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*Evaluation of the noise effects on
Visible Light Communications using
Manchester and Miller coding*

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Introduction to VLC

- Visible Light Communications (VLC) represents the usage of LEDs for both illumination and wireless data transmission;
- IEEE 802.15.7 draft standard (2011);
- World-wide unregulated, almost unlimited spectrum;
- High data rates (3 Gbps - 2014);
- Safe for the human body and for electronic equipment (unlike RF or IR);
- Omnipresent technology with reduced implementation cost;
- VLC in the Intelligent Transportation System (ITS).

VLC in the ITS

- I2V & V2V have the potential to address up to 81% of the traffic accidents.
- VLC is an alternative and/or a complement to RF based communication in several scenarios (e.g. high traffic densities lead to increased latencies, unacceptable for a reliable safety system).
- VLC could reduce the load on the RF channels;

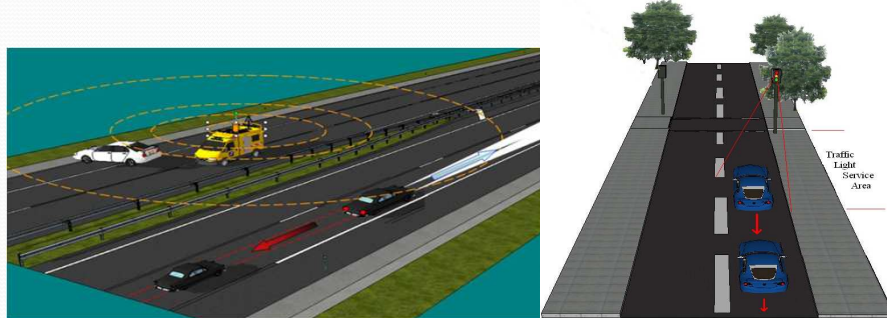


Fig. 1 – Scenarios for VLC usage in the ITS

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VLC modulations and coding

- Intensity Modulation with Direct Detection;
- IEEE 802.15.7 specifies for outdoor application (PHY I) the usage of OOK or VPPM;
- OOK with Manchester coding (11.67 – 100 kbps);
- Miller code seems better suited for MIMO applications (Fig. 2);

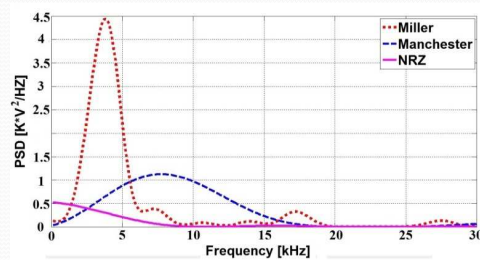


Fig. 2 – PSD for NRZ, Manchester and Miller code at 11.67 kHz

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Proposed VLC architecture

- VLC performances are strongly influenced by the communication channel (Fig. 3);
- Signal Independent White Gaussian Noise;

$$Y(t) = RX(t) \otimes h(t) + N_{Total}(t) \quad (1)$$

$$N_{Total} = \sqrt{N_{shot}^2 + N_{thermal}^2} \quad (2)$$

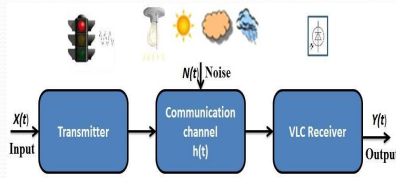


Fig. 3 – Simplified VLC channel model.

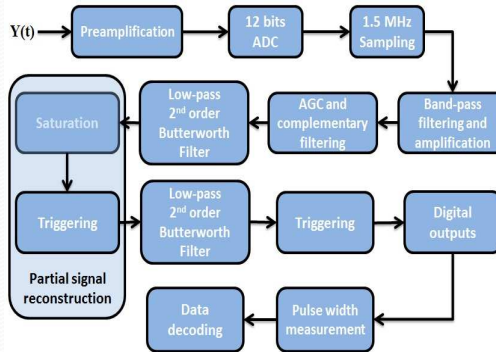


Fig. 4 – VLC receiver architecture model.

