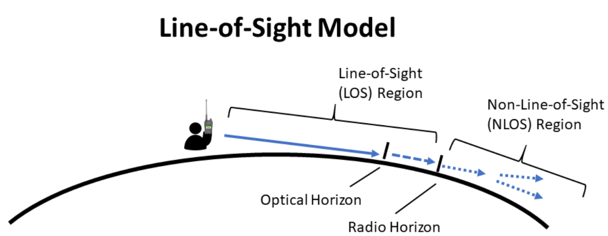
How far Can I Transmit with My GMRS Radio?
(Part II – Free Path Loss & Atmospheric Impairments)

“All radio signals diminish as distance increases between stations”

Known as ***“free path loss”*,** unobstructed radio signals diminish at a known rate over a given distance for a given frequency. This is easily calculated with reasonable precision using the formulas in Part III.

Naturally, higher received signal power equals better communications. The received signal power must be higher than the receiver threshold by some margin for meaningful and reliable communications. It should be easy to see how the radio LOS will decrease in the presence of radio wave obstructions, such as trees, buildings and hillsides. Common noise and interference further decrease reliable communications distance.



Courtesy of K0NR

IMPAIRMENTS
An impairment to a radio signal is anything that diminishes or blocks it. Terrain and trees (as shown in Figure 2.) are usually the greatest problem encountered in rural and sparsely populated suburban areas. Outdoors sports enthusiasts must pay particular attention to weather conditions as dry foliage is not as a detrimental to radio signals as wet foliage. Snow covered or wet, dense pine forests are the greatest detriment to radio signals in the GMRS/UHF range. It should be noted that much effort and scientific research has been expended on the study of fixed and mobile radio service signal propagation.

Buildings present more of a problem than foliage in urban and dense city environs. Buildings, especially steel-framed high rises, offer several problems to radio signals. The first is signal absorption by structural steel frames. The second problem is signal absorption by most all interior building materials. The third is reflection of radio signals due to micro-coatings on those buildings with glass exteriors.

As an aside, 4G/5G/6G cellular services, and civil authorities mobile radio services, in urban areas, use much higher frequencies not as affected by building impairments.

ATMOSPHERICS
This subject is probably the least understood and most maligned in the GMRS (and unfortunately, amateur radio) community. Atmospheric impairment to radio signals requires a modicum of understanding of geophysics and astrophysics. Atmospheric impairments change with frequency, weather, and solar conditions. Unlike lower frequencies in the MF, and HF ranges, UHF is not normally reflected (bounced) by the ionosphere (“SKIP”). While UHF signals do reach the ionosphere, they usually pass through, with little change in strength and direction. Ionospheric effects (Reflection & Refraction) are usually limited to those frequencies below 200 MHz. Although, refraction can rarely occur at UHF.
Commercial and Military radio systems operators have accumulated vast experience with globally deployed UHF systems. They have developed principals of critical path engineering which include the following atmospheric impairments:

1. **Atmospheric absorption** - Free space path loss
2. **Diffraction loss** - Scattering, both atmospheric and terrain induced
3. **Refraction loss** - Atmospheric dielectric variation due to diurnal atmospheric pressure changes

4. **Multipath loss** - Ground (smooth earth) and bodies-of-water reflections
5. **Noise** - Gaussian and man-made
6. **Interference** - on channel (co-channel), adjacent channel, and Intermodulation distortion (IMD)

ATMOSPHERIC ABSORPTION

Free space path loss is derived from the Friis[i] transmission equation[ii] which accounts for distance between stations and frequency. Path loss - commonly termed *attenuation* – increases as frequency and distances increase. *(See Part III)*

DIFFRACTION LOSS

Diffraction occurs when a radio wave encounters an abrupt change in either the terrain or atmosphere. Atmospheric diffraction occurs when there is an extreme change in temperature, barometric pressure, and water vapor density.

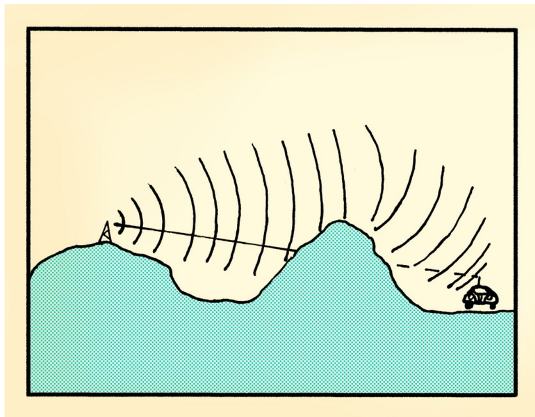


Figure 3. **Example of Diffraction** (Terrain Scattering)

REFRACTION LOSS

Refraction is "bending" of the radio wave by changes in atmospheric dielectric properties most often caused by troposphere layer temperature inversions. Typically the following meteorological conditions are found to cause ducting:

1. Warm dry air over a cooler surface
2. Surface cooling under clear skies overland
3. Developing high pressure ridges with a cold surface
4. At fronts with strong thermal contrast
5. In cold down-drafts associated with cumulonimbus clouds

Refraction loss while spawned by atmospheric conditions causes a radio wave to bend towards earth and not reach its destination on long paths, or causes the radio wave to "lift" and bypass its intended receiver, only to be received many miles beyond. The later condition is often termed "ducting". In either case the transmitted signal bypasses the intended receiver. While not common, refraction can occur at UHF under certain meteorological conditions.

