

EMC ASPECTS IN DC BUS POWER-LINE COMMUNICATIONS

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ABSTRACT

Direct-current (DC) power-line communications is a method of conveying information on an existing conductor ordinary used for supplying electric DC power. Using power line communications can eliminate the need for dedicated communication wiring thus saving space, reducing weight and installation costs as well as simplifying the maintenance of a system. In this technical contribution two front end circuits are presented and their susceptibility to interference is measured.

I. MOTIVATION

Direct-current (DC) power-line communications (PLC) is a method of sending information on an existing conductor ordinary used for supplying electric DC power. Using power line communications can eliminate the need for dedicated communication wiring thus saving space, reducing weight and installation costs as well as simplifying the maintenance of a system. These benefits are very much required for aerospace as well as for automotive applications. The work is done as part of European FP7 SCALETT project which targets new avionic architecture.

For providing a viable alternative to dedicated wires, the PLC modem needs to be very low cost to compete with copper costs and consequently, a low-complexity implementation of the modem is called for. Meeting EMC requirements is essential.

In this work we present modem architecture for power-line communication that addresses the above mentioned concerns and has good EMC properties.

II. DC-BUS PLC ARCHITECTURE

For minimizing emission one would generally employ a spectrally conservative signaling technique possibly accompanied by narrow-band filtering to optimize emission. Indeed, the proposed modem employs digital phase modulation, so it is the phase of the signal that actually carries the information and the carrier signal is of constant envelope. On top of being spectrally efficient, this modulation technique has been selected since it is inherently susceptible to various amplitude impairments.

A block diagram of the DC-BUS PLC modem (mainly physical layer) is depicted in Figure 1.

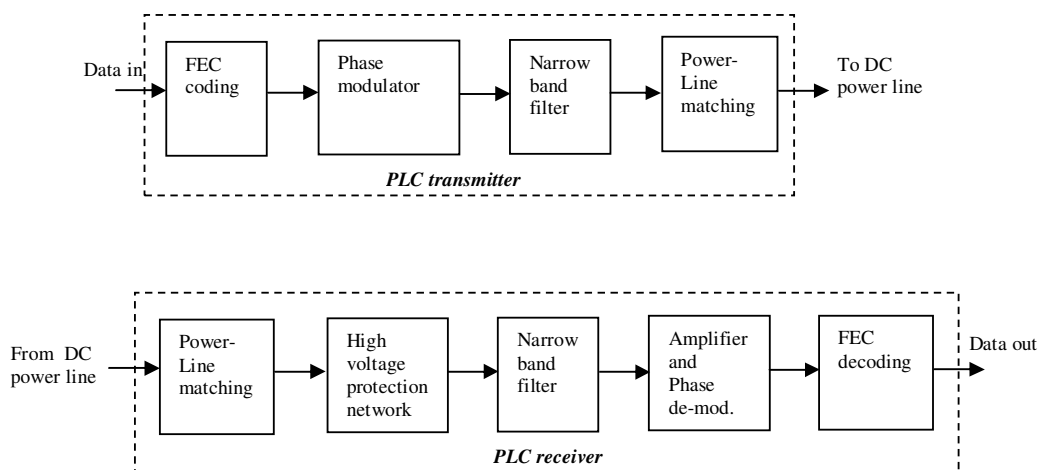


Figure 1. Transmitter-Receiver block diagram for DC-BUS PLC

Appropriate forward error correction (FEC) coding scheme is used in order to mitigate two problems: the first being errors caused by the noisy nature of the DC power line, which suffers from high-voltage bursts of random appearance times on the one hand and various periodic noises on the other hand; and the second being inter-symbol-interference caused by the fact that high data rates combined with narrow band filtering (and a low-cost receiver implementation) introduces controlled interference. It is obvious that the DC-BUS will be susceptible to in-band interference. Therefore, the modem has two operational frequency bands, and a built-in interference detection mechanism. When strong EMI field is detected in the operational band, frequency hopping occurs and the system switches to the other band.

Referring now to the receiver, for mitigating the potentially destructive effects of high voltage impulses (that can reach peak values of hundreds of volts), the receiver employs a protection network followed by a narrow band filter. Notably, to improve the modem susceptibility to radiated interference, and partially or conducted interference, the receiver employs an amplification stage that precedes the filter as described in the next section.

