RailAcoustic®
TRACK-SAFETY CONDITION MONITORING SYSTEM

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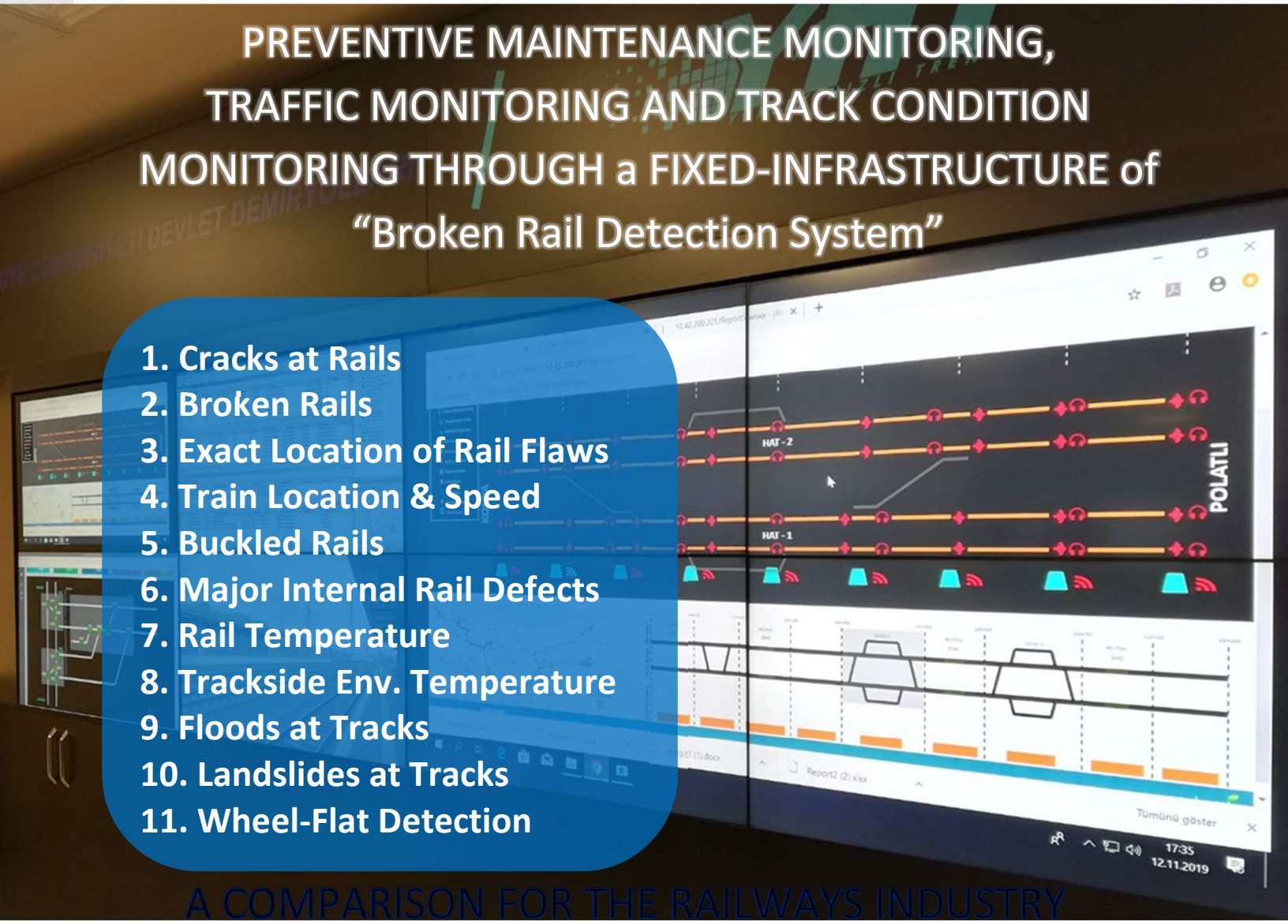
RailAcoustic®

TRACK-SAFETY CONDITION MONITORING SYSTEM

PREVENTIVE MAINTENANCE MONITORING, TRAFFIC MONITORING AND TRACK CONDITION MONITORING THROUGH a FIXED-INFRASTRUCTURE of "Broken Rail Detection System"



1. Cracks at Rails
2. Broken Rails
3. Exact Location of Rail Flaws
4. Train Location & Speed
5. Buckled Rails
6. Major Internal Rail Defects
7. Rail Temperature
8. Trackside Env. Temperature
9. Floods at Tracks
10. Landslides at Tracks
11. Wheel-Flat Detection

A COMPARISON FOR THE RAILWAYS INDUSTRY

SMART RAILROAD SAFETY

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A COMPARISON FOR THE RAILWAYS INDUSTRY

TECHNOLOGICAL COMPARISON MATRIX	Track Circuits	On-Board Ultrasonic Inspection Systems	Ultrasonic Stationary Inspection Systems	Fiberoptic Peripheral Intrusion Detection Systems	RailAcoustic® Acoustic Stationary Inspection System
Detection of FULL RAIL BREAKS	NOT RELIABLE	✓	NOT RELIABLE	NOT RELIABLE	✓
Detection of PARTIAL RAIL BREAKS	X	✓	NOT RELIABLE	NOT RELIABLE	✓
DETERMINING THE EXACT LOCATION OF RAIL FLAW	X	✓	X	NOT RELIABLE	✓
Detection of rail breaks WITHOUT A NEED OF TRAIN PASSING THROUGH THE DEFECTED ZONE	✓	X	✓	X	✓
Detection of LANDSLIDES & FLOODS	X	X	NOT RELIABLE	X	✓
TRAIN SPEED MONITORING	X	X	X	✓	✓
TRAIN MOVEMENT MONITORING	✓	X	X	✓	✓
TRACK TEMPERATURE MONITORING	X	X	X	X	✓
FLAT-WHEEL DETECTION	X	X	X	NOT RELIABLE	✓
DERAILMENT DETECTION	X	X	NOT RELIABLE	✓	✓
CONTINUOUS & REAL-TIME MONITORING	✓	X	NOT RELIABLE	✓	✓
RELIABILITY IN BROKEN RAIL DETECTION	X	✓	X	X	✓
SELF CALIBRATION & ADJUSTMENT	X	✓	X	X	✓

