Title: IEEE802.11 FH-PHY FCC 20 dB bandwidth Conformance testing

John Fakatselis, Carl Andren, Jim Snell
Harris Semiconductor
P.O. Box 883
Melbourne, Florida 32901-0883
Tel: 407-724-7535
Fax: 407-724-7094
email:candren@ccmail.mis.semi.harris.com

Introduction

In reviewing the FCC requirements from 47 CFR Sec. 15.247 which describes compliance requirements for FH systems at the 2.4 GHZ and 5.7 GHZ ISM bands the specification leaves room for interpretations that might present difficulties in obtaining approval. To mitigate the risk of misinterpretation of the specification it is probably a good idea to forward, for FCC approval, a test procedure that will eliminate interpretations of non compliance. The concern is about the 20 dB bandwidth measurement. The test procedure needs to clearly illustrate that the spectral characteristics of the preamble chosen for the FH PHY complies with the FCC sections listed below. The paper begins with the applicable FCC sections, followed by a discussion of a position that one might take to question compliance. The paper continuos with test procedure alternatives that are recommended to establish that the presently defined FH-PHY waveform is compliant.

FCC Test Requirements

The relevant specifications are:

from 47 CFR Sec. 15.247

(1) Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. The system shall hop to channel frequencies that are selected at the system hopping rate from a psuedorandomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted

signals.

(ii) Frequency hopping systems operating in the 2400-2483.5 MHz and 5725-5850 MHz bands shall use at least 75 hopping frequencies. The maximum 20 dB bandwidth of the hopping channel is 1 MHz. The average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 30 second period.

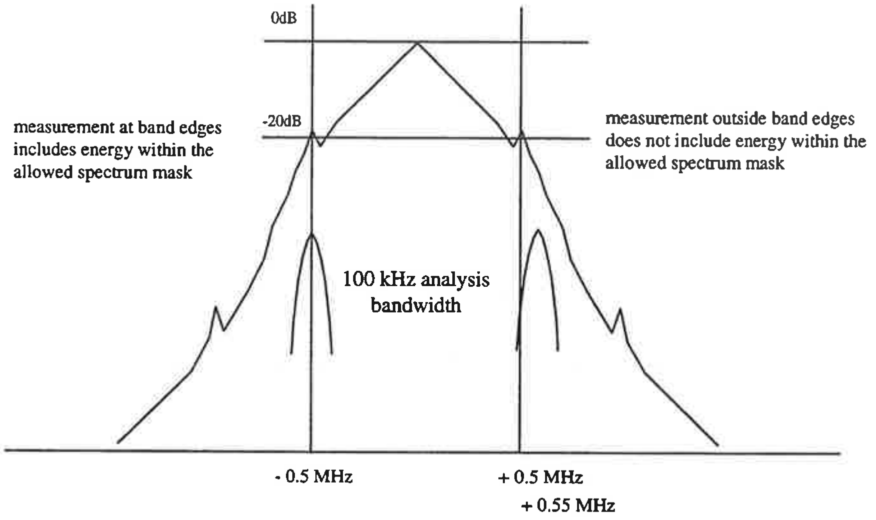
(c) If any 100 kHz bandwidth outside these frequency bands, the radio frequency power that is produced by the modulation products of the spreading sequence, the information sequence and the carrier frequency shall be either at least 20 dB below that in any 100 kHz bandwidth within the band that contains the highest level of the desired power or shall not exceed the general levels specified in Sec. 15.209(a), whichever results in the lesser attenuation. All other emissions outside these bands shall not exceed the general radiated emission limits specified in Sec. 15.209(a).

Discussion; 20 dB bandwidth

The primary question here is the measurement of the 20 dB bandwidth. One interpretation is that paragraph (ii) states that the energy outside of the 1 MHz bandwidth be 20 dB below the energy within. Another interpretation is that the level of any spurious signal outside +/- 0.5 MHz must be at least 20 dB down from the highest power within the channel when measured in some bandwidth. In related guidance to the specifications for DS systems bandwidth, the FCC suggests using a spectrum analyzer with a 100 kHz resolution bandwidth. Additionally, Paragraph (c) talks about energy outside these bands (the 2400-2483.5 MHz and 5725-5850 MHz bands) as being down 20 dB from the energy within when measured in a 100 kHz bandwidth. This would seem to support the second interpretation by similarity.

The primary problem is that the chosen modulation and signaling scheme uses FSK with a preamble containing an alternating mark-space pattern. This preamble produces two spectral lines at exactly +/- 0.5 MHz. If the second interpretation rules, we are faced with asking the question: how do you account for the energy of an impulse that falls right on the line. Theoretically, one half of the energy is on one side of the line and half on the other. Any measure taken with a 100 kHz filter at +/- 0.5 MHz will show both parts and should be adjusted down by 3 dB. See figure 1, which is a representation of the computer simulations that have been done. A fairer test is to say that the first 100 kHz bandwidth outside +/- 0.5 MHz be 20 dB down.

