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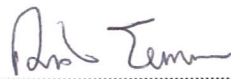
Business Process Document

Methodology for the Demonstration of Compliance with Reed FDM Systems on the AC & DC Railways

(Formerly RT/E/C/50015 Company Code of Practice Methodology for the Demonstration of Compatibility with Reed FDM Systems on the AC & DC Railways)

Endorsement & Authorisation

Endorsed by:



A Simmons, Head of Signal Engineering

Authorised by:



A McNaughton, Chief Engineer

Accepted for issue by:



for

M McManus, National Standards Manager

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Documents

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Issue record

Issue	Date	Comments
1	February 2003	New Code of Practice
2	February 2007	Document reformatted Section 7.5 (long FDM systems) added Section 7.3.2 and 8.4 added to give guidance on transient susceptibility Section 8.5 added to give guidance for multiple trains

Implementation

(Please include implementation date, if applicable.)

Compliance

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1 Purpose

The purpose of this document is to provide a methodology to demonstrate compatibility with reed FDM systems installed on the AC and DC electrified railway on Network Rail controlled infrastructure. This is achieved by:

- Providing a methodology to calculate the longitudinal voltage produced in the cable cores forming a reed FDM circuit.
- Providing a model to determine the voltage across a reed FDM receiver.
- Providing a methodology to define the permissible current in the traction supply.
- For reasonable worse case infrastructure conditions train current limits are defined.

The interference mechanisms to be considered are conductive, capacitive and inductive coupling. The coupling is between the traction supply & return conductors and the lineside cables.

This characterisation will take the form of a permissible train current which can then be compared to the EMI footprint of a piece of traction or rolling stock to enable a case to be made. Methods are included to analyse intact and faulty infrastructure.

2 Scope

2.1 Installation types covered by this Document

This document covers RR type reed FDM circuits installed on AC and DC electrified Network Rail controlled infrastructure.

This document covers reed FDM systems installed in accordance with the reed FDM system manuals [\[IB138\]](#) & [\[IB165\]](#).

The reed FDM system is used for both safety critical or 'vital' applications and non-safety critical 'less-vital' applications; both applications are covered by the analysis presented here.

Westinghouse FDM-NV and older type 'R' systems are not covered by this document. It has been accepted previously that the Westinghouse FDM-NV system is less sensitive than the reed FDM system considered here [\[120-dr0458\]](#) & [\[fx3100\]](#), thus the FDM-NV system is encompassed within the analysis presented.

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2.2 Equipment types included in this Document

The equipment covered within this document is the type 'RR' reed FDM equipment that was previously manufactured by GEC (now ALSTOM) and is now manufactured by NRS.

3 Source Documents

3.1 Network Rail Company Standards

There are no Network Rail Company Standards relating specifically to the installation of reed FDM systems. It is however assumed that all signalling equipment has been correctly installed and maintained in accordance with Network Rail Company Standards [[NR/SP/SIG11231](#)] & [[NR/SP/SIG/10660](#)].

- [NR/SP/SIG11231](#) Signalling Maintenance Testing Handbook, Issue 4, February 2006.
- [NR/SP/SIG/10660](#) Implementation of Signalling Maintenance Specifications, Issue 4, February 2005.
- [NR/GN/ELP/27010](#) Guidance for compatibility between electric trains and electrification systems, issue 2, December 2005.
- [NR/SP/SIG/50002](#) Methodology for the Demonstration of Compliance with Single Rail Reed Track Circuits on the AC Railway, Issue 2, February 2007.
- [NR/GN/SIG/19051](#) Signalling Equipment Technical Advice Notice (SIGTAN051) (Formerly RT/E/C/19051) Issue 1, December 2002.

