EVLA Memo #187
The effect of RFI on 3-bit data at C-band

Minnie Y. Mao and Rick Perley
NRAO

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Abstract

We tested the 3-bit system to determine whether strong RFI from the Satellite Belt adversely affects C-band data over the entire baseband. We see no evidence for such effects and hence conclude that there is no need to alter the frequency coverage of the current default set-up.

1 Introduction

The 3-bit samplers on the VLA enable observations of up to 8 GHz of instantaneous bandwidth. In contrast to the 8-bit samplers (with 2 GHz of instantaneous bandwidth), this wider bandwidth means it is more difficult to find RFI-free areas of frequency-space to center the basebands. At C-band (4 – 8 GHz), using the 3-bit samplers covers the entire frequency range. There was some concern that the strong RFI from satellites in the Satellite (Clarke) Belt at ∼4.0 – 4.2 GHz would saturate the 3-bit samplers thereby causing the entire baseband's data to be lost or compromised. This is not a concern with the 8-bit samplers because there is much more headroom to cope with the large RFI amplitudes. At the latitude of the VLA (34.079°N), the Satellite Belt is at declination$\sim -5.5°$.

The Observatory has considered defining the default set-up at C-band using the 3-bit system near the Satellite Belt to avoid ∼4.0 – 4.2 GHz. This would decrease the instantaneous bandwidth to 3.8 GHz, as the 3-bit samplers already span the entire 4 – 8 GHz frequency range. Moreover, having two different set-ups is not ideal and may cause confusion amongst users.

Here we test the 3-bit samplers in C-band to determine whether quality data may be obtained when there is strong RFI present, and hence whether the current default set-up is adequate, or requires modification.

2 Observations and Data Reduction

The observations were set-up at C-band using the default 3/8-bit hybrid setting. Table 1 shows the 18 fields that were observed: nine calibrators and nine "off" fields (empty fields two degrees East of the calibrator). The calibrators were selected $\sim -15 <$ declination $<\sim +49$ so as to span the area of the Satellite Belt, as well as "clean" parts of the sky. Observations were taken on the 14th of February 2014 for one hour in A-configuration. No flux calibrator was observed, thus all flux density measurements are bootstrapped off J2355+4950, which was assumed to have a flux density of 1.6 Jy. The "calibrator" fields were observed for ∼4 minutes and the "off" fields were observed for ∼1.5 minutes.

The data were reduced using AIPS. The strong RFI from satellites in the Satellite Belt is predominately at ∼4.0 – 4.2 GHz (Figure 1). The data at these frequencies are severely compromised

Scan	Source	Timerange	RA(2000.0)	Dec(2000.0)
1	J2355+4950	0/18:16:32 - 0/18:19:30	23:55:09.4582	49:50:08.340
2	J2355OFF	0/18:19:31 - 0/18:21:00	23:42:45.2600	49:50:08.340
3	J2340+2641	0/18:21:02 - 0/18:26:28	23:40:29.0295	26:41:56.805
4	J2340OFF	0/18:26:30 - 0/18:27:58	23:31:31.7400	26:41:56.800
5	J2330+1100	0/18:28:01 - 0/18:31:57	23:30:40.8523	11:00:18.710
6	J2330OFF	0/18:32:00 - 0/18:33:28	23:22:31.8540	11:00:18.710
7	J2320+0513	0/18:33:29 - 0/18:37:28	23:20:44.8566	05:13:49.953
8	J2320OFF	0/18:37:30 - 0/18:38:56	23:12:42.8600	05:13:49.950
9	J0016-0015	0/18:38:59 - 0/18:42:57	00:16:11.0886	-00:15:12.445
10	J0016OFF	0/18:42:58 - 0/18:44:26	00:08:11.0850	-00:15:12.445
11	J2323-0317	0/18:44:27 - 0/18:48:25	23:23:31.9538	-03:17:05.024
12	J2323OFF	0/18:48:27 - 0/18:49:55	23:15:31.1600	-03:17:05.024
13	J0006-0623	0/18:49:56 - 0/18:53:54	00:06:13.8929	-06:23:35.335
14	J0006OFF	0/18:53:57 - 0/18:55:25	23:58:10.8860	-06:23:35.340
15	J2358-1020	0/18:55:26 - 0/18:59:23	23:58:10.8824	-10:20:08.611
16	J2358OFF	0/18:59:25 - 0/19:00:53	23:50:10.8863	-10:20:08.611
17	J2354-1513	0/19:00:56 - 0/19:04:52	23:54:30.1952	-15:13:11.213
18	J2354OFF	0/19:04:55 - 0/19:06:23	23:46:12.7500	-15:13:11.210

