VLA Test Memorandum No. 164

GAIN CURVES FOR 1.3CM VLBI WITH A SINGLE VLA ANTENNA

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Most single-antenna VLBI projects at the VLA use just the preferred VLBI antenna identified in the VLA operator's log for that project. For 1.3cm VLBI projects we try to provide two additional calibrator antennas, and we use the VLA correlator data from the resulting three-antenna subarray to give the ratio of antenna temperature to system temperature, Tant/Tsys, as a function of time for the VLA's preferred VLBI antenna. This ratio, which is all that is needed for amplitude calibration of VLBI baselines involving the VLA, tracks the effects of the position dependent gain (the "gain curve") and the pointing errors of the preferred VLBI antenna, plus the atmospheric opacity above that antenna. For operational reasons, however, some 1.3cm VLBI projects involve just the preferred VLBI antenna. In such cases post-observing adjustments should be made for that antenna's gain curve and for the atmospheric opacity above that antenna. This memorandum provides information regarding gain curve adjustments. Suggestions regarding opacity adjustments will be dealt with in a separate test memorandum.

Crane (1991, VLA Test Memorandum No. 159) obtained VLA antenna gain data for IFs A, B, C and D on 1989 December 29-30 at an effective frequency of 22460.1 MHz. All antennas except for 21 and 22 were available. Over-the-top antenna motions were not allowed, as recommended for all 1.3cm observing including VLBI. Crane first adjusted his observations for atmospheric opacity and then fitted the gain corrections with Legendre polynomials assuming a minimum correction at a zenith angle of 40 degrees. Each antenna showed good agreement among the four IFs, so Crane tabulated for each antenna the Legendre polynomial coefficients averaged over the four IFs. He also provided Legendre polynomial coefficients for the gain corrections for an average VLA antenna, which he called antenna "29"; these gain corrections might usefully be applied to antennas 21 or 22, as well as to 1.3cm phased VLA observations. Consult Crane (1991) for a discussion of the significance of the 1989 gain correction differences from antenna to antenna, plus gain correction differences when compared with 1985 data (Crane, 1987, VLA Test Memorandum No. 149).

ANCAL in AIPS or CAL in the Caltech VLBI Analysis Programs require standard polynomial fits to the gain curve, which is the inverse of Crane's gain corrections. For each antenna, including "29", I have approximated the gain curve with the inverse of Crane's Legendre polynomial fit to the gain corrections, normalized the gain curve to its maximum, and fitted the normalized gain curve with a fifth-order polynomial using C. Walker's Fortran program "fit". Figure 1 compares the inverse of Crane's Legendre polynomial fits to the gain corrections with my standard polynomial fits to the normalized gain curves. Gain curve values from my fits are given in Table 1 every 4 degrees in zenith angle, which is sufficiently dense to permit application of interpolation schemes if desired.

Below I give complete antenna gain information, including my fitted polynomial coefficients, in the form expected by ANCAL and CAL for VLA antennas 1 through 20, 23 through 28, and "29". Two points should be kept in mind when using this gain information. First, I have assumed that each antenna has the nominal 1.3cm degrees per flux unit (DPFU) quoted by Crane & Napier (1986, Synthesis Imaging in Radio Astronomy, ASP conference series volume 6, eds. Perley, Schwab & Bridle [San Francisco: ASP], 139). Variations in DPFU from antenna to antenna are expected but no systematic measurements of these variations are presently available. Second, the VLBI correlator may use an antenna name for your project other than that assumed below. Consult the antennas file for your VLBI data and make the appropriate name substitution if necessary.

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VLA antenna 1: GAIN VLA ALTAZ DPFU=0.082
               POLY = +0.99830E+00, +0.69335E-03, -0.61046E-04,
                      -0.20542E-05, +0.38125E-07, -0.16986E-09 /

VLA antenna 2: GAIN VLA ALTAZ DPFU=0.082
               POLY = +0.99929E+00, +0.29071E-03, -0.26353E-04,
                      -0.12533E-05, +0.18808E-07, -0.71527E-10 /

VLA antenna 3: GAIN VLA ALTAZ DPFU=0.082
               POLY = +0.84344E+00, +0.42562E-02, +0.37521E-04,
                      -0.14501E-05, +0.29040E-08, +0.41362E-10 /

VLA antenna 4: GAIN VLA ALTAZ DPFU=0.082
               POLY = +0.88697E+00, +0.37490E-02, +0.31550E-04,
                      -0.18109E-05, +0.10831E-07, +0.11181E-11 /

VLA antenna 5: GAIN VLA ALTAZ DPFU=0.082
               POLY = +0.81221E+00, +0.39333E-02, +0.27406E-04,
                      -0.60410E-06, -0.45888E-08, +0.55069E-10 /

VLA antenna 6: GAIN VLA ALTAZ DPFU=0.082
               POLY = +0.91072E+00, +0.28710E-02, +0.14770E-04,
                      -0.10050E-05, +0.49226E-08, +0.81116E-11 /

VLA antenna 7: GAIN VLA ALTAZ DPFU=0.082
               POLY = +0.80521E+00, +0.46668E-02, +0.41575E-04,
                      -0.11537E-05, -0.36684E-08, +0.75107E-10 /

VLA antenna 8: GAIN VLA ALTAZ DPFU=0.082
               POLY = +0.84548E+00, +0.40646E-02, +0.32370E-04,
                      -0.12109E-05, +0.13968E-08, +0.41096E-10 /

VLA antenna 9: GAIN VLA ALTAZ DPFU=0.082
               POLY = +0.88285E+00, +0.32262E-02, +0.19441E-04,
                      -0.91732E-06, +0.24575E-08, +0.20539E-10 /

VLA antenna 10: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.88215E+00, +0.33278E-02, +0.21567E-04,
                       -0.10309E-05, +0.32000E-08, +0.20464E-10 /

