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Re:	PHY-Proposal for session 4 of 802.16
Abstract	Propose an OFDM based PHY layer that is capable of data rates of 28Mbps – 147Mbps over an RF channel of bandwidth 40 MHz. The advantages of using a multicarrier based system, as opposed to a single carrier system when the channel is frequency selective, are discussed. Bit-interleaved coding schemes that in conjunction with the OFDM transceiver are proposed and their performance derived by calculating the Eb/No required to ensure a BER = 10^{-6} (based on tight bounds derived in Ref. 2). These Eb/No are matched with reference system gain calculations.
Purpose	To present a proposal towards the BWA-PHY layer.
Notice	
Release	
IEEE Patent Policy	

AN OFDM BASED TRANCEIVER FOR BROADBAND WIRELESS ACCESS

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1.0 Introduction

The core of this proposal is a coded modulation technique that combines Orthogonal Frequency Division Multiplexing (OFDM) with Bit Interleaved Coded Modulations (BICM) for Broadband Wireless Access (BWA) in presence of strong frequency selective fading. OFDM is very effective in mitigating the multipath fading of the channel by allowing frequency domain equalization, and therefore removing the need for expensive time domain equalizers in the system. Also, by incorporating pilot tones, OFDM receivers obtain Channel State Information (CSI) that allows very fast adaptations of the channel equalization. Moreover, CSI is also used in generating likelihood metrics for decoding of the information. BICM is an effective bandwidth efficient coded modulation technique that has specifically been designed for fading channel. BICM unlike traditional Trellis Coded Modulation (TCM) schemes that maximizes the minimum Euclidean, aims at maximizing the minimum Hamming distance of the code. BICM suits Rayleigh and Ricean fading channels more than AWGN channels, since in the former case the code performance depends strongly on the minimum Hamming distance providing so called code-diversity, rather than on the minimum Euclidean distance traditionally designed for AWGN channels.

OFDM is proven to be superior in performance than single carrier modulation techniques when the channels of communication suffer from multipath fading in addition to the usual AWGN. Multicarrier techniques like OFDM distribute the information to be transmitted equally among the several carriers thereby creating several parallel extremely narrow-band sub-channels. This provides more robustness when channel suffers from multipath fading which make it frequency selective. A deep notch in the signal frequency band would severely deteriorate the performance of a single carrier scheme, a multicarrier scheme proves to be robust because only the carriers that fall within the notch would suffer while the the information on the other carriers could still be retrieved resulting in a overall superior BER performance. Wireless channels that will be encountered for BWA will often be highly frequency selective fading channels (e.g. Rummler channel models). Also, the use of pilot tones that scans through the frequency band provides CSI for coherent demodulation even in presence of fast changing channels like those encountered in BWA applications.

BICM is obtained by concatenating a binary code with a Quadrature Amplitude Modulation (QAM) via a bit-wise interleaver. This combination specially enhances the performance of coded modulation scheme in presence of fading. Heuristically speaking, the bit-wise interleaver spreads the bits of the binary code among modulation symbols. In this way, it is possible to make the code diversity be the smallest number of the error events along any error event. Then, the code diversity is maximized by well-known optimum binary convolutional codes of the given rate and complexity. The maximum likelihood decoding of the convolutional code is achieved through application of the Viterbi algorithm with an appropriate soft decision bit metric which incorporates the CSI information generated from the OFDM receiver. An additional stage of symbol-wise interleaving is introduced after the bit-wise interleaver. The purpose of this interleaver is to help the bit-wise interleaver remove the channel memory after the OFDM receiver. Finally, the standard interleaver and the outer RS code are concatenated with the BICM, in order to achieve the quasi-error free performance at the operating SNR.

It seems but natural to use an OFDM/BICM based PHY protocol to get the best performance on BWA channels. Furthermore the use of several code rates and different symbol sets like QPSK/16QAM/64QAM provides the capability to scale the data rates without changing the signaling rate.

In the rest of the document we present an OFDM scheme along with suggested approaches to coding and interleaving schemes as this technology seems to bear the most promise of providing superior performance over BWA channels. The proposed system operates over a channel bandwidth of 40 MHz and can deliver data rates of up to 147 Mbps.

