# Track Circuits Design and Analysis using Electrical Modelling and a Software Simulation Tool

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**Abstract.** This research is aimed at electrically modelling the different existing track circuits used as train detection systems. It consists of the development of a software simulation tool as an aid in the track circuit design and as a basis for installation and maintenance. This is a new approach to the modelling of track circuits, using a highly efficient software tool to comply with the requirements of the operation of railway systems and the optimization of the facilities. Its main objective is to calculate the maximum track circuit lengths, simulating the train pass when it occupies and releases the track circuit, and its frequency response that allow to minimize the time spent and the failures occurred in those facilities.

**Keywords:** track circuit, electric modelling, electric track parameters

## 1 Introduction

### 1.1 Objective

This research is aimed at electrically modelling the different existing track circuits (TC) used as train detection systems.

These are a key element for the operation of railway systems, mainly from the safety point of view and secondary also to reach a maximum and efficient use of the facilities to optimize them. Those equipments have the purpose to guarantee the safety in train exploitations, and the use different and heterogeneous technologies to find the train position and movement and to detect broken rail.

Among all these methods, track circuits are the most important ones because of their wide application and the big experience on the field. However, their functioning is highly affected by track constructive conditions and installation location that should be considered in the design and mathematical modelling.

### 1.2 Track Circuits

The purpose of train detection systems is to ensure the safety of railway operations by finding the position and movement of the train. The main functions are:

- detection of occupation,
- presence detection,
- detection of clearance or end-of-way,
- location of the head of the train,
- location of the rear of the train,
- train speed,
- train direction,
- orientation detection,
- detection of full train.

Track circuits are off-board detection systems and their operating principle is based on a signal transmission trough a track section using the rails as electrical signal conductors.

The TC is fed by a single point of the section and the signal can be received by one or two points. The signal amplitude at receiver is maximum when there is no train present. When it is present in the section, its shunt modifies the signal propagation and changes the receiver status, see Fig. 1. A similar situation happens when some failure takes place.

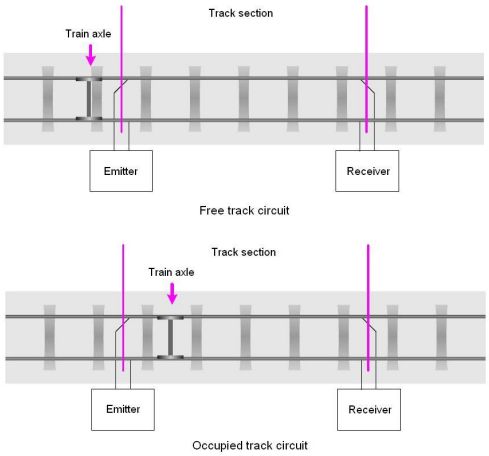


**Fig. 1.** Occupation of the track circuit

Track circuits are used to detect the train presence in the track sections in two different locations, station and open line.

At present there are several types of track circuits:

- direct current (to extinguish),
- alternating current, that are being progressively replaced by audiofrequency TCs,
- high voltage impulse,
- short TCs without insulated joints, most used in regional or metropolitan areas,
- audiofrequency.

## 2 Methodology

This research consists of the development of a software simulation tool of different Track circuits, as a help in design and as a base for installation and maintenance.

### 2.1 Electrical Modelling

These track circuit elements that have been modelled are:

- power source,
- transmission and reception cables,
- tuning unit boards; insulated joints (optional),
- track,
- receiver,
- adjacent track.

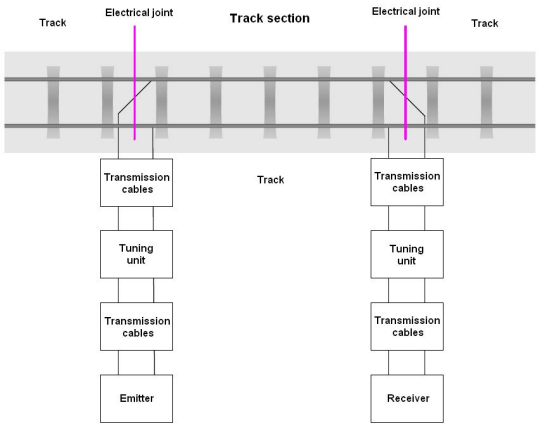


**Fig. 2.** Track circuit model

Each element is modelled by a transmission matrix and the global transmission matrix is given by multiplying the single blocks. This method is based on the use of two-port quadripole, as an intermediate element that transmits a signal from emitter to receiver connected to the entry and exit ports.

$$\begin{bmatrix} U_1 \\ I_1 \end{bmatrix} = A_{total} \begin{bmatrix} U_2 \\ -I_2 \end{bmatrix} \tag{1}$$

Once the global transmission matrix is calculated, the output current and voltage can be determined by the input current and voltage.


**Fig. 3.** Quadripole

It can also determine all currents and voltages in each point of the track circuit model.

