# A PLC Transceiver Design of In-Vehicle Power Line in FlexRay-based Automotive Communication Systems

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***Abstract* – This paper presents a power line communication (PLC) transceiver design of in-vehicle power line compliant with FlexRay communication systems. FlexRay-based in-vehicle power line communication provides a solution for high reliability without increasing weight, volume and cost of the wiring harnesses. A 16-QAM (Quadrature amplitude modulation) scheme is utilized in the transceiver design.**

**Key word: FlexRay, PLC, transceiver, automobile electronics, in-vehicle networking**

## I. Introduction

Nowadays, car electronic has been deemed as the $4^{th}$ "C" right after Computer, Communication and Consumer electronics. There exist more and more electrical control units (ECUs) for safety and comfort of occupants in the automobiles. Many novel electronic devices have been introduced and installed in recently publicized cars. Therefore, an in-car network has been proposed to control and supervise all of the automobile electronics. In 1990, the average quantity of ECUs in an automobile was fourteen. By 2000, the number of ECUs reaches forty. Notably, certain luxury automobiles can even have over one hundred ECUs.

The FlexRay standard is designed for an in-car network. It will not replace the existing network, but it can combine and integrate with existing systems, including CAN (Controller Area Network), LIN (Local Interconnection Network), MOST (Media Oriented System Transport) [1] and J1850 protocol etc. FlexRay requires 10 Mbps data rate in either one of the two channel of an ECU. If a single channel is used alone, the speed of the total data rate will reach 20 Mbps. Fig. 1 shows the feature of FlexRay when used (X-by-wire).

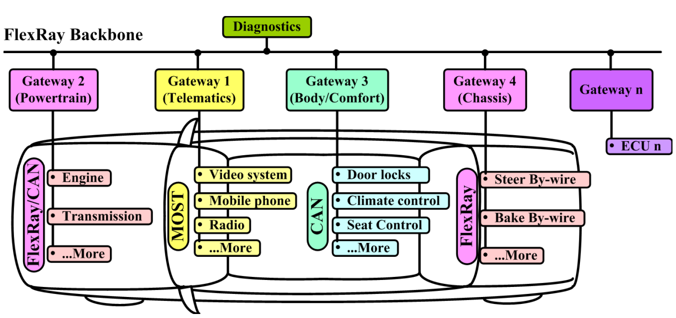


**Fig. 1. The feature of FlexRay when used (X-by-wire).**

In a vehicle, the wiring harness is the second heaviest component after the engine, providing power, control and communication to variety of modules. On the other hand, the in-vehicle PLC uses the DC power line network as the physical communication medium. There is only one channel (the vehicle DC power line) to carry out the FlexRay signals which can reduce the weight, volume and cost of the wiring harnesses. Therefore, we should modulate the signals of different FlexRay channels to higher frequency and different phases to prevent the effect of serious vehicle noise on the DC power line. Which means the quadrature amplitude modulation (QAM) scheme should be utilized in this design.

## II. Transceiver Design for FlexRay System

According to the FlexRay standards [3], two signals of the bus driver, denoted as BP (Bus Plus) and BM (Bus Minus), are used to convey bit information over a pair of twisted lines. BP and BM in fact are a pair of differential signals. The timing and amplitude characteristics of BP and BM required by the FlexRay standards are shown in Fig. 2. There are a total of four types of "Signals" in FlexRay systems, which are Data_1 Signal and Data_0 Signal in the Active State, and Idle_LP Signal, Idle Signal in the Idle State.

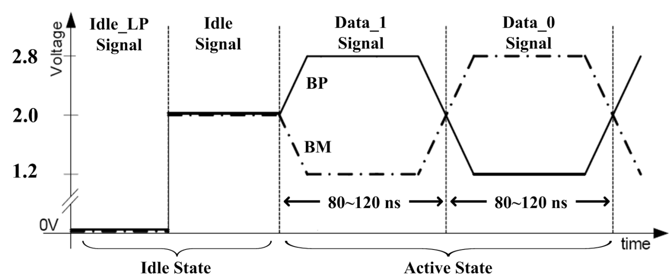


**Fig. 2. The characteristics of BP and BM.**

### *A. Design of the QAM constellation and mapping table*

There are four types of signals which can be transmitted in a FlexRay channel, and there are two channels in a FlexRay network system. In another words, there should be sixteen combination symbols transmitted in one moment. Therefore, a 16-QAM scheme is proposed in this transceiver design.

Fig. 3 shows the 16-QAM constellation of the proposed transceiver. In FlexRay standard, the important data should be transmitted thru two channels in the same time to guarantee the data correction. When channel 1 (Ch1) and channel 2 (Ch2) in a FlexRay system transmit the same data, which means it could be an important data in FlexRay system. Therefore, we arrange these kinds of data in the top-right corner (1111) and down-left cornet (1010) to prevent the effect of serious vehicle

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noise. When the signals of Idle State is transmitted (Idle, and Idle_LP), we arrange the middle area of the constellation to reduce the transition power of the proposed transceiver. Fig. 4 shows the 16-QAM mapping table for FlexRay system of the proposed transceiver design.