VLA antenna 11: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.94535E+00, +0.26381E-02, +0.12000E-04,
                       -0.17636E-05, +0.16119E-07, -0.36350E-10 /

VLA antenna 12: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.81440E+00, +0.47925E-02, +0.48861E-04,
                       -0.16022E-05, +0.57254E-09, +0.65362E-10 /

VLA antenna 13: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.97331E+00, +0.15866E-02, -0.66131E-06,
                       -0.10459E-05, +0.99851E-08, -0.23228E-10 /

VLA antenna 14: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.88346E+00, +0.33854E-02, +0.21897E-04,
                       -0.11021E-05, +0.38728E-08, +0.19024E-10 /

VLA antenna 15: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.88144E+00, +0.31877E-02, +0.19286E-04,
                       -0.87167E-06, +0.20873E-08, +0.20935E-10 /

VLA antenna 16: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.91245E+00, +0.34879E-02, +0.27739E-04,
                       -0.21829E-05, +0.17535E-07, -0.29238E-10 /

VLA antenna 17: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.86866E+00, +0.44241E-02, +0.49918E-04,
                       -0.26577E-05, +0.17672E-07, -0.10220E-10 /
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VLA antenna 18: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.96139E+00, +0.24623E-02, +0.77170E-05,
                       -0.23839E-05, +0.26618E-07, -0.82899E-10 /

VLA antenna 19: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.77687E+00, +0.50309E-02, +0.48759E-04,
                       -0.10865E-05, -0.78073E-08, +0.10186E-09 /

VLA antenna 20: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.83151E+00, +0.51104E-02, +0.73924E-04,
                       -0.31539E-05, +0.17687E-07, +0.11594E-10 /

VLA antenna 23: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.85965E+00, +0.41235E-02, +0.36397E-04,
                       -0.16447E-05, +0.62953E-08, +0.26065E-10 /

VLA antenna 24: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.91544E+00, +0.27415E-02, +0.14512E-04,
                       -0.99902E-06, +0.53543E-08, +0.43692E-11 /

VLA antenna 25: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.82342E+00, +0.40254E-02, +0.30486E-04,
                       -0.83839E-06, -0.26339E-08, +0.51901E-10 /

VLA antenna 26: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.90705E+00, +0.34446E-02, +0.25907E-04,
                       -0.18651E-05, +0.13346E-07, -0.13653E-10 /

VLA antenna 27: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.66159E+00, +0.57885E-02, +0.47140E-04,
                       +0.44222E-06, -0.35081E-07, +0.23071E-09 /

VLA antenna 28: GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.90389E+00, +0.31510E-02, +0.18512E-04,
                       -0.12138E-05, +0.63095E-08, +0.75857E-11 /

VLA antenna "29" = average VLA antenna, if applied to a single VLA antenna:
                GAIN VLA ALTAZ DPFU=0.082
                POLY = +0.88484E+00, +0.37375E-02, +0.29616E-04,
                       -0.16660E-05, +0.89798E-08, +0.83668E-11 /

VLA antenna "29" = average VLA antenna, if applied to phased VLA data using
ANCAL in AIPS:  GAIN VLA27 ALTAZ DPFU=1.0
                POLY = +0.88484E+00, +0.37375E-02, +0.29616E-04,
                       -0.16660E-05, +0.89798E-08, +0.83668E-11 /
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Table 1. Gain Curve Values

Zenith Angle (degrees)	Gain Curve Value from Standard Polynomial Fit — Antenna								
	1	2	3	4	5	6	7	8	9
82	0.6060	0.7401	0.9298	0.9019	0.9826	0.9440	0.9439	0.9443	0.9596
78	0.6269	0.7566	0.9425	0.9161	0.9882	0.9532	0.9557	0.9552	0.9677
74	0.6492	0.7739	0.9551	0.9306	0.9931	0.9624	0.9674	0.9659	0.9756
70	0.6730	0.7920	0.9671	0.9448	0.9970	0.9712	0.9780	0.9759	0.9828
66	0.6983	0.8107	0.9778	0.9581	0.9994	0.9792	0.9871	0.9846	0.9891
62	0.7248	0.8297	0.9868	0.9702	1.0001	0.9861	0.9940	0.9916	0.9941
58	0.7523	0.8489	0.9936	0.9805	0.9989	0.9919	0.9984	0.9966	0.9977
54	0.7805	0.8679	0.9980	0.9889	0.9957	0.9962	1.0001	0.9994	0.9996
50	0.8088	0.8865	0.9999	0.9950	0.9904	0.9989	0.9988	0.9998	0.9999
46	0.8368	0.9044	0.9990	0.9986	0.9831	0.9999	0.9946	0.9978	0.9983
42	0.8640	0.9213	0.9954	0.9998	0.9739	0.9993	0.9875	0.9933	0.9950
38	0.8898	0.9371	0.9891	0.9983	0.9629	0.9969	0.9776	0.9864	0.9899
34	0.9138	0.9513	0.9803	0.9943	0.9502	0.9929	0.9651	0.9772	0.9832
30	0.9355	0.9640	0.9691	0.9877	0.9362	0.9872	0.9503	0.9660	0.9749
26	0.9544	0.9748	0.9558	0.9789	0.9209	0.9800	0.9336	0.9529	0.9651
22	0.9702	0.9836	0.9407	0.9680	0.9048	0.9715	0.9152	0.9382	0.9541
18	0.9827	0.9905	0.9241	0.9553	0.8880	0.9619	0.8957	0.9223	0.9422
14	0.9918	0.9954	0.9065	0.9411	0.8708	0.9512	0.8754	0.9055	0.9294
10	0.9974	0.9985	0.8883	0.9259	0.8536	0.9399	0.8548	0.8882	0.9162
6	0.9999	0.9998	0.8700	0.9102	0.8367	0.9283	0.8344	0.8708	0.9027
2	0.9994	0.9998	0.8521	0.8946	0.8202	0.9165	0.8147	0.8537	0.8894
0	0.9983	0.9993	0.8434	0.8870	0.8122	0.9107	0.8052	0.8455	0.8828

