PRELIMINARY TEST RESULTS OF THE ELECTRONIC SWITCHING SPHERICAL ARRAY ANTENNA

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ABSTRACT

An Electronic Switching Spherical Array (ESSA) Antenna has been developed for low obiting spacecraft requiring medium gain (+13 dBic) transmit and receive relay capability through the Tracking and Data Relay Satellite Systems (TDRSS). This 145 radiating element antenna is steered with a microprocessor controller by selecting arrays of 12 elements at a time. Approximately 1800 beams can be selected for near hemispherical coverage. The primary method for evaluating this antenna is a composite Radiation Distribution Plot (RDP).

INTRODUCTION

The Electronic Switching Spherical Array (ESSA) is a general class of antenna having medium gain throughout a large coverage region, typically π steradians. The ESSA described herein is for the purpose of transmitting and receiving data on the Earth Radiation Budget Satellite (ERBS) through the Tracking and Data Relay Satellite System (TDRSS). Design, fabrication and qualification tests are funded by NASA/GSFC.

This ESSA was described in a paper given at the 1982 International Conference (Reference 1). The following paragraphs provide updated photographs of the flight hardware, describe test methods of the ESSA, and give some preliminary test results.

ESSA DESCRIPTION

Figure 1 is a photograph of the 30-inch diameter ESSA, which contains 145 disk radiating elements. The heart of the ESSA is a Switching Power Divider (SPD) which selects 12 radiating elements at a time to form a beam in the desired direction. Figure 2 is a photograph of the SPD with an RF cable for each radiating element. Figure 2 also shows the structure to which the spherical array mounts and a wire basket to support the coaxial cables. Not shown is the electronics which tells the SPD which 12 elements are to be

selected. The electronics consists of a microprocessor controller and a driver. The controller calculates the relative position of the ERBS and the TDRS and determines the desired look angle. The driver provides bias to pin diodes inside the SPD to select the appropriate elements.

TEST RESULTS

The ESSA with its 145 radiating elements is capable of generating at least 1800 beams over a hemisphere. One of the more interesting problems is evaluating the performance of such an antenna. This was done by generating a composite Radiation Distribution Plot (CRDP). A CRDP is a composite of the peak gain of all beams.

To accomplish this task, an antenna range computer and the ESSA microprocessor controller are both used. The antenna range computer operates in a standard RDP mode. This master computer sends pointing angles to the ESSA controller. The ESSA controller instructs the ESSA to form a beam in the appropriate direction. The ESSA controller also acknowledges that pointing information was received or the systems shuts down. The resultant CRDP is a printout every degree in ϕ and θ.

Figure 3 is a reproduction of a 30° by 57° section of this CRDP. It will be noted that the gain in the region shown is relatively constant varying from 14.1 dBic to 11.3 dBic. This is typical of the ESSA performance for 360° in azimuth and 82° in elevation at the first turn-on prior to optimization.

Another parameter of the ESSA of interest is the relative phase from beam to beam. This is measured in the same manner with a 30° by 57° section shown in Figure 4. The phase is relatively constant varying less than 10° from point to point over the scan region.

Figure 5 is a photograph of the test Controller for the ESSA. The Controller has several modes of operation. There is an AUTO mode which was described above for running CRDPs. There is a mode where by a value of ϕ and θ is entered via the keyboard and the Controller selects a group of 12 radiating elements which forms a beam nearest to this value of ϕ and θ. With a third mode, a single radiating element can be selected via the keyboard. Another mode automatically steps through 20 standards beams. These standard beams assure that every radiating element is used at least once for quick look testing. The dome on the Controller contains an LED for every corresponding radiating element.

REFERENCES

(1) Kudrna, Ken and Hockensmith, Richard P., 1982, “The Electronic Switching Spherical Array (ESSA) Antenna For The Earth Radiation Budget Spacecraft (ERBS)”, International Telemetering Conference 1982 Proceedings, San Diego, California, Volume XVIII, pages 271-288.

