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Slim 2m end-fed antenna for inside fiberglass fishing poles

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Summary

Fiberglass fishing poles, and the heavier special antenna poles, are good aids to get your vertical antenna high into the sky for temporary or semi-permanent use. Many amateurs have the antenna and matching circuit outside the mast. Having the antenna inside the mast or pole has advantages (less wind load and protection).

This document discusses a slim (< 9 mm) half-wave end-fed antenna for 2 m band for installation inside fiberglass poles. As it is thin, you can almost use the full length of the mast or pole. The focus is on making of the antenna instead of design. The matching circuit (for finding values for L and C) is discussed briefly as the main design document is in Dutch language only.

Of course the tuning procedure is treated also. Many vendors often don't exactly know what they sell. Therefore a test procedure to figure out whether (or not) a pole is suited is also present.

Though not treated here, the design can be modified for other frequency ranges, think of 10 m band and the lower VHF bands.

The main reason for writing this document is the Scouting summer camp net ("Zomerkampronde" in Dutch) and some new local nets (because of restriction due to COVID). Hopefully this document will encourage people to build their own fishing pole half-wave end-fed antenna.

Wim Telkamp, PA3DJS

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1. Introduction

To reduce the propagation loss at VHF/UHF, antennas need to be high above the ground as VHF/UHF range is limited by the radio horizon under normal propagation conditions and 10...100 W of RF power. You need a high building, hill top or mast to have large horizon distance.

Fiberglass masts and/or glass fiber fishing rods/poles can be used to gain antenna height. They are frequently used for temporary antenna installations. They are light-weight, have nice transport lengths, are more or less affordable and are relatively easy to install. In case of vertically polarized antennas the radiator and/or cable is wrapped around the mast, or just hangs parallel to it.

Why not put everything (antenna, matching circuit and cable) inside the mast or pole? Is it possible? Yes it's possible without rocket science! What you get is an esthetically good solution, weather protection and less wind load.

Most well designed thin wire half-wave end-fed antennas can function without additional counterpoise. The cable shield is used as counterpoise in that case. The complete antenna must be very thin to avoid that you have to remove the top section of a telescopic mast or fishing pole.

Here a thin (< 8.5 mm thick) end-fed antenna for 2 m band is discussed. The document focuses on construction. An in-depth analysis of the half wave end-fed antenna can be found here (sorry, in Dutch language only, but many graphs are self-explanatory and/or have English text in them):
http://tetech.nl/divers/HWmonopoleNL1.pdf

The complete antenna (radiator and matching circuit) fits into the top section of an 18 m Spiderbeam mast. Several fiberglass fishing poles have a hollow top section, accepting a thin wire. The radiator goes into the top section. The matching circuit goes far into the second section.

The motivation for designing the antenna is the Scouting JOTA event and the Dutch Scouting "summer camp net" ("Zomerkampronde" in Dutch).

¡Fiberglass is in decline! Nowadays carbon or carbon composite fishing poles are taking over, especially at length over 6 m. Chapter 6 gives hints to make sure you get a fiberglass pole. Using carbon or carbon composite poles is wasting your time (and perhaps money).

A graph of a thin light-weight matching circuit is shown below.

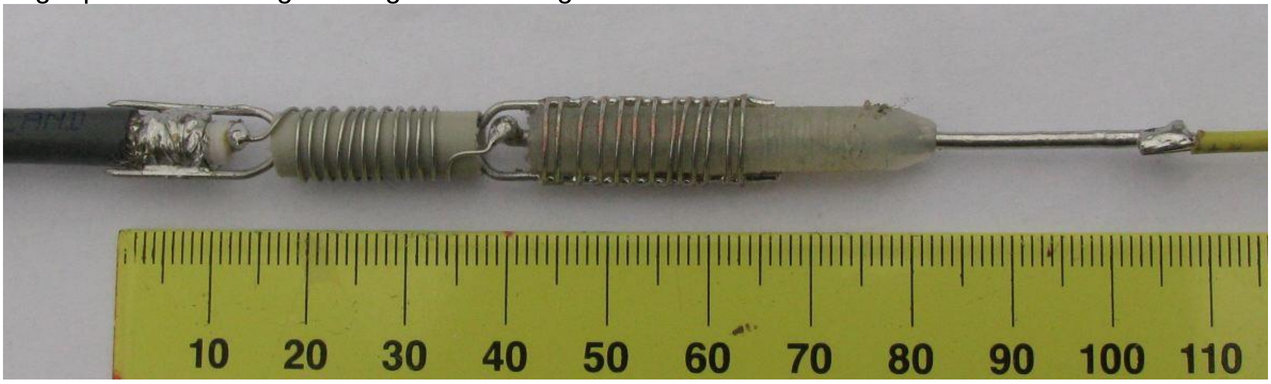

Figure 1.1, light-weight end-fed matching circuit for 2 m band

If you want to skip the analysis and design, just read chapter 3 very quickly to become familiar with the components (capacitor, radiator, ground wires, etc) and then go to chapter 4. Figure 3.1 gives an overview picture of the matching circuit.

Other languages

Just in case you need to buy in a non-English speaking area.

A “fishing pole” has generally no rings and is used without a reel. A “fishing rod” generally has rings and has a mounting provision for a reel.

Below are some translations for “fishing pole” and *fiberglass*.

Dutch: “vaste hengel”, “vaste stok”, *glasvezel*

German: “Stipprute” *glasfaser*

Spanish: “caña de mano”, “caña coup”, “caña fija”, *fibra de vidrio*

French: “canne coup”, *fibre de verre*

Italian: “canna fisse”, *fibra di vetro*

2. Technical analysis

More detailed analysis is present in:
http://tetech.nl/divers/HWmonopoleNL1.pdf (Dutch)

You may skip this chapter if you just want to build the antenna.

2.1. Electrical considerations

Small radiator diameter over radiator length ratio gives large impedance, resulting in low feed current. As we can't grab electrons from air, the feed current into the half-wave radiator equals the common mode current (braid current) in the coaxial feed line.

We can't add radials without drilling holes into the fiberglass mast, rod or pole. Doing so will reduce the strength of the mast/rod, and/or increases wind load. Adding CM suppression is troublesome as the top sections of fiber glass mast/rod haven't much room. A sleeve choke may be an option (but not necessary).

Other option is to use a thin wire so that the impedance is relatively high. The penalty for this is that the voltage is also high (Upk = 1.414*sqrt(P·R)).