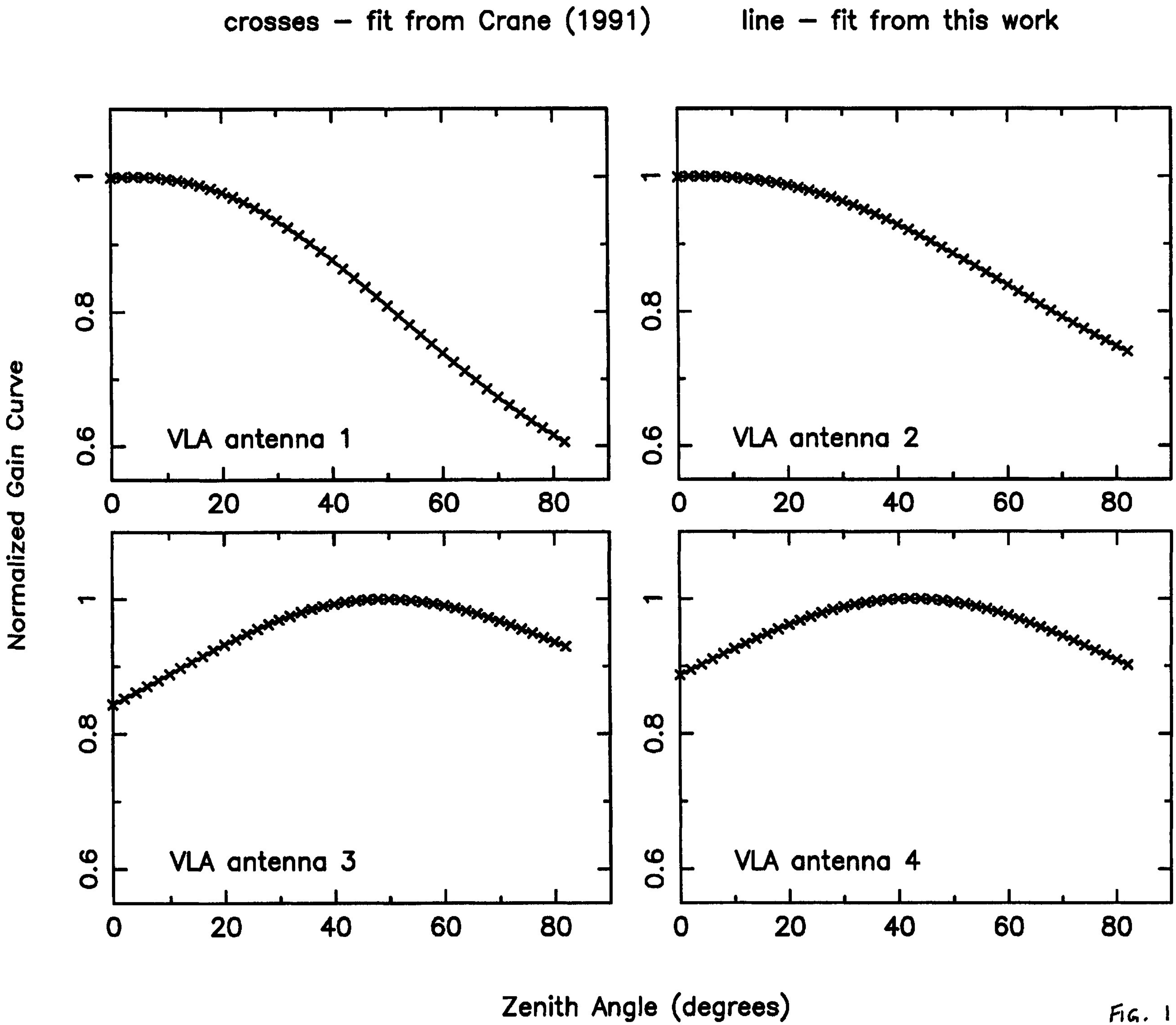
Table 1. (continued)

Zenith Angle (degrees)	Gain Curve Value from Standard Polynomial Fit — Antenna								
	10	11	12	13	14	15	16	17	18
82	0.9522	0.8640	0.9207	0.8876	0.9462	0.9639	0.8658	0.8628	0.7969
78	0.9612	0.8789	0.9350	0.8992	0.9560	0.9715	0.8820	0.8808	0.8150
74	0.9701	0.8943	0.9496	0.9111	0.9656	0.9788	0.8988	0.8997	0.8341
70	0.9784	0.9098	0.9633	0.9231	0.9746	0.9854	0.9157	0.9185	0.8537
66	0.9857	0.9250	0.9756	0.9348	0.9827	0.9911	0.9320	0.9365	0.8734
62	0.9917	0.9396	0.9858	0.9461	0.9895	0.9955	0.9474	0.9532	0.8929
58	0.9962	0.9532	0.9935	0.9568	0.9947	0.9985	0.9614	0.9679	0.9119
54	0.9990	0.9655	0.9983	0.9666	0.9982	0.9999	0.9736	0.9802	0.9298
50	1.0000	0.9762	0.9999	0.9754	0.9998	0.9997	0.9838	0.9897	0.9463
46	0.9991	0.9851	0.9983	0.9830	0.9995	0.9977	0.9916	0.9961	0.9611
42	0.9962	0.9921	0.9935	0.9893	0.9971	0.9940	0.9969	0.9993	0.9738
38	0.9915	0.9969	0.9855	0.9942	0.9928	0.9886	0.9995	0.9991	0.9842
34	0.9849	0.9995	0.9746	0.9977	0.9866	0.9816	0.9994	0.9955	0.9921
30	0.9766	0.9998	0.9609	0.9996	0.9786	0.9731	0.9966	0.9886	0.9974
26	0.9668	0.9980	0.9449	1.0000	0.9689	0.9632	0.9912	0.9787	0.9999
22	0.9557	0.9940	0.9269	0.9990	0.9578	0.9522	0.9833	0.9659	0.9997
18	0.9434	0.9881	0.9073	0.9966	0.9455	0.9402	0.9733	0.9508	0.9969
14	0.9303	0.9804	0.8867	0.9929	0.9323	0.9275	0.9614	0.9338	0.9918
10	0.9166	0.9713	0.8656	0.9882	0.9184	0.9144	0.9481	0.9154	0.9847
6	0.9027	0.9613	0.8446	0.9826	0.9043	0.9011	0.9339	0.8965	0.9760
2	0.8889	0.9507	0.8242	0.9765	0.8903	0.8879	0.9195	0.8777	0.9663
0	0.8821	0.9454	0.8144	0.9733	0.8835	0.8814	0.9124	0.8687	0.9614

