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

Submission Title: [Resolution to CID 408 of LB 87]

Date Submitted: [March 2013]

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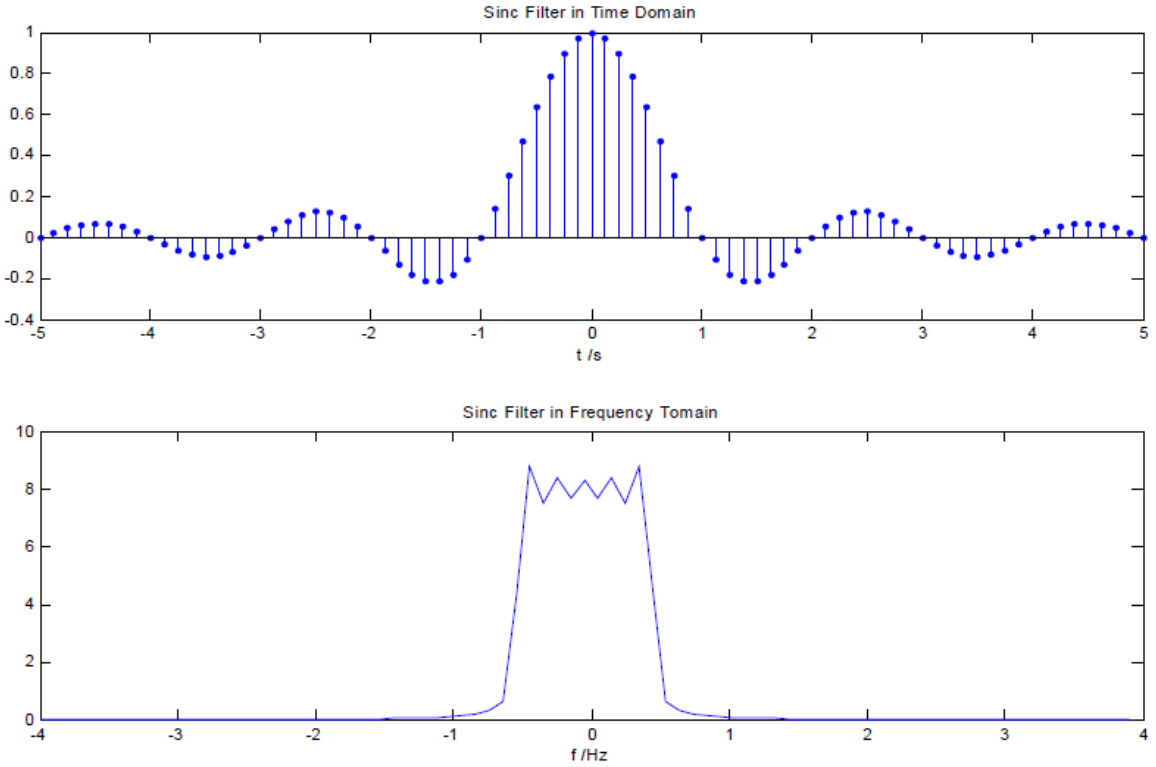
Re: [Proposed resolution to CID 408 of LB 87]

Abstract: [This document identifies filter characteristics for improved performance]

Purpose: [This document identifies filter characteristics for improved performance in TG4m.]

