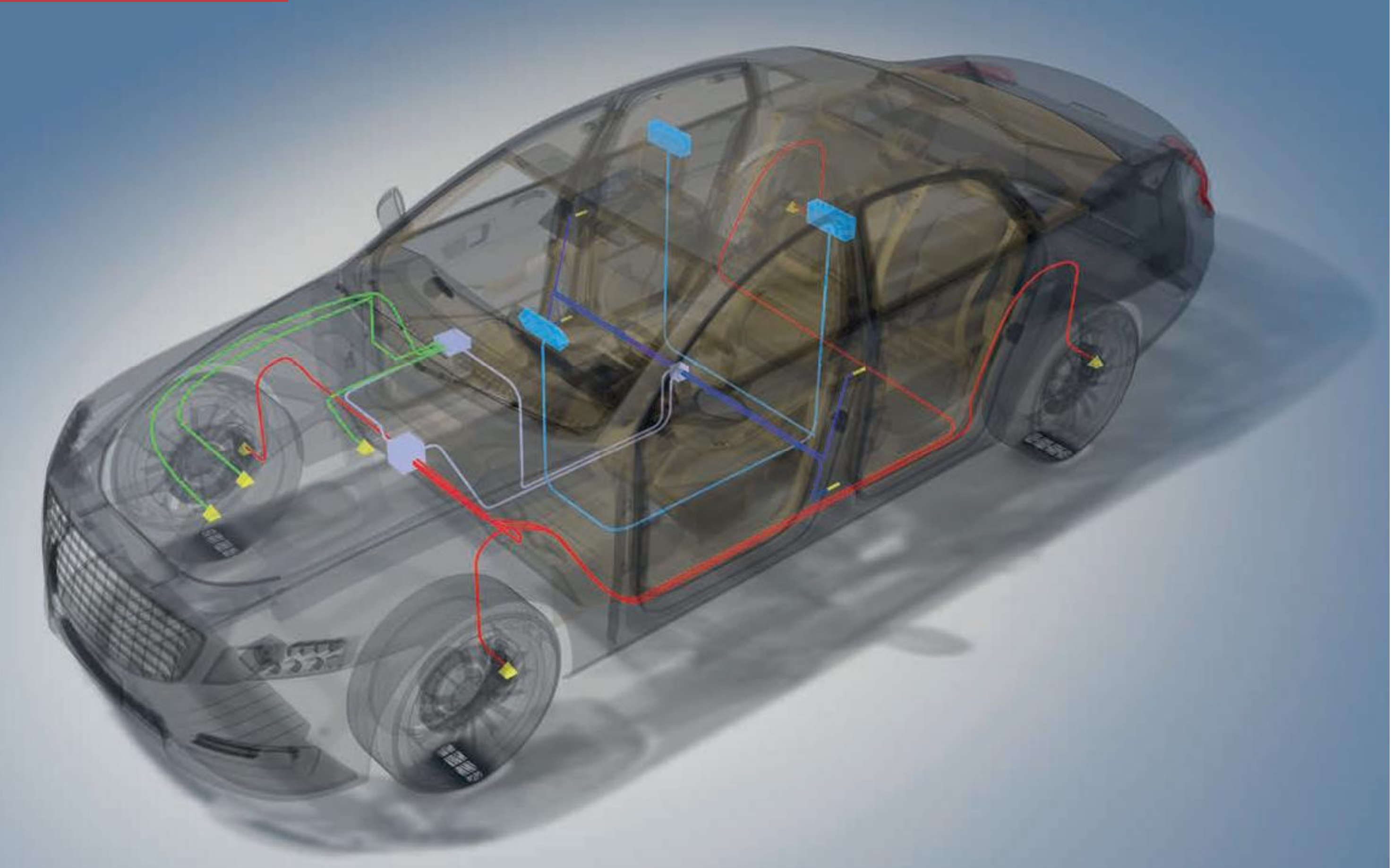

Automotive progress needs specific tests

By Jürgen Meyer, Director for Automotive, and
Dr Ernst Flemming, Product Manager for Oscilloscopes,
Rohde & Schwarz

From radar, wireless connectivity and in-vehicle networking, to cyber-security, the volume of electronics and data systems in modern vehicles is growing rapidly. This growth, in turn, drives new test and measurement challenges for vehicle manufacturers and automotive OEMs, challenges that encompass a variety of scenarios, from testing RF and Ethernet technologies, to semiconductors and electromagnetic compatibility. Some can be addressed by using and customising test technologies originally created for other sectors, whilst others require new solutions.

