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GSM COVERAGE MEASUREMENT ON RADIO EXTENDER SYSTEM FOR RAILWAYS TUNNEL

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Abstract: In this paper a short introduction to the radio coverage system for railway tunnels realised on the line Prato–Bologna, is presented. GSM coverage measurements have been conducted on three different installations. For a better results interpretation the employed measurement system has been described. Moreover measurement execution and physic characteristics of the analysed tunnels are shown. Finally results are discussed and some conclusions are drawn.
Keywords: Radio coverage, GSM extender system

1 INTRODUCTION

Linkage's quality and connection's availability are fundamental parameters to qualify a radiomobile network for important purpose. *FS* turned to radiomobile network to connect personnel on board the train and, pressed by the competition of the transport market, had to satisfy the demand of the custom in terms of quantity and quality of the offered services.

Besides a corporate image choice, the installations are an investment for the future railways requirement.

Automatic train control (ATC) will be implemented as standardised by UIC under ETCS (European Train Control System). ETCS employ GSM as transmission system to realise the bi-directional data flow between the fixed control centre and computers on the trains.

A private radiomobile network matched on railway requirement, named GSM-Railway, is actually on trial. For this reason systems capable of extending the communication inside the tunnels and in the shadow zones of the railway were realised. Particularly, at present, installations are capable of extending GSM, ETACS systems and FS private network at 450 MHz.

In the short tunnels the coverage extension is obtained by placing an antenna near the entrance. High signal attenuation is shown when placing antennas on the tunnel entrance. Practical experience suggest to place the antenna, so that the tunnel cross section's area is smaller then first Fersnel's ellipsoid section [1].

In tunnels longer than 1 km leaky cables and, eventually, internal amplification station are used. Moreover some installations have systems that permit hand-over procedures. Analog systems are chosen since they are simpler and transparent to every kind of transmission standard.

In order to check installation's efficiency and quality as well as to fix maintenance's activity, a series of measurements was done.

Data collection was done using a railway-car equipped with a coverage measurement system that travelled, at an appropriate speed, the distances that has to be analysed. With this system the distribution of the electromagnetic field in tunnel environment and in shadow zones were detected. Results made possible a comparative analysis and conclusions on the efficiency of the extension systems in railway tunnels.

2 THE MEASUREMENT SYSTEM

Field strength measurement of the carrier wave only are no longer sufficient when performed on fully digital network. GSM for example uses a complex modulation procedure. Particular effects have to be analysed like signal reflections due to multi-path transmission and problems with the protocol processing. For this reasons the Rohde & Schwarz TS9951 measurement system was employed.

TS9951 consists of one or two test mobiles interfaced with a PC (personal computer). The TS51-K1 coverage measurement software was installed on PC. Mobile terminals have an active function for the measures.

The possibility to change cell during communication is a very important function in a cellular system. To permit this, radio measurement performed by mobile stations and by BTS (Base Transceiver Station), are necessary. Particularly mobile stations collect, store and transmit level and quality measures of the serving and neighbouring cells. Measurements are performed on the multiframe of the slow associated channel (SACCH) and are provided by two indexes named RxLev and RxQual. The first one is a 6-bit index, and takes into consideration signal strength of serving or neighbouring cells (table 1, on the left). The second is a 3-bit index that provides an indication of the bit error rate (BER) as shown in table 1 (on the right). Both can be estimate on a full multiframe of SACCH (RxLevFull, RxQualFull) or on a sub-ensemble of 4 frames (RxLevSub RxQualSub). This information are refreshed and transferred to the BTS once or twice every second.

The main purpose of TS9951 is to decode SACCH channel and to provide the result of measurement. Used mobile terminals are calibrated by Rohde & Schwarz to yield measurement uncertainties less than 3 dB.

Table 1: The two indexes named RxLev and RxQual.

