Fault Location Method Research of Leaky Coaxial Cable Based on the Linear Frequency Modulation Pulse Compression

Jinxi Guo[1, a], Yang Liu[1, b], Mingxing He[2, c]

[1] School of Mechanical Electrical and Information Engineering, China University of Mining and Technology (Beijing), Beijing, 100083;

[2] School of Information and Electrical Engineering, Hebei University of Engineering, Handan, 056038;

[a]email: gjinxi2009@163.com, [b]email: liuyangebox@126.com, [c]email: kaixinlaohe@qq.com

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Abstract. A new fault location method of leaky coaxial communication cable is proposed and demonstrated in the condition of experiment, which is based on linear frequency modulation pulse compression. The principle diagram of leaky cable fault location of linear frequency modulation pulse compression and its system composition are introduction. Experiment results are presented show that, in contrast to the single pulse reflection in which the coupling losses of single energy in the leaky cable transmission is larger, linear frequency modulation pulse compression can improve transmit signal energy and range resolution of fault point after pulse compression of its echo signal.

Introduction

Leaky coaxial cable (LCX) [1] of the radio communication as a kind of advanced wireless communication technology has been widely used in railway, tunnel, mine tunnels, highway radio [2], 2.4-GHz band wireless local area network (LAN) units [3], the LTE-R system of the high speed train [4], and target detection sensor [5] and so on. However, there is rarely research for the fault location method of leaky coaxial communication cable. For the research of coaxial cable fault location, In ref. 6, using low voltage pulse reflection method in the cable fault location in which the pulse amplitude 5V transmitter, wide in 40ns-2000ns pulse cable fault location experiment was carried out. Through experiment it is concluded that the method is very effective in high fault blocking the road, because the pulse transmission will be a loss in the cable, need to launch wide pulse in long distance detection. In order to solve the problem of "blind area" of the narrow pulse time-domain reflection method, in the ref. 7, wide pulse as a detectable signal is proposed. In this paper the author select the pulse width of 10us, through twisted-pair cable test results show that the width of pulse firing method better solve the problem of the blind area in the narrow pulse test leads. Relative to the standard coaxial cable, the leaky coaxial cable with one key difference: the outer conductor of leaky coaxial cable is slotted with a series of leaky slots, allowing the signal radiation, at the same time, also increased the loss in the process of signal transmission.

The linear frequency modulation pulse compression technology is proposed to locate the leaky cable fault in this paper, with which the signal of wide pulse can further transmission distance. The increase of pulse width will cause the loss of resolution of echo, so at the receiving end corresponding pulse compression method is used to obtain the narrow pulse, and then to improve the resolution in range. The linear frequency modulation signal as a commonly is used radar waveform [8], with large time-bandwidth product, when the more width, the farther transmission distance. The narrower pulse width compressed of the echo, the higher range resolution. Linear frequency modulated pulse compression technology in other areas such as ultrasonic [9], air coupling ultrasonic testing [10-11], the electromagnetic ultrasonic testing [12], and other fields has obtained the good effect.

The principle of linear frequency modulation pulse compression

The principle diagram of the linear frequency modulation pulse compression for leaky cable fault location can be seen in Fig.1, and it contains two main parts of the generation of linear frequency modulation signal and echo signal compression. LFM signal is loaded into the synthesizer via the transmit-receive (TR) switch, and transferred in the leaky cable. The echo signal is produced at the point of leaky cable failure, and is processed by pulse compression after received the transmit-receive (TR) switch. Pulse compression processing can be divided into the mixer, matched filter, the weighted network, etc. The output waveform after pulse compression will be show in oscilloscope.

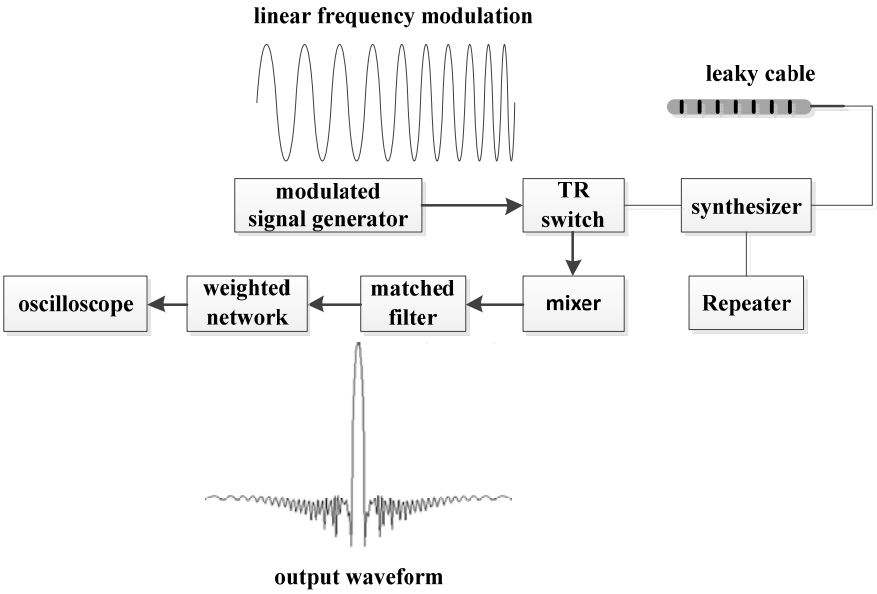

Fig.1 typical linear frequency modulated pulse compression schematic diagram in the leaky cable fault location system

Assume that the distance between fault point and testing repeater station is R, round-trip time to the point of failure for t, and the speed of pulse in the leaky coaxial cable is c. Measuring the round-trip time t from the oscilloscope, the distance of failure point is calculated by using the formula R=tc/2.

