The Ground And Its Influence

It is important that there is a thorough understanding of the material presented so far. Granted, the material can be overwhelming on first read. However, with patience and perseverance, you may find this knowledge to be invaluable to you in even the most simple of tasks where antennae of all type are concerned.

Don't be fooled by low SWR

Our discussion in this chapter involves a look at the influence that the ground and nearby objects have on the antenna and SWR in particular. This effect is not always what it appears to be. By way of explanation I mean; many an uninformed CB'er has been fooled into thinking that the 1.01:1 SWR of his fiberglass whip mounted on the bed of his pickup or van, 2 inches from the cab, is the best of all worlds. WRONG! This unsuspecting character has fallen prey to his own ignorance of the principals we are discussing in this series.

From the information and the illustrations provided last chapter, it should be obvious at this point why the CB antenna might look like it is functioning well. One need only review the discrete model antenna illustration to understand how this is total deception. The body of the pickup truck is the ground system for the antenna element. If the cab of the truck body is in close proximity to the vertical element of the antenna, there will be an increase in the capacitive component of the feedpoint impedance. Since this capacitance is a very large value (compared to the element being perpendicular to ground) radiation of RF from the antenna may indeed flow directly to ground instead of into the ether as expected, causing very high ground losses. The low SWR reading is simply an indication that the ground of the truck body has absorbed most of the RF, the added capacitive component has been inappropriately offset by added length, and there was little RF to be radiated (low radiation resistance).

This is but one of hundreds of similar false impressions that can result from ignorance of the material we are studying.

It does however, validate an old ham radio adage that has its roots at the beginning of the hobby – "Antennas should be erected as high as practically possible and free from surrounding objects". For all antenna types except ground mounted vertical antennas, this is still the best approach for maximum utility. As hams, we know from experience that we don't always have 40 acres of prairie land to raise our 100-foot tower. But we can use our knowledge of the effects of ground to our advantage when choosing the best location for that new base station vertical or raising that 50-foot tower for a beam.

It also explains the reasons for some unlikely objects proving to be a fairly decent antenna. Most of us have heard of the enterprising ham that connected a wire to his downspout and loaded up the metal gutter system on his house to work DX. It also illustrates why properly mounted and loaded mobile antennae rival fixed station performance from time to time. While these are not the best of applications, it indicates that no ham need do without a working antenna.

Signal propagation

The characteristics we have discussed so far have been relative to the ***near-field*** radiation. There are other factors known as ***far-field*** characteristics that also influence how well a signal is heard. The *far-*

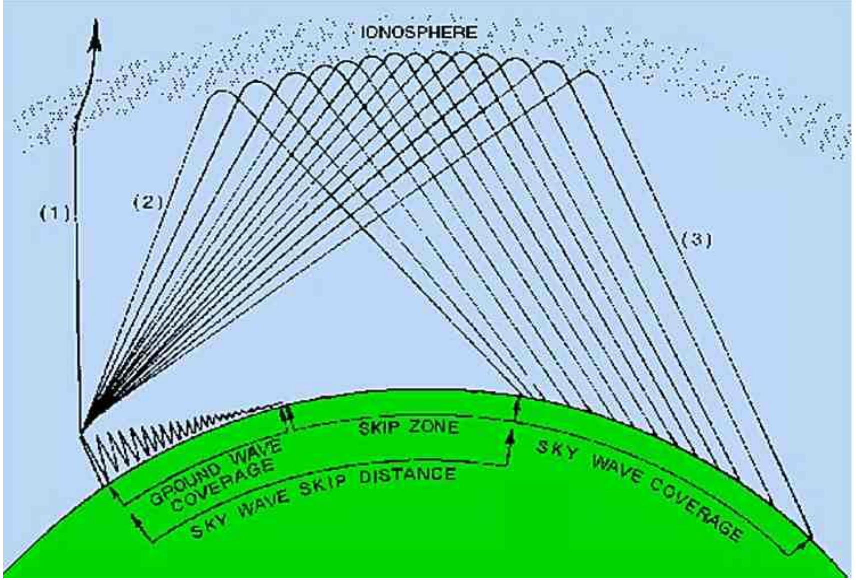
field term is used here to indicate the propagation of the RF wave into the atmosphere and reflected or refracted by the ionosphere then received some distance (more than 50 wavelengths) from the transmitting antenna. The angle of the transmitted wave (relative to the earth ground), and the conditions of the ionosphere, influence how far the signal will travel and how strong it will be when arriving at a distant receiver. We have moved from the realm of antenna theory to the area of propagation effects. This far-field analysis is often referred to as ***sky-wave*** to designate the difference the effects of the ionosphere have on the transmitted signal versus the effects of objects near the antenna (e.g. the earth ground, buildings, car body, etc.).