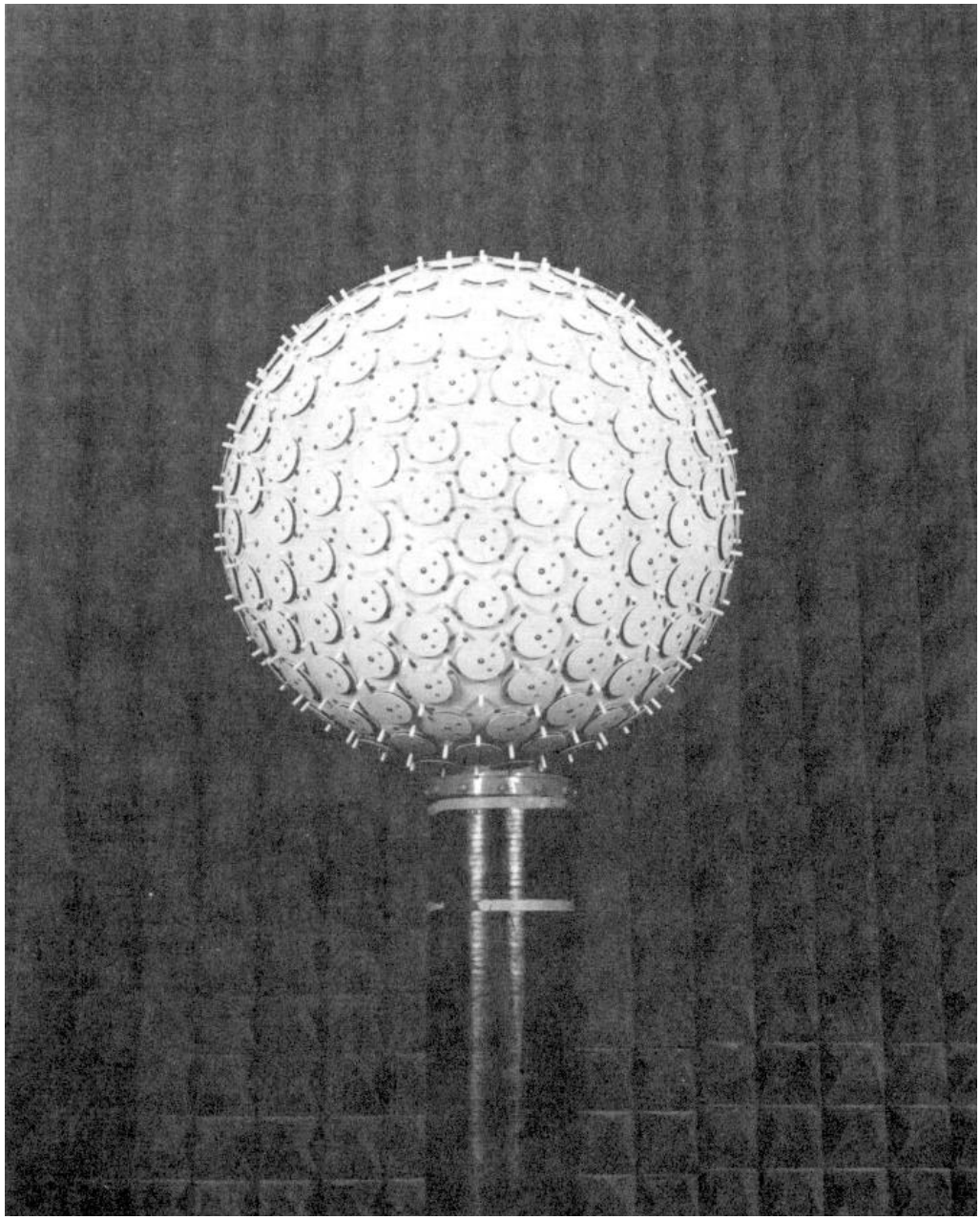

Figure 1. 30-Inch Diameter ESSA

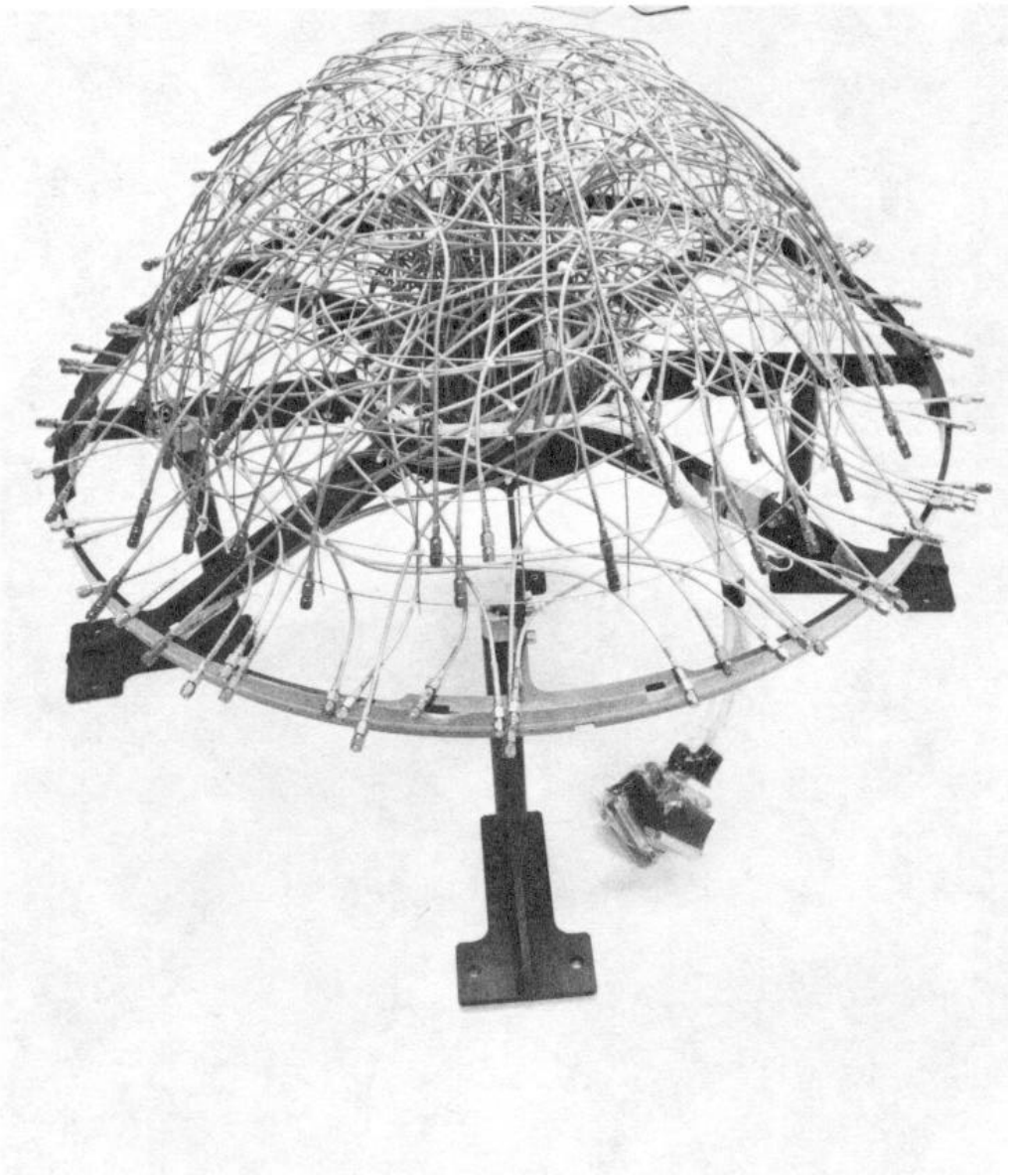

Figure 2. SPD With RF Cables

PHI DEGREES	THETA DEGREES 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
0	+136	+141	+141	+141	+140	+139	+127	+126	+127	+128	+130	+128	+122	+123	+123	+124	+124	+123	+119	+119	+118	+117	+115	+114	+116	+115	+113	+116	+118	+119
1	+136	+141	+141	+140	+140	+139	+127	+126	+127	+125	+130	+128	+122	+123	+124	+124	+124	+124	+119	+119	+118	+117	+115	+114	+116	+115	+119	+116	+121	+124
2	+136	+141	+140	+141	+140	+138	+127	+126	+127	+125	+129	+128	+123	+124	+124	+124	+124	+124	+119	+119	+118	+118	+115	+116	+116	+115	+119	+119	+122	+124
3	+136	+141	+140	+140	+140	+128	+127	+126	+127	+125	+129	+128	+123	+124	+124	+124	+124	+124	+119	+119	+119	+119	+119	+118	+116	+118	+120	+120	+122	+125
4	+136	+141	+141	+140	+140	+128	+127	+126	+128	+125	+128	+128	+123	+124	+124	+124	+124	+124	+119	+119	+119	+120	+119	+119	+117	+118	+120	+120	+123	+125
5	+135	+141	+140	+140	+139	+128	+127	+126	+128	+125	+128	+128	+123	+124	+124	+125	+124	+124	+120	+119	+120	+120	+120	+119	+119	+114	+120	+120	+123	+125
6	+135	+141	+140	+140	+140	+128	+127	+126	+128	+125	+128	+128	+123	+124	+124	+125	+124	+124	+120	+120	+121	+121	+121	+120	+119	+115	+115	+121	+123	+125
7	+135	+141	+140	+140	+139	+128	+127	+127	+127	+125	+127	+123	+124	+124	+124	+125	+125	+124	+120	+121	+121	+121	+121	+121	+120	+118	+116	+121	+123	+125
8	+135	+141	+140	+140	+139	+128	+125	+127	+128	+126	+126	+124	+125	+124	+125	+125	+124	+124	+120	+121	+122	+122	+121	+121	+121	+118	+119	+117	+125	+123	+125
9	+135	+141	+140	+140	+139	+128	+125	+127	+128	+126	+126	+124	+125	+126	+124	+125	+124	+124	+121	+122	+122	+122	+122	+121	+119	+120	+120	+125	+123	+125
10	+135	+141	+140	+140	+139	+128	+126	+127	+128	+128	+126	+124	+125	+126	+124	+124	+124	+124	+121	+122	+122	+122	+122	+122	+120	+120	+120	+125	+123	+125
