where:

N is the number of overall bytes after encoding

K is the number of data bytes before encoding

T is the number of data bytes which can be corrected.

The following polynomials are used for the systematic code:

Code Generator Polynomial: $$g(x) = (x+\lambda^0)(x+\lambda^1)(x+\lambda^2)..(x+\lambda^{2T-1}),\ \lambda = 02_{HEX} \quad (72)$$

Field Generator Polynomial: $$p(x) = x^8 + x^4 + x^3 + x^2 + 1 \quad (73)$$

This code is shortened and punctured to enable variable block sizes and variable error-correction capability. When a block is shortened to K' data bytes, the first 239-K' bytes of the encoder block shall be zero. When a codeword is punctured to permit T' bytes to be corrected, only the first 2T' of the total 16 codeword bytes shall be employed. The bit/byte conversion shall be msb first.

Each RS block is encoded by the binary convolutional encoder, which shall have native rate of 1/2, a constraint length equal to K=7, and shall use the following generator polynomials codes to derive its two code bits:

$$\begin{aligned} G_1 &= 171_{OCT} \quad FOR\ X \\ G_2 &= 133_{OCT} \quad FOR\ Y \end{aligned} \quad (74)$$

The generator is depicted in Figure 128bj.

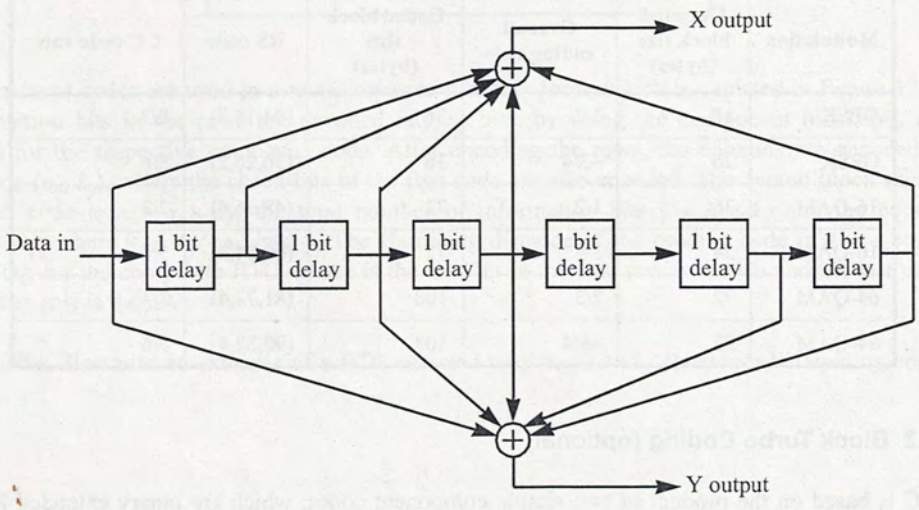


Figure 128bj—Convolutional encoder of rate 1/2

Copyright © 2003 IEEE. All rights reserved.

Puncturing patterns and serialization order which shall be used to realize different code rates are defined in Table 116cd. In the table, "1" means a transmitted bit and "0" denotes a removed bit, whereas X and Y are in reference to Figure 128bj.

Table 116cd—The inner convolutional code with puncturing configuration

	Code Rates		
Rate	2/3	3/4	5/6
d_{free}	6	5	4
X	10	101	10101
Y	11	110	11010
XY	$X_1Y_1Y_2$	$X_1Y_1Y_2X_3$	$X_1Y_1Y_2X_3Y_4X_5$

In order to allow sharing of the error correction decoder, each of the multiple data streams subdivides its data into RS blocks. Each RS block is encoded by a tail-biting convolutional encoder, which is achieved by initializing the encoders memory with the last data bits of the RS block being encoded (the packet data bits are numbered $b_b..b_n$).

Six schemes are defined, as shown in Table 116ce. As 64-QAM is optional, the codes for this modulation shall only be implemented if the modulation is implemented.

Table 116ce—Mandatory channel coding per modulation

Modulation	Uncoded block size (bytes)	Overall coding rate	Coded block size (bytes)	RS code	CC code rate
QPSK	18	1/2	36	(24,18,3)	2/3
QPSK	26	~3/4	36	(30,26,2)	5/6
16-QAM	36	1/2	72	(48,36,6)	2/3
16-QAM	54	3/4	72	(60,54,3)	5/6
64-QAM	72	2/3	108	(81,72,4)	3/4
64-QAM	82	~3/4	108	(90,82,4)	5/6

8.5.9.2.2 Block Turbo Coding (optional)

The BTC is based on the product of two simple component codes, which are binary extended Hamming codes or parity check codes from the set depicted in Table 116cf.

Copyright © 2003 IEEE. All rights reserved.

Table 116cf—BTC component codes

Component code (n,k)	Code type
(64,57)	Extended Hamming code
(32,26)	Extended Hamming code
(16,11)	Extended Hamming code
(32,31)	Parity check code
(16,15)	Parity check code
(8,7)	Parity check code

Table 116cg specifies the generator polynomials for the Hamming codes. To create extended Hamming codes, an overall even parity check bit is added at the end of each code word.

Table 116cg—Hamming code generator polynomials

n'	k'	Generator polynomial
7	4	X^3+X^1+1
15	11	X^4+X^1+1
31	26	X^5+X^2+1
63	57	X^6+X+1

The component codes are used in a two-dimensional matrix form, which is depicted in Figure 128bl. The k_x information bits in the rows are encoded into n_x bits, by using the component block (n_x, k_x) code specified for the respective composite code. After encoding the rows, the columns are encoded using a block code (n_y, k_y), where the check bits of the first code are also encoded. The overall block size of such a product code is $n = n_x \times n_y$, the total number of information bits $k = k_x \times k_y$ and the code rate is $R = R_x \times R_y$, where $R_i = k_i / n_i$, $i=x, y$. The Hamming distance of the product code is $d = d_x \times d_y$. Data bit ordering for the composite BTC matrix is the first bit in the first row is the lsb and the last data bit in the last data row is the msb.

Figure 128bk illustrates an example of a BTC encoded with (8, 4) × (8, 4) extended Hamming component codes.

Copyright © 2003 IEEE. All rights reserved.

D_{11}	D_{21}	D_{31}	D_{41}	E_{51}	E_{61}	E_{71}	E_{81}
D_{12}	D_{22}	D_{32}	D_{42}	E_{52}	E_{62}	E_{72}	E_{82}
D_{13}	D_{23}	D_{33}	D_{43}	E_{53}	E_{63}	E_{73}	E_{83}
D_{14}	D_{24}	D_{34}	D_{44}	E_{54}	E_{64}	E_{74}	E_{84}
E_{15}	E_{25}	E_{35}	E_{45}	E_{55}	E_{65}	E_{75}	E_{85}
E_{16}	E_{26}	E_{36}	E_{46}	E_{56}	E_{66}	E_{76}	E_{86}
E_{17}	E_{27}	E_{37}	E_{47}	E_{57}	E_{67}	E_{77}	E_{87}
E_{18}	E_{28}	E_{38}	E_{48}	E_{58}	E_{68}	E_{78}	E_{88}

Figure 128bk—Example of an encoded BTC block

Transmission of the block over the channel shall occur in a linear fashion, with all bits of the first row transmitted left to right followed by the second row, etc. For the $(8, 4) \times (8, 4)$ example in Figure 128bk, the output order for the 64 encoded bits would be: $D_{11}, D_{21}, D_{31}, D_{41}, E_{51}, E_{61}, E_{71}, E_{81}, D_{12}, D_{22}, \ldots, E_{88}$.

To match a required packet size, BTCs may be shortened by removing symbols from the BTC array. In the two-dimensional case, rows, columns or parts thereof can be removed until the appropriate size is reached. There are three steps in the process of shortening product codes:

Step 1) Remove I_x rows and I_y columns from the two-dimensional code. This is equivalent to shortening the constituent codes that make up the product code.

Step 2) Remove B individual bits from the first row of the two-dimensional code starting with the lsb.

Step 3) Use if the product code specified from Step 1) and Step 2) of this subclause has a non-integral number of data bytes. In this case, the Q left over lsb bits are zero filled by the encoder. After decoding at the receive end, the decoder shall strip off these unused bits and only the specified data payload is passed to the next higher level in the physical layer. The same general method is used for shortening the last code word in a message where the available data bytes do not fill the available data bytes in a code block.

These three processes of code shortening are depicted in Figure 128bl. In the first two-dimensional BTC, a non-shortened product code is shown. By comparison, a shortened BTC is shown in the adjacent two-dimensional array. The new coded block length of the code is $(n_x–I_x)(n_y–I_y)–B$. The corresponding information length is given as $(k_x–I_x)(k_y–I_y)–B–Q$. Consequently, the code rate is given by:

$$R = \frac{(k_x - I_x)(k_y - I_y) - B - Q}{(n_x - I_x)(n_y - I_y) - B} \tag{75}$$

Copyright © 2003 IEEE. All rights reserved.

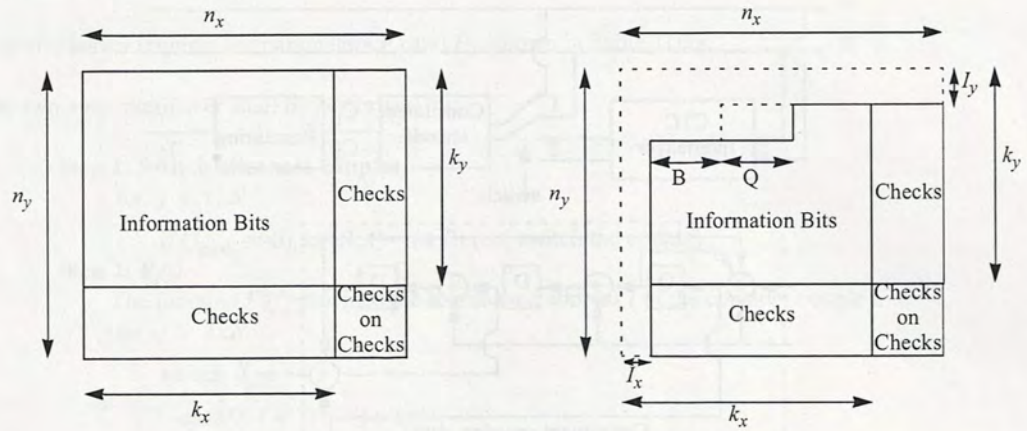


Figure 128bl—BTC and shortened BTC structure

Table 116ch gives the block sizes, code rates, channel efficiency, and code parameters for the optional modulation and coding schemes using BTC.

Table 116ch—Optional channel coding per codulation

Modulation	Data block size (bytes)	Coded block size (bytes)	Overall coding rate	Efficiency bit/s/Hz	Constituent codes	Code parameters
QPSK	16	36	~1/2	0.9	(32,26)(16,11)	I_x=11,I_y=2,B=6,Q=7
QPSK	25	36	~2/3	1.4	(8,7)(64,57)	I_x=2,I_y=16,B=0,Q=5
16-QAM	40	72	~3/5	2.2	(32,26)(32,26)	I_x=8,I_y=8,B=0,Q=4
16-QAM	56	72	~4/5	3.1	(16,15)(64,57)	I_x=4,I_y=16,B=0,Q=3
64-QAM	68	108	~5/8	3.8	(32,26)(32,26)	I_x=0,I_y=5,B=0,Q=2
64-QAM	88	108	~4/5	4.9	(16,15)(64,57)	I_x=0,I_y=10,B=0,Q=1

8.5.9.2.3 Convolutional turbo codes (optional)

8.5.9.2.3.1 CTC encoder

The Convolutional Turbo Code encoder, including its constituent encoder, is depicted in Figure 128bm. It uses a double binary Circular Recursive Systematic Convolutional code. The bits of the data to be encoded are alternately fed to *A* and *B*, starting with the msb of the first byte being fed to *A*. The encoder is fed by blocks of k bits or N couples ($k = 2*N$ bits). For all the frame sizes k is a multiple of 8 and N is a multiple of 4. Further N shall be limited to: $8 \leq N/4 \leq 1024$.

The polynomials defining the connections are described in octal and symbol notations as follows:

— For the feedback branch: 0xB, equivalently $1+D+D^3$ (in symbolic notation)
— For the *Y* parity bit: 0xD, equivalently $1+D^2+D^3$

Copyright © 2003 IEEE. All rights reserved.

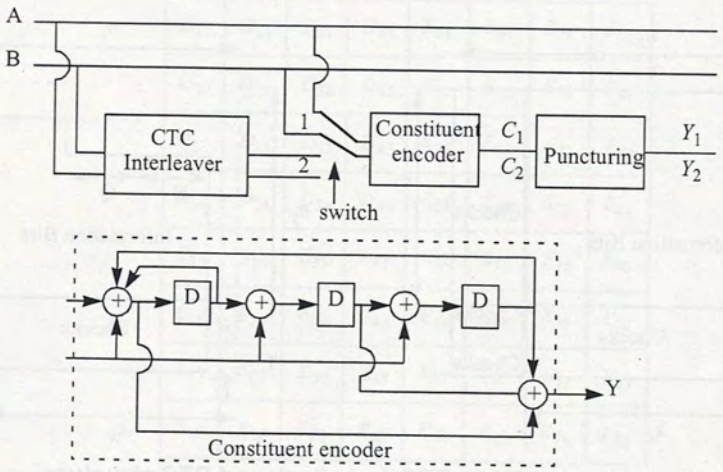


Figure 128bm—CTC encoder

First, the encoder (after initialization by the circulation state Sc_1, see 8.5.9.2.3.3) is fed the sequence in the natural order (position 1) with the incremental address $i = 0 .. N–1$. This first encoding is called C_1 encoding. Then the encoder (after initialization by the circulation state Sc_2, see 8.5.9.2.3.3) is fed by the interleaved sequence (switch in position 2) with incremental address $j = 0, \ldots N–1$. This second encoding is called C_2 encoding.

The order in which the encoded bit shall be fed into the interleaver (8.5.9.3) is:

$$A_0, B_0 .. A_{N-1}, B_{N-1}, Y_{10}, Y_{1,1} .. Y_{1,M}, Y_{20}, Y_{2,1} .. Y_{2,M},$$

where M is the number of parity bits.

Table 116ci gives the block sizes, code rates, channel efficiency, and code parameters for the different modulation and coding schemes. As 64-QAM is optional, the codes for this modulation shall only be implemented if the modulation is implemented.

Table 116ci—Optional CTC channel coding per modulation

Modulation	Data block size (bytes)	Coded block size (bytes)	Overall code rate	N	P_0	P_1	P_2	P_3
QPSK	18	36	1/2	72	11	6	0	6
QPSK	24	36	2/3	96	7	48	24	72
QPSK	27	36	3/4	108	11	54	56	2
16-QAM	36	72	1/2	144	17	74	72	2
16-QAM	54	72	3/4	216	31	2	4	10
64-QAM	72	108	2/3	288	13	144	72	216
64-QAM	81	108	3/4	324	11	172	164	16

Copyright © 2003 IEEE. All rights reserved.

8.5.9.2.3.2 CTC interleaver

The interleaver requires the parameters P_0 and P_1, shown in Table 116ci.

The two-step interleaver shall be performed by:

Step 1: Switch alternate couples

for $j = 1..N$

if (j_{mod_2} ==0) let $(B,A) = (A,B)$ (i.e. switch the couple)

Step 2: $P_i(j)$

The function $P_i(j)$ provides the interleaved address i of the consider couple j.

for $j = 1..N$

switch j_{mod_4} :

case 0: $i = (P_0 \cdot j + 1)_{\mathrm{mod}_N}$

case 1: $i = (P_0 \cdot j + 1 + N/2 + P_1)_{\mathrm{mod}_N}$

case 2: $i = (P_0 \cdot j + 1 + P_2)_{\mathrm{mod}_N}$

case 3: $i = (P_0 \cdot j + 1 + N/2 + P_3)_{\mathrm{mod}_N}$

8.5.9.2.3.3 Determination of CTC circulation states

The state of the encoder is denoted S ($0 <= S == 7$) with S the value read binary (left to right) out of the constituent encoder memory (see Figure 128bm). The circulation states Sc_1 and Sc_2 are determined by the following operations:

1) Initialize the encoder with state 0. Encode the sequence in the natural order for the determination of Sc_1 or in the interleaved order for determination of Sc_2. In both cases the final state of the encoder is $S0_{N-1}$;
2) according to the length N of the sequence, use Figure 116cj to find Sc_1 or Sc_2.

Table 116cj—Circulation state lookup table (*Sc*)

N_{mod_7}	$S0_{N-1}$							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	0	6	4	2	7	1	3	5
2	0	3	7	4	5	6	2	1
3	0	5	3	6	2	7	1	4
4	0	4	1	5	6	2	7	3
5	0	2	5	7	1	3	4	6
6	0	7	6	1	3	4	5	2

Copyright © 2003 IEEE. All rights reserved.

8.5.9.2.3.4 CTC puncturing

The three code-rates are achieved through selectively deleting the parity bits (puncturing). The puncturing patterns are identical for both codes C_1 and C_2.

Table 116ck—Circulation state lookup table (*Sc*)

Rate $R_n/(R_n+1)$	Y					
	0	1	2	3	4	5
1/2	1	1				
2/3	1	0	1	0		
3/4	1	0	0	1	0	0

8.5.9.3 Interleaving

All encoded data bits shall be interleaved by a block interleaver with a block size corresponding to the number of coded bits per the specified allocation, N_{cbps} (see Table 116cl). The interleaver is defined by a two-step permutation. The first ensures that adjacent coded bits are mapped onto nonadjacent carriers. The second permutation insures that adjacent coded bits are mapped alternately onto less or more significant bits of the constellation, thus avoiding long runs of lowly reliable bits.

Table 116cl—Bit Interleaved Block Sizes and Modulo

Modulation	Coded bits per bit interleaved block (N_{cbps})	Modulo used (d)
QPSK	288	16
16-QAM	576	18
64-QAM	864	16

Let N_{cpc} be the number of coded bits per carrier, i.e., 2, 4 or 6 for QPSK, 16Q-AM or 64-QAM, respectively. Let $s = N_{cpc}/2$. Let k be the index of the coded bit before the first permutation at transmission, m be the index after the first and before the second permutation and j be the index after the second permutation, just prior to modulation mapping, and d be the modulo used for the permutation.

The first permutation is defined by the rule:

$$m = (N_{cbps}/\ d)\cdot\ k_{mod(d)} + floor(k/\ d) \qquad k = 0,\ 1,\ ..,\ N_{cbps} - 1 \tag{76}$$

The second permutation is defined by the rule:

$$j = s\cdot\ floor(m/\ s) + (m + N_{cbps} - floor(d\cdot\ m/\ N_{cbps}))_{mod\ s} \qquad m = 0,\ 1,\ ..,\ N_{cbps} - 1 \tag{77}$$

The de-interleaver, which performs the inverse operation, is also defined by two permutations. Let j be the index of the received bit before the first permutation, m be the index after the first and before the second permutation and k be the index after the second permutation, just prior to delivering the coded bits to the convolutional decoder.

Copyright © 2003 IEEE. All rights reserved.

The first permutation is defined by the rule:

$$m = s \cdot floor(j/\ s) + (j + floor(d \cdot\ j/\ N_{cbps}))_{mod\ s} \qquad j = 0,\ 1,\ ..,\ N_{cbps} - 1 \tag{78}$$

The second permutation is defined by the rule:

$$k = d \cdot\ m - (N_{cbps} - 1) \cdot\ floor(d \cdot\ m/\ N_{cbps}) \qquad m = 0,\ 1,\ ..,\ N_{cbps} - 1 \tag{79}$$

The first permutation in the de-interleaver is the inverse of the second permutation in the interleaver, and conversely.

8.5.9.4 Modulation

8.5.9.4.1 Data modulation

After bit interleaving, the data bits are entered serially to the constellation mapper. Gray-mapped QPSK and 16-QAM as shown in Figure 128bn shall be supported, whereas the support of 64-QAM is optional. The constellations as shown in Figure 128bn shall be normalized by multiplying the constellation point with the indicated factor c to achieve equal average power.

Per-allocation adaptive modulation and coding shall be supported in the DL. The UL shall support different modulation schemes for each SS based on the MAC burst configuration messages coming from the Base Station. Complete description of the MAC / PHY support of adaptive modulation and coding is provided in 6.2.7.

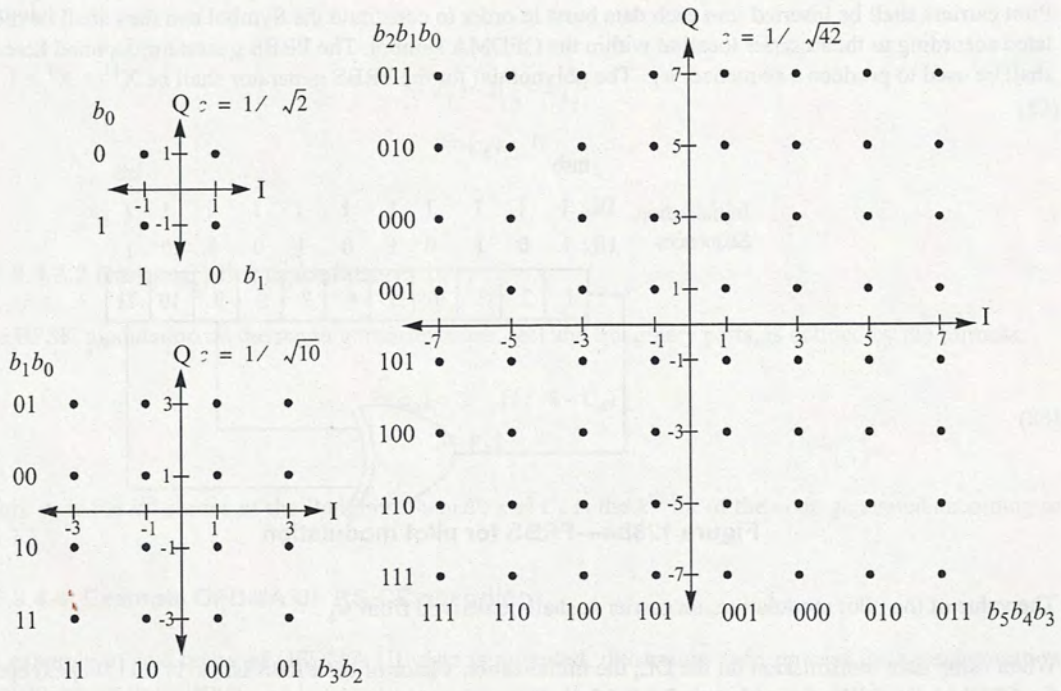


Figure 128bn—QPSK, 16-QAM and 64-QAM constellations

The constellation-mapped data shall be subsequently modulated onto the allocated data carriers.

Copyright © 2003 IEEE. All rights reserved.

8.5.9.4.2 Modulation and coding in the DL frame prefix

Rate_ID's, which indicate modulation and coding to be used in the first DL burst immediately following the FCH, are shown in Table 116cm. The Rate_ID encoding is static and cannot be changed during system operation.

Table 116cm—Rate ID encodings

Rate_ID	Modulation RS-CC rate
0	QPSK 1/2
1	QPSK 3/4
2	16-QAM 1/2
3	16-QAM 3/4
4	64-QAM 2/3
5	64-QAM 3/4
6–15	Reserved

8.5.9.4.3 Pilot modulation

Pilot carriers shall be inserted into each data burst in order to constitute the Symbol and they shall be modulated according to their carrier location within the OFDMA symbol. The PRBS generator depicted hereafter shall be used to produce a sequence, w_k. The polynomial for the PRBS generator shall be $X^{11} + X^9 + 1$.

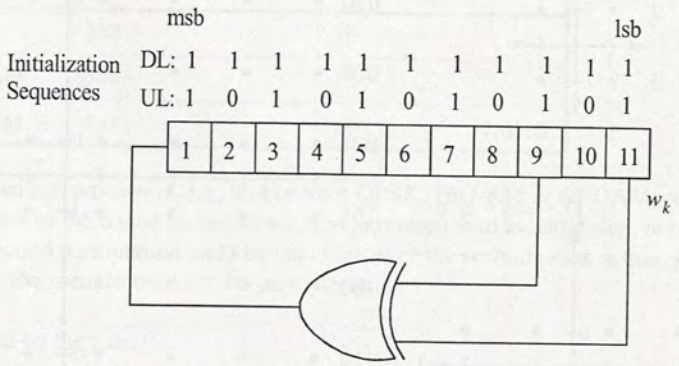


Figure 128bo—PRBS for pilot modulation

The value of the pilot modulation, on carrier k, shall be derived from w_k.

When using data transmission on the DL, the initialization vector of the PRBS is: [11111111111] except for the OFDMA DL PHY preamble (see 8.5.9.4.3.1). When using data transmission on the UL the initialization vector of the PRBS shall be: [10101010101]. These initializations result in the sequence w_k=11111111111000000001..... in the DL, and the sequence w_k=10101010101000000000.... in the UL. The PRBS shall be initialized so that its first output bit coincides with the first usable carrier (as defined in Table 116cb). A new value shall be generated by the PRBS on every usable carrier. For the PRBS allocation, the

Copyright © 2003 IEEE. All rights reserved.

DC carrier and the side-band carriers are not considered as usable carriers. Each pilot shall be transmitted with a boosting of 2.5 dB over the average power of each data tone, (including the UL preamble). The Pilot carriers shall be modulated according to the following formula:

$$\begin{aligned} \mathrm{Re}\{c_k\} &= \frac{8}{3}\left(\frac{1}{2} - w_k\right) \\ \mathrm{Im}\{c_k\} &= 0 \end{aligned} \tag{80}$$

A ranging pilot modulation exception is defined in 8.5.9.4.3.2.

8.5.9.4.3.1 Preambles pilot modulation

The initialization vector of the pilot modulation PRBS (defined in 8.5.9.4.3) for the symbol in which the DL-MAP message starts, and two consecutive symbols thereafter is [01010101010]. These three symbols serve as the OFDMA DL preamble, in the sense that they indicate where the OFDMA frame starts. The pilots shall be boosted and shall be modulated according to the following formula:

$$\begin{aligned} \mathrm{Re}\{c_k\} &= \frac{8}{3}\left(\frac{1}{2} - w_k\right) \\ \mathrm{Im}\{c_k\} &= 0 \end{aligned} \tag{81}$$

For the UL preamble, the pilots shall not be boosted and shall be modulated according to the following formula

$$\begin{aligned} \mathrm{Re}\{c_k\} &= 2\left(\frac{1}{2} - w_k\right) \\ \mathrm{Im}\{c_k\} &= 0 \end{aligned} \tag{82}$$

8.5.9.4.3.2 Ranging pilot modulation

The BPSK modulation on the ranging transmissions, real and imaginary parts, is defined by the formula:

$$\begin{aligned} \mathrm{Re}\{c_k\} &= 2 \cdot (1/2 - C_k) \\ \mathrm{Im}\{c_k\} &= 0 \end{aligned} \tag{83}$$

where c_k is the k^{th} carrier of the Ranging Channel, and C_k is the k^{th} bit of the code generated according to 8.5.7.3

8.5.9.4.4 Example OFDMA UL RS-CC encoding

An example of one frame of OFDMA UL data is provided, illustrating each process from randomization through carrier modulation.

Modulation mode: 16-QAM-1/2, Slot Offset: 50, Subchannel Offset: 3, ID_{cell}: 5, UIUC: 4 (decimal values).

Copyright © 2003 IEEE. All rights reserved.

Input Data (Hex)

45 29 C4 79 AD 0F 55 28 AD 87 B5 76 1A 9C 80 50 45 1B 9F D9 2A 88 95 EB AE B5 2E 03 4F 09 14 69 58 0A 5D F5

Randomized Data (Hex)

5B 23 80 44 35 82 06 07 47 67 CB 37 1F 1A 9D 44 0B 62 3A CC F4 F4 50 E1 30 8A 6A 80 D4 00 4E 5E 84 BA 96 57

Reed-Solomon encoded Data (Hex)

5B 23 80 44 35 82 06 07 47 67 CB 37 1F 1A 9D 44 0B 62 3A CC F4 F4 50 E1 30 8A 6A 80 D4 00 4E 5E 84 BA 96 57 3A CE 4E 81 36 AB DA 26 13 3E D1 3B

Convolutional encoded Data (Hex)

F4 51 D6 42 63 7E D1 B0 90 E7 B2 BA A5 1B E8 BA 57 B5 37 BC F7 66 B1 A6 CF 04 A4 39 69 77 02 79 A7 5D D9 05 64 F7 FF F0 BC 3E ED EA C0 34 F2 11 AF 30 E8 A5 B7 A7 EC E9 71 27 FC FF A4 44 F7 48 AA 42 ED 92 03 5E 2C 7F

Interleaved Data (Hex)

72 4C 64 A4 06 5F 16 57 99 F2 3B F2 AC 15 D2 B7 46 62 0E A0 C2 05 FD FA 8B B3 10 F5 6C 7A 9E 43 77 E5 BB 1F F2 4F 1B 9F 93 5A E3 5C ED F6 12 7E 3C 45 3B 94 CB 63 24 A1 BC F7 E3 9B BE 8F BD 2F CD 23 2E F5 42 B2 C9 8F

Carrier Mapping (subchannel carrier number - usable carrier number: I value Q value,) preamble not shown.

