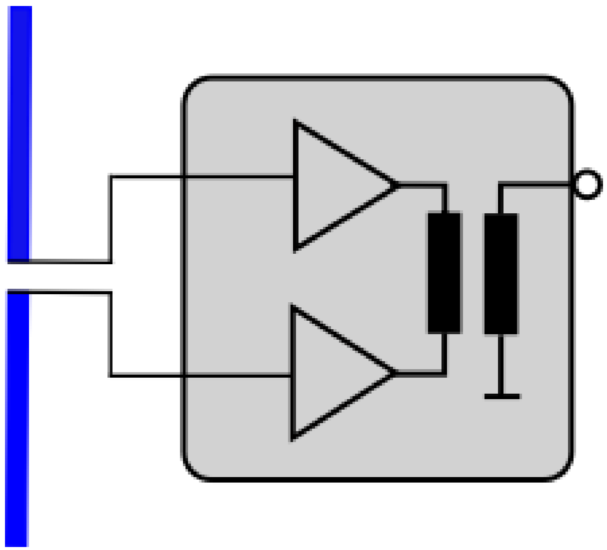


Short Active Dipole Antennas

Considerations about the use of balanced active antennas for reception.

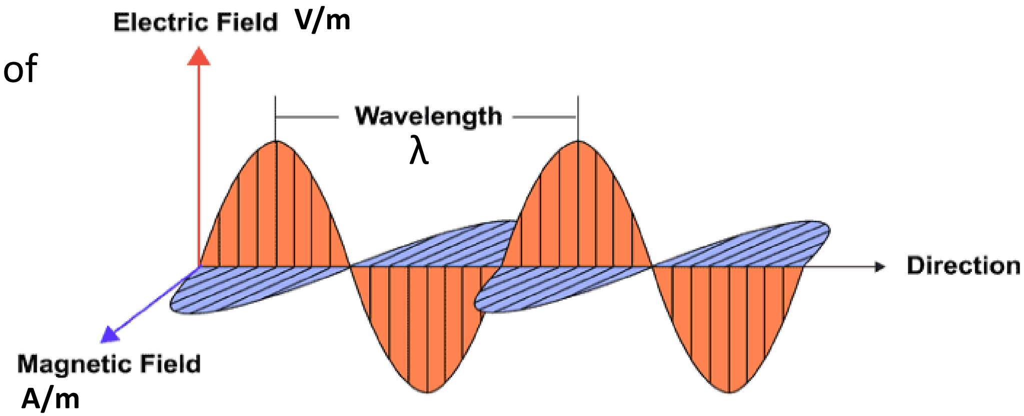
Basic principles and practical examples.

Guenter Fred Mandel, DL4ZAO
mail@activeantenna.net
www.dl4zao.de

Electromagnetic Waves

An electromagnetic wave always consists of an electric and a magnetic component

- ***E*-Field** (Electric Field) and
- ***H*-Feld** (Magnetic Field)

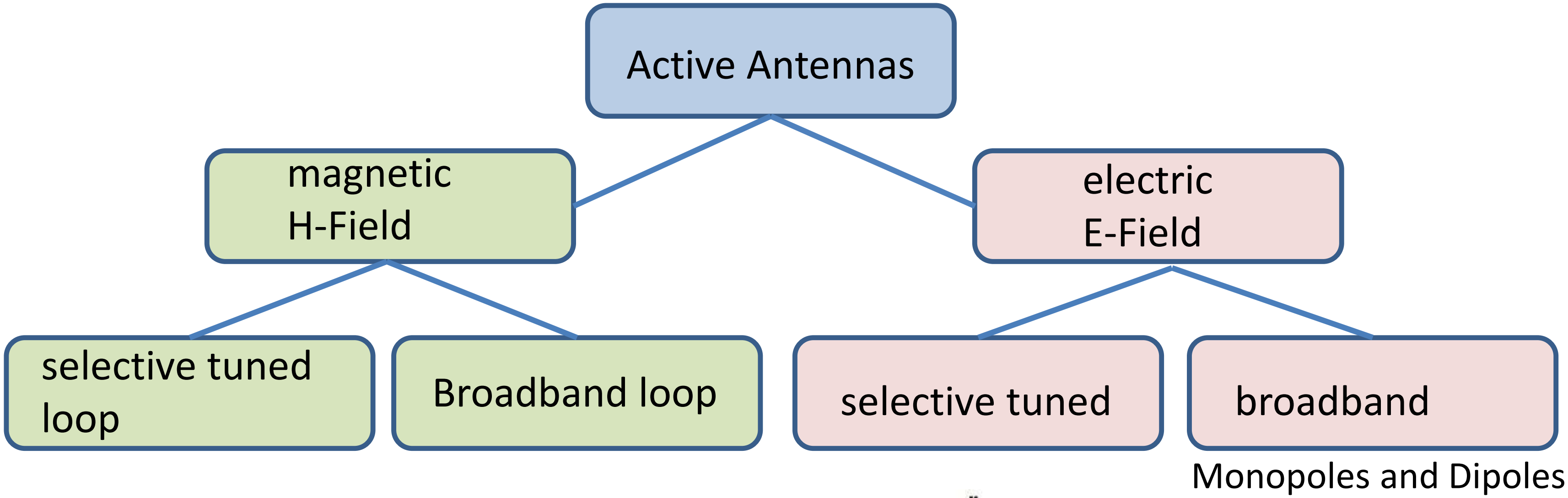


- In the far-field of an antenna, the electromagnetic wave propagates with light-speed. Electric Field and magnetic Field are in phase. They are perpendicular to each other and perpendicular to the propagation direction.

- Electromagnetic waves travelling in free space or in air have a fixed proportional relationship between the electric fieldstrengh in V/m and their magnetic fieldstrengh in A/m. The proportionality factor is named „characteristic impedance“ or „wave impedance“ and has the value of 377 Ω. (Why Ω for this factor? V/m divided by A/m has the dimension of a resistance R in Ω)

- If the electric fieldstrengh is known, the magnetic fieldstrength can be easily calculated; or vice versa. Both components are always linked together by the wave impedance of 377 Ω.

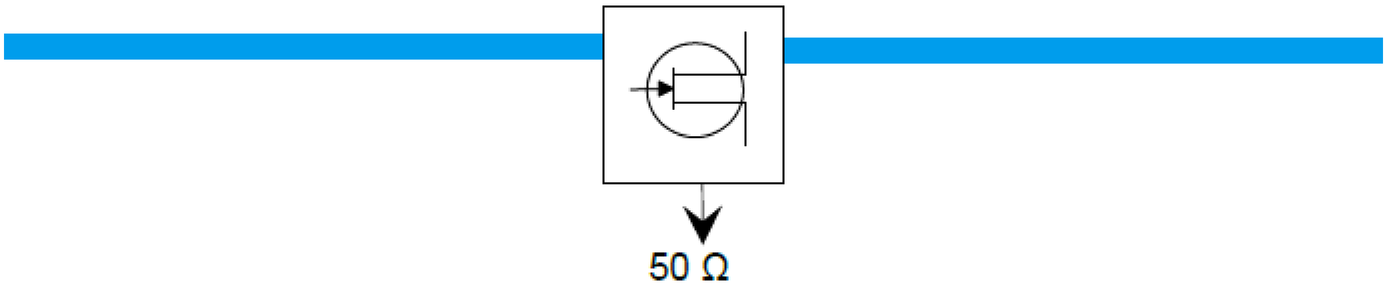
Active antenna types



Active antennas are by definition antennas in which an active element is attached directly to the electrically short radiators. They are non reciprocal and can obviously be used for reception only.

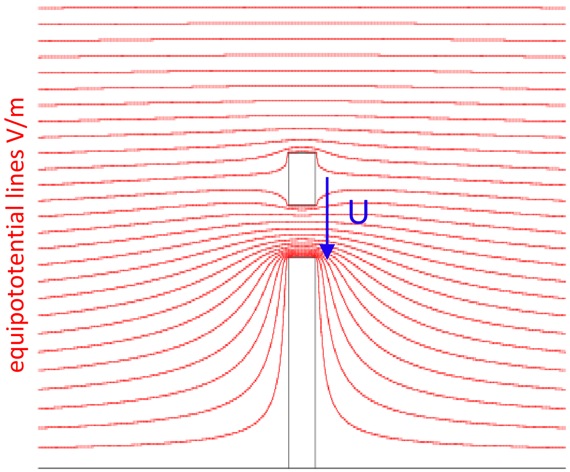
Active dipole principle

Shortening the radiator is associated with extreme changes in the impedance. For active rod or dipole antennas this is compensated by feeding the signal voltage on the terminals of the antenna directly to a very high-impedance active component (usually a field effect transistor) which acts as an impedance transformer and also commonly amplifies at the same time.

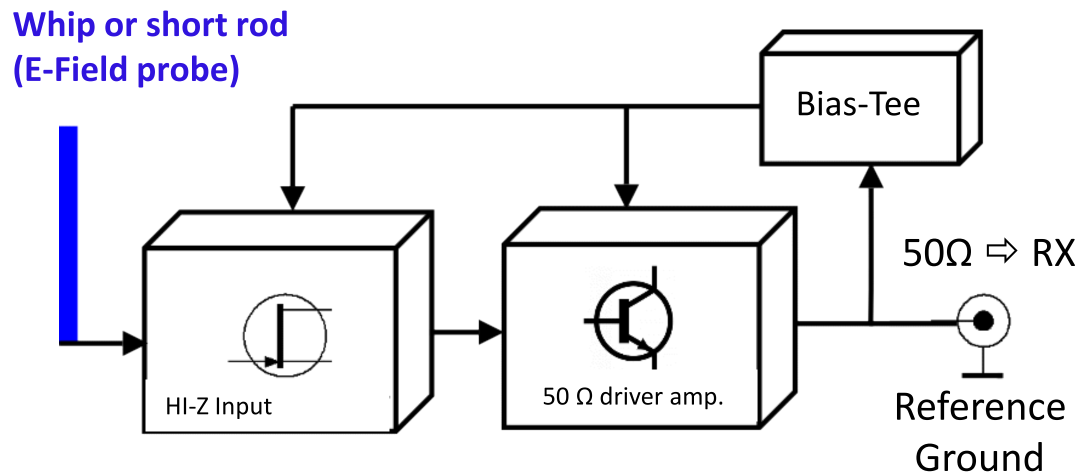


A monopole or a dipole ist defined as short, if its length is less than 0.15 λ. Short dipoles are broadband antennas. They react mainly sensitive to the electrical field of a radio wave and are therefore sometimes called E-field Antenna. Their magnetic eqivalent is the small magnetic loop, which is defined as a loop with a circumference less than 0.15 λ.

Active monopole (Whip) – principle of operation



drawing: PA3FWM

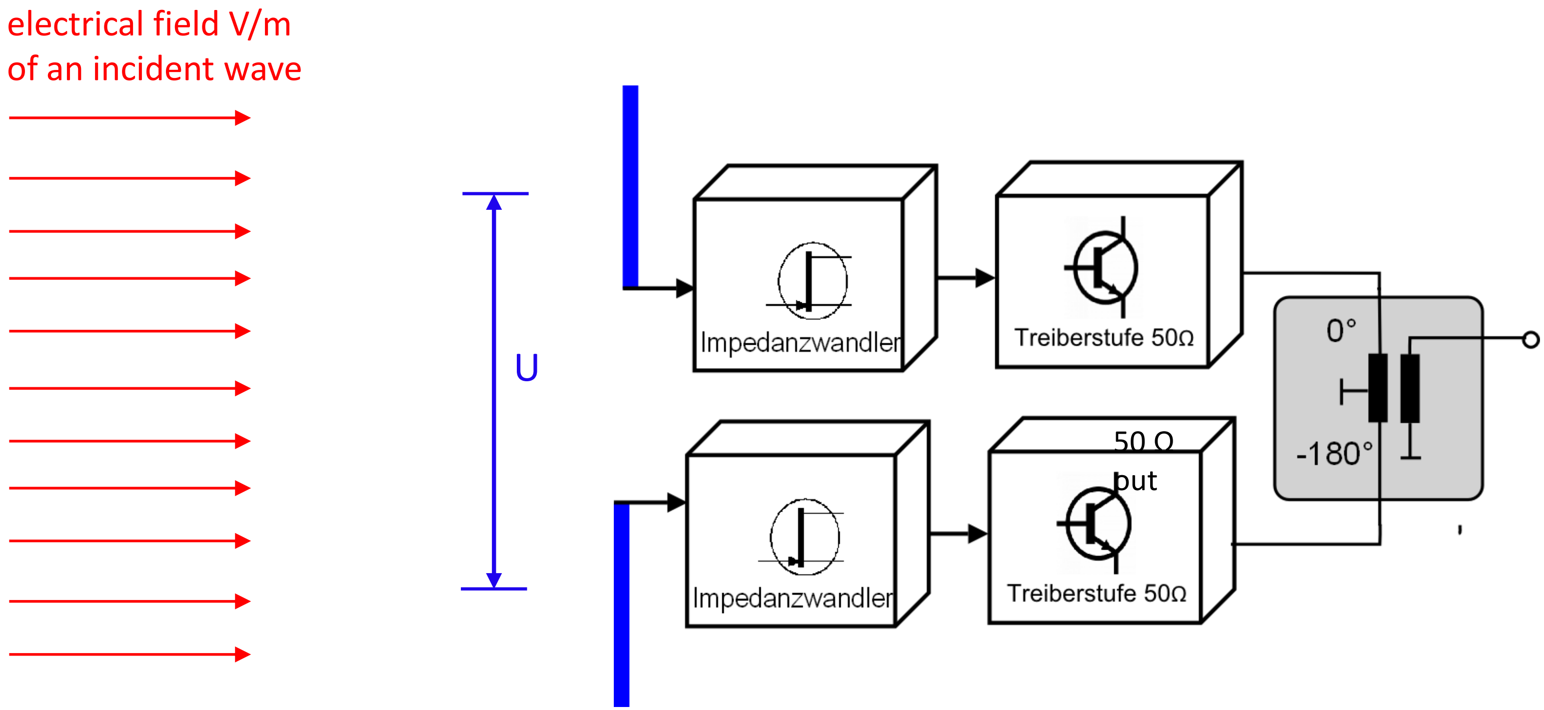


- A short antenna element (l < 0.15λ) is acting as a field probe to the electric field of an incident wave.

- A Hi-Z Impedance converter picks up the potential-difference (voltage U) to the reference ground. Reference ground is in practise the potential at the outer shield of the amplifiers connector. The reference potential varies with the heigth of the mast! [7]

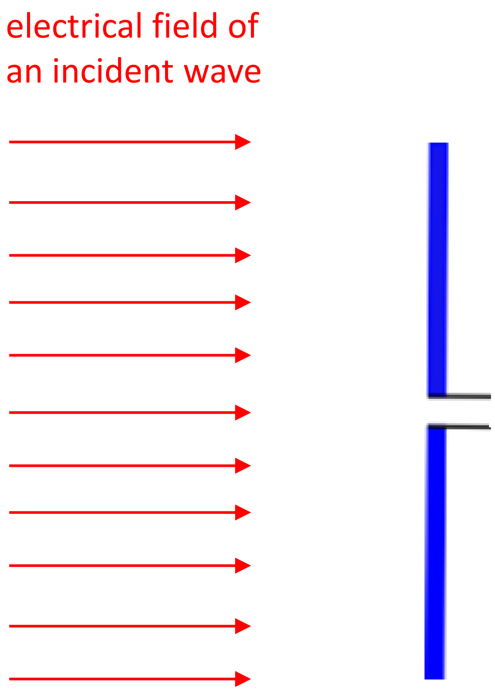
- A driver stage amplifies the power so that a 50 Ohm coaxial cable can be connected.

