Estimation of the Optical Pulse Duration with Rectangular Intensity Profile of Unknown Height

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Abstract—The quasi-likelihood and maximum likelihood algorithms of duration estimation have been synthesized and analyzed. The losses in accuracy of quasi-likelihood estimate caused by a priori lack of knowledge of pulse intensity were also found. The accuracy of the maximum likelihood estimate of duration was found to be asymptotically invariant to the presence of a priori information about the pulse intensity.

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A model of optical pulse having rectangular intensity profile is used in numerous applications of optical communications and also detection and ranging [1–6]. Let us consider the estimation of unknown duration of the optical pulse with rectangular intensity in the presence of noise background. We shall assume that a realization of Poisson process \( \pi(t) \) with the following intensity can be observed on time interval \([0, T] \):

\[
\lambda(t) = \beta_0 s(t) + \alpha,
\]

\[
s(t) = \begin{cases} 
1, & 0 \leq t \leq \tau_0, \\
0, & t < 0, t > \tau_0. 
\end{cases}
\]  

(1)

where \( \alpha \) is the a priori known intensity of optical background, \( \beta_0 \) is the unknown pulse intensity, \( \tau_0 \) is the unknown pulse duration that can take on values from interval \([T_1, T_2] \), while \( 0 < T_1 < T_2 < T \).

If intensity \( \beta_0 \) is known, the estimation of pulse duration \( \tau_0 \) can be performed by using the maximum likelihood method [7]. This method implies that the duration estimate can be determined as a position of the largest maximum of likelihood ratio functional (LRF) logarithm.

An expression for LRF logarithm [8] has the form:

\[
L_0(\tau) = \pi_\tau \ln(1 + \beta_0 / \alpha) - \beta_0 \tau,
\]

(2)

where \( \pi_\tau = \int_0^\tau d\pi(t) \). Correspondingly, the maximum likelihood estimate (MLE) is determined as follows:

\[
\tau_m = \arg\sup_{\tau \in [T_1, T_2]} L_0(\tau),
\]

(3)

However, in the event that both duration \( \tau_0 \) and pulse intensity \( \beta_0 \) are unknown, the LRF logarithm depends on two unknown parameters.
REFERENCES