Technical Brief
AN206 **Rev A0**

Radio Communication Coverage

By John Sonnenberg *Raveon Technologies Corp*

Overview

This document is a brief overview describing the range of wireless data communication coverage for various wireless technologies.

It includes VHF (150MHz bands), UHF (450MHz bands), 800/900 license free bands, and 2.4GHz ISM bands. It also compares conventional wireless technology to more advanced technologies such as LoRa.

VHF and UHF Bands

In most countries, use of data radios in these bands requires a license from the government. The radio channels in these bands are usually very narrow, like 6.25kHz, 12.5kHz, or 25kHz.

Some nations allocate a few channels in these bands for licese free-operation. In the USA the MURS channels are license free.

800/900MHz License Free bands

Many countries also allows certain 800MHz or 900MHz spectrum to be used without obtaining a license as long as the product abides by certain power, bandwidth, and operational restrictions. In the USA, these include frequency hopping, spreading spectrum, data rate limits, and power limits.

2.4GHz License Free Band

Around the world, this band is used for Wi-Fi and many other license free wireless needs.

What is LoRa?

The LoRa (short for **Lo**ng **Ra**nge) modulation scheme is a modulation technique combined with a data encoding technique that gives a broad-band spread-spectrum radio the receive sensitivity of a very narrow-band long range radio. LoRa techniques give LoRa receivers unprecedented sensitivity levels. LoRa radios can receive signals 10 times weaker than most radios.

What Affects Communication Range?

1. **Antenna gains and antenna heights.**
2. **Transmit power**
3. **Receive sensitivity**
4. **Frequency of the system**
5. **The energy per bit (data rate)**
6. **Local interference**

When a receiver's sensitivity is increased by 10 times, that is the same communication range improvement as increasing the transmitter power 10 times. If the noise-floor increase 10dB that is just like turning the transmit power down 10dB.

Typical Coverage Range

Few things in the world are actually typical. Most all areas of the world are unique, but for discussion and comparison, here are some typical range coverage numbers Raveon and others use as typical range.

Terrain	5W VHF	5W UHF	1W 800/900	2.4GHz
In open terrain, 3m antenna	10-75km	10-50km	5-30km	0.1 – 1km
Wooded environment outdoors	5-16km	2-10km	1-5km	0.05-0.1km
Urban, 1-3m antenna	5-16km	2-10km	1-5km	0.1-0.2km
Urban, roof-top antenna	7-25km	5-15km	3-7km	0.1-0.5km
Aircraft/drone line-of-site	50-200km	40-150km	30-100km	0.2-0.5km
Golf Course, 10m antenna	6-20km	4-15km	3-8km	0.1-0.3km

Forward Error Correction

FEC is commonly used to increase a receiver's sensitivity by reducing the bit-error rate of the system. LoRa radios have integrated FEC into the protocol. FEC effectively increases the energy per bit and enables the device to correct for bit errors. By adding extra overhead bits to groups of bits being transmitted, the data throughput gets reduces but the bit-error-rate is lower with weak signals, increasing the sensitivity of the receiver.

Link Margin Comparison

When one compares a LoRa radio system to a traditional UHF or VHF radio modem, we see that the communication range for LoRa is very similar to VHF and UHF, but it achieves this with much less RF power. The spreadsheet calculations below show the theoretical link margin for LoRa 900MHz compared to VHF and UHF radio systems.

	LoRa 200mW	LoRa 10mW	UHF 2W	VHF 2W
Operating Frequency (MHz)	915	915	460	160
Transmitter Output Power	23 dBm	10 dBm	33 dBm	33 dBm
Link Distance, km	180 km	40 km	150 km	450 km

Link Distance, miles	111 mi	24 mi	93 mi	279 mi
Transmit Antenna Gain (dBi)	5	5	3	3
Antenna feed loss (both ends)	1 dB	1 dB	1 dB	1 dB
Receive Antenna Gain (dBi)	5	5	3	3
Receiver Sensitivity	-128dBm	-128dBm	-115dBm	-115dBm
System Gain (dB)	151	138	148	148
Link Fade Margin (dB)	**22.2**	**22.3**	**22.8**	**22.4**
Link Path Loss (dB)	-136.8	-123.7	-129.2	-129.6
Effective Radiated Power	27	14	35	35

The theoretical calculations show that a 200mW LoRa radio will work about as long-range as a 2watt UHF radio. A 2watt VHF will work a bit longer range but it is using 2 watts. Raveon's field tests support these theoretical calculations. We've seen VHF and UHF reliably go 50-100 miles line of site, and LoRa can easily go 20-50 miles (at 1/10th the power consumption).

Although, building, forest, and foliage penetration is much better with VHF and UHF radio technology, so 900MHz systems will typically require taller antennas at the base stations and more base stations to get good coverage. This is offset by the cost and power of LoRa radios being so much lower than traditional VHF and UHF systems so building out large area networks with LoRa is a very good approach.

Increasing Communication Range

LoRa is usually used in long-range communication systems. There are many ways to increase the range of a communication system, and the LoRa protocol has implemented many of them. The others are something everyone building a wireless data system should consider.

The range of a communication system is determined by:

7. **Antenna gains and antenna heights.**
8. **Transmit power**
9. **Receive sensitivity**
10. **Frequency of the system**
11. **The energy per bit (data rate)**

Antenna gains and antenna heights can make hug improvements to the range of a communication system. Antenna performance is some of the most economical ways to improve a system. But Antenna gains are sometimes limited by regulatory rules or practical considerations.

The more **transmit power** a device radiates the further away it can be received. In the real world, you must increase power by 4-10 times to double the communication range. Sometimes even 20 times increase is needed to double the range.

A receiver with good **receive sensitivity** can pick up a signal from much further away than a poor receiver. A receiver that is 4 times (6dB) more sensitive than another receiver will greatly increase the communication range. 6dB receive sensitivity improvement is the same as transmitting 4X more power. But a 6dB better receiver will consume very little additional power. It's always better, cheaper, and more efficient to use a more sensitive receiver than a more powerful transmitter.

Every RF engineer knows the equation for RF communication that shows the higher the **frequency of the system**, the more the loss.

$$L = C + 20 * \log(D) + 20 * \log(F)$$

C is 36.6 if D is measured in miles. L is the free space path loss. You can see that the loss goes up as the distance (D) goes up and as the frequency (F) goes up. If you use a frequency like 900MHz instead of 150MHz, the path-loss is 15dB more. This common formula is often cited as proof that the atmosphere attenuates high frequencies more than lower.

We like to note that the atmosphere doesn't favor 150MHz over 900MHz. The reason the 900MHz system has more loss is that the 900MHz antennas are shorter, so they collect less energy than a 150MHz antenna that is almost 2 meters tall.

The **energy per bit (Eb/N0)** is the transmit power divided by the over-the-air data rate. In the 1940s, Claude Shannon determined the communication performance limits for channel coding. He determined that the noise floor, channel bandwidth, and the energy per bit were a fundamental limit to the ability to communicate. To this day, his theorem still stands true. If by reducing the data rate in half you get the same range improvement as doubling your power or doubling your receive sensitivity. Slow data rate radios go much farther than fast radios. It's in the physics of RF. Lora over-the-air baud rates are very slow, typically in the 900 to 22000 bits per second. This is a 100 times slower than WiFi, Bluetooth, or Zigbee but a LoRa radio will have 100 times the Eb/No as they do and 10-100 times their range.

Raveon Technologies Corporation

2320 Cousteau Court

Vista, CA 92081

sales@raveon.com

760-444-5995