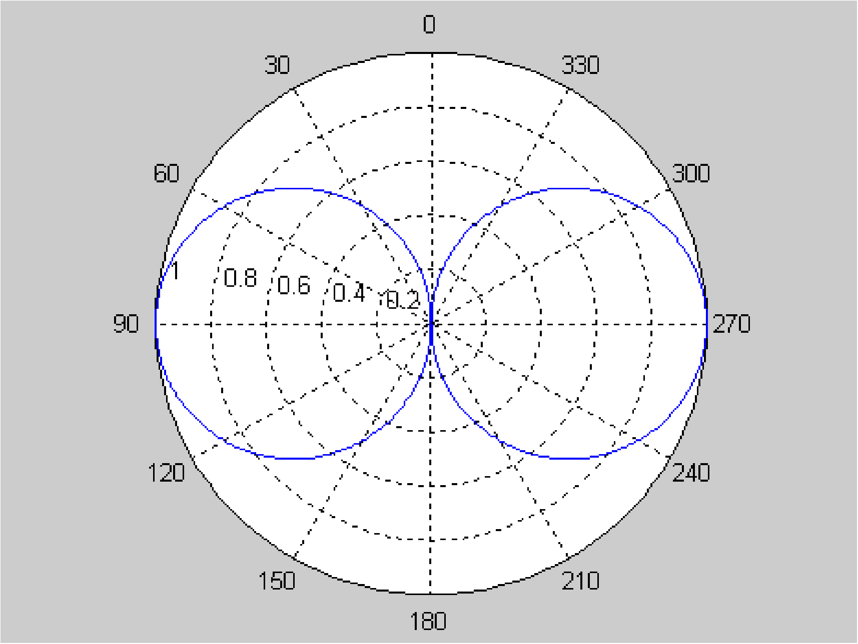
short active dipole - balanced Hi-Z amplifier



- Two antenna elements (l < 0.15λ) pick up the differential voltage U across the dipole legs
- Only the differential voltage U across the dipole legs is beeing amplified
- Unwanted common mode voltages between dipole and ground potential is rejected. (CMRR)
- This differential voltage is ideally independent from earth- mast- and coax-shield potential.

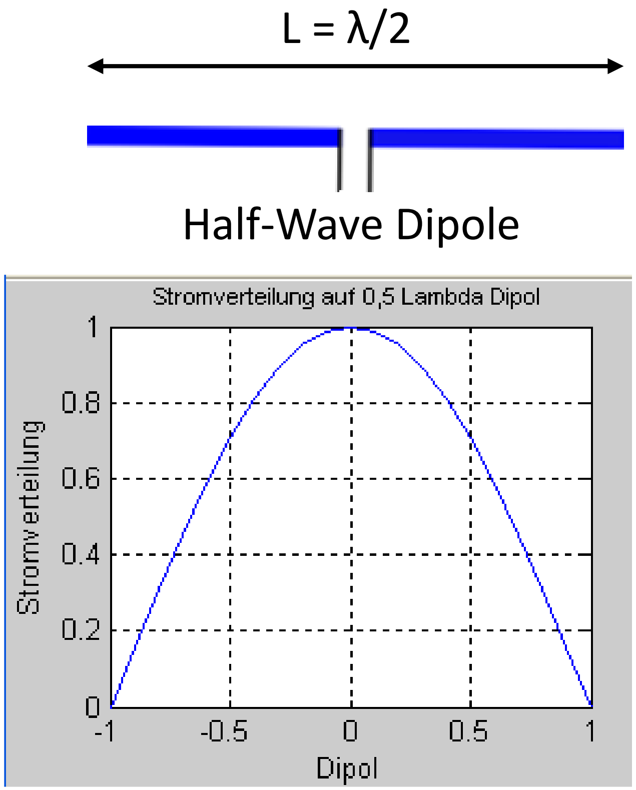
Horizontal radiation diagram of a short dipole

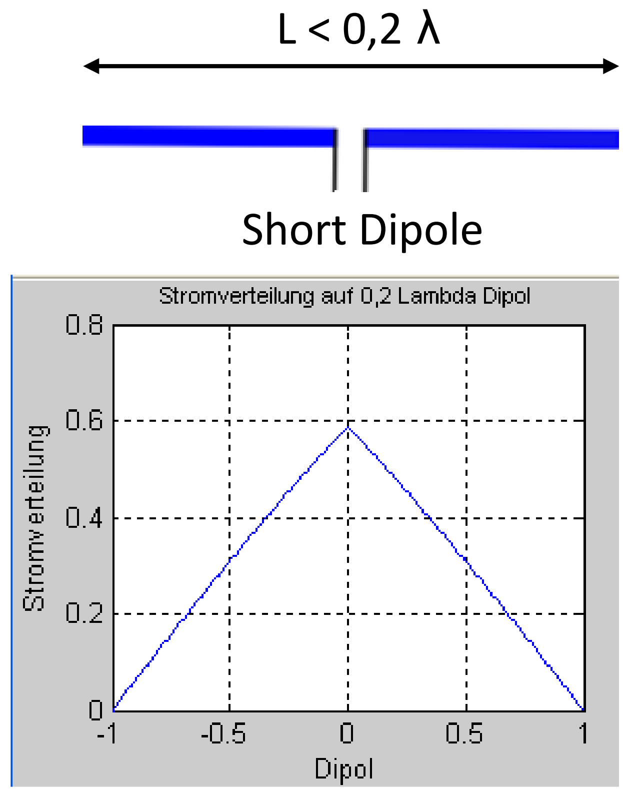




- A short dipole has a horizontal directional characteristic in the form of a lying 8
- The main lobes are perpendicular to its axis
- Along its axis there are deep nulls of the reception. The depth of the nulls depend on the Common Mode Rejection Ratio (CMRR) of the dipole amplifier.

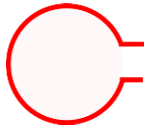
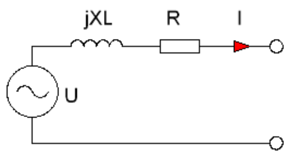
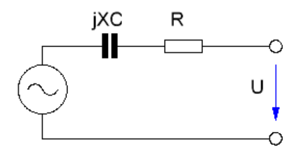
current distribution on a Dipole





Current distribution on a λ/2 Dipole is sine-shaped. With a short dipole (= length less than 0,2 λ) only a small section of the sinusoidal wave fits on the wire length. The small section of a sinus is approx. equivalent to a linear current distribution. The differential voltage between the legs of an <u>electrically short</u> dipole is not longer frequency dependent. A short active dipole is suitable as broadband receive antenna.

Duality - small magnetic loop and short dipole

 **Small Active Loop** (magnetic dipole)	 **Short Active Dipole**
Is sensitive to the H-Field H-Field probe	Is sensitive to the E-Field E-Field probe
loop current is proportional to H-Field strength	Differential Voltage across the terminals is proportional to E-Field strength
current widely independent of the frequency – useable as broadband antenna	voltage widely independent of the frequency – useable as broadband antenna
Equivalent circuit  Z=R + jX Impedance Z: small R, high jX_L (inductive)	Equivalent circuit  Z=R + -jX Impedance Z: small R, high $-jX_C$ (capacitive)
current driven in shortcut mode **Type of Amplifier required:** transimpedance-Amplifier (I/U-converter) low input impedance - balanced	voltage driven in open circuit mode **Type of Amplifier required:** Impedance converter – Hi-Z Input to 50 Ohm Out - balanced
less sensitive to earth / surroundings	sensitive to earth / surroundings much less sensitive than Monopoles/Whips

Conclusion, Active Dipole vs. Active Monopole (Whip)

Monopole:

- An active monopole Antenna senses the common mode voltage between the E-field probe antenna element to a reference potential, which should ideally be ground or earth potential. It has an omnidirectional directional diagram and receives vertically polarized signals.

- In practice, the outer conductor of the coaxial cable or, in combination with it, a conductive mast constitutes the reference potential for the Monopole on top. If mounting heigth exceeds 0.15 λ and approaches resonant lenghts, the frequency response is no longer flat, signal peaks and dips occur.

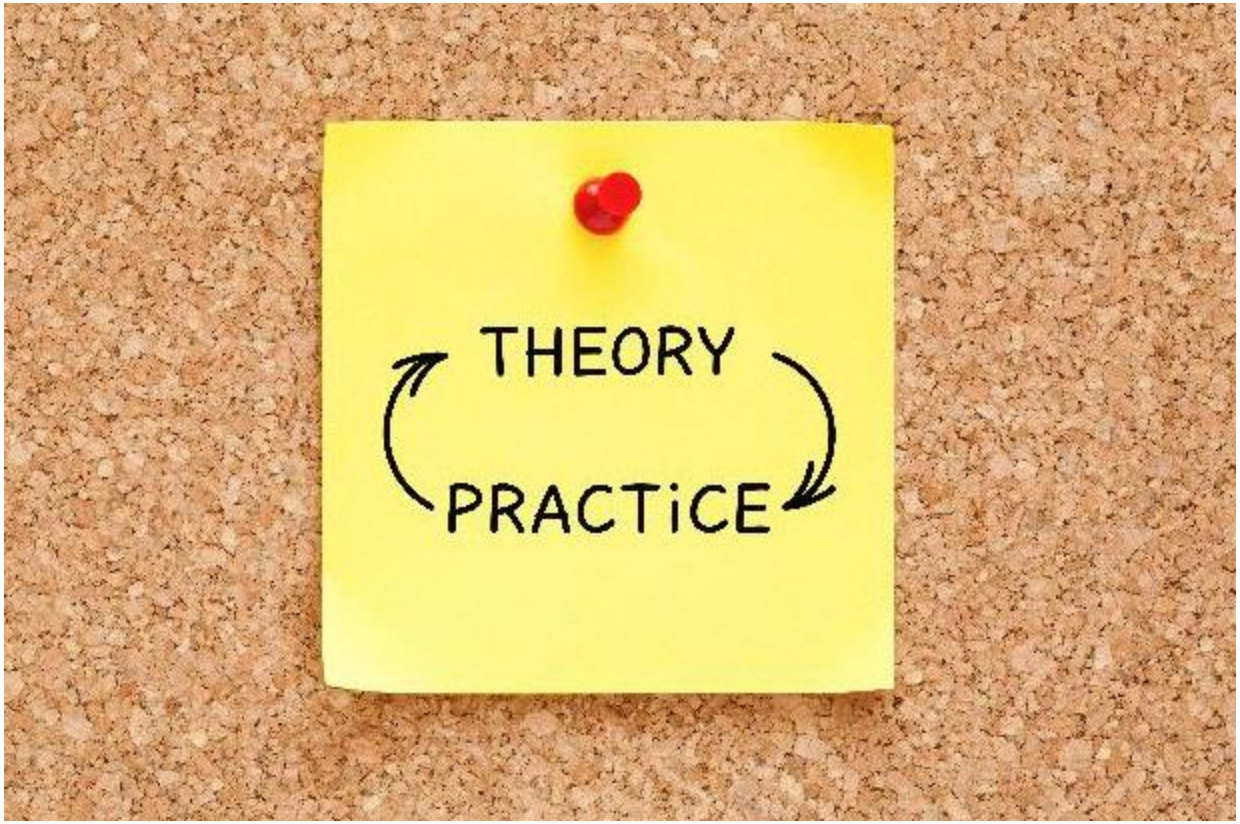
- If the active monopol is mounted on a mast, the signal voltage is greatly increased. Doubling the height results in double the output voltage. Mast resonances may disturb the gain flatness.

Dipole

- An active Dipole senses the differential mode voltage across the two dipole legs. Ideally a dipole is fully decoupled from the mast or cable-shield potential.

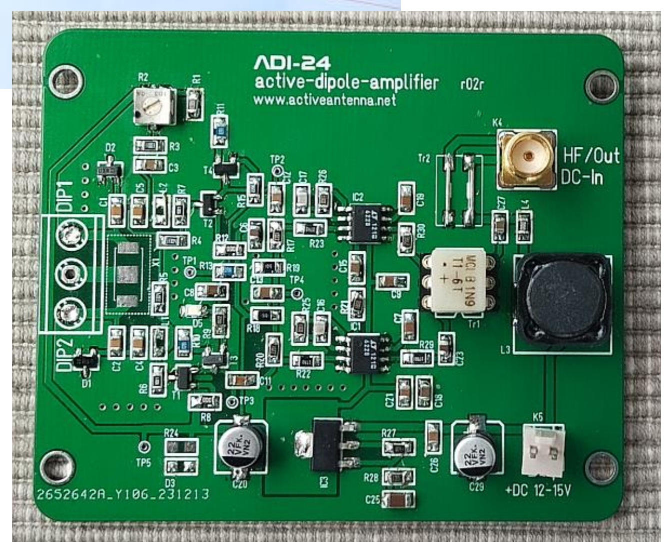
  The dipole is a directional antenna with nulls along it's axis and can be used fot either horizontally or vertically polarized reception.

- To exploit the advantages of a dipole, a balanced amplifier with a high CMRR to reject the superimposed common mode nearfield noise is required. Because a dipoles differential voltage is lower compared to U of a monopole, the balanced amplifier should be of low noise and provide some voltage gain.


THEORY
PRACTiCE

ADi-24 Active Dipole Amplifier – by DL4ZAO

2 x 1,5m (5 ft) active dipole In 6m (20 ft) height



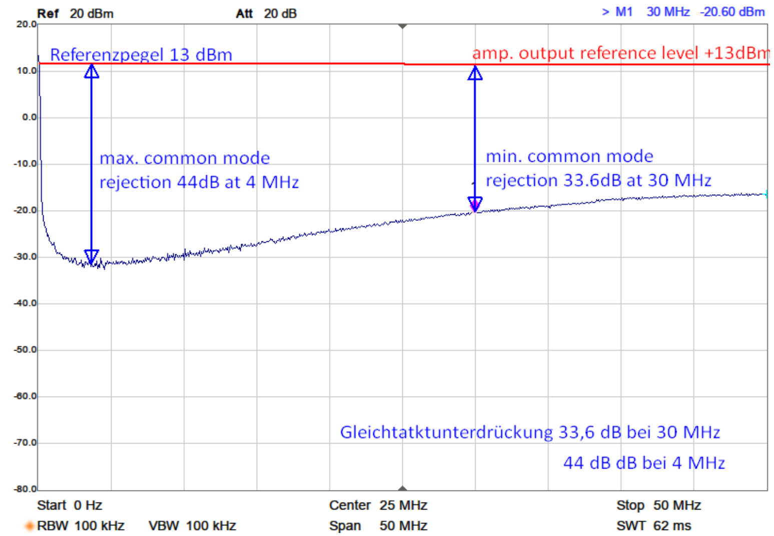
ADi-24 PCB mounted in an aluminum cast case

ADi-24 key data

ADi-24 technical information:

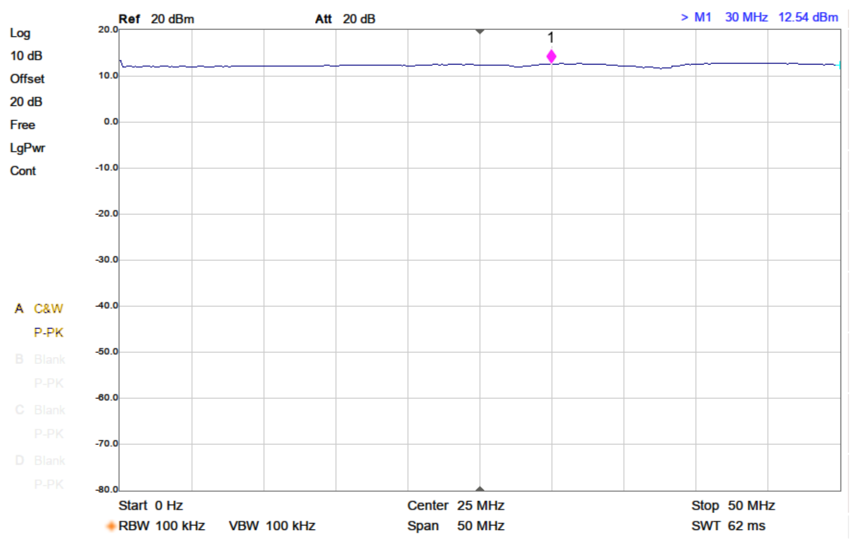
- Specified frequency range: 15 kHz – 52 MHz useful performance up to 120 MHz
- Gain: +13 dB
- gain flatness +/- 2dB,
- CMRR: 44 dB at 4 MHz, >33 dB at 30 MHz
- Intermodulation, Output Intercept Points:
- IPO2 >60 dBm, measured at 7 MHz
- IPO3: +37 dBm, measured at 7 MHz
- Power supply: stabilized DC 13,8V (12 – 15V)
- Supply Current: typical 70mA.
- Supply local or remote over the coaxial cable. (plus = inner conductor)
- Input Impedance Zin > 1MΩ at 1MHz
- Output 50Ω, VSWR <2
- Max imput voltage level: 1V eff.
- Maximum RF output level: > 13 dBm
- ESD Protection with gas discharge tube and ultra low capacitance TVS diodes

