Short-range Data Transmission Using Inductive Method

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Abstract: The paper describes a wireless short-range data transmission using the inductive method, which is designed for the transmission of short protected data messages over short distances between a moving vehicle and a stationary receiver/transmitter. The data transmission using the inductive method is designed for applications where radio or infrared data transmission is not possible or convenient to use because of one reason or another. It can be used, for example, in a municipal transport information system, where it is possible in this way to set contactless trolley-bus and tram points, to control crossroad traffic lights and simultaneously to monitor the position of individual vehicles.

Key-Words: inductive data transmission, induction coil, ASK modem, municipal transport information system, contactless point setting

1 Introduction
A wireless data communication between two devices can be realized in several ways. The first of them is the radio data transmission, which represents the most frequently used way of wireless transmission of data and multimedia. Depending on the used frequency, bandwidth, modulation, coding technique, transmitting power, etc., there exists a wealth of types of radio data transmission, from distributed voice transmission of commercial radio stations to high-speed wireless LANs. The second way is the wireless transfer using infrared or laser light – optical wireless links. The infrared data transmission is, among others, used for communication between two mobile devices over short distances. On the other hand, the optical wireless link, which operates in the visible frequency spectrum (laser), is used for high bit-rate data transmission between two stationary stations over distances of up to several kilometres.

However, the above types of the wireless data transmission are unsuitable to use in some cases. Specifically in cases when the short-range data transmission (tens of centimetres, units of metres) is required. In the case of the radio transmission it is not possible to guarantee that the frequency band used will not be interfered with whether by the same transmission system operating in close vicinity or by foreign sources. In the case of the infrared transmission the required direct line of sight between the devices and, consequently, the connection directionality is the limiting factor for its use. The inductive method can be a way out from this situation.

2 Description of the transmission system
The proposed wireless data transmission is primarily designed for the transmission of short protected data messages between a moving vehicle and a stationary device using the inductive method in the frequency band from 80 to 135 kHz. The transmission system consists of a transmitting and a receiving part according to Fig. 1.

![Fig. 1 Inductive transmission system](image)

The configuration of the transmitting and receiving module starts out from the properties of wireless data transmission:

- Amplitude Shift Keying (ASK) modulation [3], [4], [5], [6],
- carrier frequency between 80 and 135 kHz,
- bit rate 1200 or 2400 bps.

The receiving and the transmitting modules are formed by an ASK modem and circuits that, together with the receiving/transmitting induction coil, represent
a resonance circuit \cite{7}, \cite{8} tuned to the carrier frequency. The ASK modem is available as an integrated circuit. In our case we used the Philips TDA5051A – Home Automation ASK modem \cite{2}. The receiving module also contains circuits for automatic sensitivity setting.

The transmission system enables only data transmission in one direction. In case the bidirectional data transfer is needed, it is necessary to use two transmission systems. Each of them is then tuned to a different carrier frequency. At the same time, however, both systems have to be sufficiently distant from each other so that the transmitter of one system cannot affect negatively the sensitivity setting circuits of the other transmission system.

\section{Receiving and transmitting coil}

The parameters of the transmitting and the receiving coil (shape, dimensions, inductance) define the shape and density of the magnetic lines of force and in this way they determine the transfer characteristics. To obtain reliable data transmission at a high vehicle speed, one of the induction coils (receiving or transmitting) must be of oblong shape, where its longitudinal dimension copies the direction of the vehicle (see Fig. 2). At higher speeds (over 40 kmph, depending on the parameters of the transferred data) the longitudinal dimension of the coil is greater than 1 metre. It is therefore suitable for this induction coil to be stationary, while the vehicle is provided with the transmitting/receiving coil, whose dimensions have not such a significant influence on data transmission reliability.

![Fig. 2 Shape and orientation of the transmitting and the receiving coil](image)

The coils have to be oriented such that the magnetic flow induced by the transmitting coil passes through the receiving coil according to Fig. 2, no matter which of them is receiving and which is transmitting. Electromagnetic parameters of the coils, such as inductance, resistance and capacitance, determine the receiver sensitivity, which is related to the maximum transfer distance. This distance can range from several centimetres to several metres. The induction coil (receiving or transmitting) outside the vehicle can be placed under the ground or, contrariwise, it can be fixed to the trolley line (in the case of using the inductive data transmission to/from a trolley-bus in the municipal transport).

