2005.05.15

Japan

Consideration about the measurement bandwidth in spurious measurement of a radar system

1 Introduction

The measuring method of unwanted emissions of radar systems is recommended by Recommendation ITU-R M.1177-3, and the boundary between the out-of-band domain and the spurious domain is determined by the calculation formula and the-out-of-band domain mask defined in Recommendation ITU-R SM.1541-1. Therefore, the measuring method of primary radars recommended by Recommendation ITU-R M.1177-3 is important for judging the conformity with the regulation defined by Recommendation ITU-R SM.1541-1, and it is considered to be an important key parameter to decide the measurement accuracy.

Although the formula for calculating the -40dB bandwidth is defined by based on an ideal rectangular and trapezoidal waves, actual waveforms are not ideal rectangular or trapezoidal wave. Then, there are differences between the results of calculation and actual measured values. Japan has brought this issue forward.

WRC-03 also made a recommendation that further study be required to determine the boundary between the out-of-band domain and the spurious domain of primary radars because the emission spectrum of primary radars using magnetrons is not yet clarified thoroughly, which may not make the compliance with Recommendation ITU-R SM.1541 possible (Recommendation 75 (WRC-03)). Also in the ITU-R WP8B meeting held on November 2003, Japan submitted a working document on this discrepancies in this issue.

Furthermore, the influence of the far-field conditions that is requested for the measurement condition in Recommendation ITU-R M.1177-3 has also been considered while conducting a joint measurement experiment with the U.S and Japan.

This consideration has been performed according to the latest version of Recommendation ITU-R M.1177. It is shown by Recommendation ITU-R M.1177-3 that the measurement bandwidth is determined by 1/t (t is pulse width) and if the bandwidth which is determined by 1/t is grater than 1 MHz, the measurement bandwidth, close to 1 MHz should be used.

However, it became clear that the measuring results of a spectrum wave differed by difference values of resolution bandwidth (RBW). Therefore, the adequate value of RBW is required to perform the accurate measurement of a spectrum wave and spurious levels when the mask applies to the OOB domain.

This working document is the report which considered the relation between the RBWs adopted when spurious measurement was performed using a spectrum analyzer, and the error of a measurement result.

2 Simulation and Measurement

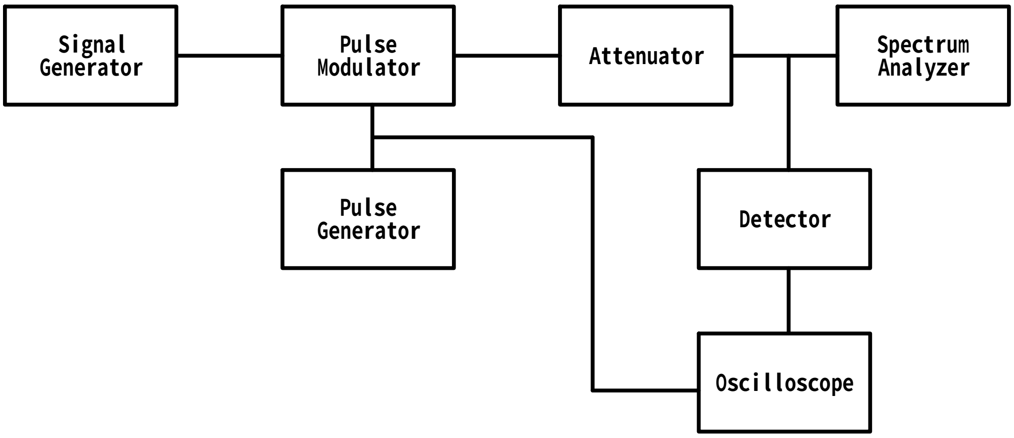
To examine the error concerning about the measurement bandwidth which indicated by Recommendation ITU-R M.1177-3, following simulations and measurement were performed.

(1) The simulation for measuring an ideal rectangular wave using ideal IF filter.
(Condition: pulse width =1uS, pulse interval =10uS)
(2) The simulation for measuring a trapezoidal wave with a Gaussian filter.
(Condition: pulse width = 0.5uS, pulse rise-time = pulse fall-time =20nS, pulse interval =1mS)
(3) Spectrum measurement for the various RBW of the spectrum analyzer which input signal is made with the signal generator and pulse modulator, and pulse shape is approximately ideal rectangular wave.
(4) Spectrum measurement for the radar system using magnetron that various RBWs are used.

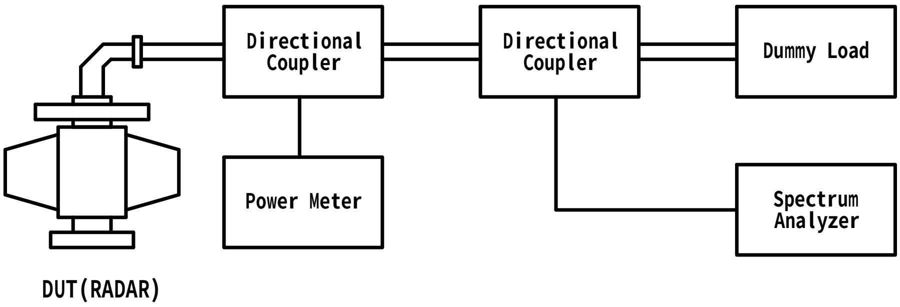
In this measurement, since the purpose of the observation of a spectrum wave is to compare with the difference of shapes of the spectrum, the measuring method is not adopted the direct method but in the wave guide output (antenna input end).

2.1 Configuration of the measurement system

Observation of the spectrum by a signal generator



Observation of the spectrum by radar equipment (antenna input end)



Mesuring instruments

Spectrum Analyzer	：Agilent	E4440A	3 Hz - 26.5 GHz

Digital Oscilloscope	: Agilent	54831	DC - 600 MHz
Peak Power Analyzer	: Agilent	8991A	
Power Splitter	: HP	11667A	DC - 18 GHz
Directional Coupler	: HP	H752C	Coupling 10dB
Directional Coupler	: HP	X752D	20dB
Dummy Load	: unknown	WDL-095	X band
Rotary Attenuator	: HP	H382A	0 - 50 dB
Rotary Attenuator	: HP	X382A	0 - 50 dB
Step Attenuator	: Agilent	8495B	0 - 70 dB
Step Attenuator	: Agilent	8494B	0 - 10 dB

2.2 Setup of measurement system

Observation of the spectrum by a signal generator

The frequency of a signal generator was set to 9400 MHz. The input of PEP of a spectrum analyzer was set to -20dBm. And the pulse width of the pulse generator was set to 100 ns and 500 ns.

The setup of a spectrum analyzer is as follows.

Center Frequency	9.4 GHz (X-band)
Span	200 MHz
Resolution Bandwidth	100 kHz-5 MHz
Video Bandwidth	Same as Resolution Bandwidth
Sweep Time	60 sec

Observation of the spectrum by radar equipment (antenna input end)

Measurement pulse width is set as the minimum pulse width (nominal 60-80 ns) of DUT.

The setup of a spectrum analyzer is as follows.

Center Frequency	9.5 GHz (X-band)
Span	3 GHz
Resolution Bandwidth	100kHz-8 MHz
Video Bandwidth	Same as Resolution Bandwidth
Sweep Time	60 sec

3 Results of simulation and measurement

The spectrum wave are shown in data 1(results of simulation) and Fig. 1-1 to 2-5(measuring data of signal generator) and Fig.3-1 to 3-3(measuring data of radar equipment).

4 Consideration

The following things were checked from the simulation and the measurement result.

- When the deferent value of RBW is used with the ideal IF filter ,the values of the difference of the value of a main lobe power and a side lobe power differs.
  (If the value of RBW is increased, the value of a side lobe will fall more greatly than that of a main lobe.)
- Also the simulation of a trapezoidal wave with a Gaussian filter, the same result as the case of an ideal IF filter was obtained.
- A relationship of measurement result between main lobe and side lobe is same when the signal generator is used as signal sauce too. Furthermore, if the conditions of RBW<1/(4 tau) are satisfied, it is shown that it can measure with the same error (less than about 0.5dB) in spite of using

different type of spectrum analyzer which have different characteristics of IF filter.

- Since the spectrum wave of an actual radar system is not an ideal rectangular wave, the grade of the difference changes with setup of the measurement bandwidth of the spectrum analyzer for every frequency component (refer to Figs. 3-2 and 3-3).

  However, under RBW<1/(4 tau) conditions, errors of measurement are few.

The result of a simulation shows that the width of a side lobe is 1/t and the width of a fundamental wave is 2/t. Therefore if measurement bandwidth is increased, a rate of the adjacent robe (the phase of adjacent robe is opposite) which is come into the IF filter of spectrum analyzer is increased.
Therefore, an error may become large when the measuring data between a fundamental wave and a side lobe is compared. As the measurement result shows, the measurement bandwidth below 1 / 4 t is required in order to lose the influence of this error.

5 Conclusion

Although the measuring method of the radar system was indicated by Recommendation ITU-R M.1177-3, the discussion was not fully carried out about the primary radar using a magnetron which needs the short pulse width below 100 ns.

It is very important point to study the error included in Recommendation ITU-R M.1177-3 which showed the measuring method in the compliance with the design objective mentioned by Recommendation ITU-R SM.1541-1 about radar systems.

Although Recommendation ITU-R M.1177-3 recommends that measurement bandwidth is calculated by 1/t. But to obtain the Spectrum correctly, less than 1/4t measurement bandwidth must be used. On the other hand, measuring time will increase when the narrow bandwidth is used as measurement bandwidth. Consider to actual situations, measuring time cannot be disregarded.

