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IEEE C802.16a-02/100

Title:

Number of pilots in OFDM FFT=256 mode with UL subchanelization.

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Naftali Chayat

Alvarion Ltd.
21a, HaBarzel Street
Tel Aviv, Israel

Voice: +972-3-6456262, +972-54-225549
Fax: +972-3-6456290
E-mail: naftali.chayat@alvarion.com

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Base Document:

Purpose:

Present the deficiencies of current text for uplink subchannelization in 802.16a in FFT=256 mode and provide an improved solution.

Notice:

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IEEE Patent Policy:

802.16a OFDM # of pilots and its relation to subchannelization

Naftali Chayat

Alvarion

Comment (1)

- This comment addresses the issue of number of pilots in the OFDM mode.

- Between 802.16a/D5 and 802.16a/D6 a major technical change has occured, by introduction of the subchannelized uplink option in the OFDM mode. I welcome this change - it is a significant improvement of the OFDM mode. Nevertheless, it calls for review of the whole OFDM clause.

Comment (2)

- In my view, the subchannelized operation will become "de facto mandatory" in all 802.16a point-to-multipoint equipment. Therefore we have to give appropriate weigth to its performance and to its implementation aspects.

Comment (3)

- The current implementation of the subchannelization is both awkward and carries a performance penalty in that in subchannelized mode each subchannel has only two pilots. The use of just two pilots creates a situation in which the diversity order of phase tracking is less than of the data, and the channel estimate cannot be maintained adequately in larger Doppler spreads.

Comment (4)

- The awkwardness usually translates to implementation complexity and to performance reduction. Here we have clusters of irregular size (some 12, some 13 subcarriers); some contain pilots, some not; the pilots are in irregular locations within the clusters. These irregularities complicate channel estimation, phase tracking, separation of data subcarriers etc. The subchannelized mode just looks as OFDM divided by a butcher's knife, rather than design for performance and for implementation.

Comment (5)

- For all the reasons above I recommend to implement the OFDM mode with 16 pilots rather than with 8. Documents 802.16a-02/35 shows that the increase in the number of pilots does not violate the regulatory masks and does not penalize the data rate. Documents 802.16a-02/36r1,37 document the changes needed to implement a regular, high performance OFDM mode.

802.16a timeline implications

- Adoption of a change carriers additional time penalty on 802.16a only if appealed in recirculation stage.
- If an agreement is achieved at this stage, there is little danger of time slip
- No additional time penalty

Subchannelized UL for the OFDM mode is a great achievement

- Provides 6 dB link budget advantage on UL
  - Allows better CPE economics, especially in licensed bands
- Improved granularity and reduced training overhead
- Implements clustered subcarrier allocation
  - Improved ACI and training performance

History of subchannelized UL

- Promoted by Alvarion for more than a year
- Finally, gained support by Nokia and WiLAN, and introduced in HIPERMAN
  - Disagreements on details
- Repeatedly rejected in 802.16
  - Opposition from both OFDMA and SC camps
- Introduced as a part of the Ballot Resolution Committee in the 802.16a/D6
  - Included some last-minute changes

Subchannelized uplink – a de-facto mandatory feature in licensed bands

- The subchannelized uplink is not just for short packets – it provides performance advantages across the board, and should be implemented in the best way possible.
  - Adequate phase tracking performance for long packets
  - Convenient and high performance training

Regularity implications

- Processing of upstream subchannelization composed of clusters calls for per-cluster processing
- In current structure each cluster is built differently
  - Some clusters contain a pilot, some don't
  - Some contain 13 pilots, some 12
  - Those with 13 each contains pilots at different location
  - Those with 13 contain some 6 training subcarriers at even locations, some 7 subcarriers at odd locations
- Implementer's nightmare
- Performance implications

- 3:{-100,...,-89}, T.T.T.T.T.T.
- 1:{ -88,...,-76}, p@-84 T.T.P.T.T.T.T
- 4:{ -75,...,-64}, .T.T.T.T.T.T
- 2:{ -63,...,-51}, p@-60 .T.P.T.T.T.T.
- 1:{ -50,...,-39}, T.T.T.T.T.T.
- 3:{ -38,...,-26}, p@-36 T.P.T.T.T.T.T
- 2:{ -25,...,-14}, .T.T.T.T.T.T
- 4:{ -13,..., -1}, p@-12 .P.T.T.T.T.T.
- 1:{   1,..., 13}, p@ 12 .T.T.T.T.T.P.
- 3:{ 14,..., 25}, T.T.T.T.T.T.
- 2:{ 26,..., 38}, p@ 36 T.T.T.T.T.P.T
- 4:{ 39,..., 50}, .T.T.T.T.T.T
- 3:{ 51,..., 63}, p@ 60 .T.P.T.T.T.T.
- 1:{ 64,..., 75}, T.T.T.T.T.T.
- 4:{ 76,..., 88}, p@ 80 T.T.P.T.T.T.T
- 2:{ 89,...,100}, .T.T.T.T.T.T

The proposed pilot structure

- Each cluster contains a pilot
  - Pilots and data have same diversity order
- Pilot always at cluster's center
  - location most representative of cluster's channel
- Each cluster is processed same way in the receiver
  - Pilot gathering for phase estimation
  - Data-pilot separation

- 1:{-104,...,-92}, p@-98 TTTTTTPTTTTTT
- 3:{ -91,...,-79}, p@-85 TTTTTTPTTTTTT
- 2:{ -78,...,-66}, p@-72 TTTTTTPTTTTTT
- 4:{ -65,...,-53}, p@-59 TTTTTTPTTTTTT
- 1:{ -52,...,-40}, p@-46 TTTTTTPTTTTTT
- 3:{ -39,...,-27}, p@-33 TTTTTTPTTTTTT
- 2:{ -26,...,-14}, p@-20 TTTTTTPTTTTTT
- 4:{ -13,..., -1}, p@ -7 TTTTTTPTTTTTT
- 1:{   1,..., 13}, p@ 7 TTTTTTPTTTTTT
- 3:{ 14,..., 26}, p@ 20 TTTTTTPTTTTTT
- 2:{ 27,..., 39}, p@ 33 TTTTTTPTTTTTT
- 4:{ 40,..., 52}, p@ 46 TTTTTTPTTTTTT
- 1:{ 53,..., 65}, p@ 59 TTTTTTPTTTTTT
- 3:{ 66,..., 78}, p@ 72 TTTTTTPTTTTTT
- 2:{ 79,..., 91}, p@ 85 TTTTTTPTTTTTT
- 4:{ 92,...,104}, p@ 98 TTTTTTPTTTTTT

The proposed training structure

- All subcarriers are used for training
- There is no need for using odd carriers only, since stations transmit with a small frequency error.
- Less interpolation side effects
- Better smoothing performance
- Uniform processing of all clusters

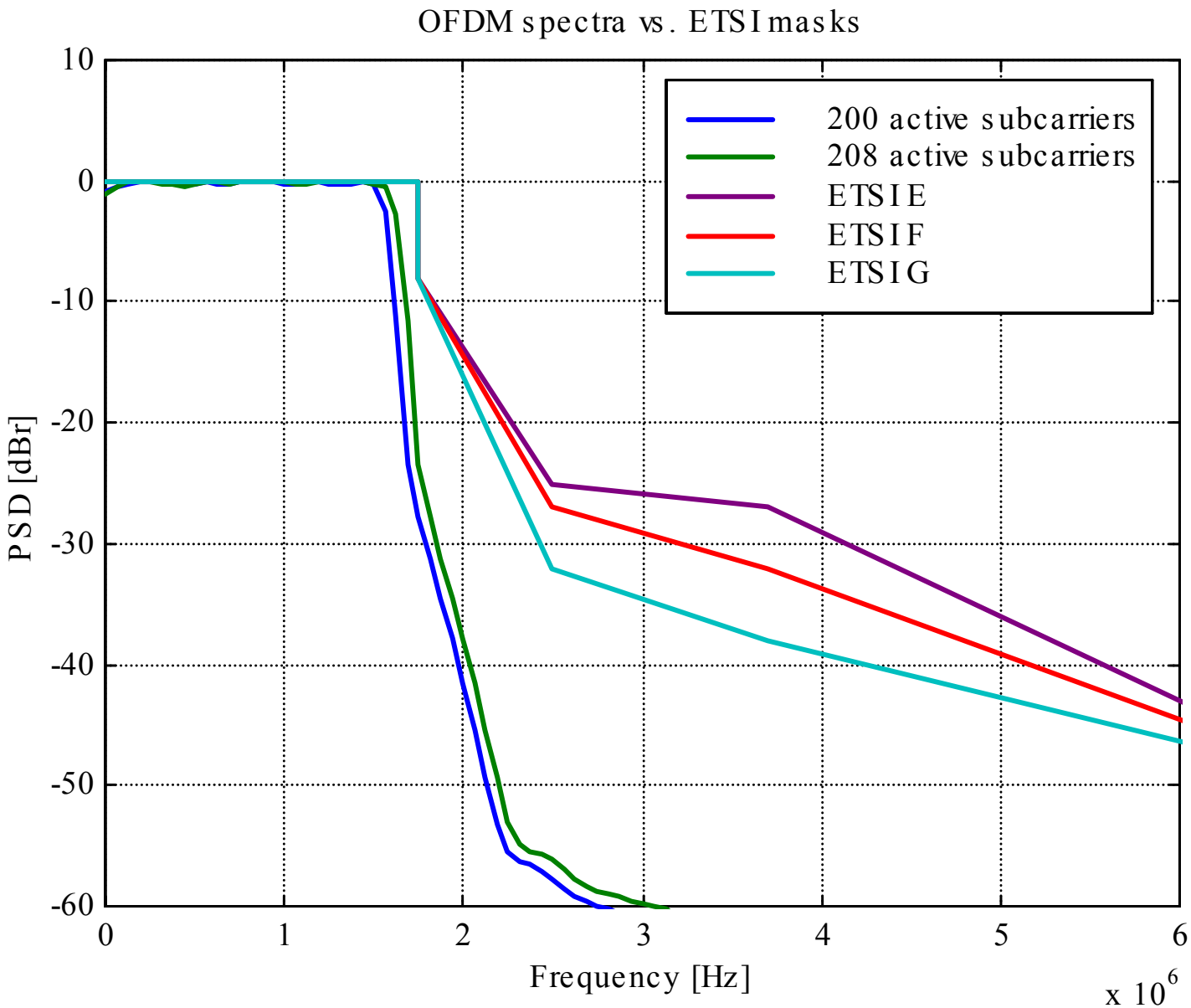
Simple construction, good PAPR

- The training sequences proposed are algorithmically constructed
  - Use two seed length-13 QPSK sequences
- No need for separate 1/4, 2/4, and 4/4 training sequences
- PAPR of 3 dB in all (1/4, 2/4, 4/4, short and long downlink) modes

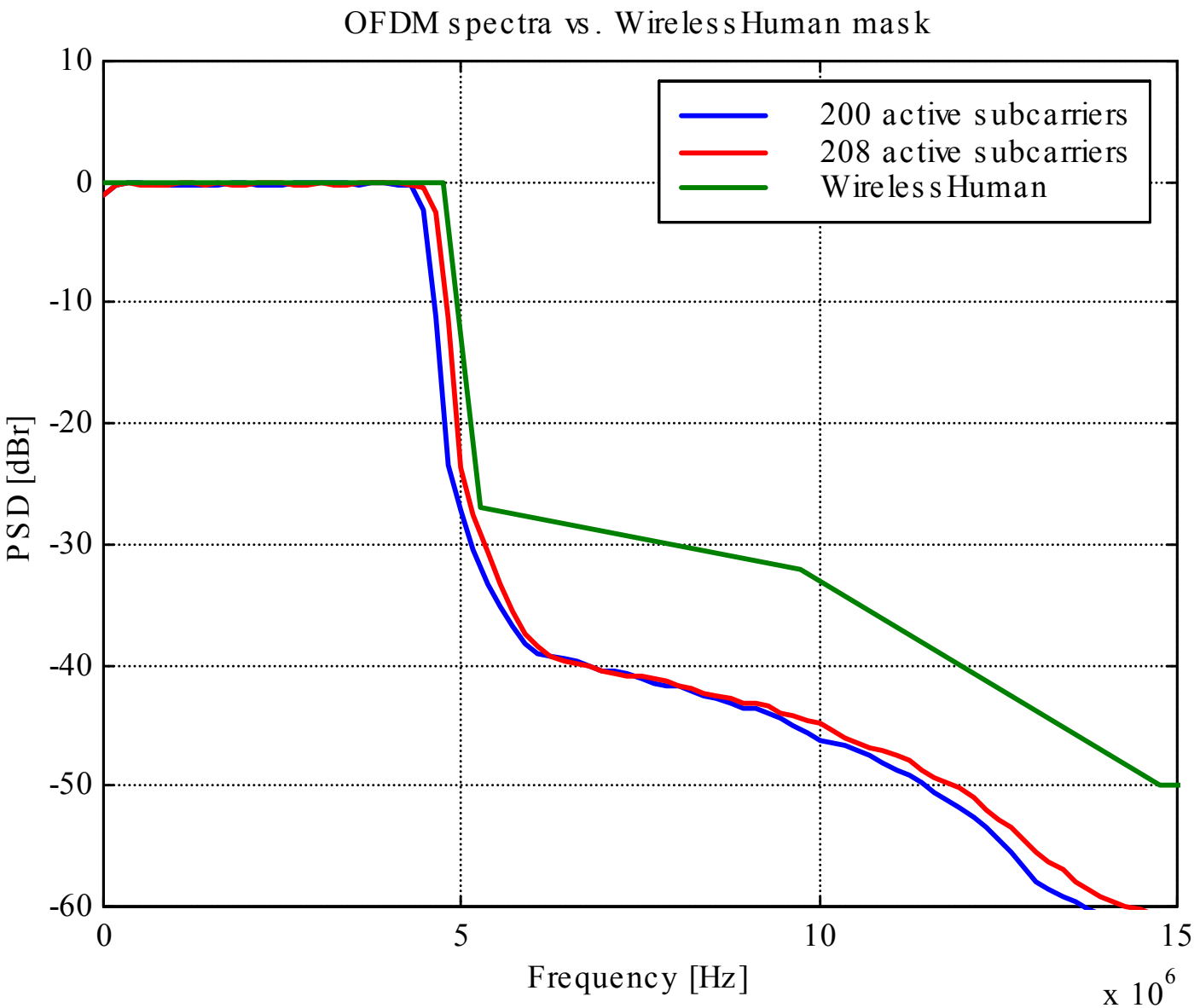
Spectral masks

- Spectral masks of ETSI
  - OK both before and after the change
- The 802.16a masks for WirelessHUMAN
  - OK both before and after the change
- MMDS masks
  - FFT size 256 with Fs=7/6 BW does not pass the mask even before the change
    - The flattop fits, the edges cut the mask

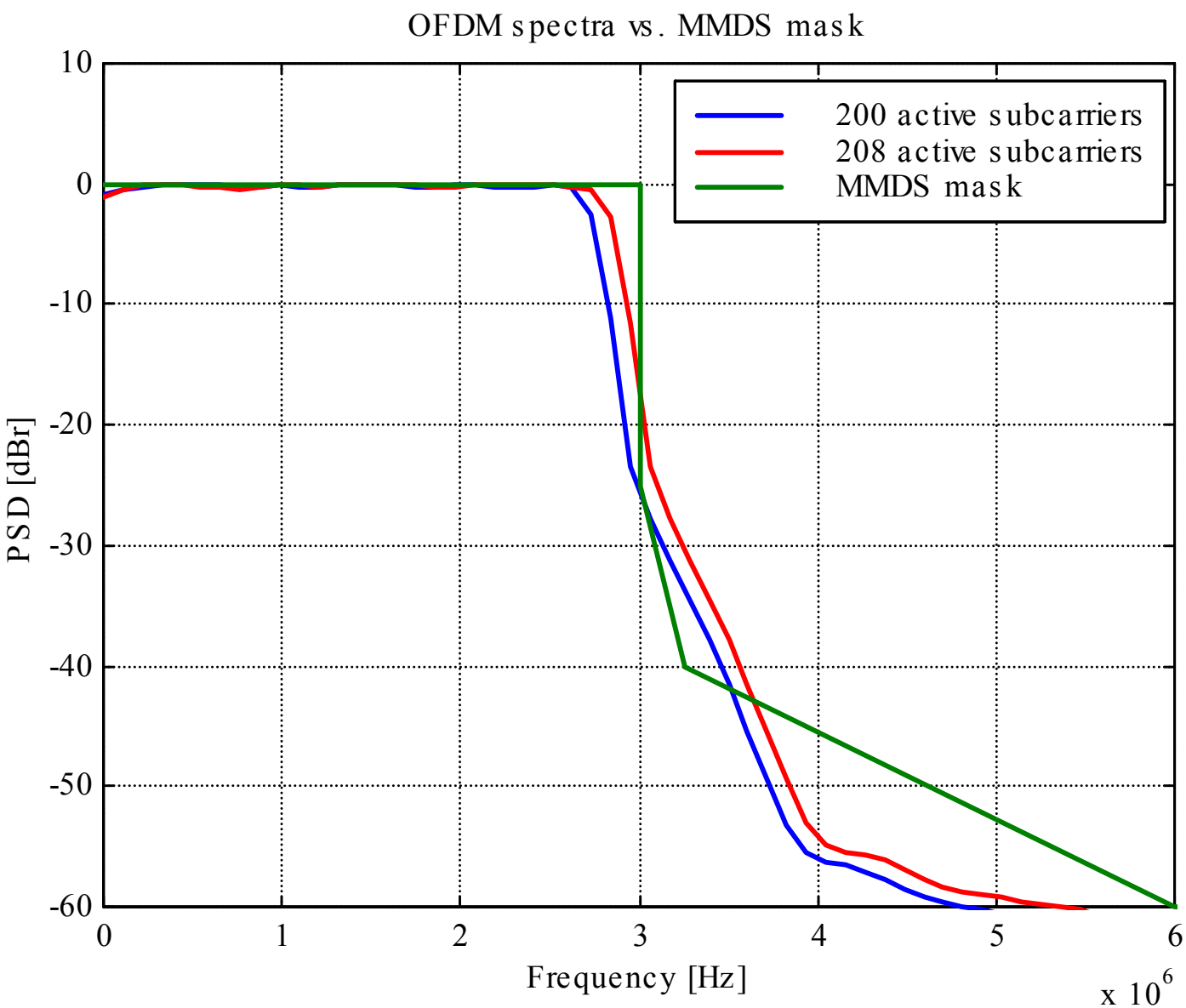
ETSI spectral masks



WirelessHUMAN mask



MMDS mask


OFDM spectra vs. MMDS mask
200 active subcarriers
208 active subcarriers
MMDS mask
PSD [dBr]
10
0
-10
-20
-30
-40
-50
-60
0
1
2
3
4
5
6
Frequency [Hz]
x 10^6

The upcoming Mobility support

- The next phase of 802.16 is supporting mobility
- Mobility calls for supporting higher Doppler spreads, training information maintenance
- Availability of adequate amount of pilots is crucial for future support of mobility

Recommendations

- Adopt the 208 subcarrier structure
  - 16 pilots, 4 pilots per subchannel
- The text is available
  - Doc 80216a-02/37 (parts 4.2, 4.3, 4.7)
    - subchannelization, pilots, focused contention
  - Document 802.16a-02/36r1 part 4
    - Preamble structure

- We have a last chance to do it right!