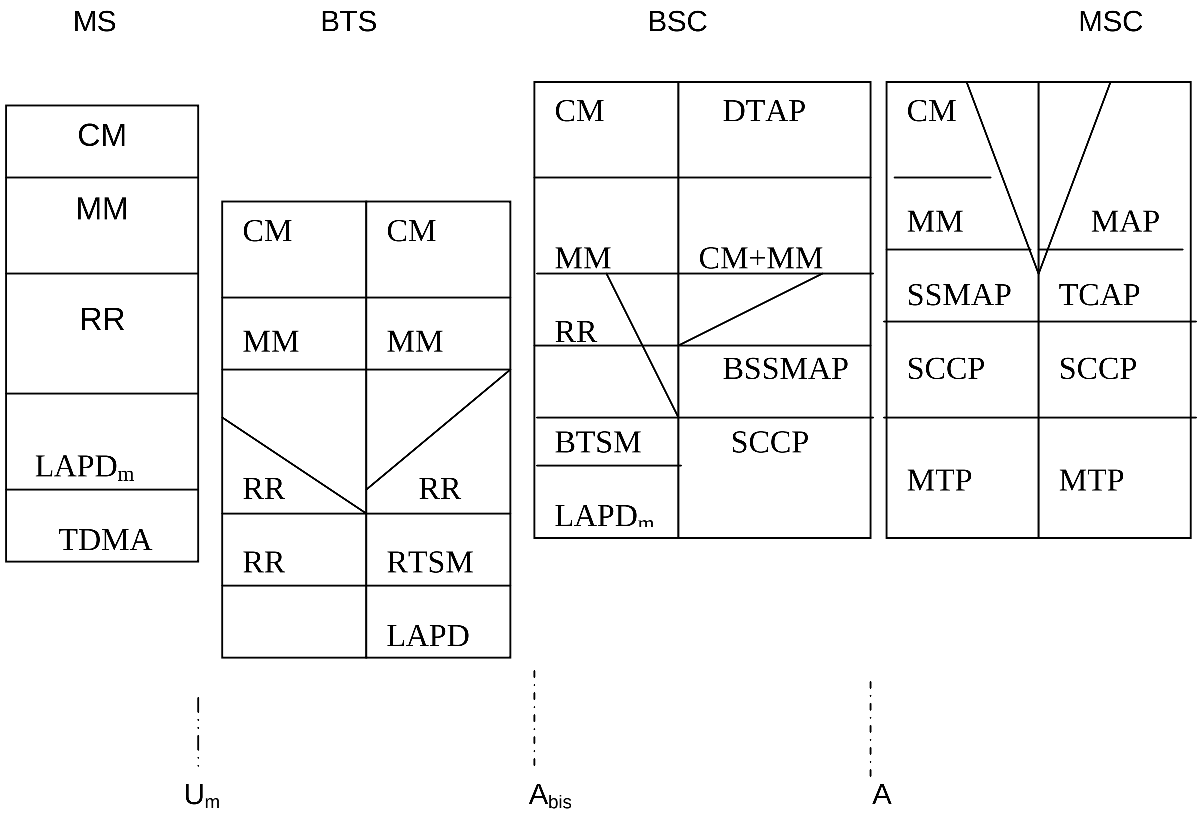


FIG.4.9.GSM Signaling protocol

MS-BTS interface (U_m): It is the radio or air interface consisting of three protocol layers

- Layer 1 Physical layer is the radio sub system layer defines the timeslot on the carrier.
- Layer 2 data link layer ($LAPD_m$) modified link access protocol for data channel. It is the signaling for GSM air interface.
- Layer 3 Network layer consists of 3 protocols

  i) Radio resource management: It is used for MS and BSC communication .It comprises paging, radio channel access, handover and radio signal control procedures.
  ii) Mobility Management: It is used for communication between MS and MSC. It handles roaming and authentication procedures.
  iii) Call management: It is used for communication between MS and MSC to call establishment, call release and access to services.

BTS-BSC A_{bis} interface: consists of three protocol layers

- Layer 1 Physical layer
- Layer 2 Data layer
- Layer 3 BTSM BTS management part is used to exchange control, information between the BSC and BTS.

BSC and MSC A interface: this protocol specifies the transport and signaling portions.

The application parts are: -

- Transport part – Message transfer part (MTP)
- Application part - BSS application part.
- Signaling part – Connection less and connection oriented signaling connection control point (SCCP)

BSSAP includes two parts

- BSS Management Application part supports all procedures between BSS and MSC that are related to resource management, maintenance and handover control.
- DTAP: Direct transfer application part provides the protocol for the interface between MS and the MSC .The DTAP is not interpreted by BSS.DTAP includes two classes of messages; mobility management and call management.

MSC – VLR interface (B): The VLR is an integral part of MSC.B interface is implemented as an internal interface since the VLR always resides within the serving MSC.

MSC – HLR interface (C): This interface uses the MAP protocol to retrieve routing information when calls to MSs are being setup through the MSC.

VLR – HLR interface (D): It use the MAP protocol to support the transfer of subscriber information and instructions relative to the cancellation or modification of the subscriber information.

MSC – MSC interface (E): The signaling on the E interface consists of two parts-

- Trunk signaling ISDN user part (ISUP)
- Inter entity signaling Uses the MAP protocol for inter MSC handovers.

MSC –EIR interface (F): It uses MAP protocol to retrieve MS equipment identity related information from the EIR to determine whether or not to provide service to MS.

VLR- VLR interface (G): It uses MAP protocol to support the transfer of subscriber information between VLRs when the associated MS moves from one VLR service area to another.

HLR – AUC interface (H): Access to the authentication data base is always accomplished through the HLR. The HLR interface to AUC is implemented as an internal interface in the MSC.

X.25 BSS and OMC interface: Allows communication between remote devices. This is a packet switched data network protocol that allows both data and control information flow between host and network.

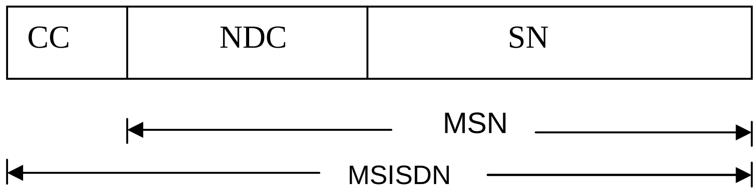
4.14. Mobile subscriber numbering plans:

There are four basic types of numbering plans for mobile subscribers.

i) MSISDN (Mobile subscriber’s ISDN number)
ii) IMSI (International mobile subscriber’s identity)
iii) TMSI (Temporary mobile subscriber’s identity)
iv) MSRN (Mobile subscriber’s roaming number)
v) IMEI (International Mobile subscriber’s equipment identity)

MSISDN (Mobile subscriber's ISDN number): It is the directory number allocated to the subscriber. The number consists of country code (CC) of the country in which the mobile station is registered, followed by national mobile number, which consists of Network destination code (NDC) and subscriber number (SN).

The maximum possible digits for MSISDN are limited to 15. In which CC may be 1 to 3 digits long allotted internationally. NDC and SN are of variable length and they together constitute MSN.

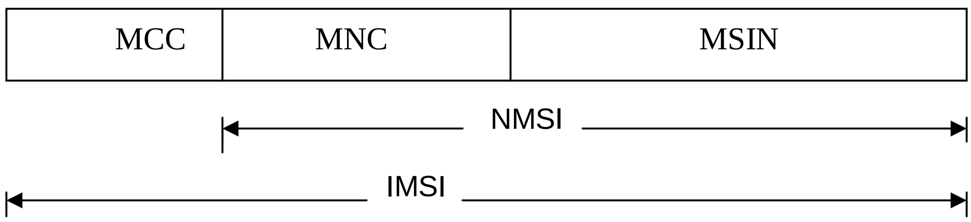


Based on CC digits, the maximum length of MSN may be 12,13 or 14 digits. MSISDN in GSM is used for digit analysis to identify the called party number. MSISDN is registered in the telephone directory and used for dialing purpose by the callers. It is stored in SIM, HLR and VLR.

IMSI (International mobile subscriber's identity): International identity of MS is identified by its IMSI (International mobile subscriber's identity), clearly tells that which MS of the world the particular customer belongs to.

IMSI code has three components.

- Mobile country code (MCC); It is a 3 digit code that uniquely identifies the country of the domicile of the subscriber.
- Mobile network code (MNC); It is a two digit code that identifies the home GSM PLMN of the mobile subscriber.
- Mobile subscriber identification number (MSIN); It is a code that identifies the MS within a GSM PLMN.



NMSI is the total combination of MNC & MSIN. MCC is 3 digit long, the digit length of MNC is also 3 digits but assigned nationally. MSIN can be maximum 9 digits long. NMSI is the total combination of MNC and MSIN. So, the highest number length for NMSI may be 12 digits. Maximum length for IMSI is 15 digits. IMSI finds its use in call routing. AUC maintains the database for IMSI.

TMSI (Temporary mobile subscriber's identity): It is a temporary number provided by VLR. This ensures confidentiality of the MS over air interface for hiding identity. It is issued temporarily within the location area of the VLR.

MSRN (Mobile subscriber's roaming number): It is suitable for the purpose of call processing when the customer goes out of home network and roams in any other VLR area having connectivity with his home network. In such cases, the HLR of the roaming subscribers request the visited VLR for allotment of the temporary number. Accordingly the visited VLR generates MSRN. GMSC (gateway MSC) uses it for routing of calls to this customer. MSRN is stored in visited VLR, HLR.

IMEI (International Mobile subscriber's equipment identity): It is provided to the customer through a unique code. Each mobile equipment has IMEI for its authentication and identification. The code is entered in SIM card of the user MS and also recorded in the data base of the EIR of mobile switching sub system. During the course of call processing, the IMEI entered in SIM is compared with the corresponding IMEI recorded in EIR.

TAC	FAC	SNR	SP

IMEI = 15 Digits

TAC – Type Approved Code
FAC _ Factory Assembly Code
SNR – Serial number
SP _ Spare

TAC is 6 digits and approved by a national body. FAC is 2 digits and this is provided by the manufacturer. SNR is 6 digits provided by manufacturer in serial sequence. SP is spare digit of unit length.

4.15. Call management:

Phases of MS to PSTN call (Mobile to land line)

1. Request for service: MS request to setup a call
2. Authentication: MSC/VLR requests the AUC for authentication parameters.
3. Ciphering: Using the above parameters, the uplink and down link are ciphered.
4. Equipment validation: MSC/VLR requests the EIR to check the IMEI for validity.
5. Call setup MSC establishes a connection to MS.
6. Handover
7. Call release

Call process: The user presses the send key after all digits have been entered.

1. MS transmits a channel request message over RACH.
2. Once the BSS receives the channel request, it allocates a SDCCH and forwards this channel assignment information to the MS over AGCH.It is over the SDCCH that MS will communicate with the BSS and MSC until a traffic channel is assigned.
3. MS transmits a service request to BSS over SDCCH. In this message it informs TMSI and location area identification (LAI). The BSS forwards the service request message to MSC.

4. After receiving the call setup request, the MSC will ask the VLR to supply subscriber parameters necessary for handling the call.
5. VLR returns a message to MSC containing service parameters for the particular subscriber.
6. MSC informs to MS that the call is proceeding.
7. MSC allocates a trunk to BSS to current MS and requests BSS to allocate TCH for MS.
8. BSS allocates a radio traffic channel and transmits this assignment to MS over SDCCH.
9. The MS tuned to the assigned traffic channel and transmits an acknowledgement to BSS.
10. At this time a voice path is established between MS and MSC.
11. MSC establishes a voice path from MSC to PSTN by sending a request including dialed digits and details specifying the trunk should be used for.
12. After this process MSC will inform to MS and it will get the ringing tone.

Call release process:

Under normal conditions, the termination of a call is;MS initiated or network initiated. In this scenario we will assume MS initiated the release of a call.

1. The mobile user initiated the release of the call by pressing end button on the MS. The MS sends a disconnect message to MSC.
2. The other party is notified of the termination of the call by a release message from the MSC. The end-to-end connection is terminated.

4.16. Handover in the GSM

In a cellular network, the radio and fixed voice connections are not permanently allocated for the duration of a call. Handover or handoff (as it is called in North America), means switching an ongoing call to a different channel or cell.

Handover is the process used to allow a call in progress to continue as the mobile terminal moves between cells. Handovers may be based on received signal strength or S/I ratio or may be based network resource management needs. The handover process may also involved registration and authentication of the terminal.

In GSM handover, once a call is established, the set-up channel is not used again during the call period. Therefore handover is always implementing handover is dependent on the size of the cell. Handover is needed in two situations where the cell site receives weak signals from the mobile unit at the cell boundary, which is the level for requesting a handover in a noise-limited environment and when the mobile unit is reaching the signal-strength holes (gapes) within the cell site.

The handover process consists of the following steps:

i. Initiation: either the mobile terminal or network identifies the need
ii. Resource reservation: The appropriate network elements reserve the resources necessary to support the handover.
iii. Execution: the actual handover connection of the network resources takes place.
iv. Completion: any unneeded network resources are freed, and access signals are exchanged following a successful handover

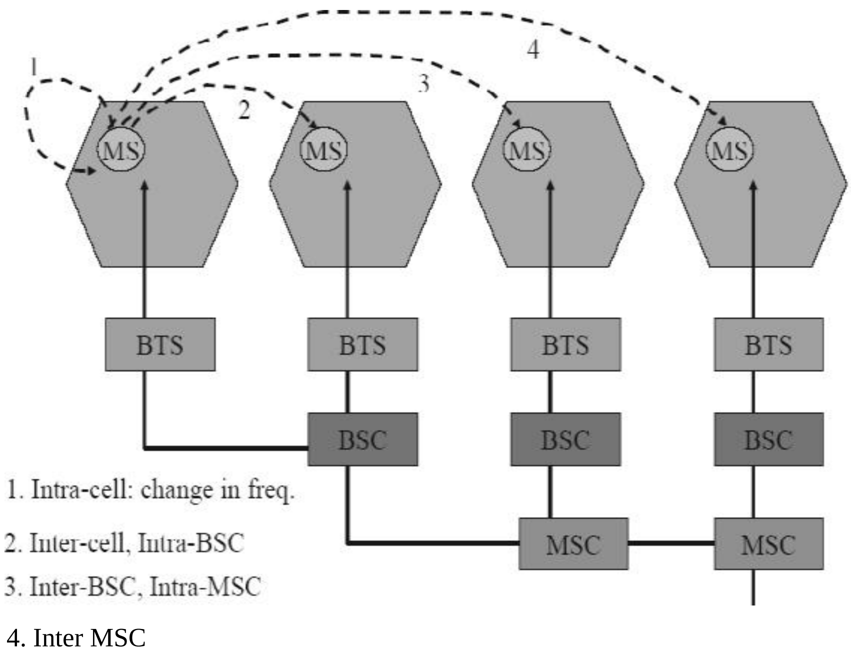


FIG.4.10. Different types of handover in the GSM

4.16.1. Types of handover in GSM

1. Intra BTS handover
2. Intra-BSC handover
3. Inter-BSC handover
4. Inter-MSC handover

Intra cell/BTS handover: The easiest type of handover is intra cell Handover where either the physical channel or the associated timeslot configuration is changed. This may become necessary if the connection on a physical channel is impaired. To evaluate connection quality, the mobile phone continuously transmits the measured RX Lev (receive level measured by the telephone) and RX Quality (bit error ratio determined) values to the base station.

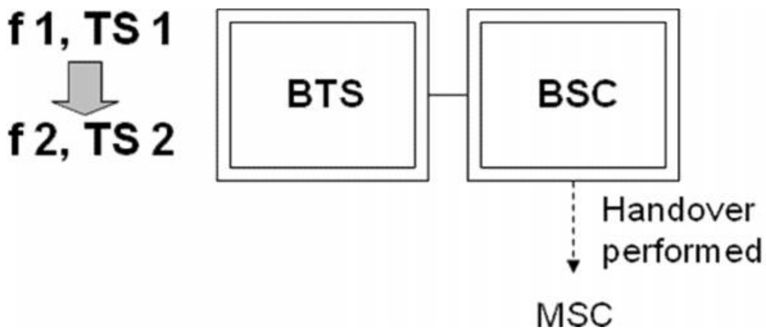


FIG.4.11. Intra cell handover

If the base station wants to hand over the mobile from one physical channel f1 to another physical channel f2, all it needs to do is to inform the mobile about the new channel number and the new timeslot TS2 configuration. The mobile changes directly to the new channel and is able to maintain both its previous settings for timing and the base station parameters. Intracell handover is also possible between different GSM bands.

Inter cell/Intra BSC handover: If the mobile phone moves from one cell to another during a call, it must be handed over to the new cell. If the neighbor cell is time-synchronous with the current cell, the base station is able to affect a finely synchronized inter cell handover. In this case, the mobile phone is transmitted on the new physical channel in the neighbor cell. Moreover, the mobile phone must be informed about the vital parameters of the new cell. The mobile phone then optionally transmits four access bursts on the new channel. Compared to the normal bursts, these are shortened which is why they cannot cause interference with other calls even if the timing is slightly incorrect. If necessary, timing is corrected in a next step and the call continued.

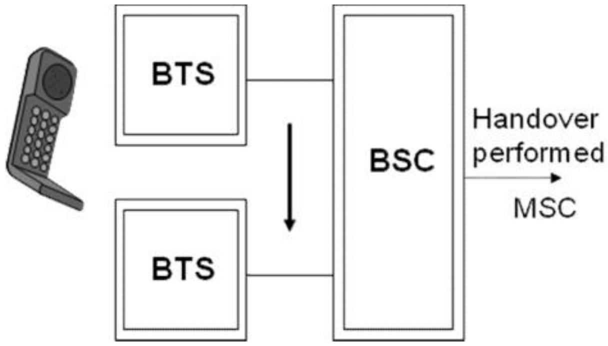


FIG.4.12. Inter cell handover

If the two cells with time offset are synchronous, the base station will effect a pseudo-synchronized or pre synchronized intercell handover. This handover is similar to the finely synchronized intercell handover, but differs in that the mobile phone is provided with information about the time offset. Usually, however, a non-synchronized intercell handover takes place. In this case, the mobile phone transmits up to 64 access bursts on the new channel by means of which the new base station determines the timing and hands it over to the mobile phone.

The mobile phone then reestablishes the call connection with the correct timing. The base station requires the mobile phone's help in order to know the new cell to hand it over to. By means of the neighbor cell list, the base station informs the mobile phone about the RF channels for the BCCH that are used by the neighbor cells. The mobile phone now cyclically measures the RF level on these channels and transmits the measurement results to the base station. Based on this information, the base station determines the point in time at which the mobile phone is handed over to which cell. Changing the physical channel both for the call and for the BCCH information is key to inter cell handover.

Inter BSC/Intra-MSC Handover: The MS constantly monitors the signal quality of the BSS-MS link. The BSC may also optionally forward its own measurement to the MS. when the link quality is poor; the MS will attempt to maintain the desired signal quality of the radio link by requesting a handover as shown in fig.4.13.

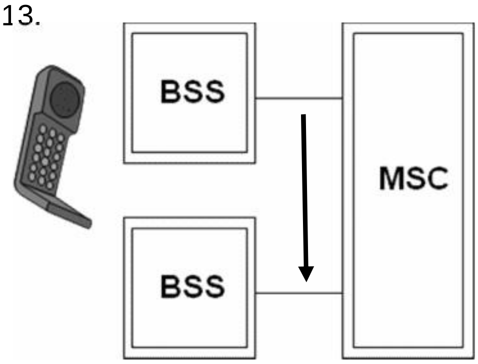


FIG.4.13. Intra-MSC Handover

Inter-MSC Handover: In this scenario we assume that a call has already been established. The serving BSS is connected to the serving MSC and the target BSS to the target MSC as shown in fig.4.14.

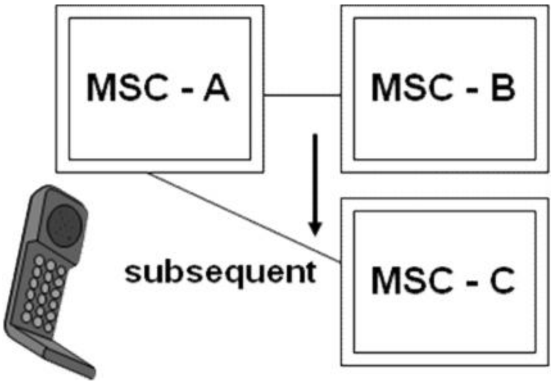


FIG.4.14.Inter-MSC Handover

Intersystem handover: If the mobile phone leaves a cell and no new cell can be found in the same system, the base station can hand over an appropriately equipped mobile phone to a cell in another system. These intersystem handovers are highly complex because two technically disparate systems must be combined with each other. Basically, there are two handover options from WCDMA to GSM: In the case of blind handover the base station simply transmits the mobile phone with all relevant parameters to the new cell. The mobile phone changes" blindly" to the GSM cell, i.e. it has not yet received any information about the timing there. It will first contact the transmitted BCCH channel, where it tries to achieve the frequency and time synchronization within 800 ms. Next, it will switch to the handed-over physical voice channel, where it will carry out the same sequence as with the non-synchronized intercell handover. For the second type of handover from WCDMA to GSM, the compressed mode is used within the WCDMA cell.

Objective:

1. The function of SIM card is Storage of subscriber related information. (T/F)
2. The mobile station performs the Radio transmission/reception (T/F)
3. BTS is a part of the Base Station Subsystem (BSS) for system management (T/F)
4. Duplexer is used for separating sending and receiving signals to/from antenna (T/F)
5. Encryption of transmission Data Streams are being done at BTS (T/F)
6. Base Station Controller reserves the Radio Channel Frequencies (T/F)
7. The Switching part, is controlled by the Mobile Service Switching Centre (MSC) in GSM. (T/F)
8. Subscriber relevant data are kept in a Database called Home Location Register (HLR). (T/F)
9. Authentication Centre (AUC), which protects User Identity and allows a Secured Transmission. (T/F)
10. GSM-900 band, 935-960MHz for Up-link (MS to BTS) and 890-915 MHz for Down link (T/F)
11. The channel spacing in GSM is of 200 KHz. (T/F)
12. The Duplex spacing in GSM will be 45MHz (between TX and RX). (T/F)
13. The Air Interface is the interface between the BTS and the MS (T/F)
14. The Physical Layer, consisting of a number of Physical Channels, (T/F)
15. The Physical Layer is a 2 Mb/s Digital Connection. (T/F)
16. One or more logical channels can be transmitted on a physical channel (T/F)
17. SCH is used to time synchronize the mobile station (T/F)
18. BCH is used for transmission of general accessible information in a cell (T/F)
19. AGCH is used for assigning an MS to a Dedicated Control Channel (T/F)
20. Vocoder is a digital hardware block (T/F)
21. GSM radio transmission is accomplished by sending data in bursts. (T/F)

Subjective:

1. Draw the block diagram of GSM architecture and name all functional entities

2. Explain mobile station and what are the functions performed by an MS?

3. Explain the units in SIM and what are the functions performed by SIM?

4. Explain the units in BTS and what are the functions performed by BTS?

5. Explain the units in NSS?

6. What are the multiple access techniques used in GSM and explain?

7. Explain the following
   a. U_m interface
   b. A interface
   c. A_{bis} interface

8. What are various types of logical channels used in GSM and explain them briefly?

9. Explain the speech coding process in MS?

10. What are various bursts in GSM and explain a normal burst?

11. Explain GMSK?

12. What are the signaling protocols used in GSM and explain them briefly?

CHAPTER-5

GSM – R (GSM for Railways)

5.0. INTRODUCTION

GSM for railways, a communication system for railway networks utilizing GSM technologies and specific applications for railway operations.

