Design of a Five Band Quad and Its Coax Feed System

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This article is a follow on to a previous article titled “Modeling Multi Band Cubical Quad Antennas with EZNEC and MATLAB”. The five band quad described in the previous article was rescaled by +0.7285% on the 17 Mtr section, +0.4409% on the 12 Mtr section, and +0.3514% on the 10 Mtr section to satisfy array performance parameter (i.e. gain, FB, FBR, and SWR) trade offs as I saw them. The MATLAB program description of the adjusted five band quad design parameters follows:

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>> quadmod4A

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=994.848   f=18.11   DE in FT=54.9336
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=998.3181   f=24.93   DE in FT=40.0448
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=1001.0343   f=28.45   DE in FT=35.1857
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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	TOTAL #WIRE SEGS	DRIVEN EL WIRE NUMBERS 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 follows

Note: All non-driven driven elements have zero Ohm termination impedances in the EZNEC model results of this document. A future analysis is planned for other termination impedance values to see how sensitive the results are to this assumption.

The EZNEC 4.0 five band quad description with the 20 Meter quad section driven follows:

EZNEC+ ver. 4.0

20 MTR 4 EL FIVE BAND QUAD 04A 7/7/2004 10:03:48 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,	44.9977	W18E1	0,	10.0023,	55	.080827	7	1	0
18	W17E2	0,	10.0023,	55	W19E1	0,	0,	65.0023	.080827	7	1	0
19	W18E2	0,	0,	65.0023	W20E1	0,	-10.002,	55	.080827	7	1	0
20	W19E2	0,	-10.002,	55	W17E1	0,	0,	44.9977	.080827	7	1	0
21	W24E2	10,	0,	45.289	W22E1	10,	9.71098,	55	.080827	7	1	0
22	W21E2	10,	9.71098,	55	W23E1	10,	0,	64.711	.080827	7	1	0
23	W22E2	10,	0,	64.711	W24E1	10,	-9.711,	55	.080827	7	1	0
24	W23E2	10,	-9.711,	55	W21E1	10,	0,	45.289	.080827	7	1	0
25	W28E2	20,	0,	45.459	W26E1	20,	9.54104,	55	.080827	7	1	0
26	W25E2	20,	9.54104,	55	W27E1	20,	0,	64.541	.080827	7	1	0

27	W26E2	20, 0, 64.541	W28E1	20, -9.541, 55	.080827	7	1	0
28	W27E2	20, -9.541, 55	W25E1	20, 0, 45.459	.080827	7	1	0
29	W32E2	30, 0, 45.459	W30E1	30,9.54104, 55	.080827	7	1	0
30	W29E2	30,9.54104, 55	W31E1	30, 0, 64.541	.080827	7	1	0
31	W30E2	30, 0, 64.541	W32E1	30, -9.541, 55	.080827	7	1	0
32	W31E2	30, -9.541, 55	W29E1	30, 0, 45.459	.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, 0,47.7086	W50E1	0,7.29137, 55	.080827	7	1	0
50	W49E2	0,7.29137, 55	W51E1	0, 0,62.2914	.080827	7	1	0
51	W50E2	0, 0,62.2914	W52E1	0,-7.2914, 55	.080827	7	1	0
52	W51E2	0,-7.2914, 55	W49E1	0, 0,47.7086	.080827	7	1	0
53	W56E2	10, 0, 47.921	W54E1	10, 7.079, 55	.080827	7	1	0
54	W53E2	10, 7.079, 55	W55E1	10, 0, 62.079	.080827	7	1	0
55	W54E2	10, 0, 62.079	W56E1	10, -7.079, 55	.080827	7	1	0
56	W55E2	10, -7.079, 55	W53E1	10, 0, 47.921	.080827	7	1	0
57	W60E2	20, 0,48.0449	W58E1	20,6.95512, 55	.080827	7	1	0
58	W57E2	20,6.95512, 55	W59E1	20, 0,61.9551	.080827	7	1	0
59	W58E2	20, 0,61.9551	W60E1	20,-6.9551, 55	.080827	7	1	0
60	W59E2	20,-6.9551, 55	W57E1	20, 0,48.0449	.080827	7	1	0
61	W64E2	30, 0,48.0449	W62E1	30,6.95512, 55	.080827	7	1	0
62	W61E2	30,6.95512, 55	W63E1	30, 0,61.9551	.080827	7	1	0
63	W62E2	30, 0,61.9551	W64E1	30,-6.9551, 55	.080827	7	1	0

64	W63E2	30,-6.9551, 55	W61E1	30, 0,48.0449	.080827	7	1	0
65	W68E2	0, 0,48.5925	W66E1	0,6.40749, 55	.080827	7	1	0
66	W65E2	0,6.40749, 55	W67E1	0, 0,61.4075	.080827	7	1	0
67	W66E2	0, 0,61.4075	W68E1	0,-6.4075, 55	.080827	7	1	0
68	W67E2	0,-6.4075, 55	W65E1	0, 0,48.5925	.080827	7	1	0
69	W72E2	5, 0, 48.78	W70E1	5,6.22002, 55	.080827	7	1	0
70	W69E2	5,6.22002, 55	W71E1	5, 0, 61.22	.080827	7	1	0
71	W70E2	5, 0, 61.22	W72E1	5, -6.22, 55	.080827	7	1	0
72	W71E2	5, -6.22, 55	W69E1	5, 0, 48.78	.080827	7	1	0
73	W76E2	10, 0,48.9085	W74E1	10,6.09151, 55	.080827	7	1	0
74	W73E2	10,6.09151, 55	W75E1	10, 0,61.0915	.080827	7	1	0
75	W74E2	10, 0,61.0915	W76E1	10,-6.0915, 55	.080827	7	1	0
76	W75E2	10,-6.0915, 55	W73E1	10, 0,48.9085	.080827	7	1	0
77	W80E2	20, 0,48.8885	W78E1	20,6.11154, 55	.080827	7	1	0
78	W77E2	20,6.11154, 55	W79E1	20, 0,61.1115	.080827	7	1	0
79	W78E2	20, 0,61.1115	W80E1	20,-6.1115, 55	.080827	7	1	0
80	W79E2	20,-6.1115, 55	W77E1	20, 0,48.8885	.080827	7	1	0
81	W84E2	30, 0,48.8871	W82E1	30,6.11285, 55	.080827	7	1	0
82	W81E2	30,6.11285, 55	W83E1	30, 0,61.1128	.080827	7	1	0
83	W82E2	30, 0,61.1128	W84E1	30,-6.1128, 55	.080827	7	1	0
84	W83E2	30,-6.1128, 55	W81E1	30, 0,48.8871	.080827	7	1	0

Total Segments: 620

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

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

No loads specified

No transmission lines specified

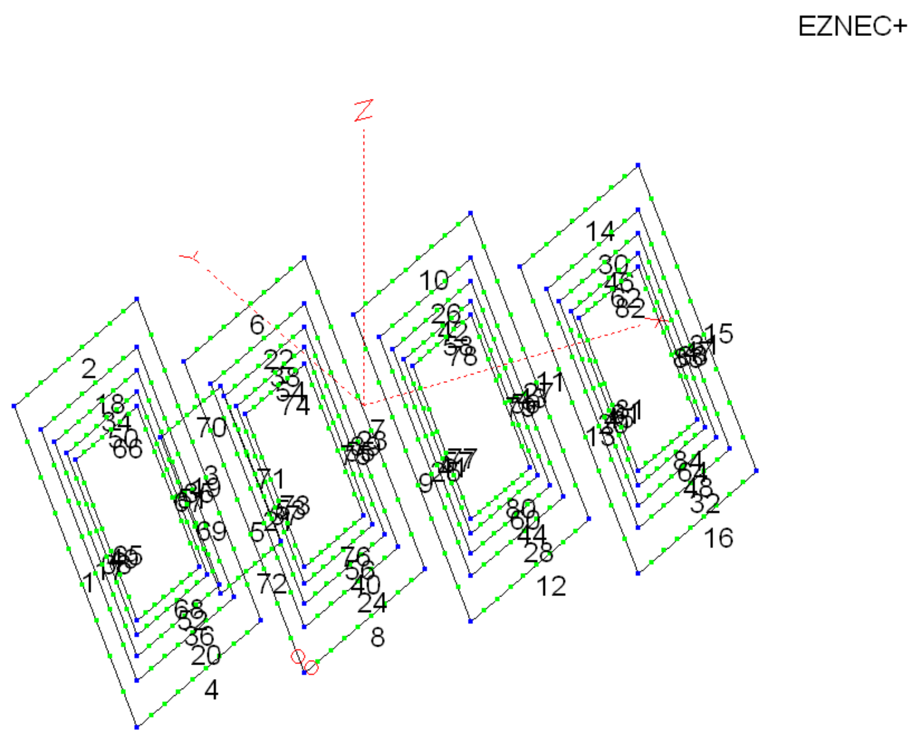
Ground type is Real, High-Accuracy

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

No.	Cond. (S/m)	Diel. Const.	Height (ft)	R Coord. (ft)

1 0.005 13 0 0

The EZNEC 4.0 20 Meter driven five band quad antenna view follows:



Figures 15A to 19A show plots the gain in dBi, the FB in dB, the front to back region FBR in dB, and ten times the SWR for a 52 Ohm coax feed (to keep all plot on same Y axis scale) versus frequency for each of the five bands. Figures 15B to 19B show the antenna driving point impedance real and imaginary parts versus frequency for each of the five bands. Figure 18A also shows the SWR versus frequency if a quarter wave Q matching section of RG11-AU coax is used to feed the 12 Meter band. The SWR is reduced from 1.67 to 1.28 at a frequency of 24.9 Mhz using the Q match. The design of the 12 Meter Q section is given in Table 1 on page 12.

Listings of all five MATLAB programs used to derive the plot results are at the back of this document. These can be cut and pasted to the MATLAB work space or a .m script file for those who want to use the programs.

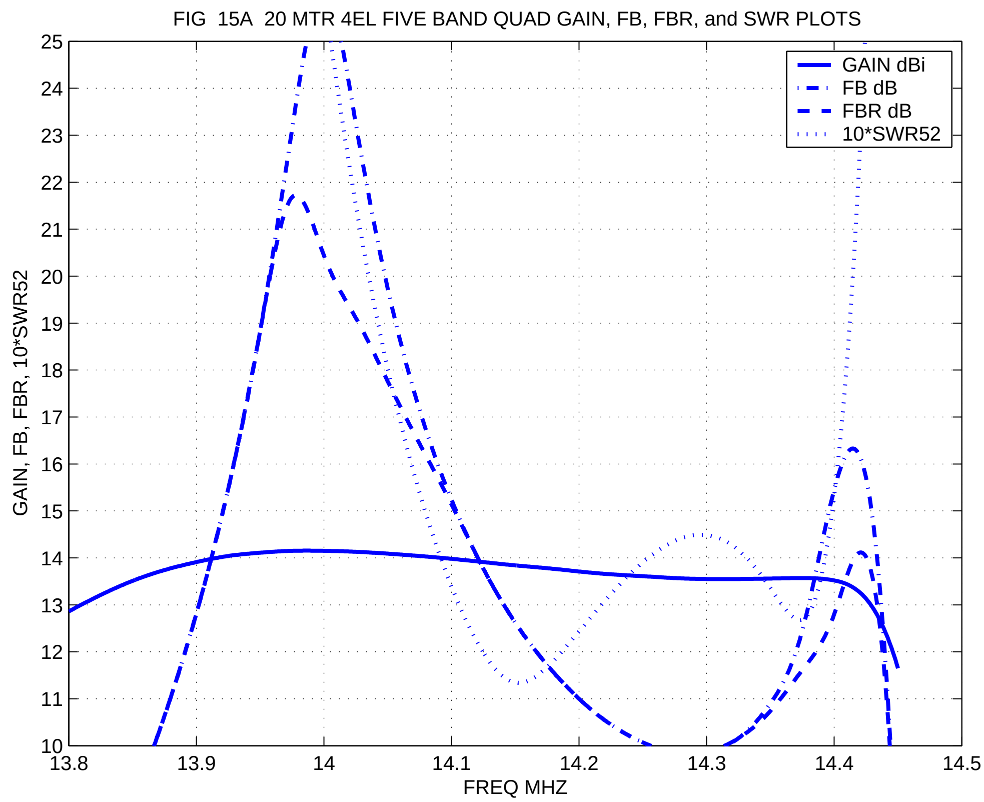


FIG 15A 20 MTR 4EL FIVE BAND QUAD GAIN, FB, FBR, and SWR PLOTS
GAIN dBi
FB dB
FBR dB
10*SWR52
GAIN, FB, FBR, 10*SWR52
FREQ MHZ

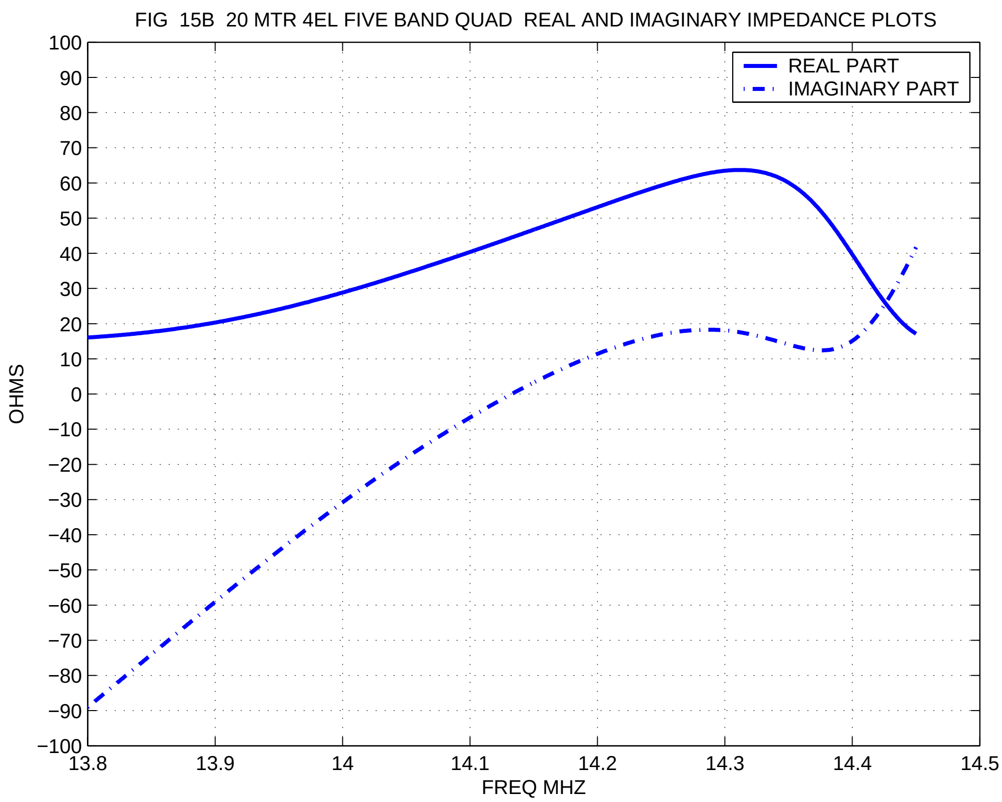


FIG 15B 20 MTR 4EL FIVE BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS
REAL PART
IMAGINARY PART
OHMS
FREQ MHZ

FIG 16A 17 MTR 4EL FIVE BAND QUAD GAIN, FB, FBR, and SWR PLOTS

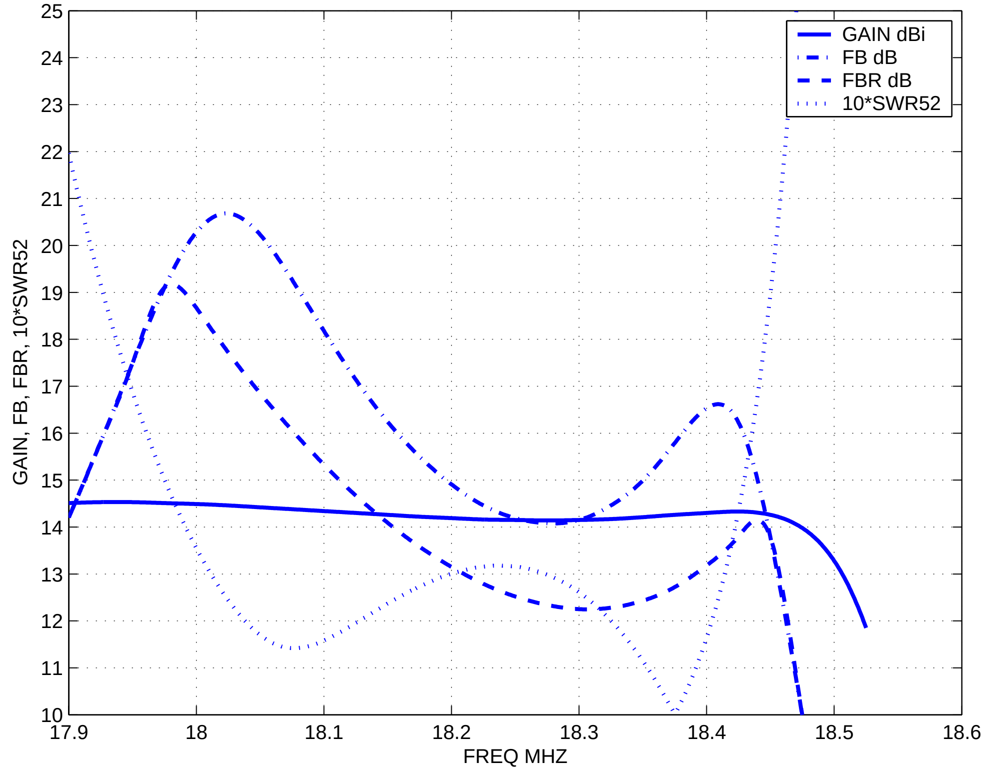
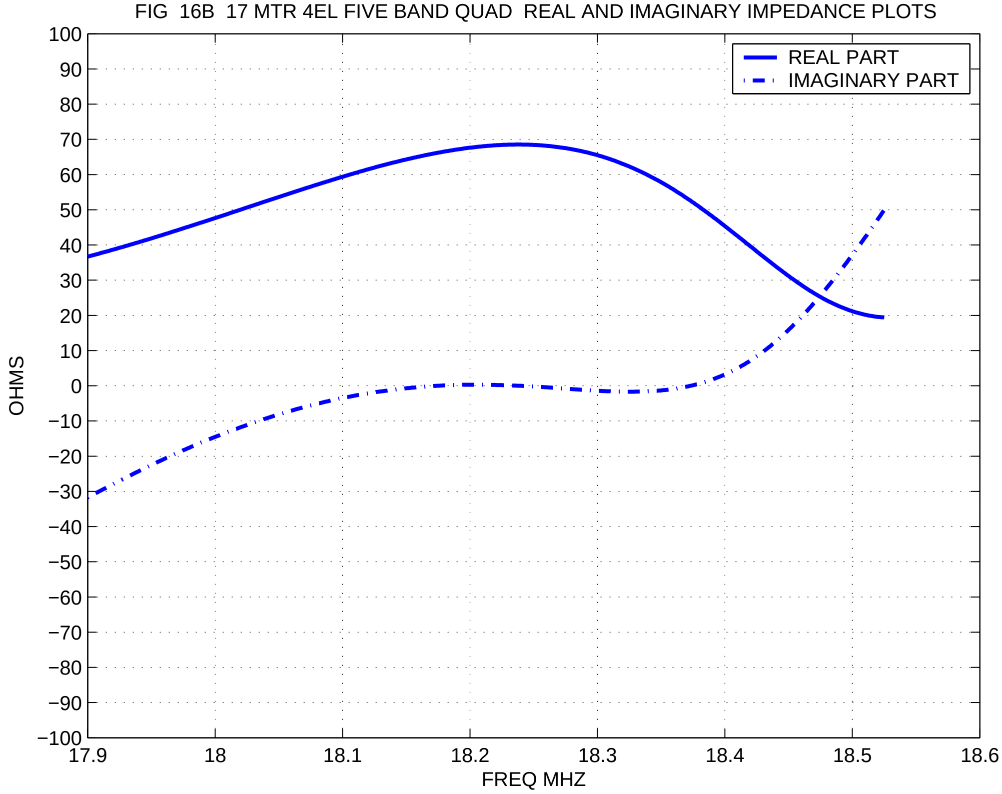


FIG 16B 17 MTR 4EL FIVE BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS



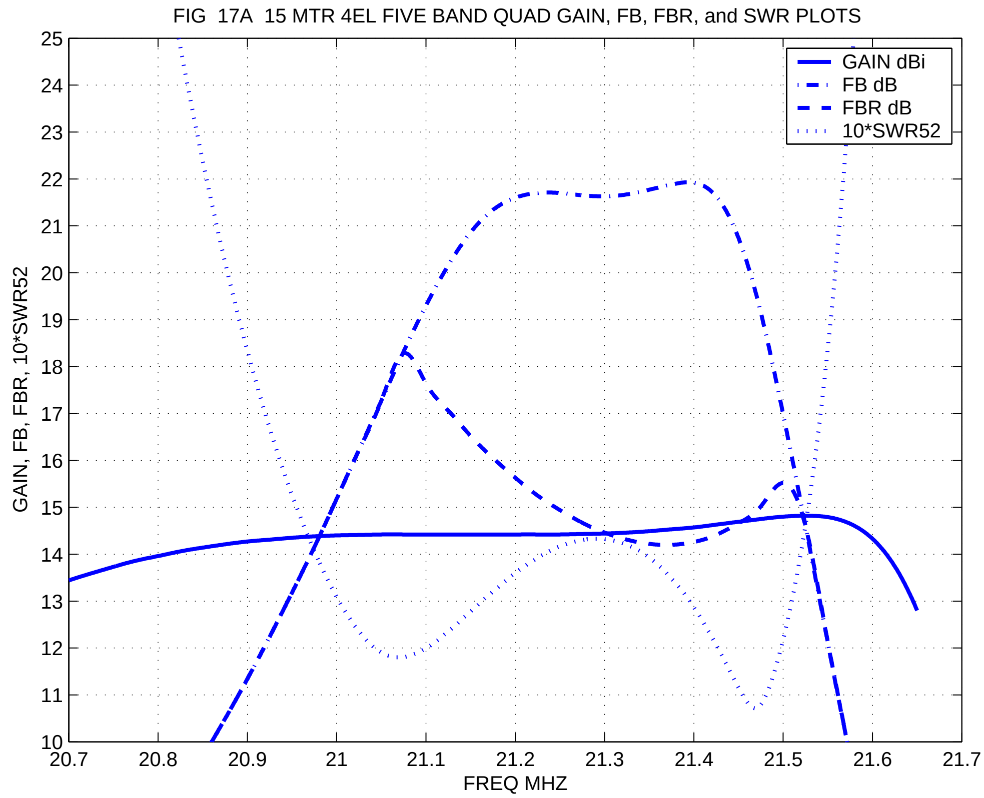


FIG 17A 15 MTR 4EL FIVE BAND QUAD GAIN, FB, FBR, and SWR PLOTS
GAIN dBi
FB dB
FBR dB
10*SWR52
GAIN, FB, FBR, 10*SWR52
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
20.7
20.8
20.9
21
21.1
21.2
21.3
21.4
21.5
21.6
21.7
FREQ MHZ