CMRR measured



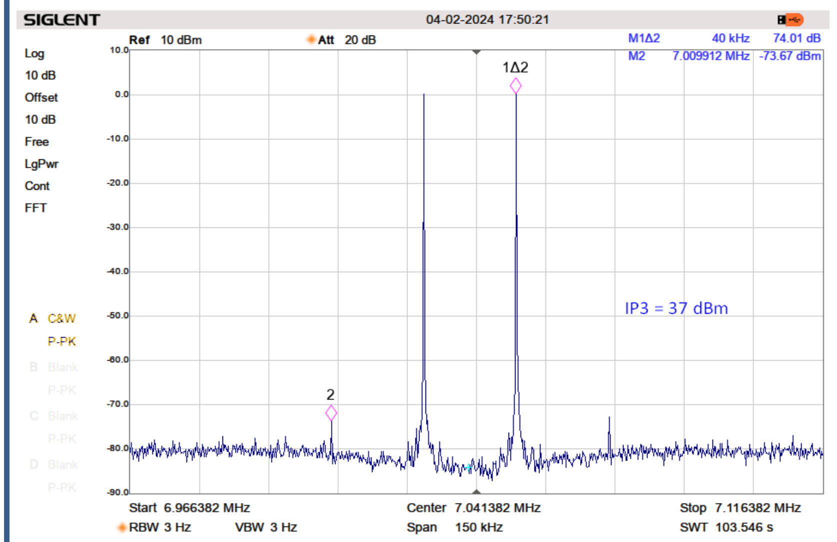
The Common-Mode-Rejection-Ratio CMRR indicates the ability of a differential amplifier to reject common mode signals that come to both inputs of the amplifier. A high CMRR is important in an active dipole application, where the relevant information is contained in the potential difference between the two dipole legs, but is also superimposed by unwanted common mode voltages to earth.
An active dipole with a high CMRR receives less noise from interfering sources in the near field and achieves deeper nulls in the radiation pattern.

ADi-24 gain flatness and IP3 measurements



Gain 20 kHz to 50 MHz: 12.5 dB
Gain flatness: better than ± 1.5 dB

Can be used out of spec up to the FM Radio Band

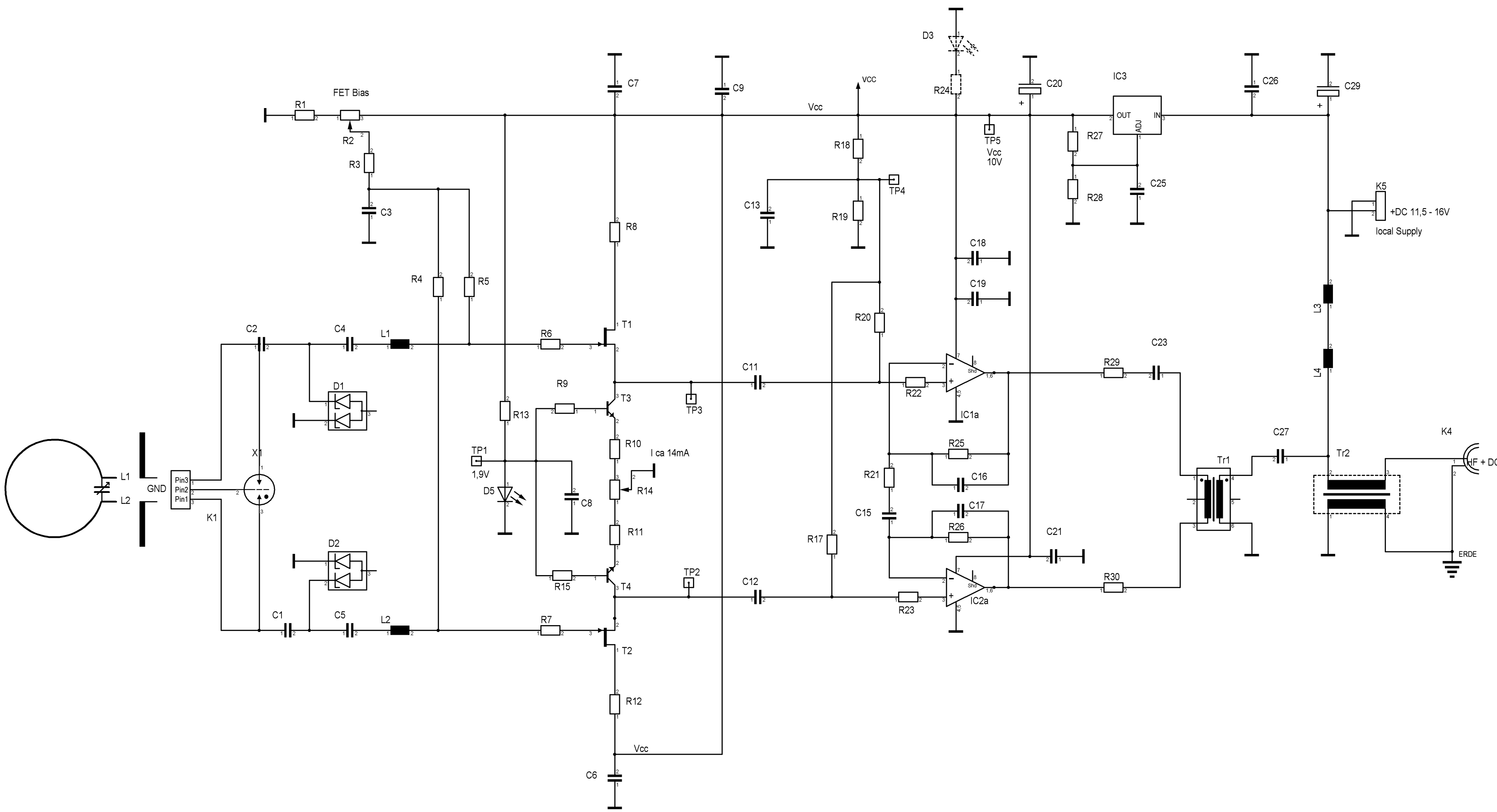


3rd Order Output Intermodulation measured at 7 MHz with two Input Signals of -12 dBm.

Output Level: 0 dBm
Intermodulation Distance: -73.7 dBm
This results in an IP3 of +37 dBm

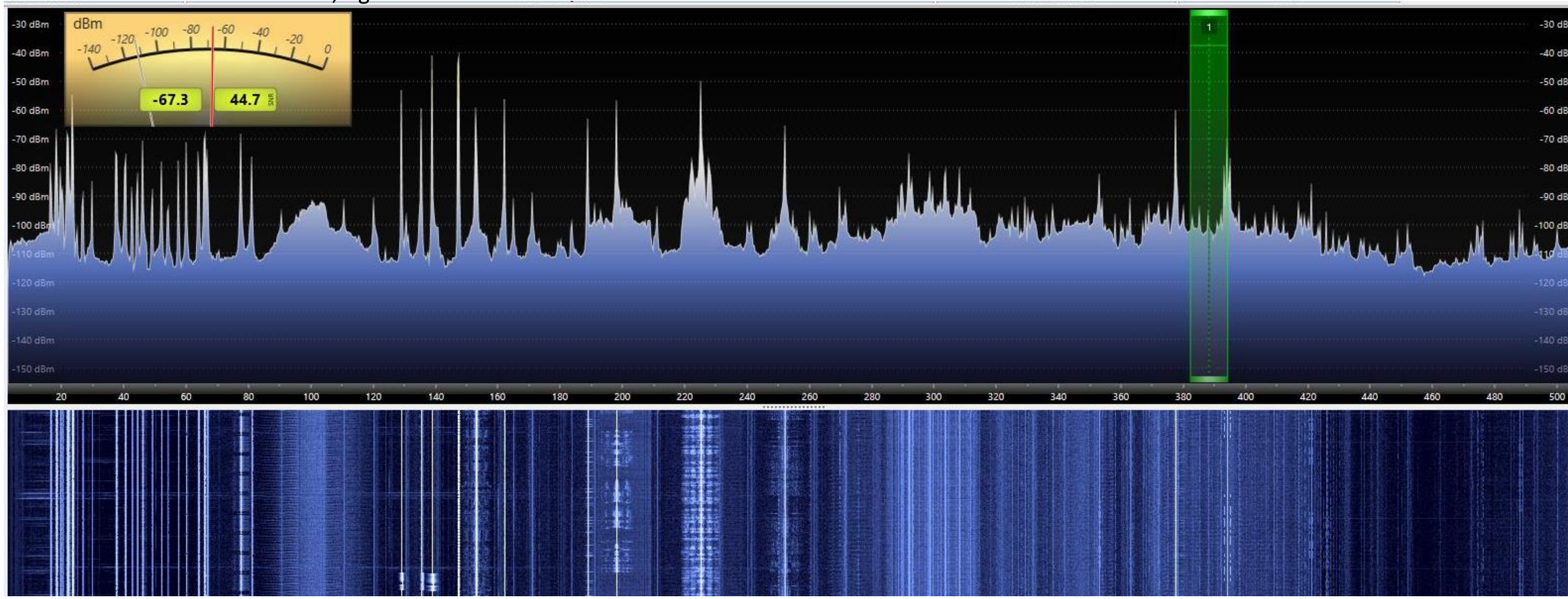
The ADi-24 amplifier has a high linearity , very low intermodulation and an excellent dynamic range.

ADi-24 active dipole amplifier - circuit diagram



ADi-24 Bandscan VLF - LW - NDB Band

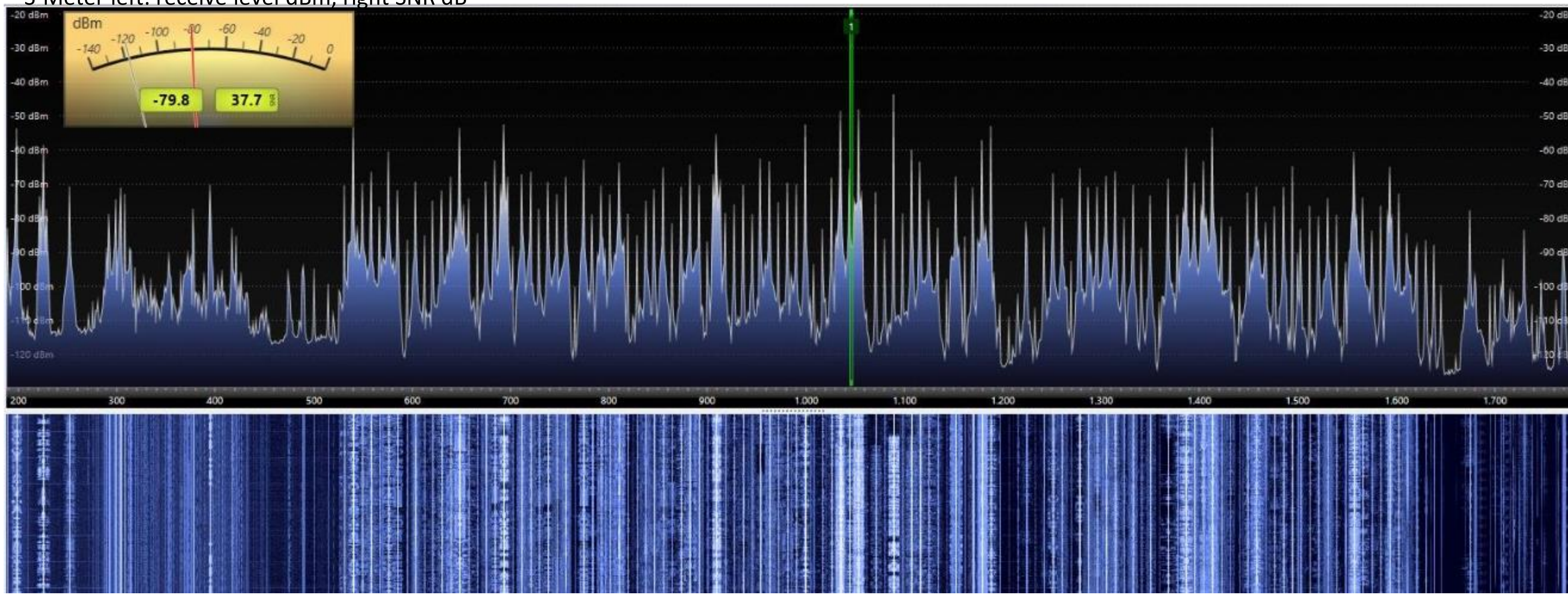
S-Meter left: receive level dBm, right SNR dB



Bandscan 15 kHz – 500 kHz
QTH: rural, near Hamburg, Germany
Time: Feb. 25th 2024, 20:00 UTC, 3 hrs. after sunset
Receiver: Perseus SDR

ADi-24 Bandscan LW-MW

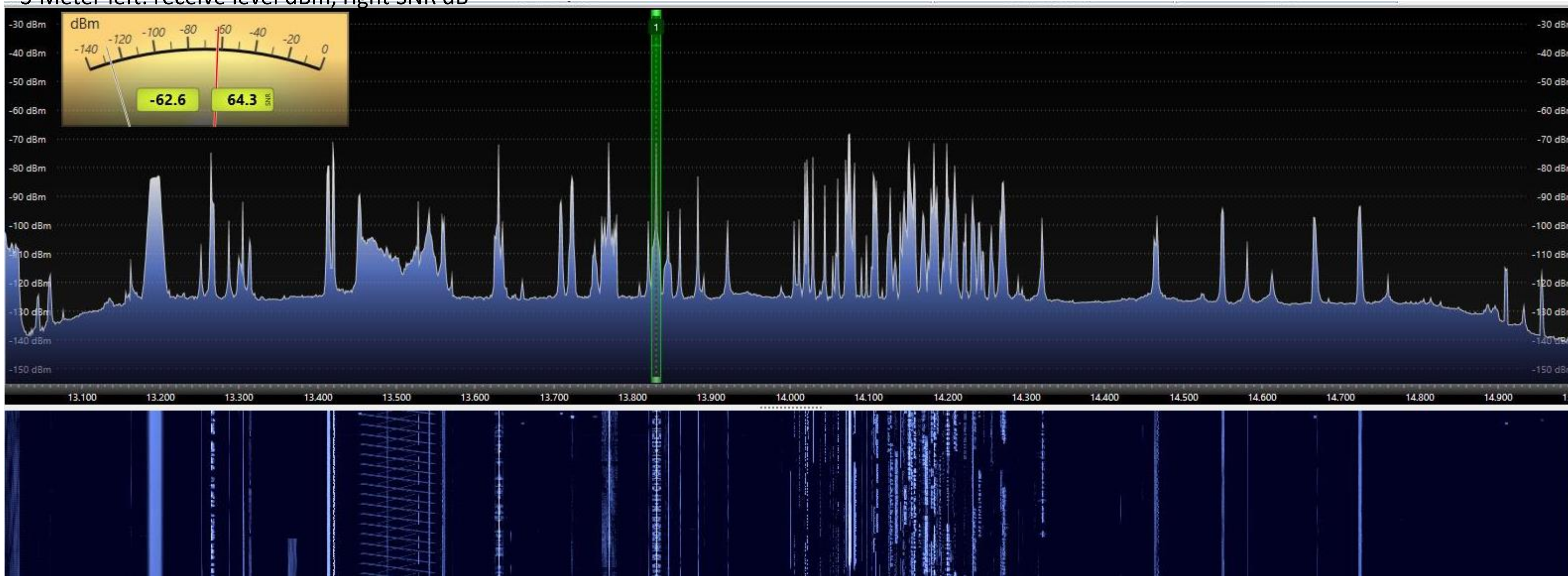
S-Meter left: receive level dBm, right SNR dB



