GE PANAMETRICS
Waltham, MA 02453

TITLE

Electron Calibration Report

GOES NO/PQ EPEAD D3 Dome

Engineer	Configuration Control
11/23/04	for D.C 11/23/04
Product Assurance	Program Physicist
11/23/04	11/23/04
Program Manager	Program Engineer
11/23/04	11/23/04

SIZE	DRAWING NUMBER	REV
A	GOESN-ENG-027	-

SHEET 1 OF 26

RELEASE AND REVISION RECORD

Rev.	Authority	Description	Release	
			Date	Approved
-	F. Hanser	Initial Release	11/23/04	R.A. Hx.

TABLE OF CONTENTS

Section	Title	Page
1.0	**INTRODUCTION**	**6**
1.1	Purpose	6
1.2	Reference Documents	6
1.3	Acronym List	6
2.0	**GEOMETRIC FACTOR DEFINITION AND MEASUREMENT**	**8**
2.1	Geometric Factor Definition	8
2.2	Experimental Measurement of the Geometric Factor	8
2.3	Equipment Setup	10
3.0	**DATA ANALYSIS AND RESULTS**	**14**
3.1	Measured Detector Areas	14
3.1.1	E1 Electron Channel Measured Areas	14
3.1.2	E2 Electron Channel Measured Areas	19
3.2	Measured Geometric Factors	23
3.2.1	E1 Electron Channel Response	26
3.2.2	E2 Electron Channel Response	26
4.0	**SUMMARY AND CONCLUSIONS**	**26**

LIST OF FIGURES

Figure	Title	Page
Figure 2-1.	EPEAD Dome Sensor Design and FOVs	8
Figure 2-2.	Calibration Configuration at MIT Van de Graaff	12
Figure 2-3.	Electronics Configuration at MIT Van de Graaff	13
Figure 3-1.	Angular Response of E1 at 0.45 MeV	18
Figure 3-2.	Angular Response of E1 at 1.22 MeV	18
Figure 3-3.	Angular Response of E1 at 2.25 MeV	19
Figure 3-4.	Angular Response of E2 at 2.05 MeV	22
Figure 3-5.	Angular Response of E2 at 2.25 MeV	23
Figure 3-6.	Measured E1 A(0,0) Values as a Function of Electron Energy	24
Figure 3-7.	Measured E1 G(E) Values as a Function of Electron Energy	24
Figure 3-8.	Measured E2 A(0,0) Values as a Function of Electron Energy	25
Figure 3-9.	Measured E2 G(E) Values as a Function of Electron Energy	25

LIST OF TABLES

Table	Title	Page
Table 1-1.	Referenced Documents	6
Table 1-2.	List of Acronyms	7
Table 2-1.	Multiplying Factors and $\Delta\Omega_i$ Values for Short Set	9
Table 2-2.	Multiplying Factors and $\Delta\Omega_i$ Values for Long Set	10
Table 3-1.	Measured E1 Detection Areas in cm^2 for 0.45 MeV Electrons	14
Table 3-2.	Measured E1 Detection Areas in cm^2 for 0.57 MeV Electrons	14
Table 3-3.	Measured E1 Detection Areas in cm^2 for 0.68 MeV Electrons	15
Table 3-4.	Measured E1 Detection Areas in cm^2 for 0.87 MeV Electrons	15
Table 3-5.	Measured E1 Detection Areas in cm^2 for 0.96 MeV Electrons	15
Table 3-6.	Measured E1 Detection Areas in cm^2 for 1.22 MeV Electrons	16
Table 3-7.	Measured E1 Detection Areas in cm^2 for 1.46 MeV Electrons	16
Table 3-8.	Measured E1 Detection Areas in cm^2 for 1.89 MeV Electrons	16
Table 3-9.	Measured E1 Detection Areas in cm^2 for 2.05 MeV Electrons	17
Table 3-10.	Measured E1 Detection Areas in cm^2 for 2.16 MeV Electrons	17
Table 3-11.	Measured E1 Detection Areas in cm^2 for 2.25 MeV Electrons	17
Table 3-12.	Measured E2 Detection Areas in cm^2 for 1.22 MeV Electrons	20
Table 3-13.	Measured E2 Detection Areas in cm^2 for 1.46 MeV Electrons	20
Table 3-14.	Measured E2 Detection Areas in cm^2 for 1.89 MeV Electrons	20
Table 3-15.	Measured E2 Detection Areas in cm^2 for 2.05 MeV Electrons	21
Table 3-16.	Measured E2 Detection Areas in cm^2 for 2.16 MeV Electrons	21
Table 3-17.	Measured E2 Detection Areas in cm^2 for 2.25 MeV Electrons	21
Table 3-18.	Measured E1 and E2 Geometric Factors and Detection Areas for Electrons	23

1.0 INTRODUCTION

1.1 Purpose

This report presents the results of the electron particle calibration of the EM EPEAD East D3 Dome detector as performed using the electron beam from the Van de Graaff (VdeG) accelerator located in Building N-10 at the Massachusetts Institute of Technology in Cambridge, Massachusetts. The data have been reduced to the geometric factors necessary to convert the E1 and E2 electron channel telemetry data into electron fluxes. The measured area vs. angle data are also given, to provide information on the angular responses of the E1 and E2 electron channels.

1.2 Reference Documents

Table 1-1 lists the documents referenced in this report. The first is the test procedure used to acquire the data, while the others are earlier Calibration Reports for the Dome electron and proton responses.

Table 1-1. Referenced Documents

Ref. #	Report Number	Date	Title
1	GOESN-RTP-129, Rev. -	Run August, 2004	EPEAD D3 Dome Calibration Procedure
2	NXT-CAL-101, Rev. -	February 16, 1988	GOES I, J, K, L & M EPS Dome Electron Channel Calibration Report
3	NXT-CAL-102, Rev. -	May 30, 1995	Calibration Report for the EPS Dome Sensor Response
4	PANA-GOESP-CR3	August 26, 1980	Energetic Particle Sensor Dome Calibration Work
5	NASA SP-3012	1964	Tables of Energy Losses and Ranges of Electrons and Positrons; M. J. Berger and S. M. Seltzer

1.3 Acronym List

The acronyms used in this report are listed in Table 1-2.

Table 1-2. List of Acronyms

Acronym	Definition
EM	Engineering Model
EPEAD	Energetic Proton, Electron, and Alpha Detector
EPS	Energetic particle Sensor
FOV	Field-of-View
GOES NOPQ	Geostationary Operational Environmental Satellite N, O, P, and Q
GSFC	Goddard Space Flight Center
I/O	Input/Output
IFC	In Flight Calibration
MIT	Massachusetts Institute of Technology
MF	Major Frame
Mf	Minor Frame
PSD	Primary Science Data
RADC	Rome Air Development Center
S/N	Signal to Noise
SEM	Space Environment Monitor
SSD	Solid State Detector
VdeG	Van de Graaff Accelerator

2.0 GEOMETRIC FACTOR DEFINITION AND MEASUREMENT

2.1 Geometric Factor Definition

The geometric factors of the E1 and E2 electron channels are defined by an integral of the detection area over solid angle. A detection area of $A(E,\Omega)$ cm^2 for electrons of energy E MeV and angle Ω, the geometric factor G(E) is given by

$$G(E) = \int A(E,\Omega)\, d\Omega \ cm^2\text{-sr} \tag{2.1}$$

where $d\Omega = (\sin\theta)\, d\theta\, d\varphi$, with θ the elevation angle and φ the azimuth angle. For an isotropic electron flux J(E) el/(cm^2-s-sr) the channel count rate is given by

$$C_{el} = \int J(E)\, G(E)\, dE \ s^{-1} \tag{2.2}$$

For an electron flux where there is also an angle dependence, the channel count rate is given by

$$C_{el} = \int J(E,\Omega)\, A(E,\Omega)\, dE\, d\Omega \ s^{-1} \tag{2.3}$$

For normal conditions the geometric factor (2.1) is used, with the count rate given by (2.2).

The design of the EPEAD Dome sensor is shown in Figure 2-1, with the D3 dome being in the center location. The D3 dome FOV is about +/-55 degrees in the elevation direction, and +/-35 degrees in the azimuth direction.

