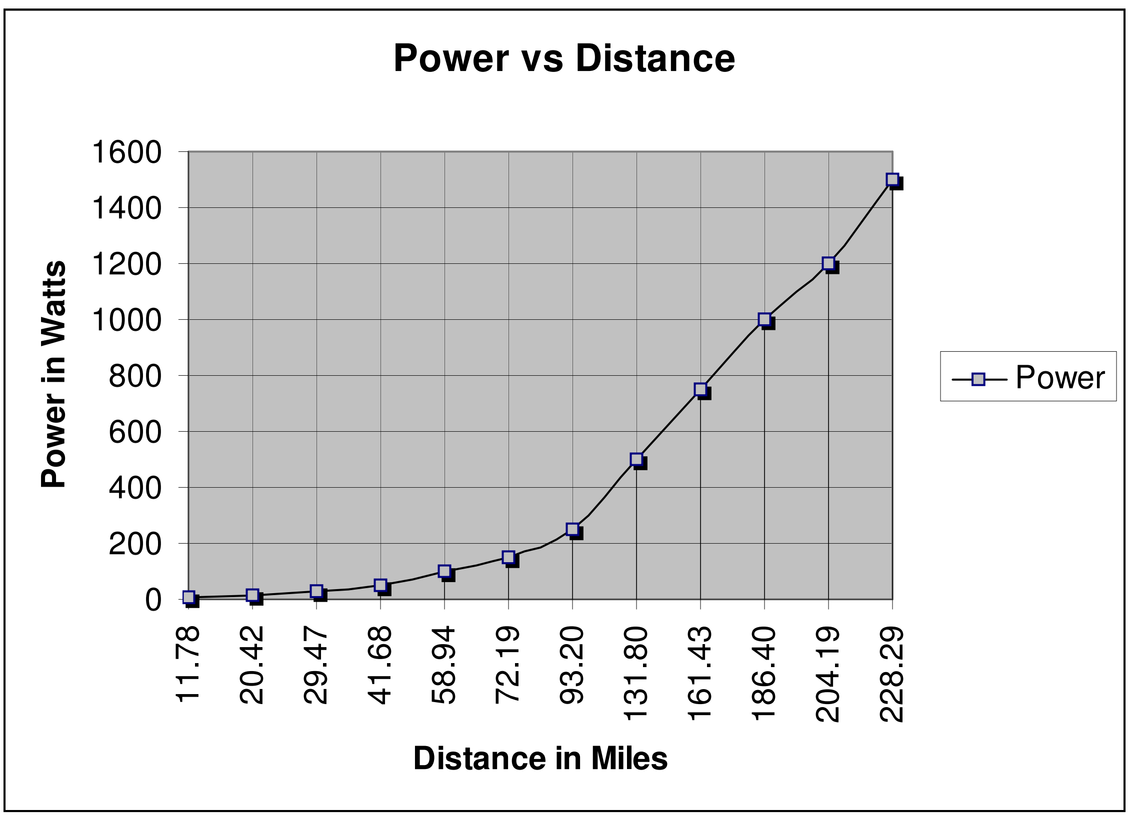
Power vs. Distance

(Vertical antenna)

