HOW FAR WILL MY RADIO TALK?

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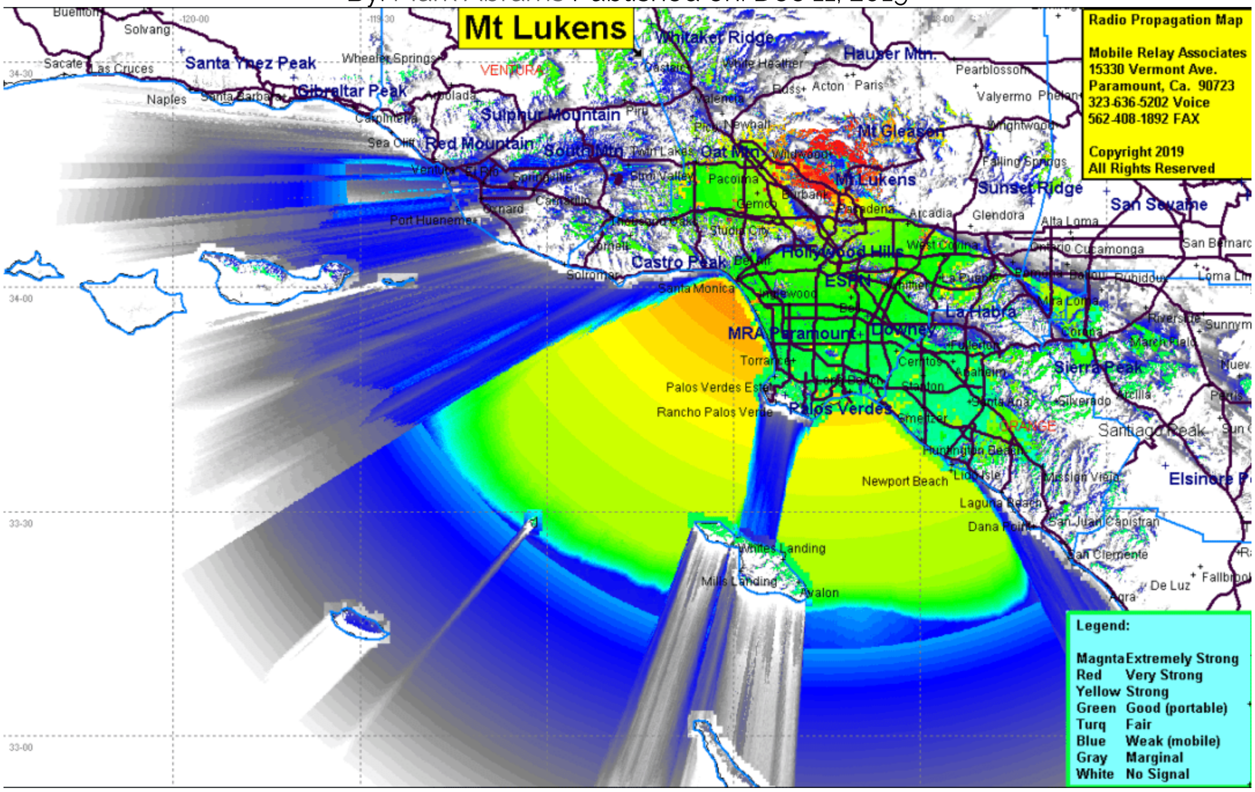

“Long Range” is commonly used by radio manufacturers as part of the description for their product. Everybody wants “Long Range”, but there is no real definition for what “long” is. The term is relative. It is also common to have the range, in miles, printed on the package so people will use it for comparison. The phrase “Up To” is often missed when reading this. This packaging is misleading, but never the less has set expectations for how to compare radios. In general they will print a longer range on a higher powered radio, but these numbers are not really based in reality. Most of the time the usable distance will fall extremely short, but there are also circumstances where it may go further.

How far will your radio really reach? The answer to this question is highly dependent upon the type of radio system you operate and where the different elements of the radio system are located. There is no simple answer to the question.

