VLA-VLBA Interference Memo No. 15

Performance Characterization of the 1-18 GHz Ailtech-Stoddart NM67-CCI7 Receiver System used as part of the Continuous RFI Environmental Monitoring Station (EMS) at the VLA

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Abstract:

Calibrated CW signals were injected into the remote controlled NM67 scanning receiver to determine its accuracy and repeatability for both frequency and amplitude detection. Intermediate frequency (IF) Gain and frequency Fine Tune controls are used to adjust for power and frequency error respectively; these pre-scan adjustments are limited to a flat power correction per scan, and frequency corrections to band edges only; because of these limitations errors are larger for wider scans. For 1 GHz scans over 1-18 GHz the amplitude error was typically less than 2.5 dB, except at 1.9 GHz where the error was 4.5 dB, and at 5.5 GHz where the error was 7.5 dB. Maximum frequency error over 1-2 GHz was 8 MHz. For 1 GHz scans over 2-18 GHz the maximum frequency error was 22 MHz. Calibrated results for this system are therefore known to within +/- 2.5 dB, and frequency accuracy to within +/- 22 MHz worst case. Errors in power and frequency are non-constant and non-linear across all 1 GHz bands, thus the application of post-processing correction factors would be difficult. A way to produce tighter results would be to run smaller scans, on the order of 100 MHz; however any range scanned requires prior determination of IF Gain and frequency Fine Tune values. At various frequency bands over 1-18 GHz 50 consecutive scans were run, each over a 30 minute period to determine detection repeatability. The receiver system is repeatable up to +/- 1 MHz in frequency and +/- 1 dB in power. Repeatability on scales from days to weeks was not tested. This receiver system is a practical tool for continuous omnidirectional RFI monitoring for 1 GHz scans over 1-18 GHz, and for direction finding. Once direction of incidence for strong sources are determined a calibrated, high-resolution spectrum analyzer should be used for signal identification.

Section 1: Description of Receiver System and Performance Tests

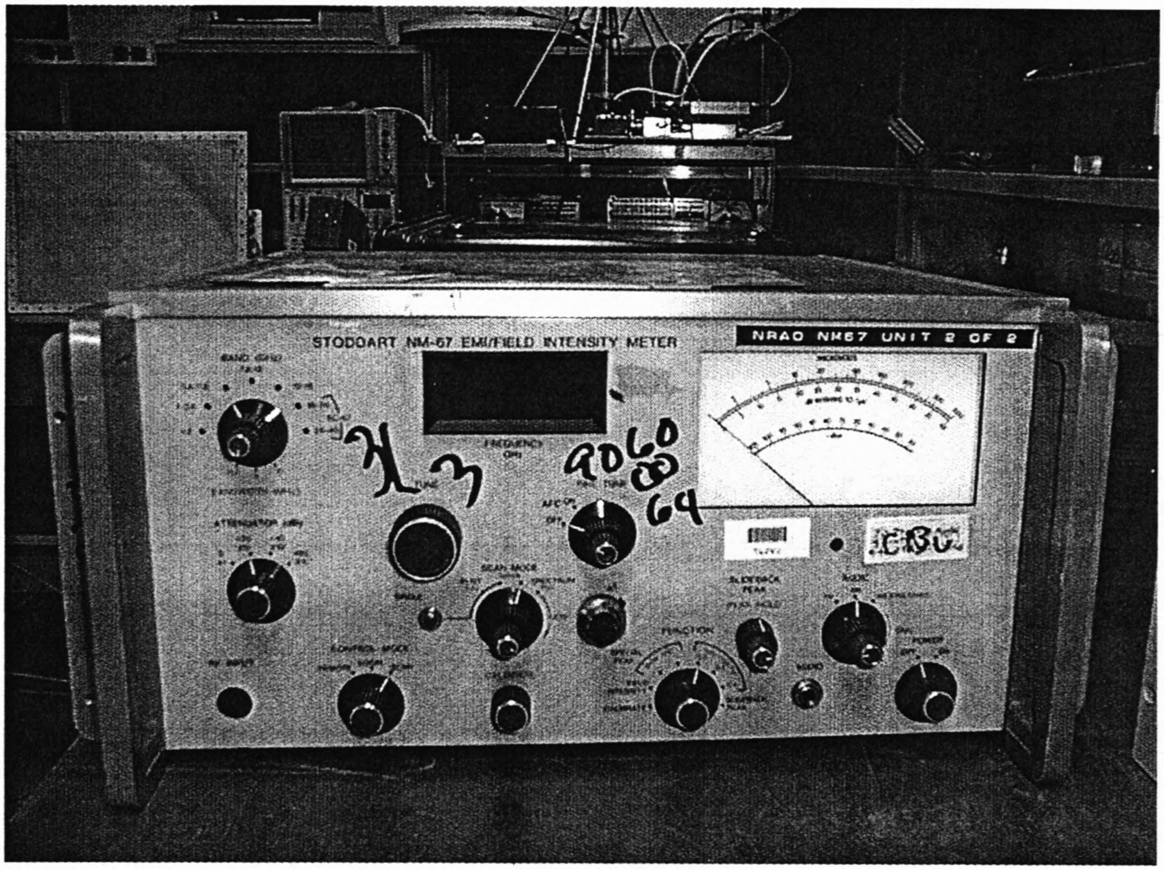
The Stoddart NM67 receiver (S/N 196) is an ambient operated superheterodyne 1-18 GHz RFI/EMI analog receiver expandable via an associated downconverter up to 40 GHz, with 120 dB of dynamic range over −107 dBm to +13 dBm (figure 1). The RBW settings are limited to 100 kHz, 1 MHz, and 10 MHz. The unit is typically used scanning over frequency and in rms peak detection mode; in peak mode at a 100 kHz RBW the internal noise floor is −90 dBm +/- 3 dB. The Stoddart controller-counter interface (CCI-7) is a digital device, which allows remote PC control, and data download over a GPIB 488 bus. The receiver and controller date from the 1960's to the 1970's, and many functions are recently repaired.[1]

This study was performed in order to quantify the error both in frequency and amplitude in CW signal detection over 1-18 GHz. Most of the study was conducted on August 18, 2000. Calibrated CW signals at various frequencies were injected into the scanning receiver while in rms peak mode and under remote CCI-7 control (figure 2). The data presented here are CCI-7 digital output converted to units of MHz and dBm via software in the control PC. Before performance tests could begin it was necessary to determine the accurate receiver settings for both the frequency and amplitude controls while under remote operation. The receiver controls of "Zero," "Fine Tune 1," and "Fine Tune 2" determine the start frequency, and the "Span" control determines the end frequency for any given scan range. Accurate values for these controls were determined by injecting calibrated signals at the desired start and end frequencies, for each scan range, and tweaking the controls until the beginning and end frequencies were defined by the detected signals, values listed in table 1. The response to input power is adjustable via the "IF Gain" control which adjusts for internal receiver error; the IF Gain has a 20 dB swing and adjustments effect both the receiver noise floor and injected signals. Accurate IF Gain values for each scan range were determined by injecting CW signals of known power into the receiver and remotely adjusting the Gain control until the detected power output from the CCI-7 was equal to the input power to the receiver. The IF Gain values applied were determined either near the scan center frequency, or at a VLA default frequency range, values listed in table 1.

The digital controller samples the receiver DC volt output; moderate care should be taken to not oversample nor undersample the receiver; oversampling results in tracing out the RBW filter, and undersampling creates the possibility for missing narrow-band signals (see tests 24 and 25). Calibration signals used were exponentially stronger than the receiver internal noise power and thus the noise floor contribution to signal + noise was systematically ignored. Before these tests were performed the following control and data lines between controller and receiver were characterized. Frequency: 1) CCI 0-10 Vdc tuning ramp to YIG oscillator tuning drivers, 2) determined that 1st CCI data acquisition pulse occurs approximately at beginning of scans, 3) YIG tuning drivers in the receiver were found to be off and NOT corrected: the ZERO, Fine Tune 1, 2 and SPAN settings adjust for this. POWER: 1) Slideback peak control for 60 dB receiver dynamic range matched to 0-2.008 Vdc receiver output (A1A4 pin 19) and matched to CCI 0-255 byte range ADC output (A1A11), 2) CCI IF Gain byte range matched to Vdc output (range and offset) and adjusted (A1A4 R11) till receiver remote and local mode noise floors correspond. The receiver-controller setups for all tests are listed in tables 1 and 2. No post processing correction factors were applied to the data neither in frequency or amplitude.

[1] *RFI Environmental Monitoring Station (EMS): Repair and Calibration of Ailtech NM67 Receiver*, IPG Student Co-op Report, Sam Field, May 19, 2000

Figure 1: NM67 EMI Receiver



(S/N 148 SHOWN HERE; S/N 196 CHARACTERIZED IN REPORT)

Figure 2: TEST SETUP FOR PERFORMANCE CHARACTERIZATION OF RECEIVER-CONTROLLER SYSTEM

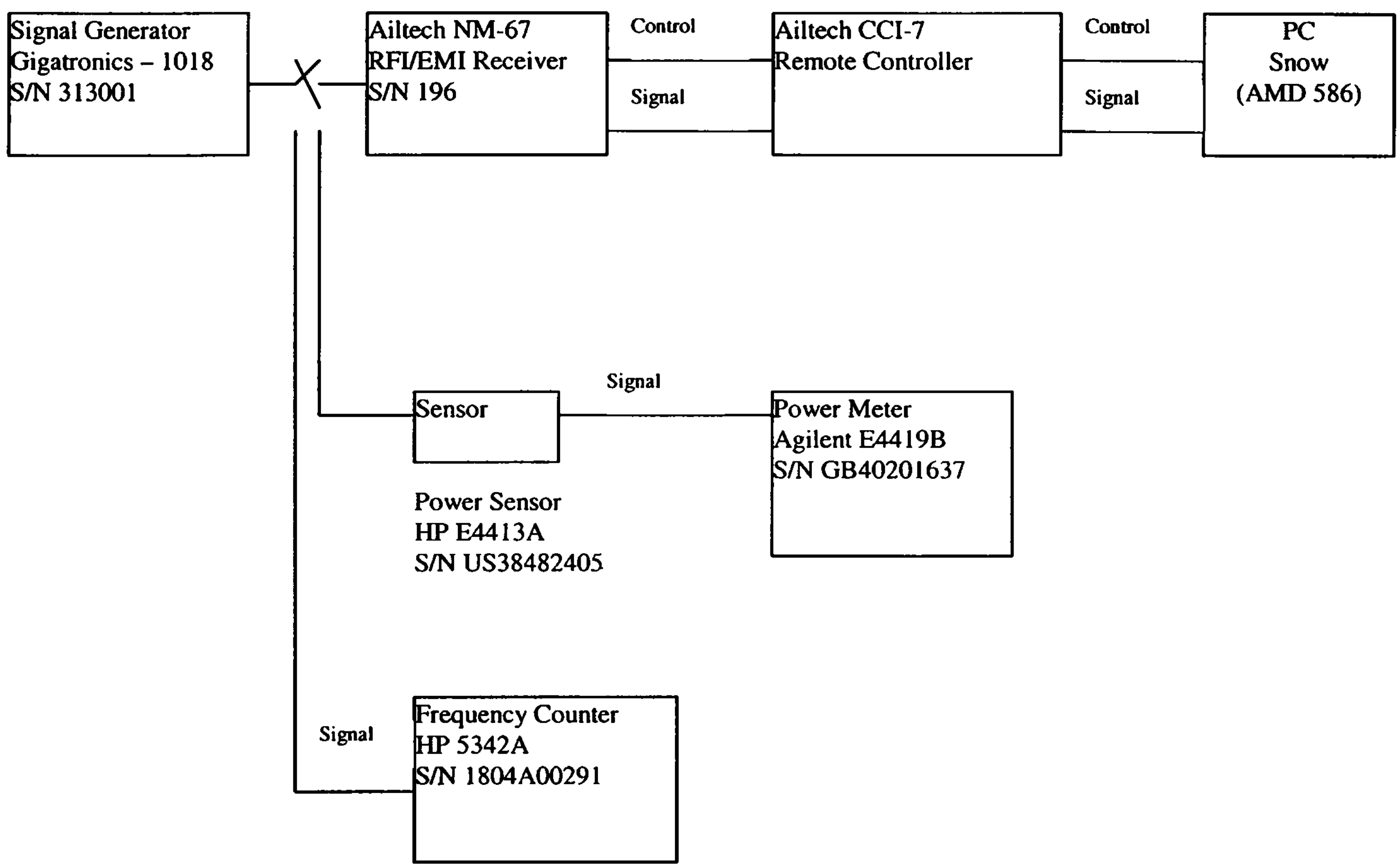


Table 1: Frequency Tuning and IF Gain Control Settings, August 2000

Frequency Scan (GHz)	RBW used (MHz)	Zero	Span	Fine Tune 1 + 2	IF Gain	IF Gain determined at (MHz)
		----------- Binary values			------------	
1.000 - 2.001	1.0	0	231	1914	35	1500
1.437 – 1.539	0.1	104	22	1914	35	1500
2.000 - 3.022	1.0	0	152	2808	36	2200
3.014 - 3.601	1.0	151	89	2808	33	3308
3.600 - 4.623	1.0	0	62	2964	45	4111
4.592 - 5.600	1.0	63	61	2964	86	4850
5.597 - 6.602	1.0	121	61	2964	35	6100
6.593 - 7.601	1.0	180	62	2964	34	7099
7.600 - 8.615	1.0	0	56	2872	32	8450
8.608 - 9.620	1.0	56	56	2872	34	9114
9.575 - 10.587	1.0	111	56	2872	35	10081
10.580 - 11.601	1.0	163	57	2872	36	11087
11.591 - 12.004	1.0	220	23	2872	37	11798
12.000 - 12.994	1.0	0	41	3148	16	12497
12.983 - 13.977	1.0	41	41	3148	22	13480
13.962 - 14.956	1.0	80	41	3148	13	14930
14.945 - 15.964	1.0	121	42	3148	22	15454
15.956 - 16.974	1.0	160	42	3148	28	16465
16.970 - 17.983	1.0	203	42	3148	25	17477
17.516 - 18.000	1.0	224	20	3148	16	17758
12.000 - 18.000	10.0	0	245	3320	37	12000

Table 2: Receiver-Controller System Setup

(Unless otherwise stated the following system setup was used for all tests)

Remote control mode via CCI-7
RMS Peak detection mode
CCI-7 frequency resolution = 1024 points
RBW = 1 MHz
Attenuator setting = 0 dB
Peak-hold time same for all tests and set by CCI-7 controller (not selectable)
IF Gain used from table 1
Frequency start, fine tune 1, 2, and scan ranges from table 1
Receiver frequency sweeping scan time = 35 seconds measured (byte = 9)
PC control software: collector.c for accuracy tests, cycle.c for repeatability tests.

Section 2: Performance Results

Test 1, Plots 1.1-1.3: Effects of frequency sweeping scan time on performance
Setup: scan times of 1.5 s, 35 s, and 320 s used for scans over 1-2 GHz.
Result: The system works equally as well at the fastest scan time of 1.5 s, and a slower scan time of 320 s; there was no scan loss in amplitude or increased error in frequency as a function of scan time. Any scan time chosen faster than (frequency scan range) / (0.7 x RBW)^2 will suffer scan loss in amplitude. For the fastest CCI-7 scan time of 1.5 s and narrowest RBW of 100 kHz, this corresponds to a maximum frequency span of 7.35 GHz. For scans much larger than 1 GHz this test should be performed.

Test 2, Plots 2.1-2.3: RBW performance
Setup: all 3 RBW settings of 100 kHz, 1 MHz, and 10 MHz were used.
Result: Remote control scans using RBW filters of 100 kHz, 1 MHz, and 10 MHz were performed, and found to be functional. In local mode the RBW filters were tested by tuning the receiver to +/- 0.5 x RBW away from injected signal frequency, where the detected signal strength was 6 dB down from peak, as expected.

Test 3, Plots 3.1-3.3: Attenuator performance
Setup: attenuator settings of 20 dB, 40 dB, and 60 dB were used.
Result: all three attenuator settings are functional. It is important to note that all three attenuator settings attenuate the receiver internal noise floor by 20 dB, but attenuate injected signals by 20 dB, 40 dB, and 60 dB accordingly. For injected signals the response (needle deflection and CCI-7 output) will be the input value minus attenuation, and as such this control works differently then typical spectrum analyzers.

Test 4, Plots 4.1-4.2: Dynamic range performance
Result: The receiver's response to power was tested at –52 dBm and –66 dBm at 1420 MHz and found to be functional to within 2.5 dB.

Test 5, Plots 5-5.1b: 1-2 GHz performance, detection accuracy and repeatability
Results A: In Plot 5 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 6 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 4.5 dB and also varies over the band.
Results B: In plots 5.1a and 5.1b 47 scans over 1-2 GHz were run and detections are shown for a single injection of 1420 MHz at –59 dBm; detection repeatability were +/- 1 MHz and +/- 0.5 dB.

Test 6, Plots 6a-6.1b: 2-3.6 GHz performance, detection accuracy and repeatability
Results A: In Plot 6a and 6b three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 9.8 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 0.71 dB and varies over the band.

Results B: In plots 6.1a and 6.1b 47 scans over 2-3 GHz were run, and detections are shown for a single injection of 2200 MHz at –59 dBm; detection repeatability were +/- 1 MHz and +/- 0.5 dB.

Test 7, Plot 7.1: 3.6-4.6 GHz performance, detection accuracy
Results: In Plot 7.1 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 18 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.41 dB and varies over the band.

Test 8, Plots 8-8.1b: 4.6-5.6 GHz performance, detection accuracy and repeatability
Results A: In plot 8 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 22 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 7.53 dB and varies over the band.
Results B: In plots 8.1a and 8.1b 47 scans over 4.6-5.6 GHz were run, and detections are shown for a single injection of 4850 MHz at –59 dBm; detection repeatability were +/- 1 MHz and +/- 1 dB.

Test 9, Plot 9: 5.6-6.6 GHz performance, detection accuracy
Results: In plot 9 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 14 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.88 dB and varies over the band.

Test 10, Plot 10: 6.6-7.6 GHz performance, detection accuracy
Results: In plot 10 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 12 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.88 dB and varies over the band.

Test 11, Plots 11-11.1b: 7.6-8.6 GHz performance, detection accuracy and repeatability
Results A: In plot 11 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 12 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.88 dB and varies over the band.
Results B: In plots 11.1a and 11.1b 47 scans over 7.6-8.6 GHz were run, and detections are shown for a single injection of 8450 MHz at –59 dBm; detection repeatability were +/- 1 MHz and +/- 0.5 dB.

Test 12, Plots 12: 8.6-9.6 GHz performance, detection accuracy
Results: In plot 12 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 11 MHz, and the error is

non constant and non linear across the band. The amplitude error was a maximum of 1.65 dB and varies over the band.

Test 13, Plot 13: 9.6-10.6 GHz performance, detection accuracy
Results: In plot 13 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 21 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.18 dB and varies over the band.

Test 14, Plot 14: 10.6-11.6 GHz performance, detection accuracy
Results: In plot 14 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 14 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.41 dB and varies over the band.

Test 15, Plot 15: 11.6-12 GHz performance, detection accuracy
Results: In plot 15 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 15 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.41 dB and varies over the band.

Test 16, Plot 16: 12-13 GHz performance, detection accuracy
Results: In plot 16 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 16 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.18 dB and varies over the band.

Test 17, Plot 17: 13-14 GHz performance, detection accuracy
Results: In plot 17 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 15 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 0.84 dB and varies over the band.

Test 18, Plots 18-18.1b: 14-15 GHz performance, detection accuracy and repeatability
Results A: In plot 18 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 9 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.65 dB and varies over the band.
Results B: In plots 18.1a and 18.1b 47 scans over 14-15 GHz were run, and detections are shown for a single injection of 14.956 GHz at –59 dBm; detection repeatability were +/- 1 MHz and +/- 1 dB.

Test 19, Plot 19: 15-16 GHz performance, detection accuracy
Results: In plot 19 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 7 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 2.12 dB and varies over the band.

Test 20, Plot 20: 16-17 GHz performance, detection accuracy
Results: In plot 20 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 3 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.65 dB and varies over the band.

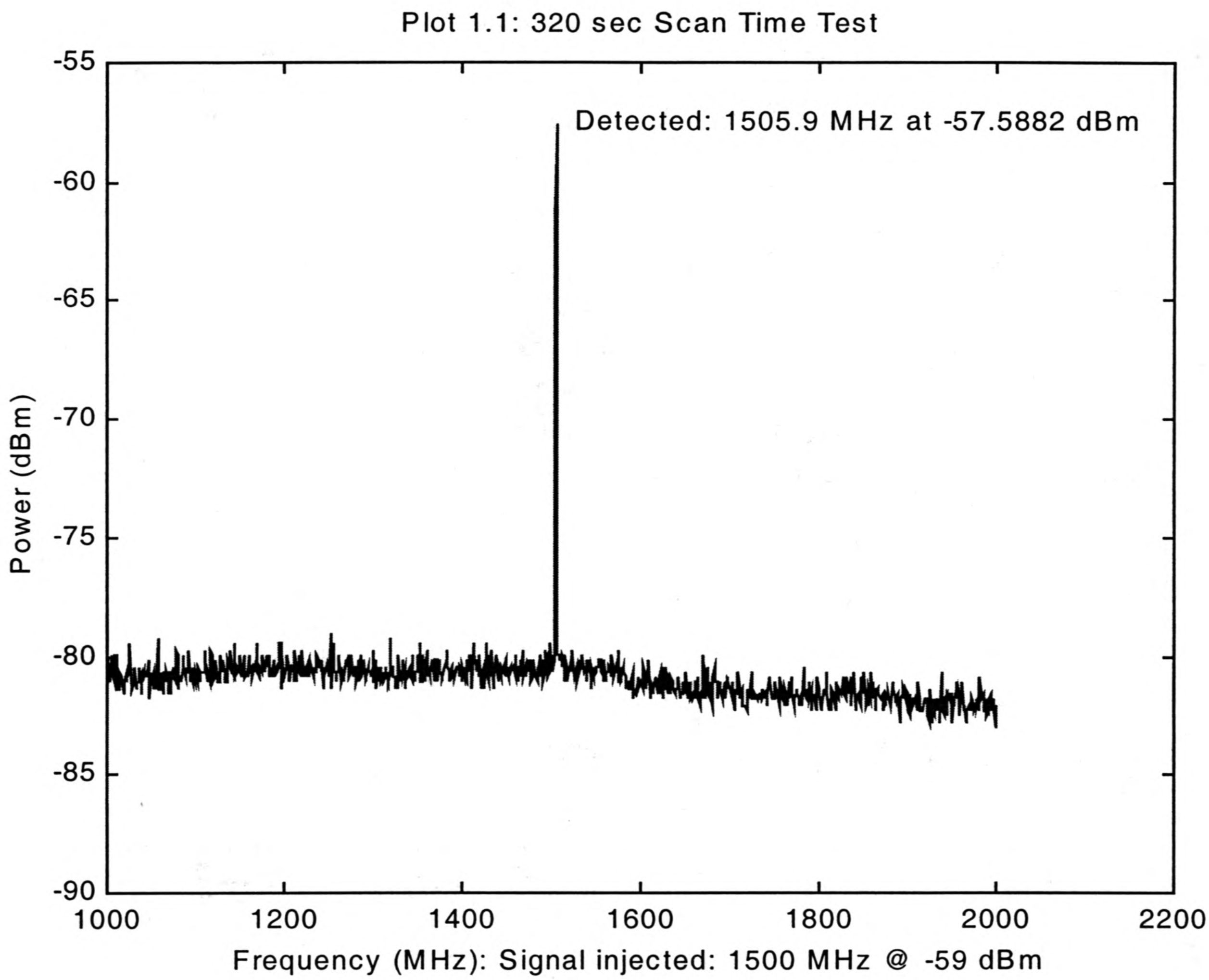
Test 21, Plot 21: 17-18 GHz performance, detection accuracy
Setup: IF Gain set at ?? GHz
Results: In plot 21 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 9 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 1.65 dB and varies over the band.

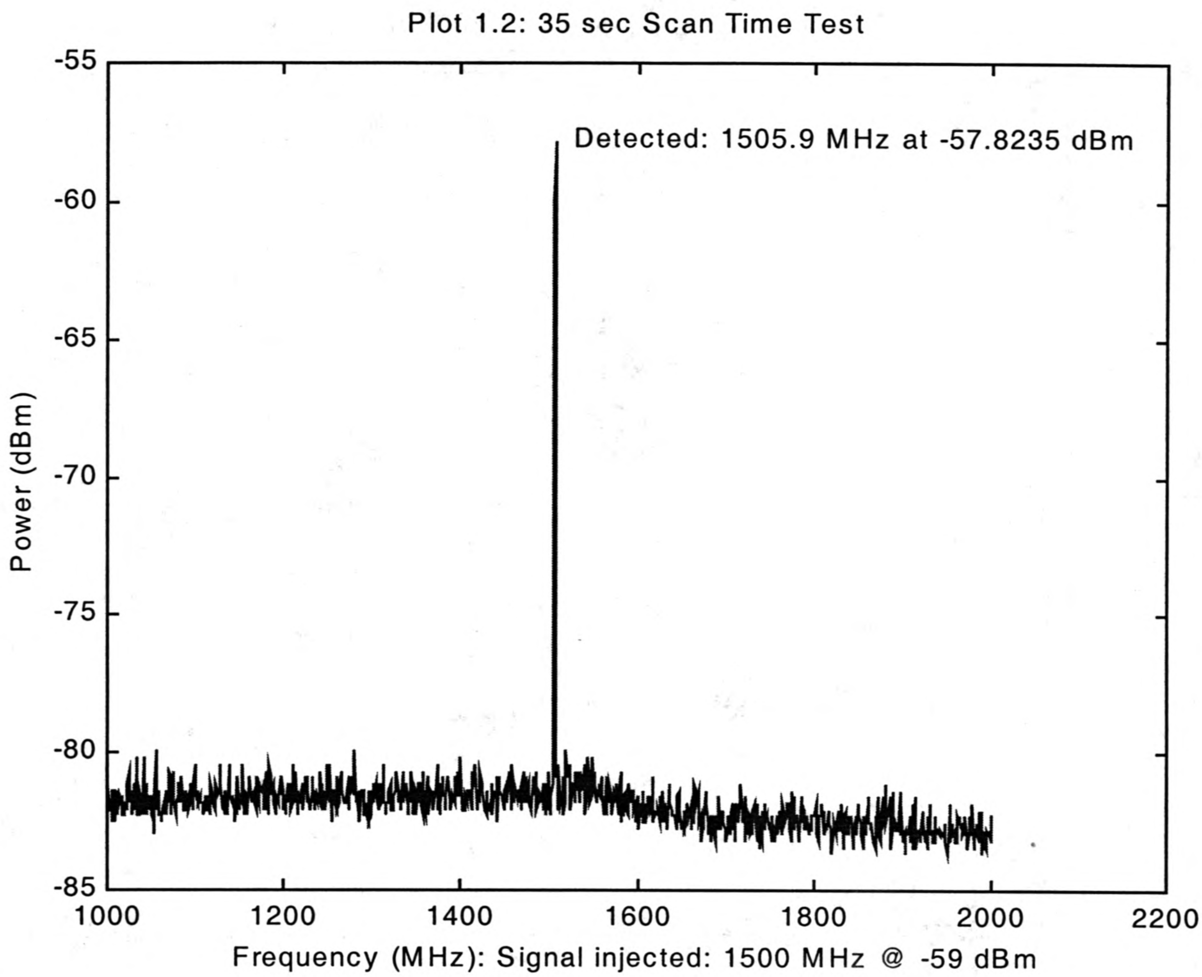
Test 22, Plot 22: 17.5-18 GHz performance, detection accuracy
Results: In plot 22 three signals of the same power were injected at different frequencies; results show that the max error in frequency at these points was 9 MHz, and the error is non constant and non linear across the band. The amplitude error was a maximum of 2.59 dB and varies over the band.

