PHOTONIC ANTENNA UNITS CONTAINING BI-DIRECTIONAL AMPLIFICATION FOR TDD AND FDD IN PICOCELL SYSTEMS

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Abstract: Photonically driven antenna units suited for use in a Radio-Over-Fibre pico-cellular distribution systems are presented. The antenna units are intended to contain bi-directional amplification paths serving the GSM, 3G mobile (UMTS) and wireless LAN bands. A design study has been carried out to assess the effects of single or dual antenna solutions in regard of loop gain due to mutual coupling between the antennas.

Introduction

Owing to the rapid developments in wireless communications, the picocell (the smallest of the personal communication cells), requires new technology to support the cost effective growth of mobile telephony and Internet data traffic. Central base stations driving distributed passive antenna units will facilitate this new bandwidth provision and Radio-Over-Fibre (ROF) is a technology proposed to achieve the carrier distribution. The replacement of coaxial cable with fibre is desirable as fibre transmission offers sufficient bandwidth with reduced loss over long distances and decreased electromagnetic interference. Low loss Single Mode Fibre (SMF) is commonly deployed outdoors while more lossy Multimode Fibre (MMF) is often pre-installed in buildings. Unfortunately MMF is not of a quality that lends itself to broadband Radio-over-Fibre. This paper introduces a Photonic Antenna suitable for use in a MMF ROF indoor Distributed Antenna System (DAS). The antenna units house an RF stage (Bi-directional amplification for TDD and FDD) intended to operate at GSM, 3G mobile (UMTS) and wireless LANs band.

The photonic antennas described in this paper consist of Multiband antennas together with Electro Absorption Modulators (EAM). The Photonic Antenna uses Multimode Fibre (MMF) and Vertical Cavity Surface Emitting Lasers (VCSELs) to realise a low cost DAS. However, the use of MMF introduces greater losses to the system than SMF and coupled with poor EAM responsivity (0.15 A/W at 845 nm) [1], the fibre system cell size would be limited to centimetres and would vary depending on the matching of the EAM to the system.

Amplification between the EAM and Antenna is therefore proposed to extend the range of the wireless network. Bi-Directional amplification for both TDD and FDD systems is required to achieve this. To avoid loop oscillation, there is a need to improve isolation between the uplink and downlink paths. For FDD systems, narrow band filters achieve this purpose. For TDD systems, time controlled switches and amplifiers are required. In both systems high isolation between channels of greater than 60 dB is achievable over a limited bandwidth. The importance of this desired isolation would be explained later on this text. However, a system capable of simultaneously supporting FDD and TDD using filters and switches would be complex, expensive and bulky.

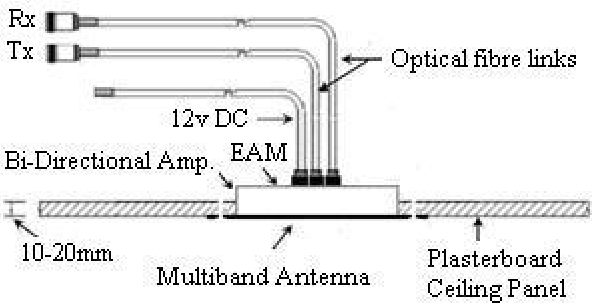


Fig.1, Photonic Antenna

To overcome this problem the Bi-Directional Amplifier system shown in Fig.2, is proposed. The system is composed of two power dividers to form 2 signal paths, one for the uplink and the other for the downlink. Isolators are required to protect the amplifiers from receiving signals in their output port. Available circulators provide 30dB isolation over a narrow band (2.4-2.5GHz), but wider band isolation is offered by dividers (30 to 40 dB over 1.6-2.7GHz). These dividers were purchased from RFLAMBDA, Canada.

