The Communication Range of 10 mW Low Power Radio

Is the communication range of the MU-2 6,500 m?

By Tomihiko Uchikawa

■ The range of radio waves

The first thing people ask when they enquire about radio equipment is "What's its range"? We answer this question with "Its line of sight range is about 600 m. In testing it was 1,200 m." Like other manufacturers, Circuit Design tries to present the best figures we can.

Both users and manufacturers seem to use a long communication range as a criteria for judging the power of radio equipment. However, there are actually all sorts of conditions that form the basis of these values, and in fact you can't judge anything simply by looking at these figures.

Actually, people are generally surprised to hear that the equipment achieved a range of 1,200 m, so in the end we have to talk in detail about the measurement conditions. In this test, communication was possible over a distance of 6,500~7,000 m with 10 mW radio module. But unfortunately, this wasn't at a ground level of 1 or 2 m.

In other words, the communication range changes significantly depending on the environment of use and data amount, and even if it achieved 600 m, you couldn't say that this was a guaranteed value for that environment. It's normal for the communication range of low power radio equipment not to be shown clearly in the manual as a specification, and it's presented only as a reference value. Having said that, since communication range is an important parameter in choosing radio equipment, manufacturers must give some sort of response regarding communication range.

There are set rules for obtaining the communication range, and if you understand this in designing a system, the completed system will operate stably in the future and will not lose the trust of the customer. Supporting and maintaining an unstable system requires labour and cost.

This technical article shows the results of a communication test of the MU-2 low power radio modem while explaining the relationship between the installation site of a radio system and its communication range.
Please also use the simple Java applet we provide on the Circuit Design website for calculating radio wave propagation characteristics as a guideline for communication range.

■ The setup of the communication range test

The test was carried out between the roof of the Circuit Design building (altitude 578 m) and the Ikedacho Art Gallery (altitude 625 m). The distance between these points is 6,500 m.
Geographically, there is a drop of about 50 m from the roof of the Circuit Design building to the Takase River at 5,000 m, and the last 1,500 m to the gallery rises about 100 m.
The height of the antennas was 10 m for the transmitting antenna and an estimated 49 m for the receiving antenna taking into account the elevation.
The measurement conditions are as shown below, but we compared the actual measurement value with the calculation results for radio wave propagation using a 2-wave model.

◇ RSSI measurement conditions
Radio: Circuit Design Low power radio modem MU-2
Working frequency: 429.2500 MHz
Transmitted power: 10 mW (10 dBm)
Antenna gain: Transmitting = 2.14 dBi, Receiving = 2.14 dBi
The base unit was installed on a utility pole in the Circuit Design grounds at a height of 10 m.
The slave unit was installed at a height of 2 m on the back of a car, and the received signal level of the slave unit and noise floor were measured at each location.

◇ Base unit installation

The base unit installed on an amateur radio pole in the Circuit Design grounds
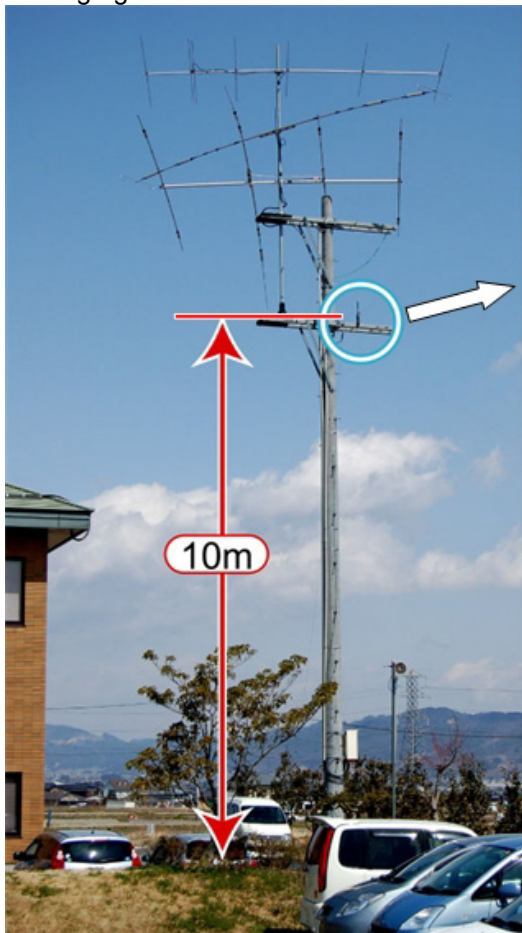
◇ Close up of the base unit

◇ Close up of the slave unit

◇ Slave unit installation

The slave unit was attached to the back of a car at 2 m above ground level.