0-13: 4/3 0, 1-53: 3 -3, 2-79: 1 -1, 3-112: 3 1, 4-148: -3 1, 5-191: 3 -1, 6-219: 3 1, 7-235: -1 -1, 8-270: 3 1, 9-288: 1 1, 10-345: 3 -1, 11-382: 3 3, 12-390: -3 -3, 13-418: -4/3 0, 14-460: 1 3, 15-506: 3 -1, 16-522: 3 3, 17-545: 3 -3, 18-580: -1 3, 19-636: -1 3, 20-662: -3 -3, 21-681: 1 -1, 22-733: 1 -3, 23-741: -1 -3, 24-786: -3 -3, 25-817: 1 -1, 26-856: -4/3 0, 27-883: 4/3 0, 28-899: -1 -1, 29-936: -3 1, 30-983: 1 3, 31-999: 3 3, 32-1042: -3 3, 33-1082: 1 -1, 34-1108: -1 -3, 35-1141: 3 -3, 36-1177: 3 1, 37-1188: 3 -1, 38-1216: 3 -1, 39-1264: 1 -1, 40-1299: -4/3 0, 41-1317: 1 1, 42-1374: -3 -1, 43-1379: -1 -1, 44-1419: 1 1, 45-1447: -3 1, 46-1489: 1 -1, 47-1535: 1 1, 48-1551: 3 3, 49-1574: -3 -3, 50-1609: -3 3, 51-1633: -3 -3, 52-1691: -1 -1,
0-13: -1 1, 1-53: -1 -3, 2-79: 4/3 0, 3-112: -1 -3, 4-148: 1 -3, 5-191: 1 3, 6-219: 1 1, 7-235: -3 -3, 8-270: 3 3, 9-288: 3 -1, 10-345: -3 1, 11-382: 3 -3, 12-390: -1 -1, 13-418: -1 3, 14-460: -3 -1, 15-506: -4/3 0, 16-522: 3 1, 17-545: 1 -3, 18-580: 3 -3, 19-636: 3 -3, 20-662: -3 -1, 21-681: 3 3, 22-733: -1 -3, 23-741: -1 -3, 24-786: 1 3, 25-817: -3 -3, 26-856: -4/3 0, 27-883: -3 -3, 28-899: 1 -1, 29-936: -4/3 0, 30-983: 3 1, 31-999: -3 -3, 32-1042: 1 3, 33-1082: -1 -3, 34-1108: -1 3, 35-1141: -3 -3, 36-1177: -1 3, 37-1188: 1 -3, 38-1216: 3 3, 39-1264: -1 -1, 40-1299: -3 -1, 41-1317: 1 -3, 42-1374: 4/3 0, 43-1379: 3 3, 44-1419: -3 1, 45-1447: -3 -1, 46-1489: -3 3, 47-1535: -3 -3, 48-1551: 3 -1, 49-1574: 1 3, 50-1609: 1 -1, 51-1633: 3 -3, 52-1691: -3 -1,
0-13: 1 -3, 1-53: -3 1, 2-79: 3 1, 3-112: 3 3, 4-148: 4/3 0, 5-191: 1 -3, 6-219: -1 -3, 7-235: -1 3, 8-270: 3 1, 9-288: -3 1, 10-345: -1 -3, 11-382: 3 -1, 12-390: 1 -3, 13-418: 1 -1, 14-460: 3 1, 15-506: -1 -1, 16-522: 1 3, 17-545: -4/3 0, 18-580: -1 -3, 19-636: -3 1, 20-662: -3 -3, 21-681: 3 -3, 22-733: -3 -1, 23-741: 1 -3, 24-786: -1 3, 25-817: -1 -3, 26-856: 4/3 0, 27-883: -1 -3, 28-899: -3 -1, 29-936: -1 1, 30-983: -3 -3, 31-999: -4/3 0, 32-1042: -1 -3, 33-1082: -3 3, 34-1108: 1 -1, 35-1141: -3 -3, 36-1177: -3 1, 37-1188: -3 3, 38-1216: 1 -1, 39-1264: 1 -3, 40-1299: 1 -1, 41-1317: -3 -1, 42-1374: -3 -3, 43-1379: 3 3, 44-1419: -4/3 0, 45-1447: 3 1, 46-1489: 1 -1, 47-1535: -1 -3, 48-1551: 1 -1, 49-1574: -3 1, 50-1609: -1 3, 51-1633: -1 1, 52-1691: -3 -3.

Copyright © 2003 IEEE. All rights reserved.

8.5.10 Control mechanisms

8.5.10.1 Synchronization

8.5.10.1.1 Network synchronization

For TDD and FDD realizations, it is recommended (but not required) that all BSs be time synchronized to a common timing signal. In the event of the loss of the network timing signal, BSs shall continue to operate and shall automatically resynchronize to the network timing signal when it is recovered. The synchronizing reference shall be a 1pps timing pulse and a 10 MHz frequency reference. These signals are typically provided by a GPS receiver.

For both FDD and TDD realizations, frequency references derived from the timing reference may be used to control the frequency accuracy of Base-Stations provided that they meet the frequency accuracy requirements of 8.5.14. This applies during normal operation and during loss of timing reference.

8.5.10.1.2 SS synchronization

For any duplexing, all SSs shall acquire and adjust their timing such that all uplink OFDM symbols arrive time coincident at the Base-Station to a accuracy of +/– 25% of the minimum guard-interval or better.

8.5.10.2 Ranging

Ranging for time (coarse synchronization) and power is performed during two phases of operation: during (re)registration and when synchronization is lost; and second, during FDD or TDD transmission on a periodic basis.

During registration, a new subscriber registers using the random access channel, and if successful, is entered into a ranging process under control of the base station. The ranging process is cyclic in nature where default time and power parameters are used to initiate the process followed by cycles where (re)calculated parameters are used in succession until parameters meet acceptance criteria for the new subscriber. These parameters are monitored, measured, and stored at the base station, and transmitted to the subscriber unit for use during normal exchange of data. During normal exchange of data, the stored parameters are updated in a periodic manner based on configurable update intervals to ensure changes in the channel can be accommodated. The update intervals shall vary in a controlled manner on a subscriber unit by subscriber unit basis.

Ranging on re-registration follows the same process as new registration.

8.5.10.3 Power control

A power control algorithm shall be supported for the uplink channel with both an initial calibration and periodic adjustment procedure without loss of data. The base station should be capable of providing accurate power measurements of the received burst signal. This value can then be compared against a reference level, and the resulting error can be fed back to the subscriber station in a calibration message coming from the MAC sublayer. The power control algorithm shall be designed to support power attenuation due to distance loss or power fluctuations at rates of at most 30 dB/second with depths of at least 10 dB. The exact algorithm implementation is vendor-specific. The total power control range consists of both a fixed portion and a portion that is automatically controlled by feedback. The power control algorithm shall take into account the interaction of the RF power amplifier with different burst profiles. For example, when changing from one burst profile to another, margins should be maintained to prevent saturation of the amplifier and to prevent violation of emissions masks.

Copyright © 2003 IEEE. All rights reserved.

8.5.11 Channel quality measurements

8.5.11.1 Introduction

RSSI and CINR signal quality measurements and associated statistics can aid in such processes as BS selection/assignment and burst adaptive profile selection. As channel behavior is time-variant, both mean and standard deviation are defined. Implementation of the RSSI and CINR statistics and their reports is mandatory.

The process by which RSSI measurements are taken does not necessarily require receiver demodulation lock; for this reason, RSSI measurements offer reasonably reliable channel strength assessments even at low signal levels. On the other hand, although CINR measurements require receiver lock, they provide information on the actual operating condition of the receiver, including interference and noise levels, and signal strength.

8.5.11.2 RSSI mean and standard deviation

When collection of RSSI measurements is mandated by the BS, a SS shall obtain an RSSI measurement from the data associated with MAC map messages. From a succession of RSSI measurements, the SS shall derive and update estimates of the mean and the standard deviation of the RSSI, and report them when solicited via REP-RSP messages.

Mean and standard deviation statistics shall be reported in units of dBm. To prepare such reports, statistics shall be quantized in 1 dB increments, ranging from –40 dBm (encoded 0x53) to –123 dBm (encoded 0x00). Values outside this range shall be assigned the closest extreme value within the scale.

The method used to estimate the RSSI of a single message is left to individual implementation, but the relative accuracy of a single signal strength measurement, taken from a single message, shall be +/– 2 dB, with an absolute accuracy of +/– 4 dB. This shall be the case over the entire range of input RSSIs. In addition, the range over which these single-message measurements are measured should extend 3 dB on each side beyond the –40 dBm to –123 dBm limits for the final averaged statistics that are reported.

The (linear) mean RSSI statistics (in mW), derived from a multiplicity of single messages, shall be updated using

$$\hat{\mu}_{RSSI}[k] = \begin{cases} R[0] & k = 0 \\ (1-\alpha_{avg})\hat{\mu}_{RSSI}[k-1] + \alpha_{avg}R[k] & k > 0 \end{cases} \quad \text{mW} \tag{84}$$

where k is the time index for the message (with the initial message being indexed by $k = 0$, the next message by $k = 1$, etc.), $R[k]$ is the RSSI in mW measured during message k, and α_{avg} is an averaging parameter specified by the BS. The mean estimate in dBm shall then be derived from

$$\mu_{RSSI\,dBm}[k] = 10\log(\mu_{RSSI}[k]) \quad \text{dBm}. \tag{85}$$

To solve for the standard deviation in dB, the expectation-squared statistic shall be updated using

$$\hat{x}^2_{RSSI}[k] = \begin{cases} |R[0]|^2 & k = 0 \\ (1-\alpha_{avg})\hat{x}^2_{RSSI}[k-1] + \alpha_{avg}|R[k]|^2 & k > 0 \end{cases} \tag{86}$$

and the result applied to

$$\hat{\sigma}_{RSSI\,dB} = 5\log(\left|\hat{x}^2_{RSSI}[k] - (\hat{\mu}_{RSSI}[k])^2\right|) \quad \text{dB}. \tag{87}$$

Copyright © 2003 IEEE. All rights reserved.

8.5.11.3 CINR mean and standard deviation

When Carrier-to-Interference-and-Noise-Ratio (CINR) measurements are mandated by the BS, a SS shall obtain a CINR measurement from the data associated with MAC map messages. From a succession of these measurements, the SS shall derive and update estimates of the mean and the standard deviation of the CINR, and report them when solicited via REP-RSP messages.

Mean and standard deviation statistics for CINR shall be reported in units of dB. To prepare such reports, statistics shall be quantized in 1 dB increments, ranging from a minimum of –10 dB (encoded 0x00) to a maximum of 53 dB (encoded 0x3F). Values outside this range shall be assigned the closest extreme value within the scale.

The method used to estimate the CINR of a single message is left to individual implementation, but the relative and absolute accuracy of a CINR measurement derived from a single message shall be +/– 1 dB and +/– 2 dB, respectively, for all input CINRs above 0 dB. In addition, the range over which these single-packet measurements are measured should extend 3 dB on each side beyond the –10 dB to 53 dB limits for the final reported, averaged statistics.

One possible method to estimate the CINR of a single message is to compute the ratio of signal power to residual error for each data sample, and then average the results from each data sample, using

$$CINR[k] = \sum_{n=0}^{N-1} \frac{|s[k,\ n]|^2}{|r[k,\ n] - s[k,\ n]|^2} \tag{88}$$

where $r[k,\ n]$ received sample n within message k; $s[k,\ n]$ the corresponding detected or pilot sample (with channel state weighting) corresponding to received symbol n.

The mean CINR statistic (in dB) shall be derived from a multiplicity of single messages using

$$\hat{\mu}_{CINR\ dB}[k] = 10\log(\hat{\mu}_{CINR}[k]), \tag{89}$$

where

$$\hat{\mu}_{CINR}[k] = \begin{cases} CINR[0] & k = 0 \\ (1-\alpha_{avg})\hat{\mu}_{CINR}[k-1] + \alpha_{avg} CINR[k] & k > 0 \end{cases} \tag{90}$$

k is the time index for the message (with the initial message being indexed by $k = 0$, the next message by $k = 1$, etc.); $CINR[k]$ is a linear measurement of CINR (derived by any mechanism which delivers the prescribed accuracy) for message k; and α_{avg} is an averaging parameter specified by the BS.

To solve for the standard deviation, the expectation-squared statistic shall be updated using

$$\hat{x}^2_{CINR}[k] = \begin{cases} |CINR[0]|^2 & k = 0 \\ (1-\alpha_{avg})\hat{x}^2_{CINR}[k-1] + \alpha_{avg}|CINR[k]|^2 & k > 0 \end{cases} \tag{91}$$

and the result applied to

$$\hat{\sigma}_{CINR\ dB} = 5\log\left(\left|\hat{x}^2_{CINR}[k] - (\hat{\mu}_{CINR}[k])^2\right|\right) \quad \text{dB}. \tag{92}$$

Copyright © 2003 IEEE. All rights reserved.

8.5.12 Transmitter requirements

8.5.12.1 Transmit power level control

The transmitter shall support monotonic power level control of 45 dB (30 dB for license-exempt bands) minimum with a minimum step size of 1 dB and a relative accuracy of +/– 0.5 dB.

8.5.12.2 Transmitter spectral flatness

The average energy of the constellations in each of the n spectral lines shall deviate no more than indicated in Table 116cn. The absolute difference between adjacent carriers shall not exceed 0.06 dB excluding intentional boosting or suppression of carriers.

Table 116cn—Spectral flatness

Spectral lines	Spectral flatness
Spectral lines from $-N_{used}/4$ to -1 and $+1$ to $N_{used}/4$	+/–2 dB from the measured energy averaged over all N_{used} active tones
Spectral lines from $-N_{used}/2$ to $-N_{used}/4$ and $+N_{used}/4$ to $N_{used}/2$	+2/–4 dB from the measured energy averaged over all N_{used} active tones

This data shall be taken from the channel estimation step.

8.5.12.3 Transmitter constellation error and test method

To ensure that the receiver SNR does not degrade more than 0.5 dB due to the transmitter SNR, the relative constellation RMS error, averaged over carriers, OFDM frames, and packets, shall not exceed a burst profile dependent value according to Table 116co.

Table 116co—Allowed relative constellation error versus data rate

Burst type	Relative constellation error (dB)
QPSK-1/2	–19.4
QPSK-3/4	–21.2
16-QAM-1/2	–26.4
16-QAM-3/4	–28.2
64-QAM-2/3	–32.7
64-QAM-3/4	–34.4

All measurement errors taken together shall be 10 dB less than the required noise level, i.e., if a specification is TX S/N = 10 dB, the measurement S/N should be at least 20 dB. For all PHY modes, measurements shall be taken with all non-guard carriers active.

Copyright © 2003 IEEE. All rights reserved.

The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure [B30]:

a) Start of frame shall be detected.

b) Transition from short sequences to channel estimation sequences shall be detected, and fine timing (with one sample resolution) shall be established.

c) Coarse and fine frequency offsets shall be estimated.

d) The packet shall be de-rotated according to estimated frequency offset.

e) The complex channel response coefficients shall be estimated for each of the carriers.

f) For each of the data OFDM symbols: transform the symbol into carrier received values, estimate the phase from the pilot carriers, de-rotate the carrier values according to estimated phase, and divide each carrier value with a complex estimated channel response coefficient.

g) For each data-carrying carrier, find the closest constellation point and compute the Euclidean distance from it.

h) Compute the RMS average of all errors in a packet. It is given by:

$$\text{Error}_{RMS} = \frac{\sum_{i=1}^{N_f} \left[\sum_{j=1}^{L_P} \sum_{k=1}^{N_{FFT}} \left\{ (I(i,j,k) - I_0(i,j,k))^2 + (Q(i,j,k) - Q_0(i,j,k))^2 \right\} \right]}{P_0 \cdot L_P \cdot N_{FFT}} \Bigg/ N_f \qquad (93)$$

where

L_P is the length of the packet;

N_f is the number of frames for the measurement;

($I_0(i,j,k)$, $Q_0(i,j,k)$) denotes the ideal symbol point of the i^{th} frame, j^{th} OFDM symbol of the frame, k^{th} carrier of the OFDM symbol in the complex plane;

(I(i,j,k), Q(i,j,k)) denotes the observed point of the i^{th} frame, j^{th} OFDM symbol of the frame,

k^{th} is the carrier of the OFDM symbol in the complex plane;

P_0 is the average power of the constellation.

8.5.13 Receiver requirements

8.5.13.1 Receiver sensitivity

The bit error rate (BER) shall be less than 10^{-6} at the power levels shown in Table 116cp for standard message and test conditions. If the implemented bandwidth is not listed, then the values for the nearest smaller listed bandwidth shall apply. The minimum input levels are measured as follows:

— At the antenna connector or through a calibrated radiated test environment,

— Using the defined standardized message packet formats, and

— Using an AWGN channel.

Copyright © 2003 IEEE. All rights reserved.

Table 116cp—Receiver minimum input level sensitivity (dBm)

Bandwidth (MHz)	QPSK		16-QAM		64-QAM	
	1/2	3/4	1/2	3/4	2/3	3/4
1.5	–91	–89	–84	–82	–78	–76
1.75	–90	–87	–83	–81	–77	–75
3	–88	–86	–81	–79	–75	–73
3.5	–87	–85	–80	–78	–74	–72
5	–86	–84	–79	–77	–72	–71
6	–85	–83	–78	–76	–72	–70
7	–84	–82	–77	–75	–71	–69
10	–83	–81	–76	–74	–69	–68
12	–82	–80	–75	–73	–69	–67
14	–81	–79	–74	–72	–68	–66
20	–80	–78	–73	–71	–66	–65

Table 116cp (as well as Table 116co) are derived assuming 5 dB implementation loss, a Noise Figure of 7 dB and receiver SNR and E_b/N_0 values as listed in Table 116cq.

Table 116cq—Receiver SNR and E_b/N_0 assumptions

Modulation	E_b/N_0 (dB)	Coding rate	Receiver SNR (dB)
QPSK	10.5	1/2	9.4
		3/4	11.2
16-QAM	14.5	1/2	16.4
		3/4	18.2
64-QAM	19.0	2/3	22.7
		3/4	24.4

Test messages for measuring Receiver Sensitivity shall be based on a continuous stream of MAC PDUs, each with a payload consisting of a R times repeated sequence $S_{modulation}$. For each modulation, a different sequence applies:

Copyright © 2003 IEEE. All rights reserved.

S_{QPSK} = [0xE4, 0xB1, 0xE1, 0xB4]
S_{16QAM} = [0xA8, 0x20, 0xB9, 0x31, 0xEC, 0x64, 0xFD, 0x75] (94)
S_{64QAM} = [0xB6, 0x93, 0x49, 0xB2, 0x83, 0x08, 0x96, 0x11, 0x41, 0x92, 0x01, 0x00,
0xBA, 0xA3, 0x8A, 0x9A, 0x21, 0x82, 0xD7, 0x15, 0x51, 0xD3, 0x05,
0x10, 0xDB, 0x25, 0x92, 0xF7, 0x97, 0x59, 0xF3, 0x87, 0x18, 0xBE,
0xB3, 0xCB, 0x9E, 0x31, 0xC3, 0xDF, 0x35, 0xD3, 0xFB, 0xA7,
0x9A, 0xFF, 0xB7, 0xDB]

For each mandatory test message, the $(R,S_{modulation})$ tuples that shall apply are:

Short length test message payload (288 data bytes): $(72,S_{QPSK})$, $(36,S_{16QAM})$, $(6,S_{64QAM})$
Mid length test message payload (864 data bytes): $(216,S_{QPSK})$, $(108,S_{16QAM})$, $(18,S_{64QAM})$
Long length test message payload (1536 data bytes): $(384,S_{QPSK})$, $(192,S_{16QAM})$, $(32,S_{64QAM})$

The test condition requirements are the following:

— ambient room temperature
— shielded room
— conducted measurement at the RF port if available
— radiated measurement in a calibrated test environment if the antenna is integrated
— RS FEC is enabled.

The test shall be repeated for each test message length and for each $(R,S_{modulation})$ tuple as identified above, using the mandatory FEC scheme. The results shall meet or exceed the sensitivity requirements set out in Table 116cp.

8.5.13.2 Receiver adjacent and alternate channel rejection

The adjacent channel rejection and alternate channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate dependent receiver sensitivity (see Table 116cp) and raising the power level of the interfering signal until the specified error rate is obtained. The power difference between the interfering signal and the desired channel is the corresponding adjacent channel rejection. The interfering signal in the adjacent channel shall be a conforming OFDM signal, not synchronized with the signal in the channel under test. For non-adjacent channel testing the test method is identical except the interfering channel shall be any channel other than the adjacent channel or the co-channel.

For the PHY to be compliant, the minimum rejection shall exceed the following:

Table 116cr—Adjacent and non-adjacent channel rejection

Modulation/coding	Adjacent channel rejection (dB)	Non-adjacent channel rejection (dB)
16-QAM-3/4	11	30
64-QAM-2/3	4	23

Copyright © 2003 IEEE. All rights reserved.

8.5.13.3 Receiver maximum input signal

The receiver shall be capable of receiving a maximum on-channel signal of –30 dBm, and shall tolerate a maximum signal of 0 dBm without damage.

8.5.13.4 Receiver linearity

The receiver shall have a minimum Input Intercept Point (IIP3) of –10 dBm.

8.5.14 Frequency control requirements

8.5.14.1 Center frequency and symbol clock frequency tolerance

At the BS, the transmitted center frequency, receive center frequency and the symbol clock frequency shall be derived from the same reference oscillator. At the BS the reference frequency tolerance shall be +/– 2 ppm.

At the SS, both the transmitted center frequency and the symbol clock frequency shall be synchronized to the BS with a tolerance of maximum 2% of the carrier spacing.

For Mesh capable devices, all devices shall have a +/– 20 ppm maximum frequency tolerance and achieve synchronization to its neighboring nodes with a tolerance of maximum 3% of the carrier spacing.

During the synchronization period, the SS shall acquire frequency synchronization within the specified tolerance before attempting any uplink transmission. During normal operation, the SS shall track the frequency changes and shall defer any transmission if synchronization is lost.

8.6 WirelessHUMAN specific components

8.6.1 Channelization

The channel center frequency shall follow the formula:

$$\text{Channel center frequency (MHz)} = 5000 + 5\, n_{ch} \tag{95}$$

where n_{ch} = 0,1,...199. This definition provides an 8-bit unique numbering system for all channels, with 5 MHz spacing, from 5 GHz to 6 GHz. This provides flexibility to define channelization sets for current and future regulatory domains. The set of allowed channel numbers is shown in Table 116cs for two regulatory domains. The support of any individual band in the table is not mandatory, but all channels within a band shall be supported.

Copyright © 2003 IEEE. All rights reserved.

Figure 128bp depicts the 20 MHz channelization scheme listed in Table 116cs. Channelization has been defined to be compatible with IEEE 802.11a for interference mitigation purposes, even though this results in less efficient spectrum usage in the middle U-NII band.

Table 116cs—Channelizations

Regulatory domain	Band (GHz)	Channelization (MHz)	
		20	10
USA	U-NII middle 5.25–5.35	56, 60, 64	55, 57, 59, 61, 63, 65, 67
	U-NII upper 5.725–5.825	149, 153, 157, 161, 165[a]	148, 150, 152, 154, 156, 158, 160, 162, 164[a],166[a]
Europe	CEPT band B[b] 5.47–5.725	100, 104, 108, 112, 116, 120, 124, 128, 132, 136	99, 101, 103, 105, 107, 109, 111, 113, 115, 117, 119, 121, 123, 125, 127, 129, 131, 133, 135, 137
	CEPT band C[b] 5.725–5.875	148, 152, 156, 160, 164, 168	147, 149, 151, 153, 155, 157, 159, 161, 163, 165, 167, 169

[a]See CFR 47 Part 15.247.
[b]Current applicable regulations do not allow this standard to be operated in the indicated band.

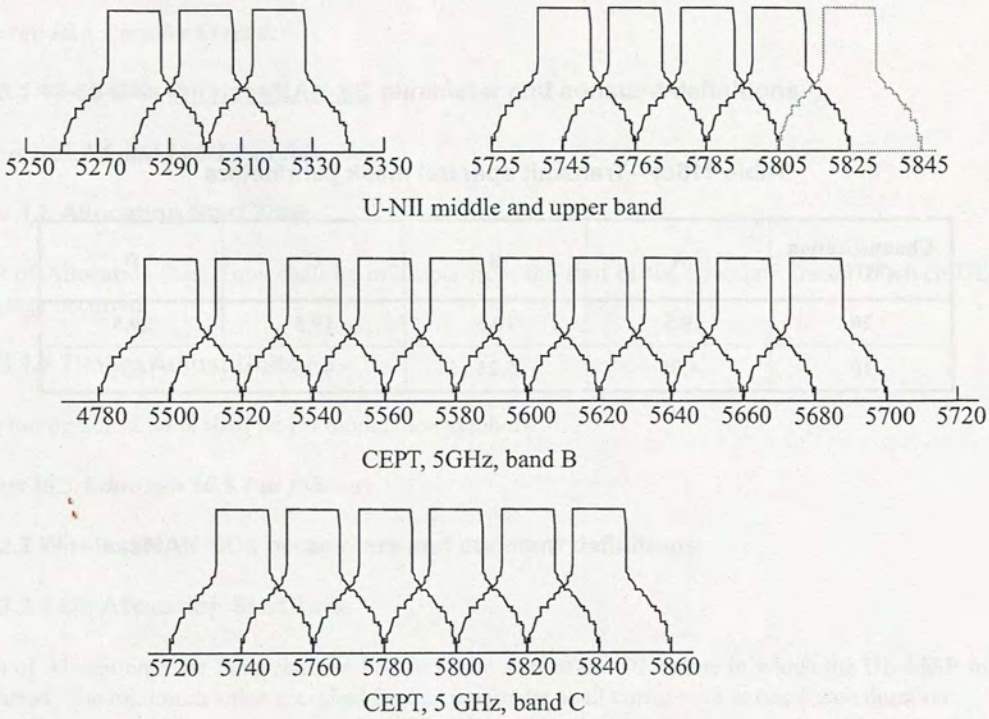


Figure 128bp—Channelization, 20 MHz

Copyright © 2003 IEEE. All rights reserved.

8.6.2 Transmit spectral mask

The transmitted spectral density of the transmitted signal shall fall within the spectral mask as shown Figure 128bq and Table 116ct. The measurements shall be made using 100 kHz resolution bandwidth and a 30 kHz video bandwidth. The 0 dBr level is the maximum power allowed by the relevant regulatory body.

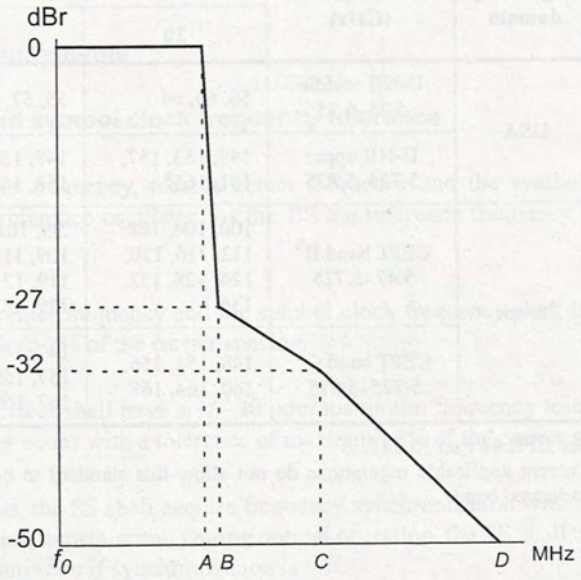


Figure 128bq—Transmit spectral mask (see Table 116ct)

Table 116ct—Transmit spectral mask parameters

Channelization (MHz)	A	B	C	D
20	9.5	10.5	19.5	29.5
10	4.75	5.25	9.75	14.75

Copyright © 2003 IEEE. All rights reserved.

10. Parameters and constants

10.1 Global values

In Table 118 change "SS UL-MAP processing time" as shown in Table 118a. Insert additional rows to Table 118 as shown in Table 118a:

Table 118a—Parameters and constants

System	Name	Time reference	Minimum value	Default value	Maximum value
BS	SS UL-MAP processing time (WirelessMAN-SC only)	Time provided between arrival of the last bit of a UL-MAP at an SS and effectiveness of that map.			200 µs
SS, BS	T17	Wait for ARQ-Reset			0.5 s
Mesh node	T18	Network Entry: Detect network	1 s		
Mesh node	T19	Network Entry: Accumulate MSH-NCFG messages		120 s	
Mesh node	T20	Network Entry: Wait for MSH-NENT / MSH-NCFG		1 s	

10.3 PHY-specific values

Change 10.3.1 header to read:

10.3.1 ~~10–66 GHz~~ WirelessMAN-SC parameter and constant definitions

Insert 10.3.1.6 and 10.3.1.7 as follows:

10.3.1.6 Allocation Start Time

Unit of Allocation Start Time shall be minislots from the start of the downlink frame in which UL-MAP message occurred.

10.3.1.7 Timing Adjust Units

The timing adjust units shall be 1/4 modulation symbols.

Insert 10.3.2 through 10.3.4 as follows:

10.3.2 WirelessMAN-SCa parameters and constant definitions

10.3.2.1 UL Allocation Start Time

Unit of Allocation Start Time shall be PSs from the start of the DL frame in which the UL-MAP message occurred. The minimum value specified for this parameter shall correspond to one frame duration.

Copyright © 2003 IEEE. All rights reserved.

10.3.2.2 Physical Slot

Physical Slots are defined as:

$$\text{Physical Slot} = 4 \cdot \text{Symbol duration}. \quad (96)$$

10.3.2.3 Timing adjust units

The timing adjust units shall be 1/32 modulation symbols.

10.3.3 WirelessMAN-OFDM parameters and constant definitions

10.3.3.1 UL Allocation Start Time

Unit of Allocation Start Time shall be PSs from the start of the DL frame in which the UL-MAP message occurred. The minimum value specified for this parameter shall correspond to a point in the frame 200 μs after the last symbol of the UL-MAP.

