RFI
RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

GSM-R
Asset & Evolution Management
10 - 11 Sept 2013 Paris UIC HQ

Session 2: GSM-R - A Success Story

2.2 GSM-R for ETCS

Fabio Senesi
Rete Ferroviaria Italiana - Head Control and Command System and Telecommunication
ERTMS Users Group - President

GSM-R for ETCS

The technology innovation represents one of the qualifying driver that enables the modernization of the Organization.

One of the most important innovations introduced by RFI, now more than 10 years ago, was the GSM-R mobile radio system, that has been one of the technology that allowed the improving of the processes and the achievement of high level of operating efficiency.

The most important application where the GSM-R system has played a leading role was the "Italian High Speed Project" where the safe communications between the Train and the Ground systems was carried by the GSM-R without any back-up communication system.

Many years passed since the beginning of our "high speed challenge" and now, after tens of thousands of kilometers and hundreds of trains that every day run on our high-speed lines……

…..we can say with a certain peace of mind that...

"***The GSM-R is an excellent technology platform, robust, highly reliable and perfectly suitable for the ERTMS / ETCS application.***"

RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

GSM-R for ETCS: *where we are… and where we want to go*

GSM-R

Key

High Speed Lines

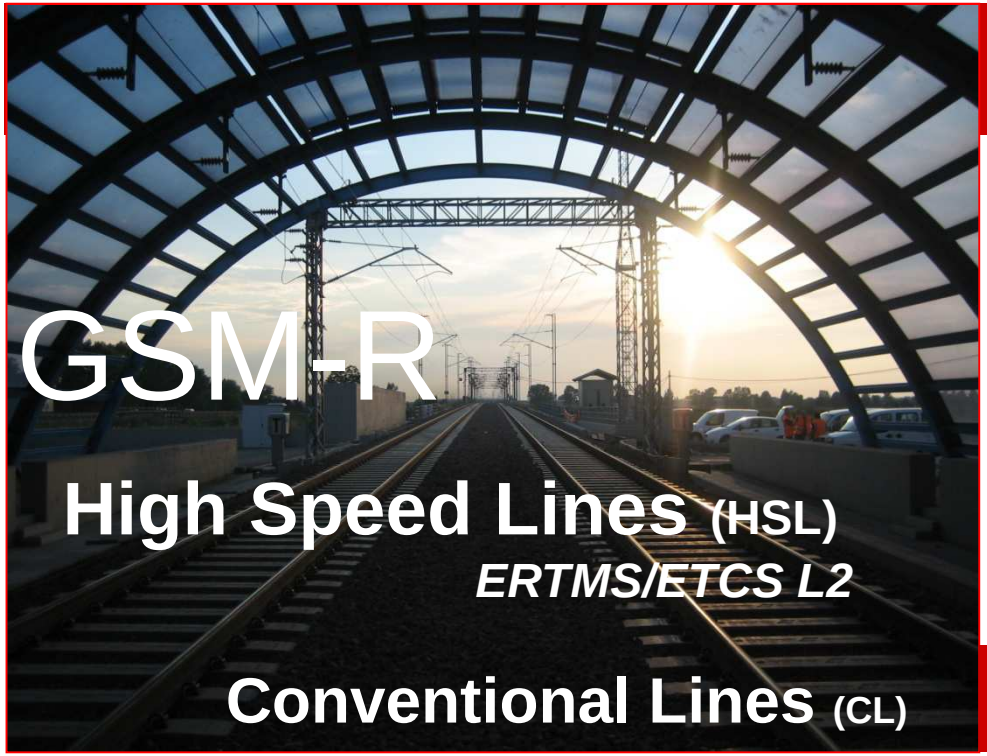
- ✓ GSM-R is the bearer for the ERTMS/ETCS Signalling System Level 2
- ✓ Strong requirements in terms of RAM (Reliability, Availability, Mantenability)
- ✓ Redundant radio coverage (double coverage)
- ✓ Quality of Service

Conventional Lines

- ✓ GSM-R is the Train to Ground communication system (Drivers-Controllers)
- ✓ Service communication between railway personnel
- ✓ The project covers the main (commercial) railway routes ~ 10.000 km
- ✓ GSM-R Network + improvements of SDH Transport Network
- ✓ Data Transport Network full IP (IP-MPLS Multi Protocol Label Switching)

RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

GSM-R for ETCS: *where we are… and where we want to go*



Key figures

- ✓ Total Length of Railway Network: **16.700 km**
- ✓ Covered by GSM-R**: 10.600 km**
- ✓ Start of implementation: **2002**
- ✓ BTS installed: **~ 1.800**
- ✓ BSC installed: **19 (CL) + 4 (HSL)**
- ✓ MSC installed: **4 (CL) + 3 (HSL)**

Services and

- ✓ **Automatic Train Control (HSL) ERTMS/ETCS L2**
- ✓ **Train to Ground Communication Services**
- ✓ **Train to Ground Data Communication**
- ✓ **Management of Railway Emergency**
- ✓ **Service Communication for Personnel**
- ✓ **Mobile Office Applications (GPRS)**
- ✓ **Added Value Services for Passengers (GPRS)**

- ❑ **GSM-R is the system adopted by RFI to fulfil efficiently and in a very integrated way the needs of mobile communications related to the whole railway process.**
- ❑ **GSM-R meets all the requirements of Voice and Data Communication related to railway services, including Automatic Train Control System over the High Speed Lines.**

RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

ERTMS: European Rail Traffic Management System
ETCS: European Train Control System Level 2
GPRS: General Packet Radio Service

GSM-R for ETCS: *where we are… and where we want to go*

Key requirements

→ RAM Requirements: ERTMS/ETCS System

Reliability, Availability, Maintainability

RFI Requirements consider the **GSM-R Subsystem** (GSM-R Network + SDH Transport Network) **at the same level of ERTMS/ETCS System** (Trackside Equipment – Distributed and Centralised)

Immobilising Failures:

mean downtime per year due to hardware DTHW,I = **8 minutes** tolerable as consequence of IMMOBILISING failures

Service Failures:

mean downtime per year due to hardware DTHW,S = **1 hour 9 minutes** tolerable as consequence of SERVICE failures.