The square box at the front contains the control CPU and batteries.

The front of the box is a solar panel, but this is not for power. It's used as a light sensor. This data and temperature sensor data is sent to the base unit.

The case is simple and cheap for testing purposes, but the photo makes it look like quality equipment.

◇ Cutaway model of the slave unit

The slave unit contains an MU-2 unit and control CPU.

The CPU collects the sensor data and sends it to the MU-2. Since the sensor is nearby in this instance, we used this configuration, but if the sensor is far away from the radio component, it's beneficial to provide a controller and power supply close to the sensor, and send the data to the radio component via an RS232C interface cable.
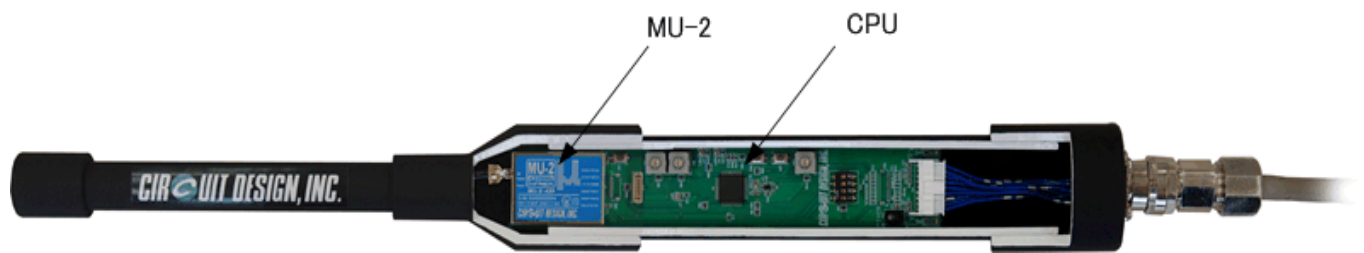

◇ Base unit circuit board

The base unit has the same case as the slave unit and the circuit board is mounted with only an MU-2 and RS232C driver. The control range with RS232C is 15 m according to the old standard, but in fact control without errors seems to be possible at about 50 m.

The length of the circuit board is the same as the antenna length of 17 cm and the unit operates stably at high frequency.

If you create a control program that enables you to check and change the internal settings with radio control, you can ensure good future maintainability, even though the radio component is installed in a high place. Moreover the MU-2 has a unique command that acquires and returns the received signal level of other units.
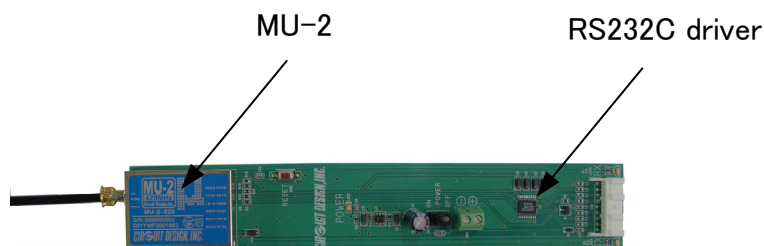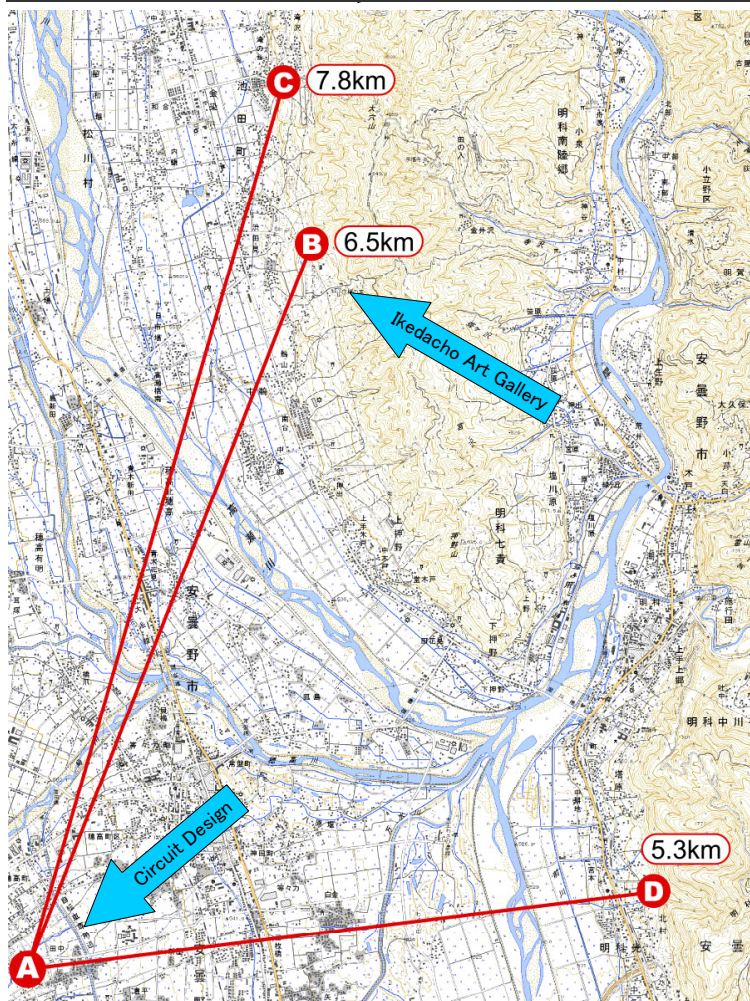
◇ Map of test site

