Applicability of HD-PLC / PaWalet Link Technology to WPT system

Naohiro KAWABATA [1)] **Hisao KOGA** [1)] **Toshiyuki WAKISAKA** [1)]

1) Panasonic Holdings Corporation, Hakata, Fukuoka, Japan

E-mail: kawabata.naohiro@jp.panasonic.com

ABSTRACT: In a wireless power transfer (WPT) system in which multiple vehicles such as EVs and E-Bikes are placed close to each other, wireless communication is used for charging control and collecting various data (images, sensors, etc.). In those systems, radio wave interference causes false detection of vehicles and security issues. We propose PaWalet Link (*1) technology, which applies HD-PLC (*2) (High-Definition Power Line Communication), a kind of high-speed power line communication technology, to near-field wireless communication as a method that achieves both high-speed communication and avoidance of radio wave interference. By superimposing the HD-PLC signal on the loop antenna, we showed that PaWalet Link technology enables high-speed communication within a limited range of several tens of centimeters and avoidance of radio wave interference using channels with different frequency bands.

KEY WORDS: power line communication, near-field communication, wireless power transfer, coil antenna, charging control

1. INTRODUCTION

The demand for wireless power transfer is increasing in the fields of small electronic devices, EV/E-Bike, and industrial equipment, and along with that, the demand for near-field wireless communication is also increasing.

Fig. 1 shows an example of an outdoor charging station for E-Scooters. In those systems, since problems such as deterioration of the contacts and maintainability of the electrodes have been caused by contact-type charging, the method of magnetic field resonance wireless power transfer is also used. Besides, wireless communication is adopted for charging control during charging via wireless power transfer and for the purpose of collecting various data (images, sensors, etc.). The requirements of the physical and data link layer are specified in ISO 15118-8 (1). When wireless communications such as Wi-Fi (*3) and Bluetooth (*4) are applied to charging station as shown in Fig. 1, multiple vehicles are placed close to each other, and radio wave interference causes false detection of vehicles and security problems. Therefore, a communication method that can limit the transmission range and avoid radio wave interference is desired.

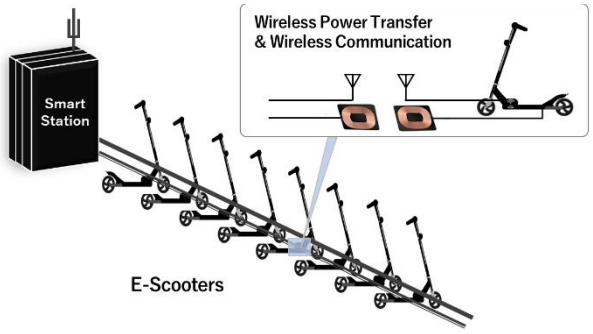


Fig. 1 Charging station for E-Scooters.

In order to solve these problems and realize high-speed communication, we studied applying HD-PLC, a kind of high-speed power line communication technology, to near-field wireless communication. HD-PLC complies with IEEE 1901 standard (2) and enables a maximum physical rate of 250 Mbps when using a frequency band of 2 MHz - 28 MHz. Furthermore, by changing the communication band via signal processing, switching between long-range and high-speed communications is possible, and having multiple channels also improves robustness. This technology is suitable as a communication method for the WPT system from two viewpoints, one is to achieve both high-speed communication and avoidance of radio wave interference and another is to suppress the influence of noise from peripheral devices.

In this paper, we report that HD-PLC is applied to near-field wireless communication and the effectiveness of using it for the WPT system.

2. HD-PLC TECHNOLOGY

HD-PLC adopts Wavelet OFDM (Orthogonal Frequency Division Multiplexing) as a physical layer modulation method and uses 432 subcarriers in a frequency band of 2 MHz - 28 MHz. Fig. 2 shows that since Wavelet OFDM enables each subcarrier to be band-limited, a 35 dB deep spectrum notch can be formed by not using any two adjacent subcarriers. Therefore, it becomes easier to avoid interference with systems using the same frequency band

and to comply with regulations for frequency allocation that is different by country or region. Furthermore, the signal processing in the Wavelet OFDM transmitter enables reducing or expanding communication bandwidth by changing the subcarrier spacing, and multiple channels can be generated.

