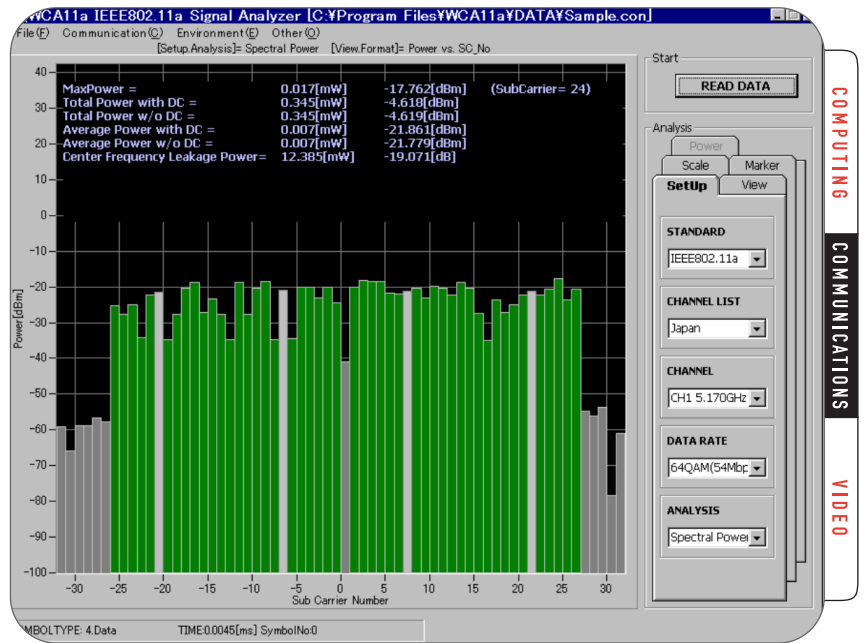# Testing Transmitted Signals for Compliance with IEEE 802.11a WLAN Standards

▶ A Test Scenario for the Emerging WLAN Standard

Among the new and emerging wireless Local Area Networking (WLAN) standards, IEEE 802.11a, also referred to as WiFi5, promises to have the most significant impact on the technology of enterprise-class networks. The standard provides avoidance of interference and substantial improvements in speed over previous methods.

Introduction

The 802.11a standard, approved in early 1999, presents many new challenges to those who design, manufacture and support network elements. It operates with more channels at higher frequencies using a new modulation scheme and spreading techniques that are not backward compatible with any of the previous IEEE WLAN standards.

This technical brief describes some of the key measurements for 802.11a Physical Layer (PHY) RF signals using the Tektronix WCA11A

Signal Analysis Software and WCA380 Wireless Communication Analyzer. The objective is to help establish a uniform testing approach that will improve design reliability and instill confidence between suppliers and customers.

A Measurement Strategy for IEEE 802.11a Transmitted Signals

The combination of the WCA11A running on a PC and the WCA380 analyzer provides a comprehensive automated strategy to measure the most important parameters of IEEE 802.11a transmitted signals. Table 1 lists the key measurements. Note that some of the measurements have not yet been standardized, so they are listed as characteristic tests.

Tektronix

Enabling Innovation

Testing Transmitted Signals for Compliance with IEEE 802.11a WLAN Standards

▶ Technical Brief

Table 1 – Measurements for IEEE 802.11a Signals

| Items	Description
Spectral Power	Measures power of each OFDM sub-carrier wave
Constellation	Measures constellation of each or whole OFDM sub-carrier wave
Constellation Normalize	Measures constellation normalized of each or whole OFDM sub-carrier wave
EVM	Measures modulation accuracy of each or whole OFDM sub-carrier wave
Center Freq Err	Measures carrier wave frequency deviation
Symbol Table	Displays demodulated symbol table
Spectrum Mask	Measures spectrum mask per 802.11a standard
*Transmit Power with OBW	Measures transmission power and occupied frequency bandwidth
*Spurious Emission	Measures spurious emission intensity
*Adjacent Channel Leakage	Measures adjacent channel leakage power
*Leakage Power	Measures the emission of secondarily emitted radio wave

* indicates characteristic test

The WCA380 has a receiver to capture and analyze IEEE 802.11a signals with the wide IQ capture bandwidth needed to make the demodulated measurements. The analyzer also features a frequency-mask trigger that can be set to capture transient events and intermittent signal fluctuations no matter when they occur.

