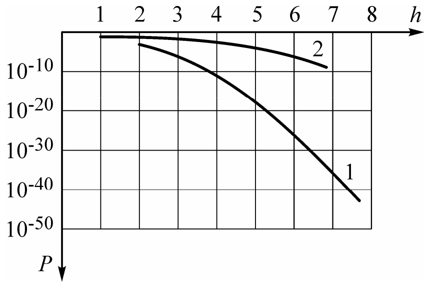

Fig. 5. The probability of pairing transition of one invariant inside the other inthe following prescribed conditions: k = 0,7; INV_1 = 1; INV_2 = 2, 3, ... , 10 curve *1* – is the coherent reception, invariant relative amplitude modulation, rectangular envelope, curve *2* – is the classical relative amplitude modulation.

The analysis of this system has shown that it has a high level of noise immunity. The chance of error in the classical algorithm with a relative amplitude modulation of at least two orders of magnitude is greater than the probability of pairing transition in the invariant system. Therefore, this system can be applied in telecommunication systems, remote control systems, and other systems, which demand high indicators for noise immunity.

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INVARIANT METHOD OF INFORMATION TRANSMISSION IN FIBER-OPTIC TRANSMISSION SYSTEMS

We have synthesized a method of controlling the distortions introduced by fiber-optic communication lines. This method is based on the use of invariant equality. Its main technical characteristics have been determined.

Keywords: invariant fiber-optic transmission system.

Classical AM Modulation in fiber-optic transmission systems (FOTS) is used to transfer information signaling in most cases.

The probability of erroneous reception in regenerators is 10^{-10}, according to the recommendations of the International Telecommunication Union (ITU) [1]. More recent ITU [2] recommendations have proposed to apply device error protection (RCD) the performance of which is based on a special transmission signal coding by means of cyclic codes. It is difficult to create a residual operating in real time at a speed of 10 Gb / s and more.

Meanwhile, the reduction of error probability can be achieved in other ways. One is suggested below.

We have the FOTS (fig. 1). A laser is used as a transmitter. A photo detector is used as a receiver. The second window of transparency is used to send the information signal.

The information signal transmission algorithm must be synthesized based on the invariant method of information processing.

Fig. 1 shows the structure of FOTS, which includes the transmitting and receiving devices and the fiber-optic transmission.

It should be noted that the cross-cutting path of the FOTS at the second window of transparency [3] is linear, provided the power output of the transmitter to not exceed the permissible value of 1 mW. The Z-transform signal reception Y (Z) on the output of the FPU will be equal to (for i-volume processing unit):

$$Y_i(Z) = \left[G(Z) \cdot H_0(Z) \cdot H_1(Z) \cdot H_2(Z)\right]_i, \qquad (1)$$

where $G_i(Z)$ – is the Z-transform of the signal transmission at the i-volume processing unit; $H_{0i}(Z)$ – the transfer characteristic of the signal shaper at the i-volume unit; $H_{1i}(Z)$ – is the transfer characteristic of fiber-optic transmission at the i-volume unit; $H_{2i}(Z)$ – the transfer characteristic of the unit (FPU) on the i-unit.

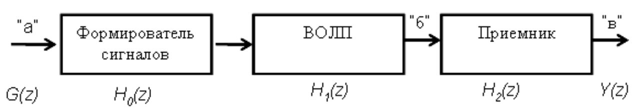

Fig. 1. The FOTS structure

In [4] an invariant equation is given, fair for any linear quadrupole:

$$\frac{G_i(Z)}{G_{i-1}(Z)} = \frac{Y_i(Z)}{Y_{i-1}(Z)}. \qquad (2)$$

Equality (2) is valid for physically realizable systems, when the denominators are not equal to zero.

FOTS are conservative systems, the characteristics of which are divided into intervals of stationarity. Thus:

$$H_{\Sigma(i-1)}(Z) \approx H_{\Sigma i}(Z) \approx H_{\Sigma(i+1)}(Z), \qquad (3)$$

where $H_{\Sigma i}(Z) = H_{0i}(Z)\cdot H_{2i}(Z)\cdot H_{2i}(Z)$ – is the transfer characteristic of through-tract FOTS on the i-unit.

Substituting expression (3) for (2), considering (1), equality (2) transforms into an identity.

