CHAPTER

3 COMMUNICATION SYSTEM FOR KAVACH

3.0 Planning of KAVACH Towers

3.1 Introduction

This chapter describes the requirements for data transmission over the air (through radio), Multiple Access scheme and Radio communication protocol for Loco and Stationary Kavach sub-systems(Loco Kavach and Stationary Kavach units) and defines the Radio communication transmission time slots and frequencies required for Stationary Kavach and Loco Kavach system.

With the advent of high speed and high density Rail Networks over IR, implementation of Automatic Train Protection (ATP) systems has become a *sine qua non* for ensuring safety of trains. Most ATP systems provide an additional layer of safety over the existing interlocking systems so as to aid the loco pilots. All the ATP systems need radio communication towers for functioning.

3.2 Need for Communication Towers

Communication between locomotive KAVACH and stationary KAVACH is exclusively through radio waves. At present, KAVACH uses spot frequencies in 400 MHz to 450 MHz band (f_0 – 441.8 MHz, f_1 – 456.8 MHz, f_2 – 416.8 MHz, f_3 – 466.8 MHz, f_4 – 426.8 MHz). Considering the scenario where a loco is moving from block station A to block station B, it should communicate with stations A and B for approximately half the distance of block section each. Without loss of generality, a block section can safely be assumed to be around 10 km. This means that one stationary KAVACH equipment should cater to around 5 km communication. An antenna at ground level can simply not perform the job. Here arises the need for communication towers to increase the range of radio coverage.

3.3 Initial Reconnaissance Survey for Towers and their Feasibility

The most important initial step in taking up tower works is to carry out initial survey studying the feasibility of towers keeping in mind factors such as height of tower, signal strength, ease of construction and maintenance of sites. During this survey, sites could be classified into Green, Amber and Red based on the difficulty of implementation.

Classification	Green	Amber	Red
Plot Size	No limitation	Poses limitation in Tower Height / Design Selection	Serious Constraints
Plot Access	No limitation	Poses possibility of Head Load	Serious Constraints
Ground Water	No limitation	Moderate saturation posing limitation in selection of tower	Extreme saturation
Soil / Rock Conditions	Good soil and non-rocky conditions	Moderately good soil	Extreme limitation in soil strength
Summary Action	None	Tackling with Design Modifications	Find alternatives before contract is awarded.

A typical survey format detailing various geographical and technical factors for identifying tower plot location is given below.

Name of the Station / IBS / LC Gates for the proposed Tower location:

S.No.	Survey Item Description	Remarks
a	Any High Rise Buildings/trees available near proposed tower location	Yes/No
b	Type of Soil-Rocky/Clay/Black Cotton/Sand etc	
c	Soil is natural mother earth or filled soil	
d	Nearest Airport available to the station/LC gate/IB& Distance in Kms	
e	Is Station/LC gate/IB situated in Forest area	Yes/No
f	Is Station/LC gate/IB situated in Coastal area (with in 15 Kms from Coast)	Yes/No
g	Tower shall be placed 46 m (Horizontal Distance) away from the Nearest track as far as possible. Is 46 m Horizontal Railway Boundary clearance available	Available/Not Available Distance between tower and nearest track centre -
h	Availability of high tension wires in near vicinity	Yes / No
i	Any water pipelines in near vicinity of tower location	Yes / No

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S.No.	Survey Item Description	Remarks
j	Availability of staff quarters/houses nearby	Yes / No
k	Availability of underground Signalling / Telecom, / Power cables / OFC	Yes / No
l	Interdistance Distance between proposed tower and Relay room	
m	Interdistance Distance between nearest track centre to railway boundary	
o	Quad cable, OFC, signalling cable paths (same side/other side of tower location)	Quad - OFC - Signalling -
p	Longitude & Lattitude coordinates of proposed tower site for Ligowave software / WPC / MSL	Longitude - Latitude - MSL - Pincode -
q	Attachment of site photos	Yes/No
r	Motorable access to the proposed site for transportation of fabricated tower materials	Yes / No
s	Any future plans by other departments for utilisation of proposed tower plot area	
t	Any sanction of ROB / RUB in lieu of LC gate	Yes / No
u	Sanction of new interlocked LC gate	
v	Other information if any	

3.4 Selection of Tower

3.4.1 Selection of Type of Tower

Based on the initial planning, drone survey, Radio Signal Strength Indicator (RSSI), site reconnaissance survey, tower types are chosen. The types of towers are discussed below.

Self Supporting Lattice Towers – They can be angular, tubular or a hybrid of both angular and tubular. Similarly, self supporting towers are either 3 or 4 legged.

Self Supporting Monopole – It is a single self supporting pole. This design is generally used to minimise foot print at the site which is easily accessible.

Narrow Based Self Supporting Lattice Tower – It is generally a 4 legged tubular tower upto 40 m height with very low foot print. It is used as a substitute to monopole when there are no aesthetic constraints.

Characteristic	4 Legged Angular	3 Legged Angular	Narrow Based	Monopole
Foot Print	4	3	2	1
Visual Appeal	4	3	2	1
Ease of Fabrication	1	2	3	4
Ease of Erection	3	1	2	4
Overall Cost	**2**	**1**	**3**	**4**
Remarks	**1 denotes lowest / cheapest / easiest** **4 denotes highest / costliest / difficult**			

Figure 1: Three Legged Angular Tower

Figure 2: Four Legged Angular Tower

Figure 3: Tubular Tower

Figure 4: Monopole Tower

Figure 5: Narrow Based Tower

Fig. 3.1

Monopole tower requires motorable road access to site, long boom cranes, space for horizontal assembly of monopole at site and lifting of monopole using crane. This means that monopole is not a recommended option over lattice tower at constrained site locations. At such locations, narrow based lattice towers are preferable. As such, it is opined that three legged tubular tower of 40 m height is preferable in line with RDSO guidelines to have uniformity and standardisation.

3.4.2 Selection of Height of Tower and Number of Towers

The height of tower and number of towers can be decided based on the following inputs.

(a) Geological conditions of site – Soil Bearing Capacity, Water Table, Drainage etc

(b) Accessibility of site for carrying material

(c) Radio network link calculations. The received signal strength should not be poorer than −85 dBm throughout the communication mandatory zones. It may be ensured that there are no obstructions in 60% of the First Fresnel Zone.

(d) The antennae for communication system of stationary KAVACH system shall be able to provide a minimum range of communication upto 1.5 km beyond the the first signal of the stationary KAVACH unit. This is typically 4.5 km in case of double distant territory. In the case of IBS / Mid-section Interlocked LC Gates, this is much smaller and hence, 15 m/20 m tower could also be explored based on survey details.

(e) Design Basis Report of complete route containing the following

- (i) Confirmation of tower (3 legged, angular / Tubular, Monopole, etc.,)
- (ii) Elevation of antenna on the tower structure
- (iii) Wind speed
- (iv) Terrain condition
- (v) Seismic conditions
- (vi) IR Code of Practice issued by RDSO to be followed for structural designs, fabrication and erection of towers. Reference to RDSO's B&S Directorate checklist on Design of Super-structure for KAVACH tower vide document dated RDSO-BnS0EBS(SB-2)/16/2020-O/o ED/BnS/RDSO dated 11/01/2021.
- (vii) Material specification

(f) Above details can be finalized by

- (i) Reconnaissance (Walk over survey)
- (ii) Ligowave software to decide the antenna height
- (iii) Drone survey to have the exact locations of stations, Signal structure, IBS and Auto goomties, kilometer stones, traction masts etc.

(g) RSSI (Received Signal Strength Indicator) Survey is required to fine tune the antennas light, which is already available with the help of Ligowave software using the longitude and latitude of tower location at stations, IBS and Auto-goomties, LC gates, etc.

(h) If we fine tune the antennas height also in the beginning, then only RSSI survey in advance of inviting EPC tender is required.

