Five Band Multi Element Quad Modeling With EZNEC 4.0 and MATLAB

Bob Hume KG6B 6-26-2004

In 1989 I put up a tri band quad for the 20, 15, and 10 Meter bands. I put up the same quad in 1983, and 1968. The dimensions came from a 1960s vintage CQ article. The boom length is 30 foot. It has four elements on the 20 and 15 Meter bands with ten foot spacing between all elements. It has a fifth element on the 10 Meter band with five foot spacing between the driven element, the reflector, and the first director. It uses separate 52 Ohm coax feed lines for each band that run to a mast mounted remote switch box. I have confirmed 347, 330, and 325 countries respectively on the 20, 15, and 10 Meter bands using this quad. My current objective is to put up a five band quad by adding 17 and 12 Meter band wires to the four elements used on the 20 and 15 Meter quad arms. I decided to explore the rescaling required to achieve gain, SWR, and FB across all five bands using EZNEC 4.0 to model the quads. First, I developed a multi band/multi element cubical quad modeling program using the MATLAB programming language that rapidly generates wire tables for export to EZNEC 4.0. This program accepts the wire diameter, driven element length, element boom locations, and percent element length scaling relative to the driven element for each band. There is a flag for choosing square or diamond quad elements. The program then creates a wire table using a matrix input for any band or band combinations desired. The first band declared in the matrix is the driven band such that the EZNEC 4.0 source wire #5 never needs to be changed. The non driven driven elements are shorted as modeled but the wire termination numbers are identified by the MATLAB program to support modeling of other termination impedance values.

The following 13 diamond quad loop band combinations were modeled using the same per band design constants. The 20, 15, and 10 Meter quads are per the 1989 design dimensions.

```
names=['20 MTR 4EL FIVE BAND QUAD';       % 1 array Figure ID numbers
       '20 MTR 4EL TRI BAND QUAD ';       % 2
       '20 MTR 4EL MONO BAND QUAD';       % 3
       '17 MTR 4EL FIVE BAND QUAD';       % 4
       '17 MTR 4EL MONO BAND QUAD';       % 5
       '15 MTR 4EL FIVE BAND QUAD';       % 6
       '15 MTR 4EL TRI BAND QUAD ';       % 7
       '15 MTR 4EL MONO BAND QUAD';       % 8
       '12 MTR 4EL FIVE BAND QUAD';       % 9
       '12 MTR 4EL MONO BAND QUAD';       % 10
       '10 MTR 5EL FIVE BAND QUAD';       % 11
       '10 MTR 5EL TRI BAND QUAD ';       % 12
       '10 MTR 5EL MONO BAND QUAD'];      % 13
```

An example printout of the MATLAB program for the 20 Meter five band quad follows.

>> quadmod89

MONO OR MULTI BAND CUBICAL QUAD DESIGN CONSTANTS @ DIAMOND ELEMENT SHAPES

FIRST BAND LISTED IS THE DRIVEN BAND. "DE" STANDS FOR DRIVEN ELEMENT
DATA ELEMENT ORDER IS REF, DE, DIR1, DIR2, ...DIRn

20 MTR QUAD DESIGN CONSTANTS
DE LENGTH CONSTANTS: k=997.6767 f=14.15 DE in FT=70.5072
ELEMENT LENGTHS AS A % FROM DE=2.976 0 -1.704 -1.725
ELEMENT BOOM LOCATIONS IN FT=0 10 20 30
SEGMENTS PER WIRE=9

17 MTR QUAD DESIGN CONSTANTS
DE LENGTH CONSTANTS: k=987.6525 f=18.11 DE in FT=54.5363
ELEMENT LENGTHS AS A % FROM DE=3 0 -1.75 -1.75
ELEMENT BOOM LOCATIONS IN FT=0 10 20 30
SEGMENTS PER WIRE=7

15 MTR QUAD DESIGN CONSTANTS
DE LENGTH CONSTANTS: k=996.9452 f=21.2 DE in FT=47.0257
ELEMENT LENGTHS AS A % FROM DE=3.071 0 -1.848 -1.77
ELEMENT BOOM LOCATIONS IN FT=0 10 20 30
SEGMENTS PER WIRE=7

12 MTR QUAD DESIGN CONSTANTS
DE LENGTH CONSTANTS: k=993.935 f=24.93 DE in FT=39.869
ELEMENT LENGTHS AS A % FROM DE=3 0 -1.75 -1.75
ELEMENT BOOM LOCATIONS IN FT=0 10 20 30
SEGMENTS PER WIRE=7

10 MTR QUAD DESIGN CONSTANTS
DE LENGTH CONSTANTS: k=997.528 f=28.45 DE in FT=35.0625
ELEMENT LENGTHS AS A % FROM DE=3.014 0 -2.066 -1.744 -1.723
ELEMENT BOOM LOCATIONS IN FT=0 5 10 20 30
SEGMENTS PER WIRE=7

MTR BAND	BAND WIRES	SEGS PER WIRE	TOTAL WIRES	#WIRE SEGS	DRIVEN ELEMENT WIRE #s 0% DEa#	100% DEb#
20	16	9	16	144	5	8
17	16	7	32	256	21	24
15	16	7	48	368	37	40
12	16	7	64	480	53	56
10	20	7	84	620	69	72

For the diamond quad loop configuration EZNEC must use a split SI source at wire number 5 (0% end)

The above table also lists the driven element wire number(s) for the non driven bands in case impedance termination effects are to be modeled in EZNEC

EZNEC 4.0 can work with up to 1500 wire segments (SEGS) total
EZNEC-M Pro version can work with up to 10,000 wire segments total
EZNEC wire table output in Meter units with zero antenna height

The EZNEC 4.0 antenna description table for the above wires with a change to feet units and a standard antenna height of 55 foot used for all 13 quad arrays follows.

EZNEC+ ver. 4.0

20 MTR 4 EL FIVE BAND QUAD 89 6/26/2004 3:33:43 PM

--------------- ANTENNA DESCRIPTION ---------------

Frequency = 14.132 MHz
Wire Loss: Copper -- Resistivity = 1.74E-08 ohm-m, Rel. Perm. = 1

--------------- WIRES ---------------

No.	End 1 Conn.	Coord. (ft) X	Y	Z	End 2 Conn.	Coord. (ft) X	Y	Z	Dia (in)	Segs	Insulation Diel C	Thk(in)
1	W4E2	0,	0,	42.165	W2E1	0,	12.835,	55	.080827	9	1	0
2	W1E2	0,	12.835,	55	W3E1	0,	0,	67.835	.080827	9	1	0
3	W2E2	0,	0,	67.835	W4E1	0,	-12.835,	55	.080827	9	1	0
4	W3E2	0,	-12.835,	55	W1E1	0,	0,	42.165	.080827	9	1	0
5	W8E2	10,	0,	42.536	W6E1	10,	12.464,	55	.080827	9	1	0
6	W5E2	10,	12.464,	55	W7E1	10,	0,	67.464	.080827	9	1	0
7	W6E2	10,	0,	67.464	W8E1	10,	-12.464,	55	.080827	9	1	0
8	W7E2	10,	-12.464,	55	W5E1	10,	0,	42.536	.080827	9	1	0
9	W12E2	20,	0,	42.7484	W10E1	20,	12.2516,	55	.080827	9	1	0
10	W9E2	20,	12.2516,	55	W11E1	20,	0,	67.2516	.080827	9	1	0
11	W10E2	20,	0,	67.2516	W12E1	20,	-12.252,	55	.080827	9	1	0
12	W11E2	20,	-12.252,	55	W9E1	20,	0,	42.7484	.080827	9	1	0
13	W16E2	30,	0,	42.751	W14E1	30,	12.249,	55	.080827	9	1	0
14	W13E2	30,	12.249,	55	W15E1	30,	0,	67.249	.080827	9	1	0
15	W14E2	30,	0,	67.249	W16E1	30,	-12.249,	55	.080827	9	1	0
16	W15E2	30,	-12.249,	55	W13E1	30,	0,	42.751	.080827	9	1	0
17	W20E2	0,	0,	45.07	W18E1	0,	9.92997,	55	.080827	7	1	0
18	W17E2	0,	9.92997,	55	W19E1	0,	0,	64.93	.080827	7	1	0
19	W18E2	0,	0,	64.93	W20E1	0,	-9.93,	55	.080827	7	1	0
20	W19E2	0,	-9.93,	55	W17E1	0,	0,	45.07	.080827	7	1	0
21	W24E2	10,	0,	45.3593	W22E1	10,	9.64075,	55	.080827	7	1	0
22	W21E2	10,	9.64075,	55	W23E1	10,	0,	64.6407	.080827	7	1	0
23	W22E2	10,	0,	64.6407	W24E1	10,	-9.6407,	55	.080827	7	1	0
24	W23E2	10,	-9.6407,	55	W21E1	10,	0,	45.3593	.080827	7	1	0
25	W28E2	20,	0,	45.528	W26E1	20,	9.47203,	55	.080827	7	1	0

26	W25E2	20,9.47203, 55	W27E1	20, 0, 64.472	.080827	7	1	0
27	W26E2	20, 0, 64.472	W28E1	20, -9.472, 55	.080827	7	1	0
28	W27E2	20, -9.472, 55	W25E1	20, 0, 45.528	.080827	7	1	0
29	W32E2	30, 0, 45.528	W30E1	30,9.47203, 55	.080827	7	1	0
30	W29E2	30,9.47203, 55	W31E1	30, 0, 64.472	.080827	7	1	0
31	W30E2	30, 0, 64.472	W32E1	30, -9.472, 55	.080827	7	1	0
32	W31E2	30, -9.472, 55	W29E1	30, 0, 45.528	.080827	7	1	0
33	W36E2	0, 0,46.4317	W34E1	0,8.56834, 55	.080827	7	1	0
34	W33E2	0,8.56834, 55	W35E1	0, 0,63.5683	.080827	7	1	0
35	W34E2	0, 0,63.5683	W36E1	0,-8.5683, 55	.080827	7	1	0
36	W35E2	0,-8.5683, 55	W33E1	0, 0,46.4317	.080827	7	1	0
37	W40E2	10, 0,46.6869	W38E1	10,8.31305, 55	.080827	7	1	0
38	W37E2	10,8.31305, 55	W39E1	10, 0, 63.313	.080827	7	1	0
39	W38E2	10, 0, 63.313	W40E1	10,-8.3131, 55	.080827	7	1	0
40	W39E2	10,-8.3131, 55	W37E1	10, 0,46.6869	.080827	7	1	0
41	W44E2	20, 0,46.8406	W42E1	20,8.15943, 55	.080827	7	1	0
42	W41E2	20,8.15943, 55	W43E1	20, 0,63.1594	.080827	7	1	0
43	W42E2	20, 0,63.1594	W44E1	20,-8.1594, 55	.080827	7	1	0
44	W43E2	20,-8.1594, 55	W41E1	20, 0,46.8406	.080827	7	1	0
45	W48E2	30, 0,46.8341	W46E1	30,8.16591, 55	.080827	7	1	0
46	W45E2	30,8.16591, 55	W47E1	30, 0,63.1659	.080827	7	1	0
47	W46E2	30, 0,63.1659	W48E1	30,-8.1659, 55	.080827	7	1	0
48	W47E2	30,-8.1659, 55	W45E1	30, 0,46.8341	.080827	7	1	0
49	W52E2	0, 0,47.7406	W50E1	0,7.25935, 55	.080827	7	1	0
50	W49E2	0,7.25935, 55	W51E1	0, 0,62.2593	.080827	7	1	0
51	W50E2	0, 0,62.2593	W52E1	0,-7.2594, 55	.080827	7	1	0
52	W51E2	0,-7.2594, 55	W49E1	0, 0,47.7406	.080827	7	1	0
53	W56E2	10, 0,47.9521	W54E1	10,7.04792, 55	.080827	7	1	0
54	W53E2	10,7.04792, 55	W55E1	10, 0,62.0479	.080827	7	1	0
55	W54E2	10, 0,62.0479	W56E1	10,-7.0479, 55	.080827	7	1	0
56	W55E2	10,-7.0479, 55	W53E1	10, 0,47.9521	.080827	7	1	0
57	W60E2	20, 0,48.0754	W58E1	20,6.92458, 55	.080827	7	1	0
58	W57E2	20,6.92458, 55	W59E1	20, 0,61.9246	.080827	7	1	0
59	W58E2	20, 0,61.9246	W60E1	20,-6.9246, 55	.080827	7	1	0
60	W59E2	20,-6.9246, 55	W57E1	20, 0,48.0754	.080827	7	1	0
61	W64E2	30, 0,48.0754	W62E1	30,6.92458, 55	.080827	7	1	0

62	W61E2	30,6.92458, 55	W63E1	30, 0,61.9246	.080827	7	1	0
63	W62E2	30, 0,61.9246	W64E1	30,-6.9246, 55	.080827	7	1	0
64	W63E2	30,-6.9246, 55	W61E1	30, 0,48.0754	.080827	7	1	0
65	W68E2	0, 0, 48.615	W66E1	0,6.38505, 55	.080827	7	1	0
66	W65E2	0,6.38505, 55	W67E1	0, 0, 61.385	.080827	7	1	0
67	W66E2	0, 0, 61.385	W68E1	0, -6.385, 55	.080827	7	1	0
68	W67E2	0, -6.385, 55	W65E1	0, 0, 48.615	.080827	7	1	0
69	W72E2	5, 0,48.8018	W70E1	5,6.19823, 55	.080827	7	1	0
70	W69E2	5,6.19823, 55	W71E1	5, 0,61.1982	.080827	7	1	0
71	W70E2	5, 0,61.1982	W72E1	5,-6.1982, 55	.080827	7	1	0
72	W71E2	5,-6.1982, 55	W69E1	5, 0,48.8018	.080827	7	1	0
73	W76E2	10, 0,48.9298	W74E1	10,6.07018, 55	.080827	7	1	0
74	W73E2	10,6.07018, 55	W75E1	10, 0,61.0702	.080827	7	1	0
75	W74E2	10, 0,61.0702	W76E1	10,-6.0702, 55	.080827	7	1	0
76	W75E2	10,-6.0702, 55	W73E1	10, 0,48.9298	.080827	7	1	0
77	W80E2	20, 0,48.9099	W78E1	20,6.09013, 55	.080827	7	1	0
78	W77E2	20,6.09013, 55	W79E1	20, 0,61.0901	.080827	7	1	0
79	W78E2	20, 0,61.0901	W80E1	20,-6.0901, 55	.080827	7	1	0
80	W79E2	20,-6.0901, 55	W77E1	20, 0,48.9099	.080827	7	1	0
81	W84E2	30, 0,48.9086	W82E1	30,6.09144, 55	.080827	7	1	0
82	W81E2	30,6.09144, 55	W83E1	30, 0,61.0914	.080827	7	1	0
83	W82E2	30, 0,61.0914	W84E1	30,-6.0914, 55	.080827	7	1	0
84	W83E2	30,-6.0914, 55	W81E1	30, 0,48.9086	.080827	7	1	0

Total Segments: 620

-------------- SOURCES --------------

No.	Specified Pos.		Actual Pos.		Amplitude	Phase	Type
	Wire #	% From E1	% From E1	Seg	(V/A)	(deg.)	
1	5	0.00	5.56	1	1	0	SI

No loads specified

No transmission lines specified

Ground type is Real, High-Accuracy

--------------- MEDIA ---------------

No.	Cond. (S/m)	Diel. Const.	Height (ft)	R Coord. (ft)
1	0.005	13	0	0

The above ground model was used on all 13 quad arrays evaluated.

It only takes about one minute to define a quad array in MATLAB program quadmod89.m, run the program, load the resulting wire table file into EZNEC 4.0, change the units from meters to feet, and change the antenna height from zero to 55 foot to obtain an array model ready to run pattern or SWR plots. The alternative of loading the 84 wire segments by hand would take a lot longer and be prone to entry errors.

Figures 1A to 13A show plots of the gain in dBi, front to back ratio (FB) in dB, front to back region ratio (FBR) in dB, and 10 times the SWR (required to get all data on one plot) for all 13 quad arrays. The SWR curves are for a 52 Ohm coax feed of each array. The FBR is based on the major back lobe in the -180+/-90 degree azimuth range from the array heading. I think the FBR is a better antenna design figure of merit than the FB. The dBi gains are based on the first vertical wave angle lobe maximum gain for each band with a 55 foot antenna height. Reference dipole dBi gains at the first vertical angle "theta" lobe maximum and the same 55 foot antenna height for the five bands are:

BAND	THETA (DEG)	DIPOLE dBi GAIN
20	16.3	7.07
17	13.2	7.66
15	11.5	7.76
12	9.9	7.49
10	8.7	7.94

The array gains in dBd relative to a dipole can be calculated by subtracting the reference dipole dBi gain from the array dBi gain on each band.

Figures 1B to 13B show plots of the driving point impedance real and imaginary parts as a function of frequency for each of the 13 quad arrays modeled. The plots allow one to assess array detuning effects when going from mono to tri band or tri band to five band designs. The plot scales on each band are the same such that a view graph of the five band plots could be laid over the tri band plots for direct visual comparisons.

Figures 14A and 14B show the difference in the azimuth gain plots for the Figure 6 15 Meter five band quad array at the maximum FBR frequency versus the maximum FB frequency. Tuning and scaling of the quad for maximum FBR rather than FB over the prime DX window frequency range of interest looks like the best option to me.

FIG 1A 20 MTR 4EL FIVE BAND QUAD GAIN, FB, FBR, and SWR PLOTS

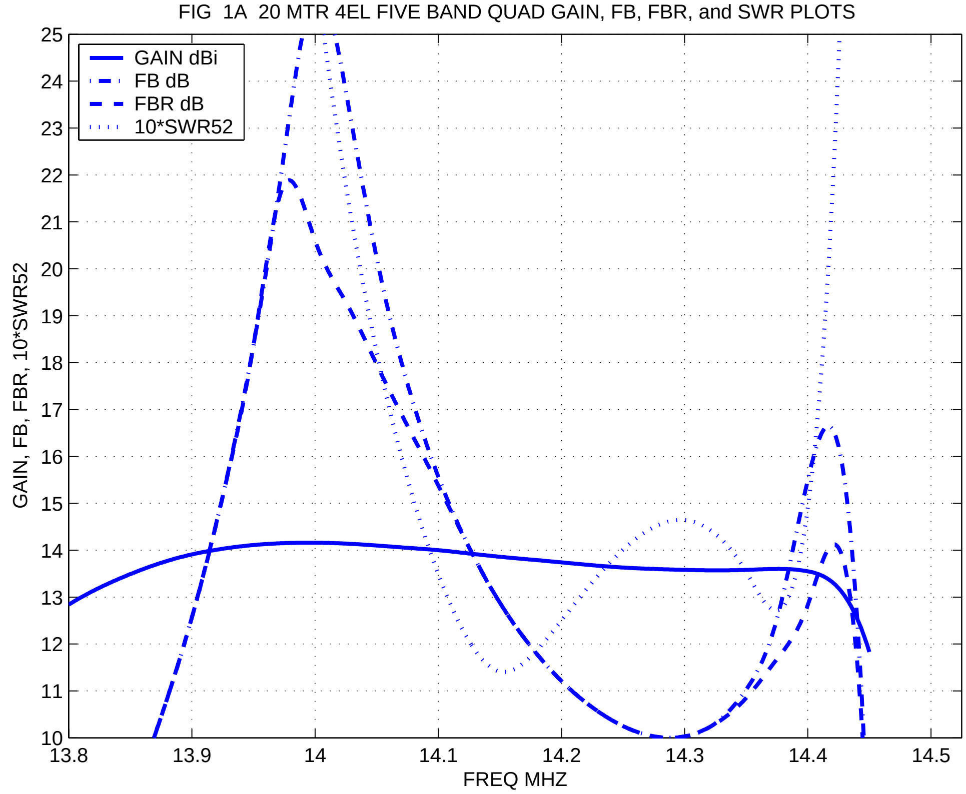
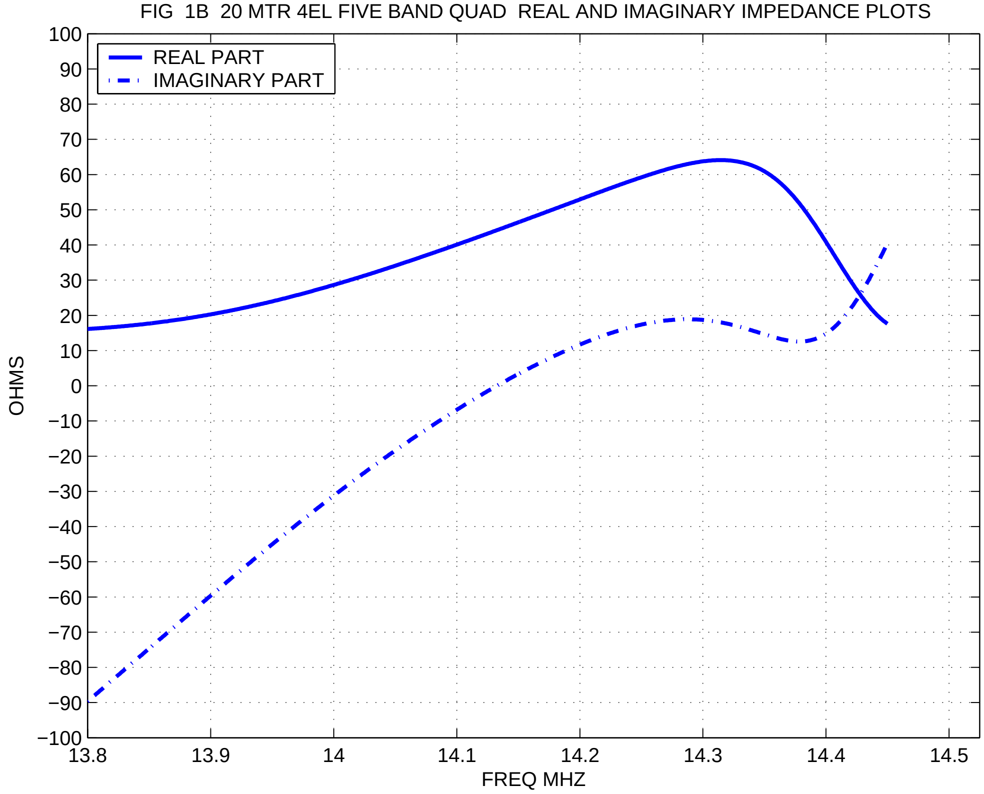


