Transmitted Waveform Description

July 14, 2008

1 Overview

To generate our signal, we utilize the Simulink simulation platform available via Mathworks. Figure 1 shows the full Simulink model used to produce, modulate, filter, and store our signal. Sections 2 and 3 detail portions of this diagram, and Section 4 presents output from a realtime spectrum analyzer to indicate our spectral occupancy.

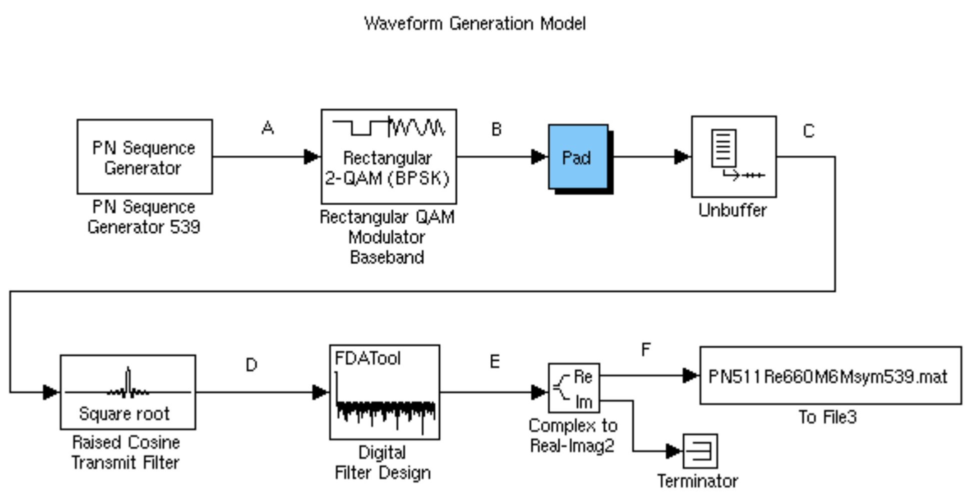

Figure 1: Simulink model used to generate the filtered transmitter waveform.

2 Digital Signal Construction

The data-bearing portion of the transmitted signal is based on a pseudo-random bit sequence produced from a linear feedback shift register (LFSR). It will be alternatively referred to here as a pseudo-random noise, or PN, sequence. The "PN Sequence Generator" block in Figure 1 is used to produce the sequence, and the relevant parameters for reproduction are:

Generator Polynomial:	[1 0 0 0 0 1 1 0 1 1]
Initial State:	[0 0 0 0 0 0 0 0 1]

The length of the PN sequence is 511 bits, and the full bit sequence is reproduced in Appendix A. Following production of the sequence (point A in Figure 1), it is modulated into a ± 1 BPSK symbol sequence with a symbol rate of 6 MSymbols/s. Consequently, the sequence requires $T_D = 511/(6 \times 10^6) = 85.2$ μs to transmit.

Between points B and C, two utility functions insert a null period with no data transmission. This null period is equal in length to T_D. Thus, prior to any filtering, our signal is a 511 symbol PN sequence, sent at a 6 MSymbol/s rate, and subject to a 50% duty cycle. This is illustrated in Figure 2.

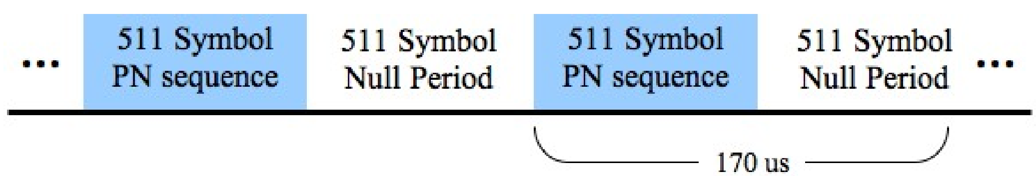

Figure 2: Transmitted signal with a 50% duty cycle.

3 Signal Filtering

3.1 Pulse-Shaping Filter

We utilize a root-raised cosine (RRC) filter with a rolloff factor of approximately 0.0455 to pulse-shape our digital data. A plot of its impulse and frequency response are shown in Figures 3 and 4, respectively.