Table 1: Source positions and observation times.

regardless of whether the 3-bit or the 8-bit samplers are used. Here we are testing to see if the remainder of the baseband will suffer from a degradation in sensitivity. Consequently, all analysis was performed on a (single-channel) 2 MHz window centered at 4.666 GHz. The resulting sensitivities are shown in Table 2.

3 Results and Discussion

Figure 2 shows the system temperature (Tsys) as a function of time. The Tsys is generally ∼30–40K. At the spectral windows corresponding to ∼4.0 – 4.2 GHz (IFs 33–34 for 8-bit, and IFs 1–2 for 3-bit), the Tsys reaches 200-300K when observing near the Satellite Belt (UTC ∼ 18:45:00 – 18:55:00 corresponds to the sources at declination -3:17:05 and -06:23:35).

Table 2 shows the rms for the observed fields using both the 8-bit and the 3-bit samplers at 4.666 GHz with a 2 MHz bandwidth. This part of the spectrum was chosen as it is free of strong RFI sources. The values are close to that predicted using the online exposure calculator and as expected, the 3-bit system is less sensitive than the 8-bit system by ∼ 14.8%. The slightly higher values of the observations compared to the theoretical may be attributed to the lack of proper flux calibration. There is no evidence for observations being less sensitive near the declination of the Satellite Belt (∼-5.5°). The rms is higher in the "off" fields at dec ∼ 5° and -10° due to the presence of sources in the field.

4 Conclusions

We see no evidence for a degradation in sensitivity in the RFI-free spectral windows when observing near the Satellite Belt using the 3-bit system at C-band. Consequently, we conclude that the current default set-up does not require any modification.