The WCA11A software resides on an external PC which is connected to the WCA380 via Ethernet (see Figures 1 and 2). The software configures the analyzer, controls the measurement and stores the resulting data on a local hard disk for analysis and display. Successive measurements can be taken and stored all at once to optimize test time and then can be recalled for analysis later.
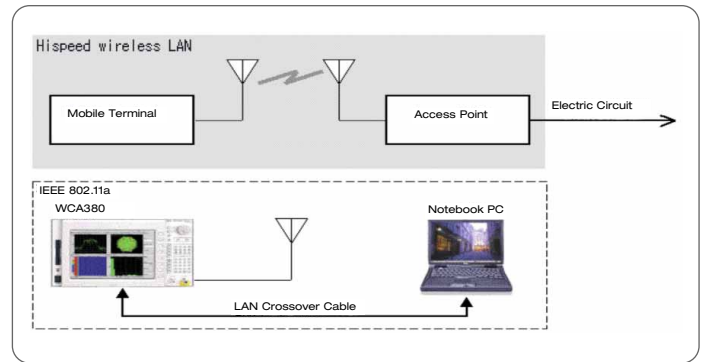
▶ *Figure 1. Hardware Configuration of IEEE 802.11a Signal Analysis Device*
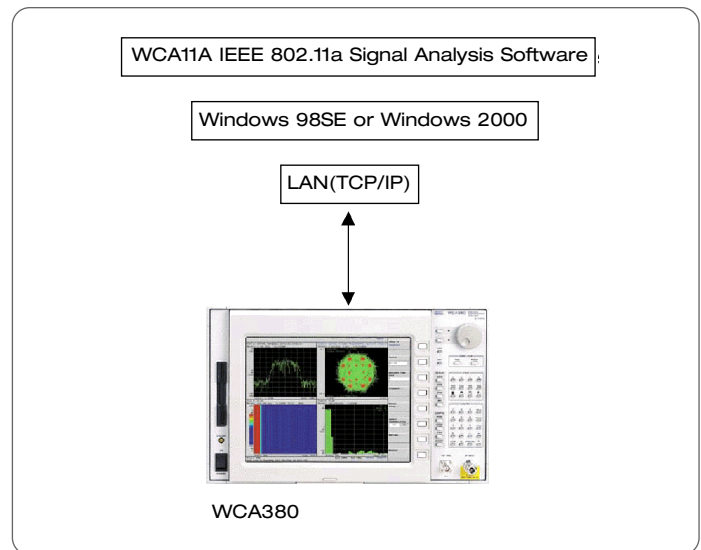
▶ *Figure 2. WCA11A Operational Software Environment*

Setting up to Take Measurements

Proper instrument settings are critical to measurement accuracy, and setting up to take WLAN signal measurements can be a real challenge with the large number of parameters that must be configured. The WCA11A software provides simple menu selections for overall signal and analysis types – the setup program does the rest. The software automatically controls the WCA380 to evaluate transmission characteristics of IEEE 802.11a RF signals precisely as defined in the standard or (where the standards do not apply) to pre-configured compliance criteria, ensuring conformance. Figure 3 shows a typical setup menu.

Menu Label	Entries/Choices	Description
Standard	IEEE 802.11a	Analysis per IEEE 802.11a specifications
	COMPLIANCE	Analysis of power measurements
Channel List	Japan North America Europe	Selection of the channel list by country (See Table 3)
	Center Frequency	Allows direct entry of any center frequency
Channel	List Selection	Selection of the channel number and carrier frequency (See Table 3)
Data Rate	List Selection	Selection of the data transmission speed of the wireless LAN system to be analyzed. Data transmission speeds for IEEE 802.11a standard are shown in Table 2.
Select the measurement specified in high-speed wireless LAN standard (IEEE 802.11a)		
Spectral Power Constellation Constellation Normalize EVM	Center Freq Error Symbol Table Spectrum Mask	
Select from compliance measurements		
Transmit Power with OBW Spurious Emission	Adjacent Channel Leakage Leakage Power	

▶ **Figure 3.** SETUP Menu

Table 2 – Data Transmission Speed and Modulation Methods for IEEE 802.11a Standard

Data Rate	Modulation Method	Encoding Rate
6 Mbps	BPSK	1/2
9 Mbps	BPSK	3/4
12 Mbps	QPSK	1/2
18 Mbps	QPSK	3/4
24 Mbps	16QAM	1/2
36 Mbps	16QAM	3/4
48 Mbps	64QAM	2/3
54 Mbps	64QAM	3/4

Table 3 – Channel Numbers and Frequencies

Country	Channel Number	Carrier Frequency [GHz]
Japan	1	5.170
	2	5.190
	3	5.210
	4	5.230
North America	36	5.180
	40	5.200
	44	5.220
	48	5.240
	52	5.260
	56	5.280
	60	5.300
	64	5.320
	149	5.745
	153	5.765
	157	5.785
	161	5.805
Europe	36	5.180
	40	5.200
	44	5.220
	48	5.240
	52	5.260
	56	5.280
	60	5.300
	64	5.320
	100	5.500
	104	5.520
	108	5.540
	112	5.560
	116	5.580
	120	5.600
	124	5.620
	128	5.640
	132	5.660
	136	5.680
	140	5.700
Center Frequency	None	60 MHz, 2.75 GHz, 3.45 GHz, 3.55 GHz, 5.75 GHz, 7.95 GHz and numeric input
		IQ