HD-PLC defines nine modes and fifteen channel IDs. Fig. 3 shows the relationship between channel ID and frequency in each mode. In XB1-1Ch mode, the symbol length is 8.192 μsec, and only one channel (channel ID: x-1) can be used. In XB1-2Ch mode, the subcarrier spacing is half that of XB1-1Ch mode and two channels (channel IDs: x-2 and x-3) can be used by performing frequency offset. Similarly, in XB1-4Ch mode, the subcarrier spacing is one-fourth that of XB1-1Ch mode and four channels (channel IDs: x-4, x-5, x-6, and x-7) are available.

In this way, multiple channels can be generated by combining changing the subcarrier spacing and frequency offset, and the user can select the optimal channel according to the transmission characteristics.

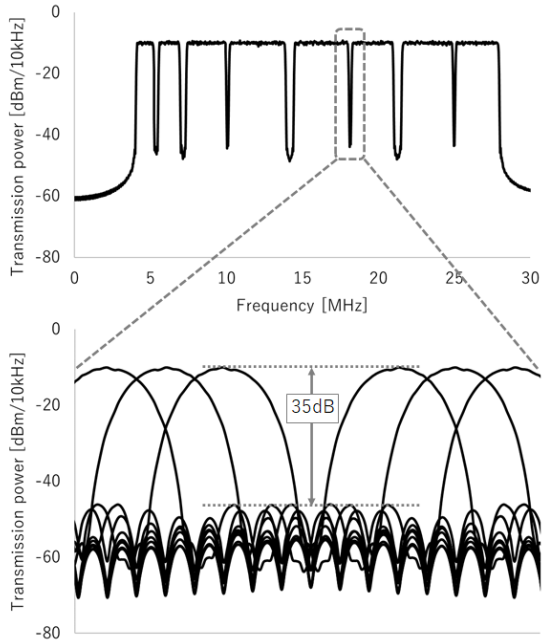


Fig. 2 Spectrum notch in Wavelet OFDM.

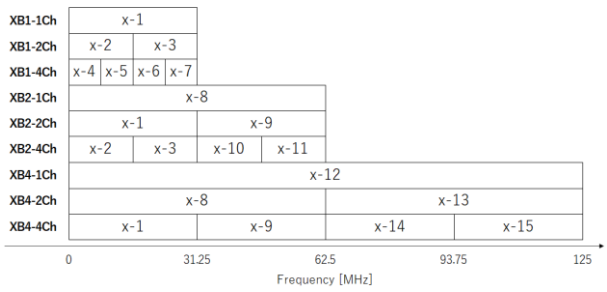


Fig. 3 Channel IDs and frequency bands in each mode.

3. PAWALET LINK TECHNOLOGY AND PERFORMANCE EVALUATION

3.1. PaWalet Link technology

In a use case that is assumed to be combined with a wireless power transfer, the distance between transmitting and receiving antennas for data transmission is a near field, therefore coupling by the magnetic field of two loop coils is suitable. Thus, the Wavelet OFDM signal is superimposed on the antenna by connecting a coil antenna to the HD-PLC terminal as shown in Fig. 4, and data is transmitted and received by the magnetic field generated from it. In this way, near-field wireless communication technology that applies Wavelet OFDM to the communication method using magnetic fields by an antenna and limits the transmission range is called PaWalet Link technology [3].

Fig. 5 shows that the magnetic field coupling of coil antennas has vertical and lateral coupling. The magnetic flux generated from one coil penetrates the other coil in the same direction when the two coils are positioned vertically, and in the opposite direction when they are horizontal. In the case of the system shown in Fig. 1, the coils are positioned often vertically, therefore we consider such an arrangement in this paper.

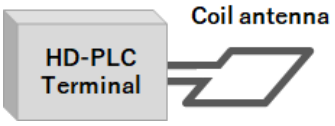


Fig. 4 Configuration of PaWalet Link.

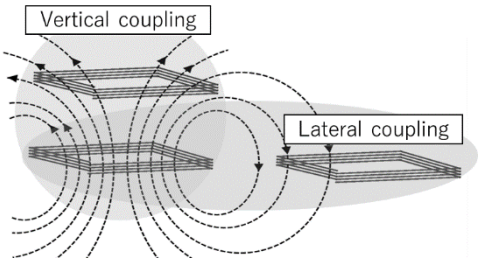


Fig. 5 Magnetic field coupling by coils.

