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# Feasibility Analysis of a Commercial CAN-PLC Communication Interface over Aircraft DC Network

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## Abstract

Since first introduced by Robert Bosch GmbH in 1980s, the Controller Area Network (CAN) bus showed good success and capability of working reliably, even in harsh environments. Multiple other sectors were seduced by the CAN-bus achieved role and importance in automotive industry. For instance in avionics, Airbus first introduced it on the A318 and A340 for cabin ventilation system control [1], and this usage keeps on increasing, specially with the focus on reducing the harness mass and complexity. For the same purpose, the interest to employ Power Line Communication (PLC) technology for airborne application is gaining ground in the frame of the More Electric Aircraft (MEA) or even an All-Electric Aircraft (AEA) architectures. Combining both technologies can reach a higher impact on reducing the cabling weight, complexity and space allocation.

This paper explores a real-case context feasibility to implement CAN-bus protocol along with PLC technology over aircraft dc power line, with respect to CAN-bus aspects, PLC principals and aeronautic standard compliance. Comprehensive CAN-PLC tests and assessment were carried out, analysing latency, Bit-Error Rate (BER) and Electromagnetic Compatibility (EMC) in alignment with the RTCA DO-160G standard requirements.

## Keywords

*PLC, CAN-bus, QPSK Modems, Latency, Bit rate, BER, HDX (half-duplex), EMC Compliance, RTCA DO-160G.*

## I. INTRODUCTION

**T**HE CAN protocol has demonstrated its reliability and success particularly in challenging conditions, and its adoption within the aerospace industry continues to grow. Simultaneously, PLC technology remains a focal point of research and development, aiming to significantly reduce harness mass and complexity across various applications. Merging both technologies has the potential to significantly advance the MEA developments.

The feasibility of such an approach is investigated in this work, to evaluate the possibility of implementing a low latency highly reliable solution, that can transmit and collect deterministic high-speed CAN data transparently over the power line, while being compliant with the DO-160G aeronautic standards.

## II. PLC CHANNEL DESCRIPTION AND ANALYSIS

The channel under study, illustrated in Fig. 1, represents a point-to-point interconnection between a switched-mode power supply, termed as PDCM on one end, along with a remote-electronic unit (REU) on the opposite end. Both devices are connected with a 25 m long shielded twisted pair (STP) cable. Comprehensive characterization, modeling, and measurements of the PLC channel can be found in [2] and [3].

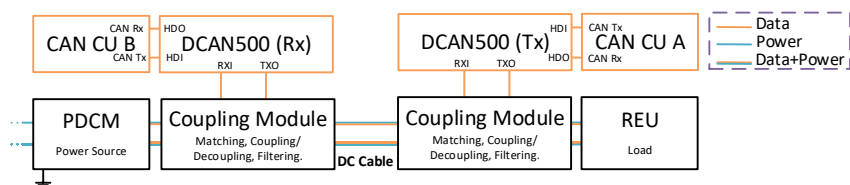


Fig. 1: CAN-PLC channel topology depicting the two-node network under investigation.

## III. CAN-PLC IMPLEMENTATION AND FUNCTIONAL TESTS

Prior efforts, as referenced in [4]- [7], have explored the potential of merging CAN and PLC, so they can coexist simultaneously. The suitable CAN-PLC interface needs to operate transparently to preserve the CAN protocol properties. As outlined in TABLE I, the majority of the already existing narrowband and broadband PLC modems come equipped with Universal Asynchronous Receiver Transmitter (UART) or a Serial Peripheral Interface (SPI) gateway feature. Yet, only a few variations of these commercially available PLC transceivers have a CAN protocol handling interface.