Testing Transmitted Signals for Compliance with IEEE 802.11a WLAN Standards

▶ Technical Brief

Test Notebook: Measurements of IEEE 802.11a Signals with the WCA11A/WCA380 System
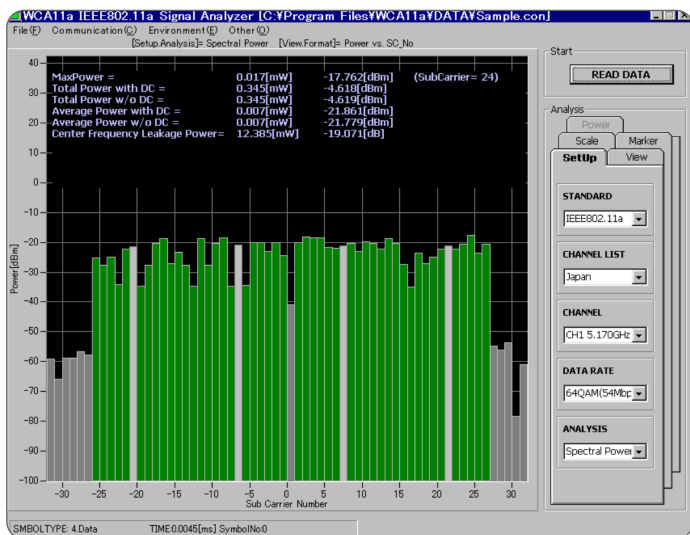
1.0 Spectral Power

Spectral Power Graphs, Power vs. Sub-Carrier Number, Power vs. Time, and Flatness measurements are made with the following procedure.

Analyzing results:

1.1 Download test data to the analysis program from the WCA380 via the Ethernet or recall a previously saved analysis result file from the File ➔ Load menu. (You can also read this information over Ethernet directly from the WCA, and this is the most common method of use.)

1.2 Select ANALYSIS Spectral Power in the SetUp Tab.

1.3 Select FORMAT Power vs. SC_No (or Power vs. Time, Flatness) in the View Tab.

The resulting display presents the power in each sub-carrier of the OFDM symbol designated with the Symbol Select in the VIEW menu. The bar graph in Figure 4 shows Power (dBm) on the vertical axis and sub-carrier number (-32 to +32) on the horizontal axis.

▶ **Figure 4.** *Display of Power vs. SC_No*

Measurement results for Spectral Power appear in the upper part of the display (see Figure 5)
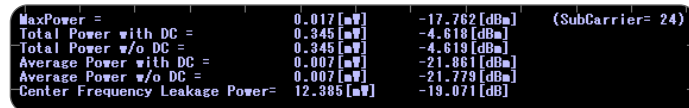
▶ **Figure 5.** *Initial Measurement Results of Power vs. SC_No*

– Max Power searches the maximum values and reads out and displays levels [mW], [dBm] and sub-carrier number.

– Total Power with DC reads out and displays total of all sub-carrier power [mW] and [dBm].

– Total Power without DC reads out and displays total of all sub-carrier power [mW] and [dBm] excluding sub-carrier 0(DC).

– Average Power with DC reads out and displays average power of all sub-carrier [mW] and [dBm].

– Average Power without DC reads out and displays average power of all sub-carrier [mW] and [dBm] excluding sub-carrier 0 (DC).

– Center Frequency Leakage Power calculates, reads and displays the carrier leakage power [dB] and [mW]. The limit is less than 2 dB in the IEEE 802.11a standard.

2.0 Leakage Power

Measures secondarily generated radio waves of 5 GHz band low power data communication systems to the limits specified in Telco Technical Standard Conformance Certification, a Japanese emissions standard. Devices sold in Japan must meet this standard.

2.1 Setting up the device under test

The device under test must continue to output a signal until the series of measurements is finished. Maximum acquisition time for the WCA380 in this mode is about 742 seconds (Block Size = 20, Repeated measurement =14 times, Span of approximately 1 GHz).

Refer to ARIB STD-T71 for details.