The eCall service

One of the factors driving increased electronic content in vehicles is legislation. Among the many examples of legislation-led technology is the European Commission's eCall initiative, where an eCall unit automatically contacts emergency services from a vehicle in the event of an accident, providing key data from its sensors. Since April 2018, car manufacturers are required to equip all new vehicles sold in the EU with an eCall module.

To ensure eCall reliability, test solutions must identify and simulate real-world problems the system could potentially encounter, for a variety of environments for mobile communication networks and even GNSS (Global Navigation Satellite System) variants. OEMs may also need to understand how to create simulations based on merging GNSS signals for even better location determination – something that has become known as 'real-time kinetics'. In addition, as mobile infrastructures develop, test solutions will be needed for next-generation eCall systems that are compatible with LTE environments.

Assisted/autonomous driving

Assisted driving is now prevalent; semi-autonomous driving is already becoming a reality, and fully autonomous driving is on the cards. As a result, test and simulation solutions for ADAS (advanced driver assistance systems) and related technologies must evolve quickly, especially radar. Reliable and interference-immune radar-based solutions are essential if ADAS technologies are to allow vehicles to negotiate complex and very dynamic urban environments. And with predictions of as many as 30 radar sensors per vehicle in the near future, sophisticated RF test and radar quality-analysis environments are now critical to ensuring reliable safety-critical radar systems.

Unfortunately, as many engineers will testify, RF-based testing and simulation can be difficult at the best of times. When considering the unique issues associated with radar systems in the automotive environment, such testing becomes even more challenging, especially as frequencies increase. This last aspect is becoming particularly important when frequencies assigned around 24GHz are phased out by 2022 in favour of frequencies around the 77GHz band. Whilst a bandwidth of 200MHz will still be available at 24GHz, providing up to 4GHz of sweep bandwidth in the 79GHz band supports radar systems with increased range resolution. Among the benefits of having more available spectrum is that systems can classify objects more easily, which assists with identifying cars, pedestrians and other obstacles. Also, with a higher bandwidth, mutual interference between radar sensors can be minimised (e.g. through the application of frequency hopping).

However, high frequencies are only one of the challenges. Other important considerations include simulating moving objects and the fact that, for practical and aesthetic reasons, automotive radar sensors are often mounted behind a vehicle bumper, emblem or body panel. Unfortunately, these complicated 'radomes' can significantly impair a sensor's function and, in worst-case scenarios, even cause it to fail.

There are test solutions that address these challenges, Rohde & Schwarz offers a suite of test technologies that can generate multi-dimensional automotive radar echo environments, measure material attenuation and reflectivity in the 77GHz and 79GHz ranges, and analyse how radomes and factors such as paint on bumpers can impact signal quality. These solutions – some of which use a modified version of technology originally developed for quick personal security scanners in airports – allow OEMs to characterise the performance of automotive radar sensors in R&D, quality assurance and production

Two technologies currently being considered are IEEE 802.11p dedicated short-range communication and 3GPP cellular vehicle-to-everything

Figure 1: (top) A differential 100BASE-Tx signal, showing its three levels and the steep edges at the signal transitions; (bottom): An automotive 100BASE-T1 signal, showing how pre-distortion masks the three levels of the PAM-3 signal

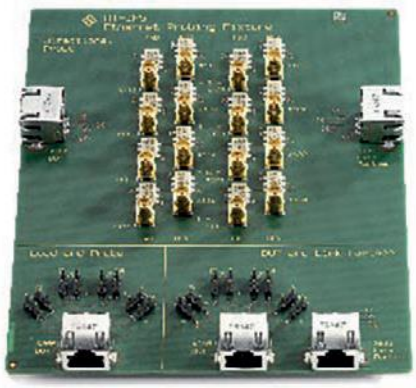

Figure 2: The R&S RT-ZF5 Ethernet probe fixture separates the full-duplex data streams of 100BASE-T1 communications

settings. Measurements, including testing to a resolution of just 2mm, can be conducted in a matter of seconds.

