

Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Use of scrambler and FEC for VLC]

Date Submitted: [28 October, 2009]

Source: [Sridhar Rajagopal, Shadi Abu-Surra, Eran Pisek] Company [Samsung Electronics]

Address [1301 E. Lookout Drive, Richardson, TX 75082, USA]

Voice:[1-972-761-7748], FAX: [1-972-761-7909], E-Mail:[srajagop@sta.samsung.com]

Re: []

Abstract: [The use of a scrambler and FEC for VLC PHY is proposed.]

Purpose: [Contribution to IEEE 802.15.7 VLC TG]

Notice: This document has been prepared to assist the IEEE P802.15. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.

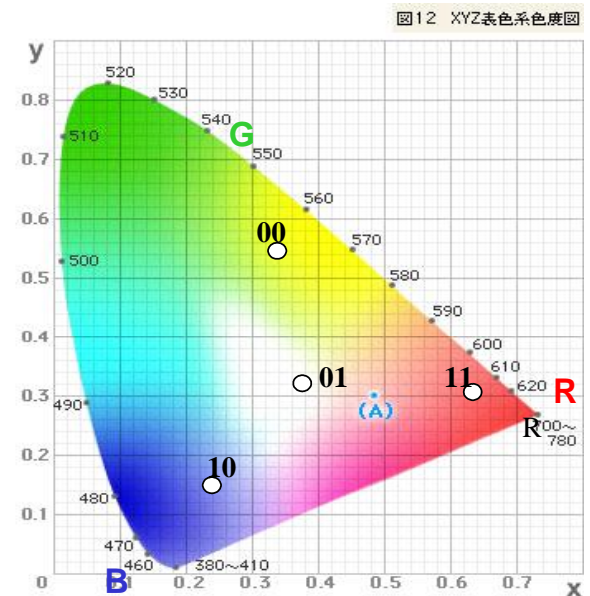
Release: The contributor acknowledges and accepts that this contribution becomes the property of IEEE and may be made publicly available by P802.15.

Motivation (1)

- **FEC:**
 - Robustness is very important for success of VLC
 - VLC link needs to function reliably in the presence of interference (ISI, other VLC networks, natural and artificial light sources) and inaccurate pointing alignment
 - Simple FECs, even with hard decisions, can provide 2-3 dB of coding gain at expense of minor reduction in throughput at very low complexity

Motivation (2)

- Scrambler
 - Many proposed modulation schemes cannot use line coding (CCM, HHW)
 - However, the data still needs to be randomized.
 - CCM : provide color balancing
 - (Example: 1111... will be always RED in figure)
 - HHW : to provide illumination (increased brightness)



Scrambler vs. line codes

Source : Wikipedia

- Scrambler replaces sequences into other sequences without removing undesirable sequences, and as a result it changes the probability of occurrence of vexatious sequences. Clearly it is not foolproof as there are input sequences that yield all-zeros, all-ones, or other undesirable periodic output sequences.
- A scrambler is therefore not a good substitute for a line code, which, through a coding step, removes unwanted sequences

However

- We believe scrambler is a viable substitute for cases, where line coding is not possible.
- Having an occasional run length excess will not have significant impact on performance
- Scrambler has additional benefit that there is no loss in throughput due to the line code.
 - can improve throughput by 20% over 8b10b
- The cost of scrambler is insignificant (XOR gates, D-Flipflops)
- Bit-insertion (bit stuffing) is an alternative approach that can be used along with a scrambler to guarantee run length
 - Adds a bit of opposite polarity if string of '0's or '1's is attained
 - Used in USB and HDLC
 - Disadvantage is a dynamic payload size

