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Editorial

Anthony C. Boucouvalas

School of Design, Engineering and Computing, Bournemouth University, Fern Barrow, Poole, Dorset BH12 5BB, UK
Email: tboucouv@bournemouth.ac.uk

Seamless integration of the technology into products which are used in our daily life, products we rely on for necessary common daily tasks, is a trademark of a mature and successful technology.

It is not often that we think of optical wireless communications (OWC) with indoor optical links within remote control units as invisible extensions to our hands used to control our daily home entertainment and other appliances while we sit and relax comfortably in our settee. OWC is a relative newcomer ubiquitous technology entering our homes in a similar manner as other hugely successful and more mature technologies such as motors and microprocessors.

There is wide diversity in the field of OWC applications which span from very short-range (mm range) optical interconnects within integrated circuits for clock distribution, for example, to high-volume ubiquitous consumer electronic products, to outdoor intrabuilding links of a few-kilometre range, and to high-performance unique links of extreme-range (45000 km) intersatellite links.

Prior to the development of fibre optics as the most successful optical waveguide, wireless point-to-point communications using optical pipes with lenses were extensively being studied at Bell Laboratories. The subsequent development and growth of low-cost fibre optic components have further facilitated OWC to complement fibre-optic links.

OWC are in use today in many diverse applications and are tailored to offer low- and very-high-speed wireless links cost effectively.

In common with other technologies within systems, their growth depends on the user problems it successfully solves, techno-economic issues, and developments/breakthroughs in constituent component technologies.

Possible OWC successful applications are numerous, spanning from payment systems, TV remote controls, and infrared data association (IrDA) ports for watches, printers, laptops, and mobile phones to last-mile broadband access, easy-to-set-up TV broadcasting links, intersatellite links, and deep-space links.

For high-volume consumer applications, the requirements and issues are for low-cost, short-range, high-dynamic-range links and robustness to ambient noise, interference, and availability of standards to allow interoperability between products.

The computer industry first pioneered through the IrDA standards for short-range optical wireless data links for computers. The first IrDA standard actually used technology which evolved from the success of the early HP programmable calculators. The main purpose of those standards is to offer low-cost and reliable connectivity between devices.

IrDA has produced standards for 115.2 kbps, 4 Mbps, and 16 Mbps optical wireless links and is currently developing for 100 Mbps and beyond. IEEE 802.11 has also produced a wireless LAN specification for optical wireless PHY.

Indoor remote control and interdevice connectivity has therefore proven to be a fertile market for OWC.

Indoor optical wireless products must comply not only with cost and usability constraints, but also with eye-safety constraints which are now an integral part of the overall system design. Eye safety in all situations is very important, and operating within the safety margins as specified by IEC regulations and other county regulations can be a frustrating and often costly consideration.

Short-range OWC links are usually power-budget limited, and techniques to improve this are widely researched. Indoor links operate in a highly variable ambient noise environment and importantly require receiver operation over a very large dynamic range, from near contact with another user to a maximum specified distance. It is hard to design low-cost receivers and systems of a very high dynamic range and high sensitivity. Most often, delicate engineering compromises come into play.

The understanding of the free-space communication channel (indoors/outdoors) intricacies is essential for the overall system development. Ambient light noise generated by proximity to various types of room lights or the sunlight fluctuates significantly, it also has variable optical and RF spectra and results in variable noise and interference at the receiver. Due to the unregulated nature of the optical radiation, interference could also occur from other products radiating IR such as TV remote controls or IR music headphones, or from neighbouring users, if there is no effective medium access control.

Outdoor terrestrial OWC over a few-kilometer links have been demonstrated at multi-Gbps data rates. In general, they are subject to different challenges since the mode of operation is different and the "channel" is subject to severe weather fluctuations as fog, snow, and rain via light scattering affecting prominently the power budget. Depending on location, links could be influenced by the position of the sun if it comes within the receiver's field of view. The challenge is very much the attainment of 99.999% link availability (lately in hybrid form with microwave links) at very high data rates under all weather conditions and building sway. The links are optimised for fixed locations, and high receiver sensitivity is desired with a narrow optical beam delivered usually by Fresnel lenses or other high-gain and directivity "optical antennas."