A 1.4 mm thick wire (1.5 mm^2 electrical installation wire in Europe) has an impedance of about 2 kOhms. 50 W input generates about 450 Vp.

A bare wire with le = 1.0 m generates lowest common mode current,
Z = 2 kOhms // -j4.9 kOhms (0.22 pF), Q factor = 8.3

Feed current at 50 W input is about 158 mArms (that is rather high).
Radiator center current is about 900 mArms

Using a thinner wire:

1. Reduces the cable common mode current
2. Increases the radiator voltage
3. Reduces the useful bandwidth.

A common mode current of 158 mArms is relatively high, but normally spoken the feed line is many wavelengths long and the cable may have some bends in it before reaching the transceiver. If so, the CM current at the connector is sufficiently attenuated due to radiation loss.

Does this cable radiation interfere with the radiation from the antenna itself? Theoretically yes.

- Some of the RF input power is converted to CM current. This introduces a loss of about 0.6 dB (for a 1.4 mm thick radiator).
- Most of the radiation from the cable's CM current points towards earth, and the current itself is about 15 dB below the radiator current.
- The average height of the cable is half that of the antenna so the strength at large distance is less, due to the lower average height.

The interference of the cable radiation is generally less than 0.5 dB. Together with the loss due to the power in the CM current, the gain of such a half wave antenna will be > 1dBi at zero elevation.

2.2. Matching

Z = 2 kOhms // -j4.9 kOhms (0.22 pF). This impedance needs to be matched to 50 Ohms with an input power of 50 W in mind. 50 W is used as most mobile transceivers are limited to 50 W output. In real world there will be cable loss, so it is unlikely that 50 W will reach the antenna itself.

Ferrite is not that efficient anymore at 145 MHz, and this is a narrow band antenna. A quarter wave transmission line transformer is practically not feasible. Where to find coaxial cable with Zc = 300 Ohms?

A simple LC matching network will do the job. Design formulas are given below:

$$Q = \sqrt{\frac{R_{rad}}{R_{in}} - 1} = \frac{X(L_s)}{R_{in}} = \frac{R_{rad}}{X(C_p)}$$

$$Q = \sqrt{\frac{R_{rad}}{R_{in}} - 1} = \frac{X(C_s)}{R_{in}} = \frac{R_{rad}}{X(L_p)}$$

X(...) = magnitude of impedance for the relevant component
for example: $X(L_S) = 2 \cdot \pi \cdot f \cdot L_S$, $X(C_p) = 1/(2 \cdot \pi \cdot f \cdot C_p)$

Figure 2.1, LC high impedance matching

The A-circuit provides some attenuation of harmonics or frequencies above the band of interest. The B-circuit basically provides better protection for nearby lightning strikes as the network removes the low frequency high energy content of the induced impulse.

However due to the long cable, the net effect will be small to negligible. If nearby lightning is an issue, cable grounding and a BPF between TRX and cable is the way to go. Please note that this will not give you protection in case of a direct hit!

For this antenna we will use the Low Pass Filter version.

When using the formulas from graph 2.1, an inductor of about 340 nH is required together with a capacitor of 3.4 pF.

When the radiator length is optimized for minimum CM current in the coaxial cable, the radiator shows some capacitive component (0.22 pF). Therefore actual capacitance will be in the 3.2 pF range. This is just 30 mm of 50 Ohms coaxial cable with solid PE or PTFE dielectric.

In real world the capacitance will be even less as the inductor has capacitance to the ground connections also.

2.3. Other frequency bands

If you want to scale the design to another frequency using 1.4 mm wire, impedance and bandwidth will change. As a guideline you can use:

Frequency [MHz]	Impedance (D = 1.4 mm) [Ohms]
30	3300
50	2800
70	2600
145	2000
220	1800
440	1400

For say 30...50 MHz, one may use a thicker inner conductor for the capacitor (for example 6 mm^2 tinned ground wire. This increases the capacitance/m for the coaxial capacitor.

When using a single transformation step (as used in the 2 m design), you may not cover the complete amateur band with good SWR. When that is required, you need to use the more elaborate two-step transformation An English language example is shown in the design document (Annex 8.3):
http://tetech.nl/divers/HWmonopoleNL1.pdf

For 27 MHz CB (26.965...27.405 MHz) you can still use the one step transformation from 50 Ohms to 3000 Ohms. You need a >6 m pole.

3. Implementation, Actual Design

3.1. Overview

Figure 3.1 shows the matching circuit:

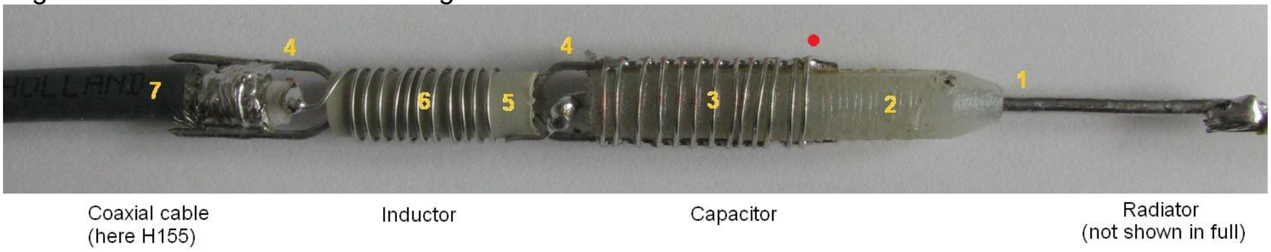

Figure 3.1 matching circuit

Radiator (not shown)
The radiator connects to the center conductor of the coaxial capacitor. The radiator length is referenced to the transition from capacitor ground to the dielectric (marked with a red dot). The radiator has a diameter of 1.4 mm (2.5 mm^2). When the radiator has no insulation and is in air, its length would be 0.95m. When inside a rod/mast/pole, the length should be reduced.

Capacitor
The capacitor has three components

- no. 1, center conductor (1.8 mm thick tinned Cu [2.5 mm^2 in Europe])
- no. 2, PE dielectric (7.2 mm thick, 30..35 mm long dielectric recycled from old RG213 coaxial cable)
- no. 3, Coaxial ground (0.5 mm thick tinned Cu, soldered onto two ground wires).

This construction allows reducing the capacitance on-site by just removing some turns.

Instead of PE dielectric, PP can also be used.

