OFDMA PHY proposal for the 802.16.3 PHY layer

IEEE 802.16 Presentation Submission Template (Rev. 8)
Document Number: IEEE 802.16.3p-01/33

Date Submitted:
2001-03-13

Source:
Zion Hadad
RunCom Technologies LTD.
Rishon Lezion, Moshe Levi 14 st.
Israel
Voice: 972-3-9528440
Fax: 972-3-9528805
E-mail: zionh@runcom.co.il

Venue:
Hilton Head, South Carolina

Base Document:
802163c-01_33r2.pdf

Purpose:
This proposal should be used as the baseline for the PHY specification of the TG3.

OFDMA PHY proposal for TG3

PHY Planning Issues

Guidelines for PHY Planning

Larger FFT's gives better multipath handling due to their longer GI

- Larger FFT's gives better spectral masks
- Less throughput overhead (GI) for larger FFT's
- OFDMA concept has many advantages

OFDM FFT Sizes Supported

The next table shows the GI length for different FFT sizes (mandatory modes only)

FFT size GI	64 (64 mode)			256 (256 mode)			1024 (1k mode)			2048 (2k mode)		
	3 MHz	6 MHz	12 MHz	3 MHz	6 MHz	12 MHz	3 MHz	6 MHz	12 MHz	3 MHz	6 MHz	12 MHz
1/32	N.A.	N.A.	N.A.	*2.6us	*1.3us	*0.6us	10.6us	*5.3us	*2.6us	21.3us	*10.6us	*5.3us
1/16	N.A.	N.A.	N.A.	*5.3us	*2.6us	*1.3us	21.3us	*10.6us	*5.3us	42.6us	21.3us	10.6us
1/8	*2.6us	*1.3us	*0.6us	*10.6us	*5.3us	*2.6us	42.6us	21.3us	*10.6us	85.3us	42.6us	21.3us
1/4	*5.3us	*2.6us	*1.3us	21.3us	*10.6us	*5.3us	85.3us	42.6us	21.3us	170.6us	85.3us	42.6us

OFDM FFT Size Planning

- Remember, Larger FFT size give longer GI and better multipath handling !!!!

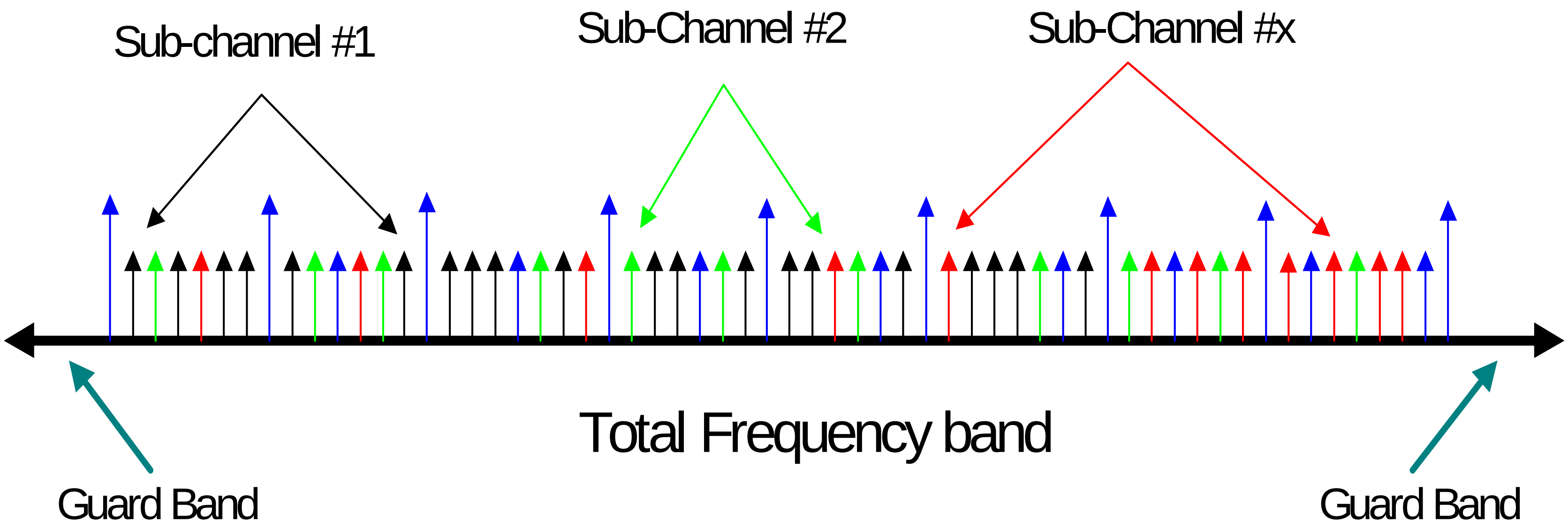
- Smaller granularity for each user, gives better throughput.

- Allocation of high data rates have better multiplexing gain

OFDMA Symbol Structure

OFDMA symbol structure

The usable carriers are divided into groups called Sub-Channels.



Dividing into Sub-Channels

when using DS each Sub-Channel contains 48 data carriers, for the US a Sub-Channel contains 53 overall carriers (Data and Pilots).

- 64 Sub-Channels for the 4k mode
- 32 Sub-Channels for the 2k mode
- 16 Sub-Channels for the 1k mode
- 8 Sub-Channels for the 512 mode
- 4 Sub-Channels for the 256 mode
- 2 Sub-Channels for the 128 mode
- 1 Sub-Channel for the 64 mode

Using Special Permutations for Carrier Allocation

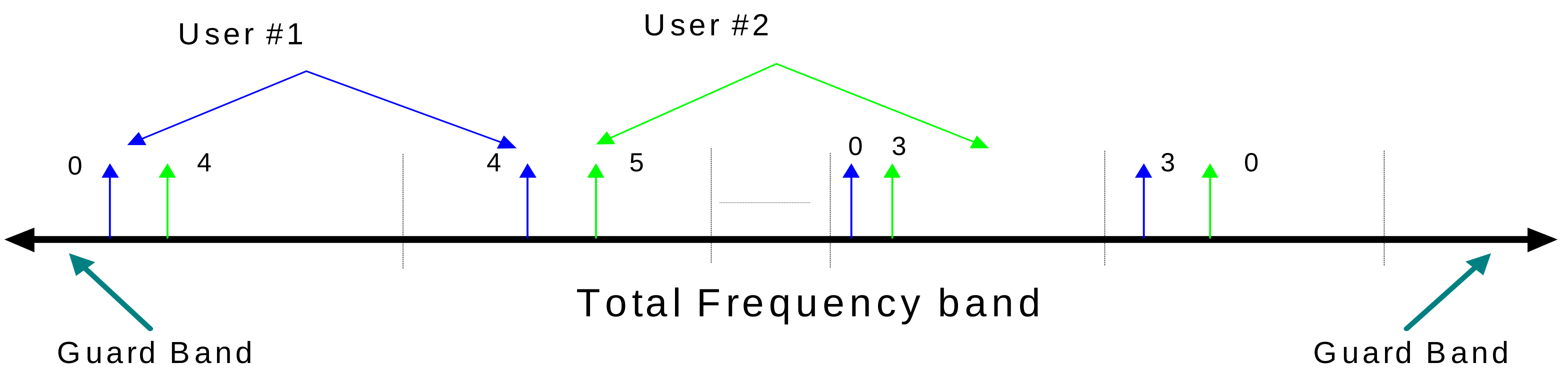
Carriers are allocated by concatenating a basic series, and cyclic permutations of it, for example (1k mode):

