Technical Report

SPECIAL NOISE BARRIER APPLICATIONS

Phase III

by
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TABLE OF CONTENTS

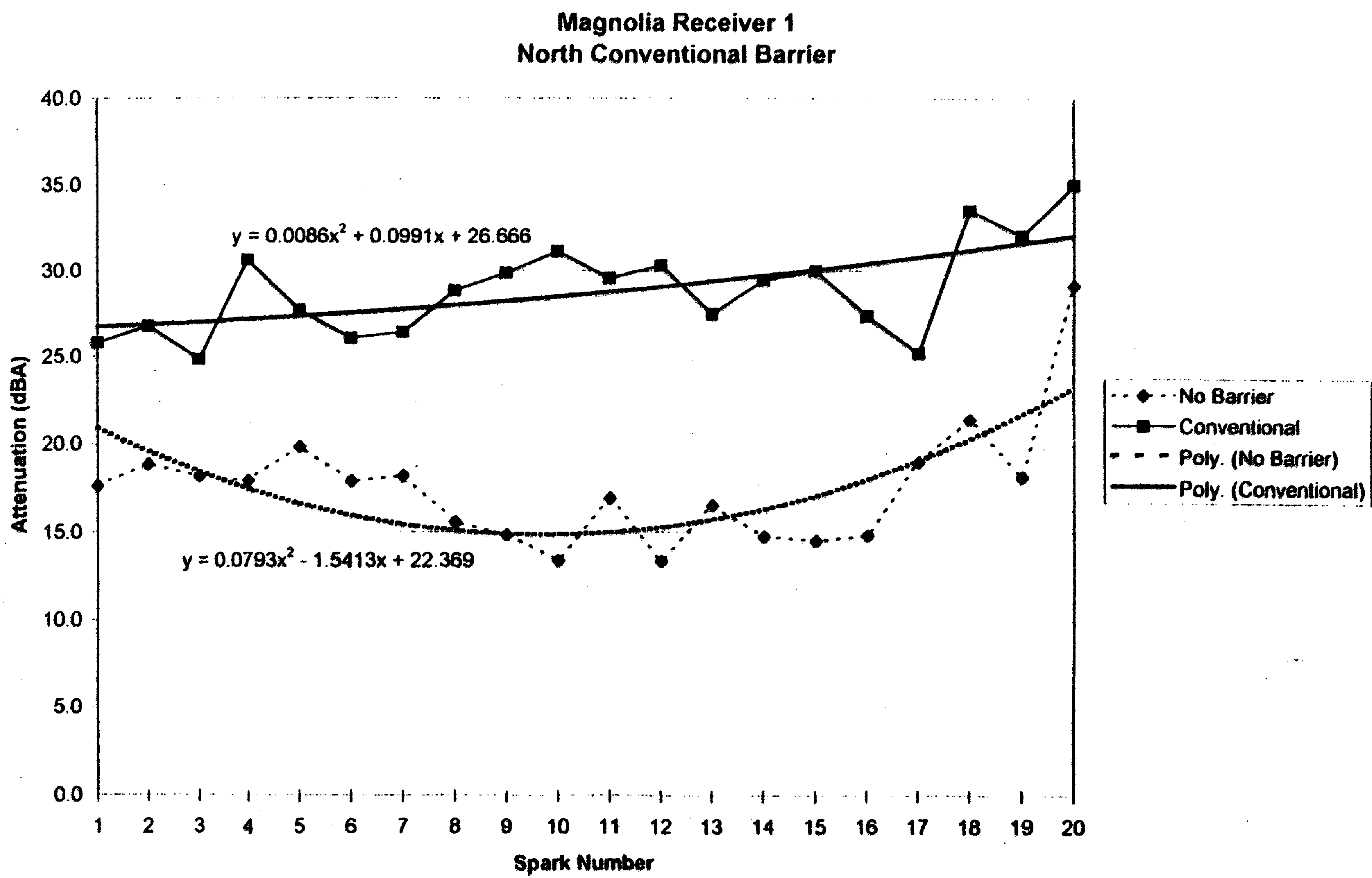
APPENDIX A
SCALE MODEL DATA FILES
CONVENTIONAL BARRIER TESTS

Magnolia Receiver 1

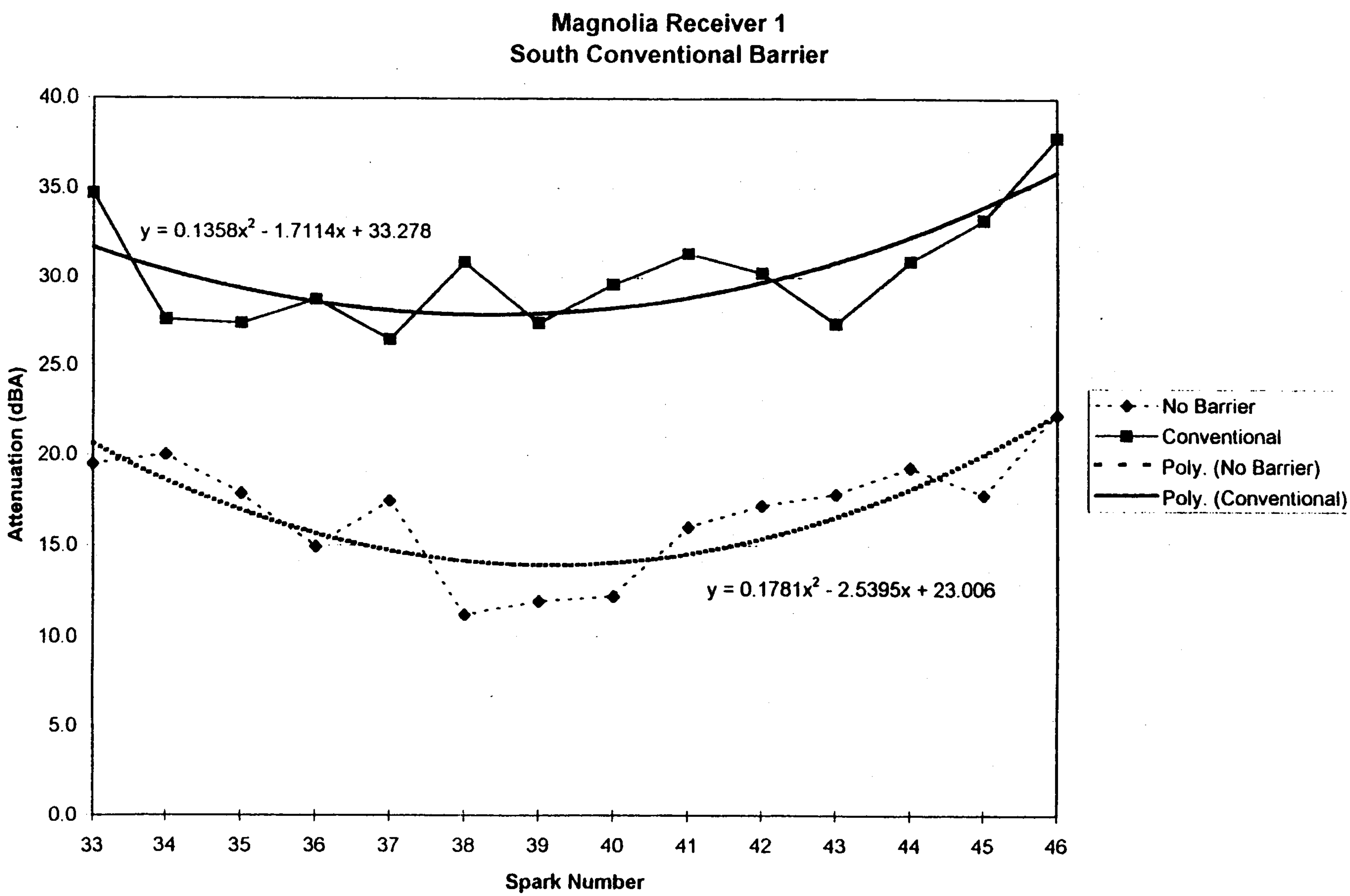
Spark Number	Station		No Barrier Attenuation: Actual No Barrier	Fitted No Barrier	Standard Error	Conventional Barrier Attenuation: Actual Conventional	Fitted Conventional	Standard Error	Insertion Scale Model
1	87+25	North	17.7	20.9	-3.3	25.8	26.3	-0.5	5.4
2	88+00	North	18.8	19.6	-0.8	26.8	26.5	0.4	6.9
3	88+75	North	18.2	18.5	-0.3	24.9	26.6	-1.7	8.2
4	89+50	North	17.9	17.5	0.5	30.6	26.8	3.9	9.3
5	90+25	North	19.9	16.6	3.2	27.7	27.0	0.8	10.3
6	91+00	North	17.9	16.0	1.9	26.1	27.1	-1.0	11.2
7	91+75	North	18.2	15.5	2.8	26.4	27.3	-0.9	11.9
8	92+50	North	15.6	15.1	0.5	28.9	27.6	1.3	12.5
9	93+25	North	14.9	14.9	-0.1	29.9	27.8	2.1	12.9
10	94+00	North	13.4	14.9	-1.5	31.2	28.0	3.1	13.2
11	94+75	North	17.0	15.0	2.0	29.6	28.3	1.3	13.3
12	95+50	North	13.3	15.3	-1.9	30.4	28.6	1.8	13.3
13	96+25	North	16.6	15.7	0.8	27.5	28.9	-1.3	13.1
14	97+00	North	14.8	16.3	-1.6	29.5	29.2	0.3	12.8
15	97+75	North	14.5	17.1	-2.6	30.0	29.5	0.6	12.4
16	98+50	North	14.8	18.0	-3.2	27.4	29.8	-2.4	11.8
17	99+25	North	19.0	19.1	-0.1	25.3	30.1	-4.9	11.1
18	100+00	North	21.4	20.3	1.1	33.6	30.5	3.1	10.2
19	100+75	North	18.2	21.7	-3.6	32.1	30.9	1.2	9.1
20	101+50	North	29.2	23.3	5.9	35.1	31.2	3.8	8.0

Spark Number	Station		No Barrier Attenuation: Actual No Barrier	Fitted No Barrier	Standard Error	Conventional Barrier Attenuation: Actual Conventional	Fitted Conventional	Standard Error	Insertion Scale Model
33	89+50	South	19.5	20.6	-1.1	34.7	31.7	3.0	11.1
34	90+25	South	20.0	18.6	1.4	27.6	30.4	-2.8	11.8
35	91+00	South	17.9	17.0	0.9	27.4	29.4	-2.0	12.4
36	91+75	South	15.0	15.7	-0.7	28.8	28.6	0.1	12.9
37	92+50	South	17.5	14.8	2.8	26.5	28.1	-1.6	13.4
38	93+25	South	11.2	14.2	-2.9	30.9	27.9	3.0	13.7
39	94+00	South	12.0	14.0	-2.0	27.4	28.0	-0.5	14.0
40	94+75	South	12.2	14.1	-1.8	29.6	28.3	1.4	14.2
41	95+50	South	16.1	14.6	1.5	31.4	28.9	2.5	14.3
42	96+25	South	17.3	15.4	1.8	30.3	29.7	0.6	14.3
43	97+00	South	17.9	16.6	1.3	27.4	30.9	-3.5	14.3
44	97+75	South	19.4	18.2	1.2	30.9	32.3	-1.4	14.1
45	98+50	South	17.9	20.1	-2.2	33.3	34.0	-0.7	13.9
46	99+25	South	22.3	22.4	0.0	37.9	35.9	1.9	13.6

Insertion Loss = 12.4



Magnolia Receiver 1
North Conventional Barrier
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Attenuation (dBA)
y = 0.0086x² + 0.0991x + 26.666
y = 0.0793x² - 1.5413x + 22.369
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Spark Number
No Barrier
Conventional
Poly. (No Barrier)
Poly. (Conventional)



Magnolia Receiver 1
South Conventional Barrier
y = 0.1358x2 - 1.7114x + 33.278
y = 0.1781x2 - 2.5395x + 23.006
Attenuation (dBA)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
33
34
35
36
37
38
39
40
41
42
43
44
45
46
Spark Number
No Barrier
Conventional
Poly. (No Barrier)
Poly. (Conventional)

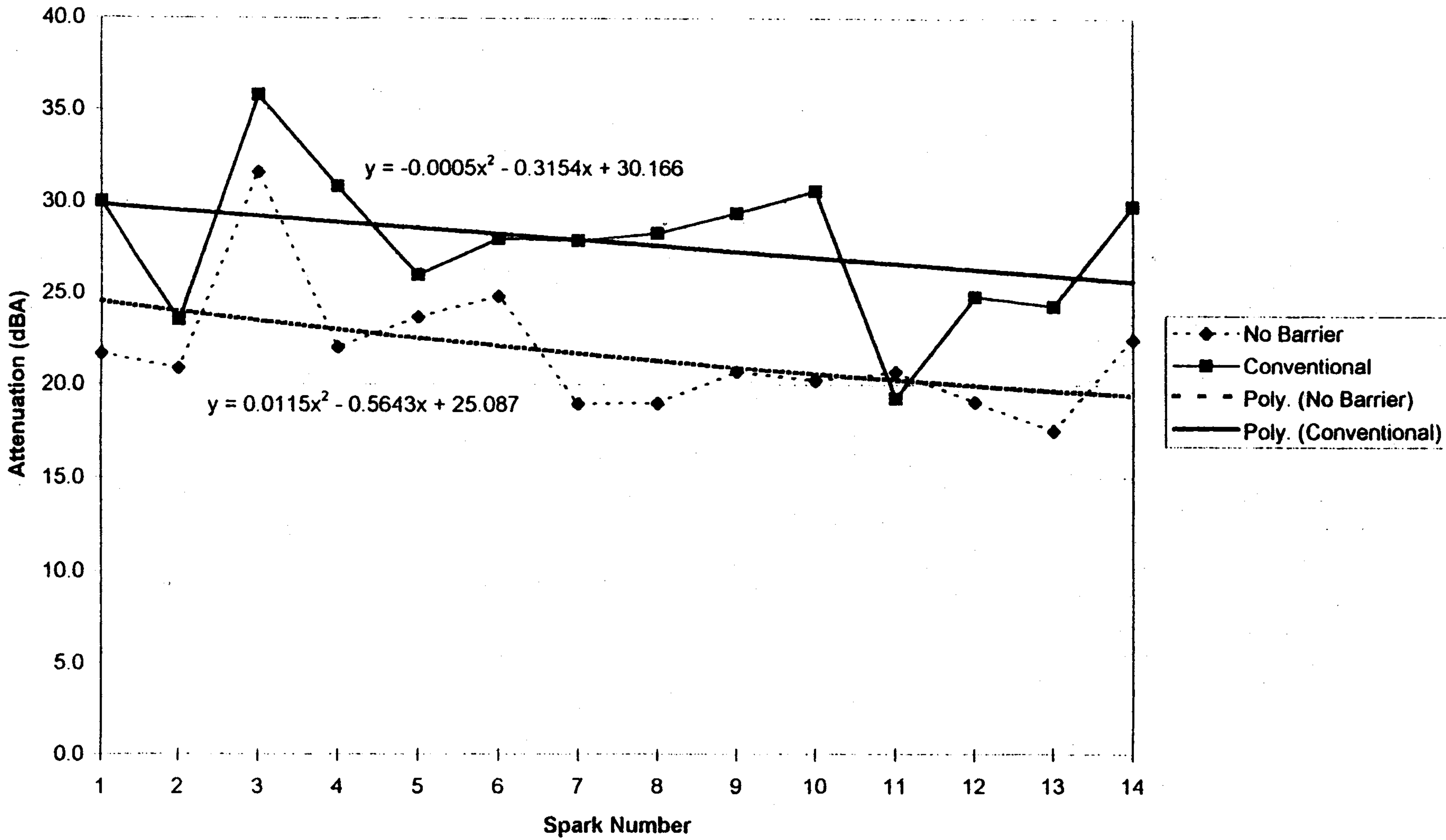
Kent Commons Receiver 2

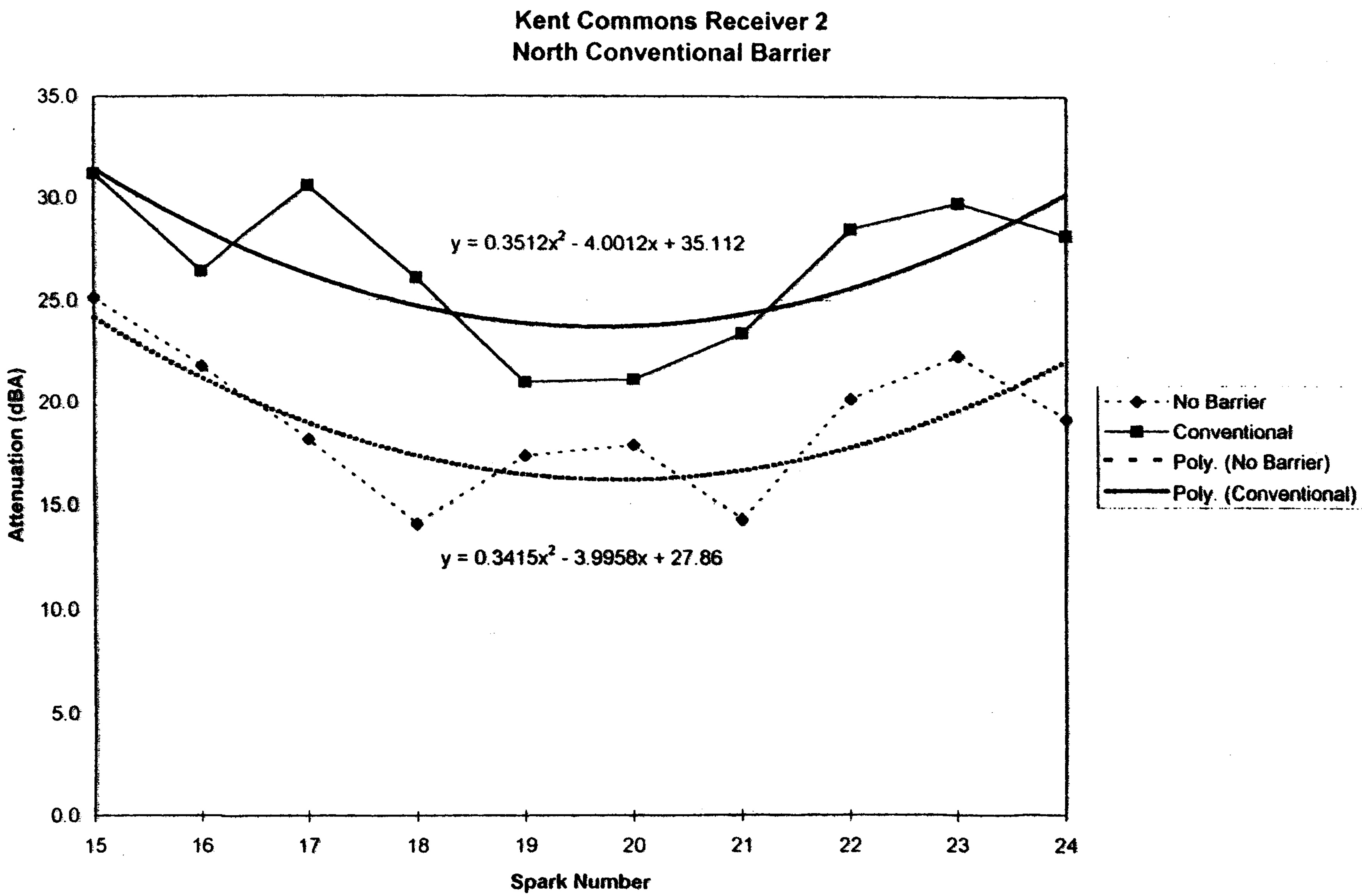
Spark Number	Station		No Barrier Attenuation: Actual No Barrier	Fitted No Barrier	Standard Error	Conventional Barrier Attenuation: Actual Conventional	Fitted Conventional	Standard Error	Insertion Scale Model
1	842+50	South	21.7	24.5	-2.8	30.0	29.9	0.2	5.3
2	841+75	South	20.9	24.0	-3.1	23.5	29.5	-6.0	5.5
3	841+00	South	31.6	23.5	8.1	35.8	29.2	6.6	5.7
4	840+25	South	22.1	23.0	-1.0	30.9	28.9	2.0	5.9
5	839+50	South	23.7	22.6	1.2	26.0	28.6	-2.6	6.0
6	838+75	South	24.9	22.1	2.7	28.0	28.3	-0.3	6.2
7	838+00	South	19.0	21.7	-2.7	27.9	28.0	-0.1	6.3
8	837+25	South	19.0	21.3	-2.3	28.3	27.7	0.6	6.4
9	836+50	South	20.7	20.9	-0.2	29.4	27.4	2.0	6.4
10	835+75	South	20.2	20.6	-0.3	30.6	27.1	3.6	6.5
11	835+00	South	20.7	20.3	0.5	19.3	26.8	-7.5	6.5
12	834+25	South	19.1	20.0	-0.9	24.8	26.5	-1.6	6.5
13	833+50	South	17.5	19.7	-2.2	24.3	26.2	-1.8	6.5
14	832+75	South	22.5	19.4	3.0	29.8	25.8	4.0	6.4

Spark Number	Station		No Barrier Attenuation: Actual No Barrier	Fitted No Barrier	Standard Error	Conventional Barrier Attenuation: Actual Conventional	Fitted Conventional	Standard Error	Insertion Scale Model
15	841+00	North	25.2	24.2	1.0	31.2	31.5	-0.2	7.3
16	840+25	North	21.8	21.2	0.6	26.4	28.5	-2.1	7.3
17	839+50	North	18.1	18.9	-0.8	30.6	26.3	4.3	7.3
18	838+75	North	14.1	17.3	-3.3	26.1	24.7	1.4	7.4
19	838+00	North	17.3	16.4	0.9	21.0	23.9	-2.9	7.5
20	837+25	North	17.9	16.1	1.7	21.1	23.7	-2.6	7.6
21	836+50	North	14.3	16.6	-2.3	23.4	24.3	-0.9	7.7
22	835+75	North	20.2	17.7	2.5	28.5	25.6	2.9	7.9
23	835+00	North	22.3	19.5	2.8	29.8	27.5	2.2	8.0
24	834+25	North	19.2	22.0	-2.8	28.2	30.2	-2.1	8.2

Insertion Loss = 6.8

Kent Commons Receiver 2
South Conventional Barrier



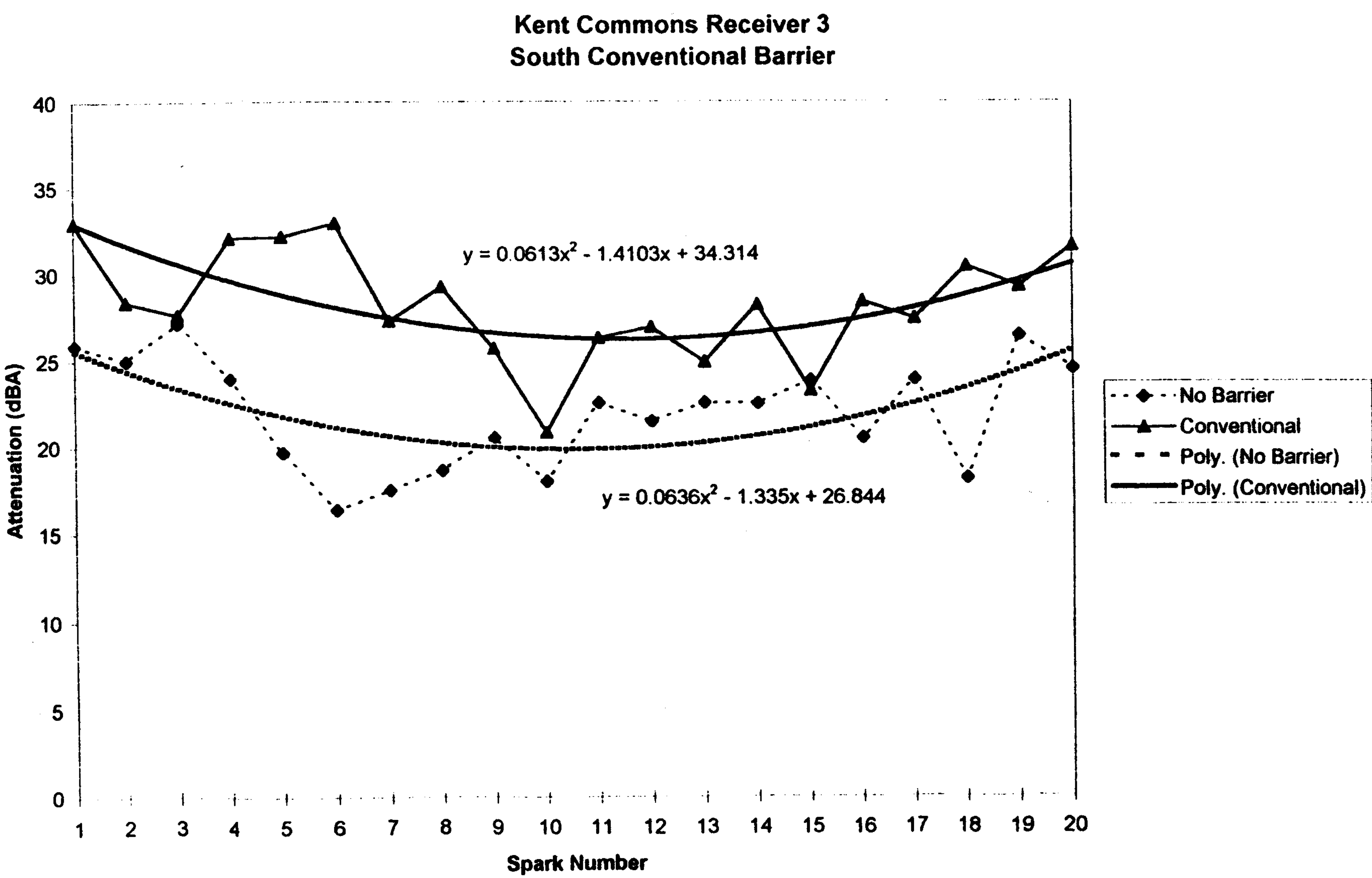

Kent Commons Receiver 2
North Conventional Barrier
y = 0.3512x2 - 4.0012x + 35.112
y = 0.3415x2 - 3.9958x + 27.86
Attenuation (dBA)
Spark Number
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
15
16
17
18
19
20
21
22
23
24
No Barrier
Conventional
Poly. (No Barrier)
Poly. (Conventional)

Kent Commons Receiver 3

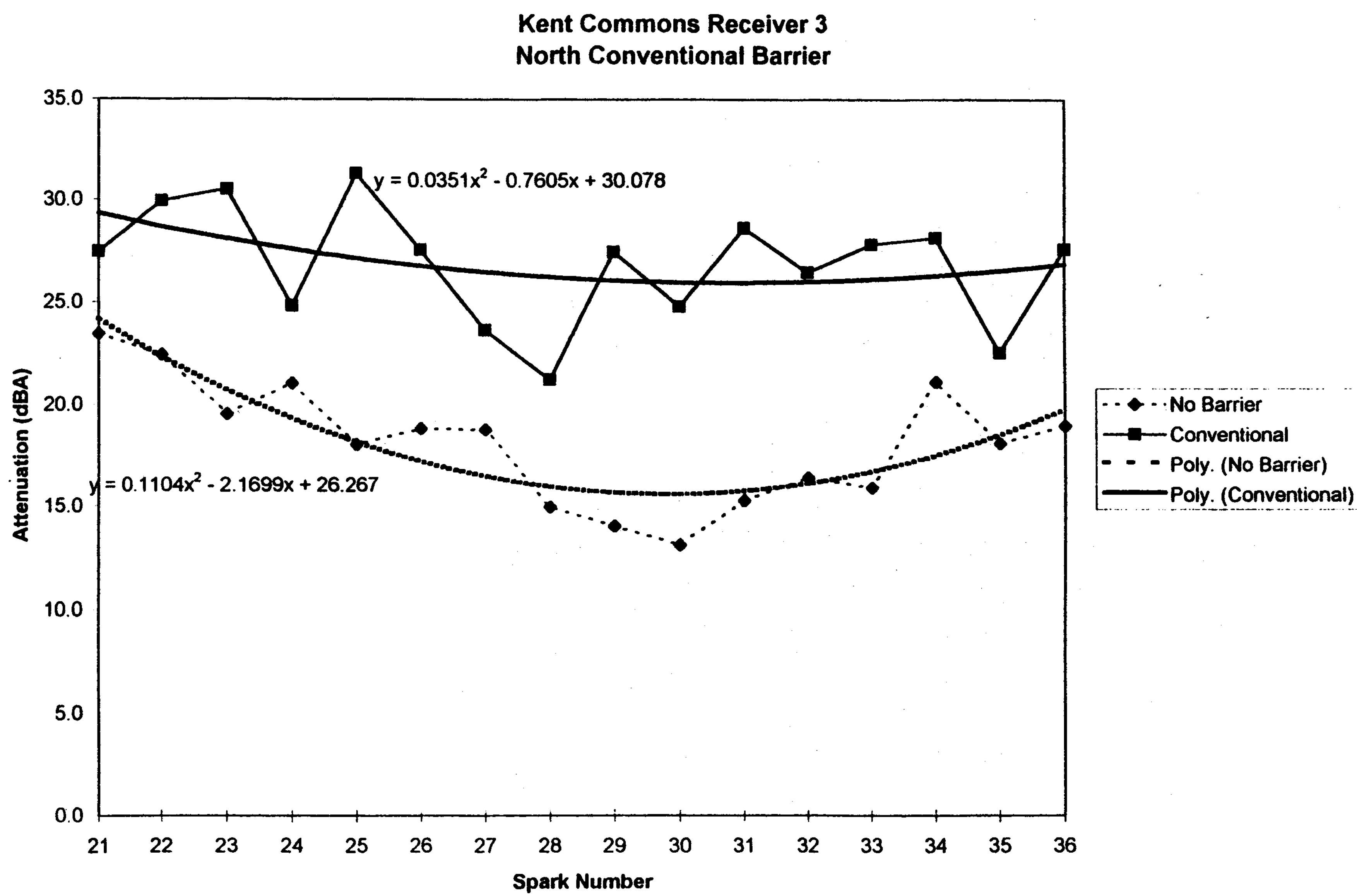
Spark Number	Station		No Barrier Attenuation Actual No Barrier	No Barrier Attenuation Fitted No Barrier	No Barrier Attenuation Standard Error	Conventional Barrier Attenuation Actual Conventional	Conventional Barrier Attenuation Fitted Conventional	Conventional Barrier Attenuation Standard Error	Insertion Scale Model
1	844+75	South	25.9	25.6	0.3	33.0	33.0	0.0	7.4
2	844+00	South	25.0	24.5	0.5	28.4	31.7	-3.4	7.3
3	843+25	South	27.2	23.5	3.7	27.6	30.6	-3.0	7.2
4	842+50	South	23.9	22.6	1.4	32.1	29.7	2.5	7.1
5	841+75	South	19.7	21.8	-2.1	32.2	28.8	3.4	7.0
6	841+00	South	16.4	21.2	-4.8	33.0	28.1	4.9	6.9
7	840+25	South	17.5	20.7	-3.2	27.3	27.4	-0.2	6.8
8	839+50	South	18.6	20.3	-1.6	29.3	27.0	2.3	6.7
9	838+75	South	20.6	20.0	0.5	25.7	26.6	-0.9	6.6
10	838+00	South	18.0	19.9	-1.9	20.8	26.3	-5.5	6.4
11	837+25	South	22.5	19.9	2.6	26.3	26.2	0.1	6.3
12	836+50	South	21.5	20.0	1.5	26.9	26.2	0.7	6.2
13	835+75	South	22.5	20.3	2.2	24.9	26.3	-1.4	6.1
14	835+00	South	22.5	20.7	1.8	28.2	26.6	1.6	5.9
15	834+25	South	23.8	21.2	2.7	23.2	27.0	-3.7	5.8
16	833+50	South	20.5	21.8	-1.3	28.4	27.4	1.0	5.6
17	832+75	South	23.9	22.6	1.3	27.4	28.1	-0.6	5.5
18	832+00	South	18.2	23.5	-5.3	30.5	28.8	1.7	5.3
19	831+25	South	26.4	24.5	1.9	29.3	29.6	-0.4	5.2
20	830+50	South	24.5	25.6	-1.1	31.6	30.6	1.0	5.0

Spark Number	Station		No Barrier Attenuation Actual No Barrier	No Barrier Attenuation Fitted No Barrier	No Barrier Attenuation Standard Error	Conventional Barrier Attenuation Actual Conventional	Conventional Barrier Attenuation Fitted Conventional	Conventional Barrier Attenuation Standard Error	Insertion Scale Model
21	843+25	North	23.5	24.2	-0.7	27.5	29.4	-1.9	5.1
22	842+50	North	22.5	22.4	0.1	30.0	28.7	1.3	6.3
23	841+75	North	19.6	20.8	-1.2	30.5	28.1	2.4	7.4
24	841+00	North	21.1	19.4	1.7	24.8	27.6	-2.8	8.2
25	840+25	North	18.1	18.2	-0.1	31.3	27.2	4.2	9.0
26	839+50	North	18.8	17.2	1.6	27.6	26.8	0.8	9.6
27	838+75	North	18.8	16.5	2.3	23.7	26.5	-2.8	10.0
28	838+00	North	15.0	16.0	-1.0	21.3	26.2	-5.0	10.3
29	837+25	North	14.0	15.7	-1.6	27.5	26.1	1.4	10.4
30	836+50	North	13.1	15.6	-2.5	24.8	26.0	-1.2	10.4
31	835+75	North	15.3	15.8	-0.5	28.6	26.0	2.7	10.2
32	835+00	North	16.4	16.1	0.3	26.5	26.0	0.5	9.9
33	834+25	North	15.9	16.7	-0.8	27.8	26.1	1.7	9.4
34	833+50	North	21.1	17.5	3.6	28.2	26.3	1.9	8.8
35	832+75	North	18.1	18.6	-0.4	22.6	26.6	-4.0	8.0
36	832+00	North	19.0	19.8	-0.8	27.6	26.9	0.7	7.1

Insertion Loss = 10.6



Kent Commons Receiver 3
South Conventional Barrier
y = 0.0613x^2 - 1.4103x + 34.314
y = 0.0636x^2 - 1.335x + 26.844
Attenuation (dBA)
Spark Number
No Barrier
Conventional
Poly. (No Barrier)
Poly. (Conventional)

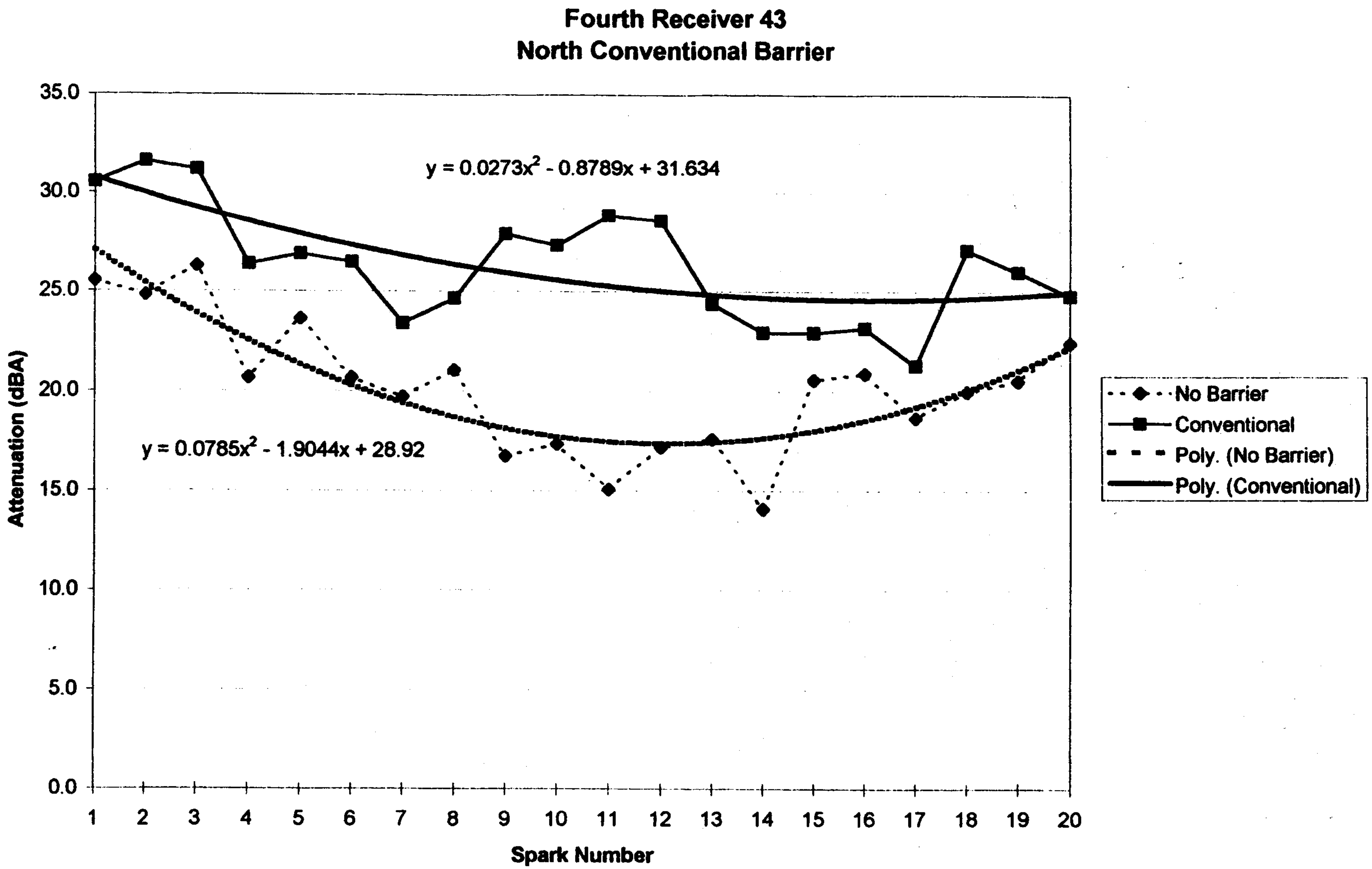

Kent Commons Receiver 3
North Conventional Barrier
y = 0.0351x2 - 0.7605x + 30.078
y = 0.1104x2 - 2.1699x + 26.267
Attenuation (dBA)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
Spark Number
No Barrier
Conventional
Poly. (No Barrier)
Poly. (Conventional)

Fourth Ave Receiver 43

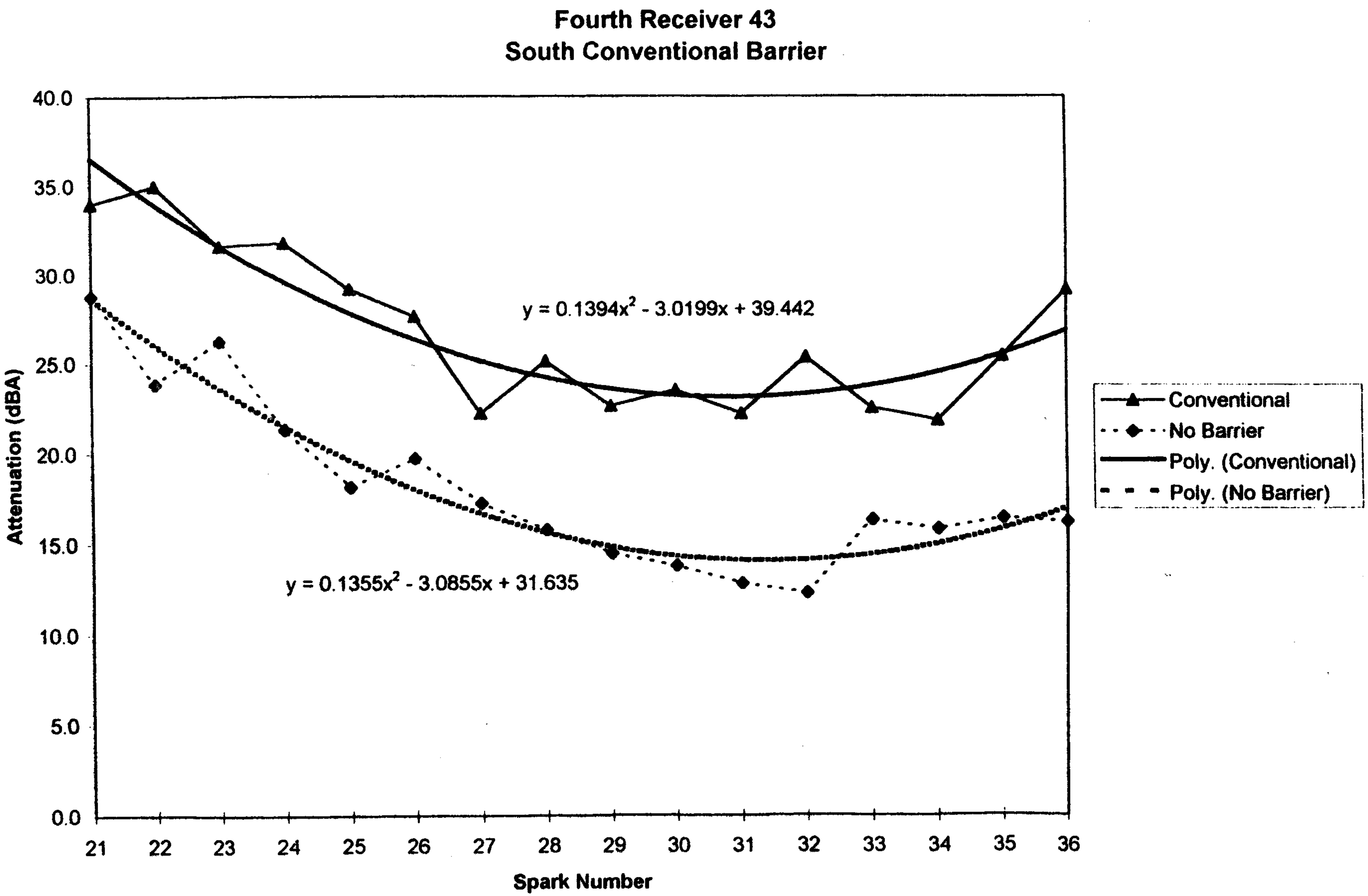
Spark Number	Station		No Barrier Attenuation: Actual No Barrier	No Barrier Attenuation: Fitted No Barrier	No Barrier Attenuation: Standard Error	Conventional Barrier Attenuation: Actual Conventional	Conventional Barrier Attenuation: Fitted Conventional	Conventional Barrier Attenuation: Standard Error	Insertion Scale Model
1	1045+50	North	25.5	27.1	-1.5	30.6	30.8	-0.2	3.7
2	1046+25	North	24.8	25.4	-0.6	31.6	30.0	1.6	4.6
3	1047+00	North	26.3	23.9	2.4	31.2	29.2	2.0	5.3
4	1047+75	North	20.7	22.6	-1.9	26.4	28.6	-2.2	6.0
5	1048+50	North	23.6	21.4	2.3	26.9	27.9	-1.0	6.6
6	1049+25	North	20.7	20.3	0.4	26.5	27.3	-0.9	7.0
7	1050+00	North	19.7	19.4	0.3	23.4	26.8	-3.4	7.4
8	1050+75	North	21.1	18.7	2.4	24.7	26.4	-1.7	7.6
9	1051+50	North	16.7	18.1	-1.4	27.9	25.9	2.0	7.8
10	1052+25	North	17.4	17.7	-0.4	27.3	25.6	1.8	7.8
11	1053+00	North	15.1	17.5	-2.4	28.8	25.3	3.6	7.8
12	1053+75	North	17.2	17.4	-0.2	28.6	25.0	3.6	7.6
13	1054+50	North	17.6	17.4	0.2	24.4	24.8	-0.4	7.4
14	1055+25	North	14.1	17.6	-3.6	22.9	24.7	-1.7	7.0
15	1056+00	North	20.6	18.0	2.6	22.9	24.6	-1.7	6.6
16	1056+75	North	20.9	18.5	2.4	23.2	24.6	-1.4	6.0
17	1057+50	North	18.7	19.2	-0.5	21.3	24.6	-3.3	5.4
18	1058+25	North	20.0	20.1	-0.1	27.1	24.7	2.4	4.6
19	1059+00	North	20.6	21.1	-0.5	26.0	24.8	1.2	3.7
20	1059+75	North	22.4	22.2	0.2	24.8	25.0	-0.2	2.7

Spark Number	Station		No Barrier Attenuation: Actual No Barrier	No Barrier Attenuation: Fitted No Barrier	No Barrier Attenuation: Standard Error	Conventional Barrier Attenuation: Actual Conventional	Conventional Barrier Attenuation: Fitted Conventional	Conventional Barrier Attenuation: Standard Error	Insertion Scale Model
21	1045+50	South	28.8	28.7	0.1	34.0	36.6	-2.6	7.9
22	1046+25	South	23.9	26.0	-2.2	35.0	34.0	1.0	8.0
23	1047+00	South	26.2	23.6	2.6	31.6	31.6	0.0	8.0
24	1047+75	South	21.3	21.5	-0.2	31.8	29.6	2.2	8.1
25	1048+50	South	18.2	19.6	-1.4	29.1	27.8	1.3	8.2
26	1049+25	South	19.7	18.0	1.7	27.6	26.3	1.3	8.3
27	1050+00	South	17.3	16.7	0.6	22.2	25.1	-2.9	8.5
28	1050+75	South	15.8	15.6	0.2	25.1	24.2	0.9	8.6
29	1051+50	South	14.5	14.8	-0.3	22.6	23.6	-1.0	8.7
30	1052+25	South	13.8	14.3	-0.5	23.5	23.2	0.3	8.9
31	1053+00	South	12.8	14.1	-1.3	22.2	23.1	-0.9	9.0
32	1053+75	South	12.3	14.1	-1.8	25.3	23.3	2.1	9.2
33	1054+50	South	16.3	14.4	1.9	22.5	23.7	-1.2	9.3
34	1055+25	South	15.8	15.0	0.8	21.8	24.5	-2.7	9.5
35	1056+00	South	16.4	15.8	0.6	25.4	25.5	-0.1	9.7
36	1056+75	South	16.2	17.0	-0.7	29.1	26.8	2.3	9.9

Insetion Loss = 7.6



Fourth Receiver 43
North Conventional Barrier
y = 0.0273x² - 0.8789x + 31.634
y = 0.0785x² - 1.9044x + 28.92
Attenuation (dBA)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Spark Number
No Barrier
Conventional
Poly. (No Barrier)
Poly. (Conventional)


Fourth Receiver 43
South Conventional Barrier
Attenuation (dBA)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
Spark Number
y = 0.1394x² - 3.0199x + 39.442
y = 0.1355x² - 3.0855x + 31.635
Conventional
No Barrier
Poly. (Conventional)
Poly. (No Barrier)

