Summary: ***Multiband Windom antennas are easy-to-build, off-center fed dipole antennas offering low VSWR on multiple amateur bands without making use of lossy trap arrangements. The ON4BAA-300 multiband Windom achieves a lower VSWR than the traditional FD4 multiband Windom on the 80, 30 and 15m amateur bands by feeding the antenna closer to one wire end than usual. VSWR performance is worse only on 17m and slightly on 40m. Results for other bands are comparable and radiation patterns are similar. Computer modelling data, construction details and measuring data are provided in this text.***

History of the Windom Antenna

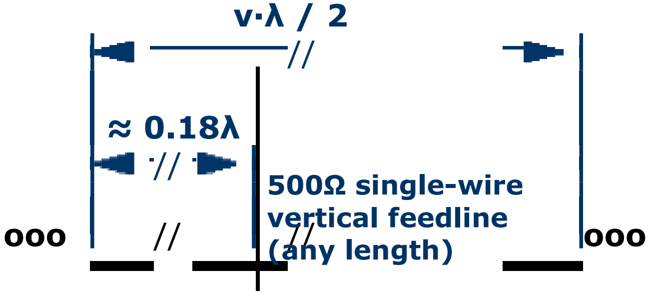
William Everitt

During the years 1923 to 1925, several single wire fed antennas (both horizontal and vertical) were being described in the ARRL's *QST* magazine. What made these antennas particularly interesting, was the fact that their single wire feedline, with a characteristic impedance of about 500Ω, could be easily matched to the valve amplifier end-stages of that time.

In October 1929, after some years of research, William L. Everitt (°1900 - †1986) and J. F. Byrne, both of the Ohio State University, published in the prestigious *Proceedings of the IRE* an exact method to tune the antenna to resonance and to match the single wire feedline. John D. Ryder, at that time student of Everitt, carried out many of the antenna measurings, according to an interview he gave in 1972.

However, Loren Windom, W8GZ, was first to reveal the antenna to the radio amateur community by describing the antenna in the September 1929 issue of *QST*. It was by Windom's name that the antenna got known outside the USA.

The Original Windom Antenna



So far, the Windom antenna (see figure below) was an off-center fed resonant dipole with a single wire feedline of any length and intended to be used on one frequency only. Its main advantages were its single wire feedline —would not be of any value anymore today because of propensity to cause RFI— and the fact that it could be easily matched to a valve amplifier.

In 1937, VS1AA was first to describe a compromise multiband Windom (see table for dimensions). The antenna can be employed on 80, 40, 20 and 10m with considerable, though acceptable levels of VSWR. Feeding is still done over a single wire, matched with a Collins filter to a valve amplifier.

What became perhaps the most popular multiband Windom design of all, was the German-made Fritzel FD4 antenna, described by the late Dr. Fritz Spillner[1], DJ2KY, in 1971. It had the same dimensions as the VS1AA multiband Windom antenna, but fitted with a 300Ω balun in its feedpoint and fed over coax. By the end of the 70's interest in the Windom antenna was revived, also by John Nagle's instructive article in *Ham Radio*[2].

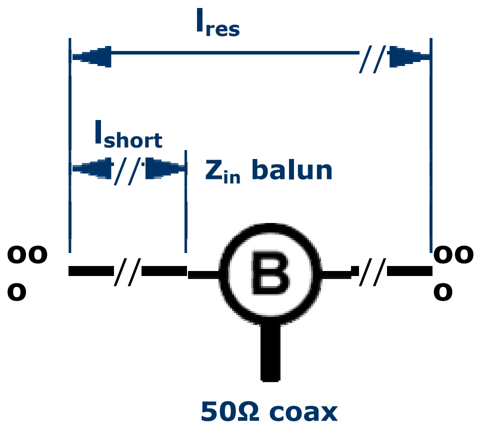
Today, many radio amateurs keep on using multiband Windom antennas with more than satisfactory results. It would not be without reason that Windom antennas are being employed during IARU HF World Championships! Nevertheless, attention for the antenna flowed a bit away over the years, especially with young ham operators (I am 29 at the time of writing). Perhaps many young hams ignore the multiband Windom antenna because of its sheer simplicity (like I did for some time) and may be thinking it is too good to be true. The complexity of feeding the G5RV, the losses in dipoles with traps and the esotheric marketing of some other antennas strangely seem to appeal more.

This article sets out to continue the tradition of the multiband Windom antenna, however by taking a careful look at its design with the latest, though proven, computer modelling techniques.

1. Fritz Spillner, DJ2KY, "Die FD4-Windom-Antenne," *QRV*, Stuttgart, **25**, Dezember 1971, pp.13-20
2. John Nagle, "Windom Antennas," *Ham Radio*, Greenville NH, May 1978, pp.10-19

Survey of Published Multiband Windom Designs (80m and up)

Rather than reinventing the wheel, every antenna project should start with a quick literature study of published similar antenna designs. Doing so for the Windom antenna (see table below), leads to the stunning revelation that, over these many years, antenna dimensions have not changed much from the original single-wire 500Ω design, whereas balun feedpoint impedances have decreased to 300 or even 200Ω! This, of course, raises concerns in any suspicous mind. Even more so, it triggered the desire to design my own version of the antenna, resulting in a feedpoint location much different from the usual, but with better VWSR performance by the way. Continue reading to read to learn all about this novel Windom antenna...



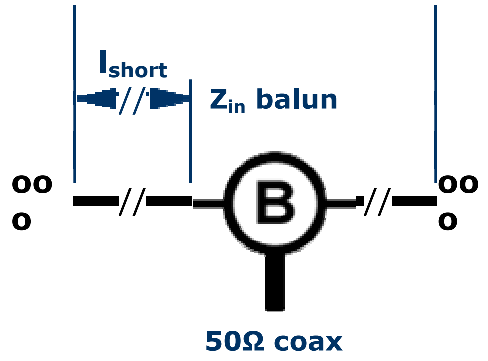
design	designed for Z_{in} (Ω)	l_{res} (m)	l_{short} (m)	offset (center = 0%)	offset (center = 90°)	h_{agl} (m) & configuration	bands (m)
VS1AA[1]	500	41.00	13.60	33.7%	60°	single-wire fed	
K3MT	450	42.06	12.65	39.8%	54°	4.6 to 13.7	
FD4[2]	300	42	14	33.3%	60°		

FD4[3]	300	41.45	13.50	34.9%	59°	≈ 8	80, 40, 20, 17, 12 & 10
I7SWX[4,5]	300	41.0	13.5	34.1%	59°		
ON4BAA	300	41.00	8.10	60.5%	36°	13.5	80, 40, 20, 15, 12 & 10
K8SYH	300	39.08	12.74	34.8%	59°		
JA7KPI	200	41.0	13.6	33.7%	60°	11.0 inverted V	80, 40, 20, 17 & 10
ON4BAA	200	41.00	6.25	69.5%	27°	13.5	80, 40, 20, 17 & 10
K4ABT	200	40.5	13.4	33.8%	60°	6.1 to 12.2	