Bandscan 200 kHz – 1750 kHz
QTH: rural, near Hamburg, Germany
Time: Feb. 25th 2024, 20:00 UTC, 3 hrs. after sunset
Receiver: Perseus SDR

ADi-24 Bandscan 19m BC and 20m Ham Band

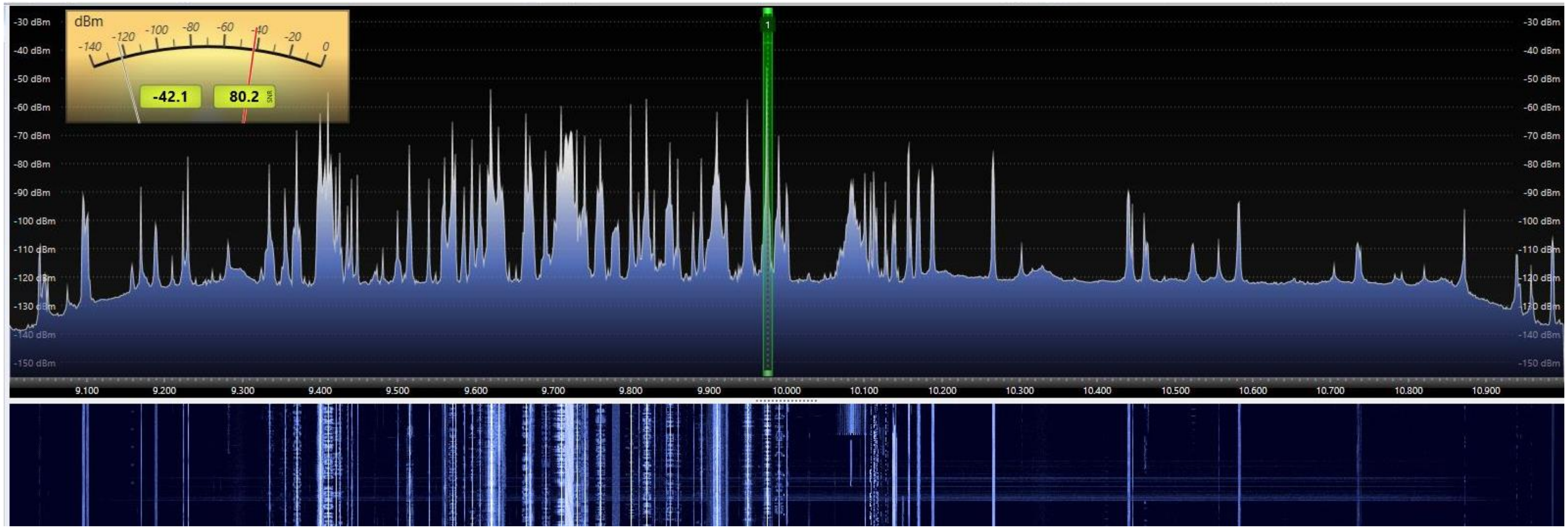
S-Meter left: receive level dBm, right SNR dB



Bandscan 13 MHz – 15 MHz
QTH: rural, near Hamburg, Germany
Time: Feb. 25th 2024, 17:00 UTC, shortly before sunset
Receiver: Perseus SDR

ADi-24 Bandscan 31m BC and 30m Ham Band

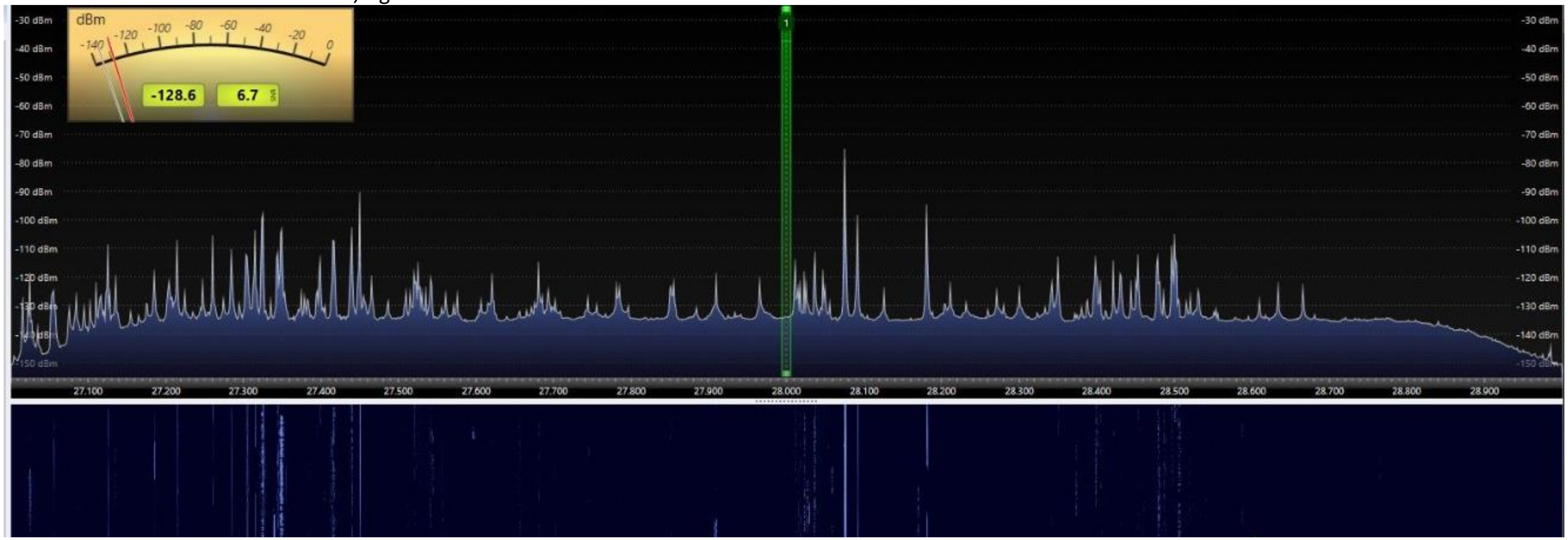
S-Meter left: receive level dBm, right SNR dB



Bandscan 9 MHz – 11 MHz
QTH: rural, near Hamburg, Germany
Time: Feb. 25th 2024, 17:15 UTC, shortly before sunset
Receiver: Perseus SDR

ADi-24 Bandscan 11m and 10m Band

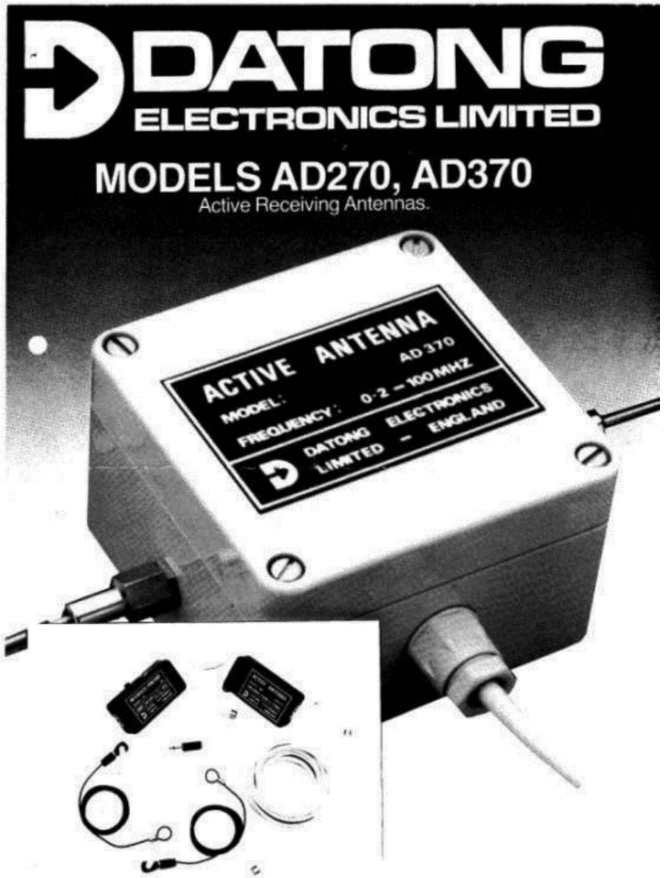
S-Meter left: receive level dBm, right SNR dB



Bandscan 27 MHz – 29 MHz
QTH: rural, near Hamburg, Germany
Time: Feb. 25th 2024, 17:00 UTC, shortly before sunset
Receiver: Perseus SDR

…more active dipole antennas

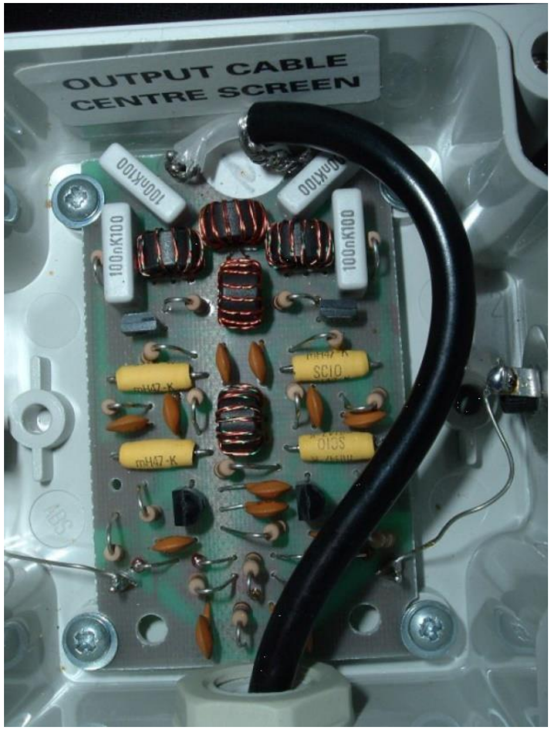
vintage Datong AD370 active dipole



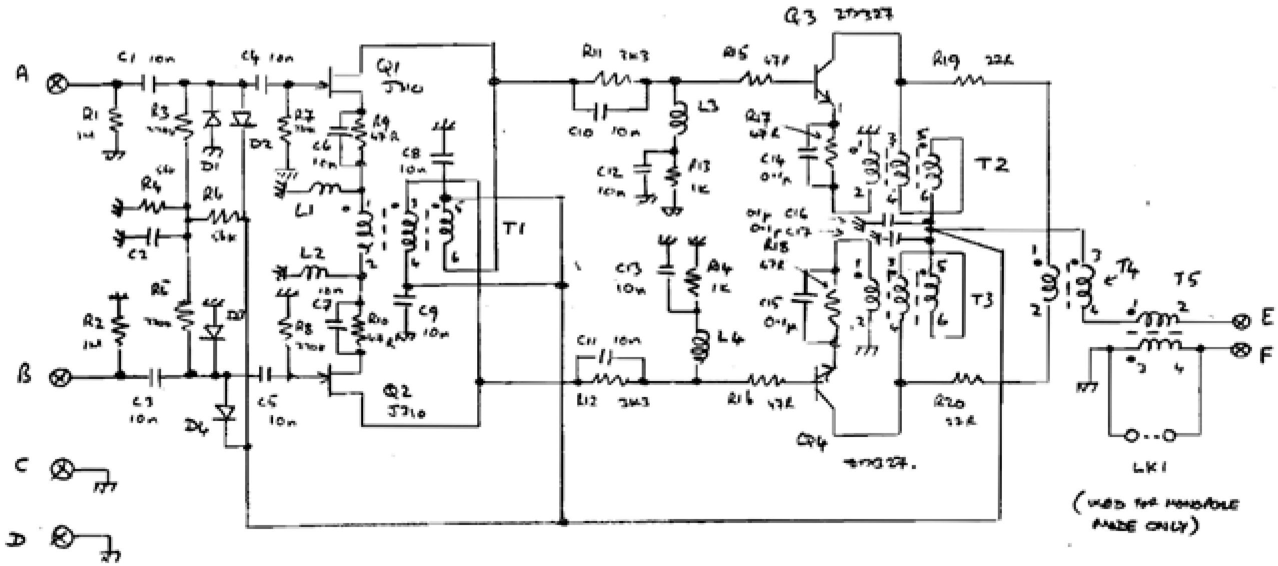
200kHz – 100MHz

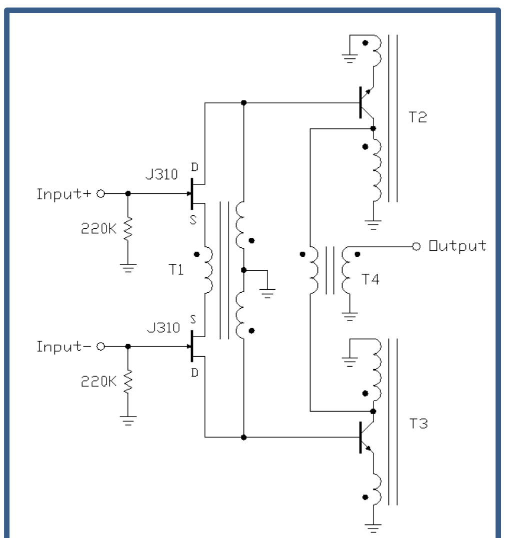
right:
Masthead Unit

Below: Bias-T
Interface Unit



Datong AD370 Head Unit circuit





The AD370 masthead amplifier uses noiseless transformer feedback in front and output-driver stage.

