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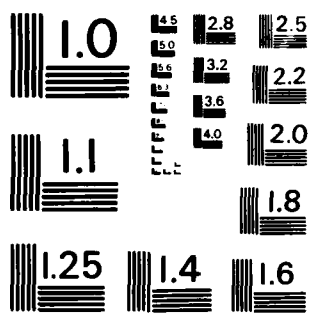
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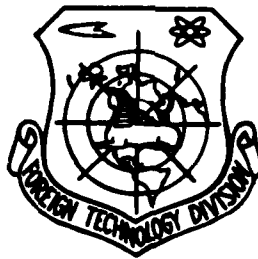
# FOREIGN TECHNOLOGY DIVISION



OPTICAL CABLE-ELECTRICAL CABLE HYBRID TRANSMISSION  
SYSTEM. THE VIDEOPHONE - THE OPTICAL CABLE  
TRANSMISSION PART

by

Tang Ding-fan, Yu Qi-lu



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OPTICAL CABLE-ELECTRICAL CABLE HYBRID TRANSMISSION SYSTEM  
THE VIDEOPHONE — THE OPTICAL CABLE TRANSMISSION PART

Tang Ding-fan, Yu Qi-lu

ABSTRACT

The already successfully developed optical cable-electrical cable communications system for the mutual transmission of videophone signals through its channels was composed of an optical communications channel, a voice conversion controller and a modified cross-connected telephone exchange structure. It could simultaneously perform the transfer of pictures and voices to transmit videophone messages. The dial tone, ring and busy signal could be transmitted through the optical channel. Through an exchanger, it was possible to communicate with other message channels. The optical message channel device could communicate with ordinary telephone receivers without a videophone terminal.

This paper mainly describes the development of the optical signal channel system briefly. After the frequency modulated voice signals (2.0 MHz) and the base band visual frequencies (1 MHz) were combined and amplified, direct intensity modulation was carried out with respect to a GaAIAS light emitting diode (LED). A step type optical cable was used to perform dual transmission. The receiver terminal used the low cost Si-PIN optoelectric diode for detection. The sensitivity of the receiver was -30.27 dbm, the unweighted visual frequency signal-to-noise ratio is  $\frac{S_{p-P}}{N_{rms}} \geq 53$  db (degree of modulation was about 50%). The operation time of nonlinearity distortion was <2%. The voice signal-to-noise ratio was  $\frac{S_{rms}}{N_{rms}} = 42$  db. The voice distortion was less than 1.5% (frequency deviation was 7 KHz). 1# LED light source and 3.5 db/km loss step type optical fibers were used to simultaneously transmit pictures

and voices. The transmission distance was 3 kilometers. The voices were clear and the pictures were sharp.

### I. THE EXPERIMENTAL SYSTEM

The schematic block diagram of the optical cable-electric cable videophone mutual communications transmission system is shown in Figure 1. This system was composed of a 1 MHz videophone terminal, a voice transformation controller, a light transmitter, a six core optical cable, a light receiver and a videophone exchanger. In addition to completing the 24 line voice transformation, the voice transformation controller also handled the transformation of functional signals such as the dial tone, the ring and the busy signal. The videophone exchanger was formed through modification of a cross-connected type telephone exchanger.

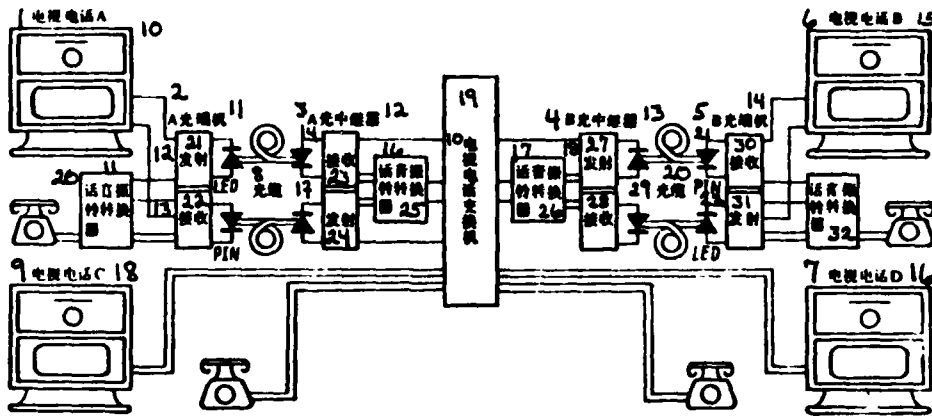


Figure 1. Block diagram of the optical cable-electrical cable hybrid transmission system.

