Erratum: Overcoming the uplink limit of satellite-based quantum communication with deterministic quantum teleportation [Phys. Rev. A **104**, 022615 (2021)]

Zhiyue Zuo, Yijun Wang, Qin Liao , and Ying Guo

(Received 8 October 2021; published 4 November 2021)

DOI: [10.1103/PhysRevA.104.059901](https://doi.org/10.1103/PhysRevA.104.059901)

Recently, a paper [1] has come to our attention which reports on independent but related work to that presented in our original paper. It was published before the publication of our own paper but not cited there. We wish to bring this reference to the readers' attention and use this opportunity to briefly discuss some similarities and differences between the two reports.

Main focus: The main focus of our work is to highlight the advantages of the continuous variable (CV) method in the satellite-based teleportation task (when some key scenarios are needed). As pointed out in the Introduction (p. 2, paragraph 5), the idea using quantum teleportation to overcome the uplink limit was first conducted by Micius [2], which is based on the discrete-variable (DV) method without deterministic. However, it is hard for the DV method (without any changes) to overcome the effects of background noise in daytime operation [3]. Fortunately, the coherent detection of the CV method can effect resistance against background noise [4], thus, we have analyzed the fidelity of daytime operation to show this unique advantage. Besides, we have proposed the experimental devices of the CV method to show that it can provide deterministic teleportation without the requirement of single-photon detectors. Note that the single-photon detectors are susceptible to damage induced by space radiation [5].

Fidelity calculation: Our work used the powerful covariance matrix for fidelity calculation, which is convenient but can only be suited for coherent-state teleportation (not general Gaussian states, such as squeezed coherent states). When averaging fidelity [1], introduces the concepts of effective transmissivity and effective excess noise, whereas we directly averaging in terms of the probability density function (PDF) of transmittance [see Eq. (10)]. In our opinion, these two ways are equivalent.

Channel modeling: Reference [1] used the phase screens for modeling satellite-based link, whereas we selected elliptic-beam approximation. Interestingly, Ref. [1] used a whole subsection to comment elliptic-beam approximation (see Sec. 3 in Ref. [1]). It claimed that the phase screen takes the inner scale and outer scale into account whereas the elliptic-beam approximation did not. This conclusion is right due to the derivation that elliptic-beam approximation is based on the classical Kolmogorov spectrum [6]. In fact, the elliptic-beam approximation has the potential to upgrade with a more complex turbulence spectrum (such as the von Karman spectrum [7]), which takes inner scale and outer scale into account. However, the difficulty is that, during re-derivation, the obtained expressions with von Karman (hypergeometric functions) are much more complex than those obtained by Kolmogorov (power functions). When it comes to simulating PDF, phase screens will require more calculation steps due to the elliptic-beam approximation that is an analysis method. In a word, the basic idea behind the elliptic-beam approximation is to give an analysis method to get the PDF in a relatively simple and accurate manner.

Quantum resources: In addition to the quantum catalysis, we provide two enhanced methods without additional quantum resources consumption (all classical operations), i.e., active attenuation and postselection methods. Note that such an attempt is meaningful since the resources in quantum satellites are limited [5].

We hope this discussion can help readers to build comprehensive views on the meaning and theoretical tools of satellite-based CV quantum teleportation.

-
- [1] E. Villaseñor, M. He, Z. Wang, R. Malaney, and M. Z. Win, Enhanced uplink quantum communication with satellites via downlink channels, *IEEE Trans. Quantum Eng.* **2**, 4102118 (2021).
 - [2] J.-G. Ren, P. Xu, H.-L. Yong, L. Zhang, S.-K. Liao, J. Yin, W.-Y. Liu, W.-Q. Cai, M. Yang, L. Li *et al.*, Ground-to-satellite quantum teleportation, *Nature (London)* **549**, 70 (2017).
 - [3] F. Xu, X. Ma, Q. Zhang, H.-K. Lo, and J.-W. Pan, Secure quantum key distribution with realistic devices, *Rev. Mod. Phys.* **92**, 025002 (2020).
 - [4] S. Pirandola, U. L. Andersen, L. Banchi, M. Berta, D. Bunandar, R. Colbeck, D. Englund, T. Gehring, C. Lupo, C. Ottaviani *et al.*, Advances in quantum cryptography, *Adv. Opt. Photonics* **12**, 1012 (2020).
 - [5] J. S. Sidhu, S. K. Joshi, M. Gundogan, T. Brougham, D. Lownes, L. Mazzarella, M. Krutzik, S. Mohapatra, D. Dequal, G. Vallone *et al.*, Advances in space quantum communications, *IET Quantum Commun.* (2021), doi: [10.1049/qtc2.12015](https://doi.org/10.1049/qtc2.12015).
 - [6] D. Vasylyev, A. A. Semenov, and W. Vogel, Atmospheric Quantum Channels with Weak and Strong Turbulence, *Phys. Rev. Lett.* **117**, 090501 (2016).
 - [7] L. C. Andrews and R. L. Phillips, *Laser Beam Propagation through Random Media*, 2nd ed. (SPIE, Bellingham, 2005).