BROADBAND WIRELESS ACCESS USING MILLIMETRE-WAVE OVER FIBRE SYSTEMS

[Invited Paper, Focused Session on Millimetre-Wave over Fibre Systems]

A. J. Seeds

Department of Electronic and Electrical Engineering,
University College London, Torrington Place, London, WC1E 7JE, England.

ABSTRACT

The paper will review technologies for providing broadband wireless access using millimetre-wave over fibre systems. Recent advances in modulated signal generation using optical phase lock loop techniques and in signal detection using optically controlled heterojunction photo-transistors will also be described.

1. INTRODUCTION

Changes in working patterns make it attractive to be able to offer wireless access both within and outside buildings. Whilst the use of diffuse field infra-red access is attractive for within-building applications, problems of scattering/attenuation in fog and foliage obstruction suggest that this is unlikely to prove a reliable technology for outdoor use. Microwave access can offer reliable performance both indoors and outdoors, allowing a single communications interface to be used with substantial gains in simplicity and cost.

Table 1 shows how raw data rate requirements increase in moving from standard telephony to high resolution video systems. The increased data rates coupled with scarcity of allocable spectrum will require the use of much higher carrier frequencies than those in the 0.9 and 1.8 GHz bands currently used for cellular voice and cordless telephone access [1].

Initially, allocations at around 29 GHz may be used for broadband access services with evolution to frequencies in the range 62 GHz to 66 GHz for such systems as the European Union RACE Mobile Broadband System (MBS). The European Union has also allocated spectrum between 40.5 GHz and 42.5 GHz for Multipoint Video Distribution Services (MVDS). Propagation considerations at these frequencies will require base station separations of a few hundred metres at most. The problem of feeding such a large number of base stations and the complexity of base station equipment therefore needs careful attention.

Digital optical fibre systems now carry the bulk of terrestrial long distance communications traffic and work is under way to bring fibre into the local network. The wideband low loss transmission properties of fibre [2] also suggest broadband wireless access architectures where the millimetre-wave signals are modulated onto optical carriers for transport between the base stations and a central station where most of the electronic processing is carried out, yielding a significant reduction in base station complexity. The main technological problems with this approach lie in the generation and demodulation of millimetre-wave modulated optical signals.

2. SOURCES

For intensity modulation schemes the only suitable directly modulated source is the semiconductor laser, and bandwidths in excess of 30GHz have been demonstrated [3]. External modulators can offer reduced dispersion penalties through low chirp operation. Mach-Zehnder interferometric modulators have been realised in both lithium niobate [4] and III-V semiconductor technologies [5] with bandwidths exceeding 50 GHz. However, if it is desired to use standard telecommunications fibre having a dispersion of 17 ps/(nm.km) the dispersion limited transmission distance will be only a few km [6]. The use of laser heterodyne techniques [7] with baseband modulation applied to only one of the laser outputs enables these limitations to be greatly reduced since the dispersion penalty then applies

0-7803-4603-6/97/$5.00 (c) IEEE

Service	Raw Data Rate
Voice (8b/8 kHz/1)	64 kb/s
CD Quality Stereo Audio (16b/44.1 kHz/2)	1.4 Mb/s
Professional Quality Stereo Audio (24b/48 kHz/2)	2.3 Mb/s
Compressed Digital Video (MPEG)	2 - 8 Mb/s
Studio Quality Digital Video (ITU-R 601)	216 Mb/s
Medical Imaging Quality Digital Video (NTT)	650 Mb/s
Studio Quality Digital HDTV	1.08 Gb/s

Table 1: Evolution to Broadband Systems.

only to the base-bandwidth. Such an approach requires either two carefully stabilised narrow linewidth lasers or an optical phase-lock loop (OPLL) to correlate the phase noise between the two lasers. Semiconductor lasers are preferred as sources due to their compactness, efficiency and relatively low cost, but their wide linewidths (typically 5MHz to 50 MHz for commercially available DFB devices) require loops having extremely wide bandwidths and short loop propagation delays [8], which are very difficult to implement. Figure 1 shows a new architecture that we have developed which overcomes this limitation, the heterodyne optical injection phase-lock loop (OIPLL).

A microwave reference signal at the required carrier frequency or one of its sub-harmonics frequency modulates the master laser (ML) producing sidebands one of which is used to injection lock the slave laser (SL). The half wave (H) and quarter wave (Q) beam plates in conjunction with the optical isolators (I), polarising beam splitter (PBS) and non-polarising beam splitter (NBS) combine the master and slave laser outputs on the photodetector which produces the heterodyne electrical output to drive a narrow bandwidth phase-lock loop, ensuring optimum tuning of the slave laser for phase noise suppression. The output from the loop is monitored using a lightwave signal analyser (LSA) and high resolution Fabry Perot Interferometer (FPI). Initial tests of this system using lasers with a beat linewidth of 36 MHz (beyond the limits for reliable operation of a conventional OPLL using bulk optics) have yielded microwave carriers with phase noise better than - 93 dBc/Hz at 100 kHz offset and locking ranges of greater than 20 GHz.