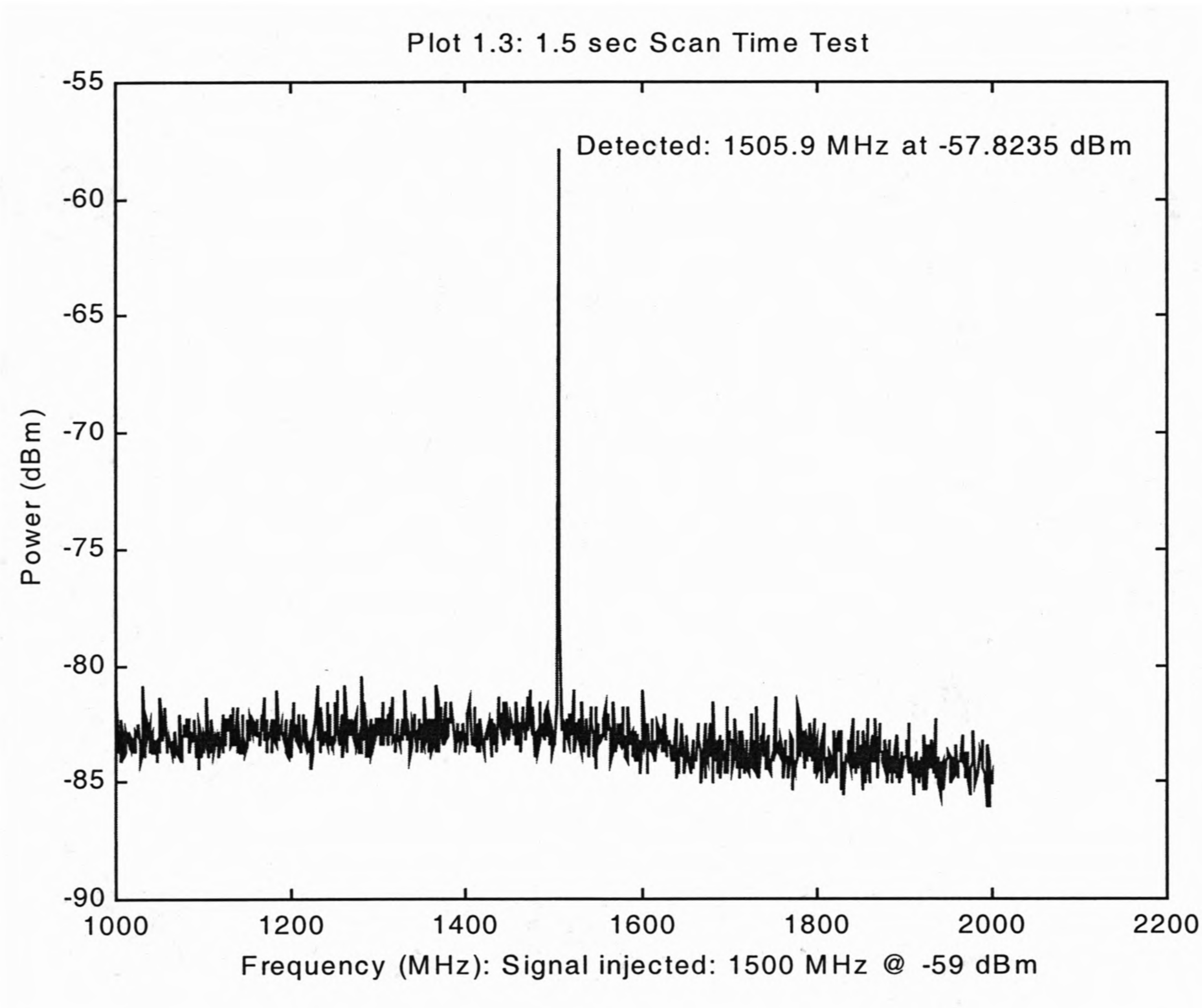
Test 23, Plots 23: Oversampling the receiver with the CCI-7 controller
Setup: RBW 10 MHz, span = 1000 MHz, # CCI points = 1024
Results: Oversampling the receiver by choosing a small value for [(frequency span) / (RBW)], results in tracing out the RBW filter shape in the controller output. Setting the span/RBW large will prevent tracing out the filter, and hence misinterpreting the filter shape for broad band RFI. For (#sampled points) >> [(frequency span) / (RBW)], the RBW filter shape is more defined in the controller output.

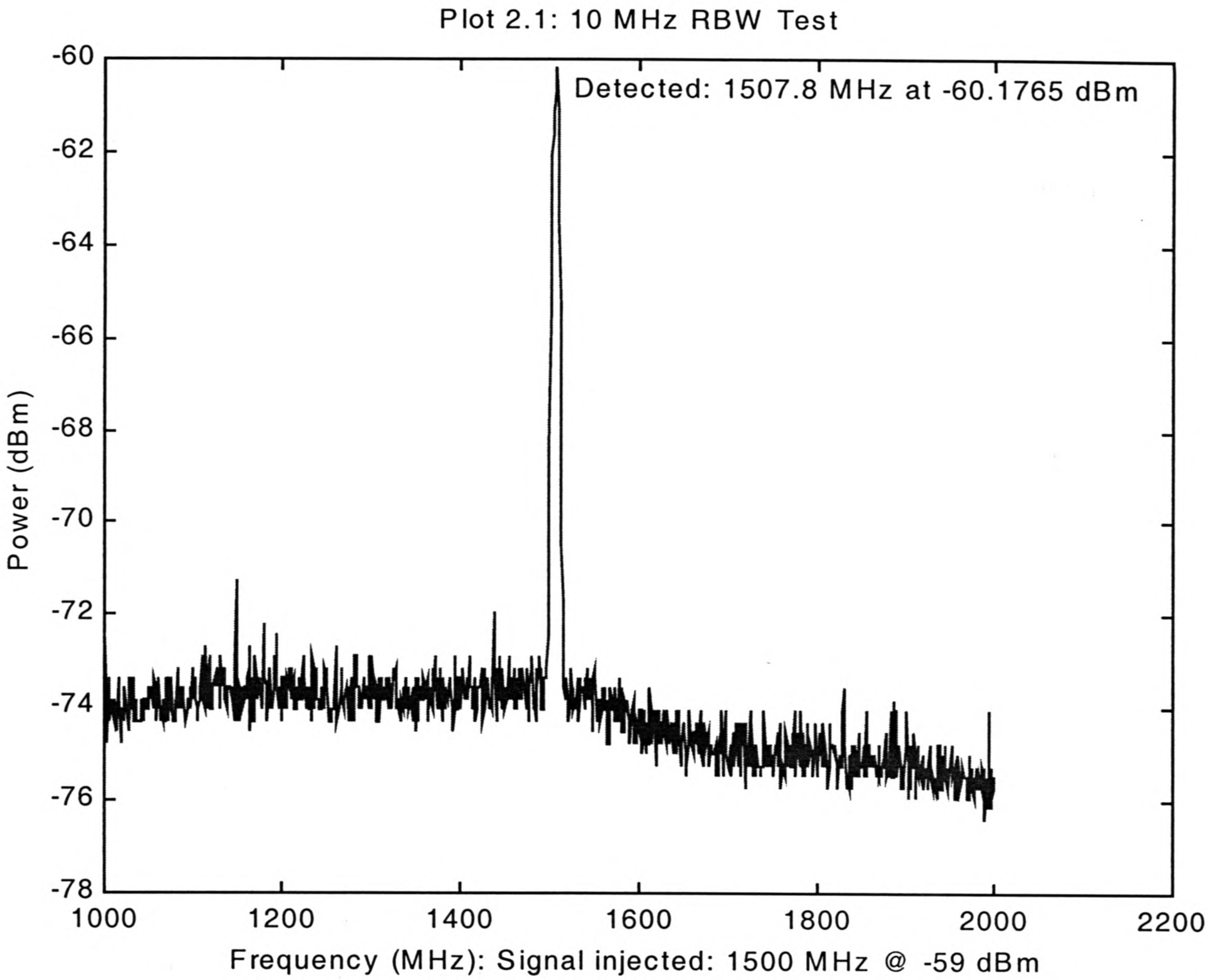
Test 24, Plots 24-24.3: Undersampling the receiver with the CCI-7 controller, missing CW signals
Setup: RBW 0.1 MHz, # CCI frequency bins = 64, scan times of 320s and 35s used
Objective: To demonstrate that if the number of times the controller discretely samples the receiver is small compared to the ratio of (frequency span) / (RBW), and an injected signal is between sampled points, and the sampling period is longer than the receiver peak-hold time, the controller will miss CW signals.
Results: Undersampling the receiver can result in missing CW signals. Also see plots 25a and 25b.

Test 25, Plots 25a and 25b: Effects of receiver Peak-hold time on CCI-7 output
Setup: In plot 25.a # CCI frequency bins = 1024, in plot 25b # CCI frequency bins = 64.
Objective: The peak-hold is the amount of time the receiver power gauge needle is held at maximum deflection while responding to the strongest signal in a scan. This test was to determine if while in remote mode the peak-hold time shows up in the controller output, possibly distorting the shape of the signal. For this test, the specified period at which the controller samples the receiver defined by [scan time / # CCI frequency samples], was chosen small compared to the peak-hold time (which is fixed in remote mode).
Result: For peak-hold time long compared to the sampling period the peak-hold effects are not significantly present in the controller output, regardless of the rate at which the controller samples the receiver and hence does not distort the data. These two setups were chosen such that had a 3 sec peak-hold time been reflected in the CCI output the peak would have been repeated over 90 MHz (90 bins in 25a and 5 bins in 25b); the peak appeared in 3 consecutive frequency bins in 25a, and only 1 frequency bin in 25b, suggesting a very short peak-hold as seen by the controller. Also see plots 24-24.3.

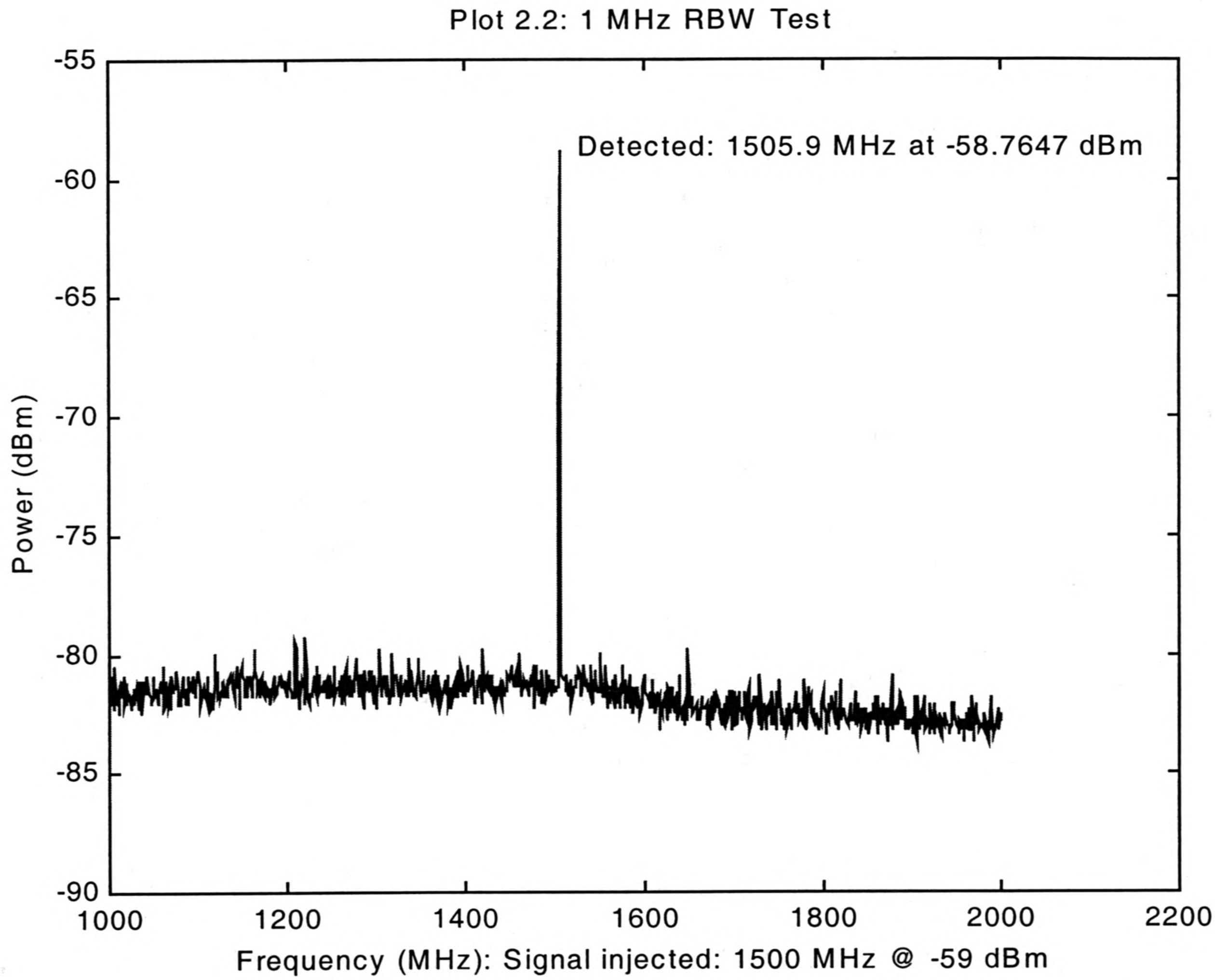

Plot 1.1: 320 sec Scan Time Test
Detected: 1505.9 MHz at -57.5882 dBm
Power (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Signal injected: 1500 MHz @ -59 dBm

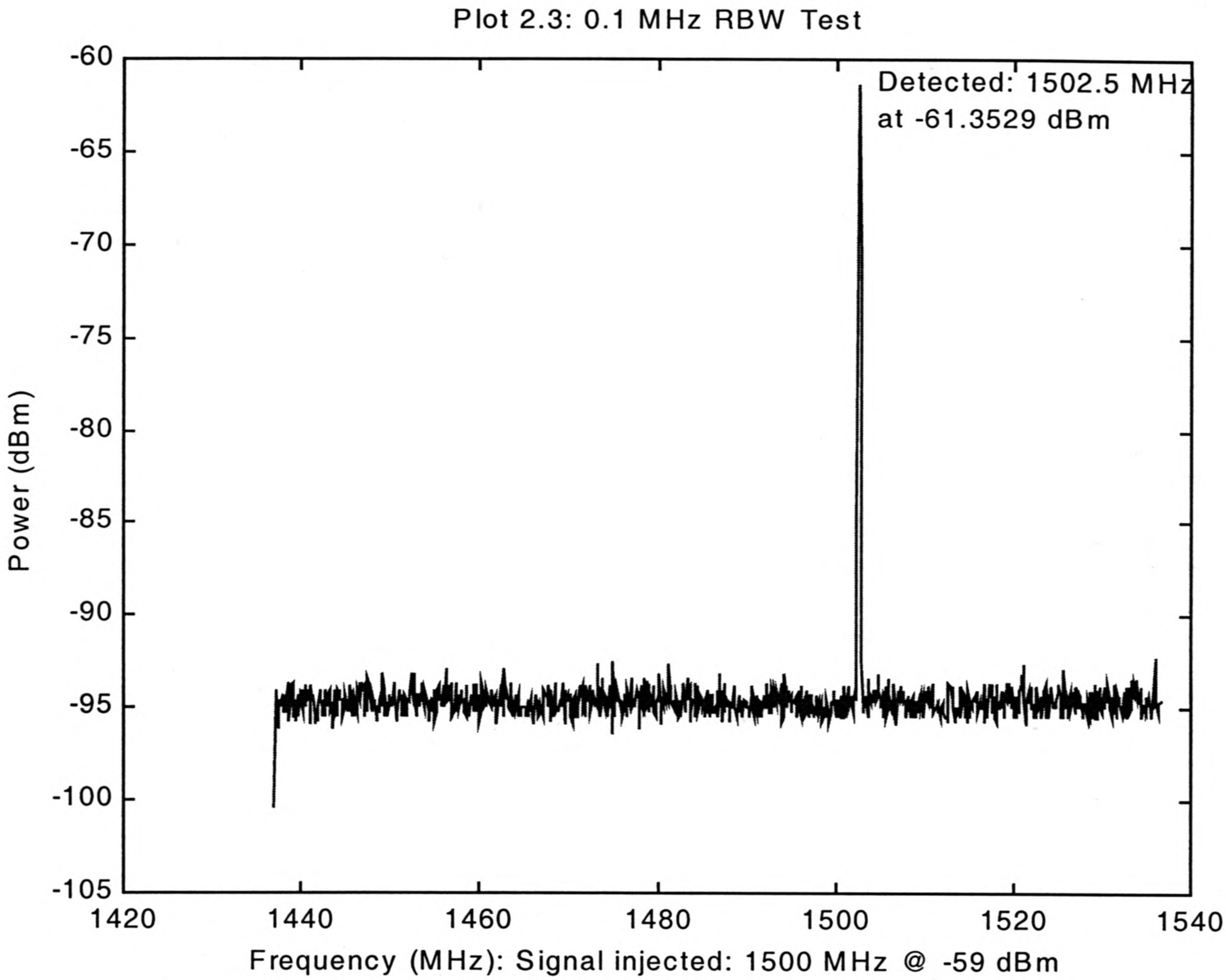

Plot 1.2: 35 sec Scan Time Test
Detected: 1505.9 MHz at -57.8235 dBm
-55
-60
-65
-70
-75
-80
-85
Power (dBm)
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Signal injected: 1500 MHz @ -59 dBm


Plot 1.3: 1.5 sec Scan Time Test
Detected: 1505.9 MHz at -57.8235 dBm
Power (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Signal injected: 1500 MHz @ -59 dBm

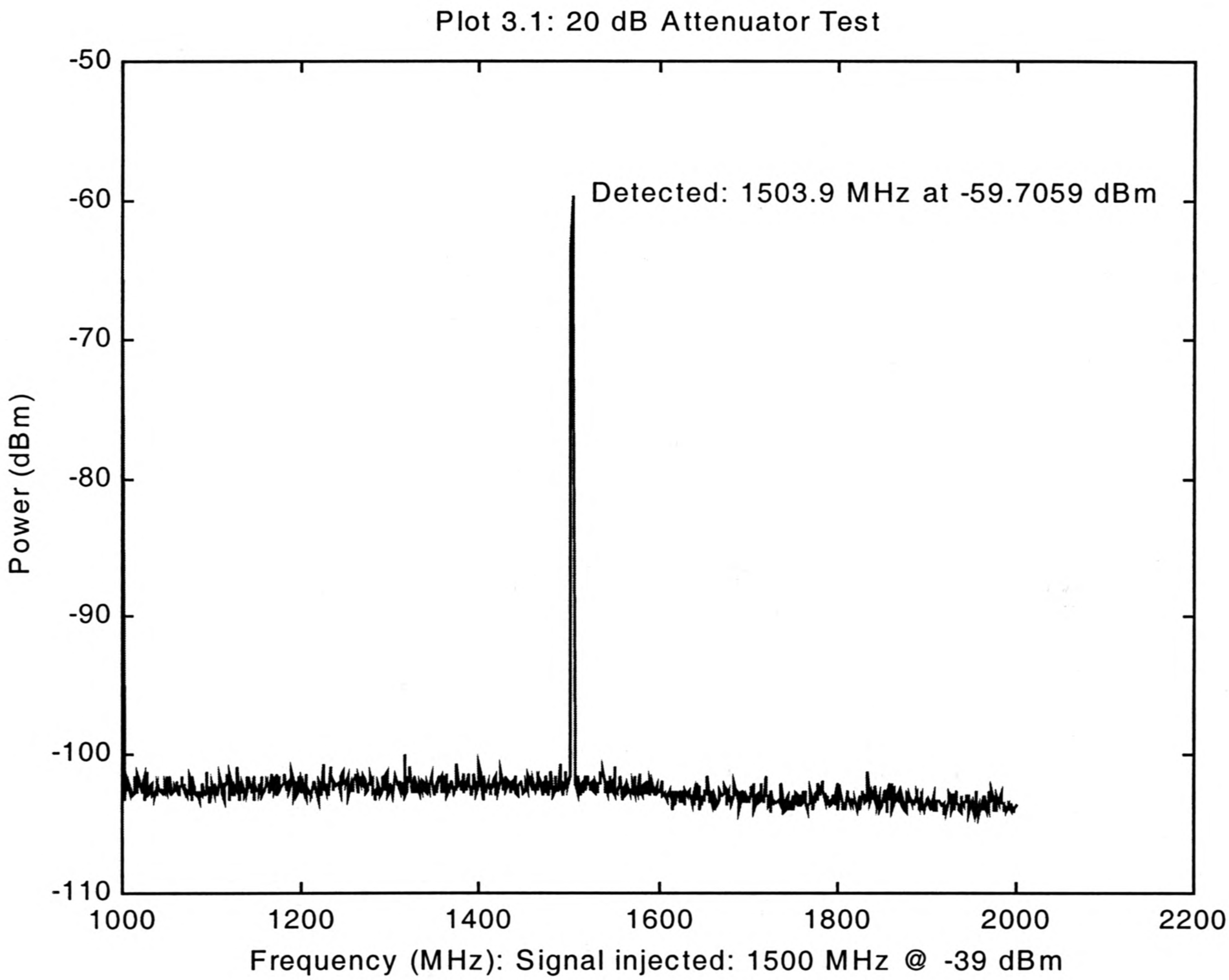


Plot 2.1: 10 MHz RBW Test
Detected: 1507.8 MHz at -60.1765 dBm
Power (dBm)
-60
-62
-64
-66
-68
-70
-72
-74
-76
-78
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Signal injected: 1500 MHz @ -59 dBm

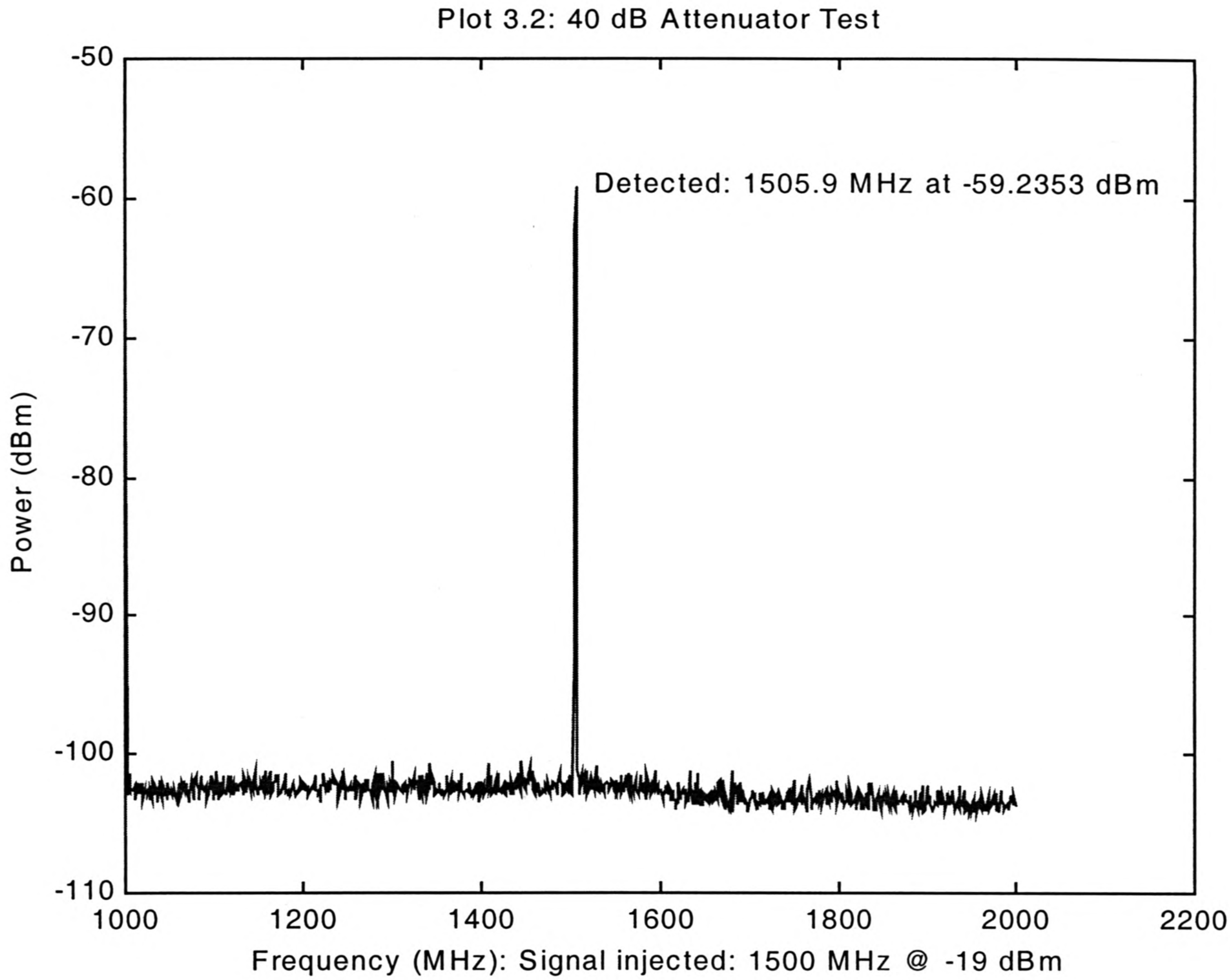

Plot 2.2: 1 MHz RBW Test
Detected: 1505.9 MHz at -58.7647 dBm
Power (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Signal injected: 1500 MHz @ -59 dBm