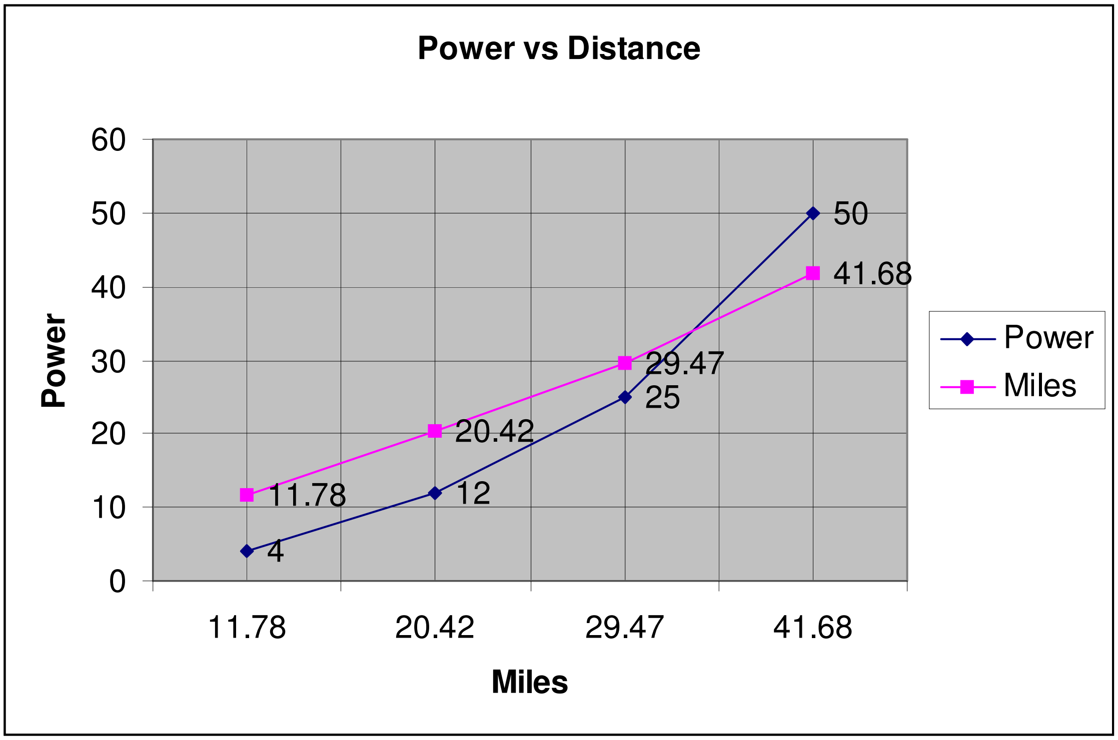
The charts below will reflect the distance an HF radio wave will travel across a flat surface. Some consideration concerning ground loss, the earth's surface curvatures, atmospheric conditions, QRM, or any other factors. Assuming each antenna has a height of at least 25-30ft talking vertical to vertical. Horizontal polarization range will be a little further due to antenna gain on TX/RX.

There are many factors that will hamper performance in a ground wave, which is very unpredictable with soil, antenna height, gain, terrain, etc. This is dead key AM power and is a very relative measurement and you will see that the formula shows some linearity but not necessarily in the real-world due to terrain or ground loss.

For this experiment we will assume 4 watts will travel 11.78 miles across a flat plain giving 1 "S" unit without any terrain or noise interference. We will also assume that the "S" meter has been properly calibrated and will have linearity errors, which may differ from the numbers obtained by formulas.



(Hi Power)



(Low Power)

The charts above are just a relative measurement and accuracy will depend upon ideal characteristics. These charts are not compensated for frequency but I will be crunching numbers later to give more realistic data. I will also be testing the chart against real-world results very soon keep checking back on my website.

The charts do reflect the same vertical antenna base to base so to speak so the results will vary dependent on the variables. Please note that the calculations are for wave travel and not power gain needed for "S" units.

The values represent the travel distance of a ground wave (non-space wave) and the transmitting antenna (at least 25-30ft from the ground). Due to the nature of HF waves and sporadic atmospheric conditions you can talk much further and the frequency of a waveform will also dictate how far it travels or should we say the resistance to travel.

Notice how the curve changes after 250 watts are obtained. I ran points up to legal limits for those that are allowed to run 1500 watts (10 meters). It almost seems that when the curve hits that 250-watt mark the range starts falling off in relation to power. At the 250-watt area the curve seems to be (more) linear than compared to the lower power ranges. The curvature in the earth will also change how far the wave will travel. Use this chart only as a reference since some of the real-world values have not been compensated fully at the 100 mile + mark, but it should give you an idea.