The dielectric has provisions to reduce the effect of moisture. The figure below (3.2) shows a sketch showing features that are not visible on the photos.

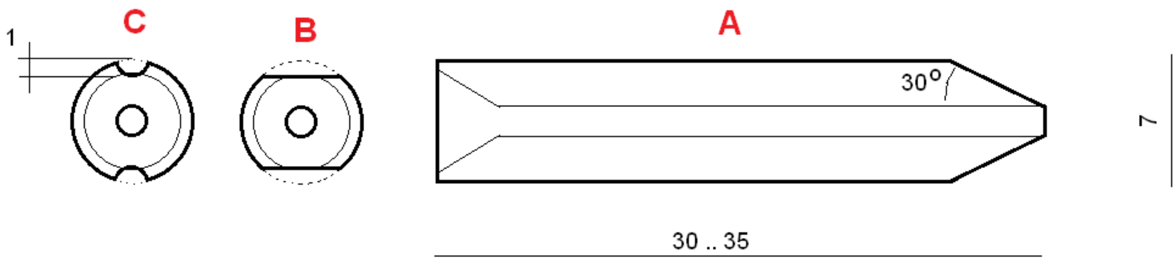

Figure 3.2, detail of capacitor dielectric (all in mm)

Figure A shows the dielectric (no. 2 in figure 3.1). The taper (right side) reduces the voltage stress at the surface, and avoids build-up of water. The conical cut (countersink) on the left has the same function (water can't reach it, and the creepage path is longer). Of course the taper angle isn't critical.

To make the antenna really slim, material is removed from the dielectric so that the ground wires (no. 4 in figure 3.1) remain inside the original diameter of 7.2 mm.

Option B (figure 3.2) is easy to make. Just clamp the dielectric and use a very sharp plane or knife to make flat sides. Figure 3.1 shows a capacitor using this option.

Option C (figure 3.2) requires a milling machine or a small gouge to make the groove. One may also use a hand saw to make a guiding slit, and then use the gouge. Figure 3.3 shows a capacitor using option C.

Try to go for option C as assembling the ground wires with the dielectric is easy. The ground wires remain in their position, so you have both hands free to wind the coaxial ground.

Ground wires

The capacitor connects to the braid of the coaxial cable via two, 1 mm tinned steel wires. The construction is shown in figure 3.3.

Figure 3.3, Ground wire construction and coil former

Use tinned steel wire. Due to the lower heat transfer (compared to Cu) soldering is easy and it is more rigid compared to copper. The modulus of elasticity of steel is about twice as high compared to copper.

It is good to apply two thick solder dots that connect the ground wires with each other. After sliding the coil former onto the ground wires, the solder dots will be inside the coil former.

Inductor

The inductor connects the center conductor of the capacitor with the center conductor of the coaxial cable.

The inductor (no. 6 in figure 3.1.) is wound around a coil former (no. 5) with Do = 6.5 mm and le = 23…25 mm. It has Di = 3.5 mm so that the ground wires can pass through it. The diameter of the coil former (6.5 mm) is just below the diameter of the dielectric. This assures that the inductor will not deform when mounting into the mast/rod. The capacitor will first jam, protecting the inductor.

This construction introduces capacitance, therefore the actual capacitor has value < 3.2 pF.

The inductor itself has 12 turns. When using 50 W and intermittent use, 0.5 mm tinned Cu wire is fine. You may use 0.5 mm enameled Cu wire for reduced loss. When using 0.7…1 mm thick Cu wire, the coil former diameter should be reduced, or the dielectric must be thicker.

Coil former

The coil former is to enable winding of the coil after assembling of the capacitor with the coaxial cable.

The coil former is made out of grey PP, as shown in figure 3.3. One may recycle solid PE dielectric from RG213 or RG8. Machining of PE dielectric from RG213 is somewhat challenging. You may use HDPE, UHMWPE or POM (Delrin), but do not use PA (nylon), PVC or other strong polar plastics.

3.2. "Component" values

Inductor

When using a 6.5 mm coil former and 0.5 mm wire, 12 turns give about 340 nH. Compressing the turns increases the inductance, stretching reduces the inductance.

Capacitor

The coaxial capacitor length is about 20 mm, with Do = 7 mm, Di = 1.8 mm, with er = 2.54. This provides about 1.8 pF. This is below the expected 2.2. pF.

Due to the large diameter, there is significant fringing (making the capacitor effectively longer). In addition the inductor has capacitance towards the ground wires that run through the coil former.

The 20 mm length is just determined by experimentation.

Coaxial cable
It is not advised to use a long run of 3 mm cable (such as RG 174). It is very light weight, but its attenuation is about 0.38 dB/m. If weight is really a concern, you may use say up to 5 m of RG174. This saves weight in the top of the pole. The remaining distance can be covered with low loss coaxial cable.

A good compromise is Belden H155. It is just a bit heavier then RG 58 (0.038 kg/m), but the loss is significantly less (0.11 dB/m).

4. Construction

4.1. Introduction

figure 3.1 is shown again below (but now of course having another figure number).

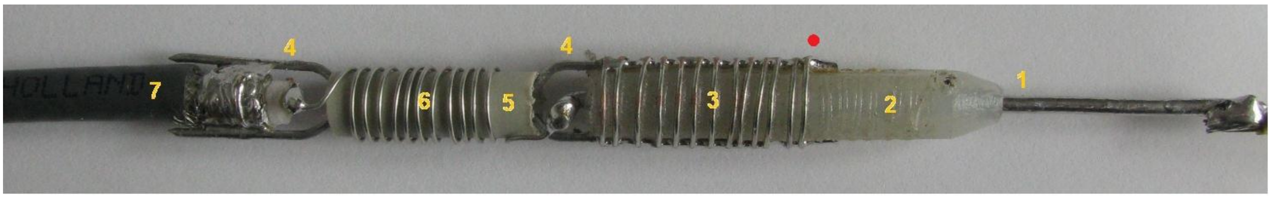

Figure 4.1 matching circuit

Reference is made to this graph as it shows all components, except for the radiator wire.

What do you need?

