# Terahertz-based ultra-high bandwidth wireless access networks

terapod

*TERAPOD is a research project supported by the European Commission through Horizon 2020 under Grant Agreement 761579.*

## TERAPOD project newsletter #2

*Nov 2018*

**Welcome to the second TERAPOD project newsletter!**

This second newsletter includes the following items:

- *Schottky barrier diode devices from ACST*
- *A record-breaking THz bridge at UCL*
- *THz device characterisation kit at NPL*
- *Dell-EMC perspective on TERAPOD use cases*

*More info is available on the project website*
*www.terapod-project.eu*

## 2nd Towards THz Communications workshop

**Save the date!!**

The ICT-09-2017 Cluster will be organising the 2nd Towards THz Communications Workshop with the support of the EC.

*THU 07-Mar-2019*

*Albert Borschette Congress Centre Rue Froissart 36, 1040 Brussels, Belgium*

The agenda will be announced shortly on the workshop webpage: http://terapod-project.eu/events/ec-thz-workshop

## ICT-09-2017 Cluster booth at EuMW 2018 in Madrid

EuMW2018 PASSION FOR MICROWAVES


Five projects from the Cluster (TERAPOD, DREAM, EPIC, TERRANOVA and ULTRAWAVE) were represented at a common booth at European Microwave Week 2018 (25-27 Sep-2018; Madrid, Spain). It was a great opportunity to present the related THz and Beyond 5G topics to a highly relevant audience and build links between the projects.

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Waterford Institute of Technology · Technische Universität Braunschweig · VIVID COMPONENTS · VLC PHOTONICS · ACST Technology Solutions for Terahertz Electronics · NPL National Physical Laboratory · DELL EMC · UCL · INESCTEC · University of Glasgow · bay photonics

# TERAPOD mixers and transceivers

The communications links at 300 GHz envisaged in TERAPOD require a new generation of transceivers and mixers. Fig. 1 shows a 300 GHz transceiver developed at ACST which features a 300 GHz transmitter and also a 300 GHz receiver which is intended for frequency-modulated continuous-wave (FMCW) radar applications and imaging. This technology will be developed in the scope of the TERAPOD project.

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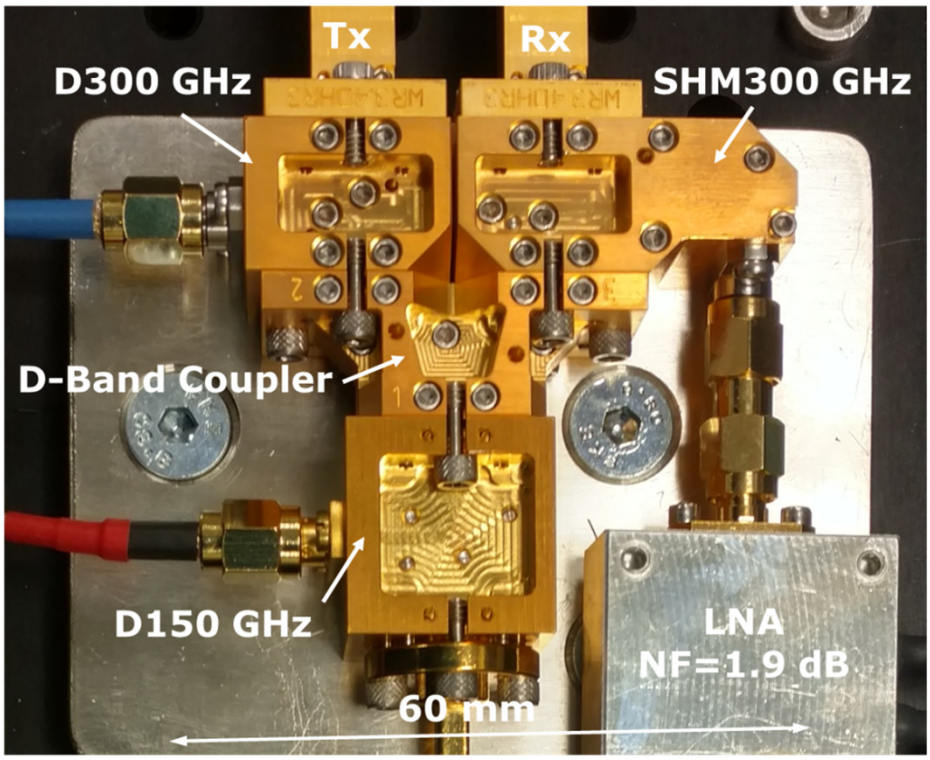
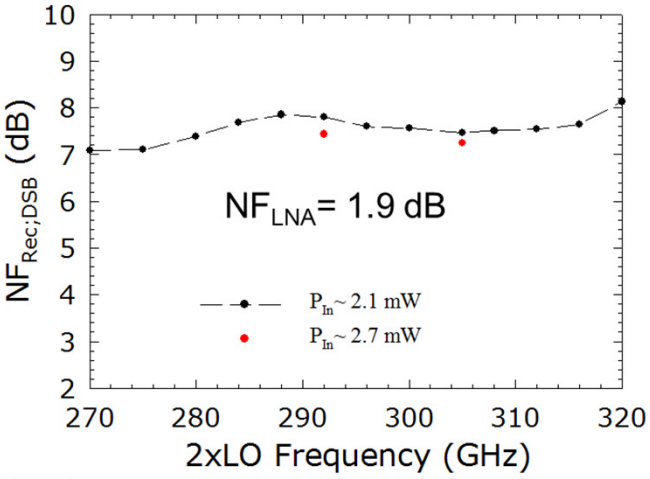
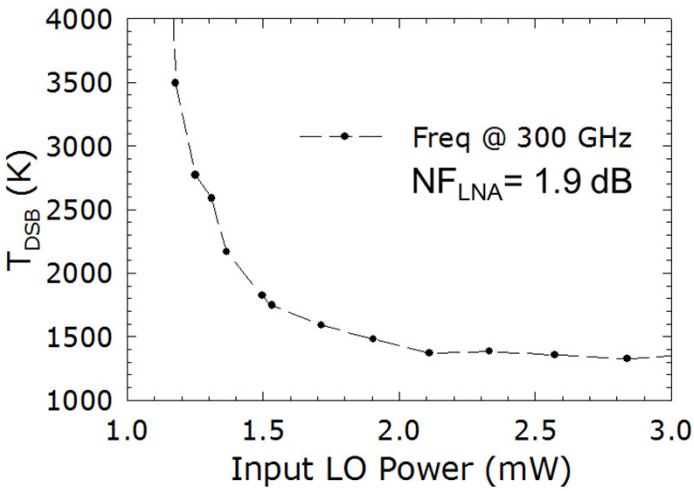



