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Fast band power measurement technique in Wi-Fi systems using spectrum analyzer

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ABSTRACT

Fast band power measurement technique used for measuring band power in wireless fidelity (Wi-Fi) devices. The difficulty during testing the band power is burst mode transmission takes longer time to measure. A test jig or specialized tool required is costly, which allows continuous mode of transmission for power measurement. The delivered average power by a Wi-Fi device depends upon the data rate which can also vary during time. The procedure proposed hereby developed using a spectrum analyzer to measure band power in the burst mode, in order to ensure repeatable results and optimized to enable fast measurements at low cost, less time and above 90% accurate.

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1. INTRODUCTION

Measurement of radio parameters like band power, peak power spectral density, process gain, and spurious is required during various stages of a radio communication system design, production, and usage. This can be achieved by transmitting a carrier of desired frequency by putting the transmitter in a continuous mode. In wireless fidelity (Wi-Fi) systems, transmission of orthogonal frequency division multiplexing (OFDM) signals will be done in burst mode for both transmit and receive paths. For transmitting these signals in the continuous mode, we have to use specialized tools or test Jigs which will cost lakhs of rupees. Procurement of the same takes time and add to the cost of the research project also. “Fast band power measurement technique in Wi-Fi system using spectrum analyzer” is the best substitute to the reverberation chamber for radiated power measurements [1], [2] and anechoic chamber test facility. The proposed method uses burst mode transmission itself.

The measurement of the band power effective isotropic radiated power (EIRP) radiated by Wi-Fi devices is a quite difficult task. Presently, Wi-Fi devices operate in different modes of the IEEE802.11 specification: b, g, a, n, and ac [3], [4]. Each mode specifies a given maximum achievable data rate and EIRP limitation. For example, the EIRP of IEEE802.11g devices is limited to 100 mW while the maximum data rate is 54 Mbps. Generally, time taken, for the wave form to get stabilized will be depending on the configured mode and it will be 15 to 20 minutes for the configured 20 MHz band width channel. For the channels with band width 40 MHz, 80 MHz, and 160 MHz default spectrum will be occupied only 20 MHz as data transfer is not happening between access point and client. The electromagnetic environment at a given moment affects the actual data rate. The measured average power delivered by the device will not be repeatable and the output signal of the device will vary.

By using an anechoic chamber and the reverberation chamber, the electromagnetic environment can be assumed to be stable for measurements performed but both are costly. The test procedure is hereby proposed to ensure fast and repeatable band power measurement of Wi-Fi systems using a spectrum analyzer with channel power option. The following section specifies about the Wi-Fi communication system in detail. The section 3, describes the proposed procedure for measurement of band power. In the section 4, measurement results are discussed.

2. RESEARCH METHOD

The term Wi-Fi refers to technology for wireless local area network (WLAN) applications based on the IEEE 802.11 standards [5]. The unlicenced frequency bands industrial, scientific and medical (ISM) have been allotted for Wi-Fi: 2.4 GHz band consisting of 14 channels, and the 5 GHz band consisting of 11 channels, each with a bandwidth of 20 MHz and other channels are used for Wi-Fi according to specific country guidelines. The modes b, g, a of 802.11 specification was followed by modes n and ac [6]–[20]. Modes a, g, n & ac based on OFDM and mode b is based on the direct sequence spread spectrum (DSSS). Modes of IEEE 802.11 specifications are shown in Table 1.

Table 1. Modes of IEEE 802.11 specification

IEEE 802.11 modes	Frequency band (MHz)	Maximum data rate (Mbps)	Modulation schemes
b	2400-2483.5	11	DSSS (BPSK,CCK)
g	2400-2483.5	54	OFDM (BPSK,QPSK,16-QAM,64-QAM)
n (20/40MHz)	2400-2483.5 5150-5350 5825-5875	130/300	OFDM (BPSK,QPSK,16-QAM,64-QAM)
a	5150-5350 5825-5875	54	OFDM (BPSK,QPSK, 16-QAM, 64-QAM)
ac (20/40/80/160 MHz)	5150-5350 5825-5875	86/200/ 433/866	OFDM (BPSK,QPSK, 16-QAM, 64-QAM,128-QAM & 256-QAM)

3. PROPOSED PROCEDURE FOR MEASURING BAND POWER

Spectrum analyzer with channel power option shall be used for band power measurement EIRP. To have fast and repeatable band power measurements, we have innovated a test method in burst mode. Test setup block diagram is shown in Figure 1. In this method we have installed a test tool to send data from access point equipment under test (EUT) to client. There may be many tools for this purpose. We have utilized JPerf/iPerf tool for data transfer between client and AP while measuring the band power. JPerf running time can be set for 60 sec. As data transmission will be happening between access point & client, so the configured bandwidth will be fully utilized. Occupied spectrum will have full power. Record the band power measurements from spectrum analyzer.

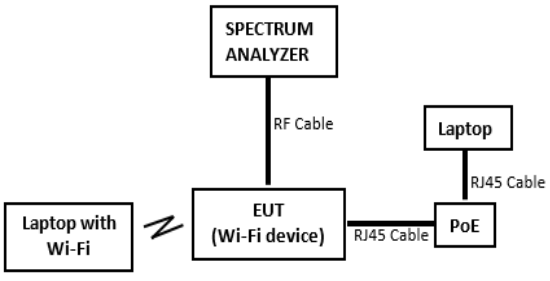

Figure 1. Test setup of block diagram

See the step for settings to run the Jperf tool:

a) Access point (AP): 1) iPerf mode: client, 2) server address & port: server IP address & port number, 3) protocol: UDP, 4) transmit time: 60 sec, 5) UDP Bandwidth: sent packets (as per the configured mode), and 6) UDP packet size: 1000 octets for 'a/b/g mode' and 4096 for 'n/ac mode'.
b) Client: 1) iPerf mode: server, 2) protocol: UDP, and 3) UDP packet size: 1000 octets for 'a/b/g mode' and 4096 for 'n/ac mode'.

c) Settings in spectrum analyzer for measuring band power: 1) press on measure button, 2) select channel power, 3) press frequency button-> enter center frequency of the channel configured, 4) enter CH BW 20 MHz/40 MHz/80 MHz/160 MHz, 5) press on trace button, and 6) select trace1 and then click on max hold.

Set the minimum data rate supported in each mode, after completing the configuration in Jperf, click on 'run JPerf' button on both laptop-1 and laptop-2 and note down band power reading from the spectrum analyzer. Band power measures the total power within the specified frequency band. Power in band is characterized by the following equation:

$$Power\ of\ Band = \sum_{f_I}^{f_h} X\ (f)$$

Where X is the input power spectrum from a specified band, f_h is the high bound of the frequency band and f_l is the low bound of the frequency band. The high and low bounds of this band can be determined from the center frequency. The levels and frequencies of peaks in a specified band will be determined by spectral peak search algorithm. This algorithm use interpolation to precisely locate frequency peaks in the power spectrum in any units or scaling. The exceeded specified threshold, we can specify whether to locate a single maximum peak or multiple peaks.

The waveforms of IEEE 802.11b and IEEE 802.11g modes showed in Figure 2 and Figure 3 respectively. The signals obtained for both modes spread in 20 MHz BW. The waveform of mode ac (BW 80 MHz) shown in Figure 4. The data transmission for 60 sec using JPerf tool is shown in Figure 5.

Figure 2. Waveform of the IEEE802.11b mode

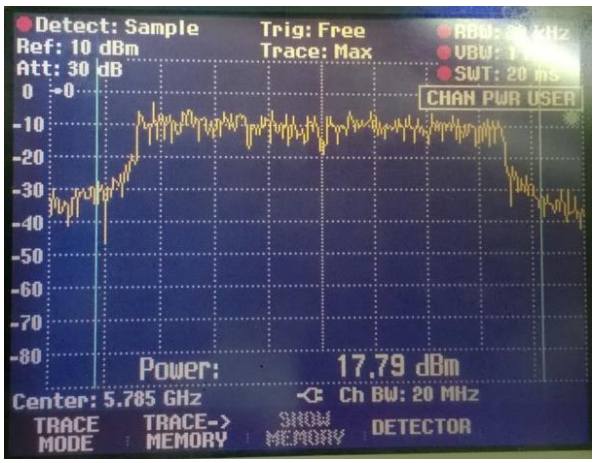

Figure 3. Waveform of the IEEE802.11g mode

Figure 4. Waveform of the IEEE802.11ac mode

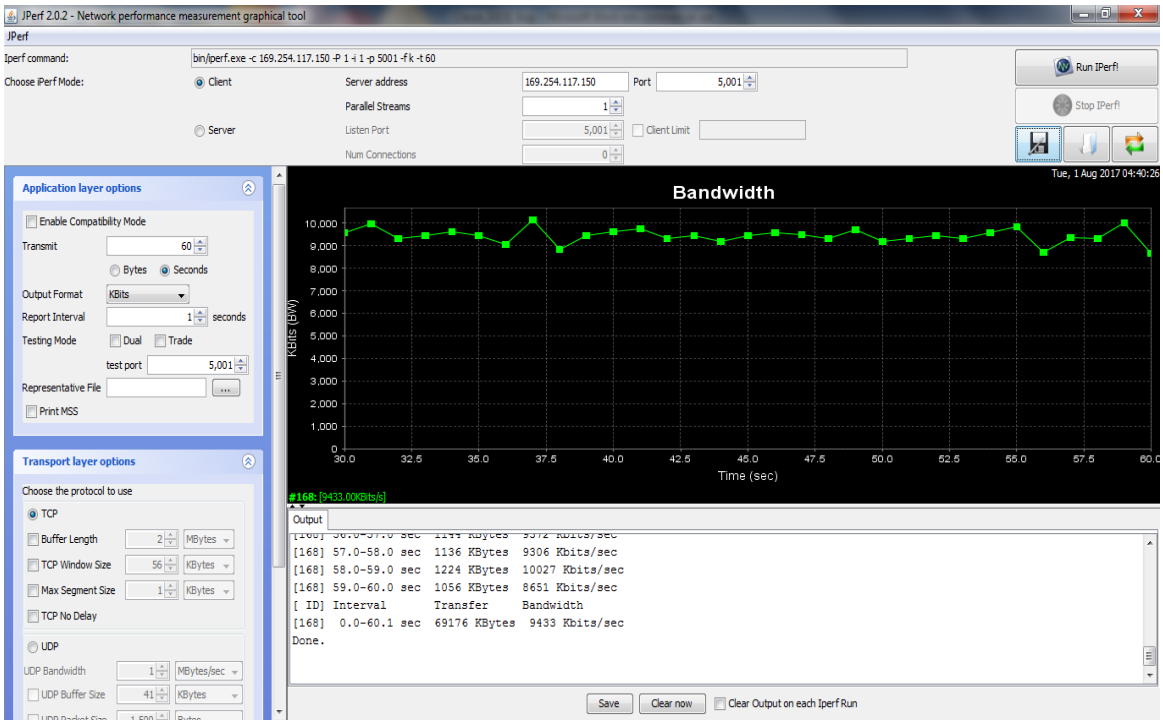

Figure 5. Data transmission for 60 sec using JPerf tool

4. RESULTS AND DISCUSSION

Table 2 displays the comparison between the measured band power of Wi-Fi cards in 2.4/5 GHz bands in three iterations, also shows that the measured band power is within the output power specified by commercially available access points manufacturers. The measurement results are same in three iterations which shows that measurement procedure is consistently giving the more or less same results. The band power measurement of a Wi-Fi device can be performed in a minutes for all channels: 1 to 14 (b/g/gn modes) & 36, 40.44, 48, 149, 153, 157, 161, 165, 169, and 173 (a/an/ac modes). By using these measurements to tune the antenna to optimize its performance at the middle frequency of the Wi-Fi band. Measured band power lies within the range of 22 dBm for Wi-Fi devices (compex).

The band power measured for commercially available Wi-Fi cards result is shown in Table 2. The output band power specified by manufacturer's is provided wherever it was available. The measured values are taken by configuring minimum data rate supported in each mode. It is observed that concurrence is achieved between the measured band power and the manufacturer's specified band power.

Table 2. Comparison chart of manufacturer's specified band power and measured band power

Wi-Fi system	Manufacturer's specified band power [dBm]	1st Iteration measured band power [dBm] (cable loss 1 dB excluded)	2nd iteration measured band power [dBm] (cable loss 1 dB excluded)	3rd Iteration measured band power [dBm] (cable loss 1 dB excluded)
Wi-Fi system with compex WLE 200NX	20±2	19.16	19.14	19.02
Wi-Fi system with compex WLE 600VX	20±2	20.03	19.83	20.13
Wi-Fi system with compex WLE 900VX	21±2	19.88	19.53	19.66
Wi-Fi system with REALTEK 8197FB (2.4GHz) chip set	25±2	21.00	21.16	21.23
Wi-Fi system with RTL 8812BRH (5 GHz) chip set	20 to 25	21.56	21.20	21.45

5. CONCLUSION

The band power measurement of Wi-Fi devices using a spectrum analyzer was hereby investigated. By using proposed measurement procedure, repeatable results achieved with less time at low cost though the data rate of Wi-Fi communications can vary during the measurement. It is observed that concurrence is achieved between the measured band power and the manufacturer's specified band power. Any Wi-Fi device can be tested in a few minutes for all channels in all modes of the Wi-Fi frequency bands. This method can be used for measurement of band power in all types of Wi-Fi devices. Using this technique will achieve low cost, less time and above 90% accuracy. Statement that what is expected, as stated in the "introduction" chapter can ultimately result in "results and discussion" chapter, so there is compatibility. Moreover, it can also be added the prospect of the development of research results and application prospects of further studies into the next (based on result and discussion).

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