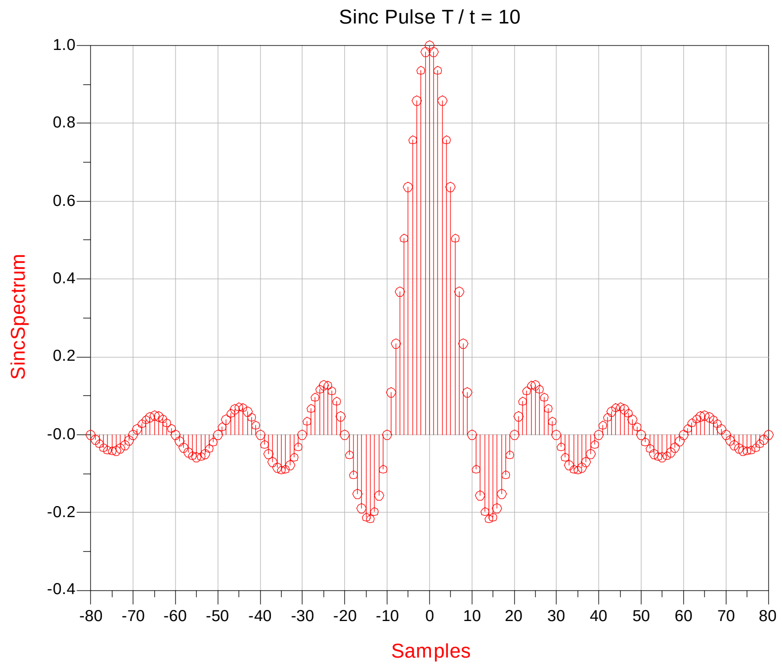
Therefore, with regard to the trade-off, between a permissible error of measurement and permissible measuring time, more study and discussion is required.

This working document which presents the relation between the measurement bandwidth of a spectrum analyzer and the measuring result of spectrum is very useful data to consider the trade-off of an error of measurement and measuring time.

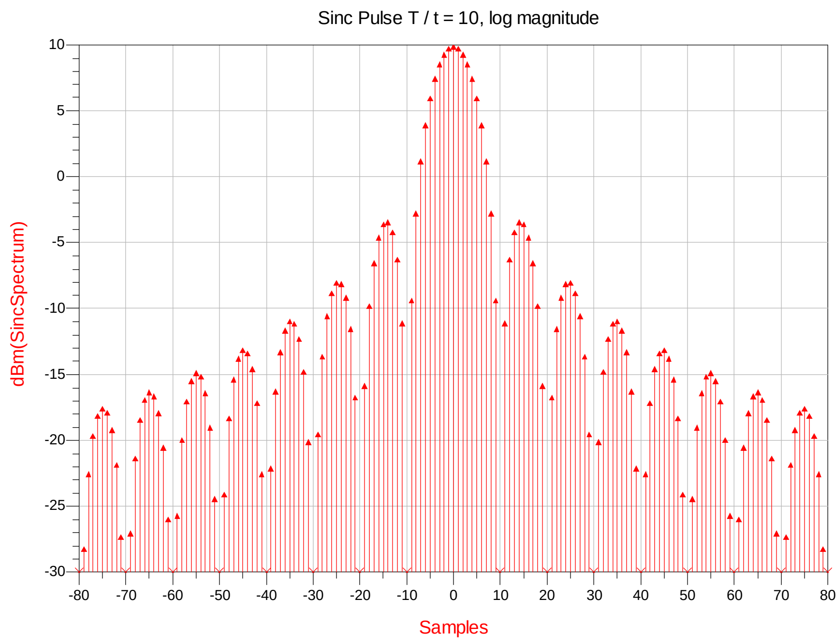
6 A future schedule

From this measurement result, Japan will continue the studies with regard to the relation between RBW and the spectrum which obtained by measurement system, with consider that the trade-off of the error of measured spectrum and the measuring time. Especially, regarding the measurement error, we believe that it needs a comprehensive study of whole measurement system, like measurement site and measurement equipment. And we will continue the studies about these items.

Using simple Sinc function, Sin(x)/x, to model spectrum analyzer measurement of Pulsed RF signal. For simplification, Duty cycle is reduced to 10, that is Pulse period T to the Pulse width t is 10(T/t=10).



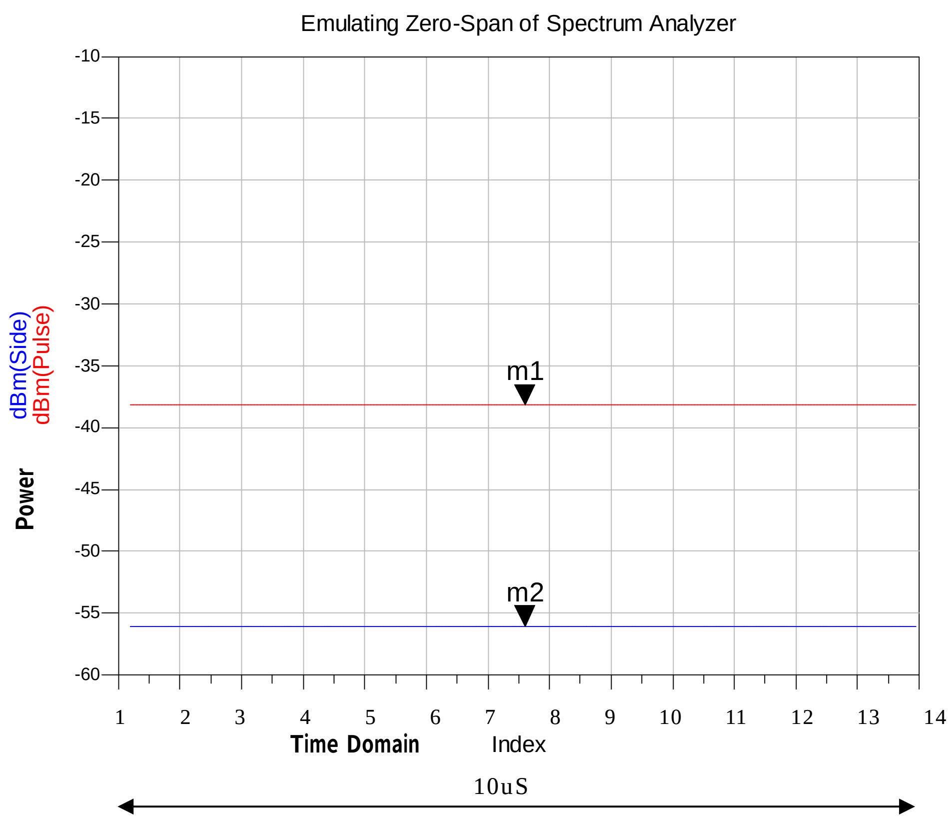
A sinc function generated in -8 * pi to +8 *pi period.



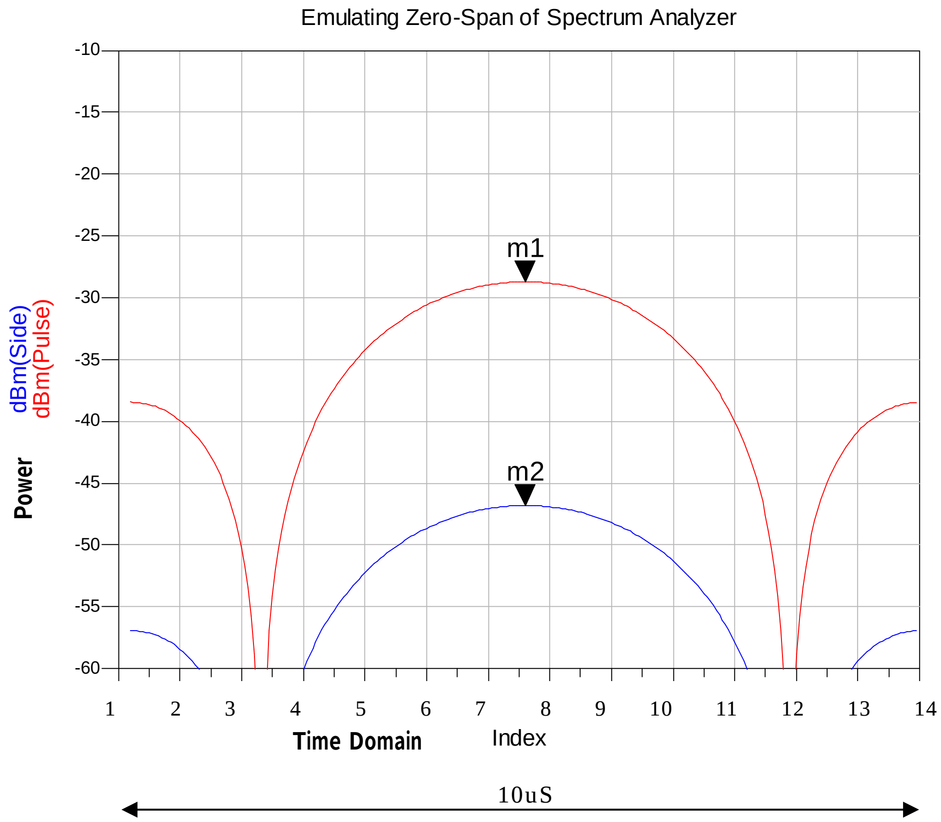
Log-magnitude plot, Please note, the mainlobe is twice the width of sidelobes.

