Deutscher Amateur-Radio-Club e.V.
Bundesverband für Amateurfunk in Deutschland

THz-Funk: geht das eigentlich?

Hermann Schumacher, DF2DR

Motivation

IEEE ELECTRON DEVICE LETTERS, VOL. 36, NO. 4, APRIL 2015 327

First Demonstration of Amplification at 1 THz Using 25-nm InP High Electron Mobility Transistor Process

Xiaobing Mei, Wayne Yoshida, Mike Lange, Jane Lee, Joe Zhou, Po-Hsin Liu, Kevin Leong, *Member, IEEE*,
Alex Zamora, Jose Padilla, Stephen Sarkozy, Richard Lai, *Fellow, IEEE*,
and William R. Deal, *Senior Member, IEEE*

Frage eines berufsbegleitenden Master-Studenten:

- *Ausbreitung?*
- *Wird das Signal nicht auf kürzester Strecke in Form von Licht abgestrahlt?*

Ausbreitung (1)

Freiraum-Dämpfung - Friissche Übertragungsgleichung

$$\frac{P_\mathrm{r}}{P_\mathrm{t}} = G_\mathrm{t} \cdot G_\mathrm{r} \cdot \left(\frac{\lambda}{4\pi R}\right)^2$$

Freiraumdämpfung

$\sim \frac{1}{R^2}$ Abnahme der Leistungsdichte

$\sim \lambda^2$ aus der Antennenwirkfläche

Freiraumdämpfung in dB:

$$D_{FS} = 20 \log_{10} \left(\frac{4\pi R}{\lambda}\right)$$

$$A_{W,max} = \frac{\lambda^2}{4 \cdot \pi} \cdot G$$

Antennengewinn (hier: Parabolantenne)

