TWTs for Point to Point D-band Wireless Links

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Abstract: *A new project to realize a point to point wireless system above 150 GHz with multigigabit per second data rate is in progress. The upper side of the D-band (151 -174 GHz) offers about 20 GHz with 3 GHz forbidden band for full duplex transmission. The aims it to enable fiber on air capacity with more than 1 km range to provide up to 45 Gb/s data rate. The wireless system works in Frequency Division Duplexing and consists of two front-ends, each of them with a transmitter powered by novel traveling wave tubes (TWT) fed by a directly modulated Resonant Tunnelling Diode (RTD) oscillator. Two TWTs are designed using the double corrugated waveguide at 151 – 161.5 GHz and 161.5 – 174.8 GHz.*

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

Introduction

Mobile traffic is increasing at a rapid pace. Videos will account for 75% of the full mobile traffic by 2023 [1]. This new scenario requires transport of high data traffic, supported by multigigabit data rate links [2]. Fiber in principles provides the needed data rate but has often unsustainable deployment costs and environmental obstacle to be deployed. Multi-gigabit per second (Gb/s) data rate wireless distribution is considered an affordable and flexible solution for backhaul.

Millimeter-waves above 100 GHz offer more than 100 GHz of fragmented wide frequency bands able to support tens of Gb/s [1 - 4]. The D-band (141 – 174.5 GHz), with a total of 28 GHz divided in three sub bands, is already under investigation by manufacturers and has been already regulated (OFCOM, FCC (US), CEPT (Europe), ETSI) for its future commercial exploitation.

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. The use of very high gain antennas with more than 40dBi is needed. However, it is arduous to guarantee 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 and attenuation. That prevents the use of high-order modulation schemes (e.g. 64 QAM - quadrature amplitude modulation) or higher.

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. To enable a PtP link 1 km long, it is needed 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 provide 16 -19 dBm [6]. Therefore, the exploitation of mm-wave spectrum above 100 GHz needs a breakthrough in transmission power, provided by Traveling Wave Tubes.

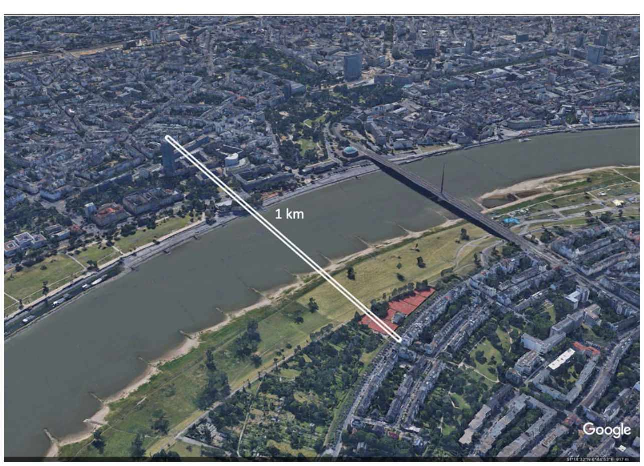

Fig. 1. DLINK concept (Dusseldorf, courtesy of Google Earth)

D-band point to point

The DLINK (D-band Wireless Link with Fibre Data Rate) project aims to demonstrate the first D-band wireless link, with data rate up to 45 Gb/s, over 1 km distance. This distance is a network requirement, e.g. in case of crossing areas where the fiber is not deployable (Fig.1). The link specifications are dimensioned for 99.99% availability, up to ITU zone K, that cover most of the region of deployment Ten 1-GHz channels will be allocated. Each channel will support about 4.5 Gb/s data rate, for a total 45 Gb/s.

DLINK is based on the integration for the first time of RTDs (Resonant Tunnelling Diodes) and TWTs (Traveling Wave Tubes) in a novel mm-wave front-end. RTD are the fastest electronic devices with demonstrated frequencies of up to 1.98 THz [5]. The advantage of using an RTD is the lack of a mixer and an amplifier from the transmitter, with improvement of low phase noise oscillator properties required for QAM transmission.

DLINK system is based on FDD (Frequency Division Duplexing) radio transmission over 20 GHz bandwidth, split in two sub-bands, 151.5 – 161.5 GHz and 161.5 -174.8 GHz.

