Multi-Standard Wireless Distribution over MMF and Plastic Optical Fibre

Y. Shi[1], H. Yang[1*], J. Herrera[2], E. Tangdiongga[1], and A.M.J. Koonen[1]

[1] COBRA Research Institute, Technical University of Eindhoven, P.O. Box 513, 5600MB Eindhoven, the Netherlands, [*] Corning Incorporated, USA

[2] Nanophotonics Technology Center, Universidad Politécnica de Valencia, Camino de Vera, s/n, 46022 Valencia, Spain

We demonstrated for the first time a radio-over-MMF and PF GI-POF transmission of simultaneous full standard wireless signals for in-building networks. Four types of RF signals (WiFi, WiMAX, UMTS and UWB) covering 1.9 GHz-5.4 GHz frequency band are successfully distributed. All transmission performances in terms of error vector magnitude are compliant with the standard requirements. Up to 1 km transmission distance of MMF and 100 m of PF POF are achieved. This work validates the idea of using a single MMF/GI-POF link as a common infrastructure for in-home networks capable of transmitting both narrow and broad band wireless services.

Introduction

Due to the dramatic increase in demand for wireless services, a low cost, high capacity optical solution to deliver multi-wireless services for in-building networks is a necessity. Employing radio-over-fibre (RoF) technology, this demand can be addressed via an optical fibre backbone for home users [1]. When wireless services reach the home residential gateway, which interfaces the in-home network with access network, a simple platform is recommended to deliver all services providing an easy to install and cost-effective solution for end users. Based on this configuration, multimode fibres (MMF and perfluorinated graded-index plastic optical fibre (PF GI-POF)) are preferred above single-mode fibre due to their large core diameter (≥50um). With the large alignment tolerances in transceiver components and fibre splices, either silica or plastic multimode fibre is attractive for indoor networks as its installation is easy and at low cost. In addition, compared to silica MMF, PF GI-POF offers further advantages such as smaller bending radius (5 mm), better tolerance.

A common and upgradable backbone infrastructure in order to simplify an in-building network is shown in Fig. 1. Wireless services from an access network go to the residential gateway before the indoor distribution. A single fibre is used to provide the universal optical connectivity. Remote antennas are distributed in each room for demanding wireless applications. The coexistence of wireless signals is particularly challenging and interesting to investigate due to the broad frequency range of wireless services and the maintenance of high quality wireless signals (narrow band and ultra - wideband) within available bandwidth.

This paper proposed a new solution for simultaneous distribution of real-world wireless services: Wireless Fidelity (WiFi) (IEEE 802.11[2]), Microwave Access (WiMAX) (IEEE 802.16[3]), Universal Mobile Telecommunication System (UMTS) (3GPP[4]), and Ultra Wideband (UWB) (ECMA-368[5]) signals over a single MMF/POF based optical infrastructure. Wireless frequency band from 1.9 GHz to 5.4 GHz is covered. Main parameters for these wireless signals using in the experiment are summarized in Table I. In our experiment, two different light sources were used to carry wireless data in order to avoid electrical spectrum overlap between UWB and WiMAX at 3.5GHz. Up to 1 km transmission distance of MMF and 100 m of PF GI-POF are achieved with the error vector magnitude (EVM) performance compliance with current radio standards.

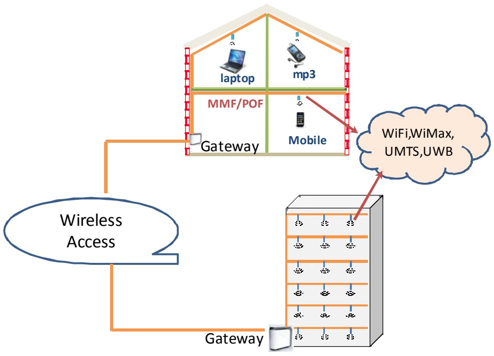

Fig. 1 Wireless for short range networks

TABLE I
PARAMETERS FOR WIRELESS SERVICES

Service	Frequency	Format	Data rate	Bandwidth
UMTS	1.9GHz	QPSK	3.84MSym/s	5MHz
WiFi	2.4GHz	16-QAM	50MSym/s	28MHz
WiMax	3.5GHz /5.4GHz	16-QAM	50MSym/s	28MHz
UWB	3.168-4.752GHz	MB-OFDM	200Mb/s	528MHz

