Pennant Antenna with Remote Termination Control

Mark Connelly, WA1ION - 19 JUL 2000

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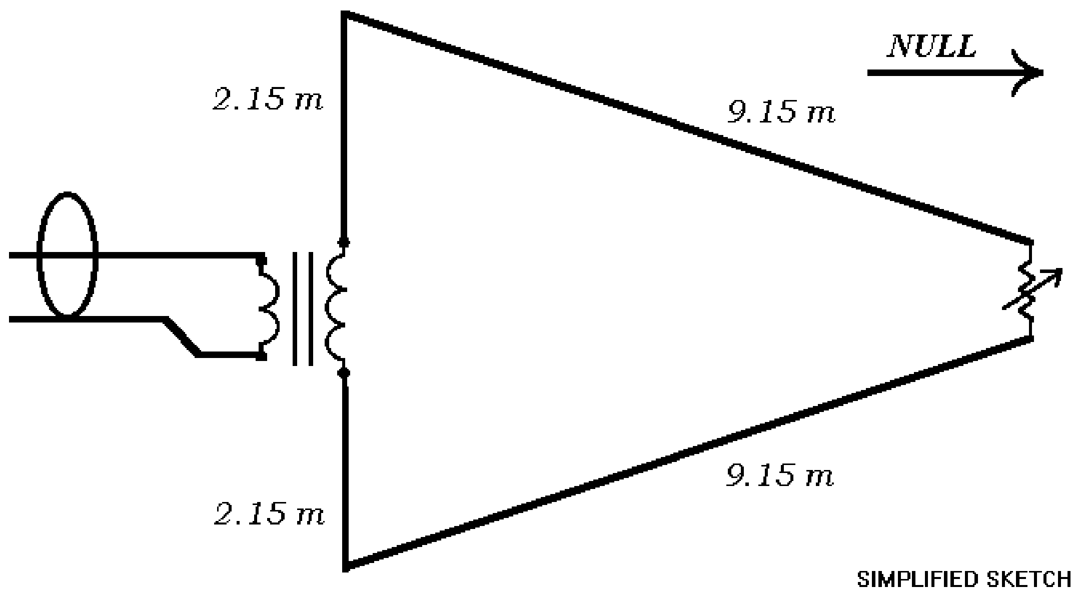


Introduction

The July 2000 issue of QST magazine published an article by Earl W. Cunningham, K6SE, entitled "Flags, Pennants, and Other Ground-Independent Low Band Receiving Antennas". The work presented in the article includes research by several other hams including Jose, EA3VY. The class of antennas discussed comprises single-turn loops terminated on the side opposite the feedpoint. The termination effects a null off the end where the terminator is located, thereby producing a cardioid (heart-shaped) directional pick-up pattern. The antenna is broadband rather than resonant. The pattern produced holds up well over a wide frequency range. Earl has run EZNEC computer simulations to calculate lengths which give a non-reactive feedpoint impedance to ensure wideband coverage. The dimensions of the antenna are small enough to permit installation in the backyards of typical suburban residences. See the figure above for pennant style antenna dimensions derived from computer optimizations.

What I have done to improve upon the original concept is to incorporate the remote termination control methods previously used with great success by Steve Byan for Beverage termination and, subsequently, by Al Merriman and Andy Ikin, for K9AY Loop termination. The merits of both of these prior implementations have been conclusively validated in real-world experiences during several Newfoundland DXpeditions.

The remotely-controlled resistance element is a "Vactrol", part number VTL5C4, made by Perkin-Elmer, formerly EG&G Vactec. It uses an LED optically coupled to a photoresistor. At 0 mA through the LED, the photoresistor is a high value, greater than 10K ohms. At 30 mA LED current, the photoresistor value decreases to less than 60 ohms. Intermediate values of LED current produce intermediate resistance values. DC is fed to the LED through RF chokes to prevent undesired loading effects at radio frequencies. DC blocking capacitors allow RF to go through the photoresistor termination without letting DC flow through it.

Remote control of the pennant's termination resistance provides optimum null depth on the principal axis (in the direction that points towards, and beyond, the termination as viewed from the feedpoint). Additionally, test data taken indicate that termination adjustment allows a certain degree of null slewing up to about 45 degrees off the principal null axis. Achievable null depth decreases as a null is placed farther (in an angular sense) from the principal axis, but slewing the null by using a slightly different termination resistance can still produce a superior null in that direction than if the deepest principal-axis null was used instead. An example would be an antenna configured with the termination west of the feedpoint. Station "A" is due west and station "B" is northwest. With the termination adjusted for the typical 35 dB or better west null of Station "A", station "B" is down about 13 dB (based on the curves in Earl's article). By slewing the null with a slightly different termination resistance, the reduction of station "A" would deteriorate, but rejection of "B" may be increased to 20 dB or so. This finding has been determined by experimentation; I have no formal simulation data to back it up. In any event, there are differences in optimum termination resistance which are affected by bearing, frequency, skip angle, weather, stray coupling to external objects / structures, and imperfections in the load at the feedpoint of the antenna. Because of these variations in the resistance needed for each optimum null solution, the ability to control the termination remotely is highly desirable, just as in the case of the K9AY Loop.

Pennant antennas seem to have a bit deeper null than Flag antennas (a rectangular version of the design), so the pennant will be the main focus of this article. Earl Cunningham's article goes into all the design permutations and it gives detailed directional patterns. His use of all these antenna types concentrates on their application in the 160, 80, and 40 meter ham bands (1.8, 3.5, and 7 MHz). I corresponded with Earl via e-mail to see if he could suggest any alterations of the design for usage on medium-wave frequencies (500 to 1800 kHz). He stated that the original dimensions would work fine, just that the efficiency (sensitivity) would be low and that amplification would be required to get gain anywhere near that of slopers, longwires, dipoles, or other conventional outdoor antennas.

See my BBVA-A documentation at *http://www.qsl.net/wa1ion/bbva/bbva_a.htm* for an amplifier design which may be suitable.