2.0 OFDM scheme

Figure 1 shows an end-to-end block diagram of a typical OFDM based system. We assume that the channel bandwidth is 40MHz with a guard band of 10MHz between adjacent RF channels to limit adjacent channel interference (ACI). The channel bandwidth is equally divided among the number of carriers used. Each carrier is an OFDM symbol is loaded with component symbols that could belong to QPSK, 16-QAM or 64-QAM signal sets. However for a given OFDM symbol the component symbols will all belong to only one of the above mention signal sets. The OFDM so composed can be represented mathematically as,

$$C(k) = (1/N)\ \_{n}\ a(n)\ e^{(j2pkn/N)}$$

Where N is the number of carriers used for the OFDM and {a(n)} is the set of component QPSK/16QAM/64QAM signals loaded onto each carrier. The above equation reveals that the OFDM symbol thus formed is infact in the frequency domain and therefore requires a transformation into time domain prior to its modulation onto an RF carrier and transmission. This is achieved by performing an Inverse Discrete Time Fourier Transformation (I-DTFT) on the sequence {C(k)}. An I-DTFT operation is a standard digital signal processing functionality that is implemented using a Fast Fourier Transform (FFT) engine (due to the nature of the mathematical operations involved, an FFT engine can also be used to perform I-FFT operations).

2.1 Guard Interval and Pilot Tones

By distributing the information to be transmitted over several carriers (or narrowband sub-channels) OFDM affords better protection against fading due to in-band spectral nulls. The performance can be improved further by adding temporal and frequency domain redundancies in the the OFDM symbol (albeit at a cost to effective bandwidth). The redundancy in time domain appears in the form of the addition of a Guard Interval (GI) which affords protection against multipathing. The redundancy in frequency domain appears in the form of pilot tones which need to be inserted to aid in channel identification and frequency domain equalization. Channel identification is needed for two reasons –

1. The channel gain for each carrier needs to be determined so that it can be equalized out to result in demodulator output which are independent of any channel gain.
2. Channel identification helps to identify carriers which are severely attenuated due to inband spectral nulls caused by multipath fading. This information can be passed on to the FEC as 'channel side information (CSI)'.

The GI is added to the OFDM symbol after the IFFT operation that transforms the OFDM symbol from frequency domain to time domain, a GI is appended to each symbol. The GI of length *Tg* typically consists of the last segment of length *Tg* of the OFDM signal being replicated. If the OFDM symbol after the IFFT operation resulted in a symbol of length *Ta* then the final OFDM signal would have a period of (*Ta* + *Tg*) in which the first and last *Tg* duration of the symbol are identical. Adding a GI to each OFDM symbol gives it protection against any multipathing as long as the multipath delay is less than the duration of the GI. While the GI results in a small penalty on the data rate it affords considerable protection against intersymbol interference due to multipathing.

The addition of pilot tones and guard intervals provide robustness to the OFDM symbol to counter the effect of multipath fading better that single carrier systems. Additional robustness can be provided by randomizing the encoded bitstream which are mapped to component symbols prior to their modulation onto the carriers. This can be done by using bitstream interleavers which can provide considerable protection against fading. This issue will be discussed in more detail in section 4.

3.0 Proposed OFDM system

The OFDM scheme proposed has the following parameters –

1. Number of carriers = 256
2. Length of Guard Interval (GI) = 1/16 of the active symbol period *Ta* (to be explained later).
3. Number of pilot carriers per OFDM symbol = 3
4. Number of carriers required for PHY managenent information (e.g. sync words, modulation type, code rate etc.) = 4

The duration of each OFDM symbol in time is equal to (1+1/16)*Ta* = 6.8_sec. The duration of the GI provides for protection against multipath delays of upto 400 nsec. As typical BWA channels are LOS channels multipath delays will not be long and 400nsec GI seems more than adequate.