→ Radio Frequency Coverage Level

Normal Condition and Fault of BTSs non-adjacent : - 92dBm coverage probability of 95% in each location interval (length: 100m)

→ System Redundancy

GSM-R Radio Coverage Redundancy

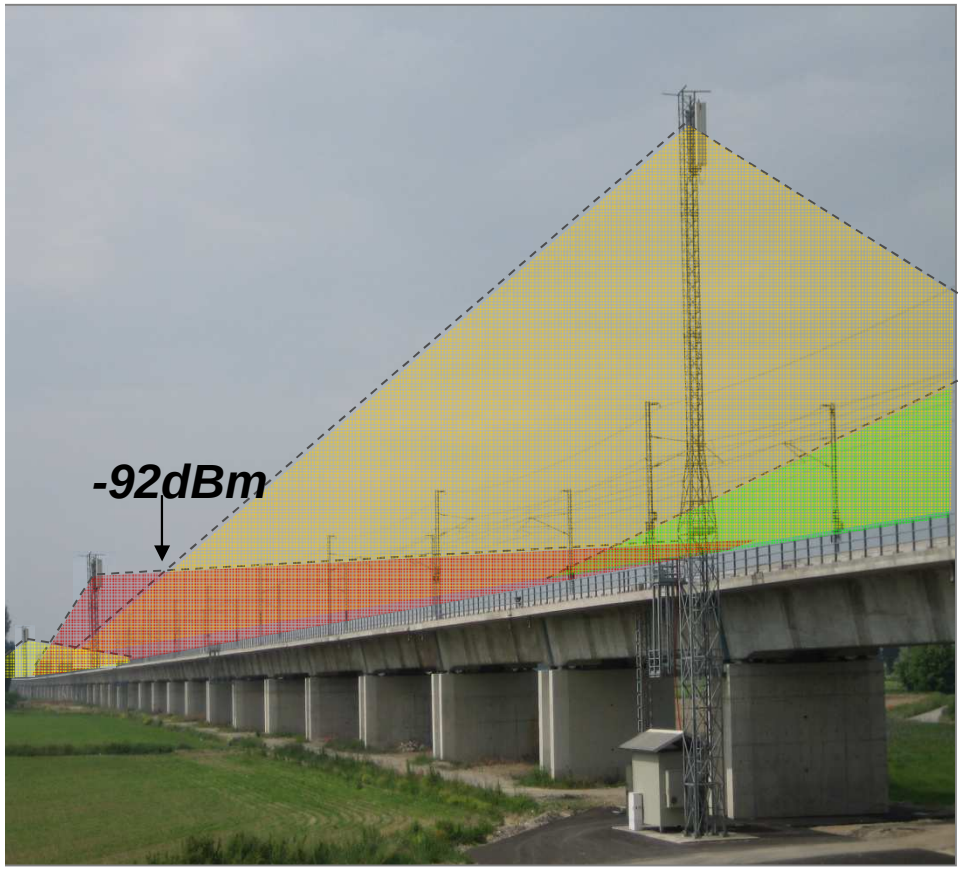
Single Fault Tolerant Architecture – LRU Level (Line Replaceable Unit) (GSM-R, SDH Transport Net)

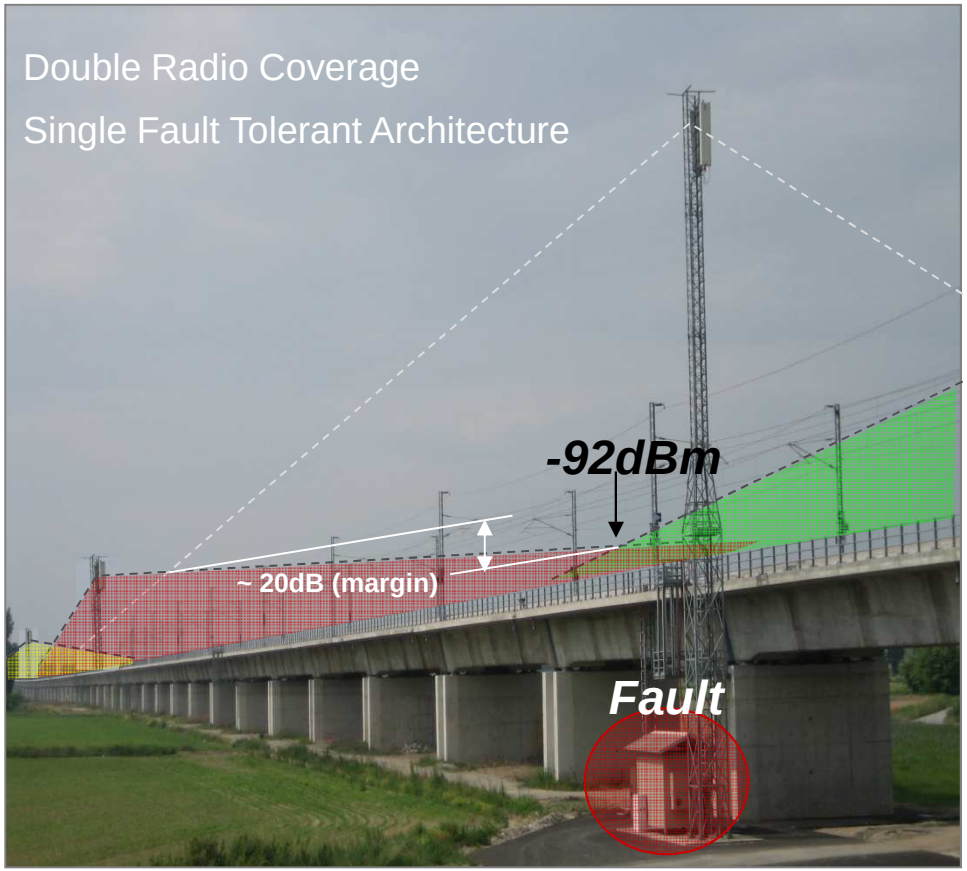
No-Break Power Supply System (both for the centralized and long track installations)

RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

GSM-R for ETCS: *where we are… and where we want to go*

Key requirements

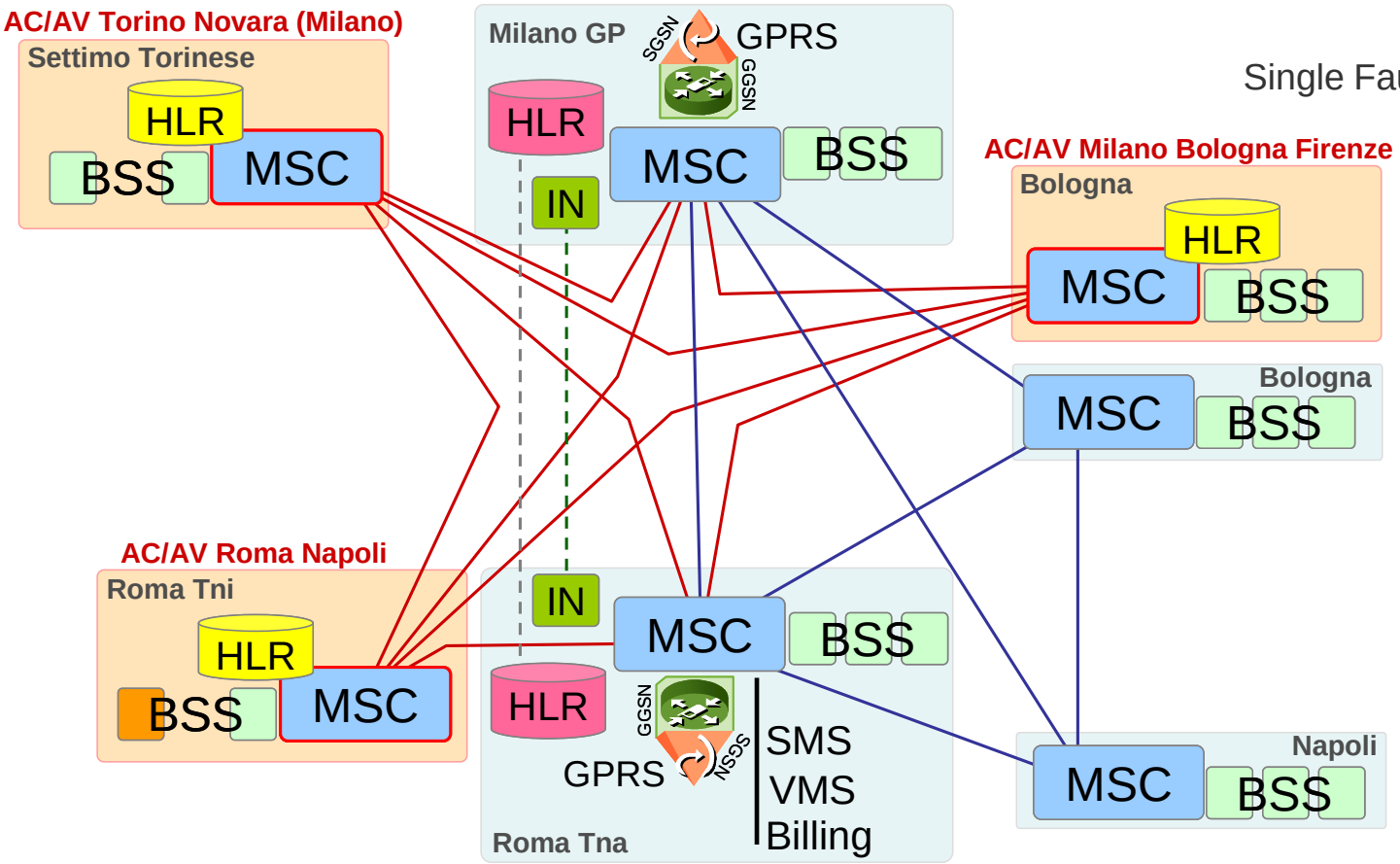




RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

GSM-R for ETCS: *where we are… and where we want to go*

Key requirements



System Redundancy

Single Fault Tolerant Architecture

Core Network ←

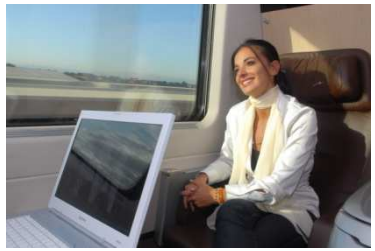
Transport Network ←

RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

GSM-R for ETCS: *where we are… and* ***where we want to go***

Evolution of GSM-R: next steps

- **Technological evolution** (move to a full-IP platform)
  - → **NSS Core: New platform (upgrade from Rel.99 to R4)**
  - → **BSS Subsystem: Flexible solutions (BSC / BTS)**
- **Architecture evolution** (catastrophic event proof)
  - → **High reliability and full disaster- recovery architecture**
  - → **Flexible, distributed and modular architecture**
  - → **Downsizing the current network taking advantage of the greater capacity of the new generation of equipment**
- **Investment protection** (…that are looking to the future)
  - → **platforms open to the deployment of new applications and to the evolution of the standards**
  - → **platforms open to the future generation of mobile communication for railways**



RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

GSM-R for ETCS: *where we are… and* ***where we want to go***

Evolution of ERTMS/ETCS: next steps

- **Technological evolution** (move to a full-IP platform)
  - → **ETCS over GPRS**

    GPRS can be used as a stepping stone from current circuit switching based technology towards any future proof mobile transmission technology.

    By enabling future possibilities of managing dense ETCS traffic, ETCS over GPRS can be seen as a missing link that brings added value by maximizing the impact of investments already made in European ERTMS infrastructures.

- **New applications**
  - → **ERTMS/ETCS L2 (+ National Signalling System) over Conventional Lines (Interoperable Corridors)**
  - → **Upgrading of the existing infrastructure for faster trains (up to 360 km/h)**
  - → **MONITORING GSM-R Interference**
  - → **ERTMS(ETCS +GSM- R) + IXL Log Analyzer: An Integrated platform**
  - → **Satellite application: Localization and Euroradio data**
- **Investment protection** (…that are looking to the future)
  - → **platforms open to the evolution of the standards**

RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

Operational Feedback

- **MONITORING GSM-R Interference:**
  - Observation of GSM-R spectrum in proximity of the railway line

- **Check deeply Operational fault: Italian High Speed Competition is by ETCS L2:**
  - Need a ERTMS Automated Analysis by data Log interpretation

RFI GSM-R Network - Deployment

Total network (km)	16700	
	Voice	ETCS
GSM-R Planned (km)	10600 (CL and HSL)	600 HSL (ERTMS/ETCS L2)
Network Constructed (km)	~ 10100	600 HSL
Network Ready for Service (km)	9540	600 HSL
Network in Operation (km)	9540 (11 December 2011)	600 HSL
Planning level (95% probability, dBm)	-85 dBm CL	-92 dBm (double coverage) (planning level in case of outage of service of one BTS)
Start of Planning	2001	---
Start of Implementation	2002	---
Network in Operation	2004	2005 1° HSL (ERTMS/ETCS L2): Rome-Naples
End of Implementation	2012	2009
End of migration	---	---

RFI
RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

Continuos observation of GSM-R spectrum in proximity of the railway line
Grides project → Dejammer

