Allen Telescope Array

Measurement of the RFCB Power Levels

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1 Introduction

The analog signal path of the Allen Telescope Array is key to the functionality of the telescope. The top level system diagram is shown in Figure 1, where one can see that the ATA is best divided in five main systems, the Antenna, the Antonio Feed, the Post-Amplifier Transmitter (PAX), the RF-Conversion Box (RFCB), and the IF-Conditioning and DSP backend. This organization is based on the path of a detected signal through the telescope, from the Antenna through the analog electronics to the digital signal processing. In this document, the focus will be on the RFCBs specifically a set of measurements done to test their performance.

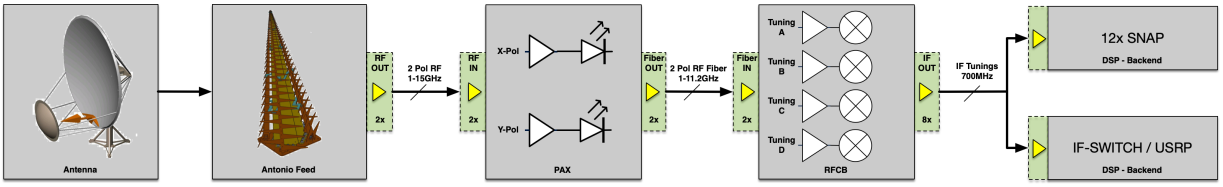


Figure 1: Top level diagram of the ATA analog signal path.

The RF converter takes the analog optical fiber signal from each antenna as input and produces four independent analog IF outputs with a bandwidth of about 700 MHz. Each of the four IF tunings (A-D) has a dedicated variable local oscillator that allows the selection of any frequency band within the primary RF band of 0.5 – 11.2 GHz and down converts it to a center frequency of 450 MHz. There are 42 RF conversion boxes installed in the signal processing room, each of which takes two inputs X-pol and Y-pol of a single antenna.The system diagram illustrating one polarisation and one tuning of an RFCB is shown in Figure 2, where the RF signal is received through the optical link on the left-hand side and directed to the IF signal conditioning on the right-hand side. The boxes in the diagram indicate the physical groupings of components within the RFCB. The fiber detection module consists of the fiber detector diode, which converts the entire band back to RF and is followed by a number of signal components that amplify, divide, and filter the signal. The output of this module is then connected to four identical signal chains, one of which is drawn in the diagram (all four are shown in Figure 3). The connection between the modules and individual components use semi-ridged coaxial cables which make it possible to measure power levels at these distinct points in the signal path.

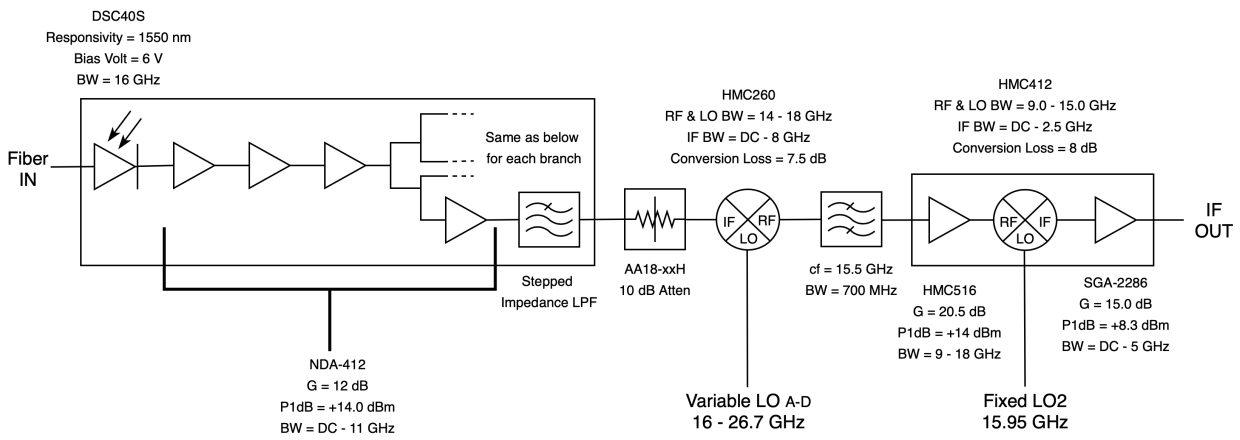


Figure 2: Schematic of the RF conversion box displaying the individual signal components and their specifications.

This document describes the power level measurements done with the RFCBs to ensure they are intact and working properly. In the first part of the document we are describing the measurement setup, equipment, and procedure. The second part presents the data collected from both a power meter and spectrum analyzer. Finally, the document is concluded with summing of finding and suggestions for future work including new measurements and possible fixes.

2 Measurement Set Up

This section describes the setup used to measure the power levels of the RFCBs. A simplified schematic of the measurement setup is shown in Figure 3. The setup begins with a noise diode which simulates signals that would normally be detected with a feed. However, a feed would bring in too many unknowns for this measurement thus the use of the noise diode. The simulated signal then goes through a coaxial cable to a PAX Box, like a real signal would with a feed. Again though, a real feed is not being used, so there are not inputs for both polarization's of the PAX Box. Hence, only the y polarization for this setup and subsequent measurements was used. Next, the signal goes through an two connected optical cables, one was too short, into the RFCB. Finally, the power meter or field fox collects the data from the tuning it is plugged into. It is important to note that the power meter and field fox acquire data from each tuning, they just have to plugged in one after another. Moreover, the y polarization and its tunnings are also measured by both the power meter and field fox. The diagram shows this occurring with dashed lines, however, because only one tuning from one polarization can be measured at a time. While the reading from the power meter is collected by hand, the field fox's data is saved in a .csv file.

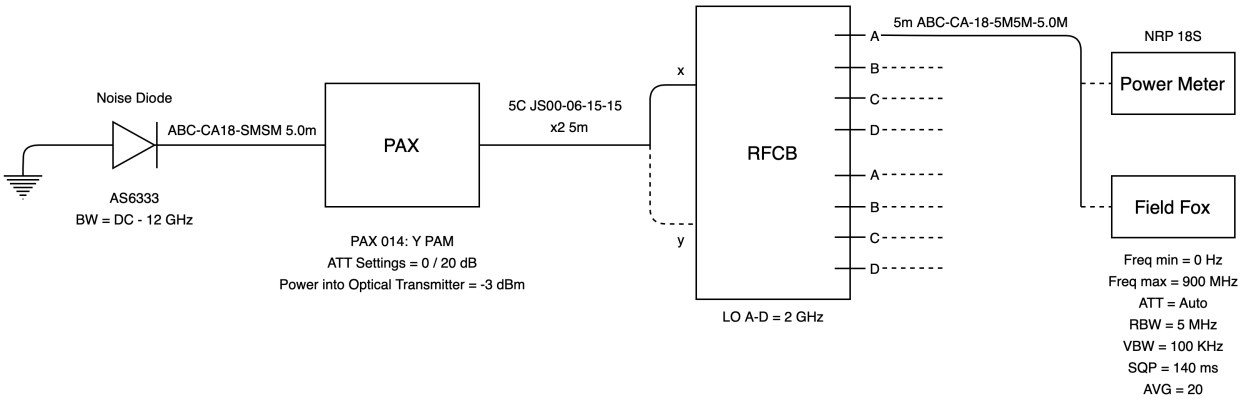


Figure 3: Schematic of the measurement setup

2.1 Hardware

This section describes the hardware components used in this measurement setup. Table 1 lists the exact components used to simulate the normal signal path to the RFCBs. It should be noted that two of the 5C JS00-06-15-15 optical cables were used as one was not long enough to reach from the signal processing room to the electronics workshop where the PAX Box and noise source was located.

Table 1: List of components used to perform RFCB measurement.

Part Number	Description
AAS6333	Noise Diode
ABC-CA18-SMSM 5.0m	Coax Cable
PB-014	PAX Box
5C JS00-06-15-15	Optical Cable
NRP 18S	Power Meter
Field Fox	Spectrum Analyzer

The configuration of the spectrum analyzer is shown in Table 2. The recorded spectrum is exported as a .csv file format, which can be directly imported into the post processing python software.

Table 2: Spectrum analyzer settings.

Description	Setting
Resolution	800 points
f_{start}	0 Hz
f_{stop}	900 GHz
RBW	5 MHz
VBW	100 KHz
Sweep Time	140 ms
Attenuator	Auto
File Format	.csv
Average	20

2.2 Measurement Procedure

The procedure used to measure each RFCB is outlined below.

- X-Polarization
    1. Connect optical cable from PAX Box to x-pol of RFCB.
    2. Connect power meter to tuning A of x-pol.
    3. Record power reading.
    4. Connect spectrum analyzer to tuning A of x-pol.
    5. Record data.
    6. Repeat steps 2-5 with tunnings B-D of x-pol.
- Y-Polarization
    7. Connect optical cable from PAX Box to y-pol of RFCB.
    8. Connect power meter to tuning A of y-pol.
    9. Record power reading.
    10. Connect spectrum analyzer to tuning A of y-pol.
    11. Record data.
    12. Repeat steps 8-10 with tunnings B-D of y-pol.

Rather than measuring all tunnings of one polarization with the power meter and then with the spectrum analyzer, one tuning is measured by each sequentially. This is required, to reduce the effect of gain drifts over time.

3 Measurement Results

The data from the power meter and spectrum analyzer are presented in this section. The power meter data, section 3.1, highlights the power outputs of all the IF tunnings while the spectrum analyzer data, sections 3.2-3.38, shows the frequency plotted against output power for each RFCB. As the spectrum analyzer data as a multitude of sections, the overarching results will be discussed below.

The spectrum analyzer plots are fairly similar which is encouraging. The overall flat hill shape of each graph is as expected, yet the ringing (small oscillations in the trend) are surprising and worrisome. Firstly, the ringing in a single RFCB can cause problems in observing, but because the ringing is in all the RFCBs, the negative impact upon observing is almost certain. Furthermore, the ringing being in all the RFCBs indicates it either a widespread deficiency in the RFCBs themselves or something external from the RFCBs is causing it. It is also worth noting that not all the plots are the same. Some plots are notably short or squished. For instance, all of the plots for X polarization for RFCB 21 are at much lower power levels than expected. This lower power level output is likewise reflected in the power meter read outs in Table 3. Some examples of squished plots, plots where the passband does not span the full range of frequencies expected, are RFCB 34-Y Polarization- Tuning A, RFCB 40-X Polarization-Tuning D, and RFCB 40-Y Polarization-Tuning B. Again, these tunnings are marked in read in Table 3 as their power meter read outs were especially low. While there are more plots of tunnings that are short or squished, those listed above are the most visually noticeable and as confirmed by the power meter read outs, likely broken.

3.1 Power Meter Results

The power meter read outs from the RFCB measurements are shown in this section. Both Figure 4 and Table 3 depict the output power of the RFCBs, both polarizations and all tunnings. Figure 4 highlights that most of the IF tunnings' power ranges from 0 – -10 dBm. In Table 3, one can see the specific tunnings, polarizations, and RFCBs that do not fall with in this range marked in red. This indicates that these IF tunings are likely damaged. It is worth noting that most the corresponding spectrum analyzer plots of the deficit IF tunnings, Secitons 3.2-3.38, are abnormal thus confirming their defectiveness. Table 3 also shows the exact output power for each tunning that is within the normal 0 – -10 dBm range.

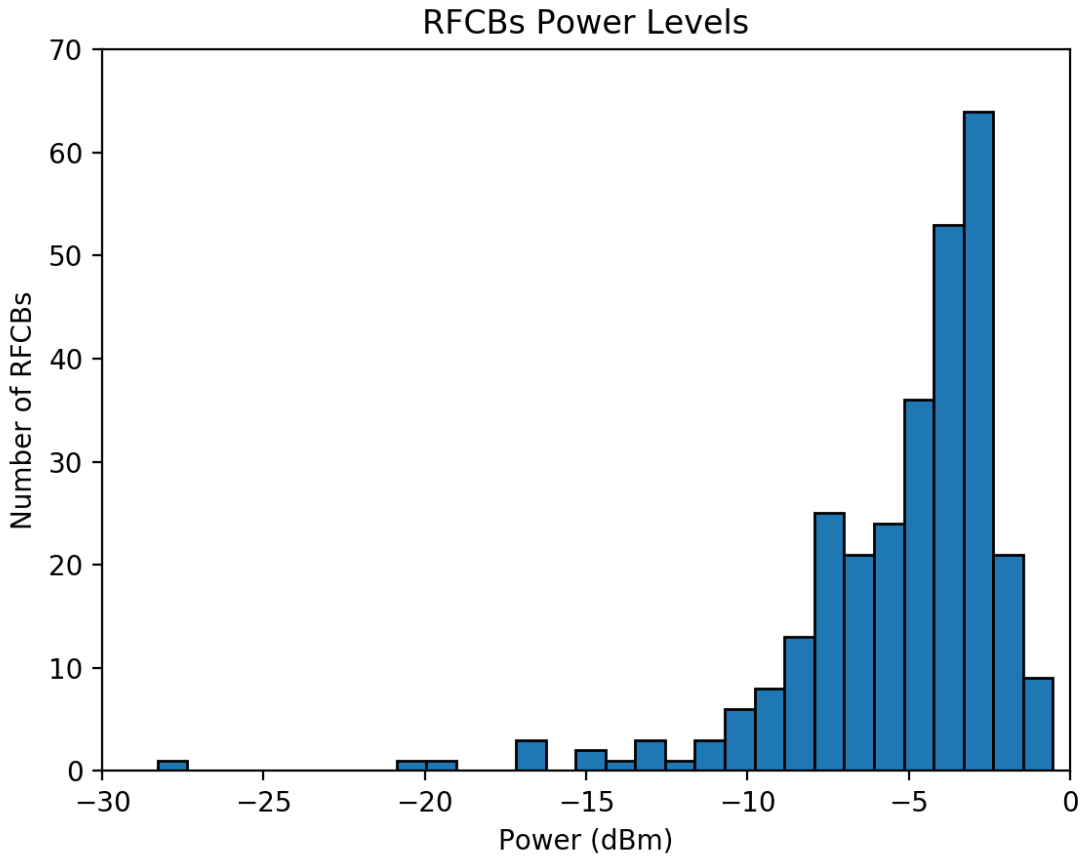


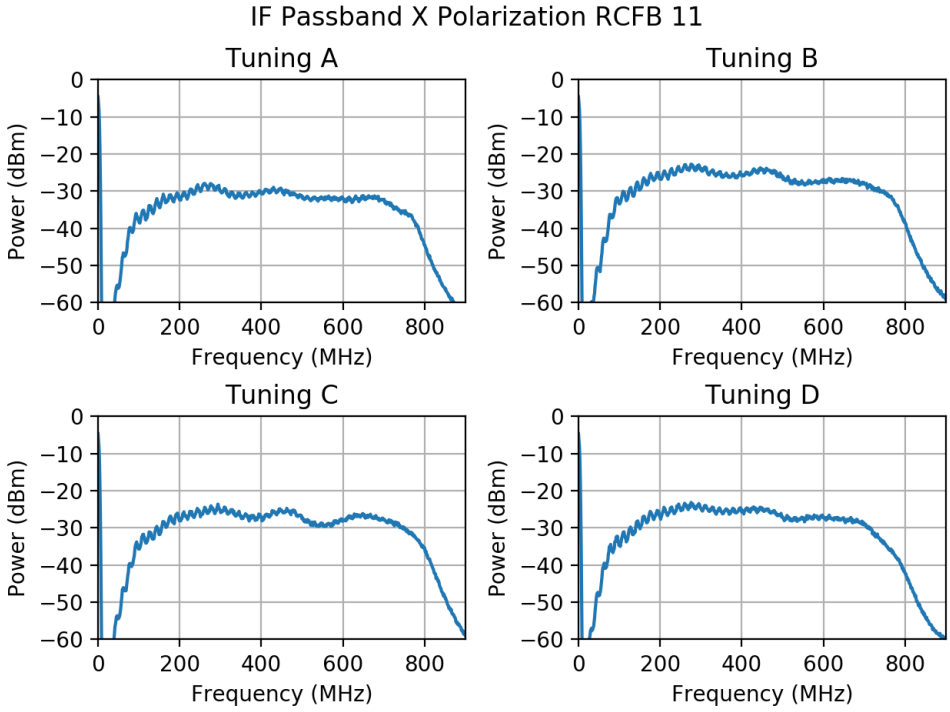
Figure 4: Histogram showing the output power of every tuning for both polarizations of all the RFCBs

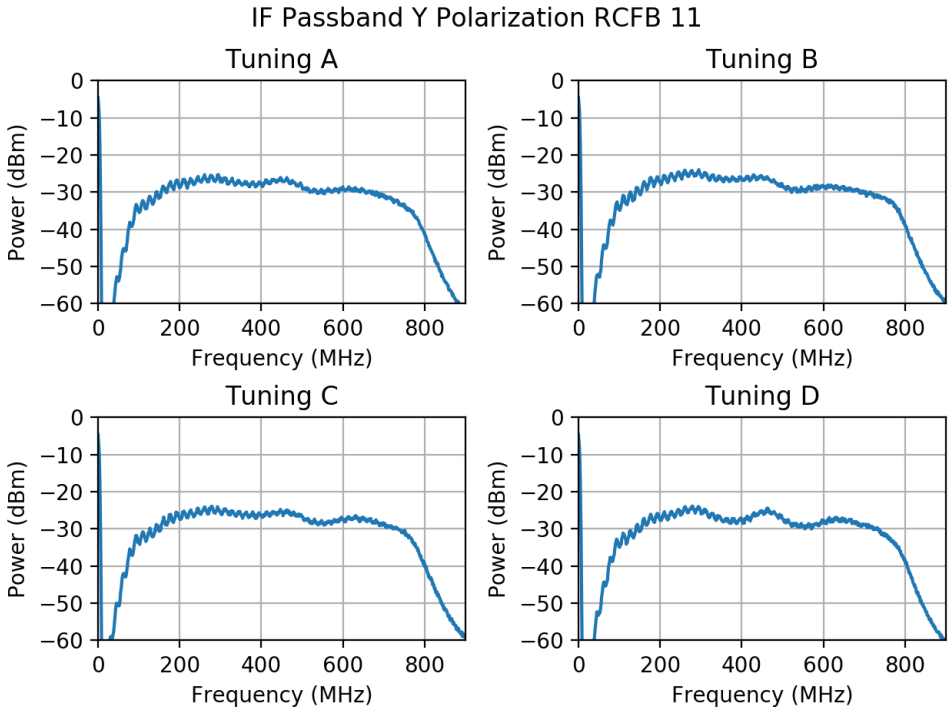
Table 3: Power meter read out of all IF tunnings.

RFCB Number	Polarization	Tuning A	Tuning B	Tuning C	Tuning D
11 (2D)	X	-7.51	-2.40	-3.31	-2.75
	Y	-4.69	-3.69	-3.11	-3.51
12 (5B)	X	-1.40	-2.85	-3.48	-2.72
	Y	-3.97	-3.40	-4.01	-3.75
13 (2J)	X	-3.82	-3.34	-6.52	-4.55
	Y	-3.46	-4.01	-4.54	-2.83
14 (4G)	X	-2.54	-3.03	-4.79	-3.87
	Y	-1.90	-3.49	-3.66	-4.13
15 (2K)	X	-2.89	-4.35	-4.26	-3.28
	Y	-2.57	-4.46	-4.10	-3.12
17 (2M)	X	-1.40	-3.30	-4.28	-4.33
	Y	-2.13	-4.06	-3.29	-3.46
18 (3D)	X	-1.64	-3.10	-2.88	-2.45
	Y	-1.09	-2.18	-2.98	-2.64
19 (5G)	X	-1.75	-2.65	-3.59	-2.47
	Y	-1.53	-3.53	-2.70	-3.27
20 (2L)	X	-1.40	-3.00	-3.38	-4.14
	Y	-2.42	-4.21	-3.88	-4.14
21 (4F)	X	-12.76	-17.08	-19.54	-20.34
	Y	-1.85	-3.63	-3.72	-2.36
22 (4H)	X	-0.99	-2.88	-2.30	-3.42
	Y	-2.44	-5.49	-3.28	-3.64
23 (3E)	X	-0.53	-4.25	-2.81	-2.04
	Y	-1.47	-3.33	-3.82	-4.15
24 (4J)	X	-2.41	-2.56	-7.58	-2.97
	Y	-1.83	-3.28	-2.52	-3.14
25 (1B)	X	-10.25	-12.91	-14.26	-12.64
	Y	-8.13	-8.30	-7.26	-8.65
26 (2C)	X	-2.58	-3.22	-2.63	-3.35
	Y	-2.65	-2.93	-3.74	-2.64
27 (1H)	X	-5.82	-7.07	-7.09	-7.56
	Y	-4.33	-6.09	-8.65	-6.14
29 (1K)	X	-3.56	-6.00	-7.36	-5.90
	Y	-2.22	-5.13	-4.05	-7.54
30 (4K)	X	-2.78	-4.74	-4.37	-5.87
	Y	-2.76	-4.40	-3.62	-3.56

Continuation of Table 3					
RFCB Number	Polarization	Tuning A	Tuning B	Tuning C	Tuning D
31 (5C)	X	-2.80	-3.84	-4.24	-4.08
	Y	-1.25	-3.41	-3.89	-2.78
32 (2A)	X	-4.19	-5.38	-5.10	-5.08
	Y	-5.30	-7.02	-5.56	-6.89
33 (1E)	X	-5.31	-6.14	-6.69	-6.68
	Y	-3.06	-5.87	-5.01	-5.48
34 (2F)	X	-16.81	-1.82	-1.82	-1.54
	Y	-2.36	-2.30	-3.66	-2.94
35 (2H)	X	-4.29	-4.01	-5.01	-3.24
	Y	-3.28	-2.55	-1.51	-2.06
36 (1D)	X	-6.94	-7.27	-8.24	-8.44
	Y	-5.48	-7.06	-7.44	-6.64
37 (2E)	X	-0.90	-3.28	-4.01	-8.12
	Y	-2.55	-5.31	-4.38	-5.14
38 (1G)	X	-4.80	-7.03	-7.20	-8.26
	Y	-5.72	-5.85	-5.83	-5.93
39 (1A)	X	-5.11	-7.17	-7.33	-5.84
	Y	-6.55	-6.96	-6.71	-6.82
40 (1C)	X	-10.74	-8.90	-7.94	-28.28
	Y	-8.63	-14.42	-9.30	-8.83
41 (4L)	X	-2.99	-4.81	-4.59	-3.40
	Y	-2.80	-3.23	-2.78	-4.37
42 (1F)	X	-8.22	-9.31	-9.55	-10.30
	Y	-2.49	-6.51	-5.59	-5.36
43 (2B)	X	-4.72	-7.69	-7.07	-6.86
	Y	-4.98	-8.25	-7.26	-5.26
44 (4E)	X	-2.11	-3.64	-3.39	-3.26
	Y	-1.43	-4.64	-2.45	-2.75
46 (3L)	X	-6.68	-16.33	-7.50	-9.26
	Y	-4.96	-14.41	-6.41	-5.13
48 (3C)	X	-2.57	-5.67	-3.02	-3.83
	Y	-2.73	-7.23	-6.10	-5.24
49 (3J)	X	-7.03	-9.04	-9.87	-9.44
	Y	-2.77	-4.03	-3.33	-4.68
51 (5E)	X	-4.84	-6.13	-7.19	-6.29
	Y	-4.56	-6.02	-7.87	-6.30
52 (5H)	X	-10.18	-10.55	-7.49	-11.39
	Y	-9.19	-11.65	-11.35	-10.37