1--videophone A; 2--optical terminal A; 3--optical relay A; 4--optical relay B; 5--light terminal B; 6--videophone B; 7--videophone D; 8--optical cable; 9--videophone C; 10--videophone exchanger; 11--voice and ring converter; 12--transmitting; 13--receiving; 14--receiving; 15--transmitting; 16--voice and ring converter; 17--voice and ring converter; 18--transmitting; 19--receiving; 20--optical cable; 21--receiving; 22--transmitting; 23--voice and ring converter.

The block diagram of the principle of the optical signal channel system is shown in Figure 2. At the light emitting end, a bias current was pre-imposed on the LED light source. The frequency modulated visual frequency signals from the output of the combination step, together with the biasing current, were imposed on the LED to make the excitation current of the LED vary linearly with the intensity of the complex signal. Hence, the output intensity of the LED began to vary with the variation of the excitation current of the LED. This meant that the variation of the optical signal intensity directly simulated the variation of the input signal. The relation between the optical power emitted by the LED and the injected current is:

$$W = A \eta_a \eta_l \eta_q \left( \frac{h\nu}{e} \right) j \quad (2-1)$$

where

- $h\nu$ : energy of the photon
- $\eta_a$ : photon excitation efficiency
- $\eta_l$ : charge injection efficiency
- $\eta_q$ : internal quantum efficiency
- A: emission area
- a: electron charge
- j: total injection current density

When the biasing direct current density is  $j_0$  and the modulation signal is  $f(x)$ , the total current density injected is:

$$j = j_0 [1 + m f(x)] \quad (2-2)$$

Therefore, the optical intensity varies with time according to the following equation

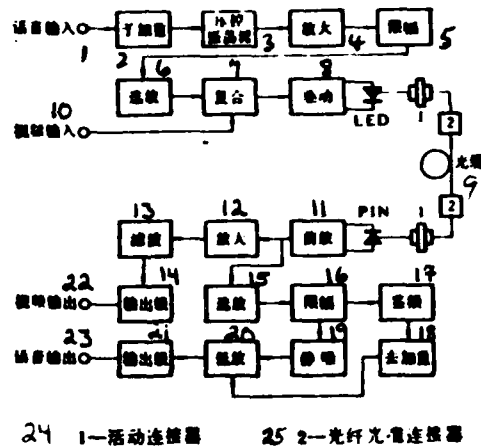
$$P(t) = P_0 [1 + m f(t)] \quad (2-3)$$

$$-1 < f(t) < 1$$

where

$P_o$  - average light power       $m$  - degree of modulation

The optical signal was transmitted by the optical cable to the receiving end. The optical detector PIN converted the received optical power linearly into electrical signals. It was changed into voltage signal by passing through a load which was then amplified and demodulated to become the original visual frequency signal and acoustic frequency signal from the transmitting end. They were then sent to the voice converter and exchanger, respectively. In summary, the working principle of the optical transmission of the direct intensity modulation videophone can be shown in Figure 3.



24 1-活动连接器      25 2-光纤光缆连接器

Figure 2. Block diagram of the optical signal channel system.

1--voice input; 2--accenting; 3--pressure controlled resonator; 4--amplification; 5--amplitude limitation; 6--selected amplification; 7--recombining; 8--driving; 9--optical cable; 10--visual frequency input; 11--pre-amplifying; 12--amplifying; 13--filtering; 14--output terminal; 15--selection; 16--amplitude limitation; 17--frequency evaluation; 18--removal of accent; 19--static noise; 20--low-amplification; 21--output terminal; 22--visual frequency output; 23--voice output; 24--1-moving connector; 25--optical fiber-optical cable connector.