2.2 Making the measurement

2.2.1 Select Compliance and Leakage Power in the SETUP tab.

2.2.2 Specify the level for RefLevel and an acquisition number for BlockSize in the POWER tab.

2.2.3 Create the waveform graph

2.2.3.1 From live measurements: Click the AutoAcquisition START button to start measurement. The instrument will automatically perform the measurement over the established range, and create a resultant waveform graph on the PC. (Figure 6). This result can now be stored as a graphic for later recall or insertion into test reports.

2.2.3.2 From stored results: Load analysis result file from the File -> Load menu, and create a waveform graph from the measurement result file.

The resulting power versus frequency number graph shows the levels of spurious emissions at each specified frequency (Figure 6). Data values are listed in the upper part of the screen. The red line overlay describes the limits specified in the standard.
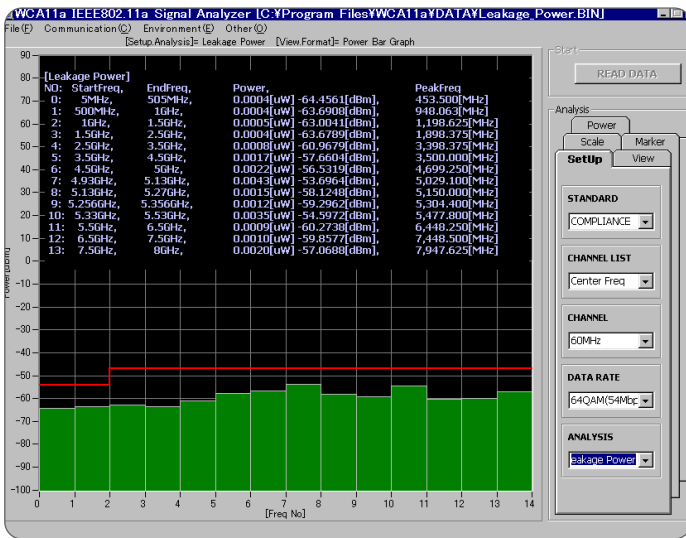

▶ **Figure 6.** *Leakage Power Display*

3.0 Display of Error Vector Magnitude of Sub-Carriers - EVM vs. SC_No

This screen displays EVM of each sub-carrier wave in a bar graph as shown in Figure 7. The limits allowed by the standard are shown in Table 4.

Analyzing results:

3.1 Download test data to the analysis program from the WCA380 via the Ethernet or recall a previously saved analysis result file from the File ➔ Load menu.

3.2 Select EVM ANALYSIS in the SETUP tab.

3.3 Select EVM vs. SC_No in FORMAT in the View Tab.
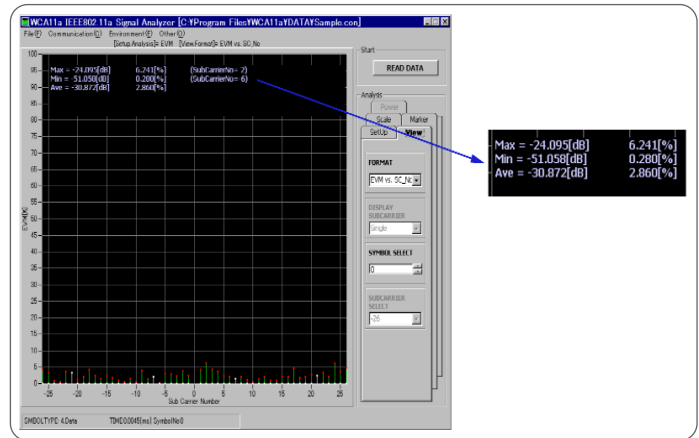
▶ **Figure 7.** *Display of EVM vs. SC_No*

VERTICAL SCALE   Designates an EVM range [%]. Initial value is 100%.

SYMBOL SELECT   Selects symbol number currently displayed in bar graph.

Measurement results are shown in the upper part of the display. They include:

Max   the maximum value of EVM (in % and dB) and sub-carrier number

Min   the minimum value of EVM (in % and dB) and subcarrier number
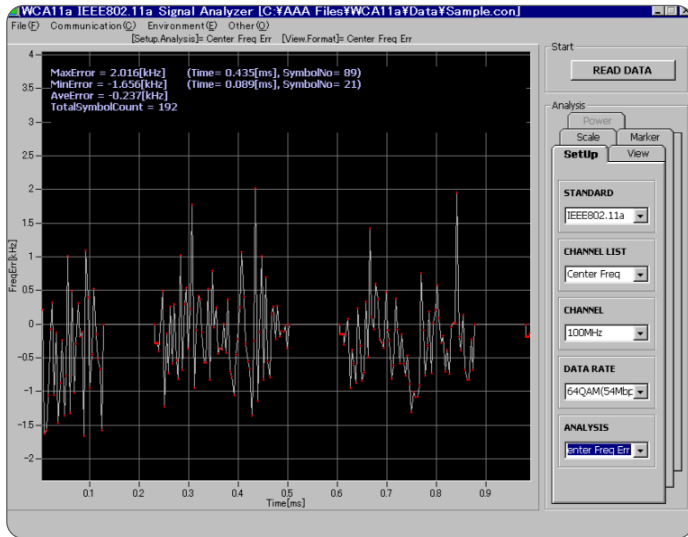
Ave   the average value of EVM

Results are recalculated for each symbol selected.