10.3.3.2 Physical Slot

Physical Slots are defined as:

$$\text{Physical Slot} = 4 \cdot \text{Sample Time}. \quad (97)$$

10.3.3.3 Timing adjust units

The timing adjust units shall be a single Sample Time.

10.3.4 WirelessMAN-OFDMA parameters and constant definitions

10.3.4.1 UL Allocation Start Time

Unit of Allocation Start Time shall be PSs from the start of the DL frame in which the UL-MAP message occurred. The minimum value specified for this parameter shall correspond to 1 FEC block.

10.3.4.2 Physical Slot

Physical Slots are defined as:

$$\text{Physical Slot} = 4 \cdot \text{Sample Time}. \quad (98)$$

10.3.4.3 Timing adjust units

The timing adjust units shall be a single Sample Time.

Copyright © 2003 IEEE. All rights reserved.

10.4 Well-known addresses and identifiers

Change Table 121 to read:

Table 121—Connection identifiers

Connection identifier	Value	Description
Initial ranging	0x0000	Used by an SS during initial ranging as part of initial ranging process.
Basic CID	0x0001—*m*	
Primary management	*m*+1—2*m*	
Transport CIDs and secondary Mgt CIDs	2*m*+1—0xFEFF	
Multicast polling CIDs	0xFF00—0xFFFD	An SS may be included in one or more multicast groups for the purposes of obtaining bandwidth via polling. These connections have no associated Service Flow.
Padding CID	0xFFFE	Used for transmission of padding information.
Broadcast CID	0xFFFF	Used for broadcast information that is transmitted on a downlink to all SS.

11. TLV-encodings

11.1 MAC management message encodings

11.1.1 UCD message encodings

11.1.1.1 UCD channel encodings

Replace Table 122 as follows:

Table 122—UCD channel encoding

Name	Type (1 byte)	Length	Value (variable length)	PHY scope
Uplink_Burst_Profile	1		May appear more than once (see 6.2.2.3.3). The length is the number of bytes in the overall object, including embedded TLV items.	All
Symbol rate	2	2	Symbol rate, in increments of 10 kBaud.	SC, SCa
Frequency	3	4	Uplink center frequency (kHz).	SCa, OFDM, OFDMA

Copyright © 2003 IEEE. All rights reserved.

Table 122—UCD channel encoding *(continued)*

Name	Type (1 byte)	Length	Value (variable length)	PHY scope
SS Transition gap	7	1	The time, as measured at the BS and expressed in PSs, between the end of a SS burst and the beginning of the subsequent SS burst. The SS shall take this into account when determining the length of the burst. The SSTG consumes the last n PS of the intervals allocated in the UL-MAP. That is, UL-MAP entries include the time for a burst's ramp down.	SC
			The time, as measured at the BS and expressed in PSs, between the end of a SS burst and the beginning of the subsequent SS burst. The SS shall take this into account when determining the length of the burst. The SSTG consumes the last n PS of the intervals allocated in the UL-MAP. That is, UL-MAP entries accommodate the RxDS burst element, which includes time for both ramp down and delay spread to clear the receiver.	SCa
Roll-off factor	8	1	0=0.15, 1=0.25 2=0.35 (SC only), 3=0.18 (SCa only) 4–255 Reserved	SC, SCa
Power adjustment rule	9	1	0=Preserve Peak Power 1=Preserve Mean Power Describes the power adjustment rule when performing a transition from one burst profile to another.	SC
Contention-based reservation timeout	10	1	Number of UL-MAPs to receive before contention-based reservation is attempted again for the same connection.	All
Channel width	11	2	Channel width, increments of 10 KHz Shall not be used in license-exempt bands	SCa OFDM, OFDMA
Initial ranging codes	12	1	Number of initial ranging CDMA codes. Possible values are 0–47.[a]	OFDMA
Periodic ranging codes	13	1	Number of periodic ranging CDMA codes. Possible values are 0–47.[a]	OFDMA
Bandwidth request codes	14	1	Number of bandwidth request codes. Possible values are 0–47.[a]	OFDMA
Periodic ranging backoff start	15	1	Initial backoff window size for periodic ranging contention, expressed as a power of 2. Range: 0–15 (the highest order bits shall be unused and set to 0).	OFDMA
Periodic ranging backoff end	16	1	Final backoff window size for periodic ranging contention, expressed as a power of 2. Range: 0–15 (the highest order bits shall be unused and set to 0).	OFDMA

Copyright © 2003 IEEE. All rights reserved.

Table 122—UCD channel encoding *(continued)*

Name	Type (1 byte)	Length	Value (variable length)	PHY scope
Initial maintenance SSTG	17	1	The time, as measured at the BS and expressed in PSs, between the end of a SS burst and the beginning of a subsequent burst residing in an Initial Maintenance slot. Or, the time, as measured at the BS and expressed in PSs, between the end of burst in an Initial Maintenance slot and beginning of a subsequent SS burst. A SS shall take this into account when determining the length of a burst in an Initial Maintenance slot. The Initial Maintenance SSTG consumes the last n PS of the intervals allocated in the UL-MAP. That is, UL-MAP entries accommodate the RxDS burst element, which includes time for both ramp down and delay spread to clear the receiver.	SCa
Subchannelization focused contention codes	18	1	Number of contention codes (C_{SF}) that shall only be used to request a subchannelized allocation. Default value 0. Allowed values 0–48.	OFDM

[a]The total number of codes shall be equal or less than 48.

11.1.1.2 UCD burst profile encodings

Change the first sentence to read:

The uplink burst profile encodings ~~for 10-66 GHz systems~~ are provided in Table 123 through Table 123c.

Replace title of Table 123 with the following: UCD burst profile encodings—<u>WirelessMAN-SC</u>

Insert Table 123a, Table 123b and Table 123c after Table 123 as follows:

Table 123a—UCD burst profile encodings—WirelessMAN—SCa

Name	Type (1 byte)	Length	Value (variable length)
Modulation type	1	1	4 msb bits: 1 =QPSK, 2 = 16-QAM, 3 = 64-QAM, 4 = 256-QAM, 5 = BPSK, 5–15 Reserved 4 lsb bits: 1 = CC+RS without block interleaving 2 = CC+RS with block interleaving 3 = no FEC, 4 = BTC, 5 = CTC, 6–15=reserved
Preamble length	4	1	4 msb: Number of Unique Words in Preamble (m= 0–15) 4 lsb: Number of PSs (4x number of symbols) in ramp up
RS Information bytes (K)	6	1	K=6–255
RS Parity bytes (R)	7	1	2 msb: R=0-16 bytes (error correction capability = 0–8 bytes) R = 17–63 reserved 6 lsb: Last RS codeword length 0=fixed, 1=shortened, 2–3=Reserved
Block interleaver depth	18	1	Number of rows (Reed Solomon code words) used in block interleaver between Reed Solomon and CC: rows = 2–66; Reserved = 0, 1, 67–255

Copyright © 2003 IEEE. All rights reserved.

Table 123a—UCD burst profile encodings—WirelessMAN—SCa *(continued)*

Name	Type (1 byte)	Length	Value (variable length)
CC/CTC-Specific parameters	19	1	0 = rate 1/2 (for BPSK, QPSK, 16-QAM) 1 = rate 2/3 (for QPSK, 64-QAM) 2 = rate 3/4 (for BPSK, QPSK, 16-QAM, 256-QAM) 3 = rate 5/6 (for QPSK, 64-QAM) 4 = rate 7/8 (for QPSK, 256-QAM) 5–255 = reserved
Unique word length	20	1	Number of symbols (U) in a Unique Word: 1= None, 2–8: $2^{<value+1>}$, 9–255 = reserved
Pilot word parameters	21	1	msb 4 bits: Pilot Word Interval [regular bursts] (Pilot word's length in symbols included in interval). 1 = no pilot words, 2–10: $2^{<value+2>}$, 11–15 reserved [STC-encoded bursts] 0=no pilot words, 1–15 = number of paired blocks between pilot words lsb 4 bits: Number of contiguous Unique Words composing a Pilot Word (1–15)
Transmit-diversity type	22	1	0 = No Tx diversity, 1 = STC Tx diversity, 2–255 = reserved
STC Parameters	23	2	4 msb: Block length (segments are paired), in symbols: 1= 64, 2 = 128, 3 = 256, 4 = 512,..., 7 = 4096, 8–15 reserved 4 lsb: Block burst profile type: 0 = CP derived from data and no UWs embedded within block 1 = CP derived from data an additional UW as first payload data element in block 2 = CP derived from UWs at beginning and end of segment 3–15 = reserved
BTC Code selector	24	1	Value used to choose set of BTC row/column codes. C_{bank}=1–3; 0,4–255 reserve

Table 123b—UCD burst profile encodings—WirelessMAN—OFDM

Name	Type (1 byte)	Length	Value (variable length)	
FEC Code type	5	1	0 = QPSK (RS+CC) 1/2 1 = QPSK (RS+CC) 3/4 2= 16-QAM (RS+CC) 1/2 3= 16-QAM (RS+CC) 3/4 4= 64-QAM (RS+CC) 2/3 5= 64-QAM (RS+CC) 3/4 6= QPSK (BTC) 1/2 7= QPSK (BTC) 3/4 or 2/3 8= 16-QAM (BTC) 3/5 9= 16-QAM (BTC) 4/5	10 = 64-QAM (BTC) 2/3 or 5/8 11 = 64-QAM (BTC) 5/6 or 4/5 12 = QPSK (CTC) 1/2 13 = QPSK (CTC) 2/3 14 = QPSK (CTC) 3/4 15 = 16-QAM (CTC) 1/2 16 = 16-QAM (CTC) 3/4 17 = 64-QAM (CTC) 2/3 18 = 64-QAM (CTC) 3/4 19–256 Reserved
Focused contention power boost	17	1	The power boost in dB of focused contention carriers, as described in 8.4.6.3.3	

Copyright © 2003 IEEE. All rights reserved.

Table 123c—UCD burst profile encodings—WirelessMAN—OFDMA

Name	Type (1 byte)	Length	Value (variable length)
FEC Code type	5	1	0 = QPSK (RS+CC) 1/2 1 = QPSK (RS+CC) 3/4 2= 16-QAM (RS+CC) 1/2 3= 16-QAM (RS+CC) 3/4 4= 64-QAM (RS+CC) 2/3 5= 64-QAM (RS+CC) 3/4 6= QPSK (BTC) 1/2 7= QPSK (BTC) 3/4 or 2/3 8= 16-QAM (BTC) 3/5 9= 16-QAM (BTC) 4/5 10 = 64-QAM (BTC) 2/3 or 5/8 11 = 64-QAM (BTC) 5/6 or 4/5 12 = QPSK (CTC) 1/2 13 = QPSK (CTC) 2/3 14 = QPSK (CTC) 3/4 15 = 16-QAM (CTC) 1/2 16 = 16-QAM (CTC) 3/4 17 = 64-QAM (CTC) 2/3 18 = 64-QAM (CTC) 3/4 19–256 Reserved
Ranging data ratio	16	1	Reducing factor in units of 1 dB, between the power used for this burst and power should be used for CDMA Ranging.

11.1.2 DCD message encodings

11.1.2.1 DCD channel encodings

Replace Table 124 as follows:

Table 124—DCD channel encoding

Name	Type (1 byte)	Length	Value (variable length)	PHY scope
Downlink_Burst_Profile	1		May appear more than once (see 6.2.2.3.1). The length is the number of bytes in the overall object, including embedded TLV items	All
BS EIRP	2	2	Signed in units of 1 dBM.	All
Frame duration	4	4	The number of PSs contained in a Burst FDD or TDD frame. Required only for framed downlinks	SC
PHY Type	5	1	The PHY Type to be used.	SC
Power adjustment rule	9	1	0=Preserve Peak Power 1=Preserve Mean Power Describes the power adjustment rule when performing a transition from one burst profile to another.	SC
Channel Nr	10	1	DL channel number as defined in 8.6. Used for license-exempt operation only.	SCa OFDM, OFDMA
TTG	11	1	TTG (in PSs)	SCa, OFDM, OFDMA
RTG	12	1	RTG (in PSs)	SCa, OFDM, OFDMA
MAC version	16	1	See 11.4.4.	All

Copyright © 2003 IEEE. All rights reserved.

11.1.2.2 DCD burst profile encodings

Change the first sentence to read:

The uplink burst profile encodings ~~for 10-66 GHz systems~~ are provided in Table 125 through Table 125c.

Replace title of Table 125 with the following: DCD burst profile encodings—WirelessMAN-SC

Insert Table 125a, Table 125b and Table 125c after Table 125 as follows:

Table 125a—DCD burst profile encodings—WirelessMAN—SCa

Name	Type (1 byte)	Length	Value (variable length)
Modulation type	1	1	4 msb bits: 1 =QPSK, 2 = 16-QAM, 3 = 64-QAM, 4 = 256-QAM, 5 = BPSK, 5–15 Reserved 4 lsb bits: 1 = CC+RS without block interleaving, 2 = CC+RS with block interleaving 3 = no FEC, 4 = BTC, 5 = CTC, 6–15=reserved
RS Parity bytes (R)	4	1	6 msb: R=0–16 bytes (error correction capability = 0–8 bytes) R = 17–63 reserved 2 lsb: Last RS codeword length 0=fixed, 1=shortened, 2-3=Reserved
DIUC Mandatory exit threshold	13	1	0–63.75 dB C/(N+I) at or below where this DIUC can no longer be used and at which a change to a more robust DIUC is required, in 0.25 dB units. See Figure 59.
DIUC Minimum entry threshold	14	1	0–63.75 dB The minimum C/(N+I) required to start using this DIUC when changing from a more robust DIUC is required, in 0.25 dB units. See Figure 59.
CC/CTC-Specific parameters	18	1	0 = rate 1/2 (for BPSK, QPSK, 16-QAM) 1 = rate 2/3 (for QPSK, 64-QAM) 2 = rate 3/4 (for BPSK, QPSK, 16-QAM, 256-QAM) 3 = rate 5/6 (for QPSK, 64-QAM) 4 = rate 7/8 (for QPSK, 256-QAM) 5–255 = reserved
Preamble length	19	1	4 msb: Number of Unique Words in Preamble (m= 0-15) 4 lsb: Number of PSs (4 x number of symbols) in ramp up
Rolloff	20	1	1 = 0.25, 2 = 0.18, 3 =.15, 4-255 = reserved
Unique word parameters	21	1	Number of symbols (U) in a Unique Word: 1= None, 2-8: $2^{<value+1>}$, 9-255 = reserved

Copyright © 2003 IEEE. All rights reserved.

Table 125a—DCD burst profile encodings—WirelessMAN—SCa *(continued)*

Name	Type (1 byte)	Length	Value (variable length)
Pilot word parameters	22	1	4 msb: Pilot Word Interval (Pilot word's length included in interval). 1 = no pilot words, 2 = 16 symbols, 3 = 32 symbols, 4 = 64 symbols, 5 = 128 symbols,..., 10 = 4096 symbols, 11–15 reserved 4 lsb: Number of contiguous Unique Words composing a Pilot Word (1–15)
Transmit-diversity type	23	1	0 = no Tx diversity, 1 = STC Tx diversity, 2–255 = reserved
Byte interleaver depth	24	1	Number of rows (Reed Solomon code words) used in block interleaver between Reed Solomon and CC: rows = 2–66 0,1,67–255 = reserved
DL Burst Transition Gap (DL-BTG)	25	1	1 msb: 0 = no DL-BTG; 1 = use DL-BTG. 7 lsb: The time, expressed in PSs, between the end of an BS burst and the beginning of a another burst with the same MAC frame. The DL Transition Gap consumes the last n PS of the intervals allocated in the DL-MAP. The minimum length of the DL Burst Transition Gap shall be at least one RxDS interval, so that ramp down can occur and delay spread can clear receivers.
STC Parameters	26	1	4 msb: block length (segments are paired), in symbols 1= 64, 2 = 128, 3 = 256, 4 = 512,..., 7 = 4096, 8–15 reserved 4 lsb: Block burst profile type 0 = Cyclic prefix derived from data and no UWs embedded within block 1 = Cyclic prefix derived from data an additional UW as first payload data element in block 2 = Cyclic prefix derived from UWs at beginning and end of segment 3–15 = reserved
BTC Code selector	27	1	Value used to choose set of BTC row/column codes. C_{bank}=1–3; 0,4–255 reserved

Copyright © 2003 IEEE. All rights reserved.

Table 125b—DCD burst profile encodings—WirelessMAN—OFDM

Name	Type (1 byte)	Length	Value (variable length)
FEC Code type	2	1	0 = QPSK (RS+CC) 1/2 1 = QPSK (RS+CC) 3/4 2= 16-QAM (RS+CC) 1/2 3= 16-QAM (RS+CC) 3/4 4= 64-QAM (RS+CC) 2/3 5= 64-QAM (RS+CC) 3/4 6= QPSK (BTC) 1/2 7= QPSK (BTC) 3/4 or 2/3 8= 16-QAM (BTC) 3/5 9= 16-QAM (BTC) 4/5 10 = 64-QAM (BTC) 2/3 or 5/8 11 = 64-QAM (BTC) 5/6 or 4/5 12 = QPSK (CTC) 1/2 13 = QPSK (CTC) 2/3 14 = QPSK (CTC) 3/4 15 = 16-QAM (CTC) 1/2 16 = 16-QAM (CTC) 3/4 17 = 64-QAM (CTC) 2/3 18 = 64-QAM (CTC) 3/4 19–256 Reserved
DIUC mandatory exit threshold	13	1	0–63.75 dB C/(N+I) at or below where this DIUC can no longer be used and where this change to a more robust DIUC is required, in 0.25 dB units. See Figure 59.
DIUC minimum entry threshold	14	1	0–63.75 dB The minimum C/(N+I) required to start using this DIUC when changing from a more robust DIUC is required, in 0.25 dB units. See Figure 59.

Table 125c—DCD burst profile encodings—WirelessMAN—OFDMA

Name	Type (1 byte)	Length	Value (variable length)
FEC Code type	2	1	0 = QPSK (RS+CC) 1/2 1 = QPSK (RS+CC) 3/4 2= 16-QAM (RS+CC) 1/2 3= 16-QAM (RS+CC) 3/4 4= 64-QAM (RS+CC) 2/3 5= 64-QAM (RS+CC) 3/4 6= QPSK (BTC) 1/2 7= QPSK (BTC) 3/4 or 2/3 8= 16-QAM (BTC) 3/5 9= 16-QAM (BTC) 4/5 10 = 64-QAM (BTC) 2/3 or 5/8 11 = 64-QAM (BTC) 5/6 or 4/5 12 = QPSK (CTC) 1/2 13 = QPSK (CTC) 2/3 14 = QPSK (CTC) 3/4 15 = 16-QAM (CTC) 1/2 16 = 16-QAM (CTC) 3/4 17 = 64-QAM (CTC) 2/3 18 = 64-QAM (CTC) 3/4 19–256 Reserved
DIUC Mandatory exit threshold	13	1	0–63.75 dB C/(N+I) at or below where this DIUC can no longer be used and where this change to a more robust DIUC is required, in 0.25 dB units. See Figure 59.
DIUC Minimum entry theshold	14	1	0–63.75 dB The minimum C/(N+I) required to start using this DIUC when changing from a more robust DIUC is required, in 0.25 dB units. See Figure 59.

Copyright © 2003 IEEE. All rights reserved.

11.1.4 RNG-RSP message encodings

Change the indicated parameters in Table 127 (do not change or remove the other parameters) to read:

Table 127—RNG-RSP message encodings

Name	Type	Length	Value
Timing adjust	1	4	Tx timing offset adjustment (signed 32-bit). The time required to advance SS transmission so frames arrive at the expected time instance at the BS. Units are PHY specific (see 10.3).
Downlink frequency override	5	4	Center frequency of new downlink channel in kHz where the SS should redo initial ranging. If this TLV is used, the Ranging Status value shall be set to 2. Shall be used for licensed bands only.
Uplink channel ID override	6	1	Licensed bands: The identifier of the uplink channel with where the SS should redo initial ranging (not used with PHYs without channelized uplinks). license-exempt bands: The Channel Nr (see 8.6.1) where the SS should redo initial ranging.

Insert under Table 127 as follows:

In addition to the RNG-RSP TLVs listed in Table 127, which are applicable to all PHYs, a set of PHY specific RNG-RSP TLVs is provided in Table 127a.

Table 127a—PHY specific RNG-RSP message encodings

Name	Type	Length	Value	PHY
Ranging symbol	12	2	Used to indicate the OFDM time symbol reference that was used to transmit the ranging code (unsigned 12-bit).	OFDMA
Ranging subchannel	13	1	Used to indicate the OFDM subchannel reference that was used to transmit the ranging code (unsigned 6-bit).	OFDMA
Ranging code	14	1	Used to indicate the ranging code that was sent by the SS (unsigned 6-bit).	OFDMA
Ranging frame number	15	1	The 8 least significant bits of the frame number of the OFDMA frame where the SS sent the ranging code.	OFDMA
AAS broadcast permission	16	1	0= SS may issue contention-based BW requests permission 1= SS shall not issue contention-based BW request	SCa OFDM OFDMA

Copyright © 2003 IEEE. All rights reserved.

Table 127a—PHY specific RNG-RSP message encodings *(continued)*

Name	Type	Length	Value	PHY
AAS broadcast capability	17	1	0 = SS can receive broadcast messages 1 = SS cannot receive broadcast messages	SCa OFDM OFDMA
Frame number	18	3	Frame number where the associated RNG_REQ message was detected by the BS. Usage is mutually exclusive with SS MAC Address (Type 8). The opportunity within the frame is assumed to be 1 (the first) if the Initial Ranging Opportunity field is not supplied.	SCa OFDM
Initial ranging opportunity number	19	1	Initial Ranging opportunity (1–255) in which the associated RNG_REQ message was detected by the Base Station. Usage is mutually exclusive with SS MAC Address (Type 8).	SCa OFDM

Insert 11.1.5 and 11.1.6 as follows:

11.1.5 REP-REQ parameters

Name	Type	Length	value
Report request	1	Compound	

The Report Command consists of the following parameters:

Name	Type	Length	value
Report type	1.1	1	Bit# 0 =1 Include DFS Basic report Bit# 1 =1 Include CINR report Bit# 2 =1 Include RSSI report Bit# 3–6 α_{avg} \ in multiples of 1/32 (range [1/32, 16/32]) Bit# 7 Reserved
Channel number	1.2	1	Physical channel number (see 8.6.1) to be reported on. (license-exempt bands only)

11.1.6 REP-RSP parameters

Name	Type	Length	value
Report	1	Compound	

Copyright © 2003 IEEE. All rights reserved.

The report consists of the following parameters (see also 8.3.2, 8.4.8 or 8.5.11 for details).

REP-REQ Report type	Name	Type	Length	value
bit #0=1	Channel number	1.1	1	Physical channel number (see 8.6.1) to be reported on.
bit #0=1	Start frame	1.2	2	Frame number in which measurement for this channel started.
bit #0=1	Duration	1.3	3	Cumulative measurement duration on the channel in multiples of T_s. For any value exceeding 0xFFFFFF, report 0xFFFFFF.
bit #0=1	Basic report	1.4	1	Bit# 0: Wireless Human detected on the channel Bit# 1: Unknown transmissions detected on the channel Bit# 2: Primary User detected on the channel Bit# 3: Unmeasured. Channel not measured
bit #1=1	CINR report	1.5	2	1 byte: mean (see also 8.3.2, 8.4.8, 8.5.11) for details) 1 byte: standard deviation
bit #2=1	RSSI report	1.6	2	1 byte: mean (see also 8.3.2, 8.4.8, 8.5.11) for details) 1 byte: standard deviation

11.2 PKM message encodings

11.2.14 Cryptographic-Suite

Change Table 136 as shown:

Table 136—Version attribute values

Value	Description
0	*reserved*
1	3-DES EDE with 128-bit key
2	RSA with 1024 bit key
~~2~~3–255	*reserved*

11.3 Configuration file encodings

Insert 11.3.7 through 11.3.9 with the following:

11.3.7 Authorization Node

The Authorization Node parameter contains the IP address of the Authorization Node.

Type	Length	Value
22	4 or 16	IP Address

Copyright © 2003 IEEE. All rights reserved.

11.3.8 Registration Node

The Registration Node parameter contains the IP address of the Registration Node.

Type	Length	Value
23	4 or 16	IP Address

11.3.9 Provisioning Node

The Provisioning Node parameter contains the IP address of the Provisioning Node.

Type	Length	Value
18	4 or 16	IP Address

11.4 Common encodings

Insert 11.4.1.2.5 through 11.4.1.2.7 with the following:

11.4.1.2.5 WirelessMAN SCa SS Demodulator

11.4.1.2.5.1 SS Demodulation Types

This field indicates the optional modulation (and FEC) types supported by a SS for DL reception. Note that QPSK, 16-QAM, and 64-QAM shall be supported, as is the Concatenated FEC without byte interleaving and no-FEC QPSK. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.7	1	Bit# 0: 256-QAM Bit# 1: BPSK Bit# 2: Concatenated RS+CC FEC with byte interleaver Bit# 3: BTC Bit# 4: CTC Bit# 5: no FEC and QAM Bits# 6–7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.5.2 Roll-off Factor

This field indicates the optional roll-off factors supported by a SS for DL reception. Note that support of a roll-factor of 0.25 is mandatory. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.8	1	Bit# 0: 0.18 Bit# 1: 0.25 Bits# 2–7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

Copyright © 2003 IEEE. All rights reserved.

11.4.1.2.5.3 UW Length

This field indicates the optional UW lengths, in symbols, supported by a SS for DL reception. Note that support of the 64 symbol UW is mandatory. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.9	1	Bit# 0: 8 Bit# 1: 16 Bit# 2: 32 Bit# 4: 128 Bit# 5: 256 Bit# 6: 512 Bit# 7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.5.4 Pilot Word Interval

This field indicates the optional pilot word intervals supported, in symbols, by a SS for DL reception. A Pilot Word interval of 256 symbols shall be supported. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.10	1	Bit# 0: 128 Bit# 1: 512 Bit# 2: 1024 Bit# 4: 2048 Bit# 5: 4096 Bits# 6–7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.5.5 Byte interleaver depth

This field indicates the interleaver depth (number of rows) supported by a SS for DL reception. The value of 0 (no interleaver) shall be supported.

Type	Length	Value	Scope
5.12.11	1	0: no interleaver support 1–64: 2–66 rows 65–255: reserved	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

Copyright © 2003 IEEE. All rights reserved.

11.4.1.2.5.6 Transmit diversity

This field indicates the types of transmit diversity supported by a SS for DL reception. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.12	1	Bit# 0: STC Transmit Diversity with CP Burst Profile Bit# 1: STC Transmit Diversity with CP and UW at beginning of block Burst Profile Bit# 2: STC Transmit Diversity with UWs placed at beginning and end of block Burst Profile Bits# 3–7: reserved, shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.5.7 STC block size

This field indicates the STC block size (block = 1/2 length of a 'STC pair') supported by a SS for DL reception. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.13	1	Bit# 0: 64 Bit# 1: 128 Bit# 2: 256 Bit# 3: 512 Bit# 4: 1024 Bit# 5: 2048 Bit# 6: 4096 Bit# 7: reserved, shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.5.8 Maximum DL channel width

This field indicates the maximum DL channel width that the SS can demodulate.

Type	Length	Value	Scope
5.12.14	2	Bits# 0–15: Channel Width, in 10 kHz increments	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.5.9 Minimum DL channel width

This field indicates the minimum DL channel width over a SS can demodulate.

Type	Length	Value	Scope
5.12.15	2	Bits# 0–15: Channel Width, in 10 kHz increments.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

Copyright © 2003 IEEE. All rights reserved.

11.4.1.2.6 WirelessMAN SCa SS modulator

11.4.1.2.6.1 SS modulation types

This field indicates the optional modulation (and FEC) types supported by a SS for UL transmission. Note that QPSK, 16-QAM, and 64-QAM shall be supported, as is the Concatenated FEC without byte interleaving and no-FEC QPSK. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.16	1	Bit# 0: 256-QAM Bit# 1: Concatenated RS+CC FEC with byte interleaver Bit# 2: BTC Bit# 3: CTC Bit# 4: no FEC and QAM Bits# 5–7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.2 Roll-off factor

This field indicates the optional roll-off factors supported by a SS for UL transmission. Note that support of a roll-factor of 0.25 is mandatory. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.17	1	Bit# 0: 0.18 Bit# 1: 0.25 Bits# 2–7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.3 UW length

This field indicates the optional UW lengths, in symbols, supported by a SS for UL transmission. Note that support of the 64 symbol UW is mandatory. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.18	1	Bit# 0: 8 Bit# 1: 16 Bit# 2: 32 Bit# 4: 128 Bit# 5: 256 Bit# 6: 512 Bit# 7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

Copyright © 2003 IEEE. All rights reserved.

11.4.1.2.6.4 Pilot word interval

This field indicates the optional pilot word intervals supported, in symbols, by a SS for UL transmission. A Pilot Word interval of 256 symbols shall be supported. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.19	1	Bit# 0: 8 Bit# 1: 16 Bit# 2: 32 Bit# 4: 128 Bit# 5: 256 Bit# 6: 512 Bit# 7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.5 Byte interleaver depth

This field indicates the interleaver depth (number of rows) supported by a SS for UL transmission. The value of 0 (no interleaver) shall be supported.

