

NATIONAL RADIO ASTRONOMY OBSERVATORY
VERY LARGE ARRAY
SOCORRO, NEW MEXICO

VLA TEST MEMORANDUM NO. 141

MEASUREMENTS OF EQUIVALENT SYSTEM TEMPERATURES

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Interferometric observations with three or more antennas can be used to measure the equivalent system temperatures of all receivers. Since such measurements are obtained from observed correlation coefficients, they include all sources of decorrelation and loss of signal (i.e. pointing errors), not just thermal noise. When combined with hot- and cold-load measurements they identify the presence of problems in addition to "hot" receivers.

The correlation coefficient ρ_{ij} on baseline i-j is given by

$$\rho_{ij} = \frac{\varepsilon \sqrt{K_i K_j} S}{\sqrt{(T_i + K_i S)(T_j + K_j S)}} ,$$

where: ε = efficiency of three-level sampling (0.81),

$K_i = \eta_i A_i / 2k_B$ = sensitivity of i^{th} antenna (η = aperture efficiency, A = collecting area),

S = flux density of calibration source,

T_i = system temperature on blank sky.

ANTSOL can be used to find an "antenna-based" correlation coefficient ρ_i for the i^{th} antenna defined, in a least-squared-error sense, by

$$\rho_{ij} = (\rho_i \rho_j)^{\frac{1}{2}},$$

or

$$\rho_i = \frac{\epsilon K_i S}{(T_i + K_i S)}.$$

This expression can be inverted to find the system temperature:

$$T_i = \left(\frac{\epsilon}{\rho_i} - 1\right) K_i S.$$

The procedure created for measuring equivalent system temperatures is as follows:

1. Observe a strong source of known flux density at all four bands with the system temperature correction disabled. 0316+413 (3C84) and 1641+399 (3C345) are used here because one is always visible, with appropriate UVLIMITS any structure is less than about 10%, and the flux densities are greater than about 10 Janskies, particularly at 2 and 1.3 cm. Recent flux densities for both sources are given in Table 1.
2. Set an arbitrary flux density of 10 Jy for 3C84 at 6 cm to prevent overflows in ANTSOL listings.
3. Use QUACK to flag first records of all scans.
4. Run ANTSOL with AVERAGE set to AMPSCALAR to reduce the effects of phase wind.

5. List ANTSOL solutions separately for the A and C IF's with LISTOPTION AMP*AMP .
6. Read ANTSOL listings and calculate system temperatures using the FORTRAN program SENSE.FOR. Since the observed correlation coefficients are multiplied by 128 in the synchronous system and by 1000 in the AMP*AMP listing, the system temperatures are actually calculated from

$$T_i = \left(\frac{128,000 \epsilon}{\rho} - 1 \right) \text{KS}$$

(except for 3C84 at 6 cm where the constant must be divided by the arbitrary flux density). At this stage identical antennas are assumed with K's of 0.0889, 0.1156, 0.0960, and 0.818 for aperture efficiencies of 0.50, 0.65, 0.54, and 0.46 at 20 cm, 6 cm, 2 cm, and 1.3 cm.

7. Print out closure errors, AMP*AMP listings, and equivalent system temperatures.
8. Examine results, and do additional flagging and redo solutions, if necessary.

For convenience steps 2 to 7 have been implemented in the file SENSE.MIC. Both SENSE.MIC and SENSE.FOR have been turned over to Paul Fisher in Operations. Such measurements are now part of Electronics test time, and the most recent results are available from the operators.

Five sets of measurements are presented in Tables 2 to 6. A significant discontinuity occurs between the second and third epochs, although before and after we see good agreement, including epochs four

and five, which were taken only 13 hours apart. The discontinuity is surprising because although the flux densities of the two calibrators were measured on the opposite sides of the discontinuity, the two sets include observations of both sources, which do agree at L and C bands. Disagreement at U and K bands is possible because the flux density scale for 3C48 (used to bootstrap 0361+413) may disagree with that for 3C286 (1641+399).

The observations in the first two epochs have been used to identify a problem with missing commands to antenna 12.

Table 1
FLUX DENSITIES OF CALIBRATORS

	<u>0316+413</u>	<u>1641+399</u>
Date	1983.March 28	1983.February 14
20 cm	17.14±0.18 Jy	7.88±0.05 Jy
6 cm	58.67±0.11	11.11±0.06
2 cm	49.77±0.31	15.08±0.14
1.3 cm	43.89±0.80	14.57±0.21

EQUIVALENT SYSTEM TEMPERATURES (K)

83JAN27 - 0316+413

ANTENNA	LA	LC	CA	CC	UA	UC	KA	KC
1	49	80	96	59	425	323	501	375
2	59	73	79	75	264	499	527	731
3	88	136	475	71	124	105	461	442
4	54	54	69	55	436	321	678	725
6	56	61	127	51	275	228	585	451
7	48	123	50	51	261	328	504	645
8	69	63	70	53	259	270	1069	348
9	65	57	60	55	333	360	244	248
10	41	45	106	57	105	118	621	465
11	43	45	59	51	160	163	850	984
12	125	123	150	136	272	263	876	900
13	46	44	63	64	118	317	466	816
14	83	85	58	60	119	134	622	920
16	52	68	47	85	281	757	1209	1229
17	97	63	59	62	218	180	625	441
18	67	60	61	54	304	280	929	1293
19	53	59	46	44	218	193	253	534
20	66	95	50	84	90	113	507	383
21	100	89	62	64	91	82	256	405
22	124	0	65	54	153	147	868	665
23	108	219	66	46	341	348	439	787
24	131	108	50	63	101	110	464	467
25	72	71	86	52	81	78	558	0
26	76	72	61	48	129	133	061	486
27	52	52	48	52	109	95	374	336
28	100	98	44	55	322	220	337	395