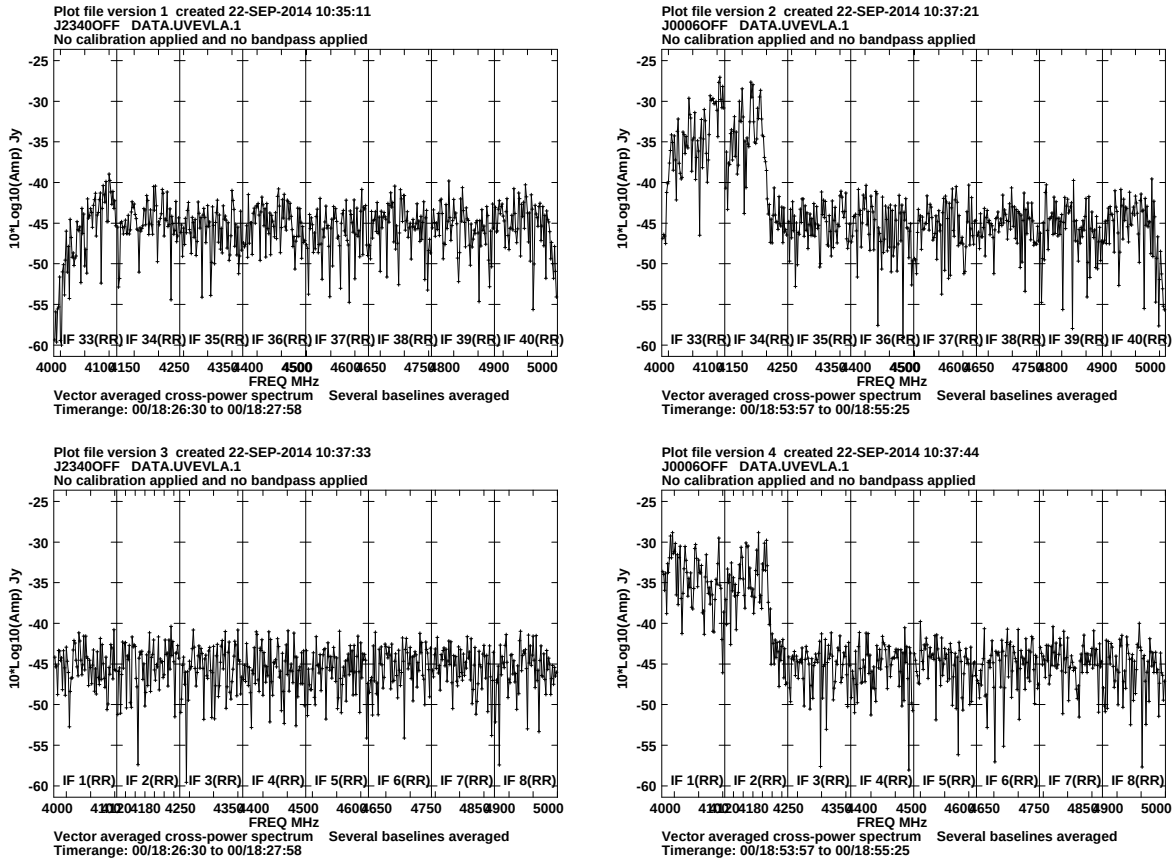

Figure 1: Left: Amplitude (in dB) as a function of frequency for J2340OFF (declination $\sim +49°$). Right: The same again for J0006OFF (declination $\sim -6^6\circ$). The Top panels display data from the 8-bit system and the Bottom panels display data from the 3-bit system. At declinations close to the satellite belt, the spectral flux density of the first two spectral windows is $\sim$10 - 15 dB higher than the "RFI-clean" spectral windows.

Source	8-bit rms ($Jy\,bm^{-1}$)	8-bit $S_{4.666\,GHz}$ (Jy)	3-bit rms ($Jy\,bm^{-1}$)	3-bit $S_{4.666\,GHz}$ (Jy)
J2355+4950	2.441e-4	1.585	2.705e-4	1.584
J2355OFF	8.730e-4		9.866e-4	
J2340+2641	2.070e-4	1.128	2.326e-4	1.127
J2340OFF	8.453e-4		1.005e-3	
J2330+11	2.077e-4	1.468	2.215e-4	1.470
J2330OFF	9.238e-4		1.099e-3	
J2320+05	2.226e-4	1.085	2.498e-4	1.084
J2320OFF	9.594e-4		1.085e-3	
J0016-00	2.719e-4	0.617	3.467e-4	0.623
J0016OFF	9.264e-4		1.108e-3	
J2323-03	2.261e-4	1.111	2.554e-4	1.103
J2323OFF	8.938e-4		1.117e-3	
J0006-06	3.090e-4	2.444	2.854e-4	2.435
J0006OFF	8.560e-4		1.071e-3	
J2358-10	2.603e-4	1.592	3.148e-4	1.590
J2358OFF	9.979e-4		1.075e-3	
J2354-15	2.484e-4	1.047	2.933e-4	1.041
J2354OFF	9.299e-4		1.095e-3	

Table 2: The rms values for the observed fields at 4.666 GHz with a 2 MHz bandwidth. The flux density provided is the measured value when bootstrapped off J2355+4950.

