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Recent Developments in Photonic and mm-wave Components for 60 GHz Fibre Radio (Invited Paper)

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1. Introduction

Millimetre-wave fibre radio systems have been an active area of research for many years [1]. The motivation for their development arises from the combination of mobility allowed by picocellular networks and the Tb/s bit-rates achievable on fibre. In particular, as bit-rate intensive services continue to be rolled out, the use of the 60 GHz region will become more attractive. However, there are many challenges in the design of 60 GHz fibre radio systems, ranging from modulation and coding issues, through to choice of architecture, devices and packaging approaches.

A generic fibre radio architecture is shown in Fig.1. Here mobile customer units (CU) communicate with radio access points (RAP) in picocells of diameters of the order of 100 m. The RAPs must be low cost and reliable, the idea being that the expensive mm-wave signal generation takes place at the central office (CO) before distribution over fibre.

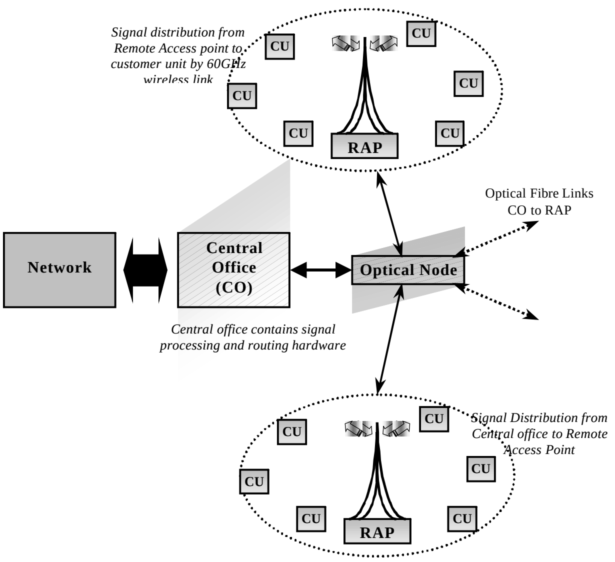

Fig.1 Basic fibre radio architecture. After S.G. Fraser.

2. Fibre radio architectures

Despite the conceptual simplicity of 60 GHz fibre radio, and many experimental demonstrations of it, consensus has yet to be reached on what the best implementation is. A number of architectures are available [2]. There are two broad architectural families (both containing sub-categories), viz.: (1) optical generation and transport of mm-wave signals at 60 GHz; (2) optical transport of the data signals with remote upconversion to 60 GHz at the base stations.

The first approach shifts complexity away from the RAPs, (which in their simplest form contain mm-wave photodiodes, amplifiers and antennas) and to the central office. However, generation of mm-wave signals is difficult given the inability of laser diodes to be directly modulated much beyond 30 GHz and the high cost of mm-wave modulators. This has led to many different approaches, such as heterodyning [3], dual mode lasers [4] and the use of external [5] and electro-absorption modulators [6]. Moreover, chromatic dispersion can degrade performance, which requires more complicated schemes to overcome it such as single sideband modulation [7]. Other dual-mode optical techniques are available including resonant enhancement lasers [8], optical phase locked loops [9], and optical amplifier spectrum slicing [10]. In this method the amplified stimulated emission (ASE) noise from an optical amplifier is spectrum sliced by an arrayed waveguide grating. The two slices generated are then modulated by a Mach-Zehnder modulator biased at quadrature to suppress the carrier. The result is a coherent beat signal. Optical amplifiers are likely to be a necessary component in metropolitan HFR architectures and hence component reuse is deemed economic.

In contrast, the remote upconversion technique uses transport of data over fibre at intermediate frequencies, with the upconversion to 60 GHz being carried out in the base stations. Remote upconversion schemes using both baseband and IF data transmission to the base-station have been demonstrated [11]. A subharmonic image reject mixer is used to multiply the incoming LO subharmonic from the base-station with the data signal. At an RF frequency of 38 GHz bidirectional data-transfer of 622 Mb/s (downlink) and 155 Mb/s (uplink) baseband signals are possible over a 2 metre radio link with a BER below 10^{-6}.

The advantage of remote upconversion of the data alone is that cheap optoelectronic components can be used in the fibre backbone and the chromatic dispersion penalty is mitigated. This is at the expense of having to perform two new operations in the base station: generation of a mm-wave local oscillator and mm-wave mixing. However, it is possible to accommodate these additional functions along with photodetection in a single device to produce an optoelectronic self-oscillating mixer [12]. In this way, one recovers the simplicity and low cost that is required of the

RAP units whilst also retaining the simplicity of using the optical network for data transport alone.

A single pHEMT operating in the highly non-linear knee region was configured as an optoelectronic self oscillating mixer fabricated using MMIC technology [12]. Oscillation at 27.35 GHz, and subsequent frequency doubling, optoelectronic detection and mixing in this single device enabled a very compact RAP. Injection locking was needed to stabilise the oscillator and reduce its phase noise, enabling transmission over 3.75 metres without amplification. This distance was subsequently increased to 38.5 m with 20 dB amplification of a 100 MHz baseband signal. Similar schemes [13] have been implemented with heterojunction bipolar transistors. In this case the separation of oscillation and mixing functions between two devices offers better signal isolation. Alternative mixer configurations such as the cascode configuration have also been sought to improve the mixer conversion gain and bandwidth.

Electroabsorption Transciever

Many fibre radio demonstrators only provide a downlink path (which is suitable for broadcast-type applications). This then obviates the need for optical sources in the RAP, leading to reduced cost and complexity. When a duplex path is required, the bit rates are often asymetrical, which can point towards the use of uncooled laser diodes at the RAP.

However, the electroabsorption transceiver (EAT) offers an elegant single-device solution to a full duplex mm-wave fibre radio system (especially when used in the so-called passive picocell mode). A major difficulty at present is the relatively low mm-wave output power, which requires the use of 60 GHz power amplifiers for some applications.

The EAT is a MQW travelling wave device capable of acting as a simultaneous photodetector and optical intensity modulator using an optical loop back configuration of the carrier. A fully packaged RAP using an EAT has been demonstrated [14]. With the addition of integrated microoptics, temperature stabilisation and two port RF capability to the initial demonstrator the problems associated with poor RF isolation appear to have been resolved. Performance indicators of a bit error rate $< 10^{-9}$ for simultaneous DPSK data transmission at 155 Mb/s validate this technique. However, the data is still transmitted to the EAT as a DSB signal, the justification being made that a Bragg grating can be used for dispersion compensation.

A far more elegant solution uses the inherent nonlinearities associated with electroabsorption modulators to upconvert a 60 GHz beat signal. The system combines the advantages of heterodyning and remote upconversion since data is transmitted at an IF to the upconverting EAT (EATX). An RF output of -30 dBm is now achievable over 27.5 km of fibre.

3. Conclusions

A review of 60 GHz fibre radio architectures has been presented, with particular emphasis on the remote upconversion approach and the electroabsorption transceiver.

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