3.2 RFCB 11 (Antenna 2D)





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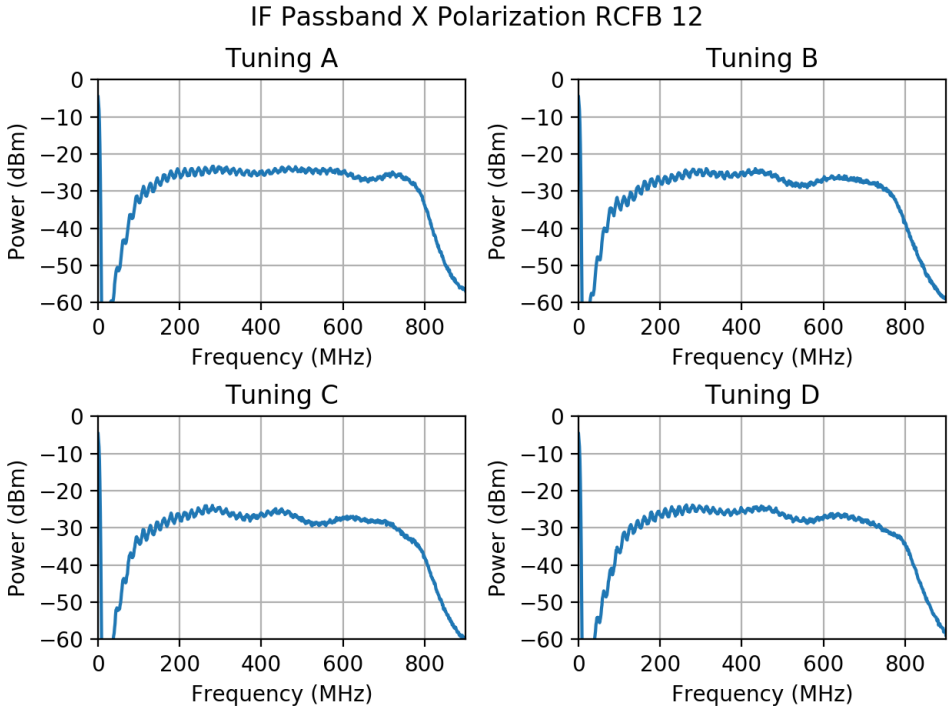
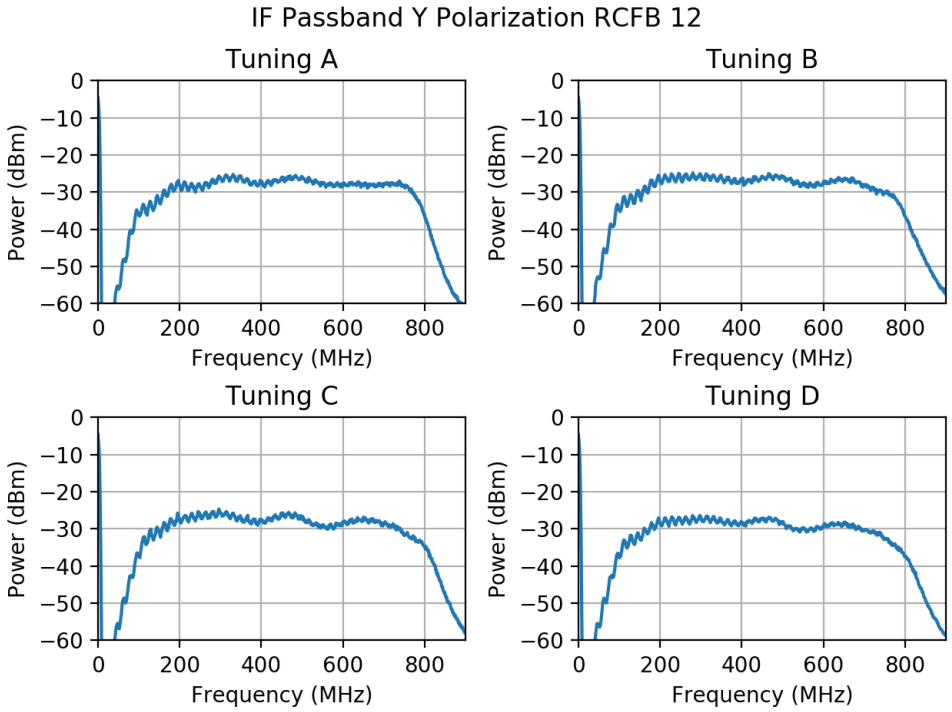
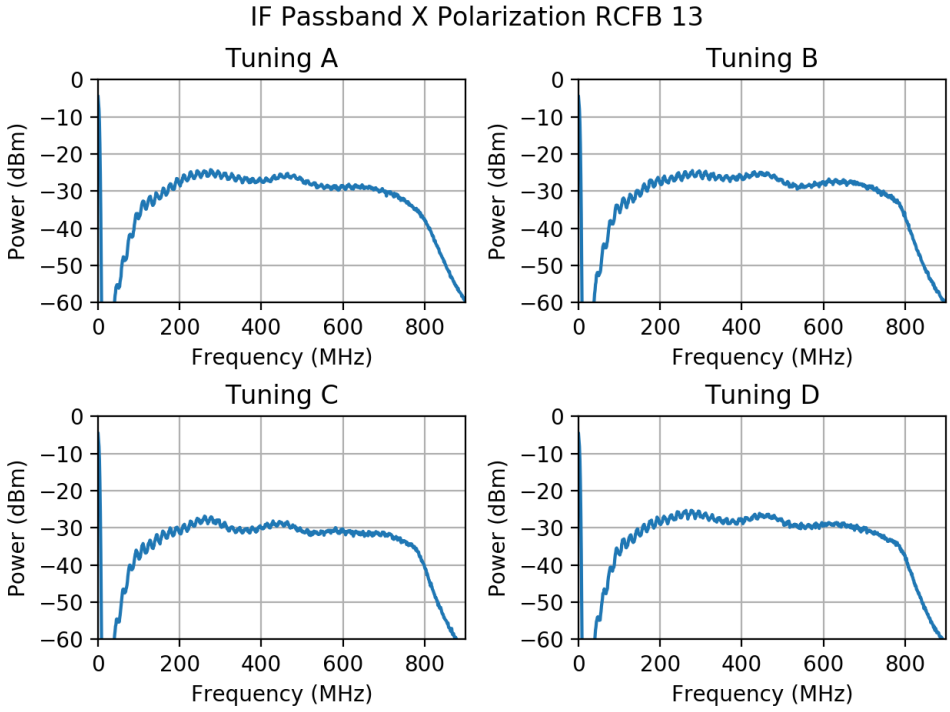
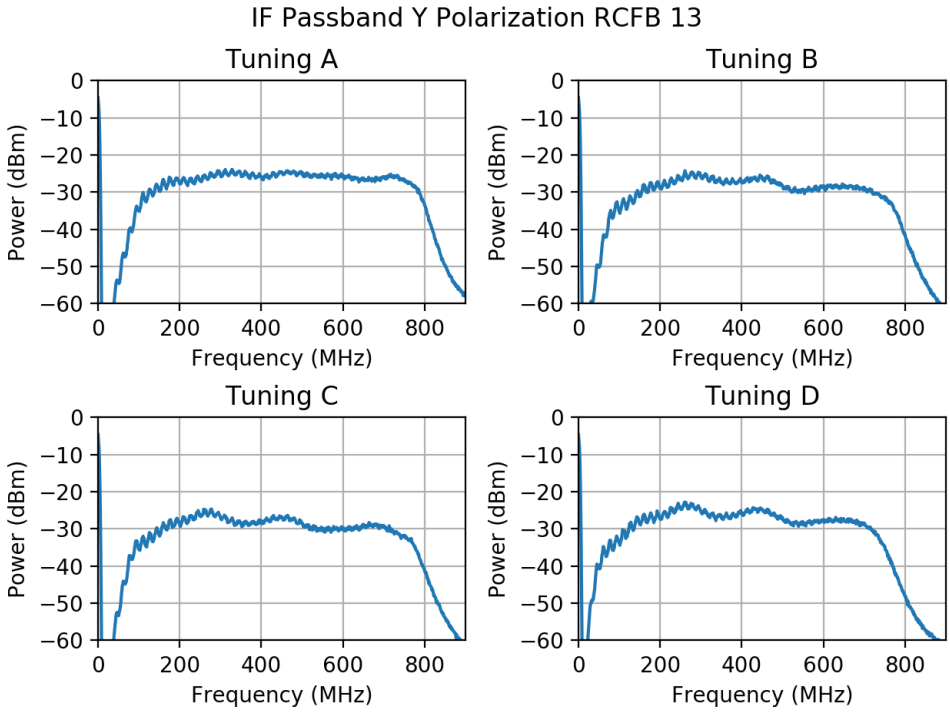




3.4 RFCB 13 (Antenna 2J)





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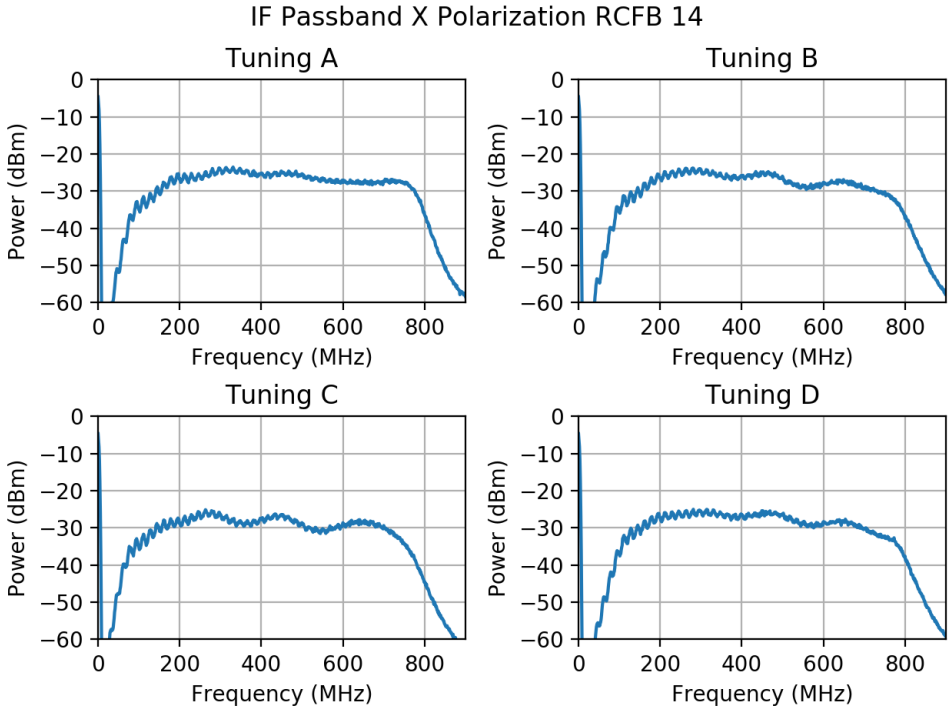

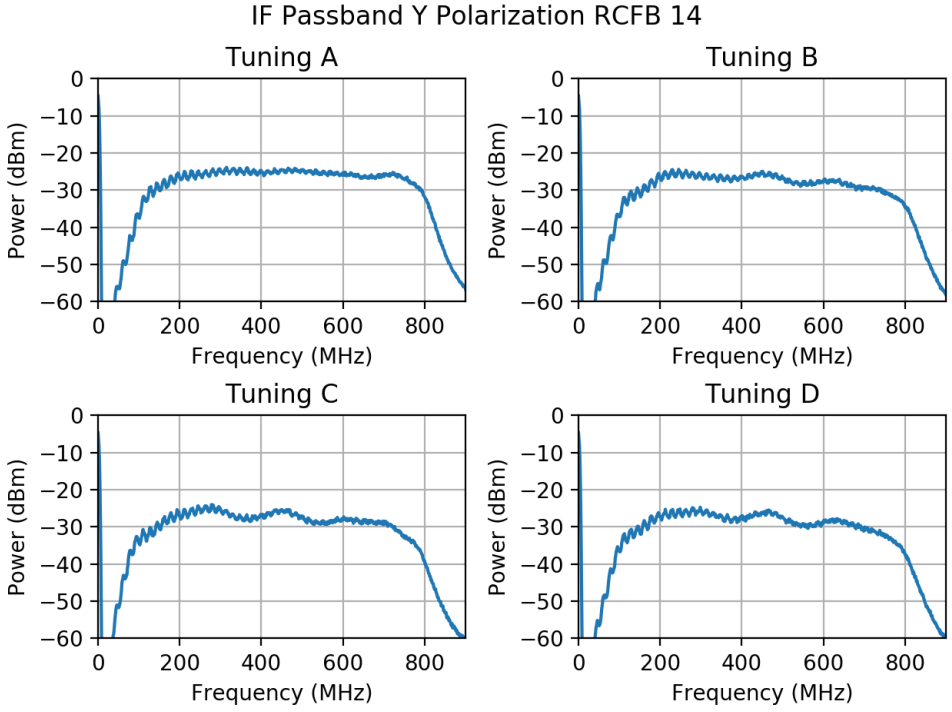

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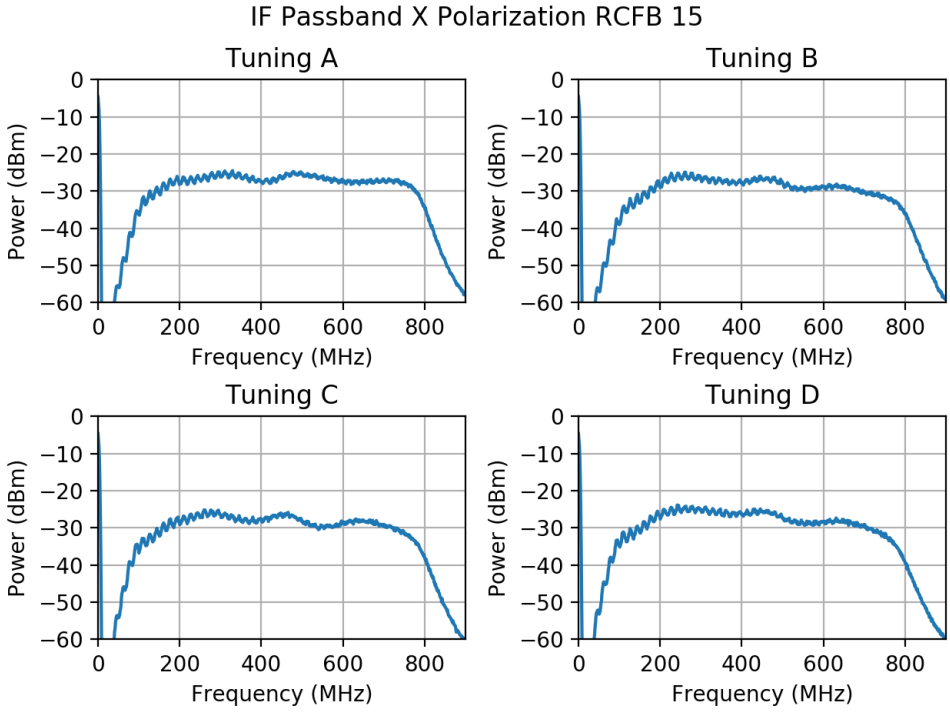

