MULTIBAND ‘TRAP’ ANTENNA

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Introduction

The story is familiar. After obtaining your radio-amateur license you like to be 'on the air' as soon as possible. Already for month you have been looking though piles of information for affordable ham gear and you finally have bought a set a little bit beyond budget. Next question is the antenna and for this you first ask around because antenna practice is still something to be gained and a commercial full-size tower-cum-multiband beam is currently out of reach. Actually, you are looking for a system that will cover a maximum number of (HF-) amateur frequency bands for a minimum of effort requiring as little 'real-estate' as possible. The build-in tuner of your new ham-gear should be able to cover all impedance excursions of this antenna since you like to play with this expensive piece of equipment for quite some time to come. Unfortunately this type of tuner only covers a small range of mismatches, usually not beyond SWR 1 : 3 - 4. Furthermore you would like to feed this antenna with coaxial cable, since this is easiest to handle and relatively insensitive to 'external conditions' like the weather, metal obstacles like roof trimming, birds nests etc.

The above considerations were background to the design of the multi-band trap antenna in this article, that should cover the as many as possible of the 'classical' HF radio-amateur bands.

Simplicity does it

One of the simplest and yet useful antenna designs is the dipole; a center-fed antenna that will resonate on every frequency for which the electrical antenna length is a multiple of 1/2 wave length. At every odd-multiple thereof the terminating impedance is 'real' and of a 'low' value, suitable for connecting to 'low' impedance transmission line and the thing to go for when also a simple antenna tuner is to be applied.

Unfortunately, the HF amateur bands are not so nicely odd-multiple related for one dipole to fulfill the above relationship. As an example let's look at an antenna of 2 x 20 m. at 10 m. above average ground, that will resonate at 3,6 MHz. with a connection impedance Z_0 = 50 Ohm. The next higher low-Z_0 frequency is at 11,1 MHz. (Z_0 = 124 Ohm) and thereafter at 18,6 MHz. (Z_0 = 126 Ohm) and 26,1 (Z_0 = 137 Ohm).

Next best approach could be an off-center fed dipole like a Windom-variation, using a transformer to 'translate' to a low value. Again, the odd relation of wavelength' will not permit one antenna (or one specific transformer ratio) to 'do the trick' of making the antenna to perform within the framework as described earlier.

An other variation to this theme may be the multi-dipole solution, each cut for a specific frequency (range) and all connected to the same balun, as only the dipole on its fundamental resonance frequency will exhibit a low enough impedance to do most of the radiation (most current). This will certainly lead to a workable situation although tweaking the system for optimal performance on each amateur band may be somewhat problematic as all antenna's are operating in each-others near-field area (mutual influence). Furthermore, a five dipole construction may not be called a simple antenna system anymore.

A different approach to the dipole theme is the W3DZZ - type of trap dipole, originally developed from a series of practical trials to obtain an antenna for multiple amateur frequencies, to be fed with high impedance transmission line and be used in connection with tube-type transmitters with a higher termination impedance than contemporary transistor equipment. When using this type of antenna with a balun into low-impedance coax, the SWR will not be low enough on 20, 15 and 10 m. radio-amateur bands to come within range of the earlier mentioned, build-in antenna tuner. Only solution is to use parallel dipoles on these frequencies like we have seen above which are taking us out of the 'simple systems' area again.

Difference of the trap dipole to other dipole solutions is, that the first is consisting of much more parameters to play with, e.g. inside length, trap inductor, trap capacitor, outside length. In principle these four (independent) variables in theory should be sufficient to solve the resonance requirements on four different frequencies, compared to a basic dipole that has only one parameter to play with. It is precisely from this view point the antenna discussion in the rest of this article has been derived.

Basic design

In these days multiple antenna design programs are available, both at a price or as free-ware, together with personal computers to take the burden out of multiple calculations of the same nature. Using these tools, various approaches have been investigated based on the model in figure 1, all to fulfill the basic requirement of resonating on at least four different radio-amateur bands.

L_1

trap

L_2

feed point

L_2

L_1

trap

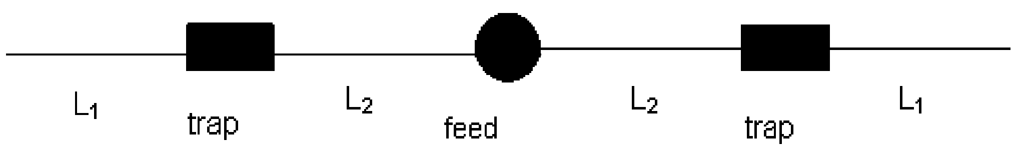


Figure 1: Trap antenna model

In the modeling phase, the trap is consisting of an ideal, lossless inductor in parallel with an ideal lossless capacitor. Further references in this article will be to this model and notation.