FIG 1B 20 MTR 4EL FIVE BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS



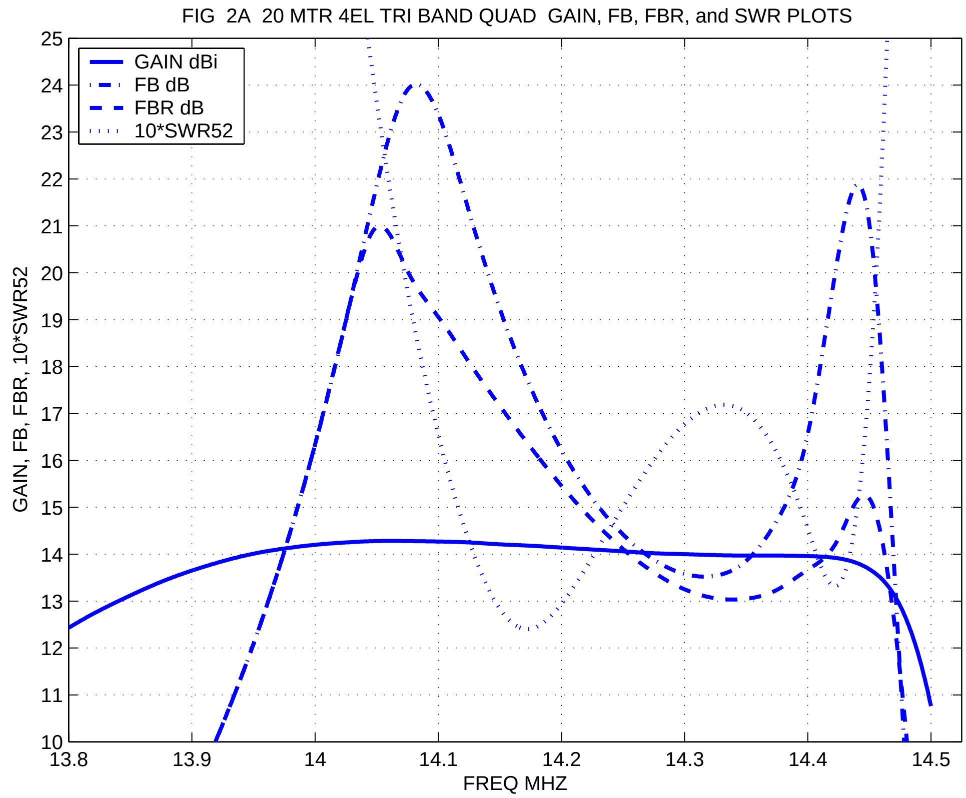


FIG 2A 20 MTR 4EL TRI BAND QUAD GAIN, FB, FBR, and SWR PLOTS
GAIN dBi
FB dB
FBR dB
10*SWR52
GAIN, FB, FBR, 10*SWR52
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
13.8
13.9
14
14.1
14.2
14.3
14.4
14.5
FREQ MHZ

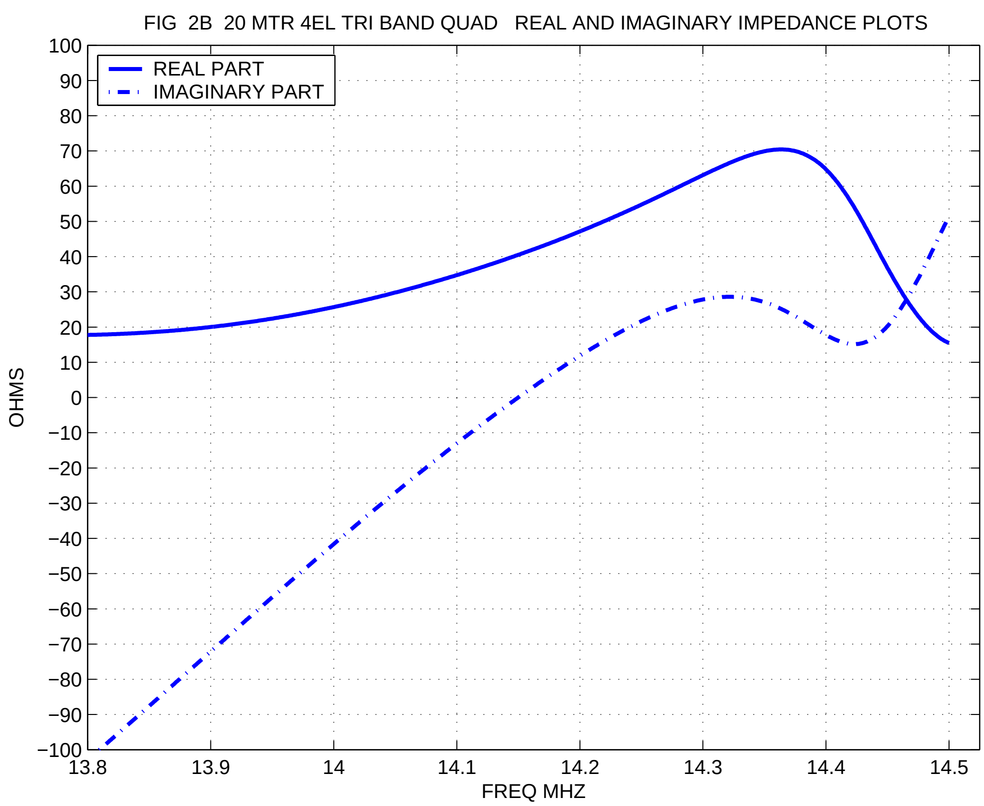


FIG 2B 20 MTR 4EL TRI BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS
REAL PART
IMAGINARY PART
OHMS
100
90
80
70
60
50
40
30
20
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
13.8
13.9
14
14.1
14.2
14.3
14.4
14.5
FREQ MHZ

FIG 3A 20 MTR 4EL MONO BAND QUAD GAIN, FB, FBR, and SWR PLOTS

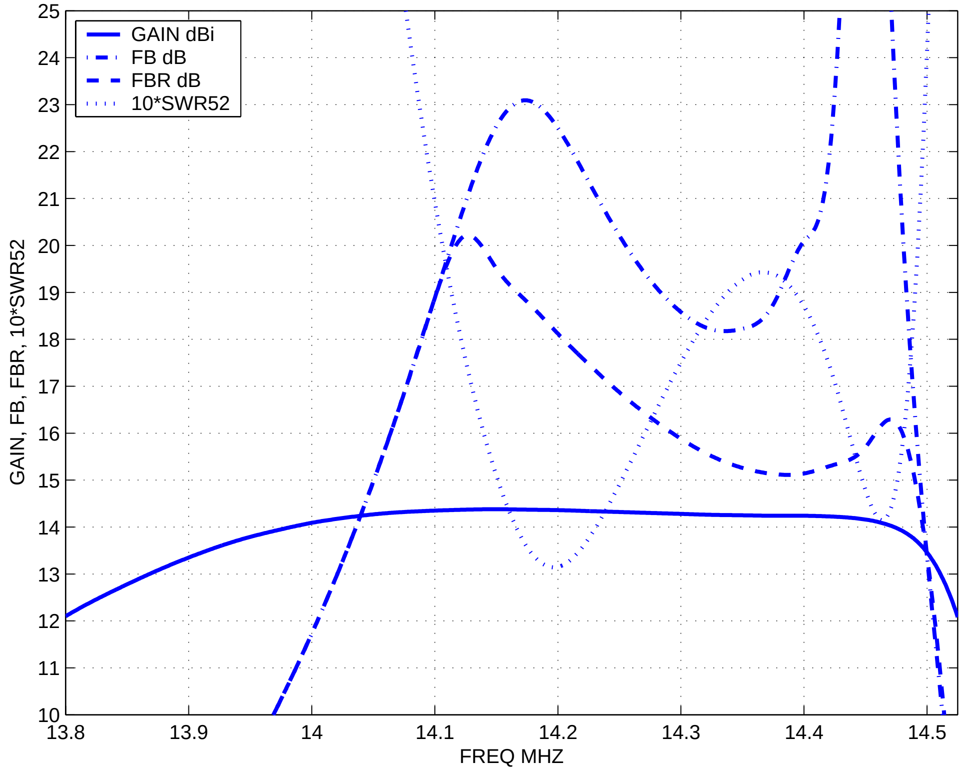
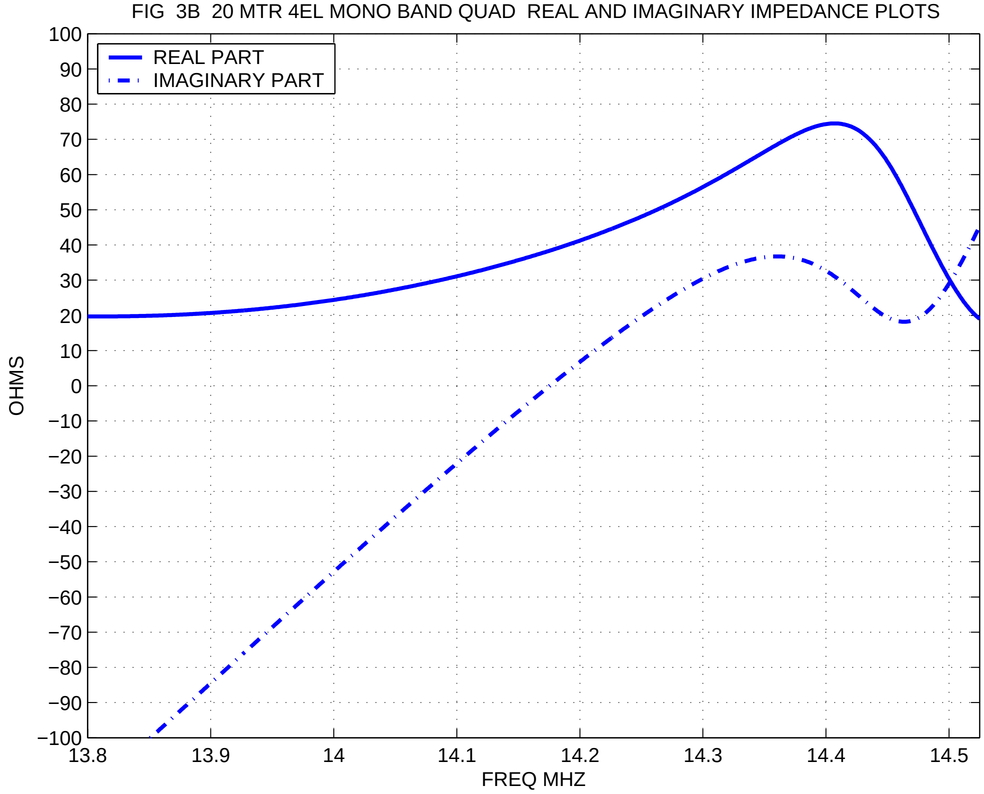


FIG 3B 20 MTR 4EL MONO BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS



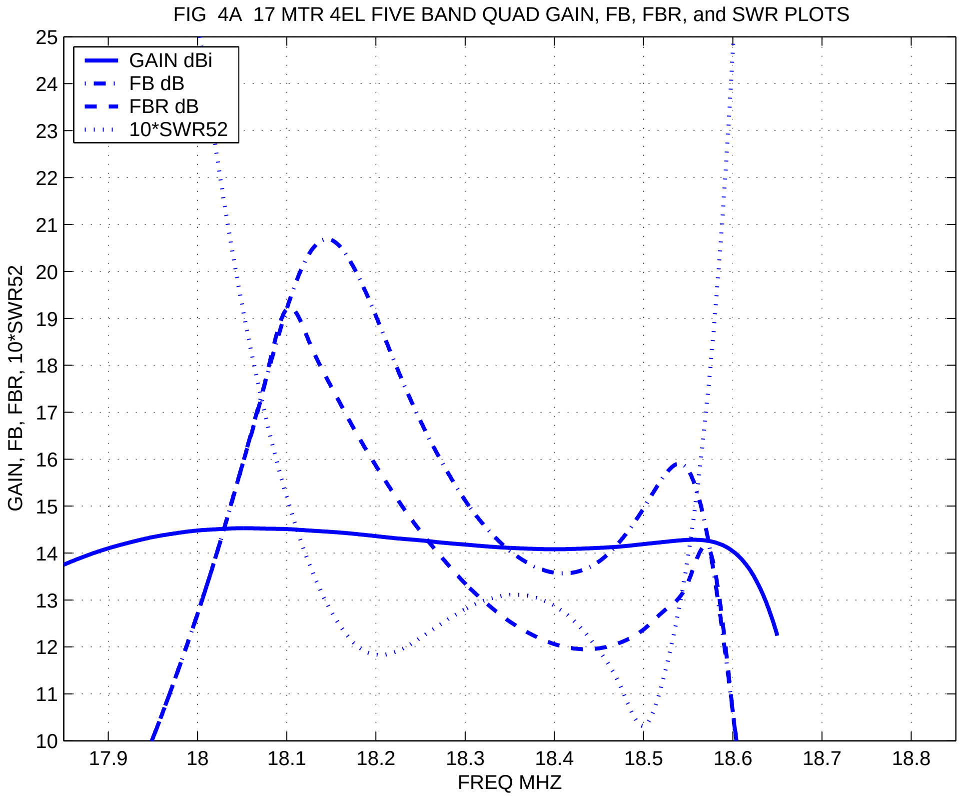


FIG 4A 17 MTR 4EL FIVE BAND QUAD GAIN, FB, FBR, and SWR PLOTS
GAIN dBi
FB dB
FBR dB
10*SWR52
GAIN, FB, FBR, 10*SWR52
FREQ MHZ
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
17.9
18
18.1
18.2
18.3
18.4
18.5
18.6
18.7
18.8

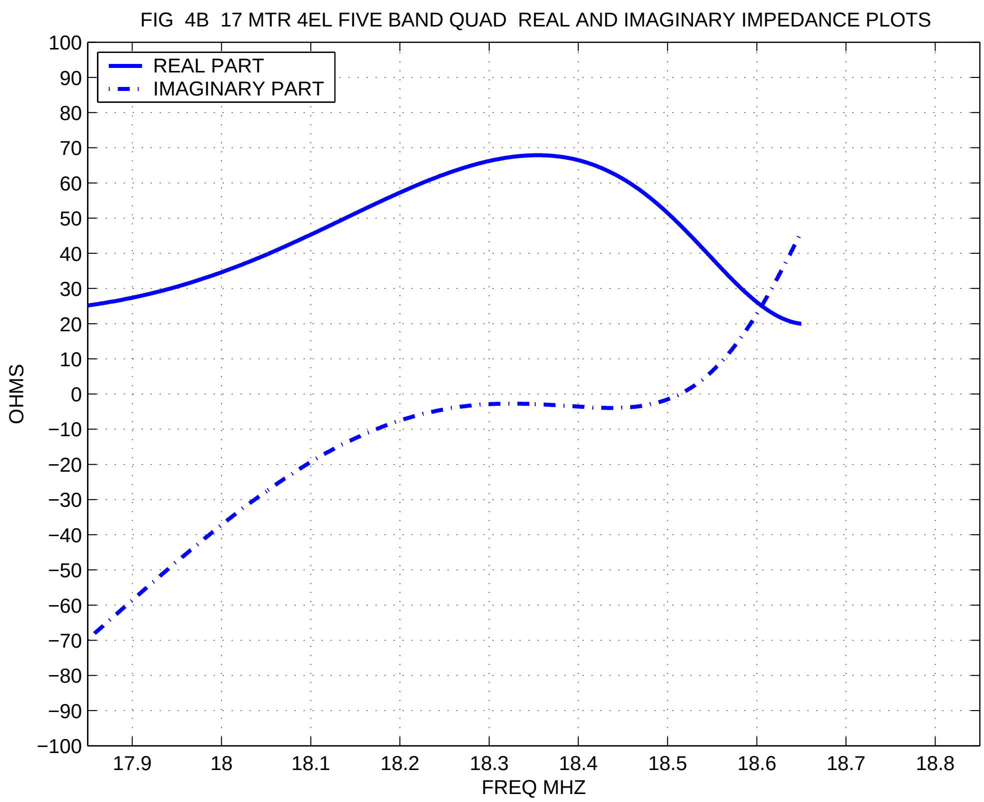


FIG 4B 17 MTR 4EL FIVE BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS
REAL PART
IMAGINARY PART
OHMS
FREQ MHZ
100
90
80
70
60
50
40
30
20
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
17.9
18
18.1
18.2
18.3
18.4
18.5
18.6
18.7
18.8

