Sectorized Base Station for FSO Ground to Train Communications

Nithin Mohan[1], Mojtaba Mansour Abadi[1], Z. Ghassemlooy[1], S. Zvanovec[2] and R. Hudson[3]

[1] Optical Communications Research Group, Faculty of Engineering and Environment, Northumbria University, Newcastle upon Tyne, UK,
[2] Department of Electromagnetic Field, Faculty of Electrical Engineering, Czech Technical University in Prague, Czech Republic
[3] The Core, Bath Lane, Newcastle Helix, Newcastle upon Tyne

Objectives

A free space optics (FSO)-based wireless technology for use in high-speed trains is proposed, where a sectorized base station using a single laser and multiple single mode fibre apertures is proposed. By doing so the link's geometrical loss is considerably reduced, thus leading to improve signal to noise ratio. The proposed system is numerically simulated and the link performance evaluated in terms of the it error rate

Introduction

Evolution and accessibility of smart-phones has led to a huge demand in the network bandwidth. The ubiquitous use of smart-phones in high speed trains pose a unique challenge in delivering fast internet services on board the trains. In Japan, high speed trains employing WiFi, Wimax and LCX wireless technologies provide internet on board with the average throughput of 1.4 Mbps [1]. In UK, Crosscountry trains have a fixed usage policy, where excessive usage leads to limited access to WiFi by the passengers. Free space optics has emerged as a popular alternative to provide high-speed internet access since it is immune to multi-path propagation and interference from other transmitters, which degrade the system performance as in RF technologies [2]. Implementation of FSO for ground-train communications (GTC) focuses on providing a large coverage area for the BS, which reduces the deployment costs and provides uninterrupted internet service with negligible handover delay. Previous works on FSO systems have provided a experimental validation on GTC. A high data rate (1 Gbps) GTC was proposed in [3], where an acquisition, tracking and pointing (ATP) mechanism based on the beaconing system was used to provide stable tracking and fast handover (i.e., 100 ms) in FSO links for high-speed trains. In [4], a high-speed image sensor based ATP mechanism was used in place of a 2-quadrant photo-diode to detect the beacon signal from the adjacent BS.

Proposed system

Theoretical models in [5], [6] have proposed employ wide optical beams to extend the trackside coverage thereby reducing the number of FSO base stations (BS). FSO links using wide divergence angle laser sources suffer from high geometric losses which may result in frequent link outages.