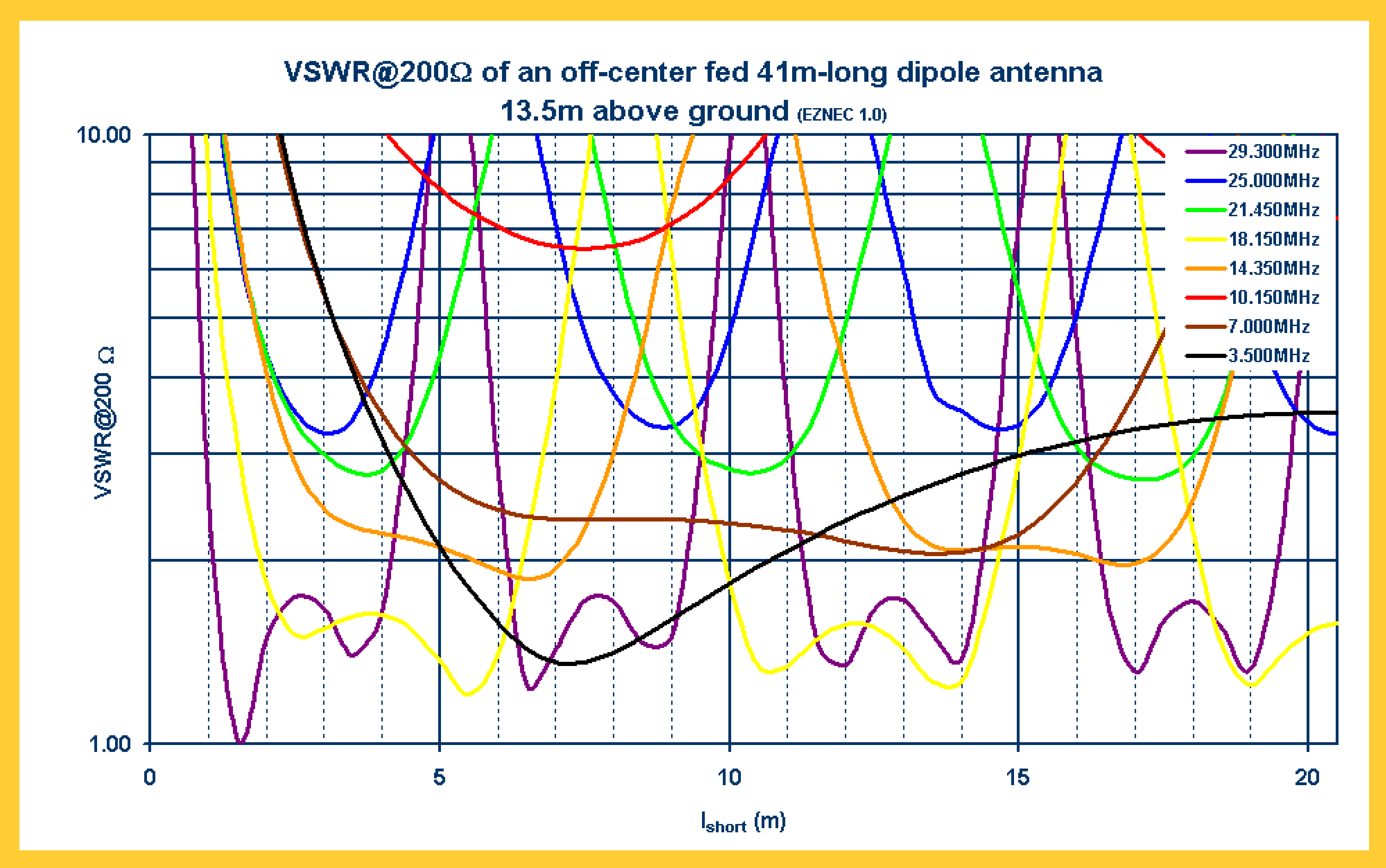
1. Karl Rothammel, Y21BK, *Antennenbuch*, Franckh-Kosmos, 10. Auflage, 1991, p.159
2. Fritz Spillner, DJ2KY, "Die FD4-Windom-Antenne," *QRV*, Stuttgart, **25**, Dezember 1971, pp.13-20
3. Karl Rothammel, Y21BK, *Antennenbuch*, Franckh-Kosmos, 10. Auflage, 1991, pp.159-162
4. Gian Moda, I7SWX, "Technical Topics," *RadCom*, March 1988
5. Erwin David, G4LQI, *HF Antenna Collection*, RSGB, 1st Edition, 1992, p.9

Note: All of the above-mentioned designs are antennas with their lowest resonant frequency in the 80m band. Scaled down versions of this antenna (e.g. 40 or 20m designs) are also possible but will not be discussed in this text.

