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GOVERNMENT OF INDIA

(भारत सरकार)

MINISTRY OF RAILWAYS

(रेल मंत्रालय)

System Requirements Specification of KAVACH (The Indian Railway Automatic Train Protection System)

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Title of Document **System Requirements Specification of KAVACH (The Indian Railway Automatic Train Protection System)**		
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Approved by RDSO **Name:** Shri Suresh Kumar, Designation: Principal Executive Director/S&T		
Abstract This document covers System Requirements specification of KAVACH (The Indian Railway Automatic Train Protection System)		

Amdt.	Date of issue	Amendment
1	22.05.2023	• Annexure A is segregated into three annexures Annexure A1 - Mode Transitions and Conditions, Annexure A2 - Configurable parameters of Onbaord KAVACH and Annexure-A3 - Configurable parameters of Stationary KAVACH • Annexure-E2: KAVACH LTE Interface Requirements is converted from Future to Optional • 3.4.2.5 – Corrections in Classification of Tags is carried out. • 3.4.2.6 (a) Toleance of +/- 100m is removed for Normal Tag placement. • 3.4.2.9 – Adjustment/Junction Tag details added. • 3.4.4 (c) and 3.4.4(d) – Frequency tuning modified from 427-430 MHz to 425-430 MHz based on new frequencies request sent to WPC. • 3.5.3- Sequence ID table is corrected for conformity. • 4.7.8.2, 4.7.8.3, 4.7.8.4, 4.7.8.5, 4.7.8.6, 4.7.8.7, – Date and Time are made as Indian Standard Time (IST) for conformity. • 4.7.8.9- Example corrected for computation of session key for conformity • 4.7.8.10 -Example corrected for Generic Message Authentication Calculation for conformity. • 4.7.8.14: Process Flow for Stationary entity KAVACH authentication: New clause added. • 4.7.8.15: new clause added for automatically update their session key. 8.1.7 - New sentence added: “Stationary KAVACH shall be able to handle Train length assignment for minimum 6 directions”. • 15 – The SIL level of Track Identification Number is corrected to Non SIL. • Sentence corrections for conformity at 3.4.2.1, 3.4.2.4, 3.4.3.1 (a), 3.4.3.1 (c) (iv), 3.4.3.2 (d), 3.4.3.2 (e), 3.4.3.3 (iii), 3.4.3.3 (v), 3.4.4 (d), 3.4.4 (g) (ii), 3.4.4(g)(v), 3.4.4(g)(vi), 3.5.2 (c) (iii), 3.5.3(h), 3.5.3 (i), 3.5.5.2 (b) & (f), 3.5.5.10, 3.5.6.3 (b), 3.5.6.3 (c), 3.5.6.3 (d), 3.5.7.2, 4.2, 4.7.1, 4.7.2, 4.7.4.3, 4.7.5.3, 4.7.6.5, 4.7.6.7, 4.7.6.9, 4.7.6.11, 4.7.8.13, 5.5 (a), 5.5 (g), 7.7, 10.1.1, 10.1.2, 10.1.3, 10.3.5, 14.3, 16.2.1, 16.2.2, 16.5.1, 16.12, 17.1, 19.4 (a), 20.1 (7), 20.1 (8, ii), • New clause added for conformity at 3.4.3.1 (viii) and 3.4.3.1 (ix), • 4.7.3.1, 4.7.3.2, 4.7.8.14, 6 (determination of speed), 9.1, 31(m). • Clauses merged for conformity at 3.5.6.3(e) to 3.5.6.3(b), • Clauses grouped for conformity at 3.5.7.8 (a) to (g).

		• Clauses made optional for conformity at 4.7.7.3Clauses deleted for conformity at 4.7.5 (f), example of 4.7.8.11, 5.1, 7.2 (b), 16.13. • CRC-16 BIT Polynomial- Deleted
Amdt-2	27.02.2024	• CL.1.4.2- Clause corrected. • CL.1.4.3- Clause modified with addition of "as (M) and" • CL.2.2.1- Clause modified with addition of "Further, the requirements of SR Authorization and recovery are also detailed". • CL.2.2.26 & CL. 2.2.27- New Annexures are added to facilitate vendors to develop RFID Tag, RFID reader and radio modem and is optional. • CL 3.4.1 (c) is shifted from CL.3.4.3 (C)- Remote Interface Unit. • CL.3.4.2.1- Clause modified with addition of "the sleepers between". • CL.3.4.2.2- Clause modified with deletion- RFID tags at all the places shall be duplicated. ~~with identical information except absolute location related to operations.~~ • CL.3.4.2.3 (f)- "or for any contradiction, requirement mentioned in specification will be prevailed". • CL.3.4.2.3 (h)- modified with addition of "Suitable measures shall be taken by firm to avoid reading of Tags from other tags". • CL.3.4.2.4 assigned linking function as SIL-4. • CL. 3.4.2.4 (b)- clause modified as "To correct the accumulated Odometry error (5 m location accuracy of RFID Tag + 5% of distance travelled from last read tag)." • CL. 3.4.2.4 (c)- clause modified as "All linking information of the tag is sent from the stationary KAVACH to the onboard KAVACH over Radio communication". • CL.3.4.3.1 (C-vi) – clause modified with modification of "USB/Ethernet interface" for downloading logs. • CL.3.4.3.2 – Clause for Provision for switching off display of signal aspect on LPOCIP is added. • CL.3.4.3.4 Clause modified with addition of "If any other voltage used, necessary provision for conversion of voltage to be ensured by firm". • CL 3.4.3.6 (e) The sequence number evaluation to discard received redundant packet by the Stationary Kavach is specified • CL.3.4.4.1- clause modified with addition of "The maximum number of dark fibres shall be four Single mode OFC per ring. Primary and secondary rings shall be used for Indian Railways Application." • CL.3.4.4.8- Clause modified with addition of "If the same state is not detected after the timeout (6 Seconds-Configurable) by any channel, a comparison of the obtained input state between input channels shall be per-

		formed by vital computer". • CL.3.5.2.3 (c)- Clause modified- "Two Direction sensing type Speed Sensor in each Pulse generator shall be used to interface for direction determination, distance and speed measurement". • CL 3.5.2.10 – Clause added specifying the requirements of cables and connectors in rolling stock. • CL. 3.5.4.2 (g)- clause modified with addition of "as per specification. In case of contradiction, the requirement as per specification will prevail." • CL. 3.5.4.5 – Clause modified as "On registering, the Stationary KAVACH shall send all the expected RFID ~~sequences~~ tags in the route. Onboard KAVACH shall monitor the same. In case of single or duplicated missing tags, information shall be sent to NMS. ~~If turn-out tag is overread by Loco, the same shall be informed to NMS."~~ • CL. 3.5.4.6 – Clause modified as "On not receiving any information from any ~~one Normal~~ RFID tag either due to both tags missing or due to any other reason, ~~50 m beyond the expected location~~ within the window limits of L_doubt over and L_doubt under, Tag missing indication shall be displayed on LP-OCIP (DMI). Tag missing information shall be sent to NMS. However, the details of Tag read shall be stored in the event logger". • CL. 3.5.4.7 – Clause modified as "If the Onboard KAVACH ~~unit~~ reads the ~~KAVACH~~ Exit RFID tag (non-KAVACH territory), it shall transit to 'Staff Responsible" mode and stop the radio communication with stationary KAVACH after the complete train passed over exit tag". • Cl. 3.5.5.2 (l)- Clause corrected as "Target speed ~~(For entering into loop line)."~~ • Cl. 3.5.5.2 (n)- New clause added. • Cl. 3.5.5.4 to 3.5.5.7 corrected as "Common/ACK and ~~ACK/~~Cancel for conformity • Cl 3.5.5.7- Clause modified with addition of "when transiting from Full supervision mode to Onsight mode/Limited supervision mode/Staff Responsible mode, Onsight mode to Limited supervision mode/Staff Responsible mode & Limited supervision mode to Staff Responsible mode." • Cl. 3.5.6.3 (c) – The word MU is expanded as "Multi Unit" • Cl. 3.5.6.3 (f)- clause added with Electro-Pneumatic (EP) or any other braking system used in Indian Railway. • Cl. 3.5.6.4 (c)- The word "configurable" is added after numerical values. • Cl. 4.7.2- clause modified with addition of "and TSRMS" for conformity. • CL 4.7.4.1 & CL. 4.7.4.2- Clause modified by adding the "new connection request and the Stationary Kavach with higher unique ID shall be primary partner." for conformity.

		• Cl. 4.7.5.1 & 4.7.5.2 –Clause modified by adding the "new connection request. TSRMS is defined as primary partner and the Stationary KAVACH" for conformity. • Cl. 4.7.5.3- Clause corrected for grammar. • Cl. 4.7.5.4 –Clause corrected for showing correct example. • Cl. 4.7.7.9 – clause added with "in non-volatile memory" • CL.4.7.8.9- Clause added with "Onboard KAVACH /TSRMS/ or adjacent stationary KAVACH". • CL. 4.7.8.10 – Clause corrected as - "The CBC-MAC (K, X) function using a secret ~~triple key K~~ authentication". Assume a message m (~~232~~ 144 bits, ~~29~~ 18 octets) with the following structure in hex notation: Because it is not a multiple of 128 bits, "14 Zero octet" must be padded ~~with zero bits before~~ at the end of data before MAC calculation as follows: ~~A 128-bit key is required for MAC calculation. This the key to be used to calculate a MAC is the Session Key K_S, derived during session establishment from K_A~~. MAC calculation requires a 128-bit Session Key K_S, generated from K_A during session establishment. This example assumes that K_S as generated above." • CL. 4.7.8.15 (b)- clause corrected with addition of "~~message~~ packet in f_0 frequency with CBC-MAC code. Access Authority message contains frequency, Time slot ~~pair~~ and Random Number R_S". • CL. 4.7.8.15 (c)- clause modified for grammar. • CL. 4.7.8.15 (d, e & f)-New clause added to complete the flow of registration. • CL.4.7.8.16 (h)- Clause modified with addition of (configured in Stationary KAVACH data base). • CL.4.7.8.15 (a) – Clause moved to 4.7.8 (i) for correct positioning of test. • CL.5.2- Clause deleted "~~Onboard KAVACH shall hold the Full Supervision Movement Authority up to the end of the current route section when communication fails~~.". • CL.5.4 (b)- Clause corrected to "Approaching signal distance f~~rom train position (absolute location)~~ the reference RFID". • CL. 9.2 modified as "Functional Onboard KAVACH unit shall transmit the location of the train to the Stationary KAVACH unit every 2 seconds. ~~in Full Supervision mode.~~" • CL.10- New Clause added for Track Profile Supervision (SIL-4). • CL.10.3- New clause added "Track Conditions (Non-SIL) (F)" • CL.20.1.2- Clause modified with addition of commencement of brake in the ~~end of~~ current route section. • CL.13.1- ~~KAVACH needs two Direction type speed sen-~~

		~~sors and therefore it needs to be provided by purchaser in case it does not already exist~~. Deleted due to repetition. • CL.15.2- clause modified with addition of "track profile received through radio". • CL.3.5.5.5, 3.5.5.6 & 15.9- clause modified as "Common /Ack ~~Cancel~~". • CL.16.3- clause modified as "~~info~~. ~~Also~~ adjacent line ~~Location adjustment~~ info data is to be communicated over radio only after physical separation of tracks. • CL.16.4- The following sentence is ready as "Station section TIN can be repeated after a designated distance (10 km minimum along the track route)". • CL.16.5- clause modified as "TINs shall be allotted in such a manner not to ~~inhibit~~ restrict permissible simultaneous movements". • CL.17.2.1 & 17.2.2- New clauses added for initiating a radio communication at Start of Mission and entering communication mandatory area. • CL.17.4, 17.5, 17.6, 17.7, 17.8 & 17.9–New clauses added to complete the flow of radio communication. • CL. 17.10 (a) – Clause modified as follows: "(typically 1.5km from Last Stop Signal of Stationary KAVACH in Absolute Block Section and upto a distance of train length beyond border tag in Automatic Block Section)". • CL. 17.10 (a) – Clause modified as follows: "No radio packet is received from the Onboard KAVACH for more than 60 cycles (Configurable) in station section / Absolute Block Section & 15 cycle (Configurable) in Automatic Block Section". • CL. 20.1.4 is added with "The system shall be functional with one radio". • CL. 20.3.3, 20.3.4 & 20.4- clause added with "commercial GSM/LTE." • CL.20.5 – New clause added for "Pulse Generator Failure". • CL.20.6 – New clause added for "Brake Interface Failure**".** • CL.20.7 – New clause added for "Odometry error**".** • CL.21.3- clause modified with addition of "location stamp in Stationary & Onboard KAVACH units" and (h) roll back added. • CL 21.4 (a)- clause added with "Electronic Interlocking". • CL.21.6 (a)- (ii) & (xvii) -clause modified- "Initiation of brake application-Loco brake command" & "Change in train configuration and braking parameter" • CL.21.6 (b) –(vii)- Clause modified- "Change in signalling, track profile or configuration related data" • CL.21.11- clause modified- It shall be possible to download and reconstruct the recorded data on a ~~portable PC.~~ Laptop.

		• CL.22.1- clause corrected with addition of tolerances in line with IS9000 & RDSO/SPN/144/2006. • CL.22.2.1 & 22.2.2- clause modified with addition of "in accordance with IEC 61000-4-29. • CL.22.2.3 & 22.2.4- clause modified with addition of "in accordance with IEC 62236-3-2". • CL.22.2.5 - clause modified with addition of "after completion of each climatic test". • CL.23.1.4 - clause modified as "The dimensions of RIU and proposed Apparatus case along with installation details shall be ~~submitted~~ included in installation and maintenance manual". • CL.23.2.3 - clause modified with addition of "ISA to be selected as per RDSO approved list of ISA panel for generic Signalling Product/System". • CL.23.2.7- Clause modified with addition of "Software evaluation (white box testing)". • CL.25.6.1- clause modified with addition of "or IRISET Lab". • CL.25.7.1 (e) - clause modified with addition of "PSR, TSR, automatic whistling of horn, train length assignment, speed margin, protection of rollback, all SOS features". • CL.31.1 (f)- clause modified with addition of "as mentioned in approved installation and maintenance manual".
Amdt-3	25.05.2024	• Spelling correction in CL. No 3.4.2.8, 3.5.5.2 (o), 3.5.6.3 (b), 4.7.7.6, 27.1 & 27.2. • CL. 4.7.8.8- Modified with addition of OTP for <S/L/T><KAVACH_ID>:<CODE>by RCIL Note: The message template shall be configurable • CL. 22.1 (7)- Modified with coorection inline with the IS: 9000 Pt. VII ,Section-I or IEC 60068-2-27 – 2008.

Table of Contents

1. Introduction

1.1. This document sets forth system, technical and performance requirements in detail for KAVACH, The Indian Railway Automatic Train Protection System (formerly known as Train Collision Avoidance System*)*.

1.2. Advantage of an interoperable system

1.2.1. The possibility of step-by-step introduction of the new technology.

1.2.2. Enabling Pan-India competition between the manufacturers of KAVACH components. Strengthening the position of the Indian Railway industry on the world market.

1.2.3. Enabling preconditions for future harmonisation in other areas of rail traffic management.

1.3. How to read and use SRS

1.3.1. The reader may refer to the functional requirement specification of KAVACH initially before going through this document.

1.3.2. The abbreviation, applicable documents and definition may be referred from functional requirement specification.

1.3.3. The technical details such as mode transition, interface protocols & requirement etc. shall be read from Annexure.

1.4. Requirements

1.4.1. This document offers solutions on how to implement a specific function.

1.4.2. The Optional and future requirements are mentioned as “O” and “F” respectively.

1.4.3. The mandatory and interoperability requirements are mentioned as “M” and “MI” respectively.

1.4.4. The implementation of track side functions will have to be defined by OEM according to the characteristics of the specific lines and the related operational needs. In any case, the requirements of this SRS related to the implemented functions shall be respected.

1.4.5. The Onboard equipment shall implement all mandatory requirements for interoperability.

2. Content of System Requirement specification

2.1 The SRS defines the System Requirements Specification of Kavach (The Indian Railway ATP).

2.2 This sub-section is intended to give a rough overview of the contents of each Annexure.

2.2.1 **Annexure-A1 -Mode Transitions, SOS and MA Handling, SR Authorization:** This Annexure describes the Mode Transitions and Conditions, mode based Onboard functions, Stationary KAVACH function w.r.t. Onboard modes. SOS and MA handling by Stationary KAVACH for the various track side condition is also detailed. Further, the requirements of SR Authorization and recovery are also detailed. (**MI)**

2.2.2 **Annexure-A2 - Onboard KAVACH Configurable parameters**: This Annexure describes the configurable parameters of Onboard KAVACH.

2.2.3 **Annexure-A3 - Stationary KAVACH Configurable parameters:** This Annexure describes configurable parameters of Stationary KAVACH.

