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PROBLEMS OF ELECTROMAGNETIC COMPATIBILITY CONTROL COMMAND DEVICES AND ROLLING STOCK

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1. Introduction

A prospect of opening of passenger rail market and introduction into the PKP network high-speed trains (over 160 km/h) is inextricably related with the use of modern rolling stock. From the electromagnetic compatibility point of view this rolling stock significantly differs from the traditional one (higher power, numerous presence of various systems and power processing and feeding devices). As a result, the issue of improvement of compatibility of the rolling stock with systems and devices of railways technical equipment, their complexity and direct influence on railway traffic safety should be treated thouroughly and as a high priority. Moreover, new measurement techniqes and technologies and new areas of knowledge concerning compatibility of device operation should be sanctioned in regulations in force.

There should be specified railway traffic control systems and devices sensitive to disruptions, and elaborated requirements conerning broadly defined rolling stock electromagnetic compatibility with railway traffic control devices (rtc). These requirements legitimised in regulations in force. It will allow the infrastructur owner to achieve several objectives, such as:

– Limiting cases of rtc devices disrupted operation,

– Elimintating of financial losses due to cases of durable breakdown of rtc devices or their elements cused by disruptions,

– Elimintating of financial losses due to rtc devices disrupted operation,

– Eliminating of risks caused by rtc devices disrupted operation,

– Improvement of railway traffic safety,

– Eliminating of work interference related to rtc devices disrupted operation.

Operation frequency analysis of railway traffic control devices

Research data published in litereature and gathered experiences indicate that track circuits and train sensors operating as track circuits are the most sensitive to disruptions.

Experiences gathered in the last few years (in different railway board) show that also axle counters are sensitive to disruptions, in particular caused by high-power locomotives.

Table 1 presents operation frequencies of track circuits, train sensors and axle counters applied in the network of Polish infrastructure owner PKP PLK S.A.

Table 1

List of operation frequences for rtc devices

Track circuit type	Operation frequency [kHz]
Classic	0,05
Jointless linear and station track	1.58; 1.86; 2.17; 2.47; 2.8
Jointless point track	7; 8; 10; 12.15; 14.6; 16.8
Train sensors	10; 14.6; 19.0; 20.8; 23.4; 26.1; 28.7; 31.5; 34.6; 38.2
Axle counter	27; 42; 46; 48; 250; 1000; 1228

The frequencies listed above, or to be more precise, frequency bands will be conisdered further.

1.1 Operation Frequency Analysis of Traction Substations and Traction Stock

The PKP PLK S.A. network uses, above traction substations with 6 and 12 halfway rectifiers. Theoretically, at the traction substation output only harmonics resulting from rectifiers operation should appear, that is 300, 600 Hz (and harmonics of these frequencies). However, for various reasons (i.e. transformers or rectifiers non-symmetry) at the substation outlet appear harmonics of 50 and 100 Hz, all their harmonics, and harmonics resulting from super-positioning of basic substations harmonics and harmonics of 50 and 100 Hz. The 50 and 100 Hz harmonics levels depend on the quality of substation elements (transformers, rectifiers).

Filters (smoothing devices) used in traction substations are quite a different issue. This refers both to a filter type and their operation or non-operation. In the aspect of disruptions, two conditions of filter operation should be assumed that is: switched filters and disabled filters. In both cases the proportions between specific harmonics are different and depend on parameters of traction substation elements. Moreover, theoretical studies and research results until now gathered indicate that substations working with resonance filters, in comparison with substations equipped with gamma filters, are less stable in terms of operation disruption. There are several reasons for it. They are, among others derangement of resonance filters and non-suppression by these filters of 50 and 100 Hz frequencies.

Traction stock generates, above all, harmonic resulting from the converters operation. Converters of locomotives and electrical multiple units produced nowadays, work on frequency band from 30 to 300 Hz. Older type locomotives work with choppers on 33 1/3 Hz, 100 Hz and 300 Hz frequencies. Static converters usually work on frequencies of a few kHz.

In practice, every traction vehicle generates specific harmonics. Their repeatability appears only in some vehicle series using the same converter type.