- 30…35 mm long piece of solid (not foam) PE dielectric of (scrap) RG 213 or RG 8 coaxial cable for the capacitor. Of course you can use fresh (new) PE, UHMWPE or PP material. Do not use polar plastics such as PA, PVC, PMMA, ABS, etc.
- 21…24 mm of PP staff with D > 6.5 mm. for the coil former. You may use a piece of solid (not foam) PE dielectric from RG 213 or RG8 as well (but machining is more difficult).
- 2 pieces of 70 mm long 1 mm thick galvanized or tinned steel wire for the ground wires
- 60..70 mm of solid 2.5 mm2 Cu installation wire (D= 1.8 mm) as center conductor that goes through the dielectric (part of capacitor)
- About 320 mm of 0.5 mm (tinned) Cu wire for the capacitor (shield)
- About 280 mm of 0.5 mm (tinned or enameled) Cu wire for the inductor
- About 1 m of 1.5 mm^2 Cu wire solid or stranded) for the radiator (D = 1.4 mm))
- 50 Ohms coaxial cable with diameter < 7 mm.
- Your favorite connector (BNC, N, PL, etc)

Tools

The antenna can be made with regular tools (knife, saw, rotating power tool, pliers, soldering iron, etc).

As most parts have circular cross section at some point, a lathe is useful (to make the taper and counter sink).

Soldering
Best is to use a temperature controlled soldering iron. However a directly mains-supplied iron with a plug-in dimmer to reduce the temperature can also be used.

Some water soluble liquid flux (here sold as Griffon S39) is useful to tin steel parts, or when soldering the ground wire around the dielectric. Liquid flux allows soldering with significantly lower temperature (compared to rosin flux) and rosin type flux isn't aggressive enough to tin steel wire.

S39 can't be used together with rosin flux, so use flux free solder when using S39. When using 60/40 SnPb solder, soldering can be done easily at 275 ^{0}C.

Do not use S39 liquid flux marketed especially for copper. You need the "universal" liquid.

Chemtronics Circuitworks CW8300 is a water soluble liquid flux that can be used together with regular solder with rosin flux, and is easy to clean. It is somewhat less aggressive compared to Griffon S39 universal.

¡Important note!

> *After using water soluble liquid flux, always clean with warm water and some soap, rinse with clean water, and let dry thoroughly.*

4.2. Capacitor construction and assembly

Dielectric
First make the PE dielectric insulator. Take about 30...35 mm dielectric from RG 213 / RG8 and remove the inner conductor.

The taper can be cut with a sharp knife. Both the taper and conical cut angle isn't critical.

If you don't have a 60 degrees center drill, you can use a 45 degrees countersink drill to make the conical cut at the underside of the dielectric. Other option is to sacrifice a drill bit using a bench grinder or similar machine/tool.

Making the groove
If you have a milling machine, you don't need further info.

Doing it by hand is more elaborate. Though option B looks easy (figure 3.2), it is not recommended. Option C is the preferred one.

Clamp the capacitor in a bench vise and use a saw to make a starting / guidance groove. You can then finish the groove with a small gouge or rotating hand tool. Check the depth of the groove with the ground wires. The ground wires should be level with the surface of the dielectric.

Ground wires
Use regular 1 mm binding wire. When available use the stiff variety (has more carbon in it). When it is fresh and shiny, you don't need to remove the stain. A quick

treatment with a yellow/green abrasive kitchen sponge is useful. Tin the steel wire. You may need liquid flux (depending on the state of the surface). Rinse with soapy water when done.

Center conductor
Just use about 60..70 mm of 2.5 mm^2 (13 AWG) electrical installation wire. Remove the insulation and bend with pliers as shown in figure 4.2.

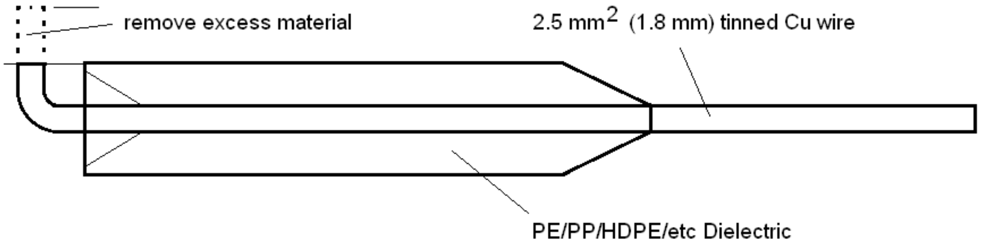

Figure 4.2, Dielectric with center conductor (part of capacitor)

Remove excess length so that you just stay within the diameter of the dielectric. Remove sharp edges. Tin the wire over its full length. This is mostly required to have a snug fit inside the dielectric.

There is no objection to use 2 mm galvanized steel. Tin it before use. This will give a very tight fit. There will not be increased loss due to the permeability of the steel.

Assembling the capacitor
When you cut grooves, it is very easy.

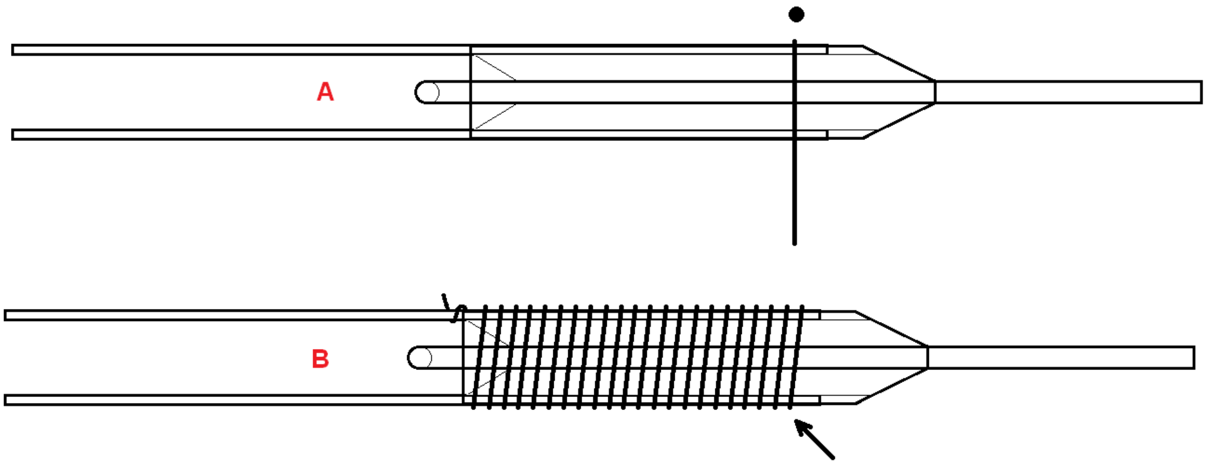

Figure 4.3, Capacitor assembly

Solder the 0.5 mm Cu wire onto one of the ground wires so that the length of the winding is 20 mm. You may do the soldering on the bench to avoid melting the dielectric. Not all of the dielectric is covered. Make sure to have about 3..5 mm excess ground wire length so that you are able to add some turns during the tuning process.