- Basic Concatenated Series:

  0 ,4 ,5 , 12, 10, 13, 1, 11, 3, 15, 14, 7, 9, 6, 2, 8, 2, 6, 7, 14, 12, 15, 3, 13, 5, 1, 0, 9, 11, 8, 4, 10, 4, 8, 9, 0, 14, 1, 5, 15, 7, 3, 2, 11, 13, 10, 6, 12, 6, 10, 11, 2, 0, 3

- After One cyclic permutation we get:

  4 ,5 , 12, 10, 13, 1, 11, 3, 15, 14, 7, 9, 6, 2, 8, 2, 6, 7, 14, 12, 15, 3, 13, 5, 1, 0, 9, 11, 8, 4, 10, 4, 8, 9, 0, 14, 1, 5, 15, 7, 3, 2, 11, 13, 10, 6, 12, 6, 10, 11, 2, 0, 3,0

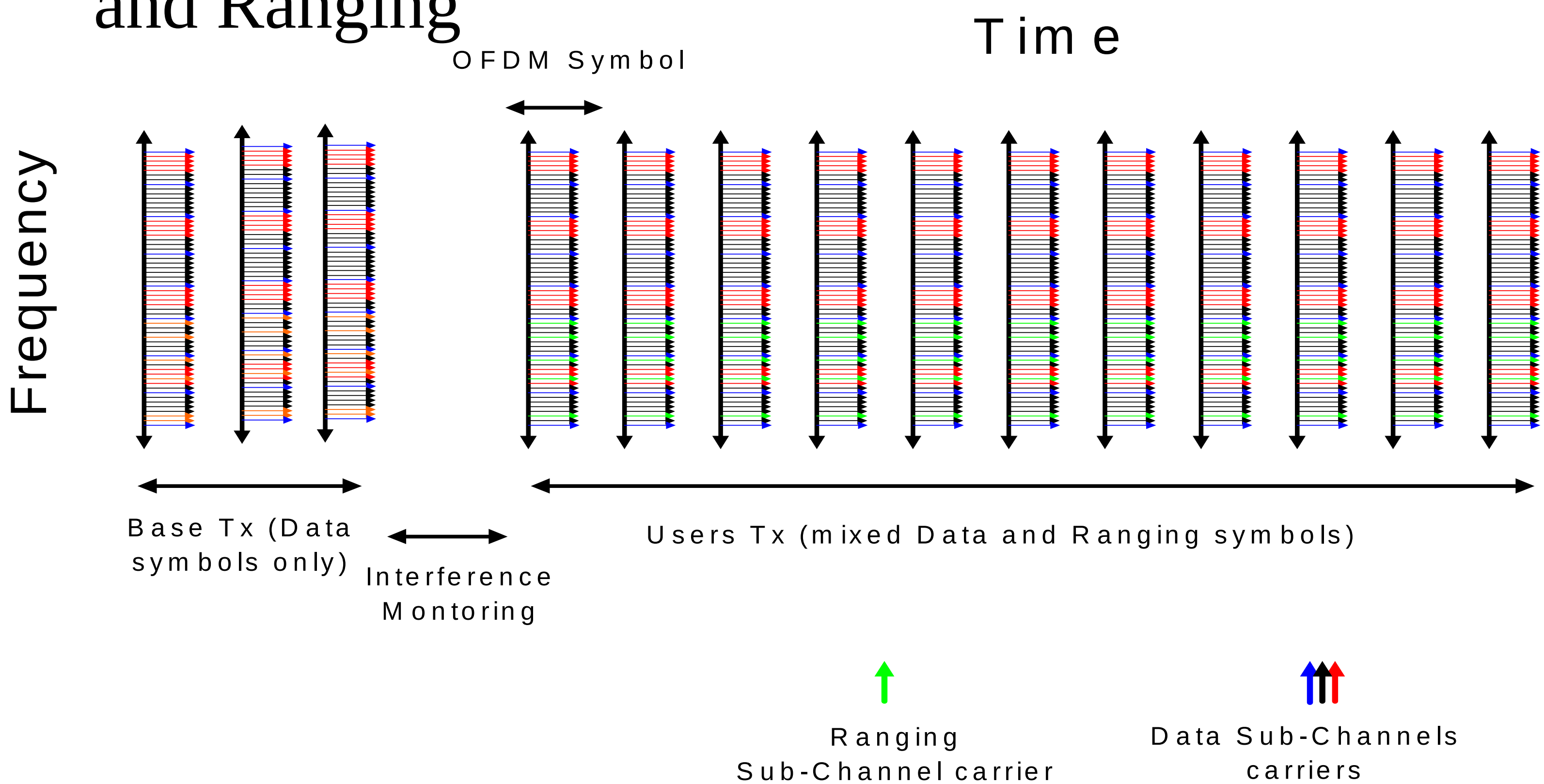


User 1 = 0 ,4 ,5 , 12, 10, 13, 1, 11, 3, 15, 14, 7, 9, 6 ....0, 3
User 2 = 4 ,5 , 12, 10, 13, 1, 11, 3, 15, 14, 7, 9, 6, 2....3, 0

System Properties and Access Methods

Access method for the 512 and above modes

DS symbols are allocated for data only, US Sub-Channels within a symbol are allocated for data and Ranging



Adaptive features

- FFT size setting
- Adaptive FEC
- Adaptive Modulation
- Adaptive Bandwidth per Allocation (by using adaptive Sub-Channel Allocation)
- Power administration (FAPC)

Coding schemes

- Concatenated RS(255,239,8) and tail biting convolutional coding (k=7, G1=171, G2=133)
- Block Turbo Codes (the same BTC as for TG1)

Coding Schemes are treated the same way by the MAC, both are block oriented, with the same block sizes