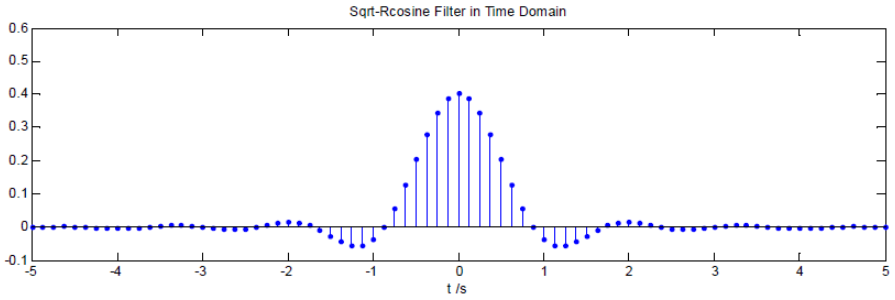
Idealized Square Filter

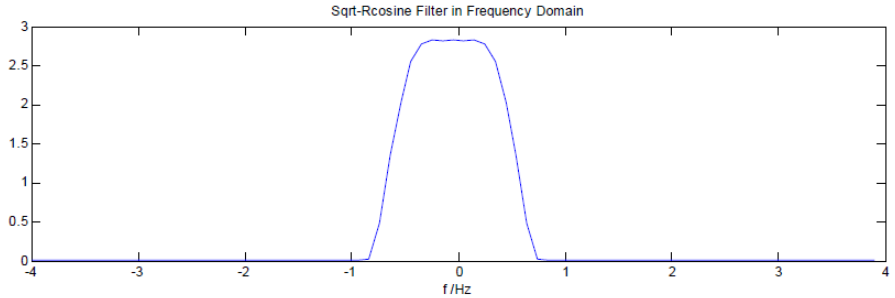
Sinc Filter in time and frequency domain

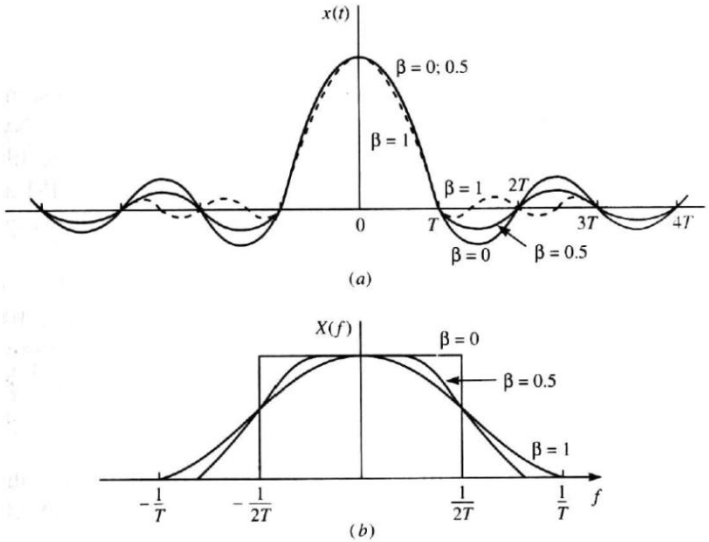


