UHF OFDM Modems for Amateur Radio Stations

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1. Introduction

This document defines a set of physical layer protocols in the Open System Interconnection model for point-to-point and point-to-multi-point operation between stations operating in the amateur radio service. These stations may be fixed, land mobile or maritime mobile and use either directional or omnidirectional antennas in the UHF bands. This document describes the format and behavior of the protocol.

Six modems with different data rates are defined to fit the various regulatory requirements and band plans from 219 to 2,450 MHz. The 937.5-Baud modems are designed to suit the current FCC regulations governing data transmission on the 219-220 and 420-450 MHz bands and be expandable to higher data rates if the ARRL regulation by bandwidth proposal is adopted by the FCC. This will also make the lowest speed version usable in the VHF bands. The 7500-Baud modems are designed to operate up to 2400 MHz with the highest rate modems fitting the largest channels available for data transmission in the ARRL Band Plan.

2. Physical Media

The physical medium interconnecting the modems defined herein is the electromagnetic spectrum. Only the VHF and UHF amateur bands have sufficient space to allow high-speed digital links, but terrestrial radio transmission is characterized by multi-path propagation due to reflection, refraction and dispersion of the signal by objects in the environment. The maximum multi-path delay depends on the local environment and ranges from 0.4 to 90 µs. Most paths have delays under 10 µs.

The OFDM modems defined here combat multi-path by creating a guard period during which the receiver ignores the energy created by multi-path propagation. The ratio between active and inactive periods must be maximized so that minimal transmitted energy is lost. Consequently the signaling rate is limited and multiple carriers must be used to achieve high data rates. The carrier spacing must be the inverse of the active period to ensure that the data on each carrier is orthogonal and prevent mutual interference. The modems described here use 937.5 or 7500-kBaud symbol rates with 1171.875 or 9.375 kHz carrier spacing. A guard period of 20% limits signal loss to 0.8 dB and results in 27 or 213 µs between adjacent sampling periods. Most inter-symbol interference exists within the guard band and is ignored.

3. Symbol Rate and Carrier Placement

A pilot carrier, which is transmitted at 3 dB above the level of the data subcarriers, is placed in the center of the carrier group. Half of the N data carriers are placed on each side of the pilot carrier and enumerated 1 through N from the lowest frequency to the highest frequency. Figure 1 shows 33 carriers, where the main lobes of the carriers occupy the bandwidth, BW. The group delay must be flat over this bandwidth to minimize FFT sampling errors. Extending beyond that limit on either side are the minor lobes of the carriers. The channel spacing must be chosen so that the minor lobes of each channel's carriers are at an acceptably low level by the first carrier of the next channel.

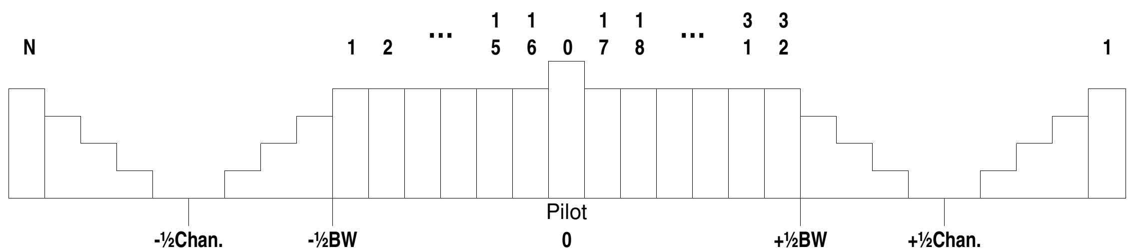

Figure 1. 33-carrier Transmission Channel Format (not to scale)

Table 1 summarizes the various numbers of carriers and data rates for the modems. All frequencies may be derived from a 19.2 MHz sampling clock that should be accurate to ±2.5 PPM for the highest data rates. The symbol rate shown includes a gap that is filled at the transmitter with a copy of the last 1/4 of each tone. This provides a continuous waveform for the receiver FFT window even though there may be jitter. The receiver will normally sample the last part of the symbol cell to avoid inter-symbol interference that may exist in the first part of each symbol.