11	+135	+140	+140	+140	+139	+133	+126	+127	+128	+128	+126	+124	+125	+126	+126	+126	+124	+120	+121	+121	+122	+122	+123	+123	+120	+121	+121	+121	+121	+127	+125
12	+135	+140	+140	+140	+131	+124	+126	+127	+128	+129	+127	+125	+126	+127	+126	+127	+127	+120	+121	+122	+123	+123	+123	+121	+121	+122	+122	+122	+127	+124
13	+135	+140	+140	+140	+131	+124	+126	+127	+128	+129	+127	+125	+126	+127	+126	+127	+128	+121	+121	+122	+123	+123	+123	+121	+122	+122	+123	+123	+127	+127
14	+135	+140	+140	+140	+131	+124	+126	+127	+128	+125	+127	+125	+126	+127	+126	+127	+128	+121	+121	+121	+123	+123	+123	+120	+122	+122	+123	+123	+123	+127
15	+135	+140	+140	+140	+131	+124	+126	+128	+129	+126	+127	+128	+126	+127	+127	+128	+128	+122	+122	+123	+123	+124	+121	+122	+123	+123	+124	+124	+123	+127
16	+135	+140	+140	+140	+131	+124	+126	+128	+129	+126	+127	+128	+127	+127	+127	+128	+128	+122	+122	+122	+123	+124	+121	+123	+123	+124	+124	+124	+124	+127
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18	+135	+140	+140	+130	+131	+124	+126	+128	+129	+126	+128	+129	+130	+128	+127	+128	+129	+123	+123	+123	+123	+121	+122	+123	+124	+125	+125	+125	+125	+124
19	+135	+140	+140	+130	+121	+124	+127	+128	+129	+127	+128	+129	+130	+130	+127	+128	+129	+123	+123	+124	+123	+121	+122	+123	+124	+125	+125	+125	+125	+124
20	+135	+140	+140	+130	+122	+124	+126	+128	+125	+127	+128	+129	+130	+131	+127	+128	+129	+123	+124	+124	+124	+124	+122	+124	+125	+125	+126	+126	+125	+124
21	+135	+140	+140	+130	+122	+124	+127	+128	+125	+127	+129	+130	+130	+131	+127	+128	+129	+124	+124	+124	+124	+124	+122	+124	+125	+126	+126	+126	+125	+124
22	+135	+140	+140	+130	+122	+124	+127	+128	+125	+127	+129	+130	+131	+131	+131	+131	+128	+129	+124	+124	+124	+124	+125	+126	+124	+125	+125	+126	+126	+125	+123
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27	+135	+140	+131	+121	+124	+127	+130	+132	+125	+128	+130	+131	+132	+132	+132	+127	+128	+129	+129	+128	+125	+126	+127	+124	+125	+126	+127	+127	+124	+124
