L-band RFI from VoIP phones.

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1 Summary.

Using the VLA in spectral line mode, we measured the RFI from a phone (NEC D-Term) placed temporarily in the vertex room of VLA antenna 6. The interference is primarily from a comb with 25 MHz spacing. Additional shielding of 70 dB (85dB at 1300MHz) is required to get the NEC phone below the harmful threshold of -200 dBm at 1325-1500 MHz, if the antenna is to observe with its own phone on, and provide uncorrupted autocorrelation spectra.

Leakage measured from antenna 6 into neighbouring antennas shows that ∼35dB shielding allows the rest of the array to continue observations. If we further invoke 13dB of interference suppression in an image, at any fringe rate, from incoherent addition of 351 baselines, (EVLA Memo 49, Perley) then 23dB suppression is enough.

More recent laboratory measurements [Fig. 1, see also memo from Mertely, 2006 Jan 05] show other VoIP phones to be better. The Avaya phone is ∼15dB quieter than the NEC and has shielding requirements over 1-2GHz of:
(a) 55dB [antenna in use, autocorrelations usable];
(b) 20dB [antenna out of use, autocorrelations of other antennas usable]. The estimated cost is under $500 per antenna, as discussed by Mertely.
(c) 8dB [antenna out of use, imaging OK, autocorrelation spectra of others possibly corrupted].

Based on the L-band measurements, we extrapolate the laboratory spectra (i.e. measured in the RFI chamber) to the expected emission levels on the array. The required shielding is ∼15dB less at C band, ∼10dB less at S band, and ∼10dB more at 330MHz. 75MHz is unmeasured, we assume it requires least as much shielding as 330MHz.

Finally, a calibration signal emitted in the vertex room of EVLA ant.14 showed ∼70dB loss to the receiver, very similar to VLA antennas 6 and 22. Independent tests by Mertely [2005 Feb 09 & 15] on EVLA L-band feed no.2 (ant.14) gave ∼65dB over 1.2-2GHz, 43dB at 1GHz. Feed no.1 (ant 13) gave ∼90dB shielding over 1-2GHz. An obvious action item is to identify the reason for the high shielding in no.1, and duplicate it.

2 Results

1. Measurements in the RFI chamber show the unshielded level of several spikes from the NEC phone over 1300-1500 MHz is -55±5 dBm, with spikes ∼5 dB higher seen below

1GHz. To keep it simple we covered just 1287-1513 MHz, RCP, IF A, 6.25 MHz BW, 50 KHz resolution, 40 sec integration at each setting.

2. The 25 MHz harmonics from the phone are strong in the autocorrelation spectra of antenna 6, and absent with the phone off. The measured levels in the receiver are -115 to -140dBm, most tones are at -130dBm. The detection threshold in autocorrelation was -150dBm. All these levels are referred to the receiver input.

3. A calibration tone was radiated in the vertex room at -70 dBm and shows up in the receiver at -140dBm. This shielding is $\sim$10 dB less than found by Ridgeway, but there were additional absorbers (people!) in the vertex room during that measurement.

4. The emission from the phone, measured on the VLA, mostly agrees with the lab measurement (Fig. 1), after accounting for the shielding from vertex room interior to L-band receiver, L_{V-Rx}, of 70 dB, consistent with the previous item.

5. However, the phone emission (or the leakage between vertex room and receiver) may be strongly frequency and direction dependent. The 1300 MHz emission in particular was 10-15 dB stronger on the VLA than in the lab.

6. Thus, the interference from a phone in the vertex room to the L-band receiver in the same antenna needs **70-85dB additional shielding, if the antenna is to produce uncorrupted autocorrelation spectra with its own phone on.**

7. Lower-level leakage (below about -170dBm, Fig.3) is seen into most other VLA antennas, where it correlates with antenna 6. Based on the measured cross-power spectra of several antennas at each 25MHz harmonic, the highest signal in other antennas (not always the closest) indicates that 35dB additional shielding of the phone, in an antenna being serviced, permits the rest of the array to continue observing. From Fig. 2, only antenna 6 is more than 35dB above the harmful threshold of -200dBm.

8. The shielding levels above are based on the ITU harmful levels for single-dish use. This test was done tracking the North pole, in D-array, so the attenuation from fringe winding was negligible. EVLA memo 49 by Perley gives the result of imaging simulations, showing that a minimum of 13dB attenuation of interference in an image occurs for **any** fringe rate, from the incoherent addition of 351 baselines. Applying this result, just 23dB reduction of the NEC VoIP phone emission would allow their use on an out-of-service antenna, while the rest of the array continued observing, even in the D or E arrays, even close to the pole where fringe rotation does not mitigate the interference.

