COIL / BALUN WINDING HELP SPREADSHEETS

By Ed Lawrence, WA5SWD

INTRODUCTION

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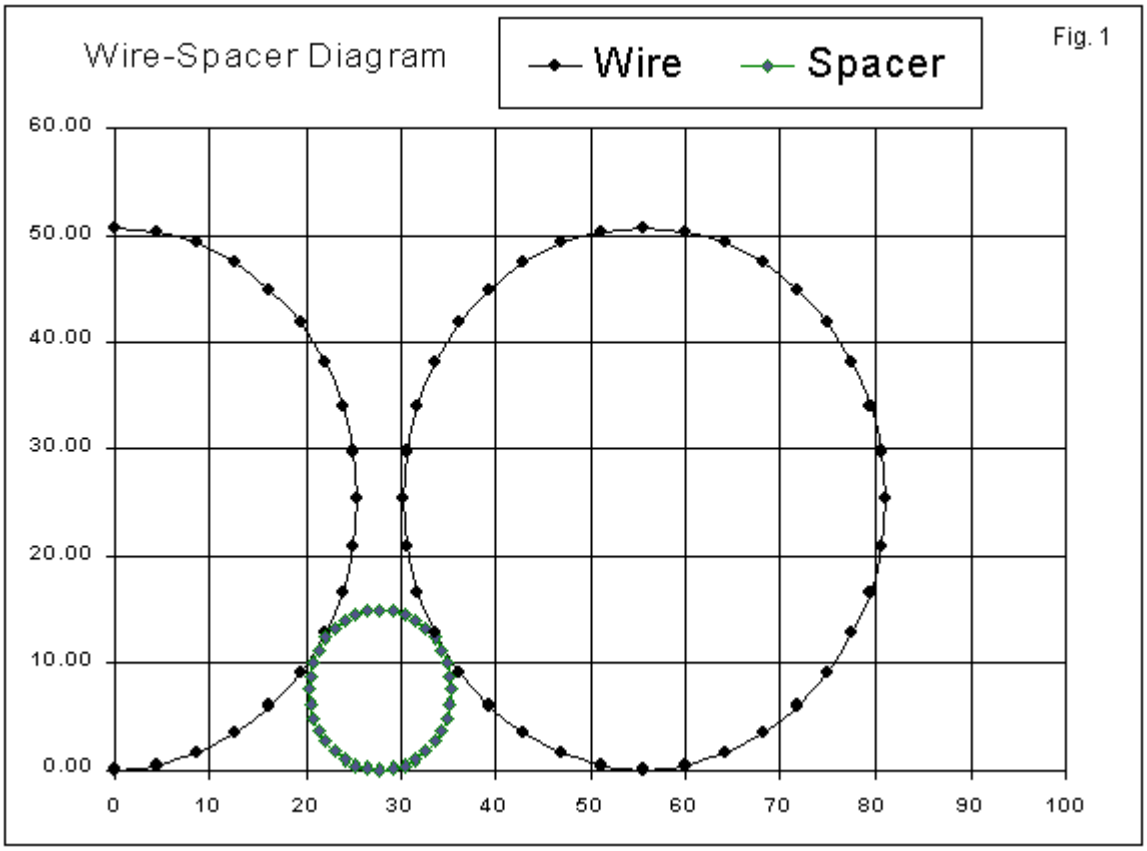
Recently, I have been winding and testing air core baluns. The testing is fairly easy since I have access to an HP 8753 Network Analyzer. Building them is time consuming. When I get done I'll write up an article on what I have found.

I have encountered problems with the mechanical aspects of balun or coil winding on PVC pipe as a form. There are only certain sizes available. We need to know these sizes if we intend to calculate the inductance.

The EXCEL spreadsheets here help with the mechanical design of coils or baluns.

Using the first sheet, we design the two wire balanced line. We choose the wire diameter and spacing. There is a handy table on page one for the usual sizes of magnet wire. There is another table for pipe sizes and thread pitch in case you can get threaded PVC pipe to use as a coil form. **Fig. 1**, taken from the spreadsheet, shows the general layout of the wires and the spacer.



The line impedance is calculated and displayed, using the formula for a pair of lines in vacuum or air, not near ground.

$$\mathbf{Z_o = 120 * \cosh^{-1}(Wire\ Spacing/Wire\ Diameter)}$$

We then choose the wire size and spacing to obtain the desired impedance. Since the spacer and form will lower this impedance a little, I try to err on the high side.

