Extended Bandwidth Test Results of the Recon Scout

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1 Introduction

This document reports on a retest of the ReconRobotics, Inc. Recon Scout, FCC ID UYXRSK2010-01, with regard to occupied bandwidth.

While the Recon Scout transmits vestigial sideband analog video, it does not (and is not required to) conform to the NTSC standard. Among other differences, the present version of the Recon Scout transmits only in black and white with no audio, and occupies less bandwidth than an NTSC signal. Future versions of the product may include audio, color video, and other data transmissions. We acknowledge that any such device will need a new certification.

The measurements reported below generally confirm the data in the original certification application. These plots also show signal details and bandwidth at -40 dB and below.

These measurements were taken while a Recon Scout views a predetermined image. The image was chosen among several candidates for worst-case bandwidth, but again, the worst case obtainable here is comparable to that in the original application.

In contrast to the previous tests, these measurements were taken with a higher dynamic range and additional notations of bandwidth were made much farther from the carrier.

This document is organized as follows. Section 2 will recap the previous testing. Section 3 will cover the test equipment and methodology used to acquire more data. This will be followed by a summary of the data in Section 4. The full data set is available in the Appendices.

2 Overview of Previous Testing

Previous testing of the Recon Scout's Emission Bandwidth was conducted on April 21, 2010 by TÜV SÜD America. This testing was performed to the standard procedure found in ANSI TIA-603-C as well as the article "The Measurement of Occupied Bandwidth" from the certification bureau of Industry Canada. The results from this testing are presented in [1].

For each of the three channels that are defined in the waiver, testing was conducted with an RBW of 10 kHz and 300 kHz. The results from this original testing are reproduced here in Table 1. Per the standards, the emission bandwidth was measured at 20 dB down from the peak of the signal. From this data, it was determined that the worst case between the three channels was 100 kHz bandwidth.

Table 1: Original test report data.

Center Frequency	*RBW 300 kHz*	*RBW 10 kHz*
433 MHz	1.08 MHz	80 kHz
439 MHz	1.01 MHz	87 kHz
445 MHz	1.19 MHz	100 kHz

3 Extended Testing

In the communication received from the FCC there was a desire for additional data with respect to the signal that was further down from the carrier. Additional testing was performed on 10 November 2010 and is outlined below.

3.1 Test Equipment and Environment

Additional testing was performed at the TÜV SÜD America SR1 test area of the Wild River facility near Taylors Falls, MN. The environmental conditions at the time of test were 23°C, with an air pressure of 99.0 kPa and a relative humidity of 25%.

The test equipment used to perform the test is shown in Table 2.

Table 2: Test equipment

TUV ID	**Model**	**Manufacturer**	**Description**	**Serial**	**Cal Due**
WRLE03371	E4440A	Agilent	Spectrum Analyzer	MY43362222	09-Aug-11
NBLE03011	LPB-2520/A	Antenna Research Association	Bicog Antenna 25-2000 MHz, 1kW	1121	Code Y

All test equipment were operated and measurements were taken by TÜV SÜD America technicians. **Although similar, the operator, test area, location, and equipment for testing are all different from the previously submitted emission bandwidth test report.** Note: Cal Code Y indicates calibration is not required when used with other calibrated equipment.

The identical Recon Scouts that were used in previous testing were used in these testing (listed in Table 3). To maintain consistency through testing, each Recon Scout was powered by a bench top power supply set to 11.1 V.

Table 3: Recon Scouts Used

Serial Number	*Center Frequency*
1209J314	433 MHz
1109J210	439 MHz
0909J066	445 MHz

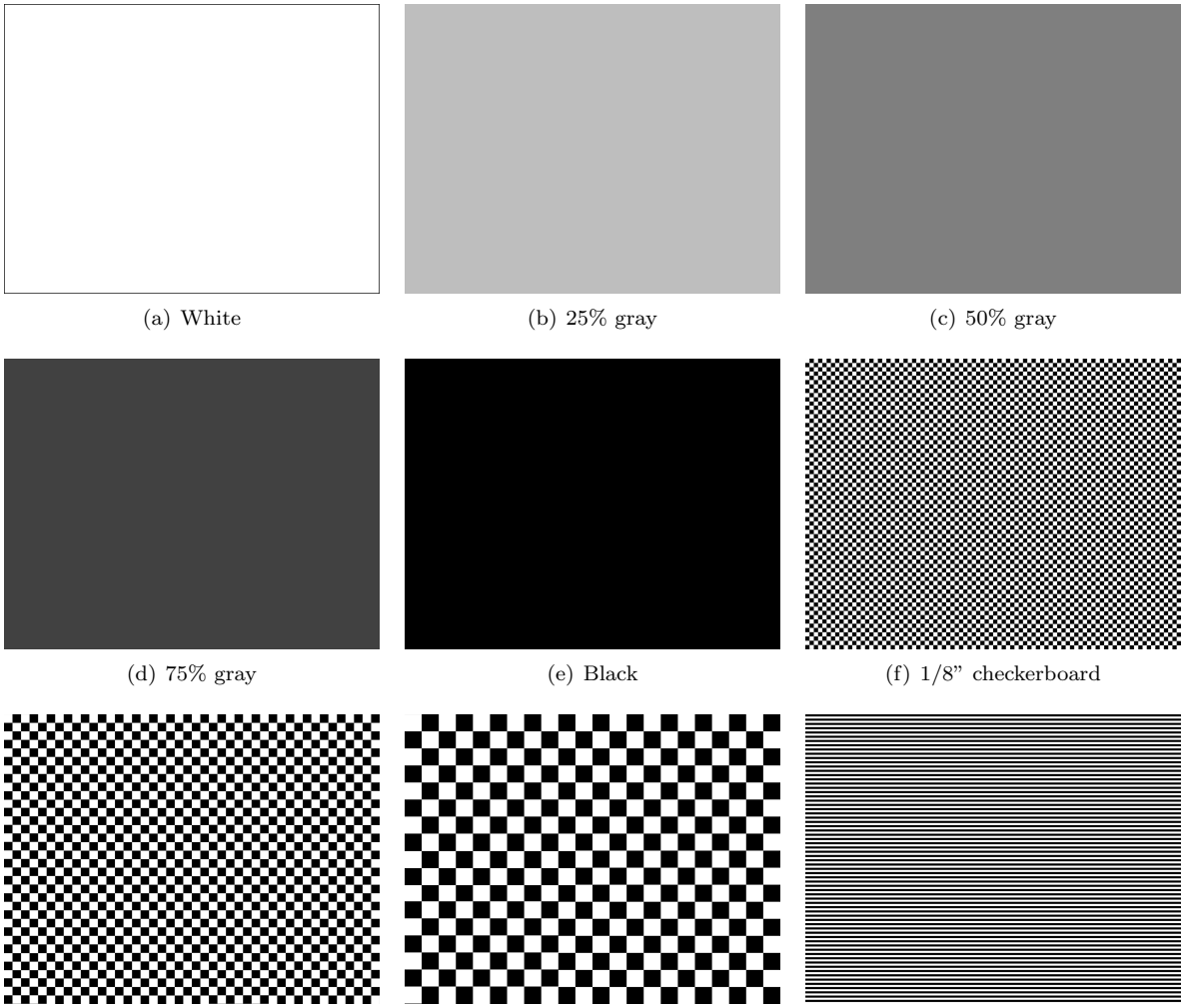
3.2 Overview of the Recon Scout Video Subsystem

The Recon Scout (UYXRSK2010-01) makes use of an extremely low light sensitive black and white analog video camera. The signal from this camera is directly input to a video modulator IC. Hard-coded firmware is used to establish what transmission frequency the modulator is outputting. As there is no integrated microphone in the device, the firmware also disables the audio carrier to reduce power consumption. Specific model numbers of components are considered proprietary, but can be provided upon request.

After modulation, the signal is then passed through multiple amplifier stages before reaching the antenna. All of this is tightly integrated internally to the device. As a result of the integration, it is not easily possible to substitute a signal generator into the system. Thus, the results shown in Section 4 were obtained by placing the Recon Scout into a fixture and having it view pre-printed patterns as shown in Figure 1. Set 6 inches from the Recon Scout shell, these images take up the entire field of view of the camera. In addition to using the pre-printed patterns, tests were conducted where the Recon Scout was positioned observing a video playing on a laptop (the screen was approximately 8.5 inches from the Recon Scout shell) tilted forward to maximize the camera's field of view of the video.

3.3 Test Patterns Used

Figure 1 shows the patterns used to perform during testing.



(a) White (b) 25% gray (c) 50% gray

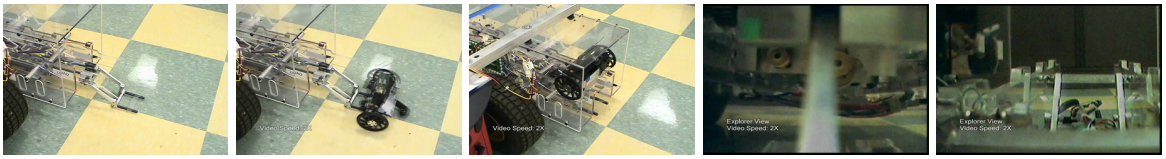
(d) 75% gray (e) Black (f) 1/8" checkerboard

(g) 1/4" checkerboard (h) 1/2" checkerboard (i) 1/16" horizontal bars

Figure 1: Static test patterns used.

In addition to the test patterns shown in Figure 1, three videos were tested:

- Video 1 - *dockingbay3.avi* - 53 seconds - In this video a miniature robot is moving on a checkered tiled surface and approaches a stationary docking station and attempts to dock. Sample scenes are shown in Figure 2.
- Video 2 - *swarm.avi* - 24 seconds - In this video a large number of miniature robots are moving around a tiled floor. In addition, this video has a black and white title screen which causes a significant change in what is observed by the camera. Sample scenes are shown in Figure 3.
- Video 3 - *bimodal-final-short-divx.avi* - 34 seconds - This video shows a series of dots representing robots and docking stations moving on the left side of the screen and the corresponding optimization function for the docking station's movements on the right hand of the screen. Sample scenes are shown in Figure 4.

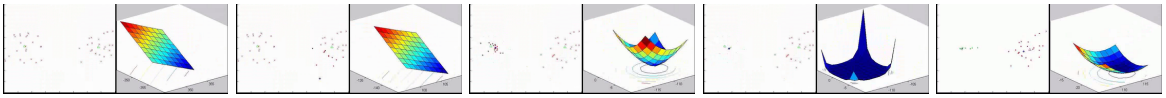


(a) (b) (c) (d) (e)

Figure 2: Sample images from the docking bay sequence.

(a) (b) (c) (d) (e)

Figure 3: Sample images from the "robot swarm"sequence.



(a) (b) (c) (d) (e)

Figure 4: Sample images from the bimodal-final-short-divx sequence.

These videos can be made available upon request.

3.4 Test Procedure

A Recon Scout was placed in a test fixture on the table in the test chamber as shown in Figure 5. A variety of test patterns (shown in Figure 1) were placed in front of the camera in order to take up the entire field of view of the camera. When the static patterns were replaced with video, the fixture was placed on the laptop as shown in Figure 6.

Using an antenna that was fixed approximately 1 m from the broadcasting Scout, the spectrum analyzer was used to capture the emission bandwidth. Measurements were taken with an RBW of 10 kHz and an RBW of 300 kHz. In order to illustrate the bandwidth and non-carrier part of the signal, the spectrum analyzer was set to allow for a higher dynamic range than previous tests. The analyzer measured with the "Max Hold" option enabled. When videos were observed, the video was allowed to repeat multiple times (videos range in duration from 24 to 53 seconds) to ensure that the maximum signals were recorded. For measurements performed with the 10 kHz RBW a span of 2-3 MHz was used to fully capture the bandwidth 40 dB down from the peak. In the case of the 300 kHz RBW, the span was expanded to 20 MHz. For both RBW values, the bandwidth at 20 dB and 40 dB down from the peak were recorded.

After cycling through a series of test patterns on the channel centered at 433 MHz, the two static patterns and two videos that resulted in the widest recorded bandwidth at 10 kHz RBW 20 dB down, 10 kHz RBW 40 dB down, 300 kHz RBW 20 dB down, and 300 kHz RBW 40 dB down were used to test the channels centered at 439 MHz and 445 MHz. In addition, a "no pattern" test was performed only on the 433 MHz where the Recon Scout was allowed to simply observe the room in which it was tested.

