Joint Research Project

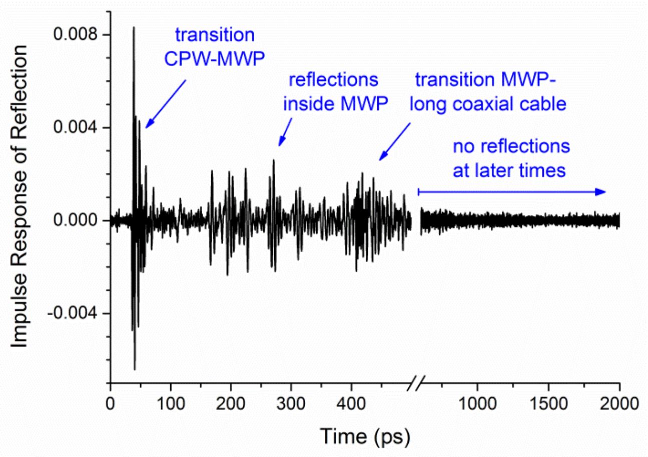
Metrology for ultrafast electronics and high-speed communications

Newsletter March 2013

Realization of an ultra-broadband voltage pulse standard utilizing time-domain optoelectronic techniques

Femtosecond optoelectronic techniques are routinely employed for the generation and detection of ultrashort voltage pulses. However, for precise measurements of such voltage pulses, i.e., for the realization of a voltage pulse standard, it is essential to (i) fully know the transfer function of the detection and (ii) be able to separate forward and backward propagating signals from each other. Within this research project a voltage pulse standard with frequency components exceeding 500 GHz and a 500 MHz frequency spacing has been realized.

The broadband voltage pulses are generated on a coplanar waveguide (CPW) by focusing a femtosecond laser beam (~800 nm center wavelength) onto a photoconductive gap that is integrated into the CPW. A second laser beam (~1600 nm center wavelength), which is synchronized to the first laser beam, is used to measure the electric field of the voltage pulses by employing the electro-optic effect of the GaAs substrate. The transfer function of the EO detection is obtained by comparing the EO signal from probe pulses which propagate once and twice through the electric-field region of the voltage pulses. The separation of forward and backward propagating signals is accomplished by measuring the voltage pulses at different positions on the CPW. As an application example the picture below shows the reflection coefficient at the CPW measurement plane with the CPW being connected to a microwave probe which, in turn, is terminated with a long coaxial cable. Different transmission line discontinuities leading to reflections are clearly visible.



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Uncertainties for waveform metrology, a compact covariance matrix representation

Near-ubiquitous computing power has changed the calibration landscape for instruments, such as oscilloscopes and vector signal analysers, so that uncertainties can be associated with a waveform in the time or frequency domain, rather than through a single parameter, such as transition-duration or the 3 dB cut-off frequency.

The challenge faced in this work was to develop a compact representation of the uncertainties so that they can be applied to time-domain or frequency-domain measurements. A covariance matrix approach, developed by NIST [IEEE Trans. MTT 54, 481 (2006)] meets the objective of accurate representation but the storage and measurements requirements scale proportional to n^2 and n respectively, where n is the number of waveform points. The covariance matrix for a 1000 point waveform can easily be represented but this is impractical for a 100,000 point waveform.

The objective of this work was to develop and verify an accurate, compact representation that scales proportional to n and allows mathematical manipulation so the result can be viewed in either the time or frequency domain. We have developed two algorithms, written in Matlab, that achieve this objective. The first algorithm was presented at the European Microwave Conference 2012 and this has now been superseded by a more robust approach. Figure 1 compares original measurements with the compact covariance model. As an example, a covariance matrix for a 4000 point waveform is compressed to about 1% of its original size, making operation with long waveforms a practical reality.

We have written high-speed versions of the algorithm in Python and C++ which will soon be available for evaluation by the stakeholders and collaborators. Full details of the algorithms and their evaluation are currently being prepared as a journal paper.

