

Contents

Acknowledgement	iii
Abstract	iv
Contents	xi
List of Figures	xii
List of Tables	xviii
1 Introduction	1
1.1 Context	2
1.1.1 Evolution of mobile wireless communication systems	2
1.1.2 New extended spectrum	4
1.1.3 Optical wireless communications	6
1.2 Research aims and objectives	8
1.3 Thesis structure	9
1.4 Methodology	10
2 Overview of visible light communications systems	11
2.1 Visible light communications	12
2.2 Transmitters	15
2.2.1 Light-emitting diodes	16
2.2.2 Lasers diodes	20
2.2.3 Modulation formats	22
2.3 Receivers	23
2.3.1 Photodetector-based VLC receiver	23
2.3.2 Image sensor or camera-based VLC receiver	25

2.3.3	Receiver noise	26
2.4	Applications	28
2.4.1	Vehicle to vehicle	30
2.4.2	Underwater communication	31
2.4.3	Positioning	31
2.4.4	Radio frequency restricted areas	32
2.4.5	Industry 4.0	33
2.5	IEEE standards	33
2.5.1	IEEE 802.15.7	34
2.5.2	IEEE 802.15.13-2023	35
2.5.3	IEEE 802.11bb	39
2.6	Polymer optical fibre communications	41
2.7	Conclusions	42
3	Novel hybrid POF/VLC links based on passive interfaces	45
3.1	Introduction	46
3.2	Hybrid POF/VLC links based on a single LED	47
3.2.1	System analysis and design of the passive fixed-wireless interface	47
3.2.2	Transmission results	52
3.3	Hybrid WDM POF/VLC links based on laser diodes	56
3.3.1	System description	56
3.3.2	Transmission results	58
3.4	Real-time MEMS-assisted beam steering for POF/VLC links	61
3.4.1	System description	62
3.4.2	System performance	67
3.5	Hybrid POF/VLC/OCC system based on a single centralized LED	71
3.5.1	System description	71
3.5.2	Experimental setup	72
3.5.3	Experimental results	74
3.6	Hybrid full-duplex POF/VLC/OCC links	78
3.6.1	Image sensor-based downlink	78
3.6.2	Photodiode-based uplink	80
3.6.3	System power budget	81
3.6.4	Downlink channel performance	82
3.6.5	Uplink channel performance	83
3.6.6	Evaluation of system tolerance to misalignment and maximum link distance	85
3.7	Conclusions	88
4	Advanced visible light, applications in positioning and communications	91
4.1	Introduction	92
4.2	High-precision 3D/2D indoor visible light positioning	94
4.2.1	System description and experimental setup	95
4.2.2	Visible light positioning channel	96
4.2.3	Artificial neural network model	97

4.2.4	Experimental results	98
4.2.5	Simulation results	100
4.3	Convergent optical fronthaul link for heterogeneous mmW/VLC wireless access technologies	105
4.3.1	System description	105
4.3.2	Frequency response	108
4.3.3	System optimization	109
4.3.4	Transmission results	111
4.4	Conclusions	116
5	Conclusions and future work	117
5.1	Conclusions	118
5.2	Future work	119
A	OFDM on IM/DD detection systems	121
B	M-QAM data processing	123
B.1	M-QAM signal data processing	124
B.2	BER to EVM relation: thresholds for M-QAM	124
B.2.1	Error probability in M-QAM	124
B.2.2	Error vector magnitude	125
B.2.3	Bit error rate	126
B.2.4	3GPP Error vector magnitude requirements	126
	List of publications	128