3 Other Details

3.1 Calibration of L-band Feed Leakage.

Data were taken with the VoIP on and off. During the off sweep a signal generator emitted 1343 MHz at -70 dBm as a calibration beacon in the vertex room, which leaked into the receiver at -141 dBm (VLA ant.6). Ylva Pihlstrom, EVLA Memo 47, Oct. 2002, got a near-identical result on VLA antenna 22: -70 dBm at 1440 MHz in the vertex room was received at -143 dBm.

Ant.14 (EVLA L-band feed no.2) was measured by us at 1397MHz, and is comparable to the VLA feeds at 1300-1500MHz, see table 1. Independent measurements by Mertely give >65dB shielding from 1200-2000MHz, but only 43dB at 1GHz for feed no.2. Feed no.1 (EVLA ant.13) gave 80-90dB shielding from 1-2GHz. See Table-2. **Action: identify the reasons (e.g. manufacturing practice?) and maintain better shielding on subsequent feeds.**

3.2 Calibration of Signal Strength

The calibration (Fig. 2) is done by comparing the line strength to the known T_{sys} in the band. The mean noise power, i.e. the pedestal under the line, is P_{sys} = ($k.T_{sys}.B$) = -137 dBm, for T_{sys}=30K, B=50KHz. A line that doubles the system noise in 1 channel is -137 dBm. The weakest line reliably identifiable in autocorrelation was 5% of P_{sys} or -150 dBm. This threshold is limited by systematics such as gain variations to well above the theoretical rms noise of $kT_{sys}B/\sqrt{2B\tau}$ = -169dBm, for integration time τ=40s.

3.3 Leakage into other antennas

The cross correlation data show that the phone signals leak into almost every other antenna. The cross-spectra have the theoretical noise, since the gain variations and other systematics that plague the autocorrelations are eliminated. Weak signals on a remote antenna (e.g. -190dBm, 20dB below the noise) are detectable when multiplied by the strong signal on the reference antenna (e.g. -140dBm, 30dB above the noise).

Antenna 22, the closest south of 6, shows signals 35-70 dB down from antenna 6 at different frequencies, (e.g. -190 dBm at 1300 MHz.) Antenna 11, just north of 6, shows little, over 100 dB down. Many antennas are about 80-90 dB down from 6, at 1300 MHz. A few antennas, not the farthest, show nothing. The leakage appears almost random with distance from ant 6, see Fig. 4. My guess is that the leakage is very frequency and direction dependent. The shielding estimates are based on worst-case assumptions.

3.4 Harmful Threshold

The HT of -199dBm is 10dB below the noise power in 5KHz (=1km/s velocity resolution at L-band), 8hr integration, 30K T_{sys}. The gain of a 1m^2 aperture at 20 cm is 25 dB, so this is equivalent to the threshold of -203dBW/m^2 received in the isotropic sidelobes, as used in other definitions, e.g. EVLA Memo 47.

NEC D-Term VoIP phone on VLA ant.6
2005 Nov 29

F MHz	M_{Rx} dBm	Mert dBm	L_{V-Rx} dB	S_{add} dB	Comment	M_{WN} dBm	S_{WN} dB
1300	-115	-53 -60	62 55	85	15 dB more than lab meas.	-178	22
1325	-129	-60 -68	69 61	71		-175	25
1343	-141	-70 -	71 -	59	cal tone, ant.6.	-193	7
1350	-126	-54 -57	72 69	74		-166	34
1375	-133	-57 -	76 -	67		-181	19
1397	-138	-68	70	60	cal tone, ant.14.	...	...
1400	-128	-54 -64	74 64	72	voip on.	-186	14
1400	-143	- -	- -	-	voip off. VLA birdie	...	...
1425	...	-62 -70	- -	68	Missed scan	...	...
1440	-143	-70 -	73 -	57	cal tone, ant.22.	...	...
1450	-133	-60 -62	73 71	67		-173	27
1475	-143	-70 -73	73 70	57		-171	29
1500	-150	-70 -70	80 80	50		-178	22

NOTES:

- M_{Rx} = Measured at VLA Antenna 6, RCP. Signal levels are referred to the receiver input by comparison to the system temperature. See Fig. 2.
- Mert = Mertely measurement of NEC VoIP, 2 runs in shielded room, +20dB room correction factor applied; see Fig. 1. Also in this column are calibration signals radiated from a signal generator set to -70 dBm, on three different occasions, at 1343, 1397, & 1440 MHz.
- L_{V-Rx} = Inferred loss from vertex room to Rx, comparing col 2, 3.
- S_{add} = Additional shielding to get M_{Rx} below the harmful threshold of -200 dBm. See Fig. 3, black curve.
- M_{WN} = Measured leakage into 'worst neighbour' antenna. Fig. 3, coloured curves.
- S_{WN} = Additional shielding required to get M_{WN} below the harmful threshold for autocorrelations.

EVLA L-Band Feeds:
Measured Shielding
from Vertex Room to Receiver.

F MHz	Feed#1 Ant.13 R dB	L	Feed#2 Ant.14 R dB
1.0	89	80	43
1.1	80	89	54
1.2	89	88	63
1.3	90	95	66
1.4	83	93	65
1.5	93	90	70
1.6	90	91	67
1.7	90	94	67
1.8	90	92	65
1.9	88	86	63
2.0	96	96	74

- Feed uncovered.
- 2005Feb09 (ant 13), F103 SN02 EVLA hybridized VLA L-band receiver with Rich Bradley prototype (narrow-band) LNAs.
- 2005Feb15 (ant 14), F103 SN32 EVLA hybridized VLA L-band receiver with Marian Pospieszalski's wideband InP production LNAs.
- LNA gain data in Mertley email 2005Dec29. Shielding data ('loopback' tests) in Mertley email 2005Dec06.

Antenna Locations
EVLA antennas are 14(W10) and 16(E14)

