Whip-Tipps

Installation, operation and functionality of 'Whip' active antennas

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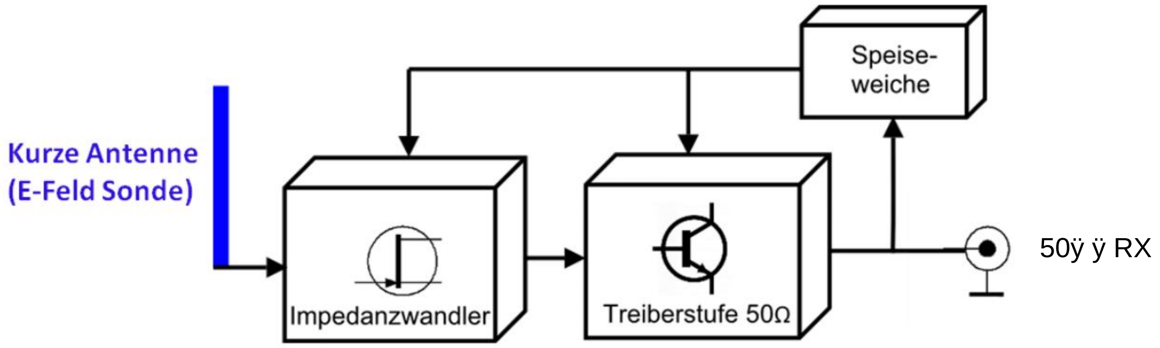
1.1 Whip E-field active antennas based on the impedance converter principle

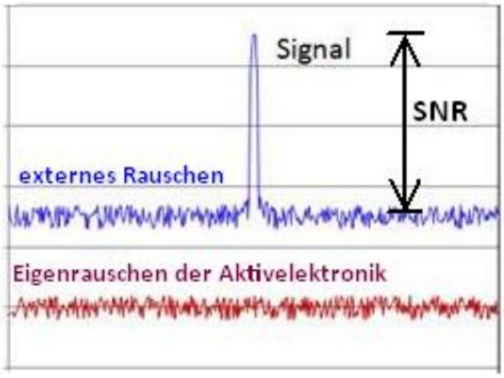
Active antennas with a short monopole in relation to the receiving wavelength - a rod or 'whip' - as a radiator and an impedance converter as an amplifier have a high impedance in their near-field behavior and react predominantly sensitively to electric fields of radio waves. The popular mini-whip [4] is also such a monopole, only with a very short radiator. In a mini-'whip', a metal surface is connected as an antenna element to an amplifier with a high-impedance input instead of a rod. The active antenna 'measures' the potential difference between the antenna element and the earth connection and conducts the probed voltage with power amplification via a coaxial cable to the receiver.
The result is a vertically polarized, omnidirectional receiving antenna. In order to achieve optimal reception results with E-field active antennas, important conditions must be observed during installation and operation.



*1.2 **Installation, height and ground connection for best SNR***

In a receiving system, the signal-to-noise ratio (SNR) is the decisive factor.
In addition to the receiver's own noise, the noise is made up of the active electronics' own noise and the external noise received by the antenna (atmospheric, galactic and man-made noise) [5]. If you want to achieve optimal reception results and a good SNR with an E-field active antenna, you have to pay attention to a few special features when setting it up.

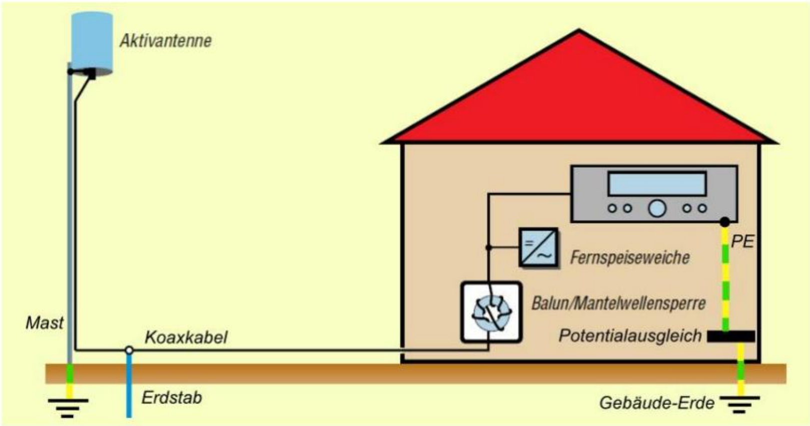
The reception voltage (signal + external noise) of an E-field whip antenna increases proportionally with the length of the antenna rod and with the mounting height above ground. To avoid overloading the active electronics, it is advisable to ensure that there is a sufficient signal-to-noise ratio and not to aim for the highest possible S-meter reading. As long as the externally received noise is significantly higher than the inherent noise of the active electronics and determines the SNR, the mounting height is sufficient.