RRCF and RCF Filters

Square root Cosine Filter in time and frequency domain







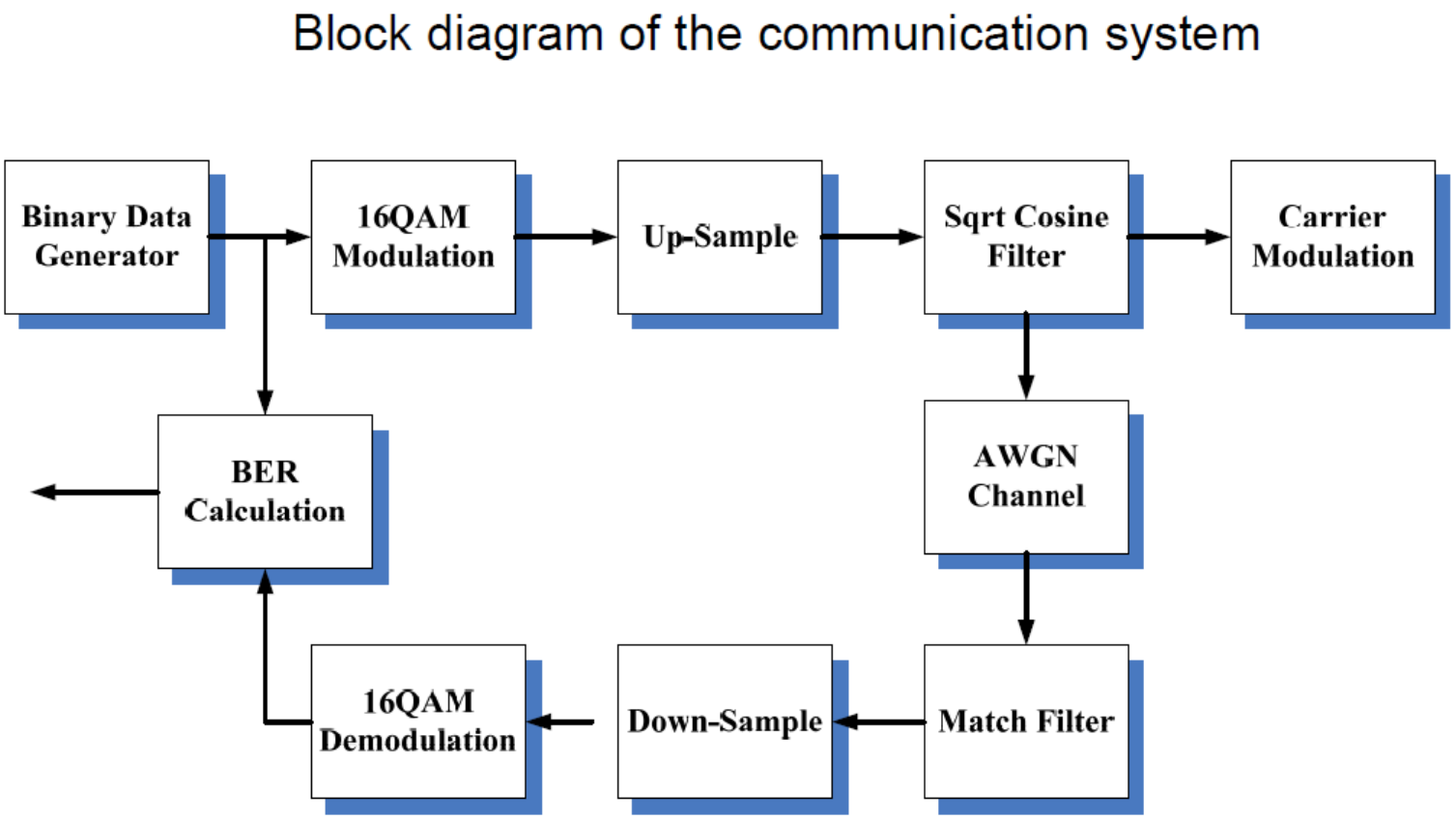
Pulses having a raised cosine spectrum.