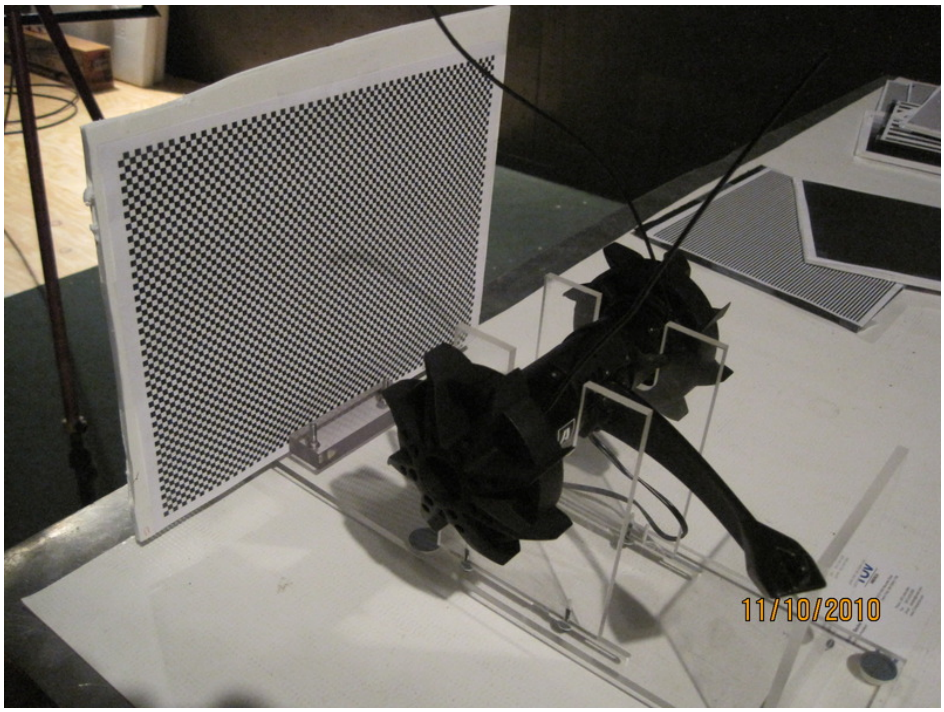
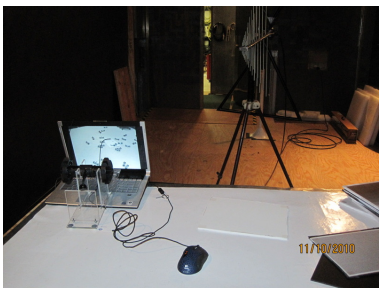
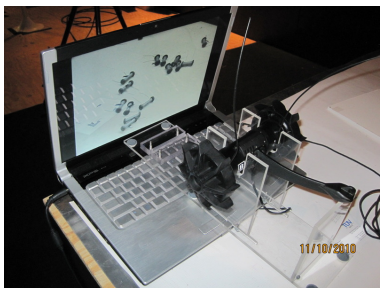


Figure 5: Sample test configuration of Recon Scout in fixture and static test pattern.



(a) Full test apparatus with testing antenna shown.



(b) Close up of Recon Scout viewing video.

(c) Close up of Recon Scout controller showing full screen of video in camera shot.

Figure 6: Sample test configuration of Recon Scout in fixture viewing laptop.

4 Results and Conclusions

Appendix A through Appendix C present the data obtained during testing on 10 November 2010. A summary of the widest bandwidth for each of the measurements for each frequency are presented here in Table 4.

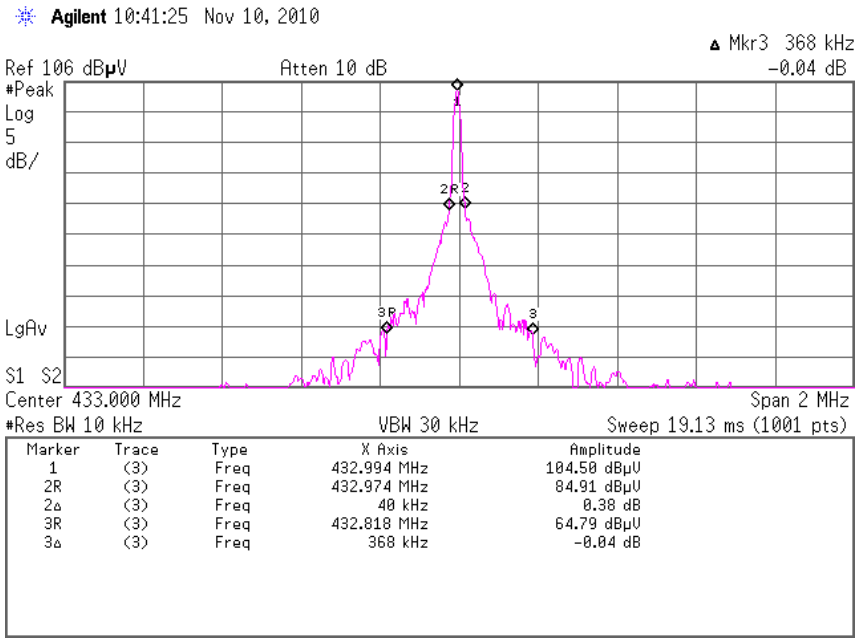
Table 4: Summary of the widest bandwidth measurements in MHz across all frequencies and patterns tested.

		10kHz RBW		300kHz RBW	
Frequency	Test Pattern	20dB measure	40dB measure	20dB measure	40dB measure
433 MHz	75% gray	0.048	0.830	**1.32**	**9.46**
	1/8" checker	0.044	**1.922**	1.30	7.26
	1/16" horizontal	**0.060**	0.996	0.90	7.20
	Video 1	0.076	1.620	1.42	**9.16**
	Video 2	**0.080**	**1.914**	**1.64**	8.94
439 MHz	75% gray	0.058	0.606	**1.52**	**9.52**
	1/8" checker	0.051	**2.163**	**1.52**	8.12
	1/16" horizontal	**0.060**	0.976	0.92	7.68
	Video 2	**0.093**	**2.112**	**1.86**	**9.00**
445 MHz	75% gray	**0.092**	1.200	1.58	10.28
	1/8" checker	0.078	**2.301**	**2.24**	**16.88**
	Video 2	**0.084**	**2.841**	**1.84**	**12.46**

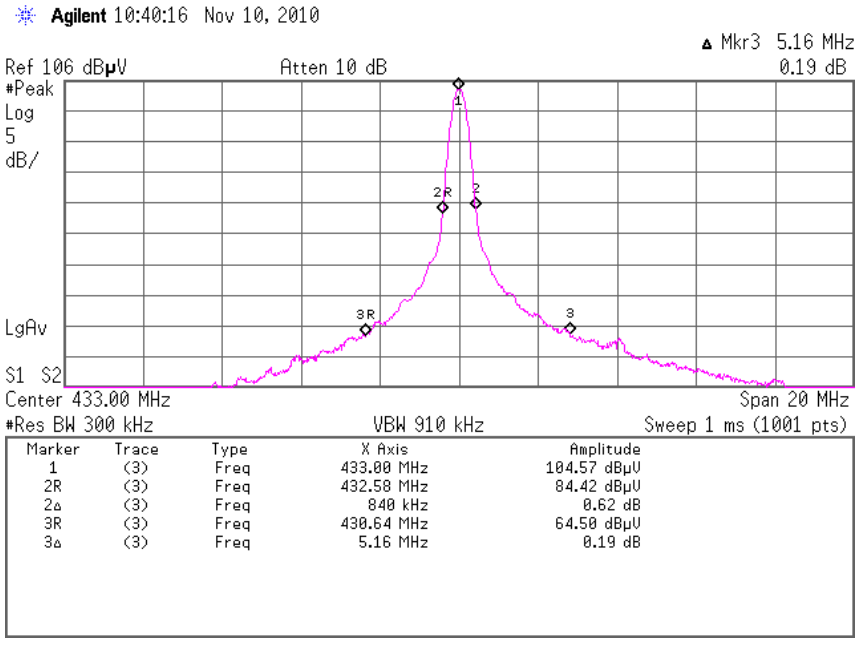
From the data in Table 4, it is clear that the widest bandwidth for a static image measured 20 dB from the peak using a 10 kHz RBW was the 92 kHz reading on the 445 MHz channel. This is very close to the previous measurement of 100 kHz. With respect to the video, under the same conditions, the observed widest bandwidth was 93 kHz, also very close to the previous measurement of 100 kHz. As has been previously mentioned, these tests were conducted in slightly different environments using slightly different equipment configurations and the net results are very close to the original.

A 433 MHz Channel Data

Figures 7 through 19 depict the testing of a Recon Scout at 433 MHz with respect to all thirteen test views (9 static patterns, 3 videos, and 1 no pattern.) A summary of the data is available in Table 5.

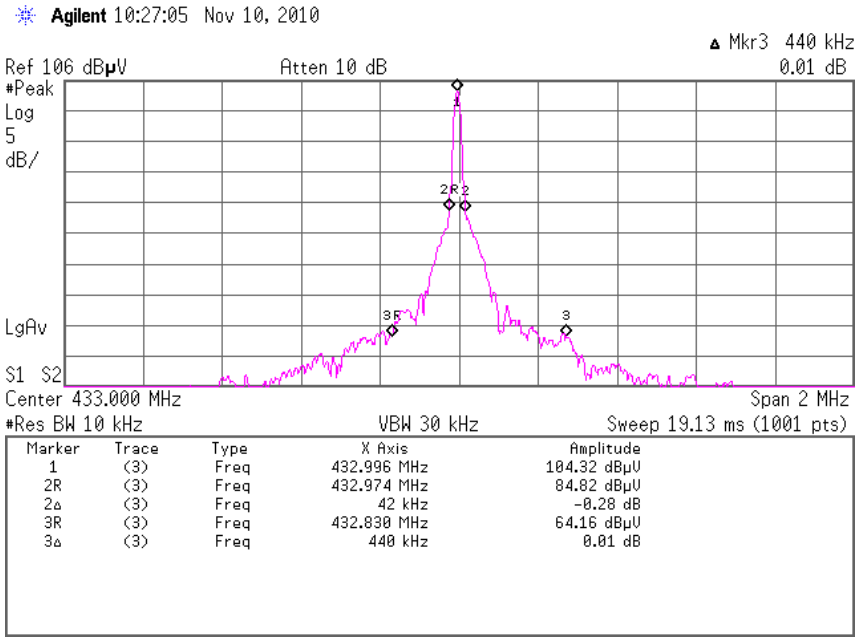


(a) 10 kHz RBW

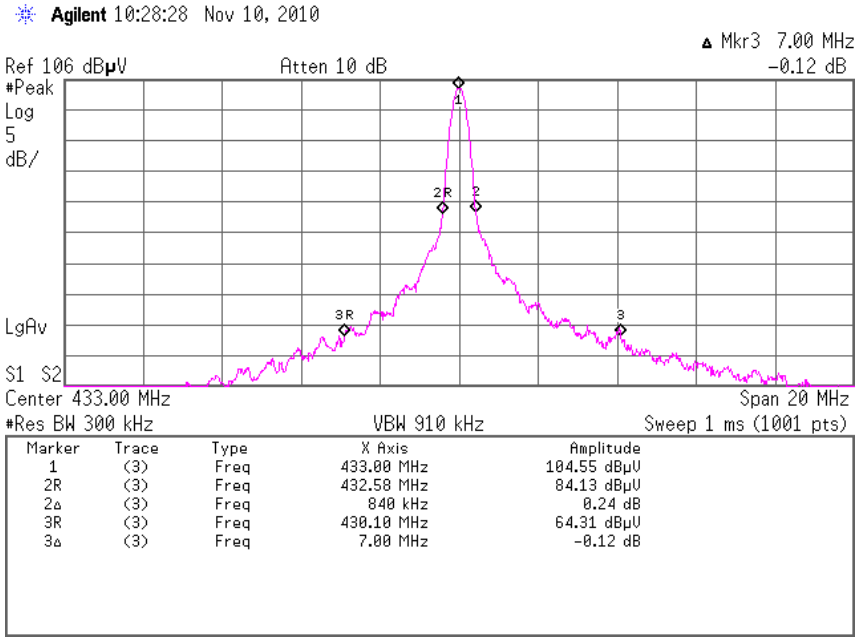


(b) 300 kHz RBW

Figure 7: Plots of 433 MHz transmission viewing white background.

