January 1998 DOC:IEEE P802.11-98/20a

Proposed Modifications to M-ary Bi-Orthogonal Waveform Presented in doc:IEEE P802.11-97/144

January 1998
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Raytheon document: mok_mod.ppt

•Submission Slide 1 Wesley G. Brodsky, Raytheon

In document IEEE P802.11-97/144 (reference [1]), an M-ary Bi-Orthogonal Keyed waveform was proposed. This document proposes some modifications to this waveform. First, we propose that the I and Q channels be offset in time by ½ a chip period, similar to Offset Quadrature Phase Shift Keying (OQPSK). Second, we propose that the Quadrature form of this modulation be used for both the "full-data-rate" and "half-data-rate" implementations of this waveform. Third, we propose adding three chips to each "Walsh symbol", to facilitate FCC approval of the waveform. The reasons for these suggestions are given next.

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Proposed Modifications

- **Offset I and Q Channels by 1/2 Chip Period**
  - Less Spectral Growth Through Saturated Power Amplifier
  - Allows Operation with 0 dB, instead of 5 dB Backoff
- **Use Quadrature form of the modulation for the half-data-rate mode**
  - Half the bandwidth for the half-data-rate mode
  - Allows 7, rather than 3, distinct frequency channels
  - Requires second, half-bandwidth filter(s)
- **Use 11 chip symbols**
  - Avoids problem with FCC requirements
  - Do not widen transmitted bandwidth
  - Data Rate = (8/11) old data rate

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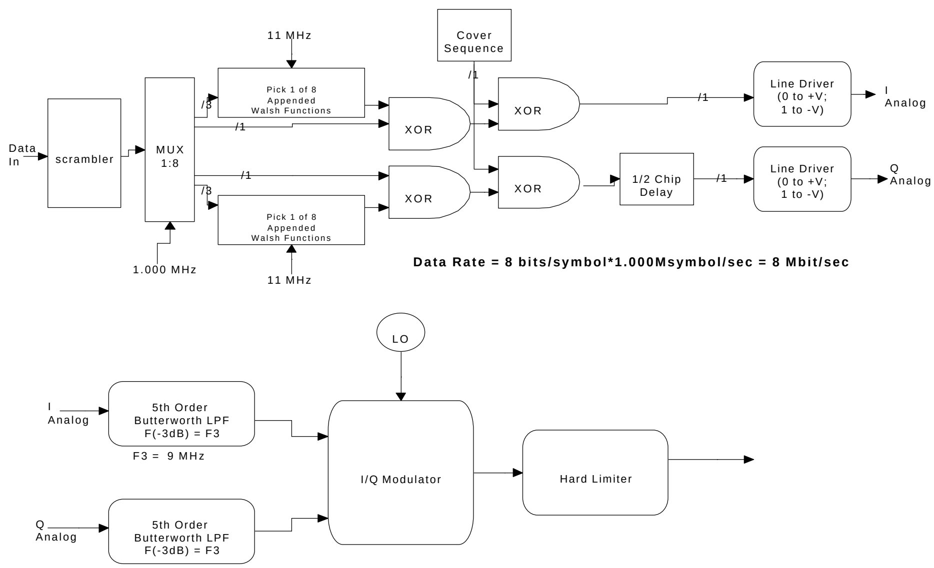
Transmitter Incorporating the Suggestions

Full-Data Rate



•Submission Slide 3 Wesley G. Brodsky, Raytheon

The waveform originally [1] proposed requires RF power amplifier backoff . We at Raytheon feel operation of the transmitter's RF power amplifier at saturation is preferable for two reasons. First, dc power efficiency is improved. Second, it is not necessary to precisely control the gain throughout the transmitter RF chain in order to precisely control RF transmitter output power. Instead, only the saturated power output of the power amplifier need be controlled. It is well known [2] that Offset Quadrature Phase Shift Keying exhibits less spectral growth through a saturated power amplifier than Quadrature Phase Shift Keying. This principle can be applied to the proposed waveform by delaying the Q channel ½ a chip period more than the I channel. Since the waveform originally proposed already requires the receiver process the signal coherently, it can distinguish the I from the Q channel, and re-align them.