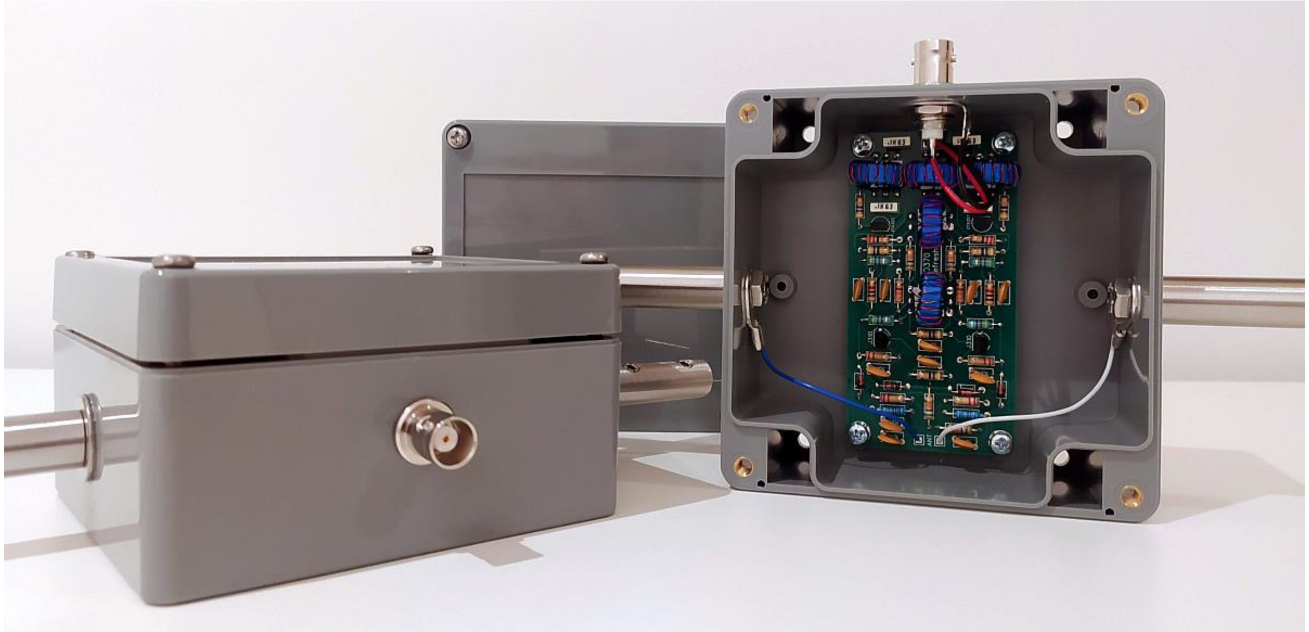
left: simplified circuit (source, Chris Trask)

2024 Replica of the Datong AD370 active dipole

An almost one-by-one replica of the Datong AD370 amplifier, individually handcrafted in Germany.
Ready built devices available on request.
For inquiry contact: titus.oxx@gmail.com

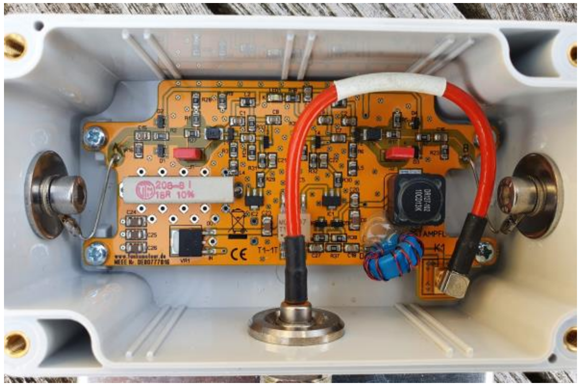
left - original Datong circuit board

below - 2024 replica



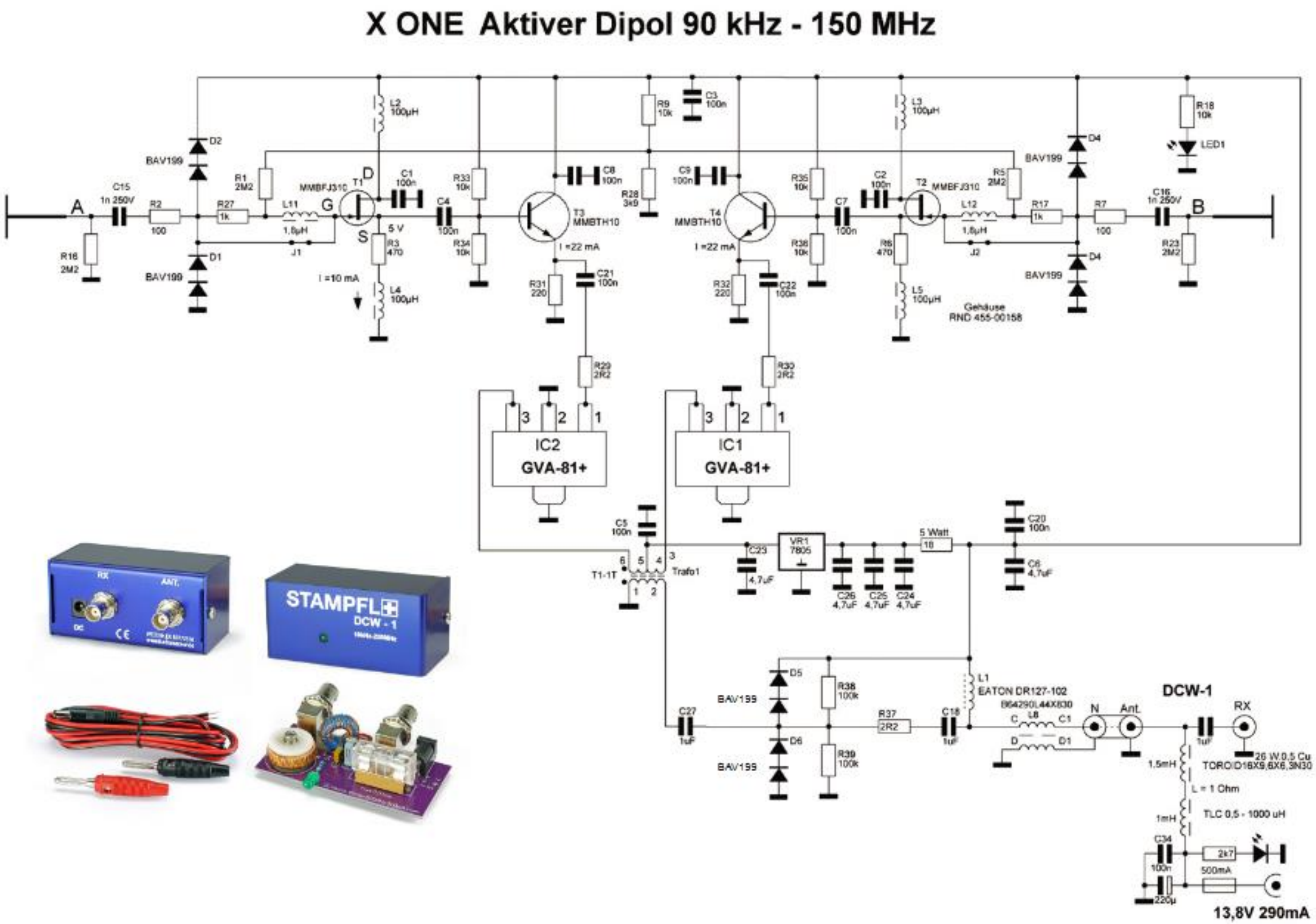
Stampfl X-ONE – swiss-made active dipole kit

Spezifikationen	
Frequenzbereich:	90 kHz bis 150 MHz
Polarisation:	Horizontal
Stromversorgung:	12 – 14 Volt / 270 mA
HF-Anschluss:	N inkl. BNC-Adapter
Länge:	0,8 m
Gewicht:	900 g



contact: https://www.heinzstampfl.ch

Stampfl X-ONE circuit diagram



Hi-Z Amplifier – by Tom Seeger, VE3PSZ

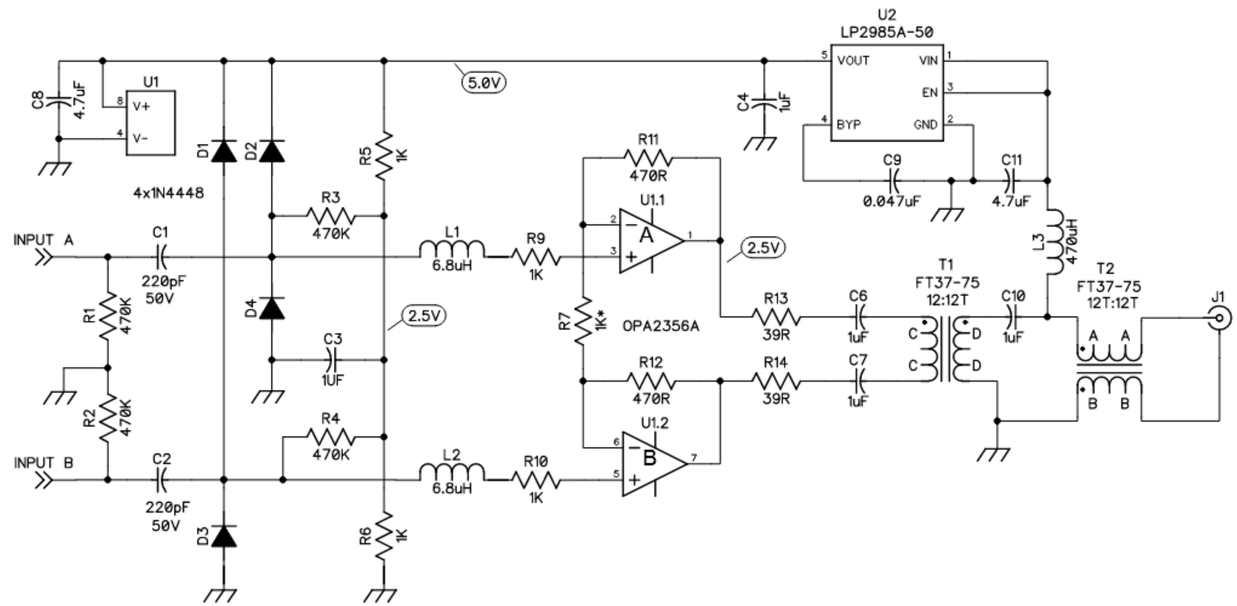
A modern state of the art design, that makes use of a low noise high-speed CMOS operational amplifier.

With only 5V supply voltage, the claimed intermodulation performance data are amazing:

1MHz +64 dBm OIP2,
7MHz +50 dBm OIP2,
2 MHz +37 dBm OIP3,
5MHz +36 dBm OIP3.

for info please contact:
thomas.b.seeger@gmail.com

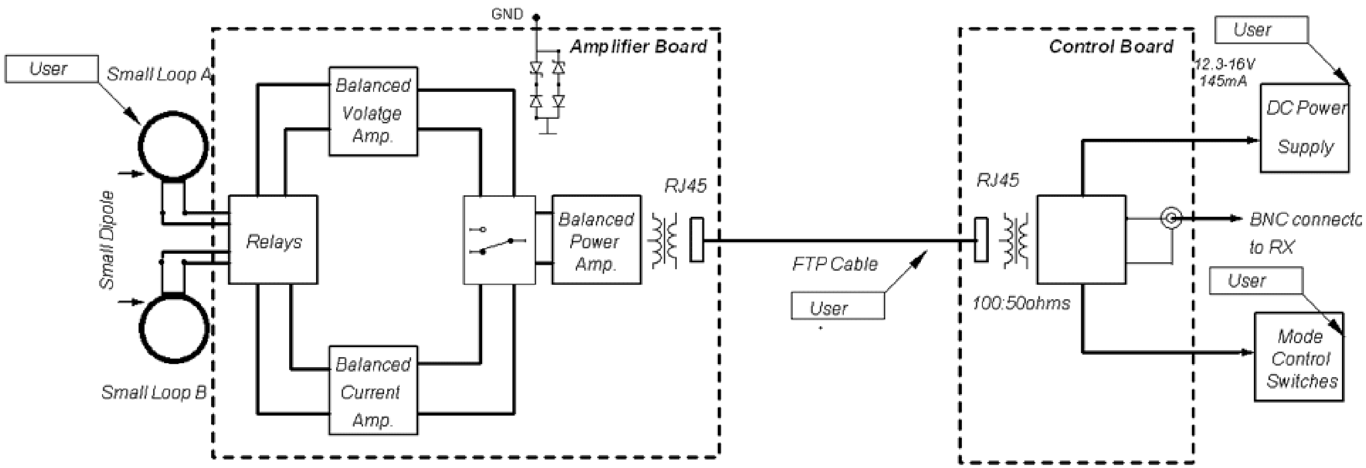
Balanced Hi-Z Amplifier - 17 June 2023

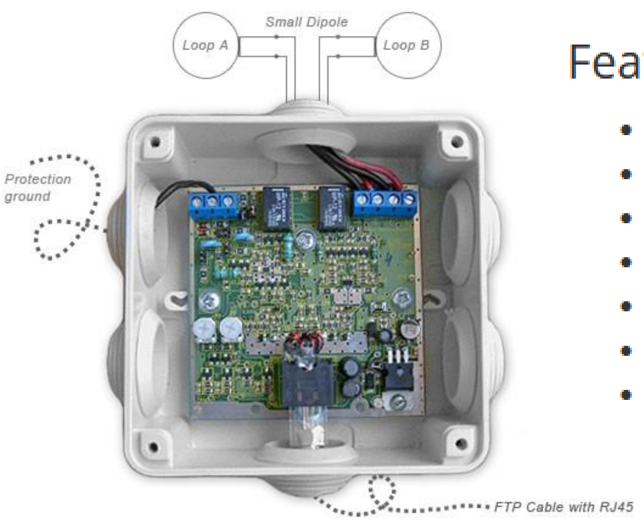


Can be used as short 10′ dipole or 25′ vertical w/either input to ground rod.
R7 can be decreased to 220 ohms if used with 10′ dipole.
Usable from 20kHz to >30MHz. Supply voltage 4 to 15V. Supply current 25mA.
All resistors 1/4W MF. All capacitors 50V multilayer ceramic.
T1 and T2 have 12 turns #28AWG or smaller magnet wire.
For best 10m results match inductance of L1 and L2.
Voltage gain of the circuit is 1+(R11/R7).
P1A = 15 dB Uses BALANCED HI-Z AMP 06-23 PCB.

Hybrid Active Antenna Amplifier AAA-1C – LZ1AQ

Block diagram. Two small loops act also as arms of a small vertical dipole





Features

- 4 remotely switched modes (Loop A, Loop B, crossed parallel loops A&B and dipole)
- Each mode can be switched immediately
- Good sensitivity and a flat frequency response
- High dynamic range
- Protected input from strong signals
- High immunity to local noise with balanced amplifiers and balanced feed line
- Balun transformer coupling for common mode noise reduction

Versatile circuit. Uses Ethernet cable for feedline, pwr. and remote control. Very comprehensive documentation on the website. Amazing price/value ratio, complete set on sale for 106 €

https://active-antenna.eu

NTi / Bonito MegaDipol MD300DX

Technical data

- Frequency range: 9kHz - 300MHz
- IP3: typ. +30dBm (@7.00 & 7.20MHz)
- IP2: typ. +78dBm (@7.00 & 7.20MHz)
- Size/weight: 98 x 90 x 38mm / 0.12kg

Whats in the Box?

- MegaDipol MD300DX
- Power Inserter CPI 1500UNI
- 2x 2.5m long radiating elements (PVC-coated, salt-water resistant stainless steel ropes)
- 2 insulators for installation (weatherproof plastic material with 4.5mm fixing hole)

OMG ?! This antenna will amaze you!

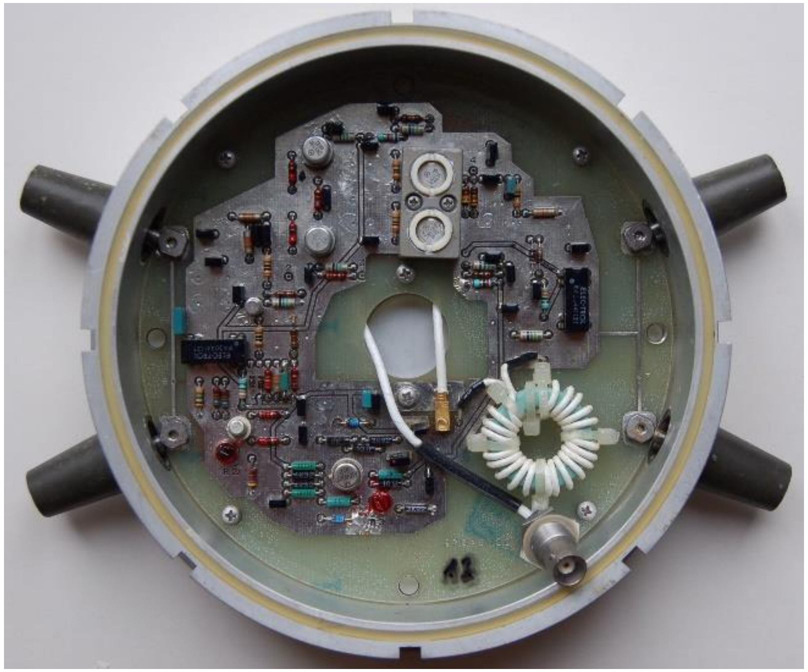
The MegaDipole 300DX is a broadband active dipole with a maximum upper working frequency of 300 MHz. The dipole reacts to the electrical component (E-Field) of the electromagnetic field and will deliver best results regarding signal strength and SNR (signal -to-noise-ratio) at locations with little or no locally generated interference. Nonetheless, the receiver to be coupled to this antenna should have a high enough dynamic range so that it can effectively process the received signals.