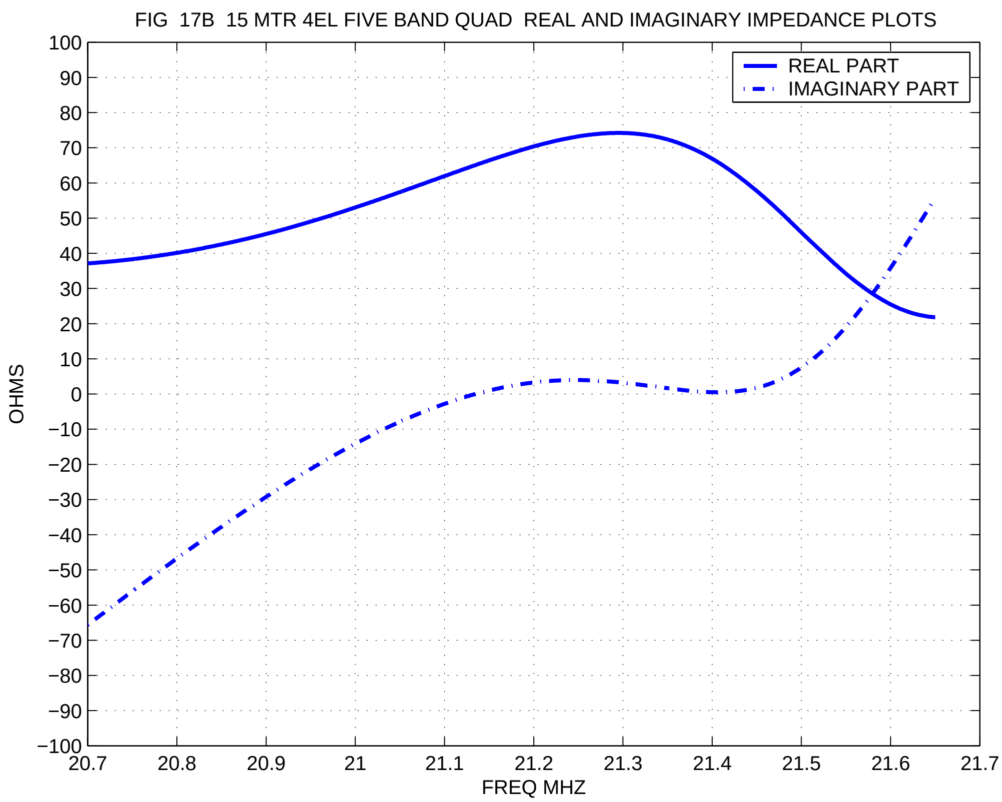


FIG 17B 15 MTR 4EL FIVE BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS
REAL PART
IMAGINARY PART
OHMS
100
90
80
70
60
50
40
30
20
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
20.7
20.8
20.9
21
21.1
21.2
21.3
21.4
21.5
21.6
21.7
FREQ MHZ

FIG 18A 12 MTR 4EL FIVE BAND QUAD GAIN, FB, FBR, and SWR PLOTS

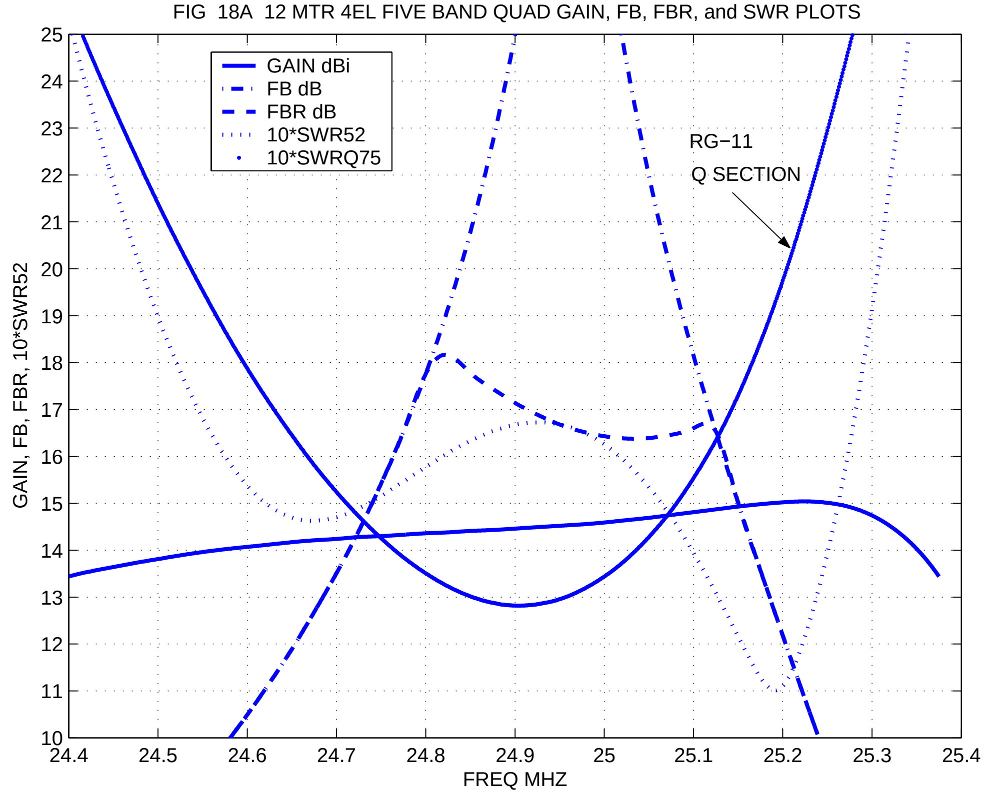
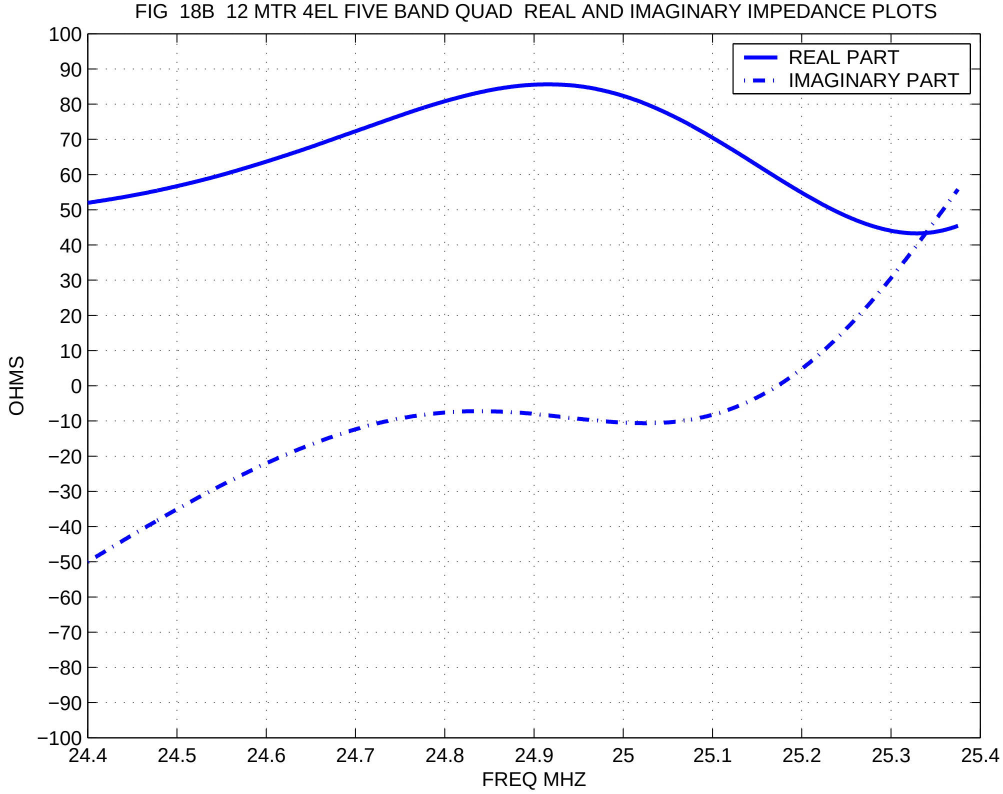


FIG 18B 12 MTR 4EL FIVE BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS



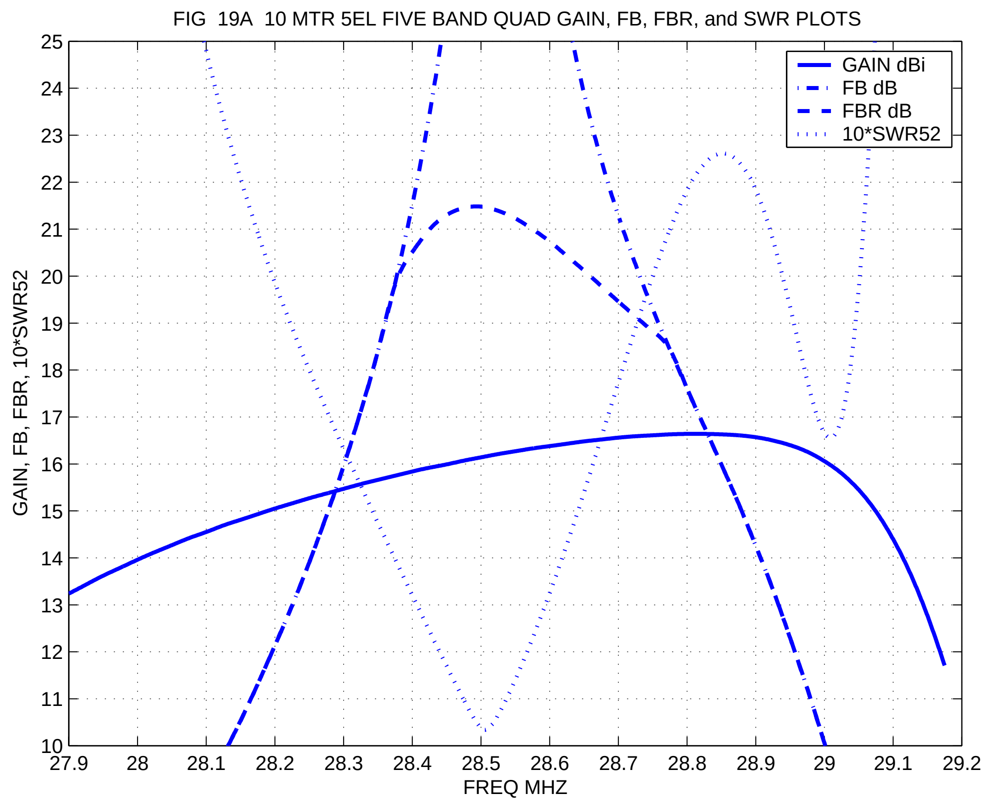


FIG 19A 10 MTR 5EL FIVE BAND QUAD GAIN, FB, FBR, and SWR PLOTS
GAIN dBi
FB dB
FBR dB
10*SWR52
GAIN, FB, FBR, 10*SWR52
FREQ MHZ

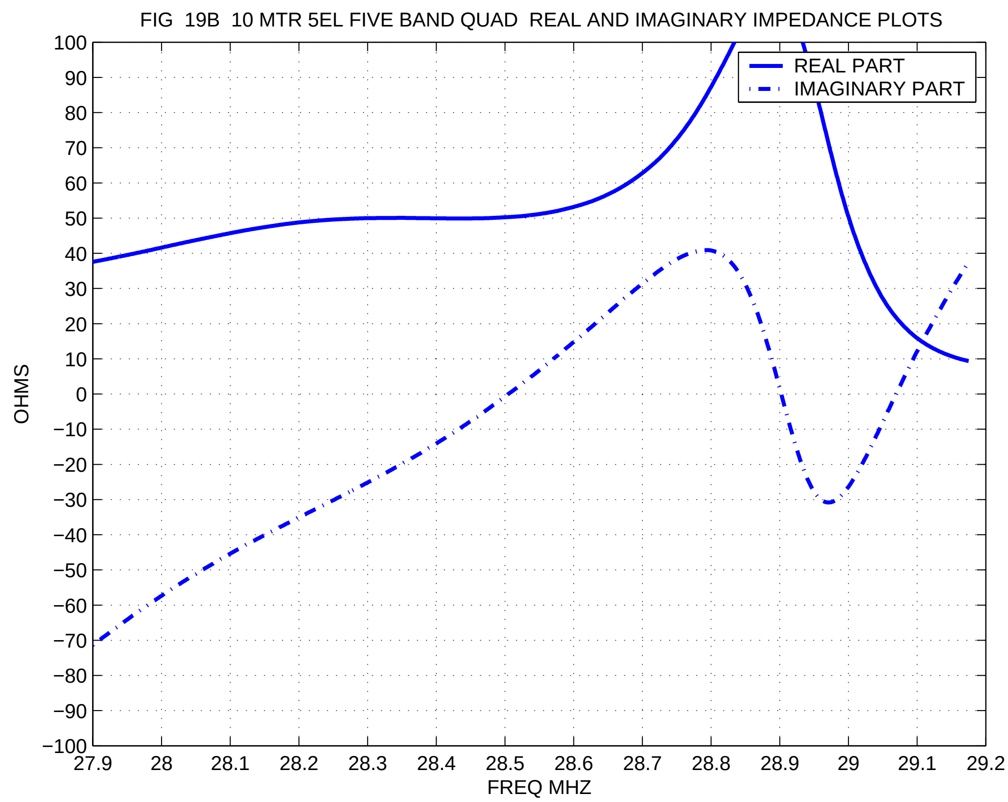


FIG 19B 10 MTR 5EL FIVE BAND QUAD REAL AND IMAGINARY IMPEDANCE PLOTS
REAL PART
IMAGINARY PART
OHMS
FREQ MHZ

Table 1 12 Meter Band Quarter Wave Q Matching Section Design

Q Section Made Of RG-11AU 75 Ohm Coax

Zo Ohms	Design Freq Mhz	L in FT	L in Inch
75.0000	24.9400	6.5152	78.1824

Use any length of 52 Ohm coax after the Q section.

FIVE BAND CUBICAL QUAD NON- DRIVEN DRIVEN ELEMENT COAXIAL FEED TERMINATION IMPEDANCE EFFECTS ON PERFORMANCE

A MATLAB program named zterm.m (see listing on page 38) was developed to calculate the impedance looking into the coaxial feed line of all four non-driven driven elements at the frequency of the driven band. The impedance calculation optionally includes a Q match run of RG11A/U coax, and a run of RG213U coax to a mast mounted band switch box. The switch box can be modeled to either put a short or open across the non-driven coax feed lines. Table 2 shows the impedance calculation for the previously described five band diamond quad antenna with a switch box that shorts the non-driven coax feeds. Table 2 includes the 12 Meter Q section match in the impedance calculations. Table 3 is a similar result but for a switch box that puts an open on each non-driven coax feed line. It should be noted that the real part of all the impedances are zero.

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>> zterm
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TABLE 2 FIVE BAND CUBICAL QUAD DRIVEN ELEMENT COAXIAL FEED TERMINATION IMPEDANCES

@ SWITCH BOX IMPEDANCE FOR NON DRIVEN BANDS IN OHMS=0

DRIVEN BAND	NON DRIVEN BAND IMAGINARY IMPEDANCES IN OHMS 20	17	15	12	10
20	0.00	-52.89	-77.40	-269.24	-35.33
17	15.30	0.00	-21.17	-54.23	4.41
15	61.28	17.94	0.00	-4.71	37.35
12	-2395.79	70.65	36.58	0.00	182.89
10	-62.14	1049.94	113.25	148.85	0.00

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>>
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>> zterm

TABLE 3 FIVE BAND CUBICAL QUAD DRIVEN ELEMENT COAXIAL FEED TERMINATION IMPEDANCES

@ SWITCH BOX IMPEDANCE FOR NON DRIVEN BANDS IN OHMS=1.000000e+010

DRIVEN BAND	NON DRIVEN BAND IMAGINARY IMPEDANCES IN OHMS 20	17	15	12	10
20	0.00	47.27	32.30	49.66	70.77
17	-163.40	0.00	118.08	131.65	-567.27
15	-40.80	-139.34	0.00	472.88	-66.94
12	1.04	-35.39	-68.35	0.00	-13.67
10	40.23	-2.38	-22.08	-86.13	0.00

>>

The MATLAB program zterm.m has comment statements that indicate how to load data into the program for a generalized coaxial cable feed system for any multi band quad design. This includes optional Q match lines on any band.

The above impedances can be added to the EZNEC 4.0 antenna models to obtain better precision in predicting the actual gain, FB, FBR, and SWR versus frequency for each band of operation.

Intuitively, the adjacent band(s) driven element resonant frequencies should be moved away from the driven band frequency for improved performance. Thus, when operating on 10 Meters it would be desirable to move the 12 Meter driven element resonant frequency even lower by having an inductive or +jX termination impedance. Conversely, when operating on 12 Meters one would like a capacitive or –jX termination on the 10 Meter quad driven element to move its resonance still higher in frequency. Viewing Tables 2 and 3 in this way for all eight adjacent band conditions indicates that Table 2 with a short on the non-driven bands is the better choice with seven of eight imaginary impedance signs in the right direction. The one conflict is when operating on the 12 Meter band with 10 Meters as an adjacent band. This could be fixed by having an extra loop of RG213U coax on the 10 Meter feed line near the switch box. Conceptually, coax feed line loops could be used on all the bands to control the termination impedances if they have a significant effect on antenna performance. Some EZNEC runs will be made to check this out. All prior EZNEC model runs used zero ohm termination impedances on all of the non-driven driven elements.

Figures 20A to 20H show the eight adjacent band antenna driving point impedance versus operating band frequency cases of interest for the five band quad. The figures are organized as follows:

Figure 20A	Z12 versus F10
Figure 20B	Z10 versus F12
Figure 20C	Z15 versus F12
Figure 20D	Z12 versus F15
Figure 20E	Z17 versus F15
Figure 20F	Z15 versus F17
Figure 20G	Z20 versus F17
Figure 20H	Z17 versus F20