Type	Length	Value	Scope
5.12.20	1	0: no interleaver support 1–64: 2–66 rows 65–255: reserved	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.6 Transmit diversity

This field indicates the types of transmit diversity supported by a SS for UL transmission. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.21	1	Bit# 0: STC Transmit Diversity with Cyclic Prefix Burst Profile Bit# 1: STC Transmit Diversity with Cyclic Prefix and UW at beginning of block Burst Profile Bit# 2: STC Transmit Diversity with UWs placed at beginning and end of block Burst Profile Bits# 3–7: reserved, shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

Copyright © 2003 IEEE. All rights reserved.

11.4.1.2.6.7 STC block size

This field indicates the STC block size (block = 1/2 length of a 'STC pair') supported by a SS for UL transmission. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.22	1	Bit# 0: 64 Bit# 1: 128 Bit# 2: 256 Bit# 3: 512 Bit# 4: 1024 Bit# 5: 2048 Bit# 6: 4096 Bit# 7: reserved, shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.8 Maximum UL channel width

This field indicates the maximum UL channel width over a SS can transmit.

Type	Length	Value	Scope
5.12.23	2	Bits# 0–15: Channel Width, in 10 kHz increments.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.9 Minimum UL channel width

This field indicates the minimum UL channel width over a SS can transmit.

Type	Length	Value	Scope
5.12.24	2	Bits# 0–15: Channel Width, in 10 kHz increments.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.10 Power control limits

This field indicates the maximum transmit power, power control range, and power control granularity that a SS can deliver to the transmit antenna over the given UL channel.

Type	Length	Value	Scope
5.12.25	3	Bits# 0–5: Max output power in dBm, from 0 to 63 dBm Bits# 6–12: Power control range, in dB, from 0 to 127 dB Bits# 13–17: Power control granularity in 0.25 dB increments, from 0.25 to 8 dB. Bits# 18–23: Reserved	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

Copyright © 2003 IEEE. All rights reserved.

11.4.1.2.7 WirelessMAN-OFDM/OFDMA FFT sizes

This field indicates the types of transmit diversity supported by a SS for UL transmission. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.26	1	Bit# 0: FFT-256 Bit# 1: FFT-2048 Bits# 2–7: Reserved, shall be set to zero	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.8 WirelessMAN-OFDM focused contention support

This field indicates the types of transmit diversity supported by a SS for UL transmission. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.27	1	Bit #0: Focused Contention Support Bits #1–7: Reserved, shall be set to zero	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.9 WirelessMAN-OFDM/OFDMA demodulator

This field indicates the different demodulator options supported by a WirelessMAN-OFDM/OFDMA PHY SS for DL reception. This field is not used for other PHY specifications. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.28	1	Bit# 0: 64-QAM Bit# 1: BTC Bit# 2: CTC Bit# 3: STC Bit# 4: AAS Bits# 5–7: Reserved	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.10 WirelessMAN-OFDM/OFDMA modulator

This field indicates the different modulator options supported by a WirelessMAN-OFDM/OFDMA PHY SS for UL transmission This field is not used for other PHY specifications. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.29	1	Bit# 0: 64-QAM Bit# 1: BTC Bit# 2: CTC Bits# 3–7: Reserved	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

Copyright © 2003 IEEE. All rights reserved.

Replace Table in 11.4.1.6 as follows:

11.4.1.6 Bandwidth allocation support

Type	Length	Value	Scope
5.15	1	~~bit #0=0: Grant per Connection~~ ~~bit #0=1: Grant per Subscriber Station (SS)~~ bit #0: Reserved Bit# 1=0: Half-Duplex Bit# 1=1: Full-Duplex Bit# 2=0: Not capable of focused contention Bit# 2=1: Capable of focused contention Bit# 3=0: No OFDM subchannelization support Bit# 3=1: OFDM subchannelization support Bits# ~~2~~4–7: *reserved*; shall be set to zero	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.4 MAC version encodings

Chance the following sentence to read:

Encodings are as defined for the Registration Request, Registration Response and DCD, including MAC version.

11.4.8 Service flow encodings

Insert 11.4.8.18 and 11.4.8.19 with the following:

11.4.8.18 ARQ TLVs for ARQ-enabled connections

11.4.8.18.1 ARQ support

This TLV indicates whether or not ARQ is available for the connection that is being setup. A value of 0 indicates the non-availability of ARQ support and a value 1 indicates otherwise. The DSA-REQ shall contain the request to use or not to use ARQ. The DSA-RSP message shall contain the acceptance or rejection of the request. ARQ shall be enabled for this connection only if both sides support it.

Type	Length	Value	Scope
[24/25].11	1	0 = ARQ Not Supported. 1 = ARQ Supported	DSx-REQ DSx-RSP

11.4.8.18.2 ARQ_WINDOW_SIZE

This parameter is negotiated upon connection setup. The DSA-REQ/DSC-REQ message shall contain the suggested value for this parameter. The DSA-RSP/DSC-RSP message shall contain the confirmation value or an alternate value for this parameter. The smaller of the two shall be used as the **ARQ_WINDOW_SIZE**.

Type	Length	Value	Scope
[24/25].12	1	1 - (ARQ_FSN_MODULUS/2)	DSx-REQ DSx-RSP

Copyright © 2003 IEEE. All rights reserved.

11.4.8.18.3 ARQ_RETRY_TIMEOUT

The ARQ retry timeout should account for the transmitter and receiver processing delays and any other delays relevant to the system.

TRANSMITTER_DELAY: This is the total transmitter delay, including sending (e.g., MAC PDUs) and receiving (e.g., ARQ feedback) delays and other implementation dependent processing delays. If the transmitter is the BS, it may include other delays such as scheduling and propagation delay.

RECEIVER_DELAY: This is the total receiver delay, including receiving (e.g., MAC PDUs) and sending (e.g., ARQ feedback) delays and other implementation dependent processing delays. If the receiver is the BS, it may include other delays such as scheduling and propagation delay.

The DSA-REQ and DSA-RSP messages shall contain the values for these parameters, where the receiver and transmitter each declare their capabilities. When the DSA handshake is completed, each party shall calculate **ARQ_RETRY_TIMEOUT** to be the sum of TRANSMITTER_DELAY and RECEIVER_DELAY.

Type	Length	Value	Scope
[24/25].13	2	TRANSMITTER_DELAY 0–655350 (10 μs granularity)	DSA-REQ DSA-RSP
[24/25].22	2	RECEIVER_DELAY 0–655350 (10 μs granularity)	DSA-REQ DSA-RSP

11.4.8.18.4 ARQ_FRAGMENT_LIFETIME

The BS shall set this parameter. The DSA-REQ or DSA-RSP messages shall contain the value of this parameter as set by the BS. If this parameter is set to 0, then the *ARQ_FRAGMENT_LIFETIME* value shall be considered infinite.

Type	Length	Value	Scope
[24/25].17	2	0 = Infinite 1–655350 (10 μs granularity)	DSA-REQ DSA-RSP

11.4.8.18.5 ARQ_SYNC_LOSS_TIMEOUT

The BS shall set this parameter. The DSA-REQ or DSA-RSP messages shall contain the value of this parameter as set by the BS. If this parameter is set to 0, then the *ARQ_SYNC_LOSS_TIMEOUT* value shall be considered infinite.

Type	Length	Value	Scope
[24/25].19	2	0 = Infinite 1–655350 (10 μs granularity)	DSA-REQ DSA-RSP

Copyright © 2003 IEEE. All rights reserved.

11.4.8.18.6 ARQ_DELIVER_IN_ORDER

The transmitter shall set this parameter. The DSA-REQ or DSA-RSP messages shall contain the value of this parameter. This TLV indicates whether or not data is to be delivered by the receiving MAC to its client application in the order in which the data was handed off to the originating MAC.

Type	Length	Value	Scope
[24/25].20	1	0 – Order of delivery is not preserved 1 – Order of delivery is preserved	DSA-REQ DSA-RSP

If this flag is not set, then the order of delivery is not preserved. If this flag is set (to 1), then the order of delivery is preserved. This parameter does not apply to fixed length SDU services (i.e., ATM).

11.4.8.18.7 ARQ_RX_PURGE_TIMEOUT

The BS shall set this parameter. The DSA-REQ or DSA-RSP messages shall contain the value of this parameter as set by the BS. If this parameter is set to 0, then the *ARQ_RX_PURGE_TIMEOUT* value shall be considered infinite.

Type	Length	Value	Scope
[24/25].23	2	0= Infinite 1–655350 (10 μs granularity)	DSA-REQ DSA-RSP

11.4.8.19 Maximum fragment length

The value of this parameter specifies the maximum size fragment a transmitter shall form or a receiver shall expect to receive.

This parameter is established by negotiation during the connection creation and connection change dialogs. The requester includes its desired setting in the REQ message. The receiver of the REQ message shall take the smaller of the value it prefers and value in the REQ message. This minimum value is included in the RSP message and becomes the agreed upon length value.

Absence of the parameter during a DSA dialog shall indicate the originator of the message desires the maximum value. Absence of the parameter during a DSC dialog indicates the current setting shall remain in force.

Type	Length	Value	Scope
[24/25].22	2	0–31 Reserved 32–2040 Desired/Agreed max. length in bytes 2041–65535 Reserved	DSA-REQ DSA-RSP DSC-REQ DSC-RSP

Copyright © 2003 IEEE. All rights reserved.

12. System profiles

12.2 Basic Mesh system profile

The Mesh system profile addresses the requirements of a system that is intended to operate in the optional Mesh configuration. Basic functionalities are mandatory for a Mesh node as they are for a PMP node, except those that are stated below as optional in this subclause. All specifications referring to optional Mesh mode in the standard shall apply to a Mesh-enabled system as mandatory.

For a Mesh-enabled system, the messages below and the corresponding functionality are always mandatory to implement:

MSH-NCFG
MSH-NENT
MSH-DSCH
MSH-CSCH
MSH-CSCF
REG-REQ
REG-RSP
PKM-REQ
PKM-RSP
SBC-REQ
SBC-RSP
TFTP-CPLT
TFTP-RSP
RES-CMD

For a Mesh enabled system, the following messages and the corresponding functionalities are mandatory/optional whenever they are optional/mandatory for a PMP system:

ARQ-Feedback

When operating in the Mesh mode, the messages below and the corresponding functionalities are not used; however, they are implemented to support the mandatory PMP mode.

DL-MAP
DCD
DSA-ACK
DSA-REQ
DSA-RSP
DSC-ACK
DSC-REQ
DSC-RSP
DSD-RSP
DSX-RVD
UCD
UL-MAP
CLK-CMP
DBPC-REQ
DBPC-RSP
DREG-CMD
MCA-REQ
MCA-RSP
RNG-REQ
RNG-RSP

Generally, the following procedures are different for a Mesh node and a PMP node:

Synchronization
Network entry
Scheduling

Copyright © 2003 IEEE. All rights reserved.

Annex A

(informative)

Bibliography

Insert the following references:

[B18] ETSI EN 301021 v1.4.1 (2001/03) Fixed Radio Systems; Point-to-multipoint equipment; Time division Multiple access (TDMA); Point-to-Multipoint digital radio systems bands in the range 3 GHz to 11 GHz.

[B19] Title 47, part 15, http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/cfr, Federal Communications Commission.

[B20] Drury G., Markarian G., and Pickavance K. *"Coding and Modulation in Digital Television,"* KLUWER ACADEMIC Publishers, 2000, USA.

[B21] Falconer, D. and Ariyavisitakul, S. L., *"Frequency Domain Equalization for 2–11 GHz Fixed Broadband Wireless systems,"* Tutorial, presented during Session #11 of IEEE 802.16 in Ottawa, Canada, Jan. 22, 2001.

[B22] Frank R. L., and Zadoff, S. A., "*Phase shift pulse codes with good periodic correlation properties,"* IRE Transactions on Information Theory, Oct. 1962, pp. 381–382.

[B23] Chu, D. C., *"Polyphase codes with good periodic correlation properties,"* IEEE Transactions on Information Theory, July 1972, pp. 531–532.

[B24] Sari H., and Karam, G., *"Orthogonal Frequency-Division Multiple Access and its Application to CATV Networks,"* European Transactions on Telecommunications (ETT), vol. 9, no. 6, pp. 507–516, Nov.– Dec. 1998.

[B25] Cantoni A., and Godara, L. C., *"Fast Algorithm for Time Domain Broad Band Adaptive Array Processing,"* IEEE Trans. Aerops. Electr. Syst., AES-18, 682, Sept. 1982.

[B26] Alamouti, S. M., *"A Simple Transmit Diversity Technique for Wireless Communications," IEEE Journal on Select Areas in Communications*, vol. 16, no. 8, pp. 1451–1458, Oct. 1998.

[B27] Viterbi, A. J., Wolf, J. K., Zehavi, E., and Padovani, R., *"A pragmatic approach to trellis-coded modulation,"* IEEE Communications Magazine, July 1989, pp. 11–19.

[B28] Wolf, J. K., and Zehavi, E., *"P2 codes: Pragmatic trellis codes utilizing punctured convolutional codes,"* IEEE Communications Magazine, February 1995, pp. 94–99.

[B29]ERC *Report 72: Compatibility Studies Related to the possible Extension Band for HIPERLAN at 5 GHz*, http://www.ero.dk/doc98/Official/pdf/REP072.pdf

[B30] IEEE 802.11a-1999: *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High Speed Physical Layer in the 5 GHz Band*, http://standards.ieee.org/reading/ieee/std/lanman, select 802.11a-1999.pdf

[B31] ETSI TS 101 475 v1.1.1 (2000-4) *BRAN HIPERLAN Type 2; Physical Layer.*

Copyright © 2003 IEEE. All rights reserved.

[B32] ITU, *ITU Radio Regulations*, Appendix S8, 1998 Edition.

[B33] U. K. Dept. of the Environment, Transport and the Regions, *Digest of environmental Statistics*, 15/3/2001, http://www.environment.detr.gov.uk/des

[B34] ETSI EN 300 674 v1.1.1 (1999-2) ERM RTTT; *Technical characteristics and test methods for Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s / 250 kbit/s) operating in the 5,8 GHz Industrial, Scientific and Medical (ISM) band.*

[B35] CEN/TC 278 prEN 12253: *Road Transport and Traffic Telematics (RTTT) - Dedicated Short Range Communication (DSRC) - Physical Layer using Microwave at 5.8 GHz.*

[B36] ERC *Report 15:Compatibility Studies Between Radar and WLANs Operating at Frequencies Around 5.5 GHz,* http://www.ero.dk/doc98/Official/pdf/REP015.pdf

[B37] ERC/DEC/(99)23 *ERC Decision on the harmonised frequency bands to be designated for the introduction of HIPERLANS, 29-11-1999,* http://www.ero.dk/doc98/official/pdf/DEC9923E.PDF

[B38] CEPT/ERC/REC 70-03 Relating to the use of short range devices (SRD), http://www.ero.dk/doc98/official/pdf/REC7003E.PDF

[B39] Johnson, D. and Dudgeon, D., *"Array Signal Processing,"* Prentice-Hall, Englewood Cliffs, NJ, 1993.

[B40] Liberti, J. C. and Rappaport, T. S., *"Smart Antenna for Wireless Communications,"* Prentice-Hall, Englewood Cliffs, NJ, 1999.

[B41] Erceg, V., et al., *"Channel models for fixed wireless access applications,"* http://www.wirelessman.org/tg3/contrib/802163c-01_29r4.pdf

[B42] Branlund, D., *"Stacked Carrier OFDM: Providing High Spectral Efficiency with Greater Coverage,"* Wireless Communications Association International 7th annual Technical Symposium, San Jose, CA, Jan. 17–19, 2001.[1]

[B43] Hagenauer J., *"The Turbo principle: Tutorial introduction and state of the art,"* in Proceedings of the International Symposium on Turbo Codes, Brest, France, Sept. 1997, pp. 1–11.

[B44] USA ITU-R WP7C/24, 8A-9B/3 (2000-2003) *"Analysis of potential interference between spaceborne SARS and U-NII devices around 5.3 GHz,"* http://www.itu.int/itudoc/itu-r/sg7/docs/wp7c/2000-03/contrib/024e.html

Insert Annex B as follows:

[1]Contact WCAI at +1(202)452 7823 or sahar@wcai.com to obtain copy.

Copyright © 2003 IEEE. All rights reserved.

Annex B

(informative)

Applicable to systems between 2 and 11 GHz

B.1 Targeted frequency bands

Table B.1 indicates frequency bands, and their allowed channel spacings, where the 2–11 GHz PHY layer may be applicable.

Table B.1—Frequency bands and channel allocation

Frequency bands (GHz) (licensed unless noted)		Allowed channel spacing	Reference
2.305–2.320 2.345–2.360		1 or 2 x (5 + 5 MHz) or 1 x5 MHz (Can be aggregated in any combinations) Interference Protection to DARS	USA CFR 47 part 27 (WCS) See FCC Docket IB95-91 for potential (increased) interference from DARS repeaters.
2.150–2.162 2.500–2.690		125 kHZ to (n x 6) MHz Single or multiple, contiguous or non-contiguous and combinations. Interference Protection to video and ITFS users	USA CFR 47 part 21.901 (MDS) USA CFR 47 part 74.902 (ITFS, MMDS)
2.150–2.160 2.500–2.596 2.686–2.688		1 MHz – (nx6) MHz (1 or 2-way) 25 kHz-(n x 25 kHz) "return" Contiguous channels preferred	Canada SRSP-302.5 (MCS) MDS service allocated to adjacent sub-bands (incl. separate "return" channels)
2.400–2.483.5 (license-exempt)		Frequency Hopping or Direct Sequence Spread Spectrum etc.	CEPT/ERC/REC 70-03 USA CFR 47 Part 15, subpart E [B19]
3.400–4.990	3.410–4.200	1.75–30 MHz paired with 1.75 MHz to 30 MHz Symmetric only. (50 MHz or 100 MHz separation)	Rec. ITU-R F.1488 Annex II ETSI EN 301 021[B18], CEPT/ERC Rec. 14-03 E, CEPT/ERC Rec. 12-08 E
	3.400–3.700	n x 25 MHz (single or paired) (50 MHz or 100 MHz separation if paired)	Rec. ITU-R F.1488 Annex I CITEL PCC.III/REC.47 (XII-99) Canada SRSP-303.4 (BWA)
	3.650–3.700	Rulemaking in progress	USA FCC Docket WT00-32
	4.940–4.990	Rulemaking in progress	USA FCC Dockets WT00-32 and ET-98-237

Copyright © 2003 IEEE. All rights reserved.

Table B.1—Frequency bands and channel allocation *(continued)*

Frequency bands (GHz) (licensed unless noted)		Allowed channel spacing	Reference
5.150–5.850 (license-exempt)	5.150–5.350	n x 20 MHz (HIPERLAN) Restricted to Indoor Use	CEPT/ERC/REC 70-03
	5.470–5.725	n x 20 MHz (HIPERLAN)	
	5.250–5.350	100 MHz Max. Restricted to Indoor Use	USA CFR 47 Part 15, subpart E [B19] USA CFR 47 Part 15, subpart C [B19]
	5.250–5.350	100 MHz Max	
	5.725 –5.850	125 MHz Max	
10.000–10.680		3.5 to 28 MHz paired with 3.5 to 28 MHz. Symmetric only 350 MHz separation	CEPT/ERC/REC. 12-05 ETSI EN 301 021 [B18]

B.2 License-exempt co-existence and interference analyses

B.2.1 Interference mitigation and sharing mechanisms

A number of license-exempt interference mitigation and sharing mechanisms are identified. Two categories are considered: mechanisms that fall within the scope of the WirelessHUMAN standard and methods that fall outside that scope.

Within the scope of the WirelessHUMAN standard, two methods are identified: DFS and transmit power control, both are mandated by the WirelessMAN standard (see 6.2.14 and 8.4.6.4 respectively) and by some regulatory regions such as ECC [B36].

Two methods outside the scope of the WirelessMAN standard are identified: antenna directivity and antenna polarization.

B.2.1.1 Dynamic frequency selection

As frequency planning is not practical in licensed-exempt bands, DFS can be used to avoid assigning a channel to a channel occupied by another system. DFS is generally based on comparison of a C/I threshold against idle time RSSI measurements. DFS is predominantly effective to combat interference from and to ground based systems, such as RLANS, RTTT, radar and other WirelessHUMAN compliant systems. It is generally ineffective to combat interference from and to airborne systems, such as airborne radars and satellites.

B.2.1.2 Transmit power control

With power control, the transmitter EIRP is reduced according to the link margin. Shorter link ranges result in lower transmitted power levels. For PMP systems, the average EIRP will typically be several dB's below the legal limit assuming that SSs are spread throughout the coverage area. For Mesh systems, this means that EIRP values decrease rapidly as customer deployment density increases. As power control is also influenced by C/I levels, the use of adaptive power control with DFS, where possible, tends to result in the most effective interference mitigation.

Copyright © 2003 IEEE. All rights reserved.

B.2.1.3 Antenna directivity

Antenna directivity, in horizontal but especially in vertical direction can significantly reduce a BWA's interference potential and resilience. Vertical directivity especially reduces the interference caused to satellite systems, which are designated primary users of part of the addressed bands. It also can significantly help reduce interference to and from indoor RLAN systems. Horizontal directivity significantly reduces the probability of interference to other systems (assuming interference is mainly caused in the main lobe), but tends to increase the severity of the interference, as the energy in the main lobe is generally higher.

B.2.1.4 Antenna polarization

Antenna cross-polarization in the 5-GHz band can achieve an isolation of up to 15 dB in LOS, but reduces significantly in near-LOS and NLOS environments. Most deployments use both horizontal and vertical polarization (circular polarization is not as common in currently known systems) to maximize spectral re-use. Polarization hence has the potential to provide some isolation between differently polarized systems, especially in LOS, but given the operational needs and implementation of most systems in the targeted spectrum, the effectiveness will be mostly marginal.

B.2.2 Services in the 5 GHz band

To enable co-existence studies, a short description of the systems and services in the 5-GHz bands is provided together with the necessary parameters for the subsequent interference analysis. This includes assumptions on parameters of WirelessHUMAN compliant systems that are beyond the scope of this standard.

B.2.2.1 WirelessHUMAN PMP system

PMP are based upon the use of a central BS with distributed SSs.

Parameters shown in Table B.2 for sample systems BWA1 and BWA2 are assumed.

Table B.2—Single U-NII BWA to SAR-4 Interference

Parameter	BWA_1	BWA_2	units
Transmitted power (antenna port)	0		dBW
Antenna high elevation gain	0	–4	dB
Building loss (dB)	0		dB
Polarization	H/V	H/V	

B.2.2.2 WirelessHUMAN Mesh system

The Mesh deployment scenario is abstracted into a regular hexagonal shape as shown in Figure B.1. On each corner of each hexagon, one Mesh node is located. By parameterizing the distance between a set of neighboring nodes, different Mesh deployment density scenario's can relatively easily be analyzed.

Copyright © 2003 IEEE. All rights reserved.

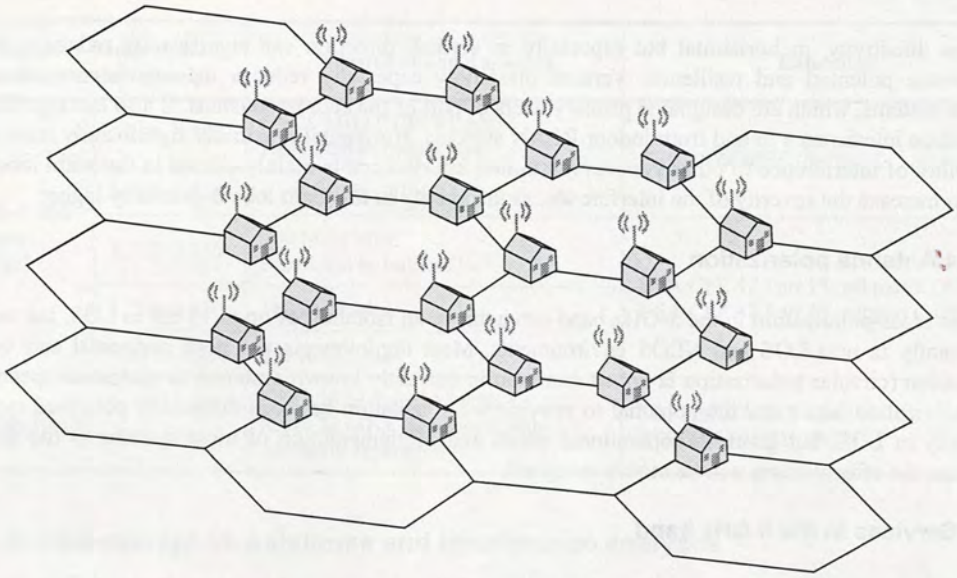


Figure B.1—WirelessHUMAN Mesh deployment model

If the distance between two nodes is denoted *r*, then from each node, there are 3 neighbors at distance *r*, 6 nodes at distance $2r\sqrt{3}/2$, 3 nodes at distance *2r*, 6 nodes at distance $3r\sqrt{3}/2$, 6 nodes at distance *3r*, 12 nodes at distance $\sim 4r\sqrt{3}/2$, 3 nodes at distance *4r*, 12 nodes at distance $\sim 5r\sqrt{3}/2$ etc.

Mesh devices that are close to each other cannot transmit at the same time on the same channel. This is normally defined in terms of extended neighborhoods, which comprises all nodes within two hops from the transmitting node. For modeling purposes, it is assumed that if a node is transmitting, all other nodes on the three hexagons that intersect on that node are silent. This translates into all nodes within a distance of *2r* being silent.

In Table B.3, the topology and traffic assumptions are shown. The Tx activity of a node depends heavily on its position in the network, i.e., the amount of traffic that has to be forwarded from or to other nodes; and the activity of neighboring nodes. To keep the analysis simple, an average of 5% is assumed (This is based on the current average household internet usage of 30 minutes per day, as well as the activity probability during this on-time).

Table B.3—Tx activity parameters

Parameter	Value
Typical hops/packet	2
Total Tx activity	5%

Based on this model, the background interference at any node can be computed, which can be added to the interference from the node in question, resulting in the overall system interference.

Copyright © 2003 IEEE. All rights reserved.

B.2.2.2.1 Antenna parameters

The Mesh device is assumed to be using omni-directional antennas at all times, which is a worst-case assumption, as non-broadcast communications between nodes could be performed with multiple antennas to reduce overall interference.

It is extremely important to notice that the Mesh device is by necessity a roof-mounted device, as it has to extend coverage in all directions. In contrast to PMP Subscriber System (SSs), which are typically installed under the eaves, the amount of vertical scattering, which is harmful to both ground-based RLAN devices and satellites, is significantly less despite the lack of horizontal directivity. This is due to the relatively good probability of clear line-of-sight of the nodes to each other due to their individual mounting location as well as the significantly shorter distances to each other than a PMP SS typically enjoys to its BS.

For these reasons, no extra scattering in the vertical direction is assumed for this evaluation besides the antenna pattern.

Table B.4—Antenna parameters

Parameter	Value
Mounting	Outdoors/rooftop
Gain (Horizontal omni-directional)	8 dBi @ 90° –22 dBi @ 0–30° –15 dBi @ 30–50°
Polarization	vertical

As shown in Table B.4, the antenna is an 8dBi gain omni-directional antenna with a –22 dBi vertical gain and worst-case –15 dBi between 30 and 50° from vertical.

B.2.2.2.2 Radio parameters

Although 10 MHz channelization is also defined, the focus here is on the mandatory 20 MHz channelization, which gives the worst case scenarios.

It is important to note that, throughout this study, the use of 6 dBW max. EIRP is assumed for all parts of the spectrum with a backoff of only 3 dB for RLAN type devices. It should be understood that this study errs on the side of caution when considering the amount of interference that can be tolerated; as an example, in a practical OFDM system, the backoff is in the order of at least 6 dB minimum, whereas the rules commonly specify at most 0 dBW maximum mean EIRP [B37] or 6dBW maximum peak EIRP [B19] for fractions of the band.

Table B.5—Relevant Radio parameters

Parameter	Value
Transmit power	28 dBm (i.e., 36 dBm max EIRP) with dynamic power control
20 dB bandwidth	21 MHz
Peak-to-Average power ratio	3 dB

Copyright © 2003 IEEE. All rights reserved.

The Rx sensitivity and C/I parameters are obtained from Table 116bj (NF=7 dB, margin = 5 dB).

For the purpose of analytical full network interference analysis, the receiver sensitivity of the Mesh system is chosen to be –75 dBm, an average of the modulation and coding mode sensitivities up to rate 1/2, 16-QAM, which will be the most likely used in practical deployments.

B.2.2.3 EESS and FSS

Two types of satellite services are deployed in the 5 GHz: fixed satellite service (FSS) and earth exploratory satellite systems (EESS) services. EESS services are provided by two distinct types of satellite: Altimeter satellites and SAR satellites.

B.2.2.3.1 Altimeter satellites

The characteristics of altimeter satellites have been derived from [B29].

Table B.6—Altimeter satellite characteristics

Parameter	Value
Bandwidth	320 MHz
Rx sensitivity	–88 dBm
On-axis antenna gain	32.5 dBi
Off-axis antenna gain	$10^{3.25}(\mathrm{Sin}(\varphi)/\varphi)^2$ [a]
Antenna size	1.2 m
Height	1344 km
Input loss = Output loss	1 dB
Coverage	$\varphi \in [-60°, 60°]$
Bandwidth	320 MHz

[a] φ is the angle between the vertical and the direction of the ground-based device.

B.2.2.3.2 SAR satellites

The characteristics of SAR-1 through SAR-4 satellites have been derived from [B29].

