Lightweight 2m/70cm dipole with increased gain at 70cm

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Multi-band dipoles are often implemented in the shortwave range with the help of traps. This means that the length of the dipole can be kept slightly smaller than lambda half (λ/2) at the lowest frequency; at the higher frequencies, the traps then shorten the effective length even further, to match the smaller wavelength. However, it would be interesting to use the full dipole length at the higher frequencies to increase the gain. With this approach, a solution for a 2-band dipole antenna for 145 and 435 MHz was sought and found, Figure 1. If no traps are used, a sinusoidal current distribution is formed on the dipole arms at each frequency with half-waves half a wavelength long at the respective frequency. This means that a λ/2 dipole for 145 MHz when operated at 435 MHz already has three half-waves, which unfortunately have a sign reversal for the middle half-wave, Figure 2.

Figure 1 Dipole with open housing,

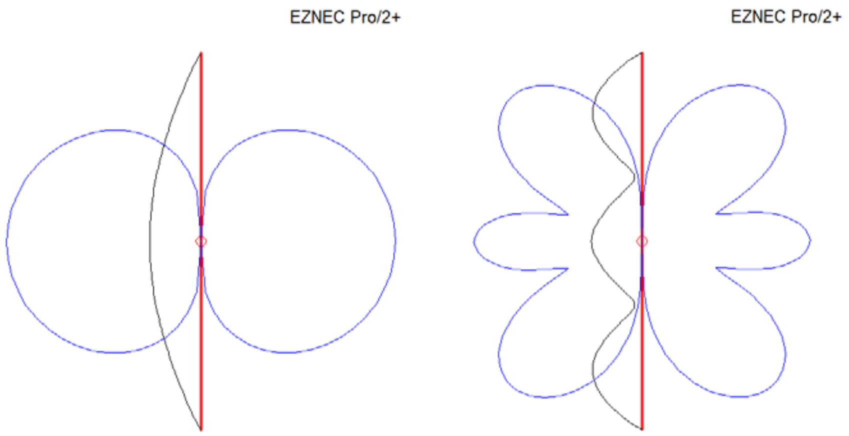

Figure 2 Left λ/2 dipole, right 3λ/2 dipole with center feed. Current pattern (magnitude only!) in black, radiation diagram in blue. Calculation with EZNEC /1/.

The corresponding radiation diagram has two rotationally symmetrical main lobes at +/-45° to the dipole axis. In the radiation lobe perpendicular to the dipole axis, the gain is therefore more than 2.5 dB worse and even 1.3 dB worse than at 145 MHz, so not a good result. Apart from that, the terminal impedance is also unfavorable with 70 Ω at 145 MHz and 100 Ω at 435 MHz.

Something shorter is much better.

Instead of dipole arms with 3/4 λ = 6/8 λ, dipole arms with only 5/8 λ are available: It is known, for example from Rothammel /2/, that the main beam direction is perpendicular to the dipole axis and with approx. 5 dBi has the highest achievable gain of a simple dipole, almost 3 dB more than the classic λ/2 dipole. However, it is also known that the terminal impedance of this dipole is far from match to 50 Ω; and at 145 MHz this dipole length is too short for a λ/2 resonance. This can all be easily examined using simulation with EZNEC.

First, the 2 x 5/8 λ dipole is modeled, see Figure 3 with the current distribution and the radiation diagram. For the lower band end of the 70 cm band, the dipole length is 87 cm. There is a section in the middle with anti-phase current, which, however, only creates a smaller side lobe in the +/- 55° direction. With center feed, the terminal impedance is approximately 94 Ω in series with a capacitive reactance of approximately 350 Ω.

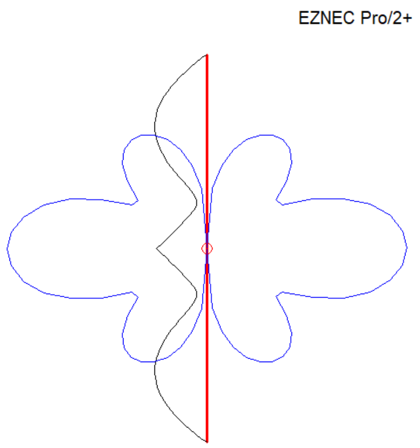

Figure 3 Current distribution and radiation diagram of the dipole with 2 x 5/8 λ length at 435 MHz.

Obviously, an inductor is needed in series to compensate for the capacitive reactance: With two inductors each measuring 0.07 µH, inserted just above and below the feed terminals (“source”) in the middle, the terminal impedance is calculated to be 127 Ω with a reactive component close to zero.

Do we now need a transformer or transforming balun to adjust the antenna to 50 Ω? Actually, not in practice, as already reported in /3/, because the simulation model lacks the additional stray capacitance between the inner ends of the two dipole arms, which arises from the specific structure of my implementation, Figure 4: The dipole arms made of 2 mm spring steel rods are inserted from the outside through the wall of a plastic housing and clamped into two luster terminals. The same luster terminals contact the small coil on the inside, which is separated in the middle. It consists of 2 x 4 turns of 0.8

mm copper wire on a 5 mm diameter coil former (sheath of an RG58 cable). There is a 50 Ω coaxial cable that leads to the SMA socket via a cable choke, i.e. without impedance transformation. Now, instead of 127 Ω, the coaxial line “sees” around 50 Ω at 435 MHz.

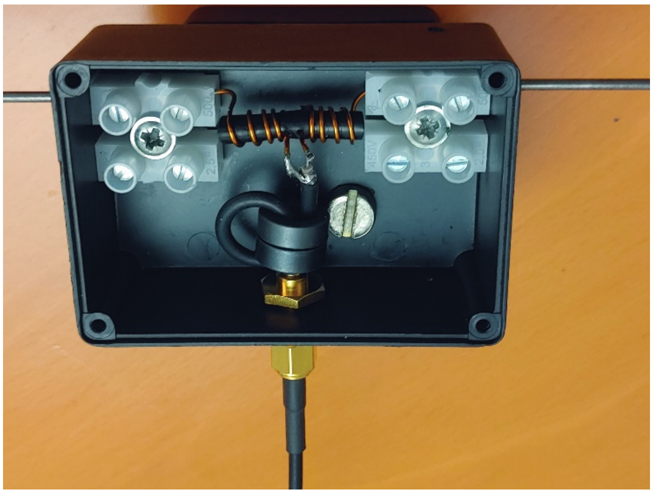

Figure 4 Dipole housing (72 mm x 50 mm) with rods made of 2mm spring steel, luster terminals (attached to the bottom of the housing), coil with center feed, coaxial cable with cable choke made of T50-43 ferrite rings.

More realistic simulation model

The simulation model must therefore be modified so that reality is better described. For this purpose, the EZNEC model is adapted to the geometry of the implementation and expanded to include a capacitance, Figure 5: In the model, the dipole arms are connected to a “wire” that carries the two half-coils (L) and the “source”; The ends of the dipole arms are exactly 87 cm apart and 3 cm apart in the middle, corresponding to the distance between the luster terminals. This is how the luster terminals are only modeled as an extension of the dipole arms. The stray capacitance (C), which partly comes from the luster terminals, is installed in a “wire” between the ends of the dipole arms: With only 0.3 pF, the effective resistance of the terminal impedance drops to around 50 Ω. The compensation of the reactive component uses the inductance of the coil which can be reduced to 2 x 0.04 µH. With the help of the simulation, the stray capacitance of the structure responsible for the match to 50 Ω thus is approximately determined - it is very small and should not be larger if, for example, larger luster terminals were used!

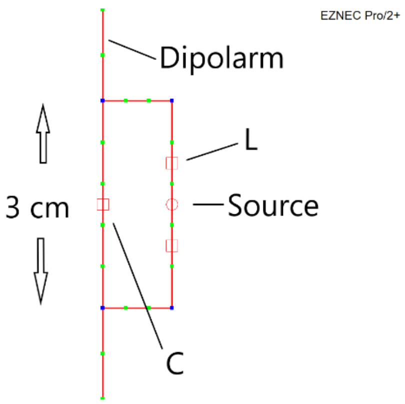

Figure 5 EZNEC wire model of the dipole inside the housing.

This would explain the impedance match at the 70 cm band, but what about the 2 m band? At 145 MHz the dipole of 87 cm length is still a bit too even despite the coil acting to lower the resonant frequency: resonance is found at 151 MHz. By increasing the dipole length by 6 cm, approximate impedance match can be achieved with a smaller inductance of about 0.031 µH for both bands. However, the side lobes then develop more strongly in the 70 cm band and the gain in this band therefore falls by 1 dB, Figure 6. In the 2 m band, the classic current distribution is formed on an inductively slightly shortened dipole with practically full gain of a λ/2 dipole.