Modern traction stock (traction vehicles, static converters, etc.) are usually equipped with filters that sufficiently suppress products of energy transformation in the stock. It is important to emphasise, that not all filters in the traction stock sufficiently suppress harmonics generated by converters. This refers, above all to static converters. Another issue is a manner of mass and earthing leading on the vehicle. Their inappropriate performance is often a cause of increase in disruption level, resulting from, among others entering of disruptions to traction networks (above all return network) beyond the installed filters.

In some cases of the use of high-power traction vehicles, an influence on sensors applied in axle counters appeared. A probable reason for this (European railways will conduct a research to explain this issue next year) are electromagnetic fields generated by rolling stock elements (traction engines, filter traction elements, etc.) or resonance in the return traction network.

2. Research Methodology

In order to provide electromagnetic compatibility between the rolling stock and railway traffic control devices, acceptable disruption parameters influencing rtc devices should be defined. In order to define acceptable disruption levels and a choice of assessment criteria for receivers of rtc devices, their features of sensibility to disruptions should be specified. The first one is defined on the basis of calculation of signal threshold values at which the receiver operates correctly. These parameters encompass: amplitude, frequency, impulse duration and impulse process time. Features of the rtc devices receiver's sensibility to disruptions are defined on the basis of disrupting signal parameters, similarly as in the case of defining sensibility and disruption parameters that may lead to improper operation of the receiver or its damage.

The issue of electromagnetic interferences may be omitted in the measurements, as the experience shows, that this type of disruptions have a negative influence at higher amplitudes of the signal. Disrupting influence in turn is significant at the continuous signal.

Research should be conducted in laboratory conditions., and for a comparison – in the field.

Laboratory analysis was conducted for:

- Subassemblies of 50 Hz track circuits with isolated joints,
- Subassemblies o jointless track circuits,
- Receivers of train sensors.

Fig. 1, 2 and 3 show examples of specific measurement systems aimed at analysis of sensitivity and resistance to disruptions of track circuits in laboratory conditions.

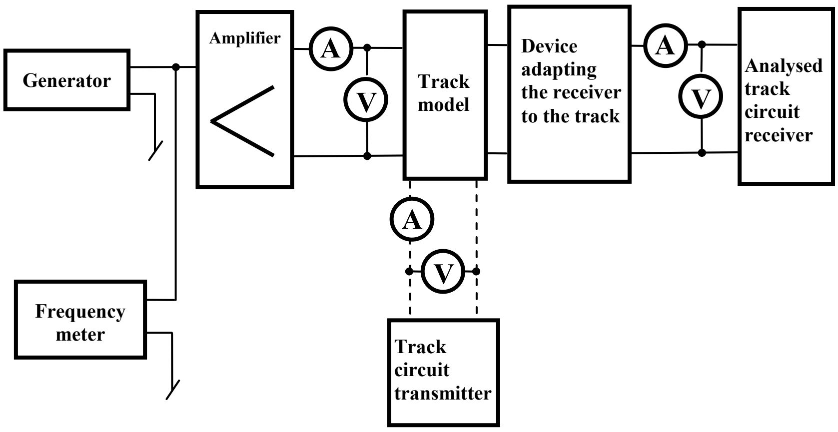
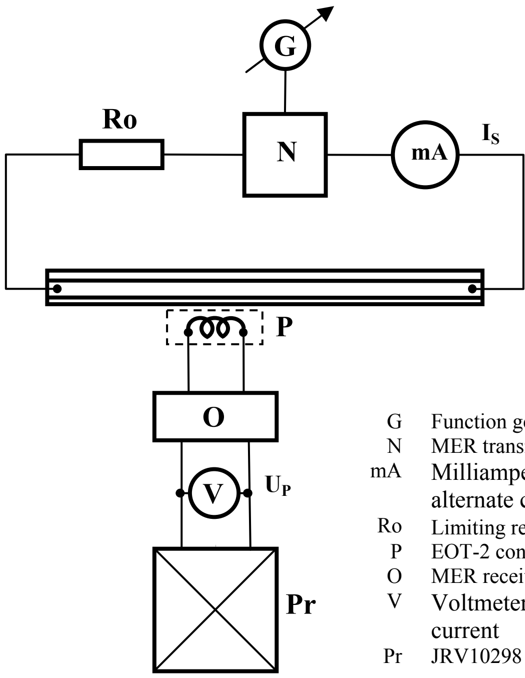


