The Relationship Between Communication Distance and Transmission Rate and Antenna Height, Transmission Power, Antenna Gain, Operating Frequency and Channel Bandwidth

First of all, radio waves propagate through space. Since the earth is an ellipsoid, influenced by curvature, the transmission distance of radio stations is closely related to the terrain surroundings, particularly the height of the antenna. In theory,the distance formula:D=$4.11\times(\sqrt{H}+\sqrt{h})$

Secondly, the received magnetic field strength and output signal to noise ratio of the radio station jointly influence the selection of modulation mode, channel bandwidth, and determine the transmission rate. The receiving field strength pr of the radio station relies on the transmission power pt of the relevant radio station and the gain loss gt/gr/lt/lr of the antenna system. Transmission loss lo is associated to distance and frequency , formula:Lo=32.45+20logf (MHz) +20logD (Km) , Pr=Pt+Gt+Gr-Lt-Lr-Lo.

The signal received by the radio antenna is demodulated by the physical layer waveform and beam nss, decoded by the channel, and output to the baseband signal. The rssi of the received signal field strength of the radio determines the snr of the received and demodulated output signal.The snr of the link is dynamically adaptive to the modulation coding scheme (mcs).

Data relation tables of waveform beam (nss),modulation and coding scheme (mcs), channel bandwidth of mimomesh broadband ad hoc network radio station and transmission rate of corresponding transmission data stream in air physical layer/interface service layer:

NSS	MCS	Coding Rate	PHY Thuoughput(Mbps)	UDP User Thuoughput(Mbps）	Mimomesh Vehicular Radio Sensitivity	Mimomesh Handheld Radio Sensitivity
1	0	BPSK 1/2	1.625	1.03	-102	-99
1	1	QPSK 1/2	3.25	2.06	-100	-97
1	2	QPSK 3/4	4.875	3.09	-97	-94
1	3	16-QAM 1/2	6.5	4.12	-95	-92
1	4	16-QAM 1/2	9.75	6.18	-92	-89
1	5	64 QAM 2/3	13	8.25	-87	-84
1	6	64 QAM 3/4	14.625	9.28	-85	-82
1	7	64 QAM 5/6	16.25	10.30	-80	-77
2	8	BPSK 1/2	3.25	2.06	-100	-97
2	9	QPSK 1/2	6.5	4.12	-97	-94
2	10	QPSK 3/4	9.75	6.18	-94	-91
2	11	16-QAM 1/2	13	8.25	-91	-89
2	12	16-QAM 3/4	19.5	12.38	-88	-85
2	13	64 QAM 2/3	26	16.21	-84	-81
2	14	64 QAM 3/4	29.25	17.62	-82	-79
2	15	64 QAM 5/6	32.5	18.94	-77	-74

Table1 MCS and Sensitivity(5MHz Bandwidth)

NSS	MCS	Coding Rate	PHY Thuoughput(Mbps)	UDP User Thuoughput(Mbps）	Mimomesh Vehicular Radio Sensitivity	Mimomesh Handheld Radio Sensitivity
1	0	BPSK 1/2	3.25	2.48	-99	-96
1	1	QPSK 1/2	6.5	4.96	-97	-94
1	2	QPSK 3/4	9.75	7.40	-94	-91
1	3	16-QAM 1/2	13	9.90	-92	-89
1	4	16-QAM 3/4	19.5	14.80	-89	-86
1	5	64 QAM 2/3	26	19.90	-84	-82
1	6	64 QAM 3/4	29.25	22.40	-82	-80
1	7	64 QAM 5/6	32.5	24.0	-77	-78
2	8	BPSK 1/2	6.5	4.96	-97	-94
2	9	QPSK 1/2	13	9.90	-94	-91
2	10	QPSK 3/4	19.5	14.80	-91	-88
2	11	16-QAM 1/2	26	19.90	-89	-86
2	12	16-QAM 3/4	39	29.90	-85	-82
2	13	64 QAM 2/3	52	39.70	-81	-79
2	14	64 QAM 3/4	58.5	43.50	-79	-77
2	15	64 QAM 5/6	65	48.1	-74	-75

Table2 MCS and Sensitivity(10MHz Bandwidth)