2.2.4 **Annexure-B- LP-OCIP- Loco Pilot's Operation-cum-indication Panel (DMI)) Display Requirements**: This Annexure details general, operational, system, technical and functional requirements for Onboard KAVACH Driver Machine Interface so that there is clear and consistent understanding between the Loco Pilot and the KAVACH system**. (MI)**

2.2.5 **Annexure-C- KAVACH Multiple Access Scheme & Radio Communication Protocol:** This document describes the requirements for data transmission over the air (through radio), Multiple Access scheme and Radio communication protocol for Onboard and Stationary KAVACH sub-systems. It also defines the Radio communication transmission time slots required for operation of KAVACH system. **(MI)**

2.2.6 **Annexure-D- KAVACH RFID Tag Data Format**: This Annexure describes the RFID tag data formats for all the possible RFID tags defined for KAVACH System**. (MI)**

2.2.7 **Annexure-E1-KAVACH UHF Radio Modem Requirements:** This Annexure describes the UHF Radio modem (406 to 470 MHz) requirements to be used for the purpose of KAVACH System. (**MI)**

2.2.8 **Annexure-E2: KAVACH LTE Interface Requirements:** This Annexure describes the LTE interface requirements for the purpose of KAVACH System operation**. (O)**

2.2.9 **Annexure-F-KAVACH RFID Tag and Fixing Arrangement Guidelines**: This Annexure describes the RFID fixing arrangement guidelines for the purpose of Kavach System.

2.2.10 **Annexure-G-KAVACH Network Monitoring System Protocol:** This Annexure describes the protocol structure for Centralized Network Monitoring System for the purpose of KAVACH System**. (MI)**

2.2.11 **Annexure-H- KAVACH RFID Tag-TIN Layout Guidelines**: This Annexure presents the guideline for preparation of RFID tag –TIN layout fo ther station and block section**. (MI)**

2.2.12 **Annexure-I-KAVACH Control Table Guidelines**: This Annexure describes the guideline for preparation of KAVACH control table based on the

SIP of the station and RFID Tag TIN layout**. (MI)**

2.2.13 **Annexure-J-Remote Interface Units**: This annexure refers to requirement of Remote interface unit which can be installed in auto, IB or gate signal etc**.(M)**

2.2.14 **Annexure-K-KAVACH Interface for Electronic Interlocking**: This Annexure describes the protocol between Stationary KAVACH and Electronic Interlocking (EI) System. **(F)**

2.2.15 **Annexure-L-KAVACH Traffic Management System Integration:** This Annexure describes the requirement for interfacing of Traffic Management system with Network monitoring system of KAVACH**. (O)**

2.2.16 **Annexure-M-KAVACH TSR Integration:** This Annexure describes the interface requirements of Stationary KAVACH with TSRMS based on the subset specification**. (MI)**

2.2.17 **Annexure-N-KAVACH BTM Integration:** This Annexure details the specifications o thef BTM interface of Onboard KAVACH interoperability in TPWS territory. **(O)**

2.2.18 **Annexure-O-KAVACH Braking Algorithm**: This Annexure describes the standard braking algorithm for uniformity. (**F)**

2.2.19 **Annexure-P- SKAVACH to SKAVACH Interface Requirements**: This Annexure specifies the interface requirements for the neighbouring Stationary KAVACH communication to perform soft handing over and taking over of Onboard KAVACH. **(MI)**

2.2.20 **Annexure-Q-KAVACH Station Master Operation and Indication Panel (SMOCIP) Requirements**: This Annexure describes the SM-OCIP requirements for the purpose o thef Stationary KAVACH System**. (MI)**

2.2.21 **Annexure-R-KAVACH Cyber Security Requirements**: This Annexure defines a common, minimum set of security measures and risk management etc. To be considered to design a system /subsystem for more stringent security levels to address the threats during cyber attack. (F)

2.2.22 **Annexure-S-E-Authority to Pass Signal at Danger** (F)

2.2.23 **Annexure-T-KAVACH-VCU Integration** (F)

2.2.24 **Annexure-U -KAVACH-EOTT Integration** (F)

2.2.25 **Annexure-V -KAVACH-CTC Integration** (F)

2.2.26 **Annexure-W- RFID Tag and Reader integration (O)**

2.2.27 **Annexure-X- Radio MODEM integration (O)**

2.3 **Subset of specification is listed below:**

(a) Temporary Speed Restriction (TSR) Management System

(b) Requirements for Report Generation Software Tool in NMS

(c) Requirements of Display Screen Software Tool in NMS

3. Basic system description

3.1. The KAVACH system shall comprise of:

(a) Trackside subsystem

(b) Onboard KAVACH unit

(c) Network monitoring system

(d) Temporary speed restriction management System.

3.2. KAVACH shall be capable of working in electrified as well as non-electrified territories.

3.3. The Onboard KAVACH unit and Track side subsystem shall not in any way infringe the schedule of dimensions being followed by the purchaser Railway.

3.4. Trackside Subsystem

3.4.1. The Trackside subsystem shall be comprised of

(a) RFID tag

(b) Stationary KAVACH Unit

(c) Remote Interface Unit

(d) Tower and Antennae

3.4.2. RFID Tag

3.4.2.1. RFID tags shall be fitted on the sleepers between the track in both stations and block section for giving trackside information to Onboard KAVACH.

3.4.2.2. RFID tags at all the places shall be duplicated.

3.4.2.3. RFID tag shall be as per following specifications:

(a) Suitable for reliable working at train speed upto 250 KMPH (minimum).

(b) Frequency of operation: 865-867 MHz

(c) Can be programmable with minimum 128 bits (including CRC) of user data.

(d) Communication Protocol – ISO-18000-6D

(e) Shall have minimum IP 68 protection. It shall work after being submerged in 1m depth water for 24 hours.

(f) Other requirements like environmental, climatic etc. As per RDSO/ SPN/144 or for any contradiction, requirement mentioned in the specification will be prevailed.

(g) Under field operating conditions RFID reader antenna shall be able to read RFID tag from a vertical distance of 700mm (maximum) from bottom of RFID reader antenna to the top of the rail level.

3.4.2.4. **Linking: (SIL-4)**

The aim of linking is:

(a) To determine whether an RFID tag has been missed or not found within the expectation window, and to take the appropriate action.

(b) To correct the accumulated Odometry error (5 m location accuracy of RFID Tag + 5% of the distance travelled from last read tag)

(c) All linking information on the tag is sent from the Stationary KAVACH to the Onboard KAVACH over Radio communication.

(d) An RFID tag is linked when its linking information is known in advance.

3.4.2.5. **Classification of Tags:** RFID tags are categorized as follows:

(a) Normal Tag

(b) LC gate Tag

(c) Adjacent Line Tag

(d) Adjustment/Junction Tag

3.4.2.6. **Normal tag:**

(a) Normal tags shall be provided in the block section as well as in station section. The maximum distance between the two normal tags shall not be more than 1000m.

(b) The Normal tag shall cater the requirement of the Inline section, Signal foot, TIN discrimination/ Turn Out, Dead Stop and Exit Tag as per the placement of the tag.

3.4.2.7. **The LC gate tag** shall be provided on both sides of the LC gate as required by operating Railway and is an optional requirement. Action in Loco Cab for LC Gate approach would be a non-SIL requirement.

3.4.2.8. **The adjacent Line tag** is used to specify the adjacent line information to

process the SoS Messages received from Onboard KAVACH, travelling on other lines.

3.4.2.9. **The Adjustment/Junction Tag** is used for absolute location correction or/and direction reset.

3.4.3. **Stationary KAVACH Unit:**

Stationary KAVACH Unit (SVK) shall comprise of

(a) Station/LC/IB KAVACH Vital Computer.

(b) Stationary KAVACH Radio Unit.

(c) Station Master Operation and Indication Panel.

3.4.4. **Station/LC/IB KAVACH Vital Computer**

3.4.4.1. The Vital Computer shall generate messages to be sent to the Onboard KAVACH based on information received from interlocking inputs, adjacent Stationary KAVACH, TSR Management system and information exchanged with the Onboard KAVACH units. Vital Computer architecture shall be minimum 2 out of 2.

3.4.4.2. The Vital Computer shall have Real Time Clock synchronization facility with GNSS clock to synchronize with other KAVACH systems in hot standby manner.

3.4.4.3. The Vital Computer shall have provision for the following:

(a) To interface with signalling inputs in a fail-safe manner.

(b) The data shall be recorded at three levels (See FRS).

(c) Ethernet port and two GSM/LTE interfaces for connectivity with Network Monitoring System (NMS) and Key Management System.

(d) To interface adjacent Stationary KAVACH, TSRMS and Radio communication (LTE/5G), EI etc. Minimum 08 no of Communication Ethernet port is required in Stationary KAVACH.

(e) To interface with OFC (Dark Fibre) for connectivity with Remote Interface unit (minimum six Port).

(f) USB/Ethernet interface to connect the laptop for downloading of log & other data for diagnostic purposes.

(g) To interface with Video Display Unit (VDU) to show real time display of Loco movements and signal aspects of the yard. However, Video Display Unit (VDU) itself is not part of the KAVACH system and optional as per requirement of the Zonal Railways needs.

(h) To interface with two numbers of Radio units.

(i) To interface with SM-OCIP.

3.4.4.4. There shall be provision of switching off display of Signal Aspect and Sig-

nal Template on LPOCIP (DMI) through Stationary Configuration Data. When configured so, Stationary KAVACH shall send Signal Aspect as 'undefined' in radio data packet sent from Stationary KAVACH Unit to Onboard KAVACH. On getting Signal Aspect as 'undefined', Onboard unit shall switch off the display of Signal Aspect and Signal Template on LPOCIP (DMI).

3.4.4.5. Stationary KAVACH and Remote Interface unit (RIU) shall work with input voltage of +110 V DC, (+30%, -20%). If any other voltage used, necessary provision for conversion of voltage to be ensured by the firm.

3.4.4.6. Stationary KAVACH shall be universally suitable for various types of signalling of Indian Railways with or without provision of colour light signalling. By default, it shall be suitable for interfacing with relays.

3.4.5. Stationary KAVACH Radio Unit

3.4.5.1. The radio communication network shall be used for the bi-directional exchange of messages between Stationary KAVACH and Onboard KAVACH.

3.4.5.2. UHF full-duplex radio communication unit shall have hot standby provision with separate cable & antenna for each radio, to communicate with Onboard KAVACH.

3.4.5.3. If no communication is received from a registered Onboard KAVACH unit for continuous 2 minutes (configurable) for absolute block section and 30 seconds (Configurable) for automatic block section), the same shall be deregistered by the Stationary KAVACH.

3.4.5.4. The Stationary KAVACH to Onboard KAVACH regular Packet shall be sent by switching radio modems at predetermined interval not exceeding 3 cycles for transmission purpose, if both radio modems are working properly.

3.4.5.5. Redundant received packet shall be discarded using sequence number. The sequence number shall be a combination of frame number, packet type, Source ID, Destination ID as shown in the table below.

Packet Type	**Possible combination**
Onboard to Station Regular Packet	Frame Number, Stationary KAVACH ID, Source Loco ID
Loco Access Request/Block section Packet	Frame Number, Source Loco ID

Table –Possible combination for validating Sequence ID

3.4.5.6. The communication mandatory area for a Stationary KAVACH shall include at least two RFID tags prior to a distance of 1km from first approaching signal of the respective Stationary KAVACH in Absolute Block Section. Communication is mandatory for the entire Automatic Block section.

3.4.5.7. The Station / Interlocked LC Gates / IBS unit shall periodically transmit in

a manner not to cause clashing of signals from two such Stationary units.

3.4.5.8. In order to improve the throughput, on recognition of radio message from a fresh loco pertaining to the territory of the Stationary KAVACH unit, the Stationary KAVACH shall allocate a Timeslot and Frequency Channel pair for Communication with that particular Onboard KAVACH unit.

3.4.5.9. Stationary and Onboard KAVACH timeslots and frequency channel pairs shall be approved by User Railway. Care should be taken so as to not allocate adjacent time slots at the same station. The typical scheme is included in Annexure-C.

3.4.6. Station Master Operation cum Indication Panel

3.4.6.1. Following indications/ buttons/ buzzers shall be given in the Station Master's OCIP:

(a) Station Master's Key.

(b) LCD display (Minimum 4 Line x 20 chars).

(c) SoS indication.

(d) Health indication.

(e) Audio Buzzer.

(f) Three Push Buttons (Common, Generation and Cancellation) to generate and cancel the SoS.

(g) Electromechanical non-resettable 6-digit counter for recording SoS operation.

(h) TSR acknowledge button.

3.4.6.2. Signalling cable shall be used for button, counter, and power supply. CAT-6 armoured cables or OFC shall be used for communication

3.4.6.3. Health Indication shall be flashing green if Stationary KAVACH is healthy and it shall be made blank when Stationary KAVACH is not healthy and Red indication shall glow.

3.4.6.4. The requirements are detailed in **Annexure-Q.**

3.4.7. Remote Interface Unit (RIU)

3.4.7.1. Remote Interface Unit (RIU) shall be used where remote signalling functions are required to be fetched to a nearby Stationary KAVACH.

3.4.7.2. Remote Interface Unit (RIU) shall have provision for interfacing with signalling inputs in a fail-safe manner.

3.4.7.3. OFC shall be the only as the media for connecting the various RIUs to the Stationary KAVACH unit. The maximum number of dark fibres shall be four Single mode OFC per ring. Primary and Secondary rings shall be used for

Indian Railways Application.

3.4.7.4. The OFC ring network shall be formed to increase availability of the network. RIU shall be connected with two modems each with two ports. The typical scheme is included in Annexure-J.

3.4.7.5. The vital communication protocol shall be compliant to CENELEC normative EN-50159 (closed communication system).

3.4.7.6. A single RIU shall be capable of communicating with two adjacent RIU units so that the operations are not affected in case of communication link failure on one side only.

3.4.7.7. A single RIU shall be capable of handling at least 32 field inputs.

3.4.7.8. RIU shall consist of Vital Input modules with minimum Two-Out-Of-Two architecture. Each vital input module shall have independent read channels to read the status of each input. If the same state is not detected after the timeout (6 Seconds-Configurable) by any channel, a comparison of the obtained input state between input channels shall be performed by vital computer. Unless same status is detected in the same input through various input channels for the definite time, corresponding input state will not be considered as safe for further processing.

3.4.8. **Tower and Antenna**

3.4.8.1. Coaxial cable suitable for UHF applications with 50Ω characteristic impedance and losses within 1dB / 10m is to be used.

3.4.8.2. The Stationary communication system for station/IBS/mid-section interlocked Gate unit shall provide communication coverage at least in the communication mandatory area for the Stationary KAVACH.

3.4.8.3. The antenna cable & antenna shall be suitable to provide a minimum range of communication. The antenna shall be tuned to minimum frequency of 425 to 430 Mhz preferably with a minimum gain of 5 dBi.

3.4.8.4. Throughout the Communication Mandatory area, the Radio Signal Strength shall have a minimum fade margin of 30 dB above receiver sensitivity. If this signal strength is not achievable, then additional Stationary KAVACH/Tower shall be planned in the block section.

3.4.8.5. The maximum length of the permanent dark zone for which radio communication interruption is permitted at single stretch is 100m. As far as possible and such dark zone shall not be in the vicinity of a stop signal.

3.4.8.6. The communication need not be mandatory in tunnels except for those which are o then immediate approach (distance corresponding to 30 seconds at the highest permissible speed of any KAVACH equipped train at that spot) of a signal.

3.4.8.7. **Requirements of Radio Holes: (F)**

(a) All efforts shall be made to avoid Radio Holes.

(b) There shall not be any stop signal or track section boundary inside a radio hole. If this is unavoidable, Movement Authority shall be extended only up to the first approaching stop signal in the radio hole area. The other signals are to be crossed by the Loco Pilot in SR Mode.

(c) The radio hole shall be indicated in the RFID layout and shall also reflect in KAVACH Control Table.

(d) When Radio hole information is received from Stationary KAVACH, Onboard KAVACH shall display "Approaching Radio Hole in XXXXm" in the context message window of LP-OCIP (DMI). The Radio Hole Symbol shall be displayed in the Radio Signal strength window

(e) When Radio hole is there, Onboard KAVACH can continue in FS mode until approaching signal foot, beyond it can continue in SR mode.

(f) Stationary KAVACH shall deregister the Onboard after deregistration timeout.

(g) Actual Radio hole distance + 10 seconds (default, 6-12 seconds) x current speed (Kmph) shall be calculated as the radio hole distance by Onboard KAVACH.

(h) Upon resumption of radio communication, a new session is to be established. The Loco Pilot may continue any valid movement authority.

3.4.8.8. Design of the Stationary KAVACH tower and foundation not being part of this Specification, Purchaser railway shall take the following actions:

(a) Purchaser railway shall decide the type of Tower - Whether Lattice type or Concrete or monopole type or any other type.

(b) Purchaser railway shall decide height of the tower. Normally tower height shall be 40 meters above the ground level. The height of the tower can be reduced as per requirement of the site by the purchaser Railway.

