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SIMULATION OF PFM CONTROL SIGNAL FOR OPTICAL FIBER TRANSMISSION

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ABSTRACT

This paper describes the required frequency bandwidth which is used as a measure for the quality of the PFM transmission system to transmit the control signals. First, the PFM signal which has been distorted due to the frequency bandwidth limit on the transmission line is analyzed by Fourier transform and secondly distortion which has been observed at the receiver is numerically analyzed to make the frequency bandwidth required for transmitting the PFM signals. According to the analysis heretofore, the 50% threshold level for shaping the received PFM signal,which is of 50 % in TTL level,is superior than the 10- and 90-% threshold levels.

1. INTRODUCTION

Although data is transmitted by means of PFM (pulse frequency modulation) in the optical communication system, the modulated signal is in many cases of rectangular pulse waveform.

For transmitting the rectangular pulses, a wide frequency-bandwidth is necessary for forming electric pulse signals. Unless the frequency bandwidth is wide, distortion may occur during the transmission along the transmission line.

In such systems, distortion is too serious to demodulate the received pulse signals without signal quality degradation since it is necessary for the non-distorted signals to be reproduced from the received signal.

In practice, for designing the PFM transmission circuits, a wide frequency bandwidth makes the receiver circuit configuration simple.

The bandwidth will be limited if the multiplexed signals are transmitted through a narrowband channel. Before designing the PFM transmission system, distortion which may occur during the transmission has to be considered.

This paper describes the numerical analysis of the bandwidth and distortion in the PFM transmission system.

2. PFM SYSTEM

Before the analysis, we should make it clear that distortion may be caused by inferior frequency response of the PFM system.

Figure 1 shows the schematic configuration of the optical-fiber PFM transmission system.

A pulse signal generated from a VCO (voltage-controlled oscillator) is frequency-modulated in accordance with the input signal used as a control signal.

The electric pulse signal obtained from the VCO is converted into the corresponding optical pulse signal by using an optical transmitter. The optical signal is thereafter transmitted to the optical receiver through the optical fiber. The received optical pulse signal is converted into the corresponding electric pulse signal. The electric pulse signal is then demodulated by using a frequency demodulator.

In the PFM system, the signal waveform received by receiver through the transmission line is considered to mainly be distorted when the input signal is modulated by electric carrier. How to minimize the distortion caused by limited frequency response will be analyzed below.

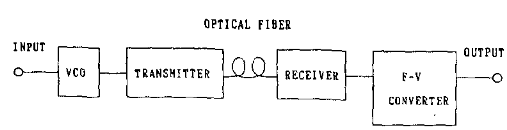


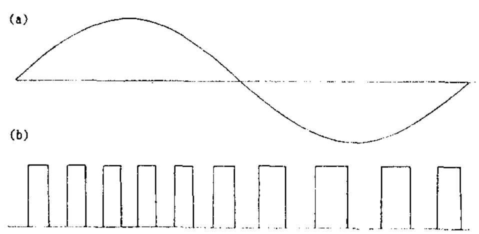
Fig.1 Configulation of the optical fiber transmission system.

3. ANALYSIS

Assume that the control signal at the input terminal is of sine-wave at 4 MHz.

The input signal and modulated PFM signal are shown in Figure 2 (a) and (b), respectively. The carrier frequency is assumed as 40 MHz, the duty ratio as 50 %, and the modulation index as 3.

When the input signal is modulated by pulse carrier signal as shown in Figure 2(b), the modulated signal frequency components spread over the wide frequency range.



(a) Input signal (modulation signal)

$v_m = V_m \sin(w_m t)$

Carrier signal

$v_c = V_c \sin(w_c t)$

(b) PFM modulated signal

$v_{ofm} = V \quad \cdots \; V_c \sin(w_c t - m_f \cos(w_m t)) > 0$

$v_{ofm} = 0 \quad \cdots \; V_c \sin(w_c t - m_f \cos(w_m t)) < 0$

m_f: Modulation index

Fig.2 Waveform of the input signal at 4MHz and PFM signal.

Figure 3 shows the frequency spectra for the PFM signal. The frequency spectra was obtained by calculating the PFM signal waveform in accordance with the FFT (fast Fourier transform) analysis of 512 points sampling.

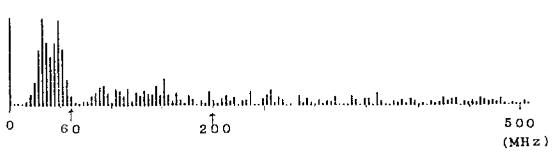


Fig.3 Frequency spectra of the PFM signal.

Figure 4 shows the algorithm for calculating the distorted PFM signal in terms of the frequency bandwidth limitation, and it depicts how the signal waveforms are distorted.

First of all, the frequency spectra for the non-distorted modulated (PFM) signal were calculated in accordance with the FFT analysis in STEPS 2 and 3. In the next process, the response function defined at frequencies above the threshold was assumed zero as shown at STEP 4. After such process, the distorted modulated (PFM) signal waveform is calculated in accordance with the IFFT (Inverse FFT) analysis as shown at STEPS 5 and 6.