Testing

Tests were performed at a site in West Yarmouth, MA as well as at my home in Billerica, MA. Findings at both locations were similar. At Billerica, maximum amplifier gain is limited because 50 kW WRKO-680 is only 5 km / 3 miles away. Amplifier or receiver overloading may be caused by WRKO and several other locals including WNRB-1510. Furthermore, the local electrical noise at Billerica (from nearby TV's, light dimmers, computers, etc.) sometimes exceeds S9, making weaker signal evaluation difficult or impossible. For these reasons, the tables below represent measurements taken at the site on Trowbridge Path in West Yarmouth (GC= 70.223 W / 41.682 N).

The vertical portion of the antenna was supported by a nylon rope going to the top of a 15 m / 50 ft. pitch pine tree. The rope was adjusted for a bottom insulator height of about 3 m: that made the top insulator height about 7.3 m. The bottom insulator was tied via nylon rope to a tent stake to provide correct tension on the vertical section of the pennant. The termination end, west of the feedpoint, was supported by a plastic-hooked non-conductive bungee cord going to low branches in another pine tree. As direct measurement of termination resistance was not possible during operation, the voltage measured at the arm of the controller's potentiometer was recorded instead. Table 3 below relates this voltage to the termination photoresistor's ohmic value.

The test results show that the pennant antenna with remote termination provides a cardioid pick-up pattern from a single antenna without the need for a phasing unit. Tests with a K9AY antenna in the same position at the West Yarmouth site a month earlier showed best-case nulls of only about 15 dB. The ground at the site is almost pure sand, so I'm sure that the more-fussy grounding requirements of the K9AY degraded its performance. The beauty of the pennant and similar designs is that ground conditions do not have much effect on the achievable null depth. A properly-constructed pennant should have at least 30 dB of null depth on the principal axis even in situations as different as a salt-marsh or a pile of rocks and sand. Height of the pennant antenna doesn't have all that much effect either (although I don't think that the bottom point should be much lower than about 2 m / 6.6 ft.). The main benefit of raising the antenna to a much greater height would be to reduce local electrical noise and, perhaps, to increase sensitivity a bit in poor-ground areas.

Coaxial Cable versus Twinlead feed

A system fed with 50 ohm coaxial cable requires Coaxial Controller, Feedpoint, and Termination box assemblies.

The Feedpoint Box provides an impedance transformation from approximately 800 ohms antenna impedance to 50 ohms receiver input impedance. This is done by means of a 16:1 RF transformer, Mini-Circuits part number T16-6T-X65 or a suitable homebrew equivalent.

A system fed with 300 ohm twinlead requires just a Twinlead Controller box and a Termination box. Twinlead goes from the controller straight to the antenna feedpoint, at which it is connected directly to the upper and lower wires of the pennant. The required impedance transformer is located in the Twinlead Controller Box.

Maximum suggested twinlead feedline length is about 30 m / 100 ft. Coaxially-fed systems can be located farther from the operating position, perhaps as much as 100 m / 328 ft. without a great amount of signal loss below 2 MHz.

The layouts of the Controller, Feedpoint, and Termination boxes are not critical. Documentation presented herein is limited to electrical schematics. Commonly-available parts are noted by value only. Unusual components are noted with vendor stock numbers. For a list of parts vendors I use often, check *http://members.aol.com/MarkWA1ION/vendors.htm* .

Test data tables below are for a coaxially-fed unamplified pennant antenna (Table 1) and for a twinlead-fed pennant system with a BBVA-A amplifier providing about 30 dB of gain (Table 2).

Stations shown are a representative sample. For an "unabridged" daytime bandscan at this site, go to "*http://www.geocities.com/MarkWA1ION/w_yarmouth_day_scan.htm*".

<u>Table 1: Pennant Antenna fed with Coaxial Cable (employing Coaxial Controller, Feedpoint, and Termination boxes) - no amplification:</u>

					COAXIAL CABLE IMPLEMENTATION				
			BEARING		dB o/S-0	*ohms*	dB o/S-0	*ohms*	dB
FREQ	CALL	ST.	DEG		**Pennant**	***Pennant***	**Pennant**	***Pennant***	**null depth**
					peak	***peak R***	**null**	***null R***	
730	WJTO	ME	6.98		**45**	***> 20K***	**39**	***54***	**6**
620	WZON	ME	17.87		**34**	***> 20K***	**30**	***54***	**4**
910	WABI	ME	18.69		**33**	***> 20K***	**30**	***54***	**3**
1170	WFPB	MA	82.99		**56**	***> 20K***	**52**	***54***	**4**
1240	WBUR	MA	189.49		**89**	***> 20K***	**82**	***486***	**7**
820	WNYC	NY	253.68		**38**	***54***	**9**	***1197***	**29**
570	WMCA	NY	253.68		**39**	***54, > 20K***	**15**	***970***	**24**
880	WCBS	NY	254.16		**48**	***54***	**15**	***970***	**33**
660	WFAN	NY	254.16		**51**	***> 20K***	**27**	***1197***	**24**
1130	WBBR	NY	254.25		**28**	***54, > 20K***	**9**	***1135***	**19**
710	WOR	NY	254.32		**39**	***> 20K***	**12**	***1070***	**27**
1050	WEVD	NY	254.50		**44**	***54***	**15**	***1018***	**29**
1010	WINS	NY	254.60		**45**	***54***	**15**	***970***	**30**
770	WABC	NY	255.53		**38**	***54***	**9**	***970***	**29**
1340	WNBH	MA	263.89		**51**	***> 20K***	**33**	***1018***	**18**
1420	WBSM	MA	266.99		**48**	***> 20K***	**30**	***1018***	**18**
1590	WARV	RI	273.36		**42**	***> 20K***	**15**	***970***	**27**
1480	WSAR	MA	273.79		**45**	***54, > 20K***	**18**	***1018***	**27**
630	WPRO	RI	276.91		**43**	***54, > 20K***	**21**	***1018***	**22**
920	WHJJ	RI	277.34		**27**	***54***	**6**	***923***	**21**
790	WSKO	RI	280.61		**39**	***54***	**18**	***781***	**21**
550	WLKW	RI	284.73		**48**	***> 20K***	**15**	***752***	**33**
990	WALE	RI	285.23		**42**	***54, > 20K***	**9**	***843***	**33**

