Antenna Selection and Transmitter Power in the 22 Meter "Hifer" Band

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Background

The frequency range from 13.553 to 13.567 MHz has long been designated for industrial, scientific and medical (ISM) use. Because many of the intended processes such as induction heating generate large amounts of RF power, many countries have adopted relaxed limits on the radiation of those signals. This article focuses on the U.S. regulations; if you live in another country, check your rules to determine compliance.

Section 15.225 of the FCC rules permits a field strength of 15,848 microvolts/meter at a distance of 30 meters from an RF radiator in the 13.553 - 13.567 MHz range. This article will show that operation in the low milliwatt range with simple antennas is possible. If you have otherwise convinced yourself that a power of tens of watts is legal, this article will not help you to defend your position! The combination of milliwatt power, a dipole (or ground plane) antenna, and weak-signal techniques has produced receptions at thousands of kilometers. The Longwave Club of America web site (http://www.lwca.org)has maintained an operator list and basic information on Hifer operation to encourage the development of weak signal techniques applicable to LF, especially at times of the year where LF operation is difficult due to atmospheric noise.

The FCC rule is really aimed at ISM users who generate large amounts of power in confined areas. I don't think that the idea of communication over a large distance was ever anticipated. Compliance with the rule would typically be done by making field strength measurements outside a building containing induction heating or RF ID equipment, for example. Some of the anticipated uses (such as RF ID) do involve intentional radiation and reception, but over a very small area. But the 15,848 uV/m is sufficiently high for long-distance communication if we understand how to deal with it. Please realize that this is a very different regulation than we have in Amateur Radio, for example. It sets a limit on field strength, and you are expected to choose your antenna and transmitter power accordingly.

It is assumed that Hifer operators will not have the accurately-calibrated equipment to measure field strengths (either electric or magnetic) at this frequency. Even if they do buy or make the measuring equipment, it would be very difficult to get any useful data at 13.5 MHz on an antenna mounted 10-20 meters up in the air. Even at distances where the induction fields are low, reflections from the ground and nearby structures will make interpretation very difficult. Most importantly, such an antenna layout is *intended* to radiate a signal at angles suitable for reflection off the E and F layers of the ionosphere. It would be impossible for most of us to take field readings even in the plane of a dipole, let alone above it.

So I will focus on the calculated E-field to be expected from a half-wave dipole or quarter-wave ground plane antenna. There is no advantage to using an antenna with "gain," such as a Yagi or Quad. Since you cannot radiate more than 15,848 uV/m in *any direction*, use of a gain antenna will only force you to reduce the transmitter power accordingly. While your real antenna will not be in free space, it is assumed that you will be getting it up in the clear as much as possible. Note that the FCC rule does not specify the transmitter location, as it does in the 160-190 kHz band. You are free to keep the transmitter in the shack and use a transmission line to connect it to the antenna. Since we will be talking about the power delivered to the antenna, you can then increase the transmitter power to compensate for any feedline loss.

Calculations

Most texts on electricity and magnetism will explore the radiation properties of small linear antennas such as monopoles and dipoles. They usually then analyze the specific case of a dipole that is a half-wavelength or a monopole (ground-plane) of a quarter-wavelength. If you are interested in the derivation of the expressions below from Maxwell's equations, I refer you to any college-level E&M book. J.D. Kraus' "Antennas" book is particularly excellent.

At distances sufficiently far enough to be able to ignore the static and induction fields, the electric field of a half-wave dipole or quarter-wave ground plane antenna is given by:

$$E = \frac{60*I}{d}\left[\frac{\cos\left(\frac{\pi}{2}*\cos(\theta)\right)}{\sin(\theta)}\right]$$

where: E = electric field in Volts/meter
I = antenna feedpoint current in Amperes
d = distance in meters
θ = angle from the axis of the antenna, in radians

The field strength is symmetrical around the axis of the antenna. The term in brackets gives the familiar "donut-shaped" pattern around the plane of the antenna. It is clear that the term is maximum when $\theta = \pi/2$ or 90°. Since we are bound by the FCC regulation to consider the maximum field strength in any direction, we will choose $\theta = \pi/2$ (at a right angle to the antenna axis). The bracketed term then equals 1, and the maximum E field is given by:

$$E = \frac{60*I}{d}$$

The problem now is that we are concerned with power, not antenna current. Fortunately, the same E&M texts nicely work out the radiation resistance of a half-wave dipole in free space, or a quarter-wave monopole over a conducting sheet. This would be 73 Ohms for the dipole, and 36.5 Ohms for the vertical. Since $P = I^2R$, we get:

$$E = \frac{7.02*\sqrt{P}}{d}$$, for the half-wave dipole, and

$$E = \frac{9.93*\sqrt{P}}{d}$$, for the quarter-wave ground plane.

We now know enough to solve for the power, P, to generate 15,848 uV/m at 30 meters:

$$P = \left[\frac{(15848 \times 10^{-6})*30}{7.02}\right]^2 = 4.6 \times 10^{-3}$$ watts, for the half-wave dipole and

$$P = \left[\frac{(15848 \times 10^{-6})*30}{9.93} \right]^2 = 2.3 \times 10^{-3}$$ watts, for the quarter-wave ground plane.

So we need to deliver 4.6 milliwatts to a half-wave dipole, or 2.3 milliwatts to a quarter-wave ground plane antenna. That's not much power, but it should be easy to generate. Transmitters thus far have included commercial synthesized signal generators, homebrew DDS-controlled rigs, and small programmable crystal oscillator modules.

Measurements

An accurate power measurement may be made at the transmitter output with an oscilloscope or RF voltmeter, assuming that you know the load impedance. At 50 Ohms, 4.6mw represents 0.48Vrms (1.36Vp-p), and 2.3mw represents 0.34Vrms (0.96Vp-p). If you want to be very accurate, you could use a simple "L" network as an antenna tuner, creating an exact 50 ohm measuring point. I suggest checking the waveform at this point with a scope. If you use the filter shown below, make the measurement after the filter, so that the waveform is sinusoidal. Most of us just create a rig that will produce the correct power into a 50 ohm load, and then connect the antenna.

The out-of-band and harmonic suppression requirements are a bit tight. The 2nd harmonic should be down 54 dB from the fundamental, and the 3rd and higher harmonics at least 64 dB. With this small amount of power, signals will quickly be lost in the noise, but I would suggest a 2-section half-wave filter at the 50 ohm transmitter output:

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O----x---0.59uH-----x----0.59uH-----x---o
     |              |               |
     |              |               |
   240pF          470pF           240pF
     |              |               |
     |              |               |
    Gnd            Gnd             Gnd
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The inductors can be small toroids, and I used 11 turns on Amidon T-50-2 cores. The capacitors should be small silver-micas. Good VHF construction techniques should be used.

Conclusions

A simple, defensible method has been presented to determine the correct antenna input power to stay within the requirements of FCC Part 15.225. Many long-distance signal receptions and a few 2-way QSO's have been made at these levels, using slow-speed CW or other weak-signal techniques.