Comparison f peak power, between main lobe and side lobe. Emulating 2 spectrum analyzers setting-up to zero-span mode, each tune into main and side lobe.
Except, the IF filter (RBW filter) used here is ideal rectangular filter, not Gaussian.

This numeric simulation try to produce measurement of one period of Pulsed RF signal with 1 us pulse width and 10 us Period.

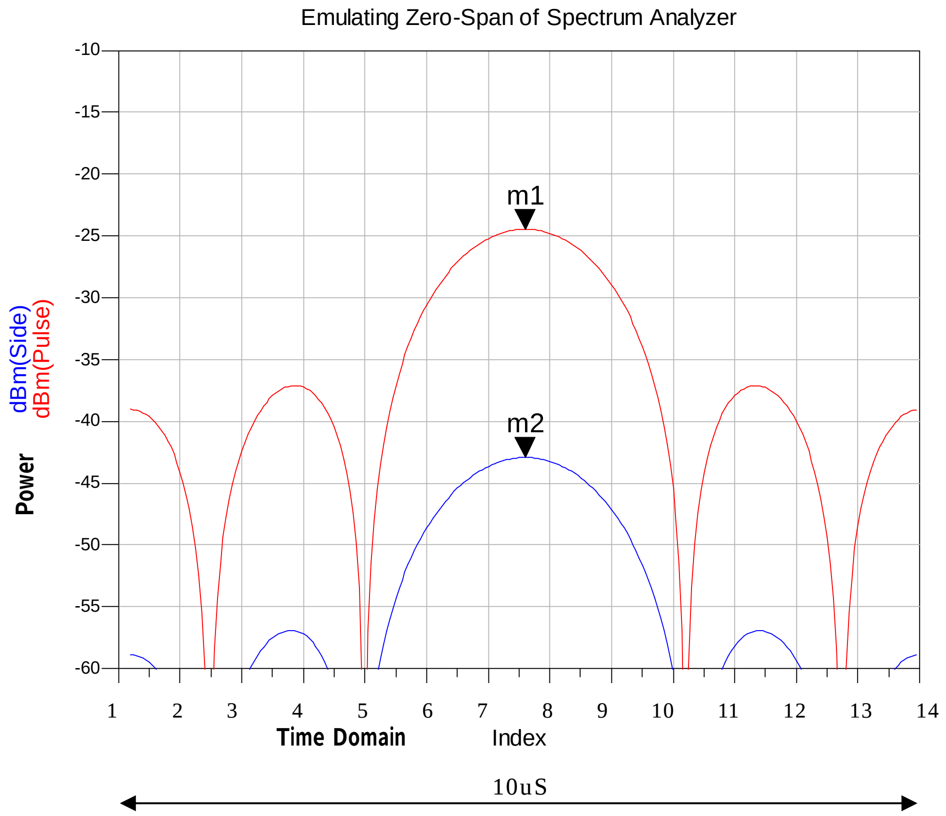


RBW 100 kHz. Only single tone is within RBW and makes CW tone.
Difference of peak power (m1-m2) is about 17.9 dB



RBW 300 kHz. 3 tone each for both main and side lobe.

Difference of peak power (m1-m2) is about 18.09 dB

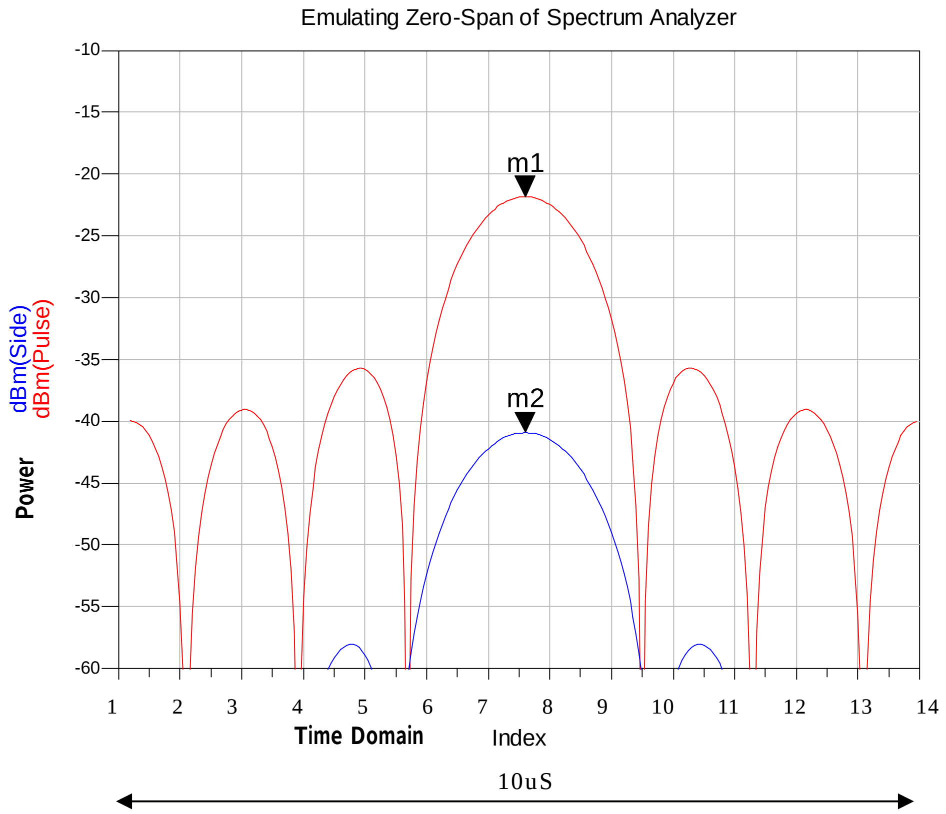


RBW 500 kHz. 5 tone each for main and side lobe.

Difference of peak power (m1-m2) is 18.47 dB.

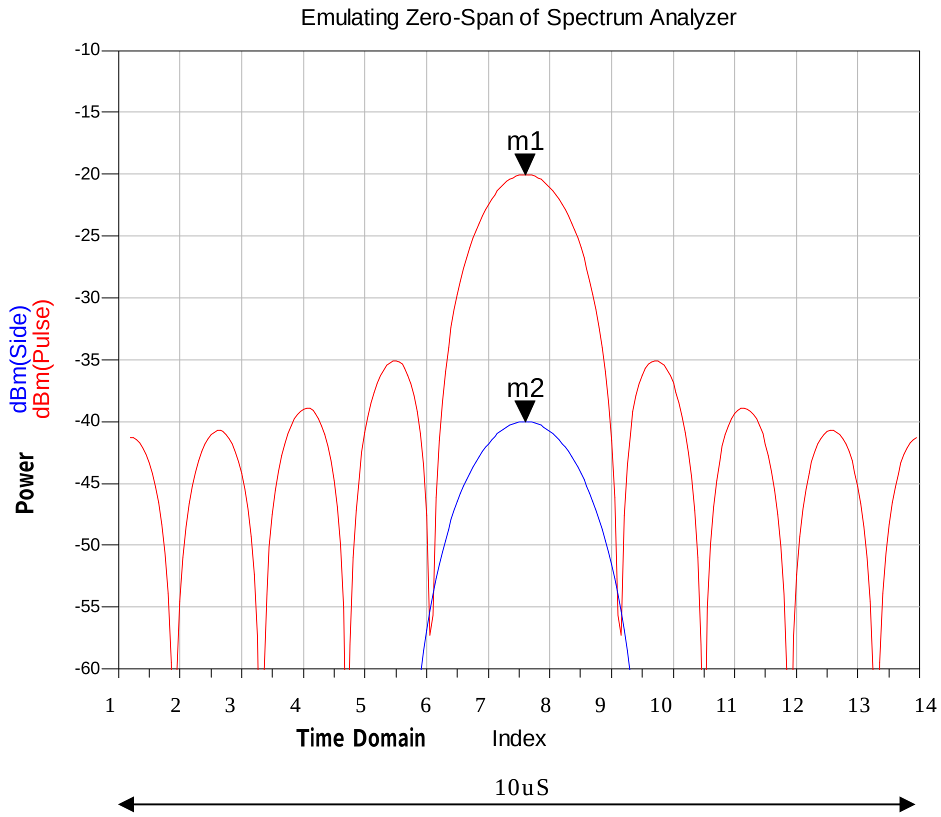
In mainlobe, power of 200 kHz tone is only a 0.6 dB below the center tone. Side lobe has steeper decline in power, more than 6 dB less power in 200 kHz offset tone.

Thus, power difference gets more and more wide.