The ground wave does not necessarily travel in straight lines at all and they tend to bounce (off objects), and become refracted. I will be covering in depth all the variables that will change this plot and hopefully we can get a better understanding on how much power do we really need?

After a certain point in distance travel the waveform will follow the curvature of the earth's surface. The ground variables (terrain, curvature, etc) can be ignored somewhat for the first 80-100 miles of travel. After 100 miles is reached the intensity will diminish and the distance will be hampered due to the effects of the earth's surface and curvature.

Now the question is why is it that I can reach a certain distance but when I increase power but I do not get the same results from the charts? Some of the waveform will be generated upward (depending on antenna height and surroundings) and will vary on the terrain. In Terman's theory the waveform takes somewhat of a concave shape and then is generated into the atmosphere. To predict we can use a formula, which I will be covering later.

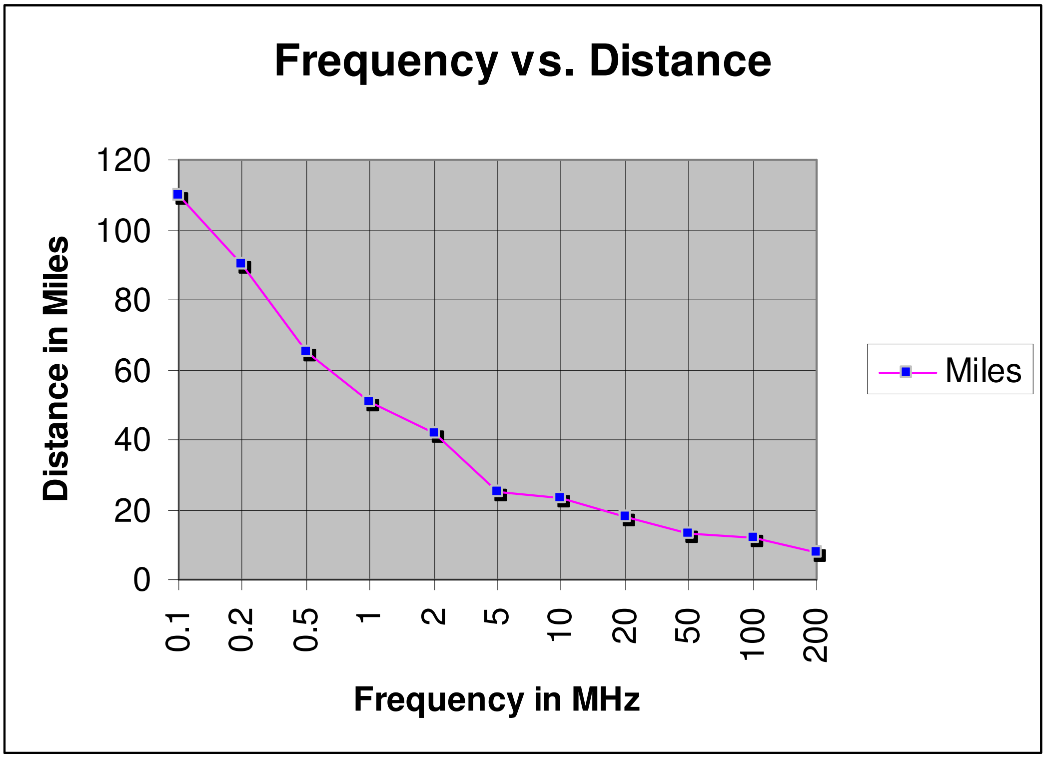
The power density laws seem to work nicely at higher (100MHz and up, line of sight) frequencies (using sky wave travel) but as you go down in frequency the atmosphere will have less resistance to the waveform. The waveform is not a perfect circle (unless ¼ wave from the ground) and antenna height plays an important part on the radiation lobes and how the beam is concentrated or will travel in a certain direction. A simple example is that of a mobile antenna that is radiating on a back bumper. The angle (most part) of the lobe (in theory) should be projected towards the front of the car, so you are facing, or driving in the best radiation angle. On the roof of a car the pattern will be more symmetrical (circle like pattern). The higher the antenna the more sky wave will be generated in theory.