NSS	MCS	Coding Rate	PHY Thuoughput(Mbps)	UDP User Thuoughput(Mbps）	Mimomesh Vehicular Radio Sensitivity	Mimomesh Handheld Radio Sensitivity
1	0	BPSK 1/2	6.5	4.92	-96	-93
1	1	QPSK 1/2	13	9.82	-94	-91
1	2	QPSK 3/4	19.5	14.73	-91	-88
1	3	16-QAM 1/2	26	19.65	-89	-86
1	4	16-QAM 3/4	39	29.47	-86	-83
1	5	64 QAM 2/3	52	39.29	-82	-79
1	6	64 QAM 3/4	58.5	44.20	-80	-77
1	7	64 QAM 5/6	65	47.45	-78	-75
2	8	BPSK 1/2	13	9.82	-94	-91
2	9	QPSK 1/2	26	19.65	-91	-88
2	10	QPSK 3/4	39	29.47	-88	-85
2	11	16-QAM 1/2	52	39.29	-86	-83
2	12	16-QAM 3/4	78	57.04	-82	-79
2	13	64 QAM 2/3	104	75.00	-79	-76
2	14	64 QAM 3/4	117	85.00	-77	-74
2	15	64 QAM 5/6	130	94.00	-75	-72

Table3 MCS and Sensitivity（20MHz Bandwidth）

For instance, two sets are 100 km apart, with a transmission power of 10 watts × 2's mimomesh broadband ad hoc network radio station ,also utilize a 6db omnidirectional antenna with a working frequency band of 1440mhz. The antenna is situated in an open and unobstructed terrain surroundings around, with a height of 400m and 25m respectively.

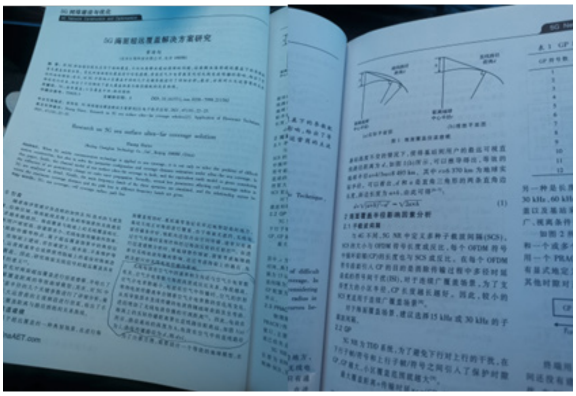
1. Calculation of transmission distance:

The limit visible distance of the earth curvature limit

$$D=4.11\times(\sqrt{H}+\sqrt{h})=4.11\times(\sqrt{400}+\sqrt{25})$$ ≈102.75kilometres

If the same conditions are in the sea, the transmission of radio waves in the sea air, the dielectric effect causes electromagnetic wave refraction, which can reach a longer distance, with the maximum distance increased by about 10%.

In addition, using MIMO multiple antennas, the diversity reception function can effectively stack the reflected signals, improve the diffraction ability in a certain proportion, and increase the actual distance by 20% - 30%.



2.The transmission rate determined by the received signal field strength to SNR, modulation mode, and transmission bandwidth.

Receiving field strength of single antenna:Pr=Pt+Gt+Gr-Lt-Lr-L0=40+6+6-19.7/100×25-19.7/100×25(32.45+20lg 1440+20lg100)≈ -94.3dBm

		12D-FB	10D-FB	8D-FB	7D-FB	5D-FB	RG-8/U
结构参数							
内导体 (Dia.mm)		4.40	3.50	2.80	2.60	1.80	2.743
绝缘体 (Dia.mm)		12.40	10.00	7.80	7.30	5.00	7.30
外导体 (Dia.mm)		13.40	11.00	8.80	8.20	5.90	8.20
外护套 (Dia.mm)		15.60	13.00	10.40	9.80	7.50	10.20
电气性能							
最大衰减 (20℃) dB/100m	150MHz	3.40	4.10	4.90	5.30	7.60	5.24
	280MHz	4.70	5.60	7.00	7.30	10.90	7.16
	350MHz	6.30	6.30	8.10	8.30	12.10	8.03
	400MHz	5.80	6.90	8.80	9.10	13.00	8.62
	800MHz	8.50	10.20	13.10	13.00	19.00	12.47
	900MHz	9.20	11.10	14.00	14.30	20.40	13.44
	1200MHz	10.90	13.40	16.70	17.00	24.20	15.60
	1500MHz	12.30	15.30	19.20	19.70	27.50	17.63
	1900MHz	14.30	17.70	22.20	22.90	31.80	21.00
内导体电阻 Ω/km, ≤		1.17	1.86	2.92	3.41	7.05	3.04
绝缘电阻 MΩ·km,≥		5000					
耐电压 AC V/min, ≥		1000					
特性阻抗 Ω		50±2					
回波损耗 dB ≥	VHF	20					
	UHF	18					

The MIMO field strength processing gain of 2x2w antenna transmission power is 3-6db, and the signal-to-noise ratio of the received output signal of the radio station is about 12db.