FIG 20A 12 MTR QUAD IMPEDANCE WHEN OPERATING 10 MTRS

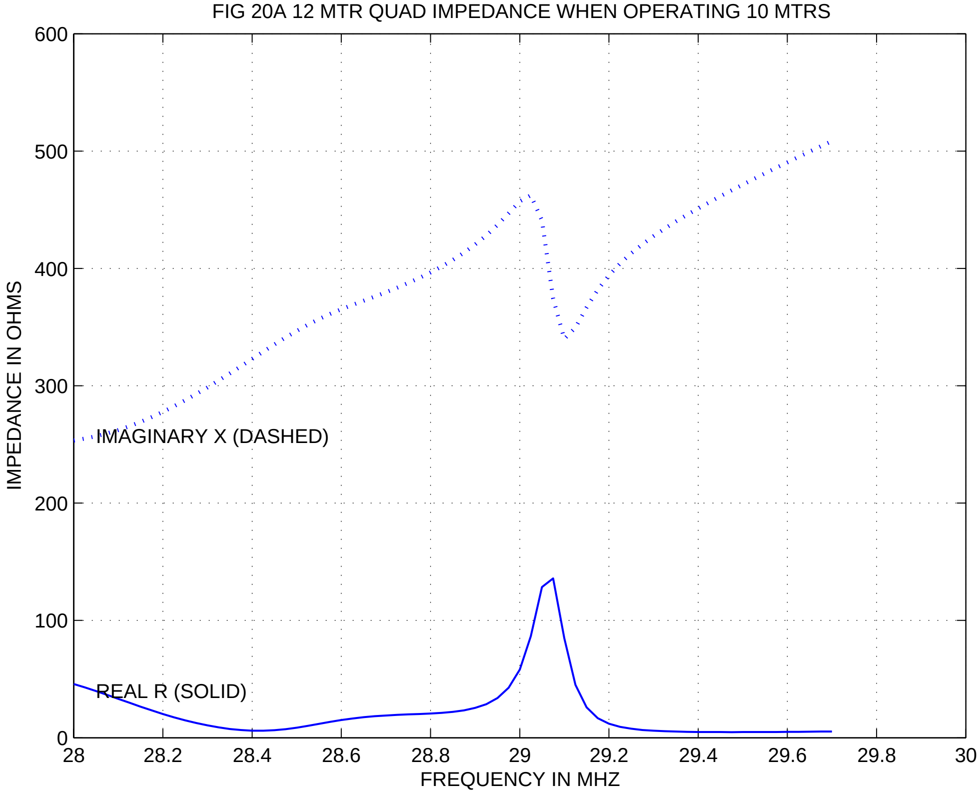


FIG 20B 10 MTR QUAD IMPEDANCE WHEN OPERATING 12 MTRS

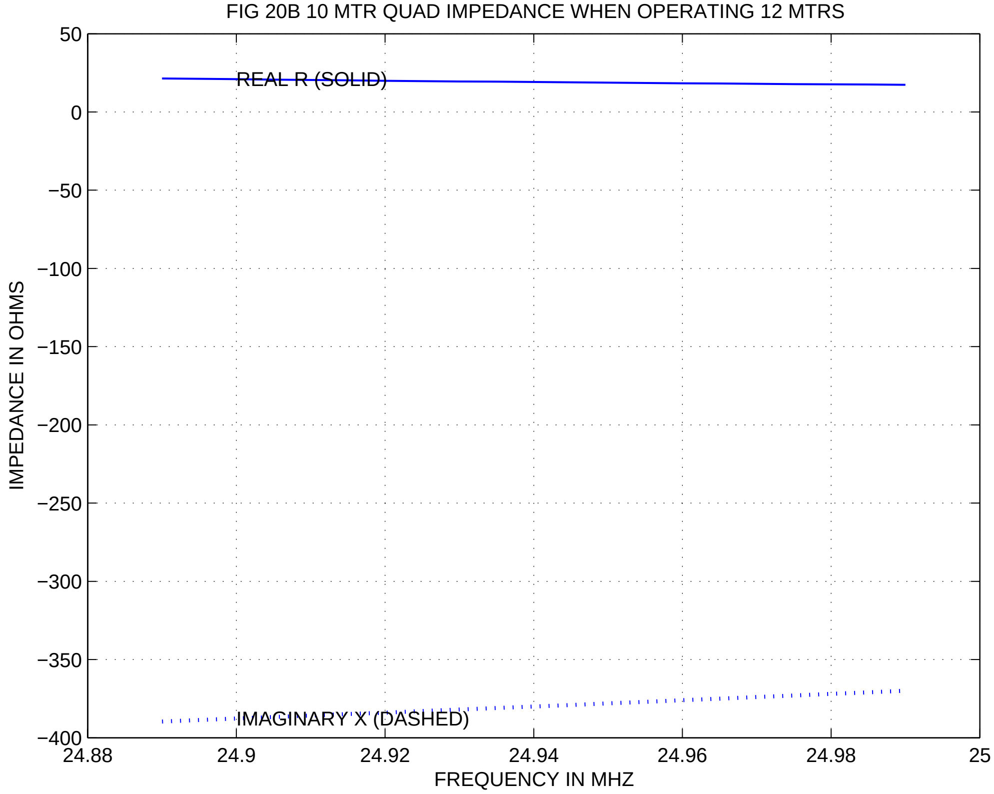


FIG 20C 15 MTR QUAD IMPEDANCE WHEN OPERATING 12 MTRS

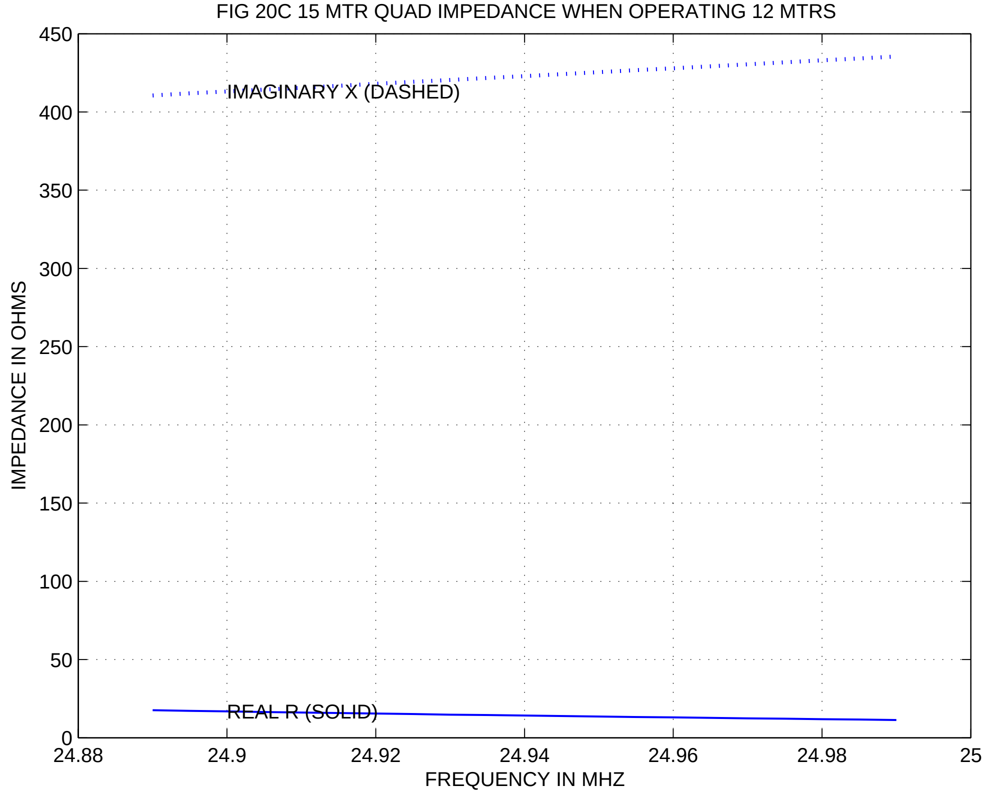
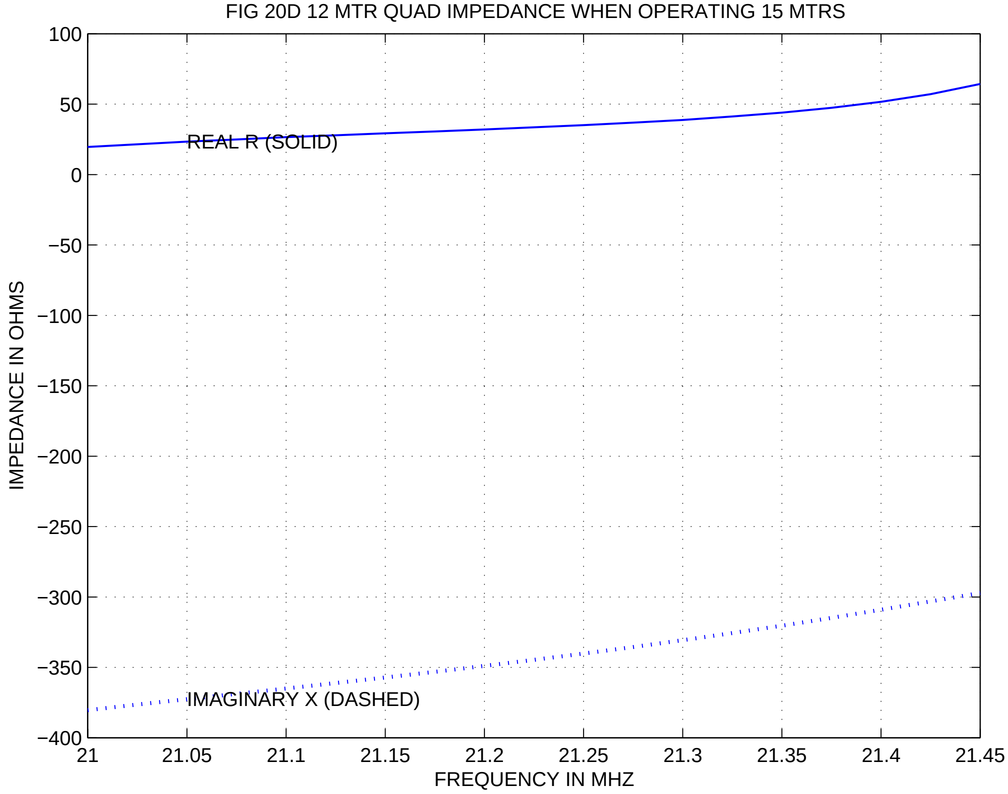


FIG 20D 12 MTR QUAD IMPEDANCE WHEN OPERATING 15 MTRS



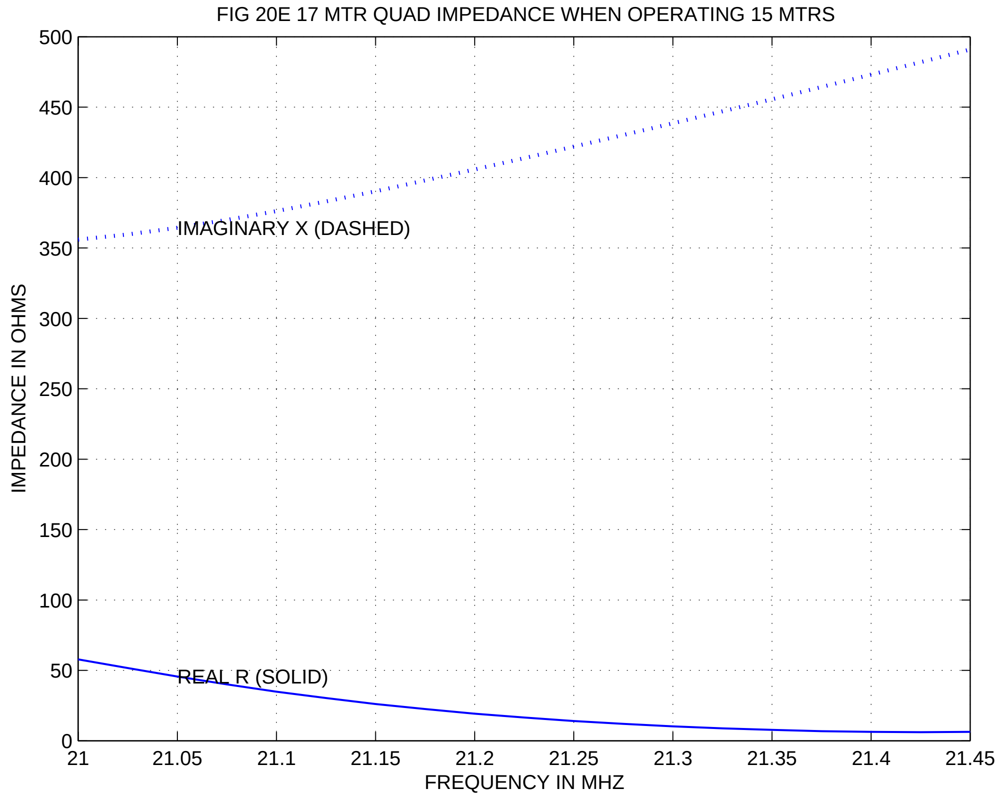


FIG 20E 17 MTR QUAD IMPEDANCE WHEN OPERATING 15 MTRS
IMPEDANCE IN OHMS
500
450
400
350
300
250
200
150
100
50
0
21
21.05
21.1
21.15
21.2
21.25
21.3
21.35
21.4
21.45
IMAGINARY X (DASHED)
REAL R (SOLID)
FREQUENCY IN MHZ

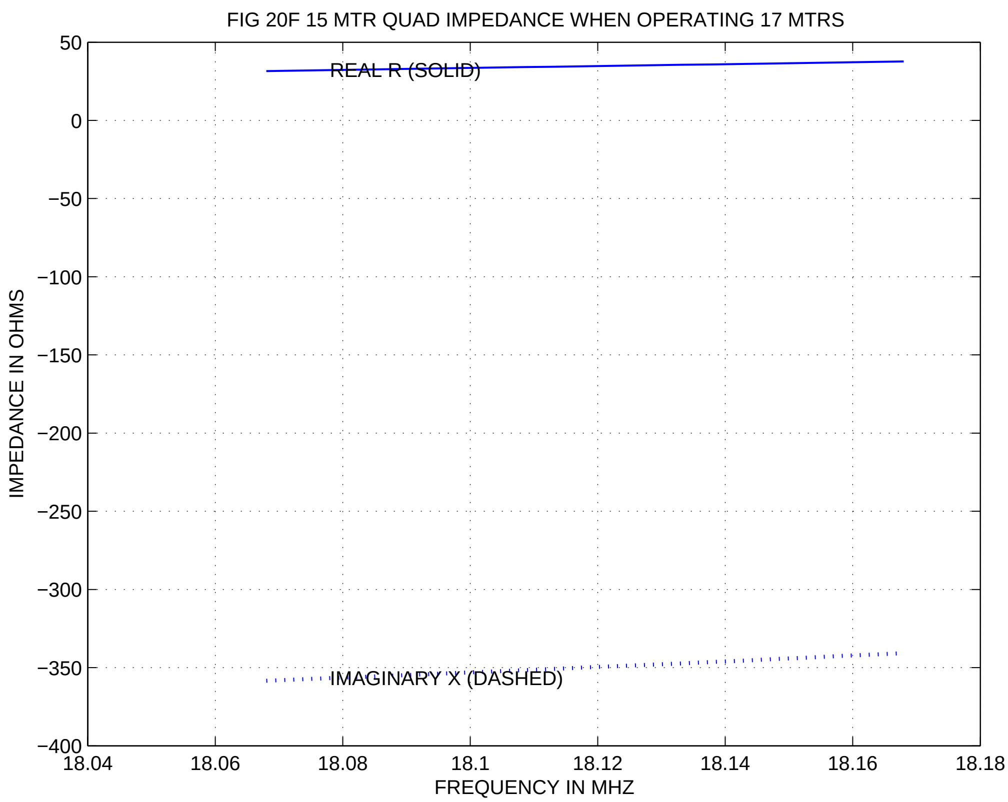


FIG 20F 15 MTR QUAD IMPEDANCE WHEN OPERATING 17 MTRS
IMPEDANCE IN OHMS
50
0
−50
−100
−150
−200
−250
−300
−350
−400
18.04
18.06
18.08
18.1
18.12
18.14
18.16
18.18
REAL R (SOLID)
IMAGINARY X (DASHED)
FREQUENCY IN MHZ

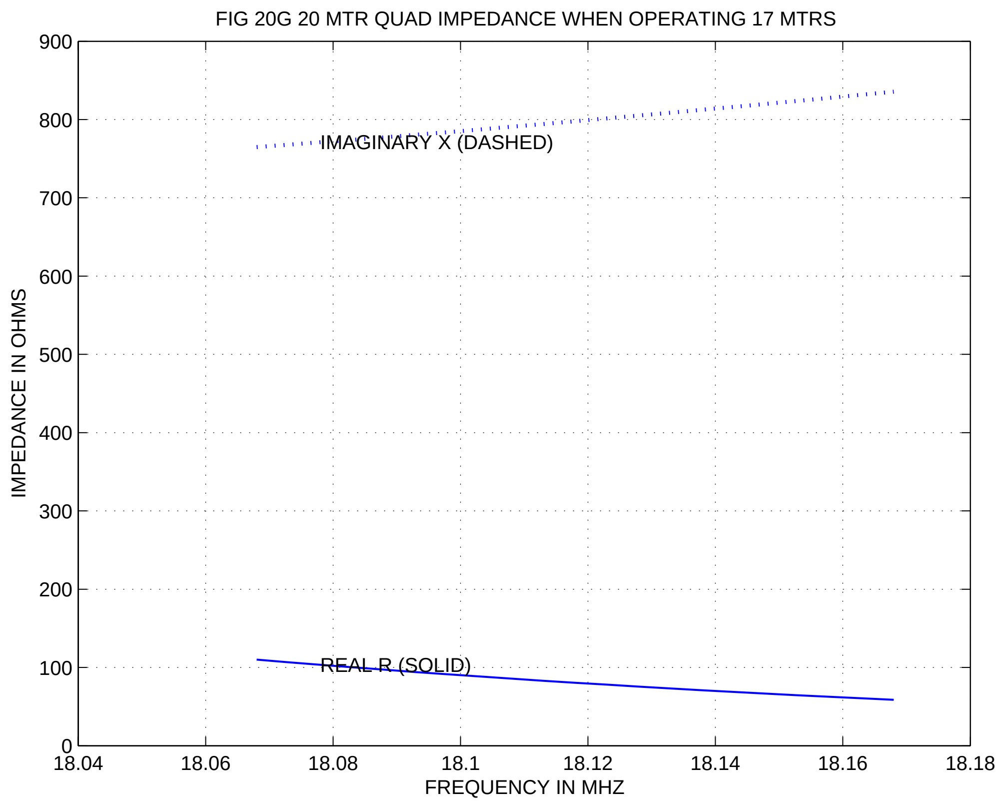


FIG 20G 20 MTR QUAD IMPEDANCE WHEN OPERATING 17 MTRS
IMAGINARY X (DASHED)
REAL R (SOLID)
IMPEDANCE IN OHMS
FREQUENCY IN MHZ
900
800
700
600
500
400
300
200
100
0
18.04
18.06
18.08
18.1
18.12
18.14
18.16
18.18

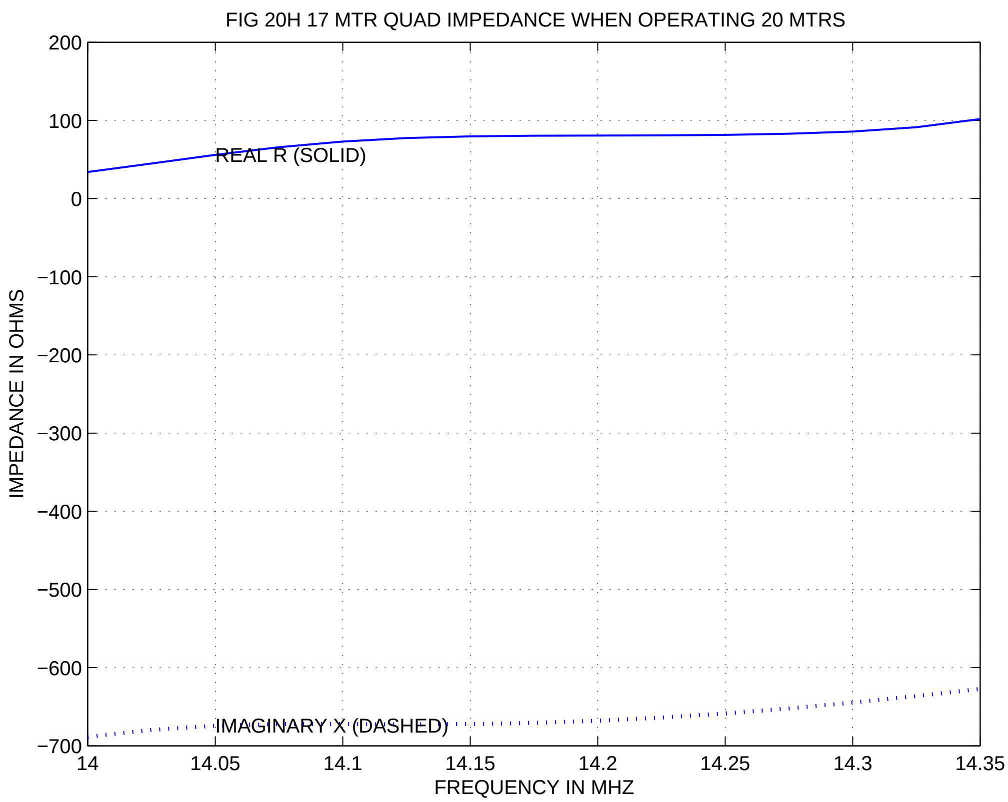


FIG 20H 17 MTR QUAD IMPEDANCE WHEN OPERATING 20 MTRS
REAL R (SOLID)
IMAGINARY X (DASHED)
IMPEDANCE IN OHMS
FREQUENCY IN MHZ
200
100
0
−100
−200
−300
−400
−500
−600
−700
14
14.05
14.1
14.15
14.2
14.25
14.3
14.35

The primary concern for modeling non-driven driven element termination impedances is the interaction between the 10 and 12 Meter arrays since the percent difference in frequency is the smallest for this adjacent band pair.

Figure 20A indicates that a termination impedance range of -j322 to +j322 Ohms will cause a significant change in the magnitude and phase of the 10 MTR band current flowing in the 12 Meter driven element that could thereby affect the 10 Meter array performance. The 10 Meter array impedance when operating on 12 Meters at a frequency of 24.94 Mhz is 19.11-j380 Ohms so a similar range of termination impedances of the 10 Meter array may affect the 12 Meter array performance. Thus, EZNEC runs using discrete termination impedance values of zero, +/-j350, and 1e10 Ohms can be used to explore the range of termination impedance affects on 10 and 12 Meter array performance interaction. If undesirable termination impedances are found, the coax feeds and band switch box could be designed to avoid them. Another major issue is the accuracy of predicting the peak FB frequency etc to properly tune each array for DX window frequencies of interest.

Figure 21A shows the 10 MTR array resonant frequency as a function of the 12 MTR array coaxial feed line termination reactance. Figure 21B shows the 10 MTR array resonant resistance as a function of the 12 MTR array coaxial feed line termination reactance. Figure 21D shows the 10 MTR array gain, FBR, and SWR at a frequency of 28.5 Mhz as a function of the 12 MTR array coaxial feed line termination reactance. . Figure 21E shows the 10 MTR array gain, FBR, and SWR at a frequency of 28.0 Mhz as a function of the 12 MTR array coaxial feed line termination reactance. . Figure 21F shows the 10 MTR array gain, FBR, and SWR at a frequency of 28.85 Mhz as a function of the 12 MTR array coaxial feed line termination reactance. The 12 MTR array coaxial feed termination reactance must be evaluated at the 10 MTR band operating frequency.

Figure 21G shows the 12 MTR quad SWR versus the 10 MTR quad coax feed termination reactance at 24.93 Mhz. The SWR for a straight 50 Ohm coax feed and a quarter wave Q section feed of the 12 MTR array are shown. Figure 21H shows the 12 MTR quad driving point impedance real and imaginary parts versus the 10 MTR quad coax feed termination reactance. Figure 21I shows the 12 MTR quad gain and front to back region gain (FBR) versus the 10 MTR quad coax feed termination reactance. Listings of the MATLAB programs q12z10.m and its SWR subroutine swrQ.m that generated Figures 21G, 21H, and 21I are at the back of this document. These programs processed data obtained from EZNEC 4.0 runs for the five band quad.

Table 3 shows all the non-operating band antenna driving point impedances at discrete operating band frequencies for the previously described five band quad array. This table should help in designing the coaxial feed system termination impedances.

It is apparent that the 10 and 12 MTR quad performances and tuning can be drastically affected by using improper coax feed termination impedance values on the non driven adjacent 12 and 10 MTR bands. The cautionary lesson is to avoid using an imaginary coax feed termination impedance (@ operating band frequency) that cancels the imaginary driving point impedance of the adjacent band quad (@ operating band frequency). The adjacent band quad is effectively tuned to resonate in the operating band if the coax feed reactance cancels the adjacent band antenna reactance. This lesson carries over to all adjacent band antenna driving point impedance cases shown in Figures 20A to 20H and Table 3 for the five band quad. The design and modeling of the five band quad must definitely pay attention to the coaxial feed system and termination impedance values to achieve good predictable performance.