Start as indicated in figure 4.3.A. The solder joint is at position of the black dot. Just wind the wire until you reach the bottom side of the dielectric (left side in the figure). As the ground wire remains in groove, you don't need to concentrate on that.

Make a temporary single turn around one of the ground rods (figure 4.3.B). You may leave out the center conductor during the winding process.

Now you have both hands free to do the soldering. Start at the position indicated with the arrow and solder the turns onto the lower ground wire. When you start at the upper rod, the first solder joint may detach and you need to start all over again.

Remove the temporary turn and solder the other ground rod. Now everything is fixed.

The easiest way is to use water soluble liquid flux (I used CW 8300 from Chemtronics). When you use griffon S39 don't use rosin cored solder!

The solder will flow much better with the liquid flux, and you can use significantly lower temperature. Remove excess solder with finishing paper or a knife. Clean thoroughly with warm soapy water to remove any flux residue. Let dry before continuing.

If you don't have copper wire, you may use tinned soft steel wire instead. It will not introduce additional loss.

Avoiding moisture around the center conductor

When pushing the center conductor inside the dielectric, you may add thick oil or petrolatum. This will fill the voids so water cannot get in. Water around the center conductor will affect performance.

Bend the wires as shown in figure 3.3. Make sure the center conductor is present before bending the wires.

Add two solder drops to join the ground wires for rigidity.

4.3. Coil former

The coil former has le = 21..24 mm, Do = 6.5 mm, Di = 3.5 mm with 45^0 conical cuts at both sides (see figure 4.4). It is made out of PE, HDPE or PP. You may use POM (Delrin), but do not use PA or PVC. See figure 3.3 for an example made out of 10 mm grey PP.

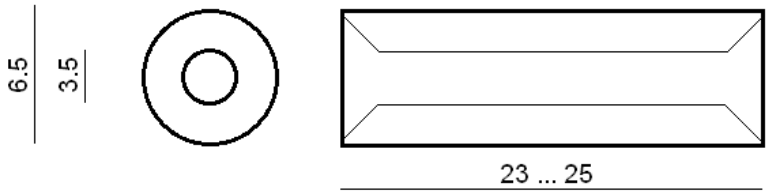

Figure 4.4, coil former

You can make it from PE dielectric of scrap RG213. You need to manually remove some material to reduce the diameter from 7.2 to 6.5 mm. When you plan to use 0.7 or 1 mm Cu wire for the coil, you need to reduce the diameter to 6 mm.

Please note that when drilling the hole (for the ground wires) to 3.5 mm, the drill may bite into the material. For plastic (and wood) I use metal drill bits, but with a modified rake/helix angle so they (virtually) don't bite (but it takes more time to drill).

Assembling the coil former
Slide the coil former onto the ground wires and bend the wires so that they easily mate with the coaxial cable braid (after removing the plastic sheath).

4.4. Assembling the coaxial cable

Instruction is for Belden H155 foam dielectric cable.

Remove 20 mm of PVC (or PE) sheath. Fold back 10 mm of the braid over itself. If you can't form the braid nicely, apply some windings of thin Cu wire around the braid (not too tight).

Use fresh cable. In case of old cable, the braid may be oxidized. If so you can't solder with rosin cored solder and need to divert to aggressive flux. This may creep under the sheath and the braid may be gone within a year. When required, use as little as possible.

Tin the braid with plenty of solder so that it is fully soaked.

Let it cool down, remove all the foil (about 10 mm). This exposes about 10mm of dielectric. Remove 5 mm of foam dielectric. Bend the inner conductor over 90^0 angle. Tin the inner conductor of the coaxial cable.

Solder the coaxial cable in between the two ground wires. When you do it quickly, the solder in the braid will not melt completely. Make sure that everything is stress-free until fully cooled down, otherwise a short circuit may occur.

Check that the now bent inner conductor of the cable doesn't project beyond the capacitor diameter. If so, it may damage the interior of the pole or mast.

You may apply epoxy to avoid ingress of water. Petrolatum (Vaseline) can be used also. Use a heat gun at low temperature. This will heat both coaxial cable and petrolatum. The petrolatum will penetrate into the coax giving good moisture protection, without stiffening the cable.

4.5. Inductor

Wind 12 turns of 0.5 mm tinned Cu wire, or enameled 0.5 mm Cu wire (preferred), around the coil former and solder the wires onto the coaxial cable and center conductor.

By moving the turns in and out, you can vary the inductance during the tuning process. As a starting point, dress the turns as shown in figure 4.1.

4.6. The radiator

When using solid non-insulated 1.5 mm^2 (D=1.4 mm) wire, the length is 0.98 m, measured from the edge of the capacitor ground (see the red dot in figure 4.1).

For insulated wire, the length depends on the thickness of the insulation. When using Alpha wire Eco Wire (thin mPPE insulation), the total length will be 0.97m.

When using regular wire with PVC insulation, it is best to start with 0.95 m, measured from the red dot.

4.7. Strain relief

As the antenna wire goes into the top section, there is no room for strain relief. As the top sections of masts and fishing rods have small internal diameters, you don't need support there. The wire will not fall down (even when using stranded wire). So the strain relief can be located well below the antenna. Figure 4.5 shows the hardware for the strain relief.

Figure 4.5, Strain relief spring connected to Belden H155 cable.

The matching circuit and radiator is on the right side (not shown), and goes into the top section of a mast or rod. On the left side is the connector (not shown). Gravity points to the left.