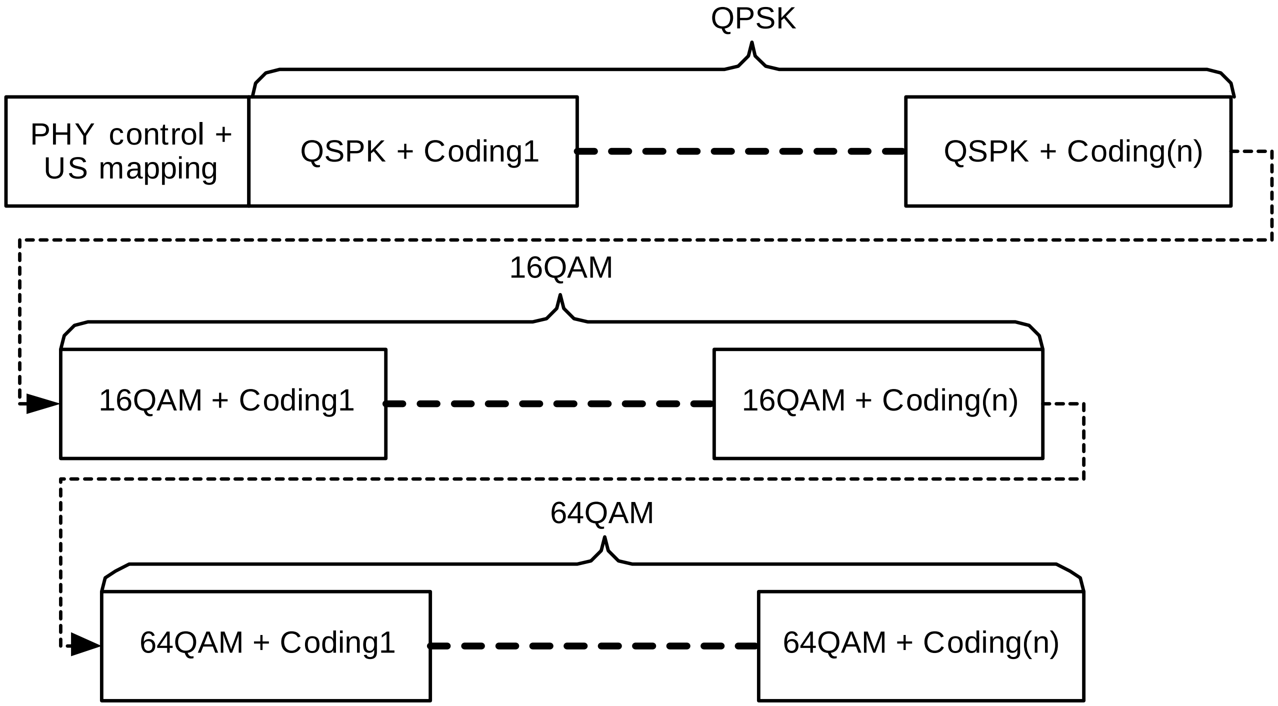
System Characteristics

- FFT size : 4096, 2048, 1024, 512
- Guard Intervals : ¼, 1/8, 1/16, 1/32
- Coding :
  - Concatenated RS(255,239,8) and tail biting convolutional coding (k=7, G1=171, G2=133)
  - Block Turbo Codes
- QPSK, 16QAM and 64QAM
- Down Stream Mapping sets the Sub-Channel allocation and parameters (modulation, coding and power)
- throughput administration based upon Sub-Channel allocation
- Sub-Channels Power Manipulation (Forward Automatic Power Control – FAPC and Backward Automatic Power Control - BAPC)

Down Stream Properties

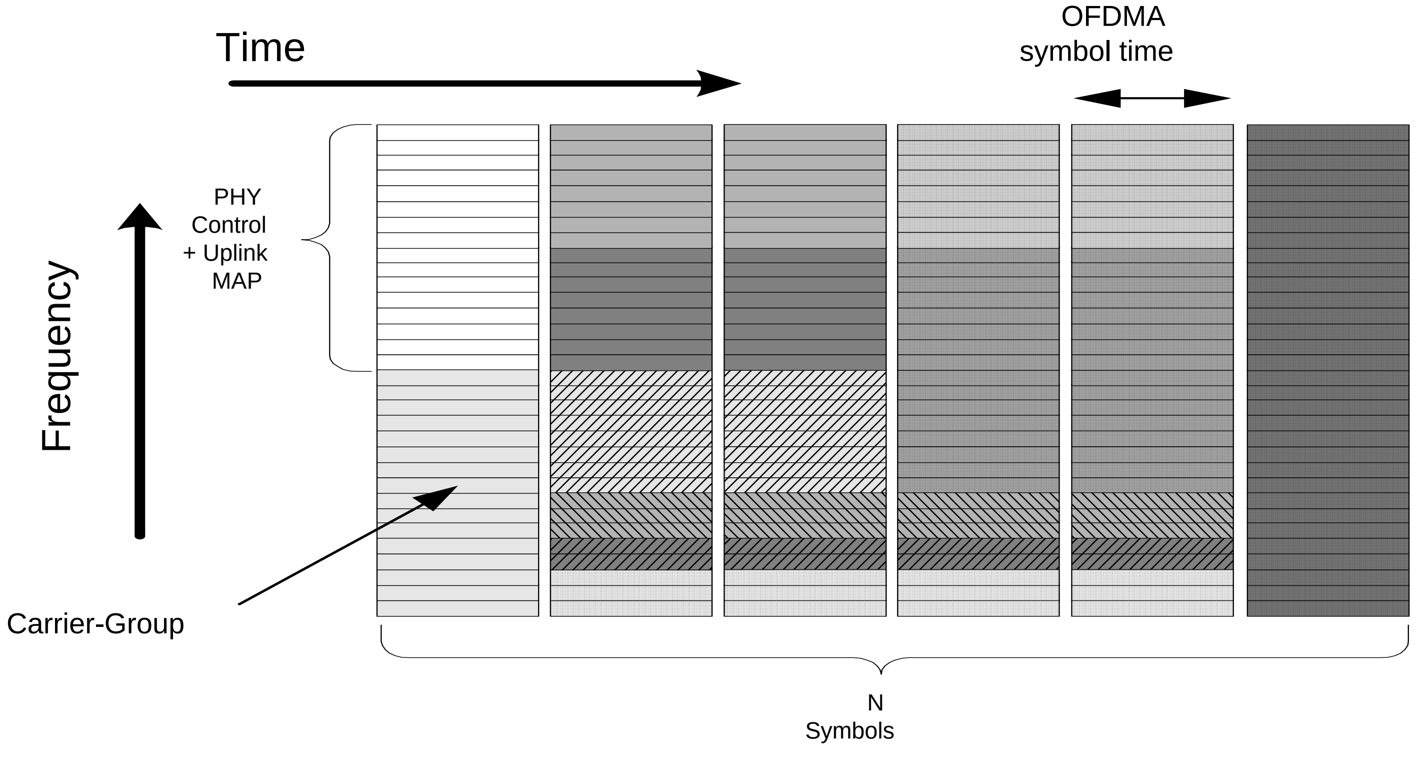
Framing Structure

Framing structure build upon TG1 principles, downstream can be divided into different modulation and coding regions.