GSM-R is the communication standard chosen by EIREN (European Integrated Railway Radio Enhanced Network) to meet the railway requirements.

Railways have some specific requirements, which are not featured in GSM Services:

- If some Emergency situation in the Locality makes all Channels busy due to sudden flood of calls, and at that particular period, Driver of a running Train tries to originate a Call and does not get Channel, a catastrophe might occur. Driver must have a facility to disconnect some unimportant Subscriber and get the Channel on Priority. Thus, Priority cum Pre-emption is an essential requirement.
- A situation may need that Track-side Maintenance persons over 20 Kms area must get same information without delay. A Commercial GSM system does not allow Group-cast Mode Communication.
- In future, all the Train Controllers will have similar Numbering scheme. If the Mobile Communications of different Zonal Railways are networked, a call from Driver will disturb all Controllers. So, Location Dependent Addressing is also needed.
- Once, Cell phones are provided to all Drivers and the Driver of a particular train e.g.7021 is needed, it would be difficult for the Controller to remember the Cell phone number of the Particular driver. It would be better, if there is Functional Addressing, which enables dialing Code of Driver of 7021, which will be analyzed by the System and the specific Driver at the Train will get the call.

These communication requirements were studied and identified by representatives of the European railway operators and the choice of GSM-R by the Railway community was motivated by its strong potential to:

- Support numerous applications due to the ISDN character of the network
- Achieve interoperability between railway networks
- Use of resources efficiently
- Reduce procurement cost
- Reduce maintenance cost
- Being open for technical evolution due to its state-of-the-art technology.

5.1. Applications of GSM – R:

The general applications of GSM – R are in the following fields –

A) Operational Voice Communication e.g. between Train Controller and Driver / Guard of a Train, Driver to Guard of the same Train, Driver / Guard of a Train to Driver / Guard of another Train, Emergency Communication, Track-side Communication, Train Support Communication or Shunting Communication.

B) Local or Wide Area voice and Data Communication.

C) Signaling requirements as used in European Railway Train management System.

D) Passenger Communication.

5.1.1. Operational Voice Communication:

Train Radio covers the wide field of Railways operational communication, which is characterised by typical functions. The main function of train radio is the communication of a train controller with the train drivers and vice versa. The requirements are:

1. Bi-directional links for Data and Voice transmission between Train Controller and the personnel (Driver and Guard) on the trains.
2. Call Setup should be possible as mobile terminated call (MTC) and mobile originated call (MOC).
3. For MOC and MTC different addressing modes are required for the call setup.
   - MTC (call from the train controller to a Train) The call setup should be possible by dialing a (temporary) train running number and a function code. An address translation function from actual train running, engine or coach number and functional identity to real PLMN subscriber number has to be realised. Furthermore, it should be possible to address different functions on board the train.
   - MOC (call from a train to a train controller terminal) the call setup should be possible by pressing a function key or dialing a short-number on the mobile station and establishing a connection to the actual responsible train controller dependent on the location of the user.
4. Multidirectional links for voice transmission from one train to multiple mobile and fixed network subscribers or a train controller station to multiple trains.

5.1.2. Emergency Communication:

A railway Emergency Call will be established either by Train Driver or Guard or by the Train Controller. It is always a voice broadcast into a number of cells forming the predefined area. Users entering the emergency area shall join the call while users leaving the emergency area will also leave the call. Typically, either a railway function on train or a controller will establish the railway emergency call. All other participants will listen to the call. If one of the other participants wants to talk he will press the push to talk button thus requiring a duplex connection. Second speaker shall get the talk function on a first come / first serve base. There is only one Second - speaker at one time.

5.1.3. Shunting Communication:

Today, Indian railways do not use Communication specifically for shunting. GSM – R will be able to provide this facility. Typically, shunting teams are groups of at most 10 members. These members should be able to communicate to each other by pressing a push-to-talk button at the mobile Telephone. For each member, it should be possible to belong to different groups at the same time. Shunting Team members shall be able to communicate with other members of the team as well as with fixed control centers. Typically, a Duplex Connection is only required for point-to-point calls, whereas Group Communication can use Simplex mode. Talking time of each talker is quite short since only few words will be exchanged.

5.1.4. Trackside Maintenance Communication:

Trackside Maintenance personnel today use Portable Emergency Telephones, connected to either the trackside installed Emergency Sockets in RE areas or Overhead Wires in Non-RE areas. Trackside maintenance personnel, in future, shall use GSM-R handheld. This may be in an initial step GSM-R or GSM handheld.

5.1.5. Local and Wide Area Communication:

Local communication at Stations and Depots generally takes place today via Railway PABX networks. To improve functionality and reachability, these PABX will be connected to GSM-R. Wide Area Communication in a modern Railway organisation is typically communication between Railway Organisational Bodies. Today mobility requirements for this type of communications exist only to a certain extent. Therefore, Wide Area Communication may be regarded as communication with low or no mobility aspects and will not use GSM - R to save capacities for operational purposes. Nevertheless, dependent on the concept of the individual railway, these subscribers may be connected in a Virtual Private Network.

5.1.6. Railway signaling requirements:

Train Control Systems in use today are only on signaling level, using Optical signals, Electromagnetic or Mechanical signals. These systems have several restrictions -- they are fixed installed alongside the track, each system needs separate cables. Railways specified a new multi-level automatic train control system, for which GSM-R can be used. The options are:

- Radio-based Fixed Block System using GSM-R, traditional signals like Axle Counters, Electronic Interlocking, Line side Signals still in operation
- Radio-based Moving Block System using GSM-R, no other Signals being in operation or Complete Radio-based Signaling System.

5.1.7. Passenger Communication Services:

Today, a Passenger does not get any information or help from the Train Personnel if he needs typical unscheduled Travel Guidance. In future, information for follow-on connections shall be accessible via Radio. Furthermore it shall be possible to book, change or cancel reservation from a running Train. Taxi reservation, plans of other integrated traffic partners like buses or regional traffic systems and hotel reservation service shall be accessible as well. Actual daily information for Business Travelers e.g. FAX and Newspaper can be transmitted via Radio to the Train. Internet Access from a running Train is a possibility, in near future.

5.1.8. Train Diagnostics:

Train online diagnostic data will be transferred to the maintenance personnel for evaluation and repair to reduce time spent for repair. Some diagnostic data will be transmitted in future under ERTMS as they are needed for automatic train control. All other diagnostic data shall be collected on the running train and transferred via radio network whenever needed. Both GSM-R and public GSM have the necessary data services to transmit the relevant data today available.

5.2. The GSM-R Network and its Structure

The typical network structure of a GSM / GSM-R based Railway Network basically does not differ much from a normal PLMN and its extensions in terms as Network Elements, Standardised Interfaces and Connectivity. Optimised Frequency Reuse pattern to increase network capacity, Micro cells in areas with high density (like railway stations) and Overlay Solutions with Speed Sensitive Handover are under introduction in public GSM and thus may only be slightly modified for railway specific use. Differences exist in the network layout and planning deriving from the critical needs of railway networks.

5.2.1. Architecture of GSM-R network:

A typical GSM-R network is built of several cells alongside the track. Each cell is equipped with one or more transreceivers, depending upon the communication density. The block diagram is shown in fig. 5.1.

The network can be divided into 5 main parts-

1. Mobile station
2. Base station subsystems(BSS)
3. Network switching subsystem (NSS)
4. Operation and maintenance subsystem (OMS)
5. Other networks

The functionality of the above systems are same as described in GSM networks except some ratings like RF powers of MS and BTS. There are different types of mobile equipments, distinguished principally by their power and application. The fixed terminals are the ones installed in driver's cab. The RF output power is 8W, and hand held sets are of 2W power. And the RF power of BTS will be 20-25 W.

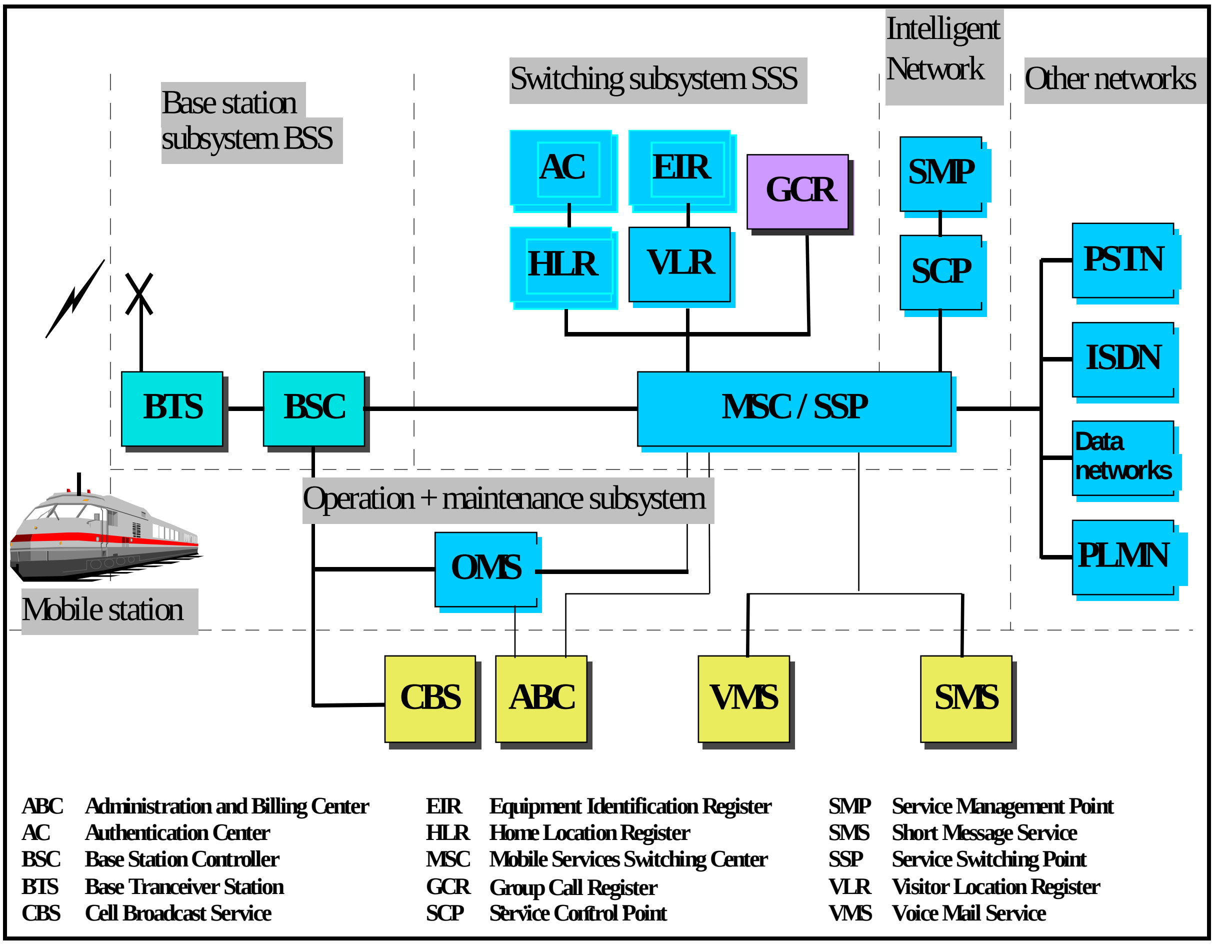


FIG.5.1.Block diagram of GSM-R network

Special requirements of GSM-R Networks are deriving from the following demands of applications using GMS-R:

- Seamless communication up to a speed of 500 km/h
- Efficient usage of a limited number of frequencies (20)

- C / I of 12 dB min (EIRENE requirement 15 dB)
- 95 % Coverage for 95 % of the time in a designated coverage area with a level of above -90 dBm
- Handover success rate of above 99,5 % even between GSM-R networks
- High availability of both transmission path and network equipment dependent on the applications in use
- Coverage inside Tunnels
- Improved coverage in Railway Stations and Shunting Areas
- Call Setup times as indicated below in 95 % of all cases, remaining 5 % in less than 1.5 times of the described period :

Call type	call setup time
Railway Emergency Call	$\leq$ 1s
Mobile-to-mobile urgent Group Call	$\leq$ 2s
All Operational Calls not covered by the above	< 5s
All Low Prioriy Calls	< 10 s

5.2.2. The typical GSM-R Network structures:

Large Railway Stations typically will have Sectorized Cells. Less populated areas with low speed tracks and bus connections just need an average voice connection. This cells may radiate as omnidirectional cells.

Figure below shows structure for low speed tracks and rural areas realised with the existing technology and common to public networks.

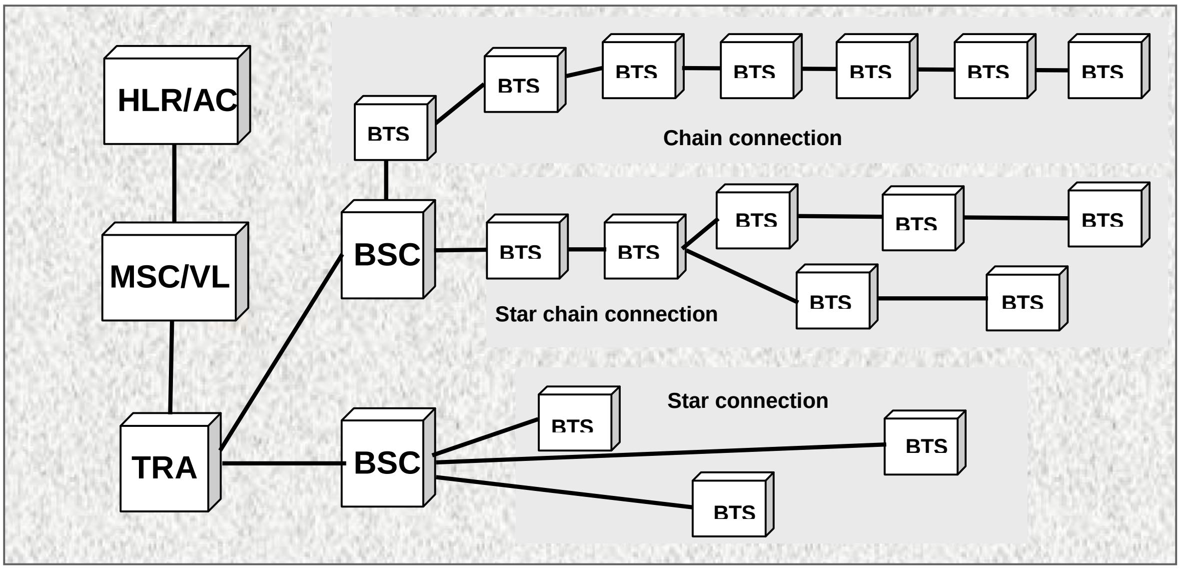


FIG.5.2.GSM-R architecture for low speed tracks and rural areas

Star connection: The BTS are connected to the BSC in star connection. This connection applies especially for sectorised BTS with several carriers.

Chain connection: The BTS are connected to BSC in chain connection via multidrop. Whenever a BTS fails or the link interface for the A_{bis} connection is defective, it switches the PCM 30 through to the next BTS. The switchover is seamless for the connection.

Star chain connection: The BTS are connected to BSC in a star chain connection via multidrop. The first two BTS are connected in chain, after the second BTS we will split-up into star. The advantage is a better usage of existing railway communication cables.

For above described cases the critical path is always the cable connecting all BTS. Since reliability of either Copper or Optic Fibre Cable in combination with the necessary line termination, is not necessarily as high as the one of BTS and BSC, even a very high reliability of BTS will not improve availability of the system. Therefore, Railway applications with high requirements for reliability will make use of the Multi-Drop Loop architecture as shown below. Furthermore the interleaving of BTS of two different loops will decrease the consequences of a single BTS or BSC failure.

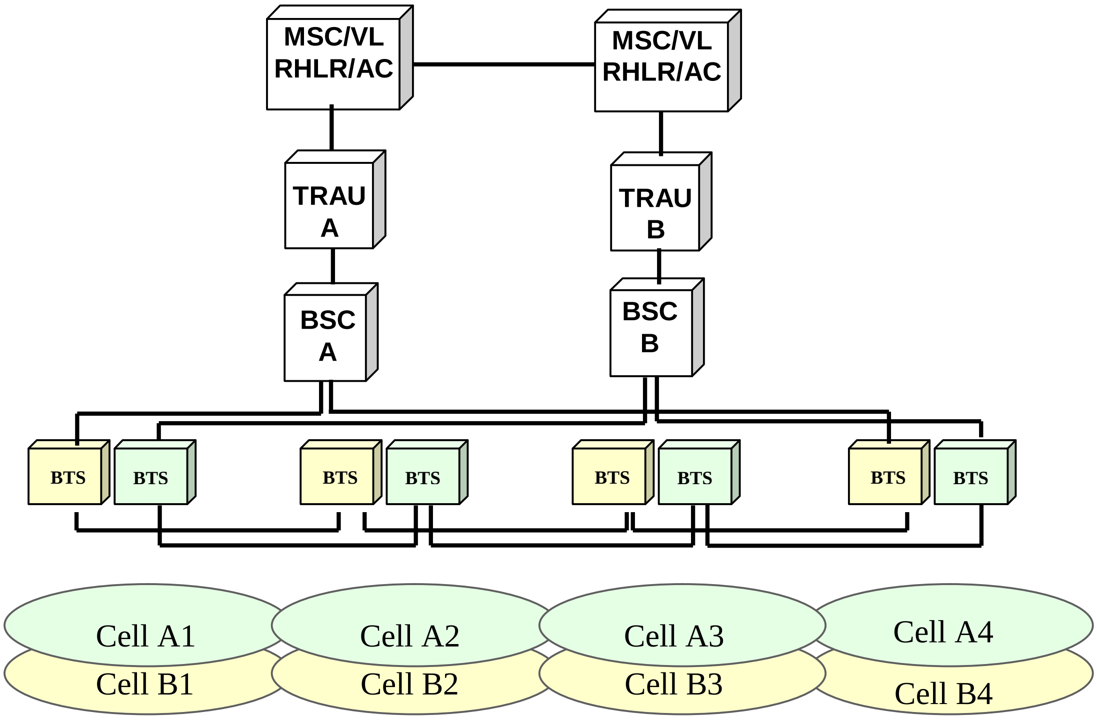


FIG.5.3.Fully duplicated network structure with overlayed radio cells

The suggested above shown case operates with a fully duplicated network structure with collocated or staggered radio cells. To allow these two network levels several functions like

- Priority of cell A1 or B1
- Other hierarchical cell parameters
- Subscriber administration
- Load distribution.

Therefore, railway applications with high requirements for reliability will make use of the multidrop loop architecture. Furthermore the interleaving of BTS of two different loops will decrease the consequences of a single BTS or BSC failure.

5.2.3. Loop multidrop connection:

The BTS are connected in a loop multidrop. Physically up to 7BTS can be connected that way in one loop using one PCM 30. For safety reasons, only 4 BTS are connected. If now the forward connection fails, BTS will switch seamless to the backward connection. That means that ongoing calls will not be dropped by loss of one transmission link.

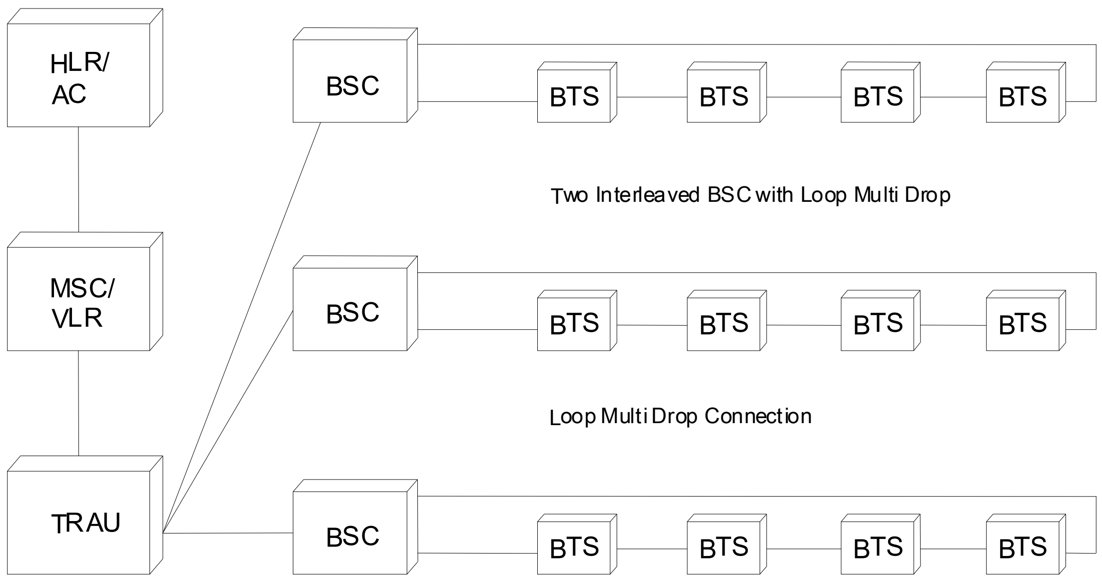


FIG.5.4.GSM-R architecture for ETCS lines (low and high redundant)

5.3. Quality requirements of GSM-R:

Quality requirements of GSM-R are based on the GSM recommendations QoS (Quality of Services) parameters.

QoS parameter	Demanded value	Probability
Call setup time	6 s	95 %
Connection establishment failure probality	1 %	100 %
Transmission failures	10^{-4} / h	100 %
Data transfer delay	450 ms	100 %
Duration of transmission failures	1 s	100 %
Recovery time (undistorted)	7 s	100 %
Error rate	10^{-3} / h	100 %

Availability of the Radio Channel is one of the key criteria for GSM-R. A typical Railway topology includes flat and hilly terrain. Traditional rail tracks have numbers of bends, (new built tracks try to avoid bends). Especially the following conditions to be taken under consideration:

- Deep and / or Long Cuttings spanned with a Bridge
- Long Tunnels
- A series of Short Tunnels with limited space between them
- Tunnel materials (natural stone, concrete, concrete with steel) and profile
- Bends and Crossings inside the Tunnel
- Dependent on the maximum planned train speed, the length of handover zones needs to be planned very carefully. Handover zones should not be at a halt area or RBC position. Inside Railway Stations, they should be reduced to a minimum.

5.4. Features of GSM - R

5.4.1 Functional Addressing

Railways have employees traveling and with daily changing duties. Not only these subscribers but also applications are addressed by Telephone Numbers and / or Functional Numbers / Names. Today these tables of telephone numbers and functional numbers / names have to be cross-referenced manually to allow identification and reachability of the person or application, which has subscription to a permanent number.

Functional addressing allows the definition of functional numbers in either HLR or IN, dependent on the preferred solution. These functional numbers represent Train Numbers + Function Code. At the beginning of a journey or a job, the Train Driver or Employee registers his mobile number (MSISDN) to the functional number (FN) of the train. From now on, until de-registration, a call to the Train Driver's Functional Number will always be forwarded to reach the Train Driver's MSISDN. At the end of the journey or job he may de-register. This applies also for change of direction of the train. If necessary, the network operator also can de-register a subscriber.

