A Coherent RF Repeater for Distributed Communications

Thomas M. Comberiate*, Kojo S. Zilevu, Jason E. Hodkin, and
Jeffrey A. Nanzer
Johns Hopkins University Applied Physics Laboratory
Laurel, MD 20723, USA

The quality of a communications link is fundamentally limited by its transmission power. In the case of a mobile or small platform, this limitation can be particularly crippling because of energy storage constraints. In addition, a single platform, especially one equipped with an omni-directional antenna, can be limited in its ability to control where its signal is broadcast spatially. The former challenge motivates the use of a repeater to boost or null the signal power at a target; the latter prompts the concept of having that repeater act as a cooperative platform in order to provide spatial diversity as well as additional power on target. Some cooperative distributed communication methods have been demonstrated (D. Brown, P. Bidigare, and U. Madhow, ICASSP 2012), but these rely on feedback from a receiver. In a noncooperative setting, repeaters can be used to sample a transmitted signal and noncoherently retransmit a modified version of it to degrade the performance of a receiver (D. Torrieri, IEEE J. Sel. Areas Commun., vol. 7, no. 4, pp. 569-575, May 1989).

In this work, we demonstrate a coherent RF repeater that operates in an open-loop format and thus can be used in either a cooperative or noncooperative setting. The repeater leverages high-accuracy ranging systems (J. Hodkin, et al., 2015 IEEE Aerospace Conference) to provide a low-variance estimate of the distance to the transmitter. This estimate is then used to update a phase shifter on the repeater platform in order to maintain phase coherence with the transmitter when the platforms are moved. The high-accuracy ranging systems use a two-tone waveform to achieve extremely small range variance, but at the cost of large range ambiguity. This two-tone waveform is time-interleaved with a disambiguating continuous wave pulse that occupies a significantly lower bandwidth, leveraging the benefits of both the two-tone and the pulse waveforms to achieve superior ranging performance. These relative-range measurements are used to adjust the phase shifter on the repeater platform to maintain phase coherence when the platforms are moved. The repeater can be used to beamform, amplifying or nulling a signal generated by another platform at a target point.

We will present an overview of the high-accuracy ranging systems concepts and the results from outdoor experiments demonstrating successful open-loop amplification and nulling of an existing communications link with the repeater. To the authors' knowledge, this is the first demonstration of a fully open-loop coherent repeater for cooperative distributed communications.