Table 2

EQUIVALENT SYSTEM TEMPERATURES (K)

83FEB14 - 1641+399

ANTENNA	LA	LC	CA	CC	UA	UC	KA	KC
1	46	75	95	59	465	362	587	458
2	56	69	79	69	304	548	576	781
3	82	129	515	67	144	126	776	823
5	120	48	52	84	151	184	995	587
6	54	63	120	50	448	259	1583	501
7	45	120	49	52	307	379	445	717
8	63	57	69	48	287	305	1055	415
10	39	46	106	57	122	139	730	568
11	40	42	60	52	126	135	431	566
12	116	116	147	124	284	285	914	935
13	45	42	65	64	125	157	2521	851
14	45	51	59	62	128	143	531	2807
16	49	70	47	95	313	937	869	1286
17	87	55	64	62	239	195	560	421
18	65	74	68	53	298	220	465	1273
19	50	55	45	44	238	208	255	574
20	55	82	51	84	102	122	685	509
21	55	46	63	69	100	92	310	505
23	63	76	67	46	376	390	460	823
24	85	61	52	66	127	138	501	534
26	44	39	64	51	148	155	743	553
27	49	48	47	50	117	104	346	350
28	60	55	42	54	355	244	344	408

Table 3

EQUIVALENT SYSTEM TEMPERATURES (K)

83MAR23 - 1641+399

ANTENNA	LA	LC	CA	CC	UA	UC	KA	KC
1	76	114	173	112	509	317	555	682
2	83	106	115	121	291	522	590	734
3	49	68	111	54	138	106	458	470
4	63	69	57	92	123	109	620	689
5	213	92	66	103	129	159	881	481
6	79	90	363	66	282	252	571	509
7	99	146	70	128	266	328	391	650
9	97	99	189	93	347	379	614	757
10	64	59	162	84	111	125	697	505
11	60	61	111	98	127	138	485	620
12	59	63	41	0	107	110	365	392
13	53	58	112	102	135	171	550	1165
14	65	81	116	104	116	125	743	812
15	62	89	113	105	764	98	653	570
16	87	140	115	280	299	1041	343	781
17	101	67	96	102	236	198	555	448
18	204	0	124	101	265	216	568	465
19	77	81	80	89	232	227	269	563
21	104	92	134	158	93	87	455	614
22	105	86	136	106	139	138	957	713
23	121	116	93	70	373	380	501	888
24	92	82	105	116	108	116	516	485
25	66	49	127	106	93	88	531	470
26	80	83	116	91	131	141	705	529
27	53	67	59	72	118	99	447	357
28	74	69	52	71	348	250	351	429

Table 4

EQUIVALENT SYSTEM TEMPERATURES (K)

83MAR28 - 0316+413

ANTENNA	LA	LC	CA	CC	UA	UC	KA	KC
1	74	106	172	114	434	261	394	383
2	81	103	123	132	268	463	530	644
3	49	67	109	53	123	94	414	411
4	60	63	56	94	113	98	734	775
5	202	95	64	99	110	139	824	433
6	75	86	369	68	263	239	513	479
7	99	147	72	121	240	295	435	576
9	97	99	201	97	339	353	636	718
10	61	54	161	87	100	111	596	466
11	58	60	105	102	117	125	434	551
12	45	48	39	36	99	102	333	333
13	55	60	116	104	118	139	709	1370
14	69	86	116	103	93	100	460	491
15	65	95	117	109	712	93	588	537
16	84	137	122	291	273	919	708	1462
17	102	68	98	104	215	175	523	395
18	175	142	128	103	233	183	430	262
19	73	76	85	95	216	208	242	514
20	86	68	113	152	92	100	658	437
21	123	109	140	162	88	79	315	474
22	136	117	141	110	129	125	839	605
23	148	140	89	69	331	327	420	738
24	119	105	104	113	97	102	455	438
25	82	62	130	109	79	77	598	492
26	96	101	106	81	126	129	631	461
27	52	67	62	75	110	95	402	318
28	97	92	53	72	304	216	300	375

Table 5

EQUIVALENT SYSTEM TEMPERATURES (K)

83MAR28 - 1641+399

ANTENNA	LA	LC	CA	CC	UA	UC	KA	KC
1	77	108	167	110	518	315	499	499
2	86	108	120	128	313	552	667	791
3	51	69	111	53	137	104	456	448
4	65	68	56	90	124	111	574	639
5	193	93	64	100	125	162	980	509
6	81	92	348	66	302	257	558	527
7	101	149	70	113	267	334	553	584
9	99	102	190	93	372	390	678	796
10	65	60	160	85	112	5174	752	543
11	61	63	103	97	134	144	516	663
12	59	62	41	38	113	115	412	396
13	55	60	110	101	132	156	543	689
14	69	85	116	106	120	135	512	563
15	63	93	114	106	801	102	682	617
16	89	145	114	285	309	1078	359	828
17	102	68	95	100	242	201	520	425
18	208	6052	124	99	265	211	509	1273
19	78	83	81	89	244	236	292	602
20	84	66	108	149	101	115	518	370
21	106	93	138	157	99	93	456	646
22	111	93	138	107	147	143	972	726
23	123	117	91	69	388	397	579	1012
24	96	84	105	116	111	120	553	538
25	70	53	126	105	91	90	558	481
26	80	84	107	85	143	167	863	639
27	55	70	59	70	117	99	463	358
28	76	72	53	72	358	253	359	440

Table 6