Differential quadrature and eight-phase phase shift keying (DQPSK and D8PSK) are used for the low and medium speed data rates to allow mobile operation in addition to fixed operation. As the station moves, the absolute phase varies as the strength and delay of multi-path rays vary so a fixed phase reference cannot be used. The high data rate uses 64-state quadrature amplitude modulation (64QAM) and is for fixed stations only. Trellis-coded modulation (TCM) is used for forward error correction (FEC) for D8PSK and for the I and Q components of the 64QAM signal constellation. The same rate ½ convolutional code use for encoding 2-bits of the D8PSK symbol is used for all bits of the DQPSK symbol. The SNR values summarized in table 1 are those required for a 10^{-5} symbol error rate. Since each frame in each carrier group contains a maximum of 2,040 symbols, the block error rate can be expected to be less than 2.2% at these levels. This is adequate for reliable operation of data link layer protocols, which are expected to provide additional error correction.

Modulation	SNR
DQPSK	9 dB
D8PSK	15 dB
64QAM	23 dB

Table 1. Expected SNR (AWGN Channel)

A modem implementing this standard may use one of the two symbol rates specified in table 2. All implementations of this modem must support D8PSK modulation. If 64QAM is supported, then a choice of D8PSK and 64QAM must be supported. If DQPSK is supported, then a choice of D8PSK and DQPSK must be supported. In any symbol rate category, the modem may support any data rate as the highest rate but must also support all lower data rates using fewer carriers as defined in the table.

Symbol Rate	**937.5 Baud**			**7,500 Baud**		
Carrier Spacing	1,172 Hz			9,375 Hz		
Guard Band	213.3 µs			26.7 µs		
FCC Frequency (MHz)	219-450	none		902-3500		
ARRL Frequency (MHz)	50-450	222-450		222-3500	420-3500	
Channel Spacing	100 kHz	200 kHz	750 kHz	750 kHz	2.00 MHz	6.00 MHz
Signal Bandwidth	78 kHz	153 kHz	603 kHz	620 kHz	1.52 MHz	4.82 MHz
Number of Carriers	65	129	513	65	161	513
DQPSK Data Rate	56 K	112 K	450 K	0.45 M	1.12 M	3.60 M
D8PSK Data Rate	112 K	225 K	900 K	0.90 M	2.25 M	7.20 M
64QAM Data Rate	225 K	450 K	1,800 K	1.80 M	4.50 M	14.40 M

Table 2. OFDM Modem Data Rates for VHF and UHF Amateur Bands

The FCC frequency row shows the frequencies on which these modems may currently be used for data transmission in the U.S. and its possessions. The ARRL frequency row shows the frequencies that will be available if the FCC adopts the ARRL regulation by bandwidth proposal. Regulations in other countries may be more or less restrictive.

The data rates shown are exclusive of framing overhead and any overhead added by the data link layer.

4. PHY-PDU Format

OFDM modems multiplex data onto multiple subcarriers. In order to prevent interference between subcarriers, the frequency spacing must be accurate. Table 3 shows the minimum accuracy of data carrier offsets from the pilot carrier required for different numbers of carriers and modulation types.

Carriers	65	129	161	513
DQPSK	±320	±160	±128	±40
D8PSK	±160	±80	±64	±20
64QAM	±10	±5	±4	±1

Table 3. Required Sampling Frequency Accuracy in PPM

In order to prevent inter-modulation of subcarriers their amplitudes must be constrained. Table 4 shows the recommended subcarrier levels relative to a single full-power carrier.

Carriers	1	65	129	161	512
Amplitude (dBc)	0	-26	-29	-30	-35

Table 4. Subcarrier Amplitude

The absolute accuracy of the pilot carrier frequency shall be ±8 carrier spacings or better.

4.1 PHY Symbols

There are four types of OFDM symbols used in the PHY-PDU:

P - The pilot symbol is an unmodulated pilot carrier at maximum power (0 dBc) for one symbol period.

N - The null symbol contains an unmodulated pilot carrier at the amplitude defined in table 4 and no data subcarriers for one symbol period. The pilot carrier is used for frequency acquisition and Doppler shift correction.