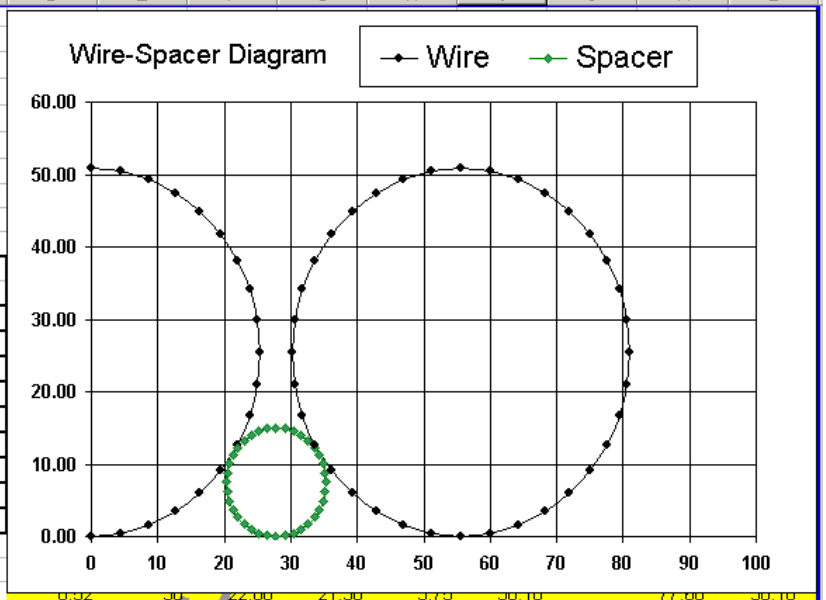
The primary function of the first sheet is to determine the size of the insulating spacer that must be wound between the wires to obtain a balanced line of the proper impedance. The wires and the spacer are plotted on a chart so you can see the wires in relationship to the spacer. It is an easy task to adjust the spacer diameter to correctly fill the gap between the wires. As you change the spacer or wire diameters, the display is updated to show the new relationship.

The first sheet Wire Table has wire size for AWG 8 down to AWG 24. Clearance drill sizes are also included.

NOTE: The examples in the text are just graphic examples. For the actual "live" EXCEL calculation worksheets, links are provided to load the sheets so the reader may run different examples.

I45 = WA5SWD

	A	B	C
1	***Note: Do not change cells with yellow fill.***		
2	ENTER		
3	Wire Radius	25.4	AWG #16
4	Wire Spacing	55.6	18 tpi
5	Z of bal. Line	51.76	
6	Spacer Diameter	15	
7	**Spacer X**	**27.8**	
8	**Spacer Y**	**7.5**	
9	Do not modify Spacer X and Y		
10	They will change automatically.		
11	**Wire Gauge**	**Wire Size**	**Clearance**
12	**AWG**	**inch**	**Drill**
13	8	0.1285	29
14	10	0.1019	37
15	12	0.0808	45
16	14	0.0641	51
17	16	0.0508	55
18	18	0.0403	59
19	20	0.032	66
20	22	0.0253	71
21	24	0.0201	74
22	Notes: I add about .0015 to radius for enamel.		
23	Example: Use #16 magnet wire to form		
24	a 55 ohm transmission line. Spacer is a		
25	round, low Relative Permitivity string. The		
26	non-air dielectric of the spacer will cause		
27	the Z to drop a bit.		
28	**Pipe**		
29	**Size**	**Threads/**	**Nom. OD (in)**
30	**(in)**	**Inch**	
31			
32	1/16	27	0.313
33	1/8	27	0.405
34	1/4	18	0.54
35	3/8	18	0.675
36	1/2	14	0.84
37	3/4	14	1.05
38	1	11 1/2	1.315
39	1 1/4	11 1/2	1.66
40	1 1/2	11 1/2	1.9
41	2	11 1/2	2.375
42	2 1/2	8	2.875
43	3	8	3.5
44	3 1/2	8	4
45	4	8	4.5



0.70	40	19.46	22.05	2.68	41.73	75.06	41.73
0.87	50	16.33	22.98	1.75	44.86	71.93	44.86
1.05	60	12.70	24.05	1.00	47.40	68.30	47.40
1.22	70	8.69	25.23	0.45	49.27	64.29	49.27
1.40	80	4.41	26.50	0.11	50.41	60.01	50.41
1.57	90	0.00	27.80	0.00	50.80	55.60	50.80
1.75	100	-4.41	29.10	0.11	50.41	51.19	50.41
1.92	110	-8.69	30.37	0.45	49.27	46.91	49.27
2.09	120	-12.70	31.55	1.00	47.40	42.90	47.40
2.27	130	-16.33	32.62	1.75	44.86	39.27	44.86
2.44	140	-19.46	33.55	2.68	41.73	36.14	41.73
2.62	150	-22.00	34.30	3.75	38.10	33.60	38.10
2.79	160	-23.87	34.85	4.93	34.09	31.73	34.09
2.97	170	-25.01	35.19	6.20	29.81	30.59	29.81
3.14	180	-25.40	35.30	7.50	25.40	30.20	25.40