Sqrt_Cosine_Filter

$$h(t) = 4R \frac{\cos((1+R)\pi t/T) + \dfrac{\sin((1-R)\pi t/T)}{4R\dfrac{t}{T}}}{\pi\sqrt{T}(1-(4Rt/T)^2)}$$

$$h(t) = \operatorname{sinc}\left(\frac{t}{T}\right) \frac{\cos\left(\frac{\pi\beta t}{T}\right)}{1 - \frac{4\beta^2 t^2}{T^2}},$$

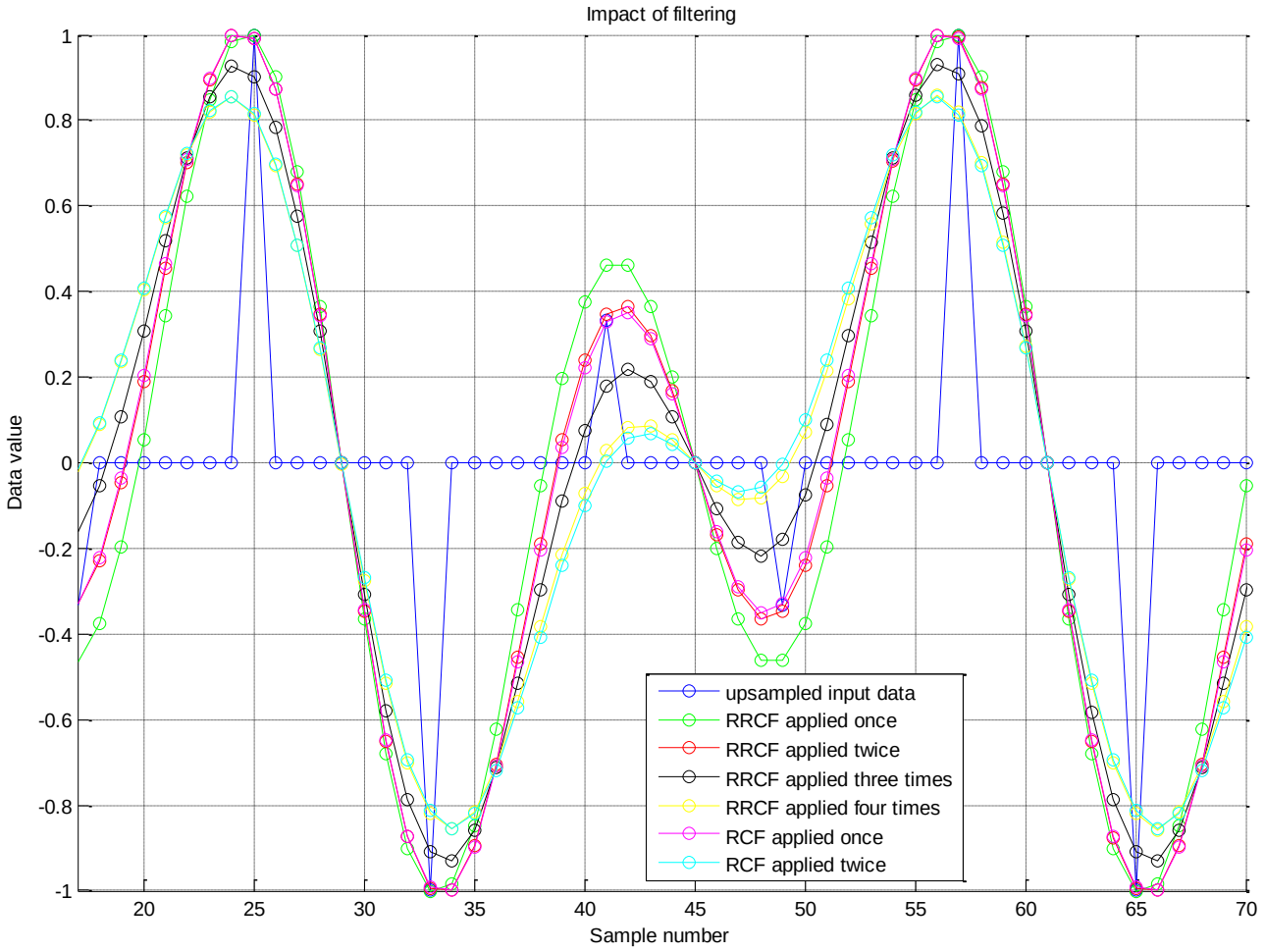
A Simulation Scenario



Simulation Details

- Input signal is a random sequence of length 10^4, modulated to 16-QAM.
- Input signal up-sampled at rate Fs = 8.
- Up-sampled signal passed through different combinations of cascaded filters:
  - Root Raise Cosine Filters (RRCF) and/or
  - Raised Cosine Filters (RCF)
  - Filters at TX and RX do not necessarily match
- Filter parameters:
  - Roll-off factor = 0.5
  - Delay: 3-5
- Filter scenario identified by the number and type of cascaded filters.

Results for Different Filtering Scenarios



Quantifying Results

- Let Fd = Filtered signal, down-sampled
- Compute D = (Fd – X)/X where X = input signal before up-sampling
- Error = standard deviation(D)* 100

Scenario	RRCF Once	RRCF Twice	RRCF Three	RRCF Four	RCF Once	RCF Twice
Error %	18	0.8	11	19	0.0	19

Best results!

Results for Binary Modulation

- Same trend observed

Scenario	RRCF Once	RRCF Twice	RRCF Three	RRCF Four	RCF Once	RCF Twice
Error %	11	0.5	7.0	12	0.0	12

Best results!

Analysis Results

- Performance sensitive to filter combination types.
- A Raised Cosine Filter or two cascaded Root Raised Cosine Filter implementations essentially exhibit Nyquist properties.
- Other filter combinations lead to ISI, e.g.:
  - A single Root Raised Cosine Filter
  - Two Raised Cosine Filters
  - A Raised Cosine Filter cascaded with a Root Raised Cosine Filter
- As shown previously, some filtering at RX required, e.g. for noise limiting purposes.
- Thus, two cascaded Root Raised Cosine Filters should be used, one at the TX and another at RX respectively.

Draft Recommendations

- Change paragraph in 20.2.4.2 to:
  - “Pulse shaping shall be applied at the transmitter using a filter equivalent to the Root Raised Cosine filter. The parameters of the filter shall be as needed to meet regulatory requirements in the band of operation. It is recommended that the receiver also use a filter equivalent to the Root Raise Cosine filter”.

References

- Yupin Zao: “Simulation of 16QAM systems”