http://dx.doi.org/10.5755/j01.eee.18.9.2800

Measurements and Processing of Signals used in a Cab Signaling System

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***Abstract*—Automatic cab signaling system used in Lithuanian Railways is uninterruptible signaling system used to transmit the information about an allowable train speed to a cab driver. The performance of this system can be disturbed by various sources of disturbances. One of the main sources is a magnetization of rails. So far there were no other methods to evaluate disturbances that can cause signaling system errors than going by train and monitoring traffic-light signals in a cab. Therefore a system to record signaling system signals was created and a method to process the signals was proposed. The method can be used to make a signal processing and decoding of the previously decoded signals. Furthermore, the proposed algorithm uses slightly different method of signal processing and is potentially more immune to disturbances caused by the rail magnetization. The proposed algorithm was used to process the real signaling system signals. The signals were recorded on a route by going on an electric train. The main results of processing and potential places of disturbances have been shown. The advantage of the proposed algorithm over the currently used one need to be investigated in further research.**

***Index Terms*—Digital signal processing, magnetization, measurement standards, spectrogram.**

I. INTRODUCTION

Lithuanian Railways use the same cab signaling system as other Baltic States and CIS (Commonwealth of Independent States) members. The automatic cab signaling system is called ALS. It is used to transmit traffic-light signals that the train is approaching to; these signals determine the allowable train speed.

The functionality of the ALS system can be disturbed by various factors. One of the main sources of disturbances is a magnetization of rails. Rapidly changing magnetization induces “noise” in the pick-up coils and can lead to a false signal decoding [1].

In order to evaluate the potentially dangerous disturbances and minimize the influence of the disturbing signals, a system to measure ALS signals was created and a method of signal processing was proposed. To analyze the efficiency of this new method, it was used to process the real ALS signals.

II. ALS OVERVIEW

The ALS system uses track circuits to detect presence or absence of a train on a road. Railway tracks are divided into sections, or blocks, that are separated from each other by insulating joints. Each block has a voltage source connected to each rail. If a train is present in a block, it’s wheels short-circuit both rails, thus the block is identified as occupied. According to this information, ALS forms traffic light signals to adjacent blocks.

Each cab has an equipment to receive these ALS signals. The coded traffic-light signals are carried through the rails and are received by a train pick-up coils. The ALS signals are pulse-coded signals with 25 Hz, 50 Hz or 75 Hz sinusoidal carrier (Fig. 1). When no code is received after last code was green or yellow, a white signal is declared. If no code is received after the yellow-red signal, it means the train entered an occupied block, and the red signal is declared [2].

The cab equipment must decode the signals and display the result in a cab dashboard. The simplified block diagram of the Cab equipment is shown in Fig. 2.

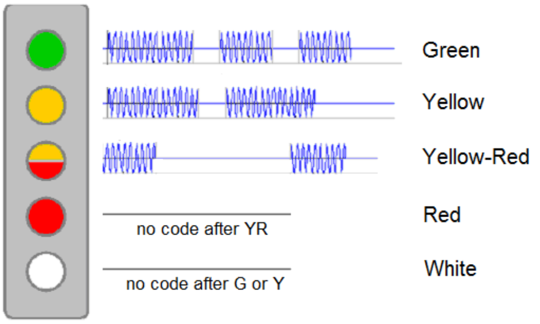


Fig. 1. Traffic-light signals displayed in a cab.

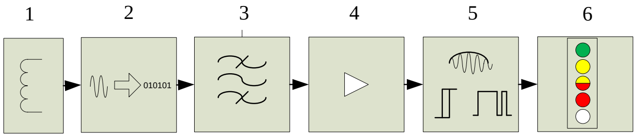


Fig. 2. A block diagram of the signal acquisition system in a cab: 1 – pick-up coils; 2 – ADC; 3 – filter; 4 – amplifier; 5 – decoder; 6 – final result.

Two pick-up coils are used, one coil above each rail. The signals from both coils are summed and converted to digital,

Manuscript received March 19, 2012; accepted May 14, 2012.

and then they are filtered, gained and decoded [3], [4].