Theory of the Multiband Windom Antenna

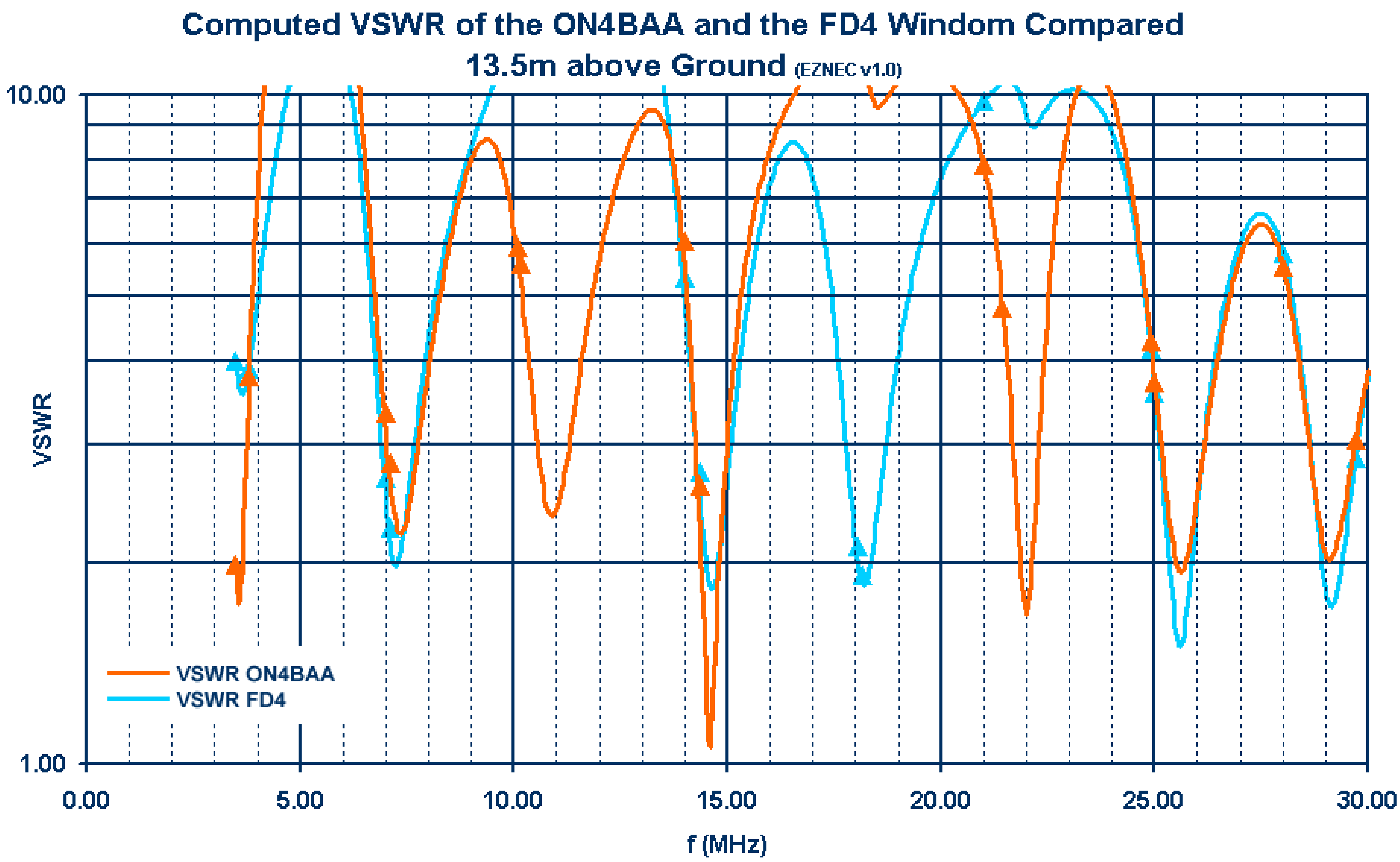


VSWR@200Ω of an off-center fed 41m-long dipole antenna 13.5m above "rich" ground (σ = 17mS/m and ε_r = 13)



VSWR@200Ω of an off-center fed 41m-long dipole antenna
13.5m above ground (EZNEC 1.0)
10.00
1.00
VSWR@200 Ω
0
5
10
15
20
lshort (m)
29.300MHz
25.000MHz
21.450MHz
18.150MHz
14.350MHz
10.150MHz
7.000MHz
3.500MHz

Comparison of Computed VSWR between the ON4BAA-300 and FD4 Windom


Computed VSWR of the ON4BAA and the FD4 Windom Compared
13.5m above Ground (EZNEC v1.0)
10.00
1.00
VSWR
0.00
5.00
10.00
15.00
20.00
25.00
30.00
f (MHz)
VSWR ON4BAA
VSWR FD4

VSWR comparison between ON4BAA-300 and FD4 Windom 13.5m above "rich" ground (σ = 17mS/m and ε_r = 13)								
design	80m	40m	30m	20m	17m	15m	12m	10m
ON4BAA-300	++	–	+++	=	–––	+++	=	=
FD4*	––	+	–––	=	+++	–––	=	=

*Note: The FD4 Windom is a 300Ω balun-fed antenna with l_{res} = 41.0m and l_{short} = 13.5m.

Conclusion: ***The ON4BAA-300 Windom achieves a lower VSWR than the traditional FD4 Windom on the 80, 30 and 15m bands by feeding the antenna closer to one wire end than usual. VSWR performance is worse only on 17m and slightly on 40m. Results for other bands are comparable.***

Computer Synthesis and Analysis of a 300Ω Coaxially-Fed Windom Antenna

Design Goal

The goal I set out, was to design a balun-fed multiband Windom antenna around the Wimo 1kW 300Ω → 50Ω balun with minimum VSWR on the SSB-segments of the Region 1 80, 40 and 20m amateur bands. Short of time, I preferred to buy a balun instead of building one myself. Based on my brief literature study and the fact that L. B. Cebik, W4RNL, showed how, anyhow, feedpoint impdance of an off-center fed dipole is highly sensitive to antenna height, a 300Ω balun seemed to be a "can-do-little-wrong" choice. By making this choice, I consciously threw away the possibility to design for *optimal* feedpoint impedance, but with the blessing of W4RNL!

Nevertheless, being a bit wary of the discrepancies between published resonant lengths and optimal feedpoint locations and impedances (see comparitive table above), I decided to redetermine by computer modelling the optimal feedpoint location for a 300Ω balun, as well as the resonant length optimum for operation in the Region 1 bandplan. Too my big surprise, the exercise resulted in an unusual design with improved VSWR performance for the not uninteresting 15m band.

I have a small Yagi beam for 20, 15 and 10m, so I was only interested in designing a 80 and 40m workhouse antenna with backup for 20m. Low VSWR on other bands were considered as a lucky extra. However, you will see this comes almost naturally with this antenna, and this design is not an exception!

Design Tools and Strategy

The only optimisation or synthesis program for wire antennas that I am aware of is Antenna Optimizer (AO) v6.5 by Brian Beezley, K6STI (click to order your copy by e-mail). Almost any dimension can be optimised with this very powerful software. The program is based on the well-known MININEC code, a speed-optimised, reduced version of an older NEC code that will run extremely fast on today's PCs.

Being based on MININEC, Antenna Optimizer carries along only one inconvenience: Ground characteristics are used only to determine the ground-reflection factor for computing the far-field radiation patterns. AO employs a perfectly conductive ground-plane when calculating antenna wire currents. This implies that ground-current losses are not accounted for. While these losses normally are negligible for horizontal antennas higher than about 0.2 wavelength, they can be significant for low horizontals and for verticals fed against poor ground systems. In these cases, the reported gain may be too high and the calculated impedance too low. For this reason, the design tool set will be complimented with **EZNEC v1.0** by Roy Lewallen, W7EL, that does not suffer from this problem, but that unfortunately does not include an optimisation engine.

Above-mentioned considerations lead to the following iterative modelling strategy:

- Resonant length is manually optimised for best Region 1 performance.
- AO automatically determines the optimal 300Ω feedpoint location with lowest VSWR on 80, 40 and 20m.
- The design synthesised by AO is analysed and checked with EZNEC.

The Antenna Optimizer and EZNEC Files

```
ON4BAA Windom FD4 for 80m and up
over ground
1 zone
13 17 0         ; dielectric constant, conductivity, height
30.000 MHz

2 copper wires, mm
wdiam = 2.26           ; antenna wire diameter
h = 13500              ; antenna height
reslength = 41000      ; resonant antenna lenght
shortleg = 8100        ; short antenna leg

longleg = reslength - shortleg

1 0 -shortleg h        0 0 h          wdiam   ; shortleg
1 0 0 h                0 longleg h    wdiam   ; longleg

1 source
Wire 1, End2
```

This .ANT file was used to optimise the Windom antenna using Antenna Optimizer (AO) v6.5 for lowest VSWR on 80, 40 and 20m bands with 300Ω input impedance. The resonant length of the antenna was optimised manually to 41m. The length of the short antenna leg was initially set to 13.5m and then left for automatic optimisation by AO. This resulted in a optimum short leg lenght of 8.1m.

One word of caution concerning the .ANT file: The wavelength considered during AO's automatic segmenting (on option that is on by default), is based on the design frequency specified in the .ANT file. For the most accurate modelling, the frequency stated should be the highest operating frequency of the antenna (around 30MHz in our case). Different modelling frequencies can be specified via AO's menu.

Download the ON4BAAWD.ANT file here.