Why do we care? The radiation pattern our antenna exhibits, will almost directly influence how well we are heard in a targeted area. This is true for vertical and horizontal antennae. The physical methods for determining and adjusting for a given radiation pattern are different, but the factors that are influencing each are the same.

The important points to remember are that, there are ***near-field*** factors and ***far-field*** factors that combine to influence the signal that is ultimately heard at a distant receiver. We are unable to control the atmospheric conditions that occur in far-field effects. We can just be aware of them and exploit them whenever possible. We can, however, control almost all *near-field* factors.

Controlling the near-field

This next illustration depicts near-field characteristics of two types. The name of each is self-explanatory. Direct near-field *space* radiation, [the zig-zag line from the start point] describes RF that travels without interference to the receiving antenna through the air. *Surface* wave near-field radiation [labeled Ground Wave Coverage in the illustration] travels along the surface of the ground, sometimes even a foot or so beneath the surface (depending on frequency, soil type, distance, etc.).



Again, why do we care? Surface waves are stronger as we decrease frequency. At higher HF frequencies, surface waves are weaker and sky waves are stronger. Conversely, the strength of sky waves is relatively low for 75, meters and below. In this low and medium frequency range ground waves and direct spatial waves play a very important role in propagation. Surface waves are stronger in vertical antennae, whereas horizontal antennae exhibit a weaker, but still present, surface near-field wave; probably due to the near-proximity to ground. The illustration also shows how sky waves may tend to leave the surface of the earth and be reflected or refracted [not shown] back to earth where received at some distance from origination (#2 and #3 in the diagram). The exact path is influenced by far-field factors that are constantly changing. Cosmologists and Physicists try to use computer models to predict such behavior with moderate success at best. Several popular ham radio software products ("HamCap" and "VOAProp" are two popular programs) use this knowledge base to help indicate possible propagation in the HF frequencies. Although based on data obtained from NASA, NOAA and other sources, it too is subject to numerous fallibilities. It does, however, serve as a very good general propagation predictor.

The specs for any antenna made commercially will publish the far-field radiation pattern for average terrain and average soil. The "average" is an arbitrary value taken from the difference between salt water, and rocky, barely conductive soil of the desert or concrete city streets.

The following comparative graphs illustrate the far-field result of different soil types (average vs. perfect). Notice the take-off angle of each soil type for the same antenna (the angle at which the largest lobe of the radiation pattern occurs relative to the plane of the ground). From the provided illustration below, you may notice there is a considerable difference. Depending on your antenna type, the purpose for which your analysis is performed, and your geographical location, a lower takeoff angle may perform better than a higher one.

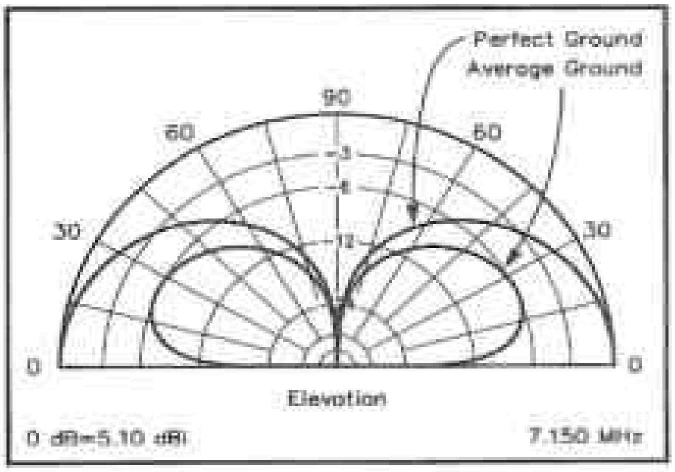


Fig 20.41—Elevation patterns for two quarter-wave vertical antennas over different ground. One vertical is placed over "perfect" ground, and the other is placed over average ground. The far-field response at low elevation angles is greatly affected by the quality of the ground—as far as 100 λ away from the vertical antenna.

