

Performance of PLC Synchronization for DOCSIS 3.1 Receiver

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Abstract— A Physical layer link channel (PLC) is a narrowband signaling channel located within the downstream OFDM channel used in data-over-service-interface specifications (DOCSIS) 3.1 system. It consists of a PLC preamble and PLC data which include information about a low density parity check (LDPC) coding rate, QAM order and interleaver depth etc. PLC preamble has +1 or -1 for PLC synchronization. In this paper, a novel method of PLC synchronization in frequency domain is proposed to demodulate a received orthogonal frequency division multiplexing (OFDM) signal correctly.

Keywords— DOCSIS 3.1, OFDM, PLC.

I. INTRODUCTION

DOCSIS 3.1 supporting 10Gbps downstream and 1Gbps upstream is published in 2014 and there are two major differences compared with the previous DOCSIS. First, an OFDM modulation with N subcarriers is used for the simplicity of a channel compensation and increasing delay spread tolerance instead of single carrier modulation. Second, a LDPC is used as the forward error correction (FEC) and has about 6 dB coding gain compared with Reed-Solomon (RS) and trellis coded modulation (TCM) used in the previous DOCSIS specifications.

Because the PLC includes modulation parameters such as a LDPC coding rate, a DOCSIS 3.1 receiver must perform a PLC synchronization first before demodulating a received OFDM signal correctly.

Section II introduces the method of the PLC synchronization and addresses the simulation results of it. Finally, concluding remarks are given in section III.

II. PLC SYNCHRONIZATION

Fig.1 shows the example of the PLC structure for 4096 subcarriers (N). As shown in Fig. 1, the red box denotes the location where the PLC synchronization must find in frequency and time domain. Because the location of PLC can be placed in any frequency position, PLC synchronization must find the last subcarrier position in frequency domain and the last OFDM symbol including PLC preamble in time domain in a blind manner. N_{prm} is the number of subcarriers for the PLC, depending on the number of total subcarriers (N).

For example, it is eight for 4096 subcarriers and sixteen for 8192 subcarriers in frequency domain. As shown in Fig. 1, 3800 subcarriers are used for user data, pilot and PCL and the

other subcarriers have zero values for guard band. PLC consists of PLC preamble occupied for 8 OFDM symbols and PLC data filled with 120 OFDM symbols in time domain. PLC preamble is modulated using binary phase shift keying (BPSK) and has +1 or -1 of well-known pattern. PLC data includes modulation parameters such as LDPC coding rate and is modulated using 16 quadrature amplitude modulation (QAM).

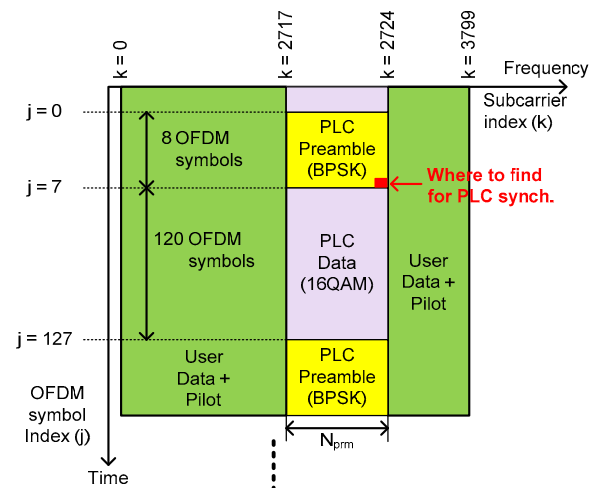


Figure 1. Example of PLC when N is 4096.

Fig. 2 shows the structure of PLC synchronization which consists of the boundary mapper, moving sum and find max block. The negative value of moving sum in frequency domain is set to zero by a limiter for hardware simplicity.

The input of boundary mapper is the received QAM symbols after a DOCSIS 3.1 receiver performs an OFDM symbol synchronization and fast Fourier transform (FFT).

Because of an OFDM symbol timing offset, the received QAM symbols including PLC preambles are rotated. Magnitude distortion happens owing to micro reflection and a frequency offset. Because the PLC preambles are +1 or -1, the power (M) in the boundary mapper shown in Fig. 2 is located around a unit circle.

Fig. 3 shows the constellation of the input of boundary mapper. Cyan circle represents the unit circle and the red boxes mean the PLC preambles.

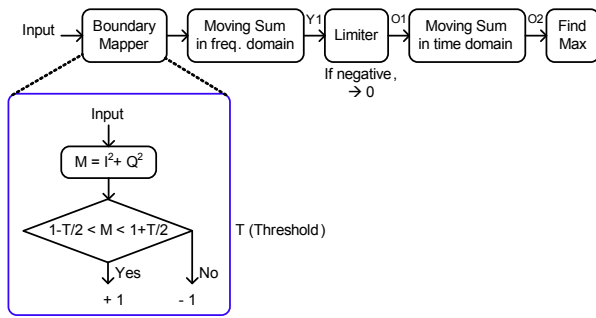


Figure 2. Block diagram of PLC synchronization.