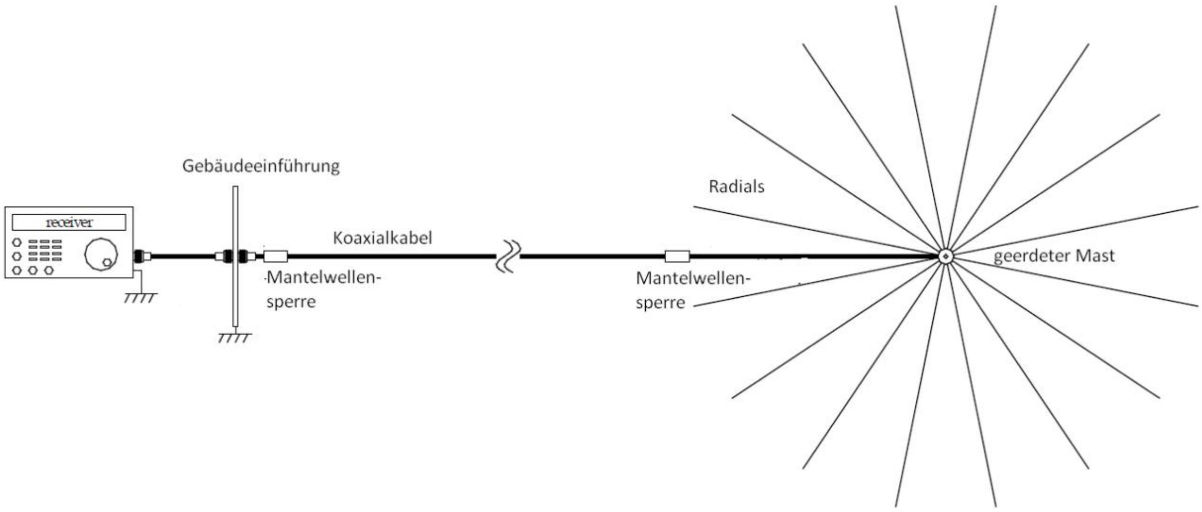
The length of a whip active antenna or the height of the mounting mast is best chosen so that a higher installation only causes an increase in the overall signal level (signal + noise) but no noticeable improvement in the signal-to-noise ratio. In practice, a height of 1 to 6 m has usually proven to be sufficient for reception of LW up to the KW range.
As a guideline: the mounting height should not be more than 15% of the wavelength of the highest frequency used. Greater heights can cause overloading of the

amplifier and intermodulation. An E-field active antenna on a higher mast or on the House roof is not recommended.

The ideal location for a whip is outside the domestic noise level, over a well-conductive ground, the ground with a radial system or over an extensive metal surface, e.g. a flat metal roof. When mounting on a conductive mast, the antenna element of the active antenna must extend beyond the mast.



A good earth connection of the active antenna plays an important role; without it, the amplifier lacks a ground reference. If there is no earth connection via the metal mast or a separate earth cable, the shield of the coaxial cable inevitably takes on the role of the earth feed or acts as an undefined counterweight. The mast and the feeding coaxial cable are therefore effective components of the active antenna system. The received signal is created from the voltage (potential difference) between the antenna element, the whip, and the potential of the earth connection on the outer conductor of the amplifier socket as a ground reference. To do this, the mast or the shield of the coaxial cable is earthed at the base point over a short distance with a rod. Radials around the base of the mast also help to improve the quality of the earth reference.