The channel bandwidth is 40MHz resulting in an inter-carrier spacing of _f = 156.25KHz and Ta = 1/_f = 6.4_sec. The time duration of the OFDM symbol is infact given by Ta and the size of the GI. Since GI is chosen to be a fraction of Ta the total duration of an OFDM can be written as (1+GI)Ta. With these equations, the above value of _f and GI of 1/16 results in an OFDM symbol duration of 6.8_sec. Typical OFDM implementations sacrifice some of the carriers to create a guard band between adjacent channels. OFDM standards like that for DVB-T have set this guard band to be about 16.5% of the channel bandwidth. This requires the use of 42 carriers to form the guard band of approximately 3.28MHz between channels. This leaves us with (256-42) = 214 carriers to use. Of these we will need to use atleast 4 more to carry operational information like the frame-sync word (if any is needed), the modulation type (QPSK/16QAM/ 64QAM), the code rate etc. Of the remaining 240 carriers we need to assign some carriers to be pilot tones whose strength is known a-priori. By measuring the gain/attenuation of these tones a frequency domain profile of the channel can be derived. This profile can then be interpolated at each of the carrier frequencies in the spectrum to aid in frequency domain equalization. Equalization is essential to ensure that the data on each carrier is independent of channel gain so that the decision process can be uniform across carriers. The spacing between pilot carriers depends on the maximum multipath spread expected. As we have assumed a GI = 1/(16_f) the minimum coherence bandwidth is 16_f therefore we choose to place one pilot every 15 carriers. This would mean that of the 210 carriers left we would need to use 14 carriers per OFDM symbol for pilot tones. This loss of bandwidth can be mitigated by using much fewer number of pilot
tones per OFDM symbol yet realizing the effect of using the full complement of 14 pilot tones per symbol by a combination of frequency and time domain interpolation of the channel gain for each of the carriers. Without getting into the specifics of this technique, it can be shown that we can choose one out of every 70 carriers to be a pilot resulting in only 3 carriers being used as pilots in any given OFDM symbol. However the set of carriers used as pilot tones is changed for every symbol in a certain sequence which is repeated every 5 OFDM symbols. If the frequency domain snapshots of 5 consecutive OFDM symbols superimposed on each other would reveal that exactly 14 of the carriers are pilots. This effect is equivalently realized by time domain interpolation. Once the interpolants are computed at every 15_f frequency, the channel gains for the intermediate frequencies can be determined by simple frequency domain interpolation. To conclude this analysis, of the 256 carriers per OFDM symbol we can use only 207 as data carriers.

Figures 3a and 3b show the block diagram of the propose OFDM transmitter and receiver.

3.1 Achievable data rates

In this section we compute the range of achievable data rates when OFDM is used in conjunction with different code rates and modulation formats. The bit rate achievable is given by the equation,

Bit rate (bits/sec) = CR x (bits/carrier)(Number of carriers)(OFDM symbol/sec)

Where CR is the FEC code rate and 'symbol' in bits/symbol corresponds to the QPSK/16QAM/64QAM component symbol.

The encoder that we propose for this system is a DVB standard concatenated code with an outer (204,188,8) Reed-Solomon code with a rate _ constraint length 7 convolution code (polynomials 133, 171) whose rate can be changed by puncturing. The code rate column figure indicate the product of the outer code rate (188/204 = 0.92) and the inner code.

<u>**Modulation Format**</u>	<u>**Code Rate**</u>	<u>**Max Data Rate**</u> (Mbits/sec)
QPSK	_ x (188/204)	28.0
QPSK	2/3 x (188/204)	37.32
QPSK	_ x (188/204)	42.0
QPSK	5/6 x (188/204)	46.66
QPSK	7/8 x (188/204)	49.0
16-QAM	_ x (188/204)	56.0
16-QAM	2/3 x (188/204)	74.64
16-QAM	_ x (188/204)	84.0
16-QAM	5/6 x (188/204)	93.32
16-QAM	7/8 x (188/204)	98.0
64-QAM	_ x (188/204)	84.0
64-QAM	2/3 x (188/204)	112.0
64-QAM	_ x (188/204)	126.0
64-QAM	5/6 x (188/204)	140.0
64-QAM	7/8 x (188/204)	147.0

4.0 RS Concatenated BICM

In this section, we describe the constituents of the RS concatenated BICM scheme of this proposal.

4.1 RS Code

The shortened RS code (204, 188, t = 8) derived from the original systematic RS (255, 239, t = 8) is used as the outer code. The code provide a quasi-error free output at input BER of 2e-4. Specially for fading channels where the BER of the coded modulation schemes increase with (Eb/N0)^(code-diversity), rather than an exponential function of Eb/N0 as it is the case for AWGN channels, the RS code provides a significant coding gain with very modest loss (0.92) in rate. Therefore , for BWA applications outer RS codes are highly recommended.