W3DZZ

As it seemed a good idea to start from basic elements of the W3DZZ, I have looked into various editions of the design. Looking in detail, one may come across different designs depending on publication source. For this model the details as given by the ARRL

Antenna Handbook have been used, taken as; L_2 = 9,75 m. (32'), L_1 = 6,7 m. (22'), L = 8,2 µH and C = 60 pF, for a trap resonance fr = 7,175 MHz. According to the handbook, "With a 75-Ohm twin-lead feeder, the SWR with this antenna is under 2 to 1 throughout the three highest frequency bands, and the SWR is comparable with that obtained with similarly fed simple dipoles on 3,5 and 7 MHz."

Modeling the W3DZZ at an antenna height of 10 meter over average ground (G = 5 mS, ε = 13), the following table may be drawn:

freq.	**reson.**	**R**	**X**	**SWR**	**gain**	**elevation**
band	**freq.**	**(Ohm)**	**(Ohm)**	**(re 50)**	**(dBi)**	**angle**
80	3.531	35.7	0	1.4	6.2	38.5*
mid band	3.7	45.8	145	11.1		
40	7.271	83.3	0	1.7	6.1	25.5*
mid band	7.05	65.5	-102	5.1		
20	15.35	257	0	5.1	7.2	27
mid band	14.175	264.1	-553	28.6		
15	22.363	115.7	0	2.3	8.9	18.5
mid band	21.225	134.1	-484	38.0		
10	32.525	150	0	3.0	10.9	13
mid band	28.85	931.7	-1491	65.8		

Table 1: Performance of the W3DZZ as modeled according to the ARRL Antenna Handbook details

On the 80 and 40 m. bands, the radiation angle is 90 degree; the asterisk in the table is pointing at the -3 dB points.

Looking at this table one finds the antenna mostly resonating outside the (radio-amateur) band limits. Also, regarding the behavior at mid-band frequencies it is clear why a simple, build-in antenna tuner will have problems handling the antenna, SWR is (sometimes far) outside the range of these simple devices. Solving these problems with parallel dipoles cut for specific frequencies will limit maximum antenna gain to around 6 dBi, where the W3DZZ is capable of delivering up to 11 dBi of gain, almost one S-point more.

Modeling the antenna at different antenna heights or above different soil types does not solve the problem; SWR and resonant frequency are hardly changing. Radiation angle will vary though, as this parameter is related to the combination of the direct and ground-reflected wave.

Discussing matters with L.B. Cebik (visit his rich web-site!) leads to the conclusion that the W3DZZ has been design for use with the pi-filter output stages of tube transmitters, that were much more permissive to odd termination impedances.

On his web-site L.B. shows more examples of trap-type antenna's. Basic principle usually is that the total length of the antenna is resonating at a lower frequency and the inner side at a higher frequency, with the parallel L-C trap to decouple the lower frequency part. This effectively turns a trap antenna into a two-band system.

Multi-band trap antennes

As discussed earlier, a trap antenna consists of four independent variables, so it should be possible to have the antenna resonate at four different frequencies. I have tested this premises modeling the antenna at 10 m. above average ground and consisting of 1,5 mm. wire. With trap resonance frequency as a first aiming parameter I have searched each solution space based on the requirement that the antenna should resonate at 3,7

MHz., 7,05 and 14,175 MHz. It appears that the solution space is quite large as may be seen in the following table.

#	**fr. trap**	**L 2 (m)**	**L 1 (m)**	**l tot. (m)**	**L μH**	**C pF**	**15 m. band**	**10 m. band**
1	6.0	7.1	8.8	31.8	4.5	156.4	23.862	32.840
2	6.4	8.4	7.9	32.6	4.7	131.6	23.072	32.278
3	6.8	9.6	7.3	33.8	5.1	107.0	22.080	31.396
4	7.0	10.1	7.0	34.2	5.2	99.4	21.774	31.034
5	7.2	10.6	6.7	34.6	5.0	97.7	21.390	30.480
6	7.4	11.1	6.4	35.0	5.0	92.5	21.302	30.181
7	7.6	11.6	6.1	35.4	5.2	84.3	21.227	29.801
8	7.8	12.1	5.8	35.8	5.2	80.0	21.073	29.294
9	8.0	12.6	5.3	35.8	5.4	73.3	21.334	29.186

Table 2: Multi-band antenna variations

At a lower trap resonance frequency than 6 MHz., it becomes difficult for the system to fulfill the resonance requirement at the basic amateur bands; with trap resonance above 8 MHz. this again is a problem.

