

Detection test of wireless network signal strength and GPS positioning signal in underground pipeline

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Abstract. In order to solve the problem of selecting positioning technology for inspection robot in underground pipeline environment, the wireless network signal strength and GPS positioning signal testing are carried out in the actual underground pipeline environment. Firstly, the strength variation of the 3G wireless network signal and Wi-Fi wireless signal provided by China Telecom and China Unicom ground base stations are tested, and the attenuation law of these wireless signals along the pipeline is analyzed quantitatively and described. Then, the receiving data of the GPS satellite signal in the pipeline are tested, and the attenuation of GPS satellite signal under underground pipeline is analyzed. The testing results may be reference for other related research which need to consider positioning in pipeline.

1. Introduction

Pipeline transportation has been widely applied to oil gas pipeline transportation industry because of its advantages of large transport capacity, low loss, safety, stability, adaptation in complex geographical environments, and automatic control, etc. And the safety and reliability of pipeline transportation industry are guaranteed by the periodic inspection, monitoring and maintenance of the pipeline [1-2]. Due to the robot's flexibility and less restriction by environment, using pipeline inspection robot which can carry detection device into the pipeline to complete real-time online detection is a fast and effective way. It is also an important developing field of the in-pipeline detection technology at present [3-6]. In order to realize the motion navigation of the pipeline inspection robot and positioning of the defects, it is necessary to know the position of the robot in the pipeline [7], that is to achieve positioning.

At present, satellite positioning technology and ground wireless signal positioning technology are two positioning technologies being used widely [8-12]. Satellite positioning technology is to install the global positioning system (GPS) receiver on the mobile carrier to



achieve position calculation. Ground wireless signal positioning technology mainly calculates the location according to 3G, 4G wireless network signal or Wi-Fi signal from mobile communication service provider ground base stations [13-14]. These two positioning technologies have been widely used for positioning of smart mobile terminals and mobile carrier because of technology maturity, cheap equipment, rapid realization and good positioning accuracy [15-17]. However, whether these two technologies are feasible for locating robots in underground pipeline, whether their signals are completely attenuated or shielded, and in what way the signals change, these problems still require quantitative data testing to explain.

In order to solve this problem, some testing are executed in the actual environment of underground pipeline in this paper. First of all, the strength variation of the 3G wireless network signal and Wi-Fi wireless signal provided by China Telecom and China Unicom ground base stations is tested actually. The attenuation variation data of these wireless signals along the pipeline is obtained, and the law of attenuation variation is analyzed. Then, the receiving data of the GPS satellite signals in the pipeline is tested, and the attenuation of GPS satellite signal caused by shielding of underground pipeline is analyzed.

2. Testing for strength of wireless network signal from ground base stations in underground pipeline

2.1 Android cell phone signal strength unit

The Android system defines two signal units for cell phone signal strength with dBm and asu. DBm is the decibels corresponding to the reference power value of 1mW. Its calculation formula is $\text{dBm} = 10 \log (\text{power value mW}/1\text{mW})$, where 0dBm represents the power value is 1mW. The greater the dBm value is, the higher the signal strength is. Because cell phone signal strength is small, its dBm value is generally negative. Therefore, the more dBm value is closer to 0, the higher the signal strength is, and the better the signal is. When dBm is below -113, there is no signal. Asu (alone signal unit) is a special signal unit defined by Google for Android cell phones. The conversion relationship between dBm and asu is $\text{dBm} = -113 + 2 * \text{asu}$. The conversion relationship shows that asu is a positive number, the greater the value of asu is, and the better the signal is. Because the physical concept of dBm is clear and easy to understand, dBm will be adopted for strength testing of the cell phone signal in this paper.

2.2 Signal strength detection APP based on Android platform

In order to detect the 3G network signal and the Wi-Fi signal from ground base stations of the mobile communication service provider, we design and develop a wireless network signal strength detection APP based on Android platform. The software supports signal strength detection for double cards. In the dual card cell phone with the telecommunications card and Unicom card, 3G signal strength of Telecom and Unicom and Wi-Fi signal strength can be detected simultaneously, as shown in Figure 1, and the obtained signal strength value and time points (accurate to milliseconds) are recorded into the database automatically.



(a) Unicom 3G signal detection (b) Telecom 3G signal detection (c) Wi-Fi signal strength detection

Figure 1. Network signal detection APP

2.3 Wireless network signal strength test

2.3.1 Test site. The test time was completed on March 17, 2016 with the highest temperature of 20°C and southwest wind 5. The site is located at Yunxiu Road, Guandu District, Kunming, and its location information is 102.7496383335 degrees north latitude, 24.945505004 degrees east longitude, and altitude of 1980.6 meters. The site environment is shown in Figure 2. The pipeline is composed of single seamless steel pipe with length of 6m by welding together. Its material is carbon steel, diameter is 1200mm, and wall thickness is 14mm. The pipeline is buried 5m underground with length of more than 500m. Its one end is open access. Signal detection device is shown in Figure 3.