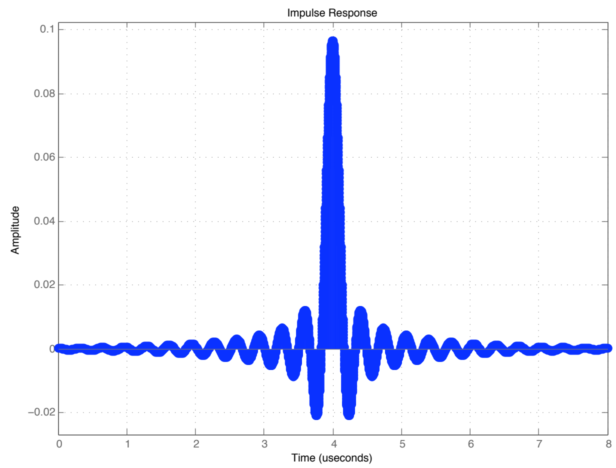

Figure 3: Impulse response of the RRC pulse-shaping filter.

3.2 Lowpass Filter

To further eliminate any adjacent channel leakage, we cascade a lowpass filter (LPF) after our RRC filter at point D in Figure 1. Plots of this filter's impulse and frequency response are shown in Figures 5 and 6, respectively.

The cumulative frequency response of both filters cascaded together is shown in Figure 7. The combination of both filters significantly attenuate the signal outside of 6 MHz, leading to virtually no adjacent channel leakage.

4 Spectrum Analyzer Measurements

To verify the claims in Section 3, we show measurements of this signal using an Aeroflex 3416 signal generator and a Tektronix 6106A realtime spectrum analyzer. For all measurements, power out of the signal generator is -15 dBm. First, Figure 8 shows the noise floor of the spectrum analyzer to be roughly -83 dBm across the band 776 - 812 MHz.

Next, Figure 9 shows a plot of the signal. The blue line indicates a peak average trace over 100 consecutive captures, while the yellow line indicates the instantaneous spectral occupancy. The MR marker indicates the peak value of the blue trace, while marker pairs M1-M2 and M3-M4 denote the 6 MHz and 12 MHz bandwidth points, respectively.

To examine any adjacent channel leakage, the power in the desired channels (788 - 800 MHz) is first measured in Figure 10 to be -20.06 dBm. Figure 11 shows the power in the upper 6 MHz adjacent channel (800 - 806 MHz) as -87.29 dBm, while Figure 12 shows the power in the lower 6 MHz adjacent channel (782 - 788 MHz) as -87.35 dBm. From these measurements, leakage outside our allocated band will be at least 67 dB below the power transmitted in-band. Realistically, leakage will be even less, due to the noise floor limitations of our measurement instruments. Based on these measurements, the noise floor of our spectrum analyzer, and the filtering applied to our signal, we are confident that any adjacent channel leakage has effectively been eliminated.

A PN Sequence Bits

The 511 bits are listed below with 32 bits per line.