3.2 Previous Safety Case Documentation

- [120-dr0458](#) "Fleet Operation on the 25 kV AC Railway between Crewe and Doncaster – Reed FDM", AEA Technology Rail, version b0, dated November 1999.
- [120-ds0016](#) "Class 373/1 Safety Assessment of the Reed FDM System on Class 373/1 Routes", AEA Technology Rail, version b0, dated April 1995.
- [120-dr0029](#) "Class 373/1 Safety Assessment of the Reed FDM System on Class 373/1 Routes Supplement A to Appendix E - Probability of Occurrence of Failure Mechanisms for Interference Coupling", AEA Technology Rail, version a0, dated April 1995.
- [fx3100](#) Fax from R. I. Taylor, TCI Rail, to T. Green, W S Atkins Rail Ltd. ref. 1992\projmgt\corresp\fx3100.doc, dated 25th June 1998

3.3 OEM Documentation

[IB138](#) “Type RR Reed Frequency Multiplex System Handbook”, GEC General Signal Ltd, dated October 1980.

[IB165](#) “Type RR Reed Frequency Division Multiplex System Manual”, GEC General Signal Ltd, dated November 1987.

3.4 Other Documents

[E1317AAF](#) “Technical Study Reed FDM & Track Circuits, mains frequency interference.” Version 1.1, WS Atkins, 23rd December 1997.

4 Infrastructure Assumptions

The main assumptions that may be made while carrying out an analysis are summarised below.

- The infrastructure is assumed to be in the worst case for inductive coupling, i.e. the traction current flows in the conductor nearest the cable and returns in the conductor farthest from the cable. This is effectively a failed infrastructure condition for the length of the exposure, a pessimistic scenario.
- The infrastructure assumed is representative of the two-track case.
- The FDM cable is assumed to be 1m away from the nearest running rail for the majority of systems. The case of a portion of the exposed cable being 0.3m away from the nearest running rail is also considered.
- The permissible transverse voltage is assumed to be 20 % of the reed receiver drop away value [[120-dr0458](#)]. This limit applies only at the operating frequencies of the reed FDM system. The bandwidth of the reed filter is ± 0.5 Hz [[NR/SP/SIG/50002](#)].
- Minimum acceptable core to earth resistance for a cable is 500 k Ω [[NR/SP/SIG/10660](#)].
- The cable forming the FDM circuit has a hard earth fault at one end and the minimum acceptable core to earth resistance at the other. Earth faults on Reed FDM systems are relatively rare. FRAME data indicates there were four

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earth faults on FDM cables in a five year period [[120-ds0016](#)]. This, coupled with a test periodicity of three months [[NR/SP/SIG11231](#)], mean that the scenario is highly pessimistic.

- Reed FDM circuits are carried in cores taken from the same layer of multicore cables [[IB138](#)] & [[IB165](#)] or in one pair of a twisted pair cable.
- The effect of isolation transformers is ignored in the analysis as presented here. This results in significant pessimism in the final calculated line current limits.

5 Description of Equipment

5.1 Overview of Reed FDM Systems

A frequency division multiplex (FDM) system is used to carry a number of signals over a single pair of cable cores. These cores are commonly contained within multicore or twisted pair cables. It is possible to carry up to 63 circuits in one pair of conductors. For each channel, an independent transmitter is provided which generates an AC signal at the particular frequency allocated to that channel; an individual receiver detects the frequency for each channel. The discrete channels within the range have been chosen to avoid supply frequency harmonics. The channel numbers of the Type RR system are grouped as follows:

- f1 – f51: 51 channels in the range of 395.25Hz to 879.50Hz, originally used for vital systems but not normally used as such adjacent to electrified railways. The channels are however used for non-vital systems alongside electrified lines;
- f81 – f92: 12 'non-vital' channels in the range of 383.25Hz to 842Hz.;
- f71 – f72: 2 'spare' channels;
- f401 – f416: another set of 16 'vital' channels for 50Hz railways, in the range 410.25Hz to 817Hz, with frequencies designed to avoid both even and odd harmonics of the mains.

The frequencies used for transmission are thus broadly in the range from 383 - 880 Hz.