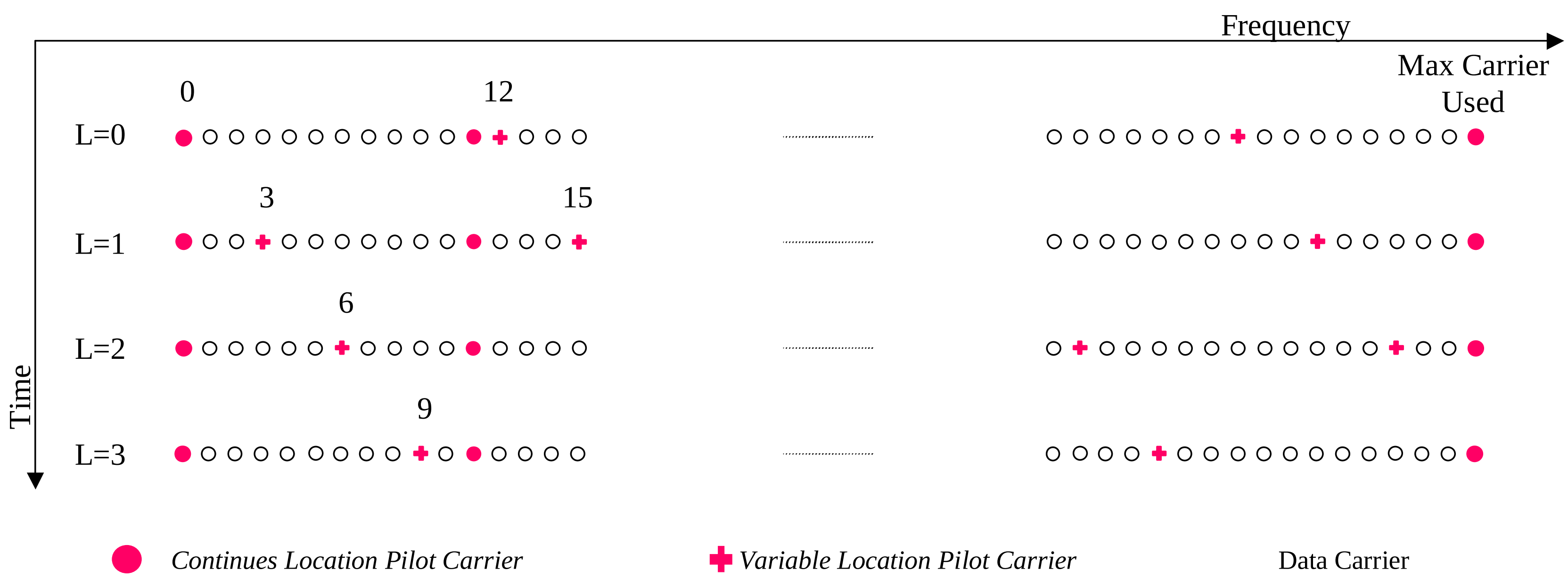
512 and above modes – framing structure

Allocation on the DS enables the use of Forward Automatic Power Control (for better power usage, and cell covering)



512 and above modes – DS Data Symbol Structure

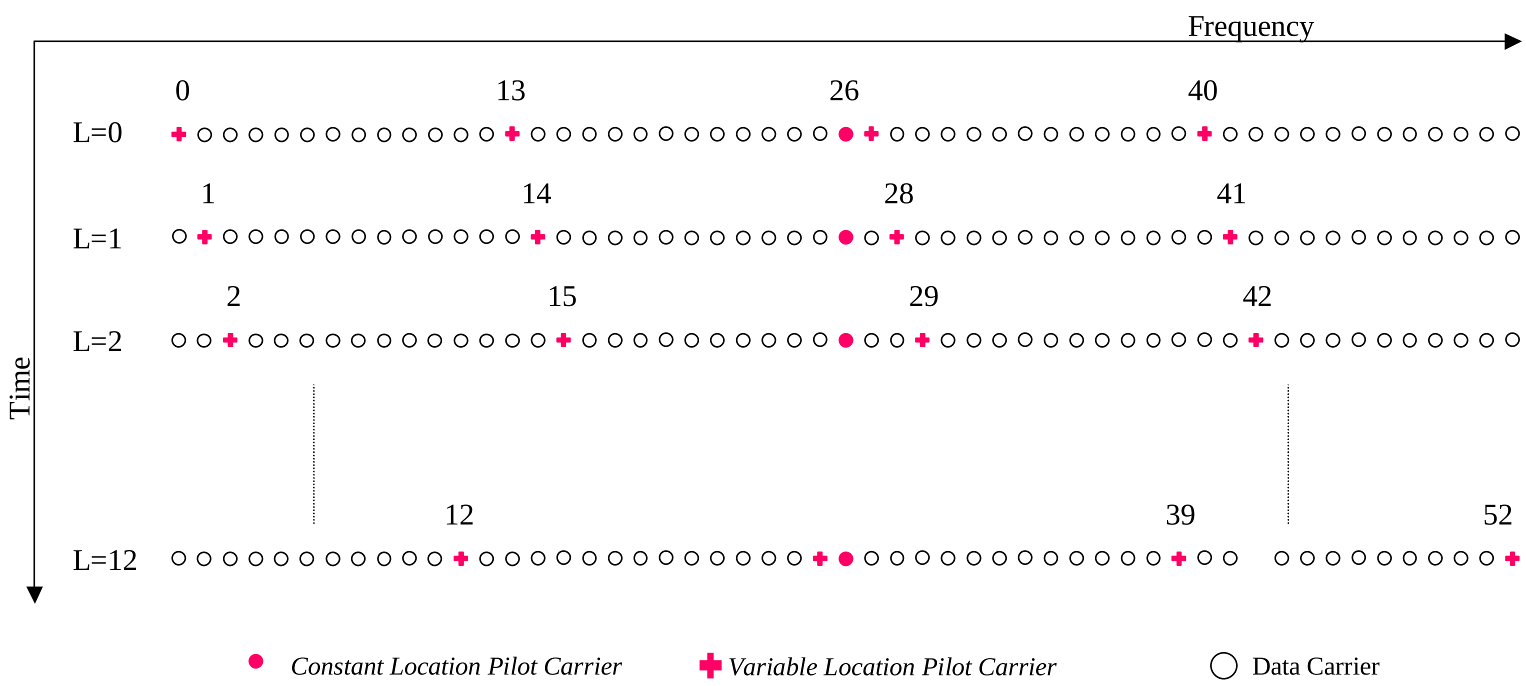
Based on variable and continues pilots.



Up Stream Properties

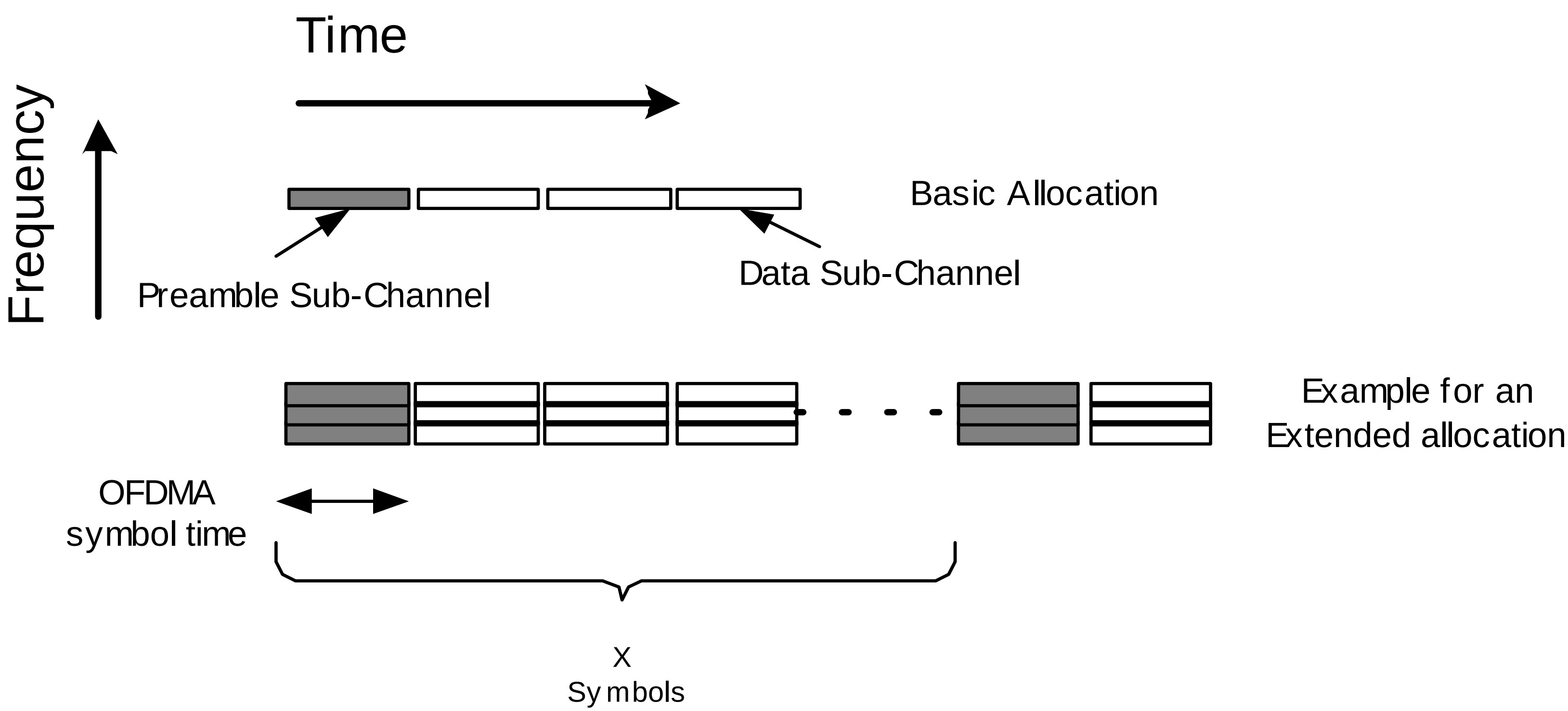
Sub-Channel structure

Every Sub-Channel contains 53 carriers (5 pilot carriers and 48 data carriers). Variable pilots are used for CSI update as well as for tracking.