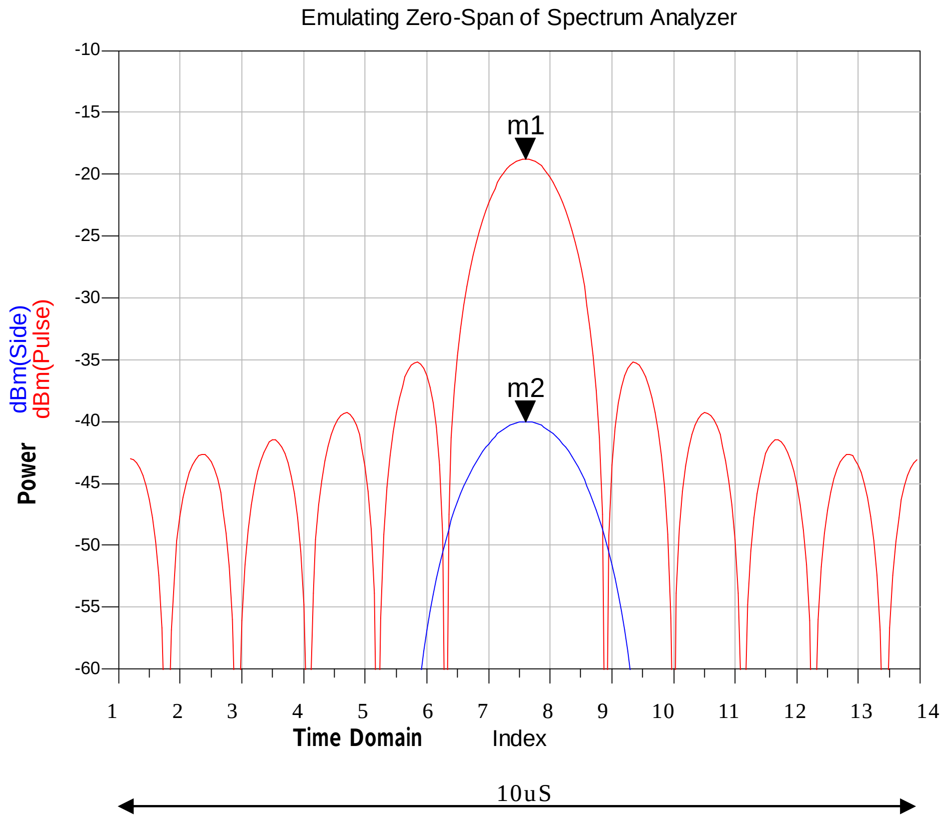
RBW 700 kHz. Bose lobes have 7tones each other.

Difference of peak power (m1-m2) is 19.08 dB.



RBW 900 kHz. Bose lobes have 9 tones each other.

Difference of peak power (m1-m2) is 19.97 dB.

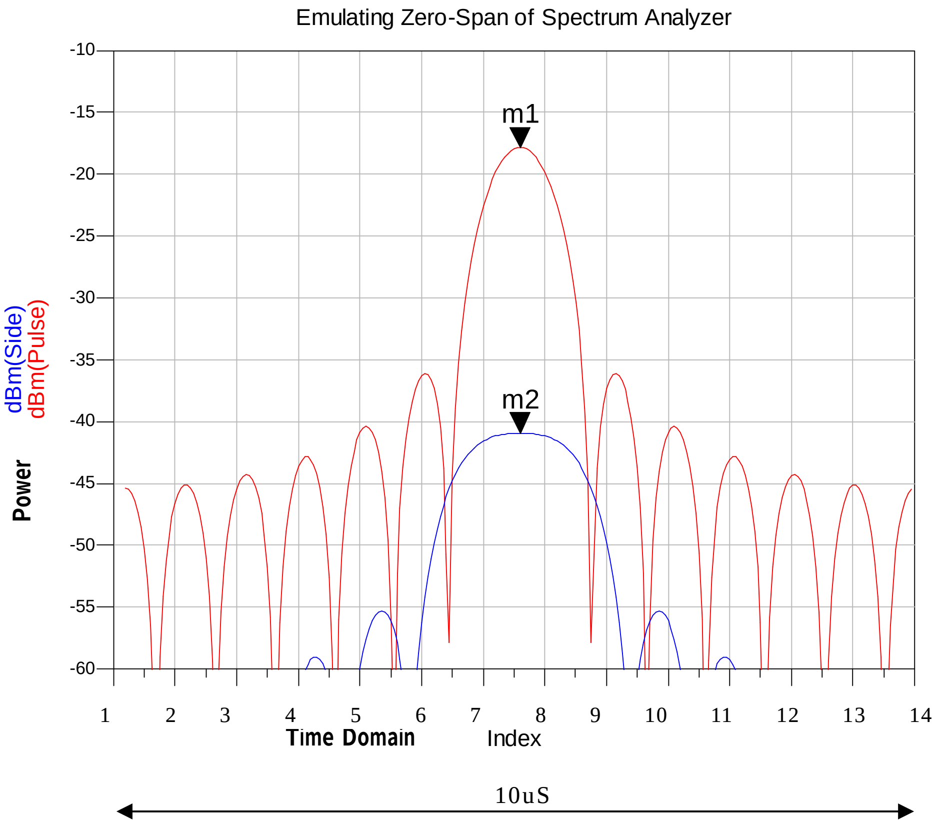


RBW 1.1 MHz. Bose lobes have 11 tones each other.

Difference of peak power (m1-m2) grows to 21.24 dB

Power of sidelobe is same since this RBW is at null carrier.

Mainlobe is adding more tones and shaping up narrower. Side lobe is not.

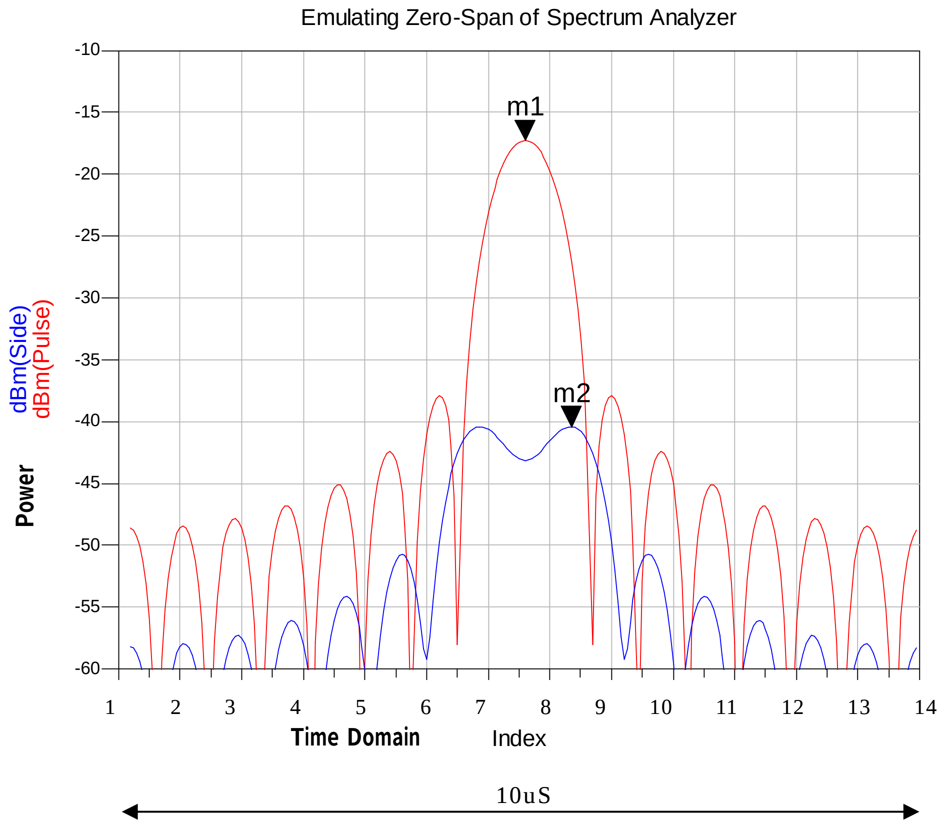


RBW 1.3 MHz. Bose lobes have 13tones.

Difference of peak power (m1-m2) is 23.08 dB.

Now, side lobe is adding power from adjacent sidelobe, which is inverses phase. This makes sidelobe to rectangular pulse, not impulse.

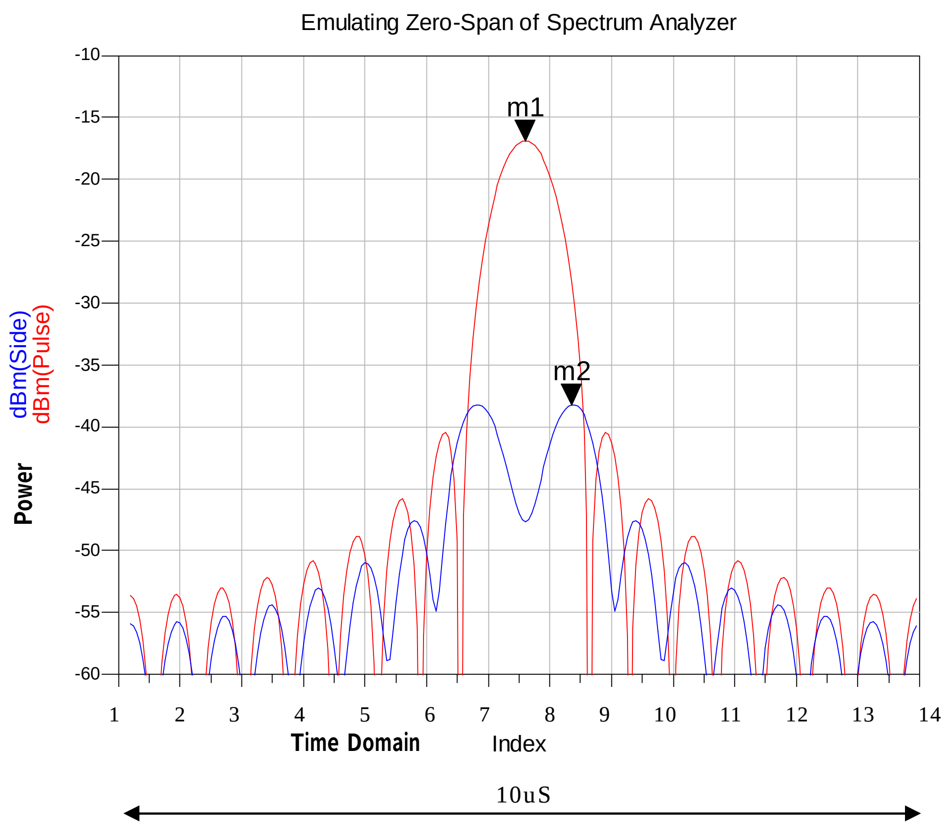
Main lobe is still adding power from within mainlobe, become narrower, impulsive.