Also available for downloading:

- The ON4BAAWD.EZ file for modelling the ON4BAA-300 Windom with EZNEC
- The FD4.EZ file for modelling the FD4 Windom with EZNEC

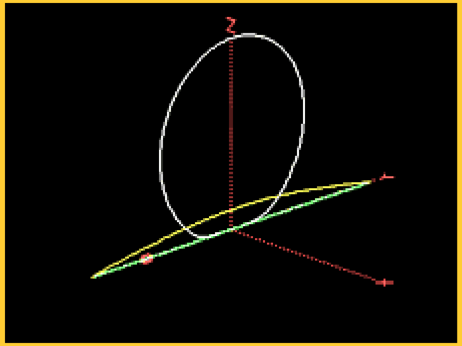
Computed Current Distribution and Radiation Patterns of the ON4BAA-300 Windom

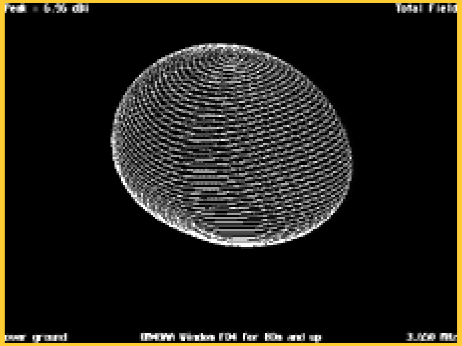
The radiation pattern is broad-side for 80m (3.650MHz), i.e. what would be expected of an off-center fed dipole. On all other bands, radiation is predominantly end-fire. The radiation patterns on 80 and 40m show high take-off angles for the main lobes. This is solely due to the low height of the antenna above ground. Putting the antenna hire up would immediately solve this problem for the serious low-band DX work.

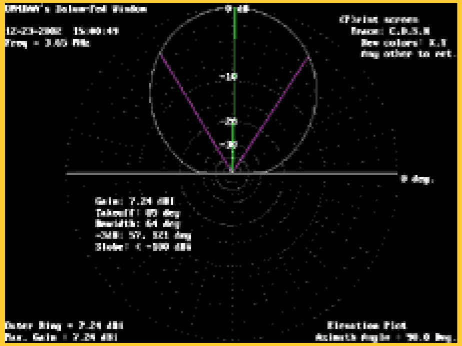
Evident from the computed current distribution at 18.100MHz (17m band) is that the antenna appears to be severly mismatched on this frequency. The low current in the short leg of the antenna is proof of an extremely high input impedance at the feedpoint. All other observed radiation patterns and current distributions are entirely normal and desired.

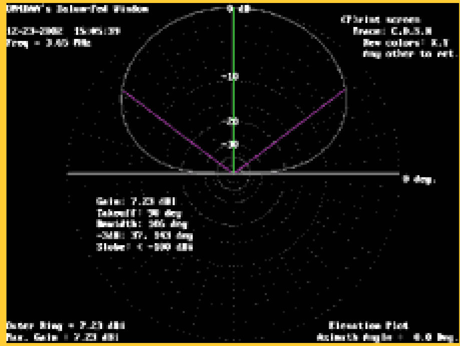
ON4BAA-300 Windom antenna 13.5m above "rich" ground (σ = 17mS/m and ε_r = 13)				
f (kHz)	current distribution & elevation pattern at 90° azimuth (EZNEC v1.0)	3D radiation pattern (AO v6.5)	elevation pattern at 90° azimuth (EZNEC v1.0)	elevation pattern at 0° azimuth (EZNEC v1.0)

_3650









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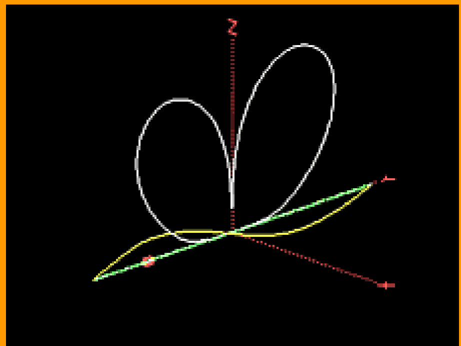