1.3 Operating an active antenna with minimal interference

E-field active antennas are placed outside the domestic noise fog. The high-impedance probe otherwise captures near-field interference from domestic and industrial sources of interference such as switching power supplies, TV sets,

Photovoltaic systems, LED lights and PLC modems.
Common mode interference is introduced by radiation onto the shield of the coaxial cable (sheath waves) or via line-bound equalizing currents via ground loops. The coaxial cable is usually connected to the PE of the house distribution via the receiver; interference voltages and currents can also be coupled in this way.

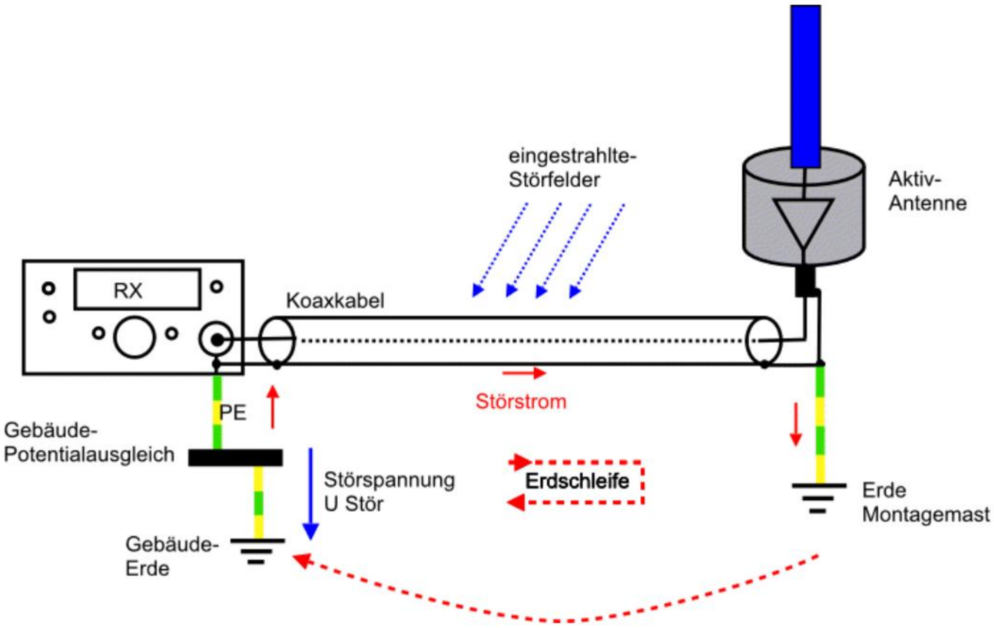


Image: Paths of interference coupling, line-guided via ground loop or radiation onto the shield of the feed line.

The spread of unwanted interference currents via the shield of the coaxial cable can be minimized by choosing a suitable installation location, choking the feed line with sheath wave traps / common mode chokes and good grounding and equipotential bonding. The coaxial shield is connected to an RF-compatible earth using the shortest possible route. Laying the feed line in the ground or on the ground also reduces the risk of radiated interference.

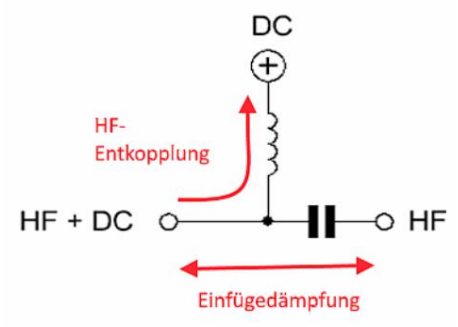
For protection reasons, the earth connection of the active electronics or the outer conductor of the output coaxial socket should be connected to an earth electrode or the earthed mounting mast via a short distance.
An earth connection solely via the coaxial cable shield via the earth connection via the protective conductor/PE in the shack does not provide sufficient protection against overvoltages. There is also the risk that interference will be introduced through a "dirty" PE house earth.

