

A short dipole for 28 MHz

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Motivation: The dx conditions on the higher bands are already good and are expected to get even better in the next few years. Since my magnetic loop antenna /1/ only reaches up to the 20-meter band and with the additional loop also up to the 15-meter band /2/, I



wanted to also use the 10-meter band. A provisional setup of an end-fed half-lambda antenna wired to a fiberglass fishing rod attached vertically to the balcony railing had had a very positive impact on my DXCC account. However, with the full length of a half-wavelength the antenna protruded far beyond my own floor height into the viewing area of the apartment above - a no-go for peaceful coexistence in the house! Therefore, an addition to the current antenna on the small balcony should be as inconspicuous as possible and not much larger or higher than the MagLoop antenna.

Figure 1 The author's antennas on the balcony

Preliminary tests and selection of the antenna concept

An attempt with a vertical quarter-lambda radiator using the balcony railing as a counterweight was frustrating as the balcony apparently is not large enough to form sufficient "mass" and tends to form a poor "ground". A short dipole would work without a counterweight: Another preliminary experiment with a helix-shaped winding of the dipole arms of a vertical dipole on a thick GRP tube was again visually too noticeable. Ultimately, I chose a lightweight dipole made of wire reduced in length by loading coils on a thin GRP rod. The dipole could be mounted vertical to the side of the MagLoop antenna, see Figure 1, or mounted horizontally in the opening of the MagLoop. With this positioning the dipole length would be limited to around 3 meters. The well-known disadvantages of shortened dipoles compared to half-lambda dipoles, such as low impedance and lower bandwidth, must therefore be accepted.

Dimensioning the loading coils using simulation

A combination of a middle section with a 12 mm diameter and two inserted GRP tubes with a 10 mm diameter, each 1 m long (available from model kit shops), is used as the support rod. This makes the total length about 2.9 m. An enameled copper wire with a diameter of 1.08 mm is used as the conductor, which is laid inside the GRP pipes and connected to external coils approximately in the middle of the dipole arms. A simulation

with EZNEC helps with the dimensioning of the coils: In Figure 2 you can see the wire model and the placement of the loading coils modeled as concentrated, i.e. assumed as point-sized inductors. The position of the loading coils in this example requires a coil inductance of $L = 3.3 \mu\text{H}$ so that the center frequency of the dipole is around 29 MHz; You could also calculate the required inductance for the 12-meter band with $5 \mu\text{H}$ and the 15-meter band with $7.5 \mu\text{H}$. The appropriate coil was calculated using the online calculator Opticoil 2.3 /3/. With a turn spacing of 2 mm (twice the wire diameter), you then need 68 turns on a body (core) diameter of 10 mm. But be careful: The online calculator also calculates the coil's intrinsic capacitance and gives the resulting self-resonance frequency (SRF) of the coil as 70.3 MHz. This means that the reactance of the coil in the high frequency range does not correspond to the nominal inductance L , but to a higher value, the apparent inductance L^* :

$$L^* = L / (1 - (f / \text{SRF})^2)$$

In the example, L^* becomes $4 \mu\text{H}$ instead of $3.3 \mu\text{H}$ at frequency $f = 29 \text{ MHz}$. So, you are looking for a lower number of turns, which results in an L^* of $3.3 \mu\text{H}$. In this case that is about 57 turns, which corresponds to an inductance (for very low frequencies) of about $2.9 \mu\text{H}$. For this coil, Opticoil further calculates the “Ohmic” resistance for the intended frequency, which results from the conductivity of copper and the thin current-carrying layer on the wire (skin effect). Since the wire required for winding the coil is almost two meters long, this resistance is significant, in the example it is around 1.5Ω . The loss of power in these resistors is another disadvantage of the shortened dipole compared to the half-lambda dipole. The quantity suitable for assessing this disadvantage is the efficiency: In EZNEC, the ideally lossless antenna (wire loss set to zero and the coil resistance as short) can be used for comparison. For our example, the efficiency is about -0.5 dB for the shortened dipole and only -0.1 dB for a dipole with a length of about 5 m (without loading coils and with the same wire). Please note that this analysis does not take into account other loss mechanisms, such as losses in dielectric materials, balun/transformer or ground losses in a real environment.