Intersatellite and deep-space links, usually of less than 100 Mbps data rate, require very-high-power laser sources and high-sensitivity receivers perhaps operating within a few dB from theoretical capacity limits coupled with top-quality optical lenses and narrowbeam tracking systems. Component operation in vacuum and subzero temperature is normal. In order to extend the OWC link range, fibre-optic amplified transmitters and fibre-optic preamplifier at the receiver, coupled with external optical Mach-Zehnder modulators, advanced power-efficient encoding techniques, forward-error correction, and perhaps coherent receivers, are used.

Forming a network outdoors can be achieved via a series of links used as hops, while indoors in a room LANs can be formed via multiple reflections from walls and ceilings and allow data reception from most locations in the room from any transmitter via diffuse IR. This user-model designs rely on the emitted radiation being diffused from reflections in a uniform manner from walls and ceilings. This is not easily achieved considering reflection losses, and at present, there are a number of future proposals for multibeam diffusers and receiver diversity techniques for improving the performance of such systems without sacrificing too much bandwidth. The cost of such systems is higher and is an important consideration ($50–$400).

Diffuse optical links require more transmit optical power than line-of-sight links. Since optical power is constrained by eye safety, power efficient and bandwidth modulation schemes are desirable and are the topic of intense research. The first two papers in this special issue concentrate on modulation schemes. The first paper presents a novel hybrid differential amplitude pulse-position modulation (DAPPM) which offers better bandwidth and/or power efficiency than PAM, PPM, or DPPM, and the second paper presents a SER and BER analysis of a new hybrid PIM-CDMA technique.

The third paper also studies modulation to jointly cancel the multipath dispersion and fluorescent light noise in IR CDMA systems. The authors show a tenfold improvement in the BER for a given SNR and processing gain due to the adaptive filter.

The fourth paper is a study on developing a transceiver capable of operating in both line-of-sight and diffuse configurations, utilising two-dimensional arrays of IR light-emitting devices and photodetectors.

The fifth paper examines the concept of an optical wireless sensor network using corner cube retroreflectors (CCRs). The sensors are interrogated using an optical beam, the reflection of which from the CCR is modulated by the CCR by the parameter to be measured. The paper examines collective and majority signal decision schemes.

The last paper in this special issue examines the performance of TinyTP, a lightweight TCP protocol over IrDA stacks.

In closing this introduction to the special issue, it remains for me to thank the authors and reviewers for their efforts and contribution in producing this special issue. I hope that you enjoy it and that it could inspire more creative research ideas in the important field of OWC.

Anthony C. Boucouvalas

Anthony C. Boucouvalas graduated with a B.S. degree in electrical and electronic engineering from Newcastle upon Tyne University in 1978. He received his M.S. and D.I.C. degrees in communications engineering in 1979 from Imperial College, where he also received his Ph.D. degree in fibre optics in 1982. Subsequently, he joined GEC Hirst Research Centre and became a Group Leader and Divisional Chief Scientist working on fibre optic components, measurements, and sensors until 1987 when he joined Hewlett Packard (HP) Laboratories as a Project Manager. At HP Labs, he worked in the areas of optical communication systems, optical networks, and instrumentation until 1994 when he joined Bournemouth University. In 1996, he became a Professor in multimedia communications and in 1999 became a Director of the Microelectronics and Multimedia Research Centre. His current research interests span the fields of wireless communications, optical fibre communications and components, multimedia communications, and human-computer interfaces where he has published over 200 papers. He has contributed to the formation of IrDA as an industry standard and he is now a Member of the IrDA Architectures Council contributing on new IrDA standards. He is a Fellow of the Royal Society for the encouragement of Arts, Manufacturers, and Commerce and a Fellow of IEE. In 2002, he became a Fellow of IEEE, for contributions to optical fibre components and optical wireless communications. He is a Member of the New York Academy of Sciences and ACM. He is an Editor of the IEEE Wireless Communications Magazine and IEEE Transactions on Wireless Networks, Associate Editorial Member for the Wireless Communications and Mobile Computing Journal, and Vice Chairman of the IEEE UK&RI Communications Chapter. He is in the Organising Committee of the International Symposium on Communication Systems Networks and Digital Signal Processing (CSNDSP), and a Member of Technical Committees in numerous conferences.