RBW 1.5 MHz. Bose lobes have 15 tones in each.

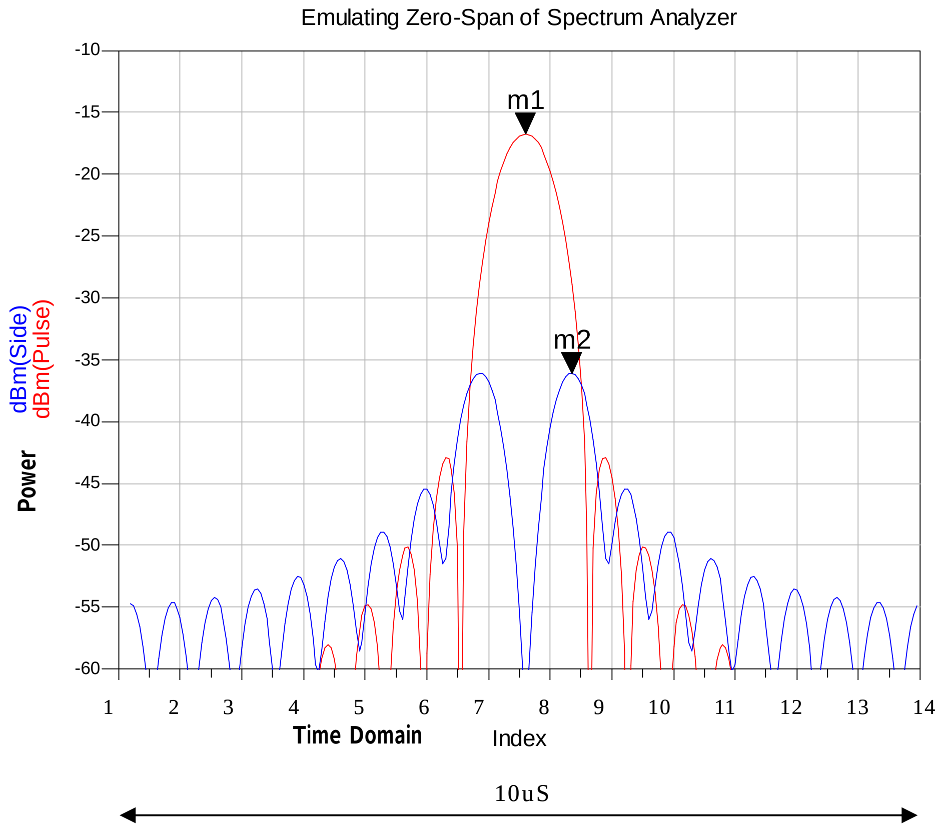
Difference of peak power (m1-m2) is 23.16 dB.

Position of peak power is no longer located at pulse center in sidelobe.



RBW 1.7 MHz. Bose lobes have 17 tones each.

Difference of peak power (m1-m2) is 21.29 dB

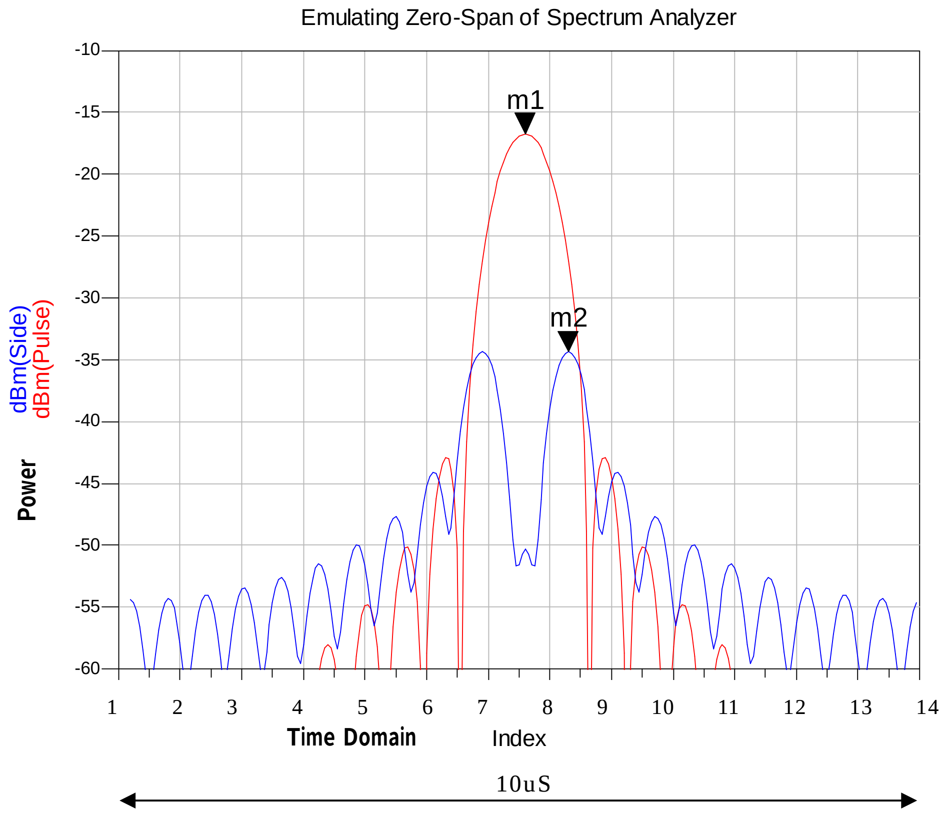


RBW 1.9 MHz. Bose lobes have 19tones.

Difference of peak power (m1-m2) is 19.34 dB.

Main lobe is adding all its tones.

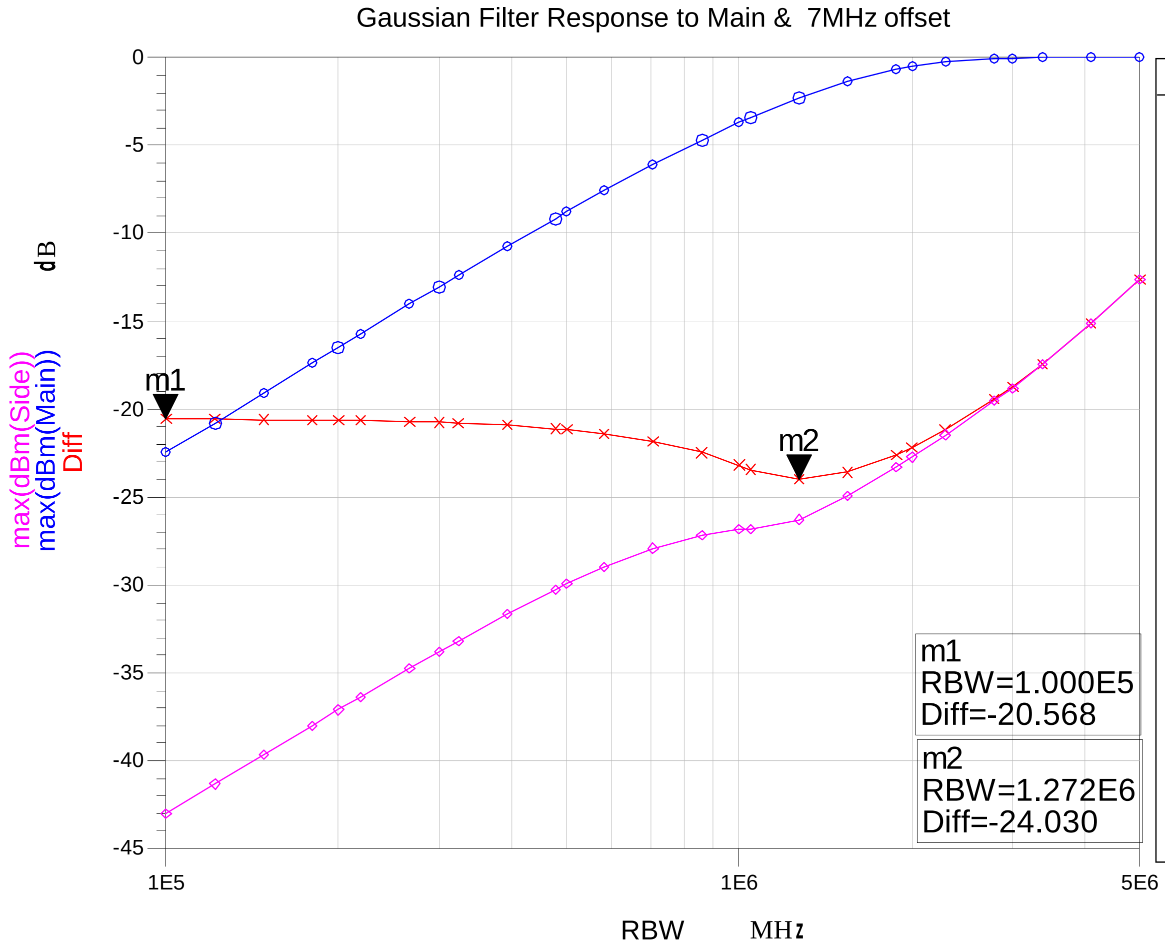
Side lobe is adding about half the power from both adjacent sidelobes. Peak is split to two pulses.



RBW 2.1 MHz. Bose lobes have 21tones.

Difference of peak power (m1-m2) is 17.61 dB

Main lobe has not grown since it already adding up almost all power. Sidelobe is still adding power since one of adjacent sidelobe is always has greater power.