Site Information			
TX Site Name	Secundrabad Jn	RX Site Name	Sitafalmandi
Radio Type	LigoPTP 6-N RapidFire	Radio Type	LigoPTP 5-23 RapidFire
Latitude	17.434	Latitude	17.428
Longitude	78.508	Longitude	78.520
TX Power	40.0 dBm	RX Threshold	-85.0 dBm
Ant. Gain	5.0 dBi	Ant. Gain	3.0 dBi
Ant. Height	35.0 meter	Ant. Height	5.0 meter
Parameters			
Frequency	441.0 MHz	Climate	Continental Temperate
Ant. Polarization	Vertical	Measurement System	Metric System
Misc. Loss	5.0 dBm	Rain Rate	0.0 mm/hr
Results			
Total Path Loss	93 dB	Thermal Fade Margin	40 dB
RX Signal Level	-44.879 dBm	Distance between sites	1.437 km
EIRP	45.0 dBm	Link availability due to rain	N/A

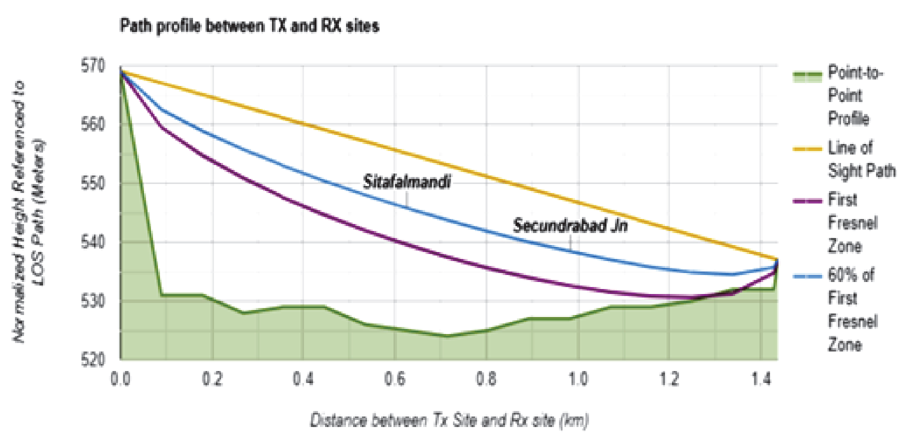

Fig.3.2 A Sample RSSI Survey using Ligowave Software

3.5 Design Engineering Activities

3.5.1 Design Approval Process

Design approval process can be summarised as below:

(a) Preparation of designs of tower sub-structure (foundation) and super-structure (tower) based on Wind Speed (IS 875 Part 3), Soil Bearing Capacity (SBC), Water Table (With / Without Saturation), Factor of Safety (2.0 as per IR Standard Code of Practice for the Structural Design of Microwave Towers of Self Supporting Type, 1982) etc.

(b) Proof checking of design by third party like CPRI / IITs.

(c) Railway approval of design by Chief Bridge Engineer (CBE).

(d) The tower designs are specific to each design agency and hence, separate approvals need to be obtained for each agency.

3.5.2 Site Specific Activities

(a) Identification of site for tower erection free from infringements and approval by division duly recommended by all stakeholders / departments.

(b) Collection of soil samples at the identified locations and their lab testing

(c) Submission of Soil Investigation Report stating SBC to railways along with relevant foundation drawing for review and approval.

(d) Final approval for "Fit for Construction" by project executing unit.

3.5.3 Site Execution Activities and Timelines

Team	Activity	Team Skill Set	Duration	Remarks
A	Site readiness and Mobilization towards work commencement	Project management and Site coordination	10 days	Involves interaction with multiple stake holders such as verification of UG cable and overhead lines, Vegetation clearance, Site leveling and marking with Railway clearances.
B	Civil foundation construction	Skilled workers for concreting, steel bar bending, shuttering activities	10 days	Activities include: Site excavation ~ 8×8×3 meters PCC bed concreting Placing of reinforcement steel. Concreting of raft and first lift column Concreting of second lift column Concreting of third and final lift with CIP Stage-wise inspection at critical milestone is carried out and recorded in site register by Railways
C	Tower erection	Skilled tower rigger	8 days	Erection of tower including ladder and cable tray working and equipment platform, staging, antenna mounts, lightning arrester/ SPDs, aviation lamp, GI earth strip along the tower, etc.
D	Tower painting	Skilled tower rigger with painting skills	4 days	Activity includes Primer coat using zinc chromate. Two coats of enamel paint alternate deep orange and white paints.

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Team	Activity	Team Skill Set	Duration	Remarks
E	Manual Curing using open pit and watering during various stages of foundation construction	Unskilled / Semi skilled labour and Supervisor	12 days	This activity timelines can be compressed subject to implementation of certified curing compounds during concreting.
F	Tower completion and verticality check	Skilled team along with RITES	1 day	Tower ready for installation of antennas, cabling, and Radio modems, levelling, fencing, ring earthing, etc.,

Note: Tower construction would take approximately 45 days per tower. By engaging four teams each of Civil, Tower and Site supervision, approximately 12 towers sites can be completed in a month with concurrent management. However, the above parallel activities will become effective after initial period of 6 to 8 weeks from the commencement of the project activities.

3.6 Inspections and Testing of Tower

3.6.1 Inspection and Tests for Foundation and Tower

S.No.	Description	Items for Testing	Remarks
1	Tests on Foundation		
1.1	Raw Material	Reinforcement sample for Tensile strength as per IS 1786	Laboratory report to be submitted
		Coarse and Fine Aggregate for fineness modulus as per IS 383	
		Cement conforming to IS standard for strength as per IS 269	
1.2	During foundation works	Slump Cone test on fresh concrete for workability to be performed at site during each stage of concreting as per IS 456	Slump value shall be between 75 to 90 and witness by Railway
		Collection of Cube samples from fresh concrete for strength check to be performed at site during each stage of concreting as per IS 456	1 sample (3 specimen) for every 5 Cu.m to be tested at lab after 28 days and report to be submitted to Railways
2	Inspections on Foundation		
2.1	During foundation works	1st inspection – Depth check of foundation and layout of foundation at PCC	Witness by Railway and recorded in Site Register

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S.No.	Description	Items for Testing	Remarks
		2nd inspection – Reinforcement check before casting of Footing and supervision of concreting of footing and 1st lift of column / pedestal	
		3rd inspection – Checking of Template fixing and supervision of concreting of final lift of column / pedestal	
3	Tests on Tower – at Factory by RITES as per Quality assurance Plan (QAP)		
3.1	Raw material to workmanship	The Tests at the Factory by RITES shall be as per agreed QAP – Refer table below for details	RITES inspector shall visit the Factory for Raw material inspection and Finished Goods inspection and submit the certificate of clearance.
4	Inspections on Tower – at Site		
4.1	Material inspection at site	4th inspection - Checking of materials for good condition, quantity as per packing list and coating thickness	Railway inspector to verify and record observations in site register
4.2	Tower Post erection	5th inspection – Checking of tightening of bolts (Randomly) and verticality check.	

3.6.2 Tower Super-structure Material Inspection by RITES – Quality Assurance Plan (QAP)

Tower super-structure material inspection is done by RITES at two stages.

1. Raw material inspection for super-structure of tower
2. Inspection of finished goods (members) of tower super-structure

RITES inspection shall be carried out in accordance with Quality Assurance Plan (QAP) that has been prepared and agreed by all the stakeholders – Railway, Tower Designer, Contractor Agency and Tower Fabricator. Necessary approvals shall be obtained from CBE. The broad guidelines of QAP and manufacturing process right from raw material to finished product are elaborated below.

S. No.	Activity	Description	Reference IS Codes - For Supply and Acceptance Criteria	Remarks
1	Raw Material Procurement	Pipes, Plates, Angles, ISMC, Hardware (HDG Bolts of Gr 8.8 and nuts)	IS 2062 for all hot rolled sections; IS 1161 / IS 1239 / IS 3601 for Pipes IS 12427 Or other equivalent	Along with supply MTC is normally expected; Also samples are usually collected and tested for Chemical and Mechanical properties at the time fabrication as a usual process

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S. No.	Activity	Description	Reference IS Codes - For Supply and Acceptance Criteria	Remarks
2	In Process Fabrication	Dimensional cut of members, assemblies, hole punching / drilling	IS 10748; IS 2062; IS 1161; IS 7215	Use of Jigs and Fixtures for assembly of sections shall be ensured.
3	Welding	Welding shall be carried out in accordance to WPS / Drawings	IS 816; IS 822; AWS D1.1	Welding shall be visually inspected and samples randomly tested by NDT methods of DPT / MPI
4	Final Inspection	Inspection of fabricated tower	Drawings	Post Fabrication final inspection of material is usually carried out
5	Galvanization	Galvanization of tower	IS 6745; IS 2633; IS 2629; Drawings	Coating thickness shall be as per drawing usually between 45 to 85 Microns depending on thickness
6	Packing and Loading	Tower despatch to site	Packing List and Drawings	Loading shall be inspected and supply quantities shall be ensured as per drawing