N9 1

N8 9

N7 26

N6 2

N5 24

N4 7

N2 27

N1 5

21 W1 E1 25

... E2 3

4 W3 E3 17

8 W4 E4 15

... E5 19

23 W6 E6 12

11 W7 ...

6 W8 E8 10

22 W9 E9 28

14 W10 ...

... E14 16

VLA:OUT 13

VLA:OUT 18

VLA:OUT 20

VPT:OUT 29

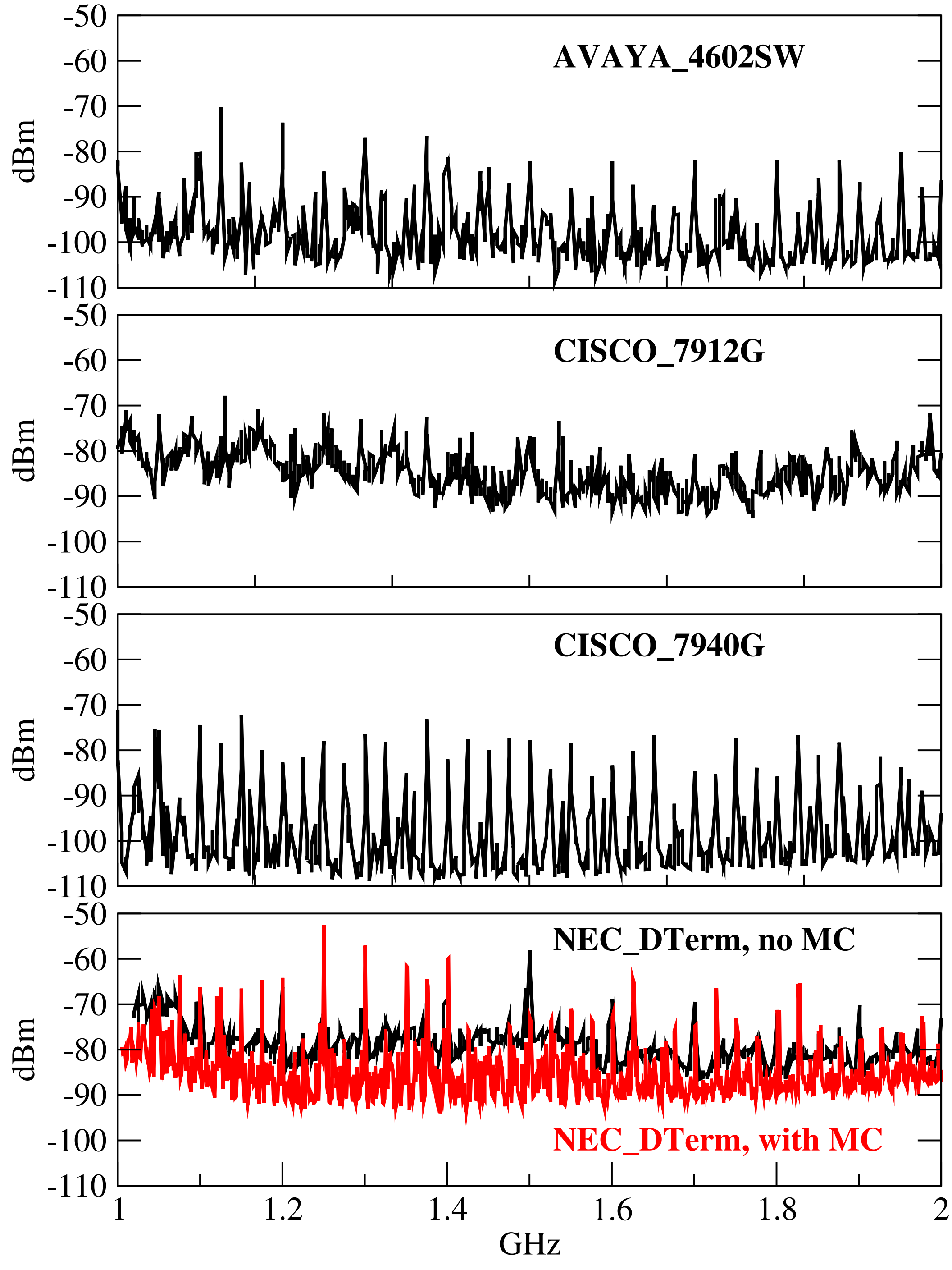

Figure 1: Spectra of several VoIP phones measured in the shielded RFI chamber. The 'chamber loss' of about 20dB has been corrected. Resolution BW 100KHz for the NEC; 1KHz for the others. 'MC = media converter unit. For full details of spectra 1-5GHz, see the memo by Merteley.

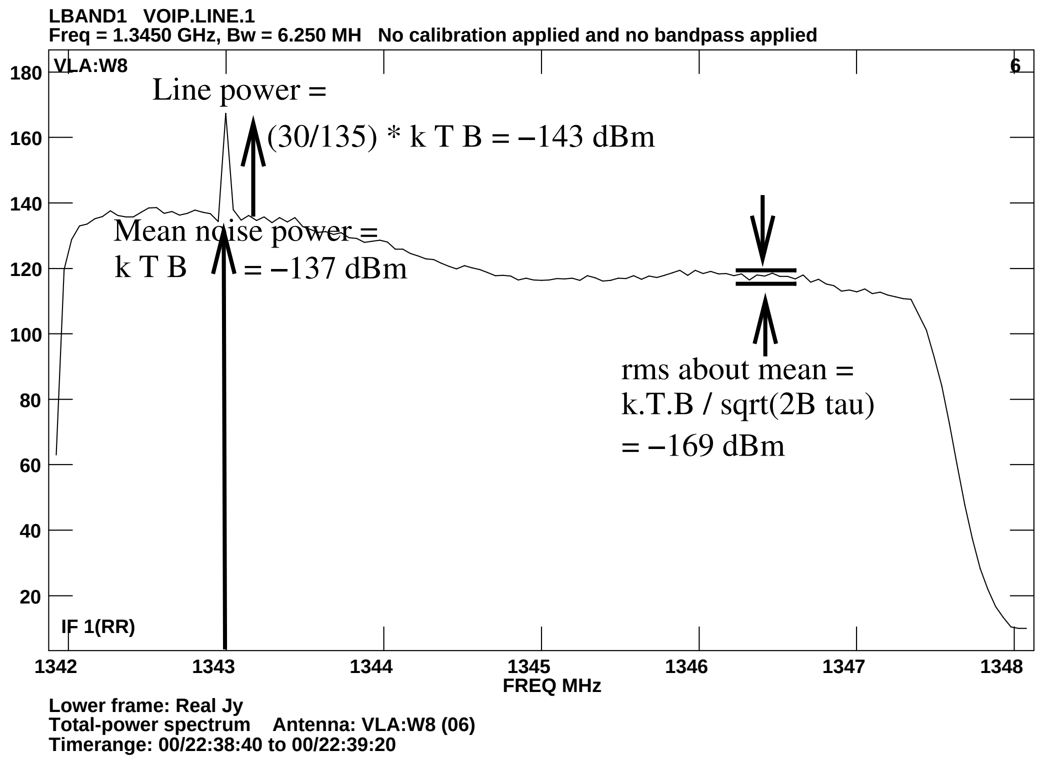

Figure 2: Autocorrelation spectra on ant.6 illustrating the calibration of the received signal in units of the system noise power. The signal of -70dBm in the vertex room leaked into the receiver at -143dBm (shielding of 73dB) at 1343MHz.