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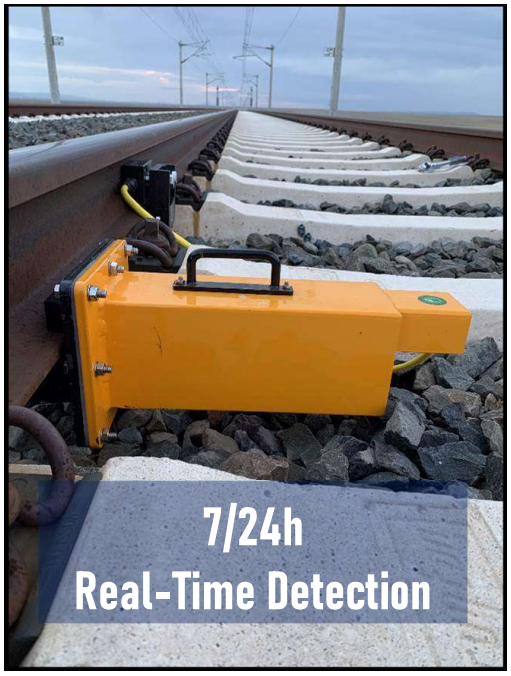
PROVEN at High Speed Line



RailAcoustic® detects the rail flaws, without a need of train passing through the defected rail section!

ACOUSTIC DOMAIN TECHNOLOGY

RailAcoustic® is in operation since late 2018 succesfully, at a 90 km double-track High-Speed Railway Line section, as a fixed-infrastructure of "Broken & Cracked Rail Detection System", with many additional features such as; train movement & speed monitoring, landslide-flood detection, flat-wheel detection and more…
And new projects are about to start!

With the latest developments in the railway signaling industry, like ERTMS transformation; a huge monitoring gap emerged due to the unattended rails of the tracks. RailAcoustic® System is competing with many technologies existing in the market, but in particular for "Broken Rail Detection", it seems to be positioned as the only complete, effective and reliable solution, so far. Considering the technical abilities of the system like Track Monitoring, Rail Temperature Monitoring, Cracked Rail Detection, Wheel-Flat detection, Landslide Detection and so on; we think that, our technology will be shifting a large field in the industry to the "Acoustic Domain", very

shortly. In this regard, we can even be transforming all the condition monitoring, track monitoring and preventive maintenance categories into this new domain.

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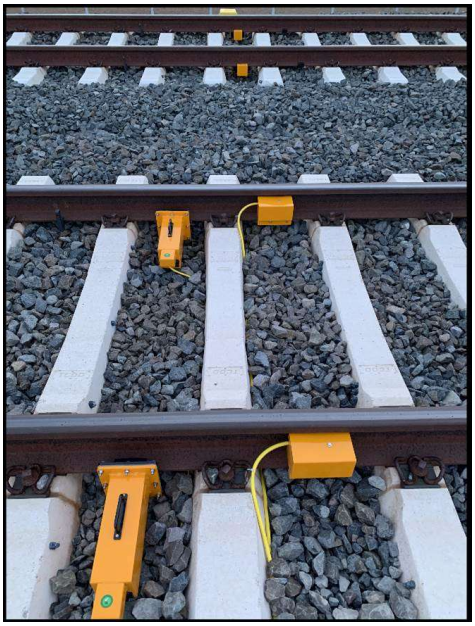
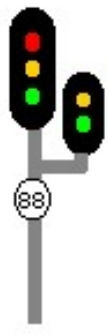


1. RAILWAYS - FOR A SAFER FUTURE

Rail System Solutions, around the world, have an increasing consideration among the transportation strategies for the reason of their being rapid, cost effective, eco-friendly and reliable.



The most important feature of a Railway System is its feature of being a highly secure system, in comparison to alternative transportation systems. So, the systems which maintain a high security standard like the railways, have to be supported by a well-conceived, straight and systematic maintenance, monitoring and safety check system which is particularly essential for the continuity of their safety level.

On the other hand, it may not always be a satisfactory answer to appeal only to human observation and

perception in such security reliant systems.

Full physical integration of the rails rely on some parameters which directly and basically affect the safety in railway transportation. In this sense, identifying or finding a broken or damaged rail segment on the track beforehand has also a great importance.

✗ Currently, the most commonly used broken rail sensing method is the track circuit that work with the basic principle of electrical continuity of the rails. However, this method mostly may induce misdetection in consequence of using the track as a line of return current flow concurrently.

✗ Axle counters which are commonly used at most railway systems anyway are not sufficient for sensing the rail breakages or damages reliably.

✗ Breakages or physical damages on high speed railway tracks happen every now and then. Currently, continuous daily visual inspections overcome a major accident on these lines but what if these inspections fail to spot a breakage one day?

✓ **RailAcoustic® Broken Rail Detection System** which has been developed by Enekom is working on the basis of sensing the acoustic signals on the rail, created by resonance with a significant frequency generated on track from a point at a far position.

✓ With this recent and unique system which the application for 2 patents have also been done and all the performance tests on a high-speed railway line (Ankara-Konya) are already accomplished, a breakage or a damage on the rail section lying between the acoustic signal application point and the detector at a far position (2Km apart) can

easily be perceived and this information is conveyed to control and data center via a fiber optic communication line.