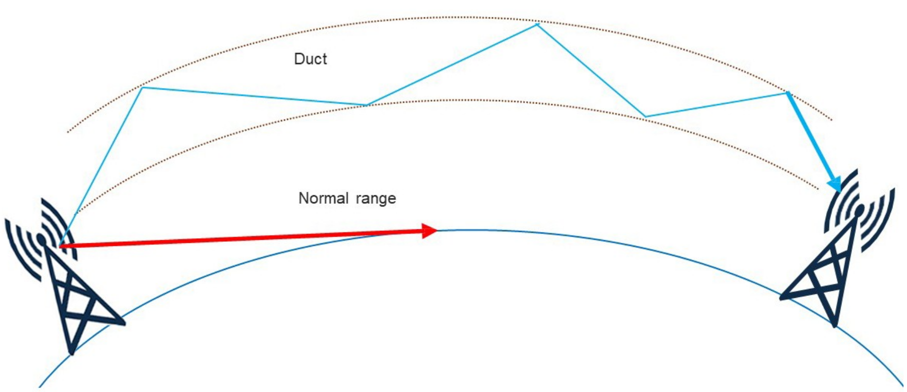


Figure 4. **ATMOSPHERIC REFRACTION** (Radio path "Lift" or "Ducting")

MULTIPATH PROPAGATION LOSS

Multipath is a mostly physical reflection (or multiple reflections) of radio wave(s) resulting in signals reaching the receiver by multiple paths. It can, in rare occurrences be caused refraction and reflection from atmospheric conditions. Multiple radio signals reaching the receiver by different paths result in partial (sometimes, total) cancellation of the primary signal. Different signal paths result in the reflected signal arriving at a slight different time than the primary. This time difference is called a phase differential. When signals are received out of phase, cancellation occurs to varying degrees, thus reducing the primary received signal strength.

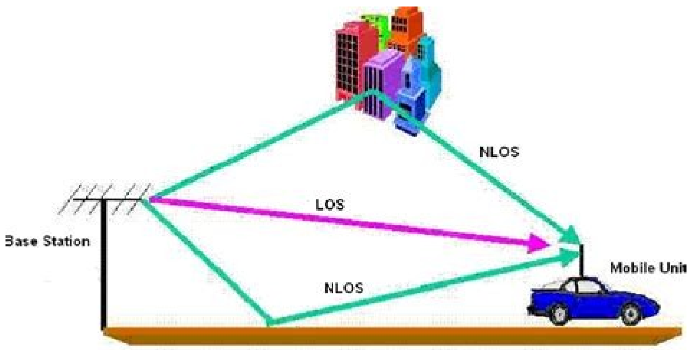


Figure 5. **MULTIPATH PROPAGATION**

Multipath propagation in fast-moving mobile situations is the cause of the rapid signal variance phenomenon known as "picket-fencing".

NOISE

Noise impairments reduce the receiving capability of the receiver thus reducing communications range.

Noise is commonly derived from the movement of electrons, both through the atmosphere and through electrical conductors. Referred to as Gaussian[iii] noise, flowing electrons through any electrical device produces radio noise. Very low level noise is not detectable by GMRS radios by virtue of the FM [iv] detection system in GMRS radios. The cosmos also generates a background noise, a remnant of the "Big Bang"*. Other sources of natural background noise are distant electrical storms (lightning). Close-by electric storms cause 'static' crashes which do disturb radio reception. While solar disturbances and geomagnetic events do disrupt lower frequencies, they seldom are a problem at UHF where GMRS lives.

Man-made electrical noise is another problem interrupting, or at least, diminishing radio reception. We are all familiar with noise generated by older fluorescent and LED lighting fixtures. Electrical transmission and supply wiring are another source of noise interference. This noise can be generated by sparking and arcing from faulty insulators to corroded hardware of dissimilar metals

There are other types of radio noise such as adjacent and co-channel interference which cause varying levels of interference. Adjacent channel interference is the inability of the receiver to reject a signal on an adjacent channel. Co-channel interference is when another transmitter is on your desired communications channel. Accidental "doubling" by two other transmitters is an example of co-channel interference.

Another form of noise is Intermodulation Distortion (IMD, or 3rd-Order Distortion) which is the mixing of multiple unwanted signals causing receiver overload, thus blocking desired communications. Trying to use a handheld radio on a hill top or mountain populated by many high-powered radio systems and being unable to receive any communications is an extreme example of IMD.

* Also referred to as ***"The Horrendous Space Kablooie"*** by Bill Waterson in his comic strip Calvin & Hobbes

i Harald T. Friis, “A Note on a Simple Transmission Formula.” Proceedings of the I.R.E. and Waves and Electrons, May, 1946, pp 254-256

ii Henry Jasik, “Antenna Engineering Handbook,” McGraw-Hill, 1961

iii Gaussian noise, named after Carl Friedrich Gauss, 1777-1855, a German mathematician and physicist. Gaussian noise is defined as: In telecommunications and computer networking, communication channels can be affected by wideband Gaussian noise coming from many natural sources, such as the thermal vibrations of atoms in conductors (referred to as thermal noise or Johnson–Nyquist noise), shot noise, black-body radiation from the earth and other warm objects, and from celestial sources such as the Sun.

iv Edwin H. Armstrong, “A method of Reducing Disturbances in Radio Signaling by a System of Frequency Modulation”, Proceedings of The Institute of Radio Engineers, Volume 24, May, 1936, Number 5.