There has been some question if the waveform proposed in [1] will meet FCC requirements with only 8 chips in each symbol. To eliminate this question, we propose adding 3 chips to each Walsh function. One of eight possible symbols is still transmitted. Each symbol now has eleven, rather than eight, chips. In order to keep enough frequency channels in the allocated band, we propose keeping the 11 Mb/s chipping rate, and decreasing the data rates to 8 Mb/s (full rate).

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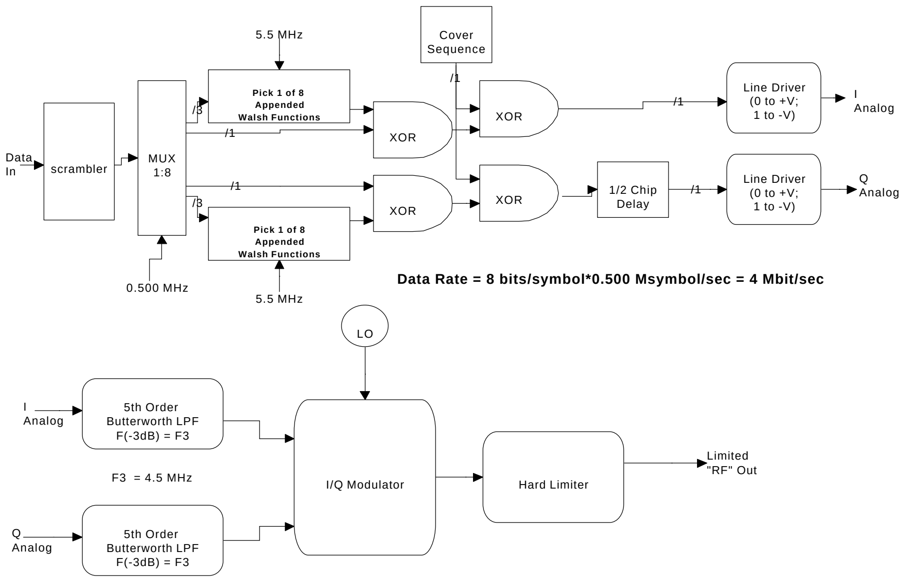
Transmitter Incorporating the Suggestions

Half-Data Rate



•Submission Slide 4 Wesley G. Brodsky, Raytheon

Binary, rather than quadrature, modulation was originally [1] proposed for the half-data-rate case. Binary modulation exhibits more spectral growth through a saturated power amplifier than does offset quadrature modulation. This is because it goes through the origin of the I/Q plane, so has a high amplitude variation. This is one reason to use Quadrature Offset modulation for the half-data-rate case. Another reason is to reduce the occupied bandwidth, even with a linear power amplifier, to allow for more channels. In a three-dimensional office environment, modeling cells as cubes, there are often up to six other networks which can interfere with the network being used. (The power level for interference is lower than the power level for reliable reception.) For this reason, at least seven different frequency channels are desired. With 11 MHz chipping, only 3 or 4 channels are achieved. We will see that 7 channels are achieved with our proposed approach. The chipping rate is 5.5 MHz, and the data rate is 4 Mb/s.

To change between modes, the transmitter and receiver would have to switch filter bandwidths. Receiver sensitivity also degrades by approximately1 dB, due to less tolerance of phase error. Because indoor propagation range typically varies as power raised to -3.4, this gives only a 7% reduction in range. We feel it is more important to avoid interference between networks.