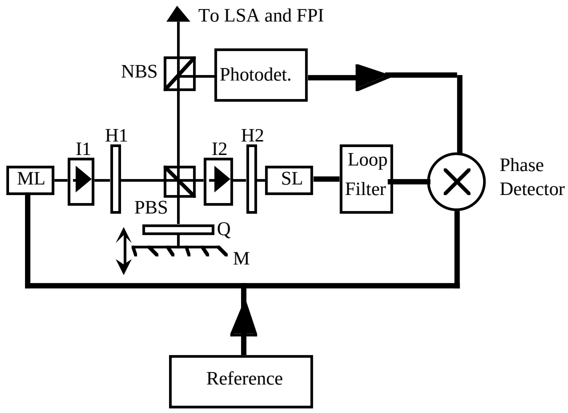

Figure 1: Heterodyne optical injection phase-lock loop.

3. DETECTORS AND DEMODULATORS

For millimetre-wave over fibre links depletion layer photodetectors are preferred and -3dB bandwidths in excess of 100 GHz have been reported [9]. Two-terminal edge-coupled heterojunction bipolar transistor (HBT) detectors having unity current gain frequencies exceeding 30 GHz have also been reported [10] and offer the important attraction of an internal gain mechanism since high gain multi-stage amplifiers are difficult to realise at millimetre-wave frequencies.

The alternative approach of using the optical signal to control or introduce signals directly into microwave devices has been of limited application owing to the very poor optical responsivities of most microwave devices [11]. The geometry of both edge-coupled and normal incidence illuminated HBTs is well adapted to combining high optical responsivity with good microwave performance. In an experiment on opto-electronic mixing of a 3 GHz RF modulated optical signal with a 2.5 GHz electrical local oscillator, using an edge-coupled device [10] we achieved an IF output 7 dB above that obtainable at RF with a 100% quantum efficient photodiode and 14 dB above that expected for such a photodiode combined with a double balanced diode mixer. These results confirm the excellent potential of the HBT as an optically controlled device, which may have significant applications in millimetre-wave over fibre systems.

4. CONCLUSION

Broadband wireless access using millimetre-wave over fibre systems offers the attractions of simplified base station architecture and suitability for both indoor and outdoor use using a common communications interface. Key challenges for the future are to determine optimum component technologies for the proposed systems and to develop volume manufacturing techniques capable of reducing the system acquisition costs to acceptable levels. A substantial contribution to this objective could come from monolithic integration of optical sources and receivers in opto-electronic integrated circuit (OEIC) form.

5. ACKNOWLEDGEMENTS

The author would like to thank his academic and industrial colleagues for their many contributions to the work described here. Special thanks are due to Dr. D. Wake (BT Laboratories) for the supply of DFB lasers and edge-coupled HBTs. Work at University College London has been supported by the United Kingdom Engineering and Physical Sciences Research Council, the European Space Agency, Nortel, the United States Air Force Office of Scientific Research, the United States Army, the UK-Israel Science and Technology Fund and the United Kingdom Ministry of Defence.

REFERENCES

1 A. J. Cooper, “Fibre radio for the provision of cordless/mobile telephony services in the access network”, Electron. Lett., 26, pp. 2054-2056, 1990.

2 A. J. Seeds, “Optical transmission of microwaves” in Review of Radio Science, ed. W. R. Stone, Oxford, New York, pp. 335-360, 1996.

3. R. S. Tucker and I. P. Kaminow, “High frequency characteristics of directly modulated InGaAsP ridge waveguide and buried heterostructure lasers”, J. Lightwave Tech., LT-2, pp. 385-393, 1984.

4. K. Noguchi, H. Miyazawa, and O. Mitomi, “75 GHz broadband Ti:LiNbO3 optical modulator with ridge structure”, Electron. Lett., 1994, 30, pp. 949-951.

5. R. G. Walker in IEE Colloq. on Microwave Opto-electronics, London, 1994.

6. R. Hofstetter, H. Schmuck and R. Heidemann, “Dispersion effects in optical millimetre-wave systems using self heterodyne method for transport and generation”, Trans. IEEE, MTT-43, pp. 2263-2269, 1995.

7. A. J. Seeds, “Coherent techniques in analogue signal transmission”, in Analogue Optical Fibre Communications, ed. B. Wilson, Z. Ghassemlooy and I. Darwazeh, Institution of Electrical Engineers, London, 1995, pp. 33-50.

8. R. T. Ramos and A. J. Seeds, “Delay, linewidth and bandwidth limitations in optical phase-locked loop design”, Electron. Lett., 26, pp. 389-391, 1990.

9. D. G. Parker, P. G. Say and A. M. Hansom, “110GHz high efficiency photo-diodes fabricated from indium tin-oxide/GaAs”, Electron. Lett., 23, pp. 527-528, 1987.

10. D. Wake, D. J. Newson, M. J. Harlow and I. D. Henning, “Optically biased edge coupled InP/InGaAs heterojunction photo-transistor”, Electron. Lett.,29, pp. 2217-2218, 1993.

11. A. J. Seeds, “Microwave opto-electronics”, Optical and Quantum Electronics, 25, pp. 219-229, 1993.