3.2. Transmission performance evaluation

In order to understand the basic characteristics of PaWalet Link, we measured the relationship between the distance between the coils and the transmission rate at channel ID: x-1. HD-PLC terminals and square coil antennas with a dimension of 3 cm were arranged as shown in Fig. 6, and best-effort communication was performed using UDP (User Datagram Protocol) while changing the distance between the coils. It was also performed with a dimension of 8 cm, and the transmission rate was measured under

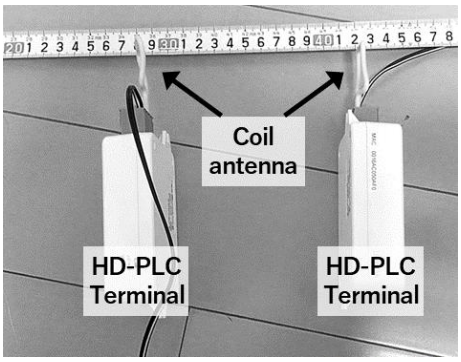


Fig. 6 Measurement environment.

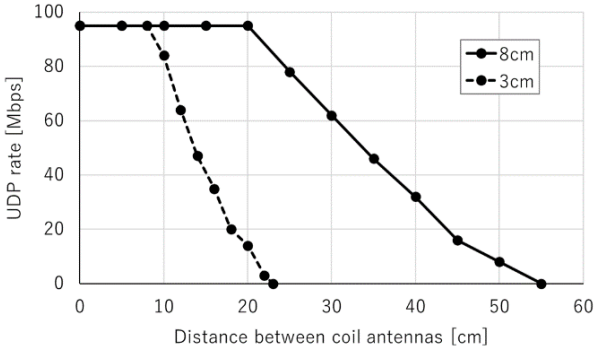


Fig. 7 UDP rate vs. distance between coil antennas.

each dimension. At this time, the output power from the terminal (i.e., input power to the antenna) was -50 dBm/Hz, which meets the standard levels for the EMC limit in Japan.

Fig. 7 shows the measurement results of the transmission rate with respect to the distance between the coils. When the distance between coils is 8 cm or less for coils with a dimension of 3 cm, and when the distance between coils is 20 cm or less for coils with a dimension of 8 cm, the maximum transmission rate of 95 Mbps can be achieved. Furthermore, the maximum transmission distance is 22 cm for coils with a dimension of 3 cm and 50 cm for coils with a dimension of 8 cm, and communication at several Mbps is possible in either case.

In the case that coils are arranged vertically, high-speed communication is possible within the range of several tens of centimeters between the coils, and the relationship between the distance between the coils and the transmission rate changes depending on the dimension of the coil. Fig. 8 shows the simulation results of the transmission rate in each condition of the coil size and the distance between the coils. There is a proportional relationship between the coil size and the distance between the coils when communicating at a specific transmission rate. Users can determine the coil size and the distance between the coils according to the desired transmission rate.

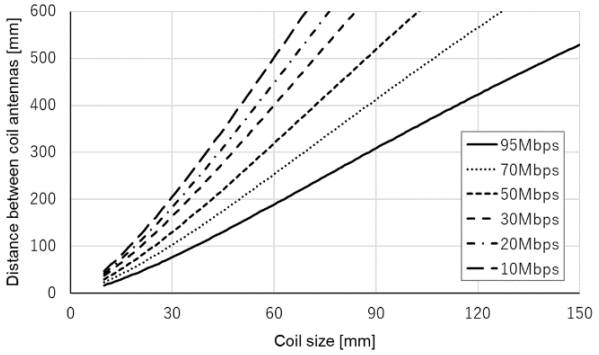
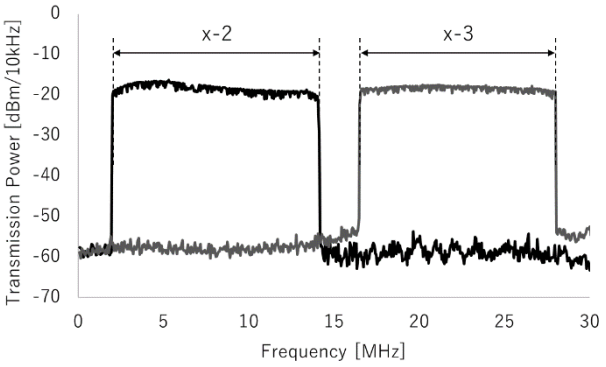