Radio signals travel line of sight from the transmitter to the receiver, passing through different obstructions. Signal strength diminishes with the square of distance, to it you move twice as far away, the signal is ¼ the signal strength. If you are 3 times as far, the signal is reduced to 1/9th of the signal.

This does not include the physical objects in the path which create more signal loss. Obtaining significant height for the antenna dramatically increases the range of the signal.

Terrain is a significant factor in radio propagation. Flat ground is much easier to predict radio coverage than hilly terrain and is much easier to cover with radio signal. When a radio signal passes through a hill, the earth (dirt, rocks, streams, etc.) that is in the direct line of sight path all add to the signal loss. Once the received signal drops below the minimum threshold to operate correctly, the radios no longer can communicate with each other. In hilly or mountainous terrain, this can happen in a distance of a few hundred feet while on flat terrain, it would take miles to have the same effect.

The atmospheric conditions also affect radio propagation. Certain areas have different kinds of problems with radio propagation due to something unique about the area. Sometimes it helps radios work better and sometimes it hinders the use of radio. Different frequencies are affected differently by atmospheric conditions, so there is no simple answer as to how a signal will propagate.

The general rule of thumb is that if you can see it, you can talk to it. The visual horizon is dependent upon your height above ground, so it will be a different distance depending upon your location. If you were on completely flat ground without hills, buildings, bridges, streams or any other man made or natural structure, you could expect to talk to about 15% beyond the visible horizon, because the radio horizon is further than the visible horizon.

The following table depicts the distance to the horizon for different visual / antenna heights. These are based upon the following formulas for determining the distance to the horizon:

Distance to Visual Horizon = Square Root (2Rh) which is approximately equal to:

$D_v = 3.57 * \text{Square Root (h)}$

Distance to the Radio Horizon: $D_r = 4.12 * \text{Square Root (h)}$

Where "h" represents the height of the antenna. This assumes that the height of the antenna is above mean sea level and the land would be at sea level. Such terrain is not common, so it takes some interpretation of the formulas to come up with the visual and radio horizons in different circumstances.

	6 Feet	100 Feet	500 Feet	1000 Feet	2500 Feet	5000 Feet	7500 Feet	10000 Feet
Visual Horizon In Miles	2.993	12.22	27.324	38.643	61.100	86.408	105.827	122.199
Visual Horizon In Km	4.828	19.710	44.071	62.327	98.548	139.367	170.689	197.095
Radio Horizon In Miles	3.455	14.103	31.543	44.596	70.513	99.720	122.131	141.025
Radio Horizon In Km	5.572	22.746	50.862	71.929	113.730	160.838	196.986	227.460

Therefore, the distance that a radio system talks is highly dependent upon the height of the antenna above ground and the height of the antenna above average terrain.

There are computer programs that predict radio coverage under a given set of parameters. The programs are reasonably accurate, but not 100% accurate. They vary by frequency and the propagation model that is used to predict the coverage, the system design, locations and many other factors.

SIMPLEX OPERATION

Simplex radios are typically operated within a small confined area such as a building or a series of buildings in a campus environment and do not use a repeater or any other infrastructure to increase the range of the radio. Depending upon the size of the building, simplex radios may not be able to talk across the entire building. This is typical in high rise buildings, particularly large buildings and old buildings that have thick concrete walls. In the city, typical range for a portable radio is about 6 blocks when outside of a building, but it can be significantly greater or less depending upon the physical obstructions between the transmitter and the receiver. Typical range for a mobile radio talking to another mobile radio in the city is about 5 miles. Typical range for portable radios outside the city is 1-2 miles while typical range for mobile radios is about 5-10 miles.

The increased range outside the city is due to the lack of obstructions such as buildings and bridges.

If one of the radios is at a high location, the range can be extended dramatically. For instance, if one mobile is parked on top of a hill, you might get 40 mile – 50 mile range. If a portable radio is located on top of the same hill, it might get 15 miles talking to another portable radio or 30 miles talking to a mobile radio. The power of the radio affects the range as a higher power radio will talk further. Other items that affect the distance if the type of antenna used by the radio (see item #2 and item #4 below).