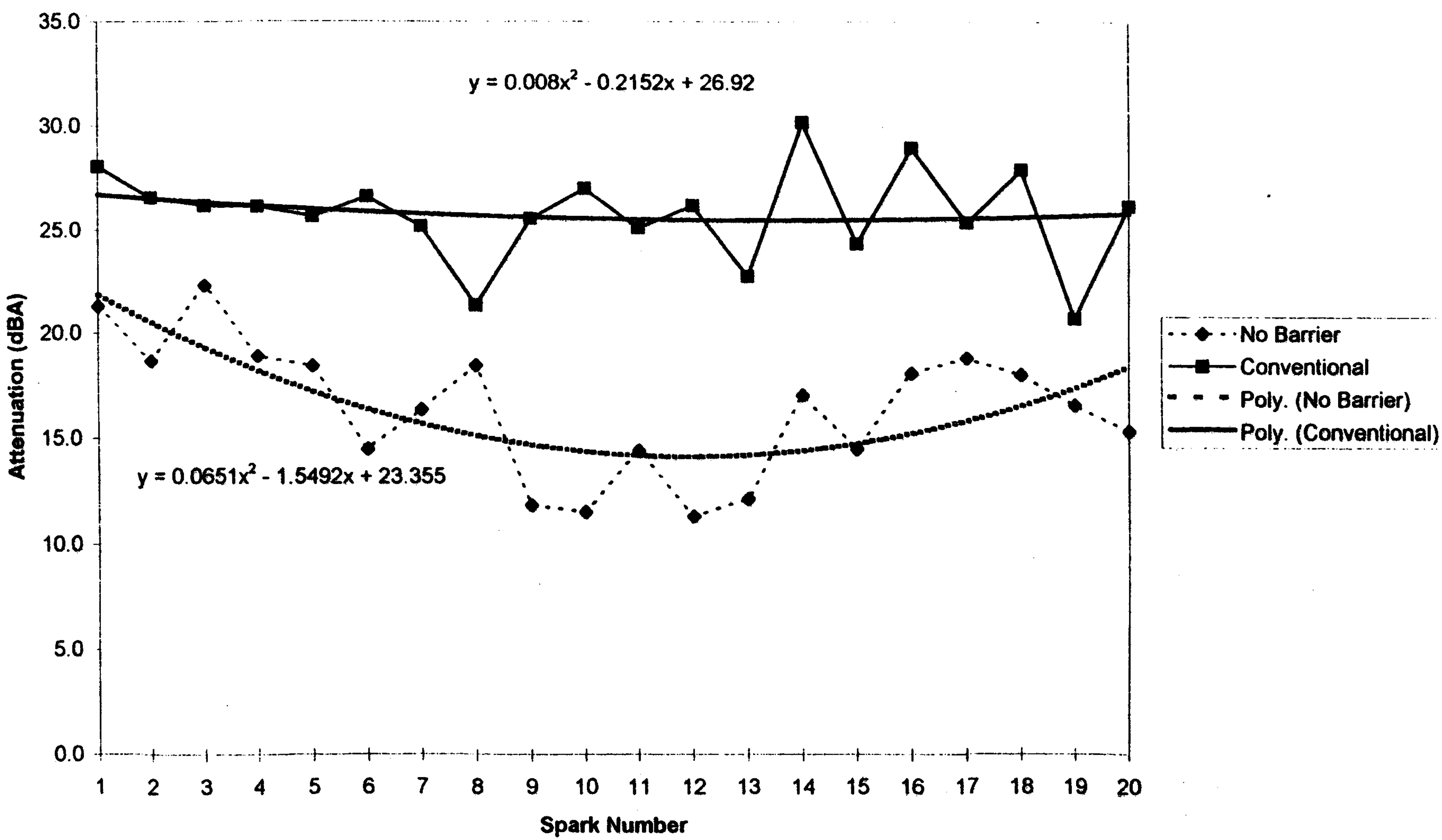
Fourth Ave Receiver 44

Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	Conventional Barrier Attenuation Actual Conventional	Fitted Conventional	Standard Error	Insertion Scale Model
1	1043+25	North	21.3	21.9	-0.6	28.1	26.5	1.6	4.6
2	1044+75	North	18.6	20.5	-1.9	26.6	26.3	0.3	5.8
3	1044+75	North	22.3	19.3	3.0	26.2	26.1	0.1	6.8
4	1045+50	North	18.9	18.2	0.7	26.1	25.9	0.2	7.7
5	1046+25	North	18.4	17.2	1.2	25.7	25.8	-0.1	8.6
6	1047+00	North	14.5	16.4	-1.9	26.7	25.7	1.0	9.3
7	1047+75	North	16.4	15.7	0.7	25.2	25.6	-0.4	9.9
8	1048+50	North	18.4	15.1	3.3	21.4	25.5	-4.1	10.3
9	1049+25	North	11.8	14.7	-2.8	25.6	25.4	0.2	10.7
10	1050+00	North	11.5	14.4	-2.9	27.0	25.3	1.7	11.0
11	1050+75	North	14.4	14.2	0.2	25.1	25.3	-0.2	11.1
12	1051+50	North	11.3	14.1	-2.8	26.2	25.3	0.9	11.2
13	1052+25	North	12.1	14.2	-2.1	22.7	25.3	-2.6	11.1
14	1053+00	North	17.0	14.4	2.6	30.2	25.3	4.9	10.9
15	1053+75	North	14.5	14.8	-0.3	24.3	25.4	-1.0	10.6
16	1054+50	North	18.1	15.2	2.8	28.9	25.4	3.5	10.2
17	1055+25	North	18.8	15.8	3.0	25.4	25.5	-0.2	9.7
18	1056+00	North	18.0	16.6	1.5	27.9	25.6	2.3	9.1
19	1056+75	North	16.6	17.4	-0.8	20.7	25.7	-5.0	8.3
20	1057+50	North	15.4	18.4	-3.1	26.2	25.9	0.3	7.5

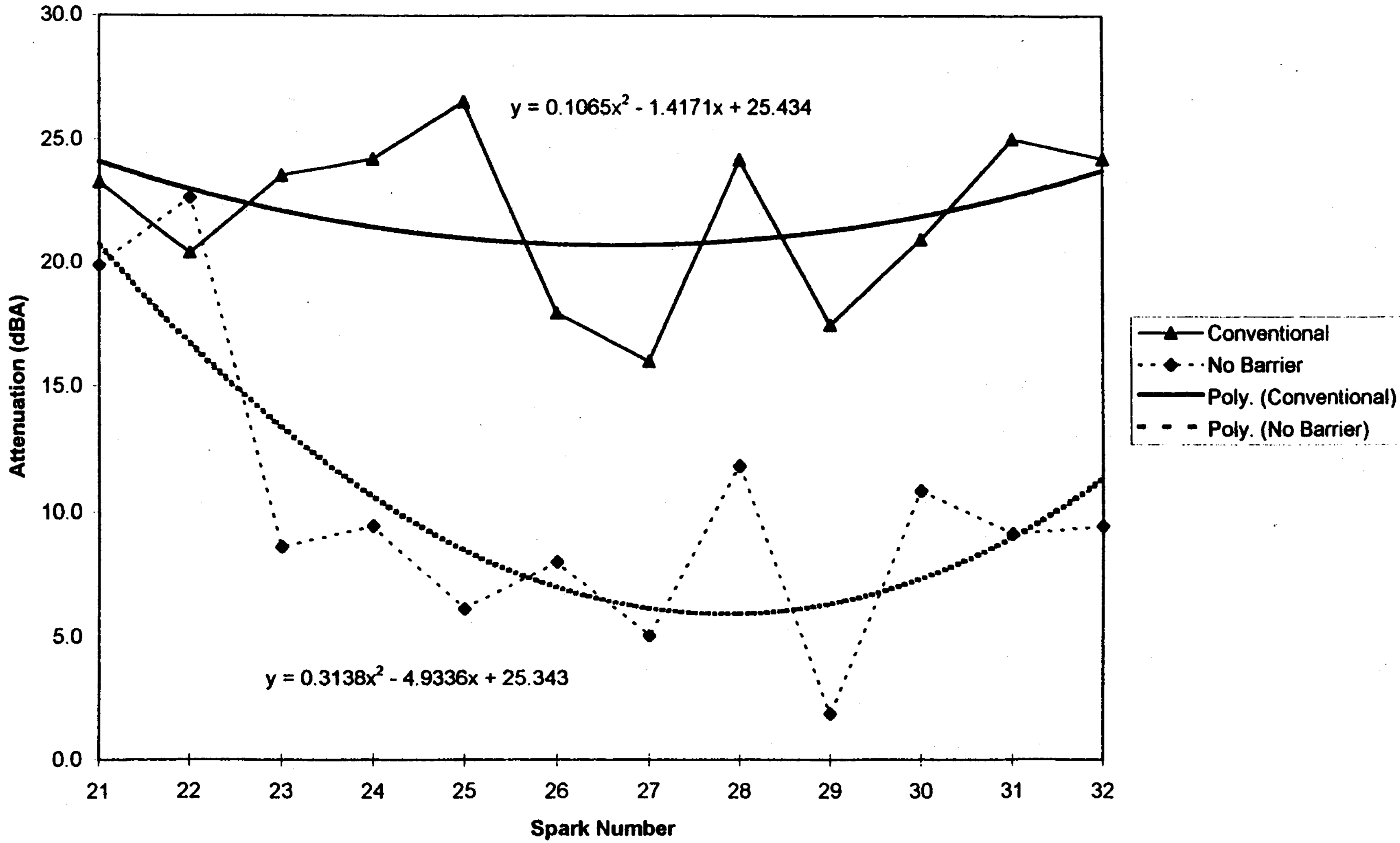
Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	Conventional Barrier Attenuation Actual Conventional	Fitted Conventional	Standard Error	Insertion Scale Model
21	1045+50	South	19.9	20.7	-0.8	23.3	24.1	-0.8	3.4
22	1046+25	South	22.7	16.7	5.9	20.4	23.0	-2.6	6.3
23	1047+00	South	8.7	13.4	-4.7	23.6	22.1	1.4	8.8
24	1047+75	South	9.5	10.6	-1.2	24.2	21.5	2.8	10.8
25	1048+50	South	6.2	8.5	-2.4	26.5	21.0	5.5	12.5
26	1049+25	South	8.1	7.0	1.0	18.0	20.8	-2.8	13.7
27	1050+00	South	5.1	6.2	-1.1	16.0	20.7	-4.7	14.5
28	1050+75	South	11.8	6.0	5.9	24.2	20.9	3.3	15.0
29	1051+50	South	1.9	6.4	-4.5	17.5	21.3	-3.8	14.9
30	1052+25	South	10.9	7.4	3.5	21.0	21.9	-1.0	14.5
31	1053+00	South	9.2	9.0	0.1	25.0	22.7	2.3	13.7
32	1053+75	South	9.5	11.3	-1.9	24.2	23.8	0.5	12.4

Insertion Loss = 11.1

Fourth Receiver 44 North Conventional Barrier



Fourth Receiver 44 South Conventional Barrier

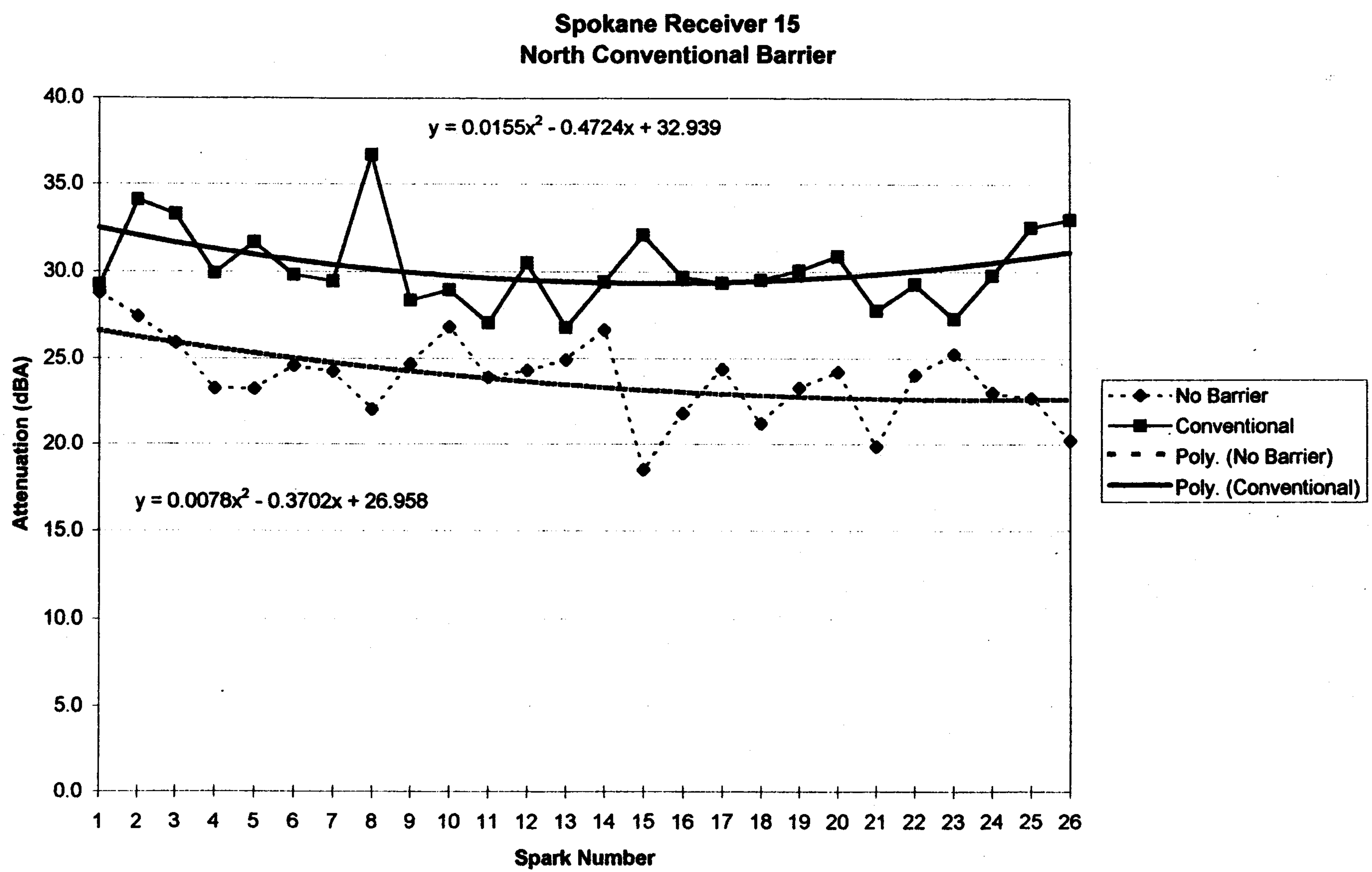


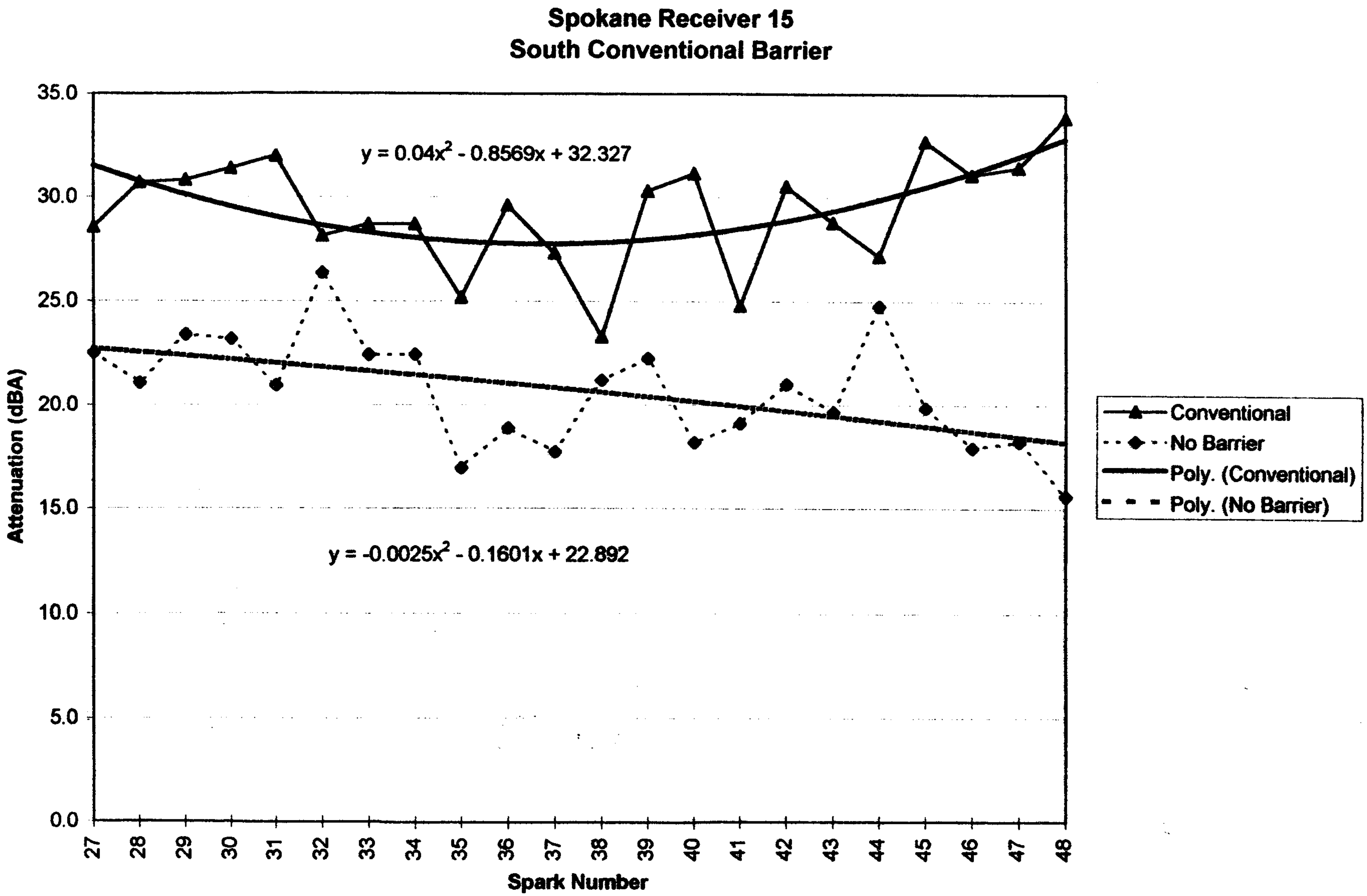
Spokane Receiver 15

Spark Number	Station		No Barrier Attenuation: Actual No Barrier	Fitted No Barrier	Standard Error	Conventional Barrier Attenuation: Actual Conventional	Fitted Conventional	Standard Error	Insertion Scale Model
1	529+00	North	28.8	26.6	2.2	29.2	32.5	-3.2	5.9
2	529+75	North	27.4	26.2	1.2	34.1	32.1	2.0	5.8
3	530+50	North	25.9	25.9	0.0	33.3	31.7	1.6	5.7
4	531+25	North	23.3	25.6	-2.3	29.9	31.3	-1.4	5.7
5	532+00	North	23.2	25.3	-2.1	31.7	31.0	0.7	5.7
6	532+75	North	24.6	25.0	-0.4	29.8	30.7	-0.8	5.6
7	533+50	North	24.3	24.7	-0.5	29.5	30.4	-0.9	5.6
8	534+25	North	22.0	24.5	-2.5	36.7	30.2	6.6	5.7
9	535+00	North	24.7	24.3	0.4	28.4	29.9	-1.6	5.7
10	535+75	North	26.8	24.0	2.8	29.0	29.8	-0.8	5.7
11	536+50	North	23.9	23.8	0.1	27.1	29.6	-2.6	5.8
12	537+25	North	24.3	23.6	0.7	30.5	29.5	1.0	5.9
13	538+00	North	24.9	23.5	1.5	26.8	29.4	-2.6	6.0
14	538+75	North	26.7	23.3	3.4	29.4	29.4	0.1	6.1
15	539+50	North	18.5	23.2	-4.6	32.1	29.3	2.8	6.2
16	540+25	North	21.8	23.0	-1.2	29.7	29.3	0.3	6.3
17	541+00	North	24.4	22.9	1.5	29.4	29.4	0.0	6.5
18	541+75	North	21.2	22.8	-1.6	29.5	29.5	0.1	6.6
19	542+50	North	23.3	22.7	0.6	30.1	29.6	0.5	6.8
20	543+25	North	24.2	22.7	1.5	30.9	29.7	1.2	7.0
21	544+00	North	19.9	22.6	-2.8	27.8	29.9	-2.1	7.2
22	544+75	North	24.0	22.6	1.5	29.3	30.0	-0.8	7.5
23	545+50	North	25.3	22.6	2.7	27.3	30.3	-3.0	7.7
24	546+25	North	23.0	22.6	0.4	29.8	30.5	-0.8	8.0
25	547+00	North	22.7	22.6	0.1	32.5	30.8	1.7	8.2
26	547+75	North	20.2	22.6	-2.4	33.0	31.1	1.8	8.5

Spark Number	Station		No Barrier Attenuation: Actual No Barrier	Fitted No Barrier	Standard Error	Conventional Barrier Attenuation: Actual Conventional	Fitted Conventional	Standard Error	Insertion Scale Model
27	530+50	South	22.5	22.7	-0.2	28.6	31.5	-3.0	8.8
28	531+25	South	21.1	22.6	-1.5	30.7	30.8	-0.1	8.2
29	532+00	South	23.4	22.4	1.0	30.8	30.1	0.7	7.7
30	532+75	South	23.2	22.2	1.0	31.4	29.5	1.9	7.3
31	533+50	South	21.0	22.0	-1.1	32.0	29.0	2.9	7.0
32	534+25	South	26.4	21.8	4.5	28.1	28.6	-0.5	6.8
33	535+00	South	22.4	21.6	0.8	28.7	28.3	0.4	6.6
34	535+75	South	22.4	21.5	1.0	28.7	28.0	0.7	6.6
35	536+50	South	16.9	21.2	-4.3	25.2	27.9	-2.7	6.6
36	537+25	South	18.9	21.0	-2.2	29.6	27.8	1.8	6.7
37	538+00	South	17.7	20.8	-3.1	27.3	27.7	-0.4	6.9
38	538+75	South	21.2	20.6	0.6	23.3	27.8	-4.5	7.2
39	539+50	South	22.3	20.4	1.9	30.3	27.9	2.4	7.6
40	540+25	South	18.2	20.2	-2.0	31.2	28.2	3.0	8.0
41	541+00	South	19.1	19.9	-0.8	24.8	28.5	-3.7	8.5
42	541+75	South	21.0	19.7	1.3	30.5	28.9	1.7	9.2
43	542+50	South	19.7	19.4	0.2	28.8	29.3	-0.5	9.9
44	543+25	South	24.8	19.2	5.6	27.2	29.9	-2.7	10.7
45	544+00	South	19.9	18.9	0.9	32.7	30.5	2.2	11.5
46	544+75	South	17.9	18.7	-0.8	31.1	31.2	-0.1	12.5
47	545+50	South	18.2	18.4	-0.2	31.4	32.0	-0.5	13.5
48	546+25	South	15.6	18.2	-2.6	33.9	32.8	1.0	14.7

Insertion Loss = 8.2


Spokane Receiver 15
North Conventional Barrier
y = 0.0155x2 - 0.4724x + 32.939
y = 0.0078x2 - 0.3702x + 26.958
Attenuation (dBA)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
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
Spark Number
No Barrier
Conventional
Poly. (No Barrier)
Poly. (Conventional)

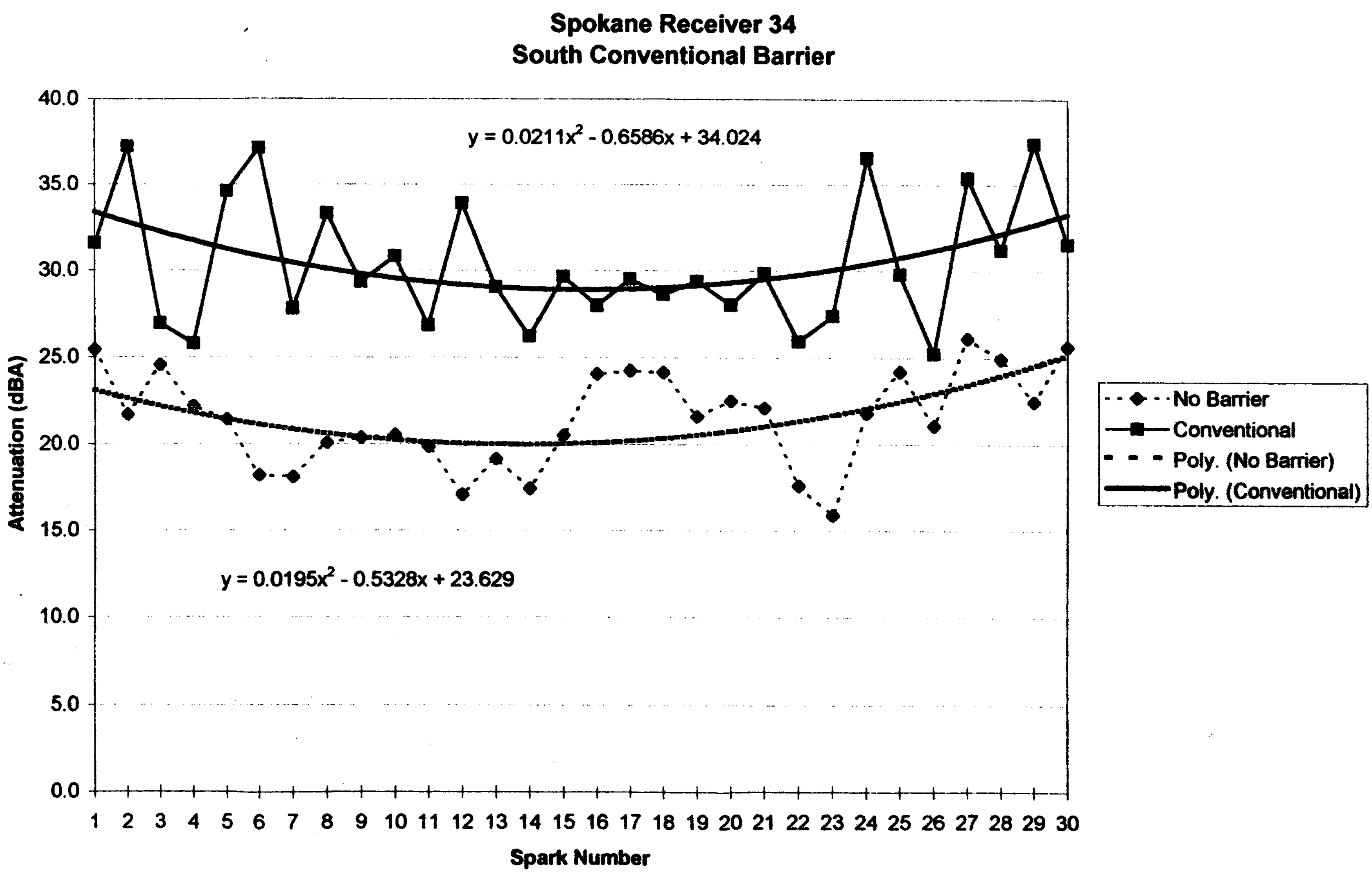

Spokane Receiver 15
South Conventional Barrier
y = 0.04x² - 0.8569x + 32.327
y = -0.0025x² - 0.1601x + 22.892
Attenuation (dBA)
Spark Number
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
Conventional
No Barrier
Poly. (Conventional)
Poly. (No Barrier)

Spokane Receiver 34

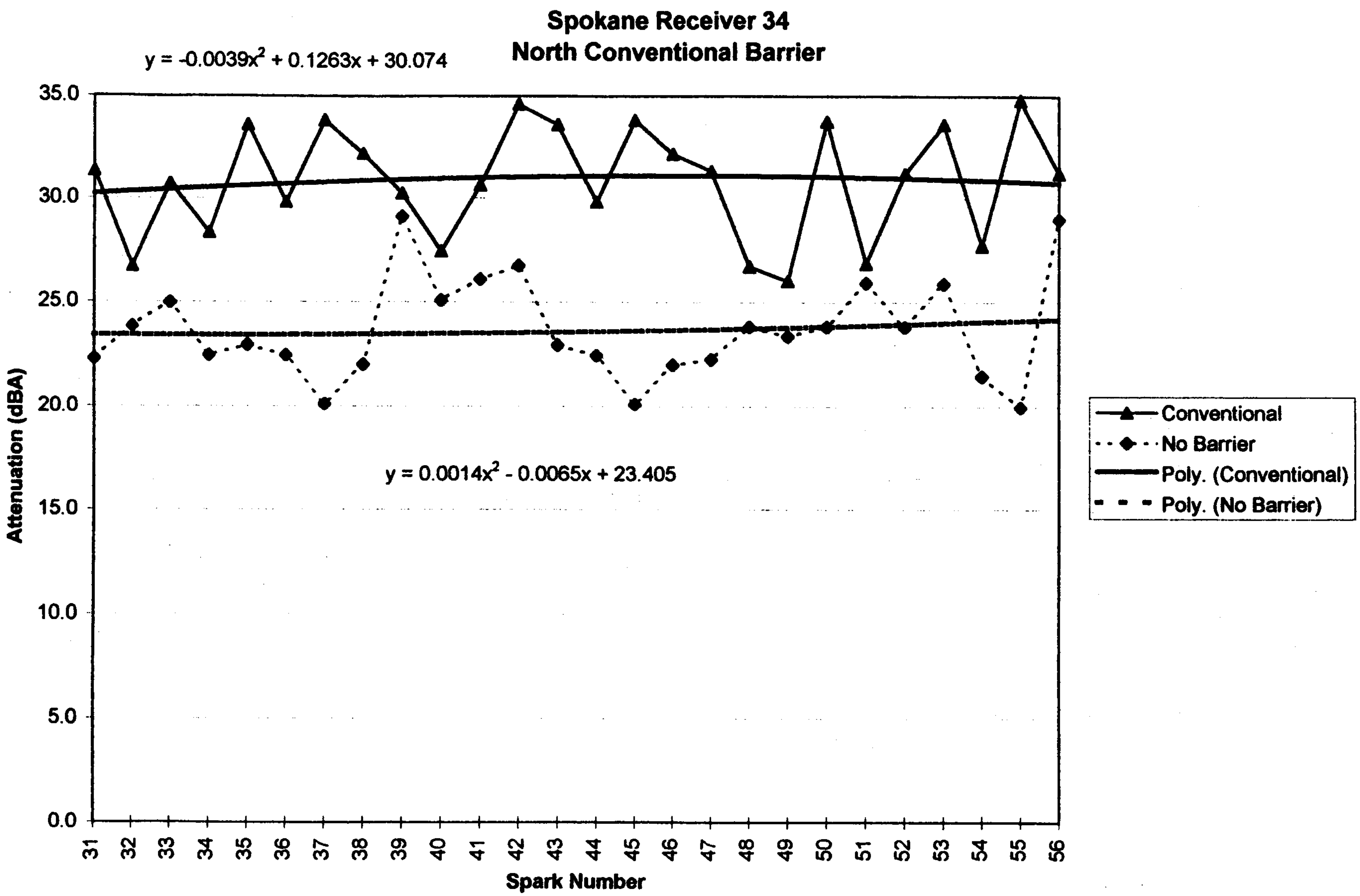
Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	Conventional Barrier Attenuation Actual Conventional	Fitted Conventional	Standard Error	Insertion Scale Model
1	527+50	South	25.5	23.1	2.3	31.6	33.4	-1.8	10.3
2	528+25	South	21.7	22.6	-0.9	37.2	32.8	4.4	10.1
3	529+00	South	24.6	22.2	2.4	27.0	32.2	-5.3	10.0
4	529+75	South	22.2	21.8	0.4	25.8	31.7	-5.9	9.9
5	530+50	South	21.4	21.5	0.0	34.6	31.3	3.4	9.8
6	531+25	South	18.2	21.1	-2.9	37.1	30.8	6.3	9.7
7	532+00	South	18.1	20.9	-2.8	27.8	30.4	-2.6	9.6
8	532+75	South	20.1	20.6	-0.5	33.3	30.1	3.2	9.5
9	533+50	South	20.4	20.4	0.0	29.3	29.8	-0.5	9.4
10	534+25	South	20.5	20.3	0.3	30.8	29.5	1.3	9.3
11	535+00	South	19.8	20.1	-0.3	26.8	29.3	-2.5	9.2
12	535+75	South	17.1	20.0	-3.0	33.9	29.2	4.7	9.1
13	536+50	South	19.1	20.0	-0.9	29.0	29.0	0.0	9.0
14	537+25	South	17.4	20.0	-2.5	26.2	28.9	-2.7	8.9
15	538+00	South	20.5	20.0	0.5	29.7	28.9	0.8	8.9
16	538+75	South	24.1	20.1	4.0	28.0	28.9	-0.9	8.8
17	539+50	South	24.3	20.2	4.1	29.5	28.9	0.6	8.7
18	540+25	South	24.2	20.4	3.8	28.6	29.0	-0.4	8.6
19	541+00	South	21.6	20.5	1.1	29.4	29.1	0.3	8.6
20	541+75	South	22.5	20.8	1.7	28.0	29.3	-1.3	8.5
21	542+50	South	22.1	21.0	1.1	29.8	29.5	0.4	8.5
22	543+25	South	17.6	21.3	-3.7	25.9	29.7	-3.8	8.4
23	544+00	South	15.9	21.7	-5.8	27.4	30.0	-2.6	8.3
24	544+75	South	21.8	22.1	-0.3	36.6	30.4	6.2	8.3
25	545+50	South	24.2	22.5	1.7	29.8	30.7	-0.9	8.3
26	546+25	South	21.1	23.0	-1.9	25.2	31.2	-5.9	8.2
27	547+00	South	26.1	23.5	2.7	35.4	31.6	3.8	8.2
28	547+75	South	24.9	24.0	0.9	31.2	32.1	-0.9	8.1
29	548+50	South	22.5	24.6	-2.1	37.4	32.7	4.7	8.1
30	549+25	South	25.7	25.2	0.5	31.6	33.3	-1.7	8.1

Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	Conventional Barrier Attenuation Actual Conventional	Fitted Conventional	Standard Error	Insertion Scale Model
31	529+00	North	22.3	23.4	-1.1	31.3	30.2	1.1	6.8
32	529+75	North	23.8	23.4	0.4	26.7	30.3	-3.6	6.9
33	530+50	North	25.0	23.4	1.6	30.7	30.4	0.3	7.0
34	531+25	North	22.5	23.4	-0.9	28.3	30.5	-2.2	7.1
35	532+00	North	22.9	23.4	-0.5	33.6	30.6	3.0	7.2
36	532+75	North	22.5	23.4	-1.0	29.8	30.7	-0.9	7.3
37	533+50	North	20.1	23.4	-3.3	33.8	30.8	3.1	7.3
38	534+25	North	22.0	23.4	-1.4	32.2	30.8	1.4	7.4
39	535+00	North	29.1	23.5	5.7	30.2	30.9	-0.7	7.4
40	535+75	North	25.1	23.5	1.6	27.4	30.9	-3.5	7.5
41	536+50	North	26.1	23.5	2.6	30.6	31.0	-0.4	7.5
42	537+25	North	26.7	23.5	3.2	34.6	31.0	3.6	7.5
43	538+00	North	22.9	23.6	-0.6	33.6	31.1	2.6	7.5
44	538+75	North	22.5	23.6	-1.1	29.8	31.1	-1.3	7.5
45	539+50	North	20.1	23.6	-3.5	33.8	31.1	2.7	7.5
46	540+25	North	22.0	23.7	-1.7	32.2	31.1	1.1	7.4
47	541+00	North	22.3	23.7	-1.4	31.3	31.1	0.2	7.4
48	541+75	North	23.8	23.7	0.1	26.7	31.1	-4.4	7.3
49	542+50	North	23.4	23.8	-0.4	26.0	31.1	-5.0	7.3
50	543+25	North	23.8	23.8	0.0	33.8	31.0	2.7	7.2
51	544+00	North	25.9	23.9	2.0	26.8	31.0	-4.2	7.1
52	544+75	North	23.8	23.9	-0.1	31.2	31.0	0.2	7.0
53	545+50	North	25.9	24.0	1.9	33.6	30.9	2.7	6.9
54	546+25	North	21.5	24.1	-2.6	27.7	30.9	-3.2	6.8
55	547+00	North	20.0	24.1	-4.1	34.8	30.8	4.0	6.7
56	547+75	North	29.0	24.2	4.8	31.2	30.7	0.5	6.5

Insertion Loss = 8.3



Spokane Receiver 34
South Conventional Barrier
y = 0.0211x² - 0.6586x + 34.024
y = 0.0195x² - 0.5328x + 23.629
Attenuation (dBA)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
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 30
Spark Number
No Barrier
Conventional
Poly. (No Barrier)
Poly. (Conventional)


Spokane Receiver 34
North Conventional Barrier
y = -0.0039x2 + 0.1263x + 30.074
y = 0.0014x2 - 0.0065x + 23.405
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Attenuation (dBA)
31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56
Spark Number
Conventional
No Barrier
Poly. (Conventional)
Poly. (No Barrier)

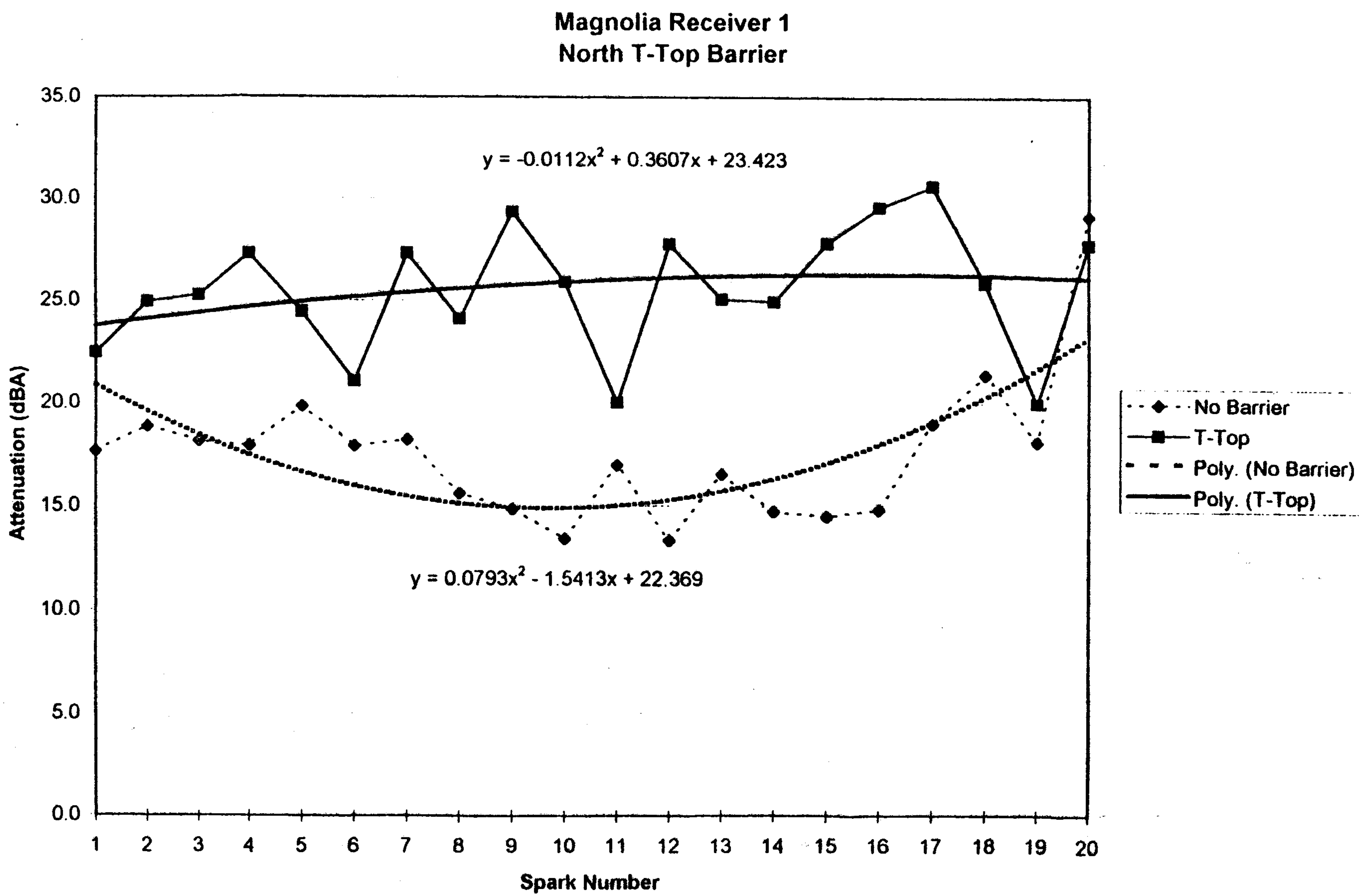
APPENDIX B
SCALE MODEL DATA FILES
ABSORPTIVE T-TOP BARRIER TESTS

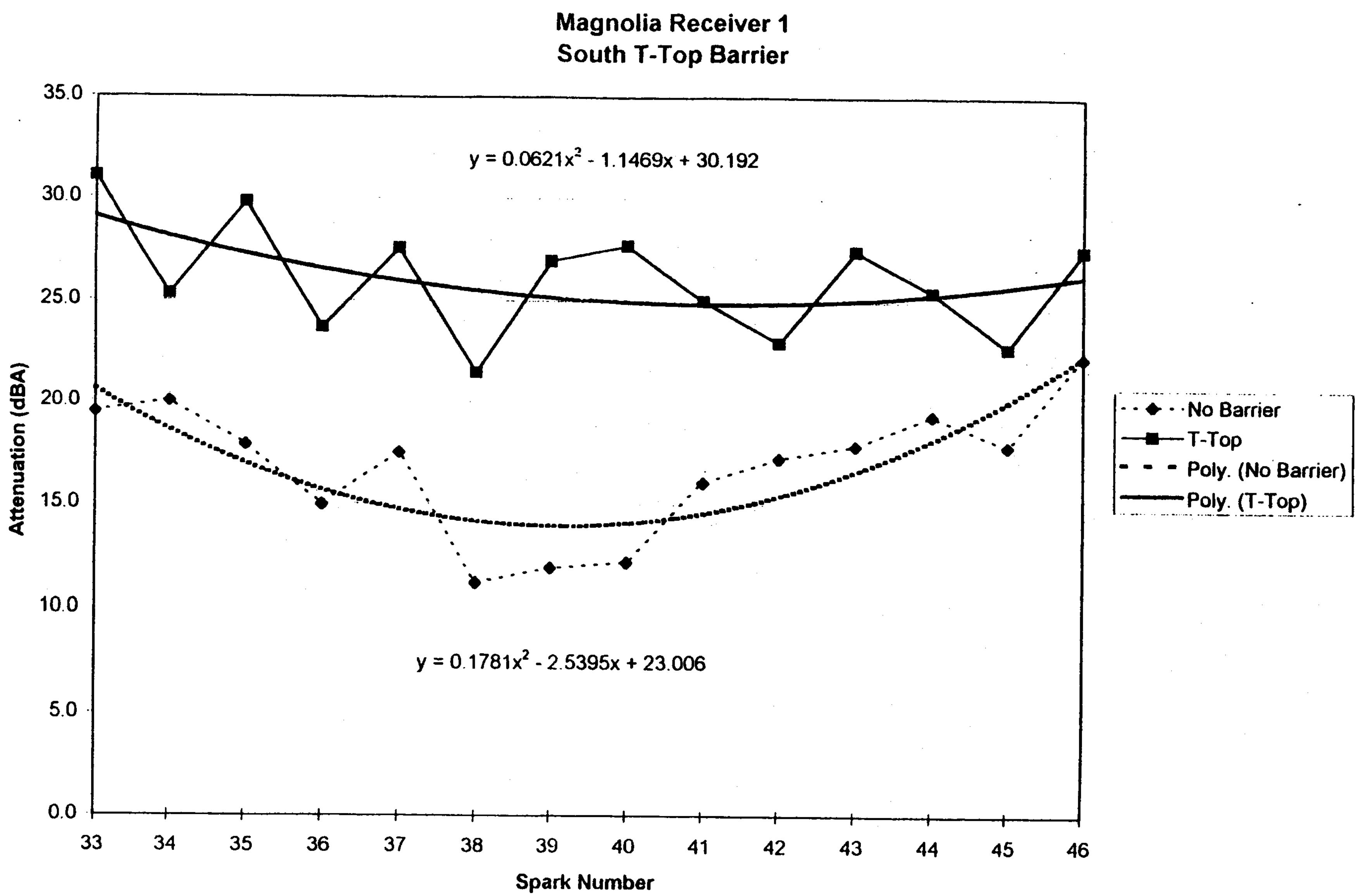
Magnolia Receiver 1

Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	T-Top Barrier Attenuation Actual T-Top	Fitted T-Top	Standard Error	Insertion Scale Model
1	87+25	North	17.7	20.9	-3.3	22.4	23.8	-1.3	2.9
2	88+00	North	18.8	19.6	-0.8	24.9	24.1	0.8	4.5
3	88+75	North	18.2	18.5	-0.3	25.3	24.4	0.9	5.9
4	89+50	North	17.9	17.5	0.5	27.3	24.7	2.6	7.2
5	90+25	North	19.9	16.6	3.2	24.5	24.9	-0.5	8.3
6	91+00	North	17.9	16.0	1.9	21.1	25.2	-4.1	9.2
7	91+75	North	18.2	15.5	2.8	27.3	25.4	1.9	9.9
8	92+50	North	15.6	15.1	0.5	24.1	25.6	-1.5	10.5
9	93+25	North	14.9	14.9	-0.1	29.4	25.8	3.6	10.8
10	94+00	North	13.4	14.9	-1.5	25.9	25.9	0.0	11.0
11	94+75	North	17.0	15.0	2.0	20.0	26.0	-6.0	11.0
12	95+50	North	13.3	15.3	-1.9	27.8	26.1	1.6	10.8
13	96+25	North	16.6	15.7	0.8	25.1	26.2	-1.1	10.5
14	97+00	North	14.8	16.3	-1.6	25.0	26.3	-1.3	9.9
15	97+75	North	14.5	17.1	-2.6	27.8	26.3	1.5	9.2
16	98+50	North	14.8	18.0	-3.2	29.6	26.3	3.3	8.3
17	99+25	North	19.0	19.1	-0.1	30.7	26.3	4.3	7.2
18	100+00	North	21.4	20.3	1.1	25.9	26.3	-0.4	6.0
19	100+75	North	18.2	21.7	-3.6	20.0	26.2	-6.2	4.5
20	101+50	North	29.2	23.3	5.9	27.8	26.2	1.6	2.9

Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	T-Top Barrier Attenuation Actual T-Top	Fitted T-Top	Standard Error	Insertion Scale Model
33	89+50	South	19.5	20.6	-1.1	31.1	29.1	2.0	8.5
34	90+25	South	20.0	18.6	1.4	25.3	28.1	-2.8	9.5
35	91+00	South	17.9	17.0	0.9	29.8	27.3	2.5	10.3
36	91+75	South	15.0	15.7	-0.7	23.7	26.6	-2.9	10.9
37	92+50	South	17.5	14.8	2.8	27.6	26.0	1.6	11.2
38	93+25	South	11.2	14.2	-2.9	21.5	25.5	-4.0	11.4
39	94+00	South	12.0	14.0	-2.0	27.0	25.2	1.8	11.3
40	94+75	South	12.2	14.1	-1.8	27.8	25.0	2.8	10.9
41	95+50	South	16.1	14.6	1.5	25.0	24.9	0.1	10.3
42	96+25	South	17.3	15.4	1.8	23.0	24.9	-1.9	9.5
43	97+00	South	17.9	16.6	1.3	27.5	25.1	2.4	8.5
44	97+75	South	19.4	18.2	1.2	25.5	25.4	0.1	7.2
45	98+50	South	17.9	20.1	-2.2	22.8	25.8	-3.0	5.7
46	99+25	South	22.3	22.4	0.0	27.6	26.3	1.3	3.9

Insertion Loss = 9.2


Magnolia Receiver 1
North T-Top Barrier
y = -0.0112x² + 0.3607x + 23.423
y = 0.0793x² - 1.5413x + 22.369
Attenuation (dBA)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Spark Number
No Barrier
T-Top
Poly. (No Barrier)
Poly. (T-Top)



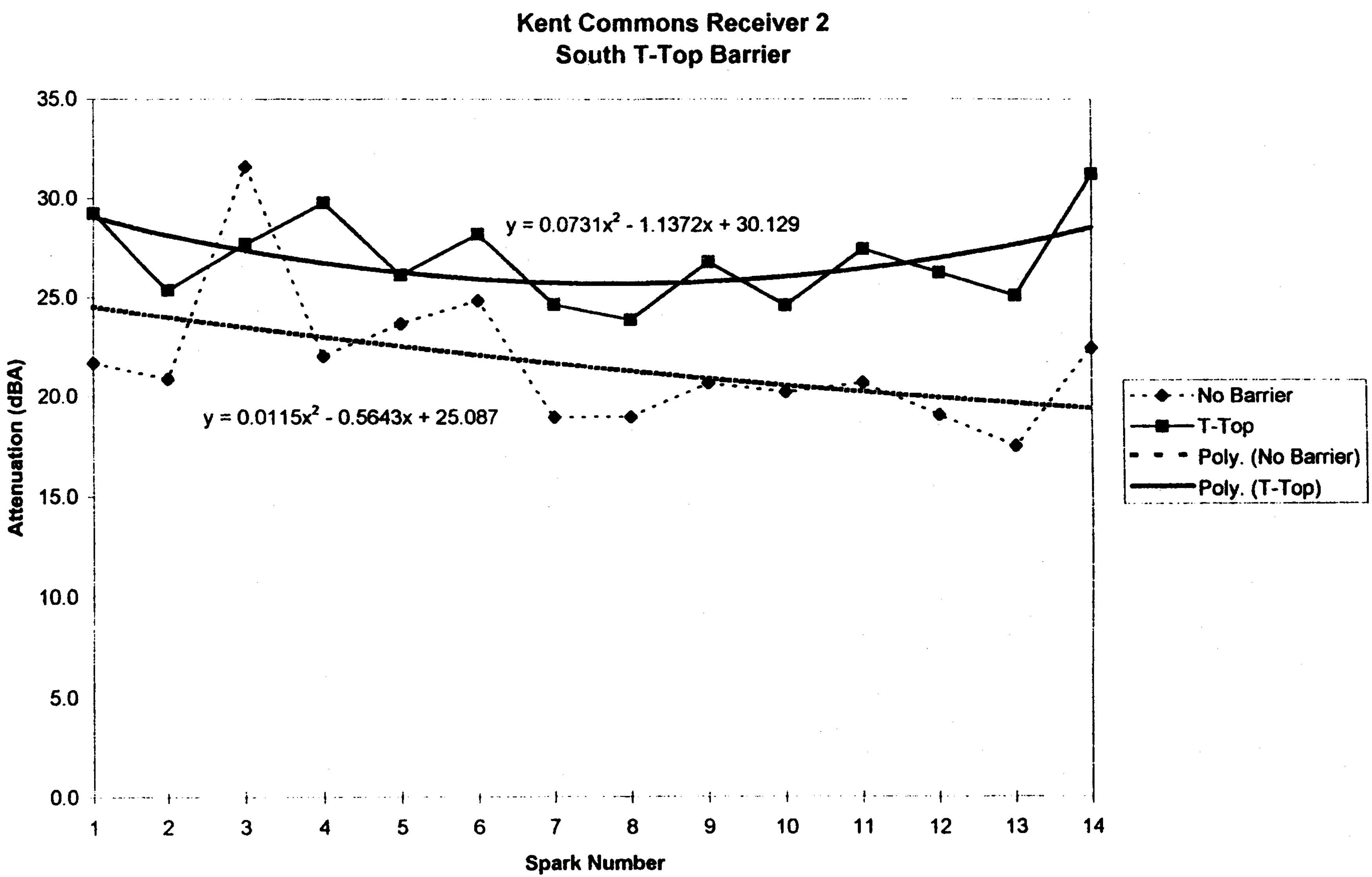
Magnolia Receiver 1
South T-Top Barrier
y = 0.0621x² - 1.1469x + 30.192
y = 0.1781x² - 2.5395x + 23.006
Attenuation (dBA)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
33
34
35
36
37
38
39
40
41
42
43
44
45
46
Spark Number
No Barrier
T-Top
Poly. (No Barrier)
Poly. (T-Top)

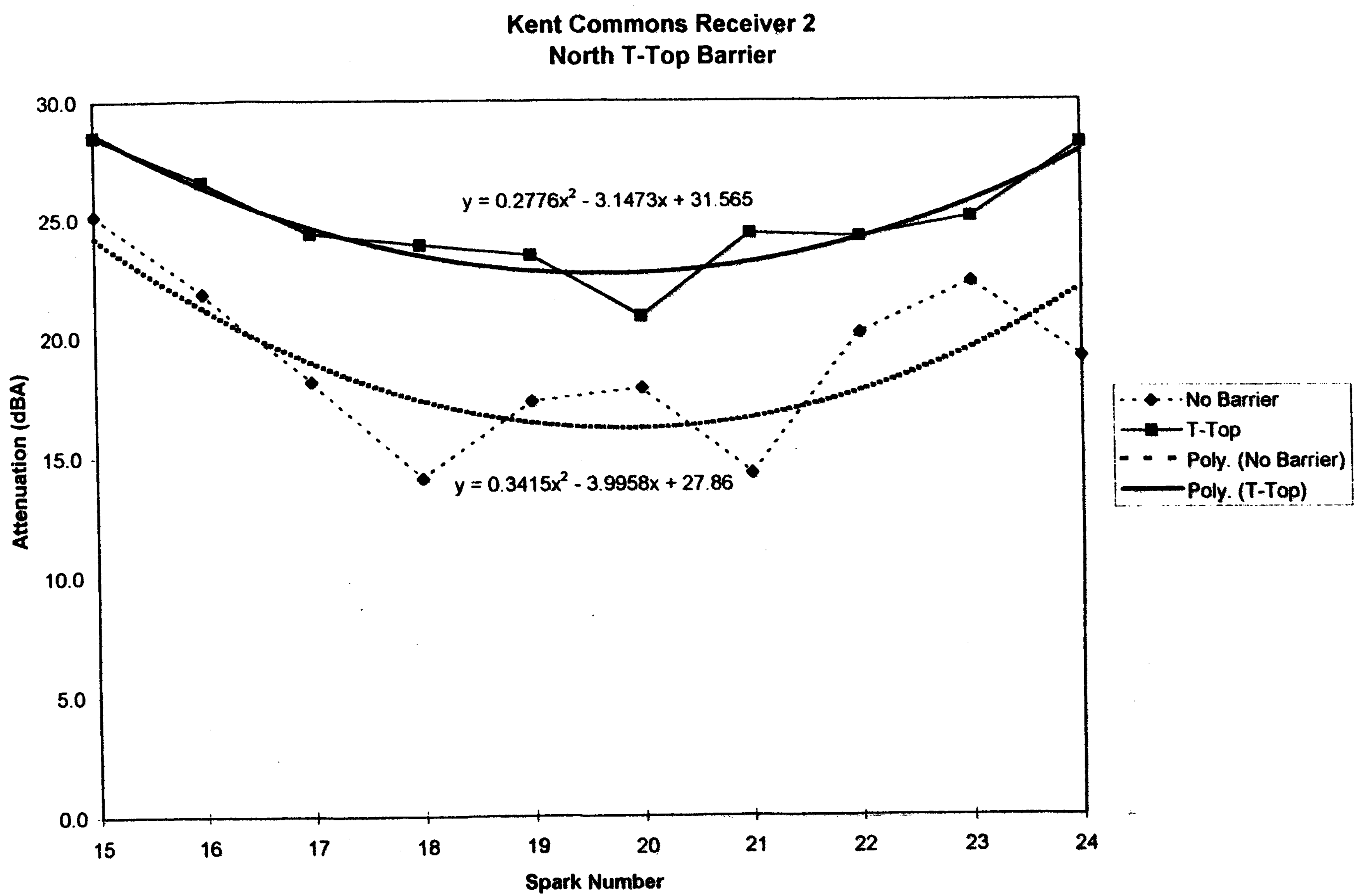
Kent Commons Receiver 2

Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	T-Top Barrier Attenuation Actual T-Top	Fitted T-Top	Standard Error	Insertion Scale Model
1	842+50	South	21.7	24.5	-2.8	29.3	29.1	0.2	4.5
2	841+75	South	20.9	24.0	-3.1	25.4	28.1	-2.8	4.1
3	841+00	South	31.6	23.5	8.1	27.7	27.4	0.3	3.9
4	840+25	South	22.1	23.0	-1.0	29.8	26.7	3.0	3.7
5	839+50	South	23.7	22.6	1.2	26.1	26.3	-0.1	3.7
6	838+75	South	24.9	22.1	2.7	28.2	25.9	2.3	3.8
7	838+00	South	19.0	21.7	-2.7	24.7	25.8	-1.1	4.1
8	837+25	South	19.0	21.3	-2.3	23.9	25.7	-1.8	4.4
9	836+50	South	20.7	20.9	-0.2	26.8	25.8	1.0	4.9
10	835+75	South	20.2	20.6	-0.3	24.6	26.1	-1.4	5.5
11	835+00	South	20.7	20.3	0.5	27.4	26.5	1.0	6.2
12	834+25	South	19.1	20.0	-0.9	26.3	27.0	-0.7	7.0
13	833+50	South	17.5	19.7	-2.2	25.1	27.7	-2.6	8.0
14	832+75	South	22.5	19.4	3.0	31.3	28.5	2.7	9.1

Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	T-Top Barrier Attenuation Actual T-Top	Fitted T-Top	Standard Error	Insertion Scale Model
15	841+00	North	25.2	24.2	1.0	28.5	28.7	-0.2	4.5
16	840+25	North	21.8	21.2	0.6	26.6	26.4	0.2	5.2
17	839+50	North	18.1	18.9	-0.8	24.3	24.6	-0.3	5.7
18	838+75	North	14.1	17.3	-3.3	23.9	23.4	0.4	6.1
19	838+00	North	17.3	16.4	0.9	23.4	22.8	0.7	6.4
20	837+25	North	17.9	16.1	1.7	20.9	22.7	-1.8	6.5
21	836+50	North	14.3	16.6	-2.3	24.4	23.1	1.2	6.6
22	835+75	North	20.2	17.7	2.5	24.2	24.2	0.0	6.4
23	835+00	North	22.3	19.5	2.8	25.0	25.7	-0.7	6.2
24	834+25	North	19.2	22.0	-2.8	28.2	27.9	0.4	5.9

Insertion Loss = 5.8


Kent Commons Receiver 2
South T-Top Barrier
y = 0.0731x² - 1.1372x + 30.129
y = 0.0115x² - 0.5643x + 25.087
Attenuation (dBA)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Spark Number
No Barrier
T-Top
Poly. (No Barrier)
Poly. (T-Top)


Kent Commons Receiver 2
North T-Top Barrier
y = 0.2776x^2 - 3.1473x + 31.565
y = 0.3415x^2 - 3.9958x + 27.86
Attenuation (dBA)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
15
16
17
18
19
20
21
22
23
24
Spark Number
No Barrier
T-Top
Poly. (No Barrier)
Poly. (T-Top)

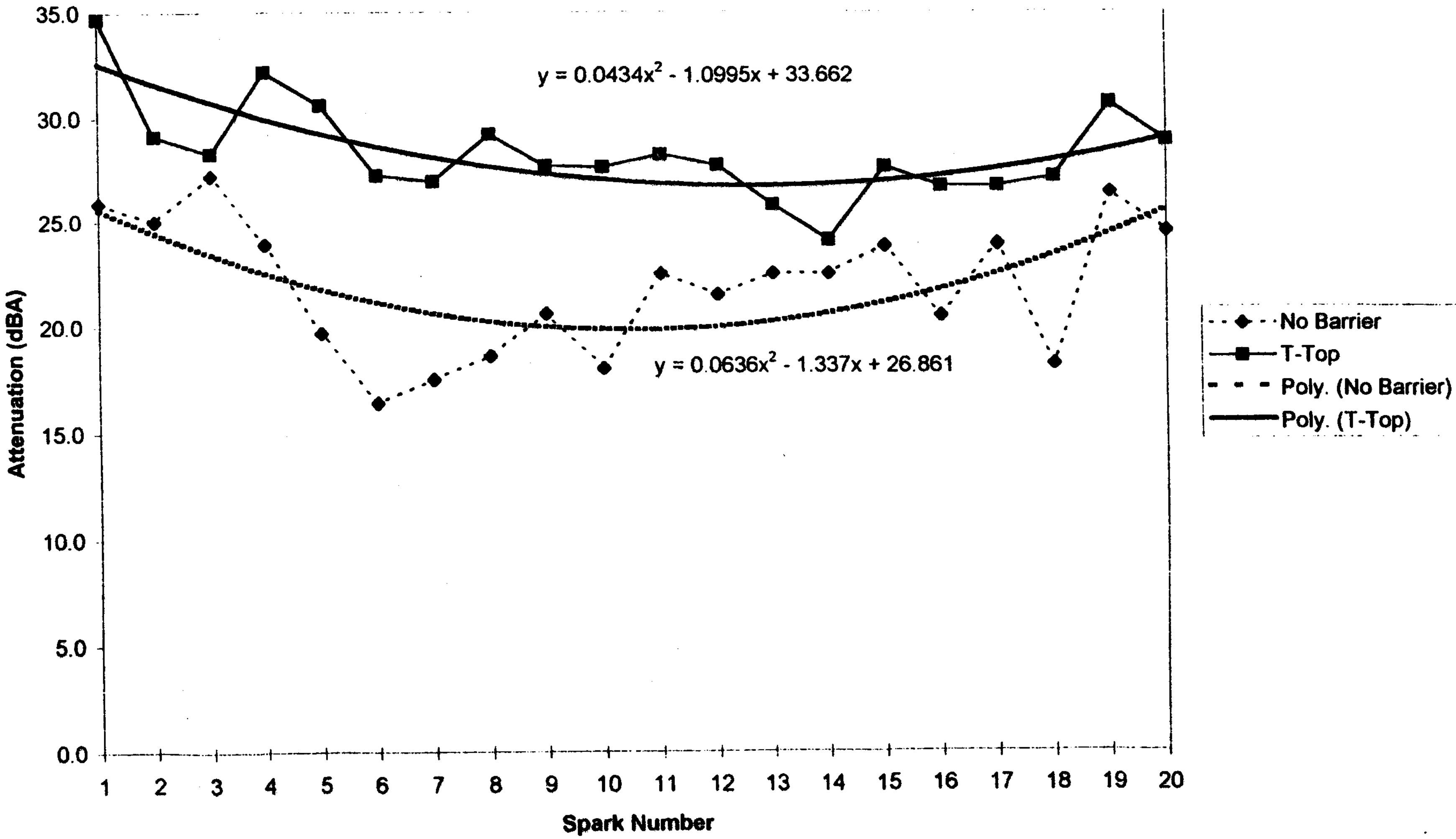
Kent Commons Receiver 3

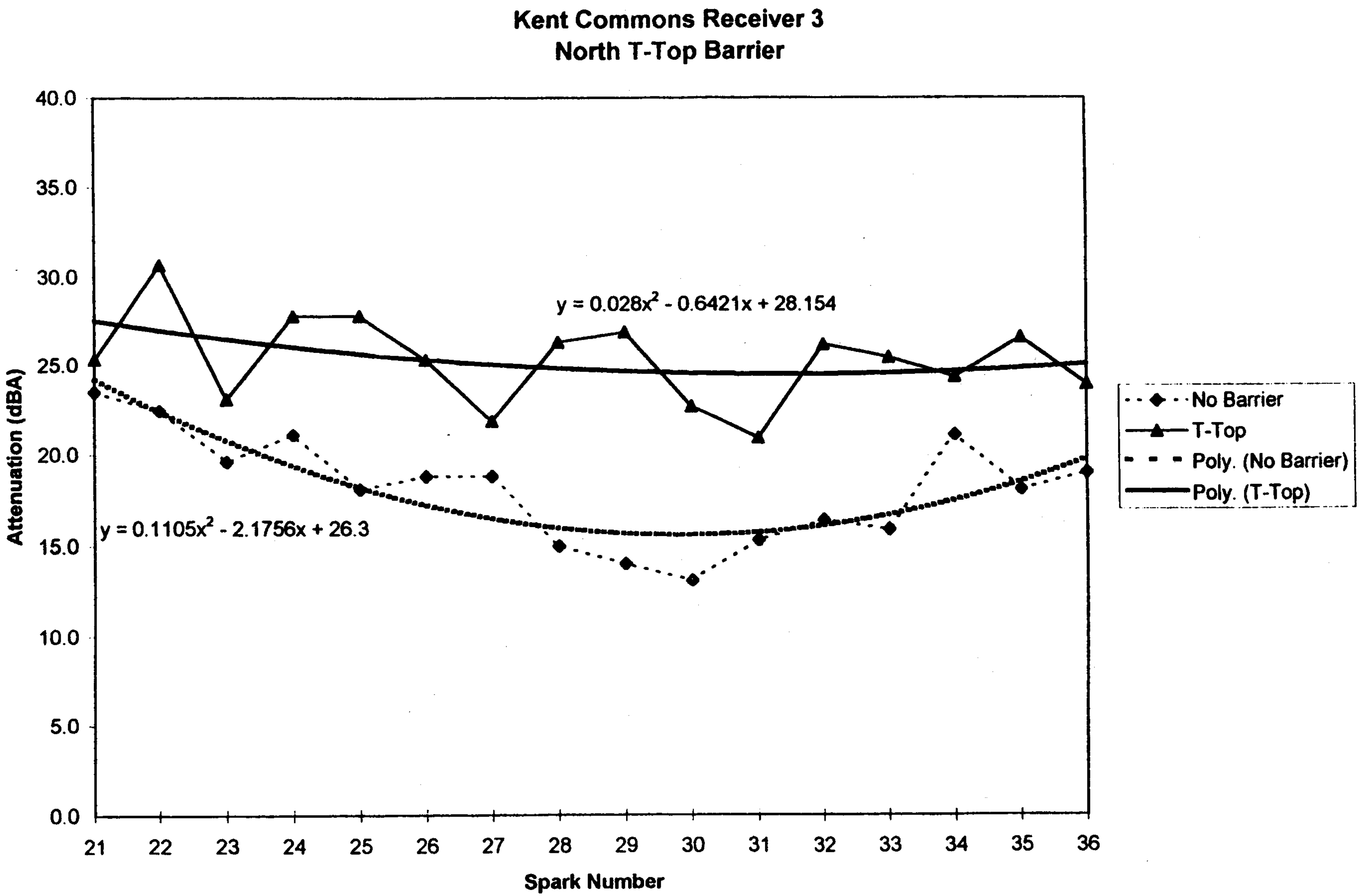
Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	T-Top Barrier Attenuation Actual T-Top	Fitted T-Top	Standard Error	Insertion Scale Model
1	844+75	South	25.9	25.6	0.3	34.7	32.6	2.1	7.0
2	844+00	South	25.0	24.5	0.5	29.1	31.6	-2.5	7.1
3	843+25	South	27.2	23.5	3.7	28.3	30.8	-2.5	7.3
4	842+50	South	23.9	22.6	1.3	32.2	30.0	2.2	7.4
5	841+75	South	19.7	21.8	-2.1	30.6	29.2	1.4	7.4
6	841+00	South	16.4	21.2	-4.8	27.2	28.6	-1.4	7.4
7	840+25	South	17.5	20.7	-3.2	26.9	28.1	-1.1	7.4
8	839+50	South	18.6	20.3	-1.7	29.2	27.6	1.6	7.3
9	838+75	South	20.6	20.0	0.6	27.7	27.3	0.4	7.3
10	838+00	South	18.0	19.9	-1.9	27.6	27.0	0.6	7.1
11	837+25	South	22.5	19.9	2.6	28.2	26.8	1.4	6.9
12	836+50	South	21.5	20.0	1.5	27.7	26.7	1.0	6.7
13	835+75	South	22.5	20.3	2.2	25.8	26.7	-0.9	6.4
14	835+00	South	22.5	20.7	1.8	24.1	26.8	-2.7	6.1
15	834+25	South	23.8	21.2	2.6	27.6	26.9	0.7	5.7
16	833+50	South	20.5	21.8	-1.3	26.7	27.2	-0.5	5.4
17	832+75	South	23.9	22.6	1.3	26.7	27.5	-0.8	4.9
18	832+00	South	18.2	23.5	-5.3	27.1	27.9	-0.8	4.4
19	831+25	South	26.4	24.5	1.9	30.7	28.4	2.2	3.9
20	830+50	South	24.5	25.6	-1.1	28.9	29.0	-0.2	3.4

Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	T-Top Barrier Attenuation Actual T-Top	Fitted T-Top	Standard Error	Insertion Scale Model
21	843+25	North	23.5	24.2	-0.7	25.4	30.2	-6.3	6.0
22	842+50	North	22.5	22.4	0.1	30.7	29.1	-2.5	6.7
23	841+75	North	19.6	20.8	-1.2	23.1	28.0	-3.7	7.2
24	841+00	North	21.1	19.4	1.7	27.8	27.1	-1.6	7.7
25	840+25	North	18.1	18.2	-0.1	27.8	26.3	-0.1	8.1
26	839+50	North	18.8	17.2	1.6	25.3	25.6	-4.7	8.4
27	838+75	North	18.8	16.5	2.3	21.9	25.0	-2.4	8.5
28	838+00	North	15.0	16.0	-1.0	26.3	24.6	2.2	8.6
29	837+25	North	14.0	15.7	-1.7	26.8	24.3	2.0	8.6
30	836+50	North	13.1	15.6	-2.5	22.7	24.1	-2.3	8.5
31	835+75	North	15.3	15.8	-0.5	20.9	24.1	1.2	8.3
32	835+00	North	16.4	16.1	0.3	26.2	24.1	3.7	8.0
33	834+25	North	15.9	16.7	-0.8	25.4	24.3	3.5	7.6
34	833+50	North	21.1	17.5	3.6	24.4	24.6	-1.5	7.1
35	832+75	North	18.1	18.6	-0.5	26.6	25.0	5.7	6.4
36	834+25	North	19.0	19.8	-0.8	23.9	25.6	-0.2	5.8

Insertion Loss = 7.1

Kent Commons Receiver 3
South T-Top Barrier



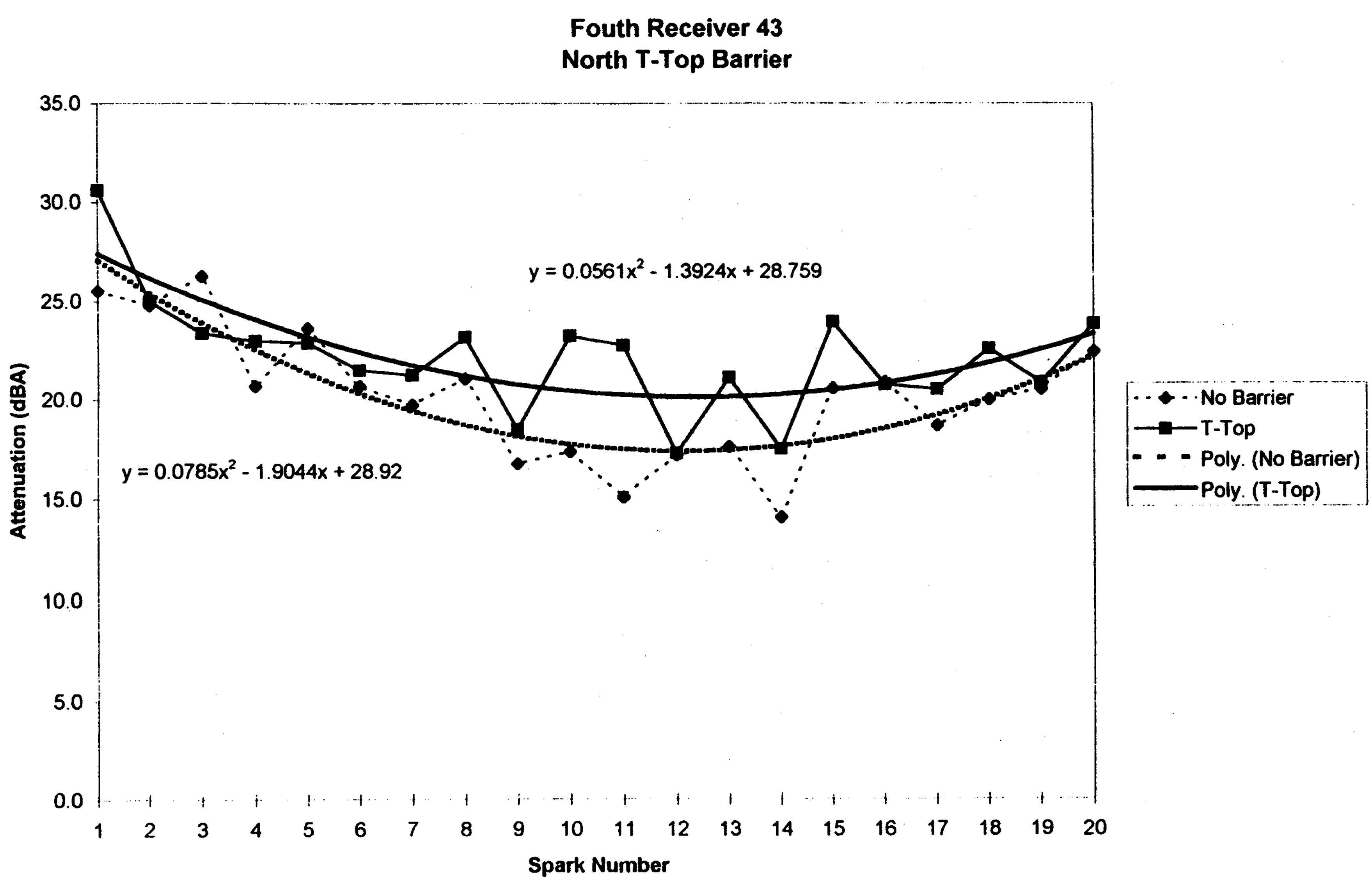

Kent Commons Receiver 3
North T-Top Barrier
Attenuation (dBA)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
Spark Number
y = 0.028x² - 0.6421x + 28.154
y = 0.1105x² - 2.1756x + 26.3
No Barrier
T-Top
Poly. (No Barrier)
Poly. (T-Top)

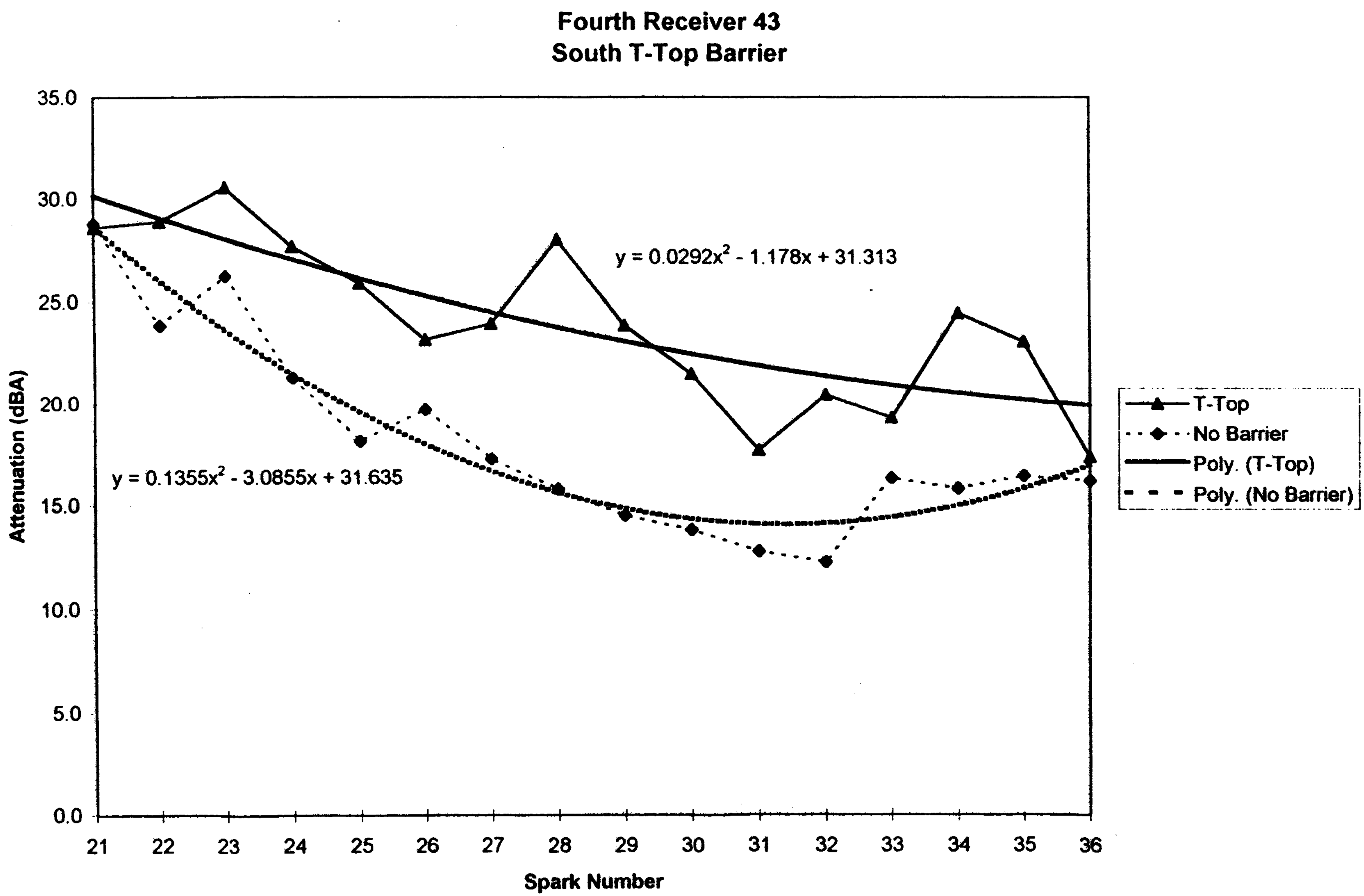
Fouth Ave Receiver 43

Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	T-Top Barrier Attenuation Actual T-Top	Fitted T-Top	Standard Error	Insertion Scale Model
1	1045+50	North	25.5	27.1	-1.5	30.6	27.4	3.2	0.3
2	1046+25	North	24.8	25.4	-0.6	25.0	26.2	-1.2	0.8
3	1047+00	North	26.3	23.9	2.4	23.4	25.1	-1.7	1.2
4	1047+75	North	20.7	22.6	-1.9	23.0	24.1	-1.1	1.5
5	1048+50	North	23.6	21.4	2.3	22.9	23.2	-0.3	1.8
6	1049+25	North	20.7	20.3	0.4	21.5	22.4	-0.9	2.1
7	1050+00	North	19.7	19.4	0.3	21.2	21.8	-0.5	2.3
8	1050+75	North	21.1	18.7	2.4	23.2	21.2	2.0	2.5
9	1051+50	North	16.7	18.1	-1.4	18.5	20.8	-2.3	2.6
10	1052+25	North	17.4	17.7	-0.4	23.2	20.4	2.8	2.7
11	1053+00	North	15.1	17.5	-2.4	22.8	20.2	2.5	2.8
12	1053+75	North	17.2	17.4	-0.2	17.3	20.1	-2.8	2.8
13	1054+50	North	17.6	17.4	0.2	21.1	20.1	1.0	2.7
14	1055+25	North	14.1	17.6	-3.6	17.5	20.3	-2.8	2.6
15	1056+00	North	20.6	18.0	2.6	24.0	20.5	3.5	2.5
16	1056+75	North	20.9	18.5	2.4	20.8	20.8	-0.1	2.3
17	1057+50	North	18.7	19.2	-0.5	20.5	21.3	-0.8	2.1
18	1058+25	North	20.0	20.1	-0.1	22.6	21.9	0.7	1.8
19	1059+00	North	20.6	21.1	-0.5	20.9	22.6	-1.7	1.5
20	1059+75	North	22.4	22.2	0.2	23.9	23.4	0.5	1.1

Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	T-Top Barrier Attenuation Actual T-Top	Fitted T-Top	Standard Error	Insertion Scale Model
21	1045+50	South	28.8	28.7	0.1	28.6	30.2	-1.6	1.5
22	1046+25	South	23.9	26.0	-2.2	28.9	29.1	-0.2	3.1
23	1047+00	South	26.2	23.6	2.6	30.6	28.0	2.5	4.4
24	1047+75	South	21.3	21.5	-0.2	27.7	27.1	0.6	5.6
25	1048+50	South	18.2	19.6	-1.4	25.9	26.2	-0.3	6.6
26	1049+25	South	19.7	18.0	1.7	23.2	25.3	-2.1	7.3
27	1050+00	South	17.3	16.7	0.6	23.9	24.5	-0.6	7.8
28	1050+75	South	15.8	15.6	0.2	28.0	23.8	4.3	8.1
29	1051+50	South	14.5	14.8	-0.3	23.8	23.1	0.8	8.2
30	1052+25	South	13.8	14.3	-0.5	21.5	22.5	-1.0	8.1
31	1053+00	South	12.8	14.1	-1.3	17.7	21.9	-4.2	7.8
32	1053+75	South	12.3	14.1	-1.8	20.5	21.4	-0.9	7.3
33	1054+50	South	16.3	14.4	1.9	19.3	20.9	-1.6	6.5
34	1055+25	South	15.8	15.0	0.8	24.5	20.5	3.9	5.5
35	1056+00	South	16.4	15.8	0.6	23.1	20.2	2.9	4.4
36	1056+75	South	16.2	17.0	-0.7	17.4	19.9	-2.6	3.0

Insertion Loss = 4.5


Fouth Receiver 43
North T-Top Barrier
Attenuation (dBA)
Spark Number
y = 0.0561x² - 1.3924x + 28.759
y = 0.0785x² - 1.9044x + 28.92
No Barrier
T-Top
Poly. (No Barrier)
Poly. (T-Top)

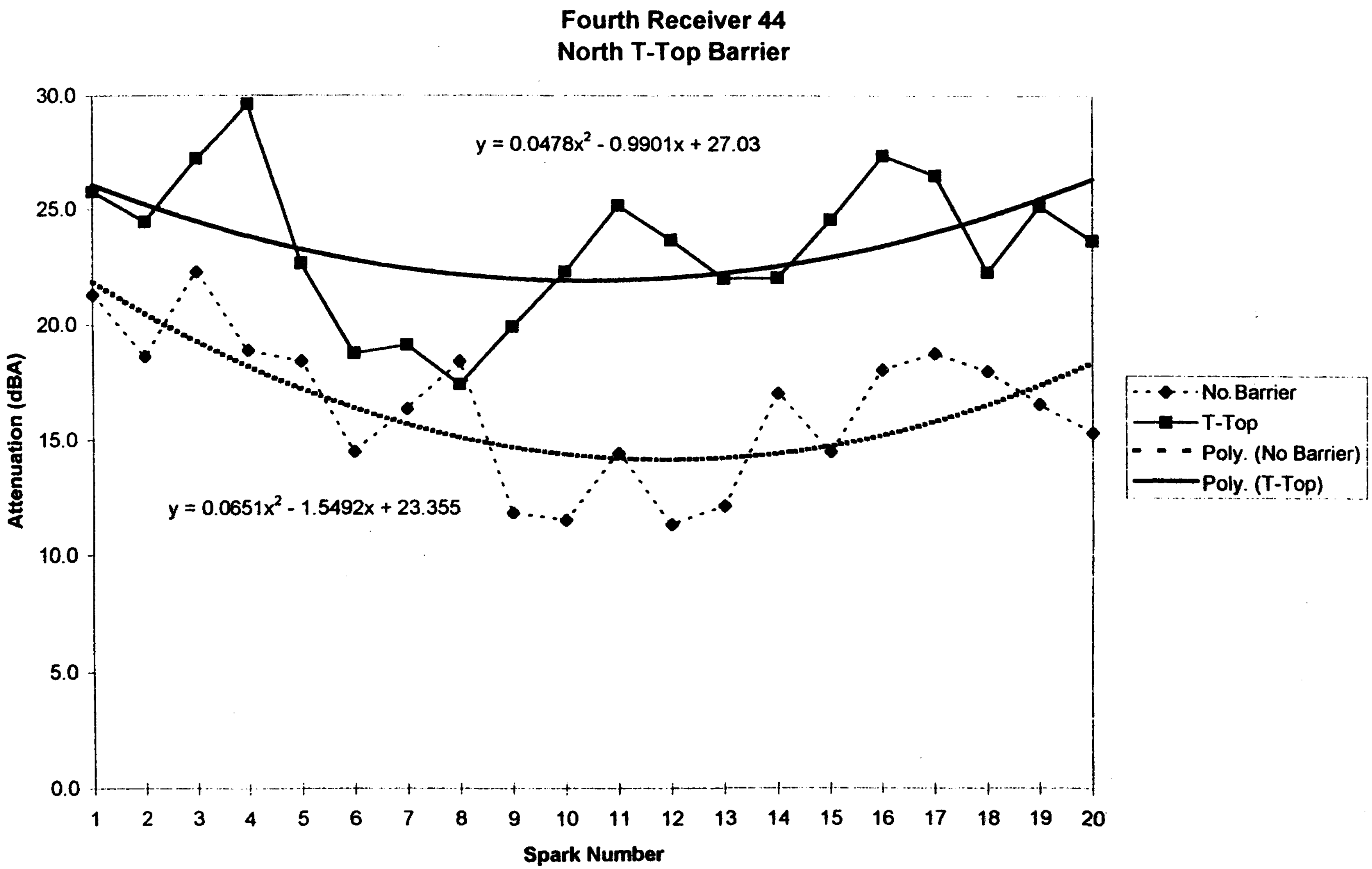

Fourth Receiver 43
South T-Top Barrier
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Attenuation (dBA)
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
Spark Number
y = 0.0292x2 - 1.178x + 31.313
y = 0.1355x2 - 3.0855x + 31.635
T-Top
No Barrier
Poly. (T-Top)
Poly. (No Barrier)

Fourth Ave Receiver 44

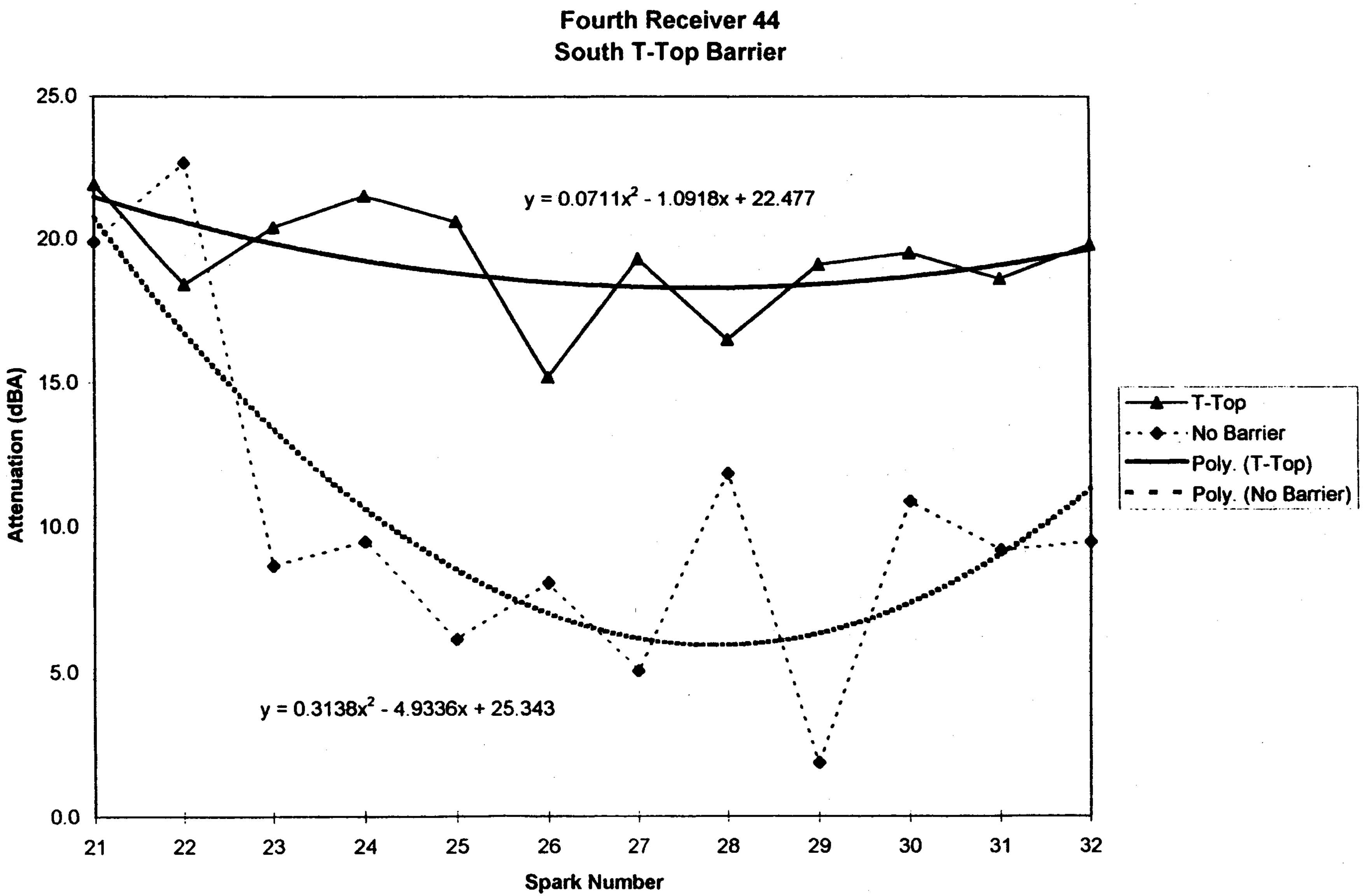
Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	T-Top Barrier Attenuation Actual T-Top	Fitted T-Top	Standard Error	Insertion Scale Model
1	1043+25	North	21.3	21.9	-0.6	25.8	26.1	-0.3	4.2
2	1044+75	North	18.6	20.5	-1.9	24.5	25.2	-0.8	4.7
3	1044+75	North	22.3	19.3	3.0	27.2	24.5	2.8	5.2
4	1045+50	North	18.9	18.2	0.7	29.6	23.8	5.8	5.6
5	1046+25	North	18.4	17.2	1.2	22.7	23.3	-0.6	6.0
6	1047+00	North	14.5	16.4	-1.9	18.8	22.8	-4.0	6.4
7	1047+75	North	16.4	15.7	0.7	19.1	22.4	-3.3	6.7
8	1048+50	North	18.4	15.1	3.3	17.4	22.2	-4.7	7.0
9	1049+25	North	11.8	14.7	-2.8	19.9	22.0	-2.1	7.3
10	1050+00	North	11.5	14.4	-2.9	22.3	21.9	0.4	7.5
11	1050+75	North	14.4	14.2	0.2	25.2	21.9	3.3	7.7
12	1051+50	North	11.3	14.1	-2.8	23.7	22.0	1.6	7.9
13	1052+25	North	12.1	14.2	-2.1	22.0	22.2	-0.2	8.0
14	1053+00	North	17.0	14.4	2.6	22.0	22.5	-0.5	8.1
15	1053+75	North	14.5	14.8	-0.3	24.6	22.9	1.6	8.2
16	1054+50	North	18.1	15.2	2.8	27.4	23.4	4.0	8.2
17	1055+25	North	18.8	15.8	3.0	26.5	24.0	2.5	8.2
18	1056+00	North	18.0	16.6	1.5	22.3	24.7	-2.4	8.1
19	1056+75	North	16.6	17.4	-0.8	25.2	25.5	-0.3	8.1
20	1057+50	North	15.4	18.4	-3.1	23.7	26.3	-2.7	7.9

Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	T-Top Barrier Attenuation Actual T-Top	Fitted T-Top	Standard Error	Insertion Scale Model
21	1045+50	South	19.9	20.7	-0.8	21.9	21.5	0.4	0.7
22	1046+25	South	22.7	16.7	5.9	18.4	20.6	-2.2	3.8
23	1047+00	South	8.7	13.4	-4.7	20.4	19.8	0.6	6.5
24	1047+75	South	9.5	10.6	-1.2	21.5	19.2	2.3	8.6
25	1048+50	South	6.2	8.5	-2.4	20.6	18.8	1.8	10.3
26	1049+25	South	8.1	7.0	1.0	15.2	18.5	-3.3	11.4
27	1050+00	South	5.1	6.2	-1.1	19.3	18.3	1.0	12.1
28	1050+75	South	11.8	6.0	5.9	16.5	18.3	-1.8	12.3
29	1051+50	South	1.9	6.4	-4.5	19.1	18.4	0.7	12.1
30	1052+25	South	10.9	7.4	3.5	19.5	18.7	0.8	11.3
31	1053+00	South	9.2	9.0	0.1	18.6	19.1	-0.5	10.0
32	1053+75	South	9.5	11.3	-1.9	19.8	19.6	0.2	8.3

Insertion Loss = 8.5



Fourth Receiver 44
North T-Top Barrier
y = 0.0478x² - 0.9901x + 27.03
y = 0.0651x² - 1.5492x + 23.355
Attenuation (dBA)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Spark Number
No Barrier
T-Top
Poly. (No Barrier)
Poly. (T-Top)


Fourth Receiver 44
South T-Top Barrier
25.0
20.0
15.0
10.0
5.0
0.0
Attenuation (dBA)
y = 0.0711x² - 1.0918x + 22.477
y = 0.3138x² - 4.9336x + 25.343
21
22
23
24
25
26
27
28
29
30
31
32
Spark Number
T-Top
No Barrier
Poly. (T-Top)
Poly. (No Barrier)

