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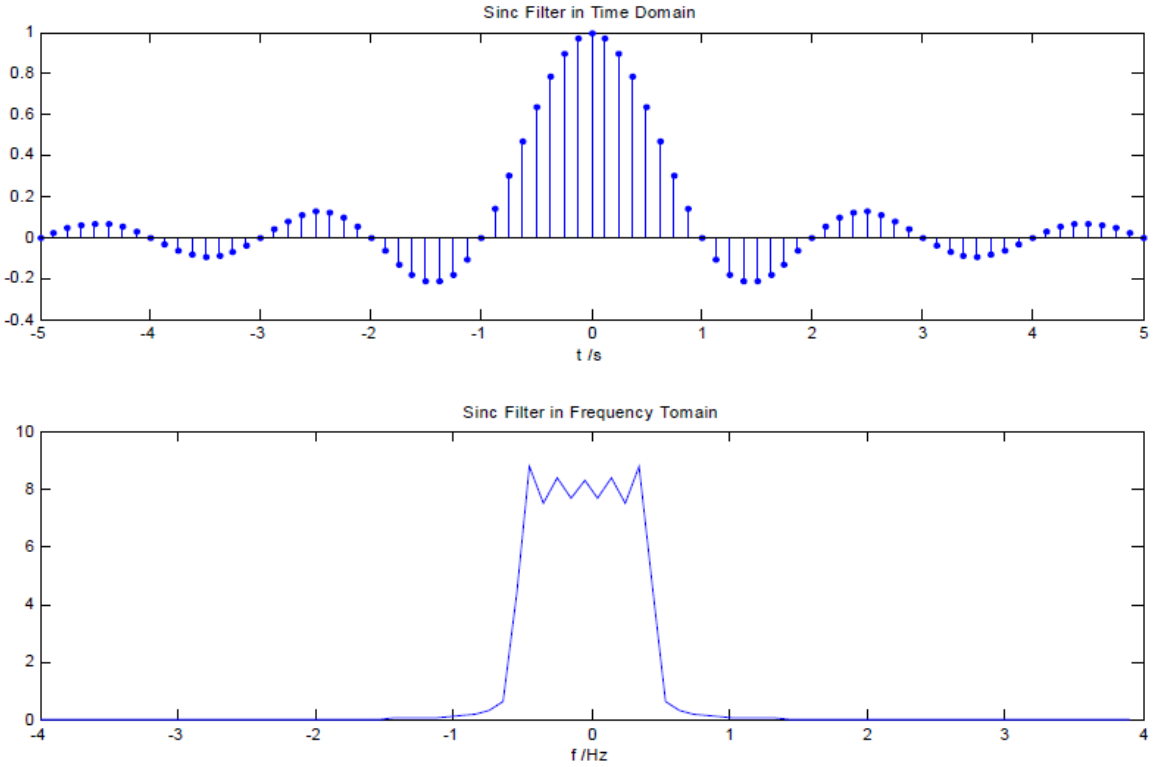
Re: [Proposed resolution to CID 408 of LB 87]

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

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

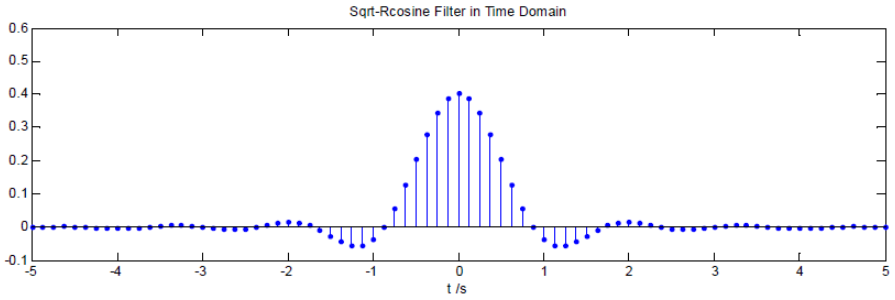
Idealized Square Filter

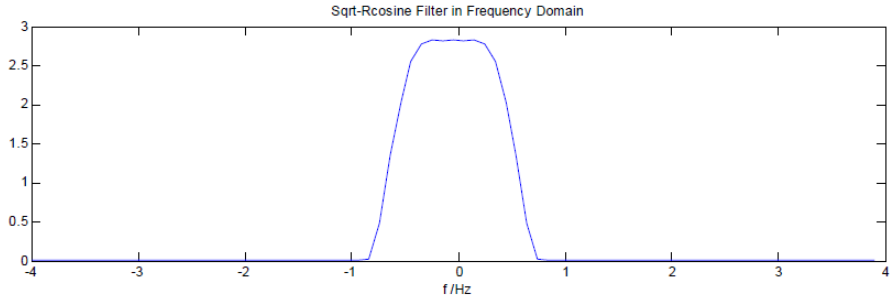
Sinc Filter in time and frequency domain

