“Invisible” DX Antenna for the Low Bands

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- **Summary**

This paper describes a multi-band DX antenna for the 160m-40m amateur radio bands with low visibility but great performance for long distance communication.
Four versions of this antenna are presented:

1. 160m inverted L
2. The mercury switch 160m/80m vertical
3. The vacuum relay 160m/80m vertical
4. The 160m/80m/40m vertical

The 160m/80m/40m vertical has on 160m an efficiency of 38 % of the ideal vertical (4.2 dB less) and 58 % on 80m (2.4 dB from ideal).

- **CQ 160m Contest January 2004**

Having a R7000 vertical for 10-40m since 2 months on top of the roof of our new house was not really the right antenna set-up for the upcoming CQ-160m-CW-Contest 2004! I was looking for an inconspicuous (people usually do not like to live next to big antennas) and easy to build antenna for the topband.
I remembered having in this contest in 1990 more than 100 DX QSOs with an inverted L antenna, but the year before only 14 QSOs to stations outside of Europe using a full size 160m dipole at 18 m and operating with exactly the same radio equipment and power. So an inverted L should be the right choice for now. In 25 m distance to the house there is a 15 m high oak tree. I could get the vertical part of the inverted L (should be as long as possible for good DX performance) about 12m high and run the 26m long horizontal part to the mast clamp of the Cushcraft R7000 vertical which is mounted on top of the roof. The radiator is quarter wave, i.e. about 38 m long for topband.

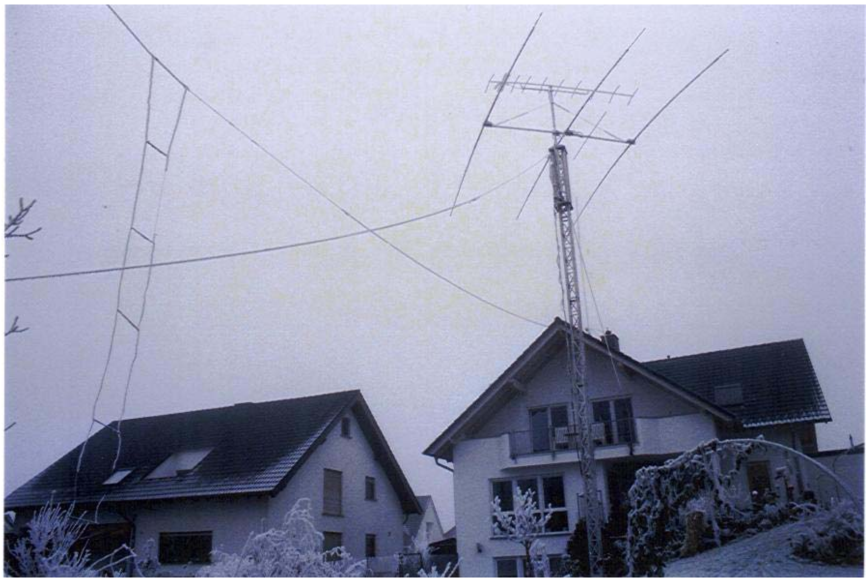


Fig. 1 – Antennas in winter with 5 mm ice layer

- **How to get an antenna on top of a tree without climbing?**

But how to get the other end of the wire on top of the oak tree? With a bow-and-arrow or a fishing rod? I tried a slingshot which is used by fishermen to catapult the fish food into the water. And this works surprisingly well! You can buy everything you need to get the antenna up in the tree in a fisher shop: Leaden sinker of about 20 g weight, fishing line and the slingshot. The sinker is connected to the fishing line and catapulted with the slingshot over the tree. Then a black 1.5 mm diameter Dyneema rope (120 kp tensile strength) is connected to one end of the fishing line and moved over the tree, ready to carry the radiator. The other end of the rope is not fixed. There is just a 2 kg steel tube at the end which can move up and down in a plastic tube in case of wind (see Fig. 2). If you do not allow this movement the rope or antenna wire will break in high winds.

- **The invisible DX Wire**

The radiator itself is made from 1 mm “DX-Wire”, a copper coated (0.08 mm) steel wire (called “copperweld” or “copperclad steel” in the US), maximal tensional load 450 N (much more robust than pure copper wire, see www.dx-wire.com). The DC resistance is about 30% higher than that of pure copper wire, but when used with RF, losses are about the same as with copper because of the skin effect. DX-Wire can easily cope with the legal 750 watts output power.