RBW (Hz)	Diff (dB)
100000.000	-20.568
121604.179	-20.580
147875.764	-20.598
179823.108	-20.624
200000.000	-20.644
218672.415	-20.664
265914.795	-20.722
300000.000	-20.771
323363.503	-20.808
393223.534	-20.936
478176.250	-21.127
500000.000	-21.182
581482.303	-21.411
707106.781	-21.838
859871.396	-22.481
1000000.000	-23.198
1045639.553	-23.457
1271541.394	-24.030
1546247.474	-23.615
1880301.547	-22.615
2000000.000	-22.220
2286525.260	-21.205
2780510.271	-19.470
3000000.000	-18.771
3381216.689	-17.435
4111700.797	-15.121
5000000.000	-12.615

Period: 1000us, Pulse width: 0.5us, Rise time: 20ns, Fall time 20ns

Figure 2-1. Pulse Responce of Spectrum Analyzer (Sample 1_IFBW=3dB, pulse width=0.1 μ S)

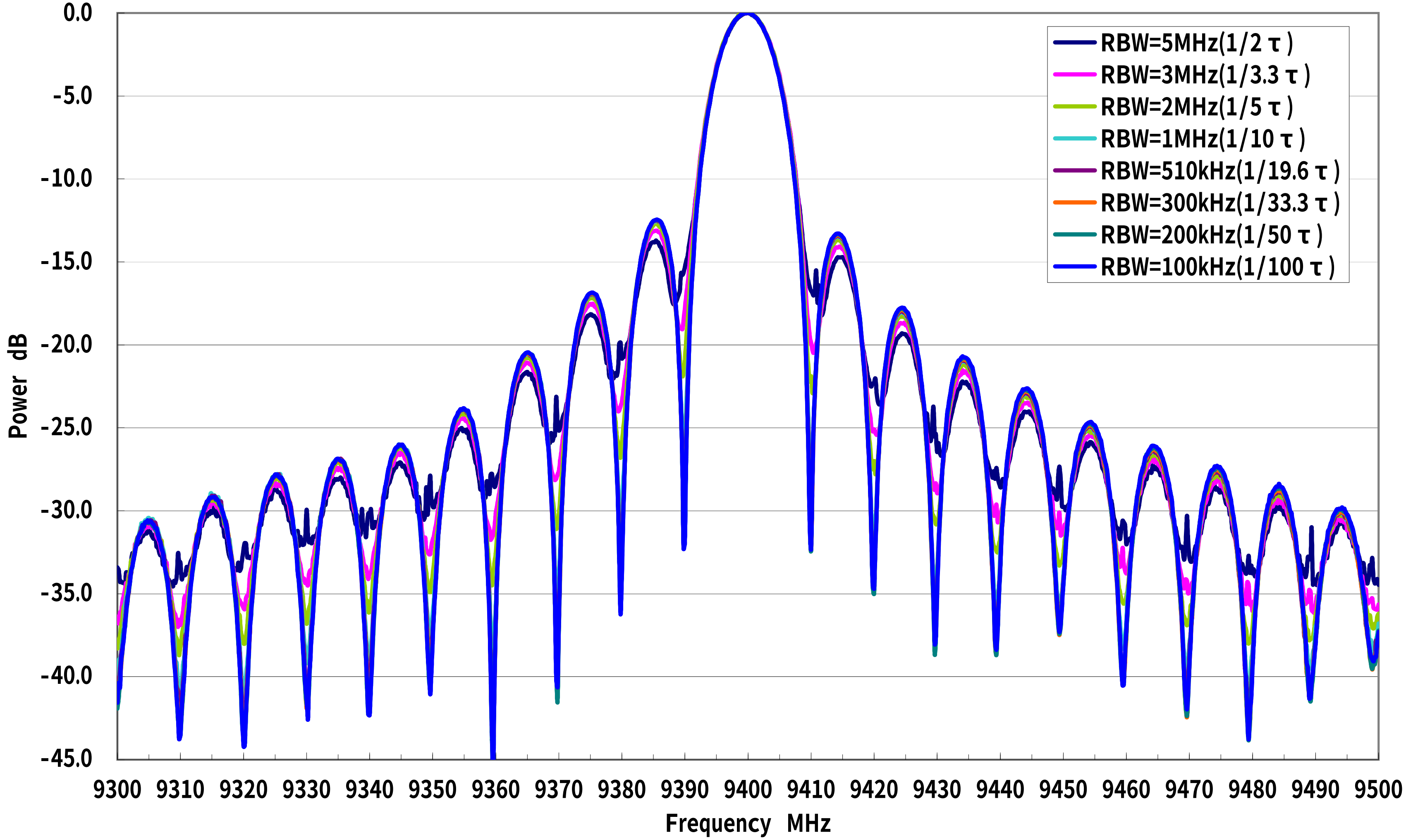


Figure2-2. Pulse Responce of Spectrum Analyzer(Sample 2_IFBW=3dB, pulse width=0.1 μ s)

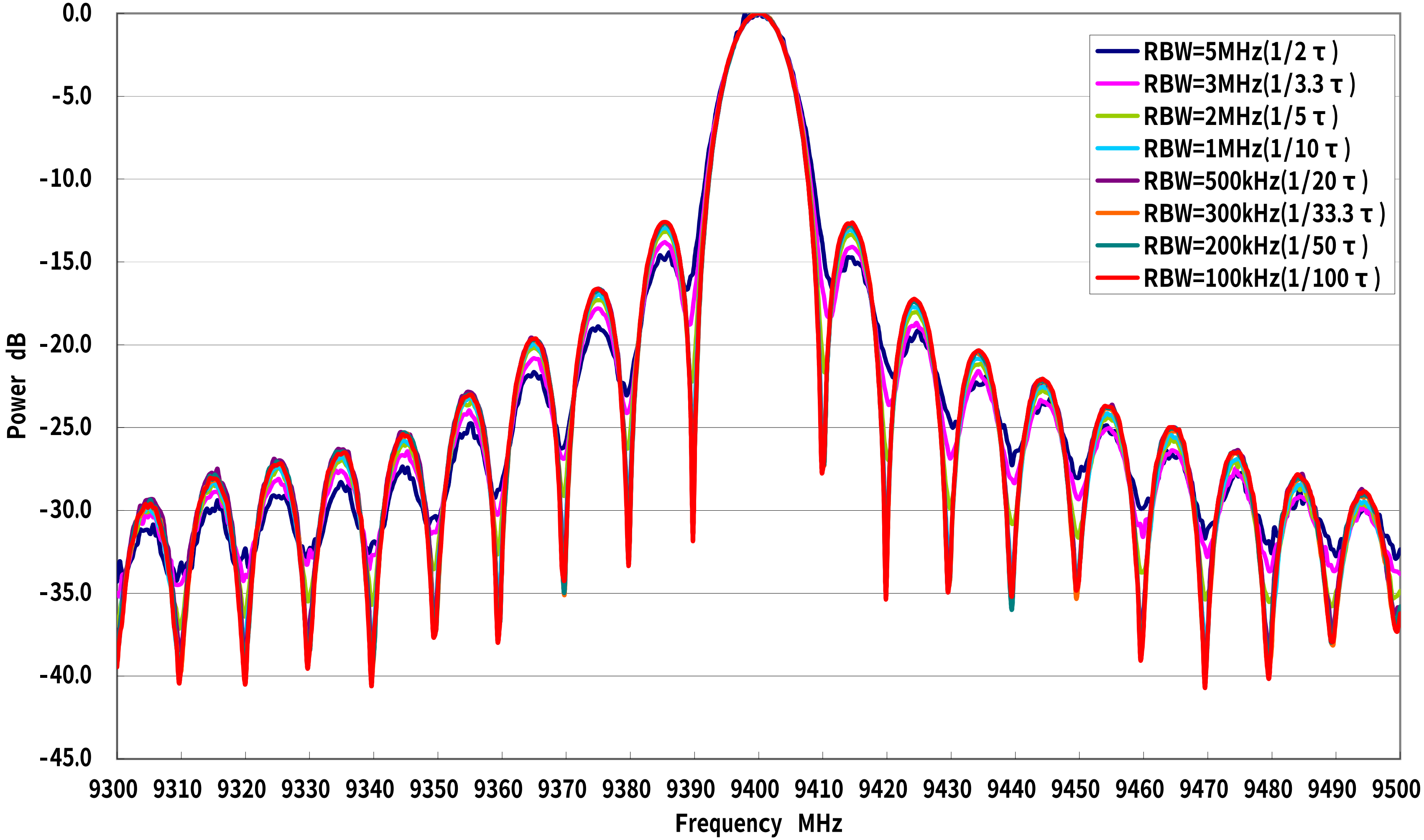


Figure2-3. Pulse Responce of Spectrum Analyzer(Sample 1_IFBW=3dB, pulse width=0.5 μ s)

