Master’s student advert: Antenna modelling and design for future THz Communications

Introduction

We are seeking a Master’s Degree level student, to perform antenna design and modelling as part of the traceability workpackage in the Meteracom project. This project provides a measurement focussed approach for future THz Communications (>100 GHz), operating frequencies planned for 6G. The research is multidisciplinary, and the successful candidate will work at PTB with, and under the supervision of, three leading scientists within the project. Because of the nature of the test-equipment, much of the experimental work will be performed by the PTB/Meteracom staff.

Although communication systems are defined in detail by specification standards, traceability “an unbroken chain of measurements from the device under test to the relevant primary SI standards", is essential to specify, buy and test components for any design.

Problem summary

THz communication systems comprise a transmitter and a receiver. The proven techniques for traceable measurement of 3-port devices, such as mixers, are limited by the availability of traceably calibrated phase-standards and oscilloscopes to 110 GHz. Above that frequency identical mixers are used to determine group-delay and dispersion for a transmitter/receiver pair as there is currently no way of ascribing errors to either the transmitter or to the receiver.

The traceability workpackage in Meteracom requires the design of a prototype receiver to provide traceability to primary standards and separate the group-delay and group-delay dispersion present in the transmitter and receiver. The resulting receiver design will require verifiable characteristics and the capability to work with a communications-like waveform.

The role of the successful candidate will be to model the existing design, testing against measured results and to design a new antenna and RF coupling filter. The expected target operating centre frequency for the receiver is 280 GHz, with an operating range of 220-340 GHz. The received signal bandwidth is mapped onto the optical comb frequency spacing (76 MHz).

The novel aspect of this work is the development of a metrology grade, resonance-free THz-receiver, providing traceability for both CW and modulated radiated THz waveforms from prototype and commercial sources. We expect several publications from this work.

Task objective and Initial work

The primary dynamic voltage standard comprises two elements: generation of a high-bandwidth electrical comb and electro-optic probing of the electric fields on the coplanar transition line. The combined useable bandwidth of the system is >500 GHz. In this system, electrical impulses (< 1 ps) at 76 MHz repetition rate are generated using a Low-Temperature Gallium Arsenide (LT-GaAs) photoconductor, illuminated by sup-picosecond optical pulses.

In a photoconductor the current, and hence low-pass signal, is proportional to the product of the optical intensity and the average voltage across the photoconductor while photo-generated carriers are present. The LT-GaAs photoconductor provides direct down-conversion of the THz RF to baseband. The coupling of the down-converted waveform to the ADC should not introduce amplitude and phase distortion into the recovered waveform.

A prototype photoconductor integrated with a Bow-Tie antenna, a planar broadband antenna design, has been successfully evaluated as a harmonic mixer with CW RF signals at 99 GHz and 99.6 GHz, using a 76 MHz optical comb. This project will result in an improved device with known and modelled characteristics and uncertainty budget. The system will be evaluated using both CW and modulated RF waveforms.

Workpackages

The work has been sub-divided into four Workpackages, to be completed by the student, with supervision and assistance by PTB and Meteracom project staff.

Modelling and assessment of an existing prototype device

This involves three tasks: first is to model the expected performance of the existing antenna design both on its own and within the test environment. The second task is to select a series of frequencies, that can be realised with the PTB equipment, to validate the model. Experimental measurements, carried out by PTB staff, will give the scalar response (sensitivity vs frequency). In the final task, the measured and modelled results will be analysed by the student, with assistance from the Meteracom staff, and the student will update the model.

The output of this workpackage is a validated vector model of the existing prototype design.

New antenna and photoconductor design

Using the knowledge gained from the first workpackage, the student will design and model a new antenna and on-substrate isolating filter. This filter will be more reproducible than the present bond-wire arrangement. A low-pass filter will be designed to couple to the ADC system. The operational range of the antenna system is expected to cover h-band (275 GHz – 330 GHz). The final design must be broadband and free from resonances. Impedance match and antenna gain are also important as there is significantly less power available at these frequencies, compared with the equipment used at 100 GHz.

The LT-GaAs photoconductor design will be specified by PTB staff who have detailed knowledge of existing systems. There may be some opportunity to tailor the device geometry to increase bandwidth or sensitivity during this phase.

The outputs of this workpackage are:

1. A completed design for the h-band antenna, RF blocking filter and low-pass filter for fabrication within the PTB laboratories.
2. A model of the new antenna design vector frequency response over the target frequency range.
3. An impedance match model and full vector response of the low-pass coupling to the ADC system.

Evaluation of the new antenna design

The new antenna design will need to be evaluated over its operating bandwidth. This comprises three tasks:

The first task is to specify a range of test frequencies for the scalar evaluation of the antenna, covering both the full bandwidth and a detailed section of the frequency band, over a 76 MHz range (one pair of comb lines). The CW measurements will be made by PTB staff. There will be uncertainty contributions due to the RF power measurement.

The student will analyse the results, considering that, at these higher frequencies, the photoconductive switch carrier lifetime may contribute more significantly to the overall frequency response. The limits of the photoconductive switch contribution will be estimated from existing data.

The second task is to compare the predicted and measured impedance match of the low-frequency filter. The detailed scalar measurements will cover the 76 MHz low-pass frequency range, providing additional data for comparison with the model.

The final task is to evaluate the receiver using vector modulated signals. This will be performed in collaboration with PTB and Meteracom project staff. Initial tests will be made using a multi-sine waveform containing a minimum of three tones. The resulting data will be analysed by the student and should explore group-delay dispersion of the photoconductive receiver.

The final evaluation demonstration will be made with a 16QAM modulation format with one or more short data sequences. It is anticipated that carrier frequencies, pattern length and symbol rate will need to be chose with care to avoid SNR issues. The student will play an important role predicting the expected behaviour and waveforms expected from the system.

The outputs of this workpackage will be:

1. The measured scalar frequency response for the receiver, coupled with the model to provide a vector response and uncertainty estimate for the receiver.
2. The vector response of the output coupling to the ADC, including impedance match corrections.
3. Performance evaluation of the system using a multi-sine waveform.
4. Design and evaluate a communications-like waveform and analyse the resulting measurements.

Documentation

As part of the project the final software and analysis will need to be documented, both in the programs and as a user's guide/operating instructions. The choice of software language must be acceptable to PTB.

Contacts

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