

Blind Point Spread Function Estimation for Enhanced Spatial Loss Analysis in Optical Time-Domain Reflectometry

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INTRODUCTION & AIM

Optical time-domain reflectometry (OTDR) is widely used for fault detection and characterization in optical fiber systems and networks. While long pulses are necessary for adequate signal-to-noise ratio and measurement range, they blur localized fault events, which becomes particularly significant in short-distance systems.

This work provides preliminary results in addressing these constraints through blind point spread function (PSF) estimation for use with deconvolution. We adapted techniques from image deconvolution literature with the goal that future work may use these results to blindly improve OTDR spatial resolution and detection fidelity.

METHOD

Krishnan et al. proposed using a normalized sparsity measure to estimate the blurring kernel in [1]. We have adopted their method for 1-D signals for estimating the PSF of an OTDR signal, adding an additional regularizer from the works in [2]. The final optimization problem is attempting to recover a pulse h from the gradient y' of a measurement y :

$$\min_{x,h} \lambda \|y' - x' * h\|_2^2 + \frac{\|x'\|_1}{\|x'\|_2} + \phi \|h\|_1 + \gamma \|D_2 h\|_2^2$$

$$s.t. \quad h \geq 0, \sum h_i = 1$$

We form an alternating minimization scheme to separate the two variables while solving. We operate on the gradients rather than the image itself as, neglecting the small contribution of attenuation, the gradients form a sparse signal defined by the events. The prior promotes this sparsity and encourages sharp edges.

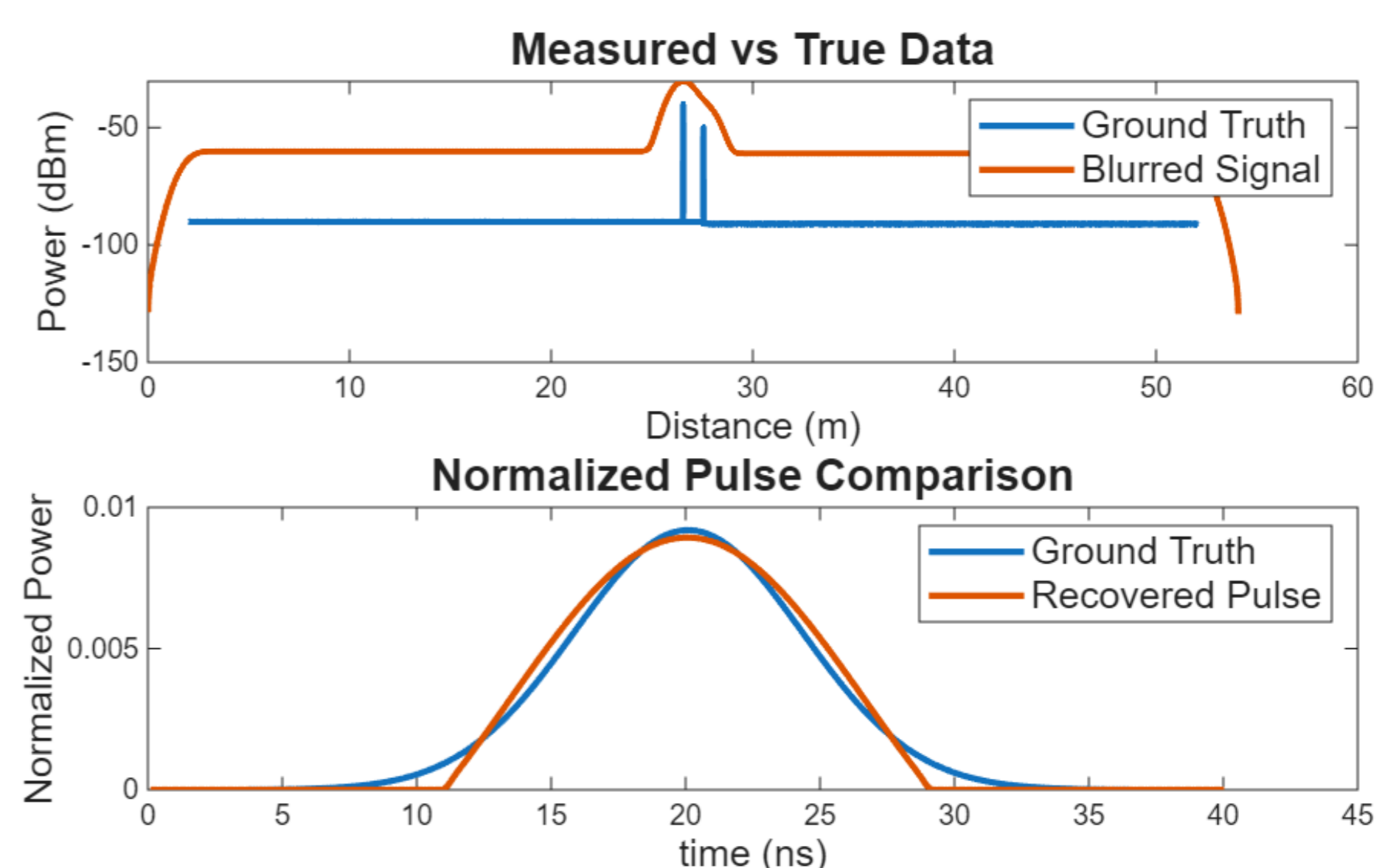
The two priors on the kernel promote centrality of the energy into the pulse profile, as the combination of sparsity and smoothness combines to promote a single smooth envelope.

RESULTS & DISCUSSION

We tested our algorithm on a simulated 50-meter fiber, with two reflective events at 25.5m (40 dB ORL) and 24.5m (50 dB ORL), as shown in the figure below with a 10ns pulse width.

The algorithm was moderately effective at recovering the original pulse, even in the presence of two combined events. This suggests that this method may offer a way to blindly recover spatial resolution, by using the output in previously proposed non-blind deconvolution methods [3].

This method, however, is sensitive to pulse width, and must be tuned accordingly. Even with proper tuning, however, longer recovered pulse widths lose the curvature. Therefore, future work will investigate stabilizing the algorithm and potentially investigating other smoothing priors on the pulse.



CONCLUSION

We present preliminary results on blind PSF estimation suggesting that future work may allow for blind OTDR spatial resolution improvement.

REFERENCES

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