Contact & further information

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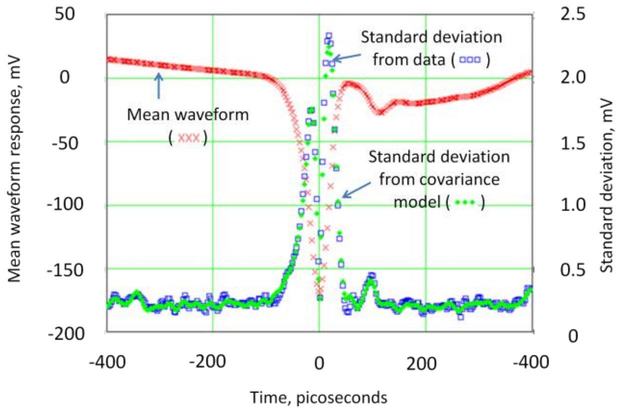
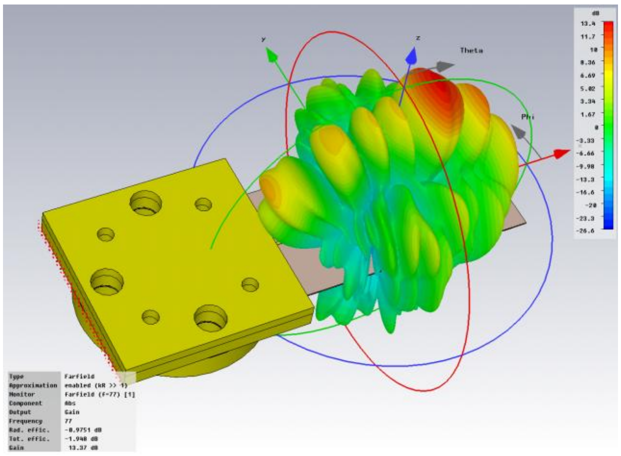


Design, fabrication and characterization of phased array antennas at 77 GHz and 94 GHz

For the frequencies of 77 GHz and 94 GHz, where more and more new applications in remote sensing and radar are appearing on the market, phased array antennas have been designed as suitable devices under test for the development of appropriate antenna calibration techniques. The planar antennas consist of arrays of 4x4 patches on RF substrates (Rogers 3003™). The patches are arranged in four linear arrays fed by a two-stage Wilkinson divider. In order to be able to measure the antenna properties using a vector network analyser with frequency extension modules, a launch adapter has been designed to convert the signal from the WR-10 waveguide flange to the microstrip line leading to the Wilkinson dividers. The picture below shows the result of the numerical calculation of the angle dependent (Theta and Phi) antenna gain of the array at 77 GHz including the waveguide adapter using the simulation software CST Microwave Studio™. Similar calculations have been performed for the 94 GHz array and for an array at 60 GHz which will be measured at LNE.

After optimizing the antennas with regard to reflection losses and antenna gain, first structures have been fabricated and the antenna gain has been measured in the Theta plane using a vector network analyser with WR-10 frequency extension modules, a rotation stage and a standard gain horn as measurement antenna. Measurement and simulations agree well. By now, new improved versions of the antenna arrays have been designed and fabrication is under way. The new antennas under test will be fully characterized in a semi-sphere using the antenna scanner in the far field.

Mechanical setup and testing of the antenna measuring system has been finished and programming as well as an uncertainty analysis is under way.



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Establishing traceability for vector signal analysers and generators

High-bandwidth real-time digital oscilloscopes seem to be a good candidate to characterize the full vector response of modern vector signal analysers and generators. One of the achievements in this project is a method to traceably calibrate wideband codedivision multiple-access (WCDMA) error vector magnitude (EVM) contributions of a source or a receiver using a real-time digital oscilloscope as the reference receiver. The results and uncertainties are presented for a receiver calibrated using four WCDMA sources from different manufacturers. Another achievement is a software tool currently developed which aims to support end users with the uncertainty calculation of the EVM of digitally modulated signals. The full waveform metrology approach will be adopted.

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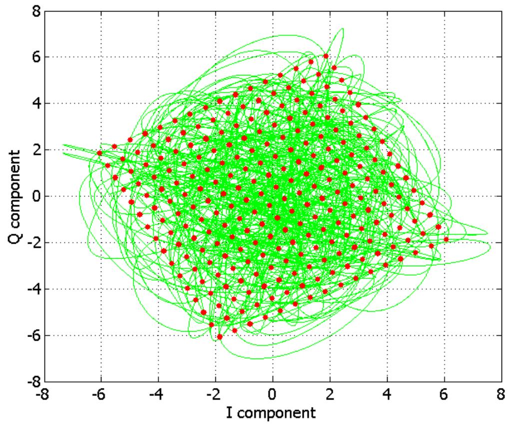

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Error vector magnitude assessment and modeling of amplifier non-linearity effects for broad-band signals

The EVM serves as a key figure-of-merit (FOM) parameter for digital modulation quality assessment. An analytical model is presented to assess amplifier non-linearity contribution to the EVM of broadband modulated signal. The development aims to support end users with accurate methods to assess EVM contribution of common RF circuit impairments common in Vector signal generator and vector signal analyzer instruments.

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