The relation between receiving field strength, signal to noise ratio and modulation mode of Mimomesh Broadband AD Hoc network radio:

Received Field Strength(dBm)	SNR(dB)	Modulation Mode(20MHz BW)
＞-82	＞20	64QAM
＞-84	＞15	16QAM
＞-94	＞10	QBPS
＞-100	＞0	BPSK

At this time, the adaptive modulation mode is at 16QAM ½ / QPSK ¾ . If the working bandwidth selected by the radio station is 20MHz, the corresponding air physical layer transmission rate is 26~19.5Mbps, as shown in the table.

3.Selection of operating frequency band.

MimoMesh broadband AD Hoc network radio is a radio developed based on software radio. The working frequency band supported by the receiver chip can be customized to 70MHz-60GHz.

According to industry applications and component conditions, UHF (450-700MHz), L Band (1000-1500MHz), S Band (2200-2500MHz) and C Band (4400-6000MHz) are available in stock. In the actual project application, relevant policy support (open frequency band, private network application and administrative application) shall be considered for the working frequency band of special wireless communication equipment, and the scheme reliability (electromagnetic environment, external interference, diffraction ability, penetration ability, air loss, etc.) shall be improved through flexible selection of frequency bands.

Establish Efficient And Reliable Dedicated Wireless Data Transmission System

Data transmission can be simply divided into two categories: wired **(including the installation of optical cables, cables or leased national telecommunication lines)**

and wireless **(establishing a dedicated wireless data transmission system or borrowing public network information platforms such as CDPD, GSM, CDMA)**.

Compared with other methods, the special wireless data transmission mode established by radio station has the advantages of less investment, fast opening, simple operation and maintenance, and the disadvantages may be relatively "not so stable and reliable".

Is wireless transmission really unstable and reliable? Obviously not all. Nowadays, TV, satellite, mobile phone and other communication tools that can not be separated from modern life almost all use wireless transmission. The reliability of wireless transmission is self-evident. Whether wireless communication or wired communication is reliable or not, it is reflected by calculating the bit error rate (BER). Generally, the bit error rate of the communication system is required to be within 10-6. In combination with the transmission error control protocol (feedback retransmission ARQ, KERMIT, XMODEM, ZMODEM, etc.), absolute error free code can be guaranteed. Moreover, the transmission efficiency of the communication system with high bit error rate will be reduced through multiple feedback retransmissions.

Why does it feel unreliable to transmit data wirelessly? In other words, why do most people think the wireless transmission system they are using is unreliable? This may be because the selected radio station is not a dedicated data transmission product.

At present, most of China's remote control and telemetry radios are based on FM analog vehicle radios plus MODEM chips. These radios are not professional data transmission products, but walkie talkies working in the 230 MHz data transmission band.It is not reliable to transmit data by using this kind of radio, because there are two serious and fundamental problems that cannot be solved: the PTT control transmission delay (more than 100ms) brings about the loss of leading data characters and the interference of redundant characters caused by FM static tail noise, especially in the application of high-speed data transmission or fast transceiver conversion (such as connecting PLC, etc.).

Because of its low price, it is widely used in scenarios with low transmission rate, short distance and low reliability requirements (where data can be collected multiple times). However, in transmission applications that require high speed, long distance and high reliability, we recommend that users choose products with direct digital modulation and demodulation, forward error correction and DSP technology, such as WDS, DATALINC and other manufacturers' equipment. Secondly, networking design and link test shall be carried out according to the distribution of master and sub stations, the site geographical environment and other specific conditions.

1.Calculation of theoretical data

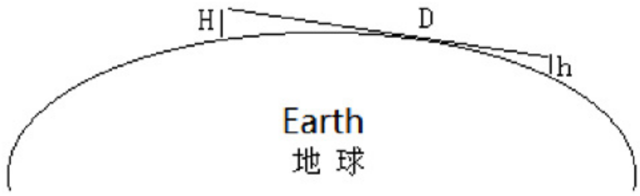
Whether two points far away can communicate smoothly. The bit error rate, anti-interference and stability of the link after communication depend on two factors in theory:

A. Visual distance transmission

The transmission of radio wave signals can be divided into three modes according to the length (frequency band) of the working wavelength: ground wave transmission (long wave), ionospheric reflection transmission (short wave), and air transmission (ultrashort wave, microwave).

The radio management department of our country mainly distributes the special wireless data transmission service to the 220-240MHz frequency band (in addition, there are 800MHz, 2.4GHz and other frequency bands), and the radio wave propagation in this band is carried out through the air. Due to the influence of the curvature of the earth, the maximum visible distance (D km) between the antennas of two points (height is H m and h m respectively) is：

$D=4.11\times(\sqrt{H}+\sqrt{h})$



Assuming that the main station antenna is erected on the top of the building (about 100m high) and the sub station antenna is erected on the top of the low building (about 4m high), $D=4.12\times(\sqrt{100}+\sqrt{4})$ = 49.44km

Considering that the 230M band radio wave has a certain diffraction ability, this kind of antenna can theoretically reach as far as about 50km. It is also assumed that the antenna height of both the main station and the sub station is 1m (such as handheld radio), so the theoretical maximum transmission distance is about 6km.