Table 1. (continued)

Zenith Angle (degrees)	Gain Curve Value from Standard Polynomial Fit — Antenna								
	19	20	23	24	25	26	27	28	"29"
82	0.9429	0.8513	0.9170	0.9453	0.9696	0.8882	0.9663	0.9309	0.9089
78	0.9554	0.8713	0.9305	0.9543	0.9774	0.9029	0.9773	0.9417	0.9225
74	0.9678	0.8925	0.9443	0.9632	0.9847	0.9180	0.9873	0.9526	0.9363
70	0.9790	0.9138	0.9575	0.9717	0.9910	0.9329	0.9949	0.9631	0.9498
66	0.9884	0.9342	0.9696	0.9794	0.9959	0.9472	0.9994	0.9728	0.9624
62	0.9952	0.9528	0.9802	0.9862	0.9990	0.9604	1.0001	0.9813	0.9737
58	0.9992	0.9690	0.9887	0.9918	1.0001	0.9722	0.9966	0.9885	0.9833
54	1.0000	0.9821	0.9950	0.9960	0.9991	0.9821	0.9889	0.9940	0.9909
50	0.9975	0.9918	0.9987	0.9987	0.9959	0.9901	0.9770	0.9978	0.9962
46	0.9917	0.9976	0.9998	0.9999	0.9904	0.9957	0.9611	0.9997	0.9992
42	0.9827	0.9994	0.9982	0.9994	0.9827	0.9990	0.9416	0.9996	0.9997
38	0.9706	0.9972	0.9938	0.9973	0.9730	0.9998	0.9190	0.9975	0.9976
34	0.9558	0.9909	0.9869	0.9935	0.9614	0.9980	0.8939	0.9935	0.9931
30	0.9385	0.9808	0.9774	0.9882	0.9481	0.9938	0.8668	0.9876	0.9861
26	0.9192	0.9671	0.9657	0.9815	0.9334	0.9873	0.8384	0.9800	0.9770
22	0.8983	0.9503	0.9521	0.9734	0.9175	0.9786	0.8094	0.9708	0.9658
18	0.8763	0.9309	0.9368	0.9642	0.9007	0.9679	0.7804	0.9602	0.9530
14	0.8536	0.9096	0.9203	0.9541	0.8834	0.9557	0.7519	0.9485	0.9388
10	0.8309	0.8870	0.9029	0.9434	0.8659	0.9424	0.7243	0.9361	0.9236
6	0.8086	0.8642	0.8854	0.9322	0.8485	0.9283	0.6981	0.9232	0.9080
2	0.7871	0.8420	0.8680	0.9210	0.8316	0.9140	0.6734	0.9103	0.8924
0	0.7769	0.8315	0.8596	0.9154	0.8234	0.9070	0.6616	0.9039	0.8848

(end text)
(figure follows)



crosses – fit from Crane (1991)
line – fit from this work
Normalized Gain Curve
VLA antenna 1
VLA antenna 2
VLA antenna 3
VLA antenna 4
0.6
0.8
1
0
20
40
60
80
Zenith Angle (degrees)

