4.1 Final publishable summary report

Executive summary

To improve the efficiency of maintenance activities in a rail network and ensure an acceptable level of safety for rolling stock operations, rails are inspected at regular intervals for structural defects, profile irregularities and excessive wear. Rails are inspected either manually or with hi-rail vehicles and test trains using traditional non-destructive evaluation techniques such as vision (including automated systems), magnetic particle inspection, magnetic flux leakage, ultrasonic and eddy current testing. The accuracy of the inspection process is of critical importance in minimising the risk of catastrophic failures, improving maintenance scheduling and optimising rolling stock operations. The inspection procedures currently employed by rail infrastructure managers are not adequately efficient as they depend on the mobilisation of a significant amount of resources, both in terms of special test equipment and expert personnel. Moreover, the inspection process needs to be carried out in segments either at night or when the line is closed to avoid disruption of normal rolling stock operations. Rail infrastructure managers due to various reasons have not benefited sufficiently from recent breakthroughs and innovation in inspection technologies that other industrial sectors are already taking advantage of.

Rails are subjected to harsh environmental conditions and the loads that they must sustain when in service are high and complex. The loads endured by rails can vary substantially, depending on axle loads, traffic speed, the performance of sleepers and wheel-rail contact conditions. In service damage can develop in the head, web or foot of the rail. In modern rail networks the majority of the defects tend to occur more often on the rail head. Apart from profile wear and irregularities, Rolling Contact Fatigue (RCF) is a particularly common surface defect found in the rail head. Rail head defects can be distinguished to those having internal origin, such as progressive transverse cracking or kidney-shaped fatigue cracks, horizontal cracking with or without transverse cracking of the rail head, horizontal cracking beneath the gauge corner, and longitudinal-vertical cracking, and those having surface origin, such as RCF damage (e.g. gauge corner cracking, etc.), and indentures. Rail web and foot defects include longitudinal and vertical cracking, star-cracking, transverse fatigue cracking, and rail foot corrosion. Catastrophic rail failure due to growth of structural defects can be avoided by careful inspection and appropriately scheduled maintenance.

The I-RAIL is Research for the Benefit of SMEs FP7 project which developed and demonstrated in the field the effectiveness of an intelligent and innovative high-speed EMAT rail inspection system deployable using any type of rolling stock or test vehicle. One of the many advantages of the EMAT method over existing technology is that it does not need physical contact with the inspected rail, can operate at a constant lift-off and is remains virtually unaffected by the speed of the train during inspection. Furthermore, the technical characteristics of the EMAT sensing systems are fairly simple and therefore do not need dedicated test trains to be deployed. This is a unique advantage which only automated vision systems have managed to exploit up-to-date since they too can be fitted in any type of train. However, the difference is that the EMAT system can detect surface and non-surface cracking regardless of the speed of the train whilst automated vision systems can only detect profile abnormalities, wear and missing bolts, etc.

To complement the development of the high-speed EMAT system, an ultrasonic phased array technique was also developed and validated in the field. A special walking stick was designed and manufactured in order to deploy the ultrasonic phased array probe. The ultrasonic phased array technique is used for the verification and accurate quantification of the defects detected by the EMAT sensing system. In addition, an intelligent decision support tool was designed and developed in order to log the defects detected and associated inspection data, and to determine the optimum maintenance action and schedule automatically.

Summary

I-RAIL (An Intelligent On-line High-Speed Rail Condition Monitoring System Deployed Via Passenger and Freight Trains) is an FP7 project funded under the Research for the Benefit of SMEs scheme. The consortium consists of 10 partners from 5 European countries. I-RAIL has focused in improving the efficiency of rail inspection and minimising the occurrence of catastrophic failures through the implementation of a novel high speed inspection system based on pitch-catch EMAT techniques which can be installed on any type of train. Ultrasonic phased array techniques have been developed and will be used for the verification and quantification of the defects detected by the EMAT system. An intelligent decision support tool has been developed and will be used to build a database of the defects detected and plan appropriate maintenance activities for the network.

The technological advances in train design in recent years have enabled the construction of more high-speed rail lines and the broader use of high-speed trains as an alternative and environmental friendly means of travel, which offers fast and reliable transportation of passengers and goods between hundreds of cities across the European continent. The increasing trend for the industry's business is forecast to continue in the forthcoming years, since rail transport is steadily becoming a more attractive option over other means of transportation for the public. This is due to the fact that train travel is generally cheaper than using a car or an airplane, and very often the fastest option to reach a destination. It is also inherently safer and far more environmentally friendly in comparison to car travel, without compromising passenger convenience. Rail tracks are increasingly being subjected to high speed heavy load traffic, and defects caused by cyclic loading, corrosion and wear, are of growing concern. Surface breaking cracks often cause more serious threats to structural integrity when compared to defects such as volumetric cavities. In particular, rolling contact fatigue (RCF) leads to crack formation and hence its detection is especially of interest.

The technology developed and implemented within I-RAIL will increase the reliability and efficiency of rail inspection by delivering a high-speed system based on Electromagnetic Acoustic Transducers (EMAT) that can be installed on any type of train. The EMAT system developed and demonstrated within I-RAIL under actual operational conditions in Entrocamento, Portugal with the help of EMEF and REFER, uses a pitch-catch technique that minimises the effect of increasing inspection speed. The system has the capability of detecting as well as quantifying the detected defects based on both signal frequency and amplitude analysis. Techniques based on ultrasonic phased arrays have been employed for verification purposes of the defects detected by the EMAT system. Intelligent Decision Support tools developed within the project permit the creation of a database for the defects detected. The I-RAIL Intelligent Decision Support tool assists in the planning of the optimum maintenance activities and scheduling. The I-RAIL project has brought together five SME partners from the UK (CIT Ltd and Sonemat Ltd), Greece (PSP S.A.) and Belgium (Akron N.V. and I-Moss N.V.) supported by four RTD performers from Belgium (D2S), the UK (University of Warwick), Cyprus (Engitec Ltd) and Portugal (ISQ) and an industrial partner from the rail sector in Portugal (EMEF S.A. representing the Portuguese Railways).

Over the last 15 years traffic on European rail networks has been continuously increasing with rolling stock travelling at higher speeds and carrying more passengers and heavier axle loads than ever before. The rail industry in Europe as well as the rest of the world is set to continue to grow at a strong pace until at least the mid of 21st century. More high-speed lines are being designed and

constructed constantly with an aim to connect not only major cities within Member States but also Europe with Far East Asia.

Severe rail accidents are relatively rare in Europe but they do occur and their frequency of occurrence and level of severity is still at an unacceptable level. Classification of rail accidents depends on their causative factor, which can be either a human error or component failure. Some of the most severe rail accidents are due to catastrophic failure of a rail section (e.g. the Hatfield accident in the UK, 2000 and Hendaye accident involving a TGV in France, 2001).

The increasing rolling stock traffic density in European rail networks means that unexpected rail failures and potential derailments caused do not only risk human casualties but also result in substantial costs due to network disruption and repairs. It is highly desirable to identify rail defects as they develop and at the earliest opportunity in a cost-efficient and reliable manner. Existing inspection systems based on specialised test trains and hi-rail vehicles are quite expensive (can exceed several million € per test train) and provide limited reliability since defects at their early stages can easily be missed or underestimated. The I-RAIL project addresses some significant deficiencies of existing high-speed inspection systems by delivering an innovative rail inspection technology with simplified deployment requirements. The I-RAIL system provides increased efficiency and improved reliability during high-speed rail inspection.

The complete I-RAIL system uses an innovative inspection technology based on guided waves produced by EMATs using a pitch-catch technique. A key aspect of the project has been the demonstration of the I-RAIL deliverables on the Portuguese rail network with the support of EMEF and REFER. The demonstration activities will be followed by further improvement of the system prior to subsequent commercialisation. The simplified schematic in figure 1 shows the overall concept of the integrated I-RAIL system.

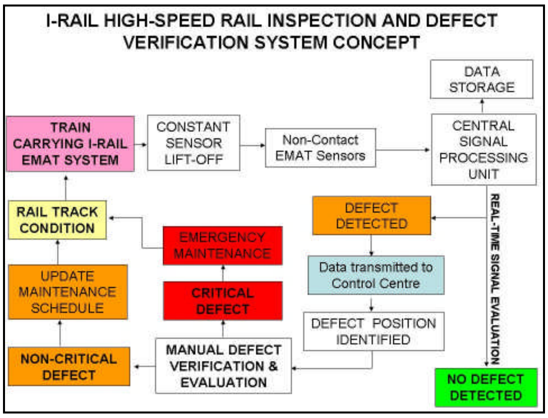

Figure 1: General schematic showing the overall I-RAIL concept.

The developed EMATs were tested in the laboratory before being integrated with the deployment mechanism and installed on the test train used for the field trials and demonstration of the I-RAIL system. The photographs in Figure 2 shows the final EMAT design and sensor setup prior to integration of the EMAT sensors with the deployment mechanism together with the pulser and data acquisition units. The schematic in Figure 4 shows the detailed design of the EMATs used in the high-speed rail inspection system.

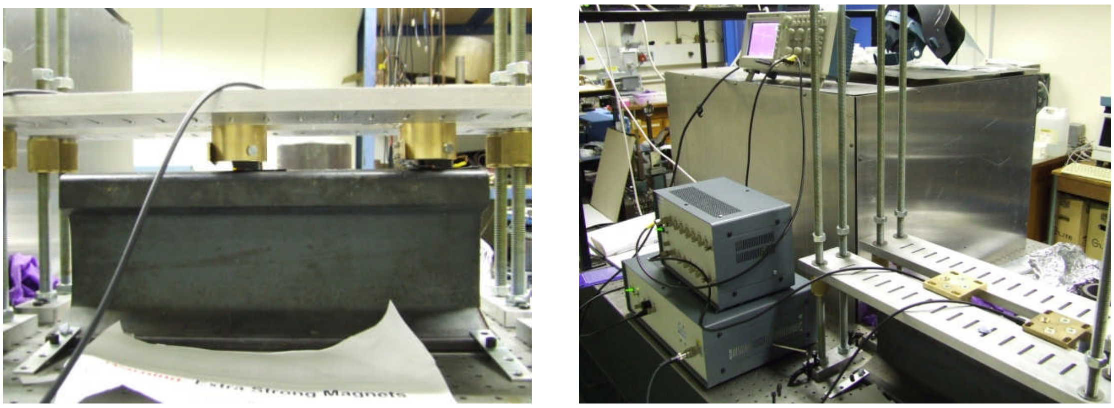

Figure 2: Photograph showing the final laboratory setup of the EMATs prior to integration with the deployment mechanism.

The photographs in Figure 3 show the deployment mechanism where the EMAT sensors are attached. The EMAT sensors can be clearly seen in the photograph on the right.

Figure 3: Deployment mechanism frame installed on the bogie of the test train.

The purpose of the ultrasonic phased arrays system has been to evaluate more accurately the defects detected by the high-speed EMAT system. For that purpose a special deployment trolley has been constructed. The detailed design of the new trolley with which the ultrasonic phased array probe is deployed is showing in the schematic of Figure 4.

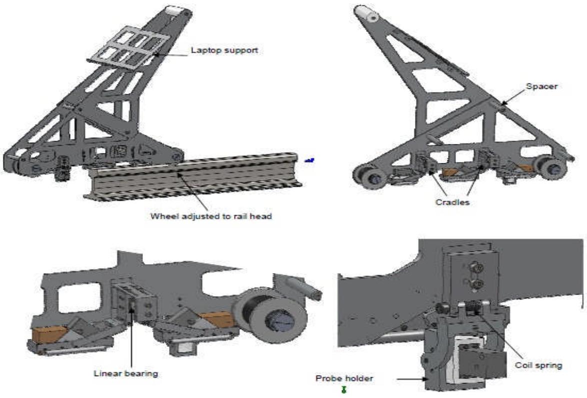

Figure 4: Detailed Schematic showing the I-RAIL ultrasonic phased array trolley.

The I-RAIL intelligent decision support software developed during the project can be used to log the data of any defects reported by the high-speed EMAT system and evaluated using the ultrasonic phased array system. In addition, the intelligent decision support tools provides to the user the optimum maintenance action and schedule depending on the type and severity of the defect logged. The whole process is automatic but can be interactive depending on the standards used by each infrastructure manager. The defect location can be automatically highlighted by placing a marker on the exact defect position.

