802.11a
Wireless OFDM LAN

http://www.vocal.com

VOCAL Technologies, Ltd. modem software libraries include a complete range of ETSI / ITU / IEEE compliant modulations, optimized for execution on ANSI C and leading DSP architectures (ADI, AMD-Alchemy, ARM, DSP Group, LSI Logic ZSP, MIPS and TI). This software is modular and can be executed as a single task under a variety of operating systems or it can execute standalone with its own kernel.

IEEE 802.11 standard specifies a 2.4 GHz operating frequency with data rates of 1 and 2 Mbps using either direct sequence (DSSS) or frequency hopping spread spectrum (FHSS). The IEEE 802.11a standard specifies an OFDM physical layer (PHY) that splits an information signal across 52 separate subcarriers to provide transmission of data at a rate of 6, 9, 12, 18, 24, 36, 48, or 54 Mbps. The 6, 12, and 24 Mbps data rates are mandatory. Four of the subcarriers are pilot subcarriers that the system uses as a reference to disregard frequency or phase shifts of the signal during transmission.

A pseudo binary sequence is sent through the pilot subchannels to prevent the generation of spectral lines. The remaining 48 subcarriers provide separate wireless pathways for sending the information in a parallel fashion. The resulting subcarrier frequency spacing is 0.3125 MHz (for a 20 MHz with 64 possible subcarrier frequency slots).

The primary purpose of the OFDM PHY is to transmit Media Access Control (MAC) protocol data units (MPDUs) as directed by the 802.11 MAC layer. The OFDM PHY is divided into two elements: the physical layer convergence protocol (PLCP) and the physical medium dependent (PMD) sublayers.

802.11a Terminology:

- The MAC layer communicates with the PLCP via specific primitives through a PHY service access point. When the MAC layer instructs, the PLCP prepares MPDUs for transmission. The PLCP also delivers incoming frames from the wireless medium to the MAC layer. The PLCP sublayer minimizes the dependence of the MAC layer on the PMD sublayer by mapping MPDUs into a frame format suitable for transmission by the PMD.
- Under the direction of the PLCP, the PMD provides actual transmission and reception of PHY entities between two stations through the wireless medium. To provide this service, the PMD interfaces directly with the air medium and provides modulation and demodulation of the frame transmissions. The PLCP and PMD communicate using service primitives to govern the transmission and reception functions.

802.11a Features:

- Figure 1 illustrates the frame format for an IEEE 802.11a frame. The PLCP preamble field is present for the receiver to acquire an incoming OFDM signal and synchronize the demodulator. The preamble consists of 12 symbols. Ten of the symbols are short for establishing Automatic Gain Control (AGC) and the coarse frequency estimate of the carrier signal. The receiver uses the long symbols for fine-tuning. With this preamble, it takes 16 microseconds to train the receiver after first receiving the frame.

PLLP preamble (12 symbols)	Rate (4 bits)	Reserved (1 bit)	Length (12 bits)	Parity (1 bit)	Tail (6 bits)	Service (16 bits)	PSBU (payload)	Tail (6 bit)	Pad

Figure 1. Frame Formats

- The signal field consists of 24 bits, defining data rate and frame length. The IEEE 802.11a version of OFDM uses a combination of binary phase shift keying (BPSK), quadrature PSK (QPSK), and quadrature amplitude modulation (QAM), depending on the chosen data rate as it is shown in Table 1. The length field identifies the number of octets in the frame. The PLCP preamble and signal field are convolutionally encoded and sent at 6 Mbps using BPSK no matter what data rate the signal field indicates, The convolutional encoding rate depends on the chosen data rate.

Custom Product Design Division
200 John James Audubon Parkway
Buffalo, New York 14228
716-688-4675

http://www.vocal.com

Table 1.Modulation Techniques

Data Rate (Mbps)	Modulation	Coding Rate	Coded bits per subcarrier	Coded bits per OFDM symbol	Data bits per OFDM symbol
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	16-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

- The service field consists of 16 bits, with the first six bits as zeros to synchronize the descrambler in the receiver, and the remaining nine bits are reserved for future use (and set to zeros). The PLCP service data unit (PSDU) is the payload from the MAC layer being sent. The pad field contains at least six bits, but it is actually the number of bits that make the data field a multiple of the number of coded bits in an OFDM symbol (48, 96, 192, or 288). A data scrambler using a 127 bits sequence generator scrambles all bits in the data field to randomize the bit patterns in order to avoid long streams of 1s and 0s.
- With IEEE 802.11a OFDM modulation, the binary serial signal is divided into groups (symbols) of one, two, four, or six bits, depending on the data rate chosen, and converted into complex numbers representing applicable constellation points. If a data rate of 24 Mbps is chosen, for example, then the PLCP maps the data bits to a 16QAM constellation.
- After mapping, the PLCP normalizes the complex numbers to achieve the same average power for all mappings. The PLCP assigns each symbol, having a duration of 4 microseconds, to a particular subcarrier. An Inverse Fast Fourier transform (IFFT) combines the subcarriers before transmission.

802.11a Implementations:

- As with other 802.11 based PHYs, the PLCP implements a clear channel assessment protocol by reporting a medium busy or clear to the MAC layer via a primitive through the service access point. The MAC layer uses this information to determine whether to issue instructions to actually transmit an MDSU.
- Operating frequencies for the IEEE 802.11a OFDM layer fall into the following three 100 MHz unlicensed national information structure (U-NII) bands: 5.15 to 5.25 GHz, 5.25 to 5.35 GHz, and 5.725 to 5.825 GHz. Table 2 shows that there are twelve 20 MHz channels, and each band has different output power limits. In the United States, the Code of Federal Regulations, Title 47, Section 15.407, regulates these frequencies.
- The IEEE 802.11a standard requires receivers to have a minimum sensitivity ranging from -82 to -65 dBm, depending on the chosen data rate.

Table 2. OFDM Operating Bands and channels

Band	Channel numbers	Frequency (MHz)	Maximum output power (up to 6 dBi antenna gain)
U-NII lower band 95.15 to 5.25 MHz	36	5180	40mW (2.5mW/MHz)
	40	5200	
	44	5220	
	48	5240	
U-NII lower band 95.15 to 5.25 MHz	52	5260	200mW (12.5mW/MHz)
	56	5280	
	60	5300	
	64	5320	
U-NII lower band 95.15 to 5.25 MHz	149	5745	800mW (50mW/MHz)
	153	5765	
	157	5785	
	161	5805	

Custom Product Design Division
200 John James Audubon Parkway
Buffalo, New York 14228
716-688-4675

http://www.vocal.com