

# Helical/helix antenna cookbook recipe for 2.4 GHz wavelans and/or WiFi applications

by

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Bookmark/refer to this page as <http://helix.remco.tk> I innocently made this cookbook recipe and placed it on my local ADSL-connected machine, never expecting that so many of you want to have this information.

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## Abstract

The helix antenna, invented in the late forties by John Kraus (W8JK), can be considered as the genius ultimate simplicity as far as antenna design is concerned. Especially for frequencies in the range 2 - 5 GHz this design is very easy, practical, and, non critical. This contribution describes how to produce a helix antenna for frequencies around 2.4 GHz which can be used for e.g. high speed packet radio (S5-PSK, 1.288 Mbit/s), 2.4 GHz wavelans, and, amateur satellite (AO40). Developments in wavelan equipment result in easy possibilities for high speed wireless internet access using the 802.11b (aka WiFi) standard.

## Theory in a birds eye view

The helix antenna can be considered as a spring with  $N$  turns with a reflector. The circumference ( $C$ ) of a turn is approximately one wavelength ( $l$ ), and, the distance ( $d$ ) between the turns is approx.  $0.25C$ . The size of the reflector ( $R$ ) is equal to  $C$  or  $l$ , and can be a circle or a square. The design yields circular polarization (CP), which can be either 'right hand' or 'left hand' (RHCP or LHCP respectively), depending upon how the helix is wound. To have maximum transfer of energy, both ends of the link must use the same polarization, unless you use a (passive) reflector in the radio path.

The gain ( $G$ ) of the antenna, relative to an isotrope (dBi), can be estimated by:

$$G = 11.8 + 10 * \log \{ (C/l)^2 * N * d \} \text{ dBi} \quad (1)$$

According to [Dr. Darrel Emerson](#) (AA7FV) of the National Radio Astronomy Observatory, the results from [1], also known as the 'Kraus formula', are 4 - 5 dB too optimistic. [Dr. Ray Cross](#) (WK00) inserted the results from Emerson in an antenna analysis program called 'ASAP'.

The characteristic impedance ( $Z$ ) of the resulting 'transmission line' empirically seems to be:

$$Z = 140 * (C/l) \text{ Ohm} \quad (2)$$

## Practical design for 2.43 GHz (aka S-band, ISM band, 13 cm amateur band)

$$l = (0.3/2.43) = 0.1234567 \text{ m} \quad ; - ) (12.34 \text{ cm}) \quad (3)$$

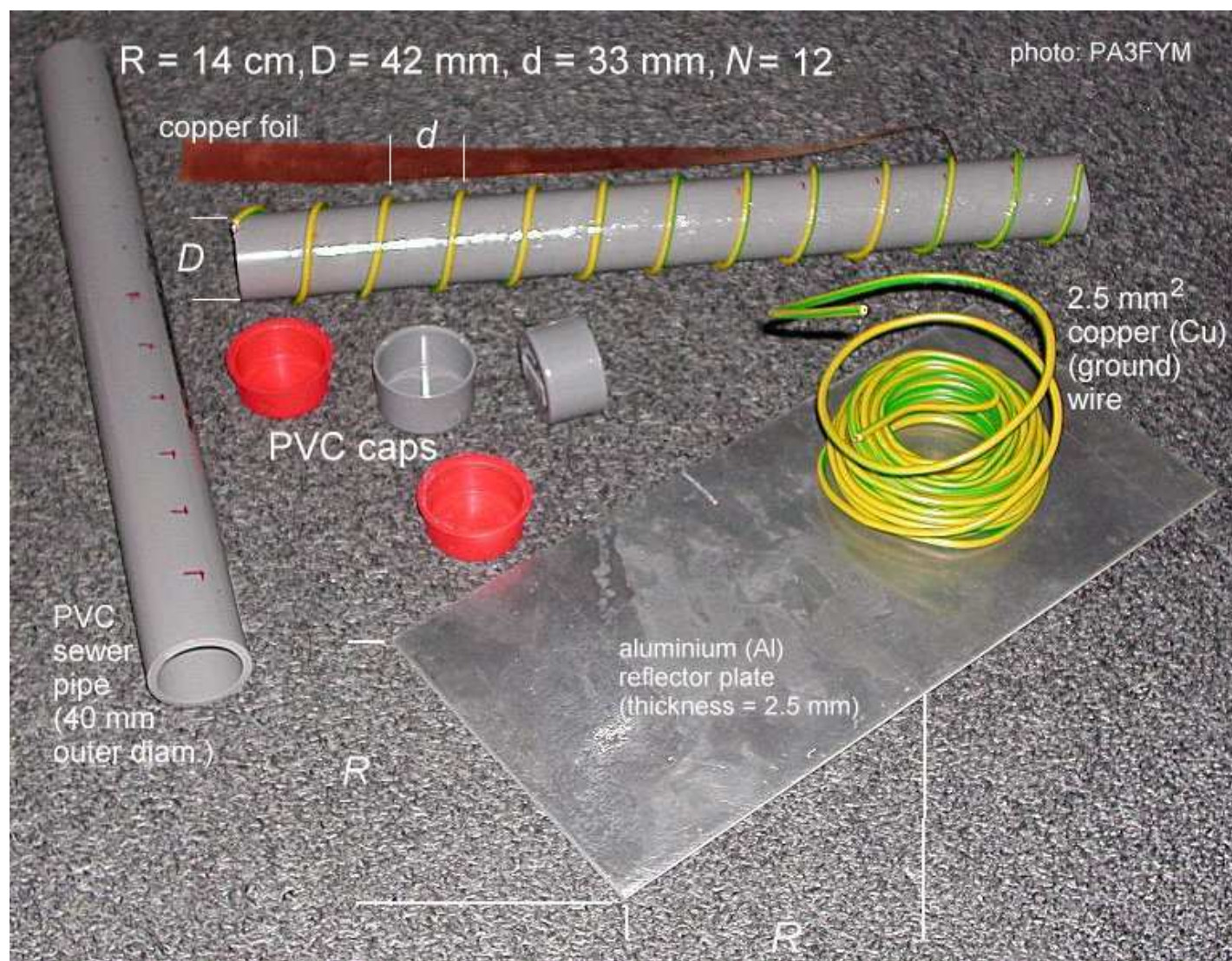
$$\text{The diameter } (D) \text{ of one turn} = (l/\pi) = 39.3 \text{ mm} \quad (4)$$

Standard PVC sewer pipe with an outer diameter of 40 mm is perfect for the job and can be obtained easily (at least in The Netherlands ;-)) from a 'do it yourself' shop or a plumber. The helix will be wound with standard wire used to interconnect 220V AC outlets in (Dutch ;-)) house holds. This wire has a colourized PVC isolation and a 1.5 mm thick copper core. Winding it around the PVC pipe will result in  $D = \text{ca. } 42 \text{ mm}$ , due to the thickness of the isolation.

$$\text{With } D = 42 \text{ mm, } C = 42 * \pi = 132 \text{ mm (which is } 1.07 \lambda) \quad (5)$$

$$\text{Now } d = 0.25C = 0.25 * 132 = 33 \text{ mm} \quad (6)$$

For distances ranging from 100 m - 2.5 km **with line of sight**, 12 turns ( $N = 12$ ) are sufficient. The length of the PVC pipe therefore will be 40 cm (3.24  $\lambda$ ). Turn the wire around the PVC pipe and glue it with PVC glue or any other glue containing tetrahydrofurane (THF). The result will be a very solid helix wound along the pipe, see figure 1 below.



**Figure 1.** Overview of some of the materials used and dimensions.

The impedance of the antenna, which is:

$$Z = 140 * (C/\lambda) = 140 * \{(42 * \pi) / 123.4\} = 150 \text{ Ohm} \quad (7)$$

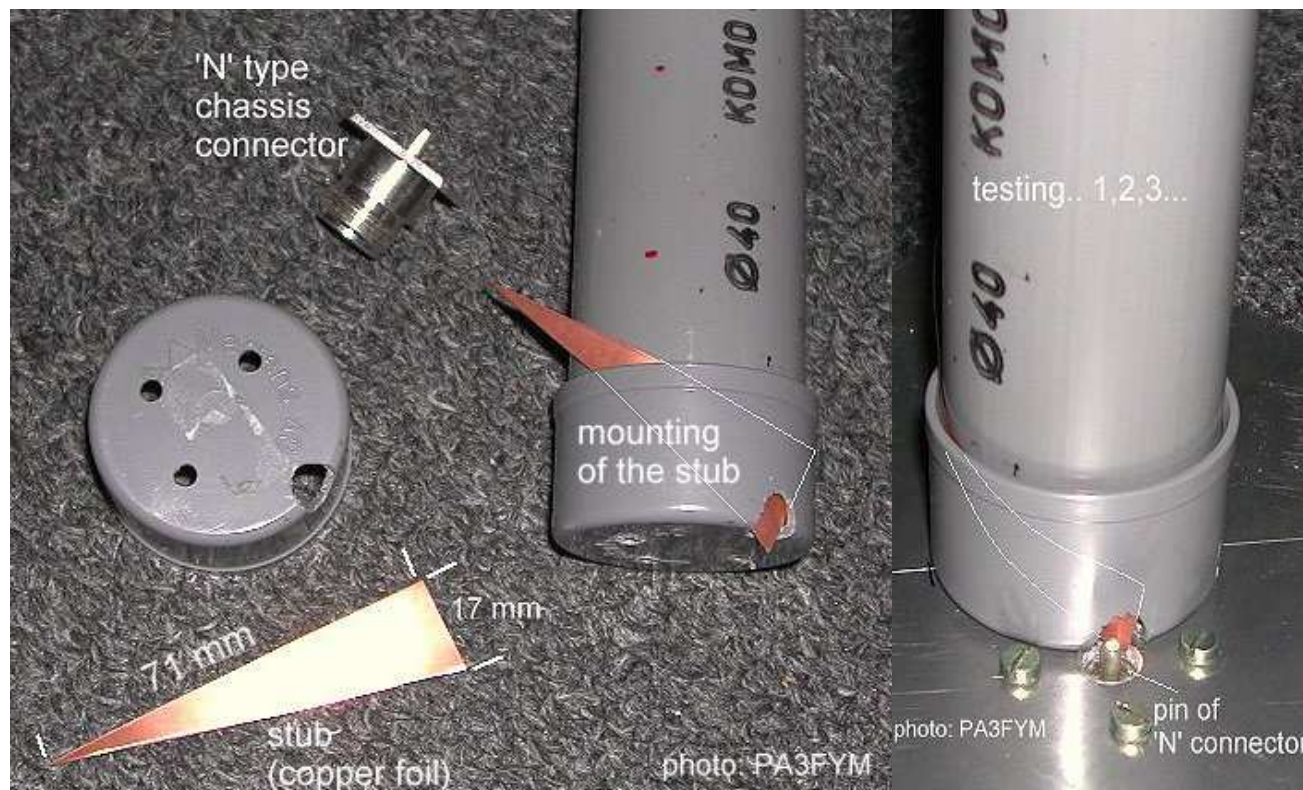
requires a matching network on order to apply standard 50 Ohm UHF/SHF coax and connectors.

The use of a 1/4-wave matching stub with an impedance ( $Z_s$ ) of :

$$Z_s = \text{sqrt}(Z_1 * Z_2) = \text{sqrt}(50 * 150) = 87 \text{ Ohm} \quad (8)$$

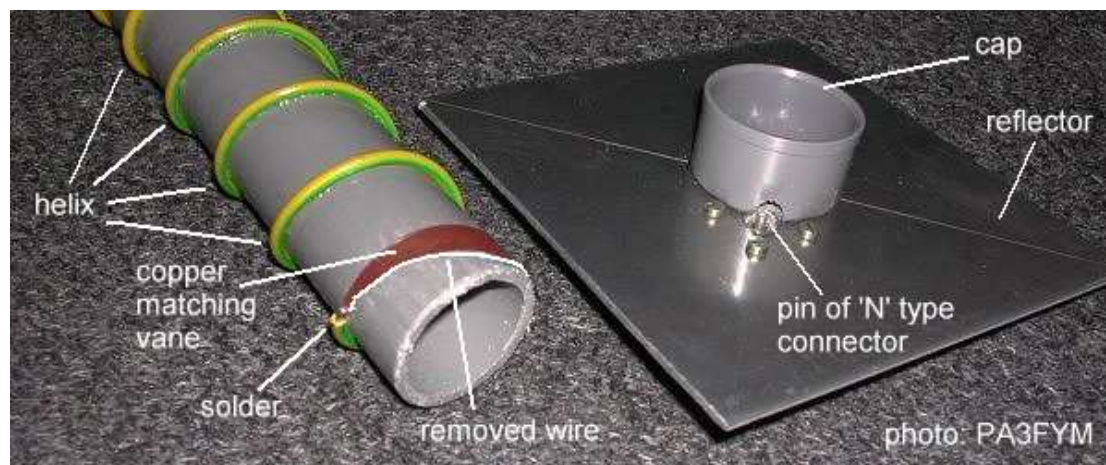
is very common. Due to the helix design, this equals 1/4 turn. However, from a mechanical point of view -bearing water proof aspects in mind when using the antenna outdoors- there are more preferred methods to match the helix to 50 Ohm. My first thoughts were to empirically decrease  $d$  for the first and second turn and match the helix using the 'trial and error'-method, while measuring the results with a directional coupler, and signal generator. Browsing the internet for while I found helices matched [this way](#), but surprisingly I bumped into the page of [Jason Hecker](#). He **really**

used an elegant way to match his helix by using a copper vane, referring to the ARRL Handbook. So, full credits go to the ARRL and Jason, and I used his dimensions for the vane. To be honest, this page seems to be a duplicate of his page, except that our helices are wound the other way around!! Yes, and I am left handed, so, is this a coincidence? It is funny anyway :-)) For details, see figure 2 (below).



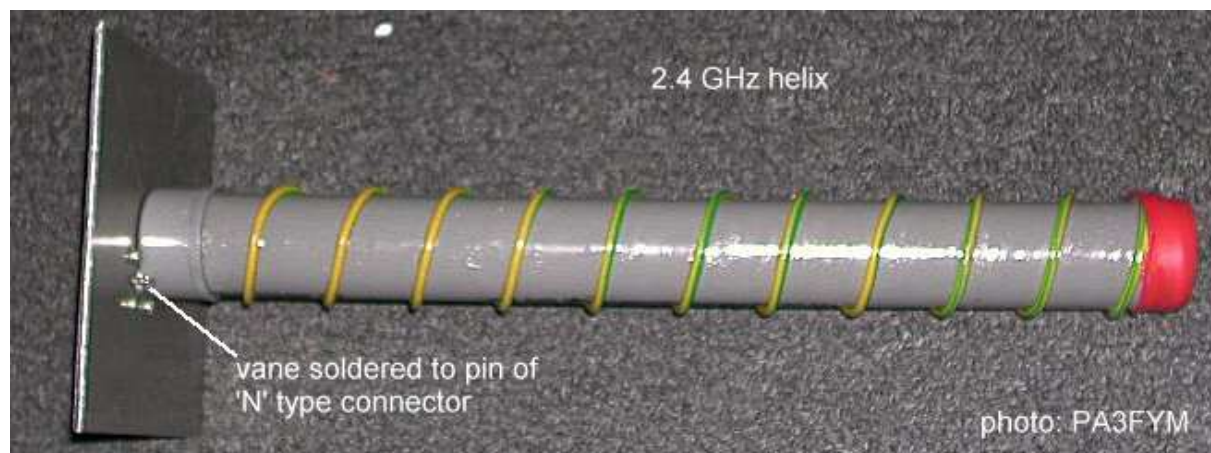
**Figures 2a and 2b.** The idea, the dimensions, and, mounting the stub. The hypotenusa of the stub should follow the wire.

Now with some luck and skills solder the stub to the helix, glue it, and prepare the contraption to be inserted into the cap, see figure 3.



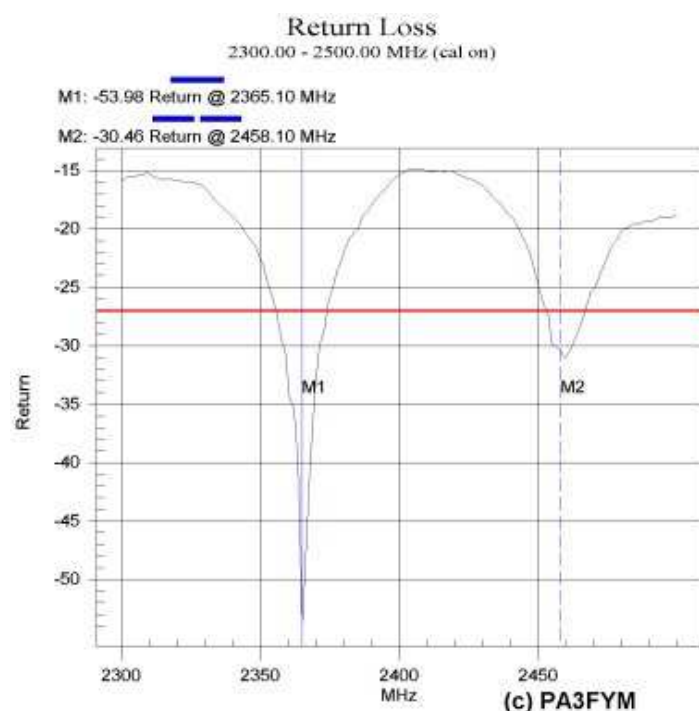
**Figure 3.** Almost finished helix antenna.

And.... ready! (figure 4)

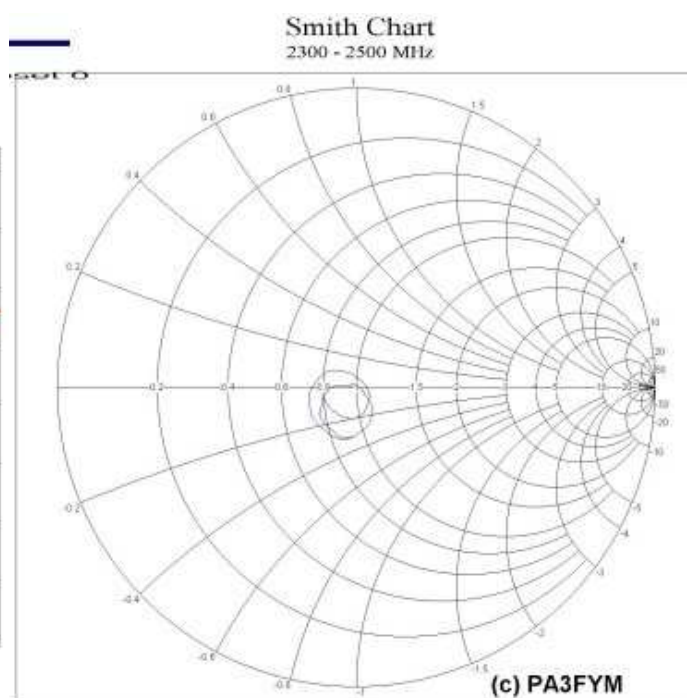


**Figure 4.** Finished 12 turn 2.4 GHz helix antenna,  $G = 17.5$  dBi or 13.4 dBi (Kraus or Emerson respectively)

The antenna was swept and measured. The results are given below (figures 5a and 5b)



**Figure 5a** Return loss (dB) from 2300 - 2500 MHz



**Figure 5b** Smith chart 2300 - 2500 MHz



**Figure 6a** Measurement setup



**Figure 6b** 'helix-in-one-hour' and Rohde & Schwarz analyser

And... finally.... the helix 'in action'!...



**Figure 7a** Beaming to my LAP (Local Access Point ;-)



**Figure 7b** 'bottom view'

It is really nice to receive feedback from people who are inspired by this page. Here a contribution from Rob Jaspers who made his helices using this page:

