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

Submission Title: Preliminary Proposal for TG4m

Date Submitted: May 2012

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Re: Call for proposals

Abstract: This contribution is prepared to identify recommendations to TG4m.

Purpose:

Regulatory Limits in TVWS
FCC 12-36, Paragraph 31

31. The revised PSD and adjacent channel emission limits that we are adopting are as follows.

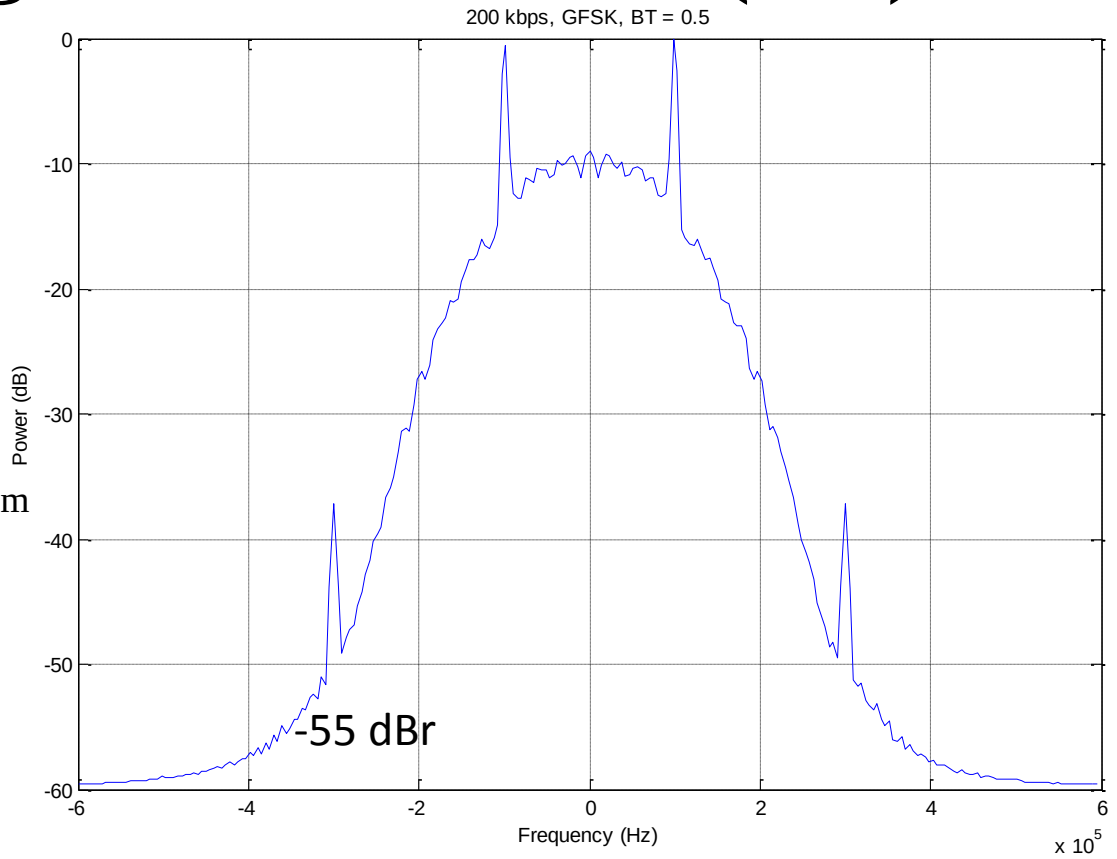
Type of TV bands device	Power limit (6 MHz)	PSD limit (100 kHz)	Adjacent channel limit (100 kHz)
Fixed	30 dBm (1 Watt)	12.6 dBm	-42.8 dBm
Personal/portable (adj. channel)	16 dBm (40 mW)	-1.4 dBm	-56.8 dBm
Sensing only	17 dBm (50 mW)	-0.4 dBm	-55.8 dBm
All other personal/portable	20 dBm (100 mW)	2.6 dBm	-52.8 dBm

Effectively, the power in a 6 MHz TV channel is distributed across the center 5.5 MHz of that channel, with 250 kHz guard-bands on each side. The adjacent channel emission limit becomes -55.4 dBr.

Outside the FCC, regulatory work still on-going. The proposal will be updated to reflect such rules once identified.

Reusing TG4g MR-FSK PHY (1/3)

- Consider MR-FSK mode with highest signaling rate:
  - 200 kbps
  - h=1.0, BT = 0.5
  - channel spacing of 400 kHz
- Spectral mask requirements met:
  - -55 dBr achieved ~ 400 kHz away from center carrier, consistent with raster definition in TG4g.
  - Guard-bands offer additional implementation buffer.
- Power concentrated ~+- 100 kHz from center frequency.
- EIRP of ~5.6 dBm for portable devices and ~15.6 dBm for fixed devices.



Sensitivity Requirements (1/3)

Channel Model Parameters		Notes
Frequency (MHz)	512	Valid Range 150-2400 MHz
Collector Antenna Height (m)	10	Hata Valid Range 30-200 m, including terrain. Erceg Valid Range 10-80m, including terrain
Endpoint Antenna Height (m)	2	Hata Valid Range 1-10 m, Erceg Fixed to 2m.
Distance (km)	1	Valid Range Hata 1-20 km, Valid Range Erceg 100m-8km
Downlink Path Loss Calculation		**Notes**
Collector Tx Power (dBm)	15.6	Subject to Tx Power Regulations
Collector Tx Antenna Gain (dBi)	2	Subject to Tx Power Regulations
Path Loss (dB)	-116.97	Must reference the right path loss from the Hata or Erceg worksheet
Shadowing Margin (dB)	-6	To buffer against variable shadowing loss
Penetration Loss (dB)	-5	For underground vaults, etc.
Endpoint Rx Antenna Gain (dBi)	2	If using same antenna for Tx, must be same as in Uplink Table
Endpoint Interference (dB)	1	Rise over Thermal Interference
Rx Power at Endpoint (dBm)	-107.37	Compare against Rx sensitivity
Uplink Path Loss Calculation		**Notes**
Endpoint Tx Power (dBm)	5.6	Subject to Tx Power Regulations. Can be different from Collector
Endpoint Tx Antenna Gain (dBi)	2	Subject to Tx Power Regulations
Penetration Loss (dB)	-5	For underground vaults, etc.
Path Loss (dB)	-116.97	Same as Downlink
Shadowing Margin (dB)	-6	Same as Downlink
Collector Rx Antenna Gain (dBi)	2	If using same antenna for Tx, must be same as in Downlink Table
Collector Interference (dB)	2	Rise over Thermal Interference
Rx Power at Collector (dBm)	-116.37	Compare against Rx sensitivity

Lower UHF carrier

Assuming fixed device

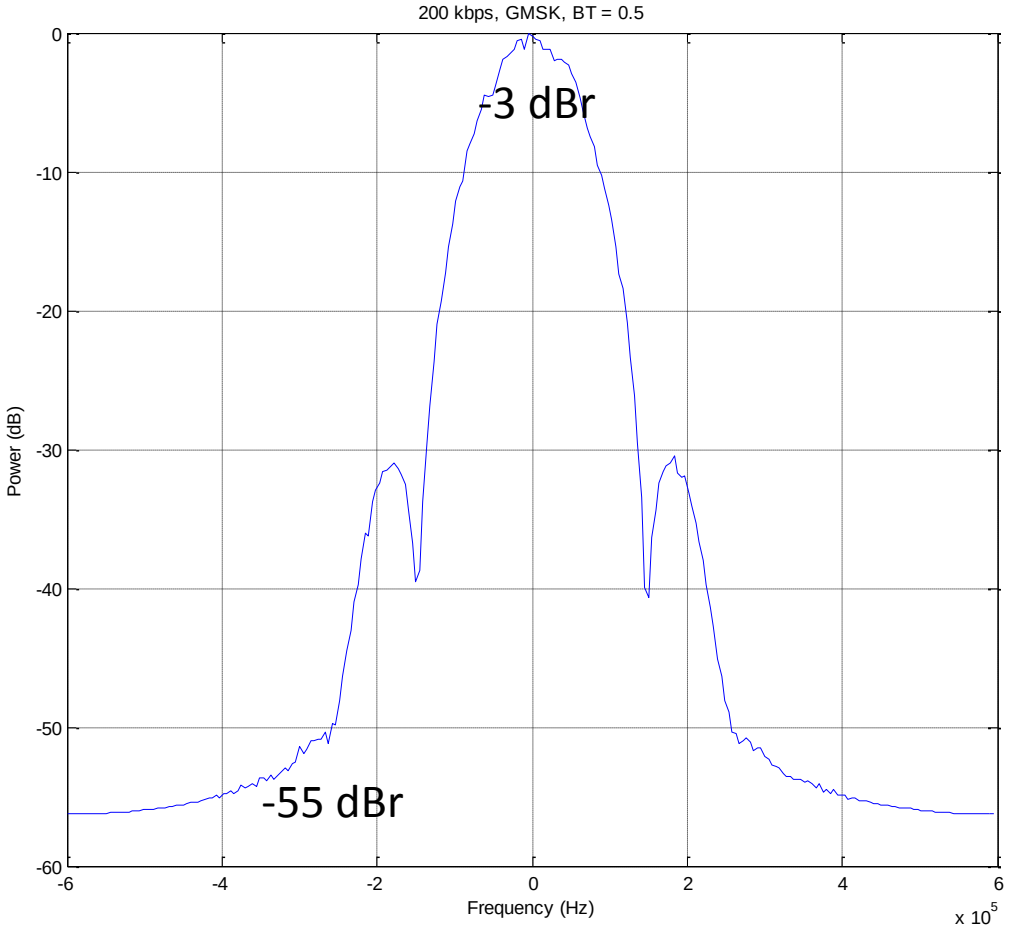
Assuming portable device

Challenging sensitivity, even at lower carriers

Recommend inclusion of strong FEC and spreading options

Reusing TG4g MR-FSK PHY (2/3)

- Consider MR-FSK mode with highest signaling rate:
  - 200 kbps
  - h=0.5, BT = 0.5
  - channel spacing of 400 kHz
- Spectral mask requirements met:
  - -55 dBr achieved ~ 400 kHz away from center carrier, consistent with raster definition in TG4g.
  - Guard-bands offer additional implementation buffer.
- 3 dB b/w at +- 50 kHz from center frequency.
- EIRP of ~4.4 dBm for portable devices and 14.4 dBm for fixed devices.
- Coherent detection gains



Sensitivity Requirements (2/3)

