4 Element Vertical Dipole Array

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NOTE:

This description is for private use only. All commercial use is prohibited. The officially valid version is only available for download on the Lagunaria DX Group website. It is intended to serve as a basis for further antenna developments. A feedback to the author is welcome.

This description has been prepared and verified to the best of our knowledge. Nevertheless, it cannot be ruled out that one or the other error has crept in. If this is the case, we would be glad about your feedback.

This description does not release the reader from using his own brain.

Christian Janssen - DL1MGB

As the initiator and leader of the DXpeditions of the Lagunaria DX Group, Chris (born in 1976) tried to deliver the best possible signal from the distant DX. This included proper antennas. After Joerg gave the idea of a 4-element vertical dipole array, Chris as a skilled metalworker took care of the implementation in working hardware.

Joerg Puchstein - DL8WPX

Jörg (born in 1960) was either an organizer or participant of DXpeditions such as VK9LM (1991, 1996 and 2014), S21XX, P29VXX, VK9CR, VK9XY, ZL7DK, VK9DNX, VK9DWX, VK9DLX and many others. He knew what mattered on radio trips around the globe. In addition to many other aspects of a DXpedition, it was above all his knowledge of antenna technology that formed the Lagunaria DX Group. When he remembered the times at the Y41ZM club station, he dug out the idea of a 4-element vertical dipole array. The ***W***illis ***I***sland ***L***ightweight ***M***onoband ***A***ntenna (WILMA) was born.

In December 2014, only a month after our DXpedition to Lord Howe Island, Joerg suddenly died much too early.

Lagunaria DX Group

It all started in 2007 when eight contesters (DJ7EO, DJ9RR, DL1MGB, DL3DXX, DL5LYM, DL6FBL, DL8OH and DL8WPX) decided to leave Germany for three weeks to do a joint DXpedition from Norfolk Island. This was followed by VK9DWX (2008), ZL8X (2010) and VK9DLX (2014). Since then, the core team has been traveling together with other fellow travelers as Lagunaria DX Group.

More information about the Lagunaria DX Group, its DXpeditions and projects can be found at

http://lagunaria-dx-group.org

Thanks to DJ2YA and DK4YJ for proofreading.

For Joe.

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Introduction

To find out who the real inventor of this form of antenna is, it would need a historian to work on this issue. Since we are not here in a history lesson, but in a lesson for practical antenna construction, we can deal very quickly with the topic. There have already been many interesting articles in magazines and books, which contributed to the development, or the better understanding of the 4-Element Vertical Dipole Array (VDA). We would like to refer to the publications of the following authors without claiming to be complete and without chronological sorting: G6XN [18], K1WA [22], K8UR [17], G3PJT [35], KB8I / K3LR / WA3FET [5], N6LF [25] / [26] and OE5CWL [32].

In 1988, it was the article of K1WA that served the club station Y41ZM [23] in Schkeuditz near Leipzig as a base to erect a passable DX antenna for 40m at the new QTH. It was a full-size 5-Element sloper array (Fig. 1). Unfortunately, this location had to be abandoned almost three years later after the German reunification.

Fig. 1 40m VDA at Y41ZM (Photo: DL3XM)

In the mid-nineties, a group around K2KW and N6BT dared to go to Jamaica several times to participate in the CQ WW CW Contest ([27] and [29]) - only with vertical antennas. The results were numerous victories both as multi-multi-team and single-band participations in the QRP categories. They used primarily vertical dipoles, assembled in arrays and set up in close proximity to the beach. The proverbial salt in the soup was the proximity to the sea, the salt water that guaranteed an optimal radiation. Furthermore, these antennas were used at the DXpedition on Kingman Reef in 2000 ([11] and [28]).

In the spring of 2008, the VDA gained an increasing public attention when 13 operators on Ducie Island (VP6DX) set a new QSO world record for DXpeditions. The 2-element VDA developed by Uli, DJ2YA, consisted of a radiator and a reflector. On the bands from 10m to 20m, the antennas placed at the beach produced loud signals all over the world.

Fig. 2 Some VDAs at TX5K (Photo: Lagunaria DX Group)

At the end of the DXpedition to Norfolk Island (VK9DNX in February 2007), we decided that the next target should be Willis Island. Joe (DL8WPX), who had already designed the 5-Element sloper system for 40m at Y41ZM, adapted the antenna type for our needs. With Europe and the USA as the main directions about 90° apart from Willis Island, you need four directions including the opposite directions. We just added a direction switch to the antenna. Done. Based on our simulations and after the reports of Team Vertical and the success of VP6DX, we were very confident that we had the right antenna selection for VK9DWX.

While we had only VDAs for the high bands at VK9DWX, we added horizontally polarized monoband Yagis at ZL8X. The location on Raoul Island forced us to rethink the antenna concept. We were confronted with a 40m high cliff, which is not as easy to model in the simulations as the sea, in the immediate vicinity of the antennas of VK9DWX. From numerous considerations and calculations, we concluded that a combination of both horizontally and vertically polarized antennas seemed reasonable. The direct comparison of the two antenna forms revealed interesting results.

This description is not a plain instruction for simply copying a VDA. It rather provides the basics of this antenna form and presents the results of numerous simulations and experiments. The way we built the antennas was mostly due to the availability of some parts. A general insight into what the components are all about should allow a design with other materials. We also explain in detail how the VDA has been developed and operated so far. Throughout the document, we have incorporated the experiences with the VDAs that we have made on DXpeditions such as VK9DWX, ZL8X, TX5K or VK9DLX.

Fig. 3 VDA lineup at the beach of Clipperton Island (Photo: Lagunaria DX Group)

Theory

General Aspects

The theory has already been extensively described (see also references in the introduction). The functionality of the 4-element VDA described here can be summarized as follows: Four dipoles arranged at a right angle vertically on a mast are each connected to the switch box via a coax cable. The shields of the coax cables are isolated from each other. In operation, one element is fed directly. The coaxial cables of the three other elements remain open. These open coaxial cables each act as a stub, which electrically lengthens the respective dipole. Thus, the three unsupported dipoles act together as a reflector.

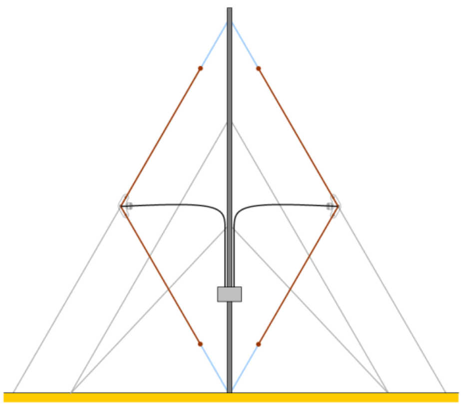


Fig. 4 Side view of a VDA

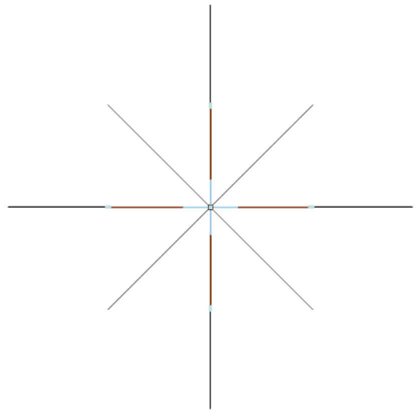


Fig. 5 Top view of a VDA

Geometry

When choosing the element spacing, you can orient yourself from traditional Yagi designs. According to [24], the optimal distance for a 2-element system is between 0.2 and 0.25 λ. If several dipoles are attached to a mast, the distance between them decreases. For a 4-element VDA, the direct distance between two feeding points is only about 0.18 λ.

This element distance therefore determines how far the feeding points are located from the central mast. The angle of guying is then determined by the mast height. An angle of 60° has proven to be reasonable in practice and enabled a safe guying of the antenna.

Since the coaxial cable electrically lengthens the dipoles of the non-fed elements as a stub, their inductive load determines antenna characteristics such as gain and F/B ratio. According to [32] we have determined an optimal value of 130 Ω for our purposes. The length of the feed line using the example of the 20m band (= 14 MHz) is calculated according to [16] (Chapter Verlustfreie Leitungen) as follows:

$$l_1 = \left(\frac{\lambda}{2\pi}\right) \arctan\left(\frac{X}{Z_L}\right)$$

$$\lambda = \frac{c}{f} = \frac{3 * 10^8\, m/s}{1.4 * 10^7\, 1/s} = 21.41375\, m$$

$$Z_L = 50\, \Omega$$

$$l_1 = \left(\frac{21.41375}{2\pi}\right) \arctan\left(\frac{130}{50}\right) m = 4.10207\, m$$

When using H155 (v_f = 0.79) as a feed line, the length is $l_{short} = l_1 * v_f = 4.10207 * 0.79 = 3.24\,m.$ This value applies to a short-circuited line. Due to the short cable length, the switch box would not be accessible from the ground. It can be lengthened by λ/4 to get the same behavior. However, it must be left open. The length of the open feed line is

$$l_{open} = \left(4.10207 + \frac{21.41375}{4}\right) * 0.79 = 7.47\,m$$

Dipole – Straight vs. Folded

The original form of the sloping dipole represents a dipole sloping from top to bottom that is attached to a mast. Considerations, calculations and experiments have shown that folding back the lower half of the dipole towards the mast results in an improvement in the radiation properties for DX connections.

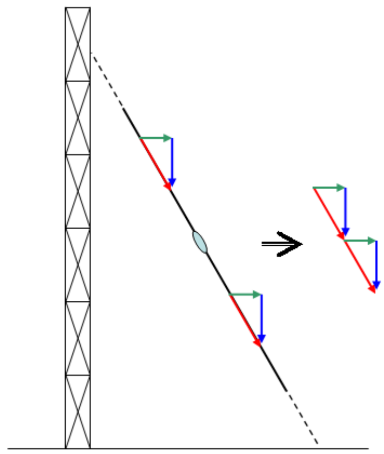


Fig. 6 Straight dipole

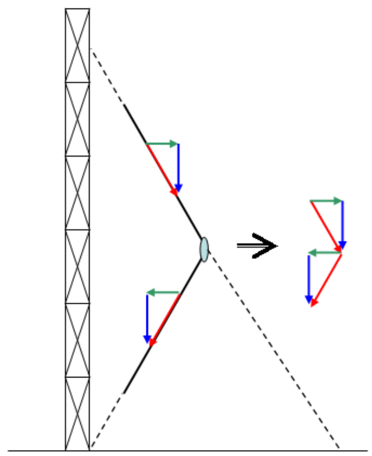


Fig. 7 Folded dipole

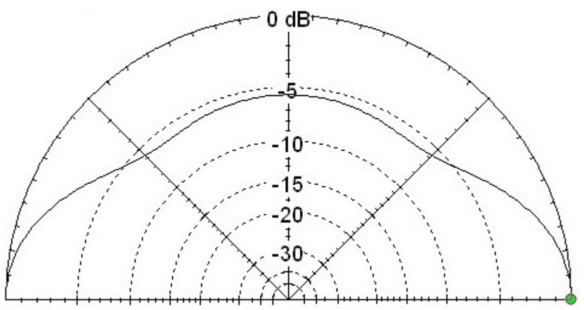


Fig. 8 Elevation radiation pattern straight dipole

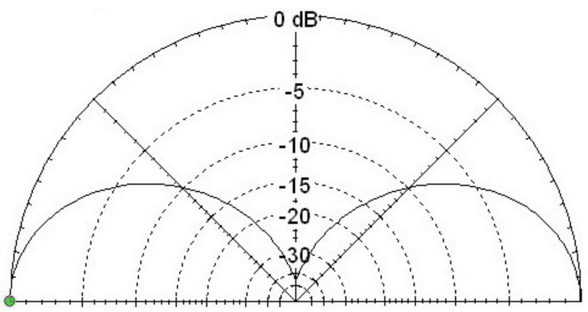


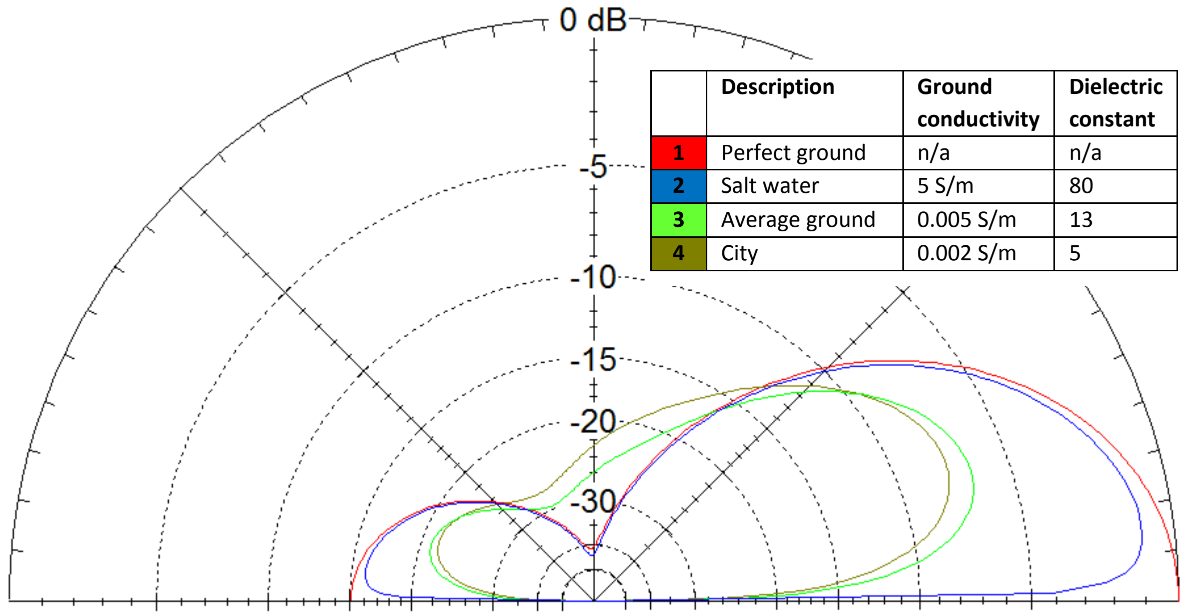
Fig. 9 Elevation radiation pattern folded dipole

The two red vectors represent the current flowing in the dipoles. These vectors can be split into a horizontal and a vertical component. The addition of the currents of the two dipole legs results in a vector consisting of a horizontal and vertical component. The radiation diagram clearly shows quite a portion of high-angle radiation caused by the horizontal component.

When the lower half of the dipole is folded back towards the mast, the currents of the two dipole legs are also added. However, in the vector addition, the two horizontal components (green) cancel each other. Only the vertical component remains. The radiation diagram has no high-angle radiation. In both cases, the mast was assumed as nonconductive.

Ground conductivity

Nothing affects the radiation characteristics of a vertically polarized antenna as much as the quality of the ground around the antenna. This is best seen in the corresponding radiation diagrams. The elevation diagram in Fig. 10 clearly shows the comparison on different soils. To find out more about the ground characteristics, we recommend the online article of DL1GLH [13].



	Description	Ground conductivity	Dielectric constant
1	Perfect ground	n/a	n/a
2	Salt water	5 S/m	80
3	Average ground	0.005 S/m	13
4	City	0.002 S/m	5

Fig. 10 Elevation radiation diagram of a VDA over differently conductive ground

It is clear that the VDA can only play its full potential directly at the sea. A maximum gain of just under 10.3 dBi can only be achieved with ideal ground conductivity. The result is clearly disillusioning with average soil conductivity. More than 3.75 dBi at an elevation angle of 20° is pretty out of reach.

In addition to ground conductivity, consideration must also be given to the angle at which the signal must be radiated in order to be the loudest in the desired target area. Numerous calculations and investigations by N6BV [30] provide information on this. Ideally, the antenna should be surrounded by salt water, but due to local circumstances, this is not always possible. In order to be able to use the antenna as long as possible, the surf and the tidal range should be taken into account and the antenna must be installed at the proper distance from the water.

On average ground, it is clearly outperformed by a conventional 3-element Yagi (see below).

Non-homogeneous terrain

When preparing for ZL8X in 2010, we faced a terrain that is no longer that easy to simulate. We had to place the antennas about 40m above the sea at a distance of about 20m from the steep coast. The ground on the plateau consisted essentially of volcanic rock covered by a layer of humus.

In EZNEC, you can enter this terrain under "Media" in "Ground Description". To what extent the results of the simulation with this information on the ground coincide with reality, has not yet been verified.

High plateau
Ground conductivity: 0.005 S/m
Dielectric constant: 13

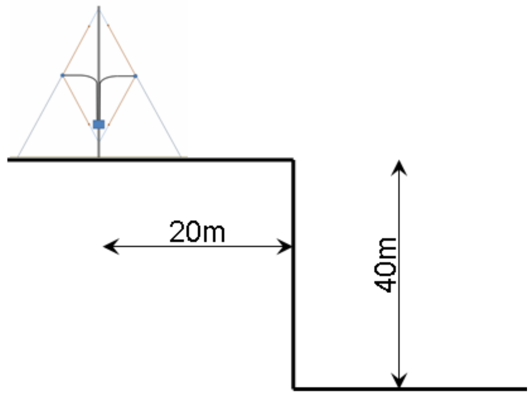
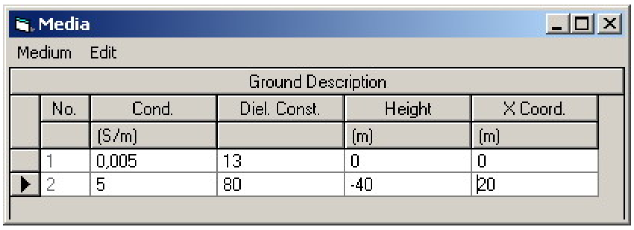


Fig. 11 Terrain profile of ZL8X location



Ground Description				
No.	Cond.	Diel. Const.	Height	X Coord.
	(S/m)		(m)	(m)
1	0,005	13	0	0
2	5	80	-40	20

Fig. 12 EZNEC window for ground characteristics definition

Sea
Ground conductivity: 5 S/m
Dielectric constant: 80

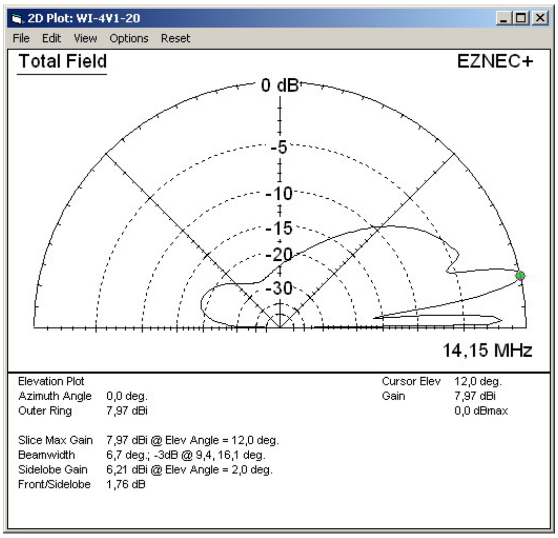


Fig. 13 Simulation on non-homogeneous terrain – Elevation radiation pattern

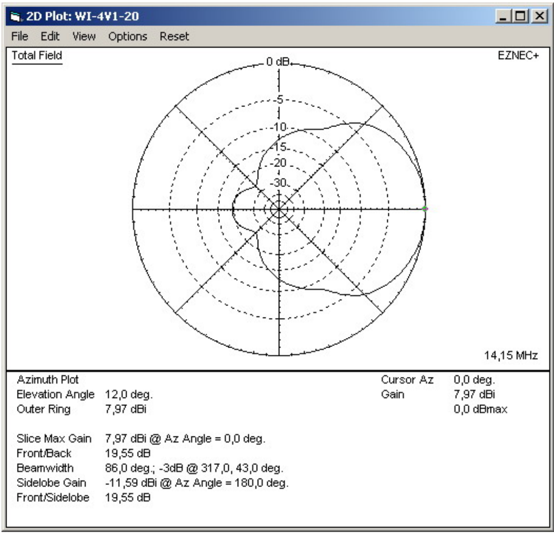


Fig. 14 Simulation on non-homogeneous terrain – Azimuth radiation pattern

Comparison with a horizontally polarized directional antenna

Let us have a look at antennas you can normally find on DXpeditions. We compare a 3-element Yagi for 20m (regardless of whether in the form of a monobander or as part of a multiband beam) in 5m or 10m height with a VDA.

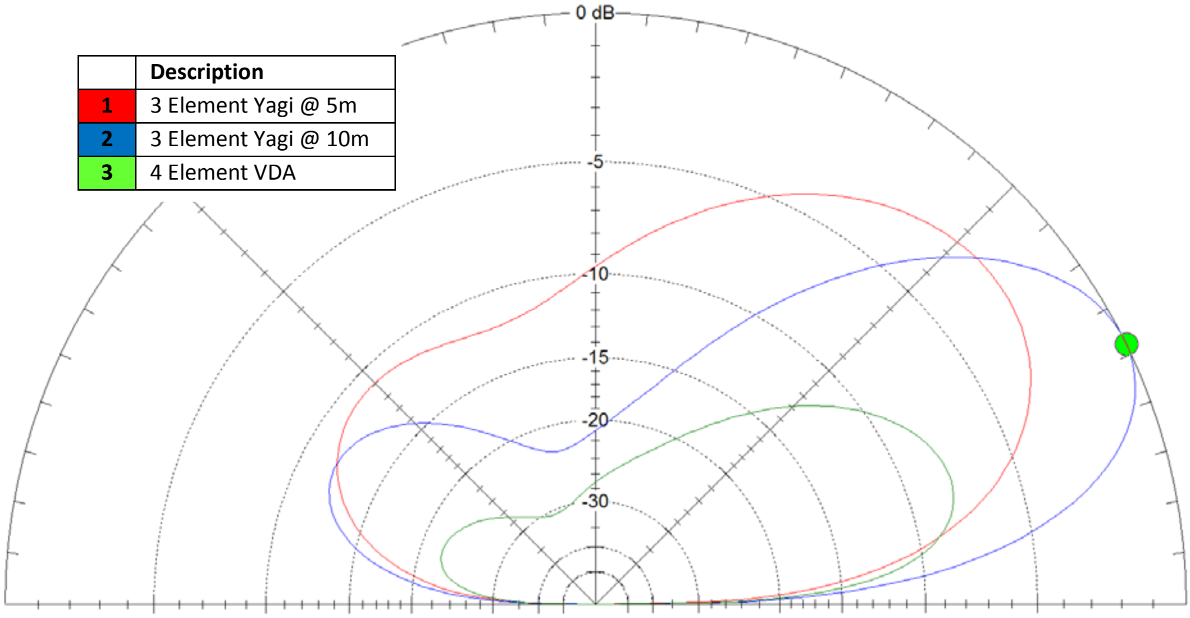


Fig. 15 Comparison Yagi - VDA, average ground, ground conductivity 0.005 S/m, dielectric constant 13

In the case of average ground conductivity (Fig. 15), the Yagi antenna is superiour compared to the VDA, if the Yagi has the appropriate height. In view of safety aspects and limited resources, this is not always possible on DXpeditions.

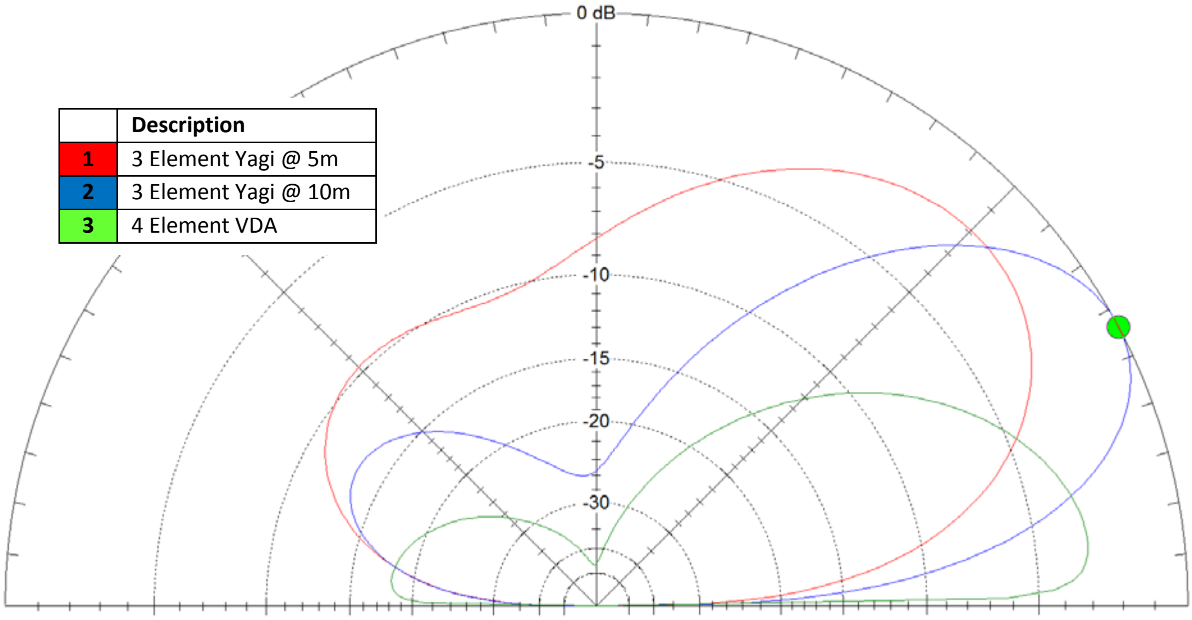


Fig. 16 Comparison Yagi - VDA, Salt water, ground conductivity 5 S/m, dielectric constant 80

The comparison at the sea is quite different (Fig. 16). As a rule, low elevation angles are required for DX contacts. The 3-element Yagi has about 3 dB more maximal gain, but only at an elevation angle of 26°. This may be sufficient for medium-range distances, but not for transmitting from the Pacific to Europe. Here, the VDA scores about 2 dB more gain (at 8°) and better coverage of the angles between 0° and 25°. In addition, there are two further advantages of the VDA. On the one hand, a 20m VDA is easier to erect than a 3-element Yagi (and remains stable in stormy weather conditions because of the smaller wind area). On the other hand, one can cover four directions without leaving the shack due to the simple directional switching. In the case of the Yagi antenna, a DXpedition usually uses a "rope rotator" as a rotary device, whose operation always requires an interruption of the radio operation or a voluntary helper to turn the antenna. With changing short path / long path propagation, this can become an ordeal.

Simulation

Which simulation software is used plays only a subordinate role. The availability or personal taste may be decisive. In our calculations, EZNEC+ from W7EL [14] was used. The freely available 4NEC2 by Arie Voors [31] would also be a good choice.

The geometrical dimensions of the dipoles are entered according to the software requirements. The source is set as shown in Fig. 17 in the case of a dipole (preferably in the positive x-direction, in order to obtain the corresponding radiation diagrams):

Sources

No.	Specified Pos.		Actual Pos.		Amplitude	Phase	Type
	Wire #	% From E1	% From E1	Seg	(V, A)	(deg.)	
1	5	100	99,0196	51	1	0	V

Fig. 17 EZNEC Source window for a VDA simulation

The coaxial cables play a role in that they compensate the reactive component of the feed point and act as a lengthening of the three reflector dipoles. For EZNEC+, the three cables are entered as follows:

Transmission Lines

No.	End 1 Specified Pos.		End 1 Act	End 2 Specified Pos.		End 2 Act	Length	Z0	VF	Rev/Norm	Loss	Loss Freq
	Wire #	% From E1	% From E1	Wire #	% From E1	% From E1	(m)	(ohms)			(dB/100 m)	(MHz)
1	1	100	99,0196	Open ckt			14,75	50	0,79	N	0	0
2	3	100	99,0196	Open ckt			14,75	50	0,79	N	0	0
3	7	100	99,0196	Open ckt			14,75	50	0,79	N	0	0

Fig. 18 EZNEC Transmission Lines window: Definition of the coax cables of the three reflector dipoles of a VDA

"End 1" is the dipole feed point, "End 2" is the open end of the coaxial cable (Open ckt). The length in the "Length" field is the mechanical length. The impedance Z0 and the shortening factor VF of the coaxial cable also have to be entered.

The central mast, if it is not conductive, can be neglected. During our simulations, several parameters were varied. The system was somewhat non-problematic regarding to small changes. This gives you the necessary tolerance for practical implementation.

Results

Table 1 summarizes the dimensions for VDAs from 40m to 10m, as used for the antennas of the Lagunaria DX Group's DXpeditions.

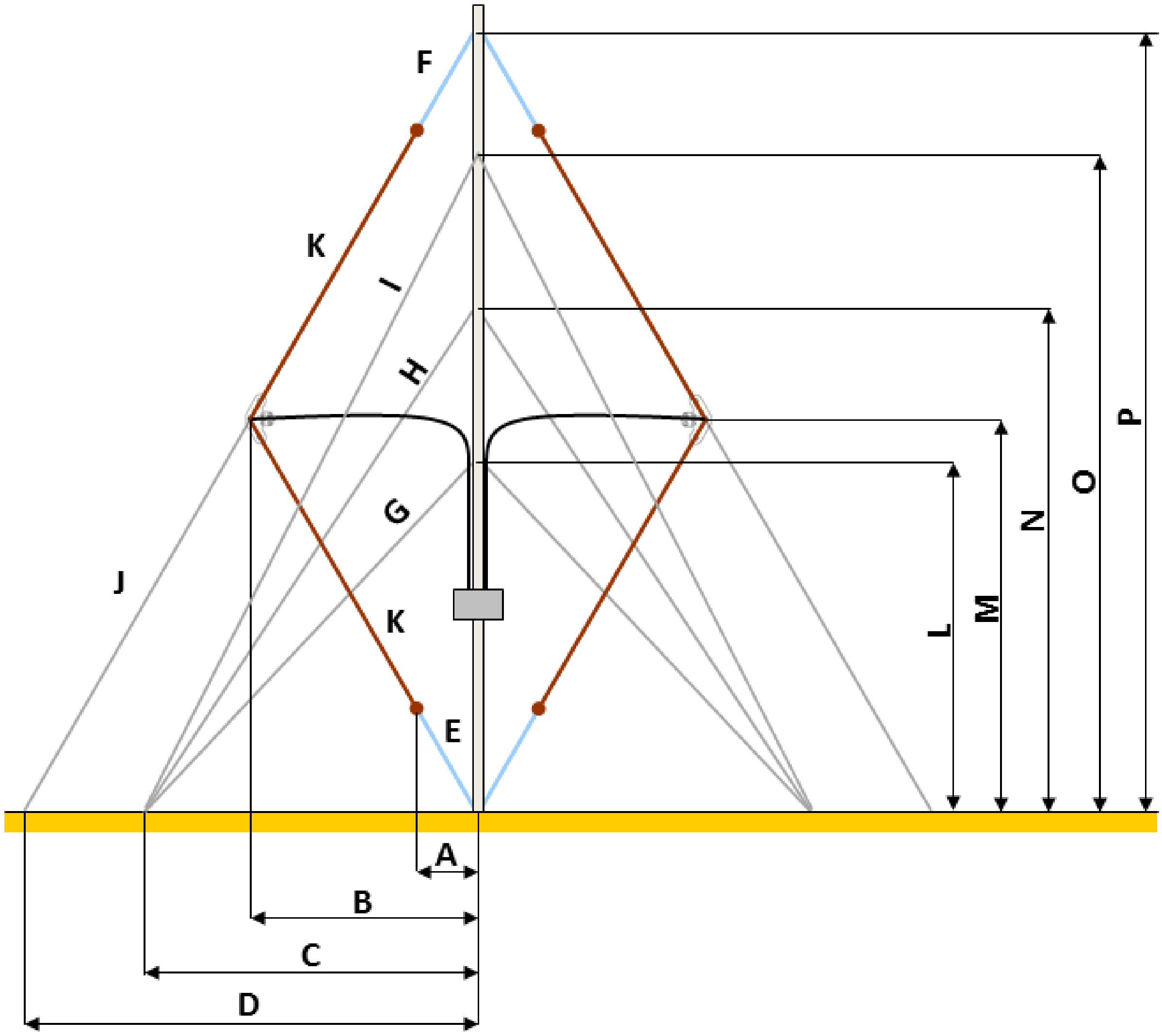


Fig. 19 Side view of a VDA with dimensions

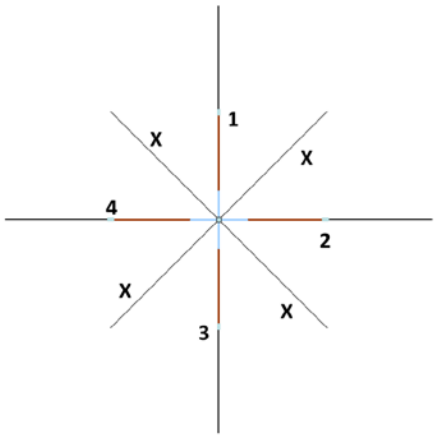


Fig. 20 Top view of a VDA (1...4 dipoles, X mast guy lines)

	40m	30m	20m	17m	15m	12m	10m
A	90	63	45	60	60	60	50
B	568	399	285	249	221	197	171
C	833	589	412	369	328	287	246
D	1178	815	583	521	464	406	348
E (bottom dipole guy line)	219	154	90	120	120	120	100
F (top dipole guy line)	180	125	90	120	120	120	100
G (bottom mast guy line)	1120	844	648	621	598	492	470
H (center mast guy line)	1486	1197	-	-	-	-	-
I (top mast guy line)	1938	-	-	-	-	-	-
J (center dipole guy line)	1197	834	596	546	485	418	355
K (dipole half)	958	671	480	377	322	274	241
L	750	604	500	500	500	400	400
M	1030	722	516	473	420	362	308
N	1230	1042	-	-	-	-	-
O	1750	-	-	-	-	-	-
P	2016	1412	1010	903	803	703	603
Coax cable	1475	1034	740	578	487	412	363

Table 1 Dimensions of a 4 Element VDA

Remarks

- All lengths are in cm
- The dimensions are the result of a simulation or a simple geometric calculation. The cuts can be a bit longer.
- The wire lengths (dimension K) are calculated for Wireman CQ532 (18 AWG, jacket thickness 0.02")
- The coax cable lengths are valid for H155 (v_f = 0.79)

In Practice

Requirements for the components

In the following chapters, you can find the requirements for the individual components of a VDA.

Mast

The mast is the central component of the antenna. In order to minimize the electrical influence of the mast on the antenna structure, the mast should be made of non-conductive material. While there are almost no limits in the case of a stationary setup, the selection of the appropriate mast is rather restricted for portable activities, especially with regard to transport or set-up time. For the 20m version, you already need an antenna support with at least 10.1 m height.

Fig. 21 12m GRP mast by Spiderbeam for VDAs from 20m to 10m (Photo: Spiderbeam)

Fig. 22 18m GRP mast by Spiderbeam for a 30m VDA (Photo: Spiderbeam)

Fig. 23 26m GRP mast by Spiderbeam for a 40m VDA (Photo: Spiderbeam)

A telescopic fiberglass mast meets all these requirements. In the case of a VDA, we require a very stable mast because of the high stress of the individual dipoles. The initial tests were carried out with GRP masts from Spiderbeam [19] (Fig. 21, Fig. 22 and Fig. 23), which made the most stable impression compared to other products. Based on the experience gained so far, we stayed with these masts and did not carry out any further tests with other masts. However, no matter what telescopic mast you use, the locking of the individual mast sections is important. Simple taping of the junctions with adhesive tape is not sufficient. Securing against inadvertent slipping should be provided, e.g. with specially prepared hose clips.

Fig. 24 Mast base of a VDA from 10m to 30m (Photo: Lagunaria DX Group)

The mast base (Fig. 24) has two tasks to fulfill. On the one hand, it should prevent the mast from sliding sideways. On the other hand, it serves as an attachment point for the ends of the four dipoles.

We had access to steel cones that were perfect for our needs. They already had the necessary four holes at an angle of 90° each. On Willis Island, where we predominantly found loose coral sand as ground, we also needed a large-area base against sinking in the ground and a ground nail against lateral slipping. With solid humus soil, as it prevails on Raoul Island, we only had to dig a small trough into the ground.

As an alternative to our metal cone, one can also imagine a solution with an old metal pot or pan. If necessary, you can also work with ground anchors, but you have to make sure that they are fixed very firmly in the ground. Otherwise, they can be pulled out of the earth by the high forces in the dipoles.

While the masts for the VDAs for 10m to 30m can be erected very easily, the size and weight of the 40m VDA requires a somewhat more elaborate construction at the base of the mast. We built a simple tilting joint (Fig. 25). Both when erecting and when the mast is mounted, it ensures that the mast cannot slip off at the base.

Fig. 25 Tilting joint for the 26m GRP mast (Photo: Lagunaria DX Group)

Dipoles

While the focus of the mast is on mechanical stability, the dipole still has one further aspect, its weight. Any unnecessary grams will cause the dipoles to sag and prevent accurate antenna guying. Sagging dipoles and cables also have a direct influence on the electrical properties (VSWR and radiation pattern).

The central element of a dipole is its feed point. The two dipole-halves, the coax cable and an additional guy line are mounted together on a center isolator. There are many possibilities to manufacture this insulator. Due to the existing raw material and the processing possibilities, we have made some insulators of 5mm thick Plexiglas according to Fig. 26. The two dipoles are fixed in the two larger holes on the two tabs, the center guy line is mounted in the center hole and the four small holes are used to secure the feed cable and thus the strain relief of the feed.

To reduce weight, we did not use complex terminals or connecting boxes for the feeding. The wires of the dipole were soldered directly to the coax cable. In order to protect the connections from water ingress and to isolate them from each other, they were protected with shrink tubing and finally sealed with a heat shrink cap with inside glue. These measures have the advantage that the dipole can be constructed with very low weight. Of course, on the other hand, it takes more effort when it comes to replacing parts such as coax cables or dipole wires.

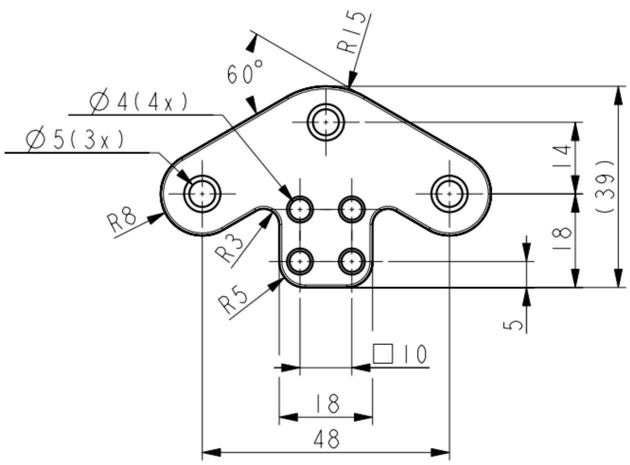


Fig. 26 Drawing of the center insulator

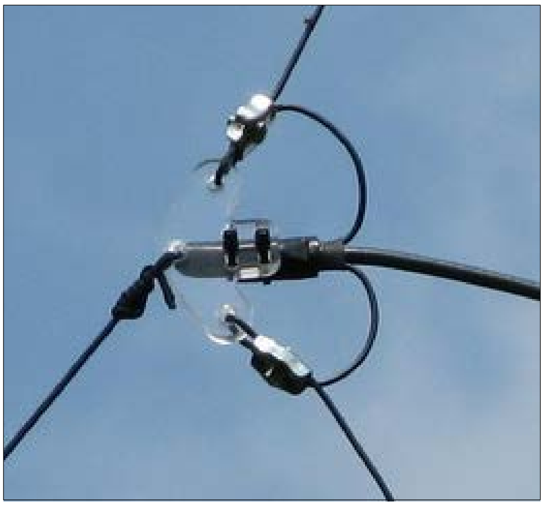


Fig. 27 Center insulator in use
(Photo: Lagunaria DX Group)

We also deliberately omitted a choke at the feed point since all the coax cables are located within the antenna and RF is induced on the cable screen between the feed point and the antenna switch. We added the choke on the coax right after the switching box that runs to the shack.

The wire used in our case was the CQ-532 from Wireman, which we purchased from Spiderbeam [19]. The copper-clad steel braid combines the good tensile strength of the steel braid and the good electrical properties of the copper. Very low strain is another argument for this wire. In principle, any other wire can be used. One only has to consider the wire thickness and the jacket material used in the simulation of the antenna.

The weight of the coaxial cable is also the focus of the selection. Of course, the cable must meet the requirements for the transmitted power used. However, too much sag of the cable has a direct influence on the VSWR and possibly also on the radiation pattern. As a good compromise, H155 was the coax cable of our choice, which with 3.9kg per 100m is as heavy as RG 58 but has only about half as much loss. H155 is also dimensioned for power up to almost 1000 watts. In addition, a large shortening factor (0.79) allows larger cable lengths and a positioning of the switch box at eye level. Alternatively, cables with an aluminum braid or copper-clad aluminum inner conductor may also be used. This means that higher power levels can be transmitted at the same weight.

Fig. 28 Insulator made of PTFE
(Photo: Lagunaria DX Group)

The search for suitable material for the isolators of the dipoles became interesting. While the insulator in the feed point is relatively uncritical (in this case only the mechanical requirements play a role), the isolators at the dipole ends have to withstand high voltages. If aggressive salt spray is an issue, there is no way around PTFE or porcelain. Due to the lower density and the better processability, PTFE is first choice (Fig. 28). Insulators made of polycarbonate were replaced immediately after the first traces of breakthrough.

Guy wires

In order to keep the antenna where it was erected, it needs guying. For the ropes, our choice was 2 mm Kevlar, as distributed by Spiderbeam [19]. It is characterized by very low lengthening (approx. 1%), high breaking load (150 kg) and high temperature resistance. Of course, its low weight was also important here. The low strain ensures that the antenna always remains in shape. The temperature resistance is particularly advantageous at the dipole ends when it comes to arcing due to salt deposits and RF.

We had good results with so-called simplex clamps (Fig. 29), as can be found in the lighting market. They are very simple to handle; they offer a surface pressure of the wire or the line (compared to the standard cable clamps, where a constriction takes place) and have the necessary protection against corrosion in the stainless steel version.

Fig. 29 Simplex clamp (Photo: Lagunaria DX Group)

When we were looking for rope tensioners, we found them at camping suppliers. The simplest, cheapest and most effective way to tighten the ropes are so-called aluminum tent-drawers (Fig. 30). They have proved most useful at VK9DWX and ZL8X very well. An unbeatable advantage is the low weight of a few grams. With the VDAs for 30m and 40m, we have used ratchet-type tension locks as they were once sold with the Titanex vertical antennas due to the higher forces in the guy lines.

Fig. 30 Rope end with tent-drawer and snap hook (Photo: Lagunaria DX Group)

In order to increase the effectiveness of the installation of the antenna, snap hooks have been attached at all ends of guy lines, which have been fixed to the ground. This makes it possible to attach the lines quickly at the anchor points, if these are equipped with appropriate eyelets. Also with the snap hooks, we chose the stainless steel variant that can resist the aggressive sea air a little bit longer than the galvanized hooks. Due to the smooth surface of these snap hooks, chafing of the guy lines is prevented.

It is important to use correct anchors for the appropriate ground. While in solid humus ground steel pegs of angle or T-profile are used, pegs of great surface and appropriate length are more suitable for loose sandy ground. Especially for VK9DWX we made over 120 v-shaped pegs of 5 mm thick steel sheet with an edge length of 7 cm, to offer sufficient support in loose coral sand. For stony ground, you can use round steel pegs. In the case of larger rock formations, drop-in anchors or concrete dowels should be used.

Fig. 31 Worm's-eye view of a VDA (Photo: Lagunaria DX Group)

Peg template

An important accessory, if you want to set up the VDA quickly and accurately, is a peg template (Fig. 32 and Fig. 33). This allows you to quickly and precisely define the necessary anchor points. Without precise positioning the anchor points, the proper installation of the antenna is not possible. This again has a strong influence on the function of the antenna. This template serves only as a work-relief, if you want to set up the antenna more than once. For a one-time installation, it is sufficient to determine the anchor points with the measuring tape.

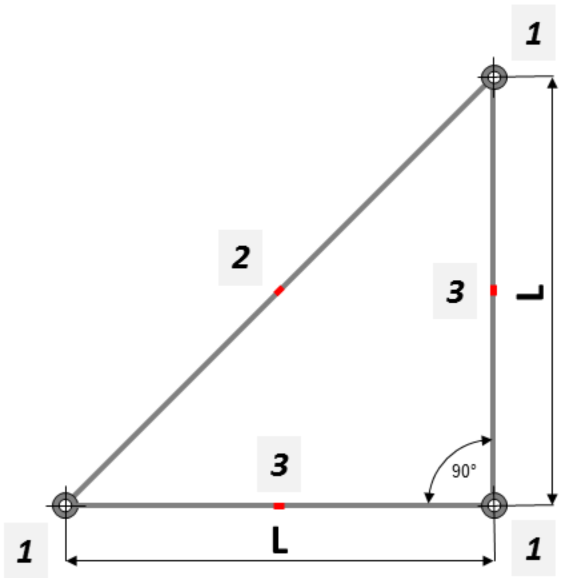


Fig. 32 Sketch of a peg template: 1. Anchor point dipole, 2. Center of antenna (mast), 3. Anchor point mast

Fig. 33 Peg template for 20m

Band	40m	30m	20m	17m	15m	12m	10m
L [cm]	1666	1153	825	737	656	574	492

Table 2 Dimensions of the peg template

Switching

Fig. 34 shows the switching of the VDA, that was used at VK9DWX in a simplified version and with the protection circuit against hot switching (according to DJ7EG) at ZL8X. The relays K1, K2 and K3 are located in the switch box at the antenna and switch the corresponding dipoles. The relays K4 to K9 are used for the hot-switching protection of relays K1 to K3. If, by mistake, the antenna direction is switched during transmission, the antenna relays K1 to K3 remain in the position in which they were before switching. The antenna direction selected during transmission is switched when the transceiver goes from transmit to receive. Only, of course, if the protection circuit is connected to the PTT of the transceiver.

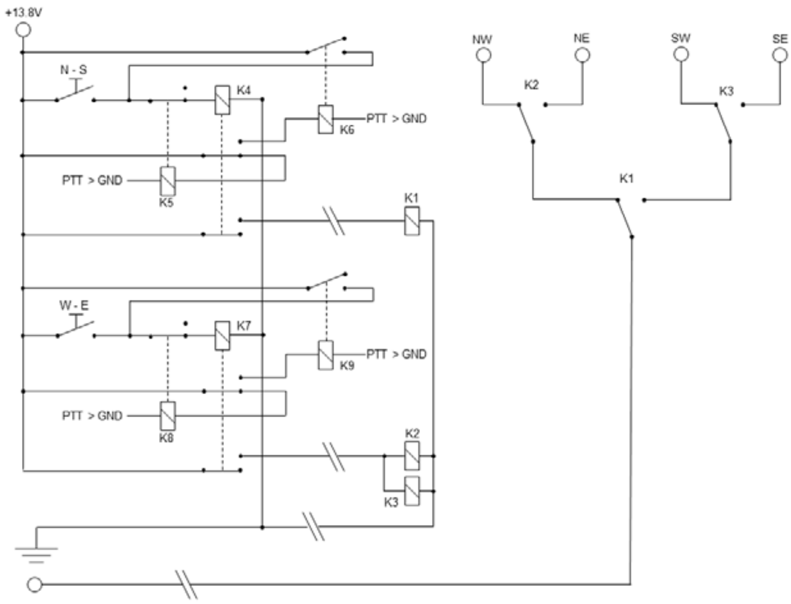


Fig. 34 Simplified diagram of the VDA switching (incl. protection circuit against hot switching)

The relays K1, K2, K3, K4 and K7 are DPDT, SPST is sufficient for relays K5, K6, K8 and K9.

The dimensioning of the antenna relays K1, K2 and K3 depends primarily on the RF power to be used. The calculation of the expected maximum voltages and currents is given by the formulas

$$Peak\ voltage\ U_S\ [V] = \sqrt{2 \times P \times R}$$

$$Peak\ current\ I_S\ [A] = \sqrt{\frac{2 \times P}{R}}$$

For a VSWR = 2: 1, different power levels result in following values:

	5 W	100 W	500 W	1000 W	1500 W
U_S (at Z = 100 Ω) [V]	32	141	316	447	548
I_S (at Z = 25 Ω) [A]	1	3	6	9	11

Table 3 Maximum voltages and currents at different power levels

The supply voltage of the relays is a further decision criterion. Due to the standardization of 12 V for a large number of our station equipment, we have decided to do so. At a length of more than 50 m, we have not been able to detect any noticeable losses due to voltage drops.

Fig. 35 Switching box of the VDA (Photo: Lagunaria DX Group)

There are no special requirements for the relays in the hot-switching protection circuit (K4 ... K9), since only small voltages at low currents are switched.

Due to availability and electrical characteristics, we chose Omron's G2RL-2 relays for the switch boxes. These are sufficient for operation with ACOM1000 power amplifiers, as we use them on our DXpeditions. They are easy to get at Conrad Electronic [6]. So far, they have survived all DXpeditions of the Lagunaria DX Group.

The switch box consists of a weatherproof (IP65) housing made of non-conductive plastic. The latter property is especially important for the function of the antenna since the individual coax cables must be switched completely (inner and outer conductors) and electrically separated from each other. The switch box is shown in Fig. 35 and Fig. 37. The five UHF sockets for the four antennas and the connection to the shack are sealed from the inside with molded gaskets (available from Spiderbeam [19]). Also visible is the connection for the control cable (Hirschmann ST-series housing plug) and a GORE vent to equalize pressure in the enclosure. The advantage of this is that no condensation water can accumulate in the housing, no small animals can settle and no salt air can penetrate (after VK9DWX and ZL8X the inner life still looks brand new). Small money that is well invested.

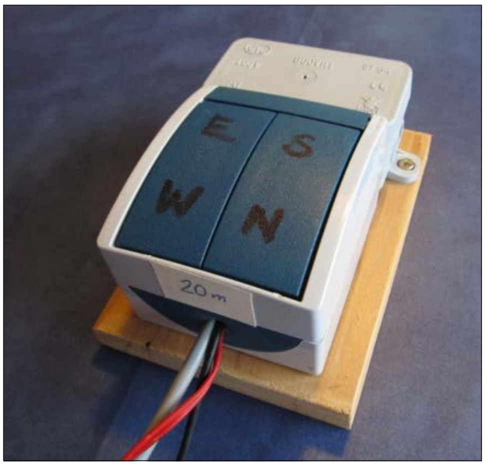


Fig. 36 VDA selector switch (Photo: Lagunaria DX Group)

Fig. 37 Interiour of the VDA switch box (Photo: Lagunaria DX Group)

Antenna directions are switched from the shack via the selector switch with the integrated protection circuit against hot switching. Fig. 36 shows a selector switch, as used at VK9DWX and ZL8X. Of course, other solutions (such as rotary switches or push buttons) are also possible. The following features characterize this wall-mounted double rocker: selection of four directions possible, easy and fast switching between the directions, mechanical stability and cheap and easy to purchase in any hardware store.

Production of the components

We will not describe the preparation of the antenna in detail. Rather, the reader should have look at the pictures the components and the assembly process and draw the right conclusions for his own setup.

Installation

Preparations

Meticulously work during the preparations, costs a little more time at the first moment, but it is rewarded by a smooth and fast erection of the antenna. The VDA is a wire antenna with quite a number of wires and guy lines. They can entangle very easily, where these come together. Once this has happened, only a complete disassembly helps to unravel all wires before starting again. This procedure can take a multiple of the time required to prepare the assembly properly.

Fig. 38 Clamp set by Spiderbeam (Photo: Lagunaria DX Group)

The process described here is intended to provide an insight into how it has proven several times on our DXpeditions. With some practice, patience and the right sensitivity, a person can set up a complete VDA (30m to 10m) in one hour, a 40m VDA in about two hours.

Assembly of the telescopic mast

With the 12m long version, the GRP mast of Spiderbeam does not have to be assembled for its full length. For the 20m version, the top section, for the 17m version, the top two sections, etc. should be omitted.

On the one hand, these sections are not needed; on the other hand, they only generate additional unnecessary wind loads, making the whole structure less stable. To secure the individual shots against slipping, it is not enough to simply wrap a few layers of adhe-

Fig. 39 Mounted clamp (left) and wrapped with adhesive tape (right) (Photo: Lagunaria DX Group)

sive tape around the stops. Such connections easily get loose in the sun or in cold wet weather and the mast collapse.

For this reason, Spiderbeam provides a special set of clips. Mount the clamps over each transition between the sections. Note: “Tight” is easily followed by “Broken”. It is necessary to develop certain sensitivity to how tightly the clamps have to be screwed so that the mast sections do not slide anymore, and so that the mast is not destroyed. To prevent the wires from threading into the clamps when the antenna is being erected, wrap the clamps with some layers of adhesive tape (Fig. 39). The lower end of the mast should remain open to allow any condensation water to drain off, however, once you have the tape already at hand, close the hole at the top.

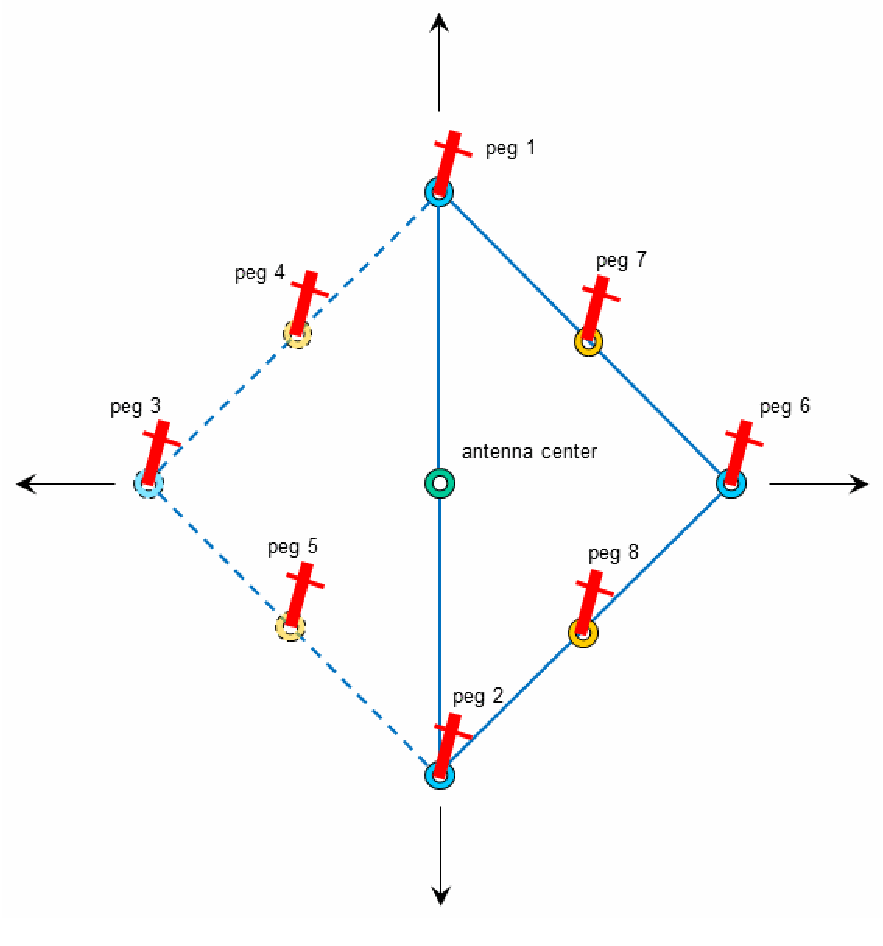
Position the anchor points

First, select the location where the antenna should stand. The total space requirement results from the position of the anchor points:

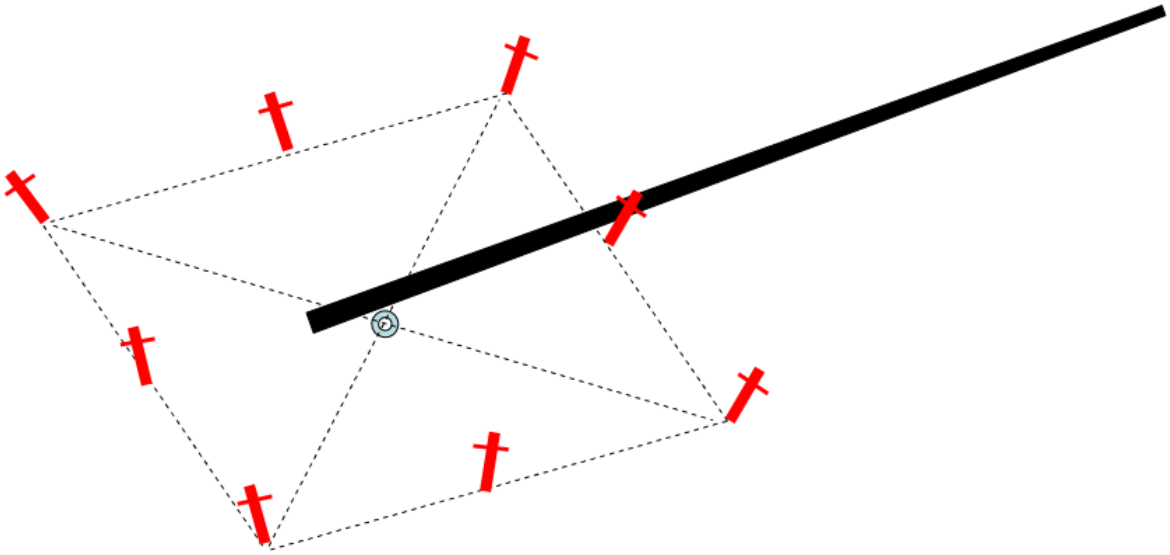
	40m	30m	20m	17m	15m	12m	10m
Space requirement [m x m]	16.7 x 16.7	11.6 x 11.6	8.5 x 8.5	7.5 x 7.5	6.7 x 6.7	5.8 x 5.8	5.0 x 5.0

Table 4 Space requirement of VDAs for 40m to 10m

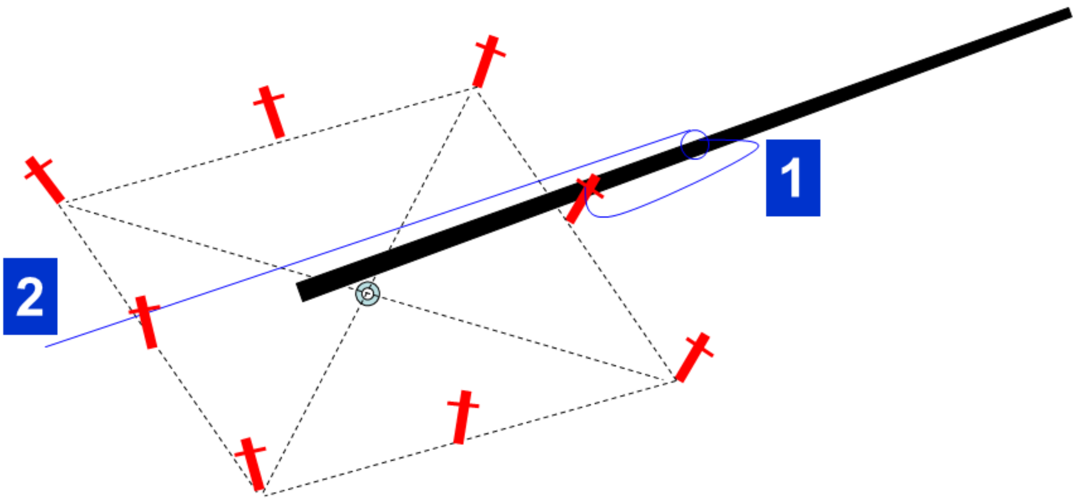
If you are planning to erect and dismantle the antenna several times, it is recommended to use a template (Fig. 32 and Fig. 33) that can be used to determine the anchor points very easily and properly. Before the pegs are driven in, you should already know in which direction the antenna should radiate later, otherwise a later change of the direction takes a lot of extra effort.



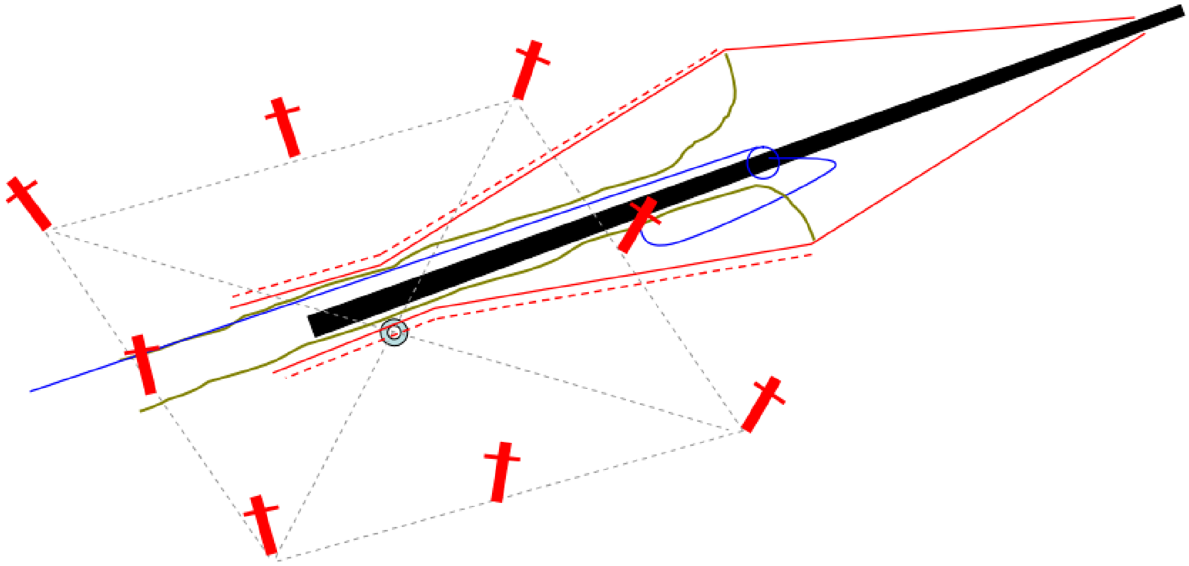
Laying out dipoles and guy lines



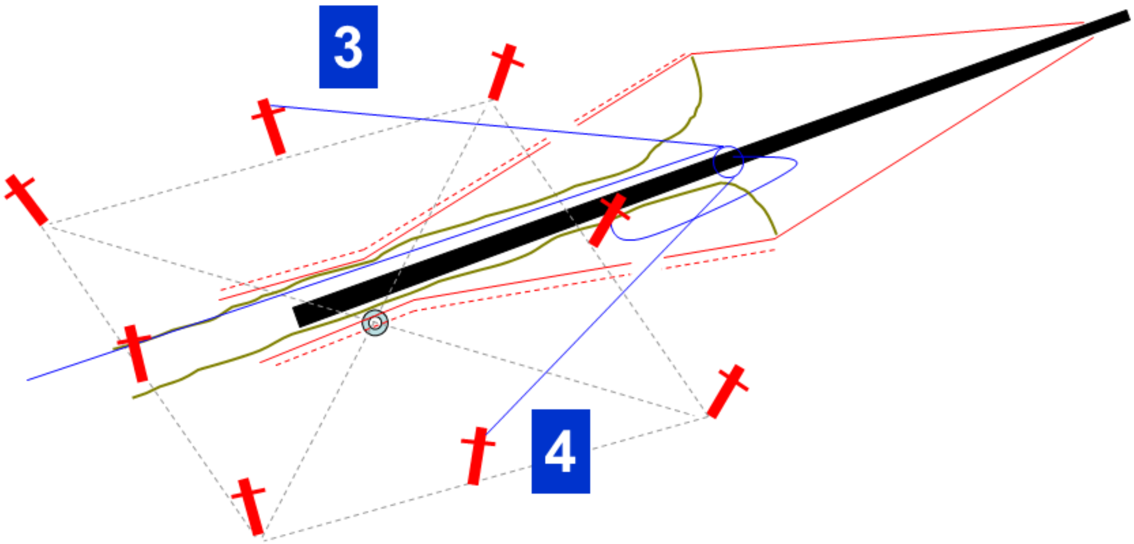
Lay out the prepared mast. Make sure that the lower end of the mast protrudes slightly over the center. For the 40m version, you should use a tilting joint in the middle.



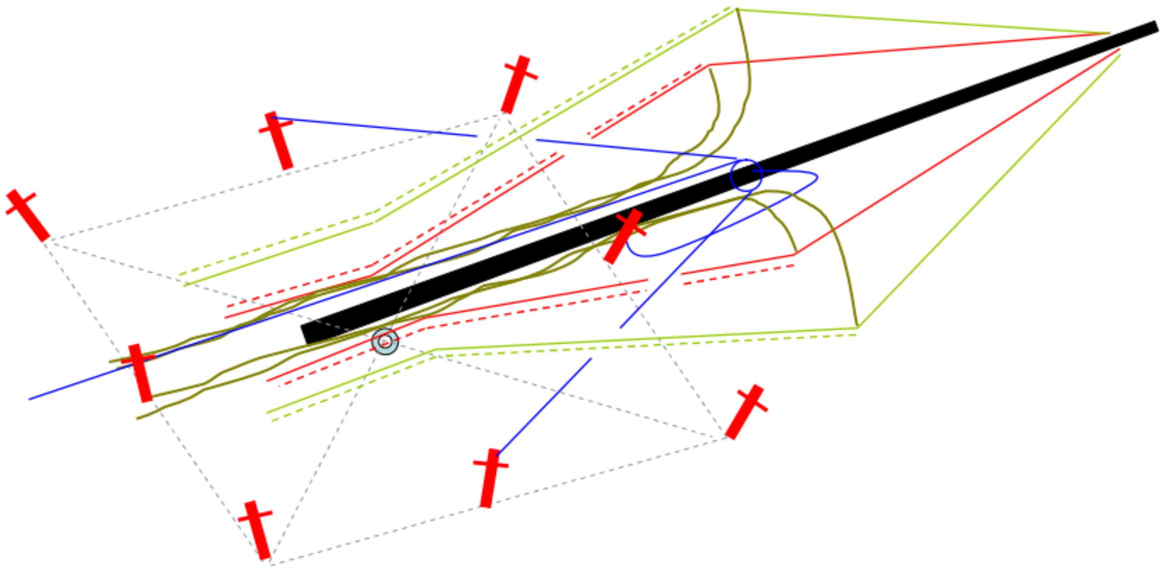
Fix mast guy lines #1 and #2 to the mast. Lay out #1 completely and attach it to the peg (with sufficient over length so that the mast is not held down half way during installation). Lay out #2 along the mast in the direction of the mast base. With the 30m version, there are two, with the 40m version, three guying levels.



Lay out the first two dipoles. Just lay down the upper ends onto the ground (they will be attached to the mast later together with the other two dipoles). Lay out the coax cable first towards the mast, then along the mast towards the base. Lay down the center dipole guy lines together with the lower halves of the dipoles.



Fix mast guy lines #3 and #4 to the mast. Place them over the coax cables and dipoles and fasten them to the pegs (not too tight, but taut enough so that the mast cannot tip sideways when erect-ing). With the 30m version, there are two, with the 40m version, three guying levels.



Lay out the other two dipoles. Just lay down the upper ends. Lay out the coax cables first towards the mast, then along the mast towards the base. Lay down the center dipole guy lines together with the lower halves of the dipoles.

Fixing the wires

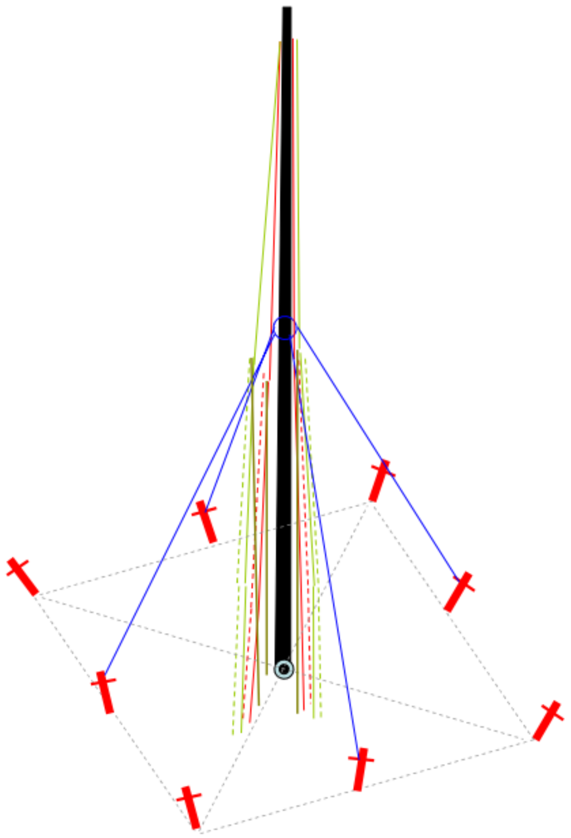
When attaching the upper dipole ends make sure that all four upper dipole guy lines have the same length. The four coaxial cables can be fixed with four loops (Fig. 40). This allows corrections after the installation (the coax cable between the feed point and the mast must be horizontal). In general, all mounts on the mast should be designed to prevent accidental slipping during installation. A few turns of adhesive tape are usually sufficient for fixing (Fig. 41).

Fig. 40 Guided coax cables (Photo: Lagunaria DX Group)

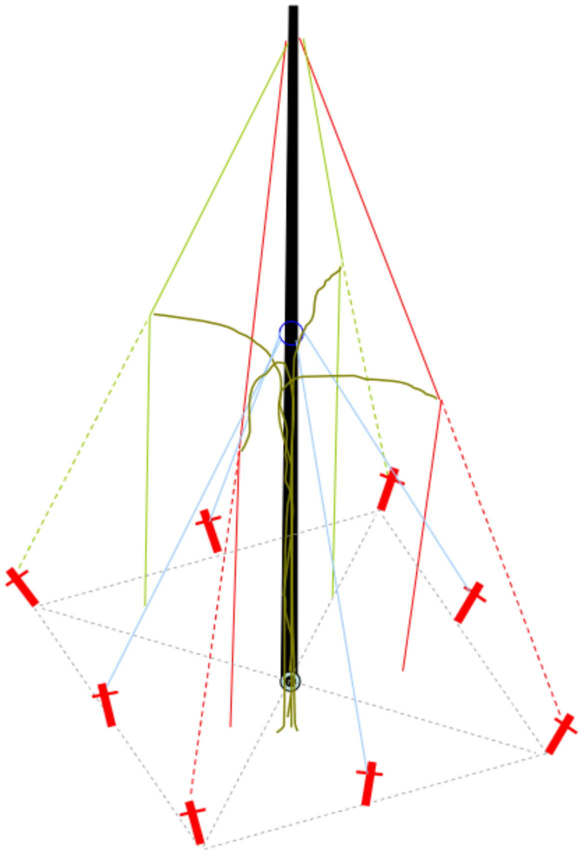
Fig. 41 Attachment of the guy lines (Photo: Lagunaria DX Group)

Erecting the antenna

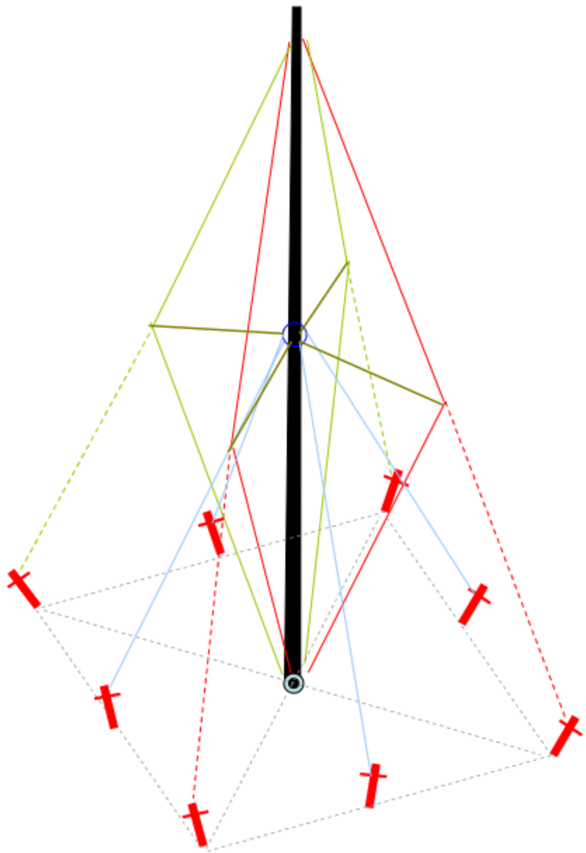
To erect the antenna, pull all the dipoles to the mast. In the first installation attempts, one can work best with a helper, later with more experience and routine you can do it alone. Due to the large number of wires and the size, the 40m version should always be built in pairs. A person takes the mast including the dipoles and coaxial cables, a second person takes the mast guy line(s) #2. Erect the mast, attach mast guy line(s) #2 to the peg and fix the mast to the base. Then the whole antenna structure is fixed vertically.



First, tighten the four mast guy lines to align the mast vertically. The dipoles can be left hanging.



The center dipole guy lines are then attached to the pegs and tightened so tightly that the upper dipole halves are tight with the mast still straight.



Fix the lower dipole legs to the mast base. Tighten them only so tightly that the lower dipole halves are tight, but the upper halves with the center guy line still form a line. Finally, the coax cables are pulled so far that they form a horizontal line between the feed point and the mast. Then attach the coax cable to the mast using adhesive tape or cable ties.

Now the switch box can be attached to the mast and the coax cables can be connected. The remaining lengths of the coax cables determine the position of the switch box on the mast. The coax cables are connected according to the directions for which the antenna has been set up (corresponding marks on coax cables and lower dipole halves simplify the assignment of the individual directions). The choke and the coaxial cable to the shack are connected at the COM port. Finally attach the control cable, and the antenna is ready to use. It is recommended to strain-relieve the two cables that go into the shack (coax cable and control cable) by fixing them to the mast base with adhesive tape.

Fig. 42 Completely wired VDA switch box (Photo: Lagunaria DX Group)

It is, of course, preferable to erect the antenna on flat terrain. The dimensions of page 14 are calculated for that. However, if you find uneven terrain, you should first set the four anchor points for the mast guy lines, then erect the complete mast with dipoles and guy lines, align the mast vertically and finally fix the dipole anchor points manually and attach the dipoles. If you already have a sense of how the antenna is supposed to look at the end, installation on uneven ground should not be a major problem. You may have to adjust the lengths of some guy lines.

Initial operation

With the dimensions in Table 1, more than ten complete VDAs have already been built. A tuning of the individual antennas was either not necessary at all or by back-folding the ends of the lower dipole-halves. If, however, a larger change is required, the antenna must completely be dismantled to make the necessary dipole adjustments.

Before applying RF to the antenna, make sure that the lower dipole ends are free and do not come into contact with high grass or other vegetation.

Operation

Here we would like to present our experience from the practical operation of the VDAs. For the DXpeditions VK9DWX, ZL8X, TX5K and VK9DLX twelve VDAs from 10m to 40m have been erected and operated. All VDAs played to the end perfectly without failures. As a rule, a correction of the resonance frequency of the antennas was not necessary. By backfolding the lower dipole ends, however, a slight correction could be made in a few cases. Only twice a VDA has slipped. In both cases, incorrect attachment of the clamps was responsible.

Of course, you can select the antenna direction manually, by changing the individual coax cables directly at the antenna. However, switching the antenna direction from the shack is a comfort that you would not want to miss in both stormy rain and midday sun. Likewise, the operator can react rapidly to changing conditions (e.g., by switching between short and long path).

The outstanding performance right on the beach amazed everyone who was working with the VDAs. Likewise, the QSO partners at the other end of the pile-ups have often thanked us for our exceptionally loud signals. What we also noticed is the reduced performance as soon as the antenna is operated further away from the sea. This turned out to be the case on Clipperton Island, where one of the VDAs was positioned slightly off the water compared to the rest of the antennas. We immediately got asked, if we had any problem with this particular band. The difference between Yagi and VDA on Kermadec Island came out more clearly. All antennas were positioned on a cliff about 40m above the sea. While on a certain band no QSOs were possible with the VDA, switching to the Yagi antenna caused the pile-up to flash up again.

Outlook / Others

We hope that this description of the 4-element vertical dipole array will be the beginning of further developments. While we operate only monoband antennas for large DXpeditions, it is certainly also possible to design the system as a multiband version. Likewise, one can still think about ways to get more gain from a VDA.

On 30m and 40m, it would be interesting to know, if a VDA beats a 4-square array. So far, we have not yet tested that extensively. The smaller space requirement as well as no necessity of radials makes the VDA on these bands an interesting alternative.

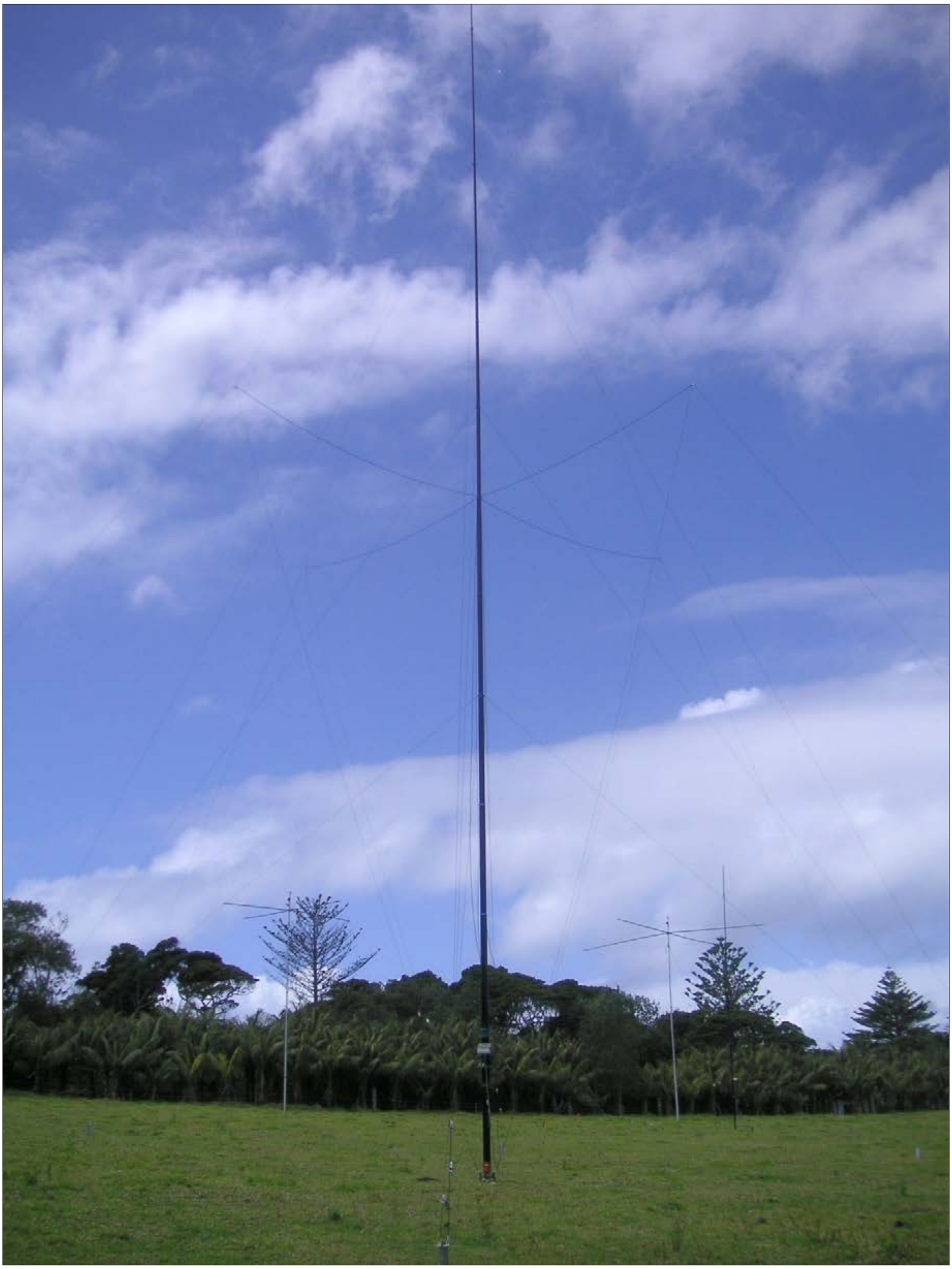


Fig. 43 The world's first portable 40m VDA used at VK9DLX on Lord Howe Island in 2014 (Photo: Lagunaria DX Group)

Bibliography

[1] BAVARIAN CONTEST CLUB. Tipps für HF-taugliche Relais [online]. Available at: http://www.bavarian-contest-club.de/projects/misc_projects/hfrelais.txt [24.03.2017]
[2] BEEZLEY, BRAIN K6STI (1995). Antenna Optimizer. Software, V6.54
[3] BÜRKLIN OHG [online]. Available at: http://www.buerklin.de [24.03.2017]
[4] CEBIK, L.B. W4RNL. Antennas – Service and Education [online]. Website, various articles, http://www.cebik.com [24.03.2017]
[5] CHRISTMAN, AL KB8I & DUFFY, TIM K3LR & BREAKALL, JIM WA3FET (1994). The 160-Meter Sloper System at K3LR. In: QST, August 1994, pp. 36-38
[6] CONRAD ELECTRONIC SE. Produktkatalog [online]. http://www.conrad.de [24.03.2017]
[7] CUTSOGEORGE, GEORGE A. W2VJN (2008). Relays used in Top-Ten Devices Products. private communications
[8] DISTRELEC SCHURICHT GMBH [online]. Available at: http://www.distrelec.de [24.03.2017]
[9] EDELSTAHL.NIRO VERSANDHANDEL [online]. Available at: http://www.edelstahl-niro.de [24.03.2017]
[10] FA-LESERSERVICE (2008). KW-Umschalter für 100W. In: Funkamateur 58 (2008) H.2, S.186...187
[11] FORCE12 INC (2001). K5K Kingman Reef DXpedition with SVDA Switchable Vertical Dipole Arrays [online]. Available at: http://force12inc.com/k5kinfo.htm [01.07.2008]
[12] GORE (2011). Screw-In Druckausgleichselemente [online]. Available at: http://www.gore.com/ [24.03.2017]
[13] LAU, HARDY DL1GLH (2012). Measurement of the ground conductivity and relative permittivity with high frequency using a open wire line (OWL) [online]. Available at: http://www.dl1glh.de/groundconductivity.html [24.03.2017]
[14] LEWALLEN, ROY W. W7EL (2008). EZNEC+. Software, V5.0.16 2008, http://eznec.com [24.03.2017]
[15] MADAY, MANFRED DC9ZP (2007). Ein Antennenschalter der besonderen Art. In: Funkamateur 56 (2007) H.12, S.1312...1313
[16] MEINKE, GUNDLACH (1992). Taschenbuch der Hochfrequenztechnik, Band 2. 5. Auflage, Berlin, Heidelberg, New York: Springer-Verlag
[17] MITCHELL, D.C. K8UR (1989). The K8UR Low-Band Vertical Array. In: CQ magazine December 1989, pp. 42...45
[18] MOXON, Les G6XN (1993). HF Antennas for All Locations. Second edition, Potters Bar Herts: Radio Society of Great Britain
[19] PAUL, CORNELIUS DF4SA (2006). Spiderbeam© High Perfomance Lightweight Antennas [online]. Available at: http://www.spiderbeam.net [24.03.2017]
[20] PERKIÖMÄKI, JARI OH6BG (2007). VOACAP Quick Guide [online]. Available at: http://www.voacap.com [24.03.2017]
[21] PETER BOGNER TECHNISCHER HANDEL-ANTENNENTECHNIK [online]. Available at: http://dx-wire.com/ [24.03.2017]
[22] PIETRASZEWSKI, DAVID K1WA (2000). 7-MHz 'Sloper System'. In: American Radio Relay League (Hg.). Antenna Book, 19th Edition, Newington: American Radio Relay League, Chapter 6 "Low Frequency Antennas", pp6-32…6-35
[23] REHBEIN, GÜNTER DL3XM (2007). Von DM3XM bis DL0XM – zur Geschichte der Klubstation [online]. Available at: http://dl3xm.dl0xm.de/dl0xm.html [24.03.2017]
[24] ROTHAMMEL, KARL Y21BK (1984). Antennenbuch. 10. überarbeitete Auflage, Berlin: Militärverlag der Deutschen Demokratischen Republik
[25] SEVERNS, RUDY N6LF (2003). Single Support Gain Antennas for 80 and 160 Meters. In: National Contest Journal, March/April 2003

[26] SEVERNS, RUDY N6LF (2004). Getting the Most from Half-Wave Sloper Arrays. In: QEX, January/February 2004
[27] SILVERMAN, KENNY K2KW & SCHILLER, TOM N6BT (1998). Verticals for Contest Expeditions [online]. Available at: http://www.k2kw.com/verticals/learning.html [24.03.2017]
[28] SILVERMAN, KENNY K2KW (1999). DXpedition Antennas for Salt Water Locations, a Study on 20m Antennas [online]. Available at: http://www.k2kw.com/k5k/dxcomp.htm [24.03.2017]
[29] STRAW, R. DEAN N6BV (1999-2001). Antennas Here are Some Verticals on the Beach. In: American Radio Relay League (Hg.). Antenna Compendium Vol. 6, First Edition Second Printing, Newington: American Radio Relay League, pp216…225
[30] STRAW, R. DEAN N6BV (1999-2001). Using HF Propagation Predictions. In: American Radio Relay League (Hg.). Antenna Compendium Vol. 6, First Edition Second Printing, Newington: American Radio Relay League, pp101…111
[31] VOORS, ARI (2017). 4NEC2. Software, V5.8.16, http://www.qsl.net/4nec2/ [24.03.2017]
[32] WEIGL, JÜRGEN A. OE5CWL (2007). Sloper-Antennen. 1. Auflage, Baden-Baden: Verlag für Technik und Handwerk
[33] WEIGL, JÜRGEN A. OE5CWL (2007). Umgebungseinflüsse auf Antennen. 1. Auflage, Baden-Baden: Verlag für Technik und Handwerk
[34] WEIGL, JÜRGEN A. OE5CWL/OE6CWL (1988). A Shortened 40-Meter Four-Element Sloping Dipole Array. In: ham radio magazine, May 1988, pp74…78
[35] WHELAN, R.C. G3PJT (1988). An Electrically-Steerable Vertical Parasitic Array for 10 MHz. In: Radio Communication 01/1988, pp24…26/29

List of Figures