In the transition from the Z-image to the amplitude-phase spectrum, we have:

$$\frac{G_i(jk\omega_1)}{G_{i-1}(jk\omega_1)} = \frac{Y_i(jk\omega_1)}{Y_{i-1}(jk\omega_1)}. \qquad (4)$$

Equation (4), is in turn, divided into equal relations of the amplitude spectra and the equality of the difference in digital spectra:

$$\left.\begin{array}{l} \dfrac{G_i(k\omega_1)}{G_{i-1}(k\omega_1)} = \dfrac{Y_i(k\omega_1)}{Y_{i-1}(k\omega_1)} \\ \varphi_i(k\omega_1) - \varphi_{i-1}(k\omega_1) = \psi_i(k\omega_1) - \\ -\psi_{i-1}(k\omega_1) \end{array}\right\}, \qquad (5)$$

where $G_i(k\omega_1)$ and $G_{i-1}(k\omega_1)$ – are the amplitude spectra at the input of the signals on the i and (i–1) blocks; $Y_i(k\omega_1)$ and $Y_{i-1}(k\omega_1)$ – are the amplitude spectra at the output of the FPU on the i and (i–1) blocks; $\varphi_i(k\omega_1)$ and $\varphi_{i-1}(k\omega_1)$ – are the phase spectra of signals at the input of the signals on the i and (i–1) blocks; $\psi_i(k\omega_1)$ and $\psi_{i-1}(k\omega_1)$ – are the phase spectra at the output of FPU signals on the i and (i–1) blocks. The first equation (5) reiterates the principle of relative amplitude modulation (OAM), and the second – the principle of relative phase modulation (RPM). Thus, to achieve a minimum probability of error in the FOTS it is necessary to "invest" the modulation parameter into the relation of the Z-image signal transmission at neighboring processing units; and at the receiving side of the modulating parameter it should be extracted by comparing neighboring blocks.

The formation of information signals in such a system is carried out at the input of the signals. The demodulation – at the output of the FPU. We shall call this system – the "invariant fiber-optic transmission system" (IFOTS).

The formation of the signals will be like so:

$$\frac{G_1(Z)}{G_0(Z)} = S_{\text{mod}1}(Z) \to G_1(Z) = G_0(Z)\cdot S_{\text{mod}1}(Z),$$

$$\frac{G_2(Z)}{G_1(Z)} = S_{\text{mod}2}(Z) \to G_2(Z) = G_1(Z)\cdot S_{\text{mod}2}(Z) =$$

$$= G_0(Z)\cdot S_{\text{mod}1}(Z)\cdot S_{\text{mod}2}(Z),$$

$$G_N(Z) = G_0(Z)\cdot\prod_{i=1}^{N} S_{\text{mod}i}(Z), \qquad (6)$$

where G_0 (Z) – is the Z-image data signal in the initial block (signal learning).

However, it is impossible to realize the algorithm of modulation according to expression (6), because at long communication sessions $N \to \infty$ and the non-recursive filter can not be physically realized. Fig. 2 shows the realized structure of the signal shaper for N = 4. It contains four blocks of delay, a key, and multipliers of FFT and IFFT. The number of taps can be different.

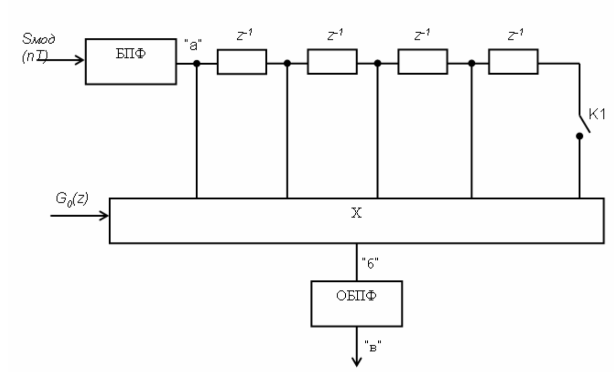

Fig. 2. The structure of the signal shaper for the N = 4 IFOTS

Modulating parameter S_{mod} (nT) in the FFT block is converted into S_{mod} (Z).

The process of forming the transfer of signals in each block consists of 2 stages. During the first stage the key K1 is locked. The signal at point "b" shall be so:

$$G_i(Z) = G_0(Z)\cdot\prod_{k=0}^{5} S_{\text{mod}(i-k)}(Z). \qquad (7)$$

In the second stage the key K1 is open. The signal at point "b" will be:

$$G'_i(Z) = G_0(Z)\cdot\prod_{k=0}^{4} S_{\text{mod}(i-k)}(Z). \qquad (8)$$

The signal transmission is shown is in fig. 3.

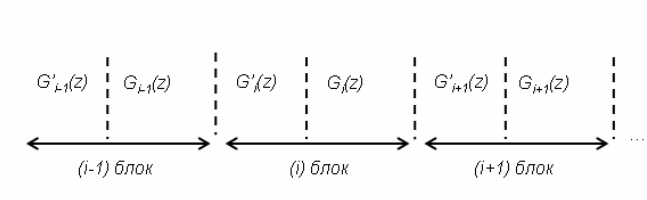

Fig. 3. Signal transmission

In accordance to the laws of digital filtering, each block at the receiving side is multiplied by the transfer characteristic of the through path. Imagine the Z-imaging signals in the form of:

$$\left.\begin{array}{l} Y_{i-1}(Z) = G_{i-1}(Z)\cdot H_{\sum i-1}(Z) \\ Y'_{i-1}(Z) = G'_{i-1}(Z)\cdot H_{\sum i-1}(Z) \\ Y_i(Z) = G_i(Z)\cdot H_{\sum i}(Z) \\ Y'_i(Z) = G'_i(Z)\cdot H_{\sum i}(Z) \end{array}\right\}. \qquad (9)$$