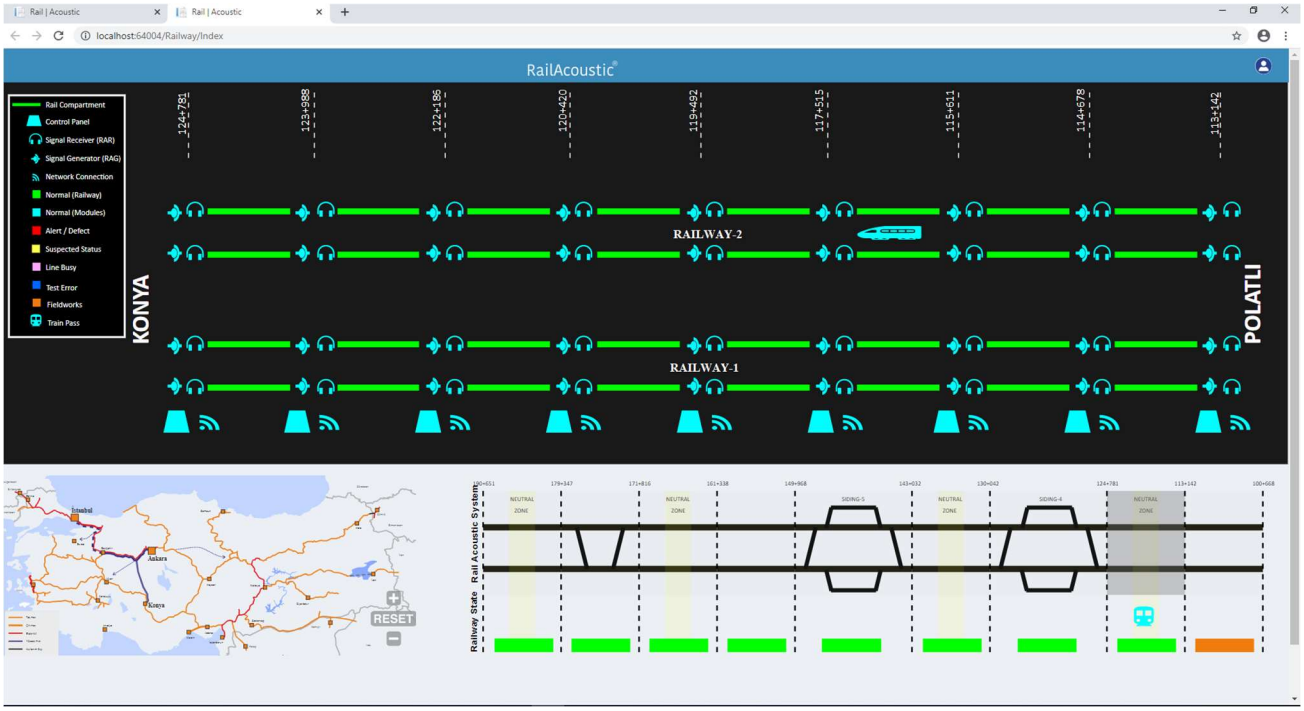
2. ADVANTAGES OF RAILACOUSTIC

RailAcoustic®, The Broken Rail Detection System of ENEKOM is a dynamic sensor system working with electronic and acoustic methods thoroughly. While a specific acoustic signal is injected to rail on one point, the transmitted acoustic signal is read from another point simultaneously. The difference between the injected and received signal levels and the shape as well as any reflection signal detected by the sending side detector reveals an accurate test result about the integrity of the rail segment in between the injection point and sensors located at a distance on both sides. The test result revealing the physical integrity condition of both of these rail segments is transmitted to control center through an IP based fiber-optic communication network.

✓ The sensor is in the state of listening to the line continuously. The noise existing in the background is monitored continuously. A synchronization signal transmitted over the rails ensures that the background noise is filtered from the received signal and the extracted information about the rail condition within line block being tested and measured is obtained in a clean manner.

✓ 5 to 60 minutes of duration between the consecutive tests of RailAcoustic® system in most of the high-speed railway applications would be enough. This duration may be decreased to seconds level and, also be increased to hours or even days level.

Under normal conditions, this kind of parameters are designed by the railway maintenance operator of the line according to the train traffic frequency of the line where the system is used. Programming of all timing parameters can be made from



operator's console in remote central control room.

✓ The computer within remote central control room sends command of starting the test to the sensing units installed on the track and exhibits test result data coming from these units on operator console audio-visually. Test result data for rails within the block being tested is produced by sensor modules fitted on the track and transmitted to the computer in central control room over the communication network. Collected data is stored in a permanent storage unit of central computer and may be reused in the future if required.

✓ Each field unit performs self- diagnostic tests with very short time intervals and saves this status information in its memory for transmitting it to central control computer afterwards. All components of the system are checked automatically by operator control computer in center continuously. The computer in remote center

sends a question per second to these units about their situation and checks whether they are in operating state or not. This information belongs to operating status of both fiber-optic communication network and vibration applying and vibration sensing modules and consequently, it is a definite data showing whether each point of entire sensing system from start to end runs correctly or not.

✗ As an alternative technology, track circuits apply an electrical signal to a certain rail block and check the continuity of the signal. However, this signal, since the rails are also used as a return current circuit, reaches to wrong results in many times.

✗ Apart from these methods, there are rail breakage sensing/analyzing processes made via ultrasonic sensors placed on a vehicle, moving on rails for testing purposes of the line. However, since these systems keep the line occupied and are not suitable for continuous measurement, cannot present the flexibility and safety, presented by RailAcoustic. On the other hand, it has also been known that ultrasonic rail breakage sensing systems mounted on the tracks cannot perform properly and effectively as well, due to various technical disadvantages based on the nature of that technology.

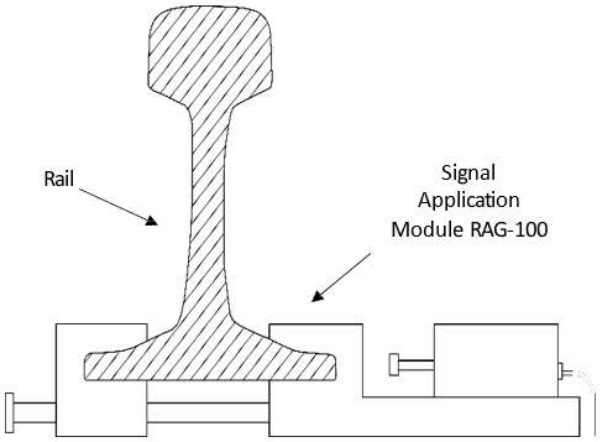
3. WORKING PRINCIPLES OF ENEKOM'S BROKEN RAIL DETECTION SYSTEM

RailAcoustic® which is fully designed and manufactured by Enekom, apart from all other broken rail sensing methods, works on the principle of applying a specific resonance frequency of vibration into the rails at a certain point of the track and then sensing this vibration simultaneously both from the sensor located near to the signal injection point and from the other sensors which are located at a faraway point on the left and right hand side of the injection point.