The principle of linear frequency modulation pulse compression

In this paper, using two kinds of test schemes are compared: a set of conventional pulse method is used for GSM-R type feeder reflex testing leaky coaxial cable; another group of linear frequency modulation pulse compression method is used for the same period of GSM-R leaky coaxial cable feeder reflex experiment.

Two excitation signal test systems using special DDS chip of AD9915, the chip can produce analog output sine wave up to 1.0 GHz frequency agility. In the test, we select a 130m leaky coaxial cable of railway 7/8 of the 860M spectrum, the attenuation in every hundred meters of 2.7dB, feed-in the signal in the one end from 3dB bridge combiner, connect matching load of 50Ω at the other end. Using network analysis to correction of S ports, eliminate the errors in line between attenuation.

The test of conventional pulse fault location

In the first set of conventional pulse method experiment, in order to avoid interference, the signal frequency of 800MHz is chosen for detection, and it's away from the working frequency in a certain distance. Used oscilloscope for sampling in cycle interrupt, observation of reflection effect is shown in Fig.2.

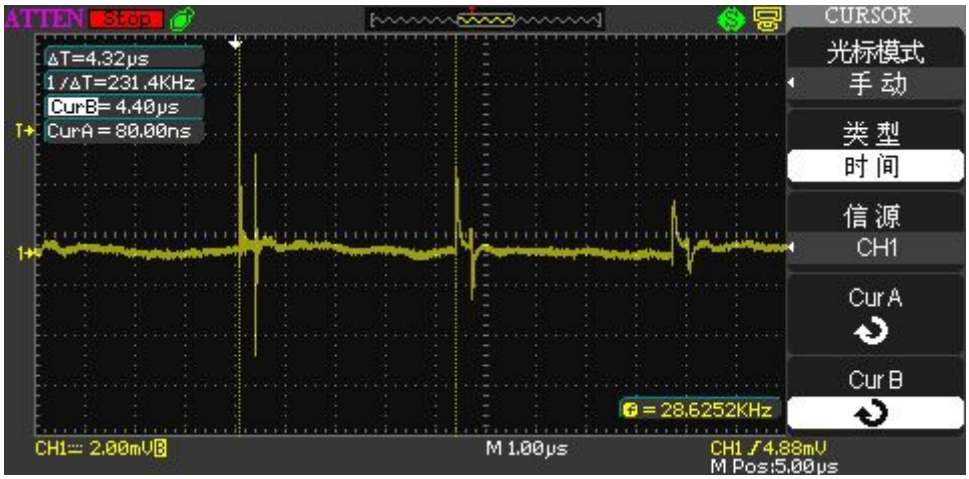

Fig. 2 GSM - R single pulse leaky coaxial cable feeder reflex test waveform figure

It is shown from data analysis in Fig.2 that by single pulse echo can be intuitive judgment of fault location, but the attenuation is relatively serious, poor practicability, it is difficult to be detected for the echo signal when detecting a greater distance; and the modulation and emission of single pulse signal are very closely related with the performance of power switch. The switching time of 320ns in the experiment, it is difficult to achieve such a high performance for small power switch in the actual detection of the leaky coaxial cable fault.

Fault location test in the method of the linear frequency modulated pulse compression

In the experiment of linear frequency modulation pulse compression for the leaky coaxial cable fault location, we choose bandwidth of 40MHz, time of 10us, center frequency of 800MHz. Detection signal coupled into the leaky cable through mixer and a bridge, separated the reflected signal by ring, after demodulation, the echo signal is sampled in mid-frequency band.

Fig. 3 The experiment waveform figure of linear frequency modulation wave feeder reflex

Test results in the Fig.3 shown that the echo signal of linear frequency modulation based pulse compression is stable, it is received easily by geophone, and the signal attenuation is small, detection range and precision degree are improved drastically. It is shown that using the method of linear frequency modulation pulse compression for leaky coaxial cable fault location is a feasible method.

Conclusions

(1) Linear frequency modulated pulse compression method is very effective for the location of the leaky coaxial cable fault. In practice, the field test was carried on a high-speed rail tunnel in

Hunan province. The testing equipment was installed in repeater station remote machine in each 2km away from the tunnel entrances. The data of leaky cable positioning system of information collection was processed in the local. Within half a year after the system installation, 7 times fault found and conformed in field, the accuracy of fault location is 10 meters.

(2) Relative to the conventional pulse excitation mode, linear frequency modulation pulse compression method can get more stable echo signal, and the echo signal attenuation is small, thus have a greater detection range and accuracy of detection.

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