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Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Link Budget for IEEE 802.16m Reference System**
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Re:	IEEE 802.16m-07/080r2– Call for Comments on Draft 802.16m Evaluation Methodology Document
Abstract	This document contains proposed text for the draft evaluation methodology for IEEE 802.16m technical proposals.
Purpose	For discussion and approval by TGm
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Link Budget for IEEE 802.16m Reference System

References

[1] Draft IEEE 802.16m Evaluation Methodology Document, IEEE 802.16 Broadband Wireless Access Working Group, April 17, 2007

[2] Mobile WiMAX – Part 1: A Technical Overview and Performance Evaluation, WiMAX Forum , February 21, 2006

1. Introduction

In this paper a case study of link budget calculation is prepared for a reference system as defined in the 802.16m requirements document. This link budget calculation is executed on the spread sheet of Microsoft Office Excel Program, and the parameters used in the link budget calculation, either uplink or downlink, are **soft linked** to their associated locations in the system parameter block, base station architecture block, mobile station block, OFDM numerology block, propagation model and OFDM permutation block. Therefore if parameter entries in any of the blocks are changed, the same parameters used in the downlink and uplink link budgets calculation will be changed accordingly to reflect these changes and new link budgets will be evaluated and displayed. Therefore this spread sheet can also be used as the sensitivity study for the 802.16m reference system. Those parameters that will affect the link budgets evaluation are listed in ***red*, *italic*** to distinguish themselves from other parameters that will have no effect in the link budget preparation.

2. Model Description

2.1 Base Station Parameters

In Table 1, it lists the parameters relevant to the base station in the 802.16m system such as the maximum base station transmitter power, the base station antenna gain, the number of transmitting and receiving antennas etc.

Table 1 Base Station Model

Parameters	Value	Unit
Number of Cells (3 Sectors)	19	
Operating Frequency	2.5	GHz
Channel Bandwidth	10	MHz
BS-to-BS Distance	2.8	kilometers
Minimum Mobile-to-BS Distance	36	meters
Maximum BS Transmit Power/Carrier	46	dBm
BS Antenna Gain	17	dBi

Antenna Pattern (3 Sector, 3 dB Bandwidth)	70	degree
Antenna Front-to-Back Ratio	20	dB
Number of BS TX Antennas	2	
Number of BS RX Antennas	2	
BS Height	32	meter
BS Noise Figure (TX/RX)	5	dB
Hardware Loss	2	dB

2.2 Mobile Station Parameters

The parameters considered in mobile station model are listed in Table 2. In the BS- MS downlink transmission it considers the QPSK modulation with 1/2 coding rate, its minimum required signal to noise ratio, SNR, is assumed to be 3.49 dB. While for the MS-MS link transmission, it uses QPSK modulation with 1/8 coding rate and the required SNR value is set at -2.5 dB.

Table 2 Mobile Station Model

Parameter	Value	Unit
Maximum MS Transmit Power/Carrier	23	dBm
MS Antenna Gain	-1	dBi
Number of MS TX Antennas	1	
Number of MS RX Antennas	2	
MS Height	1.5	meter
MS Noise Figure	7	dB
Hardware Loss	2	dB
BS-MS Modulation	QPSK 1/2	
BS-MS Modulation SNR Required	3.49	dB
MS-MS Modulation	QPSK 1/8	
MS-MS SNR Required	-2.5	dB

2.3 OFDM Numerology

IEEE 802.16m system is based on the scalable OFDM configuration, they can be operated on different bandwidth by adjusting system parameters (Table 1), base station parameters (Table 2), mobile station parameters (Table 3), and other OFDM system related parameters listed in Table 4, as the OFDM Numerology, and the Permutation Parameters, as listed in Table 5, the permutation type, to define the number of sub-carriers allocated and the number of sub-channels used.

Table 4 OFDM Numerology

Parameter	Value	Unit
Total Bandwidth	10	MHz
Sampling Frequency	11.2	MHz
NFFT Points	1024	
Sub-Carrier Spacing	10.94	KHz
OFDM Symbol Duration	91.43	μs
Cyclic Prefix Length (Fraction of Symbol Duration)	0.125	
OFDM Symbol Duration w/Cyclic Prefix	102.86	μs
DL Traffic Data Rate	2.88	Mbps
UL Traffic Data Rate	38	Kbps

Table 5 Permutation Parameters

Parameter	Value	Unit
Down Link Permutation Type	PUSC	
Up Link Permutation Type	PUSC	
DL: Number of Sub-Carriers for BS TX	840	
UL: Number of Sub-Carriers for MS TX	72	
DL: Number of Sub-Channels in BS TX	30	
UL: Number of Sub-Channels in UL Permutation	35	