Experimental setup

As shown in Fig.2, a VCSEL at 850nm with output of -4 dBm was directly modulated by WiFi, WiMAX and UMTS data while a DFB laser at 1310nm with output of 8 dBm was externally modulated by UWB data using a Mach-Zehnder modulator (MZM). Standard WiFi, WiMAX and UMTS were generated by vector signal generators (Agilent E4438C) and UWB signal was generated by a WiMedia-compliant UWB transceiver (Wisair prototype). Before transmission, a 50/50 multimode coupler was used to couple 850nm and 1310 nm optical signals to a single fibre (MMF/GI-POF). The input power of the MMF/GI-POF was measured around 0 dBm. The insertion losses of MMF at different transmission lengths of 400m, 1100m and 1500m are 1dB, 1.5dB and 3dB respectively and for 100m GI-POF is 6dB. Various signals were simultaneously transmitted through the fibre before being detected. Due to the large wavelength separation a wavelength division de-multiplexer is not needed at the receiver site. Instead, a manual switch was used with two photo detectors to detect signals at 850nm and 1310nm bands respectively. A performance comparison of various wireless signals was performed by a vector signal analyzer and an UWB analyzer.

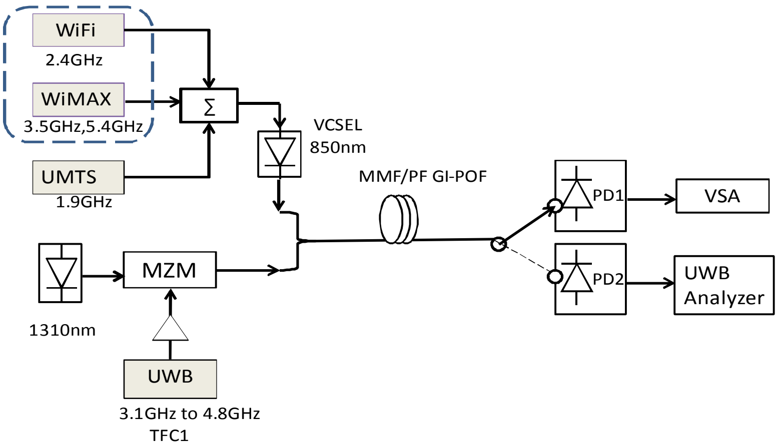

Fig. 2 Experimental setup

Results and Discussion

The system performance for different signals at different frequencies transported over various lengths of MMF and GI-POF is summarised in Fig. 3. The measured EVM is plotted as a function of the received optical power. The powers of the electrical driving signals were all set to -9 dBm.

It is clear to see that the performance of UMTS is the best among five examined signals as presented in Fig. 3 (a). It is mainly due to its low carrier frequency and a relatively low data rate. Less than 1% and 2% EVM penalties can be observed after 1500m MMF transmission and 100m POF transmission respectively. For WiFi signals, as shown in Fig. 3 (b), its performance shows more degradation with increasing fibre length. As shown in fig. 3(c) and (d), WiMAX data with higher carrier frequencies present worse performance than UMTS and WiFi due to the bandwidth limitation. The EVM penalty for WiMAX signal at 5.4 GHz is more than 2% with every increase in transmission lengths from back-to-back to 400 meters as well as from 400 to 1100 meters. The EVM values at this frequency is more than 20% at 100m POF case and thus are not plotted in the figure. In contrast, WiMAX data at 3.5 GHz experience a significant degradation from 400 meter to 1100 meters and to POF case, while negligible