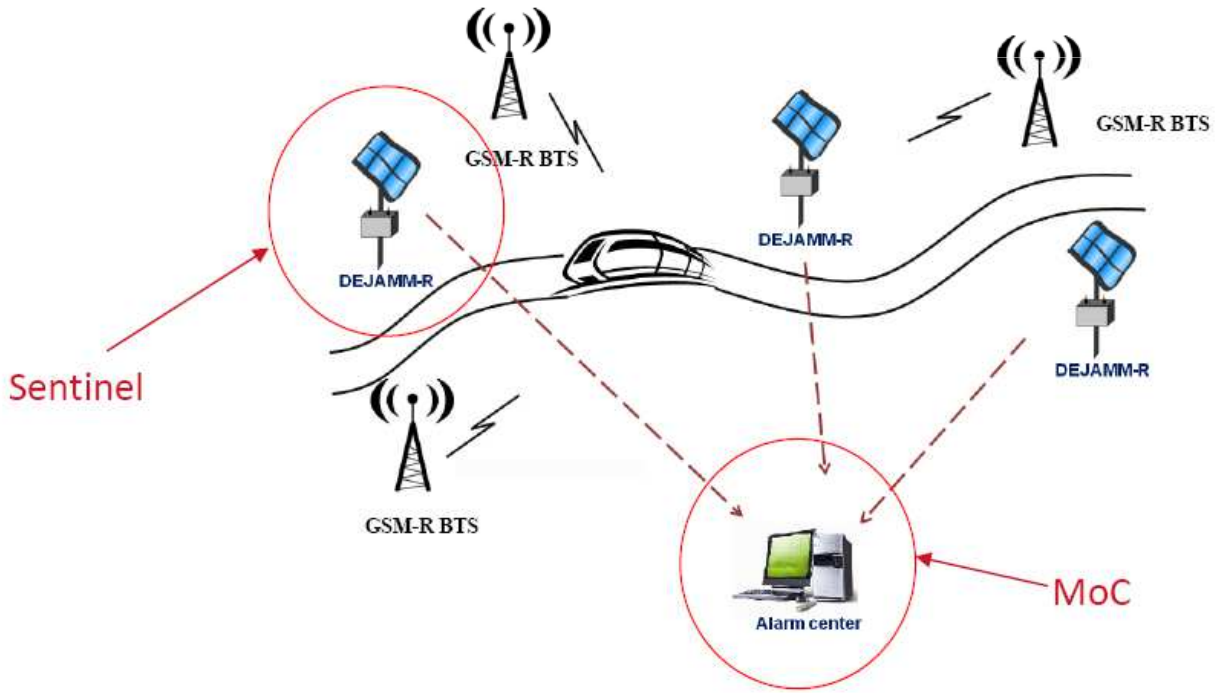
2007 : GRIDES (GSM-R Detection System) : Prototipe EU coofinanced
2012 : Dejammer (Detection of Jamming in Railway System) : industrial application
Continuous observation of GSM-R spectrum in proximity of the railway line, in order to:

1. Measure the quality of the signal transmitted by RBC (Radio Block Centre) and trains
2. Detect non-malicious or malicious interferences
3. Keep constantly updated a remote analysis centre on the current status including spectrum analysis

RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

DEJAMM-R system is architected into two main units:

- DEJAMM-R **Sentinel**
- DEJAMM-R **MoC** (Monitoring Centre)



DEJAMM-R Sentinel

To be installed in proximity of an HS railway track
Responsible for scanning of GSM-R frequency bands and report to MoC about the status and the relevant parameters (ALARM + SINR) of all the 38 GSM-R channels in less than 3 minutes (*depending on the number of messages sent to the MoC)*

Detectable Interferences:

Narrowband interference
•Sinusoidal Oscillations ; •FM transmitter; •Narrowband Gaussian Jammer
•Narrowband OFDM (e.g. DAB, DRM, DRM+, DVB-T); •Broadcast Analogue Television (e.g. PAL) ; •UMTS (CDMA 1x)

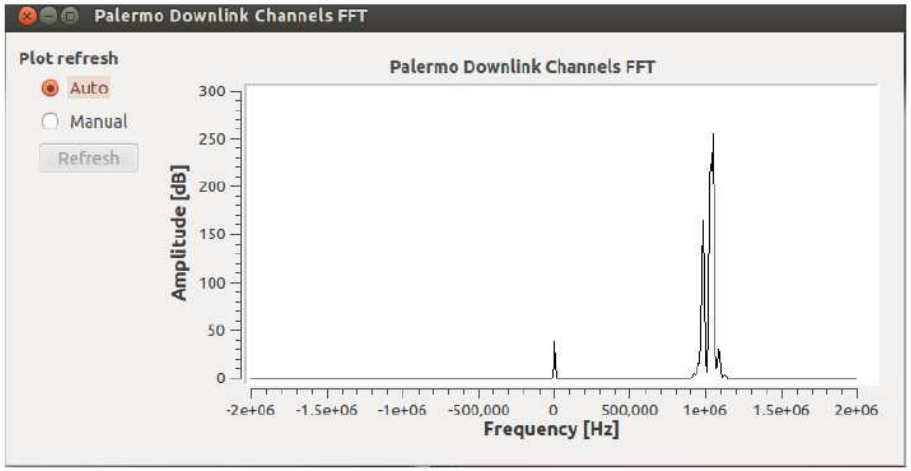
Wideband interference
•Wideband Gaussian Jammer ; •Wideband OFDM (e.g. DAB, DRM, DRM+, DVB-T)
•Broadcast Analogue Television (e.g. PAL)

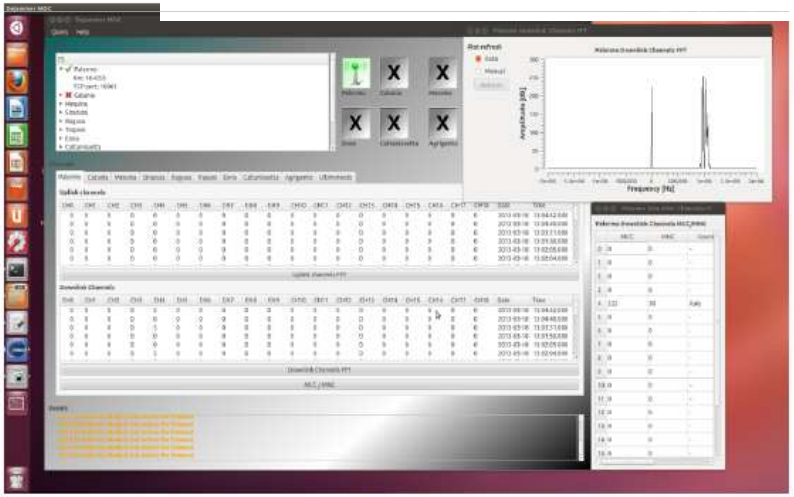
RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

DEJAMM-R MoC

- Receive data from Sentinels via a TCP/IP network (Fast Ethernet/LAN) or via GSM (GPRS)
- Can support up to 20 sentinel connections
- Highlights all received Alarms from Sentinels (GUI)
- Monitors GSM-R signal levels (SINR) received from Sentinels (GUI)
- Record and store of all received data in a suitable DataBase (MySQL)
- Possibility to make queries about one or more sentinels
- It works like a Remote Spectrum Analyzer
- Configurability through .xml file
- Multilanguage support