810	WGY	NY	292.96	24	> 20K	3	678	21
760	WVNE	MA	293.01	51	> 20K	15	616	36
830	WCRN	MA	294.60	36	> 20K	9	635	27
890	WBPS	MA	302.83	51	54	30	524	21
1200	WKOX	MA	304.41	45	> 20K	12	616	33
1060	WMEX	MA	304.43	51	> 20K	24	498	27
850	WEEI	MA	307.88	58	> 20K	39	472	19
1390	WPLM	MA	308.91	62	> 20K	45	616	17
1600	WUNR	MA	310.38	45	> 20K	27	535	18
1330	WRCA	MA	311.40	42	> 20K	15	524	27
1260	WMKI	MA	314.27	51	> 20K	33	432	18
1510	WNRB	MA	314.45	48	> 20K	27	486	21
1150	WAMG	MA	315.24	50	> 20K	32	360	18
1300	WJDA	MA	316.11	48	> 20K	33	472	15
740	WJIB	MA	316.31	44	> 20K	27	444	17
680	WRKO	MA	317.90	66	> 20K	51	335	15
590	WEZE	MA	318.74	61	> 20K	48	372	13
1430	WXKS	MA	319.01	58	> 20K	43	472	15
1090	WILD	MA	319.33	59	> 20K	44	322	15
1030	WBZ	MA	321.06	64	> 20K	48	303	16
950	WROL	MA	323.04	70	> 20K	54	353	16
1360	WLYN	MA	324.23	60	> 20K	45	285	15
800	WCCM	MA	324.43	42	> 20K	26	326	16
610	WGIR	NH	327.26	42	> 20K	27	303	15
1230	WESX	MA	330.63	54	> 20K	42	232	12
1570	WNSH	MA	332.68	42	> 20K	30	54	12
1450	WNBP	MA	337.65	51	> 20K	39	54	12
930	WGIN	NH	341.76	45	> 20K	33	54	12
1270	WTSN	NH	342.93	42	> 20K	30	54	12
870	WLAM	ME	354.28	44	> 20K	34	54	10

1440	WJAE	ME	356.69		48	> 20K	39	54	9
970	WZAN	ME	357.81		59	> 20K	45	54	14
560	WGAN	ME	358.01		51	> 20K	45	> 20K	6
1490	WBAE	ME	358.93		45	> 20K	39	54	6

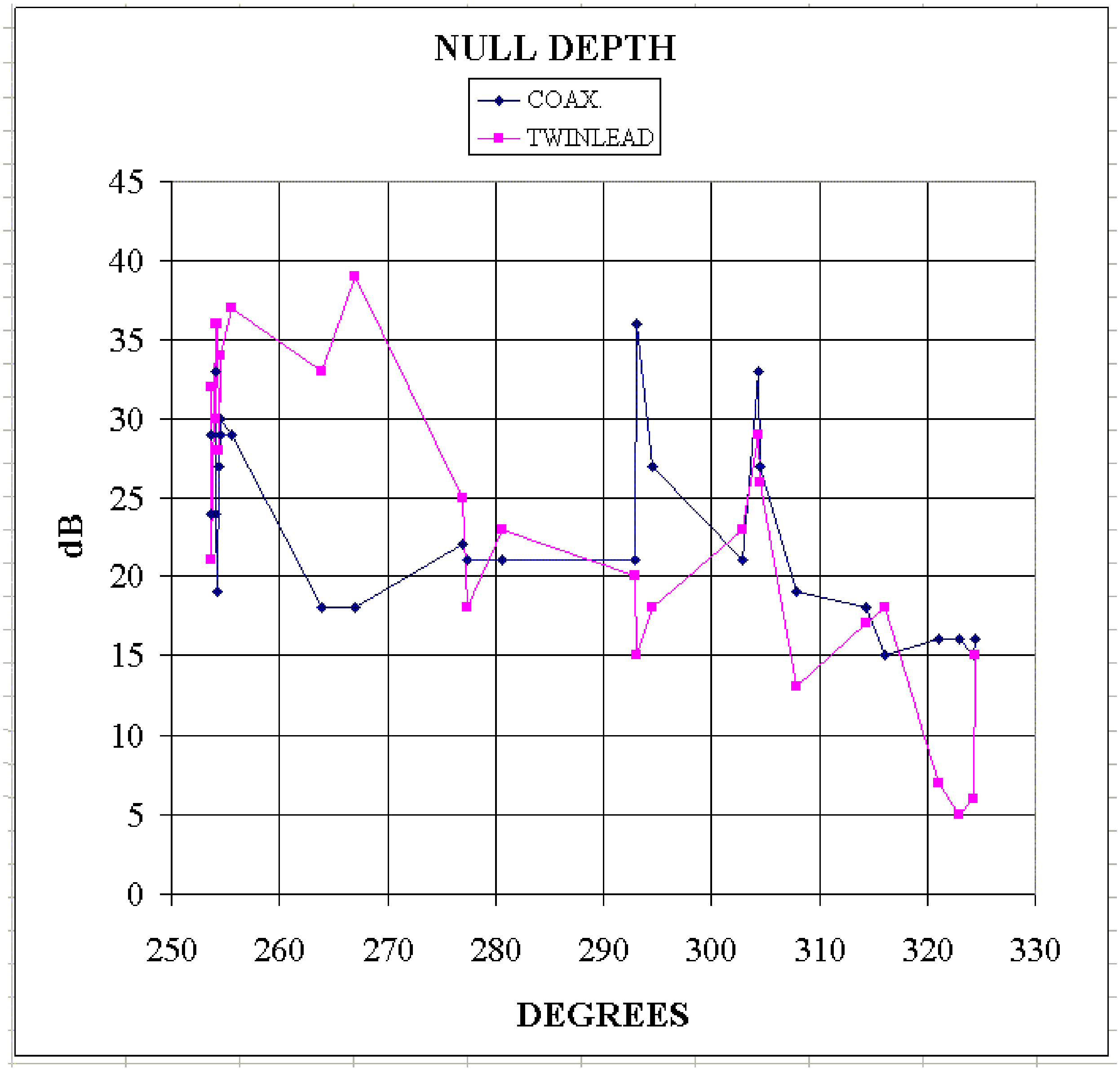
Table 2: Pennant Antenna fed with Twinlead Cable (employing Twinlead Controller and Termination boxes), 30 dB amplification:

					TWINLEAD IMPLEMENTATION				
			BEARING		dB o/S-0	*ohms*	dB o/S-0	*ohms*	dB
FREQ	CALL	ST.	DEG		**Pennant**	***Pennant***	**Pennant**	***Pennant***	**null depth**
					peak	***peak R***	**null**	***null R***	
620	WZON	ME	17.87		63	> 20K	60	54	3
910	WABI	ME	18.69		59	no var.	59	no var.	0
1170	WFPB	MA	82.99		88	54	84	> 20K	4
1240	WBUR	MA	189.49		119	54	84	2300	35
820	WNYC	NY	253.68		71	54	39	1135	32
570	WMCA	NY	253.68		73	> 20K	52	879	21
880	WCBS	NY	254.16		87	54	51	843	36
660	WFAN	NY	254.16		88	54	58	923	30
1130	WBBR	NY	254.25		81	54	45	1018	36
710	WOR	NY	254.32		73	54	45	970	28
1050	WEVD	NY	254.50		82	54	48	923	34
1010	WINS	NY	254.60		84	54	50	970	34
770	WABC	NY	255.53		70	54	33	879	37
1340	WNBH	MA	263.89		89	54	56	1018	33
1420	WBSM	MA	266.99		84	54	45	1135	39
630	WPRO	RI	276.91		81	> 20K	56	752	25
920	WHJJ	RI	277.34		60	54	42	879	18
790	WSKO	RI	280.61		74	54	51	923	23
1290	WRNI	RI	281.30		79	54	42	923	37

810	WGY	NY	292.96	**56**	***54***	**36**	***582***	**20**
760	WVNE	MA	293.01	**66**	***54, >20K***	**51**	***551***	**15**
830	WCRN	MA	294.60	**66**	***54***	**48**	***598***	**18**
890	WBPS	MA	302.83	**84**	***54***	**61**	***524***	**23**
1200	WKOX	MA	304.41	**83**	***54***	**54**	***678***	**29**
1060	WMEX	MA	304.43	**84**	***54***	**58**	***565***	**26**
850	WEEI	MA	307.88	**89**	***> 20K***	**76**	***480***	**13**
1260	WMKI	MA	314.27	**89**	***54***	**72**	***486***	**17**
1300	WJDA	MA	316.11	**82**	***54***	**64**	***455***	**18**
1030	WBZ	MA	321.06	**93**	***54***	**86**	***278***	**7**
950	WROL	MA	323.04	**94**	***54***	**89**	***306***	**5**
1360	WLYN	MA	324.23	**89**	***54***	**83**	***353***	**6**
800	WCCM	MA	324.43	**73**	***> 20K***	**58**	***295***	**15**
1450	WNBP	MA	337.65	**83**	***54***	**77**	***480***	**6**
1440	WJAE	ME	356.69	**81**	***54***	**76**	***> 20K***	**5**
970	WZAN	ME	357.81	**89**	***no var.***	**89**	***no var.***	**0**
560	WGAN	ME	358.01	**86**	***> 20K***	**74**	***54***	**12**

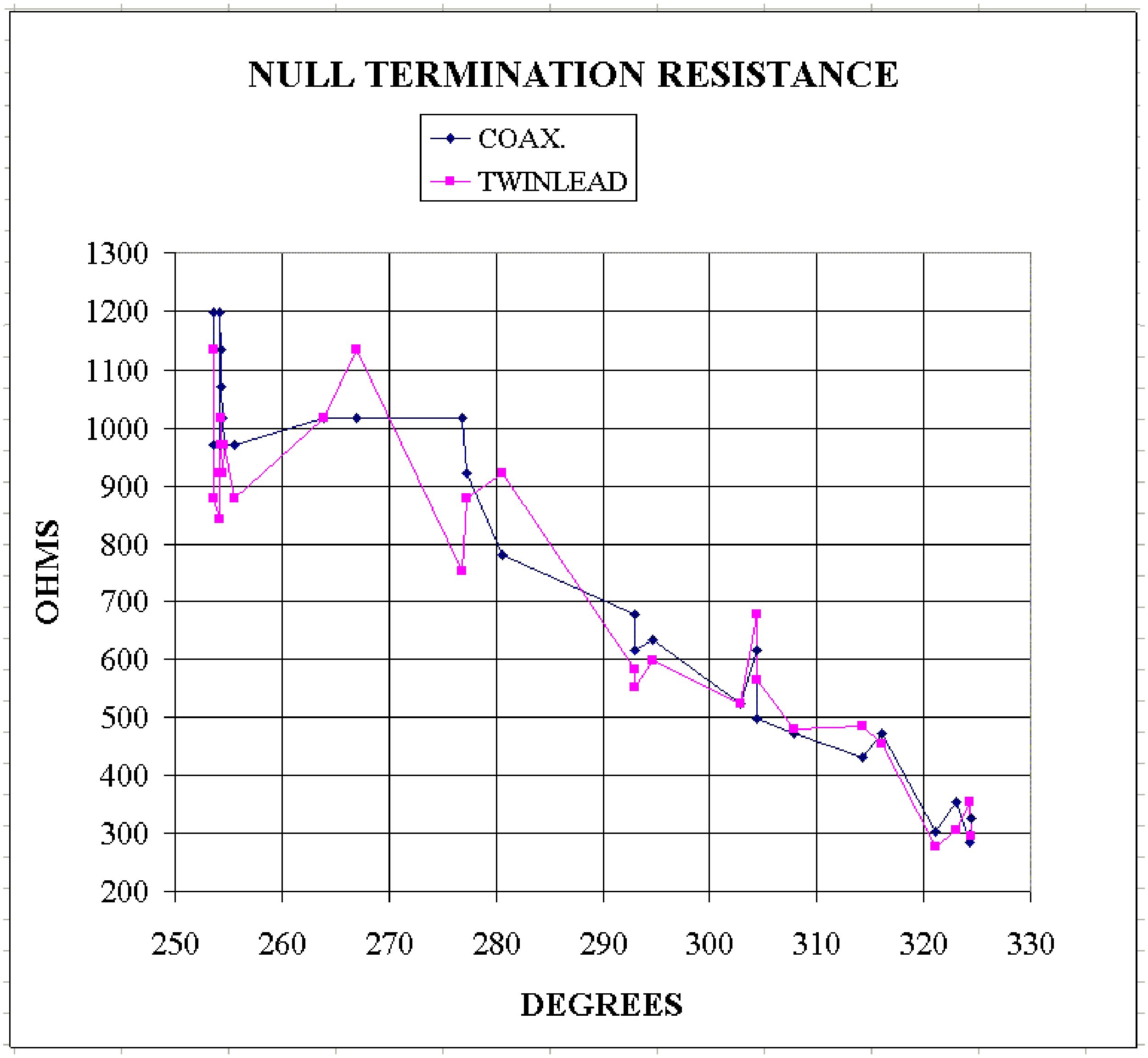
The coaxially-fed system exhibits nulls up to 36 dB with best performance at about 290 degrees and the twinlead-fed system reaches 39 dB of null depth with best performance near 270 degrees (i.e. due west). I'm not sure how the feedline chosen has an effect on best null angle, other than perhaps by unintended coupling to the antenna element. Null depth in the 250 - 330 degree bearing range is shown in Chart 1. This chart would have been extended down to 230 degrees for symmetry, but there weren't enough suitable stations on 230 - 250 degree bearings to provide useful data.

