The Impedance-Transformation Properties of Common 4:1 Balun Types
Part 4: Toroidal Current Baluns: Some Preliminary Measurements

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The true current with toroidal windings normally requires two cores, usually ferrite. Mix 43 (µ = 850 is most common because of its low cost and generally satisfactory service in the HF range. As shown in **Fig. 1**, the two winding pairs use parallel connections on the input side and series connections at the output. Some builders add a 1:1 transformer at the input to preserve the balance of the windings. However, most commercial 4:1 current baluns of this design simply connect one input terminal to the center conductor of an SO-239 coaxial cable connector, with the other lead going to ground.

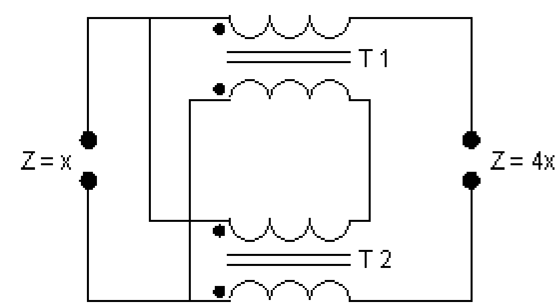


Fig. 1

Current Balun

Since each bifilar winding creates a 1:1 impedance transformer, the 4:1 impedance transformation results from the connections. In this regard, it resembles the dual ferrite bead balun that we previously examined in detail. As we look at samples of the ferrite toroidal core version of the current balun, we shall be interested in its performance relative to the ferrite bead version as well as noting differences from the performance of the voltage baluns.

Using the same test set-up and resistors employed with earlier tests, we shall look at two samples of true current baluns: the low-power indoor MFJ-911 and the CSP TLT-4-C, which is rated for higher power.

The MFJ-911

MFJ describes the 911 in the following catalog terms:

> MFJ-911: Price: $24.95: The MFJ-911 is a true 4:1 current balun/unun that transforms 200 ohm balanced and unbalanced loads to 50 ohms. The response is amazingly flat from 160-10M because it is a true Transmission Line Transformer using 100 ohm characteristic impedance transmission line. Two low permeability ferrite cores are used to easily handle 300 Watts. Change balanced to unbalanced operation with handy ground post. 2½ x 4¾ x 1 inches.

Of interest is the fact that the specification sheet that accompanies the unit reduces the response claim from “amazingly flat” down to “relatively flat.” As well, the catalog claim of 100-Ω winding does not appear on the specification sheet. Inspection of the interior shows that the Teflon wires are tightly paired, but there is nothing to indicated their characteristic impedance.

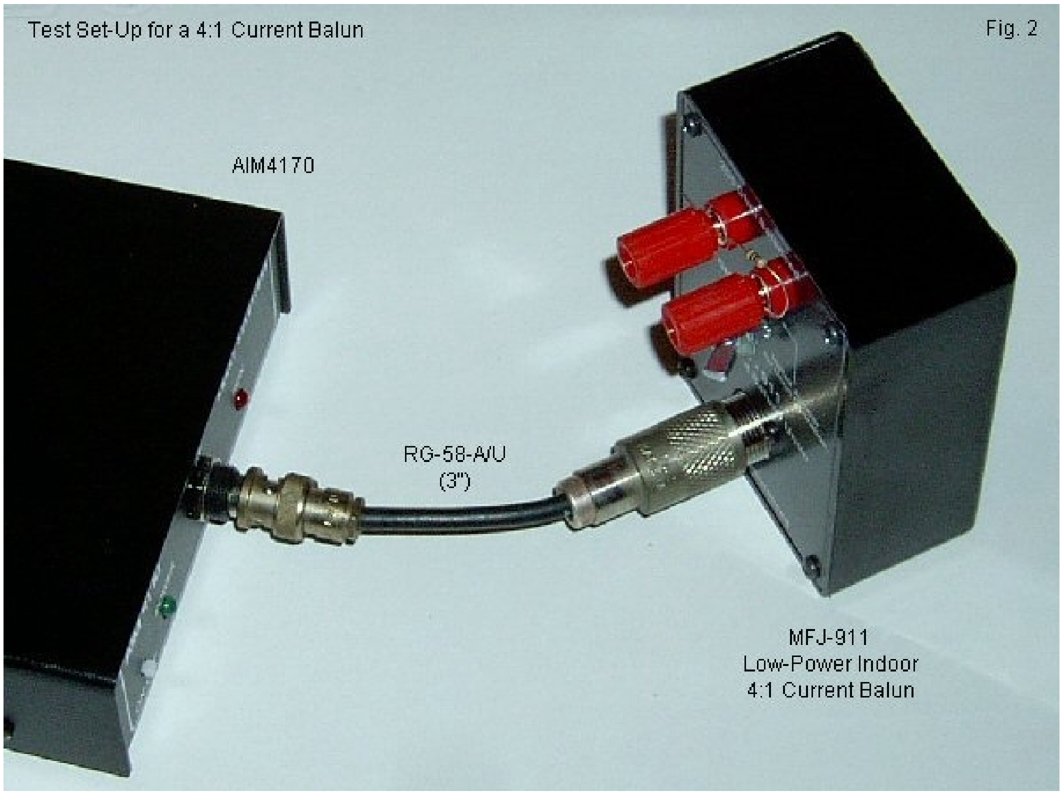
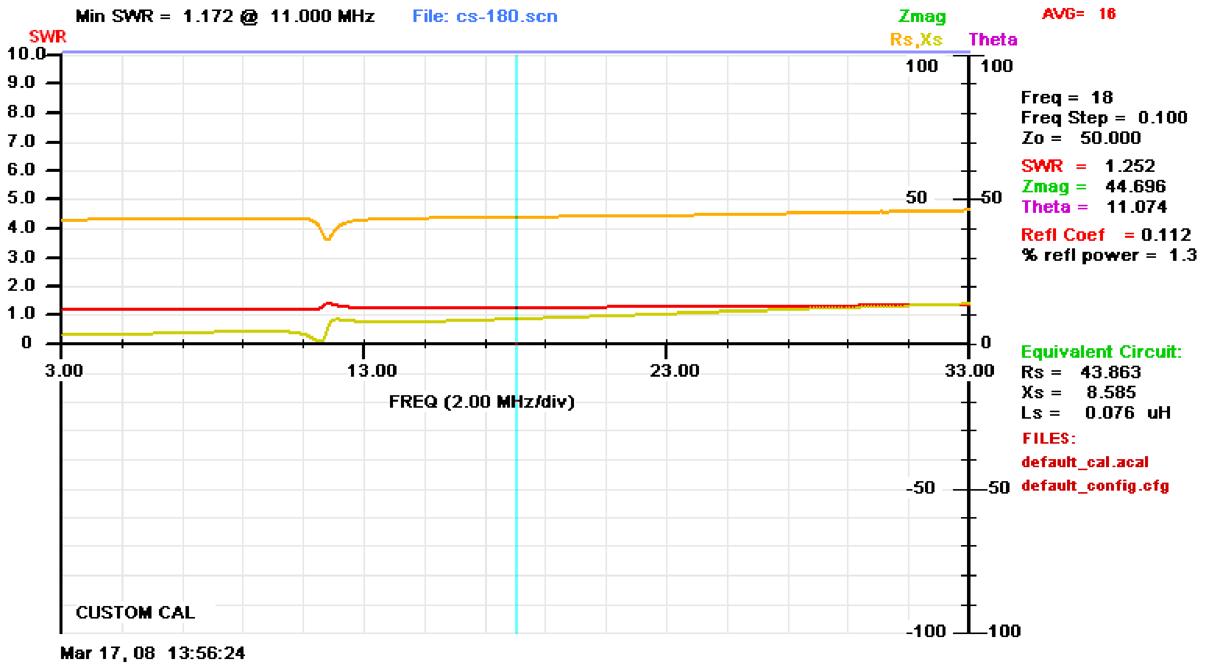


Fig. 2 shows the test set-up, with the standard 3" length of RG-58 (compensated out of the test results) between the balun and the AIM4170. I took the photo following the series of tests; hence, the binding posts are loose and show no load resistor. We shall use the same set of loads for testing the impedance transformation properties of the voltage balun, and the results will have the same appearance. Graph lines will include resistance (orange), reactance (ochre) and the 50-Ω SWR (red) over the 3 to 30 (33) MHz range. Test tables will show basic sample measurement values for 3.7, 7.0, 14.0, and 20.0 MHz. The column headings SWR50, R, and X correspond to the lines on the graph at the designated frequencies. The entries contain excess decimal places simply to allow easier identification of trends for some balun units that show only small variations. The graphs have two supplemental sets of values. At the top is the load value based on the DC resistance measurement of the test resistor. Beside it is the calculated "ideal" input resistance based on that load value followed by the 4:1 theoretical impedance transformation of the balun. The right two columns take into account the scans (described in part 1) of the actual load resistors and create adjusted "ideal" resistance and reactance values based on simple proportional-parts calculations. The goal is to provide an estimate of the input values that might be produced by an ideal 4:1 balun. The bottom row of the tables shows the amount of value change across the frequency range in the table.