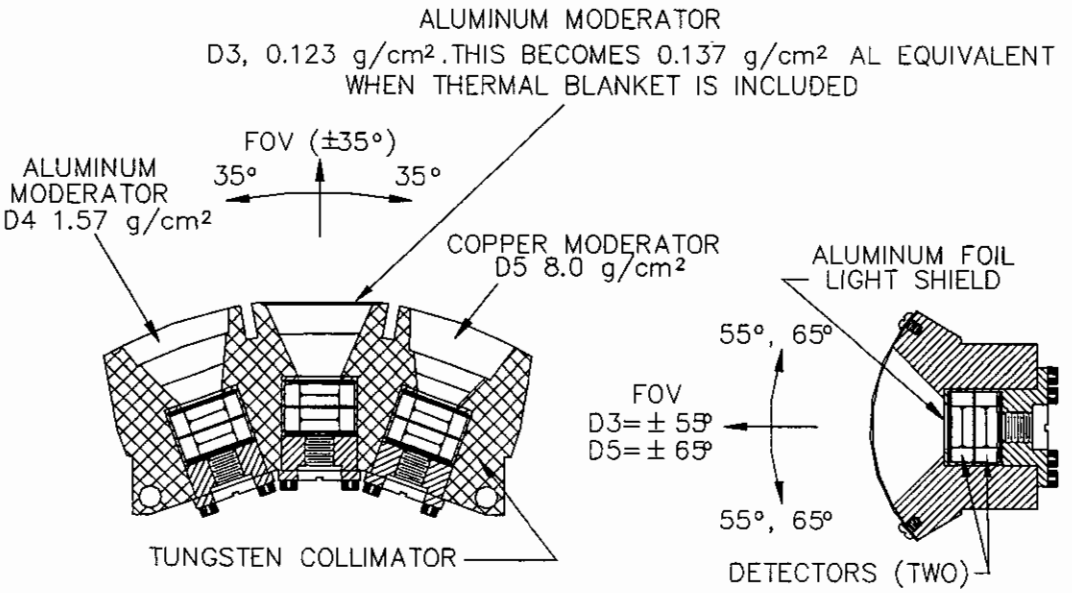

Figure 2-1. EPEAD Dome Sensor Design and FOVs

2.2 Experimental Measurement of the Geometric Factor

The experimental measurement of G(E) is done by measuring the angular response $A(E,\Omega)$ at several angles. The integrated geometric factor is then calculated by a numerical sum

$$G(E) = \sum_i A(E,\Omega_i)\, \Delta\Omega_i \tag{2.4}$$

where

$$\Delta\Omega_i = (\phi_{2i} - \phi_{1i}) \times (\sin\theta_{2i} - \sin\theta_{1i}) \quad (2.5)$$

with θ being the elevation angle and ϕ being the azimuth angle. Measurements are made at sets of angles $\Omega(\theta_i, \phi_i)$, with the subscripts 1 and 2 in (2.5) being the breakpoints between adjacent angle points. The response area at Ω_i is obtained from measured channel count rates and monitor detector count rates. For the EPEAD electron calibration at the MIT VdeG, the detection area is calculated from

$$A(E,\Omega_i) = Ct_{Ei} / T_{Ei} / Ct_{Mj} \cdot T_M \cdot A_{Mj} \cdot (D_D / D_{Mj})^2 \cdot K_M \quad (2.6)$$

where

Ct_{Ei} = the E1 or E2 dome detector counts

T_{Ei} = the counting time for the E1 or E2 dome counts (s)

Ct_{Mj} = M1 (or M2) monitor counts (s)

T_M = Monitor count time (s)

A_{Mj} = area of M1 (or M2) monitor (cm^2)

D_D = distance of D3 dome detector from electron vacuum exit (in)

D_{Mj} = distance of M1 (or M2) monitor detector from electron vacuum exit (in)

K_M = ratio of $M2_{in\ beam}$ / $M2_{out\ of\ beam}$ count rates normalized to M1 count rates

The above items are discussed in more detail in section 3.1.

The EPEAD electron calibration used measurement sets in θ_i, ϕ_i, where both varied from 0 deg to 50 deg in 10 deg steps, and a few sets where ϕ_i varied from –50 deg to +50 deg in 10 deg steps. In doing the sum of (2.4), the response symmetry was used to calculate the total G(E). Table 2-1 lists the multiplying factors (No. of bins) and the $\Delta\Omega_i$ values for the first (short) set, while Table 2-2 lists these items for the second (long) set. The short set measures a quarter of the full geometric factor, while the long set measures half of the full geometric factor.

Table 2-1. Multiplying Factors and $\Delta\Omega_i$ Values for Short Set

θ_i (degrees)	θ_2 / θ_1 (degrees)	$\Delta\Omega_i$ (sr)	No. of bins (ϕ_i = 0)	No. of bins (ϕ_i = 10, 20, 30, 40, 50)
0	-5 / +5	0.03042	1	2
10	5 / 15	0.02996	2	4
20	15 / 25	0.02859	2	4
30	25 / 35	0.02635	2	4
40	35 / 45	0.02331	2	4
50	45 / 55	0.01956	2	4

Table 2-2. Multiplying Factors and $\Delta\Omega_i$ Values for Long Set

θ_i (degrees)	θ_2 / θ_1 (degrees)	$\Delta\Omega_i$ (sr)	No. of bins (ϕ_i = -50, -40, -30, -20, -10, 0, 10, 20, 30, 40, 50)
0	-5 / +5	0.03042	1
10	5 / 15	0.02996	2
20	15 / 25	0.02859	2
30	25 / 35	0.02635	2
40	35 / 45	0.02331	2
50	45 / 55	0.01956	2

2.3 Equipment Setup

The basic calibration set-up at the MIT VdeG is shown in Figure 2-2, where the monitor detectors and EPEAD locations are shown. The M2 monitor detector is scanned in front of the EPEAD to provide corrections for a non-uniform electron beam, using the M1 monitor as a reference. During the EPEAD measurements both monitor detectors are used to provide a measure of the electron beam intensity. The air paths to the monitor detectors and to the EPEAD are used to correct the electron beam energy for energy loss in the air. The distances to the monitor detector collimators are used to provide electron beam intensity corrections for the beam at the EPEAD.

The electronics configuration is shown in Figure 2-3, with a portion of the electronics being located in the electron beam room, and some of the electronics being located in the VdeG control room. The monitor detectors were calibrated with the Compton edge of a Cs-137 gamma ray source (477 keV), and this was used along with the full energy peak measured by the monitor detectors to calculate the actual electron beam energy. The VdeG exit window was 0.003 inch of aluminum, and this along with the air paths to the monitor detectors was used to calculate a true VdeG beam energy at the exit window. The air path to the D3 detector was then used to calculate an effective electron energy at the D3 detector, which is the energy for the calibration data. The electron beam energy was thus directly calibrated for each energy data set.

The rotating table in Figure 2-2 was used to perform the azimuth angle scans, while a second pivot point on the rotating fixture was used to make elevation adjustments of the D3 dome. For most of the energy measurements the azimuth and elevation angle scans were 0 degree to 50 degrees in 10 degree steps for both, providing a total of 36 measurement points. Each azimuth scan had the 0 degree azimuth point repeated at the end of the scan to verify measurement stability. For data analysis, the multiple 0 degree azimuth points were averaged for the final area value.

The values for some of the constants in (2.6) for the EPEAD calibrations are given below.

T_{E1} = the counting time for the E1 dome counts = 4.096 s

T_{E2} = the counting time for the E2 dome counts = 16.384 s

T_M = Monitor count time = 10 s

A_{M1} = area of M1 monitor collimator = 0.1734 cm^2

A_{M2} = area of M2 monitor collimator = 0.2027 cm^2

D_{M1} = distance of M1 monitor detector collimator entrance from electron vacuum exit = 27.75 in

D_{M2} = distance of M2 monitor detector collimator entrance from electron vacuum exit = 22.5 in

D_D = distance of D3 dome detector from electron vacuum exit = 30.375 in

The remaining numbers vary for each individual measurement, although the K_M value is constant for a given electron energy run. The value of K_M is measured before and after the angle scans at each energy, and the average value is used for the data analysis. Data are checked for reasonable consistency, to ensure that there are no significant variations in electron beam properties during a particular measurement set. The monitor detector, E1, and E2 count rates are monitored during the measurements, and the VdeG beam intensity was adjusted to keep the count rates below a level where dead-time effects become important. The VdeG beam occasionally exhibited dark-current pulsations, mostly at the highest energies, and the VdeG had to be "conditioned" at a higher voltage to clean up the beam. Data from such periods was retaken, as necessary, to avoid using data contaminated by high intensity electron/bremsstrahlung background counts.