The demonstration of the complete I-RAIL system was carried out on the Portuguese rail network in Entrocamento, Portugal, with the help of EMEF and REFER. The results of the tests have been assessed by REFER, the infrastructure managing company in Portugal. The field trials and overall demonstration of the I-RAIL technology was successfully completed at the end of October 2012. The successful demonstration of the complete I-RAIL system is a key step prior to its commercialisation. The demonstration results have shown that the I-RAIL technical deliverables have the capacity of delivering a step-change in existing inspection procedures and increase substantially the competitiveness of rail transport against other less environmentally friendly modes.

The consortium has been proactive in disseminating the key results of the project in conferences and technical journals. Papers have been presented at the British Institute of NDT 2011 and 2012 Conferences, held in Telford, UK, between September 12-14 2011 and Daventry, UK, between 11-13 September 2012, respectively. At least two more paper will be presented at the CM 2013 conference held in Krakow, Poland, 18-20 June 2013 and BINDT 2013 held in Telford, UK between 10-12 September 2013. Also one paper has been submitted to the Journal of Ultrasonics and two more are under preparation and will be submitted to the journal of BINDT “INSIGHT” and NDT&E International respectively.

I-RAIL consortium acknowledgement

I-RAIL is collaboration between the following organisations: Akron N.V., Computerised Information Technology Limited, D2S International N.V., EMEF S.A., Engitec Ltd, I-Moss N.V., ISQ, PSP S.A., Sonemat Ltd and the University of Warwick. The project is co-ordinated and managed by D2S International. The research leading to these results has received funding from the Seventh Framework Programme ([FP7/2007-2013] FP7/2007-2011]) under grant agreement n° 262293 (Research for the Benefit of SMEs).

Project Website

More information about the project can be found on the project’s dedicated website www.i-railproject.eu. The website is updated on a regular basis and news regarding the development of the I-RAIL system are posted on the public section.

Description of the main S&T results/foreground

The main objectives of the I-RAIL project have been to develop and demonstrate an innovative high-speed inspection systems based on EMATs which is capable of being delivered in the field using any type of train including passenger and freight rolling stock. The development work has been carried out with reference to: a) I-RAIL inspection platform specification, b) EMATs modelling and manufacturing of sensors for high speed inspection, c) EMAT data acquisition and control unit, d) software and signal processing, e) deployment mechanism, f) ultrasonic phased arrays modelling and development of the technique for manual verification of rail defects detected by the EMAT system, and g) an intelligent decision support tool for rail defect logging and maintenance planning.

A key aspect of the project has been the demonstration of the integrated system as well as its individual subcomponents in the field followed by successful commercialisation. To achieve the objectives set in the project in full, the consortium followed a step-by-step approach in order.

The principle objectives for the I-RAIL project have been to:

- To design, develop and maintain the I-RAIL project website.
- To fully specify the I-RAIL inspection platform, including its components.
- To specify and procure samples.
- To model ultrasonic wave interaction with rail defects.
- To model the behaviour of the EMAT sensors.
- To model the ultrasonic phased array inspection technique.
- To develop the high-speed rail inspection EMAT system.
- To develop the ultrasonic phased array technique for manual rail inspection and defect verification purposes.
- To develop the intelligent decision support tool for logging defects found and optimising maintenance decision making and scheduling.
- To assess appropriate signal analysis and data handling techniques for EMATs as well as the integrated system.
- To assess the efficiency of the ultrasonic phased array technique used for the verification of various rail defects.
- To design and develop the deployment mechanism for the EMAT system.
- To develop the software for the I-RAIL EMAT system.
- To integrate the complete I-RAIL system platform.
- To disseminate the project’s achievements and main results to the rail industry and to the rest of the scientific community. Dissemination is carried out n the form of seminars, one to one discussions, flyers, technical papers, news releases, posters and public presentations and through a website dedicated to the I-RAIL project.
- To transfer knowledge developed from the RTD performers to the SMEs.
- To develop training procedures.
- To finalise the exploitation plan for the appropriate use of the technology and foreground knowledge developed and demonstrated during the project leading to the successful commercialisation of the I-RAIL system and subcomponents.
- To determine the optimum route for commercialisation and maintain interaction with infrastructure managers and standardisation bodies in Europe and overseas.

The I-RAIL project was completed successfully in October 2012. The I-RAIL EMAT rail inspection system was deployed on a specially modified test rail car and demonstrated on a test track up to speeds of 15km/h under controlled conditions. The structural integrity of the test track was verified using a walking stick incorporating an ultrasonic phased array probe with beam steering capability. The defects found were reported through the special intelligent decision support tool also developed during the I-RAIL project.

Development of the project website

As part of the I-RAIL project, D2S International hosts a website on behalf of the consortium with the domain name www.i-railproject.eu. The purpose of the website is two-fold:

1. A public area for the dissemination of information about the I-RAIL project. A project page provides an introduction to the project. In addition, a contact page on the website provides telephone and form access to D2S's scientists, and specific enquiries will be automatically forwarded to all relevant project partners. The website also supports the exploitation of the key project deliverables.

The following figure 5 shows the homepage of the website as it appears on a standard web browser. Certain project pages currently provide an overview of the project. As the project advanced, more information relating to the project activities, including project work descriptions and publications, has been added to the website. The website also hosts an electronic leaflet shown in figure 6 and a poster giving an overview of the project.

Greener and more safer trains are making rail transport a more attractive option for passengers and freight in comparison to other means of transportation.

The ever-growing need for the society to employ more environmentally friendly transportation policies is expected to further underline the economic and societal role of rail transport in achieving sustainable mobility across Europe in the years to follow. Today, the European rail network is continuously getting busier with trains travelling at higher speeds and carrying more passengers and heavier axle loads than ever before. The combination of these factors has put considerable pressure on the existing infrastructure, leading to increased demands in inspection and maintenance of rail assets. The rail infrastructure managers have shown strong demand for the development of novel high-speed techniques for the reliable and accurate evaluation of rails in order to improve the efficiency of preventive maintenance and reduce the need for corrective maintenance to the lowest possible level.

Several infrastructure related accidents in the rail industry occur due to rail failure. The

- RCM 2011
The 5th IET conference on Railway Condition Monitoring and Non-Destructive Testing
November 29-30, 2011
Derby Conference Centre, Derby, UK

Figure 5: The project website in its current form.

Project Overview

Safety assessment and rail track condition monitoring method is being developed under this project. Several infrastructure related accidents in the rail industry occur due to rail failure. The continuous increase in train traffic, axle loads and operating speeds means that the catastrophic failure of a rail section may result in severe derailments, causing loss of life, injuries, severe disruption in the operation of the network, unnecessary costs, and loss of confidence in rail transport by the public. I-RAIL seeks to practically eliminate rail failures by successfully delivering a non-contact high-speed rail condition monitoring system based on Electromagnetic Acoustic Transducer technology (EMAT).

The **key results** from the project are:

- High speed condition monitoring system;
- Ultrasound phased array defect verification system;
- Intelligent Decision Support Tool;
- Training of operators.

Contacts

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An Intelligent On-Line High-Speed Rail Condition Monitoring System Deployed Via Passanger and Freight Trains

PARTNERSHIP

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Project Funded by the European Commission

Objectives

The consortium will develop and implement an advanced rail condition monitoring system based on the use of non-contact EMAT sensors. The system will enable the fast and reliable inspection of rail tracks at high speeds.

The project's main **objectives** are accounted below:

- To overcome the limitations of current inspection procedures of rail tracks through the successful implementation of an advanced high-speed rail condition monitoring system based on EMAT technology.
- To develop advanced verification and evaluation procedures of the defects detectable by the high speed system based on ultrasonic phased arrays techniques.
- To achieve a higher level of Probability of Detection (PoD) of rail defects thus leading to the substantial improvement in the actual reliability of the European rail network.
- To develop the required software and intelligent control unit to enable automatic and real-time analysis of the defects detected and minimise human subjectivity during the interpretation and analysis of results.
- To promote the technical capabilities of European SME companies, particularly those participating in the I-RAIL project.

Activities

- The high-speed rail condition monitoring system to be developed within I-RAIL will be based on the deployment of EMAT sensors in using conventional passenger and freight trains. The EMAT sensors will be connected to an automated control unit, which will use customised software specifically developed for the I-RAIL system for automated data logging and processing in real time

- Novel ultrasonic phased array techniques will be developed for the verification and evaluation of rail defects, which are detected with the high-speed EMAT system. The Intelligent Decision Support Tools will enable the I-RAIL system to provide an immediate and automated recommendation for the optimum maintenance planning to rail infrastructure managers using this technology.

- The integration and validation of the I-RAIL system and procedures will take place during this project.

Approach

The schematic Diagram in the figure shows a simplified outline of the concept of the I-RAIL condition monitoring platform.

I-RAIL - INSPECTION AND DEFECT VERIFICATION SYSTEM CONCEPT

Figure 6: Leaflet for the I-RAIL project.

2. A secure member area to act as a repository for project related information and to allow easy transfer of electronic information between consortium partners. This secure area is only accessible with the correct username and password specific to each consortium partner.

Development of I-RAIL EMAT sensors and configuration

EMAT sensors consist of a strong permanent magnet, a coil and the casing as shown in figure 7. Rayleigh-like ultrasound waves can be generated and received by EMAT, and are useful in the detection of RCF. The waves propagate close to the surface, with the acoustic energy mostly contained within about a wavelength of the surface, and hence are inherently sensitive only to surface defects. They are predominantly affected by the deepest defect in their path, which reduces the chance of nearby but smaller surface cracks masking more distant but larger surface cracks such as deep gauge corner cracking. The waves are generated by electromagnetic coupling between the EMAT and the electrically conducting and ferromagnetic rail. Consequently, the EMATs do not require couplant, and this reduces the degree of variation of coupling condition, and potentially allows for inspection of the rail at high speed. EMATs are non-contact in both generation and detection, but liftoff of the EMAT must be controlled and cannot become too large (a sensible maximum being 2mm). The Rayleigh-like waves usually have frequency content in the range from 100kHz to 600kHz.

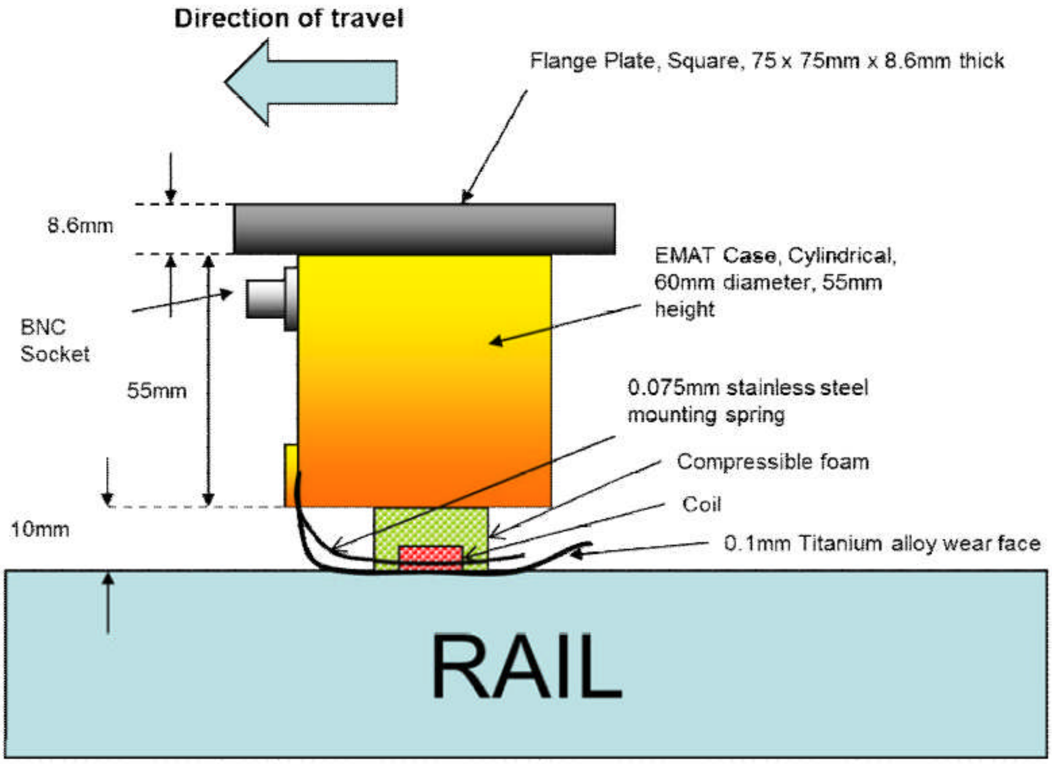


Figure 7: I-RAIL EMAT design.