1.4 Requirements for the quality of the power supply

It is particularly important for E-field active antennas such as an active whip to use a low-noise and low-interference power supply. Preferably a linearly regulated power supply; switching power supplies are often inadequately filtered and suppressed. The high-frequency switching pulses and their harmonics are propagated both by conduction and by radiation and can overlap the reception voltage in these ways and degrade the SNR.

1.5 Remote feed switch – Bias-T

A remote feeder - referred to in English as a bias-T or power injector - is used to supply operating voltage to active antennas via the existing coaxial cable. It is a T-shaped crossover through which a DC supply voltage can be fed into or fed out of the coaxial cable without any feedback.



The low-reaction connection of the direct voltage to the high-frequency line is carried out via RF chokes, whose inductive resistance represents a high resistance in the useful frequency range, but allows direct currents to pass through.

A high-quality remote feeder is an important element for interference-free reception. Good switches have the lowest possible insertion loss and a low VSWR for the continuous RF branch. The DC port should be isolated from the RF path by as much decoupling as possible so that no interference from the power supply can reach the receiver and so that the RF signal is not attenuated by losses via the DC port. A high-quality bias-T guarantees decoupling values of >50 dB between the DC port and the RF ports across the entire useful frequency range. Simply constructed remote feeders often do not meet this requirement adequately.

In particular, if the choke inductance used is too small, sufficient decoupling is not achieved at low frequencies. At high frequencies, the choke's natural resonances can impair decoupling. A remote feed switch must be sufficiently dimensioned for the supply current to be fed in. If the specified maximum current of a remote feed switch is exceeded, a ferrite choke becomes saturated and the decoupling effect decreases.

1.6 Active antenna, feed line and mast height interact

To understand the relationships, it is important not to look at the active antenna in isolation, but to see it as part of an antenna system. This system consists of the main components:

- Antenna element, usually a rod (whip) or a metal surface
- Active electronics: impedance converter / amplifier
- Height of the mast or length of the coaxial cable above ground
- Earth or an equivalent counterweight

All components interact and together form the antenna system. The mast height or the length of the ground feed to the active antenna is part of the active antenna system and plays a decisive role in its properties as a broadband antenna and in the reception voltage delivered.
Approximately, doubling the installation height leads to a doubling of the output voltage, corresponding to a +6dB increase. However, if the installation height above ground is longer than approx. 15% of the wavelength received,
Resonances increasingly occur, which lead to frequency-dependent increases and decreases in the received signal level – the broadband properties of the active antenna are lost.

The ground reference potential at the connection of the active electronics is provided via a grounded antenna carrier or otherwise, in the case of an insulated mast, via the outer shield of the coaxial cable. The connection to an RF-compatible functional earth should be made via the shortest possible route, ideally directly at the foot of the mast. Without earthing or radials, only the shield of the coaxial cable acts as a counterweight.

1.7 Practical tips in brief:

- **Vertical monopole active antennas such as a miniwhip are vertically polarized Receiving antennas with omnidirectional characteristics.**

- **Active antenna, cable and earth/counterweight work together as a complete system.**

- **The strength of the received signal level increases proportionally with the height of the antenna above ground. A higher mounting gives higher output levels, but**

- **Mast heights above a guideline value of 0.15 ÿ at the maximum usable frequency lead to ripples in the reception voltage. The result: uneven frequency response, risk of overloading the amplifier, intermodulation.**

- **In practice, a mounting height of between 1 m and 6 m above ground is sufficient for LW to KW. an equivalent counterweight for an adequate SNR.**

- **A good RF earth at the base of the mast is important for low-interference operation. If the earth potential is only supplied via the coaxial cable and the earth connection in the shack, there is a risk that interference will be introduced via the cable.**

- **Sheath wave barriers (also known as current balun, common mode choke, common mode Choke) can help to suppress interference coupling via the cable shield.**

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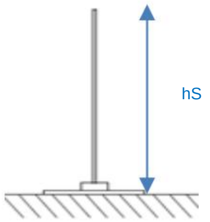
1.8 Influence of mast height on a short monopole active antenna

