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Research on Key Technologies of Digital Signal Processing based on Optical Communication

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Abstract. With the updating of communication technology, optical communication system is developing towards high speed and large capacity. In order to maintain the continuous flow of information, all-optical network came into being. Firstly, the optical communication transmission system is introduced. Secondly, according to its principle, the receiver principle is analyzed concretely. Through data optical transmission with computer, based on digital signal processing technology, four technical supports of all-optical network are proposed. Practice has proved the advantages of all-optical network.

Keywords: optical communication; digital signal processing; key technology; receiver.

1. Introduction

In order to meet the needs of human beings for information and promote the rapid development of society, information technology has developed very rapidly. The data of voice, data and video grow explosively, which also causes the multimedia information mass to grow exponentially. This puts forward higher requirements for transmission, switching and storage devices. At present, the rate of traditional dense wave is 40 Gb/s, which cannot satisfy the human demand for information. So how to use optical communication facilities, without increasing the cost of construction, to improve the optical transmission capacity is becoming more and more important. Therefore, optical communication technology coexists with coherent detection and digital signal processing technology has been invented. This brings a new starting point for optical communication technology. Fig. 1 is a block diagram of an optical communication transmission system.

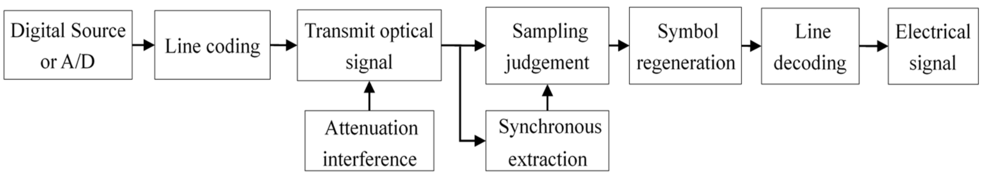

Fig 1. Block diagram of optical communication transmission system

In the process of optical communication, we first use photoelectric modulator to modulate the baseband signal on the optical carrier, and then transmit the modulated optical signal to the receiving end through the optical fiber link. When the signal arrives at the receiving end, we use coherent mixing to convert the same local oscillator light of the optical signal in the mixer. Baseband signal is sampled after digital-to-analog conversion through photodetector conversion. Finally, we put it into the chip of digital signal processing, and use digital signal processing to recover the original data. In addition, we introduce coherent technology.

Compared with the traditional direct detection optical communication system, coherent optical communication technology has incomparable advantages. Firstly, the interference mainly occurs on the basis of signal light and local oscillator light. On the one hand, the intensity of signal light can be extracted, on the other hand, the polarization information of signal light can be extracted, and then the high-order modulation code can be realized, so as to improve the utilization rate of the system. Secondly, this technology improves the sensitivity of the receiver and reduces the signal-to-noise ratio. With the introduction of coherent detection, the signal can be sampled nondestructively, depending on the technology platform of digital signal processing, optical signal transmission can be realized, while avoiding optical compensation and reducing transmission costs.

2. Optical Communication

With the rapid development of information globalization, the traditional incoherent optical transmission technology has been unable to meet the growing needs of people. With the human attention to information, digital coherent optical communication has developed into an important research direction of modern optical communication. Digital coherent optical communication has incomparable advantages over traditional incoherent optical communication. It can obtain information of optical transmission signal at high speed, such as phase, amplitude, frequency, polarization and so on. The optical communication system consists of three parts: receiver, channel and transmitter. Figure 2 shows the schematic diagram of the receiver.

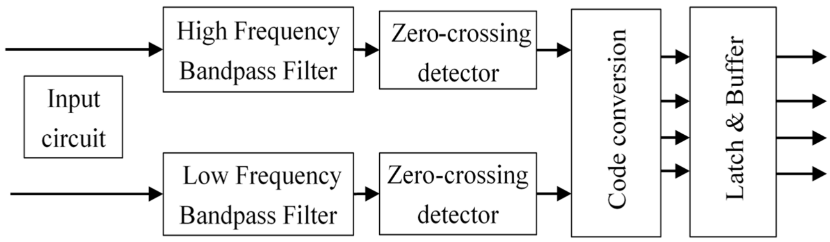

Fig 2. Principle block diagram of receiver

In common situation, the USB port for external PC is USB701, the interface chip is U702, and the model is CH372. The PC data received by USB module is sent from P701 serially and sent to PC. Figure 3 shows the workflow diagram of computer optical transmission.