Fig. 2 – Steel tube guided in plastic tube to compensate movements

On 1.8 MHz the RF current is flowing in the wire down to a depth of 0.05 mm, on 14 MHz it is just 0.02 mm, i.e. 0.08 mm copper coat is sufficient! Resistance on topband is 0.114 Ohm/m. Total losses due to resistance of the wire are in the range of 5 % (40 watts at legal power). This will warm up the thin wire a little bid, but does no cause any problems.
It is almost impossible to spot the 1mm wire in distances >20 m. The black-coated type of this wire is the least visible of all. It only gets more visible from time to time during winter, when ice is building on the wire. In winter 2004/2005 the ice layer was about 5 mm thick (see Fig. 1., the 80m-inverted L is to the left, the 160m inverted L to the right)!

- **160m Inverted L Antenna**

The inverted L is basically a top loaded vertical. The top loading is done by the horizontal part of the wire. Such an antenna should have many radials to work properly. In this 160m contest in 2004 I was using just 3 radials, each about 25 m long. The antenna was fed with 50 Ohm coax, the inner conductor connected to the inverted L wire, the coax screen connected to the radials. This antenna was easy to match because impedance was near to 50 Ohm providing a perfect SWR 1:1 at resonance frequency.
It is important to use a good insulator at the end of the wire. I first connected the wire directly to the rope. Using a 400 watts amplifier the rope melted and the wire fell to the ground! I am using now small Plexiglas insulators without any problems.
But most important: How did the antenna perform in the contest? Much better than I expected! EY, JY, D4B, A45, A61, VP5, 4J, W, JT, 5B worked with 400 watts and many European stations with just 5 watts QRP. A few days after the contest I had my first JA QSO on 160m!

- **How to match the antenna on 160m for a perfect SWR 1:1 – Antenna Efficiency**

I added radials to improve antenna performance further. Finally and still today I have 16 ground radials, average length about 20 m (in total 320 m 1.5 mm diameter magnet wire, buried about 5 cm into the ground, also an invisible but important part of the antenna).
But with increasing number of radials the SWR is increasing! This is because the inverted L with a 12 m vertical part has a radiation resistance of just about 10 Ohm (see [1], figure 9-94), a full size quarter wave vertical has 36 Ohm. But the actual impedance at the feed point is radiation resistance plus ground loss resistance. I.e. when you have a perfect match to 50 Ohm with this inverted L radiator your ground loss resistance will be 40 Ohm. 80 % (40 Ohm/50 Ohm) of your power is lost in the ground system!

With the 16 radials impedance was going down to about 25 Ohm. I.e. ground loss resistance was reduced to 15 Ohm by adding radials (this is in accordance with Table 9-1 in [1]). Antenna efficiency improved from 20 % to **40 %**, this is 3 dB! Including the losses in the DX wire efficiency is 38%, but because these losses are minor they are neglected in the following efficiency calculations. 25 Ohm means a SWR of 1:3, that's exactly where I got to. Either you use a tuner in the shack to match this load to 50 Ohm or better use stub matching. In this case you need 2 x 11m RG213 coax. One end is connected to the antenna, the other end to the feed line with a T connector. The second 11m long cable is connected to the T connector as well and is open at the end. This converts the 25 Ohm to 50 Ohm at 1830 kHz!

- **Adding 80m**

As this antenna was working very nice on topband I thought about adding 80m.
For a first test I cut the inverted L in the middle for resonance on 80m. The 12m vertical and about 7 m long horizontal wire are forming the 80m radiator. The horizontal wire is connected via a Plexiglas insulator with the rest of the wire of the former 160m antenna. This antenna works very well for DX on 80m. The radiation resistance is about 22 Ohm, ground losses are about the same as on topband. Antenna impedance is about 37 Ohm, no need for additional elements to match the antenna to the equipment. Antenna efficiency is expected at about 60 % (22 Ohm/(22 Ohm + 15 Ohm)). I cut the radiator length for best SWR on 3790 kHz. For operation in the CW band I use a MFJ VERSA TUNER V which easily handles legal power. To work on 160m I just had to take down the wire and to short cut the insulator which connects the 80m part with the additional 19m long horizontal wire to form again the original 160m inverted L.