RFI
RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

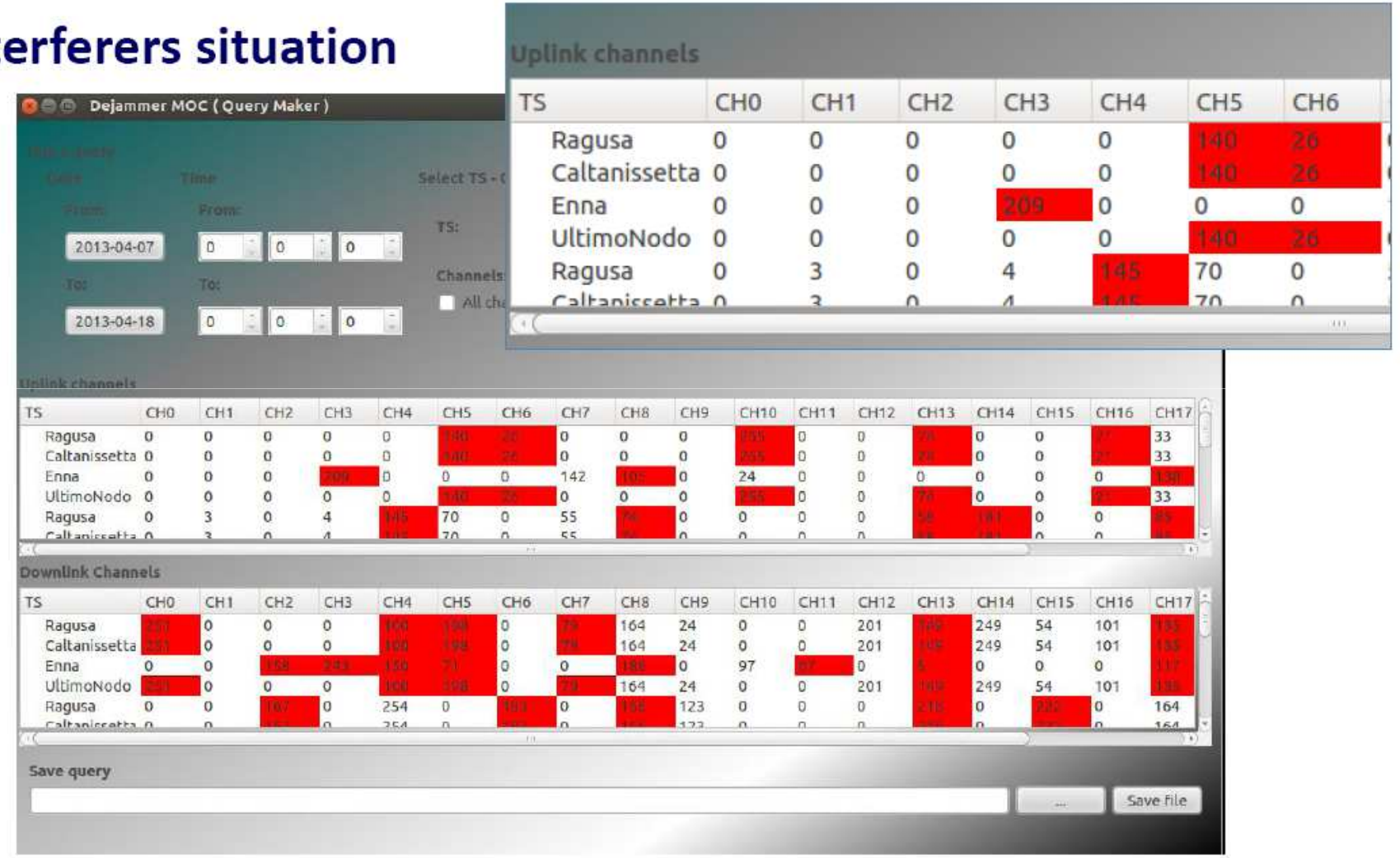




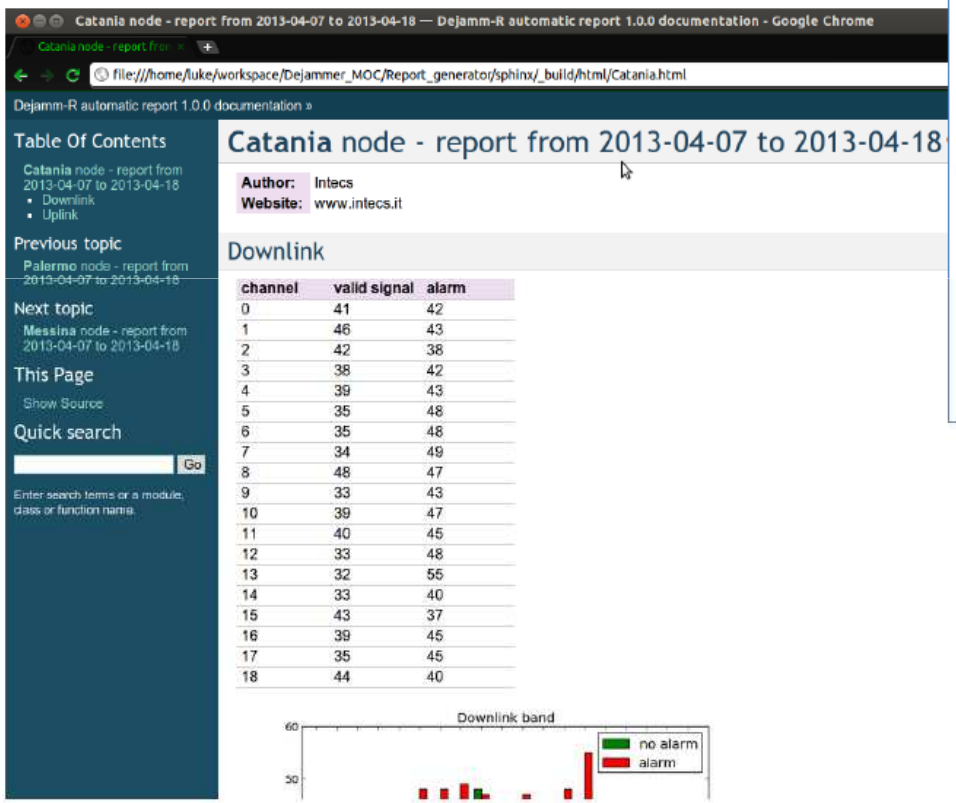
GSM-R Signal: FFT Downlink Band and MCC/MNC Parameters