TABLE I: Overview of narrowband and broadband PLC modems

Product	Frequency range	Bit rate	Modulation scheme	Gateway functionality
STMicroelectronics ST7590	[9-95 kHz]	Up to 128 kbps	OFDM-PHY, HDX mode	UART SPI, I <sup>2</sup> C
Maxim Integrated MAX2982 ZENO™	[4.49-20.7 MHz]	Up to 14 Mbps	OFDM-PHY, HDX mode	UART SPI
Yamar Electronics DCB1M EVB	[5-30 MHz]	Up to 1.4 Mbps	QPSK HDX mode	UART SPI, I <sup>2</sup> C
Yamar Electronics DCAN500 EVB	[5-30 MHz]	Up to 1.4 Mbps	QPSK HDX mode	LIN CAN2.0A/B

The DCAN500 from YAMAR Electronics Ltd [7] [8], appears to be a fitting solution for the desired application, enabling transparent operation of the CAN protocol over the power line. Specifically, the findings presented in [4] highlight its encouraging performance in terms of CAN compatibility, preservation of message priorities, promising latency, throughput, and BER. Given this context, we employed two DCAN500 narrowband PLC modems, adopting single carrier quadrature phase-shift keying (QPSK) modulation scheme. These modems formed the basis of our CAN-PLC interface. Initial experiments were conducted using the setup in Fig. 1, aiming to gain a preliminary understanding of CAN's transparency over the power line, latency, reliability, and EMC compliance tests.

#### A. Latency and Throughput Measurement

For latency and bit rate measurement, a 19.4 MHz carrier frequency was chosen to transmit a CAN message with data-length code (DLC) of 7, which is equivalent to 115 overall bits.

The selected modems are meant to operate at 500 kbit/s, where the transmitted CAN message takes 536  $\mu$ s, which leads to 214.6 kbit/s bit rate. Fortunately, this latency can be improved. The used PLC modems can be compatible with 1 Mbit/s high-speed CAN, by configuring their internal registers as detailed in [8]. This adjustment brings down the time-delay subsequently to 339  $\mu$ s, as shown in Fig. 2 (a), boosting the bit rate to 339.2 kbit/s. Likewise, Fig. 2 (b) shows the modulated superimposed PLC signal over the power line dc voltage, during the CAN message transmission.

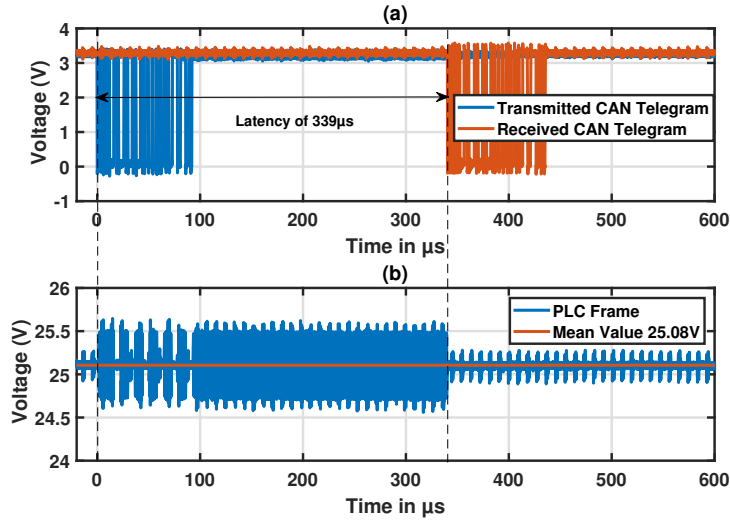


Fig. 2: Latency analysis for a 1 Mbit/s CAN message transmission over the power line. (a) Transmitted and received CAN telegrams, (b) Modulated equivalent PLC signal

#### B. BER Analysis

To identify the carrier frequencies with the highest level of fidelity, a BER sweep was done. This test allows a full BER analysis of the PLC channel, to get the data error rate for each carrier frequency. As illustrated in Fig. 3, the bandwidths with the lowest BER can be identified mainly between 13 MHz to 25 MHz, and from 27 MHz to 30 MHz.

#### C. External CAN CU-Based Analysis

In this part, an external CAN controller form Vector Informatik GmbH (VN1610) will be used as an external CAN controller unit (CU) along with the CANoe software. This replaces the pre-existing CAN CU in the DCAN500 evaluation-board (EVB).

