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

Submission Title: Proposed Resolutions to various TBDs in the FSK Draft

Date Submitted: February 2012

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Re: Action items from Jacksonville TG4k session

Abstract: This contribution is prepared to identify recommendations to TG4k.

Purpose:

Introduction

- Document 15-12-0030-00 recommended inclusion of following bands in TG4k FSK draft:
  - 433MHz ISM band
  - 169MHz European band
- Action item from Jacksonville meeting on link budget analysis for these bands
  - Document 15-11-0602-00
  - And document 15-11-0464-03 as reference
  - Some inconsistencies
- Analysis of modes at 169 MHz European band
- Proposal on an optimal Start-Frame-Delimiter 3-byte pattern

LHM Proposal on FCC Rules @ 433 MHz

- Band extends from 433.05 MHz to 434.79 MHz
- Applications include identification, location, monitoring and tracking of commercial assets
- Bi-directional communication allowed with some duty cycle and listen-before-talk requirements
- Increased transmit power allowance:
  - A field strength of E = 57,700 uV/meter measured at 3 meters
  - Thus a transmit power $P = 0.3\ E^2 = 1$ mW = 0 dBm

Link Budget Analysis, 433 MHz Band

Channel Model Parameters		Notes
Frequency (MHz)	433	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)	0	Subject to Tx Power Regulations
Collector Tx Antenna Gain (dBi)	2	Subject to Tx Power Regulations
Path Loss (dB)	-120.91	Must reference the right path loss from the Hata or Erceg worksheet
Shadowing Margin (dB)	16	To buffer against variable shadowing loss
Penetration Loss (dB)	-10	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)	**-109.91**	Compare against Rx sensitivity

Uplink Path Loss Calculation		Notes
Endpoint Tx Power (dBm)	0	Subject to Tx Power Regulations. Can be different from Collector
Endpoint Tx Antenna Gain (dBi)	2	Subject to Tx Power Regulations
Penetration Loss (dB)	-10	For underground vaults, etc.
Path Loss (dB)	-120.91	Same as Downlink
Shadowing Margin (dB)	16	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)	**-108.91**	Compare against Rx sensitivity

Bi-directional communication and TX output power of 0 dBm

Sensitivity constraints challenging but doable, thanks to the low carrier frequency

Link Budget Analysis @ 433 MHz Band, **ETSI** Rules

Channel Model Parameters		Notes
Frequency (MHz)	433	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

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Shadowing Margin (dB)	16	To buffer against variable shadowing loss
Penetration Loss (dB)	-10	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)	**-101.91**	Compare against Rx sensitivity

Uplink Path Loss Calculation		Notes
Endpoint Tx Power (dBm)	10	Subject to Tx Power Regulations. Can be different from Collector
Endpoint Tx Antenna Gain (dBi)	0	Subject to Tx Power Regulations
Penetration Loss (dB)	-10	For underground vaults, etc.
Path Loss (dB)	-120.91	Same as Downlink
Shadowing Margin (dB)	16	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)	**-100.91**	Compare against Rx sensitivity

Channel Model Parameters		Notes
Frequency (MHz)	2400	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)	24	Subject to Tx Power Regulations
Collector Tx Antenna Gain (dBi)	0	Subject to Tx Power Regulations
Path Loss (dB)	-145.65	Must reference the right path loss from the Hata or Erceg worksheet
Shadowing Margin (dB)	16	To buffer against variable shadowing loss
Penetration Loss (dB)	-10	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)	**-112.65**	Compare against Rx sensitivity

Uplink Path Loss Calculation		Notes
Endpoint Tx Power (dBm)	24	Subject to Tx Power Regulations. Can be different from Collector
Endpoint Tx Antenna Gain (dBi)	0	Subject to Tx Power Regulations
Penetration Loss (dB)	-10	For underground vaults, etc.
Path Loss (dB)	-145.65	Same as Downlink
Shadowing Margin (dB)	16	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)	**-111.65**	Compare against Rx sensitivity