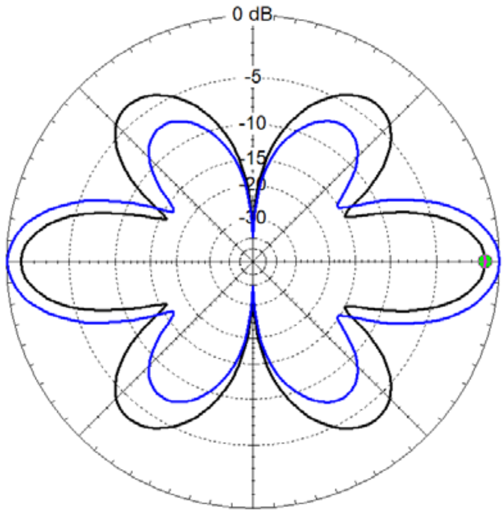

Figure 6 Comparison of the radiation patterns at 435 MHz for dipole length 87 cm (blue) versus 93 cm (black).

But there are alternatives.

In the current distribution of the dipole arms at 435 MHz, Figure 3, you can see a current maximum about 16 cm in front of the outer ends; at the same position there is a minimum of the electric field strength around the dipole arm. If a capacitive load is attached here, e.g. a small "radial", little current flows on it and there is little shortening effect. But things are different at 145 MHz, where there is a large electric field at this point, so that the radial will draw current leading to an electrical shortening of the antenna in the 2 m band. In Figure 7 you can clearly see current flow on the radials at 145 MHz and a step in the current distribution on the dipole arms. In contrast, the effect of the radials at 435 MHz is negligible because hardly any current flows to the wires.

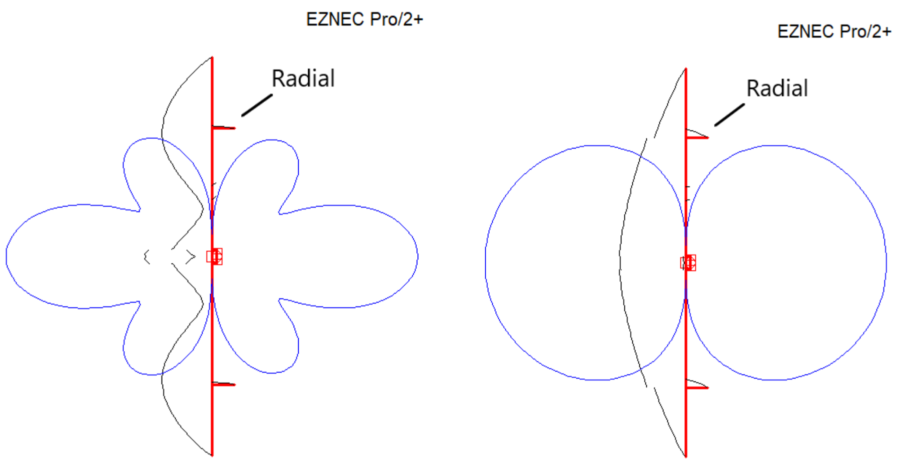

Figure 7 Dipole with radial position in current maximum at 435 MHz. Left at 435 MHz, right at 145 MHz.

A practical implementation of the radials fixed by screw sockets of a luster terminal can be seen in Figure 8. The screw sockets with soldered-on copper wires are pushed over the wire rods (dipolar arms) and screwed tight about 16 cm from the end. If necessary, the resonance frequency in the 70 cm band can also be reduced by moving the terminals away from the current maximum at 16 cm. For example, if one of the two clamps is moved outwards by 2 cm, the 2 m resonance drops by around 250 kHz and the 70 cm resonance drops by around 500 kHz; When shifted inwards, the resonance in the 70 cm band again decreases by around 500 kHz but the 2 m resonance increases by 250 kHz.

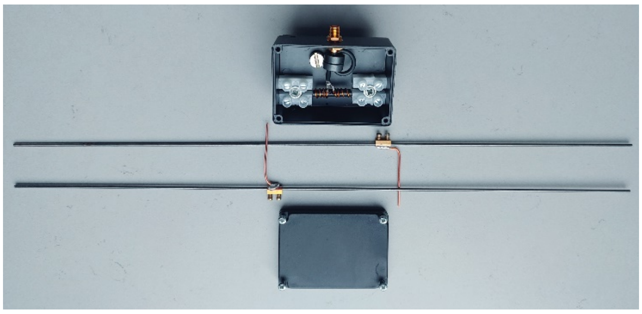

Figure 8 Dipole housing and two wire rods (2 mm x 41 cm) with screwed-on radials.