Simulation results – pulse distortions

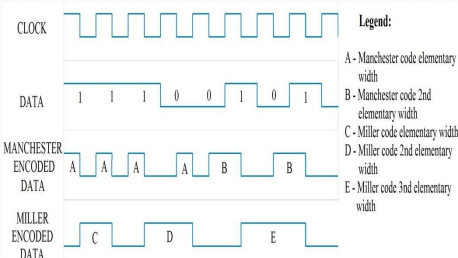


Fig. 5 – Possible pulse widths

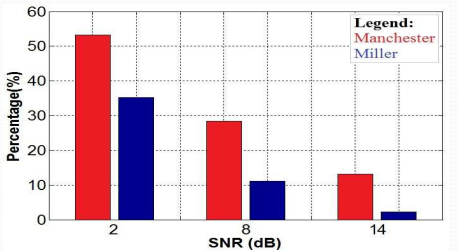


Fig. 6 – Pulse widths with distortion > 5%

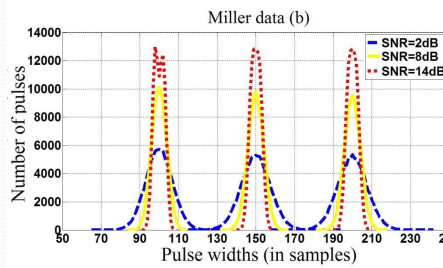
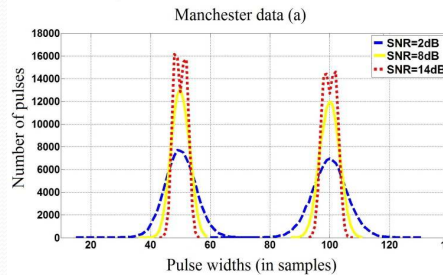


Fig. 7 – Pulse widths

BER Simulation results

- A digital data frame has been defined (Fig. 8);
- The BER performances of the VLC link are evaluated;



Fig. 8 – Structure of the data frame

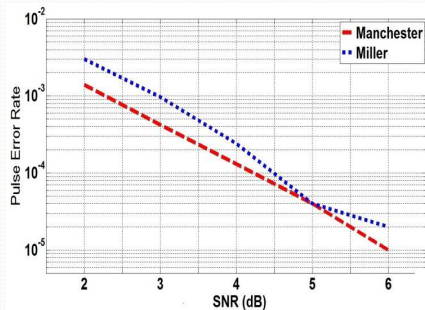


Fig. 9 – Pulse Error Ratio

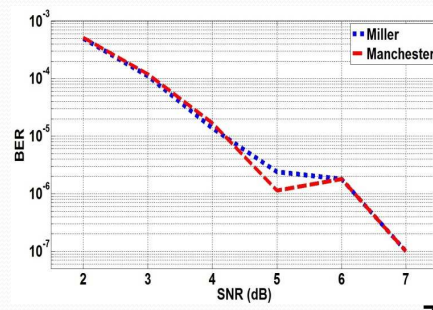


Fig. 10 – Bit Error Ratio

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Experimental Results

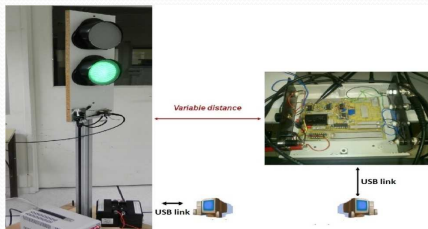


Fig. 11 – Hardware VLC system

- The similar performances of the two codes are experimentally confirmed;
- Analogic signal reconstruction;

Table I – Results at a 15 kHz modulation frequency

Emitter-Receiver Distance	Data coding	BER	Testing conditions
1 – 50 m	Manchester Miller	$<10^{-7}$	Outdoor with daylight
1-20 m	Manchester Miller	$<10^{-7}$	Indoor with artificial light

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Conclusions

- A VLC receiver architecture was proposed;
- An analysis over the noise effect on Manchester/Miller coded VLC signals was performed;
- The manner in which the noise affects the BER;
- The two codes had similar BER results;
- Since the Manchester and the Miller codes are similar in BER performances, but the latter has better channel usage, we can state that the Manchester code is adequate for single channel communications, whereas the Miller code is better suited for MIMO applications.
- As future work, we plan to improve the proposed receiver architecture, to implement it on a hardware DSP system and to test it in real conditions.

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Evaluation of the noise effects on Visible Light Communications using Manchester and Miller coding

Thank you!

Questions?

- Acknowledgement - This work was supported in part by the University of Versailles Saint-Quentin and Valeo Industry. A part of the financial support is granted by the Fond Unique Interministeriel (FUI) project named Co-Drive, supported by the Pôle de Compétitivité Mov'eo. Alin-Mihai Cailean was supported by the project "Sustainable performance in doctoral and post-doctoral research PERFORM - Contract no. POSDRU/159/1.5/S/138963", project co-funded from European Social Fund through Sectorial Operational Program Human Resources 2007-2013.

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