Table B.7—Typical space borne imaging radar characteristics

Parameter	Value			
	SAR1	SAR2	SAR3	SAR4
Orbital altitude	426 km (circular)	600 km (circular)	400 km (circular)	400 km (circular)
Orbital inclination	57°	57°	57°	57°
RF Centre frequency	5305 MHz	5305 MHz	5305 MHz	5300 MHz
Peak radiated power	4.8 Watts	4800 Watts	1700 Watts	1700 Watts

Copyright © 2003 IEEE. All rights reserved.

Table B.7—Typical space borne imaging radar characteristics *(continued)*

Parameter	Value			
	SAR1	SAR2	SAR3	SAR4
Polarization	Horizontal (HH)	Horizontal and Vertical (HH,HV,VH,VV)	Horizontal and Vertical (HH,HV,VH,VV)	Horizontal and Vertical (HH,HV,VH,VV)
Pulse modulation	Linear FM chirp	Linear FM chirp	Linear FM chirp	Linear FM chirp
Pulse bandwidth	8.5 MHz	310 MHz	310 MHz	40 MHz
Pulse duration	100 μs	31 μs	33 μs	33 μs
Pulse repetition rate	650 pps	4492 pps	1395 pps	1395 pps
Duty cycle	6.5%	13.9%	5.9%	5.9%
Range compression ratio	850	9610	10230	1320
Antenna type	Planar phased array 0.5m x 16.0m	Planar phased array 1.8m x 3.8m	Planar phased array 0.7m x 12.0m	Planar phased array 0.7m x 12.0m
Antenna peak gain	42.2 dBi	42.9 dBi	42.7/38 dBi (full focus/beam-spoiling)	42.7/38 dBi (full focus/beam-spoiling)
Antenna median sidelobe gain	–5 dBi	–5 dBi	–5 dBi	–5 dBi
Antenna orientation	30° from nadir	20–38° from nadir	20–55° from nadir	20–55° from nadir
Antenna half-power beamwidth	8.5° (El), 0.25° (Az)	1.7° (El), 0.78° (Az)	4.9/18.0° (El), 0.25° (Az)	4.9/18.0° (El), 0.25° (Az)
Antenna polarization	Linear horizontal/ vertical	Linear horizontal/ vertical	Linear horizontal/ vertical	Linear horizontal/ vertical
System noise temperature	550 K	550 K	550 K	550 K
Image swath width	50 km	20 km	16 km/ 320 km	16 km/ 320 km

For both the SAR imaging missions and the topographic missions, a minimum signal-to-noise ratio (SNR) is defined, below which the radar image pixels, and/or differential phase measurements are unacceptably degraded. Studies suggest that:

— the degradation of the normalized standard deviation of power received from a pixel should be less than 10% in the presence of interference;
— the aggregate interference power-to-noise power ratio (corresponding to a pixel SNR of 0 dB) should be less than –6 dB;
— These levels may be exceeded upon consideration of the interference mitigation effect of SAR processing discrimination and the modulation characteristics of the radiolocation/ radio-navigation systems operating in the band;
— The maximum allowable interference level should not be exceeded for more than 1% of the images in the sensor service area for systematic occurrences of interference and should not be exceeded for more than 5% of the images in the sensor service area for random occurrences of interference.

Copyright © 2003 IEEE. All rights reserved.

The data loss criteria have been fully utilized to achieve sharing with the radio determination service. This study therefore uses the degradation interference criteria to derive the sharing constraints on BWA devices. Assuming that the interfering signal distribution is white Gaussian noise the maximum acceptable interference signal is indicated in Table B.8.

Table B.8—Typical space borne imaging radar characteristics

Parameter	Value			
Noise (dBW)	−129.5	−113.8	−113.8	−122.7
Min. desired signal (dBW)	−189.7	−198.6	−187.1	−187.0
Max. acceptable interfering signal (dBW)	−135.5	−119.8	−119.8	−128.7
Receiver bandwidth (MHz)	9.8	356.5	356.5	46
Max. acceptable interfering spectral power density (dBW/Hz)	−205.4	−205.4	−205.4	−205.4
Antenna polarization	Linear horizontal/ vertical	Linear horizontal/ vertical	Linear horizontal/ vertical	Linear horizontal/ vertical
System noise temperature	550 K	550 K	550 K	550 K
Receiver front end 1 dB compression point ref to receiver input	−62 dBW input	−62 dBW input	−62 dBW input	−62 dBW input
Ground illumination area	93 km (elevation), 2.2 km (azimuth)	At 20° from nadir: 20 km (elevation), 8.7 km (azimuth)	At 20° from nadir: 40 km (elevation) 2 km (azimuth)	At 20° from nadir: 40 km (elevation) 2 km (azimuth)

B.2.2.3.3 FSS satellites

The characteristics of Fixed Satellite Service satellites have been derived from [B29].

The maximum allowable interference power spectral density tolerated by FSS satellites is given by

$$p = -42 + (G/T) - \gamma \qquad dBW/Hz \tag{99}$$

where G is the gain of the satellite antenna, T the noise temperature (G/T is termed the merit factor), and γ the link gain. FSS satellites are geo-stationary and located at 36000 km, resulting in 199 dB pathloss. In the case of the Telecom 3 network [B29], which is used as an example, γ is 0 dB, the total link equivalent noise temperature is 870 K, the gain for the 'Metropole' spot is 34 dBi and the coverage area of this spot is all of Europe. G/T then becomes 4.6 dB.

B.2.2.4 RLANs

The RLAN deployments considered here are the ETSI BRAN HIPERLAN/2 [B31] and IEEE 802.11a devices. Only indoor deployments are considered in detail. It is clear that outdoor RLAN devices cannot generally co-exist in the same channel with BWA devices in the same geographical area. However, the use of DFS, as well as the fact that the hotspot locations envisioned for outdoor RLAN deployments (such as airports and school campuses) do not generally coincide with the residential areas Mesh devices are targeted towards, easily resolve this type of RLAN deployments.

Copyright © 2003 IEEE. All rights reserved.

Table B.9—RLAN Parameters I

Parameter	Value
Antenna type	Isotropical
Tx probability RLAN device	5%
Tx power	30 dBm max EIRP with dynamic power control
Radio access	TDD/TDMA

Table B.10—RLAN parameters II[a]

Modulation	Coding rate	Rx sensitivity (dBm @ 10% PER)	C/I (dB @ 10% PER)
BPSK	1/2	–82	6
	3/4	–81	11
QPSK	1/2	–79	9
	3/4	–77	14
16-QAM	1/2	–74	16
	3/4	–70	20
64-QAM	1/2	–66	25
	3/4	–65	30

[a]Copied from [B30], Table 91.

B.2.2.5 RTTT

Road transport & traffic telematics (RTTT) devices[B34] are allocated in the band 5795-5805 MHz (2×5 or 1×10), with an extension band 5805-5815 MHz (2×5 or 1×10), which may be used on a national basis at multi-lane road junctions. These devices are split into the Road Side Unit (RSU) and the onboard unit (OBU), the parameters for which are shown in Table B.11 and Table B.12.

Table B.11—RTTT RSU Parameters

Parameter	Value
Tx power (max EIRP)	3 dBW
Rx sensitivity	–105 to –130 dBW[a]
Antenna gain	20 dB
C/I: 2 / 4 / 8 - PSK	6 / 9 /12 dB
Polarization	circular

[a] This range is merely informative. The device shall merely meet the manufacturer's claim.

Copyright © 2003 IEEE. All rights reserved.

Table B.12—RTTT OBU Parameters (–35° to +35°)

Parameter	Value	
Class	A,B,C,D	E
Re-radiated carrier power (max EIRP)	–54 dBW	–44 dBW
Antenna gain	1 dB	
Rx sensitivity	–73 dBW	–70 dBW
C/I: 2 / 4 / 8 – PSK	6 / 9 /12 dB	C/I: 2 / 4 / 8 – PSK
Polarization	circular	polarization

In analyzing the compatibility between WirelessHUMAN systems and RTTT the basic approach taken is to use the Minimum Coupling Loss (MCL) technique to determine the necessary separation distances between the two systems.

Minimum coupling loss:
$$L = P_t - max\left\{10\log\left(\frac{B_i}{B_{Rx}}\right),\ 0\right\} - I_{Rx} \quad (100)$$

where

P_t is the transmitter power

B_{Rx} is the receiver bandwidth (MHz)

B_i is the interferer bandwidth (MHz)

I_{Rx} is the tolerable interference at receiver (dBW)

Required separation distance: $d = \frac{\lambda}{4\pi} 10^{pathloss/\ 23}$ where *pathloss = L + Antenna and feeder gains and losses.*

B.2.2.6 Radar

The radar parameters used in the radar analysis are taken from [B29], [B36]. In the analysis, the MCL technique described in B.2.2.5 will be used, with the exception that for the airborne radar (radar type B), a propagation exponent 2.0 instead of 2.3 is used.

Table B.13—Relevant radar parameters

Parameter	Value				
Radar type	A	B	C	D	E
Peak EIRP (dBW)	98.6	26	60	93	97
BW_{radar} (MHz)	3	15	30	14	3
Antenna gain (dBi)	40	0	46	43	43
Tuning range (GHz)	5.30–5.60	5.70–5.80	5.40–5.82	5.25–5.85	5.60–5.65
Use	Transportable long range	Airborne	Fixed long range	Transportable multi-function	Fixed long range

Copyright © 2003 IEEE. All rights reserved.

B.2.3 WirelessHUMAN PMP interference analyses

B.2.3.1 Coexistence with SAR satellites in middle UNII

SAR-4 is used because the SAR-4 system is more interference sensitive than SAR-3, and the SAR-4 center frequency is 5.3 GHz. The SAR-4 Synthetic Aperture Radar scans a path from 20° to 55° from Nadir. This corresponds to Earth incident angles of 21° and 60°, which can be translated to angles of 69° and 30° with respect to the horizon. That is, any radiation from U-NII devices within that angular range could cause/ contribute to satellite interference.

An approach that can be used in analyzing the interference potential from Middle U-NII BWA systems into space-borne SAR-4 receiver is to determine the worst case signal power received from a single BWA transmitter at the space borne SAR. Then, the single interferer margin can be calculated by comparing the single BWA interferer level with the SAR-4 interference threshold. Knowing the SAR-4 footprint, the allowable density of active BWA transmitters can then be calculated, if a positive margin results from a single BWA interferer.

Table B.14—Single U-NII BWA to SAR-4 Interference

Parameter	BWA_1	BWA_2	units
Tx Power	0		dBW
Building loss	0		dB
Interference gain due to SS antenna directivity [B44]	−6		dB
Antenna high elevation gain	0	−4	dB
Pathloss (425.67 km)	−160.3		dB
Polarization gain (V/H –> H/V)	−3		dB
Noise figure	−4.62		dB
Noise power (46 MHz Rx bandwidth)	−122.73		dB
SAR-4 Interference threshold (I/N=−6dB)	128.71		dB
Margin (dB)	−4.71	−0.71	dB

Note that real-world antennas do not exhibit unity gain at high elevation look angles, and this feature can be used to mitigate interference.

A conclusion that can be drawn is that antenna directivity, if properly utilized, will provide interference margin for multiple transmitters. However, it should be noted that the satellite footprint is large (53 sq. km at 20° from Nadir and 208 sq. km at 55° from Nadir). Therefore, given the potential variables associated with the design, installation and maintenance of the various unlicensed transmitters, antenna directivity alone may not be sufficient to assure non-interference.

The margin calculation in Table B.14 includes 3 dB polarization loss. The fact that most PMP systems rely on polarization for maximizing channelization, as many as half of the U-NII transmitters in a given area could be transmitting on each polarization. If so, the 3 dB polarization loss may not be fully realizable.

Copyright © 2003 IEEE. All rights reserved.

If the satellite were restricted to one linear polarization and the U-NII transmitters were restricted to the other linear polarization, greater polarization isolation could be achieved. Given the operational needs of both services, this is unlikely to happen.

B.2.4 WirelessHUMAN Mesh interference analyses

B.2.4.1 Interference to EESS and FSS

B.2.4.1.1 Altimeter satellites

The interference from one Mesh node into the boresight of the SAR can be described by (see [B29])

$$P_r = \frac{P_m G_m G_a \lambda^2}{(4\pi)^2 R^2} L \tag{101}$$

where $P_m G_m = 6dBm$ (28 dBm Output power –22 dBi top lobe) is the EIRP of the Mesh antenna in the vertical direction, $G_a = 32.5dBi$ the gain of the altimeter antenna, $\lambda = 5.66cm$ the wavelength, $L = -1dB$ the input loss of the altimeter, and $R = 1344km$ the lowest orbit.

From this a value for $P_r = -132dBm$ can be obtained.

The altimeter interference threshold is –88 dBm; we can thus deduce that the altimeter can withstand the operation of huge numbers of Mesh devices simultaneously, since there is a 44 dB margin. Furthermore, the altimeter is built to provide measurements mainly over oceans and is not able to provide accurate data when a significant amount of land is in view of its antenna beam. From this analysis, it is clear that the altimeter will not suffer from the operation of Mesh networks; however, for completeness, the number of Mesh devices per square kilometer tolerable by the altimeter can be calculated.

The distance between the satellite and a Mesh node under angle φ is R tan(φ) km. Only freespace attenuation, which ignores atmospheric properties (which further attenuate the signal, especially when φ>>0) has been considered.

For simplicity, the 3 Mesh nodes that on average exist in one hexagon, are assumed to be in the centre point of the hexagon. The hexagon grid then reduces to a square grid with 3 nodes every 2 times the distance of a single set of nodes.

The value for P_r is then obtained as follows:

$$P_r = \sum_{r_1 r_2}^{3} \frac{P_m G_m G_a \lambda^2}{(4\pi)^2 R^2} L \left(1 + 4A \sum_{r_1 r_2} \operatorname{sinc}^2[2\varphi(r_1, r_2)]\right) \quad \forall \sqrt{r_1^2 + r_2^2} < \frac{R\sqrt{3}}{2} \quad \varphi = arc\tan\left[\frac{2\sqrt{r_1^2 + r_2^2}}{R}\right] \tag{102}$$

where r_1 and r_2 enumerate over the square grid, and A is the activity factor.

This derivation is easily computed numerically. According to [B33], significantly less than 15%[2] of land is used for residential areas and normally a significant fraction of the footprint covers water as well. Hence a Residential fraction of 0.05 is introduced, to simulate clusters of nodes spread out over the whole satellite footprint. The receiver sensitivity is, as discussed in B.2.2.2.2, chosen to be –75 dBm.

[2] Number includes land used for urban and other purposes, e.g., transport and recreation, and non-agricultural, semi-natural environments, e.g., sand dunes, grouse moors and non agricultural grasslands, and inland waters.

Copyright © 2003 IEEE. All rights reserved.

```
%Satellite specifications
Ga = 32.5;                  % dBi   Antenna gain
lambda = 0.0566;            % m     Wavelength
L = -1;                     % dB    Insertion Loss
R = 1344;                   % km    Height
Int_limit = 88;             % dBm Interference limit
%Mesh specifications
Rbase = 0.5;                % km    Distance between two Mesh nodes
AntGain  = 8                % dBi   Mesh antenna gain (max)
AntTop   = -22              % dBi   Mesh antenna gain (top-lobe)
RxSens      =-105           % dBW Rx sensitivity Mesh
Pout        = 28;           % dBm Max. output power Mesh
Backoff   = 3;              % dB  Average Backoff
Activity    = 0.05;
pi = 3.1415;
pathloss = -20*log10(3E8/(4*pi*5.3E9))+2.3*10*log10(Rbase*1000);
PmGm = (pathloss - AntGain + FadingMargin + RxSens) + (AntTop-AntGain) -Backoff+ 30; % dBm
Residential = 0.15;         % fraction residential landuse
Pr1 = 0;nodes =0;
for r1 = Rbase : Rbase/sqrt(Residential): R*sqrt(3)/2
   for r2 = Rbase : Rbase/sqrt(Residential): R*sqrt(3)/2
      if( sqrt(r1*r1+r2*r2) < R*sqrt(3)/2)
         nodes = nodes+3;
         phi = atan( 2*sqrt(r1*r1+r2*r2)/R );
         Pr1 = Pr1 + sinc(2*phi/pi)*sinc(2*phi/pi);
      end;
   end;
end;
Pr2=10*log10(3*lambda*lambda*(1+4*Pr1*Activity)*10^((Ga+PmGm+L)/10)/...
      ((4*pi)*(4*pi)*R*R*1E6) );
sprintf('Distance between nodes: %d m\n',Rbase*1E3)
sprintf('Interference margin to altimeter: %d dB\n',Int_limit + Pr2)
```

Figure B.2—Mesh interference code sample

The result of the simulation, as shown above, is that over 30 million nodes can be supported under the footprint, with 6 dB in interference margin. In many cases shorter distances between the nodes will result in lower used power due to power control. Hence in practice many more nodes could be supported without violating the interference limit.

B.2.4.1.2 SAR satellites

In analogy with [B29], only the case for SAR-1 satellites is examined, since this provides the worst case analysis. However, contrary to this report, it will show that, using Mesh technology, an increase in network density actually reduces the interference into the SAR satellite, since the dynamic power-control reduces the power for shorter links. The receiver sensitivity is, as discussed in B.2.2.2.2, chosen to be –75 dBm.

As can be seen from Table B.15, a Mesh network has limitations both on the maximum distance and maximum density of the network. The maximum distance that can be achieved by the Mesh network using 4 Watts EIRP is about 1 km, which retains a margin of 10 dB to the interference threshold.

Deployments with distances between nodes of one km are however exceedingly sparse and not practical except in the very early stages of service rollout (i.e., when seeding the service area).

Copyright © 2003 IEEE. All rights reserved.

Reducing the distance increases the number of nodes, but reduces the necessary power levels, hence reducing the overall interference into the satellite. Increasing the density, and hence the number of nodes to very high levels, up to about one device per 92 m would still obtain tolerable interference levels. Deployment densities of this nature, especially in the areas of major interest to the satellite community (oceanic and agrarian), are extremely unlikely.

To allow an easier comparison with the RLAN results in [B29], Table B.15 computes the number of Mesh devices that can be situated in the SAR footprint without exceeding the interference limit.

Table B.15—WirelessHUMAN Mesh devices in the SAR footprint

Parameter	Value				
Node distance	1	0.5	0.25	0.1	km
Tx antenna gain	8				dBi
Rx sensitivity	−105				dBW
path loss	115.93	109.00	10.08	92.93	dB
P_{out} required (EIRP)	2.93	−4.00	−10.92	−20.07	dBW
P_{out} required (conducted)	−5.07	−12.00	−18.92	−28.07	dBW
Freespace distance	−160.8				dB
Building attenuation	0				dB
Tx antenna gain (top lobe)	−22				dBi
Polarization loss	−3				dB
Peak-to-Average ratio	−3				dB
Rx antenna gain (main lobe)	42.4				dBi
Rx Power	−224.90	−231.82	−238.74	−247.90	dBW/Hz
SAR threshold	−205				dBW/Hz
Margin	19.54	26.46	33.38	42.54	dB/Hz
SAR footprint	22.59				dB
Tx activity	−13.01				dB
Permissible density/km^2/ch	9.91	498.78	240.22	1976.39	nodes
Nodes within SAR footprint (CEPT region)	26967	132804	654001	5380723	nodes

In Table B.15, it is assumed that all Mesh devices are located in the boresight of the SAR satellite, which provides the worst case scenario.

B.2.4.1.3 FSS satellites

The bandwidth of the Mesh device is 21 MHz (73.2 dBHz). The maximum allowable interference power spectral density tolerated by the Telecom 3 network (see B.2.2.3.3) then becomes 27 dBW/Hz.

Appendix S8 of the ITU Radio Regulations [B32] gives the method to calculate the maximum interference power produced by an earth station to a satellite receiver. When calculating the maximum interference

Copyright © 2003 IEEE. All rights reserved.

power from Mesh devices into a satellite receiver, consider all the Mesh devices under the satellite footprint as a single source. This means that the source is not specifically located, and only the direct top lobe of the Mesh antenna is taken into account.

Table B.16—Tolerable Mesh nodes for FSS operation

Parameter	Value				
Tx EIRP	–6	0	3	6	dBW
Tx antenna gain (main lobe)	8				dBi
Tx antenna gain (top lobe)	–22				dBi
Peak-to-Average Ratio	3				dB
Shielding effect	0				dB
Acceptable interference	27				dBW
Active users	1000	251	126	63	nodes (thousands)
Average Tx ratio	5				%
Tolerable nodes	300	75.4	37.8	18.9	nodes (millions)

From Table B.16, it shows that by using 4 W (6 dBW) EIRP, an enormous amount of Mesh nodes can be in operation within the FSS footprint.

B.2.4.2 Interference to RLANs

B.2.4.2.1 Immediate neighborhood analysis

B.2.4.2.1.1 'Same building' analysis (1)

In the immediate neighborhood scenario, the interference from a Mesh node to a RLAN device in the same building is analyzed (link 1 in Figure B.3).

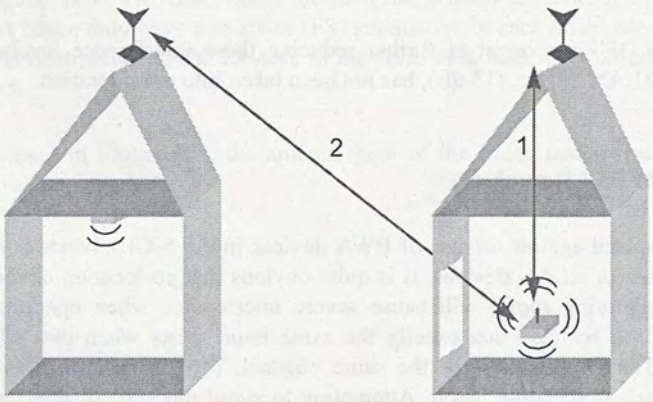


Figure B.3—Immediate neighborhood scenario

Copyright © 2003 IEEE. All rights reserved.

It is assumed for this scenario, that the distance between the Mesh node and the RLAN device in the same building is 5 m. The structural isolation plus attenuation due to multipath/scattering is assumed to be 25 dB over that distance, based to Annex 2 of [B29]. Note that this is not the same as the average 13.4 dB assumed in [B29], since we consider only placement of Mesh devices on the roof, and not placement outside in general as in the outside RLAN case. This is likely to be a very modest value for a typical (European) home with concrete ceiling and stone tile roofing. The total attenuation is then $25 + 20*\log10(4*\pi*d*f_0/c) = 86$ dB. Given the radiation pattern of a Mesh node transmitting at full 28 dBm (i.e., 36 dBm EIRP), the interference level at the RLAN = 28-22-86= –80 dBm. Taking into account the backoff, 3 dB, and the effect of the Mesh activity factor, an additional 13 dB, brings the average interference level, –97 dBm, far below receiver sensitivity values. Operation of a Mesh device on the roof, while running an RLAN network inside is hence feasible, even in the same channel.

In this scenario, to operate the RLAN at its highest modulation and coding rate (64-QAM, 3/4 coding) while the Mesh device is transmitting, would require the separation to be at least 20 meters. (instead of the 5 meters used). For 16-QAM, 1/2 coding, the separation would be 10 meters.

B.2.4.2.1.2 'Across the street' analysis (2)

Another critical consideration is the analysis of illumination of indoor RLANs in adjacent buildings. This is due to the fact that despite the larger distance, normally only one isolating building layer (which may also be a window) is situated in-between, and the Mesh antenna gain increases with the angle from the vertical axis.

It is assumed for this scenario that the street is 10 m wide, which gives an antenna gain of –15 dBi and an outdoor distance of $\sqrt{125}$=11.2m. The structural isolation plus attenuation due to multipath/scattering is assumed to be 10 dB (window plus some indoor scattering). The total attenuation is then $10+20*\log10(4*\pi*d*f_0/c) = 78$ dB. Taking into account the antenna gain, the backoff and the Mesh activity factor of the Mesh node reduces the average level at the RLAN to –78 dBm.

Of course, the numbers in the above analysis fluctuate by a number of dB's for individual deployments. The average structural attenuation was quoted to be 13.4 dB in [B29], but there may be variations in building height or terrain sloping that increase the antenna gain in the direction of the RLAN by a few dBs. Typically the above results of this subclause are broadly applicable as conservative estimates to a wide range of deployment scenarios.

Power-control and DFS can assist in further reducing these interference levels. Note that the transmit probability of the RLAN device, (13 dB), has not been taken into consideration.

B.2.4.2.2 Outdoor RLAN analysis

An argument often used against the use of BWA devices in the 5-GHz bands is that it will interfere with outdoor deployments of RLAN devices. It is quite obvious that co-location of these two types of devices on a roof (or neighboring roofs) will cause severe interference when operating in the same channel; however, it should be realized that exactly the same issue exists when two RLAN APs on a roof (or neighboring roofs) are competing for the same channel. (To be specific, this is mostly the case for HIPERLAN/2, which is schedule based. Attempting to avoid this type of interference, which works well for low duty cycles, IEEE 802.11a uses CSMA/CD. In both cases, the requirement for a DFS mechanism can gracefully resolve the problem. In addition, outdoor RLAN deployments are predominantly used for hot-spot coverage and bridging, which implies the use of down-tilted antennas and oftentimes geographical isolation for hot-spot coverage and very directive antennas for bridging, each of which

Copyright © 2003 IEEE. All rights reserved.

reduces the interference potential. In the cases where RLANs are currently used for access provisioning, WirelessHUMAN compliant systems will likely not be deployed or be used as more efficient substitutes.

BWA deployments require broad coverage and reasonable frequency re-use numbers to maintain sufficient Signal-to-Noise Ratio plus limited DFS flexibility to avoid local interference sources. Therefore, the likelihood of roof-mounted RLAN devices unable to find a sufficient noise-free channel for proper operation are rather small.

B.2.4.2.3 Network analysis

To illustrate the interference analysis further, a typical scenario consisting of a 4-node indoor RLAN network and a nearby 4-node Mesh network, is examined.

From Annex 2 of [B29], we extract that the typical indoor attenuation on top of free-space attenuation at 5 m is 4 dB for a mixture of line-of-sight through non-line-of-sight scenarios. The additional attenuation through 1 wall is 7.1 dB and the additional attenuation through 2 walls is 12.5 dB (the walls in these cases were breeze blocks and the rooms contained both wooden and metal furniture). The attenuation through a double-glazed window was found to be 7 dB.

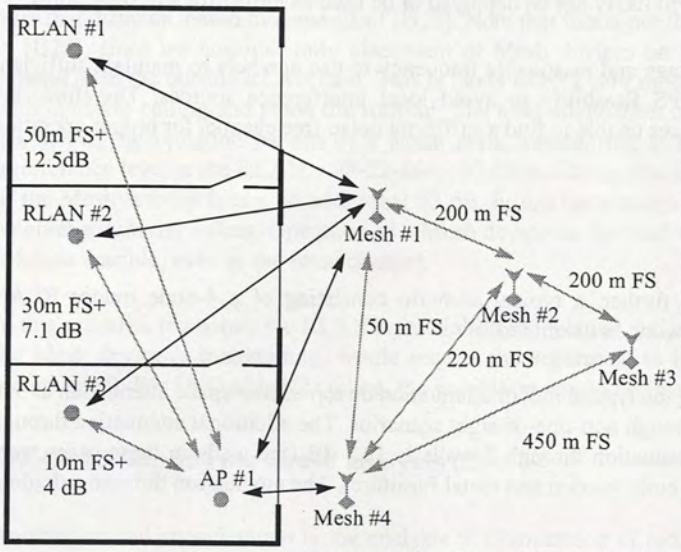
In the case under study, a SU is assumed from each of these cases in a Small Office setting. The SU in the same room is assumed at 10 m; the SU in the adjacent room at 30 m; and the SU behind two walls at 50 m.

The Small Office is assumed to be a single-floor building with a flat roof. The attenuation through the roof is 22 dB. A typical indoor cross-floor attenuation according to Annex two of [B29] is 19 dB, which is probably a fairly pessimistic value. The Mesh #4 node is situated on the roof directly atop AP #1 and provides the 'Internet access' for the RLAN service within the building. The cabling distance between the data gathering point, the AP, and the access service, Mesh #4 node, is shortest. The distance between AP #1 and Mesh #4 is assumed to be 5 m.

The nearest neighboring node, Mesh #1, is 50 m away on an adjacent building. The building attenuation is 10 dB (a window plus indoor scattering, as in B.2.4.2.1.2. It is assumed that this building is lower than the building with the RLANs, resulting in an antenna gain of –10 dBi in the direction of the RLANs, rather than the –15 dBi specified in Table B.4). Two other nodes are each 200 m away as shown in Figure B.4. All Mesh nodes are on the roof and hence only have free-space (FS) attenuation to each other. Mesh #3 is assumed to have an additional 15 dB obstruction to the RLANs in the form of a building (basically the building on which Mesh #2 is located).

Note that in the Path Losses in Figure B.4, the antenna gain of the Mesh nodes (see Table B.4) in the direction of the RLANs has been included.

Copyright © 2003 IEEE. All rights reserved.



Path	Path Loss
Mesh#1 - AP#1	50m FS + 28dB
Mesh#1 - RLAN#1	60m FS + 28dB
Mesh#1 - RLAN#2	70m FS + 28dB
Mesh#1 - RLAN#3	80m FS + 28dB
Mesh#2 - AP#1	250m FS + 33dB
Mesh#2 - RLAN#1	250m FS + 33dB
Mesh#2 - RLAN#2	260m FS + 33dB
Mesh#2 - RLAN#3	270m FS + 33dB
Mesh#3 - AP#1	450m FS + 48dB
Mesh#3 - RLAN#1	450m FS + 48dB
Mesh#3 - RLAN#2	460m FS + 48dB
Mesh#3 - RLAN#3	470m FS + 48dB
Mesh#4 - AP#1	5m FS + 52dB
Mesh#4 - RLAN#1	52m FS + 48dB
Mesh#4 - RLAN#2	32m FS + 48dB
Mesh#4 - RLAN#3	12m FS + 52dB

Figure B.4—Example network scenario

In Table B.17, the ranges and corresponding total link attenuations, which are assumed to be symmetrical, are gathered. In general, it can be observed that only nodes that are really close or in line of sight through little attenuation (particularly windows) result in significant interference.