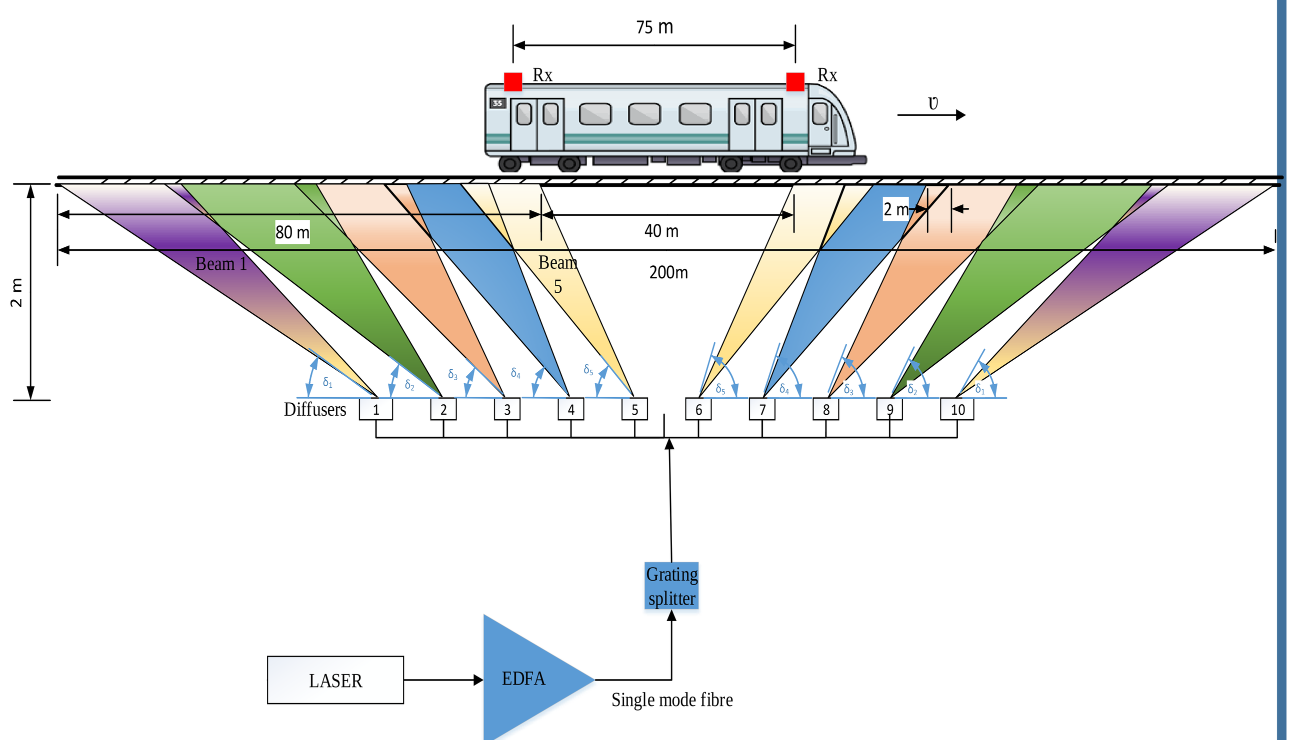

Fig. 1 Sectorised base-station concept for ground to train communications.

To mitigate the effects of geometric loss and increase the coverage length of each ground base station for ground to train communication, multiple laser beams covering the trackside is employed along with deploying large (200-250 mm diameter) receiver lenses on train and on the ground base stations as well. In this scheme a single laser source is used the output of which is amplified using an erbium doped fibre ampler (EDFA) prior to being split into 10 fibre-based transmitter (Txs). Diffusers are use at the end of the fibre-array for illuminating the track (i.e., moving train) Note the spacing between the fibres are 7 cm, and the overlapping areas of the optical beams are 2 m in order to provide seamless connectivity throughout the coverage area of 200 m. As shown in Fig. 1(a) the effective coverage area alone the track is 160 m (i.e., 2×80 m) and with a dead-zone of 40 m. The power budget analysis for ground-train communications is given by :

$$P_{rx}(l_{link}, r) = 10^{\frac{(L_{atm} l_{link})}{10}} \times 10^{\left(\frac{L_{geom}}{10}\right)} \times 10^{\left(\frac{L_{opt}}{10}\right)} P_{tx} \times e^{-\frac{2r^2}{w_R^2}} \qquad (1)$$

where P_{rx} is received power, l_{link} is the link length, P_{tx} is the transmit power for each fibre, L_{geom} is the geometric loss due to the diverging beam, L_{atm} is the atmospheric attenuation in dB/km r is the beam offset from the propagation axis and w_R is the beam waist radius. Using (1) the transmit power for each beam is calculated. For train to ground communication, three equally spaced transmitters are used for train to ground communication as shown in Fig. 2

