# A 60GHz 120Mb/s QPSK FIBRE-RADIO TRANSMISSION EXPERIMENT INCORPORATING AN ELECTROABSORPTION MODULATOR TRANSCEIVER FOR A FULL DUPLEX OPTICAL DATA PATH

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*ABSTRACT*

A high capacity millimetre-wave fibre-radio system with an elegant return path has been demonstrated for the first time using a number of novel techniques. A 60 GHz carrier signal was generated using a master/slave DFB laser configuration and a remote upconversion scheme was used to provide a fully transparent link for the data signal (120Mb/s QPSK and 20 FM TV channels). Furthermore, an electroabsorption modulator was used as a full duplex transceiver to provide an attractive strategy for the return path.

## INTRODUCTION

High capacity wireless networks of the future are likely to use millimetre-wave radio as the access medium. The bands around 60 GHz have been identified for this purpose due principally to the availability of adequate spectrum; most current systems operate at low microwave frequencies where spectral congestion is a serious problem. For any wireless network based on millimetre-wave radio systems to be viable, the cost of the infrastructure must be much lower than is currently the case. One approach that promises this cost reduction is radio-over-fibre, where radio signals at the carrier frequency are delivered over an optical network to the radio site. By this means, functions such as frequency upconversion and signal processing can be performed at a central office, which allows the radio sites to be very simple and low cost. Further benefits of this centralised approach are that expensive and delicate pieces of equipment can be located in a benign environment and costs can be shared between a number of radio sites.

Optical fibre is well known as a transmission medium with an enormous bandwidth (about 4 THz for the 1.55 µm wavelength region where erbium-doped fibre amplifiers are most effective). A significant limitation to exploitation of this bandwidth using an analogue subcarrier link is the high frequency performance of optical source and receiver devices. In particular, direct modulation of laser diodes is restricted to frequencies below the millimetre-wave band. Several techniques and devices have been developed in research laboratories around the world in recent years in an attempt to overcome this problem.

## OPTICAL MM-WAVE GENERATION

A very promising solution, based on optical heterodyning, consists of a master/slave distributed feedback (DFB) laser arrangement, where the lasers are in a series configuration and each laser contributes a single mode for optical mixing in a high speed photodiode [1]. The layout is shown in figure 1. The noise in the resulting beat signal, at the required millimetre-wave frequency, is largely eliminated by using subharmonic electrical injection in the slave laser to phase lock the modes. This technique is simple to implement and gives high power, high purity signals with wide tunability and high stability. The electrical drive to the slave laser is at a

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

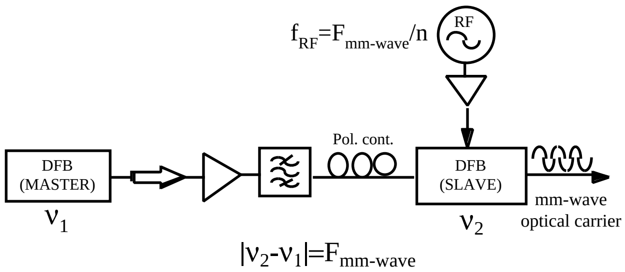


Figure 1. Experimental arrangement of the subharmonic electrically injection-locked master/slave technique.

subharmonic of the beat frequency and generates a series of sidebands. The master laser mode injection-locks one of these slave laser sidebands which results in phase noise cancellation in the output signal. The purity of the resulting mm-wave signal is then derived from that of the electrical drive source, which can have sub-Hz linewidth for example. In our work, 60 GHz signals with a phase noise approaching -100 dBc/Hz at 100 kHz offset and a linewidth of less than 10 Hz have been produced by this technique using the 5th subharmonic.

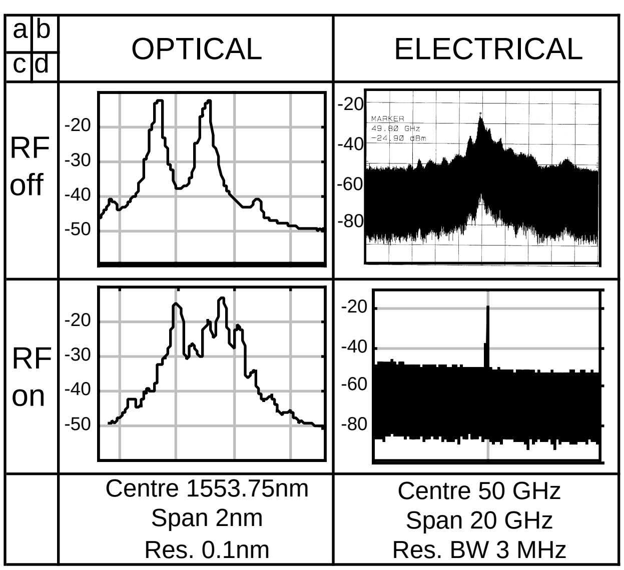


Figure 2. Optical and electrical spectra, measured with and without subharmonic electrical injection to the slave laser.

