A Fully Bi-directional 2.4GHz Wireless-over-fibre system using Photonic Active Integrated Antennas (PhAIAs)

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Abstract: A Low cost Wireless-over-fibre system has been demonstrated over 300m of MMF. Throughput and SNR as a function of RF propagation distance are shown and successful streaming of video is achieved over a 10m range.

OCIS codes: (350.4010) Microwaves; (250.7260) Vertical cavity surface emitting lasers
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1. Introduction

There is growing interest in the distribution of microwave and millimetre wave signals over optical fibre networks. The fibre provides a very low loss, wide bandwidth channel for data and will "future-proof" in-building and campus wide networks. The concept has been in use for many years in CATV and mobile phone basestations systems, but these tend to be very high cost, high performance solutions. There is now a requirement for very low cost, medium performance solutions which can be used in pico-cellular networks to efficiently deliver, WiFi, WiMax and mobile signals into buildings and around campus networks[1]. This paper describes one such solution based on the PhAIA concept : this is the intimate integration of photonic devices with antennas [2]. The fact that the photonic device and antenna are highly integrated means that very efficient impedance matching can be achieved which can lead to improved link gain. At millemetre wave frequencies, reduced antenna size could enable full monolithic integration of antennas and photonic devices. PhAIAs will also lead to reduced production and packaging costs. In [2] a partially low lost link was shown, this paper extends this to a fully low cost implementation and shows detailed link characteristics and greatly extends the achievable RF range to 10m. The system is not yet fully optimised in terms of impedance matching and antenna bandwidth and it is felt further range improvements are achievable.

2. Experimental setup for bi-directional link using PhAIAs

Figure 1 shows one of the photodiode PhAIAs. One of the difficulties of working with both photonic and antenna devices is that optical tables are normally required for the photonic devices and these large metal objects can severely effect radiations patterns and antenna performance. Thus a low-cost mount has been developed as shown in figure 1 which allows accurate alignment of the MMF to the optical device, but does not require x-y-z stages to be used. This will enable these devices to be characterized within anechoic chambers as is required for any WiFi device.

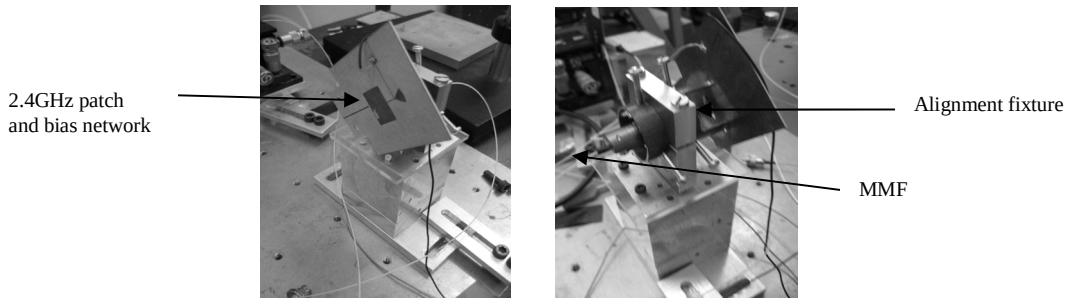

Figure 1 : Portable PhAIA with photodiode (left) Front view, (right) Back view

Figure 2 shows a diagram of two way link using a USB wireless adapter to simulate an access point in a building. There are three main differences between this configuration and that shown in [2]. Firstly this is fully low cost using two 850nm VCSELs and two photodiodes. Secondly there is no RF amplification used here – an important point for any low cost, low DC power system. Finally only one antenna-antenna link is used, this has the effect of increasing the input power to the link and this is main reason why amplification can be removed and the range has increased so

dramatically. It is felt this is a commercially viable configuration where RF power can be tapped off coaxially from an existing access point and fed into a purely coaxial transceiver.