III. RECIEVER FRONT-END DESIGN FOR ENHANCED SUSCEPTABILITY PROPERTIES

This section presents and compares between two different front-end circuits used for DC power line communication. The first circuit is based on a simple single-transistor amplifier, while the other is somewhat more involved, employing an operational amplifier.

Figure 2 presents a simple and inexpensive front-end circuit employing a single-transistor amplifier. Both the transmitter and receiver paths are shown (desired path is selected by multiplexer U5). For the purpose of this section we shall only be interested in the receive path, **Rx Amplifier Q5**. The signal path begins at the left hand side of the figure, “DC Powerline”, U5 shows the proper connection for receiving, and the output is provided at the right hand side, the point “Amp-In”. Also shown on the right are the control/bias signals “Tx_On” and “RxOn” that activate either the receive or the transmit path.

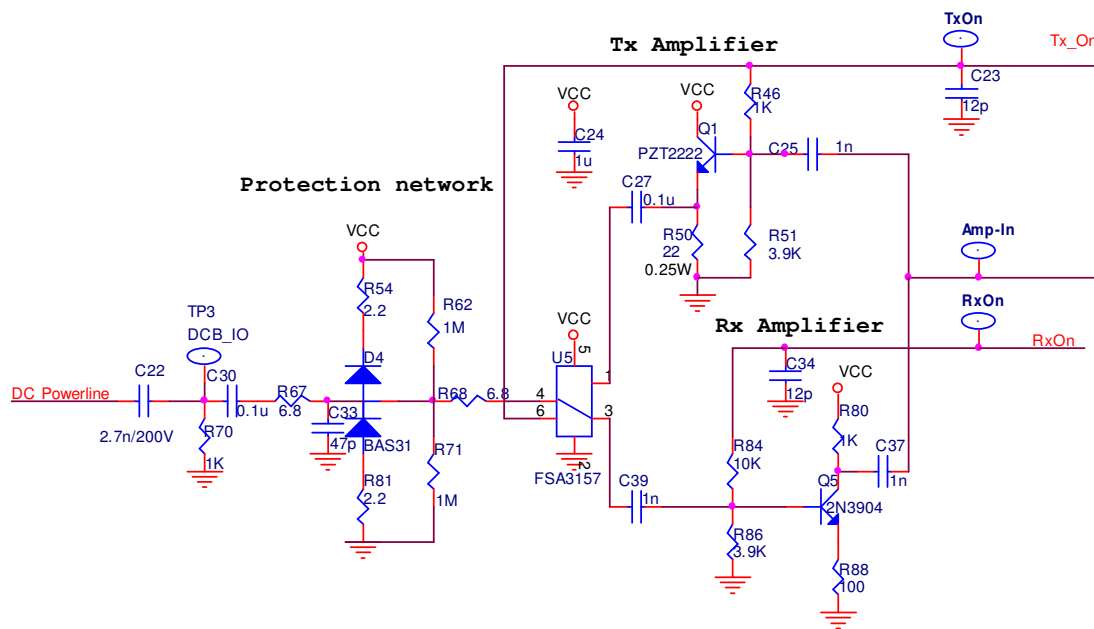


Figure 2. Single-transistor DC power line front-end

Figure 3 provides the schematics for a DC power line front end based an operational amplifier. Note that the source of the signal path (termed “DC_Line”) is shown here on the right hand side of the figure, hence the signal flows from right to left. Again, we shall be interested in the receive path whose amplification is provided by U3 (MAX4215).

