Application of Direct-Sequence Spread Spectrum Mobile Communication Used in Chinese Coal Mines

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중국의 광산에서 사용되는 디렉트-시퀀스 스프레드 스팩트럼 이동통신의 응용

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Abstract

본 논문에서는 중국의 광산에서 수행되고 있는 통신인 지하이동통신을 요약하여 설명하고, 이에 대한 문제점을 논의한다. 또한, 지하에서 스프레드 스펙트럼(spread spectrum) 통신이 장애에 강하고, CDMA가 사용하기에 용이하고 적합하다는 것을 제안한다. 그리고 중국 광산에서 사용되는 스프레드 스펙트럼 통신의 앞으로 전망을 설명하고 실행가능하고 실용적인 프로그램을 제안한다.

I. The Current Situation of Mobile Communication Used in Chinese Coal Mines

Currently, the main forms of mobile communication used in Chinese coal mines include power-line carrier, intermediate frequency, leaky cable, induction and speaker telephones system communication, etc.

1.1 Power-Line Carrier Communication

Power-Line Carrier Communication has applied in mine electric vehicle.

In 1960s, carrier control and communication technology were being applied in China. In 1970s, the model ZDD-11, ZDD-19C, ZDD-19D, ZDD-23 devices were developed. But now, a few ones are still used in China and few ones in other countries. The performance of this kind of method has not yet been perfect. This is because the kind of method is difficult to match with transmission impedance and can't be well anti-interference.

1.2 Intermediate frequency wireless communication

Intermediate frequency wireless communication is realized by 200~1000kHz wave which can penetrate through 300~500 meters deep ledge.

The main advantage of this wireless method, which transmit information with metal pipeline, rail and electric cable, is simple circuit form, thus it reduce the cost of installing all mine leaky-cable and improve the practicability and agility. This kind of method is applied in local communication and disaster relief, whose distance is in 1 km. In 1990s, the model KT14 system was used in China, which is cellular duplexing mobile communication. But, this method has not been popularized either because of its unstable and strong noise.

1.3 Leaky cable communication

Leaky cable communication is also a wireless method developed in recent decade or so.

There are enough radio magnetic fields on any section of the tunnel by coaxial cable with open hole on surface playing the role of long antenna in tunnel, this make it achieved that realizing the reversible coupling moving between the radio stations or radio and the base station. As a result, complex communication problems are transformed to that between moving stations and cables, which are very near, and good communication effects have been gained.

In 1980s, the model KT6, KDLT-1, KT6-A leaky cable systems were introduced and developed in China. The application of this method is relative widely used. The Mine Radio System Company of Canada has applied and extended Underground Internet (UI). Long distance communication can be realized by trunk line or mine moving net and UI, but the cost is very high.

1.4 Induction communication

Induction communication comes true with electromagnetic induction theory.

The magnetic antenna of moving transmitter with larger size has to be close to the inductive antenna. In 1980s, KTGH-P system was developed and FM60/130 system of Germany was introduced. In 1990s, model SC2000 from GST Company of South Africa was also introduced in China. As same to the method above, there is little use now in China because of its unstable and strong noise, too.

Nevertheless, the industrial product---narrow band (700~1200kHz) intermediate frequency induction system made in American RAM tech. Company has been used in several mine in South Africa and has got good effect. So, there are serial and transformative products.

Low frequency induction communication, another mine wireless method, had been used in all countrywide mines and got bad effect. These devices had been put aside mine pits.

1.5 Speaker telephones system is another method

In 1990s, TK100, TK200 systems were used. In the end of 1990s, the combination of radio mobile and speaker telephone was developed and used.

In these kinds of method above mentioned, the problems of mobile communication system consist of the bad performance of anti-interference, big background noise and lacking *adaptability of using environment. The experiences in past a* few decades show that new communication technology should be proposed for the special environment under coal mine.

II. Direct-Sequence Spread Spectrum Communication System

2.1 The development status of spread spectrum communication in China and foreign countries

In 1940s, Shannon, who is the founder of information theory, proposed the famous channel capacity formula. It is given as follow: $C = Blog_2(1 + S/N)$

Where C is the channel capacity in bits per second, B is the bandwidth of the channel in Hertz, and S/N is the signal-to-noise ratio. It is show that the maximum information transmission rate can be held for a system of given lower power or S/N, and broader bandwidth. This is the basic theory *for spreading spectrum communication.*

As rapid development of communication technology and appearance of LSI and MPU, spread spectrum (SS) technology comes into actual research and application times. After 1980s, spread spectrum communication had been widely applied in many fields, such as tracking, navigation, radar, remote control and mobile communication.

In China, the study of SS technology has been being undertaken continually deeper and deeper by many advanced universities and science and research departments. Whereas there is no the application of that technology in coal mine. The study about this subject just began at a few years ago.

2.2 The basic concept of spread spectrum communication

Spread spectrum communication denotes a kind of communication method in which the bandwidth of transmitted signal is much broader than that of information. It must possess two characteristic: (1) the bandwidth of transmitted signal is much broader than that of source signal; (2) the transmitted bandwidth is decided by spread spectrum function which in common uses Pseudo Noise (PN) code.

In general, it is so called spread spectrum communication when the bandwidth is spread 100 times or above.