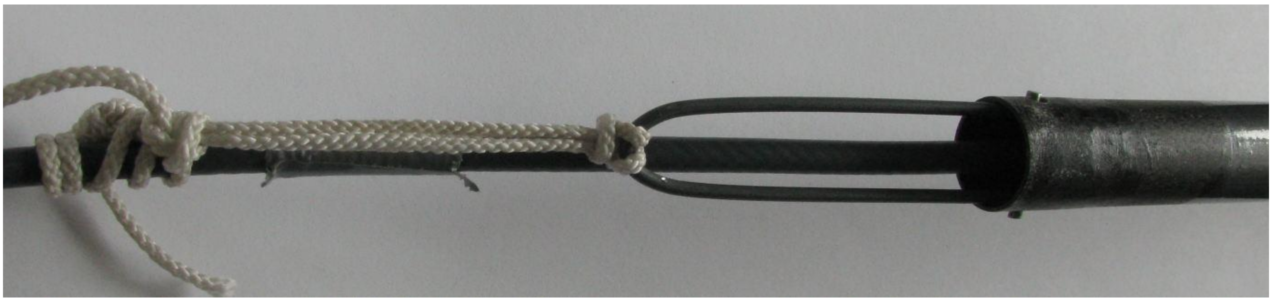

Figure 4.6, Strain relief in action

The U-shaped spring is made out of a bicycle wheel spoke. They are stiff but not brittle.

The sharp bends can be made with pliers or a bench vise and a hammer. A sharp bend is required to avoid failing of the strain relief. Remove excess length after bending so that the “ears” just go through the 3 mm holes in the fishing rod/mast. Center distance towards the edge of the section is about 8 mm.

It is important to remove sharp edges and to tin the fresh metal to avoid rust and it makes the surface very smooth. Note that when erecting and taking down the mast the ears press against the inside of another section. A smooth surface avoids wear.

Use a knot that doesn’t slide under load, but doesn’t damage the cable. You may use some tape (as shown in the figures) to avoid slipping of the knot over the cable. In this example the tape is for reference only.

For drilling holes in thin glass fiber laminate I use drill bits with modified rake/helix angle (using a bench grinder). The rake/helix angle at the tip is near zero avoiding biting of the drill bit and thereby damaging the laminate. Do not apply high pressure during drilling.

Figure 4.6 shows the strain relief in action. For fishing rods, the two holes are on the lower side of the third section (referenced from the top of the fishing rod). When using a spider beam mast with 1…1.6 m sections (12 and 18 m length), the holes are in the lower side of the second section.

When you are going to use a put over pole, you need to drill the two holes in the top of the third section to avoid weakening the pole. The top of the third section goes into the back of the second section.

5. Tuning

5.1. Introduction

Tuning is a two-step process. As a first step, tuning is done in free space. After that, the radiator length is reduced to get the best SWR when the antenna is inside the rod, pole or mast.

Make sure to start with a radiator length as discussed before. Tune the antenna outside and away from obstructions. Use some thin cord or rope to connect the top of the radiator onto a non-metal rod. The radiator should be at least 10 cm away from the rod. The cable runs straight down (as in the actual situation) and then goes to an antenna analyzer.

5.2. Tuning using an SWR indicating instrument

Do a first measurement and note SWR and frequency.

When frequency for best SWR is below the center of the band (145 MHz in ITU region 1), extend the coil (that is more space between the turns). The frequency for best SWR will go up.

When the SWR becomes worse, the capacitance is too large, so you need to remove one or two turns from the capacitor shield.

When the SWR improves after extending the coil you can further extend the coil to reach the center of the band.

When the initial frequency is above the center frequency, compress the turns to increase the inductance. When SWR becomes worse, you need to add turns around the dielectric to increase the capacitance.

An SWR < 1.3 at the center frequency will give you an SWR well below 2 within the 2 m band. You can optimize for SWR < 1.1 at the center frequency. This will give SWR below 1.5 across the EU 2 m band.

5.3. Final tuning when the antenna is inside the mast/rod

When you slide the antenna inside a fiberglass mast or pole, the frequency goes down due to the dielectric properties of the glass laminate.

Typical glass fiber telescopic fishing poles with hollow top sections (Mitchell, Abu Garcia, Shakespeare, Spro) show a drop of about 1.4% of frequency of best SWR. The wire goes party in the hollow top section.

When using (for example) Spiderbeam masts intended for antennas, the drop is in the range of 4..5%. The reason for this is heavier (thicker) tubing. For their regular masts with transport length of around 1.5 m, the wire plus matching circuit goes completely into the top section, so you have the full length available.

Tuning is done by reducing the length of the radiator only. Don’t tune using the matching circuit. This means that the antenna when operated in free space must be fine at the intended center frequency (145 MHz for ITU region 1). You just cut the radiator.

About 20 mm needs to be removed for fishing rods, but for (Spiderbeam/DX-Wire/etc) antenna masts you may need to remove 50 mm.

When done remove about 5 mm of insulation and fold back about 2..3 mm of wire. This creates a rounded termination onto the wire. Saturate it fully with solder to form a kind of droplet shape. This eases sliding the wire into the pole and it makes sure there will be no partial discharge. Figure 5.1 shows an illustration.

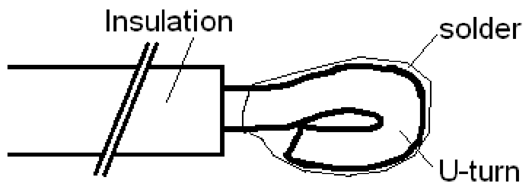

Figure 5.1, U-turn to reduce partial discharge

When there isn’t sufficient space for the large droplet, you may omit the U-turn and add a solder drop only.

6. Checking fishing poles for suitability

It is best to check your fishing rod/pole before starting an antenna project. It may save you from disappointment. Over here (the Netherlands) long glass fiber poles are more and more replaced by full carbon or carbon composite fishing poles. These types of rods aren't suitable to have an antenna inside, or wrapped around it. You need fiberglass. The resin type is not important, but epoxy resin gives the strongest rods.

Many vendors don't know exactly what they sell. Manufacturers may change the production process without notice, etc. In addition a cheap fiber glass rod can have carbon black as pigment. Above a certain carbon black percentage, electrical characteristics drop significantly and make the pole useless as a radome. You cannot judge by the color.

6.1. Electrical (RF) testing

You don't need to test the light colored telescopic poles that allow some light passage. They are suitable as they do not contain conductive materials. You also don't need to test relative short fishing poles over EUR 40.--, as they very likely contain carbon fiber. Find something cheaper.

Most fishing poles have sections of about 1 m. So lowest practical test frequency is 145 MHz, or you need to assemble the rod. You may test the parts only that will contain the antenna. Some fishing poles may have a top section of carbon instead of fiberglass. You may replace the top section with a fiberglass section, or leave it out.