### 2.2 Software Tool

The software tool and the user interface have been developed in Matlab and sometimes also with its toolbox Simulink.

The software functioning diagram is as follows:

One of the possibilities of this model is to calculate the voltage evolution during the train pass at any component of the track circuit. The volt drop can be observed as the train is passing through the track section and the track circuit is occupied and it also shows its clearance.

Besides, this model can also calculate the frequency response of track circuits in all possible configurations.

It is very significant that the resonant frequency of the track circuit when the train is not present (infinite shunt) corresponds with the working frequency of the track circuit.

This modelling code is open and can be implemented as a module inside other bigger applications.

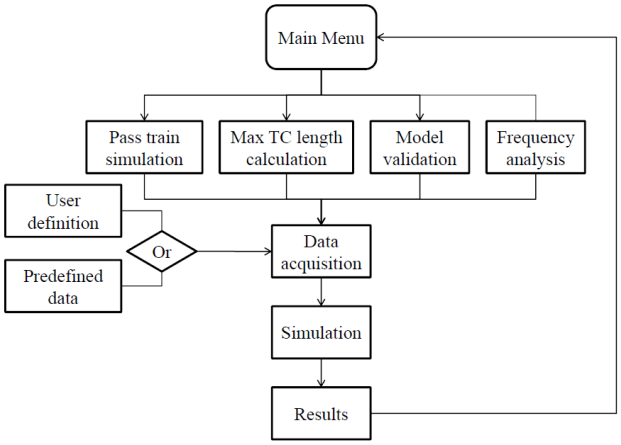


**Fig. 4.** Software blocks diagram

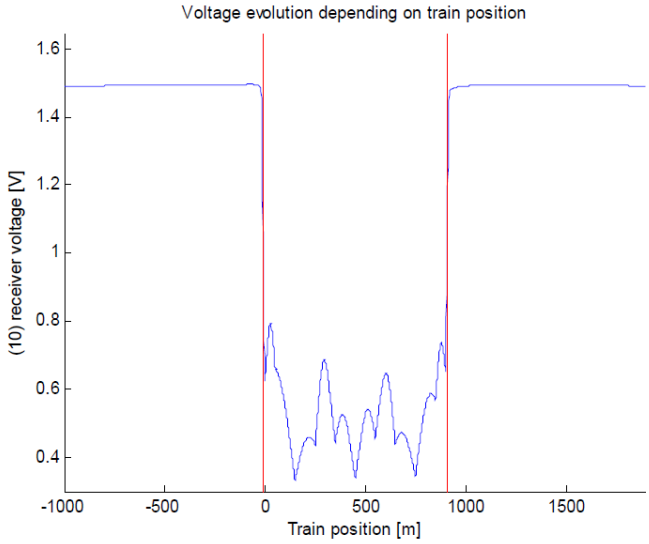


**Fig. 5.** Voltage evolution depending on train position

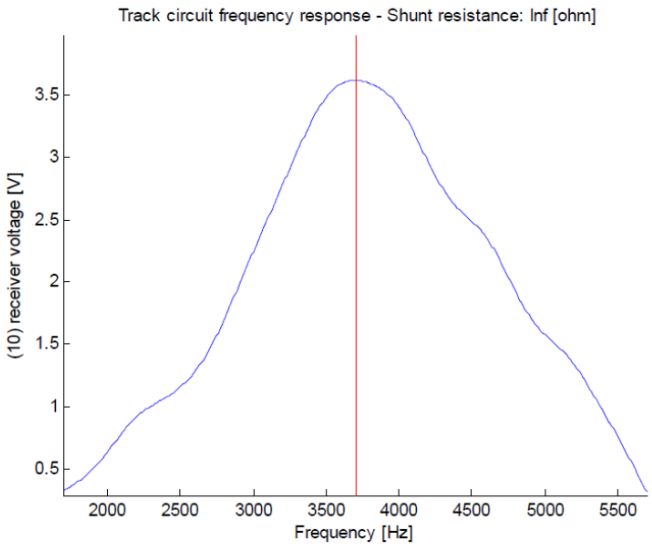


**Fig. 6.** Frequency response analysis of a track circuit

## 3 Results

In view of the results of this research it has been possible to validate this theoretical model in comparison with the real devices of TCs and to determine the track behavior versus different constructive conditions.

This is a new approach to the study of track circuits, based on a new modelling using a highly efficient tool as Matlab that allows many different modifications, such as track circuit type, electrification, track parameters, weather conditions, installations location.

This tool has many features, as determination of the TC lengths, frequency response, pass train simulation and other possible test cases. It is not a closed software and it can be implemented as an important part of a bigger model.

## 4 Practical Applications

These track circuit models have a huge range of applications for the design of the controlled sections, TC length calculation, installation and maintenance.

This tool can reduce the time and cost of TCs planning, and optimize the section lengths of TCs, reducing the risk in presence of perturbations and reduce the commissioning time. It also allows the study of innovative train detection algorithms.

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