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1 0 0 0 0 0 0 0 0 1 0 0 0 0 1 1 0 1 1 1 0 1 0 0 1 0 1 1 1 0 0 1
1 1 0 0 1 1 0 0 0 1 1 1 1 0 0 0 0 1 1 0 0 1 1 0 1 1 1 1 1 0 0 1
1 0 1 0 1 1 1 0 1 0 1 1 0 1 1 0 1 0 0 0 0 0 1 1 1 1 0 1 0 0 1 1
1 1 1 0 1 0 1 0 1 1 1 0 0 0 1 1 0 0 0 0 0 1 1 0 1 0 1 0 1 0 1 0
0 0 0 0 0 1 1 1 0 0 1 0 0 0 0 1 0 0 1 1 1 1 0 0 1 0 1 1 0 1 0 1
1 0 0 1 0 1 0 1 1 0 1 0 0 1 0 0 1 1 0 0 0 0 1 1 1 0 1 1 0 0 0 1
0 0 1 0 0 1 0 0 0 0 0 0 0 1 1 0 0 0 1 0 1 1 0 0 1 1 1 0 1 1 1 0
0 1 0 1 0 0 1 0 1 0 1 0 0 1 0 0 0 1 0 0 0 1 0 1 0 1 0 1 1 0 0 0
0 1 0 1 0 1 1 1 1 0 0 1 1 1 1 0 1 1 0 1 1 1 0 0 0 0 1 0 0 0 1 1
1 0 1 0 0 0 0 1 1 1 1 1 1 0 0 1 0 0 1 0 1 0 0 0 0 1 0 1 1 1 1 1
1 1 1 1 0 0 0 0 0 1 0 0 1 0 1 1 0 0 0 1 1 0 1 0 0 0 1 0 1 1 1 0
1 1 1 1 0 1 0 1 1 1 1 1 0 1 1 1 0 1 1 0 1 0 1 0 0 0 1 0 0 1 1 0
1 0 0 1 1 0 1 1 0 1 1 0 0 0 0 0 0 1 0 1 0 0 1 1 1 0 1 0 1 0 0 1
1 0 0 1 0 1 1 1 1 0 1 1 1 1 1 1 0 1 1 0 0 1 1 0 0 1 1 1 1 1 1 1
0 1 0 0 0 1 1 1 1 1 0 0 0 1 0 1 0 0 0 1 1 0 1 1 0 0 1 0 0 0 1 1
0 0 1 0 0 1 1 1 0 0 0 1 0 0 0 0 0 1 0 1 1 0 1 1 1 1 0 0 0 1 1
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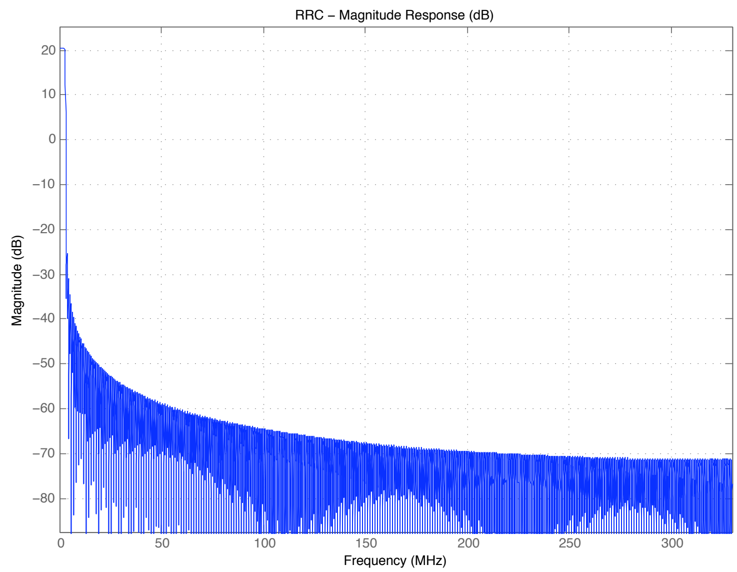
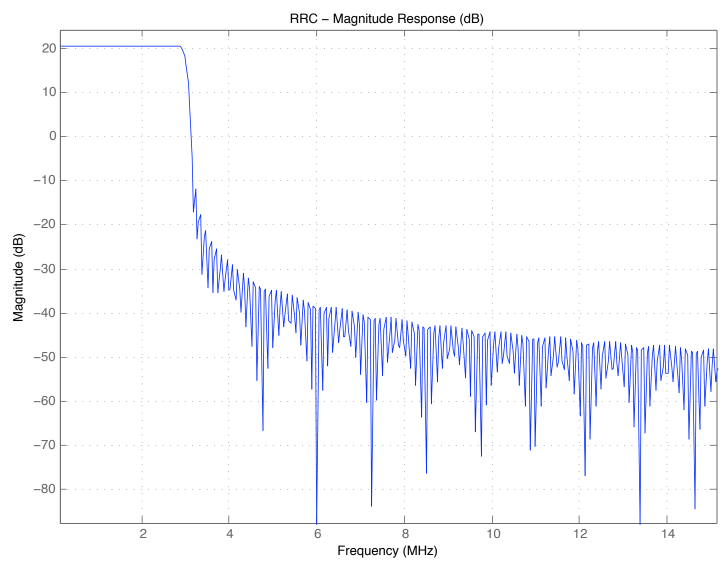


(a) Full Frequency Response



(b) Detailed Frequency Response

Figure 4: Two plots showing the magnitude frequency response of the RRC filter.

