AMFR Intercomparison Report
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1. Introduction

Intercomparisons of reflectivity (Z_{HH}) and differential reflectivity (Z_{DR}) between AMFR and King radars, as well as between these radars and simulated reflectivities based on 2DVD data at the CARE site, are presented here. The radar intercomparison was done for two times on 22 Jan 2007, and one time on 23 Jan 2007. The 2DVD intercomparison was done for two times on 22 Jan 2007.

One of these times (06:44 UTC on 22 Jan 2007 – hereafter all times in UTC) was intercompared in the last report, but a bug was discovered in the AMFR UF format conversion scripts at CSU, which may have affected those results.

2. Methodology

The methodology was similar to the last report, and is summarized briefly here.

AMFR was 34.27 km from King Radar along the 331° radial. Both radars scanned their RHIs within 3 minutes of each other, and both along the 331° radial. Thus, they were looking the same direction at about the same time, but due to inherent resolution differences between the two radars, and the longer distance from King radar, AMFR had better spatial resolution. Ground clutter and other spurious echo were not filtered except to use the filtered King reflectivity field.

The native polar coordinate data were broken down into 2-km blocks along the great circle (S), and 0.5-km blocks in altitude MSL (H). Individual gates of data from each radar were grouped into these blocks using calculations based on radar position (lat, lon, and alt), elevation angle, and slant range. The ray path calculations used the standard 4/3 Earth radius assumption. In each block median Z_{HH} and Z_{DR} of all respective gates were calculated for each radar. Calculations were done in decibel units to minimize the effect of a small number of high reflectivity gates (effect of not linearizing data should be minimal due to use of the median).

This methodology is not meant to retrieve true calibration offsets between radars, or between radars and ground truth. Instead, it is meant to provide guidance on possible calibration issues with the AMFR radar.

3. Results

a. Z_{HH} Intercomparison

Three times the radars were intercompared, ~06:22 on 22 Jan, ~06:44 on 22 Jan, and ~21:22 on 23 Jan. More times were hoped for on 23 Jan but unfortunately fewer coincident RHIs along the CARE radial occurred than previously thought. Full suites of ranges and altitudes were intercompared at these times, but for brevity in this report behavior along a particular constant altitude, and along a particular constant range, are shown.

Table 1 shows the intercomparison of Z_{HH} in the 1-1.5 km MSL altitude band, and Table 2 shows an intercomparison for the 10-12 km range band, all for ~06:22 on 22 Jan. At low altitude (1-1.5 km MSL; Table 1) there was an offset between AMFR Ku and King of approximately 9-13 dB, while the Ka offset was 20-30 dB. In all cases AMFR was lower than King. This offset showed no consistent improvement or degradation with range at Ku. There was some improvement at Ka, but this may have been just the result of the Ka radar signal succumbing to noise. At constant range (10-12 km; Table 2), the Ku offset started near 10 dB but got better with altitude. Indeed, above 4.5 km MSL, Ku was actually greater than King. Given how low King reflectivities were in this region, however (< 0 dBZ), the Ku signal may have been near the noise level. Indeed, the Ku RHI from this time suggests insignificant echo at this altitude (Fig. 1). The Ka signal everywhere was near –6 dBZ and did not vary significantly with altitude. It was likely that the Ka signal was in the noise. At this range, King Z_{HH} was > 20 dBZ, which suggested that the Ka could not detect typical snowfall Z_{HH} values at ranges beyond 10 km.

Table 3 shows the intercomparison of Z_{HH} in the 1-1.5 km MSL altitude band, and Table 4 shows an intercomparison for the 10-12 km range band, all for ~06:44 on 22 Jan. Results were similar to the previous time. Above 5 km MSL, the King Z_{HH} was still variable while the Ku was nearly constant near –8 dBZ (Table 4), further reinforcing the inference of noise overcoming the Ku signal in low reflectivity regions. This was once again supported by the Ku RHI from this time (Fig. 2). Once again, the Ka did not detect much beyond 10 km, if not closer. Note, King Z_{HH} values were lower than the previous time on this day.