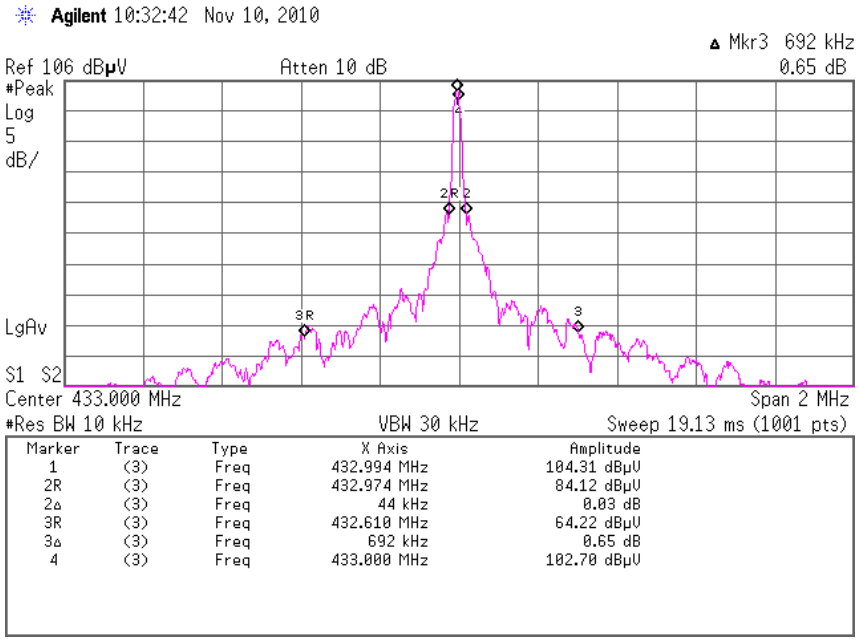


(a) 10 kHz RBW

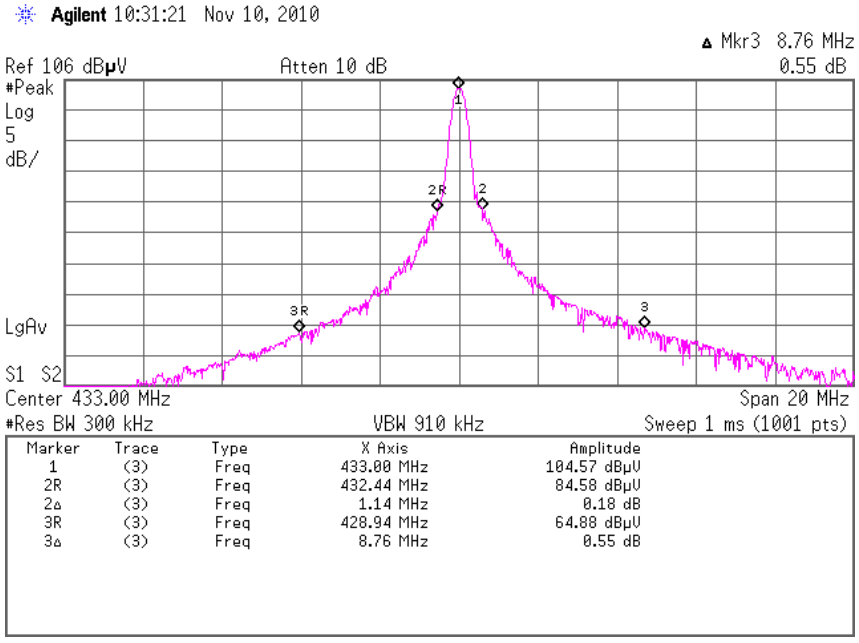


(b) 300 kHz RBW

Figure 8: Plots of 433 MHz transmission viewing 25% gray background.

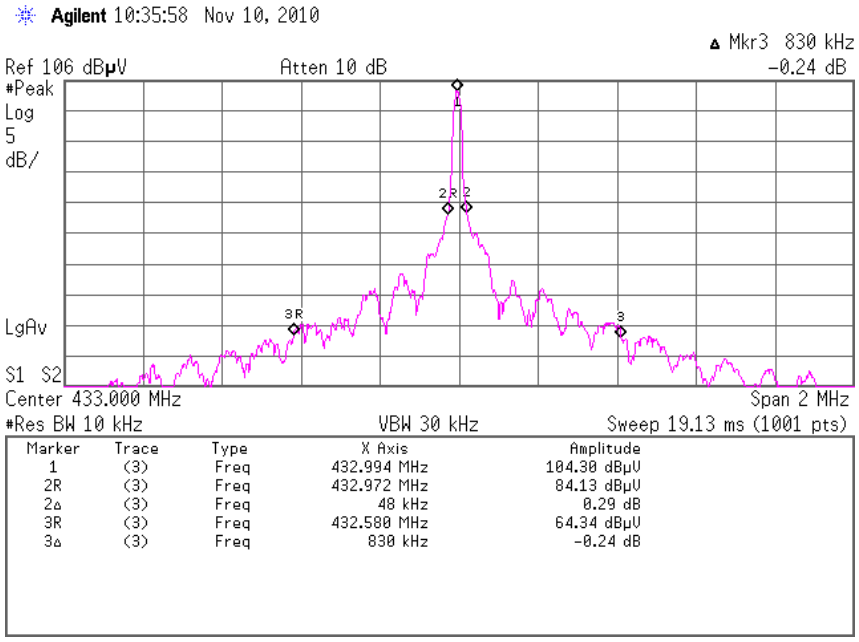


(a) 10 kHz RBW

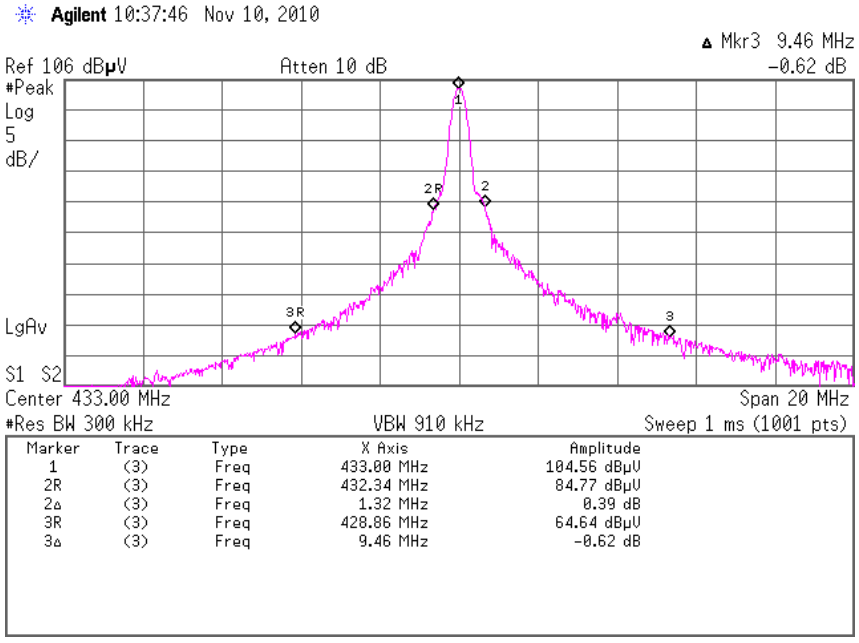


(b) 300 kHz RBW

Figure 9: Plots of 433 MHz transmission viewing 50% gray background.

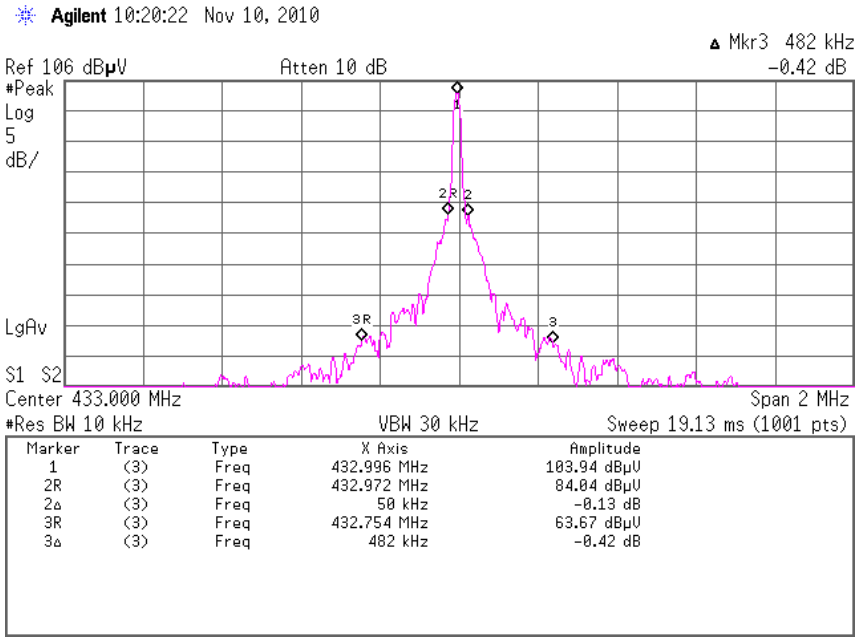


(a) 10 kHz RBW

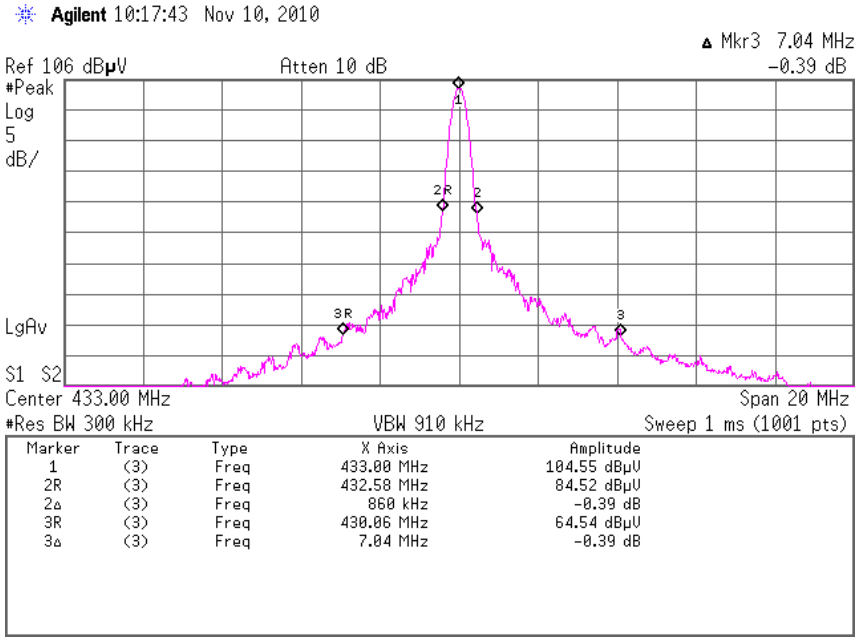


(b) 300 kHz RBW

Figure 10: Plots of 433 MHz transmission viewing 75% gray background.

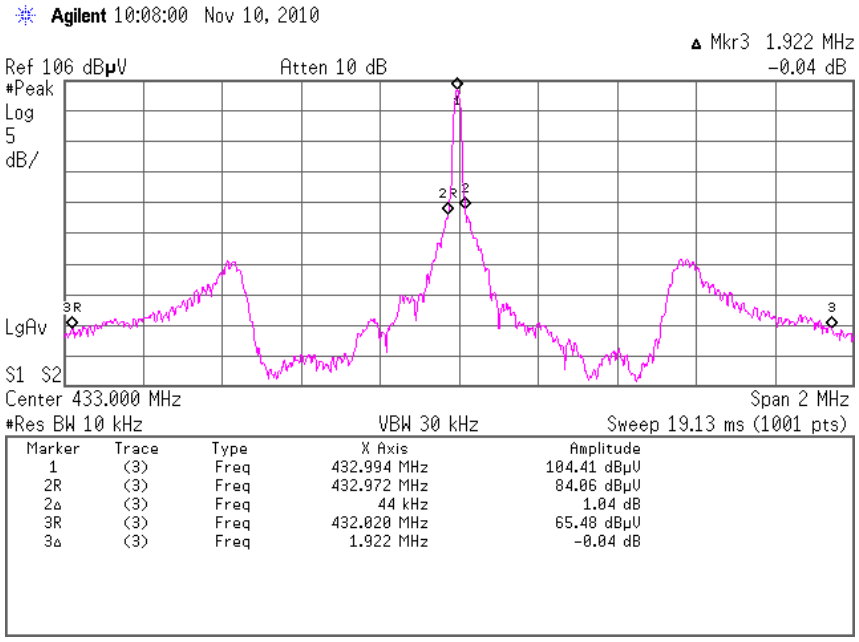


(a) 10 kHz RBW

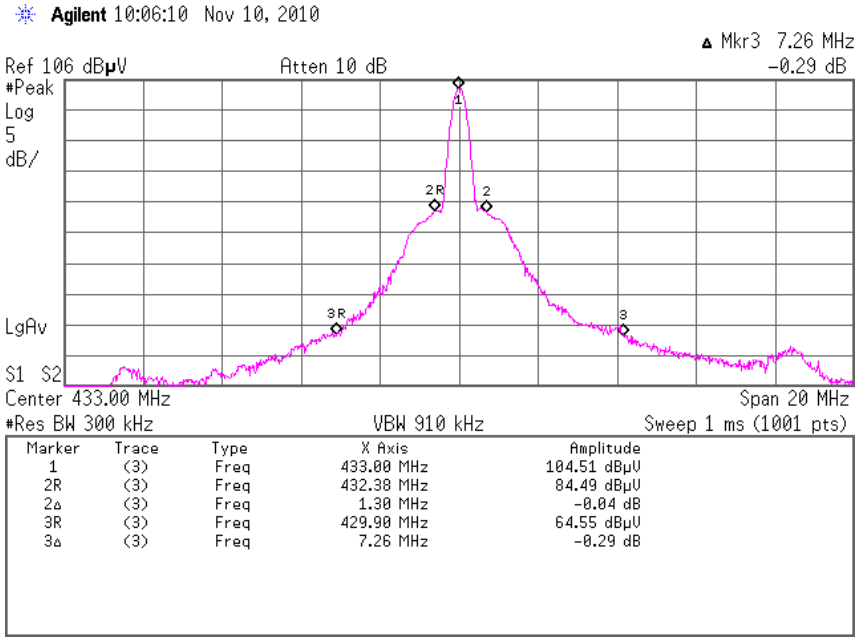


(b) 300 kHz RBW

Figure 11: Plots of 433 MHz transmission viewing black background.