FIG. 1

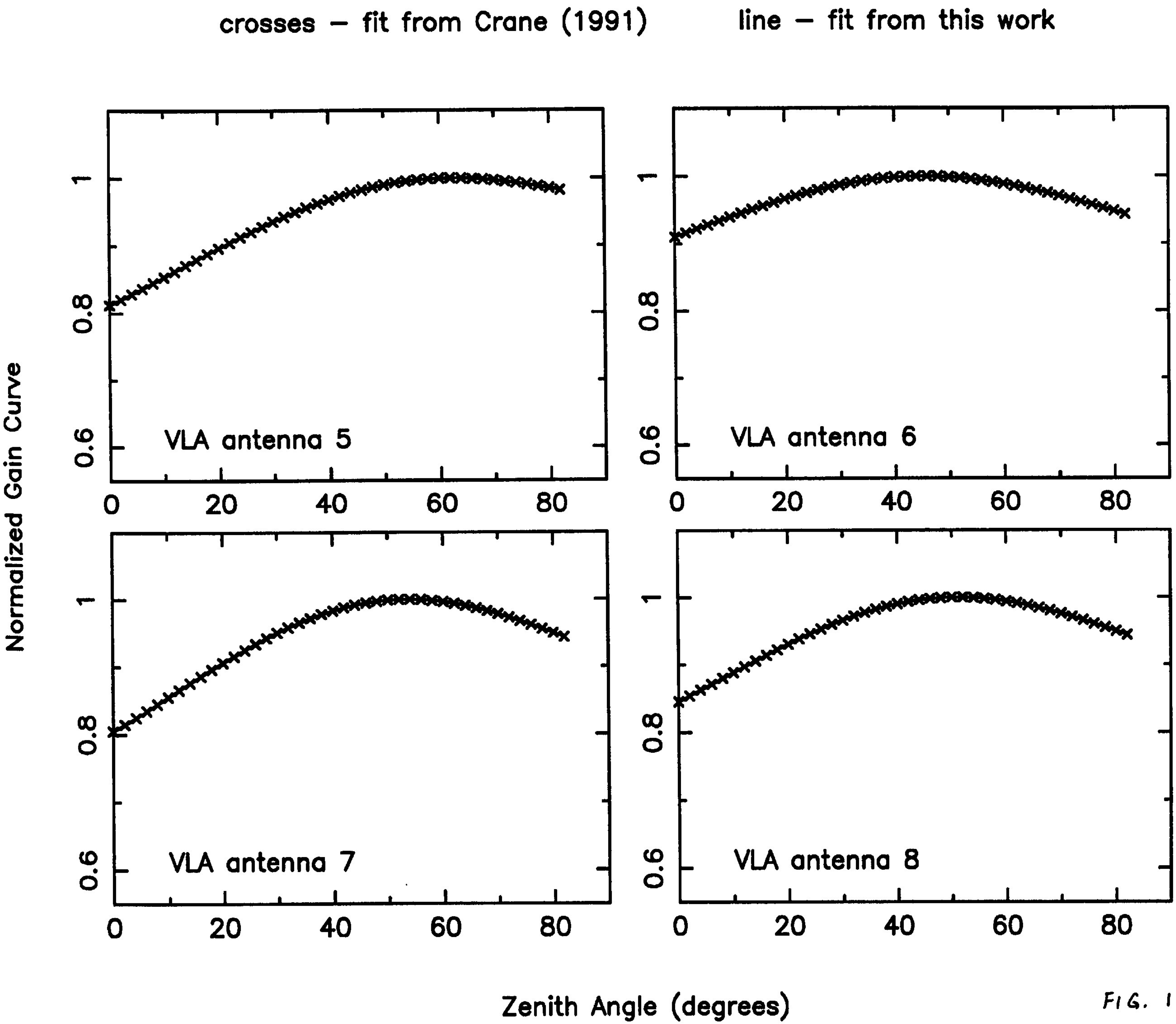

crosses – fit from Crane (1991)
line – fit from this work
VLA antenna 5
VLA antenna 6
VLA antenna 7
VLA antenna 8
Normalized Gain Curve
Zenith Angle (degrees)
0.6
0.8
1
0
20
40
60
80

FIG. 1 (CONT'D)

crosses – fit from Crane (1991)   line – fit from this work

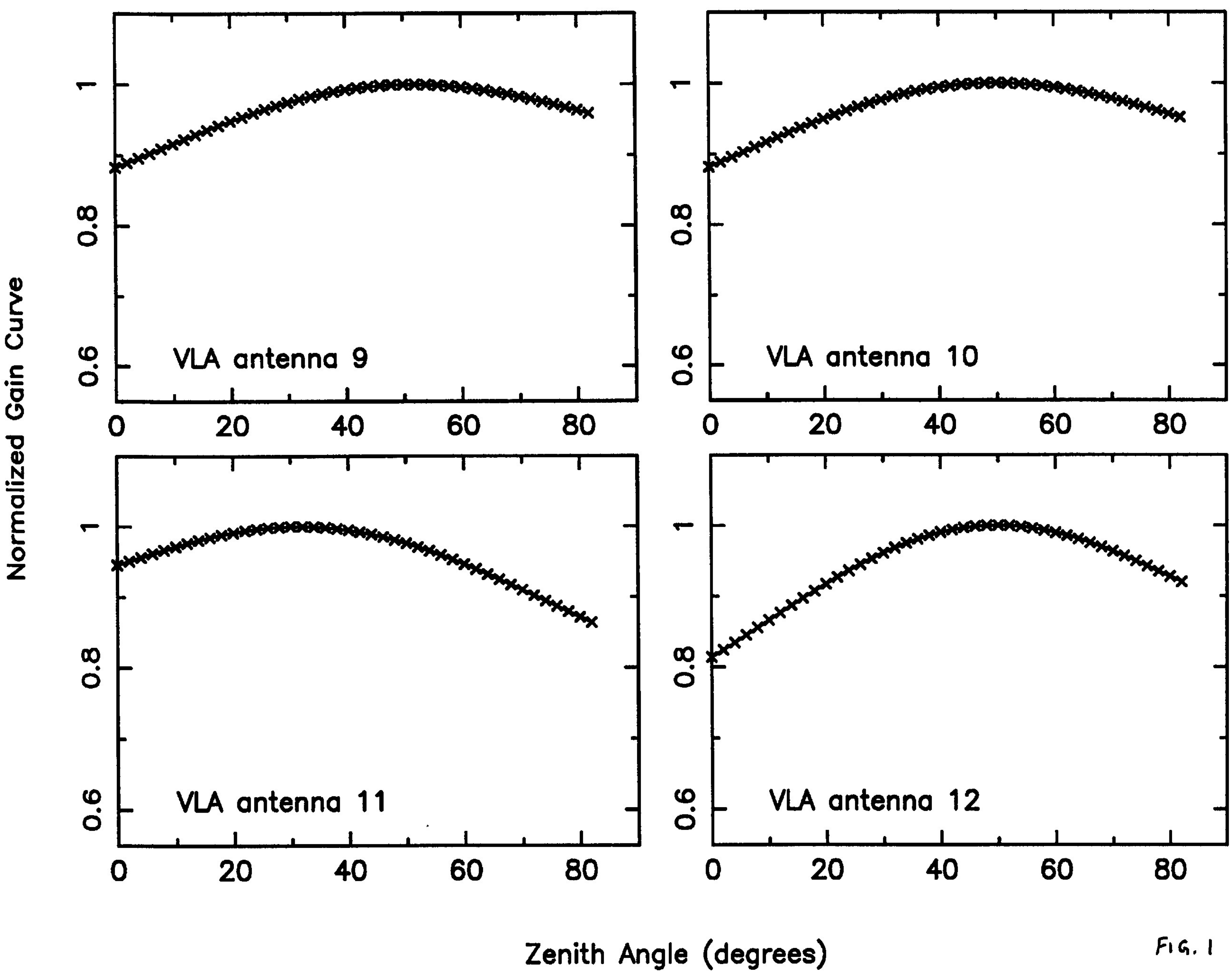


FIG. 1 (CONT'D)