Developed and manufactured by German company NTi, sold by Bonito HAM-Shop

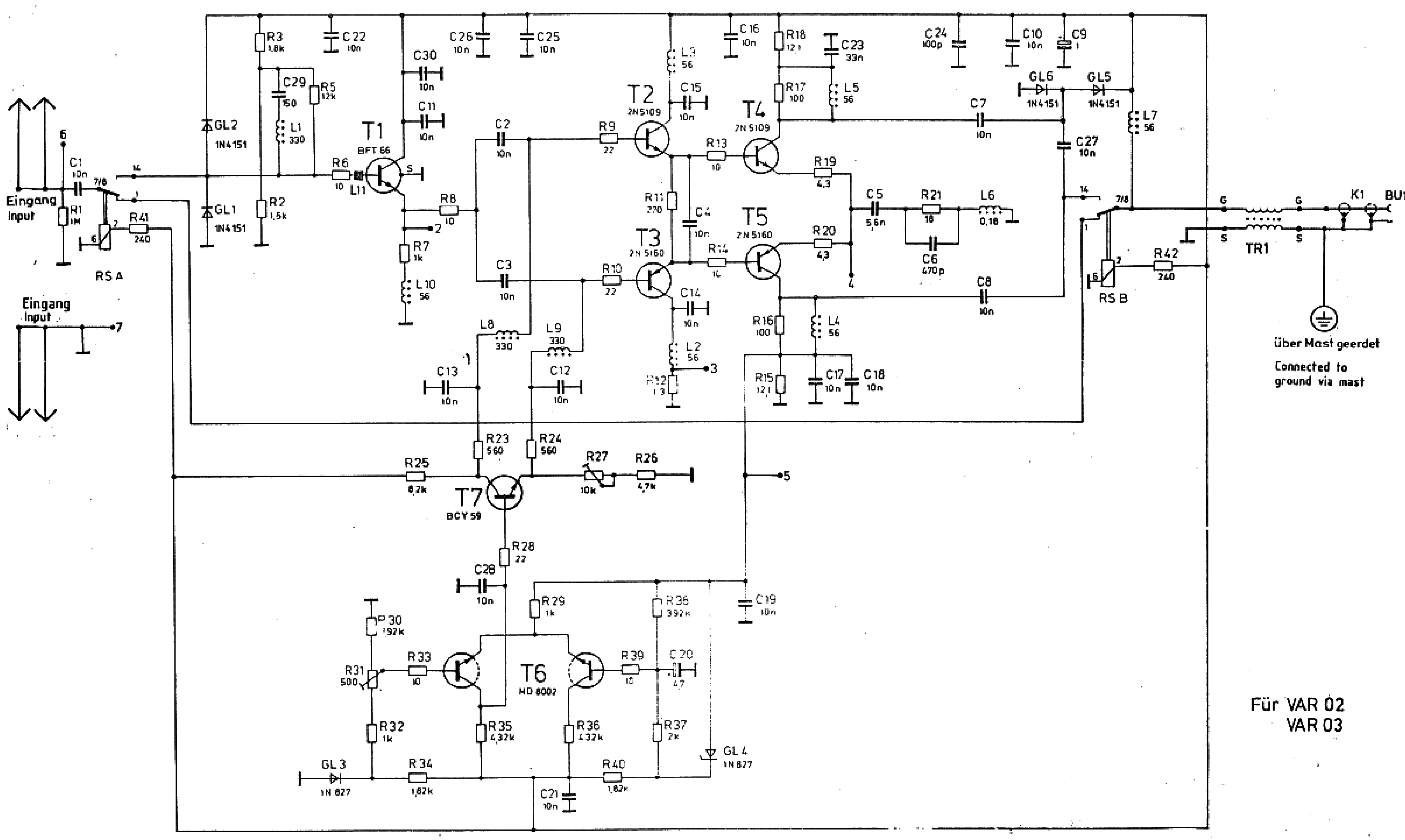
Fotos and text: citation from Bonito HAM Shop Website

https://bonito.net/hamradio/

HE002 vintage Active Dipole by Rohde & Schwarz



HE002 amplifier circuit diagram

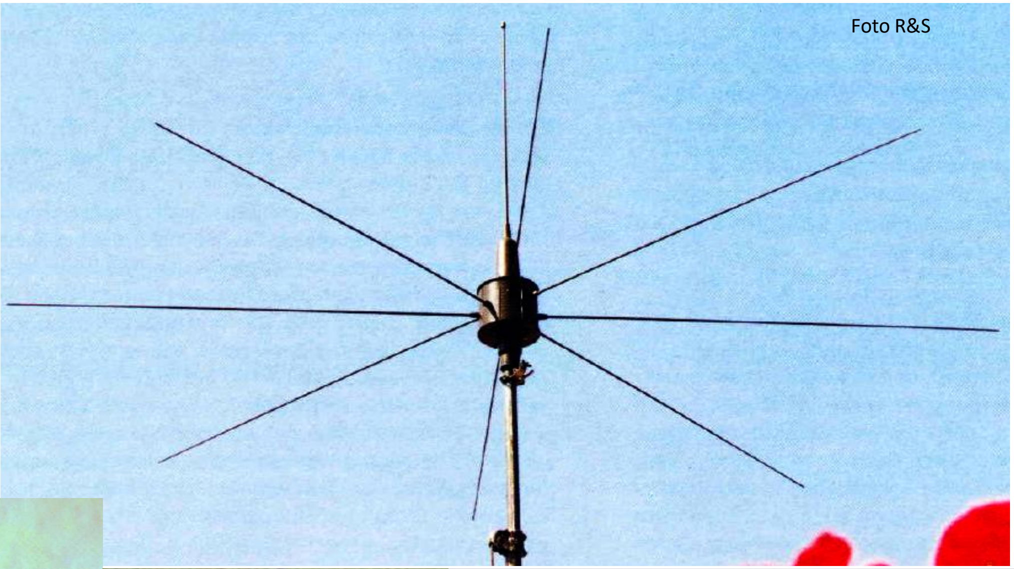


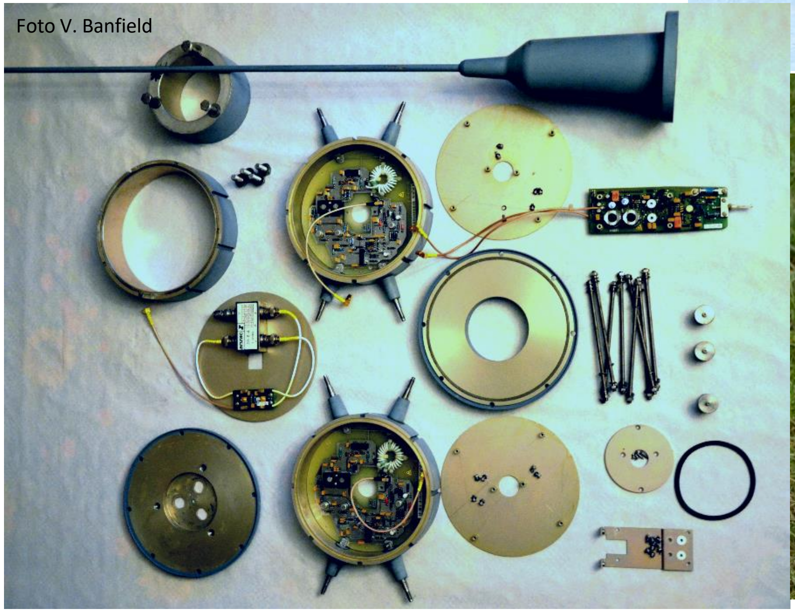
HE010 Active Dipole, Rohde & Schwarz

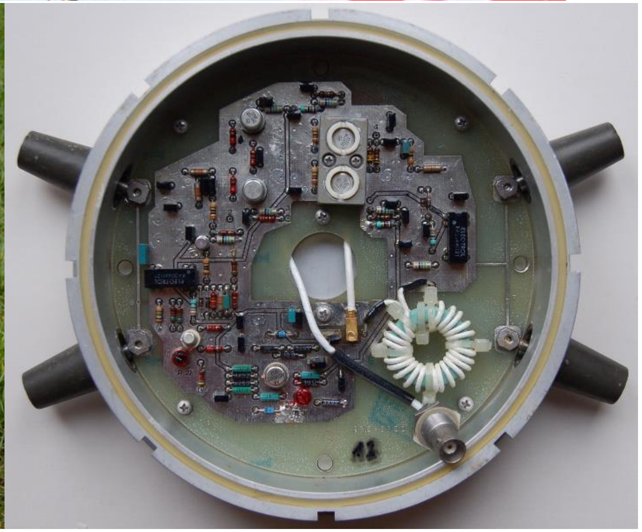
Power supply with
bias-Tee

HE015 Monopole + Dipoles, Rohde & Schwarz

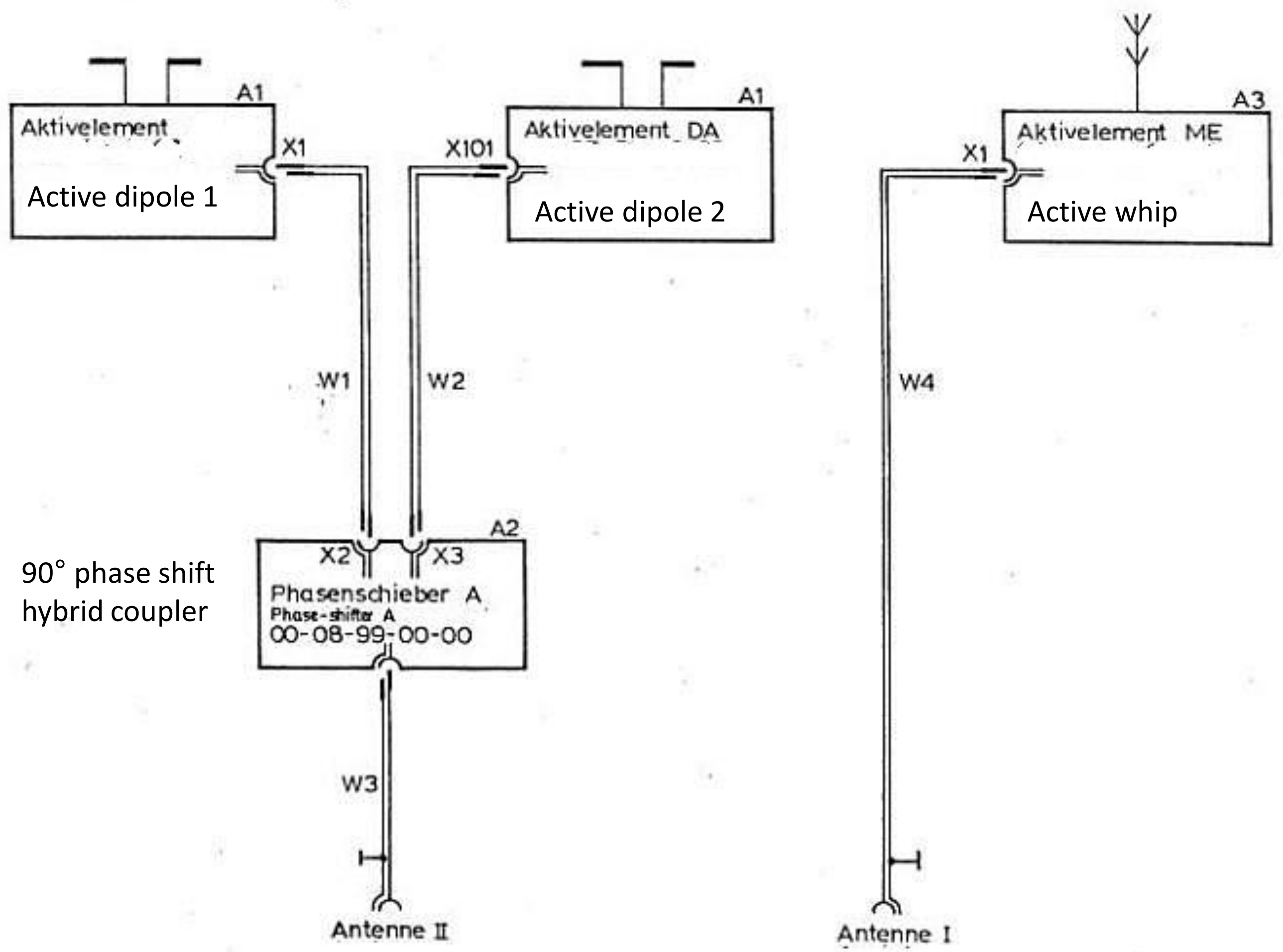
Two HE002 turnstile Dipoles coupled + Vertikal-Monopole HE011



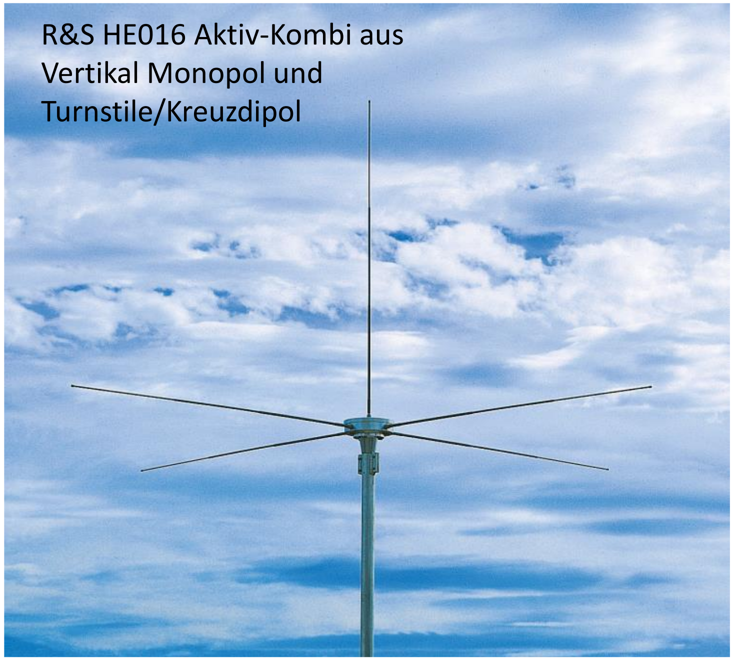


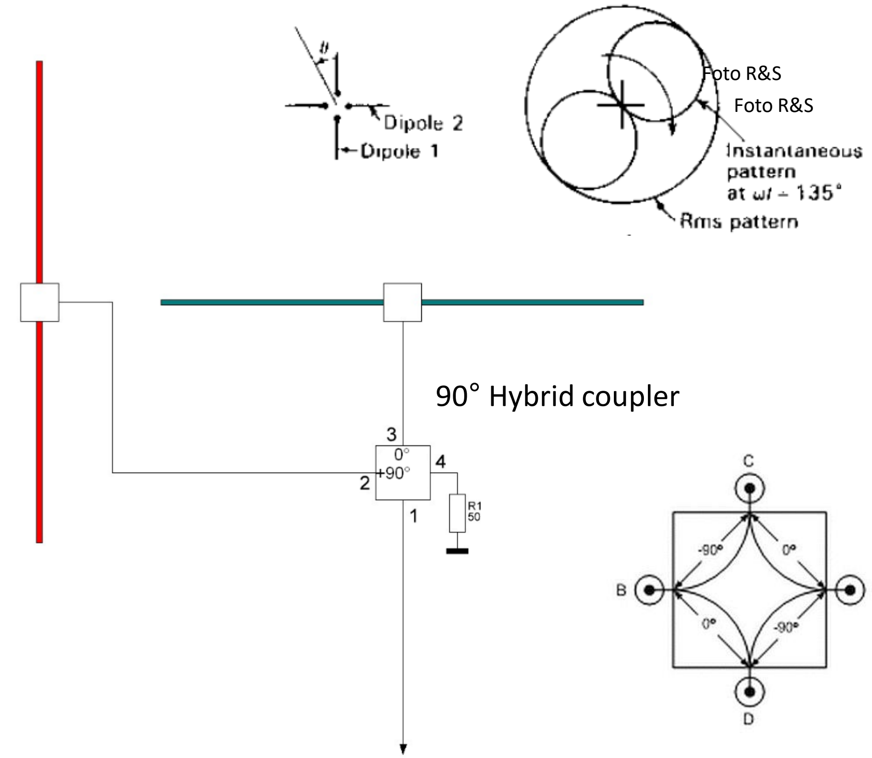


HE015 block diagram



R&S HE16 Vertikal Monopole + Turnstile Dipole combi





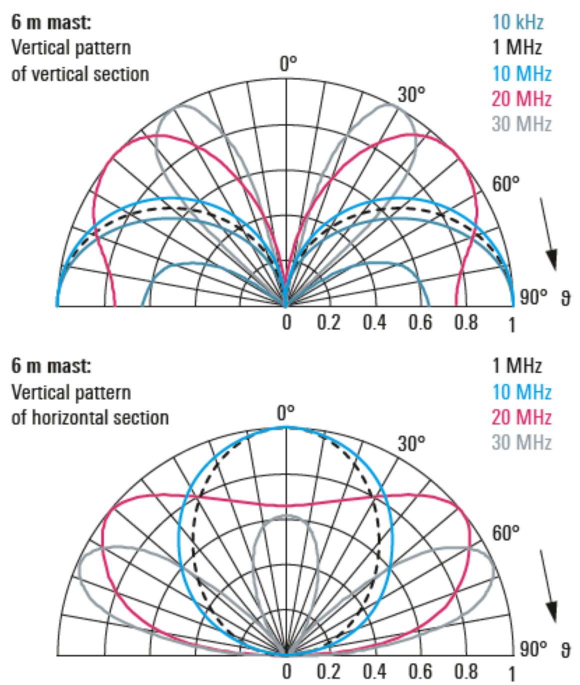
- Turnstile dipoles are a set of two identical dipoles mounted at right angles to each and coupled via a 90° phase shift hybrid-coupler.
- The cross mounted dipoles receives <u>horizontally polarized</u> radio waves perpendicular to its axis.
- In axial mode the antenna receives <u>circularly polarized</u> radio waves along its axis.
- Turnstile dipoles have advantages as NVIS (near vertical incident skywave) antenna
- They receive signals mostly reflected straight up for short to medium distance communication.