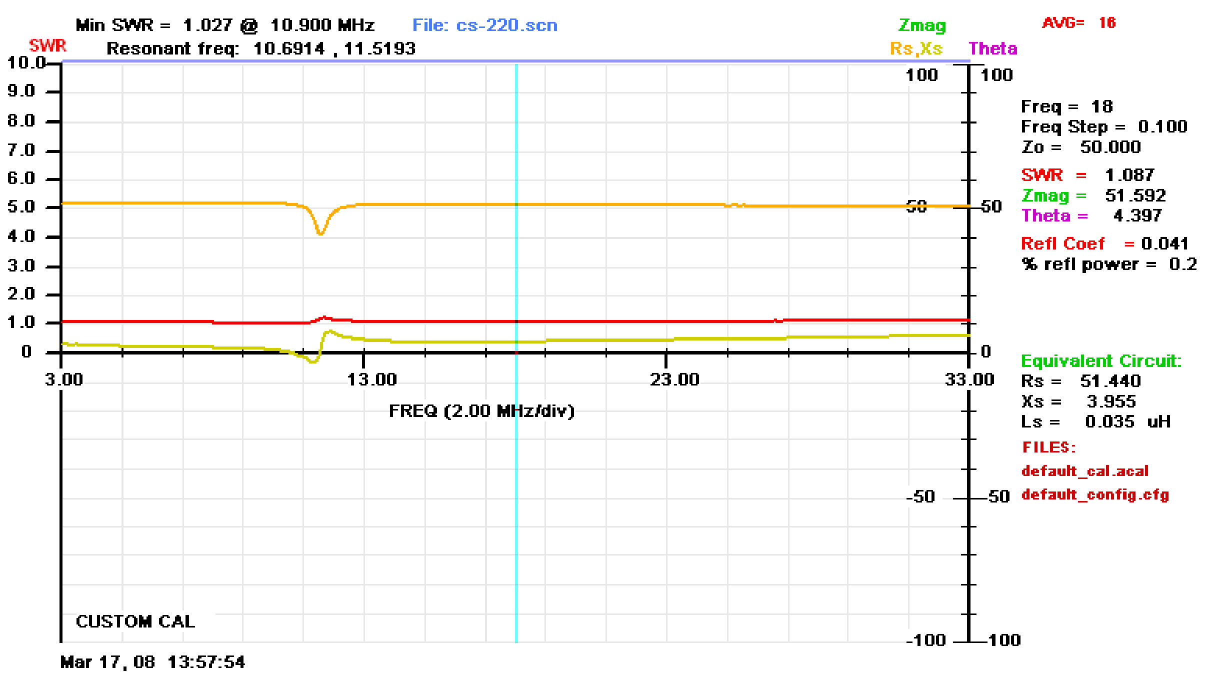
Test 1: 180 Ω and Test 2: 220 Ω: Since the nominal design load impedance for the 4:1 balun is 200 Ω, we may again combine the first two tests. The resistor values bracket the nominal load value. Along with the two side-by-side test tables, **Fig. 3** and **Fig. 4** provide the basic performance data.



MFJ-911 Current Balun: Load 181.2 Ohms

Fig. 3

Test 1: Balun with resistive load of 181.2 Ohms						Test 2: Balun with resistive load of 221.4 Ohms					
Load R	Ideal In R	Ld SWR	In SWR			Load R	Ideal In R	Ld SWR	In SWR		
181.2	45.300	1.026	1.104			221.4	55.350	1.190	1.107		
Freq	SWR50	R	X	Adj Id R	Adj Id X	Freq	SWR50	R	X	Adj Id R	Adj Id X
3.5	1.19	42.87	3.32	45.54	-0.19	3.5	1.07	51.82	2.99	55.11	-0.36
7.0	1.19	43.13	3.88	45.52	-0.37	7.0	1.06	51.84	2.02	55.09	-0.70
14.0	1.24	43.31	7.48	45.50	-0.74	14.0	1.09	51.48	4.03	55.05	-1.39
28.0	1.32	45.28	12.26	45.46	-1.49	28.0	1.11	50.93	5.36	54.97	-2.76
Delta	0.13	2.41	8.94			Delta	0.06	0.89	2.37		



MFJ-911 Current Balun: Load 221.4 Ohms

Fig. 4

The two resistive loads that surround the nominal balun load (200 Ω), yield very flat responses across the scan range. The response with the 220-Ω resistor is especially notable, since the resistance and the reactance vary only slightly, as indicated by the change range in the table. However, for both values, the measured resistance is slightly lower than the ideal values shown on the right in each table. In practical terms, the deviation is insignificant, although it provides us with a factor to track as we employ other load values.

Perhaps the most striking feature of the graphs is the set of bumps in the vicinity of 11.5 MHz. We shall track these minor aberrations to see if they are peculiar to loads in the nominal region. As well, we shall see if they grow or shrink if they are present with higher or lower load values.

Test 3: 152 Ω and Test 4: 100 Ω: As shown in **Fig. 5** and in **Fig. 6**, as well as in the test tables, the next two loads progressively reduce the load resistance to simulate loads with higher SWR values while remaining with a 2:1 SWR range.

As we decrease the load value, the aberrational bumps decrease in size. In addition, the range of input resistance and input reactance values increases across the full scan range. For these lower load values, both resistance and reactance continuously rise so that at 28 MHz, values are considerably higher than the adjusted ideal values (based upon scans of the load resistors alone).

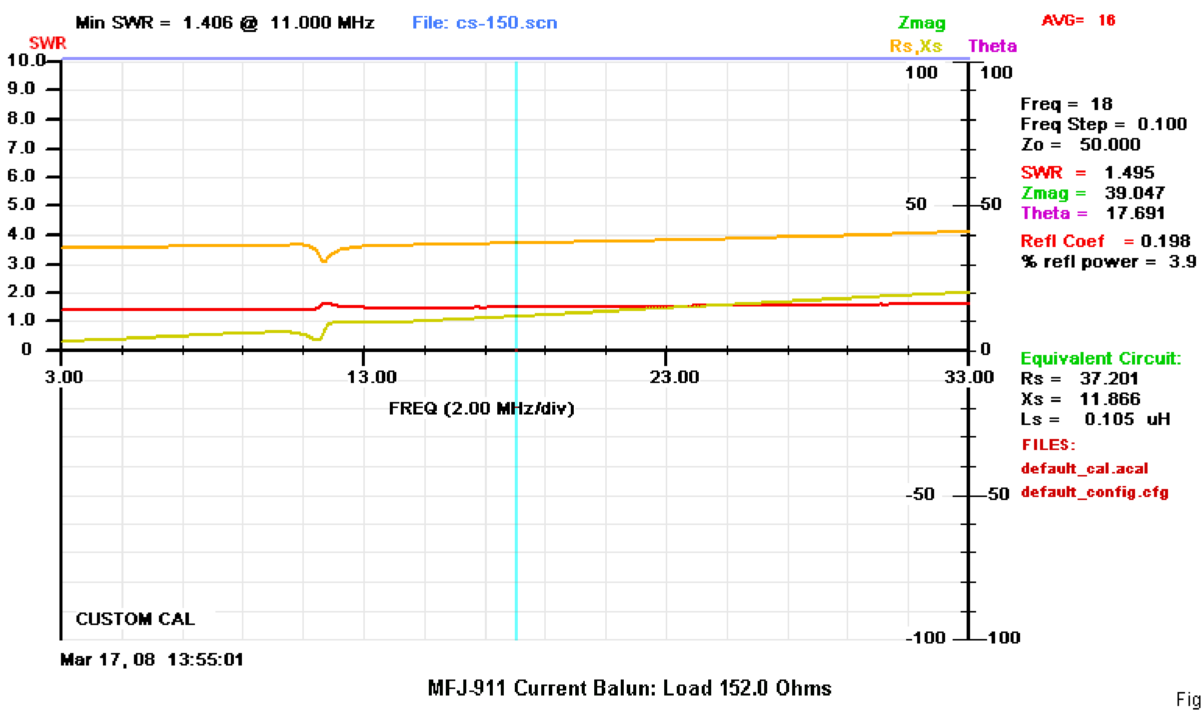
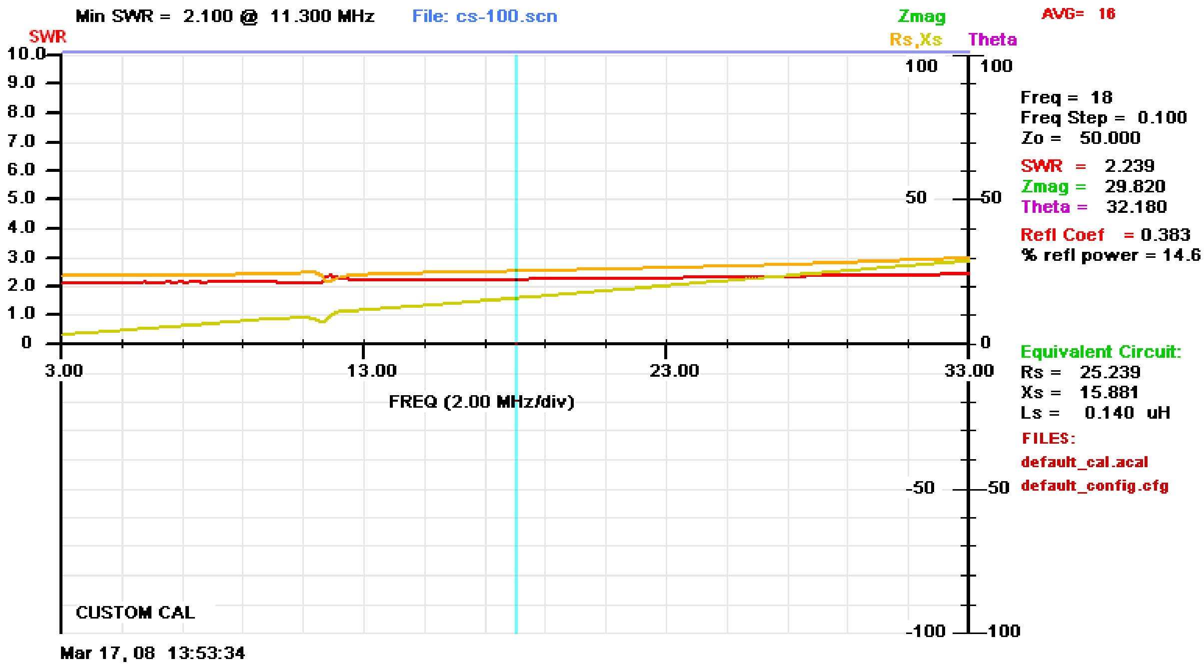