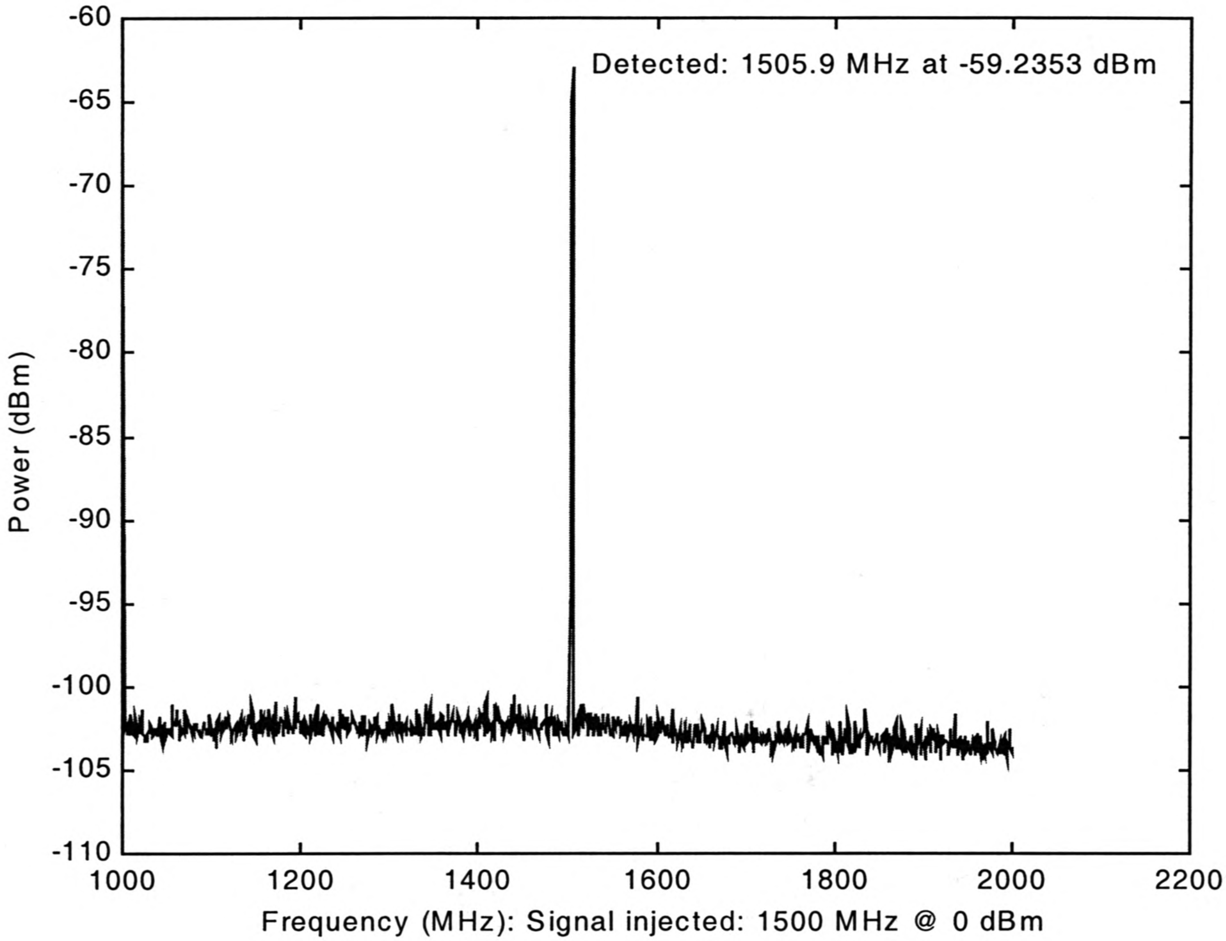
Plot 2.3: 0.1 MHz RBW Test
Detected: 1502.5 MHz
at -61.3529 dBm
-60
-65
-70
-75
-80
-85
-90
-95
-100
-105
Power (dBm)
1420
1440
1460
1480
1500
1520
1540
Frequency (MHz): Signal injected: 1500 MHz @ -59 dBm

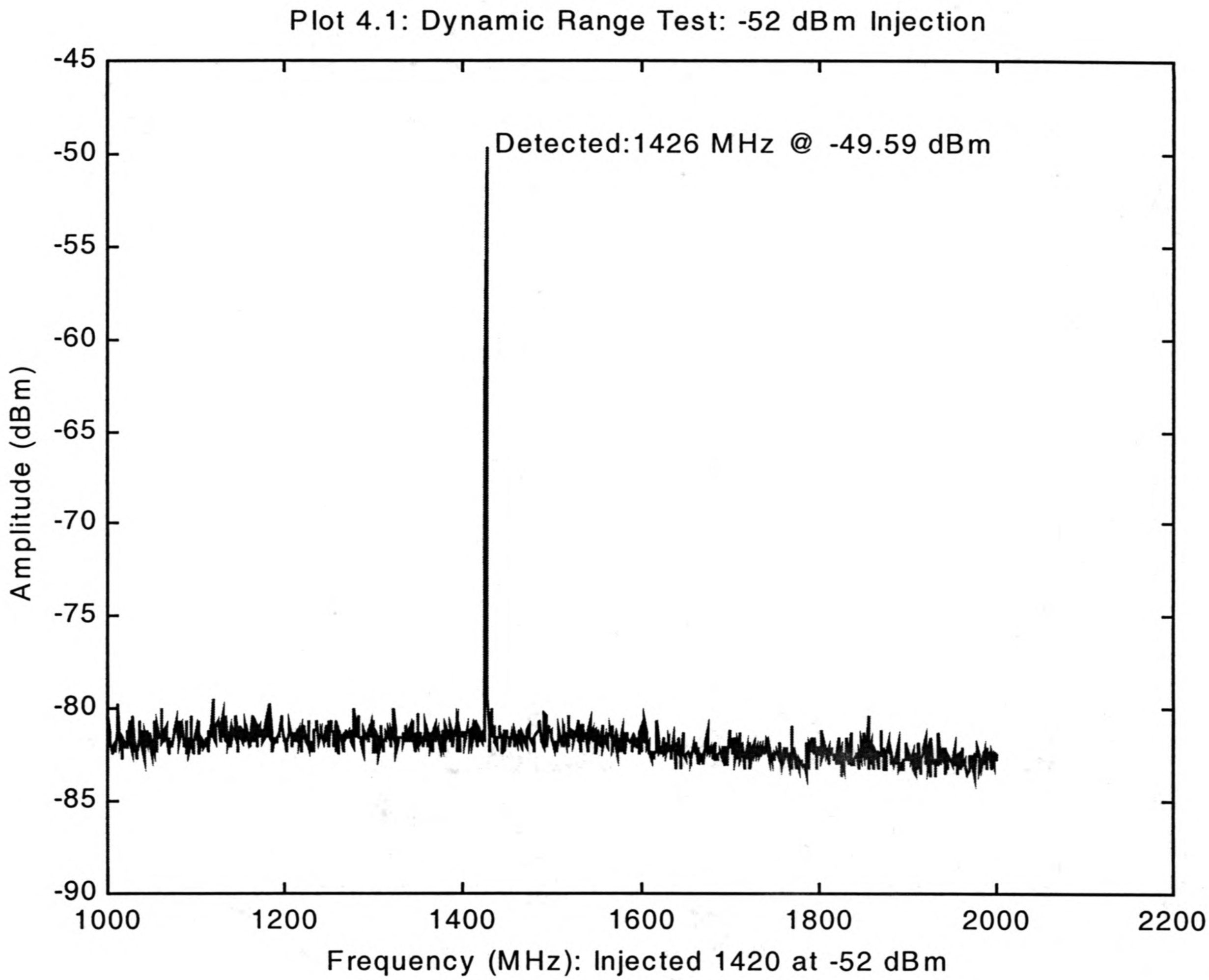


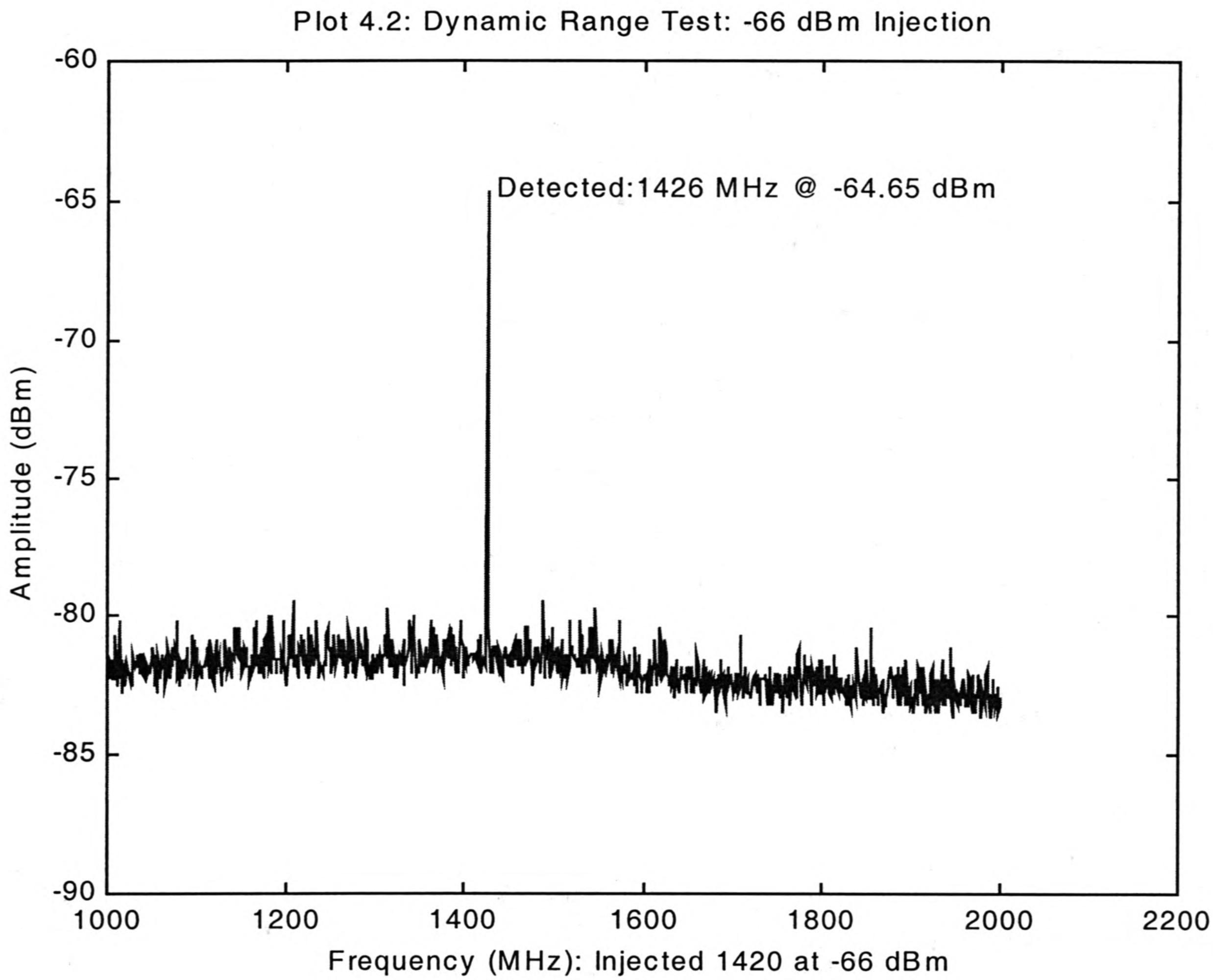
Plot 3.1: 20 dB Attenuator Test
Detected: 1503.9 MHz at -59.7059 dBm
Power (dBm)
-50
-60
-70
-80
-90
-100
-110
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Signal injected: 1500 MHz @ -39 dBm

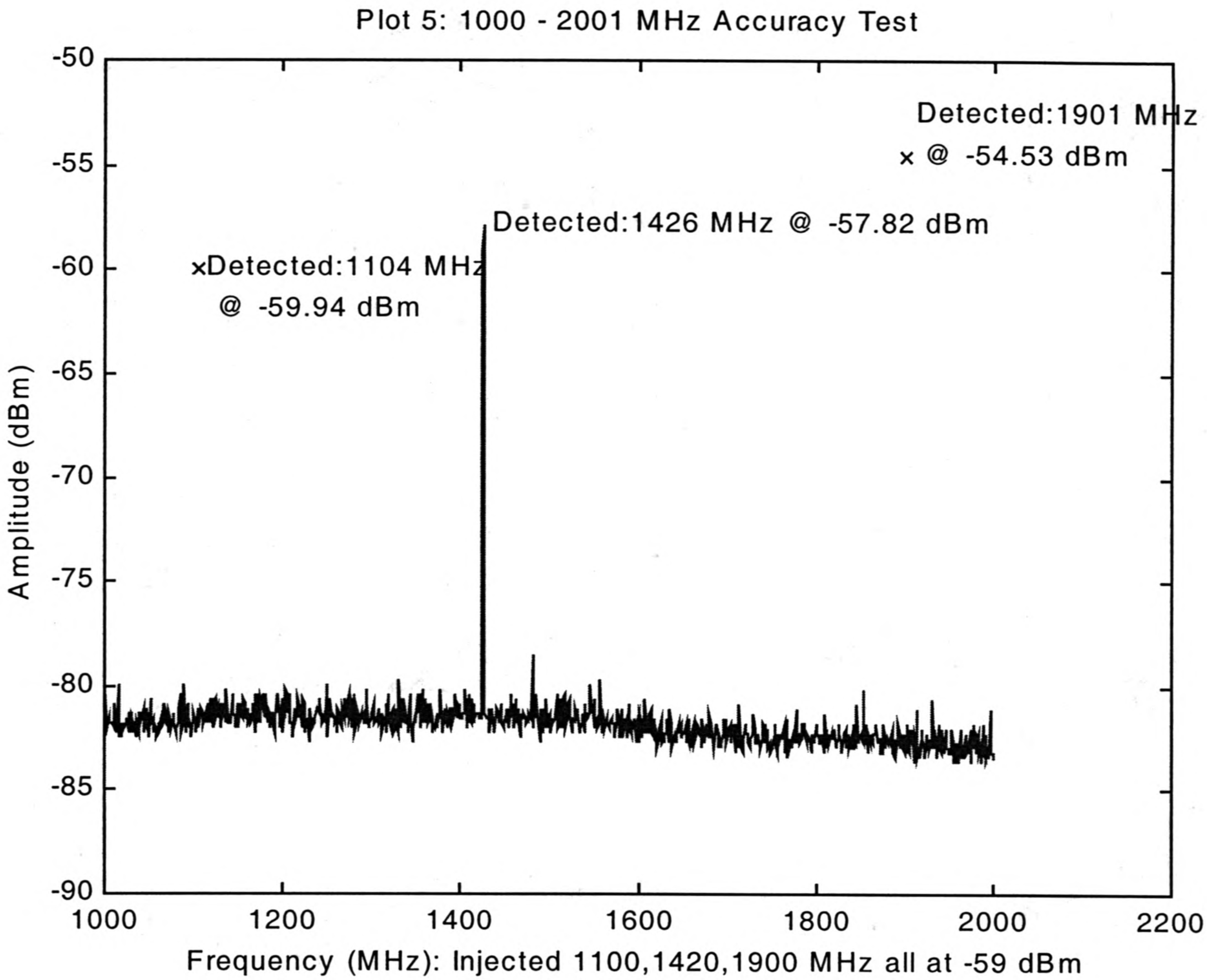

Plot 3.2: 40 dB Attenuator Test
Detected: 1505.9 MHz at -59.2353 dBm
Power (dBm)
-50
-60
-70
-80
-90
-100
-110
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Signal injected: 1500 MHz @ -19 dBm

Plot 3.3: 60 dB Attenuator Test

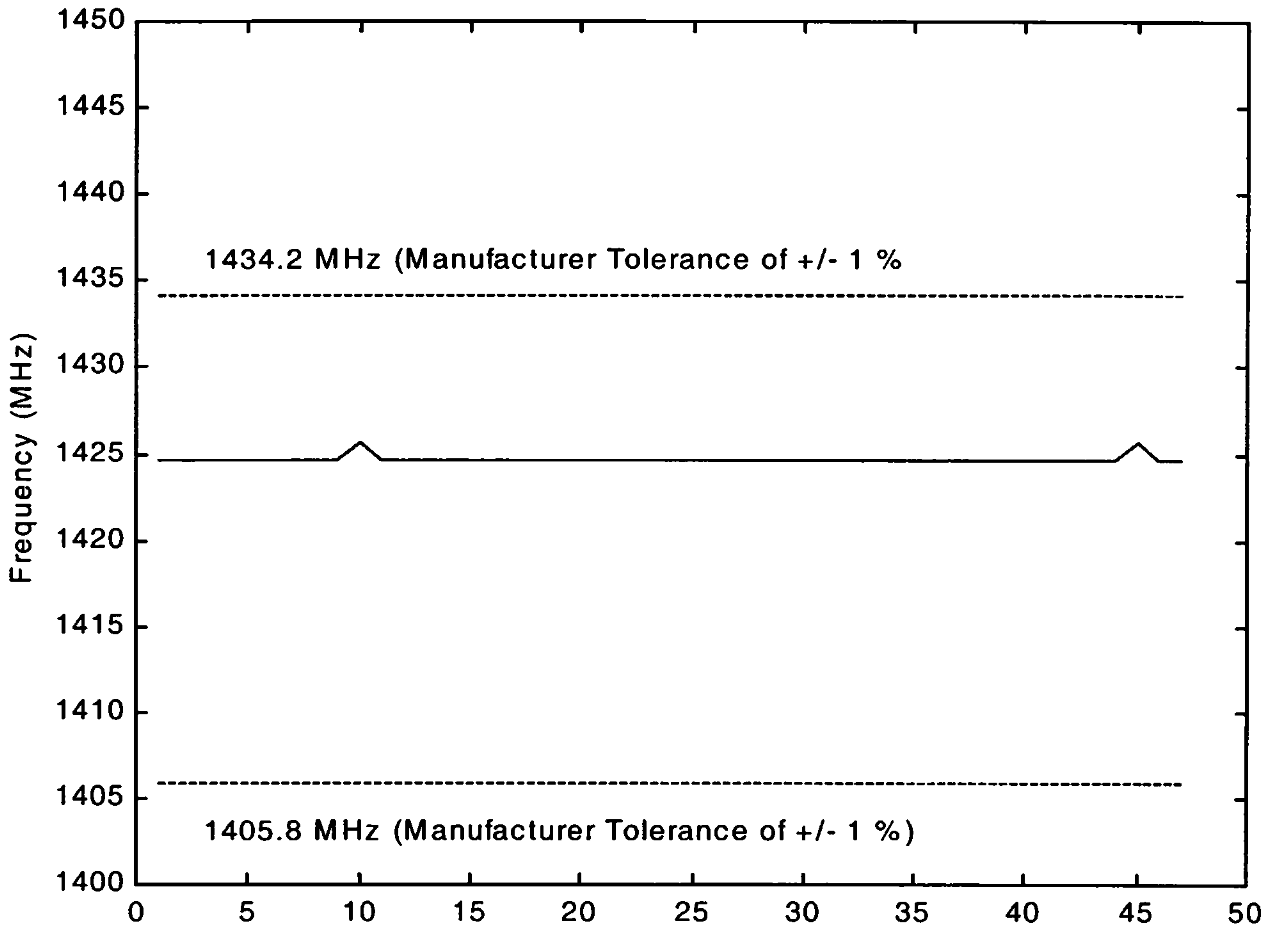



Plot 4.1: Dynamic Range Test: -52 dBm Injection
Detected:1426 MHz @ -49.59 dBm
Amplitude (dBm)
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Injected 1420 at -52 dBm


Plot 4.2: Dynamic Range Test: -66 dBm Injection
-60
-65
-70
-75
-80
-85
-90
Amplitude (dBm)
Detected:1426 MHz @ -64.65 dBm
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Injected 1420 at -66 dBm

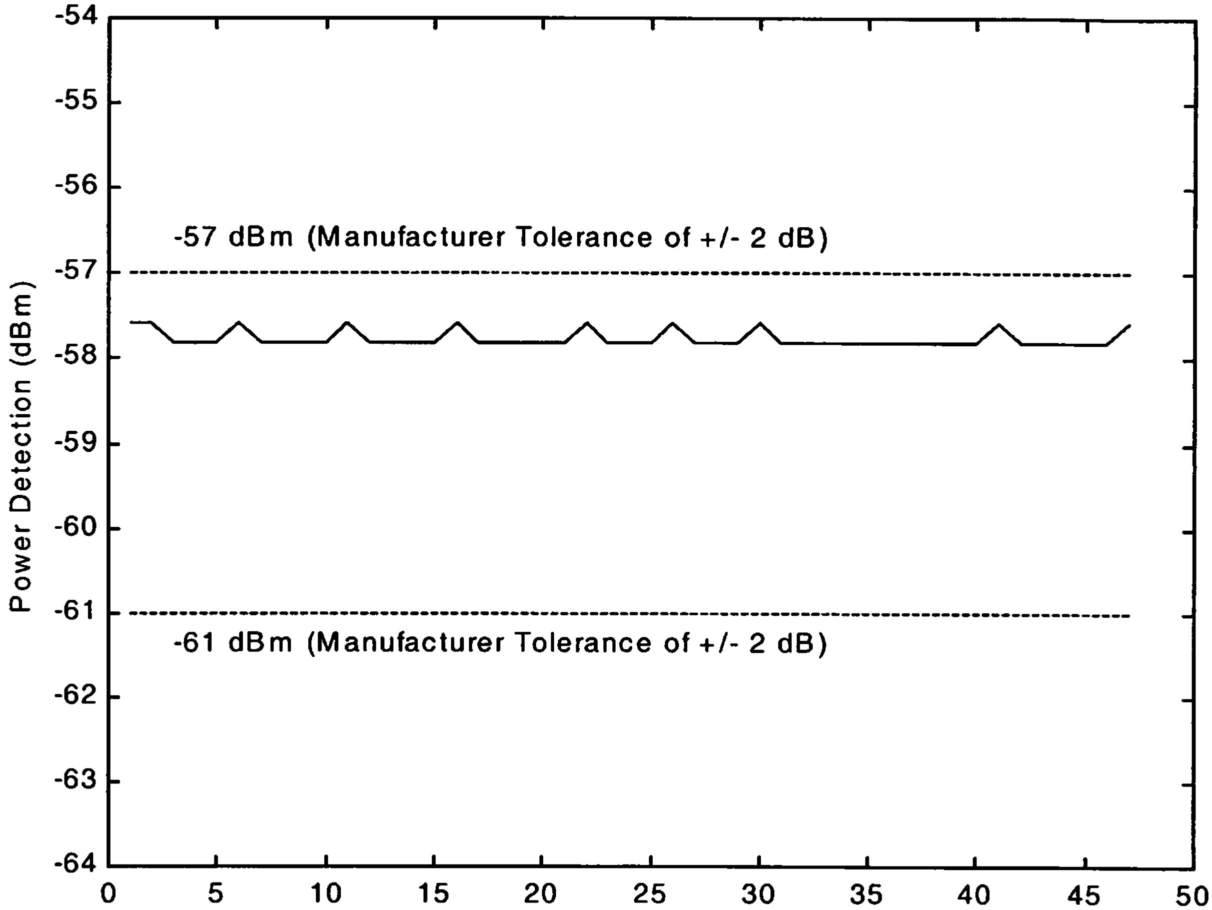

Plot 5: 1000 - 2001 MHz Accuracy Test
Detected:1901 MHz
× @ -54.53 dBm
Detected:1426 MHz @ -57.82 dBm
×Detected:1104 MHz
@ -59.94 dBm
Amplitude (dBm)
-50
-55
-60
-65
-70
-75
-80
-85
-90
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Injected 1100,1420,1900 MHz all at -59 dBm

Plot 5.1a: Repeatability Test for a 1420 MHz Injection at -59 dBm; 1000 - 2001 MHz Scan

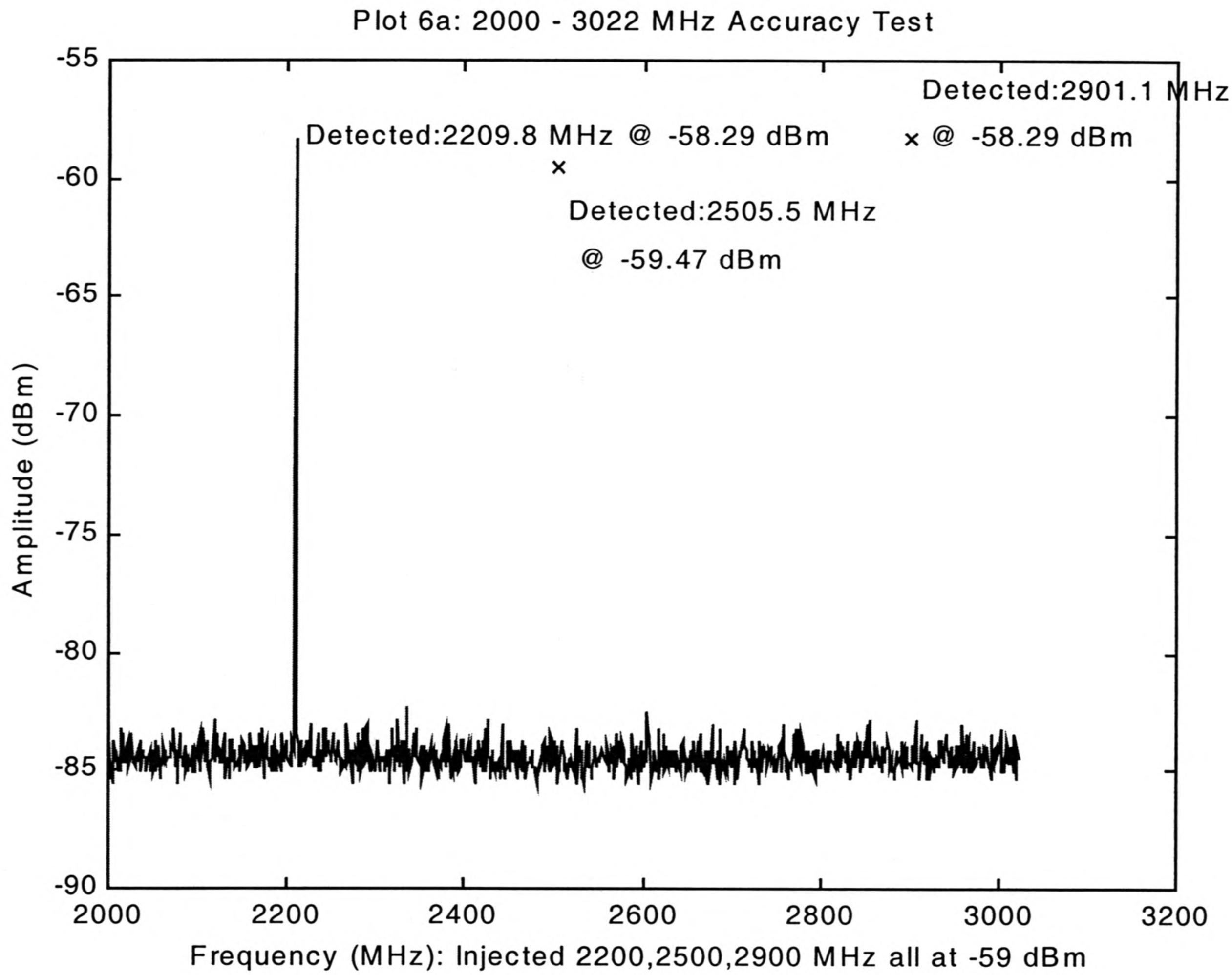


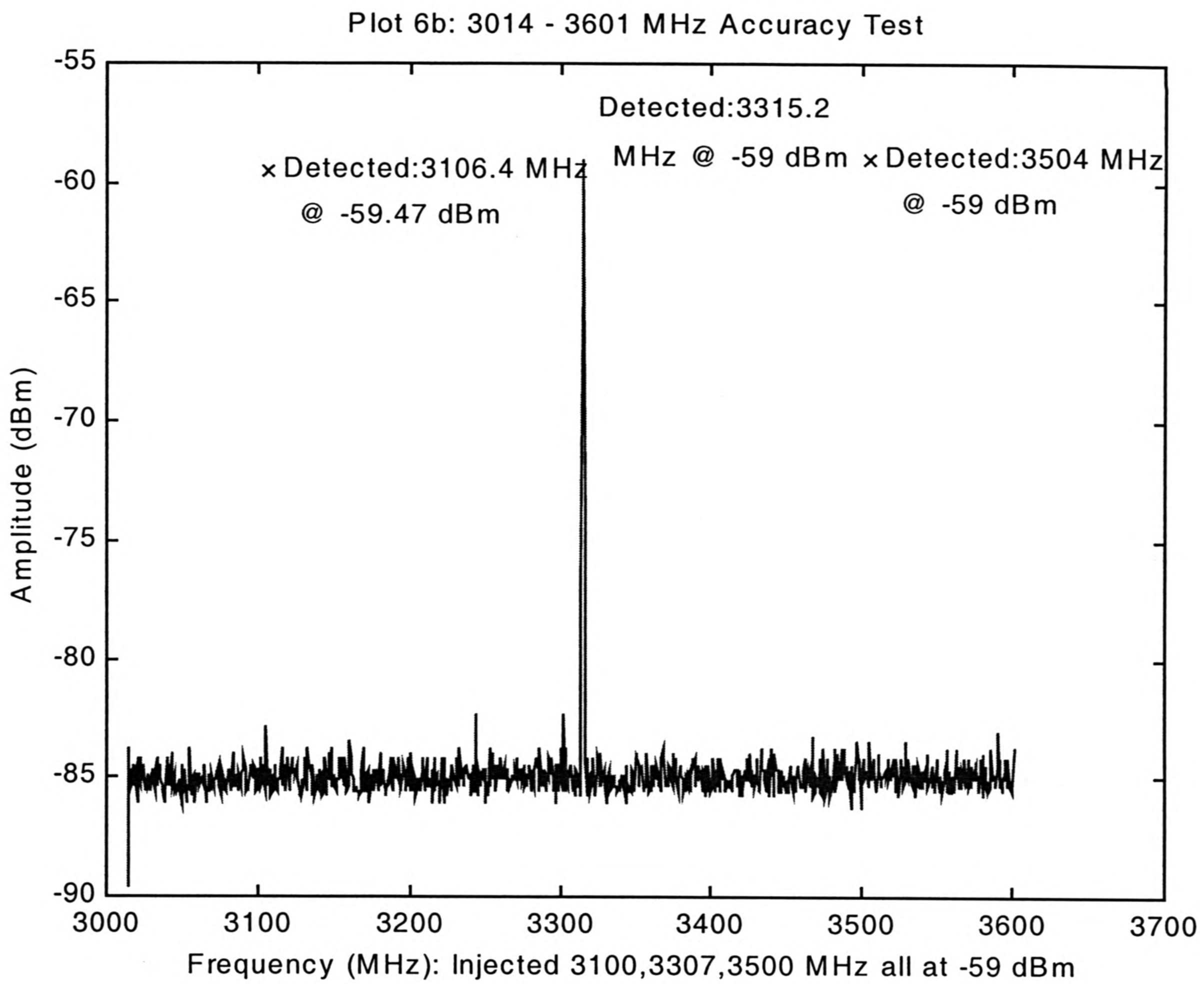
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerances

Plot 5.1b: Repeatability Test for a 1420 MHz Injection at -59 dBm; 1000 - 2001 MHz Scan



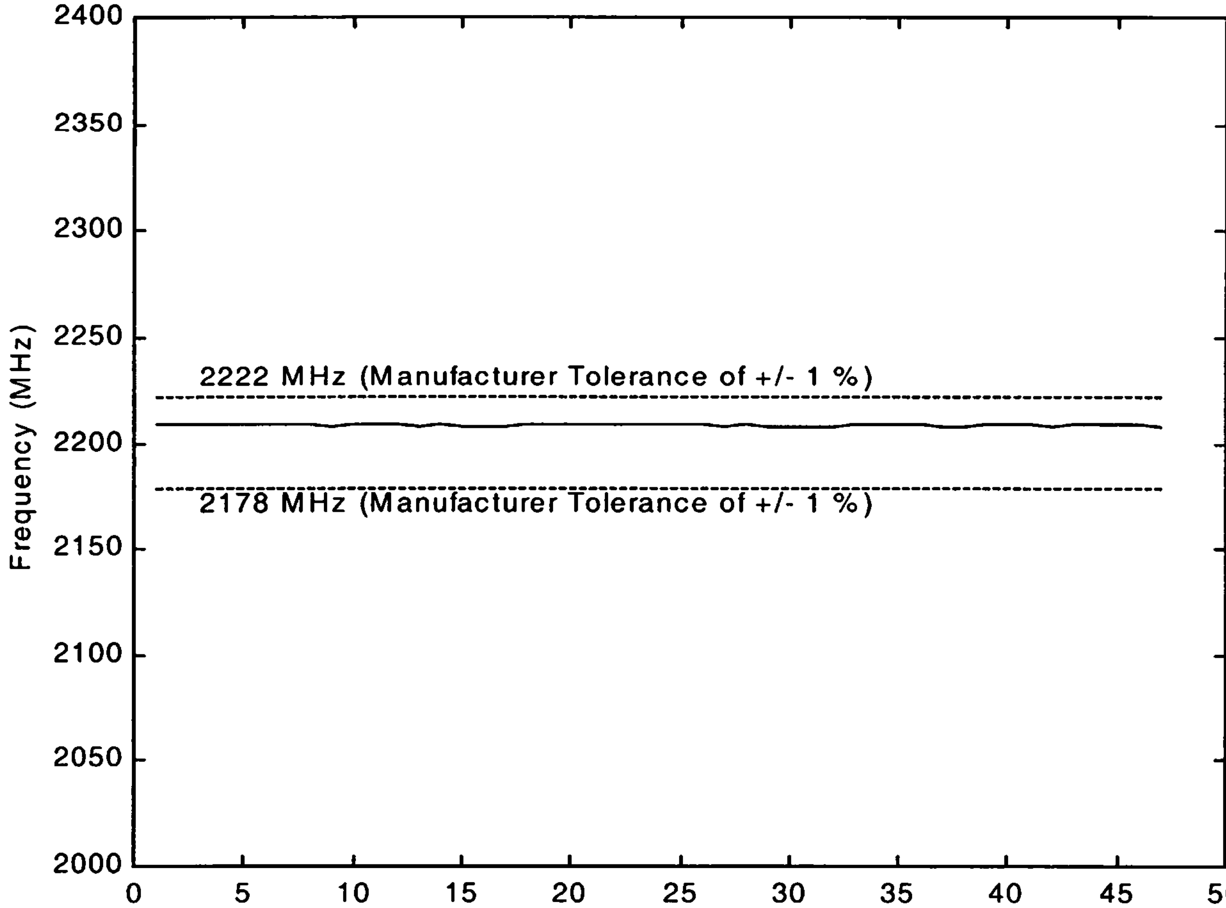
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance


Plot 6a: 2000 - 3022 MHz Accuracy Test
Detected:2901.1 MHz
@ -58.29 dBm
Detected:2209.8 MHz @ -58.29 dBm
Detected:2505.5 MHz
@ -59.47 dBm
-55
-60
-65
-70
-75
-80
-85
-90
Amplitude (dBm)
2000
2200
2400
2600
2800
3000
3200
Frequency (MHz): Injected 2200,2500,2900 MHz all at -59 dBm

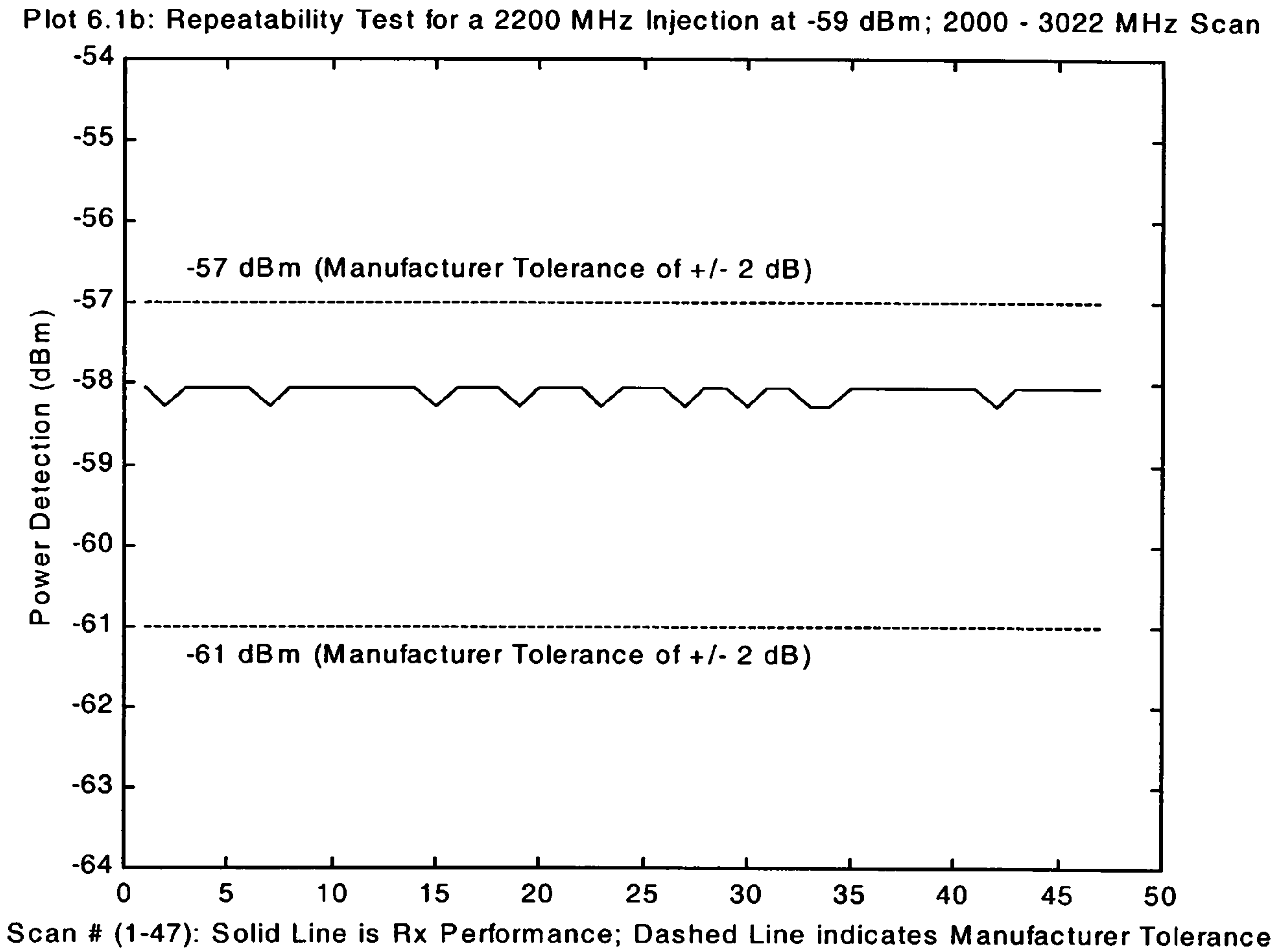


Plot 6b: 3014 - 3601 MHz Accuracy Test
-55
-60
-65
-70
-75
-80
-85
-90
Amplitude (dBm)
Detected:3315.2
MHz @ -59 dBm
× Detected:3106.4 MHz
@ -59.47 dBm
× Detected:3504 MHz
@ -59 dBm
3000
3100
3200
3300
3400
3500
3600
3700
Frequency (MHz): Injected 3100,3307,3500 MHz all at -59 dBm

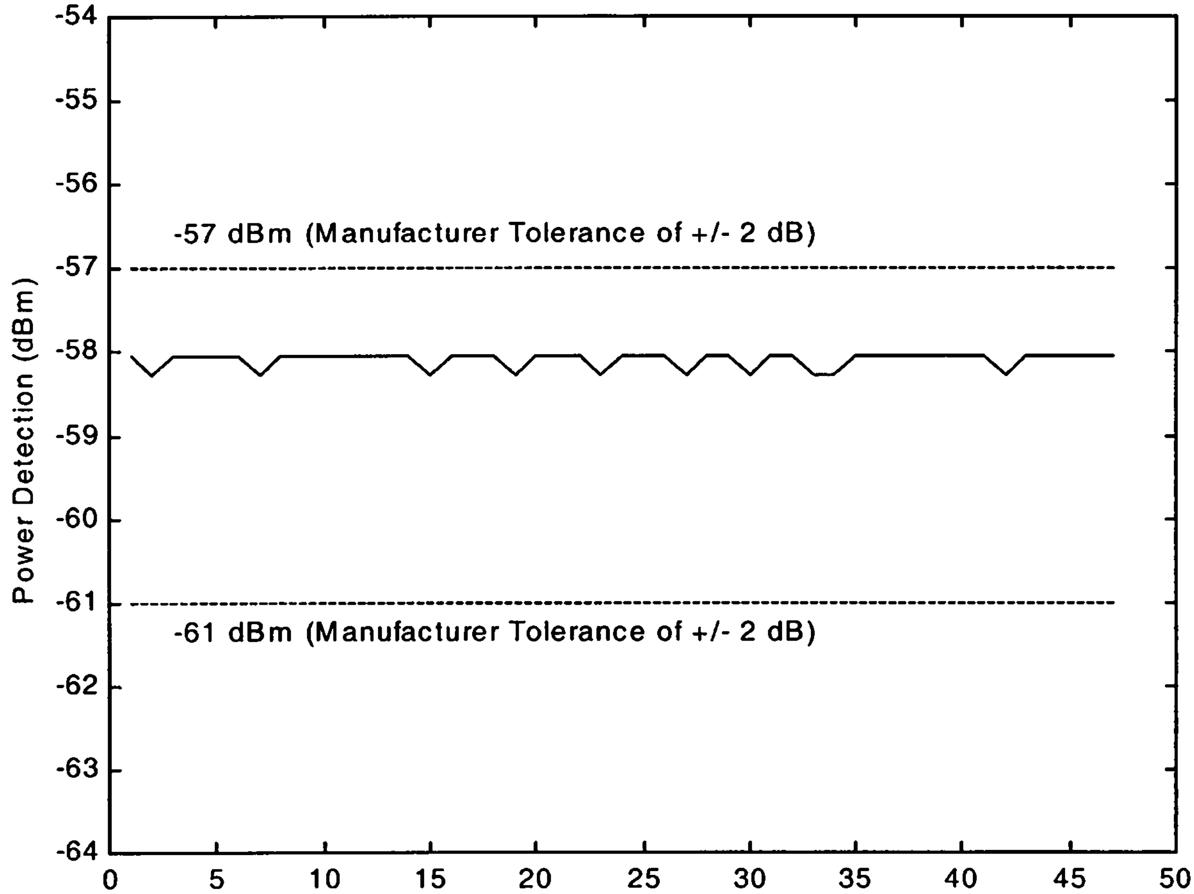
Plot 6.1a: Repeatability Test for a 2200 MHz Injection at -59 dBm; 2000 - 3022 MHz Scan



Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

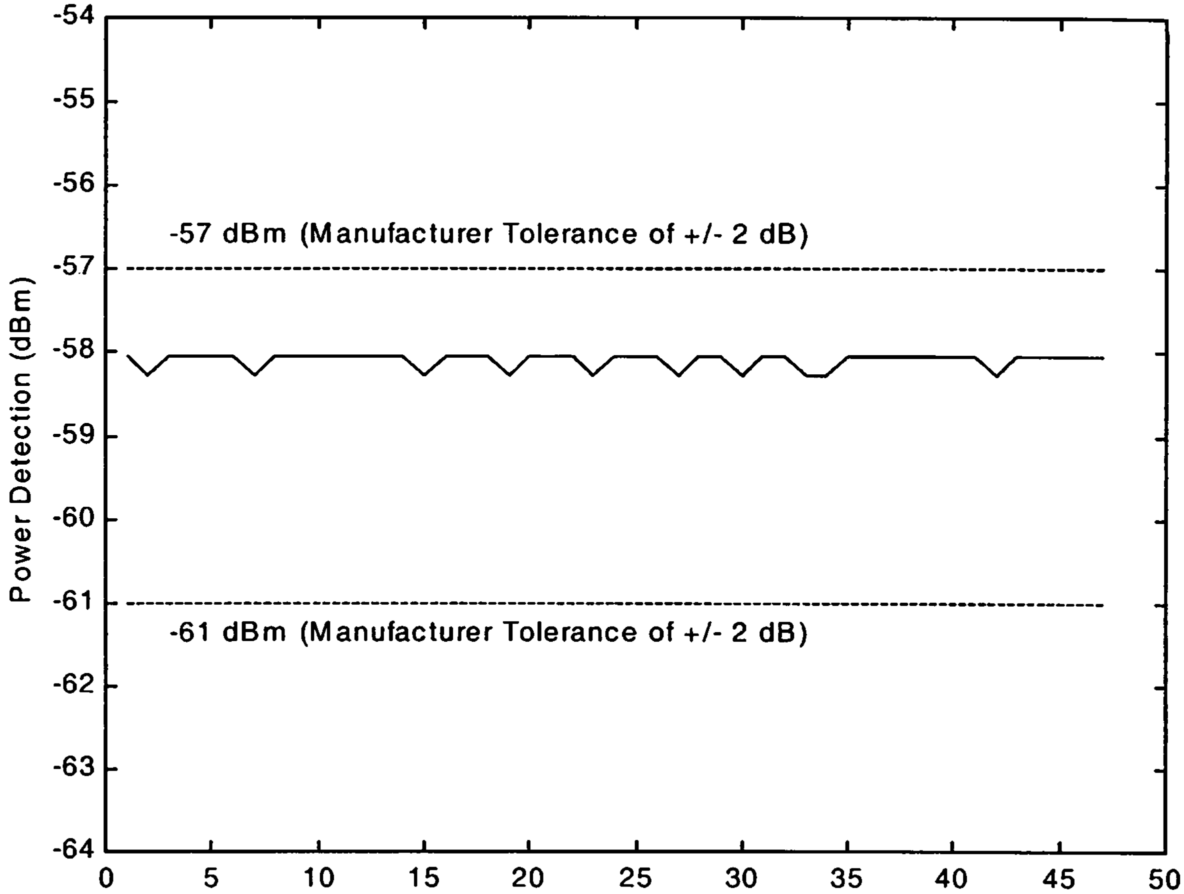

Plot 6.1b: Repeatability Test for a 2200 MHz Injection at -59 dBm; 2000 - 3022 MHz Scan
Power Detection (dBm)
-54
-55
-56
-57 dBm (Manufacturer Tolerance of +/- 2 dB)
-57
-58
-59
-60
-61
-61 dBm (Manufacturer Tolerance of +/- 2 dB)
-62
-63
-64
0
5
10
15
20
25
30
35
40
45
50
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

Plot 6.1b: Repeatability Test for a 2200 MHz Injection at -59 dBm; 2000 - 3022 MHz Scan

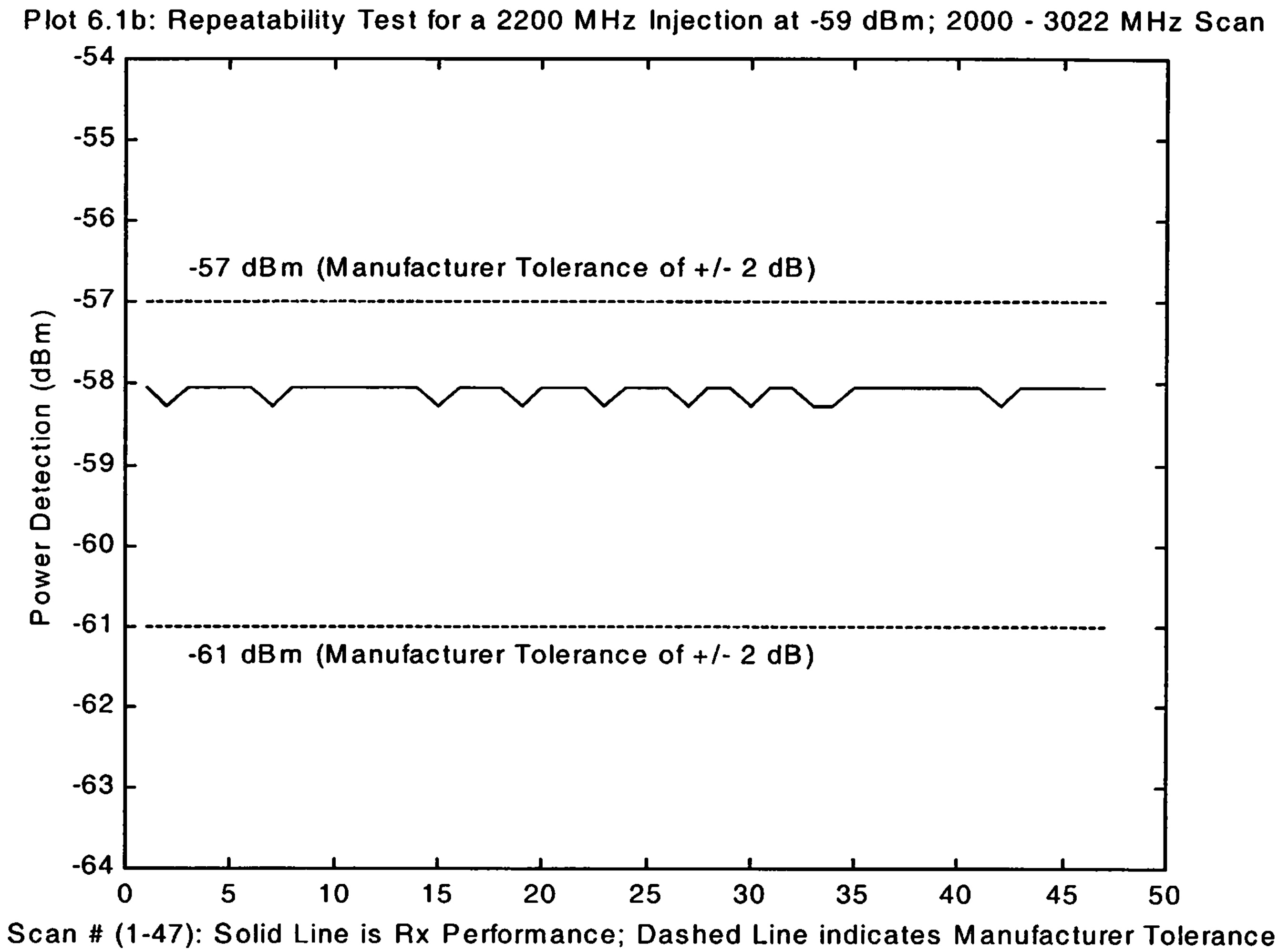


Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

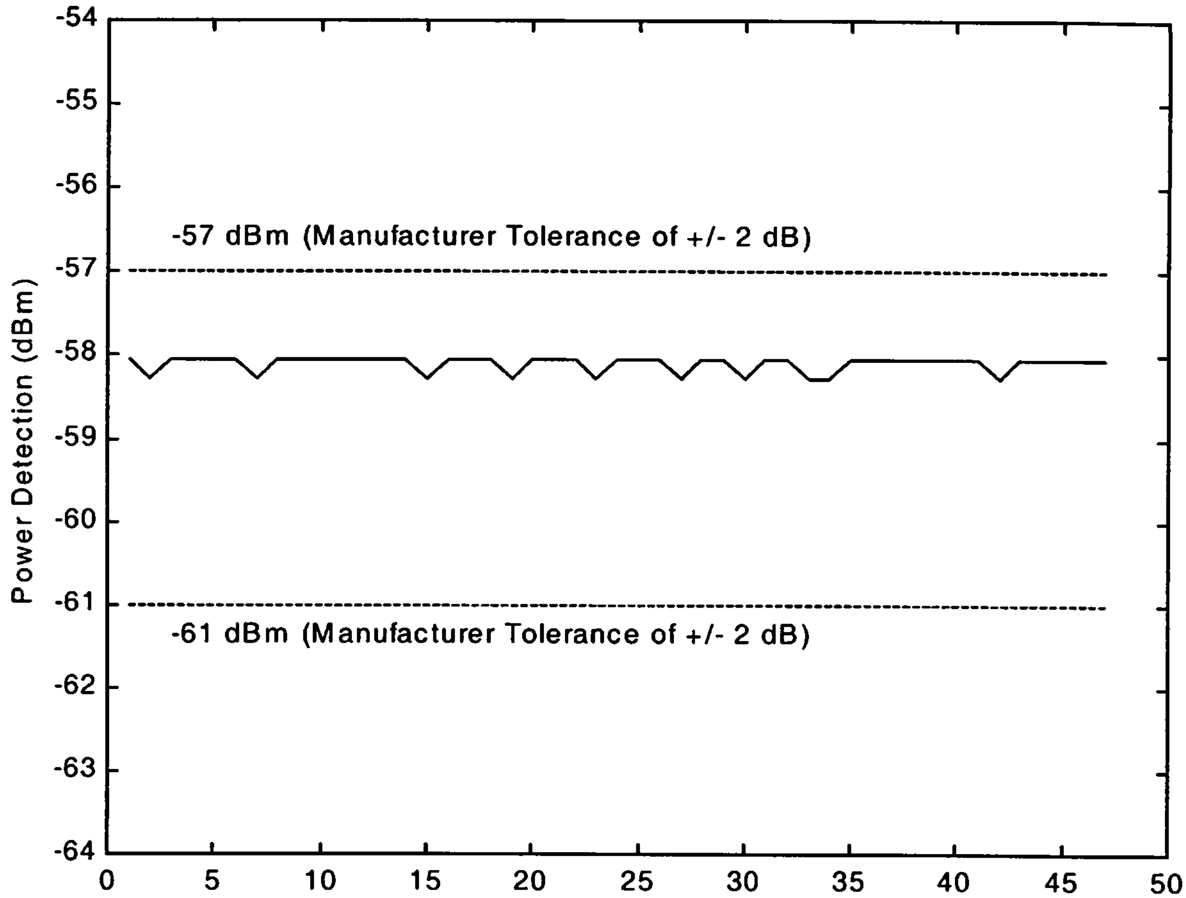
Plot 6.1b: Repeatability Test for a 2200 MHz Injection at -59 dBm; 2000 - 3022 MHz Scan



Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

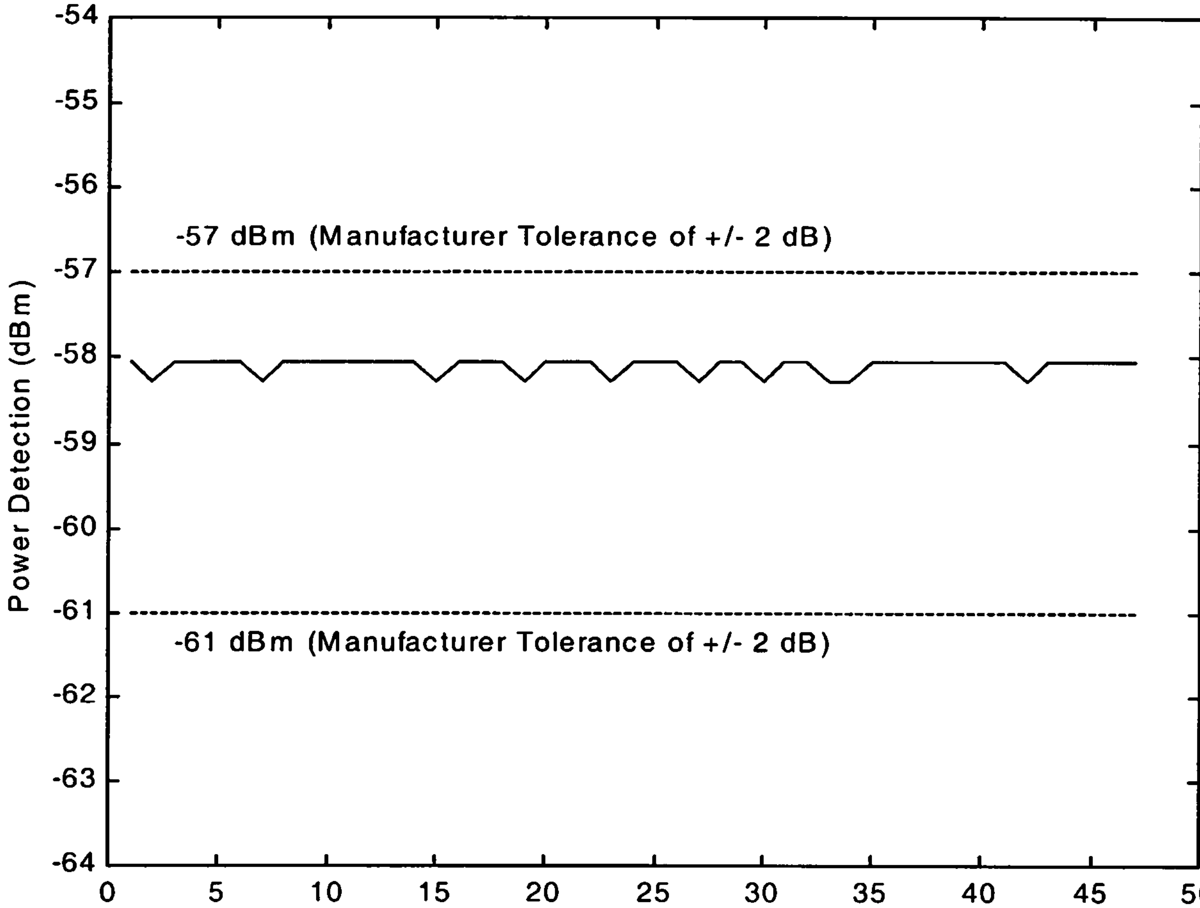

Plot 6.1b: Repeatability Test for a 2200 MHz Injection at -59 dBm; 2000 - 3022 MHz Scan
-57 dBm (Manufacturer Tolerance of +/- 2 dB)
-61 dBm (Manufacturer Tolerance of +/- 2 dB)
Power Detection (dBm)
-54
-55
-56
-57
-58
-59
-60
-61
-62
-63
-64
0
5
10
15
20
25
30
35
40
45
50
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