The electron energy calculations from the monitor detector full energy measurements used the total air path from the VdeG exit window to the detector face, and also included the loss in the 0.3 mil aluminum light shield in front of the monitor detectors. The corrected electron energy at the D3 detector, as calculated from the M1 and M2 monitor detector measurements separately, generally agreed to better than 2%. Electron energy losses in aluminum and air were calculated using the electron stopping powers in Reference 5.

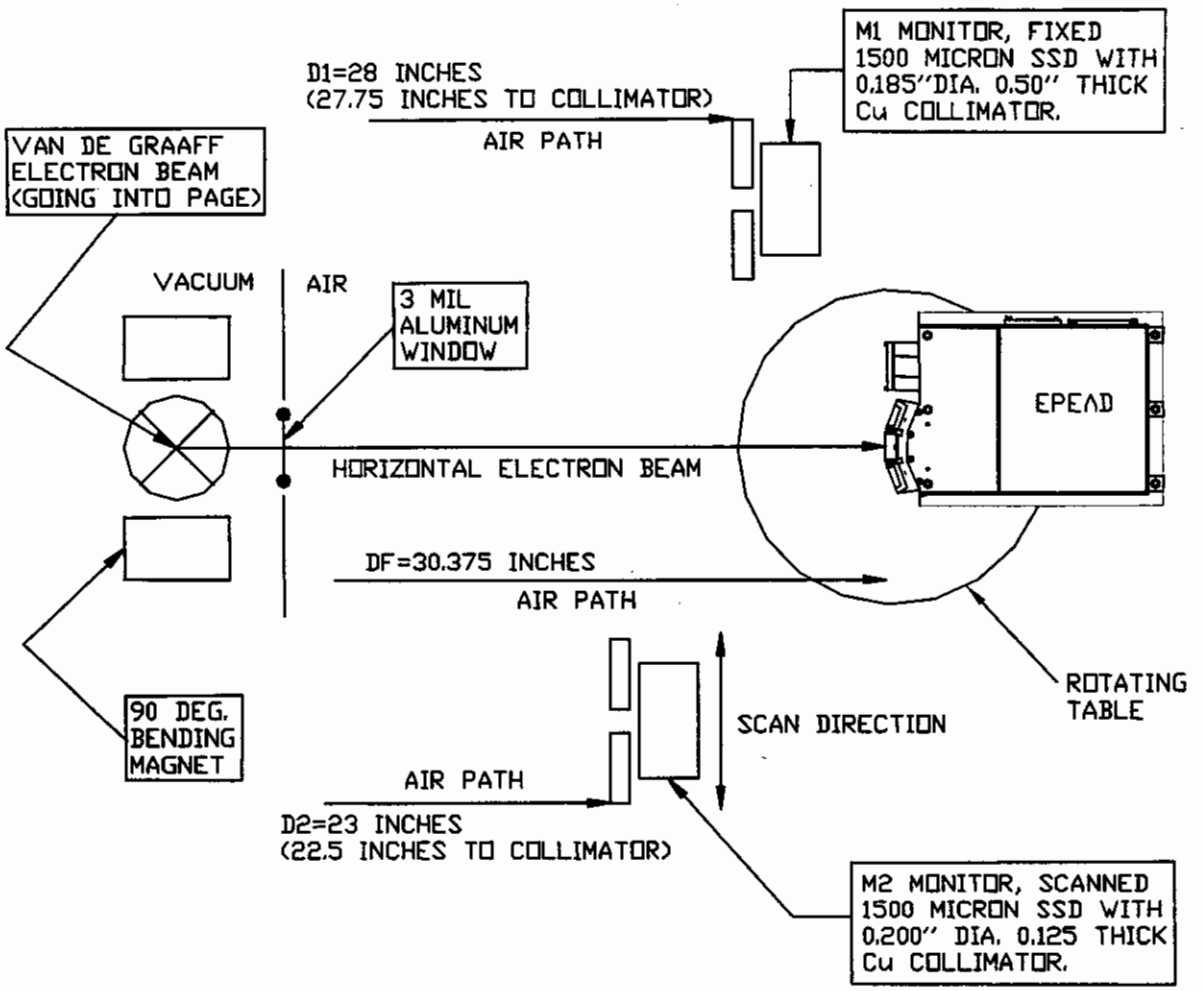

Figure 2-2. Calibration Configuration at MIT Van de Graaff

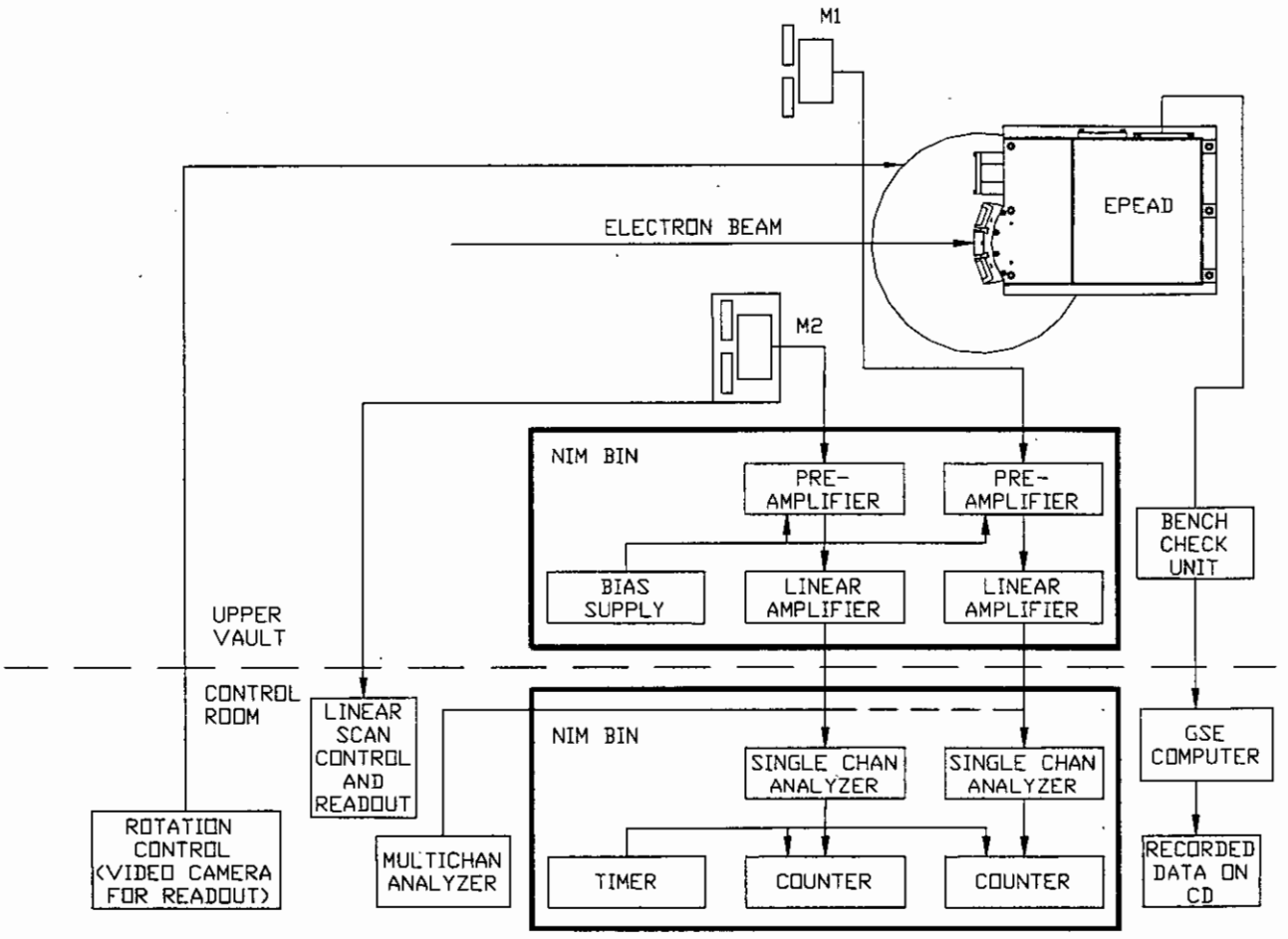

Figure 2-3. Electronics Configuration at MIT Van de Graaff

3.0 Data analysis and results

3.1 Measured Detector Areas

3.1.1 E1 Electron Channel Measured Areas

The D3 dome detector measured E1 channel areas for electrons at several energies are summarized in Tables 3-1 to 3-11. The calibrated electron energy at the D3 detector is listed for each measurement. The areas are calculated from the two monitor detector collimator areas, using the procedure described in Section 2.2. Measurements for most electron energies covered the range of 0 deg to 50 deg in 10 deg steps in both elevation and azimuth (0.45 MeV, 0.57 MeV, 0.87 MeV, 0.96 MeV, 2.05 MeV, and 2.25 MeV). Two energies covered an azimuth range of –50deg to +50 deg in 10 deg steps (0.68 MeV and 1.89 MeV), while two energies covered this azimuth range along with an elevation range of –10 deg to +60 deg in 10 deg steps (1.22 MeV and 1.46 MeV). Measurements at 2.16 MeV had only 0 deg elevation data taken for an azimuth range of 0 deg to 60 deg in 10 deg steps. Plots of the measured areas are shown in Figures 3-1 to 3-3, with the 0.45 MeV data in Figure 3-1 and the 2.25 MeV data in Figure 3-3 both being a four-fold reflection of the measure data for one quadrant of the response. The 1.22 MeV data in Figure 3-2 is a two-fold reflection of the measured data from one half of the response.

Table 3-1. Measured E1 Detection Areas in cm^2 for 0.45 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)					
	0	10	20	30	40	50
0	0.0012607	0.0010036	0.0009677	0.0006552	0.0004331	0.0002043
10	0.0008884	0.0009536	0.0008200	0.0005224	0.0003862	0.0002103
20	0.0007977	0.0007327	0.0005501	0.0006244	0.0003634	0.0001631
30	0.0006151	0.0004553	0.0006027	0.0004226	0.0002818	0.0001535
40	0.0003720	0.0003656	0.0002834	0.0002552	0.0001860	0.0000805
50	0.0002493	0.0001973	0.0001792	0.0001773	0.0001235	0.0000835

Table 3-2. Measured E1 Detection Areas in cm^2 for 0.57 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)					
	0	10	20	30	40	50
0	0.04806	0.04935	0.04424	0.03230	0.02420	0.01655
10	0.04256	0.04276	0.03873	0.03030	0.02137	0.01613
20	0.03964	0.03816	0.03239	0.02803	0.01887	0.01290
30	0.02805	0.02746	0.02579	0.02136	0.01681	0.00959
40	0.02142	0.02034	0.01922	0.01327	0.01208	0.00960
50	0.01504	0.01678	0.01443	0.01124	0.00892	0.00578

Table 3-3. Measured E1 Detection Areas in cm^2 for 0.68 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)										
	-50	-40	-30	-20	-10	0	10	20	30	40	50
0	0.0415	0.0526	0.0680	0.0779	0.0896	0.0963	0.0829	0.0861	0.0616	0.0480	0.0288