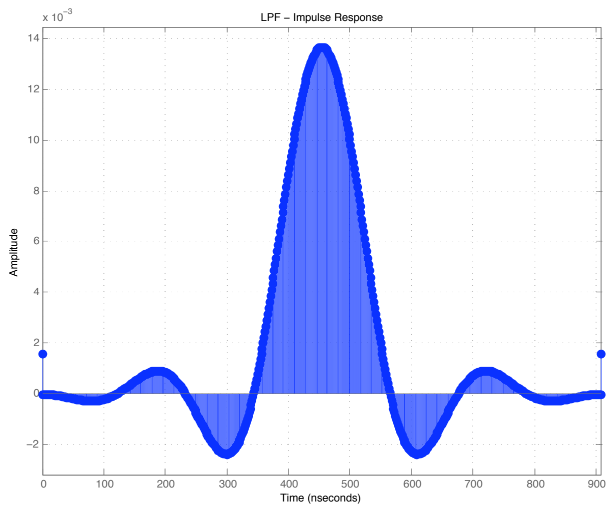
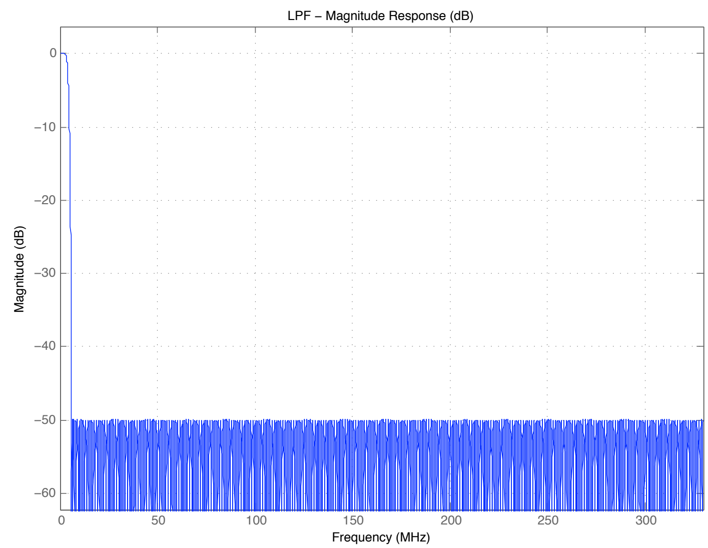
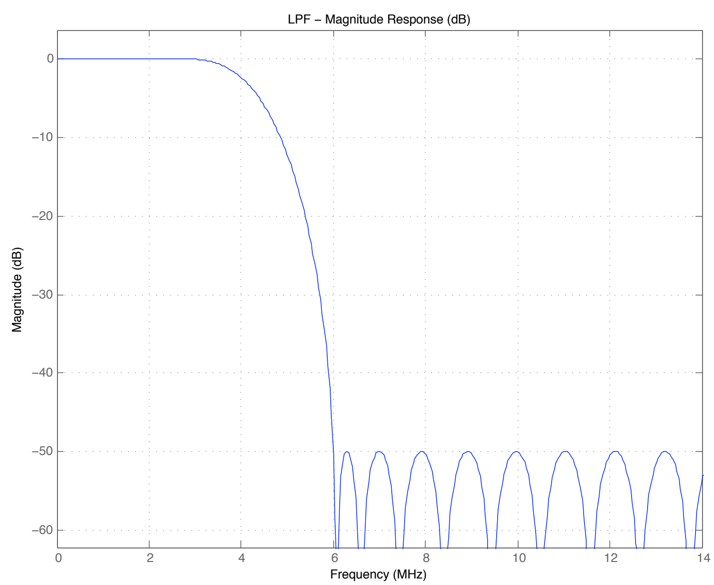


Figure 5: Impulse response of the additional lowpass filter.