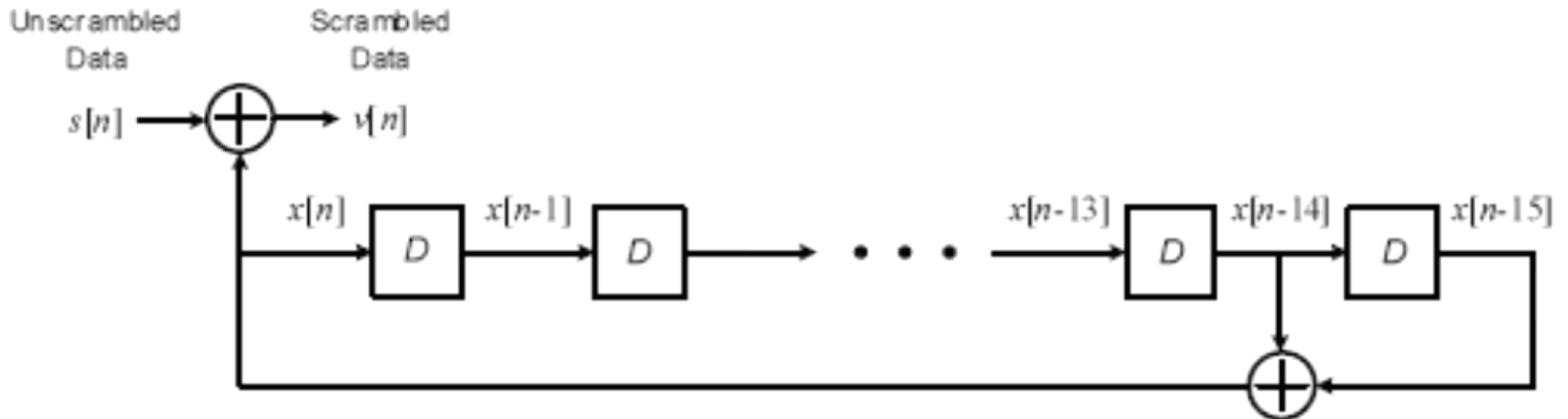
Proposed scrambler for evaluation

- The polynomial generator, $g(D)$, for the *pseudo-random binary sequence (PRBS) generator* shall be: $g(D) = 1 + D^{14} + D^{15}$, where D is a *single bit delay element*.
- *Using this generator polynomial, the corresponding PRBS, $x[n]$, is generated as $x[n] = x[n - 14] \oplus x[n - 15]$, $n = 0, 1, 2, \dots$ where “ \oplus ” denotes modulo-2 addition.*
- Used in ECMA-368 (UWB standard)
- We welcome suggestions for alternative scramblers