In a present method, signals from each pick-up coil have the same effect. If there is a noise (disturbance) in only one coil, it is summed to the clean signal and causes disturbances. Therefore a different concept was suggested to process the signals. The concept of the algorithm will be explained in the next chapter. For verification of the new algorithm, it was used to decode real signaling signals measured on a train.

III. METHODS

The Cab signaling system signals were measured in a chosen route Kaunas-Vilnius; the length of the route – 120 km. Measurements were taken using the measurement system intended for measuring magnetic flux density over the rails [5], [6]. The measuring system consists of measurement unit, two magnetic field transducers that measure magnetic flux density in three directions, frame for mounting transducers to the cab, a GPS receiver and a PC with dedicated software. The main parameters of the measuring system are listed in Table I. Parameters of the transducers used in the measurement system are displayed in Table II.

TABLE I. PARAMETERS OF THE MEASURING SYSTEM.

Parameter	Value
Measuring speed	< 600 measures / sec
Spatial resolution	<5 cm when V=90km/h
GPS coordinates rec. speed	≥1 sec.
GPS interface	Wireless Bluetooth
Data interface	USB
Power	Over USB port

TABLE II. PARAMETERS OF THE TRANSDUCERS USED IN THE MEASURING SYSTEM.

Parameter	Value
Number of measuring axes	3 (X, Y, Z)
Number of transducers	2
Magnetic flux density range	0.2 – 800 μT
Resolution	0.2 μT
Frequency range	0 – 300 Hz
Interface to measurement unit	RS485

The block diagram and general view of the system are displayed in Fig. 3 and Fig. 4, respectively.

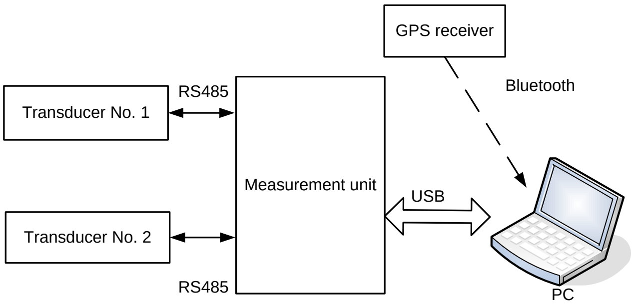


Fig. 3. Block diagram of the measuring system.

During the trip, the transducers were mounted in front of a train in order to pick-up the signaling system signals.

Magnetic flux density in three directions for each rail were recorded together with GPS coordinates and speed. These results were later used for processing.

The signal processing has been performed using a PC. The algorithm of processing is displayed in Fig. 5.

Fig. 4. General view of the measuring system.

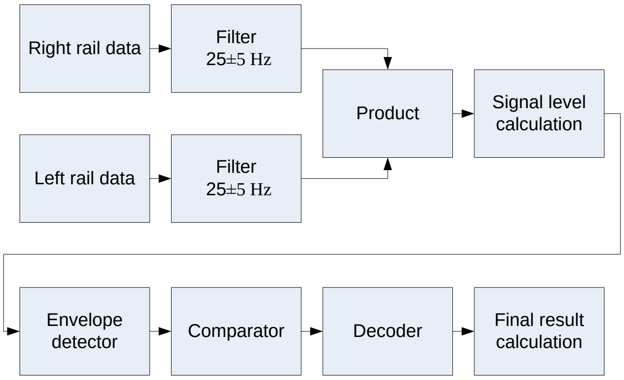


Fig. 5. Algorithm of a signal processing of the cab signaling system.

Algorithm. Recorded magnetic flux density signals for each rail are loaded from the text file. Each signal is passed through a band-pass filter with a center frequency of 25 Hz and bandwidth of 10 Hz. After filtering, both signals are multiplied together in order to minimize the influence of any residential random noise. The disturbances caused by the magnetization of rails are not correlated, therefore by performing a multiplication, their influence is minimized (canceled out), while the useful signal is maximized (squared). This is the main difference from the algorithm used today in cabs.