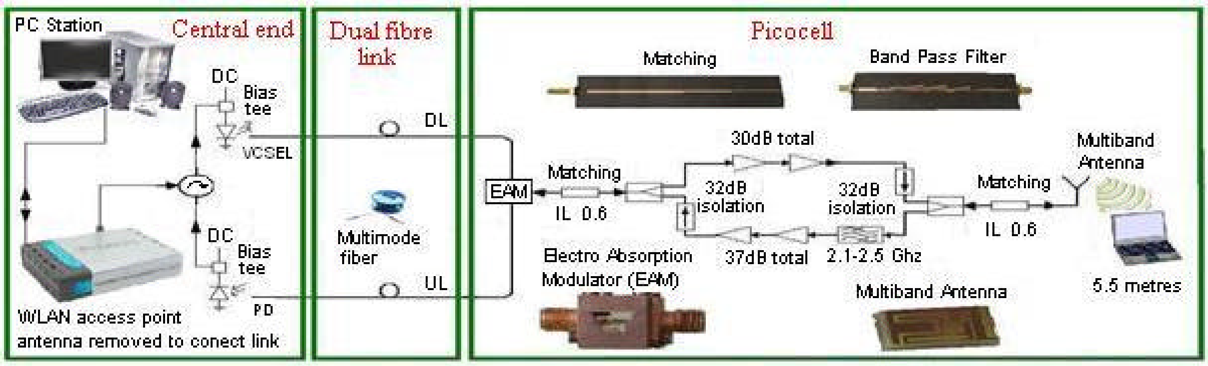
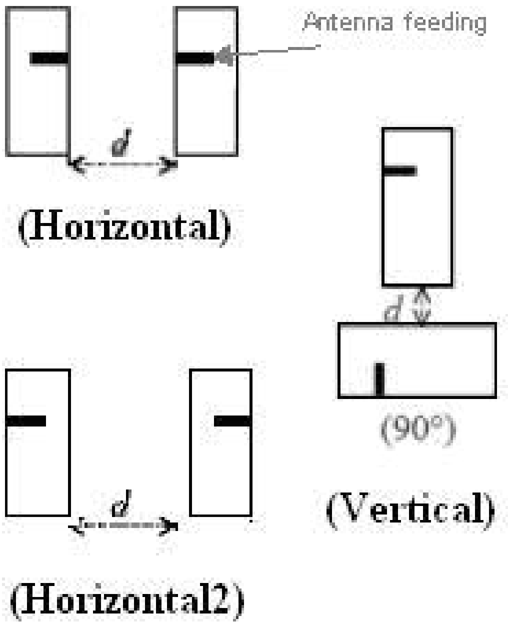


Fig.2, A complete wireless communication system

Systems such as Bluetooth and WLAN have co-channel rejection of 10dB, [2]. This, together with the receiver sensitivity of -82dBm (802.11b) achieves 5.5 metres range. This limits the amplifier gains to be no more than a total of 30dB for uplink and 37 for downlink according to link budget calculations. For the system loop to be stable, the total amplification in both paths should not be higher than the total isolation of the system loop.

A multiband antenna was designed for the system [3]. Unfortunately, multiband antennas cannot be well matched at all bands and reflections from the antenna input will decrease the isolation between signal paths in the up and down link amplifiers. It was therefore proposed to investigate the use of separate transmit and receive antennas to improve the isolation between bands.

An investigation was carried out to establish the coupling between 2 multiband antennas mounted on the same substrate, Fig.3. The graph shows that the isolation between multiband antennas is always below 30 dB when there is 18 cm of separation for the horizontal orientation between the antennas. For the system in Fig.2 with couplers offering 30 to 40 dB isolation and with the EAM well matched to the system, this antenna isolation would be sufficient to avoid oscillation.