3.6.3 Site Photographs of Ideal Conditions

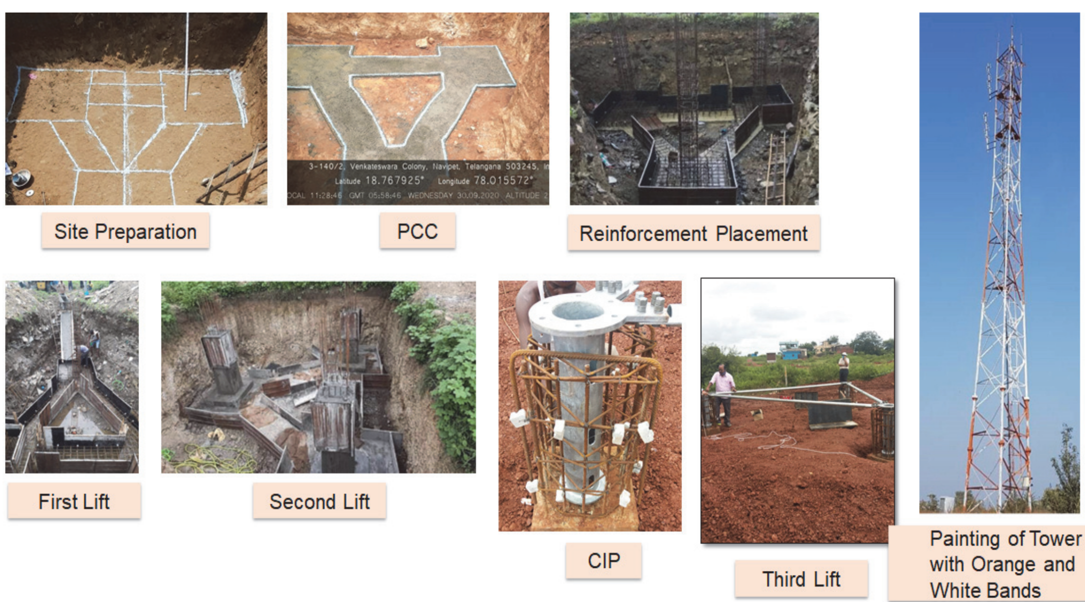


Fig.3.3 Typical Tower Site Photographs

3.7 Cable Connectivity for Tower at Stationary KAVACH Locations

Cable shall be provided at stationary KAVACH locations for tower catering to the power supply radio modems, aviation lamp and RF transmission of data. Cable connectivity diagram is shown below.

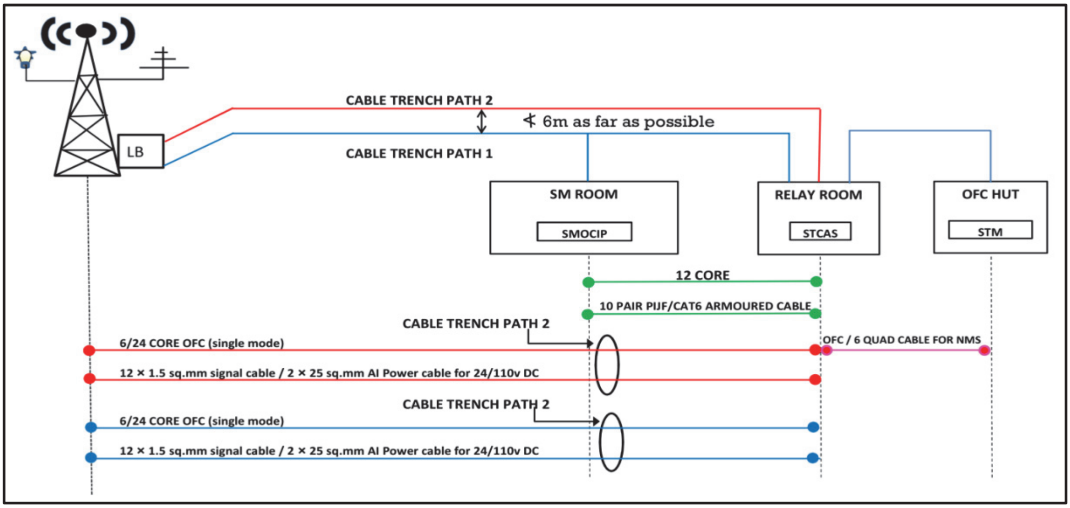


Fig.3.4 Cable Connectivity Diagram for KAVACH at Stationary KAVACH Locations

Notes for Figure 8

1. Two diversified cable paths shall be provided as far as possible, from Station KAVACH to the tower to avoid common mode failures.
2. 6/24 OFC cable in diverse path shall be provided from Stationary KAVACH to the tower to avoid common mode failures.
3. 12 Core Signalling cable or Power cable for operating Radio of aviation lamp.
4. 12 Core Signalling cable between SMOCIP to Stationary KAVACH.
5. OFC cable for NMS purpose
6. LMR-600 RF coaxial cable from the two radio modems to antennae shall be routed in the different paths.

3.8 WPC / SACFA Clearance Process

Wireless Planning and Coordination (WPC) clearance is necessary for the operation of radios in India. This clearance is for the operation of radio. Site specific clearances such as defence areas, airport area etc., are given through SACFA clearance. Revised process for the application is given below.

(a) SARALSANCHAR (Simplified Application For Registration and Licenses) a Web based Portal, for Issuing of various types of Licenses and Registration certificates is part of various Digital initiatives being taken by Department of Telecommunications.

(b) Applications to be processed in SARALSANCHAR online portal through sub-user creation
(c) A Master User has been created for Ministry of Railways for creation of Sub-Users on Saral Platform of WPC (SACFA), who can then apply further for allotment of frequencies
(d) KAVACH uses FIVE frequency spots in 400 MHz to 450 MHz band. (f0 - 441.8 MHz, f1 - 456.8 MHz, f2 - 416.8 MHz, f3 - 466.8 MHz and f4 - 426.8MHz).
(e) SCR has initially processed applications for the WPC clearance for KAVACH frequencies during December 2020 after introduction of Portal.
(f) Two Radios for each Stationary KAVACH/LC KAVACH and Two radios for each Loco KAVACH and 10% Spare radios
(g) There is a restriction of maximum 99 nos. of radios per application in the portal, hence processed with multiple applications (Six) to cater the entire 1200km on-going KAVACH project.
(h) Approval process takes 6 to 8 months and hence Railways shall initiate the process well in advance
(i) With Dealer Possession License (DPL), OEMs can import KAVACH Radios, but for supply and operation WPC license is required.
(j) Main aim of Standing Advisory Committee on Radio Frequency Allocation (SACFA) is to ensure aviation safety and security and addressed by clearance for a tower/ antenna / site (Heights > 30 Meters)
(k) Initiation of SACFA clearance after obtaining the Decision letter from WPC which is a pre- requisite to fill the online application for SACFA clearance in the portal.

3.9 Maintenance of Towers

Once KAVACH towers are erected, it is essential that they are kept in "fit" condition through regular maintenance. It generally consists of general inspection, fault tracing, checking of tower aviation lights, quarterly checking of condition of foundation, corrosion, tilt, nut and bolt tightness, distortion of members, cabling intactness, earthing, half yearly verticality check and other need based maintenance. Painting of tower is also needed every three years.

3.10 Conclusion

Successful deployment of KAVACH needs timely erection of communication tower for establishing connectivity between Stationary KAVACH and Loco KAVACH. One of the critical activities of KAVACH deployment is construction of towers and none of the testing activities could be initiated without the erection of towers. Initial reconnaissance survey for towers and their feasibility, meticulous planning, regular progress reviews with tower contractors, resolving site issues, concurrent management of tower activities are some of the key areas for meeting the targets. ADEN or

SSE/Works possessing adequate competency in Civil foundations and steel structures shall be deputed under the administrative control of S&T department for authorised working.

Station Antenna

Base station stacked Dipole type Omni directional type antenna with Gain of 9.0 dB. Frequency band is 406-512 MHZ with input impedance 50 Ohms. Four antennae used and 1- TX and 1- RX antenna for each modem.

Fig 3.5 Antenna Towers

LOCO – Radio Antenna:

Fig 3.6 LOCO – Radio Antenna

1. Gain 0 dB, Frequency band : 406 – 512 Mhz
2. Input Impedance: 50 Ohm
3. Polarization: Vertical
4. Radiation pattern: Omni directional
5. Wind rating: 200 km/hr
6. Weight (Kg): 3
7. 4 Antennae (1-TX and 1-RX antenna for each radio modem)

3.11 Fiber Classification, Standards & Constructional Features

3.11.1 Fiber Classification

Fiber Classification based on fiber types in a cable may be categorized as three types. They are:

1. Single Mode Fiber Optic Cable.
2. Multimode Fiber Optic Cable.
3. Hybrid/ Composite Cable.

1. Single Mode Fiber Optic Cable:

Designs of single-mode fiber have evolved over several decades. The three principle types and their ITU-T specifications are:

- Non dispersion-shifted fiber (NDSF) G.652

  The initially deployed type used for 1310 nm. This fiber has high dispersion at 1550 nm, hence not suitable for 1550 nm systems. To solve the shortcoming of NDSF fiber, fiber manufacturers developed dispersion-shifted fiber (DSF).