Chart 1: Null Depth



As noted in the introductory discussion, the resistance required for a null varies with the bearing of the null. Deepest nulls, in the principal design direction of the antenna, occur with resistance values of 700 to 1000 ohms. Depths of 30 dB or better, at least on stable groundwave signals, can be expected within 10 degrees of the optimum bearing with resistances in the 700 to 1000 ohm window. An interesting fact that came up, not mentioned in the K6SE article, is that nulls can be "slewed" well off the principal axis, admittedly with decreased null depth at greater bearing deviations. Tables 1 and 2 above, and Chart 2 below, show that bearings counterclockwise (anticlockwise) of optimum require null resistances greater than normal values. Nulls on bearings clockwise of optimum require null resistance values that are lower: down to about 300 ohms.

Chart 2: Null Resistance



Null resistances were measured by measuring control voltage during reception tests and then calibrating voltage versus resistance with the system brought indoors (termination box opened up). Table 3 shows the calibration factors.

Table 3: Control Voltage versus Null Resistance and Vactrol LED Current

VTL5C4 VACTROL - CONTROLLED

PENNANT ANTENNA TERMINATION

V (pot)	V (wires)	ohms	mA
<1.3	=V (pot)	> 20K	0.00
1.50	1.478	10K	0.15
1.60	1.546	2300	0.37
1.65	1.577	1570	0.50
1.66	1.583	1450	0.53
1.67	1.589	1365	0.56
1.68	1.595	1273	0.59
1.69	1.601	1197	0.61
1.70	1.607	1135	0.64
1.71	1.613	1070	0.67
1.72	1.619	1018	0.70
1.73	1.624	970	0.73
1.74	1.630	923	0.76
1.75	1.636	879	0.79
1.76	1.642	843	0.82
1.77	1.648	811	0.84
1.78	1.653	781	0.87
1.79	1.659	752	0.90
1.80	1.665	726	0.93
1.81	1.670	699	0.97
1.82	1.675	678	1.00
1.83	1.680	655	1.04
1.84	1.685	635	1.07
1.95	1.742	480	1.43
1.96	1.748	472	1.46
1.98	1.759	455	1.53
2.00	1.770	432	1.59
2.02	1.780	419	1.66
2.04	1.790	400	1.72
2.06	1.800	390	1.79
2.08	1.810	372	1.86
2.10	1.820	360	1.93
2.12	1.830	353	2.00
2.14	1.840	339	2.07
2.16	1.850	330	2.14
2.18	1.860	322	2.21
2.20	1.870	314	2.28
2.25	1.895	295	2.45
2.30	1.920	278	2.62
2.35	1.945	264	2.79
2.40	1.970	250	2.97
2.45	1.995	238	3.14
2.50	2.020	228	3.31
2.55	2.048	220	3.46
2.60	2.076	213	3.61
2.65	2.104	204	3.77

1.85	1.690	616	1.11
1.86	1.694	598	1.14
1.87	1.699	582	1.18
1.88	1.704	565	1.21
1.89	1.709	551	1.25
1.90	1.714	535	1.28
1.91	1.720	524	1.31
1.92	1.725	512	1.34
1.93	1.731	498	1.37
1.94	1.736	486	1.40

2.70	2.132	197	3.92
2.75	2.160	191	4.07
2.80	2.188	187	4.22
2.90	2.244	176	4.52
3.00	2.300	166	4.83
3.50	2.510	132	6.83
5.50	3.500	82	13.79
10.00	5.790	54	29.03

Phased Arrays

Phased arrays of pennants can be used to deepen the null (enhancing front-to-back ratio) and to focus the pick-up area into a narrower lobe, approaching Beverage-like tightness. In situations such as the 160-m band, with a narrow overall bandwidth to cover, one can make use of simple phasing methods, such as specific feedline lengths acting as delay lines. On the AM broadcast band, with a nearly 4 to 1 maximum to minimum frequency ratio, a phasing unit offering continuous shifting over 360 degrees must be used. There are many units which will provide this functionality: these include modified versions of the commercially-available MFJ-1026. The simplest phased array would be two pennants spaced a minimum of 1/12 wavelength and a maximum of 1/3 wavelength apart along the desired peak-null axis. A medium wave example: With signals to the west to be eliminated, place two pennant antennas about 50 m / 164 ft. apart on an east-west line. First, configure each antenna for best-possible cardioids nulling west. Present the two antennas' contributions to the phasing unit's inputs and then adjust the phase and amplitude controls to remove whatever vestiges of western signals that are still there to interfere with desired DX stations from the northeast, east, and southeast. See *http://members.aol.com/MarkWA1ION/phased_arrays.htm* for further discussions of phased arrays.