10	0.0349	0.0493	0.0639	0.0773	0.0836	0.0861	0.0851	0.0770	0.0575	0.0465	0.0277
20	0.0307	0.0416	0.0596	0.0657	0.0688	0.0827	0.0749	0.0577	0.0500	0.0356	0.0235
30	0.0253	0.0350	0.0516	0.0630	0.0692	0.0770	0.0774	0.0621	0.0542	0.0398	0.0288
40	0.0181	0.0265	0.0340	0.0439	0.0544	0.0575	0.0553	0.0502	0.0427	0.0319	0.0222
50	0.0133	0.0199	0.0267	0.0315	0.0390	0.0379	0.0394	0.0343	0.0286	0.0250	0.0162

Table 3-4. Measured E1 Detection Areas in cm^2 for 0.87 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)					
	0	10	20	30	40	50
0	0.2182	0.2294	0.2008	0.1639	0.1372	0.0944
10	0.2143	0.2375	0.1886	0.1671	0.1239	0.0904
20	0.1897	0.2048	0.1774	0.1412	0.1238	0.0750
30	0.1987	0.1935	0.1718	0.1476	0.1103	0.0803
40	0.1295	0.1291	0.1229	0.1072	0.0802	0.0586
50	0.1059	0.1009	0.0890	0.0766	0.0648	0.0447

Table 3-5. Measured E1 Detection Areas in cm^2 for 0.96 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)					
	0	10	20	30	40	50
0	0.2858	0.2625	0.2556	0.2234	0.1628	0.1280
10	0.2690	0.2769	0.2653	0.2103	0.1745	0.1130
20	0.2307	0.2504	0.2203	0.1920	0.1411	0.1127
30	0.2071	0.2113	0.1911	0.1577	0.1189	0.0879
40	0.1727	0.1538	0.1595	0.1295	0.1071	0.0754
50	0.1245	0.1289	0.1147	0.0891	0.0818	0.0577

Table 3-6. Measured E1 Detection Areas in cm^2 for 1.22 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)											
	-50	-40	-30	-20	-10	0	10	20	30	40	50	60
-10	0.1050	0.1626	0.1863	0.2576	0.3040	0.3063	0.3249	0.2707	0.2267	0.1858	-	-
0	0.0855	0.1695	0.2162	0.2463	0.3166	0.3314	0.3434	0.2817	0.2052	0.1807	0.1185	0.0872
10	0.0906	0.1480	0.2217	0.2721	0.3009	0.3266	0.2981	0.2952	0.2390	0.1684	0.1286	0.0726
20	0.0843	0.1318	0.1828	0.2414	0.2655	0.2982	0.3029	0.2608	0.2094	0.1756	0.1015	0.0636
30	0.0807	0.1480	0.1676	0.2204	0.2106	0.2388	0.2758	0.2524	0.1949	0.1437	0.0947	0.0648
40	0.0694	0.1074	0.1348	0.1690	0.1863	0.2103	0.2106	0.1903	0.1548	0.1048	0.0891	0.0604
50	0.0579	0.0878	0.1012	0.1354	0.1443	0.1646	0.1577	0.1707	0.1249	0.0913	0.0700	0.0409

Table 3-7. Measured E1 Detection Areas in cm^2 for 1.46 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)											
	-50	-40	-30	-20	-10	0	10	20	30	40	50	60
0	0.1204	0.1718	0.2592	0.3324	0.4798	0.4030	0.4046	0.3421	0.3079	0.2298	0.1556	0.1204
10	0.1072	0.1704	0.1956	0.2317	0.2810	0.3343	0.3069	0.2881	0.2303	0.1983	0.1471	0.1072
20	0.1226	0.1467	0.2015	0.2894	0.3652	0.3912	0.4008	0.3861	0.3014	0.2244	0.1544	0.1226
30	0.1105	0.1622	0.2154	0.3640	0.3178	0.3535	0.3724	0.4425	0.2715	0.2142	0.1435	0.1105
40	0.0997	0.1401	0.1805	0.2294	0.2815	0.3044	0.2919	0.2677	0.2319	0.1687	0.1459	0.0997
50	0.0704	0.1021	0.1357	0.2196	0.2742	0.2573	0.2442	0.2045	0.1732	0.1498	0.1167	0.0704

Table 3-8. Measured E1 Detection Areas in cm^2 for 1.89 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)										
	-50	-40	-30	-20	-10	0	10	20	30	40	50
0	0.1195	0.1710	0.2430	0.3060	0.3288	0.3822	0.3329	0.2761	0.2929	0.1758	0.1117
10	0.1169	0.1680	0.2154	0.2729	0.2961	0.3248	0.3163	0.2727	0.2336	0.1593	0.1273
20	0.1064	0.1689	0.2123	0.2545	0.2903	0.3101	0.3446	0.2858	0.2264	0.1488	0.0918
30	0.1010	0.1417	0.1880	0.2356	0.2624	0.2745	0.2699	0.2420	0.1937	0.1502	0.1282
40	0.0952	0.1266	0.1739	0.2099	0.2278	0.2415	0.2352	0.2109	0.1793	0.1355	0.0996
50	0.0678	0.0978	0.1267	0.1580	0.1766	0.1793	0.1774	0.1553	0.1302	0.0994	0.0745

