Data Transmission Using Inductive Method In Mobile Applications

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Abstract: The paper deals with a data transmission using the inductive method. This data transmission is designed for applications where radio or infrared data transmission is not possible or convenient to use because of one reason or another. It is possible to use an ASK or an FSK digital modulation for data transmission using inductive method. The paper describes advantages and disadvantages of individual digital modulations. A practical use of the data transmission is shown in conclusion.

Key-Words: Inductive data transmission, Inductive loop, ASK modulation, FSK modulation, Point setting

1 Introduction

The proposed wireless data 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 65 to 135 kHz. The data transmission operates on the basis of electromagnetic induction [8], [9]. The alternating electrical current passing through a transmitting inductive coil generates a non-stationary magnetic field which is the cause of the induced current passing trough a receiving inductive coil (receiving inductive loop) located in this magnetic field.

In the ideal case, the power required to operate the electronics data-carrying device would also be transferred from the stationary device using contactless technology. These systems are called RFID systems (Radio Frequency Identification) [10]. RFID systems are now beginning to conquer new mass markets. One example is the use of contactless smart cards as tickets for short-distance public transport.

Due to bigger distances and constructional manner it is impossible for any side of transmission system to operate in a passive mode.

2 Inductive transmission system

The transmission system consists of a transmitting and a receiving part according to Fig. 1.

The transmitting modem is formed by a modulator and coupling circuits that, together with the transmitting induction coil, represent a resonance circuit tuned to the carrier frequency.

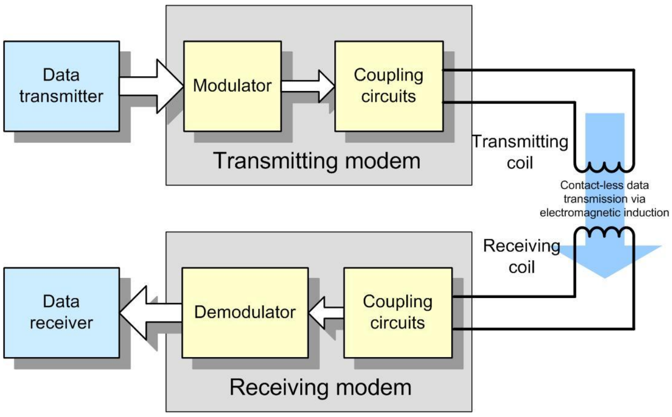

Fig. 1 Inductive transmission system

An amplifier can be a part of the coupling circuits to increase the transmitting power as is shown in Fig. 2. Capacitors C1, C2, C3 and C4 together with the transmitting coil L1 form the resonance circuit. Switches S1, S2 and S3 serve for tuning the resonance circuit.

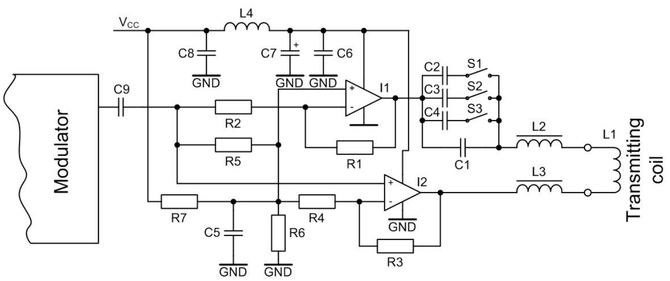

Fig. 2 Example of coupling circuits of the transmitting part

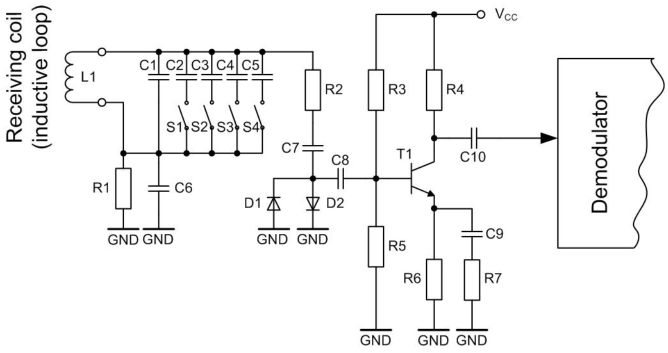

Fig. 3 Example of coupling circuits of the receiving part

The coupling circuits of the receiving part tune the receiving resonance circuit, filter the desired frequency band and amplify a received signal.