Table 4 – Allowable EVM in IEEE 802.11a

Data Transmission Speed [Mbps]	Allowable EVM [dB]
6	-5
9	-8
12	-10
18	-13
24	-16
36	-19
48	-22
54	-25

Testing Transmitted Signals for Compliance with IEEE 802.11a WLAN Standards

▶ Technical Brief

▶ **Figure 8.** *Center Frequency Error Display*

▶ **Figure 9.** *Adjacent Channel Leakage Display*

4.0 Center Frequency Error

Figure 8 displays the center frequency error over time in a line graph. The vertical axis is frequency error [kHz], and the horizontal axis is time [ms].

Analyzing Results:

4.1 Download test data to the analysis program from the WCA380 via the Ethernet or recall a previously saved analysis result file from the File ➔ Load menu.

4.2 Select CenterFreqErr ANALYSIS in the SETUP tab.

4.3 Select CenterFreqErr FORMAT in the VIEW tab.

HORIZONTAL SCALE   Specifies time range. Initial value is the time range of the data.

VERTICAL SCALE   Specifies Frequency Error range [kHz].

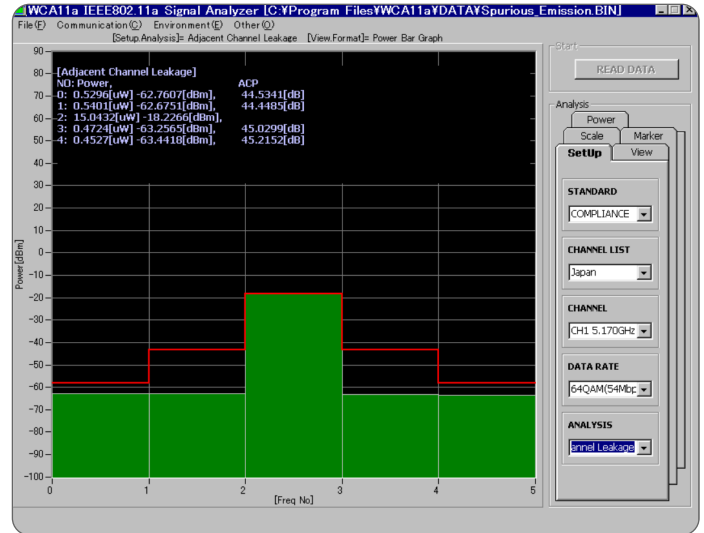Recalculation for each symbol is performed in this display.

Measurement results are shown in the upper part of the display.

MaxError — the maximum frequency error, the time it occurred and its symbol number

MinError — the minimum frequency error, the time it occurred and its symbol number

AverageError — the average frequency error

TotalSymbolCount — total number of symbols

5.0 Adjacent Channel Leakage

Measures the adjacent channel leakage power and out of bandwidth leakage power of 5 GHz band low power data communication systems in order to gain telco technical standard conformance certification.

5.1 Setting up the device under test

The device under test must continue to output a signal until the series of measurements is finished. Maximum acquisition time for the WCA380 in this mode is about 58 seconds (Block Size = 40, Repeated measurement =13 times, Span of approximately 100 MHz). Refer to ARIB STD-T71 for details.

5.2 Making the measurement

5.2.1 Select COMPLIANCE for STANDARD and Adjacent Channel Leakage for ANALYSIS in the SETUP tab.

5.2.2 Select CHANNEL in the SetUp Tab

5.2.3 Specify the level for RefLevel and an acquisition number for BlockSize in the POWER tab.

5.2.4 Click the AutoAcquisition START button to start the measurement.

5.3 Analyzing the results

5.3.1 Select COMPLIANCE for STANDARD and Adjacent Channel Leakage for ANALYSIS in the SETUP tab.

5.3.2 Load analysis result file from the File -> Load menu, and create a waveform graph from the measurement result file.

Measurement results are shown in the upper part of the display, listing the frequency number and adjacent channel leakage in microwatts and dB. The red line overlay describes the limits specified in the standard.

6.0. Spectrum Mask

Figure 10 illustrates the spectrum mask defined in the IEEE 802.11a standard. The data values for the standard mask are listed in Table 5.