Table 5 shows the intercomparison of Z_{HH} in the 1-1.5 km MSL altitude band, and Table 6 shows an intercomparison for the 10-12 km range band, all for ~21:22 on 23 Jan. This was a shallower system (snow band instead of synoptic event like 22 Jan), so the data do not extend very high in altitude. Offset ranges were about the same as the previous today, for Ku and Ka. There was a rapid decrease in Ku Z_{HH} values near the top of the system, but this was probably due to sharp reflectivity gradients near the top of this shallow system, as well as its cellular structure (Fig. 3). Once again, the Ka did not detect much beyond 10 km, if not closer.

b. Z_{DR} Intercomparison

Table 7 shows the intercomparison of Z_{DR} in the 1-1.5 km MSL altitude band, and Table 8 shows an intercomparison for the 10-12 km range band, all for ~06:22 on 22 Jan. These values were nearly constant among King and Ku, with Ku ranging from 0.5 to 1.5

dB greater than King. This offset did not show a coherent variation with range. Ka Z_{DR} values were both much less and more variable. They increased with range and with altitude, again suggesting the influence of low signal-to-noise. At higher altitudes with weaker echoes, the Ku and King Z_{DR} values were closer (Table 8). There also was a mid-level Z_{DR} maximum reflected in both Ku and King near 2 km MSL.

Table 9 shows the intercomparison of Z_{DR} in the 1-1.5 km MSL altitude band, and Table 10 shows an intercomparison for the 10-12 km range band, all for ~06:44 on 22 Jan. Z_{DR} values were slightly larger at this time, but the same general pattern as the earlier time prevailed.

Table 11 shows the intercomparison of Z_{DR} in the 1-1.5 km MSL altitude band, and Table 12 shows an intercomparison for the 10-12 km range band, all for ~21:22 on 23 Jan. Unlike the previous day, the Z_{DR} offset between Ku and King actually improved with range, and was nearly zero beyond 10 km. However, inside 10 km, the two Z_{DR} values did not appear to correlate well. At 10-12 km range, there was little offset between Ku and King Z_{DR} values at most altitudes (Table 12). Ka Z_{DR} once again did not appear to contain much information, except perhaps very close to the radar (< 10 km).

c. 2DVD Intercomparison

Table 13 shows simulated reflectivities at multiple frequencies from the 2DVD instrument at CARE, around 06:22 and 06:44 on 22 Jan 2007. These calculations were by Bringi's group based on the snow size distribution data. Also shown are King and AMFR Z_{HH} values at these times, at 0-2 km range and 0-0.5 km MSL altitude. While the King offsets were relatively small (< 5 dB), the AMFR Ku offsets were approximately 10-15 dB, and the Ka offsets were approximately 20-30 dB. Note, ground clutter may have been a factor at these altitudes, but Z_{HH} values showed significant decline in height for King and Ku in this storm (Tables 2 and 4), so there would be additional uncertainty if higher altitude values were used instead.

4. Conclusions

AMFR Ku Z_{HH} values were consistently ~10 dB lower than King radar and 2DVD at the examined times. Ka values were lower by ~20 dB or more. These offsets were much greater than simulated reflectivity differences between these frequencies (Table 13; also D. Long, M.S. Thesis, 2004). Thus, neither frequency's Z_{HH} appeared to be well calibrated on these days, although the calibration offset appeared to have been roughly constant between these days. Note, however, that there was a calibration drift prior to the analyzed times on 22 Jan, as noted in the first AMFR QC report. Obviously, Ka's calibration was worse than Ku.

Z_{DR} also did not appear to be well calibrated, with Ku ~1 dB greater than King. Ka Z_{DR} was many dB lower and did not appear to contain much information.

Overall, Ka Z_{HH} did not appear to contain useful information beyond 10 km for typical snowfall reflectivity values (10-20 dBZ at C-Band), as the signal became overwhelmed by noise. Ku appeared to contain useful information out to the maximum range of AMFR.

It is concluded that AMFR Z_{HH} and Z_{DR} calibrations at both frequencies require reexamination by UMass personnel.