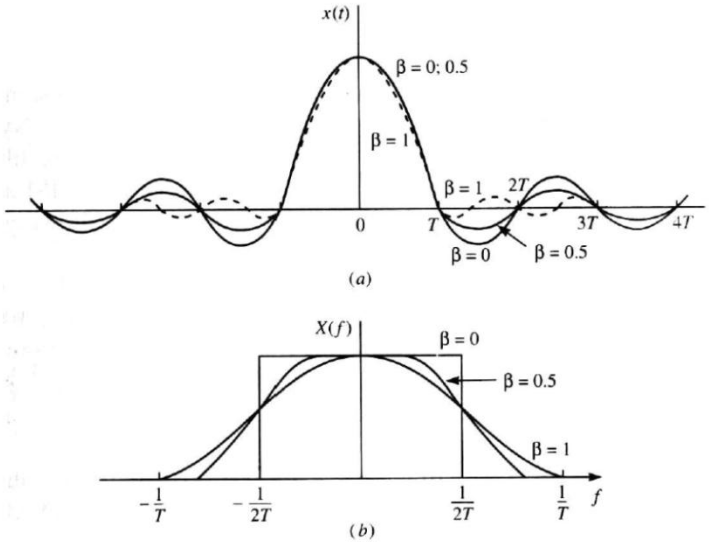


RRCF and RCF Filters

Square root Cosine Filter in time and frequency domain







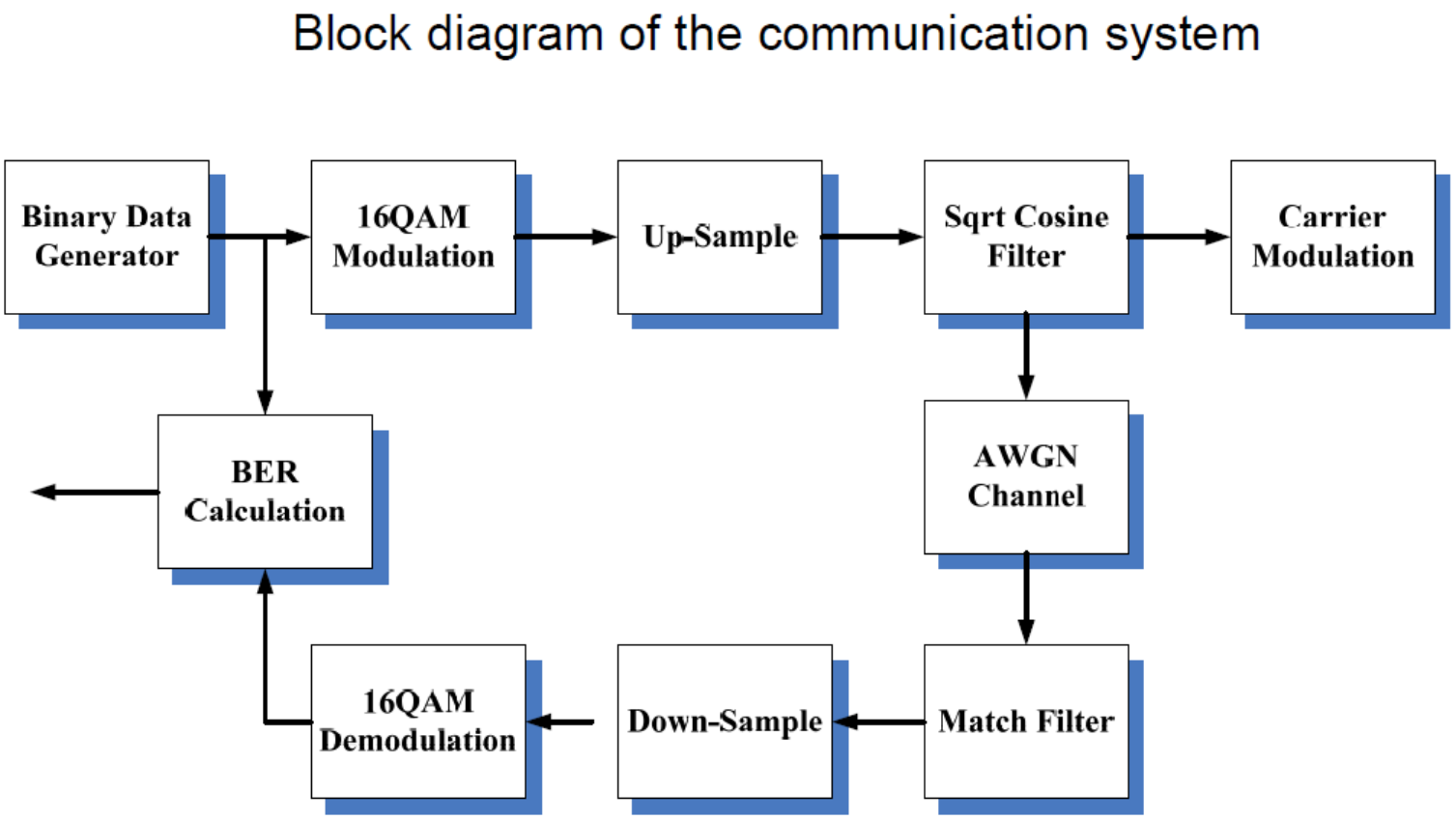
Pulses having a raised cosine spectrum.