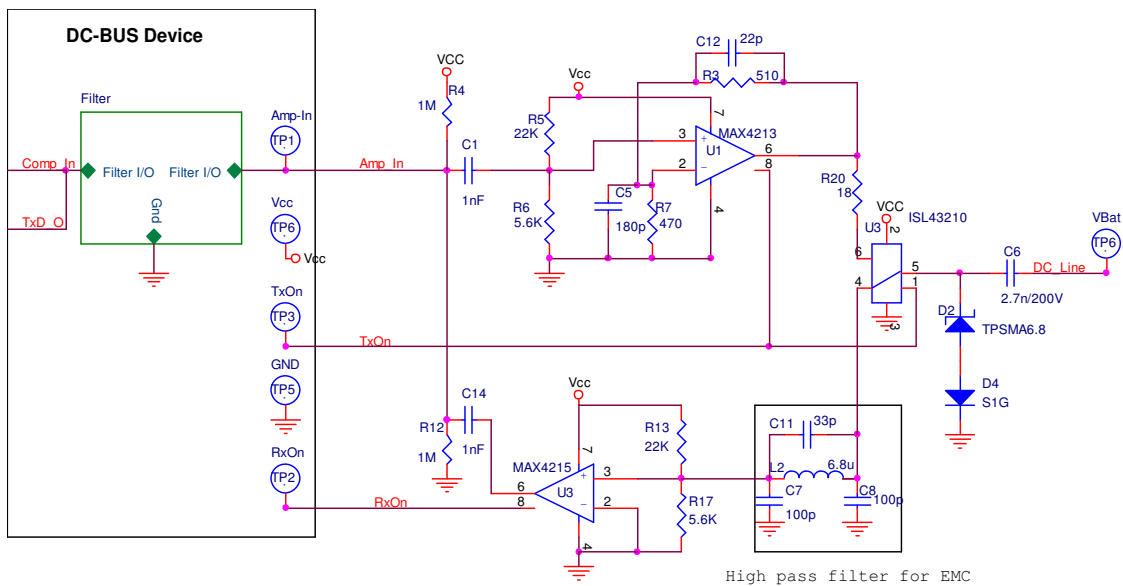


Figure 3. DC power line front-end based on Operational-amplifier

Nevertheless, a few words about the transmitted signal are in order. The DC-BUS device produces a square wave output signal which is then shaped by a band pass filter so as to limit the signal bandwidth and hence the out-of-band emission. The Tx. amplifier amplifies the signal by a factor of 2-3 to compensate for the filter attenuation. The output amplitude level is limited to 1-3V to minimize electro-magnetic radiation.

Back to the receiver, the differential amplifier in the receive path has a fixed amplification of the order of 2. Differential amplification (with respect to the DC ground terminal) combined with the preceding filter improves the receiver susceptibility to interfering signals. Note that the soft clipping approach, used in the circuit of Figure 2, is replaced here by a transient voltage suppressor (TVS), and a serial diode (whose sole purpose is to reduce the TVS capacitance).

IV. SUSCEPTIBILITY TESTS

The test setup is depicted in Figure 4. Communication over a DC power line was established between two PC's using DC-BUS evaluation boards (EVB). The carrier frequency was set to 5MHz and the data bit-rate to 470Kbps. The criterion used for measuring susceptibility was the level of interference resulting with communication interruption. Two different evaluation boards were used at the receiving side. DCB500 board employing the front-end circuit depicted in Figure 2 [2], and DCB1K board employing the circuit of Figure 3. An RF signal generator was used for generating a sinusoidal interference signal which was applied to the power lines by induction via a transformer as depicted in Figure 5.