6.1 Set up the device under test to continue to output a signal until the series of measurements is finished.

6.2 Making the measurement

    6.2.1 Select STANDARD for IEEE 802.11a, and Spectrum Mask for ANALYSIS in the SetUp Tab.

    6.2.2 Specify center frequency with CHANNEL in the SetUp Tab.

    Note: The center frequency of the WCA380 is set up automatically in this step

    6.2.3 Specify the level for Ref Level and number of acquisitions for Block size in the Power tab.

    6.2.4 Click the Auto Acquisition START button to start the measurement.

6.3 Analyzing the results

The instrument will automatically perform the measurement over the established range, and create a resultant waveform graph on the PC. (Figure 6). This result can now be stored as a graphic for later recall or insertion into test reports.
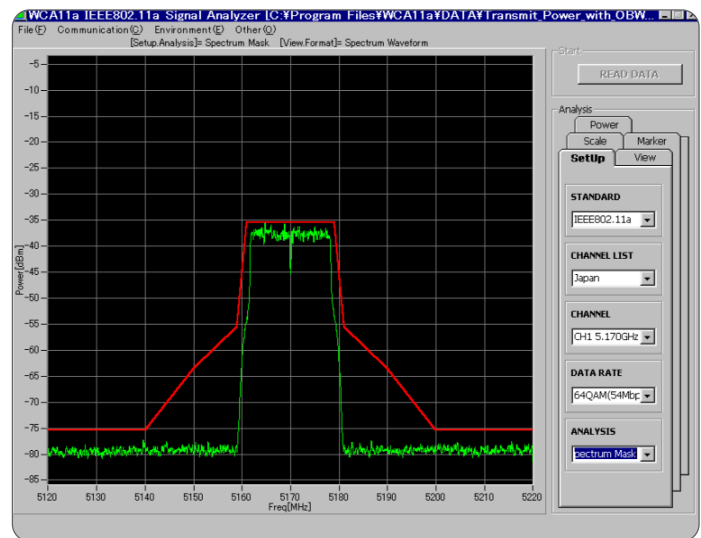
Table 5: IEEE 802.11a Standard for Spectrum Mask

Frequency Offset	Relative Level
-9 MHz to +9 MHz	0 dBc
±11 MHz	≤ -20 dBc
±20 MHz	≤ -28 dBc
< -30 MHz, > +30 MHz	≤ -40 dBc
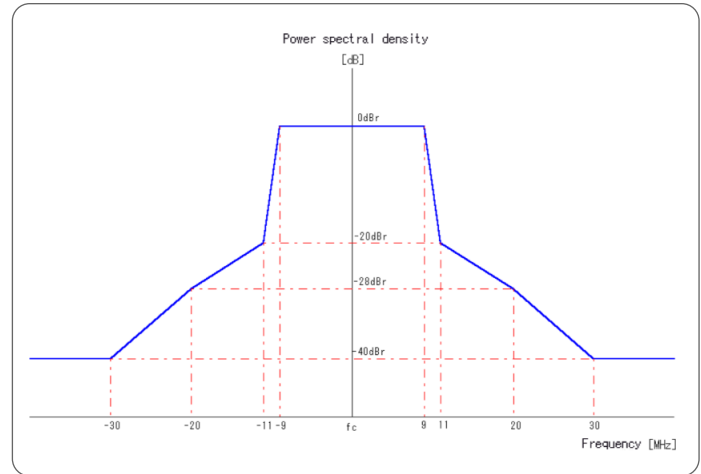
▶ **Figure 10.** *IEEE 802.11a Standard for Spectrum Mask*

Figure 11 shows the results of a spectrum mask measurement. The red line overlay is a representation of the mask defined in the standard.

▶ **Figure 11.** *Spectrum Mask Display*

Testing Transmitted Signals for Compliance with IEEE 802.11a WLAN Standards

▶ Technical Brief

Evolution of IEEE 802.11 - the many phases of WLAN standards

The purpose of IEEE 802.11 WLAN standards is to specify wireless connectivity for fixed, portable, and moving stations within a local area in an environment that can accommodate multiple types of coding, frequencies, data rates and applications. As technology has improved and the use of wireless LANs has become widespread, the standards have evolved in phases to provide a growing number of protocols and performance options.

All of the 802.11 standards have their roots in the familiar "Ethernet" wired LAN environments (as specified in IEEE 802.3, 802.4 and 802.5). They are multi-user Time Division Duplex (TDD) systems that transmit data as frames of independent packets over defined channels in a modulated carrier. Each station listens for transmissions using a Carrier Sense Multiple Access / Collision Avoidance (CSMA/CA) method where all stations are treated equally – continuous transmission connections are not allowed. The WLAN standards also address specific wireless environment issues such as power management, interference and security.

