Analysis of troposcatter communication fading characteristics under different weather conditions

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Abstract. Received signals of troposcatter communication are closely related to the weather, and there are currently few short-term analyses of the signals. The basic mode of troposcatter communication and the influence principle of weather system on the received signal were analyzed, the typical troposcatter communication link in North China was observed for a long time, the observation samples under different weather conditions on sunny and rainy days were selected, and the fading of the received signal was statistically analyzed, including signal fading, fading depth and fading speed, which provided reference for the tactical application of troposcatter communication equipment. On rainy days, or from 9 o'clock to 17 o'clock of sunny days, the propagation mode is mainly turbulent scattering, and the signal quality is poor, so it is not suitable to plan heavy-load tasks; From 19 o'clock to 8 o'clock the next morning of sunny days, the propagation mode is mainly stable layer reflection, and atmospheric waveguides often appear, and the quality of the received signal will be greatly enhanced, which can ensure large-capacity data transmission.

Keywords: Troposcatter communication; Tactical planning; Fading depth; Fading rate.

1. Introduction

Troposcatter communication is an over-the-horizon wireless communication method realized by scattering radio waves above ultrashort waves by inhomogeneous bodies in the troposphere[1], and occupies an important position in domestic and foreign military communications. Since the troposcatter channel is closely related to meteorological conditions, the power, fading and other characteristics of the received signal are greatly affected by the weather.

At present, there are a variety of methods for predicting the annual median value of transmission and troposcatter communication transmission loss [2], and ITU-R617 and NBS-101 are commonly used in engineering[3]. Mid-year losses are more suitable as the basis for long-term combat mission planning and are not suitable for short-term tactical mission planning.

With the development of troposcatter communication technology, the volume of the station type continues to decrease, and the application field has gradually sunk to the company-level tactical application. Although adaptive transmission technology has been available, communication equipment can adaptively select the communication rate in real time according to the channel situation to ensure the maximum efficiency of communication, but it is impossible to predict short-term characteristics such as transmission rate and fading amplitude in a future period, resulting in lack of basis for tactical mission planning. This paper conducts a large number of experiments on a typical scattering communication link in North China, selects the received signal samples under typical weather conditions and different time of a day for analysis, summarizes the troposcatter communication link laws under different weather conditions and different time periods, and provides corresponding reference for tactical mission planning.

2. Analysis of troposcatter communication propagation patterns

2.1 Basic theory of propagation mode of troposcatter communication

Weather is a general term for the atmospheric state (such as cold and warm, wind and rain, dry and wet, cloudy, etc.) and its changes in a certain area in a short period of time. Weather system usually refers to the atmospheric motion system with typical characteristics such as high pressure, low pressure and high pressure ridge and low pressure trough that cause weather change and distribution. All weather systems have a certain spatial scale and time scale, and have corresponding weather phenomenon distributions at different stages of development [4-5]. Different weather systems affect the radio wave propagation pattern and received signal characteristics of troposcatter communication.

In troposcatter communication, turbulent incoherent scattering theory, irregular layer incoherent reflection theory, and stable layer coherent reflection theory have been proposed[6]. In explaining the reasons for the over-the-horizon propagation of the tropospheric, turbulent incoherent scattering theory believes that it is mainly because of turbulent motion, irregular layer incoherent reflection theory believes that it is an irregular sharp layer such as the cloud margin and the junction surface of cold and warm air masses, and the stable layer coherent reflection theory believes that the main reason is the existence of a relatively stable nonlinear gradient layer in the atmosphere. All three theories can explain to some extent the radio propagation phenomenon of troposcatter communication. In general, each theory has experimental data that is relatively close to it, and also there are experimental data that deviate more from it.Every single theory can explain certain actual propagation phenomena, but it is difficult to explain most of the actual propagation alone. In general, in the structure of tropospheric media, there are both relatively stable components and randomly varying components; There are both gradient and sharp layer structures, and there are often turbulent structures. That is, all three mechanisms actually exist, and tropospheric propagation should also be the result of a combination of the three, and one or two of them may be dominated in different situations.