- Dispersion-shifted fiber (DSF) G.653

  In this type of fiber the fiber is designed in such a way that the zero-dispersion point is moved to the 1550 nm region

- Non zero-dispersion-shifted fibers (NZ-DSF) G.655

  Though DSF worked extremely well with a single 1550 nm wavelength, it exhibits serious nonlinearities when multiple, closely-spaced wavelengths in the 1550 nm were transmitted in DWDM systems.

  To address the problem of nonlinearities, non-zero-dispersion-shifted fibers (NZ-DSF) were designed by manufacturers. The fiber is available in both positive and negative dispersion varieties and is rapidly becoming the fiber of choice in new fiber deployment.

2. Multimode Fiber Optic Cable:

All fibers in the cable are multimode cables fibers only. Multi-mode optical fiber is a type of optical fiber mostly used for communication over short distances, such as within a building or on a campus. Multi-mode links can be used for data rates up to 100 Gbit/s. Multi-mode fiber has a fairly large core diameter (50/62.5µm) that enables multiple light modes to be propagated and limits the maximum length of a transmission link because of modal dispersion. The standard G.651.1 defines the most widely used forms of multi-mode optical fiber.

3. **Hybrid/Composite Cable:**

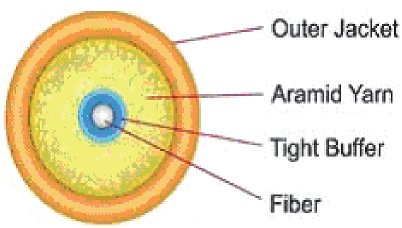
Both single mode and multimode fibers are packaged in one cable, such as 4 multimode fibers and 4 single mode fibers in a single cable.

Classification based upon application may be categorized as the following types. They are:

1. Indoor Cables
2. Outdoor fiber optic Cables
3. Direct buried Outdoor Cables

1. Indoor Cables

A single cable structure with a single fiber. Simplex cable varieties include 1.6mm & 3mm jacket sizes. Fire safety is the number one factor in selecting indoor cables, particularly those that run through plenum spaces. Indoor cables must pass the flame-retardant and smoke-inhibitor ratings.



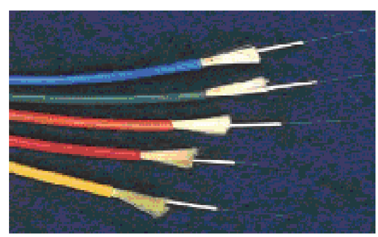


Fig.3.7 A Indoor OFC

2. Outdoor Fiber Cable

Outdoor rated tight buffered cables have riser and plenum rated versions. These cables are flexible, easy to handle and simple to install. Since they do not use gel, the connectors can be terminated directly onto the 900um fiber without difficult-to-use kits. This provides an easy and overall less expensive installation.

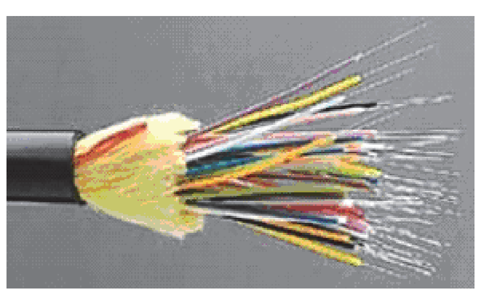


Fig.3.7 B Outdoor Tight Buffered Fiber Optic cable

3. Direct-buried (Armored Fiber Optic Cable)

Armored cables are similar to outdoor cables but include an outer armor layer for mechanical protection and to prevent damage. They can be installed in ducts or aerially or directly buried underground. Armor is surrounded by a polyethylene jacket.

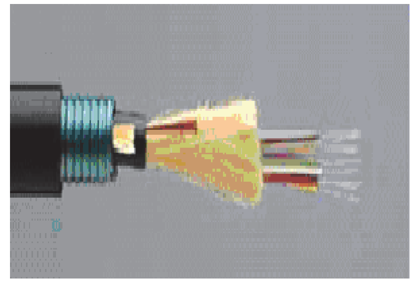


Fig.3.7 C Armored Fiber Optic cable

Armored cable can be used for rodent protection in direct burial if required. This cable is non-gel filled and can also be used in aerial applications. The armor can be removed leaving the inner cable suitable for any indoor/outdoor use. Temperature rating −40 to +85^{0}C.

3.11.2 Standards and commercial fibers

The physical dimensions of core and cladding have been standardized to ensure compatibility among splices and connectors.

The international standards for SM fiber are:

Cladding diameter	:	125 microns (micro meter)
Cladding + coating	:	245 microns (micro meter)
Core diameter	:	8 to 10 micro meter

The International standards for MM fiber are:

Cladding diameter	:	125 microns (micro meter)
Cladding + coating	:	245 microns (micro meter)
Core diameter	:	50 to 62.5 micro meters

The SM and MM Core and cladding diameters:

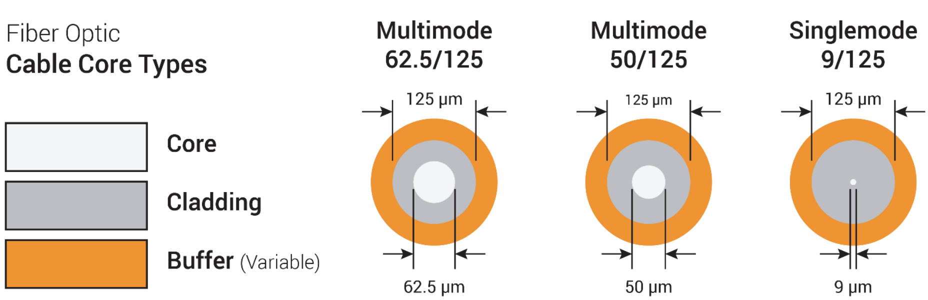


Fig.3.8 Core and Cladding diameter

Technical Specifications: Technical Specifications are as per ITU-TG.652.D and tabulated below:

Cut off wave length	Cut off wave length for 2m fiber section shall be 1320nm
Attenuationat 1310 nm between 1285 to 1330 nm at 1550 nm	≤ 0.36 dB/Km < 0.36+0.02dB/Km ≤ 0.23 dB/Km
Nominal diameter of core	8.8 µm - 9.8 µm for matched clad fiber
Nominal diameter of cladding	125 µm ± 1.0 µm
Non circularity of cladding	≤1%
Mode field concentricity error	≤0.8 µm
Primary coating	Material UV curable Acrylate, Diameter 245±10 µm. It should not have any reaction with cladding or cable material
Chromatic dispersion(CD)	@1550nm: ≤18.0 , @1625nm: ≤22.0 (ps/(nm.km))
Polarization mode dispersion (PMD)	For individual fiber : ≤0.1(ps/(km)$^{1/2}$ For cabled fiber : ≤0.4(ps/(km)$^{1/2}$
Fiber curl	≥ 4m radius of curvature
Fiber micro bend at 1550 nm	≤ 0.5 dB

3.11.3 Constructional Features

Marking on Cable

On the outer jacket of the cable there is indelible length marking at an interval not exceeding 1±.01 meter. The outer jacket is in black color and marking is in white color.

The sequential length marking shall not rub off during normal installation. The marking on the cable is as given below:

"Manufacturer/Company's trade mark, IR marking, telephone mark, laser symbol, type of cable, number of fibers, month, year of manufacture and drum number."

Identification of Fibers in Cable

Fibers are color coded with readily distinguishable& durable colors. In case of four fibers in a tube the order of colored fibers are Blue, Orange, Green and Natural. The 6 loose tubes have the following colors.

Loose Tube number	Color of loose tube
1	Blue
2	Orange
3	Green
4	Brown
5	Slate
6	White

3.12 Multiple access Techniques in Communication

FDMA

FDMA is the process of dividing one channel or bandwidth into multiple individual bands, each for use by a single user. Each individual band or channel is wide enough to accommodate the signal spectra of the transmissions to be propagated. The data to be transmitted is modulated on to each subcarrier, and all of them are linearly mixed together.