FIG 5A 17 MTR 4EL MONO BAND QUAD GAIN, FB, FBR, and SWR PLOTS

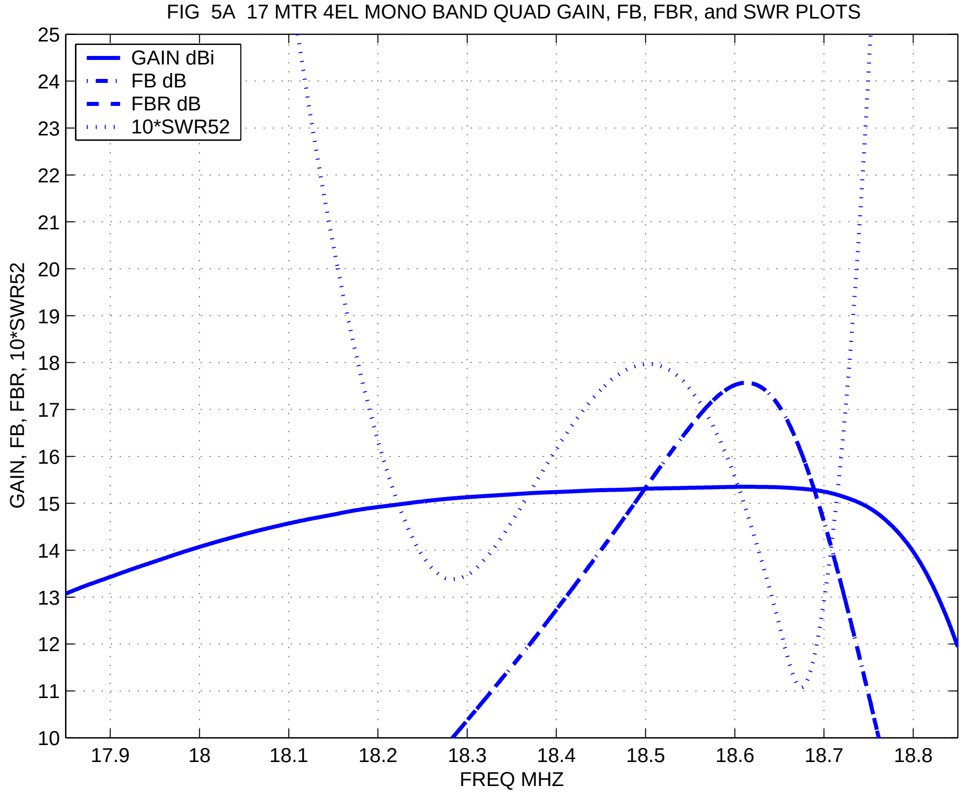


FIG 5B 17 MTR 4EL MONO BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS

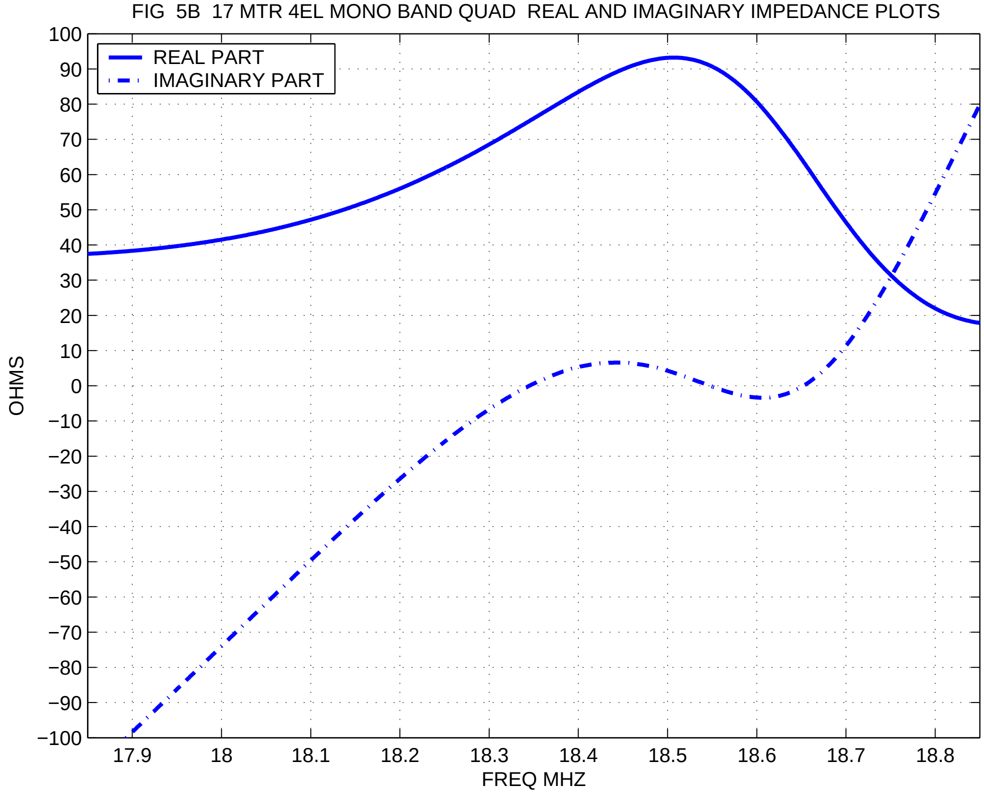


FIG 6A 15 MTR 4EL FIVE BAND QUAD GAIN, FB, FBR, and SWR PLOTS

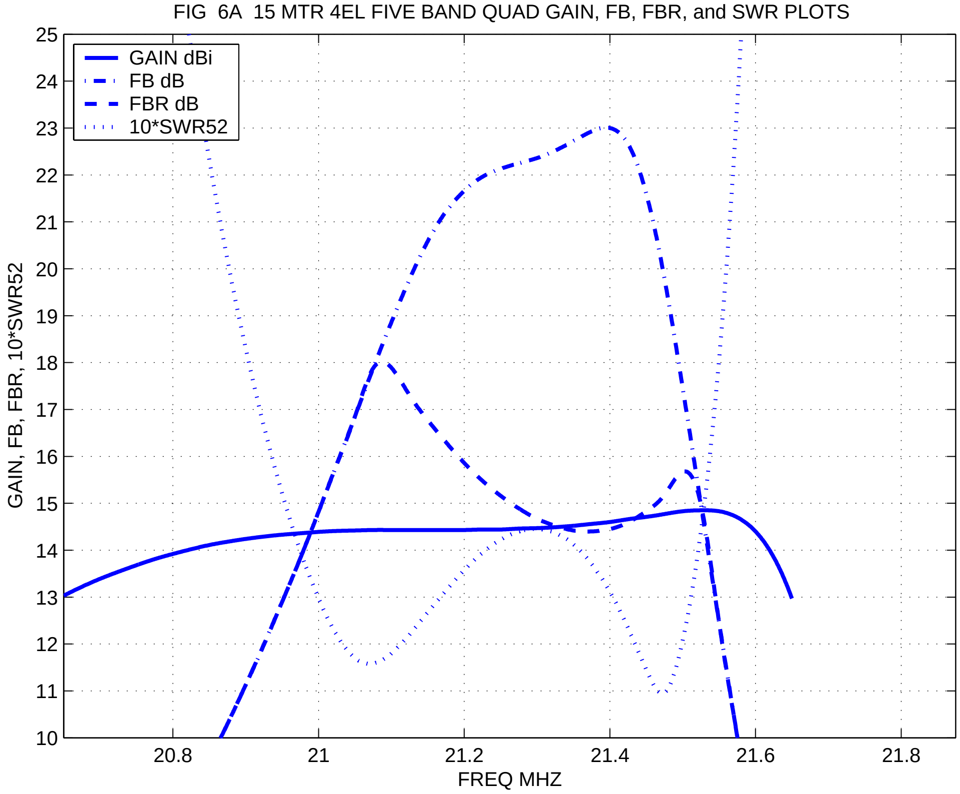
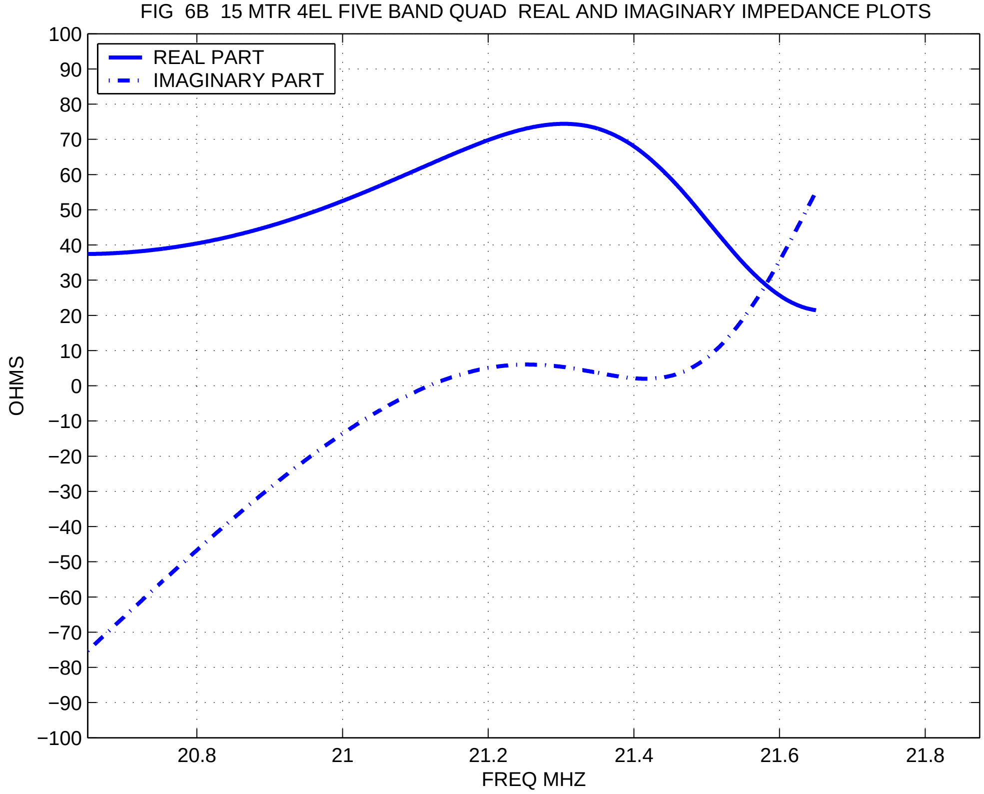


FIG 6B 15 MTR 4EL FIVE BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS



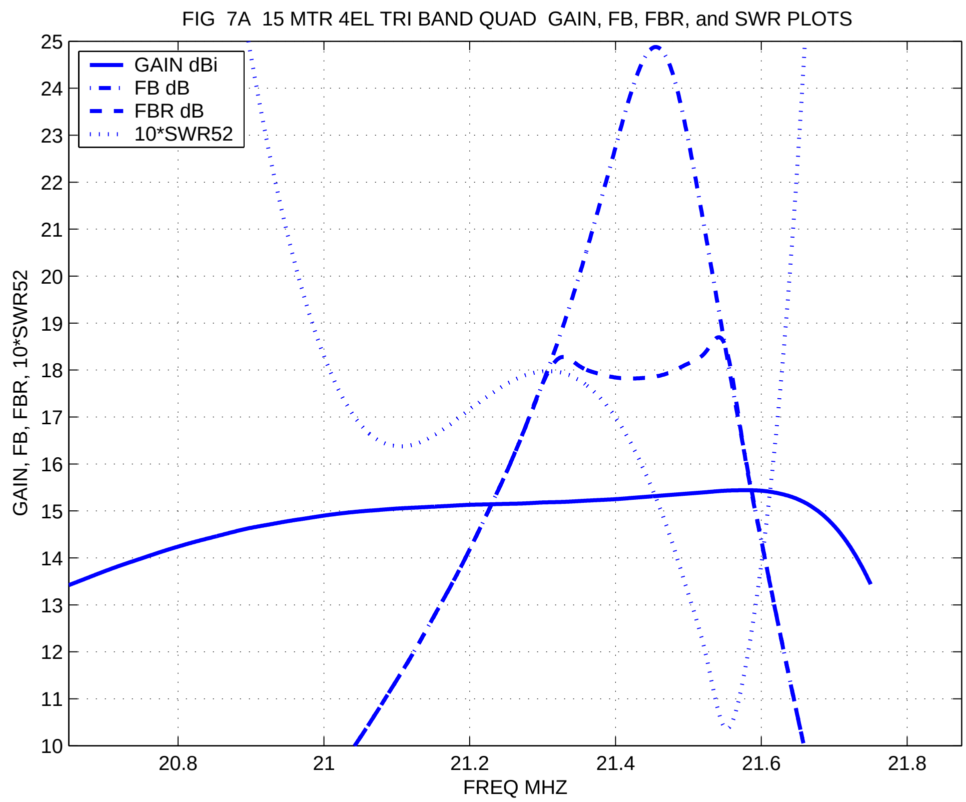


FIG 7A 15 MTR 4EL TRI BAND QUAD GAIN, FB, FBR, and SWR PLOTS
GAIN dBi
FB dB
FBR dB
10*SWR52
GAIN, FB, FBR, 10*SWR52
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
20.8
21
21.2
21.4
21.6
21.8
FREQ MHZ

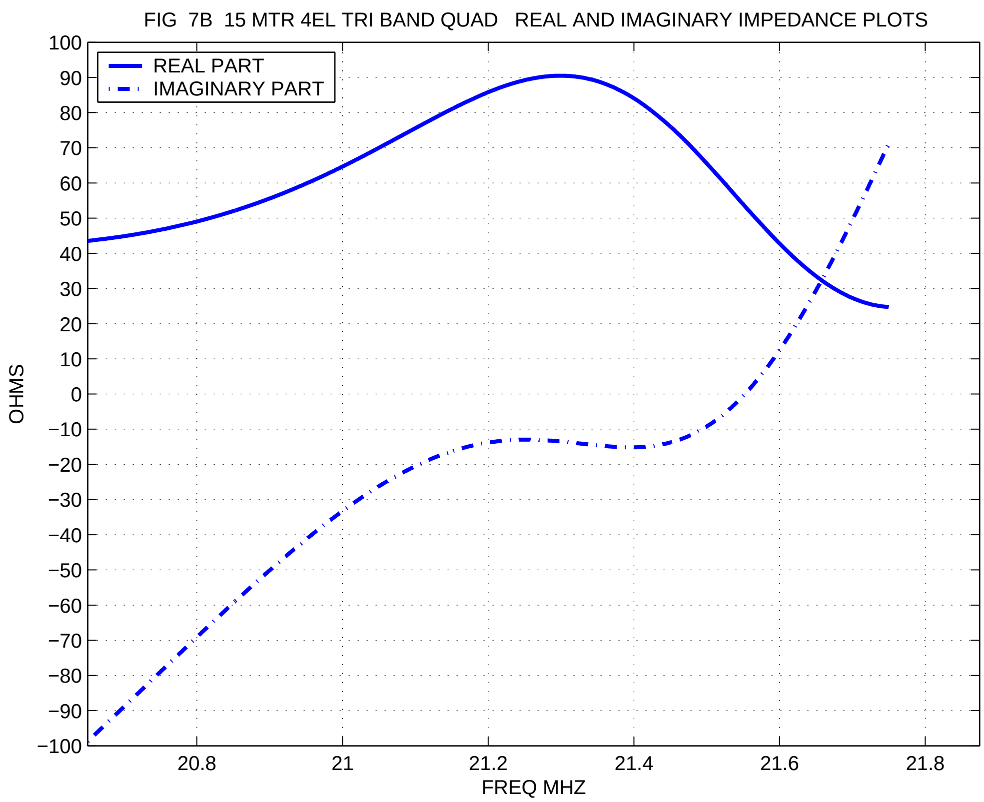


FIG 7B 15 MTR 4EL TRI BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS
REAL PART
IMAGINARY PART
OHMS
100
90
80
70
60
50
40
30
20
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
20.8
21
21.2
21.4
21.6
21.8
FREQ MHZ

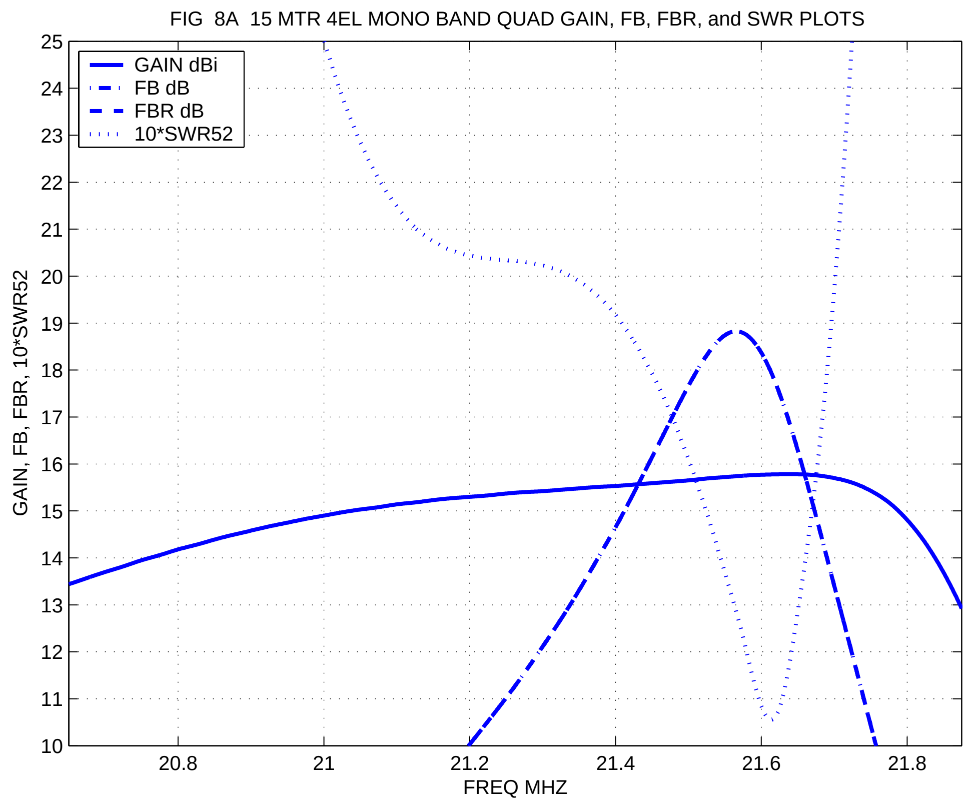


FIG 8A 15 MTR 4EL MONO BAND QUAD GAIN, FB, FBR, and SWR PLOTS
GAIN dBi
FB dB
FBR dB
10*SWR52
GAIN, FB, FBR, 10*SWR52
FREQ MHZ

