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A Study on the Characteristics of Two-Way Data Transmission for Power Line Communication Using the Rail Track by Distance

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Abstract

In order to share train safety information when trains pass through long tunnels, steep curves and single tracks, it is important to develop a real-time two-way auxiliary communications system. This study would examine the possibility of the rail tracks as the transmission lines of PLC (Power Line Communication). Moreover, the data transmission characteristics of rail track PLC by distance were evaluated. Sustainable channel transmissions were 12 to 20 MHz and 25 to 33 MHz. Furthermore, experimental results showed that the signal attenuation at each frequency of 5, 10, 15, and 20 MHz is constant within 5%. This result shows that PLC, when using 50 m of rail track, can be applied commercially within the signal attenuation threshold of -70 dBm.

Keywords: *PLC (Power Line Communication), Rail track, Return circuit line, PLC Modem, Signal coupler*

1. Introduction

When trains [1-3] pass through long tunnels, steep curves and single tracks, it is difficult to check for railroad maintenance workers and drop blocks, which has often become the cause of accidents. Figure 1 shows an example of a situation in which train safety information needs to be shared due to poor visibility. It is important to develop a real-time two-way auxiliary communications system to share train safety information, such as a CCTV video, a construction segment portable camera, and a rock-fall detection device.

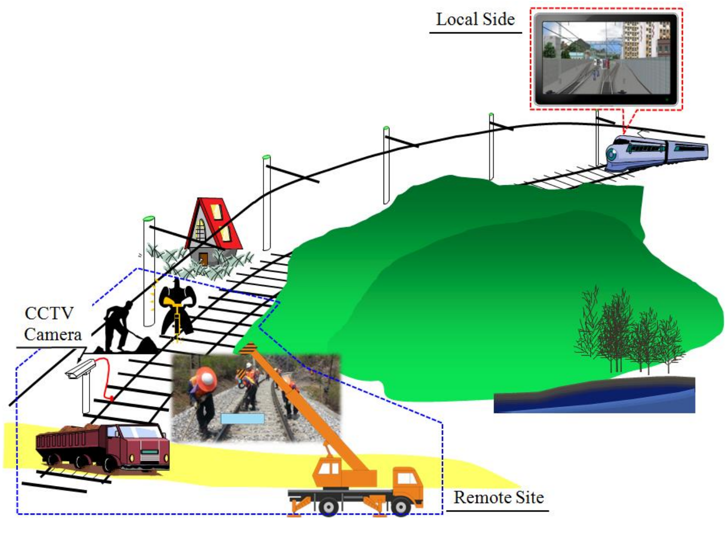

Figure 1. An Schematic Diagram of a Curved Rail Track to Have Poor Visibility

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Recently, PLC [4-8] has been studied by electric power companies, mainly for the automated measurement system for electrical power distribution to satisfy low and high speed data transmission demands. However, PLC technology has been consistently highlighted as a communications media to improve transmission speeds and reliability due to development of digital modulation techniques. The technology has been known to be cost-effective because of already existing power facilities and short installation periods. Especially in the fields of railway signaling and communications, new convergence technologies are emerging in the development of CBTC (Communication Base Train Control) and wireless video transmission systems. However, in the electric railway field, previous studies applying PLC were limited to using contact wires and messenger wires due to the risks of high voltage (i.e. 24[kV]) during installation and maintenance [9]. However, this method is dangerous due to high voltage and difficulty of installation in high locations. In addition, frequent diverging points between messenger wires and contact wires cause degradation in the signal transmission rate. As a solution to these shortcomings, this study examines if the characteristics of return circuits in rail tracks can be applied to transmission lines of PLC.

2. Rail Track PLC System

2.1 System Concepts

Communication systems for safe railway transport systems the currently uses both wired and wireless communications, but main the method to transmit safety information to running vehicles is wireless voice data transmission. Thus, if safety information data were added to the current communication operation system, it could play an important role in the prevention of accidents.