(c) In case of the tower on top of building, the typical height shall be on 4 m on top of the building.

(d) Purchaser railway to ensure that basis of design of the tower and foundation shall include wind velocity, soil bearing capacity, tower site, ladder, platform, staging, aviation lamp and earthing arrangement.

(e) Design of the tower and its foundation shall have acceptance of purchaser railway prior to commencement of their execution work.

(f) Required WPC, SACFA and any other regulatory authority clearances shall be obtained by Purchaser Railway.

3.5. Onboard KAVACH unit

3.5.1. **The Onboard KAVACH unit shall be comprised of**

3.5.1.1. Onboard KAVACH Vital Computer.

3.5.1.2. Two RFID readers consisting of RFID Reader Antenna in hot standby.

3.5.1.3. Onboard KAVACH Radio Unit consisting of two Radio Modems in hot standby with separate cables and antennae for each radio or LTE router unit (02Nos) as prescribed by the purchaser.

3.5.1.4. Two Driver Machine Interface (LP-OCIP (DMI)) for each locomotive or one LP-OCIP (DMI) for each Driving motor coach of EMU/DMU/MEMU/DEMU/Trainset etc.

3.5.1.5. Brake Interface Unit (BIU), where required.

3.5.1.6. The system shall be interfaced with LTE (O) and BTM Reader (O). Currently, ETCS SRS 2.3.0d and 2.2.2 is in vogue on Indian Railways.

3.5.2. **Onboard KAVACH Vital Computer**

3.5.2.1. The Onboard KAVACH vital computer is a system that supervises the movement of the train to which it belongs, on the basis of information exchanged with Stationary KAVACH units and other Onboard KAVACH units. Vital Computer architecture shall be minimum 2 out of 2.

3.5.2.2. The onboard KAVACH vital computer shall have Real Time Clock synchronization facility with GNSS clock to synchronize with other KAVACH systems in hot standby manner.

3.5.2.3. Onboard KAVACH vital computer shall have provision for the following**:**

(a) To interface with train interface unit & brake interface unit.

(b) The data shall be recorded at three levels (See FRS).

(c) Two Direction sensing type Speed Sensor in each pulse generator shall be used to interface for direction determination, distance and speed measurement.

(d) To interface with two RFID readers to read RFID tags fitted to the track.

(e) To interface with the BTM reader to read Balise fitted to the track in TPWS sections. (Optional)

(f) To interface with two Driver Machine Interfaces (LP-OCIP (DMI)) consisting of display arrangement & buttons/ switches for operation.

(g) Two commercial GSM/LTE interfaces for connectivity with centralized Network Monitoring System and Key Management System. It should also be operable with LTE where LTE is provided.

(h) USB interface for downloading of log & other data for diagnostic pur-

poses.

3.5.2.4. Onboard KAVACH shall be suitable for use on AC/DC Traction, EMUs/DMUs/MEMUs/ Trainsets single or multi-headed electric/diesel locomotives/ banking locomotives. The onboard KAVACH unit shall be suitable for all types of electric and diesel locomotives, including all types of microprocessor-based locomotives and Locomotives wih Distributed Power Control System (DPCS)/ Distributed Power Wireless Control System (DPWCS) running fn Indian Railways.

3.5.2.5. The equipment shall work on DC supply source normally consisting of accumulator battery and or an auxiliary generator. The nominal and limits of voltage in which the equipment shall operate satisfactorily are as under.

Type of Locomotive	**Nominal Voltage**	**Limits of Voltage**
Diesel-Electric	72 Volts DC	50 to 90 Volts DC
Electric, EMUs, DEMUs, MEMUs, Train Set etc.,	110 Volts DC	78 to 136 Volts DC

3.5.2.6. Voltage fluctuations lying between 0.6 to 1.4 times of Nominal voltage and not exceeding 0.1 second shall not cause any deviation in the functioning of the unit (Clause 5.1.1.2 of IEC 60571:2012). Voltage fluctuations lying between 1.25 to 1.4 times of Nominal voltage and not exceeding 1 second shall not cause damage to the unit. The unit may not be fully functional during these fluctuations. (Clause 5.1.1.2 of IEC 60571:2012).

3.5.2.7. The onboard KAVACH unit shall be suitable for various types of braking systems of Diesel and Electric Locomotives/EMUs/MEMUs/ DEMUs/Trainsets. The type of loco or other self-propelled vehicle, braking system and inputs for the interface would be provided by the Purchaser for retro-fitment.

3.5.2.8. Electromechanical non-resettable 6-digit counters for the recording operation of the Loco unit to Isolation Mode, Trip/Override & SoS (transmit/receive) are to be provided. The installation scheme is included in Annexure-B.

3.5.2.9. Onboard KAVACH shall interface with Loco Cab controls to determine train direction. For retro-fitment, the Loco dependent details for an interface are to be provided by the Purchaser.

3.5.2.10. **Cables and Connectors**

(a) **Data Cables**: Fire Retardant STP (Shielded twisted Pair) CAT-6 Cable or Co-Axial Cable shall be compliant to IEC 60332-1, 60332-2 & 60332-3/ EN45545 for fire.

(b) **Power Supply Cables**: Shall meet RDSO specification ELRS /SPEC/ ELEC /0019 Rev 4 or latest.

(c) The Connectors provided shall be suitable for Rolling stock application of AMPHENOLI/PHOENIX/ALLIED/HARTING or any other approved make from Electric Loco/ PS&EMU/ Motive Power directorates

of RDSO.

(d) Ingress Protection for dust and water by providing gasket & sealing of cable entry/exit along with heavy duty industrial type lock and key. Lock and key & hinges shall be of Southco/EMKA/Dirak/Jin Tay make.

3.5.3. Onboard KAVACH Radio Unit (If UHF is used)

3.5.3.1. The Onboard KAVACH Radio Unit specifications shall be similar to the Stationary KAVACH radio unit.

3.5.3.2. It shall have provision to switch to another frequency channel, whenever required.

3.5.3.3. The Onboard KAVACH Antenna shall be tuned to minimum frequency of 425-430 Mhz preferably with a minimum gain of 3 dBi antenna.

3.5.3.4. The onboard KAVACH antenna shall be able to withstand air pressure when the loco is running at a speed of 250 kmph.

3.5.3.5. The outdoor cable for connecting Onboard KAVACH and GPS / GSM / UHF Antennae shall be waterproofs (Preferably IP-67) and flame retardant.

3.5.3.6. The Onboard KAVACH, when not allotted with any time slot, it shall start transmitting in one of the reserved time slots nominated for this purpose in frequency f0.

3.5.3.7. In Block sections, if communication is not required with Stationary KAVACH, Onboard KAVACH should transmit the access request message on f0 frequency in the portion of the frame cycle nominated for this purpose so that other nearby Onboard KAVACH can directly receive the messages.

3.5.3.8. The Onboard KAVACH shall transmit through alternative radio and receive on both the Radios simultaneously and discard the redundant packet of same sequence number. The sequence number shall be a combination of frame number, packet type, source ID, Destination ID as shown in below table.

Packet Type	**Possible combination**
Regular Radio Packet from Stations/Interlocked, LC Gate/IBS to Onboard KAVACH	Frame Number, Stationary KAVACH ID, Destination Loco ID
Access Authority Packet	Frame Number, Stationary KAVACH ID, Destination Loco ID
Additional emergency packet	Frame Num, Stationary KAVACH ID

Table: Possible combination for validating Sequence ID

3.5.4. RFID Reader

3.5.4.1. Each Onboard KAVACH unit shall have two RFID readers for getting the information from RFID tags fitted on the trackside in hot standby manner.

3.5.4.2. The RFID reader shall be as per following technical specifications:

(a) Suitable to be fitted underneath Locomotive body & shall be rugged enough to withstand vibrations.

(b) Suitable for reliable working at Train speed to 250 KMPH.

(c) Frequency of operation: 865-867 MHz

(d) Should meet EN 55022, Class B for Radio Frequency disturbances.

(e) Communication Protocol shall be: ISO-18000-6D

(f) Shall have minimum IP 65 protection, if the RFID reader is placed outside of the locomotive or IP 64 protection, if the RFID reader is placed inside the locomotive. However, IP 67 is preferable.

(g) Other requirements like environmental, climatic etc. as per RDSO/ SPN/144 or as per specification. In case of contradiction, the requirement as per specification will prevail.

(h) Under field operating conditions RFID reader antenna shall be able to read RFID tag from a vertical distance of 700mm (Max) from bottom of RFID reader antenna to the top of the rail level.

(i) The installation of RFID reader antenna would be done in such a manner so that the vertical distance from bottom of RFID reader antenna to the top of the rail level is 350mm ± 50mm. The lateral centre of RFID reader antenna shall be within ± 50mm of the track centre with antennae in the horizontal plane.

3.5.4.3. When an Onboard mounted RFID reader passes over RFID tags, RFID tag shall transmit the programmed data to the RFID reader. The horizontal range of RFID reader shall not be more than 750mm under field operating conditions.

3.5.4.4. The Onboard KAVACH shall calculate the location of the train between two RFID tags dynamically based on the distance travelled from last RFID tag through speed sensing arrangement.

3.5.4.5. The Onboard KAVACH shall act as per the information received from even one RFID tag out of duplicated tags. However, in such case, it shall log the missing RFID tag & transmit the same to NMS.

3.5.4.6. On registering, the Stationary KAVACH shall send all the expected RFID tags in the route. The Onboard KAVACH shall monitor the same. In case of single or duplicated missing tags, information shall be sent to the NMS. On not receiving any information from any RFID tag either due to both tags missing or due to any other reason, within the window limits of L_doubt over and L_doubt under, Tag missing indication shall be displayed on LP-OCIP (DMI). The tag missing information shall be sent to the NMS. However, the details of Tag read shall be stored in the event logger.

3.5.4.7. If the Onboard KAVACH reads the Exit RFID tag (non-KAVACH territory), it shall transit to 'Staff Responsible" mode and stop the radio communication with Stationary KAVACH after the complete train passed over the exit tag.

3.5.5. Loco Pilot's Operation-cum-indication panel (LP-OCIP)

3.5.5.1. Loco Pilot's Operation-cum-indication panel (LP-OCIP/DMI) shall consist of the suitable display arrangement and buttons/ switches for operation.

3.5.5.2. The following functions of LP-OCIP (DMI) shall be verified & validated to Safety Integrity Level (SIL-2) of CENELEC or equivalent international standards.

(a) Communication with Onboard KAVACH.

(b) Train configuration selected by the loco pilot.

(c) SOS operation by the loco pilot.

(d) Signal Aspect display

(e) Train length display

(f) Train configuration display

(g) The function in LP-OCIP (DMI) for displaying the context messages for Loco Pilot's attention.

(h) Display of all modes of loco operation

(i) Current speed

(j) Over speed

(k) Permissibled speed

(l) Target speed

(m) Section speed

(n) Movement Authority (MA)

(o) Target distance- (distance from approaching target of EOA / Turn Out / TSR/PSR/Collision /SoS).

3.5.5.3. LP-OCIP shall have minimum 12 soft keys (including 2 spare keys for future use), 4 navigations (Up/Down/Left/Right), Brightness Control Keys, Clear Key and Enter Key.

3.5.5.4. LP-OCIP shall have three push buttons, namely SoS, Common/ACK and Cancel.

3.5.5.5. The onboard KAVACH unit shall transmit SoS message, when SoS and

Common /ACK push buttons are pressed simultaneously.

3.5.5.6. The onboard KAVACH unit shall stop the transmission of SoS message, when Common/ACK push button and Cancel push button are pressed simultaneously.

3.5.5.7. Common/ ACK push button shall be used for Loco pilot acknowledgement, such as inhibiting the unusual stoppage message in block section, when transiting from Full supervision mode to Onsight mode/Limited supervision mode/Staff Responsible mode, Onsight mode to Limited supervision mode/Staff Responsible mode & Limited supervision mode to Staff Responsible mode.

3.5.5.8. LP-OCIP shall have two indications (both in bi-color) to display system health status and SoS status.

3.5.5.9. The Onboard KAVACH unit shall display the System health status as Green as long a thes system is healthy otherwise it shall be displayed as Red.

3.5.5.10. The Onboard KAVACH unit shall display the SoS indication as Green as long as no SoS (Transmit/Receive). It shall be displayed as Red, if SoS is received or transmitted.

3.5.5.11. LP-OCIP/DMI shall have a two-position switch i.e. to change from/to leading/nonleading mode. This switch is not required for a self-propelled vehicle.

3.5.5.12. Loco Pilot's Operation-cum-indication panel (LP-OCIP/DMI) shall have an electronic buzzer to generate audio alerts / alarms.

3.5.6. Brake Interface Unit (BIU)

3.5.6.1. The KAVACH shall be capable of giving following three levels of brake commands for train braking:

(a) Normal Brake (NB) command (not applicable for EMUs and other self-propelled vehicles)

(b) Full-Service Brake (FSB) command

(c) Emergency Brake (EB) command

3.5.6.2. The Onboard KAVACH shall also give additional command, i.e. Loco Brake command in conjunction with Normal Brake / Full-Service Brake / Emergency Brake, to develop Brake Cylinder pressure up to maximum value corresponding to loco independent brake, if the train is identified as a Light Engine.

3.5.6.3. The Brake Interface Unit (BIU) features:

(a) BIU shall apply Normal, Full service & Emergency brakes of locomotives respectively based on the type of brake command received from the

Onboard KAVACH unit. In addition to these brakes, it shall also apply Loco brake, if Loco Brake command is generated by Onboard KA-VACH.

(b) BIU shall not reduce the braking level initiated by the Loco Pilot. However, Onboard KAVACH can increase the level of braking over loco pilot initiated braking as and when need arises. It shall be possible to increase the extent of the brake level (initiated by Loco unit) by the loco pilot, if he desires so.

(c) BIU shall not modify the existing braking characteristics of the locomotive (single/Multi Unit/Banking) as well as other self-propelled vehicles treated as trainers.

(d) It shall automatically cut off traction/ regression at the instance of the Onboard KAVACH unit-initiated braking & traction sha thell be enabled only after withdrawal of Onboard KAVACH unit brake commands. Loco pilot has to physically operate the traction notch subsequently, to power the train.

(e) The Onboard KAVACH hardware design shall have feasibility for interfacing to BIU either through potential free contacts or through DC voltage or current loop or Serial Communication ports as specified by Purchaser. Purchaser needs to provide interface details.

(f) The Onboard KAVACH shall have feasibility for interfacing with Universal BIUas per relevant Motive Power Directorate Specification No MP.0.01.00.31 (Rev .02) Or latest. It shall have feasibility to interface with E-70, CCB and Electro-Pneumatic (EP) or any other braking system used in Indian Railway.

3.5.6.4. **Brake Characteristics**

(a) The Onboard KAVACH shall have provision for acquiring the braking characteristics through LP-OCIP (DMI) as per the selections made by Loco Pilot at the start of the mission or whenever there is change in train consists.

(b) On formation of a new train, the Onboard KAVACH unit shall prompt Loco Pilot for selecting the train configuration.

(c) The brake characteristics shall be such that in the event of perceived danger, the Onboard KAVACH unit shall be able to stop train short of safe distance or control the speed to the desired value before target. This distance should be possible to be configured during installation with nominal values as 300m (Configurable) for Rear-end Collision prevention, stop immediately on detection or a distance of 5000m (Configurable) whichever is less for Head on Collision prevention and short of Signal at Danger in case of SPAD prevention.

(d) It shall be possible to test the working of all brake valves of Brake Interface Unit (BIU) in a Stationary condition of the train by pressing Manual

Brake Test (MBT) button by the Loco Pilot.

(e) The MBT shall be possible to be initiated through a soft key on the LP-OCIP.

(f) The braking logic of the Onboard KAVACH unit shall be so intelligent that based on the brake characteristics of the train and depending upon the speed of the train, average gradient of the location & the target, Onboard KAVACH shall decide which type(s) of brake and when to be applied to stop the train short of safe distance or control the speed to desired value before target.

(g) In case the distance available between the train and target at the instance of perceived danger is not adequate, the Onboard KAVACH unit shall apply maximum brake to reduce the speed of the train as much as possible under the circumstances so that impact can be minimized.

3.5.7. **Isolation of Onboard KAVACH**

(a) The design of the Onboard KAVACH unit equipment shall be such that its brake interface unit can be isolated by the Loco Pilot as and when required.

(b) The isolation switch and other switches along with the counters shall be provided in a uniform manner in an encapsulated box at an identifiable place within Loco.

(c) The isolation of KAVACH from brake interface shall be communicated to the Network Monitoring System through commercial GSM/LTE.

(d) The isolation mechanism must be protected and isolation of braking interface must be recorded through the counter provided.

(e) The message about such isolation shall be displayed on Loco Pilot's OCIP to inform Loco Pilot about the isolation of KAVACH.

(f) Isolation of KAVACH/ BIU shall not affect existing brake characteristics of the loco/other self-propelled vehicles.