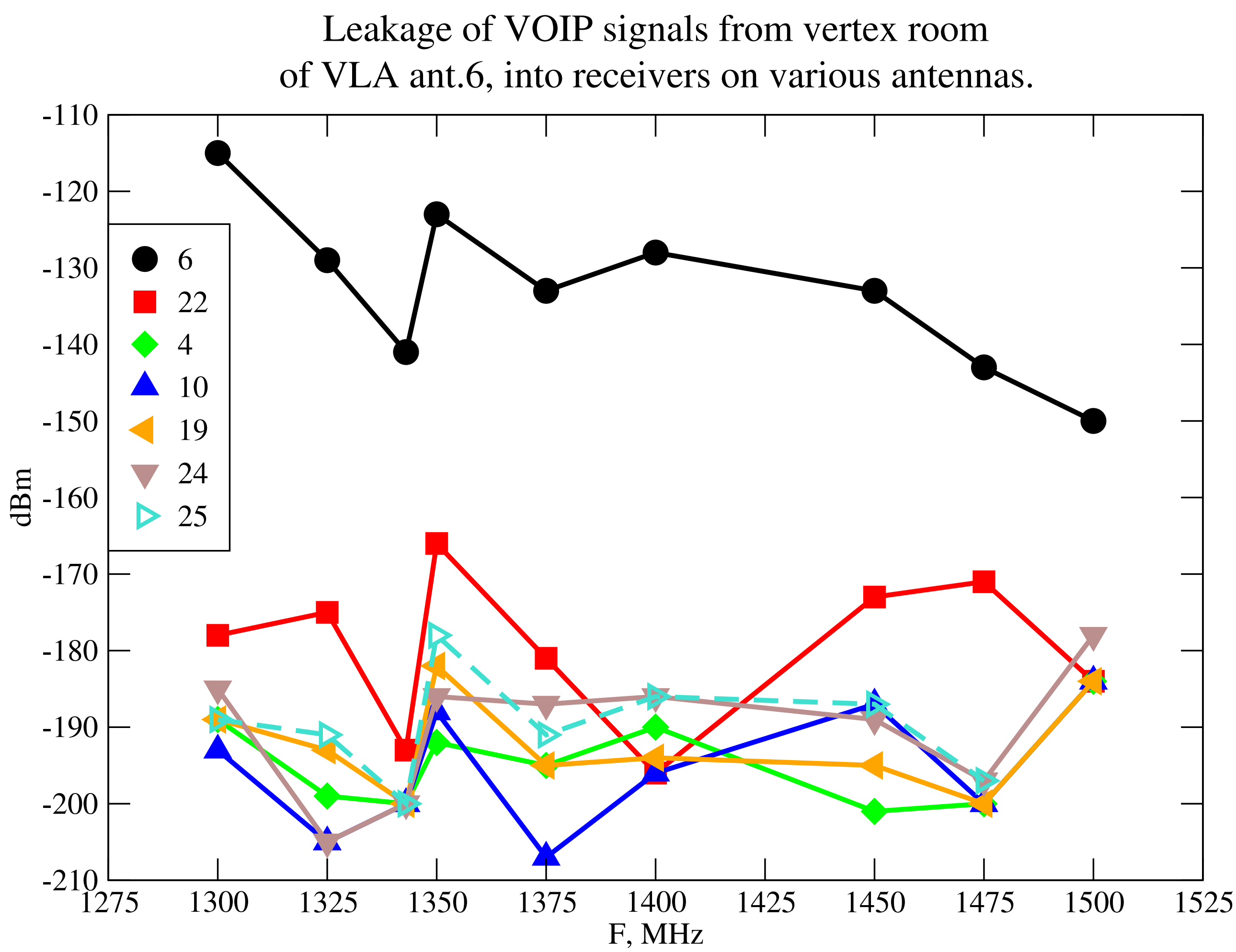
Leakage of VOIP signals from vertex room
of VLA ant.6, into receivers on various antennas.
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
dBm
6
22
4
10
19
24
25
1275
1300
1325
1350
1375
1400
1425
1450
1475
1500
1525
F, MHz