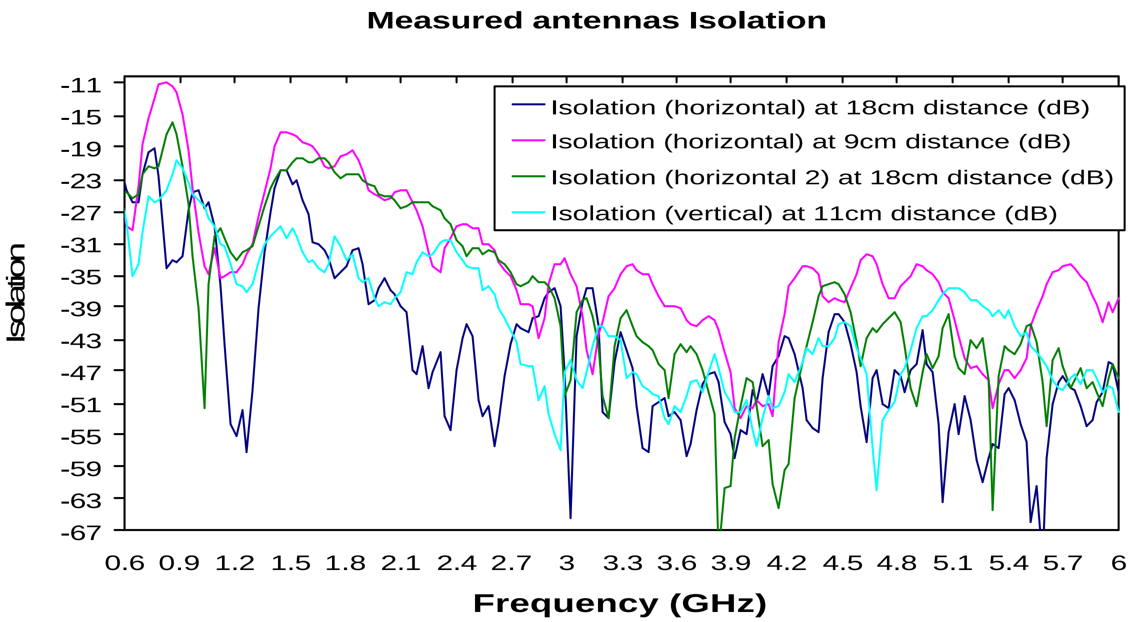


Fig.3, Isolation between two multiband antennas at different orientations

Separate and isolated narrow band antennas could offer better isolation as they can be well matched over their smaller operating bands. Another option would be to increase isolation by incrementing antenna losses in the substrate, even though this will decrease the overall efficiency of the antenna. Dual feed antennas could also be considered as high isolations of better than -40 have been reported [4].

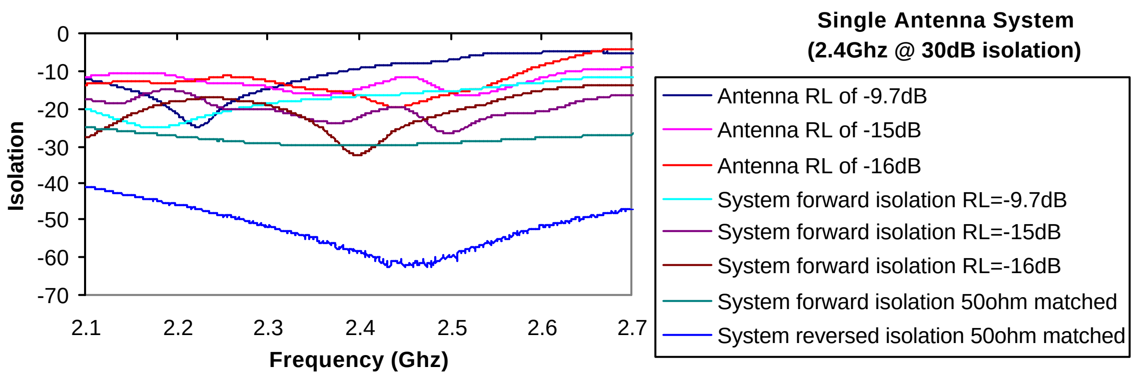


Fig.4, Isolation Return Loss relationship

Figure 4, shows the forward/reverse path isolation offered by the bi-directional loop when a single antenna is connected with various S11 matches. The antenna was connected to a 2.4GHz narrow band system composed of a power combiner/divider of 30 dB isolation and a circulator used as an isolator for the reverse power. Narrowband antennas can provide very high isolation. Figure 4 indicates that antennas with -16dB S11 can maintain the system full isolation of 30dB.

Matching circuits and Band Pass Filters with insertion losses of 1.4 have also been constructed. Matching circuits are very difficult to design for antennas and are often narrow band, BPF rarely provide greater than 10%~15% bandwidth [5]. This can be a limitation for the frequency bands operating in the system.

Conclusion

From a system point of view the replacement of a single multiband antenna and its associated combiners and isolators as in Fig.2, by two separate antennas would offer a greater immunity to oscillation in a system with bi-directional amplifiers.

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