

WIRELESS LAN MEASUREMENT SYSTEM AND DEDICATED SOFTWARE

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We have developed a measurement system for wireless LAN to address the explosive growth of wireless LAN communication. The wireless LAN measurement system has two major features. One is the signal generator system that generates the reference signal source and a signal source under compromised conditions for the performance testing of receivers. The other is the EVM (Error Vector Magnitude) measurement system that measures modulated signals of transmitter waveforms for performance testing of transmitters. We have implemented a measurement system for wireless LAN with general measurement equipment, personal computers, and dedicated software. This paper outlines the system configuration and software functions.

INTRODUCTION

A great deal of attention for Wireless LAN technology has been increasing because of its flexible network accessibility and lower infrastructure costs. High-speed wireless communication systems at 11 Mbps (IEEE 802.11b: Task Group b of Working Group 11, IEEE 802 Standards Committee), 54 Mbps (IEEE 802.11a: Task Group a of Working Group 11, IEEE 802 Standards Committee), or greater have been studied and standardized. This has led to active development of wireless LAN equipment compliant to these standards and to rising demands for measurement system.

A wireless LAN measurement system has two major features: a signal source generator for testing receiver performance that generates the reference signal and noisy signals under harsh environments, and EMV measurement of transmitted waveforms for testing transmitter performance.

We have developed IEEE 802.11b- and IEEE 802.11a-compatible software and will also support other standards in the future.

RECEIVER PERFORMANCE TEST SYSTEM

Figure 1 shows the configuration of the receiver performance test system. Baseband waveform data is created on a personal computer using dedicated software (discussed later), and transferred to the VG6000 synthesized vector signal generator. The VG6000 generates baseband waveforms, modulates them into RF (Radio Frequency) signals, and outputs them to the receiver. By controlling the signal level, receiver performance such as sensitivity can be tested.

To test performance under noisy environments, output from a noise generator can be added to the RF signals. A fading simulator instead of a noise generator can be used to test performance under fading environments.



Figure 1 Receiver Performance Test System

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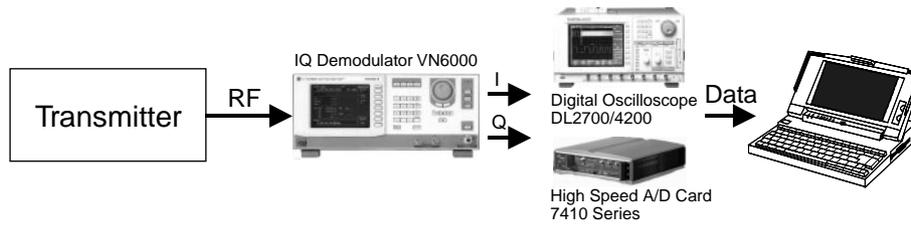


Figure 2 Transmitter Performance Test System

TRANSMITTER PERFORMANCE TEST SYSTEM

Figure 2 shows the configuration of the transmitter performance test system. The transmitter's RF signals are demodulated into baseband waveforms with the VN6000 wide-band IQ demodulator, and then collected on the DL2700/4200 digital oscilloscope. The collected data is transferred to a personal computer and transmitter performance, such as EVM (Error Vector Magnitude), can be tested by analyzing the data with dedicated software (see below).

DEDICATED SOFTWARE

There are various wireless LAN standards, such as IEEE 802.11a, IEEE 802.11b, IEEE 802.11g (Task Group g), HIPERLAN/2 (High Performance Radio Local Area Network type 2), and HiSWAN (MMAC's High Speed Wireless Access Network). IEEE 802.11a, IEEE 802.11b, and IEEE 802.11g are deployed in the United States, Japan, and other countries, HIPERLAN/2 in Europe and other countries, and HiSWAN in

Japan. This paper describes the dedicated software that supports IEEE 802.11a, which is being developed most actively.

The dedicated software is comprised of baseband waveform generation software for testing receiver performance, and baseband waveform data analysis software for testing transmitter performance.

Baseband Waveform Generation Software

The most critical requirement for this software is capability of generating waveforms that conform to IEEE 802.11a standard. Figure 3 shows the structure of an IEEE 802.11a data frame.

IEEE 802.11a uses the OFDM (Orthogonal Frequency Division Multiplexing) modulation technique for modulation, and the data rate can be changed by applying such mapping schemes as BPSK (Binary Phase Shift Keying) and QPSK (Quadrature Phase Shift Keying).