APPENDIX C
SCALE MODEL DATA FILES
SINGLE-WALL ABSORPTIVE BARRIER TESTS

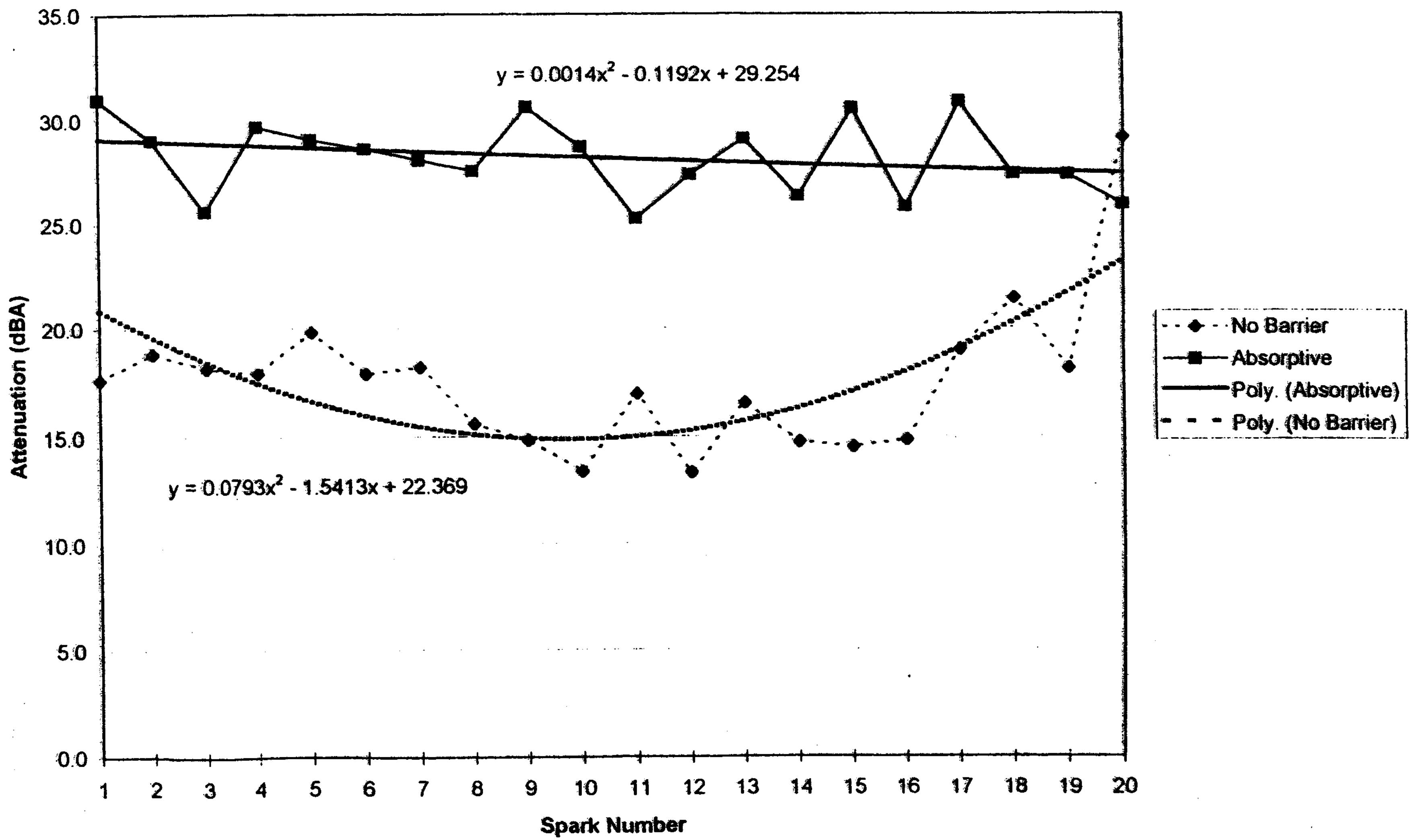
Magnolia Receiver 1

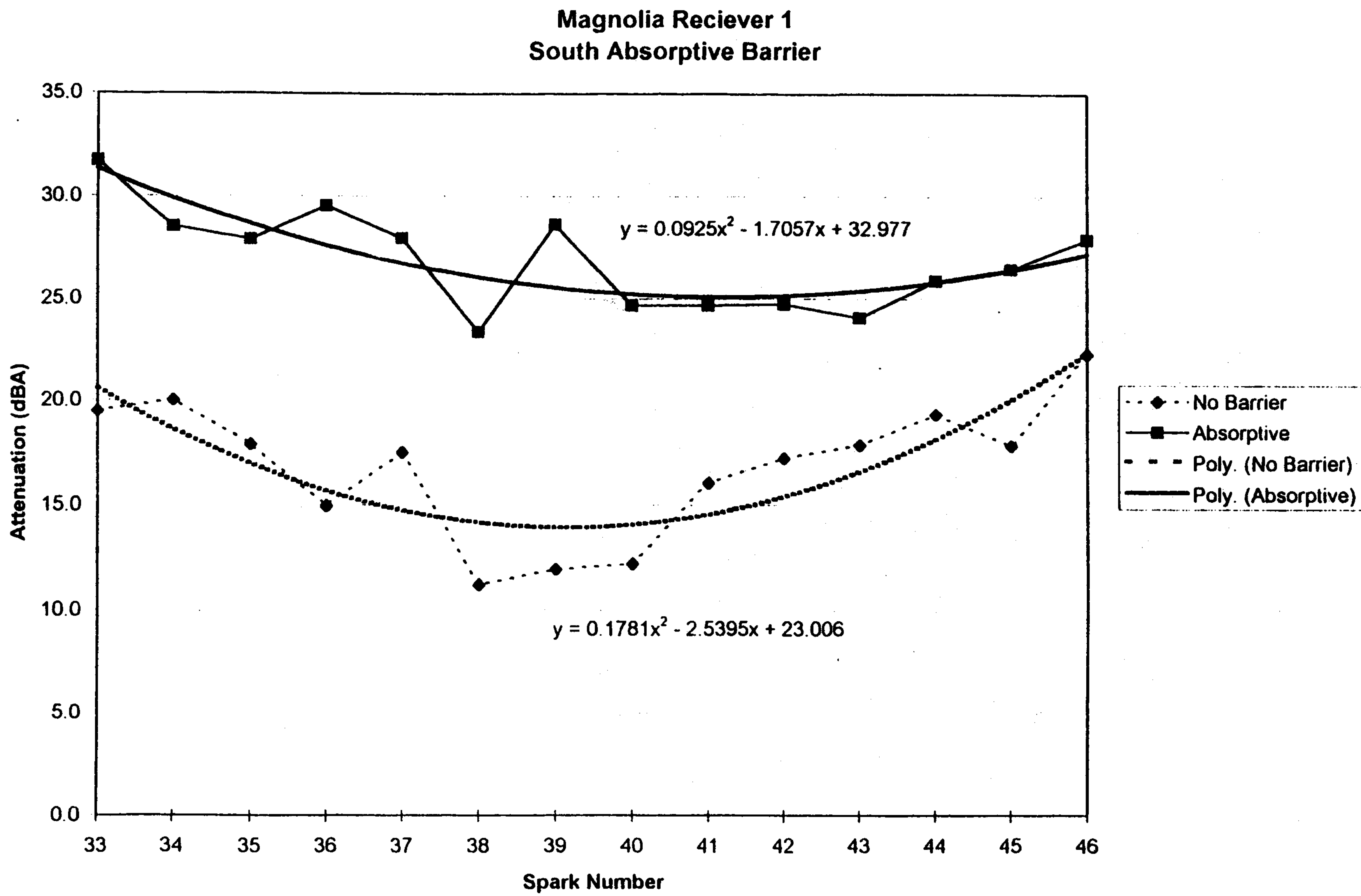
Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	Absorptive Barrier Attenuation Actual Absorptive	Fitted Absorptive	Standard Error	Insertion Scale Model
1	87+25	North	17.7	20.9	-3.3	31.0	29.1	1.9	8.2
2	88+00	North	18.8	19.6	-0.8	29.1	29.0	0.1	9.4
3	88+75	North	18.2	18.5	-0.3	25.6	28.9	-3.3	10.5
4	89+50	North	17.9	17.5	0.5	29.7	28.8	0.9	11.3
5	90+25	North	19.9	16.6	3.2	29.1	28.7	0.4	12.0
6	91+00	North	17.9	16.0	1.9	28.6	28.6	0.0	12.6
7	91+75	North	18.2	15.5	2.8	28.1	28.5	-0.4	13.0
8	92+50	North	15.6	15.1	0.5	27.6	28.4	-0.8	13.3
9	93+25	North	14.9	14.9	-0.1	30.6	28.3	2.3	13.4
10	94+00	North	13.4	14.9	-1.5	28.7	28.2	0.5	13.3
11	94+75	North	17.0	15.0	2.0	25.2	28.1	-2.9	13.1
12	95+50	North	13.3	15.3	-1.9	27.4	28.0	-0.7	12.7
13	96+25	North	16.6	15.7	0.8	29.1	27.9	1.2	12.2
14	97+00	North	14.8	16.3	-1.6	26.3	27.9	-1.5	11.5
15	97+75	North	14.5	17.1	-2.6	30.6	27.8	2.8	10.7
16	98+50	North	14.8	18.0	-3.2	25.8	27.7	-1.9	9.7
17	99+25	North	19.0	19.1	-0.1	30.9	27.6	3.3	8.5
18	100+00	North	21.4	20.3	1.1	27.4	27.6	-0.2	7.2
19	100+75	North	18.2	21.7	-3.6	27.4	27.5	-0.1	5.8
20	101+50	North	29.2	23.3	5.9	25.9	27.4	-1.5	4.2

Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	Absorptive Barrier Attenuation Actual Absorptive	Fitted Absorptive	Standard Error	Insertion Scale Model
33	89+50	South	19.5	20.6	-1.1	31.8	31.4	0.4	10.7
34	90+25	South	20.0	18.6	1.4	28.6	29.9	-1.4	11.3
35	91+00	South	17.9	17.0	0.9	27.9	28.7	-0.8	11.7
36	91+75	South	15.0	15.7	-0.7	29.6	27.6	1.9	11.9
37	92+50	South	17.5	14.8	2.8	28.0	26.8	1.2	12.0
38	93+25	South	11.2	14.2	-2.9	23.4	26.1	-2.7	11.9
39	94+00	South	12.0	14.0	-2.0	28.7	25.6	3.1	11.6
40	94+75	South	12.2	14.1	-1.8	24.7	25.3	-0.6	11.2
41	95+50	South	16.1	14.6	1.5	24.7	25.1	-0.4	10.5
42	96+25	South	17.3	15.4	1.8	24.8	25.2	-0.4	9.7
43	97+00	South	17.9	16.6	1.3	24.1	25.4	-1.3	8.8
44	97+75	South	19.4	18.2	1.2	25.9	25.8	0.1	7.7
45	98+50	South	17.9	20.1	-2.2	26.5	26.4	0.1	6.3
46	99+25	South	22.3	22.4	0.0	27.9	27.2	0.7	4.9

Insertion Loss = 11.0

Magnolia Receiver 1
North Absorptive Barrier





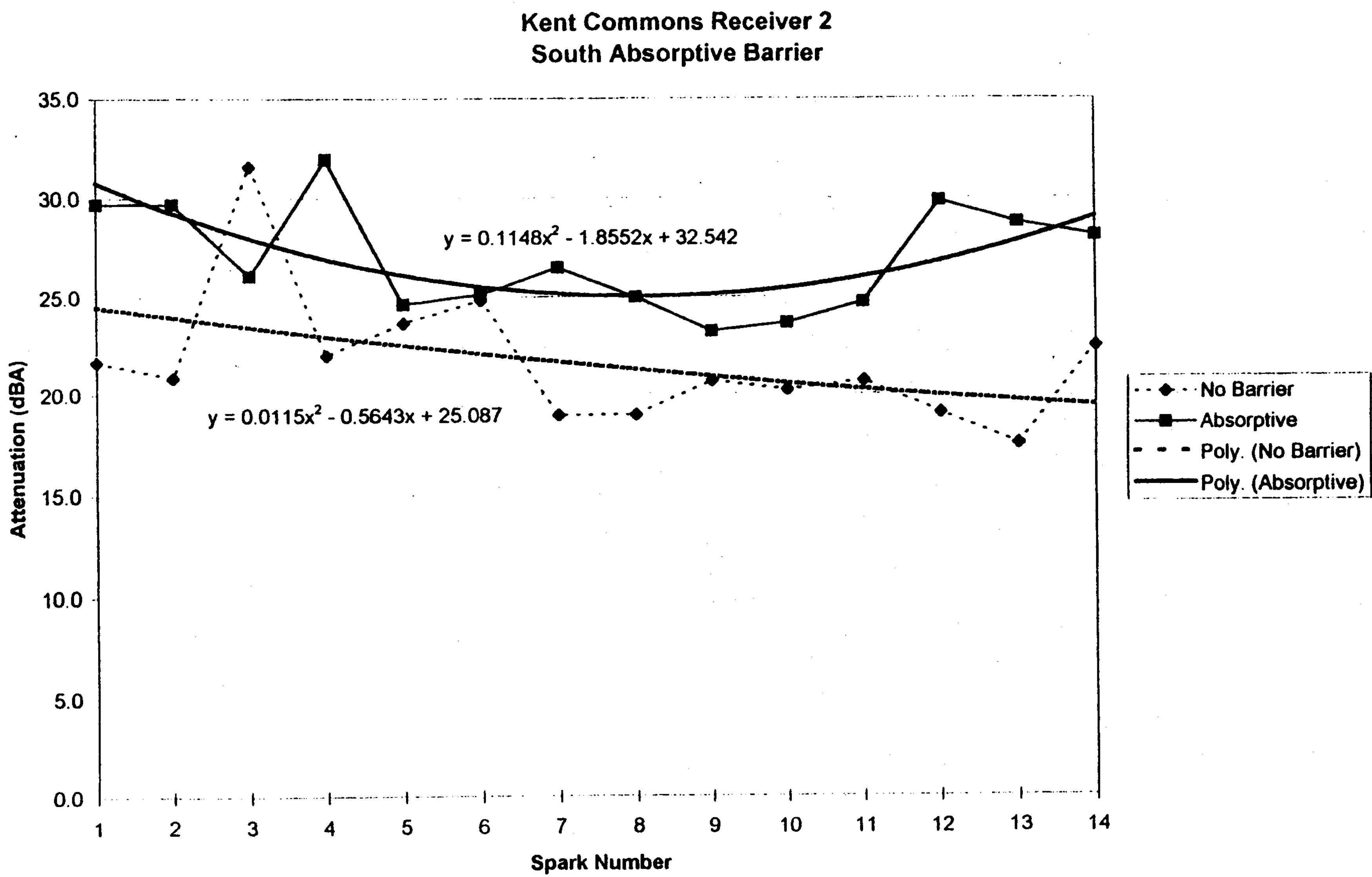
Magnolia Reciever 1
South Absorptive Barrier
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Attenuation (dBA)
y = 0.0925x2 - 1.7057x + 32.977
y = 0.1781x2 - 2.5395x + 23.006
33
34
35
36
37
38
39
40
41
42
43
44
45
46
Spark Number
No Barrier
Absorptive
Poly. (No Barrier)
Poly. (Absorptive)

Kent Commons Receiver 2

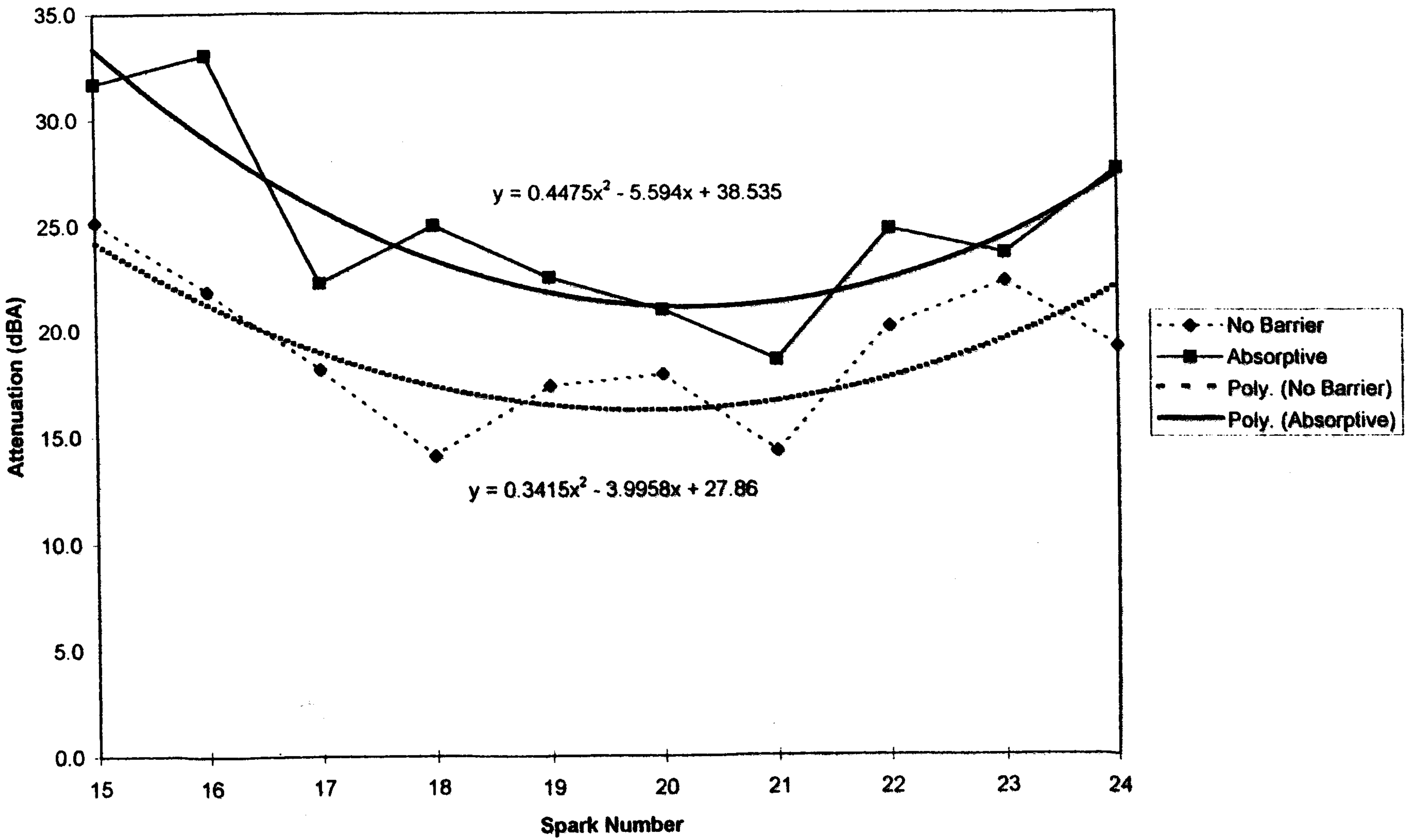
Spark Number	Station		No Barrier Attenuation: Actual No Barrier	Fitted No Barrier	Standard Error	Absorptive Barrier Attenuation: Actual Absorptive	Fitted Absorptive	Standard Error	Insertion Scale Model
1	842+50	South	21.7	24.5	-2.8	29.7	32.9	-3.2	8.4
2	841+75	South	20.9	24.0	-3.1	29.7	30.8	-1.1	6.8
3	841+00	South	31.6	23.5	8.1	26.1	29.0	-2.9	5.5
4	840+25	South	22.1	23.0	-1.0	32.0	27.5	4.5	4.5
5	839+50	South	23.7	22.6	1.2	24.7	26.4	-1.7	3.8
6	838+75	South	24.9	22.1	2.7	25.2	25.5	-0.3	3.4
7	838+00	South	19.0	21.7	-2.7	26.5	24.9	1.6	3.2
8	837+25	South	19.0	21.3	-2.3	25.0	24.7	0.3	3.4
9	836+50	South	20.7	20.9	-0.2	23.3	24.7	-1.5	3.8
10	835+75	South	20.2	20.6	-0.3	23.7	25.1	-1.4	4.5
11	835+00	South	20.7	20.3	0.5	24.7	25.8	-1.0	5.5
12	834+25	South	19.1	20.0	-0.9	29.9	26.7	3.1	6.8
13	833+50	South	17.5	19.7	-2.2	28.8	28.0	0.8	8.3
14	832+75	South	22.5	19.4	3.0	28.1	29.6	-1.5	10.1

Spark Number	Station		No Barrier Attenuation: Actual No Barrier	Fitted No Barrier	Standard Error	Absorptive Barrier Attenuation: Actual Absorptive	Fitted Absorptive	Standard Error	Insertion Scale Model
15	841+00	North	25.2	24.2	1.0	31.7	33.4	-1.7	9.2
16	840+25	North	21.8	21.2	0.6	33.0	29.1	3.9	7.9
17	839+50	North	18.1	18.9	-0.8	22.2	25.8	-3.5	6.9
18	838+75	North	14.1	17.3	-3.3	25.0	23.3	1.7	6.0
19	838+00	North	17.3	16.4	0.9	22.5	21.8	0.7	5.4
20	837+25	North	17.9	16.1	1.7	20.9	21.1	-0.1	4.9
21	836+50	North	14.3	16.6	-2.3	18.6	21.3	-2.7	4.7
22	835+75	North	20.2	17.7	2.5	24.8	22.4	2.4	4.7
23	835+00	North	22.3	19.5	2.8	23.6	24.4	-0.8	4.9
24	834+25	North	19.2	22.0	-2.8	27.6	27.3	0.3	5.3

Insertion Loss = 6.2


Kent Commons Receiver 2
South Absorptive Barrier
y = 0.1148x² - 1.8552x + 32.542
y = 0.0115x² - 0.5643x + 25.087
Attenuation (dBA)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Spark Number
No Barrier
Absorptive
Poly. (No Barrier)
Poly. (Absorptive)

Kent Commons Receiver 2
North Absorptive Barrier

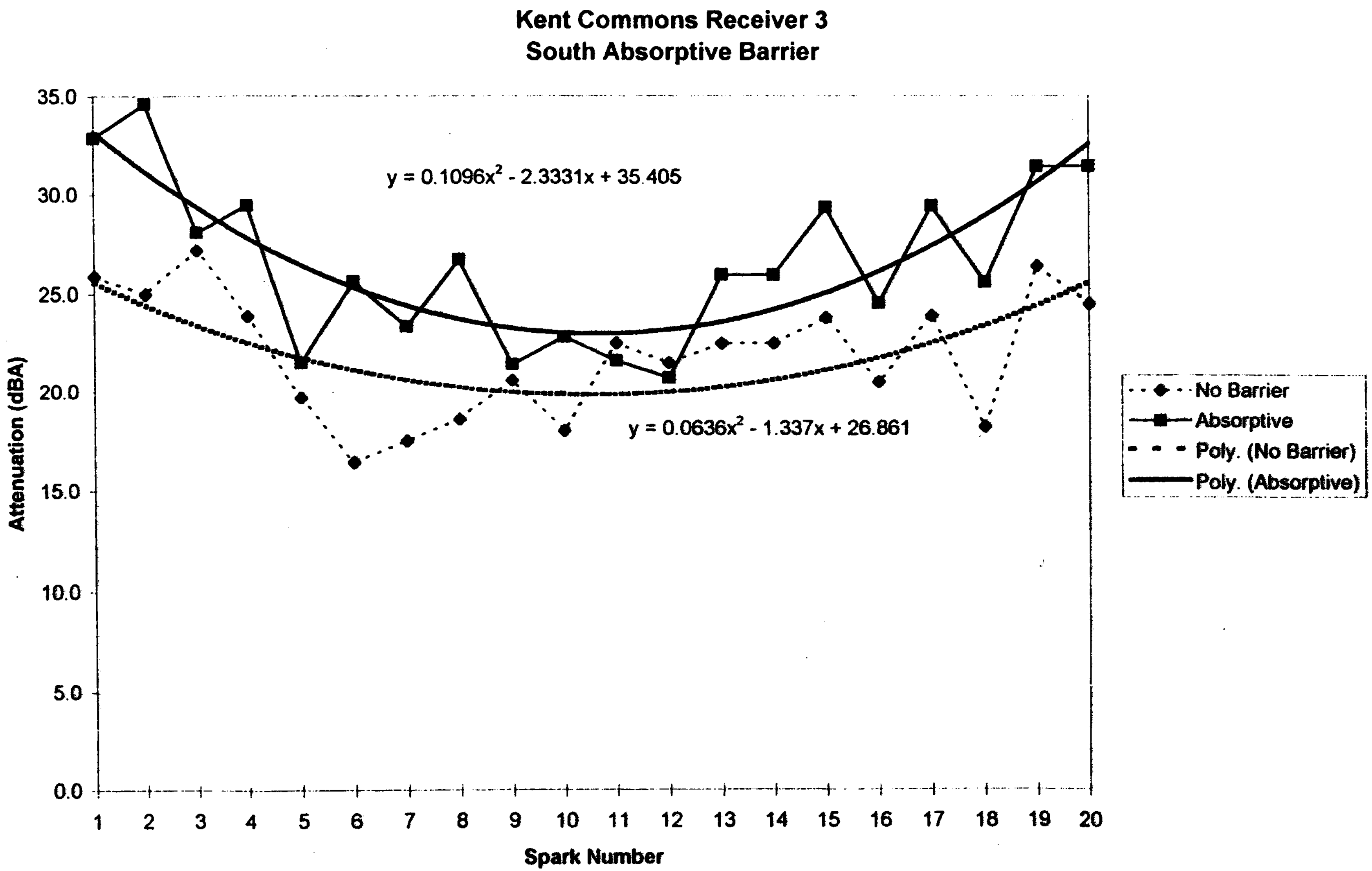


Kent Commons Receiver 3

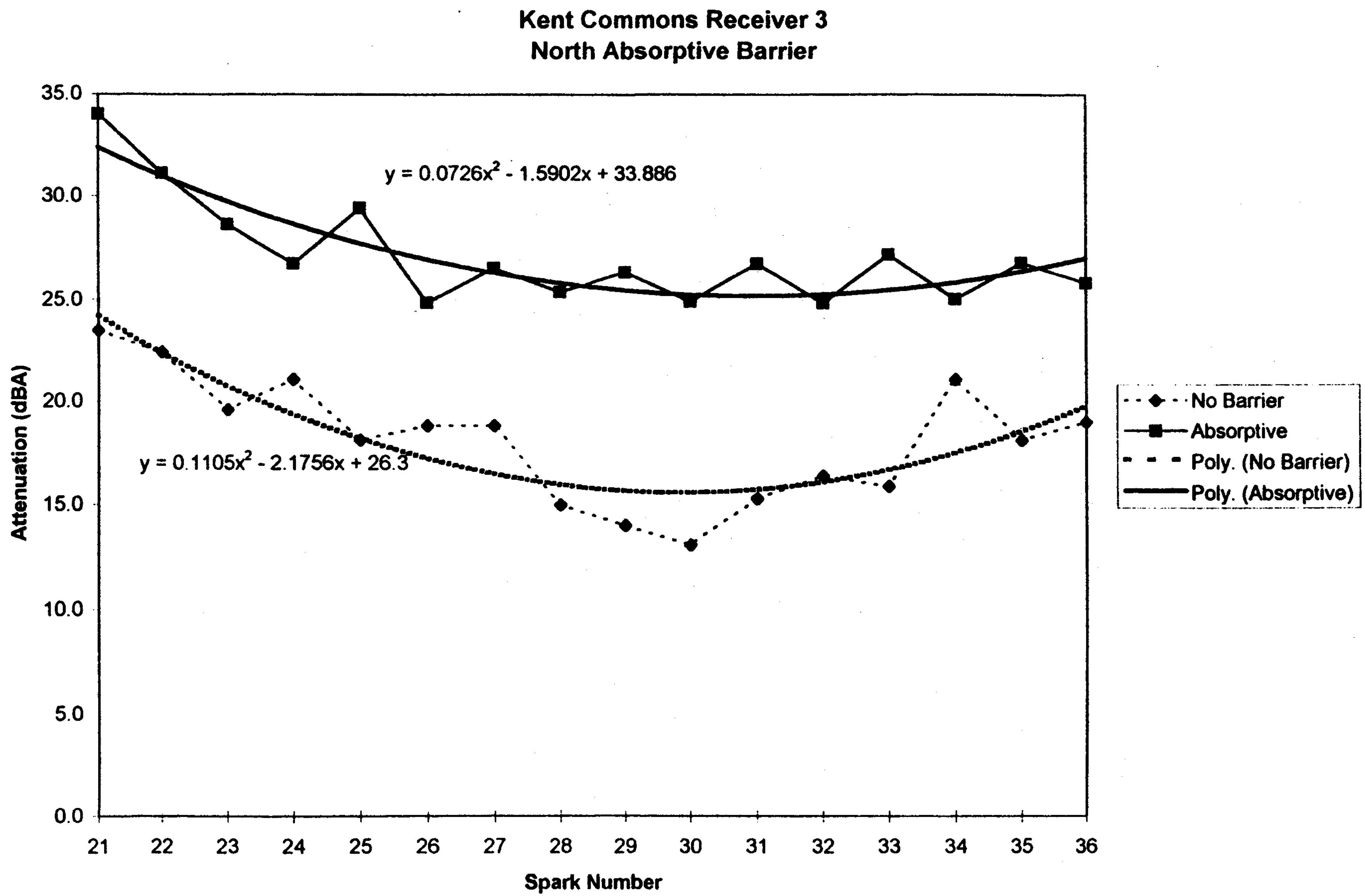
Spark Number	Station		No Barrier Attenuation			Absorptive Barrier Attenuation			Insertion Scale Model
			Actual No Barrier	Fitted No Barrier	Standard Error	Actual Absorptive	Fitted Absorptive	Standard Error	
1	844+75	South	25.9	25.6	0.3	32.9	32.6	0.3	7.0
2	844+00	South	25.0	24.5	0.5	34.6	30.6	4.0	6.1
3	843+25	South	27.2	23.5	3.7	28.1	28.9	-0.8	5.4
4	842+50	South	23.9	22.6	1.3	29.5	27.4	2.1	4.8
5	841+75	South	19.7	21.8	-2.1	21.5	26.1	-4.6	4.3
6	841+00	South	16.4	21.2	-4.8	25.6	25.1	0.6	3.9
7	840+25	South	17.5	20.7	-3.2	23.4	24.2	-0.8	3.5
8	839+50	South	18.6	20.3	-1.7	26.7	23.6	3.1	3.3
9	838+75	South	20.6	20.0	0.6	21.4	23.2	-1.7	3.2
10	838+00	South	18.0	19.9	-1.9	22.8	23.0	-0.2	3.1
11	837+25	South	22.5	19.9	2.6	21.6	23.0	-1.4	3.1
12	836+50	South	21.5	20.0	1.5	20.7	23.3	-2.6	3.3
13	835+75	South	22.5	20.3	2.2	26.0	23.8	2.2	3.5
14	835+00	South	22.5	20.7	1.8	25.9	24.4	1.5	3.7
15	834+25	South	23.8	21.2	2.6	29.3	25.4	4.0	4.2
16	833+50	South	20.5	21.8	-1.3	24.5	26.5	-1.9	4.7
17	832+75	South	23.9	22.6	1.3	29.4	27.8	1.6	5.2
18	832+00	South	18.2	23.5	-5.3	25.6	29.4	-3.8	5.9
19	831+25	South	26.4	24.5	1.9	31.4	31.2	0.2	6.7
20	830+50	South	24.5	25.6	-1.1	31.4	33.2	-1.8	7.6

Spark Number	Station		No Barrier Attenuation			Absorptive Barrier Attenuation			Insertion Scale Model
			Actual No Barrier	Fitted No Barrier	Standard Error	Actual Absorptive	Fitted Absorptive	Standard Error	
21	843+25	North	23.5	24.2	-0.7	34.0	32.4	1.7	8.2
22	842+50	North	22.5	22.4	0.1	31.1	31.0	0.1	8.6
23	841+75	North	19.6	20.8	-1.2	28.7	29.8	-1.1	9.0
24	841+00	North	21.1	19.4	1.7	26.8	28.7	-1.9	9.3
25	840+25	North	18.1	18.2	-0.1	29.4	27.8	1.7	9.6
26	839+50	North	18.8	17.2	1.6	24.9	27.0	-2.1	9.8
27	838+75	North	18.8	16.5	2.3	26.5	26.3	0.2	9.8
28	838+00	North	15.0	16.0	-1.0	25.4	25.8	-0.4	9.8
29	837+25	North	14.0	15.7	-1.7	26.3	25.5	0.9	9.8
30	836+50	North	13.1	15.6	-2.5	24.9	25.2	-0.3	9.6
31	835+75	North	15.3	15.8	-0.5	26.8	25.2	1.6	9.4
32	835+00	North	16.4	16.1	0.3	24.8	25.3	-0.4	9.2
33	834+25	North	15.9	16.7	-0.8	27.2	25.5	1.7	8.8
34	833+50	North	21.1	17.5	3.6	25.0	25.9	-0.8	8.4
35	832+75	North	18.1	18.6	-0.5	26.8	26.4	0.4	7.8
36	834+25	North	19.0	19.8	-0.8	25.8	27.0	-1.2	7.2

Insertion Loss = 8.8



Kent Commons Receiver 3
South Absorptive Barrier
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Attenuation (dBA)
y = 0.1096x² - 2.3331x + 35.405
y = 0.0636x² - 1.337x + 26.861
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Spark Number
No Barrier
Absorptive
Poly. (No Barrier)
Poly. (Absorptive)

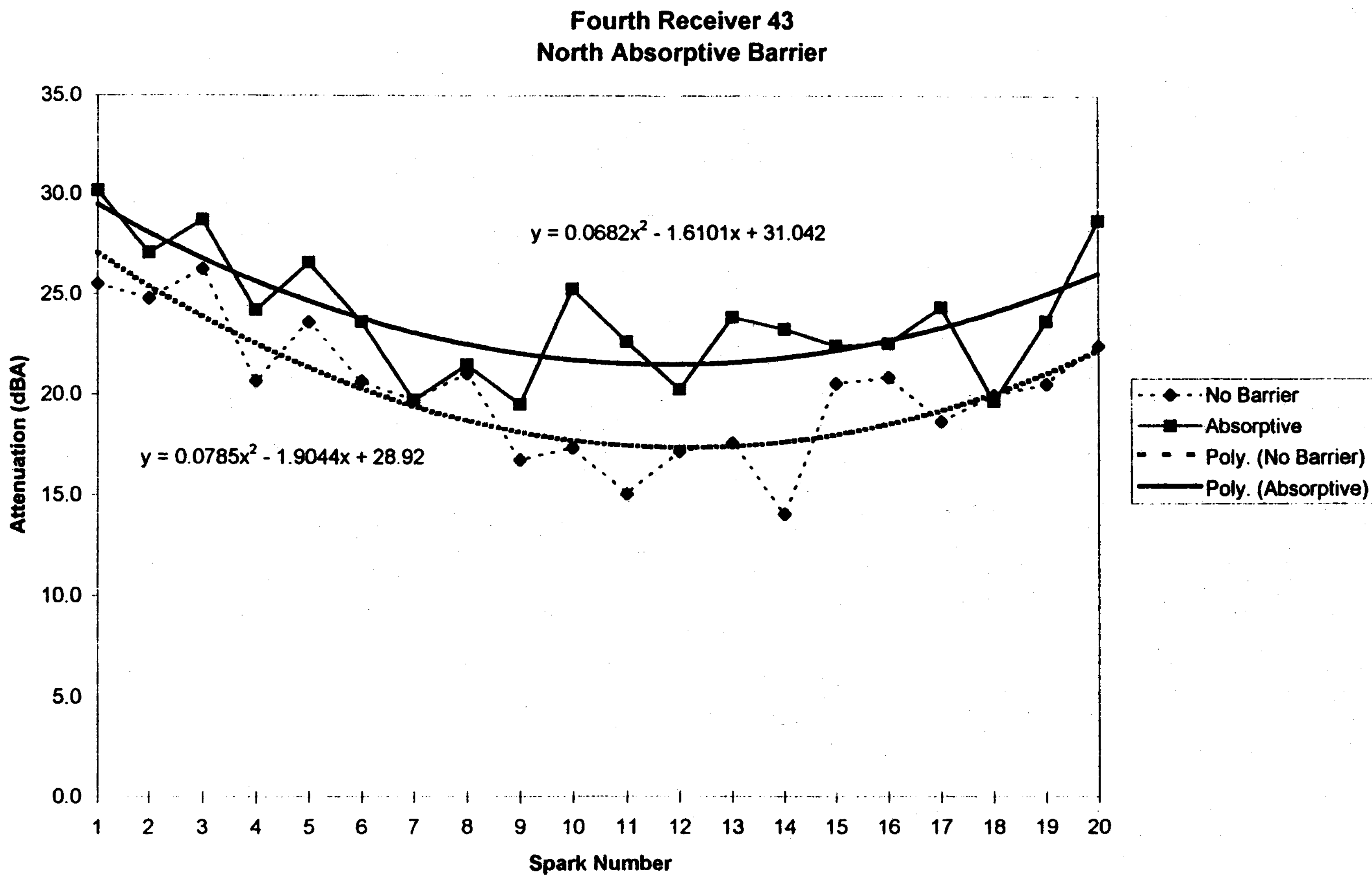

Kent Commons Receiver 3
North Absorptive Barrier
y = 0.0726x² - 1.5902x + 33.886
y = 0.1105x² - 2.1756x + 26.3
Attenuation (dBA)
Spark Number
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
No Barrier
Absorptive
Poly. (No Barrier)
Poly. (Absorptive)

Fourth Ave Receiver 43

Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	Absorptive Barrier Attenuation Actual Absorptive	Fitted Absorptive	Standard Error	Insertion Scale Model
1	1045+50	North	25.5	27.1	-1.5	30.2	29.5	0.7	2.4
2	1046+25	North	24.8	25.4	-0.6	27.1	28.1	-1.0	2.7
3	1047+00	North	26.3	23.9	2.4	28.7	26.8	1.9	2.9
4	1047+75	North	20.7	22.6	-1.9	24.2	25.7	-1.5	3.1
5	1048+50	North	23.6	21.4	2.3	26.6	24.7	1.9	3.3
6	1049+25	North	20.7	20.3	0.4	23.7	23.8	-0.2	3.5
7	1050+00	North	19.7	19.4	0.3	19.7	23.1	-3.4	3.7
8	1050+75	North	21.1	18.7	2.4	21.5	22.5	-1.0	3.8
9	1051+50	North	16.7	18.1	-1.4	19.5	22.1	-2.5	3.9
10	1052+25	North	17.4	17.7	-0.4	25.3	21.8	3.6	4.0
11	1053+00	North	15.1	17.5	-2.4	22.7	21.6	1.1	4.1
12	1053+75	North	17.2	17.4	-0.2	20.3	21.5	-1.2	4.2
13	1054+50	North	17.6	17.4	0.2	23.9	21.6	2.2	4.2
14	1055+25	North	14.1	17.6	-3.6	23.3	21.9	1.4	4.2
15	1056+00	North	20.6	18.0	2.6	22.5	22.2	0.2	4.2
16	1056+75	North	20.9	18.5	2.4	22.6	22.7	-0.2	4.2
17	1057+50	North	18.7	19.2	-0.5	24.4	23.4	1.0	4.1
18	1058+25	North	20.0	20.1	-0.1	19.7	24.2	-4.4	4.1
19	1059+00	North	20.6	21.1	-0.5	23.7	25.1	-1.4	4.0
20	1059+75	North	22.4	22.2	0.2	28.7	26.1	2.6	3.9

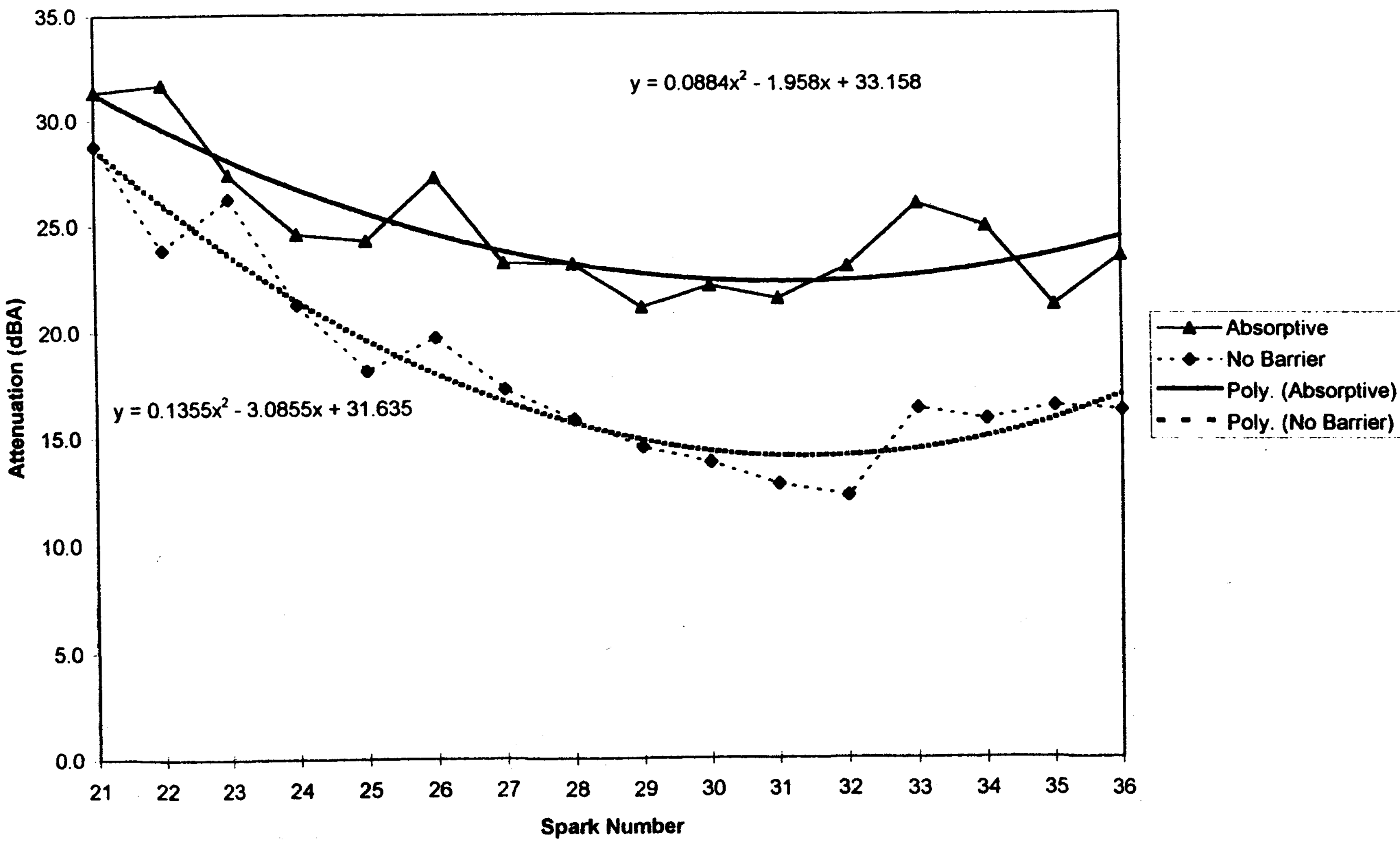
Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	Absorptive Barrier Attenuation Actual Absorptive	Fitted Absorptive	Standard Error	Insertion Scale Model
21	1045+50	South	28.8	28.7	0.1	31.3	31.3	0.1	2.6
22	1046+25	South	23.9	26.0	-2.2	31.7	29.6	2.1	3.6
23	1047+00	South	26.2	23.6	2.6	27.4	28.1	-0.7	4.5
24	1047+75	South	21.3	21.5	-0.2	24.6	26.7	-2.1	5.3
25	1048+50	South	18.2	19.6	-1.4	24.3	25.6	-1.3	6.0
26	1049+25	South	19.7	18.0	1.7	27.3	24.6	2.7	6.6
27	1050+00	South	17.3	16.7	0.6	23.2	23.8	-0.6	7.1
28	1050+75	South	15.8	15.6	0.2	23.1	23.2	0.0	7.5
29	1051+50	South	14.5	14.8	-0.3	21.1	22.7	-1.6	7.9
30	1052+25	South	13.8	14.3	-0.5	22.1	22.4	-0.3	8.1
31	1053+00	South	12.8	14.1	-1.3	21.5	22.3	-0.8	8.2
32	1053+75	South	12.3	14.1	-1.8	23.0	22.4	0.6	8.3
33	1054+50	South	16.3	14.4	1.9	26.0	22.6	3.4	8.2
34	1055+25	South	15.8	15.0	0.8	25.0	23.1	1.9	8.1
35	1056+00	South	16.4	15.8	0.6	21.3	23.7	-2.4	7.8
36	1056+75	South	16.2	17.0	-0.7	23.5	24.5	-0.9	7.5

Insertion Loss = 5.5



Fourth Receiver 43
North Absorptive Barrier
y = 0.0682x2 - 1.6101x + 31.042
y = 0.0785x2 - 1.9044x + 28.92
Attenuation (dBA)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Spark Number
No Barrier
Absorptive
Poly. (No Barrier)
Poly. (Absorptive)