Basic characteristics of the **RailAcoustic®** are as follows;

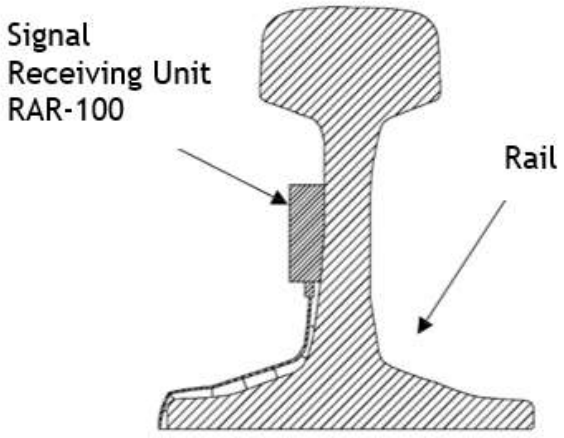
- ✓ It can be used satisfactorily and reliably at the railway lines which are rendered continuous mechanically and electrically by a welded joint,
- ✓ It can work independently from the ballast resistor value,
- ✓ The system works completely isolated from the electrical properties of the track and it can sense the broken segments on any AC, DC or un-electrified tracks,
- ✓ It doesn't interfere with any other railway signaling equipment connected to the track,
- ✓ The system modules can be easily and quickly installed or dismantled without any damage to the rails,
- ✓ Performance testing has been completed satisfactorily on Konya-Ankara high-speed railway track, which is in compliance with UIC60 standards,
- ✓ It works reliably and responsively under all weather conditions, with proven operating history since the installation of the system in mid-2018.

RailAcoustic® - Enekom's broken rail detection system consist of 5 different components; **RAG-100** acoustic signal application module, **RAR-100** acoustic signal sensing module, **RASP-100** a track-side control cabin with a number of electronic boards in it for driving RAG-100 and RAR-100 modules, an IP based fiber optic communication system for the connection of these electronic boards and all related modules to the remote computer located in the railway command center and **CCSM-100** central control software module running in this computer.



On the field, one **RAG-100**, the signal application unit and one **RAR-100**, the signal sensing unit are mounted on to the exterior side surface of the rail on up to approximately every 2 kilometers distance.

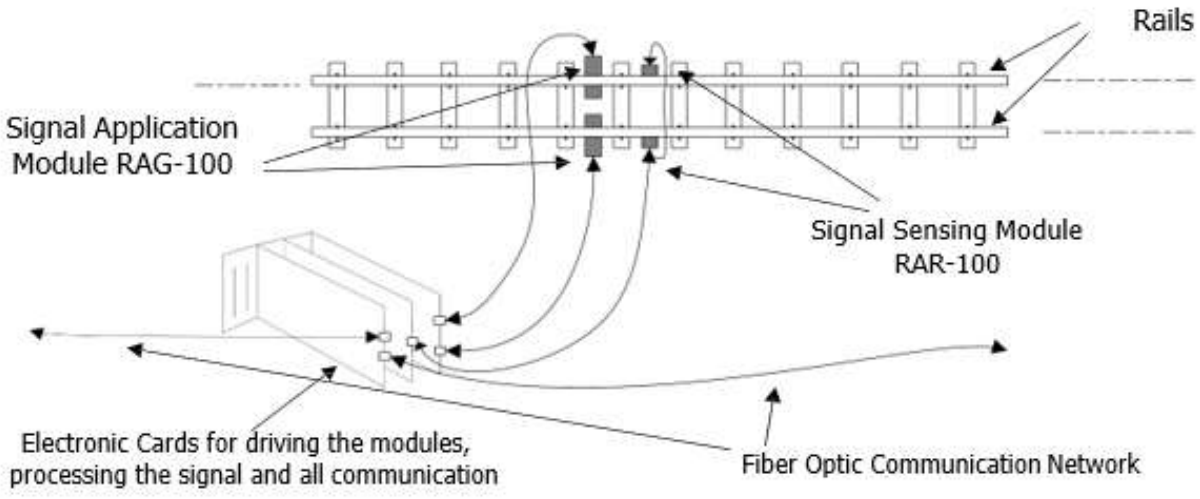
RAG-100 is designed as to be easily installed and demounted onto the rail mechanically. Both the installation and the long-term usage of this module does not require any mechanical intervention such as punching or welding. No direct or indirect damage to the static structure of the rails with long-term use of the system is expected.



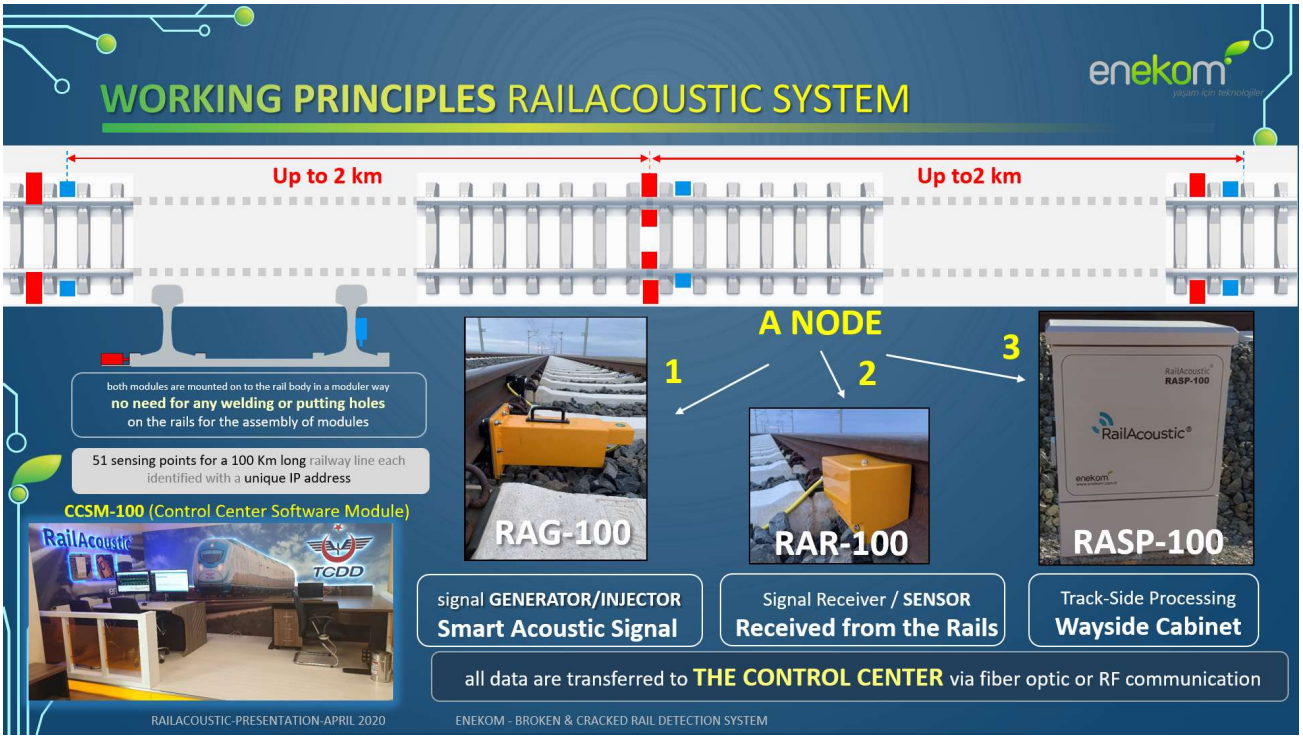
The sensor module RAR-100 is installed on to the rails at a distance of approximately 1 meter to each RAG-100, the signal application module, as to be connected on the same electronic control cabinet.