Table B.17—Link attenuations and ranges

	Link attenuation / Range							
	Mesh #1	Mesh #2	Mesh #3	Mesh #4	AP #1	RLAN #1	RLAN #2	RLAN #3
Mesh#1	----------	200 m	400 m	50 m	50 m	60 m	60 m	60 m
Mesh#2	94 dB	----------	200 m	220 m	220 m	230 m	230 m	230 m
Mesh#3	100 dB	94 dB	----------	450 m	450 m	460 m	460 m	460 m
Mesh#4	82 dB	94 dB	101 dB	----------	5 m	52 m	32 m	12 m
AP#1	110 dB	127 dB	149 dB	106 dB	----------	50 m	30 m	10 m
RLAN#1	111 dB	128 dB	149 dB	130 dB	94 dB	----------	50 m	20 m
RLAN#2	111 dB	128 dB	149 dB	126 dB	84 dB	132 dB	----------	30 m
RLAN#3	111 dB	128 dB	149 dB	121 dB	72 dB	94 dB	107 dB	----------

Copyright © 2003 IEEE. All rights reserved.

In Table B.18, the maximum power and EIRP values for each of the devices is shown. For the RLAN devices and their AP, values are chosen that reflect implementations that are currently available in the market.

Table B.18— Tx Power, conducted and EIRP (regulatory limited)

	AP	RLAN	Mesh
Tx Power (mW)	200	200	500
Antenna (dBi)	2	0	8
EIRP (dBm)	25	23	35

In Table B.19, the resulting received signal strengths are shown assuming transmission with EIRP values as shown in Table B.18. Note that especially between the Mesh nodes, the Rx values are extremely high, which would automatically be reduced by the AGC. For simplicity of computation, this is however ignored. This table is not symmetric since different antenna gains at each end can affect the perceived signal level.

Table B.19—Received Signal Levels (dBm)

	Mesh #1	Mesh #2	Mesh #3	Mesh #4	AP #1	RLAN #1	RLAN #2	RLAN #3
Mesh #1	----------	–54	–60	–42	–80	–83	–83	–83
Mesh #2	–54	----------	–54	–54	–97	–100	–100	–100
Mesh #3	–60	–54	----------	—61	–119	–121	–121	–121
Mesh #4	–42	–54	–61	----------	–84	–102	–98	–93
AP #1	–76	–93	–115	–80	----------	–72	–62	–50
RLAN#1	–79	–96	–117	–98	–72	----------	–112	–74
RLAN#2	–79	–96	–117	–94	–62	–112	----------	–87
RLAN#3	–79	–96	–117	–89	–50	–74	–87	----------

Table B.20 shows resulting sustainable modulations. The top row in each box shows the actual communication direction, the used modulation and the Noise threshold. The next four rows illustrate the effect of interference from each source (using maximum allowed EIRP). If the modulation differs from the top box, then switch to a more robust modulation scheme was mandatory to maintain 3% PER. The last column defines the interference margin. A positive value means the threshold has been exceeded and is shown in bold.

Copyright © 2003 IEEE. All rights reserved.

Table B.20—Sustainable modulation during interference

RLAN#1 =>AP#1	3/4 QPSK	-90
Mesh #1	**PER>3%**	4
Mesh #2	3/4 QPSK	-13
Mesh #3	3/4 QPSK	-35
Mesh #4	**PER>3%**	0

AP#1 => RLAN#1	3/4 QPSK	-90
Mesh #1	**PER>3%**	1
Mesh #2	3/4 QPSK	-16
Mesh #3	3/4 QPSK	-37
Mesh #4	3/4 QPSK	-18

RLAN#2 =>AP#1	2/3 64-QAM	-95
Mesh #1	1/2 QPSK	-5
Mesh #2	2/3 64-QAM	-22
Mesh #3	2/3 64-QAM	-44
Mesh #4	3/4 QPSK	-9

AP#1 => RLAN#2	2/3 64-QAM	-95
Mesh #1	3/4 QPSK	-8
Mesh #2	3/4 64-QAM	-25
Mesh #3	3/4 64-QAM	-46
Mesh #4	2/3 64-QAM	-23

RLAN#3 =>AP#1	3/4 64-QAM	-95
Mesh #1	1/2 QPSK	-5
Mesh #2	2/3 64-QAM	-22
Mesh #3	3/4 64-QAM	-44
Mesh #4	3/4 QPSK	-9

AP#1 => RLAN#3	3/4 64-QAM	-95
Mesh #1	3/4 QPSK	-8
Mesh #2	3/4 64-QAM	-25
Mesh #3	3/4 64-QAM	-46
Mesh #4	3/4 16-QAM	-18

From Table B.20, two observations can be generalized. The first is that in certain scenarios interference is unavoidable if DFS is not used. The second is that interference only occurs when nodes are really close (such as Mesh #4) or have relatively good line of sight properties (such as Mesh #1, which only has a window in-between and a reduced height antenna) to the RLAN network. The later generalization means that very few nodes in a Mesh network will cause degradation of a RLAN network. Realizing that the interference excess is relatively low, and the Mesh network uses power-control to reduce the EIRP where possible, interference from a transmitting Mesh device will be very limited. Combined with the activity factors for both devices (on average 13 dB each) and DFS mechanisms, the likelihood of interference becomes so small that it is easily handled with Automatic Request (ARQ) causing minimal degradation of performance.

B.2.4.2.4 Adjacent channel issues

A feature of the OFDM technology used in both RLANs and Mesh technology at 5 GHz, is that the adjacent channel rejection is very high, at least 35 dB (see 8.4.10.2). Since the interference levels between RLANs and Mesh devices are relatively low compare to this, it is reasonable to assume that adjacent channels using RLAN and Mesh technology will not cause any noticeable interference to each other; therefore, this requires no further consideration.

B.2.4.3 Interference to RTTT

In accordance with [B29], and [B35], the cross-polarization is assumed to be 10–15 dB to the RSU and 6–10 dB to the OBU (Table B.21 uses the lower numbers).

Copyright © 2003 IEEE. All rights reserved.

Table B.21—Needed separation distance Mesh to RSU and OBU

Parameter	RSU		OBU
P_t	6		6
B_{Rx}	10	5	10
B_i	22		22
$I_{Rx}=Rx_{sens}-C/I_{8PSK}$	−117		−90
L	119.6	116.6	92.6
Cross-polarization	10		6
Antenna & feeder gain	8		8
Separation distance	553	394	53

It should be noted that in the above calculations of Table B.21, the duty cycle of the Mesh devices, which significantly reduces the interference scenario, has not been taken into consideration.

Especially for the RSU case, where the separation distance is fairly significant, it can be shown that the interference to the Mesh device is significantly larger than the other way around. Since RTTT devices normally have a fairly high duty cycle, a close Mesh device would not be able to operate properly in this channel and would need to use the DFS mechanisms to switch to another channel. therefore, for RSUs, proper operation is virtually guaranteed by virtue of its own interference potential.

B.2.4.4 Interference to radar

For radars, a somewhat similar situation exists as with RTTT RSUs. To show this, the interference distance from radars into Mesh devices is derived, followed by the derivation of the interference distance from Mesh devices into radars. Comparing Table B.22 and Table B.23, the interference distance from radars to Mesh is much larger than the interference distance from Mesh to radars.

For analysis of the minimum distance at which an Mesh device still operates, shown in Table B.22, the most robust modulation and coding mode is used.

Table B.22—Minimum separation distance of radar to Mesh

Radar type	A	B	C	D	E	
Peak EIRP	98.6	26	60	93	97	dBW
Antenna gain	40	0	46	43	43	dBi
P_t	58.6	26	14	50	54	dBW
BW_{radar}	3	15	30	14	3	MHz
$I_{mesh}=Rx_{sens}-C/I_{BPSK1/2}$	−116					dBW
L	174.6	142.0	131.3	166.0	170.0	dB
Gain and feeder loss	48	8	54	51	51	dB
Propagation loss	222.6	150	185.3	217	221	dB

Copyright © 2003 IEEE. All rights reserved.

Table B.22—Minimum separation distance of radar to Mesh *(continued)*

Radar type	A	B	C	D	E	
Distance @ 5.5 GHz	20693	137	497	11813	17630	km
Radio horizon	51.4	346.6	51.4	51.4	51.4	km (see [B36])
Separation distance	51.4	137	51.4	51.4	51.4	km

In Table B.23, the thermal noise level has been assumed –204 dB/Hz whereas the Rx noise factor is assumed to be 5 dB. The maximum I/N is –6 dB as specified by NATO (see [B29], [B36]).

Table B.23—Minimum separation distance of Mesh to radar

Radar type	A	B	C	D	E	
P_t mesh			–2			dBW
BW_{radar}	3	15	30	14	3	MHz
Noise (dBW)	–134.2	–127.2	–124.2	–127.5	–134.2	dBW
On-tune rejection	–8.9	–1.9	0.0	–2.2	–8.9	dB (see [B29])
Max. Interference	–131.3	–131.3	–130.2	–131.3	–131.3	dBW
L			129.3			dB
Gain + feeder loss	48	8	54	51	51	dB
Propagation loss	177.3	145.3	191.6	188.3	188.3	dB
Distance @ 5.5 GHz	220.1	79.4	916.3	662.7	662.0	km

Comparing the result of Table B.22 (line 10) and Table B.23 (line 10), it is shown that in all cases, the separation distance is larger for the BWA system, forcing it effectively out of the channel used by the radar. In all cases, the separation distance is effectively limited by the radio horizon.

In the case of radar type B, which is airborne, depending on the exact location of the radar, the gain+feeder loss will reduce from +8 to –22 dB, significantly reducing the necessary separation distance. Since the angle of detection (if any) is not known, this factor has not been used in the previous tables. For the other types, the distance is limited by the radio horizon, but in practice likely much lower due to obstructions and clutter.

From Table B.22 and Table B.23, similar conclusions to the RLAN analysis in [B29] can be drawn. Sharing with maritime radars (which are not likely operating anywhere near residential areas) and S5.452 meteorological radars in band B, and radiolocation radars in both band B and C is feasible when an effective DFS mechanism is employed by the Mesh system and the radar density isn't too high.

Copyright © 2003 IEEE. All rights reserved.

B.3 Performance Characteristics

B.3.1 WirelessMAN-SCa PHY throughput and modulation efficiency

Parameter settings for the SCa PHY that influence throughput and modulation efficiency calculations are summarized in Table B.24.

Table B.24—SCa parameters used in capacity calculations

Categorization of parameter	Parameter description	Parameter symbol	Parameter values
System-dependent parameter	Channel BW (MHz)	W	1.75, 3.5, 7, 14; 1.5, 3, 6, 12
	Maximum delay spread (μs)	d	4, 10, 20
	Spectral rolloff factor	α	0.18
Link-dependent parameter	QAM constellation size	M	4, 16, 64
	Inner (convolutional) code rate	r_I	1/2, 2/3, 3/4, 7/8
	Outer (Reed-Solomon) code rate	r_O	239/ 255 ≅ 0.937
Traffic-dependent parameter	Data payload size [for burst uplinks] (bytes)	P_B	239, 717, 1195, 1673
	Data payload size [for continuous FDD downlinks]	P_C	1673, 2151, 2623, 3585
Derivative parameter	Symbol rate (Msymbol/s)	R	$R=W/(1+\alpha)$

Observe that the maximum delay spread is listed as a system-dependent parameter in Table B.24. This categorization is chosen because frame (and burst) preambles in the SC PHY are composed of Unique Words (UWs). Each UW has to be at least as long as the delay spread in the channel in order to effectively estimate the channel. The overhead associated with channel estimation (and all other frame format structures) are captured in capacity and spectral efficiency calculations.

In all calculations (namely, those in Table B.25 and Table B.26), the Unique Word length (in symbols), U, is chosen to be a power of 2, using the formula $U = 2^{\log 2(\lceil R \cdot d \rceil)}$ to achieve upward power of 2 rounding and symbol unit scaling. Moreover, all calculations assume the use of full (frame or burst) preambles are used to estimate the channel for each transmitted data block, which implies that the channel coherence time is assumed equal to the block period. In most broadband wireless access applications, coherence times are much longer than individual user transmissions. The use of full preambles is hence unnecessary as information derived from preambles from previous blocks may be used. In addition, several user data blocks may be multiplexed on a downlink transmission. For this reason, the spectral efficiency and throughput figures that are compiled should be considered conservative, particularly for downlink channels.

Copyright © 2003 IEEE. All rights reserved.

Burst transmissions (e.g., ones on an uplink) are assumed to use the frame format illustrated in Figure 128r. Applying the definitions found in Table B.24 to the frame format of Figure 128r with a burst preamble of length A symbols, and then subtracting away the associated overhead, the throughput for a burst transmission is found to be

$$T_B = \frac{8P_B R \log_2(M)}{\left(\frac{8P_B}{r_I r_O} + (A+U)\log_2(M)\right)} \tag{103}$$

Similarly, the throughput for a framed continuous transmission (e.g., transmission on an FDD continuous downlink) can be computed, using the continuous frame format. The resulting throughput is

$$T_C = \frac{8P_C R \log_2(M)}{\left(\frac{8P_C}{r_I r_O} + A\log_2(M)\right)}. \tag{104}$$

PHY modulation efficiency (in bits/s/Hz) is obtained by scaling the throughput by the BW efficiency. The resulting PHY modulation efficiencies for burst and continuous transmissions, parameterized, are, respectively,

$$E_B = \frac{T_B}{W} = \frac{T_B}{(1+\alpha)R} = \frac{8P_B \log_2(M)}{(1+\alpha)\left(\frac{8P_B}{r_I r_O} + (A+U)\log_2(M)\right)} \tag{105}$$

and

$$E_C = \frac{T_C}{W} = \frac{T_C}{(1+\alpha)R} = \frac{8P_C \log_2(M)}{(1+\alpha)\left(\frac{8P_C}{r_I r_O} + A\log_2(M)\right)}. \tag{106}$$

Table B.25 and Table B.26 contain the results of evaluating throughput and PHY efficiency expressions over a range of system and link parameters. Table B.25 focuses on burst-format transmission over a 1.75 MHz BW channel, such as one might see on the uplink of an FDD application, and assumes a burst preamble size of $A = 2U$. Table B.26 focuses on continuous-format transmission over a 6 MHz BW channel, such as one might see on the continuous downlink of a FDD application, and assumes longer frames and a frame preamble size of $A = 4U$. All calculations assume a spectral rolloff factor of $\alpha = 0.18$.

Copyright © 2003 IEEE. All rights reserved.

Table B.25—Throughput and PHY efficiency example: 1.75 MHz BW burst UL

System-dependent parameters		Link-dependent parameters		Throughput (Mbit/s)				PHY efficiency
Symbol rate (Msymb/s)	Max delay spread (Symbs)	QAM constel-lation size	Inner code rate	Packet payload size (bytes)				(Mbits/s/MHz)
				239	717	1195	1673	(P=1673)
1.5	8	4	1/2	1.37	1.38	1.39	1.39	0.79
			2/3	1.82	1.84	1.85	1.85	1.06
			3/4	2.05	2.07	2.08	2.08	1.19
			7/8	2.38	2.42	2.42	2.43	1.39
		16	1/2	2.72	2.76	2.77	2.77	1.58
			3/4	4.03	4.12	4.14	4.15	2.37
		64	2/3	5.31	5.47	5.51	5.52	3.16
			5/6	6.56	6.82	6.87	6.89	3.94
	16	4	1/2	1.36	1.38	1.38	1.39	0.79
			2/3	1.80	1.83	1.84	1.85	1.05
			3/4	2.01	2.06	2.07	2.07	1.19
			7/8	2.34	2.40	2.41	2.42	1.38
		16	1/2	2.66	2.74	2.75	2.76	1.58
			3/4	3.90	4.07	4.11	4.13	2.36
		64	2/3	5.08	5.39	5.46	5.49	3.13
			5/6	6.22	6.69	6.79	6.84	3.91
	32	4	1/2	1.33	1.37	1.38	1.38	0.79
			2/3	1.74	1.82	1.83	1.84	1.05
			3/4	1.95	2.04	2.06	2.06	1.18
			7/8	2.25	2.37	2.39	2.40	1.37
		16	1/2	2.54	2.70	2.73	2.74	1.57
			3/4	3.65	3.98	4.06	4.09	2.34
		64	2/3	4.68	5.23	5.36	5.41	3.09
			5/6	5.63	6.44	6.64	6.72	3.84

Copyright © 2003 IEEE. All rights reserved.

Table B.26—Throughput and PHY efficiency example: 6 MHz BW continuous DL

System-dependent parameters		Link-dependent parameters		Throughput (Mbit/s)				PHY efficiency
Symbol rate (Msymb/s)	Max delay spread (Symbs)	QAM constel-lation size	Inner code rate	Frame payload size (bytes)				(Mbits/s/MHz)
				1673	2151	2629	3585	(P=3585)
5.1	8	4	1/2	4.69	4.95	5.00	5.02	0.84
			2/3	6.22	6.58	6.66	6.69	1.12
			3/4	6.98	7.40	7.49	7.53	1.25
			7/8	8.12	8.62	8.73	8.78	1.46
		16	1/2	9.24	9.84	9.97	10.03	1.67
			3/4	13.65	14.68	14.90	15.00	2.50
		64	2/3	17.94	19.47	19.81	19.96	3.33
			5/6	22.10	24.21	24.68	24.89	4.15
	16	4	1/2	4.62	4.92	4.98	5.01	0.84
			2/3	6.10	6.54	6.63	6.67	1.11
			3/4	6.83	7.34	7.45	7.50	1.25
			7/8	7.91	8.54	8.68	8.74	1.46
		16	1/2	8.97	9.74	9.90	9.98	1.66
			3/4	13.07	14.45	14.76	14.90	2.48
		64	2/3	16.94	19.06	19.55	19.77	3.30
			5/6	20.60	23.58	24.29	24.60	4.10
	32	4	1/2	4.48	4.87	4.95	4.99	0.83
			2/3	5.86	6.44	6.57	6.63	1.11
			3/4	6.53	7.22	7.38	7.45	1.24
			7/8	7.51	8.38	8.58	8.67	1.45
		16	1/2	8.47	9.53	9.78	9.89	1.65
			3/4	12.03	14.00	14.48	14.69	2.45
		64	2/3	15.24	18.30	19.06	19.41	3.24
			5/6	18.14	22.42	23.53	24.04	4.01

Copyright © 2003 IEEE. All rights reserved.

B.3.2 WirelessMAN-SCa PHY link budget analysis

A link budget analysis was performed by combining various channel bandwidths and QAM constellations with the channel models found in [B41]. Figure B.5 and Figure B.6 provide two examples of the path loss versus propagation radius, using the NLOS Categories A, B and C propagation models of [B41], and assuming 3.5 GHz band operation, a 6.5 m SS antenna, and for a 30 m and 80 m BS antenna height, respectively. For reference, an example set of parameters that fully specify model Categories A, B, and C are listed in Table B.27.

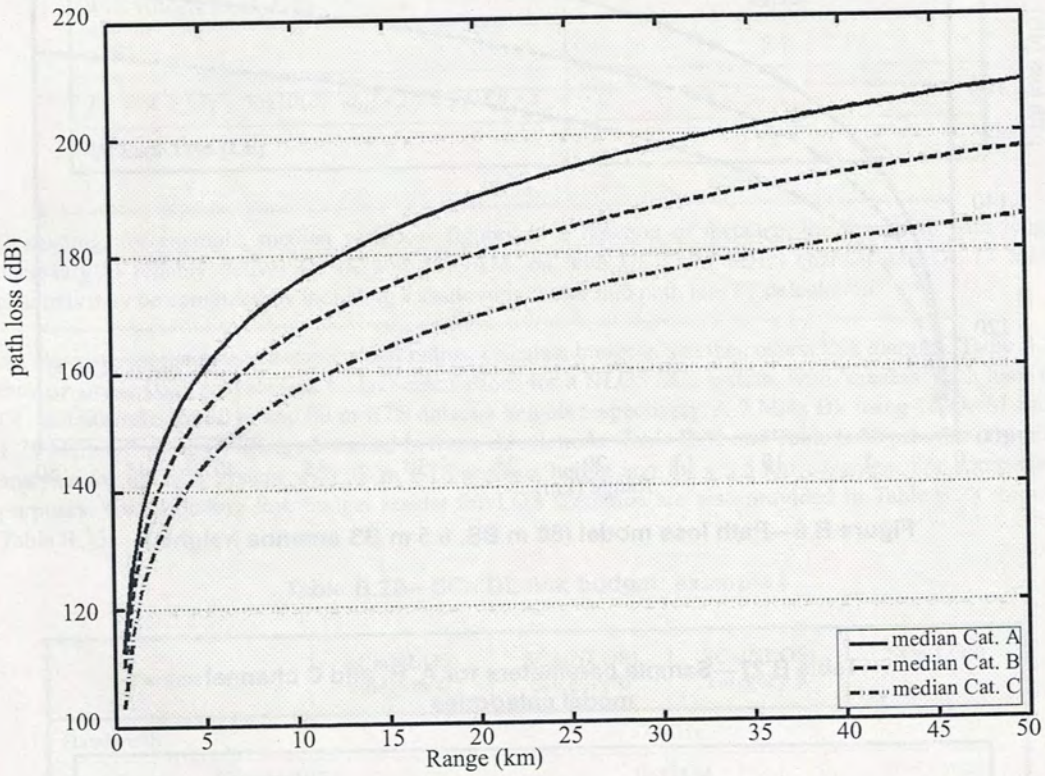


Figure B.5—Path loss model (30 m BS, 6.5 m SS antenna heights)

Copyright © 2003 IEEE. All rights reserved.

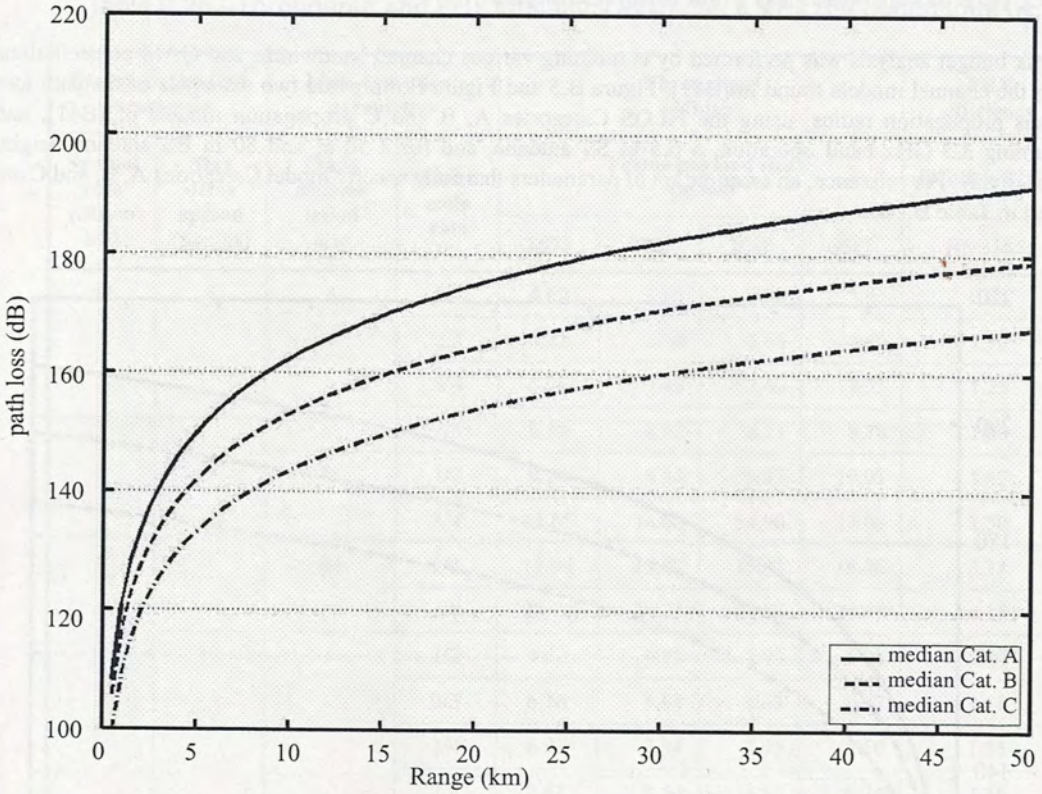


Figure B.6—Path loss model (80 m BS, 6.5 m SS antenna heights)

Table B.27—Sample parameters for A, B, and C channel model categories

Parameters	Category		
	C	B	A
	Flat few trees	Intermediate	Hilly heavy trees
a	3.6	4	4.6
b	0.005	0.0065	0.0075
c	20	17.1	12.6
Channel frequency (GHz)	3.5		
Wavelength λ (m)	0.085714		
Rx antenna height h(m)	6.5		
BS antenna height h_b(m)	30 or 80		
$\gamma = a - b \cdot h_b + c / h_b$	4.117	4.375	4.795

Copyright © 2003 IEEE. All rights reserved.

Table B.27—Sample parameters for A, B, and C channel model categories *(continued)*

Parameters	Category		
	C	B	A
	Flat few trees	Intermediate	Hilly heavy trees
$A = 20\log10(4\pi d_o / \lambda)$	83.32		
s(dB)	9.4		
$P_L = A + 10\gamma \cdot \log10(d / d_0) + DPI + DPh + s$			
4/3 Earth LOS (km)	32.5		

Evaluating, for example, median path loss figures as a function of distance, the minimum path length necessary to reliably deliver QPSK and 16-QAM, on both UL (1.75 MHz) channel and DL (7 MHz) channels may be computed by including **s** shadowing factor into path loss P_L calculation.

An alternate approach is to assume a cell radius, calculate budgets, and then assess link margins. Table B.28 through Table B.31 provide link budget calculations for a NLOS SCa system, with 'median' path loss, for UL and DL and, for 30 m and 80 m BTS antenna heights respectively. A 7 MHz DL using 16-QAM and a 1.75 MHz UL using QPSK are assumed in these calculations. Table B.32 and Table B.33 provides a similar analysis for the SCa system with 30 m BTS antenna height and for a 3.5 km coverage. For comparison purposes, corresponding link budget results for LOS scenarios are also provided in Table B.28 through Table B.33.

Table B.28—SCa DL link budget: example I

Parameter	SCa(NLOS) category C	SCa(NLOS) category B	SCa(NLOS) category A	SCa(LOS)
Bandwidth	7 MHz			
Modulation	16-QAM			
Target SNR with FEC	14 dB			
P_{1dB}	40 dBm			
Tx Antenna gain	15 dB			
Backoff	8 dB			
EIRP	47 dBm			
Cell radius for target SNR	7 km			
Pathloss [48]	−150.5 dB	−160.0 dB	−167.7 dB	−120.2 dB
Rx Antenna gain	18 dB			
Power at input to receiver	−85.5 dBm	−94.0 dBm	−102.7 dBm	−55.2 dBm
Receiver NF	5 dB			

Copyright © 2003 IEEE. All rights reserved.

Table B.28—SCa DL link budget: example I *(continued)*

Parameter	SCa(NLOS) category C	SCa(NLOS) category B	SCa(NLOS) category A	SCa(LOS)
Equivalent noise power in channel BW	−100.5 dBm			
SNR, calculated	15.0 dB	5.5 dB	−2.2 dB	45.3 dB
Fade margin	+1 dB	−8.5 dB	−16.2 dB	31.3 dB
BTS antenna height = 30 m				
SS antenna height = 6.5 m				

Table B.29—SCa UL link budget: example II

Parameter	SCa(NLOS) category C	SCa(NLOS) category B	SCa(NLOS) category A	SCa(LOS)
Bandwidth	1.75 MHz			
Modulation	QPSK			
Target SNR with FEC	12 dB			
P_{1dB}	30 dBm			
Tx Antenna gain	18 dB			
Backoff	5 dB			
EIRP	43 dBm			
Cell radius for target SNR	7 km			
Pathloss [48]	−150.5 dB	−160.0 dB	−167.7 dB	−120.2 dB
Rx Antenna gain	15 dB			
Power at input to receiver	−92.5 dBm	−102.0 dBm	−109.7 dBm	−62.2 dBm
Receiver NF	4 dB			
Equivalent noise power in channel BW	−107.6 dBm			
SNR, calculated	15.1 dB	5.6 dB	−2.1 dB	45.3 dB
Fade margin	3.1 dB	−6.4 dB	−14.1 dB	33.3 dB
BTS antenna height = 30 m				
SS antenna height = 6.5 m				

Copyright © 2003 IEEE. All rights reserved.

Table B.30—SCa DL link budget: example III

Parameter	SCa(NLOS) category C	SCa(NLOS) category B	SCa(NLOS) category A	SCa(LOS)
Bandwidth	7 MHz			
Modulation	16-QAM			
Target SNR with FEC	14 dB			
P_{1dB}	40 dBm			
Tx Antenna gain	15 dB			
Backoff	8 dB			
EIRP	47 dBm			
Cell radius for target SNR	7 km			
Pathloss [48]	−138.2 dB	−147.4 dB	−156.0 dB	−120.2 dB
Rx Antenna gain	18 dB			
Power at input to receiver	−73.2 dBm	−82.4 dBm	−91.0 dBm	−55.2 dBm
Receiver NF	5 dB			
Equivalent noise power in channel BW	−100.5 dBm			
SNR, calculated	27.3 dB	20.1 dB	9.5 dB	45.3 dB
Fade margin	13.3 dB	6.1 dB	−4.5 dB	31.3 dB
BTS antenna height = 80 m				
SS antenna height = 6.5 m				

Copyright © 2003 IEEE. All rights reserved.