The EMATs are arranged in a pitch-catch configuration (Figure 8), a layout which has been demonstrated to be able to reliably and accurately gauge the depth of surface-breaking cracks on rail samples. Much of the research done so far has used a single emitter and a single receiver at a fixed separation, scanned over the rail sample, but tests were performed at much slower speeds than the 320km/h that is proposed for this project. Two EMATs may still be sufficient, but the higher speeds may require the use of an EMAT array, or even a series of arrays. Each array consists of a single emitter and multiple receivers arranged linearly; multiple arrays may be required to get good coverage of the rail head. Using multiple receivers provides more data, so that the defect detection is seen despite the fast speed of the train conveying the array. Different EMAT coil designs generate pulses with different frequency content (also dependant on the pulse generator), amplitude and directionality.

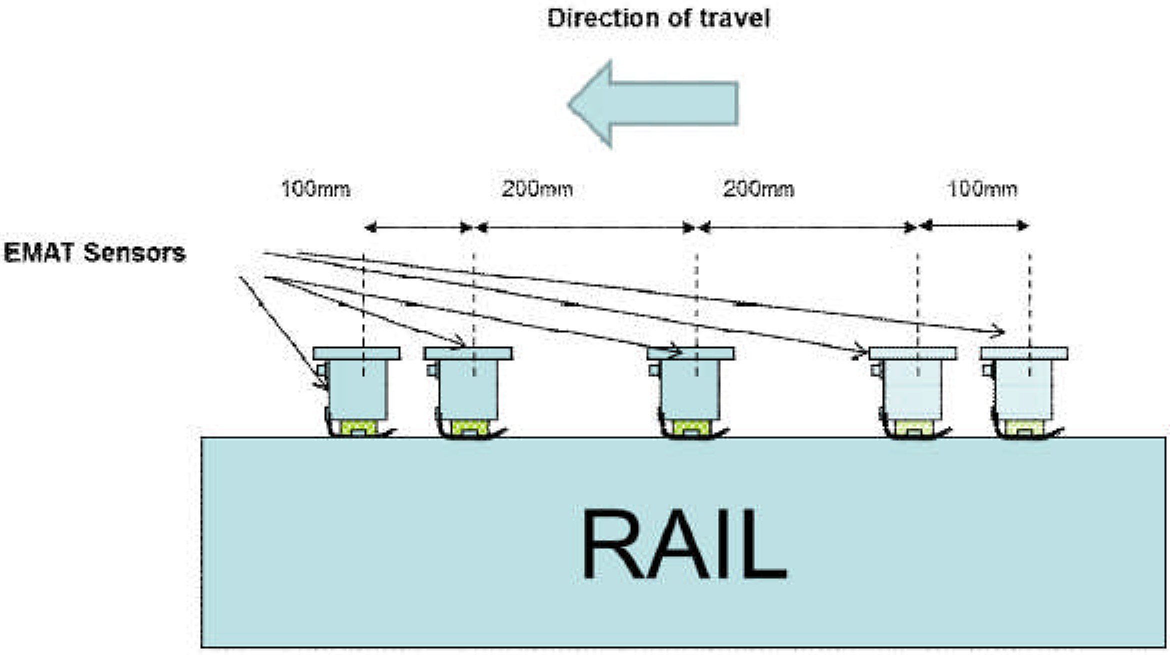


Figure 8: EMAT sensor configuration

As the EMATs scan along a rail surface, defects can be detected by effects such as the frequency content of the waves attenuated by the crack (when the emitter and receiver are either side of a defect), and the enhancement effect caused by the interference between Rayleigh-like waves and other mode-converted wave types very close to the crack (when emitter and receiver are the same side of the defect). Mode conversion from Rayleigh to bulk waves occurs due to the requirement of maintaining the boundary condition for the surface of the half-space and the crack surface. A good signal for the signal processing algorithms to work on can be achieved by amplification and filtering (Figure 9). By looking at changes in amplitude and frequency content of the signal, the depths of defects can be quantified. The relatively wide bandwidth of the EMATs allows for the gauging of cracks for a range of depths, as different frequencies will effectively probe different depths.

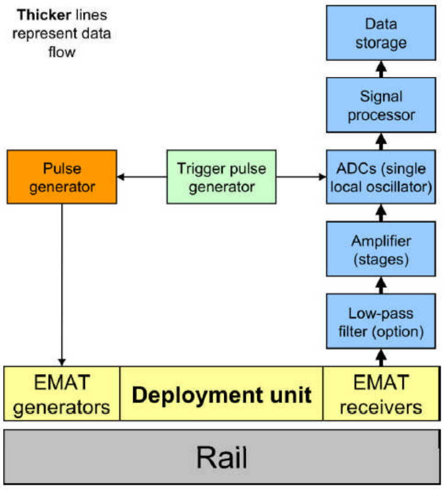


Figure 9: EMAT system setup.

The plot in Figure 10 shows the data acquired for a number of test rails and conditions using the EMAT inspection setup under laboratory conditions.

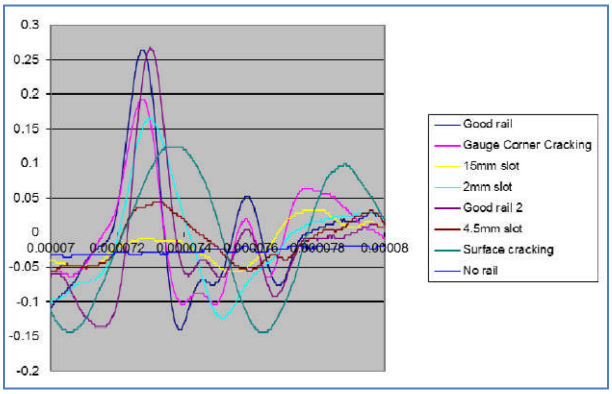


Figure 10: Plot showing EMAT results for different rails and conditions.

The EMAT sensors have no moving parts and therefore are tolerant of high vibrations.

Development of deployment mechanism

The deployment mechanism consists of a multipart continuous steel band that runs all the way around the bogie, attached to the axles as shown in figures 11 and 12. This means that the variation in standoff is minimised as this configuration has the most direct connection possible to the wheels, although vibration from the movement of the train is relatively high but tolerable.

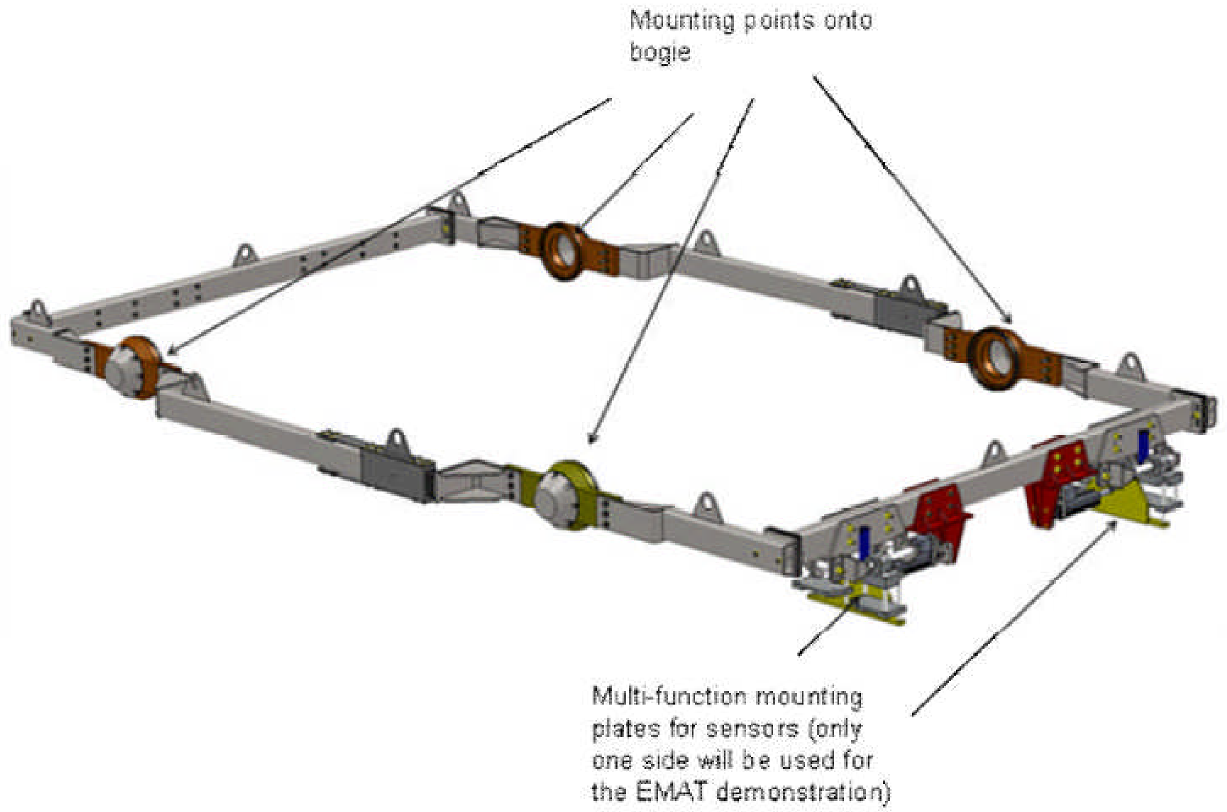


Figure 11: Schematic showing the EMAT deployment mechanism.

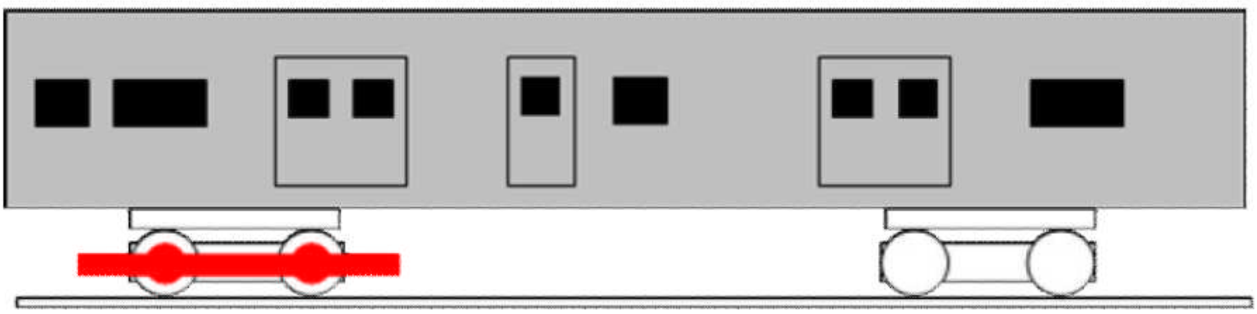


Figure 12: Position of deployment mechanism.

The schematic in Figure 13 shows the deployment mechanism as attached to the bogie.

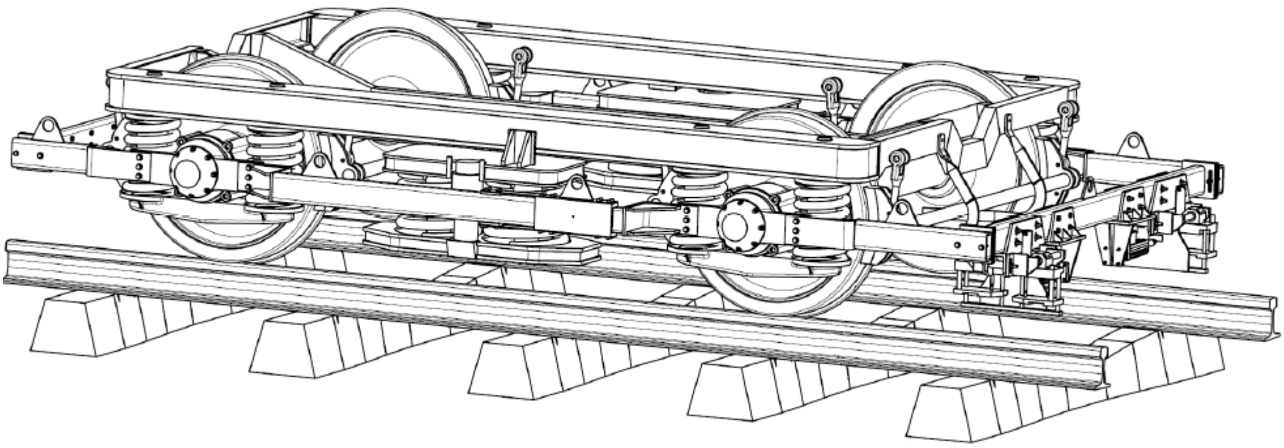


Figure 13: Detailed schematic of the deployment mechanism attached to the bogie.