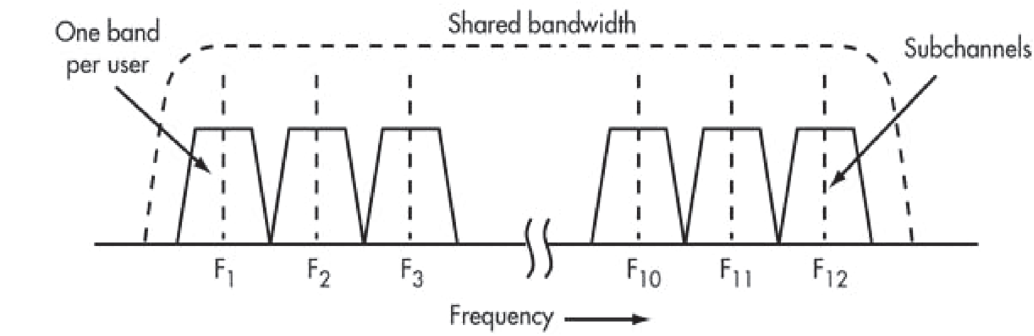


Fig.3.9

TDMA

TDMA is a digital technique that divides a single channel or band into time slots. Each time slot is used to transmit one byte or another digital segment of each signal in sequential serial data format. This technique works well with slow voice data signals, but it's also useful for compressed video and other high-speed data.

A good example is the widely used T1 transmission system, which has been used for years in the telecom industry. T1 lines carry up to 24 individual voice telephone calls on a single line. Each voice signal usually covers 300 Hz to 3000 Hz and is digitized at an 8-kHz rate, which is just a bit more than the minimal Nyquist rate of two times the highest-frequency component needed to retain all the analog content.

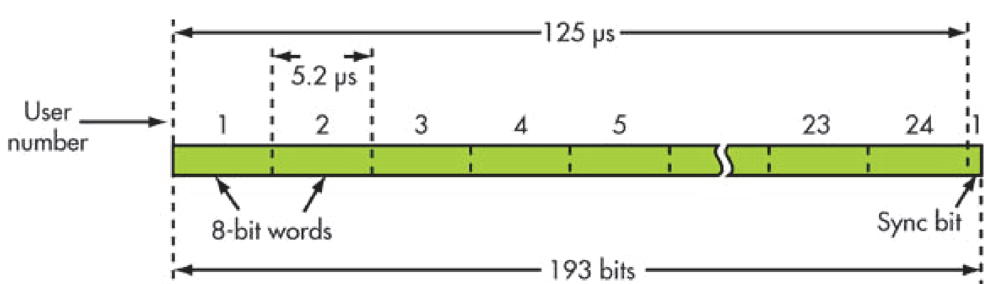


Fig.3.10

CDMA

CDMA is another pure digital technique. It is also known as spread spectrum because it takes the digitized version of an analog signal and spreads it out over a wider bandwidth at a lower power level. This method is called direct sequence spread spectrum (DSSS) as well. The digitized and compressed voice signal in serial data form is spread by processing it in an XOR circuit along with a chipping signal at a much higher frequency. In the cdma IS-95 standard, a 1.2288-Mbit/s chipping signal spreads the digitized compressed voice at 13 kbits/s.

The chipping signal is derived from a pseudorandom code generator that assigns a unique code to each user of the channel. This code spreads the voice signal over a bandwidth of 1.25 MHz. The resulting signal is at a low power level and appears more like noise. Many such signals can occupy the same channel simultaneously. For example, using 64 unique chipping codes allows up to 64 users to occupy the same 1.25-MHz channel at the same time. At the receiver, a correlating circuit finds and identifies a specific caller’s code and recovers it.

The third generation (3G) cell-phone technology called wideband CDMA (WCDMA) uses a similar method with compressed voice and 3.84-Mbit/s chipping codes in a 5-MHz channel to allow multiple users to share the same band.

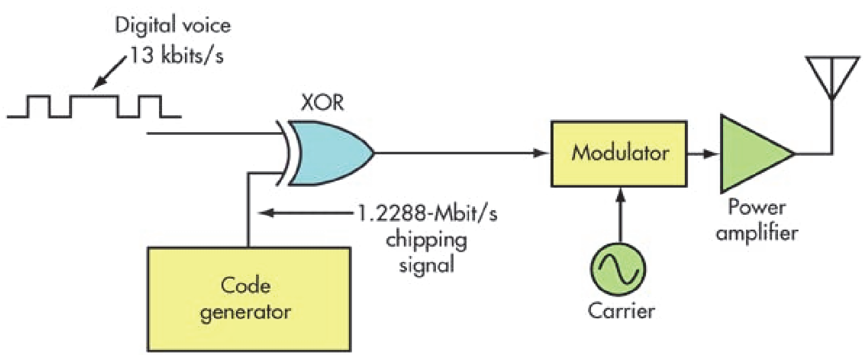


Fig.3.11

The chipping signal is derived from a pseudorandom code generator that assigns a unique code to each user of the channel. This code spreads the voice signal over a bandwidth of 1.25 MHz. The resulting signal is at a low power level and appears more like noise. Many such signals can occupy the same channel simultaneously. For example, using 64 unique chipping codes allows up to 64 users to occupy the same 1.25-MHz channel at the same time. At the receiver, a correlating circuit finds and identifies a specific caller’s code and recovers it.

The third generation (3G) cell-phone technology called wideband CDMA (WCDMA) uses a similar method with compressed voice and 3.84-Mbit/s chipping codes in a 5-MHz channel to allow multiple users to share the same band.

OFDMA

OFDMA is the access technique used in Long-Term Evolution (LTE) cellular systems to accommodate multiple users in a given bandwidth. Orthogonal frequency division multiplexing (OFDM) is a modulation method that divides a channel into multiple narrow orthogonal bands that are spaced so they don't interfere with one another. Each band is divided into hundreds or even thousands of 15-kHz wide subcarriers.

The data to be transmitted is divided into many lower-speed bit streams and modulated onto the subcarriers. Time slots within each subchannel data stream are used to package the data to be transmitted. This technique is very spectrally efficient, so it provides very high data rates. It also is less affected by multipath propagation effects.

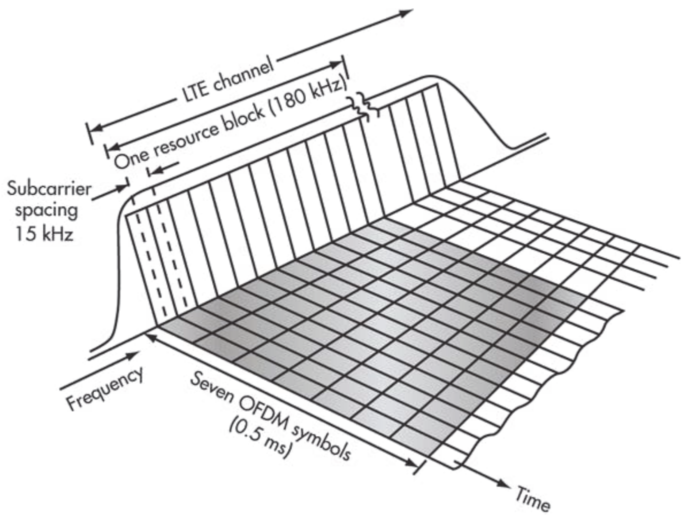


Fig.3.12

3.13 Over the Air (OTA) Requirements

- Communication between the Stationary Kavach and Loco Kavach shall be Over-The- Air (OTA) using Multiple Access
- Each Multiple Access frame cycle shall be of 2000 milli seconds.
- It shall be suitable for communication in frequency range of 406 MHz to 470 MHz.
- Loco Kavach shall use transmit frequency (f_0) in block section and at the times of emergency situations (SoS, head-on, rear-end collisions).
- Stationary Kavach and Loco Kavach shall use their respective timeslot(s) in the Multiple Access within their channel for the transmission of communication packet(s).
- Communication packets shall be of a maximum size of 1024 bits.
- Kavach sub-system shall split the packet into multiple packets if it exceeds maximum communication packet size (1024 bits).

- The transmission Over-The-Air from Radio shall be controlled by Kavach Sub-systems using Request To Send signal in the RS232.
- Kavach sub-system may transmit multiple Communication packets in a single transmission burst.
- Kavach sub-system shall transfer all the data for a single transmission burst to the Radio modem at least 20milli second before commencement of Over-The-Air (OTA).
- Kavach sub-system shall calculate the timings from commencement and completion of transmission by Radio Modem Over-The-Air (OTA) by considering the preamble, communication packet, post amble and extra stuffed bits.
- Kavach sub-system shall disable the RTS signal after completion of transmission of information data over-The-Air (OTA).
- Change of frequency or switch between the frequencies shall be completed well in Advance (15 milliseconds before commencement of Data transmission Over-The-Air (OTA)).
- In the bit-stream Over-The-Air, LSB shall be transmitted first.