Table 3-9. Measured E1 Detection Areas in cm^2 for 2.05 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)					
	0	10	20	30	40	50
0	0.5423	0.6177	0.4185	0.3074	0.2112	0.1209
10	0.5015	0.4914	0.4103	0.3254	0.2140	0.1269
20	0.4448	0.2915	0.3540	0.2893	0.1913	0.1162
30	0.3709	0.3847	0.2661	0.2461	0.1598	0.0946
40	0.2845	0.2852	0.2509	0.1458	0.1383	0.0888
50	0.2224	0.2087	0.1859	0.1383	0.0972	0.0652

Table 3-10. Measured E1 Detection Areas in cm^2 for 2.16 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)					
	0	10	20	30	40	50
0	0.4448	0.3813	0.3182	0.2510	0.1647	0.1042

Table 3-11. Measured E1 Detection Areas in cm^2 for 2.25 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)					
	0	10	20	30	40	50
0	0.3659	0.3539	0.3181	0.2094	0.1465	0.1025
10	0.3428	0.3591	0.2840	0.2104	0.1648	0.0934
20	0.3796	0.3169	0.2842	0.2073	0.1372	0.0999
30	0.3012	0.3051	0.2531	0.1676	0.1461	0.0800
40	0.2389	0.2161	0.1553	0.1166	0.1010	0.1855
50	0.1706	0.1593	0.1370	0.1033	0.0782	0.0454

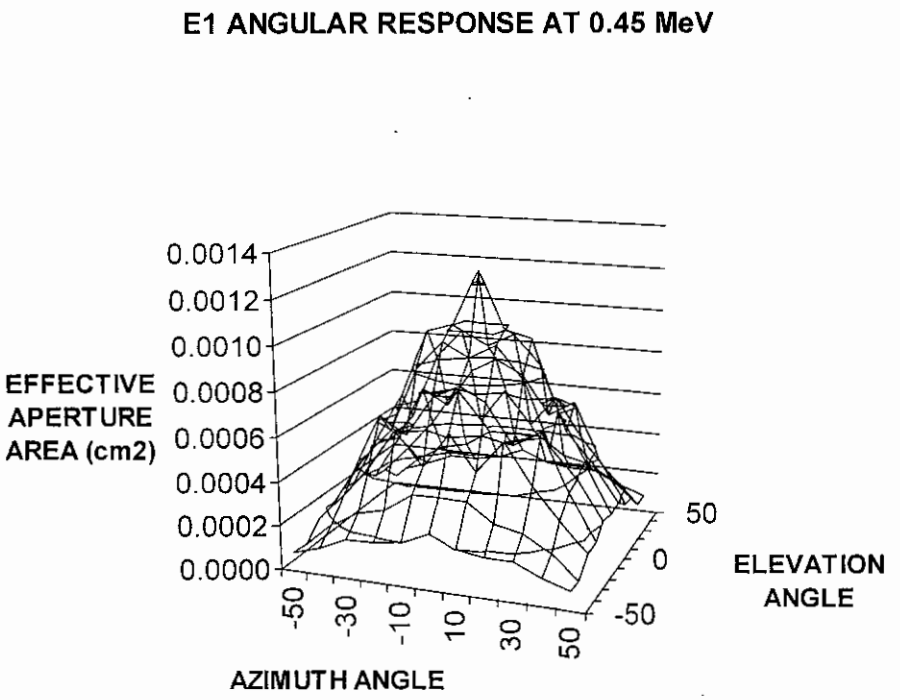

Figure 3-1. Angular Response of E1 at 0.45 MeV

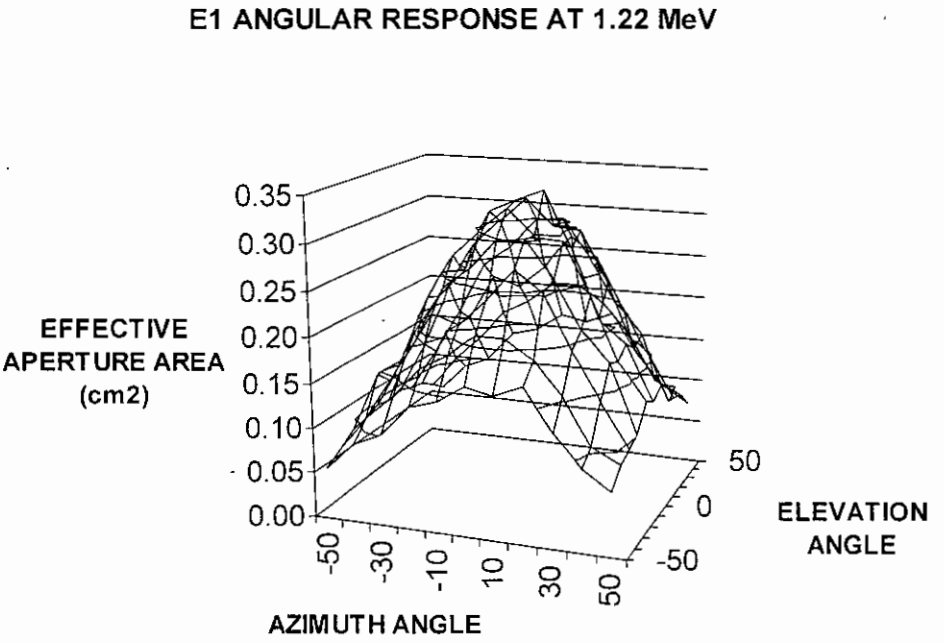

Figure 3-2. Angular Response of E1 at 1.22 MeV

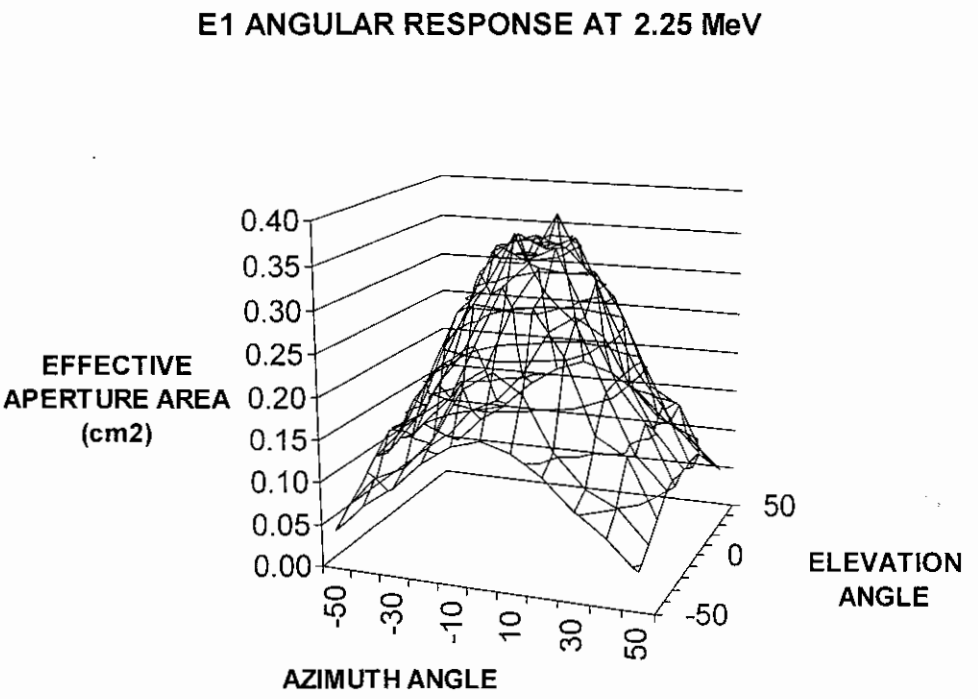

Figure 3-3. Angular Response of E1 at 2.25 MeV

3.1.2 E2 Electron Channel Measured Areas

The D3 dome detector measured E2 channel areas for electrons at several energies are summarized in Tables 3-12 to 3-17. The calibrated electron energy at the D3 detector is listed for each measurement. The areas are calculated from the two monitor detector collimator areas, using the procedure described in Section 2.2. Measurements for two electron energies covered the range of 0 deg to 50 deg in 10 deg steps in both elevation and azimuth (2.05 MeV, and 2.25 MeV). One energy covered an azimuth range of –50deg to +50 deg in 10 deg steps (1.89 MeV), while two energies covered this azimuth range along with an elevation range of –10 deg to +60 deg in 10 deg steps (1.22 MeV and 1.46 MeV). Measurements at 2.16 MeV had only 0 deg elevation data taken for an azimuth range of 0 deg to 60 deg in 10 deg steps, primarily because of machine beam pulsing problems.