Plot 6.1b: Repeatability Test for a 2200 MHz Injection at -59 dBm; 2000 - 3022 MHz Scan

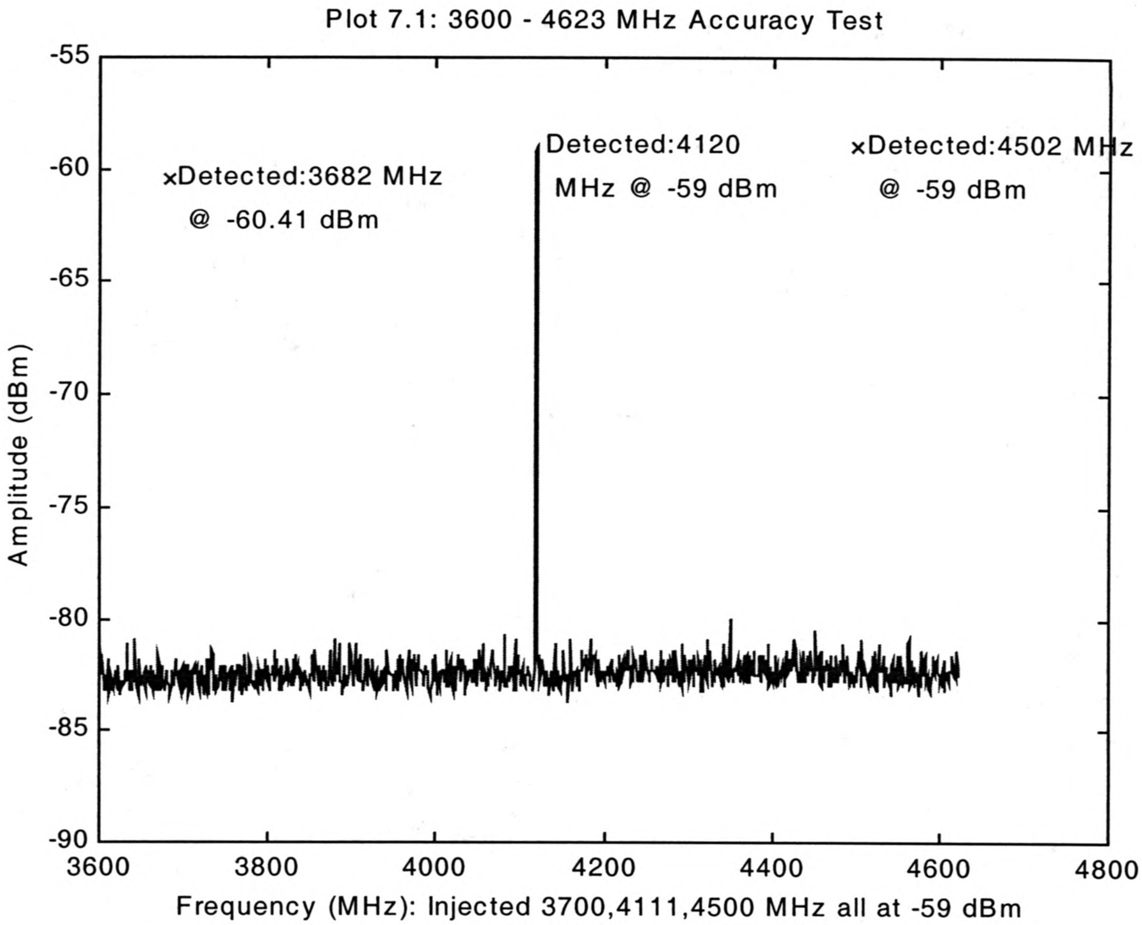


Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

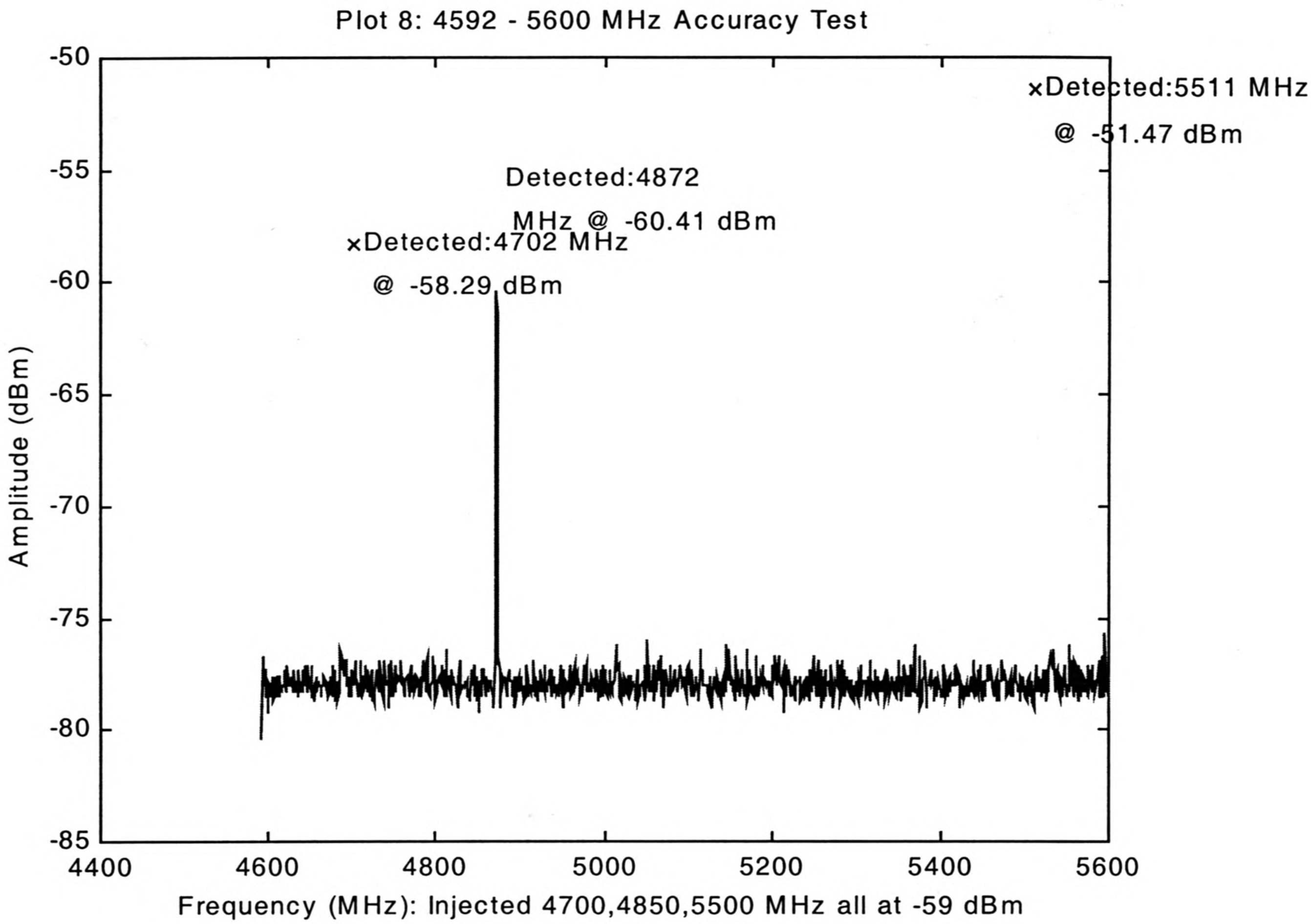
Plot 6.1b: Repeatability Test for a 2200 MHz Injection at -59 dBm; 2000 - 3022 MHz Scan



Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

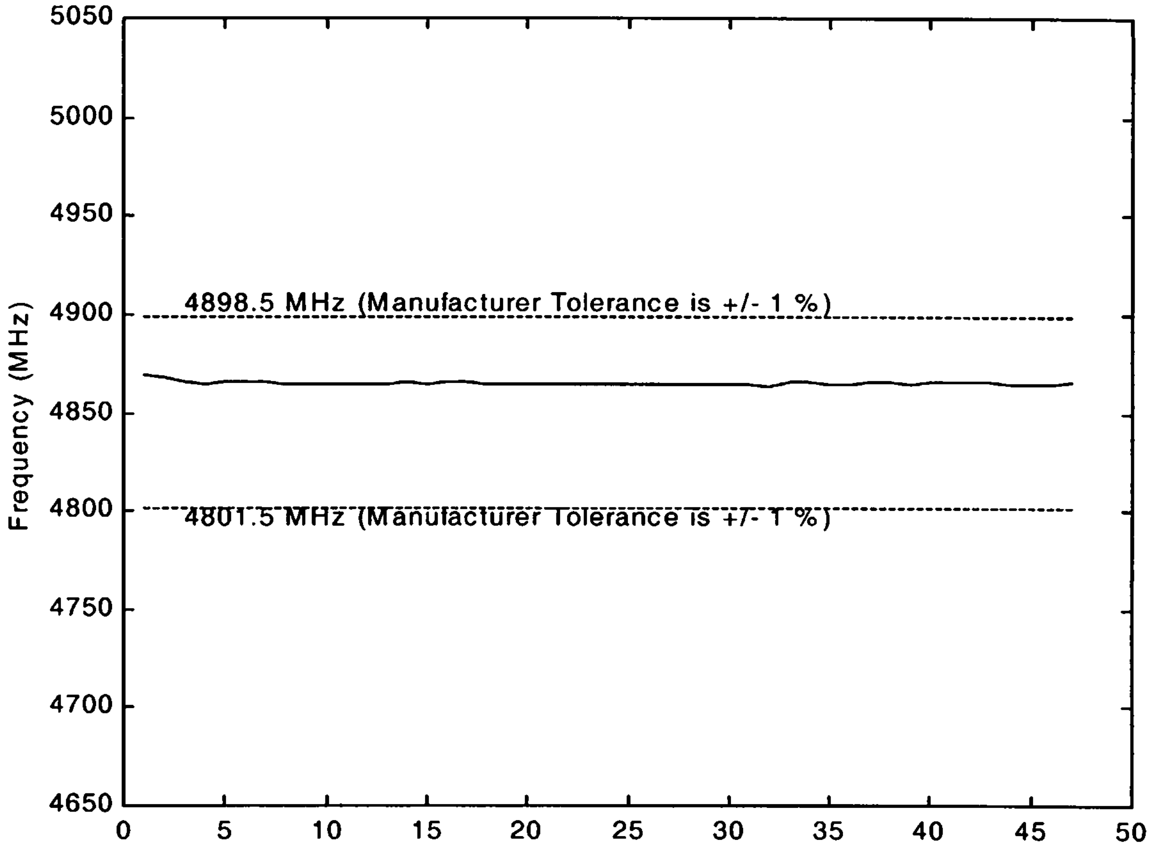


Plot 7.1: 3600 - 4623 MHz Accuracy Test
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
xDetected:3682 MHz
@ -60.41 dBm
Detected:4120
MHz @ -59 dBm
xDetected:4502 MHz
@ -59 dBm
3600
3800
4000
4200
4400
4600
4800
Frequency (MHz): Injected 3700,4111,4500 MHz all at -59 dBm

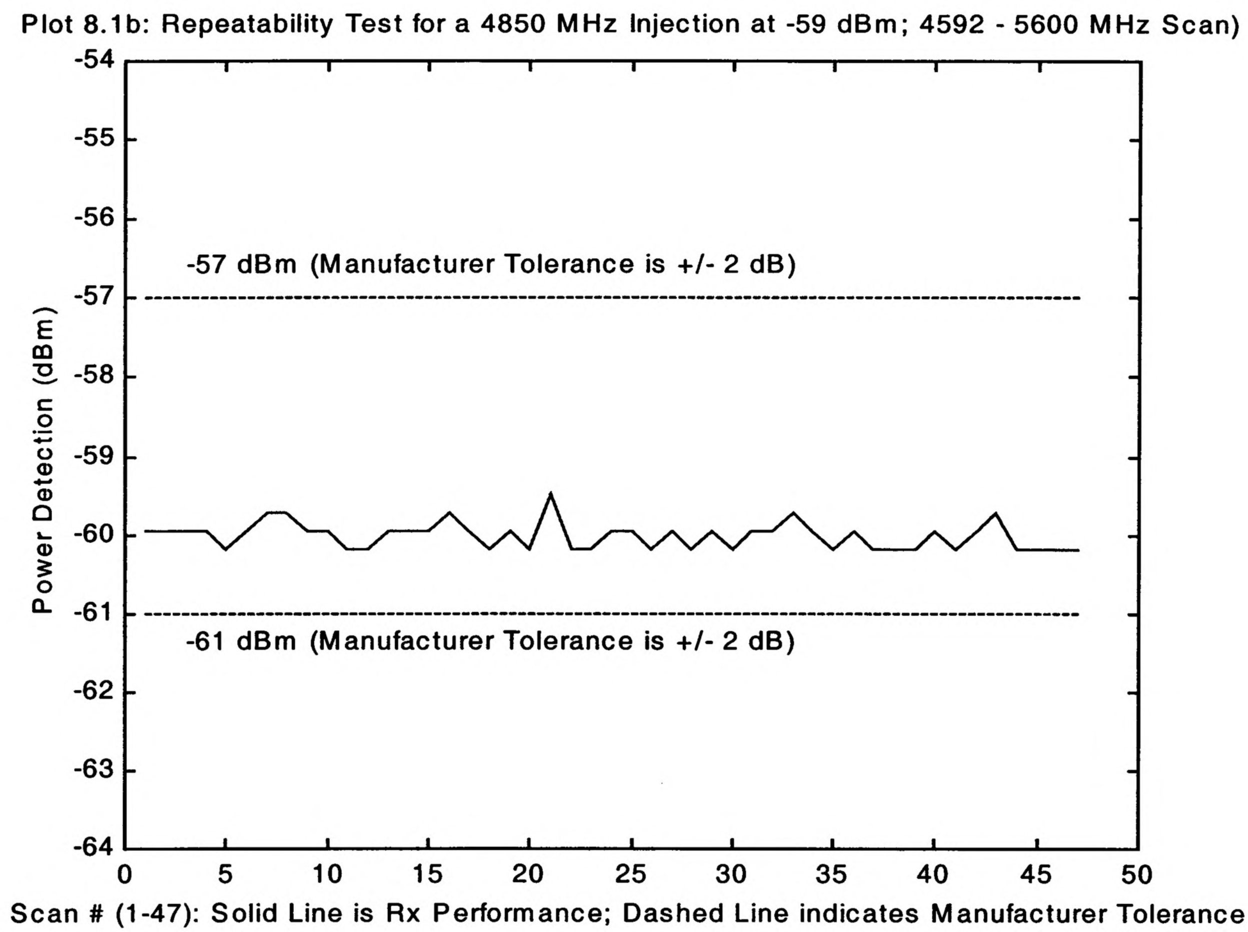


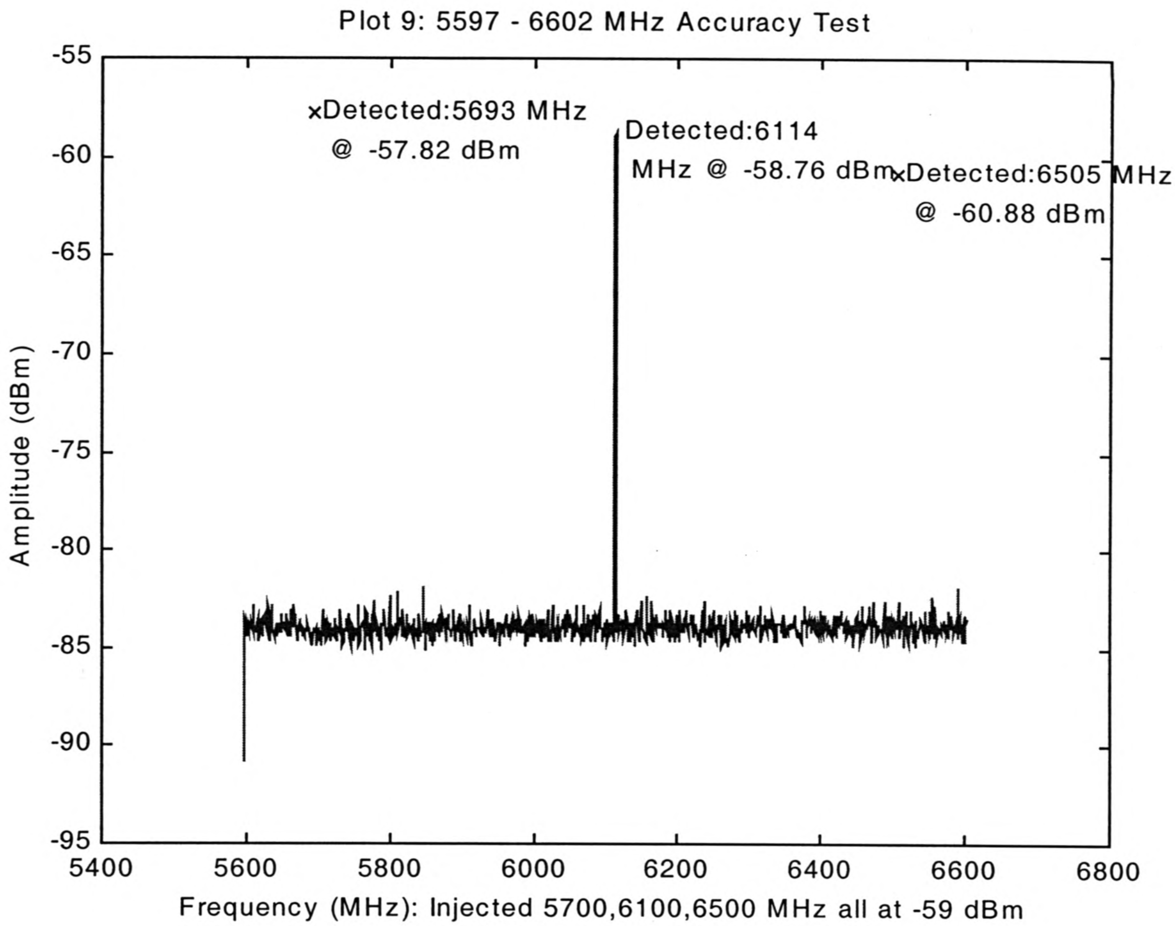
Plot 8: 4592 - 5600 MHz Accuracy Test
×Detected:5511 MHz
@ -51.47 dBm
Detected:4872
MHz @ -60.41 dBm
×Detected:4702 MHz
@ -58.29 dBm
Amplitude (dBm)
-50
-55
-60
-65
-70
-75
-80
-85
4400
4600
4800
5000
5200
5400
5600
Frequency (MHz): Injected 4700,4850,5500 MHz all at -59 dBm

Plot 8.1a: Repeatability Test for a 4850 MHz Injection at -59 dBm; 4592 - 5600 MHz Scan)

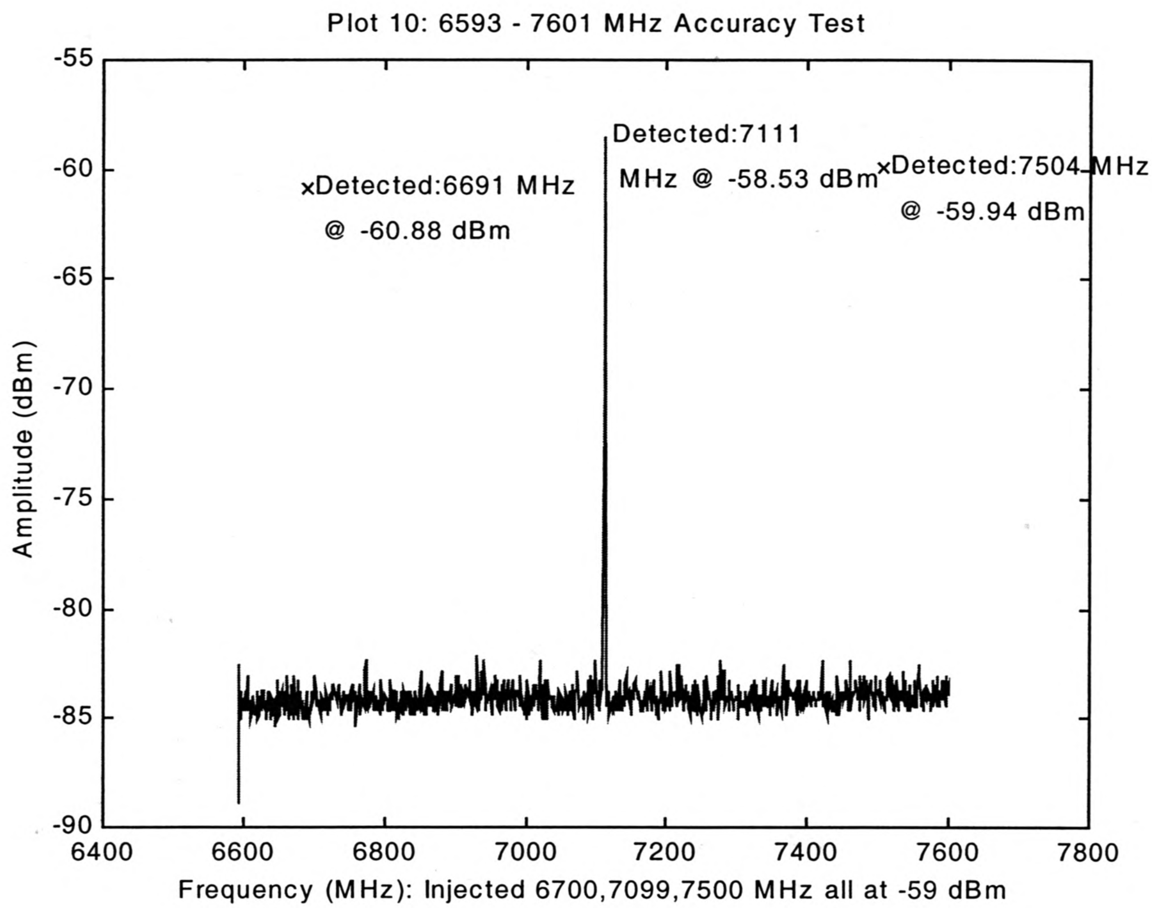


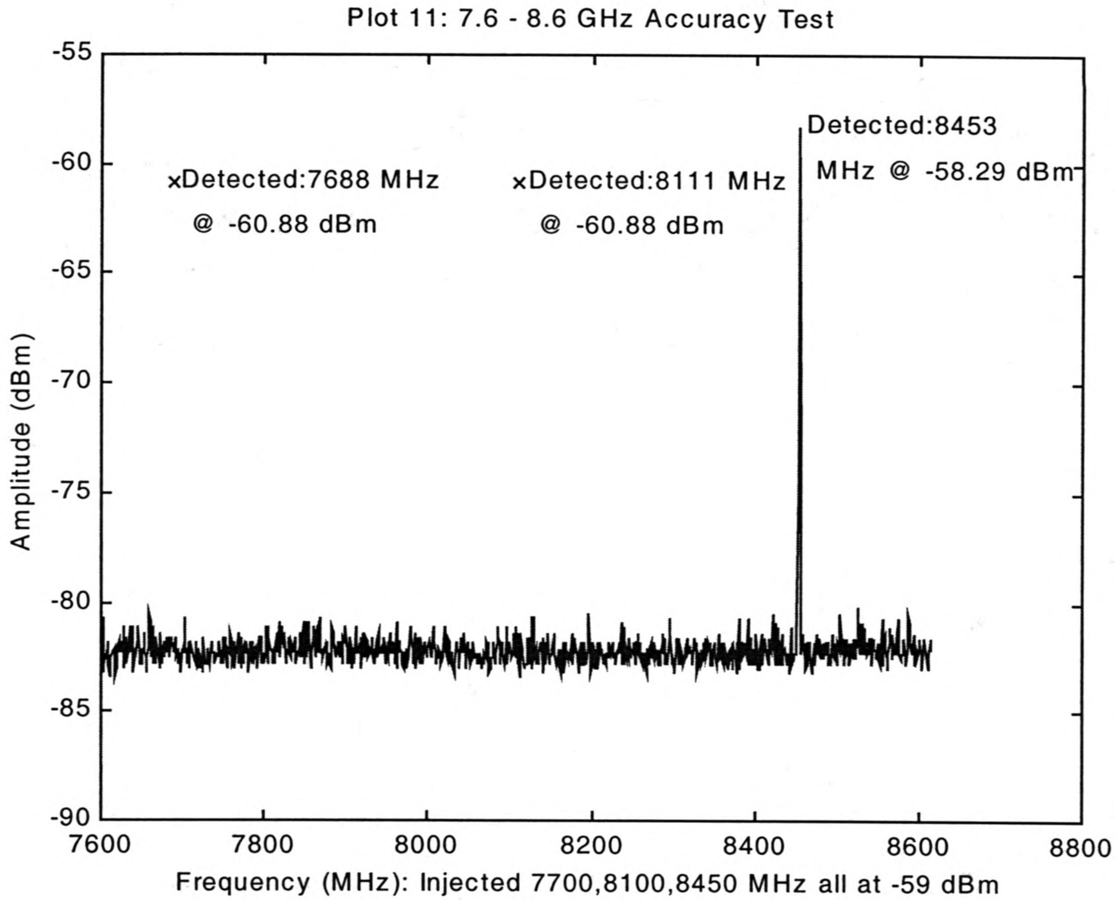
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance


Plot 8.1b: Repeatability Test for a 4850 MHz Injection at -59 dBm; 4592 - 5600 MHz Scan)
-54
-55
-56
-57 dBm (Manufacturer Tolerance is +/- 2 dB)
-57
-58
-59
-60
-61
-61 dBm (Manufacturer Tolerance is +/- 2 dB)
-62
-63
-64
Power Detection (dBm)
0
5
10
15
20
25
30
35
40
45
50
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance



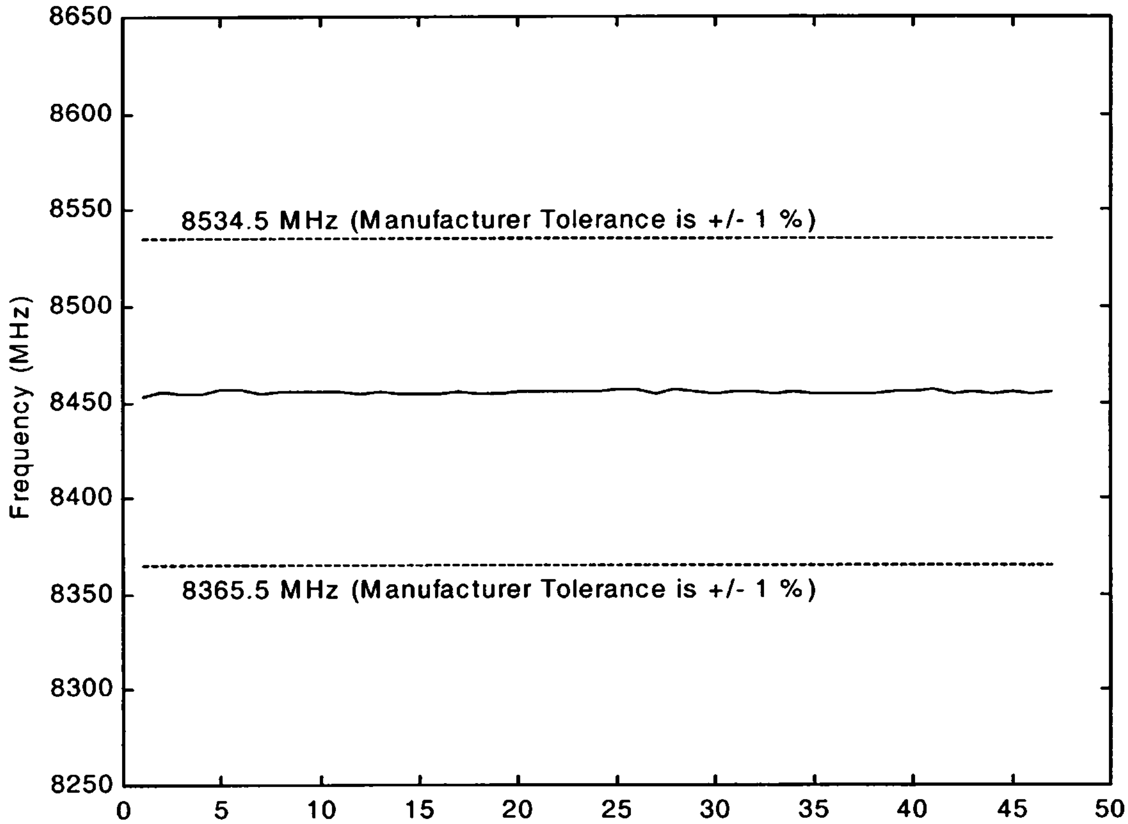
Plot 9: 5597 - 6602 MHz Accuracy Test
×Detected:5693 MHz
@ -57.82 dBm
Detected:6114
MHz @ -58.76 dBm
×Detected:6505 MHz
@ -60.88 dBm
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
-95
5400
5600
5800
6000
6200
6400
6600
6800
Frequency (MHz): Injected 5700,6100,6500 MHz all at -59 dBm


Plot 10: 6593 - 7601 MHz Accuracy Test
Detected:7111
MHz @ -58.53 dBm
Detected:6691 MHz
@ -60.88 dBm
Detected:7504 MHz
@ -59.94 dBm
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
6400
6600
6800
7000
7200
7400
7600
7800
Frequency (MHz): Injected 6700,7099,7500 MHz all at -59 dBm



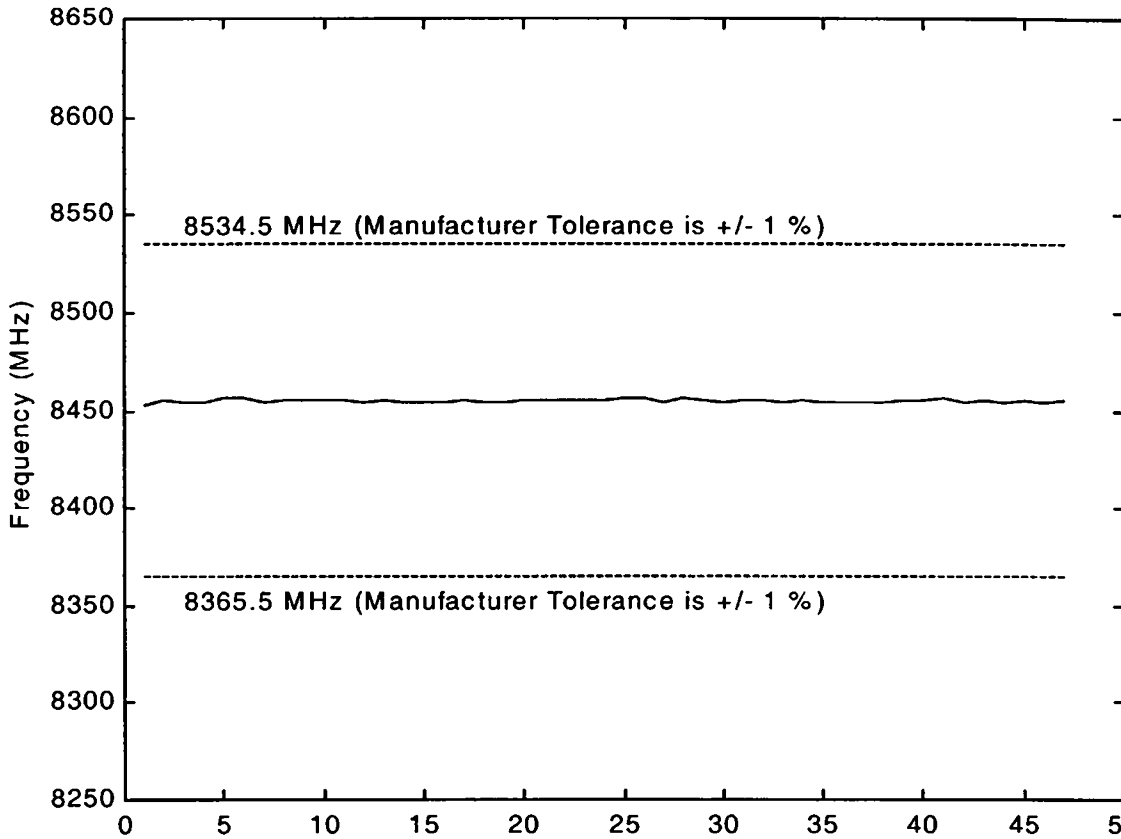
Plot 11: 7.6 - 8.6 GHz Accuracy Test
-55
-60
-65
-70
-75
-80
-85
-90
Amplitude (dBm)
×Detected:7688 MHz
@ -60.88 dBm
×Detected:8111 MHz
@ -60.88 dBm
Detected:8453
MHz @ -58.29 dBm
7600
7800
8000
8200
8400
8600
8800
Frequency (MHz): Injected 7700,8100,8450 MHz all at -59 dBm

Plot 11.1a: Repeatability Test for a 8450 MHz Injection at -59 dBm; 7600 - 8615 MHz Scan)



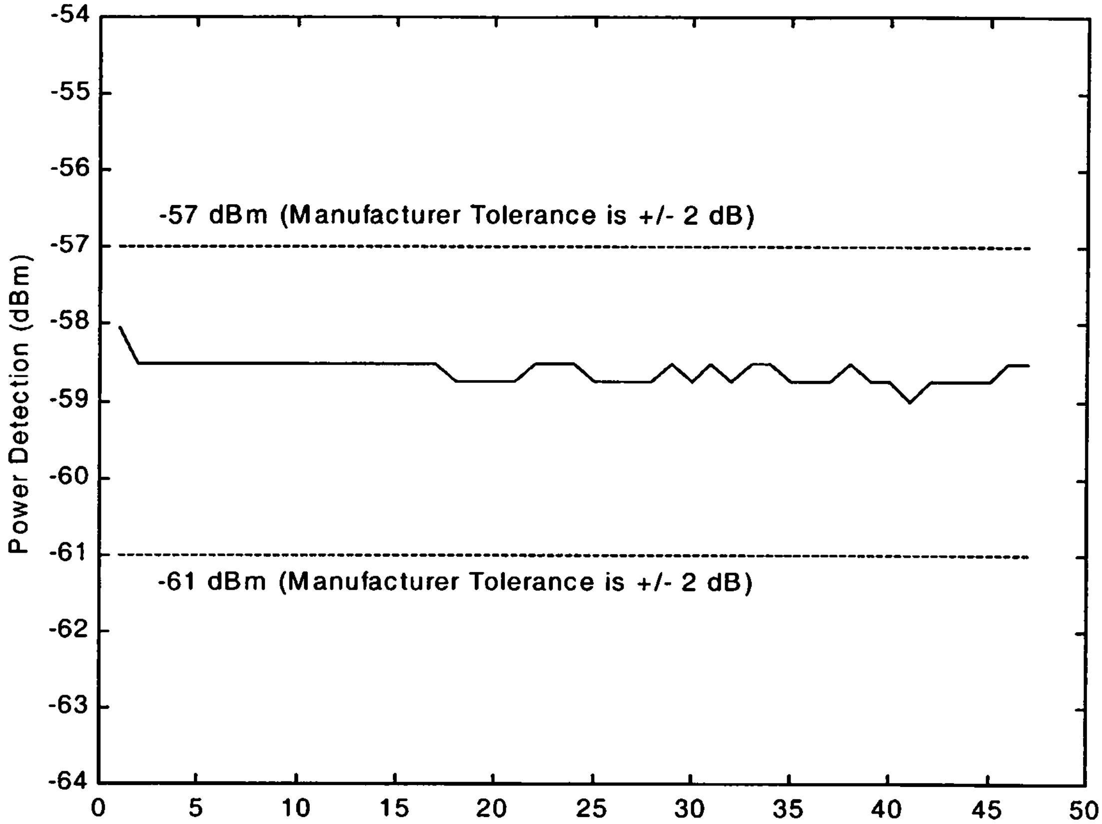
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

Plot 11.1a: Repeatability Test for a 8450 MHz Injection at -59 dBm; 7600 - 8615 MHz Scan)

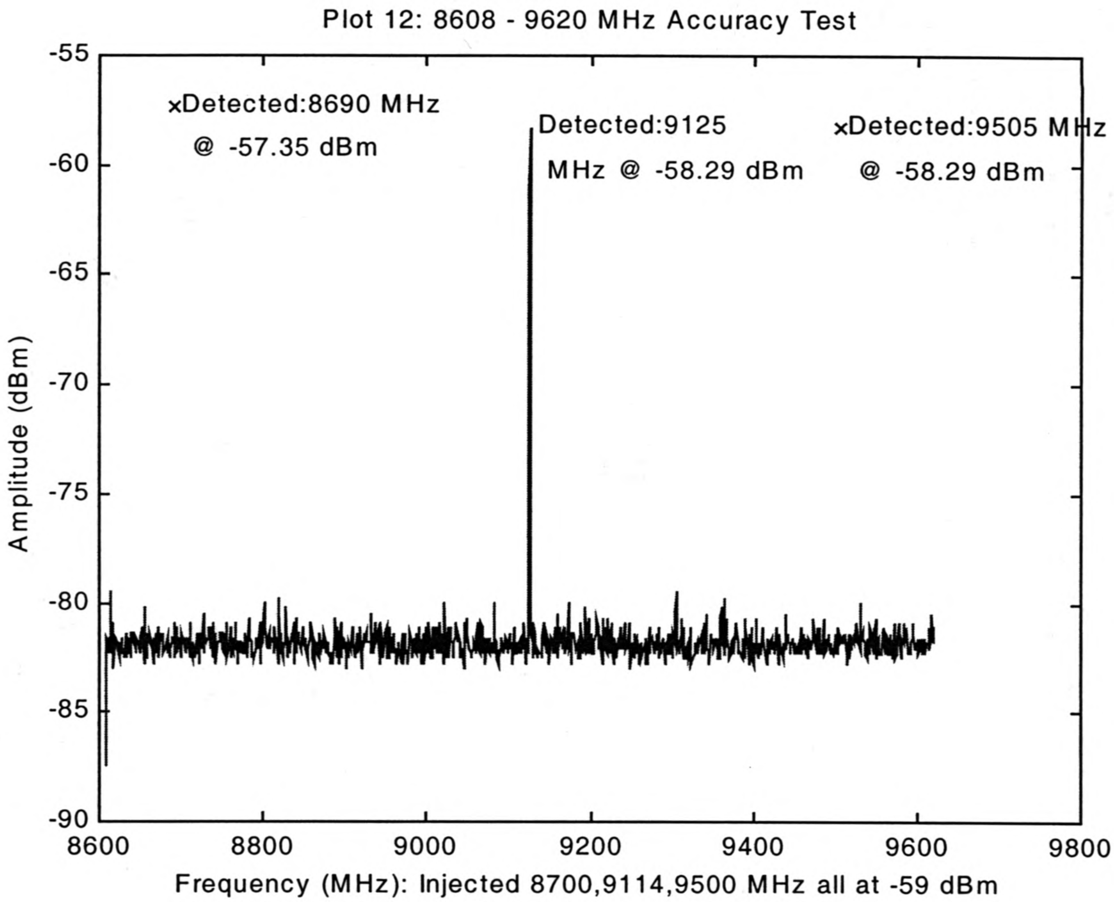


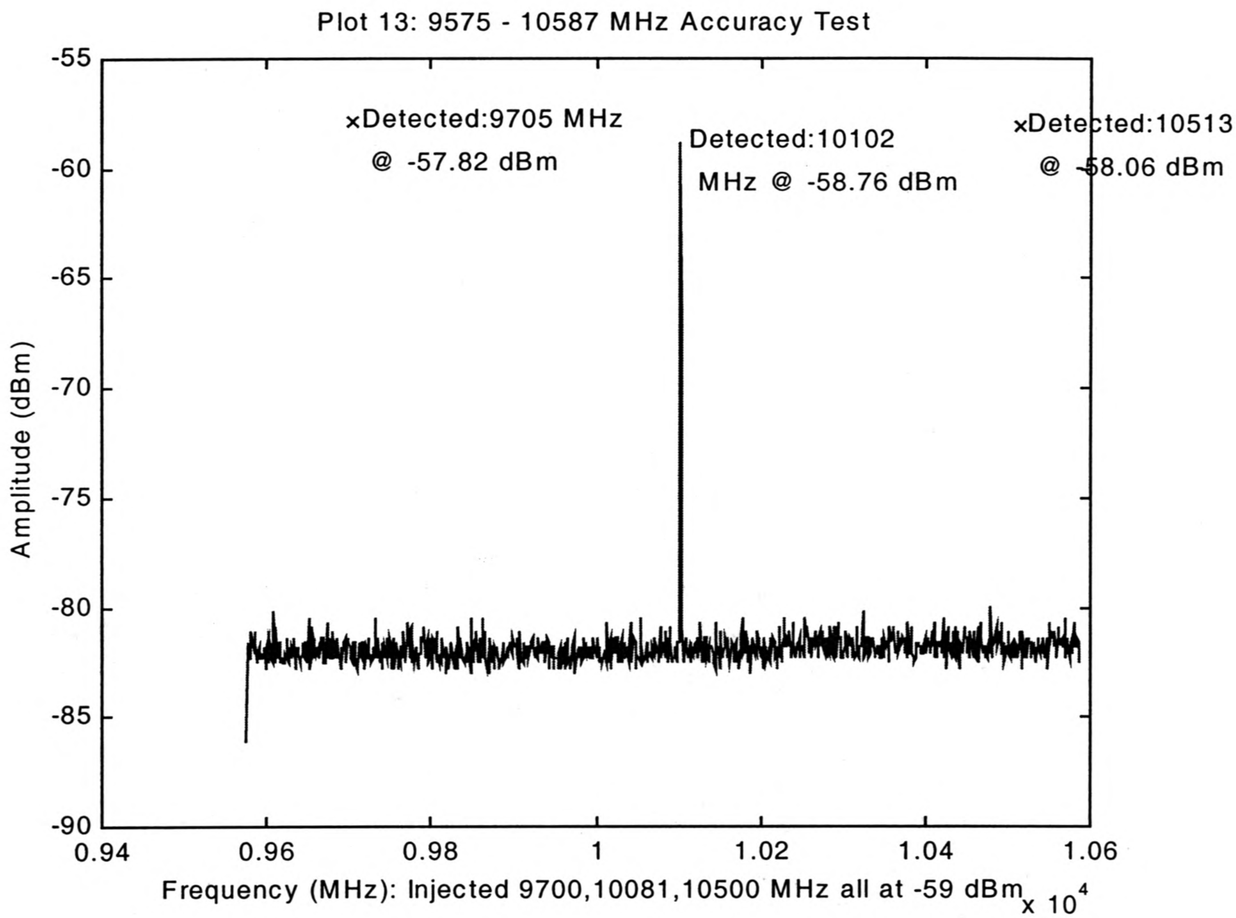
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

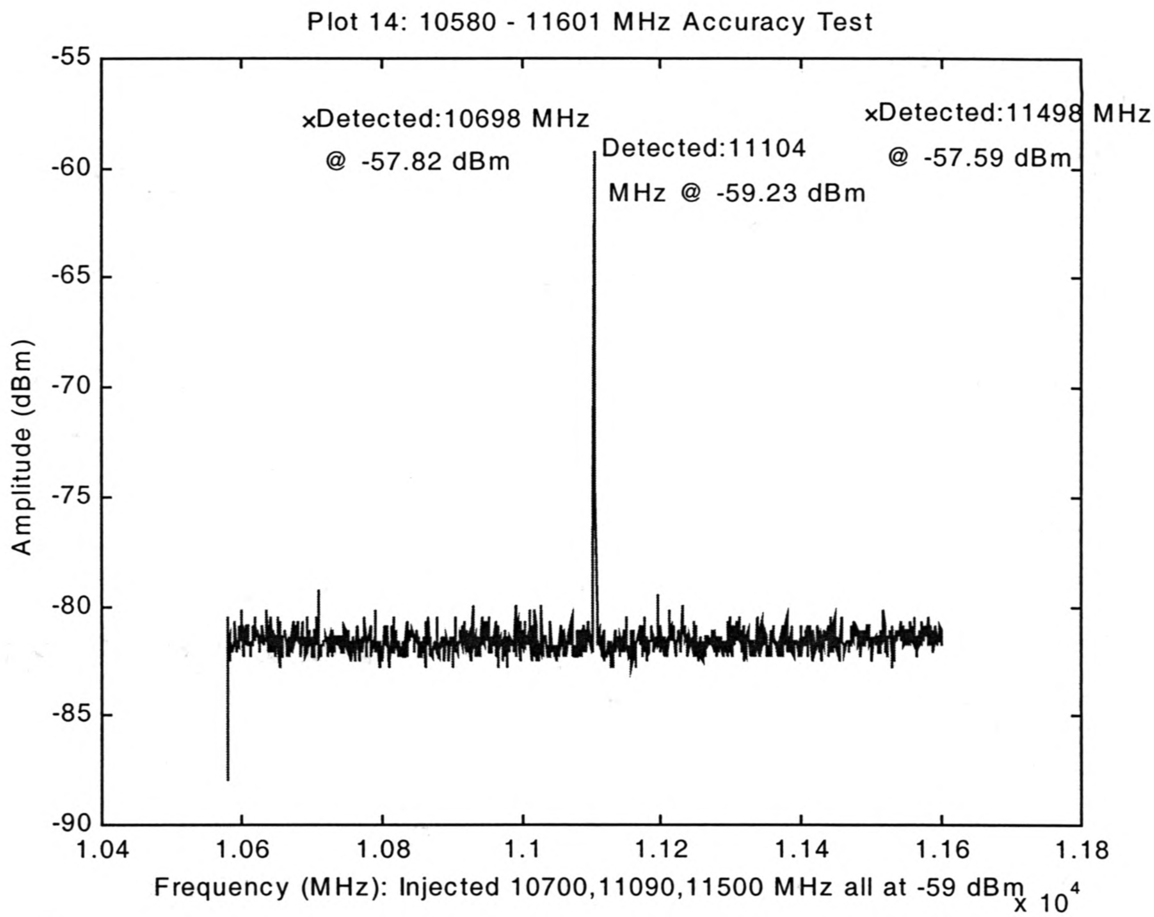
Plot 11.1b: Repeatability Test for a 8450 MHz Injection at -59 dBm; 7600 - 8615 MHz Scan)



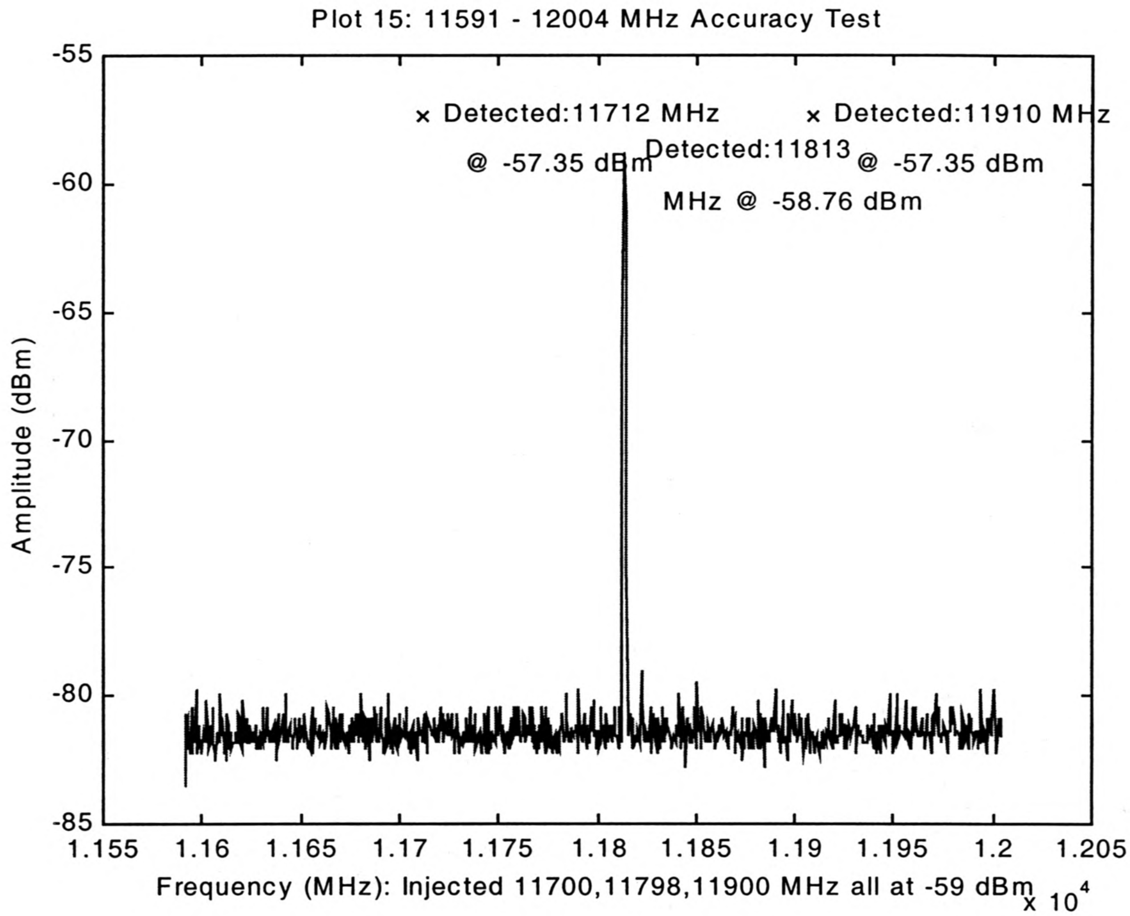
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

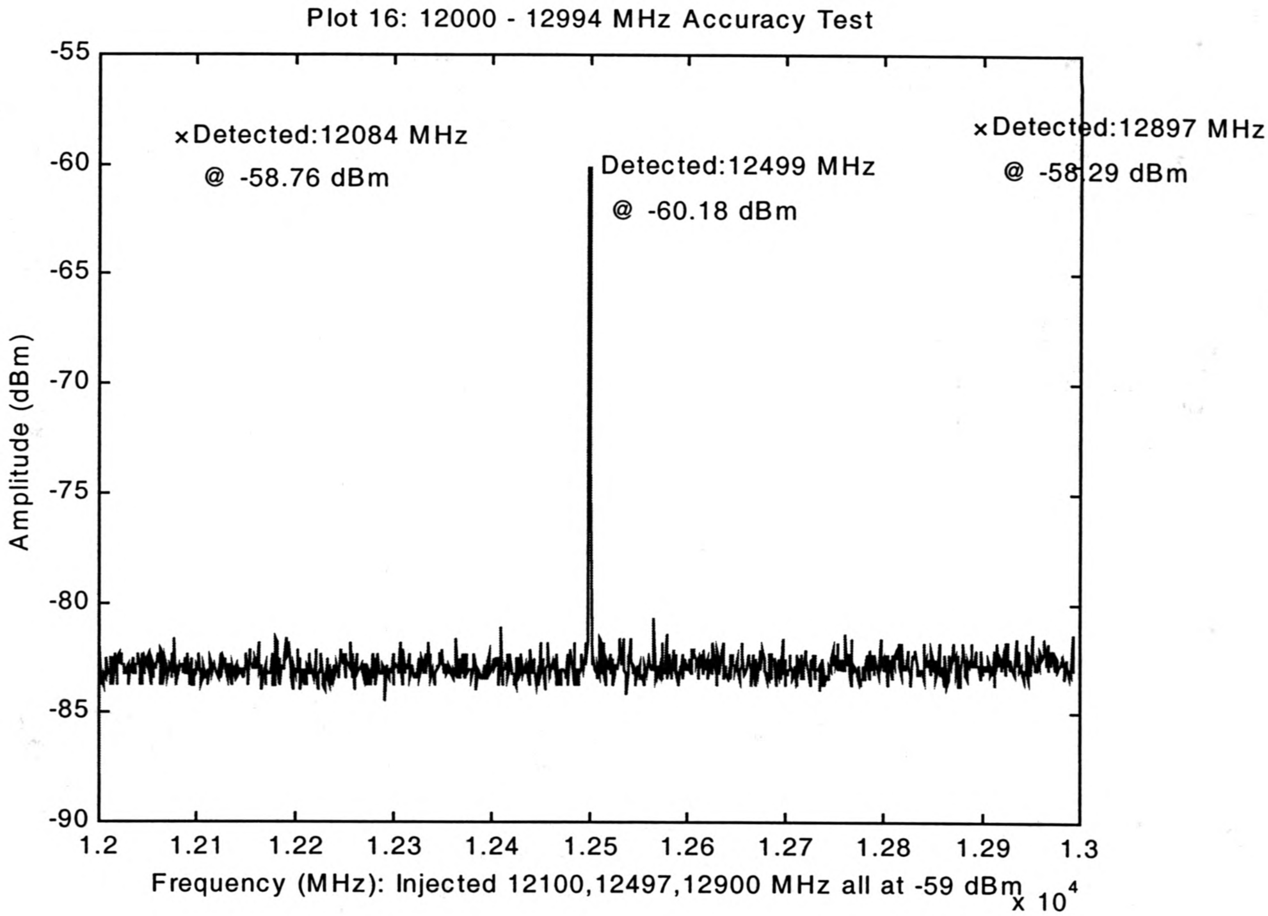

Plot 12: 8608 - 9620 MHz Accuracy Test
xDetected:8690 MHz
@ -57.35 dBm
Detected:9125
MHz @ -58.29 dBm
xDetected:9505 MHz
@ -58.29 dBm
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
8600
8800
9000
9200
9400
9600
9800
Frequency (MHz): Injected 8700,9114,9500 MHz all at -59 dBm