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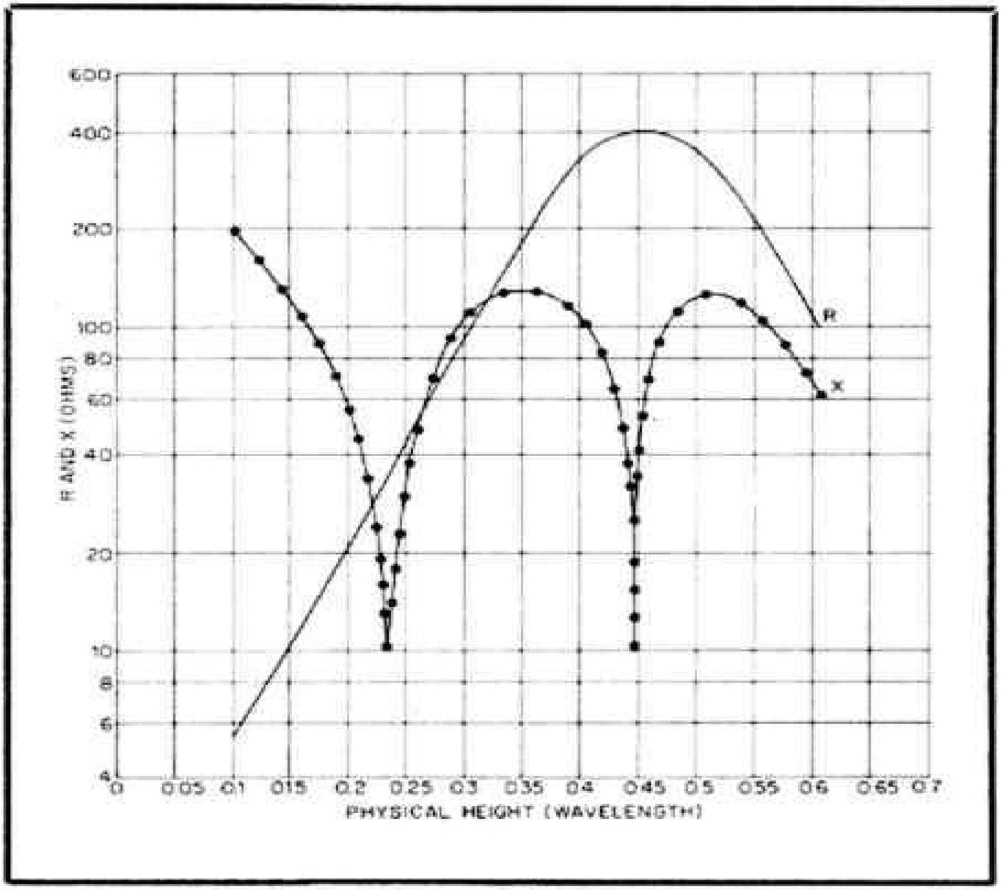
For instance, in the far northern hemisphere, it is possibly not as important to have a low radiation angle for East – West long distance propagation as it would be for the latitudes nearer the Equator. By the same logic, it is way more important on 80 and 160 meters to have a good ground system versus 10 meters.

Another consideration of near-field radiation also has to do with propagation. At frequencies of 75 meters and below, near-field ground-wave (space wave or surface wave) signals are usually much more intense than far-field sky-wave signals. Often, the far-field sky-wave signal will be strong enough to reach a receiver along with, but at a different time than, a near-field signal. The result is a signal that flutters, echoes, and fades rapidly (we often call this QSB and multi-path propagation). Our human ears can decode these fluctuations with comparative ease, whereas digital signals are difficult for computers to decode when this occurs - the computer considers the flutter and echo to be "mistakes" (computer geeks call it data errors) and will not decode the information being transmitted.

Antenna feedpoint impedance and the near-field

Near-field effects also appear when considering antenna feedpoint impedance. Proximity to ground will affect antenna impedance directly. That is to say, the closer to ground, the lower the impedance of an antenna at certain fractional wavelength heights compared to free space. Just as the length of an antenna element varies with wavelength, the impedance variations due to changes of ground proximity vary with wavelength above ground. That is kind of a long way of saying that height above ground will affect feedpoint impedance in all antennas. Height above ground in wavelengths is calculated using the same formula as used for antenna length.



Effect of ground on feedpoint impedance and radiation resistance of a horizontal dipole. Notice the dramatic change of impedance as height above ground approaches ½ and ¼ wavelength. Optimal height for this antenna would be .27 wl for 50 ohm coax. © Arrl Handbook 1980 abr.