Rx Lev	RMS level received signal	Rx Qual	Measured BER	BER (assumed value)
0	< -110 dBm	0	< 0.2%	0.14%
1	Between –110 dBm and –109 dBm	1	between 0.2% and 0.4%	0.28%
2	Between –109 dBm and –108 dBm	2	between 0.4% and 0.8%	0.57%
3	Between –108 dBm and –107 dBm	3	between 0.8% and 1.6%	1.13%
…	…	4	between 1.6% and 3.2%	2.26%
…	…	5	between 3.2% and 6.4%	5.3%
61	Between –49 dBm and -48 dBm	6	between 6.4% and 12.8%	9.05%
63	> -48 dBm	7	> 12.8%	18.10%

Results are reported by bar graph or numbers. Base Station Identification Code (BSIC) and Broadcast Control Channel (BCCH) are also displayed as well as the name of the activated base transmitter station.

Moreover TS9951 is equipped of a GPS receiver, but an external navigation system, like Travelpilot, can be added to the internal one.

In the measurement reports we will indicate the RxLevFull and RxQualFull of serving cells.

3 OPERATIVE ENVIRONMENT

On this paper some results achieved during a measurement tour on three different tunnels, are reported. In the first one (Gabbolana, 926 m) coverage is obtained using an antenna standing 50 m from the North tunnel's entrance (see figure 1a). Antenna's characteristics are shown in table 2.

In the second tunnel is placed a leaky cable (RLK 13/33 VARIO by RFS), supplied by an external equipment standing around the entrance (see figure 1b).

Table 2. Antenna's characteristics.

ANTENNA TYPE	**SIRA ETEL-29**
Frequency range	870÷960 MHz
Impedance	50 Ω
VSWR	≤1.3
Polarisation	Vertical
Gain ISO	12 dBi
Half power beam width Vertical plane Horizontal plane	 26° 65°
Front to back ratio	≥30

Both tunnels are bent and made of brick. Gabbolana's gallery has a medium radius bend, while the other has a double bend. The third installation serves two adjacent galleries (Ancini, 182 meters long, and Monte Adone, 7136 meters long) each separated by an 80 meters external trait. This installation consists of two head stations that supply each a 14 line's amplifier by means of a leaky cable. The amplification's step is of 250 meters and in such a way two extension's systems are realised as shown in figure 1c. To permit the hand-over procedure it is necessary to realise an overlap of electromagnetic fields inside the tunnel. For this reason the last amplifiers of each chain are connected by approximately 850 meters of constant coupling leaky cable (RLK 13/33 by RFS). This structure has been designed to realise an overlap area larger than 650 meters. The measurements related to this plant are not reported here.

Field strength measurement of the carrier wave only are no longer sufficient when performed on fully digital network. GSM for example uses a complex modulation procedure. Particular effects have to be analysed like signal reflections due to multi-path transmission and problems with the protocol processing.