(g) Traction cut off feature through KAVACH shall also be isolated under such events.

3.5.7.1. The system design shall be such that in case of Stop Signals at ON / End of Authority:

(a) The train shall stop as close as possible to the signal at ON.

(b) The train stops within 5m on the approach of the signal for 90% of the cases.

(c) The train stops within 30 m on the approach of the signal for 98% of the cases.

(d) On detection of incident of stop signal subsequently put back to ON, the train stops with Train Trip through application of Emergency Brakes at least after crossing the Signal if not earlier.

3.5.7.2. The speed and distance monitoring of the on-board system can only assure this when the necessary conditions are fulfilled.

(a) Brake system of the train functions as specified.

(b) Wheel/rail adhesion is sufficient for the required safe deceleration.

(c) Brake characteristics (and other train related inputs) are correctly entered into the Onboard system.

3.5.7.3. Train type/configuration shall be selected through LP-OCIP to acquire the braking characteristics of the train.

3.5.7.4. The braking algorithm used shall be suitable to the application environment, including all types of rolling stock and section.

3.5.7.5. The system should be designed in such a way to detect slip or slide and mitigate their effect to keep the error in speed (5kmph or 5%, whichever is lower) and distance (±50 m) within the limits specified. If the wheel is slipping continuously for more than 90 seconds (default, Min: 60, Max 180 seconds), Onboard KAVACH shall transit to SR Mode and prompt for acknowledgement. It shall continue to do so, till the condition of wheel slip/slide is removed. No braking to be applied if acknowledgement is received from Loco Pilot.

4. Radio Communication Security and Key Management System

4.1. Communication technique based on AES-128 security coding shall be used for communication between Stationary and Onboard KAVACH Units to comply with EN-50159.

4.2. Radio Communication shall use cryptographic techniques with security keys to transfer messages between Onboard KAVACH and Stationary KAVACH units.

4.3. When the Stationary KAVACH unit is communicating the safety related data with Onboard KAVACH, it shall verify that communication is established with an authorized Onboard KAVACH unit and vice versa. Consequently, the authenticity and integrity of any information exchanged between Onboard KAVACH and Stationary KAVACH unit shall also be verified.

4.4. In order to ensure complete protection, the above procedure shall take place each time the Onboard KAVACH and Stationary KAVACH unit effectively start a new communication session between them.

4.5. After each successful Identification & Authentication (I&A) dialogue, the data shall be protected using a Message Authentication Code (MAC).

4.6. All messages in time slots reserved for emergency messages and Loco-to-Loco direct communication, are not subjected to the aforesaid procedure of I&A dialogue due to the nature of the information conveyed by such messages.

4.7. **Key Definition & Type of Keys:**

4.7.1. The key is defined as a sequence of 128 bits. The following table summarizes the key types and usage of each type of key.

Key Name	Purpose Origin
K_A	Authentication key used for session key derivation in order to establish a safe connection between Stationary & Onboard KAVACH units. This key will be communicated by Key Management System (KMS) to all Onboard KAVACH, Stationary KAVACH and TSRMS units, and it will have a valid time period for its usage. It can be changed from time to time. Key Management System would be centralized for Indian Railways.
K_S	The session key is used for protection of data transfer between KAVACH sub units. This key will be computed by Onboard KAVACH, Stationary KAVACH, Adjacent Stationary KAVACH and TSRMS units at the time of establishment of communication session between them.

4.7.2. **Authentication Key (K_A):** Authentication Keys are a group of 2 keys. Authentication shall be identical for a group of Stationary KAVACH and Onboard KAVACH pairs, adjacent Stationary KAVACH pair and TSRMS and Stationary KAVACH pairs. This group of keys shall be stored in separate memory. The following table shows one set of Authentication keys for example.

Memory Location	Key Name	Key Code in Hex
0	Authentication Key 1	0x1234567890ABCDEF 1234567890ABCDEF
1	Authentication Key 2	0x567890ABCDEF 123456781234CDEF1234

4.7.3. **Derivation of Authentication Key K_A, for a pair of Stationary KAVACH and Onboard KAVACH**

4.7.3.1. Authentication key shall be selected based on the below formula:

Example:

Stationary KAVACH ID = 00501,

Onboard KAVACH ID = 27854

((00501 + 27854) mod2) = 1

4.7.3.2. For the pair of Stationary KAVACH (00501) and Onboard KAVACH (27854) the Authentication Key is stored in the first memory location -1 (i.e. Authentication Key 2).

4.7.4. **Derivation of Authentication Key K_A, for a pair of Stationary KAVACH and Stationary KAVACH**

4.7.4.1. The Primary partner shall generate a unique random number (two bytes) for each adjacent station and send it to secondary partner, when a new connection is required to be established. The Stationary KAVACH with higher unique ID shall be primary partner.

4.7.4.2. The Secondary partner shall generate a unique random number (two bytes) for each adjacent station and send it to the primary partner when a primary partner requests a new connection.

4.7.4.3. Authentication key will be selected based on the below formula:

Example:
Primary Stationary random number = 10502,

Secondary Stationary random number = 27854 ((10502 + 27854) mod2) = 0

For the pair of Primary Stationary KAVACH (10502) and Secondary Stationary KAVACH (27854) the Authentication Key is stored in the Zeroth memory location (i.e. Authentication Key 1).

4.7.5. **Derivation of Authentication Key K_A, for a pair of TSRMS and Stationary KAVACH**

4.7.5.1. The TSRMS shall generate a unique random number (two bytes) and send it for each Stationary KAVACH, when a new connection is required to be established. The TSRMS is primary partner and the Stationary KAVACH is secondary partner.

4.7.5.2. The Stationary KAVACH shall generate a unique random number (two bytes) and send it to the TSRMS when the TSRMS requests a new connection.

4.7.5.3. Authentication key will be selected based on the below formula.

4.7.5.4. Example:

TSRMS random number = 10501,

Stationary KAVACH random number = 27854

((10501 + 27854) mod2) = 1

4.7.5.5. For the pair of TSRMS (10501) and Secondary Stationary KAVACH (27854) the Authentication Key is stored in the Zeroth memory location (i.e. Authentication Key 1).

4.7.6. **Transmission of Authentication Key:**

4.7.6.1. Key management system (KMS) shall generate sets of Authentication Keys with a valid time period for each set. The following table illustrates the structure of Authentication Keys.

4.7.6.2. **Authentication Keys Unique ID:** Four Bytes (KMS will generate Unique ID at the time of generation of Authentication keys).

Number of Key Sets One Byte (Value: 4 in this example)

Authentication Keys	Set Name	Beginning Time	End Time
Authentication Key 1 to Authentication Key 2	Set 1	HH DD MM YY	HH DD MM YY
Authentication Key 1 to Authentication Key 2	Set 2	HH DD MM YY	HH DD MM YY
Authentication Key 1 to Authentication Key 2	Set 3	HH DD MM YY	HH DD MM YY
Authentication Key 1 to Authentication Key 2	Set 4	HH DD MM YY	HH DD MM YY

4.7.6.3. The Key validity period shall be defined by the beginning date followed by the end date of the validity period for each set (in HH DD MM YY format e.g. 15 01 01 17 means 03.00 PM on 1st January, 2017 in Hex format, in 24 hour's format). Indian Standard Time shall be used in the Authentication Keys validity period.

4.7.6.4. KMS shall generate Unique ID at the time of generation of Authentication Keys. This Unique ID shall be used to know the latest Authentication Keys available with the KMS.

4.7.6.5. KMS shall maintain 30 sets of Authentication Keys. However, the total time duration of all the Authentication Key set shall not be less than 120 days. The KMS shall add the required number of keys when the total time duration of key sets available falls to less than 60 days. However, the previous remaining keys shall not be changed during this addition of keys.

4.7.6.6. KAVACH Sub System (Stationary KAVACH, Onboard KAVACH and TSRMS Management System) shall send the Authentication Query message to KMS every 6 hours to detect whether a new set of Authentication keys is generated or not.

4.7.6.7. If KAVACH sub-systems find that new set of Authentication keys is available at KMS, it shall send a first request to Key Management System at randomized time over next 2 hours.

4.7.6.8. Randomized request shall be as follows:

Request time in a day minute = (KAVACH Subsystem ID) mod (2Hr * 60 min).

Example: For Loco ID 27854, request time = 27854 mod 120.

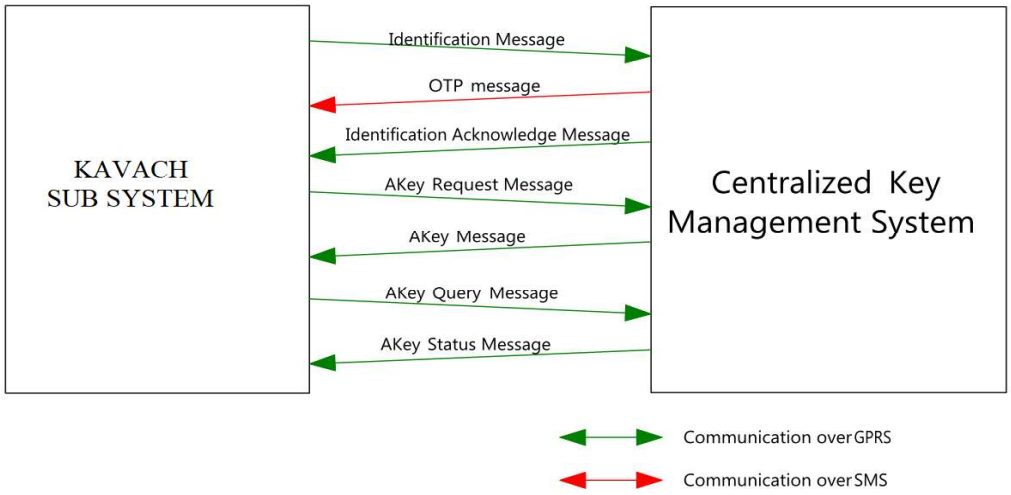
The Loco 27854 shall send its first request at 14 minutes.

(a) If the first request is not successful, it shall send request for every 5 minutes until it receives the information from the Key Management System.

(b) KMS shall send Authentication keys to KAVACH subsystem when it receives the request for same.

(c) KMS shall verify the authenticity of the request before transmitting the Authentication Keys.

(d) KMS shall have the database to store the mobile numbers of all the KAVACH subsystem units. These mobile numbers shall be used to verify the authenticity of Authentication Keys request. These mobile numbers will be fed online through a secured transaction by the RDSO.



4.7.7. Process flow for authentication key transmission

4.7.7.1. KMS is responsible for distribution of authentication keys to KAVACH systems for radio security.

4.7.7.2. KMS shall have a registered URL or a constant public domain IP for packet reception. All the KAVACH systems shall use GPRS or commercial LTE to communicate with KMS. SIM cards for this purpose shall be provided by purchaser Railway.

4.7.7.3. For LTE, the Private Key certificate shall be installed on Stationary and Onboard KAVACH systems. This shall be stored in non-volatile memory. (Optional)

4.7.7.4. KMS shall use OTP (One Time Password) over SMS technique, through GSM, to authenticate the KAVACH subsystems before sharing the Authentication Keys. KMS shall send an OTP (SMS) to the registered mobile number after receipt of Identification message.

4.7.7.5. KAVACH subsystems shall verify currently used Authentication Key set in the KMS by validating the Key set ID received in the Authentication Request message with the current Authentication set ID in the KMS.

4.7.7.6. KAVACH subsystem shall send and identification message to KMS at the

interval of every five minutes when no key is available with them.

4.7.7.7. When the request is received by the KMS for Authentication Keys, it shall send OTP to the respective KAVACH unit through SMS. KMS shall also send Identification acknowledgment message, to update the status of SMS (OTP).

4.7.7.8. KMS shall send the Authentication key message to KAVACH entities, if it receives the expected OTP.

4.7.7.9. KAVACH units shall store the Authentication Keys in non-volatile memory.

4.7.8. Packet structure between KAVACH entities and KMS

4.7.8.1. Following tables shows the packet structure to be used for communication between KMS and KAVACH units for the purpose of transmission of Authentication Keys. The packet transmission protocol shall be in UDP.

4.7.8.2. **Identification Message, 20 bytes** (KAVACH to KMS)

Field Descriptor	**Number of bytes**	**Remarks**
Start of Frame	2	0xA5, 0xC3
Message Type	1	0x90
Message Length	2	Message length in terms of bytes from Date field in CRC field (inclusive of both)
Date	3	DD: MM: YY in Hex Indian Standard Time (IST) Note: IST shall be configurable parameter.
Time	3	HH: MM: SS in Hex (IST)
Type of KAVACH unit	1	0x11 – Stationary KAVACH 0x22 – Onboard KAVACH 0x33 – TSRMS
KAVACH Unit ID	3	Stationary KAVACH ID in Hex, Onboard KAVACH ID in Hex, TSRMS ID in Hex
SIM ID	1	0x01 – Primary 0x02 – Secondary
32 Bit CCITT CRC	4	Packet CRC from message to type to SIM ID

4.7.8.3. **Identification Acknowledge Message**, 20 bytes (KMS to KAVACH)

Field Descriptor	**Number of bytes**	**Remarks**
Start of Frame	2	0xA5, 0xC3
Message Type	1	0x91
Message Length	2	Message length in terms of bytes from Date field in CRC field (inclusive of both)
Date	3	DD: MM: YY in Hex (IST)
Time	3	HH: MM: SS in Hex (IST)

Type of KAVACH unit	1	0x11 – Stationary KAVACH 0x22 – Onboard KAVACH 0X33 -TSRMS ID
KAVACH Unit ID	3	Stationary KAVACH ID in Hex, Onboard KAVACH ID in Hex, TSRMS ID in Hex
Acknowledge Status	1	0x01 – OTP sent 0x02 – KAVACH ID not registered 0x03 – Message delivery failed
32 Bit CCITT CRC	4	Packet CRC from message to type to Ack Status

4.7.8.4. **Authentication Key Request Message**, 24 bytes (**KAVACH to KMS**)

Field Descriptor	**Number of bytes**	**Remarks**
Start of Frame	2	0xA5, 0xC3
Message Type	1	0x92
Message Length	2	Message length in terms of bytes from Date field in CRC field (inclusive of both)
Date	3	DD: MM: YY (in Hex) (IST)
Time	3	HH: MM: SS (in Hex) (IST)
Type of KAVACH unit	1	0x11 – Stationary KAVACH 0x22 – Onboard KAVACH 0x33- TSRMS ID
KAVACH Unit ID	3	Stationary KAVACH ID in Hex Onboard KAVACH ID in Hex TSRMS ID in Hex
SIM ID	1	0x01 – Primary 0x02 – Secondary
OTP	4	OTP received in SMS, 4 character Alpha Numeric Code
32 Bit CCITT CRC	4	Packet CRC from message to type to OTP

4.7.8.5. **Authentication Key Message (KMS to KAVACH)**

Field Descriptor	**Number of bytes**	**Remarks**
Start of Frame	2	0xA5, 0xC3
Message Type	1	0x93
Message Length	2	Message length in terms of bytes from Date field in CRC field (inclusive of both)
Date	3	DD: MM: YY (in Hex) (IST)
Time	3	HH: MM: SS (in Hex) (IST)
Type of KAVACH unit	1	0x11 – Stationary KAVACH 0x22 – Onboard KAVACH 0x33 - TSRMS ID
KAVACH Unit ID	3	Stationary KAVACH ID in Hex, Onboard KAVACH ID in Hex, TSRMS ID in Hex

Key set Unique ID	4	Unique ID of Key Set
Number of Key Sets (n)	1	0x1E
Key set – x validity start time	4	HH DD MM YY (in Hex)
Key set – x validity end time	4	HH DD MM YY (in Hex)
Key set – x	16*2	2 keys, Each key size of 16 bytes
32 Bit CCITT CRC	4	Packet CRC from message to type to Key set –x

In above table highlighted fields will be repeated based on the number of Key sets.

4.7.8.6. **Authentication Query Message, 19 bytes (KAVACH to KMS)**

Field Descriptor	**Number of bytes**	**Remarks**
Start of Frame	2	0xA5, 0xC3
Message Type	1	0x94
Message Length	2	Message length in terms of bytes from Date field in CRC field (inclusive of both)
Date	3	DD: MM: YY (in Hex) (IST)
Time	3	HH: MM: SS (in Hex) (IST)
Type of KAVACH unit	1	0x11 – Stationary KAVACH 0x22 – Onboard KAVACH 0x33 –TSRMS ID
KAVACH Unit ID	3	Stationary KAVACH ID in Hex, Onboard KAVACH ID in Hex, TSRMS ID in Hex
32 Bit CCITT CRC	4	Packet CRC from message type to KAVACH Unit ID

4.7.8.7. **Authentication Key Status Message, 23 bytes (KMS to KAVACH)**

Field Descriptor	**Number of bytes**	**Remarks**
Start of Frame	2	0xA5, 0xC3
Message Type	1	0x95
Message Length	2	Message length in terms of bytes from Date field in CRC field (inclusive of both)
Date	3	DD: MM: YY (in Hex) (IST)
Time	3	HH: MM: SS (in Hex) (IST)
Type of KAVACH unit	1	0x11 – Stationary KAVACH 0x22 – Onboard KAVACH 0x33- TSRMS ID
KAVACH Unit ID	3	Stationary KAVACH ID in Hex, Onboard KAVACH ID in Hex, TSRMS ID in Hex
Key Set Unique ID	4	Unique ID of Key Set
32 Bit CCITT CRC	4	Packet CRC from message to type to Key Set Unique ID

4.7.8.8. **Format for One Time Password (OTP) in SMS**

OTP for <S/L/T><KAVACH_ID>:<CODE> by RCIL

Note: The message template shall be configurable.