R&S HE016 specs

Specifications

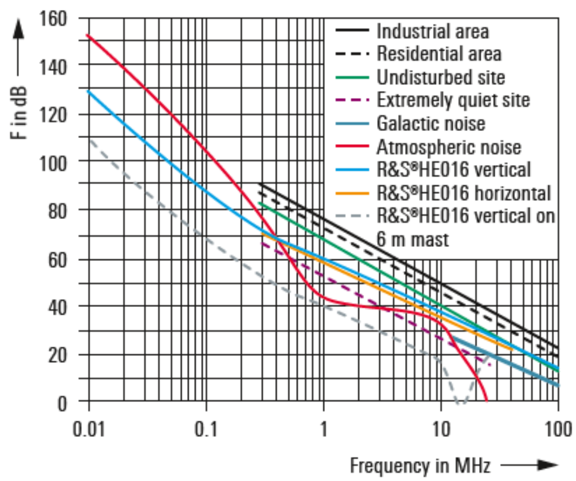
Frequency range	
Vertical polarization	9 kHz to 80 MHz
Horizontal polarization	600 kHz to 40 MHz
Input impedance	50 Ω
VSWR	
9 kHz to 20 kHz	< 3
20 kHz to 80 MHz	< 2
IP2	≥ 50 dBm (up to 30 MHz)
IP3	≥ 30 dBm (up to 30 MHz)
Power supply	21 V to 26 V DC (max. 500 mA)

Typical radiation patterns



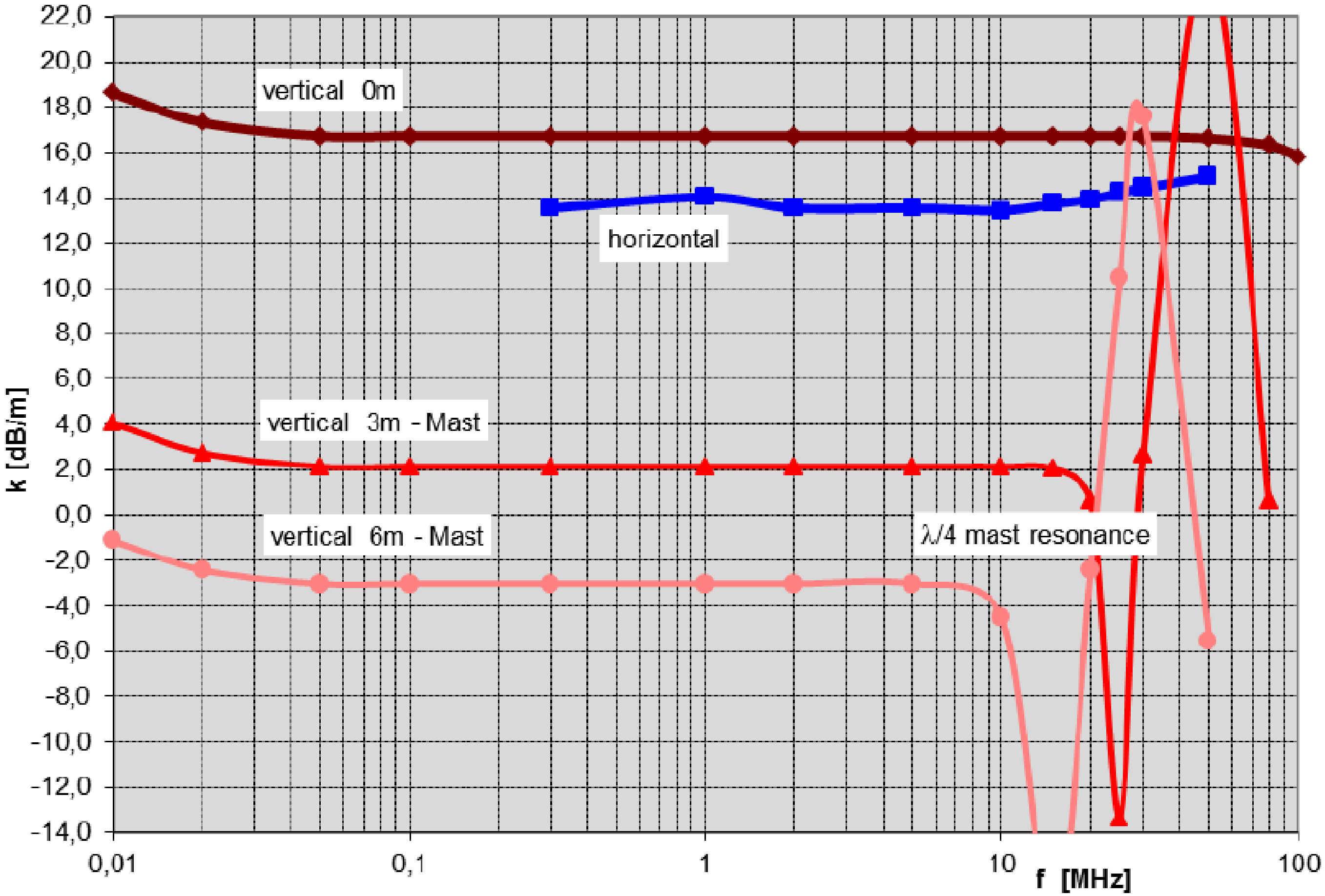
Listprice: 8160 €
Power Supply / Bias-T: 2520 €

Typical inherent noise compared with different standard noise environments



Quelle: Rhode & Schwarz

HE016 influence of mast height on antenna factor



blue: HE016 Dipole, horizontal

brown, red, orange: HE016 1m rod Monopole vertical

Diagram taken from Rohde & Schwarz HE016 (Horizontal-Dipole / Vertical-Whip)

k = $AF(dB/m) = 20 \log \frac{E(V/m)}{U}$

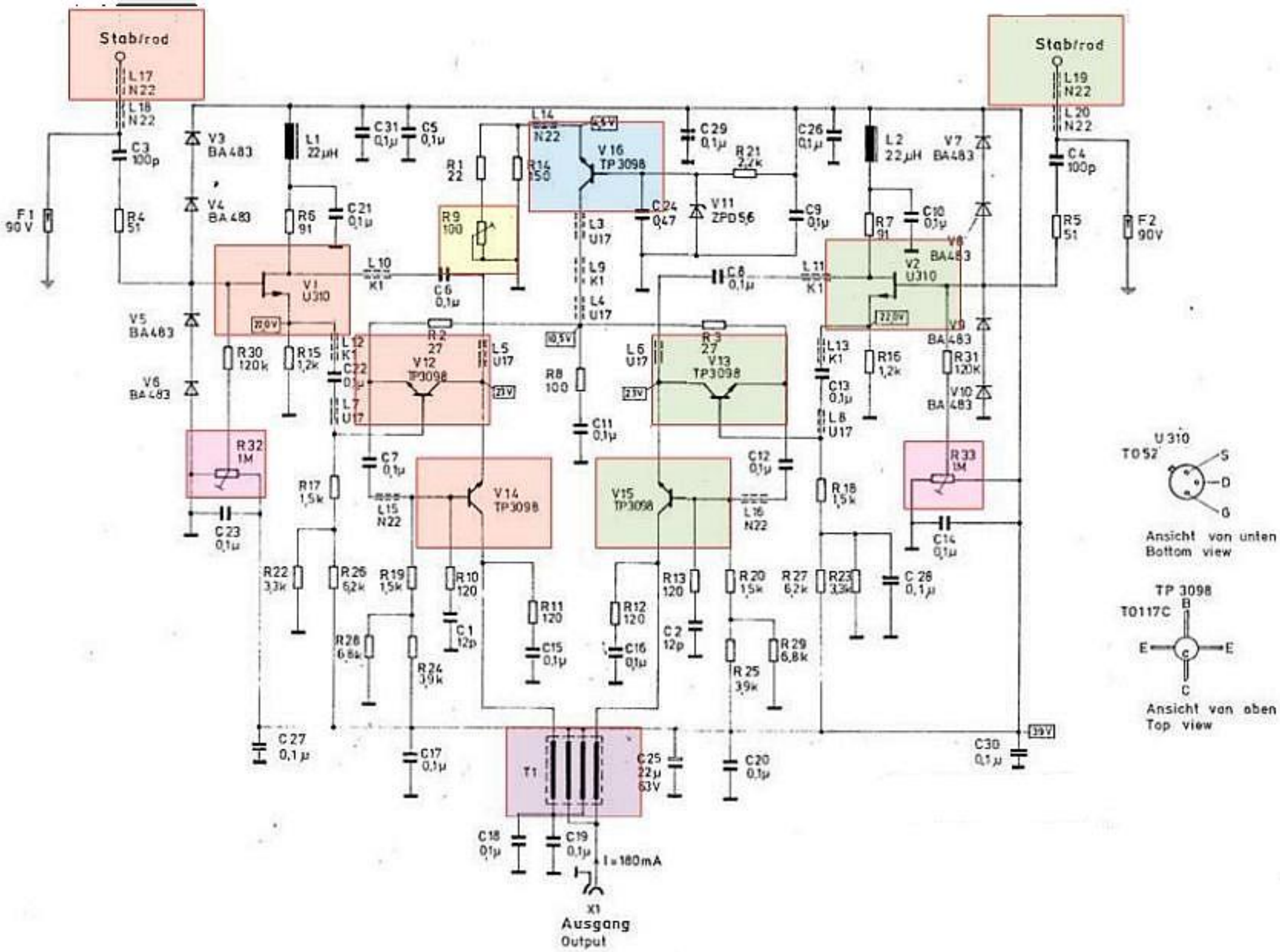
Active Receiving Antenna HD 2 A + STA 10 A/D

2 horizontally polarized Dipole Antennas combined with vertically polarized Monopole Antenna.
0,01 – 30 MHz. Obsolete, not longer in production.

ACTIVE ANTENNA SYSTEMS AAS GmbH, Hamburg, Germany

Quelle: www.aas.de

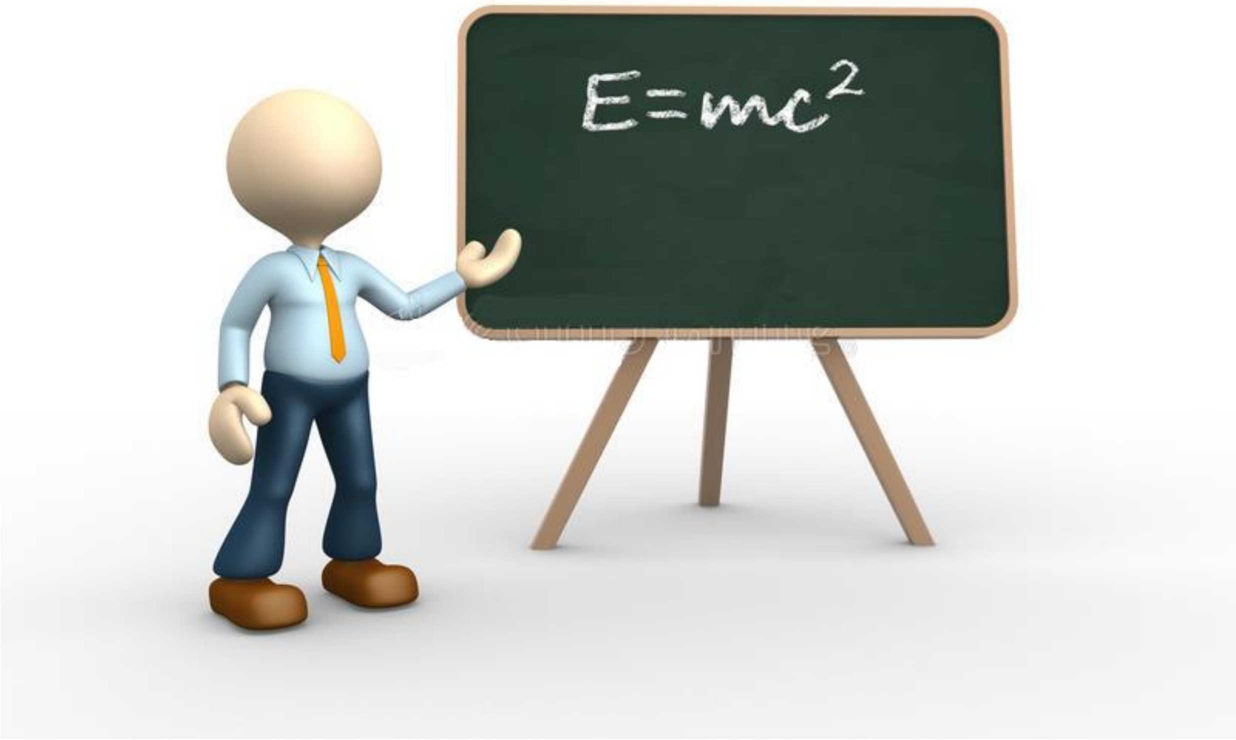
AAS HD2A Active Dipole – circuit diagram



Have fun …

…with active dipoles

Annex

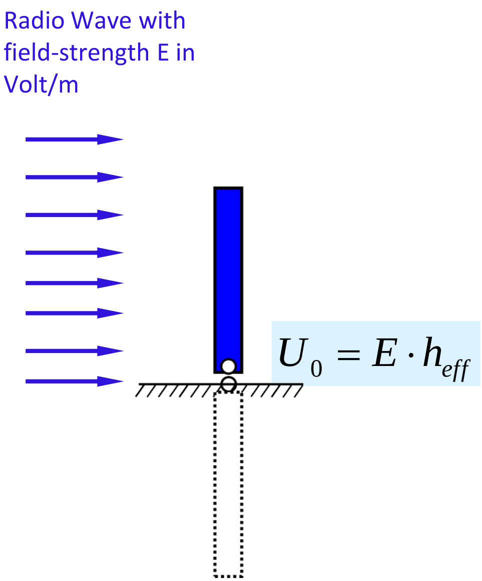


Finally yet some theoretical aspects…

effective length or effective heigth h_{eff}

- A radio wave induces an open circuit voltage U_0 across the terminals of an antenna.