Channel Model Parameters		Notes
Frequency (MHz)	512	Valid Range 150-2400 MHz
Collector Antenna Height (m)	10	Hata Valid Range 30-200 m, including terrain. Erceg Valid Range 10-80m, including terrain
Endpoint Antenna Height (m)	2	Hata Valid Range 1-10 m, Erceg Fixed to 2m.
Distance (km)	1	Valid Range Hata 1-20 km, Valid Range Erceg 100m-8km
Downlink Path Loss Calculation		Notes
Collector Tx Power (dBm)	14.4	Subject to Tx Power Regulations
Collector Tx Antenna Gain (dBi)	2	Subject to Tx Power Regulations
Path Loss (dB)	-116.97	Must reference the right path loss from the Hata or Erceg worksheet
Shadowing Margin (dB)	-6	To buffer against variable shadowing loss
Penetration Loss (dB)	-5	For underground vaults, etc.
Endpoint Rx Antenna Gain (dBi)	2	If using same antenna for Tx, must be same as in Uplink Table
Endpoint Interference (dB)	1	Rise over Thermal Interference
Rx Power at Endpoint (dBm)	-108.57	Compare against Rx sensitivity
Uplink Path Loss Calculation		Notes
Endpoint Tx Power (dBm)	4.4	Subject to Tx Power Regulations. Can be different from Collector
Endpoint Tx Antenna Gain (dBi)	2	Subject to Tx Power Regulations
Penetration Loss (dB)	-5	For underground vaults, etc.
Path Loss (dB)	-116.97	Same as Downlink
Shadowing Margin (dB)	-6	Same as Downlink
Collector Rx Antenna Gain (dBi)	2	If using same antenna for Tx, must be same as in Downlink Table
Collector Interference (dB)	3	Rise over Thermal Interference
Rx Power at Collector (dBm)	-117.57	Compare against Rx sensitivity

Lower UHF carrier

Assuming fixed device

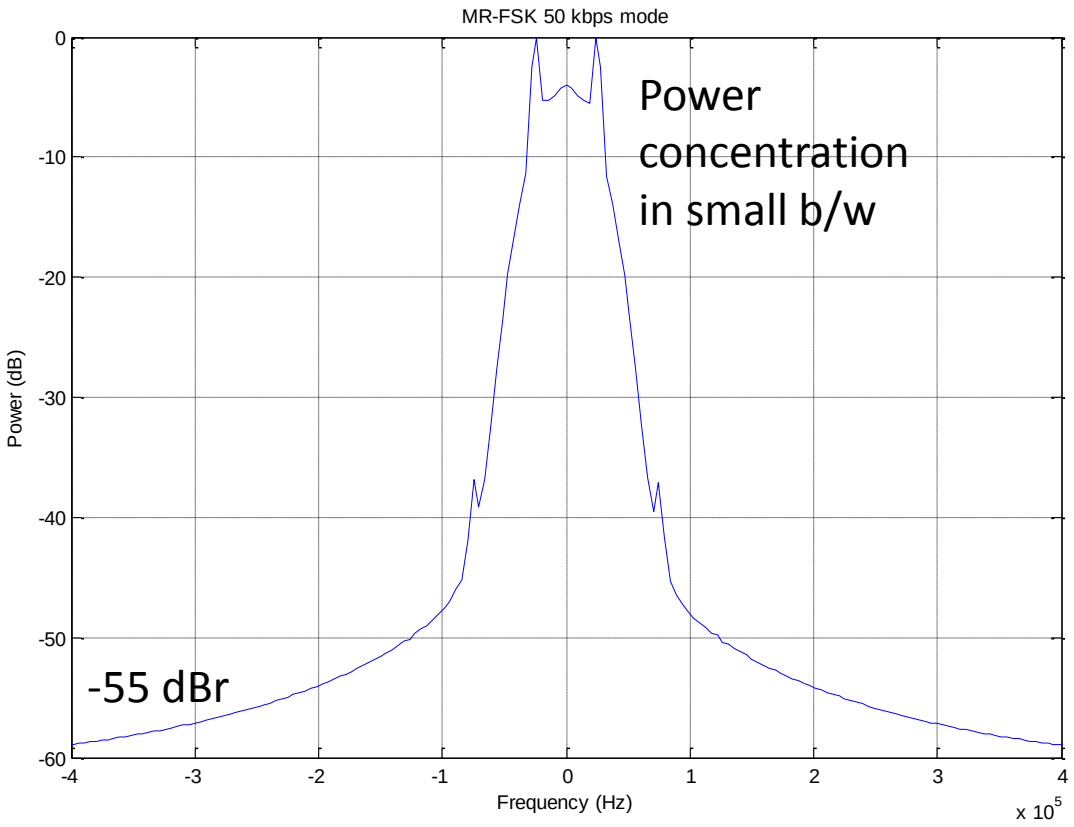
Assuming portable device

Challenging sensitivity, even at lower carriers

Recommend use of coherent detection, and inclusion of strong FEC and spreading options