Table B.31—SCa UL link budget: example IV

Parameter	SCa(NLOS) category C	SCa(NLOS) category B	SCa(NLOS) category A	SCa(LOS)
Bandwidth	1.75 MHz			
Modulation	QPSK			
Target SNR with FEC	12 dB			
P_{1dB}	30 dBm			
Tx Antenna gain	18 dB			
Backoff	5 dB			
EIRP	43 dBm			
Cell radius for target SNR	7 km			
Pathloss [48]	−138.2 dB	−147.4 dB	−156.0 dB	−120.2 dB
Rx Antenna gain	15 dB			
Power at input to receiver	−80.2 dBm	−89.4 dBm	−98.0 dBm	−62.2 dBm
Receiver NF	4 dB			
Equivalent noise power in channel BW	−107.6 dBm			
SNR, calculated	27.4 dB	18.2 dB	10.4 dB	45.3 dB
Fade margin	15.4 dB	7.8 dB	−2.4 dB	33.3 dB
BTS antenna height = 80 m				
SS antenna height = 6.5 m				

Copyright © 2003 IEEE. All rights reserved.

Table B.32—SCa DL link budget: example V

Parameter	SCa(NLOS) category C	SCa(NLOS) category B	SCa(NLOS) category A	SCa(LOS)
Bandwidth	7 MHz			
Modulation	16-QAM			
Target SNR with FEC	14 dB			
P_{1dB}	40 dBm			
Tx Antenna gain	15 dB			
Backoff	8 dB			
EIRP	47 dBm			
Cell radius for target SNR	3.5 km			
Pathloss [48]	−138.1 dB	−146.8 dB	−153.3 dB	−114.2 dB
Rx Antenna gain	18 dB			
Power at input to receiver	−73.1 dBm	−81.8 dBm	−88.3 dBm	−49.2 dBm
Receiver NF	5 dB			
Equivalent noise power in channel BW	−100.5 dBm			
SNR, calculated	27.4 dB	18.7 dB	12.2 dB	51.3 dB
Fade margin	13.4 dB	4.7 dB	−1.8 dB	37.3 dB
BTS antenna height = 30 m				
SS antenna height = 6.5 m				

Copyright © 2003 IEEE. All rights reserved.

Table B.33—SCa UL link budget: example VI

Parameter	SCa(NLOS) category C	SCa(NLOS) category B	SCa(NLOS) category A	SCa(LOS)
Bandwidth	1.75 MHz			
Modulation	QPSK			
Target SNR with FEC	12 dB			
P_{1dB}	30 dBm			
Tx Antenna gain	18 dB			
Backoff	5 dB			
EIRP	43 dBm			
Cell radius for target SNR	3.5 km			
Pathloss [48]	−138.1 dB	−146.8 dB	−153.3 dB	−114.2 dB
Rx Antenna gain	15 dB			
Power at input to receiver	−80.1 dBm	−88.8 dBm	−95.3 dBm	−56.2 dBm
Receiver NF	4 dB			
Equivalent noise power in channel BW	−107.6 dBm			
SNR, calculated	27.5 dB	18.8 dB	12.3 dB	51.4 dB
Fade margin	15.5 dB	7.2 dB	1.7 dB	39.4 dB
BTS antenna height = 30 m				
SS antenna height = 6.5 m				

Note that:

— Target SNRs assume Concatenated RS-CC or BTC FEC delivers a BER of 10^{-6} with 6 dB coding gain.
— Tx Antenna gain in all above Tables include −1.5 dB RF loss.
— Link budget evaluations provided in Table B.28 through Table B.33 are for Median path loss cases. That is, the effect of Shadow Fading (e.g., S = 9.4 dB) is not included.

B.3.3 WirelessMAN-OFDM/OFDMA PHY symbol and performance parameters

The effective bandwidth of the transmitted signal is related to the carrier spacing and the number of carriers.

In order to calculate the sampling frequency for any bandwidth, we define the bandwidth efficiency:

$$BW_{Efficiency} = \frac{f_s}{BW} \cdot \frac{(N_{used} + 1)}{N_{FFT}} = \frac{\Delta f \cdot (N_{used} + 1)}{BW} \quad (107)$$

Copyright © 2003 IEEE. All rights reserved.

where

BW is the Channel bandwidth (Hz)

f_s is the Sampling frequency (Hz)

Δf is the Carrier spacing (Hz)

$N_{used} + 1$ is the Number of active carriers used in the FFT (pilot and data carriers) + DC carrier

N_{FFT} is the FFT size.

The bandwidth efficiency is designed to be in the range of 83–95%, depending mainly on the FFT size, in order to occupy the maximum usable bandwidth but still allow adequate RF filtering.

The following tables give some calculations of the carrier spacing, symbol duration and CP duration for different masks. The sampling rate is defined as $f_s = BW \cdot 8/7$, except for 256-OFDM (see 8.4.2.4) in licensed bandwidths, which are not a multiple of 1.75 MHz. In those cases, the sampling rate is $f_s = BW \cdot 7/6$.

Table B.34—OFDM channelization parameters for licensed bands

	BW (MHz)	OFDM (N_{FFT} = 256)					
		$\Delta f(kHz)$	$T_b(\mu s)$	$T_g(\mu s)$			
				$T_b/32$	$T_b/16$	$T_b/8$	$T_b/4$
MMDS ($f_s/BW = 7/6$)	1.5	$6\frac{51}{61}$	$146\frac{2}{7}$	$4\frac{4}{7}$	$9\frac{1}{7}$	$18\frac{2}{7}$	$36\frac{4}{7}$
	3.0	$13\frac{43}{64}$	$73\frac{1}{7}$	$2\frac{2}{7}$	$4\frac{4}{7}$	$9\frac{1}{7}$	$18\frac{2}{7}$
	6.0	$27\frac{11}{32}$	$36\frac{4}{7}$	$1\frac{1}{7}$	$2\frac{2}{7}$	$4\frac{4}{7}$	$9\frac{1}{7}$
	12.0	$54\frac{11}{16}$	$18\frac{2}{7}$	$\frac{4}{7}$	$1\frac{1}{7}$	$2\frac{2}{7}$	$4\frac{4}{7}$
	24.0	$109\frac{3}{8}$	$9\frac{1}{7}$	$\frac{2}{7}$	$\frac{4}{7}$	$1\frac{1}{7}$	$2\frac{2}{7}$
ETSI ($f_s/BW = 8/7$)	1.75	$7\frac{13}{16}$	128	4	8	16	32
	3.5	$15\frac{5}{8}$	64	2	4	8	16
	7.0	$31\frac{1}{4}$	32	1	2	4	8
	14.0	$62\frac{1}{2}$	16	$\frac{1}{2}$	1	2	4
	28.0	125	8	$\frac{1}{4}$	$\frac{1}{2}$	1	2

Copyright © 2003 IEEE. All rights reserved.

Table B.34—OFDM channelization parameters for licensed bands *(continued)*

BW (MHz)		OFDM (N_{FFT} = 256)					
		$\Delta f(kHz)$	$T_b(\mu s)$	$T_g(\mu s)$			
				$T_b/32$	$T_b/16$	$T_b/8$	$T_b/4$
WCS ($f_s/BW = 7/6$)	2.5	$11\frac{35}{89}$	$87\frac{27}{35}$	$2\frac{26}{35}$	$5\frac{17}{35}$	$10\frac{34}{35}$	$21\frac{33}{35}$
	5.0	$22\frac{70}{89}$	$43\frac{31}{35}$	$1\frac{13}{35}$	$2\frac{26}{35}$	$5\frac{17}{35}$	$10\frac{34}{35}$
	10.0	$45\frac{55}{96}$	$21\frac{33}{35}$	$\frac{24}{35}$	$1\frac{13}{35}$	$2\frac{26}{35}$	$5\frac{17}{35}$
	15.0	$68\frac{23}{64}$	$14\frac{22}{35}$	$\frac{16}{35}$	$\frac{32}{35}$	$1\frac{29}{35}$	$3\frac{23}{35}$

Table B.35—OFDMA channelization parameters for licensed bands

BW (MHz)		OFDMA (N_{FFT} = 2048)					
		$\Delta f(kHz)$	$T_b(\mu s)$	$T_g(\mu s)$			
				$T_b/32$	$T_b/16$	$T_b/8$	$T_b/4$
MMDS ($f_s/BW = 8/7$)	1.5	$\frac{36}{43}$	$1194\frac{2}{3}$	$37\frac{1}{3}$	$74\frac{2}{3}$	$149\frac{1}{3}$	$298\frac{2}{3}$
	3.0	$1\frac{60}{89}$	$597\frac{1}{3}$	$18\frac{2}{3}$	$37\frac{1}{3}$	$74\frac{2}{3}$	$149\frac{1}{3}$
	6.0	$3\frac{8}{23}$	$298\frac{2}{3}$	$9\frac{1}{3}$	$18\frac{2}{3}$	$37\frac{1}{3}$	$74\frac{2}{3}$
	12.0	$6\frac{39}{56}$	$149\frac{1}{3}$	$4\frac{2}{3}$	$9\frac{1}{3}$	$18\frac{2}{3}$	$37\frac{1}{3}$
	24.0	$13\frac{11}{28}$	$74\frac{2}{3}$	$2\frac{1}{3}$	$4\frac{2}{3}$	$9\frac{1}{3}$	$18\frac{2}{3}$
ETSI ($f_s/BW = 8/7$)	1.75	$\frac{83}{85}$	1024	32	64	128	256
	3.5	$1\frac{61}{64}$	512	16	32	64	128
	7.0	$3\frac{29}{32}$	256	8	16	32	64
	14.0	$7\frac{13}{16}$	128	4	8	16	32
	28.0	$15\frac{5}{8}$	64	2	4	8	16

8893
Copyright © 2003 IEEE. All rights reserved.

Table B.35—OFDMA channelization parameters for licensed bands *(continued)*

BW (MHz)		OFDMA (N_{FFT} = 2048)					
		$\Delta f(kHz)$	$T_b(\mu s)$	$T_g(\mu s)$			
				$T_b/32$	$T_b/16$	$T_b/8$	$T_b/4$
WCS ($f_s/BW = 8/7$)	2.5	$1\frac{32}{81}$	$714\frac{4}{5}$	$22\frac{2}{5}$	$44\frac{4}{5}$	$89\frac{3}{5}$	$179\frac{1}{5}$
	5.0	$2\frac{64}{81}$	$358\frac{2}{5}$	$11\frac{1}{5}$	$22\frac{2}{5}$	$44\frac{4}{5}$	$89\frac{3}{5}$
	10.0	$5\frac{47}{81}$	$179\frac{1}{5}$	$5\frac{3}{5}$	$11\frac{1}{5}$	$22\frac{2}{5}$	$44\frac{4}{5}$
	15.0	$8\frac{10}{27}$	$119\frac{7}{15}$	$3\frac{11}{15}$	$7\frac{7}{15}$	$14\frac{14}{15}$	$29\frac{13}{15}$

Table B.36—OFDM/OFDMA channelization parameters for license-exempt bands

			OFDM	OFDMA
	$f_s/(BW)$		8/7	8/7
BW(MHz)	N_{FFT}		256	2048
10	$\Delta f(kHz)$		$44\frac{9}{14}$	$5\frac{47}{81}$
	$T_b(\mu s)$		$22\frac{2}{5}$	$179\frac{1}{5}$
	$T_g(\mu s)$	$\frac{T_b}{32}$	$\frac{7}{10}$	$5\frac{3}{5}$
		$\frac{T_b}{16}$	$1\frac{2}{5}$	$11\frac{1}{5}$
		$\frac{T_b}{8}$	$2\frac{4}{5}$	$22\frac{2}{5}$
		$\frac{T_b}{4}$	$5\frac{3}{5}$	
20	$\Delta f(kHz)$		$89\frac{2}{7}$	$11\frac{9}{56}$
	$T_b(\mu s)$		$11\frac{1}{5}$	$89\frac{3}{5}$
	$T_g(\mu s)$	$\frac{T_b}{32}$		$2\frac{4}{5}$
		$\frac{T_b}{16}$	$\frac{7}{10}$	$5\frac{3}{5}$
		$\frac{T_b}{8}$	$1\frac{2}{5}$	$11\frac{1}{5}$
		$\frac{T_b}{4}$	$2\frac{4}{5}$	$22\frac{2}{5}$

Copyright © 2003 IEEE. All rights reserved.

In Table B.37, raw bit rates are shown for typical bandwidths. The raw bite rate is defined as $N_{used} \cdot b_m \cdot c_r / T_s$, where b_m is the number of bits per modulation symbol and c_r is the coding rate.

Table B.37—OFDM/OFDMA raw bitrates (Mbps)

BW (MHz)	T_g	QPSK 1/2	QPSK 3/4	16-QAM 1/2	16-QAM 3/4	64-QAM 2/3	64-QAM 3/4
OFDM 256-FFT							
6 MHz (MMDS)	$T_b/32$	5.09	7.64	10.18	15.27	20.36	22.91
	$T_b/16$	4.94	7.41	9.88	14.82	19.76	22.24
	$T_b/8$	4.67	7.00	9.33	14.00	18.67	21.00
	$T_b/4$	4.20	6.30	8.40	12.60	16.80	18.90
7 MHz (ETSI)	$T_b/32$	5.94	8.91	11.88	17.82	23.76	26.73
	$T_b/16$	5.76	8.65	11.53	17.29	23.06	25.94
	$T_b/8$	5.44	8.17	10.89	16.33	21.78	24.50
	$T_b/4$	4.90	7.35	9.80	14.70	19.60	22.05
20 MHz (U-NII)	$T_b/16$	16.13	24.20	32.27	48.40	64.54	72.61
	$T_b/8$	15.24	22.86	30.48	45.71	60.95	68.57
	$T_b/4$	13.71	20.57	27.43	41.14	54.86	61.71
OFDMA 2048-FFT							
6 MHz (MMDS)	$T_b/32$	4.99	7.48	9.97	14.96	19.95	22.44
	$T_b/16$	4.84	7.26	9.68	14.52	19.36	21.78
	$T_b/8$	4.57	6.86	9.14	13.71	18.29	20.57
	$T_b/4$	4.11	6.17	8.23	12.34	16.46	18.51
7 MHz (ETSI)	$T_b/32$	5.82	8.73	11.64	17.45	23.27	26.18
	$T_b/16$	5.65	8.47	11.29	16.94	22.59	25.41
	$T_b/8$	5.33	8.00	10.67	16.00	21.33	24.00
	$T_b/4$	4.80	7.20	9.60	14.40	19.20	21.60

Copyright © 2000 IEEE. All rights reserved.

To order IEEE standards...

Call +1 800 678 IEEE (4333) in the US and Canada.

Outside of the US and Canada:
+1 732 981 0600

To order by fax:
+1 732 981 9667

IEEE business hours: 8 a.m.-4:30 p.m. (EST)

For Web access to IEEE standards information...

http://standards.ieee.org/

For information about IEEE standards on-line subscriptions...

http://standards.ieee.org/catalog/olis

ISBN 0-7381-3566-6

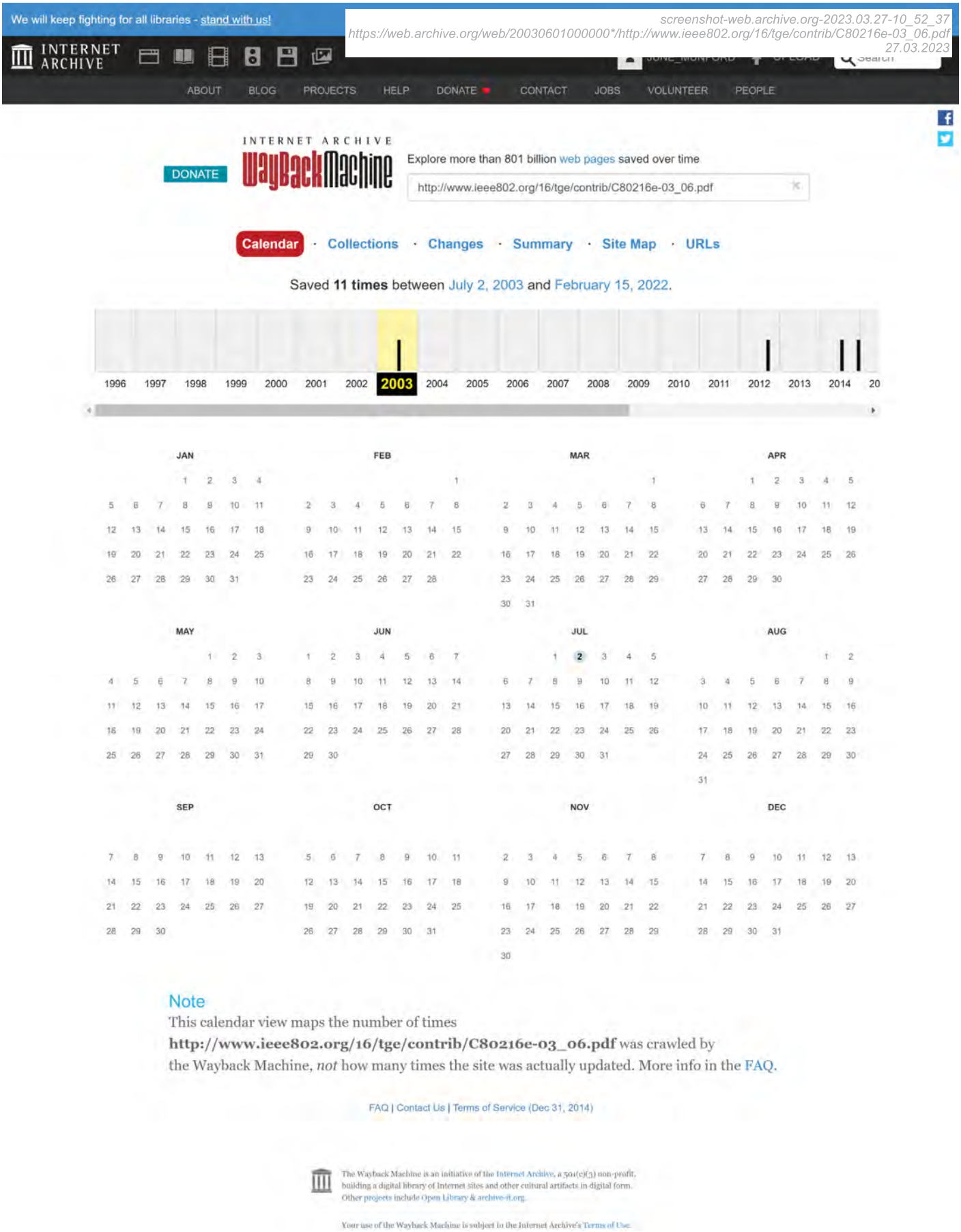


ISBN 0-7381-3566 6

RECEIVED
FEB 19 2004
ENGINEERING LIBRARY

Wert
Bookbinding
Grantville, PA
JAN-JUNE 2004
"We're Quality Bound"

APPENDIX 80216e-01


We will keep fighting for all libraries - stand with us!
screenshot-web.archive.org-2023.03.27-10_52_37
https://web.archive.org/web/20030601000000*/http://www.ieee802.org/16/tge/contrib/C80216e-03_06.pdf
27.03.2023
INTERNET ARCHIVE
ABOUT BLOG PROJECTS HELP DONATE CONTACT JOBS VOLUNTEER PEOPLE
DONATE
INTERNET ARCHIVE
WayBackMachine
Explore more than 801 billion web pages saved over time
http://www.ieee802.org/16/tge/contrib/C80216e-03_06.pdf
Calendar · Collections · Changes · Summary · Site Map · URLs
Saved 11 times between July 2, 2003 and February 15, 2022.
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 20
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Note
This calendar view maps the number of times
http://www.ieee802.org/16/tge/contrib/C80216e-03_06.pdf was crawled by
the Wayback Machine, not how many times the site was actually updated. More info in the FAQ.
FAQ | Contact Us | Terms of Service (Dec 31, 2014)
The Wayback Machine is an initiative of the Internet Archive, a 501(c)(3) non-profit, building a digital library of Internet sites and other cultural artifacts in digital form. Other projects include Open Library & archive-it.org.
Your use of the Wayback Machine is subject to the Internet Archive's Terms of Use.

INTERNET ARCHIVE
WaybackMachine
http://www.ieee802.org/16/tge/contrib/C80216e-03_06.pdf
Go
JUN JUL SEP
11 captures
2 Jul 2003 - 15 Feb 2022
2002 02 2003 2012
About this capture

Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**IEEE 802.16e Mobility System Perspective**
Date Submitted	**2003-01-10**

Source(s)		
	Itzik Kitroser	Voice: +972-3-9528440
	Yossi Segal	Fax: +972-3-9528805
	Yigal Leiba	itzikk@runcom.co.il
	Zion Hadad	yossis@runcom.co.il
		yigall@runcom.co.il
	Runcom	zionh@runcom.co.il
	Hachoma 2 St. 75655	
	Rishon Lezion, Israel	

APPENDIX 80216e-02

Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**IEEE 802.16e Mobility System Perspective**
Date Submitted	**2003-01-10**
Source(s)	Itzik Kitroser Yossi Segal Yigal Leiba Zion Hadad Runcom Hachoma 2 St. 75655 Rishon Lezion, Israel Voice: +972-3-9528440 Fax: +972-3-9528805 itzikk@runcom.co.il yossis@runcom.co.il yigall@runcom.co.il zionh@runcom.co.il
Re:	Call for contributions IEEE 80216e-02/01
Abstract	This contribution presents some notes on reference system deployment scenario and impact of the mobile environment on the current 802.16a, and answers some of the points presented in the call for contributions IEEE 80216e-02_01.
Purpose	Answering to points presented in the call for contributions
Notice	This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.
Release	The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.
Patent Policy and Procedures	The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures <http://ieee802.org/16/ipr/patents/policy.html>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential for compliance with both mandatory and optional portions of the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <mailto:chair@wirelessman.org> as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.16 Working Group. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>.

IEEE 802.16e Mobility System Perspective

Itzik Kitroser
Yossi Segal
Yigal Leiba
Zion Hadad
Runcom Technologies

1 General

This contribution presents some notes on reference system deployment scenario and impact of the mobile environment on the current 802.16a, and answers some of the points presented in the call for contributions [6].

2 Reference System Deployment Scenario

The reference system deployment scenario is based on the following assumptions:

Multi-cell, macro and/or micro

The service area is covered by a set of base-stations, where each base station contains at least one air-interface instance (i.e. at least one sector).
A sector should be able to cover an area ranging from a few hundreds of meters to 15 kilometers.

Omni-directional or sectored antennas or both

A sector may use either a directional or omni-directional antenna in a single multiple antenna formation.

Frequency reuse and cell-to-cell interference (FDD &TDD)

The system should be able to operate in either TDD or FDD mode. H-FDD operation of the mobile handset should be possible.
The sectors share the frequency and/or time resources of the system. In order to minimize mutual interference, base-stations are synchronized in frequency and in time (sections 8.4.5.1.1 and 8.5.10.1.1 in [2] define how this can be achieved).
Frequency reuse factors will range from 1/1 up to 1/6. See [5] for coverage simulation.

Level of Cell network interconnect and handoff

The base-stations share a common backbone connection through which they can communicate with each other. The system should provide all the hooks required for efficient operation of mobile-IP.
All the base-stations forming the infrastructure of the mobile network comply with a certain *mobile-operation-profile* (i.e. all support IPv4 and IPv6, all support a certain set of convergence sub-layers, etc.).

Mobile Channel Effects

The channel model is based on [4] modified to support frequencies up to 6GHz.

Doppler

Doppler channels up to 250Hz will be supported (equivalent to 100Km/H at 2.7GHz).

Dispersive Multipath – Fast Fading

Rayleigh channels up to 20usec excess delay spread

3 Impact of the mobile environment on the current 802.16a

Synchronization & Timing

No changes are required in the PHY layer synchronization and timing mechanisms. The base-stations should be synchronized to minimize system self-interference. Synchronization between base-stations simplifies the handoff procedures and facilitates fast handoff capability.

Ranging

No changes are required in the PHY layer ranging mechanism.

Power Control

Due to potential fast changes in the mobile uplink channel the power-control mechanism in [2] should be enhanced to support faster changes in the channel. The efficiency of this message should be improved as well, as it will be used sparingly.

Channel Coding

No changes are required in the PHY layer coding.

Measurement methods and messaging for handoff support

See section 2.4 in [7].

Effect on Advanced Antenna Systems MAC Protocols

Not addressed.

References

[1] IEEE Std 802.16-2001 “Part 16: Air Interface for Fixed Broadband Wireless Access Systems”
[2] IEEE P802.16a/D7-2002 “Part 16: Air Interface for Fixed Broadband Wireless Access Systems – Medium Access Control Modifications and Additional Physical Layer Specifications for 2-11 GHz”
[3] IEEE C802.16-SGM-02/23 “802.16a OFDMA PHY suitability for mobile applications”
[4] RECOMMENDATION ITU-R M.1225 “GUIDELINES FOR EVALUATION OF RADIO TRANSMISSION TECHNOLOGIES FOR IMT-2000”
[5] IEEE C80216e-03_03 “OFMDA System Simulation in a Single/Multi Cell Configuration”
[6] IEEE 80216e-02_01 “Call for Contributions on Project 802.16e”
[7] IEEE C80216e-03_05 “IEEE802.16e Mobility Enhancements”

APPENDIX C80216SGM-01

screenshot-web.archive.org-2023.03.27-10_45_31
https://web.archive.org/web/20030701000000*/https://www.ieee802.org/16/mobile/contrib/C80216sgm-02_23.pdf
27.03.2023

We will keep fighting for all libraries - stand with us!

INTERNET ARCHIVE

ABOUT BLOG PROJECTS HELP DONATE CONTACT JOBS VOLUNTEER PEOPLE

DONATE

INTERNET ARCHIVE WayBackMachine

Explore more than 801 billion web pages saved over time

https://www.ieee802.org/16/mobile/contrib/C80216sgm-02_23.pdf

Calendar · Collections · Changes · Summary · Site Map · URLs

Saved **14 times** between April 20, 2003 and December 7, 2022.

1996 1997 1998 1999 2000 2001 2002 **2003** 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 20

JAN

			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

FEB

						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	

MAR

						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

APR

		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

MAY

			1	2	3	
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

JUN

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

JUL

		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

AUG

					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

SEP

	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

OCT

			1	2	3	4
5	6	7	8	9	10	11
12	**13**	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

NOV

						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

DEC

		1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

Note

This calendar view maps the number of times **https://www.ieee802.org/16/mobile/contrib/C80216sgm-02_23.pdf** was crawled by the Wayback Machine, *not* how many times the site was actually updated. More info in the FAQ.

FAQ | Contact Us | Terms of Service (Dec 31, 2014)

The Wayback Machine is an initiative of the Internet Archive, a 501(c)(3) non-profit, building a digital library of Internet sites and other cultural artifacts in digital form. Other projects include Open Library & archive-it.org.

Your use of the Wayback Machine is subject to the Internet Archive's Terms of Use.

INTERNET ARCHIVE
WaybackMachine
https://www.ieee802.org/16/mobile/contrib/C80216sgm-02_23.pdf
Go
14 captures
20 Apr 2003 - 7 Dec 2022
MAR APR OCT
2002 20 2003 2005
About this capture

Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**802.16a OFDMA PHY suitability for mobile applications**
Date Submitted	**19.9.2002**

Source(s)	Yigal Leiba	Voice: 972-3-9528440
	Dr. Zion Hadad	Fax: 972-3-9528805
	Itzik Kitroser	yigall@runcom.co.il
	Yossi Segal	yossis@runcom.co.il
	Moshe Levinson	itzikk@runcom.co.il
	Runcom Technologies LTD.	zionh@runcom.co.il
		moshel@runcom.co.il

APPENDIX C80216SGM-02

Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**802.16a OFDMA PHY suitability for mobile applications**
Date Submitted	**19.9.2002**
Source(s)	Yigal Leiba Dr. Zion Hadad Itzik Kitroser Yossi Segal Moshe Levinson Runcom Technologies LTD. 2 Ahcoma St. 75655, Rishon Lezion Israel Voice: 972-3-9528440 Fax: 972-3-9528805 yigall@runcom.co.il yossis@runcom.co.il itzikk@runcom.co.il zionh@runcom.co.il moshel@runcom.co.il
Re:	Call for contributions, document IEEE 802.16sgm-02/08
Abstract	This document discusses channel models for mobile wireless channels, and discusses the suitability of the OFDMA PHY mode for operation over these channels
Purpose	For discussion
Notice	This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.
Release	The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.
Patent Policy and Procedures	The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures (Version 1.0) <http://ieee802.org/16/ipr/patents/policy.html>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, if there is technical justification in the opinion of the standards-developing committee and provided the IEEE receives assurance from the patent holder that it will license applicants under reasonable terms and conditions for the purpose of implementing the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <mailto:r.b.marks@ieee.org> as early as possible, in written or electronic form, of any patents (granted or under application) that may cover technology that is under consideration by or has been approved by IEEE 802.16. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>.

Mobile Channel Models

Path loss

Path loss in mobile wireless channel is typically much higher than the path loss for an equivalent fixed wireless channel. This happens because the mobile reception unit typically uses a low height omni-directional antenna, and. The higher path loss requires higher system gain, and the high variance of the path loss causes inter-cell interference. Several path loss models are widely used to characterize the path loss in mobile environments mostly based on the Okumura-Hata measurement [1], and modifications to adapt it to higher frequency bands.

