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Krzysztof Dąbrowski
OE1KDA

Konstrukcje antenowe
Tom 1

Wiedeń 2024


1924 - 2024
stulecie reformy
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Antenna structures

Volume 1

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Introduction

The present volume is a supplement to volumes 49 - 52, which discussed the theoretical basis for the function of antennas of various types and their most important solutions. There is a multitude of antenna solutions and descriptions of newer and newer designs or points of view for those known for a long time are constantly being published. For this reason, the author concentrates on the practical side, selecting descriptions of the more interesting, especially unusual designs, which became known after the publication of the previous volumes or, for various reasons, did not fit into the layout of the material in the previous volumes. It is also worth recalling that a collection of bench antenna constructions to hide from the unwanted eye is included in Volume 32.
The antenna is the matching element of the transmitter-receiver system to free space. Communications performance is significantly influenced by phenomena occurring in the space between the transmitter's and receiver's antennas - primarily in the ionosphere and troposphere. Volume 48 of the "Library of the Polish Radio Amateur" is devoted to the propagation of electromagnetic waves.
We wish you fruitful reading.

Krzysztof Dąbrowski OE1KDA
Vienna
16 December
2023

1. Antennas shortwave

1.1. Antennas dipole antennas

1.1.1. Broadband antenna fan

The antenna design covering the 20 - 10 m range consists of six dipoles arranged every 18°, so that the angle between the extreme dipoles is a right angle. Such a solution is a good compromi- nent for the widest and continuous operating range. In the case of a close arrangement of elements, i.e. with a larger number of dipoles or with the angle between extreme dipoles smaller than a right angle, and therefore stronger coupling between them, the WFS between resonance frequencies assumes large values making it impossible to adjust the antenna. Instead of being broadband, the antenna becomes multi-band. In the adopted solution, the WFS in the range above the resonance of the longest element does not exceed approximately 3, so the antenna can be easily matched using typical automatic antenna boxes. Below this resonance, the WFS assumes high values. The matching characteristic thus corresponds to that of a high-pass filter with a limiting frequency close to the resonance of the longest dipole.

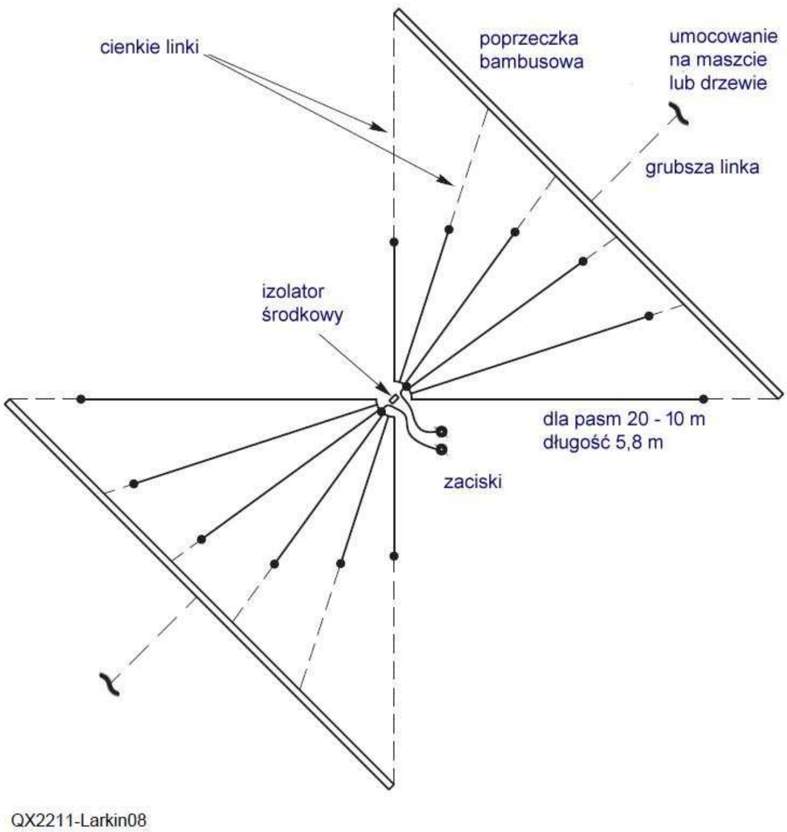


Figure 1.1.1.1: Construction of a fan antenna hung horizontally between two trees or masts. Additional cables are required, not drawn, to stabilise the crossbars in the horizontal plane.

The operating frequency range of the antenna is approximately 3:1, partly due to the reduced coupling between the dipoles and partly also due to the fact that at higher frequencies the dipoles operate as 1.5-wave and not as half-wave. The impedance waveform as a function of frequency therefore repeats near the third harmonic (and subsequent odd harmonics). The favourable ratio of the length of the shortest to the longest dipole and, at the same time, the ratio of their resonance frequencies is ~0.5, which results (for 6 dipoles) in a jump of the length of subsequent dipoles of about 0.87 - as the root of the fifth order of 0.5. Putting it mathematically: the lengths of dipoles form a geometric sequence with a quotient of 0.87. The dipole lengths were selected experimentally by the designer. The dimension of the longest dipole is calculated from the formula for a half-wave dipole l [m] = 143 v / f [MHz], where v is a shortening factor of 0.99 - 0.95 depending on the thickness of the cable and the influence of any insulation.

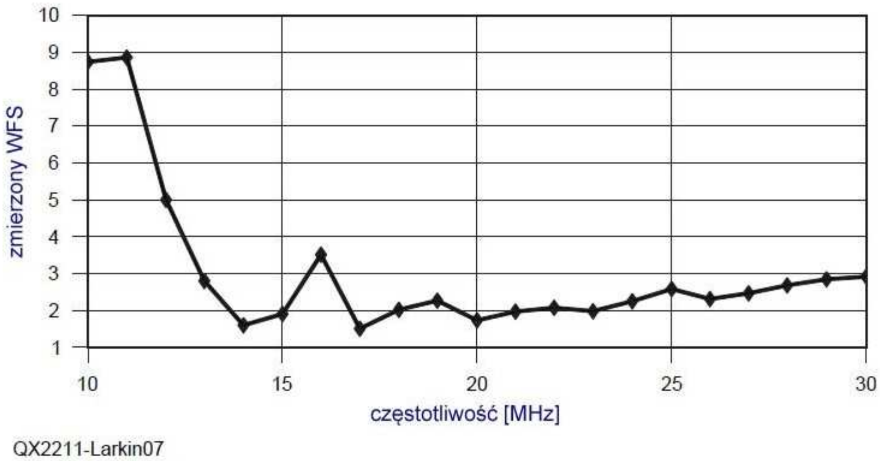


Fig.1.1.1.2 Measured WFS waveform of the antenna at 20 - 10 m bands for a 50-ohm system. Clearly visible high-pass character of the antenna.

For a ratio of the marginal dipole frequencies close to 1 (e.g. 0.8), the antenna behaves like a tethered dipole (superannuated) with a single resonant frequency and a bandwidth wider than for a single wire. For ratios lower than 0.5 (for example 0.35) between the resonant frequencies of the dipoles, bands with a high WFS appear and the antenna becomes a multiple rather than a broadband antenna. The designer recommends trying values closer to 0.5.
The directional radiation pattern of an antenna is not constant, but changes with operating frequency due to the fan-shaped arrangement of the dipoles. It differs markedly from the directional characteristics of the dipole and consists of several leaves. There are usually 3 - 4 dipoles involved in the radiation of the antenna.

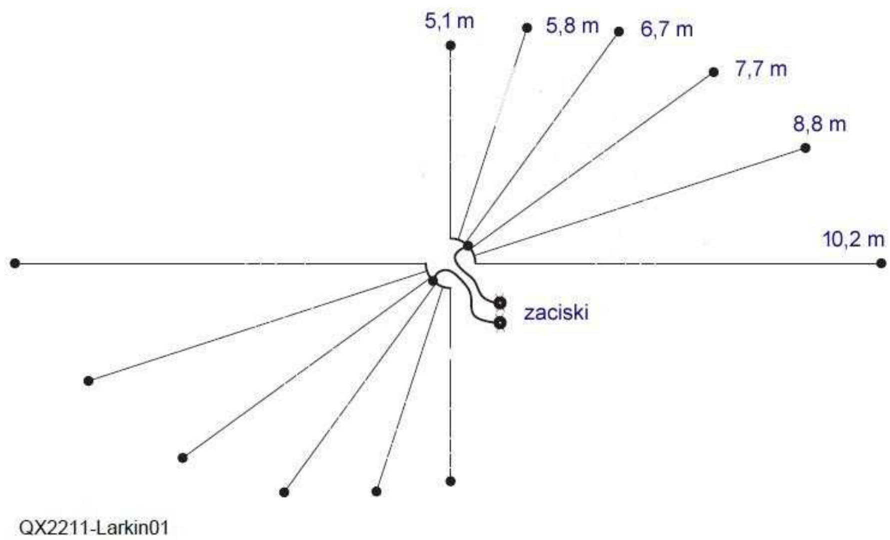


Figure 1.1.1.3: Fan antenna design for bands from 40 m upwards. The angles between the dipoles are 18 degrees. The figure shows the lengths of the dipole halves

The design in Figure 1.1.1.1 has a lower cut-off frequency of 12 MHz, the half of the longest dipole is 5.8 m long and the designer used a value of 0.85 as the string quotient. The WFS as a function of frequency in the 50-ohm system is shown in Figure 1.1.1.2. The highest value of the standing-wave ratio is about 3.5 and falls in the range near 16 MHz.

The antenna is made of a 1 mm diameter cable extended with an insulating cord so that the ends of the elements can be fixed on crossbars made of insulating material (in the original design these were bamboo crossbars). In the inverted V variant, only a single mast is needed.
The design in Figure 1.1.1.3 operates in the bands from 7 MHz to 30 MHz and in the 50 MHz band (for reso- nances at 5/2 wavelengths). The lengths of the dipole halves are 10.2, 8.8, 7.7, 6.7, 5.8 and 5.1 m and the number of strings is 0.87. The WFS waveform is shown in Figure 1.1.1.4.

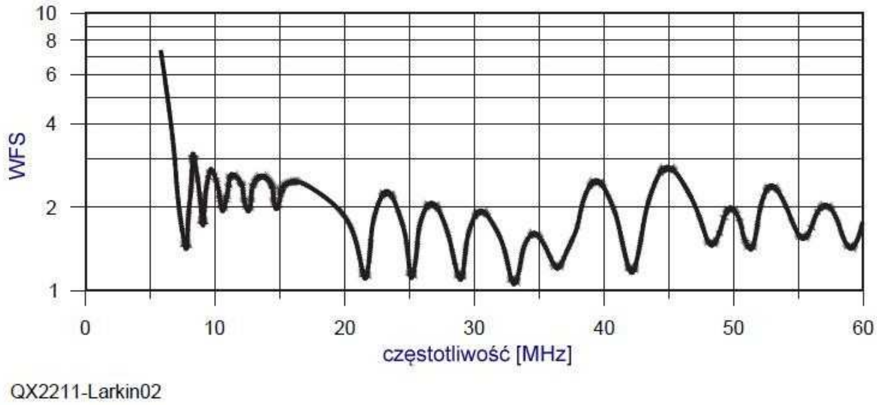


Figure 1.1.1.4: WFS waveform for the antenna in Figure 1.1.1.3 calculated by NEC2 for a 175-ohm system.

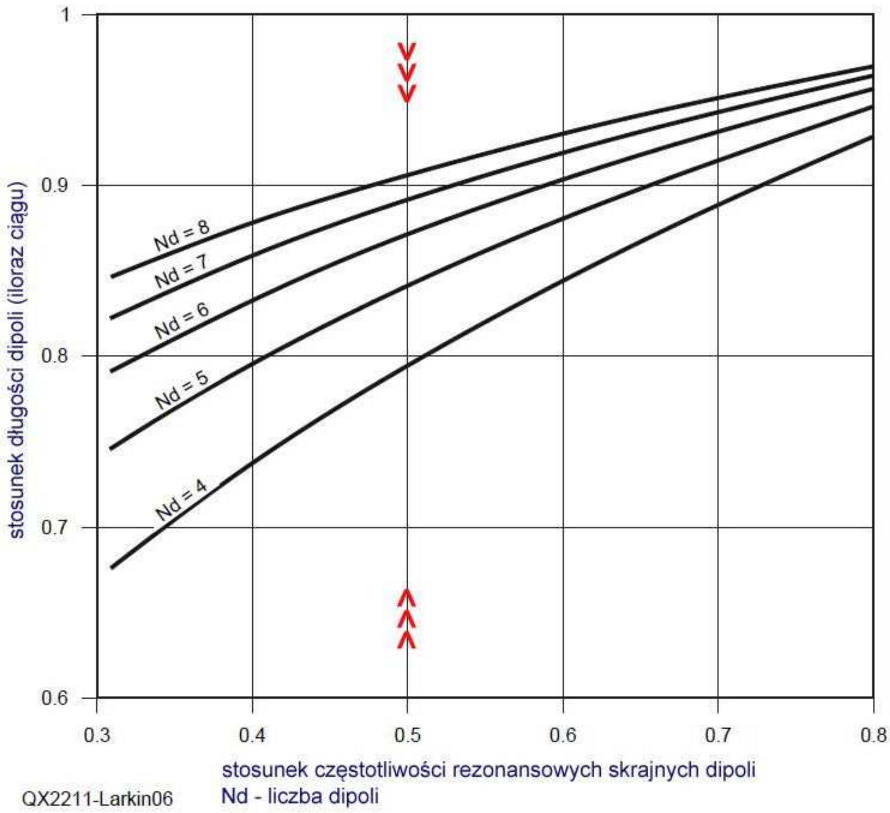


Fig. 1.1.1.5 Dependence of the dipole length ratio on the ratio of the extreme dipole resonances and their number Nd

[1.1.1.1] 'Broadband Tapered-Length Fan Dipole Antennas', Bob Larkin, W7PUA, QEX 11-12/2022 p21.
[1.1.1.2] "Collection of Broadband HF Antenna Designs", J. Pawlowski, SP3L, QEX 3-4/2020 p. 16 and 5-6/2020 p. 28.

1.1.2. Two-element directional antenna for bands 6 - 20 m

Developed in the 1960s in South America, the antenna with the sonorous (and graceful) name *Maria Maluca* operated in the 10, 15 and 20m bands. It consisted of a radiator, fed by a flat TV cable for the 15m band, and a director tuned to the 10m band. It gave measurable antenna gain in both bands. Its gain in the 20m band was similar to that of a half-wave dipole.
Computer optimisation of this design - using the MININEC programme - resulted in a 6-band antenna covering the 6 - 20 m bands. The aim of the optimisation was to achieve the highest possible directional gain with relatively small dimensions and the most favourable input impedance curve as a function of frequency in the amateur bands. The length of the antenna carrier is 1.5 and the radius of rotation is 3.9 m. The results obtained are shown in Table 1.1.2.1.

Table 1.1.2.1. Parameters of the six-band *Maria Maluca* antenna

Band widt h [m]	Input impedance* [Ω].	Profit in relation to the dipole [dBd]	12 m height gain** [dBi]	Vertical beam opening angle [°].	Back attenuation [dB]
20	28,4 - j275	0,1	8,13	23,5	0,43
17	56,9 - j62	1,2	8,45	18,6	2,63
15	34,3 + j80	5,1	12,44	15,7	13,72
12	144,7 + j317	3,1	10,64	14,0	-7,86
10	379 +j672	2,6	10,51	12,0	-5,05
6	96,4 - j383	3,4	11,27	7,1	-2,06

Notes"
* Input impedance in free space
** Above actual soil with average conductivity
Negative back attenuation in the 6, 10 and 12 m bands indicates that the main beam of the antenna is directed in the opposite direction than in the three lower bands.

Photo 1.1.2.1. Fixing the radiator

The antenna is made of aluminium profiles. The carrier has a quadrate cross-section of 40 x 40 x 15 mm and has holes of 20 mm diameter at its ends for fixing the radiator and reflector/direction. The distance between them will be 1.46 m. The two elements, measuring 7.56 and 6.56 m in length respectively, are telescopically constructed from tubes with external diameters of 24 to 12 mm (Fig. 1.1.2.3). The tubes at the junctions have four notches each, allowing them to be clamped together with clamps, which prevents tubes of smaller diameters from moving through them. The element, which is at the same time a director or

Depending on the operating band, the reflector is galvanically connected to the antenna carrier. A 20-mm-diameter fibreglass-reinforced polyamide rod, on the other hand, provides electrical isolation of the reflector elements from the carrier at the antenna terminals. The rod is pressed against the edges of the holes with a transverse M8 stainless steel screw with counter-nut (Fig. 1.1.2.1). The radiant tubes are placed on this rod and clamped onto it using clamps. These clamps serve at the same time as terminals to which the supply line is connected. They should be located at a distance of approximately 15 mm from the wall of the carrier.

Photo 1.1.2.2. Flat cable symmetrizer. In the picture connected to the measuring system

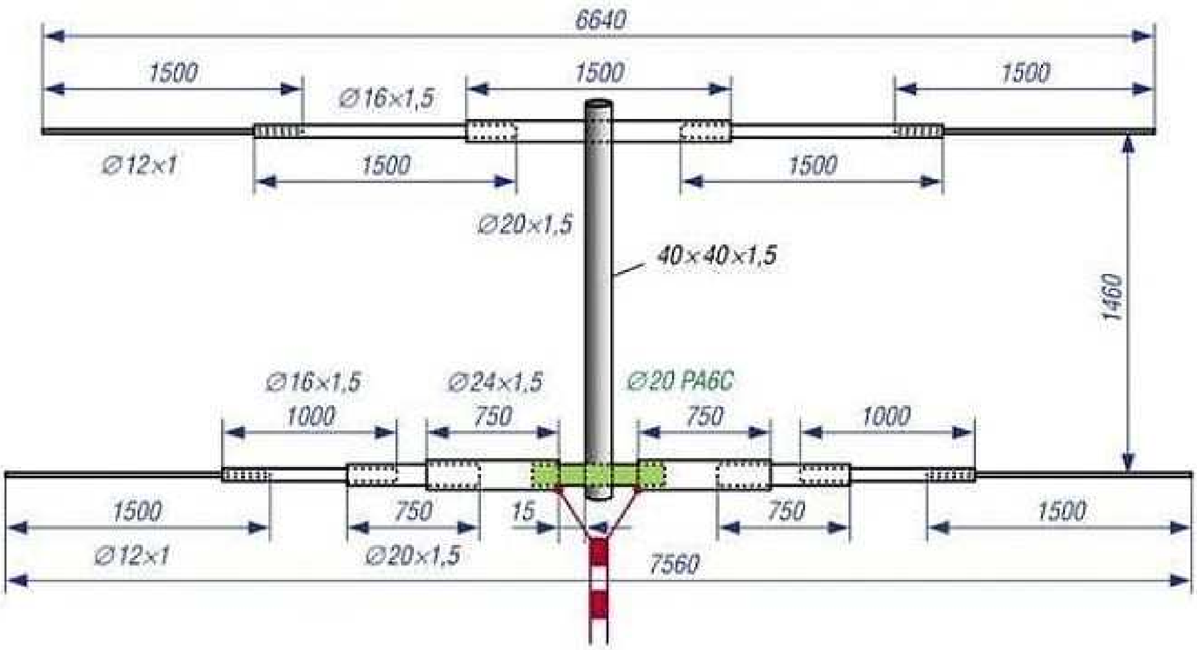


Fig. 1.1.2.3 Antenna structure. The insulating rod from Fig. 1.1.2.1 is marked in green.

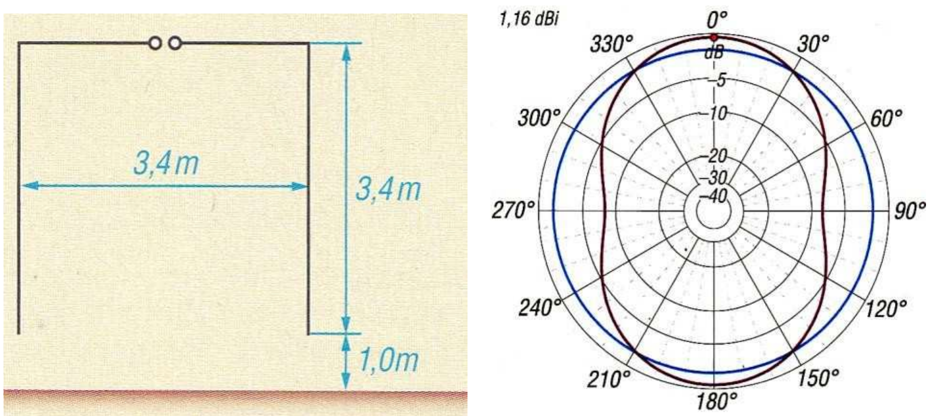
The antenna is fed symmetrically via a flat ladder cable with a wave impedance of 450 Ω. It is characterised by low attenuation, considerable durability and good resistance to external influences. The length of the feed line is essentially arbitrary, but it is possible to find a

z length ranges ensuring a favourable transformation of the antenna input impedance to values that can be h a n d l e d seamlessly by the radio's built-in automatic antenna boxes.
Wrapping the last two metres of the cable on a plastic tube - giving a bifilar cylindrical choke - ensures broadband matching of the symmetrical cable to the asymmetrical output of the transmitter. This solution ensures low attenuation over a wide frequency range. In the 50 MHz band, it amounts to 0.02 dB for the "Wireman" flat cable (CQ552), and in the 20m band with an effective length close to 1/10th of the wavelength - even only 0.01 dB.

[1.1.2.1] https://www.amateurfunk-westpfalz.de/bauanleitungen-fuer-antennen/

1.1.3. Refracted dipole antenna arms

One way to reduce the size of an antenna is to bend or kink its elements. In the simplest case, the arms of the dipole are kinked by 90° at some point and point downwards. It is also possible to direct them sideways in the horizontal plane, but then the structure takes up more space than if the arms are directed downwards. The author of [1.1.3.1] refracted the arms of a 9.8 m long dipole for the 20 m (14.1 MHz) band so that an open square was created with three sides each 3.4 m long. The ends of the arms were 1 m above the ground surface. The proximity to the ground made it necessary to extend the vertical sections to the dimensions shown in the figure. The directional characteristics of the antenna in the horizontal plane are approximately omnidirectional. The directional gain is approximately -0.53 dBi with a radiation impedance of 24 Ω. At this impedance, it is possible to match the antenna to a 50-ohm line using a quarter-wave transformer with a wave impedance of 37.5 Ω obtained by connecting two quarter-wave sections of 75 Ω cable in parallel. This method gives a very good match for antennas made with 28-ohm technology, but at 24 Ω the WFS does not exceed 1.2.



Antenna design and dimensions
Figure 1.1.3.2: Radiation characteristics of an antenna with refracted arms (blue line) compared to those of a straight dipole (violet line).

The antenna was made of PVC-insulated copper wire with an outer diameter of 3 mm.
By further refracting the antenna to form a square with four sides or even with the ends overlapping, the radiation resistance of the antenna was reduced to 11 Ω in the first case and 2.3 Ω in the second. This meant a clear reduction in antenna efficiency. The extreme case would be connecting the ends of a dipole with the help of a capacitor with variable capacitance - the result would be a magnetic antenna, which is known to have a very low radiation resistance and efficiency.

[1.1.3.1] "Platzsparender Aufbau eines Dipols durch Faltung", Christoph Kunze, DK6ED, *Funkamateur* 2/2024 p. 136

1.1.4. Moxon's oval antenna for 15 m band


Photo 1.1.4.1. Appearance of Moxon's oval antenna

Designed for field operation, the Moxon antenna is characterised by its small dimensions, considerable gain and back attenuation and a convenient radiation angle for DX operation even when mounted at low altitudes. It takes up less space than the usual rectangular Moxon antenna. Simulation showed that the shape of the antenna almost influences its properties. Much more important is the selection of the correct element length.

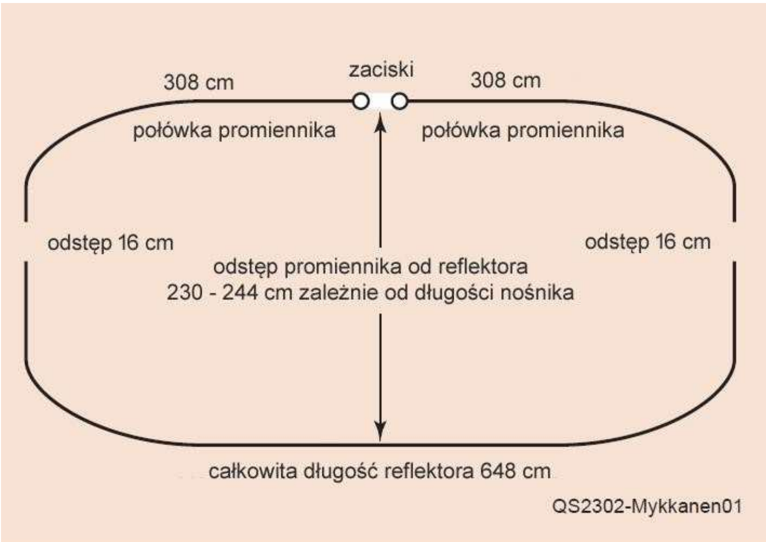


Fig. 1.1.4.1. Antenna dimensions

The solution is a simplified variant of the KG4JJH design from 2003. The antenna is made of 3-metre long telescopic fibreglass rods from rods fixed on centres on wooden boards 60 cm long and 10 cm wide, which are in turn fixed to the carrier photo 1.1.4.2) by means of U-shaped threaded rods. The antenna carrier, made of fibreglass or aluminium tubing or a wooden rod, is 244 cm long.
To fix the carrier on the mast, the designer used aluminium plates, but these can also be wooden planks (photo 1.1.4.1). The method of making the clamps on the plexiglass plate is shown in Photo 1.1.4.3. RG-58 coaxial cable was used to feed the antenna.
The ends of the radiator and reflector are connected to each other by insulators 16 mm long made of PVC tubes 20 cm long and 3/4 inch in diameter cut lengthwise. A hole cut in them and a longitudinal groove for anchoring the antenna cable (Fig. 1.1.4.4) facilitate quick installation of the antenna in field conditions. A clamp screwed onto the end of the cable also makes it easier to adjust the length of the cable when tuning the antenna.

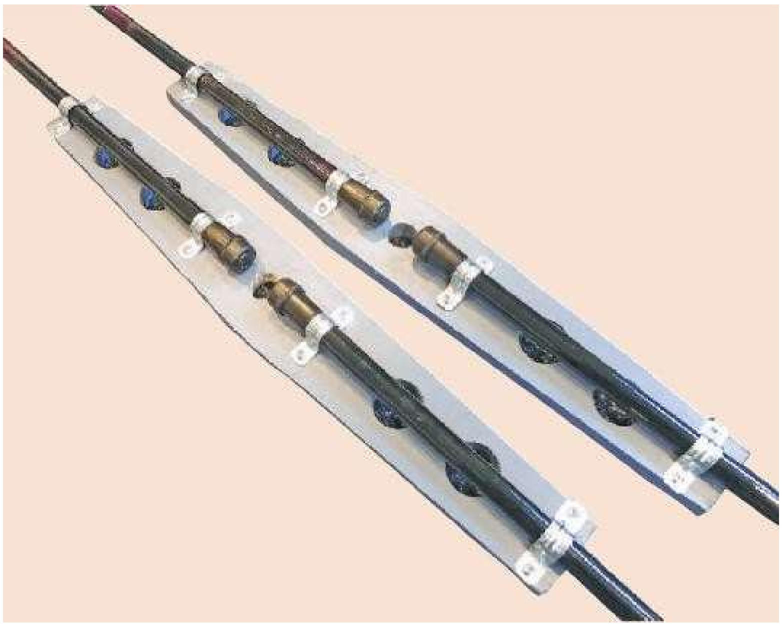



Photo 1.1.4.2. Fixing of rod ends on boards Photo 1.1.4.3.
Method of making clamps

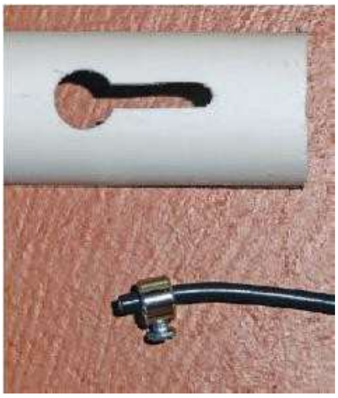


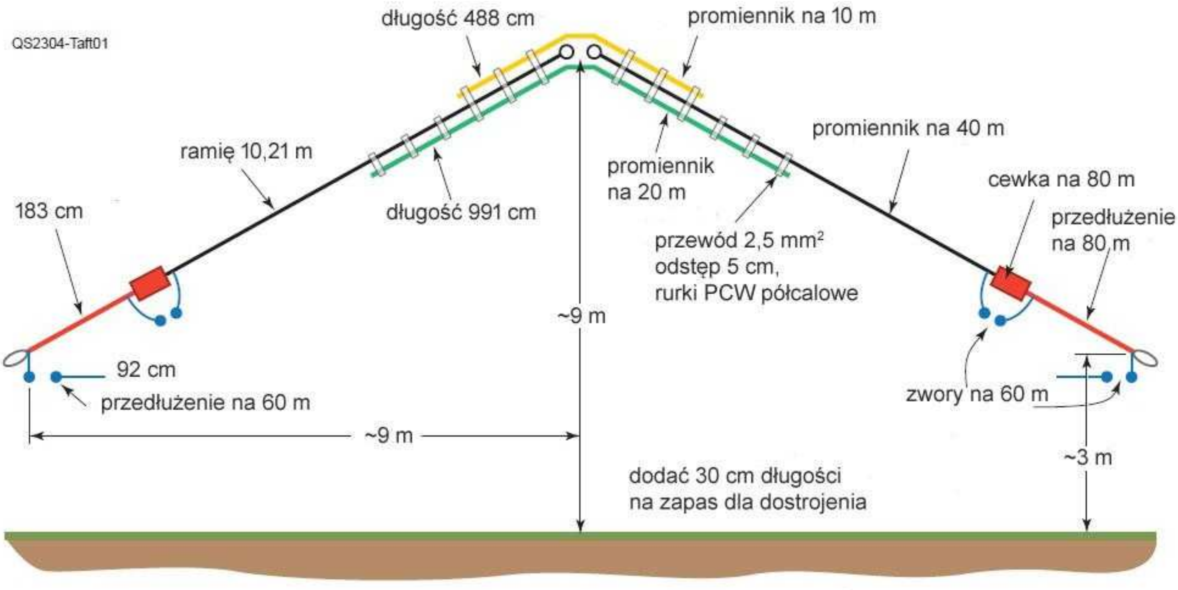

Photo 1.1.4.4. Insulators connecting the ends of the radiator and
reflector Photo 1.1.4.5. Connection of the radiator

The radiator and reflector are made of insulated cable with cross-section of 2.5 mm^2 and lengths as shown in Fig. 1.1.4.1. There are metal clamps at the ends of the cables. The clamps on the antenna terminal side should be crimped with pliers and soldered to ensure sufficient mechanical strength. The clamps at the opposite ends of the cable are fastened with screws.
In order to tune the antenna, it should be placed at a height of at least 2.5 m. The initial WFS is approximately 1.4 and the radiator wires should be carefully shortened to improve it. It is possible to achieve a WFS of less than 1.3. Once tuning is complete, the antenna can be placed at the desired height. The structure is light enough to be placed even on a 5-metre mast. It can be quickly folded and unfolded and is thus easy to transport to a field QTH.

[1.1.4.1] 'A 15-Meter Portable Oval Moxon Antenna', Toivo Mykkanen, W8TJM, QST 2/2023 p37.

1.1.5. Short-wave antenna with radiating elements passive

The multi-band dipole antenna allows operation in the 80, 60, 40, 20, 15 and 10 metre bands. The well-known concept of passive radiator antennas on 2 m and 70 cm bands propagated by the DK7ZB, among others, also works well in the shortwave range.



Antenna design and dimensions

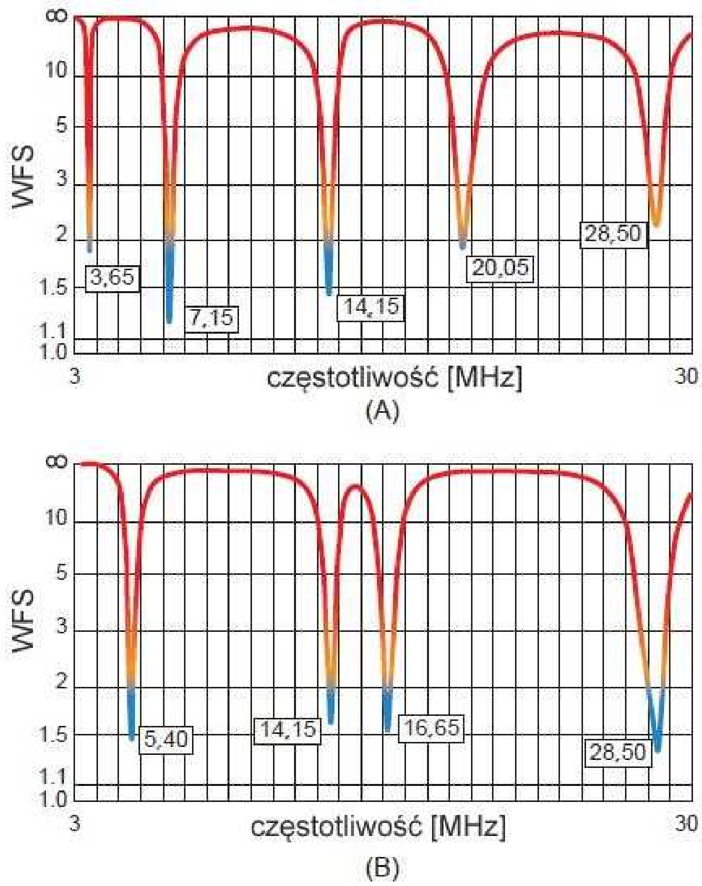


Figure 1.1.5.2: The waveform calculated by EZNEC: A - for 80, 40, 20, 15, 10 and 6 m configurations, B - for 60 m configuration, also works in 20 and 10 m bands

The concept of passive *resonator* (*coupled resonator*) antennas, i.e. electromagnetically *coupled* antennas, originates from the concept of *coaxial sleeves*.

The antenna contains three radiating elements 5 cm apart, made of 2.5 mm wire^2 . In the antenna shown in Fig. 1.1.5.1, the radiator for the 40 m band is powered, while the other two - for the 10 and 20 m bands - are electromagnetically coupled to it. They are fixed to the main radiator by PVC spacers. The radiator for the 40 m band has coils and extension leads for the 80 m band and is modelled on the study [1.1.5.2]. Operation in the 15 m band is possible because it is the third harmonic of the 40 m band and, in turn, the 6 m band is its seventh harmonic. Fig. 1.1.5.2 shows the waveform of the standing-wave ratio calculated by EZNEC. The antenna can also operate in the 60 m band after shrinking the coils and extending the radiator - done with jumpers. The computer-simulated directional characteristics show that the antenna allows vertically radiated wave (NVIS) operation in the 80, 60 and 40 m bands, in the 15 and 10 m bands the waves are radiated at low angles favourable for DX operation, and in the 6 m band (on the seventh harmonic of the 40 m band) the characteristics contain several lobes. Half-wave radiators on the 40, 20 and 10m bands provide single-leaf characteristics.


Photo 1.1.5.3. Junction box with symmetriser and two PVC struts

Photo 1.1.5.4. Rear of junction box with struts. The radiator cable for the 10 m band is at the top, for the 20 m band it is at the bottom. Orange tape on the sides of the strut on the conductor for 10 m prevents it from moving in the opening. The radiator for 40 m is routed through the centre holes

The antenna is supported in the centre on a 9m PVC mast and is shaped like an inverted V. The total length of 2.5 mm^2 nylon-insulated cable used for the three radials is 46 m. The terminals are housed in a plastic box from electrical installations (photo 1.1.5.3). A coaxial socket is also fixed on its lower wall and a ring for hanging the box on the upper wall.

PVC pipes with a diameter of half an inch and lengths of 18 cm from the electrics were used for the struts. Three pairs of holes are drilled in the struts: in the centre and symmetrically at a distance of 5 cm from it (photo 1.1.5.4). To ensure that the struts do not move on the ducting, the holes in the centre are drilled perpendicular to the upper and lower struts. The struts at distances exceeding the radiator length of 10 m are 7.5 cm long and have two pairs of holes perpendicular to each other.

The 1:1 gear symmetrizer is wound with 4 mm wire^2 in insulation on a ferrite ring core FT240-31. It consists of 2 x 10 - 12 turns wound in the W1JR manner.


Photo 1.1.5.5. Extension coil for 80 m band without connected jumper. The coil is wrapped with insulating tape to stabilise the winding and protect it from environmental influences. The coil has been painted grey for aesthetic reasons. On the right is the wire for the 80 m band and on the left is the main part of the dipole for the 40 m band

Photo 1.1.5.6 View of the strut for three wires

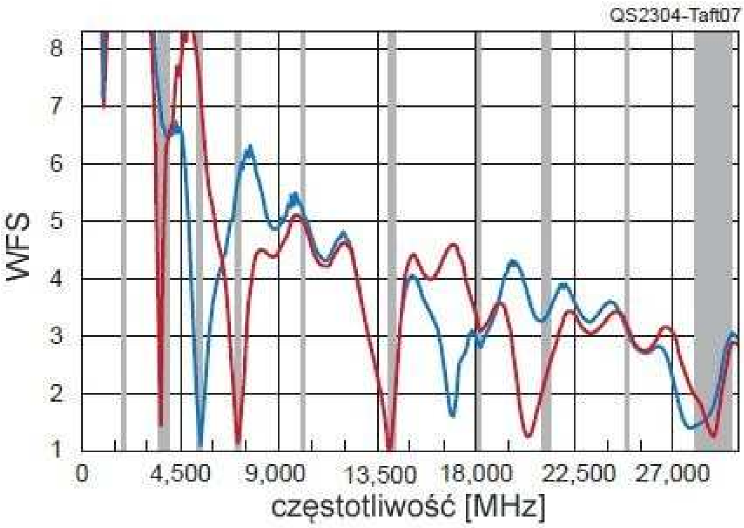


Fig. 1.1.5.7. WFS measured for an antenna suspended 6 m above the ground surface. Red graph - antenna configuration for 80, 40, 20, 15, 10 and 6 m bands, blue for 60, 20 and 10 m bands. Grey vertical rectangles show the position of the amateur bands

The extension coils for the 80 m band are wound with 4 mm2 wire on 7.5 mm diameter PVC tubes 14 cm long. For digital emission frequencies they consist of 81 coils of wire, and near the upper end of the 3.5 MHz band there should be a few less. The radiator wires should be pulled through the holes at the ends of the coils and connected with screws to the coil wire. The radiator wires should have the lengths given in Fig. 1.1.5.1 with an addition of 30 cm each for antenna tuning. The operation in the 60 m band is enabled by shunt jumpers connecting the coils and additional arm extensions.
In the K1EHZ design, after tuning, each radiator arm for the 40m band was 10.21m long, the extensions for the 80m band were 183cm each, the radiator for the 20m band was 9.91m long, the radiator for the 10m band was 4.88m long and the extensions for the 60m band were 61cm each. The tuning frequencies were 7.2, 14.2 and 28.4 MHz. In the European 40 m band, the tuning frequency should lie rather close to 7.1 MHz. The narrow operating bandwidth in the 80 m range means that a preferred sub-band has to be selected.

WFS waveforms measured with the RigExpert AA-54 antenna analyser are shown in Figure 1.1.5.7. WFS minima lay below 2 on most bands. The width of the minima was approximately 2 MHz in the 6 m band and almost 3 MHz in the 15 m band. Near the 15 m band the minimum lay around 20 MHz instead of exactly at the third harmonic - 21.6 MHz. Practical tests showed that the antenna performed well on all bands. The designer used an AT-200Pro automatic antenna box from LDG Electronics, except that it was really only necessary on the 15m band. Amongst other things, communications were carried out on the Winlinku network, and this on the lower bands also via vertically radiated wave (NVIS).

1.2. Antennas vertical

1.2.1. Three-band antenna QRP

The design of the DL4ABB is modelled on the development of an antenna for the 20 - 40 m bands of the 'QRP Guys' group. Covering the 40, 30 and 20 m bands, the antenna consists of a vertical radiator, four counterweights and a series extension coil with switchable inductance. It is designed for DX QRP operation from any location. The radiator and counterweights are made of any type of lica. The radiator is 5.18 m long and the counterweights are 3.05 m each.
The extension inductors are wound on T68-2 ring cores with 0.5 mm enamelled copper wire. The windings have 24 and 38 turns respectively. Shorting switches S1 and S2 are connected in parallel. In the 30 m band, switch S1 is open, and in the 40 m band, both switches are open. The maximum permissible HF power in this design is 10 W. The standing wave coefficients measured by the constructor were approximately 1.2 for the 20 m band after shortening the radiator to 5.08 m, and approximately 1.5 for the other bands after unwinding the three L2 coils. These are of course approximate values and depend on the influence of the environment. It is therefore better to make an antenna of the given length and wind the full number of L2 coils. These can then be adjusted to the optimum values. The mast can be of any construction, for example consisting of plastic tubes or rod elements.

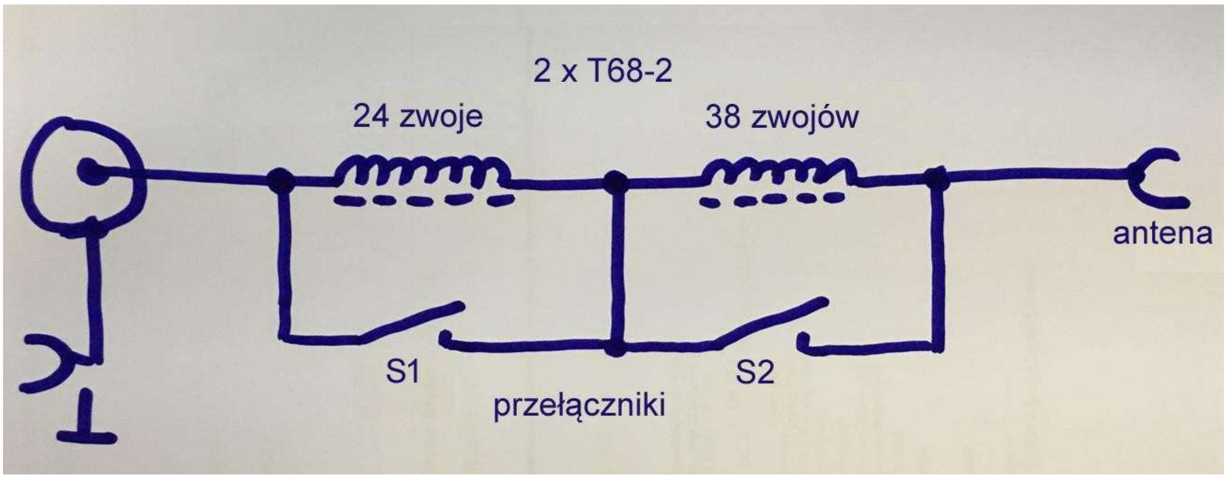


Figure 1.2.1.1 Extension coil diagram

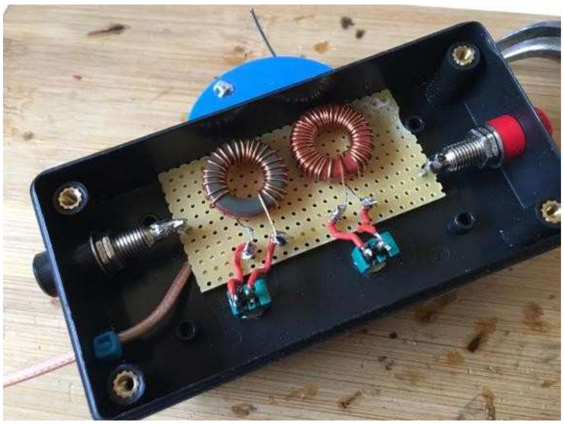
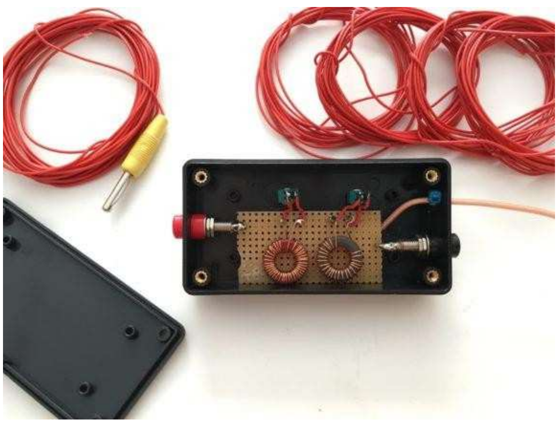



Photo 1.2.1.1. Making of the matching circuit Photo 1.2.1.2. Elements of the antenna

[1.2.1.1] https://www.hamspirit.de/9889/dreiband-vertikalantenne-fuer-qrp-betrieb/.
[1.2.1.2] https://qrpguys.com

1.2.2. Shortened dipole for the 10 m band

The antenna was designed by the designer to be mounted vertically on the balcony as a complement to the existing antenna installation, but there is nothing against mounting it horizontally. The antenna consists of three sections of fibreglass tubing with a total length of 2.9 m and diameters of 12 and 10 mm, into which a Cuem Ø 1 mm cable is pulled to form the arms of the dipole.
Extension coils are made of the same wire. For a resonance frequency of 29 MHz, the inductance of the coil must be equal to 3.2 µH. For the 12 and 15 m bands, the inductances are equal to 5 µH and 7.5 µH respectively. For a 3.2 µH coil with a winding spacing of 2 mm (double wire thickness) and an inner diameter of 10 mm, the number of windings is 57 (after taking into account the effect of the coil's own capacitance - without taking into account it would be 68 windings). In practice, it even turned out that 50 windings were sufficient. In order to lower the resonance to approx. 28.15 MHz, the designer added 8 cm long sections of wire at the end of the coil as a small capacitive load. The method of manufacture is shown in Figure 1.2.2.4. The conductors and the tube outlet are protected by a heat shrink sleeve. Holes in the tube walls (in the middle and at the ends of the coils were sealed with two-component glue. The dimensions of the antenna and the position of the coils are given in Fig. 1.2.2.1. Simulations with EZNEC show an input imtedance of 35 Ω. To match it to the 50 Ω line, a transformer with 5:3 turns wound on a ring coreFT140-43 was used. The core can withstand 100 W power without problems.

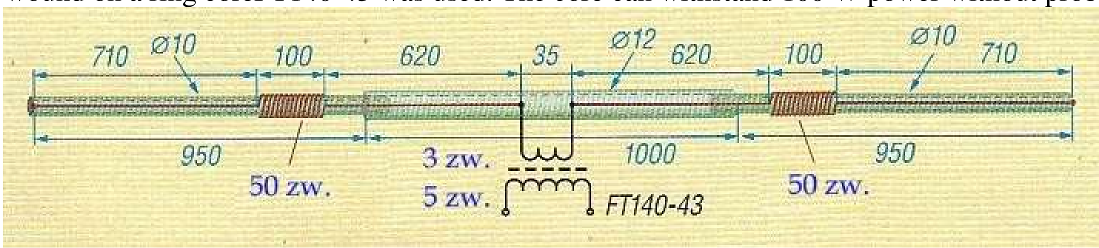


Fig. 1.2.2.1. Antenna dimensions

Fig. 1.2.2 Coil and supply assembly. On the left you can see the opening to the inside of the tube, and on the left the method of protection with heat shrink sleeve.

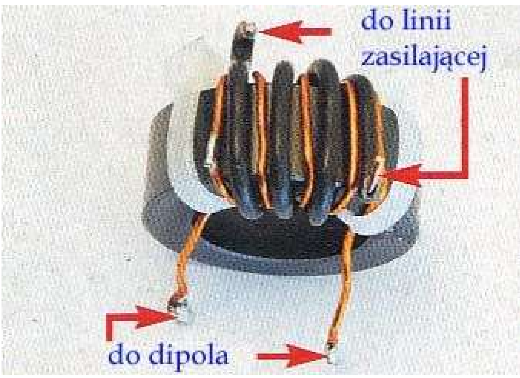
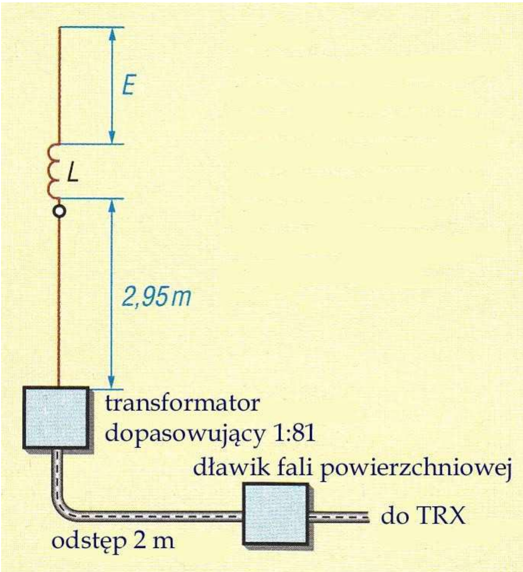


Fig. 1.2.2.3. Method of making the matching transformer
Figure 1.2.2.4 Making and securing dipole extension lugs

[1.2.2.1] "10-m-Kurzdipol für die Antennenanlage auf dem Balkon", Klaus Solbach, DK3BA, *Funkamateur* 12/2023 p. 964

1.2.3. Shortened vertical antenna for 15 m, 17 m and 20 m bands

The antenna consists of a 6-metre-long fibreglass rod (rod) serving as a carrier for two sections of wire connected together by an extension coil placed approximately 2/3 of the height of the antenna (Fig. 1.2.3.1). The lengths of the upper section E and the number of coil windings for individual bands are given in Table 1.2.3.1. Initially, the section E should be made slightly longer and shortened in the course of antenna tuning. The resonance of the antenna is influenced, among other things, by the way the coils are wound (wire thickness and spacing between coils) and their intrinsic capacitances.
The coils are wound on sections of 25 mm diameter PVC pipe (Photo 1.2.3.3). The shortening is approximately 45 % for the 20 m band, 60 % for the 17 m band and 70 % for the 15 m band. The advantage of the design is that it does not need counterweights. However, it requires the use of a surface wave attenuation choke on the power cable.



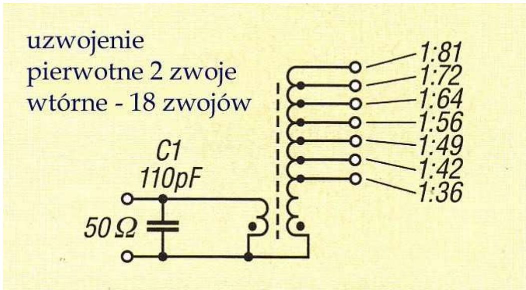
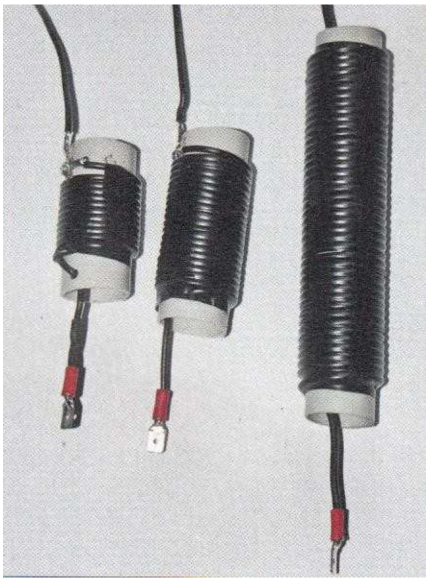


Fig. 1.2.3.1. Diagram and dimensions of the antenna Fig . 1.2.3.2. Diagram of the matching transformer



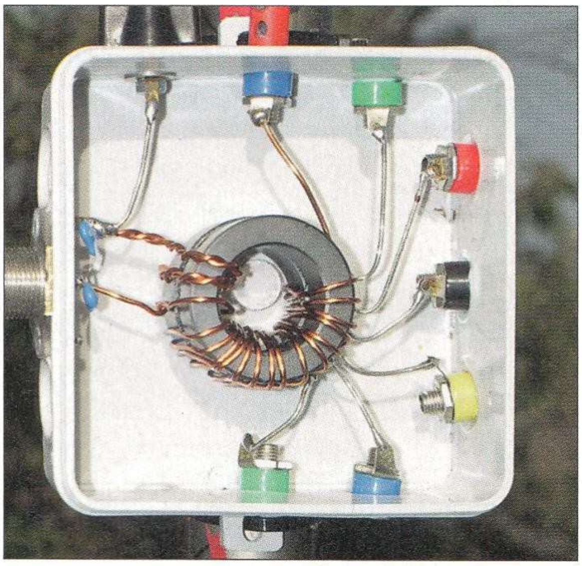


Photo 1.2.3.3. Execution of extension coilsPhoto 1.2.3.4. Execution of transformer

A magnetic transformer with a resistance ratio of 1:81 (voltage ratio of 1:9) is used to power it at the lower end. A schematic diagram of the solution is shown in Fig. 1.2.3.1, a schematic diagram of the matching transformer in Fig. 1.2.3.2 and the method of manufacture in Fig. 1.2.3.4. The transformer is wound with Cuem wire of diameter

1.2 mm on ring core FT140-43. The primary winding contains two turns and the secondary winding 18 turns with taps to allow gear selection. The maximum resistive ratio is 1:81 which gives a 4 kΩ impedance match. The maximum permissible transmit power for SSB and CW emissions is 200 W, for continuous emissions such as RTTY or FT8 this is lower. The transformer can also be wound on either T130-6 or T130-2 cores.

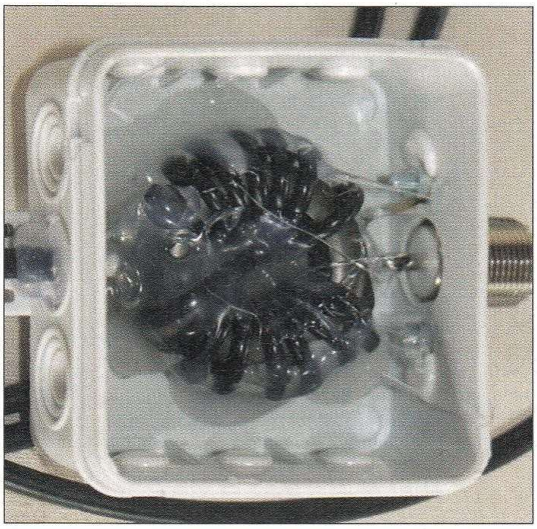


Fig. 1.2.3.5 Making the choke

The transformer and choke for the surface wave are housed in plastic wiring boxes. The choke is wound (in the manner of W1JR) also on an FT140-43 core and consists of 2 x 7 turns of RG174 coaxial cable. The cable is bonded to the core with hot glue. By placing the reactor 2 m away from the transformer, the cable screen provides a mini counterbalance to improve transformer performance.
The radiator and coil elements are made of the same wire - 1.5 mm copper lica[2] in PVC insulation. The coil windings have been taped with insulating tape. At the lower ends of the coils there are sections of wire 5 cm long ending in a contact. In this way, the lower antenna element of 2.90 m is extended to 2.95 m. The upper section E is permanently connected to the extension coil.

Table 1.2.3.1
Number of turns of the extension coil and length of the section E

Bandwidth [m]	Number of coils	Length of section E [m]
15	11	1,92
17	20	1,82
20	41	1,85

Table 1.2.3.2
Data of the matching transformer

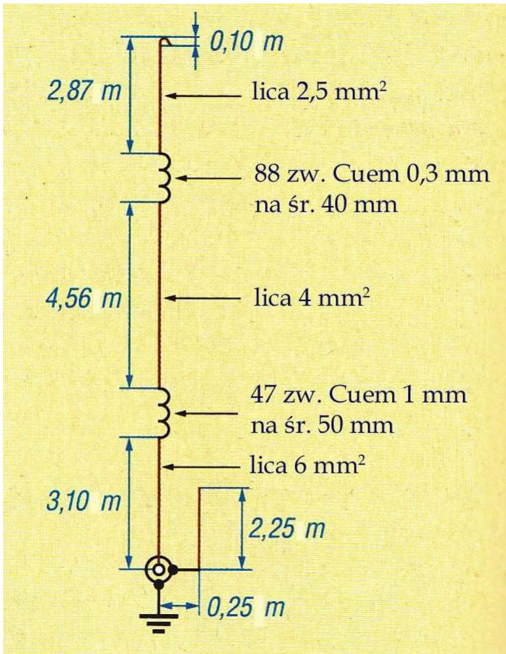
Detachment on the coil	Winding ratio	Thrust gear
18	1:9	1:81
17	1:8,5	1:72
16	1:8	1:64
15	1:7,5	1:56
14	1:7	1:49
13	1:6,5	1:42
12	1:6	1:36

The lower section is either taped or tied to the carrier with ties. The coils are connected by means of plug-in contacts from the car wiring. Instead of these, electrical cubes can be used. Ties are used to fix the upper section. The coil can also be wound spirally on a rod, in which case a single tie at the top is sufficient.
The ranges covered are narrower than for half-wave dipoles, but in practice are sufficient to cover entire bands with a WFS below 1.5 once the optimum transformer ratio has been selected. It is influenced, among other things, by the surroundings of the antenna.

[1.2.3.1] "Verkürzte EFHW-Vertikalantennen für 15 m, 17 m und 20 m", Martin Steyer, DK7ZB, *Funkamateur* 5/2023 p. 381.

1.2.4. Shortened vertical antenna for 10m, 15m and lower bands

The antenna consists of a radiator divided into three elements for the 15 m, 80 m and 160 m bands and an electromagnetically coupled radiator for the 10 m band (Fig. 1.2.4.1). The set of bands is adapted to the licence conditions for German Class E. The lower element of the radiator is tuned to the 15 m. Above this is the element separated by the lower choke for the 80 m band. The top element separated by the upper choke allows operation in the 160 m band. Due to the significant resonance distance of the 15 m and 80 m bands, the lower choke effectively separates the lower element from the rest of the antenna. The smaller resonance frequency difference in the 80 and 160 m bands makes the separation of the middle element from the upper element much weaker. Resonance in the 10 m band is provided by an additional passive radiator placed at 0.25 m on the side of the main radiator. It is grounded and electromagnetically coupled to the main radiator.



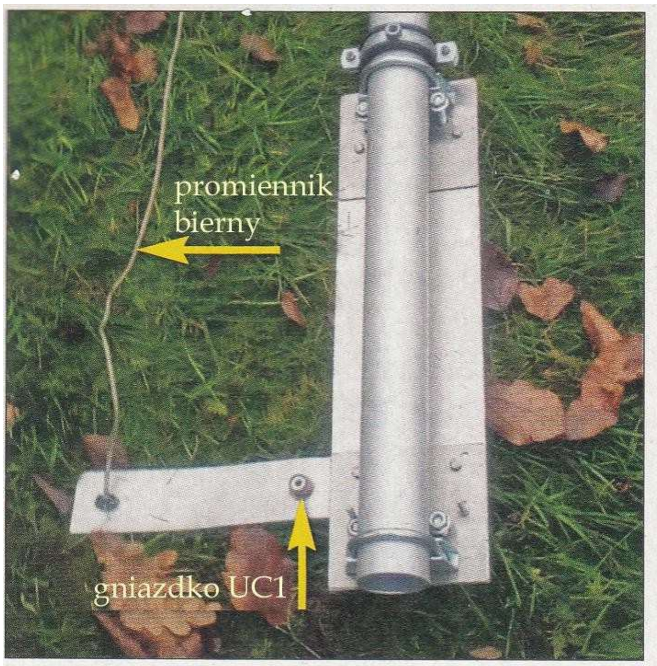
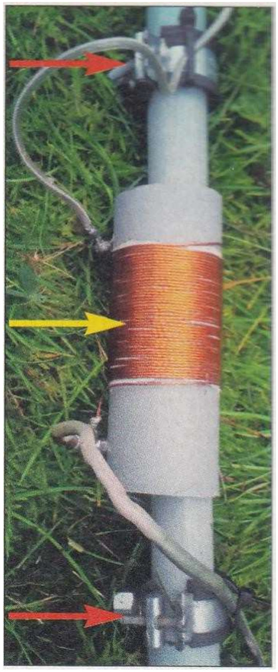


Fig. 1.2.4.1. Diagram and dimensions of the antennaFig . 1.2.4.2. Antenna base

The total height of the antenna is 10m. It uses a 10-metre fibreglass rod (rod). The construction and commissioning of the antenna are simplified compared to other multiband antennas by replacing the resonant circuits (traps) with separation chokes. The support rod stands stable and does not require lashings. The construction of the antenna base and lower choke is shown in Figures 1.2.4.2 and 1.2.4.3.
The radiator elements are made of loudspeaker wire with different cross-sections in insulation. The cross-sections were chosen according to the HF current. The four counterweights with a length of 10 m are made of loudspeaker rope with a cross section of 6 mm^2 .
The coils are wound with 1 mm Cuem wire coil by coil on 40 and 50 mm diameter PVC pipe. Metal clamps were used to fix the radiator elements and the ends of the coils.

The bandwidth for WFS below 2 is 80 kHz in the 3.5 MHz band and 50 kHz in the 1.8 MHz band. Across the 10 and 15 m bandwidths, the WFS lies below 1.5.



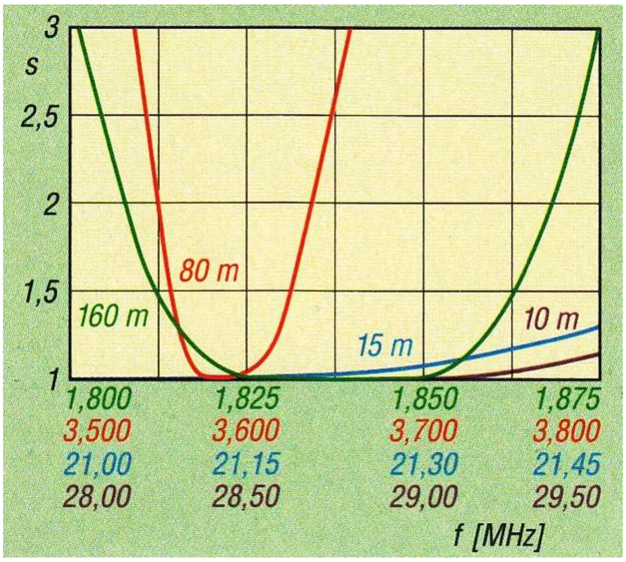


Fig. 1.2.4.3. Bottom coil fabrication. The red arrows indicate the metal clamps and the yellow arrow indicates the coil Fig. 1.2.4.4. WFS waveform in operating bands

[1.2.4.1] "Verkürzte Vertikalantenne für 10 m, 15 m und die Lowbands", Dipl.-Ing. Christoph Kunze, DK6ED, *Funkamateur* 9/2023 p. 714.

1.2.5. Broadband GP antennas

Antennas based on the WBV (*wide band vertical*) principle have an additional passive radiator electromagnetically coupled to the main radiator. This is shorter than the main radiator and thus provides resonance and matching (second local minimum WFS) at a frequency higher than the main frequency. This results in a broader low WFS characteristic, i.e. a wider operating band for the antenna. The main radiator for the 80 m band has a height of 1/4 wavelength - 21 metres - and was, in its original construction, made of 80 x 80 mm square metal profile. The antenna was originally equipped with 40 counterweights with a length of 20 metres. However, the number of counterweights could easily be reduced to 10. In the modified antenna, the 19 m high passive radiator is a wire loop 3 - 3.5 cm wide and the 21 m high main radiator is a 10 cm wide wire loop. Teflon spacers were used in its construction to obtain a stable structure.
Adding a passive radiator not only extends the antenna's operating range, but also increases the input impedance from 37 Ω to about 50 Ω with a small imaginary component, provided the distance and length of the passive radiator is selected. It must also be thinner than the main radiator. The experimentally selected spacing of the two radiators giving the lowest possible radiation angle is 1.2 m for an antenna operating in the 80 m band. However, a lower WFS is obtained with a spacing of 1.6 m. For the frequency of 3.5 MHz, an input impedance of Z = 55 + j2.7 Ω and a WFS of about 1.11 were obtained, for the
3.6 MHz - Z = 60 + j0.8 Ω and WFS 1.2, while for 3.7 MHz - Z = 40 - j0.26 Ω and WFS - 1.25.
The modified design is shown in Figure 1.2.5.1. The directional characteristic of the antenna is almost omnidirectional.

The dimensions of the antenna are calculated from the following formulae:

$\lambda_M = 3 \times 10^8 / f_M$ where f_M is the frequency of the centre of the operating range,

the length of the main radiator is lpr =
1,029 λ_M / 4
passive radiator length lpb =
0,887 / 4
the distance between the radiators is d
= 0,02 λ_M
radius of main radiator rpr =
0,001 λ_M
and the radius of the passive
radiator rpb = rpr / 3.

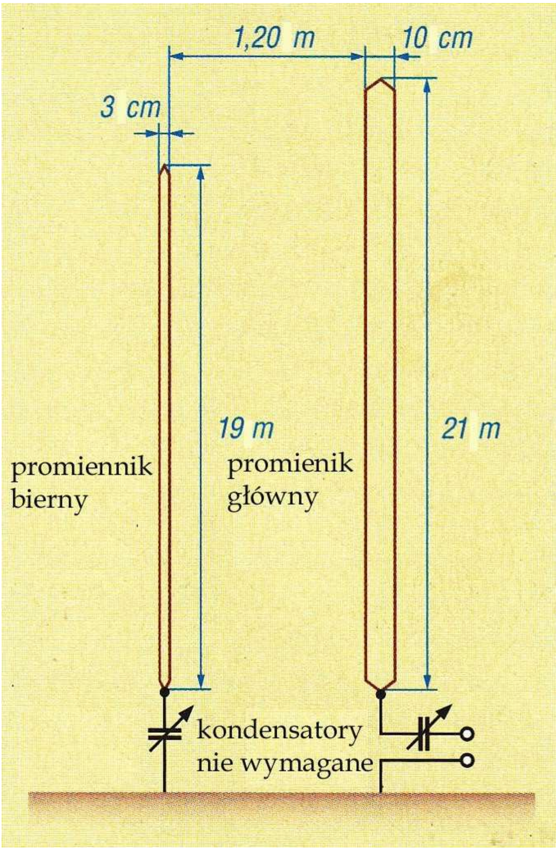


Fig. 1.2.5.1 Dimensions of antenna structure

[1.2.5.1] "Neues Konzept für breitbandige Groundplane-Antenne", Jörg Süssenbach, DF9LJ, *Funkamateur* 2/2023 p. 124.

1.2.6. Antenna HB9XBG

The HB9XBG antenna is a vertical half-wave antenna fitted with an additional quarter-wave element - both of which are extensions of the 100 Ω wave impedance line fixed on the antenna mast. The antenna operates as a vertical surface wave dipole.
It does not require counterweights and therefore takes up relatively little space. An important element to ensure that the antenna radiates at all is the surface wave blocking choke. The surface wave flowing on the outer surface of the coaxial cable screen arises as a result of the need to equalize potentials between the symmetrical and asymmetrical sides of the system. The surface effect causes the outer side of the screen to form a separate (third) conductor in the coaxial cable for high frequency. The currents flowing in it cause the waveform to radiate. Without the blocking choke, the symmetrical currents feeding the antenna and the surface current component would flow in the 100-ohm line section.

The input impedance of the 100 Ω antenna can be easily matched to the 50 Ω system impedance without the use of complex matching circuits. The section of the feed line connecting the output of the matching circuit to the radiator terminals is made of 2 x 2.5 mm loudspeaker cable in PVC iso- lation. The wave impedance of this cable is close to 100 Ω.
The designer relied on the dependence of the input impedance of a symmetrical vertical dipole on its distance from the ground surface. When the lower end of the dipole is at a height close to 1/80 of a wave, the input impedance is 100 Ω. In the HB9XBG design, the antenna terminals are located at a height of approximately 20 cm which also provides an input impedance of 100 Ω.
The matching circuit and choke are housed in a plastic waterproof case. HB9XBG, together with HB9BFM, have realised and practically tested antennas for the 20 and 40 m bands - on 22 and 10 m m masts respectively, for 100 and 1000 W power.


Photo 1.2.6.1. Implementation of circuits in the 100 W version Photo 1.2.6.2. 10 m antenna in rolled-up state

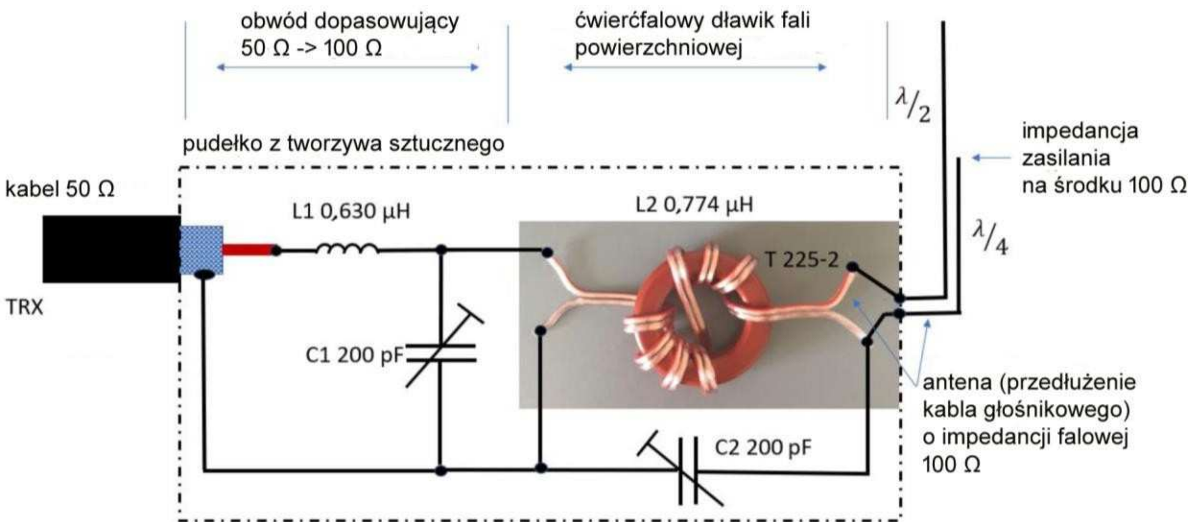


Figure 1.2.6.3 Antenna design

The antenna's operating bandwidth for a WFS below 1.5 will be in the 20 m 900 kHz range, which is well above the amateur bandwidth. The gain over ideal ground is 6 dBi. The antenna is well suited for field work (not least due to its simple assembly and disassembly) and, thanks to its low radiation angle, performs well in DX communications.

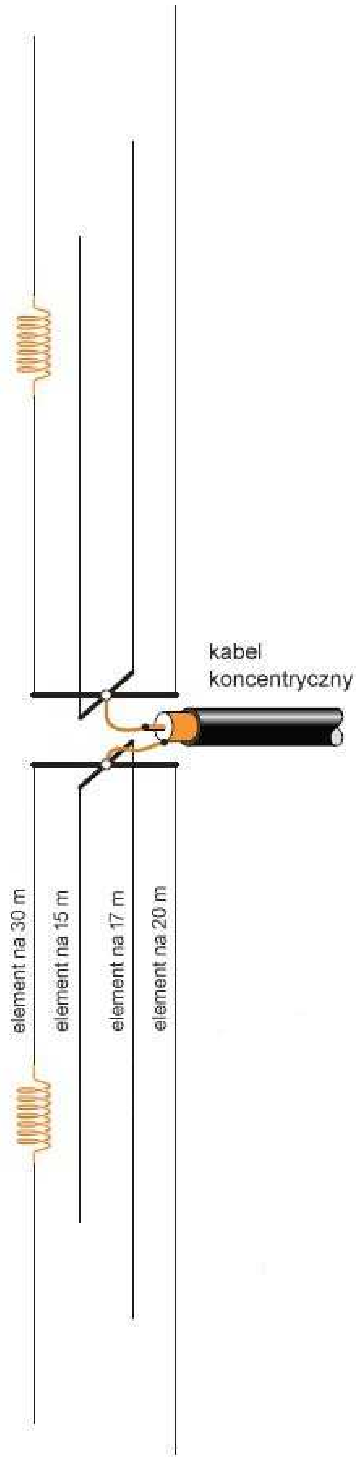
Table 1.2.6.1 Circuit elements

Bandwidth [m]	L1 [µH]	C1 [pF].	L2 [µH].	C2 [pF].	Cable lengths [m]
20	0,630	112	0,774	162	10,04
40	1,260	224	4,000	125	20,07

[1.2.6.1] "Die nützliche Mantelwelle", Walter Kägi, HB9XBG, HBradio, 6/2000 pp. 41 - 44
[1.2.6.2] "Antennenbuch", Rothammel, publ. 12, chapter 19.5.2
[1.2.6.3] "ARRL Antenna Book", Issue 24, Chapter 2.13.
[1.2.6.4] http://oe1iah.at/Hardware/Antennen/HB9XBG_Antenne.shtml

1.2.7. Vertical antenna four-band

The pendant antenna, shaped like two crossed rectangles, provides good audibility on the 30, 20, 17 and 15 m bands.
The antenna consists of four vertical dipoles fed in the classical manner at the centre. The design is lightweight and inexpensive, is based on materials that are easy to obtain, lends itself to easy installation, covers four shortwave bands and does not require frequent adjustments.
All four dipoles are connected in parallel and share common power terminals. The height of the dipoles for the 20m and 17m bands does not exceed 10.5m, while the dipole for the 30m band has to be extended electrically with coils in both arms. The height of the antenna has been chosen so that it can be hung from a tree growing at the builder's site.
The extension coils were wound with 1 mm Cuem wire[2] on 3/4 inch diameter PVC tubes 10 cm long. The winding consists of 23 coils wound coil by coil and has an inductance of 6.7 µH. The length of the winding is approximately 4.5 cm. The winding has been coated with three layers of polyurethane glue and wrapped with insulating tape for protection against environmental influences. Each radiator arm for the 30 m band consists of two 252 cm long sections connected to both ends of the coil.
The radials for the 20, 17 and 15 m bands were made from 2.5 mm insulated cable[2] . Due to the interactions between the dipoles, it is advantageous to fix all four dipoles before tuning the antenna.
The upper and lower cross-braces consist of eight sections of PVC pipe, each 23 cm long, joined at the centre by PVC quadrants. The middle cross-piece consists of two 6 mm thick plastic flat bars, 51 cm long and 5 cm wide. A UHF antenna socket (UC-1) is fixed at their intersection. Its centre contact is to be extended with a piece of thicker cable with a diameter of 2 mm, so that it sticks out on the other side of the flat bars. The socket and the flat bars are screwed together with four screws (photo 1.2.7.4). The middle and outer contacts are connected to the lower and upper dipole arms respectively. The way the arms are connected to the extended middle contact is shown in Photo 1.2.7.5.
To the holes in the arms of the upper and lower cross-pieces, the ends of the dipoles or the ends of a non-conductive line with a diameter of 3 mm are attached to supplement their length. It is best to first fix the dipole elements for the 20 m band as this determines the height of the antenna. At the ends of the shorter elements there are PVC insulators drilled through at the ends, to which sections of the extension cord are attached. In the quadrupoles at the top and bottom there are metal hoops to which a line is attached for hanging the antenna (at the top) and a tension line tied to a rod driven into the ground (at the bottom).
Ferrite rings should be applied to the feed cable to form a choke to symmetrise the antenna feed. The designer has used ferrite ring cores of material 31. The mutual influence of the elements on each other makes it necessary to select the lengths of the elements during tuning and to adjust the lengths of the extension cables accordingly. Tuning starts with a 20 m band. The standing wave ratio (WFS) obtained after tuning is shown in Table 1.2.7.2.
The antenna radiates a vertically polarised wave and does not require counterweights. The designer has achieved many intercontinental communications on it.



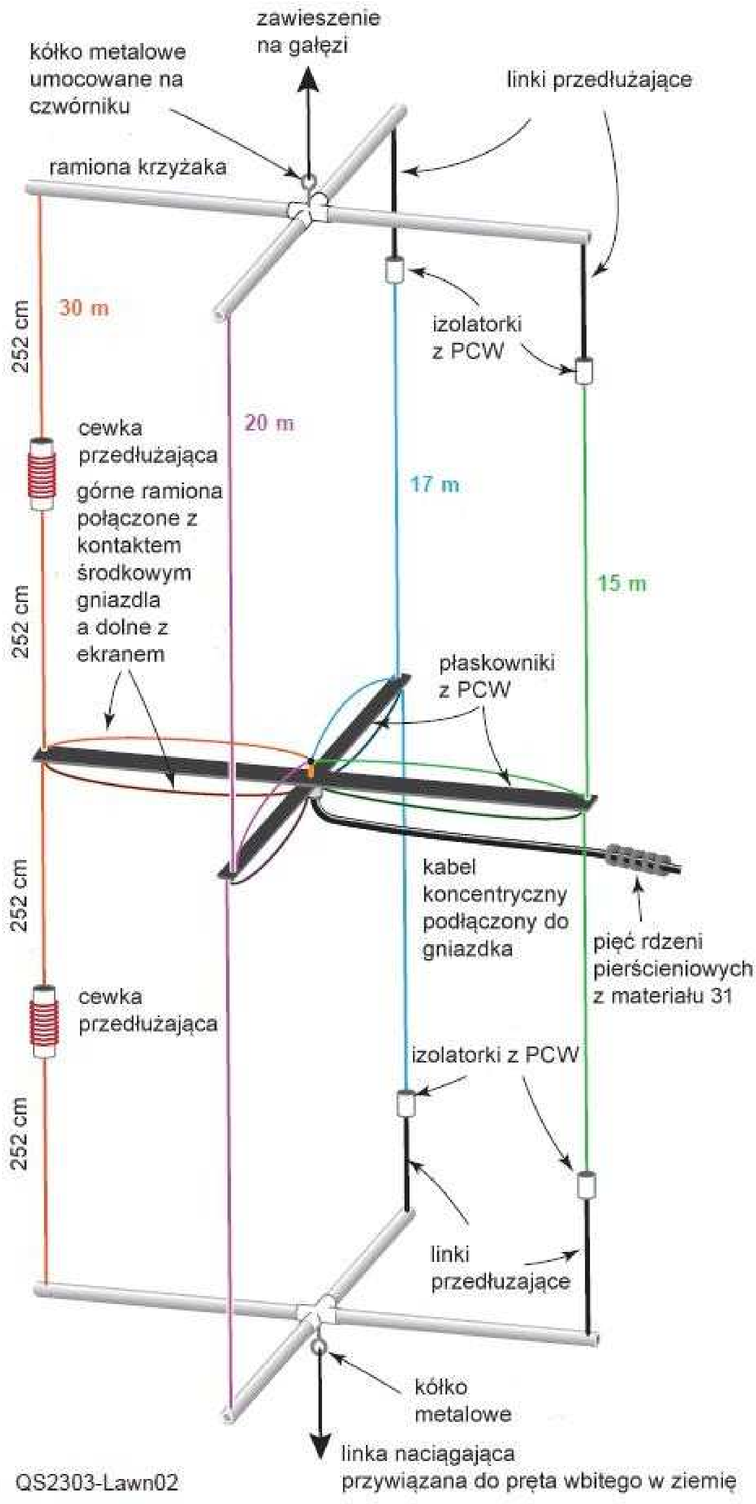


Fig. 1.2.7.1. Antenna design principle of a four-band antenna
Fig. 1.2.7.2. Antenna design and dimensions

Table 1.2.7.1.
Antenna element lengths for individual bands

Element	Length [cm]
External at 30 m	234
Internal for 30 m	252
20 m dipole arm	529

Dipole arm for 17 m	417
15 m dipole arm	352

Note: the length of the outer element for the 30 m band indicates that the connection to the antenna socket is part of the dipole. Add 15 - 20 cm for pulling through the coil body.

Table 1.2.7.2.
Antenna measurements made with RigExpert AA-600 analyser

Bandwidth [m]	Frequency [MHz]	WFS
30	10,100	1,50
	10,125	1,38
	10,140	1,40
20	14,000	1,22
	14,150	1,28
	14,340	1,60
17	18,060	1,70
	18,100	1,70
	18,160	1,80
15	21,000	1,00
	21,150	1,19
	21,440	1,50

Photo 1.2.7.3. Extension coils for the 30 m band before they are impregnated and installed
Photo 1.2.7.4. Coaxial socket is fixed under the intersection of flat bars

Photo 1.2.7.5. Connection of the upper dipole arms to the extended centre contact of the socket using a metal clamp

[1.2.7.1] 'WindChime4: A Four-Band Vertical Dipole", Richard Lawn, W2JAZ, QST 3/2023 page 30.

1.2.8. Grounded antenna half-wave

Grounded half-wave antennas usually require quite complex matching circuits. The antenna of the SP3L design has an input impedance of 50 ohms.

Gamma-type circuits are most commonly used to feed quarter-wave grounded antennas. An attempt to check by simulation whether the same solution would work for half-wave antennas showed that it is possible to design them without requiring any matching circuits. The starting point for the simulation was the design in Figure 1.2.8.1. The feed cable shield is connected to the mast just above the ground surface. The cable is further routed along the mast to a height of 1/4 wave, where its screen is again connected to the mast. The centre conductor is connected to a cable that extends along the mast and forms the lower arm of the vertical dipole. It is capacitively loaded with two wires stretched parallel to the ground surface so that this arm is shortened and its end does not touch the ground. The upper part of the mast from the height of the quarter wave upwards constitutes the upper arm.

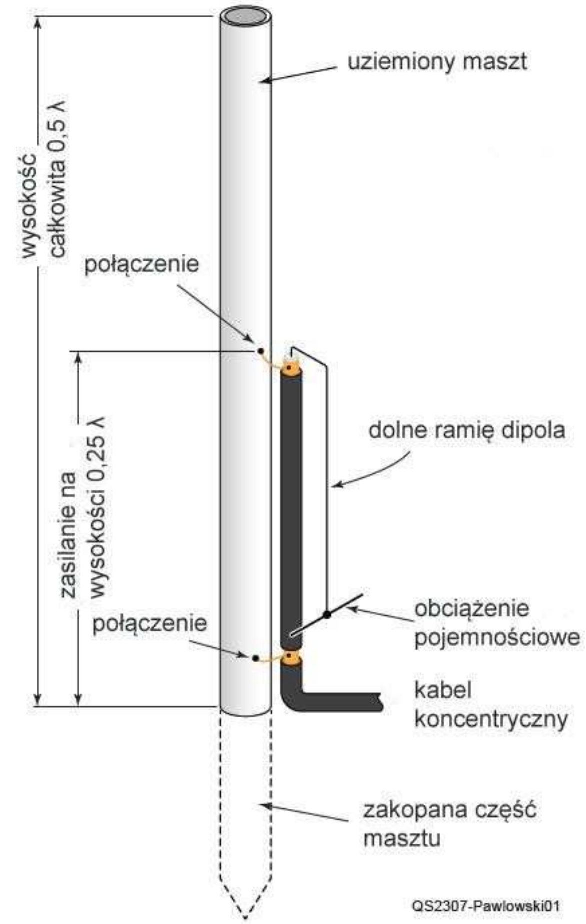


Figure 1.2.8.1: Output concept of a half-wave antenna mounted on a grounded mast

The simulation showed that very little HF current flows down the mast and that, even with a high mast ground resistance, the power loss in the ground is negligible. This means that the antenna does not require a low ground resistance. Further simulations at different ground resistances up to a very extensive counterweight system showed that the antenna behaves equally well over a wide range of ground resistances. Simulation of the antenna's maximum gain showed that it was slightly higher than for a typical quarter-wave dipole fed at the centre. However, the directional characteristics were not exactly omnidirectional and the matching bandwidth was half that of a centre-fed quarter-wave antenna. The input impedance was 22 Ω.
Figure 1.2.8.2 shows the final solution. The height of the mast is 0.6 λ thus avoiding capacitive loading of the lower arm of the dipole. The lower arm has been replaced by

through an elongated loop, the vertical wires of which are on opposite sides of the mast. This will provide an almost omnidirectional radiation pattern, and moving the feed terminal in the loop will raise the input impedance of the antenna to 50 Ω. The matching bandwidth has not improved, but it is still sufficient in practice for all bands outside the 80 m range. The antenna does not require any matching circuitry or symmetriser. The feed cable shield should be connected directly to the mast. As the antenna is earthed for DC, it also provides static discharge and safety during storms and lightning.

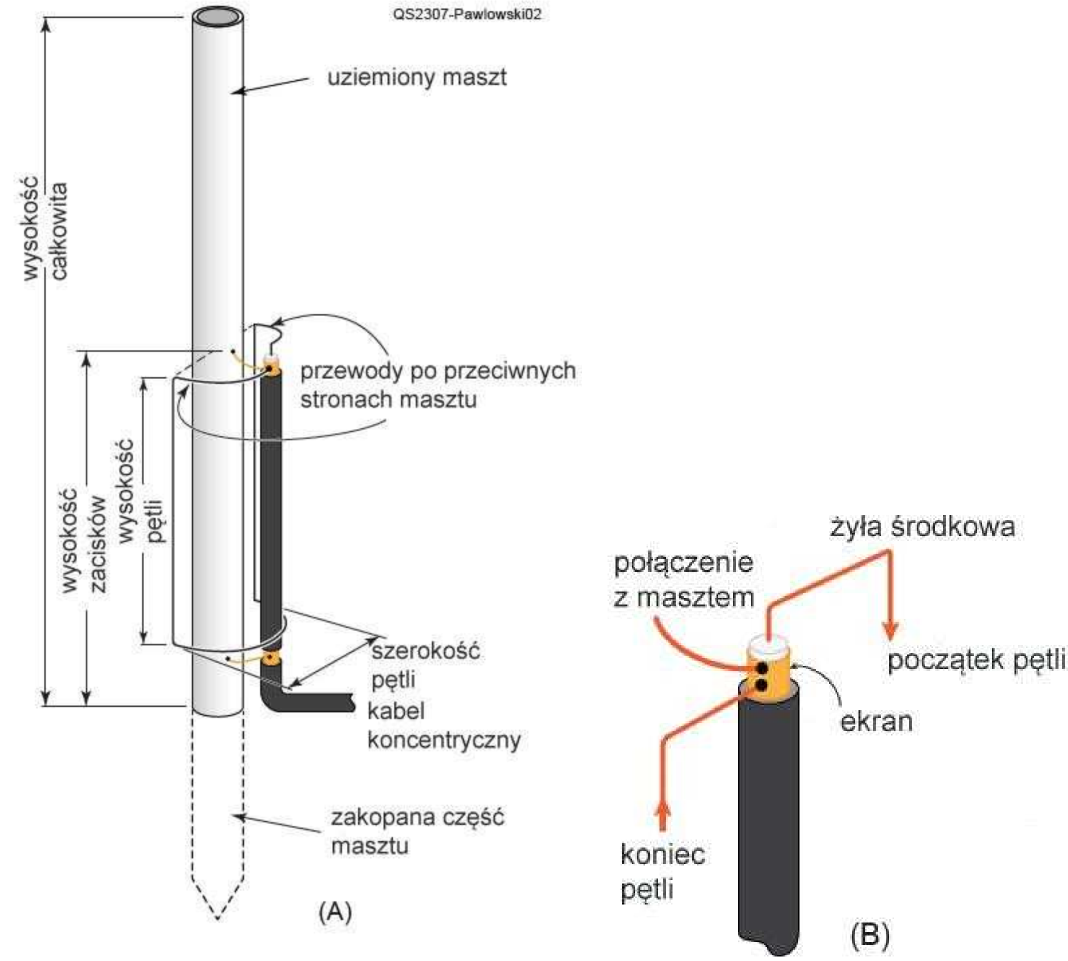


Figure 1.2.8.2: Final antenna solution (A) and feed details (B)

Table 1.2.8.1 gives the dimensions for the various amateur bands. A mast design consisting of telescopically stepped tubes and a loop made of bare 2 mm diameter wire was assumed. A comparison of the radiation characteristics with those of a vertical dipole fed at the centre shows a slightly higher gain. The deviation of the characteristic from the circle does not exceed ±0.1 dB. The principle has been tested in practice in the construction of an antenna for the 10 m band. This band has a considerable width, but it was found that scaling the antenna would allow matching across the entire 12, 15, 17 and 20 m bands. The antenna was fed through a 22 m section of RG-58 cable. At 29.08 MHz, the WFS was equal to 1.1 and at the ends of the band it was approximately 2. The simulation results agreed with the measurements of the built antenna. SP3L also made comparative measurements with a quarter-wave dipole fed at the centre.

Experiments have shown the feasibility of using a 0.6 λ mast as a half-wave grounded antenna. The narrower matching range is balanced by the almost omnidirectional radiation pattern and the gain is almost equal to that of a quarter-wave antenna fed at the end. The const- uction is mechanically robust and does not require low ground resistance. Grounding the structure increases safety during storms and the impact of static discharge.

Table 1
Antenna dimensions for different amateur bands

Dimension	30 m	20 m	17 m	15 m	12 m	10 m
Total height [m]	17,5	12,5	10	8,7	7,2	6,3
Terminal height [m]	9,8	7	5,5	4,7	4	3,5
Loop height [m]	6,09	4,37	3,35	3,03	2,51	2,25
Loop width [m]	0,64	0,48	0,35	0,26	0,22	0,2

[1.2.8.1] "DC Grounded Half-Wave Vertical", Jacek Pawłowski, SP3L, QST 7/2023 page 36.

1.2.9. Vertical 5/8 λ antenna at 10 MHz

The centre-powered 5/8 λ vertical dipole for the 10 MHz band does not require counterweights, and an innovative matching circuit allows operation on one or two bands

The design of the OH3JF antenna follows *Sirio*'s 'Gain Master' antenna for the 25.5 - 30 MHz range. *Siro's* free-standing vertical antenna is housed in a fibreglass tube. This allows it to be easily mounted on a mast. The OH3JF antenna for the 10 MHz band is 5/8 wavelength.
Its construction is shown in Fig. 1.2.9.1. The upper arm of the dipole is made of wire and the lower arm is the shield of the coaxial cable. It is connected to a choke wound with the coaxial cable feeding the antenna. Matched at the centre of the dipole is provided by a capacitor made from a section of coaxial cable open at both ends.
At a distance of 4.47 m from the capacitor (the centre of the antenna) there is a 145 cm long coaxial cable choke shorted at the end. In the OH3JF installation, the choke is about one metre above the ground surface. The upper arm of the dipole has been bent at right angles so that the horizontal section is about three metres. This was due to height restrictions at the installation site.
The antenna dimensions were selected for 10.11 MHz (29.67 m) by scaling the Sirio antenna for 27.75 MHz. The shortening factor must be taken into account when calculating the height of the tuner placement and its length. The distance of 0.177 wavelength between the coaxial capacitor and the tuner was also taken from the *Sirio antenna*. The tuner itself has a length of 0.0574 wavelength. When calculating the mechanical lengths of the Ecoflex 10 cable, the cable shortening factor - which in this case is 0.85 - must be taken into account. The factors for other cable types are given in their catalogue data.
Modelled on the *Sirio* product, the choke is wound on a grey PVC tube approximately 11 cm in diameter, contains 27 turns and has an inductance of 29 µH. The response at operating frequency is several kΩ, suggesting that it operates ied near resonance.
The coaxial capacitor in the *Sirio* antenna is 9 cm long and has a capacitance of 8.7 pF. For the same capacitive reactance (659 pF) it should have a capacitance of about 23.9 pF at 10.11 MHz. For the RFA-78 cable, the shield length should be 33 cm (the intrinsic capacitance of the cable is 73 pF/m). The insulation should be slightly longer so that the distance between the ends of the shield and the ends of the centre conductor provides sufficient voltage strength (see Photo 1.2.9.3). Both ends of the capacitor should be hermetically protected against water and moisture. All cable connection points should be protected in the same way.
The weight of the coil and the rest of the antenna causes mechanical stress on the connection points. The designer proposes to reinforce them with plastic lugs (Photo 1.2.9.4). The UHF socket is mounted on an aluminium bracket at the bottom of the choke.
The antenna was tried on telegraphy at 500 W and no problems were observed. Below the choke, the surface current was 6% of the current flowing at the centre of the dipole. The WFS over the entire 10 MHz band was about 1.2.

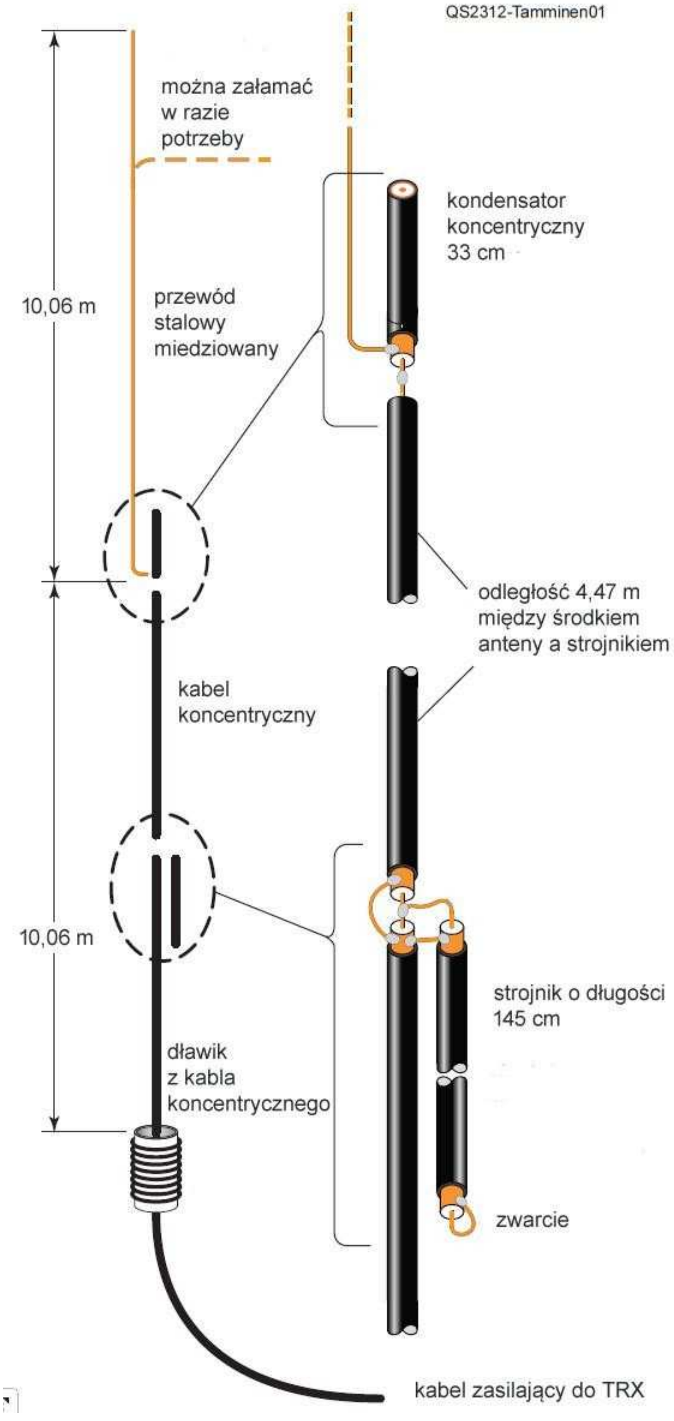


Figure 1.2.9.1: Design of a 5/8 λ vertical antenna based on a Sirio antenna. The antenna has a height of approximately 20 m and is designed for operation in the 10 MHz band.

The construction requires 20.2 m of Ecoflex 10, RG-213 or similar coaxial cable, 33 cm of thicker capacitor cable - RFA-78, RG303, etc., about 11 m of copper-coated steel cable for the top of the antenna, 46 cm of 11 - 12 cm diameter PVC tubing, and nylon rope for its tension and self-amalgamating tape to secure the joints. There can be high voltages on the choke, so the antenna should be mounted high enough not to touch it.
The design of the electrical side of the antenna and the measurements were made by OH5TM. Its important advantage is that it does not need counterweights or matching circuits. The mechanical design and vertical mounting may cause some difficulties due to its height. There is a document describing antenna designs for other amateur bands at [1.2.9.2].

Photo 1.2.9.2 The choke consists of 27 coils of coaxial cable wound on a PVC tube with a diameter of ~11 cm

Photo 1.2.9.3. A 33 cm section of thicker coaxial cable is used as a capacitor.

Photo 1.2.9.4. As reinforcement of the connections there are plastic cups to which the ends of the cables are tied by ties.

Photo 1.2.9.6 Fixing the choke to reduce its mechanical load. The choke has high high HF voltages at its top and should therefore be located as high above ground as possible

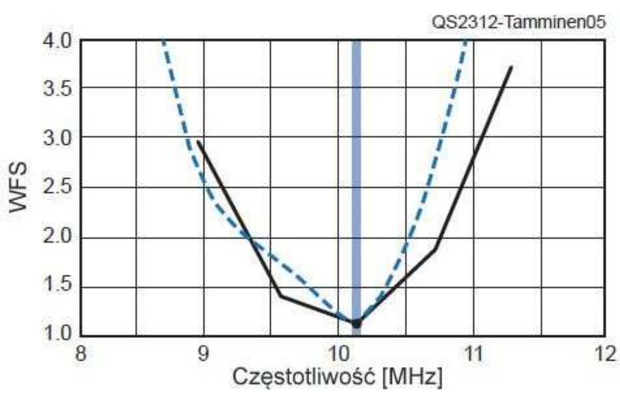


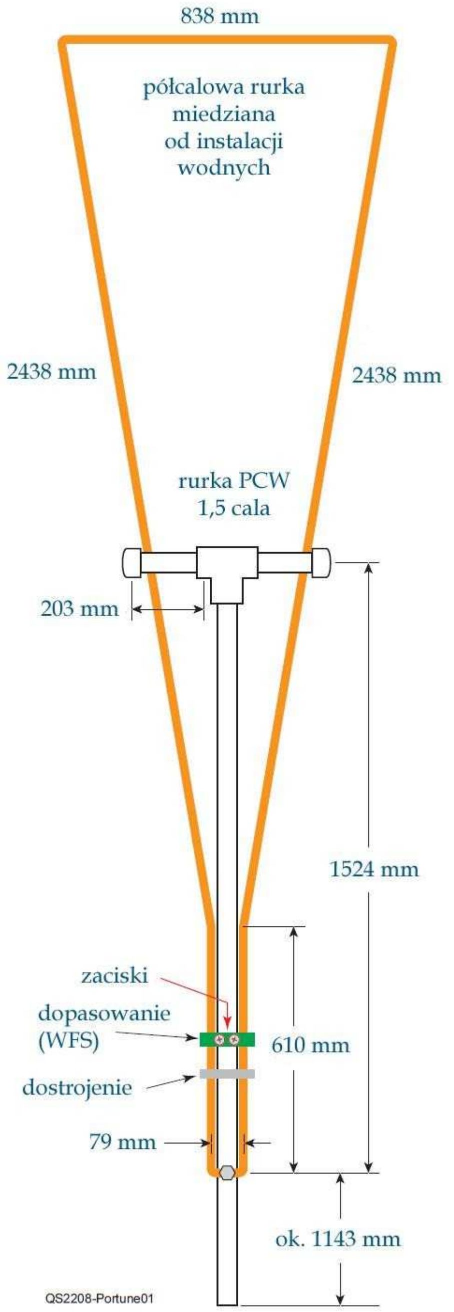
Fig. 1.2.9.5 Standing wave coefficient waveform. Black line - measurement result, blue dashed line - simulation

[1.2.9.1] "The OH3JF 5/8-Wavelength Vertical Dipole", Heiki Tammingen, OH3JF, QST 12/2023 page 32.
[1.2.9.2] https://drive.google.com/file/d/1p2w7Mu4qfzHmJa4etPatieqGre2Lpp_h/view?usp=drive_link
[1.2.9.3] qrz.com/db/oh3jf - OH3JF website on QRZ.COM

2. Antennas for the 50 MHz band

2.1. Skeleton triangular antenna for 6 m band

The skeletal delta antenna for the 6 m band presented in item [2.1.1] is characterised by ease of construction and tuning, as well as slightly better performance compared to a rectangular antenna. Because the antenna is wider at the top, the centre of its radiation is shifted upwards reducing the influence of ground losses and the dependence of the radiation chrakteristics on ground properties. A vertically placed antenna radiates a wave with horizontal polarisation. The direction of radiation is perpendicular to the plane of the antenna. The gain in the horizontal plane is approximately 6 dBi even at ground level, which corresponds to a small directional antenna located on a low mast. The bandwidth at a WFS not exceeding 2 is approximately 500 kHz.



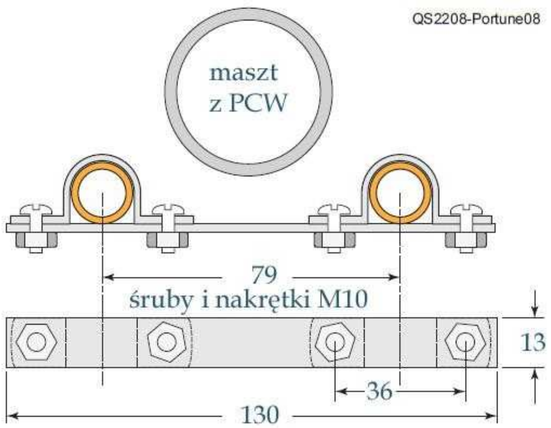
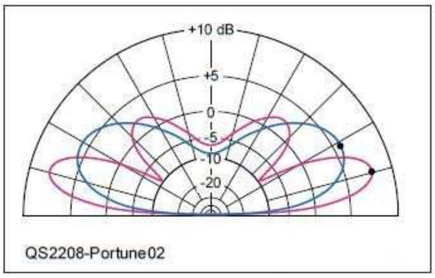
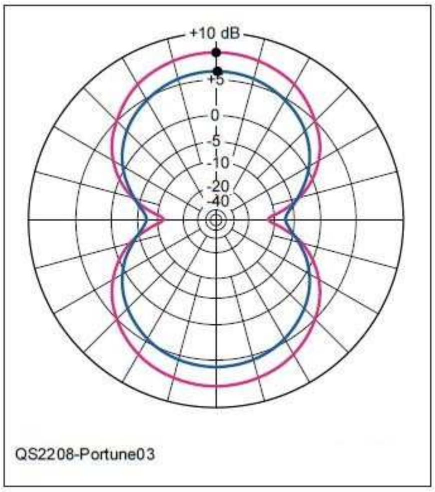


Fig. 2.1.1. Antenna dimensionsFig . 2.1.2. Feed element design

Being made of 1/2 inch diameter copper water pipe, the antenna can stand stably without the use of additional supports. It is placed on a T-shaped support (mast) made of a PVC plastic tube about 2.70 m long and 1.5 inches (~4 cm) in diameter, the lower part of which is buried in the ground. At the top of the tube is a tee for attaching horizontal arms ending in caps.
The antenna itself consists of two vertical elements each 2.44 m long bent 61 cm from the end as shown in Fig. 2.1.1, and two horizontal elements closing the loop. The upper horizontal element is 84 cm long and the lower one is 6.4 cm long.
The upper ends of the vertical elements and the ends of the upper horizontal element are flattened and bolted together using an M6 screw (photo 2.1.3). Below in the photo you can see where the vertical sides of the antenna are bent.
Slots should be cut in the transverse arms of the carrier with widths of 1.6 mm and lengths of about 57 mm for the vertical arms of the antenna to pass through. The parts of the antenna carrier must then be glued together, but the covers can only be glued on after the antenna arms have been inserted. The lower transverse part of the antenna is screwed to the vertical carrier with an M6 screw.



f = 51,9 MHz



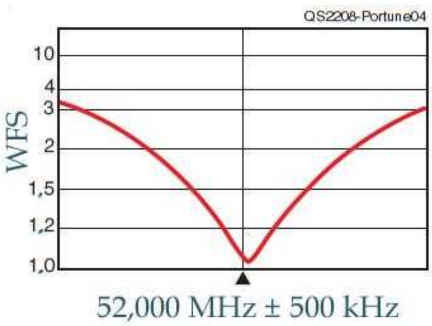


Fig. 2.1.3. Antenna radiation patterns in the vertical and horizontal planes (blue lines at 30 cm, violet lines at 3 m).
Fig. 2.1.4. Antenna matching waveform as a function of frequency

Tuning of the antenna is achieved by moving the transverse sphincter (the lower one in Photo 2.1.2), and matching is achieved by matching the feed points of the antenna. At the top of the cable, several ferrite ring cores made of material 61 are placed to provide surface wave attenuation on the feed cable screen, and on the mast below the antenna a symmetrising choke consisting of six turns of RG-8X or RG-58 coaxial cable is placed. The method of making and fixing the transverse feed ele- ments is shown in Fig. 2.1.2. The antenna's tuning range lies roughly between 45 and 57 MHz, allowing it to be tuned to the 6 m band within European limits.

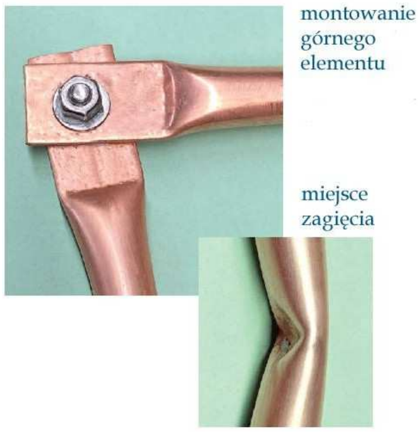


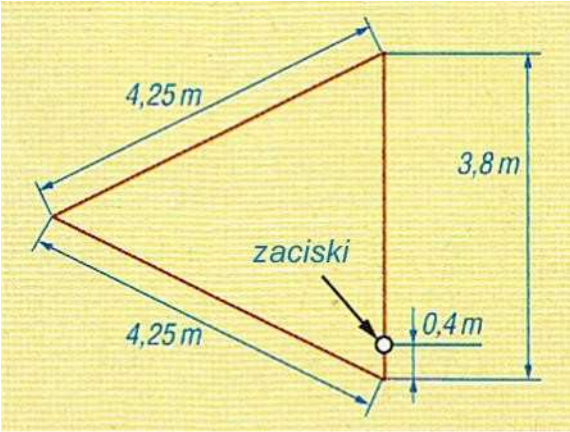
Photo 2.1.1. General view of Photo2.1.2. Structure of the lower part of the antenna Photo 2.1.3. Connection of elements at the top and place of bending of side parts

[2.1.1] 'The Inverted Hen-Delta 6-Meter Antenna', Hohn Portune W6NBC, Jim Bailey W6OEK, "QST" 8/2022 p. 30

2.2. Horizontal loop antenna for 6 m band

This triangular loop antenna with a circumference of 2 λ provides DX communications even when installed at low altitude [2.2.1].
The designer has placed it horizontally at a height of 5 m above the ground surface. The input impedance of the antenna is close to 200 Ω, which makes it possible to adjust it to 50 Ω using a 4:1 transformer. The directional characteristic in the horizontal plane shows two minima (Fig. 2.2.3a) and the directional gain calculated on the basis of simulations in Mman is 7.4 dBi. In the vertical plane, the radiation pattern has two maxima at heights of 16° and 60° (the second of which allows communication over short distances of 20 - 60 km). In practice, it turned out that under the conditions of the constructor's installation, the directional gain is close to 5 dBi, or 2.5 dBd.

While simulations of stacked structures have promised interesting results, the mechanical implementation is mechanically difficult. The antenna is horizontally polarised.



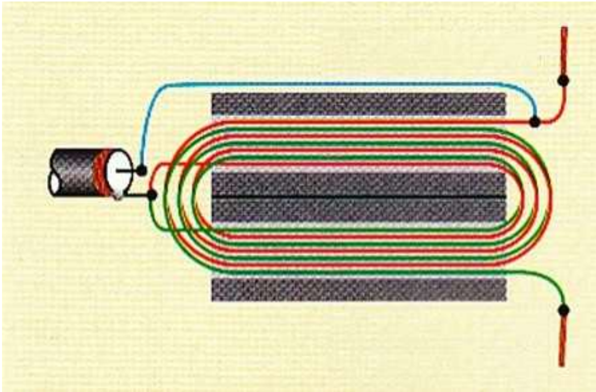


Fig.2.2.1. Dimensions of the antenna Fig. 2.2.2. Design of the matching transformer

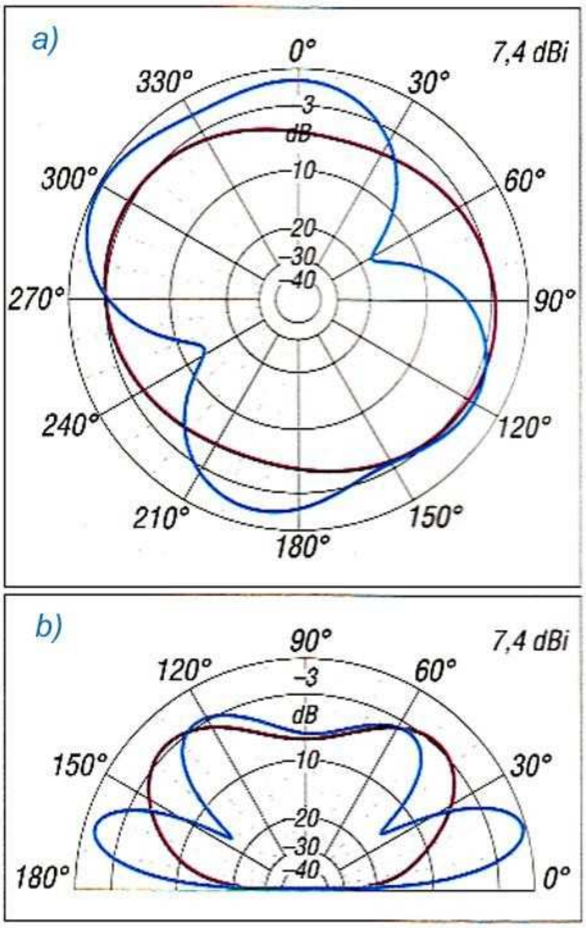


Figure 2.2.3: *Mman* simulated loop directional characteristics (a) in the horizontal plane, (b) in the vertical plane, blue plot - for 50.5 MHz, violet plot - for 28 MHz

The construction used 12.3m of military grade plastic-insulated telephone cable. The matching transformer contains 2 x 3.5 reels of polyethylene-insulated lica. The lica wires were 0.5 mm in diameter (however, to reduce losses it is better to use a larger diameter antenna wire) and the dimensions of the ferrite tube cores of material 61 were: length 28 mm and diameter 16 mm. The green and red wires in Fig. 2.2.2 are connected to the loop terminals, and there is an additional wire (in blue in the figure) from the centre conductor of the feeder cable to one of the loop terminals. The transformer terminals should be protected against loading of their

by the weight of the loop and the coaxial cable. These can be soldered to a mounting plate, to which the cable and antenna loop will also be soldered and fixed with ties.
The antenna terminals are located not in the corner of the triangle, but on its shorter side at a distance of 40 cm from it. The antenna has proven itself in over 10 years of practice and has allowed ranges in excess of 5000 km on telegraphy. According to simulations and measurements carried out by the designer, it is also possible to use the antenna in the 10m band and in emergency communications in the third channels of the CB (27 MHz) and PMR (446 MHz) bands.

[2.2.1] "Horizontale Schleifenantenne für das 6-m-Band", Eberhard von Wedelstädt, DL3ZID, *Funkamateur* 3/2024 p. 224

2.3. Hidden J antenna for 6 m band

FM communications in the 6m band and higher UKF bands use vertical polarisation, while SSB communications use horizontal polarisation. This principle applies to direct wave communications. The polarisation of waves reflected from the ionosphere undergoes changes independent of the station operator and is difficult to predict for a wave reaching the receiver. The polarisation of the transmitted wave therefore becomes unimportant.

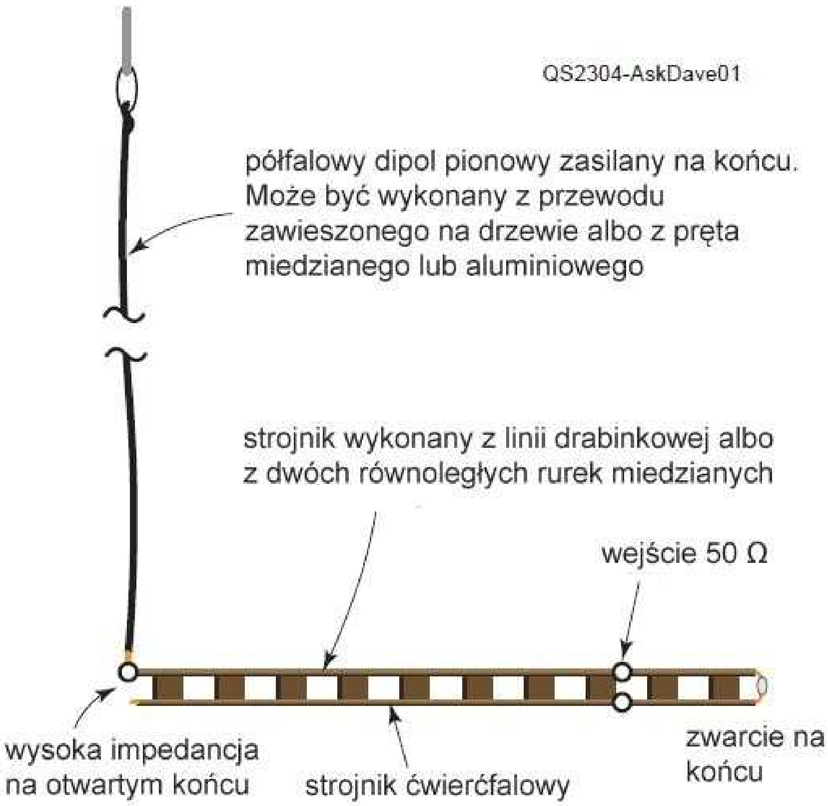


Figure 2.3.1 Antenna design

J-type antennas consist of two elements: a half-wave dipole and a quarter-wave matching tuning stub usually made of flat symmetrical line or metal tubing. The matching stub is shorted at the end. On the other open side it has a high impedance, matching the input impedance of the half-wave dipole fed at the end.
The radiator can point in any direction and need not be an extension of the tuning device. In particular, they may be placed at right angles to each other. Thus, the tuning device can be in a lying position and the radiator in a vertical position. By bending the antenna, the height of the antenna is lowered so that it can be more easily hidden from unwanted eyes.
The length of the tuner can be calculated from the formula l [m] = 71.5 / f [MHz] and the length of the radiator from the formula l [m] = 143 / f [MHz], assuming a truncation factor of 0.95. The considerable bandwidth of the 6-

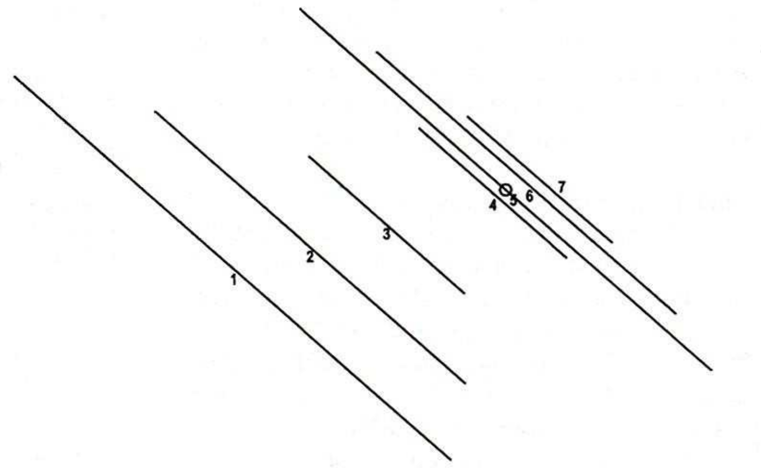
If an antenna is mounted on a tree, it is best to use insulated cable. In the case of hanging an antenna (radiator) on a tree, it is best to use insulated cable to make it. The length of the radiator can also be calculated by scaling the antenna proportionally from a 2 m band. The position of the input terminals for an impedance of 50 Ω can be found experimentally.
The antenna does not require counterweights and can be placed at any height above the ground. Preferably it should be higher than 1.5 - 2 m. Refracted antennas for any other bands can be constructed on this principle.

[2.3.1] "Ask Dave: Coax Cables, Band Noise, and A 6-Meter J-Pole Antenna", Dave Casler, KE0EG, QST 4/2023 p.50.

3. Antennas for the 70 MHz band

3.1. Short antennas for the 4 m band

Thanks to its relatively small size, the DK7ZB tri-band antenna for the 6, 4 and 2 m bands is a practical solution for anyone with limited space. In addition to the 6 m base radiator, it has two closely spaced and strongly electromagnetically coupled radiator elements for the 4 and 2 m bands. The operating principle is often referred to in the literature as the *open sleeve* principle. The element positions are chosen so that the input impedance is 50 ohms not only in the 6 m band, but also in the other bands. Passive radiator No. 6 operates in the 4 m band and radiator No. 4 in the 2 m band. The antenna contains additional reflectors for both bands. These are element No. 2 for the 4 m band and No. 3 for the 2 m band. Element No. 7 works as a director in the 2 m band. Thus, in the 2 m band the antenna works as a 3-element and in the other bands as a 2-element.
The elements for the higher bands have no effect in 50 MHz band operation, while significant currents flow in the elements for the 6 m band when operating in the 70 MHz band. A large current is induced in the passive radiator for the 4 m band when operating in the 2 m band.



Arrangement and numbering of the 3-band antenna elements

The resonance frequency in the 2 m band is 144.3 MHz and lies in the CW/SSB sub-band, with the WFS rising sharply above 145 MHz. The resonance frequencies in the other bands are 50.15 and 70.2 MHz. The antenna's aluminium carrier is 1.25 m long and has a square cross-section of 20 x 20 x 2 (1.5) mm. The elements are made of 10 x 1 mm aluminium tubing. The designer advises against the use of elements with other diameters.

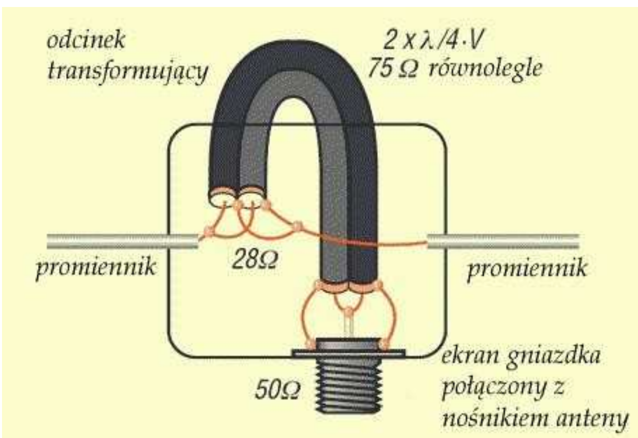
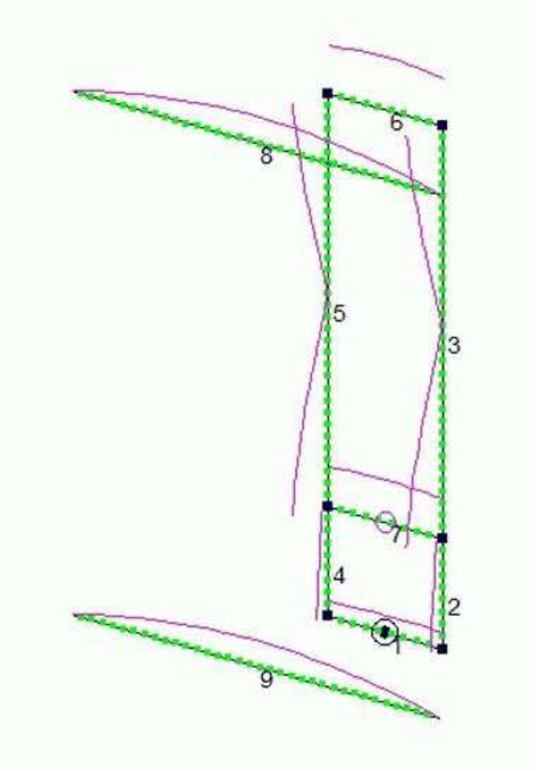


Fig.3.1.2. How to match a 28 Ω antenna to a 50 Ω feed line



Fig, 3.1.3. *Hentenna* design elements (green lines) and current distributions (purple lines)

The antenna is powered by a symmetrical choke (Photo 3.1.2). It consists of 11 coils of Aircell-5 coaxial cable wound on a 25 mm diameter PVC tube. The cable is approximately 1 m long. The coaxial socket is located in the bottom wall of the box and its screen is connected to the antenna carrier.

Photo 3.1.1. View of the DK7ZB three-band antennaFoto 3.1.2. Power supply of the three-band antenna

Tuning the antenna may in practice only require adjusting the radiator length for the 2 m band. The dimensions in Table 3.1.1 take into account the adjustments made by DK7ZB when tuning the antenna.

The two-element Yagi antenna for the 70 MHz band has a carrier length of 45 cm, an antenna gain of 4.4 dBd and a back loss of 15.5 dB. Its dimensions for the 70.2 MHz resonant frequency are given in the table
The matching of an antenna using the 28 ohm technique is shown in Fig. 3.1.2. The standing wave ratio (WFS) in the range 70.0 - 70.5 MHz does not exceed 1.2. Further matching variants for 28 ohm antennas are given in [3.1.5].

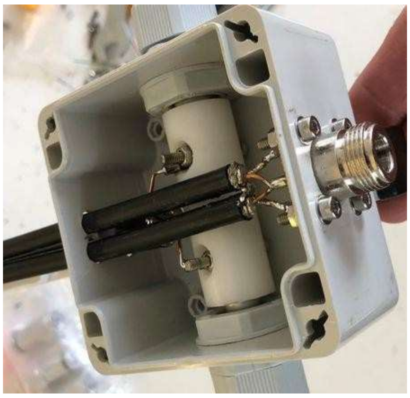



Photo 3.1.3. Two-element antenna made by DH0GSU Photo 3.1.4. Power supply for two-element antenna

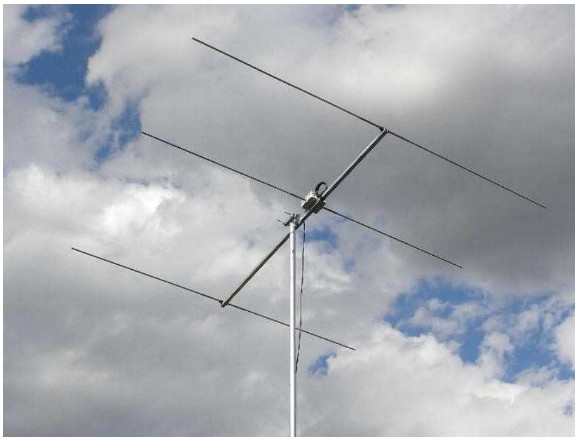
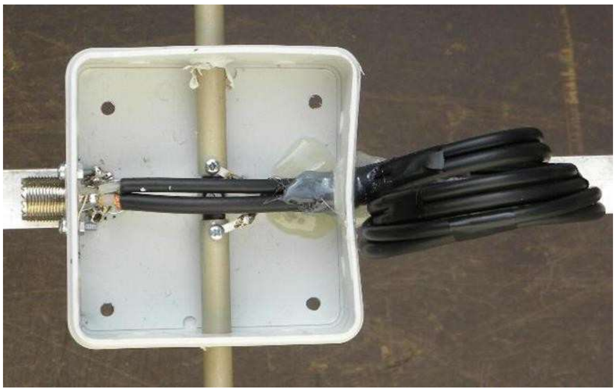



Photo 3.1.5: Three-element antenna Photo 3.1.6: Power supply for three-element antenna

The DK7ZB three-element antenna for the 70 MHz band has a carrier length of 1.55 m. It features a gain of 6.55 dBd and a back loss of 17.5 dB. The WFS in the 70.0 - 70.5 MHz band does not exceed 1.25. Unlike the two previous ones, it is made in 18 Ω technology and the method of matching is shown in Photo 3.1.6. Matching is achieved using two 50 and 75 Ω quarter-wave cable sections connected in parallel. In the picture, these are cable sections RG58 and RG59. The cable lengths are given in Table 3.1.5.
The three-element variant of the antenna made in 28 Ω technology has a gain of 5.7 dBd and a backscatter of 27 dB. The carrier length in this case is 1.35 m. The matching method is identical to that for a two-element antenna. The WFS in the band 70.0 - 71.0 lies below 1.5, and in the band up to 7.5 MHz - 1.2. The antenna dimensions for 70.2 MHz are given in Table 3.1.6.
The vertically positioned loop antenna known as *Hentenny,* supplemented with two reflectors, has a gain of approximately 7.05 dBd and a back attenuation of 12.5 dB in the 50 and 70 MHz bands. Due to feeding on two opposite sides of the loop, it radiates a horizontally polarised wave and the selection of the feeding point (element 7) on the vertical elements (distance from element 1) allows an input impedance of 50 Ω. The division of the antenna into structural elements and current distribution is presented in Fig. 3.1.3, and the antenna's appearance - in Fig. 3.1.7. The dimensions of the antenna made of 12 mm diameter tubes for 4 and 6 m bands are presented in Table 3.1.7. In the 70.0 - 70.5 MHz band, the WFS lies below 1.2.

Photo 3.1.7. Vertical loop - *Hentenna*

Table 3.1.1
Dimensions of 3-band antenna

Element	Function	Length [mm]	Position [mm]
1	Reflector 6 m	2914	0
2	Reflector 4 m	2080	300
3	Reflector 2 m	1044	600
4	Passive radiant heater 2 m	981	1000
5	Powered radiant heater 6 m	2764	1065
6	Passive radiant heater 4 m	2006	1148
7	Direktor 2 m	966	1200

Table 3.1.2
Main parameters of the 3-band antenna

Bandwidth [m]	Antenna gain [dBd].	Back attenuation [dB]	Bandwidth for WFS 1.5 [MHz].
6	4,49	8,6	1,75
4	4,29	10,8	1
2	5,43	10,6	> 2

Table 3.1.3
Dimensions of two-element 28 Ω antenna for 70.2 MHz

Element	Position [mm]	Length for 10 mm diameter [mm]	Length for 12 mm diameter [mm]*
Radiator	0	2092	2088
Direktor	430	1938	1928

Table 3.1.4
Dimensions of three-element 18 Ω antenna for 70.2 MHz

Element	Position [mm]	Length for 10 mm diameter [mm]	Length for diameter 11.5 + 8 mm [mm].
Spotlight	0	2142	2164
Radiator	600	2028	2065
Direktor	1535	1874	1907

Attention:
* the elements are composed of two tubes of the given diameters inserted into each other

Table 3.1.5
Matching cable lengths

Cable length (screen) [mm]	Cable type	Shortening ratio
715	RG58 + RG59	0,66
875	Aircell5 + cable TV cable	0,82

Table 3.1.6
Dimensions of three-element 28 Ω antenna for 70.2 MHz

Element	Position [mm]	Length for 10 mm diameter [mm]	Length for 12 mm diameter [mm]
Spotlight	0	2154	2150
Radiator	660	2026	2020
Direktor	1320	1890	1880

Table 3.1.7
Dimensions of *Hentenna* elements for 12 mm diameter

Segments (numbered according to Fig. 3.1.3)	Length for 70 MHz band [mm]	Length for 50 MHz band [mm]
1, 6, 7 (horizontal) - 0.15 λ	645	900
3, 5 (vertical) - 0.5 λ	1679	2443
2, 4 (vertical) - 0.1 λ	448	625
8, 9 (headlights) - 0.62 λ	2072	2900
Reflector-loop distance - 0.16 λ	680	975

Literature and Internet addresses

[3.1.1] http://dk7zb.darc.de/4m/2-El-4m-Yagi.htm
[3.1.2] http://dk7zb.darc.de/4m/3-El-4m-Yagi.htm
[3.1.3] https://www.qsl.net/dk7zb/Duoband/Triband-Yagi.htm
[3.1.4] https://www.qsl.net/dk7zb/Quadlong/Hentenna.htm
[3.1.5] "Biblioteka polskiego krótkofalowca" vol. 50, "Anteny ultrakrakrótko-wafalowe 1"

4. Antennas for 2 m and 70 cm bands

4.1. Yagi antenna for communications EME

The antenna described in issue 1/2023 of *Funkamateura* is designed for EME communications in the 70 cm band with the Q65 emission of the WSJT-X family. The designer used it in the field so that it was possible to shorten the feed line to 3 m and thus significantly reduce the attenuation contributed by it. The supplied power of 25 - 50 W enabled the designer to conduct communication by reflection from the moon with Q65-B emission. A power input of 100 W is possible. The antenna gain is approximately 18.4 dBi, or 16.3 dBd. With an input power of 50 W, the EIRP is approximately 3.3 kW.
Stations with more modest equipment should first try to pick up stronger correspondents and optimise their antenna position for maximum signal reception and only then start communicating.
The GTV 70-23m antenna is a 23-element Yagi antenna with a length of 5.3m. The radiator is made of two 2 mm thick aluminium flat bars bent backwards (Fig. 4.1.1). The strongest currents flow in directors D1 and D2 (Fig. 4.1.3). A characteristic feature of the design is the minimisation of the side and rear lobes.
In the case of a straight radiator, the input impedance of the antenna would be 17 Ω, but by tilting its halves back, an impedance of 50 Ω is achieved without additional losses or other adverse effects.

Table 4.1.1 Dimensions and positions of GTV 70-23m antenna elements

Element	d [mm]	l [mm]	Position on the carrier [mm]
Spotlight	2,2	339,5	40,0
Radiant (DE)	*	313,5	144,5
D1	2,2	323,5	193,0
D2	2,2	320,0	286,0
D3	2,2	310,8	468,0
D4	2,2	306,0	681,0
D5	2,2	303,9	928,0
D6	2,2	300,7	1192,0
D7	2,2	297,3	1465,0
D8	2,2	296,5	1747,0
D9	2,2	294,4	2032,0
D10	2,2	291,8	2310,5
D11	2,2	291,0	2585,0
D12	2,2	289,5	2858,0
D13	2,2	289,0	3138,0
D14	2,2	285,5	3406,0
D15	2,2	284,5	3674,0
D16	2,2	281,9	3937,0
D17	2,2	280,0	4199,0
D18	2,2	279,3	4475,0
D19	2,2	275,5	4765,0
D20	2,2	272,5	5038,0
D21	2,2	264,5	5280,0

To construct the antenna, three 3 m long wooden roof strips, at least 12 wire clothes hangers (from the laundry etc.), 3 m of 50 Ω coaxial cable and 0.4 m of 20 x 2 mm aluminium strip are required. As derived from the table, the lengths of the elements and their locations must be measured to the nearest 0.1 mm.

The antenna carrier consists of two strips overlapping each other over a length of 65 cm and fastened together with four screws. The way of fixing the antenna elements using wooden blocks cut from the third slat is shown in Photo 4.1.2. The elements are located 4.5 cm above the carrier. They are glued with hot glue in the holes drilled in the blocks.
The vertical and horizontal main beam widths are approximately 15°. Guiding the antenna to the moon is therefore only necessary every 15 minutes or so.

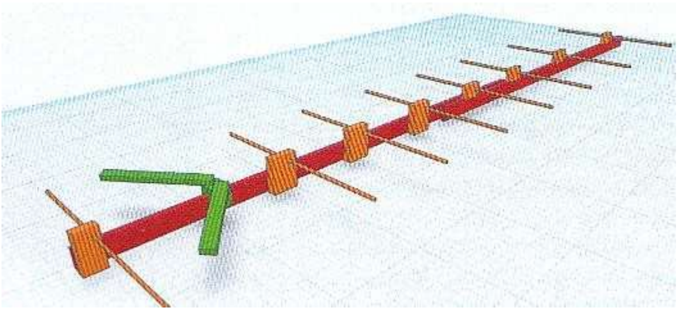


Figure 4.1.1: Computer model of GTV 70-23m antenna

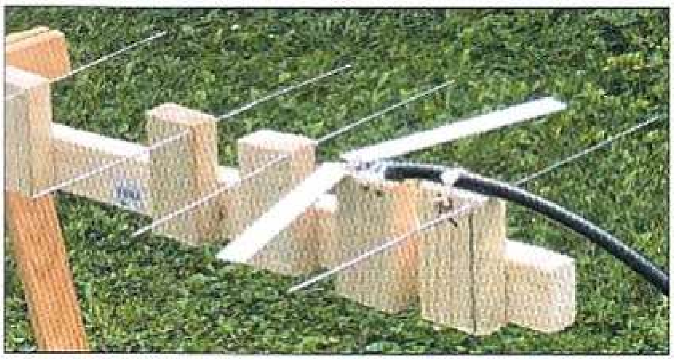


Fig. 4.1.2. Method of mounting elements on the carrier

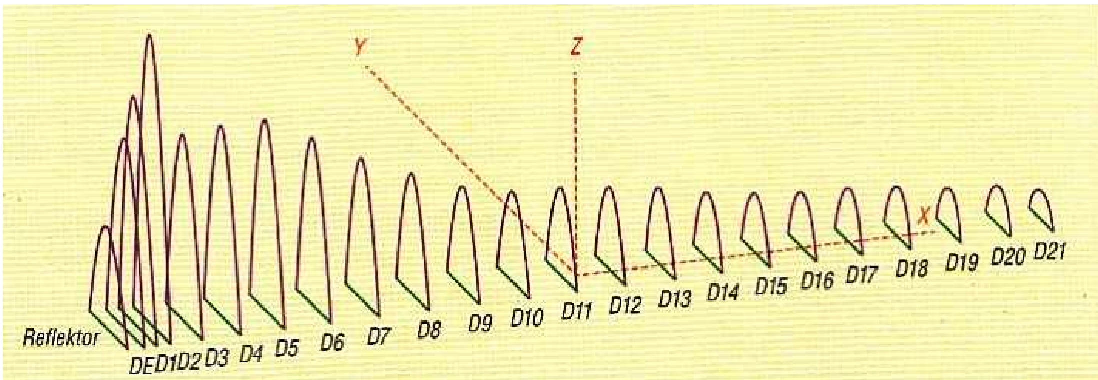


Fig. 4.1.3 Current distribution in the antenna elements

Fig. 4.1.4. Finished antenna and direction setting method

[4.1.1] "Mit selbst gebauter Yagi-Antenne auf 432 MHz zum Mond und zurück", Daniel Eberli - HB9EHD, Daniel Gautschi - HB9CRQ, Dipl. Ing. Hartmut Klüver - DG7YBN, *Funkamateur* 1/2023 p. 50.

4.2. J antenna from flat cable

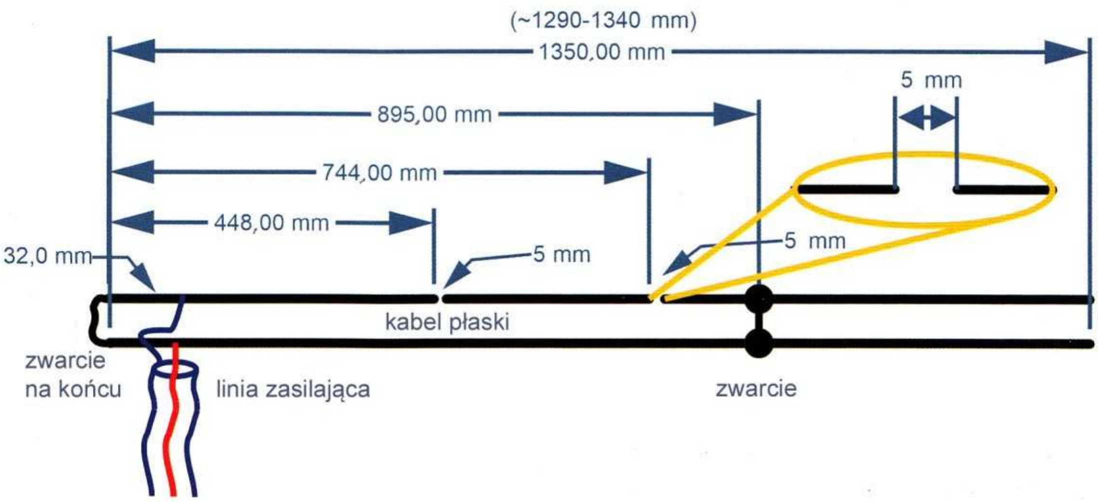


Fig. 4.2.1. Dimensions and antenna design

A structurally simple and lightweight antenna for use in the field and beyond can be made from 240 ohm flat TV cable, formerly commonly used in antenna installations, or from 450 ohm flat ladder cable. The dimensions shown in the illustration are for the version made from TV cable, but their conversion is not difficult and only requires the shortening factor to be taken into account. For 240 - 300 ohm TV cable it is about 0.8 - 0.82, for 300 ohm CQ562 it is 0.9 for 450 ohm CQ553 it is 0.85, and for 450 ohm ladder cable commonly available in ham radio shops it is 0.9. The dimensions shown in Fig. 4.2.1 change to about 34, 483, 801, 964 and 1473 mm respectively. The antenna is fed with coaxial cable (for short distances of up to a few metres it can even be RG-58) and its place of connection should be selected to obtain the lowest possible WFS, but it is sufficient for it to lie below 1.4 - 1.5. Further optimisation does not give any significant benefit and is only an unnecessary complication.

Insulate a section of approximately 1 - 1.5 cm at the cable connection point and select the soldering point of the power cable on this. The same applies to the position of the jumper.
To start with, you should also cut a cable of a longer length and choose it experimentally. Gaps in the second cable core are approximately 5 mm in length, but this is not critical. The feed cable should be fixed to the end of the antenna so that its weight does not weigh down the soldering points and cause them to break. Isolated areas should be protected against external influences, e.g. with instant glue, and heat shrink sleeves can be fitted at the ends of breaks. For field work, it is convenient to fix a loop at the top of the antenna for hanging it.
The solutions of J-type antennas for different wavebands are presented in volumes 32, 35 and 49 of the "Biblioteka polskie- go krótkofalowca".

Photo 4.2.2. Example of making the lower end

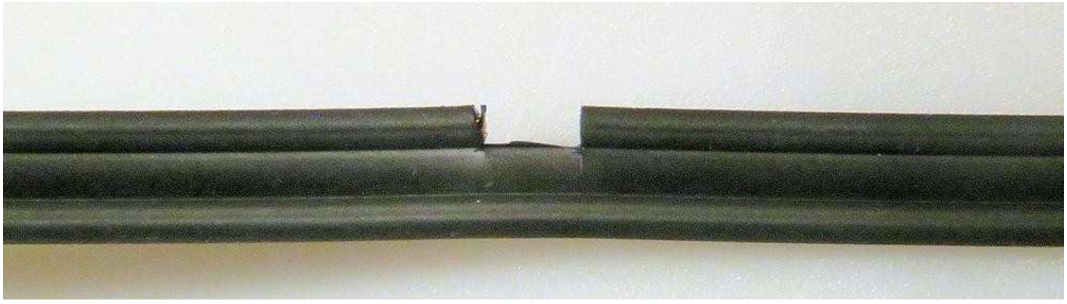


Photo 4.2.3. Example of making a break

Photo 4.2.4. Short circuit location

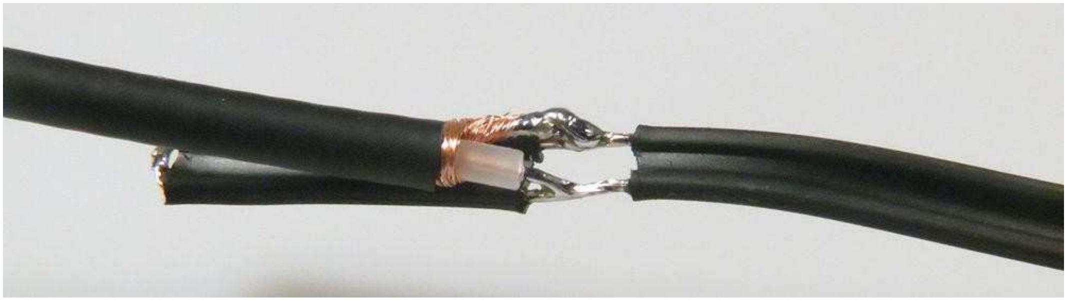


Photo 4.2.5. Connection of power supply cable

Photo 4.2.6. Loop at the top of the antenna for hanging the antenna

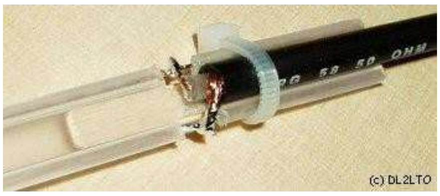


Fig. 4.2.7. Possible way of securing the gap with a heat-shrinkable jacket Fig. 4.2.8. Possible way of securing the cable at the end of the antenna.

[4.2.1] 'Slim Jim Antenne', QSP 2/2024 p24.
[4.2.2] http://oe1iah.at/Hardware/Antennen/SlimJim2-70.shtm

4.3. Triangular loop antenna for 2 m band

Located in the horizontal plane, the triangular loop has omnidirectional characteristics and is simple and cheap to implement.

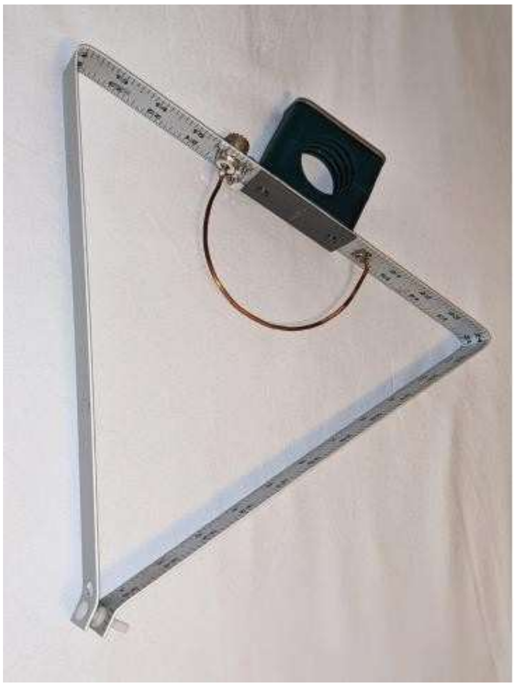


Photo 4.3.1. Triangular 2 m loop antenna with feed loop Fig. 4.3.2. Antenna dimensions

Stations operating SSB in the 2m band generally use horizontal polarisation, but some operators (often out of necessity) use vertical antennas. A small and inexpensive loop antenna helps to ensure wave polarisation compatibility and facilitates non-distant communications. Some of the do-

The solutions of the time were either difficult to build or difficult to mount on the mast. The K9BCT used a gamma-type matching circuit, but it was found that loop feeds gave better results.
An aluminium flat bar, 92 cm long and approximately 3 cm wide, was used to construct the loop. The dimensions of the antenna are shown in Figure 4.3.2. It has the shape of an isosceles triangle with arms of 29.2 cm. On the base of the triangle there is a mounting bracket and a UHF antenna socket (UC- 1). The feed loop is made of 4 mm2 copper wire with a length of 20 cm. A loop is made at its end (the wire must therefore be 2 - 3 cm longer), which is screwed to the flat bar using a metal screw with a spring washer. For good con- tact, the surface of the flat iron should be scratched. The coaxial socket and the end of the loop are located at one third of the length of the base of the triangle from its angles.
The ends of the sides of the triangle are bent over 12 mm and screwed together using an M3 plastic bolt and three nuts. The first nut and the head of the bolt press on the end of one of the arms, and the other two press on the end of the other arm. Tuning to the operating frequency is achieved by matching the distance of these ends. The tuning range of the antenna is approximately 139 - 148 MHz. The operating range width for a WFS of 2.15 is approximately equal to 2.16 MHz, thus covering the entire Euro-European 2 m band. The standing wave ratio at resonance was close to unity. As the last element, a bracket is fitted to attach the antenna to the mast.
The input impedance measured by the constructor was 49.4 - j1.43 Ω, so it was almost equal to 50 Ω. Although the antenna gain was not measured by the constructor, it appeared from simulation with 4nec2 to be slightly higher than the dipole gain. To increase the directional gain, the loops can be stacked at a vertical distance of 5/8 wave. A splitter cable is then used to feed them, with both sections from the splitter to the antennas being 5/4 wavelengths (or more generally an odd number of wavelength quarters). When calculating their lengths, the cable shortening factor must be taken into account. A VNA antenna analyser is helpful in tuning a single antenna or a pair of antennas.

Photo 4.3.3. Antenna mounted on mast

[4.3.1] 'Horizontally Polarised Two-Meter Trangle Loop Antenna', Richard Quick, W4RQ, QEX 1-2/2023 p3.

4.4. Broadband antenna UKF

The antenna allows reception of various services, broadcasting, television and ham radio in the wide band 88 - 608 MHz. The 2 m, 1.25 m (not available in Europe) and 70 cm amateur bands are covered for reception and transmission. The individual services use either horizontal, vertical or diagonal polarisation. Therefore, it is important to be able to change the polarisation easily (Photo 4.4.1). Its small dimensions also allow it to be used in the field.

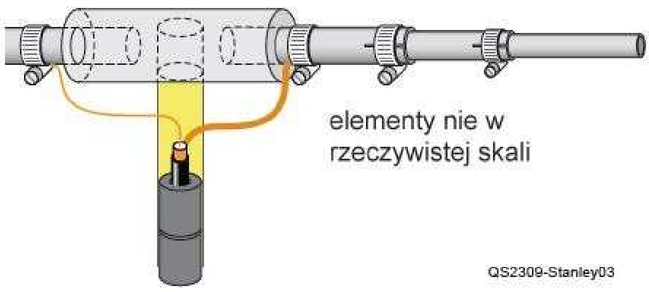


Photo 4.4.1. View of antenna in vertical polarisation
Fig. 4.4.3 Construction details. Central insulator made of HDPE

The antenna operates in the 88 - 235 MHz range as a half-wave, and in the 235 - 608 MHz range as a 3/2-wave. The radiation characteristics are shown in Fig. 4.4.2. With vertical polarisation, the directional characteristic is omnidirectional.
To reduce losses, the plastic parts of the radiator insulator and antenna holder are made of high-density polyethylene (HDPE) instead of PVC. The radiator is made of telescopically inserted aluminium tubes: two 6/8-inch x 24 cm, two half-inch x 25.5 cm and two 3/8-inch x 48.3 cm. The diameters shown are the outside diameters. The wall thickness should allow the smaller diameters to slide inside the larger ones. The ends of the tubes are notched so that they can be clamped onto the inner tubes using clamps (fig. 4.4.3).
The symmetrical choke consists of three ring cores of material 43 applied to the antenna cable. The designer used RG-8 cable with foam insulation. Alternatively, two coils of cable can be fed through cores of the appropriate size. The cable should be fed at right angles to the dipole for a length of 15 cm (not critical), and can then be bent according to the shape of the holder.
The half-wave dipole in free space has an input impedance of 72 Ω, which means for a 50 Ω system a standing wave ratio (WFS) value of 1.44. The capacitance between the halves of the dipole was balanced by connecting the feed points at a certain distance from the centre (the length of the centre wire in Photo 4.4.4 is about 8 cm. By adjusting their position, a WFS of
1. the design was optimised for the 2 m band, but the WFS in the 70 cm band is also

very good (Fig. 4.4.5). Tuning by inserting or extending the tubes and optimising the WFS by selecting the feed points should only be carried out after placing the symmetry- attenuating surface wave choke. To select the length in metres, use the formula 143 / f [MHz] for a half-wave dipole and three times the half-wave dipole for decimeter waves. It is possible to select lengths for the single frequency most important to the user, or mark with tape on the tubes their position for several selected ones. The polarisation of the dipole can be easily rotated to match the polarisation used in the operating bands.

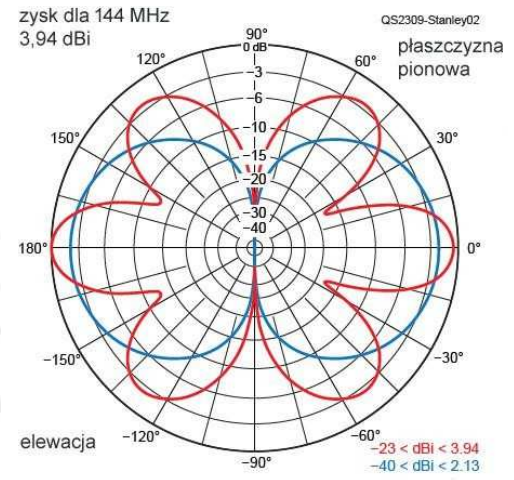


Figure 4.4.2: Radiation characteristics, blue line for metre waves, red line for decimetre waves
Fig. 4.4.3. Detail of assembly and connection of the dipole

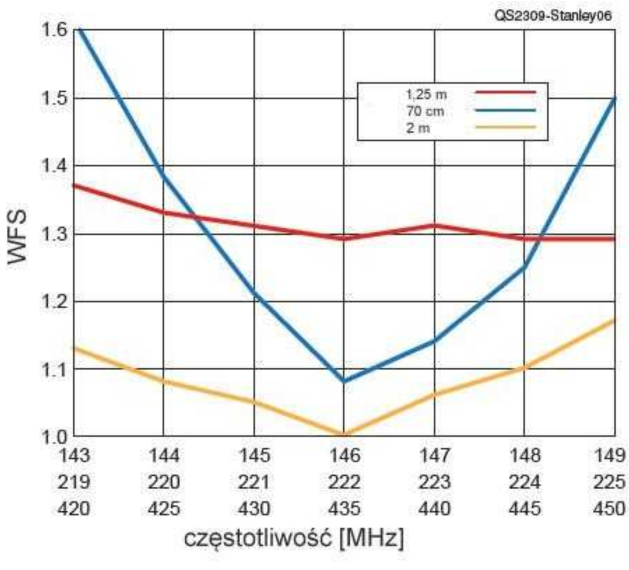


Figure 4.4.5: WFS waveforms in the amateur bands

[4.4.1] "A Utility Antenna for 88 to 608 MHz", John Stanley, K4ERO, QST 9/2023, p 36

5. Antennas for band 23 and 13 cm

5.1. Disc antenna for 13 band cm

Disc antennas are characterised by simplicity of design, considerable directivity and moderate bandwidth. They are mainly used in the 1 - 4 GHz range. In the solution presented here, it is fed by a 2-element planar antenna and contains additionally 5 directors constituting a cy- lindrical waveguide zone narrowing the radiation pattern compared to the planar antenna leaf. An additional advantage is that it does not require a symmetrizer. The relative matching bandwidth for a WFS not exceeding 2 is 5 - 7%. This is limited by the properties of the planar section as the waveguide section operates over a wide frequency range. The dimensions of the antenna depend on the operating frequency and the directional gain.

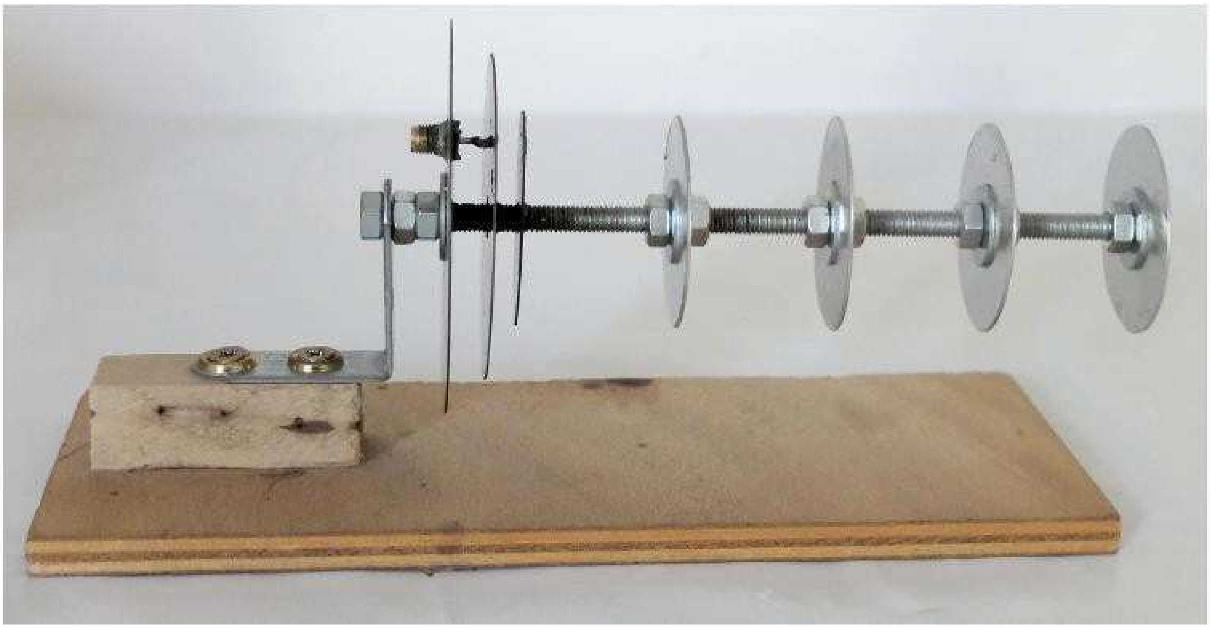


Photo 5.1.1. Disc antenna at 2.45 GHz

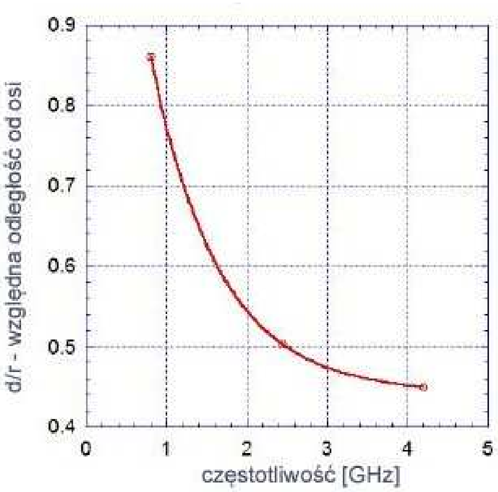


Figure 5.1.2: Relative distance of the power point from the centre of the disk for an input impedance of 50 Ω and h/r = 0,21

The carrier of the antenna described for 2450 MHz is a threaded rod, and the discs are fixed in position using nuts (Photo 5.1.1).

The design assumes a reflactor diameter of 2r equal to the wavelength and a ratio of the distance between the radiator and reflector h equal to 0.21 r. The relative distance of the feed point from the centre of the radiator in relation to the radius r is plotted in Figure 5.1.2. The red square indicates the frequency of 2.45 GHz and the corresponding d/r ratio.
The distance of the disks for the waveguide zone was assumed to be 0.25 λo (a wavelength in air of 122.45 mm).
The dimensions of the antenna obtained by simulation in the HFSS programme are given in Table 5.1.1. The disks are made of steel for reasons of mechanical stability, but they can also be made of bronze.

Table 5.1.1
Antenna data for 2.45 GHz (λo = 122.45 mm)

Parameter	Value	Parameter	Value
Overall length	137.0 mm	Carrier diameter	5.9 mm
Disc thickness	0.5 mm, is not critical	Reflector diameter	122.4 mm
Radiator diameter	66.05 mm	Reflector-radiator spacing	6.93 mm
Distance of the central SMA contact from the axis	14.97 mm	Distance 1 director from radiator	7.65 mm
Director diameters	47.7 mm	Distance between the directors	30.6 mm
Beam width (-3 dB)	44°	Directional gain	12 ± 0.5 dBi
Bandwidth (WFS < 5	5%	Waveguide zone length	1 λo

[5.1.1] 'Build Your Own 'Gun' (Disk Yagi) Antenna', by Jean Claud Hénaud, Franck Daout, QEX 5 - 6/2022 p14.

Appendix A
KF antenna - 6 m type MFJ-1898

The MFJ-1898 is a multi-band antenna covering the 40 - 6m range and designed for field operation. Like any antenna of a smaller size, it is a compromise between age and efficiency, but features a rugged design and an affordable price. It consists of an extension coil placed at the bottom and a 2.21m long stainless steel telescopic element. When fully folded, the antenna is 55 cm long and easily transportable, and 262 cm when fully extended. The bottom is terminated with a 3/8 inch diameter screw (Photo A.1) to fit many types of bases, tripods etc. Good results are obtained by adding several (for example, five) three-metre counterweights placed on the ground.

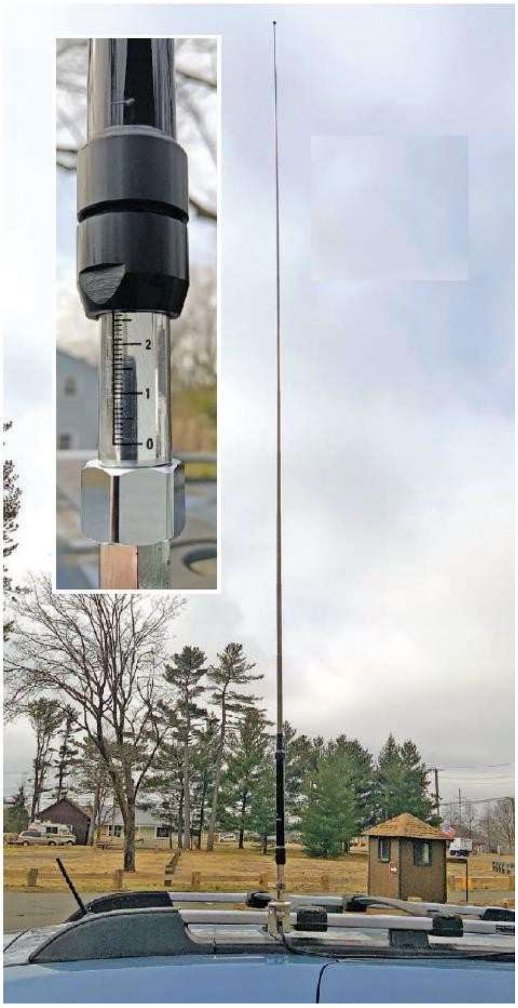


Photo A.1. MFJ-1898 is 55 cm long when the components are fully inserted (left)
Photo A.2. Field work with the antenna fixed on the roof of the car. Inside the scale for easy tuning

It is equipped with an elaborate tuning mechanism that allows you to move from one coil winding to the next. Loosen the mounting ring at the bottom of the antenna and move the whole thing up or down until the lowest WFS is achieved. To make tuning easier, the mechanism is equipped with a scale so the user can note the optimum positions for particular bands (Photo A.2). The results of the measurements are presented in Table A.1. The most favourable position fell in the lower part of the coil. In the 10 and 6 m bands, after moving to the lower position, it was necessary to shorten the telescopic part by 15 - 25 cm.

The matching range for WFS < 2 is 50 kHz wide in the 40 m band and expands for higher frequencies. For radios equipped with an automatic antenna box, obtaining a good match is not a major problem. This is particularly true for the 40 and 30 m bands.
The maximum permissible applied power is 125 W which is hardly a limitation for 100 W transmitters when operating with SSB emissions. For fixed envelope digital emissions such as FT8, however, it is recommended to lower the transmitted power.
The antenna performed well in field work with SSB and FT8 emissions in the 20m band under unfavourable propagation conditions. The results in the 40 m band were slightly worse, but this was to be expected due to its short length.
Small-sized antennas are always a compromise between their size and effectiveness, but the MFJ-1898 proved to be a successful compromise. An additional advantage is its ruggedised design.

Table A.1
MFJ-1898 antenna tuning (WB8IMY measurements, not verified in ARRL laboratory)

Frequency [MHz]	WFS	Pitch
7,18	2	12,9
10,1	1,8	6,7
14,1	1,2	3,3
18,1	1,4	2,7
21,1	1,4	1,9
24,9	1,4	1,2
28,4	1,5	0 (shortened telescopic section)
50,125	1,3	0 (shortened telescopic section)

[A.1] 'MFJ-1898 Portable HF 6-Meter Antenna', Steve Ford, WB8IMY, QST 8/2023 p45.

Literature and addresses

Yearbooks 2019 - 2024 of World Radio, Funkamateura, CQDL, QST, QEX and
QSP Websites listed at the end of the chapters

In the series "Biblioteka polskiego krótkofalowca" (Library of the Polish Shortwave Worker), the following have been published so far:

No. 1 - "D-STAR Handbook", editions 1 (2011), 2 (2015), 3 (2019) and 4 (2021)
No. 2 - "D-RATS Programme Manual" No.
3 - "Weak Signal Technique" Volume 1 No.
4 - "Weak Signal Technique" Volume 2
No. 5 - "Digital communications on shortwave"
Volume 1 No. 6 - "Digital communications on
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No 8 - "APRS and D-PRS".
No. 9 - "Electronic mail on short wave" Volume 1, Issue 1 (2012)
No. 10 - "Electronic mail on short waves" Volume 2, Issue 1 (2012) No. 11
- "German-Polish and English-Polish Dictionary" Volume 1
No. 12 - "Radio stations and receivers with digital signal processing"
Volume 1 No. 13 - "Radio stations and receivers with digital signal
processing" Volume 2 No. 14 - "Amateur radio astronomy".
No. 15 - "Data transmission in the D-STAR system".
No. 16 - "Amateur radiometeorology", 1st edition (2013) and 2nd
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No. 18 - "Long wave communications"
No. 19 - "Echolink handbook"
No. 20 - "Arduino in shortwave radio"
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No. 23 - "Weak signal technology" Volume 3, editions 1 (2014), 2 (2016) and 3
(2017) No. 24 - "Raspberry Pi in ham radio".
No. 25 - "The most popular microwave bands", issues 1 (2015) and 2 (2019)
No. 26 - "DMR Handbook" editions 1 (2015), 2 (2016) and 3 (2019), No. 326 - abridged edition (2016)
No. 27 - "Hamnet Handbook" Issue 1 (2015) and Issue 2
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No 36 - "Digital Signal Processing" No
37 - "Amateur Television".
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No 42 - "Miernictwo" Volume 1
No 43 - "Miernictwo" Volume 2
No 44 - 'Metering' Volume 3
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No. 50 - "Ultra-low frequency antennas" Volume 1, Issue 1 (2020) and 2 (2022)

No. 51 - "Short wave antennas" Volume 2, Issue 1 (2020) and 2 (2023)
No. 52 - "Ultra-wideband antennas" Volume 2, Issue 1 (2020) and 2
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