Fig. 1. Measurement system for laboratory analysis of track circuits with isolated joints



G	Function generator
N	MER transmitter
mA	Milliampere meter of 1.5 class alternate current
Ro	Limiting resistor 2Ω
P	EOT-2 converter
O	MER receiver
V	Voltmeter of 1.5 class alternate current
Pr	JRV10298 or JRB31114 transmitter

Fig. 2. Measurement system for laboratory analysis of current receivers sensitivity of jointless track circuits

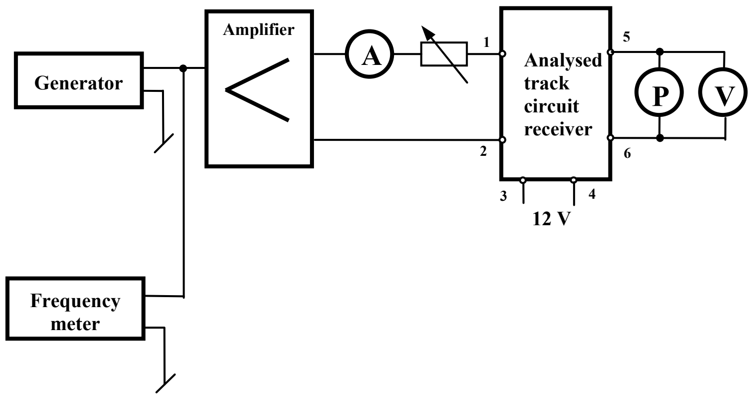


Fig. 3. Measurement system for laboratory analysis of voltage receivers' sensitivity of jointless track circuits

Field analysis should be performed according to the schemes presented in Fig. 4 and Fig. 5.

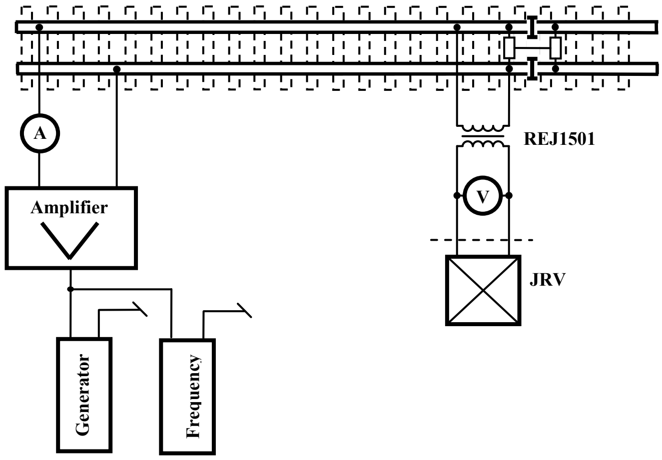


Fig. 4. Measurement system for field analysis of classic track circuit

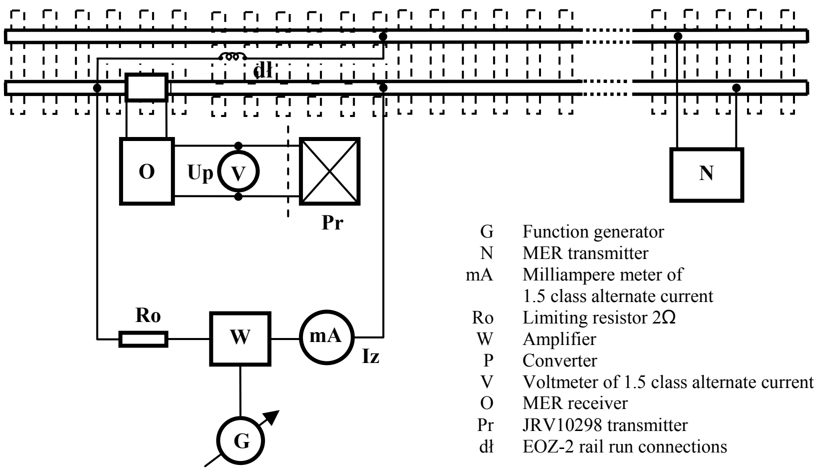


Fig. 5. Measurement system for field analysis of jointless track circuits

3. Acceptable Disruption Parameters

Depending on the effects of traction current influence, inappropriate operation of rtc devices can be defined as:

- **disrupting** – where safety conditions of railway traffic are maintained, but the disruption effects are, ie. lower railway throughput capacity, and unplanned stopping of trains (energy losses),
- **dangerous** – where safety conditions of railway traffic are not maintained (i.e. a track signalling device shows green light allowing driving, instead of red one). In any case, such a situation is unacceptable due to a potential danger of a disaster.

As all the rtc devices are located close to the tracks, and a part of them are directly connected to rails (the traction return network), they are exposed to a negative influence of traction currents.

Acceptable disruption parameters in rtc devices depend, above all on the applied device types. That is why, the devices of maximum resistance level should be used.

4. Defining of Reserve Coefficients

Features of receivers' sensitivity and characteristics of disturbance are a starting point of the disturbance assessment. Defining of disturbance acceptable parameters for a given rtc device type requires assuming adequate reserve coefficients. For track circuit receivers, being the most exposed to electric traction disruptions, acceptable disruption amplitudes should be defined for three cases:

a) free track circuit, zero working signal, the presence of disrupting signal;

b) free track circuit, the presence of disrupting signal, upon occupation of the track circuit, the receiver (transmitter) must slow down,

c) free track circuit, the presence of signal.

As a result the following terms were assumed:

A_R – amplitude of track circuit working signal;

A_p – amplitude of track transmitter attraction (induction);

A_o – amplitude of track transmitter slowdown (de-induction);

A_z – amplitude of disruptions.

$A_R : A_z = S$ – working signal to disruptions ratio.

For the cases of track circuits conditioned mentioned previously, the acceptable amplitudes of disruptions will be as follows:

– $A_z < A_P$ that is $A_z \cdot S_1 < A_P$

– S1 – coefficient of an interval of track circuit signal causing induction from disturbances of track transmitter,

– $Az < Ao$ that is $Az \cdot S2 < A0$

– S2 – coefficient of an interval of track circuit signal causing de-induction from disturbances of track transmitter,

– $AP - Az > Ao$

– $Az < AP - A0$ that is $Az \cdot S3 < AP - A0$

– S3 – coefficient of an interval between disruptions and working signal excess over induction signal.

The following values of reserve coefficients were assumed: $S_1=1{,}2$; $S_2=1{,}1$; $S_3=1{,}1$.

5. Calculating of Acceptable Parameters of Disruptions

Defining of acceptable parameters of disruptions require taking into account of track circuit sensitivity, reserve coefficients and current distribution on rails. The following issues should be considered:

a) Jointless track circuits with galvanic coupling of the receiver with the track;

b) Jointless track circuits with induction coupling of the receiver with the track;

c) Single-rail track circuits with isolated joints;

d) Two-rail track circuits with isolated joints;

For example, for track circuits from point a) calculations for the case presented in Fig. 6. were performed. The presence of asymmetry in railways was assumed due to, i.e. a rail break (marked by R_1 and R_2 resistors). For the values indicated in the picture, a maximum value of current flowing through the receiver was presented. The results are shown in Table 2. The obtained maximum value of current in the receiver (49,1%) can be defined as 50% of the total current in the railways. It means, that in the calculations of acceptable parameters, the acceptable (in this case) disruptive current (resulting from the receiver's sensitivity) should be multiplied by 2.