$$G/dB = 20 \log_{10} k \left(\frac{\pi D_{ant}}{\lambda} \right)$$

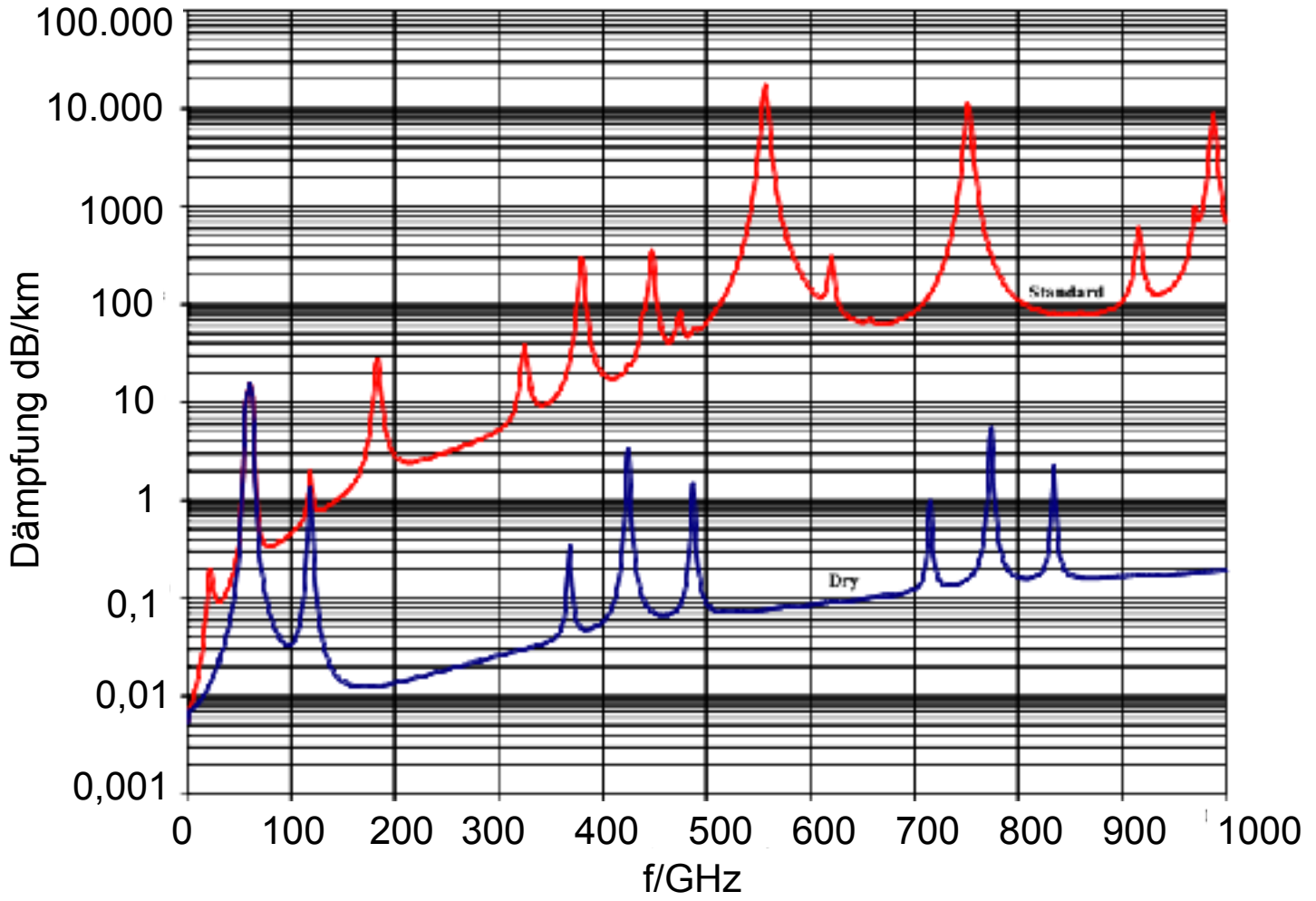
Bild: stux/Pixabay

Ausbreitung (2)

Atmosphärische Dämpfung
(ITU-R P.676-11)

Vergleiche Freiraumdämpfung
(1 km):

100 GHz: 132 dB
300 GHz: 142 dB
500 GHz: 146 dB
700 GHz: 149 dB



Nicht nur graue Theorie!

Übertragungsexperiment
R=850 m
f=240 GHz
64 GBit/s

I. Kallfass et al., 2014

Abb. aus Urheberrechtsgründen gelöscht

J Infrared Milli Terahz Waves (2015) 36:221–233

Amateurfunk-Weltrekorde

Band	Distanz/km
122 GHz	139
134 GHz	114
142 GHz	80
241 GHz	114
322 GHz	1,4
403 GHz	1,4