4.7.8.9. **Computation of Session Key (K_S):**

Random numbers, R_L and R_S, will be 16-bit in length, and it shall be generated at the time of establishment of a communication session between the Stationary KAVACH unit and Onboard KAVACH/ TSRMS or adjacent Stationary KAVACH. To compute Session Key (K_S), three parameters shall be required, which are Random Number R_S (Stationary KAVACH), Random Number R_L (Onboard KAVACH) /TSRMS/ or adjacent Stationary KAVACH and the Authentication Key (K_A).

$R_1 = (R_S | R_L) | (R_S | R_L)$
$R_2 = (R_L | R_S) | (R_L | R_S)$
$R = (R_1 | R_2)$
$K_S = AES (K_A, R)$
Where '|' means a concatenation operator

Example:

The Loco Random Number (R_L) is: 0x526A
The Station Random Number (R_S) is: 0x5694
The R_1 is: 94, 56,6A, 52, 94, 56, 6A, 52,
The R_2 is: 6A, 52, 94, 56, 6A, 52, 94, 56
The Random Number R is: 94, 56,6A, 52, 94, 56, 6A, 52, 6A, 52, 94, 56, 6A, 52, 94, 56
The Authentication Key is: 75, 46, 20,67,6E,75,4B,20,79,6D, 20,73,74,61,68,54
The Session Key in Hex is: 18,48,2C,7E,5A, A2, 33,05,71,38,68, A5, 06, AB, 4F,15

4.7.8.10. Onboard KAVACH shall generate a unique two-byte random number and send it in Access Request Packet.

4.7.8.11. On receipt of the Access Request Packet, Stationary KAVACH shall generate another unique two-byte random number and send it in Access Authority Packet.

4.7.8.12. **Generic Message Authentication Calculation (CBC-MAC):**

To calculate the CBC-MAC (**Cipher Block Chaining Message Authentication Code)** for message "m", the length in bits of the message must be a multiple of 128. If the length of a message "m" in bits is not a multiple of 128, padding is to be performed prior to the computation of the CBC-MAC. Zero bits as needed are to be added at the end of the message "m" to obtain a multiple of 128 bits. The padding data "p" is used for CBC-MAC calculation only. It does not become part of the message.

The CBC-MAC (K, X) function using a secret authentication and the value X = m | p is defined as follows:

Let X be constituted by the 128-bit blocks X_1 | X_2 |... | X_q. Let AES (K_S, X) be a block cipher function, single AES in CBC mode, enciphering the data string X using the key K_S. Then, CBC-MAC is derived by the following iteration:

Assume a message m (144 bits, 18 octets) with the following structure in hex notation:

B3,2A,B7,F0,21,04,09,D4,90,41,1A,80,CC,16,08,2B,4A,04

Because it is not a multiple of 128 bits, "14 Zero octet" must be padded at the end of data before MAC calculation as follows:

B3,2A,B7,F0,21,04,09,D4,90,41,1A,80,CC,16,08,2B,4A,04,00,00,00,00,00,00,00,00,00,00,00,00,00,00

The MAC calculation requires a 128-bit Session Key K_S, generated from K_A during session establishment. This example assumes that K_S as generated above.

The number of times MAC Loop to be run is: 2

The MAC Code is: C0, A3, CC, FE

The CRC 32 bit is: B9, 3E, E6, 0A

The final data is:
B3,2A,B7,F0,21,04,09,D4,90,41,1A,80,CC,16,08,2B,4A,04, C0, A3, CC, FE, B9, 3E, E6, 0A

4.7.8.13. **Cipher Block Chaining Message Authentication Code (CBC- MAC) Application:**

This CBC-MAC will be included as part of the message before transmitting to the other system. On reception of this message, receiver unit computes the CBC-MAC for the received message and checks against the one received in the message. If the comparison is successful, message will be used for processing. Otherwise, the message will be ignored and an error will be generated.

4.7.8.14. **Security considerations for** KAVACH **Data Packets:**

KAVACH subsystem data packets will be in multiple of bytes.

Example:

If message length is 118 bits, it should append 2 bits in the packet, thus it becomes 120 bits (15 bytes) over the Air or channel. To compute a CBC-

MAC, one more byte will be padded to make it as 128-bits. This byte will not be part of message transmission Over-The-Air or channel.

Kavach subsystem will verify the CBC-MAC code for every message before processing.

4.7.8.15. **Process Flow for Onboard KAVACH Registration:**

(a) On entering Communication Mandathe tory area in vicinity of Stationary KAVA theCH territory, Onboard KAVACH unit generates Random number R_L and sends the Access Request Packet to Stationary KAVACH system in "f_0" frequency.

(b) On reception of Access Request Packet from Onboard KAVACH Unit, Stationary KAVACH unit generates its own Random Number (R_S) and computes the session key K_S and transmits the Access Authority Packet in f_0 frequency with CBC-MAC code. The access Authority message contains frequency channel, Tim slot and Random Number R_S.

(c) The onboard KAVACH unit receives the Access Authority Packet and compute the session key K_S. The CBC-MAC will be computed for the Access Authority Packet and verify with received CBC-MAC. If CBC-MAC is successful, Onboard KAVACH starts communicating the Onboard Regular Packet.

(d) Further, Onboard KAVACH shall continue transmission of Access Request Packet if it is in the block section.

(e) In station section, if the Onboard is registered with Stationary KAVACH and continuous receipt of the regular packet, Onboard KAVACH shall stop sending Access Request Packet in f_0.

(f) The Stationary KAVACH shall send its regular packet and the communication with the registered Onboard KAVACH shall continue till the end of Stationary KAVACH communication mandatory area.

(g) When Stationary KAVACH receives the Onboard Regular Packet, it stops communicating the Access Authority message and initiates the Stationary regular packet & other packet transmission.

(h) Further, Stationary KAVACH and Onboard KAVACH units verify the CBC-MAC code for every message before processing.

4.7.8.16. **Process Flow for Stationary entity KAVACH authentication:**

(a) The primary partner shall send its ID and the random number in "command PDI version check" packet while requesting for the connection with the Stationary KAVACH (Secondary Partner)

(b) The secondary partner shall generate its random number after receiving the request.

(c) The secondary partner shall generate MAC code based on random numbers.

(d) The secondary partners send its random number and MAC code in response to request received. The primary partner shall verify the received MAC in "Message PDI version check" packet.

(e) The primary partner after receipt of valid MAC, it shall start communicating with the secondary partner.

(f) The session Key derived from this session shall be updated automatically on every update of Authentication key.

(g) The primary partner is TSRMS and Stationary KAVACH is secondary partner.

(h) In Stationary KAVACH to adjacent Stationary KAVACH communication, anyone can e thbe primary partner (configured in Stationary KAVACH data base).

(i) All KAVACH subsystems shall automatically update their session key when there is a change in Authentication Keys due to expiry of time validity or due to changse in input key set from user Railways.

4.7.9. **CRC polynomial & Calculation Algorithm**

(a) **CCITT-32 BIT Polynomial**

Polynomial: $x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$

Width: 32 bits

Truncated Polynomial: 0x04C11DB7

Initial Remainder: 0x00000000

Final Xor Value: 0x00000000

Input: Reflected

Result: Reflected

Sample Data:

0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08, 0x09

CCITT-32 Value: 0xA6E6BF30

(b) **32 bit CCITT CRC Calculation Algorithm**

Const unsigned int crc32_tbl {

00000000, 77073096, EE0E612C, 990951BA, 076DC419, 706AF48F, E963A535, 9E6495A3, 0EDB8832, 79DCB8A4, E0D5E91E, 97D2D988, 09B64C2B, 7EB17CBD, E7B82D07, 90BF1D91, 1DB71064, 6AB020F2, F3B97148, 84BE41DE, 1ADAD47D , 6DDDE4EB, F4D4B551, 83D385C7, 136C9856, 646BA8C0, FD62F97A, 8A65C9EC, 14015C4F,

63066CD9, FA0F3D63, 8D080DF5, 3B6E20C8, 4C69105E, D56041E4, A2677172, 3C03E4D1, 4B04D447, D20D85FD, A50AB56B, 35B5A8FA, 42B2986C, DBBBC9D6, ACBCF940, 32D86CE3, 45DF5C75, DCD60DCF, ABD13D59, 26D930AC, 51DE003A, C8D75180, BFD06116, 21B4F4B5, 56B3C423, CFBA9599, B8BDA50F, 2802B89E, 5F058808, C60CD9B2, B10BE924, 2F6F7C87, 58684C11, C1611DAB, B6662D3D, 76DC4190, 01DB7106, 98D220BC, EFD5102A, 71B18589, 06B6B51F, 9FBFE4A5, E8B8D433, 7807C9A2, 0F00F934, 9609A88E, E10E9818, 7F6A0DBB, 086D3D2D, 91646C97, E6635C01, 6B6B51F4, 1C6C6162, 856530D8, F262004E, 6C0695ED, 1B01A57B, 8208F4C1, F50FC457, 65B0D9C6, 12B7E950, 8BBEB8EA, FCB9887C, 62DD1DDF, 15DA2D49, 8CD37CF3, FBD44C65, 4DB26158, 3AB551CE, A3BC0074, D4BB30E2, 4ADFA541, 3DD895D7, A4D1C46D, D3D6F4FB, 4369E96A, 346ED9FC, AD678846, DA60B8D0, 44042D73, 33031DE5, AA0A4C5F, DD0D7CC9, 5005713C, 270241AA , BE0B1010, C90C2086, 5768B525, 206F85B3, B966D409, CE61E49F, 5EDEF90E, 29D9C998, B0D09822, C7D7A8B4, 59B33D17, 2EB40D81, B7BD5C3B, C0BA6CAD, EDB88320, 9ABFB3B6, 03B6E20C, 74B1D29A, EAD54739, 9DD277AF, 04DB2615, 73DC1683, E3630B12, 94643B84, 0D6D6A3E, 7A6A5AA8, E40ECF0B, 9309FF9D, 0A00AE27, 7D079EB1, F00F9344, 8708A3D2, 1E01F268, 6906C2FE, F762575D, 806567CB, 196C3671, 6E6B06E7, FED41B76, 89D32BE0, 10DA7A5A , 67DD4ACC, F9B9DF6F, 8EBEEFF9, 17B7BE43, 60B08ED5, D6D6A3E8, A1D1937E , 38D8C2C4, 4FDFF252, D1BB67F1, A6BC5767, 3FB506DD, 48B2364B, D80D2BDA, AF0A1B4C, 36034AF6, 41047A60, DF60EFC3, A867DF55, 316E8EEF, 4669BE79, CB61B38C, BC66831A, 256FD2A0, 5268E236, CC0C7795, BB0B4703, 220216B9, 5505262F, C5BA3BBE, B2BD0B28, 2BB45A92, 5CB36A04, C2D7FFA7, B5D0CF31, 2CD99E8B, 5BDEAE1D, 9B64C2B0, EC63F226, 756AA39C, 026D930A, 9C0906A9, EB0E363F, 72076785, 05005713, 95BF4A82, E2B87A14, 7BB12BAE, 0CB61B38, 92D28E9B, E5D5BE0D, 7CDCEFB7, 0BDBDF21, 86D3D2D4, F1D4E242, 68DDB3F8, 1FDA836E, 81BE16CD, F6B9265B, 6FB077E1, 18B74777, 88085AE6, FF0F6A70 , 66063BCA, 11010B5C, 8F659EFF, F862AE69, 616BFFD3, 166CCF45, A00AE278, D70DD2EE, 4E048354, 3903B3C2, A7672661, D06016F7, 4969474D, 3E6E77DB, AED16A4A , D9D65ADC, 40DF0B66, 37D83BF0, A9BCAE53, DEBB9EC5, 47B2CF7F, 30B5FFE9, BDBDF21C, CABAC28A, 53B39330, 24B4A3A6, BAD03605, CDD70693, 54DE5729, 23D967BF, B3667A2E, C4614AB8, 5D681B02, 2A6F2B94, B40BBE37, C30C8EA1, 5A05DF1B, 2D02EF8D }

Unsigned int crc_calc (unsigned intcnt, unsigned intcrc, unsigned

int * far buf)

{

unsignedinttbl_idx = 0;

unsignedintarry_idx = 0;

unsignedintcalc_crc = 0;

calc_crc = crc;

```
for (arry_idx = 0; arry_idx<cnt; arry_idx++)
{
tbl_idx = (unsigned char) (calc_crc ^ buf[arry_idx]);
calc_crc = (calc_crc>> 8);
calc_crc = calc_crc ^ crc32_tbl[tbl_idx];
}
Return(calc_crc);
}
```

5. Full Supervision Movement Authority Handling Procedure (SIL-4)

5.1. If communication with Onboard KAVACH is lost for more than 6 seconds, Full Supervision Movement Authority shall be held by the Stationary KAVACH unit until the frame offset cycle becomes maximum value.

5.2. Due to signal aspect transitions, Full Supervision Movement Authority shall be held by Stationary KAVACH for 2 seconds.

5.3. Other than these events, Full Supervision Movement Authority shall be updated as soon as information is available with the Stationary KAVACH.

5.4. **Onboard KAVACH shall receive following information from Stationary KAVACH**

(a) Aspect of the approaching signal on route.

(b) Approaching signal distance from the reference RFID.

(c) Approaching signal identity.

(d) Next signal aspect as defined in KAVACH table of control, if the signal on approach is OFF.

(e) Movement authority Type and MA (the distance for which the train is authorized to travel).

(f) Train length Information.

(g) Track Profile (PSR, TSR, Tag Linking, LC gate & Track condition)

5.5. All the above is applicable for Onsight movement authority also except for special condition mentioned in FRS and OSMA will be Non SIL.

6. Determination of Speed (SIL-4)

6.1. Directional type Pulse generators with high reliability shall be used for speed sensing.

6.2. Each Pulse generator shall have at least two independent speed output channels.

6.3. Two Pulse generators shall be fitted on either side of the locomotive on different axles preferably.

6.4. Each channel of the PGs is to be compared for determination of speed.

6.5. In case of detection of malfunction of speed determination exceeding speed sense time out or failure of a channel in a Pulse generator, the Onboard Kavach shall transit to System Failure Mode. The same shall be recorded in event logger and NMS alert is to be generated.

7. Direction (SIL-4)

7.1. There shall be three types of direction of movements, one for train such as forward or reverse, second for traffic such as UP or DN or UPDOWN or UPFAST or DNFAST etc. and the other for movement of direction such as Nominal or Reverse.

7.2. On start-up or restart, the Onboard KAVACH unit shall assume the movement of direction as undefined. It shall be derived, when Loco/Train has passed two different sets of RFID tags.

7.3. The onboard KAVACH unit shall set its absolute location and TIN as undefined before determining the direction.

7.4. The direction of movement of the train shall be determined through RFID Tags data reported by same RFID readers. Tag data reported by different RFID readers shall not be used for determination of direction.

7.5. If Absolute location value is incrementing, it shall be treated as Nominal direction. If Absolute location value is decrementing, it shall be treated as Reverse direction.

7.6. The direction of movement of trains and TIN shall be used for determining whether two trains are approaching, one following the other or going away from each other with the exception in vicinity of Adjustment tag.

7.7. The direction of operation of Onboard KAVACH shall be determined based on the position of cab control. This direction shall be used for detecting Roll back/ Forward and Reverse movement.

7.8. The Stationary KAVACH unit shall use the direction of movement of Onboard KAVACH, to find an approaching signal of the Loco/Train.

8. Train Length Assignment (Non-SIL)

8.1.1. Every Stationary KAVACH unit shall monitor the status of track section identified for measurement of train length. Stationary KAVACH located at IB/LC/Auto Section are not required to carry out Train Length assessment.

8.1.2. The stationary KAVACH unit shall communicate the time of occupation and clear status of these track sections to every Onboard KAVACH unit. Onboard KAVACH unit, based on its odometer and the timings so received,

shall calculate its train length.

8.1.3. The train length so calculated by Onboard KAVACH unit shall be updated by replacing the previously stored train length under one or more of the following conditions:

(a) If the previous train length was default train length;

(b) If the train length calculated by Onboard KAVACH differs from the previously stored train length by more than 25m (Configurable).