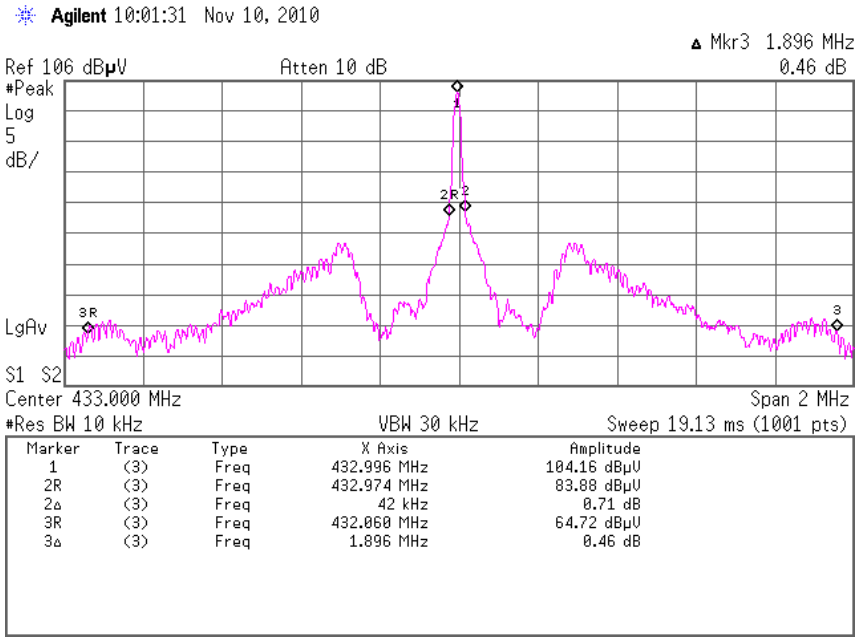


(a) 10 kHz RBW

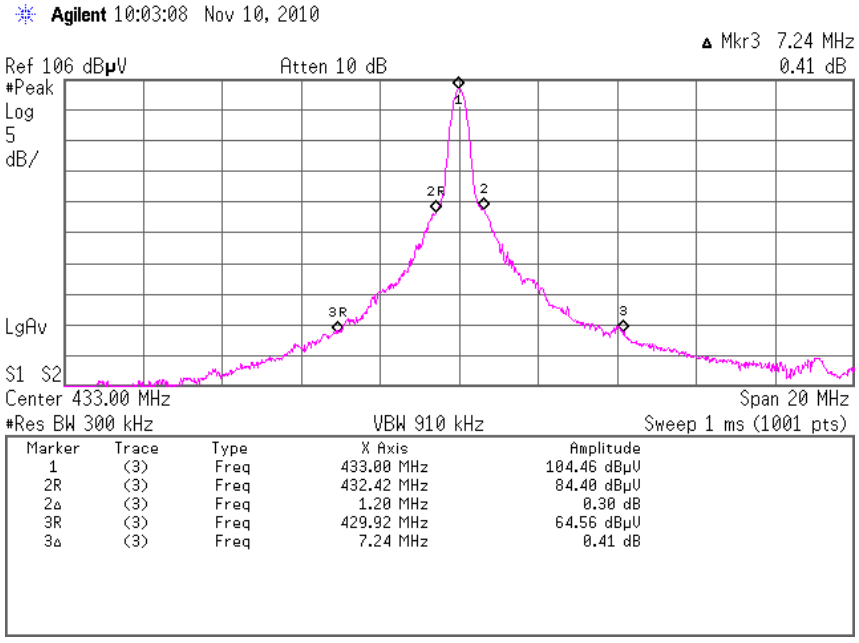


(b) 300 kHz RBW

Figure 12: Plots of 433 MHz transmission viewing 1/8" checkered background.

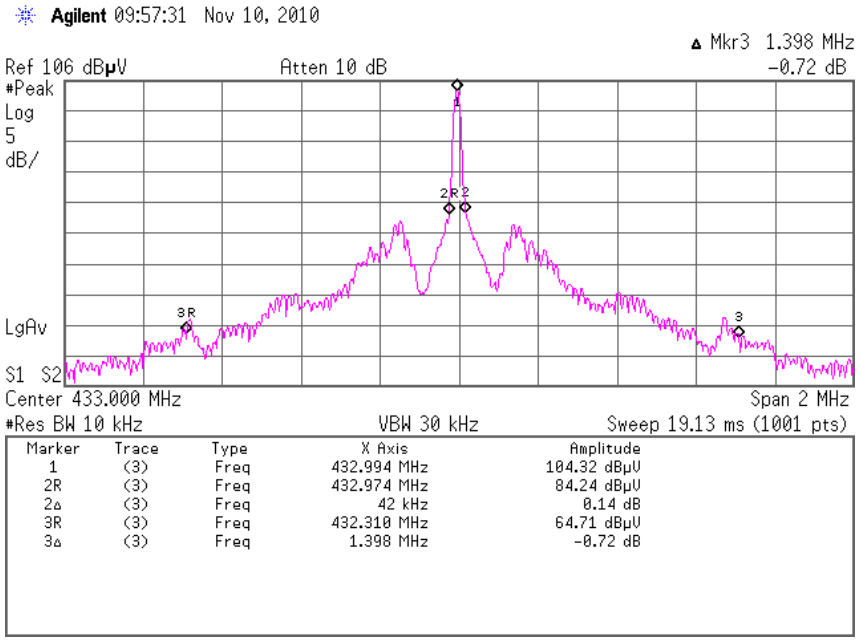


(a) 10 kHz RBW

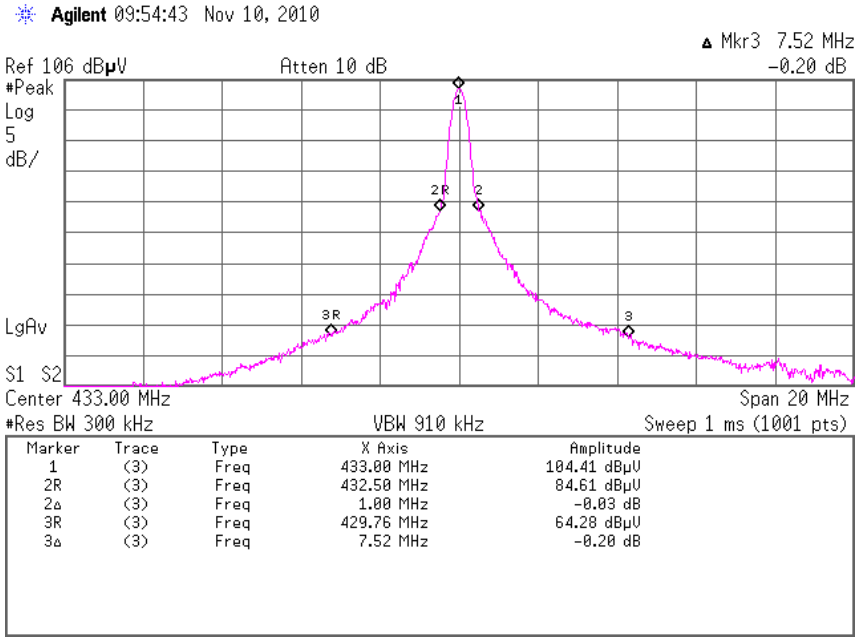


(b) 300 kHz RBW

Figure 13: Plots of 433 MHz transmission viewing 1/4" checkered background.

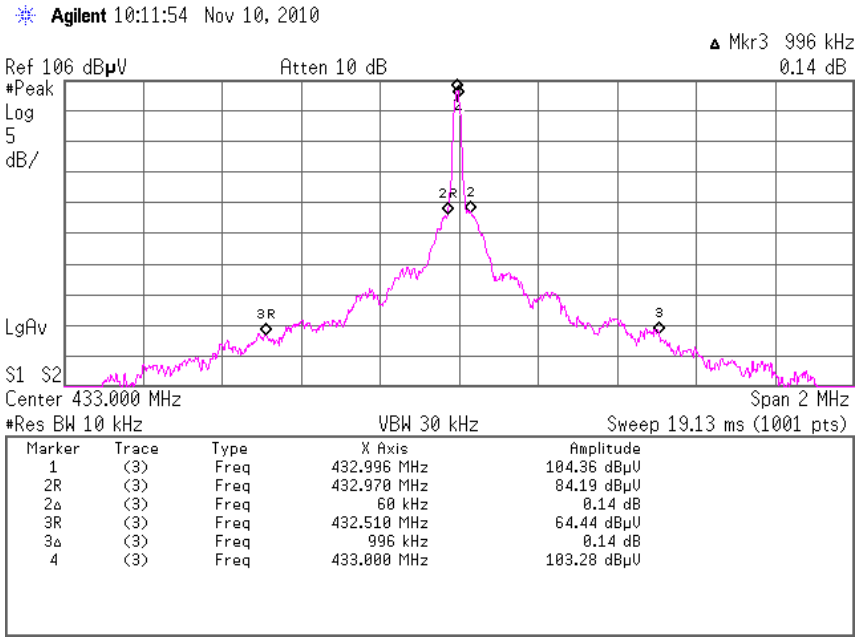


(a) 10 kHz RBW

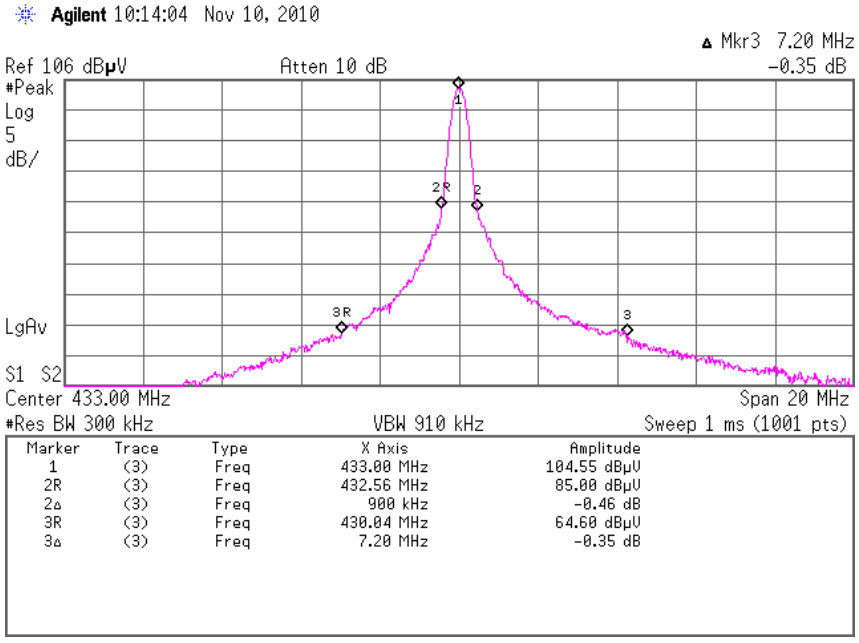


(b) 300 kHz RBW

Figure 14: Plots of 433 MHz transmission viewing 1/2" checkered background.

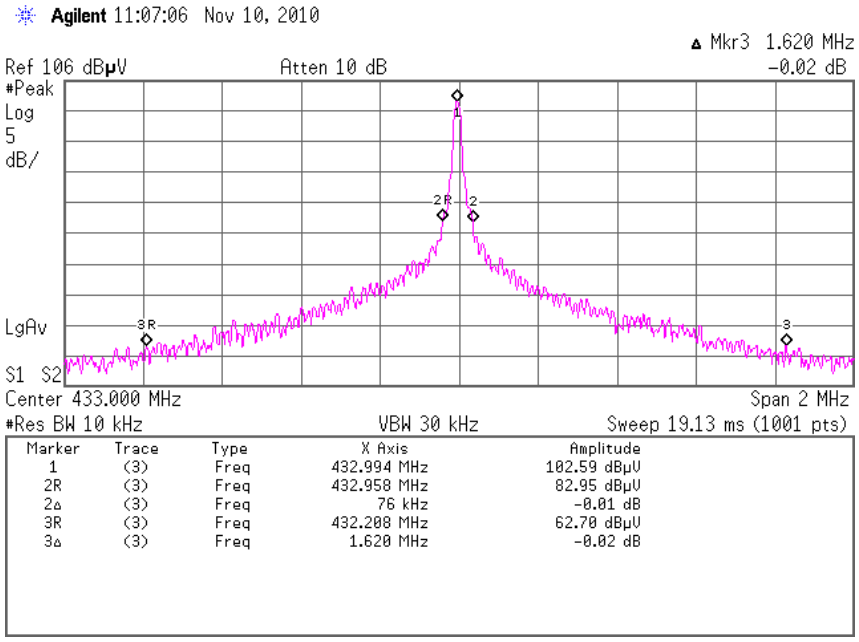


(a) 10 kHz RBW

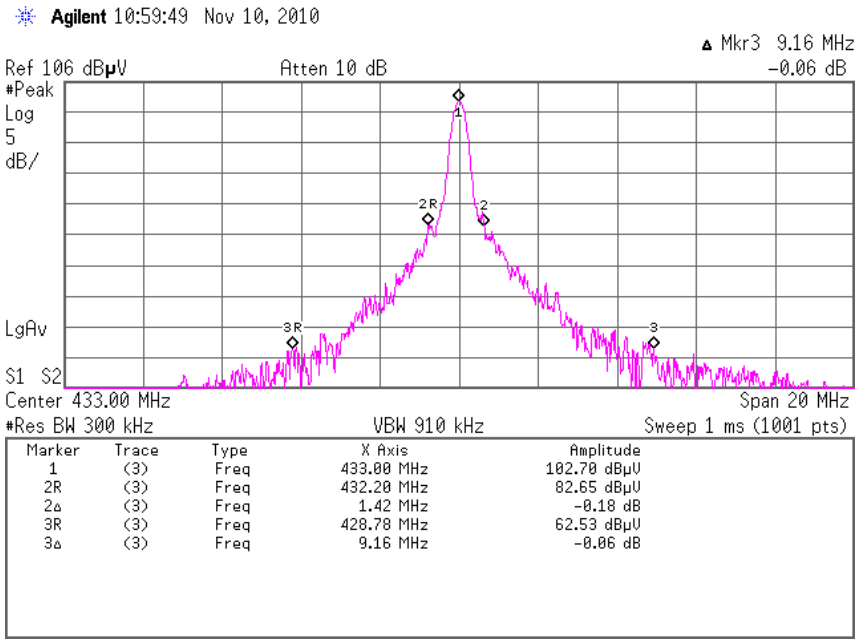


(b) 300 kHz RBW

Figure 15: Plots of 433 MHz transmission viewing 1/16" horizontal striped background.