It is clear that the solution space is continuous, although models have been calculated in steps. It is further interesting to notice that trap inductance is only varying marginally.

Looking at the upper two radio-amateur bands, one may notice that the 15 m. band is coming in reach first, later to (partly) follow by the 10 m. band. If we are faithful to our premises (four variables, so system should be solvable at four independent frequencies), model seven is the solution we are looking for. More or less as a surprise, also the 10 m. band is almost within reach in model 9, and I will come back to this later.

Antenna gain and elevation angle

To complete this first round of analysis, I further have looked into the antenna gain of the above models. Of cause this (maximum) antenna gain is in a different direction for each amateur band, at the higher bands in a multi-lobe structure with deep 'nulls' in between. Nevertheless it is clear that more antenna gain will be available with more wavelength on the antenna adding to total radiation.

Model #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
band									
80	6.2	6.3	5.8	5.8	5.9	5.9	5.9	5.9	5.9
40	6.4	6.3	6.2	6.1	6.0	5.9	5.7	5.6	5.4
20	7.0	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.1
15	9.7	9.5	9.5	9.3	9.2	8.9	8.8	8.5	8.4
10	10.6	10.5	10.6	10.7	10.7	10.8	10.8	10.7	10.5

Table 3. Antenna gain (dBi) per model and per amateur band.

In table 4 the elevation angle of maximum radiation has been calculated. This angle is the (vector) sum of direct and (ground) reflected energy. At the fixed antenna height of 10 m. above average ground, the wavelength above ground will differ per amateur band and so will the radiation angle for both of these wave to add in phase. As in table 1, radiation on the two lower band is at 90 degree, the asterisk marked numbers are showing the - 3dB angle re this maximum.

Model	1	2	3	4	5	6	7	8	9
80	38*	38*	38*	38*	38*	38*	38*	38*	38*
40	26.5*	26.5*	26.5*	26.5*	26.5*	26.5*	26.5*	26.5*	26.5*
20	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5
15	17.5	18	19	19	19.5	19.5	19.5	20	19.5
10	13	13	13.6	13.6	14	14	14	14.5	14.5

Table 4. Elevation angle.

Comparing table 4 and table 1, very little difference will be noticed, further underlining the statement that the elevation pattern is mainly determined by the height above ground and ground type.

Feed point impedance

A further interesting antenna parameter is feed point impedance as this is an important part of our starting position (low SWR). In table 5 one may find the feed point impedance of the antenna models at the center of each radio-amateur frequency band where the antenna has been designed to resonate (lower three bands), or at the exact resonance frequency (higher two bands).

Model	1	2	3	4	5	6	7	8	9
80	34.9	38	44.9	45.5	46.6	47.3	42.8	48.6	49.6
40	116.3	100.8	87.5	82.5	77.7	72.5	67.7	63.7	59.9

20	151.8	182.7	211	215.8	219	208.7	204.4	195.6	179.7
15	127.3	114.3	112.5	116.9	122.8	134.2	149.5	164.2	183.5
10	133.3	153.2	153.3	144.7	137.8	129	123.7	122.5	127.2

Table 5. Feed point impedance (real value; resonance)

It is interesting to notice a certain structure in the feed point impedances over the frequency bands and the different models. First two rows are showing a constant rising or descending tendency, the next three having a more wavy structure. It is also clear that except for the lowest band, all antenna's are exhibiting an impedance above 50 Ohms, even up to (and a little above) 200 Ohms. To obtain lowest overall SWR when connecting to one of these this antenna's, a good choice may be to have a transformer connecting the antenna to 50 Ohm coaxial line, at an impedance transformation ratio half-way highest and lowest antenna impedance, e.g. 125 to 50 Ohm (2,5 : 1).