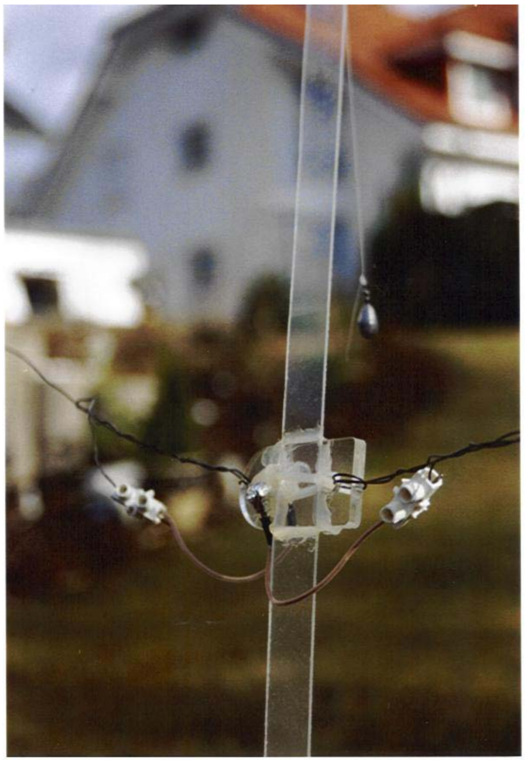


Fig. 3 – Mercury switch mechanism

To make switching between both bands more comfortable I constructed a mechanism with a mercury switch (Fig. 3). With a fishing rope the switch can be opened and closed from the ground. This worked for a while even with 750 watts legal power. But once in a strong wind, when I was transmitting on 80m, the mercury switch "exploded".
The next construction was even more comfortable using a vacuum latch relay. Which a 27 V impulse I was able to switch the antenna between 160 and 80 from the shack! Also this worked for while with legal power level but then the coil of the vacuum relay was destroyed by the high RF voltage and current on the wire.
But why not having 2 radiators in parallel: One inverted L for 160m with the horizontal part ending at the roof of the house and one inverted L for 80m connected

Fig. 4 – 1.5m horizontal part to compensate antenna movement in heavy winds

to the top of the oak tree, avoiding all these switching problems? Both radiators should be connected to the inner conductor of the coax at the feed point (see Fig. 9). This antenna should be resonant on both bands without the need for any unreliable switching!
To allow some movement in case of heavy wind the 80m and 160m inverted L wires are going from the feed point about 2 m vertical, then1.5 m horizontal (see Fig. 4) and then again vertical up the total height of 12 m. The two wires are separated by 50 cm long PVC tubes (better is Plexiglas) every 1.5 m.

- **Modelling with EZNEC**

Modelling with EZNEC proofed that theoretically this antenna should work as good as the monoband versions. Fig. 5 shows the EZNEC model of the dualband antenna with 14 radials.