To enable the FDD, two front ends are needed, one for transmission in the Upper Band (161.5 -174.8 GHz) with the receiver in Lower Band (151.5 – 161.5 GHz), the second, for transmission in Lower Band with receiver in Upper Band (Fig.2). Each front end includes one vector modulator, one Resonant tunnelling diode (RTD) powered by a TWT, and one radio receiver.

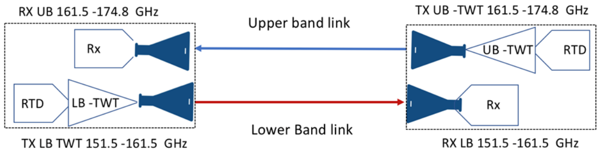

Fig. 2. DLINK system schematic

Antennas with about 38 dBi gain will be provide the directivity with a relative low angle for easy alignment. Two novel TWTs, one in 151.5 – 161.5 GHz band (Lower Band) and one in 161.5 -174.8 GHz band (Upper Band), for each front end, have been designed and are in fabrication phase.

D-band twts

TWTs above 100 GHz are not yet available in the market and only a few prototypes have been built [6, 7]. The objective is to design and build low cost TWTs suitable for the wireless market. The main elements of the TWT cost, excluding the assembly process, are the beam optics, the slow wave structure and the high voltage power supply. Regarding the SWS, the short wavelength at D-band poses fabrication difficulty for the SWS. The double corrugated waveguide (DCW) was already demonstrated easy to build by conventional CNC machining and with good electrical performance [8]. The two TWTs are designed with the same topology using a DCW. The beam voltage is set at about 14kV with 70 mA beam current. A PPM system with 0.6 T magnetic field is used to confine the electron beam. Each TWT has two SWS sections separated by a sever. WR5 flanges are used for the input and output ports.

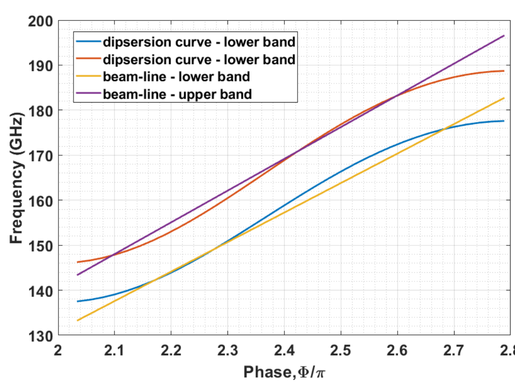

Fig. 3. Dispersion and beam line for the two D-band TWTs.

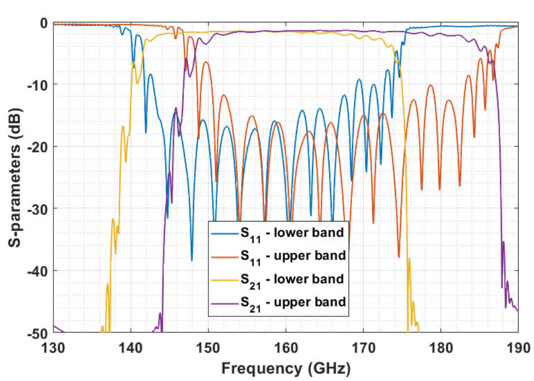

Fig. 4 S-parameters of the two TWTs

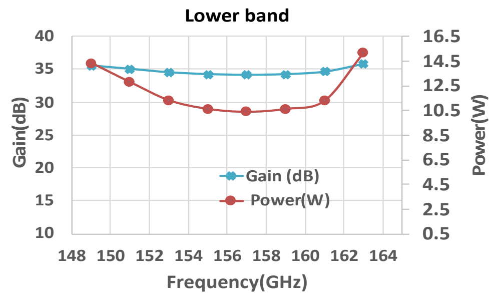

Fig. 5 Gain and output

Figure 3 shows the dispersion curve with superimposed the beam line for the Upper and Lower band TWTs. Figures 4 shows the S-parameters for the two TWTs. It is notable the wide band behavior and the good matching. The gain and output power for the Lower Band TWT are shown in Fig.5.

Conclusions

The availability of the DLINK high capacity point to point links will allows 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 parts of the DLINK TWTs are in advanced design and fabrication stage.

Acknowledgment

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