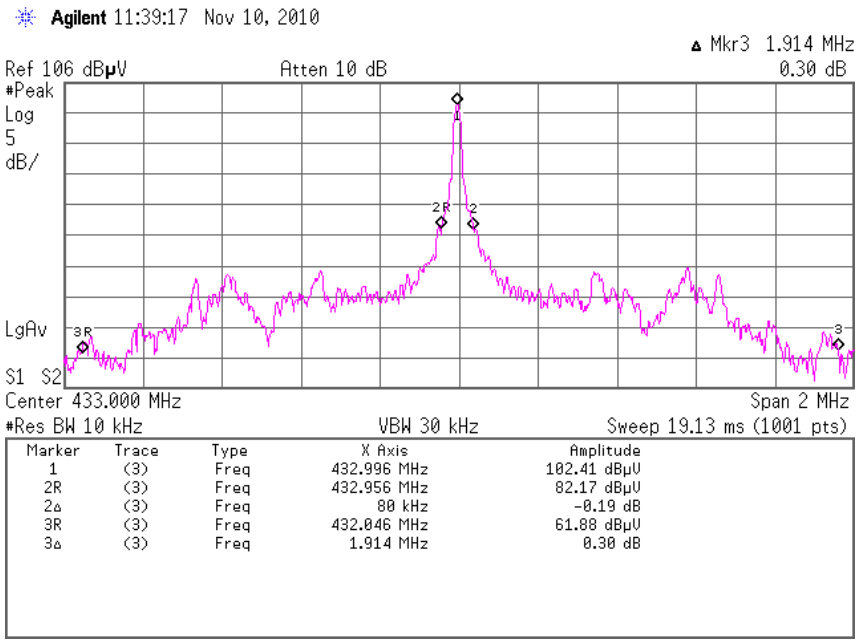


(a) 10 kHz RBW

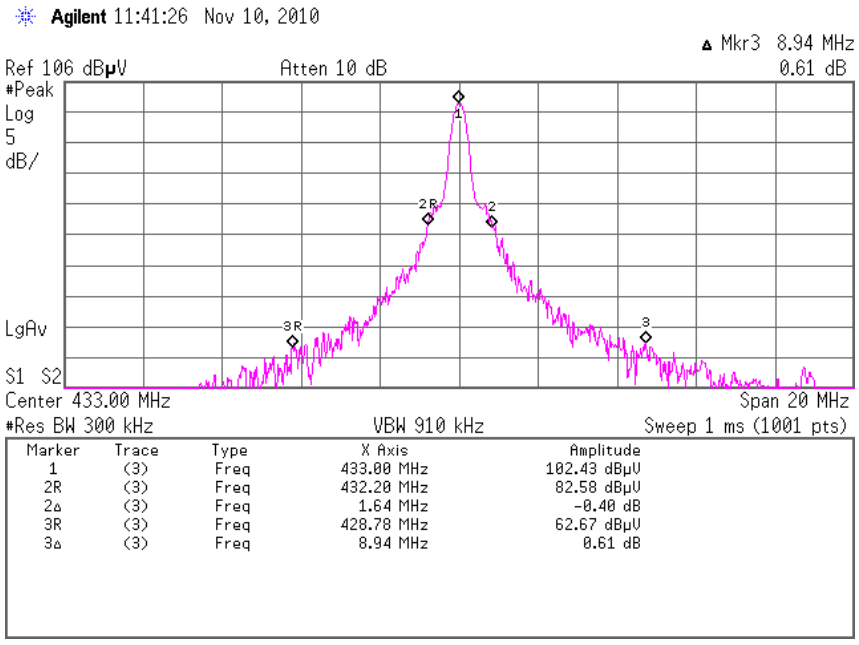


(b) 300 kHz RBW

Figure 16: Plots of 433 MHz transmission viewing video 1.

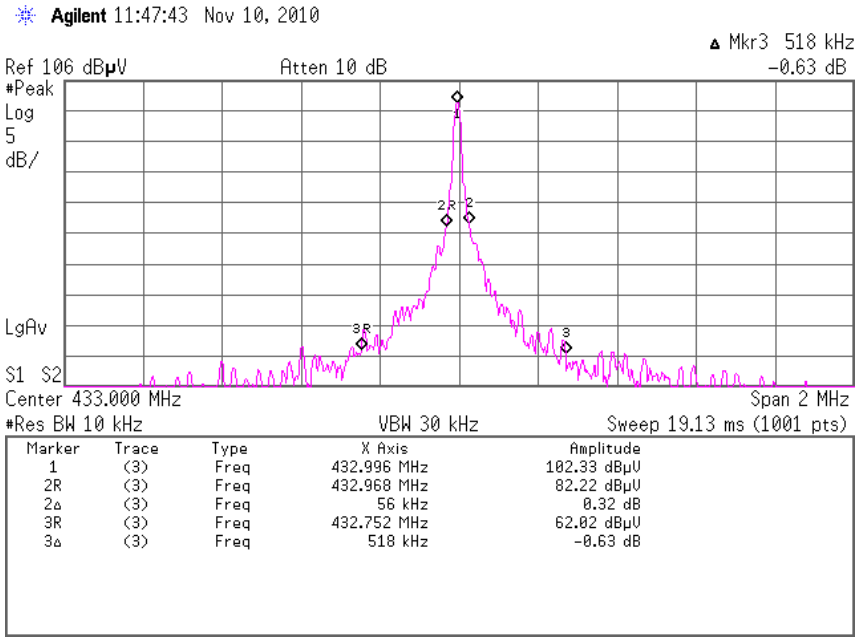


(a) 10 kHz RBW

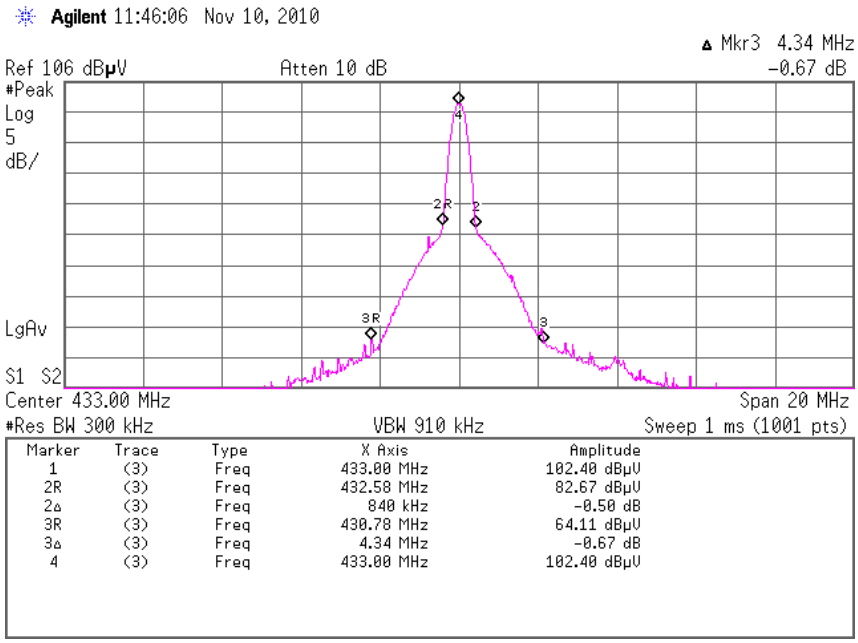


(b) 300 kHz RBW

Figure 17: Plots of 433 MHz transmission viewing video 2.

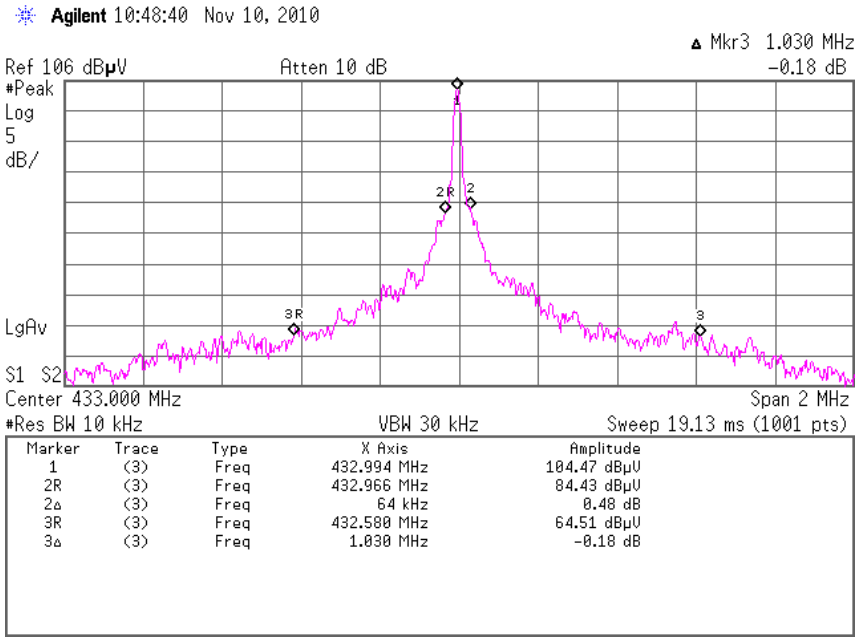


(a) 10 kHz RBW

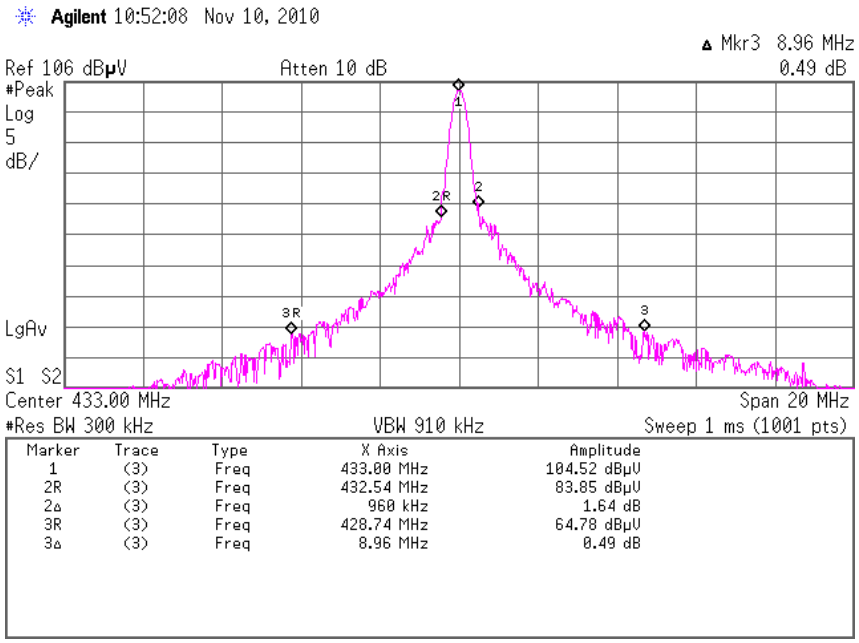


(b) 300 kHz RBW

Figure 18: Plots of 433 MHz transmission viewing video 3.