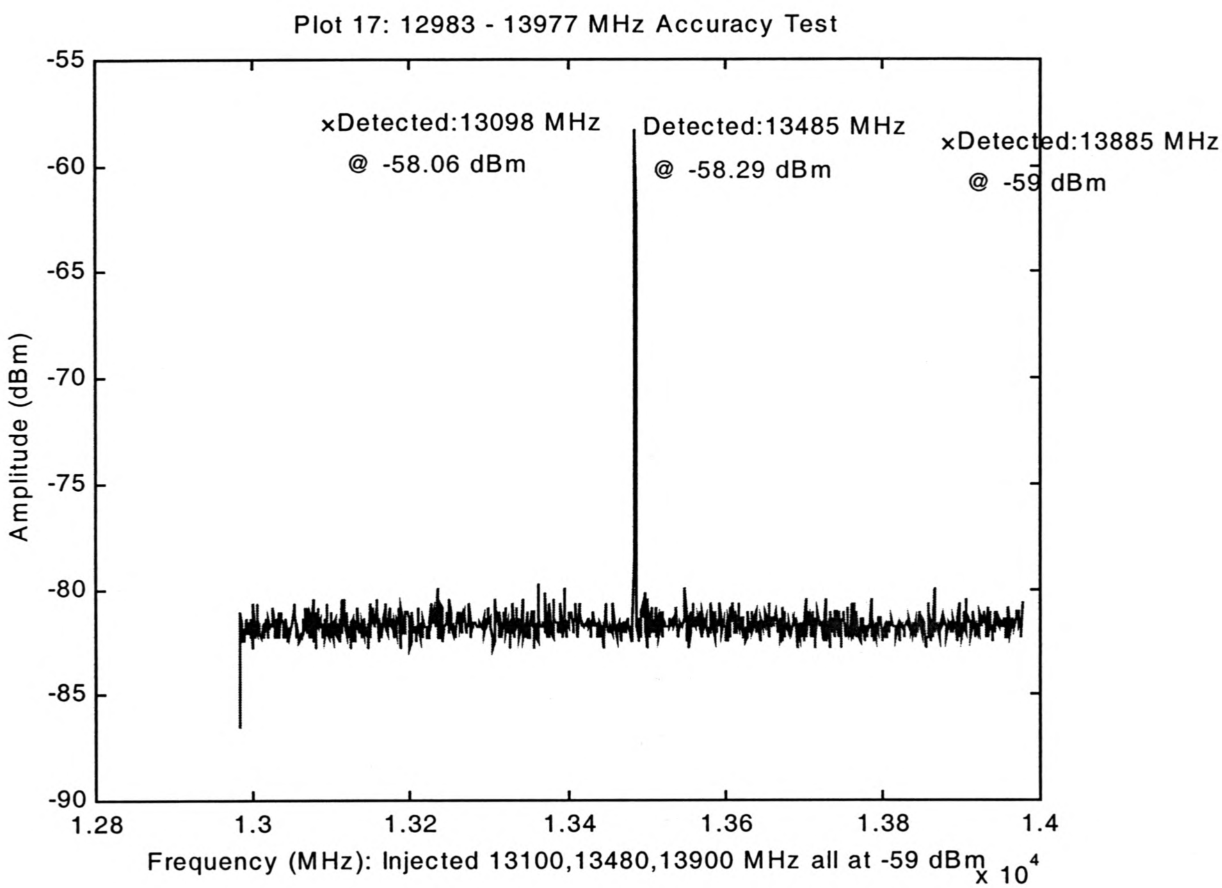

Plot 13: 9575 - 10587 MHz Accuracy Test
xDetected:9705 MHz
@ -57.82 dBm
Detected:10102
MHz @ -58.76 dBm
xDetected:10513 MH
@ -58.06 dBm
-55
-60
-65
-70
-75
-80
-85
-90
Amplitude (dBm)
0.94
0.96
0.98
1
1.02
1.04
1.06
Frequency (MHz): Injected 9700,10081,10500 MHz all at -59 dBm
x 10^4

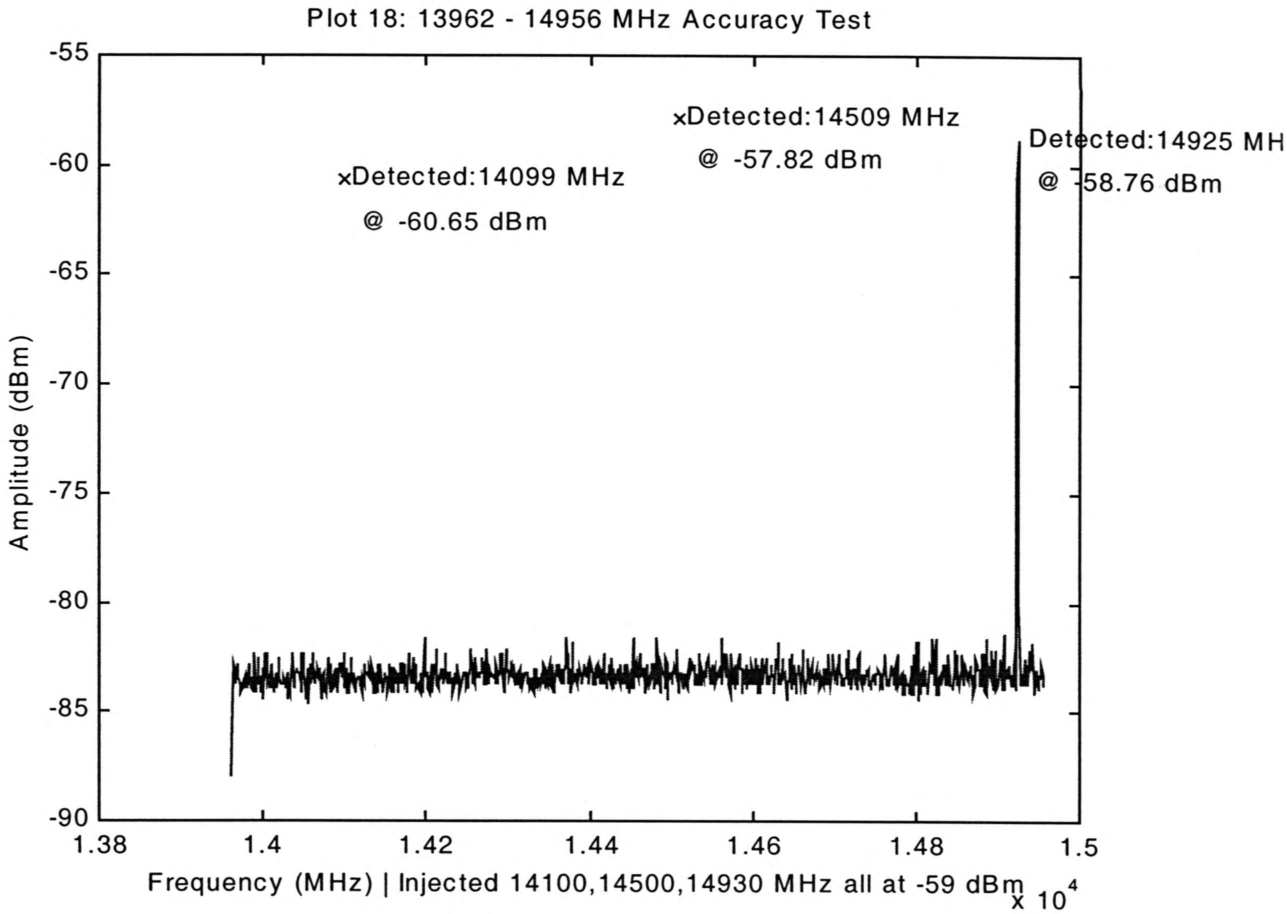


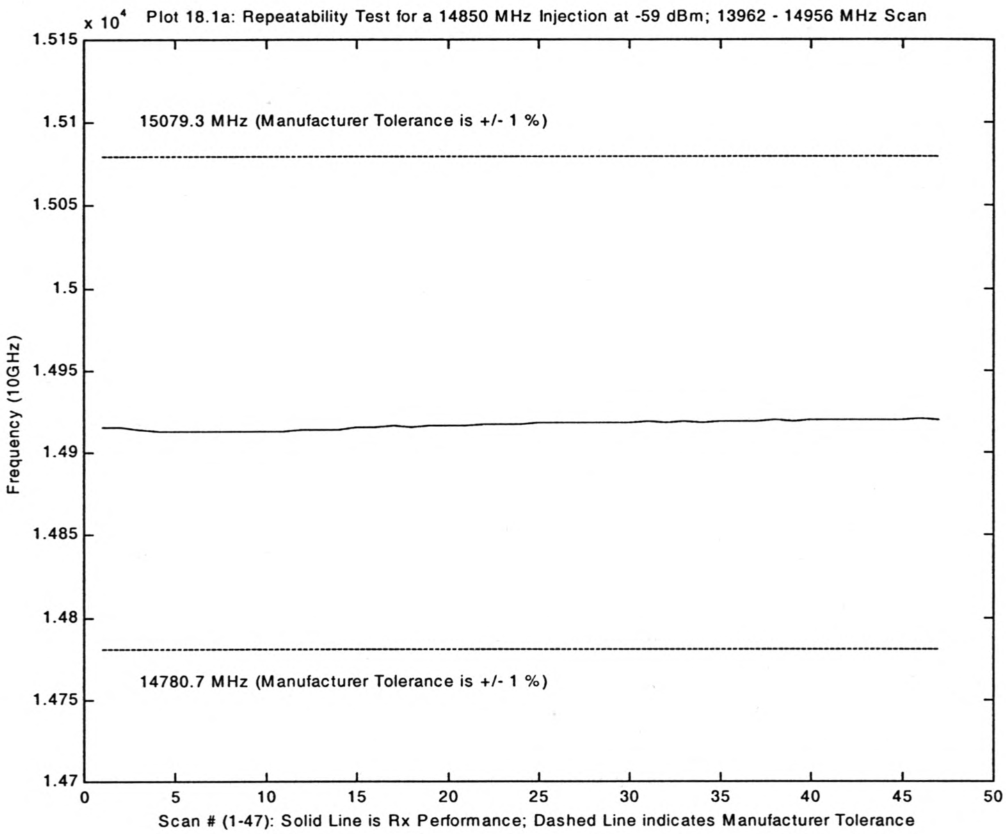
Plot 14: 10580 - 11601 MHz Accuracy Test
xDetected:10698 MHz
@ -57.82 dBm
Detected:11104
MHz @ -59.23 dBm
xDetected:11498 MHz
@ -57.59 dBm
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
1.04
1.06
1.08
1.1
1.12
1.14
1.16
1.18
Frequency (MHz): Injected 10700,11090,11500 MHz all at -59 dBm
x 10^4


Plot 15: 11591 - 12004 MHz Accuracy Test
× Detected:11712 MHz
@ -57.35 dBm
Detected:11813
MHz @ -58.76 dBm
× Detected:11910 MHz
@ -57.35 dBm
-55
-60
-65
-70
-75
-80
-85
Amplitude (dBm)
1.155
1.16
1.165
1.17
1.175
1.18
1.185
1.19
1.195
1.2
1.205
Frequency (MHz): Injected 11700,11798,11900 MHz all at -59 dBm
x 10^4

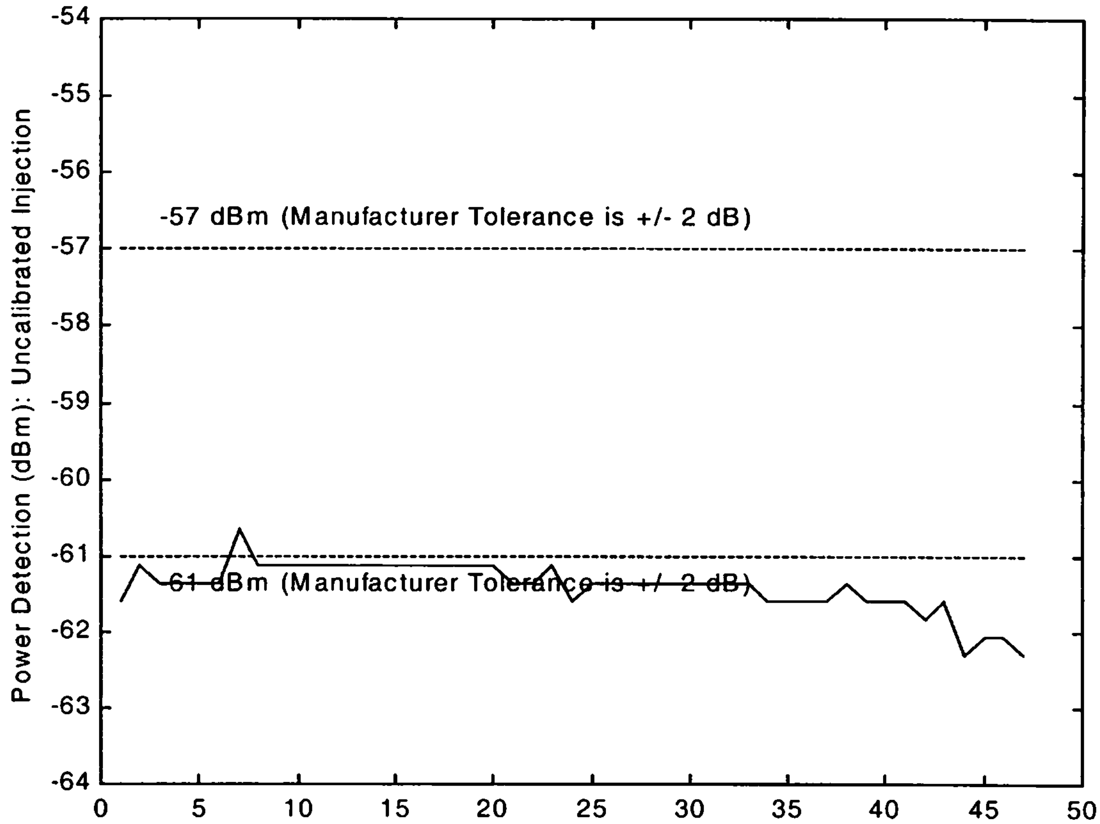

Plot 16: 12000 - 12994 MHz Accuracy Test
-55
-60
-65
-70
-75
-80
-85
-90
Amplitude (dBm)
×Detected:12084 MHz
@ -58.76 dBm
Detected:12499 MHz
@ -60.18 dBm
×Detected:12897 MHz
@ -58.29 dBm
1.2
1.21
1.22
1.23
1.24
1.25
1.26
1.27
1.28
1.29
1.3
Frequency (MHz): Injected 12100,12497,12900 MHz all at -59 dBm
x 10^4


Plot 17: 12983 - 13977 MHz Accuracy Test
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
xDetected:13098 MHz
@ -58.06 dBm
Detected:13485 MHz
@ -58.29 dBm
xDetected:13885 MHz
@ -59 dBm
1.28
1.3
1.32
1.34
1.36
1.38
1.4
x 10^4
Frequency (MHz): Injected 13100,13480,13900 MHz all at -59 dBm

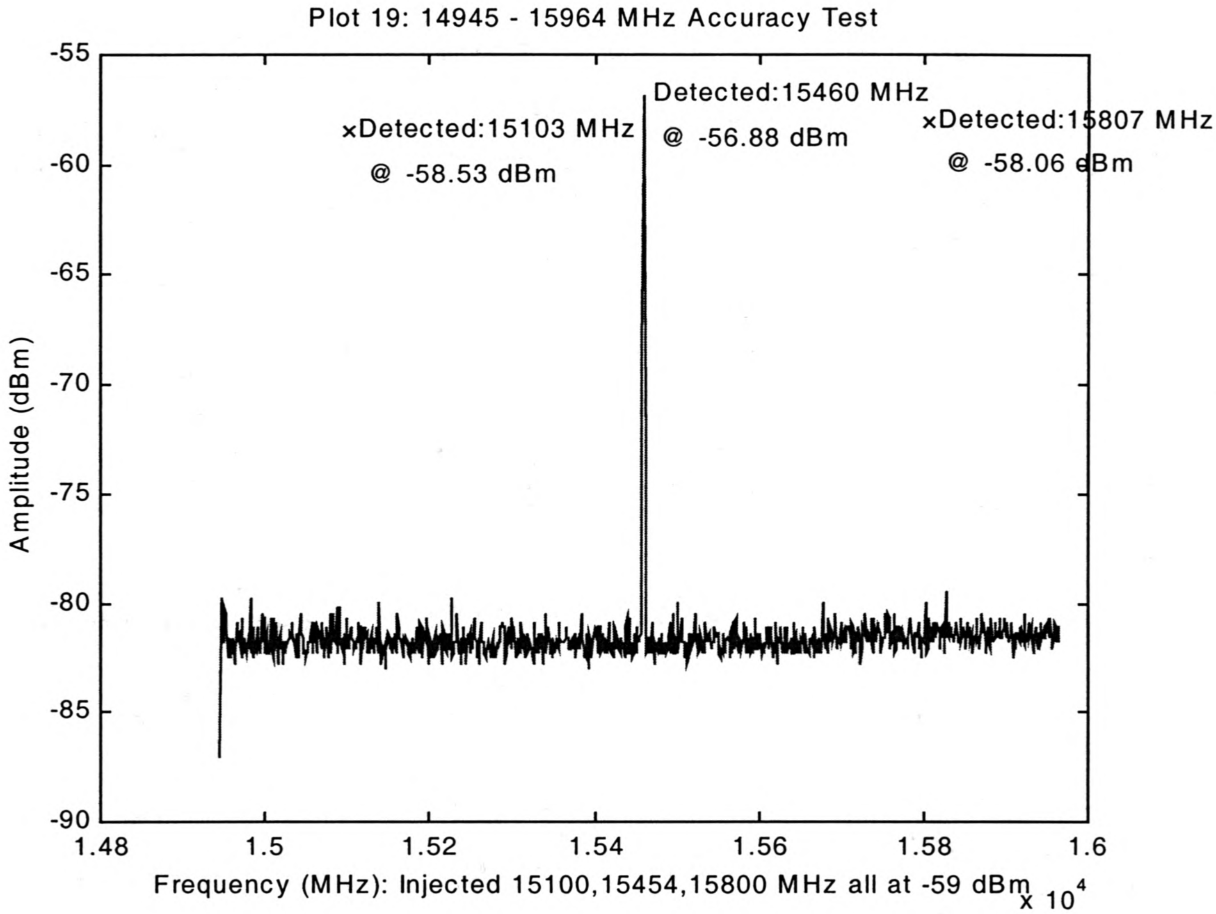

Plot 18: 13962 - 14956 MHz Accuracy Test
xDetected:14509 MHz
@ -57.82 dBm
Detected:14925 MH
@ -58.76 dBm
xDetected:14099 MHz
@ -60.65 dBm
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
1.38
1.4
1.42
1.44
1.46
1.48
1.5
Frequency (MHz) | Injected 14100,14500,14930 MHz all at -59 dBm
x 10^4


x 10^4
Plot 18.1a: Repeatability Test for a 14850 MHz Injection at -59 dBm; 13962 - 14956 MHz Scan
15079.3 MHz (Manufacturer Tolerance is +/- 1 %)
14780.7 MHz (Manufacturer Tolerance is +/- 1 %)
Frequency (10GHz)
1.515
1.51
1.505
1.5
1.495
1.49
1.485
1.48
1.475
1.47
0
5
10
15
20
25
30
35
40
45
50
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

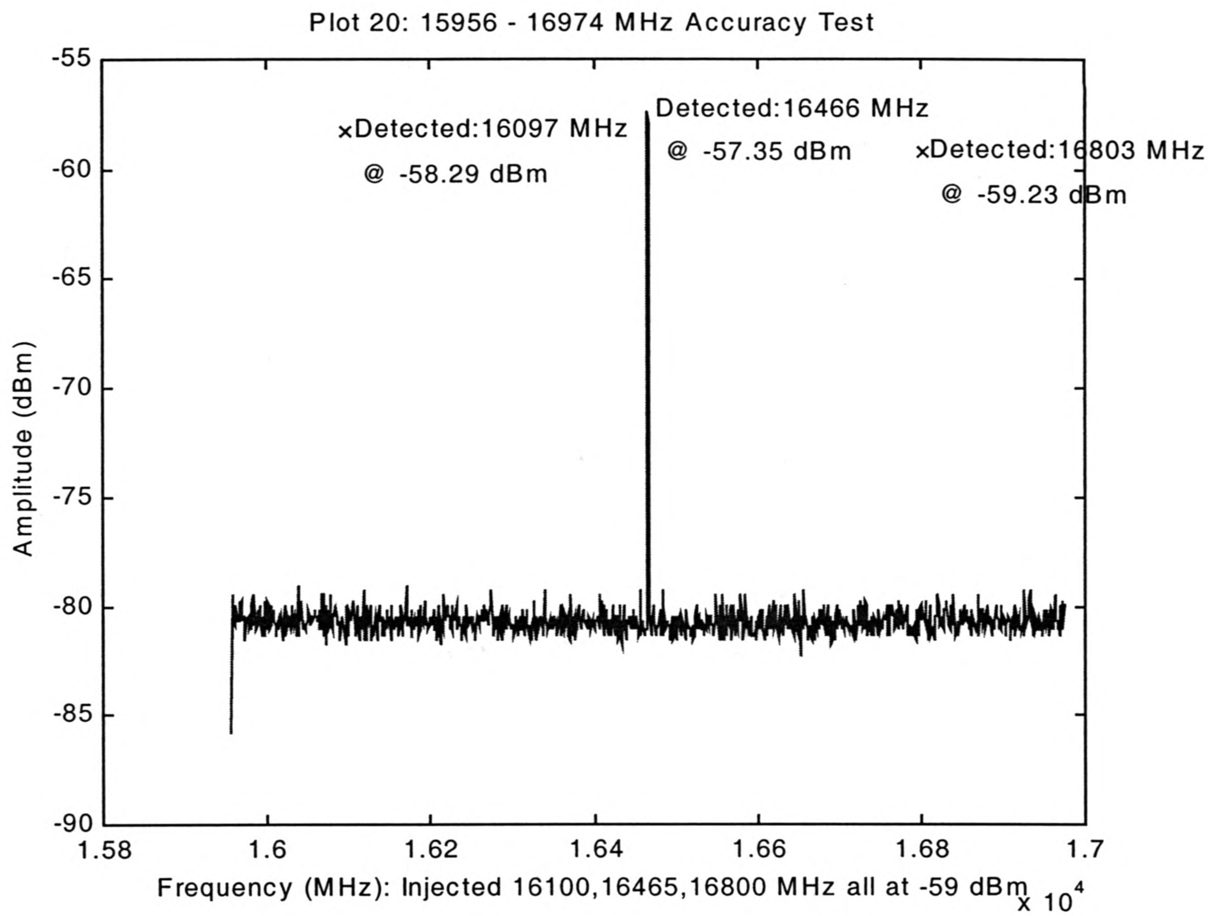
Plot 18.1b: Repeatability Test for a 14850 MHz Injection at -59 dBm; 13962 - 14956 MHz Scan



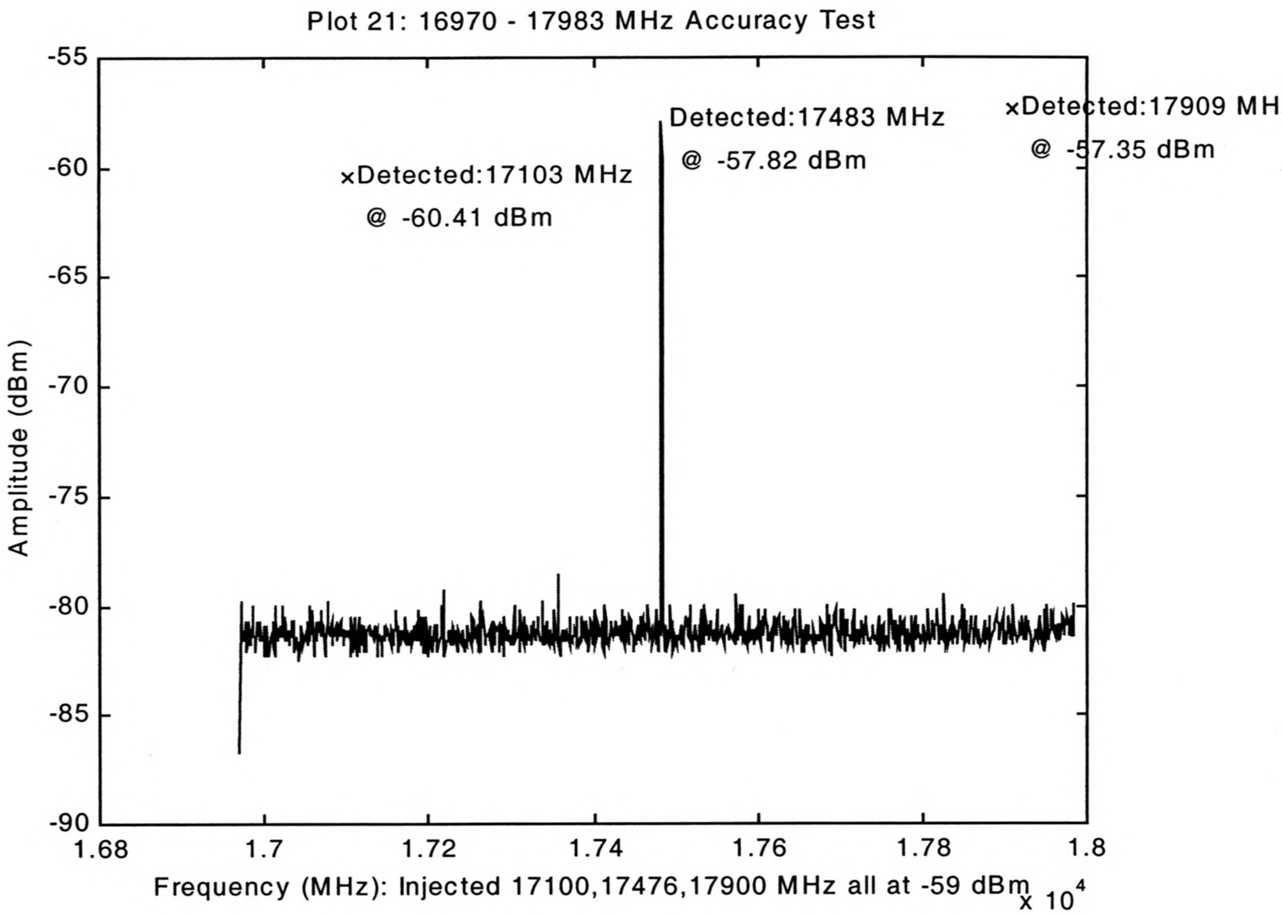
Scan # (1-47): Solid Line is Rx Performance; Dashed Line indicates Manufacturer Tolerance