- The open circuit Voltage U_0 across the terminals equals the electric field strength *E in V/m* multiplied with the effective heigth h_{eff} *of an antenna*.



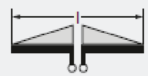
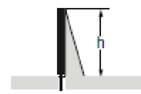
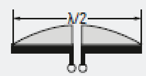
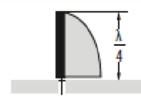
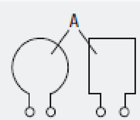
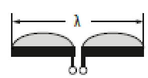
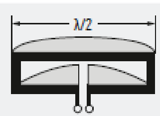
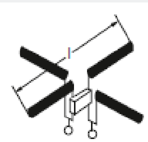
$$U_0 = E \cdot h_{eff}$$

- The effective length or effective height h_{eff} of an antenna is not identical with its geometrical length or heigth. The value depends on the type of antenna and its current distribution. h_{eff} determines the open circuit voltage developed across the antenna terminals in an incident wave with the electric field strength *E* in V/m. The h_{eff} values of selective antenna types can be taken from an antenna parameter table.

Lets do an example. From the table we read the value h_{eff} of a short dipole is ½ l. If we put a dipole with a length *l* of 1m in an incident radio wave with a field strength *E* of 2V/m then the open circuit signal voltage U_0 across the dipole terminals are calculated:

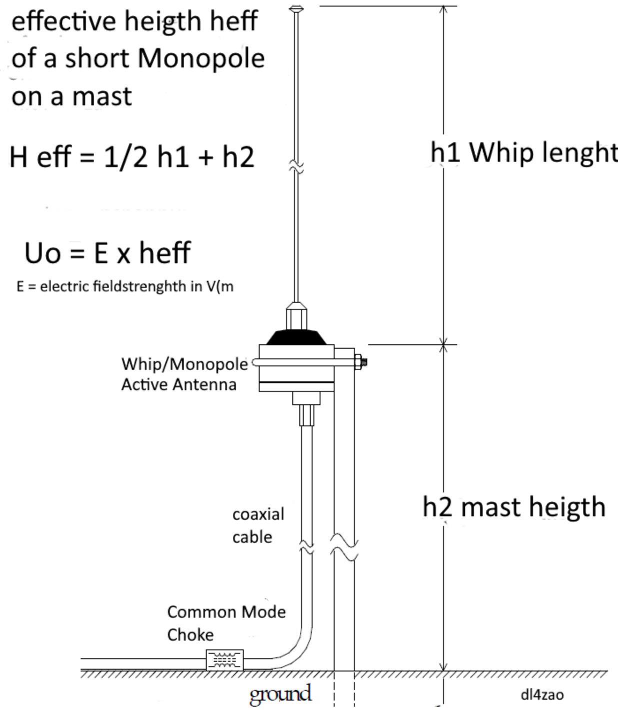
$$U_0 = 2\text{V/m} \cdot \tfrac{1}{2}\,\text{m} = 1\text{V}$$

Parameters of selected antenna types

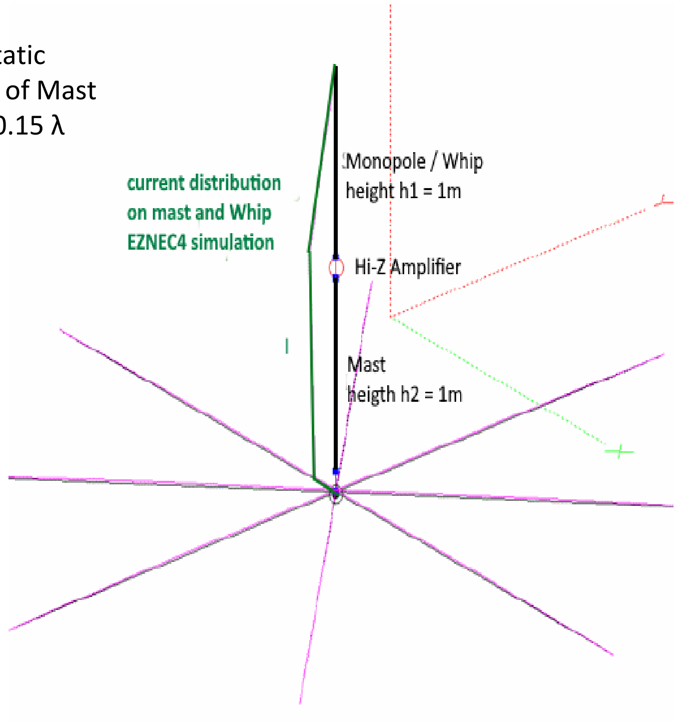
Parameters of selected antenna types			h_{eff}	
Type of antenna	**Current distribution**	**Directivity factor D**[5]	**Effective antenna length**	**Radiation resistance R in Ω**
Isotropic radiator		1 ≙ 0 dB		
Short dipole without end capacitance[7]		1.5 ≙ 1.8 dB	$\frac{l}{2}$	$20\,\pi^2\left(\frac{l}{\lambda}\right)^2$
Short antenna on infinitely conducting ground without top capacitance[8]		3 ≙ 4.8 dB	$\frac{h}{2}$	$40\,\pi^2\left(\frac{h}{\lambda}\right)^2$
Half-wave dipole		1.64 ≙ 2.15 dB	$\frac{\lambda}{\pi}$	73.2
Quarter-wave antenna on infinitely conducting ground		3.28 ≙ 5.2 dB	$\frac{\lambda}{2\pi}$	36.6
Small single-turn loop in free space		1.5 ≙ 1.8 dB	$\frac{2\pi A}{\lambda}$	$80\,\pi^2\,\frac{4\pi^2 A^2}{\lambda^4}$
Full-wave dipole		2.4 ≙ 3.8 dB		
Folded half-wave dipole		1.64 ≙ 2.15 dB	$\frac{2\lambda}{\pi}$	$4 \cdot 73.2 \cong 280$
Turnstile antenna (Hertz dipole) radiating in horizontal plane		0.75 ≙ 1.2 dB	l	$40\,\pi^2\left(\frac{l}{\lambda}\right)^2$

Short Monopole on a mast - effective heigth h_{eff}

Example: a monopole with a length of 1m in an incident radio wave with a field strength *E* of 1V/m



Applies on the quasi static approximation: heigth of Mast and Whip is less than 0.15 λ

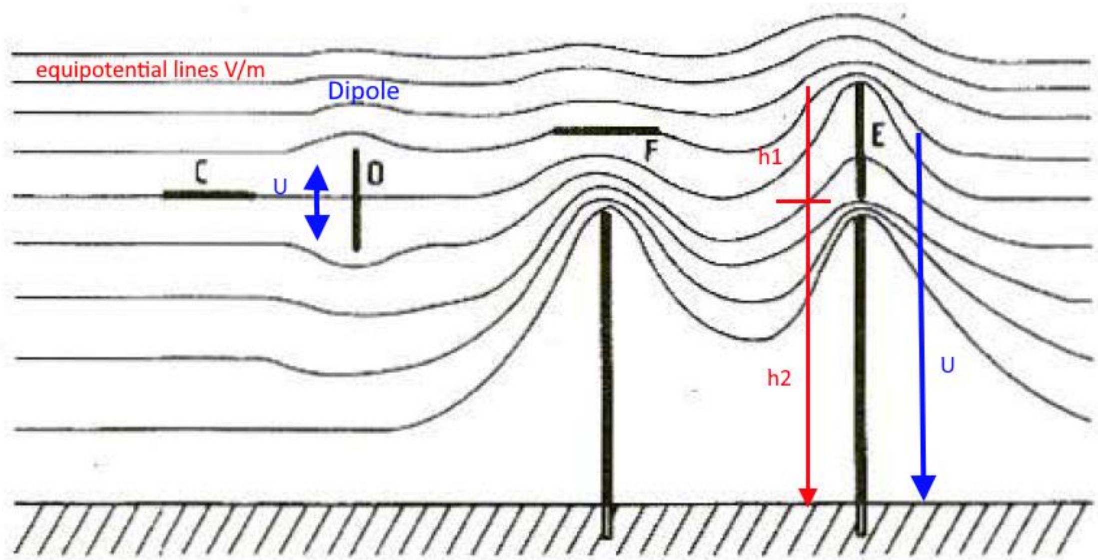


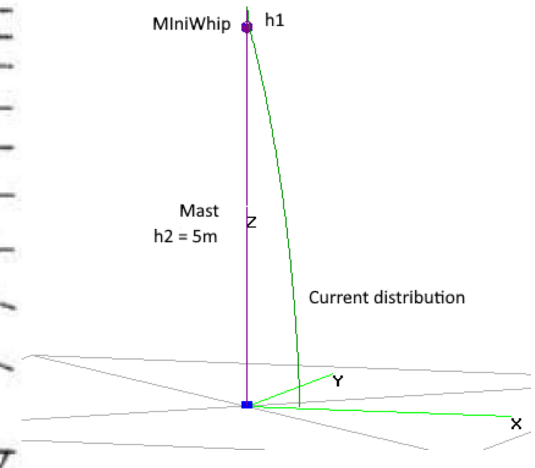
The open circuit Voltage U_0 at the input of the amplifier is calculated:

$$Uo = E \cdot h_{eff} \Rightarrow Uo = E \cdot (½\, h1 + h2)$$
$$Uo = 1\,V/m \cdot (0.5m + 1m)$$
$$Uo = 1.5V$$

Due to the current distribution, the heigth of the mast contributes with factor 1, the Whips heigth only with factor 0.5 to heff. (condition: heigth of mast and Whip do not exceed 0.15λ)

Effective Heigth Dipole vs. Monopole on a Mast





(E) EZNEC simulation, short whip on mast

(D) Dipole with a length of l

The effective heigth taken from a table :

$$h_{eff} = ½\, l$$

$$U = E \cdot h_{eff} \Rightarrow U = E \cdot ½\, l$$

E is electric field strength iV/m
h_{eff} of a short Dipole = ½l

The output voltage U of a dipole is decoupled from the mast heigth. At a given electrical field strength U depends almost completly on the dipol length .

The output voltage U of a short dipole is lower than U of a Monopole on top of a mast.

(E) Monopole with a length h1 on top of a grounded conductive mast with the length h2

The effective heigth taken from a table:

$$h_{eff} = ½\, h1 + h2$$

$$U = E \cdot h_{eff} \Rightarrow U = E \cdot (½\, h1 + h2)$$

E is electric field strength iV/m
h_{eff} of a short Monopole = ½h (from antenna parameter table)

On a Miniwhip, where h1 ist very small, the output Voltage is almost completely determined by h2, the heigth of the mast. Doubling the mast heigth h2 doubles the Voltage U

Active monopole - effects of mast heigth

If the height of a mast plus Monopole exceeds 0.15 λ it is per definition not longer considered as a electrically short Antenna.

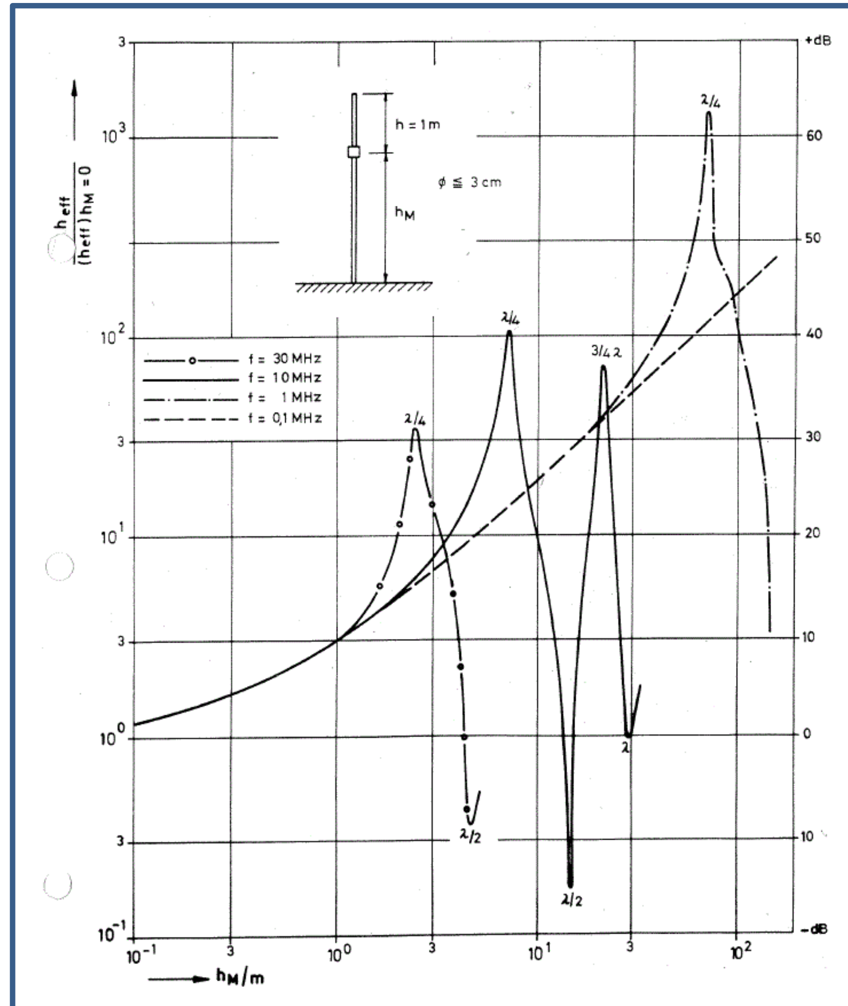
At λ/4 and odd multiples thereof we then observe voltage maxima

At λ/2 and multiples thereof we then observe voltage minima.

In order to achieve a flat frequency response the mast heigth should not be higher than 0.15 λ to stay clear of the first λ/4 resonance. A 10m mast for example has its first resonance peak at 7 MHz.

Short dipoles (l is less than 0.15 λ) are not affected by mast resonance effects. They are decoupled from the mast potential.

h_{ef}



Resonance effects at selected frequencies related to the corresponding antenna heigth

Antenna-Factor „AF“

The **Antenna Factor** (often also called transducer factor or conversion factor) is defined as the ratio of electric field strength and the measured loaded output voltage at its feed point

$$AF = \frac{electric\ field\ strenght}{output\ voltage\ at\ load\ 50\Omega}$$

For convenience the Antenna Factor is often expressed in logarithmic form:

$$\text{AF}(dB/m) = 20\log\frac{E(V/m)}{U}$$

AF = Antenna Factor
E = elecric field strength in V/m
U = voltage loaded

The Antenna Factor AF is closely related to the effective height h_{eff} *but describes the loaded voltage at the receiver input and not the open circuit voltage* U_0 *of the antenna.*

The Antenna Factor is a Figure of Merit to compare Antenna types and is a measure of the voltage an antenna produces at the receiver input. When the antenna factor is known, the field strength E surrounding the antenna can be easily calculated and vice versa.

References

[1] Website DL4ZAO, https://www.dl4zao.de, (in German, please use a web-translator)

[2] H.Lindenmeier, AGARD Lecture series No.131 1983 chapter 5-1 https://apps.dtic.mil/sti/pdfs/ADA135087.pdf#page=66

[3] Constantine A. Balanis „Antenna Theory Analysis and Design". 4th ed. 2016

[4] Rhode & Schwarz „Antenna Basics White Paper"

[5] Rhode & Schwarz „Antennas for Radio Monotoring"

[6] Rudge, Milne „Handbook of Antenna Design Vol 2" page 639

[7] Pieter-Tjerk de Boer, PA3FWM, „Fundamentals of the Mini-Whip Antenna"

[8] Jan M. Simons, PA0SIM, "The MiniWhip in EZNEC"

[9] Pieter-Tjerk de Boer, PA3FWM, "Grounding of MiniWhip and other active whip antennas"

[10] Fenu Radio, a website with receiver and antenna reviews: https://www.fenu-radio.ch/en-index.htm