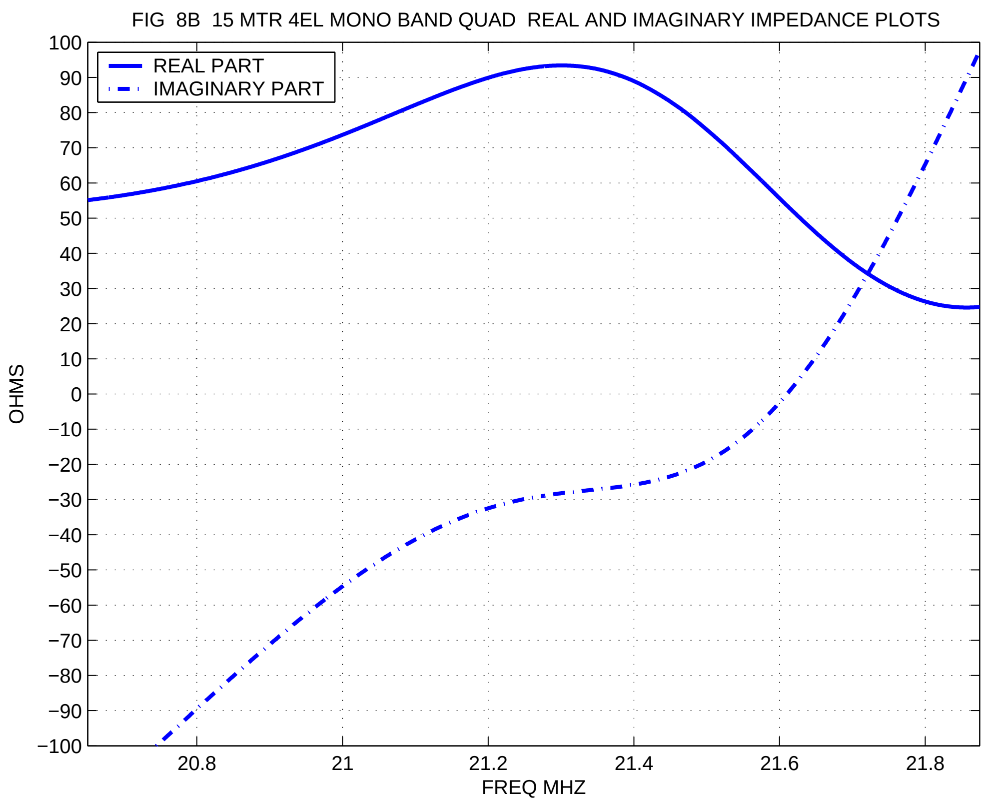


FIG 8B 15 MTR 4EL MONO BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS
REAL PART
IMAGINARY PART
OHMS
FREQ MHZ

FIG 9A 12 MTR 4EL FIVE BAND QUAD GAIN, FB, FBR, and SWR PLOTS

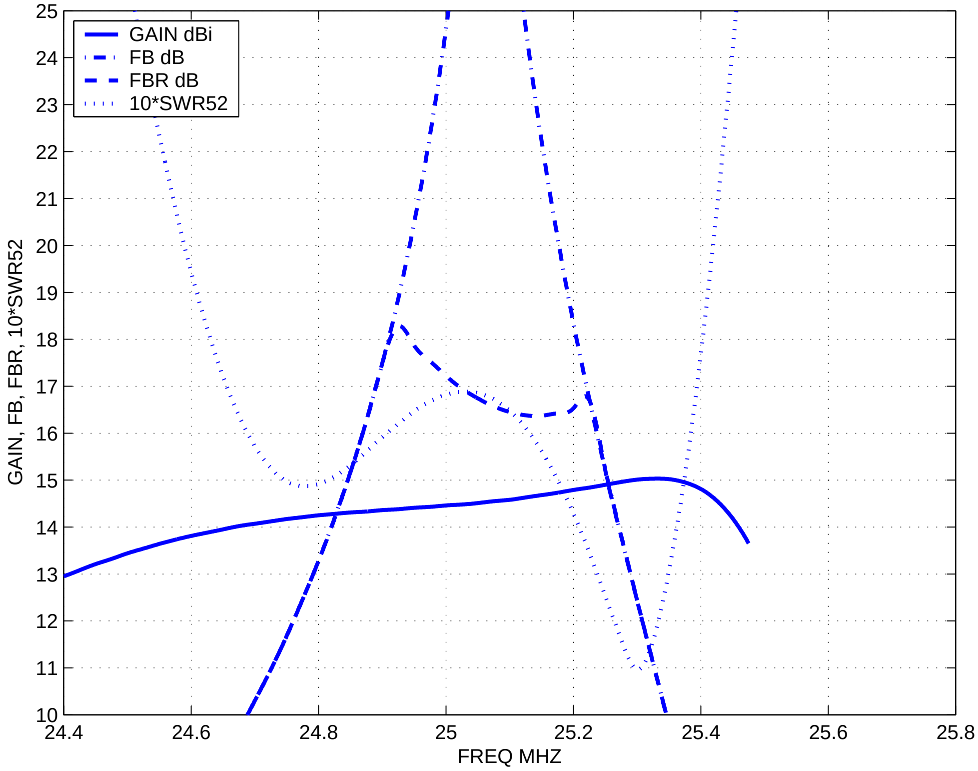


FIG 9B 12 MTR 4EL FIVE BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS

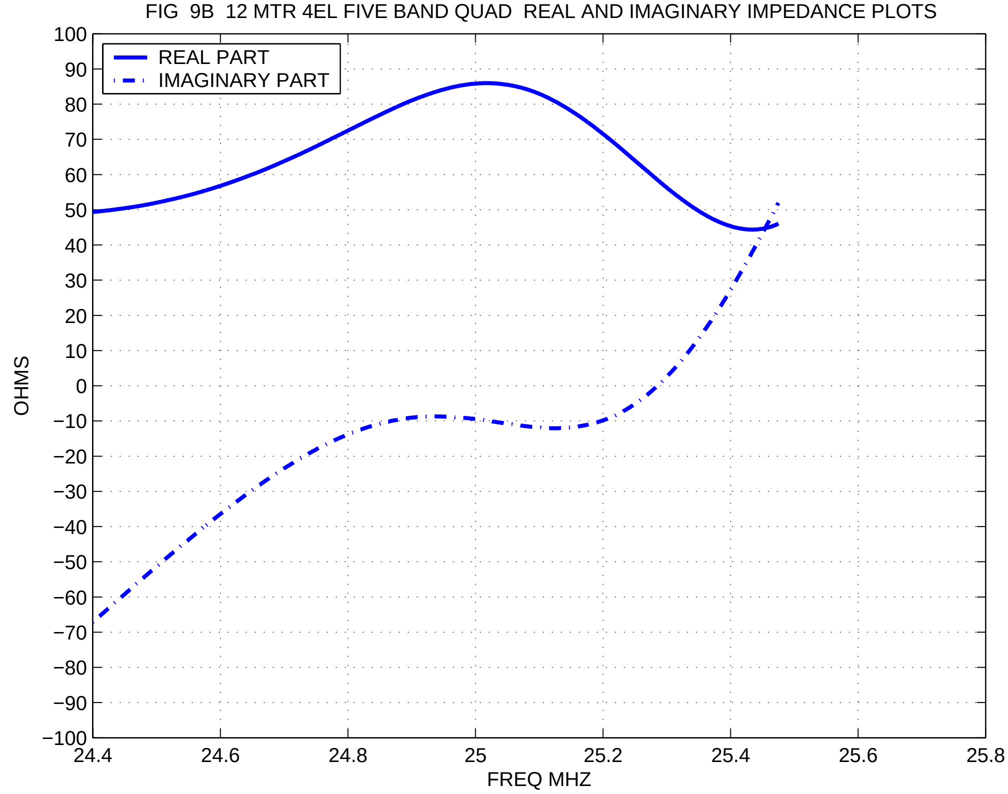


FIG 10A 12 MTR 4EL MONO BAND QUAD GAIN, FB, FBR, and SWR PLOTS

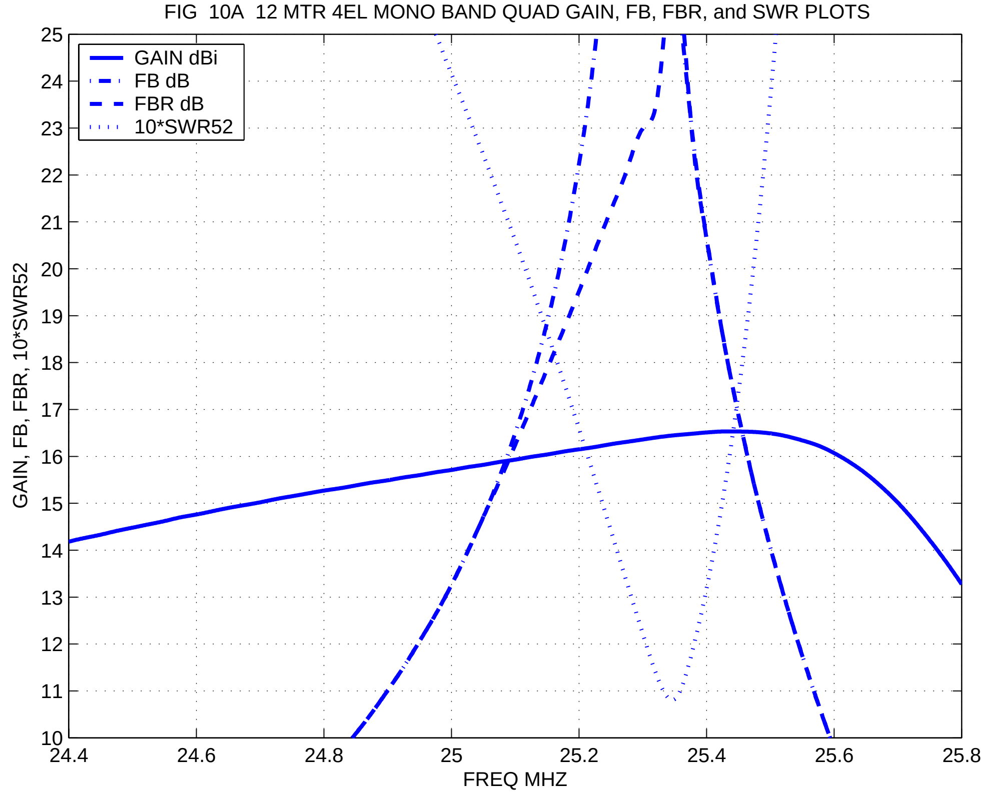
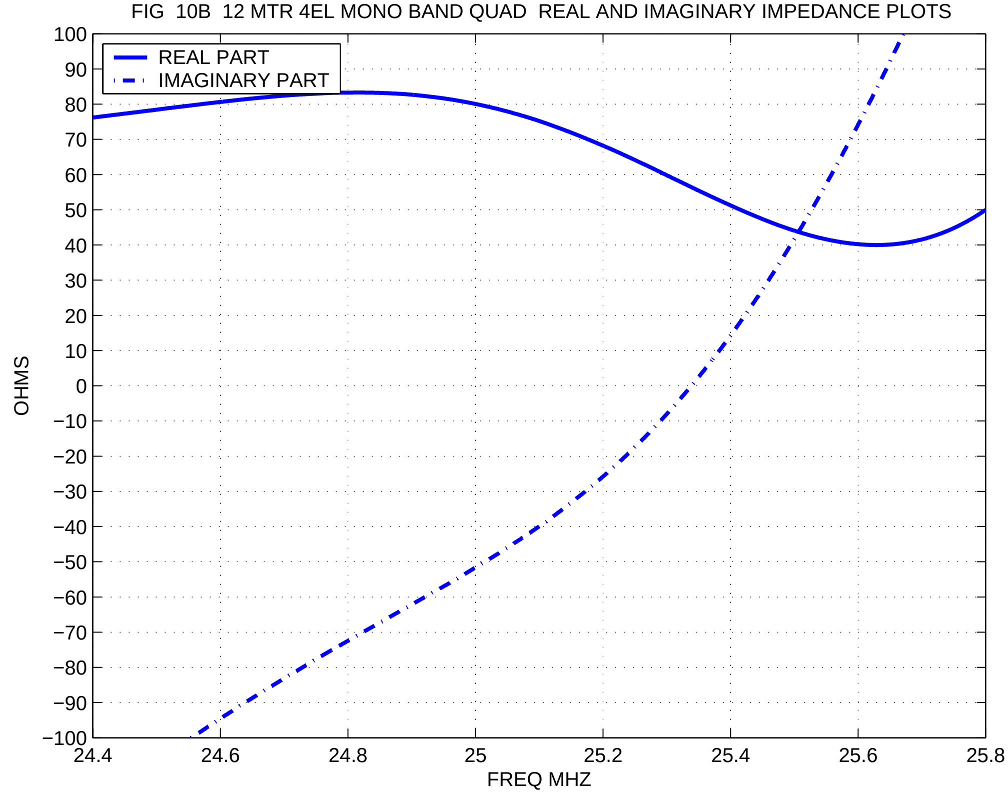


FIG 10B 12 MTR 4EL MONO BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS



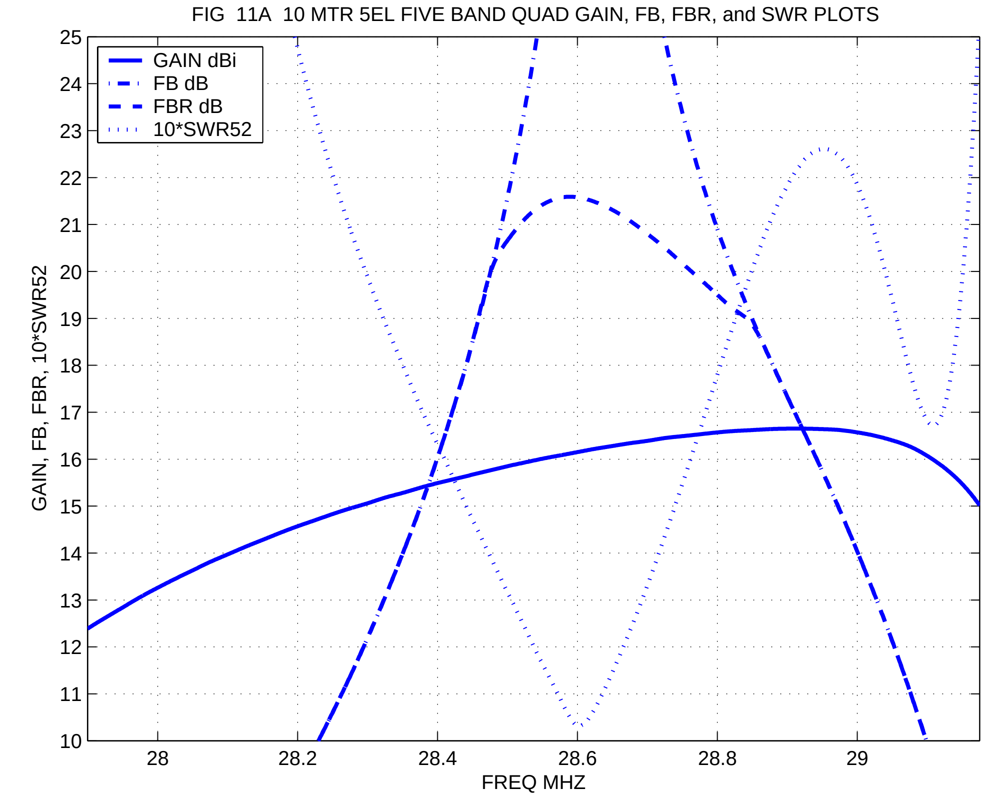


FIG 11A 10 MTR 5EL FIVE BAND QUAD GAIN, FB, FBR, and SWR PLOTS
GAIN dBi
FB dB
FBR dB
10*SWR52
GAIN, FB, FBR, 10*SWR52
FREQ MHZ

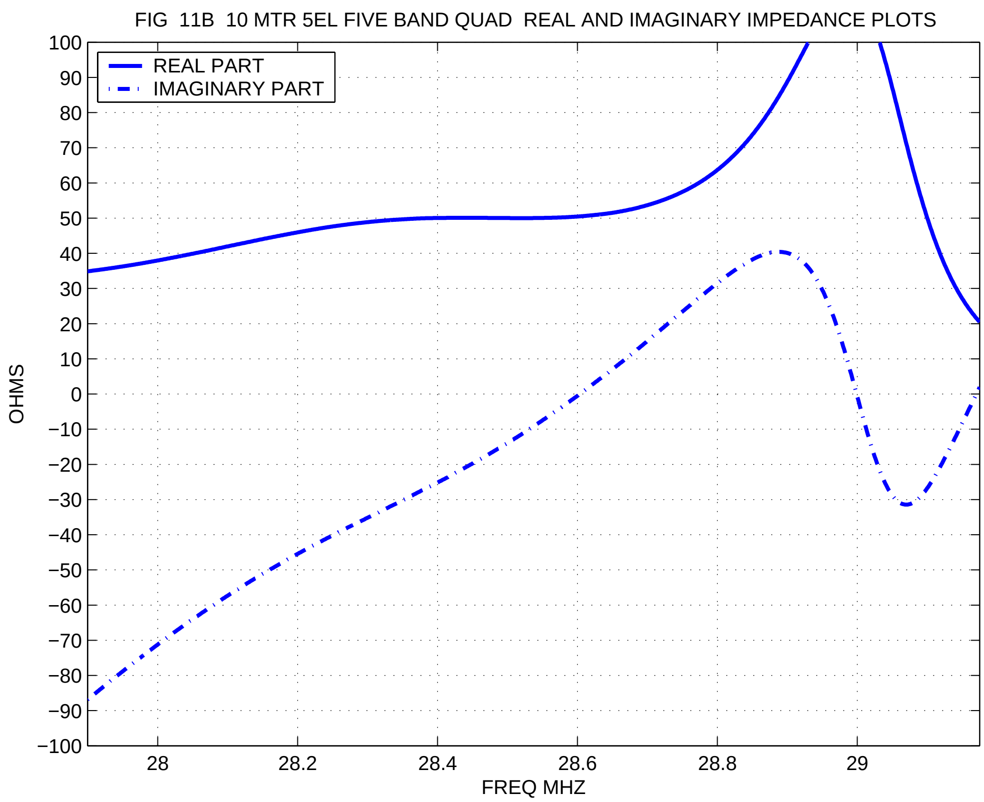


FIG 11B 10 MTR 5EL FIVE BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS
REAL PART
IMAGINARY PART
OHMS
FREQ MHZ

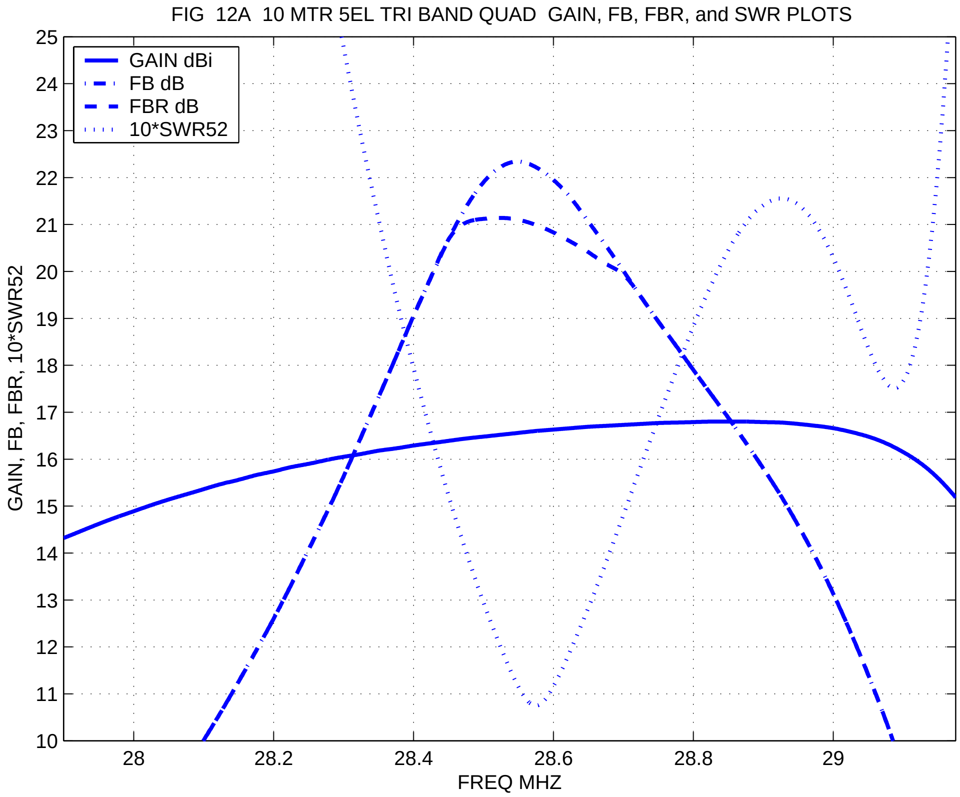


FIG 12A 10 MTR 5EL TRI BAND QUAD GAIN, FB, FBR, and SWR PLOTS
GAIN dBi
FB dB
FBR dB
10*SWR52
GAIN, FB, FBR, 10*SWR52
FREQ MHZ
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
28
28.2
28.4
28.6
28.8
29

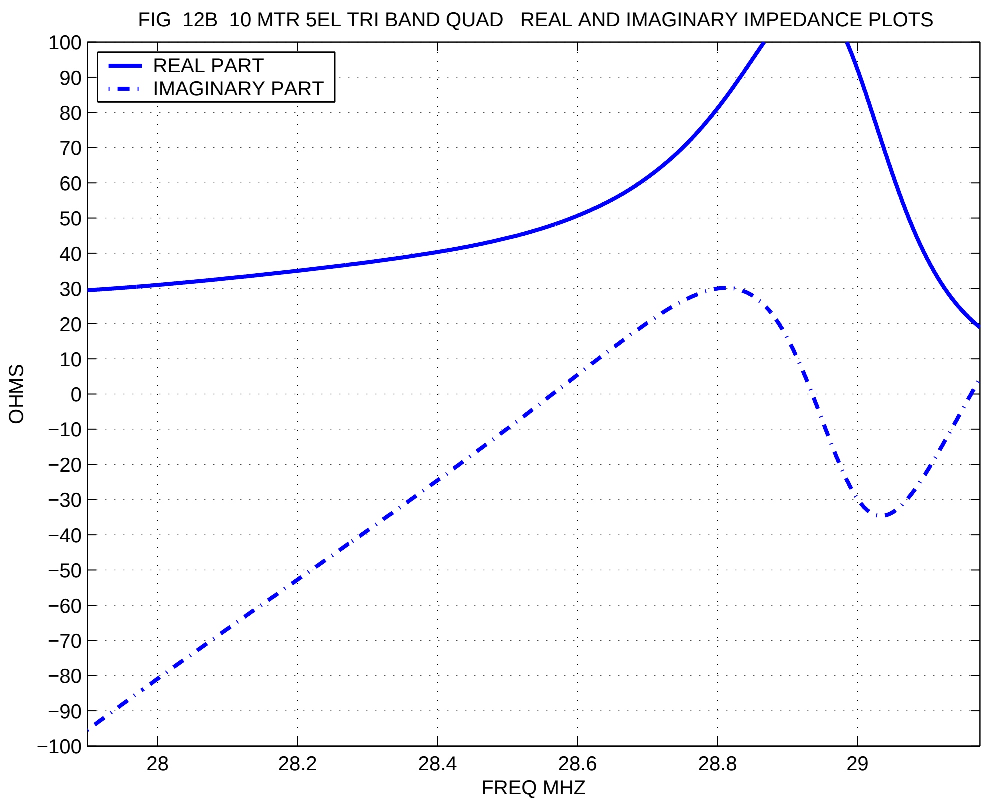


FIG 12B 10 MTR 5EL TRI BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS
REAL PART
IMAGINARY PART
OHMS
FREQ MHZ
100
90
80
70
60
50
40
30
20
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
28
28.2
28.4
28.6
28.8
29

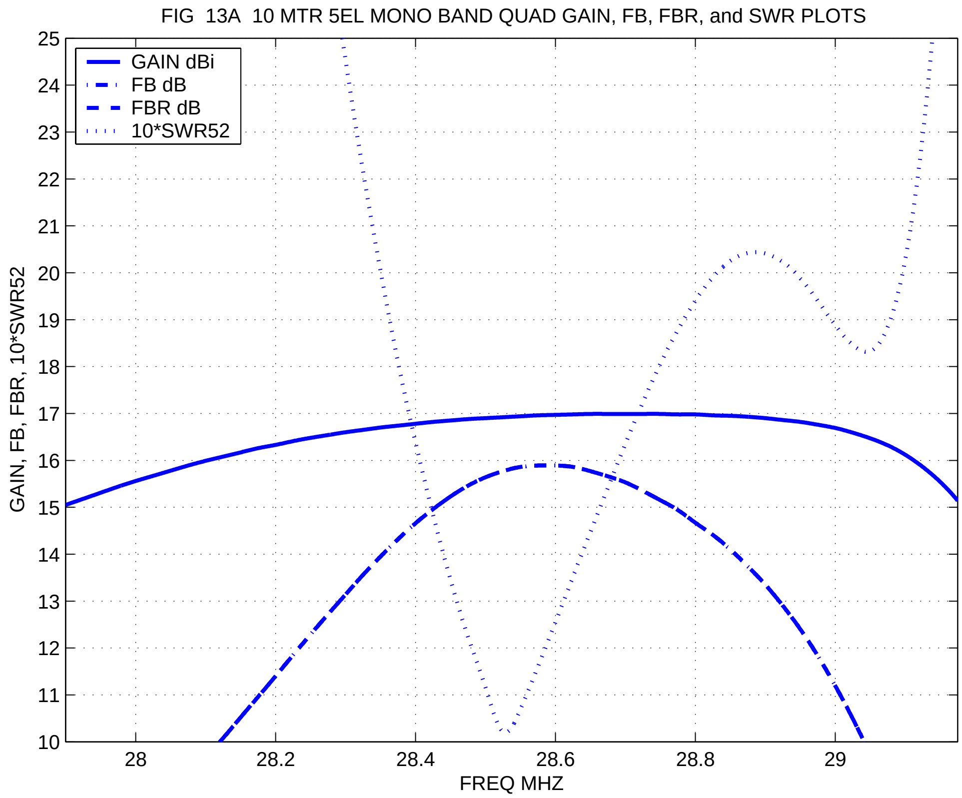


FIG 13A 10 MTR 5EL MONO BAND QUAD GAIN, FB, FBR, and SWR PLOTS
GAIN dBi
FB dB
FBR dB
10*SWR52
GAIN, FB, FBR, 10*SWR52
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
28
28.2
28.4
28.6
28.8
29
FREQ MHZ