In this map it appears that there's nothing between A and B, but there are actually many houses and trees.

◇ Cross section of the geography of the communication test, and measured values

Geographically, there is a drop of about 50 m from the roof of the Circuit Design building to the Takase River at 5,000 m, and the last 1,500 m to the gallery rises sharply about 100 m.

The height of the antennas was 10 m for the transmitting antenna and an estimated 49 m for the receiving antenna taking into account the elevation.

You can see that when the communication range is far, a height of 10 m doesn't seem very high.

The received signal strength intensity at this location was -96 dBm. The receive sensitivity of the MU-2 is -110 dBm and the noise floor was -129 dBm so communication could be established.
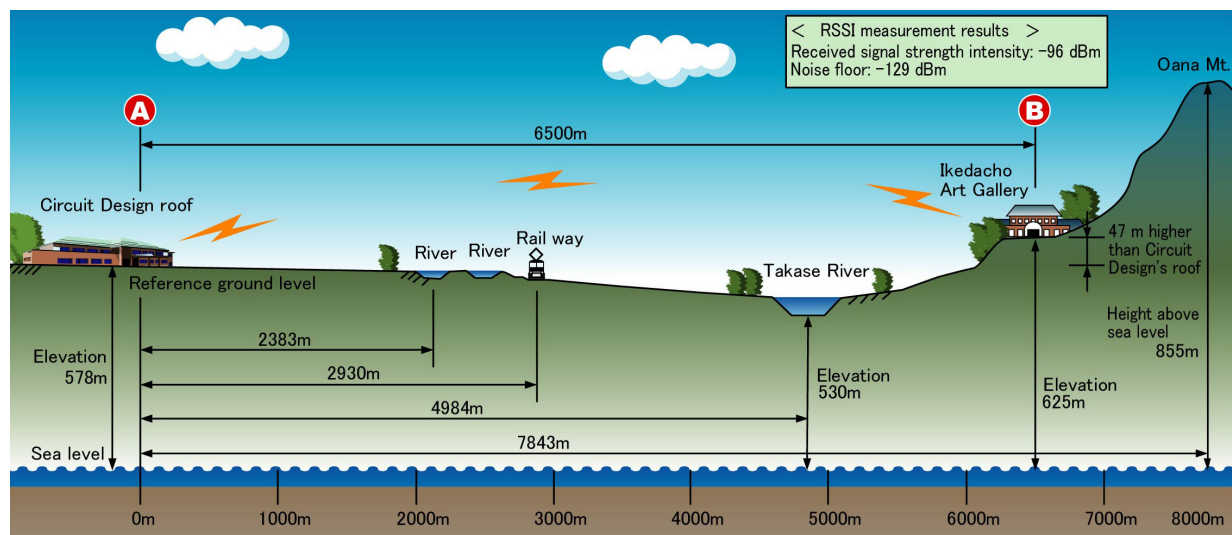
■ **Measurement results and theoretical values**

Let's compare the measurement results and the theoretical value for radio wave propagation.