Tuning and measurement results.

The inductance for compensating the capacitive reactive component of the terminal impedance was determined in the simulation to be approximately 2 x 0.04 µH. Both coils wound tightly on one coil former results in a single coil with separation in the middle and a total inductance of L = 0.08 µH. The number of turns is calculated using the Opticoil online calculator /4/: About 10 turns are required on a core with a diameter of 5 mm and a length of about 2.5 cm (fitting between the luster terminals). However, the natural resonance (**S**elf **R**esonant **F**requency) of this coil must be taken into account, which means that the "apparent" inductance L' at 435 MHz is significantly higher than the nominal inductance L calculated for very low frequencies (the corresponding relationship was described in /5/). There must therefore be fewer turns, the fewer, the higher the tuning frequency. With 8 turns, tuning to the 70 cm band was already evident with a provisional measurement of the antenna impedance with the NanoVNA in the shack. The antenna was then attached to a boom of my MagLoop support pole using a grounding clamp, Figure 1, and the impedance of the antenna was measured over the frequency range from 100 MHz to 500 MHz using the NanoVNA. For adjustment in the 2 m band, two radials, each 4 cm long, were required, while 5 cm were required in the simulation. The measurement result in Figure 9 shows good impedance match in both bands and impedance bandwidths (VSWR < 2 or S11 < -10 dB) far beyond the band limits of the 2 m and 70 cm bands. In the frequency range between the two resonance frequencies, the reflection coefficient S11 of -1 dB is quite close to 0 dB, which suggests that the losses in the antenna are not high. According to the simulation, the skin effect attenuation losses in the coil and on the dipole arms should only be around 0.3 dB, so with estimated total losses of better than 0.5 dB you should be on the safe side.

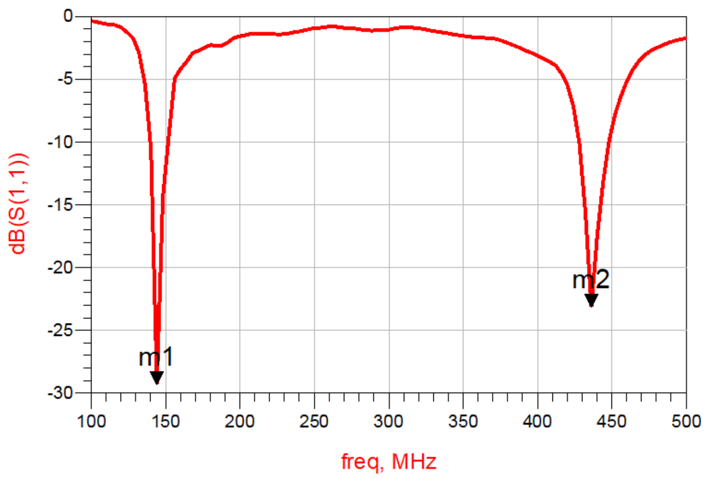

Figure 9 Measured reflection coefficient of the antenna. Marker m1 at 144 MHz, marker m2 at 436 MHz.

In addition to using the antenna as a station antenna, as in Figure 1, the antenna is also suitable as a portable antenna that can be disassembled: The individual parts - housing, wires (dipolar arms) and tuning radials - are easily transportable and can be put together with the help of a screwdriver. For example, it can be mounted on a light telescopic mast in horizontal polarization, as in Figure 10.

Figure 10 The antenna in portable operation in horizontal polarization on a GRP rod.

References

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

/2/ Rothammel's antenna book, chapter omnidirectional antennas for VHF and UHF, DARC Verlag

/3/ Klaus Solbach," Vertical 2 x 5/8 lambda dipole for the 2-meter band", CQ-DL, to be published July 2024

/4/ OptiCoil https://dxc.pi4cc.nl/tech-info/calculators/opticoil/ or Van Roy, E, PA2EVR, coil design and optimization conveniently solved with Opticoil V2.2, FUNKAMATEUR 3/21, p.199 – 201

/5/ Klaus Solbach, “10 m short dipole for the balcony antenna system”, Funkamateur, 12/ 2023