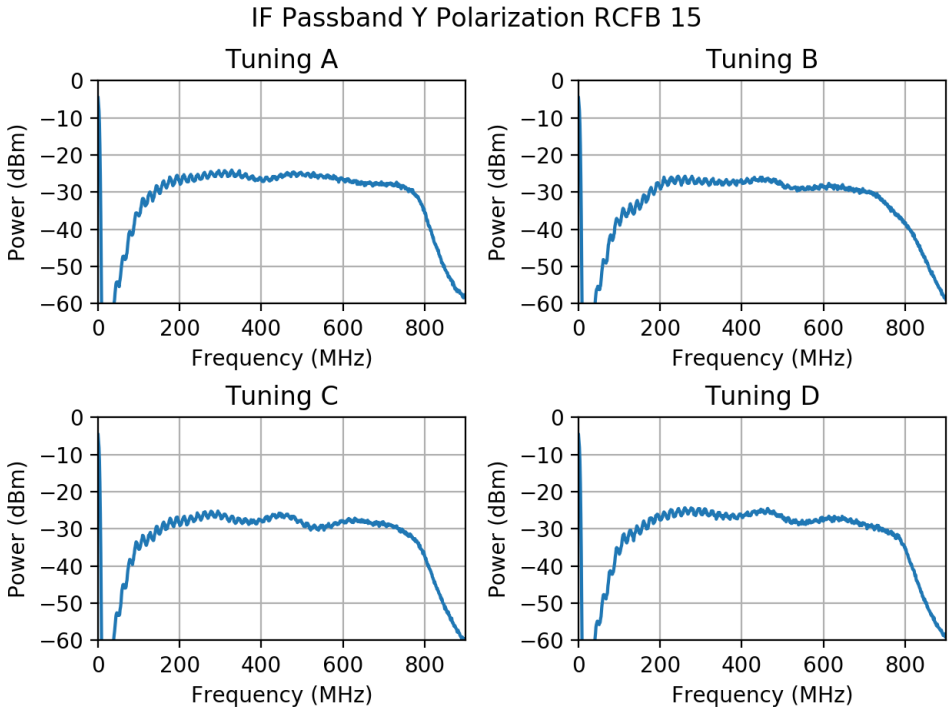

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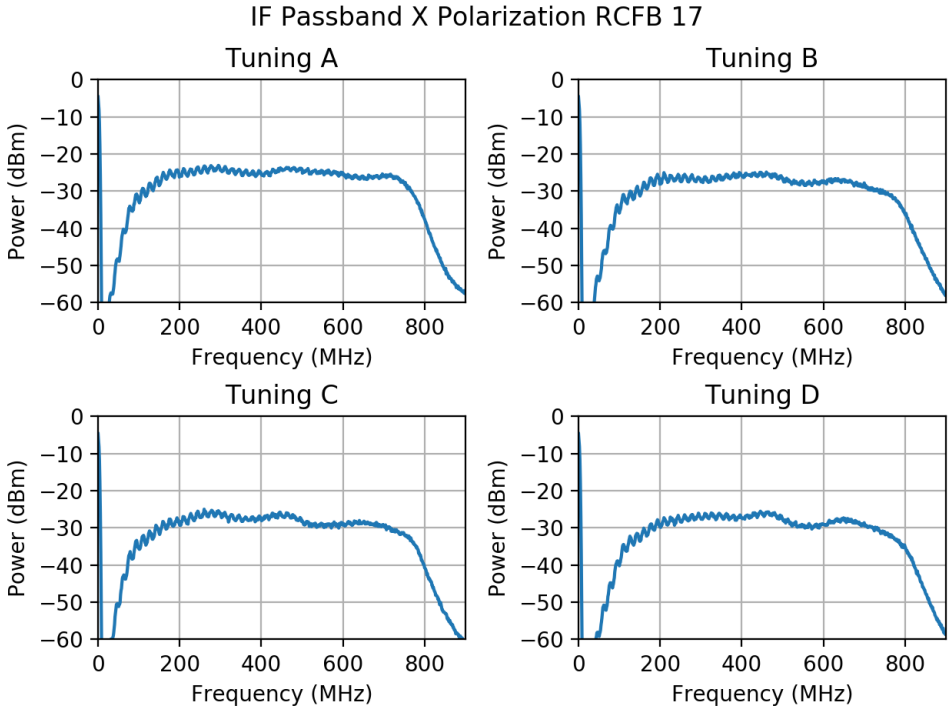
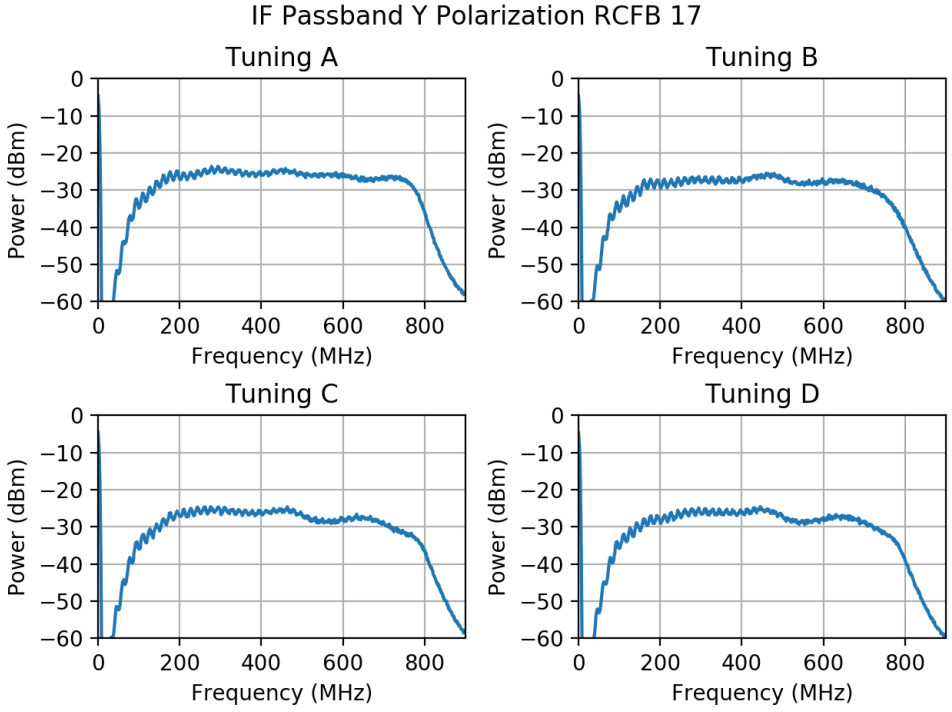
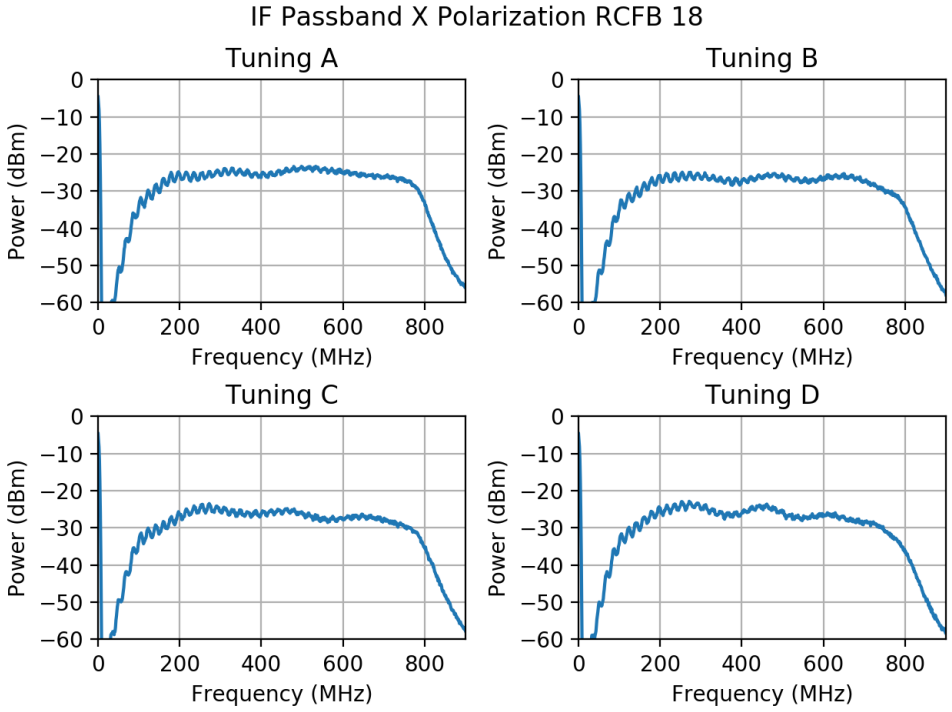
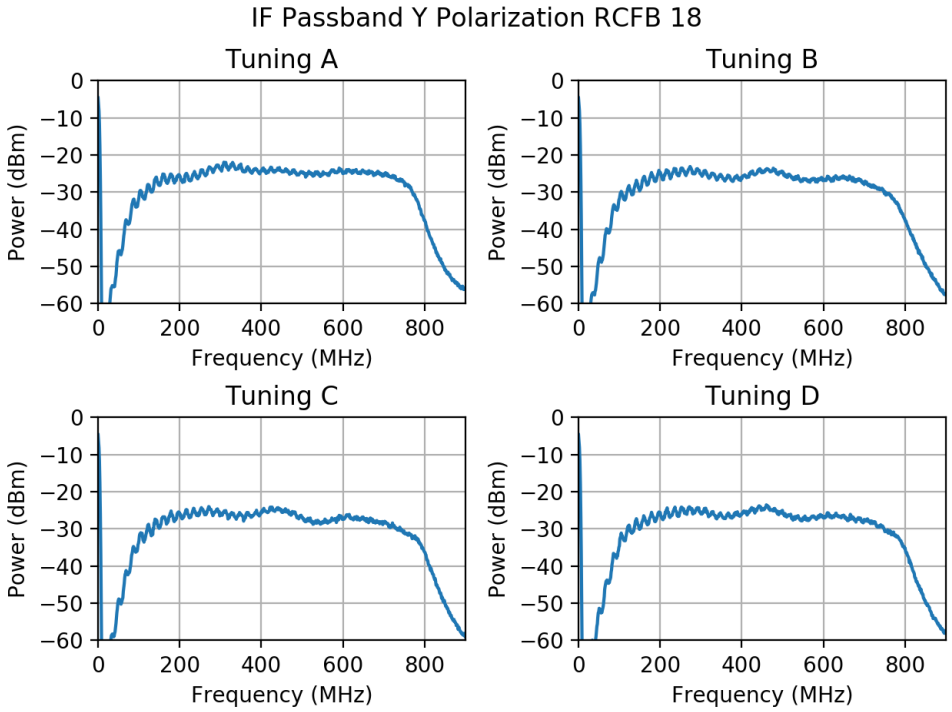




3.8 RFCB 18 (Antenna 3D)





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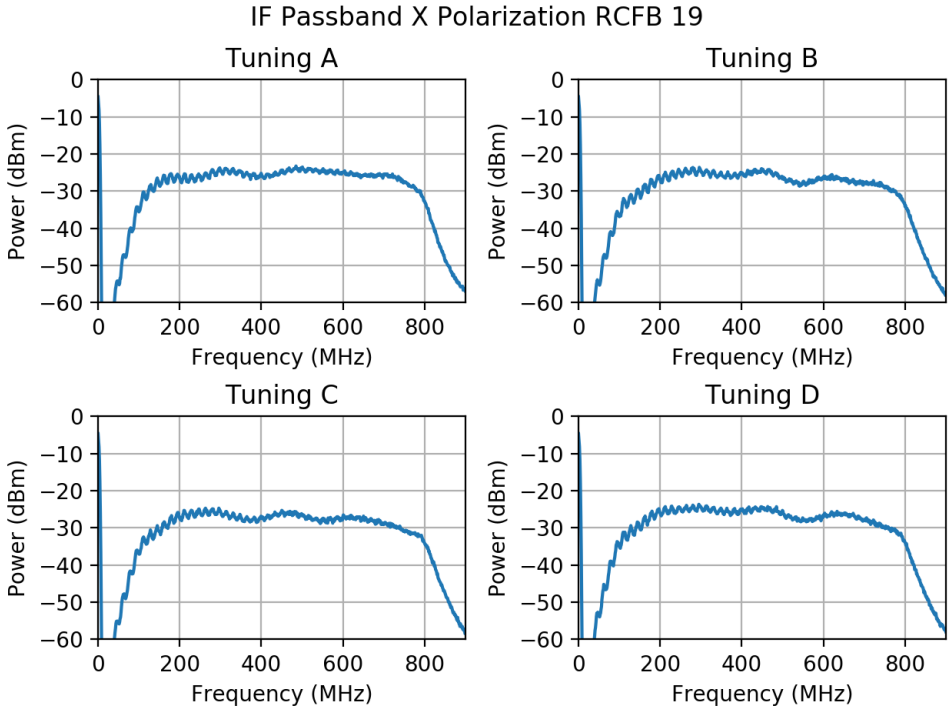
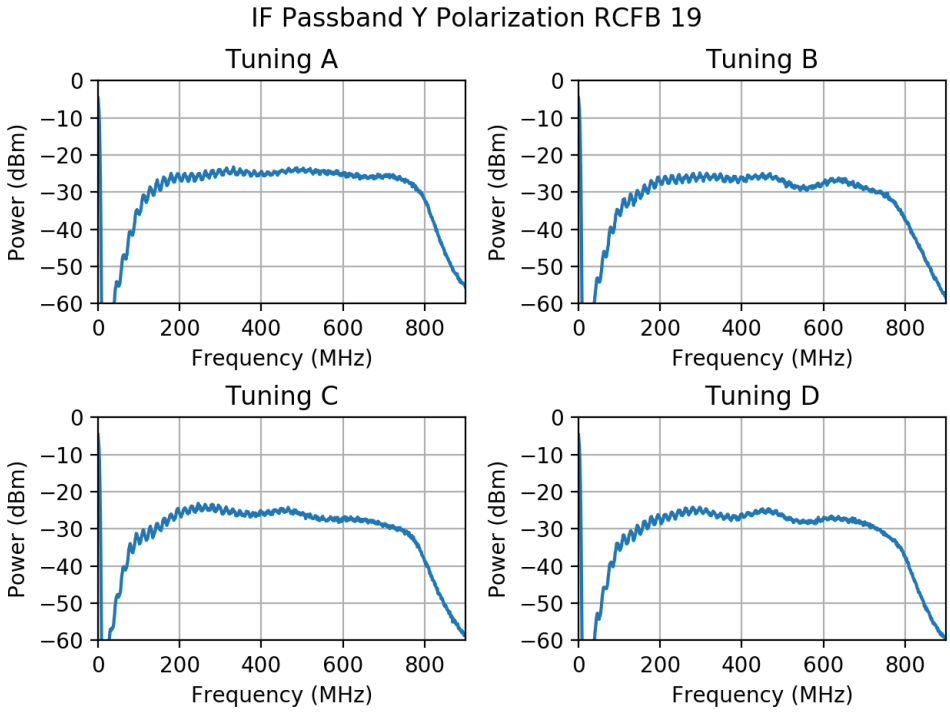
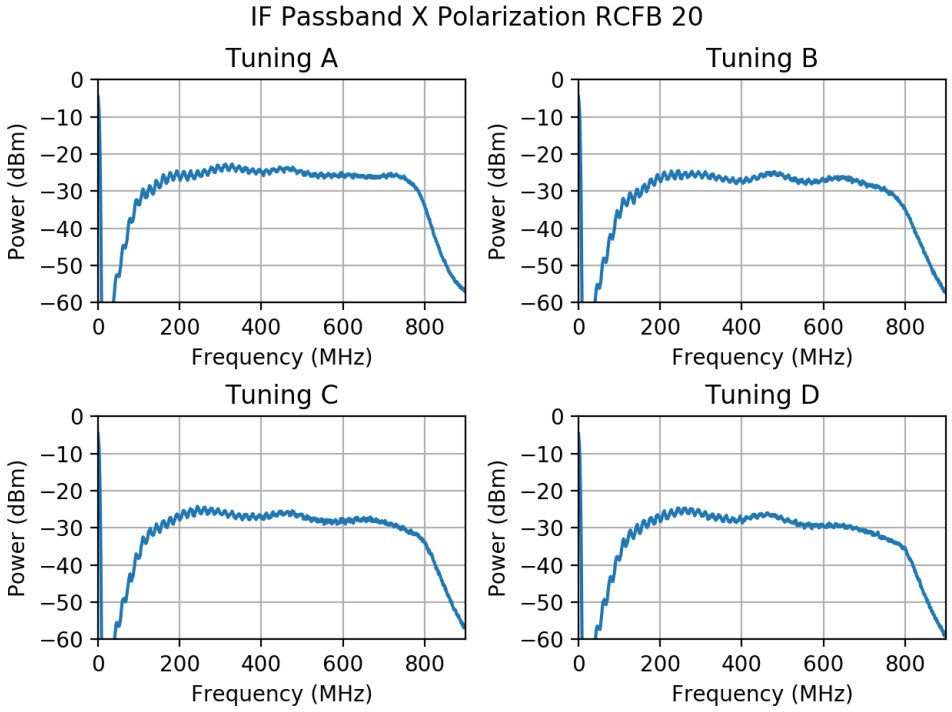
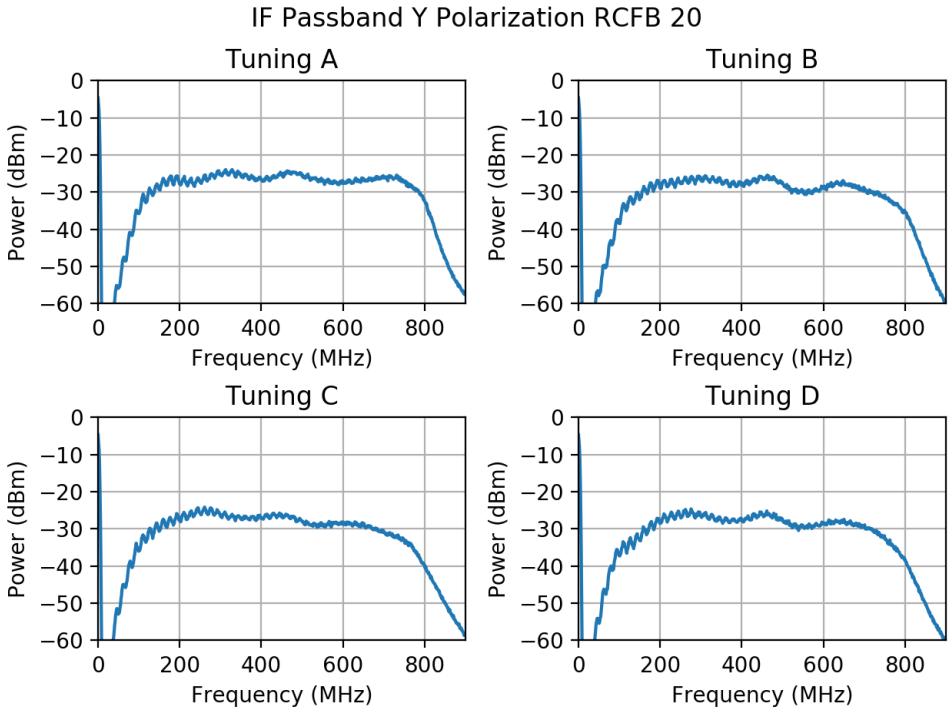




3.10 RFCB 20 (Antenna 2L)





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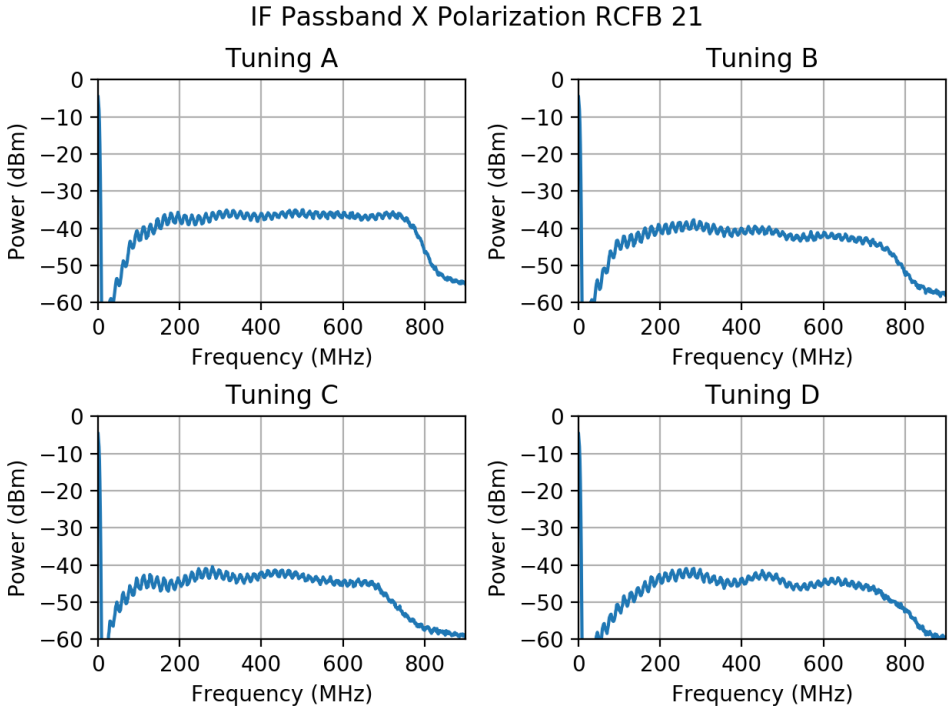
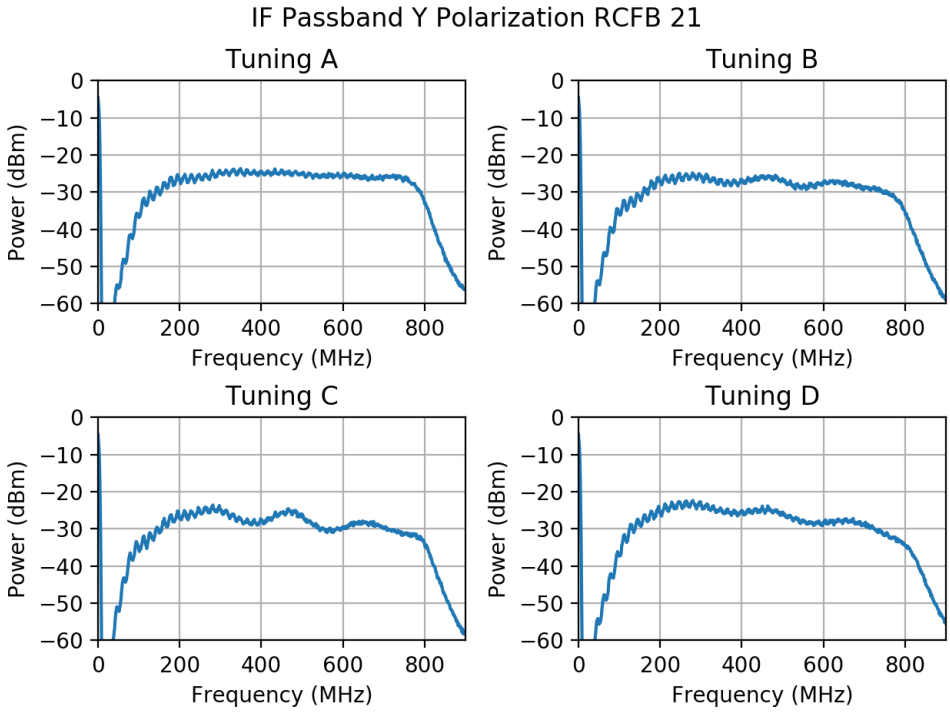
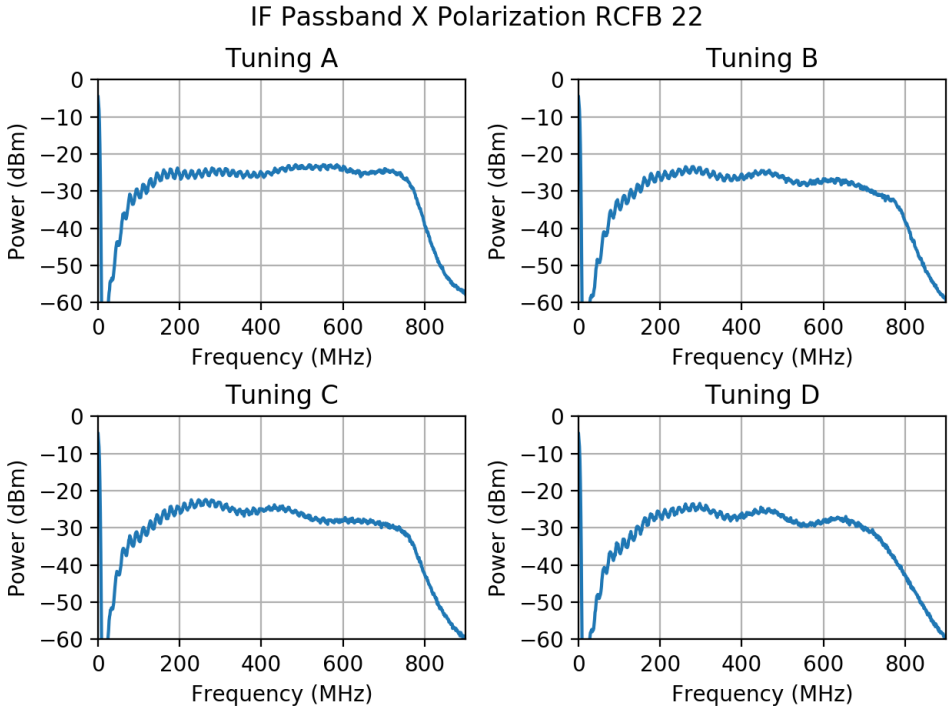
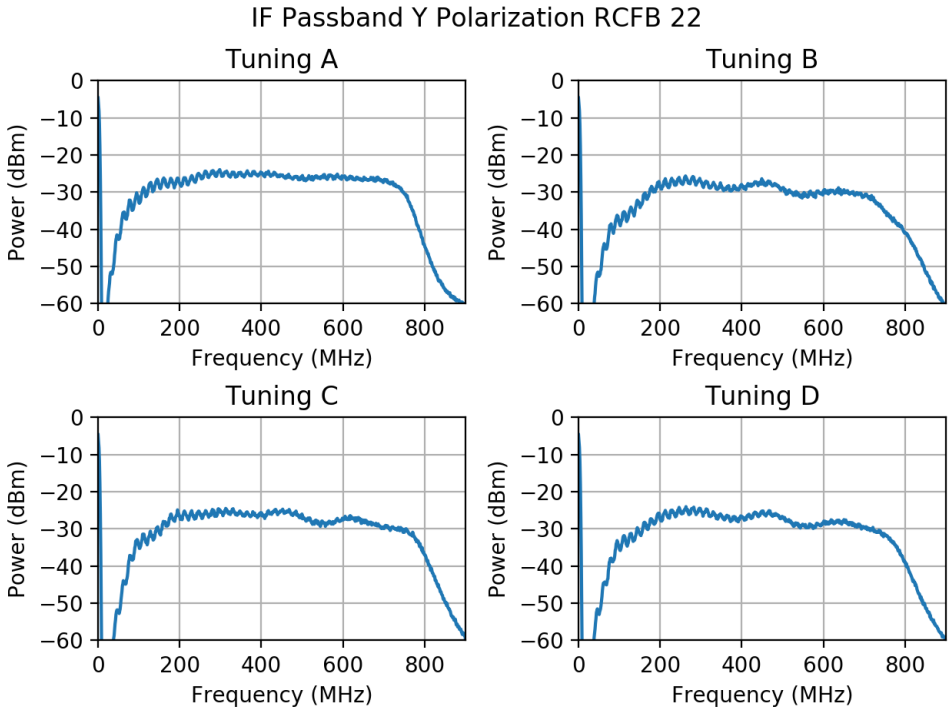