The preamble field is common to all frames. The signal field indicates the rate at which OFDM symbols in the data field are transmitted, and the data length. The modulation scheme varies depending on the data rate (6 to 54 Mbps). Table 1 shows the

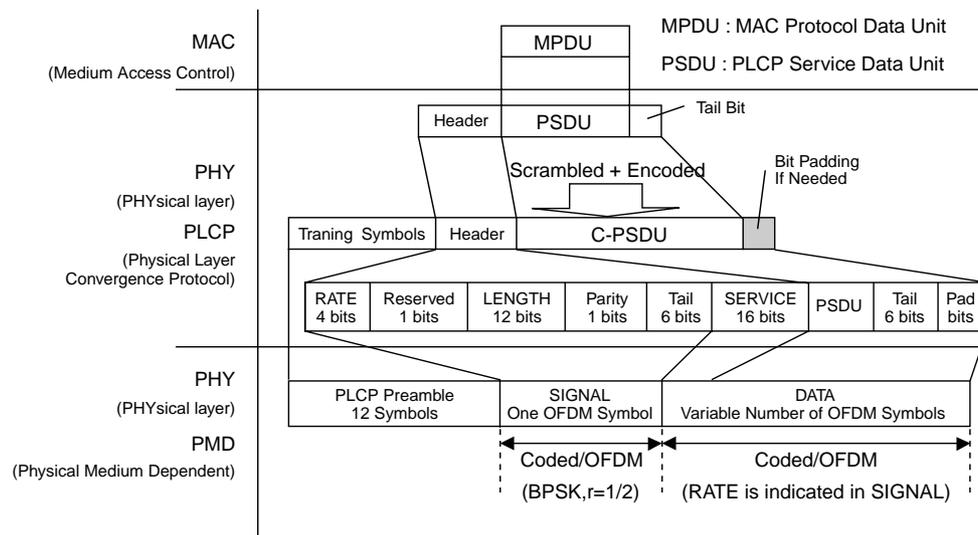


Figure 3 Structure of IEEE 802.11a Data Frame

Table 1 Data Rate and Modulation Scheme Combination

Data Rate (Mbits/s)	Modulation	Coding rate
6	BPSK	1/2
9	BPSK	3/4
12	QPSK	1/2
18	QPSK	3/4
24	16QAM	1/2
36	16QAM	3/4
48	64QAM	2/3
54	64QAM	3/4

relationship between the data rate and the modulation scheme.

As illustrated in Figure 3, this software inputs the MPDU (MAC layer Protocol Data Unit), data rate and data length and performs the following processes on them:

- Adds the header and tail bit.
- Scrambles and encodes the signals with a convolutional encoder.
- Reduces signal throughput according to the coding rate.
- Adds the padding bit as necessary.
- Applies mapping (BPSK, etc.) and OFDM modulation.
- Adds the preamble.
- Inserts an interval between frames.

After these processes are complete a basic part of the IEEE 802.11a-compatible modulated waveform data can be output. Then the software digitally filters the modulated waveform data to obtain spurious-free output. Common digital filters are provided, such as Raised Cosine, the Chebyshev, the Butterworth, and the Bessel filters, and various filter parameters can be set. Figure 4 shows an example of IEEE 802.11a baseband waveforms generated with this software, which testifies to the existence of intervals between frames.

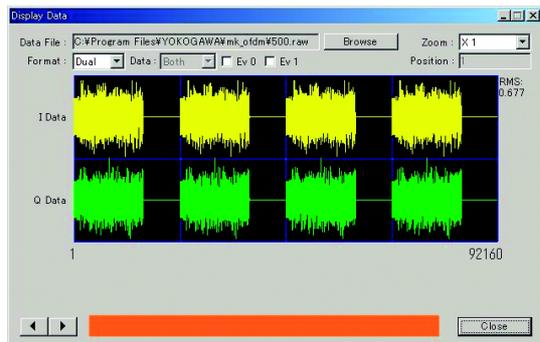


Figure 4 Example of IEEE 802.11a Baseband Waveforms

Baseband Waveform Data Analysis Software

Figure 5 is a flow chart which shows how the software analyzes IEEE 802.11a modulated waveforms.

- Data loading: Loads data collected on a digital oscilloscope onto a personal computer.
- Frame start search: Searches data from the top for the starting point of a frame by using the short training sequence section of the preamble field.
- RF offset correction: Since the data was collected in asynchronous mode, the RF offset must be corrected. The software determines and corrects the offset by measuring the phase difference of each subcarrier between symbols using the short training sequence. This process, however, cannot fully eliminate the RF offset, and fine adjustment is necessary using pilot subcarriers of a symbol where the offset can be determined and corrected by measuring phase differences of the pilot subcarriers between symbols.
- Baseband frequency offset correction: Baseband frequency offset must be corrected for the same reason as the RF offset. The software determines and corrects the offset by measuring phase differences of the pilot subcarriers in a symbol.
- Phase and amplitude correction for each subcarrier: Performs linear interpolation using the pilot subcarriers on the subcarrier phases and amplitudes (in units of dB).
- Data rate and length analysis: Demodulates (using FFT, bit information confirmation through mapping positions, bit deinterleaving, and Viterbi decoding) the signal field and analyzes the data rate and length.