Electrical Noise Considerations

As noted previously, local electrical noise can be reduced by trying different heights of the pennant system above ground. The pennant, like the K9AY, sums electrical (E) and magnetic (H) field pick-ups to produce a cardioid pattern. This is similar to using an active whip and a broadband magnetic loop as the two inputs to a phasing unit: that's what I typically use on car DXpeditions.

Since the electrical field pick-up often contains locally-generated noise to a greater extent than what's intercepted by a balanced magnetic field loop antenna, combined E-field / H-field systems like the pennant, K9AY, or Ewe might not be as "quiet" or as usable as a traditional loop for weak-signal work in average residential areas. Two or more magnetic loops used as elements of a phased array can create cardioid directionality with less local noise pick-up; the price you pay is greater null adjustment complexity as contrasted with the pennant or similar single-antenna system.

Conclusions

At most sites, the pennant antenna offers a simple single-antenna method of producing a cardioid pattern. Use of a remotely-controlled termination resistance allows a degree of slewing the null bearing and depth to reduce interference from numerous stations in the approximate opposite direction of DX targets being chased. In many cases, especially when grounding for a K9AY system is inadequate, the pennant represents the best receiving-antenna solution at sites having limited space.

Construction Drawings

Figure 1: Overall View of Antenna System

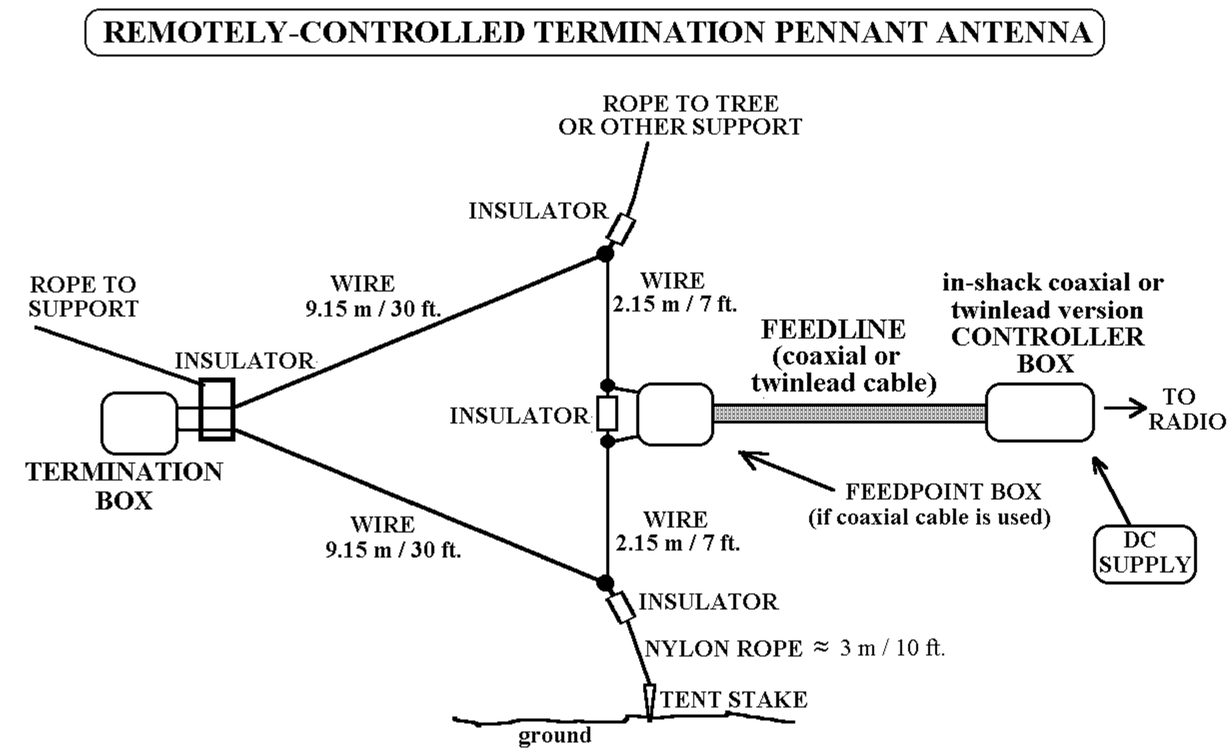


Figure 2: Twinlead Controller Box

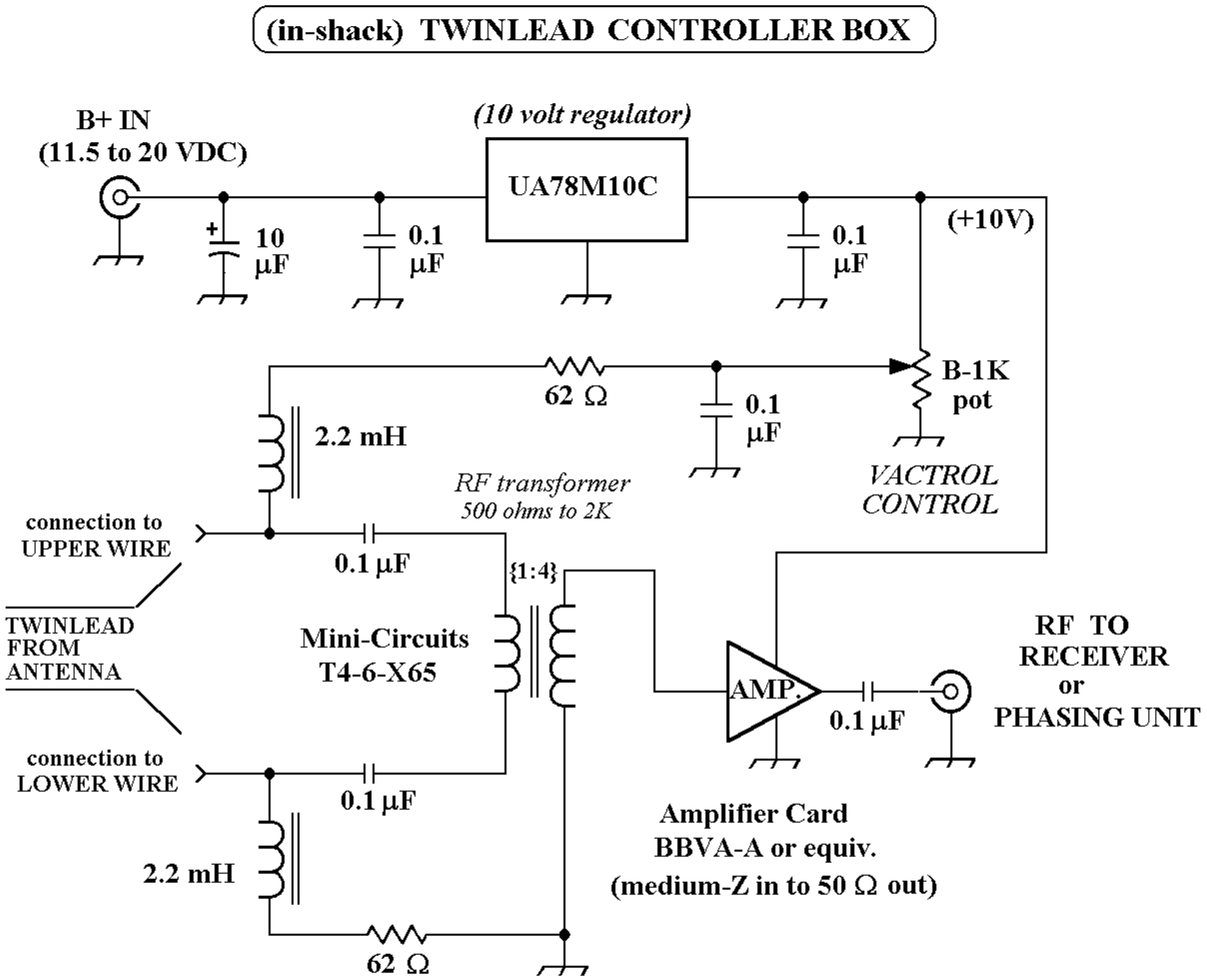


Figure 3: Coaxial Controller Box

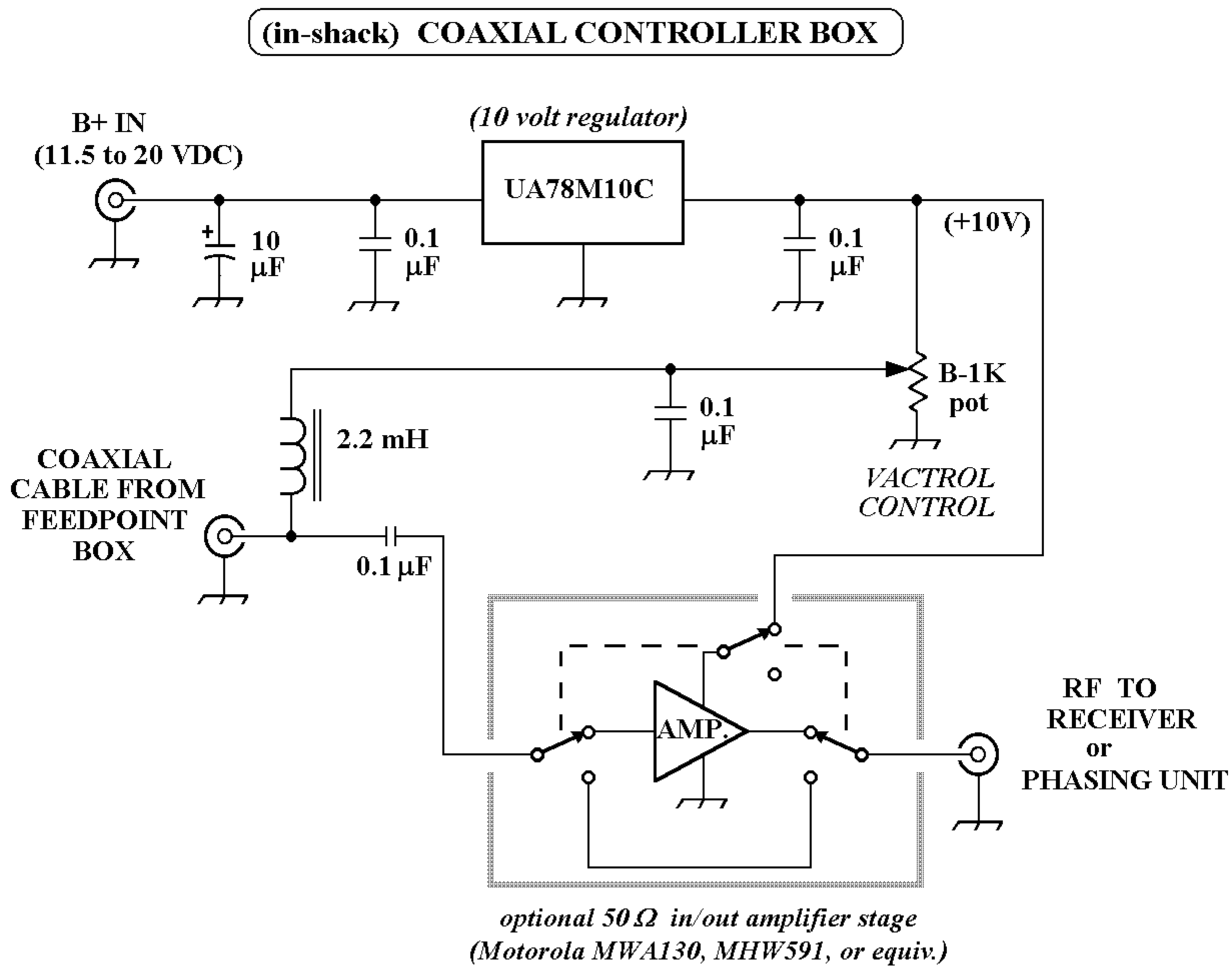


Figure 4: Feedpoint Box (for Coaxially-Fed System)