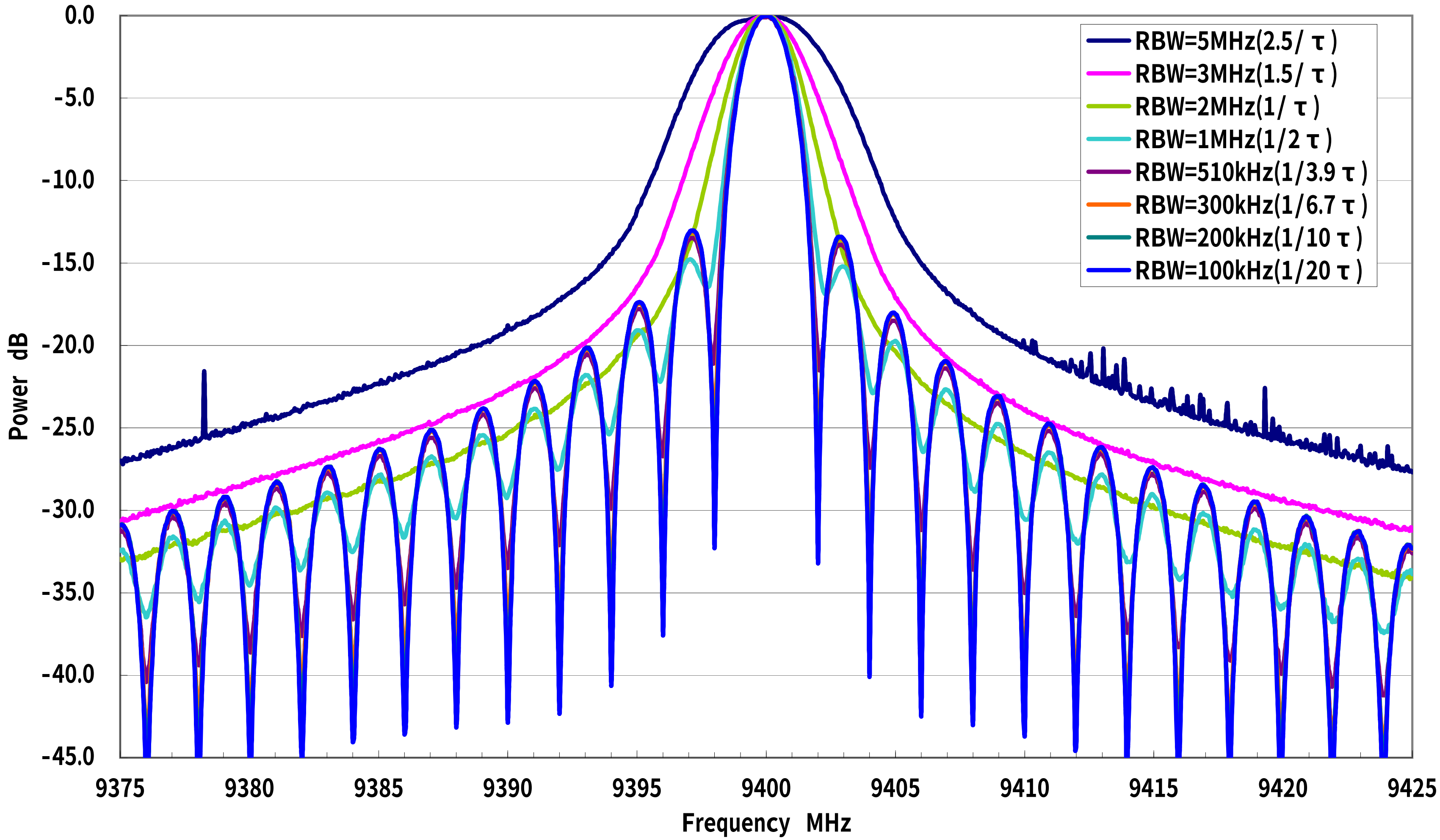


Figure2-4. Pulse Responce of Spectrum Analyzer(Sample 2_IFBW=3dB, pulse width=0.5 μ s)

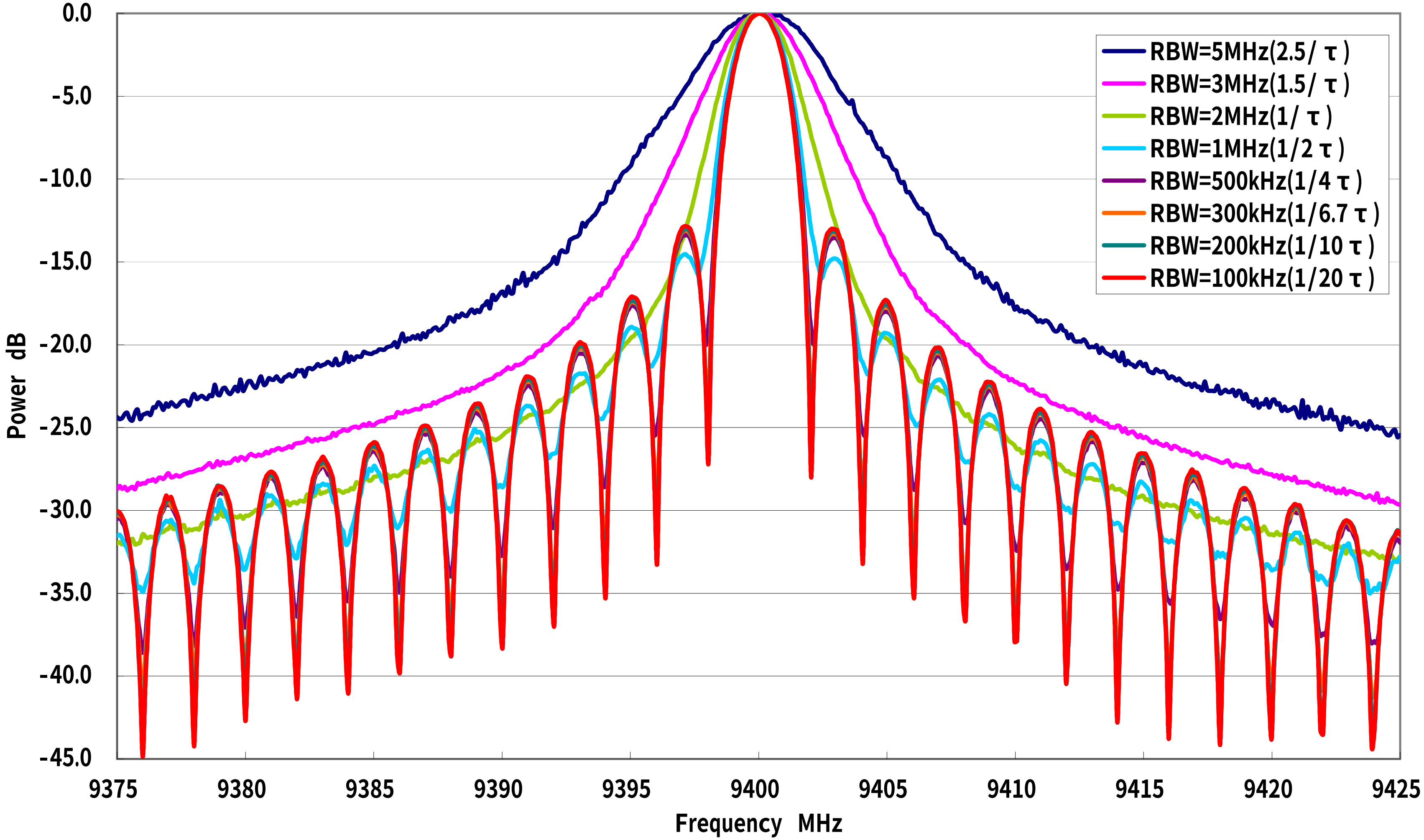


Figure 2-5. Pulse Responce of Spectrum Analyzer(Sample 2_IFBW=6dB, pulse width=0.5 μ s)