RX sensitivity requirements do-able, and less stringent than at 2.4 GHz

Link Budget Analysis, 169 MHz Band

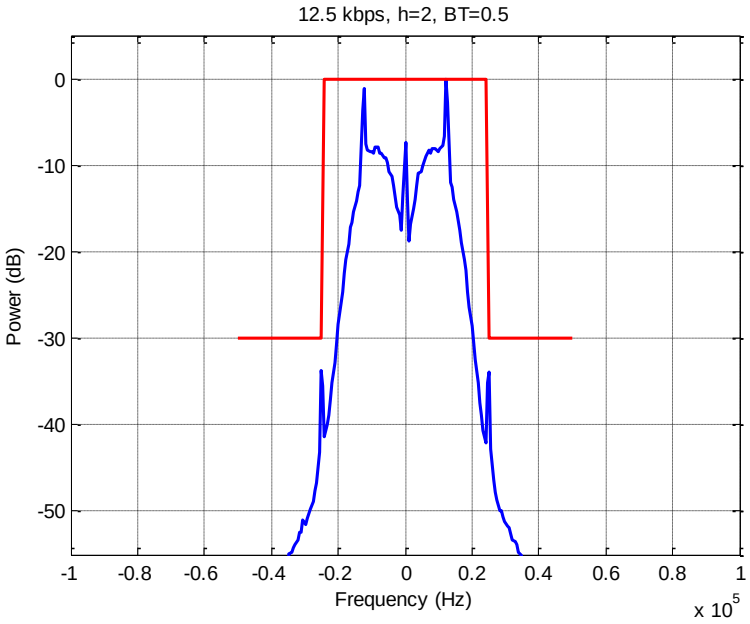
Channel Model Parameters		Notes
Frequency (MHz)	169.4	Valid Range 150-2400 MHz
Collector Antenna Height (m)	10	Hata Valid Range 30-200 m, including terrain. Erceg Valid Range 10-80m, including terrain
Endpoint Antenna Height (m)	2	Hata Valid Range 1-10 m, Erceg Fixed to 2m.
Distance (km)	1	Valid Range Hata 1-20 km, Valid Range Erceg 100m-8km

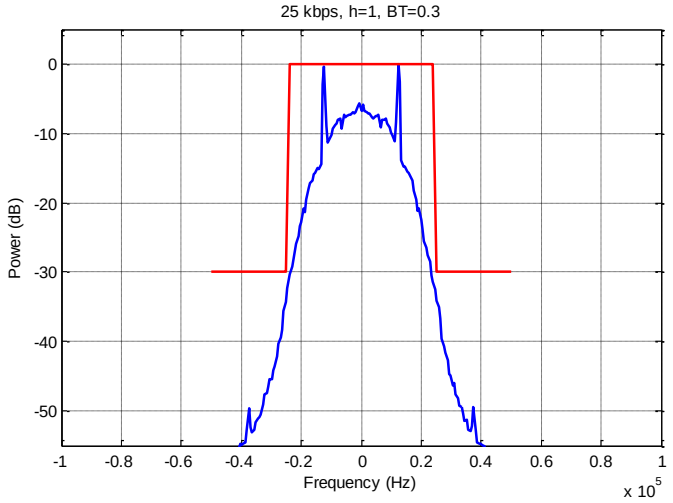
Downlink Path Loss Calculation		Notes
Collector Tx Power (dBm)	27	Subject to Tx Power Regulations
Collector Tx Antenna Gain (dBi)	0	Subject to Tx Power Regulations
Path Loss (dB)	-107.35	Must reference the right path loss from the Hata or Erceg worksheet
Shadowing Margin (dB)	16	To buffer against variable shadowing loss
Penetration Loss (dB)	-10	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)	**-71.35**	Compare against Rx sensitivity