R - The reference symbol allows the receiver to determine the starting phase and amplitude. The absolute phase of each carrier is set according to the formula:

$$\theta = 3.6315\ k^2$$

where k is the carrier index by frequency. The crest factor is less than 5 dB so the reference symbol shall be transmitted at 3 dB above the power levels in table 3 to improve amplitude and phase estimation.

D - The data symbols contain an unmodulated pilot carrier at the amplitude defined in table 4 and data subcarriers modulated as specified in section 4.3, 4.4 or 4.5 of this document for one symbol period. The number of data subcarriers is always an integer multiple of 32.

4.2 Convolutional Code

User data bits are serialized by placing the least significant bit into the bit stream first and the most significant bit into the bit stream last. Some of these bits are converted to two bits by a rate ½ convolutional encoder. The encoder circuit is shown in figure 3, where DFF is a type D flip-flop clocked at the symbol rate and XOR is a 2-input exclusive-OR gate. D_0 is the input bit and C_0 and C_1 are the two encoded output bits.

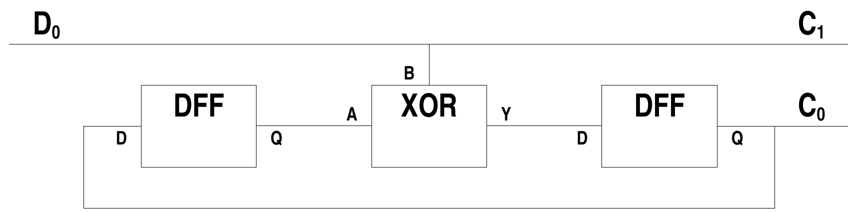

Figure 3. Convolutional Encoder

4.3 DQPSK Modulation

With DQPSK modulation, the output of the convolutional encoder is applied directly to the modulator as shown in table 5. This results in a FEC rate of ½ and one user data bit is transferred in each symbol. Successive encoded dibits are applied to higher frequency subcarriers in each carrier group.

Dibit C_1 C_0	Carrier Phase Shift
0 0	0°
0 1	90°
1 0	180°
1 1	270°

Table 5. DQPSK Encoding

4.4 D8PSK Modulation

For D8PSK modulation, the user data stream is split in half, with the even bits encoded using the convolutional encoded described in section 4.1 of this document and the odd bits applied directly to the modulator. D_0 is converted into the code-word bits C_0 and C_1 while D_1 becomes C_3. The 3 encoded bits are mapped onto each PSK symbol as shown in table 6. This results in a FEC rate of 2/3 and two user data bits are transferred in each symbol. Successive encoded tribits are applied to higher frequency subcarriers in each carrier group.

Tribit C_2 C_1 C_0	Carrier Phase Shift
0 0 0	0°
0 0 1	45°
0 1 0	90°
0 1 1	135°
1 0 0	180°
1 0 1	225°
1 1 0	270°
1 1 1	315°

Table 6. D8PSK Encoding

4.5 64QAM Modulation

For 64QAM modulation, the user data stream is split into four streams, D_0, D_1, D_2 and D_3. Pairs of bits are then encoded into 3-bit codewords. D_0 and D_2 are each encoded into two bits using the convolutional encoded described in section 4.1 of this document. D_0 is encoded as C_0 and C_1 and D_2 is encoded as C_3 and C_4, while D_1 and D_3 are applied directly to the modulator as C_2 and C_5. The first encoded tribit, $C_{0\text{-}2}$, is applied to the in-phase (I) subcarrier and the next encoded tribit, $C_{3\text{-}5}$, is applied to the quadrature (Q) subcarrier as shown in table 7. This results in a FEC rate of 2/3 and four user data bits are transferred in each symbol. Successive encoded hextets are applied to the higher frequency sub carriers until the highest frequency is reached in the carrier group.

Tribit C_2 C_1 C_0	I Amplitude
0 0 0	-0.7
0 0 1	-0.5
0 1 0	-0.3
0 1 1	-0.1
1 0 0	+0.1
1 0 1	+0.3
1 1 0	+0.5
1 1 1	+0.7

Tribit C_5 C_4 C_3	Q Amplitude
0 0 0	-0.7
0 0 1	-0.5
0 1 0	-0.3
0 1 1	-0.1
1 0 0	+0.1
1 0 1	+0.3
1 1 0	+0.5
1 1 1	+0.7

Table 7. 64QAM Encoding

4.6 OFDM Frame Format

Convolutional coding and decoding is applied to 32-subcarrier groups. The first 30 subcarriers in a group carry data and the last two subcarriers in a group carry only error-correction information. This is accomplished by sending 30 data bits through the convolutional encoder and then sending two bits with a fixed value of zero through the encoder. This causes the end-state of the encoder to always be 00 and prevents the propagation of errors between symbols during decoding.