The modulator and demodulator are practically formed by the same integrated circuit. A specific type depends on used digital modulation [5], [6] and will be discussed in subsequent sections, which deal with the ASK and FSK digital modulation.

3 Parameters of transmitting and receiving inductive 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 characteristic.

To obtain reliable data transmission at a high vehicle speed and a low transmitting power, one of the induction coils must be of oblong shape, where its longitudinal dimension copies the direction of the vehicle as is shown in Fig. 4a. In this case the horizontal distance between the coils is short (several decimetres), the reliable data transmission is possible when the transmitting coil is situated under the receiving inductive loop [1].

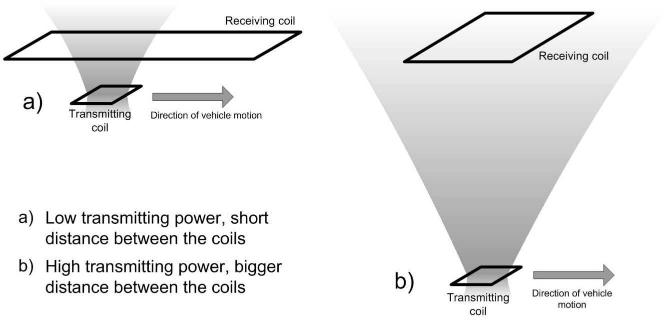

Fig. 4 Shape of receiving coil in dependence on transmitting power and the distance between the coils

The other situation is if a higher transmitting power is used. The distance between the coils can be longer and it is not necessary to keep oblong shape of the receiving inductive loop, see Fig 4b.

To be concrete, we use the receiving coil with dimensions 150 x 20 cm according to Fig. 4a and 60 x 60 cm according to Fig. 4b in our application, which solve the data transmission from a trolley-bus to a point (switch) in order to contact-less point setting.

The induction loop 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 trolley-bus in the municipal transport).

Electromagnetic parameters of the coils, such as inductance, resistance and capacitance, determine the receiver sensitivity, which is related to the maximum transfer distance.

4 Experience with ASK modulation

The modulator/demodulator is represented by the Philips TDA5051A – Home Automation ASK modem [3], whose parameters define properties of whole transmission system. The modem use ASK (Amplitude Shift Keying) digital modulation. As the communicated bit rate of the modem is not given by the manufacturer, the bit rate and the bit synchronization have to be guarantee by an additional microprocessor.

After many experimental measurements, we determined usable communication bit rate of 1200 bps for use in the mobile communications.

A disadvantage of data transmission with the TDA5051A is the undesirable variations of the bits received from the demodulator by the data receiver. This width variation depends on the signal strength, which is related to the distance between the coils. 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. For this reason, higher demands are put on the data receiver. The data receiver 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.

For this reason, it is not suitable to transfer too long data frames because of synchronous data transmission where with growing number of frame bits, the probability of erroneous frame decoding gets higher.

5 Experience with FSK modulation

The ST7538 FSK transceiver [4] made by Thomson Semiconductors is the basis of the transmitting and the receiving modem in our data transmission using the inductive method with the FSK (Frequency Shift Keying) digital modulation. The ST7538 transceiver is primarily designed for power line network communications applications, as well as the TDA5051A ASK modem. The ST7538 transceiver is more "intelligent" than the TDA5051A modem. The device operation is controlled by means of an internal register, programmable through the synchronous serial interface. Additional functions as watchdog, clock output, output voltage and current control, preamble detection, time-out, band in use are included. Additional properties are:

- 8 programmable transmission frequencies - 60 kHz, 66 kHz, 72 kHz, 76 kHz, 82.05 kHz, 86 kHz, 110 kHz and 132.5 kHz.
- Programmable baud rate up to 4800 bps.
- Receiving sensitivity 1 mVRMS.
- Carrier or preamble detection, band in use detection, mains zero crossing detection and synchronization.