28	+135	+140	+131	+121	+124	+127	+129	+132	+125	+128	+130	+131	+132	+132	+132	+128	+129	+129	+129	+128	+125	+126	+127	+124	+126	+127	+127	+124	+125	+125
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34	+135	+140	+117	+121	+124	+127	+130	+132	+125	+128	+130	+131	+132	+133	+133	+128	+128	+129	+129	+127	+128	+129	+129	+129	+121	+123	+125	+126	+127	+127
35	+135	+139	+117	+121	+124	+127	+129	+132	+125	+128	+130	+131	+132	+133	+133	+128	+128	+129	+129	+127	+128	+129	+129	+129	+121	+123	+125	+126	+127	+127
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38	+135	+133	+117	+120	+123	+127	+129	+132	+126	+129	+131	+133	+135	+135	+135	+128	+129	+129	+129	+126	+127	+128	+128	+127	+128	+122	+124	+125	+126	+126
39	+135	+134	+116	+120	+123	+127	+129	+132	+126	+129	+131	+133	+135	+135	+136	+128	+129	+129	+129	+126	+127	+127	+126	+127	+128	+129	+123	+125	+125	+126
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47	+136	+134	+134	+129	+123	+126	+129	+131	+126	+129	+131	+133	+135	+136	+136	+130	+130	+128	+128	+128	+123	+124	+125	+124	+125	+126	+126	+126	+124	+123
48	+136	+134	+134	+129	+121	+123	+125	+126	+126	+129	+131	+133	+134	+136	+136	+130	+130	+128	+128	+129	+122	+124	+125	+124	+125	+126	+126	+126	+125	+124
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50	+136	+134	+134	+129	+121	+123	+125	+126	+126	+129	+131	+133	+134	+135	+129	+130	+131	+128	+129	+129	+129	+123	+122	+124	+125	+125	+126	+126	+125	+124
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55	+137	+134	+134	+135	+130	+123	+125	+126	+127	+128	+130	+132	+135	+136	+129	+130	+130	+128	+128	+124	+125	+125	+121	+122	+123	+124	+124	+125	+124	+117
56	+137	+134	+134	+135	+130	+123	+125	+126	+127	+127	+130	+132	+135	+136	+129	+130	+130	+128	+128	+124	+125	+125	+120	+122	+123	+124	+124	+124	+124	+117