The first stage of the optical receiver of the system used a common source-common base circuit. The second stage was a common collector-common base differential amplifier circuit. The two steps were directly coupled to form a mutually resisting pre-amplifier as shown in Figure 4. The advantages were to obtain higher signal-to-noise ratio and flatter amplitude frequency response, to have a higher gain and to reduce the capacitance coupling level so that better low frequency response could be realized. In order to satisfy the phone communications characteristics, a simple and reliable static noise circuit was used in the voice channel.

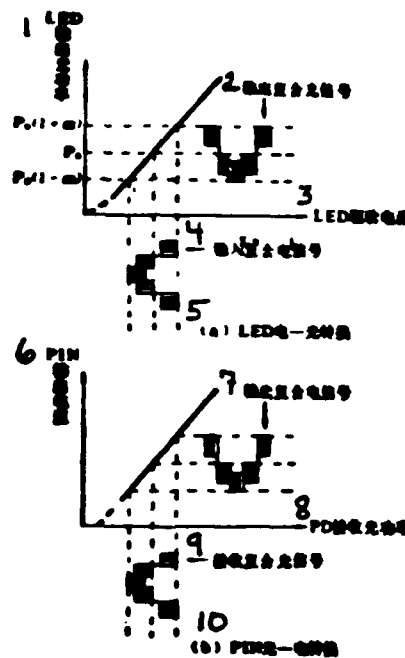


Figure 3. Principle of direct intensity modulation.

1--LED output light power; 2--output re-combined optical signal  
 3--LED driving current; 4--input combined electrical signal; 5--  
 (a) LED electrical-optical conversion; 6--PIN output current;  
 7--output combined electrical signal; 8--PD receiving light power;  
 9--received combined light signal; 10--PIN light electricity  
 conversion.

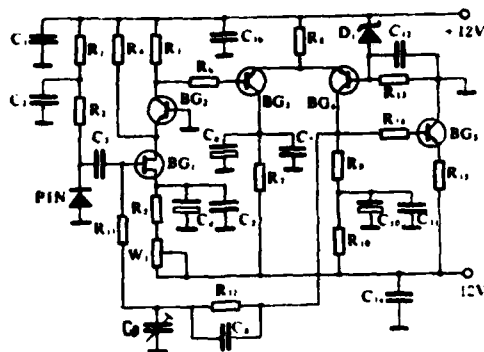


Figure 4. The pre-amplifier circuit.

## II. EXPERIMENTAL RESULTS OF TRANSMISSION CHARACTERISTICS

In order to reach the defined signal-to-noise ratio, and to enable its major characteristics to meet the requirements, the proper LED biasing current and modulation depth should be chosen. Testing with respect to the first and fourth signal channels was carried out and the experimental results indicated that when the biasing current was smaller than 25 mA, then the distortion was large. The amplitude modulated buzzing sound would increase. If the modulation depth was increased, although the visual frequency signal-to-noise ratio could be raised, then the distortion also increased. Furthermore, the picture signal would affect the quality of the voice. The amplitude modulated buzzing noise would reduce the signal-to-noise ratio of the voice. After repeated experimentation and considering various characteristics, we determined that the biasing current of the LED in the optical signal channel system should be about 40 mA and the modulation depth should be about 30-50%. The measured typical performance indicators are shown in Table 1.

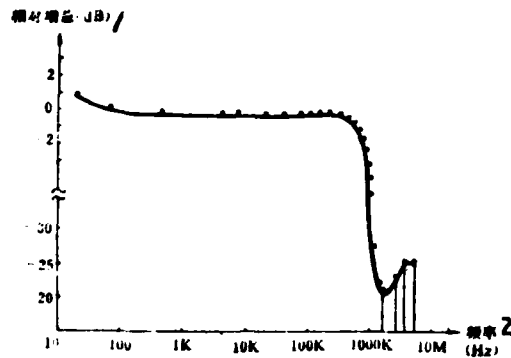


Figure 5. Visual frequency signal channel frequency response curve.