Fourth Receiver 43
South Absorptive Barrier

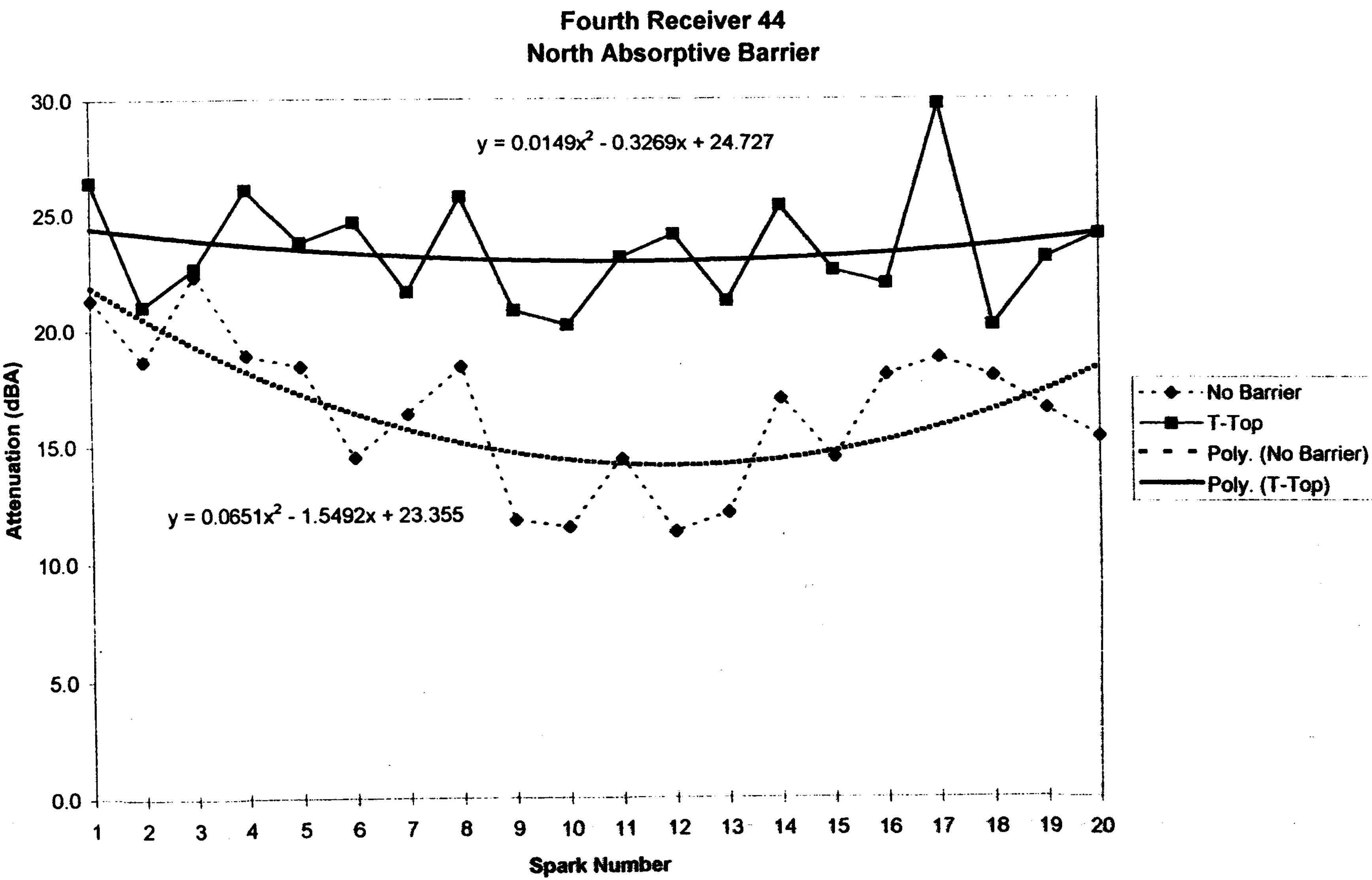


Fourth Ave Receiver 44

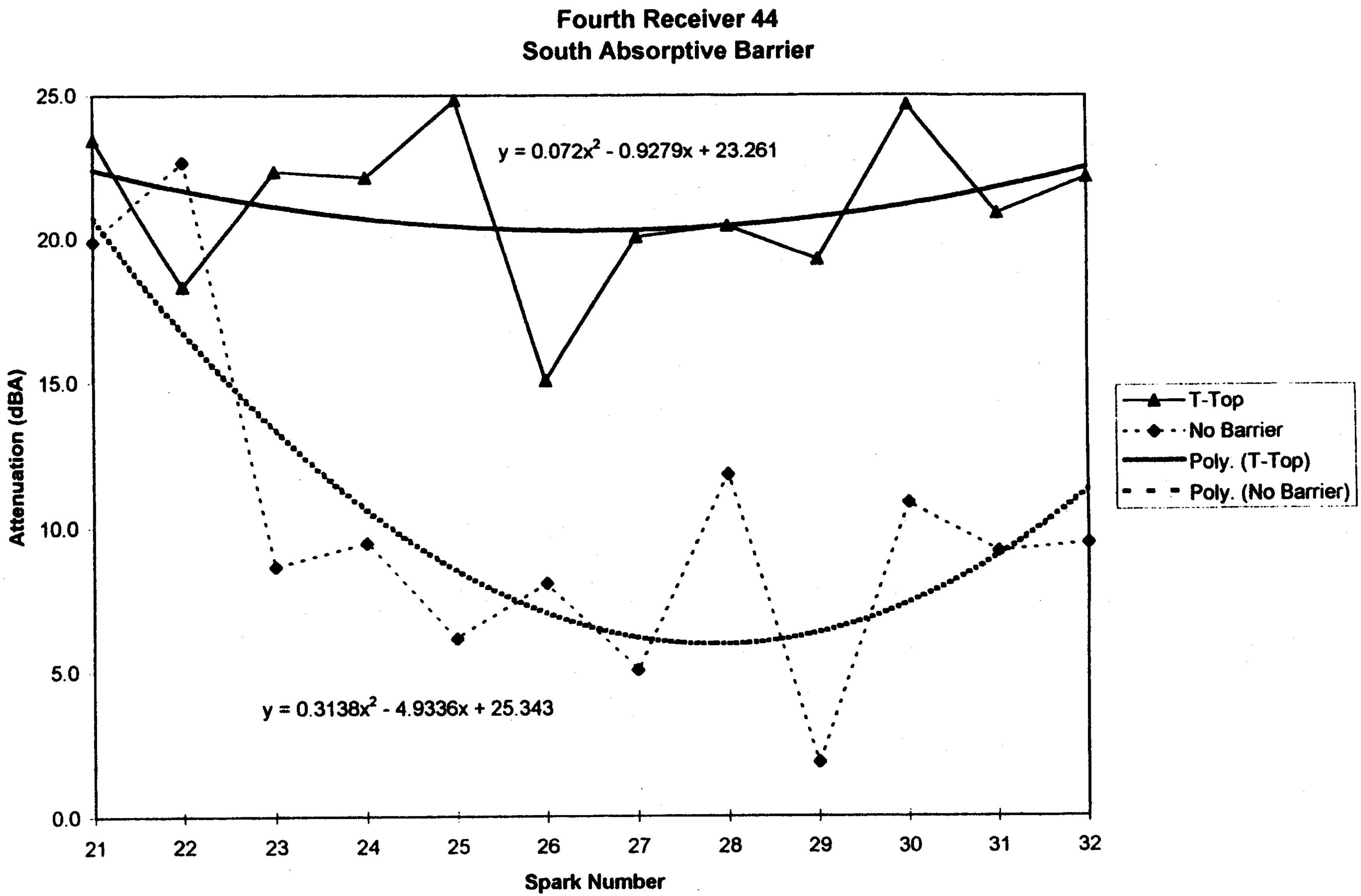
Spark Number	Station		No Barrier Attenuation: Actual No Barrier	Fitted No Barrier	Standard Error	Absorptive Barrier Attenuation: Actual Absorptive	Fitted Absorptive	Standard Error	Insertion Scale Model
1	1043+25	North	21.3	21.9	-0.6	26.4	24.4	2.0	2.5
2	1044+75	North	18.6	20.5	-1.9	21.0	24.1	-3.1	3.6
3	1044+75	North	22.3	19.3	3.0	22.7	23.9	-1.2	4.6
4	1045+50	North	18.9	18.2	0.7	26.1	23.7	2.4	5.5
5	1046+25	North	18.4	17.2	1.2	23.8	23.5	0.3	6.2
6	1047+00	North	14.5	16.4	-1.9	24.7	23.3	1.4	6.9
7	1047+75	North	16.4	15.7	0.7	21.6	23.2	-1.5	7.5
8	1048+50	North	18.4	15.1	3.3	25.8	23.1	2.7	7.9
9	1049+25	North	11.8	14.7	-2.8	20.8	23.0	-2.2	8.3
10	1050+00	North	11.5	14.4	-2.9	20.2	22.9	-2.8	8.6
11	1050+75	North	14.4	14.2	0.2	23.1	22.9	0.2	8.7
12	1051+50	North	11.3	14.1	-2.8	24.1	22.9	1.2	8.8
13	1052+25	North	12.1	14.2	-2.1	21.2	23.0	-1.8	8.8
14	1053+00	North	17.0	14.4	2.6	25.4	23.1	2.3	8.6
15	1053+75	North	14.5	14.8	-0.3	22.5	23.2	-0.6	8.4
16	1054+50	North	18.1	15.2	2.8	22.0	23.3	-1.3	8.1
17	1055+25	North	18.8	15.8	3.0	29.8	23.5	6.3	7.6
18	1056+00	North	18.0	16.6	1.5	20.2	23.7	-3.5	7.1
19	1056+75	North	16.6	17.4	-0.8	23.1	23.9	-0.8	6.5
20	1057+50	North	15.4	18.4	-3.1	24.1	24.1	0.0	5.7

Spark Number	Station		No Barrier Attenuation: Actual No Barrier	Fitted No Barrier	Standard Error	Absorptive Barrier Attenuation: Actual Absorptive	Fitted Absorptive	Standard Error	Insertion Scale Model
21	1045+50	South	19.9	20.7	-0.8	23.4	22.4	1.0	1.7
22	1046+25	South	22.7	16.7	5.9	18.3	21.7	-3.4	5.0
23	1047+00	South	8.7	13.4	-4.7	22.3	21.1	1.2	7.8
24	1047+75	South	9.5	10.6	-1.2	22.1	20.7	1.4	10.1
25	1048+50	South	6.2	8.5	-2.4	24.8	20.4	4.4	11.9
26	1049+25	South	8.1	7.0	1.0	15.1	20.3	-5.2	13.2
27	1050+00	South	5.1	6.2	-1.1	20.1	20.3	-0.2	14.1
28	1050+75	South	11.8	6.0	5.9	20.4	20.4	0.0	14.5
29	1051+50	South	1.9	6.4	-4.5	19.3	20.7	-1.5	14.4
30	1052+25	South	10.9	7.4	3.5	24.7	21.2	3.5	13.8
31	1053+00	South	9.2	9.0	0.1	20.9	21.8	-0.9	12.7
32	1053+75	South	9.5	11.3	-1.9	22.1	22.5	-0.4	11.2

Insertion Loss = 9.8



Fourth Receiver 44
North Absorptive Barrier
y = 0.0149x² - 0.3269x + 24.727
y = 0.0651x² - 1.5492x + 23.355
Attenuation (dBA)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Spark Number
No Barrier
T-Top
Poly. (No Barrier)
Poly. (T-Top)



Fourth Receiver 44
South Absorptive Barrier
y = 0.072x² - 0.9279x + 23.261
y = 0.3138x² - 4.9336x + 25.343
Attenuation (dBA)
25.0
20.0
15.0
10.0
5.0
0.0
21
22
23
24
25
26
27
28
29
30
31
32
Spark Number
T-Top
No Barrier
Poly. (T-Top)
Poly. (No Barrier)

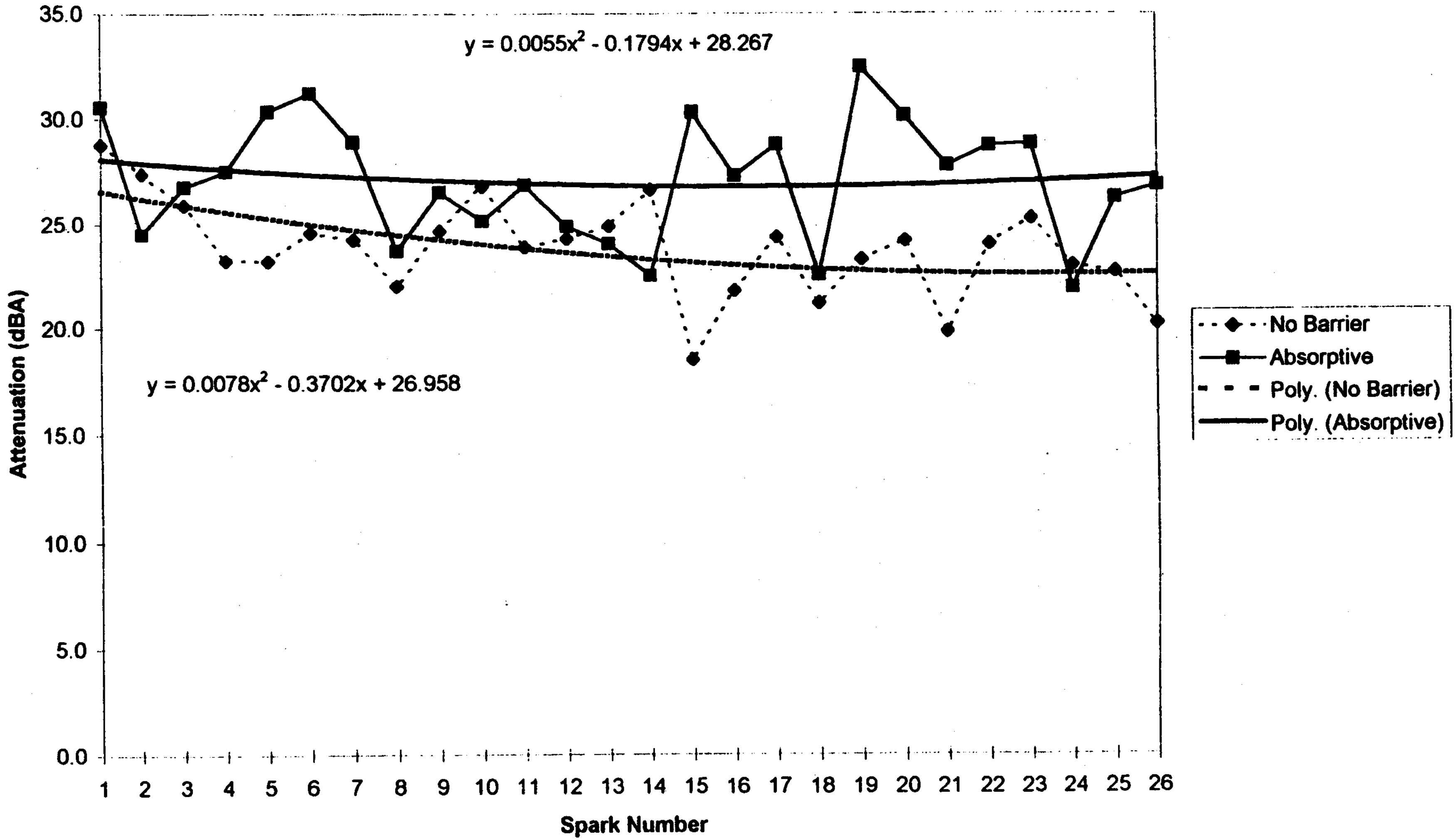
Spokane Receiver 15

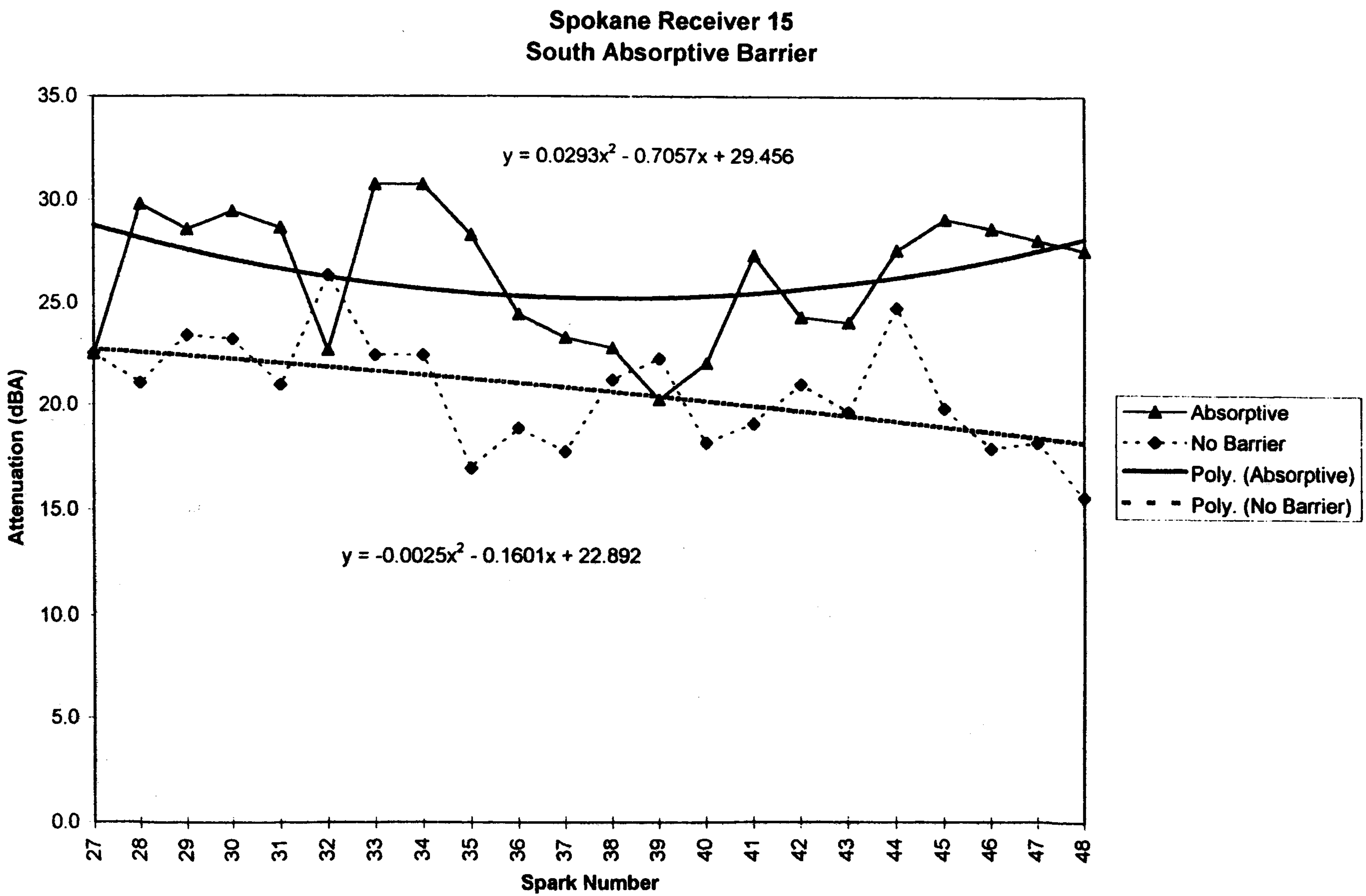
Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	Absorptive Barrier Attenuation Actual Absorptive	Fitted Absorptive	Standard Error	Insertion Scale Model
1	529+00	North	28.8	26.6	2.2	30.6	28.1	2.5	1.5
2	529+75	North	27.4	26.2	1.2	24.5	27.9	-3.4	1.7
3	530+50	North	25.9	25.9	0.0	26.8	27.8	-1.0	1.9
4	531+25	North	23.3	25.6	-2.3	27.5	27.6	-0.1	2.0
5	532+00	North	23.2	25.3	-2.1	30.4	27.5	2.9	2.2
6	532+75	North	24.6	25.0	-0.4	31.3	27.4	3.9	2.4
7	533+50	North	24.3	24.7	-0.5	28.9	27.3	1.7	2.5
8	534+25	North	22.0	24.5	-2.5	23.7	27.2	-3.4	2.7
9	535+00	North	24.7	24.3	0.4	26.5	27.1	-0.6	2.8
10	535+75	North	26.8	24.0	2.8	25.2	27.0	-1.8	3.0
11	536+50	North	23.9	23.8	0.1	26.9	27.0	-0.1	3.1
12	537+25	North	24.3	23.6	0.7	24.9	26.9	-2.0	3.3
13	538+00	North	24.9	23.5	1.5	24.1	26.9	-2.8	3.4
14	538+75	North	26.7	23.3	3.4	22.5	26.8	-4.3	3.5
15	539+50	North	18.5	23.2	-4.6	30.3	26.8	3.5	3.7
16	540+25	North	21.8	23.0	-1.2	27.3	26.8	0.5	3.8
17	541+00	North	24.4	22.9	1.5	28.8	26.8	2.0	3.9
18	541+75	North	21.2	22.8	-1.6	22.6	26.8	-4.3	4.0
19	542+50	North	23.3	22.7	0.6	32.5	26.8	5.6	4.1
20	543+25	North	24.2	22.7	1.5	30.2	26.9	3.3	4.2
21	544+00	North	19.9	22.6	-2.8	27.8	26.9	0.9	4.3
22	544+75	North	24.0	22.6	1.5	28.7	27.0	1.8	4.4
23	545+50	North	25.3	22.6	2.7	28.8	27.1	1.8	4.5
24	546+25	North	23.0	22.6	0.4	21.9	27.1	-5.2	4.6
25	547+00	North	22.7	22.6	0.1	26.3	27.2	-0.9	4.6
26	547+75	North	20.2	22.6	-2.4	26.8	27.3	-0.5	4.7

Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	Absorptive Barrier Attenuation Actual Absorptive	Fitted Absorptive	Standard Error	Insertion Scale Model
27	530+50	South	22.5	22.7	-0.2	22.5	29.5	-7.0	6.8
28	531+25	South	21.1	22.6	-1.5	29.8	29.6	0.2	7.0
29	532+00	South	23.4	22.4	1.0	28.6	29.6	-1.1	7.3
30	532+75	South	23.2	22.2	1.0	29.4	29.8	-0.3	7.6
31	533+50	South	21.0	22.0	-1.1	28.6	29.9	-1.3	7.9
32	534+25	South	26.4	21.8	4.5	22.7	30.1	-7.4	8.2
33	535+00	South	22.4	21.6	0.8	30.7	30.3	0.5	8.6
34	535+75	South	22.4	21.5	1.0	30.7	30.5	0.3	9.0
35	536+50	South	16.9	21.2	-4.3	28.3	30.7	-2.4	9.5
36	537+25	South	18.9	21.0	-2.2	24.4	30.9	-6.5	9.9
37	538+00	South	17.7	20.8	-3.1	23.3	31.2	-7.9	10.4
38	538+75	South	21.2	20.6	0.6	22.8	31.5	-8.7	10.9
39	539+50	South	22.3	20.4	1.9	20.2	31.8	-11.5	11.4
40	540+25	South	18.2	20.2	-2.0	22.0	32.1	-10.1	11.9
41	541+00	South	19.1	19.9	-0.8	27.3	32.4	-5.1	12.5
42	541+75	South	21.0	19.7	1.3	24.3	32.8	-8.5	13.1
43	542+50	South	19.7	19.4	0.2	24.0	33.1	-9.1	13.7
44	543+25	South	24.8	19.2	5.6	27.6	33.5	-5.9	14.3
45	544+00	South	19.9	18.9	0.9	29.1	33.9	-4.8	15.0
46	544+75	South	17.9	18.7	-0.8	28.6	34.3	-5.7	15.6
47	545+50	South	18.2	18.4	-0.2	28.1	34.7	-6.7	16.3
48	546+25	South	15.6	18.2	-2.6	27.6	35.2	-7.6	17.0

Insertion Loss = 9.5

Spokane Receiver 15
North Absorptive Barrier



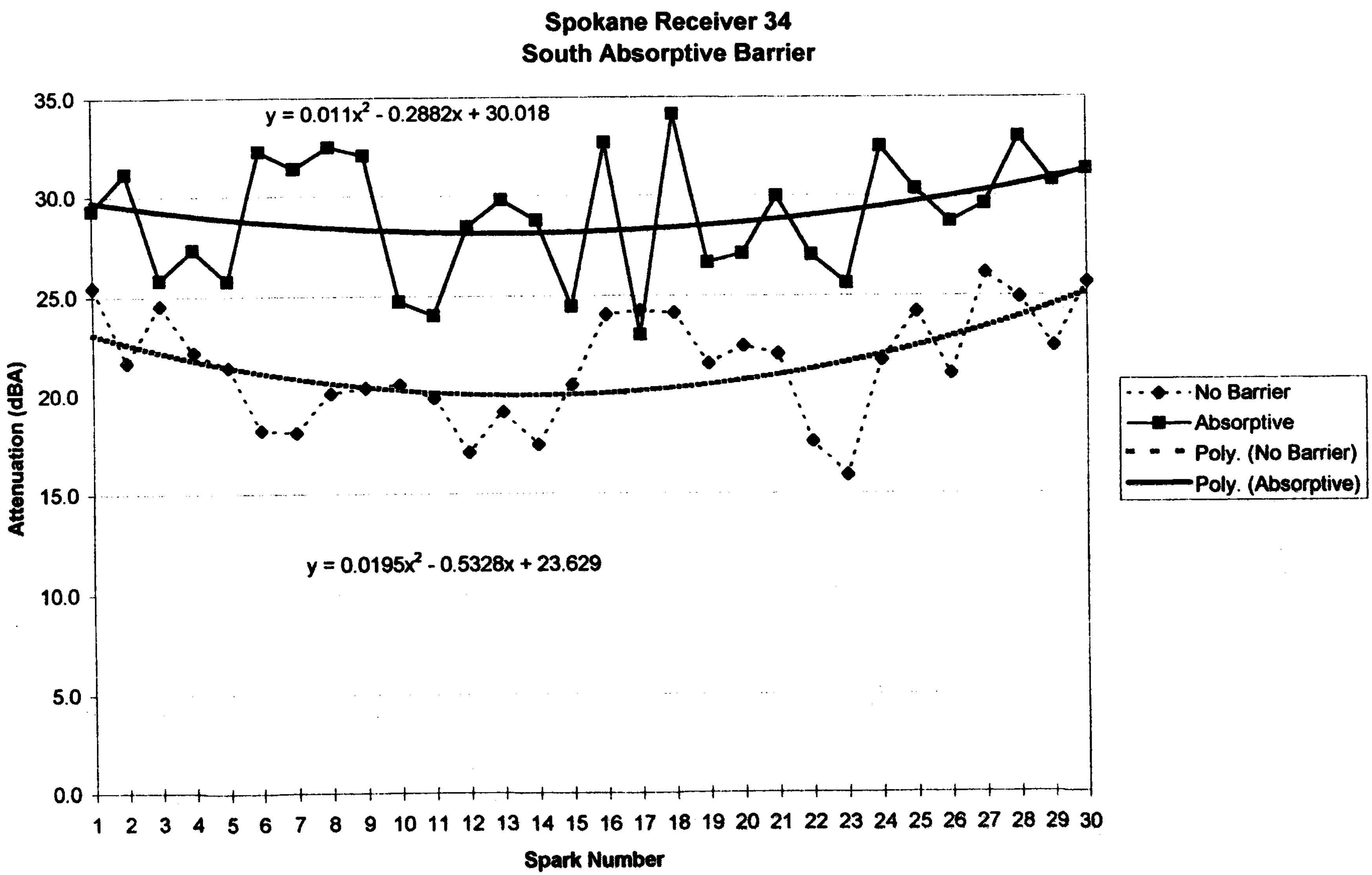

Spokane Receiver 15
South Absorptive Barrier
y = 0.0293x² - 0.7057x + 29.456
y = -0.0025x² - 0.1601x + 22.892
Attenuation (dBA)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
Spark Number
Absorptive
No Barrier
Poly. (Absorptive)
Poly. (No Barrier)

Spokane Receiver 34

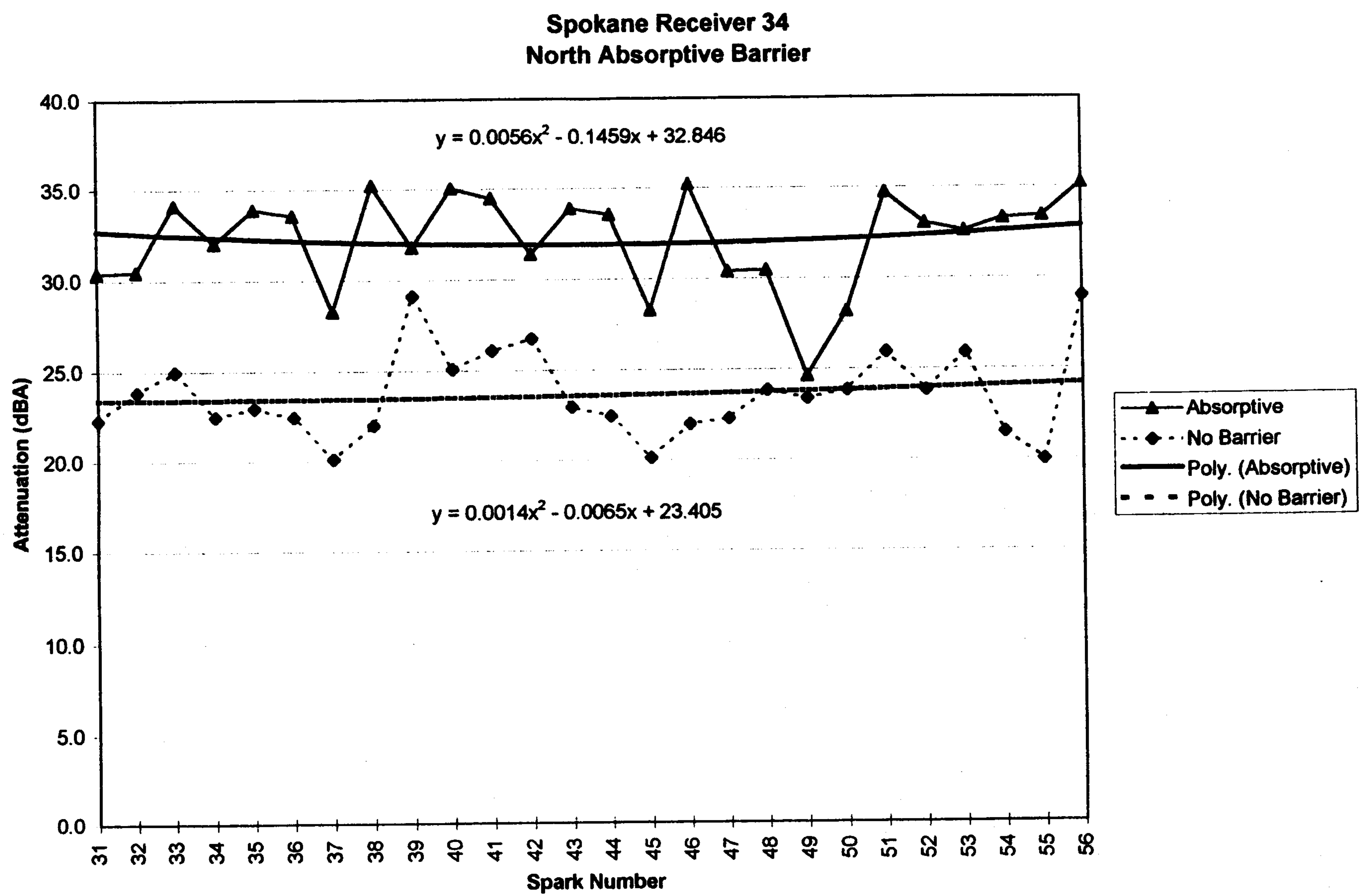
Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	Absorptive Barrier Attenuation Actual Absorptive	Fitted Absorptive	Standard Error	Insertion Scale Model
1	527+50	South	25.5	23.1	2.3	29.3	29.7	-0.4	6.6
2	528+25	South	21.7	22.6	-0.9	31.2	29.5	1.7	6.8
3	529+00	South	24.6	22.2	2.4	25.8	29.3	-3.4	7.0
4	529+75	South	22.2	21.8	0.4	27.3	29.0	-1.7	7.2
5	530+50	South	21.4	21.5	0.0	25.8	28.9	-3.1	7.4
6	531+25	South	18.2	21.1	-2.9	32.3	28.7	3.6	7.6
7	532+00	South	18.1	20.9	-2.8	31.4	28.5	2.9	7.7
8	532+75	South	20.1	20.6	-0.5	32.5	28.4	4.1	7.8
9	533+50	South	20.4	20.4	0.0	32.1	28.3	3.8	7.9
10	534+25	South	20.5	20.3	0.3	24.7	28.2	-3.5	8.0
11	535+00	South	19.8	20.1	-0.3	24.1	28.2	-4.1	8.1
12	535+75	South	17.1	20.0	-3.0	28.5	28.1	0.3	8.1
13	536+50	South	19.1	20.0	-0.9	29.8	28.1	1.7	8.1
14	537+25	South	17.4	20.0	-2.5	28.8	28.1	0.6	8.1
15	538+00	South	20.5	20.0	0.5	24.5	28.2	-3.7	8.1
16	538+75	South	24.1	20.1	4.0	32.7	28.2	4.5	8.1
17	539+50	South	24.3	20.2	4.1	23.1	28.3	-5.2	8.1
18	540+25	South	24.2	20.4	3.8	34.2	28.4	5.8	8.0
19	541+00	South	21.6	20.5	1.1	26.7	28.5	-1.8	8.0
20	541+75	South	22.5	20.8	1.7	27.1	28.7	-1.5	7.9
21	542+50	South	22.1	21.0	1.1	30.0	28.8	1.2	7.8
22	543+25	South	17.6	21.3	-3.7	27.0	29.0	-2.0	7.7
23	544+00	South	15.9	21.7	-5.8	25.6	29.2	-3.6	7.5
24	544+75	South	21.8	22.1	-0.3	32.5	29.4	3.1	7.4
25	545+50	South	24.2	22.5	1.7	30.3	29.7	0.7	7.2
26	546+25	South	21.1	23.0	-1.9	28.7	30.0	-1.3	7.0
27	547+00	South	26.1	23.5	2.7	29.6	30.3	-0.7	6.8
28	547+75	South	24.9	24.0	0.9	33.0	30.6	2.4	6.6
29	548+50	South	22.5	24.6	-2.1	30.8	30.9	-0.1	6.3
30	549+25	South	25.7	25.2	0.5	31.3	31.3	0.1	6.1

Spark Number	Station		No Barrier Attenuation Actual No Barrier	Fitted No Barrier	Standard Error	Absorptive Barrier Attenuation Actual Absorptive	Fitted Absorptive	Standard Error	Insertion Scale Model
31	529+00	North	22.3	23.4	-1.1	30.4	32.7	-2.3	9.3
32	529+75	North	23.8	23.4	0.4	30.5	32.6	-2.1	9.2
33	530+50	North	25.0	23.4	1.6	34.1	32.5	1.7	9.1
34	531+25	North	22.5	23.4	-0.9	32.0	32.4	-0.3	9.0
35	532+00	North	22.9	23.4	-0.5	33.9	32.3	1.6	8.8
36	532+75	North	22.5	23.4	-1.0	33.6	32.2	1.4	8.8
37	533+50	North	20.1	23.4	-3.3	28.3	32.1	-3.8	8.7
38	534+25	North	22.0	23.4	-1.4	35.2	32.0	3.2	8.6
39	535+00	North	29.1	23.5	5.7	31.8	32.0	-0.2	8.5
40	535+75	North	25.1	23.5	1.6	35.0	31.9	3.1	8.5
41	536+50	North	26.1	23.5	2.6	34.5	31.9	2.6	8.4
42	537+25	North	26.7	23.5	3.2	31.4	31.9	-0.5	8.4
43	538+00	North	22.9	23.6	-0.6	33.9	31.9	2.0	8.3
44	538+75	North	22.5	23.6	-1.1	33.6	31.9	1.7	8.3
45	539+50	North	20.1	23.6	-3.5	28.3	31.9	-3.6	8.3
46	540+25	North	22.0	23.7	-1.7	35.2	31.9	3.3	8.3
47	541+00	North	22.3	23.7	-1.4	30.4	32.0	-1.6	8.3
48	541+75	North	23.8	23.7	0.1	30.5	32.0	-1.6	8.3
49	542+50	North	23.4	23.8	-0.4	24.6	32.1	-7.5	8.3
50	543+25	North	23.8	23.8	0.0	28.2	32.2	-4.0	8.3
51	544+00	North	25.9	23.9	2.0	34.7	32.3	2.5	8.4
52	544+75	North	23.8	23.9	-0.1	33.0	32.3	0.7	8.4
53	545+50	North	25.9	24.0	1.9	32.6	32.5	0.1	8.5
54	546+25	North	21.5	24.1	-2.6	33.3	32.6	0.7	8.5
55	547+00	North	20.0	24.1	-4.1	33.4	32.7	0.7	8.6
56	547+75	North	29.0	24.2	4.8	35.2	32.8	2.4	8.7

Insertion Loss = 8.0



Spokane Receiver 34
South Absorptive Barrier
y = 0.011x2 - 0.2882x + 30.018
y = 0.0195x2 - 0.5328x + 23.629
Attenuation (dBA)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
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 30
Spark Number
No Barrier
Absorptive
Poly. (No Barrier)
Poly. (Absorptive)


Spokane Receiver 34
North Absorptive Barrier
y = 0.0056x2 - 0.1459x + 32.846
y = 0.0014x2 - 0.0065x + 23.405
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Attenuation (dBA)
31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56
Spark Number
Absorptive
No Barrier
Poly. (Absorptive)
Poly. (No Barrier)

APPENDIX D
SCALE MODEL EQUIPMENT, MATERIALS & METHODS

SCALE MODEL EQUIPMENT

The following equipment was used to model the source and receiver components for each of the scaled WSDOT highway projects. The source was modeled as an intense spark with an upper limit output of 120 decibels. A simple discharge circuit containing two capacitors in series was constructed and charged by a DC power supply. The capacitors were discharged by mechanically completing the circuit loop. This produced the spark used throughout the project testing. The components of the source are listed as follows:

DC Power Supply	Manufacturer	Hewlett Packard
	Type	Harrison 6206B
	Capacity	70 Volts
	Rating	1.2 Amps
	Id Number	8A2265
Capacitors (2)	Manufacturer	General Electric
	Type	Direct Current
	Capacity	55 Volts (each)
	Rating	39,000 Micro Farads
	Id Number(s)	8GF262MA & 8GF263MA
Contact Solenoid	Manufacturer	Detroit Coil Co.
	Type	Single Action AC
	Capacity	115 Volts
	Rating	15 Amps

	Id Number	9-662M
Trigger Switch	Manufacturer	Generic
	Type	Two-Way Toggle AC
	Capacity	125 Volts
	Rating	10 Amps
	Id Number	None
Charging / Switching Wire	Manufacturer	Belden Wire and Cable
	Type	20 Gauge Solid Copper
	Capacity	1000 Volts
	Rating	Not listed
	Id Number	8529
Discharge (Spark) Wire	Manufacturer	Belden Wire and Cable
	Type	THHM
	Capacity	600 Volts
	Rating	30 Amps
	Id Number	E23919

The components used to model the receiver(s) used in each of the scaled WSDOT highway projects are listed as follows:

Microphones (2)	Manufacturer	Bruel & Kjaer
	Type	No. 4135 1/4" Diameter Free-Field and Random Response

	Capacity	4 to 100kHz Open Circuit Frequency Response
	Rating	N/A
	Id Number(s)	1817420 & 1817425
Microphone Adapter(s)	Manufacturer	Bruel & Kjaer
	Type	1/4" to 1/2" No. UA 0035
	Id Number(s)	Same as microphones
Microphone Preamplifiers (2)	Manufacturer	Larson Davis Laboratories
	Type	900B 1/2" Diameter
	Id Number	900B322
Microphone Power Supply	Manufacturer	Larson Davis Laboratories
	Type	2200B Dual Independent Channels
	Capacity	-40 to +40 dB Adjustable Gain
	Id Number	0285B0181
Oscilloscopes (2)	Manufacturer	Hewlett Packard
	Type	S 4600A 2-Channel
	Capacity	100 MHtz
	Id Number	3227A13708 & 3227A13789
Desktop Computer	Manufacturer	Gateway 2000
	Type	486 Dx2/66 MHtz
	Id Number	A24256
Sound Level Calibrator	Manufacturer	Larson Davis Laboratories

Type	<u>1/2" diameter with 1/2" to 1/4"</u>
	<u>Rubber O-ring adapter</u>
Id Number	<u>CA250</u>

SCALE MODEL MATERIALS

The materials chosen for the project were selected after the literature review of past modeling efforts. All materials used were commercially available and easily cut and fastened using typical power tools and construction practices. All curved surfaces were represented by segmented flat sections of cut-to-size custom components. Each modeled site had a unique geometry consisting of varying proportions of modeled "hard" and "soft" surfaces. Concrete, pavement and gravel were modeled as hard surface material. All remaining surfaces including grass and dirt were modeled as soft surfaces.

All joints between hard surface panels were taped with 2 inch wide carton sealing tape to smooth the discontinuity between edges. A "layering" procedure described in past FHWA modeling efforts was used to represent abrupt changes in topography and all squared edges of built-up layers were sanded to a bevel edge to reduce creating possible diffraction edges within the propagation path.

Noise barriers were constructed from 1/8" plexiglass. The plexiglass was cut-to-size in strips to represent the *Phase II* barrier design heights. Each barrier height was modeled to the closest 1/16 of an inch. This limitation was due to the tolerance of the cutting equipment used by the plexiglass supplier. A twenty (20) feet barrier height, for example, was modeled as 4-13/16" tall. This measurement of 4-13/16" scales to be equal to a noise barrier of 20.05 feet. The 1/8" thickness of the plexiglass represented a scaled noise wall of 0.52 feet thick. In each case the plexiglass was cut to the most desirable height, representing the closest "over or under" scaled measurement. Each highway project had specific modeled barrier heights and they are listed later in this report.

Barrier sections were assembled to be free-standing on the modeled highway projects and were held securely together by a vinyl "divider" strip. The vinyl divider strip was a commercially available material manufactured for connecting melamine coated bathroom wall panels together.

A commercially available closed cell sponge rubber was used as the absorptive treatment to model both the T-top barrier designs and the single wall absorptive designs. The sponge rubber was 1/8" thick and 3/4" in width and came on a roll. One side of the sponge rubber had an adhesive which allowed easy fastening to the plexiglass barrier sections. Modeled T-top barrier heights were assembled allowing for the 1/8" thickness of the sponge rubber in the overall height of the barrier. The sponge rubber proved to be a good choice as it "stuck" to the top edge of the model barrier and was stiff enough to support itself providing the required T-top shape. The 3/4" width of the sponge rubber represented a scaled cap width of 3.125 feet.

Absorptive barrier designs were modeled by "sticking" the sponge rubber to the source side of the barrier wall from the top edge down. The 3/4" sponge rubber width represented providing an absorptive treatment to the top 3.125 feet of the scaled barrier wall. In both cases the sponge rubber was easily adhered to and removed from the modeled plexiglass barrier sections. The materials used in the project are listed as follows:

Platform Frame	Manufacturer	Canfor Industries
	Type	2" x 4" x 18' SYP
Platform Deck	Manufacturer	Georgia-Pacific Corp.

	Type	15/32" BC Sanded Plywood
		48" x96" Sheet Size
Hard Surface Cover	Manufacturer	Overseas-Imported
	Type	5.2mm (1/4") Meranti Hardwood
		BB/CC Underlayment grade
		48" x96" Sheet Size
Soft Surface Cover	Manufacturer	Dow Chemical
	Type	Extruded Polystyrene Type RM
		3/4" Thick, 48" x 96" Sheet Size
Model Barrier Sections	Manufacturer	Rohm & Haas
	Type	Acrylic Plexiglass
		No. 125 MCS
		1/8" Thick, 48" x 96" Sheet Size
Barrier Divider Strip	Manufacturer	Abitibi Corp.
	Type	1/8" Vinyl 2-Way Divider 96" Long
Absorptive Sponge Rubber	Manufacturer	Permatite Manufacturing
	Type	"Dortite" 100% Sponge Rubber
		No. 2650 - 1/8" Thick x 3/4" Wide
		Self Adhesive 50' Roll
Model Wood Blocking	Manufacturer	Plum Creek Manufacturing
	Type	Premium Furring Strips
		1" x 2" x 8' No Grade Stamp

MODEL CONSTRUCTION AND TESTING PROCEDURE

This section of the report discusses the steps taken in constructing and testing each of the modeled WSDOT highway projects. Each of the sites were constructed and tested in the same manner. There are three overviews presented here to describe the construction procedure, the equipment layout and testing procedure. In each of the four WSDOT model sites it was necessary to choose a compatible roadway section that fit the scale model limitations. The specifics related to this are discussed for each site and references are drawn from *Phase II* to accurately describe the extent of each model's representation. In each model the length of tested roadway was determined using the practice of "six times the length of the distance from the receiver to the source", as suggested by FHWA 1979. This technique allows for the 3 decibel per distance doubled (3dB/dd) rule to be maintained.

Construction Procedure

The objective in the construction of each site was to reproduce the chosen scaled roadway section as accurately as possible. Reproducing the curved topography unique to each site required representing the curves with separate line segments. By doing this, cross sections representing the actual topography were duplicated. The 50 to 1 scale factor was applied to all measurements taken from either contour sheets or *Phase II* elevation (Z-coordinate) information.

Each modeled site was visualized as a three dimensional representation of the actual highway project. Cross sections were chosen at 36" to 48" (150 to 200 scaled feet) spacing in all four models and situated perpendicular to the centerline of the roadway section. Each cross section detailed the overall length, width and slope changes required to reproduce the actual highway project topography. In all cross sections, the points chosen to define the line segments included the receiver location, roadway edges, barrier locations, top and bottom of drainage surfaces and points defining the most abrupt elevation changes. This procedure allowed for an efficient method of completing small shop drawings. The drawings were easily transferred to the 1/4" Meranti plywood sheets and cut out.

The cross sections were made free standing by fastening 1" x 2" blocking to their bottom side. Blocking was also fastened to the cross section top edges. This was required for attaching the hard and soft cover model panels which represented the ground surfaces. It was necessary to establish a grid on the base platform to accurately place the modeled cross sections relative to one another. This was easily accomplished and the cross sections were fastened to the base platform.

The remaining construction procedure involved cutting numerous hard and soft cover panels to be attached on top of and spanning the cross sections. Once attached, a representative topography was achieved. As mentioned earlier, hard surfaces were modeled using the 1/4" Meranti plywood and soft surfaces as 3/4" extruded polystyrene (EPS). The task of individually measuring and cutting each panel was tedious and efforts were made to provide an exacting fit. Joints where panels touched one another were taped or sanded to smooth any discontinuities and cover any remaining gaps.

Recreating the actual change in source to receiver elevation was the main control in design and assembly of each modeled highway site. Even though the topography itself was idealized in to straight line segments, every effort was made to ensure proper line of sight breaks and corresponding elevation change from the roadway to the receiver. In each model the base platform served as the zero elevation and the roadway and receiver heights were modeled relative to the this zero height. Photographs of each model appear in appendix F of this report. (A complete photo log has also been assembled and is supplemental to this report.)

Equipment Layout

The equipment layout was straight forward. The desktop computer and oscilloscopes were kept on a lab cart no closer to the model than the base platform edge. Both oscilloscopes were set up identically. One oscilloscope was connected by coax cable to the source microphone assembly and the other to the receiver microphone assembly. The microphone power supply was located "in-line" approximately half way between the microphones and the oscilloscopes. This layout was restricted by the length of available cables necessary to attach the equipment.

Each microphone was supported in an upright position with the 1/4" sensitive microphone pointing down towards the model. The source microphone was held by a homemade 1/2" CPVC plastic tubing stand. This stand was constructed so that it held the microphone assembly in a fixed position at an approximate height of 12" above the intense spark source. The legs of the microphone stand were moved several inches away from the microphone itself to minimize unwanted reflections. This arrangement allowed for quick movement of the source microphone during the testing procedure.

The receiver microphone was held by a similarly constructed plastic stand. This stand held the microphone assembly at approximately 1-3/16" above the model surface and was easily placed at any desired receiver location. This 1-3/16" measurement represented a scaled receiver to ground distance of 4.95 feet.

The intense spark source was constructed as two General Electric 39,000 micro farad capacitors wired together in series. The capacitors were held in place in a small plywood box. Ten (10) gauge solid copper wires were attached to the positive and negative terminals of the capacitor. These wires were extended approximately 1 1/2" away from the capacitor and bent to create a small gap between them. The positive wire was fit through a hole in the retracting arm of a small electric solenoid. The solenoid was attached to the front of the plywood box holding the capacitors. This arrangement allowed the mechanical closing of the spark gap which produced the intense spark used for all of the testing.

Twenty gauge solid copper wire was used to connect the capacitors to the 70 volt power supply listed previously. The power supply was located in a central position along one of the outer edges of the base platform. A small toggle switch was placed in line between the power supply and the capacitors. This switch was turned to one toggle position to charge the capacitors and could be turned to a second toggle position to operate the solenoid and close the charged circuit. The intense spark was produced when the positive and negative capacitor wires touched each other. The wiring between the capacitor/solenoid apparatus and the power supply/toggle switch was run overhead of the model.