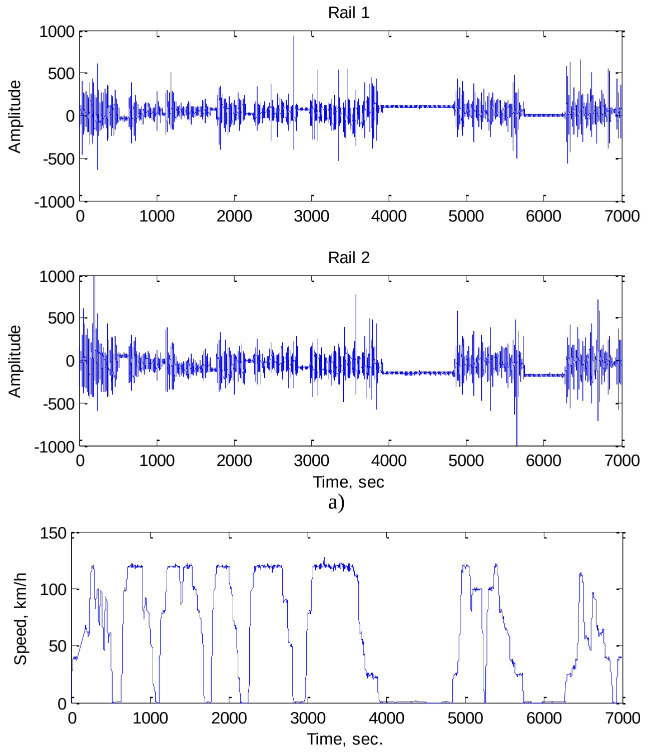
Product of signals is used for signal level calculation and envelope detection. Detected signal is passed through the comparator with calculated threshold level. The resulting binary signal is passed to the decoder where durations of each pulse and pause are calculated and packets of green, yellow and red signals are generated accordingly.

A final result is generated the same way as it is in the cab signaling system. If two of the three consecutive packets match, the decision about a present traffic-light signal is taken. If no decision is taken for 10 seconds, a code failure (white signal) is declared.

IV. RESULTS AND DISCUSSION

The primary acquired signal together with the speed profile is shown in Fig. 6. The displayed signals are in time domain.

The signals in Fig. 6 are raw signals as received from the transducers. These signals consist of signaling system signals as well as signals induced by rail magnetization and all distributive signals that can be treated as noise. The signal processing algorithm distinguishes the useful signals and performs a decoding to restore the traffic-light signals.



a)

b)

Fig. 6. Measured signal of each rail (a) and the train speed profile (b).

The final result of traffic-light signals along the route is displayed in Fig. 7.

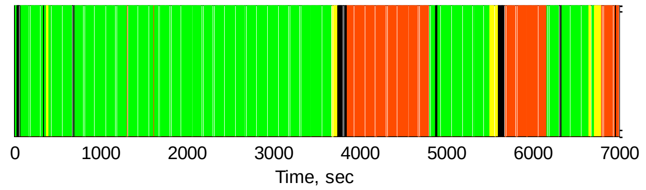


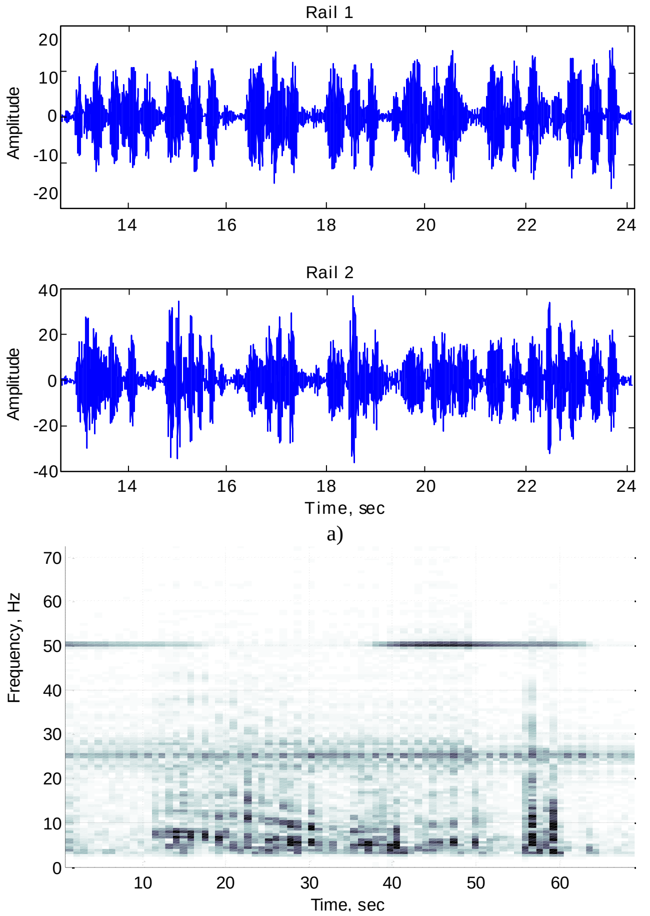
Fig. 7. Final result of traffic-light signals along the route.