Atmospheric waveguide is also an important medium for over-the-horizon propagation of troposcatter communication[7], when the available atmospheric waveguide appears, the received signal will be greatly enhanced, the fading speed and fading depth will be greatly reduced, and even close to the Gaussian channel characteristics. Generally speaking, on the sea surface, with the evaporation and diffusion of water vapor on the sea surface, the atmospheric humidity above the sea surface decreases with the increase of height, so that the atmospheric refractive index also decreases, resulting in a negative gradient change trend, which is easy to produce evaporation waveguides. Inland, the tropospheric temperature decreases on average with altitude, and for every 1 km increase in altitude in the average state, the temperature drops by 6°C[8]; However, in some cases, the temperature of a certain layer of the atmosphere increases with altitude, which is called an atmospheric inversion layer. According to the reason for the occurrence of the atmospheric inversion layer, it can be divided into radiation inversion, advection inversion, sinking inversion, frontal inversion, etc, among which, on a clear night, there will be a radiative inversion, forming a relatively stable atmospheric structure, often making the signal strength of the receiving point much different from the situation without the inversion layer.

2.2 Analysis of tropospheric propagation characteristics under two typical atmospheric structures

2.2.1 Atmospheric instability boundary layer

During clear days, the atmospheric boundary layer at mid-latitudes is basically of an unstable type. Usually in the sunny daytime, the sun heats the surface, and then heats the near-surface atmosphere, turbulent movement makes the heat transfer from the bottom up, because the boundary layer in the upper atmosphere heating has a certain time lag, so that the boundary layer temperature vertical gradient absolute value increases, the atmosphere is in an unstable layer state, then the top of the boundary layer can reach 1-2km. The thermal bubble triggered by ground heating is the driving force of the turbulence of the unstable atmospheric boundary layer, and its convective rise and fall determine the basic appearance of the boundary layer dynamic structure, so the unstable atmospheric boundary layer is called the convective boundary layer, and the drive of large-scale strong turbulence makes it have a strong mixing in the vertical direction, so it is also called the mixed layer. If the scatterer is in the convective boundary layer, the propagation mechanism of the radio wave is mainly turbulent incoherent scattering, and the fading of the received signal is serious and the transmission loss is large.

2.2.2 Atmospheric stable boundary layer

The temperature of the boundary layer increases with the increase of height, and a stable boundary layer is formed, in which turbulent heat exchange transfers heat from top to bottom, usually the thickness of the stable boundary layer is about 100-500m.

The common feature of stable boundary layers is the presence of an inversion layer, which is formed for a variety of reasons, and the surface long-wave radiation cooling at night forms an inversion layer. In a clear night, the surface due to infrared radiation cooling, the temperature drops a lot, the boundary layer heat flux is negative (downward transmission), the atmospheric structure is in a stable state, at this time the boundary layer is a stable boundary layer or night boundary layer. The height of top is low, generally only two or three hundred meters or hundreds of meters. In the stable boundary layer, the turbulent motion is very weak, the scale is also small, the interaction force between the boundary layer is weakened, forming a stable layer. In this case, the tropospheric over-the-horizon propagation is dominated by coherent reflection of the stable layer and incoherent reflection of the irregular layer, and the received signal is relatively stable, the fading is small, and the transmission loss is relatively small.

3. Measured data analysis

3.1 The link parameters

The experimental link is basically smooth spherical condition, and the link profile is shown in Figure 1. The two end stations are located in Gaoyi and Dingzhou, Hebei Province, with a link length of 107km, an antenna gain of 37dB, a test band of C band, a level sampling rate of 100Hz, and a link midpoint of Gaocheng District, Shijiazhuang, Hebei Province.