Testing Procedure

The testing procedure was similar for all four models. A series of physical measurements were taken to locate and number the testing points. The testing itself involved the calibration of the electronic equipment and the actual data collection. The steps used in the testing procedure are described below.

Each modeled site represented a multi-lane type roadway. The centerline and driving lanes of the roadway were penciled on each model. Starting at the receiver location, the perpendicular distance to the centerline of each set of lanes was measured. This distance was then multiplied by six, giving the total length of the testing field from one end of the model to the other. At the centerline of each set of modeled lanes testing points were marked at 18" intervals. Each testing point labeled by receiver and numbered in a sequential order. The 18" measurement represented a scaled distance of 75 feet along the roadway. In this way, a data set of point sources was classified and tested for each model. The data set was later converted into an equivalent line source and used in validating the objective of this study.

Before collecting any acoustical measurements the electronic and acoustical equipment was turned on and all connections between equipment were double-checked. All gains and settings on the receiving instrumentation were checked to correct for any changes from the previous day.

Before each testing session the source and receiver microphones were calibrated using the Larson-Davis sound level calibrator. The microphones were calibrated at a 114 decibel level. With the receiving instrumentation turned on, each microphone was placed inside the rubber O-ring of the calibrator and exposed to a 114 decibel tone. By recording a sample testing point through the oscilloscope and running the recorded signal through the LABVIEW software it was possible to accurately calibrate both microphones.

The remaining procedure involved discharging an intense spark over each point penciled along the model roadway. Each spark was received by the microphones and triggered a voltage readout at the source and receiver oscilloscopes. Sample source and receiver spark output are shown in Figures 1 Through 4 below. Each testing point produced similar looking but highly unique patterns. The oscilloscopes collected the spark output as voltage versus time. Each microphone reading represented 10 milliseconds of collected data. The data was saved as a unique file and was stored on floppy disk. By starting at one end of the modeled site and moving the spark source apparatus and the source microphone assembly along the roadway each model was tested. The receiver microphone location remained fixed during each testing run.

In each highway project it was necessary to test the model "as-built"' with no modeled noise barriers. Once a data set for the *no barrier scenario* was collected the same procedure was repeated with the addition of the modeled noise barriers. In each modeled site the recommendations for *Phase II* special barrier treatments were followed. A listing of the specific lengths of roadway and noise barriers modeled are included for each site below.

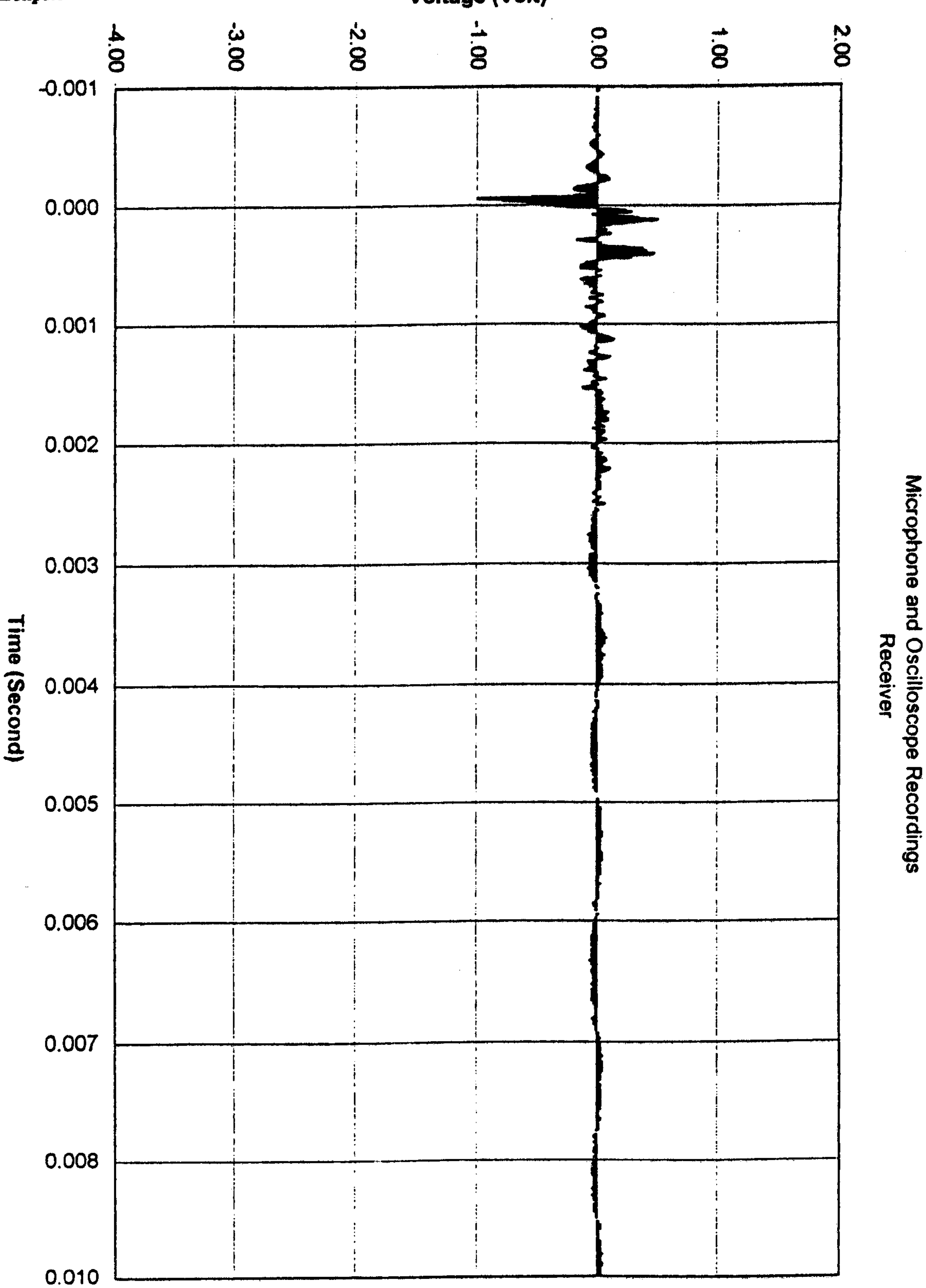


Figure 1. Typical Receiver Oscilloscope Recording

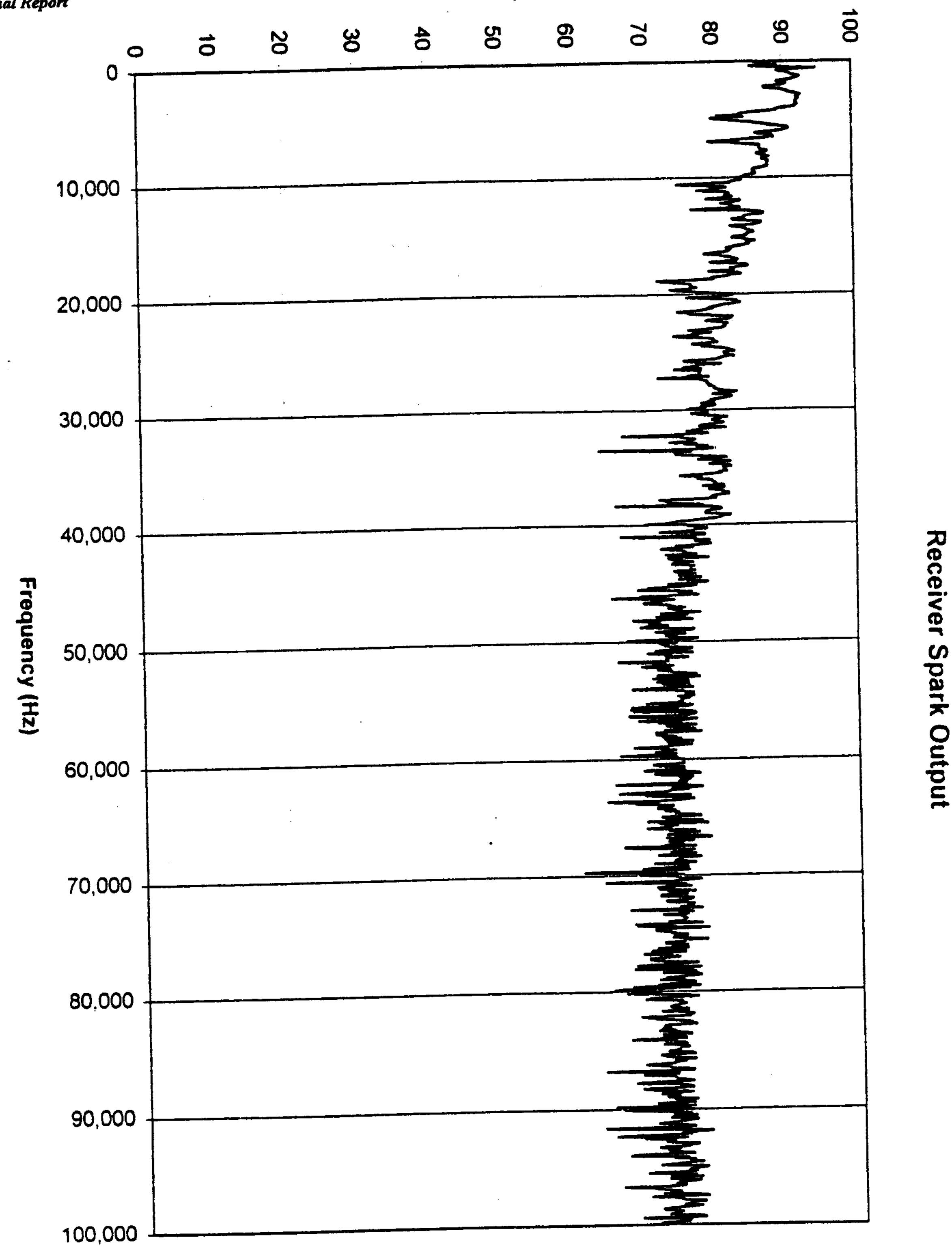


Figure 2. Typical Receiver Decibel Output

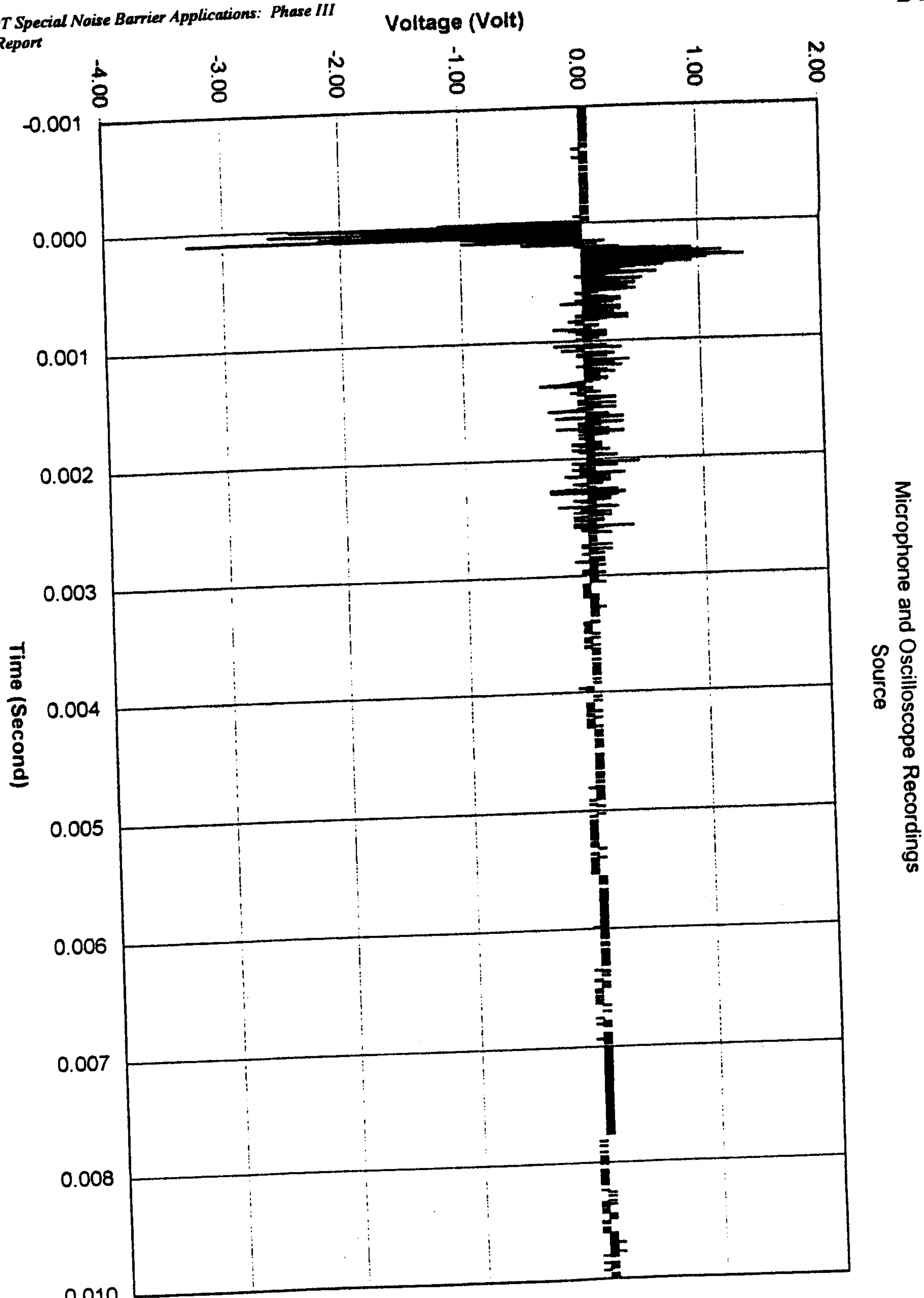


Figure 3. Typical Source Oscilloscope Recording.

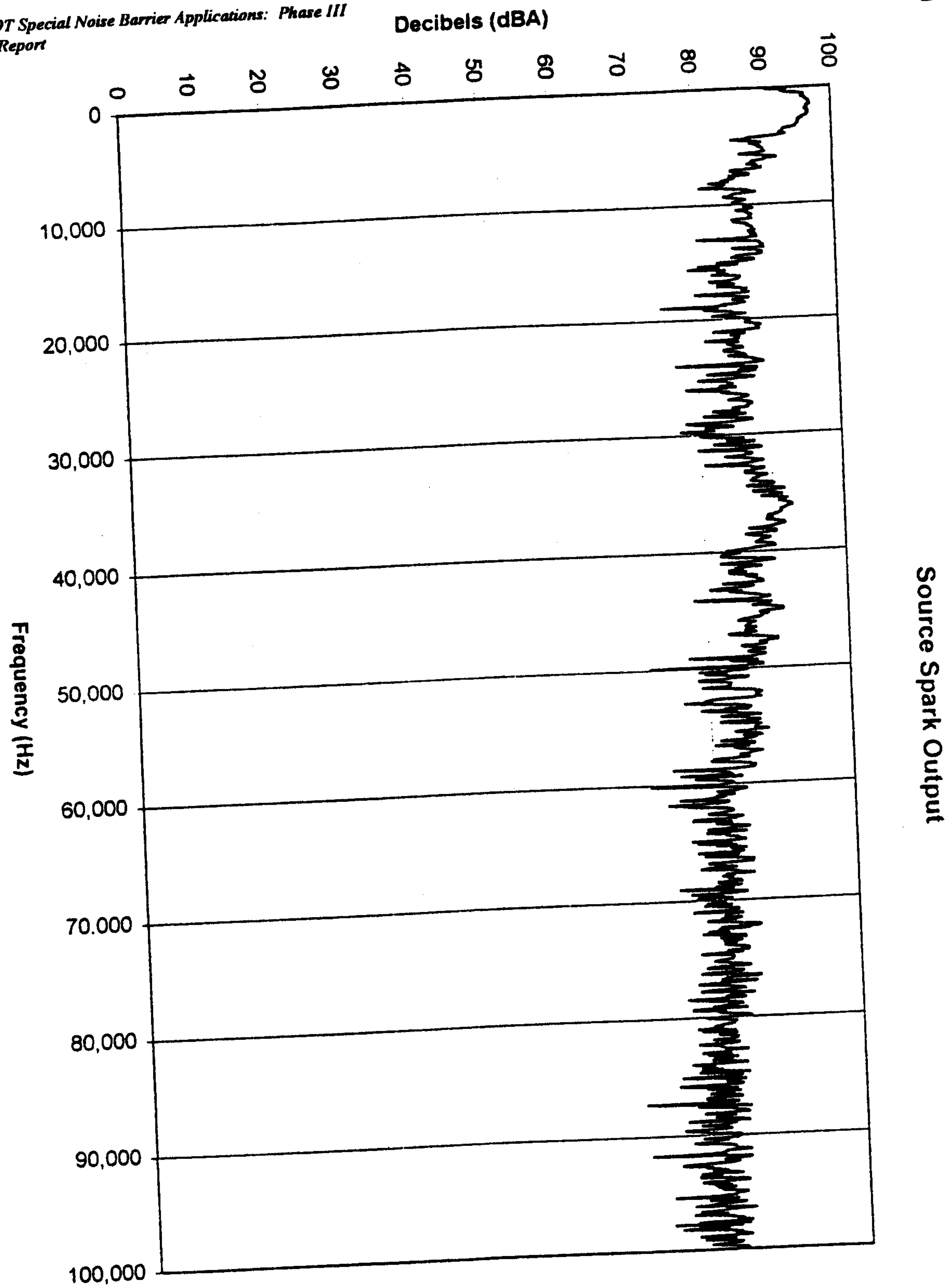


Figure 4. Typical Source Decibel Output.

Magnolia Road.

The Magnolia Road highway project is an existing section of SR-405 running between SR-522 and SR-5. This project is a six lane divided highway with a narrow median.. At the Northbound end of the project corridor are Northbound exit lanes (to SR-5) and Southbound merging lanes (from SR-5). All barrier sections as listed in *Phase II* were modeled and *Receiver No. 1* was chosen for testing. All model barrier sections were placed on the shoulder of the model roadway as close to the receiver as possible. Specific information relating to the Magnolia Road model is shown below. The labeling of the spark locations was taken directly from the stationing used in *Phase II* and a contour map provided by WSDOT.

Magnolia Road Receiver No. 1

Total number of sparks	*From/To STATION No.*	*Actual/Model Test Length*
Northbound (1-20)	Sta 87+25 to Sta 101+50	1425 feet/28.5 feet
Southbound (33-46)	Sta 89+50 to Sta 99+25	975 feet/19.5 feet

From/To BARRIER No.
BM1A thru BM1I and BM2A thru BM2F

Barrier Type Tested	*Phase II Height*	*Scale Model Height*
Conventional	20 feet	4-13/16" = 20.05'
Absorptive T-top	13 feet	3-1/8" = 13.02'
Single-wall Absorptive	16 feet	3-13/16" = 15.89'

Kent Commons Play Field

The Kent Commons Play Field project involves widening SR-167 and adding proposed HOV lanes to the roadway. The roadway project is a four lane divided highway with a narrow hard surface median. *Receiver No. 2* and *Receiver No. 3* were chosen for modeling. These receivers were close in proximity to each other being on about the same perpendicular line from the roadway. *Receiver No. 2* was much closer to the highway project. All model barrier sections were placed on the shoulder of the model roadway as close to the receiver as possible. Stationing details were again taken from WSDOT contour maps and specifics related to each receiver for Kent Commons Play Field are listed below.

Kent Commons Receiver No. 2

Total number of sparks	*From/To STATION No.*	*Actual/Model Test Length*
Southbound (1-14)	Sta 842+50 to Sta 832+75	975 feet/19.5 feet
Northbound (16-24)	Sta 841+00 to Sta 834+25	675 feet/13.5 feet

From/to BARRIER No.
BK11 thru BK28

Barrier Type Tested	*Phase II Height*	*Scale Model Height*
Conventional	19 feet	4-9/16" = 19.01 feet
Absorptive T-top	11 feet	2-1/2" = 10.94 feet
Single-wall Absorptive	14 feet	3-3/8" = 14.06 feet

Kent Commons Receiver No. 3

Total number of sparks	*From/To STATION No.*	*Actual/Model Test Length*
Southbound (1-20)	Sta 844+75 to Sta 830+50	1400 feet/28 feet
Northbound (21-36)	Sta 843+25 to Sta 832+00	1125 feet/22.5 feet

From/To BARRIER No.
BK11 thru BK28

Barrier Type Tested	*Phase II Height*	*Scale Model Height*
Conventional	19 feet	4-9/16" = 19.02 feet
Absorptive T-top	11 feet	2-1/2" = 10.94 feet
Single-wall Absorptive	14 feet	3-3/8" = 14.06 feet

Fourth Avenue.

The Fourth Avenue highway project is an existing section of SR-405. HOV lanes are proposed for the corridor. The roadway project is a four lane divided highway with a wide soft surface median. *Receiver No. 43* and *Receiver No. 44* were chosen for modeling. These receivers are located at the approximate middle point of the project corridor. *Receiver 43* is located at an elevation of approximately 24 feet above *Receiver 44.* Model barrier sections were placed on the shoulder of the model roadway as close to the receiver as possible. Spark locations were labeled using the stationing information as it appeared on WSDOT contour maps. Specifics related to each receiver for Fourth Avenue are listed below.

Fourth Avenue Receiver No. 43

Total number of sparks	*From/To STATION No.*	*Actual/Model Test Length*
Northbound (1-20)	St 1045+50 to St 1059+75	1425 feet/28.5 feet
Southbound (21-36)	St 1045+50 to St 1056+75	1125 feet/22.5 feet

From/To BARRIER No.
BFA thru BFT

Barrier Type Tested	*Phase II Height*	*Scale Model Height*
Conventional	20 feet	4-13/16" = 20.05'
Absorptive T-top	15 feet	3-5/8" = 15.10'
Single-wall Absorptive	17 feet	4-1/16" = 16.92'

Fourth Avenue Receiver No. 44

Total number of sparks	*From/To STATION No.*	*Actual/Model Test Length*
Northbound (1-20)	St 1043+25 to St 1057+25	1425 feet/28.5 feet
Southbound (21-32)	St 1045+50 to St 1053+75	825 feet/16.5 feet

From/To Barrier No.
BFA thru BFT

Barrier Type Tested	*Phase II Height*	*Scale Model Height*
Conventional	20 feet	4-13/16" = 20.05'
Absorptive T-top	15 feet	3-5/8" = 15.10'
Single-wall Absorptive	17 feet	4-1/16" = 16.92'

Spokane Community College

The Spokane College Area highway project is a proposed elevated section of the Market/Greene alternative of the North Spokane Freeway. Impacted receivers exist on both sides of the freeway. *Receiver No. 15* was chosen to model the neighborhood side and *Receiver No. 34* was chosen to model the Spokane Community College side. The freeway model was represented as a four lane highway with hard surface medians. The parallel barrier scenarios presented in *Phase II* were modeled for this project. Again, the model noise barriers were placed on the shoulders of the elevated freeway as close to the receiver locations as possible. Stationing details were taken from *Phase II* digitized alignments of the proposed freeway. WSDOT aerial photography with an imposed rendition of the freeway corridor served as the basis for the digitized alignments. Specifics related to the Spokane Community College testing are listed below.

Spokane Receiver No. 15 (Neighboorhood Side)

Total number of sparks	*From/To STATION No.*	*Actual/Model Test Length*
Northbound (1-26)	Sta 529+00 to Sta 547+75	1875 feet/37.5 feet
Southbound (16-24)	Sta 530+50 to Sta 546+25	1575 feet/31.5 feet

Spokane Receiver No. 34 (Community College Side)

Total Number of sparks	*From/To STATION No.*	*Actual/Model Test Length*
Southbound (1-30)	Sta 527+50 to Sta 549+25	2175 feet/43.5 feet
Northbound (31-56)	Sta 529+00 to Sta 546+25	1875 feet/37.5 feet

Spokane Receivers No. 15 and No. 34 (cont.)

From/to PARALLEL BARRIER No's.
B10W thru B22W (Neighboorhood Side)
B9E thru B20E (Community College Side)

Barrier Type Tested	***Phase II Height***	***Scale Model Height***
Conventional Parallel	24 feet	5-3/4" = 23.95'
Absorptive Parallel	18 feet	4-5/16" = 17.96'

APPENDIX E

LITERATURE REVIEW

Literature Review

Introduction

The purpose of the following literature review is to examine the characteristics of sound and previous efforts of scale modeling of highway noise barriers. This report includes information regarding difficulties encountered by previous researchers and techniques used to overcome the problems associated with scale modeling.

There are two types of errors which can occur in scale modeling. First, modeling techniques may improperly scale a physical process, even when the full size process is adequately understood. Second, some processes are not adequately understood in full size, so scaling them is often guesswork [Anderson, 1978]. Minimizing both types of errors is accomplished by understanding the physical process as best as possible and then using mathematical models as guidance. The types of inaccuracies are discussed as a fundamental basis to describe the other components of the model. A description of the physical processes and relevant mathematics is listed in the sections below.

Characteristics of Sound

Sound may be defined as any pressure variation (typically in air) that the human ear can detect [Cohn 1992]. The human ear picks up sound waves which have been generated by a source. The sound waves interact with the air as it travels and propagates along numerous paths toward the receiver. Understanding the acoustic fundamentals associated with the source, path, and receiver is fundamentally important to any noise study.

Sound waves have different frequencies and wavelengths. As a pressure phenomena, people can detect sound from 0.00002 Pascals, the threshold of hearing, to 200 Pascals, the threshold of pain. This difference represents a 1 million to one total range of sound pressure. Expressing this range of sound pressure on a linear scale would be exhaustive. Also, the hearing mechanism responds to changes in sound pressure in a relative manner rather than in an absolute way [Cohn, 1992]. Due to human response, it is convenient to use a relative scale to measure sound rather than an absolute scale measuring pressure. Therefore, sound pressure levels are measured in logarithmic units called decibels (dB). Sound energy is related to sound pressure level by the following formula.

$$SPL(dB)=20LOG_{10}[\frac{P}{P_o}]$$

where SPL = Sound Pressure level measured in units of dB

P = Measured sound pressure in units of Pa

P_o = Reference sound pressure (Threshold of Hearing)

The use of sound pressure level condenses the large amounts of sound pressure values and also correlates strongly with human auditory response [Cohn, 1992]. By expressing relative sound pressure on a logarithmic basis, the pressure scale is much easier to understand and utilize.

A source emits sound waves and expands spherically. During the expansion, acoustical energy disperses from several factors to develop an attenuation rate. The following formula describes the attenuation for a point source [Harris 1991]:

$$A_{total}=A_{diver}+A_{air}+A_{ground}+A_{barrier}+A_{intense}$$

where:

A_{total} = The total attenuation of sound
A_{diver} = Geometrical divergence by the spherical spreading of sound energy
A_{air} = Transfer of acoustic energy to heat energy by air molecules.
A_{ground} = Absorption or reflection of sound energy by the ground
$A_{barrier}$ = Attenuation of a noise barrier
$A_{intense}$ = Excess attenuation created by an intense source.

The first term in the above equation is from the geometrical divergence by the spherical spreading of sound from a point source. This factor is a major source of attenuation in all noise analysis. A_{diver} is mathematically described as 20log(r) + 0.6 - C [Harris 1991]. The variable, r, is the radial distance from source to the receiver in feet. The constant, C, is based upon the temperature and pressure of the medium. At 20 degrees Celsius and 1 atm, C = 0. The geometrical divergence does not depend upon the frequency of the sound wave. The 20log(r) is often simplified to a decrease of 6 dB per doubling distance or 20 dB reduction for every tenfold increase in distance.

Attenuation from air absorption, is the transfer of sound energy to heat energy. The magnitude of the air absorption is dependent upon frequency of the sound waves. For traffic emissions, the air absorption is insignificant and ignored. However, with higher frequencies the air absorption must be considered since the attenuation can be significant. A more detailed discussion is provided under anomalous air absorption.

The ground surface also impacts attenuation of sound. The ground absorbs or reflects sound energy depending on whether the surface is hard or soft. The height of the source and receiver, as well as the frequency of the propagating sound waves also effects ground absorption or reflection. One table offered by Harris. 1991 displays attenuation levels which are expected for a receiver height of 5.9 feet located at a 700 foot distance from a source at 3.9 feet above the ground. The table is reproduced below.

Frequency (Hz)	Attenuation (dB)
63	-5.61
125	1.60
250	16.60
500	24.60
1000	7.00
2000	-3.00
4000	-3.00

Choice of Scale Factor

A scale model is the replication of a full size prototype with the proportional reduction of the physical dimensions by a constant scale factor. Normalizing is a technique which keeps the prototype parameters unchanged after scaling. Physical normalizing involves picking a typical length within the model such as the roadway width and relating this width to the rest of the components in the model. For example, the noise barrier would be referred to as 1.25 roadway widths tall. The normalized parameters result in model lengths that are considered non-dimensional and are kept constant after scaling [Anderson, 1978].

The choice of the scale factor is complex. The model size is restricted by physical and acoustical considerations. The scale factor for the acoustical experiment shall be chosen after careful consideration of the factors affecting the scale model.

The physical considerations are available laboratory space and construction of the physical components of the model. The laboratory size places a lower limit on the scale factor. The scale model portrays a section of a roadway. The size of the scale model will the length of the roadway modeled divided by the scale factor. Therefore, if a 2,000 foot section of roadway is modeled at a 40 scale factor, the model size is will be 50 feet long.

The other physical consideration concerns the construction of modeled buildings and noise barriers which can place an upper limit on the scale factor. With increasing size of the scale factor, it becomes increasingly more difficult to construct objects of such miniature size.

The acoustical behavior is an equally important factor in determining the scale factor. For acoustical modeling, the wavelength of sound waves must be scaled proportionally by the scale factor, so that the wavelength is the same relative size in the scale model as the full size prototype.

To reproduce actual conditions using the scale model, the frequency of the sound waves must also be changed since the wavelength and frequency are proportional. This is dictated by the wave equation [Halliday 1988].

$$f * l = c$$

where: f = frequency (Hertz)
l = wavelength (feet)
c = speed of sound (1,100 ft/sec)

Since the medium (air) of the scale model experiment does not change then the speed of the sound will remain constant for the scale model experiment. Therefore, the range of frequencies used in acoustical scale modeling will be higher since the wavelength of the sound waves are smaller. Many of the frequencies may be in the ultrasonic range, which cannot be heard by the human ear.

The remaining sections of the literature review will discuss problems relating to complications encountered by other researchers in performing acoustical scale modeling experiments. The difficulties of acoustical scale modeling encountered are described in three categories; receiver, source, and propagation path. A receiver represents locations where humans inhabit the prototype, while the source represents the vehicular noise emissions along the roadway. The propagation path is the route sound travels from the source to the receiver. The following sections on propagation path, receiver, and source will describe problems encountered by previous investigators.

Propagation Path

The path between the source and the receiver poses several modeling considerations. Sound waves emitted from the source to the receiver in the scale model may not reflect prototype conditions due to anomalous air absorption, refraction, and reflection.

Anomalous Air Absorption

The commonly used wave equation shown earlier in the report is a simplified mathematical model that does consider all the factors influencing sound. Some of the variables considered to be negligible in the wave equation are viscosity, heat, diffusion, and humidity. These factors create disturbances in propagation processes which are considered as negligible in the development of the wave equation [FHWA, 1979]. However, these variables are not considered to be negligible for ultrasonic frequencies since air dissipates sound energy through the vibration-relaxation of oxygen molecules, catalyzed by water vapor in the air [Anderson, 1978]. Unfortunately, these variables cannot be scaled appropriately by the scale factor since it does not have the necessary dimensions of length. Therefore, the these factors create an "anomaly" in the propagation of sound energy since it cannot be scaled properly. The factors of viscosity, heat, diffusion, and humidity are called anomalous air absorption [FHWA 1979].

The anomalous air absorption can be considered as negligible for relatively low frequencies, short distances, and low humidity. On the other hand, high frequencies, long distances, and high humidity have high sound energy losses from anomalous air absorption.

Previous investigators have employed several methods to limit the effect of anomalous air absorption by controlling humidity. Some investigators try to lower the humidity as much as possible for the scale model experiment. The drawback of this method is the efforts to lower humidity is often performed in a specialized modeling facility, constructed at great expense [FHWA 1979].

The problem of reducing the humidity, is that the anomalous air absorption is extremely sensitive at low humidities. If the humidity at the time of the experiment is not precisely the design humidity, large difference can occur in the design absorption. Therefore, one researcher has conducted his experiments at high humidities, to avoid the sensitive characteristics of the anomalous air absorption. The results of his experiments required large correction factors [FHWA 1979].

Other methods have been used to correct the anomalous air absorption. Several experiments have been performed measuring insertion losses regarding the placement of buildings and noise barriers. The anomalous air absorption exists in sound measurements of before and after the insertion of the structure. Therefore, the anomalous air absorption cancels itself out, and the true insertion loss is measured. Unfortunately, this method is not exact. The insertion of a barrier or building will create additional reflections in a urban/suburban environment. The additional increase in the length of the propagation path increases the amount of the anomalous air absorption, however, many investigators have considered this to be negligible [FHWA 1979].

The most common method to restrict the amount of anomalous air absorption is to constrain the maximum frequency employed in the experiment [FHWA 1979]. This method involves using low scale factors and small models.

Some investigators have restricted the allowable path lengths by the use of time gates.

The experiment uses an impulsive sound source, emitting its sound in a short burst, and a receiver, recording the amount of sound energy collected over time. The investigators discarded all sound energy received after 20 milliseconds, where the anomalous air absorption can be significant. The drawback of this method is the restriction the method places on the model size. Another disadvantage is the sound energy received near the of end of the time gate has been weakened considerably by the amount of the anomalous air absorption, especially for high frequencies [FHWA 1979].

However, a majority of the investigations compensate for the anomalous air absorption by the use of correction factors. To perform this method, an impulsive source must be used in conjunction with a receiver capable of recording the sound energy in time increments. The path length can be calculated by multiplying the speed of sound by the amount of time. With the propagation distance known the anomalous air absorption correction factor can be added for the range of frequencies employed [FHWA 1979].

To account for anomalous air absorption for frequencies between 2,000 and 80,000 hertz, Delany used the following formula in his scale model [Delany 1978]:

$$a = \exp[3.67\log(f) - 5.75]$$

where: a = attenuation rate in dB/m
f = frequency in kHz

From the equation, Delany used a correction factor of 31.4 dB at 80,000 hertz at a distance of 30 feet. The scale model atmospheric conditions were restricted to 20-24 degrees Celsius and 40-60% humidity.

Detailed theoretical predictions of anomalous air absorption has been calculated at 20 degrees Celsius [Evans, 1971]. To calculate the absorption, the following parameters must be known; the distance of the propagation path, frequency of sound, humidity, and the atmospheric pressure. Charts correlating theses variables allow easy calculation of the anomalous air absorption over specified frequency ranges. These correction charts will provide a certain correction in decibels for given certain frequency at a known elevation.

Refraction

Sound waves radiating from a source can refract by a natural disturbance in the propagation path in the environment. It occurs when there is a vertical temperature and/or vertical wind velocity gradient. It is generally concluded that temperature refraction has a minimal effect, especially for indoor modeling situations and is ignored [FHWA 1979]

Refraction from a wind velocity gradient has a more pronounced effect then a temperature gradient. Generally, wind simulation is important only if diffraction is the predominant process of sound attenuation between the source and the receiver. For an urban/suburban environment where reflection and scattering dominate, simulation of the wind is not considered to be important [FHWA 1979].

Reflection

Types of reflection. There are several types of reflection to be considered in scale modeling; scattered, diffraction, and specular. Modeling these types of reflections accurately depend on the boundary shapes and the impedance of the surface material [Anderson 1978].

These conditions must be duplicated in the scale model to ensure that the various types of reflections occurring in the prototype is the same in the model.

In cases when the surface of an object is not relatively large and flat compared to the wavelength of a sound wave, scattering occurs. The sound wave upon striking a rough surface will scatter acoustical energy in all directions. The surface's irregularities, shapes, dimensions, and material's impedance have a drastic effect on the amount of scattering of a sound wave. Most investigators used sufficiently "hard" materials to model building and did not particularly worry about the effects of scatter reflection [FHWA 1979].

Diffraction occurs when sound encounters a reasonably straight edge of a large object. Sound diffracts around the surface edge and enters the shadow zone created by the large object. Provided the geometry of the model portrays the actual conditions, then no special efforts are needed to model diffraction.

Specular reflections are "mirror images" reflections. The sound wave reflects off a surface at an angle of incidence. In order for specular reflection to occur, a sound wave must reflect off a large and flat object relative to the size of the wavelength. Modeling this type of reflection must satisfy two conditions. First, the full size object must be reduced by the scale factor properly. Also, the acoustic impedance of materials must also be scaled properly. This is easy to do for acoustically hard surfaces, but rather difficult to do for absorptive surfaces.

Impedance. Impedance is a concern in selecting model ground covers. Impedance is a phoneme, which absorbs most of the energy that strikes a surface is transmitted immediately away [Anderson 1978]. This absorption can be characterized mathematically by localized characteristics of the surface only.

All materials have impedance which is measured by the reflection coefficient, C_r. Generally, if a sound wave experiences a specular reflection the impedance of the surface is what distinguishes the reflected wave from the incident wave, apart from the change in direction. The formula for the reflection coefficient, C_r is as follows:

$$C_r = \frac{Z\cos(A) - pc}{Z\cos(A) + pc}$$

where:
Z = Normal acoustic impedance
A = Angle of incidence of incoming wave (from normal)
p = Density of Air
c = Speed of Sound

Impedance is a complex quantity that is a function of frequency for any given reflective material. Since "A", "p", and "c" are constant, then "Z" would have to change upon scaling if the prototype material was retained [Anderson 1978]. The relationship that must exist for materials is:

$$Z_{prototype}(frequency) = Z_{model}(scaled frequency)$$

Past researchers have chosen several combinations of materials that were shown to provide proper reflective impedances upon scaling. It is accepted that modeling acoustically hard surfaces is easier than soft surfaces [FHWA 1979].

<u>Hard Surface.</u> Reflection from hard surfaces such as roads and buildings do not alter the phase of the sound waves or absorb any significant amount of energy. Therefore, the model surface must also be sufficiently hard for ultrasonic frequencies. Also, the general

practice is to ignore the impedance for hard surfaces completely, and try to minimize the absorptive capability of the surface [FHWA 1979].

Wood is often used in acoustical scale models as a hard surface. A good quality plywood lacking in core voids and plug, filled and sanded to an APA finish of "A" or "B" can provide good performance and finishibility. However, unpainted wood and concrete have minute fissures and pores which can easily absorb sound energy from ultrasonic frequencies [Day 1975]. Therefore, paint and lacquer is often used as a surface treatment for wood or concrete to replicate hard surfaces in acoustical scale models [Hegvold 1971]. Also the use of solid wood to represent man made structures is recommended to prevent transmission of sound energy through the model structure.

Other researchers have tried materials other than wood to model hard surfaces. Plexiglass is an ideal choice but is costly and requires special tooling needs. Another choice is acoustically hard vinyl used by May [1980]. FHWA [1979] states 0.5 mm sheet aluminum, 2.5 cm composition board, and a newly waxed vinyl composition laboratory floor have been used to replicate a hard surface for the scale model.

Soft Surface. Reflection from absorptive materials is a more complicated task to scale model. Grass is the most common absorptive surface in the outdoors. This is not a critical problem in an urban environment where high-rise buildings often dominate the landscape. However, modeling soft surfaces can cause problems for rural and suburban environments where grass is rather common.

Delaney uses a novel approach to model absorptive materials through the use of this equation.

$$\frac{f}{R_f n} = 10^5 m^3/kg$$

where: f = frequency
R_f = flow resistance
n = porosity

The use of the equation dictates any type of material is acceptable to use provided the quantity of the flow resistance, porosity, and scale factor, is equal to the original material in the prototype.

There are several materials that are used to model soft surfaces. A common material to model grassland is Deciban, covered with cotton velveteen [Ivey 1976]. Another material used to resemble the acoustic properties of grass is 1" extruded polystyrene (Type RM manufactured by Dow Chemical) with light tissue paper glued to its surface is an excellent match at a scale factor of 80 [Jones 1976]. Fiberboard was used by May [1980] to model a soft surface. Hayek [1990] used "outdoor carpet simulating grass" for a scale factor of 5.

Modeling The Receiver

A receiver will be placed at various locations in the scale model to simulate sensitive locations that people inhabit in the prototype. These locations will be occupied by a microphone which will receive sound energy from the source after traveling the various propagation paths.

The microphones can not be scaled properly since the smallest commercially sized microphones is 0.25 inches [FHWA, 1979]. With medium and large scale factors, the microphone becomes enlarged relative to the surrounding model.

The characteristics of the microphone must be known so other portions of the experiment can take these factors into consideration. The characteristics to be considered are the frequency response, sound energy sensitivity, and proper circuitry to record sound energy over a period of time. Also, the microphone results of the sound energy must be altered to account for directional response, anomalous air absorption, convert source emissions to traffic emissions, and conversion of band width to A-level.

Characteristics of the Microphone

Each microphone has a range of frequencies which it can "hear". Above the top end of this range, the microphone cuts off and essentially no signal is detected. Microphones used in scale modeling should have a flat frequency response for the frequencies being employed in the experiment. Using frequencies near the upper limit of the microphone capabilities may produce results indicting a higher signal than actually present. This occurs since the high frequency resonance within in the microphone results in a non-flat response. Therefore, the microphone's upper limit for flat response should determine the maximum frequency employed in the scale model [FHWA, 1979]

With the decreasing size of the microphone, larger amounts of sound energy is required to "hear". To compensate for the reduced signal from the small microphones, some investigators used special noise amplifiers to increase the signal. However, the most common method to resolve this difficultly is to increase the amount of sound energy emitted at the source [FHWA 1979].

Microphones are also sensitive to the direction of received sound energy. The directional characteristics of microphones is measured in terms of on-axis and off-axis frequency response. On-axis refers to a direction perpendicular to the diaphragm of the microphone. Microphones also experience off-axis frequency response. The off-axis response is referred to as the "directionality" of the microphone and is normally plotted as the deviation from the on-axis response mentioned above. Off axis response can introduce large error in the received sound level at the microphone.

Directionality can be very high for small microphones receiving high range frequencies. If sound energy is coming from a known direction, then the received signal can be corrected easily because the off-axis response is directly known from the microphone characteristics. If sound energy comes from many directions at the same time such as a suburban/urban environment, then the microphone must be able to receive signals with very little off-axis response [FHWA, 1979]. Absolute minimum directionality is required in acoustical scale modeling.

To reduce the directionality of microphones several techniques have been employed.

Many researchers have used nose cones adapters to reduce microphone directionality. Also, the protective grid have been removed from the face of the microphone since sound can reflect and diffract upon the protective grid prior to reaching the diaphragm. Another method to decrease the directionality of the microphone is to mount the microphone flush with the surface.

If the scale model experiment is to use time gates, proper instrumentation at the end of the microphone is required to record the amount of sound energy received over a period of time. The signal processing equipment will be composed of a preamplifier, filters, oscilloscope, plotter, and data analyzer. All of the signal processing equipment must have the same flat response at high frequencies as the microphone and emit low noise levels as mentioned above.

Alterations to the Microphone Recordings

Adjustments to the microphone recordings have to account for anomalous air absorption, conversion of source emissions to traffic emissions, and conversion of band-width frequencies to A-level. To correct for anomalous air absorption, the recordings of sound energy from the microphone have to be increased appropriately, for the frequencies and path length. The source employed in the experiment will emit sound energy over a broad band of frequencies, which will normally not duplicate traffic emissions. Therefore, the frequencies received at the microphone have to be adjusted to reflect the expected traffic emissions. The last adjustment to be made is to convert the band-width energy to A-level. This is performed to study the human response of the traffic noise levels on the impacted population [FHWA 1979].

These adjustments can be made by two methods. First, proper instrumentation at the end of the microphone can be used to perform the numerous calculations for the investigator. The second is through the use of spreadsheets to reduce the numerous calculations performed.

Modeling The Source

The sound source imposes the least restrictions on the scale model. Impulsive and continuous sources may be used in the experiment. The impulsive source discharges a short burst of sound. The use of time gates requires the use of an impulsive source so the receiver may record the energy and the determination of the path length of the reflections. Continuous sources transmits sound energy without interruption. Therefore, the sound energy at the receiver is constant from being renewed by the continuous source [FHWA 1979].

Properly modeled sources should travel along the traffic path at the approximate scaled speeds, emit the scaled acoustical impulses in the atmosphere which require exactly working parts except in miniature, and emit the acoustical sound in the same time and direction patterns [Anderson 1978]. This is highly impractical, if possible at all. To replicate the traffic noise emissions to the best possible manner three types of sources are commonly employed; air jet, speakers (horns), and an intense spark.

Types of Sources

Air jet sources generate noise by creating extremely turbulent air currents inside a tube generating loud noises over a broad band of frequencies. A source of this type is continuous in nature [FHWA, 1979]. Since the acoustical scale model will be using time gates, air jets will not be given further consideration for this experiment.

Speakers and horns are mostly used as continuous sources. However, with the proper impulsive electrical input, speaker and horns can be converted to impulsive sources [FHWA 1979].

Spark sources have two electrodes with a voltage difference which create a spark. An electrical spark ionizes the air in the gap between the two electrodes and generates an intense, impulsive loud spark. This spark typically produces a broad band of frequencies. Spark sources have been used by many investigators in past highway noise modeling experiments [FHWA, 1979].

Intense Source

The use of an intense source as a model source can create a non-linear dispersion of sound energy to the receiver. A high intensity source can create an abrupt pressure pulse which begins to propagate outward from the source, followed by an abrupt pressure refraction. A shock wave forms due to this behavior [FHWA, 1979].

The non-linear behavior of sound dispersion from intense sources occurs since sound travels faster in areas of acoustic compression instead of the areas of acoustic rarefaction. The leading front of the sound waves compress the still air as the sound propagates. The sound energy behind the leading edge travels faster than the normal speed of sound in the compressed air created by the leading front. Within microseconds, the sound energy traveling behind the leading front intercepts the leading edge and becomes a part of it. This occurrence is the creation of the sound shock wave. The high energy frequency is extracted from the propagating wave when the shock wave forms. The shock front does not completely, dissipate as it propagates, it continues to reform itself, in spite of the high frequency energy dissipation. The sound speed phenomena that caused the shock to form also causes the reformation of the shock wave. In order for the shock wave to preserve its shape, energy is transferred from low to high frequencies. The replenishment of high frequency energy helps offset the high frequency dissipation.

The sound level peaks as the sound is received, than falls below the normal dispersion rate and than levels out to a linear dispersion. The sound dissipates below the linear rate after the shock wave since the sound that should have been hear traveled faster than the normal speed of sound and created the shock wave [FHWA 1979].

The shock wave is fully formed within a centimeter and can extend to several yards depending upon the amplitude of sound emitted from the source [FHWA 1979].