On the rails, equipped with these modules, the acoustic signal is applied at a certain point on the rail is immediately measured by the sensor which is just next to the signal application unit. If this applied signal is at the previously accepted reference level and shape after it is measured by the nearby sensor, then the relevant system board in the control cabinet conveys this respecting information to the sensors which are positioned at up to 2 kilometers on the right and on the left side of the signal application point through the fiber optical network communication system.

These two neighboring sensors start listening to the connected rail until they sense the incoming acoustic signal. They pass this incoming acoustic signal induced data, to the nearby cabinet for further signal processing. All acoustic test data is collected from relevant track side cabinets via the IP based fiberoptic communication network under the control of remote command center computer for final decision making process in regards to the physical integrity of the rail segment which is being under test.



Right along with the perception, by detecting the difference in signal level, the sensing element which is located just next to the signal application point senses the vibration on the rail, first decides if the signal level is at the reference level and if the signal is acceptable then it starts to work for signal processing in order to sense the returned signals which will be received from defective rail blocks that are at a distance of 1 Km on the right and left of the route. With the perceived signal after this process, as it covers the reflected signals coming from the damaged sections of the rail, the track damage/output information in addition with the signal level results received from the right and left detectors at a distance of up to 2 kilometers are generated and this information is transferred to host computer of the central control station through the fiber optic communication line. This reflected acoustic signal guarantees the correct result when combined with the data received from both, left and right hand side detectors.



4. COMPLETED PROJECTS – RAILACOUSTIC®

RailAcoustic® Broken Rail Detection System has been installed and now operational at a 90 km section of Konya-Ankara High Speed Train Line (Double Track) and 4 km section of conventional rail line in Ankara. The contractual acceptance of the RailAcoustic® System has been granted on 30 November 2018 and the management signatures were completed on 31 December 2018. **The Final Acceptance Test of the system has been accomplished on 31 January 2019**, with a rail cutting process on the track at a random point along this 90 km RailAcoustic® equipped double track section. 2 months of trial operation was carried out between 02 December 2018 and 31 January 2019. The development process of the RailAcoustic® system continues to be carried out by Enekom with the support of the Turkish Railways Authority to achieve improvement targets such as flat wheel detection, land slide detection and animal access detection on the lines since beginning of the acceptance of system. **The second project on another High-Speed line between Sivas and Ankara is in progress!**

SITE INSTALLATION DETAILS FOR 90 KM DOUBLE TRACK HIGH SPEED LINE:

In total, 69 Sets Of (a) Track Side System Process Panel + (b) Signal Receiver (for Each Rail) + (c) Acoustic Signal Generator (for each rail) have been assembled on 212 Km long HSL track starting from

Konya City Center Rail Station and extending on Ankara direction for a 90 Km long double track section. The site installations cover both straight tracks and switch sections.

CONTROL CENTER INSTALLATION DETAILS:

- Control Center location have been chosen by the Railways Authority depending on the existing network infrastructure (i.e. Ankara Eryaman High Speed Train Station which is 100 km far from the RailAcoustic® equipped section of rail line).

- Fiber optical cable line along the tracks was already routed by the Railways Authority which is fundamentally used for data communication (the alternative is radio frequency).
- The Control Center consists of a computer set and the control software of RailAcoustic® System.
- The Control Center is capable of communicating the aforementioned 69 sets of site devices separately or entirely on an IP based network communication line.
- The Control Software performs the broken rail detection tests in a fully automatic manner at the pre-set time periods, or manually under the control center operators' control.

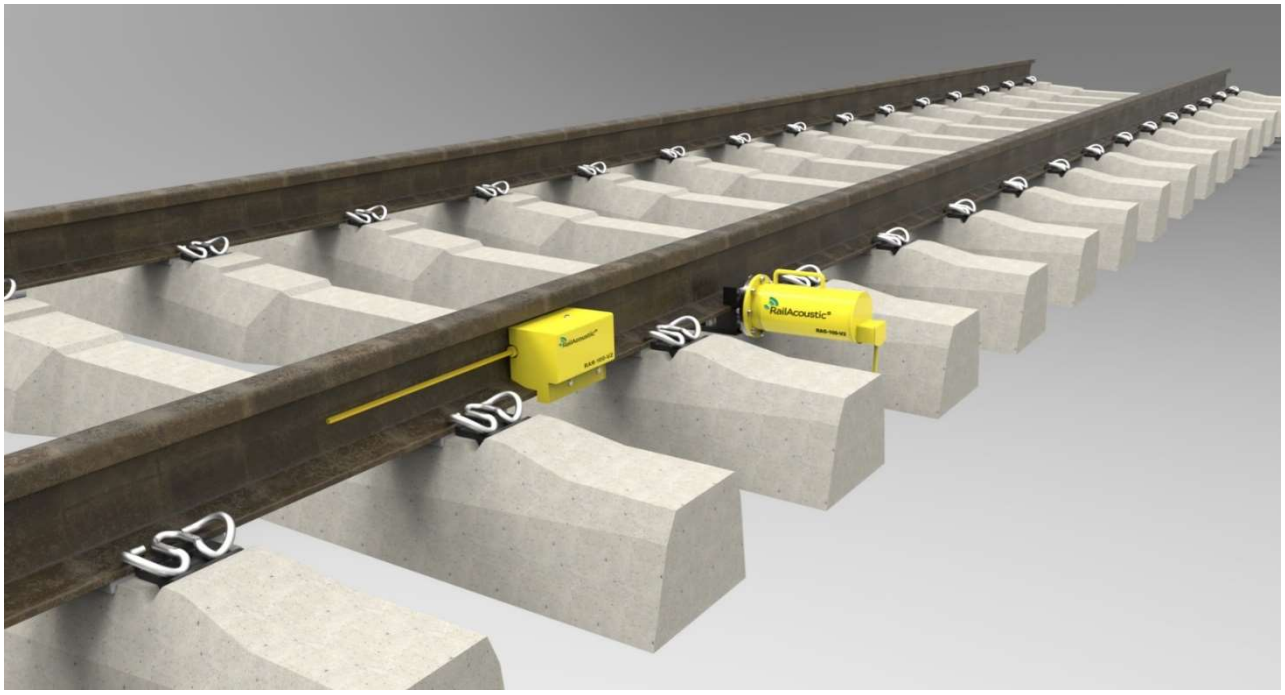
5.