FIG 21A 10 MTR QUAD RESONANT FREQUENCY VS 12 MTR QUAD TERMINATION jX

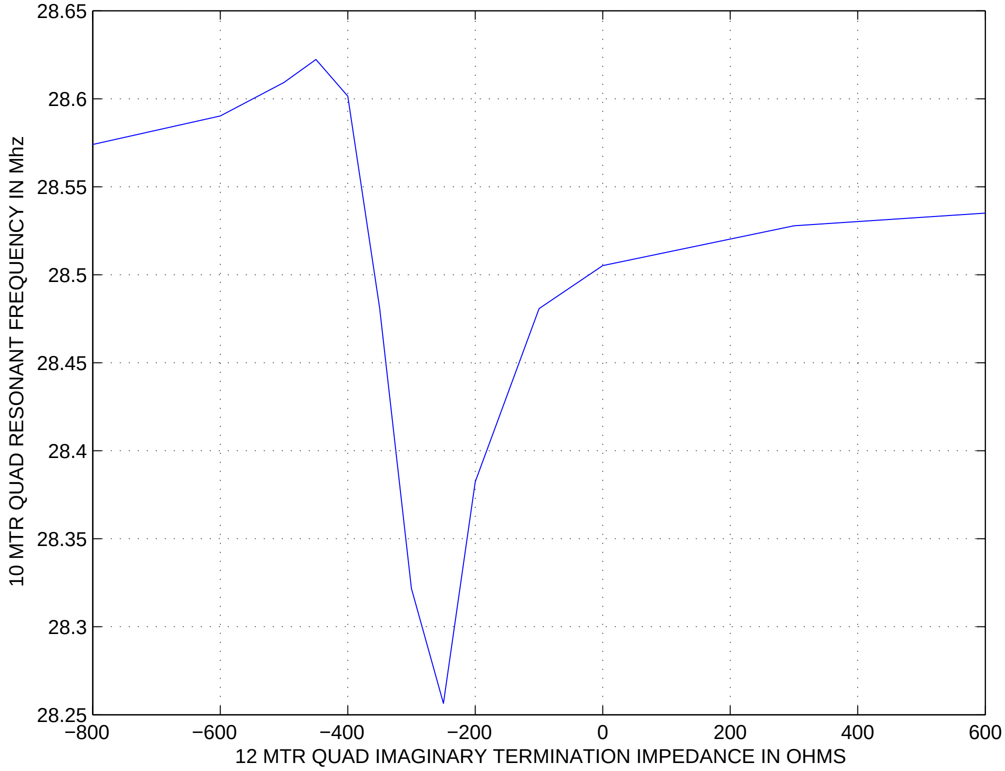
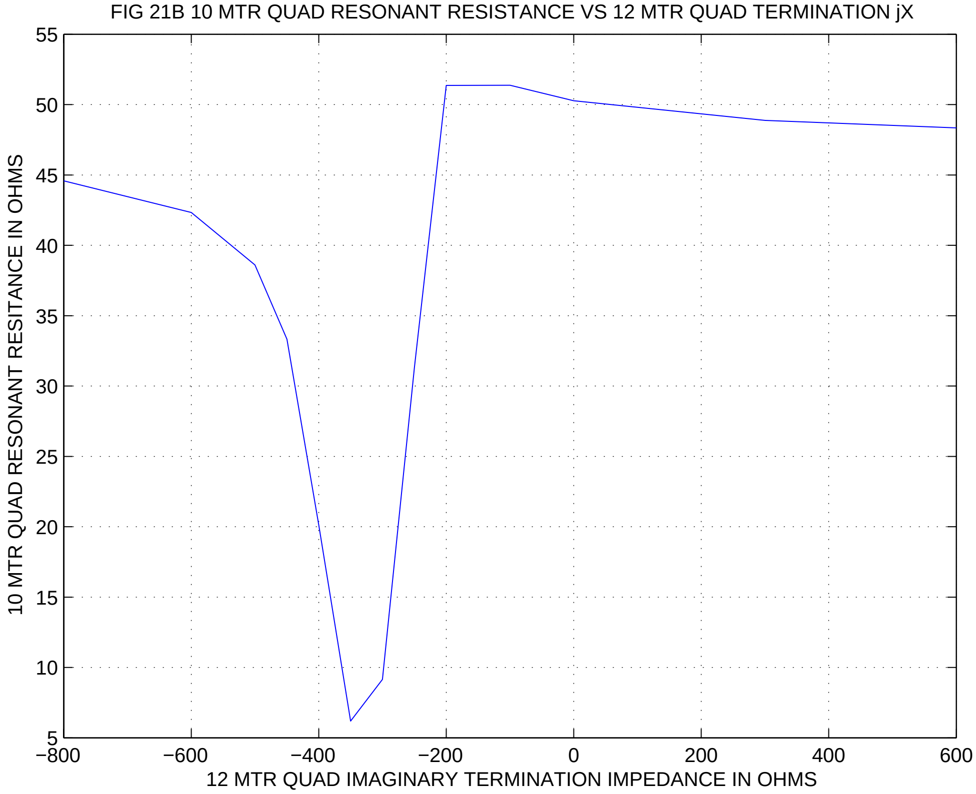


FIG 21B 10 MTR QUAD RESONANT RESISTANCE VS 12 MTR QUAD TERMINATION jX



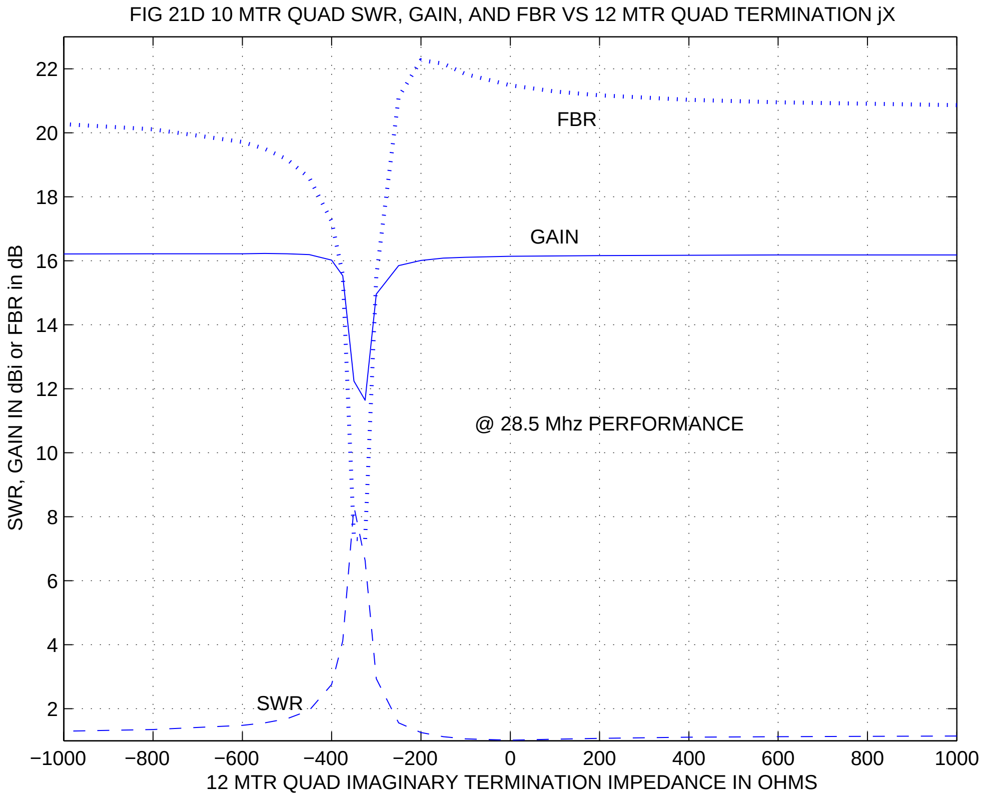


FIG 21D 10 MTR QUAD SWR, GAIN, AND FBR VS 12 MTR QUAD TERMINATION jX
SWR, GAIN IN dBi or FBR in dB
12 MTR QUAD IMAGINARY TERMINATION IMPEDANCE IN OHMS
FBR
GAIN
SWR
@ 28.5 Mhz PERFORMANCE
22
20
18
16
14
12
10
8
6
4
2
−1000
−800
−600
−400
−200
0
200
400
600
800
1000

FIG 21E 10 MTR QUAD GAIN AND FBR VS 12 MTR QUAD TERMINATION jX

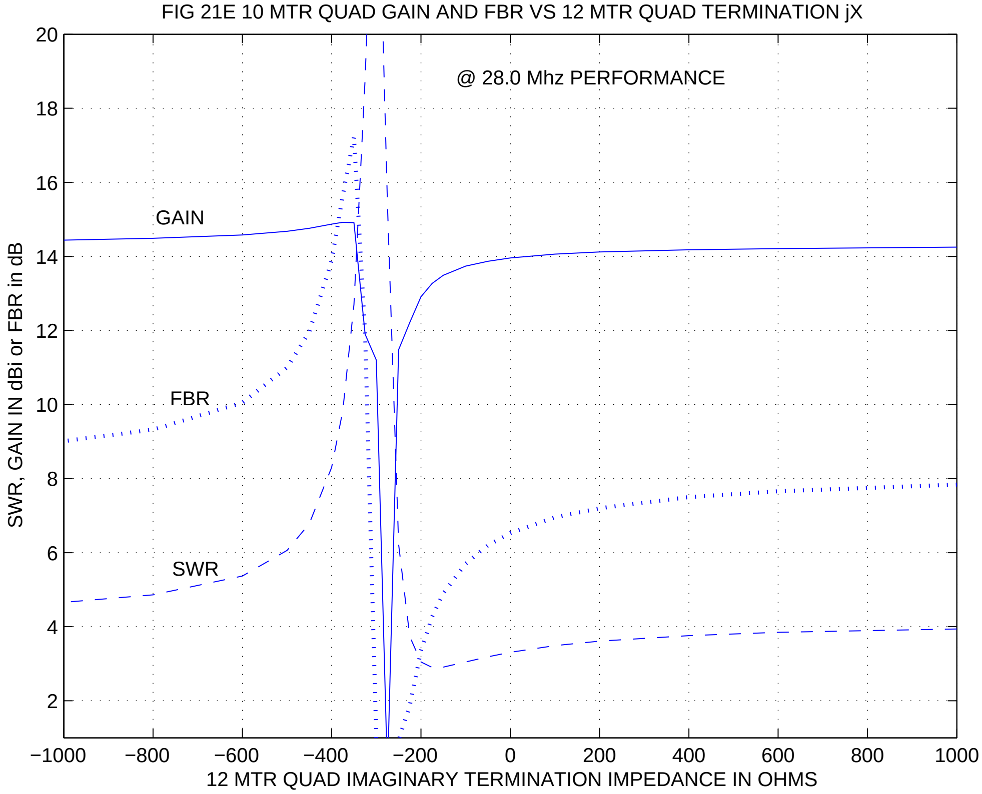


FIG 21F 10 MTR QUAD SWR, GAIN, AND FBR VS 12 MTR QUAD TERMINATION jX

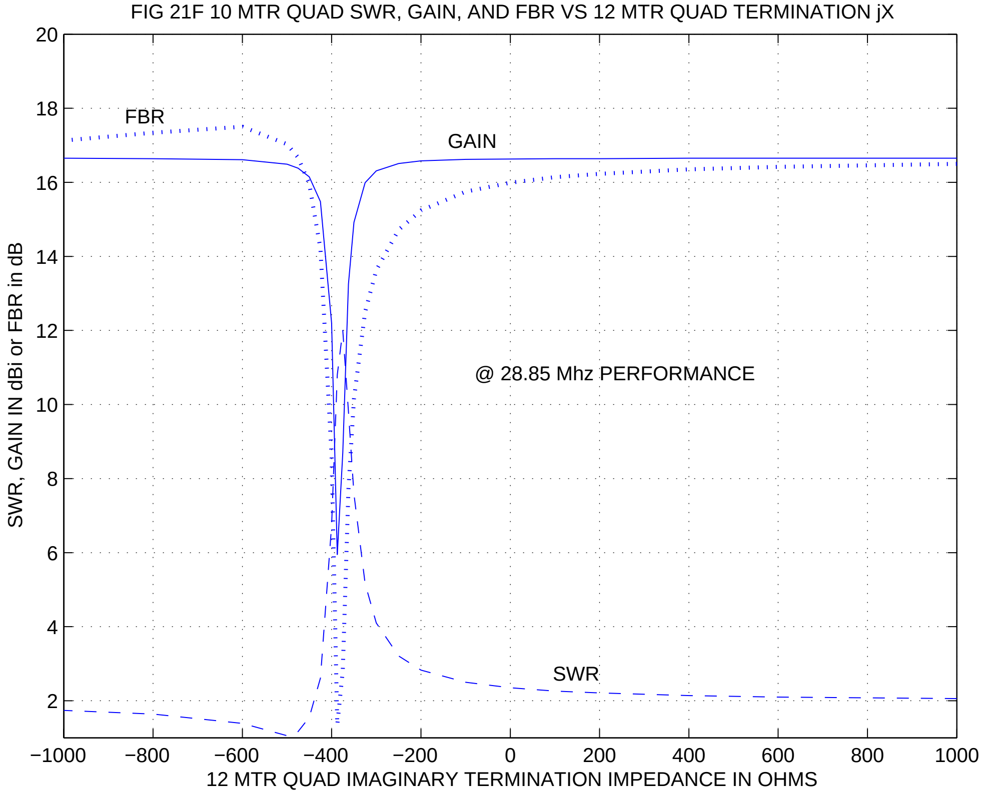


FIG 21G 12 MTR QUAD SWR VERSUS 10 MTR QUAD COAX FEED REACTANCE

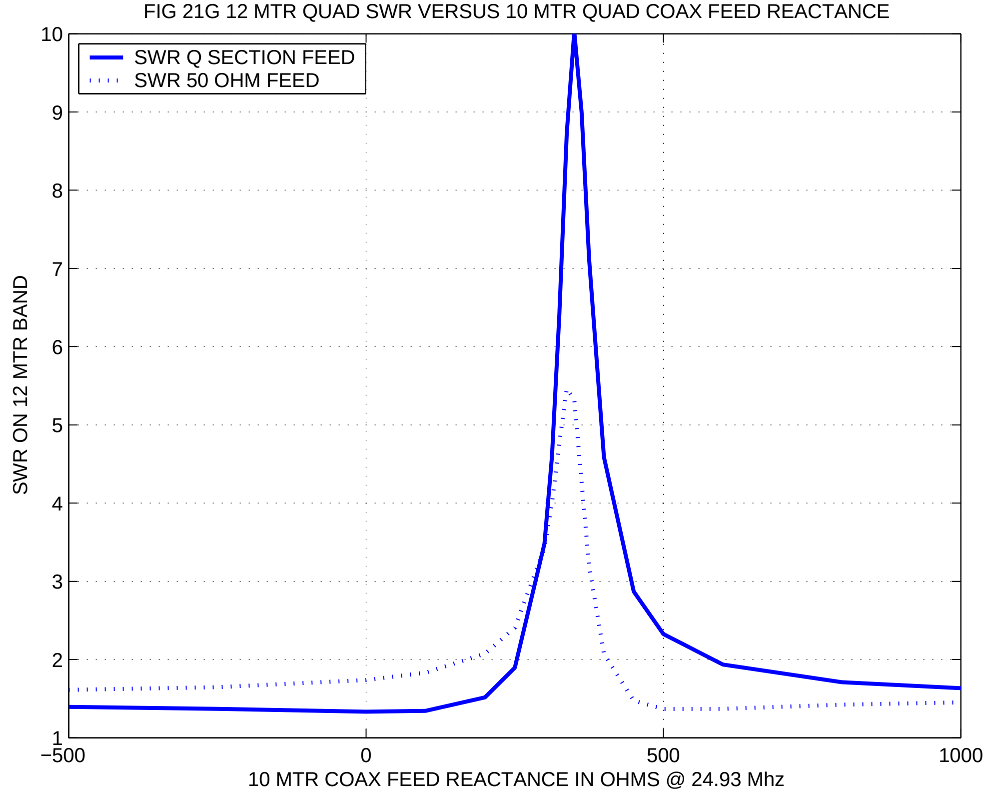


FIG 21H 12 MTR QUAD IMPEDANCE VERSUS 10 MTR QUAD COAX FEED REACTANCE

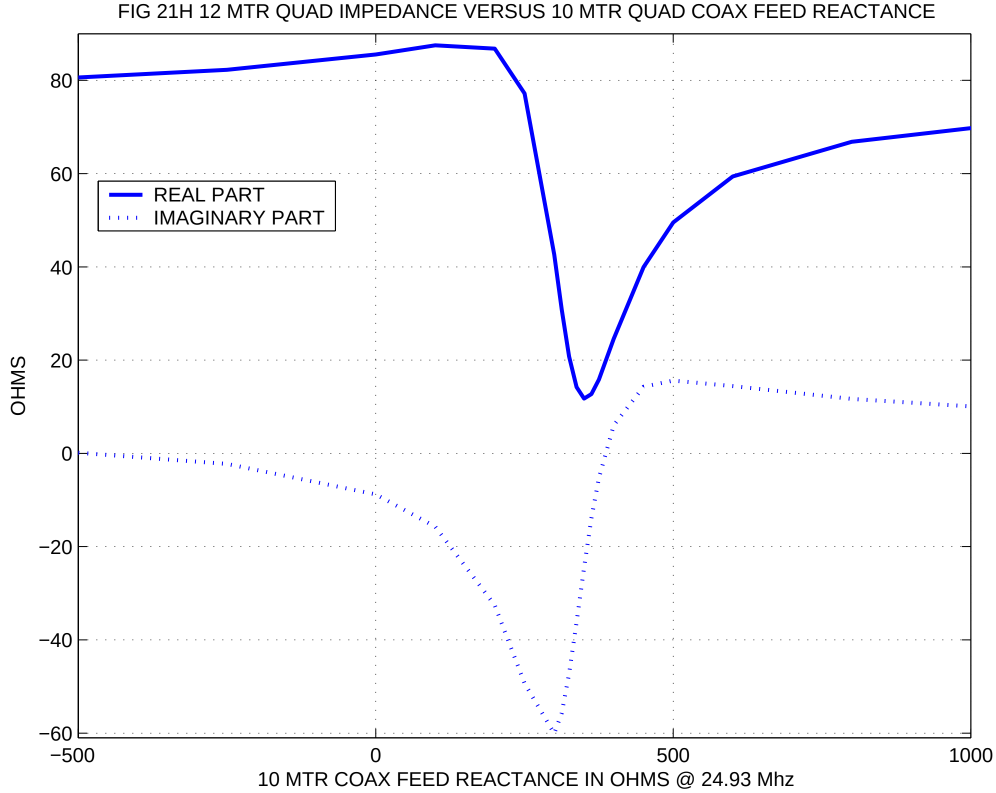


FIG 21I 12 MTR QUAD GAIN AND FBR VERSUS 10 MTR QUAD COAX FEED REACTANCE

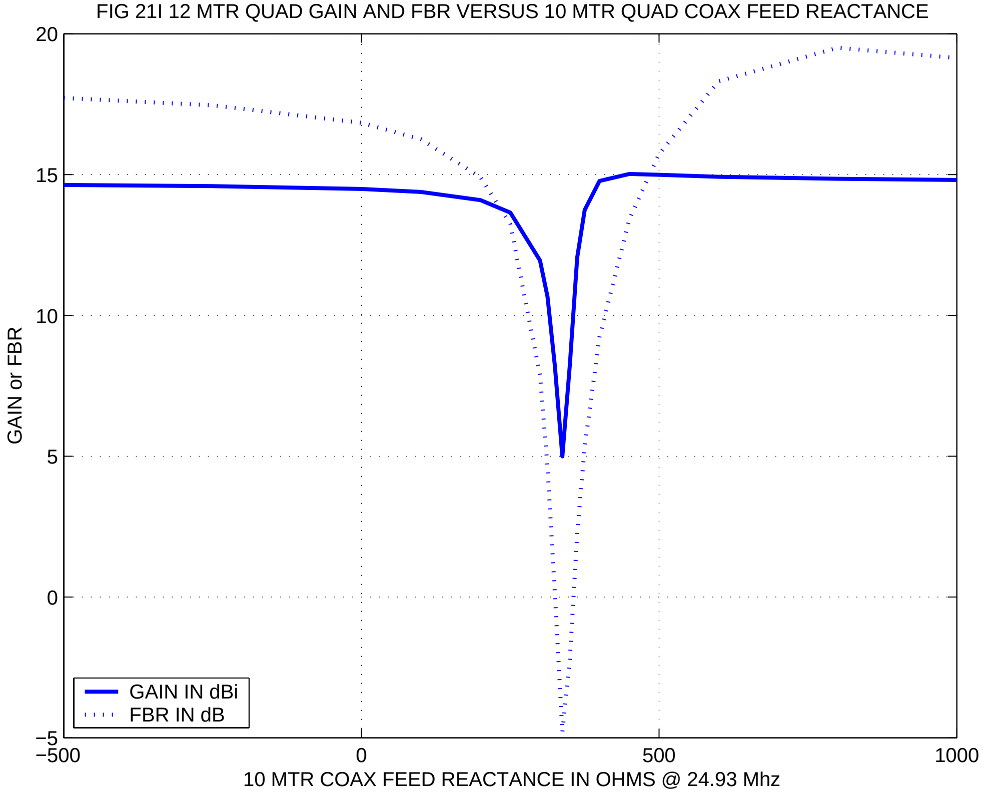


TABLE 3 NON-OPERATING BAND IMPEDANCES AT OPERATING BAND FREQUENCY FOR THE FIVE BAND QUAD

OPERATING BAND	NON-OPERATION BANDS				
	20 14.174	17 18.118	15 21.224	12 24.94	10 28.4
20	NA	80.5-j671	74.2-j1469	193-j4295	3308+j29580
17	80.5+j798	NA	34.6-j350	39-j923	30.7-j2072
15	1057+j4250	16.6+j413	NA	33.4-j345	16.5-j947
12	113-j1119	85.2+j1395	14.2+j423	NA	19.1-j380
10	77.5-j69.3	1665-j4202	37+j1176	6.1+j323	NA

@ Zero termination impedance on other non-operation bands

Figures 22A to 29A show the adjacent non-operating band coaxial cable termination reactance at the operating band frequency as a function of the RG213U coax cable loop length from the five band quad boom to mast bracket to the band switch box for the case of a switch box that puts a short across the non-operating band coax feeds. The 12 MTR feed includes the RG11A/U Q match coax in the reactance computation. Figures 22B to 29B show a similar result but for a switch box that puts an open across the non-operating band coax feeds. All eight adjacent band cases for the five band quad are covered by these figures. The curves can be used to design coax loop lengths that result in good quad performance (and accurate performance assessment using the EZNEC loads modeling capability) on every band of operation. The figure curves repeat every half wave (evaluated at the appropriate frequency) down the RG213U coax line. Table 4 shows half wave lengths on the RG213U coax versus frequency.

TABLE 4 HALF WAVE ON RG213U COAX LINE VS FREQUENCY

F Mhz	WAVE/2 IN FT
14.0000	24.1963
14.2000	23.8555
14.3500	23.6062
18.1100	18.7051
21.0000	16.1309
21.3000	15.9037
21.4500	15.7925
24.9400	13.5825
28.0000	12.0982
28.5000	11.8859
28.8500	11.7417

Commercially available five band coax switch boxes typically have the option of putting either a short or open across all non-operating coax output ports. For five band quad feed design flexibility, it would be nice to have a switch box that can individually program each unused port as either a short or open depending on which port is being used. One consideration for reliability is that it is less likely that an antenna switch box relay with corroded contacts will fail for a desired open condition than a desired short condition.

For the postulated five band quad coax feed design of this article which is based on a switch box that shorts the non driven driven elements, the fix for the residual 12 Mtr band operation problem is to use a six foot loop of RG213U coax on the 10 Mtr feed line from the boom to mast bracket to the switch box. Figure 23A and Table 2 shows that a three foot loop length results in an undesirable 10 Mtr coax feed reactance of +j182.89 Ohms while a loop length of six feet results in a more desirable reactance of –j110 Ohms. The three foot increase in feed line length will avoid the 12 Mtr quad performance degradations shown in Figures 21 G, H, and I.

For those readers who want to generate their own customized plots of coaxial feed line reactance versus loop line length such as Figures 22A to 29A and 22B to 29B the following MATLAB program listings are at the back of this article:

Figure	MATLAB program name for Figure generation
22A	Q10a12s.m
22B	Q10a12o.m
23A	Q12a10s.m
23B	Q12a10o.m
24A	Q12a15s.m
24B	Q12a15o.m
25A	Q15a12s.m
25B	Q15a12o.m
26A	Q15a17s.m
26B	Q15a17o.m
27A	Q17a15s.m
27B	Q17a15o.m
28A	Q17a20s.m
28B	Q17a20o.m
29A	Q20a17s.m
29B	Q20a17o.m

The major MATLAB subroutine used by all of the above programs is named zterm22.m. This program must include details of the coaxial feed design up to the boom to mast bracket point.