REPEATER OPERATIONS

When operating on a repeater system, whether it is conventional, trunked or networked, all communications is to and from the repeater. Therefore, the repeater defines the area of coverage. It does not matter if you are on VHF, UHF, 800MHz or 900MHz, analog or digital, the repeater defines the coverage area. You will get full advantage of the repeater coverage if you use a mobile radio. You will get reduced coverage area if you use a portable radio for the following reasons:

1. The portable radio is typically 5 watts. Mobile radios are typically 25 watts and some are as much as 100 watts.
2. The portable radio antenna is typically 20% efficient compared to a mobile antenna which is typically 90% efficient.
3. The portable radio often is inside a building which shields the radio from the signal outside the building.
4. The portable radio often is inside the vehicle which is a metal box that shields the radio from the signal outside the vehicle. Also, when the radio is lying on the seat, the radio antenna is horizontal which is called “cross polarization” of the radio antenna. Land mobile radio systems utilize vertical polarization antennas and you can lose 95% of the signal just because you have the radio lying on the seat instead of being held vertical.

The two main items that control the coverage of the repeater (more than anything else) is its location and its antenna height. Other things affect the coverage such as frequency, power, obstructions, analog vs. digital, bandwidth, antenna type, antenna pattern, etc.

The coverage maps that we offer are reasonably reliable and are available from MRA via our website but we cannot guarantee coverage because there is a margin of error with all predictions. What we can do is to provide demo radios so that you can try it and see if the results you get are within a reasonable error margin of the prediction that we provide to you. Coverage maps are available on our web site including being able to view them in Google Earth if you have a computer that will properly display Google Earth.

If you look at the coverage map for Mt Lukens at the top of this article, the different colors represent changes in signal strength. The coverage prediction takes into account geographic terrain variations in the coverage. It also takes into account the general urban clutter in the city, the general type of vegetation in the rural areas and the area off shore where the radio signal propagates over water. It does not take into account the specifics of the size and shape of each building, so the general signal level around the buildings are fairly accurate, but there are variations that are not shown. (This is especially true for the Google Earth maps that allow you to see individual buildings look around the buildings.) Also, the signal level shown is represented outside the buildings and NOT inside the buildings, which will have a significantly lower signal level.

The color code for the signal strength is listed on the map. The following is an explanation of the colors:

No.	Color	Signal Level	Explanation
1	Magenta	-28dbm	**Extremely Strong signal.** This color is generally limited to 1-2 miles of the repeater site
2	Red	-58dbm	**Very Strong signal.** This area will work well inside most buildings, even those that are built from concrete. It will generally not work in elevators or the basement.
3	Yellow	-68dbm	**Strong signal**. This area will work well inside most buildings except for many concrete buildings. It will generally not work in elevators or the basement.
4	Green	-78dbm	**Good signal.** This area will work well inside buildings when you are near the external walls of the building and not deep in the interior. It will work well with a portable radio while holding the radio in your hand while inside a moving vehicle.
5	Turquoise	-88dbm	**Fair signal.** This area will generally not work inside buildings. It may work in some areas in a moving vehicle, but there is likely to be a certain amount of signal fade. The radio will be more reliable when the vehicle is not moving.
6	Blue	-98dbm	**Weak signal.** This area will work well with a mobile radio with the antenna properly mounted outside the vehicle. It will generally not have acceptable performance for a portable radio inside the vehicle. A portable radio will generally work if outside of a vehicle and outside of a building while stationary. It may not work well while walking around the area.
7	Grey	-108dbm	**Marginal signal.** Portable will not work at all, mobile radio may go in and out of the radio signal as it moves within this coverage area.
8	White	-118dbm	**No Usable Radio Signal**