The deployment mechanism is connected to the the EMAT array by a long mounting plate coupling to the flange plates on the top of each EMAT. The flange plates are slotted in order to allow fine-tuning of the lateral adjustment of the EMATs during installation, but otherwise rigid in order to minimise any variation in stand-off.

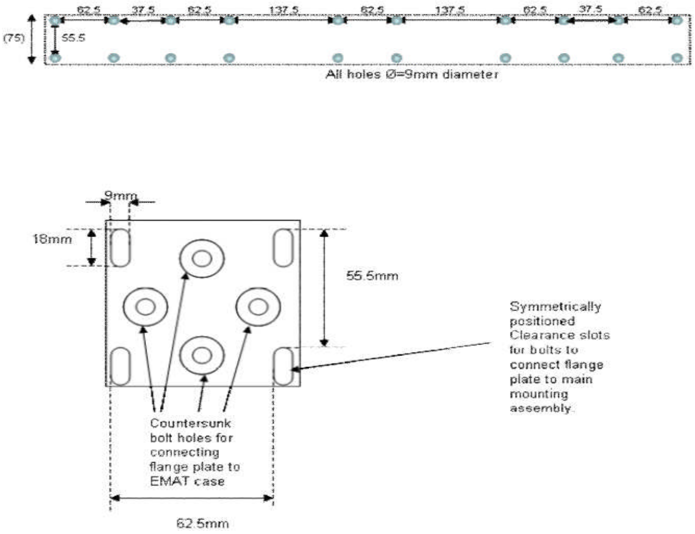
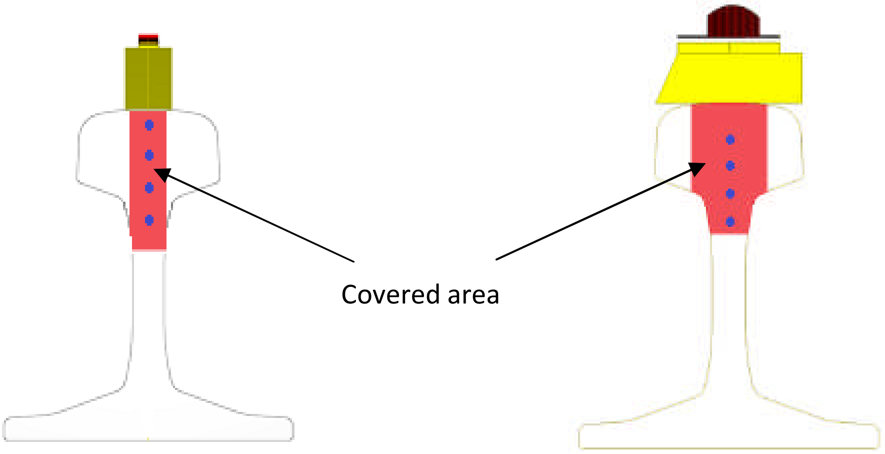


Figure 14: Schematic of flange plate and mounting plate which connects EMATs to deployment mechanism.

Ultrasonic phased array technique

The complex geometry of a rail requires a set of different approaches to guarantee the total coverage of its critical areas, and the detection of the target defects within each of those areas. The rail shape, due to its complexity, presents a number of challenges concerning coupling surface, covered area and access through the web, for which different probes and probe positions are required. Beam computations were performed in CIVA software using 5 mm Side Drilled Holes (SDH) placed at several depths within the rail, simulating the SDH's that were introduced in rail calibration samples. These holes were used as reference reflectors, to compare responses between different probes and do not intend to simulate typical defects. The ultrasonic beams were generated at angles capable of assuring the detection of the target defects that appear in the areas of interest. Actual PA tests were performed afterwards in the calibration samples with 5mm SDH's in order to verify probe suitability in detecting the target defects in the areas of interest, with an acceptable gain and without generating signal noise. The probes selection criteria were based in the amplitude of response from the 5mm SDH's, the necessary gain to bring the echoes to 80% Full Screen Height (FSH) and the absence of noise.



- 32 elements, total aperture;

- Probe longitudinal axis parallel to rail longitudinal axis;
- Straight wedge, 38mm high;
- L wave
- 4 focal points between 7 and

- 64 elements, electronic scanning (32-element sequences with 1 element scanning step);
- Probe longitudinal axis normal to rail longitudinal axis;
- Straight wedge, 38mm high;
- L wave
- 4 focal points between 20 and 60 mm in depth

Figure 15: Example of test setup for ultrasonic phased arrays.

For data acquisition in rails, a manual scanner has been developed, where all the probes can be held together. The aim is to make it possible for the probes to continually scan along the rail surface, simultaneously, with the advantage of visualization of the combined results from all the setups.

The scanner consists of four aluminum plates 5mm thick that form the main body of the structure. These plates are connected by three cylindrical spacers and two sub-frames, which have linear bearings that allow the adjustment of the probe positioning on the rail. The probes and wedges are held by the cradles, which can slide along the linear bearings. Coil springs assure that the wedges exert pressure against the rail surface, thus preventing the probes from lifting and therefore guaranteeing coupling. The schematics in Figures 16 give a brief overview of the scanner.

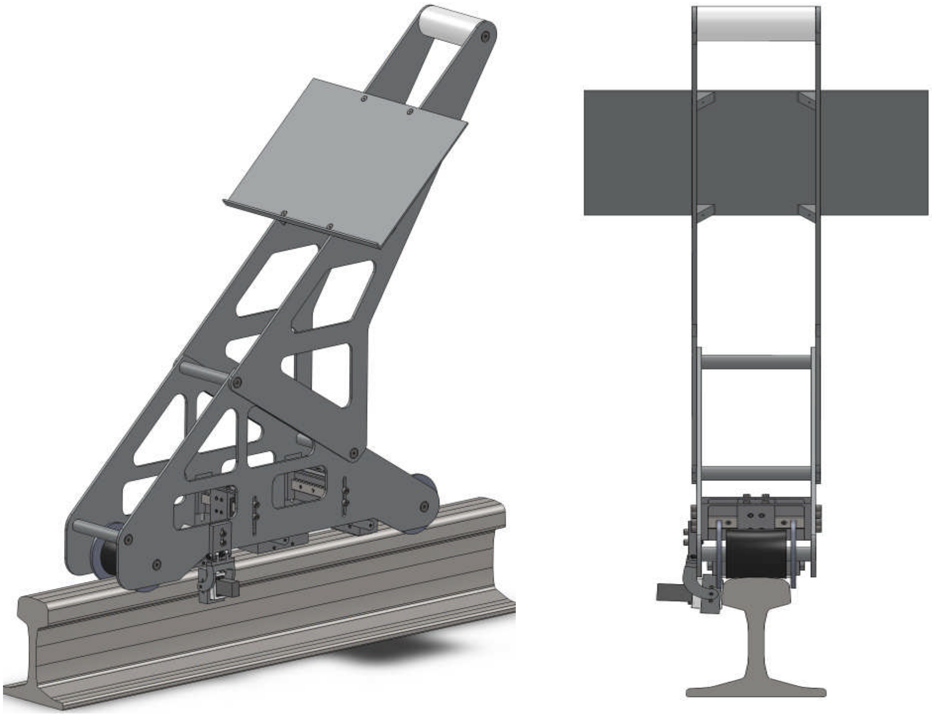


Figure 16: Side and rear view of the ultrasonic phased array scanner.

The schematic in Figure 17 shows the ultrasonic phased array probe arrangement.

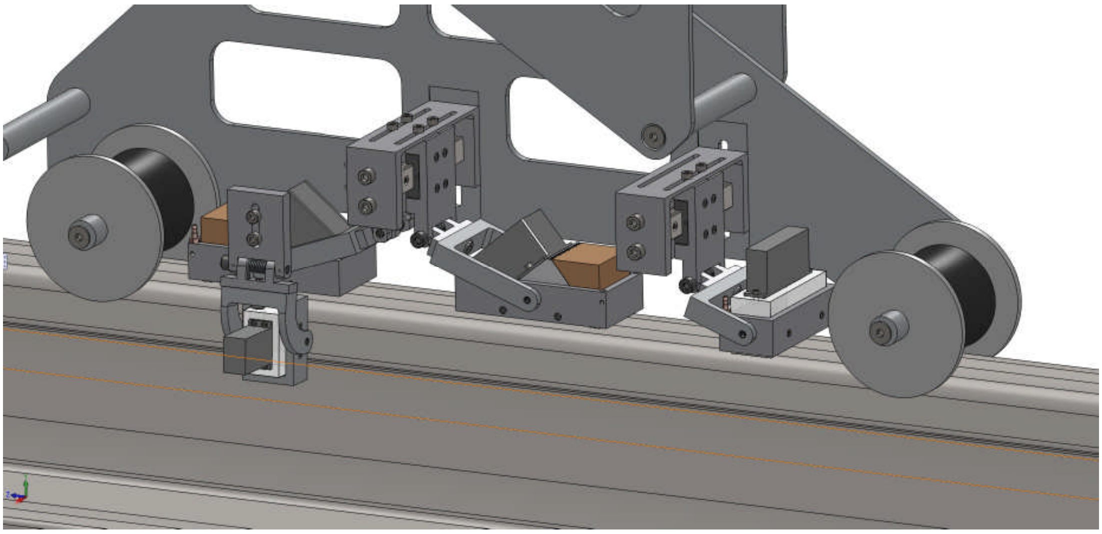
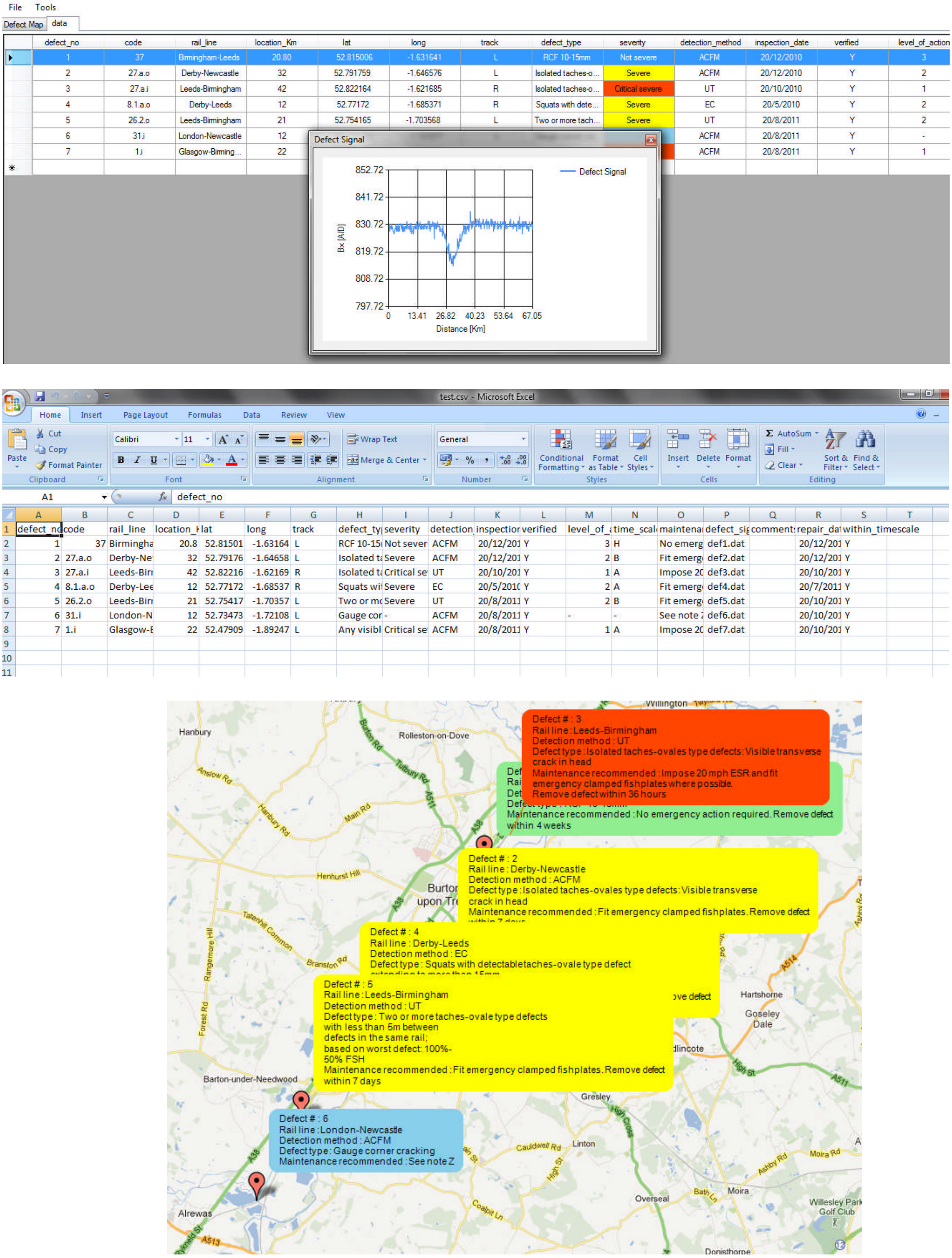


Figure 17: Schematic showing the ultrasonic phased array probe arrangement.