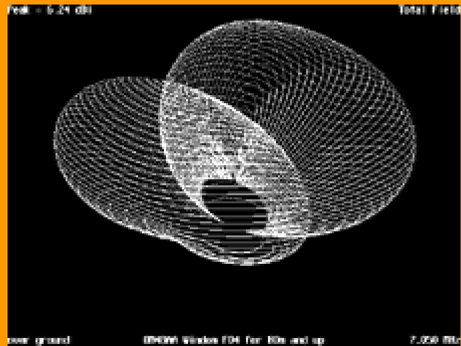

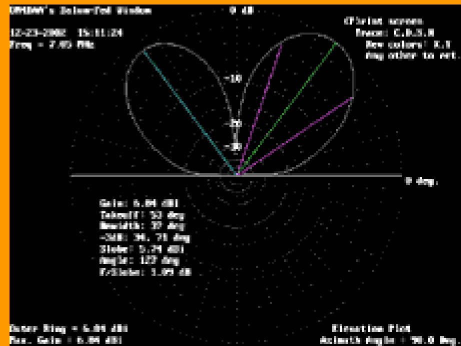

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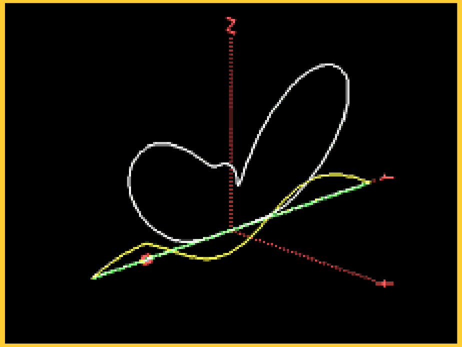
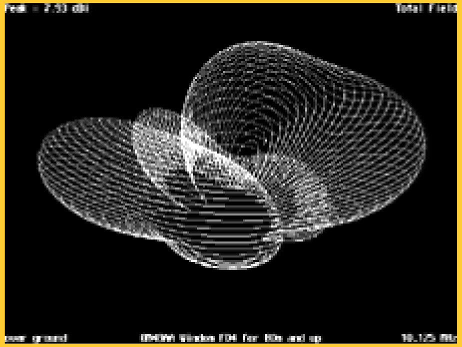
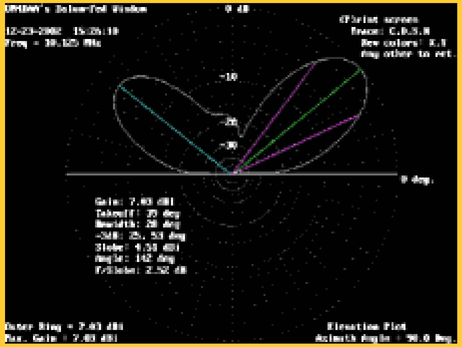
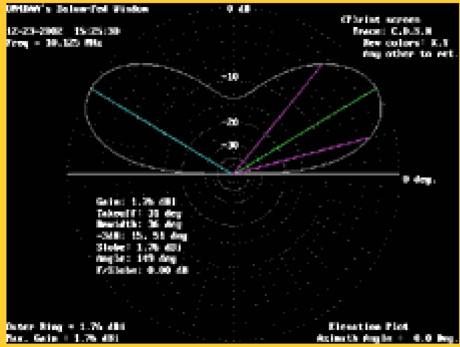
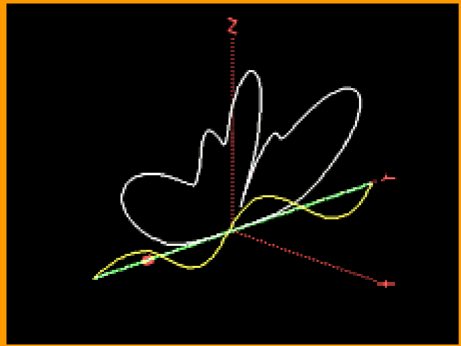
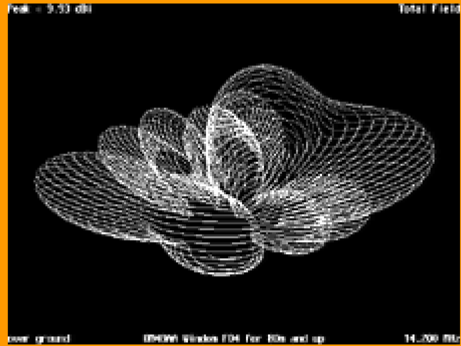
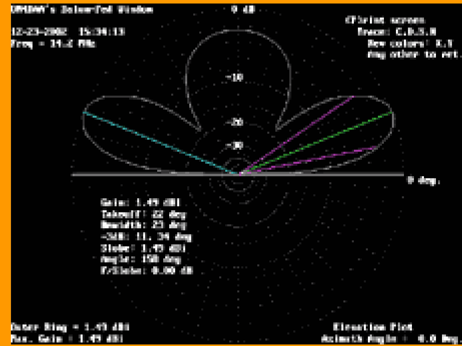
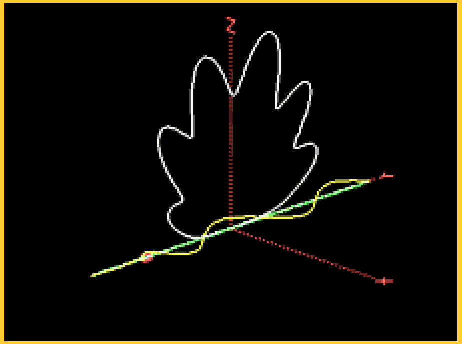
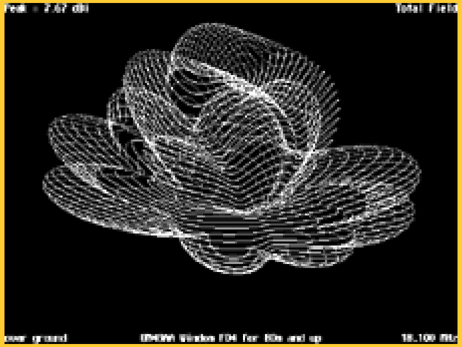
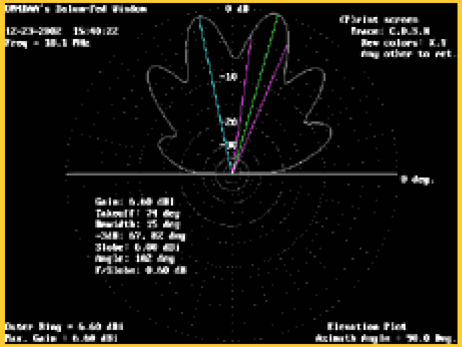
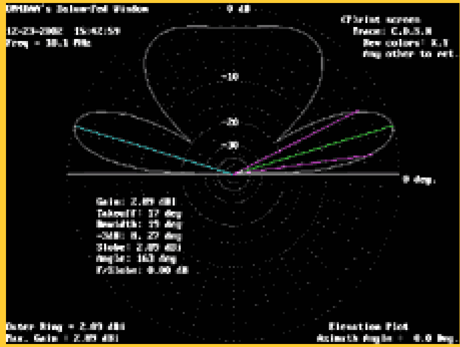
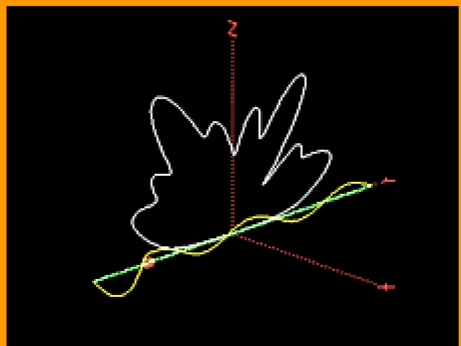
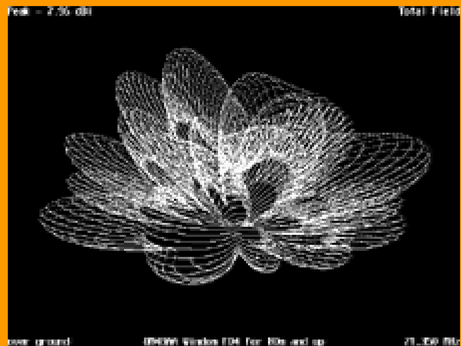
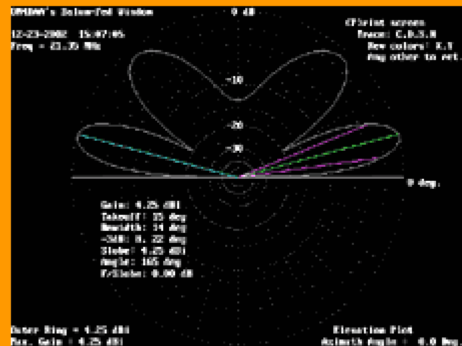
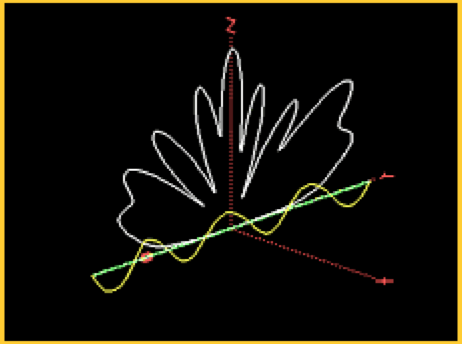
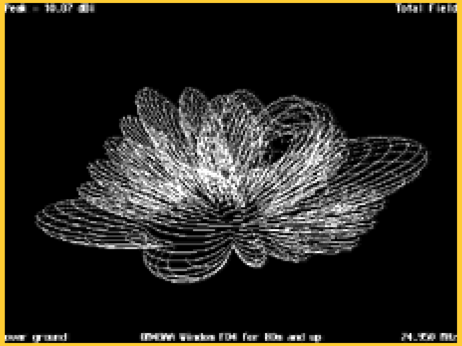
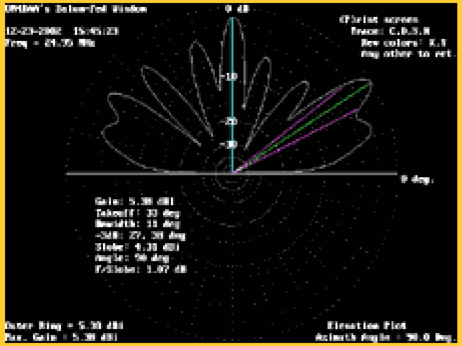
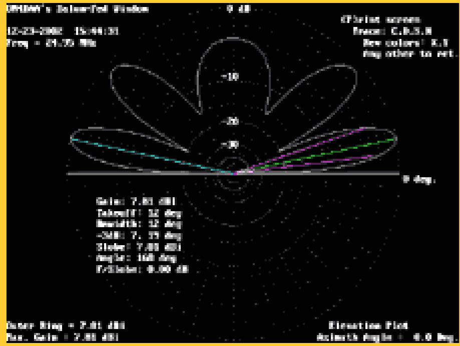
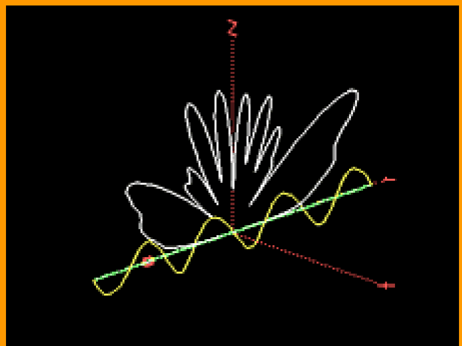
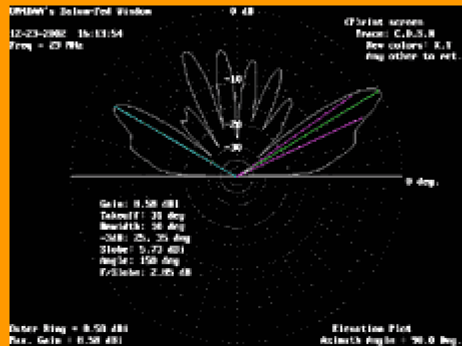
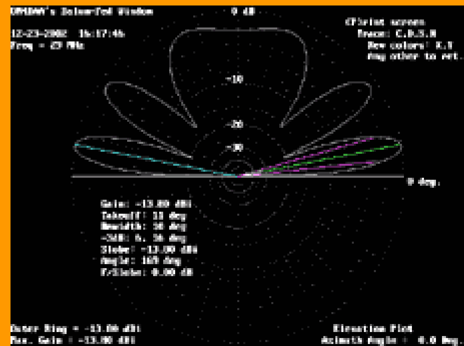