Table 1

AMFR vs. King Median Z_{HH} at 1.0-1.5 km MSL Constant Altitude
AMFR 06:21:58 and King 06:24:19 on 22 Jan 2007

Range (km)	King	AMFR Ku	AMFR Ka
1.00000	22.9700	14.5732	-9.30844
3.00000	24.0300	13.7560	-9.88737
5.00000	23.2900	13.8315	-9.93851
7.00000	24.1000	13.1566	-8.93860
9.00000	22.6200	12.7598	-7.46805
11.0000	22.6600	11.9065	-6.09274
13.0000	22.1400	10.8924	-4.91491
15.0000	21.0400	10.1973	-3.86508
17.0000	18.8100	9.95917	-2.78532
19.0000	20.1100	9.14070	-1.89482
21.0000	18.6900	9.52455	-1.17643
23.0000	16.4500	3.44653	-8.19655

Table 2

AMFR vs. King Median Z_{HH} at 10.0-12.0 km MSL Constant Range
AMFR 06:21:58 and King 06:24:19 on 22 Jan 2007

Height (km)	King	AMFR Ku	AMFR Ka
0.750000	23.9900	13.6014	-6.11883
1.25000	22.6600	11.9065	-6.09274
1.75000	18.6900	7.76254	-5.99131
2.25000	11.8600	3.19172	-6.29293
2.75000	7.27000	-0.588118	-6.47155
3.25000	5.49000	-2.78271	-6.37277
3.75000	3.48000	-3.57192	-6.31483
4.25000	-2.43000	-5.89335	-6.14477
4.75000	-7.01000	-6.64873	-6.08107
5.25000	-9.18000	-7.65053	-5.92176
5.75000	-10.5400	-8.31233	-5.68484

Table 3

AMFR vs. King Median Z_{HH} at 1.0-1.5 km MSL Constant Altitude
AMFR 06:44:29 and King 06:44:02 on 22 Jan 2007

Range (km)	King	AMFR Ku	AMFR Ka
1.00000	13.9900	5.10114	-14.4346
3.00000	13.0200	4.42905	-14.0509
5.00000	14.0300	5.08450	-11.6231
7.00000	14.1400	4.59183	-9.57297
9.00000	13.5500	3.81232	-7.90589
11.0000	12.9000	4.29387	-6.31595
13.0000	13.5600	5.43780	-4.92645
15.0000	14.7200	5.41132	-3.75058
17.0000	15.4600	5.89960	-2.68549
19.0000	15.7400	7.30641	-1.74668
21.0000	15.8200	7.35275	-1.01734
23.0000	15.8500	0.0765062	-7.59665

Table 4

AMFR vs. King Median Z_{HH} at 10.0-12.0 km MSL Constant Range
AMFR 06:44:29 and King 06:44:02 on 22 Jan 2007

Height (km)	King	AMFR Ku	AMFR Ka
0.250000	22.6600	10.6827	-5.83680
0.750000	18.9100	8.18461	-5.97255
1.25000	12.9000	4.29387	-6.31595
1.75000	11.8100	1.35288	-6.45435
2.25000	10.8300	3.37669	-6.26453
2.75000	10.9000	3.00241	-6.17348
3.25000	8.32000	0.682259	-6.16567
3.75000	6.74000	-1.98643	-6.13804
4.25000	2.48000	-5.58996	-6.12129
4.75000	-1.81000	-7.43249	-5.99978
5.25000	-3.56000	-8.03348	-5.80879
5.75000	-6.47000	-8.20653	-5.66286
6.25000	-8.52000	-8.23278	-5.47043

Table 5

AMFR vs. King Median Z_{HH} at 1.0-1.5 km MSL Constant Altitude
AMFR 21:21:51 and King 21:24:01 on 23 Jan 2007

Range (km)	King	AMFR Ku	AMFR Ka
1.00000	10.5100	-2.56360	-20.2877
3.00000	13.4100	0.755848	-16.8970
5.00000	12.2500	-1.15814	-13.3263
7.00000	11.8800	0.775721	-10.5297
9.00000	14.6000	2.88257	-8.55361
11.0000	9.82000	-1.08212	-6.85108
13.0000	12.7000	0.974374	-5.37291
15.0000	9.34000	1.29296	-4.15435
17.0000	10.7300	1.67099	-3.04474
19.0000	15.6300	2.44590	-2.13749
21.0000	13.1800	2.15060	-1.40365
23.0000	12.6000	-4.91756	-8.20005

Table 6

AMFR vs. King Median Z_{HH} at 10.0-12.0 km MSL Constant Range
AMFR 21:21:51 and King 21:24:01 on 23 Jan 2007