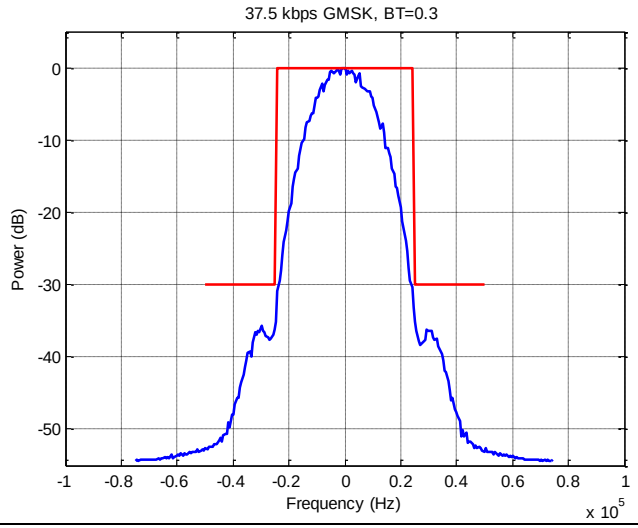
Uplink Path Loss Calculation		Notes
Endpoint Tx Power (dBm)	27	Subject to Tx Power Regulations. Can be different from Collector
Endpoint Tx Antenna Gain (dBi)	0	Subject to Tx Power Regulations
Penetration Loss (dB)	-10	For underground vaults, etc.
Path Loss (dB)	-107.35	Same as Downlink
Shadowing Margin (dB)	16	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)	**-70.35**	Compare against Rx sensitivity

It gets significantly easier for the 169 MHz band!