1--relative gain (dB); 2--frequency (Hz).

Figure 5 is the frequency response curve of the visual frequency signal channel. The relative gain of the operating frequency 8 KHz was normalized to 0 dB. The bandwidth of the 3 dB visual frequency channel was 10 Hz-1.3 MHz. In the 10 Hz to 1.0 MHz frequency range, the amplitude-frequency response was better and the inhomogeneity was  $\pm 0.5$  dB. In order to ensure the high quality transmission of 1 MHz television picture, at a frequency of 2.0 MHz, the relative gain was reduced to 33 dB and then the voice carrying frequency (2.0 MHz) had very little effect on the picture. In the 3-5 MHz frequency range, the gain increased slightly. Therefore, the weighted signal-to-noise ratio was 3-5 dB higher than the unprocessed one measured by the visual frequency noise detector.

Photographs 1 and 2 show the multiple wave response of the transmitter and the optical signal channel system, respectively. We found that the 3 dB bandwidth height of the transmitter exceeded 3.0 MHz. Judging from this, the upper limit frequency of the visual frequency bandwidth of the entire system was completely dependent on the upper limit of the frequency response of the receiver.

Table 1. Results of typical performance test

项	2 目	3 项 结 果
电 性	带宽(3dB) 4	10Hz~1.3MHz
	信噪比(Srms/Nrms) 5	53dB(未加权) 6
	低频噪声(Np-p) 8	>43dB(40Hz~1kHz)
	7项 百秒回失真 9	1% (up to 10%) 25
	秒回失真 10	5%
	同步脉冲失真 11	<2%
	非线性失真 12	2%
电 压	最大输出幅度 13	2Vp-p
	带宽(3dB) 16	200~3500Hz
	14项 信噪比(Srms/Nrms) 17	>43dB
	非线性失真度 18	<2%
光 学	最大输出幅度 19	3Vp-p
	灵敏度 20	-30.27dbm
	光源光纤输出功率 21	-14.10dbm
	实际光缆长度 22	570米 26
总 量	光路总损耗 23	7.2db
	系统余量 24	9db

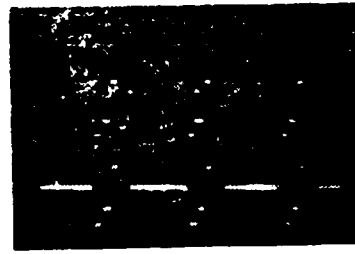
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2--item; 3--experimental results; 4--bandwidth (3dB); 5--signal-to-noise ratio; 6--53dB (unweighted); 7--visual frequency characteristics; 8--low frequency noise; 9--operating time distortion; 10--field time distortion; 11--synchronous pulse distortion; 12--non-linear distortion; 13--maximum output amplitude; 14--acoustic frequency characteristics; 15--optical characteristics; 16--bandwidth (3dB); 17--signal-to-noise ratio Srms/Nrms; 18--non-linear distortion; 19--maximum output amplitude; 20--sensitivity; 21--light source fiber end output power; 22--actual optical cable length; 23--total loss of optical path; 24--residual amount of the system; 25--1% up to 10%; 26--570 m.



Photograph 1: Multiple wave response of the transmitter.

1--upper: waveform at the LED positive electrode;  
2--lower: multiple wave input signal.



Photograph 2: Multiple wave response of the complete signal channels.

1--upper: input signal of the transmitter;  
2--lower: output signal of the receiver.

Figure 6 is the correlation curve between signal-to-noise ratio and optical power. The calculated curve was plotted based on the signal-to-noise ratio formula. Using a Si-PIN photoelectric diode as the detector, the signal-to-noise ratio expression of visual frequency base band simulated direct intensity modulation is:

$$\frac{S}{N} = \frac{2mpra}{[2q(pr+I)B+4kTBF_1/R]^{1/2}} \quad (3-1)$$

- where P : average light power received  
 m : modulation depth  
 r : response of the PIN photoelectric diode  
 a : ratio of voltage of the complete television signal and that of the picture (0.7)  
 q : electron charge ( $1.6 \times 10^{-19}$  Coulomb)  
 I : dark current of the PIN photoelectric diode  
 B : transmission visual frequency bandwidth  
 K : Boltzmann constant ( $1.38 \times 10^{-23}$  joule/degree)  
 T : absolute temperature  
 F<sub>1</sub> : noise coefficient of the receiver  
 R : equivalent input impedance of the receiver.

The values taken on the calculation were:

$$m = 0.7 \quad I = 5 \times 10^{-14} \text{ A} \quad R/F_1 = 0.7 \text{ A/W}$$

$$T = 300 \text{ K} \quad R_F = 200 \Omega \quad B = 1 \text{ MHz}$$

From the calculated curve, we found that when the received light power was -30 dbm, the signal-to-noise ratio was 44 dB. For the measured curve, when the power was -30 dbm, the unweighted signal-to-noise ratio could reach to about 53 dB. The actually measured value was higher than the calculated value. The main reason was that the parameters chosen for the calculation were not exactly the same as the actual parameters. After analyzing equation (3-1), we found that it was possible to raise the signal-to-noise ratio by increasing the equivalent input impedance of the receiver. The calculation indicated that: when using the PIN detector, in the -30dbm ~ -30dbm range,  $R/F_1$  increased by 10 times. Then S/N could be improved by 10 dB. The input amplifier stage of the receiver used an FET common source common base mutual impedance circuit whose  $R/F_1$  was high. If the  $R/F_1$  of the receiver was 10 times higher than the value chosen for the calculation, then the actual measured signal-to-noise ratio could be 10 dB higher than the calculated value.

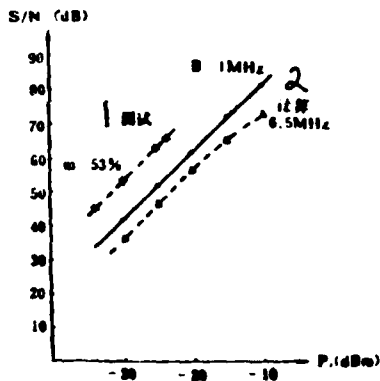


Figure 6. Signal-to-noise ratio vs. light power curve. 1--measured; 2--calculated.

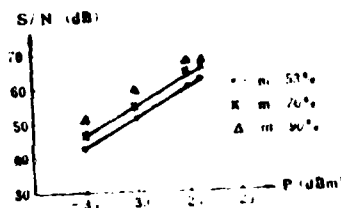
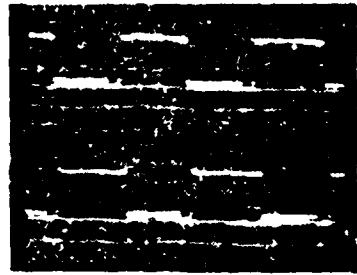


Figure 7. Experimental curves of signal-to-noise ratio vs. light power.



1 (a) 行时间失真波形  
2 (上: 输入; 下: 输出)



3 (b) 场时间失真波形  
4 (上: 输出; 下: 输入)



5 (c) 同步脉冲失真波形



6 (d) 非线性失真波形

Photograph 3. Waveform of experimental distortion characteristics

1--(a) operating time distortion wave form; 2--(upper: input; lower: output); 3--(b) field time distortion wave form; 4--(upper: output; lower: input); 5--(c) synchronous pulse distortion wave form; 6--(d) nonlinear distortion waveform

Figure 7 shows the signal-to-noise ratio vs. light power curves under different degrees of modulation. We found that the larger the degree of modulation was, the higher the signal-to-noise ratio became. However, when modulation was 90% and the input light power was near -25 dbm, the quantum noise dominated and the signal-to-noise ratio increase had been limited.

Photographs 3(a), (b), (c), (d) are the distortion wave forms of operating time distortion, field time distortion, synchronous pulse distortion and nonlinear brightness distortion, respectively.

