TESTING OF LTE BEAMFORMING

LTE is becoming the predominant wireless technology. Among several new features of this standard, the multiple input multiple output (MIMO) technology offers various advantages. It improves the throughput, extends the reach, reduces interference and improves the signal to interference plus noise ratio (SINR) with beamforming. LTE supports various modes in order to optimize the transmission settings. An LTE MIMO base station consists of a baseband unit, a remote radio head (RRH) and an array of up to eight antennas. The RRH upconverts the digital signals of the baseband unit into analog signals for each antenna.

Your task

In the described scenario, the base station software controls the weighting of the individual antenna signals to pan the main beam lobe to the UE. These signals look intricate. The relationship of the weighting among the channels is a multiplication with a complex vector due to polarization. For software tests or system debugging, it is important to examine the signals and verify the weighting, which might be either predefined according to the standard, or adaptive to the position of the UE.

Rohde & Schwarz solution

For this task, the R&S®RTO oscilloscope is a powerful exploration tool for analyzing the magnitude and phase shift between antenna channels. Due to the high acquisition rate and the high-performance FFT, signal changes can be detected quickly and no downconversion is necessary. The bandwidth of the R&S®RTO covers the defined frequency bands.

Beamforming is typically used in LTE time division duplex mode (TDD), when the signal is not contiguous. For these signals, the R&S®RTO oscilloscope has the trigger types width and window, which support capturing the downstream pulse and prevent recording of pause times. This significantly simplifies spectral analysis. A further benefit is the multichannel capability of the R&S®RTO. It can easily be extended across several oscilloscopes if more than four channels need to be analyzed in parallel.

Fig. 1: Measurement setup

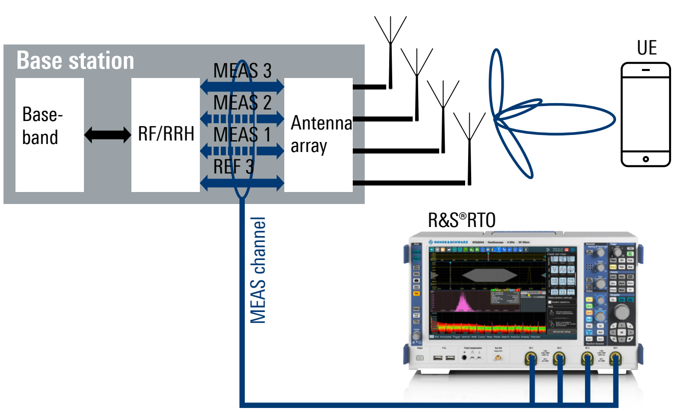
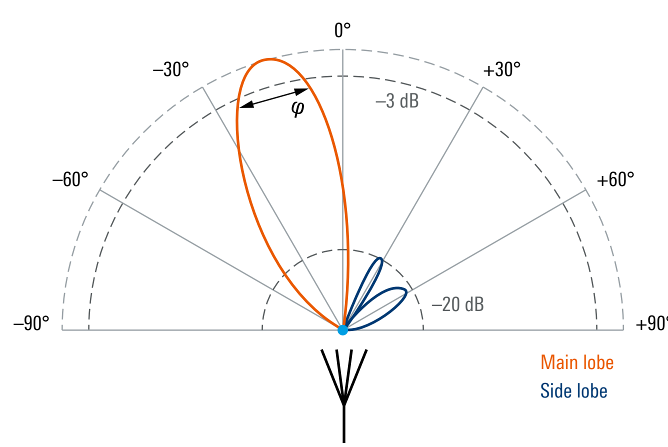


Fig. 2: Beamforming in the antenna diagram

Four antenna elements, correlated, copolarized, ½ wavelength separation, 90° shift per antenna element



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Application

In the example measurement setup, the REF and the MEAS1 channels of an LTE transmitter were connected to an R&S®RTO, which corresponds to a 1x2 MIMO system.

Vertical and horizontal settings

In a first measurement, the LTE transmitter asserts an LTE TDD signal and the oscilloscope acquires this signal using two channels with a vertical scale higher than 80% of the full scale. The horizontal scale is set to achieve a compromise between a high acquisition rate and having enough samples for the FFT and a sufficient resolution bandwidth (RBW).

The width trigger of the R&S®RTO is used to capture only the bursts of an LTE TDD signal. The gaps inbetween the pulses are ignored and the FFT measurement of the signal is not biased by the noise of the gap sections.

Fig. 3 shows a stable graph of two LTE TDD bursts captured with a width trigger of 1 ms and a large acquisition time of 20 ms. The trigger level is shown as a red dashed line.

Signal power

To check the spectral conformity of the signal, the spectrum of the REF channel is displayed below, and as expected it is a 15 MHz wide signal at 2.0175 GHz (LTE band). Weighting in terms of magnitude can be measured using the automated VRMS measurement function for the REF and MEAS channels. The ratio of RMS voltages between the REF and MEAS channels gives the magnitude of the weighting factor. Fig. 4 shows the RMS voltage measurement on the right, below are the traces of the REF (blue) and the MEAS (pink) channels. The measurement provides an accurate value since it is focused only on the signal. The trigger setup ensures that noise during a gap is excluded from the measurement.