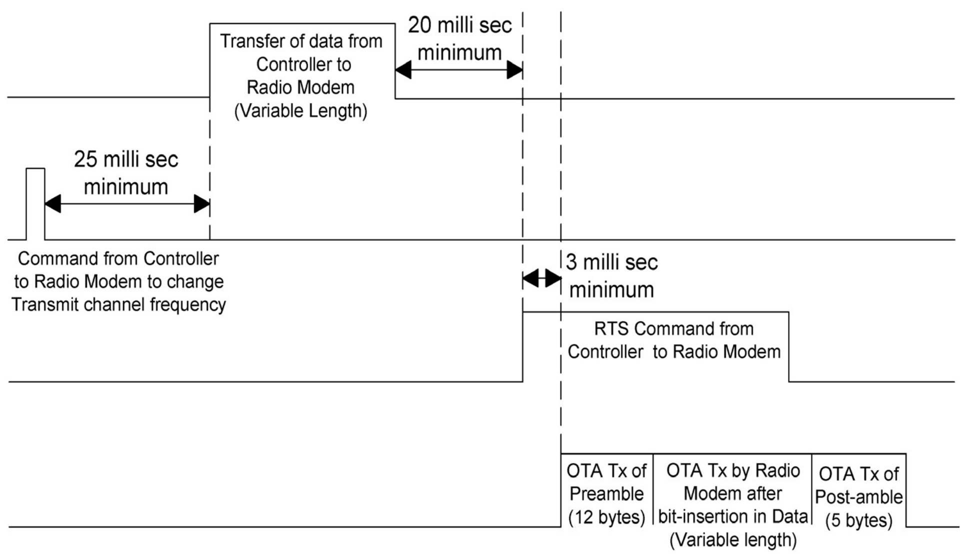


Fig.3.13 Radio Communication

3.14 Multiple Access Scheme

The optimized frame cycle structure for the TDMA/FDMA/SDMA scheme is shown in figure-4.2, as shown frame cycle is divided into basic 78 time slot position markers (position nos. 1 to 78) each of width 352 bits (18.33 m-sec). These are spaced 96 bits (5 m-sec) apart except for the four wider time slots to ensure proper frequency stabilization on change.

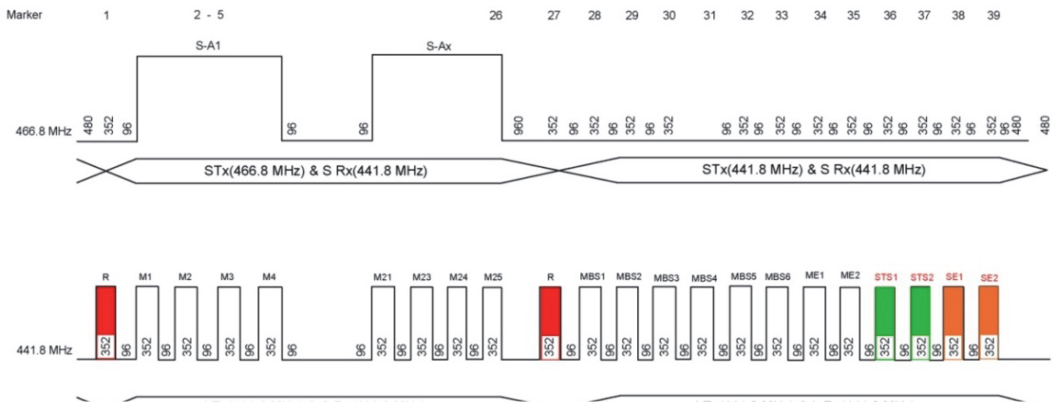


Fig.3.14

Sl. No.	Time slots	Used for	Marked as	Remarks
1	P2 to P27	Stationary Kavach and Loco Kavach communication	M-1 to M-50	Total 50 Timeslots out of 78
2	P28 to P33 and P67 to P72	Loco Kavach for broad casting communication packets in the block section	MBS-1 to MBS-12	Total 12 Timeslots out of 78. Shall switch its Tx frequency to f_0 in the block section
3	P34,35,73,74	In f_0 shall be used by the Loco Kavach for broad casting additional emergency (SoS) messages.	ME-1 to ME-4.	Total 4 Timeslots out of 78.
4	P38,39,77,78	In f_0 shall be used by the Stationary Kavach for broad casting additional emergency (SoS) messages	SE-1 to SE-4.	Total 4 Timeslots out of 78.
5	P36,37,75,76	In f_0 shall be used by the Stationary Kavach for broadcasting Access Authority messages.	STS-1 to STS-4.	Total 4 Timeslots out of 78.
6	Four time Slots P1,P27,P40 & P66	Used for frequency stabilization and frequency switching	------	Total 4 Timeslots out of 78.

* Stationary Kavach System shall transmit the Radio packet in its designated time slot*Loco Kavach System shall transmit the radio packet in its designated time slot and designated frequency channel received from stationary Kavach Unit.

* The frequency pair allotted for two adjacent stations shall be different.

* The Loco time slot for the same station shall not be adjacent to each other (minimum one time slot gap shall be kept).

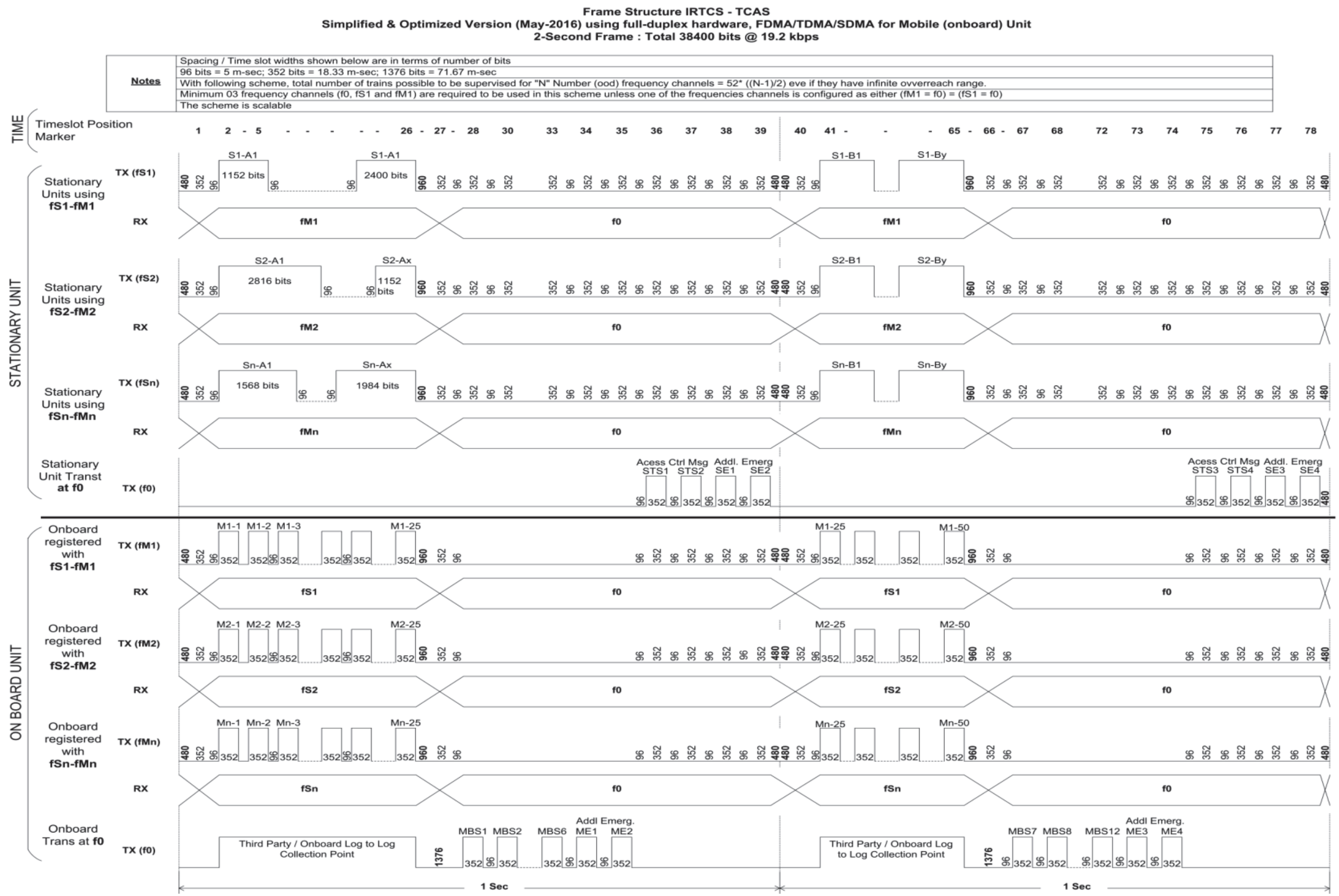


Fig.3.15 Multiple Access Scheme

3.15 Radio Modem Requirements

Radio Unit shall be as per following specifications:

(a) Shall be FCC or IC or CE certified
(b) Shall possess RTS/CTS and/or DOX modes
(c) Shall be capable of RF Data Transfer in “Bitwise” / streaming Mode
(d) RF frequency range:406-470MHz
(e) RF Channel Bandwidth : 25kHz
(f) Modes of operation Full Duplex
(g) Modulation: 2FSK at 19200 bps with linear 8th order low pass filter (raised – cosine alpha.1Approximation).
(h) Deviation: 4.3 kHz +/- 0.1 kHz. Occupied Bandwidth : 16.35 kHz +/- 0.15kHz.
(i) Operating frequencies : Ranging from 406 MHz to 470MHz
(j) Emission : according to16K0F2D
(k) Transmitter freq. stability : 1ppm
(l) Transmitter Turn-on time (Tx. Freq. stable)/ Channel Switching time: not more than 15msec
(m) Carrier Output Power: 1-10 w adjustable through software.
(n) Receiver Adjacent Channel Rejection 70dB at 25kHz

3.16 Receiver Sensitivity: 35 micro-volts for 12 dB SINAD

(a) 1 x 10^{-6} BER at -100 dBm Level for 19.2kbps and 25kHz Bandwidth
(b) Interfaces: RS232
(c) RF Impedance : 50ohm
(d) Power Supply : 10V-30V DC
(e) Set-up and Diagnostic features to be available through separate port RS232 and real time non-intrusive online diagnostics.

3.17 Functional Requirements

3.17.1 Modulation

(i) The modulation used shall be 2FSK with 19,200 baud rate with linear 8th order low pass filter (raised cosine alpha 1approximation).
(ii) Occupied bandwidth shall be 16.35 kHz +/.15 kHz
(iii) The nominal deviation shall be 4.3 kHz +/-0.1 kHz.

3.17.2 Transmission

(i) During bit stream over the air transmission, LSB shall be transmitted first.
(ii) Transmission shall start within 3ms +/- 1ms after data terminal equipment causes the signal on RTS line to be high.
(iii) RTS shall be raised before commencement of preamble transmission.

Radio modem shall transmit based on the DTR, RTS and RI signals as below:

DTS	RTS	Ring Indicator	Radio Modem
Low	*	Low	Won't transmit
High	Low	Low	Receiving or buffering Tx data
High	↑	↑	Transmit all buffered data and incoming data

DTS	RTS	Ring Indicator	Radio Modem
High	High	High	Send all data in TX buffer and continue transmitting even when TX buffer is empty
High	↓	↓	Continue transmitting remaining data in TX buffer, then unkey
↓	High	↓	Abort transmission, discard data in TX buffer and unkey immediately

* : Don't Care

↑ : Transition from low to high

↓ : Transition from high to low

3.17.3 Encoding

- The radio modem shall commence transmission by prefixing preamble (12 bytes of 0x7E) to the data received from DTE.
- The radio modem shall complete transmission by suffixing post amble (5 bytes of 0x7E) to the modified data.
- The data to be sent shall be encoded as shown in following Pseudo code. Encoder state shall be updated throughout the transmission.
  - Input _Bit = Input_bit XOR 1
  - Encoder State = Encoder State XOR Input_Bit
  - Output_Bit = Encoder State

Examples:

Case	Consecutive Flag Characters	Two bytes of User Data (having all '0's)	Two bytes of User Data having all '1's with '0' stuffing
Input bit stream	0111111001111 110	0000000000000 000	11111011111011111 01
Output bit stream	0111111101111 1110	0101010101010 1010	00000011111100000 011

Radio modem shall insert additional '0' after five consecutive '1's of data during transmission.

For example,

0x7C – 01111100 is sent OTA as011111000

0xF8 – 11111000 is sent OTA as111110000

0x7E – 01111110 is sent OTA as011111010

0xFE – 11111110 is sent OTA as111110110

The encoded data shall be scrambled before stuffing of ‘0’ bit as shown in following Pseudo code. Scrambler state shall be updated throughout the transmission.

3.17.4 Receiving

- The received data shall contain application data as well as preamble and post amble.
- Reception of complete post amble (5 bytes of 0x7E) shall act as delimiter between two successive “Receive” bursts.
- At the end of transfer of received data from radio modem to DTE, the radio modem shall additionally append “0xA5 – 0xC9 – 0xA5 – 0xC9” after the data
- After the data transfer to DTE, the EIA 232F function shall be switched to high from low, shall remain high for 2 ms and shall be switched to low again.
- Refer the below timing diagram, for data transfer between Kavach sub- system and radio modem.

3.18 LTE Radio Modem Requirements

Introduction: The LTE Radio modem requirements to be used for the purpose of future evaluation of Kavach System.

- LTE modems Dual SIM operation on one modem card will not provide sufficient level of redundancy.
- QoS on Uplink: UL QCI obeys UL TFT using Network Initiated QoS as per 3GPP TS24.008
- Operating system – Shall allow the use of a hypervisor to allows multiple operating systems to share the hardware host.
- Voltage – 24VDC or 110VDC.
- Temperature Operating Range : -40^0C to $+70^0$C ($+85^0$C for 10 mins) as per
  - EN 50155 Tx Compliance Heat, Cold, Insulation, Shock and Vibration:
  - EN50155:2017
  - Railway Applications - Electronic equipment used on rolling stock
  - (EN50155: Heat, Cold, Insulation, Vibration and Shock)
  - EN60068-2-1,EN60068-2-2, EN60068-2-30
- Compliance EMC: EN50121-3-2:2017
  - Railway Applications - Electromagnetic Compatibility - Part3-2
- Compliance Shock and Vibration : EN 61373:2017

  - Railway Applications
  - Rolling stock equipment – Shock and Vibration Tests. Category 1 ; Class B
- Compliance Fire Protection - EN45545-2:2015 Railway Applications -
  - Fire Protection on Railway Vehicles - Part 2
  - Requirements for Fire Behavior of Materials and Components.
- Compliance to Ingress Protection IEC 60529IP54
- Compliance to EN55032 Electromagnetic Compatibility of Multimedia Equipment
  - Support MVB, RS-422,RS-485
  - Support reception of GPS, GLONASS, QZSS, BeiDou
  - Support Software Defines LAN