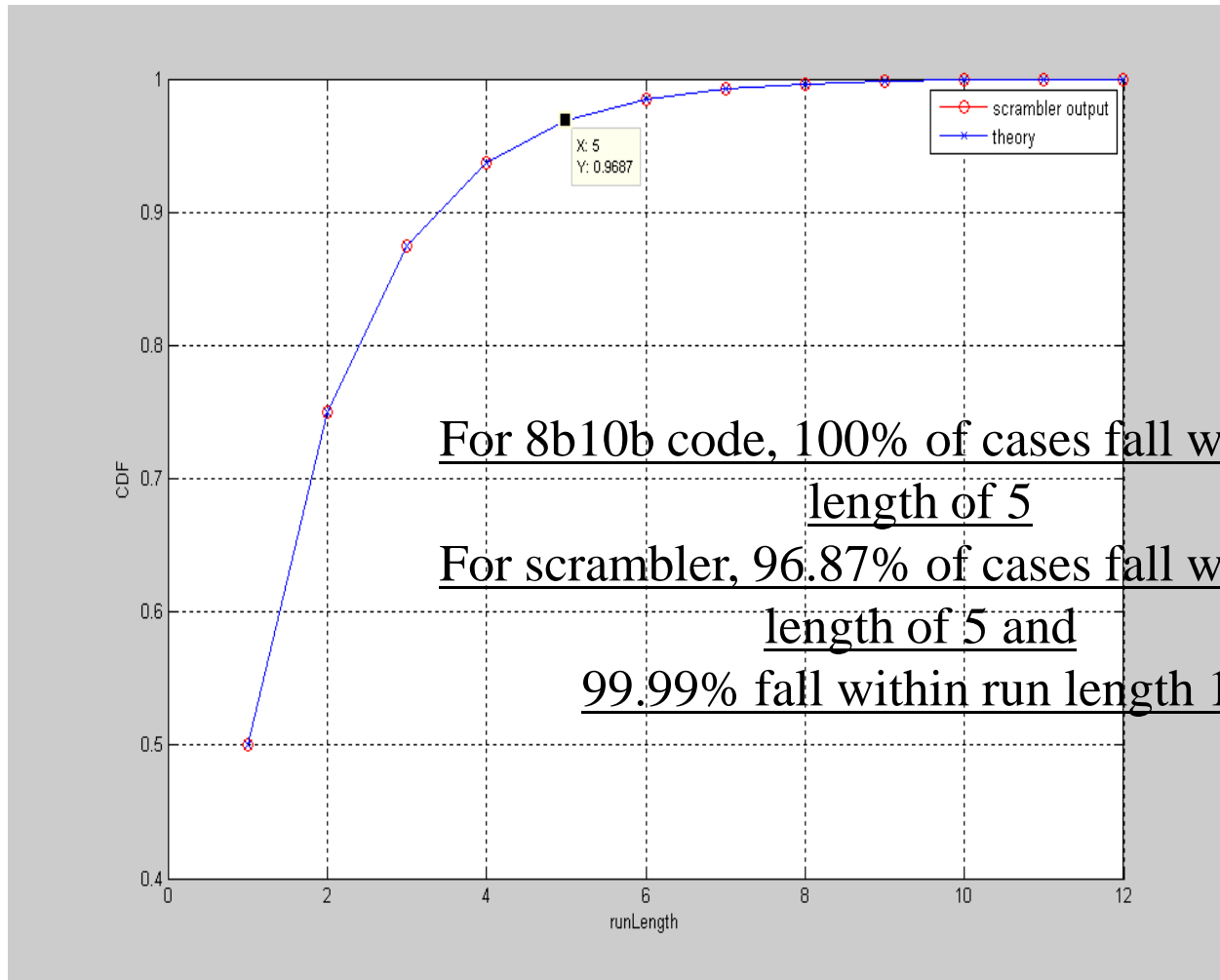
Very simple implementation

2 XOR gates and 15 D-flipflops

Can be reused for receiver descrambling



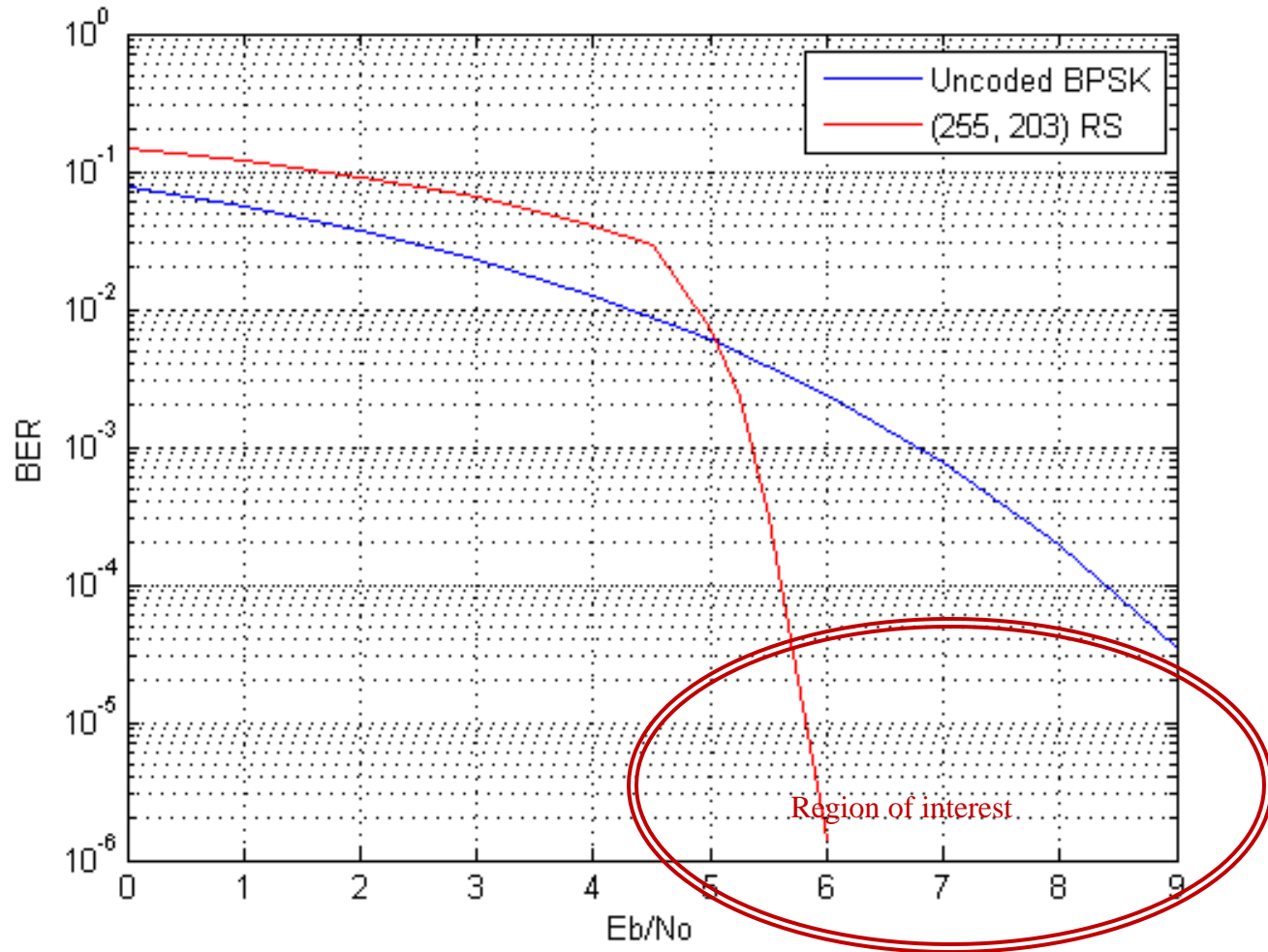
Impact of scrambler on runlength



Performance gains with FEC

- Gains of 2 - 3 dB can be expected for rate 4/5 code with RS or convolutional type of codes
 - Assuming HARD decision decoding
 - No ADC requirement at receiver
 - Further performance gains possible with soft decoding (if ADC is available for CCM etc.)
- RS codes are better for burst errors, esp. with 8b10b type of codes, where byte errors can occur

Results : RS (255, 203) : rate 4/5



Summary

- Recommend using FEC for VLC
 - Robustness
 - Interference tolerance
- Recommend using scrambler for VLC
 - Useful for modes where line coding is not possible or difficult to attain
 - Useful for higher throughput at expense of non-guaranteed run length