Particularly, distortion may be caused by inferior frequency response of the signal passing through the path between the VCO and optical transmitter in Figure 1.

Assume that the threshold voltages of the logic circuits in the transmitter are of 10 % (rising edge) and 90 % (falling edge) for the signal voltage of TTL level sent from the VCO, respectively.

Then, the distorted PFM signal waveform is calculated in terms of the frequency bandwidth in accordance with the FFT analysis.

It is important for the interval and width of the modulated signal pulse to be accurately transmitted because their deviations from the references may cause distortion in the baseband signal.

However, the PFM signal waveform does not cause any problem on condition that the threshold voltage of the logic circuits in the transmitter can be used to accurately detect the interval and width of the pulse signal satisfactorily.

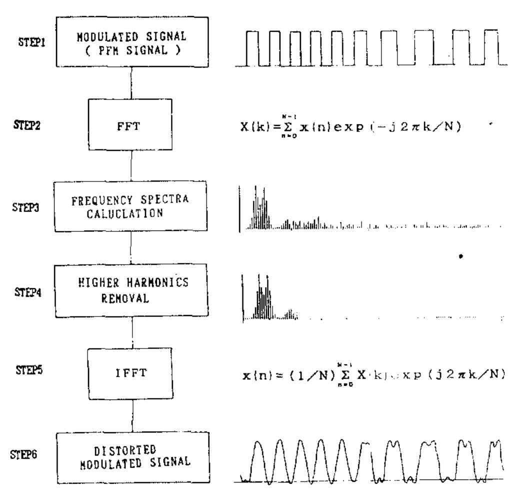


Fig.4 Algorithm for caluculating the distorted signal.

Figures 5(a) and 5(b) show the PFM signal waveforms which have been deformed due to inferior frequency responses. Figure 5(b) shows the waveform response when frequencies of more than 60 MHz has been disregarded. Note that the distorted and non-distorted waveforms are duplicated on Figure 5(a) and 5(b), respectively.

In Figure 5(a), there is little phase delay between the VCO output and the transmitter output. In FIgure 5(b), even if the thresholds are set at 10 % and 90 % respectively, phase delay can be found in a path from the VCO output to the transmitter output, because the rise time greatly differs from the fall time.

Although the rise and fall times for the signal waveform whose frequency components above 200 MHz are disregarded are almost the same as those when the frequency components are not restricted, those when the frequency components above 60 MHz are disregarded are quite a different from those when the frequency components above 200 MHz are disregarded.

Even if the frequency bandwidth is so far as of 60 MHz, the phase delay can be neglected when the waveform is completely shaped by using a comparator with a threshold of 50 % of TTL level before fed to the transmitter to operate, as shown in Figure 5(b).

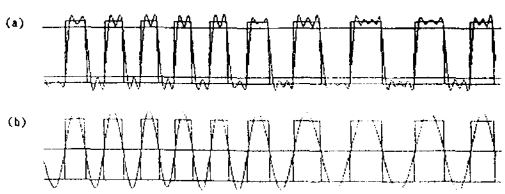


Fig.5 PFM waveforms which have been deformed.

a) When frequencies of more than 200MHz is disregarded.

b) When frequencies of more than 60MHz is disregarded.

Figure 6 shows the frequency bandwidth needed to transmit the PFM signal. As for designing the PFM transmission circuits, it is found to be desired that the frequency bandwidth needed is more than 5 times the carrier frequency if the modulation index is 3 or less.

When the frequency bandwidth is narrow, the PFM signal can be recognized as an FM signal. However, the FM signal with a bandwidth of at least ($f_c+f_m x(m_f+1)$) is needed to be transmitted as well as the normal FM transmission system. Where, f_c is the carrier frequency, f_m is the modulation frequency, and m_f is the modulation index.

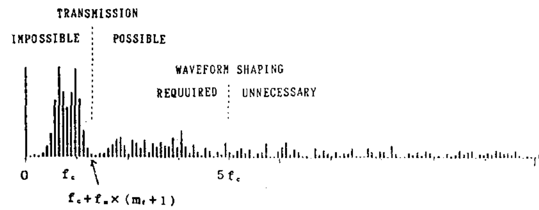


Fig.6 Relation between the bandwidth and transmission feasibility.

4. CONCLUSION

As for designing the PFM transmission circuits, it is found to be desired that the frequency bandwidth needed is more than 5 times the carrier frequency if the modulation index is 3 or less.

When the frequency bandwidth is narrow, the PFM signal can be recognized as an FM signal. However, the FM signal with a bandwidth of at least ($f_c+f_m x(m_f+1)$) is needed to be transmitted.

The relation between the bandwidth and distortion has clearly been described. It has clearly been described that the 50% threshold level is superior than 10- and 90-% threshold levels for shaping the received PFM signal at the receiver,because the 50% threshold level is hard to be influenced by the distortion caused by limited frequency response. By the use of this study, the frequency range required will be known by designer before the start of the design.

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