The signal level is represented in the unit of DBM. This means db relative to the fixed level of 0dbm which represents 1-milliwatt signal. The db scale is strictly a relative scale showing either a gain in signal or a loss of signal relative to where you started and is a logarithmic scale, therefore every time you decrease by 10db, the signal level is actually reduced by 90% or a 10:1 ratio. (If you increase by 10db, you have 10 times as much as you had before the signal increase.) Therefore level 1 (magenta) which has a -28dbm signal level is almost 1000 times weaker than 1-milliwatt. (It is actually closer to 600 times weaker than 1-milliwatt because it is -28dbm instead of -30dbm, but we will use the 1000 times weaker signal for ease of discussion.) Going from magenta to red represents a 1000:1 reduction in signal, or about 1,000,000 times reduction from 1-milliwatt. The transition from red to yellow represents a reduction from -58dbm to -68dbm which represents a 10:1 reduction in signal level or 10,000,000 times reduction from 1-milliwatt. The transition from yellow to green represents another 10:1 signal reduction or 100,000,000 times reduction from 1-milliwatt. This continues as a 10:1 signal reduction for each additional color change.
The general rule of thumb is that you need to have -100dbm of radio signal inside a building to have somewhat reliable radio coverage while moving around inside. Buildings will attenuate radio signals by varying amounts, depending upon the type of construction. The approximate values are:

Amount of Signal Loss	Type of Construction
-15db	Wood frame and stucco construction
-18db	Light industrial
-19db	Dense Commercial
-29db	Dense Urban
-29db	Underground parking structures
-30db	Metal film “low E” emission windows
-40db	Heavy concrete with “low E” windows

These values can vary considerably from one building to another depending upon the actual construction method used and the materials used in the construction. These values must be subtracted from the signal levels represented by the colors on the map to get an estimate of the signal level inside the building. This will significantly reduce the coverage inside the buildings and there are many areas inside the buildings that will significantly exceed these numbers due to specifics of the construction in a particular area of the building.

The range of a radio system is a subject that cannot be answered with a simple, straightforward response. It is influenced by a multitude of variables that come into play under different circumstances. Therefore, any claim that your radio will communicate within a specific distance, like a 2-mile, 5-mile, or 10-mile range, is either a blatant lie, an oversimplification, or a result of the person's lack of understanding of radio propagation. Radio waves, being a form of complex energy, generally adhere to predictable patterns but occasionally exhibit unexpected behavior. This means that you may experience radio signals in situations where you least expect them, while encountering a complete absence of signals when you firmly believe they should be present. Such unpredictability adds a sense of intrigue to the world of radio communication. To better understand the behavior of radio signals, it is essential to delve into the concept of radio propagation. Radio waves propagate through various mediums, such as air, water, and even buildings, which can affect their range and strength. Factors like the frequency of the radio wave, the power of the transmitting device, the presence of obstacles, the terrain, and atmospheric conditions all contribute to the overall range of a radio system. Frequency plays a vital role in determining the range of a radio signal. In general, lower frequencies tend to travel farther than higher frequencies. For example, long-wave radio signals can travel thousands of miles, while high-frequency signals, like those used in Wi-Fi networks, have a shorter range. The transmitting power of a radio device also affects its range. A higher-powered transmitter can send signals over greater distances, but it is important to note that the range is not directly proportional to the power output. Other factors, such as the quality of the antenna and the efficiency of the receiver, also come into play. The presence of obstacles, such as buildings, trees, or even mountains, can obstruct the path of radio waves and limit their range. These physical obstructions cause signal attenuation, where the radio waves lose their strength as they encounter resistance.

As a result, the range of the radio system is reduced in such scenarios. Similarly, the terrain and geographical features of an area can impact radio propagation. For instance, radio waves tend to propagate better over flat, open spaces compared to hilly or forested regions. The presence of large bodies of water, such as lakes or oceans, can also influence the range of radio signals due to the reflective properties of water. Lastly, atmospheric conditions can have a significant impact on radio propagation. Factors like temperature, humidity, and even solar activity can affect the behavior of radio waves. Changes in these atmospheric conditions can lead to phenomena like refraction, diffraction, and ionospheric propagation, which can either enhance or hinder the range of a radio system. In conclusion, the range of a radio system is a complex phenomenon influenced by numerous variables. While there are general guidelines and principles to follow, it is crucial to understand that radio signals can exhibit unexpected behavior. Factors such as frequency, transmitting power, obstacles, terrain, and atmospheric conditions all contribute to the range of a radio system. By considering these factors, one can gain a deeper understanding of radio propagation and better anticipate the behavior of radio signals.

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