Understanding 802.11a Technology and Testing Requirements

As WLAN standards emerge, test solutions will play a crucial role in the success of long-term end-user acceptance.

By Lisa Ward, Rohde & Schwarz, Matt Maxwell, Tektronix, Inc., and John Bowne, Rohde & Schwarz

Editor's Note: This article represents Part One of a two-part article. Click here ***[1] to read part two.***

Wireless networking has seen its popularity rise dramatically over the past two years. By offering high performance, flexibility and interoperability at a reasonable cost, the design and manufacturing of WLAN infrastructure and devices is in high demand. According to InstatMDR, WLAN chip sales grew 23 percent in 2001 from the previous year, and 2002 chipset units are forecast to exceed 14 million units, an increase of 75 percent from 2001. These facts equate to a high demand for fast, efficient test equipment that is easy to use as engineers work with an ongoing evolution of IEEE802.11 technology from which a WLAN is built.

While the existing 802.11b standard costs less, the newer 802.11a standard enables much higher data rates, enabling the probability of widespread adoption of WLAN technology. This article aims to provide some background on the technology and some insight to the measurement requirements of WLAN devices based on the 802.11a standard.

The rapid growth of the market for 802.11a-compliant products is likely to tax the design and production capacity of vendors serving the market. Test and measurement tools play an important role in both design and production, especially in the early stages of an emerging technology's market acceptance. Choosing the right solution for design verification or production test can make the difference between meeting and missing the all-important market &quotwindow.&quot

In order to discuss test and measurement requirements, it's important to first take an in-depth look at the standard beginning with a detailed look at Orthogonal Frequency Division Multiplexing (OFDM), the key to gaining higher bandwidth in WLANs.

Orthogonal Frequency Division Multiplexing: The Key to Higher Bandwidth

802.11a-compliant systems operate at 5 GHz, in contrast to earlier 802.11b systems that operate at 2.4 GHz. In addition, 802.11a systems use a different modulation/spreading system known as Orthogonal Frequency Division Multiplexing (OFDM) technology. Although 802.11a systems are not backward compatible with

802.11b designs, they deliver much higher data rates-up to 54 megabits per second (Mbps). Another emerging WLAN standard, 802.11g, will combine techniques from both 802.11a and 802.11b and will operate at the 802.11b frequencies.

Designers and manufacturers of wireless devices know that increasing the data rate means a decreasing bit interval with less time for the system to settle between bits. Therefore, intersymbol interference becomes more of an issue and multipath effects become problematic as the time per symbol approaches the delay spread of the system. OFDM is the solution to these problems: its basic premise is that high-speed data can be transmitted over multiple sub-carriers to reduce the data rate required of any individual carrier.

By distributing the desired data rate among a number of sub-carriers the data rate per sub-carrier reduces and the time per symbol increases proportionally. This approach also reduces errors caused by narrow-band jammers; losses can be recovered by using Forward Error Correction (FEC) on the data stream.

If the sub-carriers are harmonically related (as in Figure 1), then the center frequency of each sub-carrier will line up with the nulls in the spectral shapes of the other sub carriers, minimizing interference. The sub-carriers in Figure 1 are orthogonal to each other in a sin(x)/x pattern that is stepped at discrete harmonic intervals. Given a sampling rate and the number of sub-carriers needed, it is easy to calculate the harmonic intervals. From the 802.11a specification, the sampling rate is 20 MHz and the total number of sub-carriers is 64 (though not all are used). Dividing the sample rate of 20 MHz by 64 yields a spacing of 312.5 kHz. In 802.11a, 48 data sub-carriers, 4 pilot sub-carriers and a null center sub-carrier are defined for a total of 53 sub-carriers. Multiplying 312.5 kHz by 53 produces a total occupied bandwidth of about 16.6 MHz.