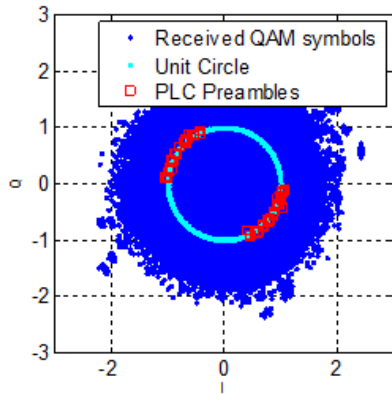


Figure 3. Constellation of the input of boundary mapper.

Fig. 4 shows the limiter output after moving sum in frequency domain for N_{prn} and the equation of limiter output is expressed in (1).

$$O1(k) = \left| \sum_{n=k}^{k+N_{prn}-1} Y1(n) \right|, \text{ for } k=0,1,2,\dots \quad (1)$$

where $Y1$ is the output of moving sum in frequency domain.

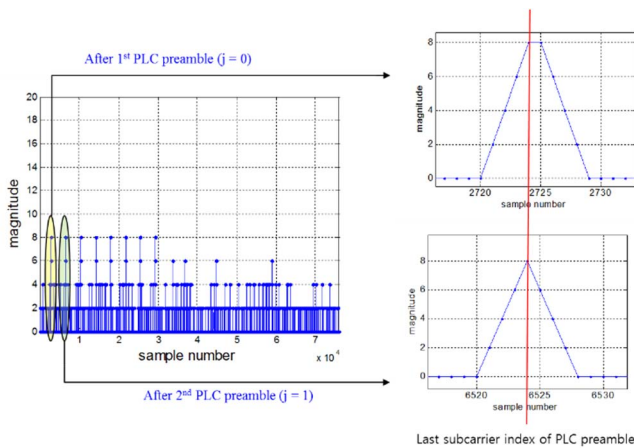


Figure 4. Output of moving sum in frequency domain.

As shown in Fig. 4, the peak value of limiter output is 8 at last subcarrier of PLC preamble after the first and second PLC

preamble because the eight subcarriers for PLC preamble have +1 or -1.

Fig. 5 shows the output of moving sum in time domain for eight OFDM symbols and the equation is expressed in (2).

$$O2(j*3800+k) = \sum_{k=0}^{3799} \sum_{i=j}^{j+7} O1\{(i-7)*3800+k\}. \quad (2)$$

where 3800 is the subcarrier number for user data, pilot and PLC and $O1$ is the output of the limiter and j is j^{th} OFDM symbol index and k is the k^{th} subcarrier index.

Because the peak value of moving sum in time domain is detected at last subcarrier of PLC preamble after eight PLC preambles, the PLC synchronization is successful.

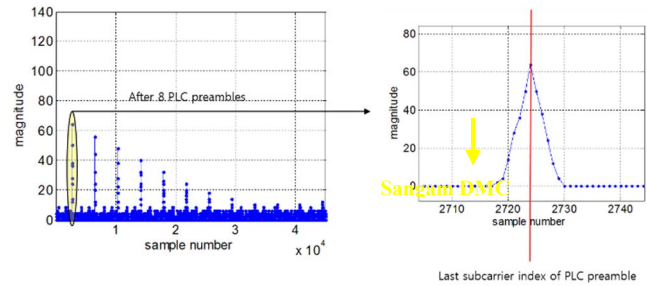


Figure 5. Output of moving sum in time domain

As shown in Fig. 6, the success probability of PLC synchronization for 4096 subcarriers has been simulated with respect to a threshold (T) when the channel is additive white Gaussian noise (AWGN) + a frequency offset (FO) + multipath. The frequency offset is 12.5 kHz and the multipath uses the video broadcasting for cable system (DVB-C2) specification.

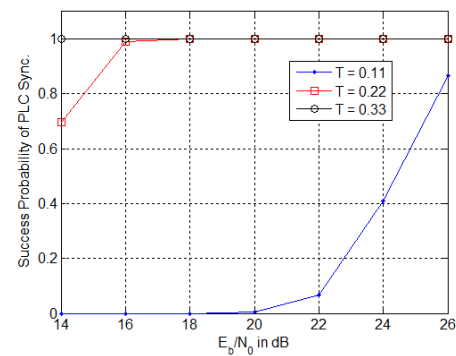


Figure 6. Success probability of PLC synchronization.

As shown in Fig. 6, the performance of PLC synchronization increases because the coverage of the boundary mapper is wider as the threshold increases. In addition, PLC synchronization for 8192 subcarriers has been simulated and operated well with the similar pattern shown in Fig. 6.

III.CONCLUSION

Because the PLC synchronization in a DOCSIS 3.1 receiver is necessary for demodulating the received OFDM signal

correctly, the method of the PLC synchronization is proposed in this paper and has been simulated for various thresholds. In addition, this method is expected to be applicable to a DOCSIS 3.1 receiver.

REFERENCES

- [1] Data-Over-Cable Service Interface Specifications DOCSIS 3.1, CM-SP-PHYv3.1-I03-140610, June 2014.
- [2] Digital Video Broadcasting (DVB); Implementation Guidelines for a second generation digital cable transmission system (DVB-C2), DVB Document A147, March 2010.
- [3] Digital Video Broadcasting (DVB); Frame structure channel coding and modulation for a second generation digital transmission system for cable systems (DVB-C2), DVB Document A138, April 2009.



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