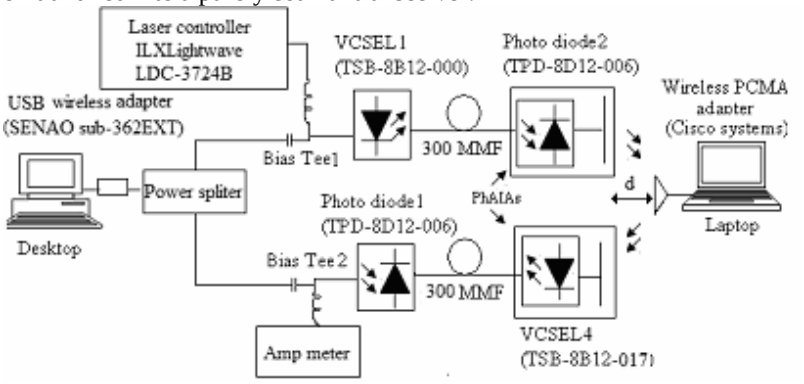

Figure 2 : Diagram of bi-directional link

To achieve this direct RF feeding the external antenna of the USB wireless adapter was removed and a coaxial connection was made to a power splitter as shown in the figure. At the laptop side, the distance between the PhAIA and the wireless PCMCIA adapter (d) was varied from 0.1 to 10 m and the results for throughput and SNR are shown in figures 3 and 4. It was found that at distances greater than 10 m the connection was difficult to maintain. In addition, the bias current of VCSEL1 in the uplink was varied from 4 to 10mA. The Aironet client utility provided with the Cisco Wireless PCMCIA adapter was used to measure the signal strength, signal quality and signal to noise ratio (SNR) and software provided by Signal Processing group in Electrical Engineering, University of Bristol was used to measure the throughput of the link. Figure 3 shows the throughput can be higher than 1Mbps in the range up to 2 m. It can be seen that the throughput cannot be measured for VCSEL bias currents of 4 and 6mA beyond a distance of 5.5 and 6.5 m respectively. However, by increasing the VCSEL bias current to 8 mA it can be seen that throughput measurements can be extended to 10m. If the bias current is further increased the achievable range is reduced, this is most likely due to signal distortion being induced by the non-linear VCSEL L-I curve. Figure 4 shows that reasonable SNR can be maintained to 10m. The set up was then used to stream video across the link and high quality video transmission was achieved to a range of 10m.

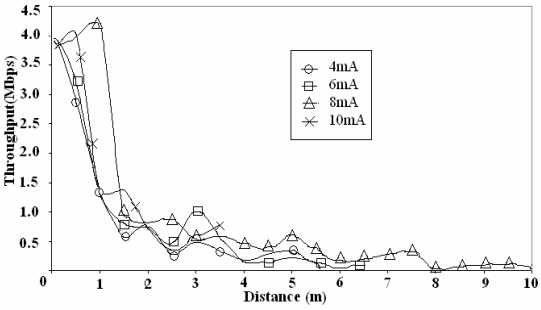

Figure 3 : Throughput vs Distance at different VCSEL1 bias currents

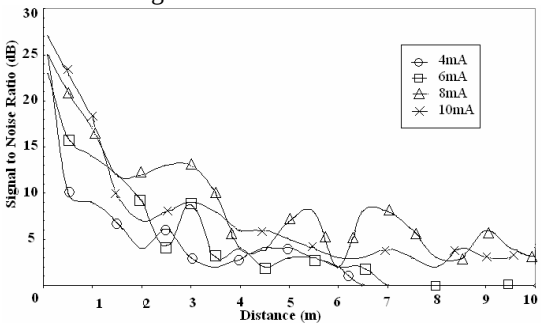

Figure 4 : Signal to Noise ratio vs Distance at different VCSEL1 bias currents

3. Conclusion

A very low-cost wireless-over-fibre link using PhAIAs consisting of low-cost VCSELs and a photodiodes has been demonstrated. Experimental results show that it is feasible to make a Wi-Fi connection between two computers over 300m of MMF using PhAIAs with an RF range of 10m. Trials are now underway using in-building and campus fibre networks to study the system performance under realistic conditions.

4. References

[1] A.Das *et al*,"Design of Low-cost MMF-Fed Indoor Wireless Networks", IEEE Trans. on microwave theory and tech,Vol.54,No.8,Aug, 2006.
[2] M.J. Cryan *et al* "A 2.4-GHz Wireless-over-fiber Transceiver using PhAIAs", Microwave and opt. tech. Lett, vol.48, no.2, pp 233, Feb 2006.