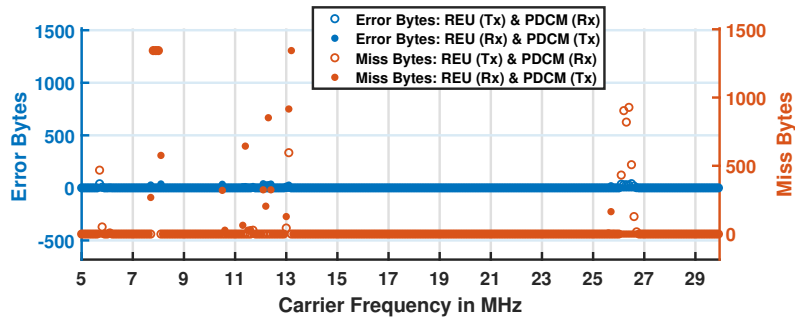


Fig. 3: Reliability analysis of the DCAN500.

This analysis allows us to operate the modems in a stand-alone mode, disconnected from their EVBs, and to validate a real-case scenario where the REU receives successive CAN messages to control an actuator. Fig. 4 depicts the test under investigation, where two consecutive CAN telegrams with 8 DLC were sent from the PDCM to the REU side in 1 Mbit/s operation mode.

The outcomes of transmitting these consecutive CAN telegrams are illustrated in Fig. 5, where  $42 \mu\text{s}$  dummy messages were produced by the modems to introduce an artificial delay. This is done to prevent the CAN CU from sending a second CAN message while the first one is still being transmitted. Notably, this delay message, carrying an ID of 0 and 0 DLC message, always wins the local arbitration between the modem and the CAN CU, particularly when the power line is still occupied. This method takes into account the PLC frame length and the brief interval between successive CAN messages, ensuring both the prevention of messages conflicts on the power line, and the protocol priority along with the bit-oriented framing mechanisms.

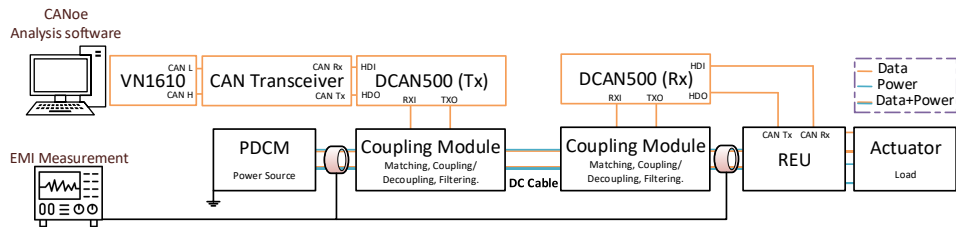


Fig. 4: Real-case scenario analysis using an external CAN controller with PLC-CAN modems.

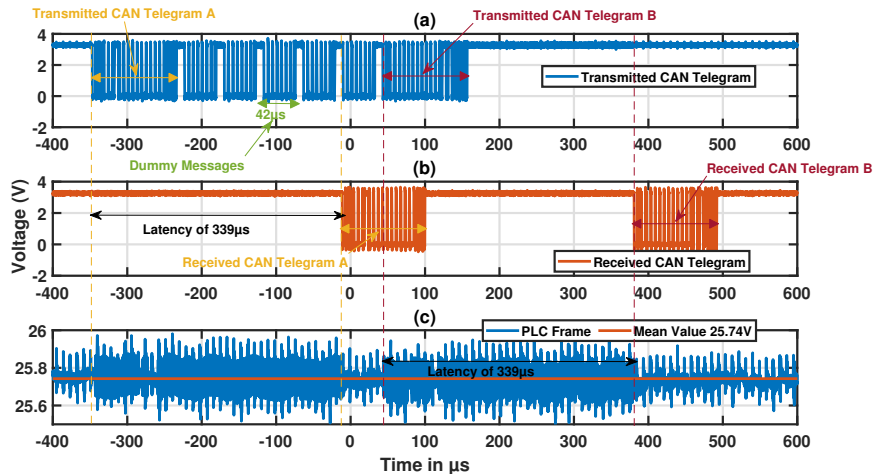


Fig. 5: Effects of transmitting consecutive CAN messages at 1 Mbit/s over the power line. (a) Transmitted CAN telegrams with the induced artificial delay, (b) Received CAN telegrams, (c) Modulated equivalent PLC frame over the power line.