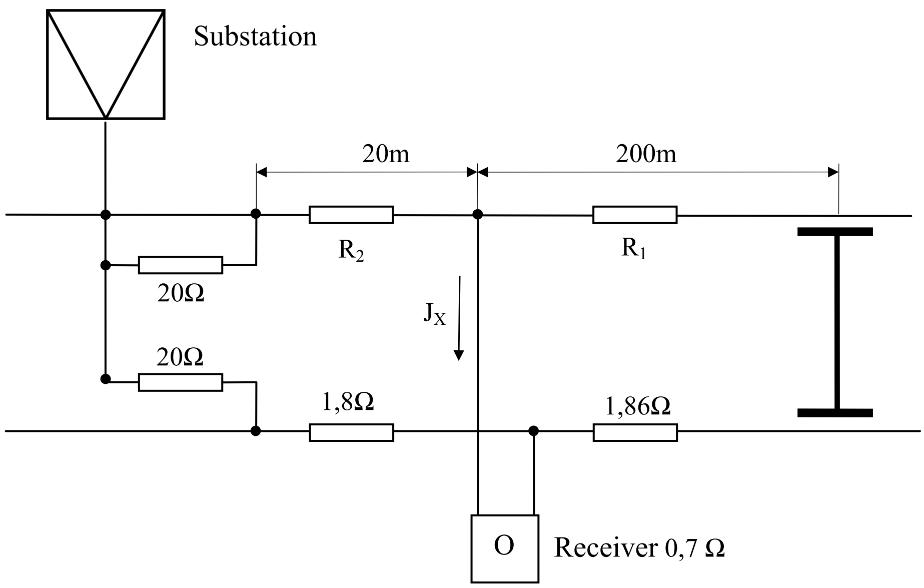


Fig. 6. Movement situation to calculate disruptions in a jointless track circuit with voltage reception

Table 2

Current flowing through the receiver for different resistance values from Fig. 6

R_1 [at R_2=18,6Ω] [Ω]	1,8	5	10	18	100k	
I_x [%]	0	3.3	7	13.1	49	
R_2 [at R_1=1,8Ω] [Ω]	18,6	30	50	150	180	100k
I_x [%]	0	11.3	22.3	38.1	39.8	49.1

6. Examples of Analyses Results

Fig. 7-10 presents examples of laboratory and filed analyses results.

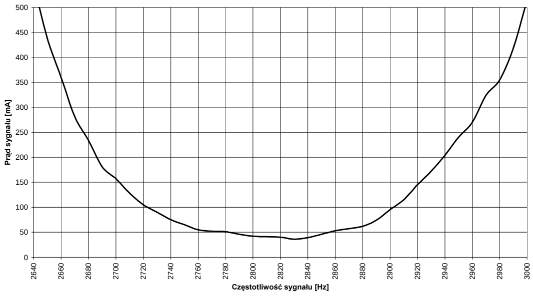


Fig. 7. Sensitivity features of MER111404/5 receiver in frequency function

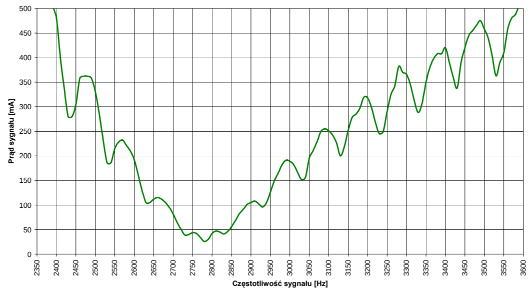


Fig. 8. Sensitivity features of MER111401/4 receiver in frequency function

Fig. 7 and Fig. 8 present features of jointless track circuit receivers working on 2800 Hz frequency. Picture 7 refers to a new type receiver, whereas Fig. 8 to an older one (year of production: 1991). The features of the new receiver are regular and symmetric with respect to the centre frequency, whereas the older receiver does not reveal these characteristics. Thus it can be assumed that railway traffic control devices should be retired after 20 years. A longer operation period leads to the loss of initial properties of their specific elements (although still working safely).