Phase shift

For the phase shift between the REF and the MEAS channels, a MATH channel is set up to calculate the phase difference. The result is shown in Fig. 5. Two things are notable:

- First, the occasional spikes on the waveform. These spikes are caused by non-symbol synchronous sampling. They can be reduced by locking the scope to the transmitter clock, setting the FFT resolution bandwidth (RBW) equal to the LTE subcarrier bandwidth of 15 kHz and adjusting the trigger position to the optimal point of 40 µs for this example. The improved phase difference is displayed in Fig. 6, which appears much smoother. The spectrum of the REF channel has also improved compared to Fig. 4

Fig. 3: Stable trigger of an LTE TDD signal

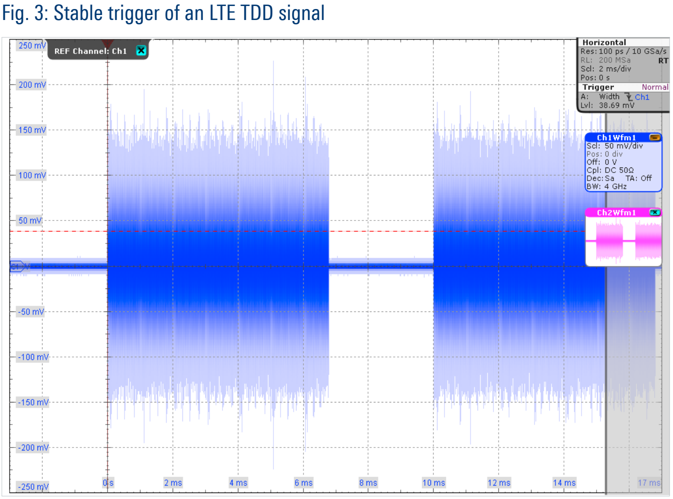


Fig. 5: Phase difference between the REF and MEAS channel

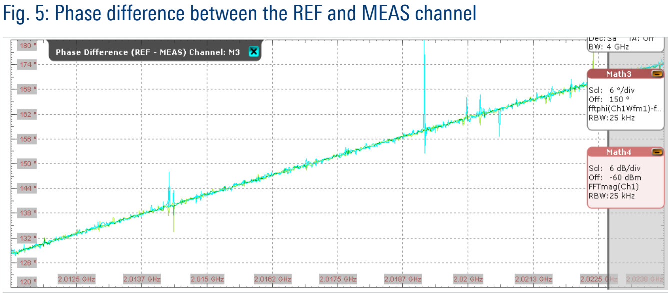


Fig. 4: Spectrum and RMS measurement of the LTE TDD signal

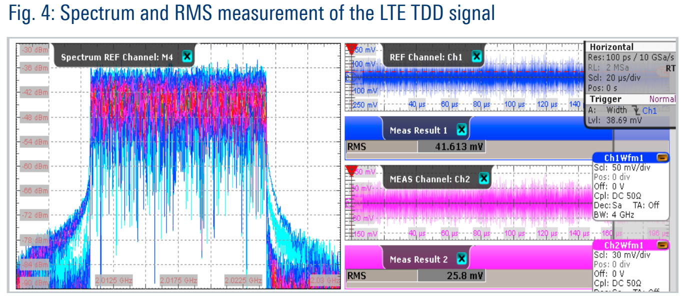
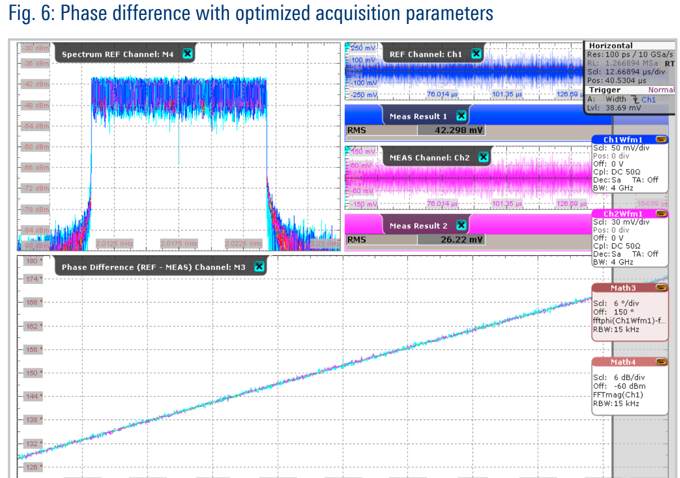


Fig. 6: Phase difference with optimized acquisition parameters



- Second, the waveform is overlaid with a linear function due to the delay of the measurement setup. The effect of the delay or any other phase deviation can easily be removed by calibrating the setup without beamforming (weighting), building a REF waveform from the phase difference graph and subtracting the REF waveform from the phase difference. Fig. 7 shows the setup in the MATH menu using the function fftphi, which calculates the phase of the selected channel

As a result of the calibration, Fig. 8 shows the phase measurement as a flat line. In order to assess the accuracy of the measurement, a waveform histogram is applied and automated measurement functions based on this histogram are used to determine the mean and the sigma of the phase measurement. The result is displayed in a signal icon on the right-hand side encircled with a red line. The offset (HMean) turns out to be less than 0.1° and the sigma (Hσ) is less than 0.25°, which is sufficient to measure the phase with 1° accuracy in a typical test scenario.