Reusing TG4g MR-FSK PHY (3/3)

- Consider MR-FSK mandatory mode
  - 50 kbps
  - h=1
  - *channel spacing of 200 kHz*
- Spectral mask requirements:
  - -55 dBr achieved ~250 kHz away from center carrier.
  - Guard-band provides needed additional buffer.
- Power concentrated in 100 kHz around channel center, *no advantage from additional 100 kHz of channel spacing.*
- EIRP of ~2.6 dBm for portable devices and 12.6 dBm for fixed devices.



Recommend changing channel spacing to 100 kHz

Sensitivity Requirements (3/3)

Channel Model Parameters		Notes
Frequency (MHz)	512	Valid Range 150-2400 MHz
Collector Antenna Height (m)	10	Hata Valid Range 30-200 m, including terrain. Erceg Valid Range 10-80m, including terrain
Endpoint Antenna Height (m)	2	Hata Valid Range 1-10 m, Erceg Fixed to 2m.
Distance (km)	1	Valid Range Hata 1-20 km, Valid Range Erceg 100m-8km
Downlink Path Loss Calculation		Notes
Collector Tx Power (dBm)	12.6	Subject to Tx Power Regulations
Collector Tx Antenna Gain (dBi)	2	Subject to Tx Power Regulations
Path Loss (dB)	-116.97	Must reference the right path loss from the Hata or Erceg worksheet
Shadowing Margin (dB)	-6	To buffer against variable shadowing loss
Penetration Loss (dB)	-5	For underground vaults, etc.
Endpoint Rx Antenna Gain (dBi)	2	If using same antenna for Tx, must be same as in Uplink Table
Endpoint Interference (dB)	1	Rise over Thermal Interference
Rx Power at Endpoint (dBm)	-110.37	Compare against Rx sensitivity
Uplink Path Loss Calculation		Notes
Endpoint Tx Power (dBm)	2.6	Subject to Tx Power Regulations. Can be different from Collector
Endpoint Tx Antenna Gain (dBi)	2	Subject to Tx Power Regulations
Penetration Loss (dB)	-5	For underground vaults, etc.
Path Loss (dB)	-116.97	Same as Downlink
Shadowing Margin (dB)	-6	Same as Downlink
Collector Rx Antenna Gain (dBi)	2	If using same antenna for Tx, must be same as in Downlink Table
Collector Interference (dB)	2	Rise over Thermal Interference
Rx Power at Collector (dBm)	-119.37	Compare against Rx sensitivity