Why the chosen position of the coils?

However, one can investigate whether a shortened dipole with the loading coils in other positions performs better or worse in terms of efficiency. It can then be seen that moving the coils further towards the dipole ends results in a higher radiation resistance (the input resistance of the loss-free dipole at resonance), but at the same time the coil inductance must increase, which goes hand in hand with a larger loss resistance. The reverse applies to the shift towards the dipole center. It turns out that only very small differences can be seen when the coil positions are moved outwards or inwards by 25 cm. The only disadvantage for a position further towards the center is a lower antenna impedance while the disadvantage of moving outwards is the decrease in the impedance match bandwidth, which for the chosen design is around $\Delta f = 470 \text{ kHz}$ at $\text{VSWR}=2$.

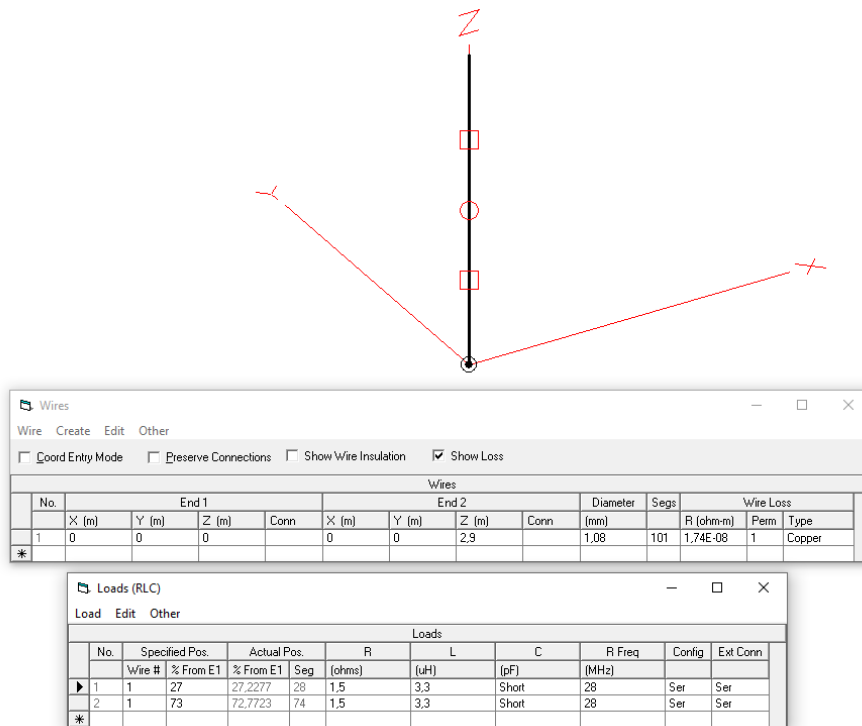


Figure 2 Simulation model of the shortened dipole in free space

Real coils need to be adjusted.

The loading coils are wound onto the outer GRP rods, see Figure 3, and are fixed with epoxy resin and a shrink tube after the tuning work has been completed and protected against moisture. The positions of the center of the coils correspond to the positions in the wire model. When testing the antenna for the first time, it turned out that the number of turns was a bit too high at 57 and had to be reduced to around 50 in order to tune the antenna to around 29 MHz - no problem, a few turns are simply unwound. As a check, a corresponding coil with 50 turns over a length of 10.5 cm was made separately on a 10 mm GRP tube and the impedance was measured with a NanoVNA: At the low frequency of 1 MHz, the measured reactance results in an inductance of approximately 2.85 μH , which practically corresponds to the inductance L , and at 29.5 MHz already an inductance of 3.3 μH , which represents the apparent inductance L^* for 29.5 MHz. From these two values you can estimate the natural resonance frequency to be $\text{SRF} \approx 80 \text{ MHz}$. These results are subject to measurement uncertainty due to the influence of the realizable coupling of the VNA to the coil, which is difficult to compensate for, but at least roughly confirm the dimensioning of the coils.

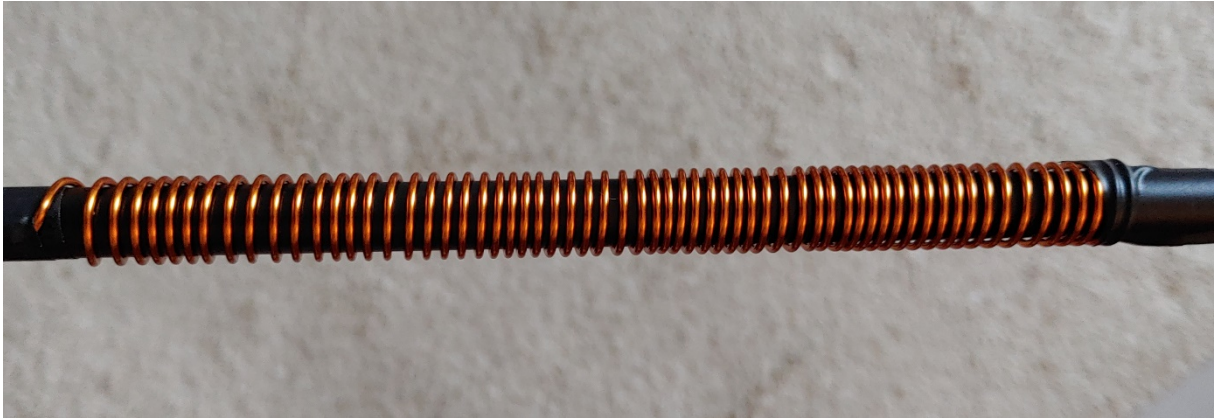


Figure 3 Loading coil on GRP pipe (60 turns x 10.5 cm) without epoxy resin and shrink tube.

A quick look at a theory problem

Above all, it shows that the dimensioning of the shortened dipole antennas using the simple wire model with concentrated inductances as a model for the loading coils leads to realistic results, although in reality the coils have a length of 10 cm. At the terminals of the two-terminal component assumed in EZNEC for a concentrated inductance, the input current is exactly equal to the output current and the current lags the voltage by exactly a quarter of a period but does not radiate - losses must be represented by an additional two-terminal component - a resistor. On the other hand, physics requires that in a dipole the real coil also radiates, and the current can vary in phase and amplitude along its axis. We get closer to reality if our model for the loading coil also includes the surrounding wire segments with the length of the real coil. Then, the radiation and variation in current required by physics can occur along the wire sections belonging to the model. However, for EZNEC it is irrelevant whether these wire segments are considered part of the inductance or are simply segments of the continuous conductor of 2.9 m length. So, it is not necessary to define extra sections of wire for the coils. However, if the loading coil in a different design becomes significantly longer than just 1% of the wavelength, the coil in the EZNEC model will have to be divided into several partial inductors with free wire segments in between, thus creating the model of a “distributed” instead of “concentrated” inductor.

A balun for impedance adjustment

The EZNEC antenna model for free space radiation results in an impedance of only 35 Ω at the 29 MHz resonant frequency, too low for a good match to the 52 Ω feed line. Instead of letting the tuner of the transceiver do the necessary impedance matching, the impedance should be transformed upward at the antenna terminals using a transformer that simultaneously fulfills the **Bal**(anced)**Un**(balanced) function between the symmetrical dipole and the unbalanced coaxial feed line. A corresponding transformer can be seen in Figure 4: The high-impedance side has five turns on the FT140-43 toroidal

core and the low-impedance side has three turns. Theoretically, however, 5:4 turns would be correct - the reason for the “wrong” dimensioning is explained further below.

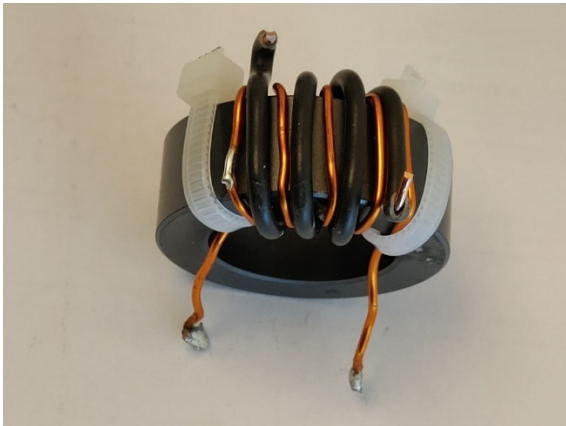


Figure 4 Transformer / Balun for coupling the dipole to the RG58 coaxial cable.

Assembly and mechanical construction

The dipole tubing is inserted through a hole at the end of an aluminum support tube and fixed. The antenna can be mounted next to the MagLoop using a cross mount on its support mast, as shown in Figure 1. The two middle antenna wires, each 62 cm long, enter the middle of the center GRP tube through slanted holes and emerge again through corresponding holes in the two adjoining thinner GRP pipes, where the loading coils are connected. The two wire ends in the middle are connected to the low-impedance side of the transformer, as shown in Figure 5. You can see that the ferrite toroidal core with the transformer windings lies around the GRP rod, with enough distance to the support tube which has an inner diameter of 38 mm. On the back of the toroidal core, the RG58 cable is connected to the high-impedance transformer winding and the coaxial cable is led out to the rear end of the support tube.

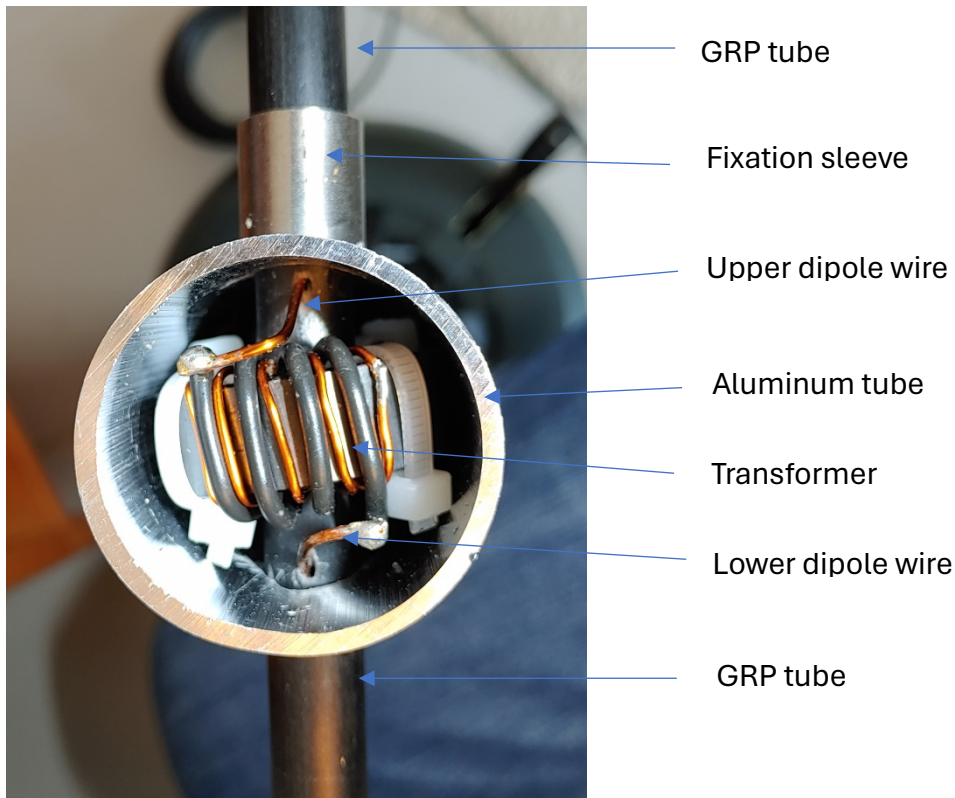


Figure 5 Support tube with transformer and dipole rod with connected middle wires

Fine-tune the center frequency.

The impedance match bandwidth of the shortened dipole antenna of less than 500 kHz should cover the lower end of the band so that CW and digital operating modes can be



optimally served. To reduce the center frequency of the finished antenna from 29 MHz to around 28.15 MHz, 8 cm long extension wires were attached to both ends of the dipole, which, when bent, create a capacitive top load and create a frequency shift of up to 1 MHz. By rolling up these “pig tails”, see Figure 6, the desired antenna center frequency could be set in the final mounting position.

Figure 6 “Pig Tail” wires (seen with shrink tube sealing) at both ends of the dipole are used to tune the frequency of the dipole.

How does the environment affect the dipole?

When installed vertically at the end of the support tube, the dipole is only 65 cm away from the MagLoop and its masts and the lower dipole arm is only about 60 cm away from the metal railing of the balcony. As expected, the dipole center frequency drops when the dipole is rotated towards the railing (the effect is like a capacitive top load), but without the impedance match suffering noticeably. However, the impedance match is

practically perfect despite the “wrong” number of windings ratio of the transformer, see the measurement of the reflection coefficient in Figure 7.

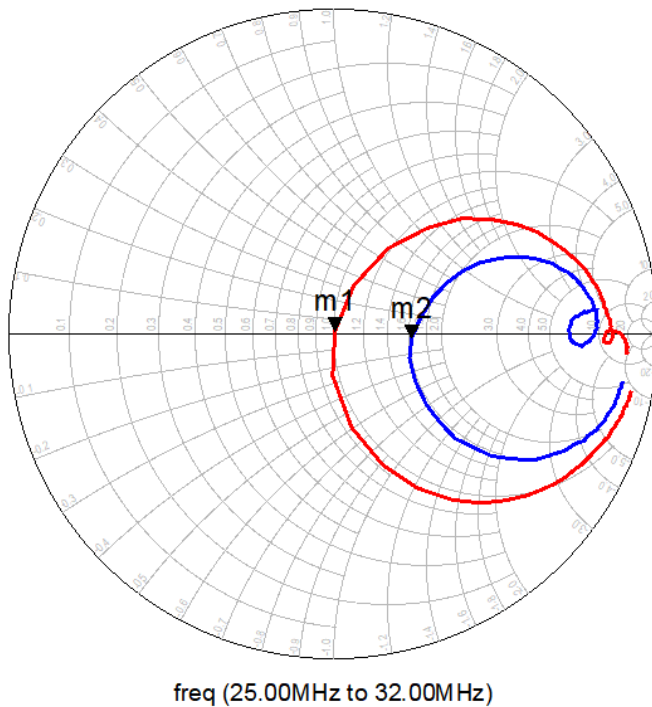


Figure 7 Measured reflection coefficient of the shortened dipole antenna when mounted vertically (red curve) and horizontally (blue). Marker m1 at 28.08MHz, marker m2 at 28.15 MHz.