5. MODULES AND COMPONENTS OF RAILACOUSTIC SYSTEM

Enekom's **RailAcoustic® Broken Rail Detection System** is an integrated system comprising of RAG- 100 the signal application module, RAR-100 the sensing module, RASP-100 the fiber optic network communication and power module and CCSM-100 the central control software module.

The components, lying through an elongated railway track and which the system's main rail-mounted and trackside units ("nodes") have a distance of up to 2 kilometers between each other are operating as attached to a fiber optic based ring topology communication network which operates on an industrial strength IP protocol.

Central Control Software Module monitors the continuity of an uninterrupted communication between each of system components and central control software module itself. At the same time, it activates a precise timing communication




RailAcoustic®
RAR-100-V2
RailAcoustic®
RAG-100-V2

sequence between neighboring signal application and sensing units in accordance with a significant test synchronization protocol.

The receiving and transmitting modules of each block are operated and scheduled according to the commands coming from the central command software of the central command computer and also the test results are transferred to this central control soft module again through the same communication line.

Full information is gathered at CCSM-100 module and transferred to system operator as visual and audio messages over a 3 LCD display system or a large wall screen module.

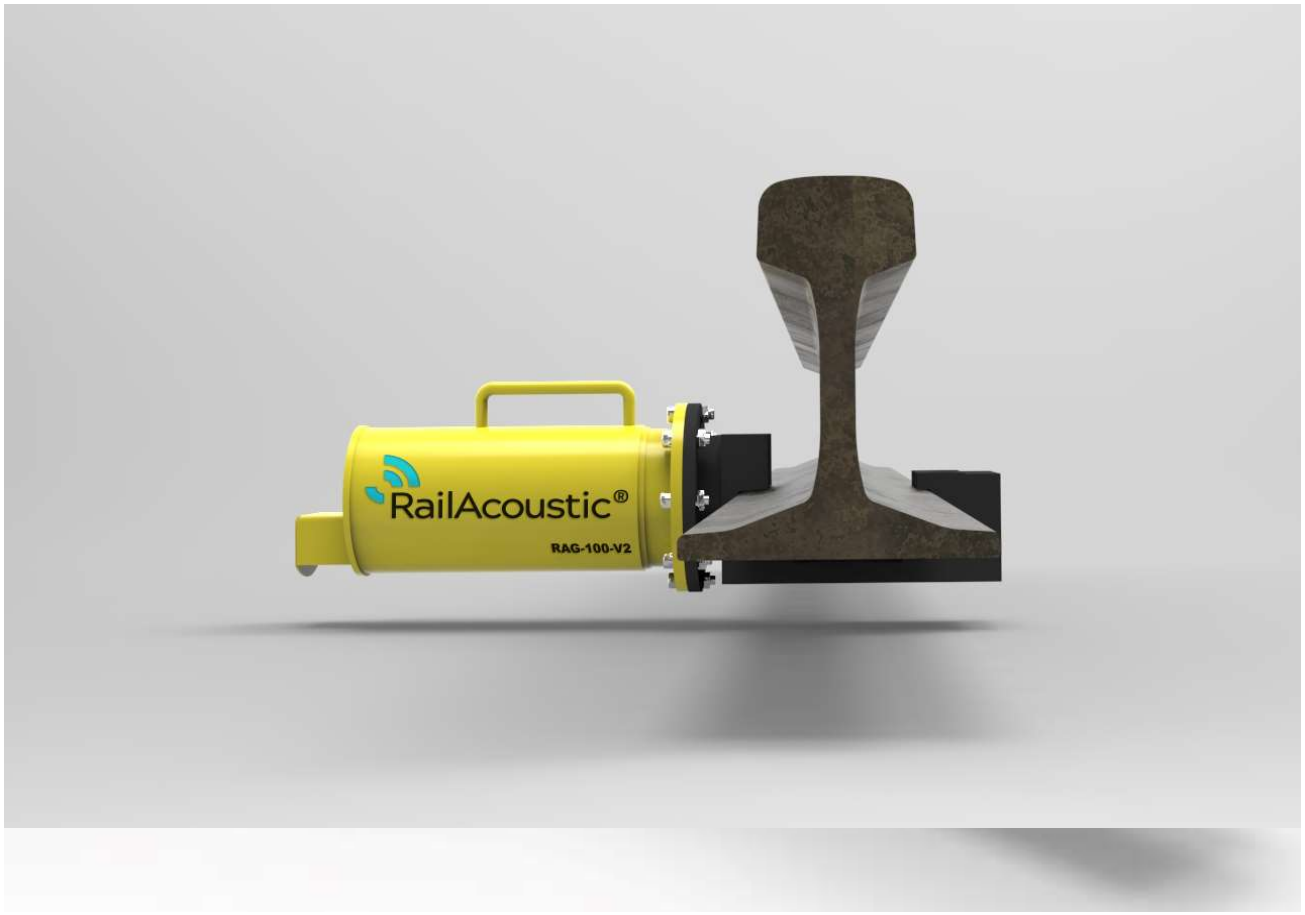
Besides, full data regarding the rail condition of all track segments and telemetry readouts are constantly recorded to the memory of the central control module for future reference. All central control soft module alarm messages are also available thru authorized personals' smart phones and sms messages.

5.1 RAG-100 Acoustic Signal Application Module

RAG-100, is an electronic acoustic signal application unit, working in short periods of time. The unit is activated by a 32-bit microprocessor, by the 'StartTEST'' command received over the Enekom RASP-100 signal processing and fiber optic communication module.