The optical and electrical spectra measured with and without subharmonic injection are shown in figure 2 for a beat frequency of 50 GHz. The two upper traces show the situation without an electrical locking signal. The electrical spectrum shows an unstable and noisy signal. When the locking signal is applied however, the purity and stability of the mm-wave output signal is improved dramatically. The residual noise level is determined by the underlying phase stability of the synthesiser used to inject the laser rather than by any impairment derived from the laser.

The stability of this technique was investigated by observing the power and purity of the locked beat signal as the master laser frequency was detuned. A detuning of up to 2 GHz could be tolerated without affecting the signal power or purity.

## REMOTE UPCONVERSION

Imposing the data signal onto the millimetre-wave carrier generated by the previously described technique can be problematic. Data signals applied to either of the lasers may lead to instability in the carrier signal depending on their bandwidth or modulation format. Furthermore, data imposed after the output of the slave laser may lead to problems as a result of any fibre dispersion which may be present in the optical link.

One method of providing full transparency and complete modulation format flexibility for a fibre-radio link is a technique that uses a separate optical path for the data signal (using wavelength division multiplexing), where the upconversion is performed at the radio site using a conventional electrical mixer.

In this work, an electroabsorption modulator (EAM) is used as the data path photodetector in such a configuration. This device consists of an intrinsic MQW electroabsorption layer sandwiched by p-type and n-type layers to form a p-i-n structure. For the downstream data path this device acts as a waveguide geometry photodiode which detects the optical signal.

## RETURN PATH

Many papers have been published over the last few years concerning the optical generation of millimetre-wave signals and the transmission of data signals in the downstream direction (from central office to remote access point). There has not been much published work however concerning the return data path. Maintaining the overall simplicity of the remote access point for a bidirectional link is a very important consideration, especially as most applications and services will require some sort of return data path. In this work, we use the EAM as a full duplex transceiver to implement a simple return data path. This technique is based on the remodulation of light not absorbed during the photodetection process in a loop-back type of configuration [2]. This architecture can simplify considerably the complexity of the radio site since no laser (and associated control circuitry) is required for the upstream path. A schematic diagram showing this type of link configuration is given in figure 3.

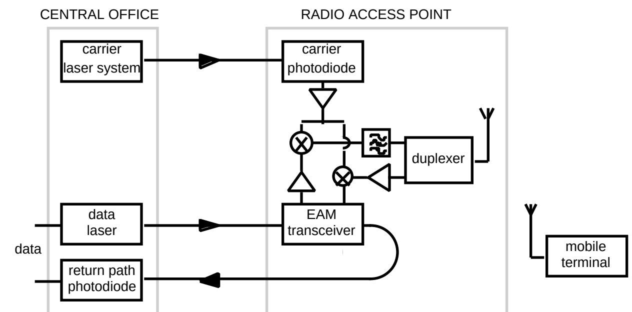


Figure 3. Schematic diagram showing the principles used in this work to implement a simple bidirectional data path.