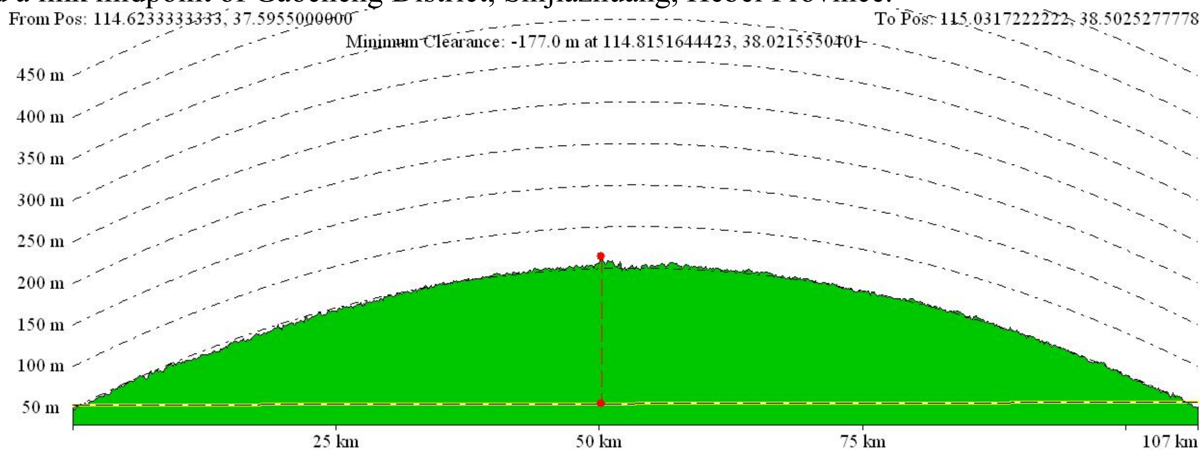

Fig. 1 Experimental link profile

3.2 Data analysis

3.2.1 Weather conditions in September 2012(Gaocheng District)

Based on the data from September 2012, there were 8 days of observations, include 4 sunny days and 4 rainy days days, and the observation time was from 0:00 to 24:00 each day. The specific whether situation is shown in the following table.

Table 1. whether parameters

Date	Whether description
1	Heavy rain ~ moderate to heavy rain, 20 °C ~ 26 °C
11	Showers ~ cloudy, 16 °C ~ 24 °C
21	Light to moderate rain ~ cloud, 17 °C ~ 23 °C

25	Light rain, 16 °C ~ 24 °C
4	Sunny, 13 °C ~ 27 °C
13	Sunny, 15 °C ~ 27 °C
16	Sunny, 13 °C ~ 25 °C
17	Sunny, 14 °C ~ 27 °C

3.2.2 Received signal analysis

The received signals were divided into two groups, sunny and rainy, and each group included 4 days of data. The median value of 10 minutes, the depth of fading within 10 minutes, and the fading rate within 10 minutes were counted, as shown in Figure 2, Figure 3 and Figure 4.

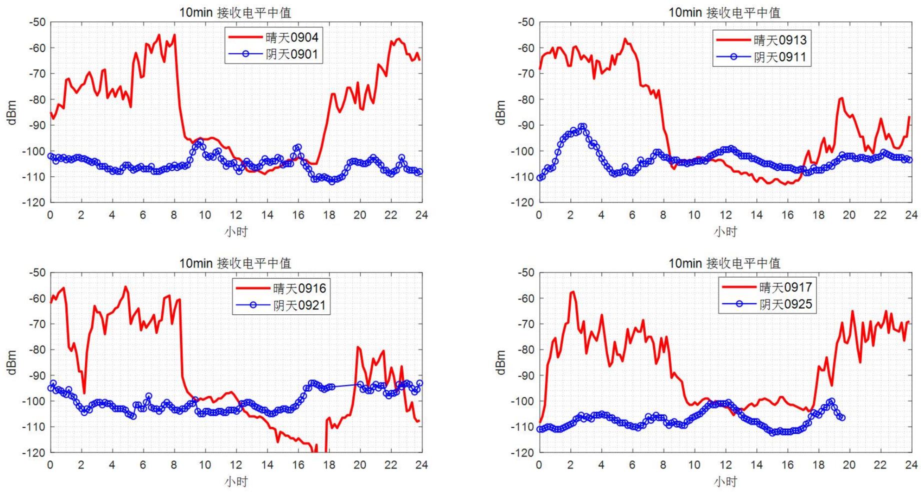

Fig. 2 The median of received signal power over 10 minutes

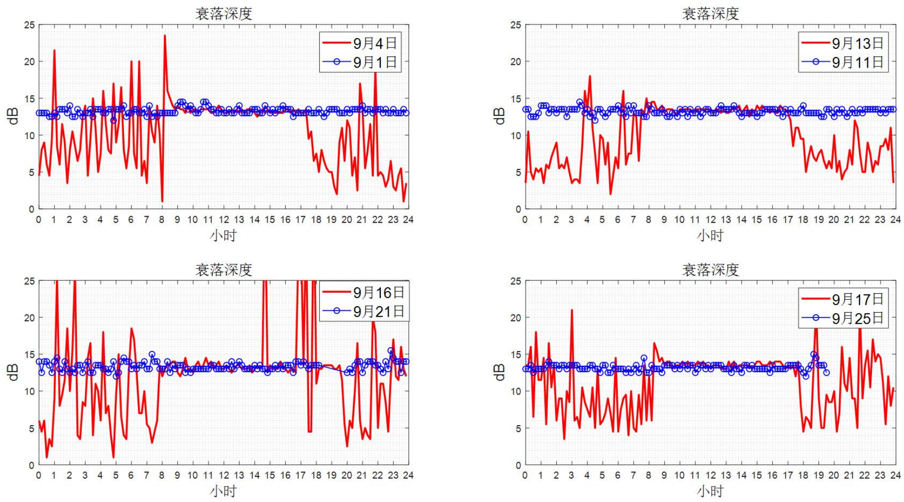

Fig. 3 The depth of fading within 10 minute

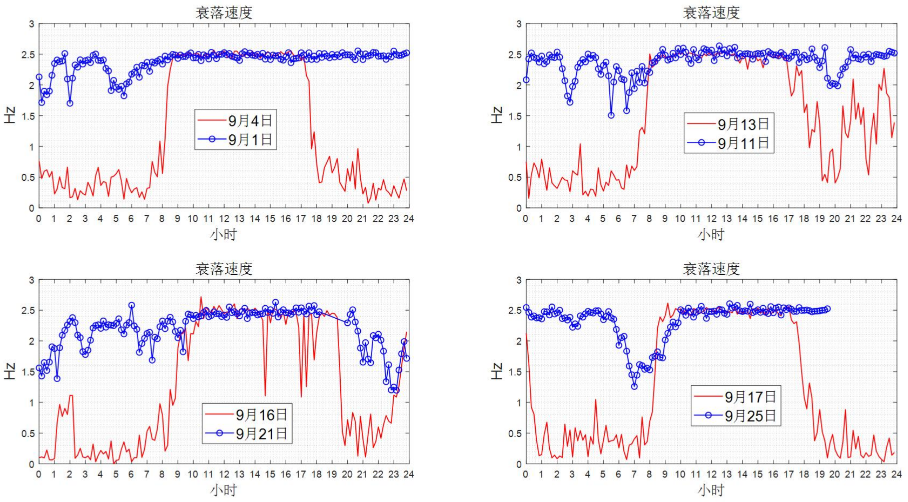

Fig. 4 The fading rate within 10 minutes

Through the analysis, it is found that in clear weather, the troposcatter communication reception signal has obvious periodic changes in one day, and the propagation pattern from 9 o'clock to 17 o'clock and 19 o'clock to 8 o'clock the next day is obviously different. The 8 o'clock and 18 o'clock propagation modes are in transition and will not be discussed in this article.