Figure 3. Gain

PHI DEGREES	THETA DEGREES 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
0	+43	+43	+44	+46	+46	+47	+50	+47	+48	+48	+48	+47	+43	+46	+48	+50	+52	+54	+54	+57	+57	+59	+59	+60	+61	+62	+61	+63	+63	+65
1	+44	+44	+44	+47	+47	+49	+51	+48	+48	+48	+49	+48	+44	+47	+49	+51	+53	+55	+56	+58	+59	+61	+60	+62	+62	+64	+63	+65	+66	+68
2	+45	+45	+45	+48	+48	+50	+52	+49	+49	+49	+50	+49	+45	+48	+50	+52	+54	+56	+57	+60	+60	+63	+62	+64	+64	+65	+65	+67	+68	+70
3	+46	+46	+46	+49	+49	+53	+53	+50	+50	+50	+52	+50	+46	+49	+51	+54	+55	+58	+58	+61	+62	+65	+65	+67	+66	+66	+66	+69	+70	+72
4	+47	+47	+47	+50	+50	+54	+54	+51	+52	+51	+53	+51	+47	+50	+52	+55	+56	+59	+60	+63	+63	+66	+67	+69	+67	+67	+68	+71	+71	+73
5	+48	+48	+48	+51	+51	+55	+56	+52	+53	+52	+53	+53	+48	+51	+53	+56	+57	+60	+61	+64	+65	+68	+68	+70	+70	+70	+69	+72	+73	+75
6	+49	+49	+49	+52	+52	+56	+57	+53	+54	+53	+53	+53	+49	+52	+54	+57	+58	+61	+63	+66	+67	+69	+70	+72	+72	+72	+71	+74	+74	+77
7	+50	+50	+50	+53	+53	+57	+58	+54	+54	+55	+54	+51	+52	+53	+55	+58	+60	+62	+64	+68	+68	+71	+71	+73	+73	+76	+73	+75	+76	+78
8	+51	+51	+51	+54	+54	+58	+55	+55	+55	+56	+54	+52	+54	+55	+56	+59	+61	+64	+65	+69	+70	+72	+73	+75	+75	+77	+75	+77	+78	+79
9	+52	+52	+53	+55	+55	+59	+55	+56	+56	+57	+54	+54	+55	+58	+57	+60	+62	+65	+67	+70	+71	+73	+74	+76	+77	+79	+78	+79	+79	+81
10	+53	+53	+53	+56	+56	+60	+56	+57	+57	+58	+55	+55	+56	+59	+58	+61	+63	+66	+69	+71	+72	+75	+75	+78	+79	+80	+80	+80	+80	+82
11	+54	+54	+54	+57	+57	+58	+57	+59	+58	+60	+56	+56	+57	+60	+58	+60	+64	+65	+70	+73	+74	+76	+77	+80	+80	+82	+82	+83	+82	+83
12	+55	+55	+55	+58	+57	+58	+59	+60	+60	+61	+57	+57	+58	+61	+59	+61	+63	+66	+71	+74	+75	+77	+78	+81	+81	+83	+83	+84	+83	+85
13	+56	+56	+56	+59	+58	+59	+60	+61	+61	+61	+59	+58	+59	+62	+60	+62	+64	+67	+70	+75	+76	+78	+79	+83	+83	+84	+85	+86	+84	+89
14	+58	+57	+57	+60	+59	+60	+61	+62	+62	+58	+59	+59	+61	+63	+61	+63	+65	+68	+70	+76	+77	+79	+82	+84	+84	+86	+86	+87	+87	+90
15	+59	+58	+58	+61	+60	+61	+62	+63	+63	+59	+60	+61	+61	+64	+62	+65	+66	+69	+71	+76	+78	+81	+83	+85	+85	+87	+87	+88	+88	+91
16	+59	+59	+59	+62	+61	+63	+63	+64	+64	+61	+61	+62	+62	+65	+63	+66	+67	+70	+72	+75	+79	+82	+84	+86	+87	+88	+88	+90	+90	+92
17	+61	+60	+60	+63	+62	+64	+64	+65	+65	+62	+62	+63	+64	+66	+64	+67	+68	+71	+73	+76	+80	+83	+86	+88	+88	+90	+90	+91	+91	+92
18	+62	+61	+61	+63	+63	+65	+65	+66	+66	+63	+63	+64	+65	+67	+65	+68	+69	+72	+74	+77	+79	+86	+87	+89	+89	+91	+91	+92	+92	+93