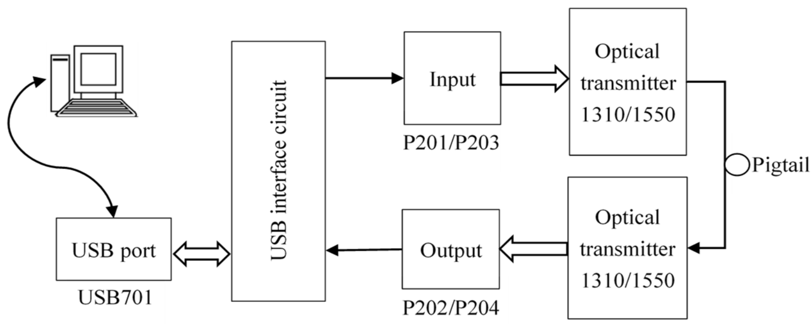

Fig 3. Workflow Diagram of Computer Data Optical Transmission

3. Digital Signal Processing

For optical communication technology, the rapid development of digital signal processing technology is an important driving force. This technology plays an important role in coherent optical communication system. When the signal is detected coherently, the information carried by the signal, especially the phase and amplitude information, can be preserved completely. When it is processed by digital signal processing, various kinds of compensation for the signal can be further realized, such as optical fiber dispersion and non-linear compensation, receiver front-end non-ideal compensation, digital clock recovery, polarization demultiplexing and dynamic equalization. Usually its processing flow can be shown in Figure 4.

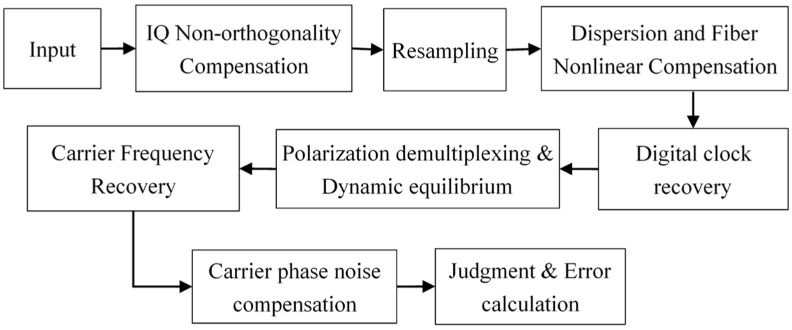

Fig 4. Digital Signal Processing Module in Coherent Receiver

4. Key Technologies

According to the current technological development, there are still some difficulties for the development of optical networks. Therefore, for a long time in the future, China will focus on the development of optical fiber network technology. For optical fiber communication, its transmission capacity is large, transmission loss is small, and it develops rapidly. However, the optical-to-electrical conversion in communication networks is limited by bandwidth, clock offset and high-power consumption. This results in low network throughput. To solve this problem, we need the support of some key technologies. Therefore, all-optical network is proposed in our country, which transfers data through nodes without conversion.

First, it involves the introduction of optical switching technology. This technology does not depend on any conversion. It only needs to transfer the input signal to the output signal in the optical domain, so that it can integrate the optical fiber technology, and finally form an all-optical network. This technology is an important technology in all-optical network, which affects the progress of optical communication to a certain extent.

Secondly, optical cross-connection technology is needed, which can be used as the core device. If we want to interconnect some waves at the nodes of the optical network, we need to cross-connect some optical signals first. We can adjust the flow distribution dynamically to adjust the wavelength. But if the optical fiber interrupts or even the service fails, the technology can automatically switch the optical signal to the backup optical fiber quickly, and then realize the protection of the optical multiplexing section, at the same time realize fault isolation, automatic routing and reconfiguration of the network, so as to ensure the continuation of the service. The technology also has the function of inserting optical signals and separating the network layer.