5.4.2. Registration: A Train Driver or employees on the Train, registers to the respective functional number by establishing an USSD dialogue via MSC / VLR to the HLR, where their MSISDN is stored (HLR_{mobile}). This HLR is establishing a dialogue to the $HLR_{functional}$ regarding the calling MSISDN. The $HLR_{functional,}$ in turn, establishes a Call Forwarding from the required Functional Number to the MSISDN. After completion, the registering Subscriber will get an acknowledgement (registered). Only one MSISDN can register under one functional number. Users trying to register to a functional number already in use will be rejected. Same way, a Functional Number is unique inside the $HLR_{functional}$ and cannot be duplicated

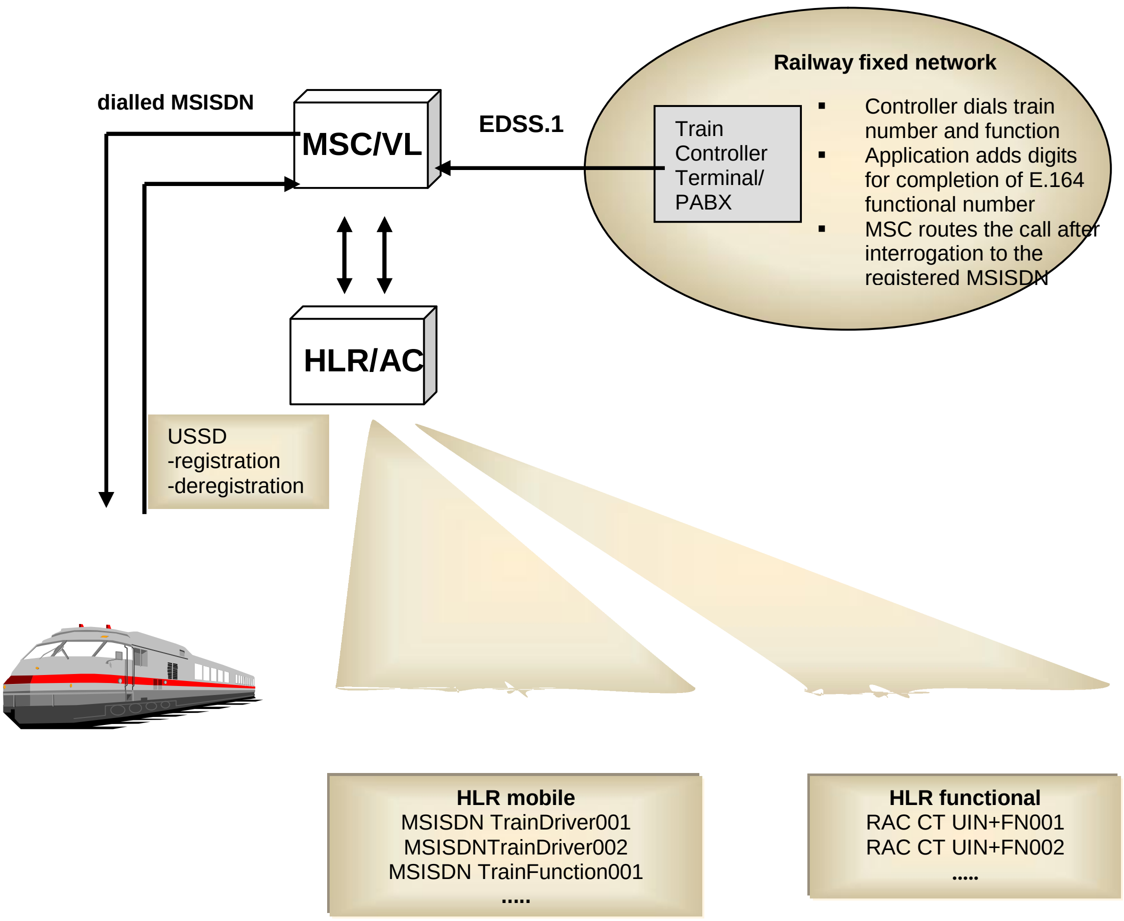


FIG.5.5.Functional addressing is to be used for ground-to-train communication.

5.4.3. Call Setup: At Call Setup, the MSC / VLR connected to the Train Controller (GMSC) performs Digit Analysis and detects a functional number. Via HLR Interrogation, the forwarded-to-number and the location (VMSC) is detected and the call to the MSISDN is established.

5.4.4. Deregistration: MSISDN registered to a Functional Number will be de-registered by the user establishing an USSD dialogue via MSC / VLR to the HLR, where their MSISDN is stored (HLR_{mobile}). This HLR is establishing a dialogue to the $HLR_{functional}$ regarding the calling MSISDN. The $HLR_{functional}$ in turn cancels the call forwarding from the required functional number to the MSISDN. After completion, the registering subscriber gets an acknowledgement (de-registered). De-registration is also possible for the Network Administrator and may be possible on certain circumstances for special users.

5.4.5. Expiration Date: All functional numbers contain a programmable validity period (in hours). During the registration process, the Expiration Date of the single member inside this functional number will be computed and stored. After exceeding the expiration date, the service ignores the function owner. It is same as in the case of de-registration. In case the value of the validity period is set to 0, the feature is switched off for this functional number. That means a registration of any member for this functional number has no time limit.

5.5. Location Dependent Addressing

Location Dependent Addressing provides the Automatic Routing of Mobile Originated Calls (MOC) to pre-defined destinations relative to the geographic area where the subscriber is roaming. The entire network of Railways is split into different types of service areas (train monitoring, train control, power supply, and sub-station).

A Train on a journey, e.g. from Delhi to Secunderabad, passes through several of these areas (e.g. train controller areas). The connection between a Train Driver and the Controller of the respective area should be easy to establish. The Train Driver should have no need to dial long numbers after he has decided in which area he is actually driving.

Therefore, the Train Driver will only dial a short number as defined in the Numbering Plan. This short number will be automatically converted into the corresponding long number(s) of the train controller(s) responsible for the area the train is actually moving trough. If a train is passing between two controller areas the connection will be made to both controllers

With MSC based Location Dependent Addressing, the location will be determined with the accuracy of the Cell, since no other location information will be available. This implies an inaccuracy within some hundred meters, since cell boundaries are overlapping. The cells are identified by means of the Location Area Code (LAC) and Cell Identifier (CI). To each shortnumber, a table containing the relevant cells and the destination number will be stored. If a call is set up with a short number, the MSC recognises the abbreviated dialling, evaluates the LAC / CI and selects the correct destination number. Then the connection will be automatically established. If a train is passing between two service/controller areas the connection will be established to both controllers.

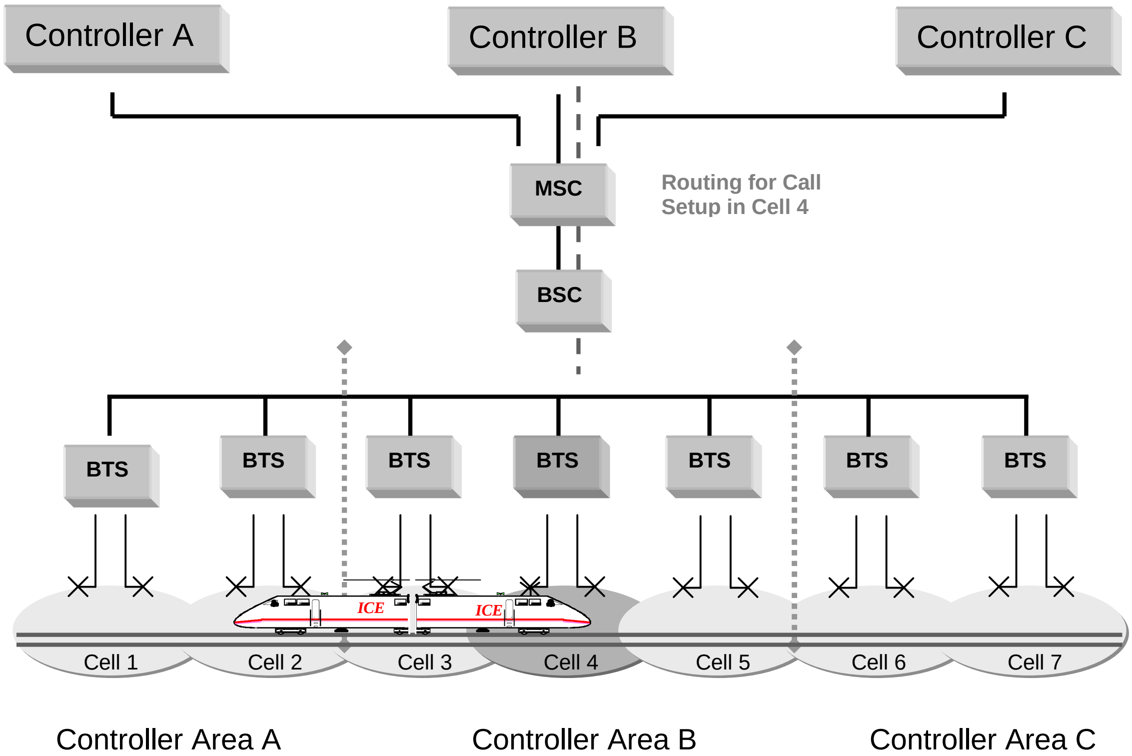


FIG.5.6.Location Dependent Addressing

5.6. Enhanced MultiLevel Precedence and Preemption (eMLPP)

Railway organisations have high performance requirements on some types of communication. This is especially the ultimate requirement for a radio channel and a very fast call setup. ERTMS has the need for a continous data connection. If a handover to neighbouring Cells is unsuccessful due to congestion on the radio channel, a preemption service is necessary to allow immediate access to a traffic channel occupied by a low priority application.

Railway Emergency Calls do need an immediate call setup in the emergency call area, no matter if free radio channels are available or not. A preemption service will release ongoing low priority calls to free traffic channels for emergency call setup. In addition, these calls shall be set up in 1 second or less. Therefore Fast Call Setup is required. Shunting Communication and Train Support Communication need different priorities than other types of communication. Therefore additional priority levels are required.

Today's GSM networks do only provide Access Class Barring and Priority as a Call-by-Call set-up function. These functions are very limited, since the Priority can only be given on a per - Base - station (access class barring) or per Subscriber basis and not be varied depending on the network situation and priority needed. Furthermore, if all traffic channels are in use or even when Congestion already exists, there is no alternative than to wait with high priority in a queue until a traffic channel can be applied. To introduce above mentioned functionality's into GSM the so-called Advanced Speech Call Item (ASCI) eMLPP is specified.

To introduce a ranking in priority, up to 7 different eMLPP levels (2 network and 5 subscriber levels) are introduced. One or more priority levels can be assigned to a mobile subscriber. According to MORANE, Network Level 1 is reserved for Railway Emergency Calls, Network Level 2 for ETCS. Maximum allowed and default priority will be stored in the HLR with the related subscriber data. When an eMLPP priority call is build up, the MSC / VLR will insert the priority into the call set-up message to the BSC.

The BSC will evaluate the Priority and give access to the appropriation channel for either call set-up or hand-over. High priority calls can gain access to resources currently being used by lower priority calls such that these lower priority users currently engaged in conversation will be pre-empted. This is particularly important in safety critical applications where users must be notified immediately and cannot wait in a queue for a free radio channel. Priority and Pre-emption is applicable for VGCS, VBS and for general public services.

5.7. Voice Broadcast Service (VBS):

Today's GSM networks are designed for point-to-point connections. Railways and other professional users need the key functionality of point-to-multipoint calls as known from Private Mobile Radio (PMR) or Public Access Mobile Radio (PAMR) are available. To introduce above-mentioned functionality into GSM, the so-called Advanced Speech Call Item (ASCI) Tele-service, the Voice Broadcast Service (VBS) was specified in GSM - R. A VBS is characterized by following key points:

- One Broadcast Call Number combines all members of a certain Group.
- For each Broadcast Call, a Service Area composed out of a number of cells is assigned
- Dialing the broadcast call number initialises the parallel set-up of connections into all Cells of the assigned service area. All members of this group being in the service area will be paged to receive a notification of the ongoing voice broadcast call
- Dependent on the call ID a priority members of the group call can decide to join the call

If a Broadcast Call Number is dialed, the MSC recognises that this number belongs to a broadcast group. The MSC retrieves all necessary information from the co-located Group Call Register (GCR), which stores Tables having

- The Group ID (1 to 7 digit depending on the length of the group call area ID)
- The Group Call Area ID (MCC + MNC + LAC + CI)
- The Group Call Reference (27 bit binary encoded field with Group ID and Group Area ID)
- The Cell List corresponding to the Group Call Area ID (max. 50 cells)
- The Dispatcher List corresponding to the group call references (up to 6 dispatchers)
- per group call reference an information whether the call is active or not
- Security Information

The MSC connects the so called Dispatcher with a duplex connection – no matter if he is mobile originated or fixed network originated – and initialises the setup of half-duplex connections into each cell of the required group call area. Members of the group actually in this area will be paged and connected via common channel down-link, that means they can only listen to the call. If a member of the group enters the Cell after beginning of the voice broadcast, he will just join the ongoing voice broadcast at his time of entry. If a member of the group leaves the voice broadcast area, he will be disconnected. The setup of a VBS is possible with eMLPP or as a normal call without priority and preemption.

5.8. Voice Group Call Service (VGCS):

In addition to the VBS prescribed functionality, a VGCS is characterised by the key point that the actual speaker can change during a call. Group members will normally listen to the ongoing Voice Group Call. As soon as the initiator of the VGCS stops speaking, he indicates that he releases the up-link. All group members will be notified that they can now request an up-link to become the next talker by using their Push-To-Talk function. A dedicated duplex channel will be allocated in the respective cell. The setup for the duplex channel for the next and any subsequent talker is as follows:

- Initial talker releases the up-link (and changes to the common down-link in this cell, if he is a mobile subscriber)
- Possible new talker sends an up-link request

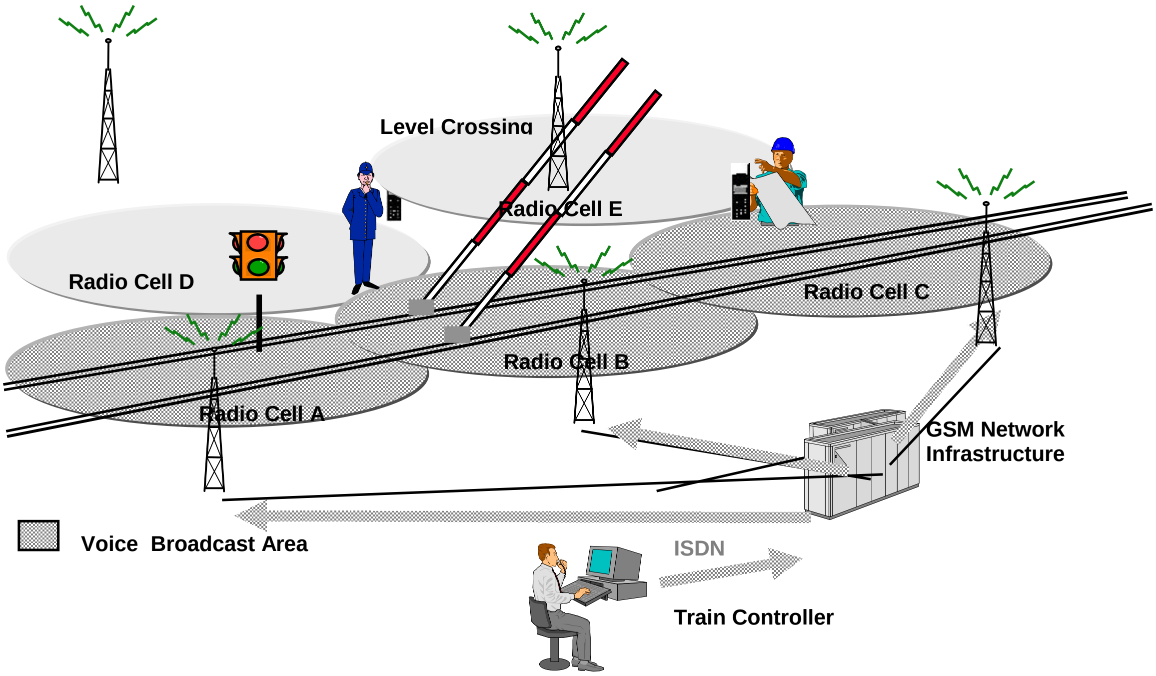


FIG.5.7.Voice Group Call Service (VGCS)

- The BSC serving this area selects the first UPLINK_REQUEST and presents it to the MSC
- The MSC serves the first UPLINK_REQUEST of all BSC in the Group Call Area
- The new talker confirms his up-link request
- The other group member get an up-link seized or up-link reject notification
- The duplex channel for the new talker is switched through

One typical application of the VGCS, the Railway Emergency Call, is shown in the following figure.

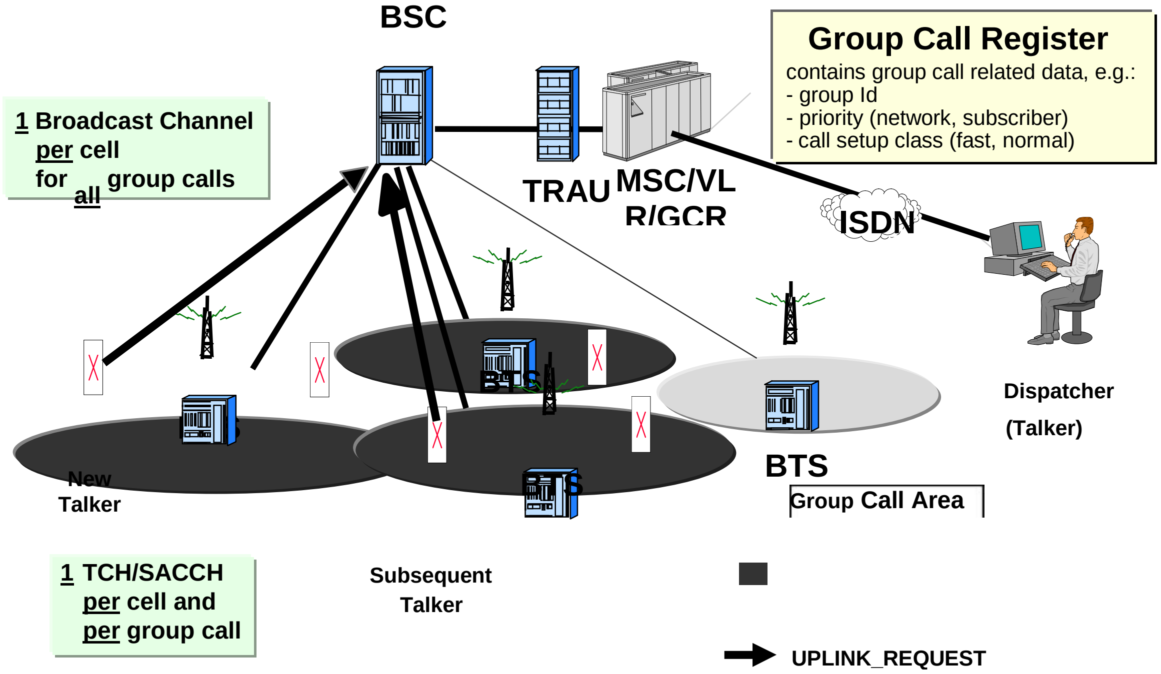


FIG.5.8.Railway emergency call by using VGCS

5.8. Implementation of GSM - R

One of the main factors that will influence the national implementation of GSM-R is the nature of the GSM network to be used. Three main options are available:

- Public GSM network;
- Private GSM network;
- Hybrid GSM network, in which a private and a public GSM network are integrated in order to potentially provide a more cost-effective implementation.

Similar implementations need to be considered for the fixed part of the communications network, leading to a large number of possible combinations for the implementation of the full communications network.

5.8.1. Using a Public GSM network

It means that the mobile side of the network will be out-sourced to a Public Network Operator. In this case, the Railway will have a limited control over the way the Network is implemented and operated, as the Railway will probably form only a small part of the Network Operator's overall customer base. The Network Operator may also have conflicting commercial considerations. In order to implement a GSM-R network using a Public GSM network, the following issues must be addressed:

- The current Areas of Coverage provided by the network operator and how this compares with the designated coverage area required for the implementation of GSM-R;
- The Level of Coverage required by the Railway and how this compares to the Level of Coverage provided by the Network Operator;
- The mechanism for the public network operator to provide any additional coverage required by the railway and organisational aspects e.g. the Access to Sites for Installation;
- The provision of special GSM solutions for Tunnels and Cuttings.
- The level of required GSM Supplementary services that are provided by the Network Operator e.g. Voice Group Call System, Voice Broadcast System and enhanced Multi Level Priority cum Preemption. Some public GSM Network Operators may not provide some or all of the additional services.

5.8.2. Using a Private GSM network

With this option, the Railway Operator is given a more or less complete degree of freedom and the network could be effectively designed to meet all of the functional and system requirements, necessarily at a certain cost. There are, however, specific aspects that need to be addressed when considering the implementation of a private network. One of the main considerations when deciding on the implementation of a Private GSM Network is to ensure that the Network conforms to the existing GSM regulations. The Availability of Frequencies will also need to be considered. The other major consideration is to ensure that the proposed network implementation will lead to a fully functional GSM-R system within acceptable budget constraints.

Before implementation, a Detailed Study is to be conducted in order to establish the Cost of providing Private GSM coverage over the designated area. This will require Survey Data of the Rail Network and the surrounding area in order to determine where Base Stations need to be implemented and the number of installations that will be required. In addition, this will highlight any aspects of planning permissions required for the base station implementations. In this type of implementation the Railway will have more direct control over the levels of performance and the ways in which these can be maintained.

5.8.3. Using a Hybrid GSM Network

Enhancements to an existing GSM Network must be considered in terms of how busy the individual Routes are and the perceived benefits of implementing them. For example, it may be most sensible to implement a Private GSM-R Network covering the Busiest Railway Routes and make use of Public GSM coverage in the other areas. Alternatively, one may choose to finance enhancements to a public network on the busier sections of the rail system and rely on the existing level of coverage for the remainder of the network.

5.9. Numbering Plan principles

Train controllers, Station Staff, etc will normally want to call a Train by its Train Number, e.g. 7021, rather than by the actual Subscriber Number associated with the Mobile Phone with the Driver / Guard. This is because the Staff of a certain regular service will change from day to day, whereas the Train Number is uniquely identified. On the other hand, Maintenance Personnel in Depots will only know a Locomotive by its Engine Number and will prefer to set up a call to a Mobile Phone within the Locomotive by this Number. In each of these situations, it is necessary to be able to call a Mobile Phone on the Train without knowing its Subscriber Number.

GSM-R network: generally uses EIRENE Numbering Plan. For example, if the Locomotive is changed during the journey, the Functional Number based on the Train Running Number will stay the same. GSM-R network users shall therefore be able to originate and receive calls using Functional Numbers. This need to comply with the requirements specified by EIRENE for the structure of Functional Numbers, whilst taking into account the Railway Private Numbering Plan and the National Numbering Plan. The EIRENE Numbering Plan also defines a set of Short Codes to be used within GSM-R networks. These short codes are not restricted to call set-up to mobile users only. Instead, their prime function is to ease the use of GSM-R for Drivers by reducing the Number of Digits to be dialed when calling the local controller or to place an emergency call.

Public Numbering plan is used by the Public Network Operator to route calls through the network and which consists of the actual telephone numbers (e.g. MSISDN numbers) of the called party Terminal Set. There may exist an overlap between the EIRENE and Public numbering plans, since for certain Call Types, the User Number (EIRENE numbering plan) may be equal to a Subscriber Number (Public numbering plan).

The establishment of the relation between a Functional Number and the Subscriber Number is performed by the user through the Registration Procedure and is removed by the user through the De-registration Procedure. This has to be performed every time the association requires an update. The association between the Functional Number and Subscriber Number is held in appropriate Routing Databases. When a call is set up, a translation from the Functional Number to the Subscriber Number is performed. Functional Numbers should be de-registered as soon as they are no longer required so that they are made available for subsequent users.

Possible options for Implementing a Functional Numbering service include:

- using Intelligent Network (IN) facilities;
- within the GSM Network's HLR using the 'follow-me' supplementary service;
- implementation of a dedicated Switch with Associated Databases.

For each of these options, the registration and de-registration aspects need to be considered carefully. In particular, this needs to be done with a view to ensuring that roaming equipment from other railways is fully interoperable with the GSM-R network implementation.

In IN-based solutions, Call Routing is considered separately from the Service Provision. Service Switching Points (SSP) are used to detect whether a Calling Party wishes to use IN functionality. If this is detected, then the information provided by the calling party is transferred to the Service Control Point (SCP) which will act upon the information provided. If the IN solution is used within the GSM-R network, then the Calling Party can dial the Functional Number, which is 'trapped' by the SSP and passed on to the SCP. The SCP then performs the translation of the Functional Number into the appropriate MSISDN number and passes this information back to the SSP. The SSP will then set up the call as requested.

It is not possible to use the same approach if a Calling Party wishes to establish a link using a Functional Number from a Fixed Terminal. For calls from fixed extensions, the Calling Party would establish contact via the fixed network by dialing the appropriate GSM-R Network Access Number (ENAN), which forms the 'trigger' for using IN services. Once the connection is established, the Functional Number is passed via the fixed network and the MSC/SSP to the Service Control Point, where it will be translated into the MSISDN number of the appropriate mobile equipment. Using this number, the call will then be set up via the GSM Network to the correct mobile extension. Alternatively, the Subscriber Number could be called using the National Destination Code plus the MSISDN number.

In the HLR implementation, the EN is dialed directly by the calling party and the call is routed through the Network to the GSM MSC. The GSM Call Forwarding Unconditional Supplementary Service is then used to translate the dialed EN into the MSISDN Number of the relevant mobile equipment and the call is set up.

With Dedicated switch implementation, the Railway does not use any number translation functionality provided by the GSM network. Calls are routed via a dedicated switch, which performs all necessary number translations. Essentially, this is an "external" Intelligent Node, although the switch does not form an integral part of the GSM network. The calling party (whether mobile or fixed terminal) must first gain access to the switch before passing the Functional Number information, in order to allow calls using Functional Numbers to be made. Once the Functional Number is passed to the switch, it will search its routing databases and translates the Functional Number into the proper MSISDN number. The switch will then attempt to complete call set-up to the mobile.

5.10. GSM – R System Planning Phases

This is the preliminary phase of system procurement and includes the following activities:

- System Feasibility Study, to perform an initial assessment of the proposed system. The aim is to determine whether the system can meet its business requirements and whether there is a sound financial case for developing it. The study consists of defining the reasons for the introduction of the new system, establishing implementation options and the assessment of their implications.
- Requirement Capture, leading to a clear definition of user requirements, both functional and non-functional. This will determine requirements relevant to the size of the network, coverage levels, interconnections, migration, terminal design, etc.
- Business Case Development, which will lead to the formal acceptance of the system procurement and will secure the funding for the project.
- Development of a System Specification, which will look at the system requirements and address issues e.g. interfacing the network to other networks and systems (location systems, signalling systems, train control systems and other telecommunications networks). It will also consider operational requirements, provision of services and facilities, system design, equipment requirements, management systems, implementation requirements, safety aspects, RAM requirements and EMC.
- Development of a Procurement Strategy, which will detail how the Network is to be procured and will deal with issues such as implementation options (private versus public network) and service provision (privately operated or outsourced).
- Development of a migration plan, which will include aspects such as the rollout plans and plans for the transfer from the old system to the new system.

In addition, the EIRENE Specifications do not comprehensively cover certain aspects of implementation and design such as coverage, frequency allocation or performance monitoring. These additional aspects of system design form an important part of the technical specification, but their needs are mainly driven by operational and business requirements. Since these will differ between individual railways, the railways must be responsible for the specification of their own system designs.

5.11. GSM – R Type Approvals

Railway environmental specifications are becoming increasingly harmonised across Europe through the work of CENELEC. However, many national requirements remain. The GSM-R type approval regime, which will form part of the conformity assessment process, will need to consist of several layers, defined as follows:

- Enhanced GSM type approval: This covers additional GSM features, which have been introduced as part of the development of the GSM-R radio system such as ASCI and R-Band. Tests are carried out against a set of harmonized standards covering the relevant GSM specifications GSM TS 11.01 and the associated CTRs.
- Railway specific Type Approval: This covers features specific to the GSM-R Radio system, which include Functional and Location Dependent Addressing and specific environmental requirements. Tests are carried out against harmonized CENELEC standards.

In order to interpret the assertion that no safety requirements are to be placed upon GSM-R, it is important for each Railway to identify exactly which applications are being referred to. In particular:

- There are many applications external to GSM-R (e.g. ETCS) which will make use of GSM-R as a bearer service;
- There are also several applications internal to GSM-R (e.g. Railway Emergency Calls, Driver/Guard and Controller calls), which are provided by the GSM-R telecommunications service and which use a GSM network as a Radio Bearer.

5.12. RAM requirements for GSM – R

The RAM requirements placed on the radio system will depend largely on the application(s) being run over the radio system. The requirements fall into two categories, operational requirements and safety requirements, while the applications can be split into two general classes, Driver / Guard to Controller communications and Train Control applications. For example, in a Driver / Guard to Controller communication application, the loss of radio communication may not physically stop the train from running. However, it will have an impact in terms of safety, as the Driver / Guard and Controller will not be able to communicate in the event of an Accident or Emergency, which may lead to train running being suspended.

In comparison, for a train control application such as full in-cab signaling, the loss of the radio bearer will lead to a loss of signaling information, and may in some cases result in the train being forced to stop. It should be noted, however, that the signaling system is assumed to be fail-safe and there will be no safety implications of losing communications.

The impact of any system failure will also depend on the location and extent of the failure. For example, the effect of the loss of radio coverage on a small stretch of a lightly used, isolated section of line will be small compared to the loss of radio coverage at a major junction or over many kilometers of busy, intersecting lines.

Care should also be taken in setting Availability levels for a given system. Whilst an overall availability can be quoted either for a whole system or for its differing failure modes, the impact of this on system design will depend on the size of the system. The availability of the Radio system should also be computed in conjunction with the availability of the rest of the Railway Infrastructure. There is no point in designing and paying for a radio system, which provides availability some orders of magnitude higher than the availability of other system elements.

Once the requirements have been set according to the steps outlined above, it is then possible to carry out a cost-benefit analysis by comparing the available network architectures and to consider what steps need to be taken to increase network resilience to support the required performance levels. The cost of any proposed solution should then be compared to the cost savings arising from the increased resilience. When specifying the RAM requirements, the Railway should bear in mind that in some instances separate availability requirements will need to be specified for the various system failure modes and not just for the system as a whole. It also demonstrates that the requirements will vary on an installation-by-installation basis.

Maintainability is closely related to the system and component design and should as such be considered in conjunction with these aspects of system specification and procurement. The ease with which an object, system or service is repaired is usually expressed as its Mean Time To Repair (MTTR). Note that the definition of MTTR includes not only the ease, with which the object, system or service can be repaired, but also the speed with which the Fault is detected and identified and the speed with which the relevant maintainer is notified and can attend to the problem. Maintainability therefore includes the aspects of Fault Detection, Fault Identification and the Notification and attendance of the relevant maintenance personnel. Maintainability will also include preventative and routine maintenance, especially the ability of an object, system or service to maintain full functionality while undergoing maintenance.

Generally, the following are the minimum required planning data for radio network planning:

- Minimum receive level of – 90 dBm for 95% location/time probability at 100m (ETCS 97%, Shunting 99 %)
- Mobile station output power 2 W (33 dBm) or 8 W (39 dBm)
- Mobile station RX sensitivity –102 dBm
- C / I_C 20 dB co-channel interference
- C / I_A 5 dB adjacent channel interference
- Antenna gain (typically 12 to 17 dB) and height above ground
- Losses in feeder cable and other components Fading margin (slow, fast)

5.13. GSM – R in Indian Railways

Indian Railways have accepted GSM-R for Mobile Train Radio Communication. Eastern, East Central and North Frontier Railways are already in Planning and Procurement stages. Similarly, in North Central Railway, GSM – R is going to be installed between Kanpur- Gaziabad section as a part of KFW Project.

The following description is related to Eastern Railway Project for GSM – R Installation between Howrah to Pradhankunta.

The Functional Requirements Specification defines the requirements of a mobile radio system satisfying the mobile communication needs of the Indian Railways. It encompasses Ground to Train Voice and Data Communications requirement together with the ground based mobile communication needs of Maintenance Staff, Station Staff and Railway Administrative and Managerial Personnel. The System shall be primarily based on the European Telecommunication Standards Institute (ETSI) Global System for Mobile (GSM) Phase-2 Standard and additional requirements specified in EIRENE and MObile RAdio for Railways Network in Europe (MORANE) SRS documents.

The Network shall support voice telephony services e.g. Point-to-Point calls, Broadcast calls, Group calls, Multi–party calls and Emergency call. All voice call services except Group calls shall be Duplex and shall be able to operate between any combination of fixed and mobile equipment users. The network shall also support Data Services which may be required by Eastern Railway in future -- Train Control applications, General data applications and Automatic

FAX and Text Messages. The network shall support Point-to-Point Data Communications data rates of at least 2.4 kb/s. All Railway-specific services e.g. Railway Emergency calls, Functional Addressing including Registration / de-registration, Location Dependent Addressing Shunting Mode and Multiple-Driver Communications will also be supported.

The planned Network is having a Coverage Probability of 95%, based on a coverage level of -98 dBm, for voice and non-safety critical data, and of - 95 dBm, on lines with ETCS levels 2 or 3 for speeds lower than or equal to 220 km/h. The coverage levels specified above, considers a maximum loss of 3 dB, between Antenna and Receiver and an additional margin of 3 dB for other factors such as Ageing. The level of coverage should be at least 95% of Time over 95% of designated Coverage Area for a radio installed in a vehicle with an external antenna. The system design is to be prepared on following consideration:

- Output Power of Base Station at Power Amplifier must be 44 dBm or better.
- BTS sensitivity shall be –107dBm or better.
- Mobile power output shall be 2W.
- Mobile sensitivity shall be –102dBm or better.

The handover success rate should be at least 99.5% over train routes under designed load conditions. Quality of service (QOS) requirement is that handover execution time shall not exceed 500 msec. An additional option is available to reduce the handover break period, namely the use of the synchronous handover capability to reduce the break period to about 150ms.

The Proposed Section for GSM – R Installation (261.27Km) can be subdivided into following sub-sections.

Sl. No.	Section	No. of running lines	Length (KM)
1	Howrah - Bally	6	8.66
2	Bally - Gurap	3	48.80
3	Gurap - Saktigarh	2 (3rd line under construction)	25.38
4	Saktigarh - Sitarampur	4	138.17
5	Sitarampur- Pradhankunta	2	40.26

The Trains running in the section are controlled from the Control Offices located at two Divisional Headquarters – Howrah (Howrah to Khana) and Asansol (Khana to Pradhankunta). The Stations are connected with the Control Offices through Railways own Microwave / Optical Fibre Communication Links. The Emergency Calls from the Trains or Trackside Maintenance Staff should land into the divisional control office. In Howrah to Pradhankunta Section, all the wayside stations are equipped with Microwave Towers. It is envisaged that the Antenna of the GSM – R Base Stations will be located in the same tower. The Central Switching equipment is proposed to be located in the Zonal Railway headquarter at New Koilaghat. The backbone communication system for the Mobile Trains Radio network, will be provided by the Railway through separate Optical Fibre Link.

The system should work with following frequency pairs:

Sl.No.	Frequency Pair	Frequency Up Link (MHz)	Frequency DN Link (MHz)
1	F1	907.8	952.8
2	F2	908.0	953.0
3	F3	908.2	953.2
4	F4	908.4	953.4
5	F5	908.8	953.8
6	F6	909.0	954.0
7	F7	909.2	954.2
8	F8	909.4	954.4
9	F9	889.6	934.6
10	F10	889.8	934.8

The main components of the system are:

- Base Station Controllers (BSCs), which controls Base Transceiver Stations (BTS), to be installed at wayside stations, are to be installed at New Koilaghat (HQ of E. Railway)
- Network Sub-Systems (NSSs) interfacing to the BSS via the GSM ‘A’ Interface, contains Mobile Services Switching Centers (MSCs) with primary responsibility for call control is to be installed at New Koilaghat. The MSC is supported by a Visitor Location Register (VLR), containing temporary details of Subscribers active within the MSC area; a Group Call Register (GCR), containing attributes of Voice Group and Broadcast Call configurations for the related MSC area and Home Location Registers (HLRs), holding subscribers details on a permanent basis.
- The Network shall also support General Packet Radio Service (GPRS) infrastructure elements supporting the respective packet radio services in future.
- Mobile equipment interfacing to the BSS.
- Subscriber Identity Modules (SIM) containing information specific to single subscribers.
- Operation and Maintenance center (OMC) for managing the network.

Mobile Switching Centre shall be fully wired for the capacity of 4000 Subscribers and expandable up to 20000 subscribers (minimum). MSC Traffic capacity shall not be less than 500 Erlangs. The MSC should have Duplicate Control Panel and should be scalable for future growth. MSC should be provided with Intelligent Network Platform based on CAMEL (Customized Application for Mobile Enhanced Logic) Phase-2 or its higher version.

There are three standard main types of terminals to be procured. These terminals have to fulfill basic services, facilities and features specified in EIRENE specification. The three types of terminals are:

- Cab Radio – for use by the driver of a train and by ERTMS/ETCS (8 Watt).
- General Purpose Radio – for general use by railway personnel (2 Watt).
- Operational Radio – for use by railway personnel involved in train operations such as shunting and trackside maintenance (2 Watt).

5.14. System Design for GSM – R for Eastern Railway

Eastern Railway has arrived at a system design for the MTRC for the section based on the system architecture of GSM-R. The salient features of the system design are as under:

Subscriber	No.	Traffic per Subscriber in Erlang	Traffic
Driver	1	0.04	0.04
Guard	1	0.04	0.04
Security Staff	2	0.05	0.10
Commercial Staff	20	0.015	0.30
Total Traffic per Train.			0.48

Traffic Originated per Train

Traffic requirement / Section Total traffic

1) Howrah to Bardhaman 12 trains/hour/section of 10 Km. - 5.76 Erlangs.
2) Bardhaman to Chota Ambana 6 trains/hour/section of 10 Km. - 2.88 Erlangs.

In each section of (10 Km.) the traffic originated from other than trains are as under:

Subscriber	Total Nos.	Traffic/Subscribers	Total traffic
Station Master	3	0.025	0.075
Maintenance staff	3	0.05	0.15
		Total	0.225 Erl

Thus total traffic envisaged for each (10-12 KM) section including the traffic originated by moving trains as well as station staff and maintenance staff:

Howrah - Bardhaman - 5.985 Erlang/Hour/Section of 10 KM.

Bardhaman - Chota Ambana - 3.105 Erlang/Hour/Section of 10 KM.

Additional Traffic from Divisional HQ. and Zonal HQ. has been taken into considerations as under :

Division	Erlang
Howrah	1.515
Asansol	1.515

Based on the above traffic requirement the no. of BTS Transceivers required for different sites have been finalized as under:

Station	No. of Transceivers in Omni-directional configuration	Additional Remarks
New Koilaghat	3	A. New Koilaghat will also house MSC,BSC and TRAU and will be the nodal center for network maintenance and management.
Howrah	2	
Liluah	2	
Dankuni	2	
Baruipara	2	
Kamarkundu	2	
Belmuri	2	B. Minimum of 2 Nos. of BTS have been considered from each locations.
Gurap	2	
Masagram	2	
Saktigarh	2	
Bardhaman	2	C. For administration requirement of the Zonal Head Quarter at New Kiolaghat the no. of BTS have been taken as 3 Nos.
Khana	2	
Paraj	2	
Mankar	2	
Panagarh	2	
Durgapur	2	
Waria	2	
Andal	2	D. Full rate duplex channels have been considered.
Raniganj	2	
Asansol	2	
Barakar	2	1TRX provides 7 duplex traffic channels.
Thaparnagar	2	
Chota Ambana	2	2 TRX – 14 Nos.
Pradhankunta	2	3 TRX - 22 Nos.

Note A: The design has been considered with OMNI sites but with directional antenna beaming in two directions.

Note B: Maximum speed has been taken is 220 KMPH.

Note C: Carrier to interference ratio has been taken as C/I > 15 dB throughout the section.

Note D: Coverage Plan has been taken as per EIRENE specification.

Objective:

1. GSM-R is the communication standard chosen by EIREN (T/F)
2. Call Setup should be possible as mobile terminated call (MTC) (T/F)
3. For MOC and MTC different addressing modes are required for the call setup. (T/F)
4. MTC is call from the Train driver to controller (T/F)
5. MOC is call from a train to a train controller terminal (T/F)
6. GMS-R provides communication up to a speed of 500 km/h (T/F)
7. Interleaving of BTS of two different loops will decrease the consequences of a single BTS or BSC failure. (T/F)
8. Up to 7 BTSs can be connected in one loop using one PCM 30. (T/F)
9. Location Dependent Addressing provides the Automatic Routing (T/F)

Subjective:

1. Explain MOC and MTC?
2. Explain location dependent addressing in GSM-R?
3. Explain voice broadcast service (VBS) in GSM-R?

CHAPTER-6

GSM-R BSS EQUIPMENT (NOKIA SEIMENS NETWORKS)

6.0. Base Station Subsystem (BSS)

The Base Station Subsystem comprises two parts, the Base Transceiver Station (BTS) and the Base Station Controller (BSC).

6.1. Base Transceiver Station (BTS) Model BS-240 / 240 II:

The Base Transceiver Station houses the radio transceivers that define a cell and handles the radio-link protocols with the Mobile Station and also Encodes, encrypts, multiplexes, modulates and feeds the RF signals to the antenna.

BTS communicates with Mobile station and BSC. The base transceiver station or BTS contains the equipment for transmitting and receiving radio signals from (transceivers) TRX units.

The Base Station equipment of the BS-240 / 240 II is the new future-proof evolution of Nokia Siemens networks (NSN s') BTS hard-ware housed in racks with the dimensions of 1600 mm X 600 mm X 450 mm (H x W x D). The first rack of Base Station is called Base rack.

6.1.1. The main components of the BTS are

• Antenna Combining equipments (ACOM)
• Carrier unit boards (CU)
• Core boards (COBA/COSA)

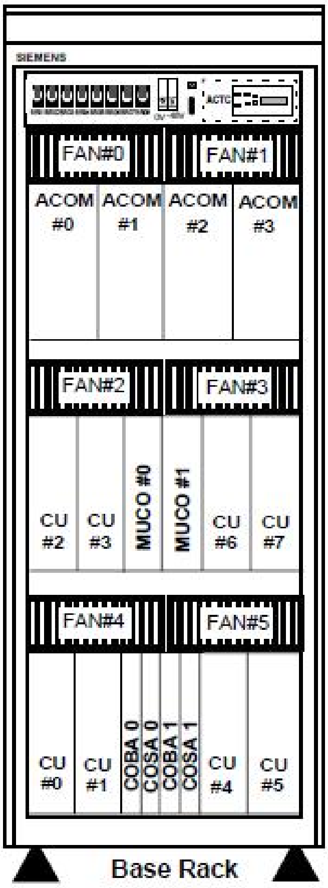


FIG.6.1. BTS Base Rack Model BS-240 / 240 II

6.1.2. Antenna Combining Modules (ACOM): These modules are configured in slot 0, 1, 2 and 3 of the base rack. The types and numbers of modules are subject to modification, it depends on the cell configuration and the type of antenna combining. The following are the few combinations of combining units.

TX - and RX - Combiner:	DUAMCO
TX - Combiner:	FICOM
RX - Multicoupler:	DIAMCO
High Power Duplexer:	HPDU

Combining Configurations

For serving cells with different numbers of carriers, certain combinations of combiner modules are required. The antenna diversity is always assumed for the uplink path. The required splitting factor only depends on the maximum carrier number per cell without yielding a reasonable technical penalty.

For downlink transmission, a trade-off between the number of antennas and the insertion loss for a given number of carriers exists. Increasing the antenna number decreases the down link insertion loss introduced by hybrid combining of carriers to one antenna. For high carrier numbers per cell, filter combining becomes advantageous with respect to insertion loss. However, filter combining has the disadvantage of higher cost and incompatibility to synthesizer frequency hopping.

6.1.2.1. DUAMCO(Duplexer Amplifier Multicoupler)

Definition of a duplexer:

A device which allows a transmitter operating on one frequency and a receiver operating on a different frequency to share one common antenna with a minimum of interaction and degradation of the different RF signals.

Duplex Operation

Duplexers are often the key component that allows two way radios to operate in a full duplex manner. Full duplex means the transmitter and receiver can operate simultaneously as opposed to the ‘push-to-talk’ manner used in non-duplex (or ‘simplex’) operating modes.

Duplexers are the devices that allow a mobile telephone to operate like a wired telephone, with either or both people speaking at any time without using a microphone switch to enable the radio transmitters.

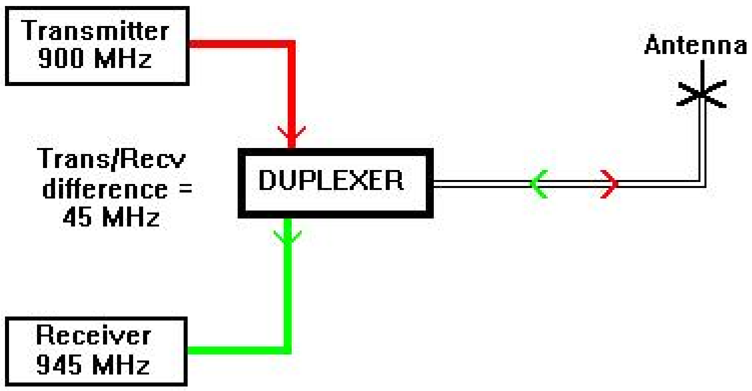


Fig.6.2. Simultaneous signal flow through a duplexer

The Receiver Multicoupler allows for the operation of two or more receivers connected to a single antenna, conserving tower space and minimizing system installation and maintenance costs. This receiver's vertical shelf capability makes it possible for a fully integrated wireless distribution system to be all on one shelf, vertically aligned with the duplexer and combiners. Consisting of a multistage amplifier and two power dividers, this compact unit provides the overall system gain and low noise loss figure, < 3dB. A primary power divider distributes equal amplitude signals to each of eight separate receivers. Two additional ports are available for future expansion. Fault monitoring indicates the proper operation of the amplifier as well as the integral power supply.

The DUAMCO x: y is named according to the number x of transmit connectors fed by the CUs and the number y of antenna connectors.

The DUAMCO x: y modules contain duplex filters for routing both the transmit and the receive path over one antenna connector. The receive and transmit part of the duplex filter, respectively, provide the substantial part of the receive and transmit band filtering required by GSM. The internal elements of the DUAMCO 8:2 are shown in fig.6.3.

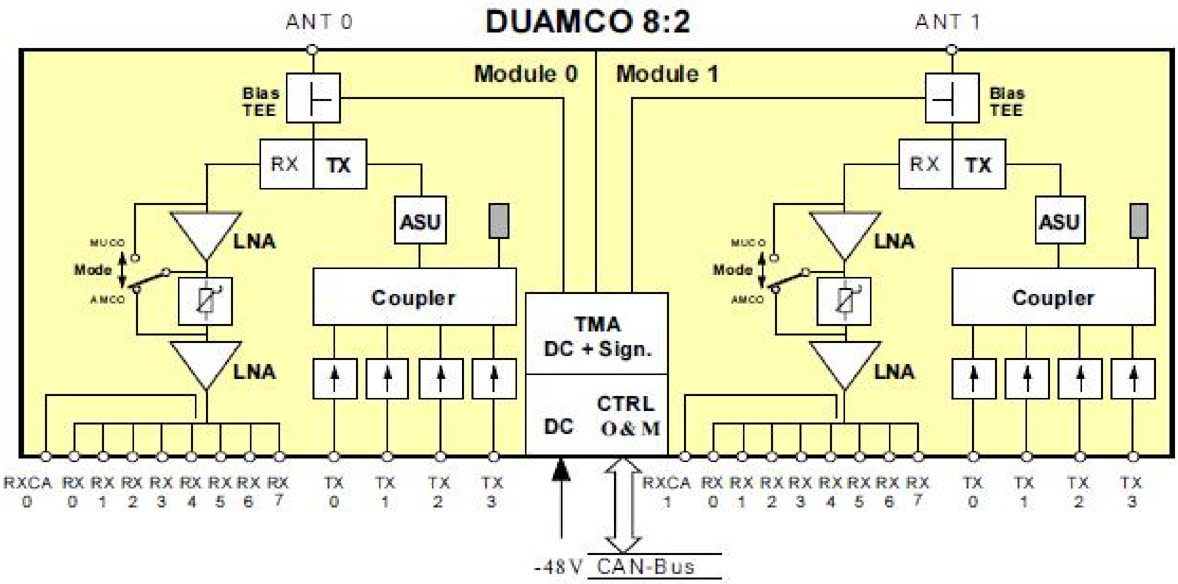


Fig.6. 3. Internal structure of DUAMCO 8:2

The receive path consists of a LNA (Low Noise Amplifier) and a power splitter. The LNA provides for a low system noise and consists of two branches. In case of malfunction of one amplifier the RX gain of the DUAMCO decreases by about 6 dB.

The power splitter distributes the received band to the CUs (Carrier Units). A splitting factor of 4 (or 8 in case of DUAMCO 8:2) is implemented in order to feed 4 (8) CUs.

6.1.3. Carrier related Modules:

6.1.3.1 Carrier Unit (CU):

The carrier unit provides all analog and digital signal processing including RF power stage for a single carrier (e.g. GSM 8 TCHs). The carrier unit interfaces with the combining equipment on one side and with the core modules on the other side.

The core boards provide functions common to all carriers within the BS240/BS240 II (e.g. clock generation, O&M processing) as well as LAPD processing for the different carriers.

Carrier Unit generates 1 TRX frequency, making 8 subscribers for that particular TRX frequency. Data conversion is done in carrier unit from $A_{bis} \leftrightarrow$ Um:

And for uplink and down link the conversion will be done as follows

- DL: TRAU frames → RF signals
- UL: 2 RF signals → TRAU frames
- up to 8 TRX / rack as CU0,CU1,CU2,CU3,CU4,CU5,CU6 and CU7

Carrier Unit (CU) consists of three units that are PATRX, SIPRO and PSU as shown in fig.6.4.

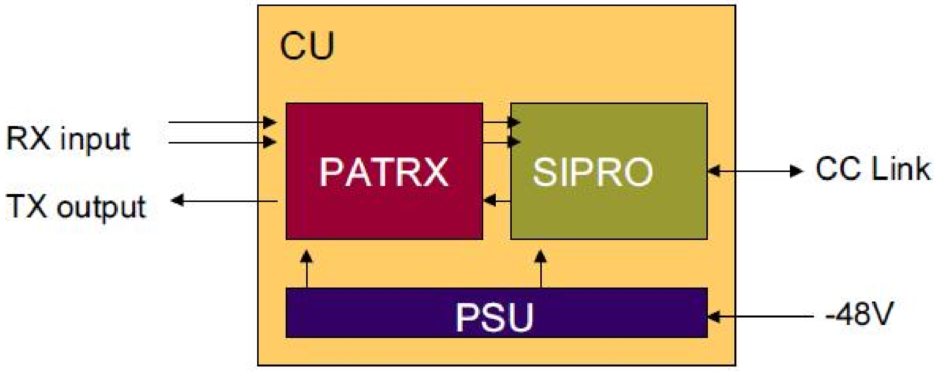


FIG.6.4. Functional diagram of Carrier Unit

6.1.3.2. Power amplifier and Transceiver Unit (PATRX):

PATRX provides the main analog functions of the CU. In uplink direction two (diversity) pre-amplified and filtered RF signals are received from the antenna combining equipment. These signals are converted to IF and channel filtered. The IF signals are then transmitted to Signal processing unit (SIPRO), where they are sampled and digitally converted to baseband.

In downlink direction the GMSK modulated signal is received from the SIPRO, I/Q modulated and converted. The resulting RF-signal is then power amplified and transmitted to the antenna combining equipment.

PATRX is able to support synthesizer frequency hopping. The unit test of the CU is supported by a special module, which provides a RF loop between downlink and uplink path.

The power control loop implements 6 static power steps (each 2 dB) and additional 15 dynamic power levels (each 2 dB).

6.1.3.3. Signal processing unit (SIPRO):

The SIPRO is another part of the Carrier Unit. It contains all digital functions of the carrier unit namely

- Signal processing in uplink and downlink (encoding, ciphering, interleaving, burst formation)
- Control of RF on PATRX
- Baseband and synthesizer hopping
- Channel control
- Radio link control

- O&M parts relevant for carrier unit
- Link to core via CC link

Additionally, the following analogue functions are located on SIPRO:

- Analogue to digital conversion (IF)
- Digital to analogue conversion (baseband)
- Local clock of CU

6.1.3.4. Core Basis (COBA):

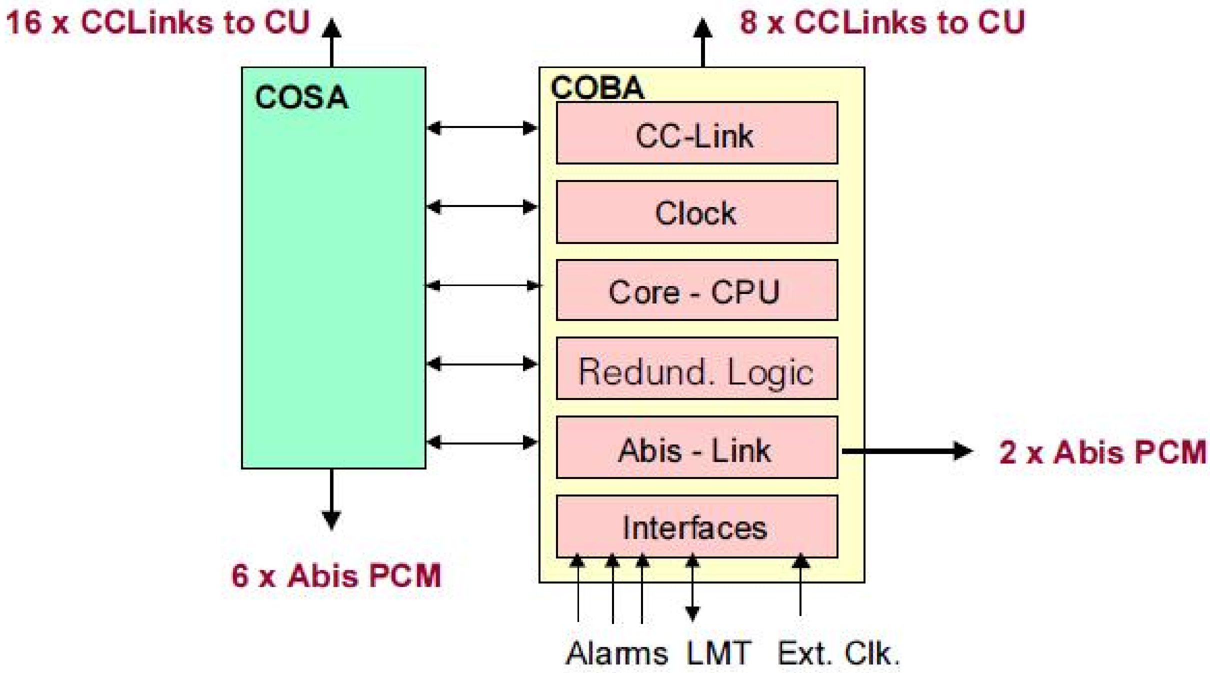


Fig.6. 5. Structure of COBA

The controller stores the SW of all BTSE units in Flash-EPROMs, supervises the SW download and terminates all internal system alarms. Beside the O&M functions the controller handles the signaling messages between BSC (A_{bis}) and CU. The COBA can be expanded with the COSA (satellite) board.

For a configuration of max 2 PCM30/PCM24 interfaces and 8 CU, only the COBA is required. An additional COSA can be mounted for expanding the BS240/241 capacity up to 8 A_{bis} and 24 CU. The cabling between A_{bis} OVPT and CU and the core unit is done via the backplane.

To achieve core redundancy (later version), the COBA board and its satellite can be duplicated. In this case one of the board pairs (COBA+COSA) is active, working as the master. The other pair is inactive/standby status (idle if HW problems have occurred). The COBA controls the switchover between active and inactive boards. Special links are provided for information exchange between the two board sets.

A COBA board can only be pulled out, if the COSA board is pulled out first. The plugin of central boards is “hot”, i.e. there is no need to switch off power first.

6.1.3.5. Redundant core: For core redundancy, the COBA and its satellite are duplicated. In this case one of the board pairs (COBA+COSA) is active, working as master. The other pair is inactive standby status. COBA controls the switchover between inactive and active.

The PSU is the DC/DC converter for the CU. The PSU generates the voltages +26/28V, +6V (only GSM1800/GSM1900), +12V, +5.3V and -5.3V for the analogue circuitry and +3.35V for the digital circuitry from a -48V primary input voltage. The PSU is mechanically integrated in the CU board.

6.2. Base Station Controller (BSC):

It acts like an exchange of BTS sites making them as users of the exchange. In general it contains all the configuration of each BSS units/systems (e.g. TRAU, BSC, BTS, RC), so that it controls and manages all the units. It connects with the TRAU (PCM-S/ A-sub interface) at one end and with BTS sites (PCM-B/ A-bis interface) at another end. The BSC can be located close to the base stations. It concentrates the traffic towards the MSC, optimizing the utilization of the associated leased lines. In addition, the BSC supports various BSC-BTS configurations (e.g., star, multidrop and loop) and star configurations towards the TRAU.

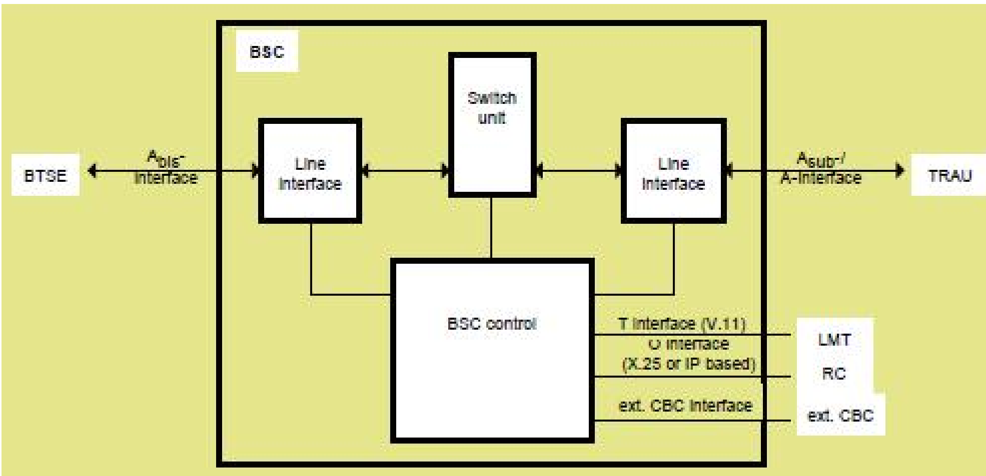


Fig.6.6.Functional structure of the BSC

The BSC is the central component of the BSS and it is responsible for

- Traffic channel switching
- Signaling information processing
- Operation and maintenance handling and alarm monitoring

The eBSC switches circuit switched traffic (voice) from the MSC via TRAU

The BSC consists of

- BSC control
- Line interface
- Switch unit.

6.2.1. BSC control

The BSC control is a multiprocessor system. It contains two main processors performing call processing and O&M tests, and a set of slave processors for peripheral tasks and for communicating between the components of the BSS. To achieve a high degree of reliability, the main processors are duplicated. A hard disk is provided as a background storage device.

One of the two main processors is the administrative processor represented by the main processor control card (MPCC). This controls the connections of the switching unit on the basis of the telephony processor messages. The other of the two main processors is the telephony processor represented by the telephony and distributor processor card (TDPC), which is responsible for message exchange with the other network entities via the peripheral pre-processors.

6.2.2. Line interface

The line interface provides the connections to the BTSs (A_{bis} interface) and TRAUs (A_{sub} interface) via standard 2 Mbit/s digital lines.

Each line interface handles four 2 Mbit/s PCM lines; each PCM line has four physical interfaces (terminal); the active physical interface is selected, on a per channel basis, under software control.

6.2.3. eBSC (enhanced BSC) Rack

The eBSC rack is composed by upper and lower shelf

Main rack’s characteristics are the following:

- No rear access for maintenance activities;
- The front door supports an alarming mechanism to detect eventual door open states;
- The rack’s door is equipped with an alarm lamp panel with different colors related to the alarm’s severity (for example: red: Critical alarm);
- Support of an optimized system cabling architecture

Upper shelf

Made of two sub shelves

Sub shelf at the top hosts rear transition modules (RTM) supporting I/O modules for Line module (LM)-E1/T1 and switching module and clock (SMAC)

Sub shelf at the bottom hosts main blades as line cards, SMAC and User plane module (UPM)

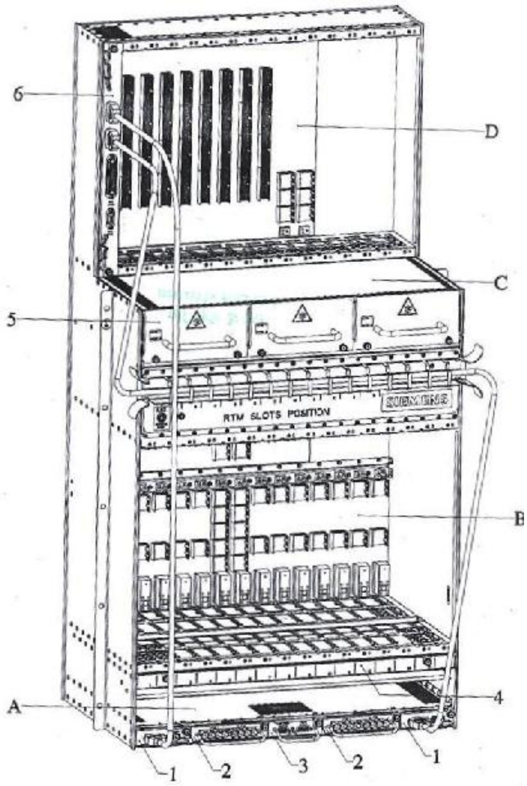


Fig.6.7. Upper shelf of eBSC

Description of shelf:

A	Air inlet
B	Blade (Board in ACTA format) area
C	Air exit zone
D	RTM boards area (slot 2 to slot 10)

Shelf configuration

ITEM 1- ShMgr: Shelf manager is the command center of the shelf. It assures the proper operation of the boards and rest of the shelf. It monitors the health of the system, retrieves inventory information.

ITEM 2- PEM: Power Entry Module provides power supply to the system

ITEM 3- SAP: Shelf alarm panel Provides shelf alarms

ITEM 4-Dust filter

ITEM 5 –FANS: Provided for cooling devices in 3 units

ITEM 6- ACFC: Alarm collection and Fan control connected to SAP through connectors left and right 2Nos.

Lamp panel unit (LPU): It is mounted on the cabinet top frame. Its function is to signaling the different alarms by different colors.

Minor	yellow
Major	Amber
Critical	Red

Lower shelf

Made of two sub shelves

Sub shelf at the bottom is identical to the one of the upper shelf and hosts main blades as line cards, SMAC, Application processor (AP), Main control processor (MCP) and User plane module (UPM).

Sub shelf at the top has lower height compared to the one of the upper shelf and hosts the RTM of the SMAC.

6.2.4. eBSC modules:

MCP Main control processor: is the central O&M controller.
Connects RC (X.25, Ethernet)1 port of 10/100 BASE T for Ethernet IP based O&M, LMT (Ethernet only) connection Hard disk for storage of software, performance measurements data etc.

SMAC Switching module and clock: Transport of all types of traffic (user and control data) between the blades of the shelf and between the shelves inserted in the rack.

Gigabit Ethernet switch (GES) module supports the transport functions of user, control and management data.

Main clock generator (MCG) module provides the central clock functionality. It generates high stable synchronization clock distributed within the shelf and used for synchronizing the line interfaces with in the shelf.

General purpose peripheral processor manages and supervises the status of GES and MCG components.

RAM memory has a size of 1GB
SMAC manages up to 21 external alarms.

AP Application processor blade is responsible for the call processing application.

AP/M Application processor Master: processing the radio resource management (RRM) and all SS7 signaling.

AP/D Application processor Dependent is processing the RRM for a number of cells.

UPM User plane module is used as packet control unit (PCU).

The main PCU functions are

Radio channel management
Protocol conversion between standard BSS GPRS and proprietary A_{bis} protocol.

LISO Line interface for STM1/OC3

LIET Line interface for E1/T1provides connections to

- BTSE (PCMB)
- TRAU(PCMS)

Via standard 2Mbps digital lines
An LIET features 16ports with two terminals each.

POWER SUPPLY

Two separated lines of -48V DC connections are provided at the top of the rack. The basic requirement on power distribution for the shelves is providing DC dual feeds.

Power switching is done at DC panel

Each main board receives the dual DC feeds provided by the shelf. The secondary voltages have to be generated on each board by using DC-DC converters.

6.3. Transcoding and Rate Adaption Unit (TRAU)

Although the Transcoding and Rate Adaption Unit (TRAU) is logically part of the BSC, it is designed to be physically located at the MSC site. This helps to save transmission capacity between the BTS and MSC site. If requires it may be located at BSC also according to application demands. Fig.6.8. Shows the functional structure of the TRAU

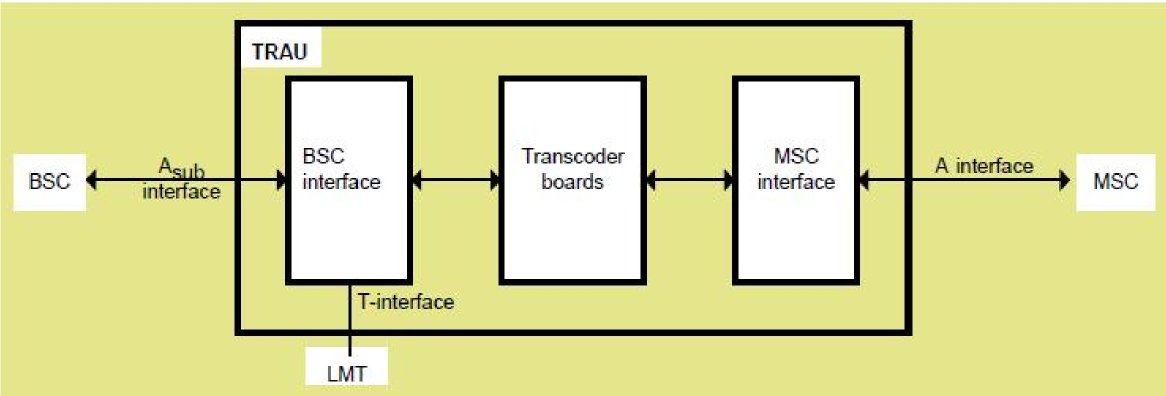


FIG.6. 8. Functional structure of the TRAU

The TRAU consists of the following functional blocks as shown in the above fig.

- BSC interface
- MSC interface
- Transcoder boards

6.3.1. BSC interface

The BSC interface is represented by the BSC interface card (BSCI) which houses the central controller of the TRAU and includes an interface to the BSC using normal PCM links with a 16 kbit/s traffic channel structure. It multiplexes the serial lines generated by the TRAC boards to build the complete lines to be sent to BSC and is transparent for the SS7 channel (64 kbit/s channel) and for the X.25 link between BSC and RC (64 kbit/s channel).

6.3.2. MSC interface

The MSC interface is represented by the MSC interface card (MSCI) which multiplexes the serial lines generated by the TRAC boards to build the complete 64 kbit/s traffic channel structure to be sent to the MSC/VLR node and processes the LAPD protocol residing in the control link of the BSC. By using a dedicated serial communication link, it sends the messages received from the BSC to the BSCI (directly or via another TRAU) and receives the messages from BSCI to be inserted in the link to the BSC.

6.3.3. Transcoder boards

Transcoder boards are represented by the transcoding and rate adaption card (TRAC) which processes 24 TRAU frames for 24 x 16 kbit/s traffic channels (uplink) with reference to the A_{sub} interface side and for 24 x 64 kbit/s traffic channels (downlink) with reference to the A interface side. They operate with speech and data on each channel, either at full-rate, half-rate and enhanced full-rate (coding and rate adaption function) and performs the DTX/VAD function (for the full-rate channels) and performs the volume control to compensate for possible losses of the speech level on a per-call basis.

6.4. The Radio Commander (RC) :

The Radio Commander (RC) comprises the operation and maintenance processors for the BSS (OMP) and the operation and maintenance terminals (OMT) which are connected to the OMP via a local area network (LAN). In this case, the OMP and OMT represent the client and server of a client-server LAN architecture.

6.4.1. Operation and maintenance processor (OMP)

The OMP used is a commercially available computer (SUN Sparc/Workgroup or Enterprise). The OMP can be optionally duplicated with hot standby redundancy. The OMP redundancy can also be supported by the use of internal hardware redundancy of the SUN server.

6.4.2. Operation and maintenance terminals (OMT)

Typically, the OMT is a graphical workstation, but given the Radio Commander’s flexibility, it is possible to work with a broad range of different types of OMTs, for graphical user interface (GUI) and command line interface (CLI) access, such as:

- SUN graphical workstations
- X-terminals
- Graphical workstations acting as X-terminal
- PCs with X-terminal emulation
- PCs/workstations with alphanumeric terminal emulation for alphanumeric access (via TELNET)

The standard configuration allows at least 8 active GUI sessions simultaneously (four of which on X-terminals) or at least 16 alphanumeric sessions in addition to GUI sessions on OMT local or remote.

The protocol stacks for transferring information between the OMC and the network entities and/or other NMC/OMCs utilize standardized protocols, procedures and services for TMN applications. The NMC can be connected via LAN/router for management activity and via LAN/router for remote login. Communication between remote OMTs and the OMP is based on TCP/IP.

The OMT for “National OMC” application (OMT/N) is connected via X.25 (X.21 port) for management activities and LAN/router for remote login. From the OMP point of view, the OMT/N is just another OMT, hence the same protocol is used.

Flexible and mobile remote access to the Radio Commander (RC) is provided via standard technologies such as

- PC/Windows NT
- LAN/ISDN/modem/mobile
- Web interface

The functionality supported includes CLI, GUI (fault management (FM), performance management (PM), configuration management (CM)), database access, and remote printing.

For increased access security, it is possible to use SSL for encryption/decryption.

The OMC <--> OMC interface is used for remote operation via TCP/IP and X-11 protocol.

The Radio Commander (RC) also provides a CORBA-based interface to allow the integration of external offline applications.

The RC also supports standardized interfaces to:

- Microwave equipment
- External alarm devices
- Stand-alone post-processing tools
- And supports standardized interfaces for remote SQL database access, remote UNIX login and remote CLI access

6.5. LMT

As local maintenance terminals (LMT) commercially-available hardware is used. The same LMT hardware with its T interfaces is used for the BSS entities (TRAU, BSC, BTS). LMT is available for operation and maintenance work at the BSS network element (TRAU, BSC, BTS) site. The proprietary interface T (X.21/V.11) is used.

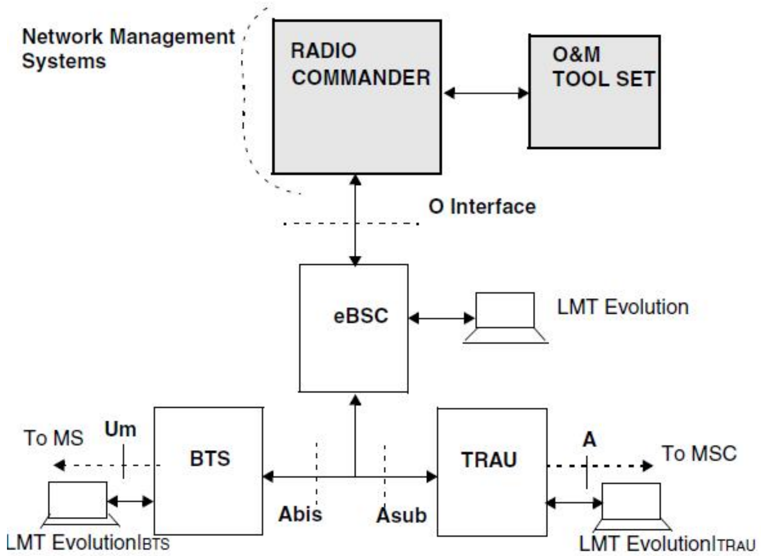


Fig.6.9. LMT Evolution and BSS system

The Local Maintenance Terminal Evolution is the O&M system interfacing its users from one side and the connected network element (eBSC, BTSE, TRAU) from the other side for Operation & Maintenance tasks.

It has been implemented according to the international standards with the main purpose of an easy portability on different software platforms. The purpose of the LMT Evolution is to support the Operation and Maintenance activities in a very efficient and user friendly way and to provide all the possible informations about the condition of a specific Network Element running in field with particular attention to eventual faults or anomalous situations. The LMT Evolution can be connected to the Network Element BSC, TRAU and to all BTS types.

6.6. The mobile equipments of GSM-R:

These are classified into two categories

- The radios in the cabin of a locomotive - also known as cab radios - are installed on board and are destined for the train conductors.
- The mobile equipments are equal to the classical GSM's but give also access to all functions that are developed for the digital radio network.

There are three types of mobiles equipments:

- for general purposes (GPH),
- for operational purposes (OPH),
- for shunting (OPS)

These three kinds of mobiles were developed in order to respond to the demands, which were imposed by the surroundings where they'll be used. The GPH serves for general purposes and as a consequence, resembles, in certain ways, to a normal GSM. The OPH is designed to withstand more severe environmental conditions, eg. works on the rail tracks. Finally, the OPS will be used during shunting operations.

6.6.1. GSM-R Cab Radio

The GSM-R Cab Radio used on Railways provides voice communications between trains and ground based organizations and personnel. The equipment is compliant with EIRENE standards

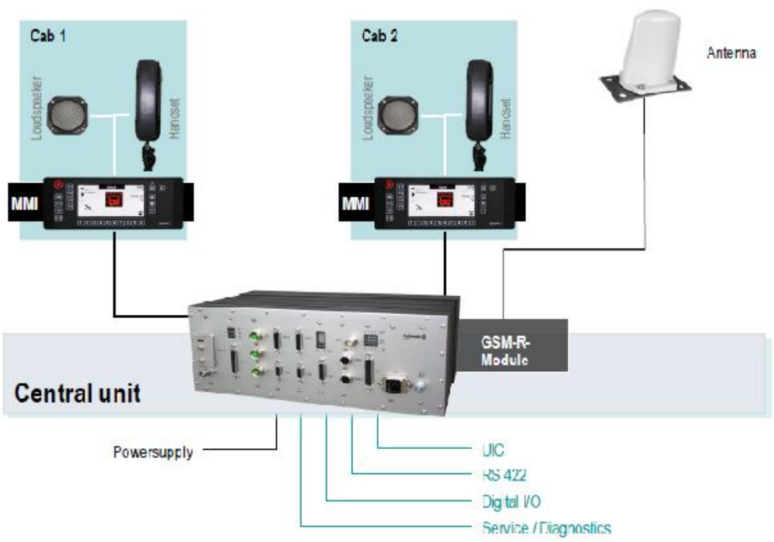


FIG.6.10.cab radio equipment

The key elements of the cab radio are

1 The Cab Radio unit
2 The Drivers Control Panel OR Man machine Interface (MMI)
3 The Handset
4 The Loudspeaker
5 The GSM-R Antenna.
6 Power supply units

The radio is enclosed within a metal housing and the Drivers Control Panel is a standalone enclosure. The radio assembly is fitted to the train using brackets which are normally custom to a particular train class, and connects to the train via a ‘gland box’ assembly that is mated with a multi way connector on the radio enclosure. All connections to the radio are made via the multiway connector with the exception of the RF connection for which there is an BNC type connector on the front panel of the radio enclosure.

The Cab Radio Transceiver Unit houses the GSM-R radio transceiver, a set of PCBs and power supplies. The power supply module converts the train power to levels required by the circuits within the radio unit.

The radio assembly enclosure main components are:

The GSM-R Transceiver Unit (containing a SIM module to provide vehicle identity). This provides the radio functions required to communicate with the GSM-R network. Radio Transceiver supports full duplex voice communication. A Class 2 transmitter will have an RF power output of 8W.

The following interfaces are used to connect various modules as follows

1	MMI	2Nos.
2	Data IN/OUT	1No
3	Service	1No.
4	BNC	1No.
5	PS	1No.
6	GND	1no.

6.6.1. 1. Control Panel:

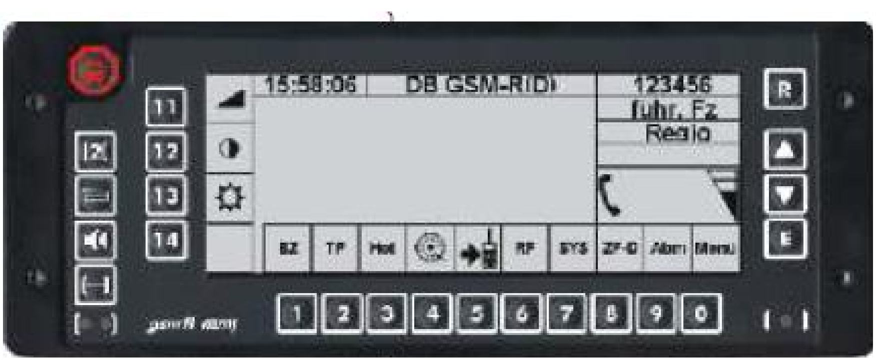


FIG.6.11. Man Machine interface (MMI)

The Drivers Control Panel also called as Man Machine interface (MMI) contains display screen, normal telephone dial keys, direct dial and special function keys. A telephone handset and separate loudspeaker are connected into the rear of the assembly to complete the Cab equipment.

Soft key buttons and their functions

1 controller/ (programmable)
2 Group call Drivers
3 Direct dial
4 Blank
5 Dial menu ---- 1 controller
  2 Multidriver calls
  3 Direct calls
  4 Repeat calls
  5 Incoming call
  6 Phone book
6 Call divert
7 Switch to control mode
8 System menu
9 Train data
10 Menu
11 Volume control
12 Screen contrast
13 Brightness
14 Return back

6.6.1. 2. HANDSET

FIG.6.12. driver's handset

The driver's handset connects to the front of the cab radio. A single, voltage free, normally open pushbutton PTT switch is incorporated into the handset and a hook switch is fitted into the cradle.

6.6.1. 3. LOUDSPEAKER

The loudspeaker is integrated within the train cab. A 4 wire audio interface port located at the transceiver unit's backplane connector

6.6.1. 4. TRAIN MOUNTED ANTENNA

FIG.6.13. cab radio's Antenna

A roof-mounted Antenna is fitted. The GSM-R Antenna is a low-profile robust assembly designed for fitting to vehicle roofs where a limited operating height is available

6.6.1. 5. POWER SUPPLY:

DC-DC Converter Power Supply Units (PSUs) convert the train supply voltage into voltage levels suitable for powering the cab radio modules.

Two power supply units are available in train cab.

Unit 1 DC-DC converter: The input of 110V DC from train supply is converted into 24VDC

Unit 2 Regulated power supply: INPUT 24V- OUTPUT 24V (16.8V-33.6V)

The output is connected through four pin connecter to cab radio

6.7. Operational Purpose Handheld (OPH)

Operational purpose handheld (OPH) designed to provide voice and data communication over private GSM-R railway networks, with a user interface that provides operations-specific functions for quick, efficient communication. The Handheld allows railway operators to equip personnel with a single device that meets essential railway functions as well as user-friendly mobile phone features.

Fig.6.14. Operational purpose handheld (OPH)

User interface supports railway operations-specific functions with OPH are:

- Voice Group Call over GSM-R
- Short operational messages
- Quick volume management
- Push-to-talk (PTT) in point-to-point mode
- Quick group call dialing
- Frequency hopping in group call

6.8. General Purpose Handheld (GPH)

General purpose handheld terminal (GPH) designed for the needs of railway staff. This provides reliable, long-lasting performance for voice and data communications over GSM-R railway networks.

FIG.6.15. General Purpose handheld terminal (GPH)

Specific features for railway operations of GPH are:

- Voice Group Call
- Quick volume management
- Push-to-talk (PTT) in point-to-point mode
- Quick group call dialing
- Frequency hopping in group call
- Two dedicated buttons for emergency call and PTT
- Short operational messages

CHAPTER-7

MAINTENANCE SCHEDULE OF MTRC SYSTEM

7.0 General

(A) Manuals, Spares, Software and Display –

1.1 Manuals: one set of hard bound as well as a soft copy of manuals of all the supplied equipment shall be made available at MSC (NMS) locations.

1.2 Spares: The available spares shall be properly documented in a hard bound register, Spares utilized and spares replenished shall be recorded with date and Time.

1.3 Software: A copy of software used for MSC/BSC/BTS shall be made available at MSC (NMS) location. These shall be documented in a hard bound register. Subsequent upgrades, updates, new versions or software patches shall be recorded in this register as and when they are available. The date of installations of software patches, updates, upgrades and new version shall also be recorded.

1.4 Displays: The following would be displayed in the display board:

A) Escalation chart with contact details for Railway & system provider.
B) Block Schematic of all installed equipment.

1.5 Log Books: The Following log books shall be maintained at each MSC/BSC location. These hard bound books shall have serialized page numbers. The official making entries in any one of these logbooks shall sign and also put the date and time.

1.5.1 Important Event Log: All important events of the day shall be recorded in this logbook. The items requiring attention of staff coming in the next shift shall be recorded in this register by outgoing shift staff. The new shift staff is expected to review this log book immediately and take appropriate action/actions if required.

1.5.2 General Activity Log: A brief record of all the work done during the shift shall be recorded in this logbook.

1.5.3 Customer complaints Record: Network/Service related complaints shall be recorded in this register. Booking of fault and time of rectification of fault shall be recorded. Feedback from user from signal defect register should also be noted on regular basis for customer complaint. Reasons for abnormal delay in rectification of the fault shall also be recorded.

1.5.4 Duty Shift Handover Register: Outgoing duty staff shall brief verbally the incoming shift staff about any important technical problem or any pending problem/problems. The same shall also be recorded in this register with all the details.

(B) NSS (MSC, IN, OMC):

Daily Schedule:

The following tasks for preventive and corrective maintenance of the system shall be carried out daily. Remedial measures shall be taken as and when required and then shall be record for analysis.

1 Health check up and monitoring of MSC Hardware.
2. Associated Signaling links and Destinations Points like IN, BSC, SMSC & ISDN links to be checked and monitored.
3. To check all running services on server.
4. Alarm Log: Checking on Alarms on OMC – Radio (Radio Commander) and OMC – Switch (Switch Commander), MSC & other Racks. Check all system alarms and initiate immediate action to clear them. The alarms must be cleared in the stipulated time and detailed analysis should be done for frequent occurring alarms and permanent remedial action should be initiated.

Note: Radio commander (RC) and Switch commander (SC) are hardware specific to NSN and nomenclature may vary for other vendors.

5 Processor load: Processor load should be checked at least 3 times during the peak traffic hours at the shift. It should be continuously monitored in event of special situations like riots, natural calamities. If processor load is found out of limit, remedial measures should be taken for permanent solution.
6. Dual processors working: Check that both the processors are working satisfactory.
7. System Clocks: Check the date and time.
8. Check for back up files: Check that the latest backup files are available for SCP, HLR etc. Backup should ensure:
   - Completeness of data
   - Ability of back up to restore the data
   - Clear identification of back up files in respect to
   - Network elements, time and date
9. Status of Signalling Links: Maintenance and record performance of 2 MB/s E1 links between BCS to BTSs, MSC to Exchange and MSC to dispatcher etc. on a daily check list for its normal path and protection path.
10. Active subscribers in HLR/VLR: Check active subscribers in VLR (visiting Location Register) and number of subs in HLR (Home Location register).
11. Maintenance and record data of A/C machine performance installed in MSC location.
12. Cleaning of Dust in AC filters. (15 Day Schedule)
13. Maintenance & record data of different power supply units in power plant like battery chargers, gravity & voltage of Lead Acid Cells (if any), Battery voltage for SMF battery, UPS and SMPS power supply etc.
14. Monitoring and check-up of IN nodes, server, ISDN line, cluster console server and clients.
15. Check all running services on IN.
16. Record O&M logs in IN logbook and keep in NMS room.
17. Testing of registration and deregistration.
18. Take Key performance indicator (KPI) of Core Network (CN) for performance log.

Note: List of KPI for core network is at Annexure 1.

19. Testing of BSNL phone and broadband internet along with Static IP for remote Login.

Weekly Schedule:

The following tasks for preventive and corrective maintenance of the system shall be carried out weekly in addition to daily routines. Remedial measures shall be taken as and when required and then shall be recorded for analysis.

1. Weekly File: Check Alarm log, restart or application error, status of correction application, software file congestion, Error record, Status of different modules, Groups Switch, Network switch, Network Synchronization, Clock reference etc.

2. Testing of Group Calls, Broad Cast Calls:

Date	Group Call initiated from Mobile No. to Mobile No. (Record Mobile No.)	Performance	Broad Cast Call initiated from Mobile No.	Performance	Name & Signature of Tech./ Supervisor

3. Testing of emergency call.
4. Testing of Call Pre-emption.

Monthly Schedule:

The following tasks for preventive and corrective maintenance of the system shall be carried monthly in addition to the weekly maintenance routines. Remedial measures shall be taken as and when required and then shall be recorded for analysis.

1. Software Control: Check for all corrections and confirmations of activations.
2. Verification of Subscriber Services: Check that all subscribers services are working and the right announcement are being provided in different scenarios.
3. Check of Supervision Data: Check all supervision parameters i.e. Blocking Supervision, Seizure Quality Supervision, Signaling Fault Supervision, Digital Path Supervision etc. Change or load the parameters, if necessary, according to the changed requirements. Verify that supervision is active and that it is set to reasonable values.
4. Check of Hard Drive Content: Verify Store allocation, free space on Hard Drives and delete/archive old files. Same action should be taken for PCs also.
5. Check Alarms: Check fitness of alarm panel, alarm interfaces, External alarms, Software records, data masking etc.
6. Reports:
   6.1 All traffic related parameters are processed for monthly reports. Specials attention and analysis is required to check congestion in SDCCH, TCH, Call Drop Rate, Handover success/failure rate and services provisioning related complaints etc.
   6.2 Top management report: Monthly reports should be prepared for Management review. The report should contain:
   - Major interruption in MSC, BSC, BTS (cell outage for more than one hour)
   - Network congestion & Quality of service

Three Month Schedule:

At a three-month maintenance interval, the following tasks for preventive and corrective maintenance of the system shall be carried out in addition to the weekly and monthly maintenance routines. Prompt remedial measures shall be taken as and when required and then shall be recorded for analysis.

1. Processor Load Measurement: Processor Load measurement results to be collected and analyzed.
2. Check and corrective measures of Announcements: Verify that announcements are working, right announcement is obtained and quality is good.
3. Check and review of Spares inventories:
4. Review of Backup and Archiving of data in different storages in various network elements.
5. Performance Management
   5.1 Production and Analysis of fault, efficiency and performance reports for various network elements, subsystems and complete network: These reports shall be generated as Management Information System & Performance reports.
   5.2 Traffic Report: Switch Traffic Report shall be generated in the mutually agreed format with system provider.
   5.3 Network Quality report: Radio performance Report shall be generated ion the mutually agreed format with system provider.
   5.4 Signaling Congestion Report: Signaling Congestion Report shall be generated in the mutually agreed format with system provider.
6. Optimization and Engineering: Including shifting/re-parenting/reconfiguration/ upgrade/ update of hardware and software as and when required.

(C) Daily Testing of Dispatcher:

1.

Date	Call initiated from Dispatcher to Mobile No. (Record Mobile No.)	Performance	Call initiated from any Mobile No. to Dispatcher Terminal (Normal Call & Emergency Call)	Performance	Name & Signature of Tech./ Supervisor

2. O & M Logs of Dispatcher Terminals to maintain at Controller’s Room in Fixed Dispatcher Terminal log book.
3. Testing of Railway exchange to dispatcher and mobile terminal (OPH/GPH) and vice-versa.

(D) Daily testing of Voice Recording System (VRS):

1. Monitor performance and any alarm of VRS Server.
2. Take key performance Indicators (KPIs) for performance measurement logs.

These key performance Indicators are as under-

(i) No. of control boards.
(ii) No. of channels
(iii) Channel status
(iv) No. of channels in Voice logger

3. Monitoring & log of visual LED indications of VRS servers.
4. Record O&M logs of VRS in NMS room in log book.

(E) <u>Daily testing of BSS (BSC, TRAU):</u>

LOGS & RECORDS:

1. Log Book has to be maintained for each and every BTS sites at BSC/NMS location. Daily log for all activities at BTS sites including the outage are to be recorded invariably without fail.
2. Monitoring of performance of BSC, TRAU and their sub system.
3. Take key performance Indicators (KPIs) for initiated counters (BTS counter and adjacent cell counter) for performance measurement logs.
   Note: List of KPI for core network is at Annexure 2.
4. Record O&M logs of BSS in NMS room in log book.

(F) <u>Maintenance Schedule of BTS:</u>

(a) <u>Maintenance schedule to be performed at NMS room:</u>

Daily Schedule:

1. Check and monitor alarm indication status of BTS on NMS.
2. Record O&M logs of BTS in log book kept in NMS room for all activities at BTS sites including their outage.

(b) <u>Maintenance schedule to be performed at BTS site:</u>

Day schedule:

During the visit to a BTS site, following points shall be checked and remedial measures shall be taken accordingly to ensure that everything is in order

1. Check for any fault in the unit or any other alarm.
2. No visual damage to the equipment or BTS room is evident.
3. The waveguides and connectors are fixed properly.
4. Air-Conditioners are functioning properly. There is no leakage of air-conditioned air through door, window or waveguide openings. The Air inlet/ filters to the cabinet are clean.
5. Indoor light and indoor emergency light are working.
6. All modules of the SMPS power plant are working properly and load is being shared by all.
7. Check up of battery sets for any corrosion and leakage.

9 To check the voltage at Battery & BTS equipment.

10. To measure the specific gravity any cell voltage in case Lead Acid Battery has been provided.
11. To clean the BTS equipment by Blower (In running condition after removing Fans).
12. To clean the Fans of BTS racks.

13. Checking of ground connections and earth bars.
14. Checking of antenna coupling unit.
15. O&M Logs and Histories of BTS are maintained at BTS sites in BTS maintenance logbook.

Monthly Schedule:

The following task for preventive and corrective maintenance of the system shall be carried out on monthly basis. Remedial measures shall be taken as and when required and then shall be recorded for analysis.

1. Surge suppresser connection and earthing connection(all Points)
2. To check Splitter mounting status.
3. To check antenna fixture mounting and Jumper status.
4. To check feeder cable dressing, hanger clamps and weather proofing status.
5. Functioning of all alarms is tested for service worthiness. Printout of all cell data to be made once in every month and subsequently checking for any false/ extra data should be carried out.
6. Monthly report to be made for Management review of the BSS/ MTRC system. This should contain Major interruptions in MSC, BSC, BTS (including cell outage for more than one hour).

Three Month schedule:

The following task for preventive and corrective maintenance of the system shall be carried out once in three month in addition to the regular daily, weekly or monthly routines. Prompt remedial measures shall be taken as and when required and then shall be recorded for analysis.

1. To measure the Transmitter (BCCH) Power level and VSWR (less or equal to 1.3) for both side of antenna and cable and waveguide.
2. Checking of Antenna Coupling Unit.
3. Cleaning of Earthing Point of Tower top.
4. To clean the cards and their back planes (in non running condition).
5. To switch the working BTS on its stand by and make stand by as working one.
6. Antenna orientation with compass and matching with preset values.
7. Antenna tilt with tilt meter and matching with preset values.
8. Signal strength testing at Site and coverage testing using OPH (Indicate signal strength).
9. Updating of data in BSS in case of any changes in the network.
10. Cell planning and RF planning should be reviewed for any possible error or change in situation due to addition, deletion or change in configuration of BTS in the network.
11. The proper connection of waveguides and connectors.
12. Alarm Log to be generated and this is to be studied and analyzed for necessary corrective action.

Yearly Schedule:

1. Signal strength, RF coverage testing and Network Optimization at site.
2. Orientation and re-alignment of antenna to achieve desired RF coverage.
3. Measurement of Earth resistance.

(G) Schedule for Taking Back up of MSC & BSS:

(a) 15 days Routine:

1. To take routine backup of MSC (Coordination Processor & main Processor) and save it on external Magnetic Optical disc (MOD) or other Tape/hard drives.

Note: Coordination Processor & Main Processor is part of MSC and responsible for call processing and signalling processing respectively.

2. To take back up of complete BSS (BSC, TRAU, BTS) and OMC-R server.
3. Any other back up seems necessary.

(b) Monthly Routine:

1. To take backup of OMC-Switch (Switch commander for NSN System) Servers & Clients
2. To save all backups of BSS and OMC-R and KPIs from OMC-R to different Hard Drive/storage device.
3. Any other back up seems necessary.
4. To take backup of VRS to different hard drive/storage device.

(c) 3 Monthly Routine:

1. To take all Backup of MSC and save it to different MOD or Tape/Hard Drive/storage device.
2. To save all back-ups of OMC-Switch, IN (servers & Clients) to different Hard Drive/ storage device.
3. To save backup of Protocol-Analyser to different Hard drive/storage device.
4. To save backup of Field maintenance terminal (LMT) to different hard drive/storage device.
5. Any other back up seems necessary.

CHAPTER-8

GENERAL PACKET RADIO SERVICE (GPRS)

GPRS is a new bearer service for GSM that greatly improves and simplifies wireless access to packet data networks, e.g., to the Internet. GPRS is a data network that overlays a second-generation GSM network. This data overlay network provides packet data transport at rates from 9.6 to 171 kbps. Additionally, multiple users can share the same air-interface resources simultaneously.

GPRS reuse the existing GSM network elements as much as possible, but to effectively build a packet-based mobile cellular network, some new network elements, interfaces, and protocols for handling packet traffic are required.

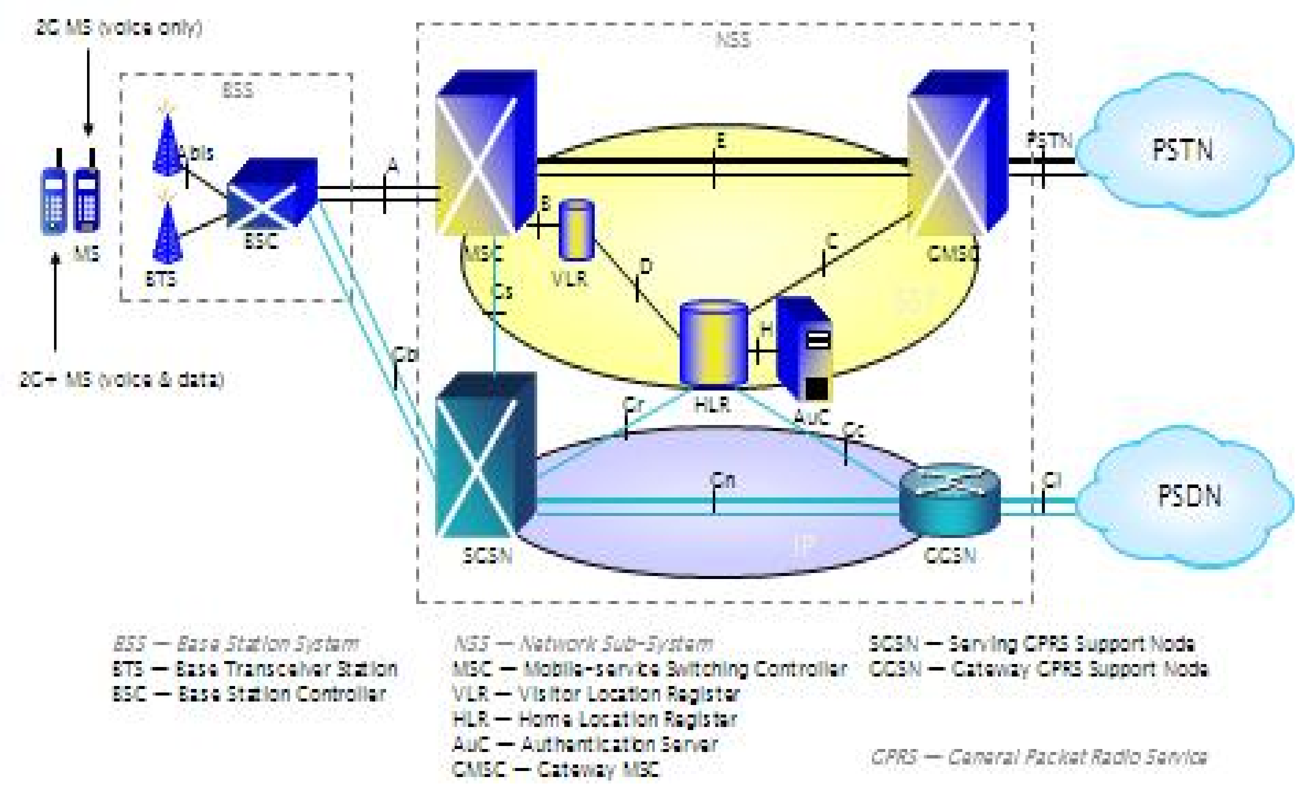


Fig.8.1. GPRS reference architecture

8.1. GPRS system architecture:

In order to integrate GPRS into the existing GSM architecture, new class of network nodes, called GPRS support nodes (GSN), has to be introduced In order to integrate GPRS into the existing GSM architecture, a new class of network nodes, called GPRS support nodes (GSN) has been introduced. GSNs are responsible for the delivery and routing of data packets between the mobile stations and the external packet data networks (PDN).

The following up gradation or modification is needed for existing GSM systems to adopt as GPRS.

GSM Network Element	Modification or Upgrade Required for GPRS.
Mobile Station (MS)	New Mobile Station is required to access GPRS services. These new terminals will be backward compatible with GSM for voice calls.
BTS	A software upgrade is required in the existing base transceiver site.
BSC	The base station controller (BSC) requires a software upgrade and the installation of new hardware called the packet control unit (PCU). The PCU directs the data traffic to the GPRS network and can be a separate hardware element associated with the BSC.
GPRS Support Nodes (GSNs)	The deployment of GPRS requires the installation of new core network elements called the serving GPRS support node (SGSN) and gateway GPRS support node (GGSN).
Databases (HLR, VLR, etc.)	All the databases involved in the network will require software upgrades to handle the new call models and functions introduced by GPRS.

8.1.1. Three classes of mobile stations (MS) are defined

(I) Class A mobile station supports simultaneous operation of GPRS and conventional GSM services.

(ii) Class B mobile station is able to register with the network for both GPRS and conventional GSM services simultaneously. In contrast to an MS of class A, it can only use one of the two services at a given time.

iii) Class C mobile station can attach for either GPRS or conventional GSM services. Simultaneous registration (and usage) is not possible. An exception is SMS messages, which can be received and sent at any time.

8.1.2. GPRS Base Station Subsystem

Each BSC requires the installation of one or more Packet Control Units (PCUs) and a software upgrade. The PCU provides a physical and logical data interface to the base station subsystem (BSS) for packet data traffic. The BTS can also require a software upgrade but typically does not require hardware enhancements. When either voice or data traffic is originated at the subscriber mobile, it is transported over the air interface to the BTS, and from the BTS to the BSC in the same way as a standard GSM call. However, at the output of the BSC, the traffic is separated; voice is sent to the mobile switching center (MSC) per standard GSM, and data is sent to a new device called the SGSN(serving GPRS support node) via the PCU over a Frame Relay interface.

8.1.3. GPRS Support Nodes

8.1.3.1 Serving GPRS support node (SGSN)

A serving GPRS support node (SGSN) is responsible for the delivery of data packets from and to the mobile stations within its service area. Its tasks include packet routing and transfer, mobility management (attach/detach and location management), logical link management, and authentication and charging functions.

The location register of the SGSN stores location information (e.g., current cell, current VLR) and user profiles (e.g., IMSI, address used in the packet data network) of all GPRS users registered with this SGSN.

8.1.3.2. Gateway GPRS support node (GGSN)

A gateway GPRS support node (GGSN) acts as an interface between the GPRS backbone network and the external packet data networks. It converts the GPRS packets coming from the SGSN into the appropriate packet data protocol (PDP) format (e.g., IP or X.25) and sends them out on the corresponding packet data network.

In the other direction, PDP addresses of incoming data packets are converted to the GSM address of the destination user. The readdressed packets are sent to the responsible SGSN.

For this purpose, the GGSN stores the current SGSN address of the user and his or her profile in its location register. The GGSN also performs authentication and charging functions. In general, there is a many-to many relationship between the SGSNs and the GGSNs:

A GGSN is the interface to external packet data networks for several SGSNs; An SGSN may route its packets over different GGSNs to reach different packet data networks

8.2. GPRS Backbone

Based on the Internet Protocol (IP) Tunnels of data and signaling messages between GPRS support nodes (GSNs). Intra-PLMN backbone network of different PLMNs connected with an inter-PLMN backbone .The gateways between the PLMNs and the external inter-PLMN backbone are called border gateway .Inter-PLMN backbone network connects GSNs of different PLMNs.

8.2.1. Internal Backbone

A roaming agreement between two GPRS network providers is necessary to install such a backbone. The internal backbone is an IP based network used to carry packets between different GSNs.

Tunneling is used between SGSNs and GGSNs, so the internal backbone does not need any information about domains outside the GPRS network. Signaling from a GSN to a MSC, HLR or EIR is done using SS7.

In a GSM/GPRS network, conventional circuit switched services (speech, data, and SMS) and GPRS services can be used in parallel.

8.3. Circuit Switched vs. Packet Switched data

• Packet Switched Data: Allocates resource only when there is data to send and Enables "always on" services
• Circuit Switched data: Resources allocated independently of if data is sent or not – Too expensive (resource wise) to allow connections all the time

8.4. SESSION MANAGEMENT, MOBILITY MANAGEMENT AND ROUTING

In this section, we describe how a mobile station (MS) registers with the GPRS network and becomes known to an external packet data network (PDN).

We show how packets are routed to or from mobile stations, and how the network keeps track of the current location of the user.

8.4.1. SESSION MANAGEMENT, PDP CONTEXT

To exchange data packets with external PDNs after a successful GPRS attach, a mobile station must apply for one or more addresses used in the PDN, e.g., for an IP address in case the PDN is an IP network. This address is called PDP address (Packet Data Protocol address). For each session, a so-called PDP context is created, which describes the characteristics of the session.

It contains the PDP type (e.g., IPv4), the PDP address assigned to the mobile station e.g.,129.187.222.10), the requested QoS, and the address of a GGSN that serves as the access point to the PDN. This context is stored in the MS, the SGSN, and the GGSN. With an active PDP context, the mobile station is "visible" for the external PDN and is able to send and receive data packets.

The mapping between the two addresses, PDP and IMSI, enables the GGSN to transfer data packets between PDN and MS.A user may have several simultaneous PDP contexts active at a given time.

The allocation of the PDP address can be static or dynamic. In the first case, the network operator of the user's home-PLMN permanently assigns a PDP address to the user.

In the second case, a PDP address is assigned to the user upon activation of a PDP context. The PDP address can be assigned by the operator of the user's home-PLMN (dynamic home-PLMN PDP address) or by the operator of the visited network (dynamic visited-PLMN PDP address). The home network operator decides which of the possible alternatives may be used. In case of dynamic PDP address assignment, the GGSN is responsible for the allocation and the activation/deactivation of the PDP addresses

8.4.2. PDP context activation procedure

Using the message "activate PDP context request," the MS informs the SGSN about the requested PDP context. If dynamic PDP address assignment is requested, the parameter PDP address will be left empty. Afterward, usual security functions (e.g., authentication of the user) are performed. If access is granted, the SGSN will send a "create PDP context request" message to the affected GGSN. The latter creates a new entry in its PDP context table, which enables the GGSN to route data packets between the SGSN and the external PDN.

Afterward, the GGSN returns a confirmation message “create PDP context response” to the SGSN, which contains the PDP address in case dynamic PDP address allocation was requested. The SGSN updates its PDP context table and confirms the activation of the new PDP context to the MS (“activate PDP context accepts”).

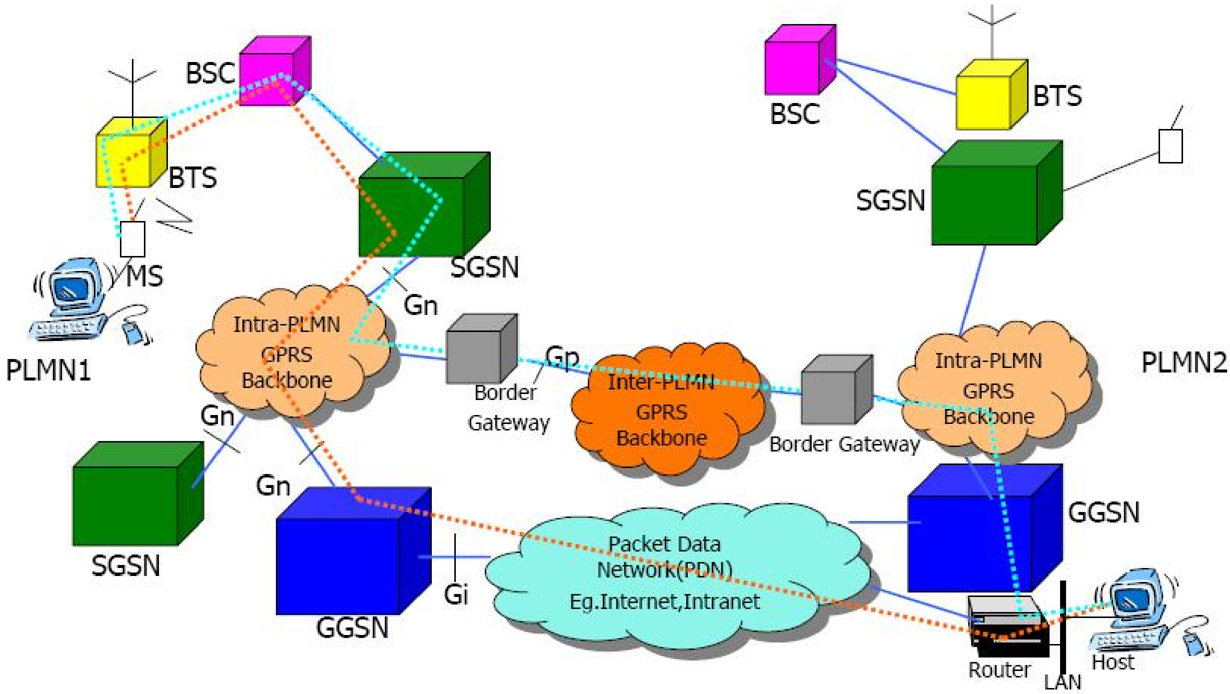


FIG.8.2. Packet Routing

We assume that the packet data network is an IP network. A GPRS mobile station located in PLMN1sends IP packets to a host connected to the IP network, e.g., to a Web server connected to the Internet.

The SGSN that the mobile station is registered with encapsulates the IP packets coming from the mobile station, examines the PDP context, and routes them through the intra-PLMN GPRS backbone to the appropriate GGSN.

The GGSN decapsulates the packets and sends them out on the IP network, where IP routing mechanisms are used to transfer the packets to the access router of the destination network. The latter delivers the IP packets to the host.

Let us assume the home-PLMN of the mobile station is PLMN2. An IP address has been assigned to the mobile by the GGSN of PLMN2. Thus, the MS’s IP address has the same network prefix as the IP address of the GGSN in PLMN2. The correspondent host is now sending IP packets to the MS. The packets are sent out onto the IP network and are routed to the GGSN of PLMN2 (the home-GGSN of the MS). The latter queries the HLR and obtains the information that the MS is currently located in PLMN1.

It encapsulates the incoming IP packets and tunnels them through the inter-PLMN GPRS backbone to the appropriate SGSN in PLMN1. The SGSN decapsulates the packets and delivers them to the MS.

8.5. Location management

The main task of location management is to keep track of the user's current location, so that incoming packets can be routed to his or her MS. For this purpose, the MS frequently sends location update messages to its current SGSN.

If the MS sends updates rather seldom, its location (e.g., its current cell) is not known exactly and paging is necessary for each downlink packet, resulting in a significant delivery delay. On the other hand, if location updates happen very often, the MS's location is well known to the network, and the data packets can be delivered without any additional paging delay.

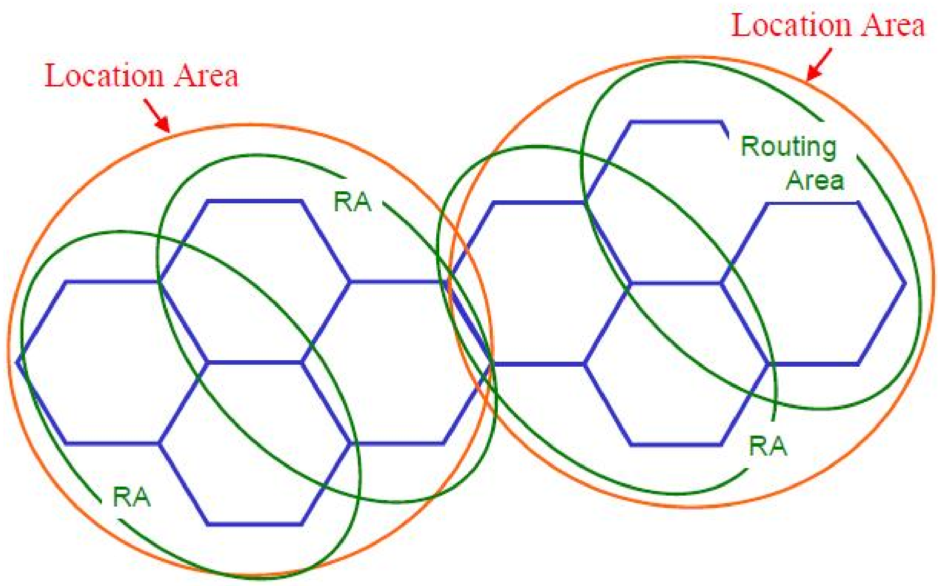


FIG.8.3.Location area management

However, quite a lot of uplink radio capacity and battery power is consumed for mobility management in this case. Thus, a good location management strategy must be a compromise between these two extreme methods.

In IDLE state, no location updating is performed, i.e., the current location of the MS is unknown to the network. An MS in READY state informs its SGSN of every movement to a new cell. For the location management of an MS in STANDBY state, a GSM location area (LA) is divided into several routing areas (RA). In general, an RA consists of several cells. The SGSN will only be informed when an MS moves to a new RA; cell changes will not be disclosed. To find out the current cell of an MS in STANDBY state, paging of the MS within a certain RA must be performed. For MSs in READY state, no paging is necessary. Whenever an MS moves to a new RA, it sends a “routing area update request” to its assigned SGSN. The message contains the routing area identity (RAI) of its old RA.

CHAPTER-9

WIRELESS LOCAL LOOP (WLL) SYSTEMS

9.1 Introduction:

In the telephone networks, the circuit between the subscriber's equipment (e.g. telephone set) and the local exchange in the central office is called the subscriber loop' or & local loop'. Traditionally, the copper wire has been used as the medium for local loop to provide voice and voice-band data services.

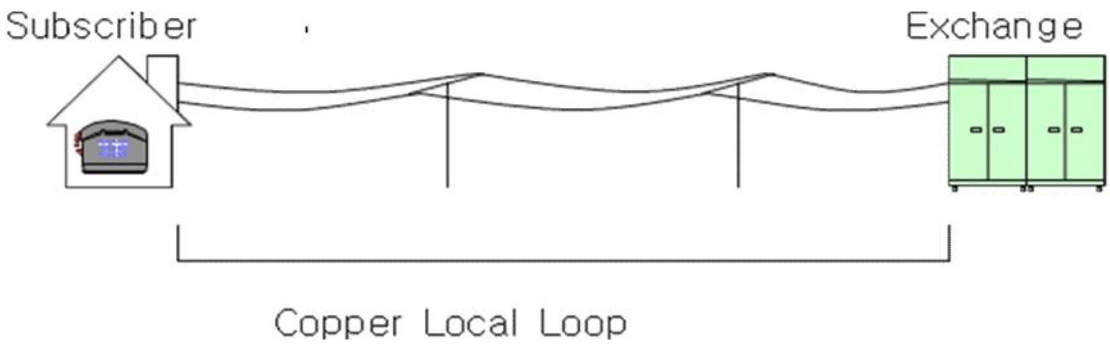


Fig.1

WLL is often called radio in the loop (RITL) or fixed-radio access (FRA)/ the "fixed wireless access (FWA). WLL is a system that connects subscribers to the public switched telephone network (PSTN) using radio signals as a substitute for copper for all or part of the connection between the subscriber and the switch. This includes cordless access systems, proprietary fixed radio access, and fixed cellular systems

Since 1980s, the demand for communications services has increased explosively. There has been a great need for the basic telephone service, i.e. the plain old telephone service (POTS) in developing countries.

On the other hand the demand for high-speed data and multimedia services at home and/or office has increased continuously. These requirements have been a motivation for innovation in local loop.

There are two remarkable challenges in local loop technologies.

One is mainly from the expansion of landscape in service types. Owing to drastic growth of Internet, to access Internet at home (or office) became an usual lifestyle today. Moreover, to enjoy multimedia services at home will not be strange in near the future. These services require broadband local loop systems. To deal with this situation in short term, the digital subscriber line (DSL) technologies, including high-bit-rate DSL (HDSL), asymmetrical DSL (ADSL), and very high- bit-rate DSL (VDSL), have been studied and developed .

Another technical advance is the wireless local loop (WLL) adopting radio as the transmission medium.

WLL has many advantages from the viewpoints of the service providers and subscribers:

i. The WLL approach significantly speeds the installation process since it can eliminate the wires, poles, and ducts essential to wired networks. Thus, WLL systems can be rapidly developed, easily extended, and are distance insensitive. Since WLL is a quick start for startup systems, wireless access is one of the viable means to meet the high demand for POTS in many developing countries.

ii. The operations and maintenance are easy and the average maintenance time per subscriber per year is short (40 min compared to 2.2 h for wire line).

iii. Using advanced digital radio technologies, WLL can provide a variety of data services and multimedia services as well as voice.

iv. Among radio systems, WLL enjoys the merits of fixed system: using high-gain directional antennas, the interference decreases. This reduces the frequency reuse distance, increases the possible number of sectors in a sectored cell, and increases, in turn, the system capacity.

Since WLL is a kind of radio system, most of the WLL systems are developed according to the standards (or their variants) for mobile systems. Basically, almost all the wireless systems or multiple access techniques can be used for WLL. However, it is also true that there exist some technologies or systems that have comparative advantages in a certain WLL environment.

Fig.2

9.2. WLL SYSTEM ARCHITECTURE

Since WLL systems are fixed, the requirement for interoperability of a subscriber unit with different base stations is less stringent than that for mobile services. As a result, there exist a variety of standards and commercial systems.

Each standard (or commercial system) has its own air interface specification, system architecture, network elements, and terminology. Moreover, although the network elements in different systems have the same terminology, the functions of the elements may differ according to systems. In this section, we present a conceptual (and typical) architecture of WLL systems.

