Demonstration of a Low-Cost Broadband Radio over Free-Space Optics System

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Introduction

Radio over fibre (RoF) systems have successfully been developed to enable the distribution of broadband, multiservice radio signals to distributed antennas [1]. They allow for efficient distribution of radio services in indoor areas where coverage would otherwise be poor. A potential downside of such systems is the need to install fibre infrastructure. This may be overcome by replacing fibre links with point-to-point free-space optical links to create radio over free-space optics (RoFSO) systems. RoFSO systems have already been developed and experimentally verified, but they make use of complex dense wavelength division multiplexing (DWDM), external modulators and EDFA amplifiers [2]. This paper therefore reports a new, simpler and low-cost RoFSO scheme where broadband multiservice radio signals are directly modulated onto a single distributed feedback (DFB) laser diode for short-range transmission. A block diagram of the system is shown in Figure 1.

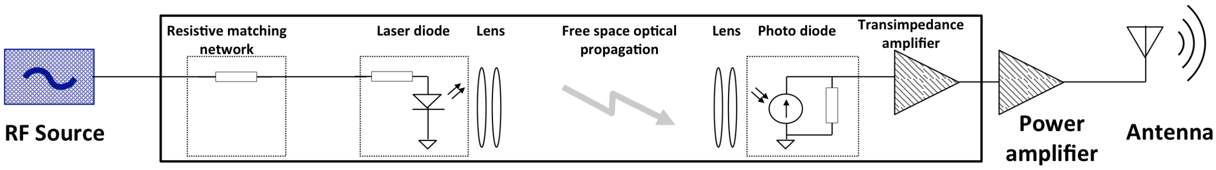

Figure 1. Block diagram of broadband radio over free-space optics link (small signal model)

A low-cost proof of concept demonstration of this RoFSO link has been carried out to illustrate the feasibility of the system. This uses a Mitshubish DFB FU-68PDF laser diode, operating at 1547nm wavelength, and simulates free-space loss using an optical fibre attenuator. A model of the system has also been developed to allow optimisation and exploration of the operating limits. This in turn uses a line-of-sight geometric loss model with 20mm fibre collimators to predict the free-space optical propagation loss [3]. The model predictions closely match the measured values for system noise and gain, as demonstrated by the plot in Figure 2. For an optical source power of 66μW, the link is limited by the laser's relative intensity noise (RIN) for an 868MHz radio frequency (RF) signal. At an optical source power of 10mW, the link becomes limited by shot noise. Similar performance is achieved both for the demonstration system and model over a broadband RF range from 868MHz (for RFID) to 2.4GHz (WiFi).

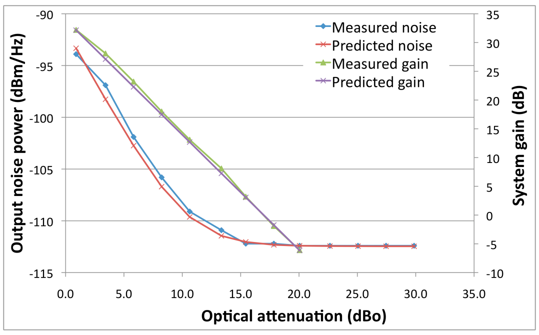

Figure 2. Graph showing measured and predicted output noise power and gain of system for a RIN limited scenario at an RF frequency of 868MHz

To gauge the linearity performance of the system, a plot of modelled and measured SFDR versus length of the free-space link has been produced. The resultant plot is shown in Figure 3. A minimum SFDR of 72-83dB/Hz$^{2/3}$ is required to enable delivery of common wireless services via optical links [4]. It can be seen that the system provides an SFDR of greater than 85dB/Hz$^{2/3}$ up to 50m using low-cost collimators and a half angle beam-width of 0.12°. By reducing the half angle beam-width it is possible to further increase the SFDR at this range.

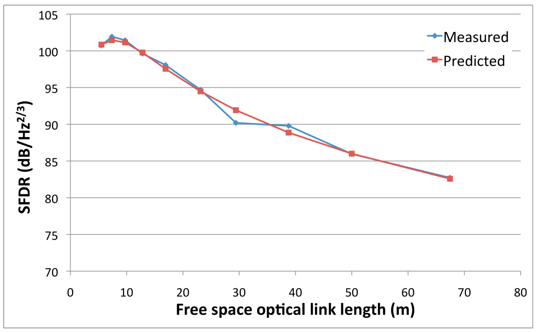

Figure 3. Graph showing predicted and measured SFDR of system for varying link lengths using a two-tone test around an RF frequency of 1GHz

Conclusion

This paper reports a new low-cost point-to-point RoFSO system suitable for multiservice operation. Using a low-power commercial laser source, it is shown to provide an SFDR of 85dB/Hz$^{2/3}$ over a range of 50m. At the conference, further results including the transmission of WiFi traffic over the demonstration system will be reported, indicating the fundamental limits of performance.

References

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