Plastic waveguides for future communication networks

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Abstract - Researchers from the KU Leuven ESAT-MICAS research group in Belgium build a multi-gigabit communication link using a plastic fiber as transmission channel.

The link consists of 120GHz transmitter and receiver chips with on-chip antenna and a Teflon tube which guides the signal from the transmitter to the receiver. Such a plastic fiber is a cheap and low-weight transmission channel for millimeter wave (mmWave) frequencies (30GHz – 300GHz). Data rates up to 12.7Gbps and distances up to 7 meters have been achieved.

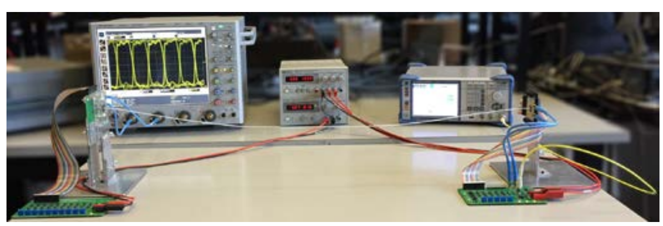
Because of technology advances it is now possible to integrate entire mmWave transceivers in a cheap CMOS technology. The advantage of entering the mmWave range is the large bandwidth which is available. With simple modulation schemes and circuit techniques high data rates can easily be achieved and the low system complexity results in low power consumption.

These high operating frequencies also enables the integration of on-chip antennas resulting in a compact and robust system. On the other hand, the transistor gain reduces for higher frequencies so there is a limit on the operating frequency. Another drawback is that at mmWave frequencies wireless transmission is challenging due to the high free space path loss which is frequency dependent.

As consequence the transmission distance is limited to the cm-range or expensive and bulky directive antennas have to be used. With plastic waveguides the transmission distance of mmWave signals can easily be extended into the meters-range. The large available bandwidths can be used to develop gigabit communication link over larger distances.

Plastic waveguide links are a valuable alternative for copper or optical links when reliable, cheap, multi-gigabit, low energy data transmission over meters distance is required. Copper links suffer from a limited bandwidth and large channel losses which limits the transmission distance.

They also have EMI problems. Optical links on the other hand can easily reach a high data rate over very large distances because their low-loss channel. However, they need electrical-optical converters and are too costly to deploy for short distances. For transmission distances up to tens of meters the plastic waveguide addresses the problems of the copper and optical links. There is no EMI, no excessive channel loss and no power consuming electrical-optical conversion.

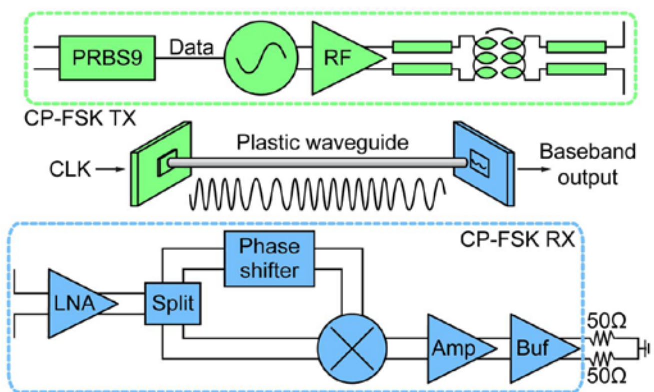


A large range of plastic fibers can be used to guide mmWaves. Circular or rectangular, hollow or filled, polypropylene, polystyrene, polyethylene or Teflon fibers are suited for this.

The dimensions of these fibers are in the millimeter range or below and are related to the frequency of the transmitted signal.

For example, measurements of a hollow, circular Teflon waveguide with outer diameter of 2mm and inner diameter of 1mm show a loss of 2.5dB/m at 120GHz. This excellent result is achieved with a plastic fiber which is designed for other applications than mmWave transmission.

Optimizing the waveguide for data transmission will lead to even better results. In optical communication over 1mm plastic optical fiber the data rate is limited by dispersion. When transmitting mmWaves through these plastic fibers, the wavelength and the dimensions of the fiber are in the same range and the number of transmitted modes is very low. As a result modal dispersion is eliminated.



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A demonstrator of the entire link is made. The demonstrator uses integrated antennas which perform the coupling between the transmitter and receiver chips and the plastic waveguide.

The chips directly launch an electromagnetic wave into the plastic waveguide and no electrical-optical conversion is required. No accurate alignment of the connector is needed. This makes this solution more robust against mechanical vibrations and results in cheap connectors.

This demonstrator uses continuous-phase FSK modulation to reduce the power consumption and to improve the link energy efficiency to 1.8pJ/bit/m for a 4-meter distance and a data rate of 7.4Gbps. The maximum data rate is 12.7Gbps for a 1-meter link and the maximum distance is 7m for 2.5Gbps. In the future data rates as high as 20Gbps and transmission distances larger than 20 meters are possible with this technology.

About the authors:

Wouter Volkaerts received the degree of M.S. in Electrical Engineering from the KU Leuven, Belgium in 2009. He is currently working as a research assistant at the MICAS laboratories of the KU Leuven towards a Ph.D. degree in the field of mmWave VCOs and transceivers.

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