3.12 RFCB 22 (Antenna 4H)





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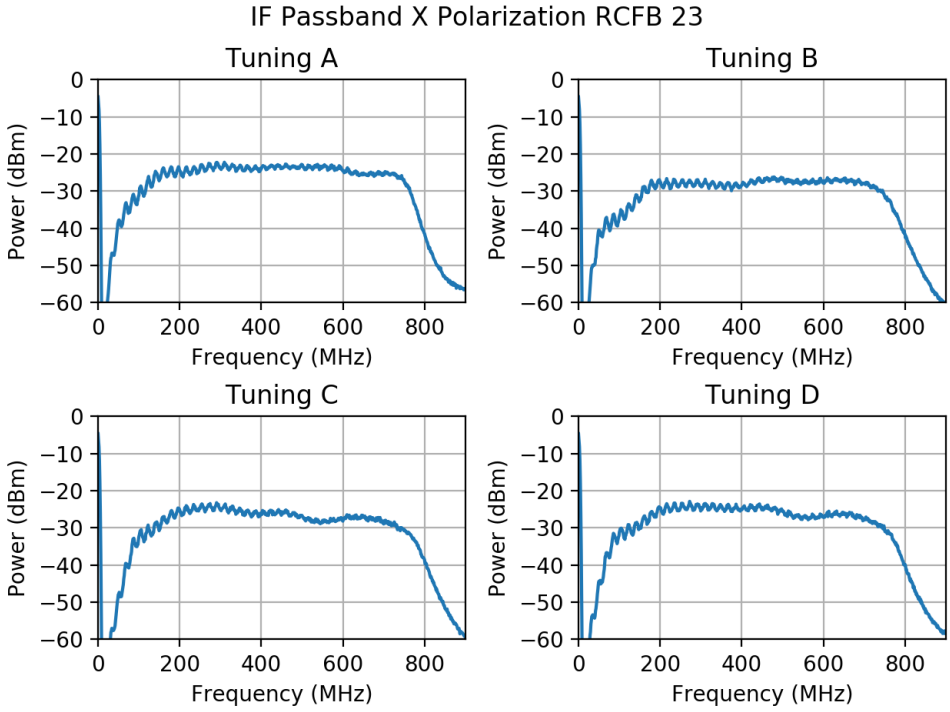
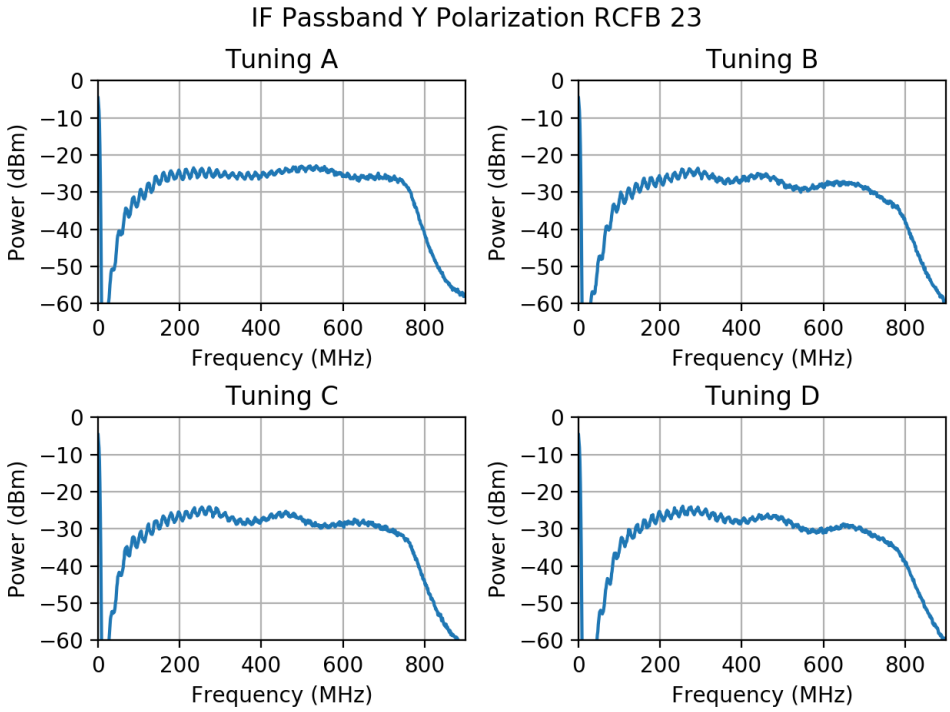
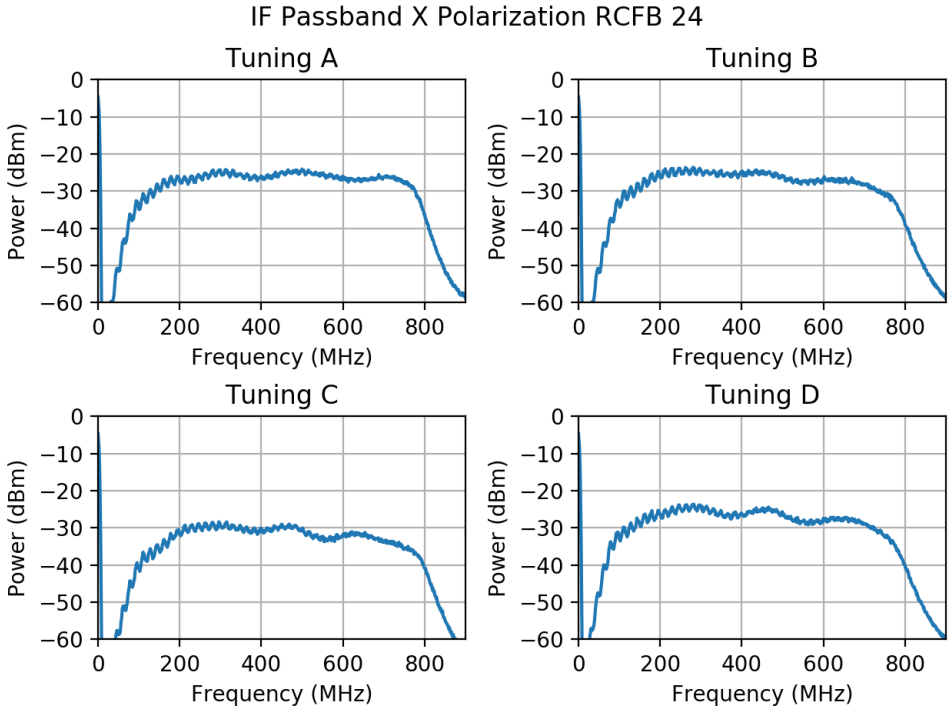
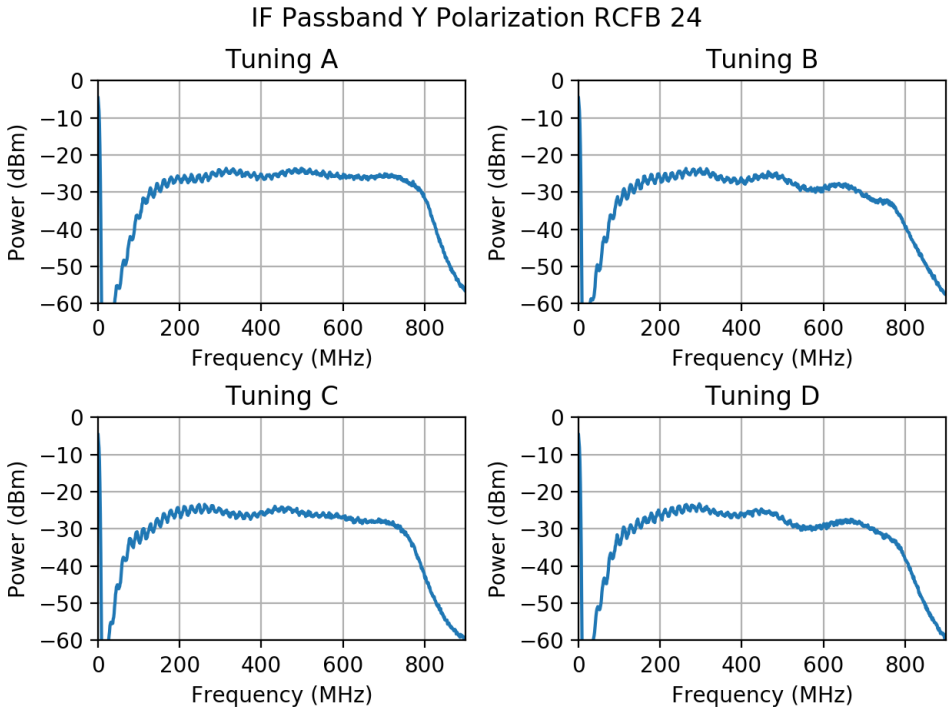


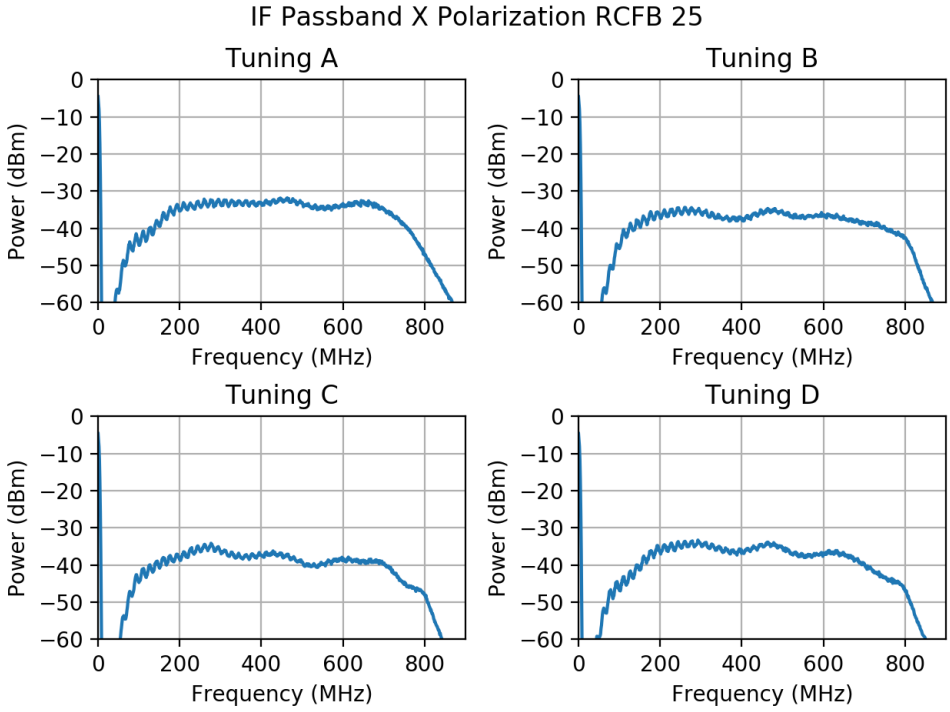


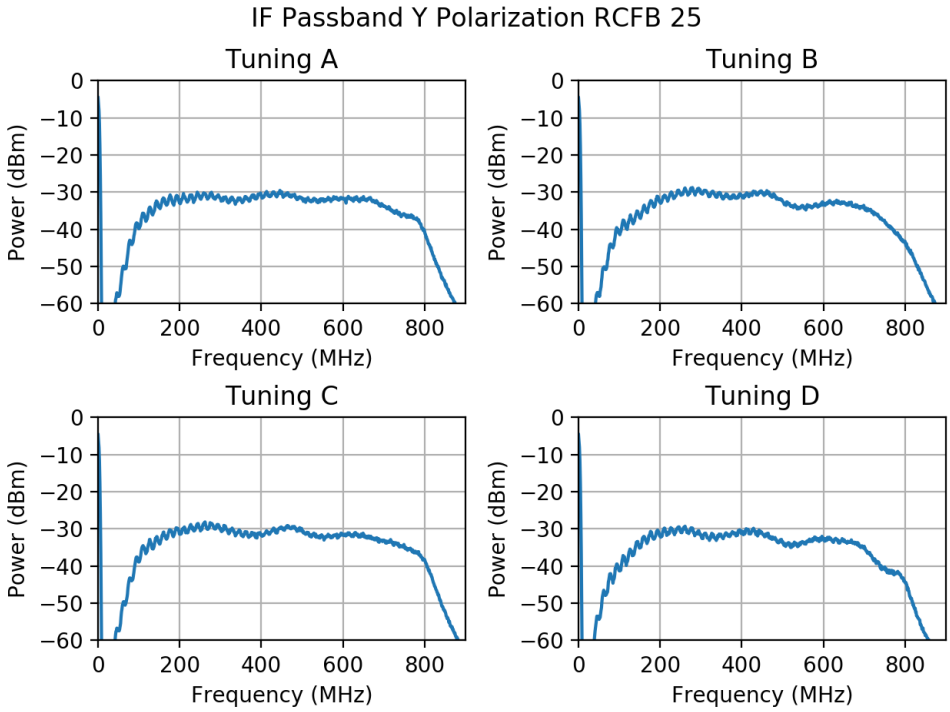
3.14 RFCB 24 (Antenna 4J)



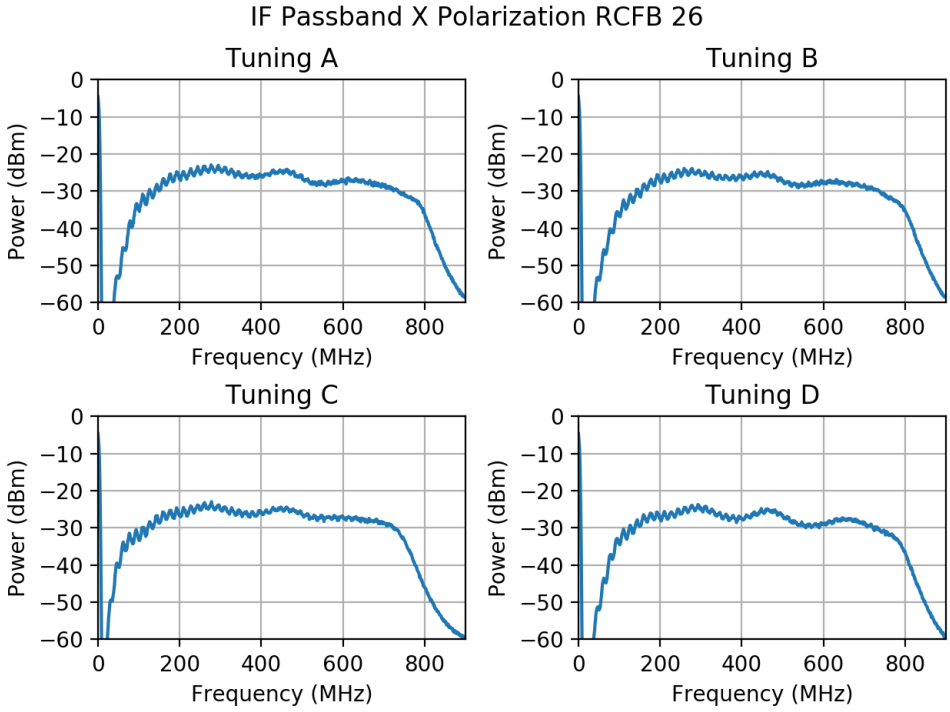


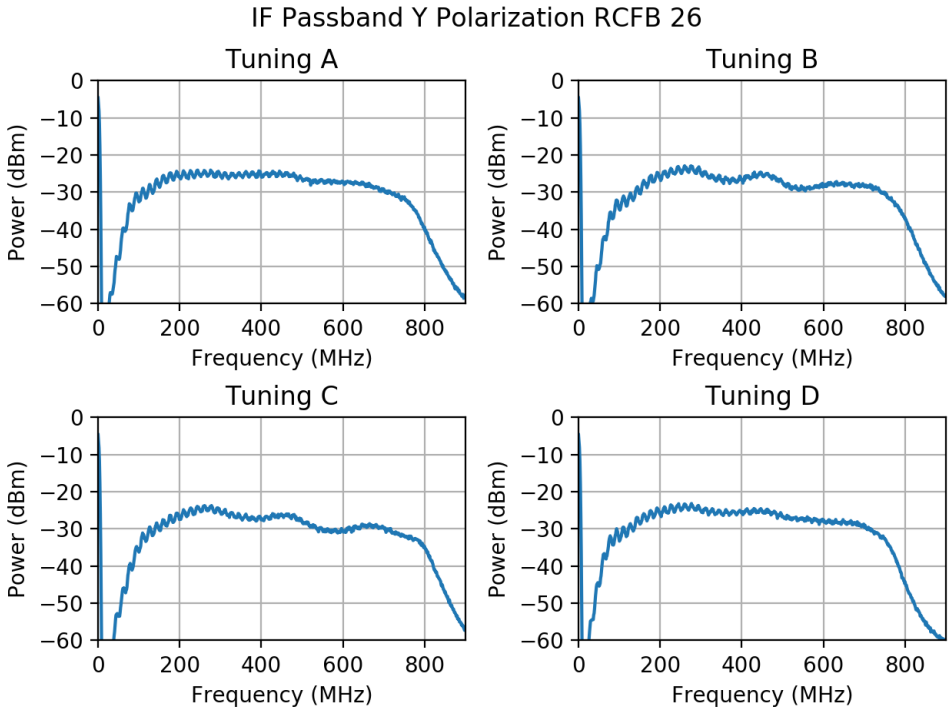
3.15 RFCB 25 (Antenna 1B)



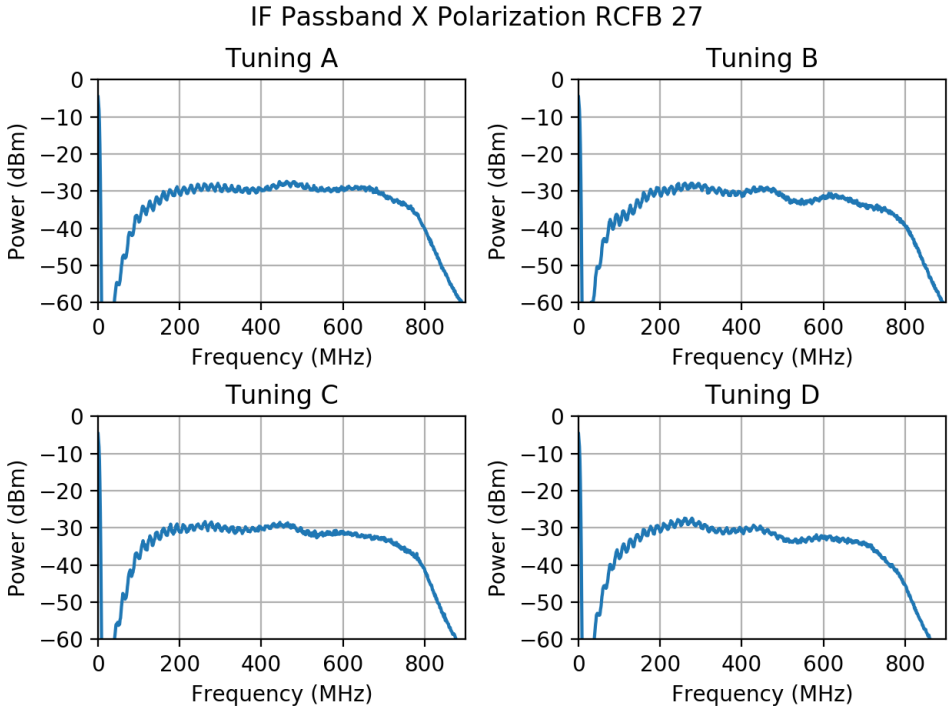


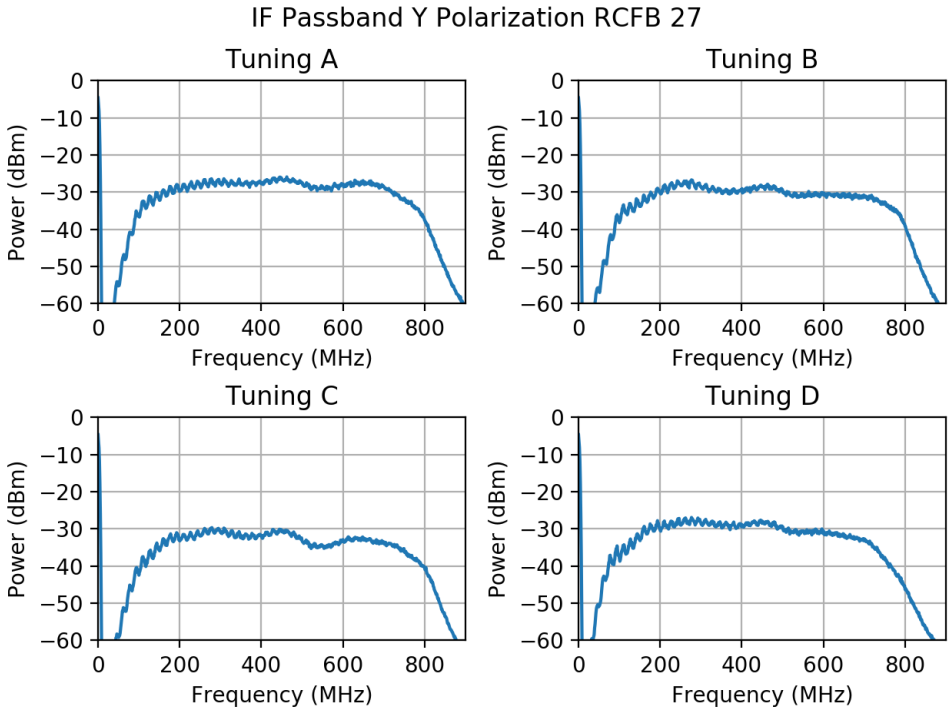
3.16 RFCB 26 (Antenna 2C)



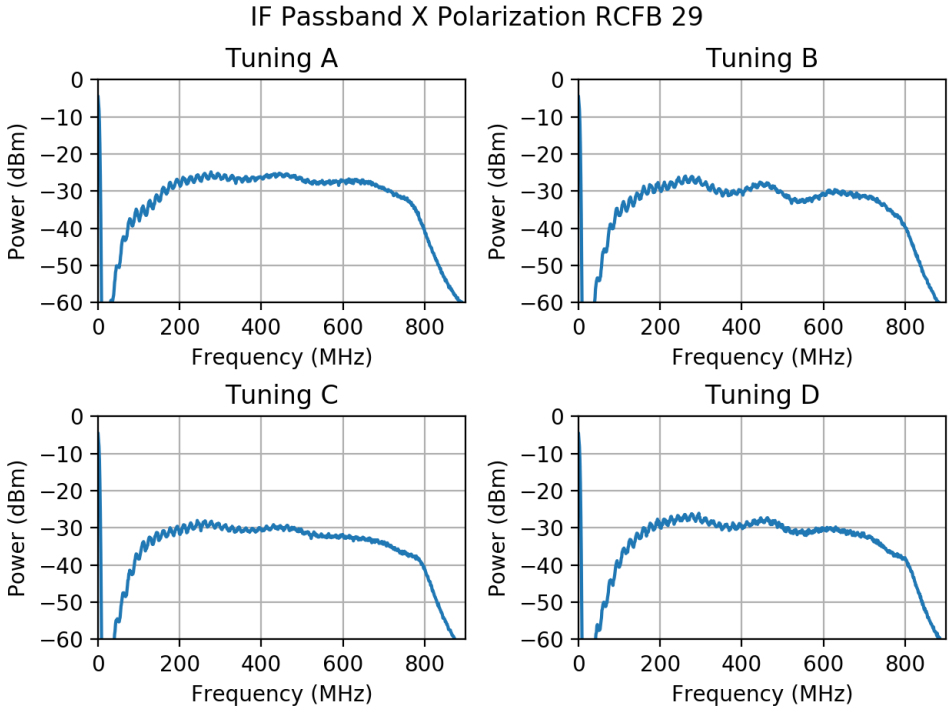


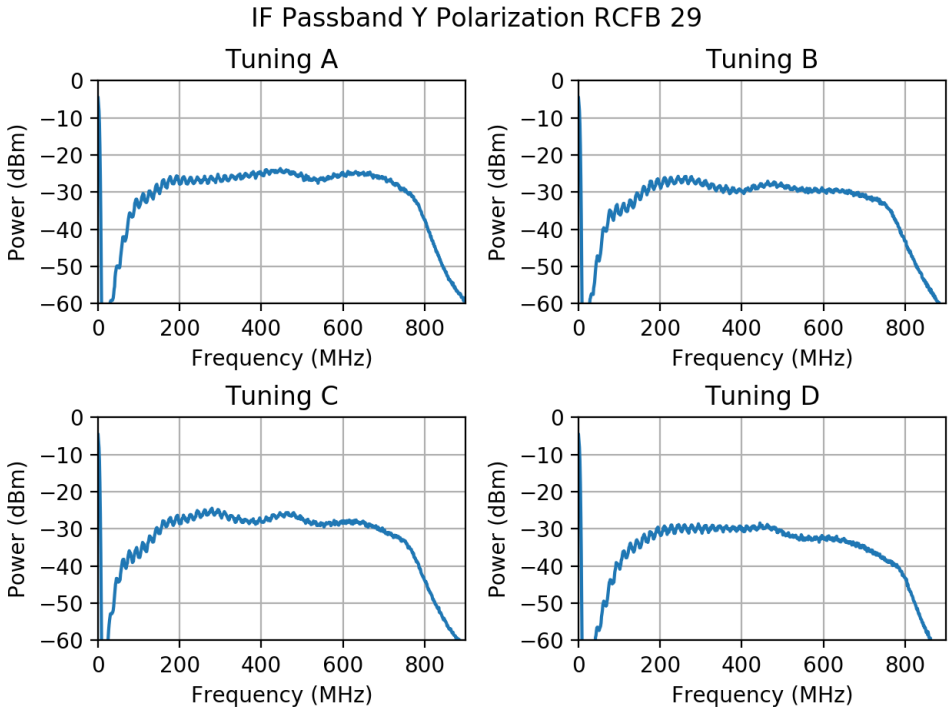
3.17 RFCB 27 (Antenna 1H)



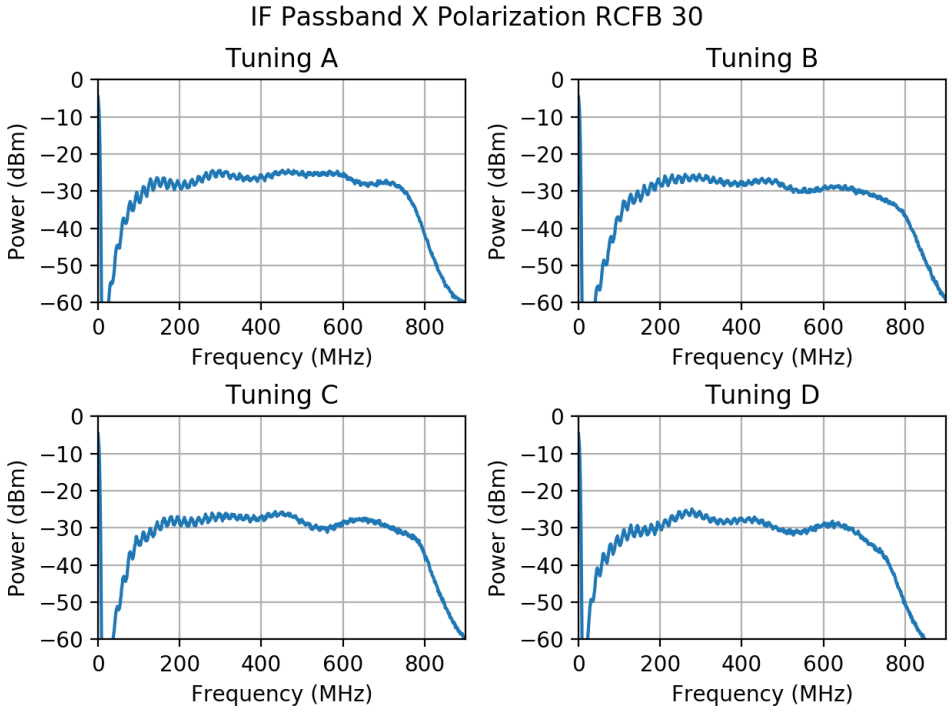


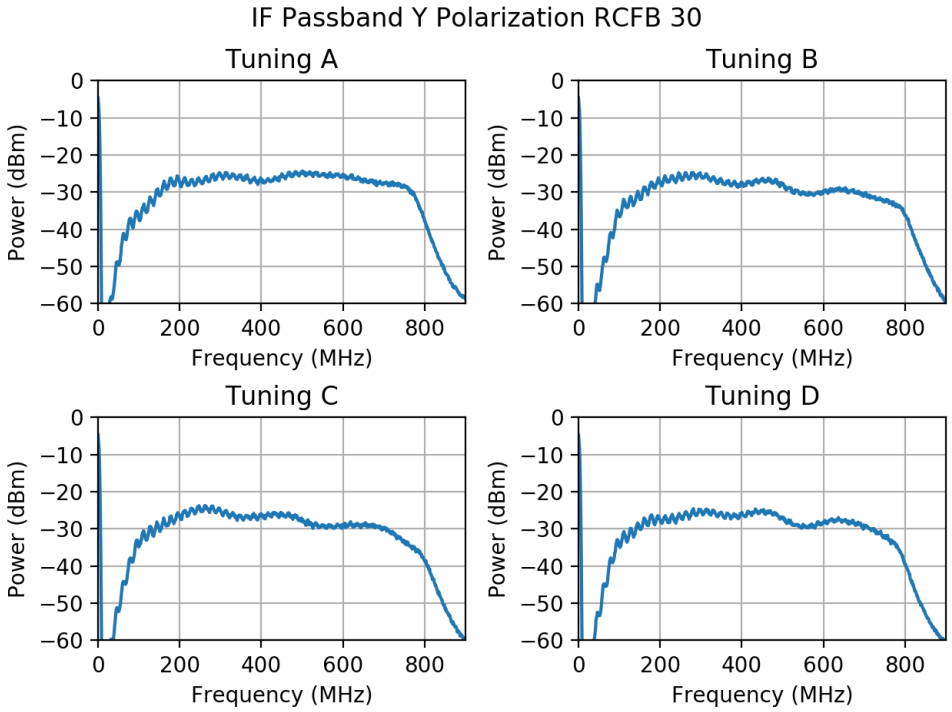
3.18 RFCB 29 (Antenna 1K)



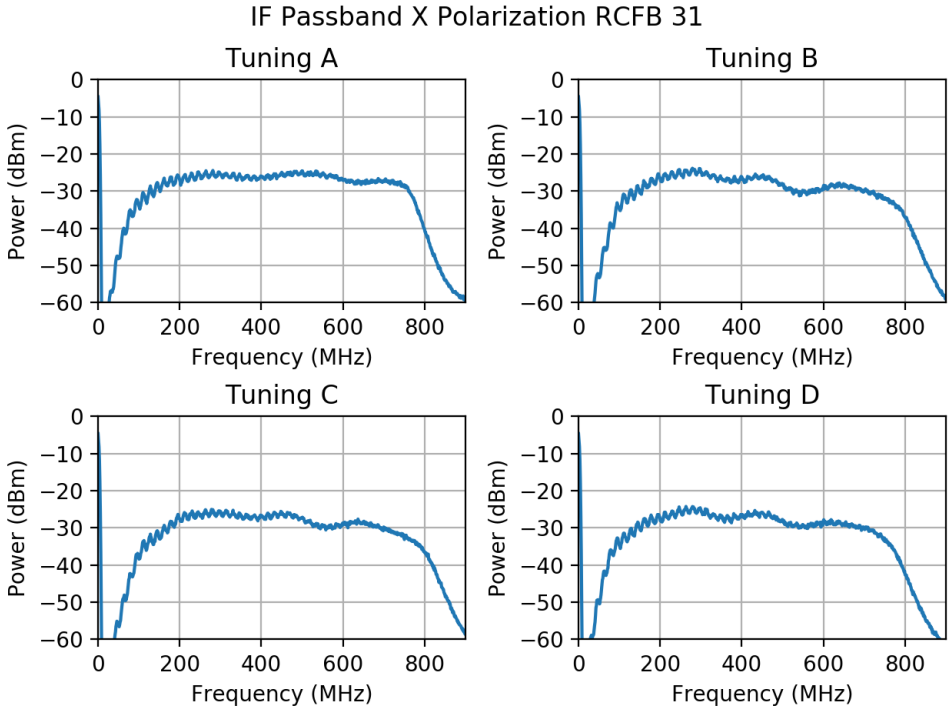


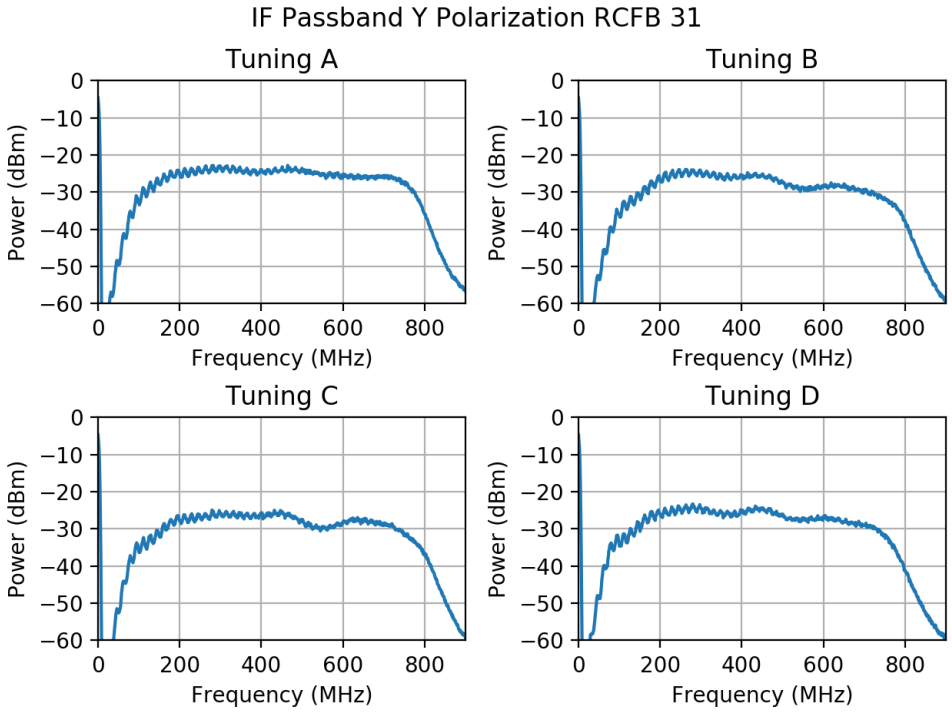
3.19 RFCB 30 (Antenna 4K)



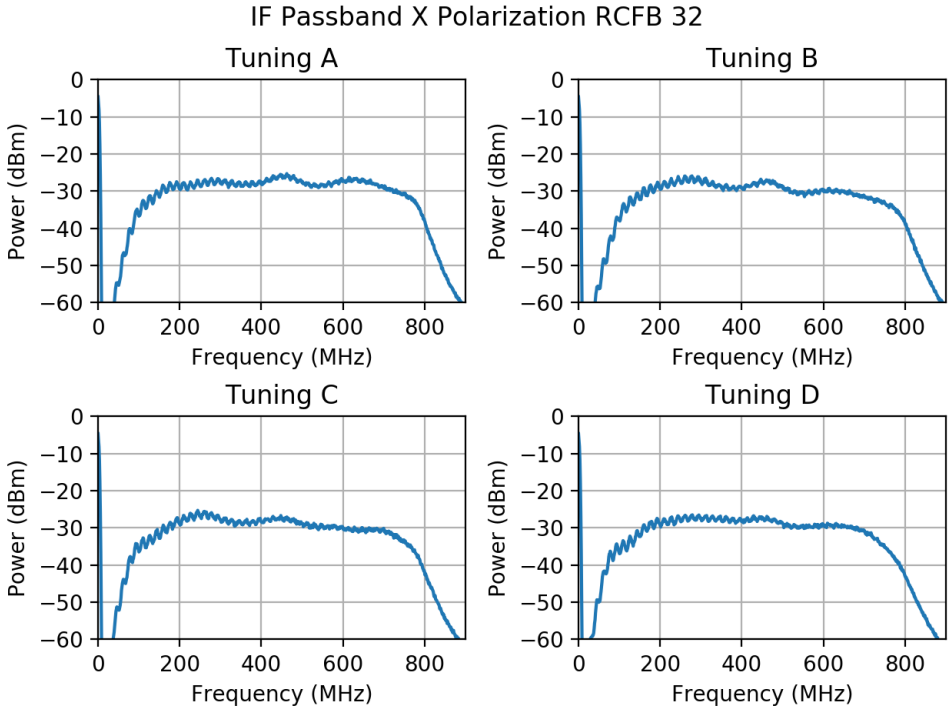


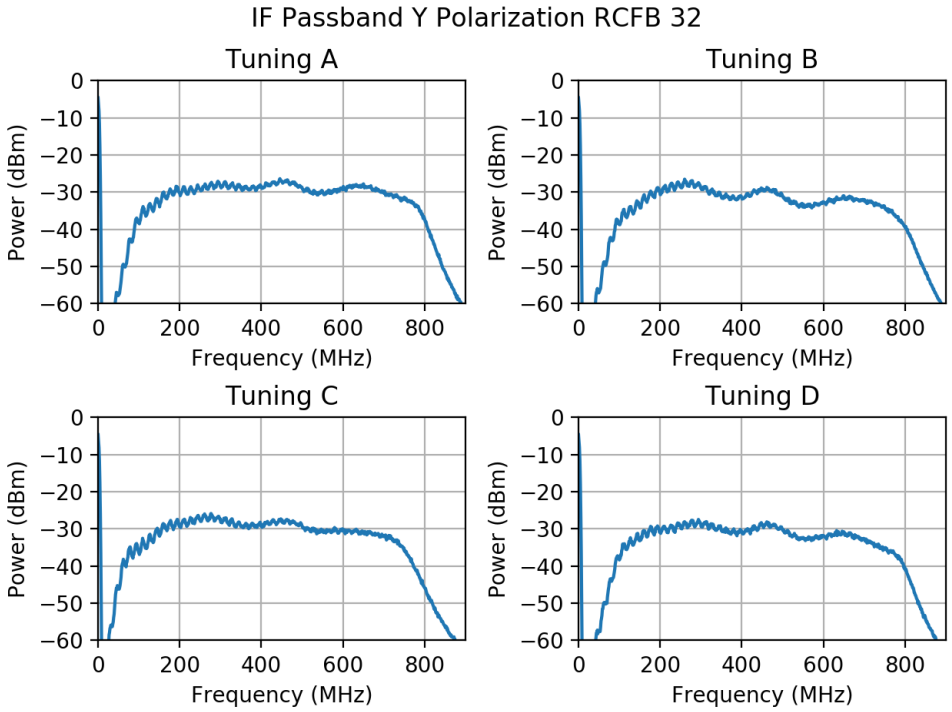
3.20 RFCB 31 (Antenna 5C)



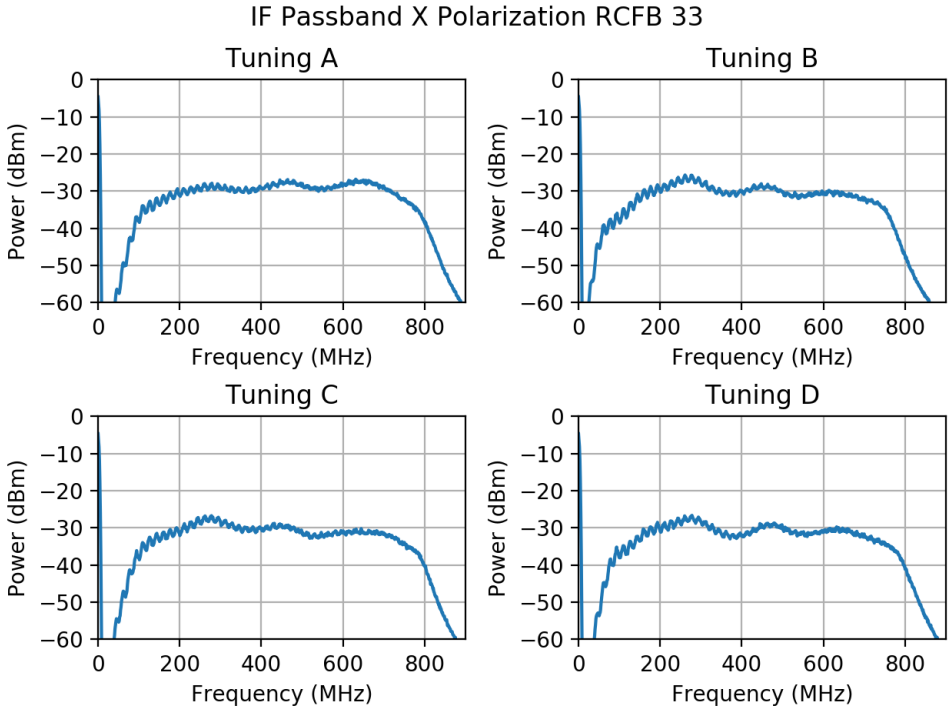


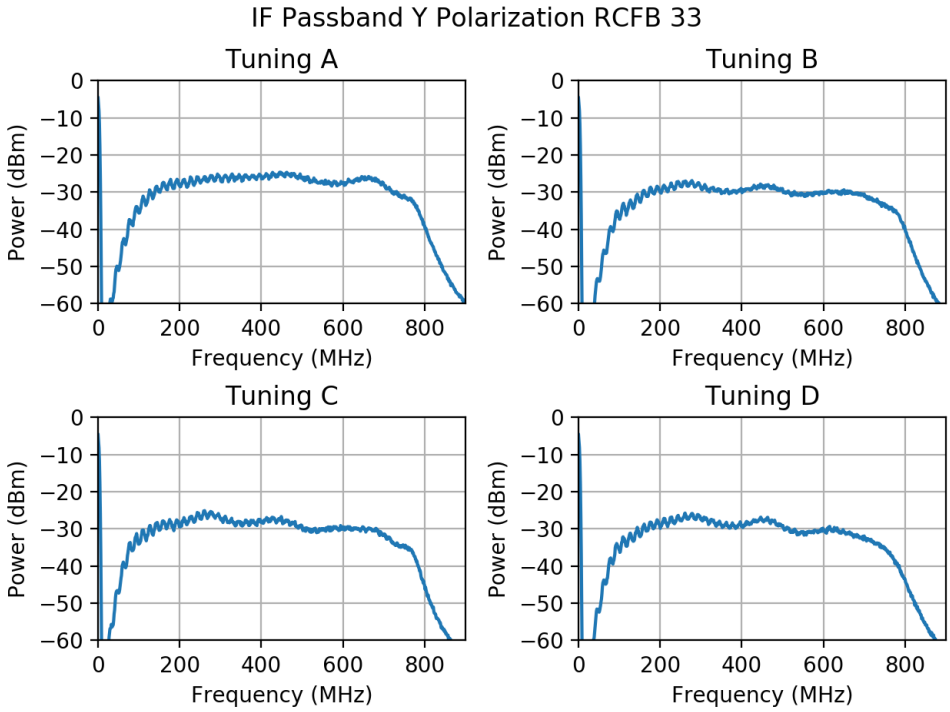
3.21 RFCB 32 (Antenna 2A)



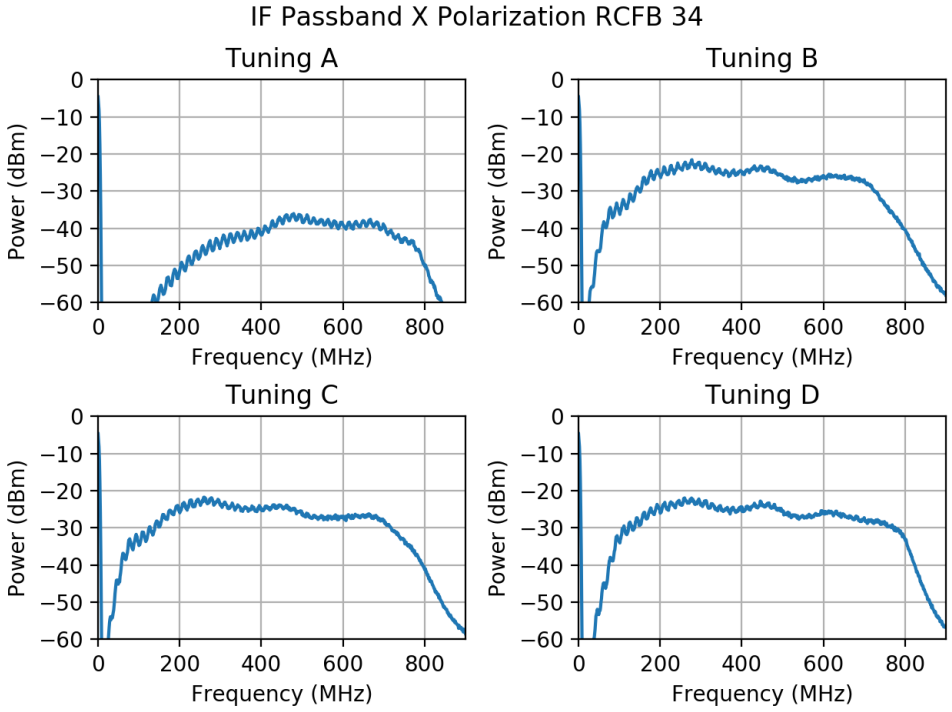


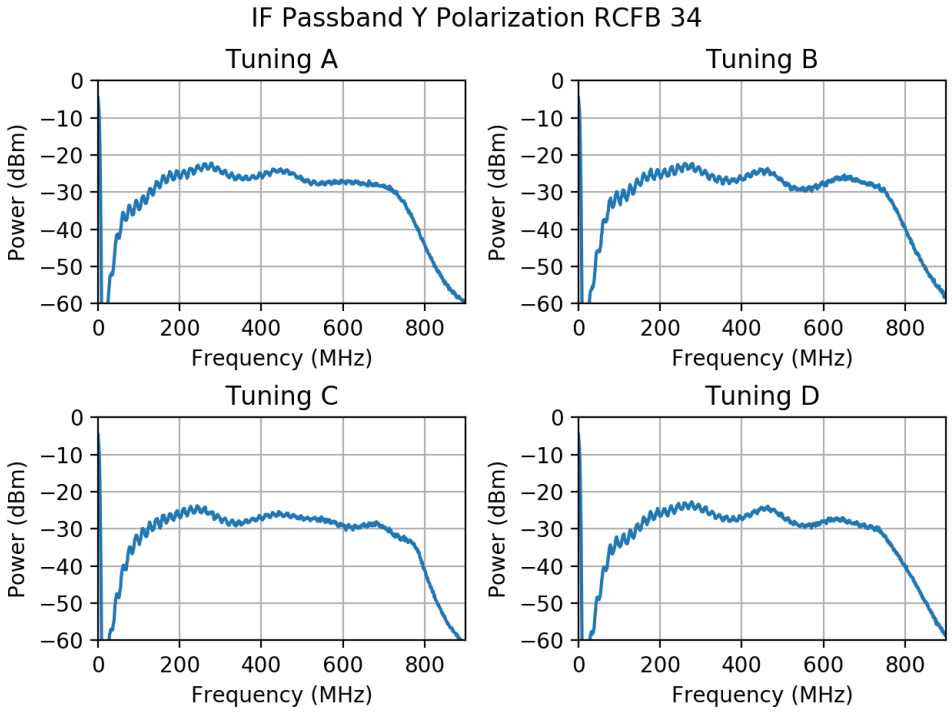
3.22 RFCB 33 (Antenna 1E)