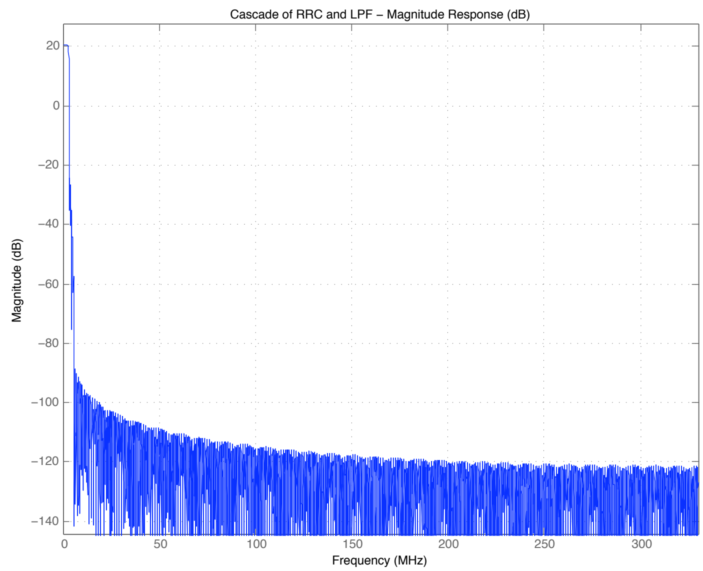


(a) Full Span Frequency Response

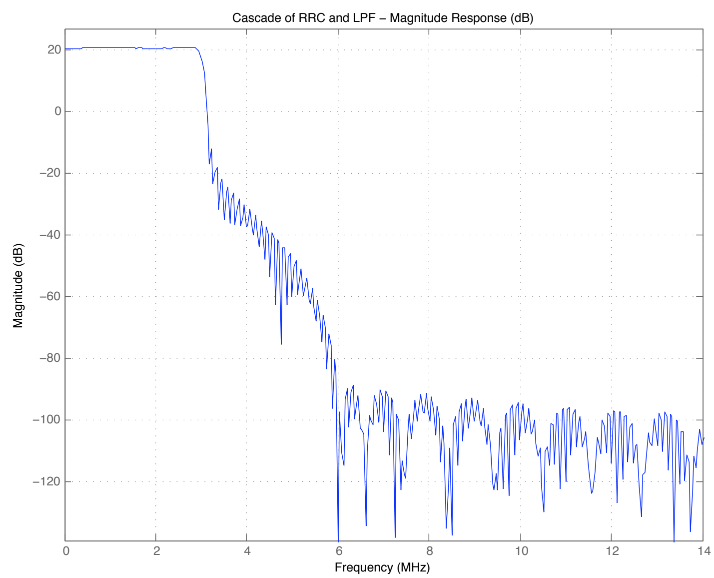


(b) Detailed Frequency Response

Figure 6: Two plots showing the magnitude frequency response of the lowpass filter.



(a) Full Span Frequency Response



(b) Detailed Frequency Response

Figure 7: Two plots showing the magnitude frequency response of the combined cascaded filters.