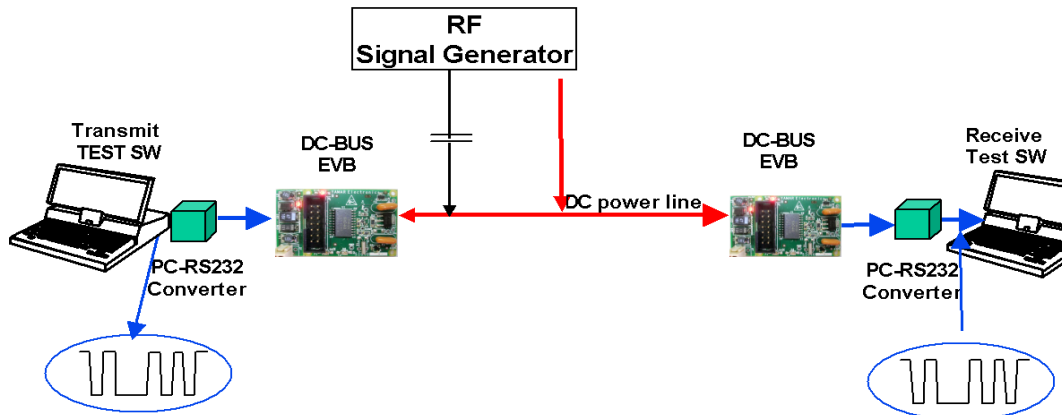


Figure 4. Direct injection of interfering signal

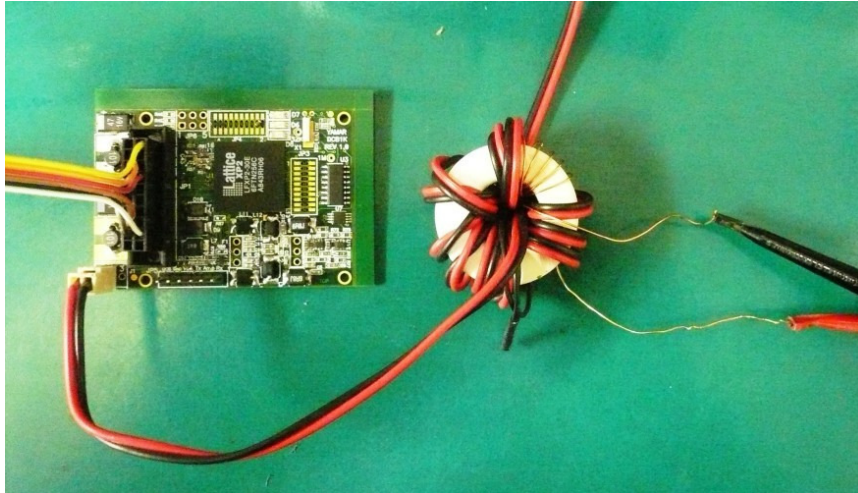


Figure 5. Induced interference test setup

The testing campaign whose results are depicted in Figure 6 was focused on susceptibility to conducted interference, as the behavior under radiated interference is quite similar. The conducted interference tests are performed by the induction of a calibrated current on the DC power lines. The figure presents the level of interference (relative to the signal level) as a function of the interference frequency. Notably, aviation wire harness is typically based on unshielded twisted pair, while in the automotive industry it is usually untwisted, unshielded wire pairs.

It is noteworthy that companies and different bodies often use their own EMC specifications, not fully compliant with known standards. The EMC measurements we report basically follow the guidelines laid down by the international special committee on radio interference [1].

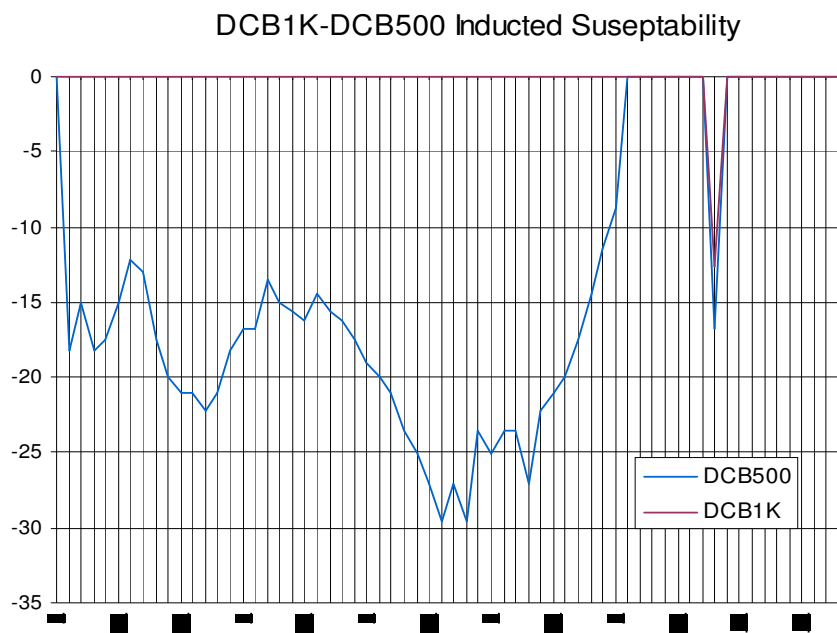


Figure 6. Conducted interference

V. CONCLUSION

A front-end based on differential amplifiers improves significantly the susceptibility performance when interference is induced on the power line by a transformer.

Since the circuit of Figure 2 does not employ a differential front-end, the susceptibility in the vicinity of the carrier frequency of 5MHz, is degraded. Recall, however, that both DCB500 and DCB1K employ a frequency hopping mechanism that allows detection of interfering signals and switching to another carrier frequency when interference is detected.

REFERENCES

- [1] *"Limits and methods of measurement of radio disturbance characteristics for the protection of receivers used on board vehicles,"* International Electromechanical Commission, international special committee on radio interference, CISPR 25:1995.
- [2] "DCB500 data sheet" - Yamar Electronics Ltd.