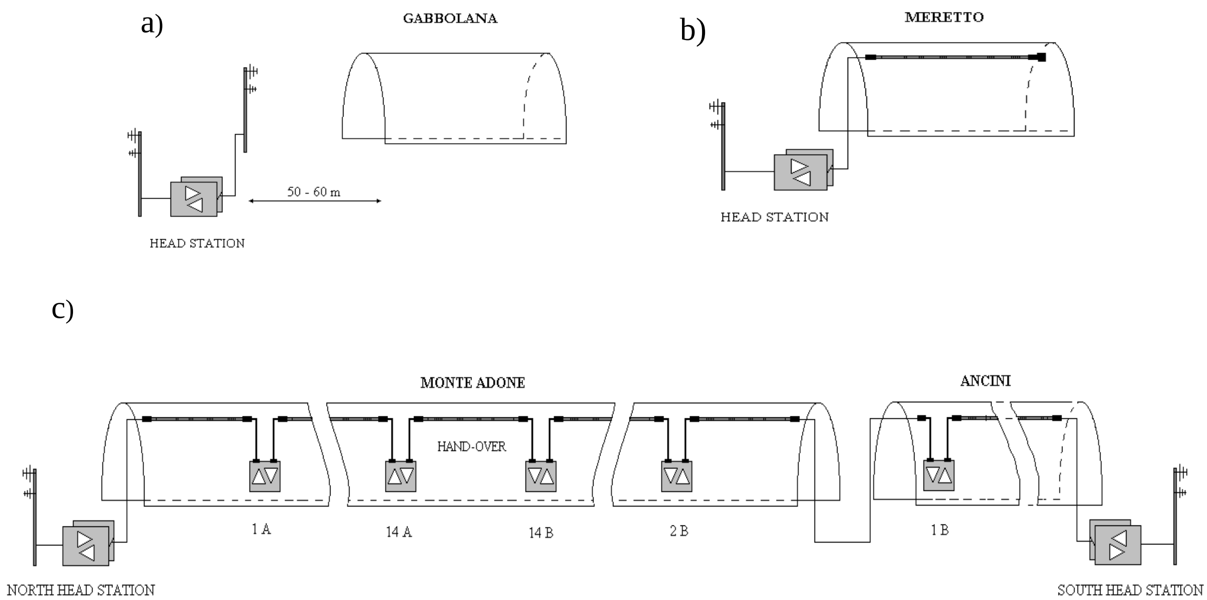

Figure 1: The operative environment.

4 MEASUREMENT EXECUTION

The TS9951 is set on a railway's wagon equipped with a omnidirectional vertical polarised antenna. This one was placed on the wagon's roof by a magnetic support and connected by a coaxial cable to TS9951. Measurements were performed covering the route at constant speed of 85 km/h. Each measurement tour was performed on the same conditions. This permit a direct comparison of the results and so a comparative analysis of the installations is possible. During the test session described on this paper the navigation system wasn't available. For this reason the diagrams later reported are in function of time instead of distance. Sampling step, extremely large and speed depending, does not permit to consider this measure as a local average (especially at high speed) [2]. Therefore the system gives qualitative results that can show "holes" on electromagnetic coverage but that are not suitable for a detailed study of the field distribution.

5 RESULTS AND DISCUSSION

Figure 2 shows the results obtained in Meretto's gallery. Diagrams indicate how the signal level goes up, from the South entrance in compliance with the regression line visible on the same picture.

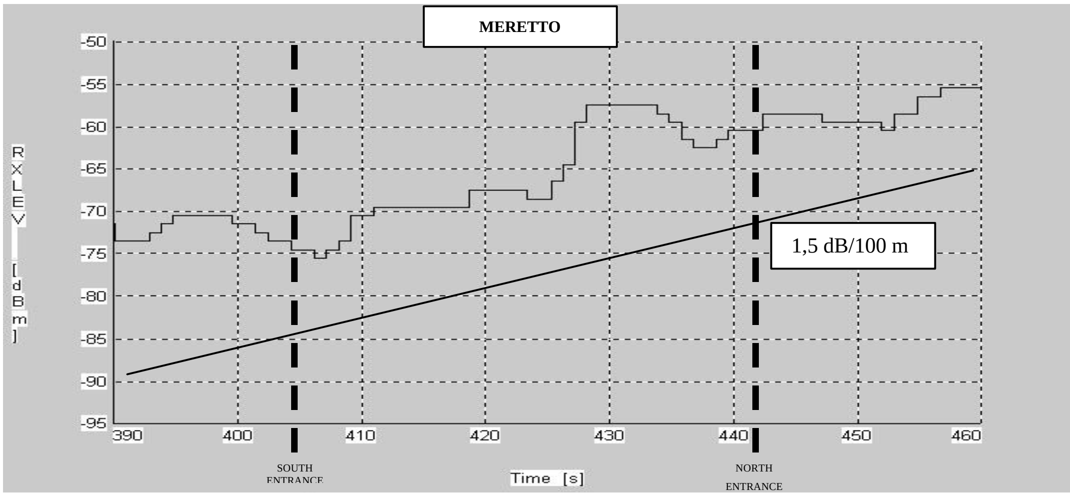

Figure 2: RxLev in Meretto's gallery.