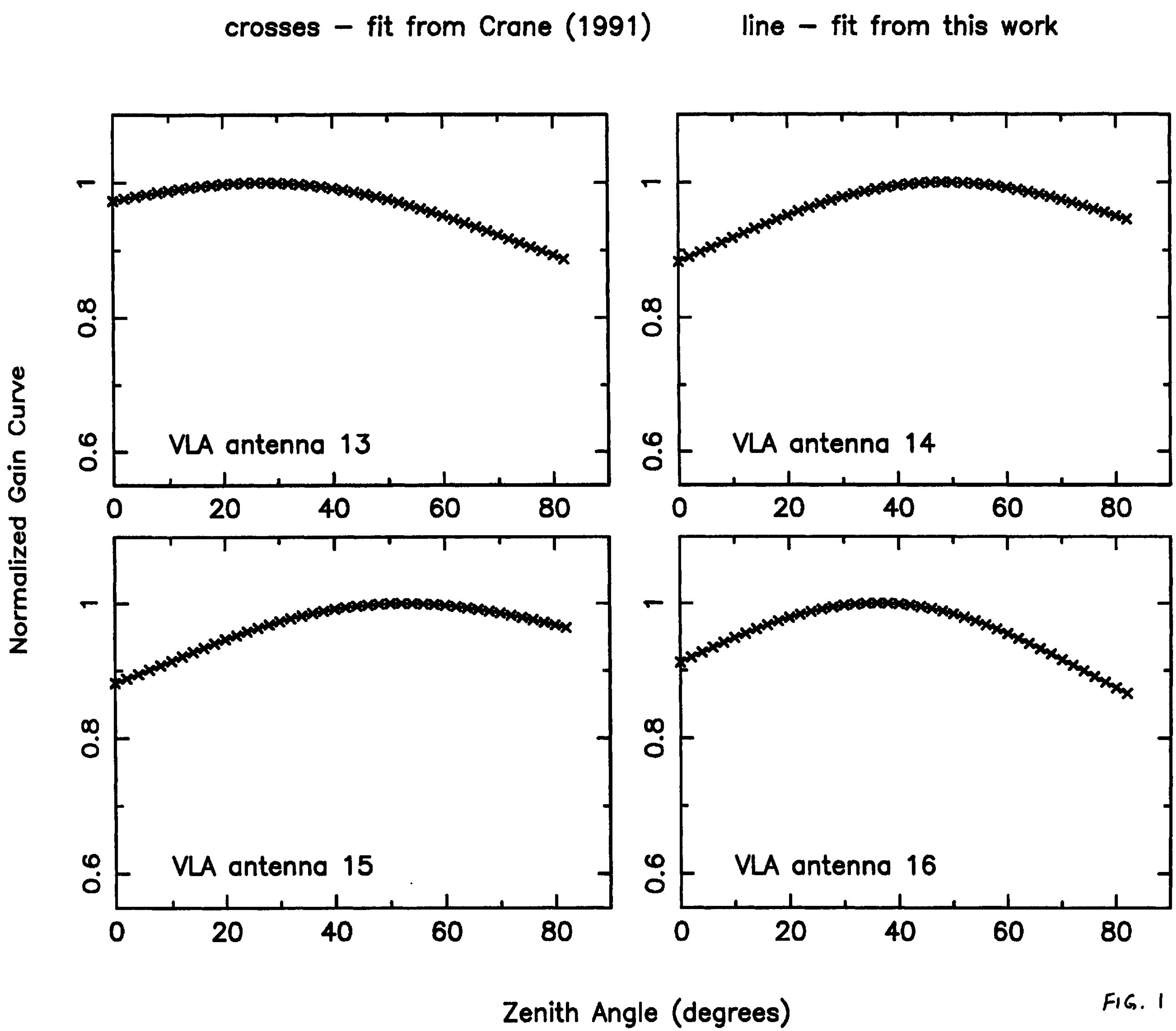

crosses – fit from Crane (1991)
line – fit from this work
Normalized Gain Curve
VLA antenna 13
VLA antenna 14
VLA antenna 15
VLA antenna 16
0.6
0.8
1
0
20
40
60
80
Zenith Angle (degrees)

FIG. 1 (CONT'D)