3.19 Future LTE-R Test Setup for KAVACH

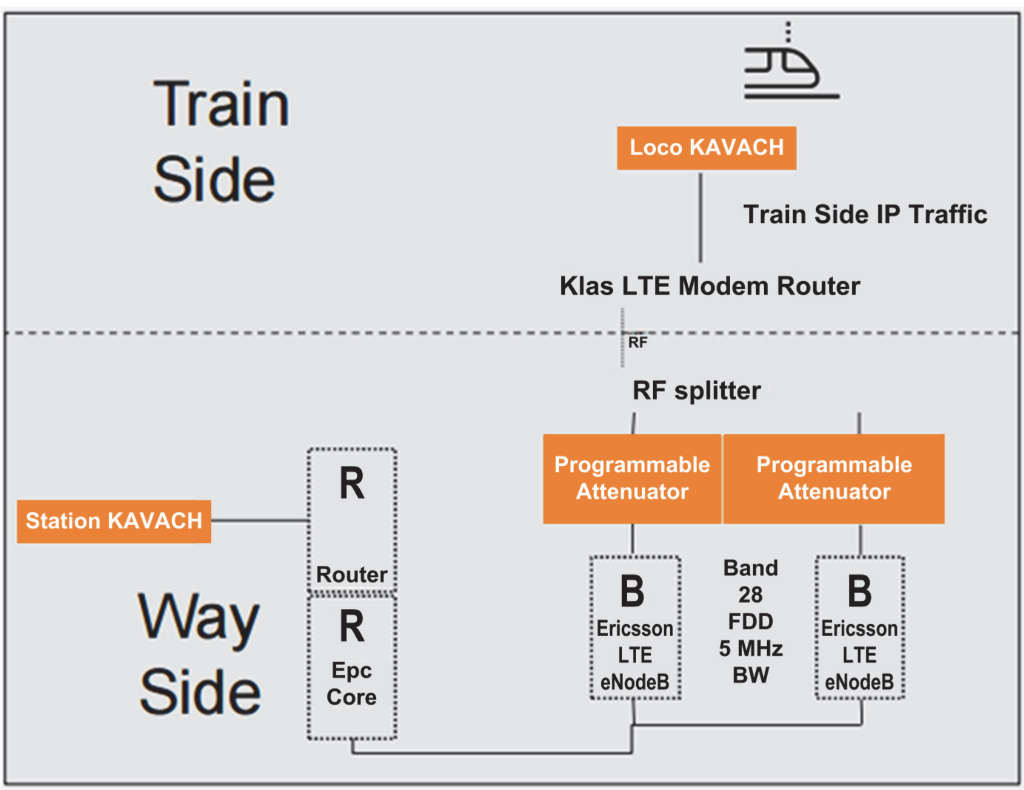


Fig. 3.16 Multiple Access Scheme

LTE Test Lab-KAVACH Connectivity Diagram

Scenari-1 Basic Communication b/w Loco Kavach to Stationary Kavach

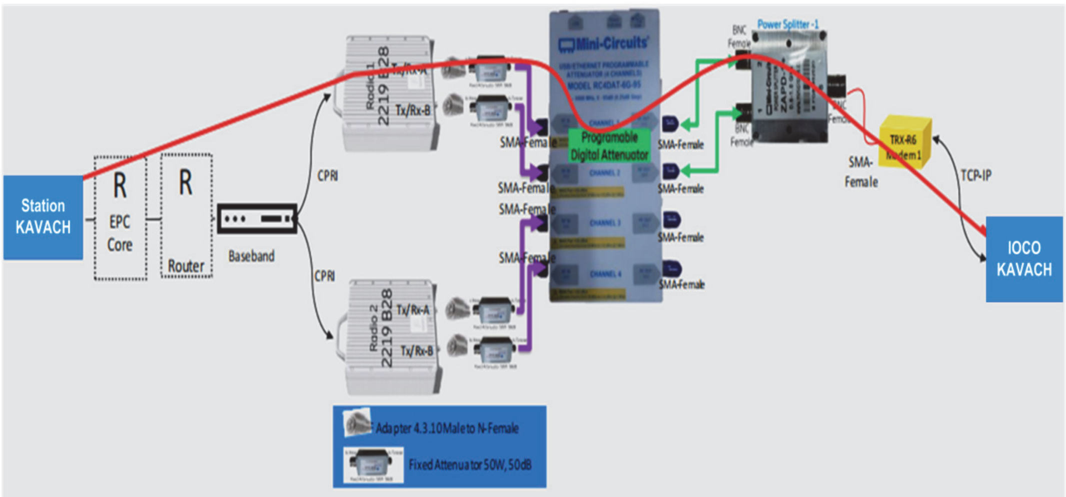


Fig. 3.17 Loco / Station Communications

LTE Test Lab-KAVACH Connectivity Diagram

Scenari-2 Radio/Sector Handover

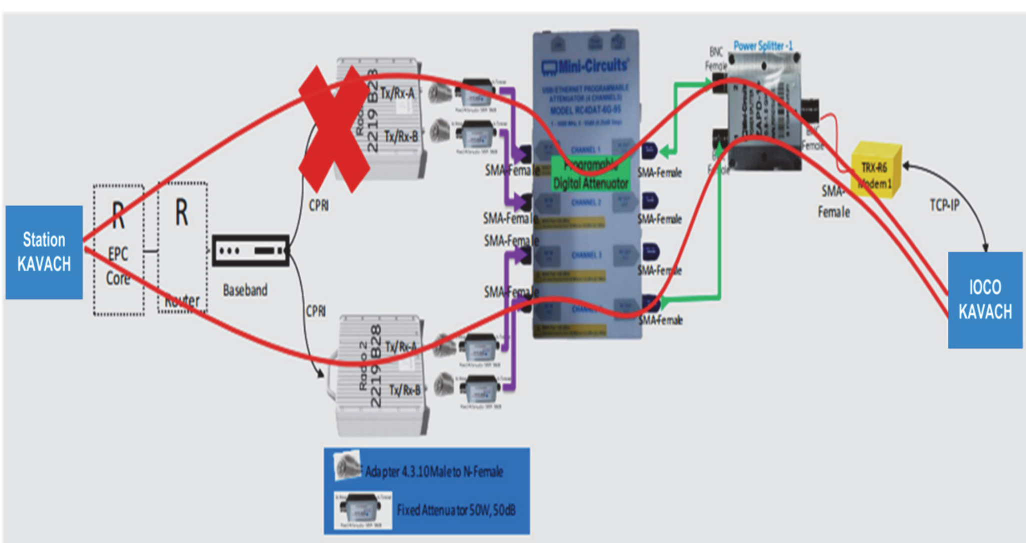


Fig.3.18 Station to Loco Communication

LTE Test Lab-KAVACH Connectivity Diagram

Scenari-3 Loco KAVACH communicating via both Modems

- Active/Active

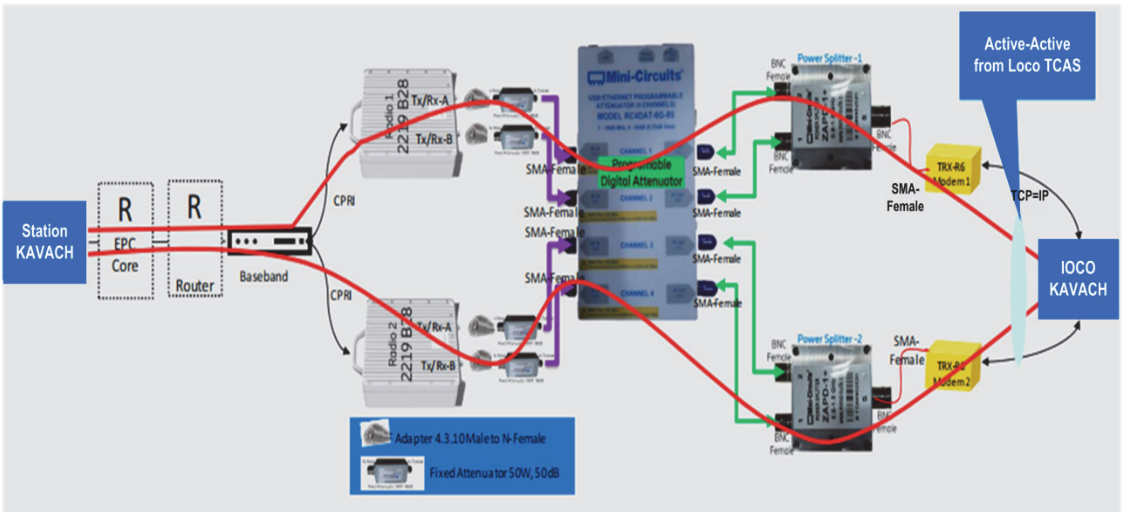


Fig.3.19 Loco to Modems Communications

LTE Test Lab-KAVACH Connectivity Diagram

Scenari-4 Loco to Loco Communication

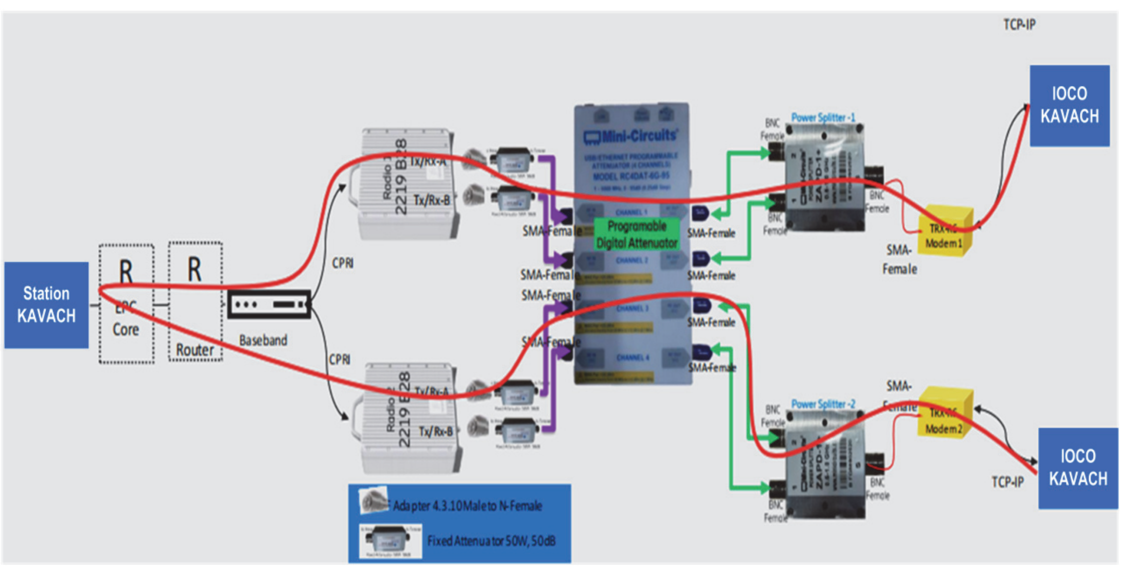


Fig.3.20 Loco to Loco Communication