The measurement can be easily extended to more channels (see drawing on the bottom: Measurement setup for more channels). For example a 1x4 MIMO would require a four-channel R&S®RTO oscilloscope. Using a power splitter for the REF signal and three oscilloscopes, a 1x8 MIMO system could be analyzed by connecting the splitter output to each scope and allocating the remaining seven signals to the free oscilloscope channels.

For a more detailed analysis of LTE signals, the R&S®RTO can be combined with the R&S®VSE vector signal explorer software to measure additional parameters such as error vector magnitude (EVM), I/Q imbalance and the constellation diagram.

Fig. 7: Formula editor to calculate the phase difference without bias

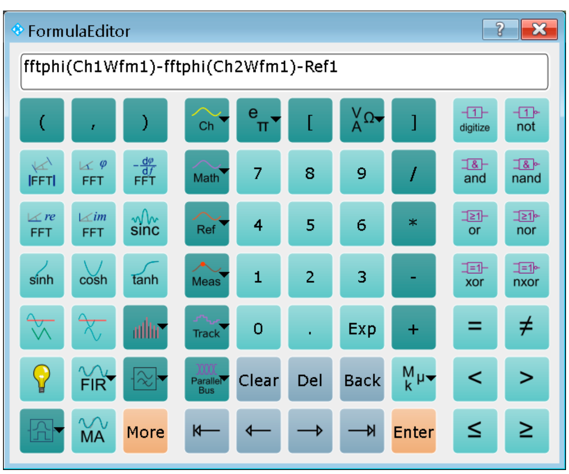


Fig. 8: Calibrated phase difference between the REF and MEAS channels

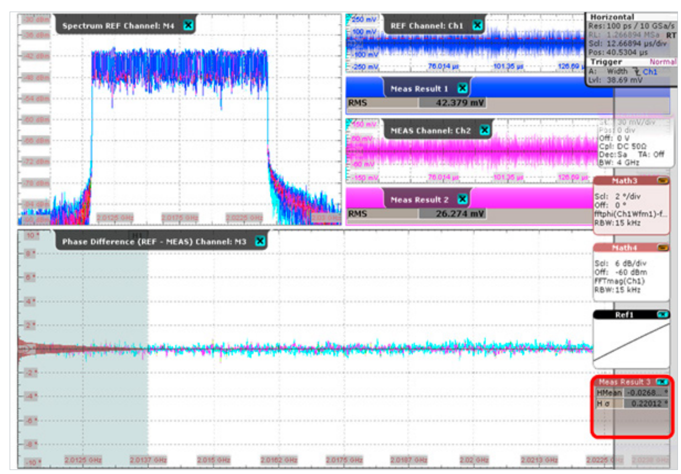
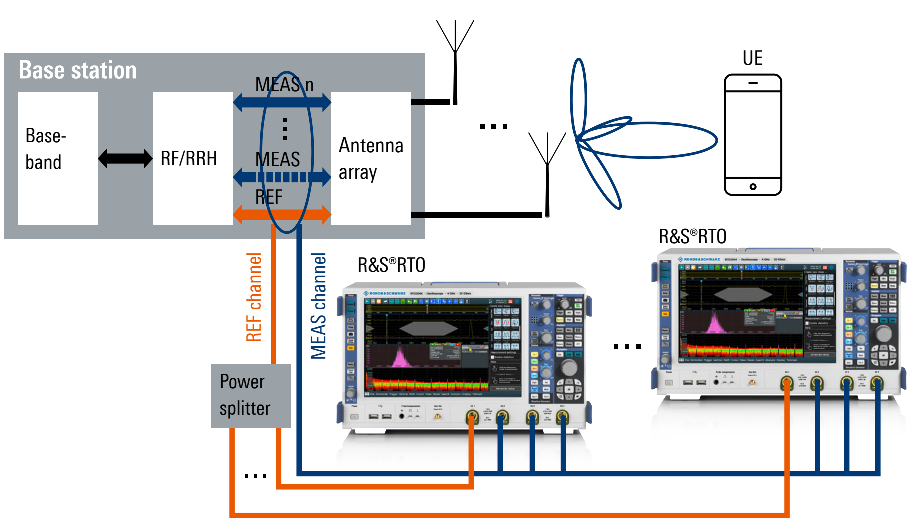


Fig. 9: Measurement setup for more channels



Summary

LTE beamforming can be accurately tested with one or more R&S®RTO digital oscilloscopes for a 1x2, 1x4 or even a 1x8 MIMO system. Magnitude and phase are examined with sufficient accuracy in a typical test scenario. The measurement does not require any dedicated software and can be accomplished with the standard R&S®RTO firmware.

References

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