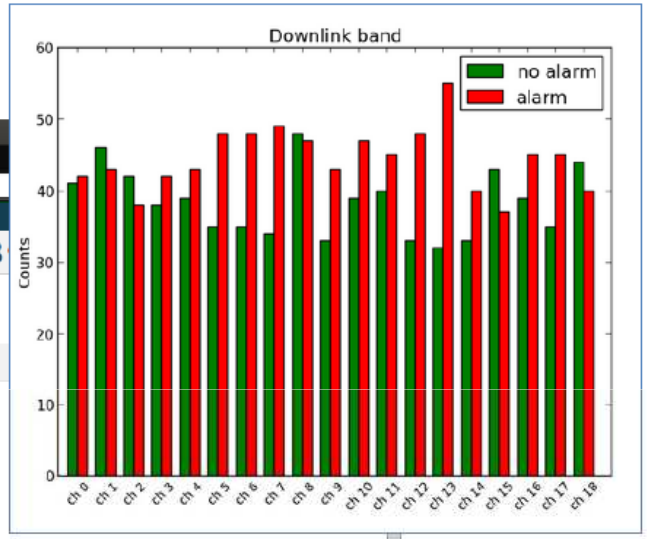
Country and Provide Codes

Interferers situation



Single channel report





RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

Automated Analysis

What direction is moving RFI to push the envelope of ERTMS monitoring and troubleshooting?

A new project code-named ERTMS Log Analyzer (named MISTRAL) is in charge of designing an automated processing engine with the following guidelines:

- A Functional Representation of the RBC+ EVC
- A model validated through Model Checking and Formal Methods
- Active Monitoring of Functional Scenarios
- Verify & Validation support in the case of new track scenario
- Comparison between train rides
- Real-Time or Post-Processing detailed Analysis of operating anomalies

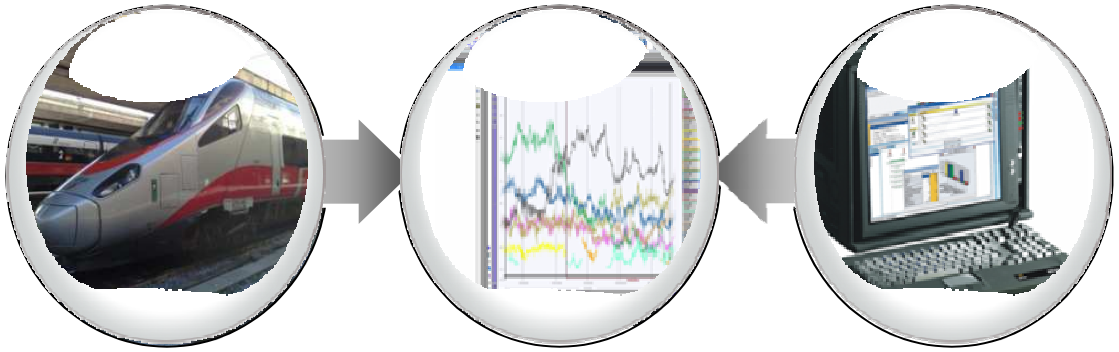
Testing Equipements

- Test Trains:
  - 5 Test Trains/Carriages
  - Three equipped with GSM-R Instrumentation
  - One for HSL exclusively (Y1)
  - One for both HSL and Conventional Lines (Archimede)
  - One for Conventional Lines (Talete)
  - One awaiting order for Conventional Lines (Aldebaran)
  - One awaiting order for HSL (Y2)
- Portable Data Collection systems
  - NetProbe Trolleys rel. 1.0 or 2.0
  - Triorail Handsets
- OMC-R
  - Call trace
  - KPI performance monitoring
- Network Monitoring
  - Web-based National statistics.
  - Monitoring Probes at HSL control Centres
  - NetAnalyzer for troubleshooting in regional departments

RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

System Evolution – One Platform

ETCS e IXL | **Data Collection** | **GSM-R**



Data sources are correlated and analyzed to provide a unified view

RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

Driving Parameters

Parameter	Class
Aggregated Train Run	General
Aggregated Train Stops	General
Incident Analysis on “Train Trips”	General
Static vs Dynamic Speed Profile	Speed Analysis
Speed Profile vs Temporary Speed Restrictions	Speed Analysis
Average TX/RX Power along the line	Radio Frequency
Average TX/RX Quality along the line	Radio Frequency
Successful Calls	ETCS Call Counters
Drop Calls	ETCS Call Counters
Disconnected Calls from Ground System	ETCS Call Counters
Unknown Reason Disconnected Calls	ETCS Call Counters
Standard Deviation of Odometry Errors	ETCS
Number of TNV_CONTACT timeouts	ETCS
Number of missing information points	ETCS
RBC Handover with the same MT	ETCS
Movement Authority Missing Acknowledge	ETCS
LAPD/LAPB protocol errors	ETCS

Requirements Samples – Incident Hit Ratio

nid_engine	nid_operational	Train Trips	Data
7	9637	1	12/11/10 22:35
202	9517	1	7/10/10 19:39
217	9528	1	11/10/10 15:23
227	9530	1	20/10/10 17:04
227	9612	1	27/10/10 8:16
236	9505	1	13/8/10 11:35
238	9532	1	24/10/10 17:00
244	9513	1	25/8/10 15:57
245	9527	1	26/8/10 20:56
246	9522	1	29/8/10 12:13
250	9532	1	16/7/10 17:19
250	9530	1	9/9/10 16:40
5804	9530	2	18/7/10 16:11
5816	9626	1	29/10/10 14:50
5825	9510	1	17/10/10 8:00
5831	9603	1	21/7/10 11:24
5831	9522	1	24/7/10 12:52
5833	9522	1	15/11/10 12:02
5839	9526	1	29/10/10 14:05
5846	9513	1	8/8/10 15:50
5847	9534	1	7/10/10 20:19
5852	9530	1	22/7/10 16:59
5855	9501	1	11/9/10 9:24
5858	9507	1	19/7/10 12:58
5941	9377	1	26/8/10 18:35
5944	9359	1	22/7/10 19:40
5944	9357	1	7/10/10 18:44
5945	9350	1	13/8/10 10:50
5945	9358	1	22/9/10 22:33
5957	9374	1	26/10/10 12:40
5962	9350	2	16/9/10 11:02
5964	9374	1	29/8/10 12:29