Although this appears a somewhat odd ratio, one will find a good proposition in Jerry Sevick's book on "Transmission line transformers" (ISBN 1-884932-66-5) in his 1 : 2,25 model, showing high efficiency over all frequencies of our wish list and above. An analysis of this transformer may be found at "Transmission-line transformers".

Bandwidth

The multiband antenna we are looking for, is to be used within the tuning range of a build-in auto tuner, e.g. SWR< 4. Let's see how our models perform within those limits when connected to the above mentioned 1 : 2,25 impedance transformer, i.e. related to a system impedance of 112,5 Ω. Since the lowest model numbers did not perform well on 15 m., we will leave these out of the table.

Model	**4**	**5**	**6**	**7**	**8**	**9**
80	3.591	3.608	3.629	3.563	3.592	3.580

	3.821	3.856	3.890	3.802	3.872	3.928
40	6.864	6.890	6.912	6.918	6.946	6.977
	7.343	7.314	7.294	7.269	7.254	7.243
20	13.775	13.726	13.732	13.725	13.692	13.658
	14.731	14.709	14.700	14.718	14.720	14.715
15	21.289	21.037	20.836	20.693	20.616	20.861
	22.345	22.070	21.851	21.692	21.599	21.842
10	30.480	30.076	29.656	29.217	28.789	28.684
	31.657	31.236	30.796	30.337	29.875	29.743

Table 6. Boundary frequencies within SWR = 4 limits.

From table 6 it may be concluded that starting form model 6, all antennas comply well with the 4 -bands target. In fact model 9 also covers a large part of the ten meters band without sacrificing performance on lower frequencies, so this should be the model to go for. It's clear however, that four variables may be selected to cover four bands but we need a fifth variable when we also would like to include this fifth frequency band.

Sensitivity to ground conditions

All models have been designed at ten meters above average ground, i.e. conductivity 5 mS/m and ε is 13. If this is to be an explicit requirement, only those living on such average ground could profit. Let's find out how the best model from our earlier tests is performing above different ground conditions, i.e. 'good' at 20 mS and ε is 20 (flat country and high moist soil) and bad conditions at 1 mS/m. with ε = 5 (rural, densely populated), as in table 7.

		good	average	bad
band		**soil**	**soil**	**soil**
80:	fr (MHz)	3.731	3.738	3.752
	Zo (Ω)	39.0	49.6	61.6
	gain (dBi)	7.3	5.9	4.4
	elevation (degree)	40.5*	38*	33.5*
40:	fr (MHz)	7.063	7.069	7.076
	Zo (Ω)	59.6	59.9	59.3
	gain (dBi)	6.2	5.4	4.3
	elevation (degree)	29.0*	26.5*	23.0*
20:	fr (MHz)	14.180	14.173	14.165
	Zo (Ω)	184.7	179.7	173.8
	gain (dBi)	7.7	7.1	6.4
	elevation (degree)	30.0	29.5	28.5
15:	fr (MHz)	21.335	21.334	21.335
	Zo (Ω)	184.7	183.5	183.7
	gain (dBi)	8.9	8.4	7.8
	elevation (degree)	19.5	19.5	19.0

10:	fr (MHz)	29.190	29.186	29.180
	Zo (Ω)	126.8	127.2	126.8
	gain (dBi)	10.8	10.5	10.0
	elevation (degree)	14.5	14.5	14.0

Table 7. Sensitivity of model 9 to ground conditions

The antenna model is not very much influences by ground-type as far as resonance frequency is concerned or connection impedance. Antenna gain (maximum) is diminishing marginally with worse ground conditions which is to be expected as this is the vector summation of ground and reflected wave energy. In the same manner the elevation angle is influenced.

Sensitivity to antenna height

To find out the sensitivity to antenna height, I have modeled model 9 at different levels above average ground conditions, as may bee seen in table 8.

height (meters)		**10**	**12.5**	**15**	**17.5**	**20**
amateur band						
80:	fr (MHz)	3.738	3.736	3.734	3.740	3.748
	Zo (Ω)	49.6	57.1	64.1	72.4	79.1
	gain (dBi)	5.9	6.4	6.6	6.2	6.2

