

MATHEMATICAL MODEL OF THE LEAKAGE CHANNEL OF ACOUSTIC INFORMATION BY MODULATING THE LIGHT FLUX

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Abstract: The considered channel of information leakage potentially represents a probable risk of information leakage. The formation of a leak channel is associated with the use of lighting devices. The calculated estimated values of the leak channel channel indicate its high potential danger. The considered model of the leakage channel of acoustic information by means of modulation of visible light based on digital modulation methods makes it possible to use a maximum likelihood receiver to receive a coded signal susceptible to intersymbol interference and additive white Gaussian noise.

Keywords: ACOUSTIC LEAK CHANNEL, MODULATION OF THE VISIBLE LIGHT, MODEL OF THE LEAKAGE CHANNEL

1. Introduction

Data transmission in the optical channel of information leakage (CIIC) with non-coherent light sources was carried out through intensity modulation and direct registration on the photodetector (see Figure 1). For this, the transmitted signal must be real and non-negative. In practice, this is achieved using single-carrier modulation methods such as multi-level impulse positional modulation (M-PPM) and multi-level impulse amplitude modulation (M-PAM), as well as using complex modulations such as multi-level quadrature amplitude modulation (M-QAM), as well as optical orthogonal frequency multiplexing (O-OFDM). Conventionally, the average optical power is defined as the first moment of a transmitted signal, while the average electric power is defined as the second moment of a transmitted signal. In practice, the dynamic range can be linearized through alignments only between the levels of the minimum and maximum radiated optical forces. In addition, to comply with sanitary standards for eye-safe flicker and fading of light in the working room and / or design requirements for heat dissipation also impose a limit on the average optical power dissipated by the visible light-emitting diode. Due to these limitations, there is a fixed relationship between the average electrical power and the average optical power of single- and multi-carrier signals, which varies with the offset setting, i.e., a combination of DC offset and signal dispersion.

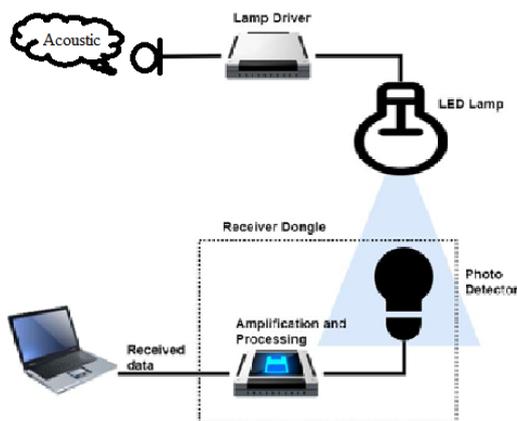


Fig.1 The structure of the information leakage channel by means of modulating the intensity of light.

2. Modulation of optical signals

Unlike the radio frequency (RF) system, where the signal carrying the data modulates the complex bipolar electric field emitted by the antenna, the signal modulates the intensity of the optical radiation of the LED in the visible range in the OCIS system, and therefore it must be real, unipolar and non-negative. Since the LEDs are incoherent light sources, it is difficult to collect the signal power in a single electromagnetic mode and to provide a

stable carrier in the case of a CCAI indoors. Therefore, it is not possible to create an efficient coherent receiver, such as a superheterodyne receiver, commonly used in radio frequency transmission. Practical low-cost optical carrier modulation for QCIM can be achieved by directly converting the intensity of visible light into a photocurrent in a non-coherent manner. Information in this case is encoded in the envelope of the transmitted signal, and there is no information about the phase of the signal.

Single carrier impulse modulation is a suitable option for organizing data transmission to a PCCS. Information can be encoded by pulse width, such as pulse width modulation or interval pulse modulation. In addition, information can be encoded at a pulse position, for example, M-PPM. Alternatively, the information may be encoded in the pulse amplitude, for example, M-PAM.

Consider the detection of digital pulse modulation position (PPM) in the presence of intersymbol interference and additive white Gaussian noise. As is well known, digital pulse position modulation is widely used in optical communication systems with intensity modulation, such as fiber optic and satellite systems, mainly due to the high efficiency of their average power. The bandwidth of the CMIS inside rooms is severely limited due to multipath optical propagation and the inevitable intersymbol interference (MI).