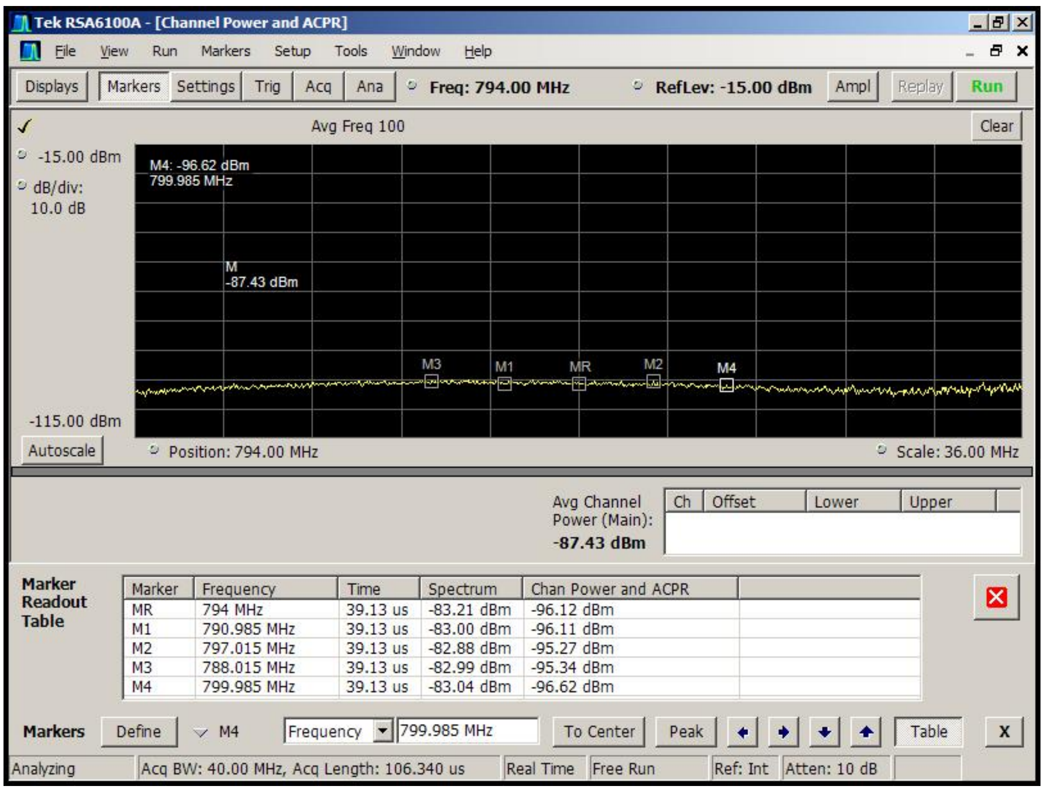


Figure 8: Signal analyzer noise floor with no input present.

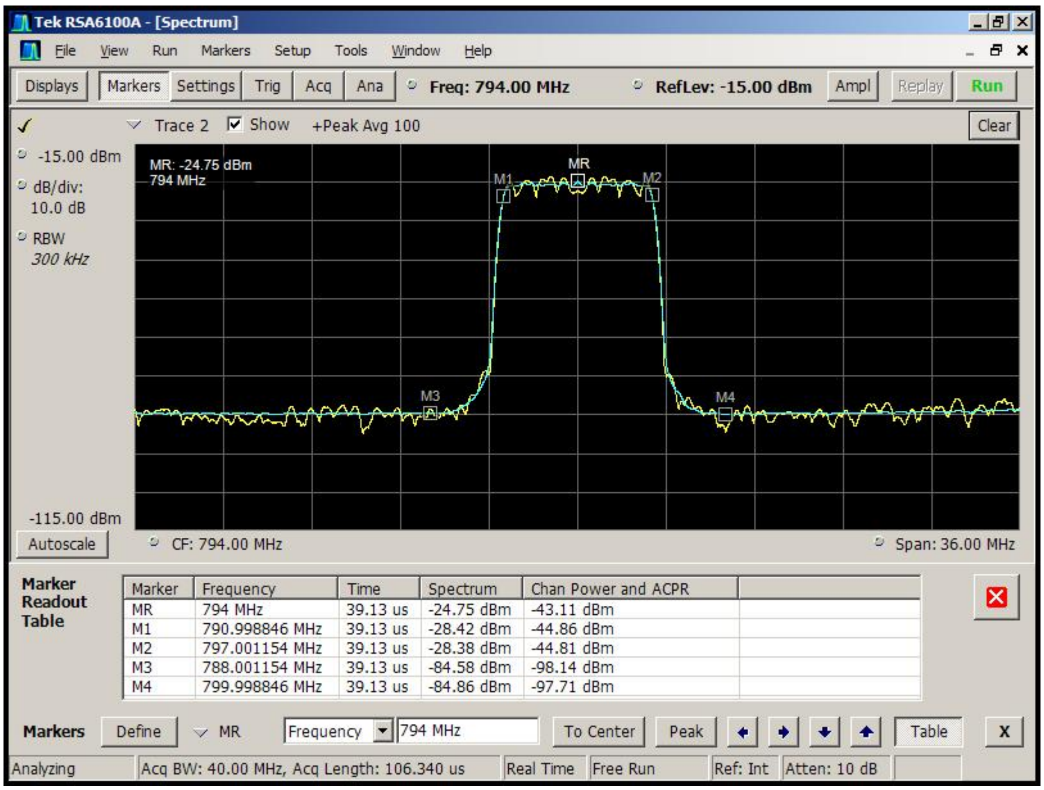


Figure 9: Spectral occupancy of the waveform. Blue trace indicates a peak average while yellow trace indicates instantaneous occupancy.