Instructions: Look up wire DIAMETER in table. Enter RADIUS in B2. Enter Spacing in B3. The Z of the line will be shown in B4. Now correct the wire radius for the enamel . Change B2. Ignore the Z now shown in B4. Adjust the Spacer Diameter to just overlap the wire boundry. If you want to wind on a threaded plastic pipe, refer to the PIPE table for TPI. Divide into 1000 to get mils for Wire Spacing.(B3)

TPI = 18 | 55.56 | WA5SWD

[Click for live EXCEL Version of Sheet One]

G1 = WA5SWD

	A	B	C	D	E	F	G	H
1	*Note: Do not change cells with yellow fill.*						WA5SWD	
2	Small Coil Inductance-Single Layer Solenoid							
3	N is number of turns. Note: Include1/2 turns							
4	Inductance is in uH or 1E-6H							
5	uH = ((R^2)*(N^2))/((9*R)+(10*L)							
6	This is for single layer coils. For baluns, enter the values for one winding							
7	All in inches							
8	Wire Diameter	0.051						
9	Wire Spacing	0.056						
10	Coil Radius	0.551	0.683	0.856	0.976	1.213	1.463	0.446
11	Coil Length	0.555	0.471	0.387	0.359	0.331	0.303	0.695
12	Input N	9	7.5	6	5.5	5	4.5	11.5
13	uH	2.34	2.42	2.28	2.33	2.59	2.68	2.39
14	nH	2336.81	2418.14	2277.34	2327.17	2585.52	2675.96	2394.97
15	WIRE LENGTH	34.24	35.14	35.03	36.43	40.77	43.97	35.58
16	Form Length, bifilar	1.12	1.03	0.95	0.92	0.89	0.87	1.26
17	F_{low}(MHz)	3.50	3.50	3.50	3.50	3.50	3.50	3.50
18	X_L at F_{low}	51.39	53.18	50.08	51.18	56.86	58.85	52.67
19								

20	Schedule 40 Dimensions				Wire Gauge	Wire Size	Clearance
21	Pipe Size (in)	O.D.	I.D.	Wall	AWG	inch	Drill
22	1/8"	0.405	0.249	0.068	8	0.129	29
23	1/4"	0.54	0.344	0.088	10	0.102	37
24	3/8"	0.675	0.473	0.091	12	0.081	45
25	1/2"	0.84	0.602	0.109	14	0.064	51
26	3/4"	1.05	0.804	0.113	16	0.051	55
27	1"	1.315	1.029	0.133	18	0.040	59
28	1-1/4"	1.66	1.36	0.14	20	0.032	66
29	1-1/2"	1.9	1.59	0.145	22	0.025	71
30	2"	2.375	2.047	0.154	24	0.020	74
31	2-1/2"	2.875	2.445	0.203			
32	3"	3.5	3.042	0.216			
33	3-1/2"	4	3.521	0.226			
34	4"	4.5	3.998	0.237			
35							

Click for live EXCEL Version of Sheet Two

Sheet two above does the basic calculations to estimate coil inductance from wire size, form diameter, and coil length. You enter Wire Diameter, Wire Spacing, number of turns, Frequency and Coil Radius. Coil Radius is naturally 1/2 the form diameter. The sheet calculates the inductance and the reactance at your frequency of interest. There is more Pipe sizes and Wire Tables here for easy reference.