Figure 2. Test site



Figure 3. Signal detection device

2.3.2 Test instruments and tools. The instruments and tools used in the test include Android test cell phone (dual card), cell phone slot, mobile carrier, pulling cable, stopwatch, traction motor, measuring tape (50m), and flashlight.

2.3.3 Test scheme. (1) The pipeline one end is open, and the underground length is more than 500m. In view of security inside the pipeline, such as lacking in oxygen, the distance entering into the pipeline to measure is set to 45m.

(2) Before the start of measurement, putting the cell phone pre-installed test APP into the cell phone slot, which is fixed on the mobile carrier. The length of the pulling cable is 45m. Its one end is bound to rear end of the mobile carrier, another end is bound to the rotating shaft of the traction motor, and the traction motor is located at the entrance the pipeline.

(3) The mobile carrier is carried into the pipeline by the experimenter. When the pulling cable being tightened the distance into pipeline reaches 45m, and this position is used as the starting point of measurement.

(4) At the beginning of measurement, the experimenter in the pipeline presses the detection signal strength button on APP, meanwhile, the experimenter at the entrance of the pipeline starts the traction motor. The mobile carrier will move outwards at a constant speed along the axis of the pipeline under the action of the pulling cable. In this process, APP automatically detects the signal strength at each point, and records the detected value and the detected time point in the database.

(5) When the mobile carrier goes back to the entrance of the pipeline, the experimenter presses the APP detection stop button to complete a measurement.

(6) In order to reduce the error, repeat above measurement steps for the same wireless network signal provider, to get the average. Each measurement must begin at the same starting point in pipeline.

2.3.4 Data processing method. After the measurement, the testing data stored in the database is taken out for analysis. Since the records in each measurement include the signal strength detection value and the detection time point, the detection time point needs to be converted into the depth distance into the pipeline, and then we can further analyze the law of change between the signal strength and the distance into the pipeline.

Assuming that a measurement have N detection data $\{s_1, \dots, s_i, \dots, s_N\}$, each detection data is a two-dimensional vector that contains the signal strength and the detection time point $s_i = [p_i \quad t_i]^T$ ($i = 1, \dots, N$), where p_i is the signal strength value with, unit of dBm, t_i is the detection time point with, unit of ms. If the distance from the starting point of measurement to the entrance of the pipeline is L, the relationship can be transformed as follows:

$$s'_i = [p_i \quad d_i]^T = \begin{bmatrix} 1 & 0 \\ 0 & \frac{-L}{t_N - t_1} \end{bmatrix} s_i + \begin{bmatrix} 0 \\ \frac{t_N}{t_N - t_1} L \end{bmatrix} \quad (i = 1, \dots, N)$$

Transforming s_i into a two-dimensional vector $s'_i = [p_i \quad d_i]^T$ ($i = 1, \dots, N$) containing

the signal strength and the distance into the pipeline, where d_i is the distance into the pipeline with, unit of m, then, N detection data $\{s'_1, \dots, s'_i, \dots, s'_N\}$ containing the distance into the pipeline can be obtained. The repeated measurements need to take the average after being merged.

2.3.5 Test results. Draw the testing data using the distance into the pipeline as the abscissa and the signal strength as the ordinate, and then the curves between the signal strength and the distance into the pipeline can be obtained. Figure 4 and figure 5 show how the measured Unicom 3G and Telecom 3G signal strength changes with the distance into the pipeline respectively.

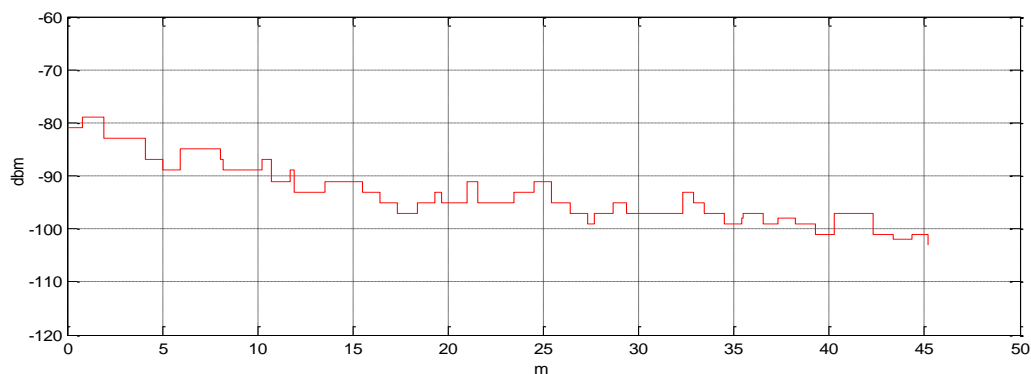


Figure 4. The curve of the Unicom 3G signal strength with the distance into the pipeline