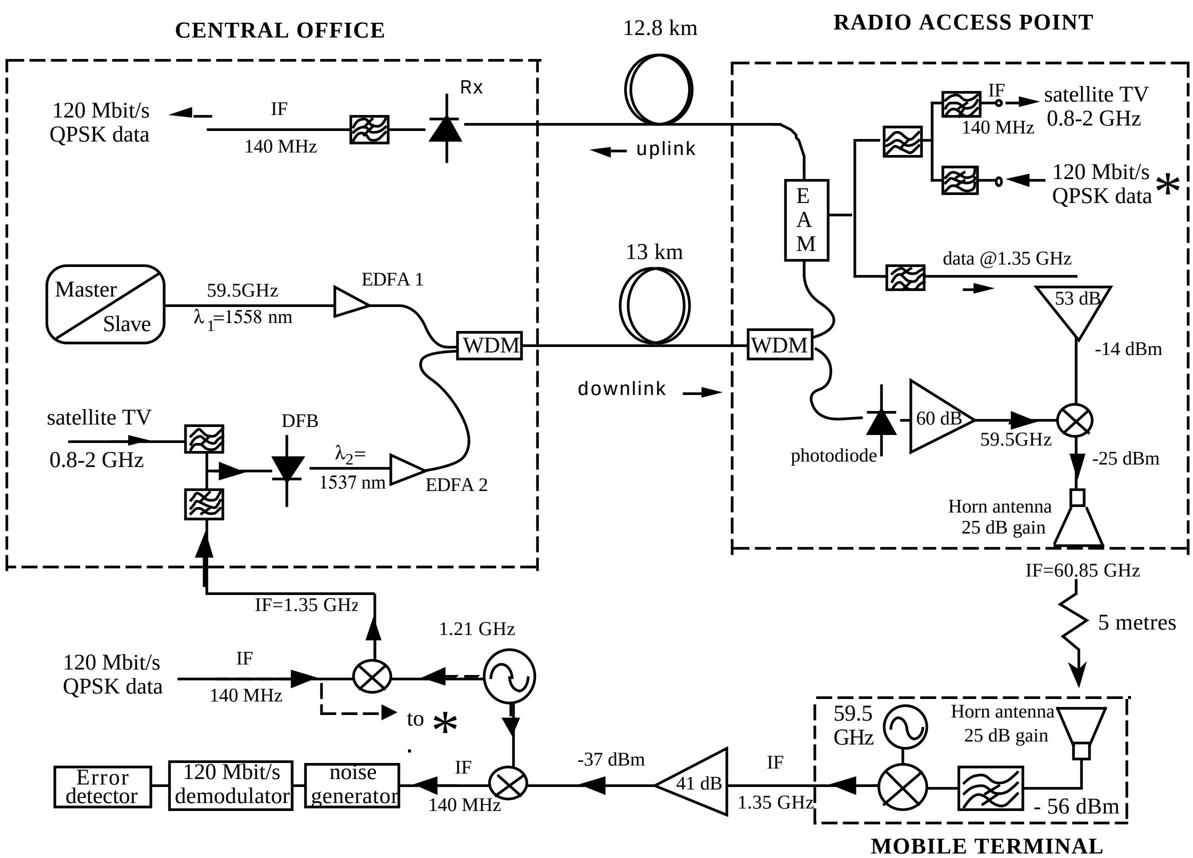


Figure 4. Layout of 60GHz fibre-radio transmission system.

## TRANSMISSION EXPERIMENT

These techniques have been combined in a 60 GHz fibre-radio transmission experiment. The layout of this experiment is shown in figure 4. The downstream signal consisted of QPSK data at 120 Mb/s (upconverted to 1.35 GHz) and 20 FM TV channels from the Astra satellite. This signal was transmitted over 13 km of step-index fibre using a DFB laser with a wavelength of 1537 nm. A pair of DFB lasers was used to produce a 59.5 GHz carrier signal. The slave laser was modulated at 11.9 GHz (5th subharmonic) with a power level of 14.7 dBm in order to phase lock the two optical modes. The downstream signal was remotely upconverted to the 60 GHz band using this carrier signal for onward radio transmission over a free space path of 5 m using a standard gain horn antenna.

The upstream path consisted of 120 Mb/s QPSK data at an IF of 140 MHz and was applied directly to the electroabsorption modulator via a duplexer/multiplexer.

Figure 5 shows the bit-error-ratio (BER) vs. bit energy / noise ($E_b/N_0$) at various stages of the system. BER measurements better than $10^{-9}$ were achieved at all of these stages. There was a 1 dB penalty on the received QPSK signal at the output of the EAM which is attributed to the demultiplexer allowing adjacent FM TV channels through to interfere with the QPSK data signal. For the uplink there was a minimal 0.25 dB power penalty.

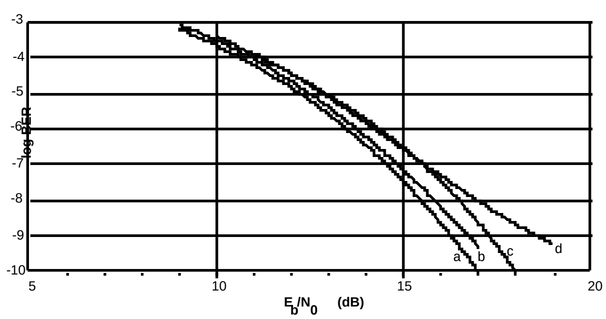


Figure 5. Bit-error-ratio vs. $E_b/N_0$ at various stages of the fibre-radio system.

a back to back
b upstream data path
c downstream data path
d full 60 GHz fibre-radio downlink

## CONCLUSION

High quality transmission has been demonstrated in a fibre-radio experiment at 60 GHz using a number of novel techniques. Carrier signals with a single sideband phase noise of only -100 dBc/Hz at 100 kHz offset have been generated using a master/slave DFB laser arrangement, and remote upconversion has been used to provide a fully transparent data path and to avoid problems associated with fibre dispersion. A return path has been demonstrated using an electroabsorption modulator transceiver which acts as a photodetector for the downstream path and as a modulator in a loop-back configuration for the upstream path. This is the first demonstration of a high capacity 60 GHz fibre-radio system that incorporates an attractive strategy for the return path. The novel techniques used in this system are promising in terms of cost and practicality for widespread deployment in future broadband wireless systems.

## REFERENCES

[1] L. Noël, D. D. Marcenac, and D. Wake, "Optical millimetre-wave generation technique with high efficiency, purity and stability", Electron. Lett., vol.32, pp.1997-1998, 1996.

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