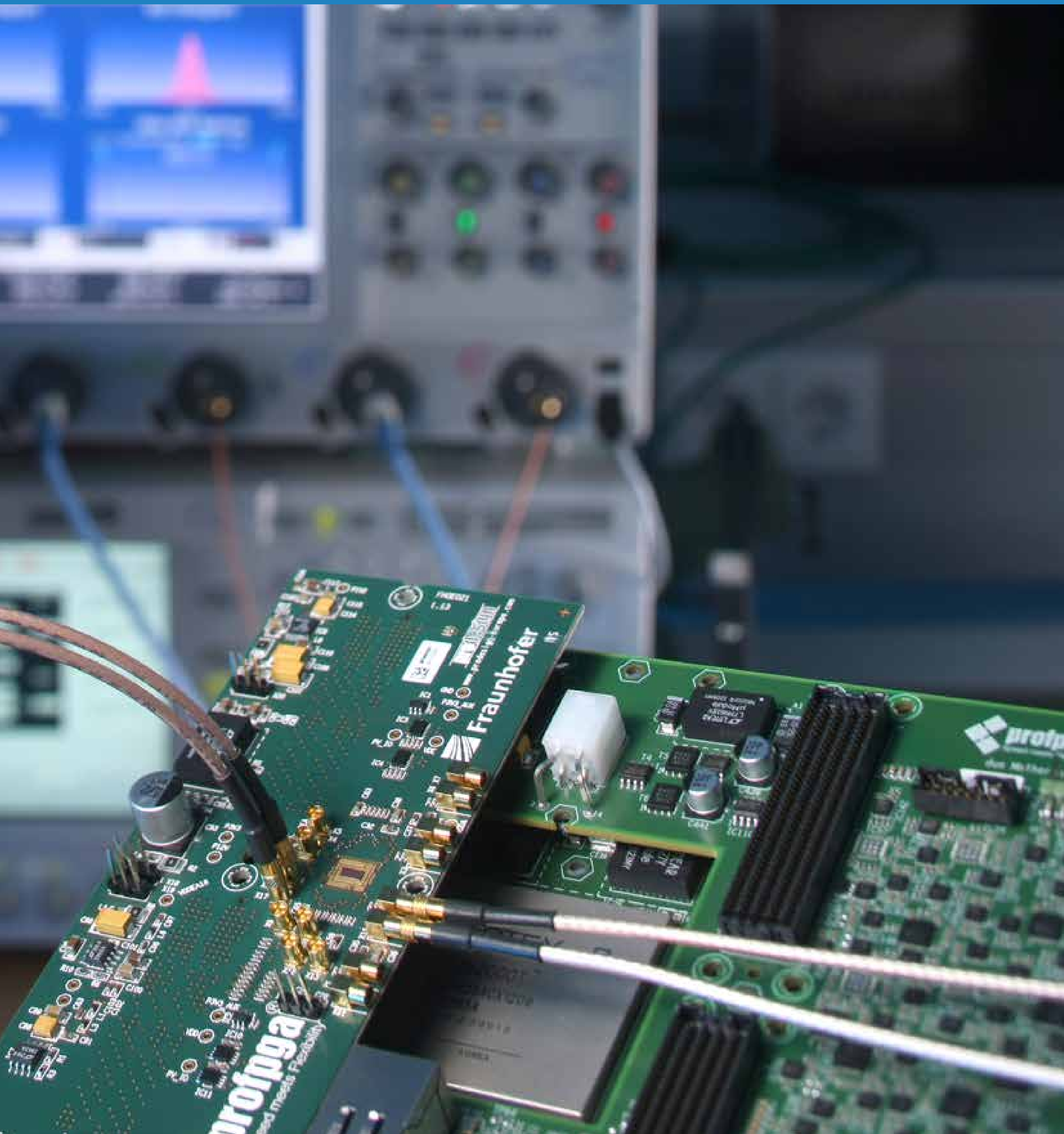
HIGH-SPEED DATA TRANSFER OVER COPPER WIRES

A new high-speed link allows data to be transmitted using a ten-meter copper wire at a rate of 10 Gbit/s in real time. The electronic component is ideal for use in high-bit-rate data streaming applications such as driver assistance systems, high-resolution cameras, and multimedia applications in vehicles.