Height (km)	King	AMFR Ku	AMFR Ka
0.250000	12.6400	4.40765	-6.77683
0.750000	11.7600	3.96205	-6.82073
1.25000	9.82000	-1.08212	-6.85108
1.75000	8.56000	-6.75640	-6.85829
2.25000	-9.06000	-10.3781	-6.73051

Table 7

AMFR vs. King Median Z_{DR} at 1.0-1.5 km MSL Constant Altitude
AMFR 06:21:58 and King 06:24:19 on 22 Jan 2007

Range (km)	King	AMFR Ku	AMFR Ka
1.00000	0.610000	1.44994	-14.9650
3.00000	0.610000	1.32721	-14.4269
5.00000	0.640000	1.47721	-12.7255
7.00000	0.770000	1.54684	-10.7957
9.00000	0.850000	1.74337	-9.49181
11.0000	0.710000	1.68975	-8.39948
13.0000	0.710000	1.72524	-7.58283
15.0000	0.710000	1.69110	-7.12071
17.0000	0.660000	1.65641	-6.92820
19.0000	0.560000	1.73847	-6.51517
21.0000	0.780000	1.46128	-6.52531
23.0000	0.640000	1.69365	-7.13969

Table 8

AMFR vs. King Median Z_{DR} at 10.0-12.0 km MSL Constant Range
AMFR 06:21:58 and King 06:24:19 on 22 Jan 2007

Height (km)	King	AMFR Ku	AMFR Ka
0.750000	0.590000	1.55491	-8.72906
1.25000	0.710000	1.68975	-8.39948
1.75000	0.810000	1.69809	-8.71304
2.25000	0.850000	2.29252	-7.54999
2.75000	0.780000	1.72226	-6.79710
3.25000	0.690000	1.32628	-6.48696
3.75000	0.560000	1.14504	-6.38746
4.25000	0.720000	0.885016	-6.16304
4.75000	0.720000	0.807159	-5.97165
5.25000	0.610000	0.671226	-5.99371
5.75000	0.0400000	0.477442	-5.85640

Table 9

AMFR vs. King Median Z_{DR} at 1.0-1.5 km MSL Constant Altitude
AMFR 06:44:29 and King 06:44:02 on 22 Jan 2007

Range (km)	King	AMFR Ku	AMFR Ka
1.00000	0.970000	1.50165	-14.7085
3.00000	0.880000	1.75683	-13.4067
5.00000	0.920000	1.72229	-11.7685
7.00000	0.870000	1.81975	-9.99144
9.00000	0.960000	1.88230	-8.18329
11.0000	0.840000	1.81910	-7.56353
13.0000	0.790000	1.56961	-7.26279
15.0000	0.710000	1.41025	-6.93419
17.0000	0.740000	1.32818	-6.74506
19.0000	0.610000	1.35991	-6.76529
21.0000	0.580000	1.20753	-6.57784
23.0000	0.600000	1.21259	-6.88124

Table 10

AMFR vs. King Median Z_{DR} at 10.0-12.0 km MSL Constant Range
AMFR 06:44:29 and King 06:44:02 on 22 Jan 2007

Height (km)	King	AMFR Ku	AMFR Ka
0.250000	0.570000	1.55797	-9.95822
0.750000	0.720000	1.48057	-9.30997
1.25000	0.840000	1.81910	-7.56353
1.75000	0.900000	1.82226	-6.71911
2.25000	0.710000	1.85007	-7.27752
2.75000	0.730000	1.65863	-7.58316
3.25000	0.710000	1.40366	-7.03606
3.75000	0.620000	1.34123	-6.47114
4.25000	0.590000	1.00378	-6.03786
4.75000	0.520000	0.845922	-5.82843
5.25000	0.440000	0.667127	-5.81915
5.75000	0.350000	0.628113	-5.73806
6.25000	0.870000	0.586588	-5.74113

Table 11

AMFR vs. King Median Z_{DR} at 1.0-1.5 km MSL Constant Altitude
AMFR 21:21:51 and King 21:24:01 on 23 Jan 2007

