Factors That Seem to Make For Unsuccessful HF Antennas

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I've had the unfortunate experience of either constructing, or assisting volunteers who have utilized, HF antennas that turned out to be basically unworkable --- unable to either hear or contact stations that are normally able to be reached with conventional dipoles at normal heights of 20-40 feet.

I've come to the conclusion that there are two factors that can doom an HF antenna:

- **short length** leading to extremely low "radiation resistance" and resulting miniscule efficiency; and

- **nearly complete absorption of the signal** by nearby attenuating structures (usually man-made houses or buildings or the ground or a poor desired connection to the ground).

(There's another factor that I'll skip in this paper: extraordinarily high loss antenna designs. These are usually short, end-fed transformer-based antennas that magically work on "all bands" with "low SWR" – usually have designed in losses due to lossy transformers, and even intentionally added resistors to cover up poor SWRs.....here's just ONE example of calculations of losses (https://wv0h.blogspot.com/2015/01/loss-in-deployed-end-fed-wire-and-91.html). If you're going to use a "multi-band transformer based" antenna, get one from a really proven manufacturer.)

Also remember the reciprocity theorem for antennas: an antenna/transmission line system that wastes most of the power coming out of a transmitter.....will also waste most of the power of an incident electromagnetic radio signal that you're trying to receive!

The purpose of this article is to explain these so that others can avoid them.

Additional Internet resources that give a range of ideas on how to put antennas in difficult circumstances: http://www.bvarc.org/pdf/HF_Antennas_by_KD5FX.pdf http://www.qsl.net/nf4rc/2018/HOA&ApartmentAntennas.pdf

Short length → Low Radiation Resistance –> Low Efficiency

Most hams know that a typical half-wavelength-long dipole at resonant frequency appears to be nearly pure real resistance of around 50 ohms. In other words, the copper wires somehow turn electrical power into radiated electromagnetic waves such that the accepted power will have a ratio between the voltage and the current of 50. Feed it with 50 volts RMS and the current flow at the feed terminals will be 1 ampere. 50 Watts gets radiated.

This isn't the case at all when that antenna is shortened drastically. Not only is there now a huge series capacitive reactive component (needing series inductance to overcome, and that series inductance has LOSS RESISTANCE) but the RESISTIVE part of the true radiation resistance takes a nosedive, and much of the resistive component MEASURED at the feedpoint may have to do with LOSSES (particularly if some sort of GROUND CONNECTION of part of that feedpoint impedance...as is the case with so many “vertical” monopoles). .

> W8JI provides a very extensive discussion of true radiation resistance: https://www.w8ji.com/radiation_resistance.htm For even more math, see: http://www.eie.polyu.edu.hk/~em/hdem06pdf/12%20Antenna%20Properties.pdf

This reference: http://www.radio-electronics.com/info/antennas/dipole/short-dipole-antenna.php indicates the radiation resistance of a dipole that instead of being ½ wavelength, is less than 1/10 the wavelength, is given by:

> Radiation resistance = 20 * (3.14 * L / wavelength) ^2

Basically, as an antenna is shortened, the true radiation resistance does down by the square of the shortening. That tiny true radiation resistance is in SERIES with all the effective resistive losses of your coax, all the connections, any tuner resistive losses and a huge resistance if you are trying to use a ground connection. Since power dissipation is I^2R, relativey LITTLE of your power goes to the (useful) radiation resistance, and more and more of your transmitter's output power is consumed by all the other losses in your system.... You can easily lose 90% even 99% of your power....

Using that formula we get the following values, used as examples of what can happen:

Amateur Radio Band	**Antenna total length in meters**	**Radiation Resistance**
80meters	2meters (> 6 feet)	0.12 ohms
80meters	10 meters (> 30 feet)	3 ohms
20 meters	2 meters (> 6 feet)	2 ohms

When your radiation resistance is LESS THAN AN OHM......the loss resistances of simple wires become enormous. You take most of your transmitted (or received) energy and turn it into waste heat.

The moral of this part of the story is use the LONGEST conductor you can for your antenna, and use the highest quality tuner etc possible if you're going to use a shortened antenna.

ABSORBED BY NEARBY STRUCTURE

Once I built a fairly full sized antenna – which should have had relatively high efficiency --- but suspended it at about 10-15 feet between tall buildings. Attempts to use this antenna for amateur communication on both 80 and 40 meters were nearly completely fruitless. I've come to believe that a likely reason is simply attenuation of the signal by all the absorbing materials in the nearby buildings, and in the ground underneath. There wasn't any clear path for radio energy to escape and even make it into the sky without having to pass through apartment after apartment, through all kinds of wiring, steel, concrete, structural metal etc.