OFDM frames consist of 19, 36 or 70 symbols transmitted over a 32-subcarrier group. The frame format is shown in figure 2 and uses the following symbols to specify the use of each subcarrier during each symbol period:

N = Null symbol - no subcarriers
R = Reference symbol with fixed phase
D = Data dibits
Z = Zero bits to flush the encoder state to zero

Each frame starts with a null (N) symbol followed by a reference (R) symbol and then symbols that carry data. If QPSK is used, there are 30 bits per symbol and 68 data symbols, for 8PSK there are 60 bits per symbol and 34 data symbols, and for 64QAM there are 120 bits per symbol and 17 data symbols. The reduction in frame length with increasing modulation complexity minimizes frequency accuracy requirements. Each OFDM frame holds 255 data bytes, which simplifies the implementation of Reed-Solomon codes for 8-bit symbols.

	0	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	32	33	34	35	SYM
1	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
2	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
3	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
4	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
5	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
6	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
7	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
8	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
9	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
10	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
11	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
12	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
13	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
14	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
15	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
16	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
17	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
18	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
19	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
20	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
21	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
22	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
23	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
24	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
25	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
26	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
27	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
28	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
29	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
30	N	R	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	
31	N	R	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	
32	N	R	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	
SC																																					

Figure 2. Frame Format for 32 Subcarrier Group using D8PSK

4.7 OFDM PHY-PDU Format

OFDM frames are multiplexed into the transmission channel in both the frequency and time domains. Frames are mapped onto the data subcarriers in 1 to 16 32-subcarrier groups starting with the lowest frequency and proceeding to the highest frequency. The pilot carrier is skipped. Additional frames are transmitted sequentially in time keeping the same frequency ordering. The format of the PHY-PDU is shown in figure 3 for 128 data subcarriers.

	Frame 0	Frame 4	Frame 8	Frame 12	Frame 16	Frame 20	Frame 24
Pilot Carrier	Frame 1	Frame 5	Frame 9	Frame 13	Frame 17	Frame 21	Frame 25
	Frame 2	Frame 6	Frame 10	Frame 14	Frame 18	Frame 22	Frame 26
	Frame 3	Frame 7	Frame 11	Frame 15	Frame 19	Frame 23	Frame 27

Figure 3. PHY PDU Format (28 frames on 4 carrier groups)

The PHY-PDU begins with transmission of a full-amplitude pilot carrier for 1 frame time. The high amplitude single carrier allows the receiver to acquire carrier frequency lock more easily. OFDM frames containing user data are then transmitted. This takes 1/6 to 1 frame-times per frame depending on the number of subcarriers used.

Modulation	DQPSK	D8PSK	64QAM
937.5 Baud	13.4	26.0	49.3
7500 Baud	107.1	208.3	394.7

Figure 4. Frames per Second for Different Modems

5. PHY Service Interface

The modem user accesses the physical layer service through a physical service access point PHY-SAP. This section describes the physical layer service offered to the user in terms of events, called service primitives, that cross the PHY-SAP.

5.1 Data Transmission

There are six service primitives associated with data transmission.

The user issues **PHY-TXSTART.request** to start transmission of a PHY-SDU. The parameters are the number of data carrier groups and the modulation type.

The provider issues **PHY-TXSTART.confirm** when it is ready to receive at least 255 user data bytes for transmission.

The user issues **PHY-DATA.request** to transmit one block of data. The parameter is 255 bytes of user data. This request is only valid between PHY-TXSTART.confirm and PHY-TXEND.request primitives.

The provider issues a **PHY-DATA.confirm** when it is ready to receive another data block (255 bytes).

The user issues **PHY-TXEND.request** to complete transmission of a PHY-SDU.