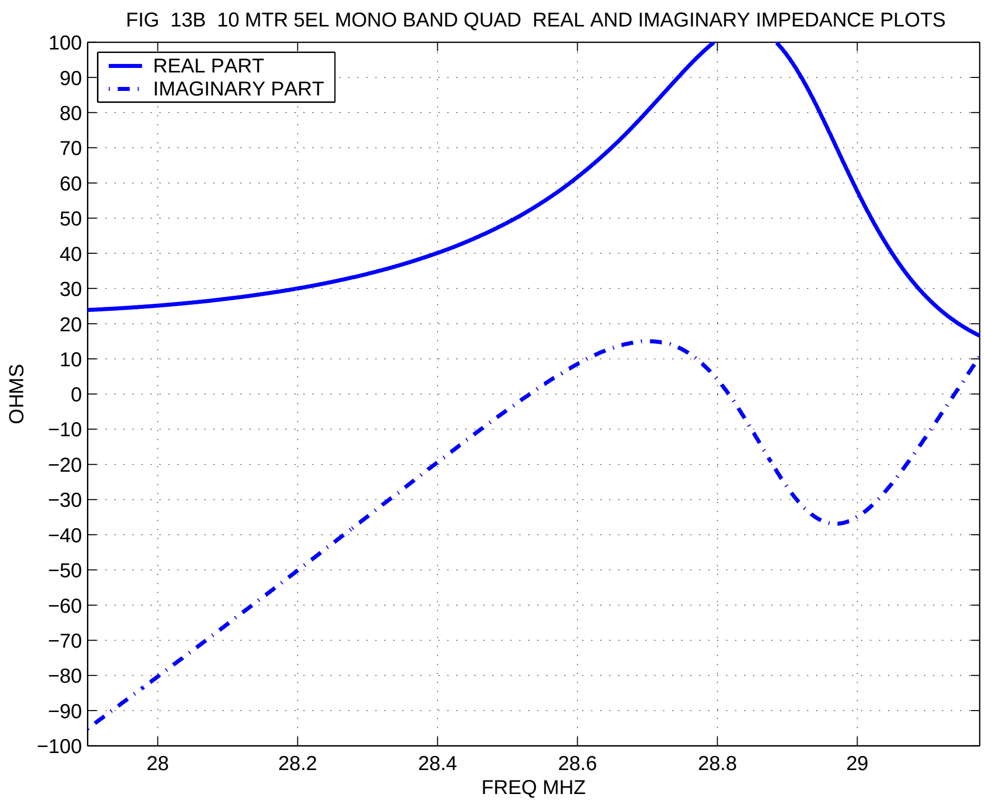
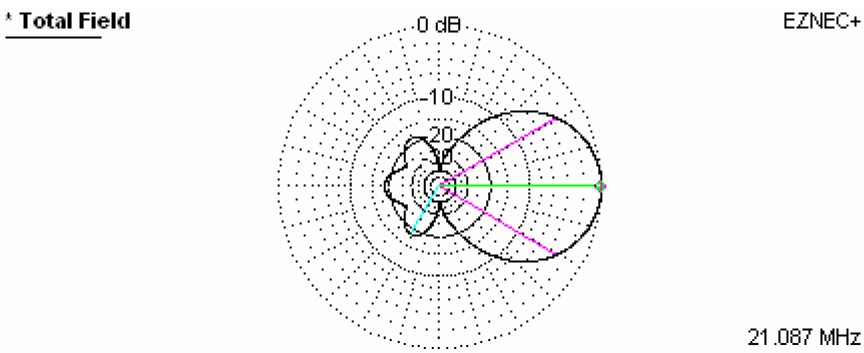


FIG 13B 10 MTR 5EL MONO BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS
REAL PART
IMAGINARY PART
OHMS
100
90
80
70
60
50
40
30
20
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
28
28.2
28.4
28.6
28.8
29
FREQ MHZ

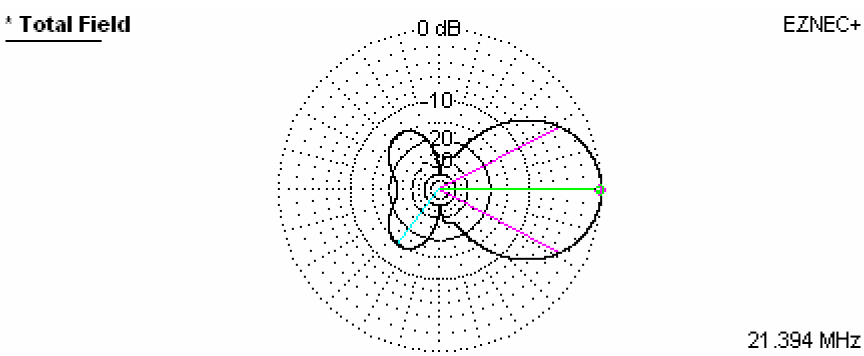
Figure 14A Maximum FBR Frequency Plot For Fig 6 Quad Array



Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	11.5 deg.	Gain	14.43 dBi
Outer Ring	14.43 dBi		0.0 dBmax

Slice Max Gain 14.43 dBi @ Az Angle = 0.0 deg.
Front/Back 18.36 dB
Beamwidth 60.6 deg.; -3dB @ 329.7, 30.3 deg.
Sidelobe Gain -3.79 dBi @ Az Angle = 237.8 deg.
Front/Sidelobe 18.22 dB

Figure 14B Maximum FB Frequency Plot For Fig 6 Quad Array



Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	11.5 deg.	Gain	14.59 dBi
Outer Ring	14.59 dBi		0.0 dBmax

Slice Max Gain 14.59 dBi @ Az Angle = 0.0 deg.
Front/Back 23.01 dB
Beamwidth 55.6 deg.; -3dB @ 332.2, 27.8 deg.
Sidelobe Gain 0.16 dBi @ Az Angle = 232.4 deg.
Front/Sidelobe 14.43 dB

MATLAB PROGRAM quadmod89.m

The purpose of this program is to create a multi band multi element quad design wire table for export to EZNEC 4.0. The program has comment statements that should make it easy to use. It can model any single or multi band quad of either the diamond or square configuration on the 20, 17, 15, 12, 10, and 6 Meter bands as coded. A listing of the program (or .m file MATLAB script) follows.

```
% M-file quadmod89.m
% MATLAB program designed to create an exportable wire table for the EZNEC or
EZNEC-PRO
%   antenna modeling programs for any mono band or multi band
%   multi element Cubical Quad antenna in either the diamond or square loop
%   shape configuration.
%
% A note for radio amateurs not familiar with the MATLAB programming
% language follows. MATLAB is a powerful high level scientific programming
% language commonly used by college students and professional engineers.
% The student version of MATLAB can be downloaded from the Mathworks web
% site for $100. The professional version of MATLAB currently costs $1900.
% Both PC and MAC versions are available.
%
% Written by Bob Hume KG6B on 6/26/2004  (310) 376-4192 (H) 814-7557 (W)
%  e-mail: rwhume@adelphia.net
% Final EZNEC export file wire end locations and sizes are in meter units
%       with zero antenna height (i.e at center point of quad loops)
% Export wire file includes the number of EZNEC segments used to model
%       each wire.
% See detailed instructions on how export the quad wire table file generated
%       by this program to EZNEC at the end of this program listing.
%
%square=1; % Activate this line (remove leading %) for a square quad loop
configuration.
%           EZNEC should use a source at the middle of wire #5 for the
%           driven band for the square loop configuration
square=0; % Activate this line for a diamond quad loop configuration.
%           EZNEC should use a split SI source at the 0% end of wire #5
%           for the driven band for the diamond loop configuration.
% Select all bands common bare copper wire diameter in feet "dia"
%       on following line(s).
%       Note that EZNEC 3.0 can not properly model wire with a thick layer of
%       insulation. Enamel covered magnet wire can be properly modeled
%       since the insulation layer is very thin.
%dia=.06408/12; % #14 wire diameter in feet
dia=.08081/12; % #12 wire diameter in feet (new wire gauge selected for 2004 design)
%dia=.09074/12; % #11 wire diameter in feet (actual 1989 wire gauge)
```

```
%
% Select Meter bands in quad on next line(s) that define matrix "bandset"
%bandset=[20 17 15 12 10]'; % MTR bands in quad. Choose one or all of the 20, 17,
%       15, 12, 10, or 6 MTR bands in any order except that the first band listed is
%       the driven band for which the antenna is evaluated. Consider the 1500 wire
%       segment limit of EZNEC 4.0 when choosing the number of bands and
%       elements in the quads. The driven band uses "segsA" segments per wire. The
%       non driven bands use "segsB" segments per wire. There are four wires per
%       quad loop. EZNEC may give a warning using 5 segments per wire but
%       this is OK since the currents in the non driven band element wires are
%       small.
%
segsA=9; % Segments per wire for driven band Quad wires (use odd integer)
segsB=7; % Segments per wire for non driven band Quad wires (use odd integer)
%
% Remove leading % on one of the below lines to activate and select a quad antenna
%       design option
%bandset=[20]'; % Mono band option 20
%bandset=[17]'; % Mono band option 17
%bandset=[15]'; % Mono band option 15
%bandset=[12]'; % Mono band option 12
%bandset=[10]'; % Mono band option 10
%bandset=[20 15 10]'; % Tri band option 20 driven
%bandset=[15 10 20]'; % Tri band option 15 driven
%bandset=[10 20 15]'; % Tri band option 10 driven
bandset=[20 17 15 12 10]'; % Five band option 20 driven
%bandset=[17 15 12 10 20]'; % Five band option 17 driven
%bandset=[15 12 10 20 17]'; % Five band option 15 driven
%bandset=[12 10 20 17 15]'; % Five band option 12 driven
%bandset=[10 20 17 15 12]'; % Five band option 10 driven
%
%
NRbands=length(bandset);
wnr=zeros(NRbands,7);
wnr(:,1)=bandset;
nt=0;
segtotal=0;
%
disp(' ')
if square==1
   disp('MONO OR MULTI BAND CUBICAL QUAD DESIGN CONSTANTS @
SQUARE ELEMENT SHAPES')
else
   disp('MONO OR MULTI BAND CUBICAL QUAD DESIGN CONSTANTS @
DIAMOND ELEMENT SHAPES')
end
```

```
disp(' ')
disp('FIRST BAND LISTED IS THE DRIVEN BAND. "DE" STANDS FOR DRIVEN
ELEMENT')
disp('DATA ELEMENT ORDER IS REF, DE, DIR1, DIR2, ...DIRn')
for bandNR=1:NRbands % Band case loop
MTRband=bandset(bandNR); % Selected MTR band in loop
%
% MODEL THE QUAD DESIGN CONSTANTS FOR EACH BAND ON THE
FOLLOWING LINES.
%   THE PROGRAM QUAD MODEL ASSUMES THAT ONE REFLECTOR PER
BAND IS USED.
%   ONLY QUAD METER BANDS USED IN THE MATRIX "bandset" NEED BE
MODELED
if MTRband==20
% 20 MTR Quad design constants follow
k=997.6767; % Driven Element (DE) Length*Frequency Design Product in FT*MHZ
units
f=14.15;    % DE Design Frequency in Mhz
if bandNR==1
   segs=segsA; % segs=EZNEC segments per wire. segs must be odd for square quad
loops
else
   segs=segsB;
end
elper=[2.976 0 -1.704 -1.725]'; % Percent change from driven element (DE) size for
%                              each element.
%                              Order: REF, DE, DIR1, DIR2, ...DIRn etc
elspace=[0 10 20 30]'; % Element locations along boom in ft (@ Reflector=0)
%                     Order: REF, DE, DIR1, DIR2, ...DIRn etc
disp(' ')
disp('20 MTR QUAD DESIGN CONSTANTS')
end
%
%
if MTRband==17
% 17 MTR Quad design constants follow
k=987.6525; % DE Length*Frequency Design Product in FT*MHZ units
f=18.11;  % DE Design Frequency in Mhz
if bandNR==1
   segs=segsA; % segs=EZNEC segments per wire
else
   segs=segsB;
end
elper=[3 0 -1.75 -1.75]'; % Percent change from driven element (DE) size for
%                              each element.
%                              Order: REF, DE, DIR1, DIR2, ...DIRn etc
```

```
elspace=[0 10 20 30]'; % Element locations along boom in ft (@ Reflector=0)
%                               Order: REF, DE, DIR1, DIR2
disp(' ')
disp('17 MTR QUAD DESIGN CONSTANTS')
end
%
%
if MTRband==15
% 15 MTR Quad design constants follow
k=996.9452; % DE Length*Frequency Design Product in FT*MHZ units
f=21.2;  %  DE Design Frequency in Mhz
if bandNR==1
   segs=segsA; % segs=EZNEC segments per wire
else
   segs=segsB;
end
elper=[3.071 0 -1.848 -1.770]'; % Percent change from driven element (DE) size for
%                          each element.
%                          Order: REF, DE, DIR1, DIR2, ...DIRn etc
elspace=[0 10 20 30]'; % Element locations along boom in ft (@ Reflector=0)
%                               Order: REF, DE, DIR1, DIR2
disp(' ')
disp('15 MTR QUAD DESIGN CONSTANTS')
end
%
%
if MTRband==12
% 12 MTR Quad design constants follow
k=993.935; % DE Length*Frequency Design Product in FT*MHZ units
f=24.93;  % DE Design Frequency in Mhz
if bandNR==1
   segs=segsA; % segs=EZNEC segments per wire
else
   segs=segsB;
end
elper=[3 0 -1.75 -1.75]'; % Percent change from driven element (DE) size for
%                          each element.
%                          Order: REF, DE, DIR1, DIR2, ...DIRn etc
elspace=[0 10 20 30]'; % Element locations along boom in ft (@ Reflector=0)
%                               Order: REF, DE, DIR1, DIR2
disp(' ')
disp('12 MTR QUAD DESIGN CONSTANTS')
end
%
%
if MTRband==10
```

```
% 10MTR Quad design constants follow
k=997.528; % DE Length*Frequency Design Product in FT*MHZ units
f=28.45;  % DE Design Frequency in Mhz
if bandNR==1
   segs=segsA; % segs=EZNEC segments per wire
else
   segs=segsB;
end
elper=[3.014 0 -2.066 -1.744 -1.723]'; % Percent change from driven element (DE) size
for
%                           each element.
%                           Order: REF, DE, DIR1, DIR2, ...DIRn etc
elspace=[0 5 10 20 30]'; % Element locations along boom in ft (@ Reflector=0)
%                                Order: REF, DE, DIR1, DIR2, DIR3
disp(' ')
disp('10 MTR QUAD DESIGN CONSTANTS')
end
%
%
if MTRband==6
% 6 MTR Quad design constants follow
k=997.528; % DE Length*Frequency Design Product in FT*MHZ units
f=51.0;  % DE Design Frequency in Mhz
if bandNR==1
   segs=segsA; % segs=EZNEC segments per wire
else
   segs=segsB;
end
elper=[3.014 0 -2.066 -1.8]'; % Percent change from driven element (DE) size for
%                                Order: REF, DE, DIR1, DIR2, DIR3
elspace=[17 20 24 30]'; % Element locations along boom in ft (@ Reflector=0)
%                                Order: REF, DE, DIR1, DIR2, DIR3
disp(' ')
disp('6 MTR QUAD DESIGN CONSTANTS')
end
%
%
disp(['DE LENGTH CONSTANTS:   k=',num2str(k),'   f=',num2str(f),'   DE in
FT=',num2str(k/f)])
disp(['ELEMENT LENGTHS AS A % FROM DE=',num2str(elper')])
disp(['ELEMENT BOOM LOCATIONS IN FT=',num2str(elspace')])
disp(['SEGMENTS PER WIRE=',num2str(segs)])
%
elcirc=(k/f)*(1+elper/100); % Element total length (i.e. of all four sides) matrix in ft
elarm=elcirc/(4*sqrt(2)); % Diamond Quad arm length matrix in ft
%
```

```
n=length(elper); % Number of elements in Quad
A=zeros(4*n,8); % Blank EZNEC wire table. Column 8 for number of segments per wire
%
if square==0 % Diamond quad loop configuration
for i=1:n % Quad element number index i
   s=elspace(i,1);
   a=elarm(i,1);
   m=[s 0 -a s a 0 dia segs; % Wire coordinates matrix for diamond Quad element i
      s a 0 s 0 a dia segs;
      s 0 a s -a 0 dia segs;
      s -a 0 s 0 -a dia segs];
   A(4*(i-1)+1:4*(i-1)+4,:)=m;  % Wire coordinate accumulation for all n Quad elements
end
end
%
if square==1 % Square quad loop configuration
for i=1:n % Quad element number index i
   s=elspace(i,1);
   c=elarm(i,1)/sqrt(2); % Half side dimension of loop
   m=[s -c -c s c -c dia segs; % Wire coordinates matrix for square Quad element i
      s c -c s c c dia segs;
      s c c s -c c dia segs;
      s -c c s -c -c dia segs];
   A(4*(i-1)+1:4*(i-1)+4,:)=m;  % Wire coordinate accumulation for all n Quad elements
end
end
%
A(:,1:7)=(12*2.54/100)*A(:,1:7); % Convert wire dimensions from Feet to Meters
%
nt=nt+length(A);
segtotal=segtotal+segs*length(A);
wnr(bandNR,2)=length(A);
wnr(bandNR,3)=segs;
wnr(bandNR,4)=nt;
wnr(bandNR,5)=segtotal;
wnr(bandNR,6)=nt-length(A)+5;
wnr(bandNR,7)=nt-length(A)+8;
%
if bandNR==1
   B=A;
else
   Bold=B;
   nB=length(Bold);
   nA=length(A);
   B=zeros((nB+nA),8);
   B(1:nB,:)=Bold;
```

```
   B((nB+1):(nB+nA),:)=A;
end
end % End of bands loop
%
qall=B; % EZNEC wire table matrix for use in other MATLAB programs.
% The next three lines of MATLAB code create an ASCII text file for
%  wire table file "qall" which is compatible with the EZNEC wire
%  table import file requirements.
fid = fopen('qallw','wt'); % Open and write to ASCII text file qallw
fprintf(fid,'%f %f %f %f %f %f %f\n',B'); % ASCII text file of B
fclose(fid); % close file
%
if square==1
disp(' ')
disp('              SEGS       TOTAL  DRIVEN ELEMENT WIRE NUMBER')
disp('   MTR   BAND   PER  TOTAL #WIRE  MIDDLE OR 50% POINT IN WIRE')
disp('   BAND  WIRES  WIRE WIRES SEGS   DE#')
disp([wnr(:,1:6)])
disp(' ')
   disp('For the square quad loop configuration EZNEC must use a single source')
   disp('  at the center (50%) of wire number 5')
else
disp(' ')
disp('              SEGS       TOTAL  DRIVEN ELEMENT WIRE NUMBERS')
disp('   MTR   BAND   PER  TOTAL #WIRE   0%   100%')
disp('   BAND  WIRES  WIRE WIRES SEGS   DEa#  DEb#')
disp([wnr])
disp(' ')
   disp('For the diamond quad loop configuration EZNEC must use a split SI source')
   disp('  at wire number 5 (0% end)')
end
disp(' ')
disp('The above table also lists the driven element wire number(s) for the non driven')
disp('  bands in case impedance termination effects are to be modeled in EZNEC')
disp(' ')
disp('EZNEC 4.0 can work with up to 1500 wire segments (SEGS) total')
disp('EZNEC-M Pro version can work with up to 10,000 wire segments total')
disp(' ')
disp(' ')
disp('EZNEC wire table output in Meter units with zero antenna height follows')
type qallw % EZNEC Wire table file in export compatible ASCII text file form
%
% To export the ASCII wire table file "qallw" to EZNEC follow these steps.
% 1.) Run program quadmod89.m in the MATLAB work space to create file "qallw"
% 2.) Open EZNEC
% 3.) Click on the "WIRES" tab
```

```
% 4.) Click on the "Other" button
% 5.) Select "Import Wires From ASCII File"
% 6.) Select "Replace Existing Wires"
% 7.) Locate file "qallw" on the path C:\MATLAB7\work\qallw
% 8.) Double click file "qallw"
% 9.) Click "Other"
% 10.) Click "Change units"
% 11.) Select feet and click OK
% 12.) Click "Wire"
% 13.) Select "Change Height by ..."
% 14.) Enter antenna height in feet and click OK
% 15.) In EZNEC window click the "Ground Type" tab
% 16.) Select real or perfect ground option and click OK
% 17.) In EZNEC window click the "Sources tab"
% 18.) Enter the source as follows for the square or diamond loop
%      For square quad loops EZNEC should use a source at the middle of wire #5
%      For diamond quad loops EZNEC should use a split SI source at the
%          0% end of wire #5
%      The source only needs to be set up one time for all "bandset" case
%      runs
% The above steps 1 to 17 can be performed in about a minute for each
%   "bandset" case. The program thereby makes it possible to evaluate large
%   multiband multielement quad arrays very quickly using EZNEC. Manual
%   wire table entry errors and tedium are avoided using this program.
%
% Also see MATLAB programs zcon.m and quadk1.m which use the EZNEC
%  antenna impedance versus frequency data table output "LastZ.txt"
%  obtained from an EZNEC SWR plot run
%  to plot SWR versus frequency using a 75 Ohm RG11AU quarter wave Q
%  section match to a RG213U 50 Ohm coaxial feed line.
```

MATLAB PROGRAM zcon.m

The purposes of this program are:

1.) To create a reformatted matrix of driving point impedance frequency, real part, and imaginary part from the NEC 4.0 SWR run file LastZ.txt.
2.) Create a plot of the real and imaginary parts versus frequency
3.) List the resonant frequencies and resistances precisely using curve fitting.