When you place a half wave dipole in parallel with and close to the pole, the antenna experiences a frequency drift and impedance drift. When a fishing pole is suited, only the center frequency goes down somewhat. Impedance at resonance should virtually not change. For a center-fed half wave dipole, you may accept an impedance change up to 10%. Same is valid for the bandwidth; it may change up to 10%.

How to check that in a shop?

If you have a (scalar) antenna analyzer, construct a half wave dipole that has a very good match and balance at some center frequency (SWR < 1.2). A thin dipole doesn't have a good match at 50 Ohms without matching!

Now place the fishing pole (or just one section) parallel to the antenna and measure SWR again. Make sure your arm/body or environment doesn't affect the measurement. You should notice a small change in center frequency only. A carbon fishing rod will change the center frequency and SWR becomes excessive.

When you test separate sections, test the last section (thickest one) also when it contains the radiator and/or matching circuit. The last section may have another construction (this is not applicable for 2m, but may be relevant for a CB or 10 m band antenna.

I use my 2 m half wave end-fed together with a RigExpert AA-1000 or AA-1400 in Smith Chart display.

A simple half-wave dipole with 50 Ohms impedance at resonance is shown below

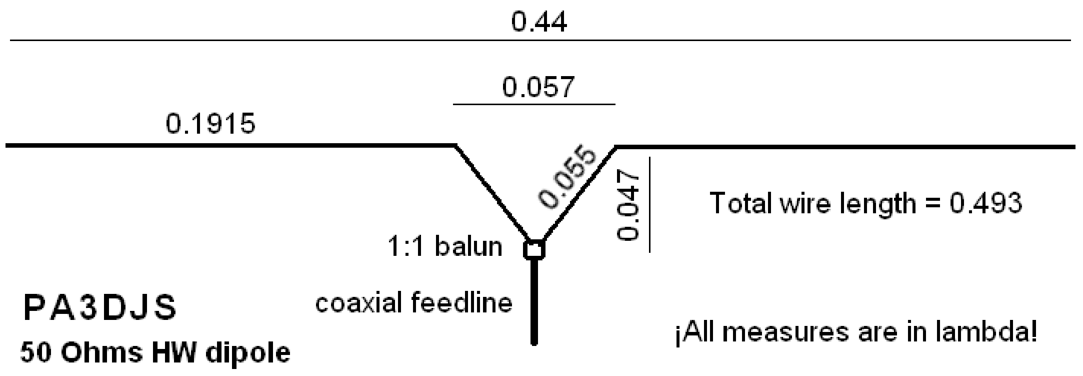

Figure 6.1, drawing of insert for telescopic fishing poles

For 2 m band, you need to multiply all numbers with 2.07, when using insulated wire, multiply with 2.0. You may need to tune depending on the support structure, wire thickness, etc. You need to add some ferrite material at the dipole to feed line transition that serves as a balun. Use material 43 or 61 or similar material from other vendors.

6.2. Testing/Inspecting mechanically

Testing for fitness is impossible, as it depends on many factors (duration of dynamic load and wind). Fishing poles (or fiberglass masts intended for antennas) will and may bend under intended load, so they can withstand significant loads. However fishing poles are not designed as safety critical products. When it breaks, no one is hurt mostly in its intended use.

In an antenna application it may hurt somebody when it breaks and falls from height. Daily flexure in combination with UV exposure will negatively affect material properties. So you should take into account that it will break at some day. At high altitude and/or southern part of South America, UV exposure is strong, compared to for example the Netherlands. So fatigue may occur sooner in such regions.

At least you need to start with a fully functional product. You may likely buy a pole that is outdated for a special price. It may sit in a shop for many years. So check it.

Just looking to the sections will not always reveal cracks/damage (from experience). You need to assemble the rod, flex it and listen to it. Now cracks should be visible.

I didn't follow above guideline…
I bought some new old stock (4 fiberglass fishing poles with varying length). When assembled at home, cracks were visible at the joints! They could be repaired with epoxy impregnated Kevlar rope and are in service for almost 5 years now (April 2021).

6.3. Put in, put over and telescopic masts/poles

6.3.1. Put over and put in poles

When a fishing pole is used for a long time, put over is the way to go. Water can't seep into the interior, and the pole will not collapse (as may happen with telescopic poles). Put in poles are also suited, but water may enter via the joints.

There is one disadvantage of put over or put in poles. When erecting, you need to slide every section over the cable in case of erecting vertically. When having a friend to help you, this disadvantage disappears, as she/he can hold the pole while you slide the next section over the cable. It can be done alone, even with the pole almost vertically leaning towards another object. You just need a provision to fix the pole so that the lower end is not standing on the cable.

Another option is to assemble the complete pole horizontally, except for the section where the strain relief is located. Then slide the antenna with cable from the underside into the pole, put the wire into the top section, install the strain relief and assemble the two parts. When done, put the pole up. Of course you need sufficient horizontal space to do this.

6.3.2. Telescopic poles

Telescopic fishing poles may have an advantage when you make a provision so that you can erect the pole while the cable can enter from the underside. The graph below (figure 6.2.A and B) shows an example that can be made out of plastic or (ply)wood.