Fig. 5

Test 3: Balun with resistive load of 152.0 Ohms					
Load R	Ideal In R	Ld SWR	In SWR		
152.0	38.00	1.22	1.32		
Freq	SWR50	R	X	Adj Id R	Adj Id X
3.5	1.41	35.78	3.46	37.86	-0.15
7.0	1.42	36.00	5.03	37.85	-0.22
14.0	1.48	36.38	9.81	37.83	-0.38
28.0	1.58	39.51	17.54	37.78	-0.68
Delta	0.17	3.73	14.08		

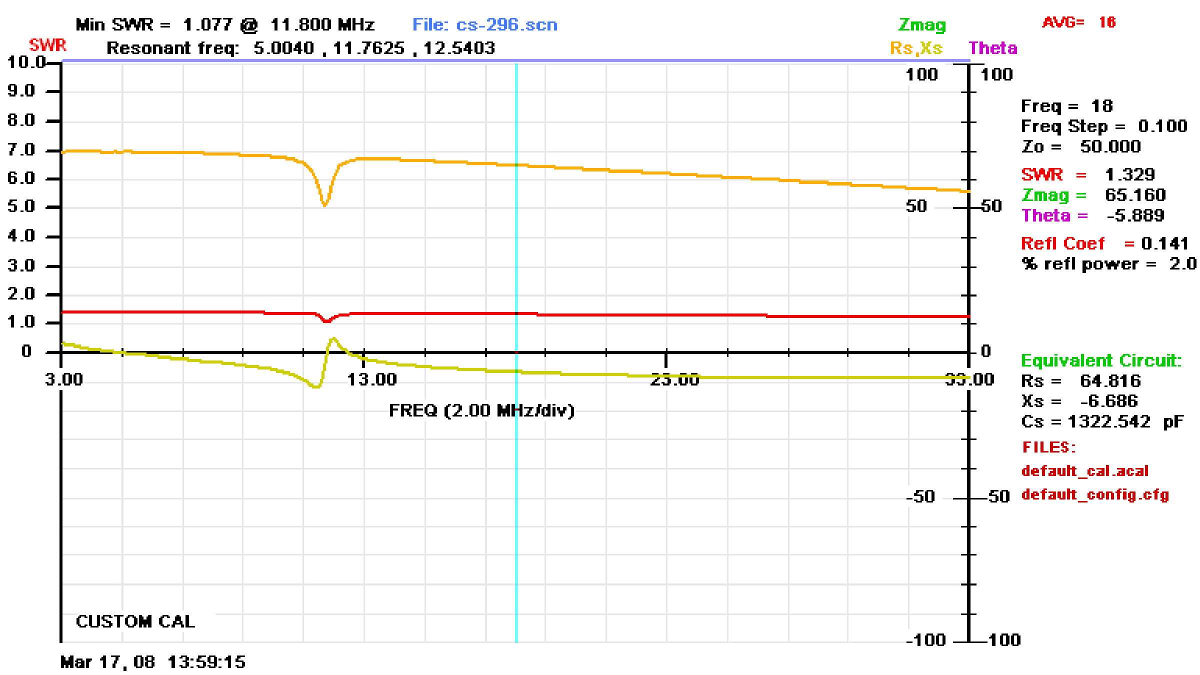
Test 4: Balun with resistive load of 100.3 Ohms					
Load R	Ideal In R	Ld SWR	In SWR		
100.3	25.08	1.85	1.99		
Freq	SWR50	R	X	Adj Id R	Adj Id X
3.5	2.13	23.59	3.62	25.06	0.03
7.0	2.14	23.85	6.34	25.06	0.09
14.0	2.21	24.42	12.55	25.06	0.20
28.0	2.36	27.90	24.58	25.05	0.42
Delta	0.23	4.31	20.96		



MFJ-911 Current Balun: Load 100.3 Ohms

Fig. 6

Test 5: 295 Ω and Test 6: 390 Ω: When we employ load resistance values above nominal, some facets of the current balun behavior change, as indicated in **Fig. 7, Fig. 8**, and the test tables. Most striking is the growth of the 11.5-MHz aberration in the curves. Equally important is the fact that with loads greater than nominal, the resistance decreases with increasing frequency. As well, the reactance curve becomes increasingly capacitive, although the value reaches a maximum and then gradually becomes less capacitively reactance at the upper end of the scan.

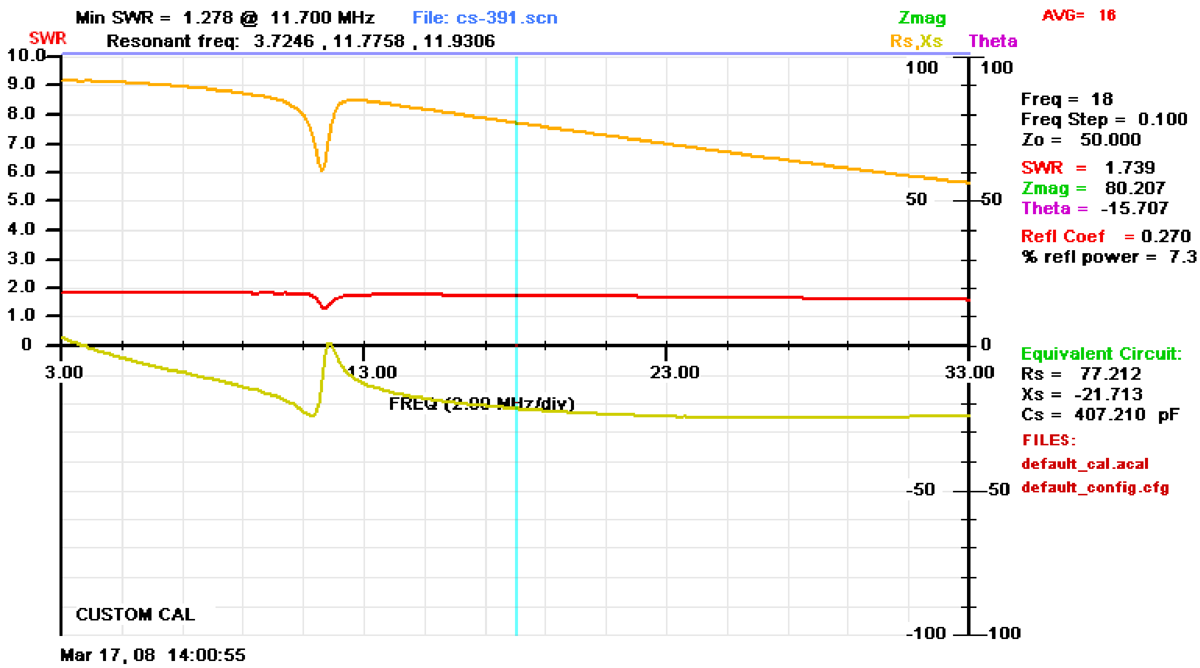


MFJ-911 Current Balun: Load 296.5 Ohms

Fig. 7

Test 5: Balun with resistive load of 296.5 Ohms					
Load R	Ideal In R	Ld SWR	In SWR		
296.5	74.13	1.59	1.48		
Freq	SWR50	R	X	Adj Id R	Adj Id X
3.5	1.40	69.60	2.21	73.91	-0.42
7.0	1.39	69.11	-2.29	73.86	-1.10
14.0	1.35	66.81	-3.91	73.75	-2.46
28.0	1.26	58.92	-8.70	73.55	-5.19
Delta	0.14	10.68	-10.91		

Test 6: Balun with resistive load of 391.5 Ohms					
Load R	Ideal In R	Ld SWR	In SWR		
391.5	97.88	2.10	1.96		
Freq	SWR50	R	X	Adj Id R	Adj Id X
3.5	1.83	91.65	0.91	97.40	-1.37
7.0	1.82	89.65	-9.27	97.27	-2.61
14.0	1.76	83.27	-16.35	97.01	-5.08
28.0	1.64	62.70	-24.70	96.50	-10.03
Delta	0.19	28.95	-25.61		



MFJ-911 Current Balun: Load 391.5 Ohms

Fig. 8

For higher load values, the input resistance is lower than ideal across the frequency range of the scan. As a result of this factor, coupled with the slope of the resistance curve, the resistance in the upper reaches of the scan drops to about 60% of ideal with the 391-Ω load. Since the capacitive reactance tends to rise with frequency except at the highest frequencies in the scan, the decreasing resistance is masked by a relatively flat SWR value, if we only measure that factor.

Test 7: 560 Ω: The final purely resistive load simulates an SWR of about 3:1. **Fig. 9** and the associated test table show the results of using a high load resistance value. The numbers and curves show the continuing trends as they become ever more vivid.