169 MHz Mode Analysis

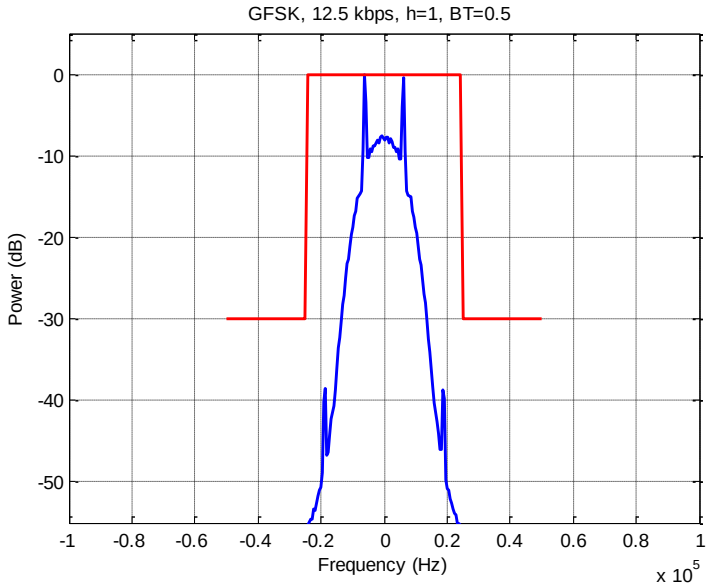


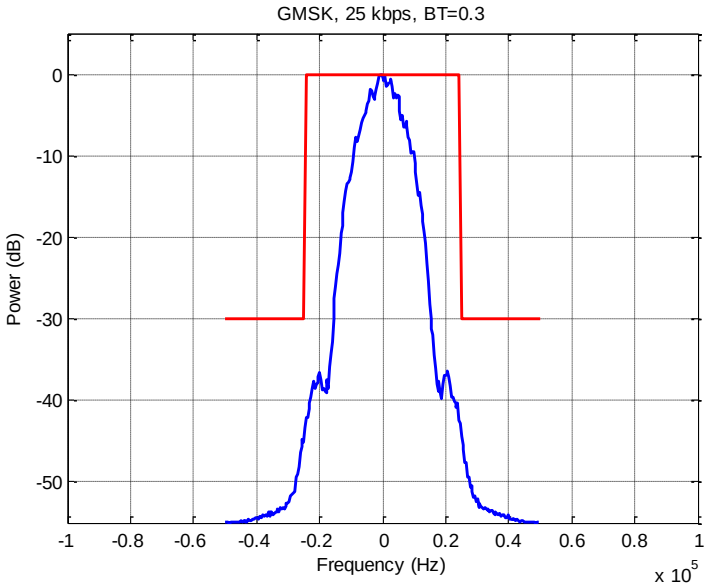




The current modes can fit but with little implementation margin

Proposed Modes at 169 MHz





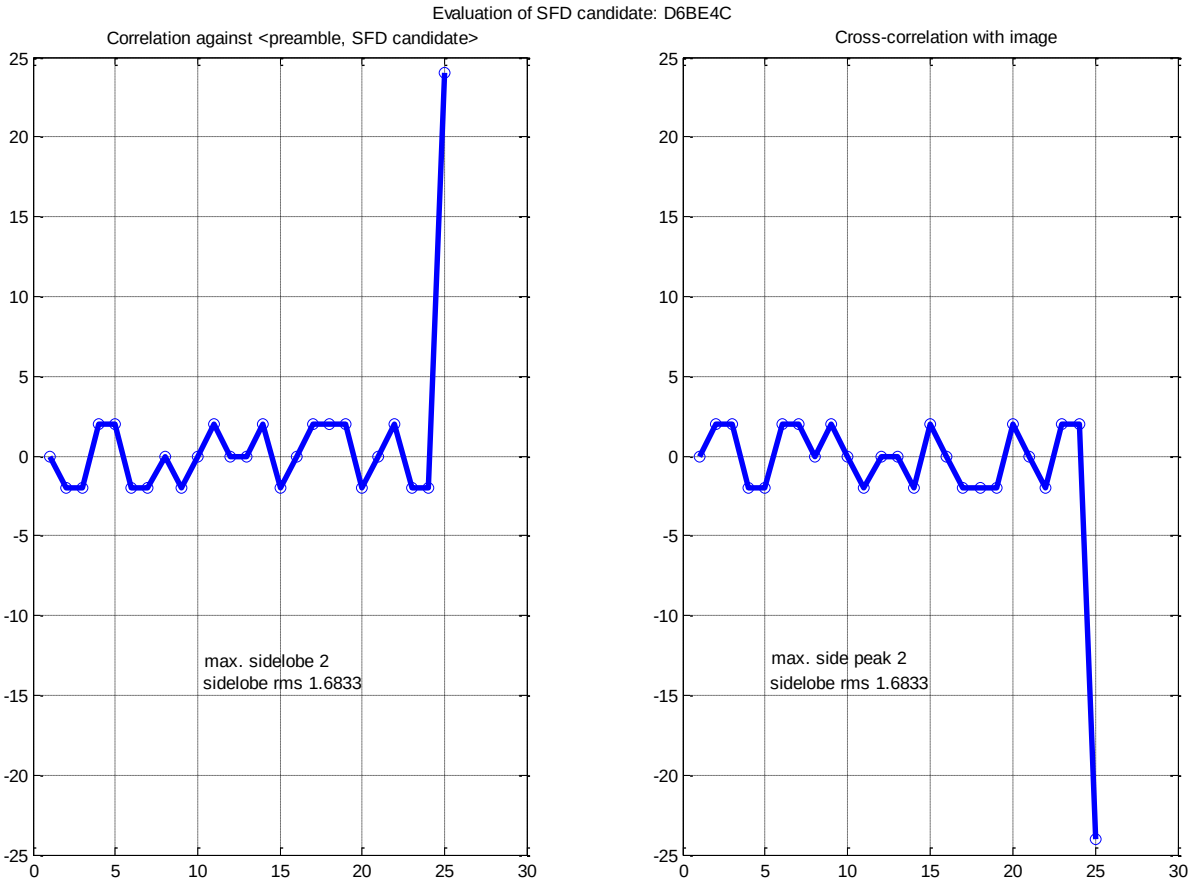
Mode 1: N/A
Mode 2: 25 kbps, h=0.5
Mode 3: 12.5 kbps, h=1

Proposed Properties of TG4k FSK SFD

- A 3-byte pattern (already agreed to in Jacksonville)
- Balanced
- Relatively short strings of 1's or 0's
- Good auto-correlation properties
- Low cross-correlation against preamble
- Low cross-correlation against self image