IVN and V2X

Transmission of data within and between vehicles but also with the road and comms infrastructure is driving significant developments in both in-vehicle networking (IVN) and Vehicle-to-X (V2X) communication technology – both with significant implications for automotive testing.

With IVN, the demand from automotive safety and infotainment applications for high-speed transmission of large data volumes within a vehicle has seen a trend toward automotive Ethernet and away from the more conventional MOST (Media Oriented Systems Transport) bus implementations. Indeed, a specific automotive Ethernet standard (IEEE 100BASE-T1, based on the OPEN Alliance BroadR-Reach physical layer) has been created; it uses full-duplex Ethernet communications via an unshielded Ethernet twisted pair cable.

For automotive Ethernet, a key T&M requirement is for performance verification in conformance testing, which requires the measurement of interference and attenuation on the twisted-pair cables. However, if problems occur during signal transmission, traditional Ethernet protocol analysis may not be adequate. As a result, companies are seeking more sophisticated automotive Ethernet conformance test solutions.

When it comes to vehicle-to-vehicle and vehicle-to-infrastructure networks, two technologies are currently being considered: IEEE 802.11p dedicated short-range communication (DSRC) and 3GPP cellular vehicle-to-everything (C-V2X). The first will expand on the Wi-Fi standard IEEE-802.11, whilst 4G LTE forms the basis for C-V2X, with a roadmap to 5G V2X. In Europe and the US, vehicle manufacturers are investigating both technologies, whereas Chinese automotive manufacturers are already moving down the path of C-V2X.

Independent of the standard, a fundamental requirement for the successful application of V2X communications is robust RF testing. In the case of C-V2X, for example, the ability to analyse 4G and 5G communications will be essential. However, it should also be recognised that leading semiconductor manufacturers are looking to support V2X solutions on a chip, in which case chip-level testing will also be important.

Debugging automotive Ethernet

Debugging automotive Ethernet networks is not a trivial task. The 100BASE-T1 Ethernet interface, based on BroadR-Reach technology, has now been standardised by the IEEE 802.3bw working group. Implementing automotive networks with this new standard brings a host of development changes, including a 100Mbit/s data rate that is significantly greater than traditional bus systems. The emergence of the 100BASE-T1 automotive Ethernet standard is easing the bandwidth issues of existing in-vehicle bus systems, at the cost of more complex debug challenges.

Featuring full-duplex Ethernet communications over an unshielded Ethernet twisted pair, 100BASE-T1 signals use PAM-3 modulation with differential signal levels between -1V and +1V. The transmitted signals must be pre-distorted by an equaliser to be carried reliably over an unshielded cable, with minimal RF leakage. It is this extensive pre-distortion applied to a 100BASE-T1 Ethernet signal that makes it difficult for developers to judge how effectively a bus is carrying data by simply analysing its electrical signals.

Standardised compliance tests for 100BASE-T1 interfaces involve measuring electrical characteristics using an oscilloscope and a network analyser. An Ethernet protocol analysis tool that records all the Ethernet data traffic can be used to verify that an electronic control unit (ECU) is correctly handling the communications. Beyond this, however, it is difficult to perform detailed root-cause analysis because transmission errors are only recorded as telegram errors.

For a more in-depth analysis, it becomes necessary to combine a suitable trigger and decode bundle with the chosen oscilloscope. By enabling developers to directly correlate electrical signals with the transmitted telegram content, for example, Rohde & Schwarz's trigger and decode bundle for 100BASE-T1, makes it possible to debug bus issues in automotive Ethernet applications as easily as with traditional CAN bus implementations.