Spectrum Measurements



The figure above shows the two spectral lines at the band edges that are due to the preamble on a 400 byte packet. Since the lines are right at the band edge, a filter at the band edge captures the whole of the energy in the spike and some of the energy within the +/- 0.5 MHz. Figure 2 shows the computer simulation of repeated 400 byte packets and figure 3 shows what happens when the preamble is not included. Since the FCC has stated that they want the worst case, we feel that the preamble must be included.

The 802.11 scheme is a packet communications system which uses packets with a small percentage of header and the rest random data. There are three effects that cause energy to be found outside +/- 0.5 MHz.

- The bursty nature of packets. The 802.11 specification call for up to 8 us of power turn and off ramping to minimize this.
- The spectral energy of the normal modulation sidebands. This has been addressed by restricting the modulation deviation at the expense of efficiency and using Gaussian FSK filtering to further minimize the occupied bandwidth.
- The percentage of the energy that is in the preamble that puts two spurs exactly at the boundaries.

A reasonable test is to use repeated data packets of average length and integrate the energy for at least 100 mS. That way the occurrence of an occasional short packet will not bias the results. When running this test with a HP 8594E or equivalent it is possible to let the instrument make all the necessary calculations. This instrument uses an unknown algorithm for the measurements. While a computer simulation of the spectrum analyzer would be best for determining the exact degree of the problem, we do not have enough insight to the workings of the analyzer to make the simulation. Some analyzers will no doubt use the FFT approach for analysis as we used in the simulations. In this case the results should be similar.

Figure 2, Spectrum with preamble.