Each of the standards defines protocols in support of a wireless Basic Service Set (BSS) – a group of two or more wireless stations within a cell coverage area that have recognized each other and established communications. The BSS can be made up entirely of peer wireless stations (or nodes) that "meet" temporarily in an ad hoc network to exchange data directly. More commonly, each BSS also contains a fixed access point (AP) node that forms a bridge between the wireless stations and a wireline LAN. In this "infrastructure" mode, stations within the BSS communicate with each other through the AP and are able to access stations outside the coverage area via the LAN through their APs (in this mode, the AP is analogous to the Base Station in a mobile phone network).

Performance Choices in the Physical Layer

Typically, a radio card in the station (or AP) provides the RF and data management functions of the 802.11 standard. Data is packed and unpacked between the Medium Access (MAC) layer (data link to the

digital station or network) or and Physical (PHY) layer using the Physical Layer Convergence Protocol (PLCP). The PHY layer builds the data packets and performs the scrambling, spreading and modulation functions for wireless transmission and reverses the process for reception. The PLCP is a key enabler of evolution and choices in the WLAN, allowing the introduction of new wireless RF performance in the PHY while minimizing changes to the MAC (or the underlying station/network).
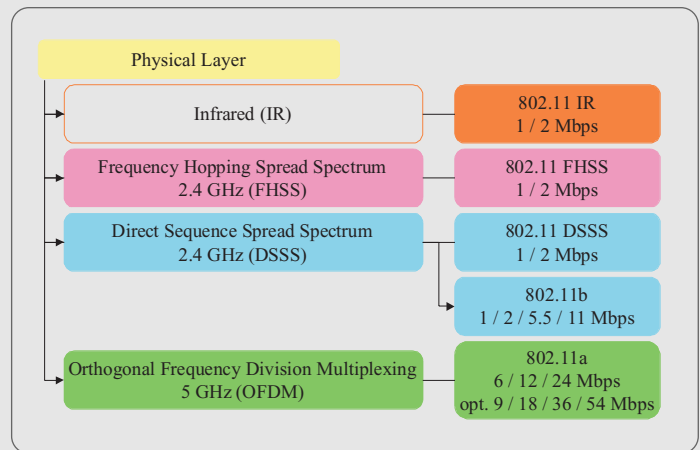
▶ *Figure S1. Evolution of IEEE WLAN standards Physical Layers*
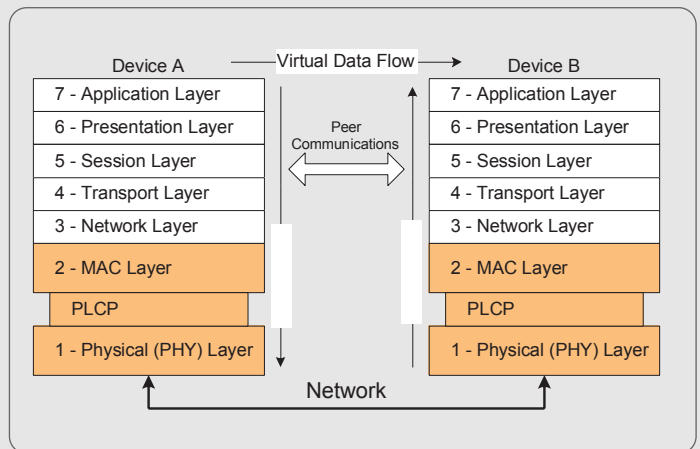
▶ *Figure S2. Simplified diagram of protocol layers in a WLAN*

802.11

The initial 802.11 standard was released in 1997, defining MAC and PHY functionality in both the infrared and RF domains. Two variations of RF technology are specified – Direct Sequence Spread Spectrum (DSSS) and Frequency Hopped Spread Spectrum (FHSS) – both designed to operate in the 2.4 GHz unlicensed Industrial, Scientific and Medical (ISM) band. The DSSS system supports data rates of 1 Mbps and 2 Mbps, using Digital Binary Phase Shift Keying (DBPSK) and Digital Quadrature Phase Shift Keying (DQPSK), respectively.

802.11b

In 1999, the 802.11b standard (also known as WiFi) introduced new spreading and modulation techniques to increase data rates to 5.5 Mbps and 11 Mbps on up to three simultaneous channels in the same 2.4 GHz band. It is backwards compatible with 802.11 DSSS technology and continues to support the same techniques for 1 Mbps and 2 Mbps data rates.

802.11b uses DBPSK and DQPSK for the lower data rates and Complementary Code Keying (CCK) for the 5.5 Mbps and 11 Mbps rates. An alternative method for the higher data rates, Packet Binary Convolutional Coding (PBCC), is permitted by the standard, but not required.