Plots of the measured areas are shown in Figures 3-4 for 2.05 MeV, and Figure 3-5 for 2.25 MeV. Both plots are four-fold reflections of the measure data for one quadrant of the response.

Table 3-12. Measured E2 Detection Areas in cm^2 for 1.22 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)											
	-50	-40	-30	-20	-10	0	10	20	30	40	50	60
-10	0.000000	0.000000	0.000084	0.000063	0.000242	0.000110	0.000187	0.000201	0.000067	0.000111	0.000000	0.000000
0	0.000000	0.000064	0.000152	0.000133	0.000250	0.000181	0.000185	0.000123	0.000198	0.000024	0.000030	0.000000
10	0.000000	0.000000	0.000093	0.000093	0.000144	0.000084	0.000107	0.000221	0.000070	0.000069	0.000028	0.000000
20	0.000000	0.000033	0.000054	0.000128	0.000043	0.000084	0.000127	0.000061	0.000018	0.000055	0.000000	0.000000
30	0.000000	0.000000	0.000000	0.000000	0.000000	0.000019	0.000000	0.000000	0.000000	0.000037	0.000000	0.000000
40	0.000000	0.000000	0.000000	0.000019	0.000000	0.000000	0.000000	0.000037	0.000000	0.000000	0.000000	0.000000
50	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Table 3-13. Measured E2 Detection Areas in cm^2 for 1.46 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)											
	-50	-40	-30	-20	-10	0	10	20	30	40	50	60
0	0.000083	0.000202	0.000388	0.000481	0.001046	0.000791	0.000700	0.000605	0.000441	0.000429	0.000164	0.000083
10	0.000144	0.000000	0.000043	0.000634	0.000368	0.001540	0.000542	0.000818	0.000507	0.000655	0.000076	0.000144
20	0.000000	0.000252	0.000260	0.000315	0.000384	0.000259	0.000244	0.000343	0.000156	0.000097	0.000041	0.000000
30	0.000060	0.000000	0.000019	0.000434	0.000134	0.000164	0.000149	0.000294	0.000154	0.000036	0.000097	0.000060
40	0.000000	0.000000	0.000000	0.000161	0.000320	0.000119	0.000130	0.000426	0.000040	0.000056	0.000032	0.000000
50	0.000000	0.000000	0.000185	0.000000	0.000087	0.000000	0.000071	0.000059	0.000142	0.000046	0.000048	0.000000

Table 3-14. Measured E2 Detection Areas in cm^2 for 1.89 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)										
	-50	-40	-30	-20	-10	0	10	20	30	40	50
0	0.0030	0.0043	0.0086	0.0153	0.0270	0.01717	0.01888	0.00691	0.00724	0.00498	0.00038
10	0.0068	0.0104	0.0153	0.0218	0.0336	0.03145	0.02189	0.01724	0.01265	0.00674	0.00301
20	0.0039	0.0110	0.0204	0.0284	0.0278	0.02408	0.00691	0.00461	0.00314	0.00178	0.00098
30	0.0047	0.0085	0.0186	0.0168	0.0248	0.02555	0.02387	0.02543	0.01544	0.00614	0.00462
40	0.0037	0.0082	0.0013	0.0020	0.0035	0.00605	0.00740	0.00702	0.00785	0.00579	0.00420
50	0.0013	0.0020	0.0035	0.0060	0.0074	0.00702	0.00785	0.00579	0.00420	0.00198	0.00192

Table 3-15. Measured E2 Detection Areas in cm^2 for 2.05 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)					
	0	10	20	30	40	50
0	0.03148	0.03631	0.02620	0.01797	0.01063	0.00596
10	0.02781	0.02724	0.02117	0.01908	0.00794	0.00333
20	0.02226	0.01657	0.01838	0.01303	0.01008	0.00200
30	0.01765	0.02020	0.01520	0.02821	0.00615	0.00129
40	0.01307	0.01467	0.01099	0.00473	0.00600	0.00183
50	0.00852	0.00934	0.00703	0.00503	0.00288	0.00091

Table 3-16. Measured E2 Detection Areas in cm^2 for 2.16 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)					
	0	10	20	30	40	50
0	0.01871	0.02713	0.02340	0.01359	0.00881	0.00286

Table 3-17. Measured E2 Detection Areas in cm^2 for 2.25 MeV Electrons

Elevation Angle (degrees)	Azimuth Angle (degrees)					
	0	10	20	30	40	50
0	0.03495	0.03284	0.02229	0.01489	0.00863	0.00555
10	0.02939	0.02572	0.02207	0.01690	0.01369	0.00434
20	0.02500	0.02184	0.01776	0.01295	0.00689	0.00429
30	0.02604	0.02258	0.01736	0.01140	0.00994	0.00401
40	0.01120	0.01518	0.00536	0.00546	0.00218	0.00125
50	0.00590	0.00782	0.00515	0.00410	0.00254	0.00106