Test 7: Balun with resistive load of 561.0 Ohms					
Load R	Ideal In R	Ld SWR	In SWR		
561.0	140.25	3.02	2.81		
Freq	SWR50	R	X	Adj Id R	Adj Id X
3.5	2.62	131.17	-2.22	139.82	-2.61
7.0	2.61	124.03	-25.85	139.40	-5.13
14.0	2.52	105.75	-41.57	138.56	-10.16
28.0	2.34	61.31	-47.24	136.87	-20.23
Delta	0.28	69.86	-45.02		

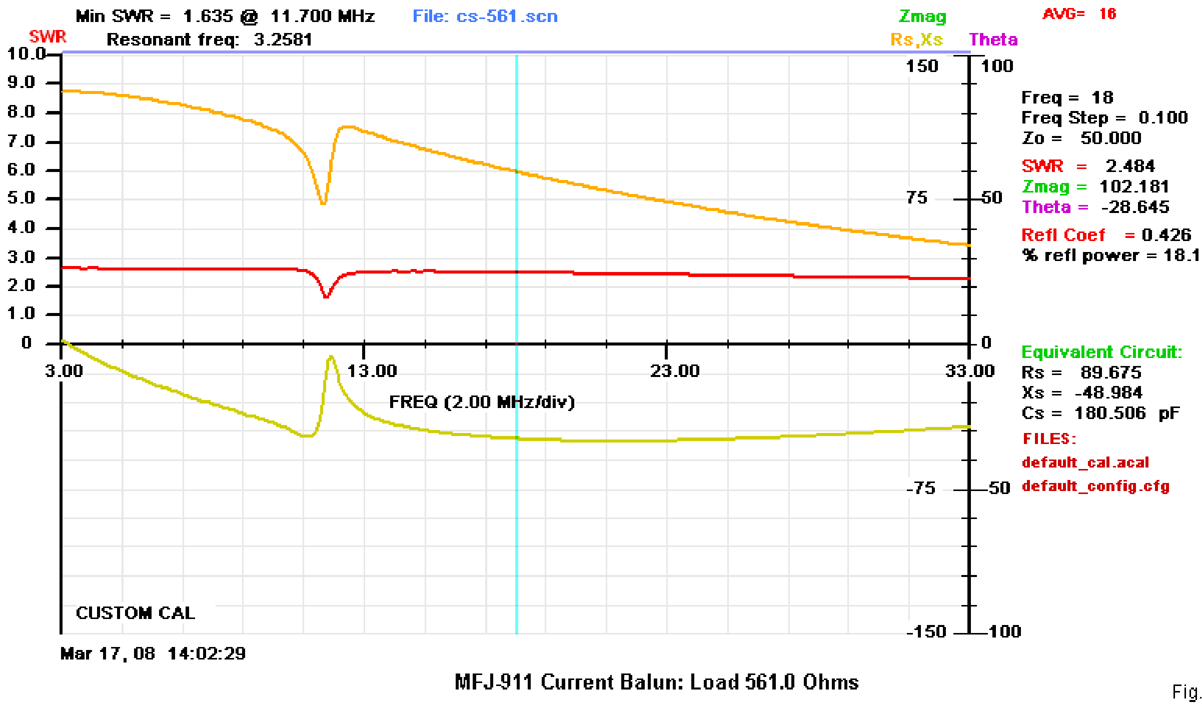


Fig. 9

The drop in resistance with rising frequency shows about a 3:1 range from 3 to 33 MHz. Accompanying the drop is a reactance curve that is wholly capacitive across the scan. It reaches a peak value near the mid-range marker on the graph. As the SWR line shows, the combined effect yields a relatively constant 50-Ω SWR value at the device input. The aberrant bumps in the resistance and reactance curves around 11.5 MHz are very pronounced. However, the extreme values remain within the overall range of both resistance and reactance, and the combined effect yields only a small change in the resulting SWR value.

Test 8: 181.2 – j117.3 Ω @ 14 MHz: Since the final test employs a series combination of resistance and capacitive reactance over a narrow frequency range (13 to 15 MHz), we may dispense with the graph, since it shows only relatively flat lines. The data table provides the key information on the performance of the device with this sample load. As in the tests of voltage baluns, the table also includes values derived from testing the dual ferrite-bead 4:1 balun, since those values closely approximate ideal 4:1 transformations of both the resistance and the reactance at the load.

Test 8: Balun with a complex load of 181.2 - j117.3 Ohms					
	Ideal SWR: 1.978:1				
	MFJ-911				
Freq	SWR50	R	X		
13	1.95	38.03	-27.07		
14	1.89	36.99	-24.67		
15	1.83	36.40	-22.36		

The 911's seeming improved SWR values relative to the calculated value based upon the load may tend to obscure the reality of the impedance transformation if we do not measure both resistance and reactance. For both parameters, the 911 produces lower than ideal values. However, the values are considerably better than those produced by either voltage balun (part 3) using the same load.

The aberrant bumps in the entire set of test scans for the 911 led me to examine carefully the case contents. Various manipulations of the core positions relative to each other and to the aluminum panel yielded no detectable change. However, hand capacitance to the pair of cores and their windings did suppress the bumps (but, of course, led to very shaky scan curves). The bumps may be an internal resonance in the windings. Its appearance on the full-sweep scans seems abrupt. However, as shown in **Fig. 10**, a narrower scan shows a gentler view of the phenomenon, despite the use of the 561-Ω resistive load.

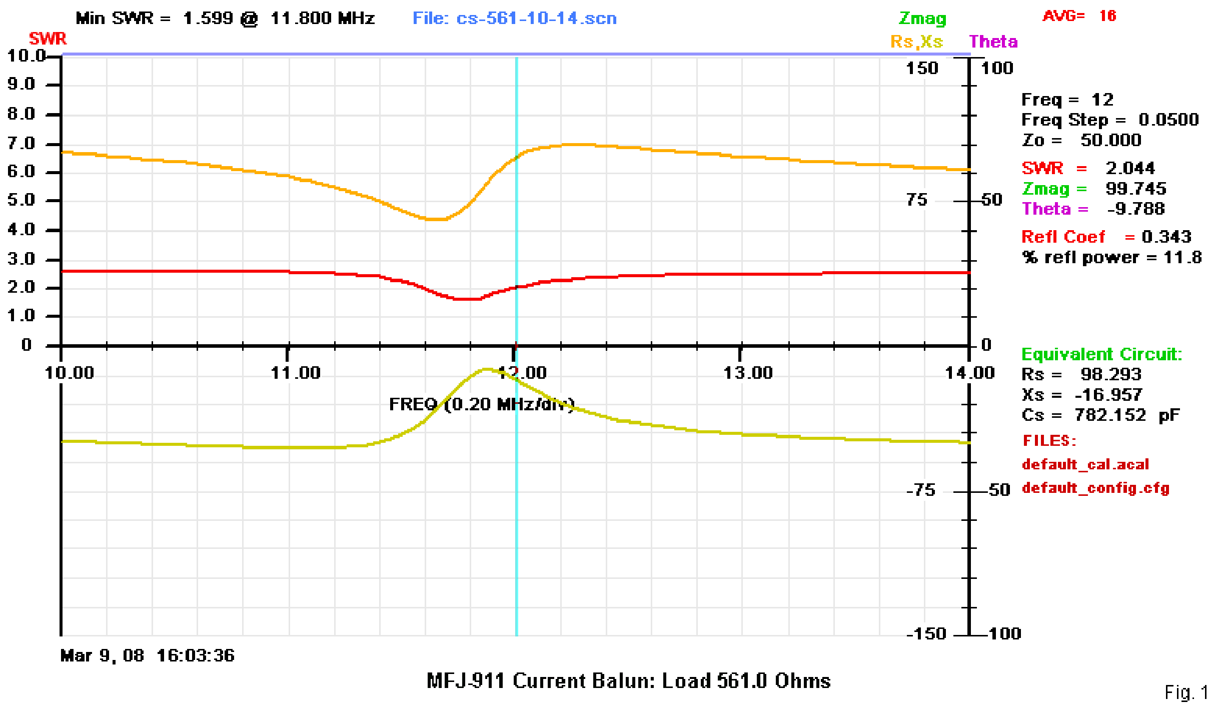


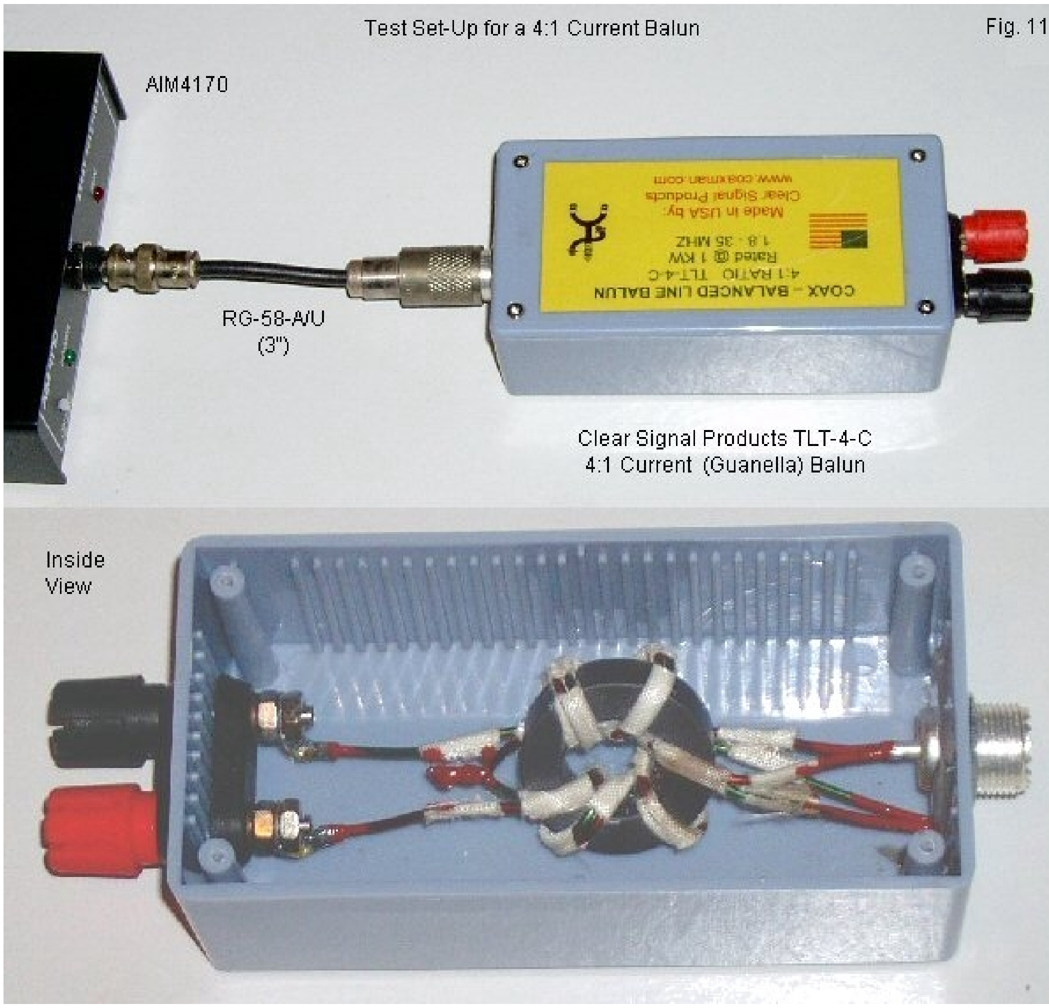
Fig. 10

Interestingly, the minimum resistance and reactance points occur at different frequencies ad never reach extreme values, even using a 0.05-MHz increment between scan points. Whatever the source of the aberrant behavior, it does not appear to be severe enough to hinder effective use of the 911 4:1 current balun in standard applications.