https://dk5nj.de/2022/03/16/new-world-record-on-the-134-ghz-band/

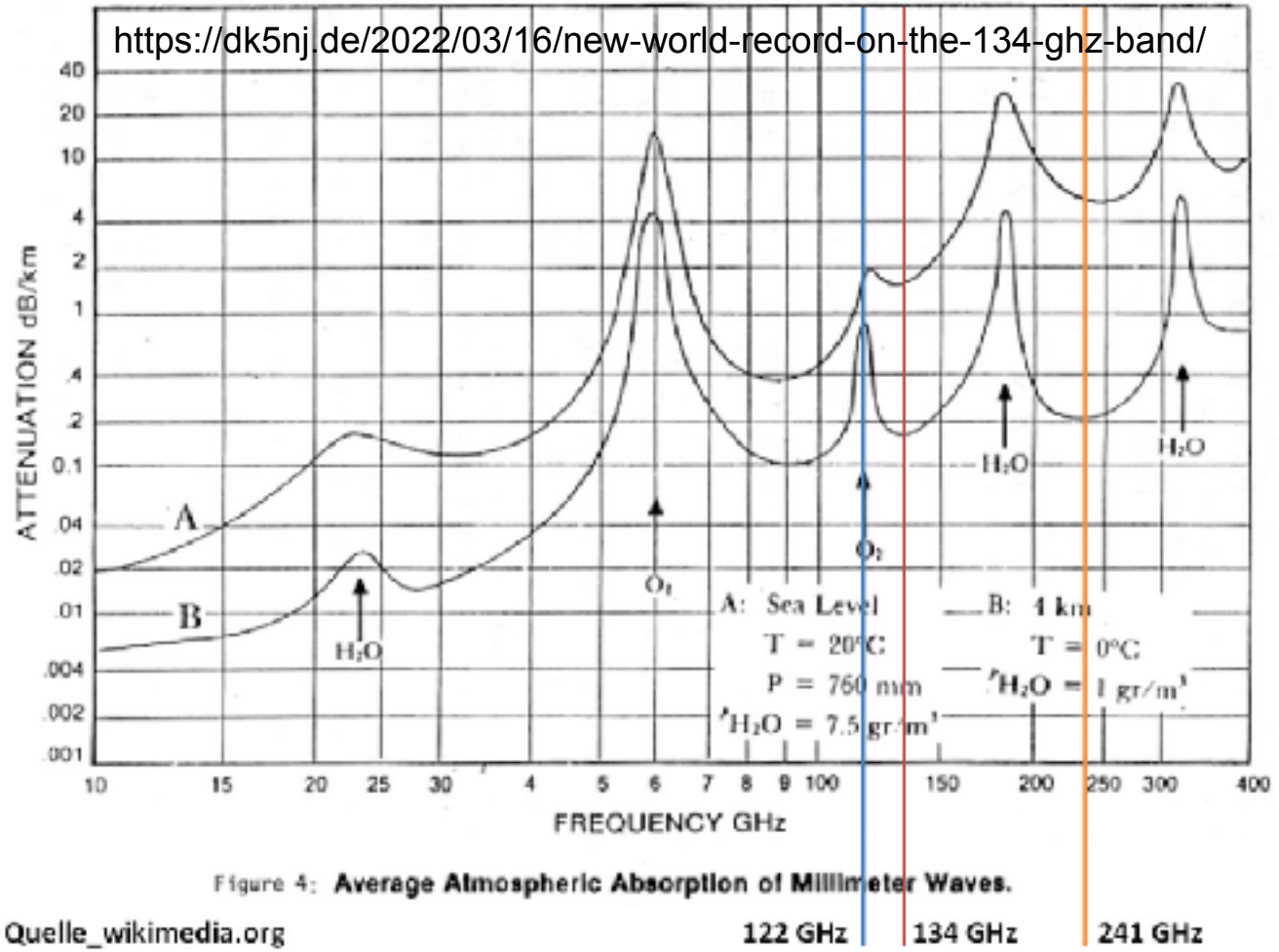