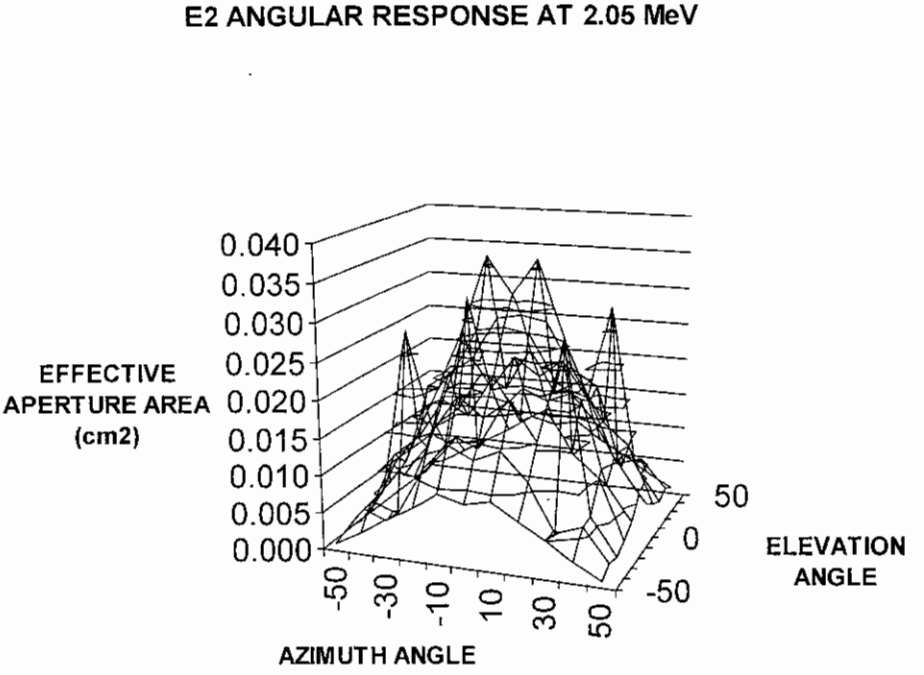

Figure 3-4. Angular Response of E2 at 2.05 MeV

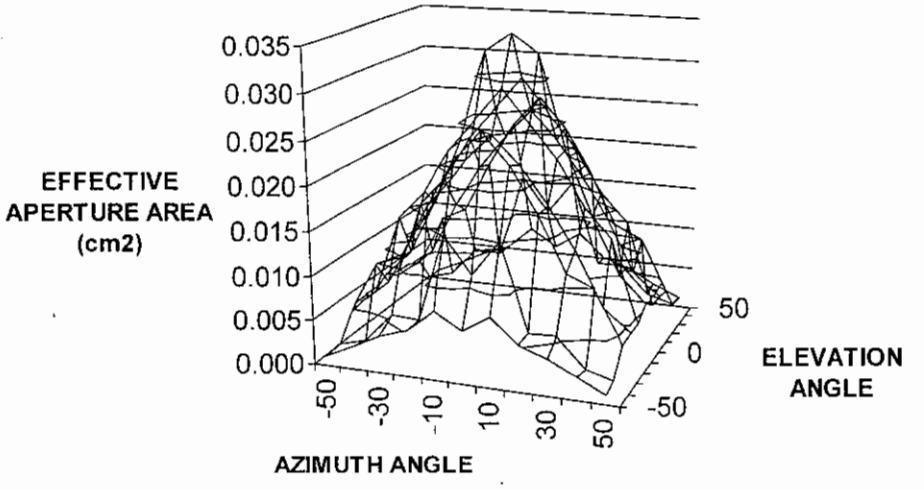

Figure 3-5. Angular Response of E2 at 2.25 MeV

3.2 Measured Geometric Factors

The measured geometric factors, obtained by integrating over the angular measurements given in Tables 3-1 through 3-17, and the A(0, 0) area values, for both E1 and E2, are summarized in Table 3-18. The angular measurements have been extended by symmetry to cover the full FOV, and the integrations use the data from -50 deg to +50 deg for both elevation and azimuth. The 2.16 MeV G(E) values are calculated from the 0 degree elevation summed data, using the G(E)/(summed 0 degree elevation data) ratio for the 2.25 MeV measurements. The E1 results for A(E,0,0) and G(E) are shown in Figures 3-6 and 3-7, while the E2 results are plotted in Figures 3-8 and 3-9. The previous electron calibration data from Ref. 2 are also shown in the figures, and are in reasonable agreement with the present data. Nominal fits to the combined G(E) data are shown in Figures 3-7 and 3-9.

Table 3-18. Measured E1 and E2 Geometric Factors and Detection Areas for Electrons

Electron Energy	E1 Channel Values		E2 Channel Values	
(MeV)	G(E) (cm^2-sr)	A(0, 0) (cm^2)	G(E) (cm^2-sr)	A(0, 0) (cm^2)
0.45	0.001391	0.001261	-	-
0.57	0.07434	0.04806	-	-
0.68	0.1606	0.09628	-	-
0.87	0.4306	0.2182	-	-
0.96	0.5301	0.2858	-	-
1.22	0.5877	0.3314	0.000201	0.000110
1.46	0.6964	0.3343	0.000517	0.001540
1.89	0.6348	0.3822	0.03566	0.01717
2.05	0.8059	0.5423	0.04101	0.03148
2.16	0.6838	0.4448	0.03349	0.01871
2.25	0.6220	0.3659	0.03995	0.03495