Rail track PLC is performed by overlapping several to tens of MHZ high-frequency modulation signals on a return circuit line by using a PLC modem and signal coupler. Figure 2 represents the rail track PLC concept design in an electric railway. In this

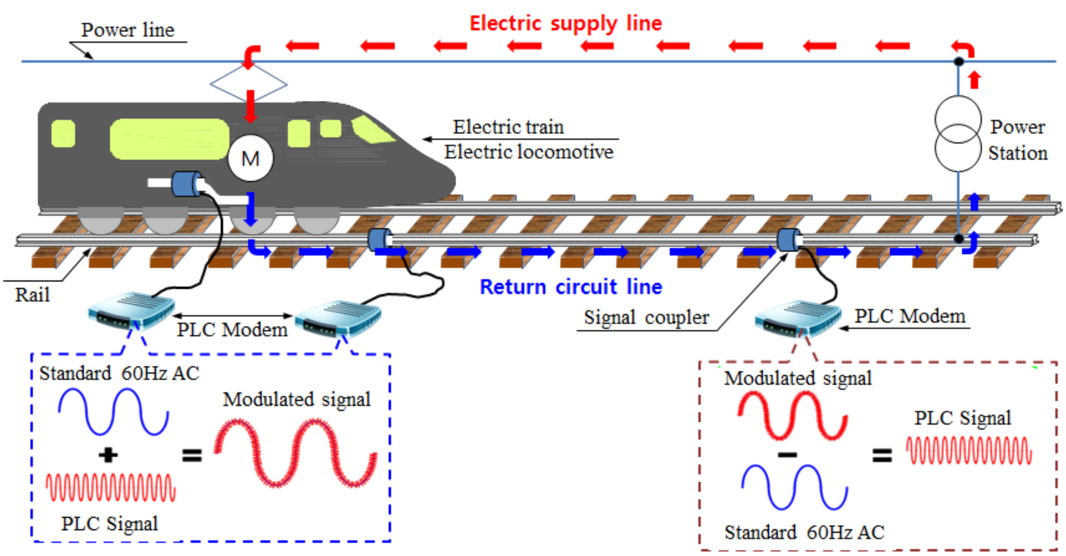


Figure 2. The Schematic Diagram of Concept on Rail Track PLC

Figure, the power supply system at the substation creates a closed circuit with the rail track, the electric car, and the power line. In this system, electricity flows into the railway substation through the return circuit rail. The system consists of a signal coupler, PLC modem, function generator, and CCTV. The related components and specifications,

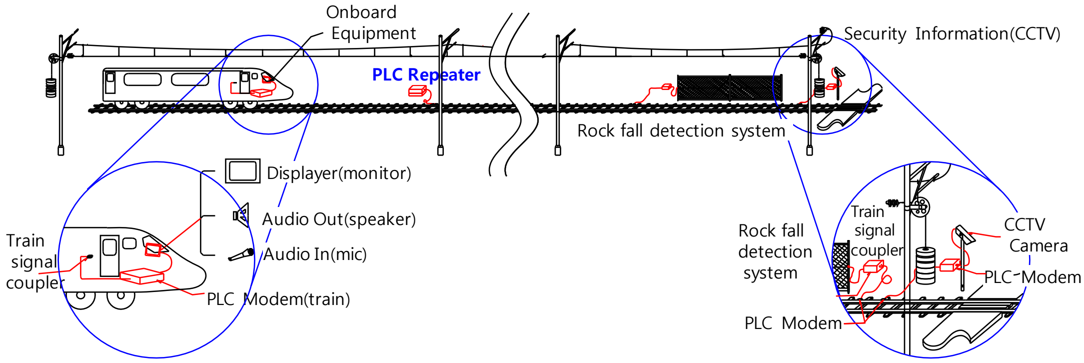


Figure 3. The Applications of Rail Track PLC System

Table 1. The Devices of Rail Track PLC in Electric Railway

Device Name	Specification
Signal Coupler	- Direct Contact - In/Out : BNC
PLC Modem	- Frequency band : 1.7 ~ 30Mhz - Interface : In(BNC), Out(TCP/IP)
Function Generator	- Frequency range : 0 ~ 20Mhz - Wave Type : Sign wave
Spectrum Analyzer	- Waveform type : RF_ID - Frequency range : 0 ~ 50Mhz - Center frequency : 20MHz - Span 50MHz
Digital(CCTV)Camera	- Type : Network Camera(TCP/IP)