19	+63	+62	+62	+64	+64	+66	+66	+67	+68	+64	+64	+65	+66	+68	+66	+69	+70	+73	+75	+78	+80	+87	+88	+90	+90	+92	+92	+93	+93	+94
20	+64	+63	+63	+65	+65	+67	+67	+69	+65	+65	+66	+67	+67	+69	+67	+70	+71	+74	+76	+79	+81	+86	+89	+91	+91	+93	+93	+94	+95	+95
21	+65	+64	+64	+66	+66	+68	+68	+70	+65	+66	+67	+68	+68	+70	+68	+71	+72	+75	+77	+80	+82	+87	+90	+92	+93	+94	+94	+96	+96	+96
22	+66	+65	+65	+67	+67	+69	+70	+71	+66	+67	+68	+69	+70	+71	+72	+72	+73	+76	+78	+81	+83	+88	+90	+93	+94	+95	+95	+96	+97	+96
23	+67	+66	+66	+68	+68	+70	+71	+72	+67	+69	+69	+70	+71	+73	+73	+73	+75	+77	+79	+82	+86	+89	+91	+93	+95	+96	+97	+95	+96	+97
24	+68	+67	+67	+69	+69	+71	+72	+73	+68	+70	+70	+71	+72	+74	+74	+74	+75	+78	+80	+83	+88	+90	+92	+94	+94	+95	+96	+97	+97	+98
25	+69	+68	+69	+70	+69	+70	+72	+72	+69	+71	+71	+72	+73	+75	+75	+74	+76	+78	+81	+84	+89	+91	+93	+94	+95	+96	+97	+98	+98+100	
26	+70	+69	+70	+70	+69	+71	+72	+74	+70	+72	+72	+73	+74	+76	+76	+75	+76	+79	+82	+85	+90	+92	+94	+95	+96	+98	+98	+99+100+100		
27	+71	+70	+71	+71	+70	+72	+73	+75	+71	+73	+73	+74	+75	+77	+78	+76	+78	+80	+82	+86	+91	+93	+95	+96	+97	+99+100+100+100+101				
28	+73	+71	+72	+72	+71	+74	+74	+76	+72	+74	+75	+75	+76	+78	+79	+77	+79	+81	+83	+87	+92	+94	+96	+97	+98+100+101+100+101+102					
29	+74	+72	+73	+73	+72	+75	+75	+77	+74	+75	+76	+76	+77	+79	+80	+78	+80	+82	+84	+89	+91	+95	+97	+98	+99+101+102+101+102+103					
30	+75	+73	+72	+74	+73	+76	+76	+78	+75	+76	+77	+77	+78	+80	+81	+79	+81	+83	+85	+90	+91	+94	+98	+99+100+102+101+102+103+104						
31	+76	+74	+73	+75	+74	+76	+77	+79	+76	+77	+78	+79	+79	+81	+82	+80	+82	+84	+86	+91	+92	+95	+98+100+101+103+102+103+104+105							
32	+77	+74	+74	+76	+75	+77	+78	+80	+77	+78	+79	+80	+80	+82	+83	+81	+83	+85	+87	+92	+93	+96	+98+101+102+102+103+104+105+106							
33	+78	+75	+75	+77	+76	+78	+79	+81	+78	+79	+80	+81	+81	+83	+84	+82	+84	+86	+88	+93	+95	+97	+98+102+103+103+104+105+106+107							
34	+79	+76	+76	+78	+77	+79	+80	+82	+79	+80	+81	+81	+82	+84	+85	+83	+85	+87	+89	+94	+95	+98	+99+101+102+104+105+106+107+108							
35	+80	+76	+77	+79	+78	+80	+81	+83	+80	+81	+82	+83	+83	+85	+86	+85	+86	+89	+90	+95	+96	+99+100+101+103+104+106+107+108+109								
36	+81	+77	+78	+80	+79	+81	+82	+84	+81	+83	+83	+84	+85	+86	+87	+88	+89	+92	+93	+96	+97+100+101+100+104+105+107+108+109+110									
37	+82	+78	+79	+81	+80	+83	+83	+85	+83	+84	+85	+85	+86	+88	+88	+90	+91	+93	+95	+97	+98+101+102+101+103+106+108+109+110+111									
38	+83	+79	+80	+82	+82	+84	+85	+86	+84	+85	+86	+86	+87	+89	+90	+91	+92	+94	+96	+97+100+101+103+102+104+107+109+109+111+112									
