Link Budget Analysis for Broadband Services in IEEE 802.22b

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Abstract

- **This contribution presents some information of link budget analysis for 802.22b task group based on the use cases and CPE definitions.**
- **This presentation focuses on the link budget analysis in the case of using higher order modulation such as 256QAM which would be considered for use of broadband service extension in 802.22b.**

Use Cases Considering in 802.22b

Table 1 Use Cases Considering in 802.22b (source: doc. IEEE 802.22-12/0025r4)

Category	Usage Cases	Properties
A) Smart Grid & Monitoring	A1) Regional Area Smart Grid/Metering	-Low capacity/complexity CPEs -Very large number of monitoring CPEs -Fixed and Potable CPEs -Real time monitoring -Low duty cycle -High reliability and security -Large coverage area -Infrastructure connection
	A2) Agriculture/Farm House Monitoring	
	A3) Critical Infrastructure/Hazard Monitoring	
	A4) Environment Monitoring	
	A5) Homeland Security/Monitoring	
	A6) Smart Traffic Management and Communication	
B) Broadband Service Extension	B1) Temporary Broadband Infrastructure (e.g., emergency broadband infrastructure)	-Fixed and Portable CPEs -Higher capacity CPEs than Category A) -High QoS, reliability and security -Higher data rate than Category A) -Easy network setup -Infrastructure and Ad hoc connection
	B2) Remote Medical Service	
	B3) Archipelago/Marine Broadband Service	
C) Combined Service	C1) Combined Smart Grid, Monitoring and Broadband Service	• Category A) and B)

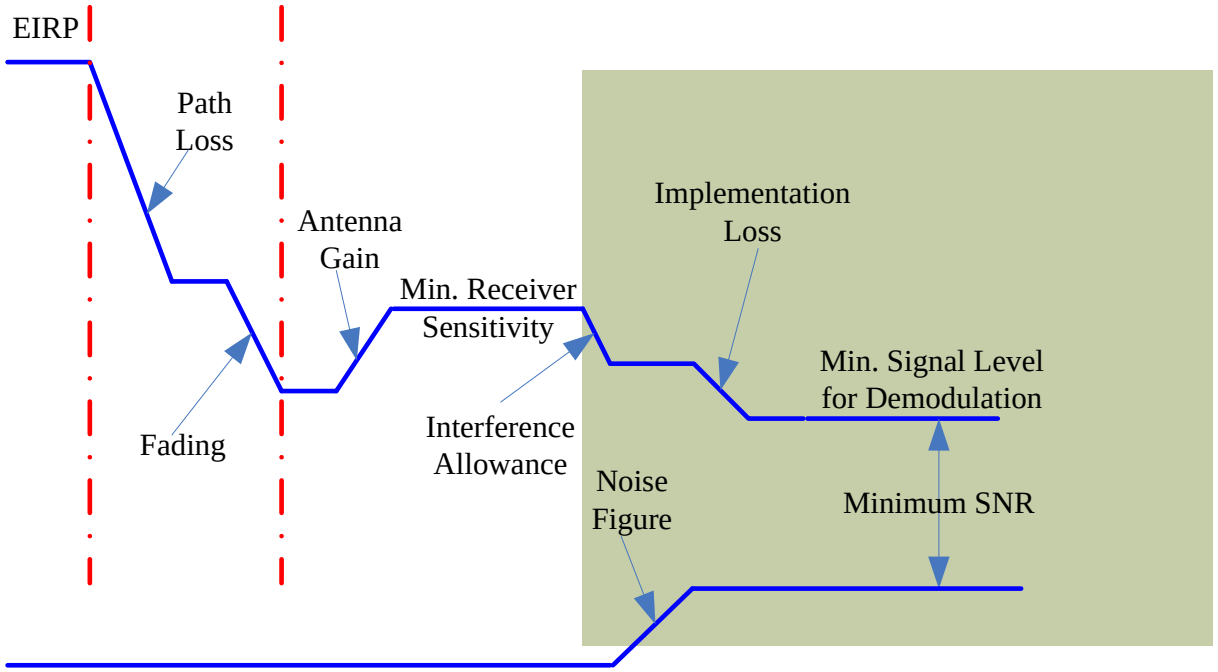
Key Technical Issues

- **Regulatory constraints**
  - Stringent out-of-band emission mask
  - Power spectral density (PSD) limit

Table 2 Key spectrum mask elements in TVWS (FCC 3rd MO&O)

Type of TV bands device	Average Transmission Power (6 MHz)	EIRP Power Limit (6 MHz)	PSD Limit (100 kHz)	Adjacent Channel Limit (100 kHz)
Fixed	30 dBm (1 Watt)	36 dBm (4 Watt)	12.6 dBm	-42.8 dBm
Personal/Portable	20 dBm (100 mW)	20 dBm (100 mW)	2.6 dBm	-52.8 dBm
Type of TV bands device	Average Transmission Power (6 MHz)	EIRP Power Limit (6 MHz)	PSD Limit (100 kHz)	Adjacent Channel Limit (100 kHz)