8.1.4. The accuracy of the train length measurement by Onboard KAVACH unit shall be within ± 25 meters.

8.1.5. The stationary KAVACH unit shall have provision of configuring the time correction offset from +1000 ms to -1000 ms with resolution 10 ms to compensate for delay, if any, in clear / occupied status of track sections due to track repeater relays.

8.1.6. The stationary KAVACH unit shall also have provision for configuring the maximum time period of occupation of track sections, to differentiate between occupation by Train or by probable fault of track detection. If the occupation period of these track sections is beyond the configured period of time, Stationary KAVACH unit shall abort transmission of the timings for calculation of train length. This time period limit for occupation would be configured as per characteristics of track section as provided by purchaser railway. Typically, in case of failure of AT & BT track circuits i.e. remaining occupied for more than 3 minutes (programmable from 0 to 10 minutes in step of 30 seconds), Stationary KAVACH unit shall not transmit packet & shall log it.

8.1.7. Two track circuit (say AT & BT in sequence in the traffic direction of train movement) at the entry to the block section shall be identified at each station for train length measurement. The track circuits identified shall be such that all the trains entering into a block section pass over these track circuits. Stationary KAVACH shall be able to handle Train length assignment for minimum 6 directions.

8.1.8. The status of these track circuits shall be taken as input to the Stationary KAVACH unit.

8.1.9. Stationary KAVACH, on establishing AT occupied & then BT occupied, shall communicate the time offset from the frame cycle reference for 'BT occupied' (Loco entered at an AT/BT boundary) & corrected time offset from the frame cycle reference for 'AT cleared' (last vehicle cleared over AT/ BT boundary) to concerned Onboard KAVACH.

8.1.10. Onboard KAVACH shall log its location at a resolution of better than 200 ms for the last 20 Seconds which shall be used by Onboard KAVACH for precise location for train length calculation.

9. Train location (SIL-4)

9.1. The onboard KAVACH unit shall compensate the location of the train with RFID mount distance, operating cab and direction of travel.

9.2. The functional Onboard KAVACH unit shall transmit the location of the train to the Stationary KAVACH unit every 2 seconds.

9.3. The onboard KAVACH unit shall transmit the position, speed and length of the train every 2 seconds to its CTC, when LTE is available. (F)

9.4. The onboard KAVACH unit shall transmit the event-based health packet to the NMS, when LTE is available. (F)

10. Track Profile supervision (SIL-4)

10.1. **Turnout Speed**: Turn out speed describes the start distance from the entry signal foot tag, the speed of the approaching turnouts and the length of the applicable speed**.**

10.2. **Permanent Speed Restriction:** The permanent speed restriction describes the static speed type, i.e. U- Static speed applicable for all categories of trains, A- Static speed for category 'A' trains (LE/Passenger Trains), B- Static speed for category 'B' trains (Loaded goods Trains), C- Static speed for category 'C' trains (Empty goods Trains), speed value (Kmph), and length of PSR in meter. This is a continuous profile.

10.3. **Temporary Speed Restrictions**

10.3.1. The temporary speed restriction is defined to enable an intermittent type of speed restriction to cater for degraded track conditions or facilitate staff work.

10.3.2. All Temporary Speed Restrictions are independent of each other. An individual Temporary Speed Restriction cannot affect, nor be affected by, any other individual Temporary Speed Restriction.

10.3.3. When two or more temporary speed restrictions overlap, the Onboard KAVACH shall use the most restrictive speed of the overlapping temporary speed restrictions.

10.4. **Gradient:** Engineering gradient shall be taken from index plan of the engineering department and shall be mentioned for every rise (R), Level, or fall (F) with respective distances.

10.5. **LC gate:** This shall specify the LC ID (Numeric ID and Alpha Suffix), LC manning type (Manned/unmanned), LC Class (Special, A, B1, B2, B, C and D), LC distance (meter) and LC Auto whistling enabled.

11. Track Conditions (Non-SIL) (F)

11.1. The Track Condition function is used to inform the loco pilot about special condition in front of the train.

11.2. There are two types of track condition – profile type and location type.

11.3. The starting point of a profile type (P) or location type (L) track condition shall be evaluated considering the max safe front end of the train.

11.4. The end point of the profile type (P) or Location type (L) shall aconsider the min safe rear end the of the train for Non stopping area (P), Tunnel stopping area (P), Reversing area (P), fouling mark (L) and Kavach territory exit (L).

11.5. The end point of other track conditions shall take into account the min safe front end of the train.

11.5.1. **Max Safe front end-** The maximum safe front end position differs from the estimated position by the Under reading amount in the distance measured from the reference RFID tag plus the Location accuracy of the reference RFID tag.

11.5.2. **Min safe front end:** The minimum safe front end position differs from the estimated position by the Over reading amount in the distance measured from the reference RFID tag plus the Location accuracy of the reference RFID tag.

11.5.3. **Min safe rear end:** It is the train length plus min safe front end of the train.

11.6. The following actions shall be performed once a track condition has been received:

(a) Indicate on DMI

(b) Supervision of track conditions by Onboard KAVACH.

11.7. The train is permitted to run without any track condition information given from the trackside. The default state shall then be used by the Onboard KAVACH.

12. Prevention of Signal Passing at Danger (SIL-4)

12.1. In case of any conflict between signal aspect, point, position, berthing track section, signal aspect sequence and TIN, the Stationary KAVACH unit shall transmit most restrictive aspect of that signal and shall reduce the movement authority accordingly.

12.2. The stationary KAVACH unit shall check route information configured on the basis of the KAVACH Control Table of Stationary KAVACH.

12.3. The off aspect and Full Supervision movement authority for LSS shall be transmitted by Station/LC/ IB unit only when LSS is off, and it is ensured that the concerned Line Clear is available.

13. Protection of Roll Back (Non-SIL)

13.1. The onboard KAVACH unit shall be capable of detecting Roll Back of the train through train interface. It shall apply brake and give audio/visual warning if the train has rolled back by more than 5 meters (configurable).

13.2. During roll back, movement authority and other target distances shall be incremented or decremented depending on the locomotive absolute position.

13.3. It shall be possible for the Loco Pilot to reverse the train, if the situation so warrants, by changing the mode of Onboard KAVACH to 'Reverse Mode'.

13.4. To protect a traction unit from roll away and unwanted reverse movements, the Onboard KAVACH shall monitor the direction of movement in relation to the permitted direction.

13.5. The roll away/reverse movement intervention shall be indicated on the LP-OCIP (DMI).

14. Prevention of Head on & Rear end Collisions (Non-SIL)

14.1. Onboard KAVACH units either directly or through the Stationary KAVACH unit, shall be capable of detecting head on collisions, rear end collisions of trains/locos on a single line, multiple lines in all possible scenarios based on the track identification, the speed of the trains, train location, train length, train direction movement (Nominal/Reverse) etc.

14.2. In case of head on collision situation, Onboard KAVACH units of both the trains shall automatically apply brakes immediately with warning either in Absolute or in Automatic Block Section.

14.3. In case of a rear end collision situation, the Onboard KAVACH unit of only rear train shall automatically apply brakes to bring it to stop short of a stipulated distance (300m in block section, configurable) from the train ahead. There shall be no brake application in the train ahead on account of rear end collision situation. The rear end collision message shall be displayed with the details to the rear approaching Onboard KAVACH only.

14.4. When the speed of the Onboard KAVACH reaches Zero Kmph, the brakes shall be released.

14.5. As soon as the head-on collision or rear end collision, as the case may be, the situation is over, the application of brakes of the Onboard KAVACH unit shall be withdrawn.

14.6. In Station sections, the Stationary KAVACH shall prevent train collisions with the help of SPAD and TIN conflict.

14.7. In case two Onboard KAVACH units are detected by Stationary KAVACH moving towards each other on same TIN in block section in the communication mandatory area, the SoS command would be generated by Stationary KAVACH for both. On reception of such Onboard KAVACH specific SoS

from Stationary KAVACH Unit, the trains would be stopped through automatic application of the brakes.

14.8. The target distance and permitted speed shall be displayed on DMI.

15. Auto whistling on approach of Level Crossing Gate (Non-SIL)

15.1. The feature of auto whistling on approach of level crossing gate is optional and Purchaser Railway shall decide for its incorporation.

15.2. The Onboard KAVACH shall display the level crossing gate information (Gate ID) on LP-OCIP (DMI), when the approach of LC Gate is detected through LC Gate Tags/ track profile received through radio. The format for displaying LC gate information is as follows:

<LC_Manning_Type> LC Gate
<LC_ID_Numeric><LC_ID_Alpha_Suffix> approaching in
<LC_Distance > meters

15.3. The Onboard KAVACH unit shall blow the Loco horn at LC gate, based on the information received from the LC gate tag / track profile. Whenever information regarding LC gate is available from both track profile and LC tag, Onboard KAVACH shall process the first input.

15.4. The Onboard KAVACH unit shall not blow the horn for LC gate, if movement authority is less than the LC gate distance from its current position.

15.5. The Onboard KAVACH shall not blow the horn for LC gate, if the loco is at standstill.

15.6. The Onboard KAVACH unit shall blow the horn for LC gate, on reading the tag, if MA information is not available.

15.7. The Onboard KAVACH unit shall not blow the horn for LC gate, when it is in Standby, Isolation, Non-Leading and System failure mode.

15.8. A continuous whistling shall commence from a distance of 600m on the approach of LC Gate till the time that train reaches LC Gate. However, whistling pattern shall be configurable and shall be decided by the purchaser Railway in case pattern other than continuous whistling is required.

15.9. It shall be possible to cancel the auto-whistling by pressing Common /Ack button alone.

15.10. The Interface details for auto-whistling shall be provided by the Purchaser.

16. Track Identification Number (Non SIL)

16.1. Each track shall have a designated Track Identification Number (TIN).

16.2. Each Block section shall have a single unique designated TIN. Block Section TIN can be repeated after a designated distance (50 km minimum along the track route).

16.3. To avoid unnecessary SOS generation, adjacent TINs to be incorporated in the radio packet and adjacent line tag. Adjacent line info data is to be communicated over the radio only after physical separation of tracks.

16.4. Each line in the station section having berthing portion shall have different TINs. Station section TIN can be repeated after a designated distance (10 km minimum along the track route)

16.5. TINs shall be allotted in such a manner not to restrict permissible simultaneous movements.

16.6. The onboard KAVACH unit shall be able to self-deduce the change in its TIN whenever it changes the TIN section.

16.7. There shall be no case of assignment or deduction of wrong TIN by Onboard KAVACH unit on reading the RFID tag.

17. Radio Communication Arrangement

17.1. Station/ IB/ Gate KAVACH unit as well as an Onboard KAVACH unit shall have hot standby radio for higher availability.

17.2. **Initiating a Radio Communication:** The Onboard KAVACH unit shall commence transmission of the Radio packet to the Stationary KAVACH unit:

17.2.1. **While the start of mission in KAVACH communication mandatory area & while entering the from non KAVACH area to KAVACH communication mandatory area.**

17.2.1.1. On reading RFID Tag, Onboard KAVACH shall display the message "**KAVACH Territory Entry**" in LP-OCIP and Absolute location.

17.2.1.2. Prior to the determination of the direction, Onboard Kavach shall transmit Absolute location as read from the Tag, direction as undefined, TIN as zero, and RFID tag read.

17.2.1.3. After establishing the direction, the Onboard KAVACH unit shall commence transmission of absolute location and TIN as per the direction on the basis of data read from RFID Tag through Access Request Packet. Whenever Onboard KAVACH unit tries to establish communication with a new Stationary unit for the first time, it shall do so by Random Access Method within the time slots reserved for this purpose on frequency f_0.

17.2.1.4. Subsequently, Stationary KAVACH shall register the Onboard KAVACH.

17.2.2. **While entering to KAVACH communication mandatory area from non communication mandatory area:**

17.2.2.1. Onboard KAVACH determines that it has entered a communication mandatory area based on the information received from RFID Tag.

17.2.2.2. On entering a communication mandatory area in the vicinity of Stationary

KAVACH territory, the Onboard KAVACH unit generates Random number R_L and sends the Access Request packet to a Stationary KAVACH system in "f_0" frequency.

17.2.2.3. On reception of Access Request Packet from Onboard KAVACH Unit, Stationary KAVACH unit generates its own Random Number (R_S) and computes the session key K_S and transmits the Access Authority Packet in f_0 frequency with CBC-MAC code. Access Authority Packet contains frequency, Timeslot and Random Number R_S.

17.2.2.4. The onboard KAVACH unit receives the Access Authority Packet and compute the session key K_S. The CBC-MAC will be computed for the Access Authority Packet and verify with received CBC-MAC. If CBC-MAC is successful, Onboard KAVACH starts communicating the Onboard Regular Packet.

17.2.2.5. When Stationary KAVACH receives the Onboard Regular Packet, it stops communicating the Access Authority Packet and initiates the Stationary regular packet & other packet transmission.

17.2.2.6. Further, Stationary KAVACH and Onboard KAVACH units verify the CBC-MAC code for every message before processing.

17.3. The Stationary KAVACH unit shall transmit the Access Authority Packet in f_0 to the Onboard KAVACH unit, if it receives the Access Request Packet from Onboard KAVACH unit with valid Absolute location and direction.

17.4. Once, the Onboard KAVACH unit receives an Access Authority Packet from Stationary KAVACH unit, the Onboard KAVACH unit shall send its regular packet in the frequency channel and time slot as specified in the Access Authority Packet sent by Stationary KAVACH. Further, Onboard KAVACH shall continue transmission of Access Request Packet if it is in the block section.

17.5. The Stationary KAVACH shall send its regular packet and the communication with the registered Onboard KAVACH shall continue till the end of Stationary KAVACH communication mandatory area.

17.6. In the station section, if the Onboard KAVACH is registered with Stationary KAVACH and on continuous receipt of the regular packet, Onboard KAVACH shall stop sending Access Request Packet in f_0.

17.7. If the registered Onboard KAVACH does not receive the Stationary KAVACH regular packet for beyond time out, the Onboard KAVACH shall send Access Request Packet in f_0 in the station section also.

17.8. The Manual SOS and Unusual stoppage messages shall be transmitted by Onboard KAVACH unit as and when required, on frequency (f_0).

17.9. The Onboard KAVACH and the Stationary KAVACH shall not interfere mutually while transmitting on frequency f_0.

17.10. **Terminating a Radio Communication:** The Stationary KAVACH shall stop communication with the Onboard KAVACH unit, when one of the following conditions occurs Onboard KAVACH unit.

a) When the Onboard KAVACH unit moves beyond the Last Stop Signal of the Stationary KAVACH Unit as per communication mandatory, are configured (typically 1.5km from Last Stop Signal of Stationary KAVACH in Absolute Block Section and u pto a distance of train length beyond border tag in Automatic Block Section)

b) If the direction is invalid.

c) No radio packet is received from the Onboard KAVACH for more than 60 cycles (Configurable) in station section / Absolute Block Section & 15 cycle (Configurable) in Automatic Block Section.

17.11. The radio frame cycle refresh rate shall be 2 seconds for the Stationary KAVACH.

17.12. If a packet having a source frame number prior to that of any other packets processed by a KAVACH unit, the same shall be discarded by the KAVACH unit for the purpose of the operation. However, such packet shall be forwarded to NMS by the Stationary KAVACH.

17.13. In case there is no gap between the Communication Mandatory area of two adjacent Stationary KAVACH the procedure defined in **Annexure-P** to be followed.

17.14. **Frame Offset cycle calculation by the Stationary KAVACH unit**

17.14.1. This clause describes how the Stationary KAVACH unit prepares the "frame offset cycle" field in its radio communication packet.

17.14.2. The stationary KAVACH unit calculates the frame offset cycle based on the frame number received in the Onboard KAVACH packet.

$$\text{Frame offset cycle} = \frac{\left\{\begin{array}{l}\text{Stationary KAVACH frame number} - \\ \text{Onboard KAVACH frame number} \\ \text{(received in the last radio packet).}\end{array}\right.}{2}$$

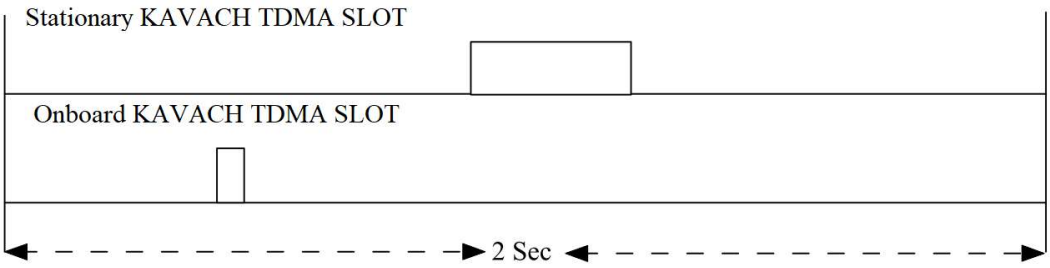
Note: The above subtraction is cyclic.

17.14.3. Depending on the Time slots allocated for the Stationary and the Onboard KAVACH units as per the multiple access protocol, the frame offset cycle will be zero or one.