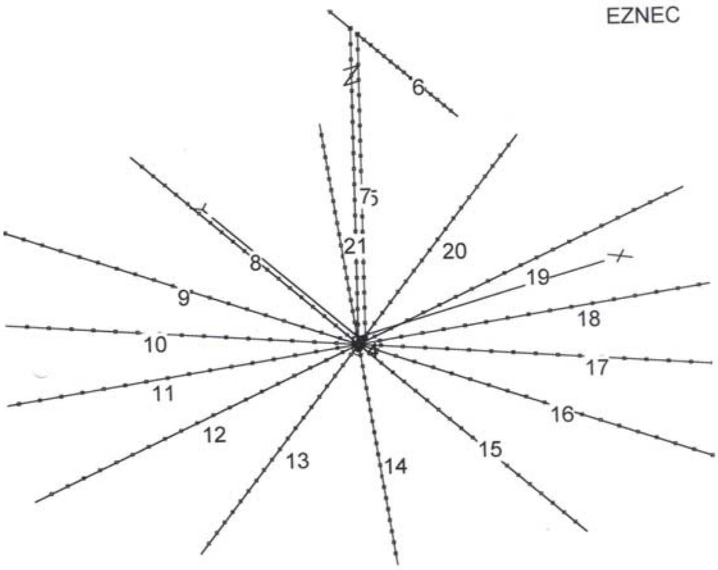


Fig. 5 - EZNEC model of the 160m/80m antenna with 14 radials

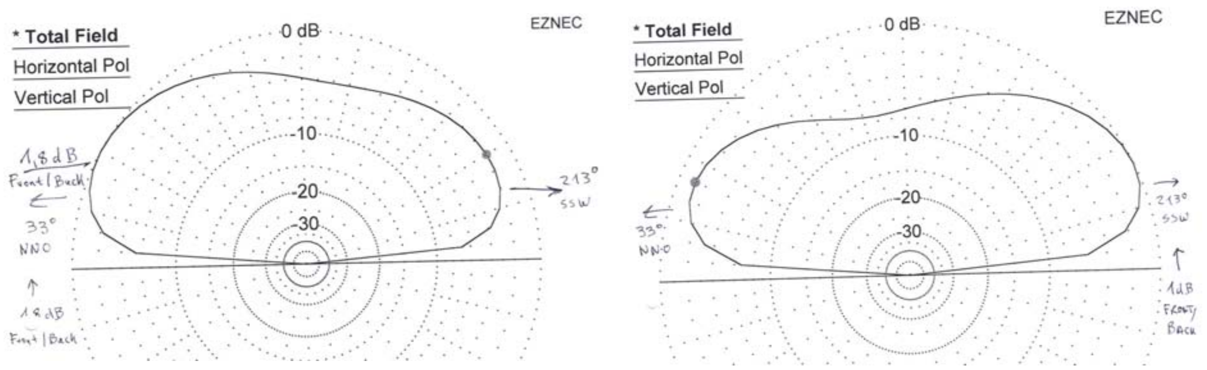


Fig. 6 - Vertical pattern 160m and 80m

Due to the horizontal part of the inverted L the antenna has also some high angle radiation component which is good for short distance QSOs and contest operation. As you can see in Fig. 6 there is some small directivity in direction of the horizontal wire: 1.8 dB front to back ratio on 160m, 1 dB on 80m. In my case maximum gain is at NNE on 160m and at SSW on 80m, but hardly to recognize in practice as there are “obstacles” (house, trees etc.) in both directions. The radiation angle at maximum gain is about 25 degrease on 80m, and 30 degrease on 160m, good for long distance communication on both bands.

- **Adding 40m**

As this antenna performed now very well on both bands and I did not see any difference to the monoband versions, why not adding a quarter wave vertical for 40m? It took just 2 hours to add a 10m long DX wire between the vertical wires for 80m and 160m and to connect this wire as well to the common feed point. I.e. the 40m radiator is in the middle between the 160m and 80m wire in about 25 cm distance from both (see Fig. 7). After cutting the wire to the right length SWR was 1:1 on 7040 kHz! Some minor adjustments were required at the 80m wire, which just took a few minutes and the antenna was working on 3 bands! This antenna mounted on the ground and surrounded by trees outperforms the R7000 on top of the roof, despite the fact that it also has the 1.5 m horizontal part for movement adjustment. To avoid this, a fibreglass pole could be used to carry the 40m radiator, but then the antenna would be more visible.
One evening in QSO with VP8LP on 40m the SWR was suddenly increasing. Looking out of the windows I saw in the darkness flames about 8m over ground! The PVC insulator near the end of the 40m radiator was burning. When I stopped transmission the fire went out. I replaced the PVC insulators by 50 cm long Plexiglas pipes with 6 mm diameter. SWR was perfect again and no troubles since that.
Radiation resistance of a quarter wave wire vertical is 36 Ohm. Ground loss resistance of the 16 radials at 7 MHz is 13 Ohm. I.e. perfect match to 50 Ohm (36 + 13) and efficiency 73 % (36/(36+13).

Fig. 7 – Vertical part of the „invisible antenna“ with the PVC insulators, including now also the 40m radiator.

- **How can performance be increased further?**

As described above the antenna actually installed has (including the losses in the thin radiator) on 160m after all an efficiency of 38 % of the ideal vertical (4.2 dB less) and 58 % on 80m (2.4 dB from ideal), whereby the ideal vertical would be a quarter wave long vertical radiator with a infinite number of endless radials (i.e. with no ground loss).
To maximize efficiency, the ground loss resistance needs to be minimized and the

Fig. 8 – 80m part connected to the oak tree

radiation resistance should be maximized. If you manage to extend the vertical part of the inverted Ls e.g. to 18m (using higher trees, fibreglass pole, tower…) the radiation resistance will increase to 22 Ohm on topband (same radiation resistance as it is now on 80m) improving efficiency to 60 % (**1.8 dB**). On 80m this would increase radiation resistance to about 34 Ohm, because 18m is nearly quarter wave. Efficiency improves from 60 % to 70 % (**0.7 dB**), of course no difference on 40m because the 40m radiator is still a quarter wave vertical.