All recorded values are comprised in a strip of 6 dB around this line that climbs with a slope of 1.5 dB/100 m. Complete signal dynamic inside the tunnel is about 17 dBm.

Figure 3 shows that near the South entrance high values of RxQual are detected.

This behaviour can be attributed to the different delays of each received signal's components. Particularly, around the entrance two mains signal components can be located. The first is the direct component from BTS while the second comes from the gallery's coverage extension system and shows higher delay. Generally receiver permits to operate on channels with a maximum delay spread of 16 μs, but also with lower delays some receiver's problems can be detected. However data reported in picture 3 shows short duration of the worst RxQual values, and so no heavy consequences on telephone conversations are given.

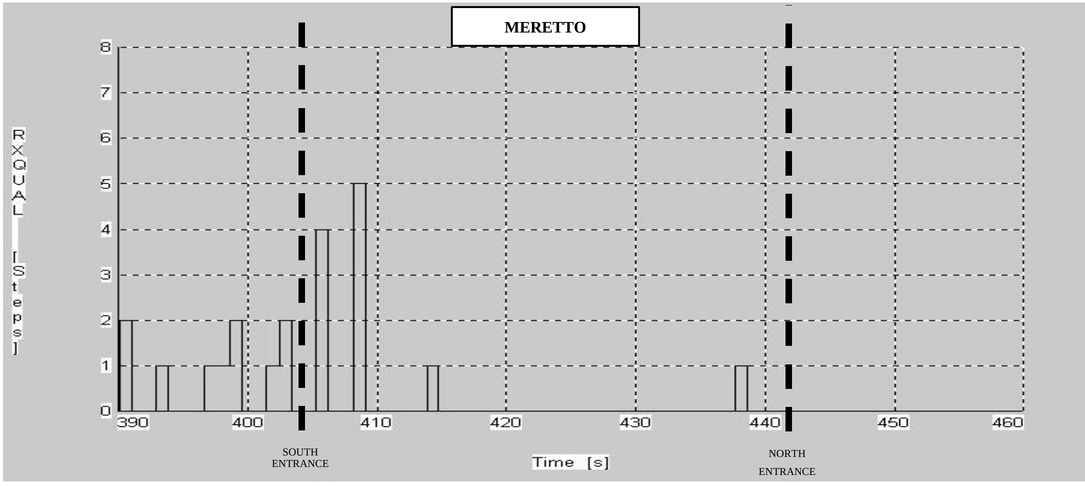

Figure 3: RxQual in Meretto's gallery.

Picture 4 shows the signal level measured in Gabbolana's gallery.