2.4 Propagation Parameters

The channel propagation parameters are listed in Table 6. In the large–scale path loss model to compute the average path loss for an arbitrary transmitter-receiver distance, a log-normal distribution model is used to account for the random shadowing effect at every location along the transmitter – receiver path due to trees and other cluster and a value of 8 dB is considered for this case study. A Rayleigh fading model is used to describe the small-scale fading loss due to the Doppler frequency effect originating from the movement of the environment and/or the mobile. It is assigned 2 dB for this Doppler frequency modulation loss. A 3 dB is assigned to consider the interference loss due to adjacent and co-channel interferences from the same system and other same spectrum co-sharing systems. For an EM wave transmitting from the Base Station apparatus or from the mobile handheld set to the receiver mobile handheld set via various buildings in its transmission path a 10 dB is allocated for this penetration loss. In the modem and system hardware realization, it assigns 2 dB for this implementation loss.

Table 6 Propagation Model

Parameter	Value	Unit
Log-Normal Shadowing Loss	8	dB
BS Shadowing Correlation	0.5	

Penetration Loss	10	dB
Interference Loss	3	dB
Fast Fading Loss	2	dB

3. Link Budget

Based on the parameters for the system, the base station, the mobile, OFDM permutation and propagation loss, the processes in the calculation of the down budget, from Base station to Mobile Handheld Set, and the uplink budget, from Mobile Handheld Set to Mobile Handheld Set, and their results are tabulated in Tables 7 and 8 respectively.

Table 7 Downlink Link Budget

Base Station Infrastructure		
Parameter	Value	Unit
Maximum BS Transmit Power/Carrier	46.0	dBm
OFDM Symbol Duration w/Cyclic Prefix	102.86	μs
OFDM Symbol Duration	91.43	μs
Cyclic Combining Gain	0.5	dB
BS Antenna Gain	17.0	dBi
EIRP	165.9	dB
DL: Number of Sub-Carriers for BS TX	840	
Power per Occupied Sub-Carrier	136.6	dBm

Mobile Station (Handset)

Parameter	Value	Unit
MS Antenna Gain	-1.0	dB
Number of MS RX Antennas (Gain)	3.0	dB
MS Noise Figure	7.0	dB

Margins

Parameter	Value	Unit
Log- Normal Shadowing Loss	8	dB
Fast Fading Loss	2.0	dB
Interference Loss	3.0	dB
Penetration Loss	10.0	dB
Hardware Loss	2.0	dB
Total Margin	25.0	dB

Mobile Rx Sensitivity

Parameter	Value	Unit
Thermal Noise	-174	dBm/Hz

Sub-Carrier Spacing	10.94	KHz
Modulation	QPSK 1/2	
SNR Required	3.49	dB
RX Sensitivity (per Sub-carrier)	-123.1	dBm
RX Sensitivity (Composite)	-93.9	dbM
System Gain	261.7	dB
Maximum Allowable Path Loss	236.7	dB

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Table 8 Uplink Link Budget

Mobile Station (Handset)		
Parameter	Value	Unit
Maximum MS Transmit Power/Carrier	23	dBm
TX Antenna Gain	-1.0	dBi
EIRP	22.0	dBm
UL: Number of Sub-Carriers for MS TX	*72*	
Power per Occupied Sub-carrier	3.43	dBm
MS Antenna Gain	-1	dBi
Number of MS RX Antennas (Gain)	3.0	dB
RX Noise Figure	7.0	dB

MS Noise Figure

Parameter	Value	Unit
Log- Normal Shadowing Loss	8	dB
Fast Fading Loss	2.0	dB
Interference Loss	3.0	dB
Penetration Loss	10.0	dB
Hardware Loss	2.0	dB
Total Margin	25.0	dB

Mobile Rx Sensitivity

Parameter	Value	Unit
Thermal Noise	-174	dBm/Hz
Sub-Carrier Spacing	10.94	kHz
Modulation	QPSK 1/8	
SNR Required	-2.50	dB
RX Sensitivity (per sub-carrier)	-129.1	dBm
RX Sensitivity (Composite)	-110.5	dBm
System Gain	134.5	dB

Maximum Allowable Path Loss	109.5	dB

4. Program file

The Excel spread sheet to run the downlink and uplink budgets is attached here for reference and as stated in the introduction one can change parameters entered in italic in tables from Table1 through Table 6 to identify various system architectures considered to review their resulting link budgets. To open this excel file, hit CTRL + mouse (left button)

Link-Budget