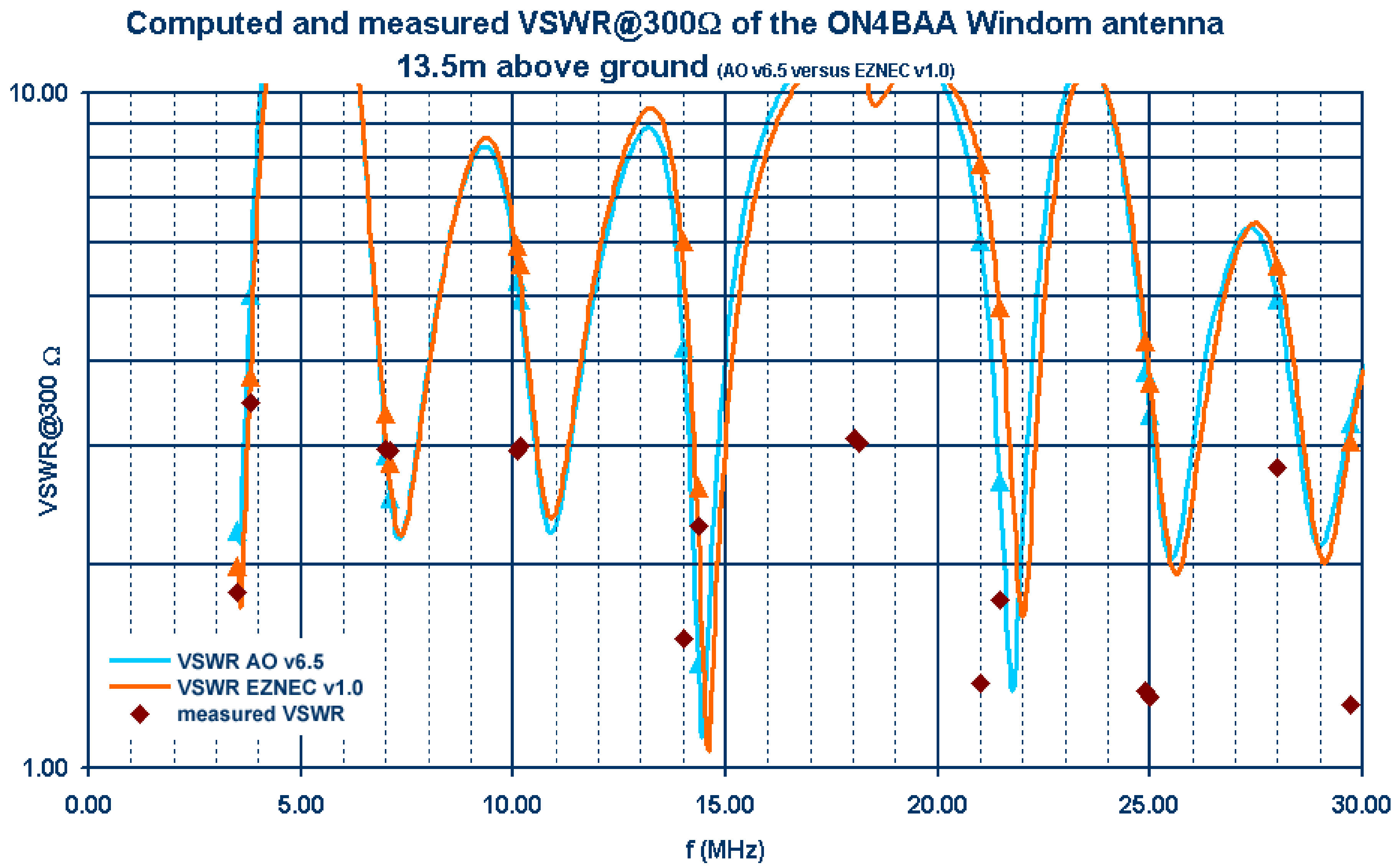
14200				
18100				
21350				

24950				
29000				

Computed Feedpoint Characteristics of the ON4BAA-300 Windom

Below graph and table clearly show how Antenna Optimizer v6.5 consistently reports lower feedpoint impedances than EZNEC v1.0. As explained before, this is due to AO using a perfectly conductive ground-plane for the calculation of the antenna currents.

EZNEC should be reporting the more reliable result, but AO results happen to be closer to the measured results due to the proximity of a flat building roof, not modelled in any of these simulations. How the antenna can be modelled also taking into account the influence of a flat roof will be explained later.