The provider issues **PHY-TXEND.confirm** when PHY-SDU transmission is complete.

5.3 Data Reception

There are three service primitives associated with data reception.

The provider issues **PHY-RXSTART.indication** to signal the start of a new PHY-SDU. The single parameter is RSSI which is the pilot carrier amplitude in dBnV.

The provider issues **PHY-DATA.indication** to transfer one block (255 bytes) of user data. The user must accept data at the rate it appears at the PHY-SAP.

The provider issues **PHY-RXEND.indication** to indicate the end of a PHY-SDU. The single parameter is RXERROR, which has one of the following values:

NoError. This value is used to indicate that no error occurred during PHY-SDU reception.

FormatViolation. This value is used to indicate that the format of the received PHY-SDU was in error. This condition is detected by a FEC error.

CarrierLost. This value is used to indicate that during the reception of the incoming PHY-SDU the carrier was lost and no further processing could be accomplished. This condition is detected by the absence of the final all zeros symbol.

UnsupportedRate. This value is used to indicate that a nonsupported number of carriers or modulation type was detected.

5.3 Clear Channel Assessment

There are three service primitives associated with clear channel assessment (CCA). These are used to hold off transmission when the channel is in use by another station.

The user issues **PHY-CCARESET.request** when it wishes to reset the CCA logic.

The provider issues **PHY-CCARESET.confirm** when the CCA logic is reset.

The provider issues **PHY-CCA.indication** to indicate the presence or absence of RF energy in the currently selected channel. The single parameter is STATE, which has the value BUSY or IDLE.

6. PHY Protocol

This section describes the actions taken by this physical layer entity in response to stimulus from the physical media and physical service access point.

6.1 PHY-TXSTART.request

When a PHY-TXSTART.request is received, the receiver is disabled if this is a half-duplex link. The transmitter is then enabled and the center carrier is transmitted and a PHY-TXSTART.confirm is issued to the user.

6.2 PHY-DATA.request

When a PHY-DATA.request is received, the data block is saved and a PHY-DATA.confirm is returned to the user. Data blocks are accumulated until enough are present to transmit one frame on each carrier group.

6.3 PHY-TXEND.request

When a PHY-TXEND.request is received, any required padding frames are generated and the last frames are transmitted on all carrier groups. The pilot and data carriers are then disabled. If this is a half-duplex link, the receiver is enabled. A PHY-TXEND.confirm is then issued.

6.4 Pilot Carrier Detect

If a pilot carrier is detected with an amplitude exceeding RSSI_CCA the receiver will attempt to synchronize to the carrier frequency and then issue a PHY-RXSTART.indication.

6.5 Null and Reference Symbols

When the null symbol appears and all data carriers disappear, the receiver waits for reappearance of data carriers. Their reappearance initiates decoding of the first symbol which is the phase reference and is interpreted as the value zero. The receiver then begins decoding data symbols. For DQPSK and D8PSK, the phase reference for each subcarrier applies to the next symbol on that subcarrier and is replaced with the phase of the next symbol following its decoding. For 64QAM, the phase reference is applied to all following symbols in the frame on that subcarrier.

6.6 Data Symbols

The receiver decodes data symbols for each carrier in a carrier group sequentially, starting with the lowest frequency subcarrier. The decoded data is accumulated until the end of the frame. When the end of each frame is reached a PHY-DATA.indication is issued to the user with the value of the 255 bytes encoded in the frame. There may be 1 to 16 PHY-DATA.indications for each frame-time, depending on the number of carrier groups that are active.

6.7 Data Carrier Loss

When the data carriers disappear, a PHY-RXEND.indication is passed to the user and the receiver waits for another frame.

6.8 Pilot Carrier Loss

If the pilot carrier disappears during a period when there are no data carriers, a PHY-CCA.indication (IDLE) is passed to the user and the receiver waits for a pilot carrier with no data carriers. If the pilot carrier disappears during a period when data carriers are present, a PHY-RXEND.indication (CarrierLost) is issued and the receiver waits for a pilot carrier with no data carriers.

6.9 Noise Level Increase

If the receiver detects an increase in RF energy within the channel that is not the pilot carrier, but exceeds RSSI_CCA for more than one symbol period, it sets CCA_STATE to BUSY and issues a PHY-CCA.indication (BUSY).