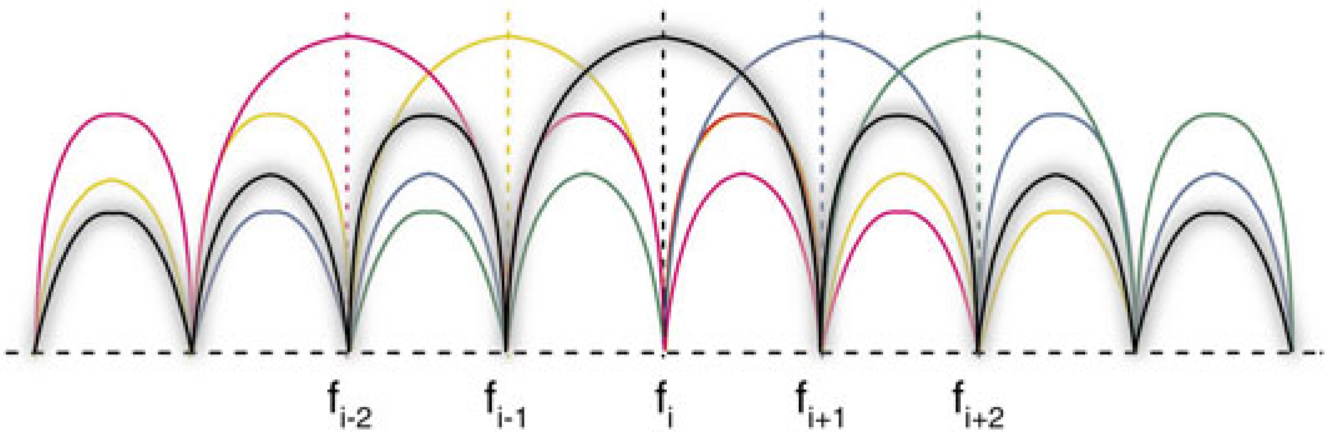

Figure 1. 802.11a sub-carrier frequency distribution

PLCP Layer - A Closer Look at the 802.11a Packet

The Physical Layer Convergence Protocol (PLCP) layer resides directly above the physical layer and below the Medium Access Control (MAC) layer and provides an interface that allows a common MAC layer definition to be used for all 802.11 sub-standards. In the PLCP layer the user data is contained in the PLCP Service Data Unit (PSDU). A PLCP preamble and header fields are added to this data to create a PLCP Protocol Data Unit (PPDU).

The PLCP Preamble is the first field of the PPDU and consists of 10 short training symbols and a pair of longer training sequences. These training sequences help the receiver find and lock onto the transmitted packet. Following the preamble is the signal field that contains important information for the receiver. For example, since each packet of data is sent independently, the receiver does not know what data rate is being used to transmit the user's information. The first four bits of the signal field contains this rate information. In addition, the signal field contains information on how many bits are contained in the packet and a parity bit to aid in error correction. (For a complete list of the fields contained in the header and their functions, please refer to clause 17, sub-clause 3.2 of the IEEE 802.11a standard.) This is illustrated in Figure 2. Following the SIGNAL symbol, the first symbol of the data stream occurs. At the beginning of the data stream, there is a service field containing 16 bits. The first seven bits are all set to zero and are used to synchronize the scrambling sequences in the receiver with those in the transmitter. The scrambler is started at the same time that the SERVICE field is sent but is initialized to a non-zero pseudo-random value. The remaining nine bits of this field are currently reserved and set to zeros. After all of the data in the PLCP Service Data Unit (PSDU) is sent, another TAIL field (filled with all zeros) is sent to return the convolutional encoder to the zero state. Lastly, a series of zeros is transmitted to fill the remaining positions within this final symbol.

The IEEE 802.11a standard provides a table, duplicated for reference here, of the data rates possible in 802.11a and the modulation and coding methods that are used to obtain each data rate. For example, if a data rate of 24 Mbps is desired, the standard specifies that a 16-QAM-modulation mapping technique be used and that the data be block encoded with a rate 1/2 encoder. Because 16-QAM encodes 4 bits into a single output value, the Number of Bits per Sub Carrier (NBPSC) value is 4. Since there are 48 data sub carriers in 802.11a, there will be 192 (48*4) coded bits per OFDM symbol. Because a rate 1/2 encoder is used to achieve the 24 Mbps, each OFDM symbol will contain 96 (192/2) NDBPS (data bits per symbol).