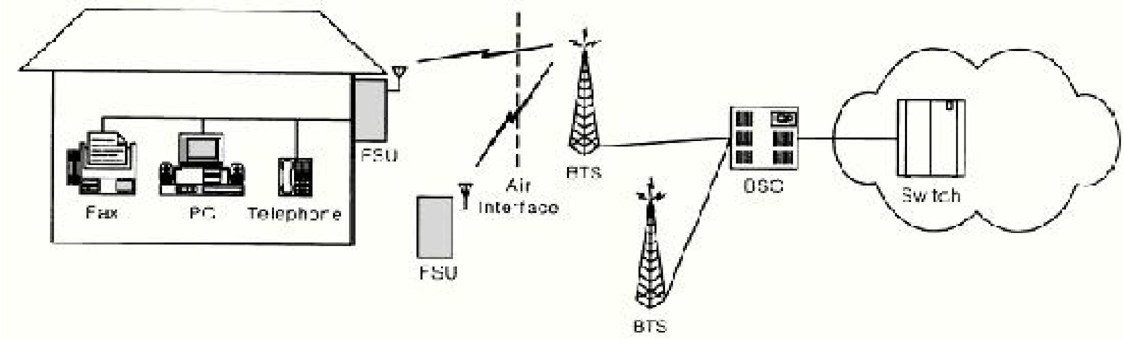


Fig.3. Typical architecture of WLL

The fixed subscriber unit (FSU) is an interface between subscriber's wired devices and WLL network. The wired devices can be computers or facsimiles as well as telephones. Several systems use other acronyms for FSU such as the wireless access fixed unit (WAFU), the radio subscriber unit (RSU), or the fixed wireless network interface unit (FWNIU). FSU performs channel coding/decoding, modulation/demodulation, and transmission/reception of signal via radio, according to the air interface specification. If necessary, FSU also performs the source coding/ decoding. When a dummy telephone set is used, FSU may perform dial-tone generation function for users so as not to be aware of WLL system. FSU also supp orts the computerized devices to be connected to the network by using voice-band modems or dedicated data channels.

There are a variety of FSU implementations. In some types of commercial products, an FSU is integrated with handset. The basic functions of this integrated FSU are very similar to those of the handset for mobile communications, except that it does not have a rich set of functions for mobility management. Another example of FSU implementation is a high-capacity, centralized FSU serving more than one subscriber. Typical application of this type of FSU can be found in business buildings, apartment blocks, and the service area where some premises are located nearby.

A BSC controls one or more BTSs and provides an interface to the local exchange (switch) in the central office. An important role of BSC is to transcode between the source codes used in wired network and that at the air interface. From the above roles, a BSC is often called the radio port control unit (RPCU) or the transcoding and network interface unit (TNU). WLL systems do not need to offer mobile services basically, even if some systems provide limited mobile services. Thus, for example, there is no home and visitor location register (HLR/VLR) in a WLL system and its overall architecture may be simpler than that of the mobile systems.

As one can easily guess, the WLL services depend not only on the functionality of FSU, BTS, BSC, and air interface specification but also on the service features provided by the switch in the central office. For example, when WLL is used as a telephony system, there are the basic telephony services and supplementary services. If the air interface provides a transparent channel to the switch, these service features depend totally on the switch functions. So, we hereafter focus on the air interface specifications related to WLL services rather than the service features by the switches.

9.3. WLL SERVICE REQUIREMENTS

The communication service requirements depend heavily on the socio economical situations of the service areas. In general, the WLL services required in developing countries and/or regions can differ from those in developed ones.

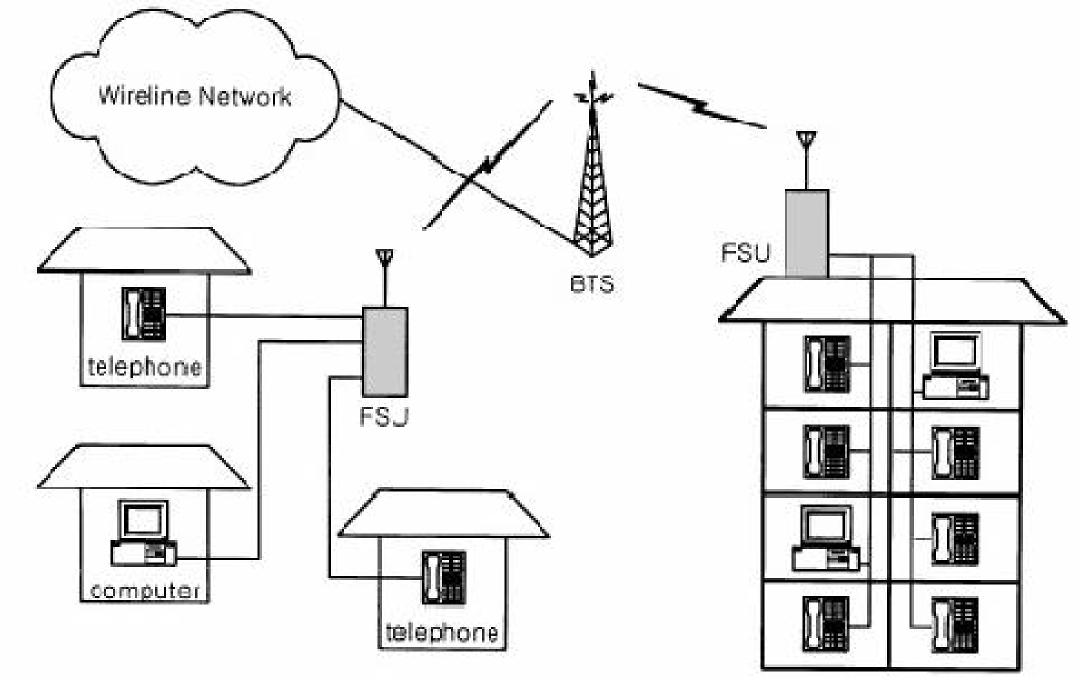


Fig.4. Fixed subscriber unit serving for multiple users

Developing countries/regions for these areas, the emphasis points of WLL service requirements can be summarized as follows:

i. In terms of service coverage, a wide area should be covered within a relatively short period.

ii. Specially, for the regions with dense population, a high-capacity system is indispensable. Here, capacity means the available number of voice channels for given bandwidth.

iii. On the other hand, there may exist wide areas with sparse population. For these service areas, if a small population with low traffic load resides nearby, a centralized FSU serving more than one subscriber can be a solution.

iv. The service fee per subscriber must be low so as to offer the universal service. For this, a high-capacity system is again needed and the cost of system implementation and operation should be low.

v. The system should be implemented rapidly so that the services might be launched quickly. In choosing systems, the possibility of the rack of social overhead capitals (e.g. loads or electronic power) in some areas also should be considered.

As a tradeoff to fulfill the requirements of high capacity with low service fee, a medium-quality and relatively low data-rate of channel (typically, up to 16 kbps) may be unavoidable. Using this channel, only voice and/or voice-band low-speed data communications are possible. However, the service requirements to the advanced services (e.g. high-speed data and broadband communications) will arise after (or with) the penetration of POTS.

Objective:

1. WLL is a system that connects subscribers to the public switched telephone network (PSTN) using radio signals (T/F)
2. Multiple access techniques can be used for WLL (T/F)
3. The fixed subscriber unit (FSU) is an interface between subscriber's wired devices and WLL network (T/F)

Subjective:

1. What are the WLL service requirements?
2. Explain WLL system architecture?

ANNEXURE-1

Wireless planning & coordination (WPC)

The wireless planning & coordination (WPC)Wing of the Ministry of Communications, created in 1952, is the National Radio Regulatory Authority responsible for Frequency Spectrum Management, including licensing and caters for the needs of all wireless users (Government and Private) in the country.

It exercises the statutory functions of the Central Government and issues licenses to establish, maintain and operate wireless stations.

WPC is divided into major sections as

i. Licensing and Regulation (LR),
ii. New Technology Group (NTG)
iii. And Standing Advisory Committee on Radio Frequency Allocation (SACFA).

Standing Advisory Committee on Radio Frequency Allocation (SACFA).

SACFA makes the recommendations on major frequency allocation issues, formulation of the frequency allocation plan, making recommendations on the various issues related to International Telecom Union (ITU), to sort out problems referred to the committee by various wireless users, Siting clearance of all wireless installations in the country etc.

Guidelines for dealing with WPC

Obtaining AIP (Agreement-in-Principle)

This is the first step for obtaining the permission to use a particular frequency for the new application such as MTRC, ACD and INMARSAT etc.

Railways should apply in the format which is available at website of WPC (www.wpc.dot.gov.in).

Normally, AIP is issued for a specified period between 3months to one year and during that period, operating license should be obtained.

The AIP is only valid for the quantities of equipments mentioned therein. Normally the application of AIP should be routed through Railway Board but regular chasing with WPC is required for obtaining the AIP by concerned Railways.

Application for renewal should be sent well within the validity period if required.

Obtaining the Import license:

The Import license should be obtained by the firm who is executing the work for importing the radio equipments from abroad, if required. The following documents are required to be enclosed with the application:-

i. Application in the required format;
ii. Draft of Rs. 500/- in favour of Pay & Accounts Officer (Hqrs) DoT/New Delhi (code No. 0691).
iii. Equipment literature.
iv. Copy of AIP.

While applying for Import license, the no. of equipment should not exceed than that mentioned in AIP. This should be applied directly by the supplier and no reference needs to be made to the Board

Obtaining SACFA (Standing Advisory Committee on Radio Frequency Allocation) clearance:

The procedure for obtaining SACFA clearance for various sites of new application is detailed at WPC website.

The entire process has now been computerized and made available online.

The application for obtaining SACFA clearance should be filed online and ID number is generated automatically after filling the application form.

Complete application form should be given as hard copy along with following documents

i. Application in the required format along with a demand draft of Rs 1000/- per ID drawn in favour of Pay & Accounts Officer (Hqrs) DOT/New Delhi (code No.0691)
ii. ID acknowledgement form
iii. Map

WPC will issue a WPC acceptance number through a letter and that letter along with the above mentioned documents should be submitted to all the SACFA members (the desired number of copies as detailed in the WPC website) for obtaining the clearance.

As soon as WPC issues an acceptance number, the application also gets transmitted to all SACFA members online also automatically.

It is advised that the Railways should chase up with the concerned SACFA members for the early clearance.

Once the main SACFA members clear the application, WPC issues final site clearance. This document is required for obtaining operating license.

Obtaining the Operating license:

The regular license for operating the frequency should be obtained within the currency of AIP.

The following documents need to be attached along with application:-

i) Application in the required format;
ii) Copy of valid AIP
iii) Type of radio equipment & model along with Invoice copy and delivery challan of the equipment.
iv) Copy of SACFA site clearance
v) Draft for license fee and royalty, if applicable. (This will differ from case to case and will have to be obtained from WPC)

The application should be sent directly to WPC by Zonal Railways and need not be routed through Board.

Granting SACFA clearance to other applicants:

The following procedure should be adopted for granting SACFA clearance to the site clearance applications of other telecom users: -

i) Application should be examined and comments should be issued within 15 days.
ii) The NOC should be mailed to SACFA Cell of Board at the address sacfacell@rb.railnet.gov.in and also a hard copy should be sent to Board's office.
iii) Copy need not be endorsed to SACFA Secretariat/WPC.
iv) In case of deficiency in the application such as Map is not attached, spot frequency not mentioned, difference in geo-coordinates given in the application and map etc. should be brought to the notice of the applicant under intimation to this office at the above address

ANNEXURE-2

CODE DIVISION MULTIPLE ACCESS (CDMA):

CDMA is based around a form of transmission known as Direct Sequence Spread Spectrum. The CDMA history can be directly linked back to the 1940s when this form of transmission was first envisaged. As electronics technology improved, it started to be used for covert military transmissions in view of the facts that the transmissions look like noise, it is difficult to decipher without the knowledge of the right codes, and furthermore it is difficult to jam.

With the revolution in cellular telecommunications that occurred in the 1980s a then little know company named Qualcomm working on DSSS transmissions started to look at this as the basis for a cellular telecommunications multiple access scheme - CDMA - code division multiple access.

The concept of CDMA had to prove in the field and accordingly Qualcomm was joined by US network operators Nynex and Ameritech to develop the first experimental CDMA system. Later the team was expanded as Motorola and AT&T (now Lucent) joined to bring their resources to speed development.

As a result this it was possible to start writing a specification for CDMA in 1990. With the support of the Cellular Telecommunications Industry Association (CTIA) and the Telecommunications Industry Association (TIA) a standards group was set up. This group then published the standard for the first CDMA system in the form of IS-95, resulting in the formal publication of IS-95-A in 1995.

The first CDMA system was launched in September 1995 by Hutchison Telephone Co. Ltd. in Hong Kong and SK Telecom in Korea soon followed along with networks in the USA.

This was only one cellular telecommunications system, although it was the first. Its development lead on to the CDMA 2000 series of standards.

Key elements of CDMA

CDMA is a form of spread spectrum transmission technology. It has a number of distinguishing features that are key to spread spectrum transmission technologies:

- Use of wide bandwidth*:* CDMA, like other spread spectrum technologies uses a wider bandwidth than would otherwise be needed for the transmission of the data. This results in a number of advantages including an increased immunity to interference or jamming, and multiple user access.
- Spreading codes used*:* In order to achieve the increased bandwidth, the data is spread by use of a code which is independent of the data.
- Level of security*:* In order to receive the data, the receiver must have knowledge of the spreading code, without this it is not possible to decipher the transmitted data, and this gives a measure of security.
- Multiple access*:* The use of the spreading codes which are independent for each user along with synchronous reception allow multiple users to access the same channel simultaneously.

CDMA technology advantages

The use of CDMA offers several advantages and it is for this reason that CDMA technology has been adopted for many 3G cellular telecommunications systems.

- Improvement in capacity*:* One of the chief claims for CDMA is that it gives significant improvements in network capacity.
- Improvement in handover/handoff*:* Using CDMA it is possible for a terminal to communicate with two base stations at once. As a result, the old link only needs to be broken when the new one is firmly established. This provides significant improvements in terms of the reliability of handover / handoff from one base station to another.

CDMA has been a particularly successful technology. CDMA technology has been used in all the 3G cellular telecommunications systems in one form or another and has enabled significant improvements to be gained over previously technologies used in 2G systems.

CDMA spread spectrum basics

The key element of code division multiple access (CDMA) is its use of a form of transmission known as direct sequence spread spectrum (DSSS).

Direct sequence spread spectrum is a form of transmission that looks very similar to white noise over the bandwidth of the transmission. However once received and processed with the correct descrambling codes, it is possible to extract the required data.

When transmitting a CDMA spread spectrum signal, the required data signal is multiplied with what is known as a spreading or chip code data stream. The resulting data stream has a higher data rate than the data itself. Often the data is multiplied using the XOR (exclusive OR) function.

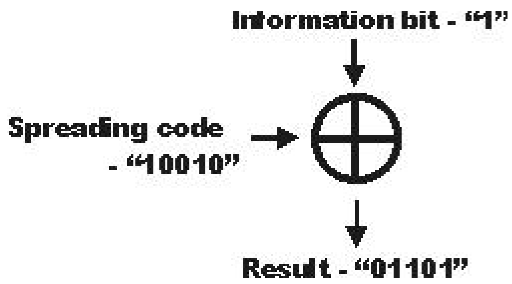


FIG.1. CDMA spreading

Each bit in the spreading sequence is called a chip, and this is much shorter than each information bit. The spreading sequence or chip sequence has the same data rate as the final output from the spreading multiplier. The rate is called the chip rate, and this is often measured in terms of a number of M chips / sec.

The baseband data stream is then modulated onto a carrier and in this way the overall signal is spread over a much wider bandwidth than if the data had been simply modulated onto the carrier. This is because; signals with high data rates occupy wider signal bandwidths than those with low data rates.

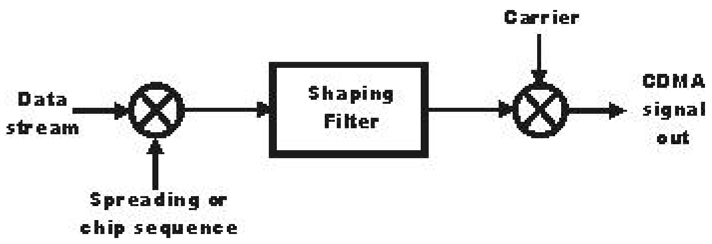


FIG.2. CDMA spread spectrum generation

To decode the signal and receive the original data, the CDMA signal is first demodulated from the carrier to reconstitute the high speed data stream. This is multiplied with the spreading code to regenerate the original data. When this is done, then only the data with that was generated with the same spreading code is regenerated, all the other data that is generated from different spreading code streams is ignored.

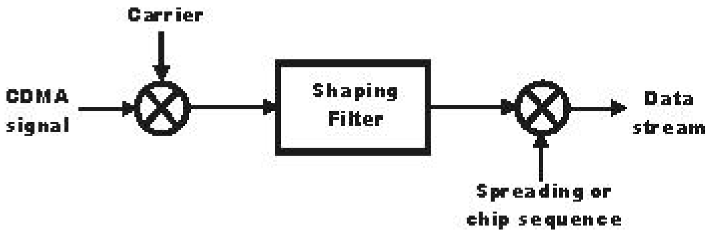


FIG.3. CDMA spread spectrum decoding

The use of CDMA spread spectrum is a powerful principle and using this CDMA technique, it is possible to transmit several sets of data independently on the same carrier and then reconstitute them at the receiver without mutual interference. In this way a base station can communicate with several mobiles on a single channel. Similarly several mobiles can communicate with a single base station, provided that in each case an independent spreading code is used.

CDMA spread spectrum encode / decode process

In order to visualize how the CDMA spread spectrum process operates; the easiest method is to show an example of how the system actually operates in terms of data bits, and how the data is recovered from the CDMA spread spectrum signal.

The first part of the process is to generate the CDMA spread spectrum signal. Take as an example that the data to be transmitted is 1001, and the chip or spreading code is 0010. For each data bit, the complete spreading code is used to multiple the data, and in this way, for each data bits, the spread or expanded signal consists of four bits.

1	0	0	1	Data to be transmitted
0010	0010	0010	0010	Chip or spreading code
1101	0010	0010	1101	Resultant spread data output

With the signal obtained and transmitted, it needs to be decoded within the remote receiver:

1101	0010	0010	1101	Incoming CDMA signal
0010	0010	0010	0010	Chip or spreading code
1111	0000	0000	1111	Result of de-spreading
1	0	0	1	Integrated output

NB: 1 x 1 = 0   1 x 0 = 1

In this way it can be seen that the original data is recovered exactly by using the same spreading or chip code. Had another code been used to regenerate the CDMA spread spectrum signal, then it would have resulted in a random sequence after de-spreading. This would have appeared as noise in the system.

The spreading code used in this example was only four bits long. This enabled the process to be visualised more easily. Commonly spreading codes may be 64 bits, or even 128 bits long to provide the required performance.

CDMA spreading gain

The bandwidth of the CDMA spread spectrum signal will be much wider than the original data stream. To quantify the increase in bandwidth, a term known as the spreading gain is used. If the bandwidth of the CDMS spread spectrum signal is W and the input data bit length or period 1/R then the CDMA spreading gain can be defined:

Spreading gain = W/R

It is found that the larger the spreading gain of the CDMA spread spectrum signal, the more effective the performance of the system is. This is because the wanted signal becomes larger. In the example shown above, the spreading gain is four, as seen by the fact that four "1"s are generated for each required data bit. Data produced by other dispreading codes would appear as noise and can be discarded as it would be lower in value.

The principle behind CDMA spread spectrum communications is relatively straightforward. The same code must be sued within generation and decoding of the CDMA spread spectrum signal to enable the data to pass unchanged through the system. The use of a different code in transmission and reception results in a signal similar in character to noise being generated and this can be discarded.

CDMA Orthogonal Spreading Codes

The CDMA orthogonal spreading codes are one of the major elements within the whole CDMA system. The CDMA orthogonal spreading codes are combined with the data stream to be transmitted in such a way that the bandwidth required is increased and the benefits of the spread spectrum system can be gained.

The CDMA codes are specific to each channel / user so that the different users can gain access to the system and communicate as required.

CDMA codes and correlation

The concept of CDMA is based around the fact that a data sequence is multiplied by a spreading code or sequence which increases the bandwidth of the signal. Then within the receiver the same spreading code or sequence is used to extract the required data. Only when the required code is used, does the required data appear from the signal.

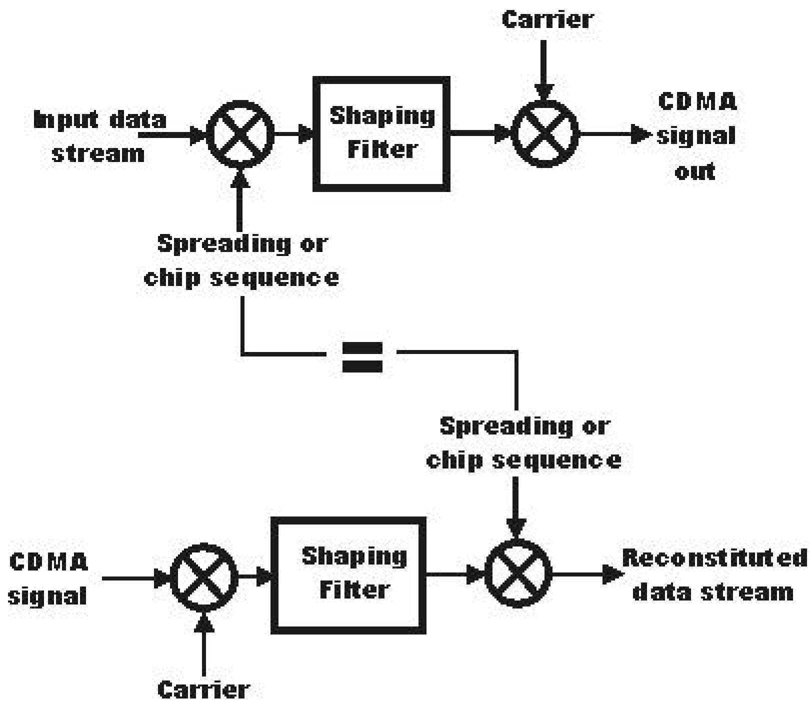


FIG.4. CDMA system showing use of spreading codes

The process of extracting the data is called correlation. When a code exactly the same as that used in the transmitter is used, then it is said to have a correlation of one and data is extracted. When a spreading code that does not correlate is used, then the data will not be extracted and a different set of data will appear. This means that it is necessary for the same spreading code to be used within the transmitter and receiver for the data to be extracted.

CDMA code types

There are several types of codes that can be used within a CDMA system for providing the spreading function:

- PN codes: Pseudo-random number codes (pseudo-noise or PN code) can be generated very easily. These codes will sum to zero over a period of time. Although the sequence is deterministic because of the limited length of the linear shift register used to generate the sequence, they provide a PN code that can be used within a CDMA system to provide the spreading code required.

They are used within many systems as there is a very large number that can be used.

A feature of PN codes is that if the same versions of the PN code are time shifted, then they become almost orthogonal, and can be used as virtually orthogonal codes within a CDMA system.

- Truly orthogonal codes: Two codes are said to be orthogonal if when they are multiplied together the result is added over a period of time they sum to zero. For example a codes 1 -1 -1 1 and 1 -1 1 -1 when multiplied together give 1 1 -1 -1 which gives the sum zero. An example of an orthogonal code set is the Walsh codes used within the IS95 / CDMA2000 system.