Intelligent Decision Support Tool

An Intelligent Decision Support Tool was developed in order to log the detected defects, assess their severity and optimise maintenance actions and scheduling. The I-RAIL intelligent Decision Support Tool software can help the infrastructure managers maintain a detailed defect record as well as make accurate decisions based on standards easily and reliably. Even an employee with very little railway experience can easily make accurate decisions using this software tool. The screenshots in Figure 18 shows aspects of the software.



defect_no	code	rail_line	location_Km	lat	long	track	defect_type	severity	detection_method	inspection_date	verified	level_of_action
1	37	Birmingham-Leeds	20.80	52.815006	-1.631641	L	RCF 10-15mm	Not severe	ACFM	20/12/2010	Y	3
2	27.a.o	Derby-Newcastle	32	52.791759	-1.646576	L	Isolated taches-o...	Severe	ACFM	20/12/2010	Y	2
3	27.a.i	Leeds-Birmingham	42	52.822164	-1.621685	R	Isolated taches-o...	Critical severe	UT	20/10/2010	Y	1
4	8.1.a.o	Derby-Leeds	12	52.77172	-1.685371	R	Squats with dete...	Severe	EC	20/5/2010	Y	2
5	26.2.o	Leeds-Birmingham	21	52.754165	-1.703568	L	Two or more tach...	Severe	UT	20/8/2011	Y	2
6	31.i	London-Newcastle	12						ACFM	20/8/2011	Y	-
7	1.i	Glasgow-Birming...	22						ACFM	20/8/2011	Y	1
*												

A1 defect_no

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	defect_nc	code	rail_line	location_I	lat	long	track	defect_ty	severity	detection	inspectior	verified	level_of_a	time_scal	maintenai	defect_sig	comment:	repair_dat	within_timescale	
2	1	37	Birmingha	20.8	52.81501	-1.63164	L	RCF 10-15	Not sever	ACFM	20/12/201	Y	3	H	No emerg	def1.dat		20/12/201	Y	
3	2	27.a.o	Derby-Ne	32	52.79176	-1.64658	L	Isolated ta	Severe	ACFM	20/12/201	Y	2	B	Fit emerge	def2.dat		20/12/201	Y	
4	3	27.a.i	Leeds-Birr	42	52.82216	-1.62169	R	Isolated ta	Critical se	UT	20/10/201	Y	1	A	Impose 20	def3.dat		20/10/201	Y	
5	4	8.1.a.o	Derby-Lee	12	52.77172	-1.68537	R	Squats wi	Severe	EC	20/5/2010	Y	2	A	Fit emerge	def4.dat		20/7/2011	Y	
6	5	26.2.o	Leeds-Birr	21	52.75417	-1.70357	L	Two or mo	Severe	UT	20/8/2011	Y	2	B	Fit emerge	def5.dat		20/10/201	Y	
7	6	31.i	London-N	12	52.73473	-1.72108	L	Gauge cor	-	ACFM	20/8/2011	Y	-	-	See note 2	def6.dat		20/10/201	Y	
8	7	1.i	Glasgow-E	22	52.47909	-1.89247	L	Any visibl	Critical se	ACFM	20/8/2011	Y	1	A	Impose 20	def7.dat		20/10/201	Y	
9																				
10																				
11																				

Defect # : 3
Rail line : Leeds-Birmingham
Detection method : UT
Defect type : Isolated taches-ovales type defects: Visible transverse crack in head
Maintenance recommended : Impose 20 mph ESR and fit emergency clamped fishplates where possible.
Remove defect within 36 hours

Def
Rai
Det
Defect type : RCF 10-15mm
Maintenance recommended : No emergency action required. Remove defect within 4 weeks

Defect # : 2
Rail line : Derby-Newcastle
Detection method : ACFM
Defect type : Isolated taches-ovales type defects: Visible transverse crack in head
Maintenance recommended : Fit emergency clamped fishplates. Remove defect within 7 days

Defect # : 4
Rail line : Derby-Leeds
Detection method : EC
Defect type : Squats with detectable taches-ovale type defect extending to more than 15mm
ove defect

Defect # : 5
Rail line : Leeds-Birmingham
Detection method : UT
Defect type : Two or more taches-ovale type defects with less than 5m between defects in the same rail; based on worst defect: 100%-50% FSH
Maintenance recommended : Fit emergency clamped fishplates. Remove defect within 7 days

Defect # : 6
Rail line : London-Newcastle
Detection method : ACFM
Defect type : Gauge corner cracking
Maintenance recommended : See note Z

Figure 18: Some aspects of the I-RAIL Intelligent Decision Support Tool.

I-RAIL System Installation

The I-RAIL EMAT system was successfully installed on a test vehicle provided by REFER with the help of EMEF. The photographs in Figure 19 shows the deployment mechanism where the EMAT sensors are attached.

Figure 19: Deployment mechanism frame installed on the bogie of the test train.

The photograph in figure 20 shows the complete deployment mechanism with the EMATs also in place.

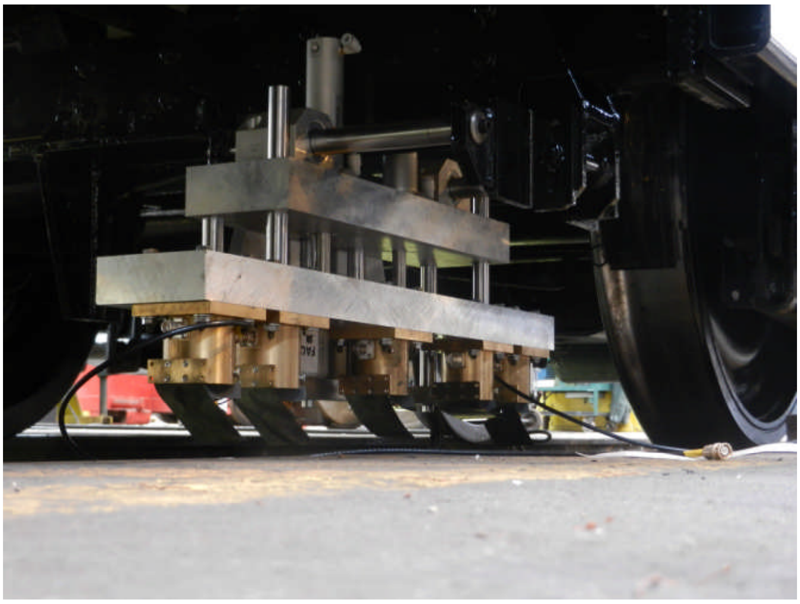


Figure 20: Complete deployment mechanism with I-RAIL high-speed rail inspection EMATs in place.

Field Trials

The principal objectives of the field trials and demonstration can be summarised as follows:

- To demonstrate that the I-RAIL high speed inspection system can be installed and operated on an inspection train.
- To demonstrate that the ultrasonic phased array system is capable of performing detailed inspection of highlighted problem areas.
- To test the intelligent decision-making support software is able to collate the combined results from both systems in a comprehensive manner.
- To obtain performance data from the system that can be used for exploitation and dissemination activities.
- To gain experience of installation and operation of the high speed inspection system.
- To allow future improvements to the hardware and software components of the system based on our experiences and data from the demonstration.

In order to perform the field trials and demonstration, use of a test train and towed testing car has been obtained, as well as a section of railway track in Portugal (courtesy of REFER). These tests were performed near rail depot in Entroncamento, Portugal (see figure 21), in October 2012. The section of track was approximately 500m long and consisted of a number of fishplate bolted sections of individual length 30 m.

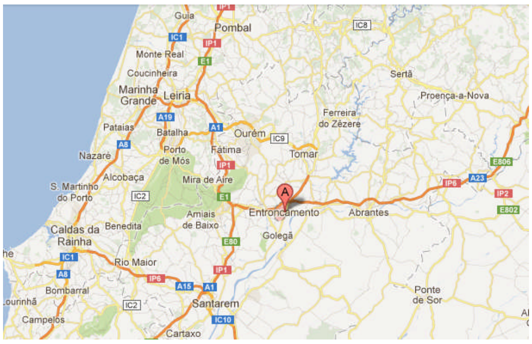


Figure 21: location of the tests, Entroncamento, Portugal

Prior to this deployment in the field, the elements of the integrated inspection system had only been used for laboratory level trials. In order to prepare the system for use in a much more realistic environment a number of adaptations were required. The EMAT designs were made more robust compared to the original versions, designed to cope with variations in standoff above the rails of up to 10mm by “gliding” the EMAT coils just above the rail surface on a titanium skid. An EMAT array was employed during trials involving five EMATs (a single transmitter in the centre of the array with two detection EMATs at an acceptable standoff above the rails, nominally 10mm with some variation expected. The assembly also included a pneumatically driven actuator to lower the EMATs into position or raise them clear of the track when not in use, and an electrically driven actuator to adjust the tracking of the EMATs over the rail.

In order to capitalise on the field trials for purposes of dissemination and exploitation, the procedures were captured both on video and by a large number of photographs, and resultant data was captured on two independent computer systems. These images and data have been collated and are available to all consortium members for use in any future dissemination activity, as well as for the creation of advertising material and as validation data for future exploitation. Figure 22 shows some of the equipment in place.

Figure 22: Installation of the supporting electronics. The EMAT pulse generator and amplifiers are in the foreground while the pneumatic and electronic controls for the deployment frame are towards the back of the compartment.

The trials performed consisted of three passes of the inspection wagon over regions of the 500m length of track scheduled to be inspected. The track consisted of a number of sections bolted together, giving a regular series of effectively infinitely deep cracks to act as a reference to confirm the position of the sensors.

Figure 23: The inspection carriage being towed by the engine prior to commencement of the inspection at Entroncamento.

A recording of the waveforms obtained from all EMATs after fitting to the deployment frame but before the inspection carriage was moved was taken to act as a reference for the rest of the proceedings. Following this, independent recordings were made on two separate computer systems as the carriage was moved over the 500m section of track. During the first scan a computer error caused the data recorded on one of the systems to be lost – other than that all data was successfully recorded. The results from the secondary system are shown below in figures 24-26:

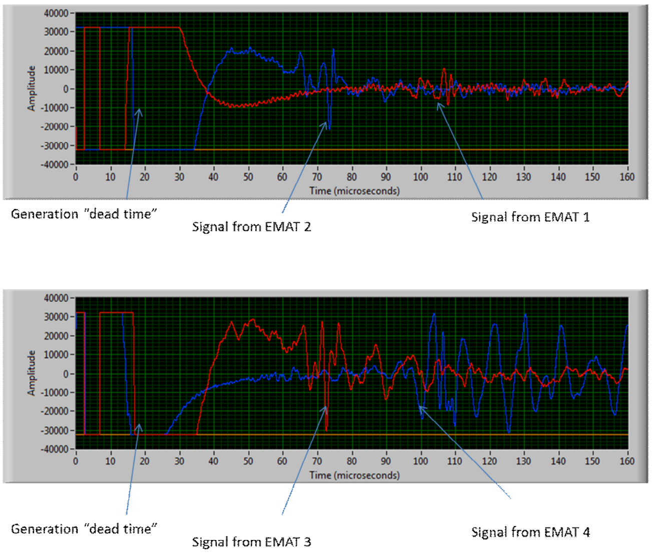


Figure 24: Single-shot results from the four detection EMATs mounted beneath the train, before the train was moved.