Some rough guidelines:
2 MHz, 45 to 100 miles daytime
10 MHz, 25 miles
20 MHz, 20 miles
30 MHz, 17 miles
(See chart below)

The 11.78 miles figure I am using is based upon Terman's short antenna principles and formulas. In theory the wave should travel around 18 miles at 27-28 MHz, but I have also taken into account the sensitivity of the "S" meter and terrain.

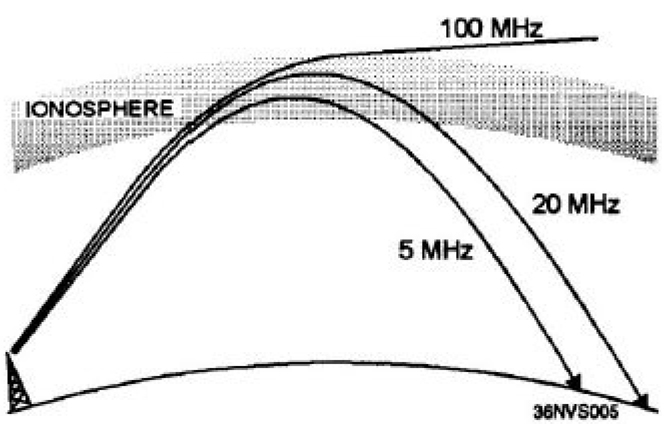
Updates and new charts coming soon!

*Note all calculations are relative at this point you may be able to receive a signal better than 1 "S" unit at 11.78 miles away depending on your antenna height, location, and sensitivity of your radio.



Frequency

The lower the frequency of a radio wave, the more rapidly the wave is refracted by a given degree of ionization. The picture below shows three separate waves of differing frequencies entering the ionosphere at the same angle. You can see that the 5-MHz wave is refracted quite sharply, while the 20MHz wave is refracted less sharply and returns to earth at a greater distance than the 5MHz wave. Notice that the 100MHz wave is lost into space. For any given ionized layer, there is a frequency, called the *escape point,* at which energy transmitted directly upward will escape into space. The maximum frequency just below the escape point is called the **critical frequency.** In this example, the 100MHz wave's frequency is greater than the critical frequency for that ionized layer.