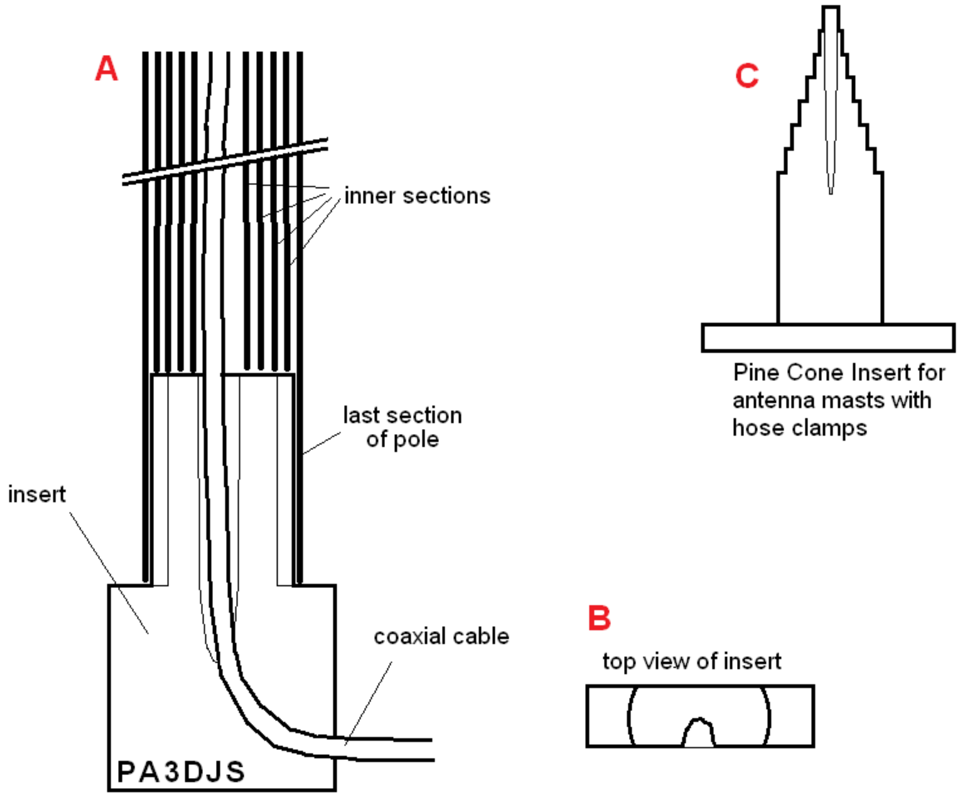

Figure 6.2, drawing of insert for telescopic fishing poles

First the wire and matching circuit are put into the top and second section and the strain relief is installed (antenna horizontal). Then the insert is put into the last section and the pole can be located vertically. Now the rod can be erected vertically to its full length.

The main disadvantage of telescopic fishing poles is unintended collapse. When one section collapses, the complete pole may collapse, resulting in damage beyond repair. Tape will avoid collapse in most cases. For (semi) permanent installation, rubber coated hose clamps may be a better solution.

6.3.3. Big telescopic antenna poles

The big poles intended for antennas (DXwire, Spiderbeam, DX-Engineering, Sotabeams, etc) are all telescopic and may come with fixation hardware.

I own an 18 m Spiderbeam mast (came with mounting hardware to avoid collapse). I made a pine cone insert that is put into the underside of the pole (figure 6.2.C). Each smaller section is 15 mm higher, so there is room for the rubber coated hose clamps. Installation/raising of the mast is very easy, as long as the cable can run freely (without loops or bends).

The pine cone insert has a plate under it so that the insert doesn't dig itself into soft soil. It also keeps the pole clean. Sand between sections will sure cause damage.

6.3.4. Guy wires and other support methods

One may consider guy wires. This is mostly required for the > 10 m masts. Fishing rods generally don't need guy wires up to moderate wind conditions. The guys reduce bending moment, but they do increase compression force onto the sections. This will increase the risk of collapse of telescopic masts.

Forces on guys are relatively low so relative thin guy wire can be used. For plastic rope use a safety factor of about 5. So the breaking strength should be at least 5 times the force due to wind load.

Dyneema lines are amazing. They are very thin and therefore have minimal contribution to the wind load. Stretch is also significantly less compared to nylon or polyester.

Dyneema has a slippery surface. Keep in mind that knots and bends for say polyester or nylon rope, may not be reliable when used with Dyneema rope, They have more strength reduction compared to knots and bends in nylon (PA) rope. They may even untie themselves when loaded. Also eye splices behave differently when using Dyneema. If you want the full benefits of Dyneema, you need to do some homework.

Keep guy wire elevation angle low! At 60 degrees elevation, the compression force on the mast sections is 1.7·(horizontal force). For 45 degrees compression force equals horizontal force. For 30 degrees the compression force is 0.58·(horizontal force).

In case of Scouting and availability of wood poles, one may build a tripod out of 6 m or 8 m poles. The tripod can be used during raising the mast, and it may serve as a support without additional compression force on the section.

Other option is to put-up a single wood pole with guy wires and lash the mast onto the that pole. This eliminates the compression force onto the fiberglass antenna pole.

6.3.5. Lashing fishing poles onto wood poles

Fishing poles are strong lightweight products, but the fiberglass material is relatively brittle (compared to wood). The tubes can easily be crushed. Scouts frequently overestimate the strength of fiberglass poles!

Lashing is part of the Scouring curriculum and is also used during field/outdoor activities. A long fishing pole can be lashed onto a large wood pole and walked-up, reaching heights well above 14 m.

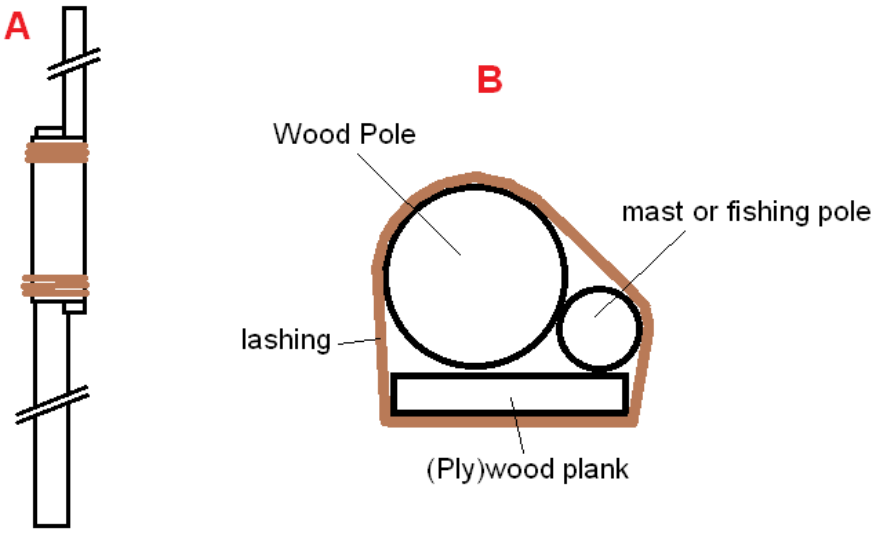

Figure 6.3, drawing of insert for telescopic fishing poles

When using a (ply)wood plank you can make a very stiff and secure connection with low rope tension (see figure 6.3.A and B). Though not shown, it is good to round the edges of the plank to reduce the strain on the rope.

Adding a lashing in the middle of the plank does not give better performance. This method reduces pole crushing significantly. One may first wrap the mast or fishing pole with thin rope (whipping) to avoid point pressure. Point pressure may occur when having a rough wood pole.

You have reached the end of this document. Good luck constructing and using your slim 2 m band half-wave end-fed antenna!
Wim Telkamp, PA3DJS