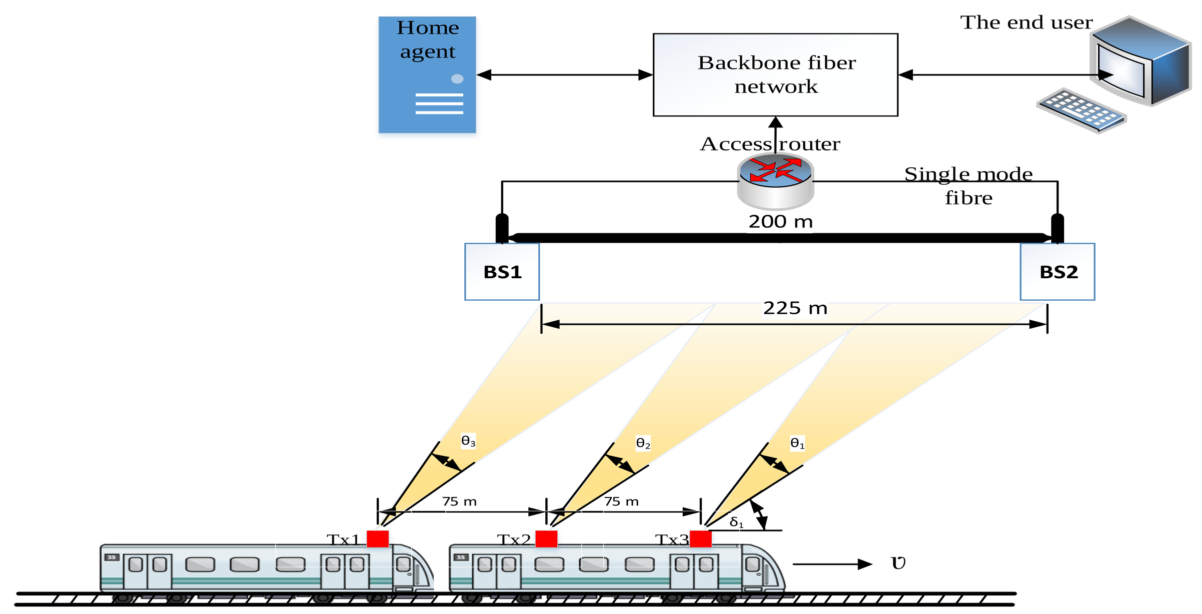

Fig. 2 Train to ground communications

Effect of turbulence

Atmospheric turbulence caused by variations in refractive indices due to temperature variations, change in humidity induces irradiation fluctuations at the receiver causing severe degradation of the signal and can also result in link outage.

The strength of turbulence can be determined by the scintillation index given by [2]:

$$\sigma_I^2 = \frac{\langle I^2 \rangle - \langle I \rangle^2}{\langle I \rangle^2} \qquad (2)$$

where $\langle . \rangle$ denotes the ensemble average equivalent to long-time averaging with the assumption of an ergodic process and I is the optical intensity of the propagating wave in turbulent channel.

Based on (2), the strength of turbulence can be classified as weak fluctuations regime (σ_I^2<1), moderate fluctuations regime ($\sigma_I^2 \cong$ 1) and strong fluctuations regime ($\sigma_I^2 > 1$) . If a receiving aperture is larger than a spatial scale size that produces the irradiance fluctuations, the receiver will average the fluctuations over the aperture and the scintillation will be less compared to scintillation measured with a point receiver [7].

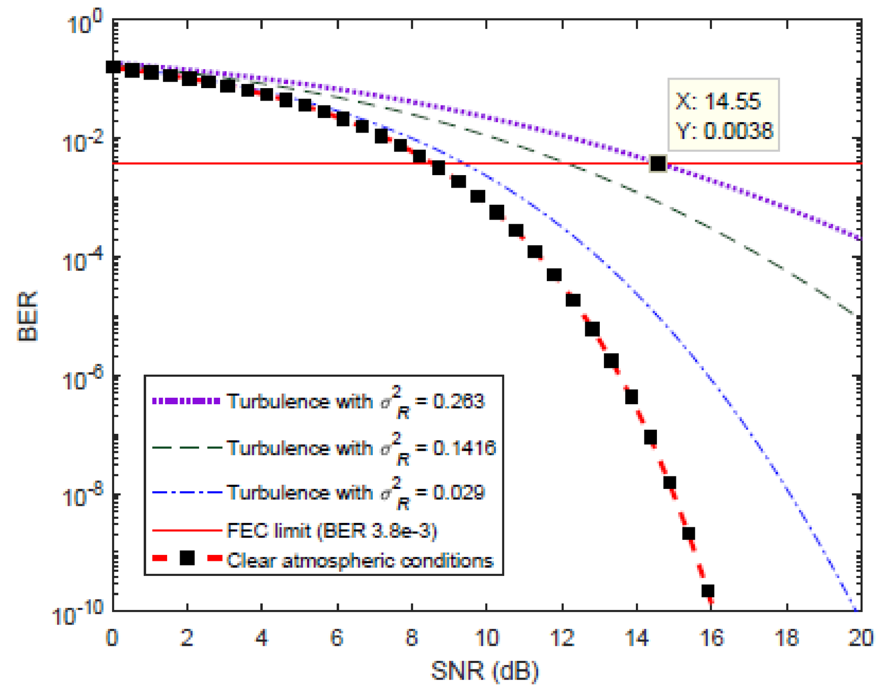

Fig. 3 Average BER for σ_R^2 = 0.263, 0.1416 and 0.029

Numerical simulations have been performed for varying strengths of weak turbulence for a link length of 100 m as shown in Fig. 3. It is observed that the system SNR should be greater than 14.55 to achieve FEC limit. Forward error correcting codes can be employed to improve the BER of the system.

Acknowledgement

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