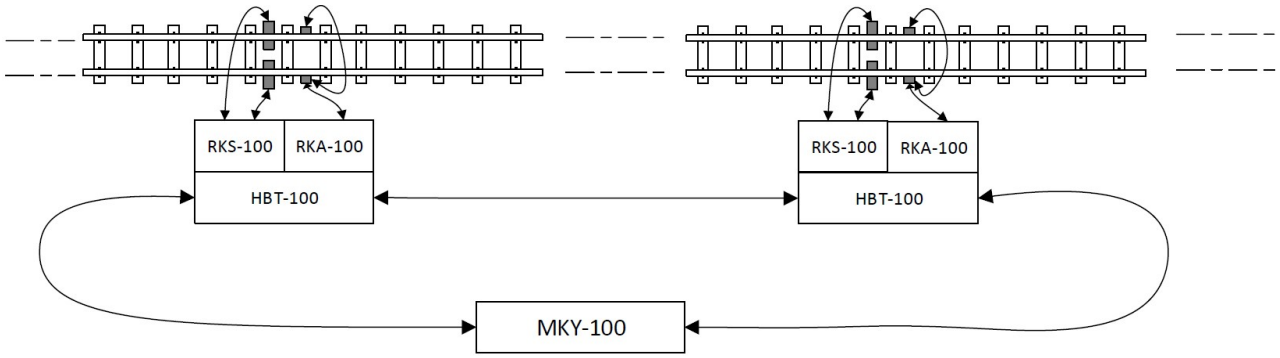
The 'StartTEST'' command is generated and transmitted from CCSM-100 central control software module to each track-side RAG-100 signal generation module one by one. In a normal test procedure, just after 'StartTEST'' command is received from CCSM-100, five or more vibration block signals with short periods of time between each, are applied to the relevant rail segments by each RAG-100 module.

RAR-100, the acoustic signal sensing module begins to measure the applied signal's strength and conveys the information of whether the measured signal strength is in



the accepted range through the fiber optic communication network to the central control software module CCSM-100 via the track-side module communication board which is in the RASP-100 track-side control cabin.

Each RAG-100 acoustic signal application module applies a vibration signal to the rail on the purpose of this rail-resonation induced signal being sensed by a neighboring sense module RAR-100, positioned just 1 mt away and at the same time by two other remote sensing modules RAR-100, which are located at a distance of up to two kilometers on the right and on the left to this signal application point.



5.2 RAR-100 Acoustic Signal Sensing Module

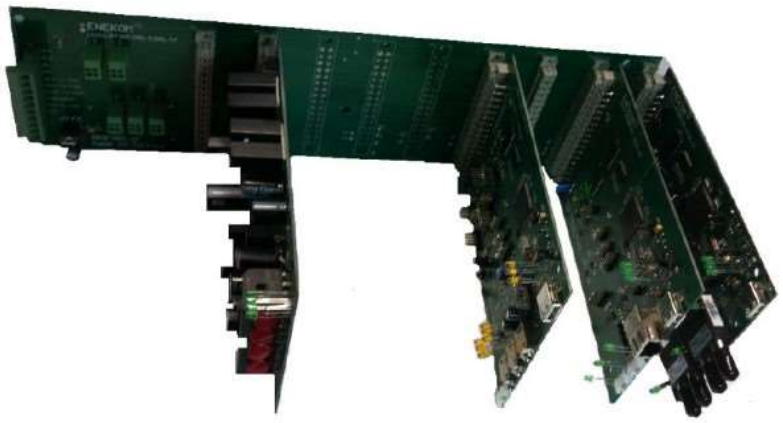
RAR-100 measures and reviews the signal levels received from 2 RAG-100 signal application modules in different frequency and time segments which are located on both sides of the attachment point and produces information of whether a broken rail segment on each block are sensed or not. In addition, it senses whether the signal produced by a RAG-100 signal application module which is positioned at a distance of approximately one meter to its attachment point are in reference signal levels or not

and also this module detects the reflected signals from the defected or damaged rail segments located on both sides of the track.

RAR-100 signal sensing module works concurrently with the signal application modules RAG-100, placed at a distance of up to 2 kilometers on both sides and when the testing starts, it evaluates the measured signals coming from 2 kilometers on each side, together with the previously measured reference background noise levels transmitted over RASP-100 communication module, from the central control software module CCSM-100 and derives a clear signal by sorting out this signal from the background noise. RAR-100 sensing module processes this signal, it produces the information of whether a breakage or a damage exists or not. At the same time, the sensing module reviews the returned reflection signals. At the end, a result information is generated by the module, belonging to both side rail segments' physical integrity level and transferred to central control software module via RASP-100 communication module.

5.3 RASP-100 Control Cabin and Electronic Boards

One of the main components of RailAcoustic® Broken Rail Detection System is a control cabin which is positioned alongside the track. This cabin provides a solid housing to a number of electronic Boards which are utilized for controlling the track-side system modules, providing a communication environment in between these Boards and the CCSM-100 central control software module via the fiber optic communication environment.



This metal cabin is designed each time in a flexible manner according to the general technical specifications of the railway project in which it is used. In general, it is designed and manufactured in order to protect the electronic system boards from all climatic and environmental extreme conditions and maintain the system's integrity accordingly. It is supposed to be installed at least 50 cm above the ground level. This metal cabinet is mounted approximately at a distance of 3 meters next to the track.

There are three electronic boards inside the RASP-100 module:

1- RKS-100: Vibration signal generation board driver
2- RKA-100: Vibration signal receiving board driver
3- HBT-100: Vibration signal processing board

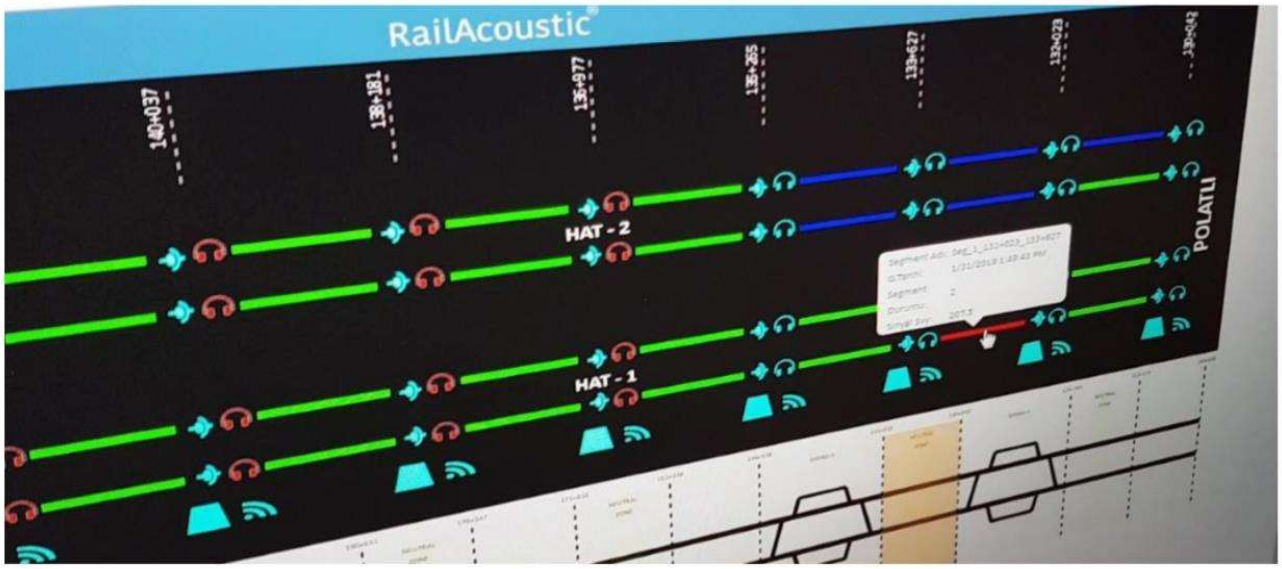
The RAR-100 module is connected to HBT-100 signal processing board via RKA-100 driver.