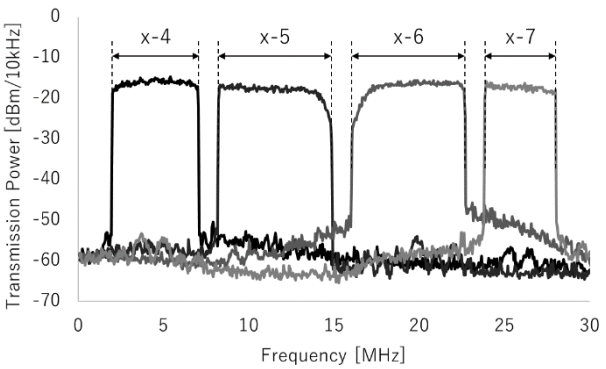
Fig. 8 Transmission rate in each condition of the coil size and the distance between the coils.

3.3. Interference avoidance using multiple channels

PaWalet Link technology has multiple modes and channels as shown in Fig. 3. Fig. 9 shows examples of the transmission spectrum. Fig. 9(a) shows the XB1-2Ch mode and Fig. 9(b) shows the XB1-4Ch mode. Each mode has multiple channels (two or four) in the same frequency band as the XB1-1Ch mode and changing the transmission power and/or forming notches are possible, as necessary. Since the frequency band used in each channel does not overlap, radio wave interference can be avoided.



(a) XB1-2Ch mode.



(b) XB1-4Ch mode.

Fig. 9 Transmission spectrum.

Specifically, in such a system shown in Fig. 1, it is possible to avoid mutual radio wave interference by assigning different channel IDs (e.g., x-2 and x-3, x-4 and x-5, etc.) to adjacent vehicles. Furthermore, if there is a low SNR (Signal-to-Noise Ratio) frequency band, the communication quality can be improved by selecting a different channel ID from the band.

4. EXPECTED USE CASES

We expect that PaWalet Link and HD-PLC technology can be applied not only to systems in which multiple vehicles are placed close to each other as shown in Fig. 1 but also to various other WPT systems.

One of them is the application for the Dynamic Wireless Power Transfer (DWPT) system, which is attracting attention as a future charging infrastructure. As with metered parking system, communication between the system administrator and the various devices/equipment/vehicles in the DWPT system is essential for usages such as vehicle authentication (whether vehicle supports WPT), grasping the charging status, and sending and receiving billing information. Furthermore, communication is also required for connecting with Energy Management System (EMS). Using PaWalet Link for near-field wireless communication and HD-PLC for wired communication realizes building a local network in a short construction period and at a low cost because new wiring for communication becomes unnecessary. The local network also can be connected easily to a wide area network such as 5G.

In addition to systems for EV/E-Bike, we suppose this technology can be applied to industrial robots that run autonomously in factories. This technology can contribute to efficient operation by controlling charging, collecting various data stored in robots, and detecting the position of robots within the range of radio waves.

5. CONCLUSION

We showed that the PaWalet Link technology, which applies HD-PLC to near-field wireless communication, is effective as a communication method for a WPT system in which multiple vehicles are placed close to each other and for a DWPT system. By using PaWalet Link technology, high-speed and secure communication with a limited range is possible, and because it uses the same modulation method as HD-PLC, a hybrid network of wired and wireless communication can be constructed easily.

In the future, we will aim not only for EV/E-Bike but also for a wide range of utilization in the e-Mobility field, such as drones and industrial robots.

REFERENCES

(1) ISO, *Road vehicles - Vehicle to grid communication interface - Part 8: Physical layer and data link layer requirements for wireless communication*, ISO 15118-8:2020, 2020.

(2) IEEE Standards Association, *IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications*, IEEE Std 1901-2020, 2021.

(3) Panasonic Corporation, “Panasonic Develops World's First Near Field Communication Technology Using Wavelet OFDM.” https://news.panasonic.com/global/press/en211110-2 (accessed March 24, 2023).

TRADEMARKS

(*1) PaWalet Link is a trademark of Panasonic Holdings Corporation.

(*2) HD-PLC is a registered trademark or trademark of Panasonic Holdings Corporation in Japan and in other countries.

(*3) Wi-Fi is a registered trademark of Wi-Fi Alliance.

(*4) Bluetooth is a registered trademark of Bluetooth SIG, Inc.