The Clear Signal Products TLT-4-C

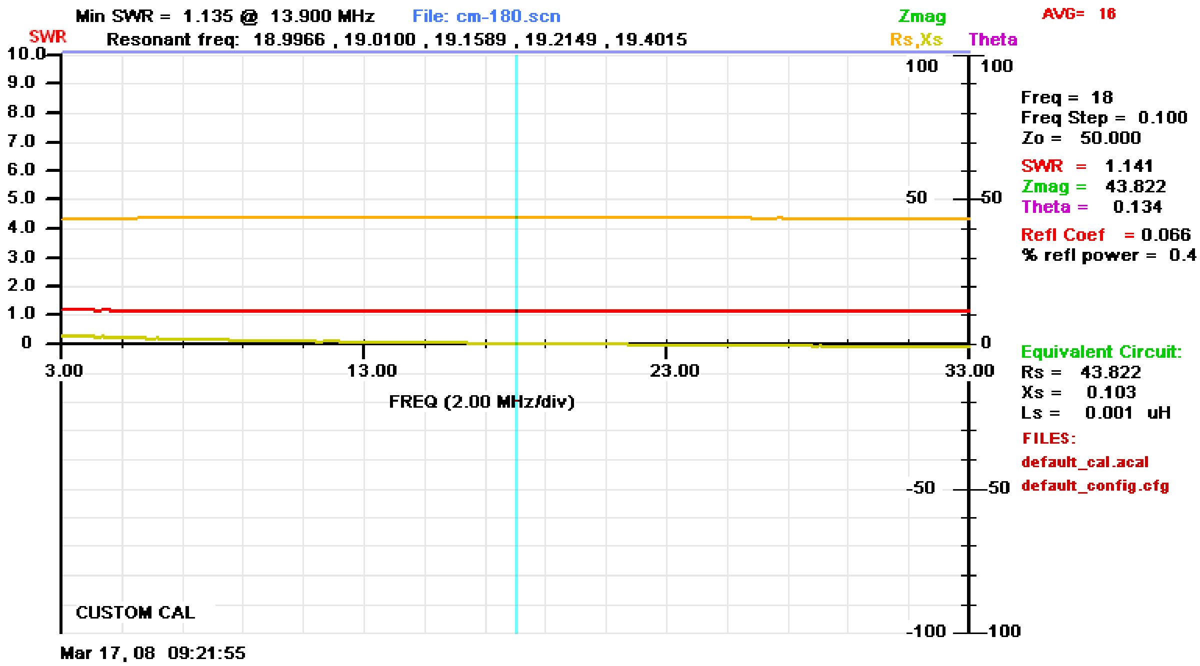
More recently, cores with much higher permeability values have appeared. The cores permit the use of far fewer turns per winding. Some older Guanella designs have small resonance bumps (in the case of the MFJ-911 at about 11.5 MHz) that the need for fewer winding turns eliminates. The requirement for fewer turns per winding also allows both windings to employ the same core. Clear Signal Products produces such a balun (and a fully sealed outdoor version) using a single core for which µ = 1500 from Ceramic Magnetics of Fairfield, NJ. The high-µ allows a single 1.375"-diameter by 0.375"-thick core to carry both windings, which require only 3 turns each with wire spacing set for a 100-Ω characteristic impedance via glass tape. The case uses gray UV-resistant PVC, normally with a compatible sealant. I am indebted to Michael LaPuzza, KM5QX, of Clear Signal Products for sending me an unsealed unit to scan for this series. (See http://www.coaxman.com.)

Fig. 11 shows the test set-up, with the standard 3" length of RG-58 between the balun and the AIM4170. (Although the line is less than 1% of a wavelength at the highest frequency scanned it was calibrated out of the tests.) We shall use the same set of loads for testing the impedance transformation properties of the voltage balun, and the results will have the same graphic and tabular appearance as earlier version, as described at the beginning of this part.



A reminder: The goal of the tests is to determine the accuracy of the impedance transformation using loads both close to ideal value and loads more distant from the ideal value. In many instances, employing simply an SWR measure does not tell the full story of the transformation over the complete frequency range. A given SWR value may result from an indefinitely large combination of resistance and reactance values. To what degree and under what circumstances a 4:1 balun design is a precision impedance transformer is the key question for the scans. The tests do not include determining the maximum power handling capability of the unit or the total impedance to common-mode currents as a measure of the balanced-to-unbalanced function of the unit.

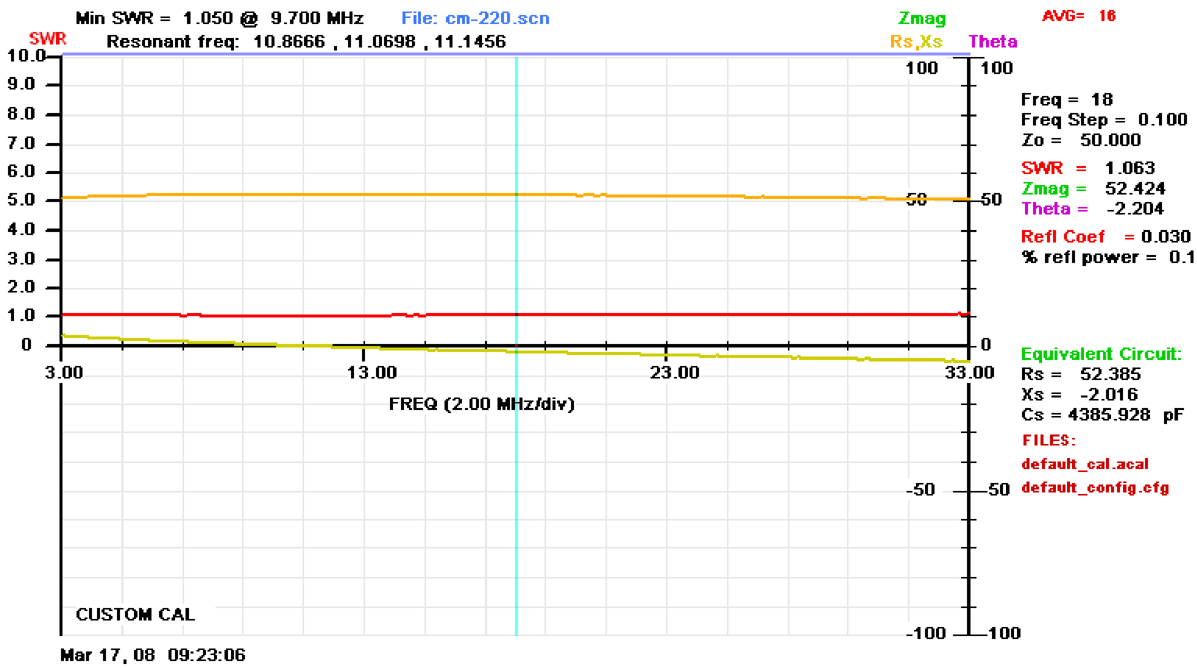
Test 1: 180 Ω and Test 2: 220 Ω: Since the nominal load impedance is 200 Ω, the first two test loads surround it. **Fig. 12** and **Fig. 13** provide scan graphs for the two resistive loads. The test tables are side-by-side between the graphs. Both graphs (and test tables) show quite flat resistance curves with a slight peak in the middle frequency region. The reactance curves are very shallow, but still wider than the calculated range of the reactance associated with the load resistors.



CSP TLT-4-C 4:1 Balun: 181.2 Ohms

Fig. 12

Test 1: Balun with resistive load of 181.2 Ohms							Test 2: Balun with resistive load of 221.4 Ohms					
Load R	Ideal In R	Ld SWR	In SWR				Load R	Ideal In R	Ld SWR	In SWR		
181.2	45.300	1.026	1.104				221.4	55.350	1.190	1.107		
Freq	SWR50	R	X	Adj Id R	Adj Id X		Freq	SWR50	R	X	Adj Id R	Adj Id X
3.5	1.17	43.13	2.73	45.54	-0.19		3.5	1.07	51.50	3.31	55.11	-0.36
7.0	1.15	43.68	1.71	45.52	-0.37		7.0	1.05	52.30	1.36	55.09	-0.70
14.0	1.14	43.84	0.51	45.50	-0.74		14.0	1.06	52.62	-0.95	55.05	-1.39
28.0	1.15	43.34	-0.67	45.46	-1.49		28.0	1.09	51.35	-4.24	54.97	-2.76
Delta	0.03	0.71	-3.40				Delta	0.04	1.27	-7.55		



CSP TLT-4-C 4:1 Balun: 221.4 Ohms

Fig. 13

Test 3: 152 Ω and Test 4: 100 Ω: The test loads below the ideal value aim for SWR values of about 1.33:1 and 2.0:1. **Fig. 14** and **Fig. 15** provide the scan graphics, along with side-by-side data sample tables. As appears to be typical of 4:1 balun designs, the lower load resistance values result in very flat resistance curves with values very close to calculated ideals. The reactance curves show a small rise in inductive impedance in contrast to reactance curves for more nearly ideal load values.

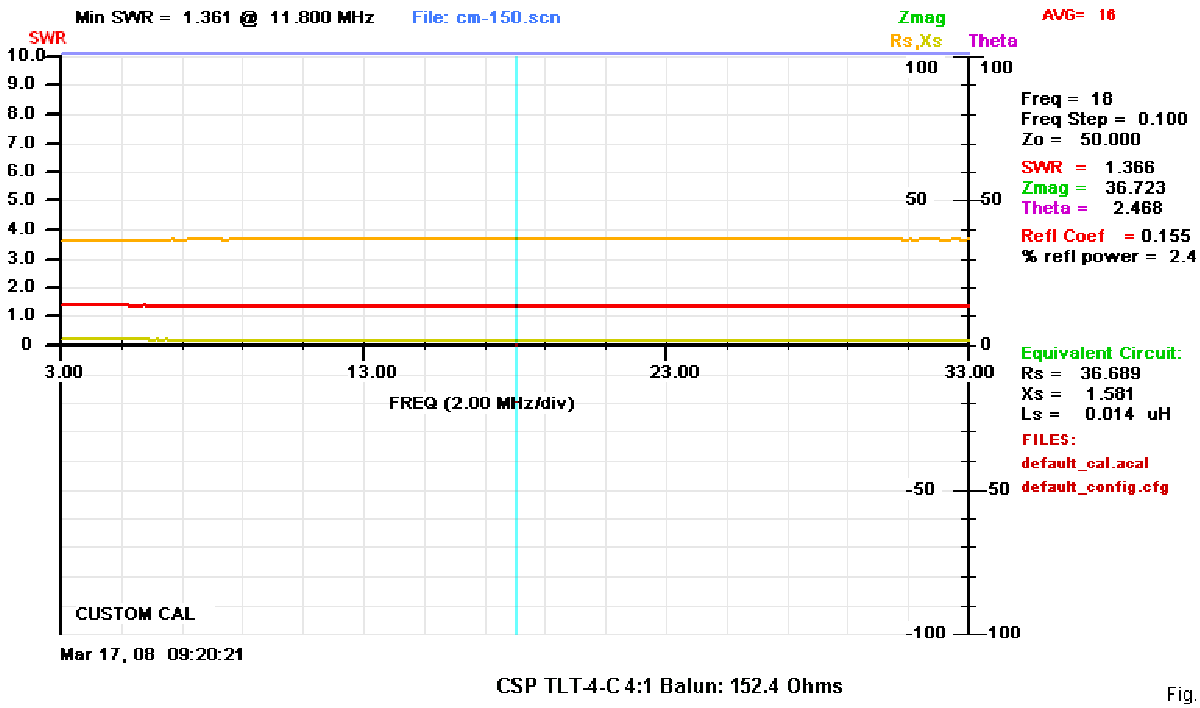


Fig. 14

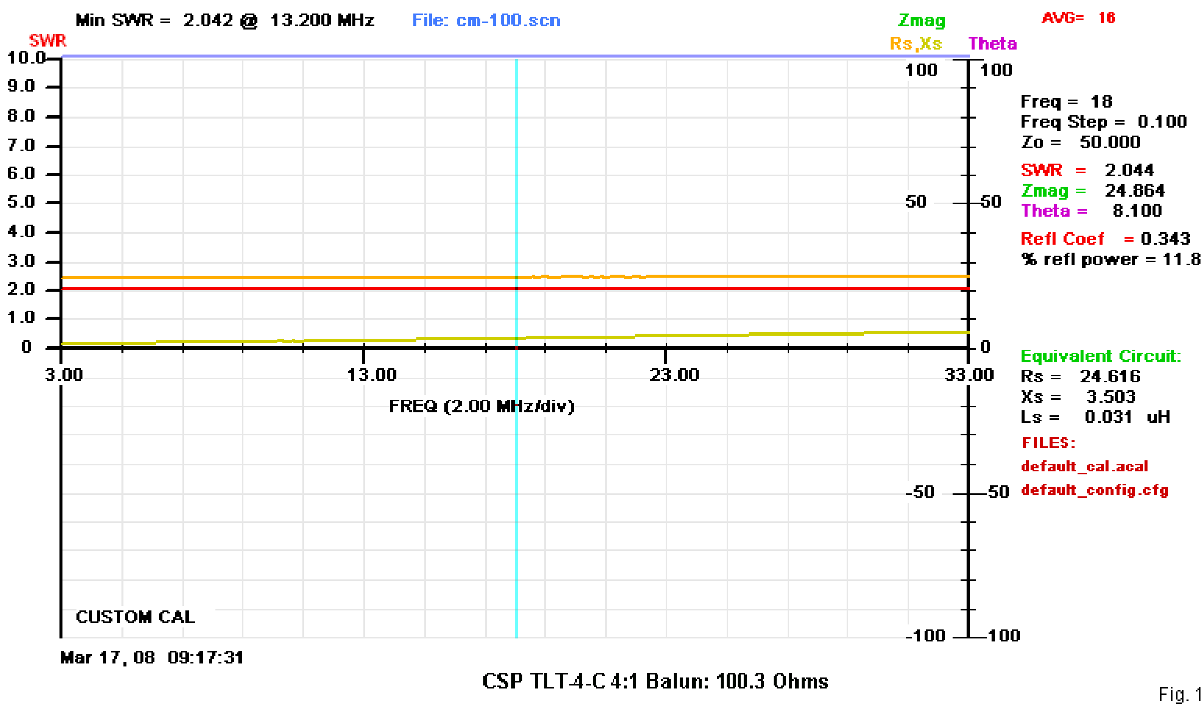


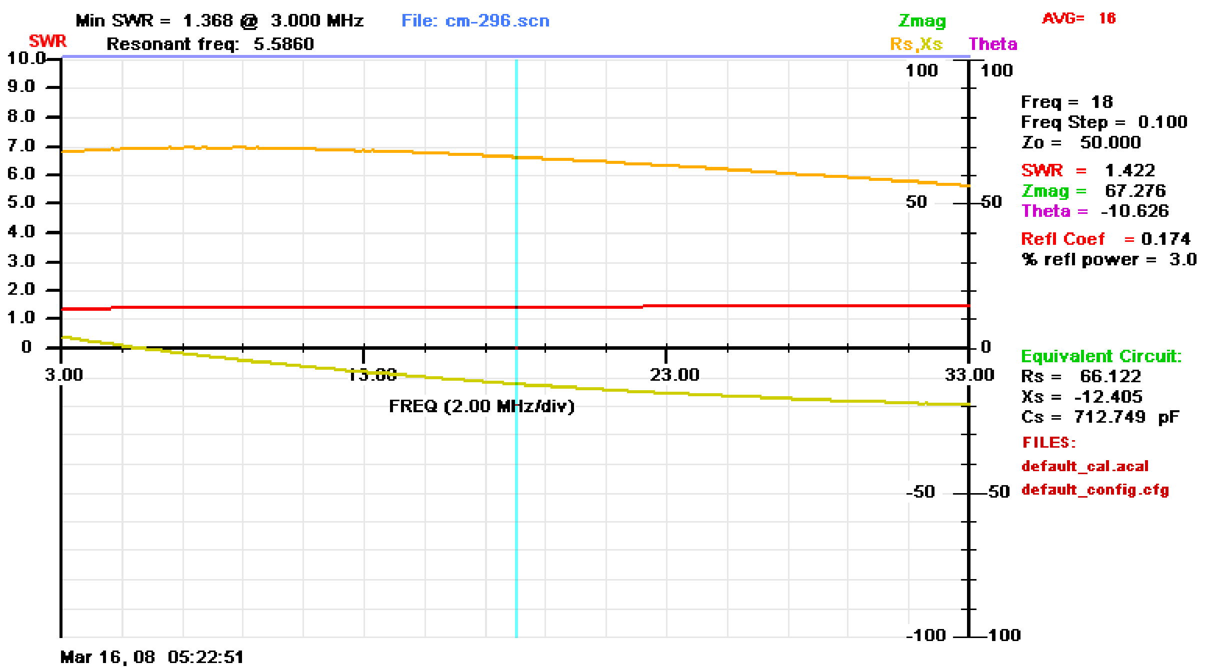
Fig. 15

Test 3: Balun with resistive load of 152.0 Ohms					
Load R	Ideal In R	Ld SWR	In SWR		
152.0	38.00	1.22	1.32		
Freq	SWR50	R	X	Adj Id R	Adj Id X
3.5	1.39	36.08	2.32	37.86	-0.15
7.0	1.37	36.49	1.87	37.85	-0.22
14.0	1.36	36.73	1.56	37.83	-0.38
28.0	1.00	36.61	1.70	37.78	-0.68
Delta	0.39	0.65	-0.17		

Test 4: Balun with resistive load of 100.3 Ohms					
Load R	Ideal In R	Ld SWR	In SWR		
100.3	25.08	1.85	1.99		
Freq	SWR50	R	X	Adj Id R	Adj Id X
3.5	2.07	24.24	1.76	25.06	0.03
7.0	2.05	24.40	1.99	25.06	0.09
14.0	2.05	24.47	2.91	25.06	0.20
28.0	2.05	24.73	5.00	25.05	0.42
Delta	0.02	0.49	3.24		

As the load value decreases, the total change of resistance and of reactance across the frequency spectrum increases. The amount is more numerically noticeable with respect to reactance than to resistance. However, neither total change would amount to something detectable in operation.

Test 5: 295 Ω and Test 6: 390 Ω: The next two tests use load resistance values higher than ideal, but with the SWR values of 1.33:1 and 2.0:1 as rough targets. **Fig. 16** and **Fig. 17** show the results graphically, with test sample tables to aid the identification of trends. The progression of higher load values show remarkably flat SWR curves. However, the resistance and reactance curves show distinct slopes. The resistance curve peaks in the 7 MHz region and declines thereafter. The decline is sharper with rising load values and the values never reach calculated ideal values. The reactance curves begin inductively at 3 MHz but become significantly more capacitive with rising frequency.