5.4 CCSM-100 Central Control Software Module

CCSM-100 is capable of sensing any broken or damaged rail segment on every 2 kilometer blocks and submitting this information to the operator over a 3-screened computer as visual and audio messages in communication with the IP network directory of the site spread electronic modules belonging to RailAcoustic® Broken Rail Detection System through a track-side fiber optic communication network cabinet, named RASP-100.

The software is written for Windows and Linux operating systems and developed by using the Java and Phyton languages. In order to be able to login to the system or to intervene, a pre-defined encrypted password should be entered.

All the tracks through the route are monitored at the control central by the operator over a dynamic visual, extended on 3 screens enhanced diagrammatically and in visual blocks representing approximately 2 kilometers track. Trouble-free rail segments on the screen will be represented with green color, blocks under test will be represented by yellow and the identified fractured rail segments, if any will be represented by red.



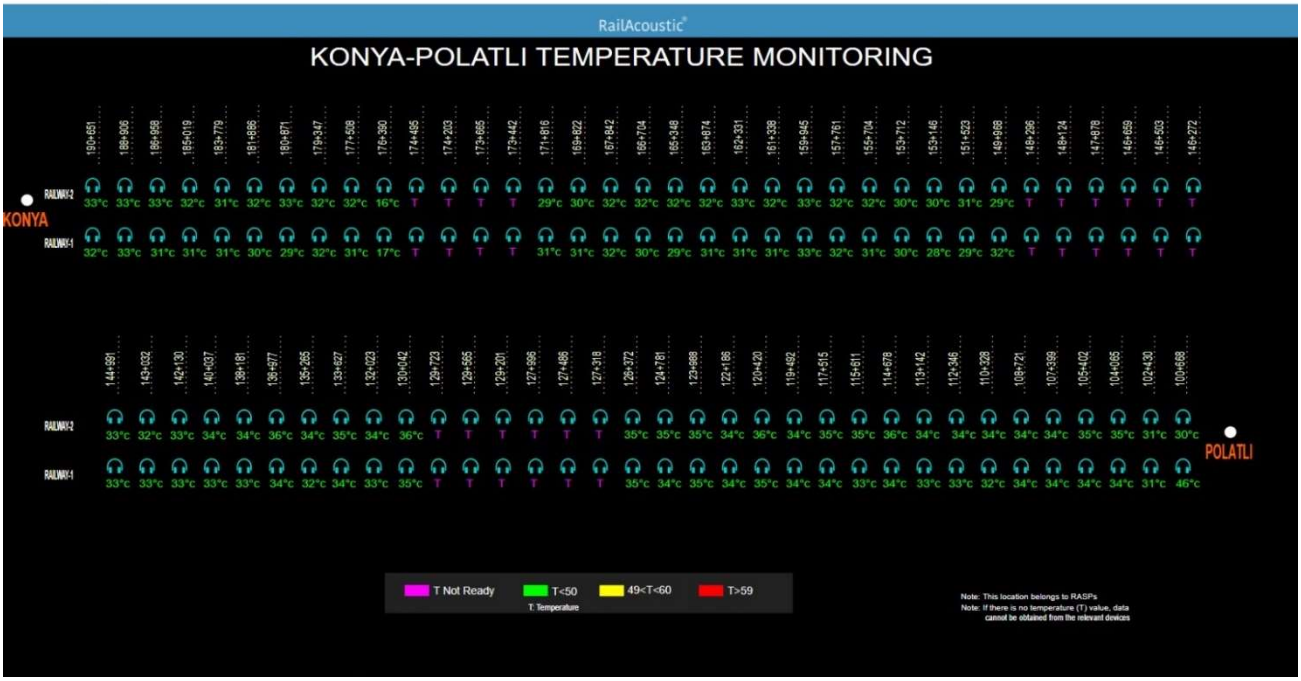
Broken Rail Indication On The Monitoring Screen of Command Center Computer

If any breakage is perceived in any rail block, the color of the represented rail section will turn into red from yellow and the computer will alert out operator audio visually. The audible alarm can be silenced only by the authorized personnel and providing recording at the same time.

Yet another function of CCSM-100 is to make time dependent recording for the diagnostic information of the whole components of the system and for the test results of the rail blocks and also achieving this information when needed.

All information stored in the HDD and flash memory can be printed out by user password only.

One of the most useful features of Railacoustic system realtime continuous rail temperature measurements at each node point. This feature is heavily in use by the maintenance teams of the railways maintenance department. The system is also capable of giving some other critical environmental data to the remote command center operators such as air temperature and humidity.



6. ABOUT ENEKOM IN BRIEF

Enekom was founded under the “Technologies for Life” slogan in 2009 and has been active in electric-electronic and machine design and manufacturing fields in the body of ODTU-TEKNOKENT (METU-TECHNOPOLIS) established in the land of Middle East Technical University in Ankara.

The company has developed new technologies especially in railway and automotive sectors and put them into market successfully thanks to its highly professional personnel who are pioneer and productive in their fields.

Enekom made applications for 4 patents which shall support its unique design and manufacture understanding within these sectors in the next coming years.

There is a number of government backed research projects, we continue to work on, at the moment. The company has some technology development and support agreements signed with several engineering companies currently.

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