US allocation

Basic allocation of 4 Sub-Channels, the first used as a preamble the rest as data. Allocation can be increased by allocating Sub-Channels or more time symbols.



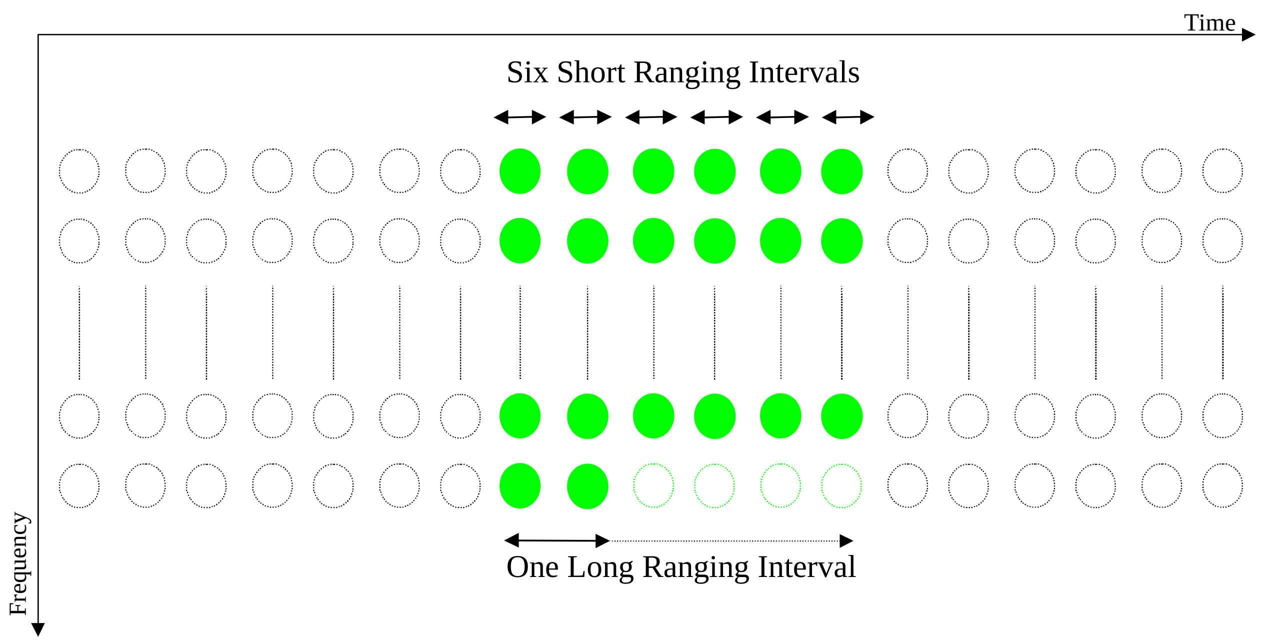
Using CDMA like Synchronization (Preamble based only)

Using CDMA like Synchronization

- The CDMA like synchronization is achieved by allocating one or several Sub-Channels for Ranging or fast bandwidth request purposes.
- Onto the Ranging Sub-Channels users modulate a Pseudo Noise (PN) sequence using BPSK modulation
- The Base Station detects the different sequences and uses the CIR that he derives from the sequences for:
  - Time and power synchronization
  - Decide on the user modulation and coding
  - Bandwidth allocation

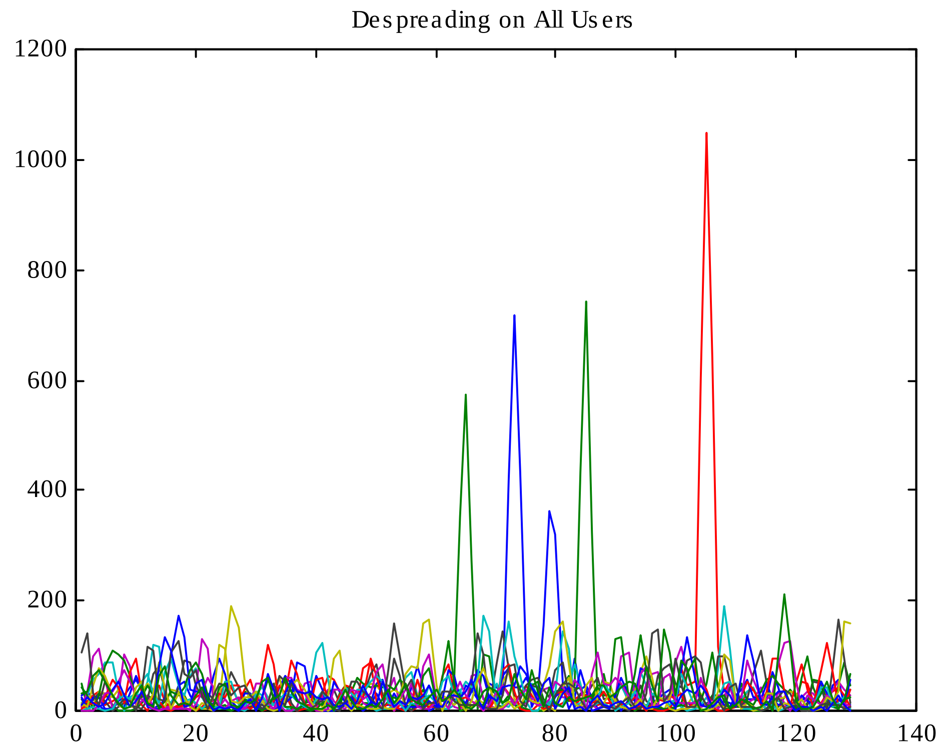
Ranging Interval

- Long Ranging – for initial synchronization, taking care of possible ambiguity in the time of arrival
- Short Ranging – for maintenance ranging and fast bandwidth request
- Several Ranging interval could be allocated.