Because 100BASE-T1 communication is based on simultaneous transmission of bi-directional data, any signal measurement on the bus extracts superimposed data streams. To analyse the two data streams they must be separated, using directional couplers such as those found on the R&S RT-ZF5 Ethernet probing fixture. Inserting the probe in the Ethernet line separates the data streams, allowing an oscilloscope to be used for non-intrusive recording of the 100BASE-T1 communications.

The signal streams the probe extracts are still subject to the pre-distortion imposed by the equaliser in the 100BASE-T1 transmitter to protect their transport over the unshielded twisted pair. The next step is for the oscilloscope to equalise the signals to return them to their undistorted state, and then extract and display the transmitted data telegrams and idle frames. Correlation of the 100BASE-T1 signals with the content of the telegrams – coupled with extensive triggering capabilities that can, for instance, be used to display isolated telegrams based on their source or destination addresses – enables the powerful analysis and diagnostic capabilities increasingly needed for automotive Ethernet.

100BASE-T1 decoding

100BASE-T1 decoding provides a way of revealing the timing relationship between bus communications and other signals. For example, the start time of an ECU can be determined by measuring the length of time between triggering an oscilloscope on the 12V supply and the arrival of the first valid telegram. A similar approach can be used to verify the stability of communications over the bus. In this case the scope is configured to trigger on short-term interruptions of the supply voltage, so the developer can analyse the number of bus anomalies those interruptions cause.

Electromagnetic interference can cause sporadic bus errors that are difficult to debug without further analysis. However, the ability to decode 100BASE-T1 communications means that developers can analyse bus communications across all OSI-protocol layers, using the timing correlation of the measurements to identify coupling from interference sources.

Consider the measurement shown in Figure 5, where the MAC and idle frames of a 100BASE-T1 signal are correctly transmitted at the start of the recording. The data stream is then interrupted. In the lower signal, the frequency spectrum of the interfering signal (marked in grey) is plotted, showing the cause – an interference peak at 2MHz. This combination of protocol-specific decoding with the range of analysis tools provided by the oscilloscope (e.g. frequency spectrum) simplifies debugging of complex issues such as intermittent interference. EW

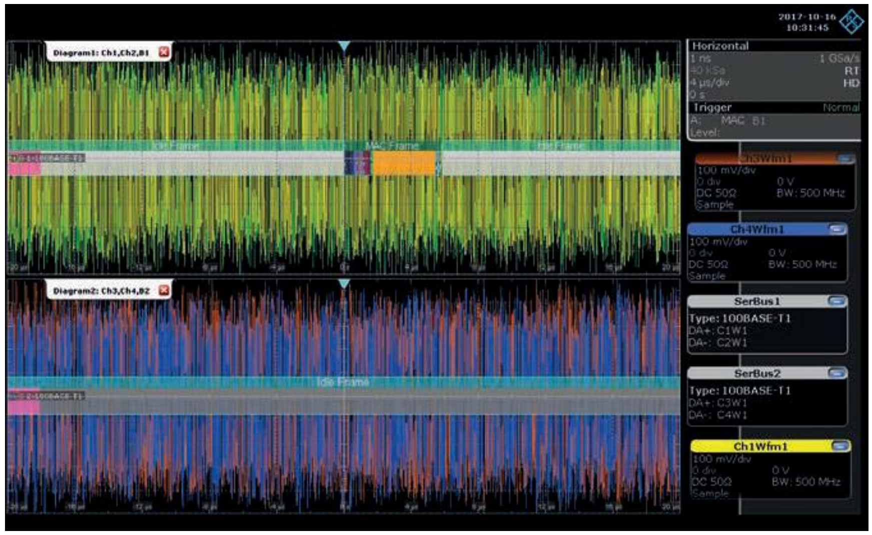

Figure 3: 100BASE-T1 decoding of full-duplex communications. The MAC frame is coloured, whereas the idle frames are grey

Figure 4: This screenshot shows the two levels of the differential 100BASE-T1 signal correlated with the decoded telegram content

Figure 5: Pinpointing a sporadic interruption in bus communications by combining protocol and frequency analyses