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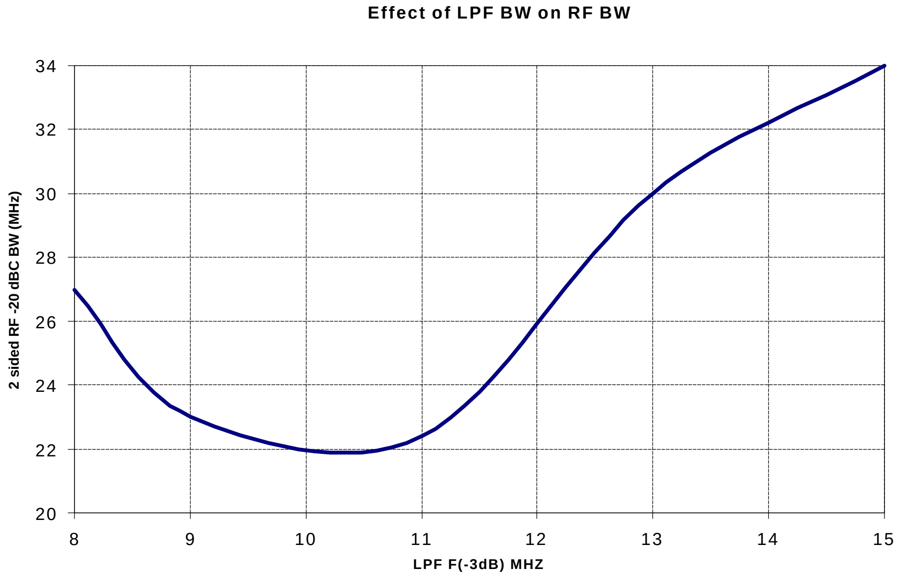
Selection of Low Pass Filter Bandwidth

Full-Data-Rate Case



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We ran a simulation to determine the performance of the waveform we propose. Both the I and Q baseband "rails" were filtered by a 5th order Butterworth Low Pass Filter of -3dB bandwidth F3. We determined the spectrum on the hard limiter output from the FFT of the RF waveform with random data applied to the modulator. The figure above shows how the bandwidth between the two points 20 dB below the peak of the signal varied as F3 was changed. We selected F3 = 9 MHz.

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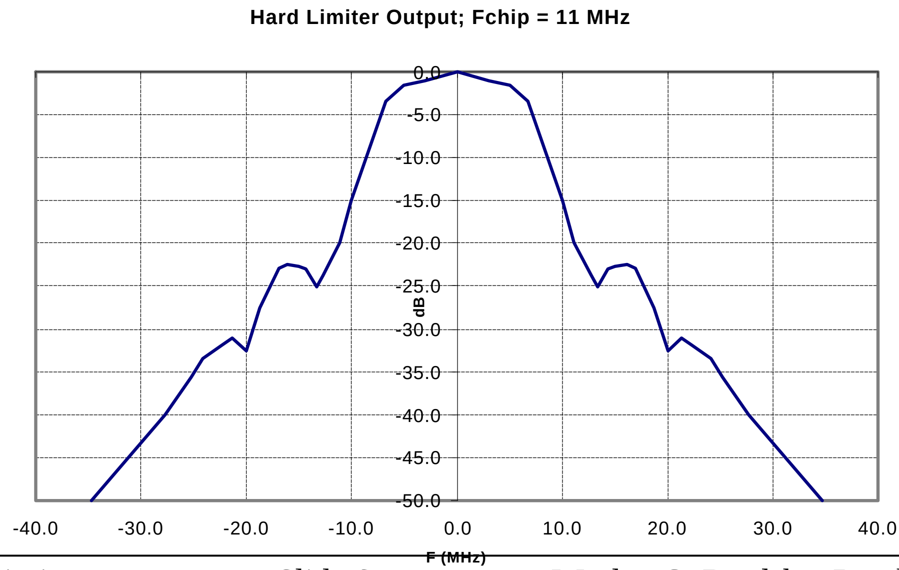
Output of Hard-Limited Transmitter Incorporating Suggestions

Full-Data-Rate (Spectrum Would be halved for Half-Data-Rate)



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Waveform Proposed by us:

Full Data Rate:

The spectrum that a spectrum analyzer would give in "peak hold" mode was estimated from the simulation output spectrum. From this, it is obvious that 3 or 4 channels would fit into the 83 MHz band, even though this is the output of a hard limiter. This spectrum does not meet the present IEEE802.11 spectral mask requirements for the 1 and 2 Mb/s Direct Sequence waveforms. However, there is no reason a new mask could not be used for the new waveform, as long as FCC requirements are met.