Table 2. The Safety Function of Rail Track PLC in Electric Railway

Title	Safety information
Various safety information on the front transmitted to the train	Railroad crossing safety condition
	Front construction information
	Rock-fall prevention Operating status
	Operating state of the switch(rail crossing)
Information on the approaching train transmitted to ground	Location information of the approaching train
	Distance of train approaching
	Occupied lines of the approaching train etc

as shown in Table 1, are as follows: a direct contact type signal coupler, a PLC modem for transmission of data communication, a function generator, a spectrum analyzer and data transmission CCTV. Table 2 shows the main safety information about a rail track PLC.

2.2 Experimental Method

To implement PLC using a rail track, it is necessary to evaluate its communication propagation characteristics in field. Figure 4 contains the photos and a schematic drawing of a rail track PLC test conducted by KORAIL. The signal coupler was connected to one side of the rail track. Propagation characteristics from an electric locomotive with an increase of track distance were evaluated. This test used on the direct contact-type signal coupler method to decrease insertion loss and to improve impedance characteristics of a transmission media. The PLC test between EL(electric locomotive) and rail track was also conducted by connecting a contact-type signal coupler, notebook through PLC modem, and CCTV camera. In order to be close to ‘ 0Ω ’ of coupling loss (contact resistance), the contact surface of the rail was polished. Test with an increase of track distance was as well performed with the same as above-mentioned method. The transmission characteristics (i.e. attenuation) by distance were obtained by measuring a 50 m section 5 times in 10 m spaces.

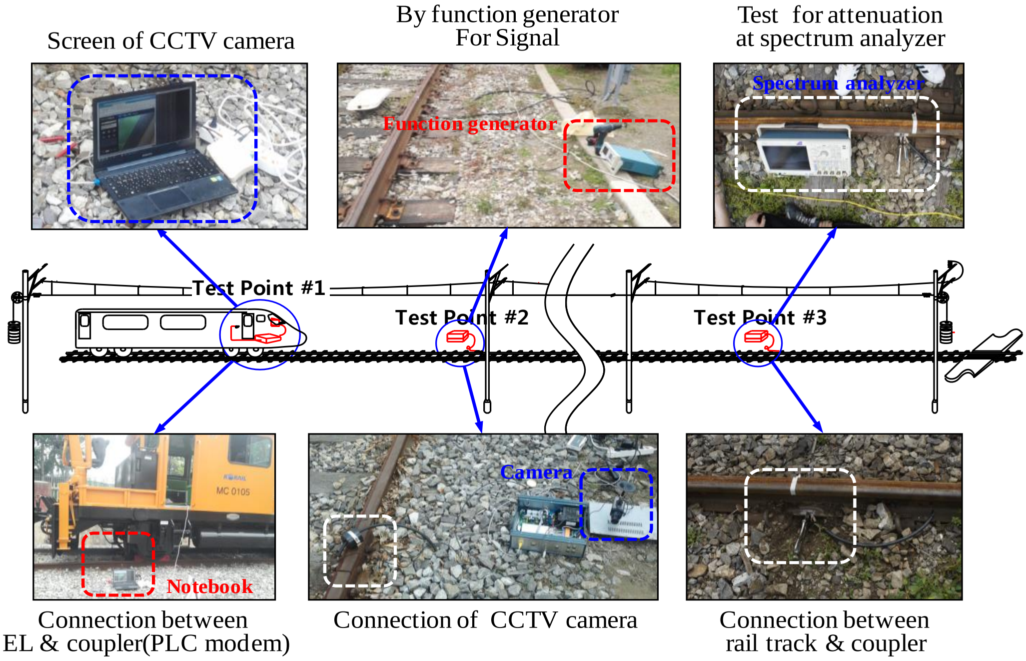


Figure 4. The Photos and Schematic Drawing Of Rail Track PLC Test by Distance

3. Test Results

3.1 Propagation Characteristics with the Distance of Track

Figure 5 represents the maximum attenuation trend in the full range of the 20 MHz frequency at a distance of 10 m. As the frequency increases, the signal attenuation rate decreases a minimum of -10 dBm to a maximum of -45 dBm.