*Fig. 1: A 300 GHz transceiver developed at ACST.*

*Fig. 2a (above): Schottky-based subharmonic 300 GHz mixer from ACST and, 2b (below) the noise performance.*

Fig 2a shows a sub-harmonic mixer with local oscillator frequency from 135-160 GHz and RF input frequency from 270-320 GHz. It is able to down-convert a signal in the 300 GHz frequency range to an intermediate frequency (IF). The IF signal is matched with 50 Ω and can be tuned from DC-18 GHz.. This device is used for heterodyne reception, typically for telecommunication systems, radars, imaging *etc.* The Noise Figure (NF) represents the degradation (in dB) of the signal-to-noise ratio (SNR) of the RF signal after the receiver. The Noise Temperature is another method of quantifying this effect using a different notation.



## THz 25 Gbps wireless bridge

The main aim of TERAPOD is to enable the use of THz wireless technologies in data centres. This breakthrough would improve network performance in general and in particular would greatly enhance the capacity for switching and re-configurability. A key part of the first year of the project has been the development of a bench-top laboratory demonstrator. It is important to recognise that the core of the network in a data centre is based on optical links. It was therefore decided that the key user-based scenario would be a wireless bridge which could connect photonic network elements.

At the laboratory of one of the TERAPOD partners (UCL) the first bench-top demonstration of such a THz wireless bridge integrated on an optical network link has been performed. The demonstration was done using TERAPOD devices for both the transmitter and receiver. The bridge achieved a record throughput of 25 Gbps for a single change and 75 Gbps using three optical channels transmitted simultaneously across the wireless link.