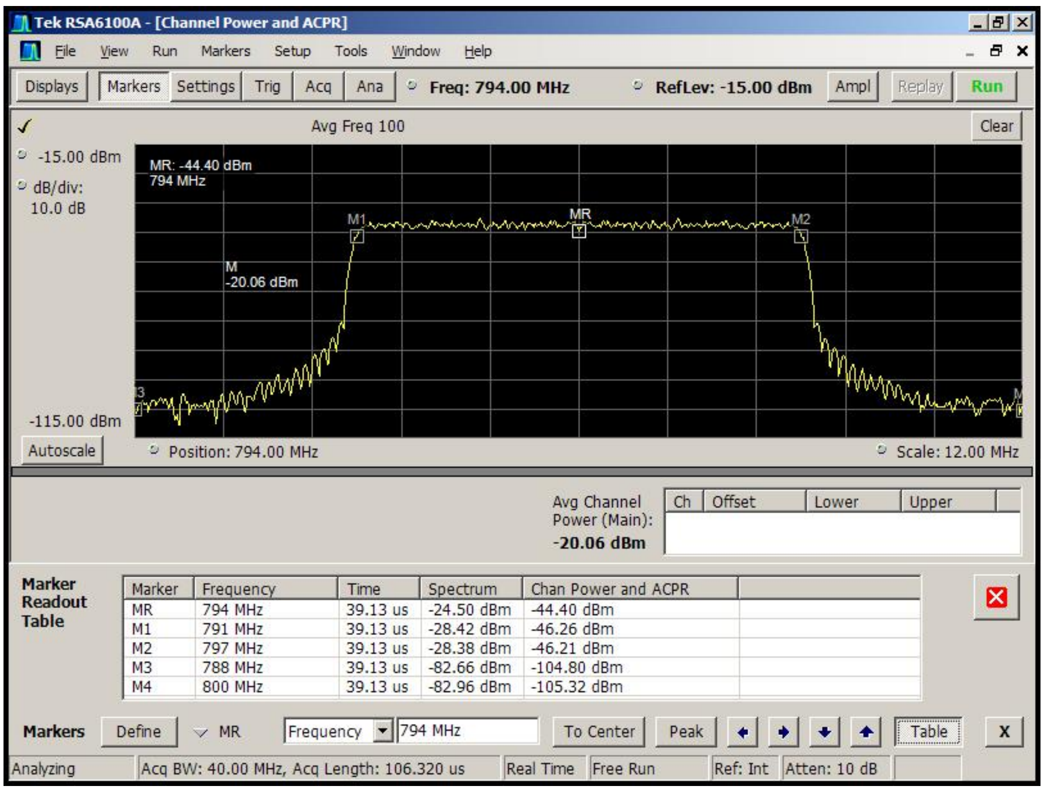


Figure 10: Power across occupied spectrum from 788 MHz to 800 MHz.