We have used communication bit rate of 4800 bps, transmission frequency 110 kHz, the coupling circuits according to Fig. 2 and Fig. 3. We obtained very good results with this modem configuration, better than using the ASK transmission system described above. If we want to compare the ASK and the FSK system that we used, the experimental results speak volumes about the use of the FSK system for reliable data transmission in mobile applications. Advantages of the FSK communication system:

- Higher communication speed. It means that it is possible to use smaller inductive loops in mobile applications.
- Higher reliability of the FST system is given by positive properties of the FSK modulation for interference resistance and by good parameters of the ST7538 transceiver, as well.
- Longer communication distance with using the same transmitting power. We reach longer communication distances between the transmitter and the receiver with using the FSK system than with the ASK system with the same transmitting power. The transmitting power is determined indirectly by measuring the amplitude of voltage on the transmitting inductive coil. This voltage reaches values up to 150 V (peak to peak) in the ASK system. It is possible to carry on the communication at the distance up to 6 m. The same distance, minimally, is reached with 1/3 transmitting power by using the FSK inductive transmission system (50 V amplitude of voltage on the transmitting coil).
- Flexibility of the communication parameters of the FSK system is given with the possibility of software configuration of the ST7538 transceiver.

6 Structure of beamed data frames suitable for mobile applications

In the proposed inductive transmission system we have used the synchronous data transmission organized into short data frames [1]. The data frames have to preserve the following criterions in order to obtain the reliable data transmission in mobile applications between a vehicle in motion and the stationary device:

- Each frame starts with a 8 bit synchronizing sequence of "01010101b" that serves for bit synchronization of the transmitting modulator and the receiving demodulator.
- An 8 bit start mark "01111110b" follows the synchronizing sequence. The start mark serves as unique identification of the frame start.
- The data transmitter ensures a bit transparency that prevents the presence of the start mark "01111110b" inside the frame.
- The 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 (CRC12), 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.

It is sufficient to transfer 36 information bits in our tested experimental application, so the structure of this frame is shown in following Fig. 5.

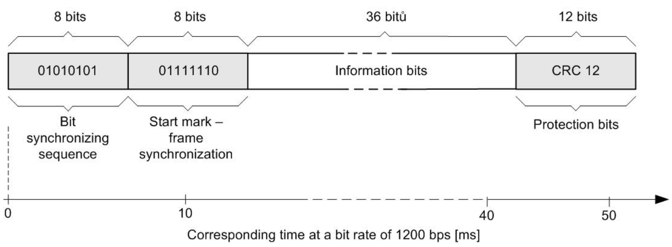

Fig. 5 Example of suitable structure of the data frame

7 Practical use of the inductive data transmission in mobile applications – accurate identification of vehicle position

The inductive data transmission offers use for an accurate identification of position of municipal transport vehicle, for example.

Collection points are placed over the observed area – a city, a vehicle depot and so on.

Each collection point consists of inductive loop (receiving coil) and receiving modem. Each vehicle contains inductive data transmitter that transmits constantly information about vehicle.

The collection points are interconnected via RS-485 bus or radio, for example. The information about vehicle received from the vehicle during its passing around the collection point is retranslated to a control centre (dispatching), where is analyse and processed.

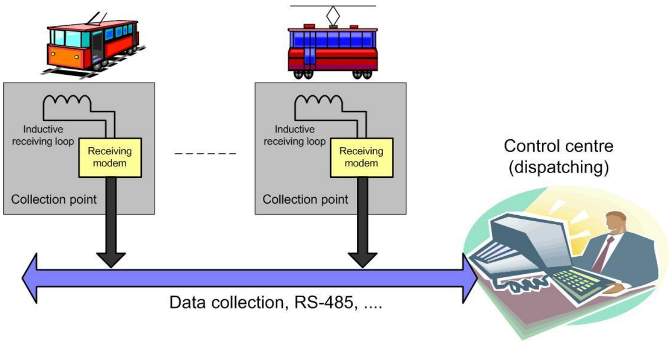

Fig. 6 Accurate identification of vehicle position

The transmission in one direction only is sufficient for monitoring vehicle positions.

Since the designed data transmission using inductive method enables only data transmission in one direction, in case the bidirectional data transfer is needed, it is necessary to use two inductive transmission systems, see Fig. 7.

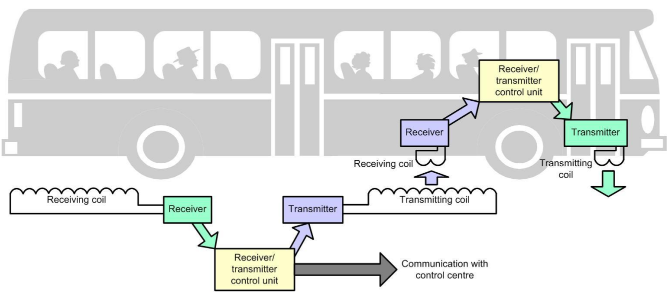

Fig. 7 Realization of bidirectional transmission system

Each of them is then tuned to a different operating frequency. 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 if a simultaneous data transmission is required.