Link Budget



Thermal Noise Floor = -174dBm/Hz + 10log(BW) = -106.2 dBm for 6 MHz TV band

- **Interference allowance, receiver implementation margin, and noise figure has been considered when calculating the minimum receiver sensitivity according to Ref. 1**
  - ✓ **BS: 5.9 dB**
  - ✓ **CPE: 9.1 dB**

Receiver Minimum Sensitivity: ½-rate coded QPSK

R_{SS} (dBm) = Reference Thermal Noise Density Level
+ Noise Figure + Effective Channel Bandwidth
+ Required Signal-to-Noise Ratio
+ Receiver Implementation Margin + Interference Allowance

Source: Ref 1.

Table 228 — Normalized CNR per modulation for BER= 2×10^{-4}

Modulation—FEC rate	Normalized CNR (dB)	
	AWGN (default)	Multipath channel[20]
CDMA code	1.2	5
QPSK, rate: 1/2	4.3	8.1

Table 231 — Minimum receiver sensitivity requirement for QPSK rate: 1/2 at BER= 2×10^{-4}

TV channel bandwidth (MHz)	6	7	8
Base station receiver sensitivity (dBm)	–94.5	–93.8	–93.2
CPE receiver sensitivity (dBm)	–91.3	–90.6	–90.0

R_{SS} for QPSK, rate=1/2 at BER= 2×10^{-4},decoder implementation margin 1.1 dB

TV channel BW (MHz) (decoder implementation margin)	6	7	8
R_{SS} of BS (dBm)	-96	-95.3	-94.7
R_{SS} of CPE (dBm)	-92.8	-92.1	-91.5

Receiver Minimum Sensitivity: 256-QAM

Cyclic prefix: $\frac{1}{16}$ *FFT period*

Code rate	1/2	2/3	3/4	5/6	7/8
Data rate (Mb/s)	18.15	24.2	27.22	30.25	31.77
Spectral efficiency	3.03	4.03	4.53	5.04	5.29

- **Data rate of 64-QAM with 5/6-rate coding is 22.7 Mbps (Max. data rate in the IEEE 802.22-2011)**
- **40% higher data rate can be achieved by using 256-QAM**

The required SNR for 256-QAM and code rate 7/8 at BER = 2×10^{-4} is: 29.8 dB

Receiver Minimum Sensitivity: 256-QAM

- **Assumptions: (Ref. 1)**
  - ✓ **Noise figure: 3 dB for BS, 6 dB for CPE**
  - ✓ **Interference allowance: 1 dB for BS and CPE**
  - ✓ **Receiver implementation margin**
    - **1.9 dB for BS**
    - **2.1 dB for CPE**

R_{SS} for 256-QAM, rate 7/8 at BER = 2×10^{-4} decoder implementation margin 1.7 dB, AWGN channel

Channel Bandwidth	6 MHz	7 MHz	8 MHz
R_{SS} for BS (dBm)	-68.8	-68.1	-67.5
R_{SS} for CPE (dBm)	-65.6	-64.9	-64.3

Link Budget Calculation

- **Channel bandwidth: 6 MHz**
- **Calculation in Channel 51 (center frequency: 695 MHz):**
  - Both fixed or portable devices can be used
- **256-QAM, rate = 7/8, BER = 2×10^{-4}**
- **Receiver Sensitivity**
  - BS: -68.8 dBm
  - CPE: -65.6 dBm
- **LOS: Free Space**
- **NLOS (Modified Okumura-Hata Model, Ref. 2.)**
  - Tx antenna height: 30 m (AGL)
  - Rx antenna height: 5 m (AGL)

Link budget example

Parameter		LOS	NLOS	Notes
Frequency (MHz)		695		
Tx EIRP Power (dBm)		36.0		EIRP for BS & H-CPE
Tx Antenna Height (m)		30.0		
Rx Antenna Height (m)		5.0		
Tx Antenna Gain (dBi)		6.0		Included in the EIRP
Path Loss (dB)	Distance = 2km	95.3	98.3	
Required Eb/No (dB)		21.6		BER =2×10^{-4}
Required CNR (dB)		29.8		256-QAM, Code rate = 7/8
Rx Sensitivity	BS	-68.8		
	CPE	-65.6		

Link Margin (dB) example

Distance	LOS		NLOS	
	BS	H-CPE	BS	H-CPE
2 km	**9.5**	**6.3**	**6.5**	**3.3**

Maximum Transmission Distance

Scenarios	Maximum Transmission Distance (km)	
	LOS	NLOS
BS → H-CPE H-CPE → H-CPE	4.82	2.48
H-CPE→ BS	6.97	3.08

References

1. IEEE 802.22-2011, July 2011
2. IEEE 802.15-11-0684-09-004m: TG4m Technical Guidance Document, Mar. 2012