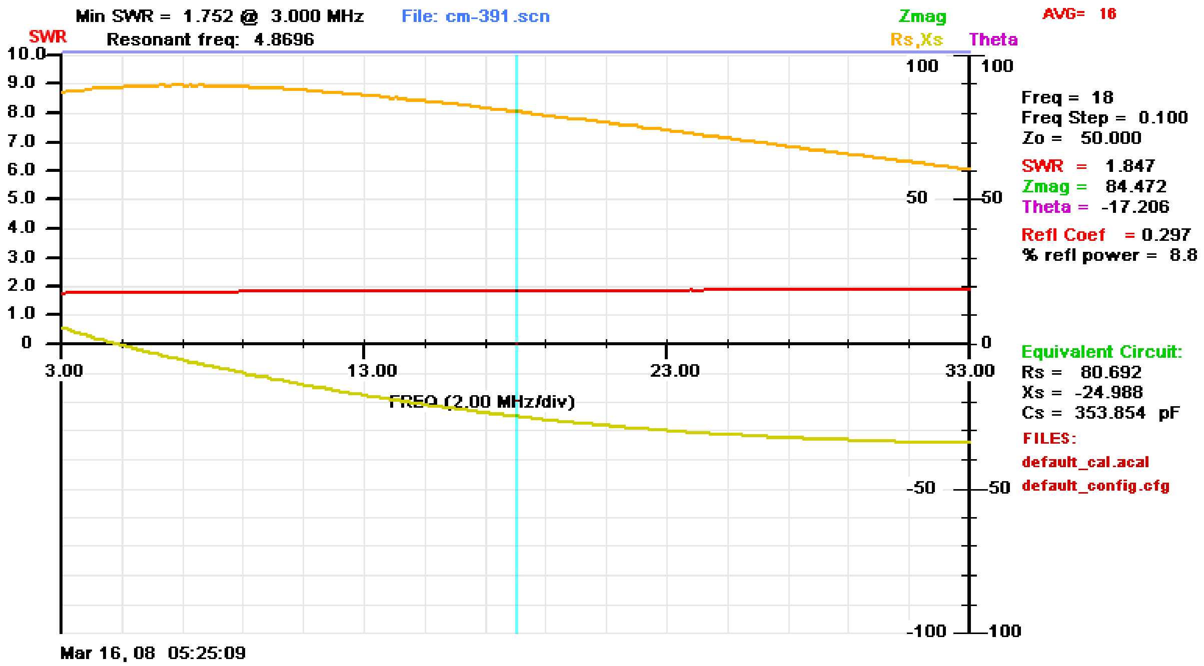


CSP TLT-4-C 4:1 Balun: 296.5 Ohms

Fig. 16

Test 5: Balun with resistive load of 296.5 Ohms					
Load R	Ideal In R	Ld SWR	In SWR		
296.5	74.13	1.59	1.48		
Freq	SWR50	R	X	Adj Id R	Adj Id X
3.5	1.37	67.86	4.91	73.91	-0.42
7.0	1.39	69.41	1.00	73.86	-1.10
14.0	1.40	69.42	-4.46	73.75	-2.46
28.0	1.42	65.90	-12.32	73.55	-5.19
Delta	0.04	3.52	-17.23		

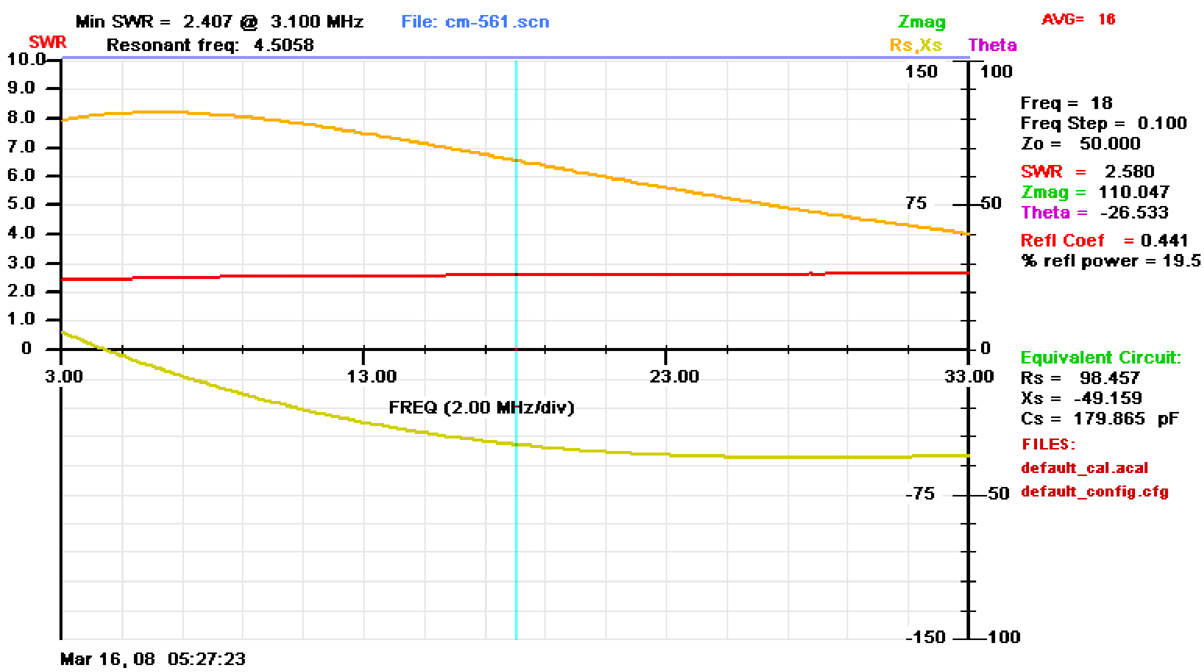
Test 6: Balun with resistive load of 391.5 Ohms					
Load R	Ideal In R	Ld SWR	In SWR		
391.5	97.88	2.10	1.96		
Freq	SWR50	R	X	Adj Id R	Adj Id X
3.5	1.76	87.12	7.07	97.40	-1.37
7.0	1.80	89.77	-0.14	97.27	-2.61
14.0	1.82	88.99	-10.66	97.01	-5.08
28.0	1.84	80.49	-24.98	96.50	-10.03
Delta	0.09	9.28	-32.05		



CSP TLT-4-C 4:1 Balun: 391.5 Ohms

Fig. 17

Test 7: 560 Ω: The final test load simulates an SWR value of about 3:1 at the load end of the balun. **Fig. 9** supplies the scan graph, with the test table below it. The trends that first appeared with the 296-Ω load continue. (Note the Y-axis expansion to 150 Ω maximum value to accommodate the input values.) The curves become steeper, except for the SWR line, which is close to flat. The slight rise in its value results largely from the fact that the capacitive reactance levels off above about 23 MHz and begins a slow decline toward the upper end of the scan spectrum.



CSP TLT-4-C 4:1 Balun: 561.0 Ohms

Fig. 18

Test 7: Balun with resistive load of 561.0 Ohms					
Load R	Ideal In R	Ld SWR	In SWR		
561.0	140.25	3.02	2.81		
Freq	SWR50	R	X	Adj Id R	Adj Id X
3.5	2.42	119.47	12.13	139.82	-2.61
7.0	2.49	124.42	-2.01	139.40	-5.13
14.0	2.54	121.63	-23.09	138.56	-10.16
28.0	2.57	100.63	-47.69	136.87	-20.23
Delta	0.15	23.79	-59.82		

Test 8: 181.2 – j117.3 Ω @ 14 MHz: The final test employs a single sample of a series combination of a load resistance and capacitance. The reactance shown results from the use of a 96-pF capacitor in series with the listed resistor. The goal of this test was to determine, at least for the sample, how close to ideal calculated input values that the balun transformation of resistance and reactance would come. The results from 13 to 15 MHz appear in the following test table.

Test 8: Balun with a complex load of 181.2 - j117.3 Ohms					
	Ideal SWR: 1.978:1				
	CSP TLT-4-C 4:1 Current Balun				
Freq	SWR50	R	X		
13	1.94	35.48	-24.41		
14	1.88	34.76	-22.03		
15	1.82	34.39	-19.63		

The table also lists the values obtained for the dual ferrite-bead 4:1 balun, since its values closely track calculated values (45.3 – j29.33 Ω at 14 MHz). The TLT-4-C balun values come closer to the bead balun and to the ideal than any other balun in this series of tests (which fall far short of sampling even a significant, let alone a major portion of the marketplace).

Conclusion

The Guanella 4:1 current balun has a target use of a relatively narrow range of load and input impedance values. The test scans used here are not intended to form a positive or negative judgment about baluns based on the use of load values with a considerable span of values. Rather, the goal has been to characterize balun performance within the limited scope of test units available for scanning with the AIM4170.

The test units in this part of these preliminary exercises in measuring the impedance transformation characteristics of 4:1 baluns employ two different approaches to constructing Guanella current baluns. The MFJ unit employed separate cores of low μ and used a larger winding per core (16 turns). In contrast, the CSP unit used a very-high-μ core with fewer turns per winding (3) and placed both windings on the same core. The CSP unit also appears to have used greater care in assuring that the bifilar winding maintained a characteristic impedance of 100 Ω.

As a consequence, the CSP balun lacks the resonance bump that appears in the MFJ unit near 11.5 MHz. In addition, its characteristics come closer to matching the performance shown by the dual ferrite-bead balun investigated in part 2 of this series of notes. To allow a readier comparison among the current baluns, the following table may be useful.