The transmitter and receiver in the reed FDM system consist of a reed filter and an amplifier. The reed filter is a high-q band-pass filter, which passes only the frequency allocated to the particular channel and excludes all others with a nominal bandwidth of ± 0.5 Hz. The selectivity of the reed filters is such that the system can be operated with frequencies as close as 4 Hz; hence a very large number of channels can be accommodated within a small range of frequencies.

A full technical description of the operating characteristics of reed FDM systems is given in GEC manuals IB138 and IB165 [\[IB138\]](#) & [\[IB165\]](#).

5.2 The Vital Reed Filter

The reed filter contains a pair of tuned reeds. Each is a short bar of a special alloy, clamped at one end and shaped so as to vibrate at a specific frequency, which is set during manufacture. It is placed such that it lies along the axis of a coil, with its free end between the poles of a permanent magnet, as illustrated in figure 1.

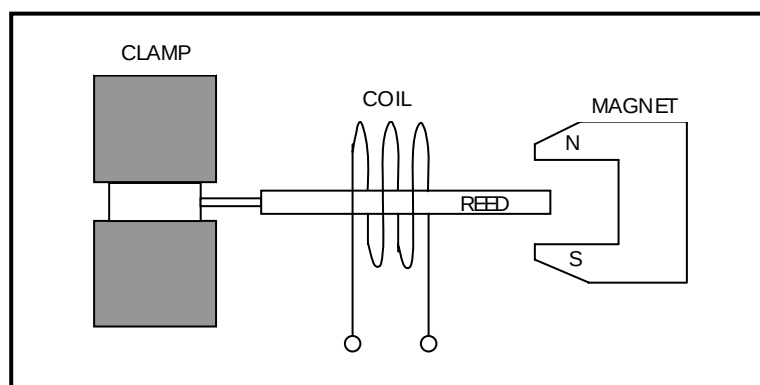


Figure 1: Basic Reed

If a current flows in the coil, it magnetises the reed, which is therefore displaced by the field of the permanent magnet. If the current is made to vary sinusoidally the reed will oscillate in the field. At most frequencies the amplitude of the oscillation is small, but if the frequency of current flowing in the coil coincides with the natural frequency of vibration of the reed, the amplitude becomes very large. Alternatively, if the assembly is vibrated mechanically, the reed will oscillate between the poles of the magnet, causing a voltage to appear between the terminals of the coil. This voltage is small unless the frequency of the impressed vibration is the same as the resonant frequency of the reed, in which case it will become much larger.

The complete reed filter consists of two of these reed assemblies tuned to the same frequency, mechanically coupled together. An AC current in one coil will cause the reed of the other coil to oscillate, hence inducing a voltage in the secondary coil. This voltage is only significant if the reeds are oscillating at their resonant frequency. The device can therefore be seen to act as a band-pass filter; only signals having the frequency to which the reeds have been tuned are coupled through the coils.

5.3 System Classification

The reed FDM systems can be implemented as vital or non-vital systems depending on the application.

5.3.1 Vital Reed FDM System

Vital reed FDM systems are used for the control and indication of safety critical functions between an interlocking and trackside signalling equipment. They are normally used in fairly limited applications in specific areas. Vital systems generally utilise twisted pair cabling to transmit the signals between the trackside equipment and the interlocking, although multicore is sometimes employed. When

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multicore cabling is used the two cores that form the circuit must be taken from the same layer within the cable.

The trackside equipment may be some distance from the interlocking; the use of vital FDM provides a method by which the interlocking can control signalling equipment at a greater distance more economically than if individual circuits were required by each function. A typical layout of vital reed FDM systems is shown in figure 2 below.