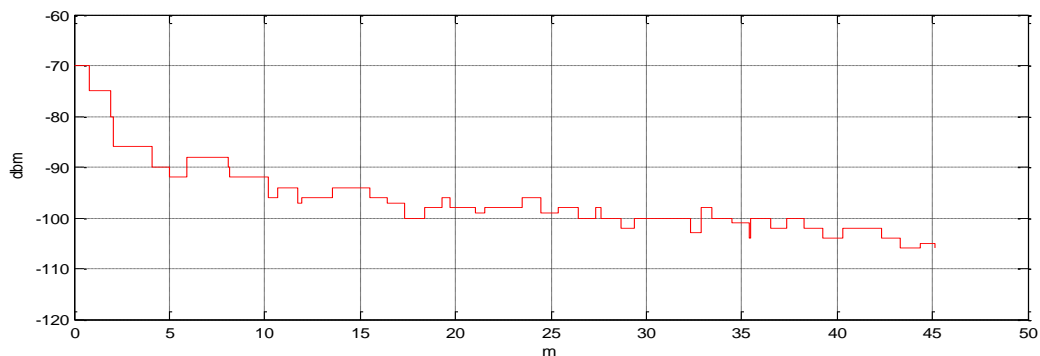


Figure 5. The curve of the Telecom 3G signal strength with the distance into the pipeline

Analysis of the above two figures shows that:

(1) Near the entrance of the pipeline, the distance into the pipeline is less than 10m, the 3G signal strength of China Unicom and China Telecom are both at a normal level, it can perform normal data communication and positioning, but the signal strength rapidly decays from -70dBm to -90dBm.

(2) Where the distance into pipeline is between 10m - 35m, Unicom and Telecom 3G signal strength continues to decay with the pipeline distance increase, but the attenuation rate is smoother than the previous. The value of signal strength is between -90dBm to -100dBm, and data communication and positioning function can be maintained, but the network signal is weak and the stability is not good.

(3) After the distance into pipeline is more than 35m, Unicom and Telecom 3G signal strength are further attenuated less than -100dBm. The network signal is very poor, and data communication and positioning cannot be performed. When the distance into pipeline reaches 45m, the signal has been almost gone.

In addition, it is found during the measurement that Wi-Fi signals provided by the external hotspot could not be searched under the underground pipeline environment. This indicates that the underground pipeline has a stronger attenuation shielding effect on Wi-Fi, and the feasibility of using the external Wi-Fi signal for positioning in the pipeline is bad.

3. GPS location information testing in underground pipeline

3.1 Testing

In order to test the acquisition of GPS location information in underground pipeline, we developed APP software that can read GPS location information under the Android platform. It can record the number of satellites and real-time location information, and store the results and time points in the database, as shown in figure 6. The test scheme is the same as before.



Figure 6. GPS location detection APP

3.2 Test results

The test results data are shown as in table 1.

Table 1. Detected number of satellites with the distance into the pipeline underground 5m

Burial depth of pipeline	Distance	Detected	Valid	Real-time longitude (eastern longitude)	Real-time latitude (northern latitude)
5m	1	5	4	102.7496383335	24.945505004
	3	2	1	0	0
	5	0	0	0	0
	15	0	0	0	0
	20	0	0	0	0

Analysis of the test data in the table shows that when pipeline is underground, due to angle shielding and pipeline shielding effect, the number of GPS satellites that can be detected sharply drops to 0 with the distance into the pipeline increasing to 5m, and the GPS

positioning cannot work normally, the output of latitude and longitude position information is empty.

4. Conclusions

In this paper, in order to solve the problem of selecting positioning technology for inspection robot in underground pipeline environment, the signal strength of 3G network and GPS location signal is tested in actual underground pipeline, and the following conclusions are obtained.

(1) Due to the shielding effect of underground pipeline, Unicom and Telecom 3G signal strength is attenuated with the distance into pipeline increasing. After the distance into pipeline is more than 35m, signal strength is less than -100dBm, the network signal is very poor, and data communication and positioning cannot be performed. Therefore, if the operation depth entering pipeline exceeds 35m, it is not suitable to use the ground base station network signal for positioning.

(2) The underground pipeline has a stronger attenuation shielding effect on Wi-Fi, and the feasibility of using the external Wi-Fi signal for positioning in the pipeline is bad.

(3) As the distance into the pipeline increases, the number of GPS satellites that can be detected drops sharply to zero, and GPS positioning technology is not suitable for underground pipeline.

(4) For the inspection robot positioning problem in underground pipeline environment, it is a more reasonable and feasible solution to further study and develop independent positioning technology which does not depend on external signal of pipeline.

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