Driving has become simpler and safer: Navigation systems help us find our way; head-up displays project the tachometer or speedometer straight onto the windshield; driver assistance systems featuring multiple cameras help ensure safe and reliable transportation; and real-time image transmission enables drivers to spot dangerous situations in good time and react immediately.

Now driving can be made even easier. Imagine the driver relaxing while the car uses its camera-based assistance system to navigate through commuter traffic, while the passengers watch a sporting event live via Internet TV. Tomorrow's rolling sports studio will broadcast 4K images from every conceivable angle. And if you happen to have missed your favorite program, a recording will be streamed straight to the vehicle from the compact and energy-efficient data center. It all sounds simple, but presents developers with a significant challenge since such applications rely on reliable and high-speed data transfer.

10+ Gbit/s data link speeds up data transfer via cable

Infotainment and security-relevant control data are transferred concurrently and independently of each other over one and the same connection. These parallel applications call for a high data throughput over a simple and low-cost copper wiring harness that combines the advantages of low weight, minimal power consumption and short delays in data transmission.

"HIGH DATA THROUGHPUT WITH A SIMPLE AND COST-EFFECTIVE COPPER CABLE"

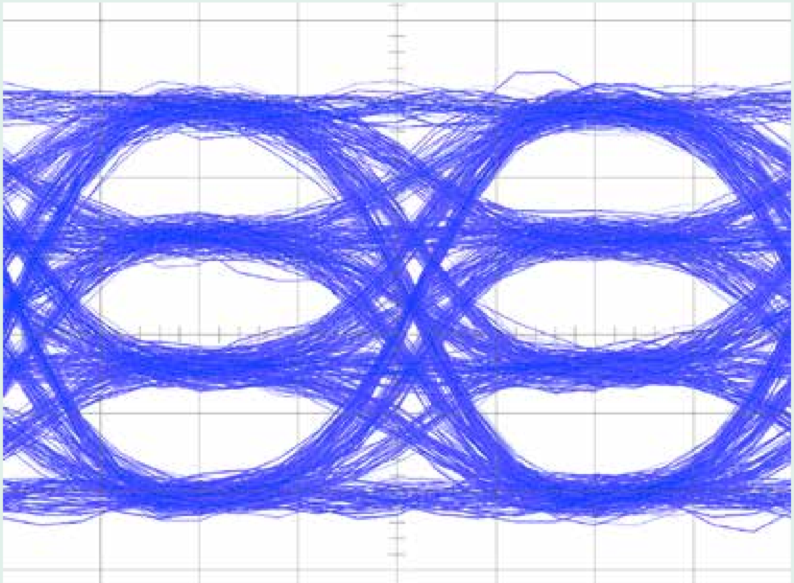
It's a challenge that Dr. Norbert Weber and his team eagerly accepted, developing a new broadband transmission system for high-bit-rate data streaming. A new high-speed link allows for data rates of 10 Gbit/s via twisted-pair copper cables. The system uses a twisted-pair cable of between 10 and 15 meters in length and consumes less than 1 watt per transmitter/receiver pair. What's more, the minimal time required to process the signals enables real-time video data for human-machine interaction. The development's universal design makes it possible to concurrently transmit a range of content with varying requirements, thereby merging connections that previously ran in parallel in a single data transfer cable.