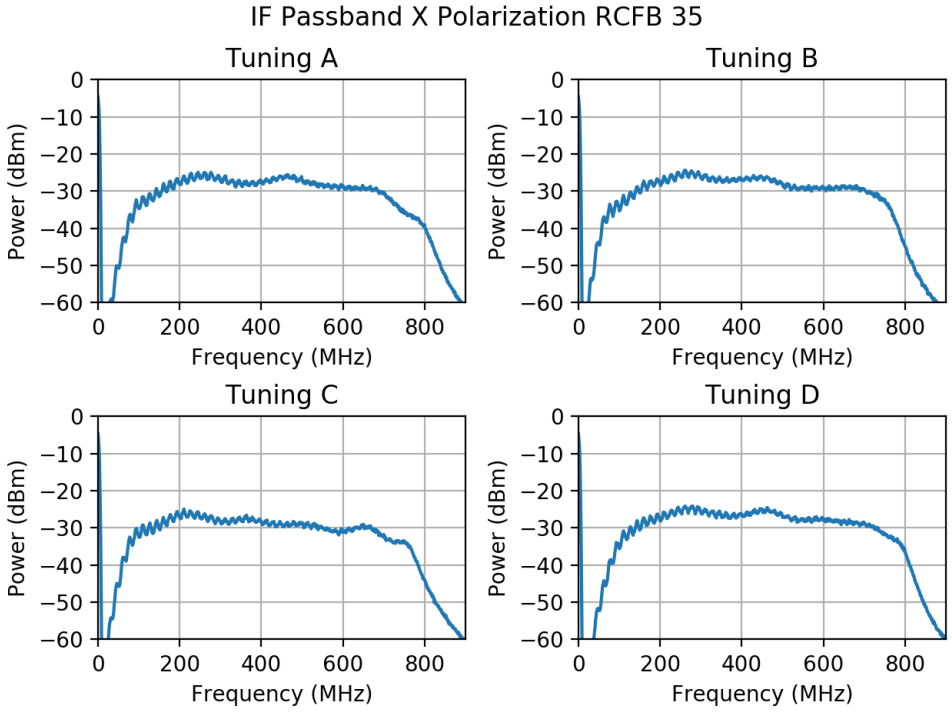


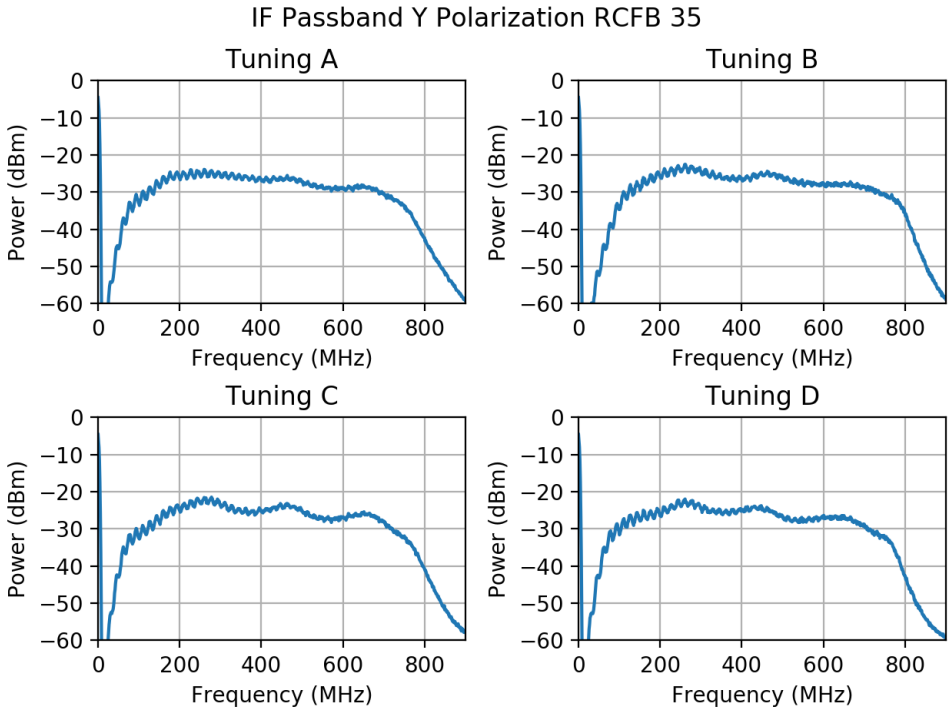
3.23 RFCB 34 (Antenna 2F)



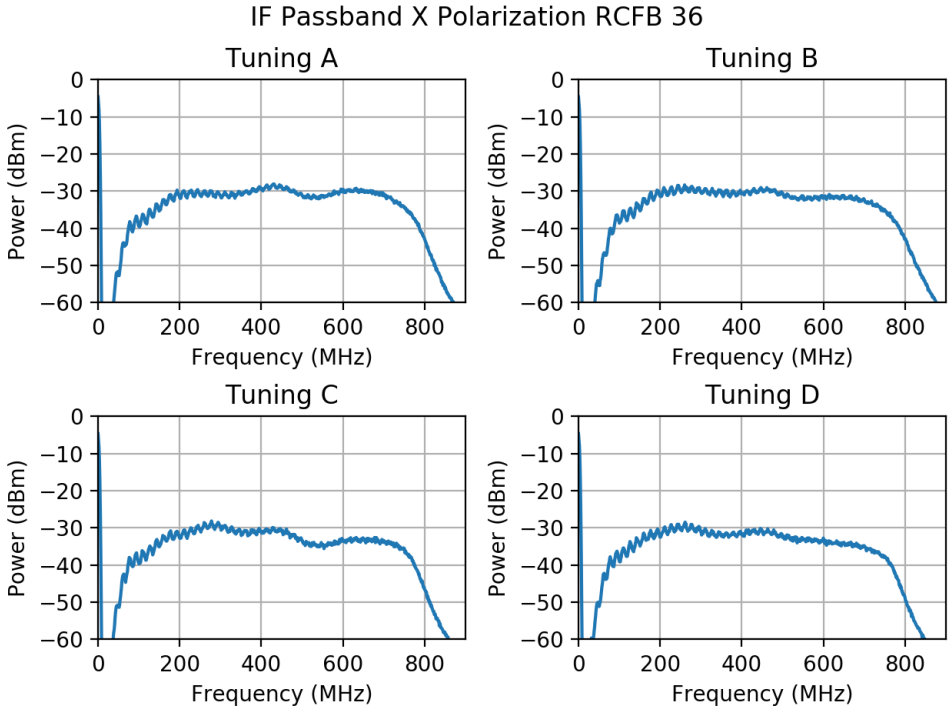


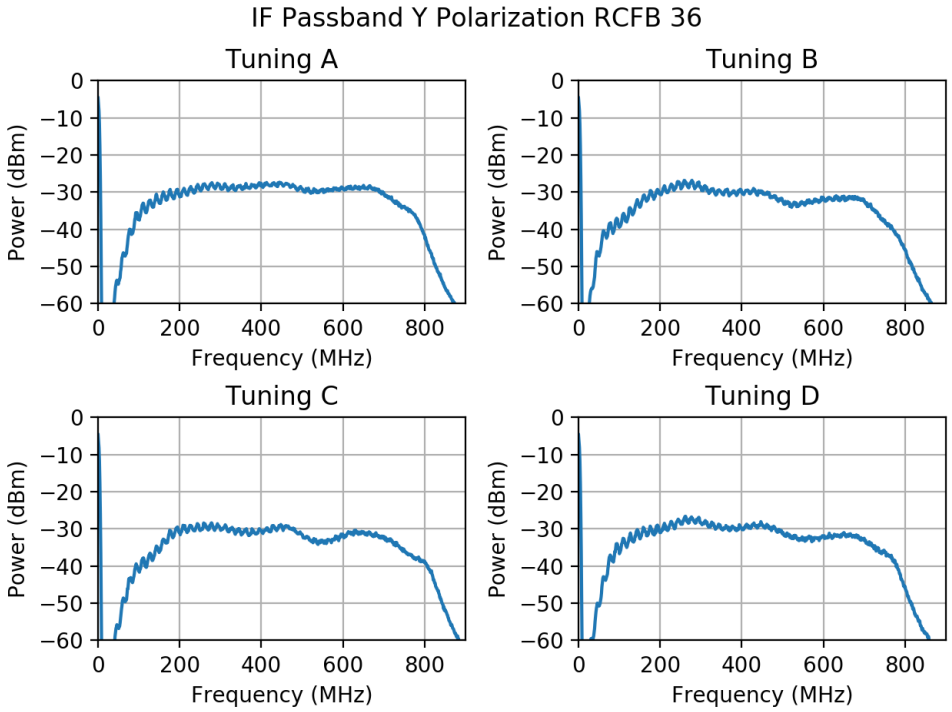
3.24 RFCB 35 (Antenna 2H)



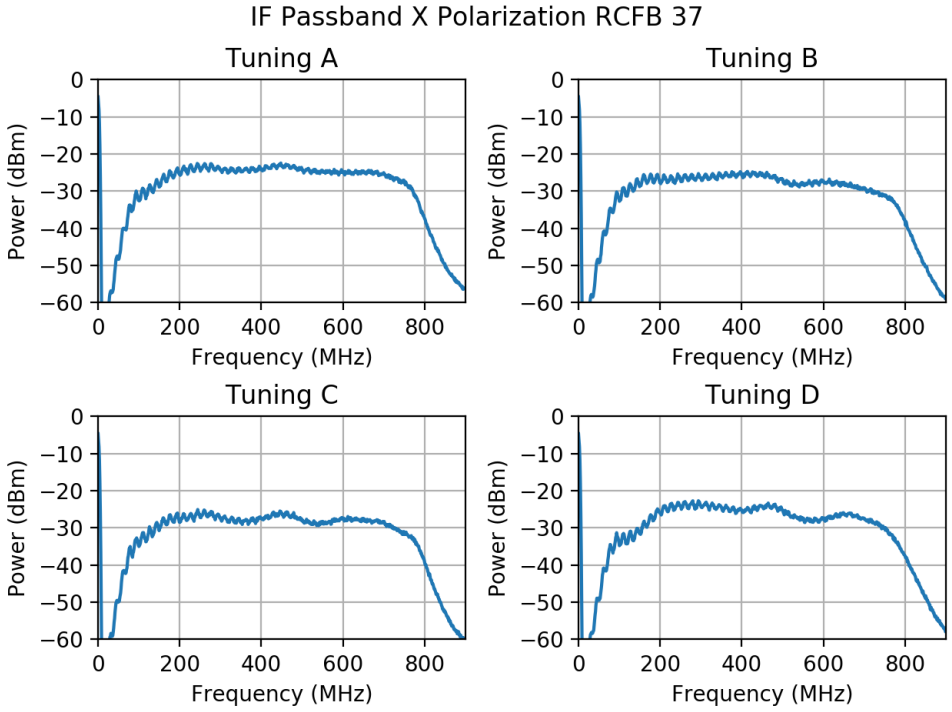


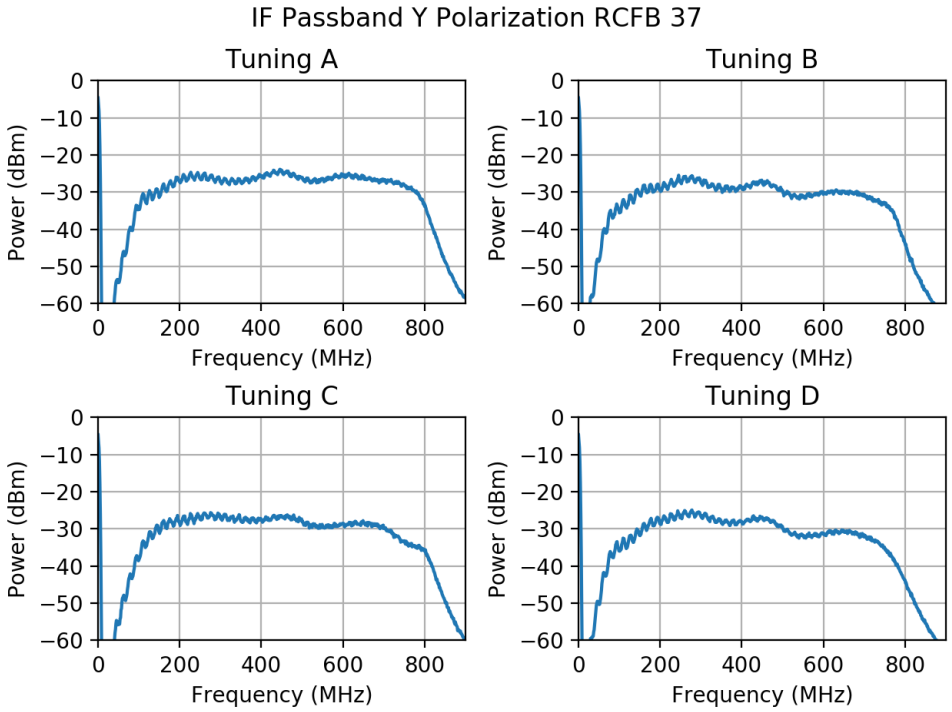
3.25 RFCB 36 (Antenna 1D)



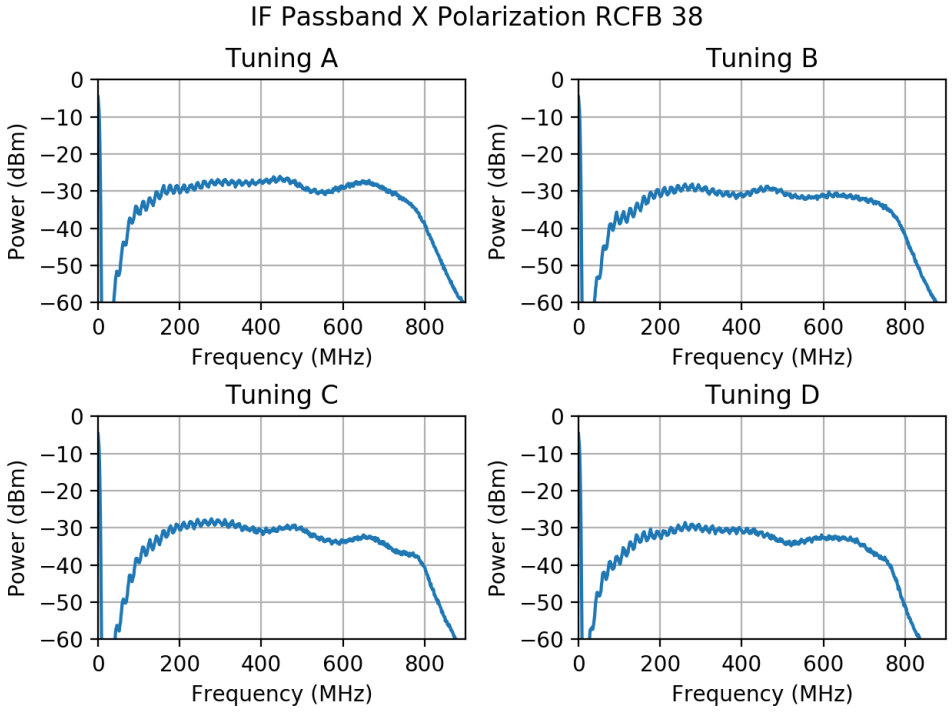


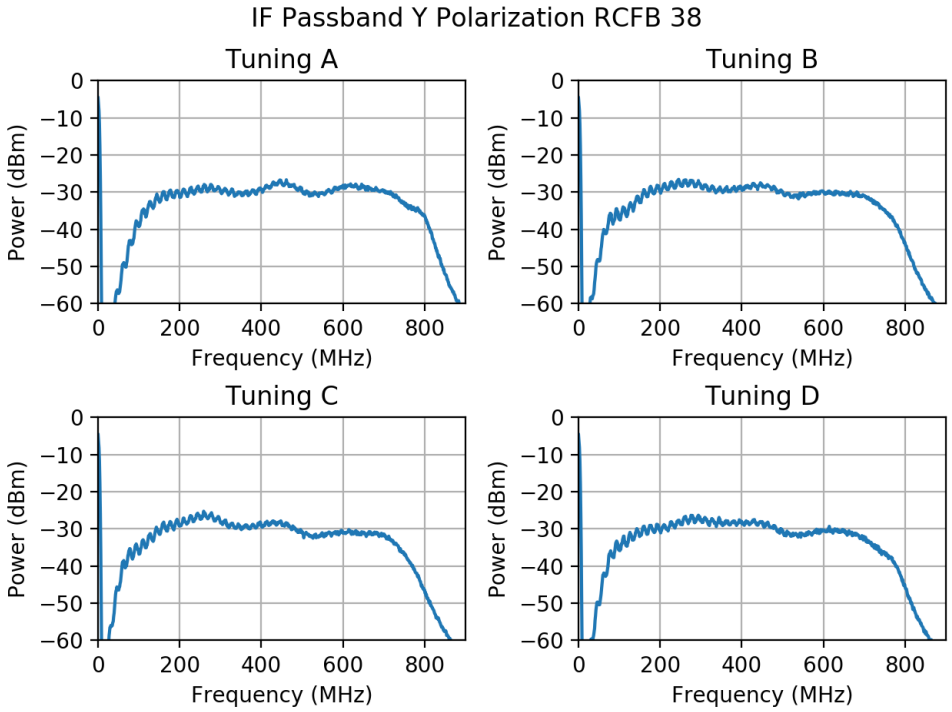
3.26 RFCB 37 (Antenna 2E)



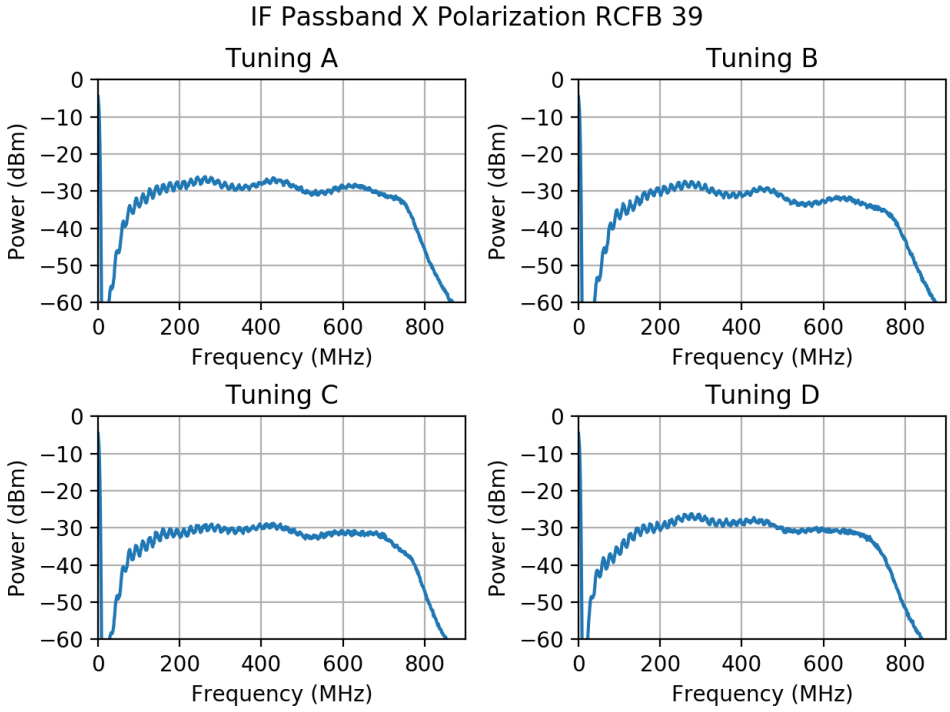


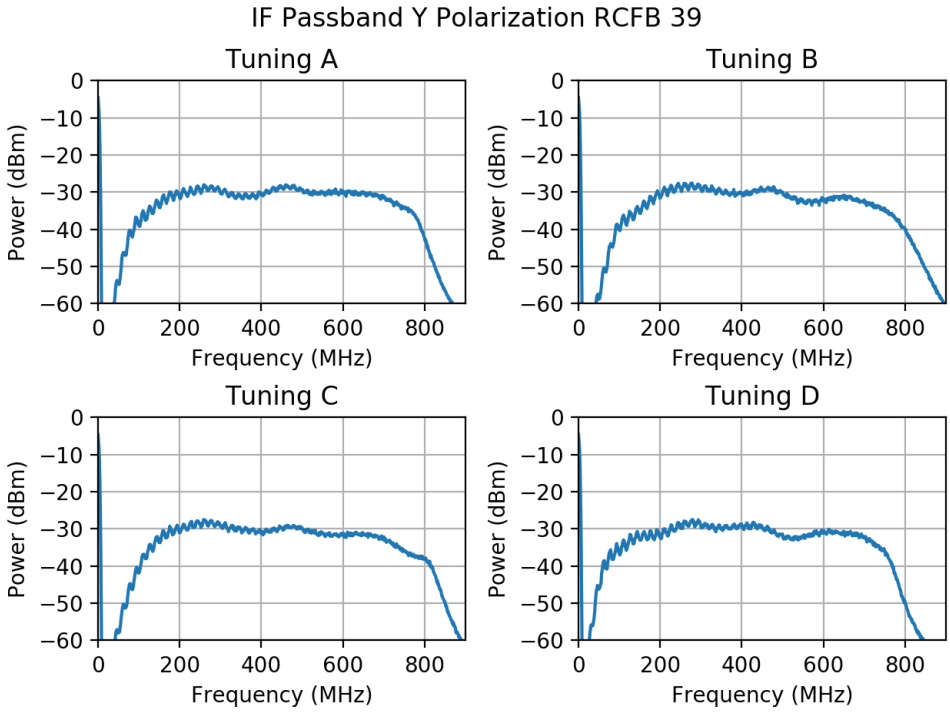
3.27 RFCB 38 (Antenna 1G)