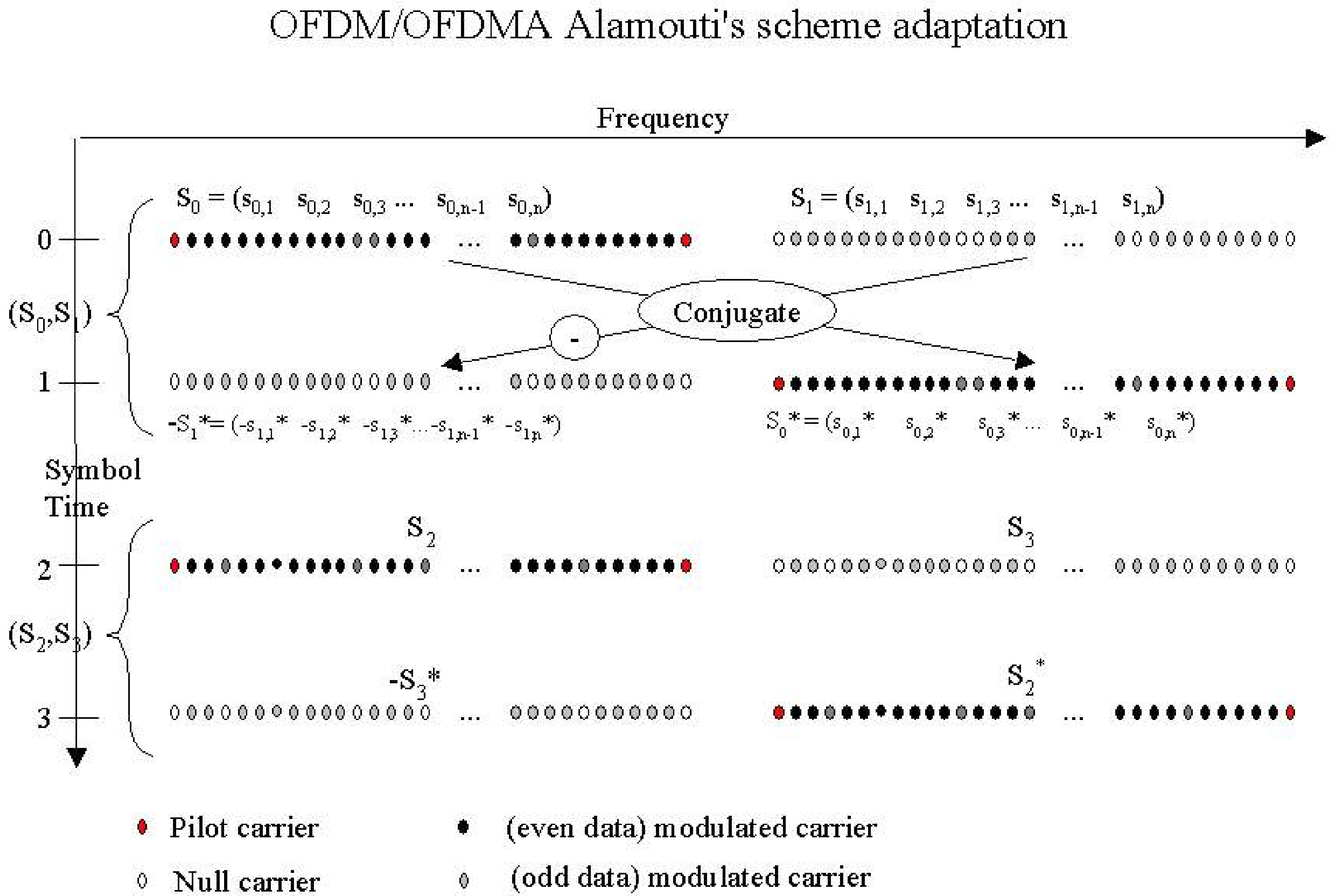
Ranging Results

- Colliding codes can be separated
- No Slotted-Aloha inefficient based mechanism
- Small Ranging Intervals, and faster response time

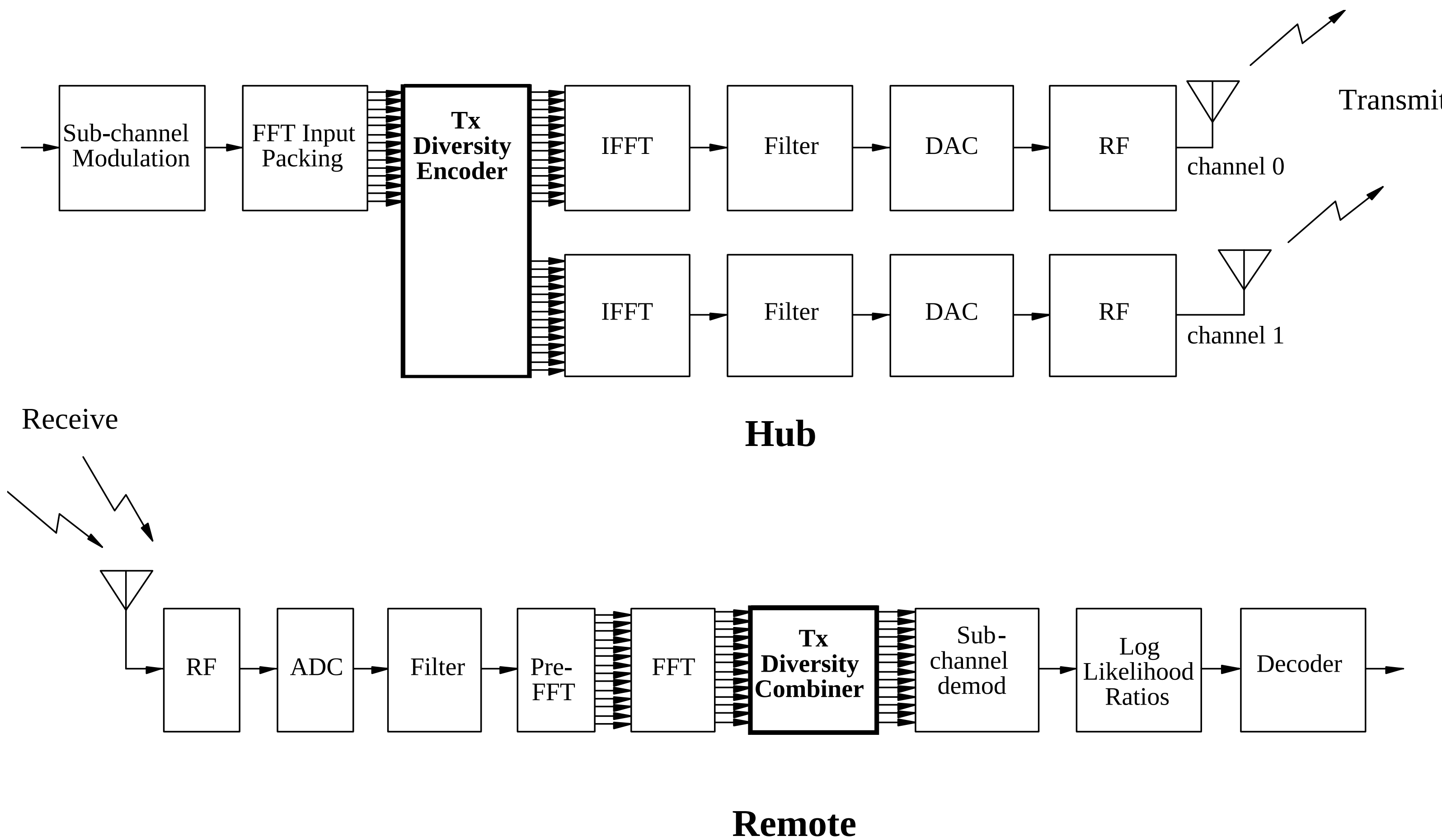


Supporting Space Time Coding

Alamouti Transmission Scheme



Alamouti Block Diagram



Supporting Broad-Band Adaptive Antenna

Adaptive Antenna Array

- Broad-Band Antenna Arrays are a well known technology for many years.
- OFDMA capabilities could be enhanced by using Adaptive Antenna Arrays
- Current system design and framing structure gives full support for Broad-Band Adaptive Antenna Array Technology

OFDMA System - Throughput

System Throughput

The table was calculated for 3MHz channel, using the 2k mode.