The researchers can draw on years of broadband data transfer experience. Back in 2004, they teamed up with German semiconductor manufacturer Inova Semiconductors to develop systems that enable point-to-point data transfer at data rates of up to 1 Gbit/s via copper cable. This technology is branded as APIX (automotive pixel link) and has been successfully employed in series production for some years now by various automotive manufacturers. In 2009 this was followed by APIX2, featuring a data transfer rate of 3 Gbit/s – a technology now integrated in all of BMW's current models. Even so, constantly increasing data rates made it necessary to develop a 10+ Gbit/s data link, an undertaking begun in 2011 as part of a funding project under the leadership of Norbert Weber. "Already we can see the magic 10 Gbit/s on the horizon," said Roland Neumann at the time, as the head of development at Inova Semiconductors considered the needs of the automotive industry. But how is it that such quantities of data can be transferred over a single copper cable?

Equalizers compensate for the drawbacks of cable networks

If you're looking to transmit high-bit-rate signals over a simple twisted-pair cable, you soon run into the problem that these signals extend over an extremely wide range of frequencies. However, twisted-pair cables are of only limited use for high frequencies, since attenuation soars with increasing frequency. The upshot is that the high-frequency portions of the signal are suppressed and that data bits sent along the cable are heavily distorted and subject to time spreading. By the end of the cable, all you have is a worn-out signal. There is also a significant spread of time delays, which ultimately results in transmission errors (bit errors).

To compensate for the poor transmission characteristics of the cable, analog equalizers and special filter circuits in the transmitter and receiver combine to generate an inverse property in the cable so that the final signal exhibits an extremely flat frequency curve. This allows the decision logic in the receiver to clearly reconstruct the signal transmitted. In practical terms, this means that a 3 Gbit/s signal such as that required by the APIX2 standard can be effectively transmitted using a 10-meter cable.



An eye diagram of the data transmission format employed, PAM4

How broadband data transfer works

At the heart of the technology is PAM4 modulation, whereby two bits rather than one are transmitted in a given time slot. This means that only half the bandwidth is required, allowing developers to keep using the same standard cable as before. To further improve the performance of the equalizers, the decision was also made to install digital-analog converters in the transmitter and analog-digital converters in the receiver. Equalization is now done digitally and can also be modified via the FPGA test platform.

10 Gbit/s calls for paradigm shift in technology

Many common twisted-pair cables have other undesirable features. Owing to the way the cable is made, there is a slump in the frequency response around the 3 gigahertz mark – i.e. a point at which there is a very high level of attenuation. A high-bandwidth signal can no longer be transmitted along such a cable. In order to transmit signals with a bandwidth of 10 Gbit/s, the scientists had to find another way (see page 39). In collaboration with IC designers, the Communications department at Fraunhofer IIS developed a waveform that takes up less bandwidth than the signal form used previously. The signal also has manageable requirements as regards CMOS technology – ultimately the entire circuit is meant to fit on as small a chip as possible and consume as little power as possible so that it can be used in a series product.

Diverse areas of application for 10 Gbit/s technology

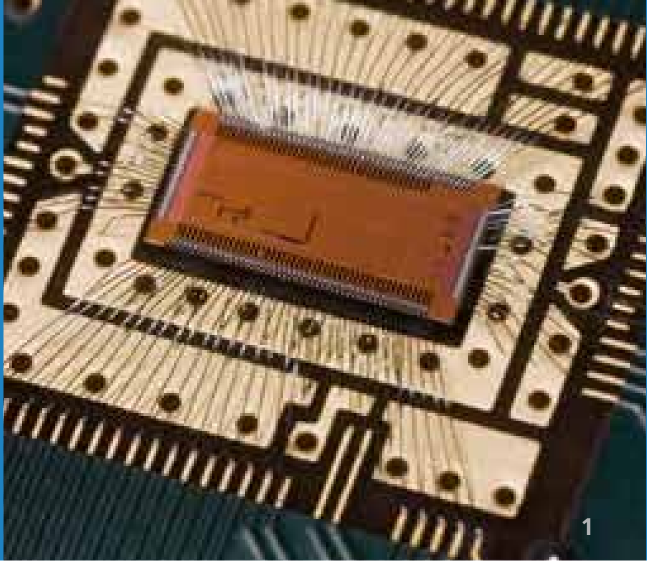
While relaying video signals has provided the main impetus for high data rates, other areas also have to deal with ever increasing amounts of data. At some point, every computer could have a 10 Gbit/s data interface – a project on which Apple has already embarked with its Thunderbolt interface. But to get from the computer to the local network, you have to bridge much more than the three meters that Thunderbolt currently offers. The same applies to networking server racks, an application which currently makes use of optical connections. An electrical copper-cable connection would be a significantly more flexible and cost-effective option.