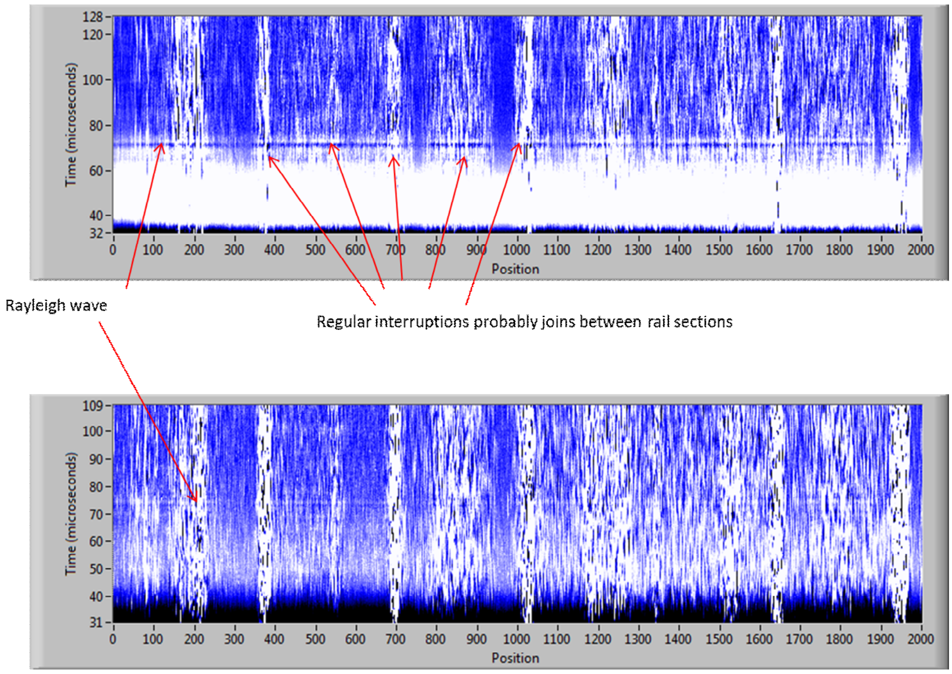


Figure 25: Results from the rolling scan on EMATs 2 and 3 from the second run, showing the detected Rayleigh wave and absence of the same due to rail section joints.

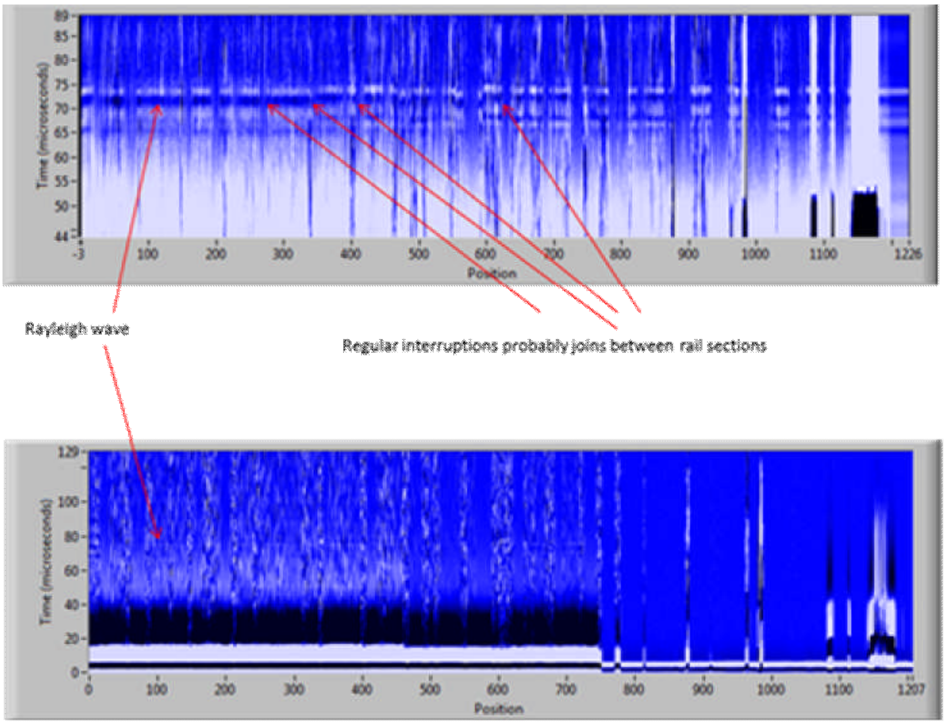


Figure 26: Results from the rolling scan on EMATs 2 and 3 from the third run, showing the detected Rayleigh wave and absence of the same due to rail section joints. In contrast to the previous data, signal averaging and software filtering techniques were used when acquiring these results, giving improved signal: noise ratio at the cost of reduced spatial resolution.

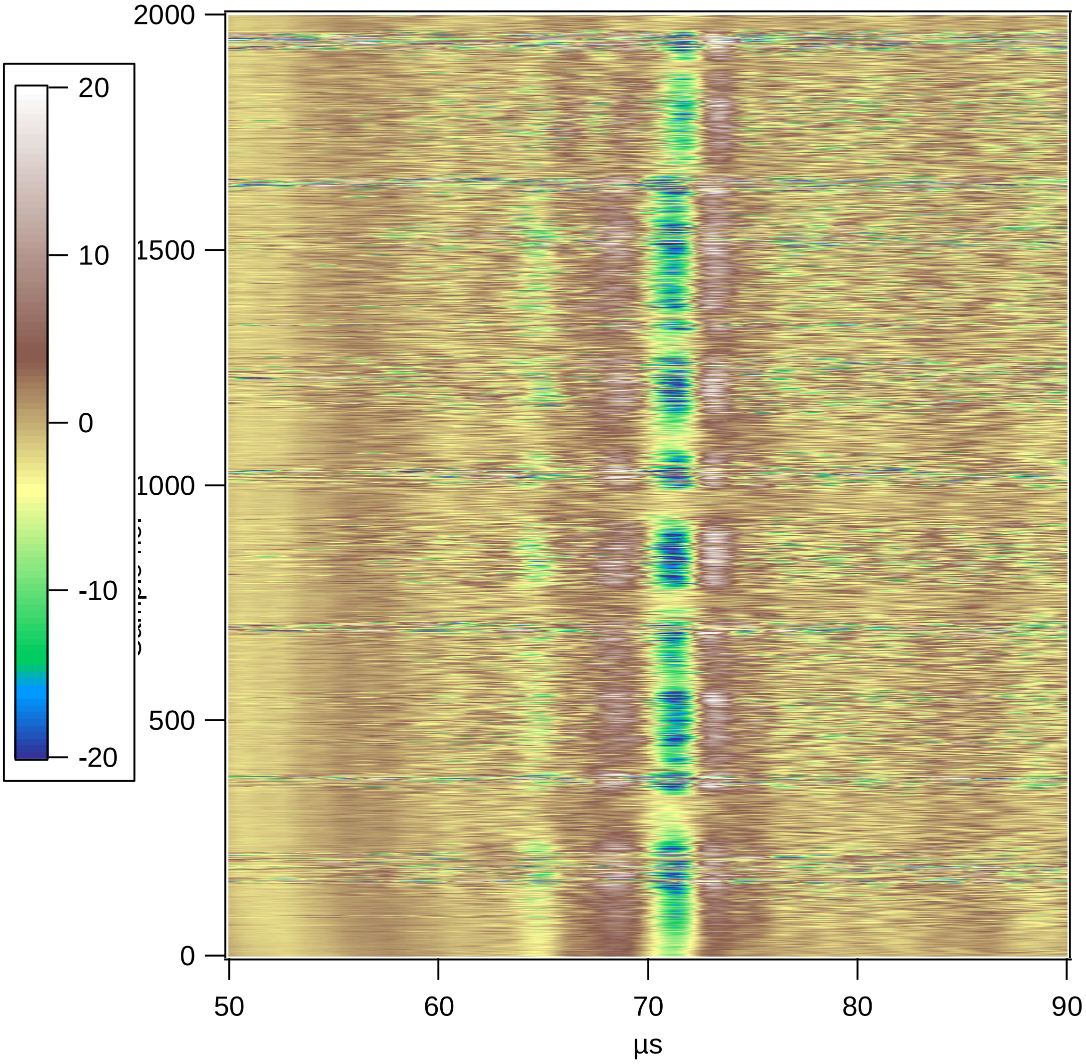


Figure 27: Results from the second scan EMAT 2 after post-processing with software filters and time windowing, showing the regions of reduced Rayleigh wave amplitude more clearly. These results indicate regions of reduced track quality as well as joins between the track sections, but may also be influenced by the standoff variations between the EMATs and the track.

These results show that signals can be obtained from all the detection EMATS, however due to issues with bowing of the mounting frame due to magnetic attraction the signal strength was different from each EMAT. This was not an insurmountable problem and can be corrected in future field trials with a more robust frame. The data clearly shows a sequence of regular interruptions to the EMAT signal, almost certainly caused by the sensor array passing over the regular joints between sections of track. Other regions of poor signal strength may indicate areas of interest potentially containing defects. The primary computer system was able to record data from all four on all the runs, but is designed only to show the defect summaries rather than the raw data. The results from the primary computer system during the second scan are shown below in figures 28 and 29:

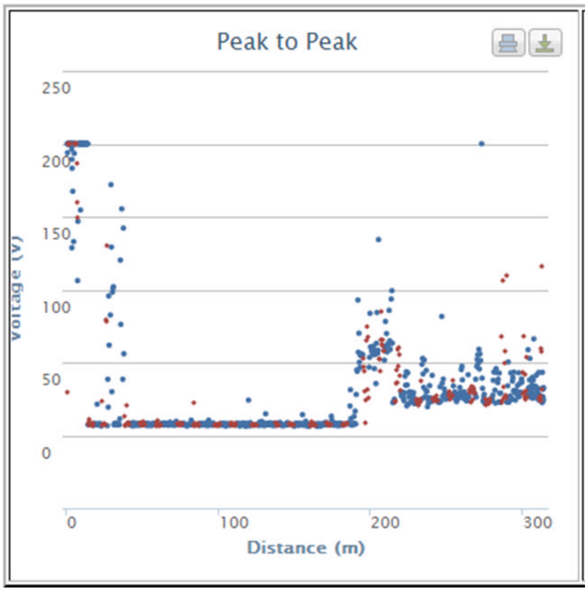
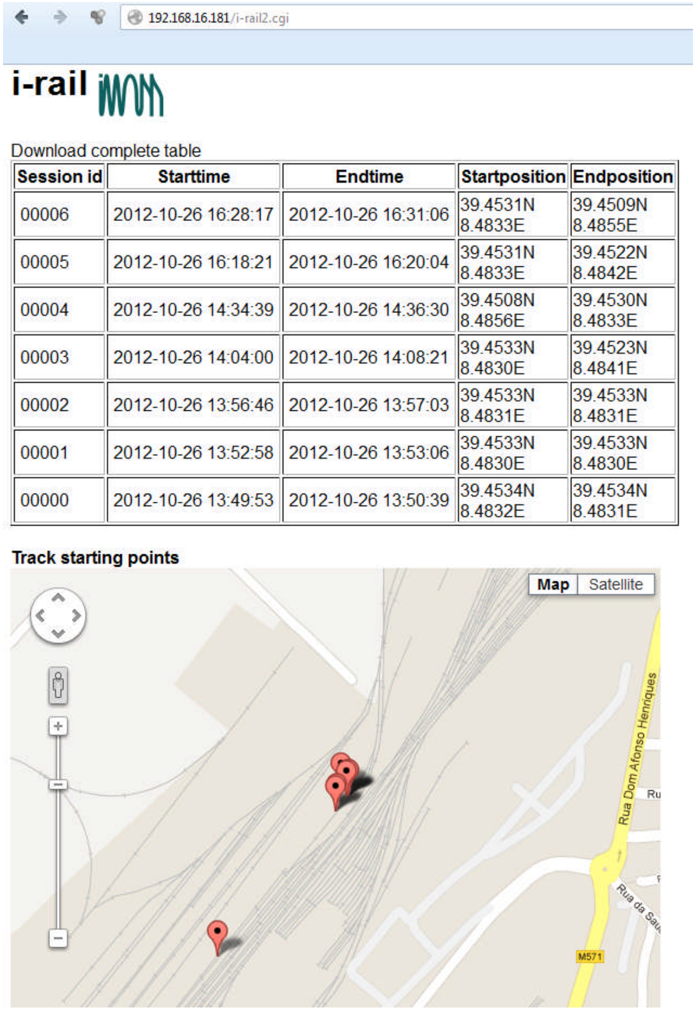


Figure 29: Results obtained from the primary computer system during the initial run.