Characteristics of Sources

The spectrum of frequencies to be employed in the acoustical scale model is the traffic noise frequencies multiplied by the scale factor. Pure tones are not used in scale modeling since localized distortions can occur in the model which are not present in the prototype. The source does not need to model the proper amplitude of each frequency since this can be corrected at the receiver, but must have sufficient band width to provide data over the full frequency in the range of the traffic spectrum. Therefore, several octaves must be provided to capture most of the A-level of the prototype spectra [Anderson, 1978]. Therefore, broad band frequencies are employed. A few investigators have used 1/3 band widths, however most use full band widths frequencies. Below is the chart for the range of frequencies within a full and 1/3 octaves.

Octave	Low Frequency	High Frequency
31.5	23.63	47.25
63.0	47.25	94.00

125.0	94.00	187.50
250.0	187.50	375.00
500.0	375.00	750.00
1000.0	750.00	1500.00
2000.0	1500.00	3000.00
4000.0	3000.00	6000.00
8000.0	6000.00	12000.00

1/3 Octave	Low Frequency	High Frequency
27.50	23.50	29.50
31.50	29.50	35.44
39.38	35.44	47.25
55.13	47.25	59.06
63.00	59.06	70.75
78.50	70.75	94.00
109.50	94.00	117.25
125.00	117.25	140.63
156.25	140.63	187.50
218.75	187.50	234.38
250.00	234.38	281.25
312.50	281.25	375.00
437.50	375.00	468.75
500.00	468.75	562.00
625.00	562.00	750.00
875.00	750.00	937.50
1000.00	937.50	1125.00
1250.00	1125.00	1500.00
1750.00	1500.00	1875.00
2000.00	1875.00	2250.00
2500.00	2250.00	3000.00
3500.00	3000.00	3750.00
4000.00	3750.00	4500.00
5000.00	4500.00	6000.00
7000.00	6000.00	7500.00
8000.00	7500.00	9000.00

Speaker and spark sources can generate a broad band of frequencies with fairly equal amounts of energy are spark sources [FHWA 1979]. The sources do not have to replicate traffic noise emissions, since amount of frequencies will be adjusted to reflect the traffic emission after the receiver has recorded the sound energy through the use of filters [FHWA, 1979].

Prototype sources, vehicles, are typically non-directional within $\pm$ 3 dB. In acoustical scale modeling, this limited directionality may be considered as negligible. Speaker and horns are directional sources while sparks sources are the least directional point sources [FHWA 1979].

The sources have to be able to generate considerable amounts of acoustical energy to be received by the microphone. The source must produce a signal to overcome background noise, electronic noise, anomalous air absorption, and attenuation by structures. Spark sources are capable of generating up to 120 dB, while speakers and horns are limited due to their small size [FHWA 1979].

The impedance of the sources must also be considered acoustical scale modeling. The potential problem lies in the fact that the extreme pressure levels close to the source may interact non-linearly with the model ground surface [Anderson 1978]. The prototype sources are elevated above the roadway and are not affected by nearby surfaces due to their high impedance. Speaker and horn sources have low impedance and the power output generated is dramatically affected by nearby surfaces which can be reflect energy back to the speaker or horn. Spark sources, on the other hand, have high impedance and nearby surfaces have very little affect on the amount of power output [FHWA 1979].

The source position has been modeled at an effective height of zero (0.0) for automobiles and medium trucks and for heavy trucks approximately 8.2 feet [FHWA, 1979]. Most researchers have shown little concern over source height and modeled the source at near zero height or actually embedded the source in the roadway. Some researchers have also neglected the horizontal "lane to lane" placement of the source, choosing to model only one lane of traffic on the roadway. Other concerns when modeling the source are related to the horizontal position along the roadway plus vehicle motion. The movement of vehicles along the roadway, at constant speed, integrates to a legitimate incoherent line source [Hayek, 1990].

Other Scale Model Procedures

Unwanted Reflections

Large laboratory rooms are difficult to achieve anechoic conditions for the model testing since the walls often reflect some acoustical energy back into the model. Past researchers have relaxed this modeling requirement by attaching fiberglass insulation to these unwanted reflection areas to minimize their effect [FHWA, 1979]. The use of time gates can also exclude any unwanted reflections. However, this method places a restriction on the length of reflected paths within the model.

Reference Methods

There are two reference methods employed in acoustical scale modeling for highway noise. The first method is placing a microphone near the source to act as the reference point, and other microphones at receiver locations so that the propagation path loss between the source and the receiver can be tabulated [FHWA 1979].

The second method is a direct measure of the insertion loss of a noise barrier. A scale model is constructed without the noise barrier and tested for acoustical performance with microphones and sources. Then, the noise barrier is constructed into the model and tested for acoustical performance with the microphones and sources. The difference between the two models is the direct insertion loss due to the noise barrier [FHWA 1979].

Conversion of a Point Source to a Line Source

The unit of measure for actual highway noise tests is l_{eq} since it is the time average of sound energy. So throughout the noise measurements of the scale model, equivalent l_{eq} levels are recorded. Each vehicle on a straight highway is a perfect line source since it continually emits the same amount of noise provided the vehicle travels at a constant speed.

However, for an acoustical scale model, point sources must replicate the highway, a line source. The common practice of most investigators is to model the roadway as six times the length of the distance from the receiver to the line source. This maintains the 3 dB per doubling distance (3 dB/dd) [FHWA 1979].

The mathematical models stipulate the point sources can be spaced three times as far as the closest receiver in order to replicate the line source. However, many investigators model the sources much closer, generally less then 10 - 30 cm [FHWA 1979].

Measure of Success

Most investigators analyze their results using statistics. Scale models are generally successful for complex modeling scenarios because there is not currently a proper mathematical method which exists to predict noise levels.

In every case, the acoustical scale model test will not be known to be a success or failure until the full size prototype has been built to allow comparison of actual noise levels and predicted noise levels. Some investigators have used a correlation coefficient of 0.9 or better to measure success. However, most investigators declare success when results for simple scale models are within 3 dB broad band and within 7 dB for single bands. Complex suburban and urban geometries often produce scale models within 4-5 dB of the full size prototype [FHWA 1979].

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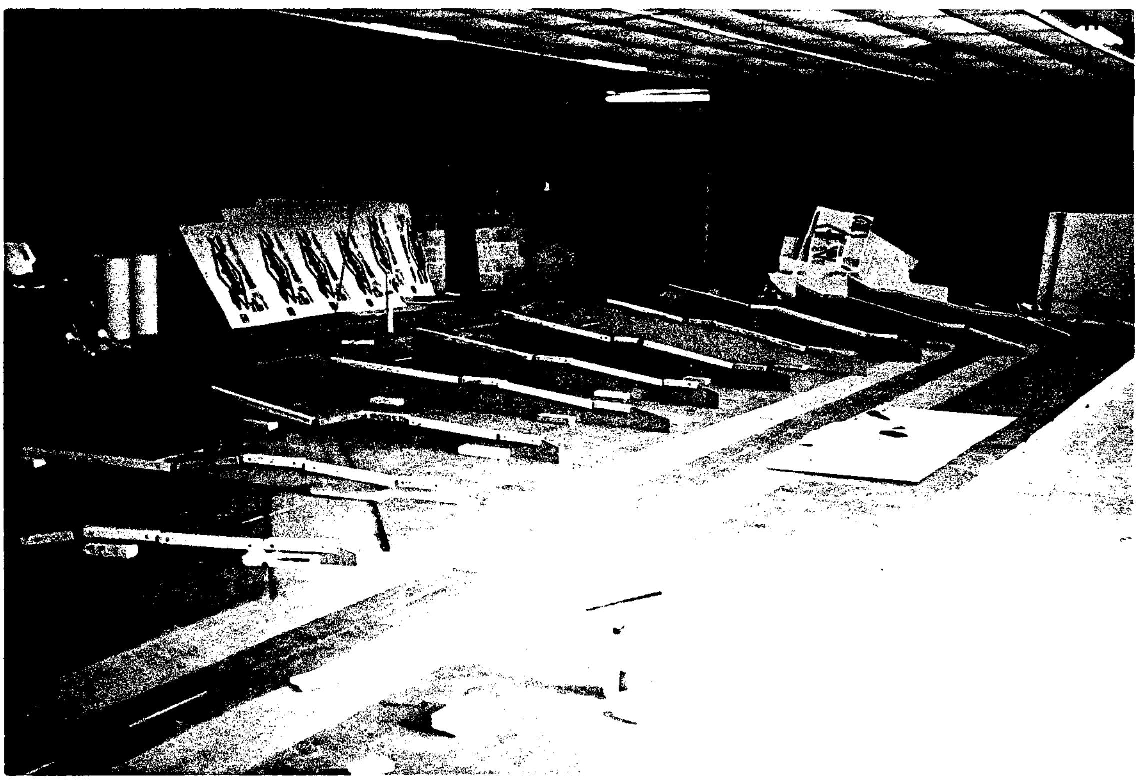
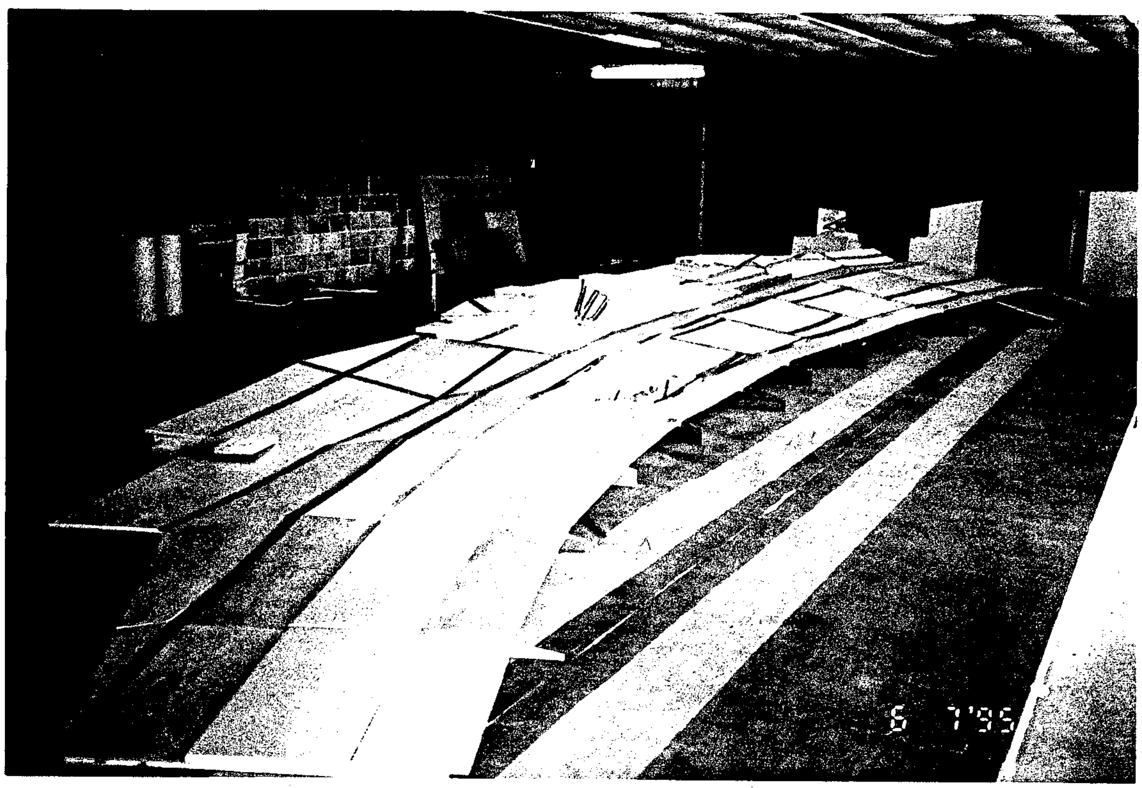
APPENDIX F

PHASE III PROJECT PHOTOGRAPHS

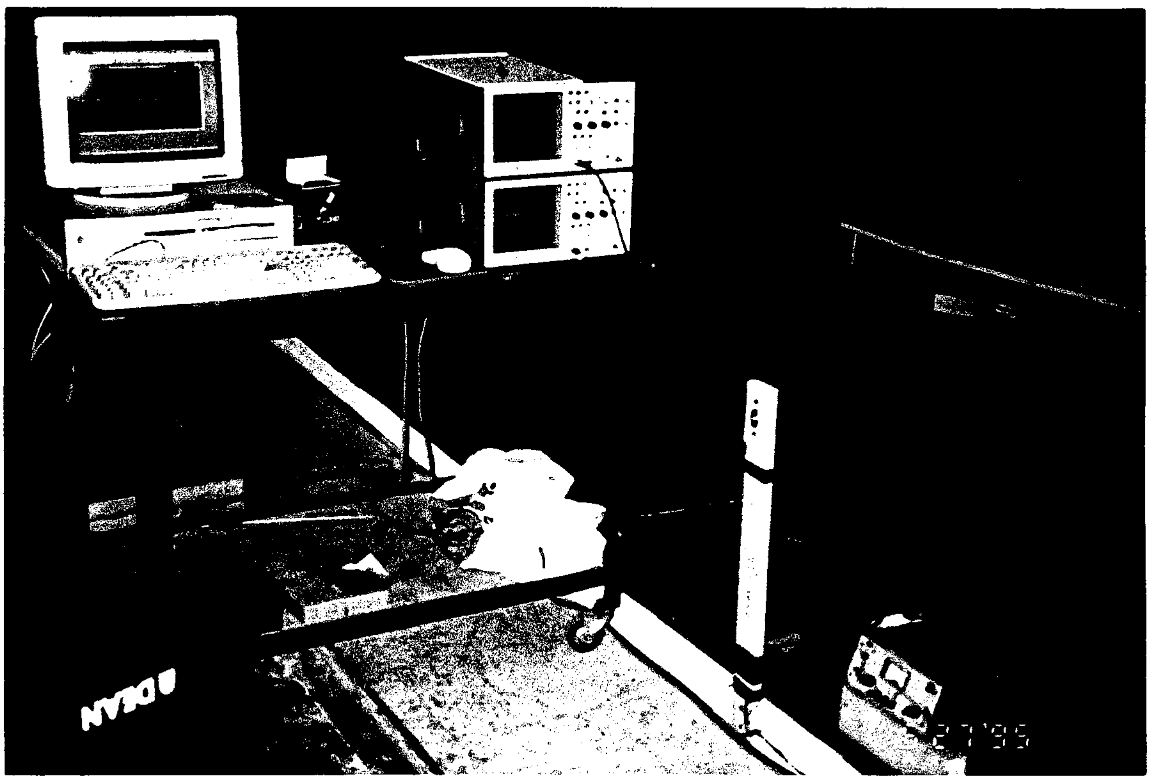
Photograph No. 1 - Base Testing Platform



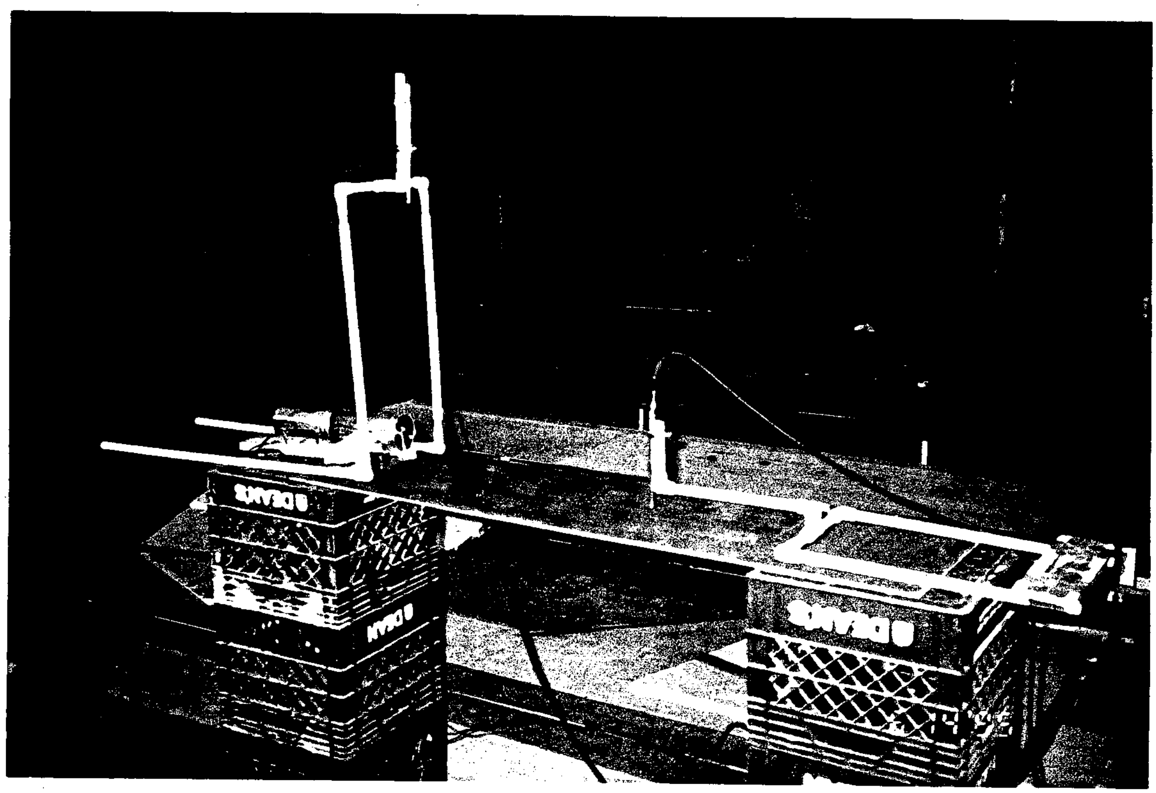
Photograph No. 2 - Layout of Model Cross Sections (Fourth Ave.)



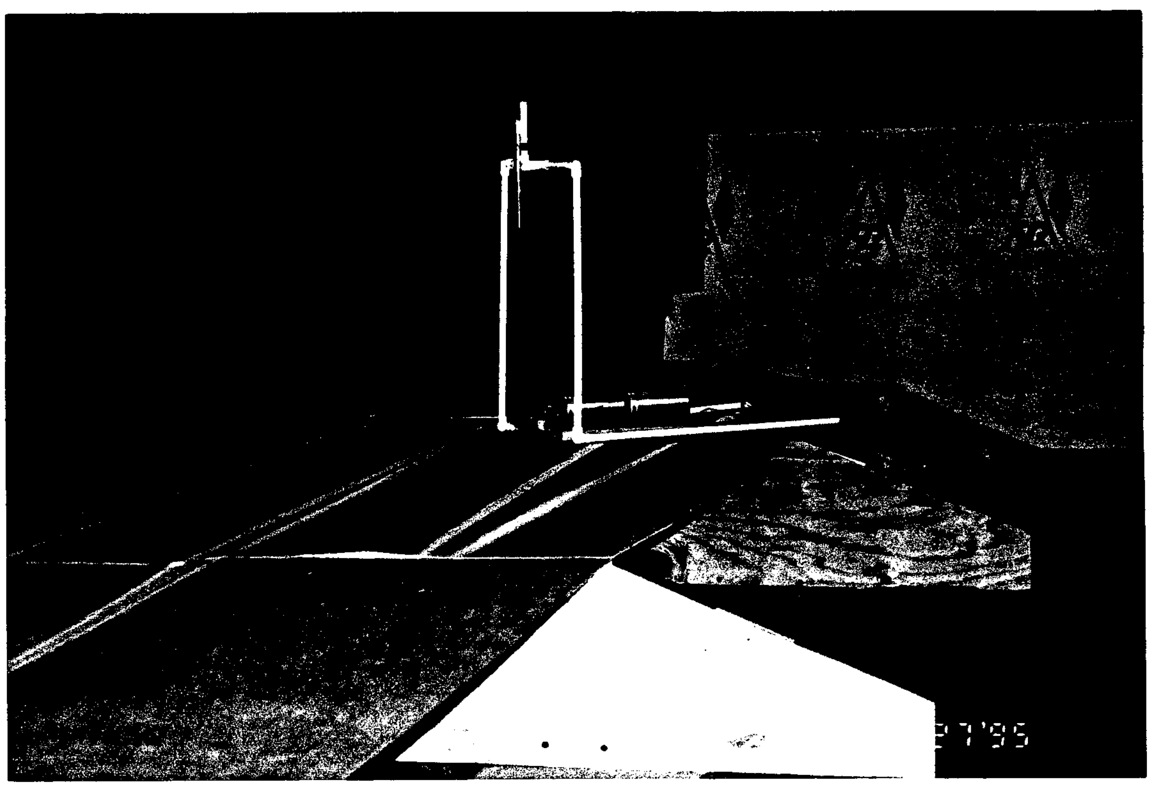
Photograph No. 3 - Hard/Soft Surface Cover Panels on Cross Sections



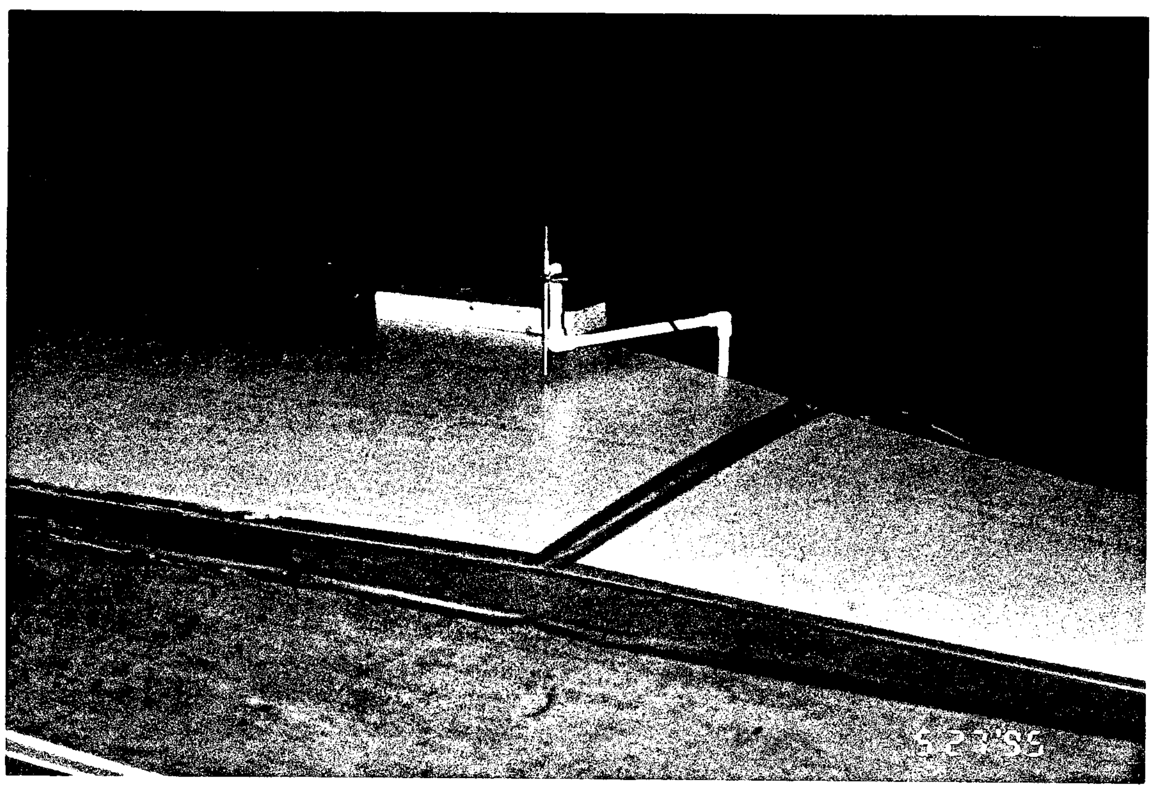
Photograph No. 4 - Desktop Computer and Oscilloscopes



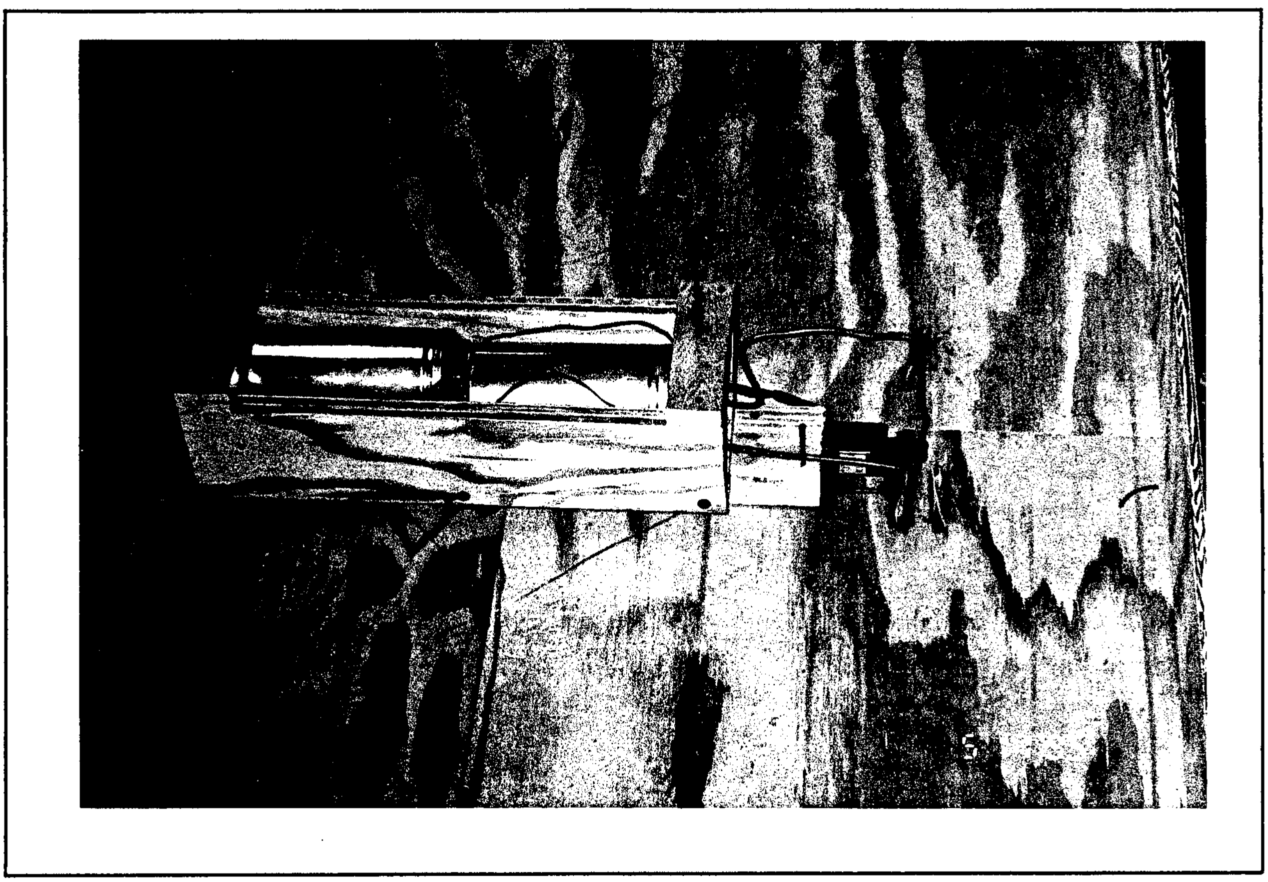
Photograph No. 5 - Microphone Assemblies



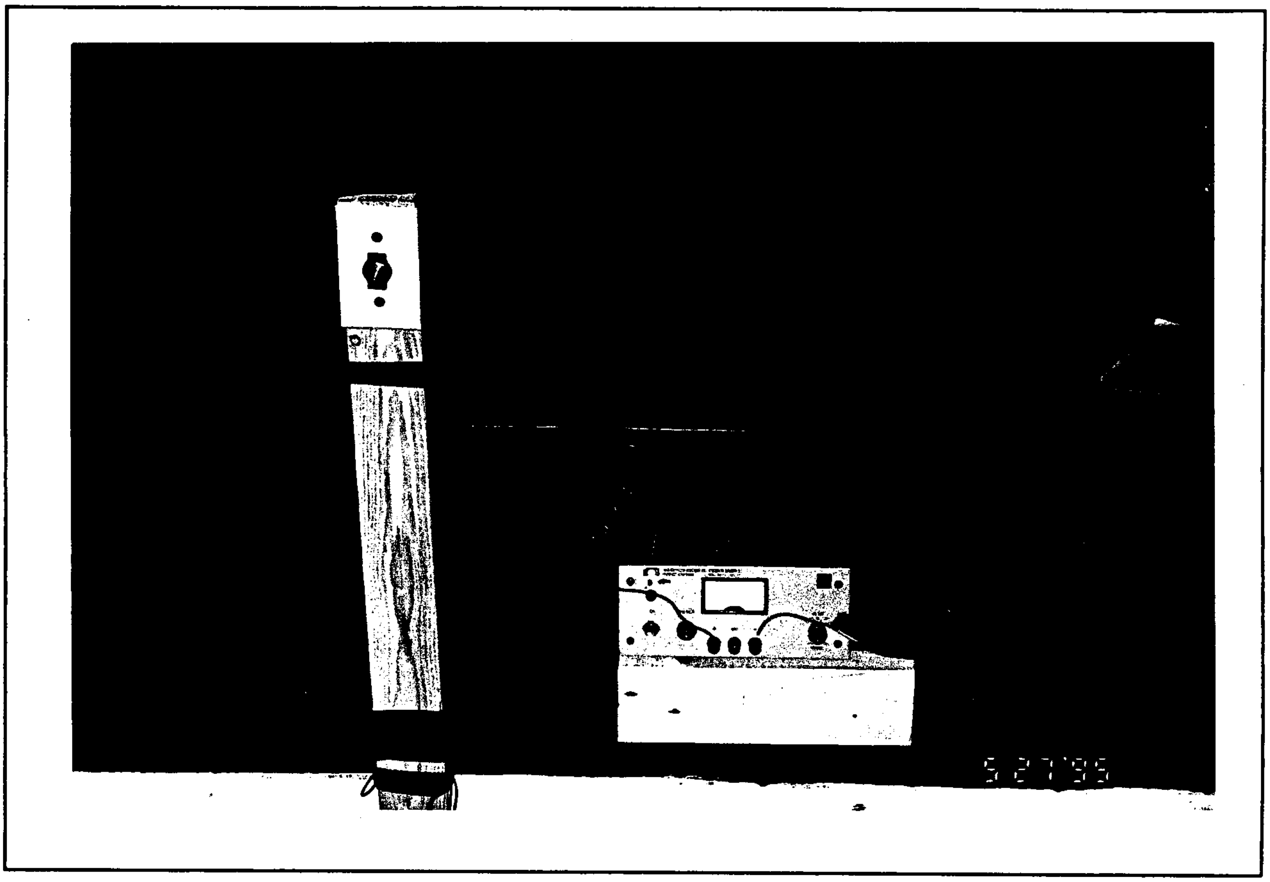
Photograph No. 6 - Source Microphone Assembly



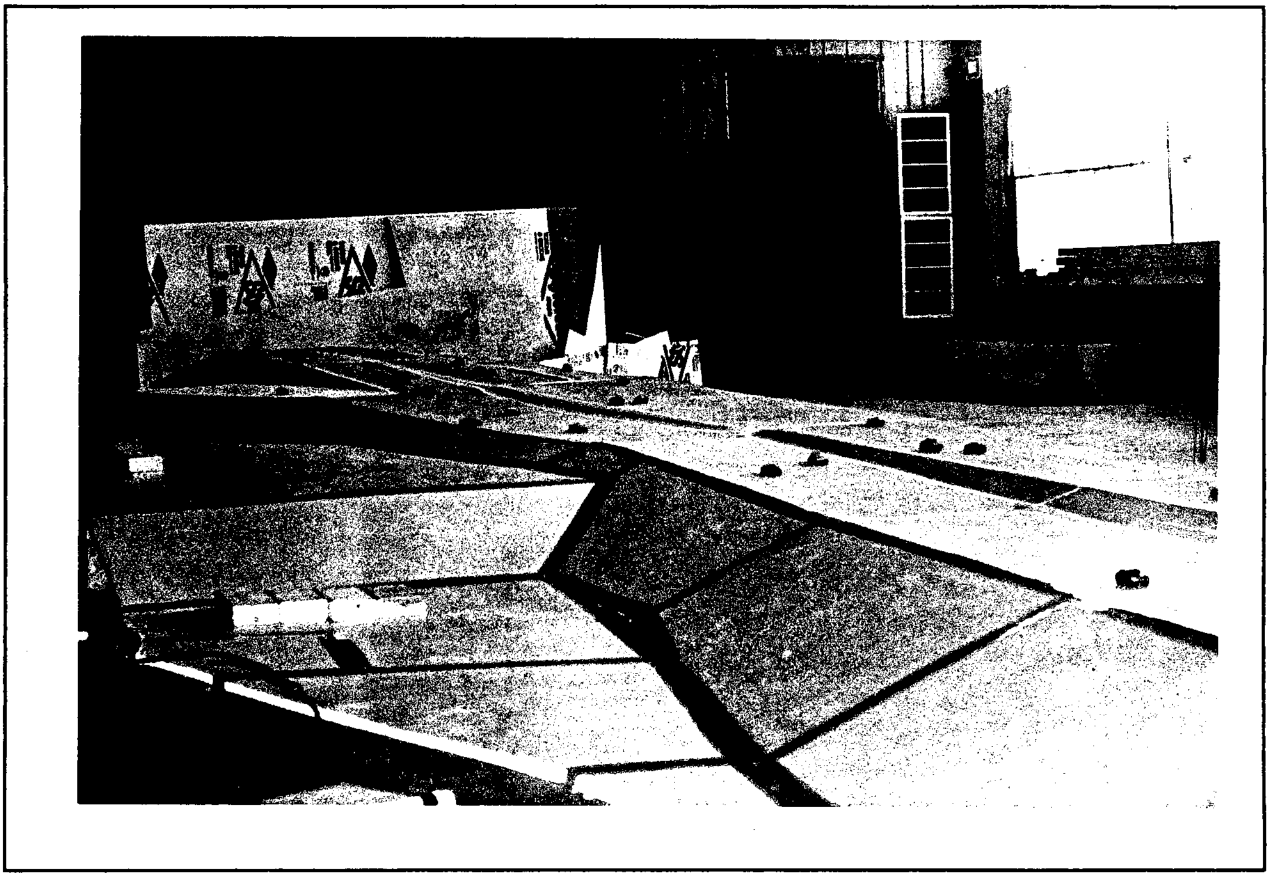
Photograph no. 7 - Receiver Microphone Assembly



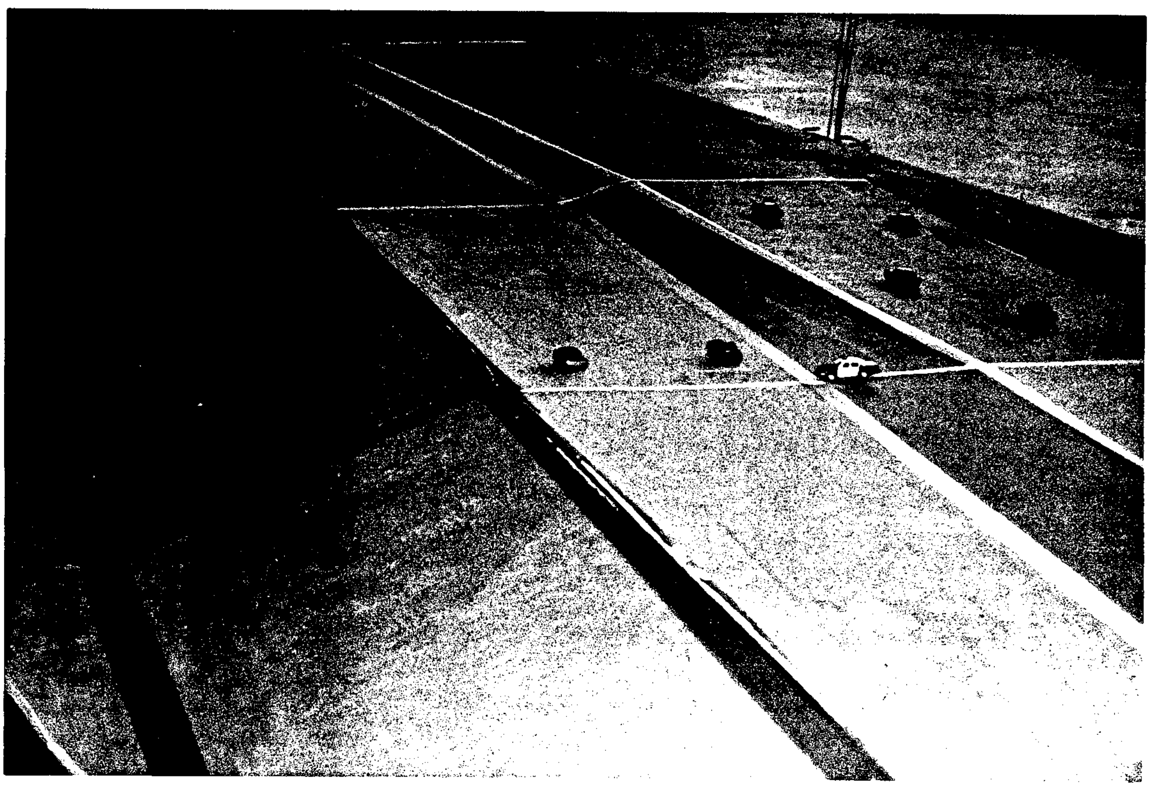
Photograph No. 8 - Charging Capacitor/Source Spark Assembly



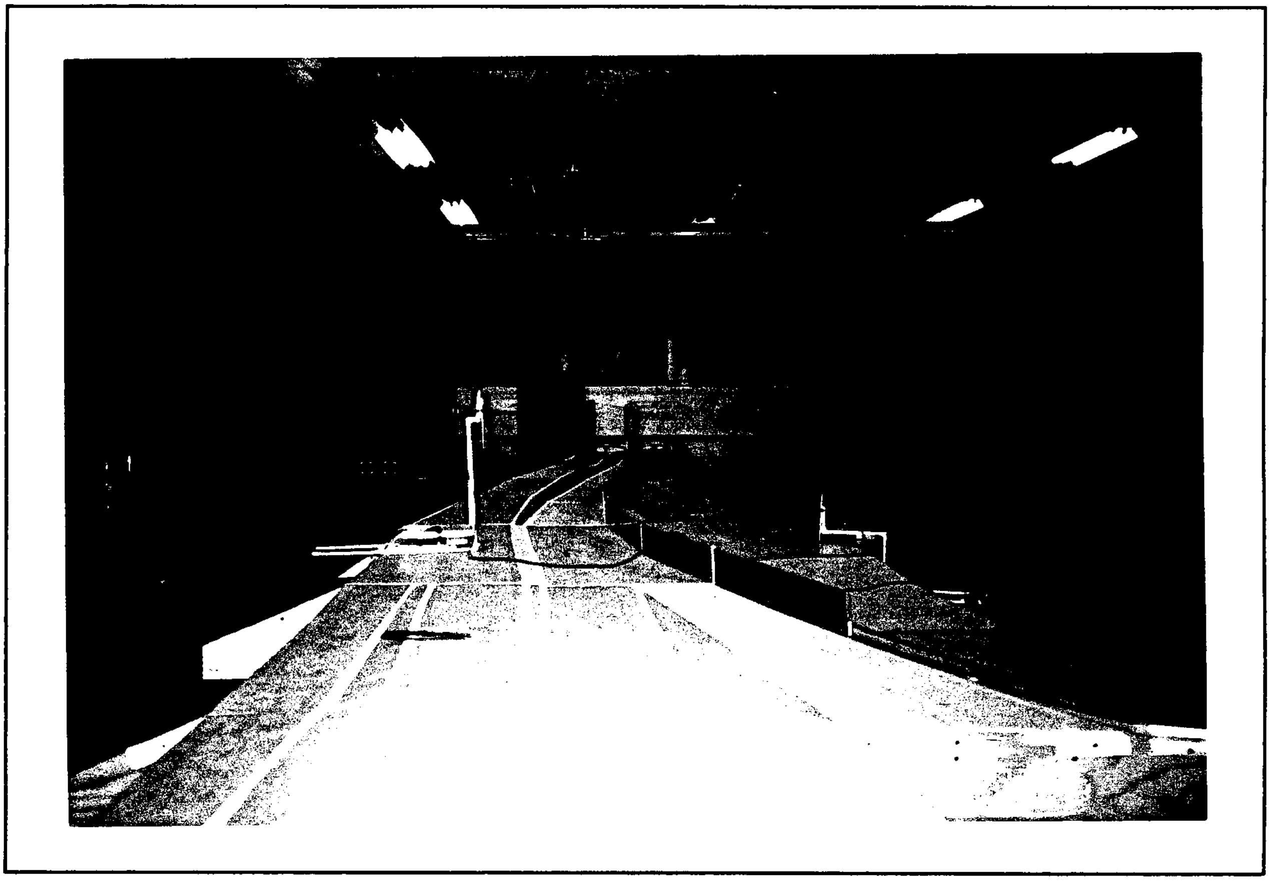
Photograph No. 9 - Spark Source Power Supply



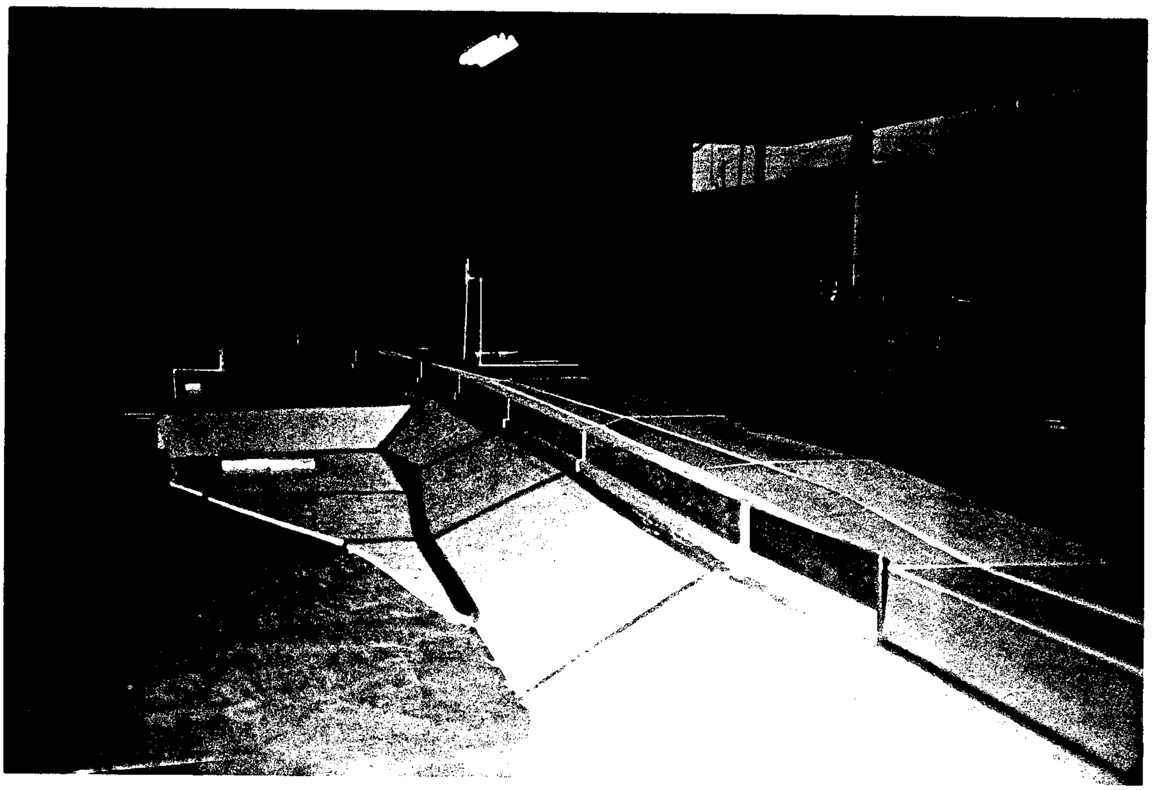
Photograph No. 10 - Magnolia Road Model (No Barrier)



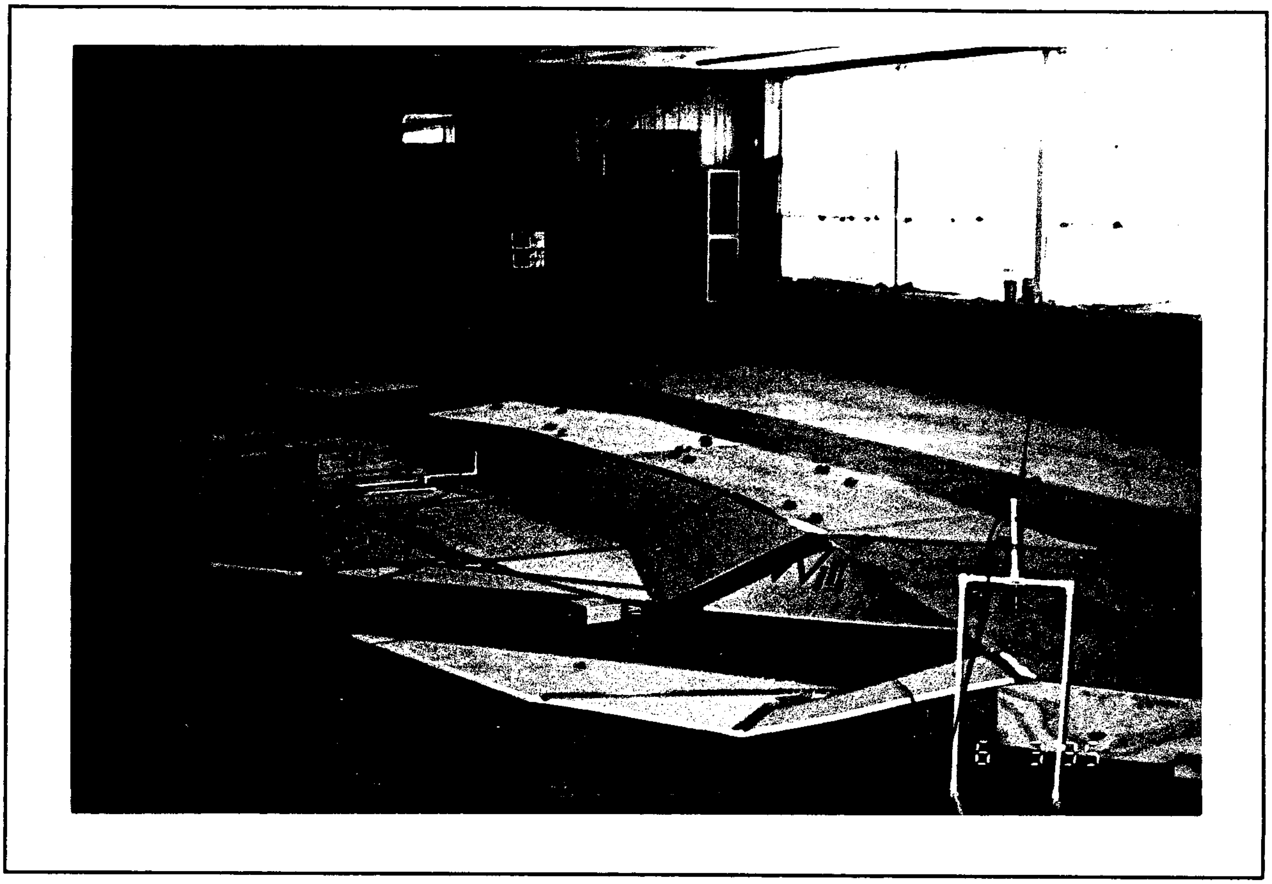
Photograph No. 11 - Magnolia Road Model (No Barrier)



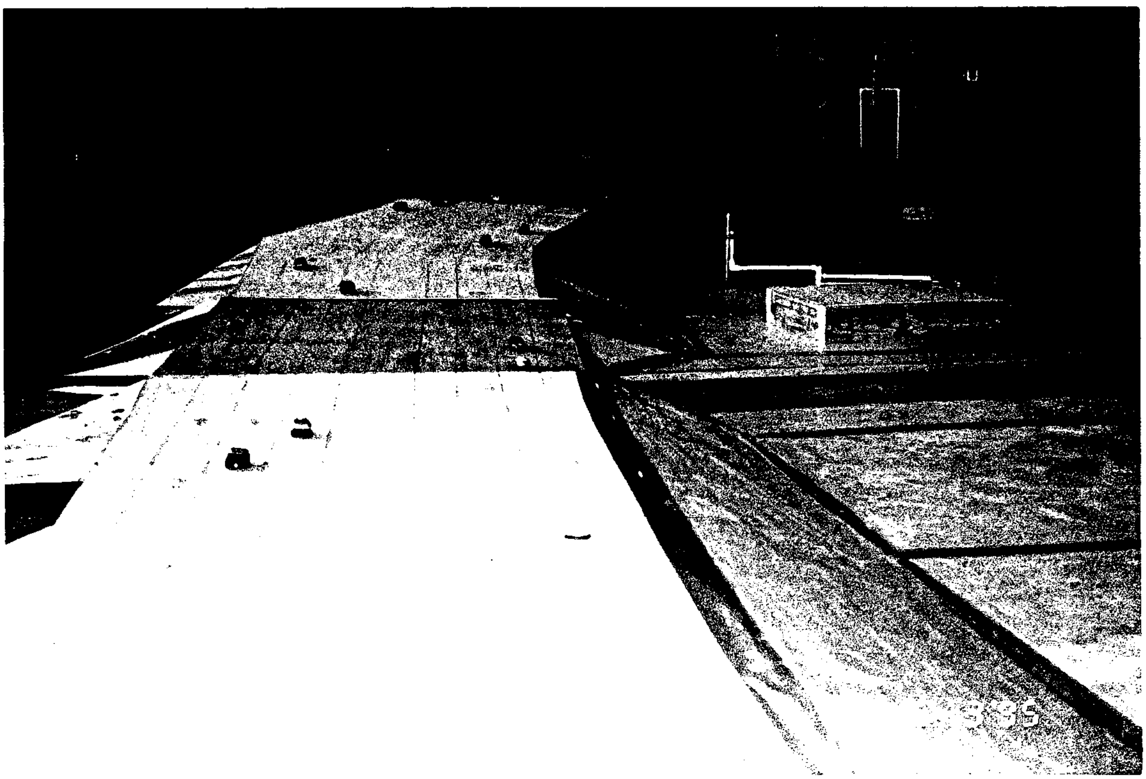
Photograph No. 12 - Magnolia Road Model (20' Conventional Barrier)



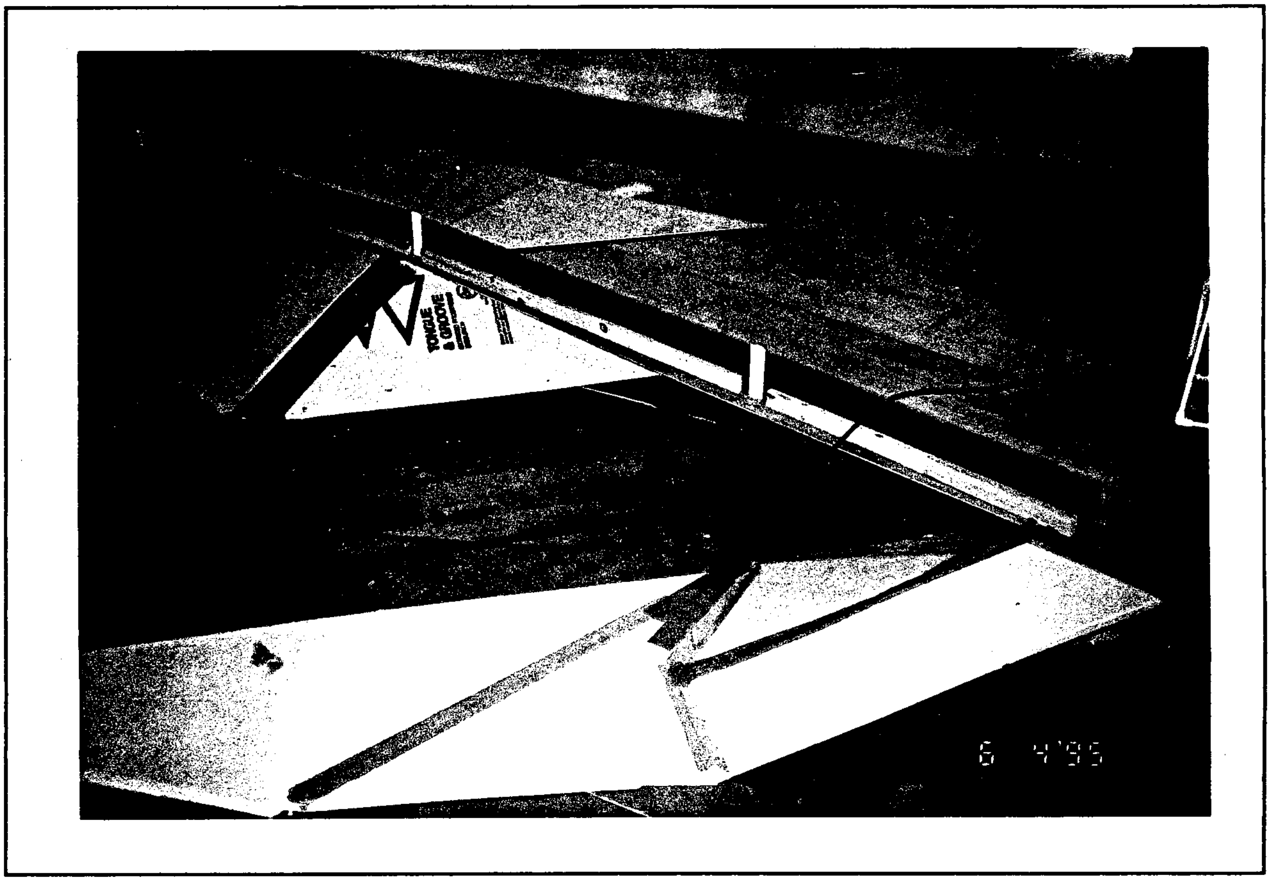
Photograph No. 13 - Magnolia Road Model (20' Conventional Barrier)



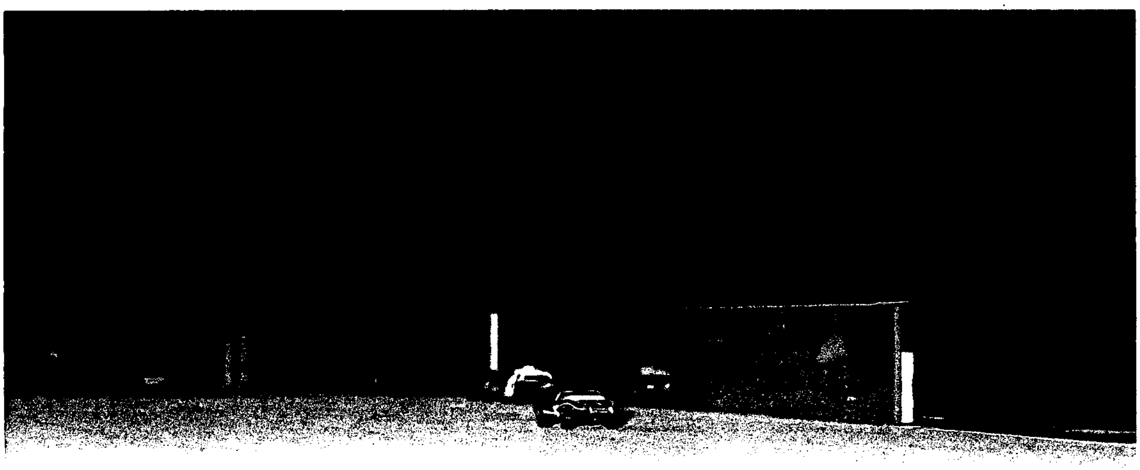
Photograph No. 14 - Kent Commons Model (No Barrier)



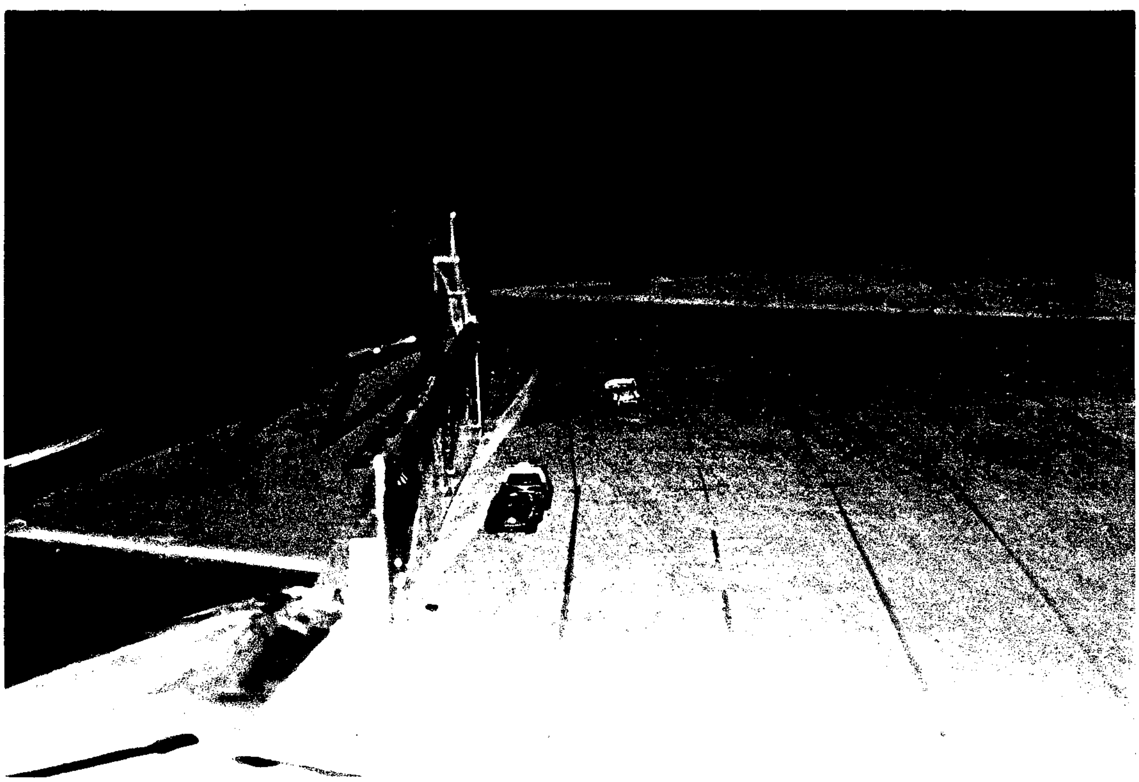
Photograph No. 15 - Kent Commons Model (No Barrier)



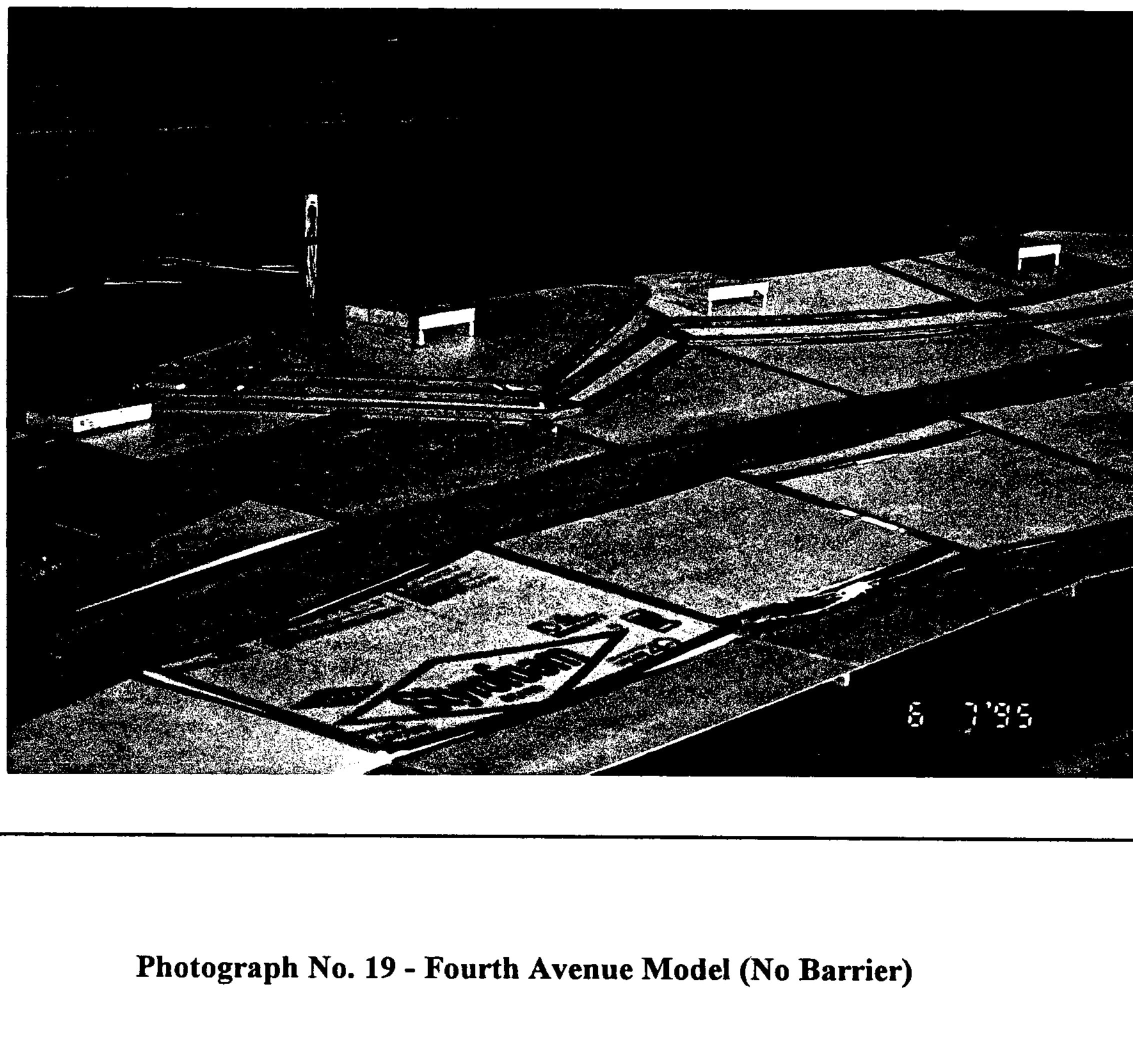
Photograph No. 16 - Kent Commons Model (19' Conventional Barrier)



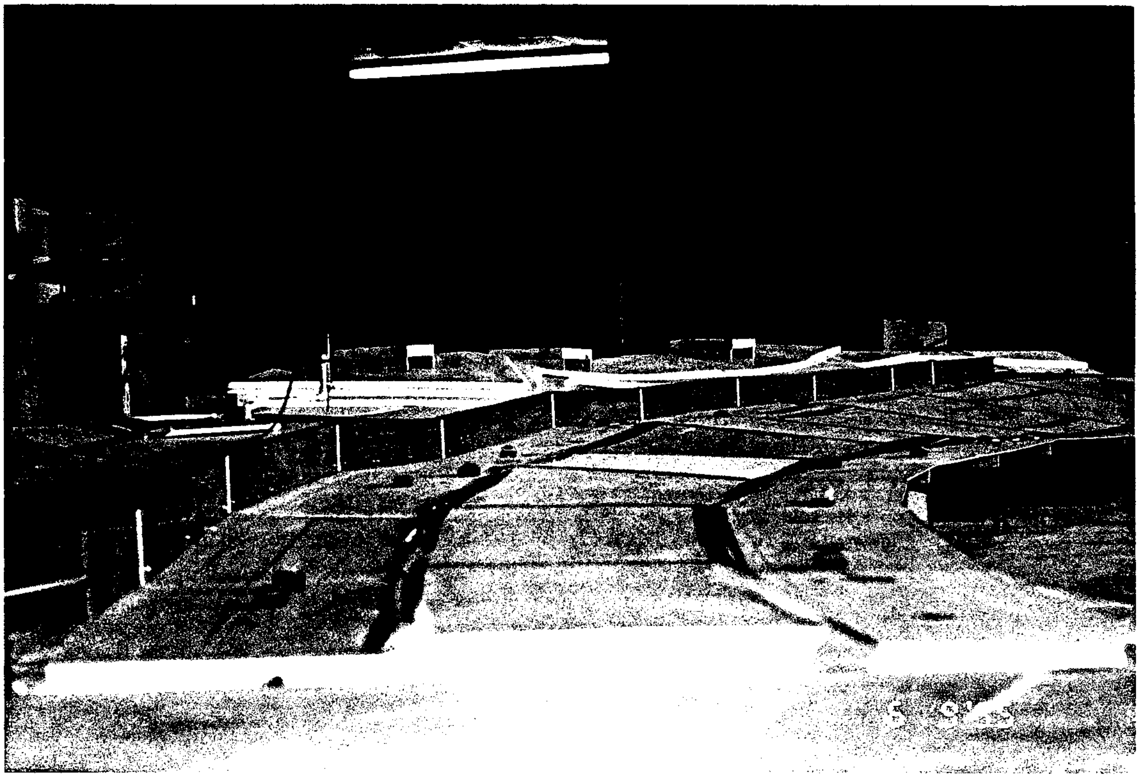
Photograph No. 17 - Kent Commons Model (11' Absorptive T-top Barrier)



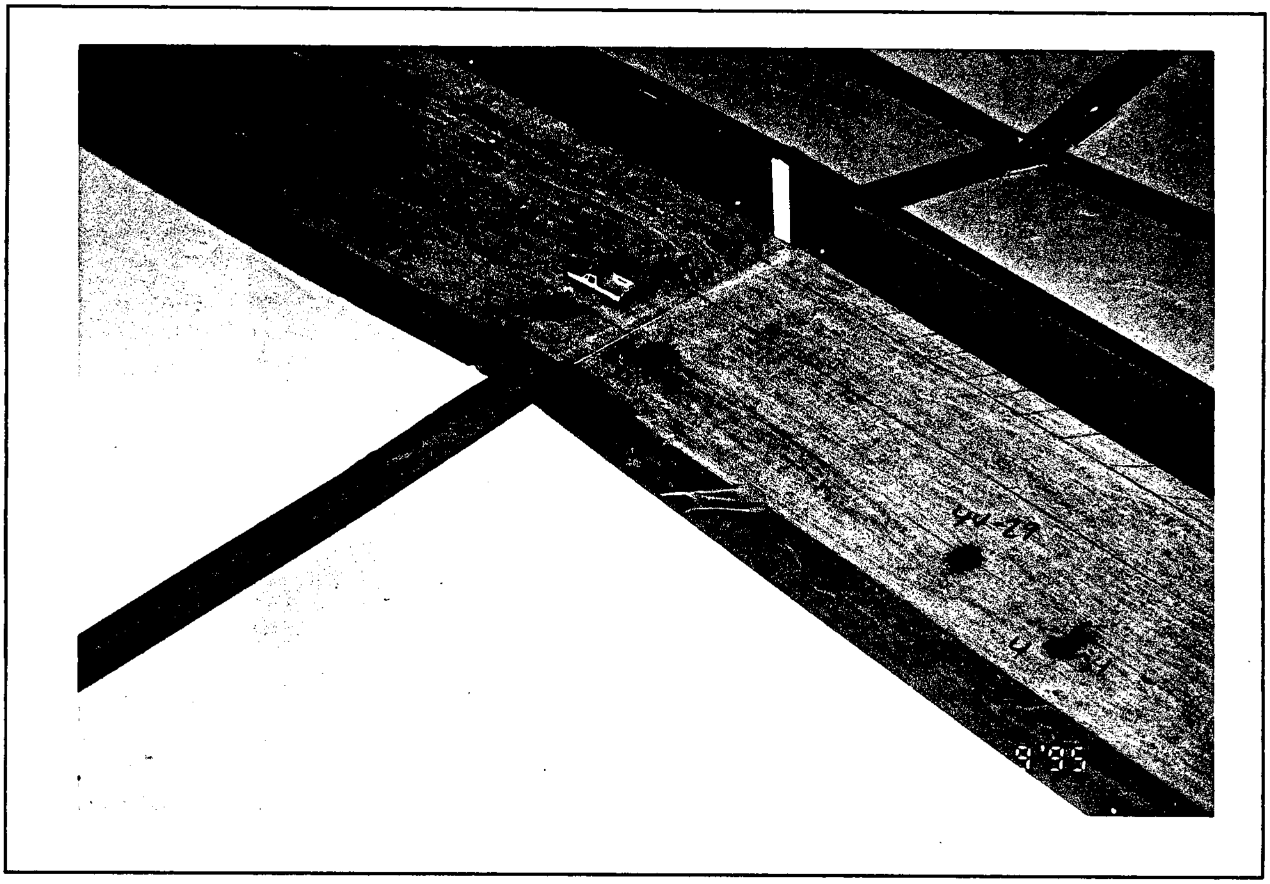
Photograph No. 18 - Kent Commons Model (14' Single Wall Absorptive)



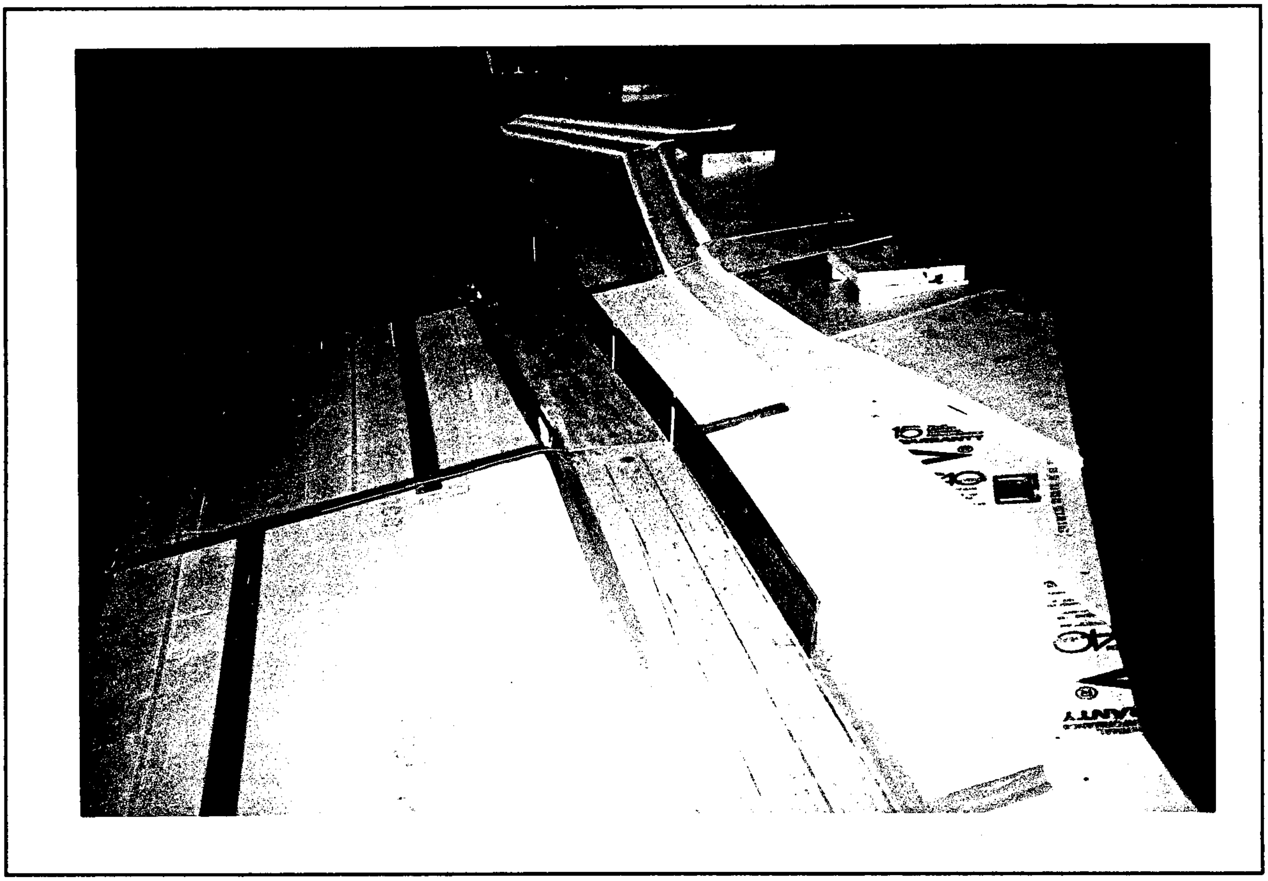
Photograph No. 19 - Fourth Avenue Model (No Barrier)



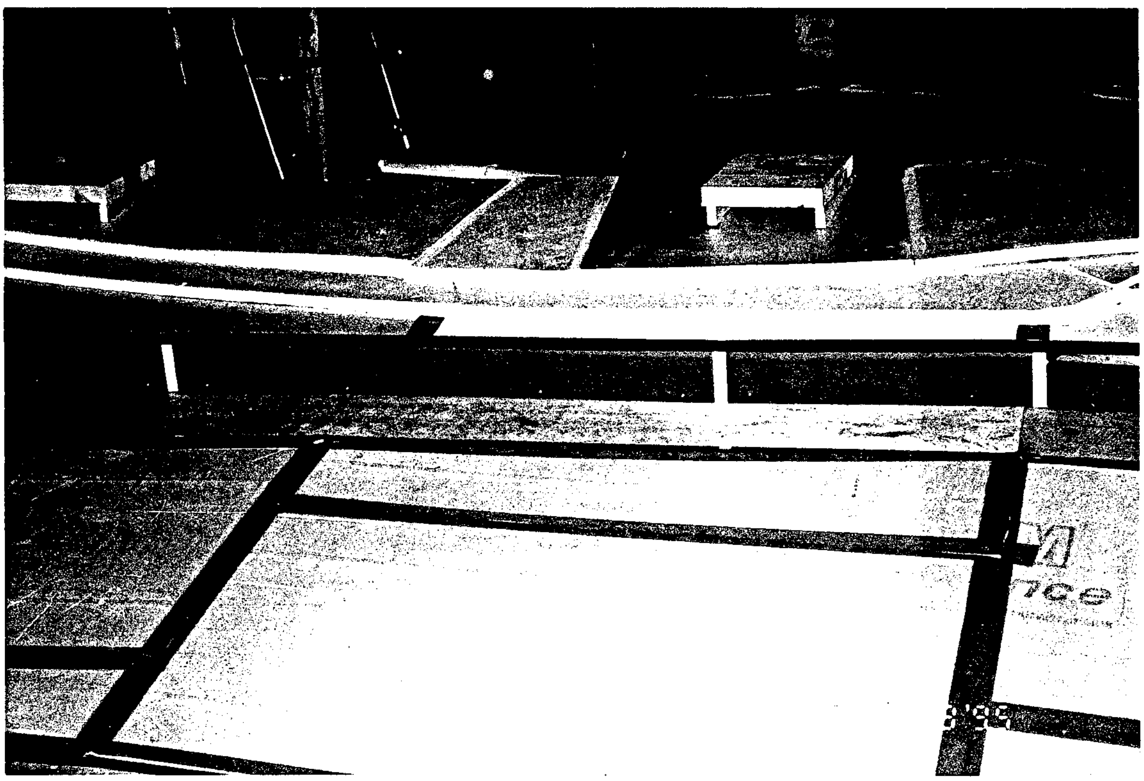
Photograph No. 20 - Fourth Avenue Model (15' Absorptive T-top Barrier)



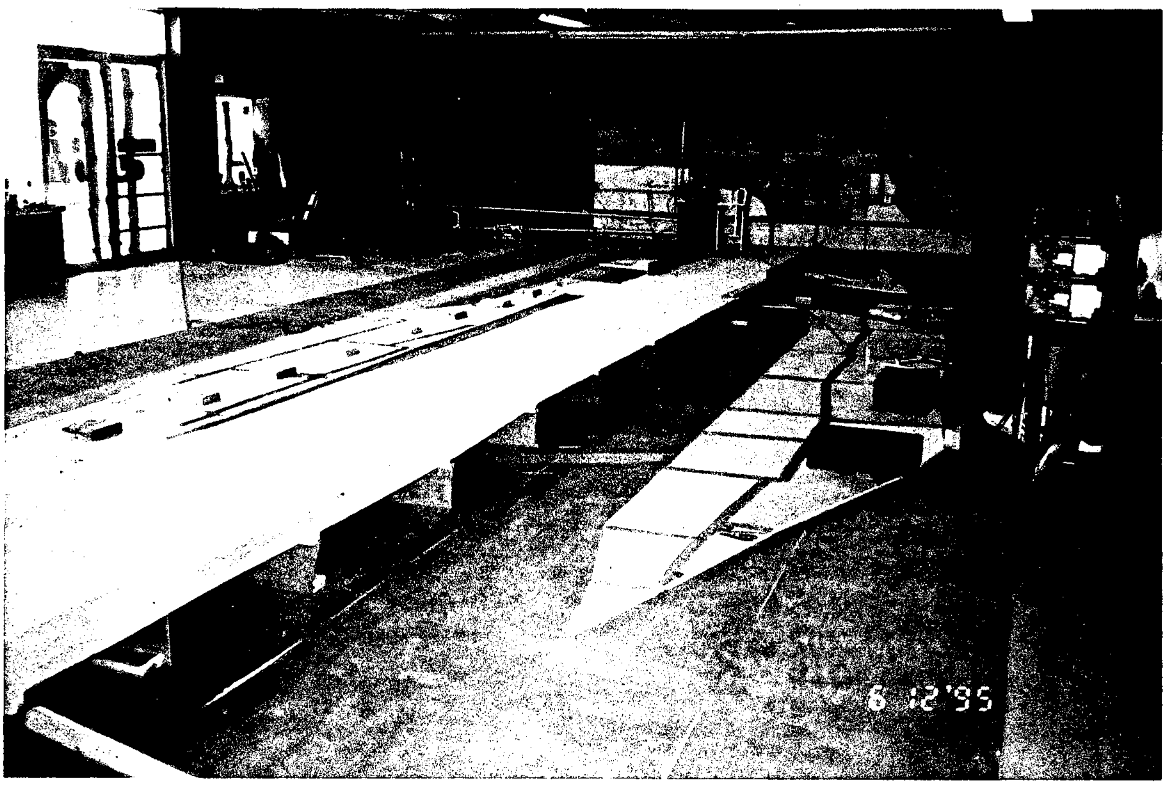
Photograph No. 21 - Fourth Avenue Model (15' Absorptive T-top Barrier)



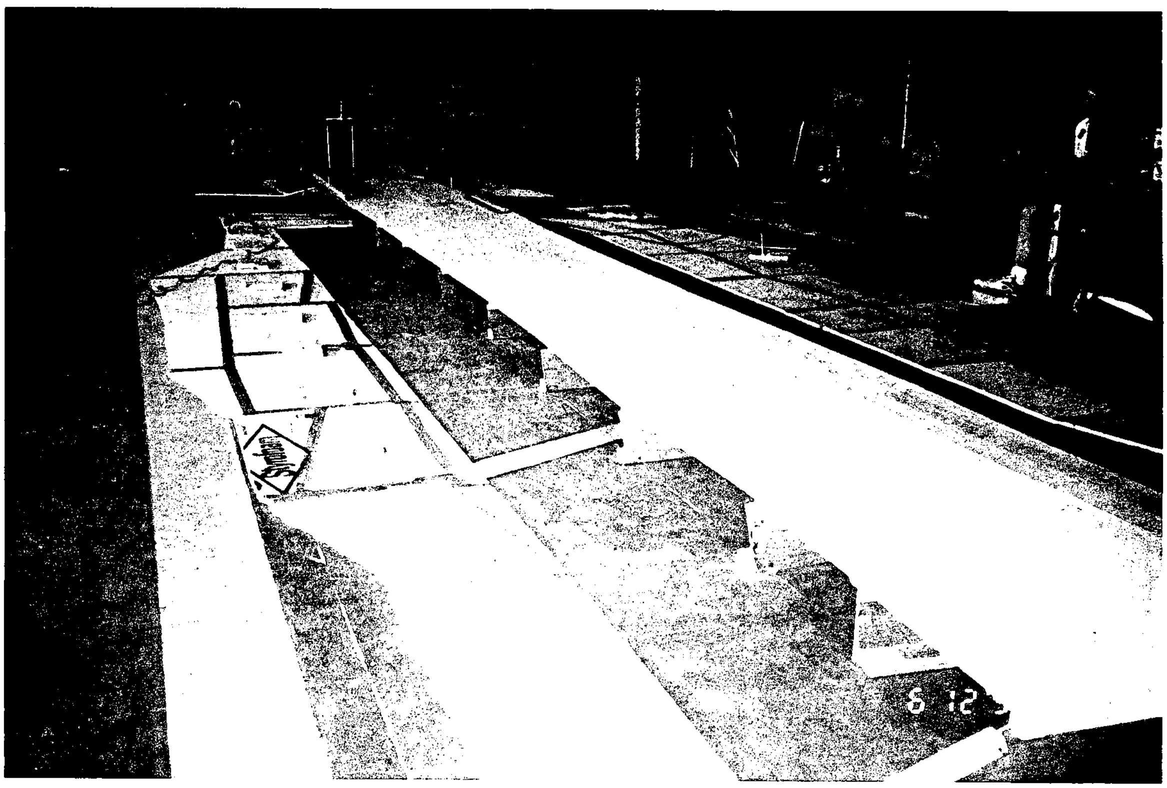
Photograph No. 22 - Fourth Avenue Model - (17' Single-wall Absorptive Barrier)



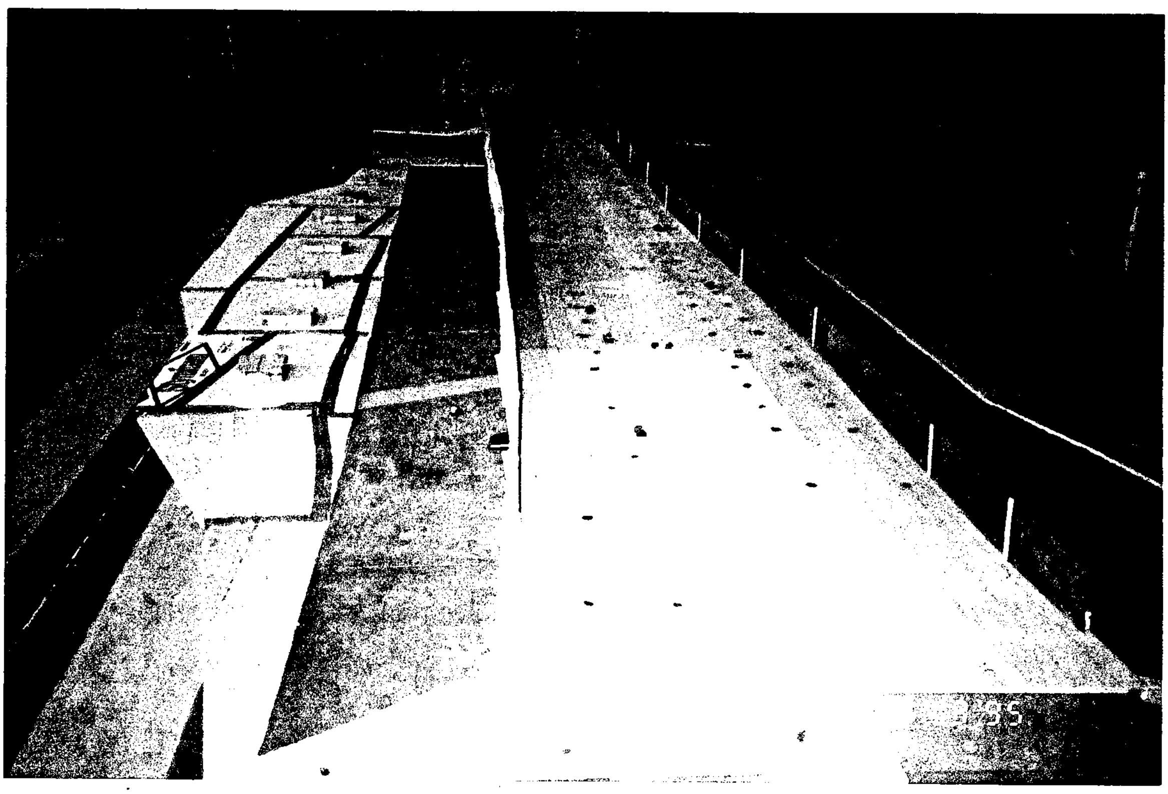
Photograph No. 23 - Fourth Avenue Model (17' Single-wall Absorptive)



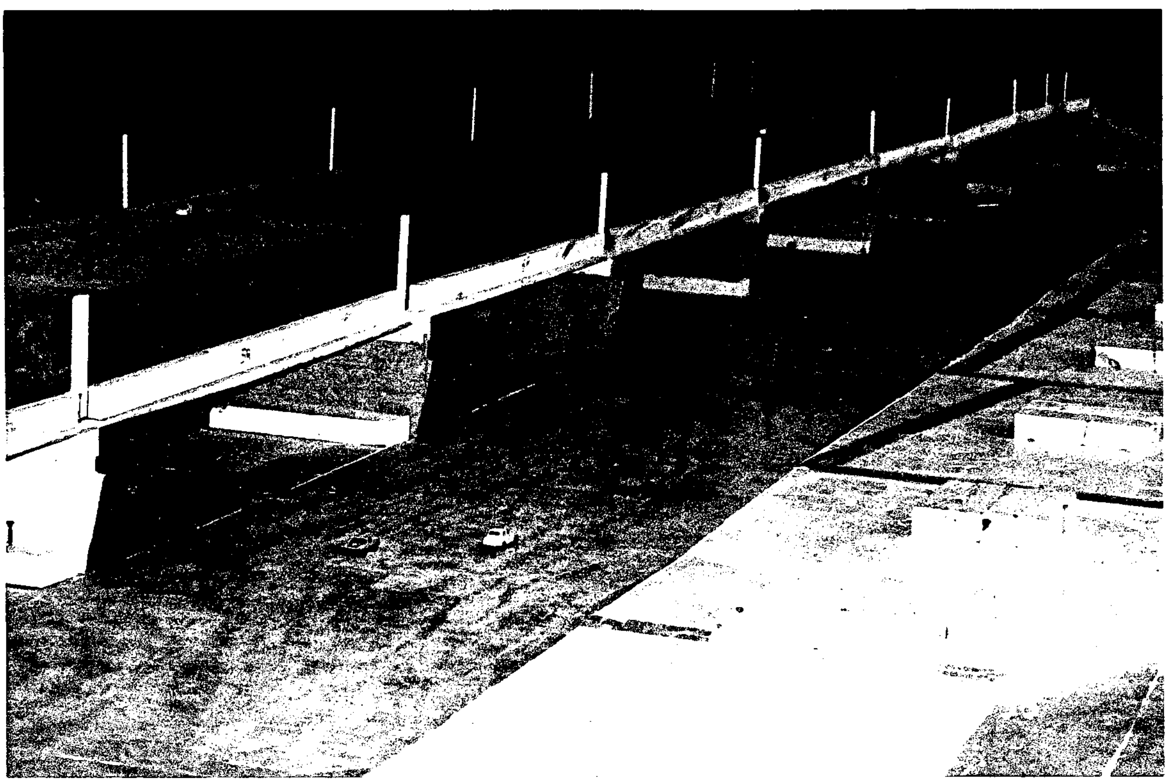
Photograph No. 24 - Spokane College Model (No Barrier)



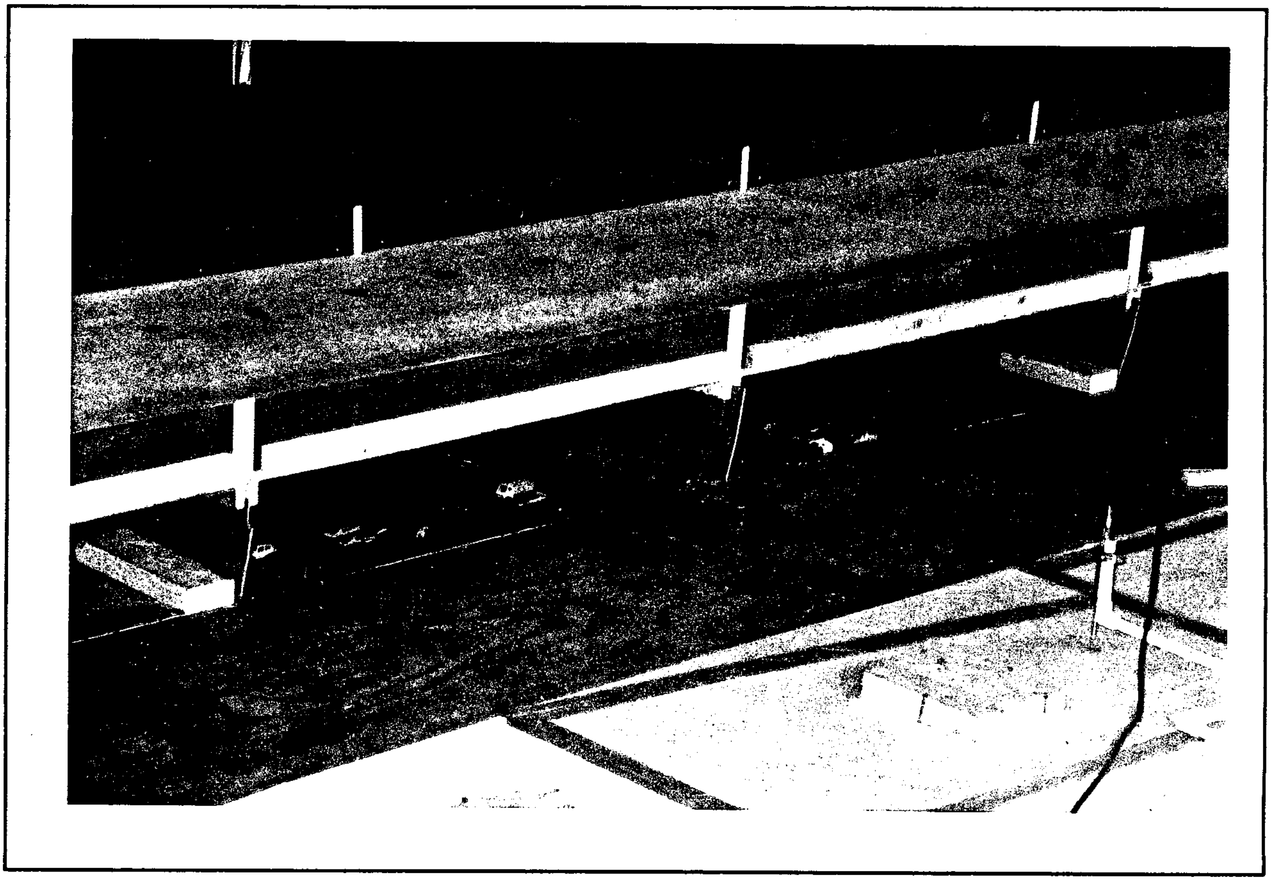
Photograph No. 25 - Spokane College Model (No Barrier)



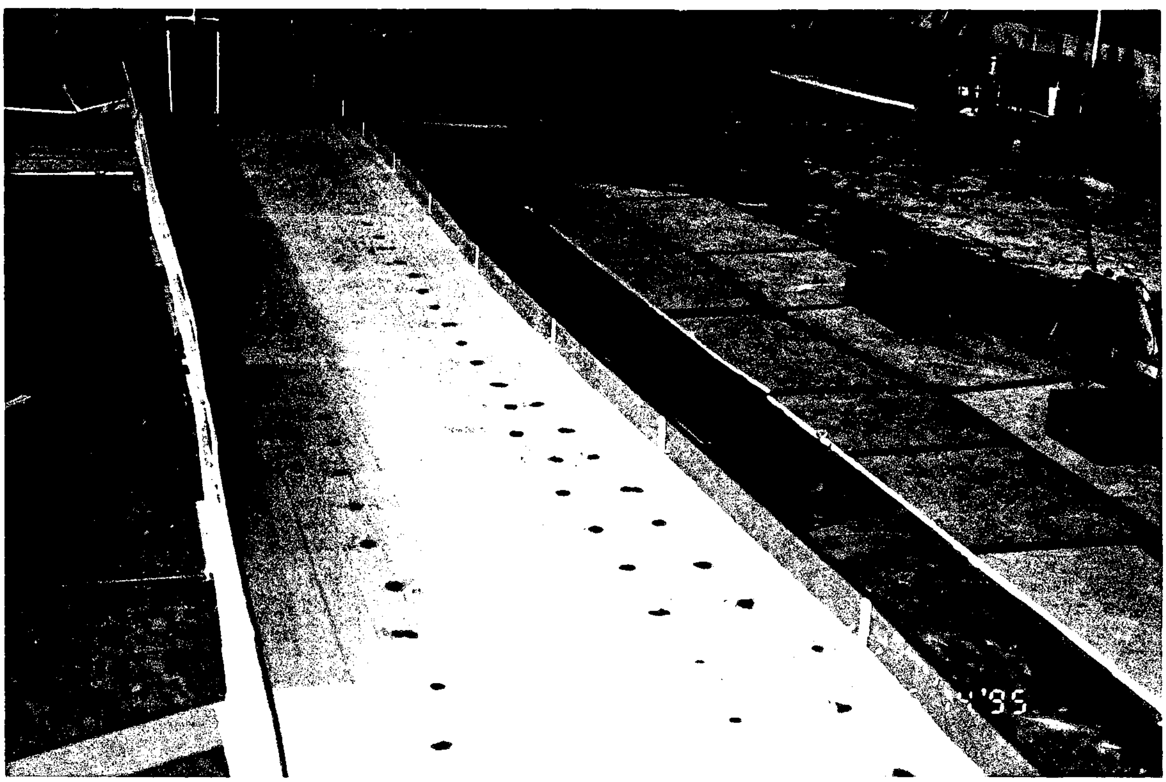
Photograph No. 26 - Spokane College Model (24' Conventional Parallel Barriers)



Photograph No. 27 Spokane College Model (24' Conventional Parallel Barriers)



Photograph No. 28 - Spokane College Model (18' Absorptive Parallel Barrier)



Photograph No. 29 - Spokane College Model (18' Absorptive Parallel Barriers)