(a) 10 kHz RBW



(b) 300 kHz RBW

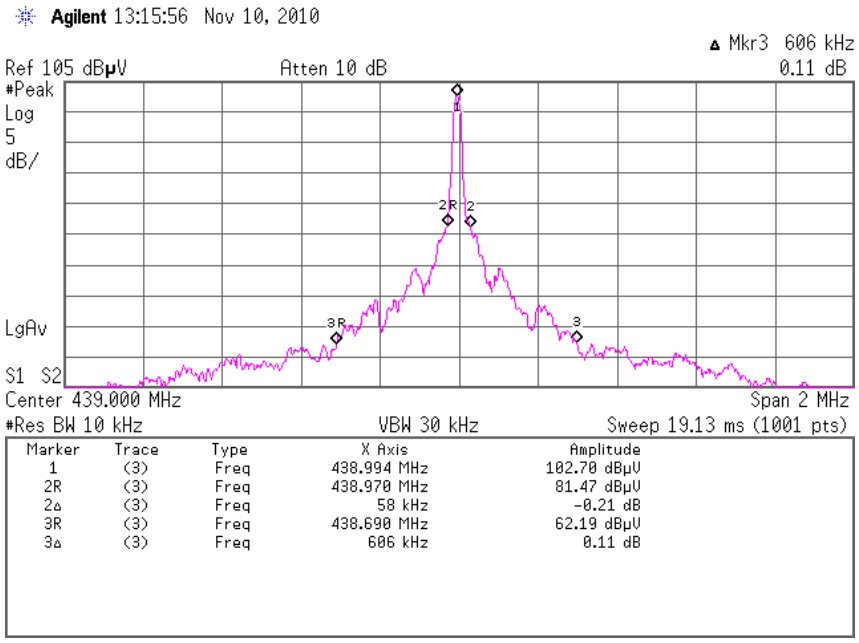
Figure 19: Plots of 433 MHz transmission viewing no pattern.

Table 5: Summary of results for Recon Scout broadcasting at 433 MHz. All measurements in MHz. Peak values are boldfaced.

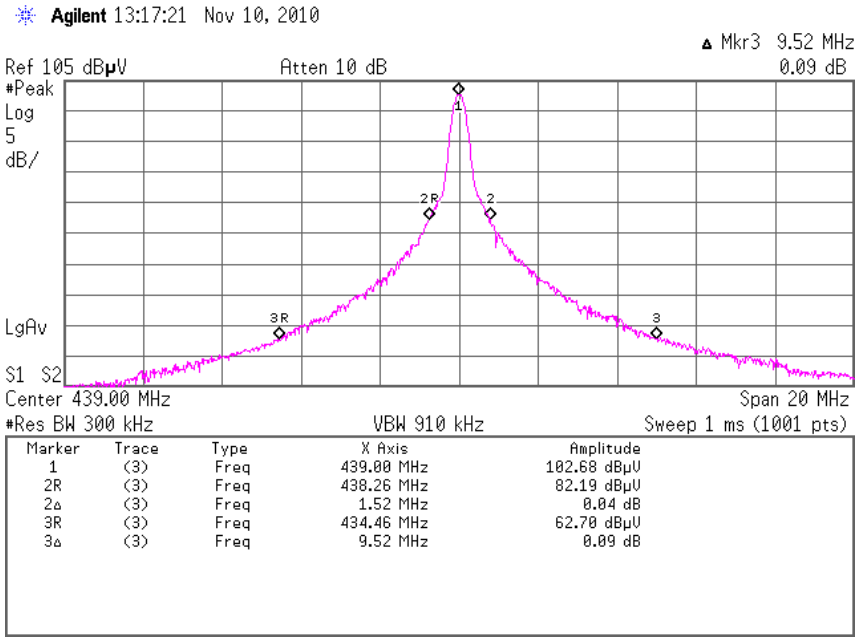
	10kHz RBW		300kHz RBW	
Test Pattern	20dB measure	40dB measure	20dB measure	40dB measure
White	0.040	0.368	0.84	5.16
25% gray	0.042	0.440	0.84	7.00
50% gray	0.044	0.692	1.14	8.76
75% gray	0.048	0.830	**1.32**	**9.46**
Black	0.050	0.482	0.86	7.04
1/8" checker	0.044	**1.922**	1.30	7.26
1/4" checker	0.042	1.896	1.20	7.24
1/2" checker	0.042	1.398	1.00	7.52
1/16" horizontal	**0.060**	0.996	0.90	7.20
Video 1	0.076	1.620	1.42	**9.16**
Video 2	**0.080**	**1.914**	**1.64**	8.94
Video 3	0.056	0.518	0.84	4.34
No pattern	0.064	1.030	0.96	8.96

B 439 MHz Channel Data

Figures 20 through 24 depict the testing of a Recon Scout at 439 MHz with respect to test views (3 static patterns and 2 videos) selected as the highest bandwidth in Table 5. A summary of the data is available in Table 6.

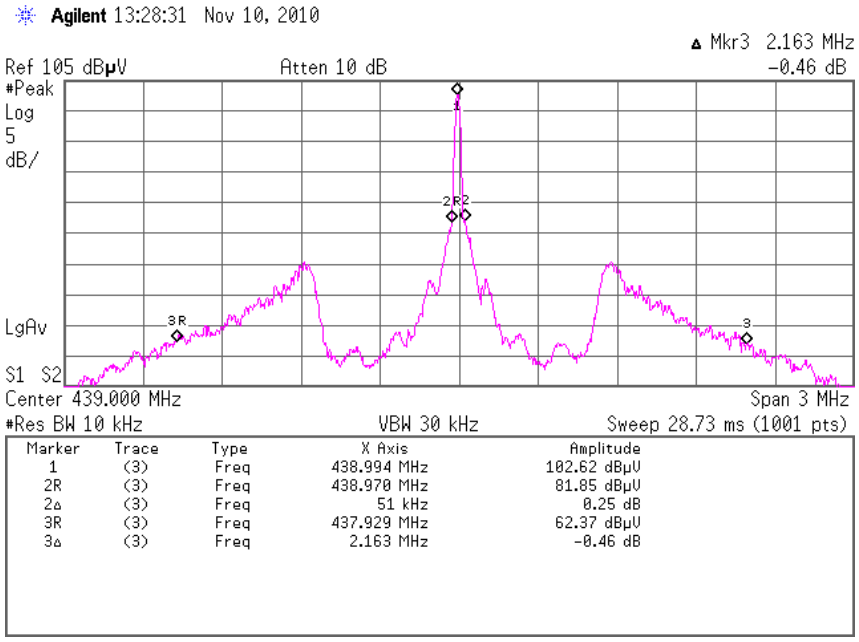


(a) 10 kHz RBW

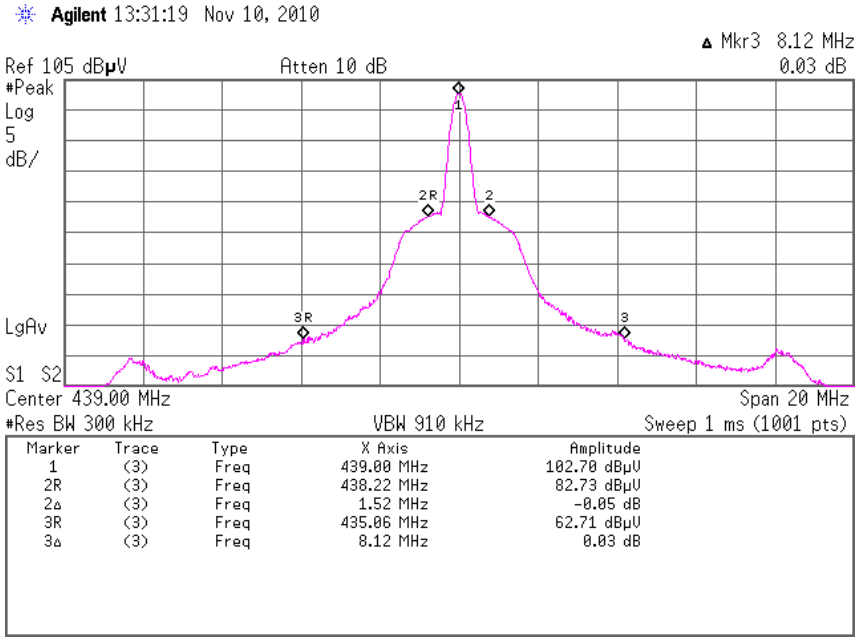


(b) 300 kHz RBW

Figure 20: Plots of 439 MHz transmission viewing 75% gray background.

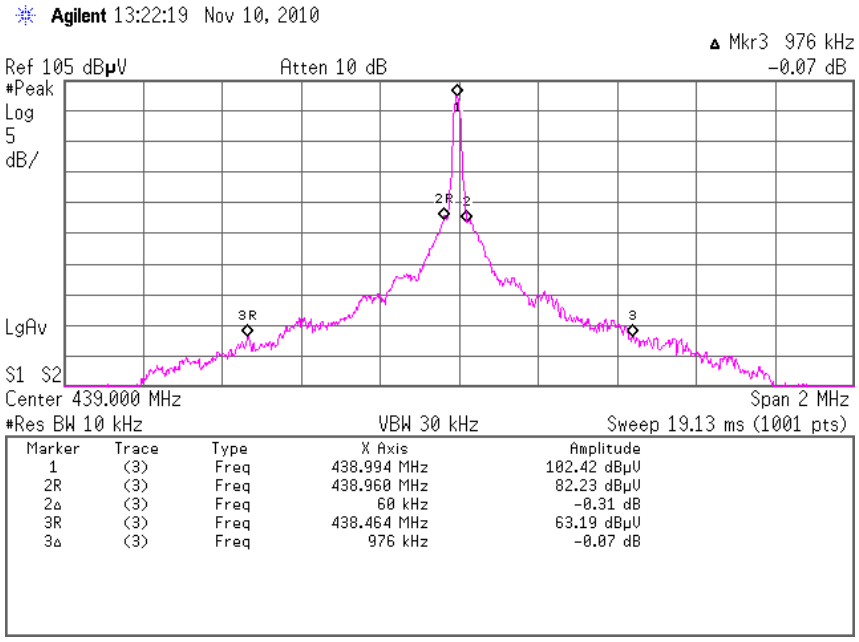


(a) 10 kHz RBW

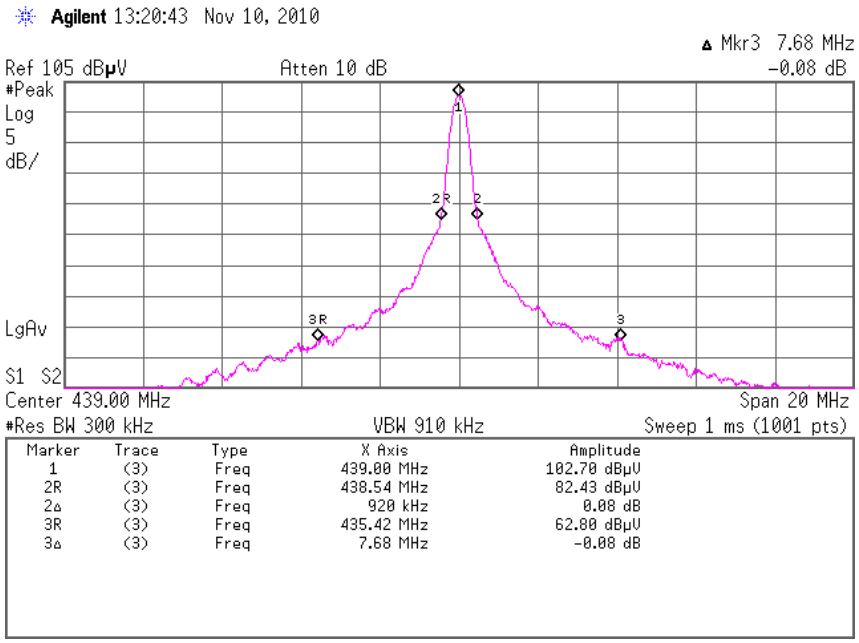


(b) 300 kHz RBW

Figure 21: Plots of 439 MHz transmission viewing 1/8" checkered background.