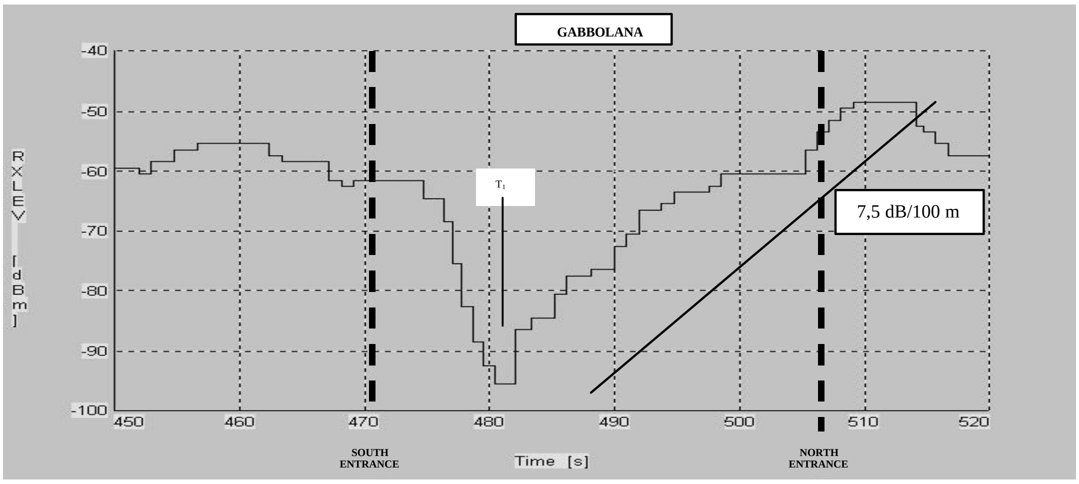

Figure 4: RxLev in Gabbolana's gallery.

It is possible to see as the signal goes down beginning the South entrance for about 250m, where the coverage is due to the external field only. In this point (T_1) there is the minimum signal level and the highest RxQual values. From T_1 to the North entrance signal level goes up in compliance with a regression line of 7.5 dB/100 m.
On North tunnel's entrance, where the head station (HS) is located, no propagation's phenomena capable to degrade heavily signal quality are noticed.

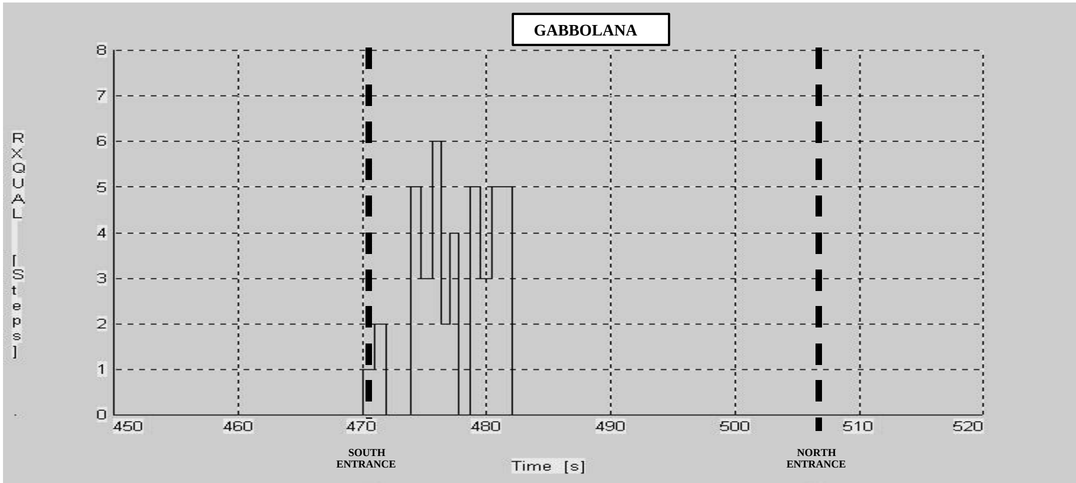

Figure 5: RxQual in Gabbolana's gallery.

REFERENCES

[1] G.BRAMBILLA, "Estensione delle comunicazioni radio terra-treno nelle gallerie e nelle zone d'ombra elettromagnetica del tracciato ferroviario", in italian, *Ingegneria Ferroviaria*, pp. 811-820, November 1996.

[2] W.C.Y. LEE, "Estimate of local average power of a mobile radio signal" IEEE Trans., Vol VT-34, No. 1, 1985

[3] A.CORAIOLA. SCHULZE BUXLOH, G. THÖNNEβEN, "Leaky Coaxial Cable with Length Indipendent Antenna Receiving Level", International Wire and Cable Symposium, Reno, Nevada, November 1992.

[4] A.CORAIOLA "Cellular Radio Communication System for Railway Tunnell", WCRR 1994, The Congress Proceedings.

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