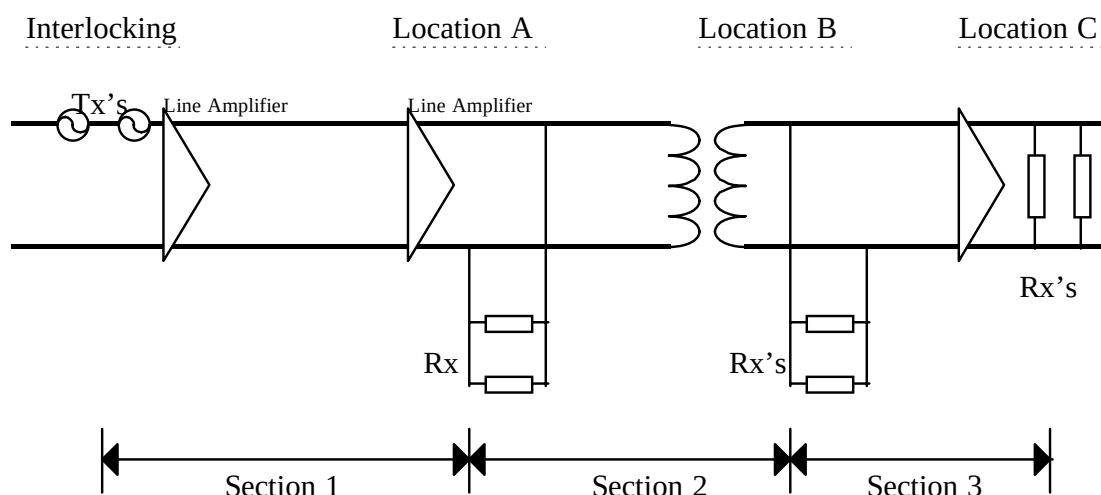


Figure 2: Typical vital reed FDM system

The system shown in figure 2 is typical of a control system with transmitters at the interlocking. An indication system would have the transmitters distributed throughout the system with receivers concentrated at the interlocking.

The line is sectionalised to reduce the effect of interference induced into the cable cores. The maximum permitted length of a section is 2 km. The line is sectionalised by the use of line isolating transformers and line amplifiers. The line amplifier is a uni-directional amplifier that is used to counter-act the attenuation in the line. The voltage gain of the amplifier is not greater than 2 [B138]. The voltage gain of the amplifier is not the same across the frequency range, the gain increases with frequency. The line amplifiers also have a choke to provide AC immunity.

This sectionalisation means that transverse voltages present in one section of the system should not be additive with the following section because a phase shift, nominally a reversal, will occur at isolation transformers. In very long systems the slightly non-perfect cancellation at sectionalisation points, that is not significant in short systems, may become significant.

5.3.2 Non-Vital Reed FDM Systems

Non-vital reed FDM systems have essentially similar design criteria to the vital systems but may incorporate equipment which is not necessarily to 'fail - safe' standards. Multicore cable may be used rather than twisted pair for transmitting the signals. The non-vital systems are used for transmission of less safety critical controls and indications to and from the signaller's console.

The non-vital reed equipment in the RR3xxx range has the reed filter and amplifier in one 'Q' style case and contains one vibrating reed and one dummy reed.

6 Infrastructure Assumptions

The methodology presented utilises the following assumptions:

- The traction current flows in the conductor that is closest to the FDM cable. This will lead to the maximum possible longitudinal voltage due to this current flow being calculated.
- All of the traction current returns to source via the conductor that is furthest from the FDM cable. Since the 'go' and 'return' current are essentially the same this will result in the largest difference in the induced voltages for the 'go' and 'return' current and hence the most pessimistic results.
- A section length of 4 km is assumed, this allows for the non-perfect cancellation of common mode voltages at one sectionalisation point.
- The voltage induced into the cores of a twisted pair cable or two cores from the same layer of a multicore cable is the same [\[120-dr0458\]](#).
- A factor of 2 is included to account for the presence of a line amplifier immediately preceding the receiver in question, as discussed in section 3.3.1.
- Carson Pollaczek equations are suitable for the calculation of longitudinal voltages in the railway environment [\[120-dr0458\]](#).

7 Susceptibility Analysis

7.1 Hazards to Reed FDM Systems

Two effects of interference must be considered, namely:

- that which could cause a reed receiver to be energised or be maintained energised in the absence of a transmitted signal
- that which would cause a reed receiver to de-energise its output when the transmitted signal is present