A simulation with EZNEC shows why: Figure 8 shows the wire model of the dipole antenna with the MagLoop in the installation situation on the metallic balcony. The current distribution, which is induced by excitation of the dipole, can be seen above the model wires. Significant current amplitudes, all approximately out of phase with the dipole current, can be seen on the MagLoop, the two pole spacers and the top of the balcony railing. When the dipole is excited with 1 A, up to 0.25 A flows on the MagLoop and from the support mast via the spacers to the balcony railing. The arrows indicate that if the current on the dipole flows at one moment flows upwards, the currents on the MagLoop flow in approximately the opposite direction - i.e. approximately in anti-phase. Although these currents do not couple any power into the MagLoop, they still generate radiation. This radiation is predominantly vertically polarized and approximately omnidirectional (equally strong in all directions) in the azimuth plane like that of the dipole, of course not quite as strong as that of the dipole, but approximately in anti-phase! The effect is similar to that seen in a Yagi antenna due to a reflector element that is “parasitically” excited by the dipole: the radiation pattern of the dipole is deformed by the superposition of the radiation with the radiation of the reflector, the resonance frequency of the dipole is shifted, bandwidth is reduced, and the dipole radiation resistance is reduced by coupling to the reflector. In our case, the simulation results in a reduction in the dipole resonance frequency of around 90 kHz and a dipole impedance

of around $20\ \Omega$ instead of $35\ \Omega$. As Figure 7 shows, the dipole impedance reduced in this way can be easily transformed to the characteristic impedance of the coaxial cable with the transformer of turns ratio of 3:5. The bad news is that the impedance match bandwidth (at $VSWR=2$) is now only about 280 kHz, instead of the already quite low 470 kHz from the simulation of the dipole in free space.

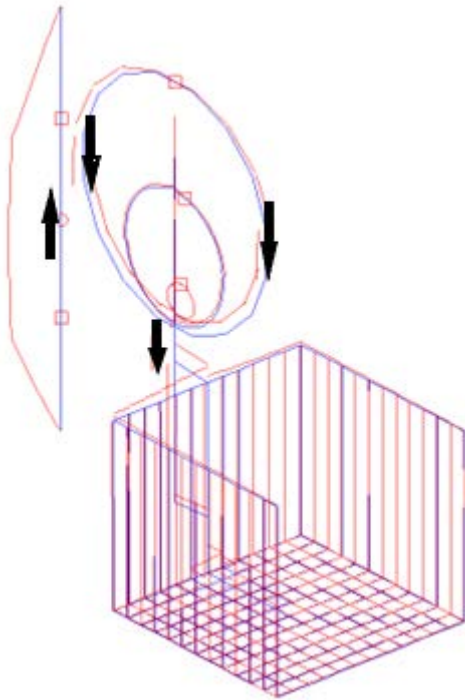


Figure 8 Simulation of the currents on the dipole, the MagLoop and the balcony railing. Wire model in blue, current distribution in red. Arrows indicate the relative current directions.

Additional losses due to the induced currents on conductors?

The currents induced by the dipole antenna in the metallic conductors in the nearby area could cause considerable attenuation losses if the metals used had very low conductivity or if there were significant resistances at the connection points of conductors. This is not the case when you look at the MagLoop with its low-resistance conductors. Such resistance could most likely occur at the screw connections on the balcony railing, but most of the currents indicated there are relatively small. In the simulation model with ideal connections and copper assumed for all metal parts, the power losses due to the induced currents result in additional attenuation (or a reduction in the efficiency of the dipole antenna) of only about 0.5 dB; In reality, the losses on the balcony railing are likely to be significantly higher due to poorer conductivity (steel instead of copper in the simulation) and higher contact resistance on screw connections in places.

Alternative: Horizontal mounting of the dipole in the MagLoop

Horizontal mounting of the dipole was also tried out: The short dipole was mounted horizontally on the support tube of the MagLoop so that the center of the dipole lies in the plane spanned by the conductor loops of the MagLoop and the dipole axis is perpendicular to the conductor loop plane. Because of this symmetrical arrangement, the currents induced by the dipole on the MagLoop just cancel each other out, which is also confirmed by the simulation in EZNEC. Despite the “intimate” nesting, the two antennas are therefore practically decoupled (the dipole does not couple into the MagLoop and vice versa) and their far fields in the horizontal plane are polarized “orthogonally” to each other - the dipole horizontally and the MagLoop vertically. Without induced “countercurrents”, the dipole antenna behaves almost as if it were in free space, without additional losses and without reducing the impedance match bandwidth and with a corresponding impedance of around 35Ω . The transformation with the given transformer/balun then results in significant mismatch, as shown in Figure 7. For this assembly, the number of turns ratio would have to be changed to 4:5.