Table 2 、3、4 shows the statistical results of received signals over different time periods.

Table 2. The statistical results of received signals(0 o'clock -7 o'clock)

date	1	11	21	25	4	13	16	17
median（dBm）	-105.5	-104.0	-101.0	-108.5	-76.0	-63.5	-66.5	-76.5
Mean depth of fading（dB）	13.12	13.29	13.31	13.14	9.64	7.21	9.64	9.4
Mean speed of fading（Hz）	2.19	2.24	2.06	2.32	0.38	0.47	0.28	0.45

Table 3. The statistical results of received signals(19 o'clock -24 o'clock)

date	1	11	21	25	4	13	16	17
median（dBm）	-106.	-102.5	-95.0	-105.0	-69.5	-93.5	-92.0	-73.0
Mean depth of fading （dB）	13.30	13.20	13.56	13.25	6.68	7.10	10.12	10.62
Mean speed of fading（Hz）	2.48	2.37	1.84	2.50	0.39	1.24	0.95	0.28

Table 4. The statistical results of received signals(9 o'clock -17 o'clock)

date	1	11	21	25	4	13	16	17
median（dBm）	-104.0	-104.0	-102.5	-107.5	-103.0	-108.5	-106.0	-101.0
Mean depth of fading（dB）	13.45	13.16	13.20	13.18	13.28	13.40	14.00	13.55
Mean speed of fading（Hz）	2.47	2.50	2.42	2.46	2.50	2.47	2.37	2.48

It can be seen that for the 4-day sample on a sunny day, the distribution law is that the power of 9 o'clock to 17 o'clock is significantly lower than the power of 19 o'clock to 8 o'clock the next day, and the median power is between -108.5dm ~ -101dBm. According to the analysis of section 2, the reason is that the atmospheric convection is relatively sufficient at 9 o'clock to 17 o'clock, the atmospheric structure is dominated by turbulent motion, the radio wave propagation mode is mainly turbulent incoherent scattering, the link loss is large, resulting in small reception power, the average fading depth is between 13dB~14dB, and the fading speed is between 2Hz~2.5Hz, which is a more typical scattering channel.

While on a clear evening, between 19 o'clock and 7 o'clock the next morning, because the radiation inversion has formed a relatively stable atmospheric structure, the propagation conditions have become better, so the receiving level is relatively large, the median power is between -93.5dBm ~ -63.5dBm, and the fading is relatively small, not more than 10.62dB from the sample, and the fading speed is less than 1Hz.

For rainy days, because the radiation inversion cannot be formed at night, its 24-hour median level, fading depth and fading rate do not change much, which is basically the same as 9 o'clock to 17 o'clock on a sunny day, and the propagation mode is mainly turbulent incoherent scattering.

4. Summary

With the development of technology, troposcatter communication equipment gradually tends to be miniaturized, and vehicle-mounted stations, backpack stations and box-type stations in the form of single antennas have gradually become the main equipment forms, and the application mode has gradually sunk to the rapid mobile tactical application at the battalion and company level. Taking a typical scattering communication link in North China as an example, this paper analyzes the propagation characteristics under different weather conditions and at different times, and on rainy days， or from 9 o'clock to 17 o'clock on sunny days, the propagation mode is mainly turbulent scattering, the signal quality is poor, and it is not suitable to plan heavy-load tasks. From 19 o'clock to 8 o'clock the next morning on a sunny day, due to the existence of radiation inversion, the propagation mode is mainly stable layer reflection, and atmospheric waveguides often appear, and the quality of the received signal will be greatly enhanced, which can ensure large-capacity data transmission. This conclusion can provide a reference for tactical application planning.

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