8 Contact-less trolley bus point setting

A transmission data frames from a vehicle to point (switch) system is the basis of the contact-less point setting. The data frame contains information about required a vehicle direction, a vehicle number and additional information needful for possible automatic contact-less point setting. This frame is transmitted by vehicle continuously – frame by frame.

We distinguish manual and automatic point control. If the manual point control is used the transferred data frame carries information about direction to which the point has to be set. This transmitted direction is determined by the vehicle driver through the control buttons on vehicle control panel.

The automatic point control can be:

- Automatic point control on the basis of knowledge of vehicle position – a vehicle inductive transmission unit is connected to the vehicle board information system. The knowledge of vehicle position comes out from a logical position, which is defined by departures from vehicle stops or from GPS system. The vehicle transmission unit transmits constantly the point setting command for up to three points, for example. Fig. 8 shows the example of a frame of this automatic point setting type.

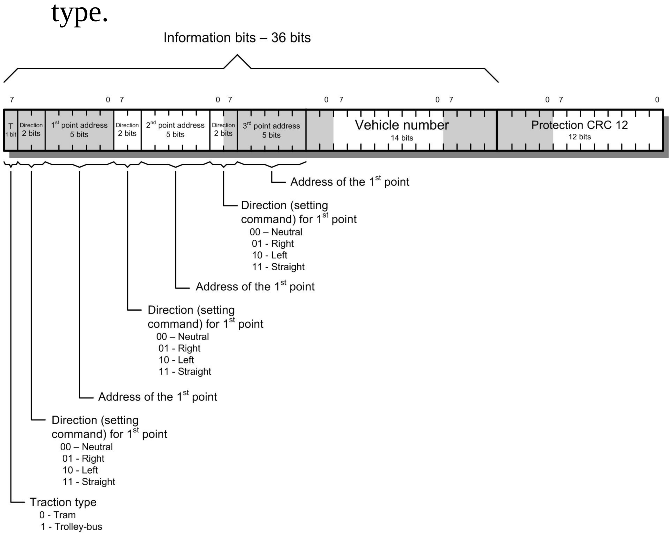

Fig. 8 Example of frame for automatic point control

A control unit of the point receives the frames from a vehicle. If one of the addresses in frame corresponds to the address of the point, it executes the setting command.

- Automatic point control on the basis of destination – the vehicle transmits a code of destination except for traction type, setting command and vehicle number, see Fig. 9.

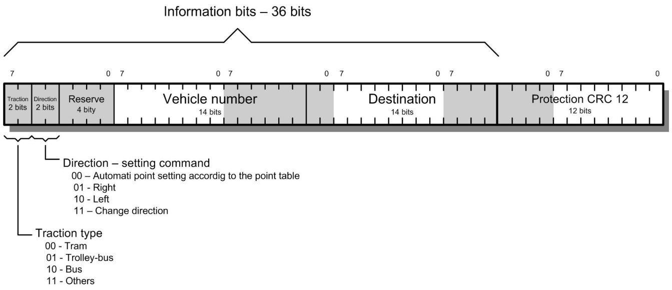

Fig. 9 Example of frame for automatic point control

If it is not possible to get the destination code from board information system, a simple keyboard can be connected to the vehicle transmission unit, which a bus driver can use before its way to enter the destination code.

A table of points must exist in the control unit of the point that consist of the following items: point address, destination code and direction. So the control unit of point can accomplish the point setting on the basis of its address and received destination code.

Of course, other possibilities of automatic point setting can exist. It depends, for example, on information we can get from the vehicle board information system.

9 Conclusion

Inductive Coupling is a method for transmission of data using coils to transmit and receive electromagnetic fields. This paper represents an application of this predominant process.

In our work we aimed to create transmission system with use of cheap components suitable for applications in municipal transport information system.

Additional task was to specific communication protocol for automatic contact-less trolley bus point setting application.

It is possible to find many applications where the inductive data transmission is convenient to use because of one reason or another. A vehicle registration during their arrival/departure to/from a vehicle depot can be an example. The ASK and the FSK digital modulations have been used in our experiments. We reach better results with the FSK modulation. Application of contact-less trolley bus point setting starts to be applied in several cities in the Europe.

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Acknowledgements: This work was supported by the grant Agency of the Czech Republic (project No. 102/03/1033) and by the Ministry of Industry and Trade of the Czech Republic (project No. FI-IM/228).