The actual path taken by the radio waves to reach the receiving antenna is very complicated, but here we'll simplify the environment and think about it in terms of a theoretical expression. We'll avoid difficult parameters and by taking some slight liberties, we'll apply a 2-wave model of radio wave propagation. In the 2-wave model used here, we're assuming that the ground is a perfect conductor with no reflection loss.

The formula for the 2-wave model is explained elsewhere, and here we'll show the calculation results found using the Java applet on the Circuit Design website.

For radio communication it's necessary to establish a 1st Fresnel zone[1]. In this case, the communication distance is 6,500 m so at the middle point at 3,250 m, the radius of the 1st Fresnel zone is 34 m. Therefore, if the height of both antennas is 34 m, when the 2-wave model is applied, the propagation loss is 95.3 dB and the received power is -81.1 dBm. (If the antenna height is very high, please note the height pattern[2].)

We'll assume that the received power of -81.1 dBm is the power that can ideally be obtained.

If we perform the calculation with the same conditions in free air, the propagation loss is 101.4 dB and the received power is -87.1 dBm, therefore the calculation result with the 2-wave model when the height of both antennas is 34 m is stronger by 6 dB.

On the other hand, in the actual test situation the transmitting antenna is at 10 m and the receiving antenna is at 49 m, therefore when the 2-wave model is applied with these values, the propagation loss is 99.4 dB and the received power is -85.1 dBm.

Here the actual measurement result for received power is -96 dBm, so there is 14.9 dB attenuation from the ideal received power, and about 10.9 dB from the calculated value for the actual test situation.
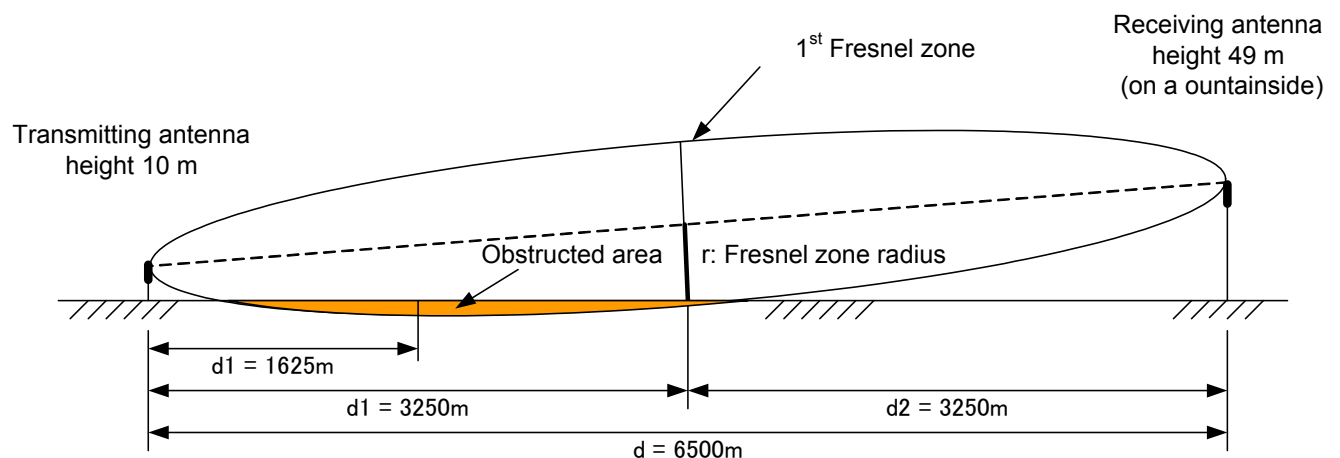
Fresnel zone calculation

Fresnel radius at the middle point

$$r = \sqrt{\frac{\lambda d_1 d_2}{d_1 + d_2}} = \sqrt{\frac{0.7 \times 3250 \times 3250}{6500}} = 33.7[m]$$

Fresnel radius at the 1/4 point

$$r = \sqrt{\frac{\lambda d_1 d_2}{d_1 + d_2}} = \sqrt{\frac{0.7 \times 1625 \times 4875}{6500}} = 29.2[m]$$

Clearly there are obstacles inside the Fresnel zone, so we can infer that propagation loss is occurring.

* 1 - For details about the Fresnel zone, please refer to the technical information and calculation tools on the Circuit Design website.

