EMF EXPOSURE ASSESSMENT OF RAILWAYS SYSTEMS' WORKERS: THE EXPERIENCE IN ITALY

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In recent years occupational exposure to electromagnetic fields of railway engine drivers has been widely investigated in Italy.

A first measurement campaign [1] was performed by ISPESL in cooperation with Trenitalia S.p.A. (the transportation company of the Italian National Railways); surveys on static and ELF magnetic fields were performed over 8 different models of engine or electrified train. All measurements were performed on board during real service condition, implying the presence of two engine drivers. The routes involved in surveys ranged from a few tens of km (Rome-Nettuno) to hundreds of km (Rome-Florence).

The actual electrification system of Italian railway network is wholly based on 3 kV DC lines, and the main sources of static magnetic field inside the engines are the electric line itself, wiring, traction motors and other equipments supplied by direct current.
The main sources of ELF magnetic field are power traction systems and supply units, traction motors, equipments supplied by alternate current and wiring.

Measurements were performed both inside the driving cab and in the high-voltage corridor, which is typically in the rear of the cab, when potentially accessible by personnel.
A Metrolab ETM-1 Hall effect meter was used in order to measure static magnetic fields.
As far as concerns ELF magnetic fields, the peculiar pattern of absorption currents and traction condition implies extremely complex waveforms and frequency spectrum varying at any instant. A simplified approach was however adopted, based on the use of broad-band field meters operating in a frequency range comprehensive of all expectable contributions, monitoring the changes of the fields during the various phases of traction; several different meters were employed at the same time in order to get the maximum information.
A W&G EFA-1 meter was used in order to characterize the spatial pattern of the magnetic field in the frequency range 5 Hz-30 kHz, by means of spot measurements. A W&G EFA-3 meter was employed to measure and store the magnetic field (same frequency range as above) in a fixed location of the engine control board during all the trip time with temporal step of 5 s. An Enertech Emdex Lite personal monitor was used to measure and store individual engine driver exposure to magnetic field in the frequency range 40 Hz-1 kHz. The meter was worn by the driving operator at the waist; it was synchronized with EFA-3 and set-up at the minimum permittable step of 10 s. Last, a similar Microrad HT-300 personal monitor operating with same set-up was placed at the seat of the second engine driver, about 50 cm above the floor, to measure and store the magnetic field during all the trip time.
A similar measurement protocol has been recently applied in Switzerland [2], where AC 16.7 Hz electrification system is in use.

Results on 8 different engines or electrified trains in use in Italy showed that the average exposure to magnetic static field was little higher than the background geomagnetic field; in few areas or points it could occasionally reach levels in the order of 1 mT.
The average exposure to ELF magnetic field was in the order of 1-2 μT, with higher levels (few μT) only for engine E 402 A, as reported in Tab.1 and Tab.2 (ETR 500 train); spot measurements showed that close to wiring or specific equipment the fields values could occasionally reach several tens of μT.

Tab.1. Engine E 402 A, traction motors and auxiliary systems supplied by AC current

EFA 3 Peak values B [µT]			ENERTECH RMS values B [µT]			MICRORAD RMS values B [µT]		
AVG	MAX	STD DEV	AVG	MAX	STD DEV	AVG	MAX	STD DEV
4.88	16	2.06	1.48	19.66*	1.13	2.43	6.77	1.39

*Passage of the driver inside the engine corridor.

Tab.2. ETR 500 train: traction motors and auxiliary systems supplied by AC current

EFA 3 Peak values B [µT]			ENERTECH RMS values B [µT]			MICRORAD RMS values B [µT]		
AVG	MAX	STD DEV	AVG	MAX	STD DEV	AVG	MAX	STD DEV
2.49	10.0	1.01	0.53	2.45	0.29	0.72	1.56	0.38

In order to give an evidence for the complexity of the signals, in Fig.1 the trend of predominant frequency component of magnetic field vs time is reported for an ETR500 train in movement, measured by means of frequency counter of W&G EFA-3 meter (B > 1µT).

