

Long range millimeter wave wireless links enabled by traveling wave tubes and resonant tunnelling diodes

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Abstract—This paper describes a new project to realize a high data rate point to point wireless system above 150 GHz. The upper end of the D-band spectrum is used (151 -174 GHz) for full duplex transmission. The aims it to enable a full fiber on air with more than 1 km range to provide up to 45 Gb/s data rate. The system consists in a transmitter using a directly modulated Resonant Tunnelling Diode (RTD) oscillator and powered by novel traveling wave tubes (TWT).

Keywords—millimeter waves, D-band, links, wireless, TWT, RTD, Point-to-point, capacity

I. INTRODUCTION

The congestion of existing mobile networks, the crucial role of data in the fourth industrial revolution and new data-hungry applications such as augmented reality, real-time remote medicine, car-to-car communications imply a revolution in the distribution of internet beyond the fibre. It is predicted that videos will account for 75% of the full mobile traffic by 2023 and, by 2021, PCs will account for only 25% of traffic [1]. This new scenario requires high complexity and densification of networks both for mobile and fixed access, with very high data rate backhaul [2]. Multi-gigabit per second (Gb/s) data rate wireless distribution is emerging as the most affordable solution to satisfy data demand and complement fibre, that often has high deployment costs. The millimetre waves (mm-waves) portion of the spectrum offers the wide frequency bands needed for multi-Gb/s transmission. Presently, most of the available bands below 100 GHz are already used. Point to point (PtP) links up to E-band (71-76 GHz, 81-86 GHz) are in the market. Following this move up in frequency, the need for higher and higher capacity can be solved. Millimeter-waves above 100 GHz, where more than 100 GHz of fragmented frequency bands are still not exploited, can support tens of Gb/s, as demonstrated by the research in solid state transmitters up to 400 GHz [3, 4]. In particular, the D-band (141 – 174.5 GHz), with a total of 28 GHz divided in three sub bands, is attracting the interest of big manufacturers and the attention of the main standardization and regulatory bodies, OFCOM, FCC (US), CEPT (Europe), ETSI [5] for paving the way for its commercial exploitation

II. CHALLENGES

Above 100 GHz, the high atmosphere and rain attenuation and the low transmission power of solid-state amplifiers, make it arduous to build wireless links with adequate range and with the 99.99% availability required by telecom operators, unless very simple modulation schemes are used due to the sharp reduction in signal to noise ratio (SNR) with

distance. That prevents the use of high-order modulation schemes (e.g. 64 QAM - quadrature amplitude modulation) or higher. For instance, below 100 GHz, E-band links are adverted to reach theoretically 10 Gb/s data rate with 2 GHz bandwidth, but probably in clear sky. If 99.99% availability, required to operate in common ITU rain zones, is considered, a substantial reduction of performance is expected. In the case of D-band, the total link losses (ITU zone K, 42mm/h rain) at upper frequency (175 GHz), for 1 km distance, are about 160 dB, against e.g. 130 dB at 28 GHz. A PtP link needs about 40 dBm (10W) saturated transmission power for 64 QAM. No solid-state power amplifier (PA) can provide this high power. GaN PAs at 100 GHz reach 30 - 32 dBm. D-band InP technology PAs could reach 16 -19 dBm [6]. Therefore, the exploitation of mm-wave spectrum above 100 GHz needs a breakthrough in transmission power.

III. D-BAND POINT TO POINT

The DLINK project aims to demonstrate the first D-band wireless link, unprecedented data rate up to 45 Gb/s, over 1 km distance, with 99.99% availability, in ITU zone K, for high capacity wireless networks (Fig.1). It will be built by integrating for the first time RTDs (Resonant Tunnelling Diodes) and TWTs (Traveling Wave Tubes) to exploit their complementarity in a novel mm-wave system.

A. System

DLINK system consists of two front ends, one for transmission in the Upper Band with receiver in Lower Band, the second, for transmission in Lower Band with receiver in Upper Band (Fig.2). Each front end includes one vector

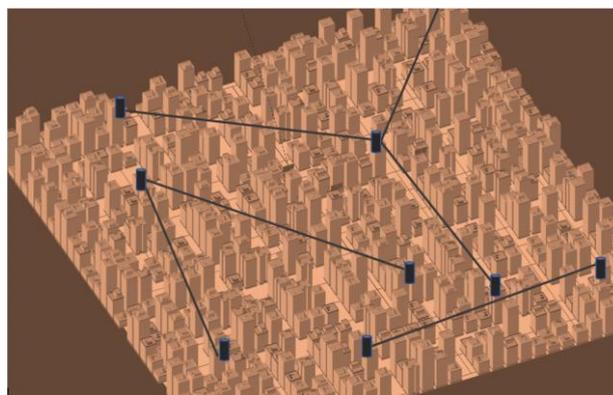


Fig. 1. DLINK concept

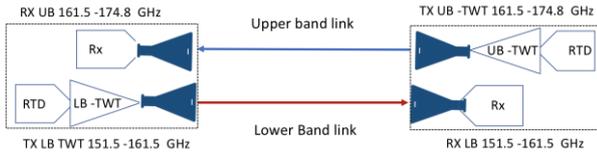


Fig. 2. DLINK system schematic

modulator, one RTD, one TWT, and one receiver. Antennas with about 38 dBi gain will be used. Two novel TWTs, one in 151.5 – 161.5 GHz band and one in 161.5 -174.8 GHz band, for each front end, will be designed and built. The two front ends covering the 20 GHz useful bandwidth will provide for the first time a wide band link in FDD, for long distance, for new insight in D-band propagation.