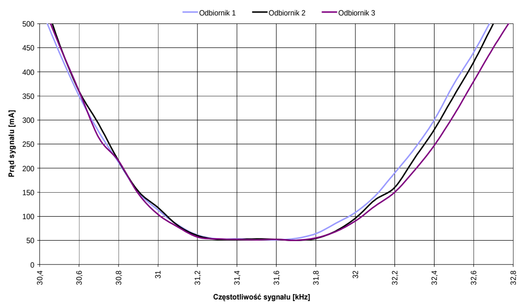


Fig. 9. Sensitivity features of a jointless track circuit receiver of current type

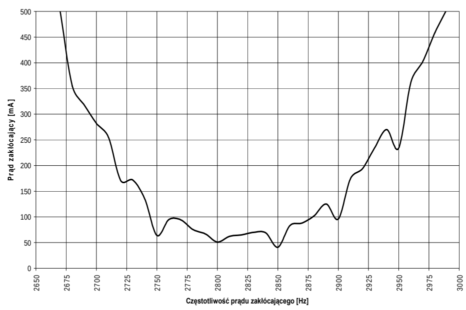


Fig. 10. Sensitivity features of a jointless track circuit receiver on a disruptive continuous signal

Fig. 9 presents features of jointless track circuit receivers operating as train sensors. The characteristics measured for three receivers are identical. It is a proof of their perfect technical condition.

Fig. 10 shows sensitivity features of jointless track circuit receivers measured on the railway. The characteristics measured in laboratory conditions are identical. It appeared that the applied measurement systems give identical results and thus measurements may be conducted in laboratory conditions. This may significantly reduce their cost and time required for their performance.

Fig. 11 and Fig. 12 showing values of acceptable parameters of disturbances for jointless track circuit receivers, indicate that old-type receivers present very irregular features (compare with Fig. 8), whereas new-type receivers have regular characteristics. Moreover, acceptable values of disruptive currents ARE twice as much higher for new-type receivers. This fact leads to an obvious conclusion that old-type receivers should be retired.

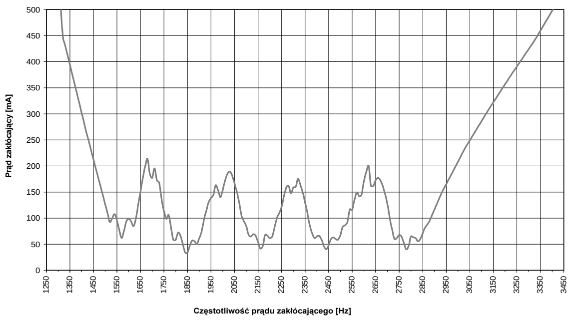


Fig. 11. Values of acceptable parameters of disturbances for old-type current jointless track circuit receivers

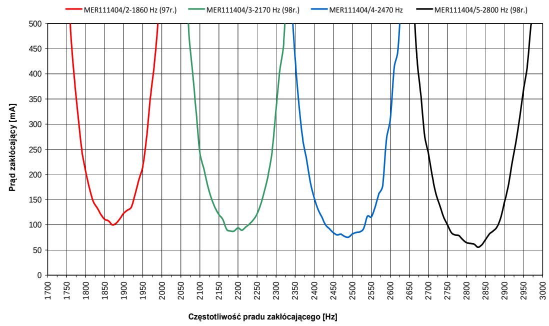


Fig. 12. Values of acceptable parameters of disturbances for new-type current jointless track circuit receivers

7. Conclusion

On the basis of the performed analyses and research, it can be assumed that:

By means of the adopted methods of laboratory and field analyses of sensitivity features of track circuit receivers, the analogous results were obtained. It allows conducting only laboratory analyses, which will reduce costs and time needed for their performance.

Old-type railway receivers of jointless track circuits should be retired due to parameter non-compliance and significantly higher sensitivity to disruptions.

The obtained values of acceptable parameters of disruptions should be applied to define maximum disruption levels generated by the rolling stock (including traction vehicles) to the traction network.

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Keywords: disruption, electromagnetic compatibility, railway traffic control devices.

Ключові слова: відмова, електромагнітна сумісність, пристрої залізничної автоматики.

Ключевые слова: отказ, электромагнитная совместимость, устройства железнодорожной автоматики.