	elevation (degree)	38*	35.5*	32.5*	29.0*	25.5*
40:	fr (MHz)	7.069	7.078	7.087	7.094	7.096
	Zo (Ω)	59.3	66.1	67.4	63.3	56.7
	gain (dBi)	5.4	5.3	5.5	6.0	6.7
	elevation (degree)	26.5*	21.5*	40.0	34.0	29.5
20:	fr (MHz)	14.173	14.164	14.127	14.123	14.133
	Zo (Ω)	179.7	155.8	153.4	163.3	166.8
	gain (dBi)	7.1	8.1	8.3	8.2	8.3
	elevation (degree)	29.5	23.5	19.5	17.5	15.0
15:	fr (MHz)	21.334	21.342	21.345	21.322	21.341
	Zo (Ω)	183.5	191.2	182.8	185.4	191.9
	gain (dBi)	8.4	8.6	9.2	9.2	9.1
	elevation (degree)	19.5	15.5	13.0	11.5	10.0
10:	fr (MHz)	29.186	29.169	29.176	29.173	29.162
	Zo (Ω)	127.2	125.2	128.4	127.7	127.1
	gain (dBi)	10.5	11.0	11.0	11.2	11.3
	elevation (degree)	14.5	11.5	9.5	8.5	7.5

Table 8: Sensitivity of model 9 to antenna height

As with table 7, we find no dramatic deviations from the basis antenna characteristics. Main difference are in the elevation angle of maximum radiation, so this parameter should be considered for a particular application.

A five band variation.

Above we have modeled a four band antenna, based on four variables, for 80, 40, 20, and 15 meter radio-amateur band. For a fifth band we need an extra variable, that should exhibit most action on the highest frequency band. Such a variable may be found in the addition of a top capacitor, consisting of a few short length' of antenna wire attached to the antenna ends, each 40 cm long and connected from the center as in figure 2.

L1

trap

L2

feeder

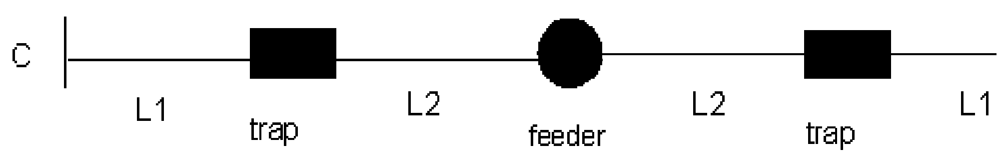
L2

L1

trap

C

C



Figuur 2: Model 9 with top capacitors is model 10

Feeding this new model into an antenna design program, we obtain the following table.

	80	**40**	**20**	**15**	**10**
fres.(MHz)	3.616	7.002	14.066	20.824	28.648
Zo (Ω)	48.0	59.9	193.2	181.0	120.6
gain (dBi)	5.8	5.3	7.1	8.4	10.6
elevation (dgr)	38.5*	26.5*	29.5	20	14.5
SWR < 4	3.520	6.918	13.586	20.377	28.176
between:	3.801	7.208	14.587	21.305	29.196

Table 9: Trap-antenna with top-capacitors (model 10)

As in previous sensitivity models, parameters have shifted only marginally and it appears we have designed a truly practical five band antenna, that will exhibit SWR < 4 on and over all of the 'classical' HF-bands.

Practical designs

The antenna to fully comply with the design goals for a four band antenna with SWR < 4 is model seven as in figure 3.

6,1 m.

6,1 m.

11,6 m.

11,6 m.

5,2 µH

5,2 µH

84,3 pf

84,3 pf

coax trafo

1 : 2,25

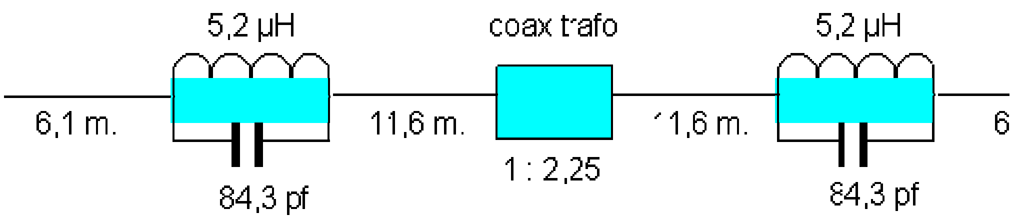


Figure 3: 4-band trap antenna

This model describes the antenna for 80, 40 20 and 15 m. amateur band, that will also cover part of the FM area of the 10 m. band. The model is not sensitive to ground type or exact antenna height and will cover all four bands within SWR < 4.

Five band design

The antenna design to cover much of five HF amateur frequency bands may be seen in figure 4.

5,3 m.