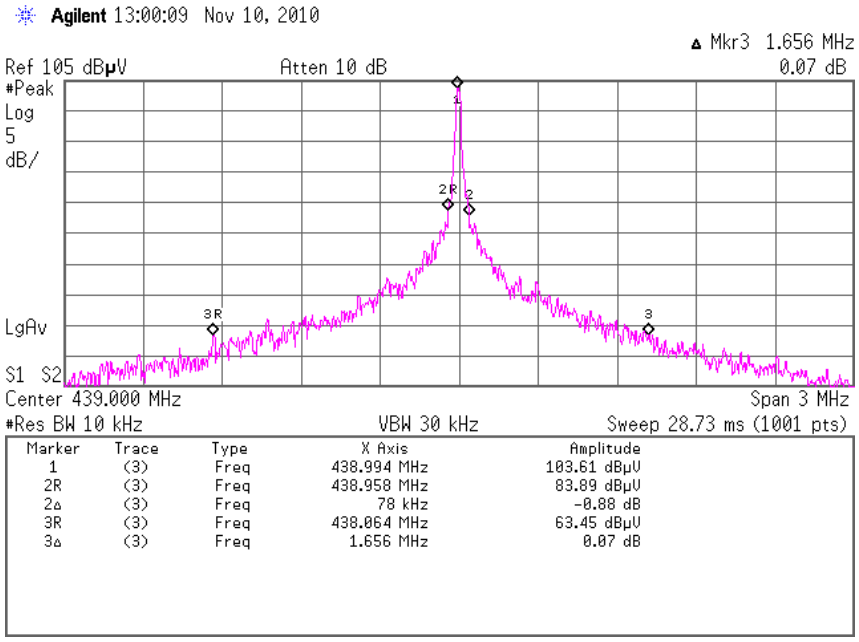


(a) 10 kHz RBW

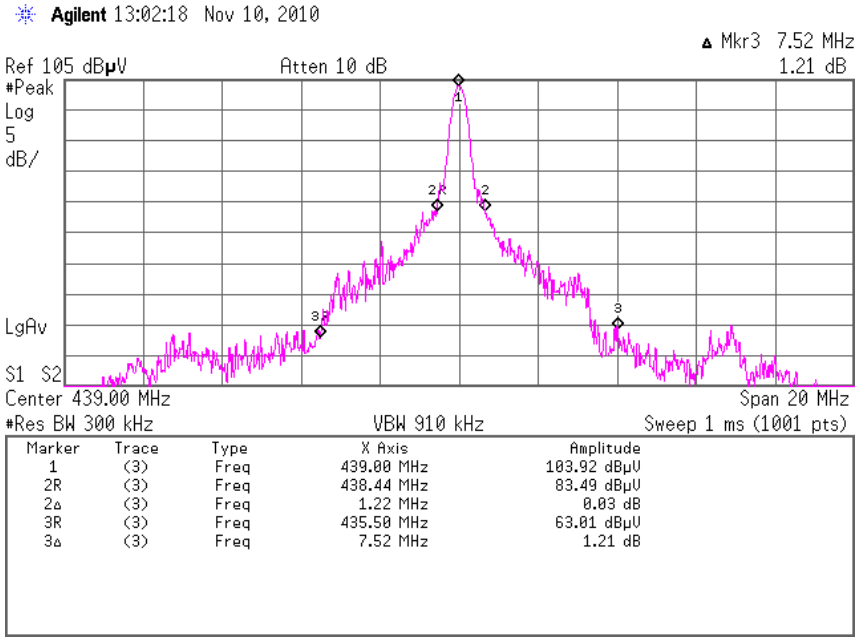


(b) 300 kHz RBW

Figure 22: Plots of 439 MHz transmission viewing 1/16" horizontal striped background.

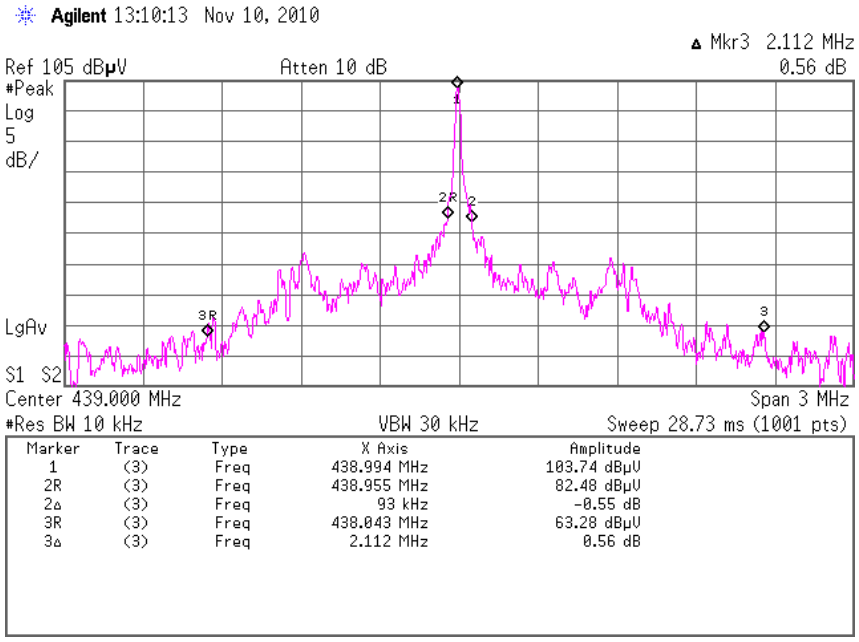


(a) 10 kHz RBW

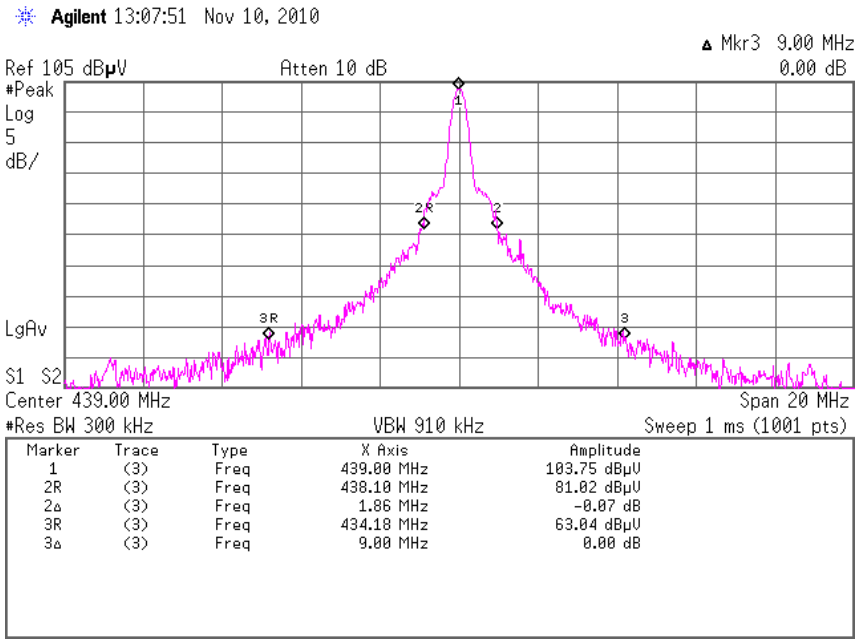


(b) 300 kHz RBW

Figure 23: Plots of 439 MHz transmission viewing video 1.



(a) 10 kHz RBW



(b) 300 kHz RBW

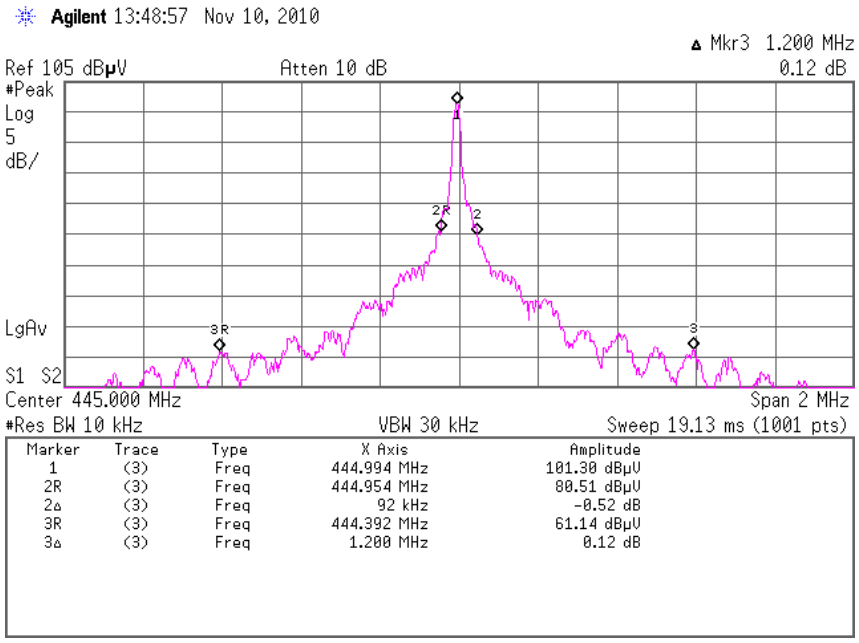
Figure 24: Plots of 439 MHz transmission viewing video 2.

Table 6: Summary of results for Recon Scout broadcasting at 439 MHz. All measurements in MHz. Peak values are boldfaced.

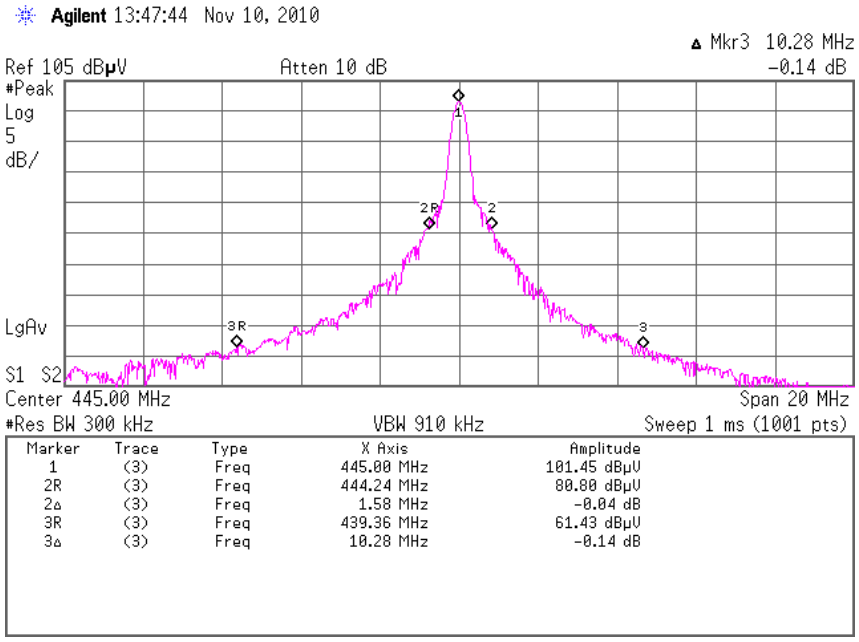
	10kHz RBW		300kHz RBW	
Test Pattern	20dB measure	40dB measure	20dB measure	40dB measure
White				
25% gray				
50% gray				
75% gray	0.058	0.606	**1.52**	**9.52**
Black				
1/8" checker	0.051	**2.163**	**1.52**	8.12
1/4" checker				
1/2" checker				
1/16" horizontal	**0.060**	0.976	0.92	7.68
Video	0.078	1.656	1.22	7.52
Video 2	**0.093**	**2.112**	**1.86**	**9.00**
Video 3				
No pattern				

C 445 MHz Channel Data

Figures 25 through 29 depict the testing of a Recon Scout at 445 MHz with respect to test views (3 static patterns and 2 videos) selected as the highest bandwidth in Table 5. A summary of the data is available in Table 7.

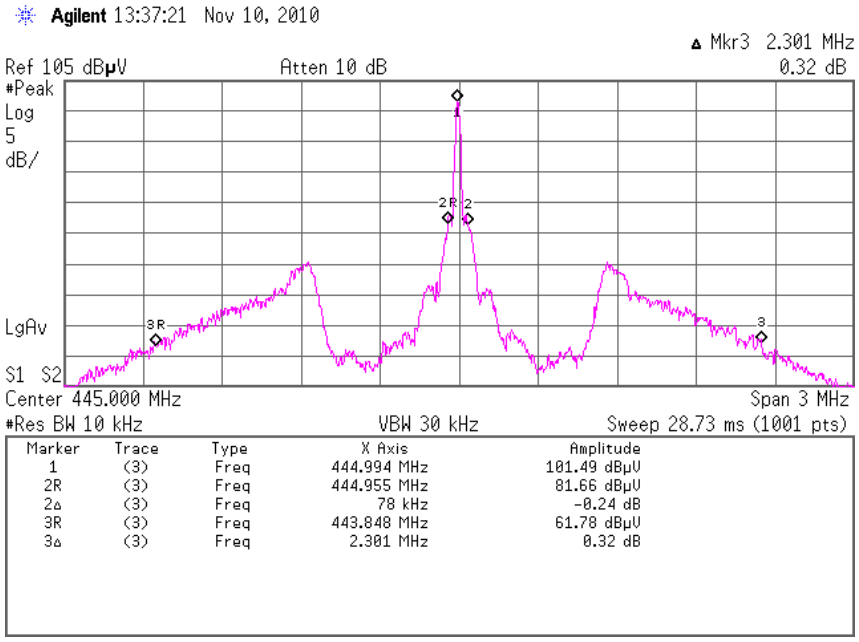


(a) 10 kHz RBW

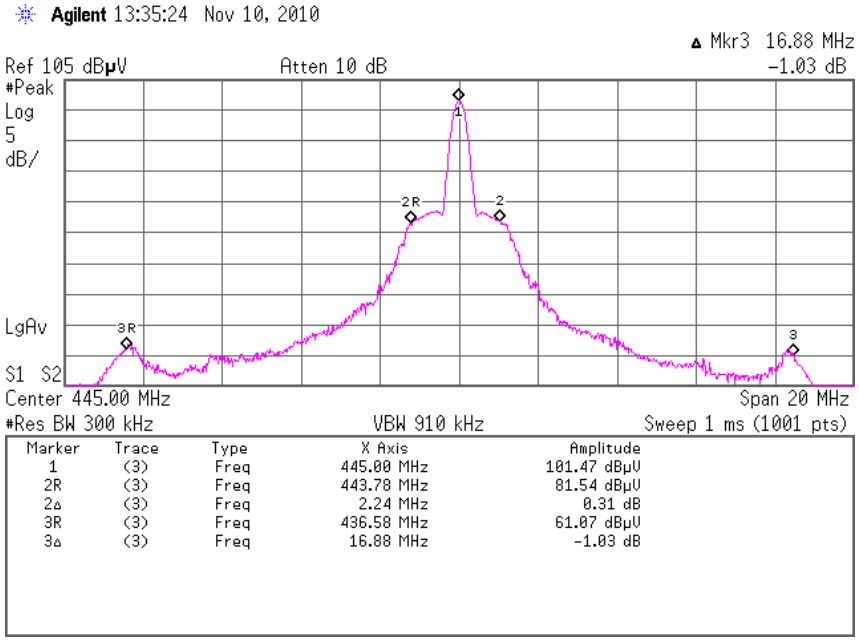


(b) 300 kHz RBW

Figure 25: Plots of 445 MHz transmission viewing 75% gray background.