2.3 The model of direct-sequence spread spectrum communication system

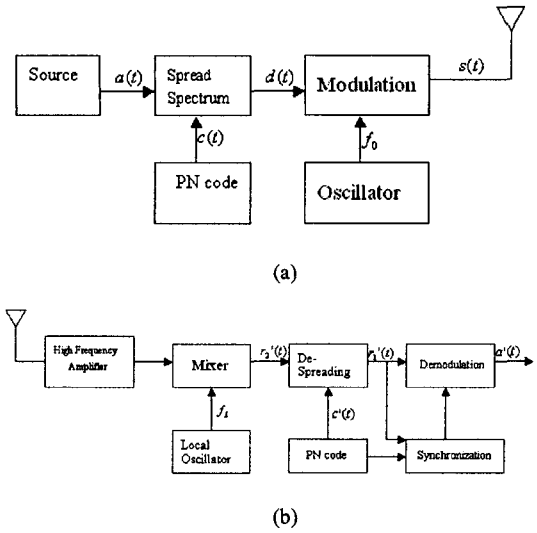

Figure 1. Communication System (a)transmitter(b)receiver

We study the model with a direct-sequence spread spectrum (DSSS) communication system whose SS function is PN. Figure 1 shows that (a) is the transmitter simplified by spread spectrum and modulation; (b) is the receiver simplified by de-spreading and demodulation. A (t), the output of source, is information stream; PN code generator generate a high-speed pseudo noise code c (t); Let a (t) multiply by c (t) or add in mod 2, then a SS sequence is got. This code sequence occupy broad frequency band so as to spread spectrum. Let the spread sequence modulate the carrier, the spread radio signal s (t) is got. In receiver, the received spread signal pass through high frequency amplifier and mixing-frequency and then multiply by PN code that is same frequency and phase to transmit PN code. After de-spreading and demodulation, the information a (t) can be gained. For interference and noise is irrelated to PN code, they can be degraded greatly after correlated demodulation.

2.4 The main advantages of DSSS

Spread spectrum communication is a relative new method and an important development direction in this field. It has many advantages over traditional methods. These include

(1) It has strong ability of resisting against many kinds of interference, for example, the white gaussian noise, single frequency and other spread spectrum signals. As been proved that the broad the spectrum is spread, the stronger ability of anti-interference is. This is most estimable to coal mine communication, which consists in much heavy industrial interference and noise.

(2) DS method is easily realized in CDMA. Many users who share one channel use different SS sequences whose cross-correlation coefficients are quite small. There is almost no interference among these users. Thus CDMA has been achieved, which is more efficient and convenient than FDMA and TDMA.

(3) It is very easy to share the channel with other communication devices. Because its power density is very low, it doesn't intervene other devices and get interference from others.

(4) Digital and analog signals can be compatible with each other. Digital signals are transmitted immediate and analog signals are also done after transforming from analog to digital.

(5) It is very efficient in resisting multipath fading and measuring accurately. So, it is further applied in detection, remote-detection, remote control, navigation, space communication and electronic-countermeasure fields. Otherwise, the DSSS is most widely applied because it is much easier to be realized, more reliable and lower power cost. In general, spread spectrum communication will possess wide development prospect.

III. The Prospect of Applying Spread Spectrum Communication to Mobile Communication Used in Chinese Coal Mines

According to the analysis above, we propose the SS scheme combining the leaky-cable method and intermediate frequency induction one. The first method is used in main tunnel to transmit signal, the next is used in other tunnels or places where gas explosion and collapse maybe occur. All those utilize the SS with strong ability of anti-interference and the advantage to be easily realized in CDMA. The whole new wireless information communication network performs reliably. This scheme can make not only the main network reliable, but also the special places straightway due to intermediate frequency induction communication.

(1) Leaky-cable spread spectrum communication: The SS device is formed by special serial SS CMOS chip of American STANFE Telecommunication Company appended sound coding circuits. The leaky part selects KT6 system. The new leaky-SS system can be got by replacing the base and vehicle desks and handset of KT6 system with SS system. The performances of new system are as follows: none control

centre; entering network randomly for any sub-machine to realize CDMA; extending communicated distance; structuring all mine network and connecting any person at any time and any site; being compatible sound and data to form leaky cable high-speed link, taking on all communicating and inspecting tasks in the coal mine. Otherwise, an equipment of combining leaky cable with inducted channel need to be developed, so as to provide signals through two channels.

(2) Study of communication penetrating through mine ground: The theory and practice prove that the electric wave reduces strength of penetrating through the ground with increase of frequency. The penetrable strength for 30w power is 300m at frequency 30MHz; 800m at 15MHz; 1300m at 5MHz. The reliability is maybe destroyed by many kinds of interference in common communication at low frequency. Now, the contradiction has been solved by using SS communication. It can hold connection even though heavy collapse takes place. So, the prospect of applying spread spectrum communication to mobile communication used in Chinese coal mines will be resplendent.

It is easy to put the scheme in practice except the SS part. The structure of this system and that above are alike but then need prepare many circle ring antennas and adjust properly transmitted power.

IV. Summary

We have analyzed the application of DSSS mobile communication used in Chinese coal mines. The methods we proposed were testified in Fuxin coal main, Liaoning province, China from 1998 to 2000. The better effect had been gained. This proves that the application of DSSS mobile communication would get much widely extending and popularizing in coal mines in the future.

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