To sum up, **the relative height of the antenna is the most important factor determining the farthest communication distance.**

B. Receiving field strength

The radio wave is sent from the radio station, passes through the feeder and antenna, and propagates to the distance through the air medium. The signal is attenuated until it reaches the remote receiver. The field strength level is：

Pr=Pt+Gt+Gr-Lt-Lr-Lo

Pr: normal receiving level (dBm)

Pt: sending power (dBm)

Gt, Gr: transceiver antenna gain (dBm)

Lt, Lr: transceiver feeder loss (dBm)

Lo: free space loss (dBm), Lo=32.45+20logf (MHz)+20logD (Km)

The signal to noise ratio of the demodulated output signal will be different due to the different field strength of the radio wave signal arriving at the receiver, which will affect the system's decision and cause bit error. If the field strength is too small, even if the distance is closer, the receiver will not receive the signal. Therefore, **the receiving field strength is the second important factor determining the communication distance.**

The threshold level difference between the receiving field strength Pr and the receiver (When the BER is less than 10-6, the field strength level value required by the receiver is generally -110dBm, and the indicators of different equipment are different) is the fading reserve. The greater the difference between Pr and the receiving threshold level, the more fading reserves, the stronger the anti-interference capability of the equipment, and the less bit error. Generally, the fading reserves are required to be above 20dB.

2.Spot-field testing

Because the actual environment of the site cannot be absolutely flat and open, for example, hills, buildings and forests will affect the propagation of radio waves to varying degrees. Therefore, before the implementation of the project, it is necessary to conduct on-site radio wave propagation and receiving field strength test (accurate to how many dBm). Later, according to the site environment and work requirements, determine the power, erection height, antenna type and other parameter information of the main station and each sub station, so that the uplink and downlink signals have the required anti-interference capability, and achieve efficient and reliable wireless data transmission.

Conclusion: As long as you select a radio station with high technical indicators and stable and reliable quality, and then determine the antenna type, erection height and power of the radio station through Spot-field testing, your wireless data transmission system will be able to operate stably, reliably and efficiently.

Questions and Answers about transmission distance:

Mat-Drone Base:
Q1: What’s the maximum range that the ground devices could cover? Could you please make a list?
Q2: We want to lift a drone at 150-200 meters of altitude, what’s the coverage range at that altitude?

Sinosun-Johnson Yang:
A1: As we all know, radio communication, is to use electromagnetic waves to transmit information, and, electromagnetic waves travel through space, so, the transmission distance of radio communication equipment, it's the same as our usual walkie-talkie, is closely related to the terrain environment of practical application, for the same pair of communication equipment, it is possible from hundreds of meters, kilometers or tens of kilometers even to hundreds of kilometers.
MimoMesh broadband ad hoc network radio, using the most advanced software platform and MN-MIMO waveform technology, is the most powerful private network communication radio, in the same terrain environment, the transmission distance is much farther than any similar product in the world. For example, Silvus, Persistent, DTC, we often test and PK with them in the same terrain environment, and our transmission distance is more than twice as long as theirs. To be specific：
1.2 watts plus 2 watts of handheld:
A. Air to ground line of sight, 50-100km
B. Ground to ground on flat terrain, 5-10km
C. Ground to ground clusters of buildings or op and down hills, 1-3km
2.10 watts plus 10 watts of backpack or vehicular:
A. Air-to-ground line of sight, 100-200km
B. Ground to ground on flat terrain, 10-30km
C. Ground-to-ground in clusters of buildings or op and down hills, 5-10km

A2: In theory, that is, the Earth's curved force formula, $D=4.11x(\sqrt{H}+\sqrt{h})$, It can be roughly calculated and estimated, a 200-meter-high relay by UAV can cover, $D=4.11x(\sqrt{200}+\sqrt{1})\approx 60km$, of course, this refers to the flat terrain environment.

And, the propagation properties of electromagnetic waves, it is also very different from the frequency of electromagnetic waves, that is, the wavelength of electromagnetic waves, the higher the frequency, the shorter the wavelength, diffraction and penetration capabilities for steep hills and dense buildings are also poor. Therefore, the lowest possible working frequency will be selected in the complex terrain environment. However, the lower the operating frequency, the worse the electromagnetic interference environment, especially for broadband communication equipment, the distance will be closer. So broadband transmission will choose frequencies that are neither too low nor too high, such as L band and UHF, S band.