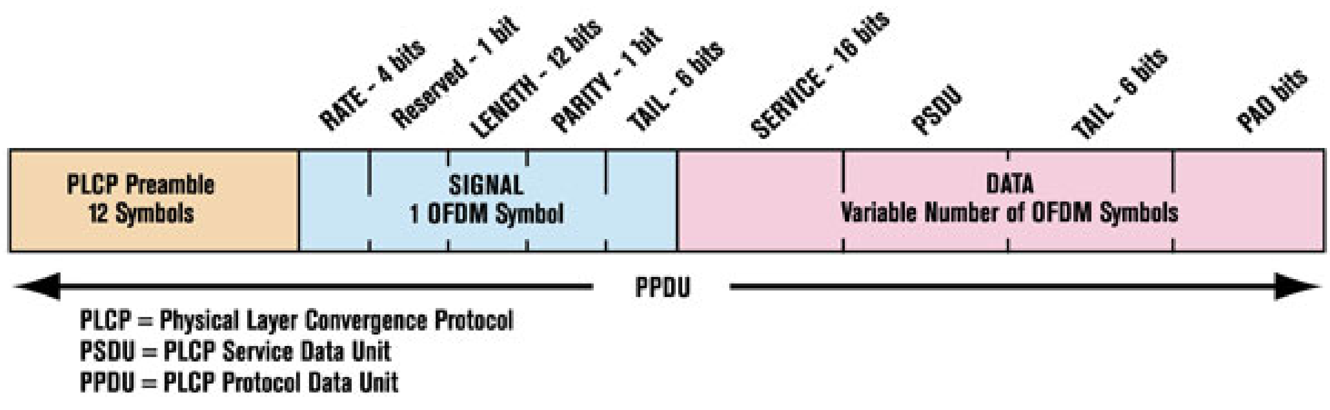

Figure 2. 802.11a transmission packet sequence

Following an OFDM Packet Through the System

Figure 4 shows the OFDM implementation specified in the 802.11a standard. The best way to approach this diagram is to follow a packet through the system.