The process of demodulation is in the division of the first part of $G_i(Z)$ by $G_i'(Z)$. Then:

$$S'_{\mathrm{mod}i}(Z)=\frac{G_0(Z)\cdot\prod_{k=0}^{5}S_{\mathrm{mod}(i-k)}(Z)\cdot H_{\sum i}(Z)}{G_0(Z)\cdot\prod_{k=0}^{4}S_{\mathrm{mod}(i-k)}(Z)\cdot H_{\sum i}(Z)}. \qquad (10)$$

The validity of expression (10) is based on the properties relative to the medium through-tract IFOTS spread and the validity of equation (3).

Fig. 4 shows the structure of the IFOTS receiving part.

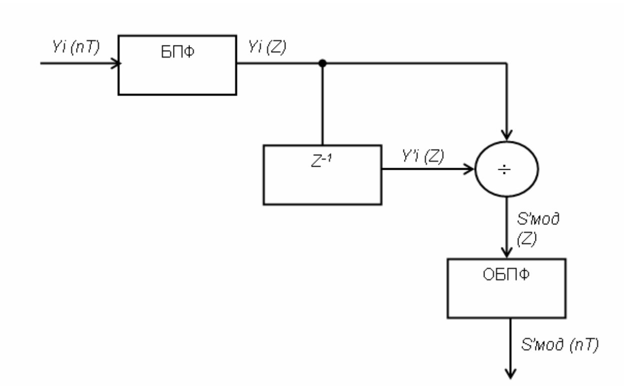

Fig. 4. Structure of the IFOTS receiving part

Note that in this algorithm there is a compensation of amplitude frequency distortions of the FCHI in the IFOTS pass-through. This in turn, leads to the compensation of the dispersion properties of fiber-optic transmission, an increase in the signal-to-noise ratio and reduction of error possibilities.

This section should indicate the advantages and disadvantages of the presented method. The undeniable benefits may include the compensation for amplitude frequency distortions and medium phase-frequency distortions of propagation. This makes it possible to increase the length of the regeneration area, while maintaining the probability of false acceptance; or substantially reduce the probability of error for fixed length area regeneration.

Disadvantages include speed increase of the basic signal transmission. Basically, redundancy was introduced into the signal transmission, making it possible to improve the quality indicators.

However, along with the compensation of amplitude frequency and phase-frequency distortions, an increase in additive noise is observed.

Let us estimate the intrinsic noise using the known relation [5]:

$$\sigma^2=\frac{\Delta_0^2}{12}\sum_{n=0}^{\infty}h^2(nT)+\frac{\Delta^2}{12}\sum_{j=1}^{N}\sum_{n=0}^{\infty}h_j^2(nT), \qquad (11)$$

where Δ_0 – is the quantization step in input words; $h(nT)$ – is the impulse response digital filter; $h_j(nT)$ – is the a truncated quantization impulse response of the digital filter of the j-order noise source; Δ – is the step of signal processing in the digital filter (DF); N – is the number of DF taps.

Usually the calculations are done as so: $\Delta_0 = \Delta$, and $h(nT) = h_j(nT)$. Then expression (11) is simplified.

The value of additional self-noise in gear will be equal to (for $N = 4$):

$$\sigma^2_{\text{собств.ПРД}}=\frac{\Delta^2}{12}\cdot 5\cdot\sum_{n=0}^{\infty}h^2(nT)=\frac{5\Delta^2}{3}. \qquad (12)$$

The extra noise value at reception will be:

$$\sigma^2_{\text{собств.ПРМ}}=\frac{4\Delta^2}{12}=\frac{\Delta^2}{3}. \qquad (13)$$

The total value of additional noise will be equal to:

$$\sigma^2_{\sum\text{собств}}=\sigma^2_{\sum\text{собств.ПРД}}+\sigma^2_{\sum\text{собств.ПРМ}}=2\Delta^2. \qquad (14)$$

If you receive a communication channel with noise (photon noise), the value of its IFFT block output will be equal to [4]:

$$\sigma^2_{\text{доп.КС}}=\sigma^2_{\text{КС}}\sum_{n=1}^{\infty}h^2(nT)=2\sigma^2_{\text{КС}}, \qquad (15)$$

where σ^2_{KC} – communication channel noise power.

The structure of the IFOTS for the compensation of amplitude frequency distortions and medium phase-frequency distortions of propagation has been developed. The specifications technical had been defined. The developed method can be widely applied in fiber-optic transmission systems.

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