6.10 Noise Level Decrease

If CCA_STATE is BUSY and receiver detects an decrease in RF energy to a level less than RSSI_CCA for a period exceeding 16 symbol periods, it sets CCA_STATE to IDLE and issues a PHY-CCA.indication (IDLE).

7. PHY Management Interface

The management interface provides a means for the user to configure the modem and to collect performance information. The service primitives are defined in this section. Management operations apply to all local PHY-SAPs.

7.1 Configuration Management

The service primitive **PHY-CONFIGURE.request** transfers configuration data to the modem. There are three parameters, RSSI_CCA, TM and TC. RSSI_CCA is the CCA logic threshold expressed as a fraction of ADC full scale. TC and TM are the number of carrier groups (1-16) and the modulation type (0=DQPSK, 1=D8PSK and 2=64QAM). They will retain a value of zero if the specified option is not implemented.

7.2 Performance Management

There are two service primitives that are used to request modem status information.

The user issues a **PHY-STATUS.request** to request the current value of counters held within the modem.

The provider issues a **PHY-STATUS.confirm** to return the current value of all management objects. The management objects are 32-bit unsigned binary values and are not modified when read. The following values are returned:

CCA_STATE – clear channel assessment logic state (BUSY or IDLE).

RSSI_CCA – RF energy level above which channel is declared BUSY.

RSSI_IDLE – average amplitude of RF energy in channel during IDLE states.

RSSI_BUSY – amplitude of RF energy in channel when last PHY-CCA.indication (BUSY) was issued.

RSSI_DATA – signal level of pilot carrier when last PHY-RXSTART.indication issued in dBnV (dB above 1 nanovolt).

The following objects are counters:

TIME – increments every millisecond.

CARRIER_DETECT – increments when a PHY-CCA.indication with a value of BUSY is issued.

FRAMES_LOST – increments when a frame terminates abnormally.

PDUS_RECEIVED – increments when a PHY-RXEND.indication is issued.

FRAMES_RECEIVED – increments when a PHY-DATA.indication is issued.

PDUS_TRANSMITTED – increments when a PHY-TXEND.confirm is issued.

FRAMES_TRANSMITTED – increments when a PHY-DATA.confirm is issued.

All management object values (including counters) are reset to a value of zero when power is applied to the modem.

8. Recommended Operating Frequencies

Operating frequencies must be selected to fit with existing ARRL band plans and FCC regulations. There are no restrictions on occupied bandwidth for data transmission above 902 MHz. In the 219-220 and 420-450 MHz bands, the maximum occupied bandwidth for data transmission is 100 kHz. In all other bands above 50 MHz the maximum bandwidth is 20 kHz. The ARRL regulation by bandwidth proposal would change these limits to 100 kHz below 220 MHz and no limit above 222 MHz.

The following frequencies are recommended for operation of the OFDM modems specified in this document. They are allocated to high-speed data, packet or experimental use in the ARRL band plans. The *italicized* entries assume adoption of the ARRL regulation by bandwidth proposal by the FCC. Use should be coordinated with local band-planning committees.

Band	Maximum Channel Width	Sub-Band
6 m	*100 kHz*	*51.12 – 51.48 MHz*
	100 kHz	*51.62 – 51.98 MHz*
2 m	*100 kHz*	*145.50 – 145.80 MHz*
1¼ m	100 kHz	219.00 – 220.00 MHz
	100 kHz	*223.52 – 223.64 MHz*
70 cm	100 kHz	420.00 – 426.00 MHz
	6 MHz	*420.00 – 426.00 MHz*
33 cm	2 MHz	903.00 – 906.00 MHz
	2 MHz	915.00 – 918.00 MHz
23 cm	6 MHz	1,248.00 – 1,258.00 MHz
	6 MHz	1,288.00 – 1,294.00 MHz
	2 MHz	1,297.00 – 1,300.00 MHz
13 cm	2 MHz	2,300.00 – 2,303.00 MHz
	2 MHz	2,396.00 – 2,399.00 MHz

Table 7. Recommended Frequencies

In the 420-450 MHz band, OFDM modems may be used for digital amateur television with no bandwidth restrictions.