5,3 m.

12,6 m.

12,6 m.

5,4 µH

5,4 µH

73,3 pf

73,3 pf

coax trafo

1 : 2,25

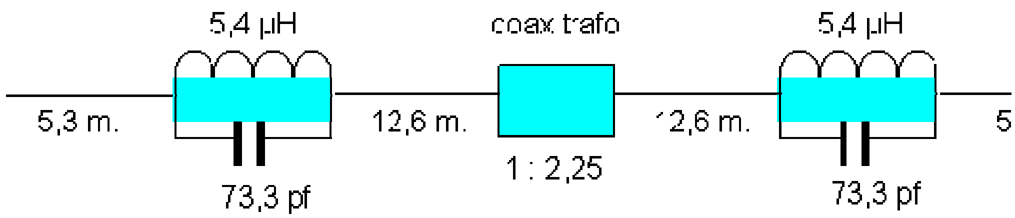


Figure 4: Antenna for most part of the five classical HF bands

In this design, also all frequencies within the 80, 40, 20, and 15 m. amateur bands are covered, including the FM-part on ten meter. An (small) external tuner will help to also include all of the ten meter band, but this addition is outside the design goals of this article.

Extended five-band design

A full five-band solution may be found in figure 5, which is the antenna system of figure 4 with top capacitors applied. The 40 cm. wire ends may be strapped along a short piece of wood or pvc material to straighten out.

5,3 m.

5,3 m.

12,6 m.

12,6 m.

5,4 µH

5,4 µH

73,3 pf

73,3 pf

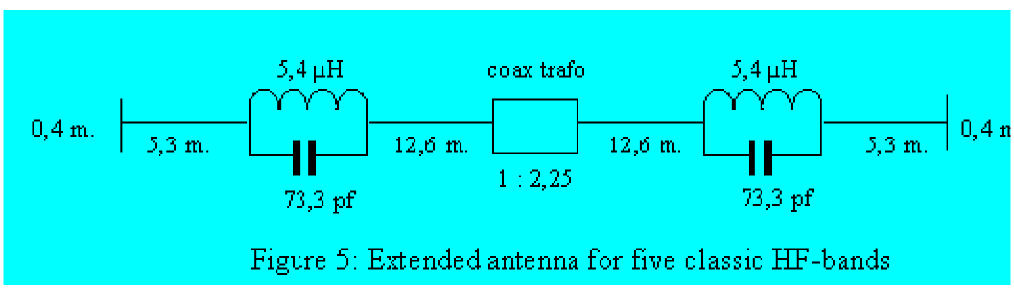
coax trafo

1 : 2,25

0,4 m.

0,4 m.

Figure 5: Extended antenna for five classic HF-bands



This design will cover all five classical HF amateur bands within SWR < 4 limits. As the design is equal to figure 4 except for the top capacitors, both may be tested using identical components.

Traps

Simplest method to make traps in general and the traps for this design in particular, is to take a short piece of pvc drainage pipe e.g. outside diameter 40 mm. For this material end-caps are available to turn this 'coil form' into a neat little box, perfectly fit for the resonating capacitor. When using 2 mm. pvc-clad electricity wire, 13,5 turn on this coil former will yield an inductance of 5,4 μH.

One may check this value by connecting a series resistor of 22 Ω and connect this series circuit to a HF generator set to 648 kHz. (calibrate against BBC in Europe). Voltage over the resistor should be equal to voltage on the inductor (also voltage on the resistor should be 0,7 time total voltage). For amateurs with a different taste, same method will work using a series resistor of 47 Ω on a generator tuned to 1,386 (calibrate against Voice of Russia).

At these low frequencies, parasitic effects will not yet be too noticeable.

Capacitor value may be found by resonating with the trap coil at 8.00 MHz., e.g. using a dip meter, calibrated against the transceiver. A good way to make and tune this capacitor is to use a piece of RG58 coax cut to resonance, as this will make a very good high-voltage capacitor. When using RG58U, this piece will be around 65 cm. long and by resonating directly to the trap coil on 8 MHz. also the parasitic coil capacitance will be included. When ready, make sure a short length of inner cable will extend beyond the braiding as this will prevent the end from arcing. The length of coax capacitor may be folded inside the 'box', preferably perpendicular tot the coil windings as will least influence final trap resonance and trap Q.