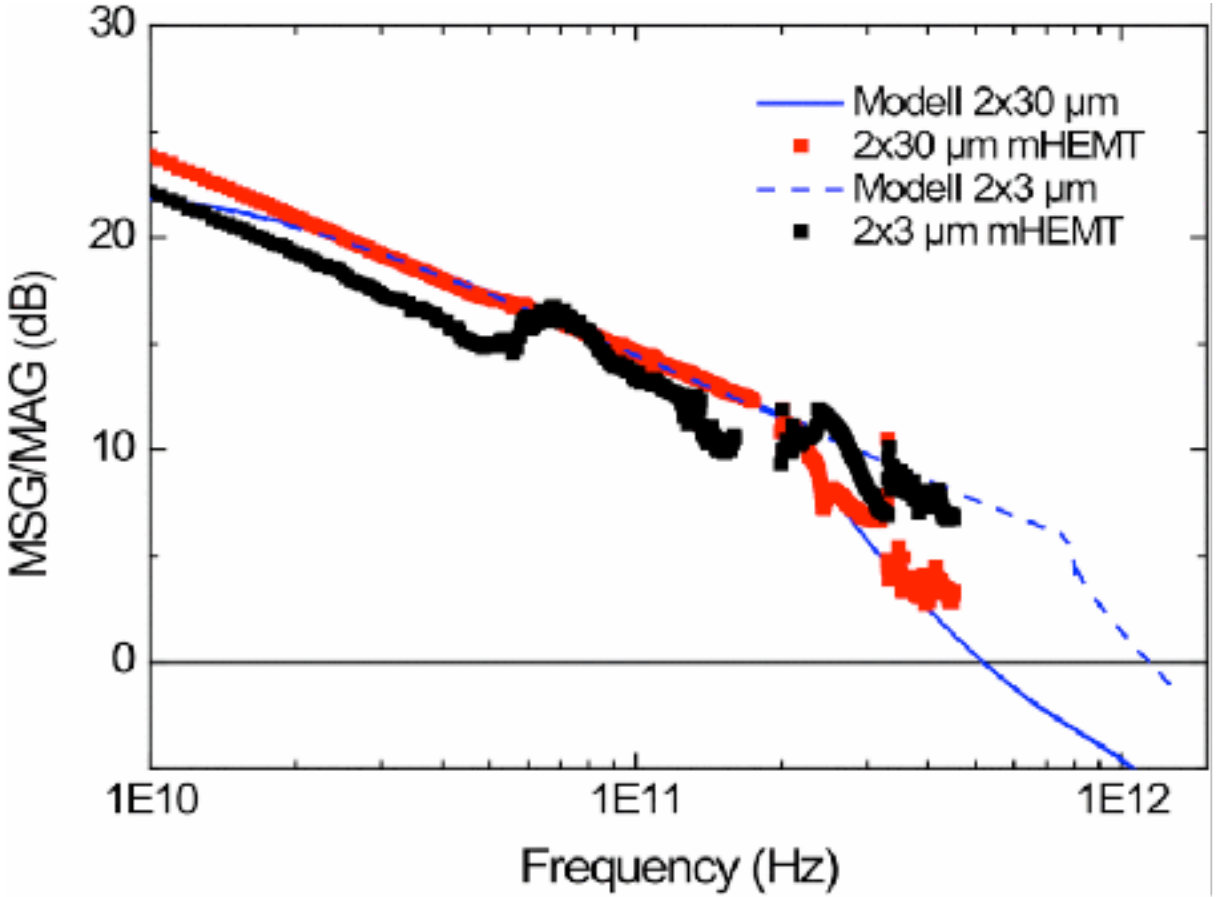
Figure 4: **Average Almospheric Absorption of Millimeter Waves.**