Modulation	Bits per sub-carrier	code rate	Net bit rate (Mbps) for different Guard intervals			
			1/4	1/8	1/16	1/32
QPSK	2	1/2	2.06	2.29	2.4	2.49
	2	2/3	2.74	3.05	3.21	3.33
	2	3/4	3.09	3.43	3.61	3.74
16-QAM	4	1/2	4.11	4.57	4.8	4.98
	4	2/3	5.49	6.1	6.42	6.65
	4	3/4	6.17	6.86	7.83	7.47
64-QAM	6	1/2	6.17	6.86	7.2	7.47
	6	2/3	8.23	9.15	9.63	9.98
	6	3/4	9.26	10.29	10.83	11.2

Power Concentration

Power Concentration

- In the Up Stream due to Sub-Channel allocation (53 carriers per Sub-Channel) a **15dB** gain for the 2k mode is achieved for one Sub-Channel allocation.
- In the Down Stream due to Sub-Channel allocation (53 carriers per Sub-Channel) a **10dB** gain can be achieved for one Sub-Channel busted (FAPC).
- This additional power gain enables better communication range, penetration into buildings, and a better coverage.
- This additional gain could be used for:
  - Bigger cell radius
  - Better coverage and availability
  - Better capacity
  - Chipper and smaller power amplifiers
  - Simpler antennas

Power Concentration - Example

Estimating the cell radius for the system with the following parameters:

- 3MHZ channel Bandwidth
- 64QAM modulation
- One Sub-Channel transmission
- Receiver NF=4dB
- Assuming power emission of 30dBm
- using a 30° antenna at the SS and 60° at the BS
- Simple propagation model for LOS and NLOS

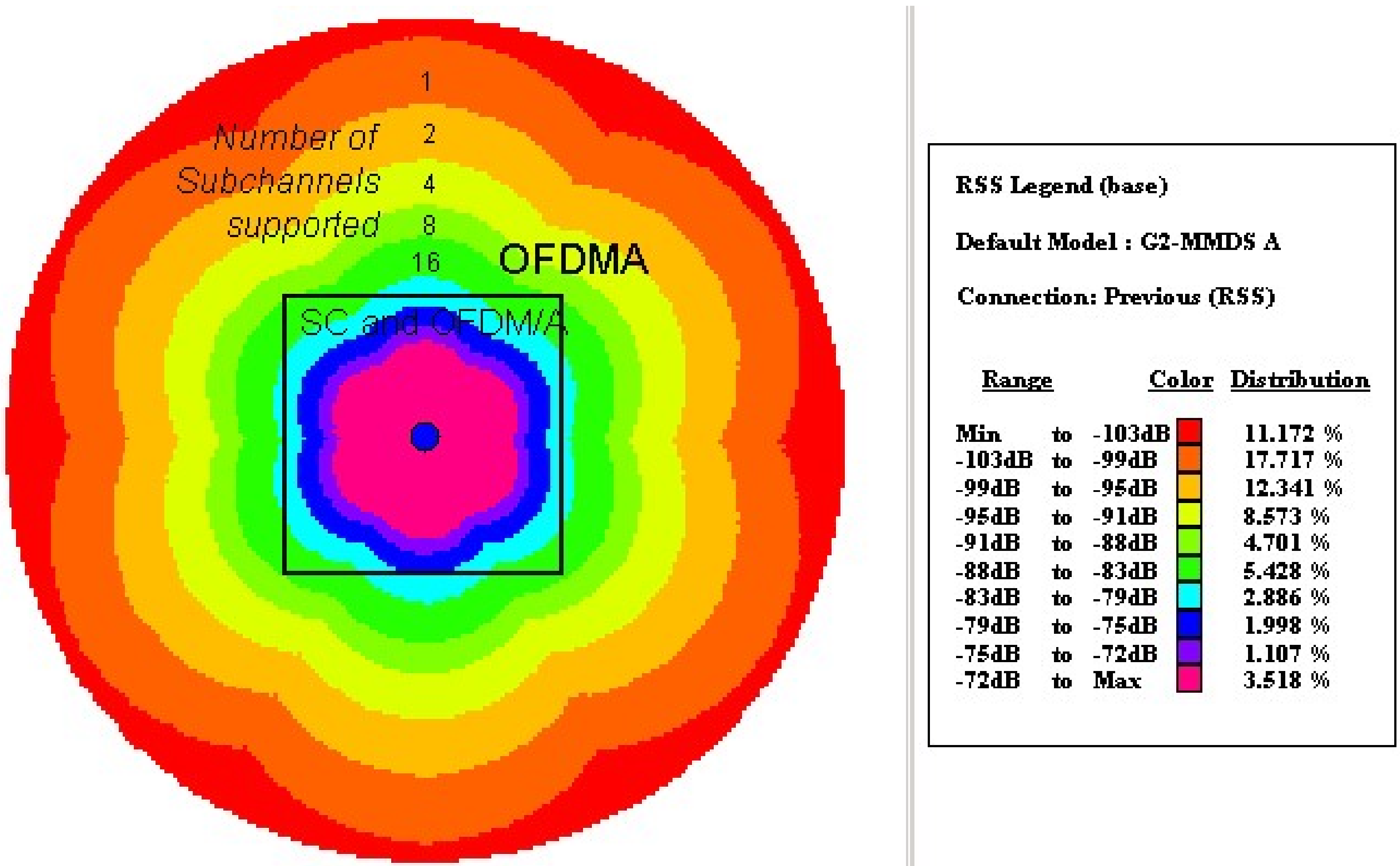
We get the following results:

64 mode: 4.8Km for LOS, 690m for NLOS

2k mode: 26.9Km for LOS, 1.64km for NLOS

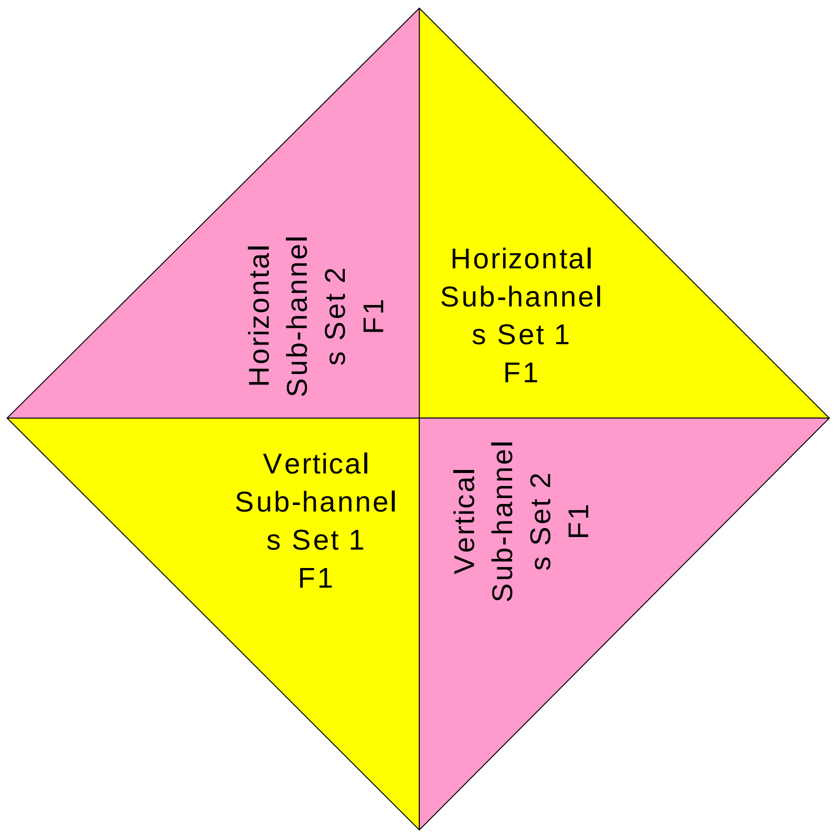
Cellular Deployment and Sectorization

Cell dimensions of OFDM and SC



Using a Reuse Factor of 1

By allocating different Sub-Channels to different sectors we can reach reuse factor of 1 with up to 12 sectors (changing the polarity enhances the performance)



Throughput Enhancement

For a Full capacity cell deployment and no interferers we gain up to 25% in the throughput.