B. Specifications

The target is to provide fiber data rate level wireless for more than 1 km, exploiting the wide frequency band above 150 GHz.

Ten 1-GHz channels will be considered. If 64 QAM 5/6 is assumed, each channel can provide about 4.5 Gb/s data rate, for a total 45 Gb/s.

C. D-band Travelling Wave Tubes

Travelling Wave Tubes (TWTs) are wide band vacuum electronic amplifiers widely used in microwave communications. A TWT (Fig. 3) is made by an electron gun, a slow wave structure (SWS), a collector, a magnetic focusing system and vacuum RF windows to seal the flanges. The electron gun generates an electron beam with given current and voltage, confined by the magnetic system along the SWS. The SWS permits the transfer of energy from the beam to the input RF fields, by slowing down the field phase velocity close to the speed of the electrons. This mechanism permits to achieve multi-Watt power at mm-waves making TWTs the only solution for mm-waves high power amplification. Helix SWSs, typical of microwaves, have excellent performance, but are not feasible above 70 GHz due to the small dimensions required. Due to high cost and technology challenges, TWTs above 100 GHz are not available in the market and only a few prototypes have been built [7]. The objective is to build low cost TWTs based on the double corrugated waveguide, already demonstrated easy to build by conventional CNC machining and with good electrical performance [8,9].

D. Resonant Tunnelling Diodes

Resonant tunnelling diodes (RTDs) are the fastest electronic devices with demonstrated frequencies of up to 1.98 THz [10]. State of the art RTD based transmitters include 2 mW, 15 Gbps at W-band using on-off keying (OOK) and amplitude shift keying (ASK) [11] and 1 mW with 110 GHz modulation bandwidth at 260 GHz [12]. The fastest reported wireless data rates using RTD based transmitters include 34 Gbps at 500 GHz using single channel and 56 Gbps using dual channel links [13]-[14].

On this project, we are developing D-band RTD transmitters with integrated vector modulators as TWT drivers. The use of a higher order modulation scheme such as quadrature amplitude modulation (QAM) is crucial to meeting the target data rates. To do this, very low-phase noise oscillators (< -90 dBc/Hz at 100 kHz offset and < -110 dBc/Hz at 1 MHz offset) are needed and are being developed. A key

advantage of this approach is the lack of a mixer and an amplifier from the transmitter, and this further enhances the low phase noise oscillator properties required for QAM.

At the heart of a vector modulator is a Lange coupler in a reflection topology with PIN diodes or FETs acting as switches on the coupled and direct ports [15]. Such a modulator which employs InP-based InGaAs PIN diodes [16] is being developed on this project at D-band. Since both RTDs and PIN diodes can be realised from the same InP-based material system, therefore through hetero-epitaxial integration (Fig.4) the monolithic integration of the modulator and transmitter will be implemented. Thus, the ultimate goal is the demonstration of an InP-based RTD/PIN diode technology as a low cost wireless transmitter technology, and one which can be used to drive a TWT.

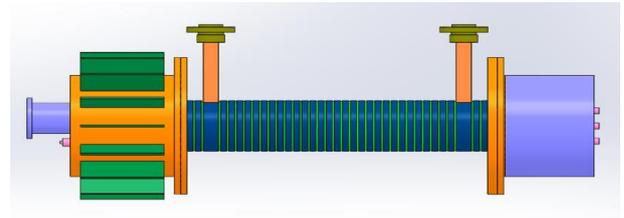


Fig. 3. Traveling wave tube

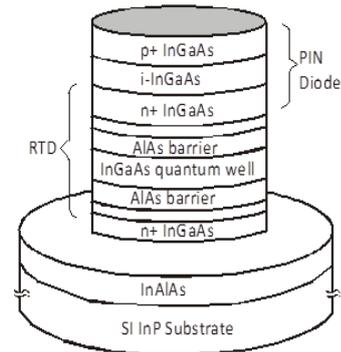


Fig. 4. Resonant tunnel diode (RTD) and PIN diode

IV. CONCLUSIONS

The availability of the high capacity point to point links will allow to connect sections of networks where the fiber cannot be deployed. The DLINK project aims to produce innovative front end at D-band to exploit the wide band to transmit multigigabit data rate. The components of the DLINK system are in advanced design stage.

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