Quelle_wikimedia.org

122 GHz 134 GHz 241 GHz

Bauelemente: mHEMT

Abb. aus Urheberrechtsgründen gelöscht



A. Leuther *et al*., "20 nm Metamorphic HEMT technology for terahertz monolithic integrated circuits," *2014 9th European Microwave Integrated Circuit Conference*, Rome, Italy, 2014, pp. 84-87

600 GHz Verstärker (achtstufig)

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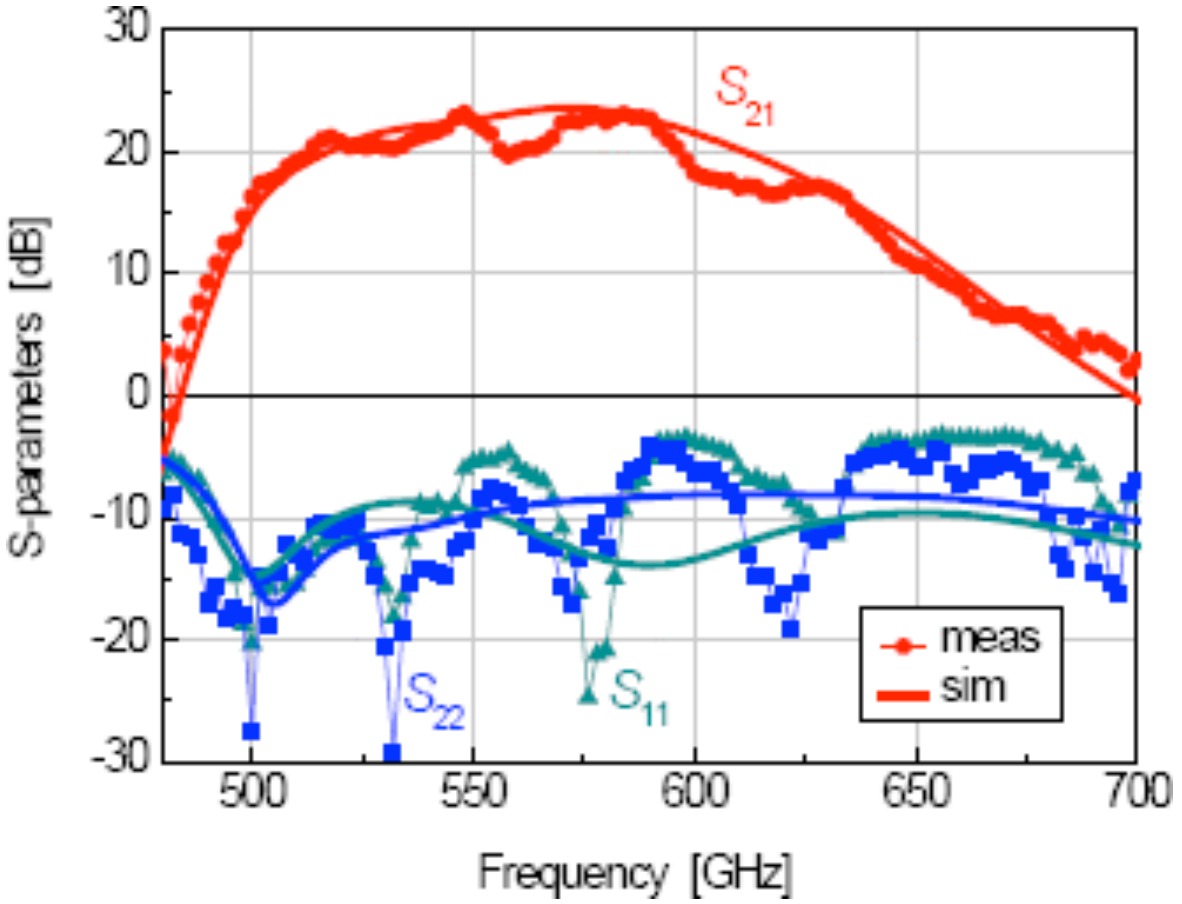
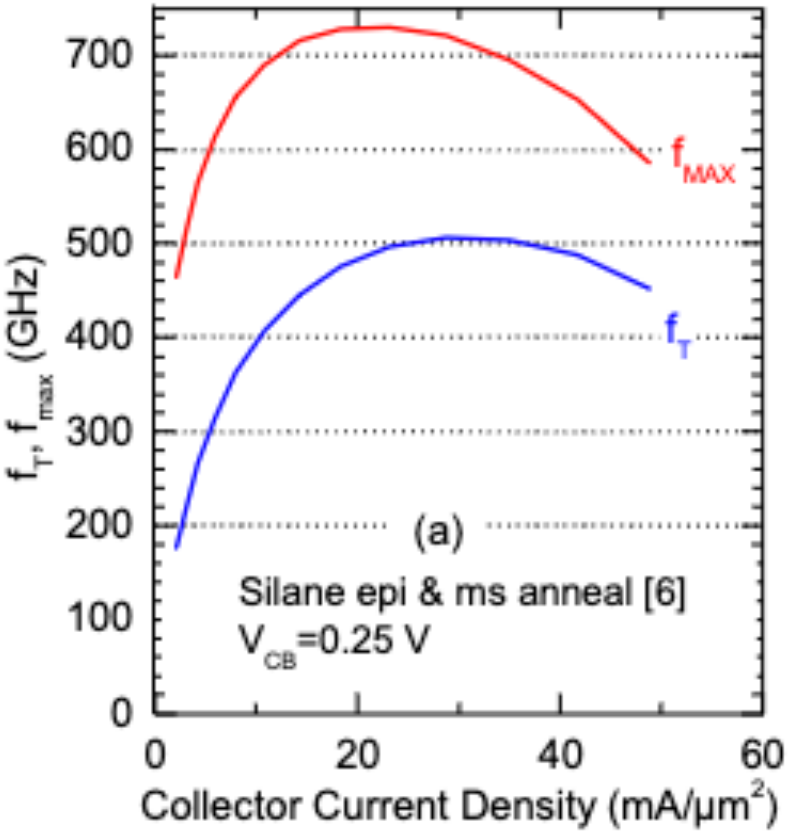