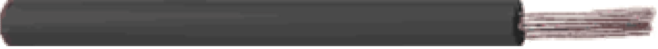


Computed and measured VSWR@300Ω of the ON4BAA Windom antenna
13.5m above ground (AO v6.5 versus EZNEC v1.0)
10.00
1.00
VSWR@300 Ω
0.00
5.00
10.00
15.00
20.00
25.00
30.00
f (MHz)
VSWR AO v6.5
VSWR EZNEC v1.0
measured VSWR

Also visible on this graph, is the trade-off decision that was taken concerning VSWR perfomance on the 80 and 40m bands: the resonant length of the antenna was chosen so that the first peak of high VSWR is fitted as neatly as possible between the 80 and 40m bands. For the IARU Region 1 HF bandplan, the radioamateur bands above 80m are not exact harmonics of the higher end of the 80m band. At the end, the resonant length of the antenna was chosen for minimum VSWR on 80, 40 and 20m. Consequently, the high-end 80m band underperformance is an expectable and unavoidable result.

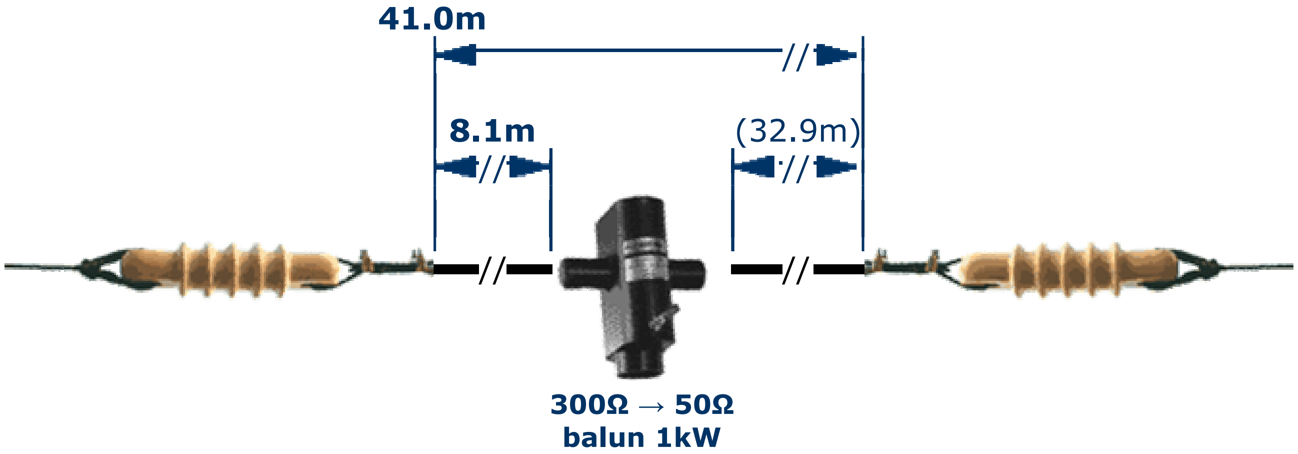
ON4BAA-300 Windom antenna 13.5m above "rich" ground (σ = 17mS/m and ε_r = 13)

f (MHz)	VSWR @ 300Ω (AO v6.5)	Z_{in} (Ω) (AO v6.5)	VSWR @ 300Ω (EZNEC v1.0)	Z_{in} (Ω) (EZNEC v1.0)	I (A) @ P = 1kW (EZNEC v1.0)	U (V) @ P = 1kW (EZNEC v1.0)
3.650	2.82	210+j257	2.073	231.2+j183.8	2.080	614.3∠+38.49°
7.050	2.69	114–j46	2.825	112.1–j65.89	2.987	388.4∠–30.44°
10.125	5.10	162–j376	5.424	177.2–j420.4	2.376	1084∠–67.14°
14.200	2.38	418–j294	3.499	495.7–j476.6	1.420	976.7∠–43.88°
18.100	12.68	2637–j1747	11.932	3547+j337.9	0.531	1892∠+5.44°
21.350	3.37	267–j364	5.576	404.5–j666.9	1.572	1226∠–58.76°
24.950	3.59	113–j168	3.990	128.2–j238.0	2.793	755.0∠–61.69°
29.000	2.13	143+j31	2.063	149.5–j43.89	2.586	403.0∠–16.35°



Physical Construction of the ON4BAA-300 Windom

Dimensions of the ON4BAA-300 Windom



Antenna Wire

There happens to be a lot of fuss about antenna wire. Most radioamateur shops sell "special" antenna wire at unreasonably high price, whilst most of the claims made about these wires are untrue. The situation reminds me a bit of the many loadspeaker cable myths. However, a less expensive and even better alternative exists.

For all my wire antenna projects I have always used extremely flexible and relatively cheap black-coloured 4mm² HO7V-K4 wire (also called VOBst in Belgium), made out of 51 tinned-copper braided strands. The tinned-copper braided strands are what make the wire so extremely flexible. The tin around each of the copper strands prevent the copper from oxidating and makes soldering of the wire easier. After all, VOBst wire is designed for use in bathrooms! Nevertheless, I always make sure to cap the wire ends with a dot of clear glue. Better safe than sorry. The black PVC insulating sheet is perfectly UV-resistant, so neither there any problems.

I operated my antennas for many years without any issues despite some severe weather, salt and strain exposure. You probably will have to order this cable from your local electric hardware store, but most European stores will be able to get it for you without much delay.

Connecting the Balun in a Weather-Proof Way

As mentioned earlier, the antenna was designed around a WiMo 1kW 6÷1 balun. However, any other 300Ω → 50Ω balun with appropriate power rating and proper weather sealing will do just fine. European citizens can easily order the WiMo balun online from the WiMo shop. Shipment out of Germany is usually very quick and correct. The balun is well-designed with appropriate strain reliefs, watter gutter and stainless steel connection hardware. The unit cannot be opend because it is filled with a raisin.

I screwed a UHF-to-N adaptor on the female UHF-connector of the balun. This way, I could solder an "almost water-tight" N-connector to my coaxial cable. Of course, after connecting, everything should be properly taped "bottom upwards" (see figure) also to prevent water from entering the connection.

The little wire lugs provided with the balun were first soldered and then crimped to the antenna wires. The lugs were then bolted to the balun with the stainless steel hardware. Glue was inserted between the PVC sheet of the antenna wire and the plastic of the wire lug. Since the lugs are not of stainless steel, I sprayed a tiny bit of metal varnish on the connection, just to make sure. (In Belgium it rains nearly all the time and this in combination with the North Sea salt spray in the air does no good!)

The balun was hung from a black PP rope with a slightly adapted rolling hitch knot in combination with a Flemish figure eight knot as a stop knot. (For more information about knots and rope, please continue reading.)

rolling hitch **Flemish figure eight stop knot**

In my opinion, it is difficult to build a balun any better or cheaper than WiMo did. If, anyhow, you would like to give it a try, I would recommend to first read some chapters of the following balun reference work: Jerry Sevick, W2FMI, *Transmission Line Transformers*, ARRL, 1996.