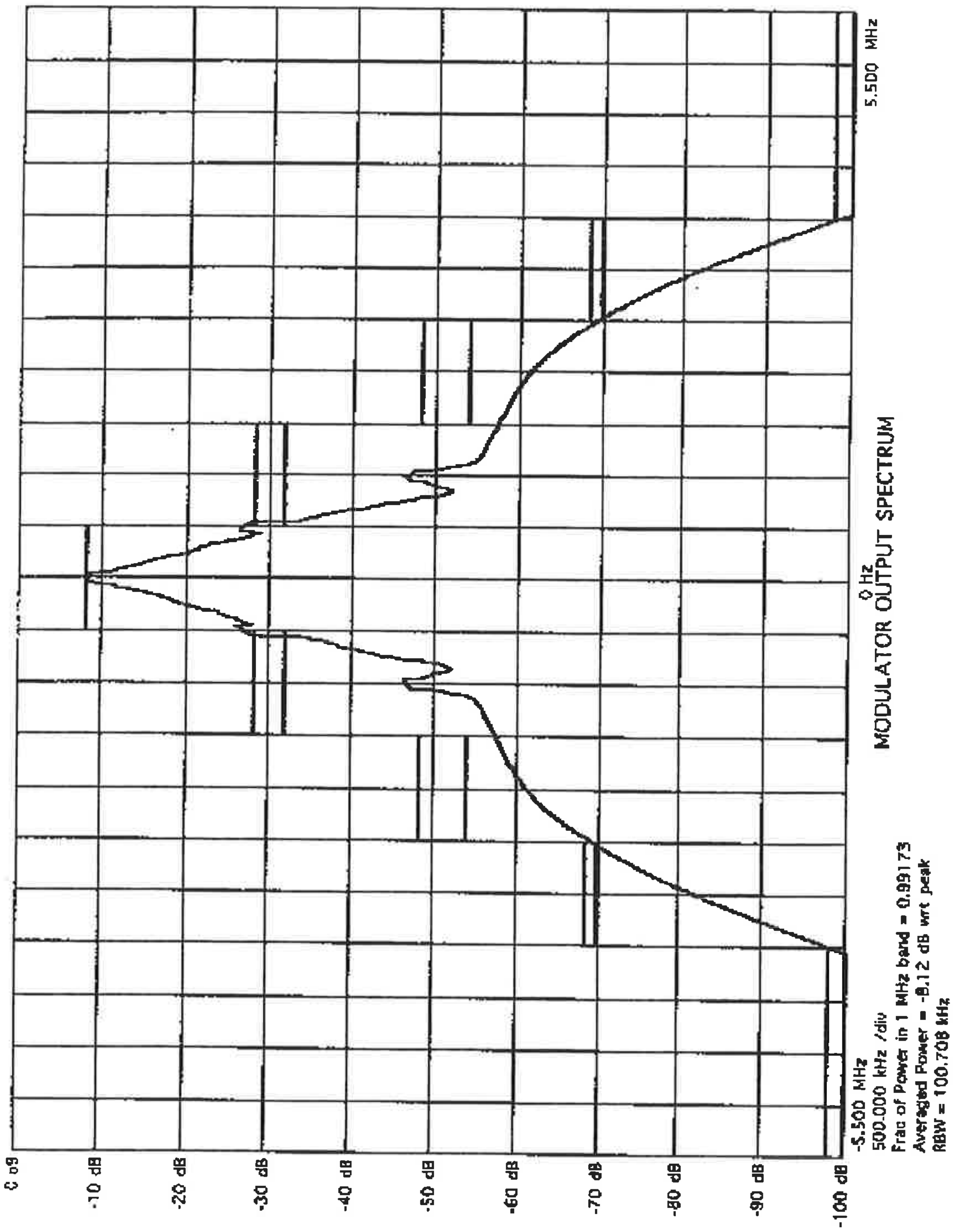
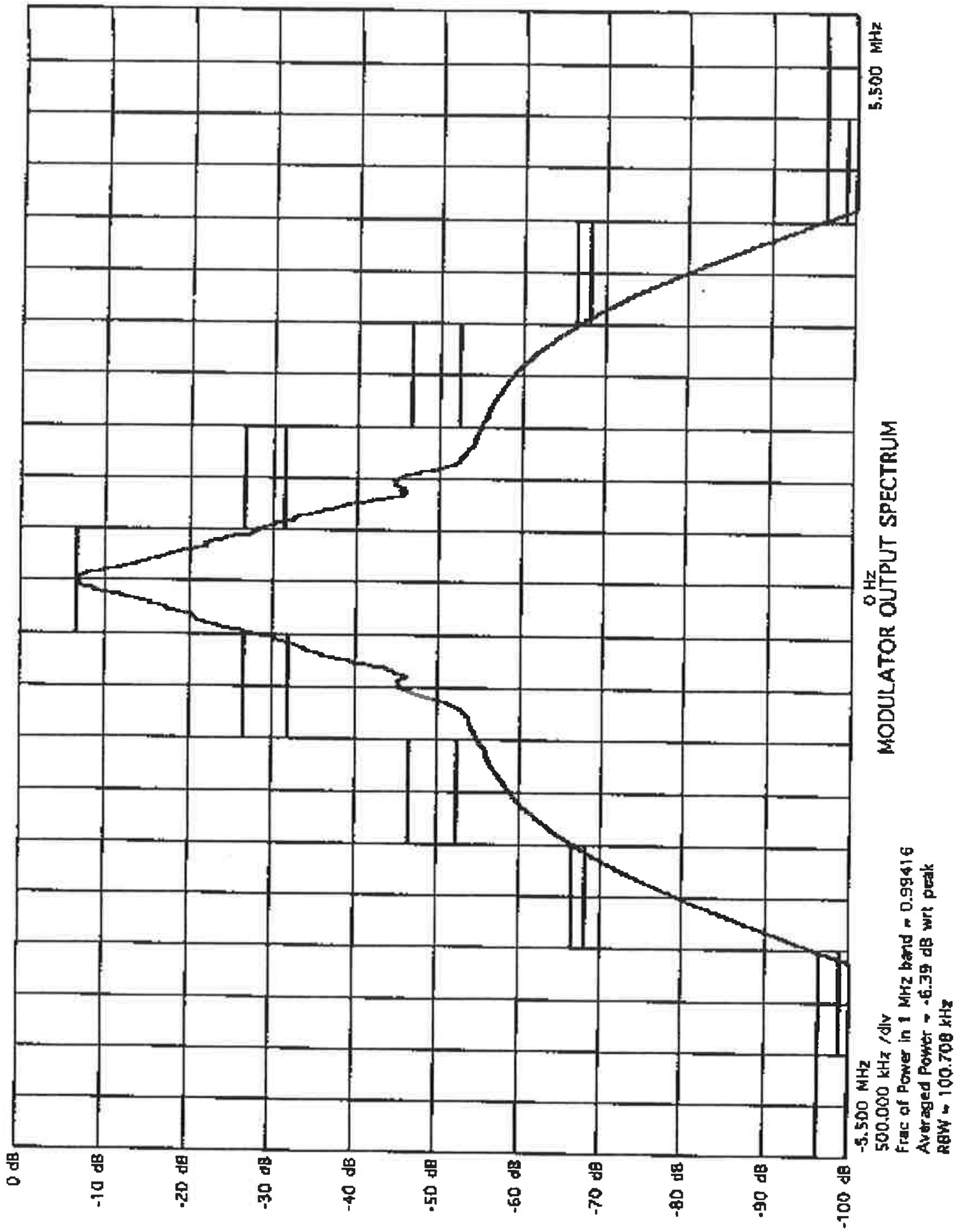


Figure 3, spectrum without preamble



As earlier mentioned, the test should be run where the first 100 kHz outside the +/- 500 kHz boundaries should be 20 dB down from the energy at the peak. Thus the 20 dB energy measurement should be made at +/- 550 kHz from the frequency of the energy peak. Alternatively, the separation of the 20 dB down frequencies should be verified to be no more than 1.1 MHz apart when measured with 100 kHz bandwidth.

All other tests are simple by comparison. Testing the frequency hopping pattern is possible, but not necessary as the hopping pattern can be determined by inspection of the design. An examination of the spectral energy of the hopper will show the evenness of the frequency visitation by the flatness of the spectrum. The test should be run with a digital analyzer that can average the spectrum for an integer number of epochs of the hopping sequence.

TEST PROCEDURES

20 dB bandwidth

Set up the radio under test to send packets of 400 bytes repeatedly. Using a suitable spectrum analyzer, measure the energy of the peak of the spectrum using a setting of 100 kHz for the analysis bandwidth and a video bandwidth of 10 Hz. From this measurement, find the points where the spectrum is 20 dB down and verify that they are no more than 1.1 MHz apart.