Proposed Comment Resolution for CID # 187 (MR-O-QPSK PHY)

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Title:	Proposed Comment Resolution for CID # 187 (MR-O-QPSK PHY)
Date Submitted:	September 19, 2011
Source:	Michael Schmidt - Atmel (email: michael.schmidt@atmel.com)
Re:	Task Group 15.4g sponsor ballot comment resolution
Abstract:	Proposed comment resolution for CID #187 (MR-O-QPSK PHY)
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CID 187

Comment:

The commenter states: "O-QPSK has two modes: Minimum FSK and Offset QPSK using raised-cosine pulse shaping. Usually, root-raised cosine pulse shaping is used for reducing ISI. Using raised-cosine instead of root-raised cosine can worsen ISI. Also, it is unclear how differential detection can be used for offset-QPSK, where the phase changes half-way through any symbol duration. Either coherent or non-coherent detection is possible for Minimum FSK."

The commenter proposes the following:

"Use the root-raised cosine (RCS) pulse shaping instead of the raised cosine. Check the feasibility of differential QPSK in the context of offset QPSK. If it is not feasible, suggest/mandate the use of coherent demodulation for the RCS based offset-QPSK."

Response:

Reject. No change required.

Cont. CID 187

Response:

- It is well-known, that a raised-cosine impulse is a so called Nyquist-impulse. Any Nyquist-impulse g_T meets the first Nyquist criteria with respect to the symbol time parameter $T \in \mathbb{R}$:

$$g_T(kT) = 0 \text{ for } k \in \mathbb{Z} - \{0\} \text{ and } t \in \mathbb{R} \qquad (1)$$

- Hence, there is no inter symbol interference (ISI) caused by a raised cosine impulse.

Cont. CID 187

- A root-raised cosine impulse is a so called $\sqrt{\text{Nyquist}}$-impulse. For a $\sqrt{\text{Nyquist}}$-impulse g_T, equation (1) is not necessarily met, i.e. there is usually ISI. However, equation (1) is met for the auto-correlation function of g_T. This reflects the overall impulse response in conjunction with optimal receive filtering matched to g_T.
- In TG4g, the receive filter is left unspecified. In the context of the transmitter accuracy specification (EVM) it is, therefore, reasonable to specify a transmit Nyquist-impulse rather than a $\sqrt{\text{Nyquist}}$-impulse.
- Note that a raised-cosine filter is also used for the O-QPSK PHY operating at the 780 MHz band and the BPSK PHY operating in the 868 MHz and 915 MHz band according to Std IEEE 802.15.4-2011.

Cont. CID 187

- There is no Minimum FSK mode specified for the MR-O-QPSK PHY. What is specified is O-QPSK with either half-sine shaping (915 MHz and 2450 MHz band) and raised-cosine shaping (470 MHz, 868 MHz, 780 MHz, 917 MHz, and 950 MHz band).
- O-QPSK with half-sine shaping is similar to an MSK signal but it is not equivalent (see Appendix).

Cont. CID 187

- Regardless of the shaping impulse used, non-coherent differential demodulation is not always applicable to an O-QPSK signal sequence.
- In conjunction with code spreading, a differential demodulation is feasible in some cases by decorrelating against a transformed code set of the spreading code words. This strongly depends on the code set used for bit-to-chip mapping. However, it is not recommended or a target of the MR-O-QPSK PHY to perform differential demodulation at the chip level, due to noise enhancement and /or multi-path enhancement.
- For $(N, 1)$-DSSS with $N > 1$, bit-differential encoding (BDE) is introduced at the bit-level (rather than at the chip level) in order to support differential demodulation after de-spreading.

Appendix

For a continuous phase signal with modulation index h

$$x(t) = \exp\left[j\pi h \sum_{k=0}^{\infty} \alpha(k) q(t - kT)\right] \quad \text{with } \alpha(k) \in \{-1, 1\}$$

the well-known approximation

$$\hat{x}(t) = \sum_{k=0}^{\infty} \exp\left[j\pi h \sum_{\ell=0}^{k} \alpha(\ell)\right] c_0(t - kT)$$

delivers a linear model for x, which is based on the main Laurent-impulse c_0. For $h = 1/2$ this simplifies to

$$\hat{x}(t) = \sum_{k} j^k \beta(k) c_0(t - kT)$$

with

$$\beta(k) = \beta(k-1)\alpha(k) \tag{2}$$

Cont. Appendix

- Equation (2) shows that an MSK signal obtains a recursive part on the data (chip) stream, whereas an O-QPSK signal (as specified in IEEE P802.15.4g/D5, page 114 line 51) does not[1].
- Equation (2) also reflects some difference on the nature of the signal. An MSK signal obtains a (chip) differential encoder and consequently implicitly supports (chip) differential demodulation.
- For the MR-O-QPSK PHY a differential encoder is deliberately introduced by BDE in conjunction with $(N, 1)$-DSSS. However, it is introduced at the bit level rather than at the chip level in order to exploit the processing gain.

[1] In order to apply an MSK (direct) modulator for O-QPSK transmission with half-sine shaping, the recursive part must be removed by pre-coding the data (chip) sequence.