Figure 8 is the acoustic frequency signal channel frequency response curve. The relative gain at 800 Hz was normalized as 0 dB. Then in the frequency range 300-3500 Hz, the maximum inhomogeneity was  $\pm 1.5$  dB.

Figure 9 shows the relation curves between the acoustic frequency signal-to-noise ratio, distortion and received light power. From the figure, we found when the modulation frequency deviation was increased, then the signal-to-noise ratio was also increased. However, the distortion was also correspondingly increased. When the frequency deviation was 7 KHz and the received light power was -30 dbm, the voice signal-to-noise ratio was about 43 dB and the distortion was less than 2%.

From the measured data, we found that when the power varied from -20 dbm to -32 dbm the signal-to-noise ratio variation was very small. From -32 dbm to -36 dbm, the signal-to-noise ratio gradually declined. The reason was that the carrier frequency amplitude was alternated to approach the limiting voltage of the amplitude limiting level of the frequency evaluator and the noise variation was large. When the optical power was lower than -36 dbm and -44 dbm, the carrier frequency amplitude was alternated to below the limiting amplitude voltage of the amplitude limiting

device and the noise was increasing rapidly. Simultaneously, the effective value of the signal was decreased. Therefore, the signal-to-noise ratio dropped rapidly and correspondingly the degree of distortion was increased accordingly. However, even when the power was dropped to -42 dbm, the signal-to-noise ratio could still reach 32 db. Therefore, if this signal channel is used for voice transmission, its transmission range can reach 5 kilometers.

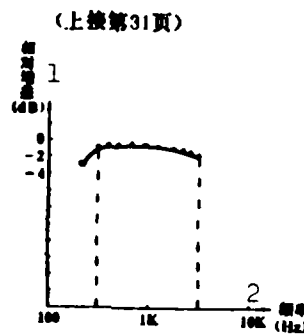


Figure 8. The voice frequency response curve.  
1) relative gain (db); 2) frequency (Hz)

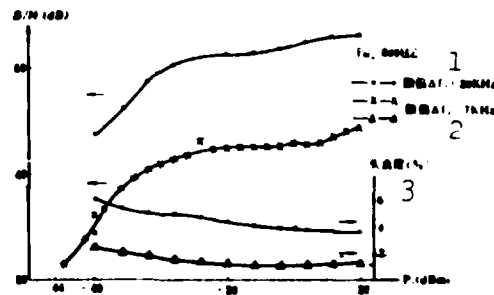


Figure 9. The correlation curves of the voice frequency signal-to-noise ratio, the degree of distortion, and the receiving light power.  
1) frequency deviation; 2) frequency deviation; 3) degree of deviation.

### III. CONCLUSIONS

The sensitivity of the optical receiver was -30.27 dbm for this light signal channel system, when the degree of modulation was about 50% and the randomly contaminated signal-to-noise ratio was 53 db. Using the second signal channel as an example, the light power at the end of the optical fiber circuit (the receiving end of the detector) was -21.30 dbm. Therefore, the remaining light power was about 9 dbm. If the LED was biased at 50 MA, then the residual light power could reach 14 dbm. Using optical fibers with a 3.5 db/km loss and taking into account the decrease of residual light energy due to characteristic deterioration, the transmission range could be ensured to be greater than 3 kilometers.

In order to accomplish the original duty requirements, a four channel (four receiving and four transmitting) optical signal communications system was developed. It worked normally in all channels. A trial transmission was carried out in a technical fair at the Culture Palace in Kwiling on May 1 to 3, 1981. The results were good. In the field test on a railroad loop, the optical signal channel system was placed in an equipment room 15 meters away from the electrical engine. The strong electromagnetic interference created intermittantly by the electrical engine had no effect on the voice and signal. This proved that the characteristic of this optical cable system is stable and reliable under intense electromagnetic interference.

This system adopted the direct simulated intensity modulation. The transmission characteristics are stable, the electrical circuit is simple, and the cost is comparatively low. It is suitable for the information transmission of a short range, small capacity videophone. It can operate in environments with strong electromagnetic interference such as ships, naval vessels, airplanes, and steel factories. It can be given to the secret communications department for a trial use.