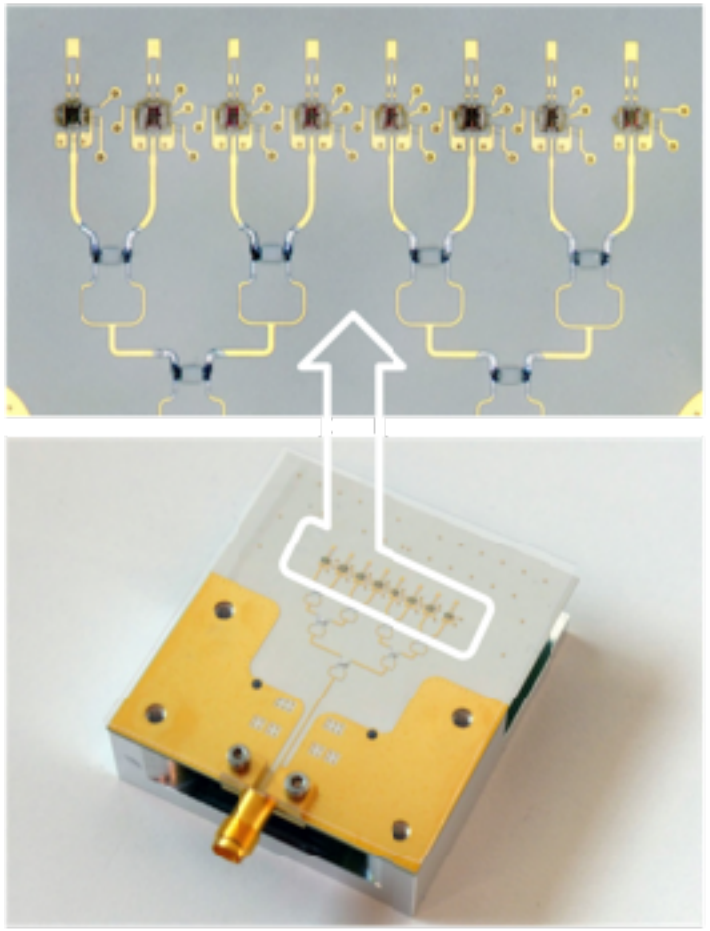
Si/SiGe BiCMOS-Technologien

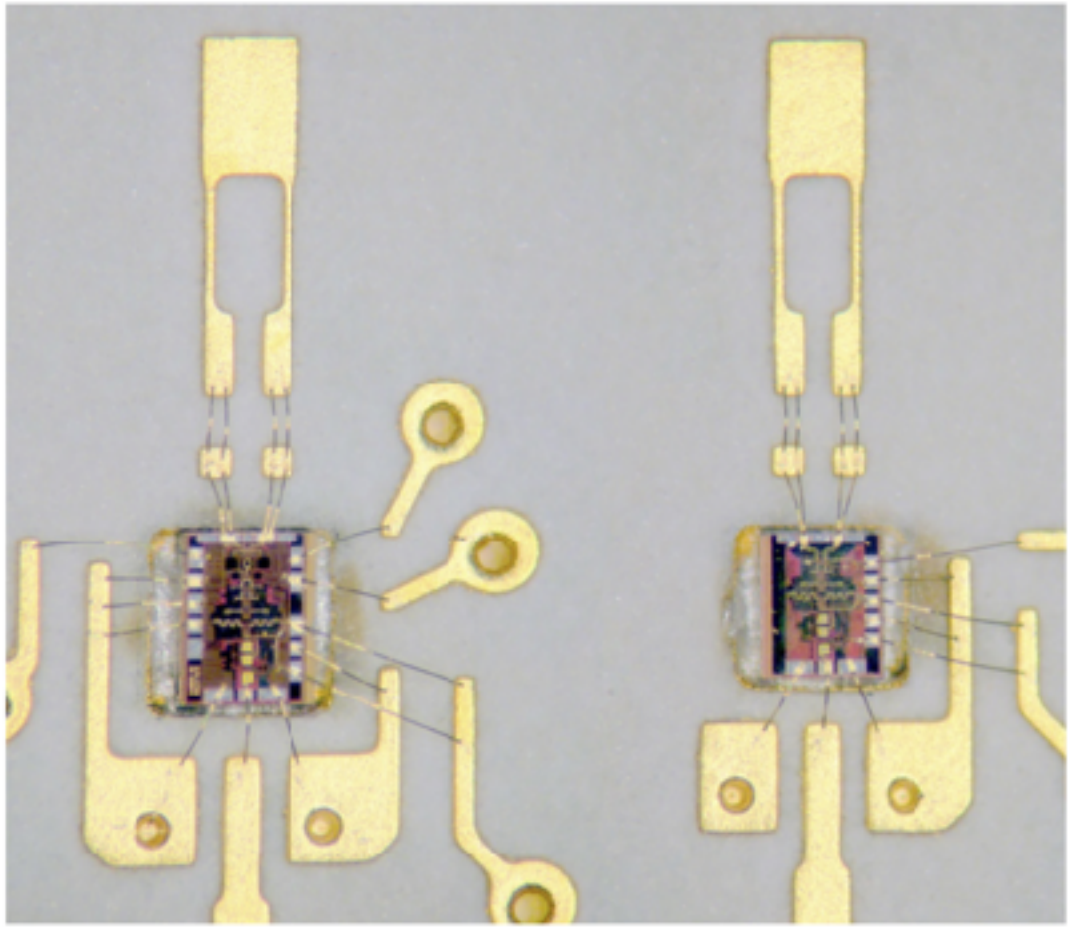
Abb. aus Urheberrechtsgründen gelöscht



H. Rücker and B. Heinemann, "Device Architectures for High-speed SiGe HBTs," *2019 IEEE BiCMOS and Compound semiconductor Integrated Circuits and Technology Symposium (BCICTS)*, Nashville, TN, USA, 2019, pp. 1-7