4.2 Outer Interleaver

The outer interleaver is a byte-wise convolutional interleaver with interleaving depth, I = 12, which is based on the Forney approach. The main role of the outer interleaver is to break bursts errors at the Viterbi decoder output, and hence to achieve a better usage of the error correction capability of the RS code.

4.3 Inner Convolutional Codes

The inner convolutional codes are all derived by puncturing the standard (171, 133) rate _, 64 state convolutional code. In total, we consider 5 codes, rate _, rate 2/3, rate _, rate 5/6, and rate 7/8. The puncture patterns are given in the following table:

Code rate	Puncturing pattern	Transmitted sequence
_	X:1 Y:1	X1 Y1
2/3	X:1 0 Y:1 1	X1 Y1 Y2
_	X:1 0 1 Y:1 1 0	X1 Y1 Y2 X3
5/6	X:1 0 1 0 1 Y:1 1 0 1 0	X1 Y1 Y2 X3 Y4 X5
7/8	X:1 0 0 0 1 0 1 Y:1 1 1 1 0 1 0	X1 Y1 Y2 Y3 Y4 X5 Y5 Y6 X7

4.4 Binary Inner Interleaver

The output of the binary convolutional code is sent through a bit-wise interleaver. The role of the interleaver is to spread the encoder bit across different OFDM channel, and across different QAM symbols. This interleaver is crucial to the BICM performance in fading environment, since it makes the code diversity equal to the free minimum distance of the inner code. The ideal interleaver for this purpose is a random interleaver.

The structure of the interleaver is as follows. The serial output of the inner code is demultiplexed into 2 bit sreams. For nQAM, each bit sream is demultiplexed further into v = log2(n) /2 new bit sreams. In this way, log2(n) bit stream is obtained. Each bit sream is interleaved with a block interleaver of depth 126. The output is log2n interleaved bit stream which forms a single stream of nQAM symbols. The nQAM symbols are sent through another stage of interleaving which provides a more uniform spread of bits across OFDM carriers.

4.5 Symbol Inner Interleaver

The symbol interleaver permutes the QPSK/QAM symbols inside each OFDM frame.

4.6 QAM Constellation

Each OFDM frame consists of QAM symbols. Here we have allowed 4 PSK, 16 QAM, and 64 QAM. In some cases that SNR is high, even 256 QAM can be considered. In all cases, the constellation bit mapping has to be Gray mapping, for best performance in presence of fading.

5.0 Performance Over Fading Channels

In this section, the performance of the proposed BICM scheme over Ricean fading channels with K = 10 dB will be presented. For this purpose, depending on its input BER, we assume 4 operating points for the RS decoder. These points are BER = 1e-4, 2e-4, 1e-5, 1e-6. Note that our RS code is designed to give a quasi-error free output at input BER = 2e-4.

Eb/N0 required to achieve post inner code BER’s with the rate _ code.

BER ⇨ / Modulation format ⇩	2e-4	1e-4	1e-5	1e-6
4 PSK	3.6 dB	3.88 dB	4.89 dB	5.90 dB
16 QAM	6.7 dB	7.0 dB	8.0 dB	9.0 dB
64 QAM	10.23 dB	10.54 dB	11.54 dB	12.54 dB
256 QAM	14.24 dB	14.54 dB	15.55 dB	16.55 dB

Eb/N0 required to achieve post inner code BER’s with the rate 2/3 code.

BER ⇨ / Modulation format ⇩	2e-4	1e-4	1e-5	1e-6
4 PSK	4.53 dB	5.00 dB	6.70 dB	8.30 dB
16 QAM	7.60 dB	8.10 dB	9.75 dB	11.40 dB
64 QAM	11.15 dB	11.64 dB	13.30 dB	15.00 dB
256 QAM	15.16 dB	15.66 dB	17.30 dB	19.00 dB

Eb/N0 required to achieve post inner code BER’s with the rate 3/4 code.