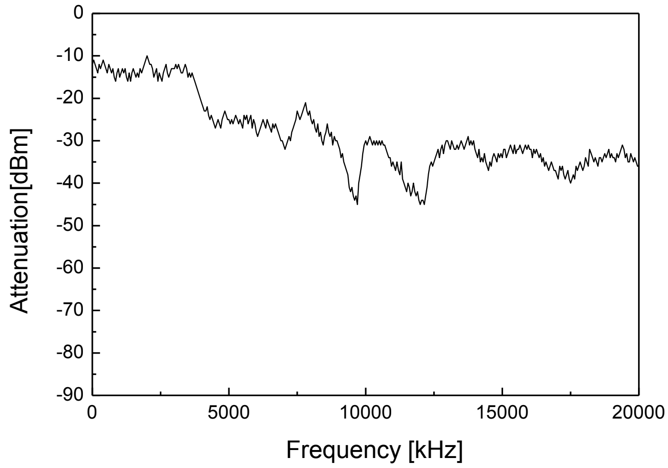


Figure 5. Attenuation Measurement Result of the Test in Wide Bands at a Distance of 10 M

3.2 Transfer Characteristics between the Electric Locomotive and Rail

As the result of the PLC test between the EL and rail shown in Figure 6, on average

Figure 6. Photos of Rail Track PLC Test between EL and Rail Track

950byte were measured when loading 1kilo-byte of data on ICMP (Internet Control Message Protocol), the size of the packet loaded on the network is shown in Formula (1).

$$\text{Data size} = \text{Ethernet header size(14 Bytes)} + \text{IP header size (20Bytes)} + \text{Data size (1000Bytes)} + \text{CRC size (4Bytes)} \quad (1)$$

Therefore, in Formula (1), data size uses transmission data calculated to be 1038 byte to use Formula (2) to calculate the bit rate.

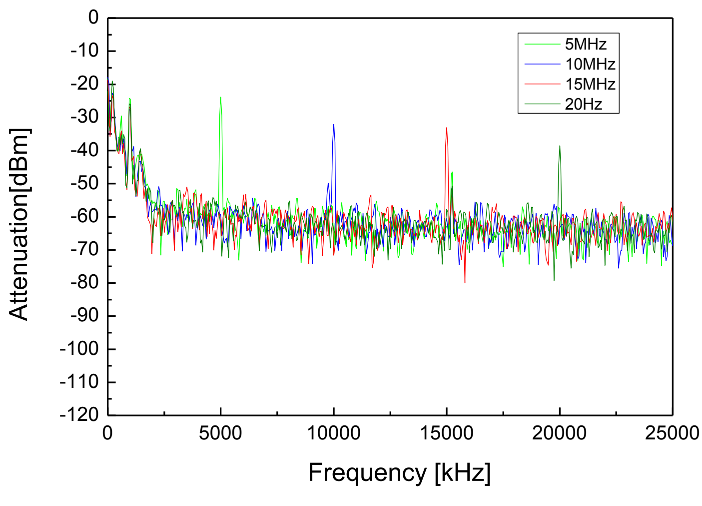
$$Bitrate[Kbps] = \frac{packetlength \times 8(bit / byte) \times 2}{Responsetime} \quad (2)$$

Here, the constant 8 represents a whole number, which converts bytes into bits. The constant 2 denotes the time where the measured value returned in place. The average transmission time in one direction for an hour is approximately 590msec. The average transmission speed by substituting in Formula (2) is 17.48kbps as shown in Formula (3) and the CCTV (640 x 480) video is about 5 ~ 10 F/s.

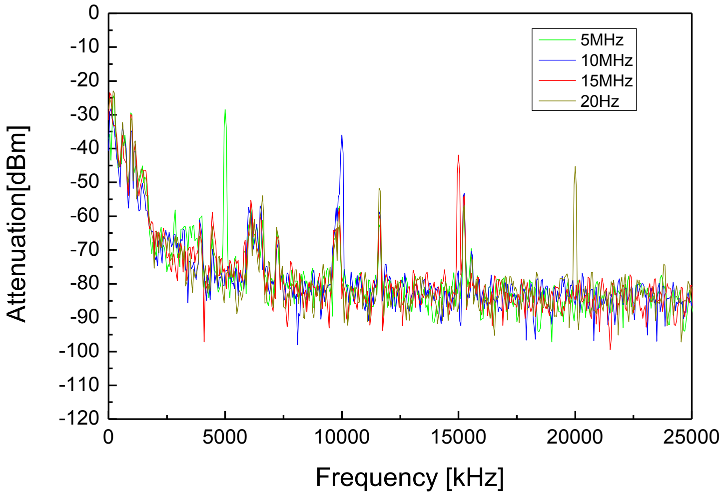
$$Bitrate[Kbps] = \frac{1038 \times 8 \times 2}{950} = 17.48Kbps \quad (3)$$

3.3 Propagation Characteristics According to Rail Track Distance

Figure 7 (a) and (b) show the signal attenuation changes measured from the rail track PLC test at the distances of 5 m and 50 m, respectively. In each case, ± 5 volts and 5 ~ 20MHz of sinusoidal waves as a signal generator are applied. In Figure 7(a) at the distances of 5 m, there was approximately -23 to -38 dBm attenuation at frequencies 5, 10, 15, and 20MHz. For 50 m figure 7(B), there was signal attenuation of -24 dBm to -45 dBm. Figure 8 represents the maximum value trend according to full range frequency at the 10 m mark. Figure 8, as frequency increased, signal attenuation rate was minimized to -10 dBm to maximum of -45 dBm.



(a) 5 m



(b) 50 m

Figure 7(B). Attenuation Measurement Schematic Diagram at Frequency 5, 10, 15, And 20MHZ at 50 M

Figure 8 represents the changes in signal attenuation derived from the rail track PLC test in the range of 10 ~ 50 m. The signal attenuation at each frequency of 5, 10, 15, and 20 MHz is approximately constant within 5%. This result shows that rail track is possible to use commercially within the signal attenuation threshold of -70 dBm [6].

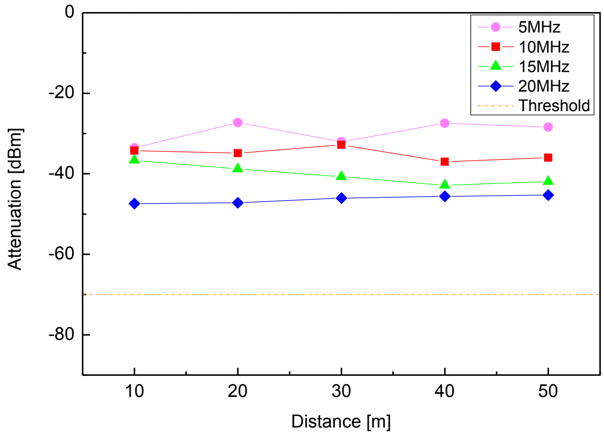


Figure 8. Attenuation Variation with an Increase of Track Distance

4. Conclusion

This study would examine the possibility of the rail tracks as the transmission lines of PLC. Moreover, the data transmission characteristics of PLC by distance were evaluated. The findings are as follows. As the frequency increases in the full range of the 20 MHz, the signal attenuation rate at a distance of 10 m decreases a minimum of -10 dBm to a maximum of -45 dBm. Sustainable channel transmissions were 12 to 20 MHz and 25 to 33 MHz. It was proven that PLC via rail track is feasible in the two above bands The signal attenuation at each frequency of 5, 10, 15, and 20 MHz is constant within 5%. This result shows that PLC using 50 m of rail track is possible to apply commercially within the signal attenuation threshold of -70 dBm.

Acknowledgments

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