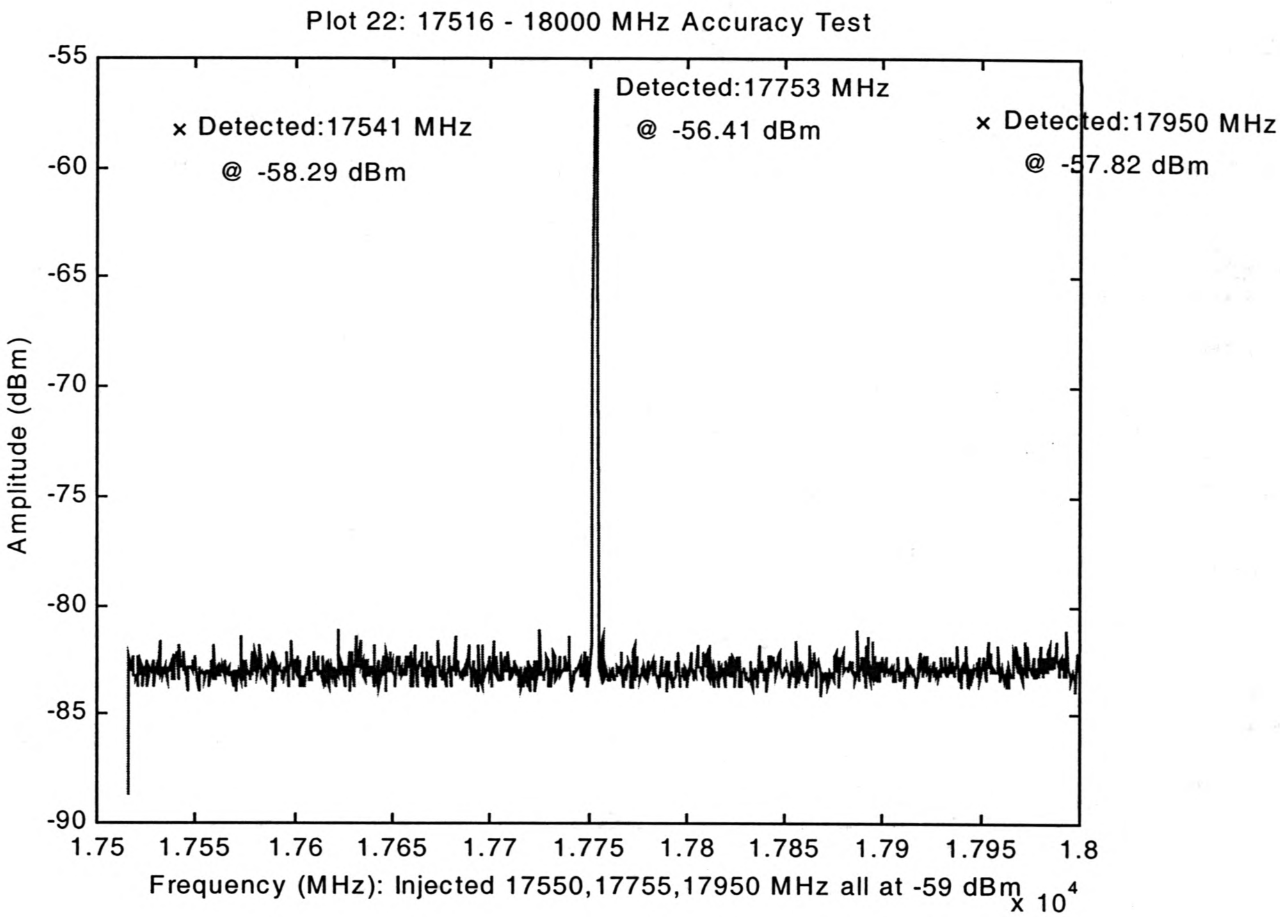


Plot 19: 14945 - 15964 MHz Accuracy Test
Amplitude (dBm)
Frequency (MHz): Injected 15100,15454,15800 MHz all at -59 dBm
x 10^4
Detected:15460 MHz
@ -56.88 dBm
×Detected:15103 MHz
@ -58.53 dBm
×Detected:15807 MHz
@ -58.06 dBm
-55
-60
-65
-70
-75
-80
-85
-90
1.48
1.5
1.52
1.54
1.56
1.58
1.6

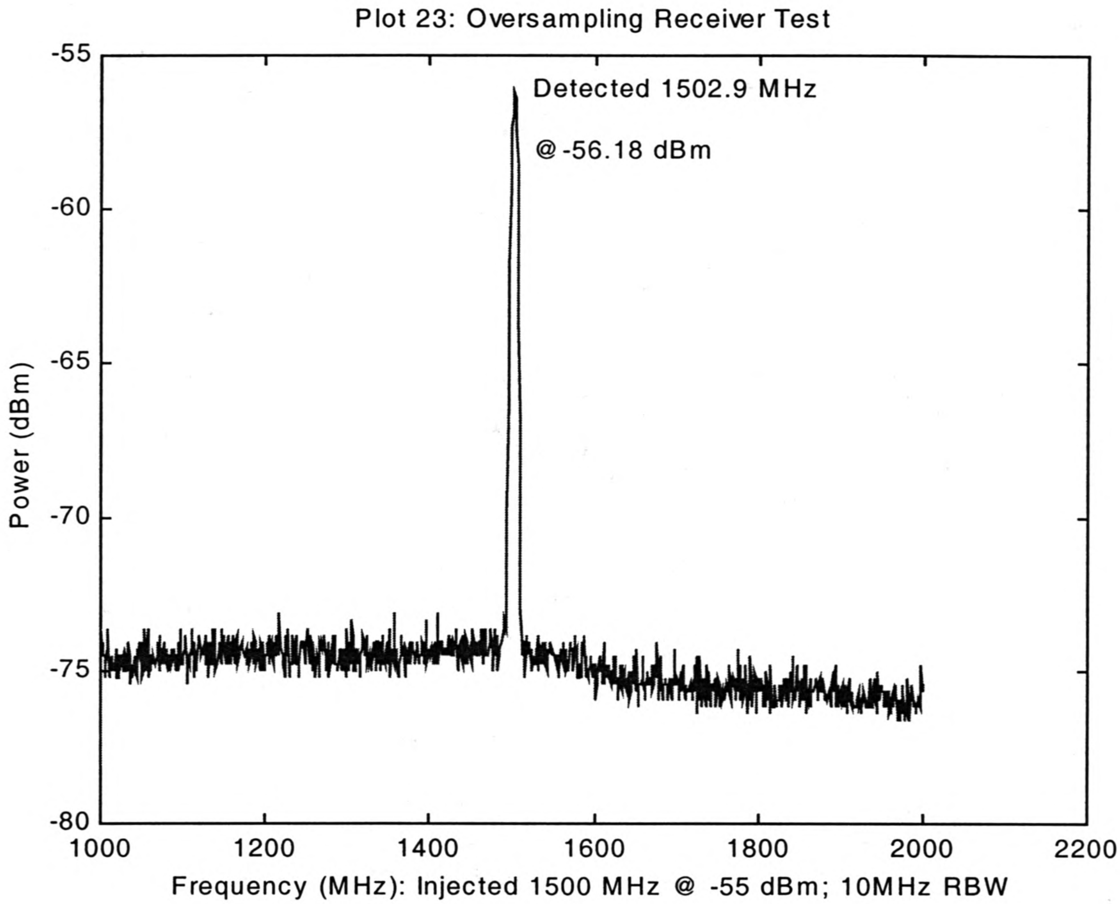


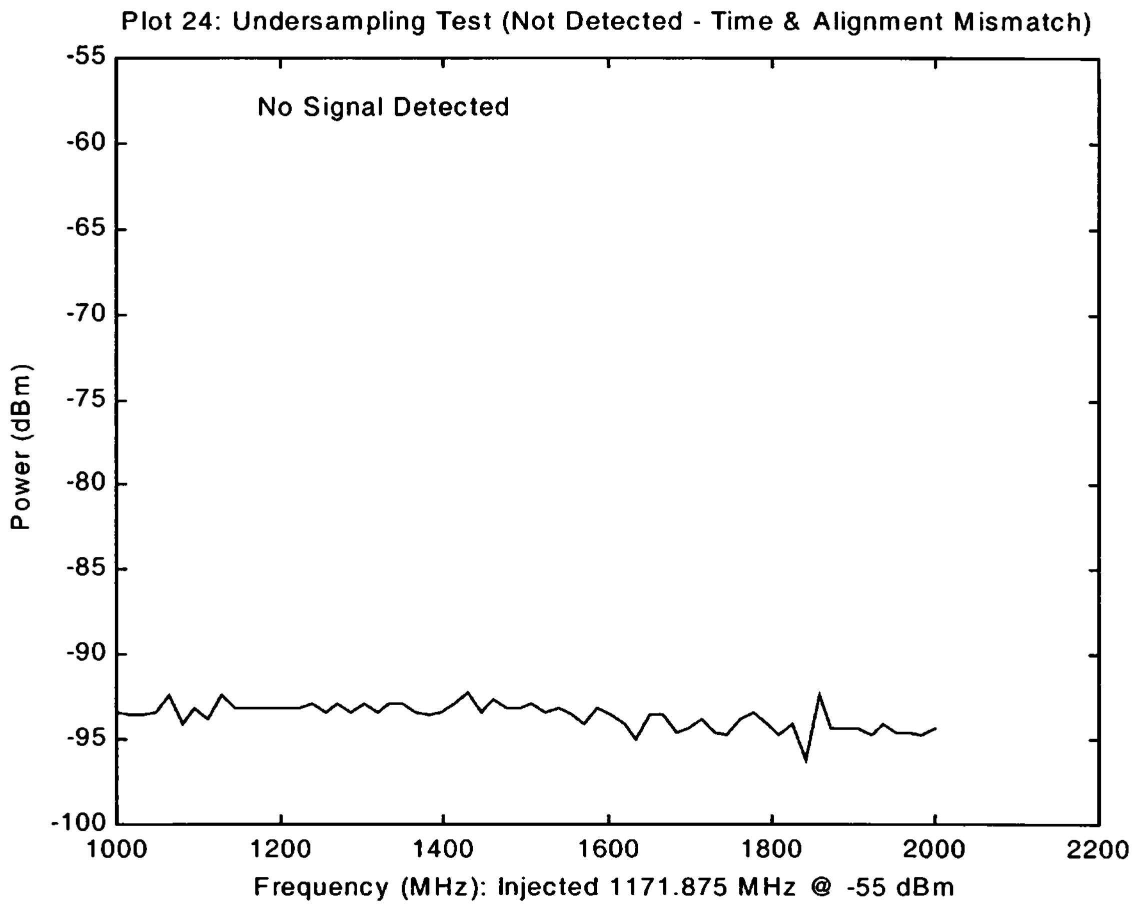
Plot 20: 15956 - 16974 MHz Accuracy Test
-55
-60
-65
-70
-75
-80
-85
-90
Amplitude (dBm)
xDetected:16097 MHz
@ -58.29 dBm
Detected:16466 MHz
@ -57.35 dBm
xDetected:16803 MHz
@ -59.23 dBm
1.58
1.6
1.62
1.64
1.66
1.68
1.7
x 10^4
Frequency (MHz): Injected 16100,16465,16800 MHz all at -59 dBm


Plot 21: 16970 - 17983 MHz Accuracy Test
×Detected:17103 MHz
@ -60.41 dBm
Detected:17483 MHz
@ -57.82 dBm
×Detected:17909 MH:
@ -57.35 dBm
Amplitude (dBm)
-55
-60
-65
-70
-75
-80
-85
-90
1.68
1.7
1.72
1.74
1.76
1.78
1.8
x 10^4
Frequency (MHz): Injected 17100,17476,17900 MHz all at -59 dBm

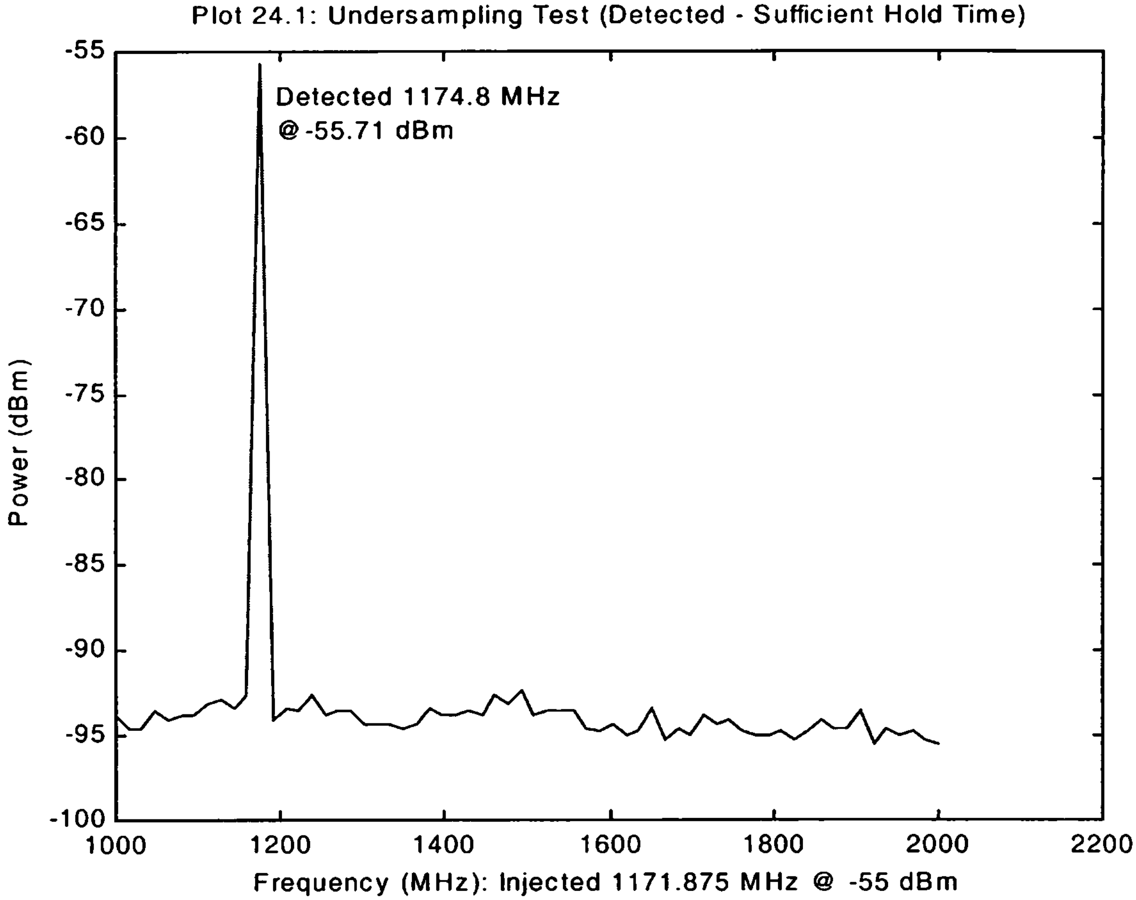


Plot 22: 17516 - 18000 MHz Accuracy Test
Detected:17753 MHz
@ -56.41 dBm
Detected:17541 MHz
@ -58.29 dBm
Detected:17950 MHz
@ -57.82 dBm
-55
-60
-65
-70
-75
-80
-85
-90
Amplitude (dBm)
1.75
1.755
1.76
1.765
1.77
1.775
1.78
1.785
1.79
1.795
1.8
Frequency (MHz): Injected 17550,17755,17950 MHz all at -59 dBm
x 10^4


Plot 23: Oversampling Receiver Test
Detected 1502.9 MHz
@-56.18 dBm
Power (dBm)
-55
-60
-65
-70
-75
-80
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Injected 1500 MHz @ -55 dBm; 10MHz RBW

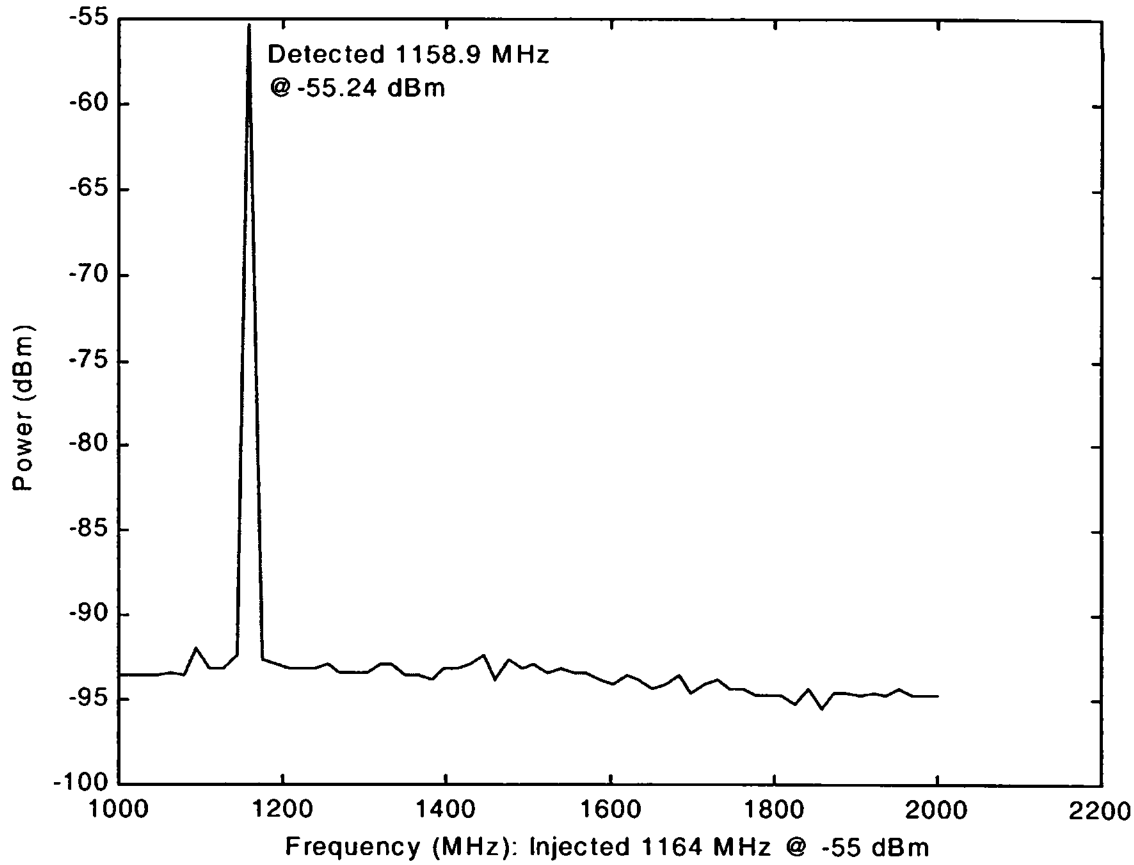


100 kHz RBW, 320 sec scan time, CCI bins

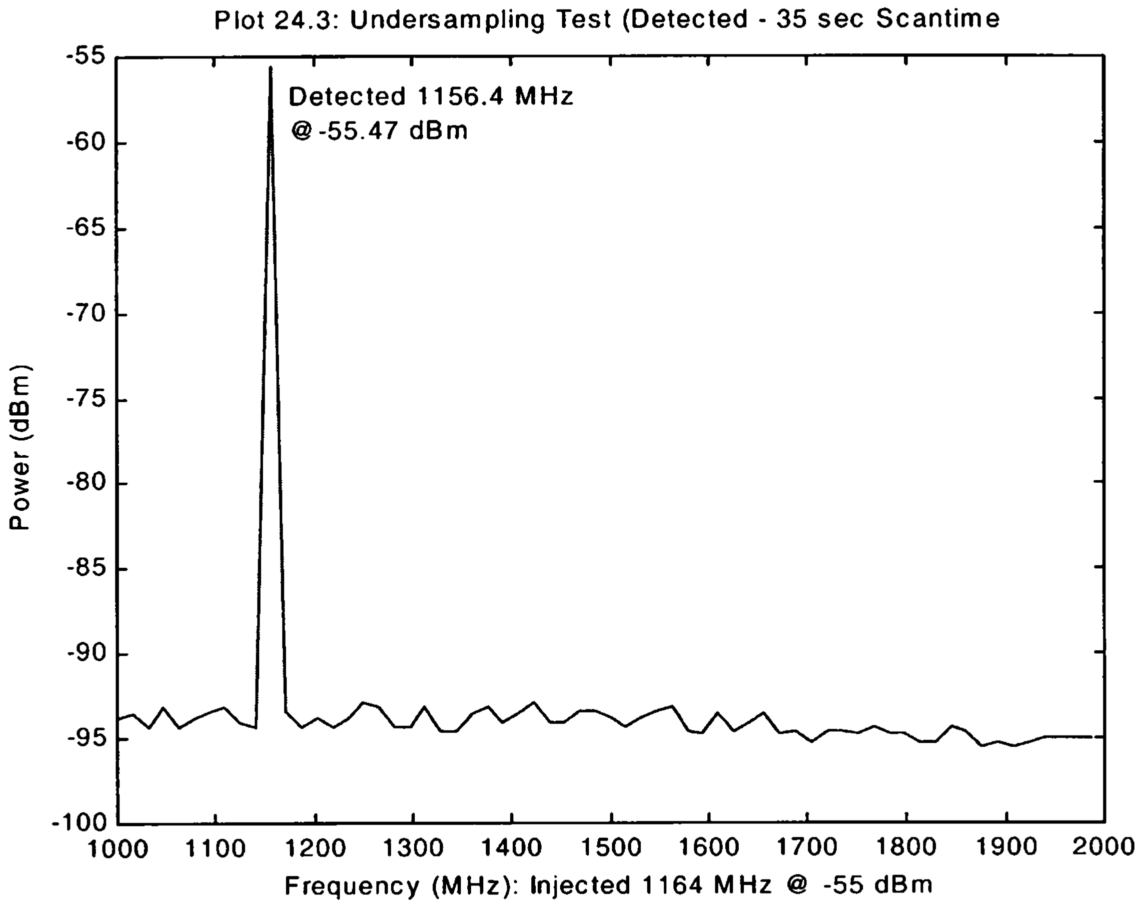


100 kHz RBW, 35 sec scan time, 64 CCI bins

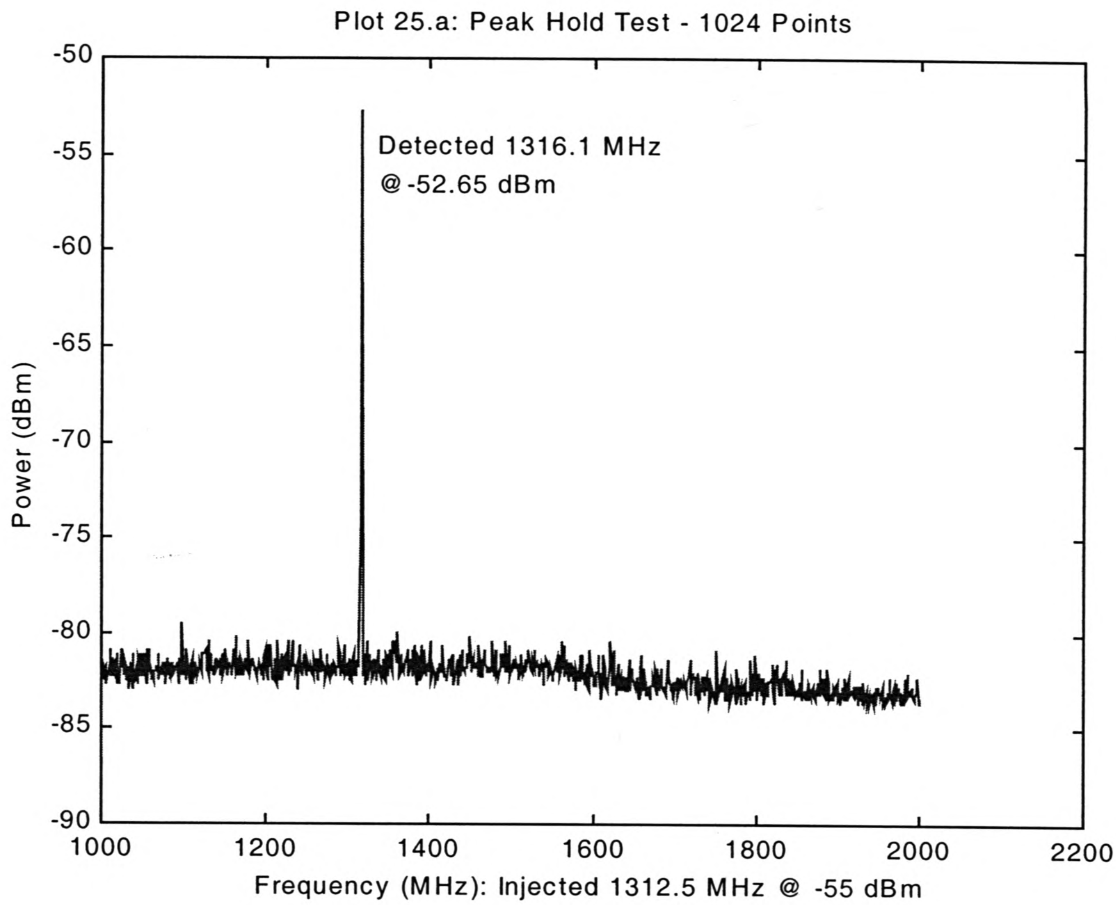
Plot 24.2: Undersampling Test (Detected - 320 sec Scantime)

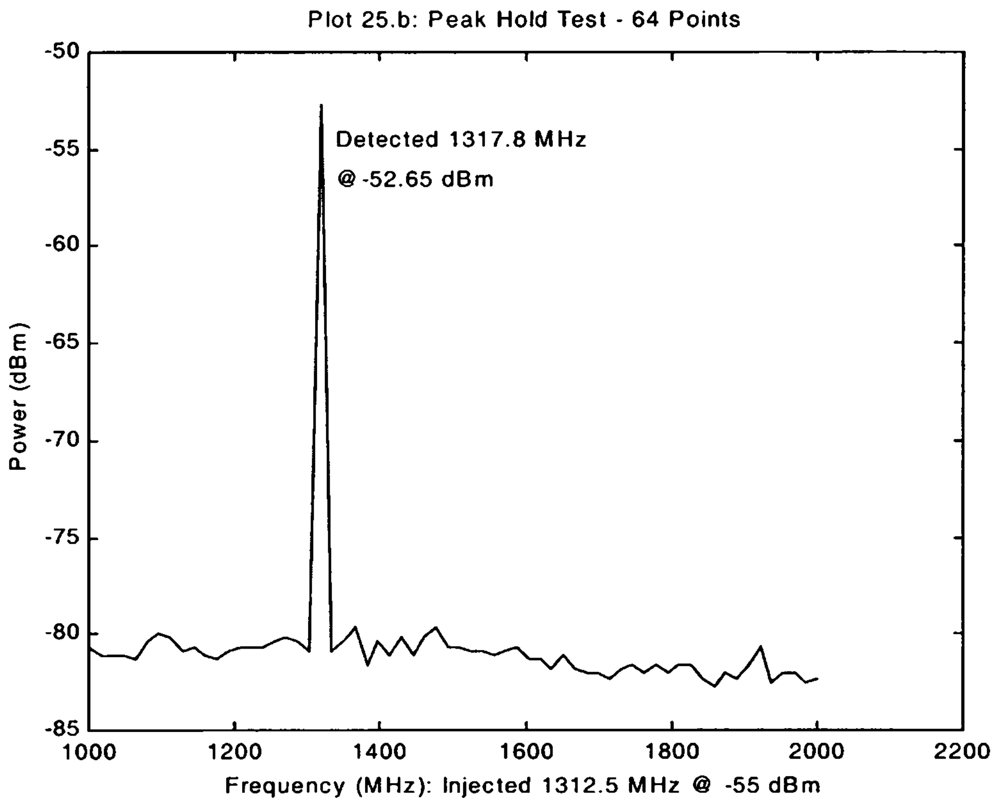


100 kHz RBW, 320 sec scan time, 64 CCI bins



100 kHz RBW, 35 sec scan time, 64 CCI bins


Plot 25.a: Peak Hold Test - 1024 Points
Detected 1316.1 MHz
@ -52.65 dBm
Power (dBm)
-50
-55
-60
-65
-70
-75
-80
-85
-90
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Injected 1312.5 MHz @ -55 dBm


Plot 25.b: Peak Hold Test - 64 Points
Detected 1317.8 MHz
@ -52.65 dBm
Power (dBm)
-50
-55
-60
-65
-70
-75
-80
-85
1000
1200
1400
1600
1800
2000
2200
Frequency (MHz): Injected 1312.5 MHz @ -55 dBm