Insulators, Cable Clamps, Ropes and Knots

At the antenna ends I use two second-hand porcelain insulators, salvaged from a shipping vessel in the harbour of Ostend. The antenna wire is fixed with two 4mm stainless steel cable clamps to a small length of black polypropylene (PP) rope that loops through the connection hole of the porcelain insulator. A similar procedure is used to connect the antenna wires to the strain reliefs of the balun. (See pictures.) For your information, the stainless steel clamps and black polypropylene (PP) rope were bought in a sailing hardware shop.

I never make nots in antenna wires, only in the ropes that connect the insulators to the supporting structures! To tie the PP rope to the insulator, it is convenient to use a bowline knot, sometimes in combination with a Flemish figure eight knot as a stop knot. (Reload this webpage to start the tying animations again.) For instructions and more animated knots, please refer to the excellent page of the 42nd Brighton (Saltdean) Scout Group, East Sussex, UK.

bowline knot

Flemish figure eight stop knot

Installation

The antenna is installed at an average height of 1.5m above flat building block roofs, the building block itself being approximately 12m high and located on the top of a small hill in the center of Zaventem (XXm ASL, QTH locator: JO 20 FV, 125km away from the North Sea coast, 11km northeast from Brussels). Ground conductivity and relative permitivity at HF frequencies are estimated at 17mS/m and 13 respectively.(See *World Atlas of Ground Conductivity*.) The antenna is kept up in the air by attaching it at several points to 2m high chimneys.

Both the short and the long leg of the antenna are folded about 90° at approximately 50% of their respective lengths, this to make the antenna fit on the available roof space. The interesting by-product of this action is a slightly more omni-directional radiation pattern. The effect on the input impedance of the antenna should be very limited.

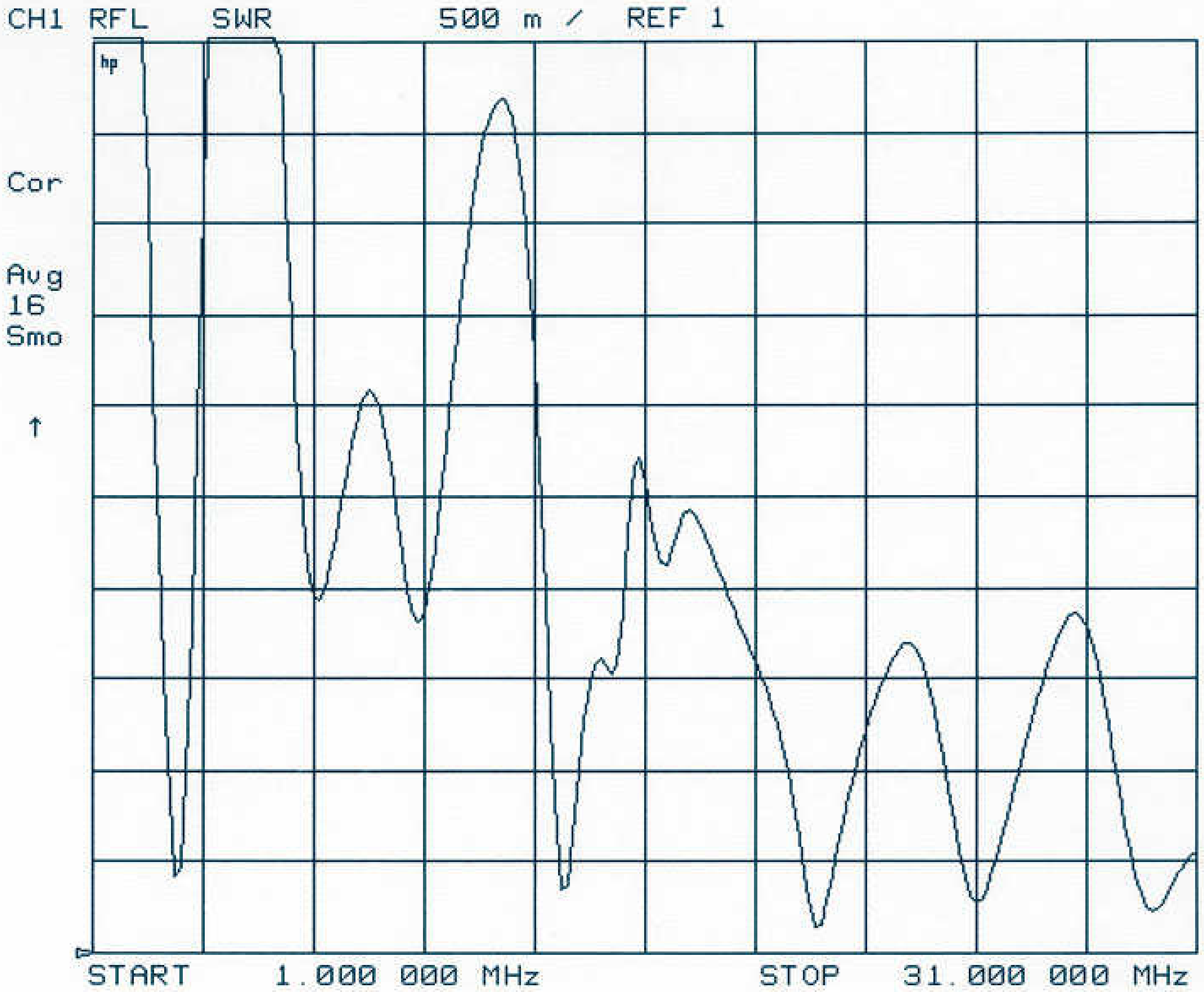
Modelling the Bent ON4BAA-300 Windom over a Flat Roof

Working on it, come back soon!

information about modelling a flat roof top

The overall lower measured VSWR of the antenna when compared with the computed VSWR must be entirely due to the proximity of the supporting building, significantly influencing the antenna's resonant frequency and input impedance. This phenomenom has been modelled by L. B. Cebik, W4RNL and graphs were published in his "Fundamentals of Off-Center-Fed Dipoles" antenna technical.

Measured VSWR Performance of the Bent ON4BAA-300 Windom over a Flat Roof


CH1 RFL SWR 500 m / REF 1
hp
Cor
Avg
16
Smo
START 1.000 000 MHz
STOP 31.000 000 MHz

BACK

marker	band	f (MHz)	VSWR
0	80m	3.500	1.817
1	80m	3.800	3.484
2	40m	7.100	2.956
3	30m	10.10	2.955
4	20m	14.000	1.557
5	20m	14.350	2.277
6	17m	18.15	3.029
7	15m	21.45	1.769
8	12m	24.99	1.274
9	10m	28.000	2.794
10	10m	29.700	1.244

Figure & table: VSWR of the bent ON4BAA-300 Windom antenna ove a flat roof, as measured with a calibrated HP8752C vectornetworkanalyzer

Please also refer to the above section for a detailed descirption of the physical installation of the measured antenna.

VSWR was measured by means of a HP8752C vectornetworkanalyser with the reference plane for calibration at the antenna feedpoint, i.e. right at the coaxial connector of the balun. As can be appreciated from the adjoining graph and table, the antenna has superb VSWR characteristics on all HF bands, including WARC. Furhtermore, apart from the 80m and 10m bands, VSWR is nearly constant inside all other HF radioamateur bands.