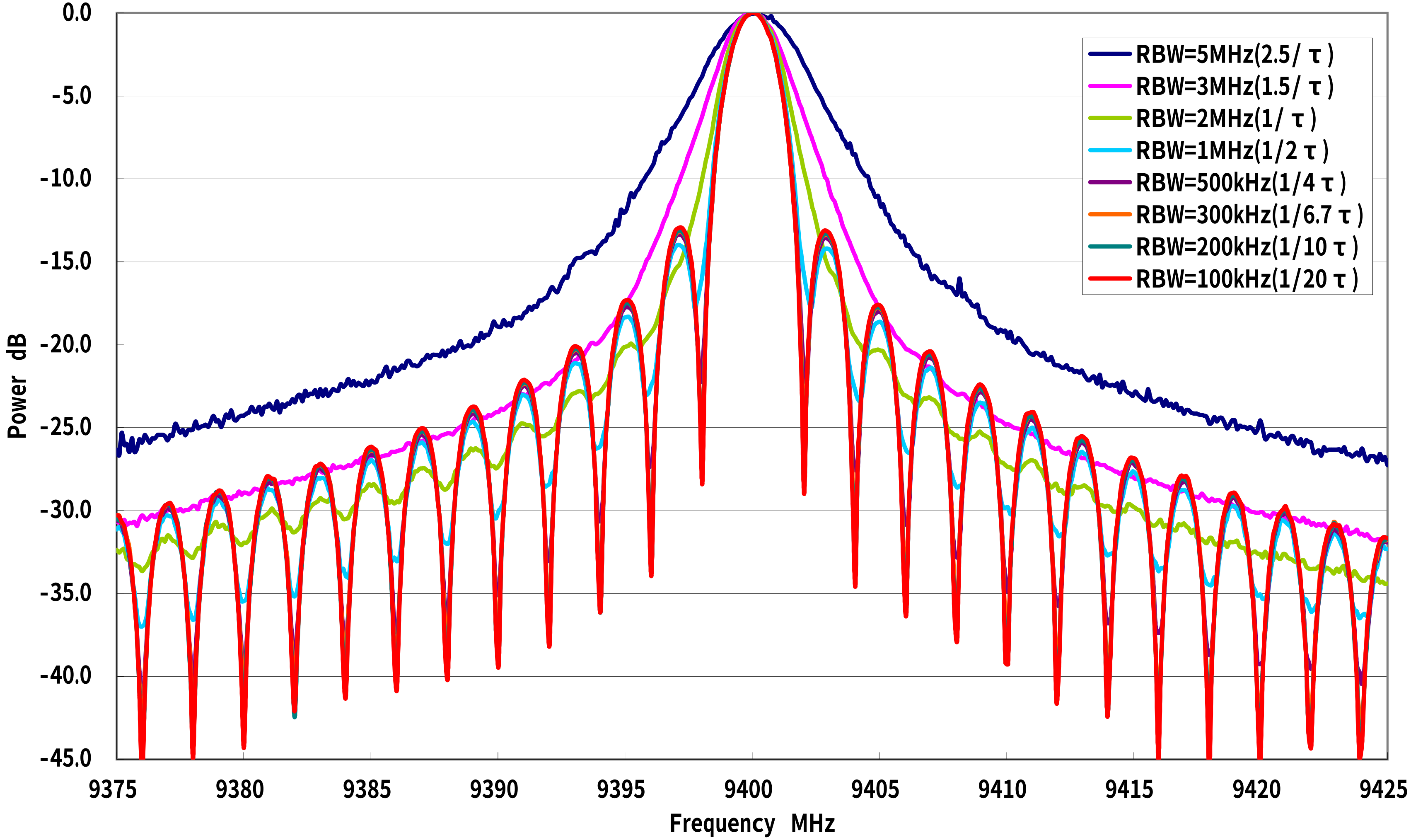


Figure 3-1. Radar Pulse Responce of Spectrum Analyzer (X-band 25kW Maritime Radar)

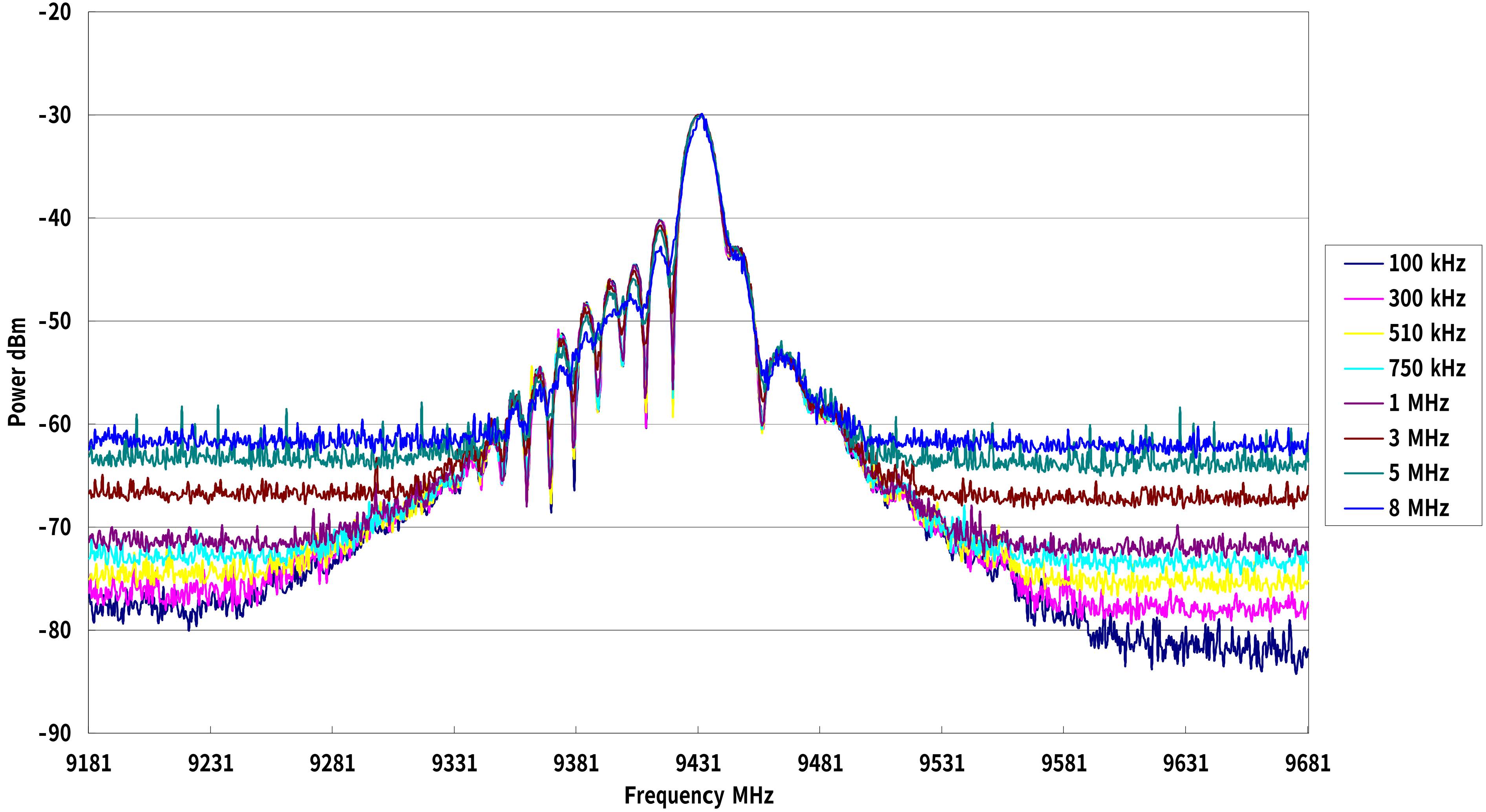


Figure 3-2. Radar Pulse Responce of Spectrum Analyzer (9351-9434 MHz)

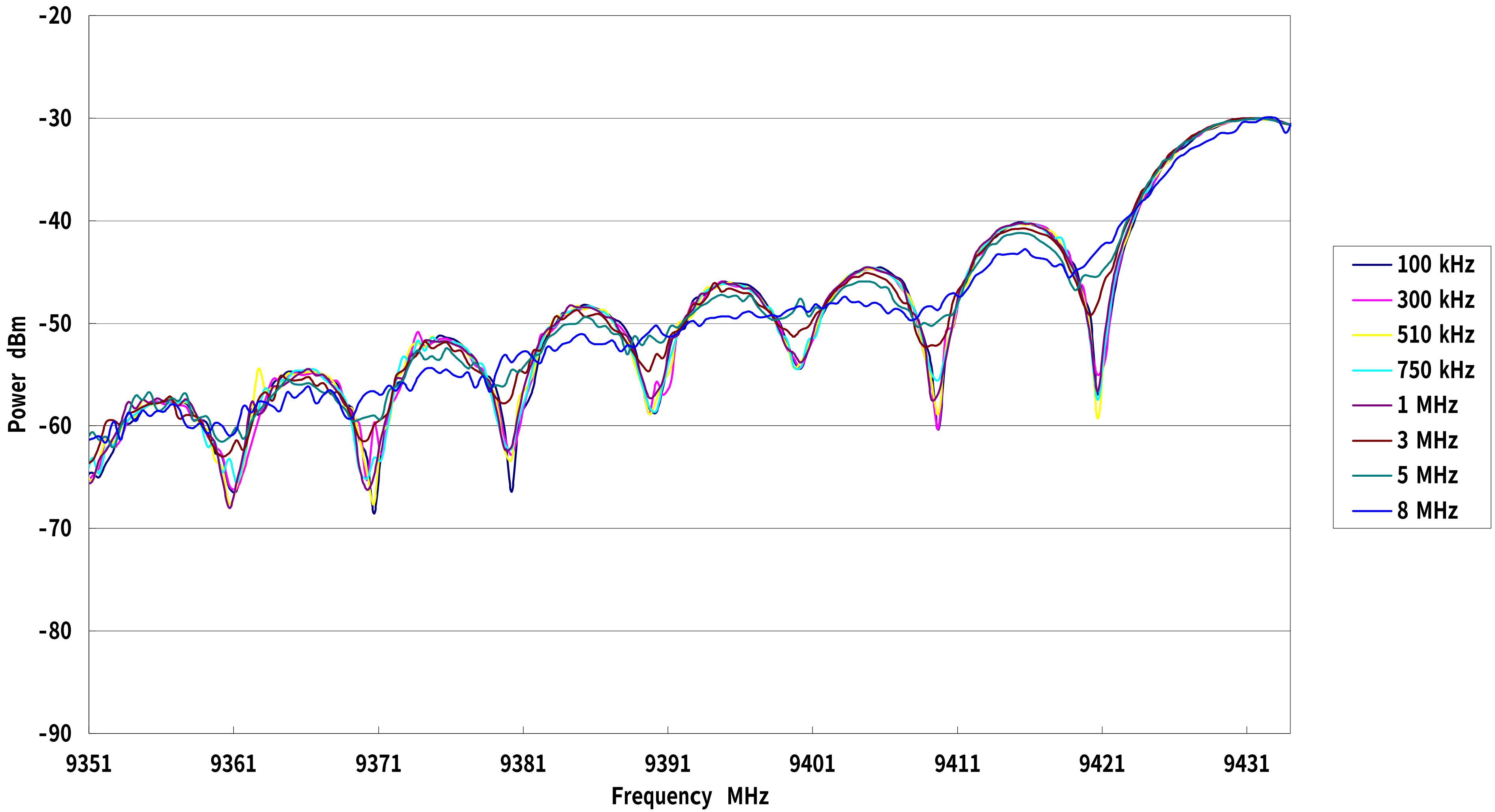


Figure 3-3. Radar Pulse Responce of Spectrum Analyzer (9434-9485 MHz)