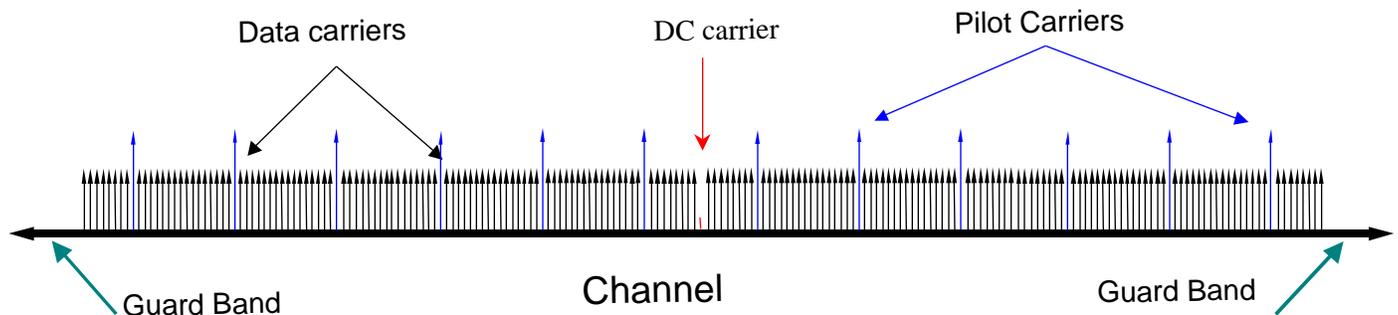


Project	IEEE 802.16 Broadband Wireless Access Working Group < http://ieee802.org/16 >	
Title	802.16b PHY: Spectral mask related issues and carrier allocations	
Date Submitted	2001-03-10	
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Re:	Contributions to the 802.16b PHY draft in response to Call for Comments	
Abstract	This document describes the FWA Channel allocations in the U-NII band trading off 802.11a legacy, deployment issues and FCC regulations. It also provides the transmit spectral mask and data/pilot carrier allocations for 256 and 1024 FFT exploiting 802.1a legacy components.	
Purpose	Incorporation of proposed text in 802.16b draft standard PHY. Discussion of accompanying notes of explanation.	
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17.3.5.9 OFDM Modulation

17.3.5.9.1 256 FFT

The pilot allocation for 256-FFT is shown in Figure ???. Carrier 0 is the DC carrier and not used. Between the pilot carriers, 16 data carriers are allocated, allowing for a total of 196 data sub-carriers, 12 pilot carriers and 1 DC carrier, for a total of 205 carriers. The other 51 carriers (-103 and below, as well as 104 and above) serve as guard-band. In total, there are then 4 regularly spaced blocks of 48 data carriers.



17.3.5.9.2 1024 FFT

The initial pilot allocation for 1024-FFT is similar to that of 256-FFT. The block of 205 carriers is copied 4 times leaving one null-carrier inbetween. In total, 48 pilot carriers are then available. In total, there are then 16 regularly spaced blocks of 48 data carriers (or 4 of 96), each of which can be used as OFDMA sub-channel.

In the downstream, the pilot carriers are permuted from their initial position in each base station burst according to:

$$\text{VariablePilotPosition}(N \times T_{\text{Symbol}}) = [\text{VariablePilotPosition}((N-1) \times T_{\text{Symbol}}) + 5]_{\text{mod } 18}$$
, where N is a positive integer.

17.3.8.3 USA Regulatory Requirements

The interpretation of Title 47, §15.407 below is provided for convenience. No rights may be derived from this text, and accuracy is not guaranteed.

The lower U-NII band is restricted to indoor use only. As at least one device on an FWA link needs to be outdoors (typically the base station), this band is not available for FWA. As a result of this, the rule that the device must meet the maximum -27 dBm/MHz limit below 5250 MHz and above 5350 MHz applies. For the upper U-NII, the limits are maximum -27 dBm/MHz below 5715 MHz and above 5835 MHz, and maximum -17 dBm/MHz in the band 5715 - 5725 MHz and 5825 - 5835 MHz.

In the middle U-NII band, the peak transmit power is limited to the lesser of 250 mW and $11+10\log(B_{26dB})$ dBm, with the peak power density not exceeding 11 dBm/MHz. In the upper U-NII band, the peak transmit power is limited to the lesser of 1W and $17+10\log(B_{26dB})$, with the peak power density not exceeding 17 dBm/MHz. For any directional antenna gain over 6 dBi, both are reduced by the number in excess.

17.3.8.4 Operating Channel Frequencies

17.3.8.4.1 Operating Frequency Range

The 802.16b PHY shall operate in the 5 GHz band as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic specific regulatory domains e.g. global, regional, and national. The particular channelization to be used for this standard is dependent on such allocation as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In the USA, the FCC is the agency responsible for the allocation of the 5 GHz U-NII bands.

In some regulatory domains several frequency bands may be available for 802.16b PHY based FWA devices. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains and of bands within the domains shall be indicated by PLME attributes **RegDomainsSupported** and **FrequencyBandsSupported**.

17.3.8.4.2 Channel Numbering

Channel center frequencies are defined at every integral multiple of 5 MHz above 5 GHz. The relationship between center frequency and channel number is given by the following equation:

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

where $n_{ch} = 0, 1, \dots, 200$. This definition provides a unique numbering system of all channels with 5 MHz spacing from 5 GHz to 6 GHz to provide flexibility to define channelization sets for all current and future regulatory domains.

17.3.8.4.3 Channelization

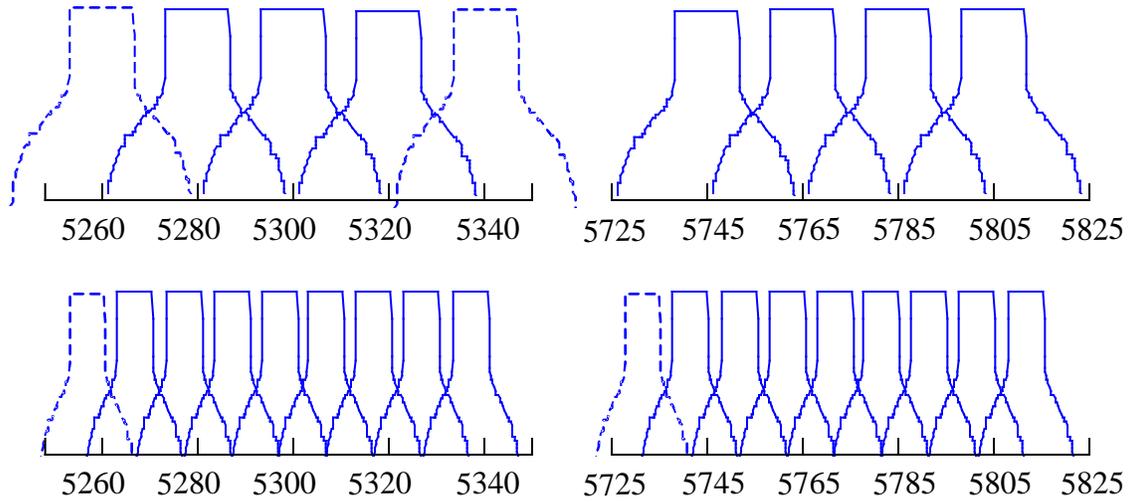
The set of valid operating channel numbers by regulatory domain is defined in Table ???. The bracketed numbers are optional channels, the others are mandatory.

Regulatory domain	band	20 MHz channelization	10 MHz channelization
USA	U-NII-middle 5.25-5.35GHz	(52), 56, 60, 64, (68)	(51), 53, 55, 57, 59, 61, 63, 65, 67
USA	U-NII-upper 5.725-5.825GHz	149, 153, 157, 161	(146), 148, 150, 152, 154, 156, 158, 160, 162

Figure ??? shows the channelization scheme for this standard which shall be used with the FCC U-NII frequency allocation. The middle U-NII subband accommodates 3 channels of 20MHz, while the upper U-

NII band supports 4 channels. Both U-NII bands accommodate 8 channels of 10 MHz. Additionally, two optional 20 MHz channels are defined in the middle U-NII band and one 10 MHz channel in each of the bands.

Figure 1 USA frequency channel plan



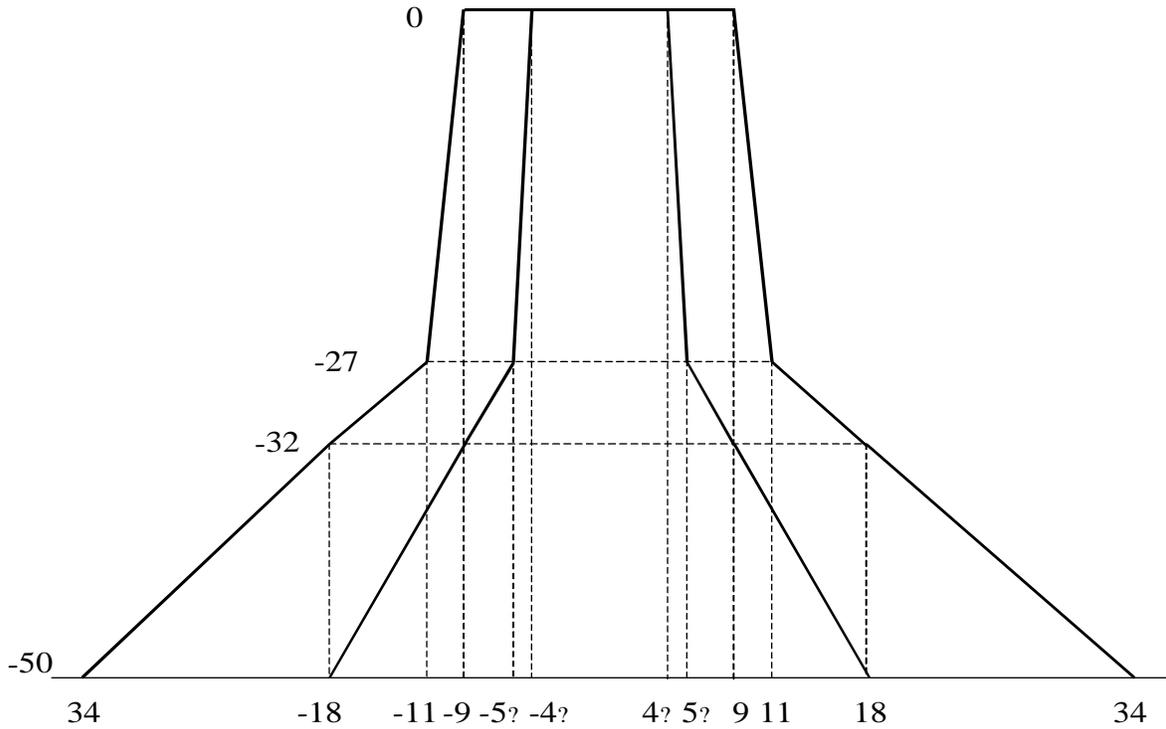
17.3.9.1 Transmit Power Levels

The maximum allowable output power according to FCC regulation is shown in Table ???

Regulatory Domain	Band	Maximum Output Power		Comments
		20 MHz	10 MHz	
USA	U-NII middle	23 dBm	20 dBm	Up to 6 dBi antenna gain
USA	U-NII upper	29 dBm	26 dBm	Up to 6 dBi antenna gain

17.3.9.2 Transmit Spectrum Mask

The transmitted spectral density of the transmitted signal shall fall within the spectral mask as shown (in dBr vs MHz) in Figure ???, for both the 10MHz and 20MHz channelization. The measurements shall be made using 100 kHz resolution bandwidth and a 30 kHz video bandwidth.



Using an over-sampling factor of 16/15 of the channel bandwidth and the sub-carrier allocations as shown in 17.3.5.9, the occupied bandwidth can be computed as in Table ???. For convenience, the symbol durations as well as the guard-intervals 1/64 through 1/4 durations are shown.

Channel(MHz)	FFT size	256	1024
20	Sub-carrier (kHz)	83 1/3	20 5/6
	occupied BW	85.42%	85.73%
	Symbol (us)	12	48
	Guard = 1/32	3/8	1 1/2
	1/16	3/4	3
	1/8	1 1/2	6
10	Sub-carrier (kHz)	41 2/3	10 5/12
	occupied BW	85.42%	85.73%
	Symbol (us)	24	96
	Guard=1/64	3/8	1 1/2
	1/32	3/4	3
	1/16	1 1/2	6
	1/8	3	12

 Note:

This note is not part of the proposed standard text. It is merely here to explain the above proposal.

FFT sizes

It is obvious that 64-FFT is not proposed in this text. One look at the spectral mask should already give some idea why. One of the main problems with a cohesive standard that includes 64-FFT, is that it has

a negative impact on the other FFT sizes as well. For example, it would require inserting more null-carriers and pilot-carriers in the 256-FFT and 1024-FFT carrier allocation, which expands the occupied bandwidth increasing the filtering cost while not buying anything useful. It is Nokia's feeling, that since 64-FFT is at best optional (we would rather get rid of it altogether), it can be designed as an afterthought and should not drive the description of the mandatory modes.

Pilot Carriers

Permutating the pilot-carriers within +/- 8 carriers of the initial position in subsequent symbols of a burst as designed for 1024-FFT downstream is possible everywhere. Nokia isn't necessarily against it if it is clearly shown to be advantageous.

Channelization vs bandedge requirements

In comparison to 802.11a, the first channel in the middle U-NII band is optional. This is due to the fact, that it requires a high-end filter to meet the band-edge requirement using this channel. Channel 68 is in a similar situation. Whether this is do-able depends both on the FFT size used and the filtering/processing cost one is willing to bear. Hence, to provide vendor-flexibility, these channels are optional.

Moving the channels in the middle band by 10 MHz would allow more easily for 4 channels. This however would increase the co-existence problems with WLAN's due to the overlapping channelization. With the proper filtering, it is possible to have 5 channels in the upper band. However, this would again create co-existence problems with 802.11a. Therefore, the group needs to carefully consider the trade-offs between optimizing co-existence, optimizing capacity, and the effect of cost with regard to the above issues.

Channelization vs deployment scenario's

It should be noted that we have only 7 (mandatory) 20 MHz channels available, with the middle U-NII band providing 6 dB less link-budget. In practice this will mean, that every provider is going to the high power bands first.

A few example scenarios now need to be considered:

- Rural area, no competition: coverage provided by one base stations
- Rural area, competition: overlapping coverage provided by non-co-located base stations
- Suburban area, no competition: coverage provided in a cellular fashion with many base stations
- Suburban area, competition: coverage provided in a cellular fashion with many, non-co-located base stations

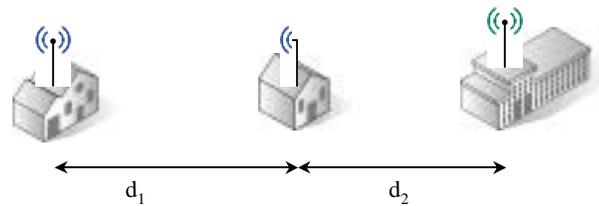
In the first case, the use of 20 MHz channels makes sense. However looking at the fourth scenario, it should, without going into detail, be obvious to everybody that the number of channels is insufficient for this inherently interference limited scenario. For this scenario, the 10 MHz channel definition is necessary. We've looked at 5 MHz channels, but there doesn't seem to be any obvious reason to include those given the drawback in power due the way the FCC rules are written, as well as the added complexity.

Spectral mask vs adjacent channel rejection vs performance

The major goal in the designing the spectral mask should be the optimization of the system performance. The major aspects of this optimization are the bandwidth occupancy and the desensitization (as defined in the 802.11 standard).

Solely optimizing the bandwidth usage from a single device perspective should not be the goal as the ability to efficiently use the adjacent channels has a major impact on the system performance.

The desensitization in the unlicensed bands forms a much bigger problem than that in the licensed bands, as it is impossible to do any RF-planning on the location of devices using adjacent channels.



Instructive is the consideration of the trivial deployment above. The distance results in a power difference at the competitor base station of $27\log_{10}(d_1 / d_2)$. Assuming the CPE at max. 4km from its base station and min. 100 meters from the competitors base station, we see a power difference of roughly 43 dB. It should be clear that a desensitization of at least 50 dB would be required to minimally support this scenario.

Note that counting on antenna patterns to resolve this issue is mostly a fallacy. Although the probabilities of severe adjacent channel interference become slightly more friendly, the possibility of the competitor being in the antenna's mainbeam can not be discounted (unless perhaps "needle-beam" antennas are used, which Nokia deems to be a bad fit given the user-installability goal). Additionally, the NLOS environment will spread energy, so a massive front-to-back ratio won't help anyway.

It should therefore be clear that packing the available channel as full as possible for a given FFT size does not provide maximum overall system performance. In the design above, we have attempted to strike a balance.