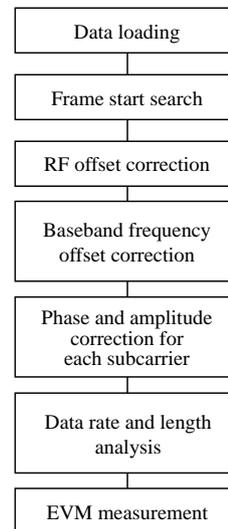


Figure 5 Analysis of Modulated Waveforms

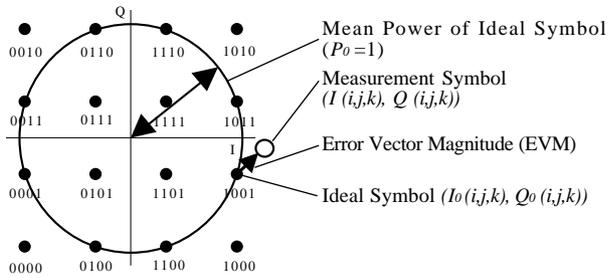


Figure 6 Concept of EVM

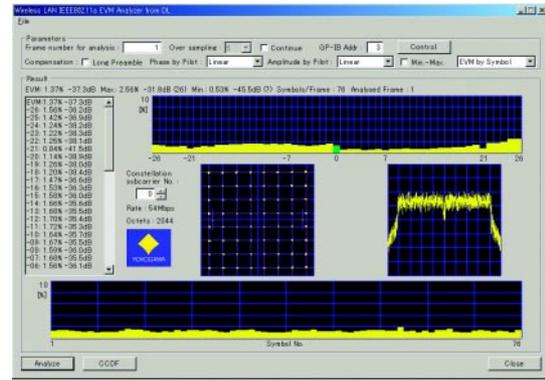


Figure 7 Example of Analysis Results

- EVM measurement: Determines the mapping scheme of the data symbols from the data rate obtained in step 6, measures the amplitude with the mapping position of the pilot subcarriers, and finds the ideal mapping position. The software calculates the EVM by computing a vector from the mapping position obtained through FFT analysis of each data symbol to the ideal mapping position. The EVM can be calculated according to the following equation:

$$EVM = \frac{\sum_{i=1}^{N_f} \sqrt{\sum_{j=1}^{N_s} \left[\sum_{k=1}^{52} \{ (I(i,j,k) - I_0(i,j,k))^2 + (Q(i,j,k) - Q_0(i,j,k))^2 \} \right]}}{N_f \times 52 \times N_s \times P_0}$$

Where

- N_f : Number of analyzed frames
- N_s : Number of symbols per frame
- $I(i,j,k)$: I value for k th subcarrier for j th symbol of i th frame
- $I_0(i,j,k)$: Ideal I value for k th subcarrier for j th symbol of i th frame
- $Q(i,j,k)$: Q value for k th subcarrier for j th symbol of i th frame
- $Q_0(i,j,k)$: Ideal Q value for k th subcarrier for j th symbol of i th frame
- P_0 : Mean power.

Figure 6 shows the concept of the equation.

Figure 7 shows an example of the analysis results by the baseband waveform data analysis software. With this software, the input signals can be analyzed to determine the data rate and length, and to calculate the EVM based on the mapping scheme (64QAM: 64 Quadrature Amplitude Modulation in Figure 7) in relation to the data rate. The EVM and constellation for each subcarrier can also be visually confirmed.

We generated the reference signal with the receiver performance test system and obtained an EVM average of approximately 2% with the transmitter performance test system. This value sufficiently meets the IEEE 802.11a standard which specifies a maximum EVM of 5.62% (-25 dB) or less for the peak data rate of 54 Mbps.

CONCLUSION

This wireless LAN measurement system relies on software in dealing with processes that depend on the communication protocol used. Therefore, various communication protocols can be covered by modifying the software. We believe that this can be also achieved for other wireless LAN and mobile communication systems and will develop appropriate software as soon as possible. ◆

REFERENCES

- (1) IEEE 802.11a-1999 (Supplement to IEEE 802.11-1999)
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