\section{Structure and parameters of the data being transferred}

In the proposed transmission system we have used the data transmission with following parameters to obtain reliable data transmission at higher vehicle speeds:

- the data transmission is synchronous, organized into frames, the frame starts with a 12 bit synchronizing sequence of 57E hex, a transmitting device ensures bit transparency that will prevent the presence of the 7E hex character inside the frame,
- the data frames are as short as possible, consisting of the necessary number of information bits and protection bits,
- data protection of information bits is at least 12 bits (CRC 12), it has no ability to correct error bits (self-correcting code causes unacceptable redundancy),
- the frames are transmitted in fast succession, there is no time delay between the frames.

In the case a small transmitting power is used, the data transmission between the coils is possible only over distances of several tens of centimetres and we can write, with some simplification, that a reliable data transmission can be realized only when the smaller induction coil is situated directly above the longer induction coil (see Fig. 2). To receive reliably at least one frame, the transmitting and the receiving induction coil have to be within their mutual range for at least twice longer than the time necessary for transmitting one frame.

So the length of the longer induction coil determines the maximum vehicle speed when the data transmission can still be considered reliable. This length is given by the equation

\begin{equation}
L = \frac{2 \cdot v_{\text{max}} \cdot N}{R},
\end{equation}

where \(v_{\text{max}}\) is the maximum vehicle speed for which we require reliable data transmission, \(N\) represents the total number of bits of the transferred frame, and \(R\) is bit rate.

For example, we can assume a vehicle speed of 80 kmph, a bit rate of 1200 bps and a number of information bits of 36. The whole frame is formed by 60 bits including the synchronizing sequence and the protecting bits (see Fig. 3). According to equation (1) the length of the induction coil has to be at least 2.22 m
so that at least one frame can be captured reliably at the vehicle speed considered.

This width variation depends on the signal strength, which is related to the distance between the coils.

As shown in Fig. 5, if the distance between the coils is small, bit “1” is much wider than bit “0”. With growing distance between the coils, bit “1” gets shorter and bit “0” gets longer, as shown in Fig. 6.

Fig. 3 Example of transferred frame

A disadvantage of data transmission with ASK modulation (Fig. 4) is the undesirable variation of the width of bits received by the receiving module.

For this reason, higher demands are put on the receiving device, which is connected to the receiving module. The receiving device continuously searches for the synchronizing sequence in the received data and on the basis of this sequence it has to determine correctly the bit centres so that reliable data transmission can be ensured, independent of the distance between the receiving and the transmitting coil.

5 Experimental verification of data transmission using inductive method

Using the inductive method, we have realized practically the data transmission to/from trams of the municipal transport. Two induction square-shape coils with an edge of 20 cm were fixed to the tram bogie. One of them was the receiving and the other the transmitting coil. The coils were approximately 2 metres from each other.

The stationary coils are of rectangular shape with, dimensions 15 x 200 cm, and they were placed on the ground between the rails so that their longitudinal dimension copied the direction of the tramline. Again, one of them is the receiving and the other the transmitting coil. The distance between them was approximately 10 metres.
The inductance of each of the coils was approximately 700 µH. A TDA5051A ASK modem [2], mentioned above, was used in the receiving and transmitting modules. We chose a carrier frequency of 125 kHz for data transmission to the vehicle, and 135 kHz for transmission in the opposite direction. The transmitting power was set such that the transmitting signal could not be captured on the neighbouring tramline.

The transmitting device (inside and outside the vehicle) continually transmitted a 60-bit frame according to Fig. 3 at a bit rate of 1200 bps. There was no time delay between the frames. The data received were immediately forwarded by the receiving devices (inside and outside the vehicle) to laptop computers. In this way we had an immediate knowledge of the number of erroneously and correctly received frames during single sessions.

The vehicle ran over the stationary coils at speeds of approximately 60 to 75 kmph during our measurement. More than 50 data sessions were captured on the whole. At least one frame was captured both inside and outside the vehicle. It represents 100 percent reliability of data transmission during the whole experimental measurement. At lower vehicle speeds (60 kmph) up to 4 frames were captured correctly, which corresponds to the theoretical assumptions.

6 Conclusion
An advantage of inductive data transmission is the possibility of determining exactly the vehicle position at a moment when communication is in progress. This fact can be used, for example, in the information system of municipal transport where, with a mutually interconnected inductive transmission system, it is possible to monitor the position of municipal transport vehicles, set the points or control traffic lights on crossroads in order to improve municipal transport smoothness.

The data transmission described is currently being experimentally tested in the municipal transport, where it is applied to contactless control of trolley and tram points. The vehicle continually transmits the frame that carries addressees and setting instructions for up to three points. This frame is updated according to the information obtained from the board computer every time the vehicle stops at a stop. Since there are no more than three points between the stops, setting the points becomes automatic along the whole vehicle route.

References:

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