802.11a

Also introduced in 1999, 802.11a supports data rates from 6 Mbps up to 54 Mbps on up to eight simultaneous channels in the 5 GHz Unlicensed National Information Infrastructure (UIII) band - substantial improvements over previous standards. The standard (also known as WiFi5) is not directly compatible with other IEEE WLAN standards (including 802.11b and its pending enhancement, 802.11g), however it can coexist because it uses the identical 802.11 MAC layer to access the network.

802.11a uses a completely different spreading and modulation method in its Physical Layer at the higher data rates – Orthogonal Frequency Division Multiplexing (OFDM). While the 802.11a PHY is very similar to the ETSI HiperLAN/2 standard used in Europe, however,

differences in their MAC layers and contention with European military channels will need to be reconciled in future revisions to allow them to coexist.

802.11g

At this writing, 802.11g has not yet been approved. The most recent revision would support data rates of up to 54 Mbps on up to three simultaneous channels in the 2.4 GHz band. It would be compatible with 802.11b – radio cards from one standard would interface directly with those from the other. 802.11g uses OFDM spreading and modulation to achieve the higher data rates.

Trends

802.11b has become the most popular system for business and institutional wireless LAN's. It is accepted worldwide and is represented in a steady stream of products and a growing installed base of networks. The introduction of 802.11g products to 802.11b networks would be a straightforward upgrade path to higher data rates.

However, the 2.4 GHz band is becoming more crowded and is subject to interference from other networking technologies (such as Bluetooth), cordless phones and microwave ovens. The three channel capacity of 802.11b/g can become an issue in dense BSS environments, imposing limits on the power and range as stations compete for access.

802.11a is gaining favor as products are introduced. The appeal of the 5 GHz band with its broader spectrum and lack of interference from traditional sources is a strong incentive for some users. The large number of channels and higher data capacity also enhance its acceptance; however, the non-compatibility issue continues to be a strong deterrent.

The trend to multiple or multi-mode radio interfaces is the most likely near-term compromise for interoperability and coexistence. Radio cards that support both 802.11a and 802.11b to bridge the two technologies have already begun to appear on the market.

Conclusion

By all indications, IEEE 802.11a will have a significant impact on the technology of enterprise-class networks. The standard presents many new measurement challenges to those who design, manufacture and support network elements. The Tektronix WCA11A Signal Analysis Software and WCA380 Wireless Communication Analyzer offer an integrated, comprehensive measurement strategy with a library of automated measurements and extensive analysis capabilities that will address those challenges today, and in the future, as WLAN standards continue to evolve. The objective is to help establish a uniform testing approach that will improve design reliability and instill confidence between suppliers and customers.

References

1. Resources
   WECA and Wi-Fi:

2. Standards
   Get IEEE 802™ at http://standards.ieee.org/getieee802/

3. Websites
   a. Wireless Ethernet Compatibility Alliance (WECA)
      http://www.wi-fi.org/
   b. IEEE 802.11 Workgroup http://grouper.ieee.org/groups/802/11/
   c. Wireless LAN news http://www.80211-planet.com/
   d. IEEE 802.11b News http://weblogger.com/

Contact Tektronix:

ASEAN / Australasia / Pakistan (65) 6356 3900

Austria +43 2236 8092 262

Belgium +32 (2) 715 89 70

Brazil & South America 55 (11) 3741-8360

Canada 1 (800) 661-5625

Central Europe & Greece +43 2236 8092 301

Denmark +45 44 850 700

Finland +358 (9) 4783 400

France & North Africa +33 (0) 1 69 86 80 34

Germany +49 (221) 94 77 400

Hong Kong (852) 2585-6688

India (91) 80-2275577

Italy +39 (02) 25086 1

Japan 81 (3) 3448-3111

Mexico, Central America & Caribbean 52 (55) 56666-333

The Netherlands +31 (0) 23 569 5555

Norway +47 22 07 07 00

People's Republic of China 86 (10) 6235 1230

Poland +48 (0) 22 521 53 40

Republic of Korea 82 (2) 528-5299

Russia, CIS & The Baltics +358 (9) 4783 400

South Africa +27 11 254 8360

Spain +34 (91) 372 6055

Sweden +46 8 477 6503/4

Taiwan 886 (2) 2722-9622

United Kingdom & Eire +44 (0) 1344 392400

USA 1 (800) 426-2200

USA (Export Sales) 1 (503) 627-1916

For other areas contact Tektronix, Inc. at: 1 (503) 627-7111

Updated 17 June 2002

For Further Information

Tektronix maintains a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology. Please visit **www.tektronix.com/mobile**

Tektronix

Enabling Innovation