Range (km)	King	AMFR Ku	AMFR Ka
1.00000	0.750000	2.01396	-8.87994
3.00000	0.830000	1.22148	-8.56513
5.00000	0.870000	1.43920	-6.99859
7.00000	0.540000	1.34450	-6.73134
9.00000	0.600000	0.985552	-6.70222
11.0000	0.830000	0.906234	-6.20194
13.0000	0.700000	0.768784	-6.17342
15.0000	0.620000	0.558803	-6.11377
17.0000	0.440000	0.429030	-6.19528
19.0000	-0.140000	0.132153	-6.28594
21.0000	-0.180000	-0.402159	-6.12187
23.0000	-0.360000	0.911160	-6.18308

Table 12

AMFR vs. King Median Z_{DR} at 10.0-12.0 km MSL Constant Range
AMFR 21:21:51 and King 21:24:01 on 23 Jan 2007

Height (km)	King	AMFR Ku	AMFR Ka
0.250000	0.630000	0.501839	-6.68578
0.750000	0.670000	0.789515	-6.47600
1.25000	0.830000	0.906234	-6.20194
1.75000	0.840000	-0.331730	-6.09436
2.25000	0.740000	-1.50052	-5.97912

Table 13
AMFR and King vs. 2DVD on 22 Jan 2007
0-0.5 km MSL Constant Altitude and 0-2.0 km Constant Range
Radar Time set to AMFR
Radar Values are Median Z_{HH}

2DVD

Time	C	X	Ku	Ka	Snow Rate (mm/h)
06:21	29.37	28.80	27.86	21.37	1.130
06:22	30.96	30.26	29.14	19.47	1.171
06:23	33.28	32.12	29.97	19.04	1.199

Radars

Time	King	Ku	Ka
06:22	25.570	13.855	-11.031

2DVD

Time	C	X	Ku	Ka	Snow Rate (mm/h)
06:43	26.24	25.40	24.07	16.93	0.863
06:44	21.73	21.38	20.95	16.47	0.409
06:45	22.87	22.17	21.03	12.51	0.292

