Vehicle Power Line Communication (VPLC) using SDR demonstrator

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Abstract—This paper deals with the implementation of a power line communication system for vehicle (VPLC) using ETTUS platforms combined with GNU Radio environment. This flexible platform allows many configurations of the PHY and MAC layers of the PLC system. They can be tested in a real PLC environment, indoor or in-vehicle. In conjunction with ETTUS USRPs platform and daughter cards, the signal processing performed in software is transmitted over a real channel. Several parameters and scenarios have been tested thanks to the different daughter cards without changing the signal processing.

Index Terms—Component, formatting, style, styling, insert.
(key words)

I. INTRODUCTION

Today the car manufacturers have to face with an increase of electronic nodes (ECU) connected each other. The ECUs already use networks like CAN and Flexray, but the number of specific wired always increase. One solution to reduce the amount of wires would be to use the PLC technology that is currently being developed for domestic networks to transmit information or at least some of it, over the 12V power distribution system found in cars. These solutions have been studied in [1], [2]. The proposed solutions are mostly based on the current standard Home Plug AV [3]. However, the in vehicle channels and indoor channels are different.

At the same time, Software-defined radio (SDR) has been defined to help the wireless operators to maximize their investments in multiple mobile standards and base stations. With such approach, many of the drawbacks involved with a classical approach (specify FPGA, DSP designs, RF designs) fall down as one can re-use sub-parts of an existing radio system, and just adapt its operation through code reprogramming. Similar approach can be adopted for wired communication, and more specifically for PLC communication, the radio link is in this case the wired PLC. The paper will present the proposed SDR PLC demonstrator.

II. ETTUS USRP2 PLATFORM FOR VEHICLE POWER LINE COMMUNICATION (VPLC)

In our VPLC system, the SDR approach can be considered to be a “wired” communication system, where some of its functional components, such as modulations, coding, synchronization, etc., are implemented in software. This makes it possible to configure the signal according to the requirements of the application and the characteristics of the communication channel. The software generated signal is then applied to the USRP platforms that are connected to a host computer through USB or Ethernet connections. A project that has investigated SDR and cognitive radio using USRP2 cards is presented in [4].

To help the designer, the GNU Radio Companion is a friendly environment for the development of baseband processing thanks to a set of pre-defined block sets, which enables to build a complete radio chain without developing specific code (most of the time). However, the MATLAB simulation tool can be used to generate the signal, allowing then comparison between simulations and real results over real channels.

Ettus Research Company provides the USRP hardware platform supporting any carrier frequency between DC and 4.4 GHz, for a bandwidth up to a few MHz depending on the board. Then RF to baseband conversion sub-system is ready for prototyping (except specific requirements in terms of transmitting power, depending on each application). Comparison between simulation and real environment can be performed using the same developed algorithms and tools. Our SDR VPLC system operates at the center frequency of 12.5 MHz and uses orthogonal frequency division modulation (OFDM/DMT) modulation for transmission. The performances over DC links are studied. During the tests, the parameters can be adjusted, such as FFT size, cyclic prefix duration, equalization, bit rate with a great efficiency. Fig. 1 illustrates the USRP2 board. We can observe the two ADC and DAC interfaced with the FPGA which makes the interface with the signal processing processor and the channel.

III. SDR DEMONSTRATOR ARCHITECTURE

The SDR demonstrator aims to produce the PLC signal without implementing all the hardware. It includes four parts: the upper layer data generator, the PHY layer signal generator, the supervisor and the analog interface. In Fig. 2, the supervisor will modify the system parameters according to the considered channel (plc, wired, wireless), the tested parameters (coding, fft size, cp length).
The supervisor configures the RF stage and transmits the signal from the GPP to the board. The parameters we can modify through the GNU Radio interface and supervisor are given in TABLE I.

For PLC, the widely used OFDM modulation is applied. The transmitted OFDM waveform can be expressed as:

$$ s(t) = \frac{1}{\sqrt{N_p}} \sum_{n=0}^{N_p-1} R_{\text{real}} \left\{ c_m \prod_{j=0}^{p-1} \left( e^{j 2 \pi j t / \Delta_{\text{OFDM}}} \right) \right\} $$  \hspace{1cm} (1)

With $N_p = M/2$, $M$ the FFT size, $c_m$ the complex symbol on sub-carrier $F_m$. The sub-carrier spacing $\Delta_{\text{OFDM}}$ is defined as $1/T_{\text{OFDM}}$ with $T_{\text{OFDM}}$ the OFDM symbol duration. The OFDM parameters are based on home network ones. The standards HPAV and HD-PLC are investigated for in-vehicle communication. Those standards have been applied in car to measure data throughput on DC channels [5].

The VPLC platform has been tested for PLC transmissions, both in indoor PLC (220V electrical power) and VPLC environments (12V DC power). Two USRP2 board are used, one for the transmitter and one for the receiver, allowing a point to point transmission. The two boards are externally synchronized.

Fig. 3 illustrates the transmitted signal we obtained over DC line.

IV. CONCLUSION

Using the SDR approach, we are able to test many PLC parameters, for indoor and vehicle environments. Different experimental measurements show the entire possibilities offered by this kind of rapid prototyping. In future work, the software waveform generation will be enhanced in order to perform test in real time.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Configurations</th>
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</thead>
<tbody>
<tr>
<td>N =4, I channel</td>
<td>real signal, bandwidth = 12.5 MHz</td>
</tr>
<tr>
<td>N=4, I&amp;Q complex channels</td>
<td>complex signal, bandwidth = 25 MHz, external I&amp;Q combination</td>
</tr>
<tr>
<td>N=4, I&amp;Q, two independent real channels</td>
<td>real signal, bandwidth = 12.5 MHz, two independent transmissions, multiple output</td>
</tr>
<tr>
<td>N=512, I channel</td>
<td>real signal, bandwidth = 195, 31 KHZ, for narrow bandwidth</td>
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ACKNOWLEDGMENT

This work has been carried out by the CIFAER project, initiated and supported by the ANR and by the French Premium Cars Competitiveness Cluster ID4car.

REFERENCES