Download complete table

Session id	Starttime	Endtime	Startposition	Endposition
00006	2012-10-26 16:28:17	2012-10-26 16:31:06	39.4531N 8.4833E	39.4509N 8.4855E
00005	2012-10-26 16:18:21	2012-10-26 16:20:04	39.4531N 8.4833E	39.4522N 8.4842E
00004	2012-10-26 14:34:39	2012-10-26 14:36:30	39.4508N 8.4856E	39.4530N 8.4833E
00003	2012-10-26 14:04:00	2012-10-26 14:08:21	39.4533N 8.4830E	39.4523N 8.4841E
00002	2012-10-26 13:56:46	2012-10-26 13:57:03	39.4533N 8.4831E	39.4533N 8.4831E
00001	2012-10-26 13:52:58	2012-10-26 13:53:06	39.4533N 8.4830E	39.4533N 8.4830E
00000	2012-10-26 13:49:53	2012-10-26 13:50:39	39.4534N 8.4832E	39.4534N 8.4831E

Track starting points

Figure 30: Scan location information saved by the primary computer system.

A video diary of the proceedings was made during the demonstrations, as well as numerous still photographs of the assembled inspection equipment and the inspection taking place. In addition to the technical results this forms an information package which will serve as a basis for further generation of interest in the technology and future promotional activities.

The high speed inspection system has been assembled and tested on a train at speeds of up to 15 kph. Despite some callibration issues with the installation the consortium partners were able to obtain signals from the system. Signal amplitude showed detection of the section joints between the rails and other regions of low signal which may be indicative of poor track quality.

Technical transfer of know-how from RTDs to SMEs

The know-how developed by RTDs was successfully transferred to the participating SMEs of the project through the provision of detailed technical reports, training workshops and seminars.

Dissemination of knowledge

Some key aspects of the technology developed have been or are in the process of being disseminated to the general scientific community and industrial stakeholders through journal publications, conference presentations and exhibitions.

Potential Impact of the I-RAIL Project

The European rail industry is in a state of rapid transformation aimed at meeting the increasing safety, environmental, societal and economic demands set for modern rail transport. Rail interoperability, defined as the operational and technical integration of the different national railway systems in the European Union and the accession countries, is a key element in this transformation. Efficient transport and mobility are the lifeblood of the European economy and an indispensable factor in Europe's competitive and sustainable growth, enhancing communication, economic growth and social stability. As with any modern transport network, European transport must have, as a key component, a well coordinated, smoothly functioning international rail system. The main challenge for the European rail industry is to develop maximum passenger/customer value. Trains have to be safe, clean, reliable, and on time, both for passengers and goods. Improved services will give rail transport a huge competitive edge, making it the best way to combine low travel time with easy accessibility to both leisure and professional hubs while maintaining environmental impact to a minimum.

Maintenance costs for the European rail industry range to several billion Euros every year and it is estimated that it represents 30-40% of the industry's overall operating costs. The simultaneous increase in rail traffic and improvement in safety means that maintenance costs will see an unprecedented increase by 2020, harming the long-term prospects and sustainability of the European rail industry as a whole unless proper action is taken on time. To address this pressing problem the industry will have to successfully implement new and efficient maintenance strategies and inspection methodologies which will reduce to an absolute minimum equipment-related delays and accidents.

The widespread application of the developed I-RAIL inspection platform in the field will benefit the rail industry and lead to a substantial reduction in the inspection and maintenance costs of the rail infrastructure managers by allowing an evolution from corrective to preventive maintenance strategy. The results of this project are expected to increase the competitive position of participating SMEs by enabling them to provide new inspection and equipment and services to the rail industry. This will improve their economic outlook over the forthcoming years and open new job opportunities.

The achievements and results produced within the I-RAIL project will have a significant number of positive impacts as it will contribute to the improvement of the: a) safety record within the rail industry, b) reliability of rail transport and c) of industrial competitiveness in Europe, particularly for the SMEs participating in the consortium. I-RAIL will also be a key component on the road towards achieving the safety and business targets set for the European rail industry and will help push forward the European rail research agenda further. Widespread application of the I-RAIL platform will decrease inspection times and associated costs by up to considerably whilst it will improve the reliability of the rail network.

Moreover, due to the decreased accuracy offered by current techniques, the use of preventive and reactive maintenance is not efficient enough. A significant improvement in inspection reliability achieved through the application of the I-RAIL systems could result in a further 10% reduction in maintenance times to be achieved. This could potentially lead to an overall reduction in current maintenance times and costs of up to 20%. In addition, this project will significantly contribute to the improvement of punctuality in train travel times through the minimisation of the number of broken or severely damaged rails found each year on the European rail networks. Severely damaged and broken rails can cause substantial delays and disruption to train travel due to imposed emergency speed restrictions and the need to carry out emergency maintenance. In the UK alone, approximately 3000 severely damaged rails (including 300 broken rails) are found on average every year, resulting in more than 579,267 minutes delay and 30 million Euros in associated costs [Network Rail 2007 statistics]. By improving the accuracy of the inspection procedure the I-RAIL technology can improve defect detectability at earlier stages and enabling punctual maintenance so as to avoid train travel disruption. As train travel reliability and punctuality will improve, more passengers will choose to leave their cars and use the trains instead. Also more freight will be carried by rail instead of trucks.

SMEs will benefit directly from the technological developments resulting from this project not just within Europe but globally. The cost advantages of being a ‘local’ organisation are more than offset by the technical capability that will benefit the participating SMEs. Through a process of international dissemination the participating SMEs are in a position to access the massive international market for the rail inspection and condition monitoring. The trend is for the rail industry to grow further thus ensuring the sustainable viability of the I-RAIL technology. Therefore, for the SMEs participating in the project there is a significant impact both at European and international level. It is expected that the successful commercialisation of the I-RAIL deliverables will result in the creation of at least 10-12 new jobs within 36 months after the systems have been commercialised in full. It should also be emphasised that the commercialisation of the I-RAIL system will also help safeguard existing jobs in the current difficult economic environment.

The commercialisation of the I-RAIL equipment and services will be primarily achieved directly through the participating SMEs. To ensure a successful exploitation after the project, the partner SMEs have also considered to launch a new company following the project’s end in order to promote the exploitation of the I-RAIL technology further. The mission of this new company will be to sell the I-RAIL system and provide services to the rail industry worldwide. This company will be jointly owned by the consortium companies and its shares will be distributed in line with each companies’ financial input into this project.

Project Website

More information about the project can be found on the project’s dedicated website www.i-railproject.eu. The website is updated on a regular basis and news regarding the development of the I-RAIL system are posted on the public section.

4.2 Use and dissemination of foreground

Section A

Development of the project website

As part of the I-RAIL project, D2S International hosts a website on behalf of the consortium with the domain name www.i-railproject.eu. The purpose of the website is two-fold:

1. A public area for the dissemination of information about the I-RAIL project. A project page provides an introduction to the project. In addition, a contact page on the website provides telephone and form access to D2S's scientists, and specific enquiries will be automatically forwarded to all relevant project partners. The website also supports the exploitation of the key project deliverables.

The following figure shows the homepage of the website as it appears on a standard web browser. Certain project pages currently provide an overview of the project. As the project advanced, more information relating to the project activities, including project work descriptions and publications, has been added to the website. The website also hosts two electronic leaflets and a poster giving an overview of the project.

An Intelligent On-Line High-Speed Rail Condition Monitoring System Deployed Via Passenger and Freight Trains

Project Overview

Greener and more safer trains are making rail transport a more attractive option for passengers and freight in comparison to other means of transportation.

The ever-growing need for the society to employ more environmentally friendly transportation policies is expected to further underline the economic and societal role of rail transport in achieving sustainable mobility across Europe in the years to follow. Today, the European rail network is continuously getting busier with trains travelling at higher speeds and carrying more passengers and heavier axle loads than ever before. The combination of these factors has put considerable pressure on the existing infrastructure, leading to increased demands in inspection and maintenance of rail assets. The rail infrastructure managers have shown strong demand for the development of novel high-speed techniques for the reliable and accurate evaluation of rails in order to improve the efficiency of preventive maintenance and reduce the need for corrective maintenance to the lowest possible level.

Several infrastructure related accidents in the rail industry occur due to rail failure. The

Highlights

- RCM 2011
The 5th IET conference on Railway Condition Monitoring and Non-Destructive Testing
November 29-30, 2011
Derby Conference Centre, Derby, UK

Partnership

Figure 1: The project website in its current form.

2. A secure member area to act as a repository for project related information and to allow easy transfer of electronic information between consortium partners. This secure area is only accessible with the correct username and password specific to each consortium partner.

Partners have been asked to make links from their websites to the I-RAIL project website in order to help improve the website's ranking in search engines. Currently the following partners have established links from their company websites:

1. D2S
2. ISQ
3. Engitec
4. I-Moss.
5. Sonemat.

Project posters and leaflets

An A0 poster has been created by the consortium and a leaflet is currently being designed. Posters, leaflets and brochures are planned until the end of the project as dissemination material.

Co-ordination activities

There was a certain degree of cooperation between coordinator and the consortium of the INTERAIL project. At the time of writing some meetings have taken place between the coordinator and the consortium mentioned as well as an I-RAIL presentation during an INTERAIL consortium meeting held at Birmingham University in September.

Use of foreground, dissemination and exploitation activities

Patents, copyrights, registrations of trademarks or other IPR exploitation activities are under consideration or already in place for several subcomponents of the I-RAIL system. For the integrated system IPR activities are under discussion between the consortium members. Discussions regarding commercialisation have also been initiated. A number of copyrights are already in place for the software packages already created including the I-RAIL intelligent decision support tool, signal processing methodology, data acquisition and data analysis.

One of the main ideas in terms of commercial exploitation is the creation of a new joint venture between the SMEs which will sell the I-RAIL system in its integrated form to rail infrastructure managers. The new company will also provide services and will redistribute the profit arising according to the shares owned by the original companies participating in the new venture.

The final exploitation and dissemination of knowledge document has been drafted and approved by the consortium partners. This document details the past, current and future efforts undertaken for exploitation and dissemination. The dissemination activities undertaken during the 24M period are summarised in the following table.

Overview of Dissemination of Knowledge- Scientific publications

Date	**Type**	**Title/link**	**Type of audience**	**Countries addressed**	**Size of audience**	**Partners involved**
November 2010	I-RAIL website	www.i-railproject.eu	General public	Worldwide	500+ per month	All
September 2011	Conference and Exhibition	BINDT 2011	NDT and condition monitoring	International event	150+	UoW
January 2012	Journal Publication	Journal of Ultrasonics	NDT	Worldwide	2000+	UoW
September 2012	Conference and Exhibition	BINDT 2012	NDT and condition monitoring	International event	150+	UoW

June 2013	Conference and Exhibition	CM 2013	NDT and condition Monitoring	International event	150+	D2S, UOW, ENGITEC
September 2013	Conference and Exhibition	BINDT 2013	NDT and condition monitoring	International event	150+	UOW
TBC	Journal publication	Journal of BINDT	NDT and condition monitoring	Worldwide	5000+	UoW
TBC	Journal publication	Journal of NDT & E International	NDT and condition monitoring	Worldwide	10000+	UoW

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[2]	Main leader	Title	Date/Period	Place	Type of audience[3]	Size of audience	Countries addressed
1	Conference and exhibition	UOW and SONEMAT	BINDT 2011	September 2011	UK	Scientific	150+	All
2	Meeting with De Lijn	I-MOSS and D2S	Meeting	May 2012	Belgium	Technical	4	Belgium
3	Conference and exhibition	UOW and SONEMAT	BINDT 2012	September 2012	UK	Scientific	150+	All
4	Meeting with TWI	SONEMAT	Meeting	September 2012	UK	Technical	1	UK
5	Presentation at INTERAIL meeting	SONEMAT	INTERAIL Consortium Meeting	October 2012	UK	Scientific	20	UK, Portugal, Belgium, Greece, Cyprus, Italy and France
6	Conference and Exhibition	UoW, ENGITEC, D2S	CM conference 2013	June 2013	Poland	Scientific	150+	All
7	Conference and Exhibition	UoW and SONEMAT	BINDT 2013	September 2013	UK	Scientific	150+	All

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[2] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[3] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

Section B (Confidential[4])
Part B1

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[5]:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
Copyright	Yes	N/A	N/A	I-RAIL Intelligent Decision Support Tool	CIT
Copyright	Yes	N/A	N/A	I-RAIL data logger and user software	I-MOSS
Copyright	Yes	N/A	N/A	I-RAIL data analysis software	I-MOSS and PSP
Patent	Yes	TBC	TBC	EMAT sensor array design	SONEMAT
Patent	Yes	TBC	TBC	Ultrasonic phased array walking stick	AKRON
Patent	Yes	TBC	TBC	I-RAIL deployment system	CIT

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[4] Note to be confused with the "EU CONFIDENTIAL" classification for some security research projects.

[5] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

Part B2

Type of Exploitable Foreground[6]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[7]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Prototype	EMAT sensor design	Yes	TBC	EMAT sensor manufacturing and maintenance services	1. Rail 2. Oil and gas 3. Nuclear	2014	A patent is currently being prepared	SONEMAT,CIT
Prototype	Deployment mechanism	Yes	TBC	Deployment mechanism for sensors	1. Rail	2014	A patent is currently being planned for 2014	CIT
Software	EMAT data capture and analysis software	Yes	TBC	Software sales and upgrades, services	1. Rail 2. Oil and gas 3. Nuclear	2014	Copyright	I-MOSS, SONEMAT, PSP
Software	I-RAIL Intelligent Decision Support Tool	Yes	TBC	Software sales and upgrades, services	1. Rail	2013	Copyright	CIT, PSP

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[19] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

[7] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Prototype	Ultrasonic phased array unit	Yes	TBC	Manufacturing of system, sales and provision of services	1. Rail	2014	Patent planned for submission in 2014	Akron

The foreground produced during the I-RAIL project has arisen in many forms including prototypes, software and reports.

The EMAT sensors design developed has multiple uses apart from its application in the rail industry. Apart from rail inspection, the EMAT sensors developed herewith can be used to inspect other assets such as pipelines, offshore platforms, nuclear power installations, etc. For the commercialisation, patenting and further development SONEMAT is the responsible partner although the other SMEs also have an interest in this area.

The developed deployment mechanism is dedicated for application in the rail industry only. The improvement of the design and subsequent commercialisation is the responsibility of CIT in collaboration with the other SMEs of the consortium. The deployment mechanism has crucial importance as it is responsible for the delivery of the sensors on the rail network during the inspection process. A patent is considered to safeguard the IPR.

The developed ultrasonic phased array system has also a dedicated application which is related to the rail industry. The responsible SME for the commercialisation of this system is Akron. A patent is also considered.

The I-RAIL Intelligent Decision Support Tool is related primarily to the rail industry although with certain modifications it can be used for other purposes too. The responsible partners for its commercialisation are CIT together with PSP. The software is protected by Copyright.

The I-RAIL software packages for data logging and signal processing can be used for any type of EMAT data processing regardless of the application of the inspection. The software packages are protected by Copyrights and the responsible partners for commercialisation are I-MOSS and SONEMAT.

The rail industry has widely recognised the need for measurable and valid innovation, especially in inspection and maintenance procedures of rail tracks in order to improve existing safety standards and accommodate the needs of modern Europe for increased mobility based on environmentally friendly means of transport. This necessity has also been stimulated by the reforms that the rail industry has been requested to undergo according to the new EU Directives. For the aforementioned reasons, the development of reliable inspection procedures based on innovative and close-to-market technologies is timely and should not be delayed any further. The I-RAIL project developed an intelligent and innovative high-speed EMAT rail inspection system which can be deployed using any type of rolling stock or test vehicle. One of the many advantages of the EMAT method over existing technology is that it does not need physical contact with the inspected rail, can operate at a constant lift-off and is remains virtually unaffected by the speed of the train during inspection. Furthermore, the technical characteristics of the EMAT sensing systems are fairly simple and therefore do not need dedicated test trains to be deployed. This is a unique advantage which only automated vision systems have managed to exploit up-to-date since they too can be fitted in any type of train. However, the difference is that the EMAT system can detect surface and non-surface cracking regardless of the speed of the train whilst automated vision systems can only detect profile abnormalities, wear and missing bolts, etc.

The fact that the I-RAIL high-speed rail condition monitoring system is relatively cheap to make, means that effectively all trains travelling on the network can be fitted with it. Thus the condition of the whole rail network can be monitored with the same efficiency as if a permanently-mounted condition monitoring system had been fitted along its full length. The fact that virtually all rail damage occurs effectively only when trains are passing over them means that the efficiency of condition monitoring using the I-RAIL EMAT system will be as good as if the rails were to be continuously monitored in-situ.

The ultrasonic phased array technique developed during I-RAIL will be used to manually inspect the rail line on which the EMAT system operates. The same technique will be used to inspect defects found by the EMAT system in the field.

The I-RAIL technology has the potential to revolutionise rail inspection and maintenance procedures thus increasing substantially the competitive advantage of the SMEs involved in the project as well as the European rail industry as a whole.

Rail infrastructure managers admit that inspection results influence profoundly their maintenance planning as well as their strategy for future inspection scheduling. Although, the rail industry has until now remained attached to traditional based inspection techniques which have been proven to offer an acceptable level of reliability the vast majority of infrastructure managers are prepared to adopt new technologies and procedures within a reasonable time frame which in most cases lies between twelve and thirty-six months after proper certification has been obtained.

Increasing traffic density, rolling stock speeds and axle loads are resulting in more complicated inspection schedules while the cost-efficiency of the non-destructive evaluation process itself is gradually decreasing and the desirable level of operational reliability is becoming more difficult to maintain. Integrated inspection strategies coupled with measurable innovation in inspection technology can lead to significant improvements in operational cost efficiency and reliability without the requirement for a fundamental shift in the existing understanding of the inspection process and standards.

Modern transport networks require a well coordinated, smoothly functioning international rail system. Rail operations need to be safe, reliable and punctual with minimum disruption involved. This applies for both passengers and goods transportation via rail. The achievement of measurable improvement in the quality and efficiency of rail services can increase the competitive position of rail companies in the transport market. The European rail sector generated in excess of 400 billion passenger-kilometres and 241 billion tonne-kilometres worth of business in 2008. The graphs in Figure 2 show the passenger and freight traffic trends in Europe since 1950. The EU has set ambitious growth targets for the European rail industry which involve the doubling of rail passenger traffic and the tripling of freight traffic by 2020 in comparison to 2005 levels. It also aims to increase the rail transport market share to 15% and improve existing train travel times for most destinations by 15-20% by the same year. In order for the rail industry to achieve the growth targets set by the EU for the forthcoming years, rail traffic density has to increase, while at the same time train delays need to be minimised. New rail freight motorways across Europe will not be in place by 2020. Hence, in order for the rail freight industry to achieve the growth targets set by the EU for the forthcoming years, freight rolling stock traffic density has to increase too. This means that train delays need to be minimised, whilst cost-efficiency and reliability of freight operations need to be optimised. The map shown in figure 3 presents the extent of the European rail freight network which currently comprises 150,000km of rail track [Source: ERIM Database 2007].

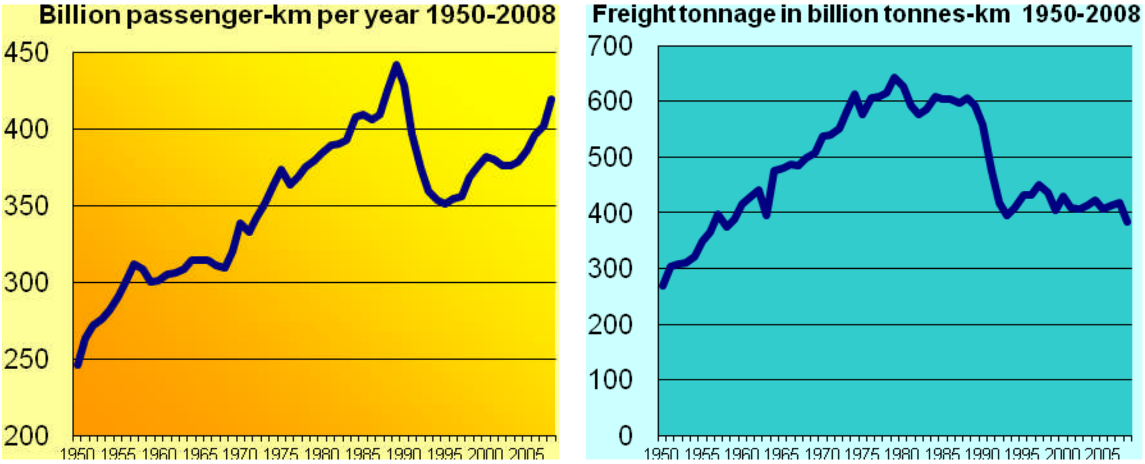

Figure 2: Graphs showing the passenger (left) and freight (right) commercial traffic in Europe over the last 60 years (Data Source: UIC statistics).

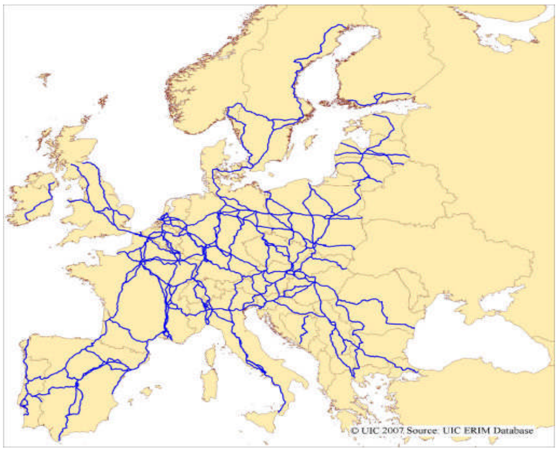

Figure 3: The European rail freight network [Source: ERIM Database, 2007].

One of the highest priorities for the European rail industry is currently the significant improvement of safety of the railroad system, involving an at least 50% reduction in current rail transport fatalities by 2020. This will increase the pressure on the maintenance of rail infrastructure. Maintenance costs for the European rail industry range to 20 billion Euros every year and it is estimated that it represents 15% of the industry's overall operating costs. The simultaneous increase in rail traffic and improvement in safety means that maintenance costs will see an unprecedented increase by 2020, harming the long-term prospects and sustainability of the European rail industry as a whole unless proper action is taken on time. To address this pressing problem the industry will have to successfully implement new and efficient maintenance strategies and inspection methodologies which will reduce to an absolute minimum equipment-related delays and accidents. The widespread application of the I-RAIL methodology has the potential of leading to a dramatic reduction in the overall number of broken rails throughout the European rail network.

The application of non-contact EMAT sensors that can operate at high-speed without loss of resolution offers immense new advantages in rail inspection. First of all the system can be deployed using virtually any type of rolling stock without variation in the overall performance of the inspection system. Moreover, the EMAT sensors are cheap, easy to make and easy to deploy at speed since they do not require physical contact with the rail. In addition, the control system has also a relatively low cost. The fact that the I-RAIL system can be deployed by virtually any type of rolling stock vehicle makes it unique since all conventional high-speed rail inspection systems require special test trains in order to be deployed. Since the I-RAIL system has a low cost, it is non-contact and can be installed on passenger and freight rolling stock, several systems can be used to continuously monitor the condition of a singl rail line during normal rail operations. This removes the need to close down the line and carry inspection activities during night (green zone activity) or carry out visual inspection while trains are running (red zone activity) with physical danger to the inspection engineers carrying out the task.