Radars

Time	King	Ku	Ka
06:44	22.820	12.598	-10.517

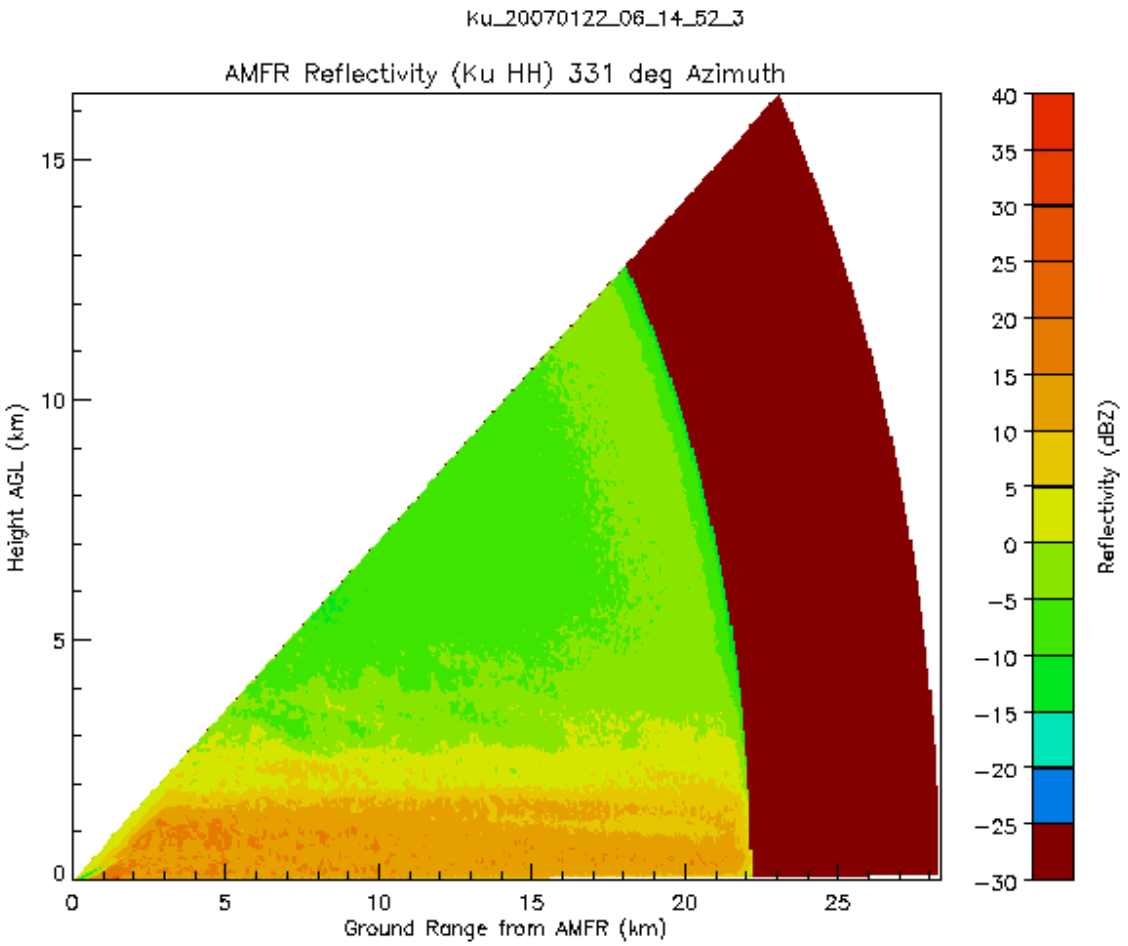

Figure 1. RHI of Z_{HH} from AMFR at 06:21:58 on 22 Jan 2007.