What is more suitable for dx - mounted vertically or horizontally?

Unfortunately, theoretical radiation diagrams and knowledge of the far-field polarization of the antenna from the EZNEC simulation alone are not sufficient for a prediction, since not only the balcony with the metallic railing influences the far-field characteristics. Attenuation, transmission, reflection, and diffraction from one's own house (the house wall is only 2 m away from the dipole) and reflections and diffraction from the surrounding four-story apartment blocks as well as the ground only 6 m below the balcony are likely to have a major influence. In order to decide which mounting position ensures the best dx results, two sets of transmissions were carried out in WSPR mode around midday, in quick succession in vertical mounting and in horizontal mounting. The reports on <https://www.wsprnet.org/drupal/wsprnet/spots> gave a clear picture: vertical mounting brought in significantly more reception reports and significantly higher reception levels, especially from Australia, Asia and America, than horizontal mounting. The theoretically lower efficiency of the vertically mounted antenna and the theoretically higher ground attenuation of the vertically polarized wave seem to be outweighed by the omnidirectional flat radiation of the vertical dipole.

Operating experiences

The full 100 W transmission power of my transceiver is not a problem for the FT140 ferrite core or the dipole itself, but the near-field amplitudes at this power level at the edges of the surrounding apartments are already above the valid EMC limits.

Unfortunately, shortening the dipole does not lead to a reduction in the safety distance to be maintained, rather the opposite.

Compared to the previous provisional half-lambda dipole above the balcony railing, the short dipole on the MagLoop mast performs weaker - with FT8 operation it feels like it

takes more attempts to log dx QSOs and the average reports are clearly worse. The losses (lower gain and efficiency) due to shortening of the dipole and the “countercurrents” on the MagLoop and the balcony railing are certainly part of the explanation. The provisional half-wave dipole was not or less affected by both problems due to its extension far beyond the height of the MagLoop. On the opposite, the shortened dipole is a few meters lower under the roof edge of the house than the provisional half-wave dipole. Because the wavelengths of the short waves are in the same order of magnitude as the dimensions of the house, the wave diffraction known from optics plays a major role in the wave propagation to and from the antennas on the balcony: the radiation from the shortwave antennas propagates through the Diffraction effect also across the house and also reaches directions that should actually be shaded. In contrast to an antenna on a house roof, without the wave diffraction around your own building and around the neighboring buildings, the radiation from the antennas mounted far below the edge of the roof would essentially only be high-angle radiation, which is useless in the 10 meter band. However, this diffraction across the roof becomes stronger the shorter the distance between the radiation sources and the height of the roof is, and therefore the half-wave dipole had an advantage simply due to its length.

Weather resistance

The external coils must be fixed and protected against rainwater, otherwise the dipole center frequency of the antenna will shift by a few hundred kHz when it rains. To fix the coils and seal the holes in the GRP pipes, 2K epoxy glue was generously applied and enclosed with shrink tubing.

References:

/1/ Klaus Solbach, DK3BA: Verbesserung der Anpassung einer Magnetantenne,
FUNKAMATEUR 3/2023, S. 194

/2/ Klaus Solbach, DK3BA: Frequenzerweiterung von Magnetantennen mittels Zusatzschleife,
FUNKAMATEUR 4/2023, S. 304

/3/ <https://dxc.pi4cc.nl/tech-info/calculators/opticoil/> oder Van Roy, E, PA2EVR, “Spulendesign und -Optimierung komfortabel gelöst mit Opticoil V2.2“,
FUNKAMATEUR 3/21, S.199 - 201