N58 = WA5SWD

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**Drill**	**Decimal**	**mm**		**Drill**	**Decimal**	**mm**		**Drill**	**Decimal**	**mm**		**Drill**	**Decimal**	**mm**
2	80	0.0135				0.0610	1.55			0.1220	3.1		6	0.2040	
3		0.0138	0.35		1/16	0.0625			1/8	0.1250				0.2047	5.2
4	79	0.0145				0.0630	1.6			0.1260	3.2		5	0.2055	
5	1/64	0.0156			52	0.0635				0.1280	3.25			0.2067	5.25
6		0.0157	0.4			0.0650	1.65		30	0.1285				0.2087	5.3
7	78	0.0160				0.0669	1.7			0.1299	3.3		4	0.2090	
8		0.0177	0.45		51	0.0670				0.1339	3.4			0.2126	5.4
9	77	0.0180				0.0689	1.75		29	0.1360			3	0.2130	
10		0.0197	0.5		50	0.0700				0.1378	3.5			0.2165	5.5
11	76	0.0200				0.0709	1.8		28	0.1405			7/32	0.2188	
12	75	0.0210				0.0728	1.85		9/64	0.1406				0.2205	5.6
13		0.0217	0.55		49	0.0730				0.1417	3.6		2	0.2210	
14	74	0.0225				0.0748	1.9		27	0.1440				0.2244	5.7
15		0.0236	0.6		48	0.0760				0.1457	3.7			0.2264	5.75
16	73	0.0240				0.0768	1.95		26	0.1470			1	0.2280	
17	72	0.0250			5/64	0.0781				0.1476	3.75			0.2283	5.8
18		0.0256	0.65		47	0.0785			25	0.1495				0.2323	5.9
19	71	0.0260				0.0787	2			0.1496	3.8		A	0.2340	
20		0.0276	0.7			0.0807	2.05		24	0.1520			15/64	0.2344	
21	70	0.0280			46	0.0810				0.1535	3.9			0.2362	6
22	69	0.0292			45	0.0820			23	0.1540			B	0.2380	
23		0.0295	0.75			0.0827	2.1		5/32	0.1562				0.2402	6.1
24	68	0.0310				0.0846	2.15		22	0.1570			C	0.2420	
25	1/32	0.0313			44	0.0860				0.1575	4			0.2441	6.2
26		0.0315	0.8			0.0866	2.2		21	0.1590			D	0.2460	
27	67	0.0320				0.0886	2.25		20	0.1610				0.2461	6.25
28	66	0.0330			43	0.0890				0.1614	4.1			0.2480	6.3
29		0.0335	0.85			0.0906	2.3			0.1654	4.2		E	0.2500	
30	65	0.0350				0.0925	2.35		19	0.1660			1/4	0.2500	
31		0.0354	0.9		42	0.0935				0.1673	4.25			0.2520	6.4
32	64	0.0360			3/32	0.0938				0.1693	4.3			0.2559	6.5
33	63	0.0370				0.0945	2.4		18	0.1695			F	0.2570	
34		0.0374	0.95		41	0.0960			11/64	0.1719				0.2598	6.6
35	62	0.0380				0.0965	2.45		17	0.1730			G	0.2610	
36	61	0.0390			40	0.0980				0.1732	4.4			0.2638	6.7
37		0.0394	1			0.0984	2.5		16	0.1770			17/64	0.2656	
38	60	0.0400			39	0.0995				0.1772	4.5			0.2657	6.75
39	59	0.0410				0.1004	2.55		15	0.1800			H	0.2660	
40		0.0413	1.05		38	0.1015				0.1811	4.6			0.2677	6.8
41	58	0.0420				0.1024	2.6		14	0.1820				0.2717	6.9
42	57	0.0430			37	0.1040			13	0.1850			I	0.2720	
43		0.0433	1.1			0.1043	2.65			0.1850	4.7			0.2756	7
44		0.0453	1.15			0.1063	2.7			0.1870	4.75		J	0.2770	
45	56	0.0465			36	0.1065			3/16	0.1875				0.2795	7.1
46	3/64	0.0469				0.1083	2.75		12	0.1890			K	0.2810	
47		0.0472	1.2		7/64	0.1094				0.1890	4.8		9/32	0.2812	
48		0.0492	1.25		35	0.1100			11	0.1910				0.2835	7.2
49		0.0512	1.3			0.1102	2.8			0.1929	4.9			0.2854	7.25
50	55	0.0520			34	0.1110			10	0.1935				0.2874	7.3
51		0.0531	1.35		33	0.1130			9	0.1960			L	0.2900	
52	54	0.0550				0.1142	2.85			0.1969	5			0.2913	7.4
53		0.0551	1.4		32	0.1160			8	0.1990			M	0.2950	
54		0.0571	1.45			0.1181	2.9			0.2008	5.1			0.2953	7.5
55		0.0591	1.5			0.1181	3		7	0.2010			19/64	0.2969	
56	53	0.0595			31	0.1200			13/64	0.2031				0.2992	7.6