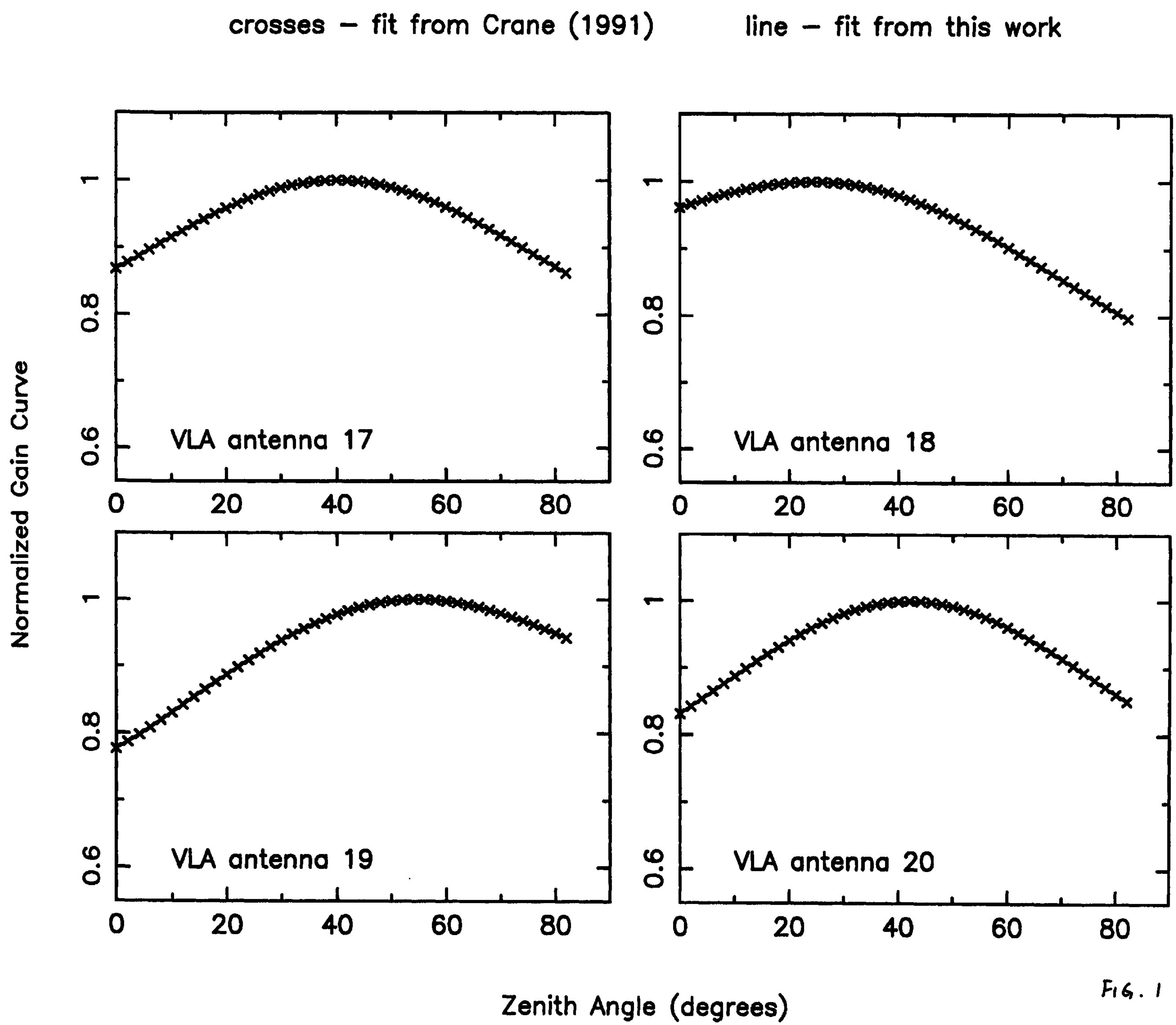

crosses – fit from Crane (1991)
line – fit from this work
Normalized Gain Curve
Zenith Angle (degrees)
VLA antenna 17
VLA antenna 18
VLA antenna 19
VLA antenna 20
0.6
0.8
1
0
20
40
60
80

FIG. 1 (CONT'D)

