



# HF Antennas: Vertical or Horizontal?

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## Summary

If you can have only one antenna and can chose between a vertical HF antenna or a relatively high horizontal HF antenna, **go for the horizontal antenna!** **Wide-band active small magnetic receiving loops** (not to be confused with tuned magnetic loops) offer, when mounted close to the ground, improved noise immunity at reception.

## Modelling results

In January 2008, —as little as three months before his lamented dead— L. B. Cebik, W4RNL (SK) published what was going to be the last entry of his seminal *10–10 News* series.<sup>1</sup> It turned out to be an interesting gain comparison of **single element 28.4 MHz antennas modelled over various ground types** of which a summary is presented here (Table 1). His findings seem to fit well with what John Devoldere, ON4UN modelled and published for equivalent antennas on the lower HF bands.<sup>2</sup> This led me to write up the following synopsis.

**Table 1: Gain & elevation angle of single element 28.4 MHz antennas over various ground types<sup>1</sup>**

polarisation	antenna	$h_{agl}$	salt water	very good	average	very poor
vertical	$\frac{\lambda}{4}$ monopole with 32 buried radials	0	4.27 dBi 11°	-0.56 dBi 24°	-0.31 dBi 27°	-1.69 dBi 29°
vertical	$\frac{\lambda}{2}$ dipole	1 ft	5.64 dBi 8°	0.69 dBi 17°	0.55 dBi 18°	0.15 dBi 21°
vertical	$\frac{\lambda}{4}$ monopole with 4 elevated radials	$\frac{\lambda}{4}$	6.31 dBi 7°	0.82 dBi 14°	1.15 dBi 16°	1.24 dBi 19°
horizontal	$\frac{\lambda}{2}$ dipole	$\frac{\lambda}{2}$	8.36 dBi 29°	7.73 dBi 28°	7.24 dBi 28°	6.48 dBi 27°

## Horizontal HF antennas

### ... benefit from nearby ground gain

At a height of about  $\lambda/2$ , the nearby ground reflection of a horizontal HF antenna will start to be constructive at interesting take-off angles for long-distance ionospheric contacts. This will provide a net gain over the antenna in free-space.

## Vertical HF antennas

### ... suffer from nearby ground loss

This is not the case with vertical HF antennas. Nearby ground only contributes loss. This even more so when the ground forms part of the return path of the radiating structure. Even when far-away ground reflections may cause the directivity of a vertical HF antenna at low take-off angles to be much higher than that of a horizontal HF antenna, its net gain will still be lower at those angles. This makes the horizontal HF antenna a clear winner, at least for what transmission is concerned. Note that gain and directivity are not synonyms; gain takes into account losses, directivity does not.

## Vertical HF antennas still remain useful

Vertical HF antennas do have their merit though. At the lower end of the HF spectrum, the  $\lambda/2$  height requirement for horizontal antennas can become cumbersome (even though horizontal phased arrays have a less stringent minimum height requirement). A vertical HF antenna can get away with a height of only  $\lambda/4$ . Furthermore, if the return conduction current of a vertical radiator flows through salt water, losses will be lower. Finally, the directivity of a vertical HF antenna can be effectively employed at the reception end to cancel out high-angle interference caused by near-by stations. This is why some stations use receive-only phased arrays of verticals on the low bands.

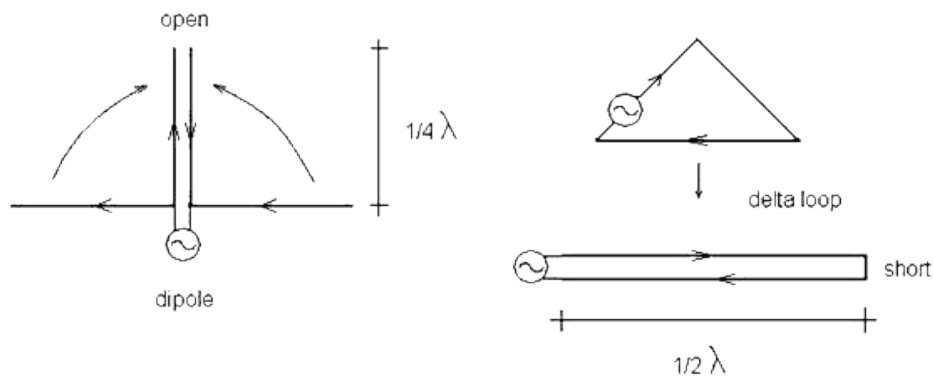
## Polarisation & noise

Polarisation is not really an issue at HF. This is because the ionosphere is mainly an anisotropic medium, i.e. it messes up polarisation. However, horizontally polarised antennas are again preferred over noisier verticals because of the following considerations pertaining to the polarisation of noise signals:

1. Earth-to-cloud lightning (QRN) is vertically polarised.
2. Vertically polarised man-made noise (QRM) propagates longer distances over ground than horizontally polarised man-made noise. Consequentially, the capture area for vertically polarised man-made noise is much larger than that of horizontally polarised man-made noise —actually, by a factor of the difference in ground wave propagation distance squared!

## Common mode input impedance & noise

Antenna input impedances differ between differential and common mode, as well as between different antenna types.<sup>3</sup> The differential and common mode input impedance of an antenna can be derived by considering the antenna as a two-wire, respectively single-wire, transmission line (Figure 1). My [article about common mode chokes](#) explains this in further detail. Antennas with a high common mode input impedance (see Table 2) will receive less noise from interfering sources in the near field.