Sqrt_Cosine_Filter

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

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

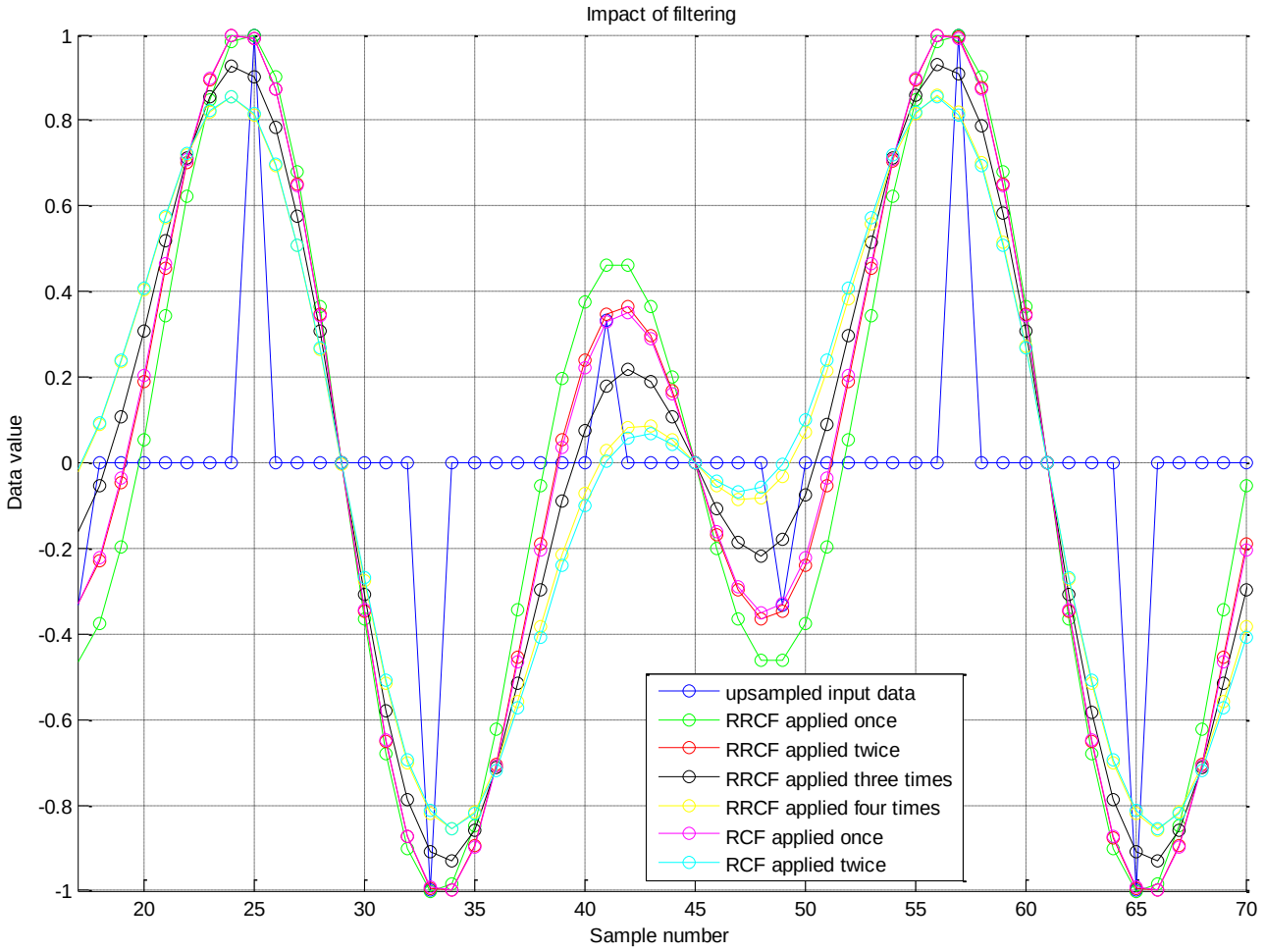
A Simulation Scenario



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 with a roll-off factor of 0.5. 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 with a roll-off factor of 0.5”.

References

- Yupin Zao: “Simulation of 16QAM systems”