Half Data Rate

By halving the chipping rate and data rate, the spectrum is halved. The bandwidth between -20 dBc points is then 11 MHz. We achieve 7 distinct channels, with a saturated power amplifier.

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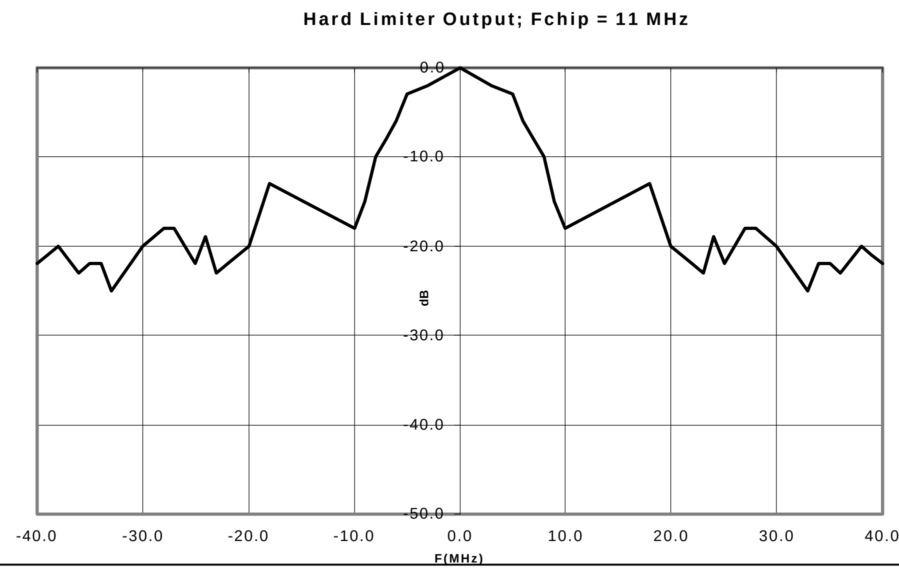
Output of Hard Limiting Transmitter for Waveform Proposed in IEEE P802.11-97/144