**Figure 1:** Deriving the conducted common mode input impedance of a center-fed half-wave dipole and an edge-fed full-wave delta loop. *Source: ©2007 Jan Simons, PA0SIM*

**Table 2: The differential and common mode input impedances of two antenna types**

input impedance	differential mode	common mode
center-fed half-wave dipole	low	low
full-wave loop	low	high
folded half-wave dipole	medium	high

## Small magnetic loops

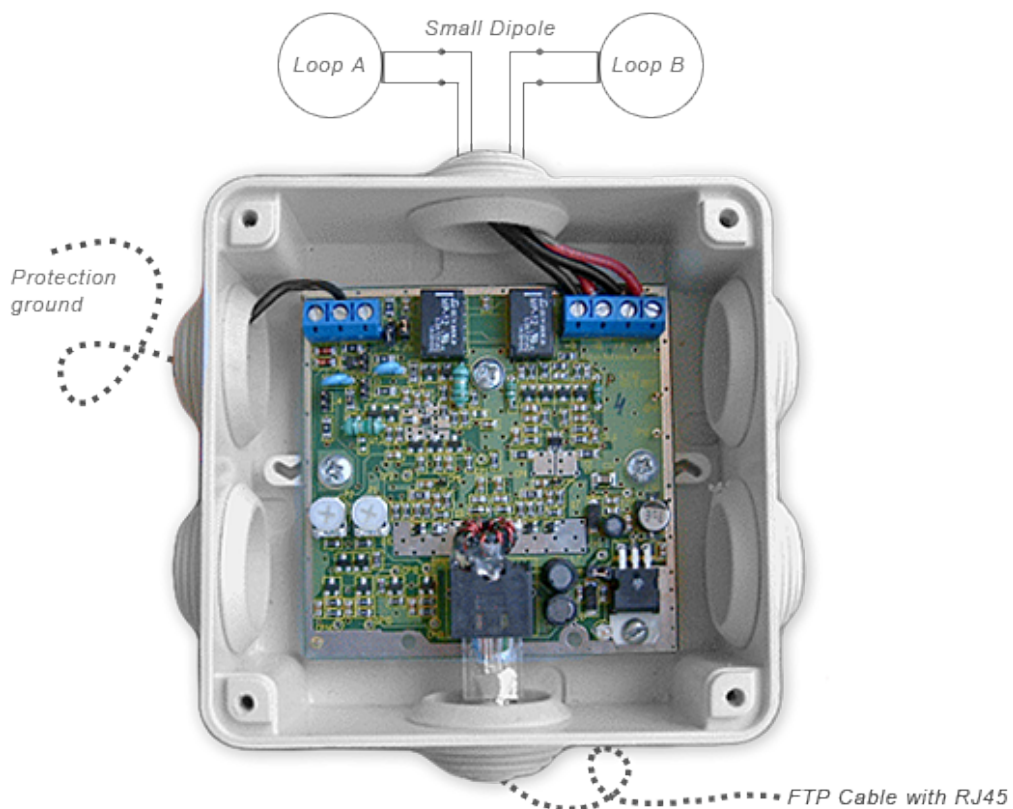
The above mentioned points about the polarisation of noise also hold true for **wide-band active small magnetic receiving loops** (not to be confused with tuned magnetic loops) when mounted close to the ground.

However, there is an additional reason why active small magnetic receiving loops are so successful at **improving noise immunity**:

3. Namely, the magnitude of the electrical field strength  $|\mathbf{E}|$  **in the near field** of human made noise sources is often much higher than 376.37 times the magnitude of the magnetic field strength  $|\mathbf{H}|$ .

**Small** magnetic loops with a circumference  $C < \frac{\lambda}{10}$  are not sensitive to the more pronounced electrical field strength emitted by nearby noise sources.

## Listen exclusively to the magnetic field



Only plane waves in the far field exhibit the characteristic impedance of free space, which is exactly:

$$Z_0 = \frac{|\vec{E}|}{|\vec{H}|} = \sqrt{\frac{\mu_0}{\epsilon_0}} = \mu_0 \cdot c_0 \approx 376.73 \Omega \quad (1)$$

where:

$c_0 = 299\,792\,458 \frac{\text{m}}{\text{s}}$ : the speed of light in free space

$\mu_0 = 4\pi \cdot 10^{-7} \frac{\text{H}}{\text{m}}$ : the free space permeability

$\epsilon_0 = \frac{1}{\mu_0 c_0^2}$ : the absolute permittivity of free space

$Z_0$ : the characteristic impedance of free space

## References

1. L. B. Cebik, W4RNL. No. 58: The Revere theory of vacation antennas. Published 2008. <http://www.cebik.com/>
2. John Devoldere, ON4UN. *On4un's Low Band DXing*. 5th ed. The American Radio Relay League, Inc.; 2010. <https://www.arrl.org/shop/ON4UN-s-Low-Band-DXing>
3. Jan M. M. Simons, PA0SIM. Antenna common mode impedance. Published March 2007. [http://www.pa0sim.nl/Antenna common mode impedance.htm](http://www.pa0sim.nl/Antenna%20common%20mode%20impedance.htm)



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