The directions for using zcon.m follow:

In NEC 4.0 click SWR
Select SWR sweep parameters
Run SWR sweep
Click File,View File
Open file LastZ.txt
Select all file numbers below “Freq Mhz”
Edit, Copy
In MATLAB work space type “ z=[“
Put cursor after [
Click Edit, Paste
Type “];” after last number in file
Type “ zcon” , then carriage return to run program
Program outputs will appear
The reformatted file was cut and pasted to MATLAB program quad89.m in all of the z suffix impedance matrices that were then used to obtain an integrated data matrix of the frequency, gain, FB, FBR, real part, and imaginary part for each antenna array.

LISTING OF MATLAB PROGRAM zcon.m FOLLOWS

```
% zcon.m
% MATLAB program for converting EZNEC SWR data file output
% Converts EZNEC z matrix data to condensed form for input to
%  MATLAB program quadk1.m
% Plots real and imaginary parts of Z versus frequency
%  For either case of one (square quad loops) or two
%   (diamond quad loops) sources used to drive antenna.
% Run EZNEC SWR tab, get z data from: File, View File, LastZ
% Cut and paste LastZ data to z=[paste data, then ]; in MATLAB work space.
global z zout % Copy this line to MATLAB work space before running this program
% Run this program (zcon) in MATLAB work space
% Cut and paste zout data from work space to quadk1 Q section SWR program
%  as a data matrix.
nz=length(z);
if z(1,1)==z(2,1)  % split EZNEC sources case with two rows per frequency
zout=zeros(nz/2,3);
for g=1:nz/2
   k=2*g-1;
   zout(g,1)=z(k,1);
   zout(g,2)=z(k,3);
   zout(g,3)=z(k,4);
end
else              % single EZNEC source case. One row per frequency
   zout=zeros(nz,3);
   zout(:,1)=z(:,1);
   zout(:,2)=z(:,3);
   zout(:,3)=z(:,4);
end
zout % Converted file output F, R, X columns
%
plot(zout(:,1),zout(:,2),'LineWidth',1)
hold on
plot(zout(:,1),zout(:,3),':','LineWidth',2)
grid
text(zout(3,1),zout(3,2),'REAL R (SOLID)')
text(zout(3,1),zout(3,3),'IMAGINARY X (DASHED)')
xlabel('FREQUENCY IN MHZ')
ylabel('IMPEDANCE IN OHMS')
```

```
title('FIG 3 DRIVING POINT REAL R AND IMAGINARY X VERSUS
FREQUENCY')
%
prevz=zout(1,3);
j=0;
clear nref
for i=2:nz
   r=zout(i,3)/prevz;
   if r<0
      j=j+1;
      nref(j,1)=i; % Loop detects all resonant frequencies
   end
   prevz=zout(i,3);
end
for j=1:length(nref)
nrefj=nref(j,1);
Fr=polyval(polyfit(zout(nrefj-2:nrefj+1,3),zout(nrefj-2:nrefj+1,1),2),0);
Rr=polyval(polyfit(zout(nrefj-2:nrefj+1,1),zout(nrefj-2:nrefj+1,2),2),Fr);
disp(' ')
disp(['Resonant Frequency Fr in MHZ=',num2str(Fr)])
disp(' ')
disp(['Resonant Resistance in Ohms=',num2str(Rr)])
disp(' ')
disp(' ')
end
```

MATLAB PROGRAM quad89b.m

The purpose of this program is to create the Figure 1A to Figure 13A and Figure 1B to 13B plots from the antenna data matrices contained in MATLAB program quad89.m. A listing of this program follows.

```
% M-file quad89b.m
global ant ants theta DPLdBi
quad89 % MATLAB program souce for 13 array data matrices
names=['20 MTR 4EL FIVE BAND QUAD';  % 1 array ID numbers
      '20 MTR 4EL TRI BAND QUAD ';  % 2
      '20 MTR 4EL MONO BAND QUAD';  % 3
      '17 MTR 4EL FIVE BAND QUAD';  % 4
      '17 MTR 4EL MONO BAND QUAD';  % 5
      '15 MTR 4EL FIVE BAND QUAD';  % 6
      '15 MTR 4EL TRI BAND QUAD ';  % 7
      '15 MTR 4EL MONO BAND QUAD';  % 8
      '12 MTR 4EL FIVE BAND QUAD';  % 9
      '12 MTR 4EL MONO BAND QUAD';  % 10
      '10 MTR 5EL FIVE BAND QUAD';  % 11
      '10 MTR 5EL TRI BAND QUAD ';  % 12
      '10 MTR 5EL MONO BAND QUAD']; % 13
%
plots=['  GAIN, FB, AND FBR PLOTS';
       '  SWR PLOT               '];
fmin=[13.8 13.8 13.8 17.85 17.85 20.65 20.65 20.65 ...
      24.4 24.4 27.9 27.9 27.9]; % plot min freqs
fmax=[14.525 14.525 14.525 18.850 18.850 21.875 21.875 ...
      21.875 25.8 25.8 29.175 29.175 29.175]; % plot max freqs
%
for i=1:13
   q=ants{i}; % Select i th of 13 antenna data matrices
   f=q(:,1); % Frequency in MHZ
   gain=q(:,2); % gain in dBi
   fb=q(:,3);
   fbr=q(:,4);
   swr52=q(:,7); % swr with 52 Ohm coax feed
   real=q(:,5);
   imag=q(:,6);
   gg=1; % Set gg=1 for gain, fb, fbr, swr52 plots
```

```
  if gg==1
  plot(f,gain,'LineWidth',2)
  hold on
  plot(f,fb,'-.','LineWidth',2)
  plot(f,fbr,'--','LineWidth',2)
  plot(f,10*swr52,':','LineWidth',2)
  grid
  axis([fmin(i) fmax(i) 10 25])
  set(gca,'ytick',[10:1:25])
  hold off
  legend('GAIN dBi','FB dB','FBR dB','10*SWR52',2)
  xlabel('FREQ MHZ')
  ylabel('GAIN, FB, FBR, 10*SWR52')
  title(['FIG  ',num2str(i),'A  ',names(i,:),' GAIN, FB, FBR, and SWR PLOTS'])
  %print
  fig
  keyboard
  end
  zz=1; % set zz=1 for real and imaginary parts of impedance plots
  if zz==1
     plot(f,real,'LineWidth',2)
     hold on
     plot(f,imag,'-.','LineWidth',2)
     %lr=length(real);ri=zeros(2*lr,1);
     %ri(1:lr,1)=real;ri(lr+1:2*lr,1)=imag;
     axis([fmin(i) fmax(i) -100 100])
     set(gca,'ytick',[-100:10:100])
     grid
     hold off
     legend('REAL PART','IMAGINARY PART',2)
     xlabel('FREQ MHZ')
     ylabel('OHMS')
     title(['FIG  ',num2str(i),'B  ',names(i,:),'  REAL AND IMAGINARY IMPEDANCE
PLOTS'])
     %print
     fig
     keyboard
  end

end
%
```

MATLAB PROGRAM fig.m

This program is used in MATLAB program quad89b.m to prepare a figure for export to an MS Word document. A listing of this short program follows.

```
% M-file fig.m
% Contains code line for exporting a MATLAB figure
disp(' ')
disp(' print -depsc2 fig1.eps -tiff ')
disp(' ')
disp('fig memory location path:  C/matlabR12/work')
disp(' ')
print -depsc2 fig1.eps –tiff
```