PPM will be considered as a simple non-linear block code; in particular, the block $\log_2 L/L$ L block code consisting of a set of L binary L-sets with a unit Hamming weight. Therefore, equalizers designed for common block codes can be applied to L-PPM. On the other hand, since the main feature of PPM used in this article is that PPM is a block code, the results are applied directly to all binary and non-binary block codes, including multidimensional grouping codes.

3. Channel model

The model for transmitting L-PPM over channels with MI is shown in Fig. 2

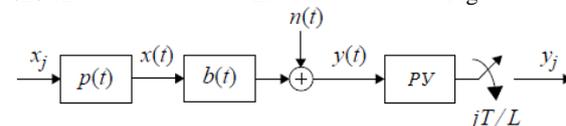


Fig.2. Model channel OKUI with intensity modulation L-PPM.

In the transmitter containing a digital microphone forming the sequence with the speed L/T . The sequence is controlled by a transmission filter with a pulse shape $p(t)$, so that the transmitted signal is defined as:

$$x(t) = \sum_{j=-\infty}^{\infty} x_j p(t - jT/L)$$

Then the received signal $y(t)$ is defined as:

$$y(t) = \sum_{j=-\infty}^{\infty} x_j g(t - jT/L) + n(t)$$

where $g(t)$ is the convolution $p(t)$ with the channel impulse response $b(t)$, and $n(t)$ is the additive white Gaussian noise with two-way power spectral density N_0 . Such a signal can be filtered by a bleaching filter, and then restored at a frequency of the L/T chip without affecting the performance of the receiver. The resulting equivalent channel with discrete time can be represented as:

$$y_j = \sum_{m=-\infty}^{\infty} h_m x_{j-m} + n_j$$

where h_m is the discrete time impulse response, and the noise sequence n_j is white Gaussian noise with dispersion $\sigma^2 \equiv N_0/\gamma$, where γ is the geometric mean of the total spectrum:

$$\gamma = \exp \left[\frac{T}{L} \int_{L/2T}^{L/2T} \log \left(\frac{T}{L} \sum_{k=-\infty}^{\infty} |G(f - kl/T)|^2 \right) df \right].$$

The samples y_j are grouped into blocks of length L . The noise sequence n_k has the autocorrelation function $R_n(m) = \sigma^2 \delta_m \mathbf{I}$, resulting in a white spectrum: $Z_n(z) = \sum R_n(m) z^{-m} = \sigma^2 \mathbf{I}$. When the x_k characters are chosen independently and uniformly from the PPM alphabet, the range of characters is also white: $S_x(z) = (1/L)\mathbf{I}$.

A computationally efficient sequence detector selects a sequence of scalar values $\{j\}$ or, equivalently, a sequence of characters $\{k\}$ that minimizes the following expression:

$$\sum_{j=0}^{\infty} \left| y_j - \sum_{m=0}^{\infty} h_m \hat{x}_{j-m} \right|^2$$

Since x_j is the output of the block coder, not all sequences $\{x_j\}$ are valid, therefore only valid sequences $\{x_j\}$ are searched. When input x_k characters are chosen uniformly and independently of the PPM alphabet, on the other hand, as assumed here, each sequence of $\{x_k\}$ characters is equally likely, so all sequences of $\{x_k\}$ characters are searched using the Euclidean norm.

When a channel has a finite memory m , the received sequence y_k represents a noisy observed value of a signal with a finite number of states. The sequence can be found by finding the path of the minimum length through the lattice, which is best achieved using the Viterbi algorithm. The probability of a symbol (block) error for a sequence detector is well approximated at a high signal-to-noise ratio by the expression:

$$P_e = Q(d_{min}/2\sigma),$$

where $\sigma^2 = N_0/\gamma$ variance of each component n_k и d_{min} - the minimum distance between the received sequences.

The considered model of the leakage channel of acoustic information by means of modulation of visible light based on digital modulation methods makes it possible to use a maximum likelihood receiver to receive a coded signal susceptible to intersymbol interference and additive white Gaussian noise.

4. Conclusion

The considered channel of information leakage potentially represents a probable risk of information leakage. The formation of a leak channel is associated with the use of LED lighting devices. The calculated estimated values of the leak channel channel indicate its high potential danger. To counter the information leakage channel in question, it is necessary to develop technical and administrative countermeasures.

5. Literature

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