Multipath

Operation over broadband mobile wireless channels implies ability to operate even in fading channels in which significant multipath is present. In [1], [3], [4] and [5] it is shown that RMS delay spread for wireless mobile channels (mostly in 900MHz and 1900MHz) range anywhere between several hundreds of nanoseconds to several tens of microseconds. The large delay spreads are present in both vehicular and pedestrian mobility situations due to the small height of the antennas, and the fact that the mobile unit is typically using omni-directional antennas.

Doppler and fast fading

Doppler frequency shift can be estimated by $f_{carrier} \cdot V_{Vehicle} / C$ (ignoring the angle of the movement). In order to estimate the Doppler effect at our target frequency bands, lets calculate for the MMDS (2.5GHz) and UNII (5.8GHz) bands. Assuming a vehicle speed of 100Km/H we get a maximal Doppler shift of about 230Hz for MMDS, and about 540Hz for UNII. The Doppler power spectrum used to characterize the fast fading can either be estimated as a flat spectrum as shown in [6], or follows the Jakes model [7].

Impact of mobile channel on OFDMA PHY

Timing synchronization

Timing synchronization in an OFDMA receiver is based primarily on the strong auto-correlation properties of the OFDMA waveform. This autocorrelation is a consequence of the cyclic prefix part of the waveform. The passage of the OFDMA waveform through the wireless channel smears the autocorrelation because the CP collects somewhat different multipath than original instance of the symbol. The longer the CP relative to the channel delay spread, the less the autocorrelation is smeared. For OFDMA, CP even for a fairly broad 14MHz channel can be up to 32usec, in conformance with delay spreads expected in a mobile environment.

Frequency synchronization

Carrier frequency synchronization is an essential component in every coherent receiver. In OFDMA this synchronization is even more crucial as transmission bursts from several transmitters are synchronously combined in the uplink.
Frequency synchronization in OFDM receivers is generally based on a pre-FFT stage that handles the fractional frequency offset (i.e. the part that is not an integer multiple of sub-carrier spacing) and a post-FFT stage that handles the integer frequency offset.
The pre-FFT stage will usually utilize the OFDMA waveform autocorrelation. As discussed with regard to the timing synchronization, the OFDMA waveform displays strong autocorrelation even in severe multipath conditions due to the fact the duration of the CP greatly exceeds the channel delay spread.

The post-FFT stage will usually utilize the pilot tones to correct the integer frequency offset. In OFDMA 166 out of the 1702 used carriers are pilots. This provides a processing gain in excess of 20dB for the pilots PN series autocorrelation peak.
Frequency synchronization in a mobile environment is more challenging due to the Doppler frequency shift and the fast fading effects. These effects tend to smear the sub-carriers and introduce inter-carrier-interference. OFDMA symbols are short enough (a typical value would be 300usec in a 6MHz MMDS channel) even relative to the highest Doppler spectral component, so the channel response can be assumed fairly stable across one symbol. With the help of the carrier frequency synchronization techniques mentioned above, even one OFDMA symbol is enough to extract accurate carrier frequency estimations, and ensure both downlink and uplink synchronization.

Channel estimation and demodulation

Channel estimation in OFDMA receivers is based on pilot sub-carriers. In OFDMA there are both constant location pilots and variable location pilots. The variable location pilots are arranged such that one of every 12 sub-carriers is a pilot. This means that by using the pilots from one symbol, a channel estimate with length of up to 1/12 of the symbol can be done. This capability, combined with the length of the OFDMA symbols enables fast, per symbol, estimation of the channel. Thus OFDMA does not require a downlink preamble, and does relay require that a transmission burst be shorter that the channel coherence time.

Channel coding

The OFDMA PHY support a mandatory RS-Convolutional block code and optionally turbo codes. Both these codes are robust, and have been used in fixed as well mobile environments.

Ranging and power control

The process of ranging has an important role in maintaining the uplink channel integrity by keeping the received power at the BST within the allowed bounds. In a mobile environment ranging has to be more frequent because of the existence of fast fading effects in the channel. The OFDMA PHY can support the fast power control loop necessary in a mobile environment. The features that enable this are,

- Short frame duration – 2mS is the current minimum supported.
- The CPE can do ranging frequently, with small chances of collision – CDMA code ranging enables multiple CPE to perform ranging in parallel without collisions and with excellent processing gain at the BST
- Fast power control – The downlink map contains a power control IE that provides a BW efficient means for controlling the CPE transmitted power

Inter-system interference

Due to the large variance in a mobile system path loss, inter-cell interference is a common occurrence in mobile wireless systems. The OFDMA PHY is designed such that sub-channels can be composed from several distinct permutations of sub-carriers. This feature enables significant reduction in inter-cell interference because even on occasions where the same sub-channel is used at the same time in two different cells, there is only a partial collision on the actual sub-carriers.

Performance estimates/simulations

In May 1998, a consortium of 17 broadcasters, network operators, manufacturers of professional and domestic equipment and research centers, lead by T-NOVA (formerly Deutsche Telekom Berkom), launched the MOTIVATE project funded by the European Commission in the ACTS Program (Advanced Communications Technologies and Services), to investigate the practical and theoretical performance limits of DVB-T for mobile

reception. MOTIVATE partners performed a considerable amount of work both in the Laboratory (simulations, tests campaigns) and in the field (field trials, demonstrations) to achieve the project goals [8]. DVB-T is a close kin of 802.16a OFDMA PHY that operates in VHF/UHF frequencies and supports 8K and 2K FFT modes. The report demonstrates operation in a mobile environment at velocities exceeding 200Km/H.

References

[1] “Field Strength and Its Variability in VHF and UHF Land Mobile Service”, Y. Okumura, E. Ohmori, T. Kawano, K. Fukuda, REV. ELEC. COMM. LAB., VOL 16, SEPTEMBER-OCTOBER 1968

[2] “A New Path-Gain/Delay-Spread Propagation Model for Digital Cellular Channels”, Larry J. Greenstein, Vinko Erceg, Yu Shuan Yeh, Martin V. Clark, IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 46, NO. 2, MAY 1997

[3] “Path Loss, Scattering, and Multipath Delay Statistics in Four European Cities for Digital Cellular and Microcellular Radiotelephone”, Scott Y. Seidel, Theodore S. Rappaport, Sanjiv Jain, Michael L. Lord, Rajendra Singh, IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 40, NO. 4, NOVEMBER 1991

[4] “900MHz Multipath Propagation Measurements for U.S. Digital Cellular Radiotelephone”, Theodore S. Rappaport, Scott Y. Seidel, Rajendra Singh, IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 39, NO. 2, MAY 1990

[5] “Propagation Measurements and Models for Wireless Communication Channels”, Jorgen B. Andersen, Theodore S. Rappaport, Susumu Yoshida, IEEE COMMUNICATIONS MAGAZINE, JANUARY 1995

[6] “3-D Mobile Radio Channel Statistics”, Richard H. Clarke, Wee Lin Khoo, IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 46, NO. 3, AUGUST 1997

[7] “Microwave Mobile Communications”, W. C. Jakes, New York: Wiley, 1974

[8] MOTIVATE report to the 36th DVB-TM meeting, 26,27 January 2000

APPENDIX TERRY01

screenshot-catalog.libraries.psu.edu-2023.03.29-11_29_39
https://catalog.libraries.psu.edu/catalog/37412093/marc_view
29.03.2023

MARC View

LEADER 03371cam a22006974a 4500			
001 37412093			
003 SIRSI			
005 20220602164424.0			
006 m o d			
007 cr cnu|||unuuu			
008 040807t20022002inua ob 001 0 eng d			
010			z| 00112047
015			a| GBA323523 2| bnb
019			a| 54115907 a| 667096393 a| 729549301 a| 748106017 a| 858430103 a| 1044270408 a| 1056318023 a| 1058616981 a| 1061007571 a| 1064736364 a| 1073055138 a| 1103263573 a| 1153016535
019			a| MARS
020			a| 0768658667 q| (electronic bk.)
020			a| 9780768658668 q| (electronic bk.)
020			a| 9780672321573
020			a| 0672321572
020			z| 0672321572
024	8		a| 1815418
035			a| (OCoLC)56109474
040			a| N$T b\| eng e\| pn c\| N$T d| OCLCQ d| YDXCP d| OCLCG d| OCLCQ d| OCLCA d| IDEBK d| VLB d| OCLCQ d| CEF d| AZU d| NHM d| OCLCQ d| OCLCF d| OCLCQ d| CNNAI d| OCLCQ d| WYU d| OCLCO d| UAB d| AU@ d| VT2 d| OCLCO d| LDP d| OCLCO d| UtOrBLW
049			a| UPMM
050		4	a| TK5105.78 b| .T47 2002eb
072		7	a| COM x| 020090 2| bisacsh
072		7	a| COM x| 020050 2| bisacsh
072		7	a| COM x| 043020 2| bisacsh
082	0	4	a| 004.6/8 2| 22
084			a| ST 200 2| rvk
100	1		a| Terry, John, d| 1966- 0| http://id.loc.gov/authorities/names/n2002154090
245	1	0	a| OFDM wireless LANs : b| a theoretical and practical guide / c| John Terry and Juha Heiskala.
264		1	a| Indianapolis, Ind. : b| Sams, c| [2002]
264		4	c| ©2002
300			a| 1 online resource (viii, 315 pages) : b| illustrations
336			a| text b| txt 2| rdacontent
337			a| computer b| c 2| rdamedia
338			a| online resource b| cr 2| rdacarrier
504			a| Includes bibliographical references and index.
505	0		a| 1. Background and WLAN Overview -- 2. Synchronization -- 3. Modulation and Coding -- 4. Antenna Diversity -- 5. RF Distortion Analysis for OFDM WLAN -- 6. Medium Access Control (MAC) for IEEE 802.11 Networks -- 7. Medium Access Control (MAC) for HiperLAN/2 Networks -- 8. Rapid Prototyping for WLANs.
588	0		a| Print version record.
650		0	a| Wireless LANs. 0| http://id.loc.gov/authorities/subjects/sh2002000555
650		0	a| Orthogonalization methods. 0| http://id.loc.gov/authorities/subjects/sh98004572
650		6	a| Réseaux locaux sans fil.
650		6	a| Méthodes d'orthogonalisation.
650		7	a| COMPUTERS x| Data Transmission Systems x| Wireless. 2| bisacsh
650		7	a| COMPUTERS x| Data Transmission Systems x| Broadband. 2| bisacsh
650		7	a| COMPUTERS x| Networking x| Local Area Networks (LANs) 2| bisacsh

ASK A LIBRARIAN
ASK A LIBRARIAN

650		7	a| Orthogonalization methods. 2| fast 0| (OCoLC)fst01048524
650		7	a| Wireless LANs. 2| fast 0| (OCoLC)fst01176206
650		7	a| Drahtloses lokales Netz. 2| gnd
650		7	a| OFDM. 2| gnd
650		7	a| Electrical & Computer Engineering. 2| hilcc
650		7	a| Engineering & Applied Sciences. 2| hilcc
650		7	a| Telecommunications. 2| hilcc
655		0	a| Electronic book.
655		4	a| Electronic books.
700	1		a| Heiskala, Juha. 0| http://id.loc.gov/authorities/names/n2002154091
776	0	8	i| Print version: a| Terry, John, Ph. D. t| OFDM wireless LANs. d| Indianapolis, Ind. : Sams, ©2002 z| 0672321572 w| (DLC) 00112047 w| (OCoLC)48361954
856	4	0	u| https://go.oreilly.com/pennsylvania-state-university/library/view/-/0672321572/?ar
949			a| Electronic resource w| ASIS c| 1 i| 37412093-1001 l| ONLINE m| ONLINE r| Y s| Y t| ONLINE u| 5/13/2022 o| .STAFF. Safari Online ALL from WCM 20220419

ASK A LIBRARIAN

PennState

Copyright @2019 The Pennsylvania State University. All rights reserved. Except where otherwise noted, this work is subject to a Creative Commons Attribution 4.0 license. Details and exceptions.

Legal Statements | PSU Hotlines

PENN STATE UNIVERSITY LIBRARIES

Libraries Home (814) 865-6368
Libraries Intranet (Staff Only)
Accessibility Help
Website Feedback
Policies and Guidelines
Staff Directory

ASK A LIBRARIAN

screenshot-catalog.libraries.psu.edu-2023.03.29-11_28_53
https://catalog.libraries.psu.edu/catalog/37412093
29.03.2023



OFDM wireless LANs : a theoretical and practical guide / John Terry and Juha Heiskala

Author: Terry, John, 1966-

Published: Indianapolis, Ind. : Sams, [2002]

Copyright Date: ©2002

Physical Description: 1 online resource (viii, 315 pages) : illustrations

Additional Creators: Heiskala, Juha

ASK A LIBRARIAN

Access Online

go.oreilly.com

Search inside at Google Books

Contents:

1. Background and WLAN Overview -- 2. Synchronization -- 3. Modulation and Coding -- 4. Antenna Diversity -- 5. RF Distortion Analysis for OFDM WLAN -- 6. Medium Access Control (MAC) for IEEE 802.11 Networks -- 7. Medium Access Control (MAC) for HiperLAN/2 Networks -- 8. Rapid Prototyping for WLANs.

Subject(s):

Wireless LANs
Orthogonalization methods
Réseaux locaux sans fil
Méthodes d'orthogonalisation
COMPUTERS—Data Transmission Systems—Wireless
COMPUTERS—Data Transmission Systems—Broadband
COMPUTERS—Networking—Local Area Networks (LANs)
Drahtloses lokales Netz
OFDM
Electrical & Computer Engineering
Engineering & Applied Sciences
Telecommunications

ASK A LIBRARIAN

Genre(s):

Electronic book

ISBN:

0768658667 (electronic bk.)
9780768658668 (electronic bk.)
9780672321573
0672321572

Bibliography Note:

Includes bibliographical references and index.

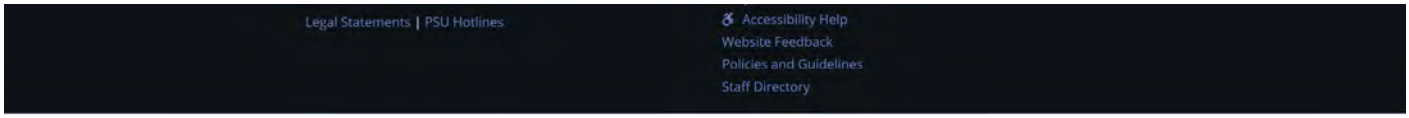
View MARC record | catkey: 37412093

PennState

Copyright ©2019 The Pennsylvania State University. All rights reserved. Except where otherwise noted, this work is subject to a Creative Commons Attribution 4.0 license. Details and exceptions.

PENN STATE UNIVERSITY LIBRARIES
Libraries Home (814) 865-6368
Libraries Intranet (Staff Only)

ASK A LIBRARIAN


Legal Statements | PSU Hotlines
Accessibility Help
Website Feedback
Policies and Guidelines
Staff Directory

APPENDIX TERRY02

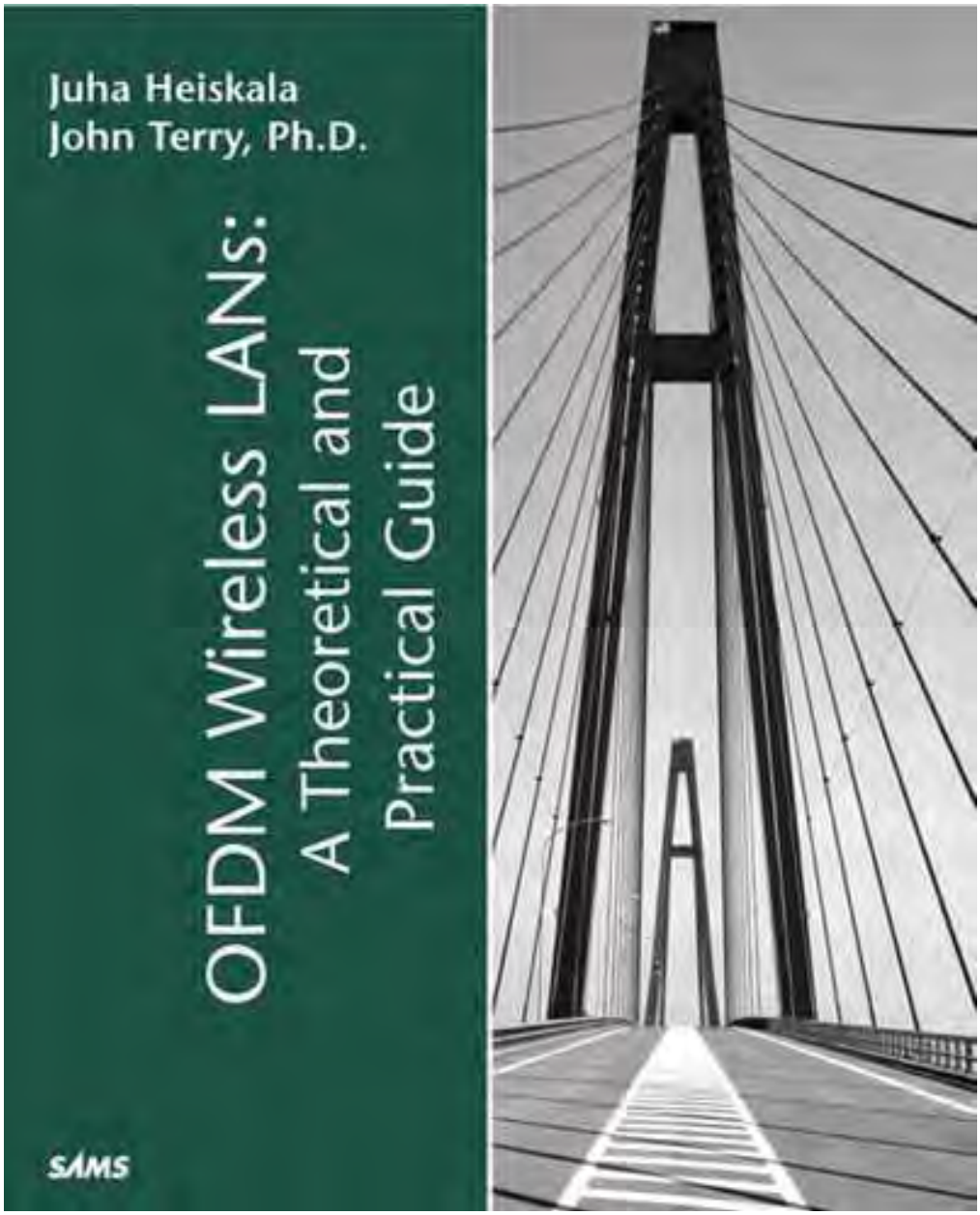
O'REILLY

BOOK

OFDM Wireless LANs: A Theoretical and Practical Guide

Write the first review

By John Terry, Juha Heiskala



Continue

TIME TO COMPLETE:

8h 42m

TOPICS:
802.11

PUBLISHED BY:
Sams

PUBLICATION DATE:
December 2001

PRINT LENGTH:
336 pages

OFDM Wireless LANs: A Theoretical and Practical Guide explores OFDM WLAN basics, including components of OFDM and multi-carrier WLAN standards. This book also provides a practical approach to OFDM by including software and hardware examples and detailed implementation explanations. And it defines and explains the mathematical concepts behind OFDM necessary for successful OFDM WLAN implementations.

About the Publisher

SAMS publishes professional reference books for programmers and developers, web developers, designers, networking and system administrators. SAMS is also a leading authority on developments in the Microsoft .NET Suite. With over 45 years expertise in technical training, SAMS produces the most widely used professional reference books available for programmers and developers.

More about Sams

Resources

Purchase book

Copyright

Copyright © 2002 by Sams Publishing

All rights reserved. No part of this book shall be reproduced, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without written permission from the publisher. No patent liability is assumed with respect to the use of the information contained herein. Although every precaution has been taken in the preparation of this book, the publisher and author assume no responsibility for errors or omissions. Nor is any liability assumed for damages resulting from the use of the information contained herein.

Library of Congress Catalog Card Number: 00-112047

Printed in the United States of America

First Printing: December 2001

04 03 02 01 4 3 2 1

Figures 2.4, 6.7, 6.8, 6.11 and 6.13-6.16 have material in part or full reproduced with permission from IEEE Std. 802.11a-1999, Copyright © 1999, by IEEE. The IEEE disclaims any responsibility or liability resulting from the placement and use in the described manner.

Trademarks

All terms mentioned in this book that are known to be trademarks or service marks have been appropriately capitalized. Sams Publishing cannot attest to the accuracy of this information. Use of a term in this book should not be regarded as affecting the validity of any trademark or service mark.

Warning and Disclaimer

Every effort has been made to make this book as complete and as accurate as possible, but no warranty or fitness is implied. The information provided is on an “as is” basis. The authors and the publisher shall have neither liability nor responsibility to any person or entity with respect to any loss or damages arising from the information contained in this book.

Credits

Associate Publisher

Linda Engelman

Acquisitions Editor

Dayna Isley

Development Editor

Rebecca Greenberg

Managing Editor

Charlotte Clapp

Project Editor

Carol Bowers

Copy Editor

Michael Henry

Indexer

Ron Strauss

Technical Editors

Tony Reid, Douglas B. Williams

Team Coordinator

Pamalee Nelson

Media Developer

Dan Scherf

Interior Designer

Anne Jones

Cover Designer

Aren Howell

Page Layout

Octal Publishing, Inc.

Channel Estimation

Channel estimation is the task of estimating the frequency response of the radio channel the transmitted signal travels before reaching the receiver antenna. The impulse response of a time varying radio channel is usually [20] represented as a discrete time FIR filter

Equation 2.66

$$h(\tau;t) = \sum_n \alpha_n(t) e^{-j2\pi f_c \tau_n(t)} \delta(\tau - \tau_n(t))$$

WLAN applications generally assume that the channel is quasistationary, that is, the channel does not change during the data packet. With this assumption the time dependency in **Equation 2.66** can be dropped

Equation 2.67

$$h(\tau) = \sum_n \alpha_n e^{-j2\pi f_c \tau_n(t)} \delta(\tau - \tau_n)$$

Then the discrete time frequency response of the channel is the Fourier transform of the channel impulse response

Equation 2.68

$$H_k = DFT\{h_n\}$$

Hence the channel estimation process outputs the $\hat{H}_k$, an estimate of the channel frequency response for each subcarrier.

Channel estimation is mandatory for OFDM systems that employ coherent modulation schemes. Otherwise correct demodulation would not be possible. Knowledge of the channel can also improve the performance OFDM with noncoherent modulation schemes, although the $\hat{H}_k$ are not needed for demodulation in this case. The improvement can be achieved when an error control code is used in the system, in which case the channel knowledge can help the code decoder do a better job.

Frequency Domain Approach for Channel Estimation

Frequency domain channel estimation can be performed with two main approaches. The first method uses training data transmitted on every subcarrier. This method is applicaple to WLAN systems. The second method uses correlation properties of the frequency response of a multipath channel, and training information that is transmitted on a subset of the subcarriers. This approach is used in broadcast OFDM systems.

Channel Estimation Using Training Data

The long training symbols in the WLAN preamble, **Figure 2.4**, facilitate an easy and efficient estimate of the channel frequency response for all the subcarriers. The contents of the two long training symbols are identical, so averaging them can be used to improve to quality of the channel estimate. DFT is a linear operation, hence the average can be calculated before the DFT. Then only one DFT operation is needed to calculate the channel estimate. After the DFT processing, the received training symbols $R_{1,k}$ and $R_{2,k}$ are a product of the training symbols X_k and the channel H_k plus additive noise $W_{1,k}$.

Equation 2.69

$$R_{l,k} = H_k X_k + W_{l,k}$$

Thus the channel estimate can be calculated as

Equation 2.70

$$\hat{H}_k = \frac{1}{2}(R_{1,k} + R_{2,k})X_k^*$$

Equation 2.71

$$= \frac{1}{2}(H_k X_k + W_{1,k} + H_k X_k + W_{2,k})X_k^*$$

Equation 2.72

$$= H_k|X_k|^2 + \frac{1}{2}(W_{1,k} + W_{2,k})X_k^*$$

Equation 2.73

$$= H_k + \frac{1}{2}(W_{1,k} + W_{2,k})X_k^*$$

where the training data amplitudes have been selected to be equal to one. The noise samples $W_{1,k}$ and $W_{2,k}$ are statistically independent, thus the variance of their sum divided by two is a half of the variance of the individual noise samples.

Channel Estimation Using Pilot Subcarriers and Interpolation

If the subcarriers are very close to each other, like in broadcast standards (e.g. DVB) the frequency domain correlation of the channel frequency response can be used to estimate the channel, even if training data is not available for all the subcarriers. The coherence bandwidth of the channel

is usually approximated [20] as the inverse of the total length of the channel impulse response

Equation 2.74

$$(\Delta f) \approx \frac{1}{\tau_{\max}}$$

When the subcarrier spacing is much less than the coherence bandwidth, the channel frequency response on neighboring subcarriers will be practically identical. For example, the DVB standard takes advantage of this by not sending training information on all subcarriers, hence more data can be transmitted. The pilot subcarriers in DVB are divided into two sets. The first set is regular pilot subcarriers that are similar to the WLAN pilots subcarriers; known data is constantly transmitted on them. The second set is called scattered pilots; known data is transmitted only intermittently transmitted on the subcarrier. Then the channel estimation is performed by interpolating the frequency response of the subcarriers that do not have training information from the known subcarriers. We do not describe this algorithm in detail, a description of a method can be found in Speth et. al. [25].

Time Domain Approach for Channel Estimation

The channel estimation can also be performed using the time domain approach, before DFT processing of the training symbols. In this case, the channel impulse response, instead of the channel frequency response, is estimated. The following derivation of the channel estimator uses IEEE 802.11a standard training symbols as an example, but the same approach can be applied to any OFDM system that includes training symbols. The received time domain signal during the two long training symbols is

Equation 2.75

$$r_{1,n} = h * x_n + w_{1,n}$$

The time domain convolution can be expressed as a matrix vector multiplication. The circular convolution matrix is formed from the training data as

Equation 2.76

$$X = \begin{bmatrix} x_1 & x_{64} & x_{63} & \cdots & x_{64-L+2} \\ x_2 & x_1 & x_{64} & & x_{64-L+3} \\ \vdots & & \vdots & & \vdots \\ x_{63} & x_{62} & & & x_{64-L} \\ x_{64} & x_{63} & & \cdots & x_{64-L+1} \end{bmatrix}$$

The parameter L defines the maximum length of the impulse response that can be estimated, and X is in general a rectangular matrix. The channel impulse response vector is

Equation 2.77

$$h = \begin{bmatrix} h_1 \\ h_2 \\ h_3 \\ \vdots \\ h_L \end{bmatrix}$$

Then the convolution is expressed as

Equation 2.78

$$r_{l,n} = h * x_n + w_{l,n} = Xh + w_l$$

The channel impulse response estimate can then be formed by

Equation 2.79

$$\hat{h} = \frac{1}{2} X^{\dagger}(r_{1,n} + r_{2,n})$$

Equation 2.80

$$= \frac{1}{2} X^{\dagger}(Xh + w_1 + Xh + w_2)$$

Equation 2.81

$$= X^{\dagger}Xh + \frac{1}{2} X^{\dagger}(w_1 + w_2)$$

Equation 2.82

$$= h + \frac{1}{2} X^{\dagger}(w_1 + w_2)$$

where $X^{\dagger}$ denotes Moore-Penrose [22] generalized inverse of X. The channel frequency response estimate is then formed by calculating the DFT of the impulse response estimate

Equation 2.83

Exercise 5 The simulation tool implements the frequency domain channel estimation algorithm. Write a Matlab script for the time-domain algorithm and compare the performance of the algorithms.

Exercise 6 The simulation tool allows to run simulations with perfect synchronization or with partial or full synchronization. Experiment how the performance of the system degrades compared to perfect synchronization as the various synchronization algorithms are activated.

Analysis of the Time Domain and Frequency Domain Approaches for Channel Estimation

The advantage of the time domain approach is improved performance, when the maximum length of the impulse response can be limited to a number significantly less than the number of subcarriers. The rationale is that the frequency domain estimator has to simultaneously estimate all the subcarriers, whereas the time domain estimator needs to estimate only the taps of the impulse response. When the number of subcarriers is large compared to the number of channel taps, the signal energy used to estimate each H_k is significantly less than the signal energy used to estimate each h_n. In other words, it is easier to estimate fewer parameters given a fixed amount of data. For example, in the IEEE 802.11a system the number of subcarriers is 52, and the maximum length of the channel can be assumed to be less than the cyclic prefix length of 16 samples. Thus the frequency domain algorithm estimates more than three times the number of parameters than the time domain algorithm.

The drawback of the time domain method is that additional computations are required. The $\frac{1}{2} X^{\dagger}(r_{1,n} + r_{2,n})$ operation requires $64 \cdot L$ multiplications, which are not needed at all in the frequency domain estimator. This is the usual engineering trade-off; better performance usually implies higher costs in one form or another.

Enhancing the Channel Estimate

The correlation of the channel frequency response between different subcarriers can be used to further improve the quality of the channel estimate. **Figure 2.16** shows an example of the channel amplitude response for a IEEE802.11a system. It can be seen that the neighboring subcarriers are highly correlated. We will not go to the details of this method, but refer to [12] for a full discussion. The paper shows that in some conditions performance very close to ideal channel estimation can be achieved. Unfortunately, this improvement does not come without a price; significantly more computations are required than to calculate the simple frequency domain channel estimator.

Figure 2.16. Example of a channel amplitude response.