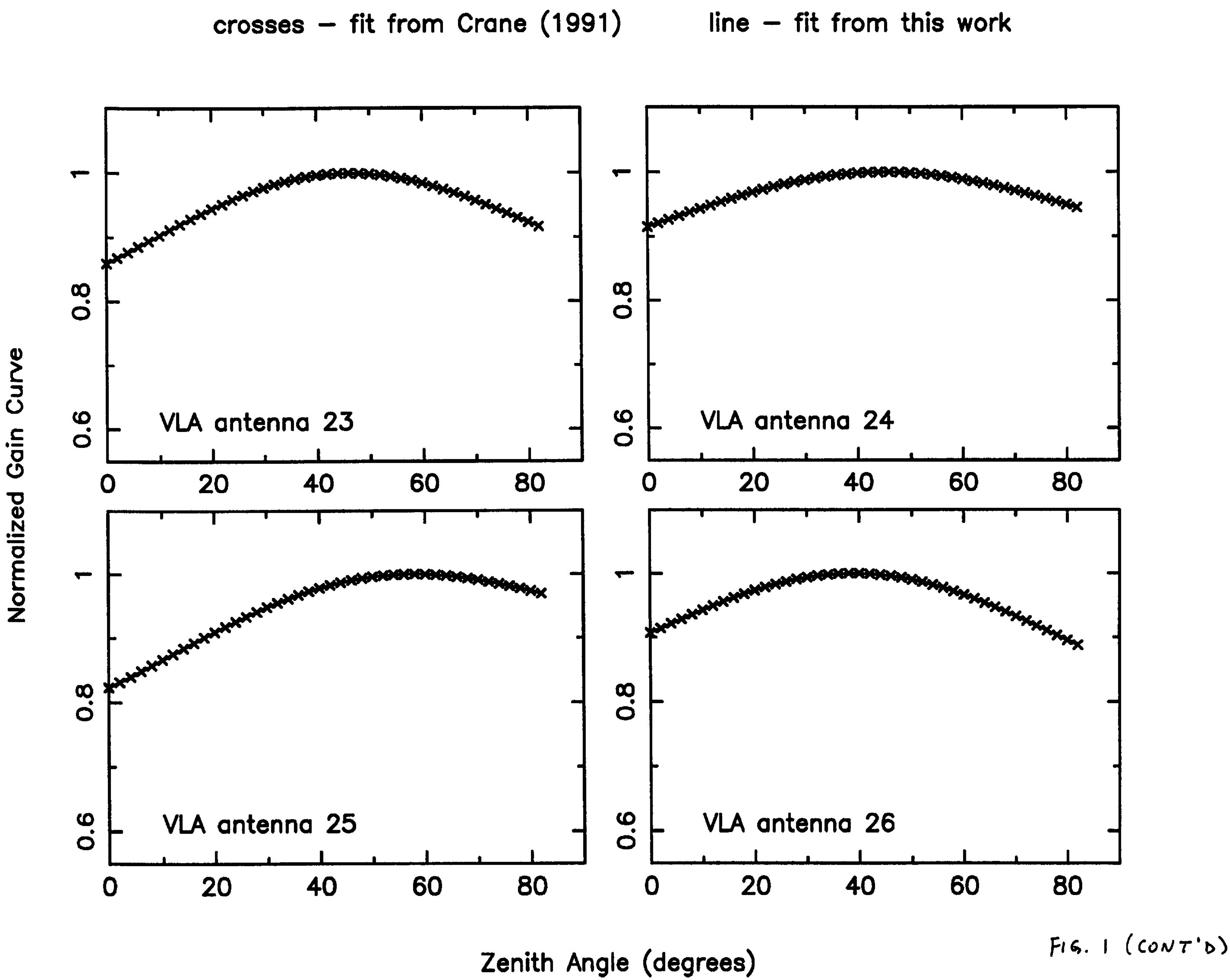

crosses – fit from Crane (1991)
line – fit from this work
Normalized Gain Curve
VLA antenna 23
VLA antenna 24
VLA antenna 25
VLA antenna 26
0.6
0.8
1
0
20
40
60
80
Zenith Angle (degrees)

FIG. 1 (CONT'D)

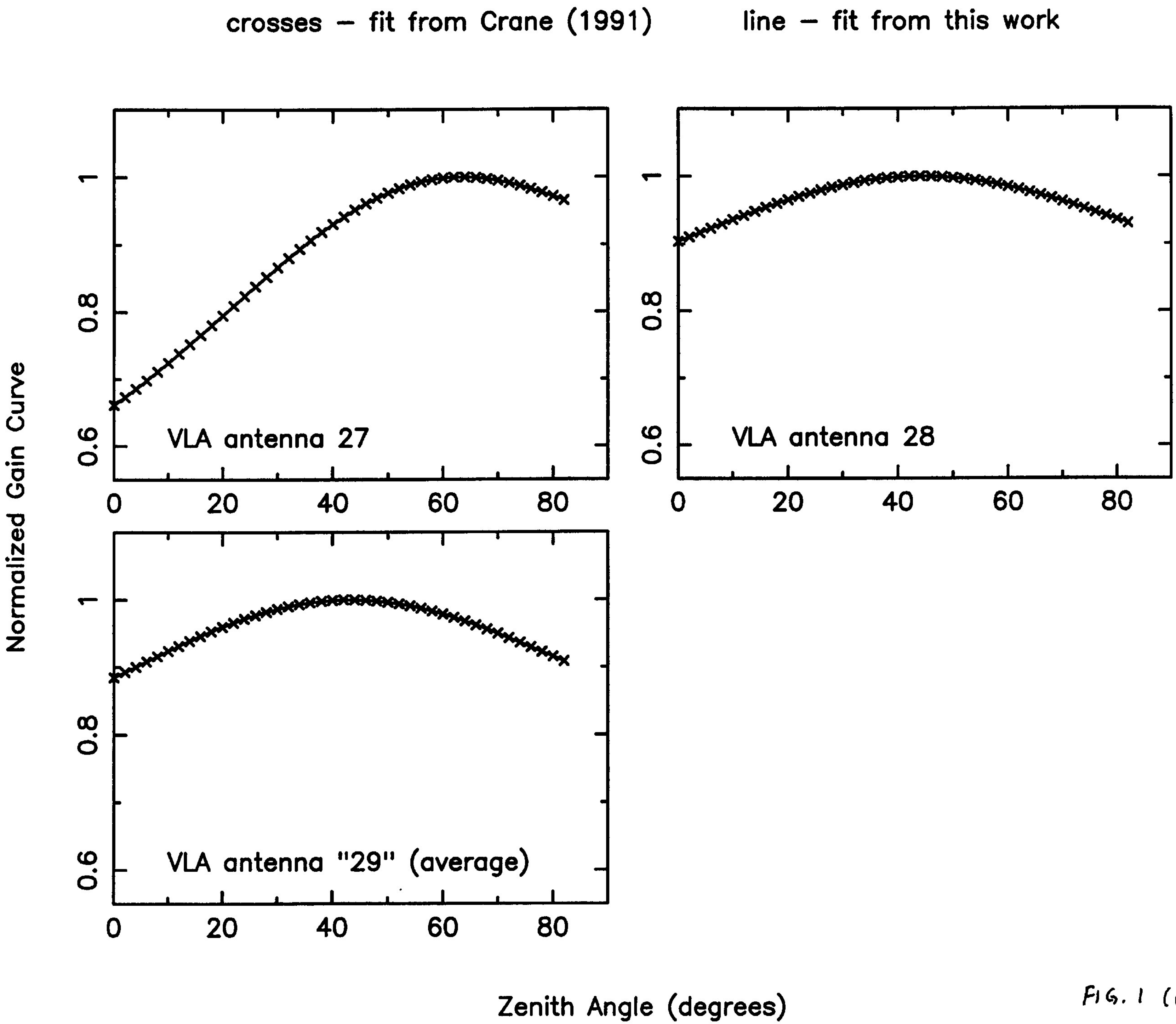

crosses – fit from Crane (1991)
line – fit from this work
Normalized Gain Curve
1
0.8
0.6
0
20
40
60
80
VLA antenna 27
VLA antenna 28
VLA antenna "29" (average)
Zenith Angle (degrees)

FIG. 1 (CONT'D)