BER ⇨ / Modulation format ⇩	2e-4	1e-4	1e-5	1e-6
4 PSK	5.12 dB	5.70 dB	7.7 dB	9.70 dB
16 QAM	8.2 dB	8.8 dB	10.80 dB	12.8 dB
64 QAM	11.80 dB	12.40 dB	14.40 dB	16.4 dB
256 QAM	15.8 dB	16.40 dB	18.40 dB	20.4 dB

Eb/N0 required to achieve post inner code BER’s with the rate 5/6 code.

BER ⇨ / Modulation format ⇩	2e-4	1e-4	1e-5	1e-6
4 PSK	5.70 dB	6.50 dB	9.00 dB	11.52 dB
16 QAM	8.90 dB	9.60 dB	12.1 dB	14.6 dB
64 QAM	12.40 dB	13.17 dB	15.6 dB	18.2 dB
256 QAM	16.5 dB	17.1 dB	19.6 dB	22.2 dB

Eb/N0 required to achieve post inner code BER's with the rate 7/8 code.

BER ⇨ / Modulation format ⇩	2e-4	1e-4	1e-5	1e-6
4 PSK	6.30 dB	7.30 dB	10.60 dB	14.0 dB
16 QAM	9.4 dB	10.4 dB	13.70 dB	17.0 dB
64 QAM	13.0 dB	14.0 dB	17.3 dB	20.6 dB
256 QAM	17.0 dB	18.0 dB	21.30 dB	24.6 dB

6.0 Addressing Evaluation Criteria

The following part discusses how the proposed system meets the evaluation criteria.

1. Meets system requirements

The proposed OFDM scheme uses a channel bandwidth of 40MHz and is capable of delivering upto 159Mbps provided the SNR is high enough to meet the required BER of 10^{-6}. The inherent advantages of multicarrier systems over single carrier systems in the presence of multipathing and fading in terms of BER performance makes OFDM (and possibly DMT) the most promising approaches to implementing the BWA-PHY.

2. Spectrum Efficiency

The spectrum efficiency of this system ranges between 0.7 bits/sec/Hz for rate _ QPSK to 3.675 bits/sec/Hz for rate 7/8 64-QAM.

3. Simplicity of Implementation

Admittedly, the signal processing involved in OFDM systems is computationally intensive compared to typical single carrier systems. The most computationally intensive block is the FFT engine. But a size 256-FFT is easily implementable (DVB-T and DAB standards for OFDM require 2048 and 8192-FFT !). The other signal processing blocks are fairly standard and so is the error decoding part of the receiver. As for the transmitter the FEC is very simple to implement and the IFFT engine is the same as the FFT engine. In conclusion, the implementation difficulty of a OFDM system is probably slightly more than single carrier systems.

4. Resource flexibility and utilization

The channel bandwidth is 40MHz which seems within reason (we used this number from some proposals made for 802.16-session 3). The utilization percentage is about 83% of the spectrum which is in line with typical OFDM systems. The non used part of the spectrum is essentially part of the OFDM spectrum that is used as guard bands between channels to suppress ACI.

5. Data-Rate Scalability

The data rate scalability allows a wide range of possible data rates by changing the code rate and modulation formats. However appropriate Eb/No must be used to ensure that a certain code rate and certain modulation rate will guarantee a BER of 10^{-6} at the output of the FEC.

6. Reference system gain

The reference system gain, based on the assumption the noise figure of 0dBm, a constant transmit power backoff (our assumption) from the saturated transmit power of 30dBm, is shown below.