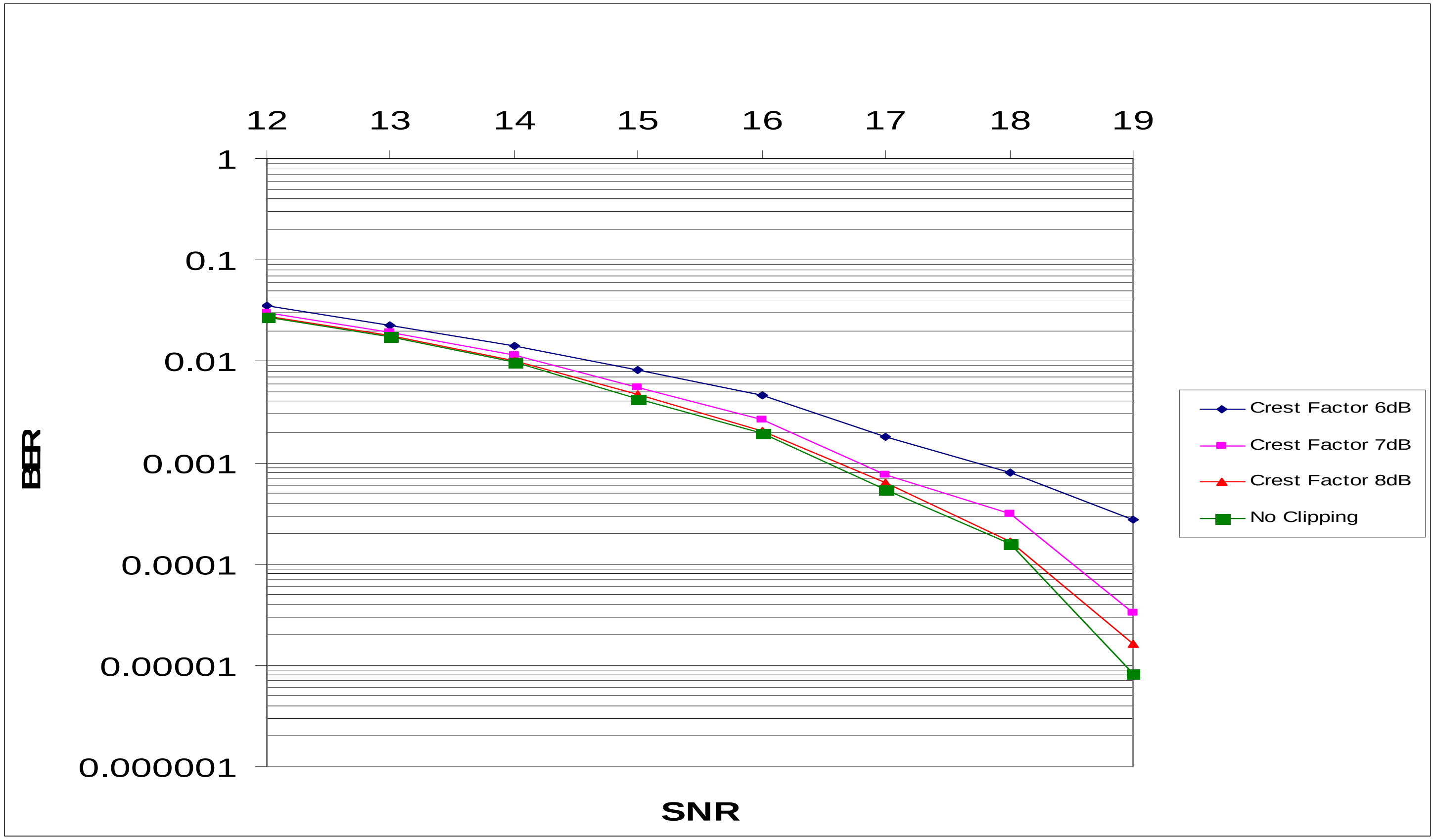
For Multi-Cell environment with a dynamic allocation the improved are expected to sharply increase.

PAPR Reduction

PAPR Reduction

- Using shaping on the signal peaks
- Limiting the PAPR to a constant value by vector reduction
- Possibility to use some pilot carrier for PARP reduction

Crest Factor (Down Stream)



BER/SNR for different Crest Factor achieved by clipping for a 2k FFT 16QAM OFDM Symbol (Uncoded)

OFDMA System Summary

Advantages - Summary (1)

- Averaging interference's from neighboring cells, by using different basic carrier permutations between users in different cells.
- Interference's within the cell are averaged by using allocation with cyclic permutations.
- Enables orthogonality in the uplink by synchronizing users in time and frequency.
- Enables Multipath mitigation without using Equalizers and training sequences.
- Enables Single Frequency Network (SFN) coverage, where coverage problem exists and gives excellent coverage.

Advantages - Summary (2)

- Enables spatial diversity by using antenna diversity at the Base Station and possible at the Subscriber Unit.
- Enables adaptive modulation for every user QPSK, 16QAM and 64QAM
- Enables adaptive carrier allocation in multiplication of 53 carriers (one Sub-Channel) up to full Symbol capacity
- Gives Frequency diversity by spreading the Sub-Channel carriers all over the used spectrum.
- Gives Time diversity by optional interleaving of Sub-Channels in time.
- Time Space Coding for better performance and channel handling

Advantages - Summary (3)

- Using the cell capacity to the outmost by adaptively using the highest modulation a user can use for the uplink, this is allowed by the gain added when less carriers are allocated (**15dB** gain for the 2k mode), therefore gaining in overall cell capacity.
- Reaching users with higher modulation and capacity in the down Stream by power concentration on specific Sub-Channels at the down Stream (up to **10dB** more gain on a Sub-Channel) using FAPC.
- The power gain can be translated to distance 2.5 times the distance for R^4 (NLOS) and 5.5 time for R^2 (LOS).
- Enabling the usage of Indoor Omni Directional antennas for the users.
- MAC complexity is the same as for TDMA systems.

Advantages - Summary (4)

- Allocating carrier by OFDMA/TDMA strategy.
- Using Small burst per user with granularity of 48 symbols for better statistical multiplexing and smaller jitter.
- User OFDM symbol with large FFT size gives better immunity to channel multipath.
- Using sophisticated ECC schemes to the outmost by error detection of disturbed frequencies.
- Gives a reuse factor of 1

Advantages - Summary (5)

- Efficient Methods for PARP reduction
- DFS used by the Base Station
- Antenna diversity
- Antenna array could be supported