In my test antenna I drilled a small hole in the end caps to allow a short piece of nylon rope through the trap. A knot in this rope will secure the end-caps while at the same time provide for a mechanical connection of the antenna wire, separating the mechanical from the electrical connection for better mechanical and electrical strength.

Total trap construction may be seen in picture 1. Look at the small dimensions in compare to the match box. Tywraps wave been used for ease of winding and taking the load of the wing-nut electrical connection.

Picture 1: Trap construction with inside capacitor and 5,4 µH inductor

The impedance transformer

The impedance transformer with a step-up ratio of 1 : 2,25 is a bit out of the usual, but a Jerry Sevick design as in figure 6 is doing a good job.

■ A

■ B

RG 58

RG 58

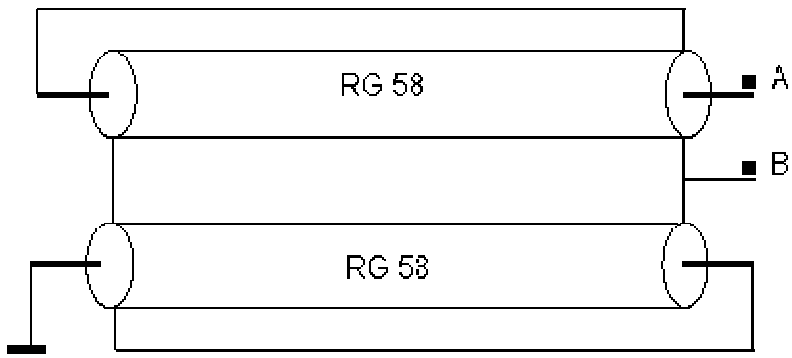


Figure 6. A 1 : 2.25 transmission line transformer.

To get a high enough input to output separation, Jerry configures the transformer on a large K5 (NiZn) type of ferrite toroide by MH&W Inti (TDK) with a permeability of 290, with five turns of good quality RG58 coax. The outer plastic encapsulation has been removed for ease of handling. This is fully allowed as braidings are carrying the same voltage (see figure 6) and the ferrite core has a very high electrical resistance (> 1 MOhm.cm). The picture in figure 7 depicts Jerry's set-up.

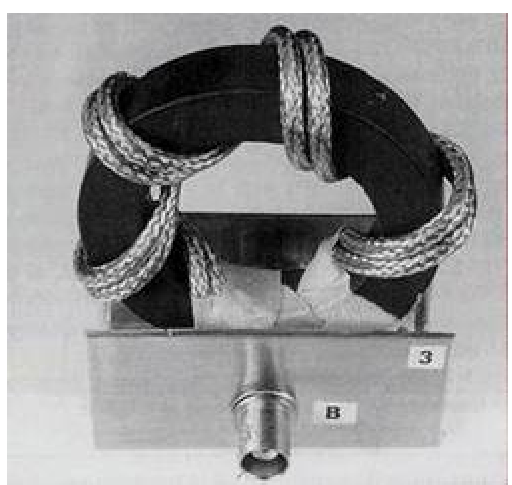


Figure 7: The 1 : 2.25 impedance test transformer by Jerry S

Connection details may be taken from figure 6. Feed line is connected between position B and ground; between position A and ground one will find 1,5 times the input voltage, so 2,25 time impedance.

Ferrite type 'K' may not be around too much any more but may be replaced by type 4B1 by Ferroxcube. As stated before, main function of core material is to obtain a high input to output impedance on the transmission lines. Therefore any type of ferrite material and number of turns will do, as long as total impedance is high enough at the lowest operating frequency (around 150 Ohm for a single coil) and self dissipation of the transformer is within material limits (see Ferrite materials, check at highest operating frequency)

For my test antenna I made the transformer by winding (8) each coax separately on a single 36 mm. 4C65 toroide by Ferroxcube. This transformer performs as predicted with 3,5 MHz. as a lower limit. The other materials (and larger coil formers) already were within specification below 1 MHz., and all are still highly efficient to over 30 MHz.

Total transformer has been placed inside a box made of drainage pipe, this time of somewhat larger diameter and again closed by end-caps. A simple hook construction provides for a hoisting position and a small piece of 'trespa' is reinforcing this position while at the same time providing for a mechanical attachment for the antenna wires to take the load of the electrical connections (wing-nuts). Picture 2 is showing the construction and also a number of turns of RG58 coax, to ensure separation between the a-symmetrical feed-line and antenna plus transformer as a RF choke.