Full-Data-Rate Case



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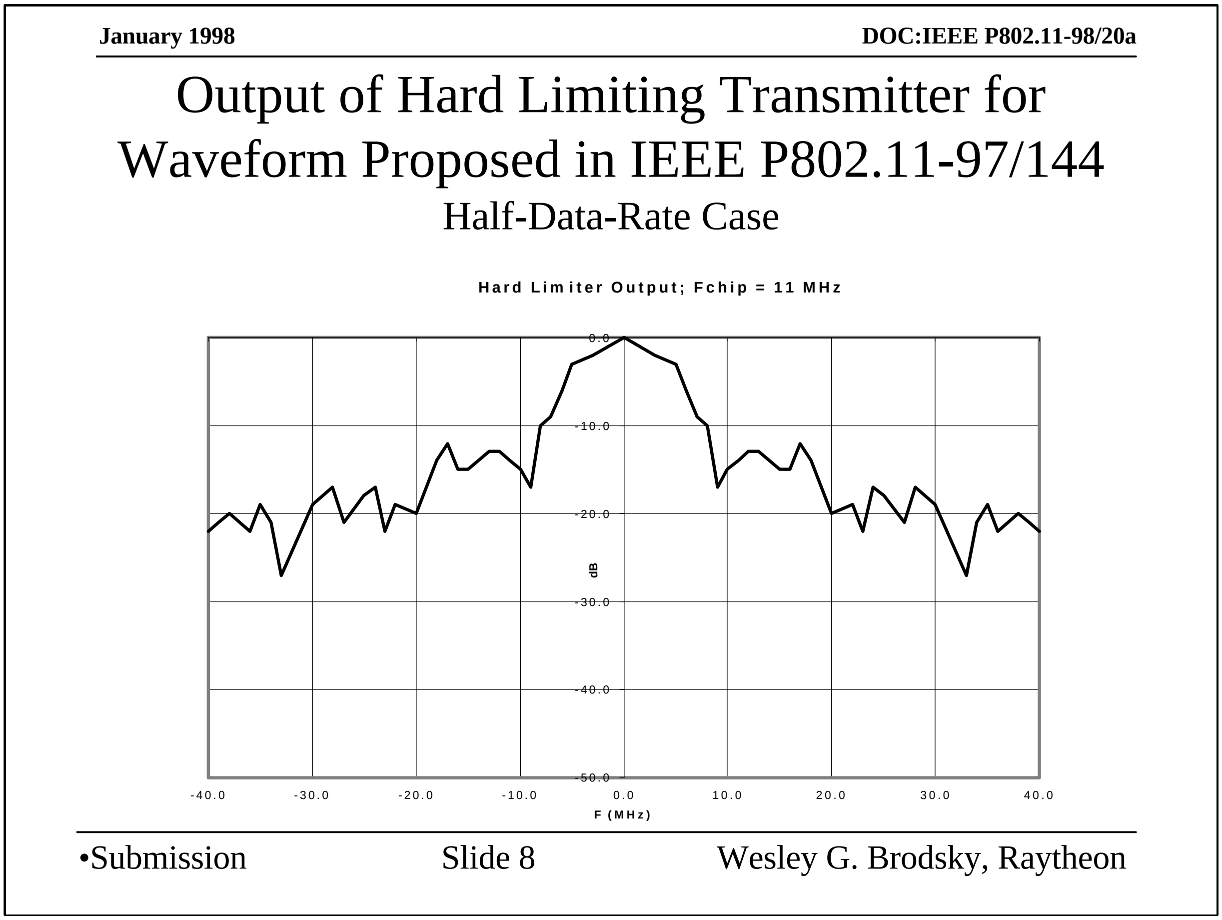
Originally [1] Proposed Waveform:

Full data rate:

For the sake of comparison, the case of I and Q aligned in time was simulated. This is what was originally proposed. The same procedure to find the best bandwidth for the single I-channel 5th order Butterworth LPF was repeated. The best bandwidth was 5.5 MHz. The above figure shows the resulting spectrum, again at the hard limiter output. The bandwidth between the -20 dBc points is 60 MHz. Only one channel would fit in the allocated band.



originally [1] Proposed Waveform:

Half data rate:

Originally binary, rather than quadrature, modulation was proposed for the half-data-rate case. Binary modulation exhibits more spectral growth through a saturated power amplifier than does offset quadrature modulation. This is because it goes through the origin of the I/Q plane, so has a high amplitude variation. We simulated this modulation. The same procedure to find the best bandwidth for the single I-channel 5th order Butterworth LPF was repeated. The best bandwidth was 5.5 MHz. The above figure shows the resulting spectrum, at the hard limiter output. The bandwidth between the two -20 dBc points is approximately 60 MHz. (Even thought the data rate was halved, this method still uses a chipping rate of 11 MHz.) Only one channel would fit in the allocated band.

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Effects of Proposed Changes

- Positive
  - Use Saturated Tx Power Amplifier.
  - More Channels in half-data-rate mode.
  - More likely FCC approval.
- Negative
  - More filters per unit.
  - Lower data rates (8/11).
  - Approximately 7% Range Reduction for half-rate mode.

•Submission Slide 9 Wesley G. Brodsky, Raytheon

References:

[1] Carl Adren (Harris); "Proposed 802.11 High Rate PHY Technique;" doc:IEEE P802.11-97/144; November 11, 1997

[2] R. Ziemer and R. Peterson; Digital Communications and Spread Spectrum Systems; Macmillan, New York; 1985 (Section 3-3.2; "Quadrature and Offset Quadrature Phase-Shift Keying").