Thirdly, all-optical relay technology is needed. In optical fiber communication system, the loss will attenuate the optical signal, and then the dispersion will lead to the widening of the bandwidth of the optical pulse, resulting in inter-symbol interference. Therefore, in a long transmission system, it is usually necessary to rely on the repeater to process and amplify the attenuated or distorted optical signal after a long transmission distance in the optical fiber. Generally speaking, for the traditional optical fiber communication, optical/electrical relay is used. Although the loss and dispersion of optical fiber are reduced to some extent, the current system will become expensive and complex if used for multi-channel multiplexing. In the case of optical fiber loss, optical amplifier is usually chosen to amplify the optical signal, which can not only reduce the cost, but also serve as the basis for all-optical communication.

Finally, we need to introduce optical add-drop multiplexing system. This system mainly uses inserting or separating one or more wavelengths from the multi-wavelength channel, and then can select the up-and down-path signals to adjust in the transmission equipment. Generally speaking, the devices that can realize the add-drop and multiplexing in the optical domain can be realized. It does not process all IP packets. It usually only needs to transmit downloaded information to the processing device, and usually does not need to process information. Because of its transparency, the format of information can be processed without restriction, allowing different networks to be reused, which can improve reliability.

The phenomenon of energy transfer induced by two beams can be called amplification effect. Usually it can be expressed by the strength coupling equation:

$$\frac{dI_s}{dz} = -g_B I_p I_s + \alpha I_s \tag{1}$$

$$\frac{dI_p}{dz} = -g_B I_p I_s - \alpha I_p \tag{2}$$

In principle, the transmission characteristics of light in optical fibers are centered on frequency shift (ν_B). Its gain full width $\Delta\nu_B \approx \frac{1}{\pi\Gamma_B}$ and Γ_B represent phonon lifetime. This characteristic conforms to Lorentzian function curve.

$$g_B(\nu) = g_0 \frac{(\Delta\nu_B / 2)^2}{(\nu - \nu_B)^2 + (\Delta\nu_B / 2)^2} \tag{3}$$

For many reasons, its spectral shape can be approximated by the Gauss curve. At this time, the spectral shape will be between the Lorentz curve and the Gauss curve.

$$f_B(\nu) = k \frac{\left(\frac{\Delta\nu_{B1}}{2}\right)^2}{(\nu - \nu_B)^2 + \left(\frac{\Delta\nu_{B1}}{2}\right)^2} + (1-\mathrm{k})\exp(-2.773(\frac{\nu - \nu_\mathrm{B}}{\Delta\nu_{\mathrm{B2}}})^2) \tag{4}$$

In this case, K denotes the linear weight coefficient, the center frequency shift denotes ν_B, $\Delta\nu_{B1}$ denotes the Lorentz spectral line width, and $\Delta\nu_{B2}$ denotes its Gauss spectral line width. Fig.5 shows that the actual spectral lines can be combined by the weights of Lorentz linear sum and Gauss linear sum.

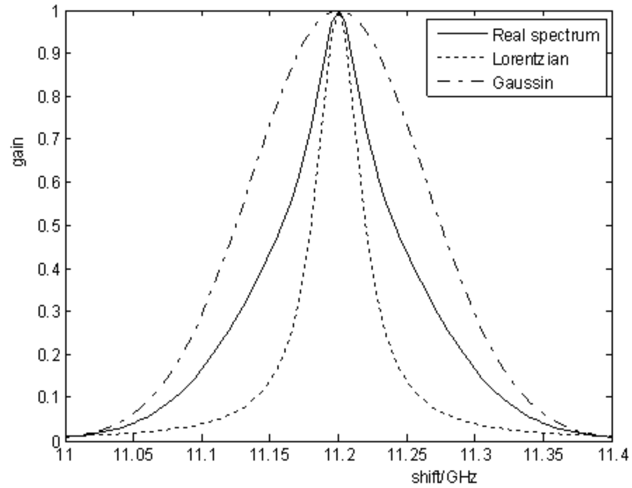

Fig 5. Scattering spectrum

5. Conclusion

All-optical network has high speed and high capacity, and it is developing towards intelligent direction. At the same time, the optical signal processing technology based on this technology is also developing rapidly. All-optical network will have a great impact on cable communication network. Although there are still some drawbacks, it is the trend of communication technology development and has a broad application prospect.

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