Lower UHF carrier

Assuming fixed device

Assuming portable device

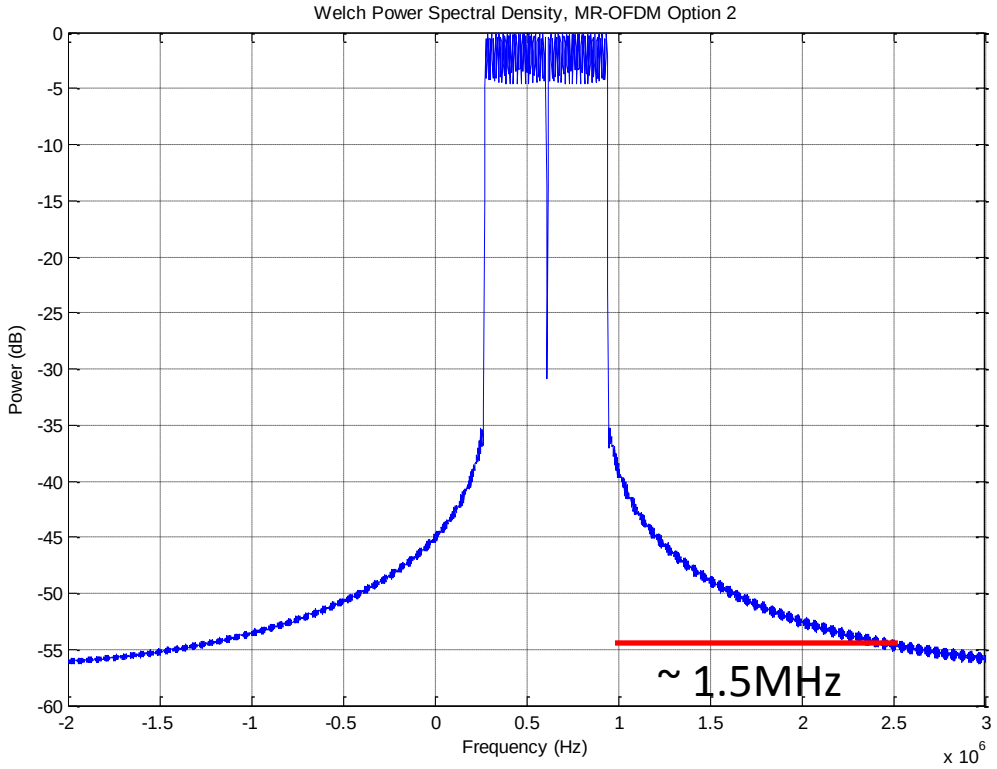
Challenging sensitivity, even at lower carriers

Recommend inclusion of strong FEC and spreading options

FEC and Spreading Features

- Low TX power leads to receiver sensitivity constraints similar to those in LECIM (TG4k) where the link budget requirement per the PAR is 120 dB.
- Features to increase link budget should include strong forward error correction and spreading:
  - Convolutional coding option with K=7
  - Interleaving for added robustness under burst error
  - Spreading for sensitivity increase
- Recommend adoption of FEC/interleaving and spreading schemes per LECIM FSK PHY, see sub-clauses 19.2.2.4-6 of 15-12-0089-04