As can be seen from the above figure, there are a few disturbances that are marked in solid black. They correspond to the white signal in a cab dashboard, when no signal is decoded after the green or yellow signal. The yellow and yellow-red signals were received while the train was stopped in stations.

The disturbances that were observed during this research were of two types: disturbances caused by the rail magnetization, and disturbances due to absence of signaling system signals. The first type of disturbances occurred 3 times, while the second time occurred only in train stations.

One of the disturbances caused by rail magnetization together with its spectrogram is displayed in Fig. 8. The signal is zoomed in the time axis as compared to the spectrogram view in order to see better the disturbances in the signal. At 25 Hz we can see signals of signaling system, and at 50 Hz we can see AC train traction signals [7].

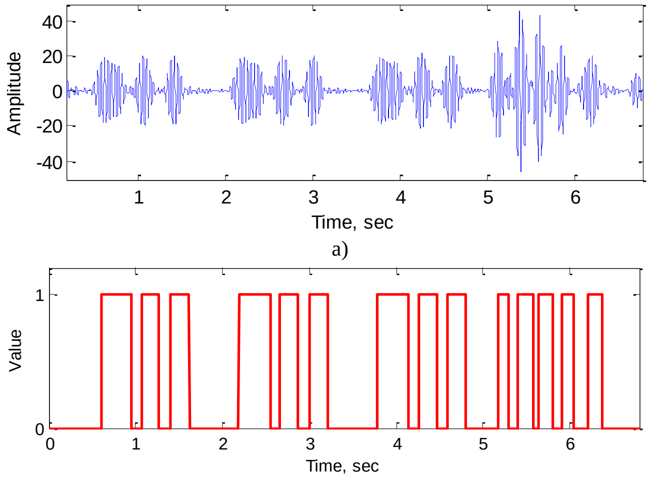
As can be seen in the spectrogram (Fig. 8), from 10th to 60th second there is a strong low frequency noise. It is caused by the rail magnetization. This noise is partially filtered by pass-band filter, but not enough to avoid the disturbances. Fig. 9 demonstrates how the noise due to the rail magnetization can disturb restoration of signals.



a)

b)

Fig. 8. Signal of each rail (after band-pass filtering) (a) and its spectrogram (before filtering) (b); location of disturbances caused by rail magnetization.



a)

b)

Fig. 9. "Green" ALS signal from transducer (a) and restored signal (b).

The first three packets (0–5 sec.) are not affected by noise (disturbances), and the forth packet (5–7 sec.) is distorted by the magnetization of rails. The resulting restored signal (Fig. 9, b) is affected by this error.

V. CONCLUSIONS

The proposed algorithm for processing the cab signaling system signals was successfully tested with real ALS signals. The multiplication of both rail signals is an alternative to the current algorithm where summation is used. This makes the processing more immune to the disturbances caused by rail magnetization, because the latter is not correlated between both rails.

Furthermore, the proposed signal processing can be used to identify potential disturbances along different routes by processing already recorded signals.

An advantage of the proposed algorithm over the currently used still needs to be identified in further research.

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