MATLAB PROGRAM quad89.m

The purpose of this program is to create data matrices for each of the 13 antenna arrays containing the frequency, gain, FB, FBR, real part of Z, and imaginary part of Z information obtained from the EZNEC 4.0 antenna runs. The EZNEC 4.0 run frequency step that I used is every 25 Khz. The program uses a spline fit to create a new smoothed data matrix in 1 Khz steps for use in program quad89b.m to create plots. The cell matrix ants{i} where i=1 to 13 for the 13 antenna arrays can be used to view the 1 Khz data files after running quad89.m. Minima, maxima, or threshold antenna parameter values can be quickly determined with a 1 Khz precision using these files. A listing of the program follows.

```
% M-file quad89.m
% Program date 6-19-2004
% Comparison of 5 band, tri band, and mono band quads of same per band dimensions
% Five band quad is 20,17,15,12,10 MTR bands
% Tri band quad is 20,15,10 MTR bands
% 20,15,10 MTR quads use KG6B 1989 design dimensions
% EZNEC 4.0 antenna modeling results
% #12 copper wire elements
% Antenna at 55 foot above ground
% Unused driven elements shorted
%
% The Gain, FB, and FBR values are based on a fixed vertical wave
%   angle "theta" for each band at the first vertical main lobe maximum.
% The theta degree vales are 20 MTR=16.3, 17 MTR=13.2, 15 MTR=11.5,
%   12 MTR=9.9, 10 MTR=8.7
% The theta matrix for the 11 modeled antenna configurations follows
theta=[16.3 16.3 16.3 13.2 13.2 11.5 11.5 11.5 9.9 9.9 8.7 8.7 8.7]';
% DIPOLE dBi gain at above theta angles and 55 foot height above ground
% follows
DPLdBi=[7.07 7.07 7.07 7.66 7.66 7.76 7.76 7.76 7.49 7.49 7.94 7.94 7.94]';
%
% Format of following g subscripted matrices is
% Column 1= Frequency in MHZ
% Column 2=Gain in dBi
% Column 3=FB in dB
% Column 4=FBR in dB where FBR=Front to Back Region gain.
%   The back region is 180+/-90 degrees from the antenna heading.
%
```

```
% 20 MTR FIVE BAND QUAD FOLLOWS
q20b5g=[13.8000   12.8400    5.6600    5.6600 % @ theta=16.3 deg
   13.8250   13.2000    7.0600    7.0600
   13.8500   13.4900    8.6300    8.6300
   13.8750   13.7300   10.4500   10.4500
   13.9000   13.9100   12.5700   12.5700
   13.9250   14.0300   15.1500   15.1500
   13.9500   14.1100   18.3700   18.3700
   13.9750   14.1500   22.4800   21.8000
   14.0000   14.1600   25.8900   20.6000
   14.0250   14.1400   23.7800   19.2900
   14.0500   14.1000   20.2300   17.9600
   14.0750   14.0500   17.5500   16.6500
   14.1000   14.0000   15.5700   15.3800
   14.1250   13.9300   14.0600   14.0600
   14.1500   13.8600   12.8800   12.8800
   14.1750   13.8000   11.9500   11.9500
   14.2000   13.7400   11.2100   11.2100
   14.2250   13.6800   10.6500   10.6500
   14.2500   13.6300   10.2500   10.2500
   14.2750   13.6000   10.0300   10.0300
   14.3000   13.5800   10.0300   10.0300
   14.3250   13.5700   10.3100   10.3000
   14.3500   13.5800   11.0300   10.8500
   14.3750   13.6000   12.5400   11.6800
   14.4000   13.5500   15.5000   12.8300
   14.4250   13.1900   16.2100   14.0500
   14.4500   11.8300    7.3700    7.3700];
%
```

```
% 20 MTR TRI BAND QUAD FOLLOWS
q20b3g=[13.8000   12.4300    4.0800    4.0800 % @ theta=16.3 deg
   13.8250   12.8000    5.1100    5.1100
   13.8500   13.1200    6.2400    6.2400
   13.8750   13.4100    7.4800    7.4800
   13.9000   13.6500    8.8500    8.8500
   13.9250   13.8500   10.3800   10.3800
   13.9500   14.0100   12.0900   12.0900
   13.9750   14.1200   14.0600   14.0600
   14.0000   14.2000   16.3400   16.3400
   14.0250   14.2500   18.9800   18.9800
   14.0500   14.2800   21.8600   20.9800
   14.0750   14.2800   23.9000   20.0400
   14.1000   14.2700   23.3800   19.0600
   14.1250   14.2500   21.3000   18.0900
   14.1500   14.2100   19.2300   17.1600
   14.1750   14.1800   17.5500   16.2800
   14.2000   14.1400   16.2200   15.4600
   14.2250   14.1000   15.1900   14.7300
   14.2500   14.0600   14.4200   14.1100
   14.2750   14.0200   13.8800   13.6100
   14.3000   14.0000   13.5800   13.2500
   14.3250   13.9800   13.5400   13.0600
   14.3500   13.9700   13.8600   13.0500
   14.3750   13.9700   14.7200   13.2400
   14.4000   13.9600   16.5600   13.6700
   14.4250   13.9100   20.4200   14.3400
   14.4500   13.6800   21.0400   15.1900
   14.4750   12.9000   11.4600   11.4600
   14.5000   10.7600    3.5800    3.5800];
%
```

```
% 20 MTR MONO BAND QUAD FOLLOWS
q20b1g=[13.8000   12.1000    3.1200    3.1200 % @ theta=16.3 deg
   13.8250   12.4600    3.9300    3.9300
   13.8500   12.7800    4.8000    4.8000
   13.8750   13.0800    5.7500    5.7500
   13.9000   13.3500    6.7600    6.7600
   13.9250   13.5900    7.8600    7.8600
   13.9500   13.7900    9.0400    9.0400
   13.9750   13.9500   10.3300   10.3300
   14.0000   14.0900   11.7300   11.7300
   14.0250   14.1900   13.2700   13.2700
   14.0500   14.2700   14.9700   14.9700
   14.0750   14.3200   16.8500   16.8500
   14.1000   14.3500   18.8800   18.8800
   14.1250   14.3700   20.9200   20.2100
   14.1500   14.3800   22.5400   19.5100
   14.1750   14.3700   23.0900   18.8000
   14.2000   14.3600   22.5000   18.1200
   14.2250   14.3400   21.3600   17.4700
   14.2500   14.3200   20.2100   16.8700
   14.2750   14.3000   19.2600   16.3400
   14.3000   14.2800   18.5800   15.8800
   14.3250   14.2600   18.2100   15.5100
   14.3500   14.2500   18.2200   15.2600
   14.3750   14.2400   18.7400   15.1300
   14.4000   14.2400   20.0900   15.1400
   14.4250   14.2200   23.2400   15.3300
   14.4500   14.1600   32.8600   15.7000
   14.4750   13.9800   22.8300   16.2300
   14.5000   13.4600   13.3800   13.3800
   14.5250   12.0800    6.5200    6.5200];
%
```

```
% 17 MTR FIVE BAND QUAD FOLLOWS
q17b5g=[17.8500   13.7500    6.0200    6.0200 % @ theta=13.2 deg
   17.8750   13.9400    6.9100    6.9100
   17.9000   14.1000    7.8700    7.8700
   17.9250   14.2300    8.9200    8.9200
   17.9500   14.3400   10.0600   10.0600
   17.9750   14.4200   11.3300   11.3300
   18.0000   14.4800   12.7000   12.7000
   18.0250   14.5100   14.2100   14.2100
   18.0500   14.5300   15.8600   15.8600
   18.0750   14.5200   17.5800   17.5800
   18.1000   14.5100   19.2000   19.2000
   18.1250   14.4800   20.3700   18.5100
   18.1500   14.4500   20.6700   17.5400
   18.1750   14.4100   20.0900   16.6600
   18.2000   14.3600   19.0500   15.8600
   18.2250   14.3100   17.8800   15.1200
   18.2500   14.2700   16.8100   14.4600
   18.2750   14.2200   15.9000   13.8800
   18.3000   14.1800   15.1200   13.3500
   18.3250   14.1400   14.5100   12.9100
   18.3500   14.1100   14.0500   12.5400
   18.3750   14.0900   13.7400   12.2600
   18.4000   14.0800   13.5800   12.0600
   18.4250   14.0900   13.6000   11.9600
   18.4500   14.1100   13.8200   11.9700
   18.4750   14.1400   14.2800   12.1000
   18.5000   14.1900   14.9500   12.3700
   18.5250   14.2400   15.6900   12.8000
   18.5500   14.2800   15.7700   13.3800
   18.5750   14.2500   14.0100   14.0100
   18.6000   14.0400   10.6300   10.6300
   18.6250   13.4600    6.7200    6.7200
   18.6500   12.2400    2.8400    2.8400];
%
```

```
% 17 MTR MONO BAND QUAD FOLLOWS
q17b1g=[17.8500   13.0700    2.3100    2.3100 % @ theta=13.2 deg
   17.8750   13.2600    2.6500    2.6500
   17.9000   13.4300    3.0000    3.0000
   17.9250   13.6000    3.3600    3.3600
   17.9500   13.7600    3.7400    3.7400
   17.9750   13.9200    4.1300    4.1300
   18.0000   14.0700    4.5300    4.5300
   18.0250   14.2100    4.9500    4.9500
   18.0500   14.3400    5.3800    5.3800
   18.0750   14.4600    5.8200    5.8200
   18.1000   14.5700    6.2800    6.2800
   18.1250   14.6700    6.7400    6.7400
   18.1500   14.7600    7.2300    7.2300
   18.1750   14.8500    7.7200    7.7200
   18.2000   14.9200    8.2200    8.2200
   18.2250   14.9800    8.7400    8.7400
   18.2500   15.0400    9.2700    9.2700
   18.2750   15.0900    9.8100    9.8100
   18.3000   15.1300   10.3700   10.3700
   18.3250   15.1600   10.9400   10.9400
   18.3500   15.1900   11.5200   11.5200
   18.3750   15.2200   12.1100   12.1100
   18.4000   15.2400   12.7300   12.7300
   18.4250   15.2600   13.3600   13.3600
   18.4500   15.2800   14.0000   14.0000
   18.4750   15.2900   14.6600   14.6600
   18.5000   15.3100   15.3300   15.3300
   18.5250   15.3200   16.0000   16.0000
   18.5500   15.3300   16.6300   16.6300
   18.5750   15.3400   17.1800   17.1800
   18.6000   15.3500   17.5200   17.5200
   18.6250   15.3500   17.5200   17.5200
   18.6500   15.3400   17.0600   17.0600
   18.6750   15.3100   16.0600   16.0600
   18.7000   15.2500   14.6100   14.6100
   18.7250   15.1200   12.8500   12.8500
   18.7500   14.9100   10.9200   10.9200
   18.7750   14.5400    8.8800    8.8800
   18.8000   13.9700    6.7800    6.7800
   18.8250   13.1200    4.6400    4.6400
   18.8500   11.9400    2.4400    2.4400];
%
%
```

```
% 15 MTR FIVE BAND QUAD FOLLOWS
q15b5g=[20.6500   13.0300    4.3500    4.3500 % @ theta=11.5 deg
   20.6750   13.2200    4.9000    4.9000
   20.7000   13.3900    5.4700    5.4700
   20.7250   13.5400    6.0700    6.0700
   20.7500   13.6800    6.7000    6.7000
   20.7750   13.8100    7.3600    7.3600
   20.8000   13.9200    8.0500    8.0500
   20.8250   14.0200    8.7600    8.7600
   20.8500   14.1100    9.5200    9.5200
   20.8750   14.1800   10.3000   10.3000
   20.9000   14.2400   11.1300   11.1300
   20.9250   14.2900   11.9900   11.9900
   20.9500   14.3300   12.9000   12.9000
   20.9750   14.3600   13.8300   13.8300
   21.0000   14.3900   14.8200   14.8200
   21.0250   14.4100   15.8300   15.8300
   21.0500   14.4200   16.8500   16.8500
   21.0750   14.4300   17.8800   17.8800
   21.1000   14.4300   18.8600   17.8900
   21.1250   14.4300   19.7800   17.3000
   21.1500   14.4300   20.5900   16.7700
   21.1750   14.4300   21.2200   16.3000
   21.2000   14.4300   21.6600   15.8600
   21.2250   14.4400   21.9600   15.4800
   21.2500   14.4400   22.1300   15.1600
   21.2750   14.4600   22.2500   14.8900
   21.3000   14.4700   22.3600   14.6700
   21.3250   14.4900   22.5200   14.5200
   21.3500   14.5200   22.7200   14.4200
   21.3750   14.5600   22.9300   14.4000
   21.4000   14.6000   23.0000   14.4500
   21.4250   14.6600   22.6600   14.5900
   21.4500   14.7100   21.6000   14.8300
   21.4750   14.7700   19.7900   15.1800
   21.5000   14.8300   17.4600   15.6700
   21.5250   14.8500   14.9800   14.9800
   21.5500   14.8300   12.4600   12.4600
   21.5750   14.7000   10.0200   10.0200
   21.6000   14.4000    7.6200    7.6200
   21.6250   13.8500    5.2800    5.2800
   21.6500   12.9700    2.9900    2.9900];
%
```

```
% 15 MTR TRI BAND QUAD FOLLOWS
q15b3g=[20.6500   13.4200    3.0800    3.0800 % @ theta=11.5 deg
   20.6750   13.5700    3.4100    3.4100
   20.7000   13.7200    3.7500    3.7500
   20.7250   13.8600    4.1100    4.1100
   20.7500   13.9900    4.4800    4.4800
   20.7750   14.1200    4.8700    4.8700
   20.8000   14.2400    5.2700    5.2700
   20.8250   14.3500    5.6800    5.6800
   20.8500   14.4500    6.1200    6.1200
   20.8750   14.5500    6.5600    6.5600
   20.9000   14.6400    7.0300    7.0300
   20.9250   14.7100    7.5100    7.5100
   20.9500   14.7800    8.0000    8.0000
   20.9750   14.8400    8.5200    8.5200
   21.0000   14.9000    9.0500    9.0500
   21.0250   14.9500    9.6100    9.6100
   21.0500   14.9900   10.1800   10.1800
   21.0750   15.0200   10.7800   10.7800
   21.1000   15.0500   11.4000   11.4000
   21.1250   15.0700   12.0400   12.0400
   21.1500   15.0900   12.7300   12.7300
   21.1750   15.1100   13.4300   13.4300
   21.2000   15.1300   14.1800   14.1800
   21.2250   15.1400   14.9800   14.9800
   21.2500   15.1500   15.8100   15.8100
   21.2750   15.1600   16.7300   16.7300
   21.3000   15.1800   17.7100   17.7100
   21.3250   15.1900   18.7900   18.2700
   21.3500   15.2100   20.0000   18.0900
   21.3750   15.2300   21.3400   17.9300
   21.4000   15.2500   22.7400   17.8400
   21.4250   15.2800   24.0800   17.8200
   21.4500   15.3100   24.8500   17.8500
   21.4750   15.3400   24.4700   17.9500
   21.5000   15.3700   22.8800   18.1400
   21.5250   15.4000   20.7600   18.4100
   21.5500   15.4300   18.5400   18.5400
   21.5750   15.4400   16.4000   16.4000
   21.6000   15.4300   14.3700   14.3700
   21.6250   15.3700   12.4500   12.4500
   21.6500   15.2500   10.6100   10.6100
   21.6750   15.0300    8.8300    8.8300
   21.7000   14.6800    7.0800    7.0800
   21.7250   14.1600    5.3900    5.3900
   21.7500   13.4400    3.7200    3.7200];
```

```
%
% 15 MTR MONO BAND QUAD FOLLOWS
q15b1g=[20.6500   13.4400    2.5500    2.5500 % @ theta=11.5 deg
   20.6750   13.5700    2.7900    2.7900
   20.7000   13.7000    3.0300    3.0300
   20.7250   13.8200    3.2900    3.2900
   20.7500   13.9500    3.5500    3.5500
   20.7750   14.0600    3.8300    3.8300
   20.8000   14.1800    4.1100    4.1100
   20.8250   14.2800    4.4000    4.4000
   20.8500   14.3900    4.7000    4.7000
   20.8750   14.4900    5.0100    5.0100
   20.9000   14.5800    5.3300    5.3300
   20.9250   14.6700    5.6600    5.6600
   20.9500   14.7500    6.0000    6.0000
   20.9750   14.8300    6.3400    6.3400
   21.0000   14.9000    6.7000    6.7000
   21.0250   14.9700    7.0800    7.0800
   21.0500   15.0300    7.4600    7.4600
   21.0750   15.0800    7.8500    7.8500
   21.1000   15.1400    8.2600    8.2600
   21.1250   15.1800    8.6800    8.6800
   21.1500   15.2300    9.1200    9.1200
   21.1750   15.2700    9.5600    9.5600
   21.2000   15.3000   10.0300   10.0300
   21.2250   15.3300   10.5200   10.5200
   21.2500   15.3700   11.0200   11.0200
   21.2750   15.4000   11.5500   11.5500
   21.3000   15.4200   12.1100   12.1100
   21.3250   15.4500   12.6900   12.6900
   21.3500   15.4800   13.3100   13.3100
   21.3750   15.5100   13.9700   13.9700
   21.4000   15.5300   14.6500   14.6500
   21.4250   15.5600   15.3800   15.3800
   21.4500   15.5900   16.1400   16.1400
   21.4750   15.6200   16.9100   16.9100
   21.5000   15.6500   17.6600   17.6600
   21.5250   15.6900   18.3100   18.3100
   21.5500   15.7200   18.7400   18.7400
   21.5750   15.7500   18.7900   18.7900
   21.6000   15.7700   18.3700   18.3700
   21.6250   15.7800   17.5000   17.5000
   21.6500   15.7800   16.2900   16.2900
   21.6750   15.7600   14.8900   14.8900
   21.7000   15.7000   13.4100   13.4100
   21.7250   15.6000   11.9300   11.9300
```

```
   21.7500   15.4300   10.4400   10.4400
   21.7750   15.1800    8.9700    8.9700
   21.8000   14.8100    7.5300    7.5300
   21.8250   14.3200    6.1100    6.1100
   21.8500   13.6900    4.7200    4.7200
   21.8750   12.9200    3.3600    3.3600];
%
%
```

```
% 12 MTR FIVE BAND QUAD FOLLOWS
q12b5g=[24.4000   12.9500    4.4100    4.4100 % @ theta=9.9 deg
   24.4250   13.0800    4.8000    4.8000
   24.4500   13.2100    5.2000    5.2000
   24.4750   13.3200    5.6100    5.6100
   24.5000   13.4400    6.0400    6.0400
   24.5250   13.5400    6.4900    6.4900
   24.5500   13.6400    6.9500    6.9500
   24.5750   13.7300    7.4500    7.4500
   24.6000   13.8100    7.9600    7.9600
   24.6250   13.8800    8.5000    8.5000
   24.6500   13.9500    9.0700    9.0700
   24.6750   14.0200    9.6600    9.6600
   24.7000   14.0700   10.3000   10.3000
   24.7250   14.1200   10.9600   10.9600
   24.7500   14.1700   11.6800   11.6800
   24.7750   14.2100   12.4600   12.4600
   24.8000   14.2500   13.2800   13.2800
   24.8250   14.2800   14.1800   14.1800
   24.8500   14.3100   15.1700   15.1700
   24.8750   14.3300   16.2600   16.2600
   24.9000   14.3600   17.4900   17.4900
   24.9250   14.3800   18.8600   18.2800
   24.9500   14.4100   20.4800   17.8700
   24.9750   14.4300   22.3600   17.5300
   25.0000   14.4600   24.6100   17.2200
   25.0250   14.4800   27.2600   16.9500
   25.0500   14.5100   29.6800   16.7400
   25.0750   14.5500   29.8200   16.5700
   25.1000   14.5800   27.4200   16.4500
   25.1250   14.6300   24.6500   16.3800
   25.1500   14.6800   22.2200   16.3700
   25.1750   14.7300   20.1700   16.4200
   25.2000   14.7900   18.3400   16.5300
   25.2250   14.8400   16.7200   16.7000
   25.2500   14.9000   15.2100   15.2100
   25.2750   14.9600   13.8000   13.8000
   25.3000   15.0100   12.4300   12.4300
   25.3250   15.0300   11.1000   11.1000
   25.3500   15.0200    9.7800    9.7800
   25.3750   14.9500    8.4900    8.4900
   25.4000   14.8100    7.1900    7.1900
   25.4250   14.5600    5.9000    5.9000
   25.4500   14.1800    4.6000    4.6000
   25.4750   13.6500    3.3000    3.3000];
%
```

```
% 12 MTR MONO BAND QUAD FOLLOWS
q12b1g=[24.4000   14.1800    4.7600    4.7600 % @ theta=9.9 deg
   24.4250   14.2600    4.9700    4.9700
   24.4500   14.3300    5.1900    5.1900
   24.4750   14.4100    5.4100    5.4100
   24.5000   14.4800    5.6500    5.6500
   24.5250   14.5500    5.8900    5.8900
   24.5500   14.6200    6.1400    6.1400
   24.5750   14.7000    6.4000    6.4000
   24.6000   14.7600    6.6700    6.6700
   24.6250   14.8300    6.9500    6.9500
   24.6500   14.9000    7.2400    7.2400
   24.6750   14.9600    7.5400    7.5400
   24.7000   15.0200    7.8600    7.8600
   24.7250   15.0900    8.1900    8.1900
   24.7500   15.1500    8.5300    8.5300
   24.7750   15.2100    8.8900    8.8900
   24.8000   15.2700    9.2700    9.2700
   24.8250   15.3200    9.6700    9.6700
   24.8500   15.3800   10.0900   10.0900
   24.8750   15.4400   10.5300   10.5300
   24.9000   15.4900   11.0100   11.0100
   24.9250   15.5500   11.5100   11.5100
   24.9500   15.6000   12.0600   12.0600
   24.9750   15.6600   12.6300   12.6300
   25.0000   15.7100   13.2600   13.2600
   25.0250   15.7700   13.9600   13.9600
   25.0500   15.8200   14.7100   14.7100
   25.0750   15.8800   15.5500   15.4600
   25.1000   15.9300   16.5000   16.2500
   25.1250   15.9900   17.5900   17.0500
   25.1500   16.0400   18.8600   17.8600
   25.1750   16.1000   20.3600   18.6800
   25.2000   16.1500   22.2400   19.5200
   25.2250   16.2000   24.6900   20.3900
   25.2500   16.2600   28.1900   21.2500
   25.2750   16.3100   34.1900   22.1100
   25.3000   16.3600   42.6400   22.9900
   25.3250   16.4100   32.0700   23.8700
   25.3500   16.4500   26.6300   26.6300
   25.3750   16.4800   23.2000   23.2000
   25.4000   16.5100   20.6400   20.6400
   25.4250   16.5300   18.6000   18.6000
   25.4500   16.5300   16.8800   16.8800
   25.4750   16.5200   15.3700   15.3700
   25.5000   16.4900   14.0500   14.0500
```

```
   25.5250   16.4300   12.8500   12.8500
   25.5500   16.3400   11.7500   11.7500
   25.5750   16.2300   10.7200   10.7200
   25.6000   16.0700    9.7600    9.7600
   25.6250   15.8700    8.8500    8.8500
   25.6500   15.6300    7.9900    7.9900
   25.6750   15.3400    7.1600    7.1600
   25.7000   15.0100    6.3800    6.3800
   25.7250   14.6300    5.6200    5.6200
   25.7500   14.2100    4.9000    4.9000
   25.7750   13.7600    4.2100    4.2100
   25.8000   13.2700    3.5400    3.5400];
%
%
```

```
% 10 MTR FIVE BAND QUAD FOLLOWS
q10b5g=[27.9000   12.3900    2.2500    2.2500 % @ theta=8.7 deg
   27.9250   12.6200    2.7500    2.7500
   27.9500   12.8400    3.2600    3.2600
   27.9750   13.0600    3.7700    3.7700
   28.0000   13.2600    4.3000    4.3000
   28.0250   13.4500    4.8500    4.8500
   28.0500   13.6300    5.4100    5.4100
   28.0750   13.8100    5.9800    5.9800
   28.1000   13.9700    6.5800    6.5800
   28.1250   14.1300    7.1900    7.1900
   28.1500   14.2800    7.8200    7.8200
   28.1750   14.4300    8.4700    8.4700
   28.2000   14.5700    9.1500    9.1500
   28.2250   14.7000    9.8600    9.8600
   28.2500   14.8300   10.6000   10.6000
   28.2750   14.9500   11.3700   11.3700
   28.3000   15.0600   12.1900   12.1900
   28.3250   15.1800   13.0600   13.0600
   28.3500   15.2800   13.9800   13.9800
   28.3750   15.3900   14.9600   14.9600
   28.4000   15.4900   16.0300   16.0300
   28.4250   15.5800   17.2000   17.2000
   28.4500   15.6700   18.5000   18.5000
   28.4750   15.7600   19.9500   19.9500
   28.5000   15.8500   21.5800   20.6600
   28.5250   15.9300   23.4900   21.1200
   28.5500   16.0100   25.7500   21.4200
   28.5750   16.0800   28.4500   21.5700
   28.6000   16.1500   31.4500   21.5800
   28.6250   16.2200   33.2400   21.4800
   28.6500   16.2800   31.8600   21.3100
   28.6750   16.3400   29.2800   21.0800
   28.7000   16.3900   26.9100   20.8000
   28.7250   16.4500   24.9500   20.5000
   28.7500   16.4900   23.3800   20.1700
   28.7750   16.5300   22.0500   19.8400
   28.8000   16.5700   20.9000   19.5000
   28.8250   16.6000   19.9000   19.1800
   28.8500   16.6200   18.9800   18.8600
   28.8750   16.6400   18.1400   18.1400
   28.9000   16.6500   17.3300   17.3300
   28.9250   16.6500   16.5400   16.5400
   28.9500   16.6400   15.7400   15.7400
   28.9750   16.6200   14.9100   14.9100
   29.0000   16.5700   14.0300   14.0300
```

```
   29.0250   16.5000   13.1000   13.1000
   29.0500   16.4000   12.1200   12.1200
   29.0750   16.2700   11.0600   11.0600
   29.1000   16.0700    9.9400    9.9400
   29.1250   15.8100    8.7500    8.7500
   29.1500   15.4700    7.5000    7.5000
   29.1750   15.0100    6.1900    6.1900];
%
```

```
% 10 MTR TRI BAND QUAD FOLLOWS
q10b3g=[27.9000   14.3200    5.7500    5.7500 % @ theta=8.7 deg
   27.9250   14.4700    6.2300    6.2300
   27.9500   14.6200    6.7100    6.7100
   27.9750   14.7600    7.2200    7.2200
   28.0000   14.8900    7.7400    7.7400
   28.0250   15.0200    8.2800    8.2800
   28.0500   15.1400    8.8300    8.8300
   28.0750   15.2500    9.4100    9.4100
   28.1000   15.3600   10.0100   10.0100
   28.1250   15.4700   10.6200   10.6200
   28.1500   15.5600   11.2600   11.2600
   28.1750   15.6600   11.9200   11.9200
   28.2000   15.7400   12.6000   12.6000
   28.2250   15.8300   13.3200   13.3200
   28.2500   15.9000   14.0700   14.0700
   28.2750   15.9800   14.8300   14.8300
   28.3000   16.0500   15.6300   15.6300
   28.3250   16.1100   16.4700   16.4700
   28.3500   16.1800   17.3200   17.3200
   28.3750   16.2300   18.1800   18.1800
   28.4000   16.2900   19.0500   19.0500
   28.4250   16.3400   19.8800   19.8800
   28.4500   16.3900   20.6800   20.6800
   28.4750   16.4400   21.3700   21.0400
   28.5000   16.4800   21.9000   21.1200
   28.5250   16.5200   22.2300   21.1400
   28.5500   16.5600   22.3400   21.1000
   28.5750   16.6000   22.2200   20.9900
   28.6000   16.6300   21.9500   20.8300
   28.6250   16.6600   21.5600   20.6300
   28.6500   16.6900   21.0600   20.4100
   28.6750   16.7100   20.5500   20.1600
   28.7000   16.7300   20.0100   19.9300
   28.7250   16.7500   19.4600   19.4600
   28.7500   16.7700   18.9300   18.9300
   28.7750   16.7800   18.4200   18.4200
   28.8000   16.7900   17.9000   17.9000
   28.8250   16.8000   17.3900   17.3900
   28.8500   16.8000   16.8800   16.8800
   28.8750   16.8000   16.3500   16.3500
   28.9000   16.7900   15.8000   15.8000
   28.9250   16.7800   15.2200   15.2200
   28.9500   16.7500   14.5800   14.5800
   28.9750   16.7100   13.8900   13.8900
   29.0000   16.6600   13.1300   13.1300
```

```
   29.0250   16.5800   12.3000   12.3000
   29.0500   16.4800   11.4000   11.4000
   29.0750   16.3400   10.4300   10.4300
   29.1000   16.1500    9.3800    9.3800
   29.1250   15.9100    8.2800    8.2800
   29.1500   15.5900    7.1200    7.1200
   29.1750   15.1800    5.9100    5.9100];
%
```

```
% 10 MTR MONO BAND QUAD FOLLOWS
q10b1g=[27.9000   15.0500    6.4800    6.4800 % @ theta=8.7 deg
   27.9250   15.1800    6.8500    6.8500
   27.9500   15.3100    7.2200    7.2200
   27.9750   15.4400    7.6000    7.6000
   28.0000   15.5600    7.9900    7.9900
   28.0250   15.6700    8.4000    8.4000
   28.0500   15.7800    8.8100    8.8100
   28.0750   15.8900    9.2200    9.2200
   28.1000   15.9900    9.6600    9.6600
   28.1250   16.0800   10.0800   10.0800
   28.1500   16.1700   10.5200   10.5200
   28.1750   16.2600   10.9600   10.9600
   28.2000   16.3300   11.4000   11.4000
   28.2250   16.4100   11.8500   11.8500
   28.2500   16.4800   12.2900   12.2900
   28.2750   16.5400   12.7200   12.7200
   28.3000   16.6000   13.1400   13.1400
   28.3250   16.6500   13.5600   13.5600
   28.3500   16.7000   13.9500   13.9500
   28.3750   16.7400   14.3200   14.3200
   28.4000   16.7800   14.6600   14.6600
   28.4250   16.8200   14.9600   14.9600
   28.4500   16.8500   15.2300   15.2300
   28.4750   16.8800   15.4600   15.4600
   28.5000   16.9000   15.6400   15.6400
   28.5250   16.9200   15.7700   15.7700
   28.5500   16.9400   15.8600   15.8600
   28.5750   16.9600   15.8900   15.8900
   28.6000   16.9700   15.8900   15.8900
   28.6250   16.9800   15.8600   15.8600
   28.6500   16.9900   15.7700   15.7700
   28.6750   16.9900   15.6600   15.6600
   28.7000   16.9900   15.5300   15.5300
   28.7250   16.9900   15.3500   15.3500
   28.7500   16.9900   15.1500   15.1500
   28.7750   16.9800   14.9400   14.9400
   28.8000   16.9800   14.6700   14.6700
   28.8250   16.9600   14.4100   14.4100
   28.8500   16.9500   14.1000   14.1000
   28.8750   16.9300   13.7400   13.7400
   28.9000   16.9000   13.3500   13.3500
   28.9250   16.8600   12.9000   12.9000
   28.9500   16.8200   12.4000   12.4000
   28.9750   16.7600   11.8300   11.8300
   29.0000   16.6900   11.1900   11.1900
```

```
   29.0250   16.5900   10.4900   10.4900
   29.0500   16.4700    9.7200    9.7200
   29.0750   16.3200    8.8800    8.8800
   29.1000   16.1200    7.9700    7.9700
   29.1250   15.8600    7.0100    7.0100
   29.1500   15.5400    5.9900    5.9900
   29.1750   15.1400    4.9200    4.9200];
%
%
```

```
% Format of following z subscripted matrices is
% Column 1=Frequency in MHZ (matches range and increment of
%          prior non z subscripted matices)
% Column 2=Real part of driving point impedance in Ohms
% Column 3=Imaginary part of driving point impedance in Ohms
q20b5z=[13.8000   16.1398  -89.6625
   13.8250   16.7879  -82.1309
   13.8500   17.6793  -74.6231
   13.8750   18.8403  -67.0866
   13.9000   20.2768  -59.6287
   13.9250   21.9910  -52.2523
   13.9500   23.9646  -45.0330
   13.9750   26.1942  -38.0052
   14.0000   28.6460  -31.2101
   14.0250   31.2813  -24.6401
   14.0500   34.0999  -18.3933
   14.0750   37.0464  -12.4474
   14.1000   40.0877   -6.8134
   14.1250   43.2238   -1.5383
   14.1500   46.4291    3.3378
   14.1750   49.6634    7.7649
   14.2000   52.9232   11.6863
   14.2250   56.1579   14.9406
   14.2500   59.2178   17.3711
   14.2750   61.9103   18.7012
   14.3000   63.7437   18.7035
   14.3250   63.8662   17.2098
   14.3500   60.9038   14.6054
   14.3750   53.2549   12.6208
   14.4000   40.8765   14.7926
   14.4250   27.2501   24.4256
   14.4500   17.6274   40.5667];
%
```

```
q20b3z=[13.8000   17.7610 -102.9572
   13.8250   18.0349  -95.2783
   13.8500   18.4906  -87.5988
   13.8750   19.1473  -79.8499
   13.9000   20.0142  -72.1175
   13.9250   21.0990  -64.3859
   13.9500   22.4017  -56.7117
   13.9750   23.9296  -49.1108
   14.0000   25.6753  -41.6142
   14.0250   27.6267  -34.2087
   14.0500   29.8019  -26.9811
   14.0750   32.1774  -19.9161
   14.1000   34.7429  -13.0335
   14.1250   37.5214   -6.3712
   14.1500   40.5113    0.0261
   14.1750   43.7028    6.1045
   14.2000   47.1382   11.8322
   14.2250   50.8335   17.0692
   14.2500   54.7532   21.6603
   14.2750   58.9038   25.3510
   14.3000   63.1287   27.8217
   14.3250   67.0741   28.5675
   14.3500   69.9031   27.0542
   14.3750   69.9546   23.0456
   14.4000   64.7805   17.7579
   14.4250   52.8156   15.1765
   14.4500   36.7921   20.2626
   14.4750   23.0766   33.7706
   14.5000   15.4751   51.5093];
```

```
%
q20b1z=[13.8000   19.7024 -116.0005
   13.8250   19.7180 -108.1653
   13.8500   19.8790 -100.3277
   13.8750   20.1980  -92.4085
   13.9000   20.6830  -84.4900
   13.9250   21.3409  -76.5403
   13.9500   22.1729  -68.6103
   13.9750   23.1910  -60.7056
   14.0000   24.3922  -52.8430
   14.0250   25.7745  -45.0069
   14.0500   27.3581  -37.2658
   14.0750   29.1314  -29.6055
   14.1000   31.0946  -22.0379
   14.1250   33.2755  -14.5819
   14.1500   35.6813   -7.2773
   14.1750   38.3168   -0.1608
   14.2000   41.2325    6.7699
   14.2250   44.4689   13.4180
   14.2500   48.0367   19.6853
   14.2750   52.0251   25.4175
   14.3000   56.4589   30.4169
   14.3250   61.3280   34.3001
   14.3500   66.4501   36.5075
   14.3750   71.2721   36.2395
   14.4000   74.3373   32.6858
   14.4250   72.8460   26.0462
   14.4500   63.6389   19.4399
   14.4750   47.3292   19.2218
   14.5000   30.3973   29.0107
   14.5250   18.9755   45.4189];
%
```

```
%
q17b5z=[17.8500   25.1602  -69.7608
   17.8750   26.1601  -64.1782
   17.9000   27.3760  -58.5967
   17.9250   28.8230  -53.0600
   17.9500   30.5020  -47.6383
   17.9750   32.4498  -42.3629
   18.0000   34.6073  -37.2097
   18.0250   36.9941  -32.2957
   18.0500   39.5823  -27.6714
   18.0750   42.3937  -23.3350
   18.1000   45.2984  -19.3330
   18.1250   48.3015  -15.7190
   18.1500   51.3498  -12.5795
   18.1750   54.3650   -9.8432
   18.2000   57.2484   -7.5387
   18.2250   59.9918   -5.7183
   18.2500   62.4544   -4.3545
   18.2750   64.5597   -3.3886
   18.3000   66.2387   -2.8846
   18.3250   67.3743   -2.7404
   18.3500   67.8630   -2.8639
   18.3750   67.5994   -3.1723
   18.4000   66.4650   -3.5619
   18.4250   64.3237   -3.9123
   18.4500   61.1468   -3.8848
   18.4750   56.8461   -3.2057
   18.5000   51.4608   -1.5268
   18.5250   45.2243    1.5716
   18.5500   38.5237    6.5048
   18.5750   31.9000   13.5712
   18.6000   26.1422   22.7405
   18.6250   21.9473   33.8254
   18.6500   19.9701   46.1102];
%
```

```
q17b1z=[17.8500   37.4636 -110.3467
   17.8750   37.8528 -104.3902
   17.9000   38.3433  -98.3682
   17.9250   38.9456  -92.2987
   17.9500   39.6656  -86.2239
   17.9750   40.5253  -80.1377
   18.0000   41.5179  -73.9944
   18.0250   42.6645  -67.8701
   18.0500   43.9738  -61.7852
   18.0750   45.4788  -55.6838
   18.1000   47.1549  -49.6318
   18.1250   49.0357  -43.6446
   18.1500   51.1375  -37.7955
   18.1750   53.4624  -32.0349
   18.2000   55.9969  -26.4404
   18.2250   58.8009  -21.0285
   18.2500   61.8252  -15.9092
   18.2750   65.0651  -11.0900
   18.3000   68.5362   -6.6903
   18.3250   72.1838   -2.7727
   18.3500   75.9494    0.6060
   18.3750   79.7436    3.3303
   18.4000   83.4743    5.3029
   18.4250   86.9324    6.3448
   18.4500   89.8911    6.5309
   18.4750   92.0733    5.8165
   18.5000   93.1605    4.2587
   18.5250   92.7963    2.1009
   18.5500   90.6787   -0.2415
   18.5750   86.6178   -2.2631
   18.6000   80.6883   -3.3483
   18.6250   73.0959   -2.8831
   18.6500   64.4870   -0.3652
   18.6750   55.2903    4.3960
   18.7000   46.4468   11.3392
   18.7250   38.3486   20.2875
   18.7500   31.4961   30.7306
   18.7750   26.0135   42.3354
   18.8000   21.9680   54.5809
   18.8250   19.2955   67.1341
   18.8500   17.8464   79.8165];
%
```

```
%
q15b5z=[20.6500   37.4214  -75.2969
   20.6750   37.5557  -70.4693
   20.7000   37.8346  -65.6334
   20.7250   38.2560  -60.8534
   20.7500   38.8294  -56.0658
   20.7750   39.5660  -51.3652
   20.8000   40.4299  -46.7082
   20.8250   41.4493  -42.1242
   20.8500   42.6213  -37.6677
   20.8750   43.9239  -33.2786
   20.9000   45.3698  -29.0579
   20.9250   46.9582  -24.9330
   20.9500   48.6861  -20.9907
   20.9750   50.5213  -17.1987
   21.0000   52.4986  -13.6265
   21.0250   54.5555  -10.2531
   21.0500   56.7111   -7.1211
   21.0750   58.9292   -4.2820
   21.1000   61.1775   -1.7314
   21.1250   63.4307    0.5536
   21.1500   65.6634    2.4152
   21.1750   67.7834    3.9413
   21.2000   69.7923    5.0470
   21.2250   71.5383    5.7514
   21.2500   72.9702    6.0418
   21.2750   73.9565    5.8603
   21.3000   74.3974    5.4183
   21.3250   74.1458    4.6046
   21.3500   73.0776    3.7115
   21.3750   71.0353    2.7751
   21.4000   68.0321    2.1376
   21.4250   63.9490    2.0417
   21.4500   58.9947    2.7884
   21.4750   53.3045    4.6475
   21.5000   47.0455    7.9303
   21.5250   40.8427   12.6807
   21.5500   34.9018   19.0346
   21.5750   29.7890   26.6680
   21.6000   25.6827   35.4822
   21.6250   22.8789   45.0977
   21.6500   21.4566   55.1572];
%
```

```
q15b3z=[20.6500   43.5285  -98.7390
   20.6750   44.1414  -93.8209
   20.7000   44.8638  -88.8596
   20.7250   45.7074  -83.9215
   20.7500   46.6779  -78.9362
   20.7750   47.7957  -74.0065
   20.8000   49.0414  -69.0823
   20.8250   50.4404  -64.2011
   20.8500   52.0014  -59.4187
   20.8750   53.7103  -54.6848
   20.9000   55.5814  -50.1022
   20.9250   57.6194  -45.6074
   20.9500   59.8238  -41.2980
   20.9750   62.1625  -37.1558
   21.0000   64.6672  -33.2507
   21.0250   67.2734  -29.5854
   21.0500   69.9922  -26.2142
   21.0750   72.7718  -23.1806
   21.1000   75.5598  -20.5119
   21.1250   78.3210  -18.1687
   21.1500   81.0151  -16.2984
   21.1750   83.5069  -14.8261
   21.2000   85.7998  -13.8090
   21.2250   87.7208  -13.1919
   21.2500   89.2076  -12.9664
   21.2750   90.1546  -13.1436
   21.3000   90.4828  -13.4777
   21.3250   90.0869  -14.0564
   21.3500   88.9184  -14.5784
   21.3750   86.8923  -15.0371
   21.4000   84.0715  -15.1535
   21.4250   80.3925  -14.7902
   21.4500   76.0439  -13.7813
   21.4750   71.0839  -11.9879
   21.5000   65.5497   -9.2224
   21.5250   59.8393   -5.4539
   21.5500   53.9459   -0.5336
   21.5750   48.2528    5.4121
   21.6000   42.7927   12.4535
   21.6250   37.8406   20.4923
   21.6500   33.5291   29.4114
   21.6750   29.9846   39.0591
   21.7000   27.2948   49.4240
   21.7250   25.5347   60.1696
   21.7500   24.7276   71.2242];
%
```

```
q15b1z=[20.6500   55.1080 -118.1829
   20.6750   55.7761 -113.4013
   20.7000   56.5277 -108.5880
   20.7250   57.3750 -103.8083
   20.7500   58.3160  -98.9901
   20.7750   59.3686  -94.2341
   20.8000   60.5155  -89.4865
   20.8250   61.7754  -84.7828
   20.8500   63.1523  -80.1752
   20.8750   64.6337  -75.6080
   20.9000   66.2283  -71.1791
   20.9250   67.9377  -66.8182
   20.9500   69.7599  -62.6156
   20.9750   71.6674  -58.5452
   21.0000   73.6831  -54.6638
   21.0250   75.7551  -50.9694
   21.0500   77.8931  -47.5058
   21.0750   80.0507  -44.2922
   21.1000   82.1946  -41.3635
   21.1250   84.2962  -38.6555
   21.1500   86.3291  -36.2957
   21.1750   88.1912  -34.2295
   21.2000   89.8982  -32.4879
   21.2250   91.3200  -31.0277
   21.2500   92.4192  -29.8589
   21.2750   93.1272  -28.9835
   21.3000   93.3966  -28.2124
   21.3250   93.1471  -27.6559
   21.3500   92.3531  -27.0743
   21.3750   90.9443  -26.5164
   21.4000   88.9523  -25.7759
   21.4250   86.3065  -24.7820
   21.4500   83.1285  -23.4178
   21.4750   79.4234  -21.5977
   21.5000   75.1589  -19.1877
   21.5250   70.6130  -16.1331
   21.5500   65.7061  -12.3192
   21.5750   60.7303   -7.7733
   21.6000   55.6466   -2.4283
   21.6250   50.6617    3.7231
   21.6500   45.8714   10.6391
   21.6750   41.3959   18.2623
   21.7000   37.2949   26.6440
   21.7250   33.6981   35.5595
   21.7500   30.6392   44.9871
   21.7750   28.1577   54.9815
```

```
  21.8000   26.3062   65.2594
  21.8250   25.1223   75.8918
  21.8500   24.6065   86.7062
  21.8750   24.7568   97.6673];
%
```

```
%
q12b5z=[24.4000   49.3671  -67.1589
   24.4250   49.8412  -63.1742
   24.4500   50.4367  -59.2158
   24.4750   51.1396  -55.2432
   24.5000   52.0039  -51.3441
   24.5250   52.9983  -47.5093
   24.5500   54.0992  -43.7668
   24.5750   55.3772  -40.0667
   24.6000   56.7810  -36.4534
   24.6250   58.3380  -32.9978
   24.6500   60.0237  -29.6298
   24.6750   61.8293  -26.4833
   24.7000   63.7964  -23.4866
   24.7250   65.8303  -20.7095
   24.7500   67.9850  -18.1081
   24.7750   70.2361  -15.8187
   24.8000   72.4781  -13.8437
   24.8250   74.7421  -12.1372
   24.8500   76.9513  -10.7775
   24.8750   79.0806   -9.7430
   24.9000   81.0511   -9.0604
   24.9250   82.7392   -8.7354
   24.9500   84.1776   -8.7593
   24.9750   85.2233   -9.0335
   25.0000   85.8293   -9.4426
   25.0250   85.9422  -10.0962
   25.0500   85.4993  -10.7759
   25.0750   84.5162  -11.3961
   25.1000   82.9383  -11.8676
   25.1250   80.7579  -12.0689
   25.1500   78.0978  -11.8088
   25.1750   74.9995  -11.1014
   25.2000   71.5380   -9.8245
   25.2250   67.8410   -7.8911
   25.2500   63.9497   -5.1621
   25.2750   60.0934   -1.6832
   25.3000   56.2645    2.5967
   25.3250   52.7618    7.6277
   25.3500   49.6477   13.4702
   25.3750   47.1309   19.9964
   25.4000   45.3378   27.2631
   25.4250   44.4352   35.0862
   25.4500   44.6073   43.3578
   25.4750   46.0371   51.9503];
%
```

```
q12b1z=[24.4000   76.1956 -119.6976
   24.4250   76.7464 -116.4282
   24.4500   77.3048 -113.1931
   24.4750   77.8590 -109.9344
   24.5000   78.4324 -106.7628
   24.5250   79.0011 -103.6449
   24.5500   79.5440 -100.5859
   24.5750   80.0976  -97.5480
   24.6000   80.6225  -94.5443
   24.6250   81.1296  -91.6368
   24.6500   81.6016  -88.7248
   24.6750   82.0263  -85.9258
   24.7000   82.4214  -83.1479
   24.7250   82.7336  -80.4279
   24.7500   82.9849  -77.6955
   24.7750   83.1975  -75.0446
   24.8000   83.2775  -72.4627
   24.8250   83.2916  -69.8609
   24.8500   83.1933  -67.2931
   24.8750   82.9966  -64.7143
   24.9000   82.6875  -62.1369
   24.9250   82.2079  -59.5817
   24.9500   81.6405  -57.0069
   24.9750   80.9187  -54.3828
   25.0000   80.0556  -51.6187
   25.0250   79.0570  -48.8636
   25.0500   77.9079  -46.0103
   25.0750   76.6307  -43.0179
   25.1000   75.2052  -39.9245
   25.1250   73.6111  -36.6716
   25.1500   71.9170  -33.1938
   25.1750   70.1059  -29.5941
   25.2000   68.1982  -25.7804
   25.2250   66.2209  -21.7449
   25.2500   64.1225  -17.4258
   25.2750   62.0023  -12.8443
   25.3000   59.7877   -8.0111
   25.3250   57.6056   -2.8888
   25.3500   55.4217    2.5377
   25.3750   53.2895    8.2225
   25.4000   51.2272   14.2957
   25.4250   49.2370   20.6553
   25.4500   47.3556   27.3384
   25.4750   45.6084   34.3913
   25.5000   44.0576   41.7427
   25.5250   42.7067   49.3672
```

```
   25.5500   41.5996   57.3673
   25.5750   40.7606   65.6330
   25.6000   40.2197   74.2064
   25.6250   39.9789   83.0357
   25.6500   40.1214   92.1600
   25.6750   40.6426  101.5791
   25.7000   41.5759  111.1563
   25.7250   42.9547  120.9287
   25.7500   44.7973  130.8837
   25.7750   47.1438  140.9137
   25.8000   49.9993  151.1333];
%
```

```
%
q10b5z=[27.9000   34.8805  -86.8550
   27.9250   35.5337  -82.8020
   27.9500   36.2649  -78.8325
   27.9750   37.0674  -74.9860
   28.0000   37.9478  -71.2250
   28.0250   38.8956  -67.5371
   28.0500   39.8780  -64.0397
   28.0750   40.8983  -60.6332
   28.1000   41.9610  -57.3249
   28.1250   42.9937  -54.1659
   28.1500   44.0281  -51.1393
   28.1750   45.0158  -48.2550
   28.2000   45.9528  -45.4465
   28.2250   46.8349  -42.7734
   28.2500   47.6161  -40.1817
   28.2750   48.2880  -37.6325
   28.3000   48.8504  -35.1809
   28.3250   49.3170  -32.6991
   28.3500   49.6555  -30.2619
   28.3750   49.9118  -27.6716
   28.4000   50.0338  -25.1676
   28.4250   50.0736  -22.5173
   28.4500   50.0859  -19.7477
   28.4750   50.0530  -16.9078
   28.5000   50.0166  -13.9277
   28.5250   49.9955  -10.8236
   28.5500   50.0513   -7.4841
   28.5750   50.1808   -4.0741
   28.6000   50.4490   -0.5037
   28.6250   50.8923    3.2458
   28.6500   51.5079    7.0408
   28.6750   52.4269   10.9724
   28.7000   53.6914   15.0709
   28.7250   55.3270   19.2631
   28.7500   57.4535   23.4262
   28.7750   60.1887   27.5186
   28.8000   63.6940   31.5420
   28.8250   68.1310   35.1957
   28.8500   73.6942   38.2186
   28.8750   80.5713   40.1403
   28.9000   88.7972   40.0804
   28.9250   98.0711   37.0547
   28.9500  107.1965   29.5495
   28.9750  113.6614   16.6432
   29.0000  113.5969   -0.7827
```

```
  29.0250  104.1339  -17.8627
  29.0500   87.0272  -28.8433
  29.0750   67.3651  -31.2937
  29.1000   50.0413  -26.7474
  29.1250   36.6797  -18.2438
  29.1500   27.1134   -8.2782
  29.1750   20.4472    1.9551];
%
```