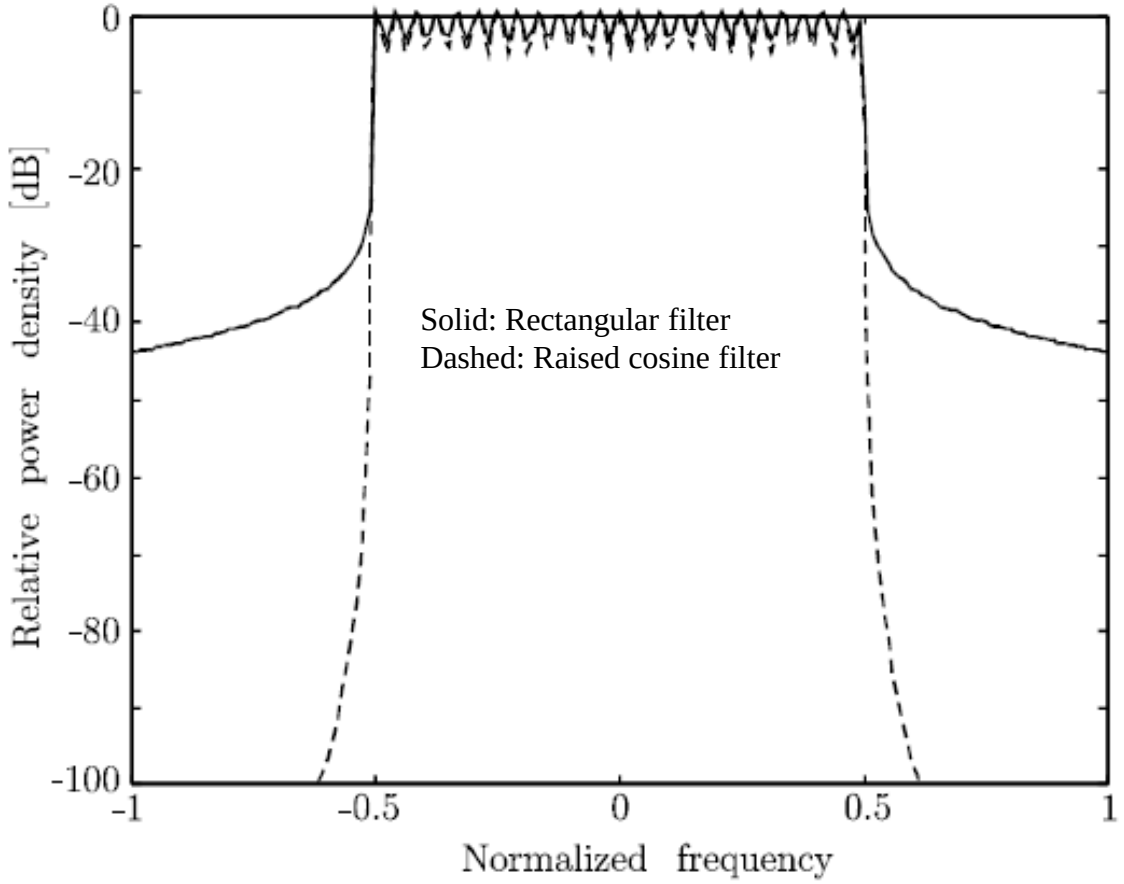
TX Spectrum Issues for MR-OFDM



- High out of channel emissions for OFDM modes, ~1.5MHz for side-lobe tapering to -55 dBm in this example.
- That would leave only ~3 MHz of "useful b/w" in a 6 MHz TV channel and ~5 MHz in a 8 MHz TV channel.

Recommend TX Spectrum Filtering

Raised Cosine Filtering



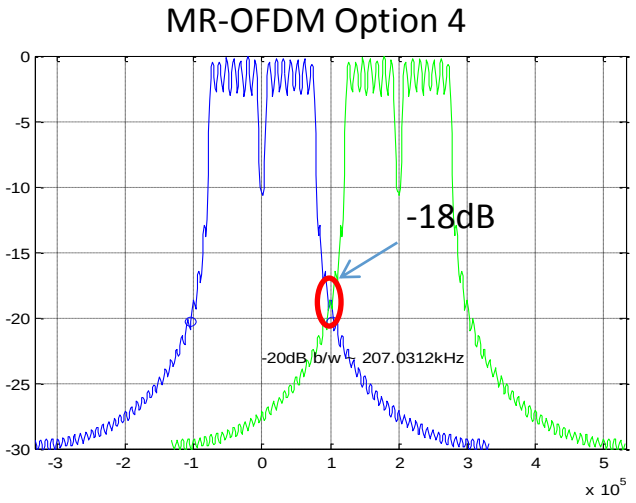
Significant improvements in spectral mask

Reference: http://www.sm.luth.se/csee/sp/research/report/esb96rc.pdf

Reusing TG4g MR-OFDM Modes

	Channel Spacing (kHz)	"Nominal" b/w (kHz)	b/w -6dB (kHz)	b/w -20dB (kHz)	Channel Edge intersect (dB)	EIRP (dBm) portable/fixed device
MR-OFDM Opt 4	200	156	156	207	-18	~5/~15
MR-OFDM Opt 3	400	281	281	346	-23	~7/~17
MR-OFDM Opt 2	~~8~~600	552	553	627	~~-25~~ -18	~10/~20
MR-OFDM Opt 1	1200	1094	1093	1166	-21	~13/~23