39	+84	+80	+81	+83	+83	+84	+86	+87	+85	+86	+87	+87	+89	+90	+91	+92	+93	+95	+97	+98+101+102+102+103+105+107+109+110+112+112									
40	+85	+81	+82	+84	+84	+85	+87	+88	+86	+87	+88	+88	+90	+91	+92	+92	+94	+96	+98	+99+101+102+102+104+106+107+110+111+112+113									
41	+86	+82	+83	+85	+85	+86	+88	+89	+87	+88	+89	+89	+91	+92	+93	+93	+95	+97	+99	+99+102	+98+103+105+107+108+110+112+113+114									
42	+87	+83	+84	+86	+86	+87	+89	+90	+88	+89	+90	+90	+92	+93	+94	+94	+96	+98+100	+95	+98	+99+102+106+108+109+111+111+114+114									
43	+88	+84	+85	+87	+87	+88	+90	+91	+89	+90	+91	+91	+93	+94	+95	+95	+97	+99+101	+96	+98+100+102+107+109+110+112+106+109+114										
44	+89	+85	+85	+88	+88	+89	+91	+92	+90	+91	+92	+92	+94	+95	+96	+96	+98+100+102	+99	+99+101+103+107+109+111+113+107+108+109											
45	+90	+86	+86	+89	+89	+90	+92	+92	+91	+92	+93	+93	+95	+95	+97	+97	+99+100	+99+100+100+101+104+105+110+111+113+107+109+110												
46	+91	+87	+88	+90	+90	+91	+93	+93	+92	+93	+94	+94	+96	+96	+98	+98+100	+98+100+101+101+102+105+106+111+109+112+109+110+110													
47	+92	+88	+89	+91	+91	+93	+94	+95	+93	+94	+95	+95	+96	+97	+99	+99+101	+99+101+102+102+103+106+107+110+110+112+113+110+112													
48	+94	+89	+91	+92	+94	+95	+97	+98	+94	+95	+96	+96	+98	+98+100+100+102+100+102+103+103+104+107+108+110+111+113+114+115+116																
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50	+96	+91	+93	+94	+96	+97	+99	+99	+96	+97	+98	+98	+99+100+101+102+103+102+104+106+107+106+108+110+112+113+115+115+117+118																	
51	+97	+92	+94	+95	+97	+98+100+100		+97	+98	+99	+99+100+101+102+103+104+103+106+107+108+106+109+110+113+114+116+116+118+118																			
52	+98	+93	+95	+96	+98	+99+101+101+102			+99+100+100+101+101+102+103+105+104+107+108+109+108+110+111+113+114+116+117+119+119																					
53	+99	+94	+96	+97	+99+100+102+102+104				+99+101+100+102+101+103+104+106+106+108+109+110+110+111+112+114+115+117+118+119+118																					
54	+100	+95	+97	+98	+99+101+103+103+104+100+102+101+103+102+104+105+107+107+109+110+111+111+111+113+115+116+118+118+120+119																											
55	+101	+96	+98	+99+100+102+104+104+105+101+103+102+102+103+105+106+108+108+110+111+112+112+112+113+115+117+118+119+121+120																												
56	+101	+97	+98+100+101+103+105+105+106+102+103+103+103+104+106+107+109+109+111+112+113+113+113+114+116+117+119+120+121+121																												