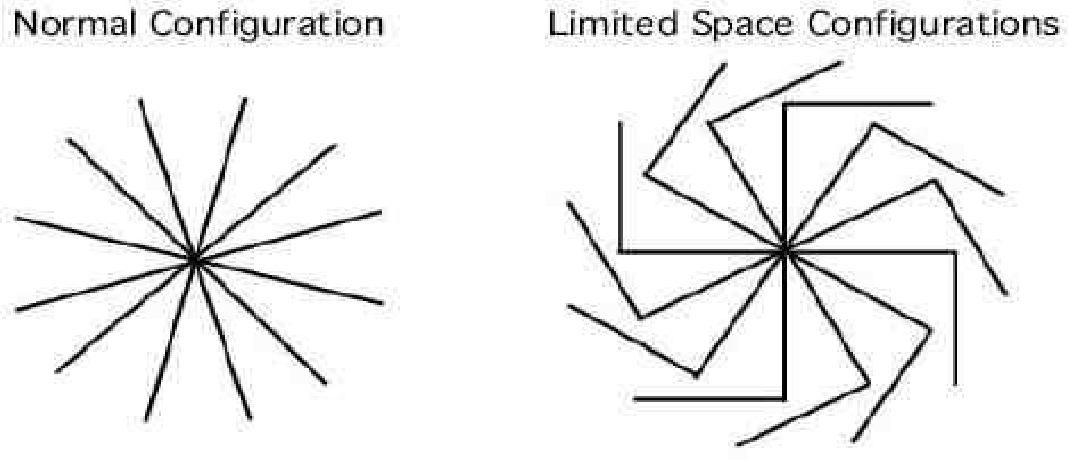
It should be obvious from the graph shown, that the effect is more noticeable for heights approaching ½ and ¼ wavelength. It is this proximity effect that makes ¼ wave vertical antennas exhibit much lower impedance than ½ wave horizontal dipoles more than ¼ wave or ½ wave above ground.

Whether we are talking about a completely flat horizontal mounted dipole, or an inverted “V” dipole, the closer any part of the antenna is to ground, the lower the characteristic impedance will be below ½ wavelength and the lower the radiation resistance. By the same token, more RF absorption will take place by the ground or surrounding objects as indicated by the radiation resistance curve on the supplied chart. Although the graph indicates elevation is above ground, objects like trees, buildings, and mountains can be considered to be the same as ground.

Earlier we mentioned we have the ability to control some of the near-field conditions that affect our radiation pattern and strength. These conditions affect how well the RF from our vertical antenna is radiated (or not). One of the factors in determining antenna efficiency is known as ground return loss or ground absorption loss. Strength of signal (power) is often lost to the ground where poor ground quality is present. Imagine a huge, high-power resistor connected across the antenna terminals. That is what poor ground conductivity amounts to. Poor ground conductivity contributes to system inefficiency more than almost any other factor in vertical antenna types. The poorer the grounding system the higher the resistance and correspondingly, the ground losses. On the ocean, this is hardly a problem, as this is as near to a perfect ground (extremely low resistance and loss) as we can practically come. But few hams live or work on the ocean. Most of us have to use the ground given to us where our ham shack is located. The conductivity of ground at your location will vary considerably from any place in town or across the state.

Improving ground conductivity

Ground conductivity can be improved by artificial means. An example would be the radial ground system of a vertical antenna. This series of wires or wire lattice is constructed to purposely improve the near-field surface conductivity and intensity and lower the ground related I^2R losses. An increase in near-field intensity translates to a noticeable change in the radiated RF intensity and takeoff angle of the radiated pattern and an increase in antenna system efficiency (radiation resistance is almost all in radiating elements rather than I^2R components). As a general rule of thumb, more and shorter radials are better than fewer and longer radials for a given frequency. Since the ground radials are a part of the antenna system, size DOES matter. Radials of no less than 4 in number but usually 12 to 16, of 1/8 to ¼ wavelength are preferred. The number of radials is not critical within this range, however, more than 30 radials does not provide a significant increase in signal strength or system efficiency vs. cost and conservation of effort. When the vertical is elevated (as in a roof mounting), connecting the radials in a downward sloping angle will further lower the takeoff angle and help control the impedance of the antenna.



Normal and Limited Space Radial Placement for Vertical Antennae.

The possible exception to this phenomenon is the elevated dipole antenna like the loop antenna and loop arrays. They are by no means immune to ground proximity effect, but they are much less affected by ground where feedpoint impedance is concerned. The far-field radiation pattern of loops and loop arrays are affected to the same degree as other above ground antenna types. It is not, however, necessary to construct a radial ground system for this or any other horizontal dipole or loop antenna including beams derived from these types.

Health and safety factors

Near-field radiation has considerations that go beyond communication, to health and safety. The intensity of both the electric and magnetic fields in the near-field are several orders of magnitude higher than, say, 100 wavelengths away. In fact, higher frequency, high intensity, RF waves can penetrate objects such as buildings, cables, and even human skin. At low power levels this is not a concern, but we often operate at very high RF power levels. High power levels mean more penetration of objects. High intensity RF radiation of the human skin can be lethal or at a minimum, damaging to human tissue for some frequencies. It is precisely for this reason the FCC has issued near-field operating power safety limits for each frequency band in which hams are licensed.

The current operating limits and safety guidelines are printed in ARRL publications and on the web site:

http://www.arrl.org/news/rfsafety
and the FCC bulletin:
http://www.fcc.gov/oet/info/documents/bulletins/#65