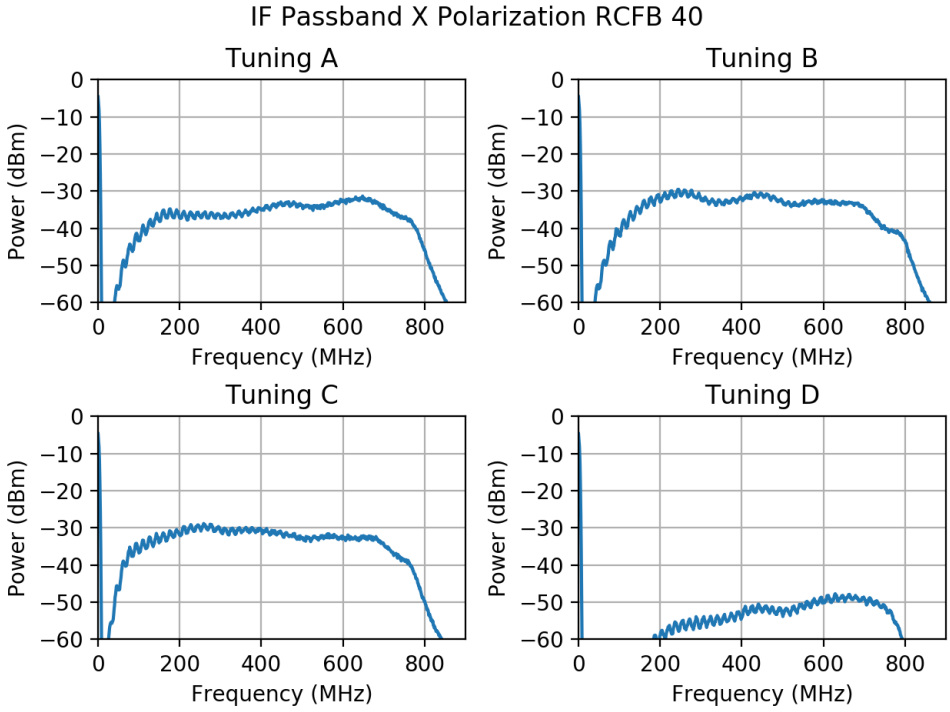


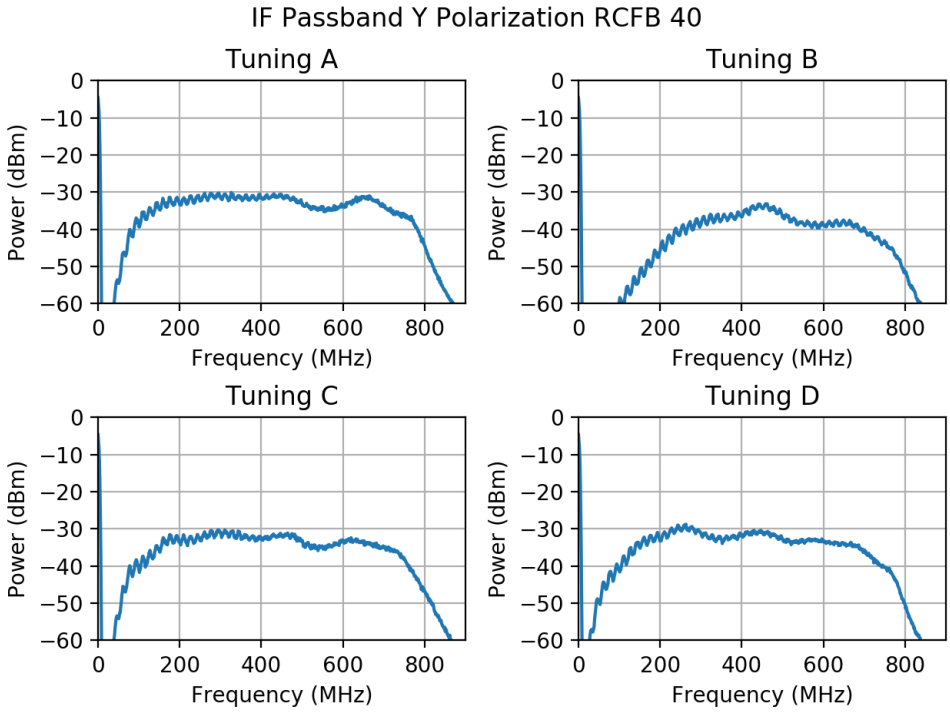
3.28 RFCB 39 (Antenna 2A)



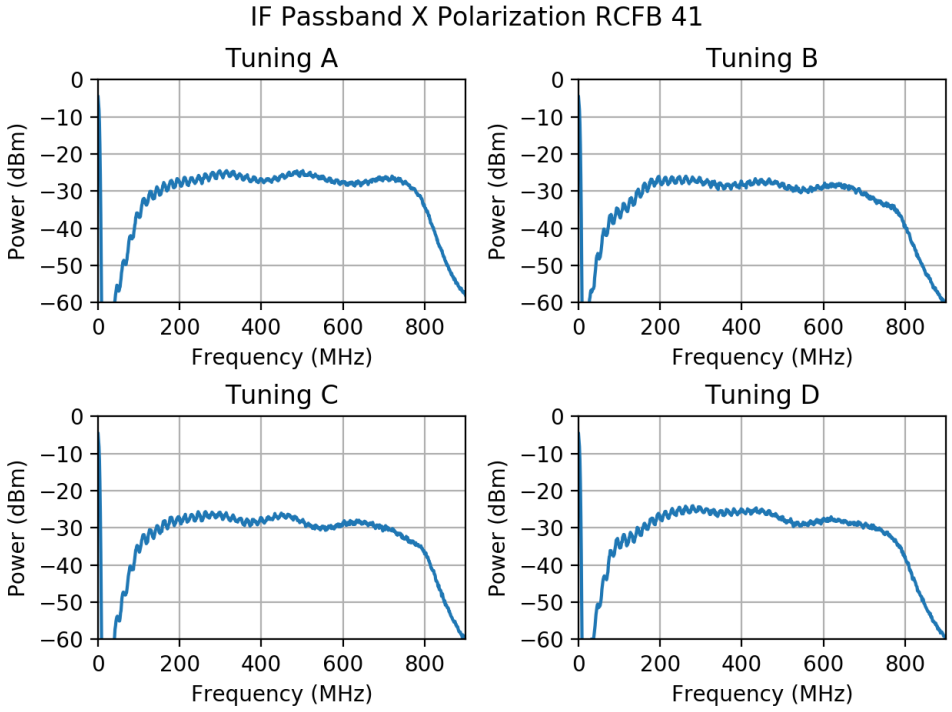


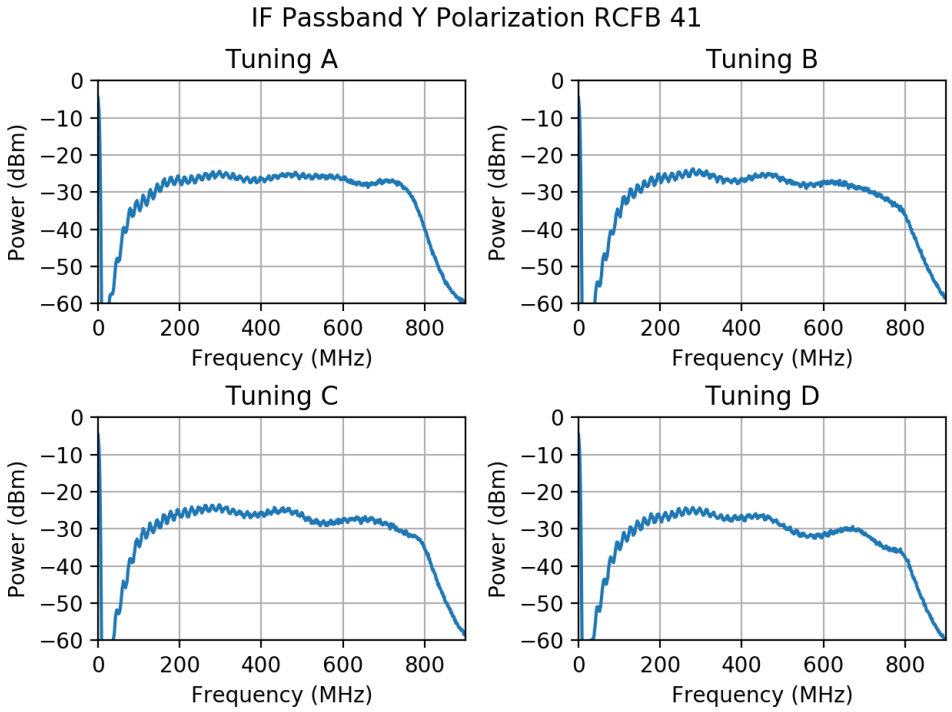
3.29 RFCB 40 (Antenna 1C)



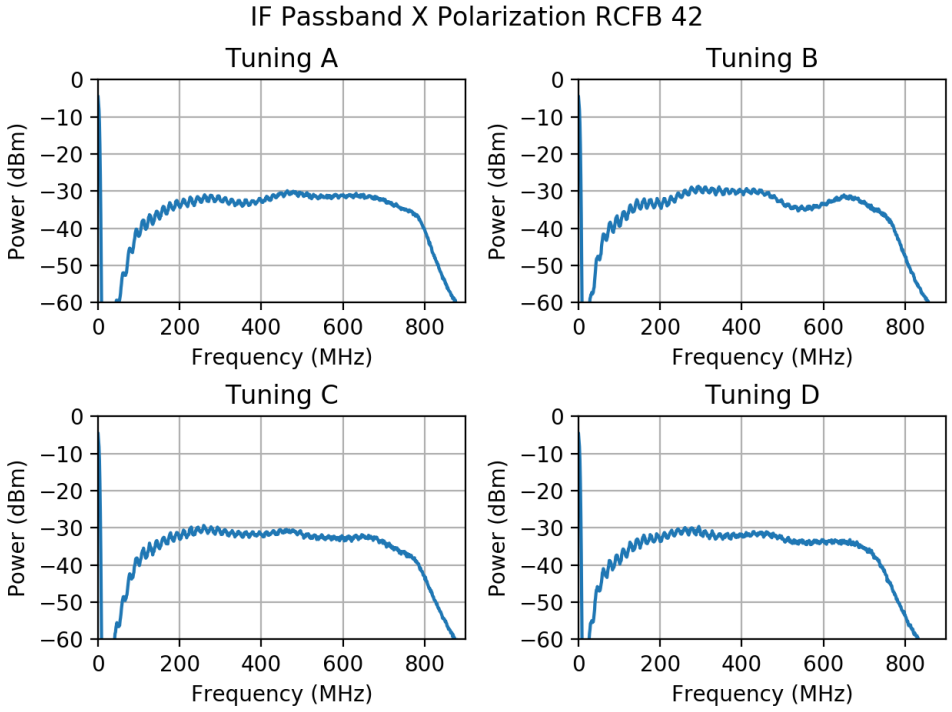


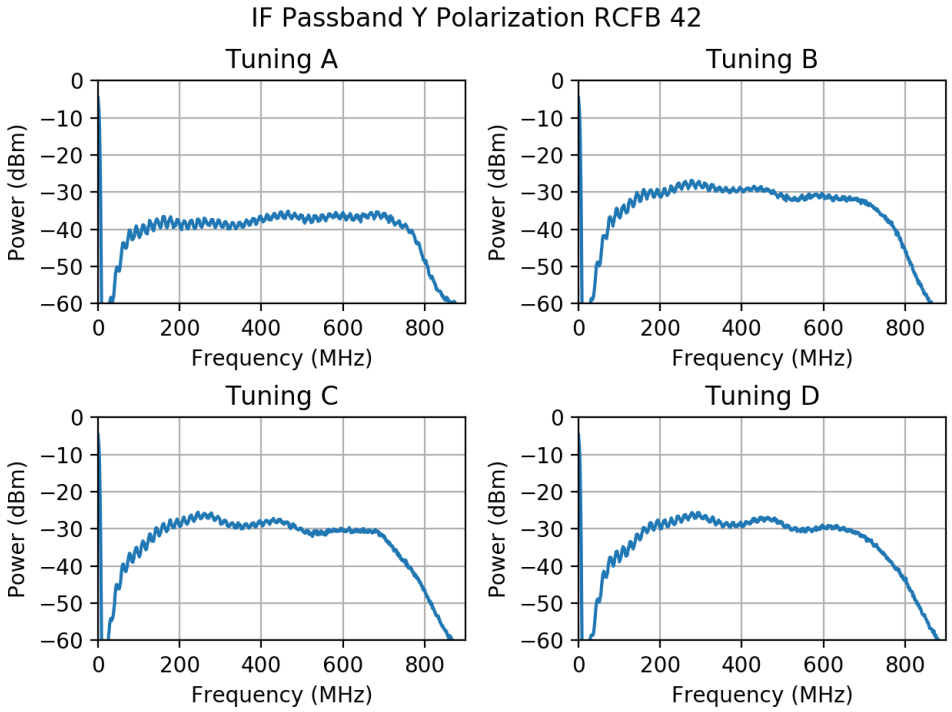
3.30 RFCB 41 (Antenna 4L)



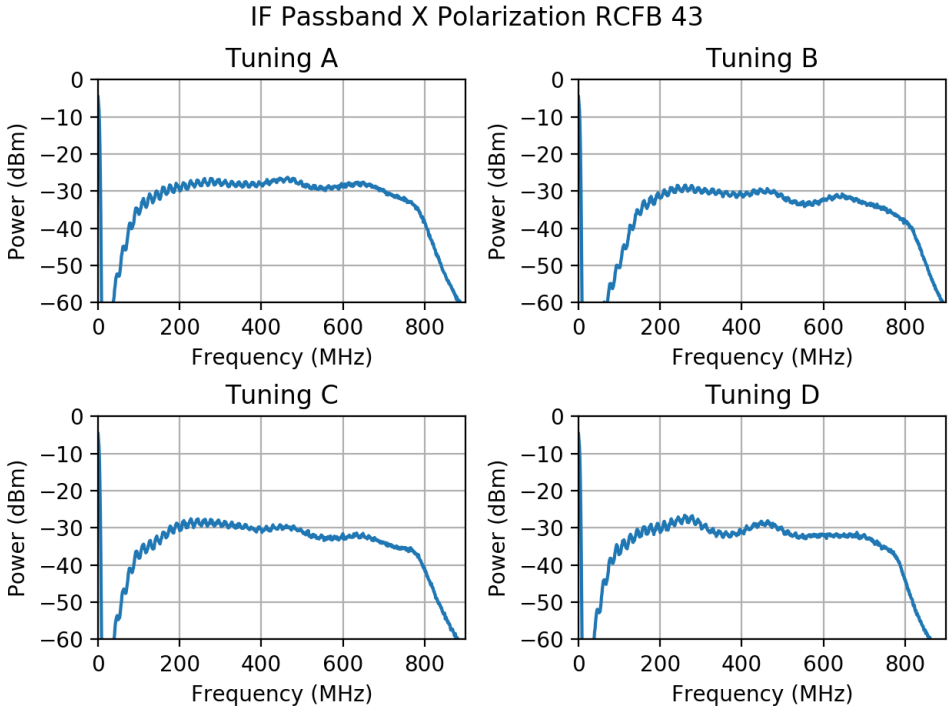


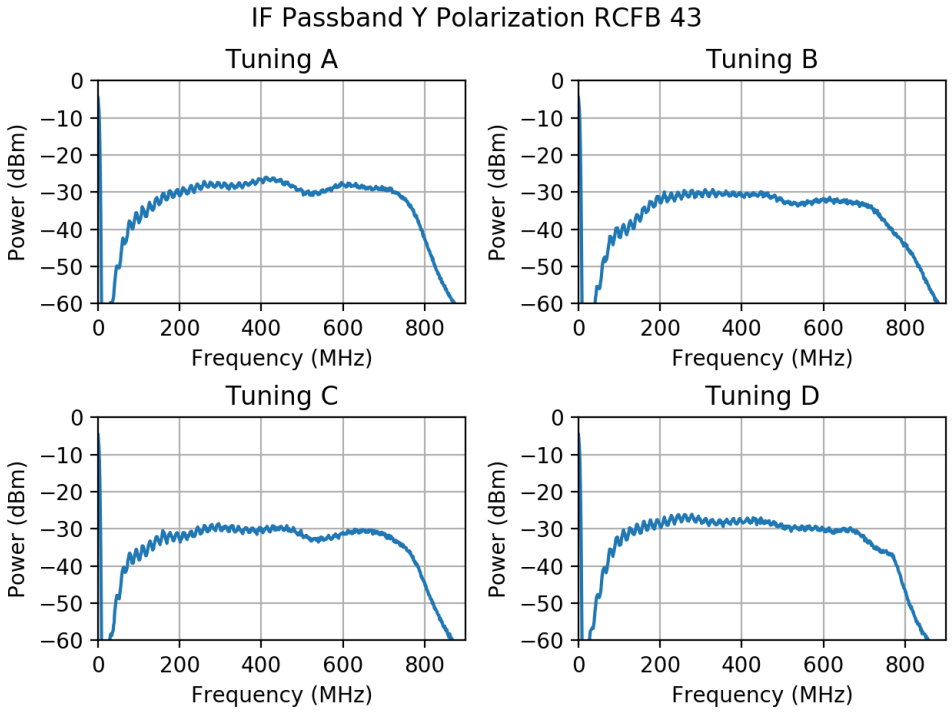
3.31 RFCB 42 (Antenna 1F)



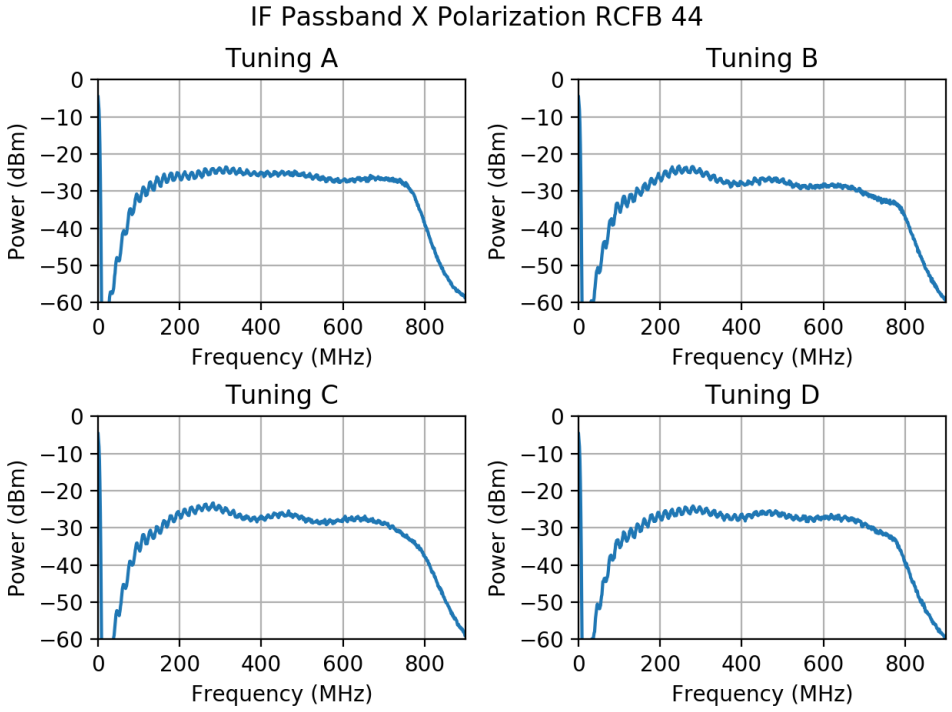


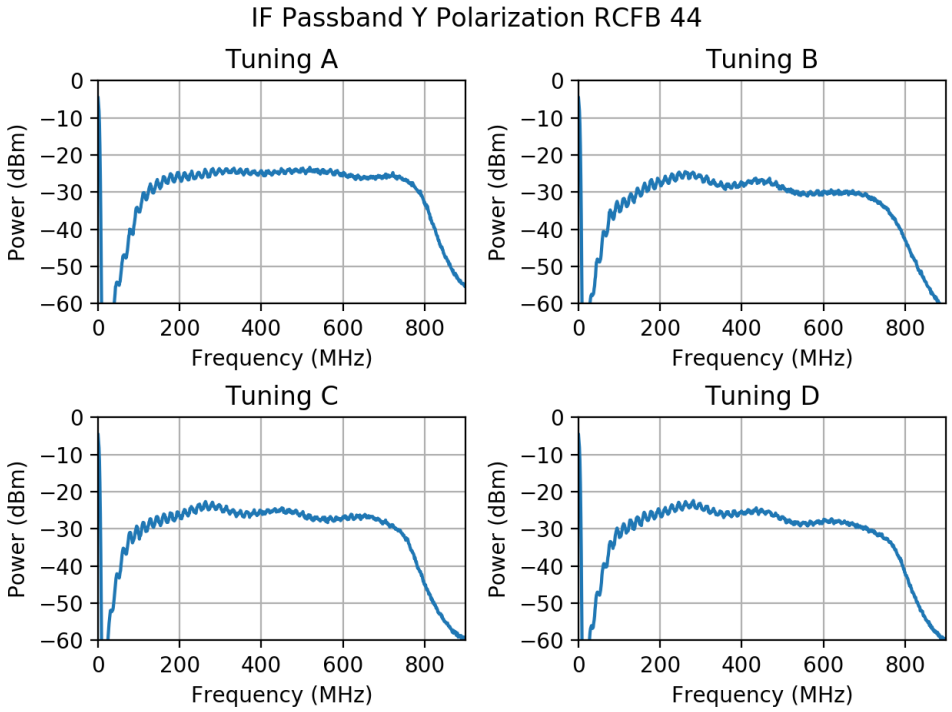
3.32 RFCB 43 (Antenna 4E)