Another potential application lies in the relay of broadband antenna signals from what the automotive industry calls smart antennas. This way, data no longer has to be transferred in analog mode – which is prone to errors – but can be converted into a digital signal directly at the antenna.

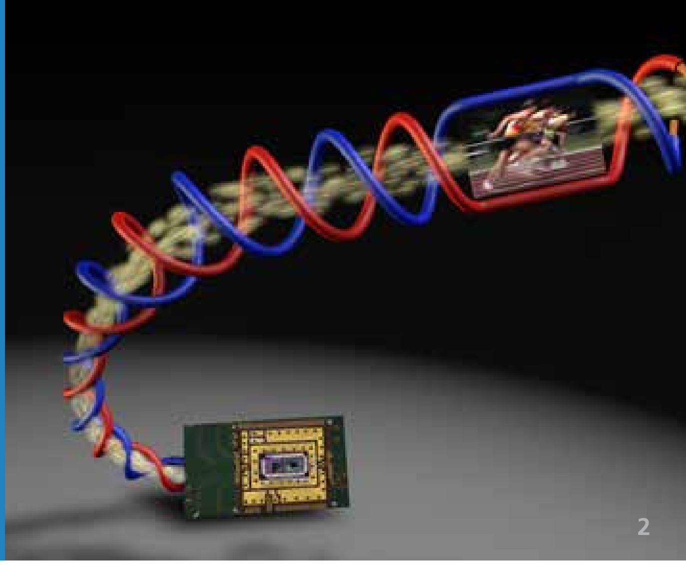
Medical technology has similar data transfer requirements. Take for instance an x-ray computer tomograph. Here, the high-definition x-ray images have to be transferred from the x-ray camera that revolves around the patient to a storage unit within the device. This means data rates of 10 Gbit/s and more. Professional camera systems also generate signals with extremely high bit rates since they operate in HD mode or at high speeds – sometimes both. As a result, camera interfaces also demand data rates over 10 Gbit/s.

Data rates of 12 Gbit/s and more in view

High-definition cameras and displays will drive up data rates far beyond those currently used in automotive applications. Accordingly, there are plans to achieve data rates of up to 12 Gbit/s in future applications, as the automotive industry is now demanding. Fraunhofer IIS is already working on the task. ■



1



2

THE 10+ GBIT/S PHYSICAL LAYER

Features

– *Transfer over twisted-pair copper cable*
– *Takes up less than three gigahertz bandwidth thanks to PAM4 modulation*
– *Power dissipation for transmitter/receiver pair less than 1 watt*
– *Range of 10–15 meters*

Areas of application

– *Transmission of video signals for 4K displays*
– *Networking of server racks*
– *Signal transmission via smart antennas*
– *X-ray computed tomography*

For more information on IC Design and Design Automation at Fraunhofer IIS, please visit:
www.iis.fraunhofer.de/icdea

1 *IC with integrated sensor and receiver electronics.*

2 *Efficient 10+ Gbit/s high-speed physical layer for the next generation of video transmission.*

CONTACT

Dr. Norbert Weber, head of Optical Sensors and Communication Technology Group
Phone +49 9131 776-9210
norbert.weber@iis.fraunhofer.de