#### IV. EMC PRE-COMPLIANCE ASSESSMENT

The EMC compliance measurements of the conducted emissions were made at both sides of the channel, when transmitting the CAN-PLC frames as differential mode (DM) signals from the PDCM side. Additionally, the noise floor was measured to

distinguish the dc-dc converter switching noise as illustrated in Fig. 6. Both switching noise level and data signal level exceed the 40 dB $\mu$ A of the standard limitation, which makes the investigated setup compliant with the *Cat B-interconnecting bundles*.

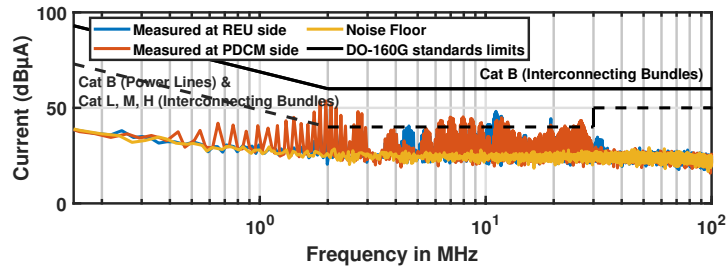


Fig. 6: Measurement of the common mode (CM) noise according to the DO-160G standard. Dashed black represents *Cat B-power lines & Cat L,M,H-interconnecting bundles* limits. Solid black indicates the *Cat B-interconnecting bundles* limits.

The data signal level appearing at the 19.4 MHz carrier frequency can be reduced below 40 dB $\mu$ A, when opting for 1 V<sub>pp</sub> data signal amplitude instead of 2 V<sub>pp</sub> as shown in Fig. 7.

For this assessment, a low-noise lab power supply is used to ensure that the solution aligns with the *Cat B-power lines* and *Cat L,M,H-interconnecting bundles*, regarding data signal level impact.

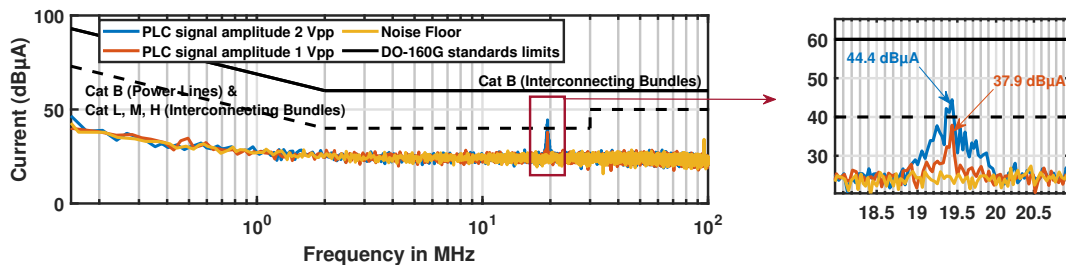


Fig. 7: DO-160G compliance with lower data signal amplitude over a low-noise power supply.

## V. CONCLUSION

This paper has investigated the feasibility to combine both CAN and PLC aspects for airborne use. The CAN-PLC solution was effectively implemented in a lab environment over a two-nodes network, operating at 1 Mbit/s with 339  $\mu$ s latency.

The introduced latency resulted from how CAN messages were packed into PLC frames, preserving the inherent properties of the CAN protocol. Transmitting consecutive CAN messages was possible with an extra artificial delay. This delay ensures the CAN controller doesn't begin transmitting a subsequent message until the preceding one has been fully transmitted.

In terms of EMC compliance with DO-160G, it was shown that this depends essentially on the power supply noise and the data signal level, which can be adjusted to certify the solution for more categories. Also with respect the BER, an analysis was conducted to identify the carrier frequencies with the highest reliability and fidelity level.

Further complementary work is required with a complex multi-node CAN-bus network involving multiple communication participants, to truly assess whether this solution is apt for real-world airborne scenarios. Additionally, an electronic-based alternative solution is currently being explored, to achieve a reduced latency and ensure CAN-PLC functionality.

## ACKNOWLEDGMENT

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