Simultaneous Transmission via Sound and Light: Squeezing and Uncertainty

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May 24, 2025

Abstract

In this note, the authors explore the acoustic communication channel and the free space optical channel. These channels are assumed to be operating simultaneously in the proposal. That is, the line of sight for the FSO link is also the acoustic communication channel. The two channels are jointly addressed by a device that generates laser signals as well as mechanical signals vibrating the air.

If we have a laser link from point a to point b over free air, and the air is also modulated acoustically at the same time, then we have two modalities carrying information at the same time. The acoustic modulation will act as "turbulence" for the FSO link. At the same time, the propagation of light through the air will heat the air and change its acoustic transmission properties. Thus what is generating the signal on one mode acts as a noise source for the second mode.

We must decide how incoming bits will be optimally sub-divided onto the two links. The acoustically generated turbulence which acts as optical noise, will have to be analyzed such that we inject acoustic information only in a way which minimizes the turbulence. Turbulence is captured in the "alpha" and "beta" order parameters of the FSO link. This is not a relay channel. It is not a broadcast channel either. It may however be seen as a type of two-input, two-output or MIMO channel. In an extreme case, the two inputs can become fused if the laser aperture also acts as a "drum" surface for generating the acoustic vibrations. This limit is interesting because it reduces the MIMO to a regular SISO channel, but it becomes a higher dimensional, namely two dimensional, SISO channel where the dimensions are in signal space, not in physical transmission antenna configuration space.

For modulation, a type of quadrature amplitude modulation can be implemented, where one axis is allotted to one modality. However the noise on the two axes will be different (and correlated) and so we would obtain a type of squeezing effect, much like in quantum optics with squeezed light which has a lot of applications. The correlated nature of the two axes' noise might also contribute to a type of uncertainty principle. This would lead to fundamental physical limits on data transmission rates. The capacity characterization of this channel therefore becomes an important future investigation.