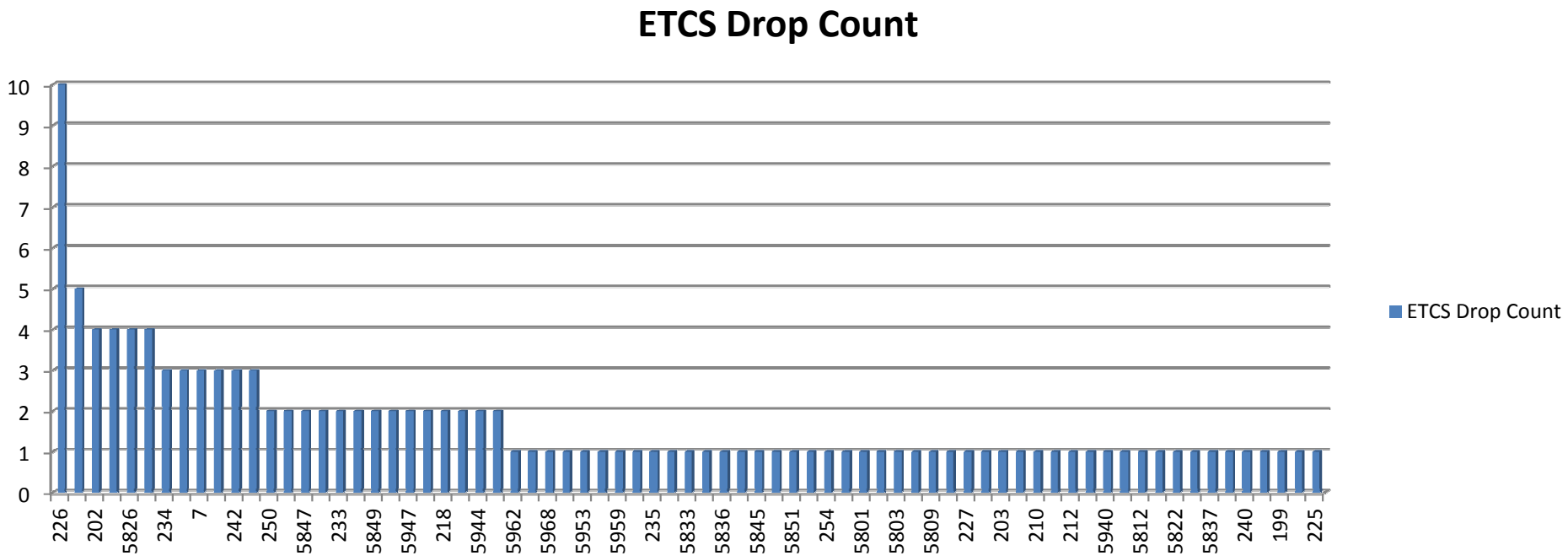
The following table provides Train Trips break-down by NID_Engine:

- NID_Engine of faulty train
- Il NID_Operational of faulty train run
- Number of occurrencies
- Timestamp of event

Note: Same NID_Engine can appear on multiple lines.

RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

Requirements Samples – EURORADIO Stack Errors

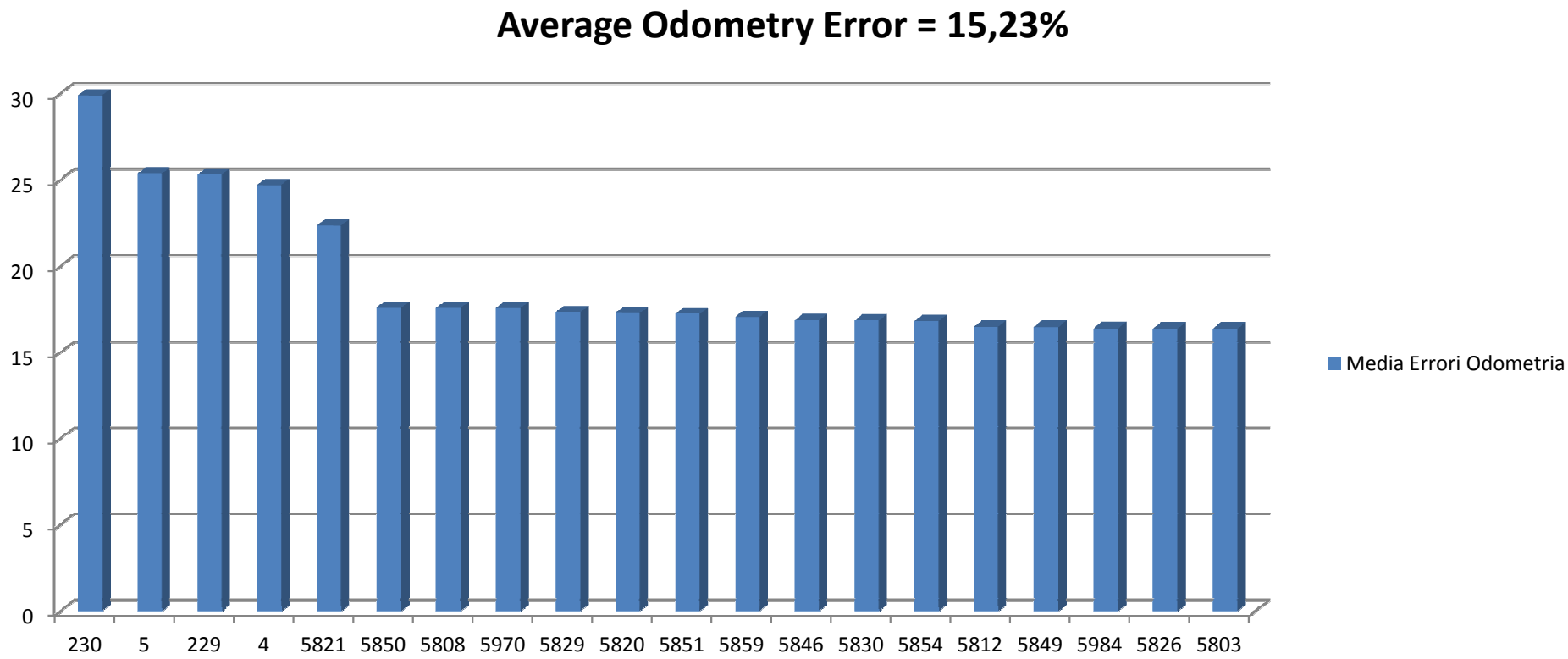


This chart provides ETCS call closed by NID_Engine:

- Disconnection is evaluated on ETCS channel
- DISCONNECTION_REQUEST X.224 is missing
- One of two endpoints closes the call without DISCONNECTION_REQUEST message or whenever RBC requires the disconnection

RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

Requirements Samples - Odometry

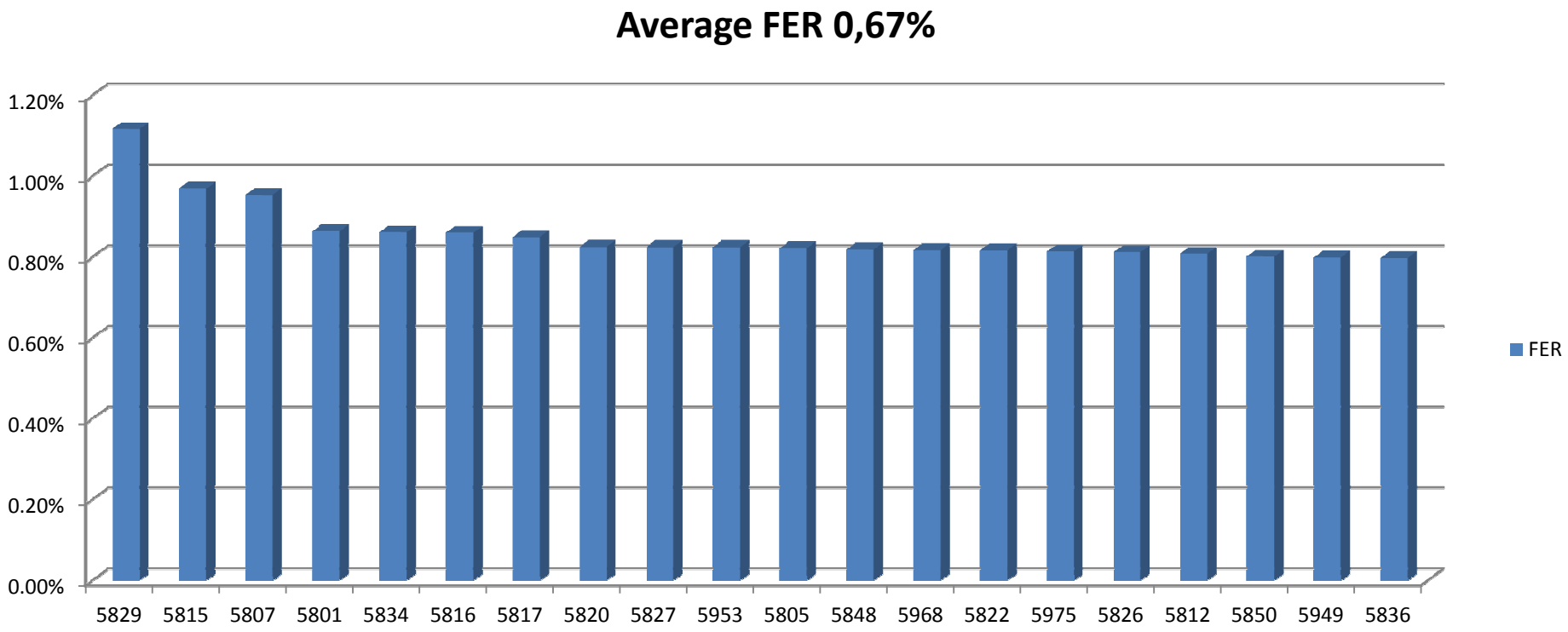


This chart provides Worst Odometry errors associated to their NID_Engine:

- Parameter is evaluated as sum of Under Reading and Over Reading Errors
- Over reading Under reading are taken straight from Train Position Reports

RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

Requirements Samples – Radio Problems

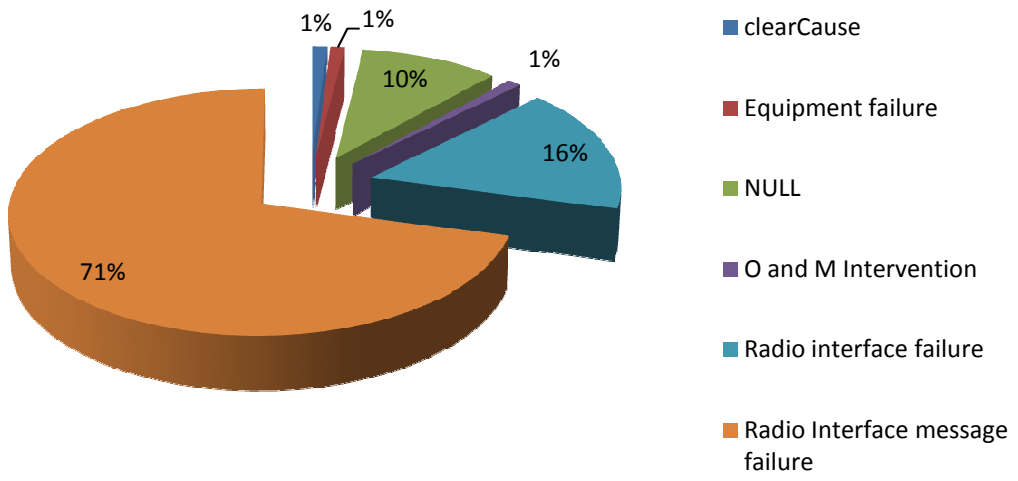


This chart provides average Frame Error Rate associated to its NID_Engine:

- Parameter is evaluated at LAPB level
- FER is more than Zero if LAPB packets are retransmitted

RFI
RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

Requirements Samples – GSM-R Call Clears



GSM-R Train Trip Cause Break-Down

As anyone can spot large part of failures belong to Radio Interface GSM-R Errors

- Radio Interface Message Failures (GSM-R) account for over 71%
- Radio Interface Failure in general (EURORADIO) accounts for 16%
- Another 10% is due to unspecified causes.

RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

New Challenges

- Deeper ETCS investigation
- ETCS Application Layer Analysis at functional level
- Design requirements validation (e.g. vs FFFIS)
- Formal requirements description language
- Extended data collection platform (e.g. EVC Logs)
- Automated incident analysis
- Certified Engine

RFI
RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

New Data Sources

Schematic Plan Management

- Main design Data (Name, Revision, Date, Supplier, Initial and Final Km.
- Balise, Track Circuits and all other relevant items along the line
- Altitude and Speed profiles

Network parameter configuration

- Track Circuit Installation Rules
- Balise Telegram Tables
- RBC Message Tables
- RBC Condition Tables

Train-Ground Communication

- Performs the acquisition of RBC-MSC communication
- Aggregates traffic by HSL, NID_Engine, NID_Operational, Direction, Type, involved RBCs

Ground-Ground Communication

- Interlocking Status Update
- RBC to RBC communication
- Interlocking to Interlocking communication

Diagnostic Trains Data

- Track Quality Index
- Electric and Tracion
- Telecommunication
- Balise

RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

Requirements Validation

Speed Profile

- Evaluates:
  - Static Speed Profile (through schematic plans)
  - Dynamic Speed Profile (trough radio messages)
  - Slowdowns
- The system also evaluates TSRs events

Voltage and Phase Condition Change Transmission

- Verifies that Voltage and Phase Conditions Change are properly sent to the train accordingly to implementation guidelines.
- It also monitors and evaluates hot box measurement systems

Rendezvous Logic

- Verifies Balise linking in terms of:
  - First Item
  - Proper Direction
  - Proper Sequence

RBC radio coverage

- The system verifies that interval between two messages is less than TNV_Contact timeout.
- In case such an event occurs the system evaluates that EVC complies with such parameter.

RFI
RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

Thank you for your attention !

Fabio Senesi

RFI
RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO

page intentionally left blank