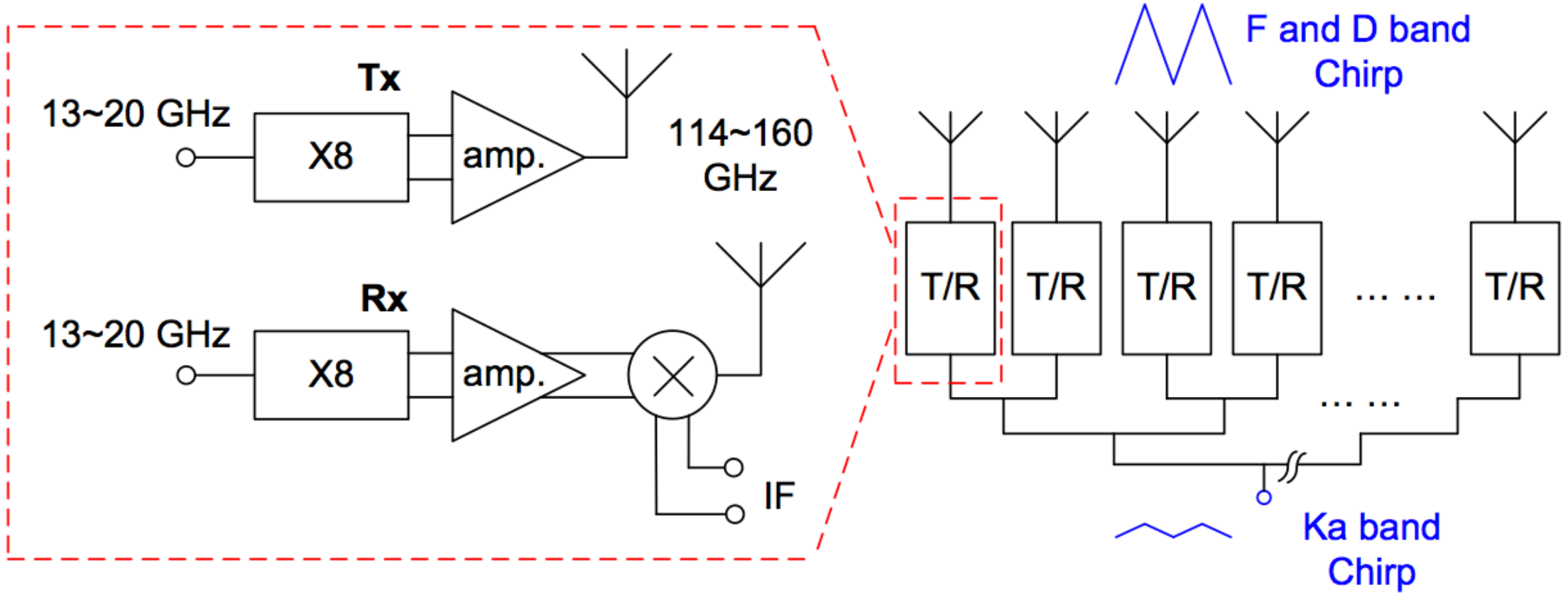
100-160 GHz FMCW-Radar



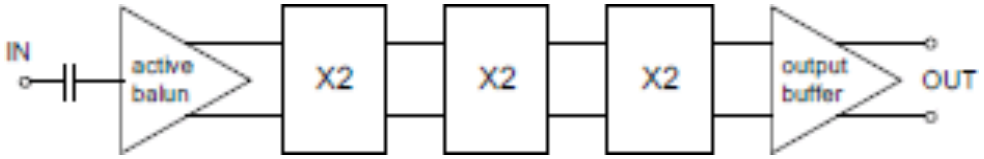


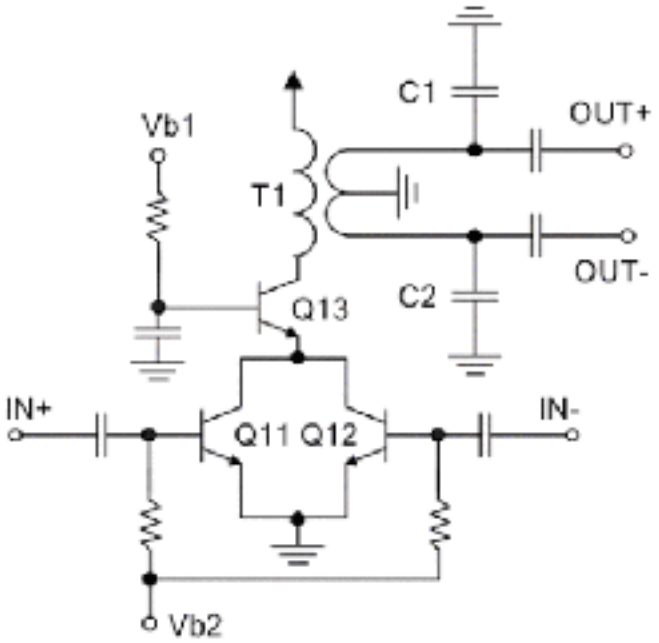
Quelle: Shuai Yuan, Institut für elektronische