An antenna is said to be "electrically short" if the dimension of the antenna length is significantly shorter than a quarter of the wavelength at the operating frequency. (L << ÿ/4)

In homogeneous electromagnetic fields, short monopoles, such as a mini whip, show a dependence of the antenna voltage u on the height, in contrast to symmetrical, dipole-like antennas. The reason for this is the frequency-dependent or runtime-dependent current distribution that occurs along the shield of the coaxial cable shield or a conductive mast. The current maximum occurs at the ground, while the maximum of the voltage distribution is found at the upper end of the radiator. The
The field strength picked up by the whip depends not only on the size of the antenna element (rod or metal surface), but also on the installation height above ground [8], [11].

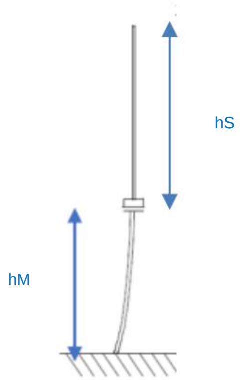
The term “effective height” or “useful height” is used to determine the output voltage. The effective height or useable height *hN* of an antenna is not identical to its actual length or height.
It is a conversion factor that describes the relationship between the reception field strength E and the
Antenna generated open circuit voltage u describes: u = E ÿ hN

For short monopoles directly on the ground with the radiator length hS, the effective antenna height is equal to half the height of the radiator.

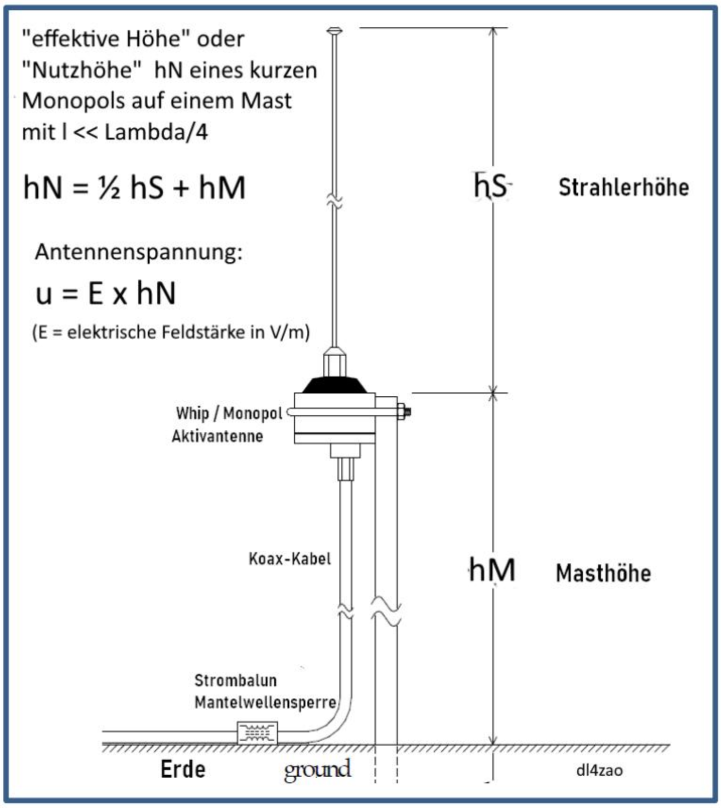


hN = ½ hS

If the antenna is mounted higher on a mast or support tube, the effective
Antenna height hN according to the relationship:



hN = ½ hS + hM

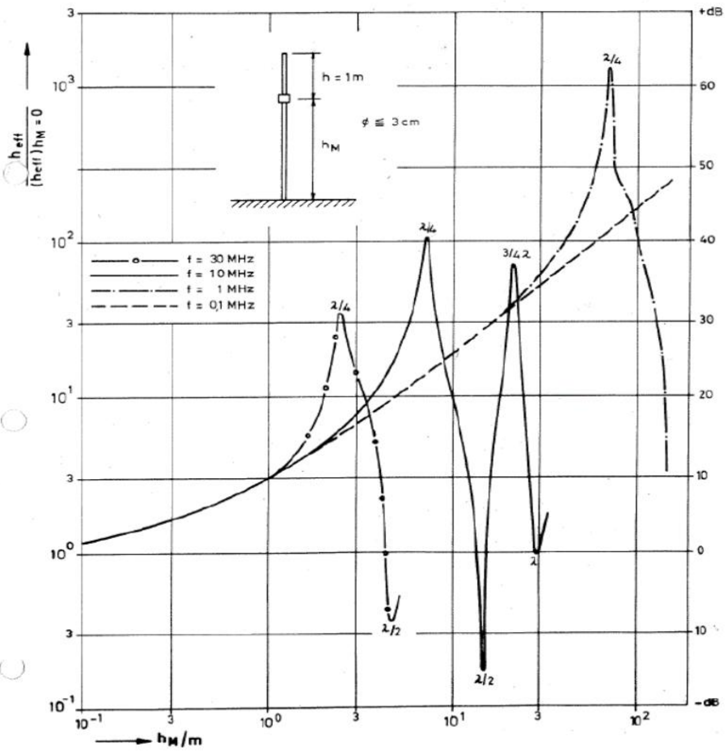


The antenna voltage shows a pronounced dependence on the mast height above ground. As soon as the radiator and mast height are no longer small in relation to the operating wavelength (hS + hM) / ÿ > 0.15), the voltage and current distribution on the mast becomes increasingly wavy. With increasing height, mast resonances form and the reception voltage becomes frequency-dependent with peaks and dips.

The curves on the right show the influence of the mast height on the ripple of the antenna voltage of a 1m antenna rod on a mast with height hM in m.

At heights of ÿ/4 and at ÿ/2 and multiples thereof, pronounced resonance peaks with exaggerations and cancellations occur.

Graphic: HK Lindenmeier, DUK-ASS company document



1.9 ***Properties of an electrically short antenna***

The power that an antenna can extract from the electromagnetic field is described by its effective area A [2].

$$A = \frac{\lambda^2}{4\pi} D$$

D is the 'directivity factor', which is given in the literature as 1.64 for the half-wave dipole and 1.5 for the electrically short dipole. Analogously, a D of 3.28 or 3 applies to the short monopole. This means that a monopole that is small compared to the wavelength ÿ has an effective area and thus a reception power that is only about 10% lower than a full-grown resonant ÿ/4 monopole. The effective area of a short lossless radiator is independent of the antenna dimensions.

If it is true that an electrically shortened antenna has only slightly less gain or effective area than a resonant antenna, why do we bother with quarter-wave or half-wave antennas? [6] A closer look at the complex base impedance makes it clear why

a power adjustment to the extreme impedance of an electrically short monopole with passive matching elements L and C is unrealistic:

For very short antennas, the base resistance Zin consists of the series connection of the radiation resistance and the loss resistance as well as a small capacitance. The radiation resistance RS of a short monopole of length l is calculated according to the relationship

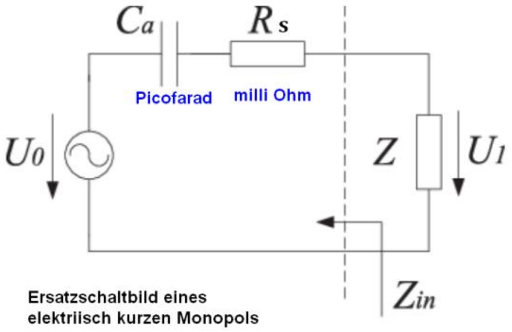
$$R_S = 395 \times \left({}^{l}/_{\lambda} \right)^2$$

For antenna lengths l such as the Mini-Whip, the radiation resistance at low frequencies is in the milliOhm range. In series with this, the antenna capacitance Ca is a few picofarads - a very high capacitive reactance.

1.10 Equivalent circuit of a short radiator

In the simplified electrical model, an antenna element that is very short in relation to the wavelength behaves like a voltage source with a very small internal resistance in series with a capacitor Ca of a few picofarads. The size of the series capacitance depends on the dimensions of the antenna element.

The complex base impedance Zin = R + jXC is therefore composed of a series connection of a very small resistance R with a large capacitive resistance -jXc. The open circuit voltage U0 the source is proportional to the received electric field strength.