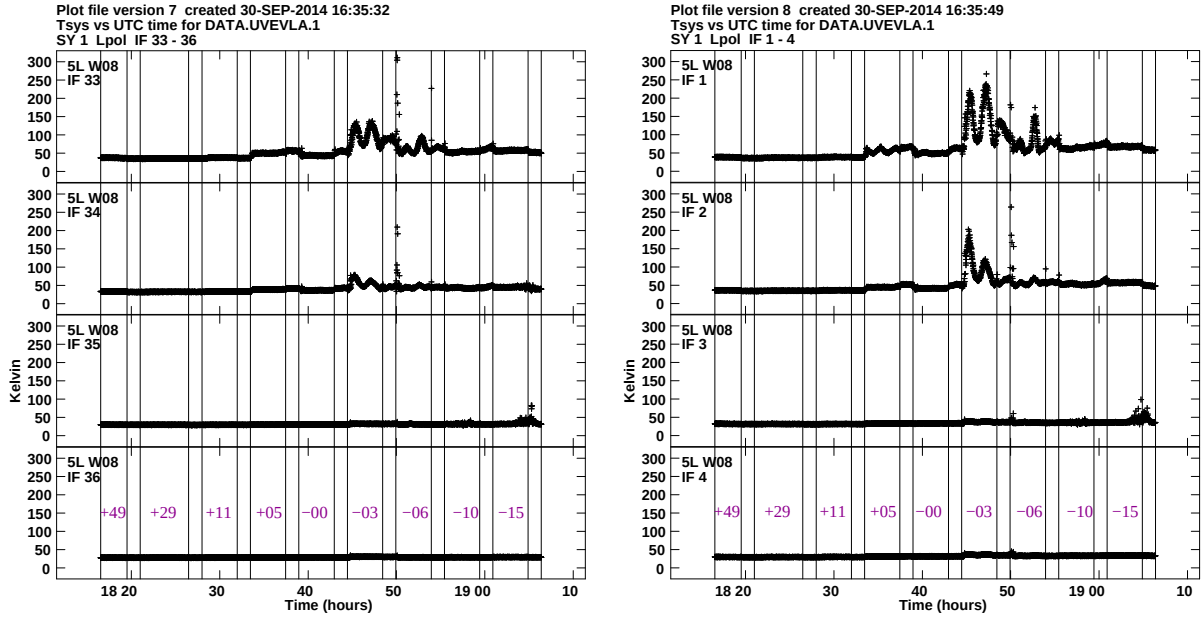

Figure 2: Left: System temperature vs UTC time for each spectral window from EA05 using the 8-bit samplers. Scan boundaries are shown as vertical lines. The declinations of the sources are marked in magenta on the lowest panel. Only the first four spectral windows are shown in each plot as the remaining spectral windows look similar to the bottom two spectral windows. Right: Same as left panel except using 3-bit samplers.

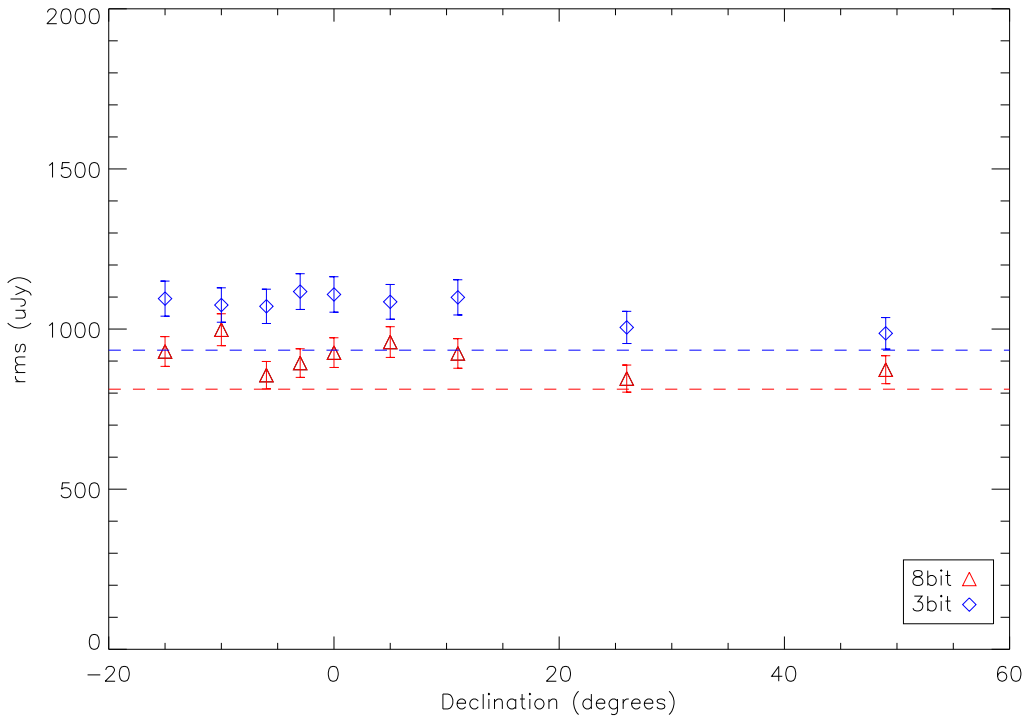

Figure 3: The rms of the "off" fields plotted as a function of declination. Errors on the rms were measured to be $\sim 5\%$. There is no evidence that the rms increases near -5.5°, the declination of the Satellite Belt. The dashed lines are the theoretical rms as determined using the online exposure calculator.