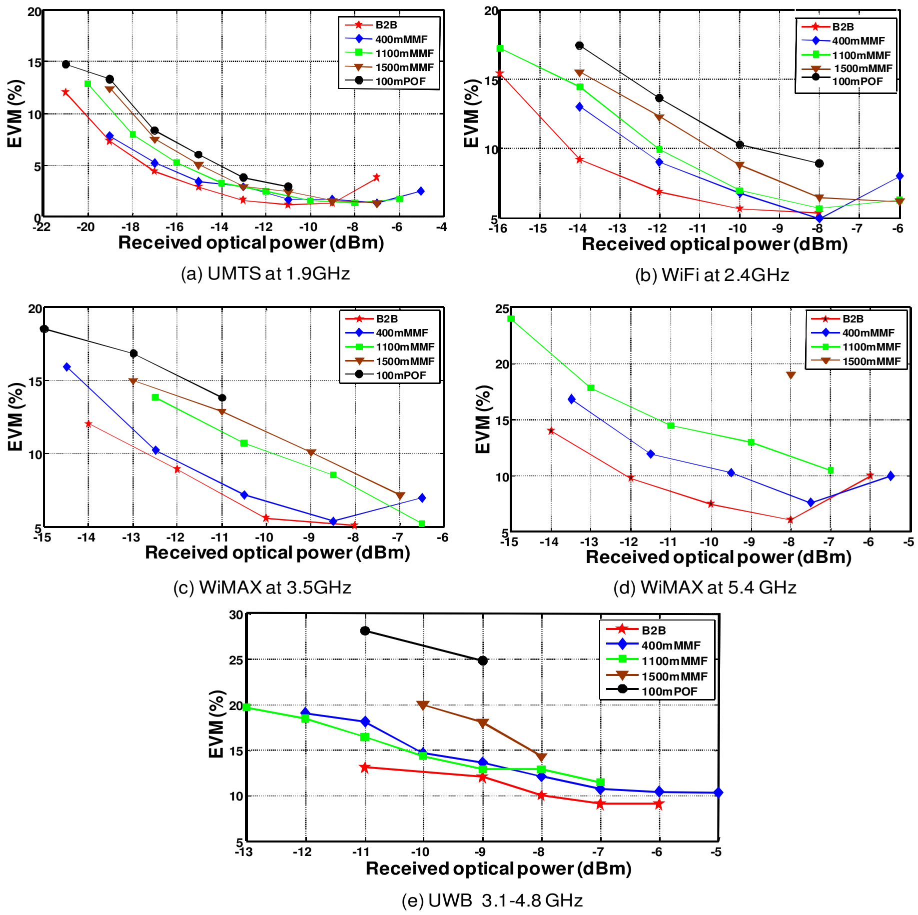

Fig.3 System performance

penalty can be seen between 1100m case and 1500m case. This is probably due to a transmission dip in the frequency response of the 1100m MMF at 3.5GHz. Note that the EVM requirement for the QPSK UMTS and 16-QAM WiFi signals are 17.5% and

11.2% respectively. All measurements of UMTS signals are under this requirement and for WiFi signals, the received power should be not less than -10 dBm for 100m POF and 1500mMMF transmission cases. Although the EVM requirement for WiMAX data is more strict (6% for 16QAM), the performance of WiMAX at 3.5GHz is still compliant with the standard when the transmission length up to 1 km. In this experiment, no electrical amplifier was used for UMTS, WiFi and WiMAX data before modulating the laser and the power of those three signals were set to the same level for fair comparison. So for better performance of WiMAX signals, enlarging the electrical power going to the laser can be considered.

In contrast of narrow band signals, UWB signal occupies more than 1.5 GHz frequency band (TFC1) and its power spectral density is less than -41.3dBm/Hz [5], which means UWB requires more link bandwidth and power budget. In MMF transmission cases, the power limitation dominates the signal degradation where large insertion losses are introduced by the MZM (9 dB) and optical coupler (3 dB). Although the carrier frequency of the UWB signal (centred at 3.9GHz) is relatively high compared to UMTS and WiFi, the system performance still complies with the standard requirement (EVM<15.5%.). But for POF case, the system has to deal with extra large attenuation and bandwidth limitation (less than 8 GHz) introduced by POF. It is clear to see that the penalty between 1500m MMF and 100m POF shows significant increasing.

Considering the system bandwidth, from Fig. 3(a)-(c), it is worth to observe GI-POF doesn't give much influence for narrow band signals with low frequencies. But for high frequency signals, both narrow band wireless services and UWB signal have to counter the bandwidth limitation by POF. On the other hand, since UWB signals are quite signal-to-noise limited, the EVM performance suffers more than narrow band signals. Possible solutions could be using direct modulation instead of external modulation, low noise amplifier and high output laser.

Conclusions

This paper presents a promising solution to distribute real-world wireless services for indoor networks. Five types of RF signal simultaneous transmission up to 1500m MMF and 100m POF has been successfully achieved. This work validates the idea of using a single MMF/GI-POF link as a common infrastructure for in-home networks capable of transmitting both narrow and broad band wireless services, covering 3.5GHz frequency region.

All the performance of the RF signals are in line with the standard requirements if the fibre transmission length is less then 1km. for a typical in-building network, this transmission length is sufficient for a multi-standard RF distribution system to the end users.

References

[1] Koonen et. al., "Optimisation of In-Building Optical Networks", ECOC 2009, Paper P6.15.

[2] IEEE Std 802.11n-2009: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification, 2009.

[3] IEEE 802.16 Standard for local and metropolitan area networks "Part 16: Air Interface for Fixed Broadband Wireless Access Systems", 2009

[4] 3GPP TS 36.800v9.0.0 "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA)", (Release9), 2009

[5] ECMA-368 standard: "High Rate Ultra Wideband PHY and MAC Standard", 2008