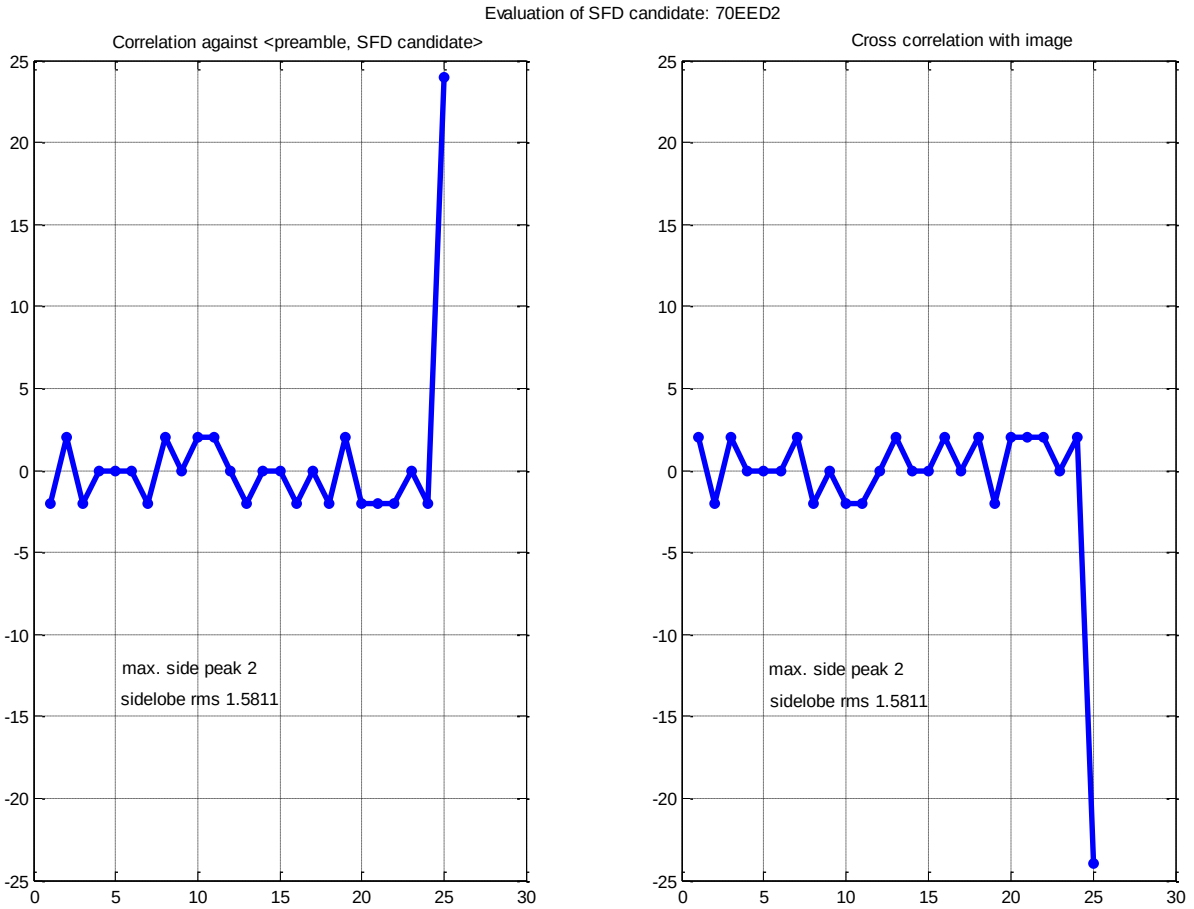
Candidate SFD Pattern: D6BE4C (hex)

- Candidate SFD pattern is: 1101 0110 1011 1110 0100 1100
- 14 ones, 10 zeros
- Longest run is 5 ones
- Max side-lobe is 2
- Side-lobe RMS is ~ 1.7



Candidate SFD Pattern: 70EED2 (hex)

- Candidate SFD pattern is: 0111 0000 1110 1110 1101 0010
- 13 ones, 11 zeros
- Longest run is 4 zeros
- Max side-lobe is 2
- Side-lobe RMS is ~ 1.6



Best candidate in all categories!

Conclusions

- Link budget analyzed for operation at 433 MHz and 169 MHz bands.
- Low effective path loss makes up for the reduced TX power.
- Some tweaks in the operating modes for the 169 MHz band needed to fit regulatory requirements.
- A 3-byte SFD pattern is proposed: 0111 0000 1110 1110 1101 0010
- The pattern is balanced and can be shown to have good correlation properties.