N58 = WA5SWD

Drill	Decimal	mm
N	0.3020	
	0.3031	7.7
	0.3051	7.75
	0.3071	7.8
	0.3110	7.9
5/16	0.3125	
	0.3150	8
O	0.3160	
	0.3189	8.1
	0.3228	8.2
P	0.3230	
	0.3248	8.25
	0.3268	8.3
21/64	0.3281	
	0.3307	8.4
Q	0.3320	
	0.3346	8.5
	0.3386	8.6
R	0.3390	
	0.3425	8.7
11/32	0.3438	
	0.3445	8.75
	0.3465	8.8
S	0.3480	
	0.3504	8.9
	0.3543	9
T	0.3580	
	0.3583	9.1
23/64	0.3594	
	0.3622	9.2
	0.3642	9.25
	0.3661	9.3
U	0.3680	
	0.3701	9.4
	0.3740	9.5
3/8	0.3750	
V	0.3770	
	0.3780	9.6
	0.3819	9.7
	0.3839	9.75
	0.3858	9.8
W	0.3860	
	0.3898	9.9
25/64	0.3906	
	0.3937	10
X	0.3970	
Y	0.4040	
13/32	0.4062	
Z	0.4130	
	0.4134	10.5
27/64	0.4219	
	0.4331	11
7/16	0.4375	
	0.4528	11.5
29/64	0.4531	

Drill	Decimal	mm
15/32	0.4688	
	0.4724	12
31/64	0.4844	
	0.4921	12.5
1/2	0.5000	
	0.5118	13
33/64	0.5156	
17/32	0.5313	
	0.5315	13.5
35/64	0.5469	
	0.5512	14
9/16	0.5625	
	0.5709	14.5
37/64	0.5781	
	0.5906	15
19/32	0.5938	
39/64	0.6094	
	0.6102	15.5
	0.6229	16
5/8	0.6250	
41/64	0.6406	
	0.6496	16.5
21/32	0.6562	
	0.6693	17
43/64	0.6719	
11/16	0.6875	
	0.6890	17.5
45/64	0.7031	
	0.7087	18
23/32	0.7188	
	0.7283	18.5
47/64	0.7344	
	0.7480	19
3/4	0.7500	
49/64	0.7656	
	0.7677	19.5
25/32	0.7812	
	0.7874	20
51/64	0.7969	
	0.8071	20.5
13/16	0.8125	
	0.8268	21
53/64	0.8281	
27/32	0.8438	
	0.8465	21.5
55/64	0.8594	
	0.8661	22
7/8	0.8750	
	0.8858	22.5
57/64	0.8906	
	0.9055	23
29/32	0.9062	
59/64	0.9219	
	0.9252	23.5
15/16	0.9375	

Drill	Decimal	mm
	0.9449	24
61/64	0.9531	
	0.9646	24.5
31/32	0.9688	
	0.9843	25
63/64	0.9844	
1	1.0000	

SCREW	TAP	BODY
#80	3/64	1/16
#1	53	49
#2	50	44
#3-48	47	39
#3-56	45	39
#4-40	43	33
#4-48	42	33
#5-38	38	1/8
#5-44	37	1/8
#6-32	36	28
#6-40	33	28
#8	29	19
#10-25	25	11
#10-32	21	11
#12-24	16	7/32
#12-28	14	7/32
1/4-28	3	1/4
1/4-20	7	1/4
5/16-18	F	5/16
5/16-24	I	5/16
3/8-24	Q	3/8
7/16 -14	U	7/16
7/16 -20	25/64	7/16
1/2	29/64	1/2
9/16-12	31/64	9/16
9/16-18	33/64	9/16
5/8-11	17/32	5/8
5/8-18	37/64	5/8
3/4-10	21/32	3/4
3/4-16	11/16	3/4
7/8-9	49/64	7/8
7/8-14	13/16	7/8
1-8	7/8	1
1-14	7/8	1

WA5SWD

Sheet three (the 2 images above) has drill sizes with decimal inch values. Metric drills are included. Then, because there was room, I included tap and body drill information for machine screws from #80 up to 1 inch.

Click for live EXCEL Version of Sheet Three

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Brief Biography of the Author

Ed Lawrence has worked as an Electronic Technician since 1958. He has been active in Amateur Radio since 1964 and presently holds an Extra Class License. Over the years his writing credits include articles in 73 magazine, QCWA, various club newsletters and www.antennex.com. Ed has worked at a lot of interesting places, including North American Aviation, Lear Stereo Division and Texas Instruments, from which he retired in 1991. Since then Ed has worked mostly as a Contract IC Mask Designer on microprocessor and cell phone chips for many of the major players. Work locations have varied but include Switzerland, Ireland, Pennsylvania, Texas, Arizona, Washington and Oregon. Ed also has his Certified Flight Instructors rating, but is not presently a very active pilot due to his nomadic life style. Presently Ed works at RFSAW, Inc in the Dallas, TX area. There he assists in test and development for RFID Passive Global Tags.

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