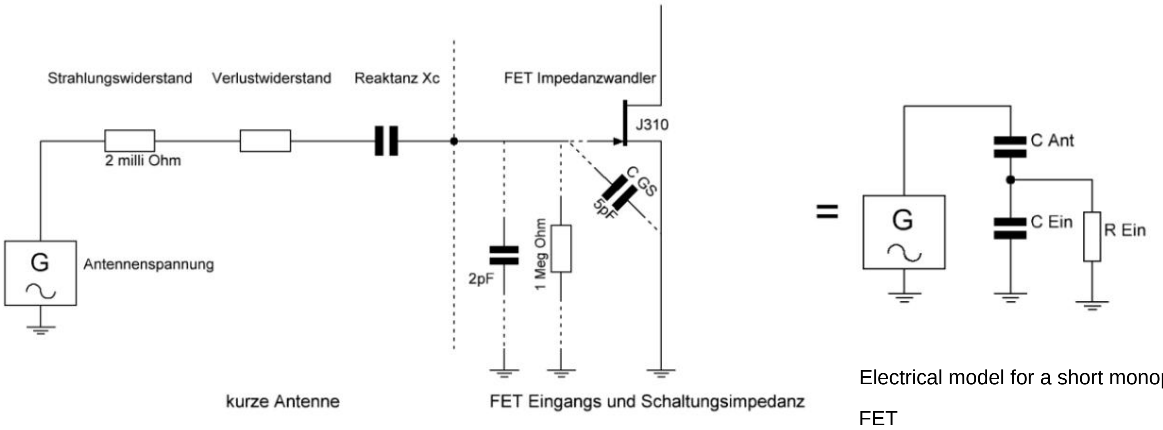
If the base impedance Zin, which is dominated by the high capacitive resistance, is loaded with a receiver input of Z = 50ÿ, the reception voltage U1 collapses to very small values due to the voltage division Zin / Z. In this case, there is no longer enough reception voltage available at the receiver for a good signal-to-noise ratio.

In order to be able to take the idle reception voltage with low losses, the load impedance Z must be high in relation to Zin; voltage adjustment instead of power adjustment. This is achieved by an active impedance converter, which takes the voltage at a high impedance and amplifies the power so that a 50ÿ load can be operated. If the impedance converter amplifier and the short antenna element are integrated into a functional unit, this is called an active antenna.

1.11 AktivWhip – short monopole with impedance converter amplifier.

In the equivalent circuit, the whip can be seen as a generator with a very small internal resistance, which is coupled to the amplifier input via a series capacitor of a few picofarads. The reactance Xc of the antenna capacitance CAnt, which assumes very high values at low frequencies,

forms a capacitive voltage divider with the input resistance of the FET and the reactance of the gate-source capacitance and the circuit capacitances, which reduces the input voltage at the gate of the FET. The higher the antenna capacitance CAnt , the less the effect of the
Voltage division is noticeable. In order to be able to measure the open circuit voltage with low losses, a high-resistance impedance converter with low input capacitance is required. The input impedance of the FET impedance converter is essentially determined by the parasitic capacitances of the FET and the circuit structure.



Electrical model for a short monopole with FET
Impedance converter

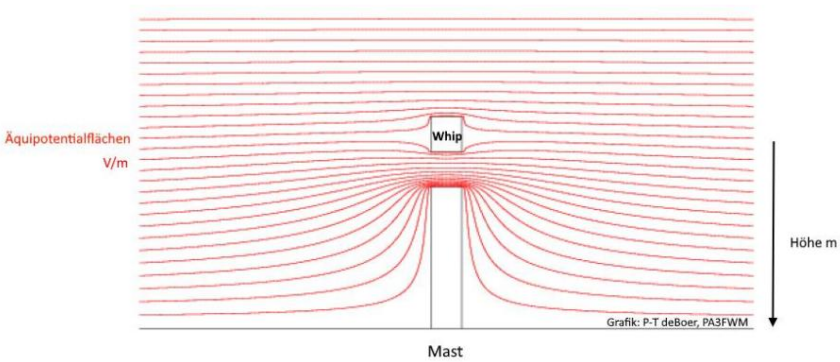
1.12 Principle of operation of short ‘whip’ E-field active antennas

For the sake of simplicity, the considerations in this section assume that the height of the mast and the antenna element are short in relation to the wavelength (L << ÿ/4) and that the signal to be received is vertically polarized. These conditions can be assumed to be met for active antennas in the range from VLF to the lower HF range.