Figure 3:

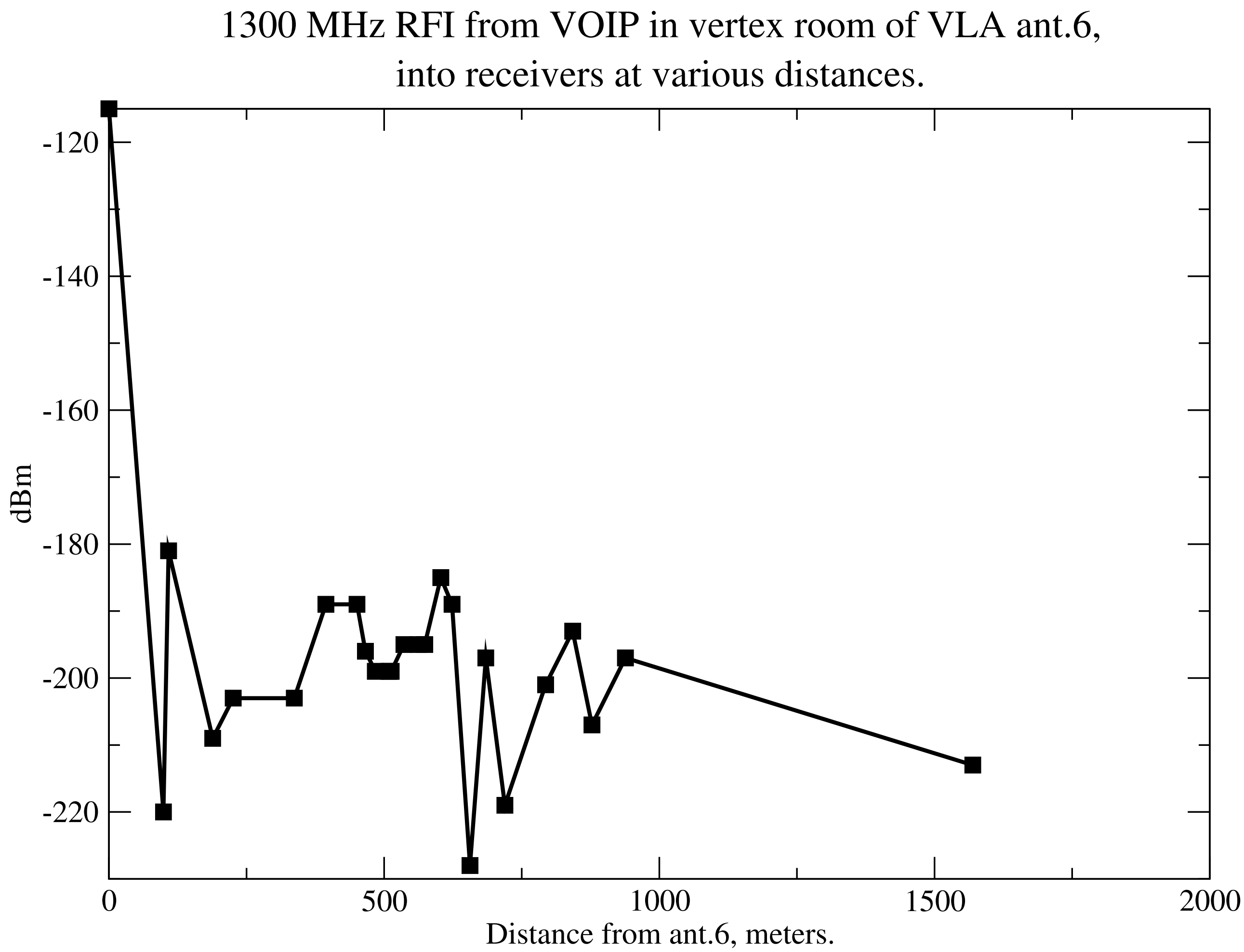
1300 MHz RFI from VOIP in vertex room of VLA ant.6,
into receivers at various distances.
-120
-140
-160
-180
-200
-220
dBm
0
500
1000
1500
2000
Distance from ant.6, meters.

Figure 4: