Measurement Architectures for the 802.11 WLAN PHY Layer

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This paper looks at the requirements of the 802.11 PHY layer specification and how a measurement architecture, the Anritsu MT8860A has been developed to meet the specification.

The IEEE 802.11 PHY Layer Specification.

The IEEE specification contains a number of parameters which successful designs are intended to conform with. The purpose of the specification is to ensure interoperability with not only other WLAN transmit and receive systems, but also to ensure that the WLAN system does not fail in the presence of other types of co-existent transmit/receive systems, or cause undue interference to other users of the spectrum. Specifications are often written well in advance of the deployment of actual systems, consequently there may be ambiguities in the interpretation when confronted with actual devices.

The specification describes three different types of PHY layer implementation. These are Infrared, frequency hopping and Direct Sequence Spread Spectrum. DSSS is the most popular implementation.

This paper will look at several aspects of the 802.11 PHY DSSS layer and see how the specification can be interpreted to produce measurement systems. Although the 802.11 layer is a generic standard, implementation varies from country to country to conform with local spectrum licensing conditions. These local conditions affect the maximum power for transmit and the frequency spectrum availability.

Although some generic continuous transmission test modes have been suggested by the IEEE, not all manufacturers have adopted these suggestions so the test set has to cope with pulsed transmission for all the measurands.

This paper describes a specific architecture, the Anritsu MT8860A test set, developed to test a number of the PHY layer measurands.

Both transmitter and receiver tests are described.

Transmitter Measurements

Rise and Fall Time

Transmit Power on Ramp
The specification states that the power on ramp from 10% to 90% of the maximum power should not exceed 2μs in duration.

Output Power

Varies from region to region. The largest permissible power is 1W for a ‘b’ device in the USA. More typically the power output reaches approximately 20mW. These specifications are for the average power. If the card does not have a continuous transmit mode then the power is calculated from the power in the pulse.

WLAN cards have power control loops and these are individually calibrated.

Frequency Measurements

The transmitted frequency should be ±25ppm of the carrier frequency for ‘b’, but ±20ppm for ‘a’.

Conventional frequency counters are designed to measure CW signals. Counters are normally based on sampling gate front ends with a sub sampling LO. Signal identification requires several shifts of the LO, if the signal is pulsed or modulated then the counter often fails to measure correctly.

An alternative method for measuring the frequency on a modulated carrier is to use a Costas Loop. A digital implementation of this circuit can extract the carrier frequency, even under pulsed conditions.

Spectrum Mask

The spectrum mask defines the interference to adjacent channels. The ‘b’ specification refers to a Sin x/x profile for the transmitted signal and the mask is defined around this profile.
The transmitted spectral products must be less than –30 dBr (dB relative to the Sin x/x peak) for:-
fc – 22 MHz < f < fc –11 MHz; and
fc + 11 MHz < f < fc + 22 MHz;
and less than –50 dBr for:-
f < fc – 22 MHz; and
f > fc + 22 MHz.
Where fc is the channel center frequency.
The transmit spectral mask is shown below. The measurements must be made using a 100 kHz resolution bandwidth and a 100 kHz video bandwidth.

The data payload for this test is not defined. Transmitting different payloads, such as all 1’s and all 0’s makes a difference to the peak power. As the peak levels vary with the data, the instrumentation needs to track the peak level and define the mask test limits relative to the tracked peak level on a sweep by sweep basis.

Carrier Suppression

Carrier must be suppressed to better than –15dB.

Receiver Measurements

PER:- Packet Error Rate

The packet error rate is defined at one set power level. This sets the effective sensitivity required for an operating design.
The IEEE specification states that the Packet Error Ratio must be less than 8% at a PSDU length of 1024 packets for an input level of –76dBm measured at the antenna connector for a data rate of 11Mbit/s with CCK modulation.

PER with Co-Channel Interference

Adjacent channel rejection is defined between any two channels with >25 MHz separation. The adjacent channel rejection must be equal to or better than 35 dB, with a PER of 8 x 10–2 using 11 Mbit/s CCK modulation and a PSDU length of 1024 packets.

Test Set Requirements.

For transmit testing power, frequency, spectral flatness and EVM.
The measurement needs can be met with a dedicated architecture designed to measure these measurands.

The test set comprises of several key blocks.

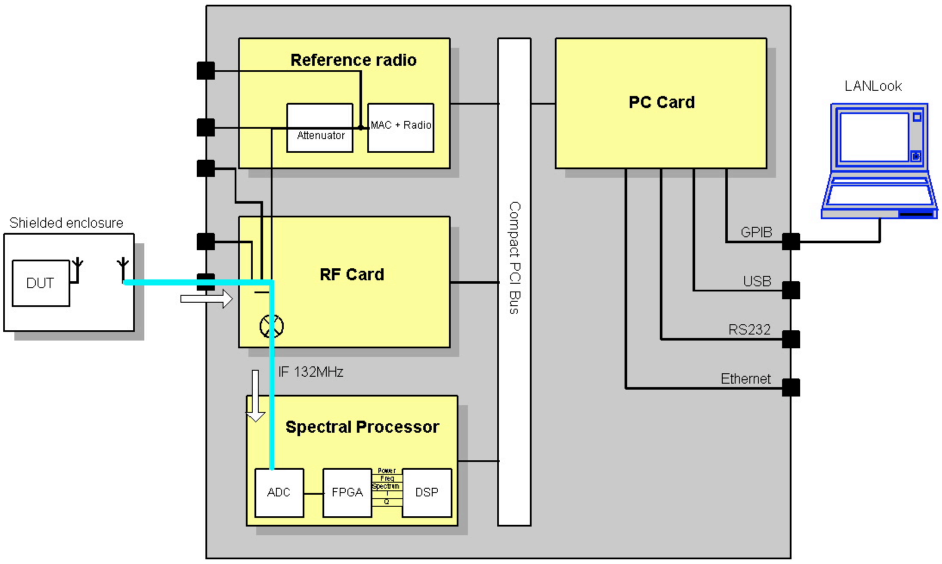

Figure 1. Block Diagram of MT8860A showing DUT transmitter measurement path

RF Card:-Narrowband down converter. This is a self-contained Dual IF based receiver that can down convert from either the 2.4GHz ISM band or the 5.8GHz ISM band. The LO is set between the 2 ISM bands and band selection is achieved by swapping between upper and lower sidebands. The final IF output is at 132MHz.

To keep the signal level in the optimum operating range for the digital IF in the spectral card, the down converter uses a RF sub-ranging architecture with switchable IF gain blocks and RF attenuators. Gain switching is automatic.

Spectral Processor Card

The spectral card is a digital signal processor. The 12bit ADC is clocked at 176 Ms/s. To achieve the resolution required over the whole dynamic range, a sub ranging architecture is adopted, with variable gain IF stages.

The digital signal processing is implemented in a FPGA. 2 parallel blocks are required.

Block 1. Time Domain measurements. The power profile of the 802.11 burst is measured. The I and Q measurements from the digital IF are squared to produce the output power. The Power measurement can be gated. These gates are also used to select the data for the spectrum measurement so that the spectrum is measured from the transmit data and does not include data from the ramp on and ramp off phases.

Block 2. Frequency Domain measurements. Conventional analogue IF spectrum analysers use swept Local oscillators to build up a picture of a modulated signal by convolution. This takes time as the oscillator has to be swept slowly across the band at a speed low enough to allow the IF filter to settle. This can produce some misleading results on time varying signals. In contrast a digital IF captures the data in one sweep and then uses a Fourier Transform to produce the spectrum.

The implementation in the test set uses a new type of FFT implemented in hardware, the Pipeline Fourier Transform. This transform provides a considerable speed improvement over a conventional FFT, and has a number of other advantages in terms of filter shape.

The specification calls for a measurement to be made with the equivalent of a 100KHz resolution bandwidth filter. The PFT works on the basic principle of successively splitting the frequency band from the previous stage in to two further sections. The effect of this is that the PFT splits the entire RF input band into the equivalent of X times 100KHz gaussian filters sub-bands simultaneously. The signal power is measured in each of these sub-bands at 44 million times a second. The frequency response of the filters in each stage of the PFT has a good roll off and is not re-entrant within the band, unlike a conventional sin x/x response. This provides good isolation between adjacent bins. The output from each sub-band is then plotted to provide the frequency spectrum.

Golden Radio and Power Control Loop

Packet Error Rate.

The packet error rate test uses a golden radio and an external power levelling loop. The golden radio is used to generate the test packets. All the protocol is handled within the radio chipset. The power control loop is used to accurately control the power from the golden radio and to eliminate any amplitude drift of the golden radio. To test the PER the radio sends out a test packet. The control loop and the electronic step attenuator determine the power level. Immediately after the transmission has taken place, the electronic attenuator sets itself to low attenuation ready for the receive mode. The device under test receives this packet and then replies sending an acknowledgement to the golden radio. The acknowledgement is received at a high power level compared with the transmitted test packet, so does not inadvertently contribute to the PER. This test method saves having to probe the registers within the WLAN DUT but can only be realised by using an electronic step attenuator, which is fast enough to change state between transmission and reception.

PER with Inter-modulation or Adjacent carrier.

These tests require an interfering signal to be combined with the signal from the golden radio. This is achieved by arranging a switched path to connect 1 or 2 interfering sources into the signal path of the DUT.

Conclusion

This paper outlines the requirements of the PHY layer and how the architecture of the Anritsu MT8860A has been developed to be a flexible platform to make measurements on the primary measurands.

Acknowledgements
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