* 2 - For details about the height pattern, please refer to the technical information and calculation tools on the Circuit Design website.

◇ Applet for calculating radio wave propagation characteristics

If we enter the conditions for the test in the applet for calculating radio wave propagation characteristics, received power of -85.1 dBm should be obtained at the Ikedacho Art Gallery at 6,500 m. The actual measured value was -96 dBm.

The reason for this is probably that, although line of sight was achieved as explained above, a Fresnel zone was not actually achieved.
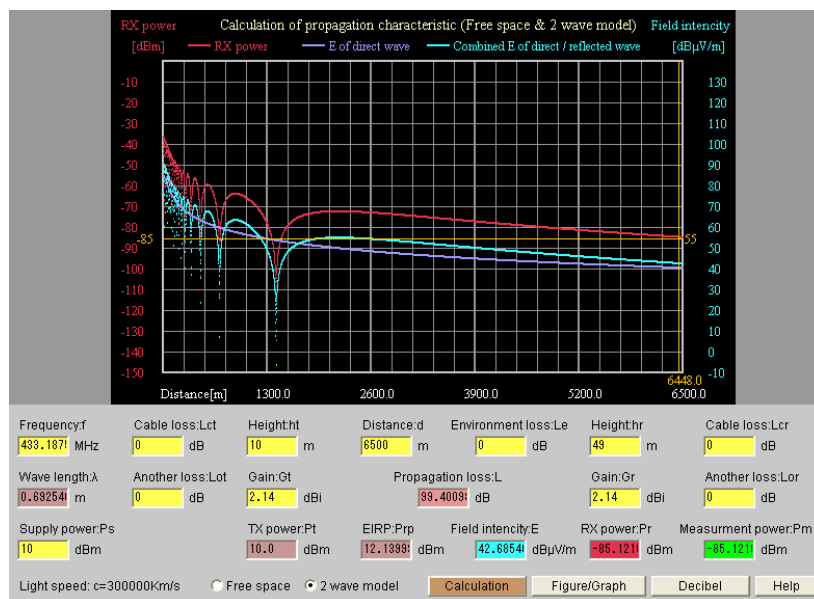
The image at above is the Java applet for calculating the Fresnel zone on the Circuit Design website.

■ Summary

Above we compared the measurement result and theoretical value concerning the relationship between the installation site of the radios and the communication range. The actual path taken by the radio waves to reach the receiving antenna is very complicated, but here we simplified the environment and considered it in terms of a theoretical expression.

The cause of this attenuation is very likely that a Fresnel zone was not achieved in the test environment. In addition, we didn't measure the directivity of the antennas to find the optimum direction, which may also have resulted in some loss.

However, if we just showed the communication range, you would tend to think that it's pretty good.

The communication range of low power radio equipment is often regarded as problematic. Achieving a long communication range requires that the electric field intensity at the location of the receiver is at a sufficient level for signal demodulation. As the results of this test show, the installed height of the antennas of 400 MHz or 1,200 MHz radio equipment should be as high as the system permits. (However, you must also check the height pattern.) Locating the equipment high up involves cost, but it's essential for consistently stable operation of the system.

1. Ensure a Fresnel zone and line of sight

   If there are no obstacles inside the Fresnel zone, you can use the free air propagation calculation.

2. To achieve this, locate the equipment as high as possible

3. Take into account height pattern in the antenna height

A transmitting antenna height of 10 m is quite high from the point of view of normal installation height, but it isn't sufficient from the viewpoint of radio waves transmission.

■ Other considerations

When you install radio equipment, there are many other points to consider besides the Fresnel zone and height pattern.

They cannot be covered in this technical article, but please consider the following points.

1. Ensure that the antennas are both in the same plane of polarisation

2. Install the equipment taking into consideration the directivity pattern

3. Ensure that mobile devices are not shadowed by the human body

More than anything else, it's important to measure the actual electric field intensity at the site. If this measurement is not possible, use the electric field intensity (receive level) measurement function of the radio to find the best spot.

The receive sensitivity of the MU-2 radio modem used in this case is -110 dBm, therefore there is a margin of 14 dB in the received power of -96 dBm at the Ikedacho Art Gallery. For a system that must withstand practical use, a margin of about 20 dB is desirable. If a 20 dB margin cannot be maintained, think about using a relay unit.

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