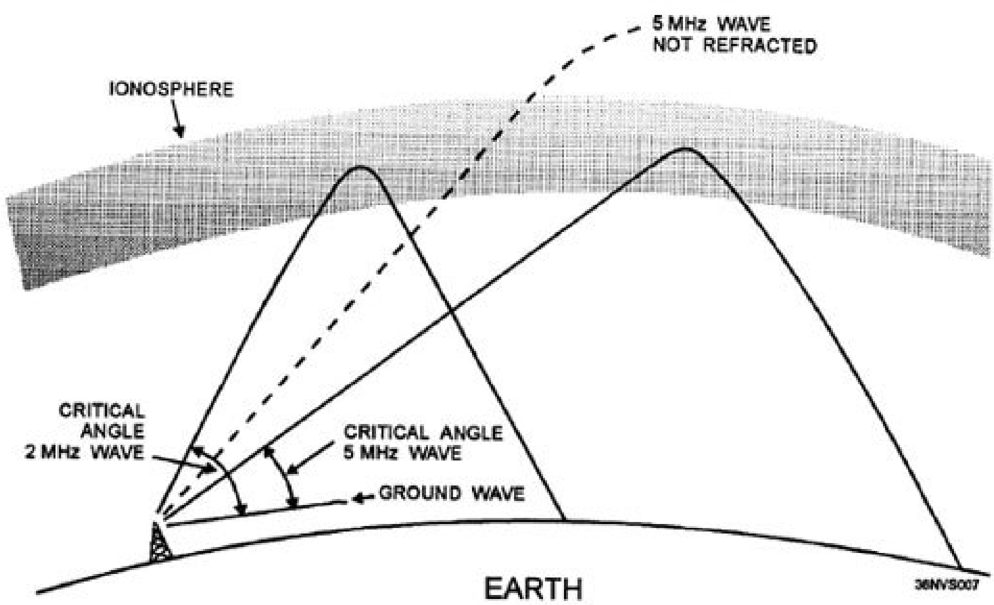
Frequency vs. Refraction and Distance

The critical frequency of a layer depends upon the layer's density. If a wave passes through a particular layer, it may still be refracted by higher layer if its frequency is lower than the higher layer's critical frequency.

Angle of Incidence and Critical Angle

When a radio wave encounters a layer of the ionosphere, that wave is returned to earth at the same angle (roughly) as its *angle of incidence.* The figure below shows three radio waves of the same frequency entering a layer at different incidence angles. The angle at which wave A strikes the layer is too nearly vertical for the wave to be refracted to earth, however, wave B is refracted back to earth. The angle between wave B and the earth is called the critical angle. Any wave, at a given frequency, that leaves the antenna at an incidence angle greater than the critical angle will be lost into space. This is why wave A was not refracted. Wave C leaves the antenna at the smallest angle that will allow it to be refracted and still return to earth. The critical angle for radio waves depends on the layer density and the wavelength of the signal. The figure below-Incidence angles of radio waves.

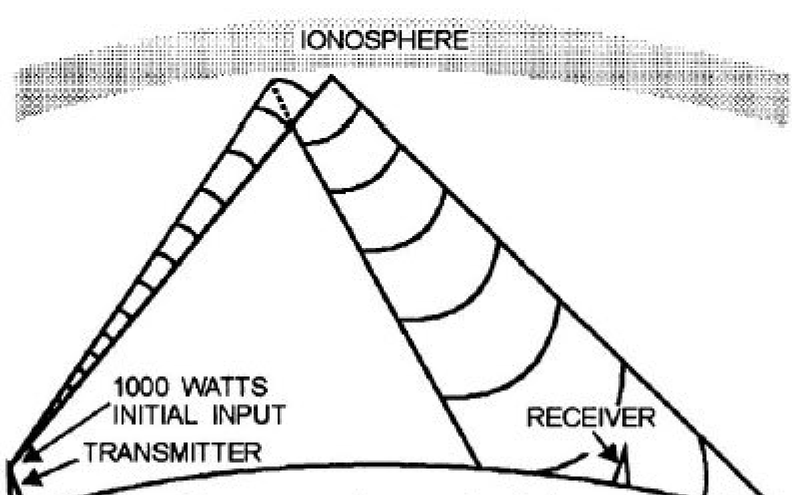
As the frequency of a radio wave is increased, the critical angle must be reduced for refraction to occur. Notice that the 2MHz wave strikes the ionosphere at the critical angle for that frequency and is refracted. Although the 5MHz line (broken line) strikes the ionosphere at a less critical angle, it still penetrates the layer and is lost. As the angle is lowered, a critical angle is finally reached for the 5MHz wave and it is refracted back to earth.



Effect of frequency on the critical angle

FREESPACE LOSS

Normally, the major loss of energy is because of the spreading out of the wavefront as it travels from the transmitter. As distance increases, the area of the wavefront spreads out, much like the beam of a flashlight. This means the amount of energy contained within any unit of area on the wavefront decreases as distance increases. By the time the energy arrives at the receiving antenna, the wavefront is so spread out that the receiving antenna extends into only a small portion of the wavefront. This is illustrated below.



Freespace loss principle