The absorption of a signal through the structure of a building can be in the range of 30-50 DECIBELS based on carefully done measurements at multiple frequencies of gutted office buildings just before implosion. A 30-dB loss means that a KILOWATT (1,000 watt) signal is reduced to 1 watt effective power --- or less than most handheld walkie talkies. A walkie talkie signal (say, 5 watts) is reduced to FIVE MILLIWATTS --- or what you might get with a one transistor oscillator circuit operated by a AAA battery.

REF: https://ws680.nist.gov/publication/get_pdf.cfm?pub_id=33178

(See charts below of the incredibly high losses, from 50 MHz and up. Losses at lower frequencies might be somewhat lower, but these are such extreme losses that one must believe that buildings basically obliterate radio waves.)

The ground is NOT your friend in most cases – the last two pages of this reference show how raising a vertical antenna made a 13 db difference in received signal strength in a carefully done experiment. My low-antenna design might have been "warming the earthworms" but it wasn't radiating very well! Read this reference for more information: http://audiosystemsgroup.com/AntennaPlanning.pdf

The moral of this part of the story is --- give your antenna the widest possible view of the sky, not just "straight up" but all the way down to the horizon if possible. That usually means getting it higher, and further away from buildings.

CONCLUSION

The conclusion for getting an antenna that actually WORKS for your transmitter/receiver is this: choose an antenna that is as long as you can make it up to a half-wavelength (or maybe longer) --- and get it "into the clear" --- get it as clear of surrounding buildings, brick, concrete, metal etc....as possible. Don't let it be SHIELDED by manmade structures. At microwave frequencies, TREES become a very significant attentuator, but at HF this is much less of a problem.

REF: REF: https://ws680.nist.gov/publication/get_pdf.cfm?pub_id=33178:

Table 17. 50 MHz frequency band.

Structure/Location	Freq. (MHz)	Ref. level (dBm)	Median (dB)	Mean (dB)	Std. Dev. (dB)
New Orleans, LA apartment	50	−3.7	−35.9	−37.5	13.1
Philadelphia, PA sports stadium					
First inside walk; horiz. polar.	50	0.0	−34.0	−29.5	15.5
Second inside walk; horiz. polar.	50	0.0	−44.4	−42.8	8.8
Inside walk; vert. polar.	50	0.0	−36.8	−32.8	14.2
Outside walk; horiz. polar.	50	0.0	−32.8	−27.8	15.5
Outside walk; vert. polar.	50	0.0	−41.8	−36.0	18.4
Phoenix, AZ office					
Colorado Springs, CO, CO hotel complex					
First walk-through, Receive site 1	50	−23.7	−62.8	−58.0	17.6
Second walk-through, Receive site 1	50	−29.2	−58.2	−56.2	11.1
First walk-through, Receive site 2	50	−57.6	−14.9	−12.3	5.3
Second walk-through, Receive site 2	50	−31.5	−62.9	−57.8	12.4
Grocery Store (Boulder, CO)	50	−35.4	−45.1	−43.1	12.0
NIST office (Gaithersburg, MD)	50	−21.3	−68.6	−62.1	16.5
Shopping mall (Bethesda, MD)					
Receiver site 1	50	−47.3	−49.4	−47.2	5.9
Receiver site 2	50	−48.9	−44.4	−42.2	9.7
Discovery office (Silver Spring, MD)	50	−21.6	−64.2	−63.7	11.4
Washington, DC convention center					
Receiver site 1	50	−19.1	−63.9	−62.3	12.5
Receiver site 2	50	−26.3	−50.6	−49.8	14.4
Receiver site 3	50	−13.3	−67.4	−65.3	15.5
Horizon West Apartment (Boulder)					

REF:
REF: **Table 27. Mean values of scenarios used for structure/building attenuation statistics.**

Scenario	50 MHz	150 MHz	225 MHz	450 MHz	900 MHz	1.8 GHz	2.4 GHz	4.9 GHz
1	−37.5	−27.9	−33.1	−39.7	−34.2	−34.0	NA	NA
2	−32.8	−39.2	−34.2	−28.7	−27.2	−26.5	NA	NA
3	−58.0	−37.6	−39.5	−30.0	−34.1	NA	NA	NA
4	−43.1	−36.0	−43.0	−29.2	−33.8	−39.3	NA	NA
5	−62.1	−41.6	−44.1	−46.9	−57.7	−55.6	NA	NA
6	−47.2	−46.5	−49.9	−52.8	−44.6	−33.3	NA	NA
7	−63.7	−55.7	−60.3	−52.4	−70.4	−67.2	NA	NA
8	−65.3	−66.0	−62.3	−57.3	−66.4	−58.2	NA	NA
9	NA	−24.9	−25.9	−25.4	−27.0	−25.6	−17.5	−36.3
10	−50.3	−33.7	−34.1	−37.8	−42.7	−39.7	−41.1	−48.5
11	−50.2	−54.8	−43.3	−37.9	−28.9	−26	−62.7	−59.9

https://ws680.nist.gov/publication/get_pdf.cfm?pub_id=33178