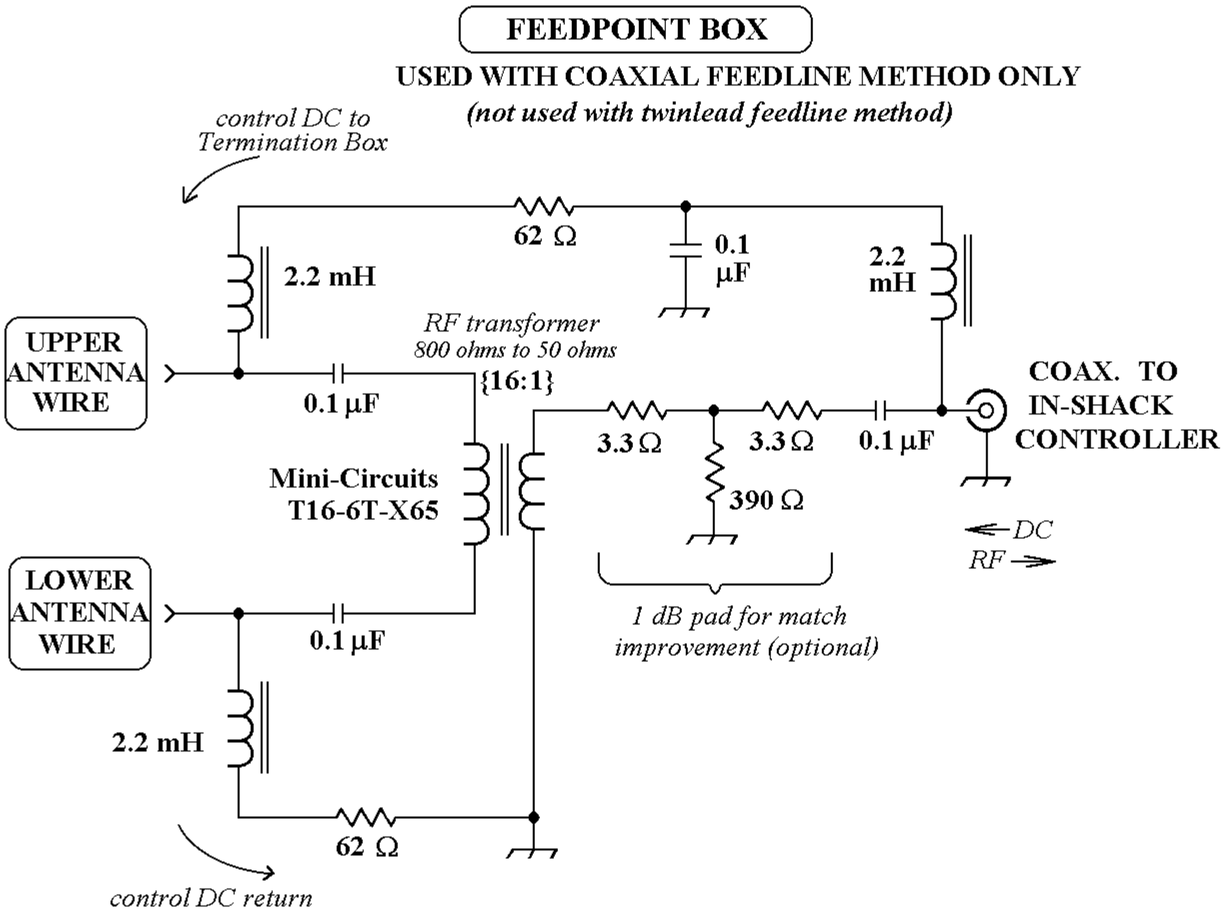
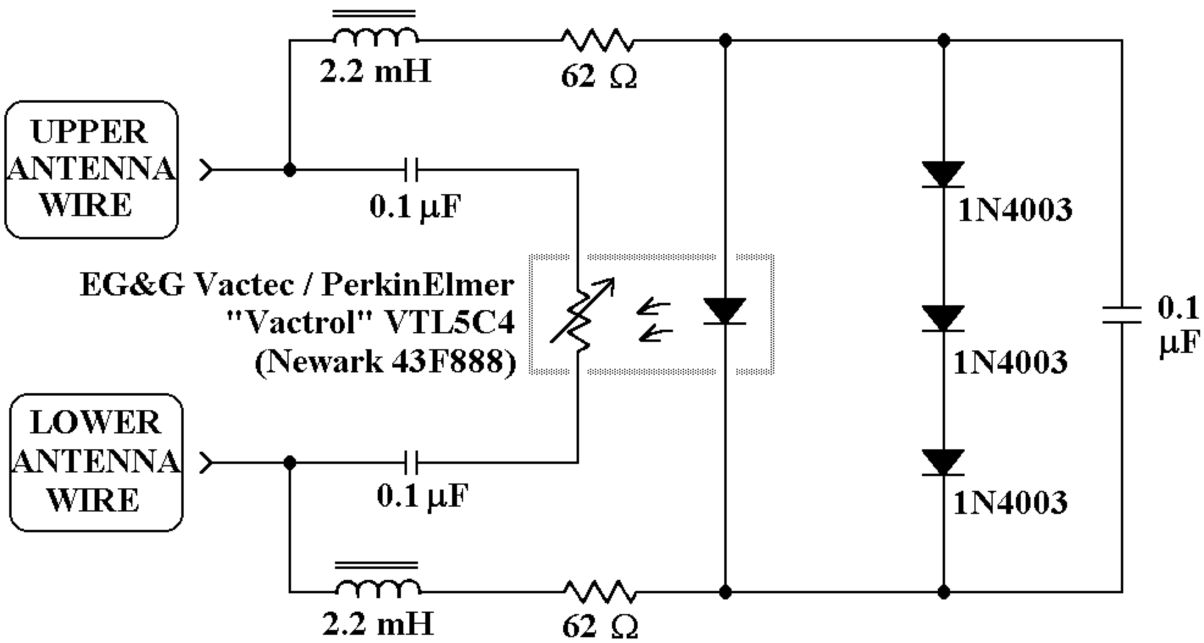


Figure 5: Termination Box

TERMINATION BOX

same box is used regardless of feedline type



Notes

(1) 1N4003 diodes clamp maximum voltage to ≈ 2 VDC, corresponding to ≈ 30 mA through Vactrol LED. This sets photoresistor to minimum value, about 54 Ω.

(2) Box may be fitted with a hook to facilitate rope attachment.

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