Picture 2: Impedance transformer 1 : 2.25 on two 4C65 toroides

Picture 3 provides a better view on the back of the transformer box including the 'trespa' re-enforcing and pulling plate.

Picture 3: Transformer box, back-side, resting on lid (taken off)

The RF choke

As mentioned above, we are to couple a symmetrical dipole antenna to an a-symmetrical transmission line. This usually is accomplished by some sort of balancing device, sometimes a balancing transformer with or without a transformation ratio. The 1 : 2,25 impedance transformer in our multi-band antenna has no balancing properties. Balancing the transmission line currents to an antenna is to ensure that all transmission-line current is going into the antenna and not anywhere else e.g. to the outside of the feed cable. A good way of preventing is outer current to become a significant portion of total RF current, is by means of enhancing the outside impedance by means of a choking action. A simple way of providing for such a choke is to have a length of feed-line coiled up; around ten turns of feed-line on a diameter of 10 - 15 cm. usually provides for a high enough impedance over a large portion of HF amateur bands. To make a compact design this RF choke has been wound inside the transformer housing, which happened to have the right diameter of 10 cm.

To make this RF-choke effective, the transceiver should have a low impedance to ground as choke to trx-ground impedance effectively makes a voltage divider. Connecting all shack equipment together usually provides for a low enough ground impedance at the same time ensuring equal potential on all equipment as a safety precaution.

Practical experience

As a practical test a have constructed a model 9 type of antenna. As predicted, all HF amateur frequencies on 80, 40, 20, 15 and 10 m. were within reach of the build-in tuner of my Kenwood TS440s rig. Even on 18 m. a low SWR could be made.

As a second test I checked for lowest impedance at each HF band without using the tuner. It showed that this 'resonance frequency' was sometimes outside the specific amateur band, although the build-in tuner apparently did not seem to mind. As it happens, my test antenna has been set-up over unknown ground conditions (presumably poor), was tied to a highest point at around 9 m. and sloping down to the far ends at around 6 m., at one end not even fully extended for real-estate reasons.

Modeling the exact situation, the program came up almost exactly on target, enforcing again my confidence in this application and my calculations. Based on this confidence, I re-calculated the trap to have the antenna perform on the original target frequencies, because wires were already cut to size. For those who also like to prune the antenna to specification for their environment, I give the following table based on local experience.

Keeping trap resonance frequency as a constant, I noticed that for every 10 % rise in trap inductance, antenna resonance on

80 m. went down by ca 0.5 %

40 m. went down by ca 0.5 %

20 m. went up by ca 0.5 %

15 m. went up by ca 0.2 %

10 m. did hardly change

These ratio's were constant over a large range of inductor change. Most remarkable of all: above changes went all in the right direction for my antenna set-up.

Conclusions

In this article we investigated a field of trap antenna's to cover more than two HF amateur band. Out of the solution space we selected three models that satisfied the starting conditions that the design should exhibit good figures on gain and radiation angle and show low enough impedance figures (SWR) to connect directly to 50 Ohm coaxial transmission line of any length without excessive additional losses and to be within range of a simple build-in antenna tuner of modern HF transceivers.

Final design is showing a 'standard' antenna gain of 6 dBi for the lower HF-bands (80 and 40 m.) rising to higher values for higher bands up to 11 dBi for the highest HF amateur band. Be aware though that these maximum gain figures will be in somewhat different directions depending on the specific band. As with all designs, elevation angle is mostly depending on the antenna height above ground, therefore this design should preferably be used at 10 m. or above, although good results already have been obtained at 8 m. Antenna height will also (slightly) influence resonance frequency.

It goes without saying that this is the best multiband antenna around with many DX-contacts to prove this. This usually is the claim by most antenna designers and am not very different at that.

This exercise taught me a few practical 'laws' on wire antenna's that I will present without further comments:

- every piece of wire is an antenna,

- antenna gain almost exclusively depend on antenna size relative to wavelength, starting from about 1/10 wave length,

- an antenna system is more effective with characteristic impedance closer to feed line and TRX requirements. Even a high gain antenna will loose its efficiency when much energy is dissipated in cable / transformer losses,

- a dipole antenna is more efficient for DX operation when higher above ground, as this will lower the elevation angle, - for local operation the antenna should be positioned much lower but not (much) lower than about 1/10 wavelength above (not so perfect) ground to prevent excessive ground loss.

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