17.14.4. **Case 1: Frame Offset cycle = Zero**

When the Stationary KAVACH processes the Onboard KAVACH packet before its time slot, the frame offset cycle will be Zero. In this case the Onboard KAVACH Time slot shall be before 150-200 ms of the Station-

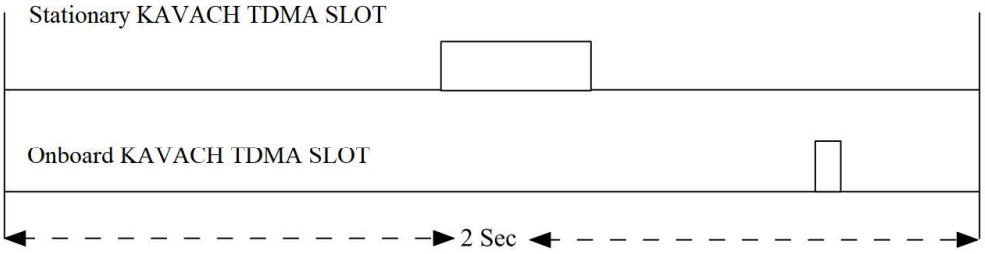
ary KAVACH time slot. The following figure shows the scenario for frame offset cycle Zero.



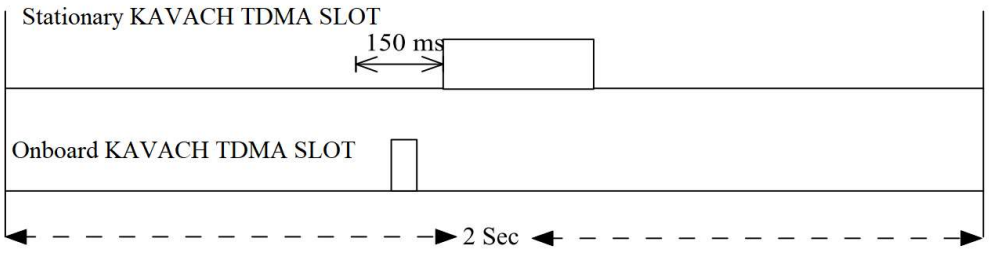
17.14.5. **Case 2: Frame Offset cycle = One**

When the Stationary KAVACH processes the Onboard KAVACH packet after its time slot or less than 150-200m sec before its time slot, the frame offset cycle will become one. The following two figures show the scenario for frame offset cycle one.

17.14.6. **Case 2(a): The Onboard KAVACH Packet received after Stationary KAVACH unit Time Slot**



17.14.7. **Case 2 (b): The Onboard KAVACH packet received within 150ms-200ms prior to the Stationary KAVACH time slot.**



Note: 150-200 m sec time is specified to complete the Interprocessor communication. The packet will be accepted as a valid packet if at least two processors receive the same packet.

18. Connectivity of Stationary KAVACH unit with interlocking.

18.1. The Stationary KAVACH unit shall be capable of taking potential free inputs

from interlocking through double cutting arrangement. It shall be capable of taking minimum 256 inputs. There shall be provision for expansion by providing additional Input cards or by cascading suitable Interface Units. The requisite number of Vital Input cards shall be supplied with each Stationary KAVACH as per site requirement. The requirement of spare parts of each type shall be indicated by purchaser for better system availability.

18.2. When the Stationary KAVACH interfaces with EI directly, there is no need of Vital Input Cards. However, a minimum of two vital input cards shall be supplied along with each such Stationary KAVACH for connecting other hardwired field inputs.

18.3. The status of track circuits nominated for computing the train length measurement shall be read through Vital Input Cards only. If these relay statuses are read through Remote Interface Units, the delays are to be accounted for, by the Stationary KAVACH.

18.4. The capacity of the Stationary KAVACH shall be restricted to 70% of its "Design Capacity" in terms of number of inputs, number of routes and number of trains (whichever is lower) that can be handled, to avoid undesired behaviour of the KAVACH when its operation reaches beyond design capacity.

18.5. The break status of potential free contact shall indicate absence of input.

18.6. Signal aspect status, position of points, berthing track circuit status, status of track circuits nominated for computing train length, status of the block instrument Line Closed condition shall be interfaced to Stationary KAVACH.

18.7. The IBS & Gate unit shall not require inputs for point position, track circuits nominated for computing train length & berthing track circuit status. The gate unit shall not require input for status of the block instrument Line Closed condition.

18.8. The movement authority shall be held by Stationary KAVACH for a period of 2 second (minimum) to 5 seconds (maximum) in case of flickering of signal. Further a provision to adjust this duration in multiples of 100 m sec is to be made available.

19. Other Requirements

19.1. In case of more than one situations/ scenario existing at the same time, the Onboard KAVACH unit shall take action as per the most restrictive situation/ scenario.

19.2. The Onboard KAVACH unit shall make speed profile/ brake curve for different situations based on movement authority, speed restriction and other information as received from the Stationary KAVACH unit or other Onboard KAVACH unit.

19.3. The Onboard KAVACH unit shall take action as per the most restricted speed profile/ brake curve at any point of time.

19.4. Once a situation is detected by the Onboard KAVACH unit based on the information received by it, which warrants application of brake & further update of information is not available, the action for brake application shall be initiated or continued if already initiated as per the brake curve at the time receipt of last information. Further update of the brake curve shall be done only after start of receipt of further information.

19.5. The RFID tag sequence (shall include Gate tags if available) received from the Stationary KAVACH shall be verified for their availability and send the information to NMS over commercial GSM/LTE in case of missing tags.

19.6. The RFID tag sequence received from Stationary KAVACH shall be validated by the Onboard KAVACH and the Onboard KAVACH shall apply brakes in case of reading an unexpected tag (except for gate tags). In case of Tag missing, the brakes shall not be applied.

20. Failures and fallback Procedures

20.1. Radio communication failures:

20.1.1. A radio communication failure shall be deemed to have occurred when 30 seconds (configurable) for Absolute Block Section and 10 seconds (configurable) for Automatic Block Section have passed since the last packet received from Stationary KAVACH in the communication mandatory area.

20.1.2. If the last packet received from Stationary KAVACH is more than 6 seconds older, the signal aspect and signal description shall be made blank. However, the Onboard KAVACH shall continue to function in Full Supervision mode and shall supervise the Full Supervision Movement Authority received in latest packet till the commencement of brake in the current route section.

20.1.3. In the event of a Radio Communication failure longer than applicable timeout, the Onboard KAVACH unit shall transit to degraded mode as specified in mode transition table and shall seek acknowledge from Loco Pilot. If Loco Pilot does not acknowledge within stipulated time of 15 seconds (Configurable), Onboard KAVACH shall apply the brake. In addition, it shall send the message to Network Monitoring System through commercial GSM/LTE. Stationary KAVACH shall send the Fault message to Network Monitoring System through Ethernet/GSM/ commercial LTE interface.

20.1.4. In the event of a failure of only one radio when other radio is providing radio communication in hot standby, the Onboard KAVACH unit should log the fault. The Onboard KAVACH unit shall also send the message to Network Monitoring System through GSM/ commercial LTE. The Stationary KAVACH unit shall send the Fault message to Network Monitoring System. The system shall be functional with one radio.

20.2. RFID Reader failures:

20.2.1. In the event of an RFID reader failure (both readers), the Onboard KAVACH unit should stop radio communication and shall switch to System Failure mode. Fault shall be logged. In addition, it shall send the message to

Network Monitoring System through GSM/commercial LTE.

20.2.2. In the event of any one RFID reader failure, the Onboard KAVACH unit should log the event. In addition, it shall send the message to Network Monitoring System through GSM/commercial LTE. A system shall be functional with one RFID reader.

20.3. **GPS/GNSS failure (F)**

20.3.1. **When the Aerial View is available:** Incremental difference between the CPU time and GPS time is to be cross checked. If the incremental difference between CPU and GPS time is not matched, the time reference shall change to other GPS. If the difference between two GPS is greater than the frame interval, a message shall be sent to the NMS.

20.3.2. Diverse make of GPS is preferable to avoid common cause failures.

20.3.3. In the event of failure of both – GPS/GNSS and Real Time Clock (RTC), the Onboard KAVACH unit shall stop radio communication and shall switch to System Failure mode. In addition, it shall send the message to Network Monitoring System through commercial GSM/LTE.

20.3.4. In the event of failure of both GPS/GNSS and RTC, Stationary KAVACH unit should stop radio communication and shall switch to System Failure mode. Fault message shall be communicated to Network Monitoring System through an Ethernet interface. In addition, it shall send the message to Network Monitoring System either through Ethernet or commercial GSM.

20.3.5. If the incremental difference is also not matching with second GPS or both systems are failing, then the system shall work on CPU time for 30 minutes, (default, Min:10, Max:60) until the situation is stabilized. If there is no stability after GPS time-out, the Loco shall transit out of FS Mode to SR mode. The following message shall be displayed on LP OCIP. Ack SR mode- GPS Fail.

GPS1 Fix	GPS2 Fix	GPS1 PPS	GPS2 PPS	Time Mismatch	GPS Selection	NMS fault
0	0	x	x	x	(a) Wait for GPS fix at powerup. (b) Normal running: run for 30min and transit to System Failure Mode.	Yes
0	1	x	0	x	System failure	Yes
0	1	x	1	x	GPS2	Yes
1	0	0	x	x	System failure	Yes
1	0	1	x	x	GPS1	Yes
1	1	0	0	x	System failure	Yes

GPS1 Fix	GPS2 Fix	GPS1 PPS	GPS2 PPS	Time Mismatch	GPS Selection	NMS fault
1	1	0	1	x	GPS2	Yes
1	1	1	0	x	GPS1	Yes
1	1	1	1	0	Run with GPS1. Incremental tests to be done. No matching run in SR mode.	Yes
1	1	1	1	1	GPS1	No

Note-1: Leap year correction: When both GPS frame numbers are incremented by 1 sec at the time of leap year Incremental difference with CPU time should be compensated automatically without affecting system functionality.

Note-2: GPS frame integrity by CPU.

20.4. **LP-OCIP (DMI) communication failures:**

(a) In the event of Active Cab/Desk LP-OCIP (DMI) communication failure, the Onboard KAVACH unit shall switch to System failure mode. In addition, it shall send the message to Network Monitoring System through GSM/ Commercial LTE.

(b) In the event of Non-Active Cab/Desk LP-OCIP (DMI) communication failure, the Onboard KAVACH unit shall log the fault. In addition, it shall send the message to Network Monitoring System through GSM/ Commercial LTE.

20.5. **Pulse Generator (PG) Failure:**

20.5.1. A pulse generator failure shall be deemed to have occurred when the difference of the speed detected by both the PG is more than 5 Kmph (Configurable) for a frame cycle time.

20.5.2. Onboard KAVACH shall transit to system failure mode. The Onboard KAVACH unit shall log the fault. In addition, it shall send the message to Network Monitoring System through Commercial GSM/ LTE.

20.6. **Brake Interface Failure:**

20.6.1. If there are failures of brake interface such as pressure feed back fail or traction cut off feed back fail, etc. which compromise the safety of train supervision, the Onboard KAVACH shall switch to system failure mode**.**

20.6.2. The Onboard KAVACH unit shall log the fault. In addition, it shall send the message to Network Monitoring System through Commercial GSM/ LTE.

20.7. **Odometry error:**

20.7.1. Stationary KAVACH shall generate Onboard-specific SOS when it deter-

mines the odometry error beyond a configurable tolerance (default: 120 m), i.e. when there is an abnormal change in travelled distance between two position reports with respect to live speed received from Onboard Kavach.

20.8. **Communication fails with TSRMS or adjacent Stationary Kavach or Electronic Interlocking:**

20.8.1. Stationary KAVACH shall extend **SR Authorization** to Onboard Kavach when the communication fails with TSRMS or adjacent Stationary Kavach or Electronic Interlocking. On recovery of the link, Stationary Kavach shall extend Onsight Movement Authority.

21. Logging of events

21.1. Logging of events shall be done with date, time and location stamp.

21.2. Time reference for the entire KAVACH network should be synchronized. Logging shall be done every two seconds. In addition, logging shall also be done based on the occurrence of certain events.

21.3. Following events related to dangerous situations shall be logged along with date, time and location stamp in the Stationary and the Onboard KAVACH units.

(a) Signal Passing at Danger

(b) Head On Collision

(c) Rear End Collision

(d) All SoS messages

(e) Train Trip

(f) Unusual stoppage

(g) Loco Pilot Alert Messages on LP-OCIP (DMI)

(h) Roll back

21.4. Following the events of failures/abnormal/ Specific conditions and their recovery shall be logged along with the date, time and location stamp in relevant KAVACH.

(a) Communication failure of Onboard KAVACH/ Adjacent Stationary KAVACH/TSR Management System/ Electronic Interlocking.

(b) Input failures wherever applicable

(c) Failure of KAVACH unit due to any reason shall be logged in the Network Monitoring System.

(d) Brake interface unit isolation

(e) All types of Brake application actuated by KAVACH unit with duration, speed & distance measurements

(f) Restart of KAVACH unit due to any reason

(g) All failure messages

(h) Non-Leading Mode

(i) Train Length Assignment/measurement

(j) Mode Transition

(k) MBT

(l) Every RFID tag

21.5. The following information shall be logged every two seconds or based o then occurrence of certain events:

(a) In the Onboard KAVACH unit data logger:

(i) Date

(ii) Time

(iii) Loco ID

(iv) Speed

(v) Absolute Location

(vi) Train movement direction (Nominal/Reverse)

(vii) Location of the last RFID tag passed

(viii) TIN

(ix) Type of Brake application

(x) System faults, if any

(b) In the Stationary KAVACH unit data logger:

(i) Date

(ii) Time

(iii) Onboard radio packets received

(iv) Status of all signalling inputs

(v) Signalling information packets sent

(vi) Track Profile sent

(vii) Station emergency message (SoS)

(viii) System faults, if any

21.6. The following events shall trigger the logging:

(a) In Onboard KAVACH unit event logger:

(i) Update of Movement Authority

(ii) Initiation of brake Application-Onboard brake command.

(iii) Change of type of braking application.

(iv) Removal of brake application.

(v) Change in KAVACH Mode.

(vi) Acknowledgement by loco pilot

(vii) SPAD

(viii) Passing of RFID Tag.

(ix) Change in TIN.

(x) One RFID tag missing out of 2.

(xi) Both (duplicated) RFID tags missing.

(xii) Data mismatch between duplicated RFID tags.

(xiii) Change in Signal Aspect.

(xiv) Passing of signal.

(xv) Transmission of emergency messages.

(xvi) Reception of emergency messages.

(xvii) Change in train configuration and braking parameter.

(b) In Station/ IBS/ Gate unit data logger:

(i) Entry of new train.

(ii) Change in input to station unit from interlocking.

(iii) Emergency messages received from Onboard KAVACH.

(iv) Transmission of emergency messages generated by the Stationary KAVACH.

(v) Change in signalling, track profile or configuration related data

21.7. The logged data shall be displayed through the user-friendly GUI.

21.8. The fetching of data should be password protected.

21.9. The KAVACH equipment should record information to an accuracy which shall enable a clear view of the way in which loco has been driven so as to reconstruct a certain situation (accident, equipment performance and Loco Pilot's action).

21.10. The events logged in event logger, shall have Safety Integrity Level of SIL-2 as per CENELEC or equivalent standards.

21.11. It shall be possible to download and reconstruct the recorded data on a Laptop.

21.12. After the restoration of link failure, the event logger of Stationary KAVACH must ensure that all packets generated in the previous 24 hours (minimum) are transmitted to NMS in FIFO manner. This data can be sent at an adaptive speed. NMS shall not send SMS based on this information. However, sending current data shall be given preference.

21.13. Event logger of the Onboard KAVACH shall ensure that all the packets generated within last 24 hours (minimum) are transmitted to NMS (When LTE is available) after the restoration of link failure in the FIFO. The speed of sending this data shall be adaptable. Priority shall be given for sending current data. SMS shall not be generated by NMS based on this data.

22. Environmental Requirements

22.1. The KAVACH equipment shall withstand the following environmental tests, except for BIU, as per the specifications mentioned in relevant clauses of RDSO/SPN/144/2006 or latest as applicable. The BIU shall be tested as per standards of Motive Power/ Traction Directorates of RDSO.