Figure 4. Relative Phase

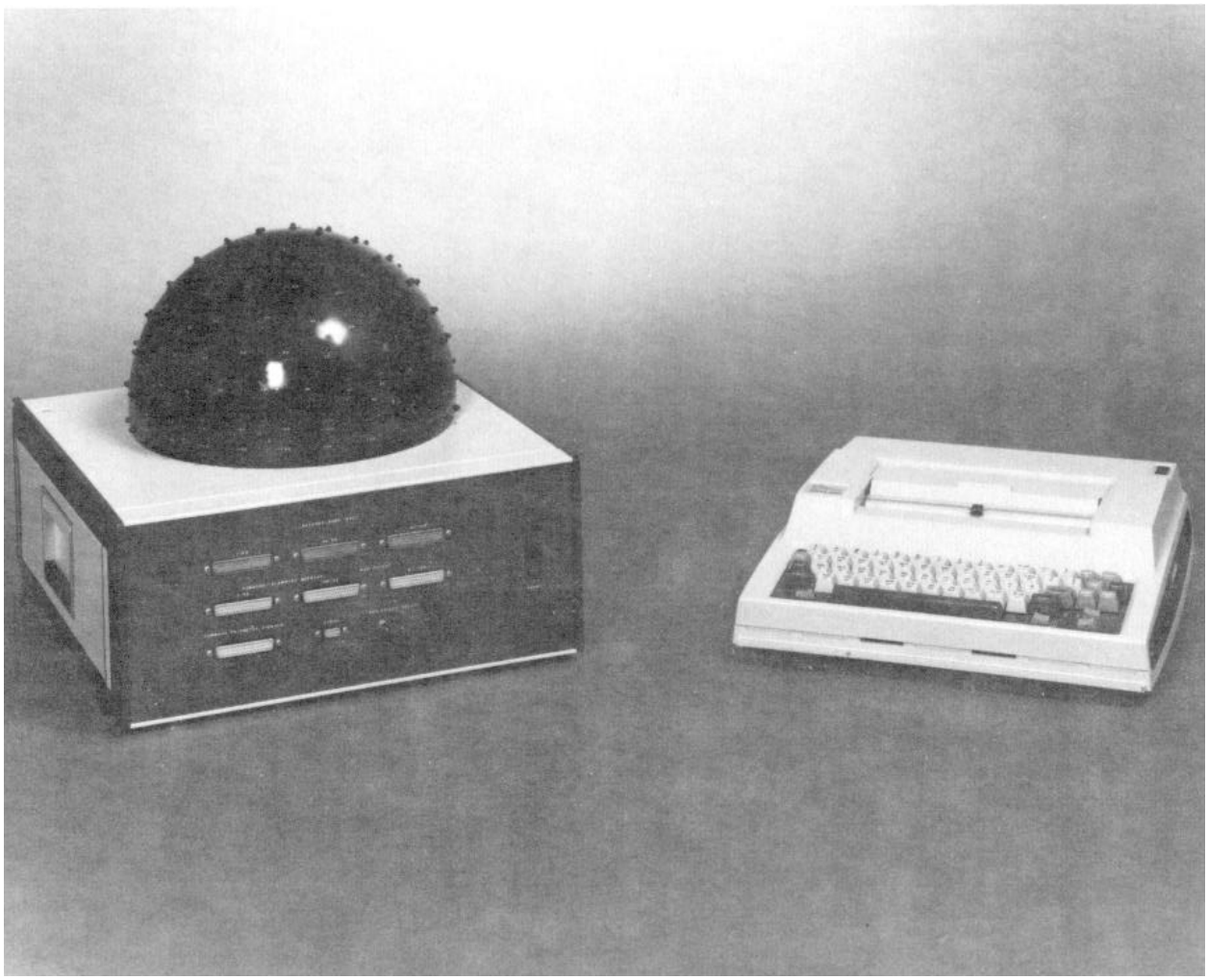

Figure 5. ESSA Test Controller