According table 9-1 in [1] a system with 60 radials each 0.30 lambda long (48m on 160m times 60 = 2880m wire!) has a ground loss resistance of 6.6 Ohm. This is about 10 times (!) the amount of wire buried in the ground now just to get down from 15 Ohm to 6.6 Ohm. With the current 10 Ohm radiator efficiency would increase to 10/(10+6.6)=60 % (also 1.8 dB), with the 22 Ohm radiator to 22/(22+6.6) = 77% (**2.8 dB**), on 80m from 60 % to 34/(34+5) = 87 % (**1.6 dB**), on 40m from 73 % to 36/(36+5) = 88 % (**0.8 dB**).

But you have to consider the significant additional efforts to achieve these quite small benefits. Our property is too small for such a large radial system.

Fig. 9 – Feed point of the 160m/80m antenna and radials connected to galvanized plate

- **How does the antenna perform in the daily DX operation?**

I am using this antenna on 160m and 80m since about 2 years and added 40m one year ago. DXCC and WAZ award (30 zones required on 160m) were achieved on topband. 150 different DXCC entities were worked on 160m during this 2 year period. Highlights being QSOs with KH6AT over the very difficult polar path, Peter Island 3Y0X, Galapagos HC8N and many more.

On 80m the number of worked DXCC entities was increased from156 to 229 today.

Last year I participated in the CQ-WW-DX-CW-Contest QRP all bands, output power limited to just 5 watts. During the 48 hours period of the contest 987 contacts were made, 437 with this antenna on 160, 80 and 40. VY2ZM in Canada copied the QRP signal on 160m! Many US stations and other DX could be worked on 80m and 40m.

Seeing these results the described antenna seems to be a good compromise in respect to visibility, available ground for antenna installation and installation efforts. The whole antenna can be built with material cost of less than 100 US$.

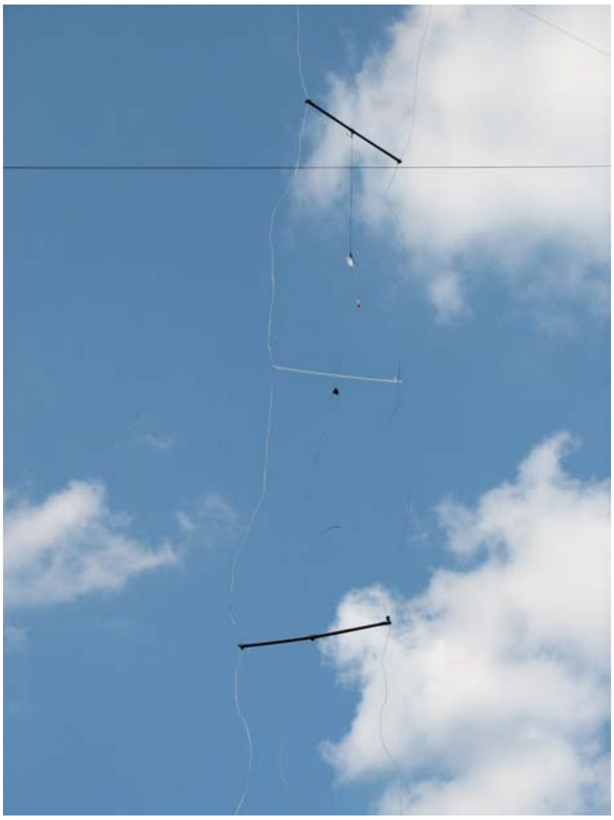
- **Low band DXing from VU4 Andaman Island**

We are planning to use a similar antenna system for the low bands on Andaman Island at the Hamfest in April 2006. To be independent from the availability of trees or buildings as antenna mounting points we will have a 18m long and a 12m long fibreglass pole from Spiderbeam (Thanks to Con DF4SA www.spiderbeam.net !). We are also planning to have about 16 radials. If sufficient space is available the system may be extended to a 2 element array for 80m and 40m with 16 radials per element.

References:

[1] ON4UN´s “Low Band DXing”, Fourth Edition, published by the ARRL

Additional photos:



“Hot” end of the 40m radiator – 2 insulators are made from PVC, the one in the middle next to the hot end is made from Plexiglas. The horizontal wire is part of a 30m dipole.

Horizontal part to compensate movements in heavy wind

“Hot” end of the 80m inverted L with Plexiglas insulator and insulating tube to avoid that the wire touches the branches of the tree.

End of the vertical part, 80m inverted L left, 160m inverted L to the right, both with plexiglas insulators connected with Dyneema rope.