q10b3z=[27.9000   29.4765 -95.4281

27.9250	29.8134	-91.7606
27.9500	30.1754	-88.1075
27.9750	30.5627	-84.5043
28.0000	30.9791	-80.9110
28.0250	31.4304	-77.3081
28.0500	31.8875	-73.7895
28.0750	32.3602	-70.2522
28.1000	32.8754	-66.7205
28.1250	33.3750	-63.1942
28.1500	33.9153	-59.7110
28.1750	34.4518	-56.2394
28.2000	35.0037	-52.7303
28.2250	35.5848	-49.2552
28.2500	36.1761	-45.7635
28.2750	36.7857	-42.2530
28.3000	37.4160	-38.7725
28.3250	38.0889	-35.2287
28.3500	38.7884	-31.7167
28.3750	39.5530	-28.0812
28.4000	40.3385	-24.5298
28.4250	41.1901	-20.8910
28.4500	42.1459	-17.1989
28.4750	43.1861	-13.5112
28.5000	44.3350	-9.7889
28.5250	45.6150	-6.0465
28.5500	47.0872	-2.1879
28.5750	48.7369	1.6175
28.6000	50.6403	5.4546
28.6250	52.8069	9.3100
28.6500	55.2677	13.0356
28.6750	58.1548	16.6854
28.7000	61.5380	20.2368
28.7250	65.4268	23.5573
28.7500	69.9317	26.4162
28.7750	75.1747	28.6080
28.8000	81.1671	29.9600
28.8250	87.8898	29.9196
28.8500	95.1330	27.9527
28.8750	102.2980	23.4641
28.9000	108.3652	15.7838
28.9250	111.7895	5.1075
28.9500	110.7012	-7.6475
28.9750	104.0187	-20.2048
29.0000	92.1552	-29.8142

```
   29.0250   77.4213  -34.3360
   29.0500   62.4693  -33.6194
   29.0750   49.0860  -28.9062
   29.1000   38.2518  -21.7193
   29.1250   29.8660  -13.2378
   29.1500   23.5784   -4.3659
   29.1750   18.9211    4.5402];
%
```

q10b1z=[27.9000   23.8831 -95.0921

27.9250	24.1340	-91.4194
27.9500	24.4211	-87.7236
27.9750	24.7490	-84.0425
28.0000	25.1200	-80.3354
28.0250	25.5452	-76.5872
28.0500	26.0081	-72.8863
28.0750	26.5192	-69.1314
28.1000	27.1030	-65.3567
28.1250	27.7237	-61.5544
28.1500	28.4241	-57.7781
28.1750	29.1771	-53.9894
28.2000	29.9989	-50.1463
28.2250	30.9115	-46.3227
28.2500	31.9010	-42.4782
28.2750	32.9801	-38.6195
28.3000	34.1541	-34.7958
28.3250	35.4487	-30.9237
28.3500	36.8552	-27.1017
28.3750	38.4106	-23.1941
28.4000	40.0919	-19.4090
28.4250	41.9381	-15.5977
28.4500	43.9974	-11.8004
28.4750	46.2544	-8.0922
28.5000	48.7274	-4.4719
28.5250	51.4614	-0.9698
28.5500	54.5303	2.4667
28.5750	57.9008	5.6257
28.6000	61.6626	8.5259
28.6250	65.7771	11.0956
28.6500	70.2484	13.0914
28.6750	75.1494	14.4388
28.7000	80.4399	14.9855
28.7250	85.8926	14.4979
28.7500	91.3396	12.6613
28.7750	96.4426	9.1648
28.8000	100.6810	4.1265
28.8250	103.4091	-2.5528
28.8500	103.9050	-10.4779
28.8750	101.5700	-18.7687
28.9000	96.1907	-26.5256
28.9250	88.2790	-32.5322
28.9500	78.5550	-36.0634
28.9750	68.0295	-36.8033
29.0000	57.6311	-34.9285

```
   29.0250   48.1576  -30.9132
   29.0500   39.9242  -25.2986
   29.0750   32.9714  -18.6980
   29.1000   27.3498  -11.5790
   29.1250   22.8510   -4.1654
   29.1500   19.3126    3.2660
   29.1750   16.5484   10.6875];
%
antg=cell(1,13);
antz=cell(1,13);
ant=cell(1,13);
ants=cell(1,13);
antg={q20b5g q20b3g q20b1g q17b5g q17b1g q15b5g q15b3g q15b1g ...
      q12b5g q12b1g q10b5g q10b3g q10b1g};
antz={q20b5z q20b3z q20b1z q17b5z q17b1z q15b5z q15b3z q15b1z ...
      q12b5z q12b1z q10b5z q10b3z q10b1z};
   n=13;
for i=1:n
   g=antg{1,i};
   z=antz{1,i};
   a=zeros(length(g),7);
   a(:,1:4)=g;
   a(:,5:6)=z(:,2:3);
   zant=a(:,5)+j*a(:,6);
   rho52=(zant-52)./(zant+52);
   swr52=(1+abs(rho52))./(1-abs(rho52));
   a(:,7)=swr52;
   ant{1,i}=a;
   xx=(a(1,1):.001:a(length(g),1))';
   aa=zeros(length(xx),7);
   aa(:,1)=xx;
   for k=2:7
      x=a(:,1);
      y=a(:,k);
   yy=spline(x,y,xx);
   aa(:,k)=yy;
end
   ants{i}=aa;
end
global ant ants theta DPLdBi
```