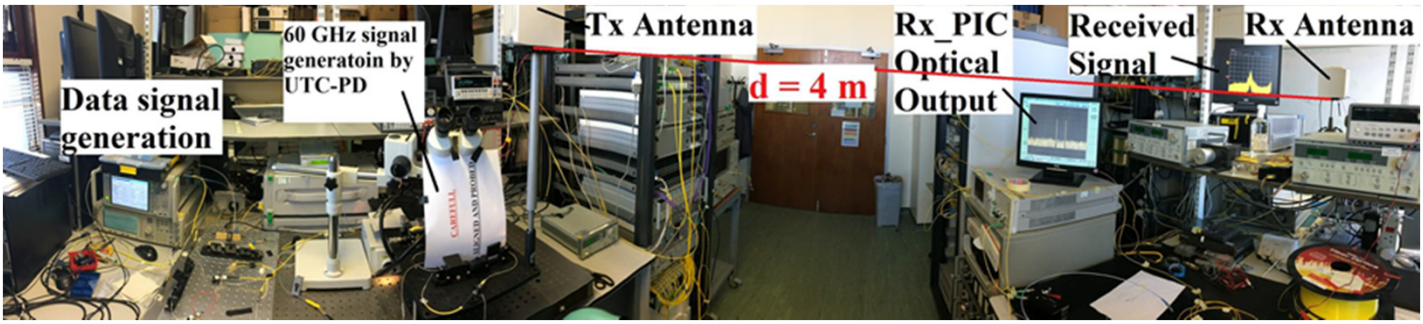



*Fig. 3: The 25 Gbps wireless bridge at the UCL labs*

This early demonstration shows the viability of the TERAPOD system plan for integration with a data centre network and was presented at OFC 2018:

H. Shams, T. Li, C. C. Renaud, A. J. Seeds, R. Penty, M. Fice and I. White
*Digital Radio over Fiber Distribution using Millimetre Wave Bridging*
OFC 2018, paper Th2A.69; https://doi.org/10.1364/OFC.2018.Th2A.69

The project work continues to develop this lab set-up into a robust packaged system solution suitable for full demonstrations *in situ* in a real data centre at TERPOD partner Dell-EMC in Cork, Ireland.

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## THz device characterisation

TERAPOD will produce a range of THz transmitters and receivers based on RTD, UTC-PD and SBD technologies. These devices need to be carefully characterised in order to quantitatively evaluate and compare their performance. The challenging task of obtaining accurate measurements in the THz domain is being addressed by the TERAPOD partner NPL (Teddington, UK). It has established a test apparatus based on a lamellar interferometer for measuring the broadband frequency spectrum of devices, and a set-up for determining the beam profile of THz emitters.

Heterodyne detection has long been established as the most accurate, high-resolution, traceably calibrated technique for measuring signal frequencies and spectral profiles. Heterodyne measurements use a local oscillator (LO) of known frequency, amplitude and phase which is mixed with the source signal to produce a signal at the difference frequency that is proportional to the amplitude of the source. This lower frequency output signal can be more easily detected and analyzed using low-frequency circuits.

Unfortunately, laboratory signal analysers are not suitable for broad spectral profile THz sources since the bandwidth is limited by the input waveguide. Instead a free-space broadband interferometer may be employed: the interferogram produced by the device is a Fourier transform of the source spectrum, which can be recovered by applying an FFT (fast Fourier transform) algorithm to the acquired data. In order to fully characterize a THz emitter, its spectrum must be measured using both a narrow-band heterodyne signal analyzer and a broadband free-space optical interferometer, which is the focus of NPL work.

## Lamellar interferometer

A type of interferometer that is particularly suitable for broadband spectroscopy at THz frequencies is a Michelson interferometer with a lamellar mirror, where a split mirror acts as both a beam-splitter and a moveable mirror. The lamellar mirror consists of two parts, each comprising several lamellae or “fingers”, with one part being fixed and the other moveable (Fig. 4). Although the frequency resolution is low (~1 GHz, limited by the mirror scan length) this design avoids using a separate beam-splitting element, is polarization insensitive and can be ultra-broadband.

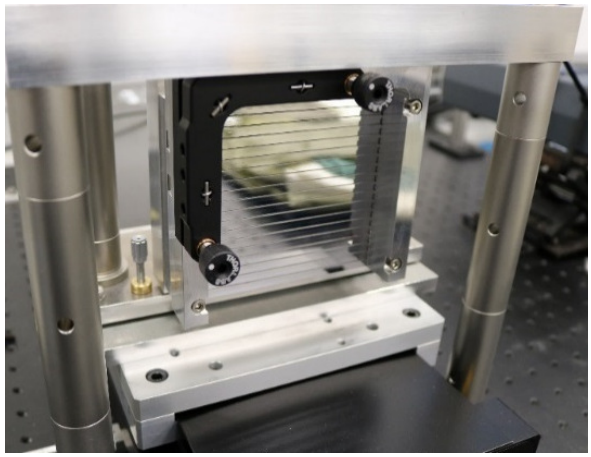

*Fig. 4: Schematic showing principle of operation (above) and photograph (right) of the lamellar split mirror at NPL.*

## Emitter beam profile measurement

Characterization of emitter (transmitter) beam profiles and detector (receiver) acceptance cones has long since been accepted as an essential tool in designing microwave and mm-wave communication systems. There are extensively developed and well understood techniques for antenna characterisation, and specialised facilities are available to perform the required measurements. However, none of these as yet exists for THz devices. Electronic THz emitters produce relatively low powers (commonly <100 µW), have short wavelengths (<1 mm), and there is a lack of compact, high sensitivity detectors. These factors combine to make spatial characterisation of THz beams severely challenging.