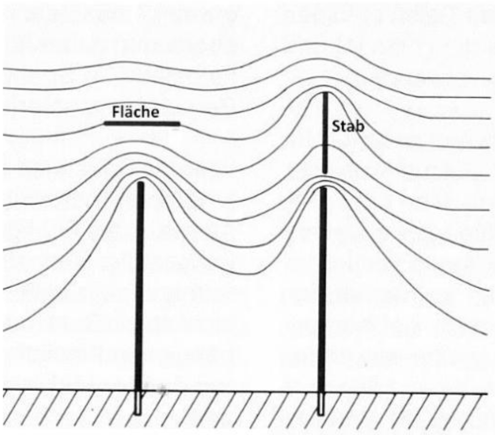
A mini whip is one of the electrically short monopole antennas. The antenna length includes the height of the antenna elements (whip, rod, surface) and the height of the mast above the ground or counterweight.

Pieter-Tjerk deBoer, PA3FWM has studied the function of the MiniWhip using scientific methods. In his paper “Fundamentals of the Mini-Whip Antenna” [6], [7] he describes the functionality using a quasi-static field simulation. The abbreviated quote from this is:

*“An electromagnetic wave creates (imaginary) field lines around the antenna.
The potential increases with height, the field lines form surfaces staggered in height with the same voltage against ground (equipotential surfaces).
A conductive mast or the shield of a coaxial cable distorts the equipotential surfaces. Close to the receiving element, the potential is hardly any different than at the same height far away from the mast. The assumption that the potential is measured at a height of several meters against ground is therefore quite correct."*



The passive antenna element (whip) of the active antenna takes on the potential of the equipotential surfaces penetrating it and acts as a voltage probe. The impedance converter amplifier measures the voltage difference between the whip and the amplifier ground connection at a high impedance. The ground connection on the amplifier coaxial socket takes its potential from the outer shield of the coaxial cable or from the conductive mounting mast. "Amplifier ground" is therefore the potential of the coaxial cable sheath or, in the case of a conductive mast, the potential of the mast on which the active antenna is mounted. For short masts (hS + hM / ÿ ÿ 0.15), it corresponds approximately to the earth potential, but differs from the actual earth potential with increasing height.



Grafik D. Burchard [10]

The graphic on the left shows again the field distortions caused by a grounded mast, a ground wire or by the shield of the coaxial cable connected to earth.

A horizontal conductor or even a small surface as an antenna element disturbs the field only insignificantly, they assume the potential of the environment. Even a short vertical rod distorts the field only slightly. It assumes the average potential of its environment.

A grounded mast or the grounded shield of a coaxial cable distorts the field considerably. At the top of the mast, the earth potential is practically present

For this reason, the average length of a rod is only half taken into account when determining the effective usable height hN of the active antenna, but the height of a grounded mast is taken into account in its entirety.

From the field representations shown above, it can also be deduced that an E-field monopole active antenna receives vertically polarized waves. The shape of the antenna element, whether rod or surface, and its orientation, vertical or horizontal, are irrelevant. The horizontal directional characteristic is omnidirectional.

In an impedance converter active antenna, the open circuit voltage of the antenna element is taken with a high impedance field effect transistor. The voltage difference to the ground potential at the connection of the active antenna is amplified in power so that the signal can drive a coaxial cable to the receiver.
The signal voltage at the receiver input corresponds - possibly reduced by the voltage losses in the amplifier - to the potential difference between the antenna element and the mast tip, or the ground connection of the active electronics.

1.13 Sources, references and further reading

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[4] Roelof Bakker, PA0RDT – "Mini Whip"

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