Comparisons Among Sampled 4:1 Current Baluns

Test 1: Balun with resistive load of 181.2 Ohms

	Dual Ferrite Bead Current Balun			MFJ-911 Current Balun			CSP TLT-4-C 4:1 Current Balun				
Freq	SWR50	R	X	SWR50	R	X	SWR50	R	X	Adj Id R	Adj Id X
3.5	1.12	44.73	0.56	1.19	42.87	3.32	1.17	43.13	2.73	45.54	-0.19
7.0	1.12	44.67	0.38	1.19	43.13	3.88	1.15	43.68	1.71	45.52	-0.37
14.0	1.14	44.06	0.45	1.24	43.31	7.48	1.14	43.84	0.51	45.50	-0.74
28.0	1.17	42.97	1.25	1.32	45.28	12.26	1.15	43.34	-0.67	45.46	-1.49
Delta	0.05	1.76	0.69	0.13	2.41	8.94	0.03	0.71	-3.40		

Test 2: Balun with resistive load of 221.4 Ohms

	Dual Ferrite Bead Current Balun			MFJ-911 Current Balun			CSP TLT-4-C 4:1 Current Balun				
Freq	SWR50	R	X	SWR50	R	X	SWR50	R	X	Adj Id R	Adj Id X
3.5	1.08	53.74	0.47	1.07	51.82	2.99	1.07	51.50	3.31	55.11	-0.36
7.0	1.07	53.68	-0.22	1.06	51.84	2.02	1.05	52.30	1.36	55.09	-0.70
14.0	1.06	52.85	-0.93	1.09	51.48	4.03	1.06	52.62	-0.95	55.05	-1.39
28.0	1.03	51.12	-1.24	1.11	50.93	5.36	1.09	51.35	-4.24	54.97	-2.76
Delta	0.04	2.62	-1.71	0.06	0.89	2.37	0.04	1.27	-7.55		

Test 3: Balun with resistive load of 152.0 Ohms

	Dual Ferrite Bead Current Balun			MFJ-911 Current Balun			CSP TLT-4-C 4:1 Current Balun				
Freq	SWR50	R	X	SWR50	R	X	SWR50	R	X	Adj Id R	Adj Id X
3.5	1.34	37.41	0.80	1.41	35.78	3.46	1.39	36.08	2.32	37.86	-0.15
7.0	1.35	37.21	0.86	1.42	36.00	5.03	1.37	36.49	1.87	37.85	-0.22
14.0	1.36	36.88	1.35	1.48	36.38	9.81	1.36	36.73	1.56	37.83	-0.38
28.0	1.39	36.14	2.90	1.58	39.51	17.54	1.00	36.61	1.70	37.78	-0.68
Delta	0.06	1.27	2.10	0.17	3.73	14.08	0.39	0.65	-0.17		

Test 4: Balun with resistive load of 100.3 Ohms

	Dual Ferrite Bead Current Balun			MFJ-911 Current Balun			CSP TLT-4-C 4:1 Current Balun				
Freq	SWR50	R	X	SWR50	R	X	SWR50	R	X	Adj Id R	Adj Id X
3.5	1.95	25.65	0.90	2.13	23.59	3.62	2.07	24.24	1.76	25.06	0.03
7.0	1.96	25.59	1.45	2.14	23.85	6.34	2.05	24.40	1.99	25.06	0.09
14.0	1.97	25.45	2.63	2.21	24.42	12.55	2.05	24.47	2.91	25.06	0.20
28.0	2.01	25.22	5.26	2.36	27.90	24.58	2.05	24.73	5.00	25.05	0.42
Delta	0.06	0.43	4.36	0.23	4.31	20.96	0.02	0.49	3.24		

Test 5: Balun with resistive load of 296.5 Ohms

	Dual Ferrite Bead Current Balun			MFJ-911 Current Balun			CSP TLT-4-C 4:1 Current Balun				
Freq	SWR50	R	X	SWR50	R	X	SWR50	R	X	Adj Id R	Adj Id X
3.5	1.44	71.76	-0.13	1.40	69.60	2.21	1.37	67.86	4.91	73.91	-0.42
7.0	1.43	71.27	-2.13	1.39	69.11	-2.29	1.39	69.41	1.00	73.86	-1.10
14.0	1.41	69.77	-4.29	1.35	66.81	-3.91	1.40	69.42	-4.46	73.75	-2.46
28.0	1.36	66.24	-7.13	1.26	58.92	-8.70	1.42	65.90	-12.32	73.55	-5.19
Delta	0.08	5.52	-7.00	0.14	10.68	-10.91	0.04	3.52	-17.23		

Test 6: Balun with resistive load of 391.5 Ohms

	Dual Ferrite Bead Current Balun			MFJ-911 Current Balun			CSP TLT-4-C 4:1 Current Balun				
Freq	SWR50	R	X	SWR50	R	X	SWR50	R	X	Adj Id R	Adj Id X
3.5	1.87	93.31	-1.07	1.83	91.65	0.91	1.76	87.12	7.07	97.40	-1.37
7.0	1.86	92.38	-5.07	1.82	89.65	-9.27	1.80	89.77	-0.14	97.27	-2.61
14.0	1.83	89.72	-10.18	1.76	83.27	-16.35	1.82	88.99	-10.66	97.01	-5.08
28.0	1.75	82.66	-16.22	1.64	62.70	-24.70	1.84	80.49	-24.98	96.50	-10.03
Delta	0.12	10.65	-15.15	0.19	28.95	-25.61	0.09	9.28	-32.05		

Test 7: Balun with resistive load of 561.0 Ohms

	Dual Ferrite Bead Current Balun			MFJ-911 Current Balun			CSP TLT-4-C 4:1 Current Balun				
Freq	SWR50	R	X	SWR50	R	X	SWR50	R	X	Adj Id R	Adj Id X
3.5	2.65	132.45	-3.28	2.62	131.17	-2.22	2.42	119.47	12.13	139.82	-2.61
7.0	2.63	130.29	-12.31	2.61	124.03	-25.85	2.49	124.42	-2.01	139.40	-5.13
14.0	2.56	122.75	-23.38	2.52	105.75	-41.57	2.54	121.63	-23.09	138.56	-10.16
28.0	2.43	107.11	-35.50	2.34	61.31	-47.24	2.57	100.63	-47.69	136.87	-20.23
Delta	0.22	25.34	-32.22	0.28	69.86	-45.02	0.15	23.79	-59.82		

All three baluns show different characteristics, as well as common features. In the region of the most ideal load values and with smaller load values, the current baluns are fairly precise impedance transforming devices. As we raise the resistance of the load, all three baluns tend to show greater departures from ideal impedance transformation values, although all yield relatively flat SWR curves. The dual ferrite-bead balun and the CSP unit show comparable performance with less variation tan the MFJ dual core unit. At the extreme 3:1 SWR load (561 Ohms), The MFJ unit shows less change in reactance across the scan spectrum, but a greater change in the measured input resistance. As well, the MFJ unit has a bump in the curve near 11.5 MHz that is lacking in the other two units.

Special Note

Measurements show that for the current baluns, with loads higher than the ideal load impedance, the resistance value at the input decreases with rising frequency. At the same time, the input reactance becomes increasingly capacitive for the same frequency range. The higher that the load resistance is relative to an ideal load, the steeper that the curves become for both resistance and reactance. At the same time, the 50-Ω SWR values calculated for the resistance and reactance remain relatively constant, even with the 561-Ω load.

The behavior of the resistance and reactance for loads that are not matched to the balun's characteristic impedance and configuration do not represent material limitations or similar possible flaws in design. Rather, they are inherent factors in the design itself. The balun consists of sections of transmission line operated over a wide frequency range. When we attach a load to a simple transmission line that is higher than the line's characteristic impedance, the input end of the line will show values of resistance and reactance follow the same patterns displayed by the baluns. As we increase the length of the transmission line within the first quarter wavelength, the resistance decreases more and the reactance becomes even more capacitive. The MFJ-911 has more turns than the CSP TLT unit (although the exact characteristic impedance of the 911 winding might not be certifiable) and therefore shows a greater reduction in resistance and a greater increase in capacitive reactance, despite a relatively stable set of SWR values.

In fact, the calculated values for simple lines are within a few percent of the measured values for the balun. Since the load resistors for these tests are not perfect, and since the test measurements have a limited range of precision, it is not possible to separate the transmission-line impedance transformation with unmatched loads from any other source of variation. For example, the CSP TLT unit with loads with greater than ideal resistance shows a low-frequency inductive reactance, a performance facet that falls outside the transmission-line account. For most practical purposes, however, the values shown by the measurements are in accord with the behavior of the loads relative to the impedance transformation properties of the transmission lines that underlie them.

For most applications that fall within small SWR limits, all three units would provide satisfactory impedance transformation service in the HF amateur bands. The ferrite bead-balun and the CSP TLT-4-C units are somewhat superior in this category of evaluation. The tests, of course, do not speak to the power-handling capabilities of any of the units. Nor do they assess the common-mode current attenuation characteristics of the units.

Moreover, the tests, while likely indicative of typical impedance transformation performance from well-designed baluns of each type, represent only a tiny portion of the available 4:1 balun units on the market. The tests—including the voltage baluns of part 3—are at most suggestive of what one can expect by way of impedance transformation from 4:1 baluns of past and present designs. Unfortunately, the purchaser of a balun may not be able to estimate performance from appearance, since so many available units come in sealed cases. The alternative is to actually measure the performance in tests similar to those undertaken here using either the inexpensive AIM4170 or a VNA capable of similar measurements.

All of the units tested in this series, except one purchased unit, were donated for the tests or borrowed. Therefore, the tests do not in any way represent an endorsement or criticism of any product. The tests arose out of curiosity relative to impedance transformation properties of 4:1 baluns bred by the relative absence of such information. The availability of a relatively accurate test instrument made the test possible. In one sense, these tests are only the first faltering steps toward fully characterizing balun performance for units effecting an impedance transformation as well as a transition from balanced to unbalanced terminal conditions. Over time, each part of this series may show some expansion if other units become available for testing. Ultimately, each balun user will have to be responsible for assessing the impedance transformation capabilities of any 4:1 balun purchased.