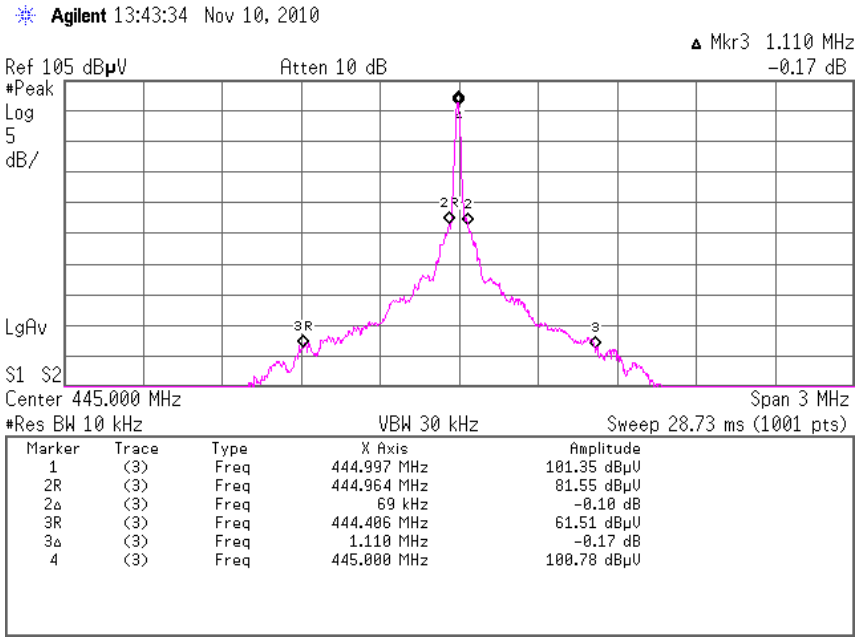


(a) 10 kHz RBW

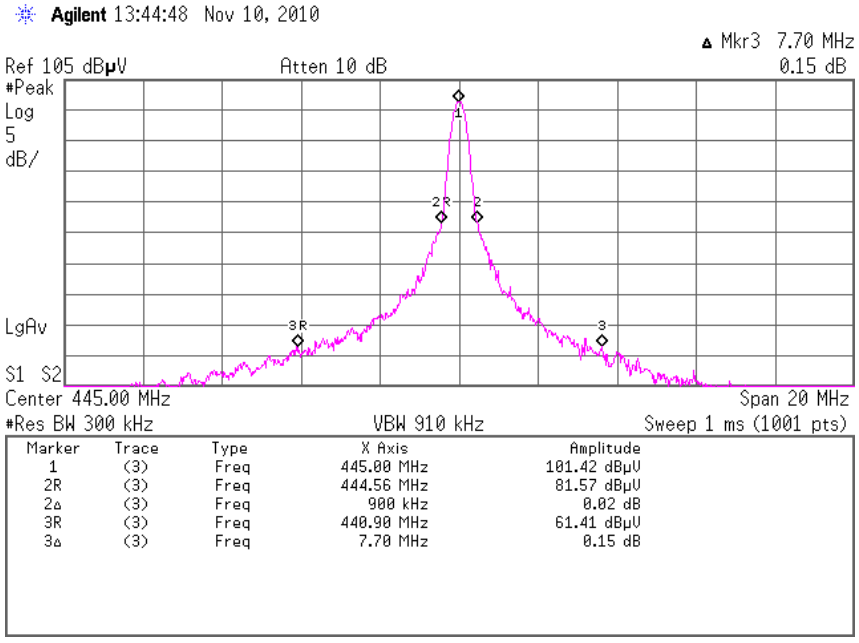


(b) 300 kHz RBW

Figure 26: Plots of 445 MHz transmission viewing 1/8" checkered background.

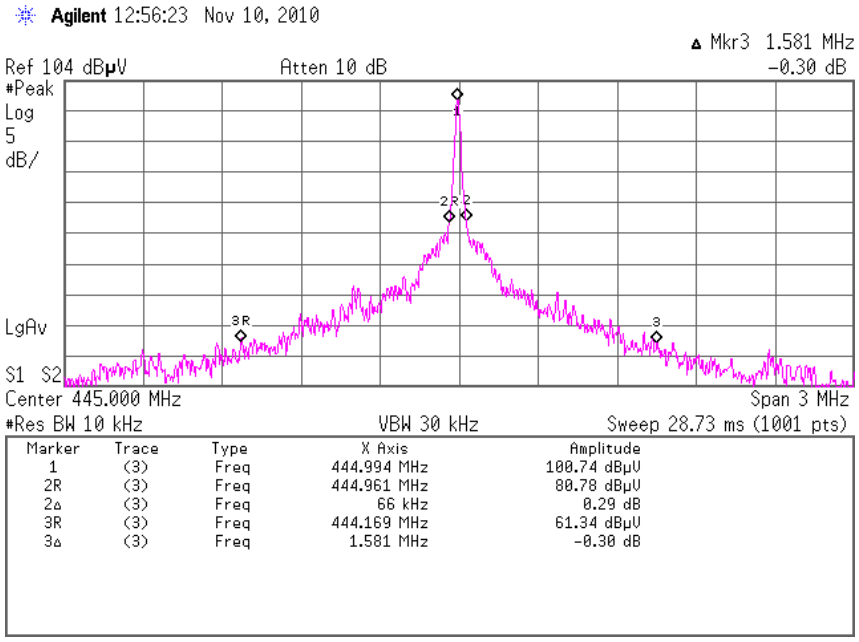


(a) 10 kHz RBW

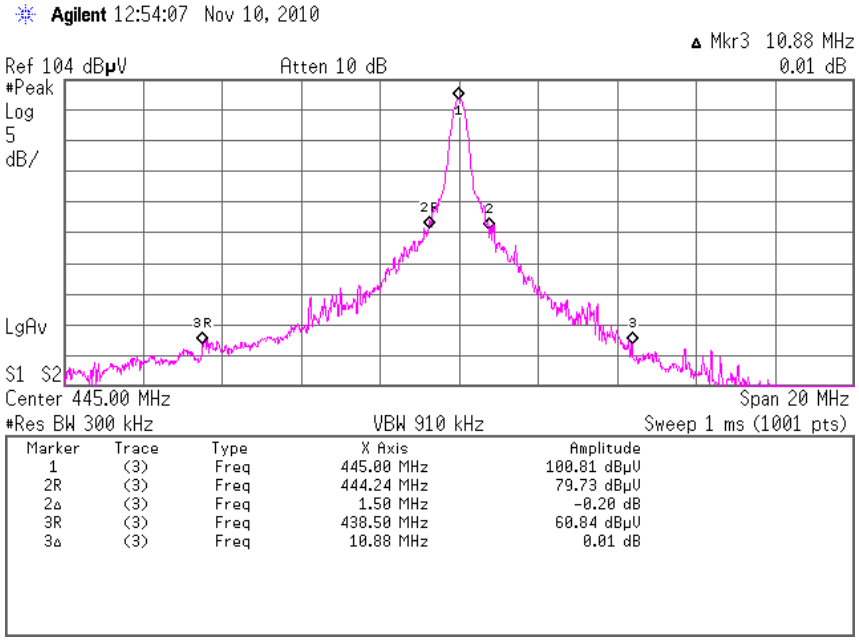


(b) 300 kHz RBW

Figure 27: Plots of 445 MHz transmission viewing 1/16" horizontal striped background.

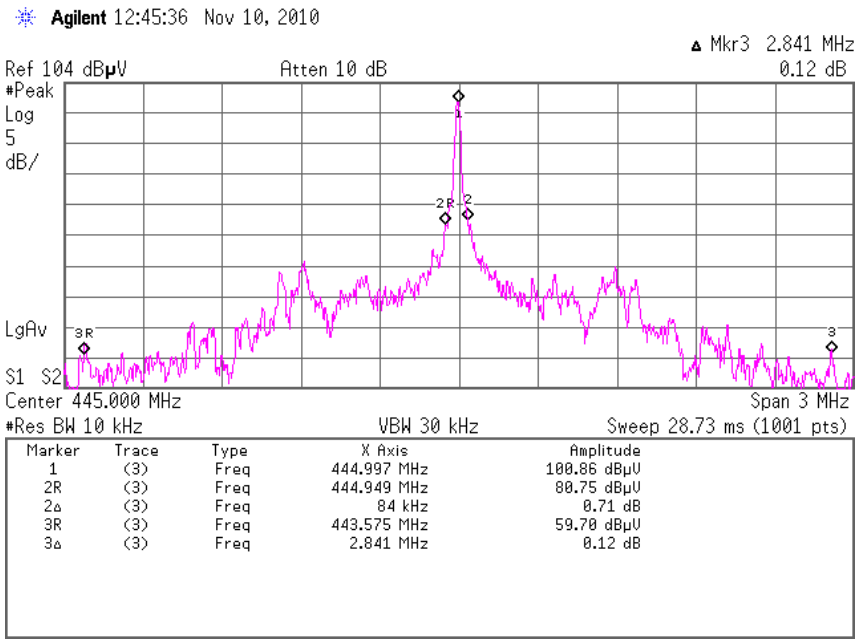


(a) 10 kHz RBW

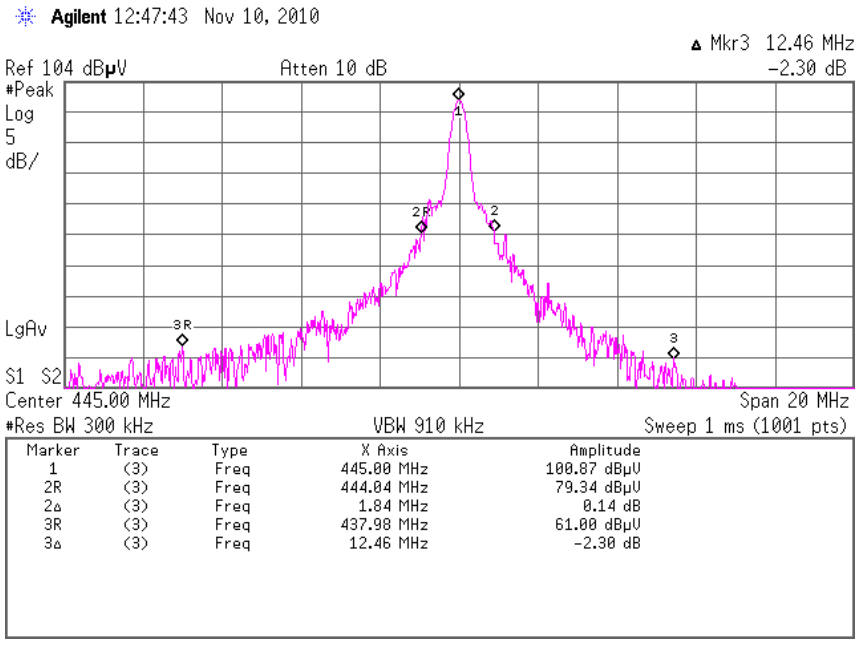


(b) 300 kHz RBW

Figure 28: Plots of 445 MHz transmission viewing video 1.



(a) 10 kHz RBW



(b) 300 kHz RBW

Figure 29: Plots of 445 MHz transmission viewing video 2.

Table 7: Summary of results for Recon Scout broadcasting at 445 MHz. All measurements in MHz. Peak values are boldfaced.

	10kHz RBW		300kHz RBW	
Test Pattern	20dB measure	40dB measure	20dB measure	40dB measure
White				
25% gray				
50% gray				
75% gray	**0.092**	1.200	1.58	10.28
Black				
1/8" checker	0.078	**2.301**	**2.24**	**16.88**
1/4" checker				
1/2" checker				
1/16" horizontal	0.069	1.110	0.90	7.70
Video	0.066	1.581	1.50	10.88
Video 2	**0.084**	**2.841**	**1.84**	**12.46**
Video 3				
No pattern				

References

[1] G. S. Jakubowski and J. T. Schneider, "Test Result Summary, Recon Scout," TÜV SÜV America Inc, Tech. Rep. WC1001408 Rev B, 21 April 2010.