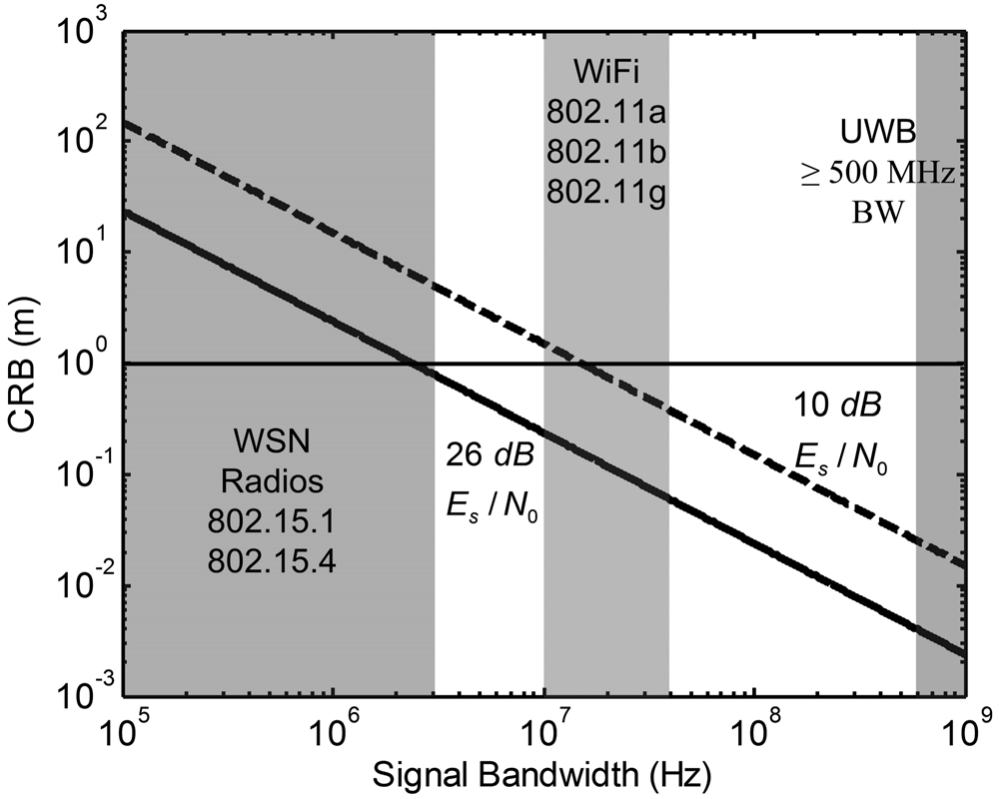
- Recommend channel spacing of 600 kHz for option 2, per document #15-12-0043-43v0.
- Allows channel allocation with highest density and optimal use of transmit power.
- Add TX filter per earlier slide, e.g. RC or RRC



(Source: S. Shearer)

Position Location Requirements

- Per CRB, variance of range estimate in white noise, sigma^2 >= c^2/(4pi^2*bw^2*SNR), where
  - bw = signal bandwidth
  - SNR is the signal energy to noise ratio
  - c is speed of light
- Thus bound on ranging uncertainty inverse proportional to signal b/w
- Also, to resolve multipath of dT, the b/w of the complex signal envelope must span at least 1/dT
  - Typical multipath <1 us, thus envelope must span >1 MHz.
- Ref: Viterbi, "Foundations of Digital Wireless World, Selected Works"



For ranging purposes, include mode with signal b/w spanning ~1 MHz or higher.

Proposal Summary

- FSK PHY Options
  - Adopt MR-FSK PHY, with channel spacing of 100 kHz for the 50 kbps mode
  - Strong FEC and interleaving as in 19.2.2.4-5 of 15-12-0089-04
  - Spreading as in 19.2.2.6 of 15-12-0089-04
- OFDM PHY Options
  - Adopt MR-OFDM PHY, with channel spacing of 600 kHz for Option 2
  - With addition of TX filtering, e.g. based on raised cosine
- Ranging with signal of ~1 MHz or higher bandwidth