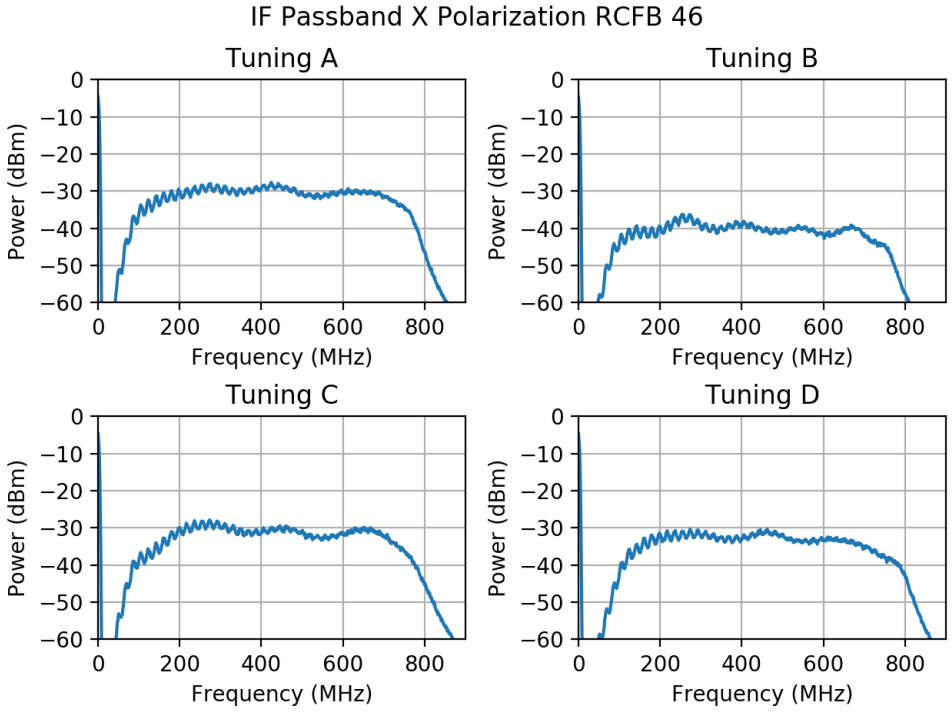


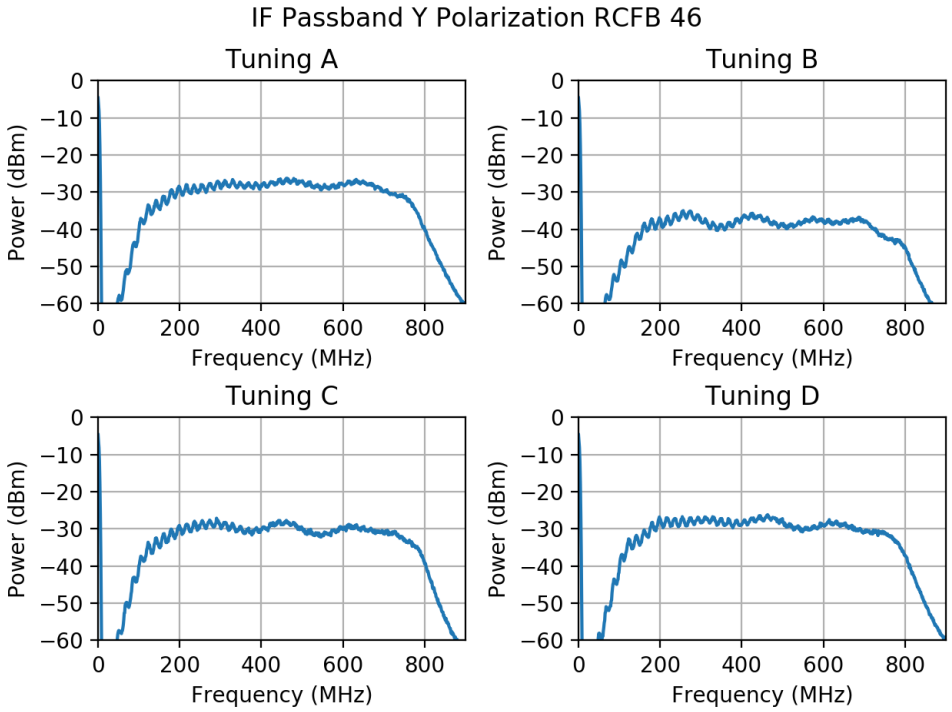
3.33 RFCB 44 (Antenna 4E)



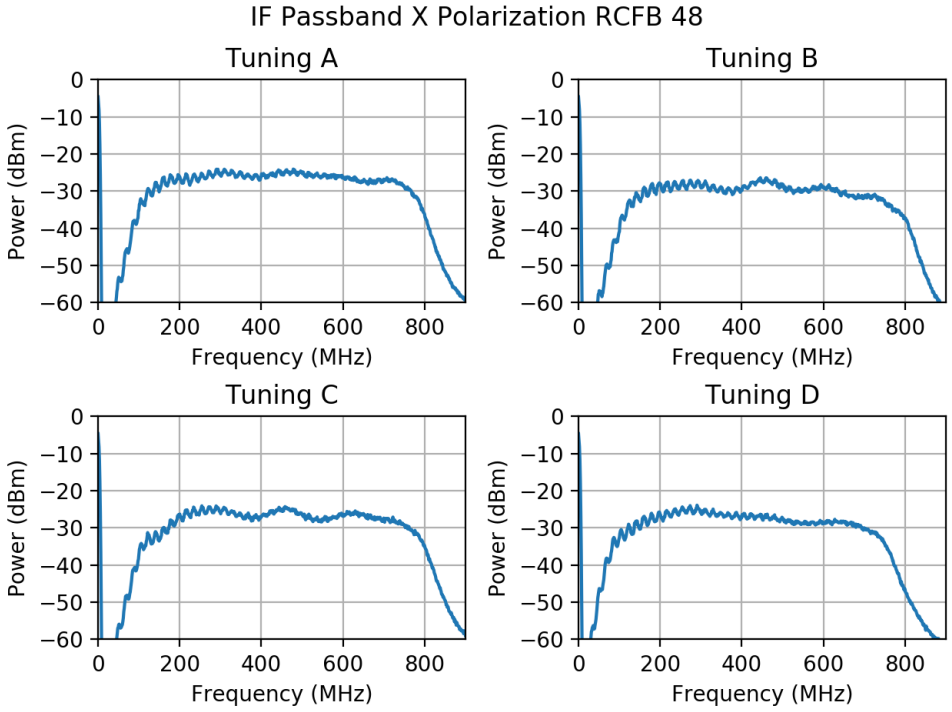


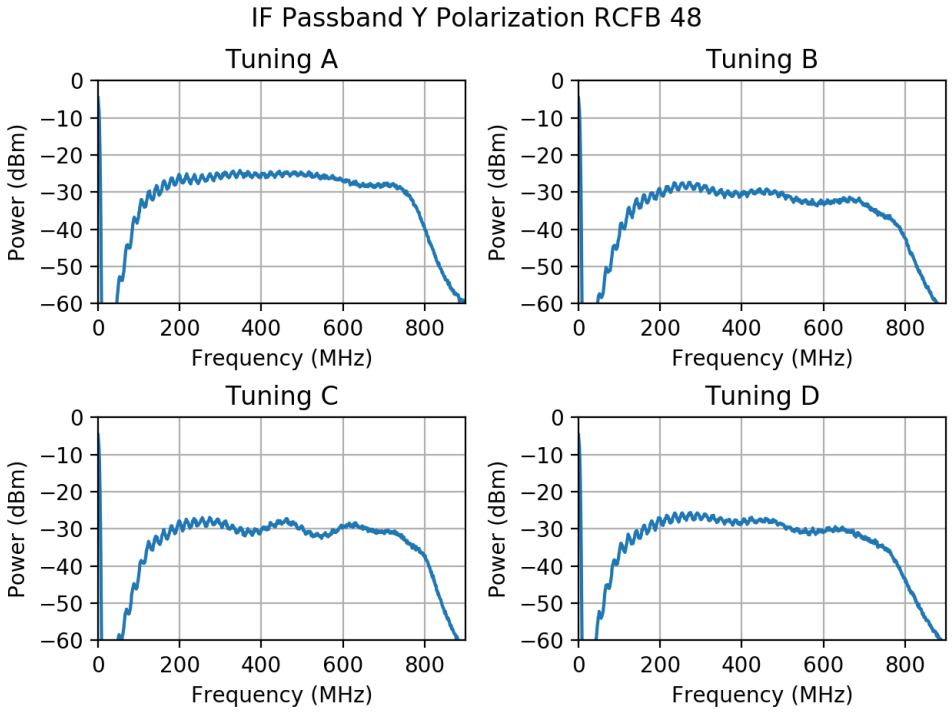
3.34 RFCB 46 (Antenna 3L)



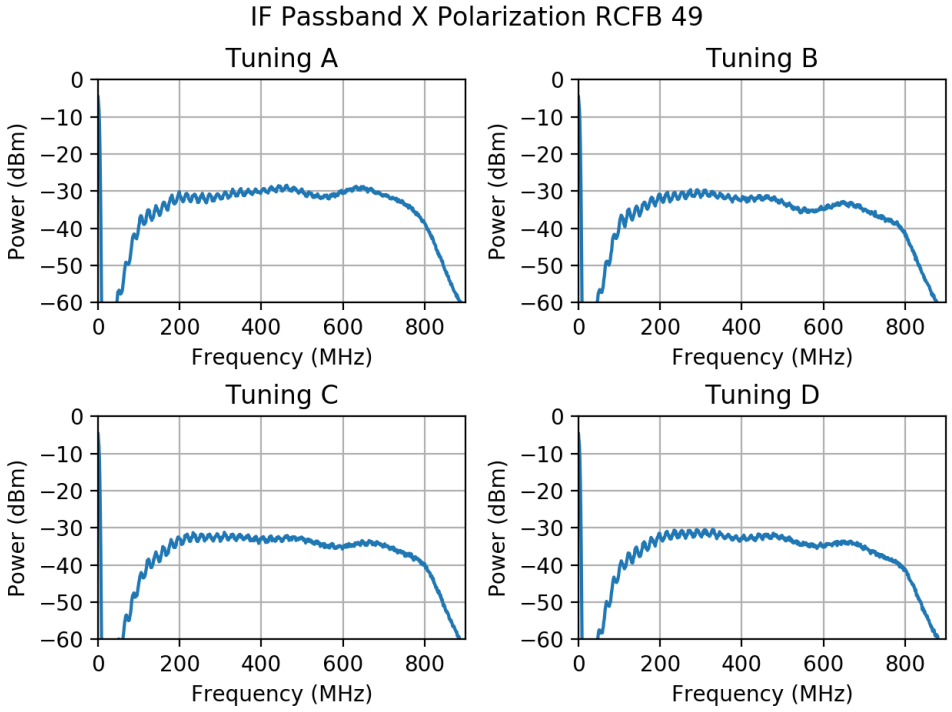


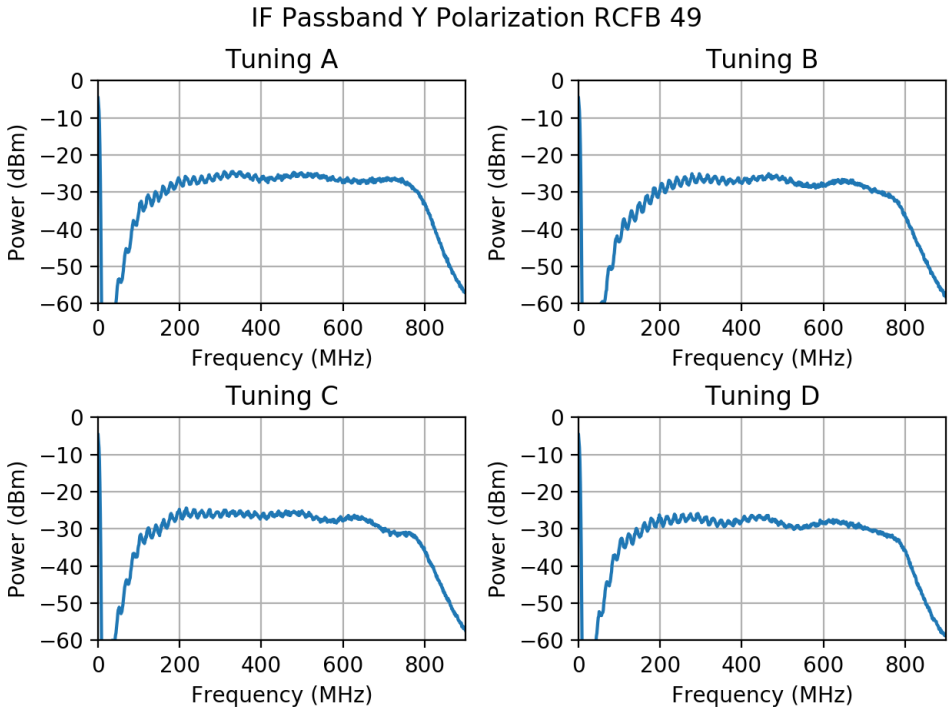
3.35 RFCB 48 (Antenna 3C)



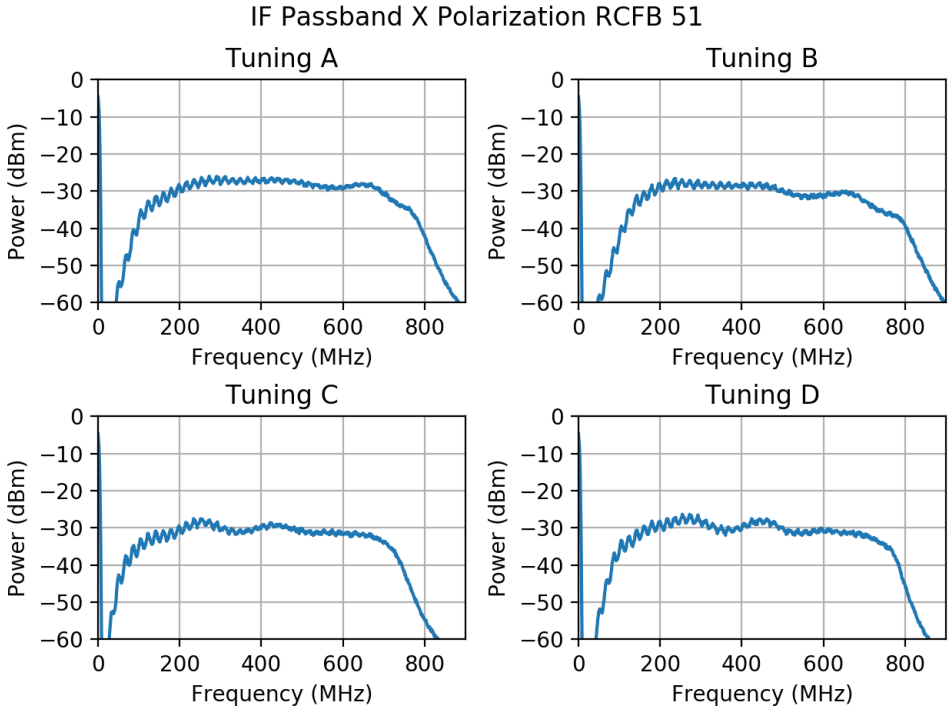


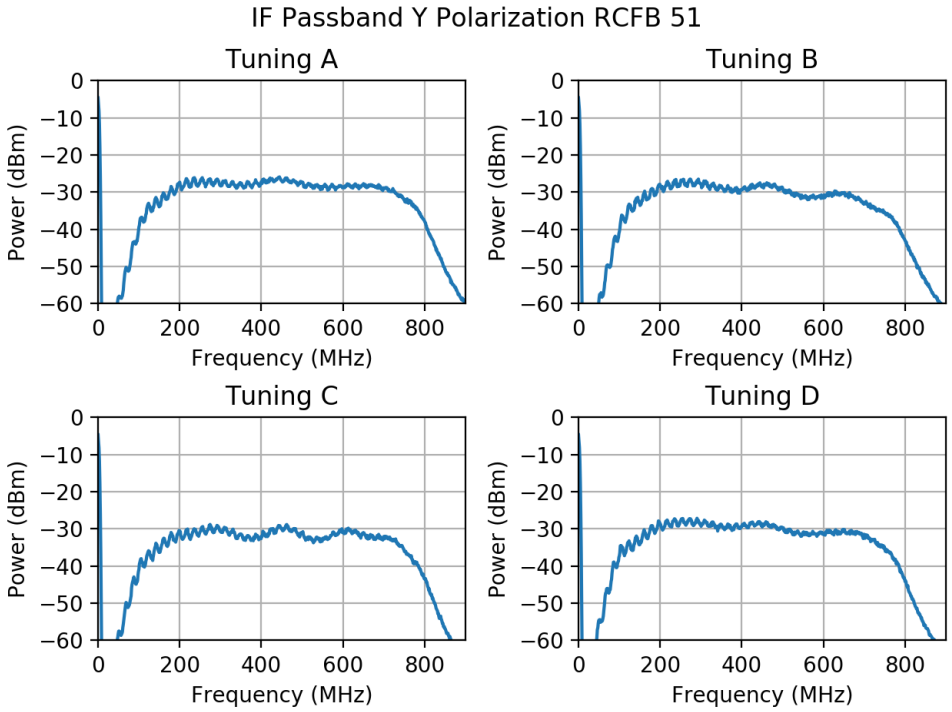
3.36 RFCB 49 (Antenna 3J)



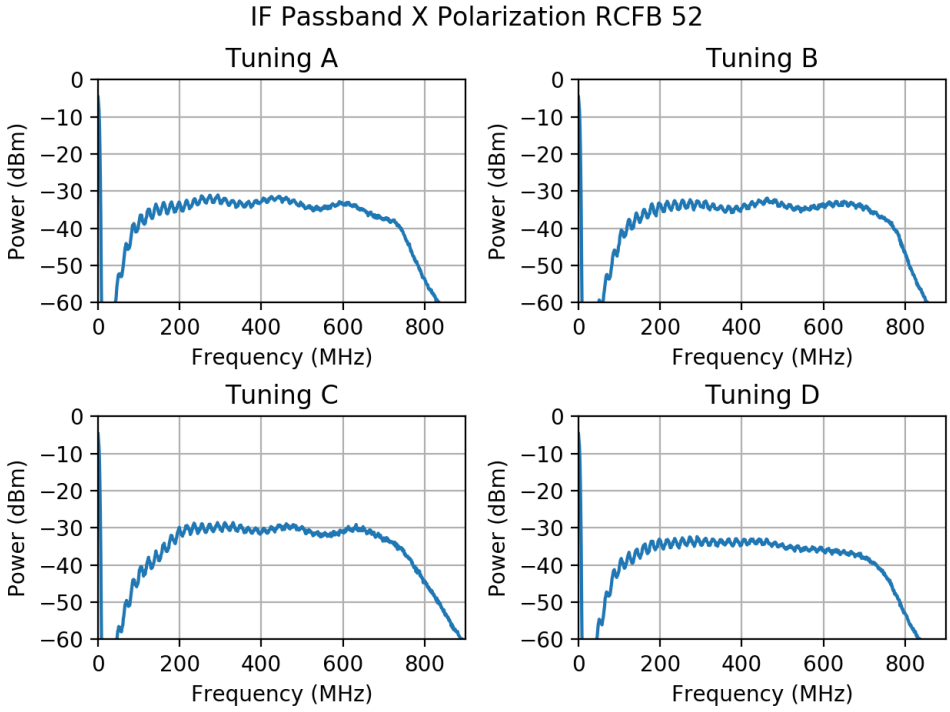


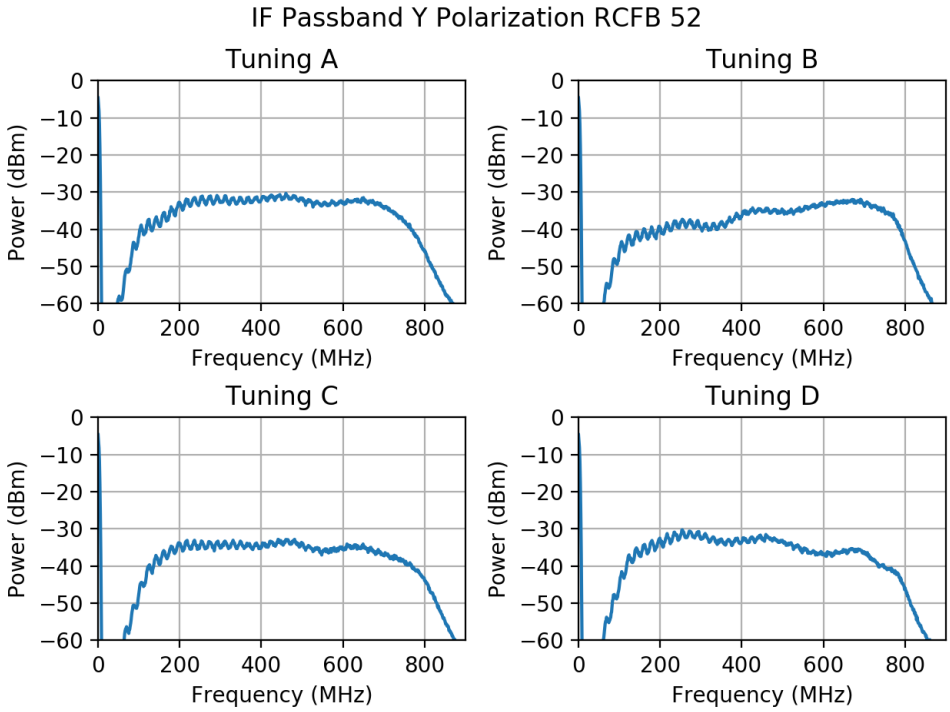
3.37 RFCB 51 (Antenna 5E)





3.38 RFCB 52 (Antenna 5H)





4 Conclusion

For the most part, the power meter results are encouraging. Out of 296 IF tunnings, 275 had their power range from 0 – -10 dBm. The remaining 21 tunnings fell below -10 dBm thus indicating a defect. Currently, the precise defect or defects causing these lower power readings are unknown and therefore need further investigation with future measurements.

The spectrum analyzer results are more mixed than that of the power meter. While the shape of most of the passbands are as expected, the ringing that appears in all 296 IF tunnings is not. Furthermore, the source of the ringing is as yet unknown and needs to be investigated in future measurements. The discovery of the ringing is the most concerning and important out of all the finding from these measurements, for due to how widespread it is, it can significantly impact telescope observations.