Extra-Lightweight Rotary Dipole for the 2- and 10-Meter Band

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With the new license class N, the 10-meter band becomes interesting again for the first DX experiences. While newly licensed hams can easily activate the 2-meter band and the 70-centimeter band for operation in frequency modulation by means of inconspicuous vertical antennas, the 10-meter band is somewhat more demanding in terms of accommodating an antenna. An easy way to quickly get QRV at 10-meter should be in portable operation. A corresponding antenna could also be a worthwhile DIY project. The dipole antenna described below works in the 2-meter band in addition to the 10-meter band, so that the 145 MHz band can also be accessed in SSB and CW. The antenna weighs about 340 g with a wingspan of 3 m and a pack size of just under 1 m. Together with a small GRP telescopic mast, it can be set up for a short time at many attachment points, provisionally on the balcony or at the garden shed, or with a tripod stand in nature, whereby my favourite is the setup on a bicycle rack on a vehicle.

Antenna Design

The proposal is a shortened dipole with extension coils in both dipole arms. The design of the antenna was created with the help of EZNEC /1/, see the table of wire sections. The dimensions of individual wire sections represent the actual dimensions in the later realization. Since the antenna wires are partly routed in a GRP tube during implementation, further information on the "wire insulation" is also necessary in order to make the simulation realistic, especially for the 2-meter band.

Wires

Wire Create Edit Other

☐ Coord Entry Mode ☐ Preserve Connections ☑ Show Wire Insulation ☐ Show Loss

Wires													
No.	End 1				End 2				Diameter	Segs	Insulation		
	X (m)	Y (m)	Z (m)	Conn	X (m)	Y (m)	Z (m)	Conn	(mm)		Diel C	Thk (mm)	Loss Tan
1	0	1,465	0		0	1,46	0	W2E1	5	1	1	0	0,01
2	0	1,46	0	W1E2	0	1,01	0	W3E1	2	11	1	0	0,01
3	0	1,01	0	W2E2	0	0,965	0	W4E1	5	3	3	1	0,01
4	0	0,965	0	W3E2	0	0,52	0	W5E1	1	11	3	0,4	0,01
5	0	0,52	0	W4E2	0	0,47	0	W6E1	3	7	1	0	0,01
6	0	0,47	0	W5E2	0	-0,47	0	W7E1	1	11	3	0,4	0,01
7	0	-0,47	0	W6E2	0	-0,52	0	W8E1	3	7	1	1	0,01
8	0	-0,52	0	W7E2	0	-0,965	0	W9E1	1	11	3	0,4	0,01
9	0	-0,965	0	W8E2	0	-1,01	0	W10E1	5	3	3	1	0,01
10	0	-1,01	0	W9E2	0	-1,46	0	W11E1	2	11	1	0	0,01
11	0	-1,46	0	W10E2	0	-1,465	0		5	1	1	0	0,01

Table: List of wire sections in the EZNEC simulation model

The extension coils are located in Wire #5 and #7 and were calculated with the OptiCoil app /2/: With 42 turns over a length of about 5 cm on the GRP rod of 8 mm diameter, an inductance of 2.4 µH is calculated. This inductance applies to very low frequencies and is in good agreement with my measurement /3/. Unfortunately, the specification of the coil's self-resonance frequency is very inaccurate – my own measurement showed about 160 MHz instead of 111 MHz in the app. This means that the effective inductance at 29 MHz is already 2.48 µH; in the EZNEC simulation, the coils are therefore modelled as a "trap" by adding the corresponding intrinsic capacitance of the coils (here about 0.4 pF) together with a loss resistance of 2 Ω. The position of the coils is chosen so that there is a distance of about half a wavelength at 145 MHz between the two coils, so that the dipole can also be operated in the 2-meter band. In contrast to 28 MHz, however, at this frequency the coils in the EZNEC model must be distributed over three smaller concentrated inductors in order to model the effect of the coil length of 5 cm better than is possible with a single concentrated inductor in the middle of the corresponding wires.

The simulation results in a current distribution at 28 MHz on the shortened dipole, Figure 1a, with an almost constant amplitude between the coils (load) and a linear drop to the dipole ends behind the coils. From this current distribution follows the classic radiation diagram of a dipole with the main beam direction perpendicular to the antenna wire and zeros in the axis direction, see Figure 2a. In the 2-meter band, however, the dipole is already three half wavelengths long and you can see three half waves in the current distribution, where the middle half wave corresponds to a lambda half dipole with center feed. Since the coils are not tuned trap circuits and do not block perfectly, the outer conductor sections are still excited and the other, albeit weaker, half-waves form in the current distribution; however, this current is almost opposite phase to the middle section, which is not shown in the magnitude representation of the current. Accordingly, the radiation diagram appears like a cloverleaf with four main directions and deep nulls in between, see Figure 2b.

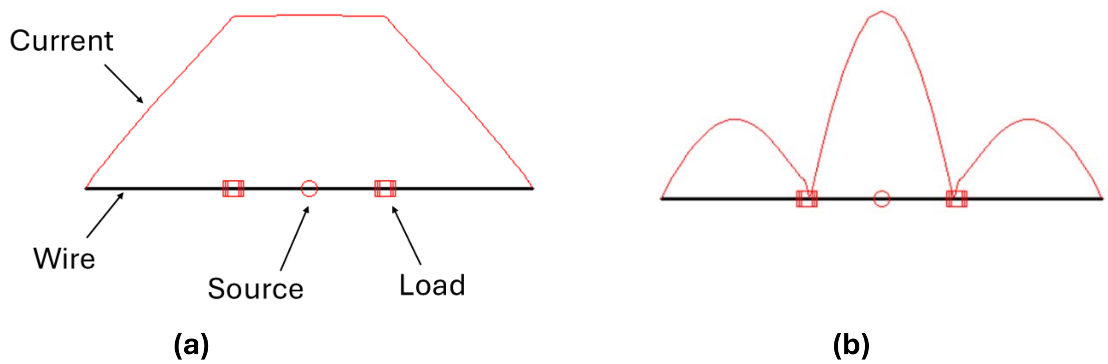

Figure 1 Current distribution on the dipole (wire) with coils (load) and with power supply in the middle (source). (a) at 28 MHz, (b) at 145 MHz.

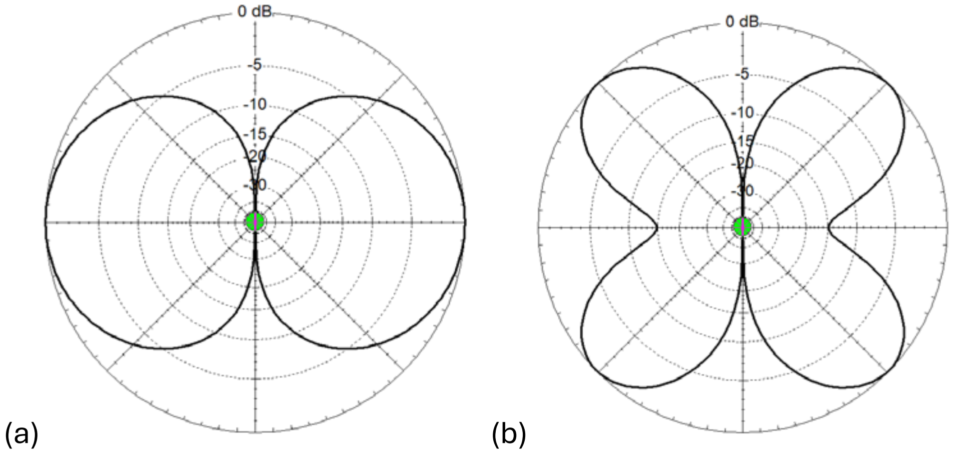

Figure 2 The azimuth radiation diagrams of the dipole in the EZNEC model at (a) 28 MHz and (b) 145 MHz

Practical realization

The design as a portable dipole requires a disassembly of the antenna into smaller parts, as shown in Figure 3: The dipole arms consist of two rods that are inserted into each other and the two dipole arms are inserted into a carrier box and attached. The carrier box connects the dipole arms to a coaxial cable that leads to the connection to the transceiver. The pack size of all parts together remains less than one meter.

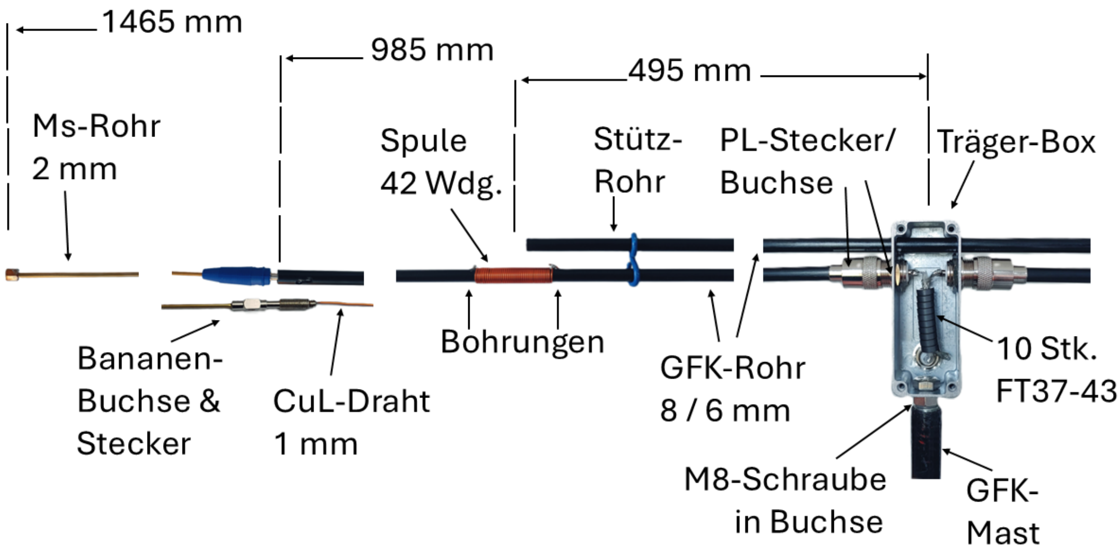

Figure 3 Structure of the dipole antenna. Lengths measured from centre of the carrier box.

The design of the dipole is based on the use of lightweight GRP tubes with 8 mm outer diameter and 6 mm inner diameter. On a dipole arm corresponding to Fig. 3, the enamelled copper antenna wire on the GRP tube is wound into a coil and led inwards through a hole into the tube to the PL connector. From the other end of the coil, another wire is led through a hole in the tube in the other direction to a banana socket and soldered there. This bushing is inserted into the tube in the appropriate position and glued there with epoxy glue (glue entry through holes). There, a banana plug can make contact to the outer part of the dipole arm, a light 2 mm brass tube of just under 50 cm in length, which is soldered into the plug; on the picture you can see a soldered spacer bolt at the end of the tube as accident protection. On the other hand, the PL connector must be drilled out to a width of 8 mm so that the GRP tube can be inserted. The enamelled copper wire is only soldered to the inner conductor of the PL connector, so that the housing of the carrier box does not come into contact with the dipole arms. By screwing PL plugs to the PL sockets, the carrier box can already support the dipole arms; however, another GRP rod is pushed into the carrier box above the dipole arms, so that the dipole arms can be hooked in via small loops for mechanical relief. The GRP and brass tubes are available from model shops in 1m rods, e.g. Modellbau-Lindinger.

In the carrier box you can see a short bare coaxial cable, which is connected to the dipole arms at the top and suppresses unwanted sheath currents (cable choke) by means of 10 pcs. FT37-43 toroidal cores on the outer conductor braid. The short cable section leads to a BNC socket on the back of the box for connecting the coaxial cable downwards. At the bottom of the box there is still an M8 screw, which is picked up by the upper end of my telescopic mast, where a corresponding plastic socket is glued in.

Results

Measurements of the antenna impedance with a NanoVNA were performed after calibration to the wire end in the BNC socket. Figure 4 a) shows the reflection factor of the dipole when set up at a height of about 5 m. The circular measurement curve is typical of the characteristics of a centre-fed dipole with an impedance curve like that of a series resonant circuit. At the resonance frequency 27.99 MHz (blue marker), the impedance is only 30 Ω, corresponding to a VSWR ≈ 1.69, which was to be expected due to the shortening of the dipole from a good 5 m of a "full size dipole" to only 3 m. As you can see from the Smith Chart in Fig. 4a, a match to 50 Ω can be realized by a capacitance in parallel connection "**CP"** – the transformation path follows the blue circle: The dipole impedance at the frequency **f_0** (slightly above the resonant frequency) is transformed into the centre of the Smith Chart, where the impedance is 50 Ω. The optimal capacitance is around 100 pF. If a capacitor of this capacitance were actually connected parallel to the antenna input, the impedance in the 2-meter band would be almost short-circuited, since the reactive resistance of the capacitor is reduced by the frequency ratio, i.e. by a factor of about 5. The solution is a cable that runs open-circuit at the end with a length of half a wavelength at 145 MHz. This does not change the impedance in the 2-meter band, as any impedance transforms back into the same impedance over half a wavelength. In the 10-meter band, the line has only about one tenth of a wavelength according to the wavelength ratio, so that a capacitive reactive impedance of about 1.4 x characteristic impedance of the cable is created. That means about 80 pF at 28 MHz, which is close to the ideal value.

In the measurement, a 68 cm long RG58 cable was connected in parallel at the BNC socket via a BNC T-piece. With the improved match, the bandwidth at VSWR=2 increases to about 530 kHz; this small relative bandwidth of only about 1.9 % of the centre frequency is also to be expected because of the shortening of the dipole. In Figure 4b), in addition to the VSWR in the 10-meter band, the VSWR in the 2-meter band is shown with a much larger relative bandwidth of about 5.5 % of the centre frequency, since the dipole in this band is not shortened.

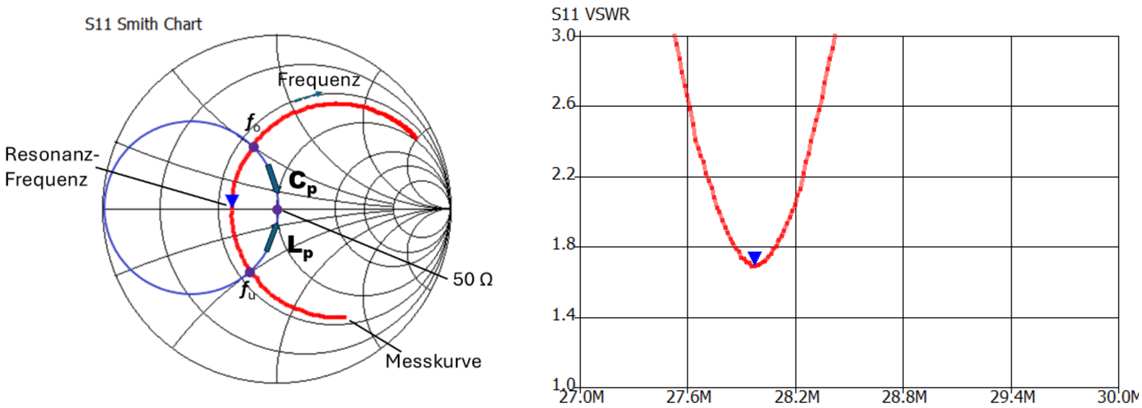

Figure 4a) Measured dipole reflection factor in the 10-meter band and representation of the VSWR. Bandwidth at VSWR=2: About 410 kHz.

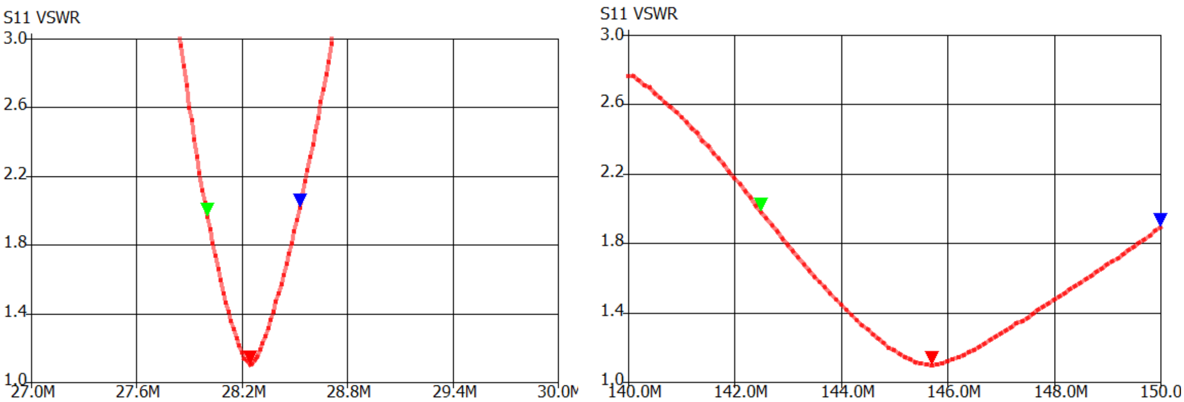

Figure 4b) Measured VSWR of the dipole with matching element. Bandwidth at VSWR=2: About 530 kHz in the 10-meter band and about 8 MHz in the 2-meter band.

If the dipole is to be operated higher up in the 10-meter band, the dipole ends could be shortened: 1 cm shifts the frequency by about 150 kHz, but in about the same way in the 2-meter band. If the coils are extended by one turn, the frequency is lowered by about 200 kHz in the 10-meter band and by about 100 kHz in the 2-meter band. The position of the coils is decisive for the centre frequency in the 2-meter band: A shift outwards of 1 cm results in a reduction of about 1.7 MHz, while the centre frequency in the 10-meter band increases by 90 kHz per cm!

As can be seen in the Smith Chart in Figure 4a), there is also an alternative matching circuit with equivalent results: Instead of parallel connection of a capacitance, an inductor "LP" can also be connected in parallel at the dipole terminals, with the effect that the match frequency $\mathbf{f}_U$ is now below the resonance frequency of the dipole. So, you first have to tune the dipole to a higher frequency in order to land in the desired operating frequency range. In this case, the outer brass tubes were shortened by 3 cm each to achieve about 400 kHz upward shift in the 10-meter band. A coil with about 0.4 µH (8 turns over about 10 mm length on a piece of GRP tube with a diameter of 8 mm) then provides adjustment at about 28.12 MHz. In this case, too, the match of the dipole in the 2-meter band is degraded by this measure, but only slightly, since the impedance of the coil increases with the frequency ratio, i.e. by a factor of about 5. But this can also be easily prevented by a capacitance parallel to the coil, which creates a parallel resonance at 145 MHz – i.e. creates an open-circuit for the 2-meter band. In this case, a 3 pF ceramic capacitor was soldered on. This capacitance is unproblematic because it is too small to have a noticeable influence on the match in the 10-meter band. The advantage of this method is that the coil and capacitor can still be inserted into the carrier box.

Due to the design with plug connections, the antenna is more suitable for operation in "good weather"; the antenna becomes somewhat more robust if at least the coils are coated or sealed with epoxy resin (e.g. UHU Plus Schnellfest) together with the holes in the GRP tubes. For a permanent installation of the dipole, the plug connections and the PL plugs would also have to be sealed. It would be better to do without the plug connections altogether, similar to /4/.

For the portable operation of the dipole, I use a lightweight GRP telescopic mast with 5 segments (33 mm to 18 mm diameter, weight about 540 g), which has a length of 4.8 m. Placed on the bicycle rack behind the motorhome, the dipole then reaches a height of about 5.9 m above the ground. The dipole itself weighs a total of only 340 g, which, together with the 200 g of a coax cable (5 m RG58), can be easily carried by the mast. With the output power of my station of about 70 W in the 10-meter band, there was only a slight increase in the temperature of the coils on the dipole arms, matching the assumed RF resistance of about 2 Ω per coil – even a full 100 W of high-frequency power should be able to cope without any problems.

References

/1/ EZNEC Antenna Software by W7EL, download https://eznec.com

/2/ OptiCoil 2.3 Web Version, unter https://dxc.pi4cc.nl/tech-info/calculators/opticoil/

/3/ Klaus Solbach, DK3BA: Measuring and understanding RF coils using the VNA, https://www.uni-due.de/hft/amateurfunk_en.php

/4/ Klaus Solbach, DK3BA: Short dipole for the balcony antenna system,
https://www.uni-due.de/hft/amateurfunk_en.php