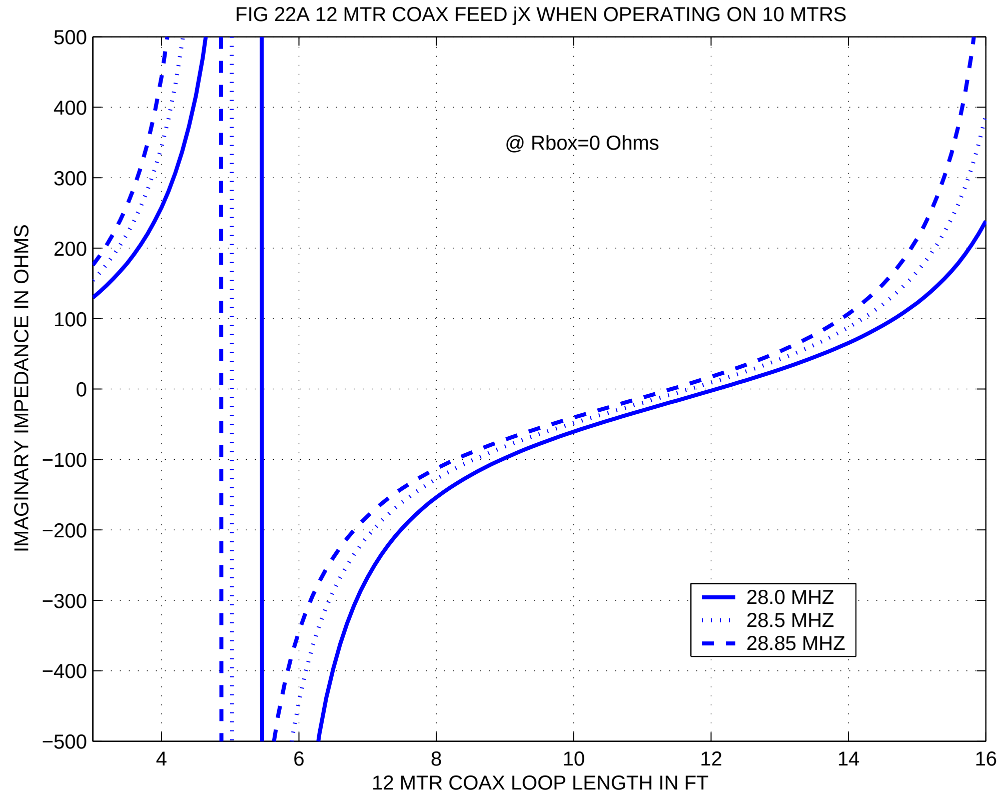


FIG 22A 12 MTR COAX FEED jX WHEN OPERATING ON 10 MTRS
@ Rbox=0 Ohms
28.0 MHZ
28.5 MHZ
28.85 MHZ
IMAGINARY IMPEDANCE IN OHMS
12 MTR COAX LOOP LENGTH IN FT
500
400
300
200
100
0
−100
−200
−300
−400
−500
4
6
8
10
12
14
16

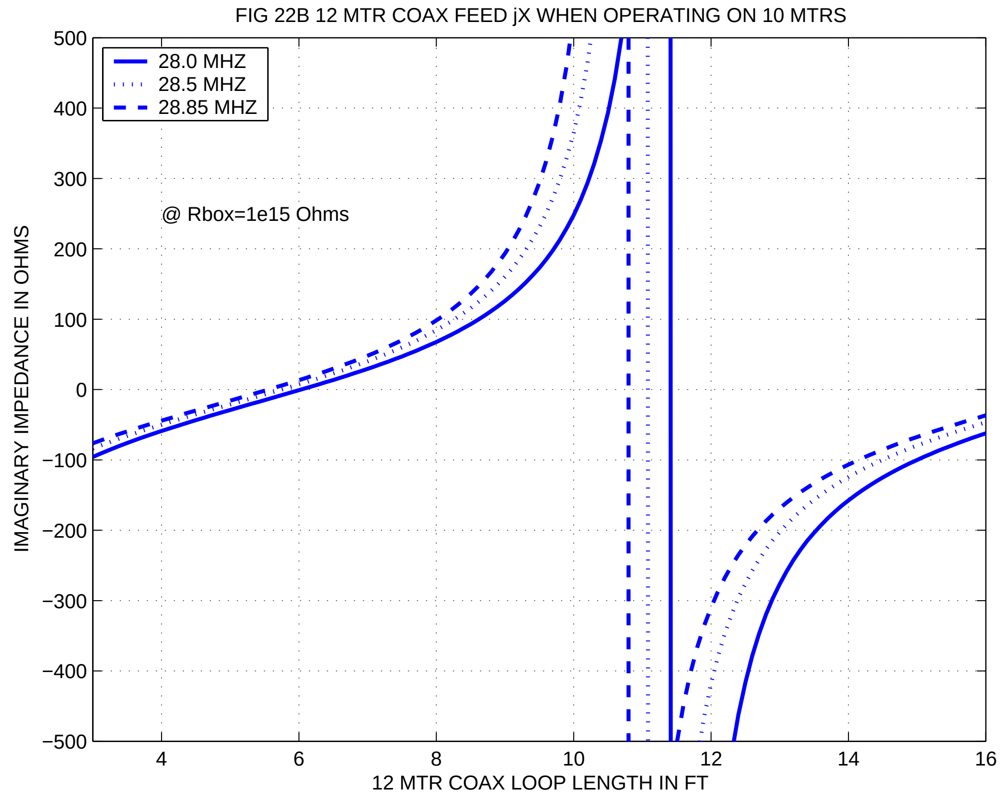


FIG 22B 12 MTR COAX FEED jX WHEN OPERATING ON 10 MTRS
28.0 MHZ
28.5 MHZ
28.85 MHZ
@ Rbox=1e15 Ohms
IMAGINARY IMPEDANCE IN OHMS
12 MTR COAX LOOP LENGTH IN FT
500
400
300
200
100
0
−100
−200
−300
−400
−500
4
6
8
10
12
14
16

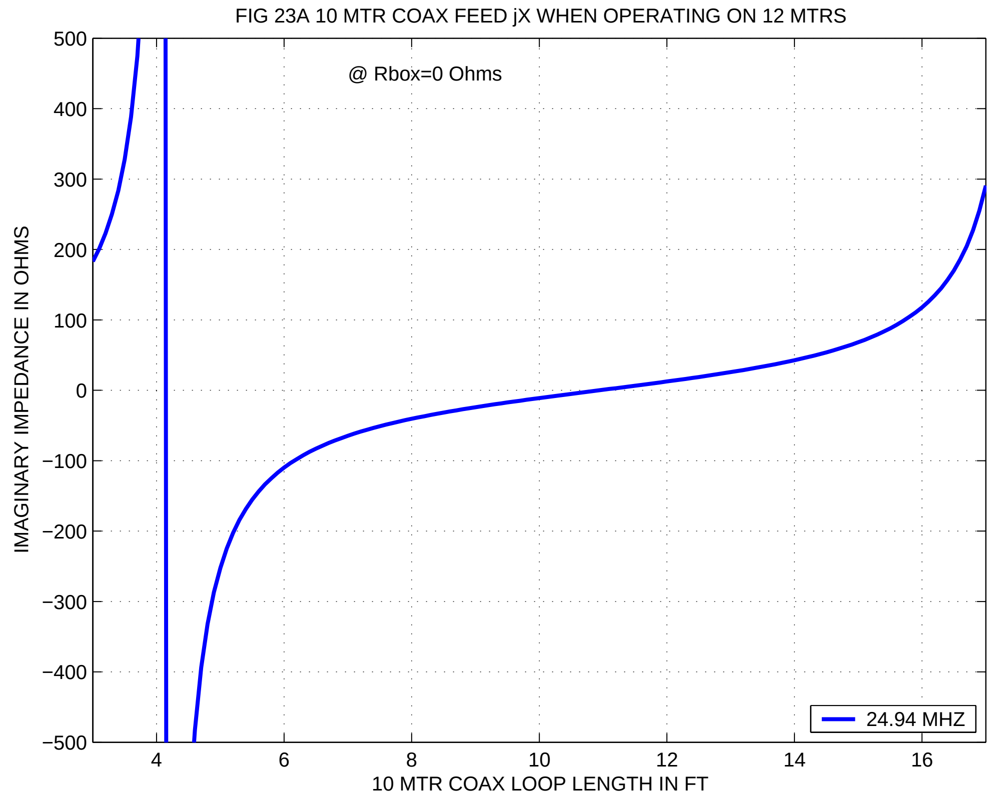


FIG 23A 10 MTR COAX FEED jX WHEN OPERATING ON 12 MTRS
@ Rbox=0 Ohms
24.94 MHZ
IMAGINARY IMPEDANCE IN OHMS
10 MTR COAX LOOP LENGTH IN FT
500
400
300
200
100
0
−100
−200
−300
−400
−500
4
6
8
10
12
14
16

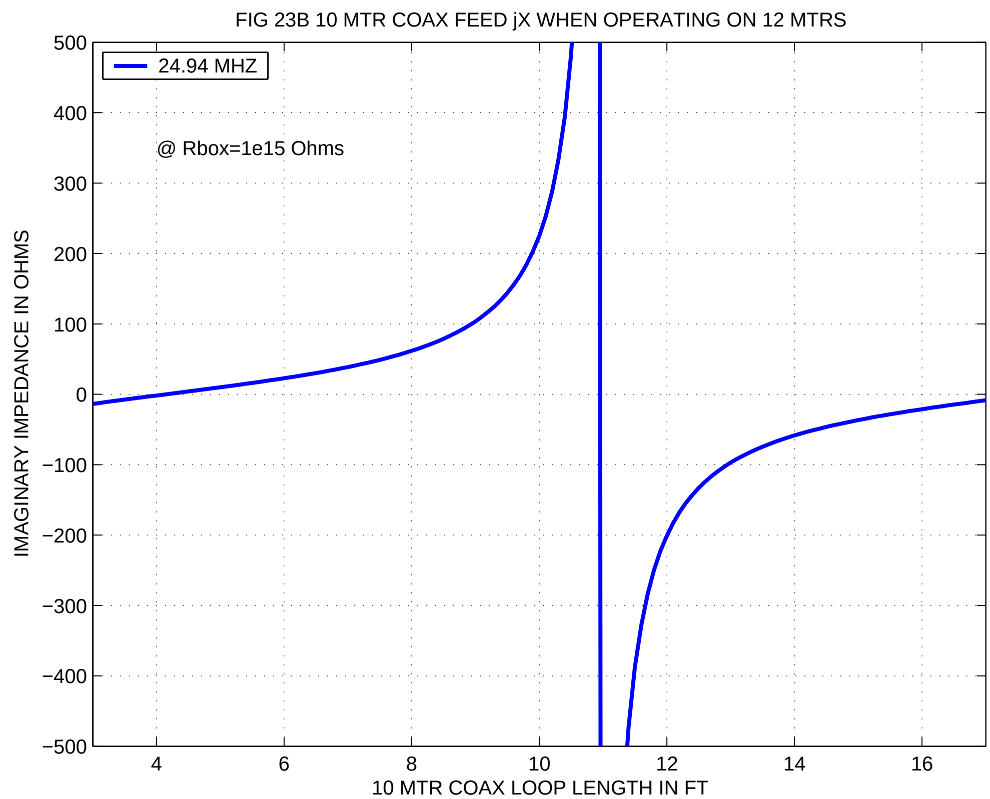


FIG 23B 10 MTR COAX FEED jX WHEN OPERATING ON 12 MTRS
24.94 MHZ
@ Rbox=1e15 Ohms
IMAGINARY IMPEDANCE IN OHMS
10 MTR COAX LOOP LENGTH IN FT
500
400
300
200
100
0
−100
−200
−300
−400
−500
4
6
8
10
12
14
16

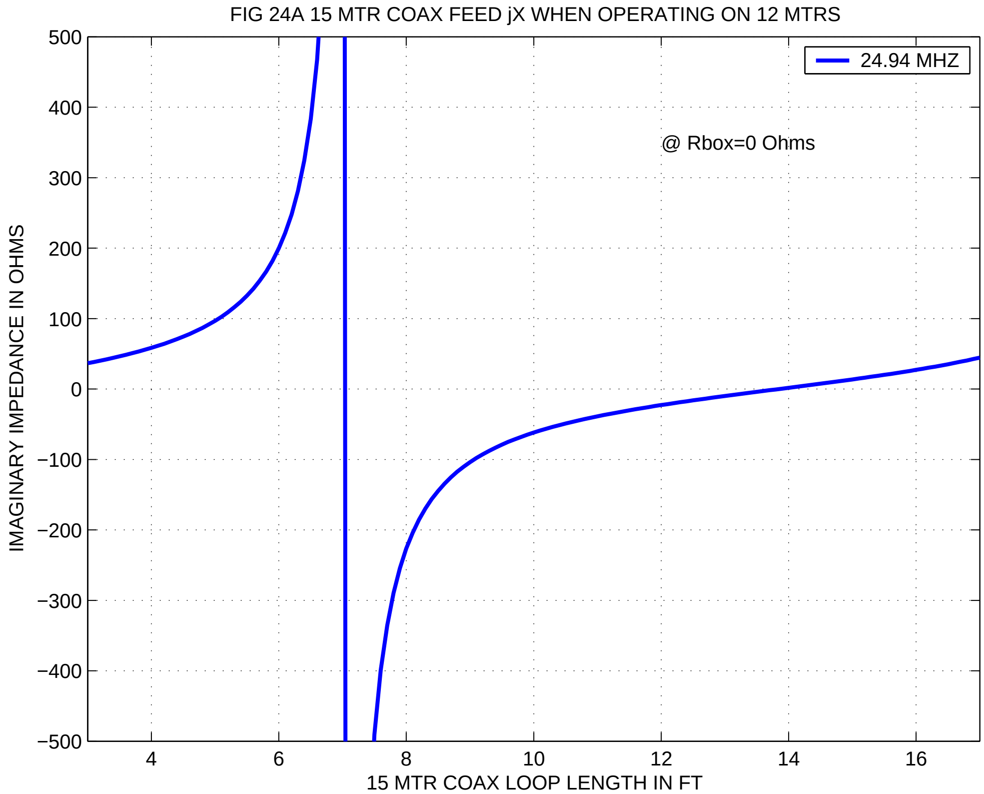


FIG 24A 15 MTR COAX FEED jX WHEN OPERATING ON 12 MTRS
24.94 MHZ
@ Rbox=0 Ohms
IMAGINARY IMPEDANCE IN OHMS
500
400
300
200
100
0
−100
−200
−300
−400
−500
4
6
8
10
12
14
16
15 MTR COAX LOOP LENGTH IN FT

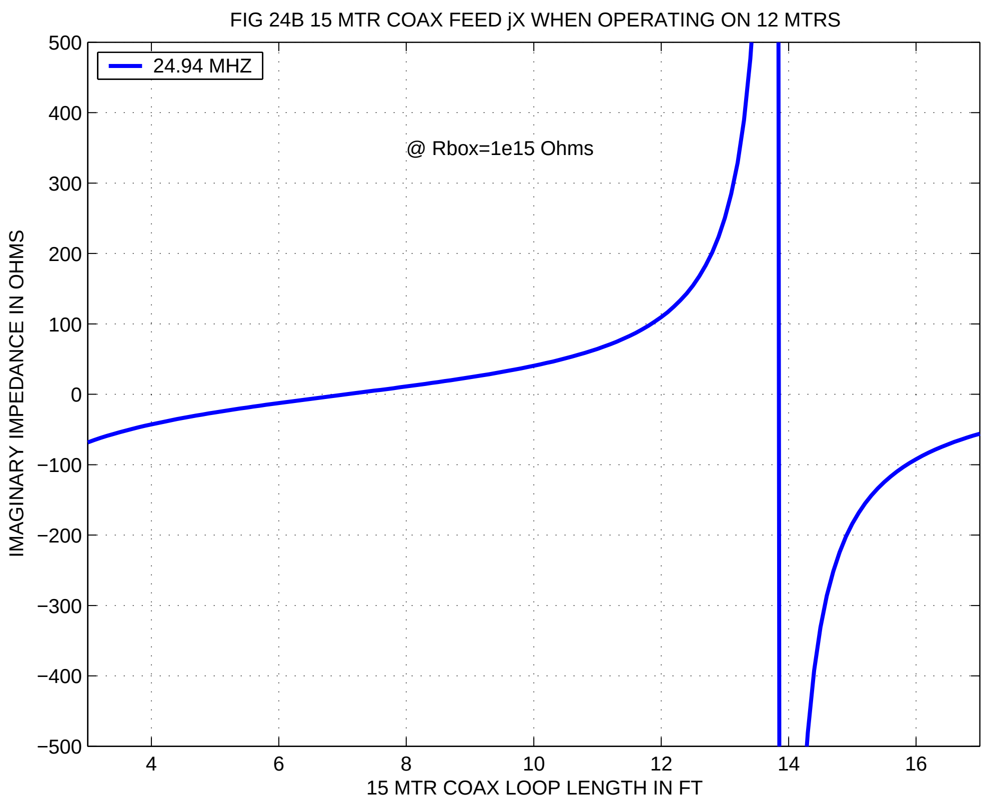


FIG 24B 15 MTR COAX FEED jX WHEN OPERATING ON 12 MTRS
24.94 MHZ
@ Rbox=1e15 Ohms
IMAGINARY IMPEDANCE IN OHMS
500
400
300
200
100
0
−100
−200
−300
−400
−500
4
6
8
10
12
14
16
15 MTR COAX LOOP LENGTH IN FT

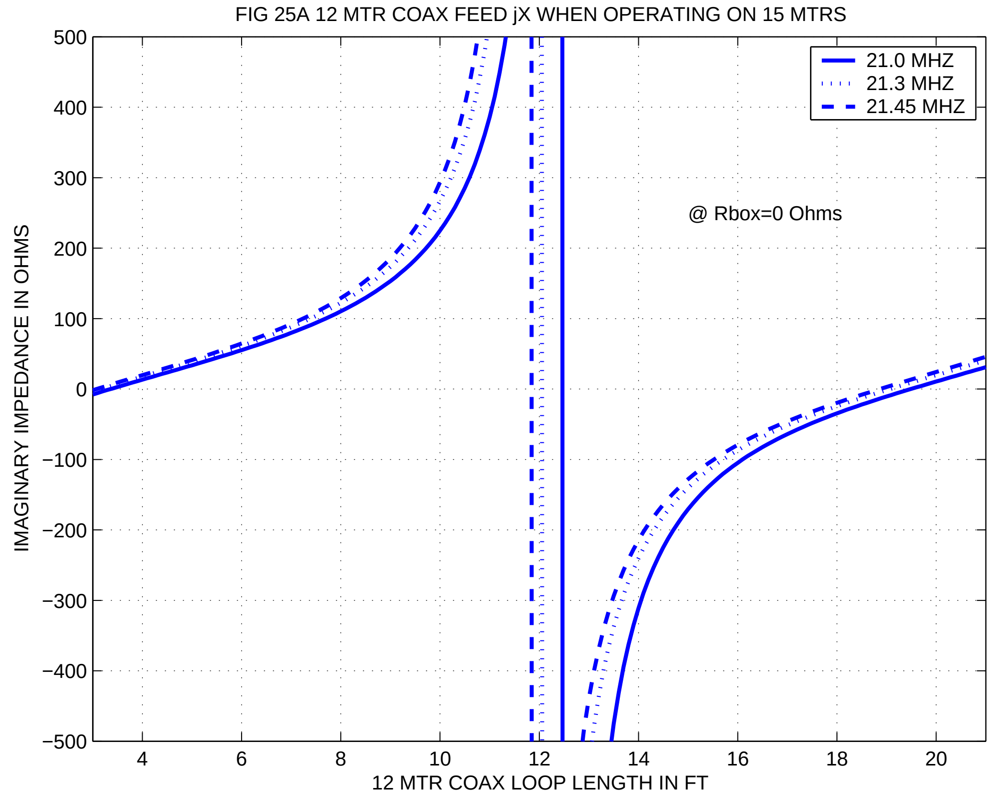


FIG 25A 12 MTR COAX FEED jX WHEN OPERATING ON 15 MTRS
21.0 MHZ
21.3 MHZ
21.45 MHZ
@ Rbox=0 Ohms
IMAGINARY IMPEDANCE IN OHMS
12 MTR COAX LOOP LENGTH IN FT
500
400
300
200
100
0
−100
−200
−300
−400
−500
4
6
8
10
12
14
16
18
20

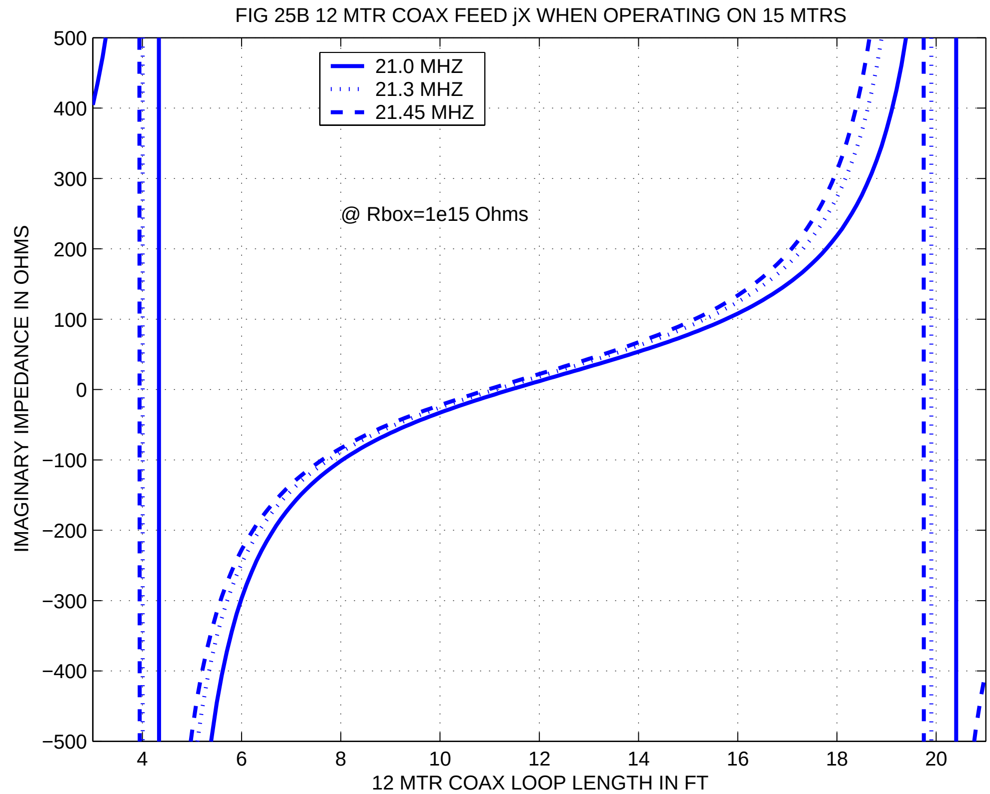


FIG 25B 12 MTR COAX FEED jX WHEN OPERATING ON 15 MTRS
21.0 MHZ
21.3 MHZ
21.45 MHZ
@ Rbox=1e15 Ohms
IMAGINARY IMPEDANCE IN OHMS
12 MTR COAX LOOP LENGTH IN FT
500
400
300
200
100
0
−100
−200
−300
−400
−500
4
6
8
10
12
14
16
18
20

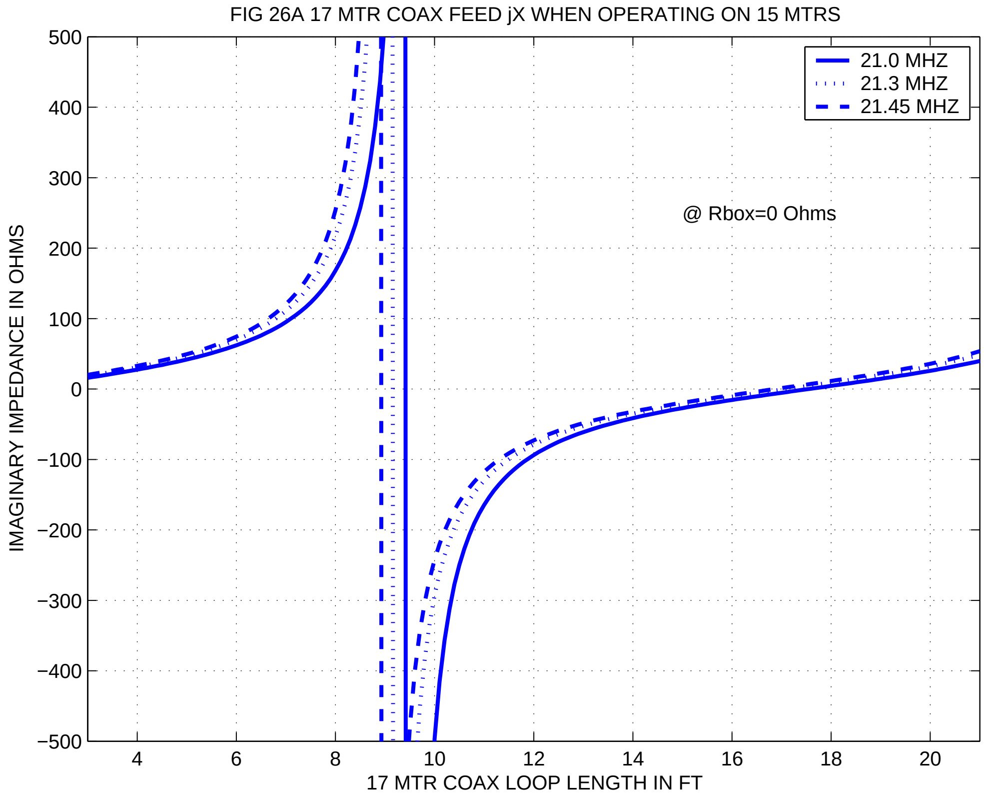


FIG 26A 17 MTR COAX FEED jX WHEN OPERATING ON 15 MTRS
IMAGINARY IMPEDANCE IN OHMS
17 MTR COAX LOOP LENGTH IN FT
21.0 MHZ
21.3 MHZ
21.45 MHZ
@ Rbox=0 Ohms
500
400
300
200
100
0
−100
−200
−300
−400
−500
4
6
8
10
12
14
16
18
20

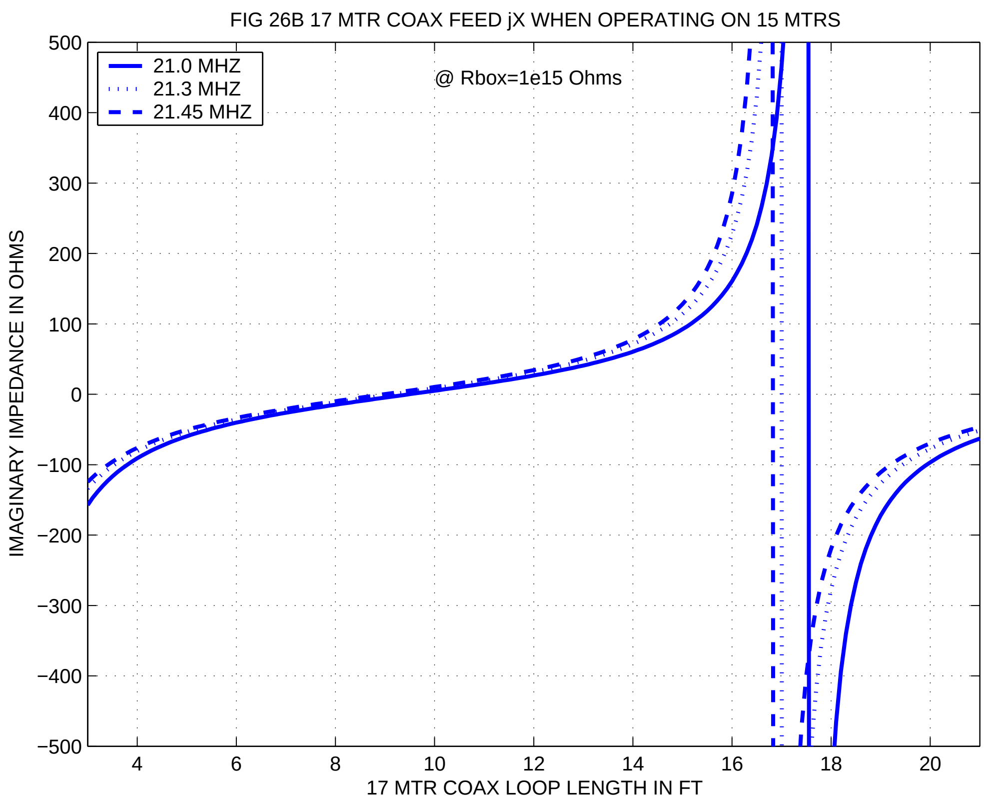


FIG 26B 17 MTR COAX FEED jX WHEN OPERATING ON 15 MTRS
IMAGINARY IMPEDANCE IN OHMS
17 MTR COAX LOOP LENGTH IN FT
21.0 MHZ
21.3 MHZ
21.45 MHZ
@ Rbox=1e15 Ohms
500
400
300
200
100
0
−100
−200
−300
−400
−500
4
6
8
10
12
14
16
18
20

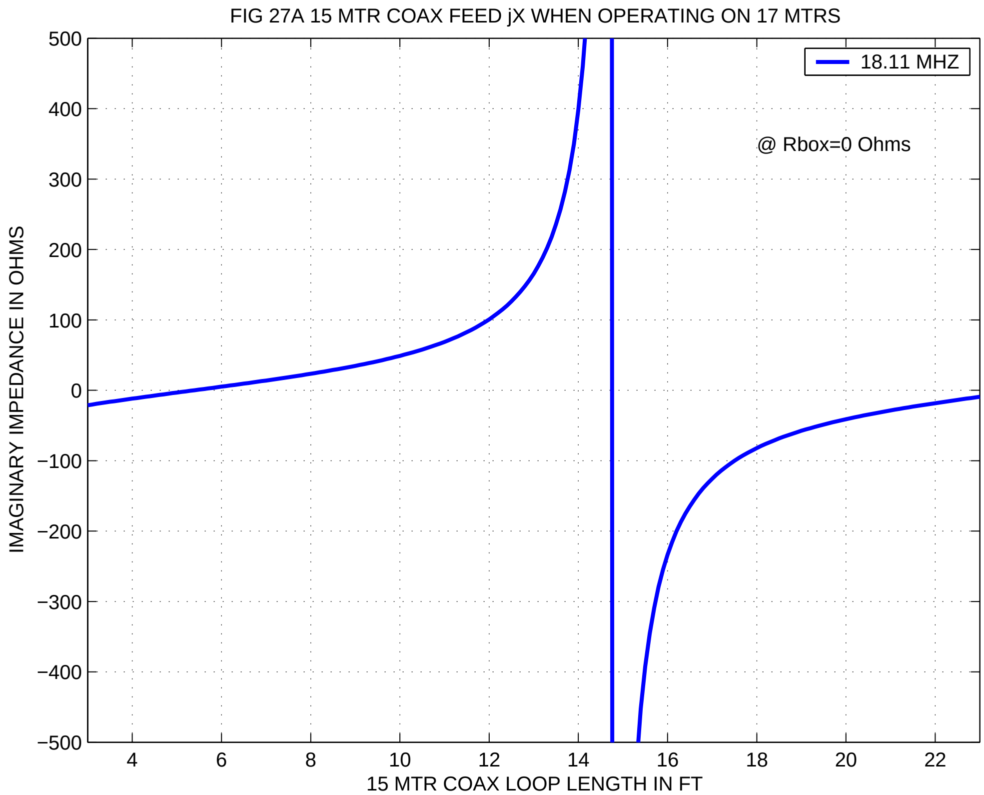


FIG 27A 15 MTR COAX FEED jX WHEN OPERATING ON 17 MTRS
18.11 MHZ
@ Rbox=0 Ohms
IMAGINARY IMPEDANCE IN OHMS
15 MTR COAX LOOP LENGTH IN FT
500
400
300
200
100
0
−100
−200
−300
−400
−500
4
6
8
10
12
14
16
18
20
22

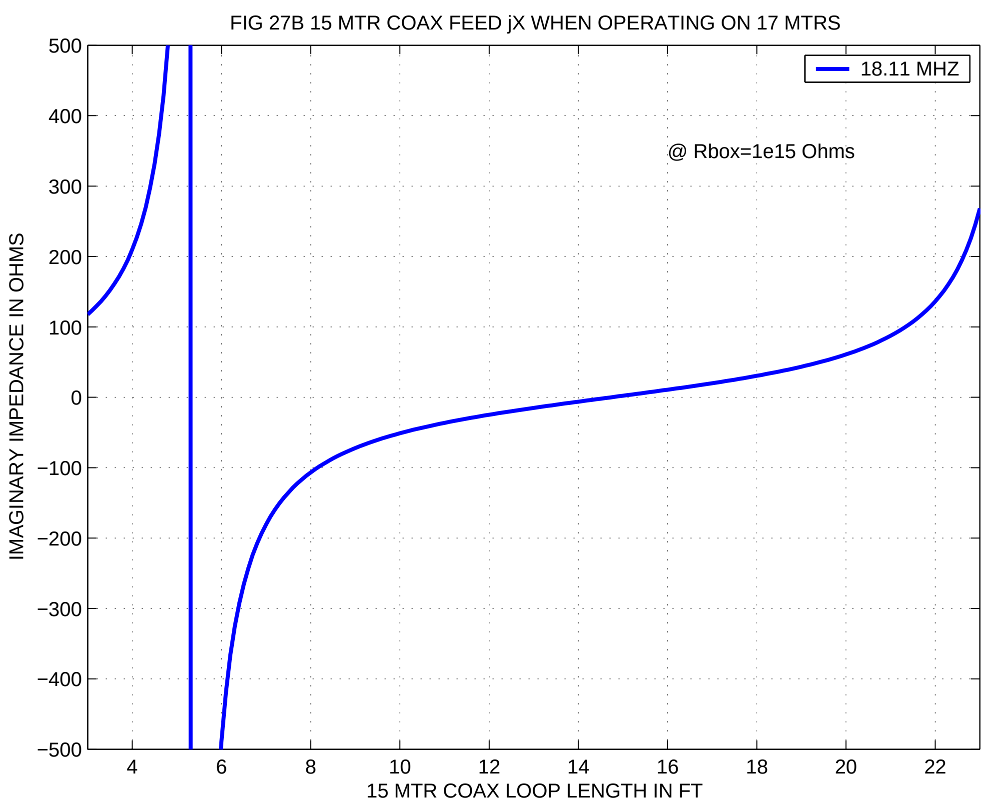


FIG 27B 15 MTR COAX FEED jX WHEN OPERATING ON 17 MTRS
18.11 MHZ
@ Rbox=1e15 Ohms
IMAGINARY IMPEDANCE IN OHMS
15 MTR COAX LOOP LENGTH IN FT
500
400
300
200
100
0
−100
−200
−300
−400
−500
4
6
8
10
12
14
16
18
20
22

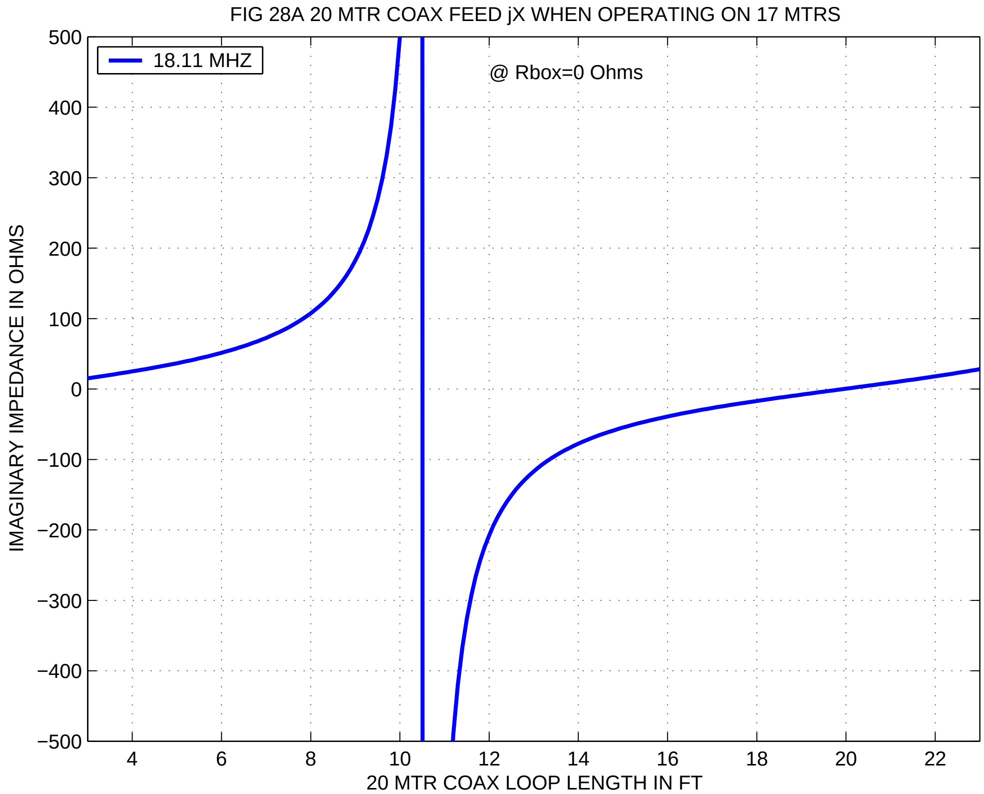


FIG 28A 20 MTR COAX FEED jX WHEN OPERATING ON 17 MTRS
18.11 MHZ
@ Rbox=0 Ohms
IMAGINARY IMPEDANCE IN OHMS
20 MTR COAX LOOP LENGTH IN FT
500
400
300
200
100
0
−100
−200
−300
−400
−500
4
6
8
10
12
14
16
18
20
22

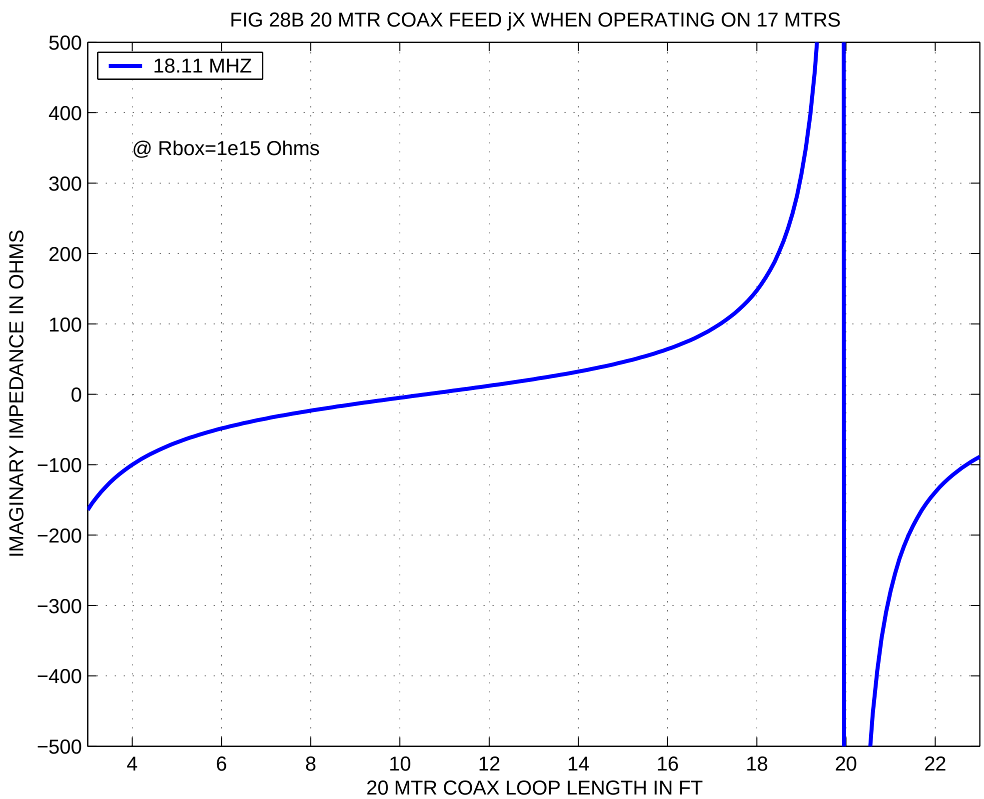


FIG 28B 20 MTR COAX FEED jX WHEN OPERATING ON 17 MTRS
18.11 MHZ
@ Rbox=1e15 Ohms
IMAGINARY IMPEDANCE IN OHMS
20 MTR COAX LOOP LENGTH IN FT
500
400
300
200
100
0
−100
−200
−300
−400
−500
4
6
8
10
12
14
16
18
20
22

FIG 29A 17 MTR COAX FEED jX WHEN OPERATING ON 20 MTRS

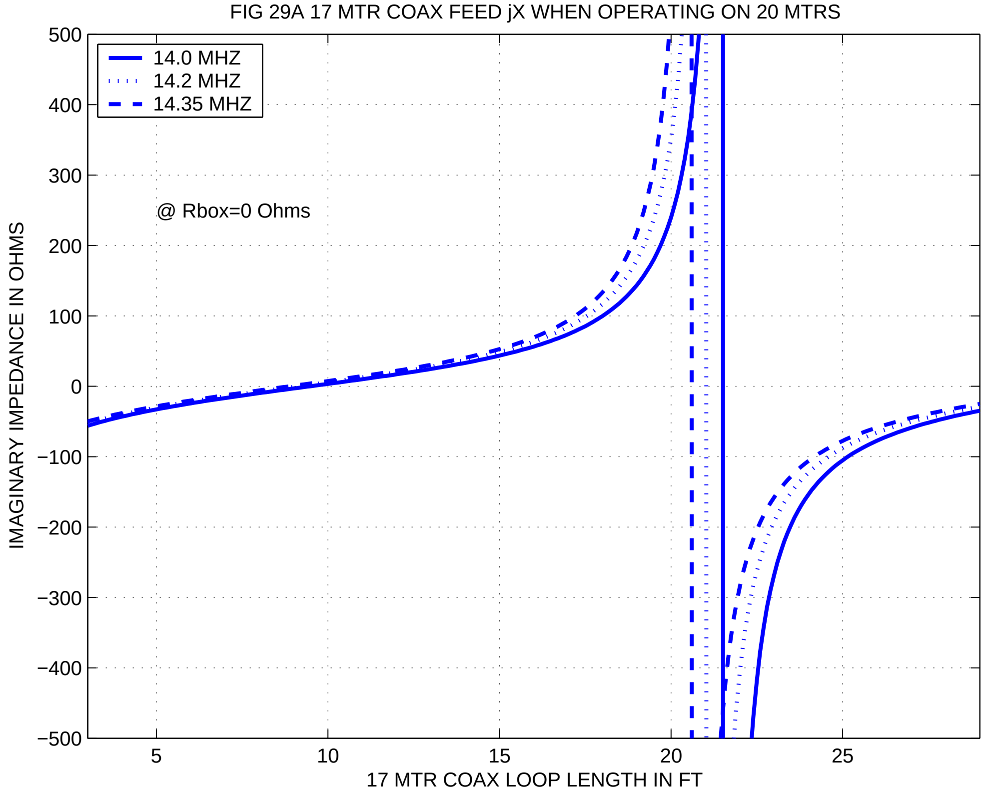
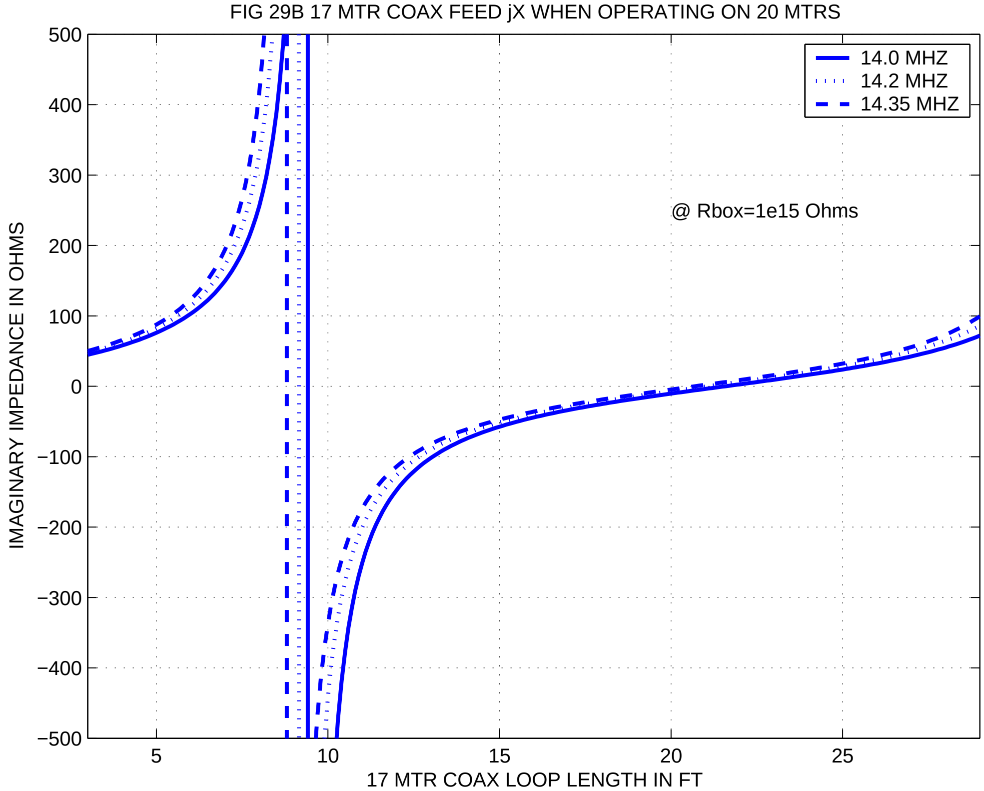


FIG 29B 17 MTR COAX FEED jX WHEN OPERATING ON 20 MTRS



MATLAB PROGRAM zterm.m LISTING

```
% M-file zterm.m
% Program computes coaxial feed line termination impedances of non driven
%  driven elements for a five band (20 17 15 12 10 MTR Bands) cubical quad
%  antenna with a diamond configuration.
clear all
format short
F=[14.174 18.118 21.224 24.94 28.4]'; % Per band impedance evaluation frequencies
(Mhz)
lambda=983.5712./F; % Free space wavelegth in feet @ F
%
Rq=75; % RG11A/U coax Q match line Zo in Ohms
Cq=20.5; % RG11A/U coax Q match line capacitance per unit length (pf/FT)
vfq=1016/(Rq*Cq); % Velocity factor of Q section RG11A/U coax line
lambdaq=lambda*vfq; % One wave length on Q match line in feet @ F
%
Ro=50; % RG213U coax feed line Zo value in Ohms
Co=29.5; % RG213U coax capacitance per unit length (pf/FT)
vfo=1016/(Ro*Co); % Velocity factor of RG213U feed line
lambdao=lambda*vfo; % One wave length on RG213U feed line in feet @ F
%
de=[70.5072 54.9336 47.0257 40.0448 35.1857]'; % Driven element loop lengths in feet
Larm=de/(4*sqrt(2)); % Driven element quad arm lengths in feet. For a diamond quad
this
%                   is the feed line length to the boom
Lboom=[5 5 5 5 10]'; % Boom feed line lengths in feet to mast
Lloop=[3 3 3 3 3]'; % Feed line loop lengths from mast to switch box
Lq=[0 0 0 6.5152 0]'; % Length of Q section line in feet (Only 12 MTR band Q section)
L213=Larm+Lboom+Lloop-Lq; % Length of RG213U feed line in feet to switch box
%
Rbox=zeros(5,1); % @ Switch box short on non driven coax feeds
%Rbox=1e10*ones(5,1); % @ Switch box open on non driven coax lines
%
zall=zeros(5,5);
for b=1:5
for nb=1:5
thetaq=2*pi*Lq(nb)/lambdaq(b); % Q section line phase shifts in radians
gammaxq=j*thetaq; % Q match cable low loss approximation
theta213=2*pi*L213(nb)/lambdao(b); % RG213U line phase shifts in radians
gammax213=j*theta213; % RG213U cable low loss approximation
Rb=Rbox(nb);
% z213 is impedance looking into RG213U coax terminated by switch box on
%     other end
```

```
z213=Ro*(Rb.*cosh(gammax213)+Ro*sinh(gammax213))./(Ro*cosh(gammax213)+Rb.
*sinh(gammax213));
% z is impedance looking back into coax line at antenna feed point
z=Rq*(z213.*cosh(gammaxq)+Rq*sinh(gammaxq))./(Rq*cosh(gammaxq)+z213.*sinh(g
ammaxq));
if b==nb
   z=0;
end
zall(b,nb)=z;
end
end
ba=[20 17 15 12 10]';
zz=imag(zall);
disp(' ')
disp('TABLE 2 FIVE BAND CUBICAL QUAD DRIVEN ELEMENT COAXIAL FEED
TERMINATION IMPEDANCES')
disp(' ')
disp(['@ SWITCH BOX IMPEDANCE FOR NON DRIVEN BANDS IN
OHMS=',num2str(Rbox(1,1))])
disp(' ')
disp('DRIVEN     NON DRIVEN BAND IMAGINARY TERMINATION
IMPEDANCES IN OHMS')
disp(' BAND      20         17         15         12         10')
disp(' ')
for i=1:5
fprintf(1,'%5.0f %10.2f %10.2f %10.2f %10.2f %10.2f\n',ba(i,1),zz(i,:));
end
disp(' ')
```

MATLAB PROGRAM quadmod4A.m LISTING

```
% M-file quadmod4A.m
% MATLAB program designed to create an exportable wire table for the EZNEC 4.0 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 7/4/2004  (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.
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.
% 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 500 wire
%       segment limit of EZNEC 3.0 ($100 cost) 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. (Or use EZNEC 4.0 version with 1,500 wire
%       segment modeling limit).
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=994.84804; % 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=998.31811; % 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=1001.0343; % 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 %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:\MARLAB6p5\work\qallw
% 8.) Double click file "qallw"
% 9.) Click "Other" button
% 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 quad4A.m LISTING

```
% M-file quad4A.m
% Five band quad configuration 04A EZNEC 4.0 output data files
% Based on quadmod4A.m runs made 7-4-2004
% EZNEC antenna files QA20.EZ, QA17.EZ, QA15.EZ, QA12.EZ, QA10.EZ
% Five band quad is 20,17,15,12,10 MTR bands
% #12 copper wire elements
% Antenna at 55 foot above ground
% Unused driven elements shorted
global ant4A theta DPLdBi
% 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 z prefixed 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.
% Column 5=Real part of driving point impedance in Ohms
% Column 6=Imaginary part of driving point impedance in Ohms
```

```
% 20 MTR FIVE BAND QUAD FOLLOWS
z20=[13.8000 12.86 5.75 5.75   16.0681  -89.0620
   13.8250 13.21  7.17  7.17   16.7372  -81.5394
   13.8500 13.51  8.78  8.78   17.6535  -74.0429
   13.8750 13.74 10.63 10.63   18.8435  -66.5206
   13.9000 13.91 12.81 12.81   20.3131  -59.0815
   13.9250 14.04 15.47 15.47   22.0635  -51.7301
   13.9500 14.11 18.83 18.83   24.0757  -44.5428
   13.9750 14.15 23.12 21.68   26.3438  -37.5560
   14.0000 14.15 26.04 20.44   28.8331  -30.8104
   14.0250 14.13 23.25 19.11   31.5022  -24.2988
   14.0500 14.09 19.74 17.76   34.3486  -18.1197
   14.0750 14.04 17.15 16.43   37.3160  -12.2493
   14.1000 13.98 15.24 15.14   40.3685   -6.6975
   14.1250 13.91 13.77 13.77   43.5053   -1.5114
   14.1500 13.84 12.62 12.62   46.6986    3.2711
   14.1750 13.78 11.72 11.72   49.9062    7.6009
   14.2000 13.71 11.00 11.00   53.1213   11.4217
   14.2250 13.65 10.45 10.45   56.2890   14.5742
   14.2500 13.61 10.07 10.07   59.2542   16.9039
   14.2750 13.57  9.86  9.86   61.8117   18.1424
   14.3000 13.55  9.87  9.87   63.4578   18.0774
   14.3250 13.55 10.16 10.16   63.3280   16.5766
   14.3500 13.56 10.90 10.74   60.0579   14.0865
   14.3750 13.57 12.45 11.61   52.1226   12.4202
   14.4000 13.52 15.45 12.80   39.6578   15.1125
   14.4250 13.13 15.70 14.02   26.2897   25.2695
   14.4500 11.65  6.75  6.75   17.1588   41.6861];
```

```
% 17 MTR FIVE BAND QUAD FOLLOWS
z17=[17.8500 14.41 11.35 11.35   32.2766  -42.0277
   17.8750 14.47 12.72 12.72   34.3740  -36.7884
   17.9000 14.51 14.20 14.20   36.6764  -31.7624
   17.9250 14.53 15.81 15.81   39.1867  -27.0182
   17.9500 14.53 17.49 17.49   41.8677  -22.5105
   17.9750 14.51 19.10 19.10   44.7158  -18.3419
   18.0000 14.49 20.28 18.67   47.6355  -14.5316
   18.0250 14.46 20.68 17.72   50.6330  -11.1489
   18.0500 14.42 20.23 16.85   53.6294   -8.1258
   18.0750 14.38 19.27 16.06   56.5628   -5.5827
   18.1000 14.34 18.18 15.33   59.3688   -3.4878
   18.1250 14.30 17.14 14.67   61.9845   -1.8709
   18.1500 14.26 16.24 14.09   64.2913   -0.7185
   18.1750 14.22 15.50 13.58   66.2088    0.0026
   18.2000 14.19 14.91 13.15   67.6218    0.2945
   18.2250 14.16 14.46 12.79   68.4108    0.1659
   18.2500 14.15 14.19 12.52   68.4210   -0.2003
   18.2750 14.14 14.08 12.34   67.4923   -0.8241
   18.3000 14.15 14.15 12.25   65.5006   -1.4219
   18.3250 14.17 14.46 12.28   62.2797   -1.6887
   18.3500 14.21 14.99 12.43   57.8142   -1.3223
   18.3750 14.26 15.79 12.72   52.0737    0.1499
   18.4000 14.30 16.53 13.18   45.3639    3.2157
   18.4250 14.33 16.23 13.80   38.1749    8.3694
   18.4500 14.26 13.78 13.78   31.1778   15.8880
   18.4750 13.98  9.99  9.99   25.2231   25.6577
   18.5000 13.28  6.01  6.01   21.1695   37.1811
   18.5250 11.85  2.04  2.04   19.4128   49.9243];
```

```
% 15 MTR FIVE BAND QUAD FOLLOWS
z15=[20.6500 13.10 4.42 4.42   36.5206  -75.2557
   20.6750 13.27  4.97  4.97   36.7512  -70.4381
   20.7000 13.44  5.55  5.55   37.1270  -65.6118
   20.7250 13.59  6.16  6.16   37.6453  -60.8427
   20.7500 13.73  6.80  6.80   38.3161  -56.0653
   20.7750 13.86  7.47  7.47   39.1531  -51.3821
   20.8000 13.96  8.17  8.17   40.1195  -46.7425
   20.8250 14.06  8.91  8.91   41.2428  -42.1832
   20.8500 14.14  9.68  9.68   42.5211  -37.7582
   20.8750 14.21 10.49 10.49   43.9319  -33.4093
   20.9000 14.27 11.34 11.34   45.4870  -29.2396
   20.9250 14.31 12.24 12.24   47.1830  -25.1754
   20.9500 14.35 13.18 13.18   49.0190  -21.3081
   20.9750 14.38 14.15 14.15   50.9536  -17.6062
   21.0000 14.40 15.18 15.18   53.0271  -14.1373
   21.0250 14.41 16.22 16.22   55.1673  -10.8828
   21.0500 14.42 17.27 17.27   57.3947   -7.8864
   21.0750 14.42 18.32 18.28   59.6650   -5.1985
   21.1000 14.42 19.30 17.64   61.9453   -2.8096
   21.1250 14.42 20.16 17.06   64.2040   -0.6965
   21.1500 14.42 20.86 16.52   66.4106    0.9846
   21.1750 14.42 21.34 16.05   68.4675    2.3341
   21.2000 14.42 21.60 15.63   70.3730    3.2647
   21.2250 14.42 21.70 15.25   71.9791    3.8160
   21.2500 14.42 21.70 14.94   73.2304    3.9781
   21.2750 14.43 21.65 14.67   74.0003    3.7106
   21.3000 14.44 21.63 14.46   74.1966    3.2341
   21.3250 14.46 21.67 14.31   73.6821    2.4525
   21.3500 14.49 21.77 14.22   72.3561    1.6607
   21.3750 14.53 21.88 14.20   70.0831    0.9039
   21.4000 14.57 21.92 14.26   66.8933    0.5116
   21.4250 14.63 21.63 14.41   62.6996    0.7124
   21.4500 14.69 20.74 14.66   57.7135    1.7820
   21.4750 14.75 19.15 15.02   52.0753    3.9623
   21.5000 14.80 16.98 15.52   45.9489    7.5445
   21.5250 14.82 14.60 14.60   39.9335   12.5447
   21.5500 14.79 12.12 12.12   34.2211   19.1003
   21.5750 14.65  9.68  9.68   29.3451   26.8929
   21.6000 14.33  7.28  7.28   25.4911   35.8369
   21.6250 13.74  4.93  4.93   22.9495   45.5617
   21.6500 12.80  2.62  2.62   21.8098   55.7154];
```

```
% 12 MTR FIVE BAND QUAD FOLLOWS
z12=[24.4000 13.44 6.17 6.17   51.9665  -50.0481
   24.4250 13.55  6.63  6.63   52.9518  -46.1811
   24.4500 13.64  7.10  7.10   54.0515  -42.3968
   24.4750 13.73  7.60  7.60   55.2976  -38.6995
   24.5000 13.81  8.12  8.12   56.7049  -35.0807
   24.5250 13.89  8.66  8.66   58.2262  -31.5975
   24.5500 13.96  9.23  9.23   59.8942  -28.2434
   24.5750 14.02  9.85  9.85   61.7387  -25.0630
   24.6000 14.07 10.49 10.49   63.6702  -22.0474
   24.6250 14.12 11.17 11.17   65.7036  -19.2512
   24.6500 14.17 11.89 11.89   67.8291  -16.7011
   24.6750 14.21 12.68 12.68   70.0653  -14.3931
   24.7000 14.24 13.51 13.51   72.3023  -12.3739
   24.7250 14.28 14.41 14.41   74.5447  -10.6524
   24.7500 14.30 15.42 15.42   76.7646   -9.2958
   24.7750 14.33 16.53 16.53   78.8863   -8.2641
   24.8000 14.36 17.76 17.76   80.8070   -7.6180
   24.8250 14.38 19.16 18.16   82.5095   -7.2544
   24.8500 14.41 20.78 17.78   83.9219   -7.2614
   24.8750 14.43 22.70 17.44   84.9509   -7.5041
   24.9000 14.46 24.98 17.14   85.5249   -7.9960
   24.9250 14.49 27.61 16.89   85.5819   -8.6745
   24.9500 14.52 29.80 16.68   85.1200   -9.3810
   24.9750 14.55 29.57 16.53   84.0181  -10.0072
   25.0000 14.59 27.10 16.43   82.3479  -10.4767
   25.0250 14.64 24.40 16.38   80.0993  -10.6287
   25.0500 14.69 21.99 16.39   77.3040  -10.4132
   25.0750 14.75 19.94 16.46   74.0933   -9.6398
   25.1000 14.81 18.15 16.60   70.4646   -8.2462
   25.1250 14.87 16.53 16.53   66.6556   -6.1419
   25.1500 14.93 15.01 15.01   62.6689   -3.3081
   25.1750 14.98 13.57 13.57   58.6746    0.3305
   25.2000 15.02 12.18 12.18   54.8416    4.8038
   25.2250 15.04 10.82 10.82   51.2862   10.1133
   25.2500 15.01  9.49  9.49   48.1936   16.2239
   25.2750 14.92  8.16  8.16   45.7206   23.0578
   25.3000 14.74  6.83  6.83   44.0403   30.5952
   25.3250 14.45  5.51  5.51   43.3016   38.6750
   25.3500 14.03  4.20  4.20   43.7305   47.1221
   25.3750 13.44  2.89  2.89   45.4414   55.8035];
```

```
% 10 MTR FIVE BAND QUAD FOLLOWS
z10=[27.9000 13.24 4.26 4.26   37.5722  -71.3994
   27.9250 13.43  4.81  4.81   38.5126  -67.7133
   27.9500 13.62  5.36  5.36   39.5084  -64.1439
   27.9750 13.79  5.94  5.94   40.5350  -60.6835
   28.0000 13.96  6.53  6.53   41.6104  -57.3613
   28.0250 14.12  7.14  7.14   42.6919  -54.1566
   28.0500 14.27  7.77  7.77   43.7320  -51.1180
   28.0750 14.42  8.42  8.42   44.7377  -48.2281
   28.1000 14.55  9.09  9.09   45.7138  -45.3882
   28.1250 14.69  9.80  9.80   46.6259  -42.6989
   28.1500 14.81 10.53 10.53   47.4264  -40.1194
   28.1750 14.93 11.31 11.31   48.1535  -37.5896
   28.2000 15.05 12.13 12.13   48.7662  -35.0911
   28.2250 15.16 12.98 12.98   49.2329  -32.6413
   28.2500 15.27 13.90 13.90   49.5907  -30.1903
   28.2750 15.37 14.89 14.89   49.8229  -27.7188
   28.3000 15.47 15.95 15.95   49.9869  -25.1609
   28.3250 15.57 17.12 17.12   50.0234  -22.5913
   28.3500 15.66 18.40 18.40   50.0644  -19.8526
   28.3750 15.75 19.85 19.81   49.9973  -17.0404
   28.4000 15.84 21.51 20.51   49.9504  -14.0663
   28.4250 15.92 23.44 20.99   49.8998  -10.9825
   28.4500 15.99 25.78 21.30   49.9140   -7.7213
   28.4750 16.07 28.71 21.45   49.9970   -4.3175
   28.5000 16.14 32.45 21.48   50.2377   -0.7417
   28.5250 16.21 35.89 21.39   50.5656    2.8973
   28.5500 16.27 34.33 21.23   51.1635    6.7232
   28.5750 16.33 30.70 21.00   51.9946   10.7063
   28.6000 16.38 27.84 20.74   53.1819   14.7828
   28.6250 16.43 25.63 20.43   54.6945   18.9171
   28.6500 16.48 23.90 20.12   56.7369   23.1199
   28.6750 16.52 22.48 19.79   59.4081   27.3266
   28.7000 16.56 21.29 19.46   62.7979   31.3662
   28.7250 16.59 20.25 19.14   66.9998   35.1108
   28.7500 16.61 19.30 18.83   72.4118   38.2909
   28.7750 16.63 18.44 18.44   79.1115   40.3828
   28.8000 16.64 17.61 17.61   87.2630   40.7994
   28.8250 16.64 16.80 16.80   96.4391   38.2248
   28.8500 16.63 15.99 15.99  105.8638   31.1847
   28.8750 16.61 15.16 15.16  112.7576   18.7097
   28.9000 16.57 14.26 14.26  113.5873    1.6551
   28.9250 16.50 13.33 13.33  104.9480  -15.8009
```

```
  28.9500 16.40 12.30 12.30   88.0287  -27.7305
  28.9750 16.26 11.22 11.22   68.1808  -30.7473
  29.0000 16.06 10.06 10.06   50.4597  -26.3936
  29.0250 15.80  8.85  8.85   37.0013  -18.0800
  29.0500 15.45  7.56  7.56   27.1860   -8.0003
  29.0750 14.99  6.22  6.22   20.4908    2.2348
  29.1000 14.40  4.83  4.83   15.9008   12.1090
  29.1250 13.67  3.40  3.40   12.8376   21.1260
  29.1500 12.77  1.90  1.90   10.7523   29.6118
  29.1750 11.71  0.37  0.37    9.3655   37.4433];
%
%
ant4A1=cell(1,5);
ant4A1={z20 z17 z15 z12 z10};
ant4A=cell(1,5);
for i=1:5
   ant1=ant4A1{i};
   f=ant1(:,1);
   ff=(min(f):.001:max(f))';
   ant2=zeros(length(ff),6);
   ant2(:,1)=ff;
   for k=2:6
      m=ant1(:,k);
      ant2(:,k)=spline(f,m,ff);
   end
   ant4A{i}=ant2;
   end
% Cell matrix output ant4A is same as z prefix data but in 1 Khz frequency steps
% Column 1= Frequency in MHZ (in .001 Mhz steps)
% 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.
% Column 5=Real part of driving point impedance in Ohms
% Column 6=Imaginary part of driving point impedance in Ohms
```

MATLAB PROGRAM quad4Abb.m LISTING

```
% M-file quad4Abb.m
global ant4A theta DPLdBi
global f z    % inputs
global swrq swr52  % outputs
quad4A % MATLAB program souce for 5 array data matrices
names=['20 MTR 4EL FIVE BAND QUAD';  % 1 array ID numbers
      '17 MTR 4EL FIVE BAND QUAD';  % 2
      '15 MTR 4EL FIVE BAND QUAD';  % 3
      '12 MTR 4EL FIVE BAND QUAD';  % 4
      '10 MTR 5EL FIVE BAND QUAD']; % 5
%
plots=['  GAIN, FB, AND FBR PLOTS';
        '  SWR PLOT               '];
fmin=[13.8 17.9 20.7 24.4 27.9]; % plot min freqs
fmax=[14.5 18.6 21.7 25.4 29.2]; % plot max freq
%
for i=1:5
   q=ant4A{i}; % Select i th of 5 antenna data matrices
   f=q(:,1); % Frequency in MHZ
   gain=q(:,2); % gain in dBi
   fb=q(:,3); % FB in dB
   fbr=q(:,4); % FBR in dB (Front to Back Region)
   real=q(:,5);
   imag=q(:,6);
   z=real+j*imag; % Complex antenna driving point impedance
   swrQ % SWR subroutine
   %rho52=(z-52)./(z+52);
   %swr52=(1+abs(rho52))./(1-abs(rho52));
   swr52=swr52;
   swrQ75=swrq;
   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)
   %if i~=4
   plot(f,10*swr52,':','LineWidth',2)
   if i==4
   plot(f,10*swrQ75,'.','LineWidth',1)
   end
   grid
```

```
   axis([fmin(i) fmax(i) 10 25])
   set(gca,'ytick',[10:1:25])
   set(gca,'xtick',[fmin(i):.1:fmax(i)])
   hold off
   if i~=4
   legend('GAIN dBi','FB dB','FBR dB','10*SWR52',1)
   else
   legend('GAIN dBi','FB dB','FBR dB','10*SWR52','10*SWRQ75',1)
   end
   xlabel('FREQ MHZ')
   ylabel('GAIN, FB, FBR, 10*SWR52')
   title(['FIG  ',num2str(i+14),'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)
      axis([fmin(i) fmax(i) -100 100])
      set(gca,'ytick',[-100:10:100])
      set(gca,'xtick',[fmin(i):.1:fmax(i)])
      grid
      hold off
      legend('REAL PART','IMAGINARY PART',1)
      xlabel('FREQ MHZ')
      ylabel('OHMS')
      title(['FIG  ',num2str(i+14),'B  ',names(i,:),'  REAL AND IMAGINARY
IMPEDANCE PLOTS'])
      %print
      fig
      keyboard
   end

end
%
```

MATLAB PROGRAM swrQ.m LISTING
(This is a SWR subroutine for a quarter wave Q section match or straight 52 coax feed.)

```
% M-file swrQ.m
% Computes SWR "swrq" versus frequency for a quarter wave Q match.
% Program as coded uses a 75 Ohm RG11 coax Q section followed by
%   any length of 52 Ohm coax.
% Program can be set for other Q section line types by changing Rq and
%   Cprime (and computed velocity factor "vf") to values for the line type.
% Program also computes SWR "swr52" for a 52 Ohm coax feed without the Q
%   section.
format short
global f  z    % inputs
global swrq  swr52  % outputs
% f=column matrix of Mhz frequencies
% z=column matrix of complex antenna driving point impedances (Ohms)
Rq=75; % Q match line Zo value in Ohms (For RG11 coax it is 75 Ohms)
Cprime=20.5; % Q match line capacitance per foot in pf/FT units
%            (For RG11 coax it is 20.5 pF/FT)
vf=1016/(Rq*Cprime); % Velocity factor of Q section line
Fdmat=[14.174 18.118 21.224 24.94 28.4]; % Q section design frequencies
fm=mean(f); % mean of input frequencies (Mhz)
for b=1:5 % Auto detect Q section design frequency loop
   if abs(fm-Fdmat(b))<1.5
      Fd=Fdmat(b);
   end
end
lambdaQ=vf*983.5712/Fd; % One wavelength on Q section line in feet @ Fd Mhz
xQ=0.25*lambdaQ; % Length of quarter wave Q section in FT for @ Fd
lambda=vf*983.5712./f; % One wavelength on Q section line in feet @ f Mhz
theta=2*pi*xQ./lambda; % Q section line length in radians of phase shift @ f Mhz
gammax=j*theta;
% z1=complex impedance looking into Q section input port (Ohms)
z1=Rq*(z.*cosh(gammax)+Rq*sinh(gammax))./(Rq*cosh(gammax)+z.*sinh(gammax));
R52=52; % swrq @ 52 Ohm coax of any length after quarter wave Q section
rhoq=(z1-R52)./(z1+R52); % Reflection coefficient on 52 Ohm coax line with Q section
swrq=(1+abs(rhoq))./(1-abs(rhoq));
rho52=(z-R52)./(z+R52); % Reflection coefficient on 52 Ohm coax line without Q
section
swr52=(1+abs(rho52))./(1-abs(rho52)); % swr52 without Q section match
%
disp(' ')
disp('Quarter Wave Q Section Made Of RG11 Coax')
disp(' ')
disp('   Zo Ohms   Design F  L in FT  L in Inch')
```

```
disp([Rq Fd xQ 12*xQ])
disp(' ')
```

MATLAB PROGRAM fig.m LISTING
(Used to export MATLAB figures to a MS Word document)

```
% 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
```

Note: MATLAB programs, quadmod4A.m, quad4A.m, and quad4Ab.m.
EZNEC antenna models QA20.EZ, QA17.EZ, QA15.EZ, QA12.EZ, and QA10.EZ used in article results.

MATLAB Programs for Generating Figures 22A to 29A and 22B to 29B Follow

```
% M-file zterm22.m
% Subroutine for Q10a12s.m , Q10a12o.m etc
% Program computes coaxial feed line termination impedances of non driven
%  driven elements for a five band (20 17 15 12 10 MTR Bands) cubical quad
%  antenna with a diamond configuration.
%clear all
global Lloop zz F Rbox lambdao
format short
%F=[14.174 18.118 21.224 24.94 varF]'; % Per band impedance evaluation frequencies
(Mhz)
lambda=983.5712./F; % Free space wavelegth in feet @ F
%
Rq=75; % RG11A/U coax Q match line Zo in Ohms
Cq=20.5; % RG11A/U coax Q match line capacitance per unit length (pf/FT)
vfq=1016/(Rq*Cq); % Velocity factor of Q section RG11A/U coax line
lambdaq=lambda*vfq; % One wave length on Q match line in feet @ F
%
Ro=50; % RG213U coax feed line Zo value in Ohms
Co=29.5; % RG213U coax capacitance per unit length (pf/FT)
vfo=1016/(Ro*Co); % Velocity factor of RG213U feed line
lambdao=lambda*vfo; % One wave length on RG213U feed line in feet @ F
%
de=[70.5072 54.9336 47.0257 40.0448 35.1857]'; % Driven element loop lengths in feet
Larm=de/(4*sqrt(2)); % Driven element quad arm lengths in feet. For a diamond quad
this
%                   is the feed line length to the boom
Lboom=[5 5 5 5 10]'; % Boom feed line lengths in feet to mast
%Lloop=[3 3 3 3 3]'; % Feed line loop lengths from mast to switch box
Lq=[0 0 0 6.5152 0]'; % Length of Q section line in feet (Only 12 MTR band Q section)
L213=Larm+Lboom+Lloop-Lq; % Length of RG213U feed line in feet to switch box
%
%Rbox=zeros(5,1); % @ Switch box short on non driven coax feeds
%Rbox=1e10*ones(5,1); % @ Switch box open on non driven coax lines
%
zall=zeros(5,5);
for b=1:5
for nb=1:5
thetaq=2*pi*Lq(nb)/lambdaq(b); % Q section line phase shifts in radians
gammaxq=j*thetaq; % Q match cable low loss approximation
theta213=2*pi*L213(nb)/lambdao(b); % RG213U line phase shifts in radians
gammax213=j*theta213; % RG213U cable low loss approximation
Rb=Rbox(nb);
% z213 is impedance looking into RG213U coax terminated by switch box on
```

```
%     other end
z213=Ro*(Rb.*cosh(gammax213)+Ro*sinh(gammax213))./(Ro*cosh(gammax213)+Rb.
*sinh(gammax213));
% z is impedance looking back into coax line at antenna feed point
z=Rq*(z213.*cosh(gammaxq)+Rq*sinh(gammaxq))./(Rq*cosh(gammaxq)+z213.*sinh(g
ammaxq));
if b==nb
   z=0;
end
zall(b,nb)=z;
end
end
ba=[20 17 15 12 10]';
zz=imag(zall);
plt=0;
if plt==1
disp(' ')
disp('TABLE 2 FIVE BAND CUBICAL QUAD DRIVEN ELEMENT COAXIAL FEED
TERMINATION IMPEDANCES')
disp(' ')
disp(['@ SWITCH BOX IMPEDANCE FOR NON DRIVEN BANDS IN
OHMS=',num2str(Rbox(1,1))])
disp(' ')
disp('DRIVEN     NON DRIVEN BAND IMAGINARY TERMINATION
IMPEDANCES IN OHMS')
disp(' BAND      20         17         15         12         10')
disp(' ')
for i=1:5
fprintf(1,'%5.0f %10.2f %10.2f %10.2f %10.2f %10.2f\n',ba(i,1),zz(i,:));
end
disp(' ')
end
```

```
% M-file Q10a12s.m
clear all
global Lloop zz F Rbox lambdao
Rbx=0; % Switch box resistance across non-driven bands
bb=5; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=4; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=16; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=28.0;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
hold on
F(bb,1)=28.5;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,':','LineWidth',2)
%
F(bb,1)=28.85;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
```

```
   z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'--','LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('12 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 22A 12 MTR COAX FEED jX WHEN OPERATING ON 10 MTRS')
text(9,350,'@ Rbox=0 Ohms')
legend('28.0 MHZ','28.5 MHZ','28.85 MHZ',2)
hold off
```

```
% M-file Q10a12o.m
clear all
global Lloop zz F Rbox lambdao
Rbx=1e15; % Switch box resistance across non-driven bands
bb=5; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=4; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=16; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=28.0;
ii=0;
for var=c1:.1:c2
    ii=ii+1;
    Lcc(ii)=var;
    Lloop(nbb,1)=var;
    zterm22
    z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
hold on
F(bb,1)=28.5;
ii=0;
for var=c1:.1:c2
    ii=ii+1;
    Lcc(ii)=var;
    Lloop(nbb,1)=var;
    zterm22
    z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,':','LineWidth',2)
%
F(bb,1)=28.85;
ii=0;
for var=c1:.1:c2
    ii=ii+1;
    Lcc(ii)=var;
    Lloop(nbb,1)=var;
    zterm22
```

```
    z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'--','LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('12 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 22B 12 MTR COAX FEED jX WHEN OPERATING ON 10 MTRS')
text(4,250,'@ Rbox=1e15 Ohms')
legend('28.0 MHZ','28.5 MHZ','28.85 MHZ',2)
hold off
```

```
% M-file Q12a10s.m
clear all
global Lloop zz F Rbox lambdao
Rbx=0; % Switch box resistance across non-driven bands
bb=4; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=5; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=17; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=24.94;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('10 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 23A 10 MTR COAX FEED jX WHEN OPERATING ON 12 MTRS')
text(7,450,'@ Rbox=0 Ohms')
legend('24.94 MHZ',4)
```

```
% M-file Q12a10o.m
clear all
global Lloop zz F Rbox lambdao
Rbx=1e15; % Switch box resistance across non-driven bands
bb=4; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=5; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=17; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=24.94;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('10 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 23B 10 MTR COAX FEED jX WHEN OPERATING ON 12 MTRS')
text(4,350,'@ Rbox=1e15 Ohms')
legend('24.94 MHZ',2)
```

```
% M-file Q12a15s.m
clear all
global Lloop zz F Rbox lambdao
Rbx=0; % Switch box resistance across non-driven bands
bb=4; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=3; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=17; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=24.94;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('15 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 24A 15 MTR COAX FEED jX WHEN OPERATING ON 12 MTRS')
text(12,350,'@ Rbox=0 Ohms')
legend('24.94 MHZ',1)
```

```
% M-file Q12a15o.m
clear all
global Lloop zz F Rbox lambdao
Rbx=1e15; % Switch box resistance across non-driven bands
bb=4; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=3; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=17; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=24.94;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('15 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 24B 15 MTR COAX FEED jX WHEN OPERATING ON 12 MTRS')
text(8,350,'@ Rbox=1e15 Ohms')
legend('24.94 MHZ',2)
```

```
% M-file Q15a12s.m
clear all
global Lloop zz F Rbox lambdao
Rbx=0; % Switch box resistance across non-driven bands
bb=3; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=4; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=21; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=21.0;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
hold on
F(bb,1)=21.3;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,':','LineWidth',2)
%
F(bb,1)=21.45;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
```

```
    z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'--','LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('12 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 25A 12 MTR COAX FEED jX WHEN OPERATING ON 15 MTRS')
text(15,250,'@ Rbox=0 Ohms')
legend('21.0 MHZ','21.3 MHZ','21.45 MHZ',1)
hold off
```

```
% M-file Q15a12o.m
clear all
global Lloop zz F Rbox lambdao
Rbx=1e15; % Switch box resistance across non-driven bands
bb=3; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=4; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=21; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=21.0;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
hold on
F(bb,1)=21.3;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,':','LineWidth',2)
%
F(bb,1)=21.45;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
```

```
   z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'--','LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('12 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 25B 12 MTR COAX FEED jX WHEN OPERATING ON 15 MTRS')
text(8,250,'@ Rbox=1e15 Ohms')
legend('21.0 MHZ','21.3 MHZ','21.45 MHZ',4)
hold off
```

```
% M-file Q15a17s.m
clear all
global Lloop zz F Rbox lambdao
Rbx=0; % Switch box resistance across non-driven bands
bb=3; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=2; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=21; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=21.0;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
hold on
F(bb,1)=21.3;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,':','LineWidth',2)
%
F(bb,1)=21.45;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
```

```
   z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'--','LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('17 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 26A 17 MTR COAX FEED jX WHEN OPERATING ON 15 MTRS')
text(15,250,'@ Rbox=0 Ohms')
legend('21.0 MHZ','21.3 MHZ','21.45 MHZ',1)
hold off
```

```
% M-file Q15a17o.m
clear all
global Lloop zz F Rbox lambdao
Rbx=1e15; % Switch box resistance across non-driven bands
bb=3; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=2; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=21; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=21.0;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
hold on
F(bb,1)=21.3;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,':','LineWidth',2)
%
F(bb,1)=21.45;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
```

```
   z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'--','LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('17 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 26B 17 MTR COAX FEED jX WHEN OPERATING ON 15 MTRS')
text(10,450,'@ Rbox=1e15 Ohms')
legend('21.0 MHZ','21.3 MHZ','21.45 MHZ',2)
hold off
```

```
% M-file Q17a15s.m
clear all
global Lloop zz F Rbox lambdao
Rbx=0; % Switch box resistance across non-driven bands
bb=2; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=3; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=23; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=18.11;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('15 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 27A 15 MTR COAX FEED jX WHEN OPERATING ON 17 MTRS')
text(18,350,'@ Rbox=0 Ohms')
legend('18.11 MHZ',1)
```

```
% M-file Q17a15o.m
clear all
global Lloop zz F Rbox lambdao
Rbx=1e15; % Switch box resistance across non-driven bands
bb=2; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=3; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=23; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=18.11;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('15 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 27B 15 MTR COAX FEED jX WHEN OPERATING ON 17 MTRS')
text(16,350,'@ Rbox=1e15 Ohms')
legend('18.11 MHZ',1)
```

```
% M-file Q17a20s.m
clear all
global Lloop zz F Rbox lambdao
Rbx=0; % Switch box resistance across non-driven bands
bb=2; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=1; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=23; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=18.11;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('20 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 28A 20 MTR COAX FEED jX WHEN OPERATING ON 17 MTRS')
text(12,450,'@ Rbox=0 Ohms')
legend('18.11 MHZ',2)
```

```
% M-file Q17a20o.m
clear all
global Lloop zz F Rbox lambdao
Rbx=1e15; % Switch box resistance across non-driven bands
bb=2; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=1; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=23; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=18.11;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('20 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 28B 20 MTR COAX FEED jX WHEN OPERATING ON 17 MTRS')
text(4,350,'@ Rbox=1e15 Ohms')
legend('18.11 MHZ',2)
```

```
% M-file Q20a17s.m
clear all
global Lloop zz F Rbox lambdao
Rbx=0; % Switch box resistance across non-driven bands
bb=1; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=2; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=29; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=14.0;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
hold on
F(bb,1)=14.2;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,':','LineWidth',2)
%
F(bb,1)=14.35;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
```

```
   z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'--','LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('17 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 29A 17 MTR COAX FEED jX WHEN OPERATING ON 20 MTRS')
text(5,250,'@ Rbox=0 Ohms')
legend('14.0 MHZ','14.2 MHZ','14.35 MHZ',2)
hold off
```

```
% M-file Q20a17o.m
clear all
global Lloop zz F Rbox lambdao
Rbx=1e15; % Switch box resistance across non-driven bands
bb=1; % Operating band # in order 20=1, 17=2, 15=3, 12=4, 10=5
nbb=2; % Adjacent non-operating band
c1=3; % Starting coax loop length in ft
c2=29; % Ending coax loop length in ft
Rbox=Rbx*ones(1,5);
F=[14.174 18.118 21.224 24.94 28.4]';
Lloop=[3 3 3 3 3]';
F(bb,1)=14.0;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp(' ')
disp('QUARTER WAVE IN FEET ON RG213U COAX')
disp(' ')
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'LineWidth',2)
%
hold on
F(bb,1)=14.2;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
   z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,':','LineWidth',2)
%
F(bb,1)=14.35;
ii=0;
for var=c1:.1:c2
   ii=ii+1;
   Lcc(ii)=var;
   Lloop(nbb,1)=var;
   zterm22
```

```
    z12on10(ii)=zz(bb,nbb);
end
disp([F(bb,1) lambdao(bb,1)/4])
plot(Lcc,z12on10,'--','LineWidth',2)
%
axis([c1 c2 -500 500])
grid
xlabel('17 MTR COAX LOOP LENGTH IN FT')
ylabel('IMAGINARY IMPEDANCE IN OHMS')
title('FIG 29B 17 MTR COAX FEED jX WHEN OPERATING ON 20 MTRS')
text(20,250,'@ Rbox=1e15 Ohms')
legend('14.0 MHZ','14.2 MHZ','14.35 MHZ',1)
hold off
```

Listing of MATLAB programs q12z10.m and swrQ.m used to generate Figures 21G, 21H, and 21I follows:

```
% M-file q12z10.m
% Five band quad 12 Mtr section performance vs jX termination reactance
%    of 10 Mtr quad @ 24.93 Mhz
global f z    % inputs to swrQ.m
global swrq swr50  % outputs from swrQ.m
% EZNEC run data follows
% "m" data matrix columns are defined as follows:
% col 1=10 Mtr jX termination in Ohms
% col 2=12 Mtr gain in dBi
% col 3=FB in dB
% col 4=FBR in dB
% col 5=Real part of 12 Mtr array driving point impedance in Ohms
% col 6=Imaginary part of 12 Mtr array driving point impedance in Ohms
% col 7=SWR @ 50 Ohm coax feed to 12 Mtr array
m=[-1000 14.66 26.07 17.94 79.06 2.118 1.58  %  EZNEC run data matrix
   -750 14.65 24.41 17.86 79.68 1.368 1.59
   -500 14.63 26.94 17.72 80.63 0.1327 1.61
   -250 14.59 27.76 17.46 82.27 -2.272 1.65
   0 14.49 28.12 16.84 85.54 -8.79 1.74
   100 14.38 26.16 16.25 87.5 -15.74 1.83
   200 14.09 20.59 14.90 86.8 -32.57 2.07
   250 13.65 15.82 13.24 77.19 -49.34 2.41
   300 11.95 7.88 7.88 42.64 -60.1 3.43
   312.5 10.66 4.62 4.62 30.84 -55.69 4.0
   325 8.21 0.14 0.13 20.78 -47.3 4.77
   337.5 4.99 -4.8 -4.8 14.23 -36.23 5.46
   350 8.25 -2.2 -2.2 11.76 -24.53 5.32
   362.5 12.05 2.25 2.25 12.7 -13.93 4.26
   375 13.74 5.33 5.33 15.84 -5.303 3.2
   400 14.77 9.24 9.24 24.59 6.015 2.07
   450 15.02 13.42 13.42 39.95 14.3 1.47
   500 14.99 15.73 15.73 49.54 15.62 1.37
   600 14.92 18.31 18.31 59.4 14.42 1.37
   800 14.85 20.61 19.5 66.83 11.67 1.42
   1000 14.81 21.68 19.14 69.76 10.06 1.45
   1250 14.79 22.41 18.92 71.58 8.882 1.47
   1500 14.77 22.84 18.79 72.6 8.154 1.49];
%
x=m(:,1);
gain=m(:,2);
fb=m(:,3);
fbr=m(:,4);
real=m(:,5);
```

```
imag=m(:,6);
z12=real+j*imag;
swr50=m(:,7);
n=size(m);
n=n(1,1); % number or rows in m matrix
SWRQ=zeros(n,1);
SWR50=SWRQ;
f=24.93;
for k=1:n
   z=z12(k);
   swrQ
   SWRQ(k)=swrq;
   SWR50(k)=swr50;
end
%
plot(x,SWRQ,'LineWidth',2)
hold on
plot(x,SWR50,':','LineWidth',2)
axis([-500 1000 1 10])
grid
legend('SWR Q SECTION FEED','SWR 50 OHM FEED',2)
xlabel('10 MTR COAX FEED REACTANCE IN OHMS @ 24.93 Mhz')
ylabel('SWR ON 12 MTR BAND')
title('FIG 21G 12 MTR QUAD SWR VERSUS 10 MTR QUAD COAX FEED
REACTANCE')
%
keyboard
plot(x,real,'LineWidth',2)
hold on
plot(x,imag,':','LineWidth',2)
axis([-500 1000 -61 90])
grid
legend('REAL PART','IMAGINARY PART',2)
xlabel('10 MTR COAX FEED REACTANCE IN OHMS @ 24.93 Mhz')
ylabel('OHMS')
title('FIG 21H 12 MTR QUAD IMPEDANCE VERSUS 10 MTR QUAD COAX FEED
REACTANCE')
%
keyboard
plot(x,gain,'LineWidth',2)
hold on
plot(x,fbr,':','LineWidth',2)
axis([-500 1000 -5 20])
grid
legend('GAIN IN dBi','FBR IN dB',3)
xlabel('10 MTR COAX FEED REACTANCE IN OHMS @ 24.93 Mhz')
```

```
ylabel('GAIN or FBR')
title('FIG 21I 12 MTR QUAD GAIN AND FBR VERSUS 10 MTR QUAD COAX
FEED REACTANCE')
```

```
% M-file swrQ.m
% Computes SWR "swrq" versus frequency for a quarter wave Q match.
% Program as coded uses a 75 Ohm RG11 coax Q section followed by
%   any length of 52 Ohm coax.
% Program can be set for other Q section line types by changing Rq and
%   Cprime (and computed velocity factor "vf") to values for the line type.
% Program also computes SWR "swr52" for a 52 Ohm coax feed without the Q
%   section.
format short
global f z    % inputs
global swrq swr50  % outputs
% f=column matrix of Mhz frequencies
% z=column matrix of complex antenna driving point impedances (Ohms)
Rq=75; % Q match line Zo value in Ohms (For RG11 coax it is 75 Ohms)
Cprime=20.5; % Q match line capacitance per foot in pf/FT units
%             (For RG11 coax it is 20.5 pF/FT)
vf=1016/(Rq*Cprime); % Velocity factor of Q section line
Fdmat=[14.174 18.118 21.224 24.94 28.4]; % Q section design frequencies
fm=mean(f); % mean of input frequencies (Mhz)
for b=1:5 % Auto detect Q section design frequency loop
   if abs(fm-Fdmat(b))<1.5
      Fd=Fdmat(b);
   end
end
lambdaQ=vf*983.5712/Fd; % One wavelength on Q section line in feet @ Fd Mhz
xQ=0.25*lambdaQ; % Length of quarter wave Q section in FT for @ Fd
lambda=vf*983.5712./f; % One wavelength on Q section line in feet @ f Mhz
theta=2*pi*xQ./lambda; % Q section line length in radians of phase shift @ f Mhz
gammax=j*theta;
% z1=complex impedance looking into Q section input port (Ohms)
z1=Rq*(z.*cosh(gammax)+Rq*sinh(gammax))./(Rq*cosh(gammax)+z.*sinh(gammax));
R50=50; % swrq @ 50 Ohm coax of any length after quarter wave Q section
rhoq=(z1-R50)./(z1+R50); % Reflection coefficient on 52 Ohm coax line with Q section
swrq=(1+abs(rhoq))./(1-abs(rhoq));
rho50=(z-R50)./(z+R50); % Reflection coefficient on 52 Ohm coax line without Q
section
swr50=(1+abs(rho50))./(1-abs(rho50)); % swr52 without Q section match
%
table=0; % Set table=1 for table printout
if table==1
disp(' ')
disp('Quarter Wave Q Section Made Of RG11 Coax')
disp(' ')
disp('   Zo Ohms   Design F  L in FT  L in Inch')
```

```
disp([Rq Fd xQ 12*xQ])
disp(' ')
end
```