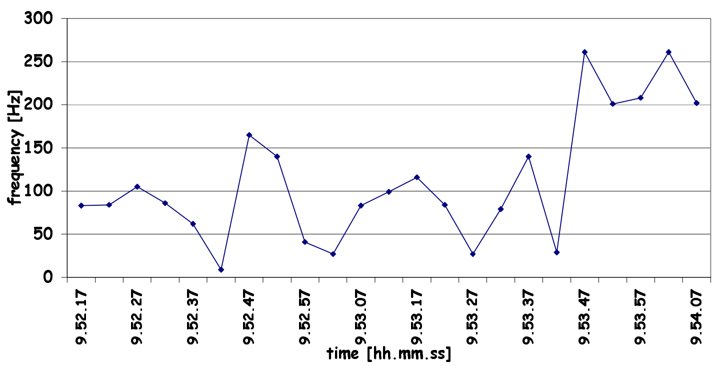

Fig.1: Fundamental frequency component of ELF magnetic field vs time on ETR500 train.

To better describe the phenomenon, in the frame of a research project promoted by Trenitalia S.p.A. in cooperation with ISPESL, National Institute of Health, and some Italian universities, the problem of low-frequency magnetic field emissions in railway and engines has been successively addressed by a more refined procedure [3]. In particular, a theoretical approach has been proposed for the characterization of magnetic fields inside both the engine-driver cab and passengers' compartments, where the non-stationary characteristics of the magnetic flux density time-series are identified, quantitatively described, and related to the physics of the process that generates the fields. This is done via a Fourier-based spectral estimation technique, leading to characterization of the magnetic flux density in the time-frequency plane. Quantitative considerations related to safety assessment have been addressed by extending the ICNIRP index for exposure to multiple frequency fields, developed in guidelines [4] and guidance [5].

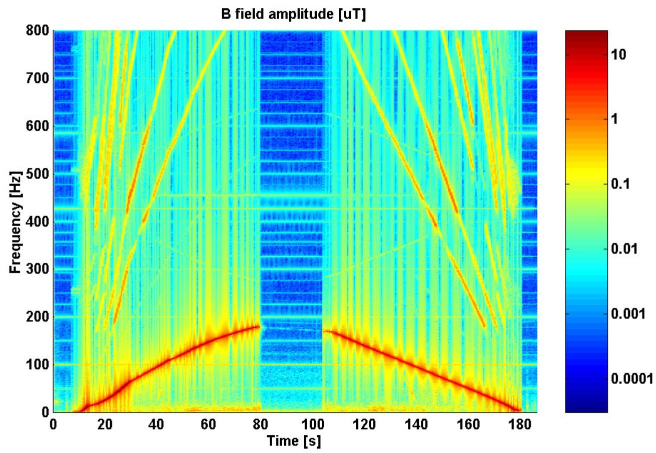

Fig.2: Example of time-frequency plot. The information on amplitude of frequency component is given by the colour. The red line indicates the main frequency of traction current during the test. Courtesy by Trenitalia S.p.A.

In the same cooperation frame, more recent activities have been done in order to extend the protocol to the RF fields generated by service signalling and driving automation systems. To such aim, the algorithm has been adapted for electromagnetic fields in the frequency range 100 kHz - 2.5 GHz, and pilot measurements of RF electric and magnetic fields have been performed on TAF (high frequentation) trains, as representative of overall condition.

Broad and narrow-band measurements carried out above train in movement showed values 20% higher than in still train condition, at very low field values, well below ICNIRP reference levels, with the main contribution at the frequency of 230 kHz.

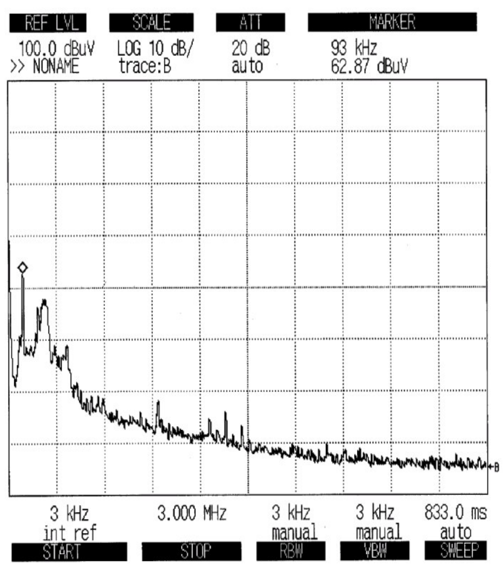

Fig.3: Example of spectrum acquisition of magnetic field during train movement (max hold modality)

The following measurement protocol for RF fields has been produced, also based on national regulation on assessment of exposure to RF fields for general public:

- narrow-band measurements are necessary only if broad-band results are higher than 75% of the lower reference level in the given frequency range;
- electric field measurements must be done over the whole range 100 kHz - 2.5 GHz;
- magnetic field measurements can be limited to the range 100 kHz - 30 MHz, unless special characteristics of the sources.

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