SN	Test Type	Equipment Condition	Severity	Specification
1	Dry heat test (Operation)	Operating	For functional trials: Temp. 70 ºC, Duration: 16 hrs.	IS: 9000 Pt. III Section: V
	Dry heat test (Storage)	Non-operating	Temp. 75ºC, Duration: 16 hrs.	
2	Cold Test (Operation)	Operating	Temp. –10ºC ± 3^0C, Duration: 2 hrs.	IS: 9000, Pt. II
3	Change of Temp Test	Operating	-10 ±3^0C to +70ºC±2^0C, Duration: 7 hrs at each temperature. Rate of change: 1ºC per Minute. No. of cycle: 03	IS: 9000 Pt. XIV Section: II
4	Damp heat test (steady state storage)	Operating	RH 93% (+2 %, -3%) @ 40±2^0C Duration = 4 days	IS: 9000 Pt. IV
5	Damp heat test (Cyclic)	Operating (Fully functionl during one-hour period towards end of each cycle. Stabilization shall be done at 25ºC ±3^0C.)	RH 95% (+1 %, -5%) @ 40ºC ±2^0C (high), No. of cycles = 6	IS: 9000 Pt. V Section-II
6	Bump Test (Package)	Non-operating	400 m/Sec^2 peak, 1000 bumps per axis Duration: 6 milliseconds No. of axes: 03	IS: 9000 Pt. VII Section II
7	Mechanical Shock	Power off Condition (At the end of the test, the assembly shall be subjected to performance test)	Peak acceleration: 20g Pulse Duration: 11 m.sec (Half sine pulse). Total No. of shocks: 18 No. of axes: 3 shocks in each direction Equipment in unpacked condition shall be subjected Mechanical Shock. In addition to physical checks, the assembly shall be subjected to performance test.	IS: 9000 Pt. VII , Section-I or IEC 60068-2-27 -2008

SN	Test Type	Equipment Condition	Severity	Specification
8	**Vibration test**			IS: 9001 Pt. XIII
(i)	Onboard KA-VACH	Non-operating	5 Hz to 150 Hz Acceleration A: 3g 20 sweep cycles on 3 axes	
(ii)	Stationary KAVACH/TSRMS	Non-operating	5 Hz to 350 Hz Acceleration A: 2g 20 sweep cycles on 3 axes	
9	Salt Mist test			IS: 9000 Pt. XI
(i)	On Board (inside cab)	Non-operating	Procedure 3: Salt Duration: 2hrs, Mist Duration =22 hours 35±3^{0}C, RH: 93% (+2 %, -3%) No. of cycles: 03	
(ii)	On Board (outside cab	Non-operating	Procedure 2: Salt Duration: 2hrs, Mist: Duration=7 days 35±3^{0}C, RH: 93%(+2 %, -3%) No. of cycles: 04	
(iii)	In door	Non-operating	Procedure 3: Salt Duration: 2hrs, Mist Duration =22 hours 35±3^{0}C, RH: 93% (+2 %, -3%) No. of cycles: 03	
(iv)	Out door (On Track /Track side)	Non-operating	Procedure 2: Salt Duration: 2hrs, Mist: Duration=7 days 35(+/-)3ºC, RH: 95% No. of cycles: 04	
10	Dust test	Non-operating	1 hour only	IS: 9000 Pt. XII
11	7 KV discharge Test	Non operational	.....	RDSO/SPN/144/2006: Clause 9.4.1.
12	Environmental Stress Screening (ESS) test	(PCB Cards)	……	RDSO/SPN/144/2006: Clause 9.3 serial no.13
(i)	Thermal Cycling	Non operational	.....	
(ii)	Power Cycling	Non operational	.....	

Note: Environmental Stress Screening (ESS) test is part of routine test and same shall be carried out during production/testing of all modules on an 100% basis.

22.2. **Other type tests: (Only Applicable for Rolling stock equipment)**

22.2.1. Variation and interruption of voltage supply (Class: S2) to equipment tests as per clause 5.1.1.2 and 5.1.1.3 of IEC 60571 -2012 in accordance with IEC-61000-4-29 or relevant clause of latest amendment / issue.

22.2.2. Supply over-voltage and surge tests as per clause 5.2 & 12.2.7 of IEC 60571 -2012 in accordance with IEC-61000-4-29 or relevant clause of latest amendment / issue. Electrostatic discharge tests shall be carried out as per Clause 9.4.1 of RDSO/SPN/144/2006 or relevant clause of latest amendment.

22.2.3. Transient burst and susceptibility test as per clause 5.5 of IEC 60571-2012 in accordance with IEC 62236-3-2 or relevant clause of latest amendment / issue.

22.2.4. Radio interference test as per clause 5.5 & 12.2.8 of IEC 60571-2012 in accordance with IEC 62236-3-2 or relevant clause of latest amendment / issue.

22.2.5. Insulation test as per clause 12.2.10 of IEC 60571 -2012 or relevant clause of latest amendment / issue after completion of each climatic test.

22.3. **Remote Interface Unit (RIU):**

22.3.1. Type testing as per RDSO/SPN/144/2006 or latest shall be carried out for all the equipment such as Communication Modem, Remote Interface Unit and Charger treating this equipment as track side. For battery the operating temperature shall be up to 60°C.

23. Design and V&V Documents

23.1. **Design Documents**

23.1.1. The manufacturer shall, as a minimum, submit followings hardware and software design documentation.

(a) System Requirement specification

(b) Failure mode effect analysis (FMEA)

(c) Data modification (User Configuration) manual

(d) Operating manual

(e) Detailed User, Installation and Maintenance manual along with pre-installation, pre-commissioning and Maintenance check lists duly included safety related application condition.

23.1.2. Firms shall use these documents at 22.1.1 (c), (d) and (e) during the trials and shall place these documents at the respective stations. The utility of these documents shall be cross checked before the trials are allowed by RDSO. In case of insufficiency, the trial would not be permitted.

23.1.3. The card wise power supply requirement shall be submitted.

23.1.4. The dimension of RIU and proposed Apparatus case along with installation details shall be included in installation and maintenance manual.

23.1.5. The estimated Mean Time Between Failures (MTBF) & Mean Time Between Wrong Side Failures (MTBWSF) figures for each sub-system & each complete KAVACH unit shall be submitted.

23.1.6. The MTBF of Stationary KAVACH unit (excluding radio modems, GPS, GSM modems) shall be minimum 60,000 Hrs.

23.1.7. MTBF for the Onboard KAVACH unit (excluding RFID reader, Radio modems, GPS and GSM modems) shall be minimum 40,000 Hrs.

23.1.8. MTBF of RFID reader as well as an RFID tag, Radio Modems, GPS and GSM modems shall be minimum 1,00,000 Hrs.

23.2. **Verification and Validation (V&V) document:**

23.2.1. The manufacturer shall provide a report containing verification and validation documents approved by the accredited validation agency except for NMS. Key Management System need not be developed by prospective KAVACH vendors.

23.2.2. The test procedure shall be based on system design. The methodologies to be adopted for various tests shall be decided taking into account the system design / configuration and shall be submitted to RDSO.

23.2.3. Verification & Validation of the software and hardware shall be done by the Independent Safety Assessor (ISA) as per Safety Integrity Level – 4 (SIL-4) of CENELEC standards or equivalent. ISA to be selected as per RDSO approved list of ISA panel for a generic Signalling Product/System.

23.2.4. ISA will perform the card level & system level fail safety test and the firm shall submit the certificate and compliance of the report to RDSO.

23.2.5. For Network Monitoring System and Key Management System, the independent V&V team of OEM shall check and documentation to this effect shall be submitted to RDSO.

23.2.6. Network Monitoring System and Temporary Speed Restrictions Management System (SIL-4) are not included in KAVACH specification. However, the Packet structure for interfacing KAVACH-NMS and KAVACH-TSRMS are part of KAVACH specification.

23.2.7. The ISA assessment shall be carried out and all the concerned Verification & Validation documents are required to be submitted to RDSO. The documents shall include Hazard log, PHA (Preliminary Hazard Analysis), SSHA (Sub System Hazard Analysis), FHA (Functional Hazard Analysis), THR (Tolerable Hazard Rate) evaluations, Reliability evaluations, Software evaluation (white box testing), Protocol evaluation and Generic Application Safety Case.

24. Operational availability

24.1. The operational availability in terms of successful trips (without spurious

braking, Track Identification failures, etc.) Shall not be less than 98.5% on a weekly basis.

$$Availability = \frac{Mean\ Up\ time}{Mean\ Up\ time + Mean\ Down\ time}$$

24.2. The operational availability (without spurious braking, Track Identification failures, etc.) shall be calculated by the RAMS Manager of the firm. This data shall be analysed for periodically (monthly basis) for the entire life cycle of the system. Monthly reports shall be forwarded to RDSO.

25. Tests and Verification

25.1. The following sequence of tests shall be conducted:

(a) Routine Tests.

(b) Acceptance Test.

(c) Type Tests.

(d) System Acceptance Tests.

(e) Interoperability Tests.

(f) Field Trials.

25.2. Routine Tests

25.2.1. The following shall comprise the routine tests and shall be conducted by manufacturer on each equipment and the test results shall be submitted to the inspection authority before inspection. The validation report of application data in proper format shall also be submitted to the inspection authority in advance:

(a) Visual inspection.

(b) Insulation Resistance tests.

(c) Applied high voltage tests.

(d) Card level/ module level check.

(e) Card-level functional tests on all the cards.

(f) System level functional tests / Performance Test.

(g) System diagnostic tests.

(h) Environmental stress screening test.

25.3. Acceptance Tests

25.3.1. The acceptance tests are carried out as per sampling plan on the lot offered for inspection. The following tests shall comprise acceptance tests:

(a) Visual inspection.

(b) Insulation Resistance tests.

(c) Applied high voltage tests.

(d) Card level/ module level check.

(e) Card-level functional tests on all the cards.

(f) System level functional tests/ performance tests.

(g) System diagnostic tests.

25.4. **Type Tests**

25.4.1. The following tests shall constitute type tests:

(a) Visual inspection.

(b) Insulation Resistance tests.

(c) Applied high voltage tests.

(d) Card level/ module level check.

(e) Card-level functional tests one card of each type.

(f) System level functional tests/ performance tests.

(g) Environmental / Climatic tests.

(h) Vibration tests, abrasive environment tests.

(i) System diagnostic tests.

(j) **Integration tests**: Integration tests to integrate the various sub-systems of the KAVACH and demonstrate correct operation of all internal and external interfaces.

25.4.2. Only one each equipment shall be tested for this purpose. The equipment shall successfully pass all the type tests for proving conformity with this specification. If the equipment fails in any of the type tests, RDSO may call for other equipment/ card(s) of the same type and subject it to all tests or to the test(s) in which failure occurred after taking necessary corrective and preventive action. No failure shall be permitted in the repeat test(s).

25.5. **Functional Tests**

25.5.1. The functional tests shall be carried out after successful type test and internal V&V testing. The functional tests shall be carried out to demonstrate that the complete KAVACH system operates correctly in accordance with the Specifications. The functional tests shall sequence through all required operations to prove that the system performs in accordance with the Specification and that the local configuration of data is correct. Where necessary, input conditions shall be simulated.

25.6. **Interoperability tests**

25.6.1. The KAVACH system developed by a vendor shall be interoperable with existing vendors. This shall be tested in RDSO lab or IRISET Lab for communication between Onboard KAVACH of applying vendor with Sta-

tionary KAVACH of existing vendors and Stationary KAVACH of applying vendor with Onboard KAVACH of existing vendors.

25.7. **Field Trials**

25.7.1. Before the start of passenger field trial for 30 days, the following shall be submitted to RDSO: -

(a) The RFID layouts, Tag data, KAVACH control table and wiring diagrams shall be got approved before the start of the trial.

(b) All executive and application data.

(c) Braking parameter for a different type loco and various combinations of load.

(d) Functional test documents duly checked by internal V&V shall be submitted to RDSO.

(e) 10 trips of Light Engine trial with all feature i.e. loop line speed control, SPAD Prevention, head on collision, rear end collision, PSR, TSR, automatic whistling of horn, train length assignment, speed margin, protection of rollback, all SOS features with "No issue" with finalised parameters shall be submitted.

25.7.2. The functional test and field trial format will be available in RDSO website.

25.7.3. The operational availability shall be as per applicable clause.

26. For Approval under developmental Order

26.1. For approval in Absolute Block Section, the firm has to conduct 30-day passenger trials on nominated trial section.

26.2. For Semi high speed fo 160 kmph, the trial shall be conducted in nominated section with light engine and formation.

26.3. For approval in Automatic Block Section, the firm has to conduct trials for a cumulative distance of 5000 km of loco run and 2500 hrs of RIU operation. After approval, each firm shall continue to demonstrate reliable performance of RIUs during a performance monitoring period of an additional 5000km of loco run over 2500 hours.

26.4. There shall not be any occurrence of spurious EBs on account of KAVACH during the trial. If there are any such spurious EBs, the firm shall carry out necessary Corrective action and start the trialsa fresh.

27. For Approval

27.1. 1 million hour's operation time, at least 2 year's experience with different equipments including safety analysis, detailed documentation also of minor changes during operation time. (Ref- EN-50129 -2003)

27.2. The operation time for the loco, station shall be calculated separately.

27.3. The firm shall submit the documental evidence throug theh NMS log for the above.

28. Quality Assurance

28.1. All materials and workmanship shall be of good quality. Since the quality of the equipment bears a direct relationship to the manufacturing process and the environment under which it is manufactured, the manufacturer shall ensure Quality Assurance Program of an adequate standard.

28.2. All test instruments shall be available by the manufacturer.

28.3. The manufacturer shall have a detailed Quality Assurance Plan to ensure the quality of the product. The manufacturer shall also possess ISO certification for the product.

29. Packing

29.1. The equipment shall be so packed that it can withstand bumps and jerks encountered on a road/ rail journey including handling during its transit.

30. Marking

30.1. Markings on the equipment shall comply with Clause 12.1 and 12.2 of RDSO specification RDSO/SPN/144/2006 or relevant clauses of latest amendment.

30.2. The words “Indian Railway Property” shall be engraved / embossed on every unit in letters of 5mm size (minimum) at a conspicuous place.

30.3. The anodized name plate shall be firmly attached to every unit and shall show the following information.

(a) Name of trade mark of the manufacturer.

(b) Serial number of the unit.

(c) RDSO specification number.

(d) Name of the equipment.

(e) Operating voltage: 110VDC/72 VDC or as appropriate.

(f) Month and year of manufacture.

31. Documentation and Training

31.1. The manufacturer shall provide the following documents for eac piece ofh equipment, which constitutes KAVACH system

(a) Two copies of Manuals of Installation, Operations and Maintenance for each type of equipment

(b) Diagnostics procedure including troubleshooting charts.

(c) The procedure to check complete Stationary unit, the Onboard ka-

vach unit in the Loco shed & also inspection.

(d) List of equipment to be used for carrying out various tests on the Onboard & stationary unit

(e) Detail maintenance schedule & maintenance procedures including frequency to maintain various KAVACH equipment.

(f) List of spares, tool kit etc. to be provided to the user as mentioned in approved installation and maintenance manual.

(g) Adequate training in installation, operation and maintenance practices to be imparted to Railway staff.

(h) Pre-installation checklist, pre commissioning checklist and maintenance checklist are also to be submitted.

32. Sampling Procedure for Acceptance Test

32.1. Visual inspection shall be conducted on all the units offered in a lot. The modules shall be tested as per the sampling plan given below**:**

Test Description	Onboard KAVACH Unit	Stationary KAVACH Unit	TSRMS	RFID Tags	Network Monitoring System	RIU
IR Test	**N/2**	**N/2**	**N/2**	**-**	**-**	**N/2**
HV Test	**N/2**	**N/2**	**N/2**	**-**	**-**	**N/2**
Card / Module Level Check	**N/2**	**N/2**	**N/2**	**-**	**-**	**N/2**
Card Level Functional Check	**N**	**N**	**N**	**N/10**	_	**N**
System Level Functional Check	**N**	**N**	**N**	_	**N**	**N**
System Diagnostic Test	**N/2**	**N/2**	**N/2**	_	**N**	**N/2**

32.2. The Brake Interface Unit shall be got checked by directorates of Motive Power/ PS & EMU depending on the type of locomotives.

33. Purchaser Railways -Role

(a) Vital inputs

(b) Type of tower.

(c) Height of tower.

(d) Design basis for foundation.

(e) WPC Clearance.

(f) Type of loco, brake system, input interface details or other self-propelled vehicle

(g) Interface details of brake system

(h) SIM Cards

(i) Nomination of AT & BT track circuits and their occupancy period

(j) Direction sensing type speed sensors

(k) Auto whistling at Level Crossing Gates, whistling pattern, interface details

(l) VDU requirement at station

(m) Requirement of spares.

34. Site Acceptance of KAVACH system in Railway

34.1. Before the beginning of the revenue service, at the First Specific Application level, the results obtained by the firm and collected in the KAVACH Generic Application Safety Case shall be confirmed by experimental testing on a real line and with a real train, simulating all the fault scenarios (including odometry faults, RFID tags message loss etc.) in degraded track conditions.

34.2. Before employing the KAVACH system in the real environment for the first specific application, this specific application shall be covered by a Safety Case and related ISA report. The activities shall be performed according to the allocated SIL as defined in CENELEC standard EN-50129.

35. Infringement of Patent Rights.

35.1. Indian Railway is not responsible for infringement of Patent rights due to similarity in design, manufacturing process, use of components used in design, development of manufacturing of such equipment and any other factor which may cause dispute.