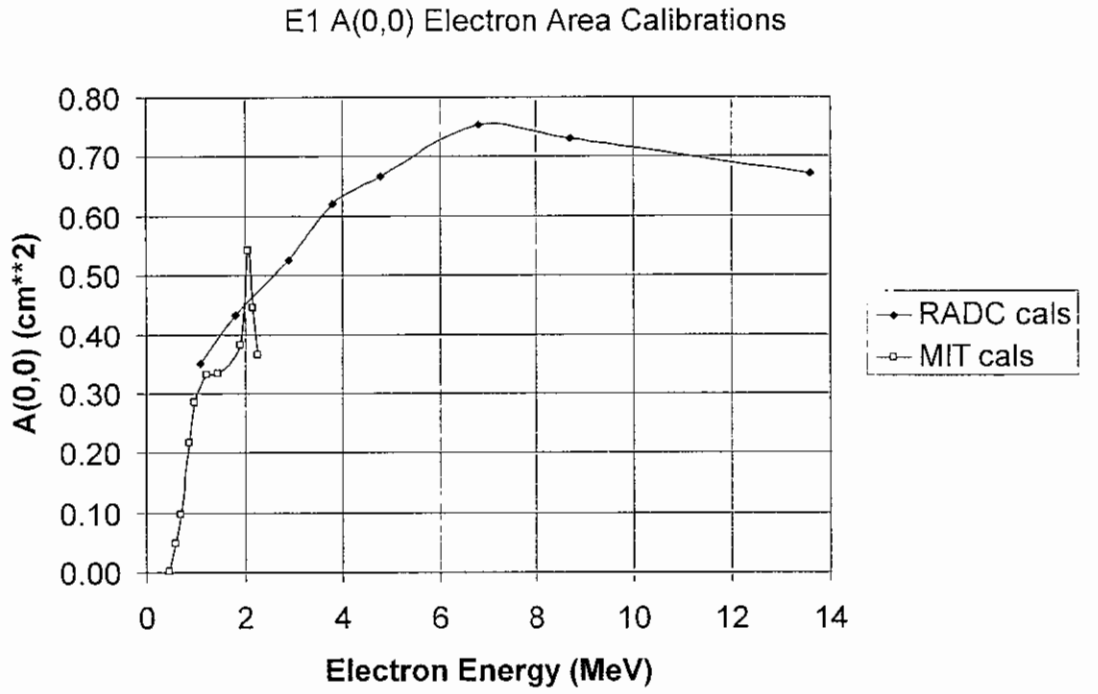

Figure 3-6. Measured E1 A(0,0) Values as a Function of Electron Energy

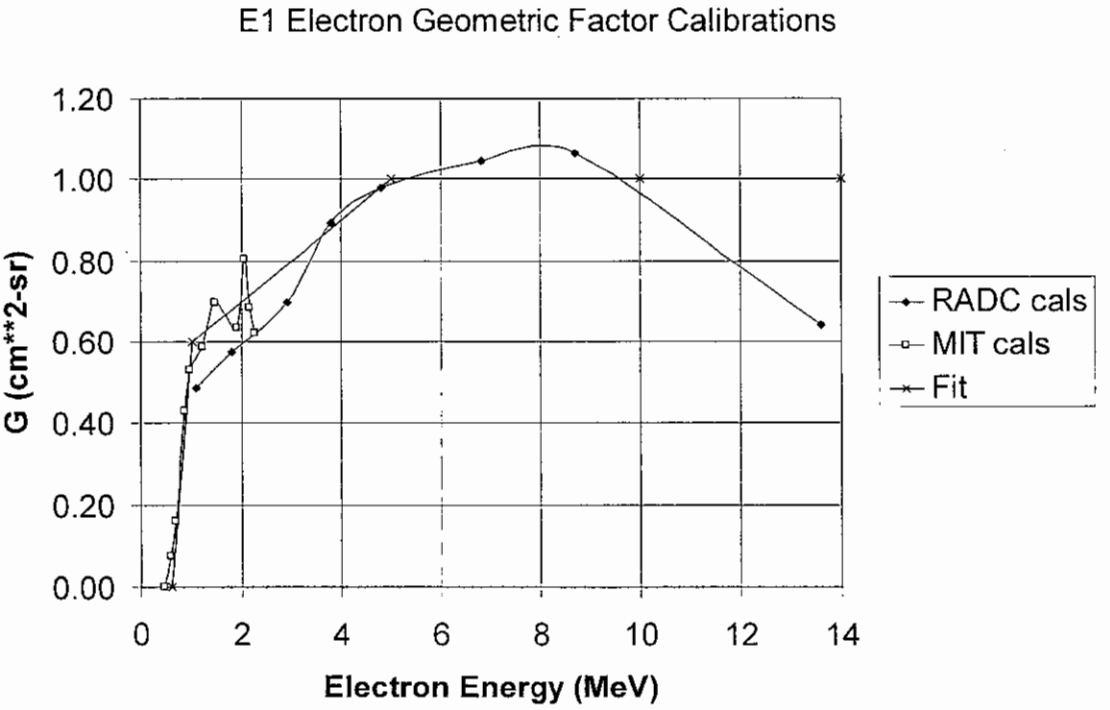

Figure 3-7. Measured E1 G(E) Values as a Function of Electron Energy

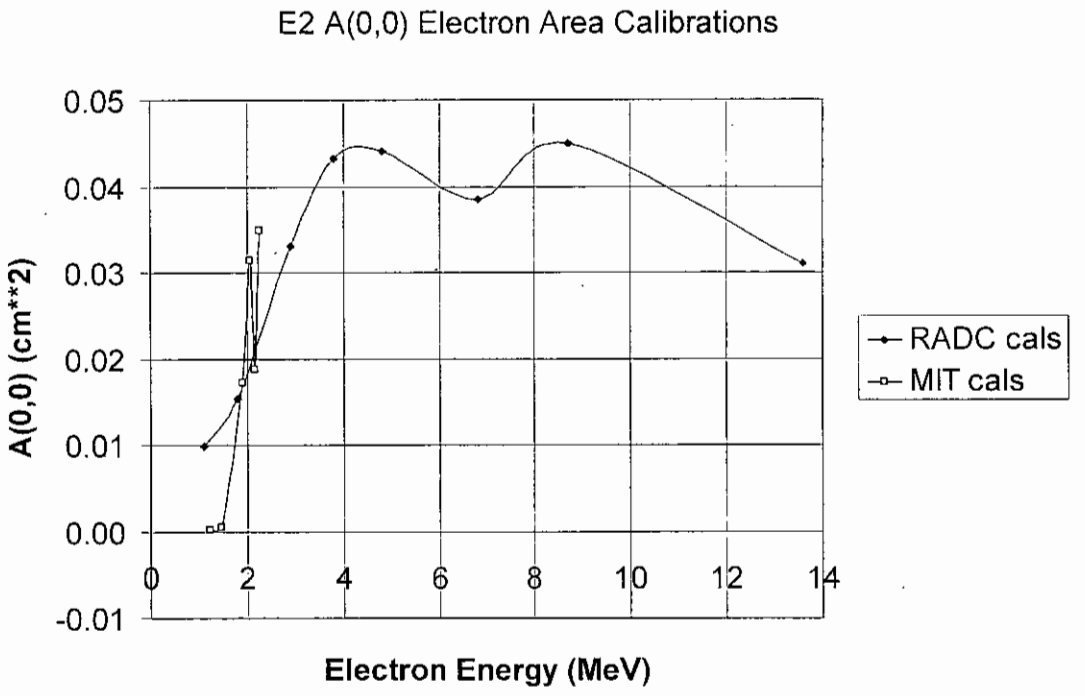

Figure 3-8. Measured E2 A(0,0) Values as a Function of Electron Energy

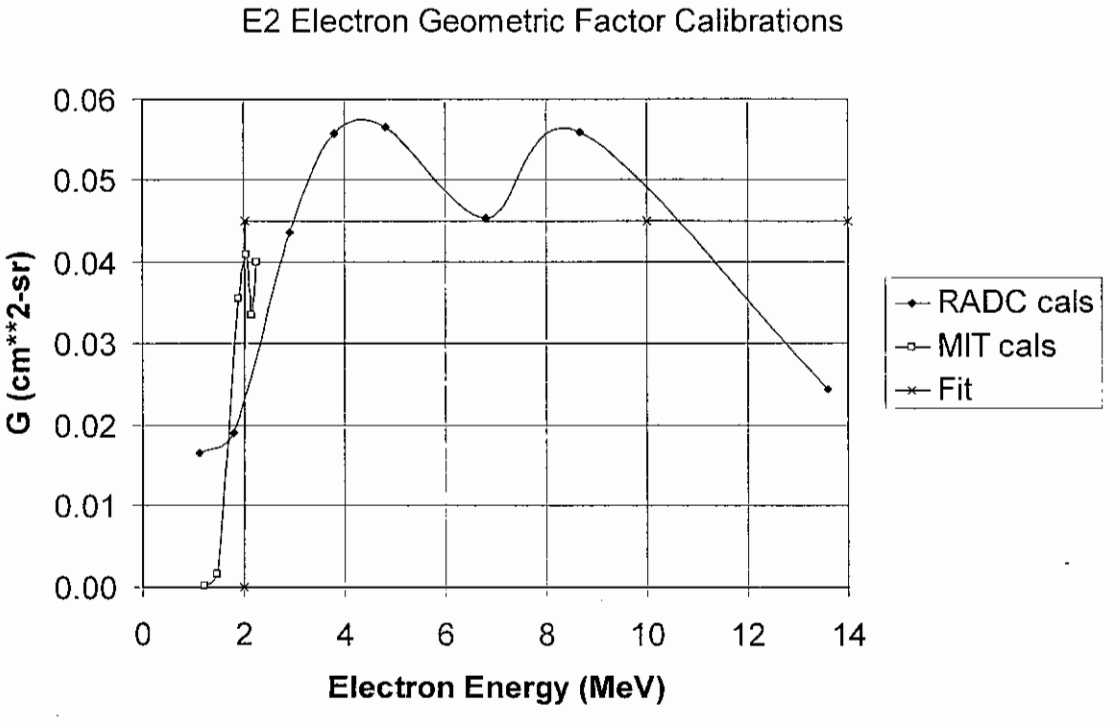

Figure 3-9. Measured E2 G(E) Values as a Function of Electron Energy

3.2.1 E1 Electron Channel Response

The E1 electron channel shows a fast rise in the geometric factor over the range of about 0.6 MeV to 1 MeV, with a slower rise from 1 MeV to about 5 MeV (Figure 3-7). The geometric factor at 1 MeV is about 0.6 cm^2-sr, rising to about 1.0 cm^2-sr at 5 MeV, and is approximately flat at 1.0 cm^2-sr above 5 MeV. The A(0, 0) area has the same general shape as the geometric factor. The accuracy of the area and geometric factor measurements is about 20%.

The E1 channel angular responses peak at 0 deg elevation and azimuth angles, and fall off at the FOV edges as shown in Figures 3-1 to 3-3. The azimuth angular response falls to half at about +/-35 deg, which is about the maximum nominal angular response defined by detector/collimator geometry. The elevation angular response falls to half at about +/- 45 deg, which is slightly narrower than the maximum nominal angular response of +/-55 deg defined by the detector/collimator geometry. There is a slight energy dependence to the angular response, which is caused by electron scattering in the D3 aluminum shield. For general in-orbit electron response, the geometric factors of Table 3-18 can be used along with the Ref. 2 values for higher energies. A reasonable approximation is to use a linear form going from 0.0 cm^2-sr at 0.6 MeV, to 0.6 cm^2-sr at 1 MeV, to 1.0 cm^2-sr at 5 MeV, and flat at 1.0 cm^2-sr for higher energies.

3.2.2 E2 Electron Channel Response

The E2 electron channel shows a fast rise in the geometric factor near 2 MeV, and flat at higher energies (Figure 3-9). The geometric factor at 2 MeV and above is about 0.045 cm^2-sr. The A(0, 0) area has the same general shape as the geometric factor. The accuracy of the area and geometric factor measurements is about 20%.

The E2 channel angular responses peak at 0 deg elevation and azimuth angles, and fall off at the FOV edges as shown in Figures 3-4 and 3-5. The azimuth angular response falls to half at about +/-30 deg, which is near the +/-35 deg maximum nominal angular response defined by detector/collimator geometry. The elevation angular response falls to half at about +/-35 deg, which is narrower than the maximum nominal angular response of +/-55 deg defined by the detector/collimator geometry. The angular response does not vary much with energy, although the present data are for a narrow energy range. For general in-orbit electron response, the geometric factors of Table 3-18 can be used along with the Ref. 2 values for higher energies. A reasonable approximation is to use a step function form going from 0.0 cm^2-sr to 0.045 cm^2-sr at 2 MeV, and flat at 0.045 cm^2-sr for higher energies. This is in reasonable agreement with the value of 0.05 cm^2-sr recommended in Ref. 2, and is a good average of the MIT and RADC data shown in Figure 3-9.

4.0 SUMMARY AND CONCLUSIONS

The E1 and E2 electron channels of the EPEAD D3 dome have been calibrated at the MIT VdeG over an electron energy range of 0.45 MeV to 2.25 MeV. The results are in reasonable agreement with previous calibrations of these channels. The calibrated geometric factors can be used to reduce in-orbit count rate data to electron fluxes. The energy and angular responses are in reasonable agreement with the expected theoretical responses.