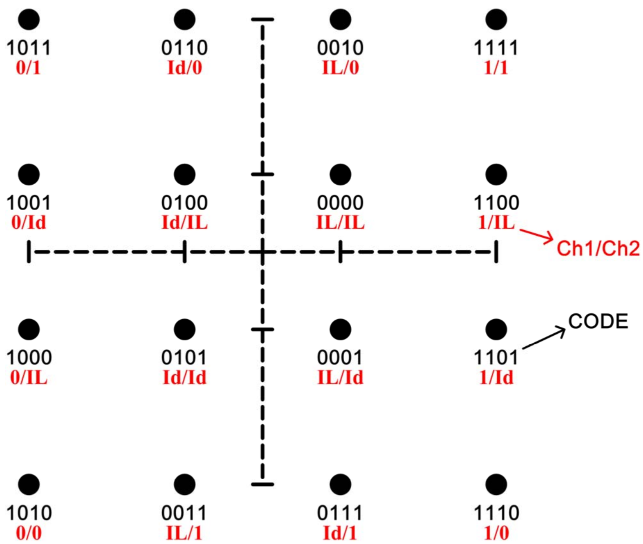


**Fig. 3. The proposed 16-QAM constellation.**

| Q | Q' | I | I' | Ch1 | Ch2 | 16-QAM | |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | IL | IL | 0.311V | 45° |
| 0 | 0 | 0 | 1 | IL | Id | 0.311V | -45° |
| 0 | 0 | 1 | 0 | IL | 0 | 0.850V | 75° |
| 0 | 0 | 1 | 1 | IL | 1 | 0.850V | -105° |
| 0 | 1 | 0 | 0 | Id | IL | 0.311V | 135° |
| 0 | 1 | 0 | 1 | Id | Id | 0.311V | -135° |
| 0 | 1 | 1 | 0 | Id | 0 | 0.850V | 105° |
| 0 | 1 | 1 | 1 | Id | 1 | 0.850V | -75° |
| 1 | 0 | 0 | 0 | 0 | IL | 0.850V | -165° |
| 1 | 0 | 0 | 1 | 0 | Id | 0.850V | 165° |
| 1 | 0 | 1 | 0 | 0 | 0 | 1.161V | -135° |
| 1 | 0 | 1 | 1 | 0 | 1 | 1.161V | 135° |
| 1 | 1 | 0 | 0 | 1 | IL | 0.850V | 15° |
| 1 | 1 | 0 | 1 | 1 | Id | 0.850V | -15° |
| 1 | 1 | 1 | 0 | 1 | 0 | 1.161V | -45° |
| 1 | 1 | 1 | 1 | 1 | 1 | 1.161V | 45° |

* Id = Idle, IL = Idle_LP

**Fig. 4. The 16-QAM mapping table of the proposed transceiver.**

### *B. Design of the transceiver*

Fig. 5 shows the block diagram of the proposed ECU nodes in a FlexRay-based PLC network system. The component of each node contains a host microcontroller (μC), a communication controller (CC), a bus guardian (BG) and a PLC transceiver. Traditionally, there should have two drivers in a FlexRay network system to drive the two different channels. In recent research, the noise on the DC power line in vehicles always appear in lower frequency because the mechanical actions. Therefore, the proposed PLC transceiver should modulate the original FlexRay signals from Communication Controller to higher frequency (over 70 MHz) to prevent the noise which come from other ECU nodes, engine, entertainment device, mechanical-electronic device, etc. on the vehicle DC power line.

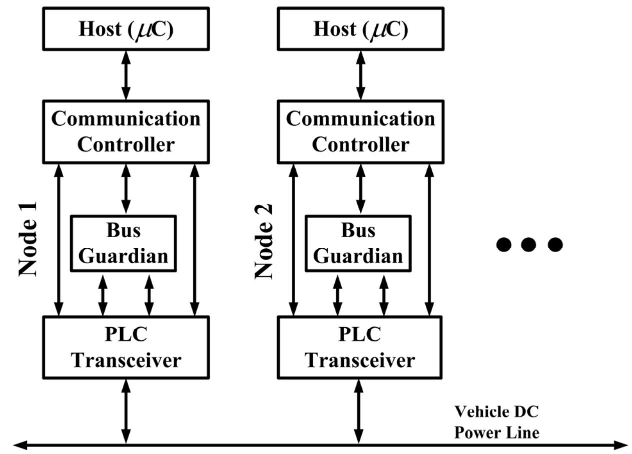


**Fig. 5. Block diagram of ECU nodes in a FlexRay-based PLC network system.**

## III. CONCLUSIONS

In this paper, in order to reduce the weight, volume and cost of the wiring harnesses in the vehicles, a PLC transceiver for in-vehicle power line in FlexRay-based system is presented. A 16-QAM constellation and mapping table are proposed in this paper which is more suitable for the original FlexRay network systems. The FlexRay-based PLC network will not immolate any data rate and high reliability of original FlexRay standard, but provide more choices when user want to reduce the weight or cost of the vehicle.

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