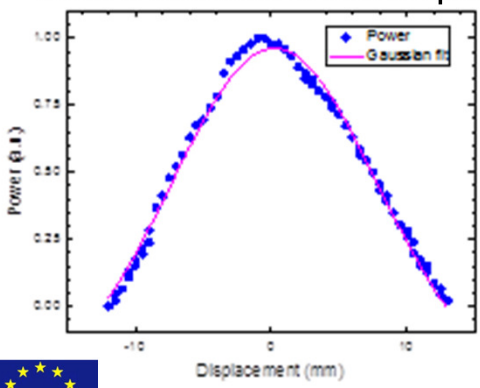


*Fig. 5: Test measurement of a Gaussian THz emitter using the NPL THz beam profiler.*

A THz beam profiler for laboratory use has been established at NPL. The apparatus is based on a commercial pyroelectric detector and features an aperture which is raster scanned across the emitter. An example of the output is shown in Fig. 5.

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## Dell-EMC perspective on TERAPOD use cases

Dell EMC, represented by its research team based in Cork (Ireland), is the data centre use case provider in the TERAPOD project. The team has been active in FP7 and H2020 projects since 2013 and had previously partnered with the TERAPOD coordinator, WIT, in the successful SOLAS project which investigated the application of SDN architectures within and between data centres.

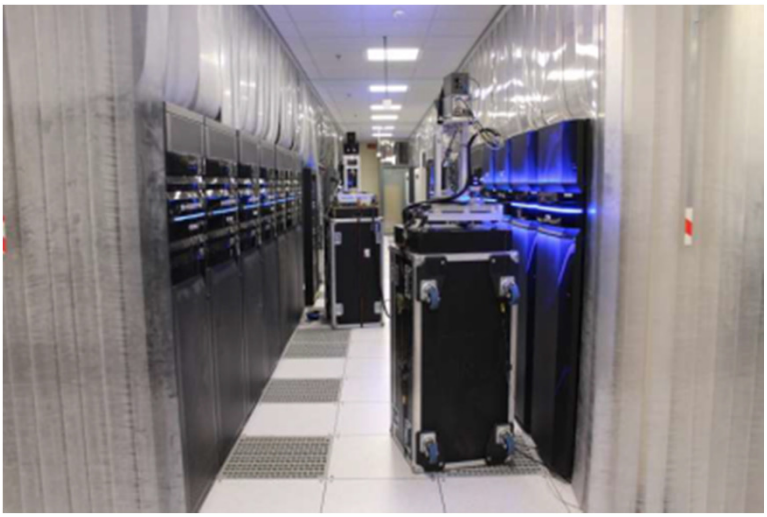
TERAPOD provides Dell EMC with an early insight into THz technology and the numerous application possibilities it may deliver to the IT industry.

Dell EMC represents the data centre operator and supplier in the project, highlighting its need for flexible high bandwidth networks. Dell EMC's contribution to the TERAPOD project is focussed on:

(i) The definition of innovative and relevant use cases, exploring the use of THz wireless communication within the data centre.

(ii) Monitoring the alignment of technical project aspects with the needs of the use cases.

(iii) Validating and evaluating the technical outcomes of the project, in order to determine the scenarios in which they can best be leveraged, to achieve cost and performance optimisation within the data centre.



Dell EMC is leveraging its expertise in data centre infrastructure and strategy, to provide a unique perspective and depth of experience that is of fundamental importance to the success of the project, also building on its experience in software defined networks, from completed EU-funded projects such as SOLAS and NEAT.

*Fig. 6: Channel measurements being performed by TU Braunschweig researchers at the Dell EMC data centre in Cork (Ireland).*

At the core of the TERAPOD project is the demonstration of the unique THz components, wireless communication methods, architectures and protocols, to enable the operation of THz wireless communication and connection in the data centre use case. Dell EMC is leading this activity in the project and to date the project team has defined four use case scenarios for demonstration purpose. Over the next 18 months Dell EMC is planning to demonstrate the operation of a wireless 100 Gbps transmission link between two top-of-rack switches in its Data Centre Lab in Cork (Ireland). The THz components for this demonstration are currently being developed collaboratively by the world-leading THz technology partners in the project.

Dell EMC is very excited by its role in the TERAPOD project and the potential of wireless THz technology to significantly impact some of the current challenges experienced by all data centre operators: managing data traffic hotspots, cabling complexity that leads to increased service operations costs and cabling density that reduces cooling efficiency.

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