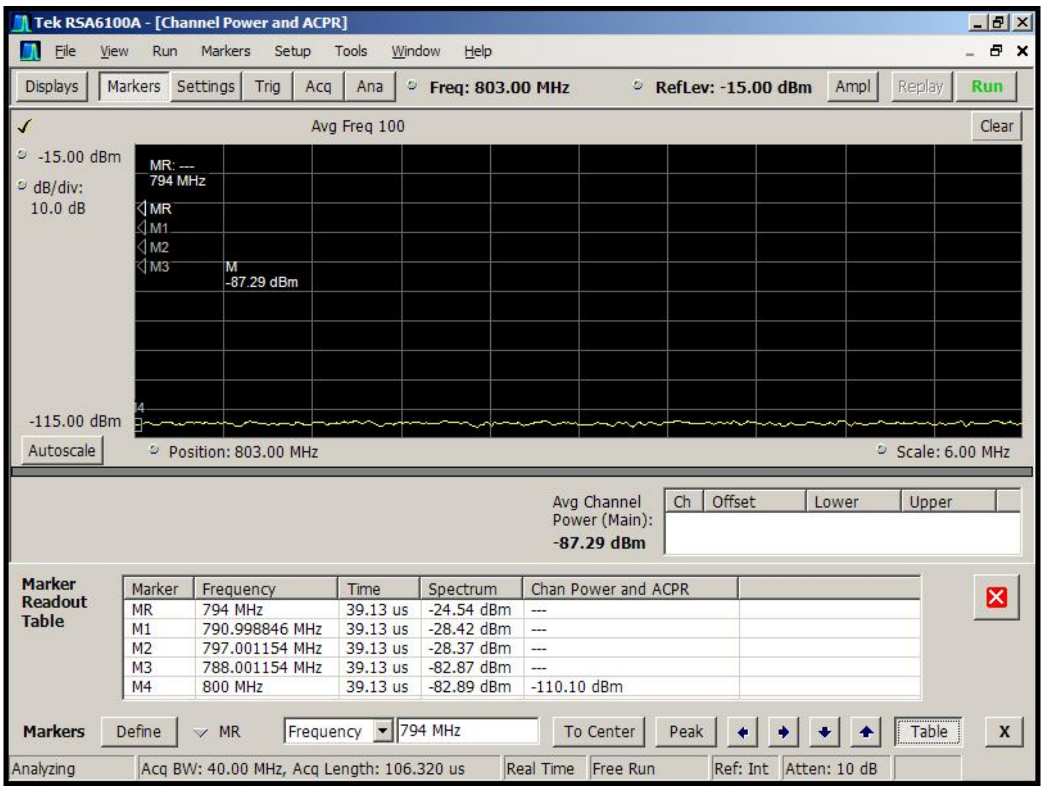


Figure 11: Power across upper adjacent channel (channel 69).

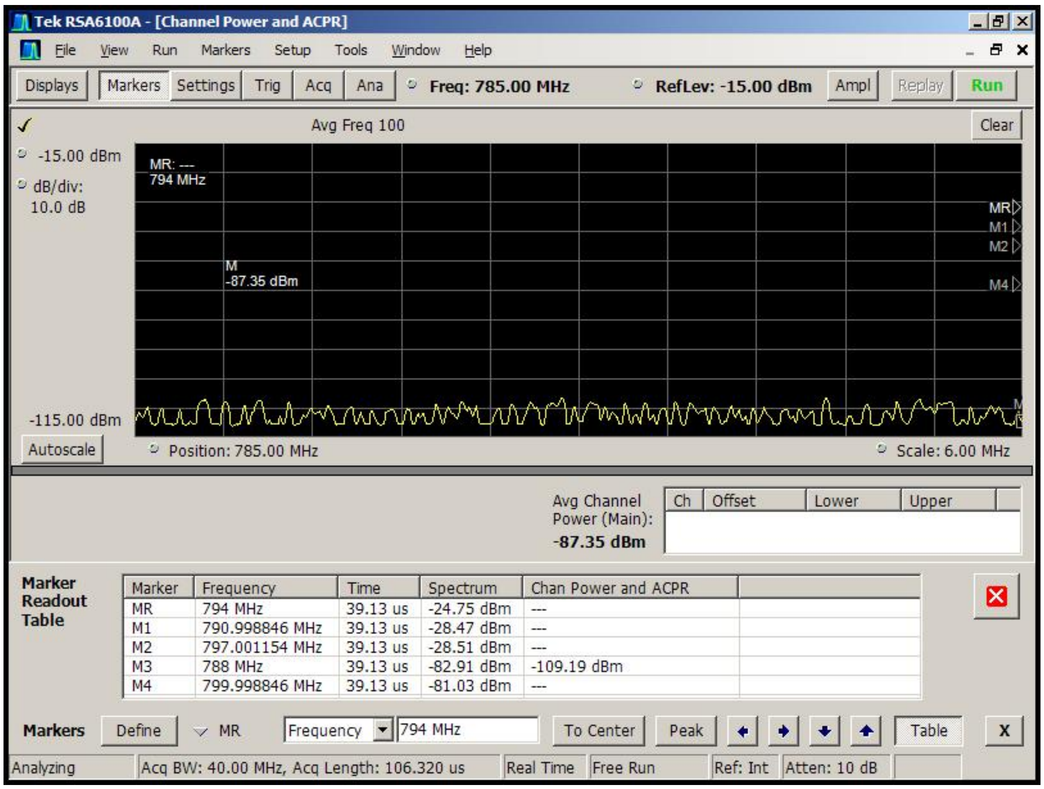


Figure 12: Power across lower adjacent channel (channel 66)