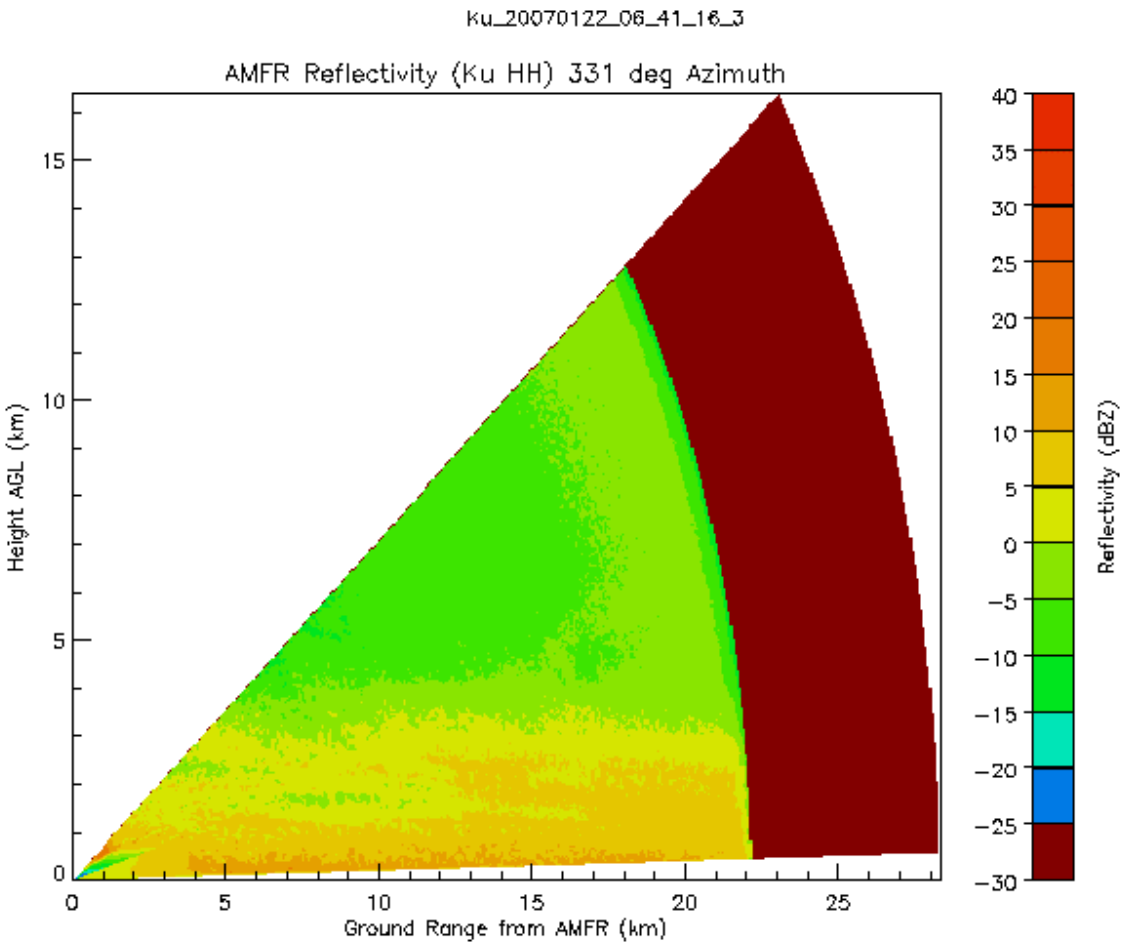

Figure 2. RHI of Z_{HH} from AMFR at 06:44:29 on 22 Jan 2007.

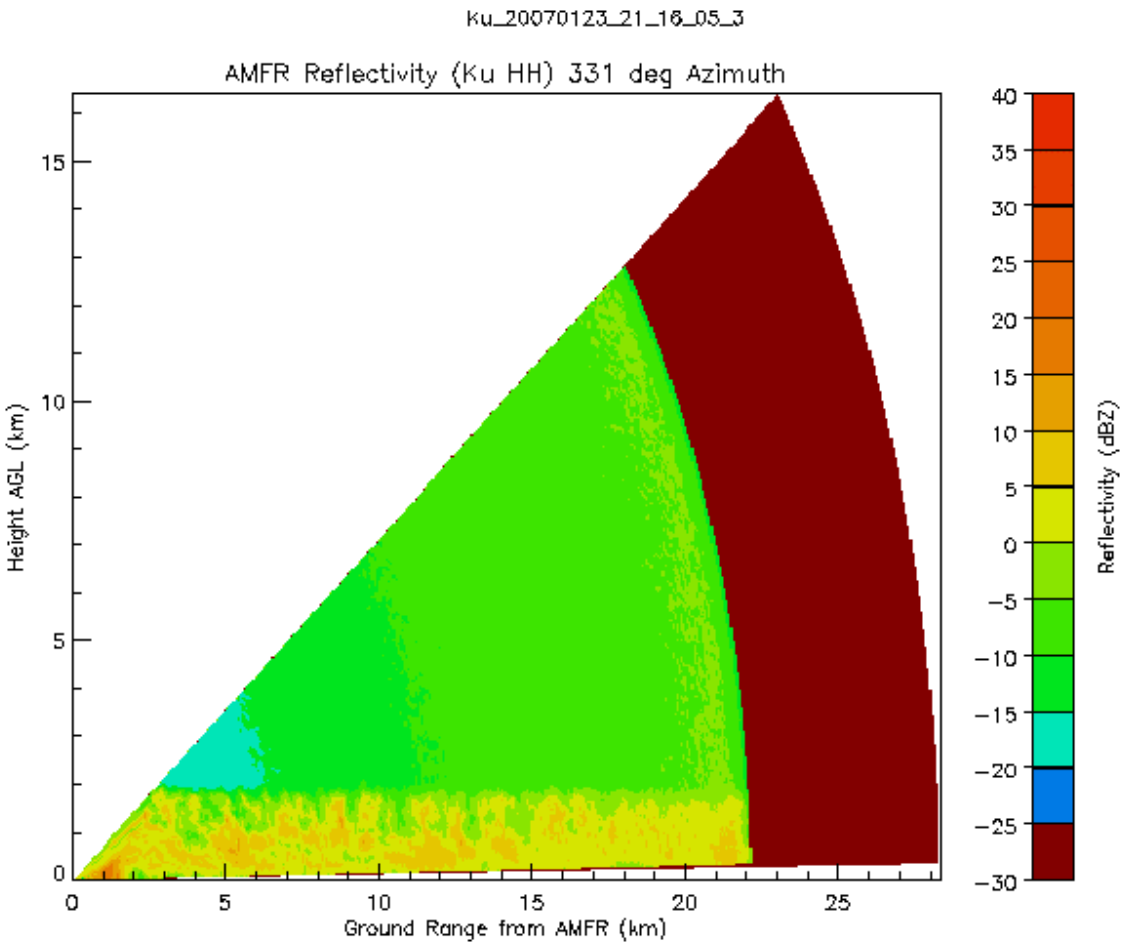

Figure 3. RHI of Z_{HH} from AMFR at 21:21:51 on 23 Jan 2007.