Gaussian Channel

modulation	code rate	C/N for BER=2e-4 after Viterbi (dB)	implementa tion loss (dB)	sensitivity (dBm)	transmitter backoff (dB)	transmitted power (dBm)	system gain, link loss (dB)
QPSK	1/2	**3.1**	**2.5**	-93.11	**7.5**	22.50	115.61
QPSK	2/3	**4.9**	**2.5**	-91.31	**7.5**	22.50	113.81
QPSK	3/4	**5.9**	**2.5**	-90.31	**7.5**	22.50	112.81
QPSK	5/6	**6.9**	**2.5**	-89.31	**7.5**	22.50	111.81
QPSK	7/8	**7.7**	**2.5**	-88.51	**7.5**	22.50	111.01
16QAM	1/2	**8.8**	**3**	-86.91	**7.5**	22.50	109.41
16QAM	2/3	**11.1**	**3**	-84.61	**7.5**	22.50	107.11
16QAM	3/4	**12.5**	**3**	-83.21	**7.5**	22.50	105.71
16QAM	5/6	**13.5**	**3**	-82.21	**7.5**	22.50	104.71
16QAM	7/8	**13.9**	**3**	-81.81	**7.5**	22.50	104.31
64QAM	1/2	**14.4**	**3.5**	-80.81	**7.5**	22.50	103.31
64QAM	2/3	**16.5**	**3.5**	-78.71	**7.5**	22.50	101.21
64QAM	3/4	**18**	**3.5**	-77.21	**7.5**	22.50	99.71
64QAM	5/6	**19.3**	**3.5**	-75.91	**7.5**	22.50	98.41
64QAM	7/8	**20.1**	**3.5**	-75.11	**7.5**	22.50	97.61

modulation	code rate	Ricean Channel C/N for BER=2e-4 after Viterbi (dB)	implementation loss (dB)	sensitivity (dBm)	transmitter backoff (dB)	transmitted power (dBm)	system gain, link loss (dB)
QPSK	1/2	**3.6**	**2.5**	-92.61	**7.5**	22.50	115.11
QPSK	2/3	**5.7**	**2.5**	-90.51	**7.5**	22.50	113.01
QPSK	3/4	**6.8**	**2.5**	-89.41	**7.5**	22.50	111.91
QPSK	5/6	**8**	**2.5**	-88.21	**7.5**	22.50	110.71
QPSK	7/8	**8.7**	**2.5**	-87.51	**7.5**	22.50	110.01
16QAM	1/2	**9.6**	**3**	-86.11	**7.5**	22.50	108.61
16QAM	2/3	**11.6**	**3**	-84.11	**7.5**	22.50	106.61
16QAM	3/4	**13**	**3**	-82.71	**7.5**	22.50	105.21
16QAM	5/6	**14.4**	**3**	-81.31	**7.5**	22.50	103.81
16QAM	7/8	**15**	**3**	-80.71	**7.5**	22.50	103.21
64QAM	1/2	**14.7**	**3.5**	-80.51	**7.5**	22.50	103.01
64QAM	2/3	**17.1**	**3.5**	-78.11	**7.5**	22.50	100.61
64QAM	3/4	**18.6**	**3.5**	-76.61	**7.5**	22.50	99.11
64QAM	5/6	**20**	**3.5**	-75.21	**7.5**	22.50	97.71
64QAM	7/8	**21**	**3.5**	-74.21	**7.5**	22.50	96.71

modulation	code rate	Rayleigh Channel C/N for BER=2e-4 after Viterbi (dB)	implementation loss (dB)	sensitivity (dBm)	transmitter backoff (dB)	transmitted power (dBm)	system gain, link loss (dB)
QPSK	1/2	**5.4**	**2.5**	-90.81	**7.5**	22.50	113.31
QPSK	2/3	**8.4**	**2.5**	-87.81	**7.5**	22.50	110.31
QPSK	3/4	**10.7**	**2.5**	-85.51	**7.5**	22.50	108.01
QPSK	5/6	**13.1**	**2.5**	-83.11	**7.5**	22.50	105.61
QPSK	7/8	**16.3**	**2.5**	-79.91	**7.5**	22.50	102.41
16QAM	1/2	**11.2**	**3**	-84.51	**7.5**	22.50	107.01
16QAM	2/3	**14.2**	**3**	-81.51	**7.5**	22.50	104.01
16QAM	3/4	**16.7**	**3**	-79.01	**7.5**	22.50	101.51
16QAM	5/6	**19.3**	**3**	-76.41	**7.5**	22.50	98.91
16QAM	7/8	**22.8**	**3**	-72.91	**7.5**	22.50	95.41
64QAM	1/2	**16**	**3.5**	-79.21	**7.5**	22.50	101.71
64QAM	2/3	**19.3**	**3.5**	-75.91	**7.5**	22.50	98.41
64QAM	3/4	**21.7**	**3.5**	-73.51	**7.5**	22.50	96.01
64QAM	5/6	**25.3**	**3.5**	-69.91	**7.5**	22.50	92.41
64QAM	7/8	**27.9**	**3.5**	-67.31	**7.5**	22.50	89.81

7.0 Conclusion

We propose a 256 carrier based OFDM transceiver that is capable of data rates in the range of 28Mbps to 147Mbps and is ideally suited for Broadband Wireless Access (BWA) based PHY protocols. System requirements are discussed along with the benefits accrued, in terms of superior BER performance for multipath fading environments, as compared to single carrier systems. DVB-T and DAB standards which have adopted OFDM based PHY layer and performance in the field have proved its superioirty over other competing technologies like VSB etc. OFDM seems to be the most promising of technologies that can be adapted as a PHY layer standard for 802.16.

REFERENCES

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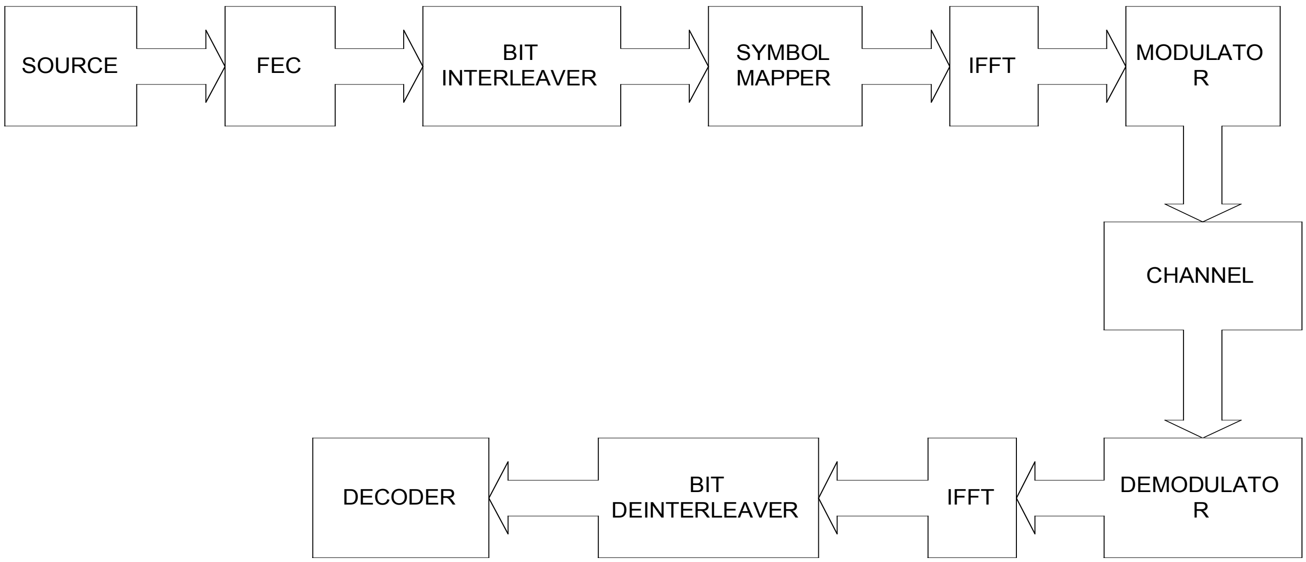

FIGURE 1

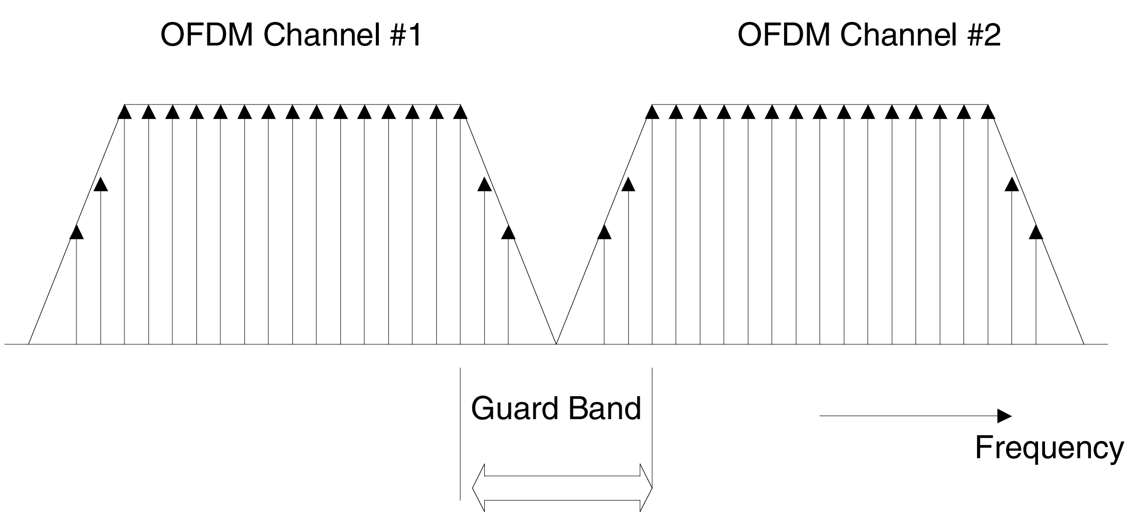

FIGURE 2

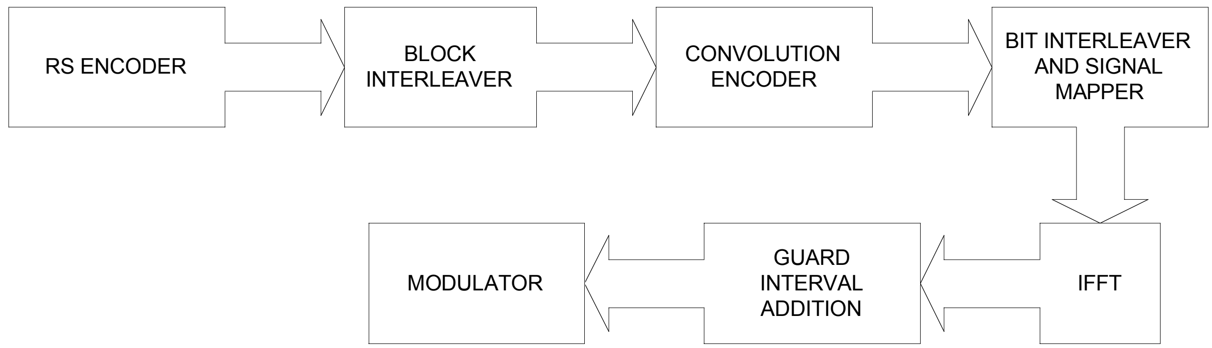

FIG 3a OFDM TRANSMITTER

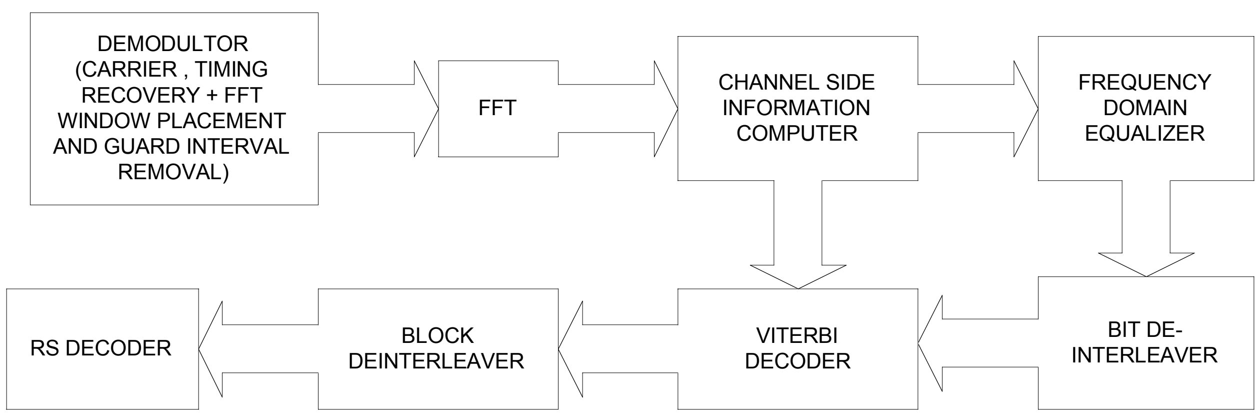

FIG 3b OFDM RECEIVER