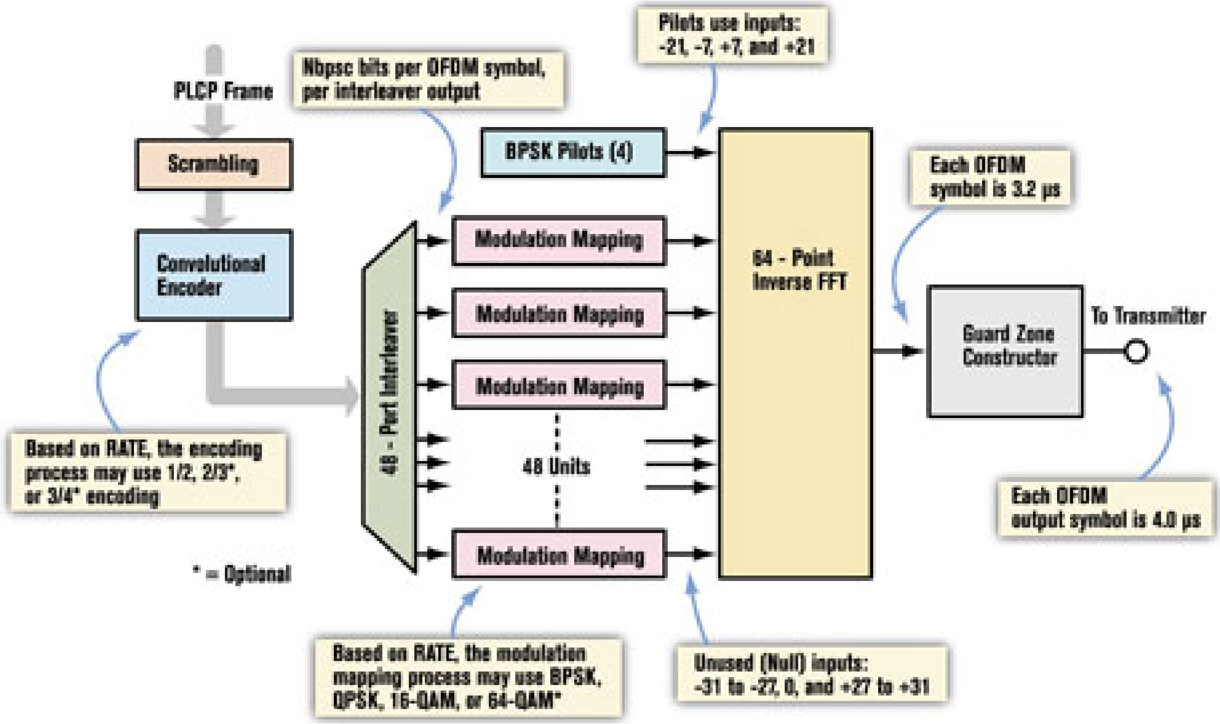

Figure 4. 802.11a OFDM modulation architecture

First, a complete PLCP data frame (this discussion will be limited to the DATA symbols of the frame) is passed through a scrambler. This scrambled block of data passes through a convolutional encoder. The RATE field of the SIGNAL symbol determines the rate at which the encoder is set: rate 1/2, rate 2/3, or rate 3/4.

After all of the bits are encoded (thereby adding the forward error correction terms into the frame) they pass into a 48-port interleaver. The interleaver acts like a demultiplexer, in that input data is distributed across a number of output ports. The interleaver guarantees that adjacent coded input bits are not mapped to adjacent sub-carriers. It also distributes adjacently coded input bits evenly across the output constellation. Based on the NCBPS (Number of coded bits per symbol) setting value, the interleaver will pass a set of NCBPS bits into each of the 48 Modulation Mapping units at the same moment in time. The Modulation Mapping units convert the bits into pairs of scaled I and Q values.

These values go into 48 of the 64 inputs on the IFFT (Inverse Fast Fourier Transform); four other inputs are dedicated as pilots for 52 total active streams. The remaining inputs are set to zero. Once in each symbol time interval (four microseconds), the IFFT operation is performed. The resulting stream of time domain data spans 3.2 microseconds. In order to make capturing the data on the receive side easier, the Guard Zone Constructor element extracts a copy of the final 0.8 &#956s of the symbol data and places it in front of the symbol waveform. This provides a transition zone between the previous symbol stream and that of the current symbol. The resulting symbol time is exactly 4.0 microseconds.

Figure 5 depicts the transmission process for an entire packet. The vertical axis is labeled in sub-carrier index levels &#151 in effect, frequency. The gap at the Oth index indicates that this index is not used.

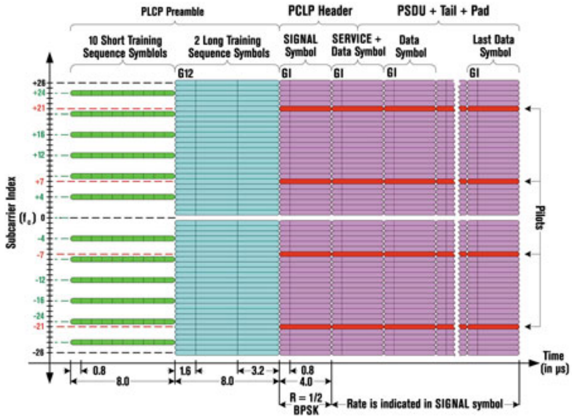

Figure 5. 802.11a transmission process diagram

During the initial portion of the packet, ten short training sequences are transmitted on every 4th sub-carrier, skipping the 0th sub-carrier. These short training sequences do not use a guard interval.

Next, the long training sequences are sent on all of the 52 sub-carriers, including the four sub-carriers reserved for the pilots. A double guard interval is placed at the beginning of the first long training sequence.   Next, the SIGNAL symbol is sent on the 48 data sub-carriers. This is always encoded with the BPSK mode for the Modulation Mapping elements and rate one-half for the convolutional-encoding rate. For this symbol, the standard 0.8 ms guard interval is used. Note that the pilots start at the same time as the SIGNAL symbol and continue until the end of the packet. Lastly, the SERVICE+DATA symbol and the remainder of the DATA symbols are sent on the 48 data sub-carrier indexes.

Links:
[1] http://www.wirelessdesignmag.com/scripts/ShowPR.asp?PUBCODE=055&ACCT=0024780&ISSUE=0211&RELTYPE=WEF&PRODCODE=00000&PRODLETT=B