Bauelemente und Schaltungen

Blockdiagramm FMCW-Radar

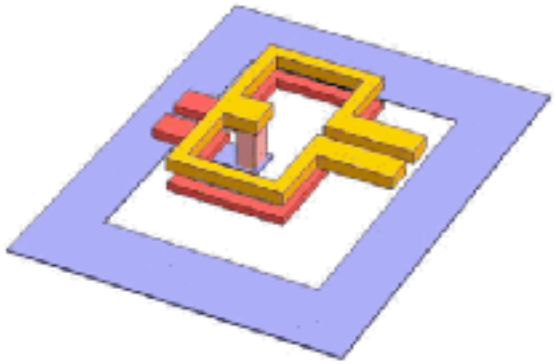


Schlüsselkomponente: Frequenzmultiplizierer





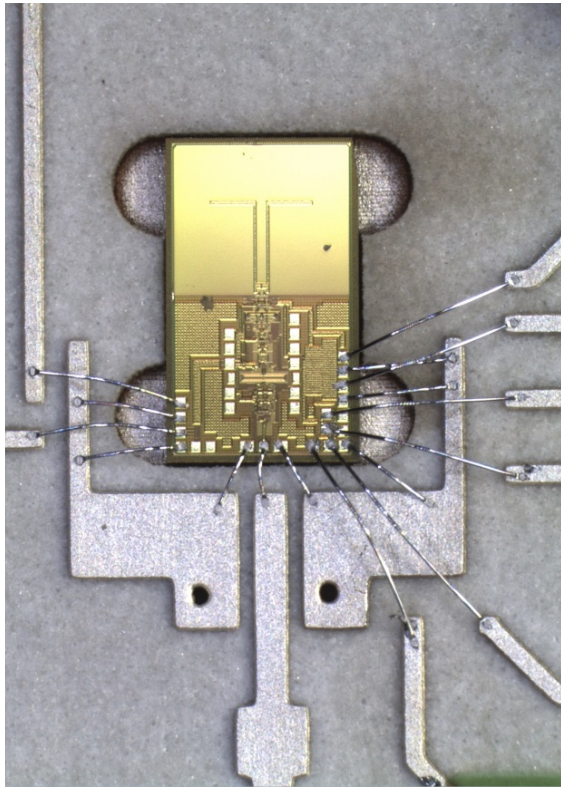
(a)



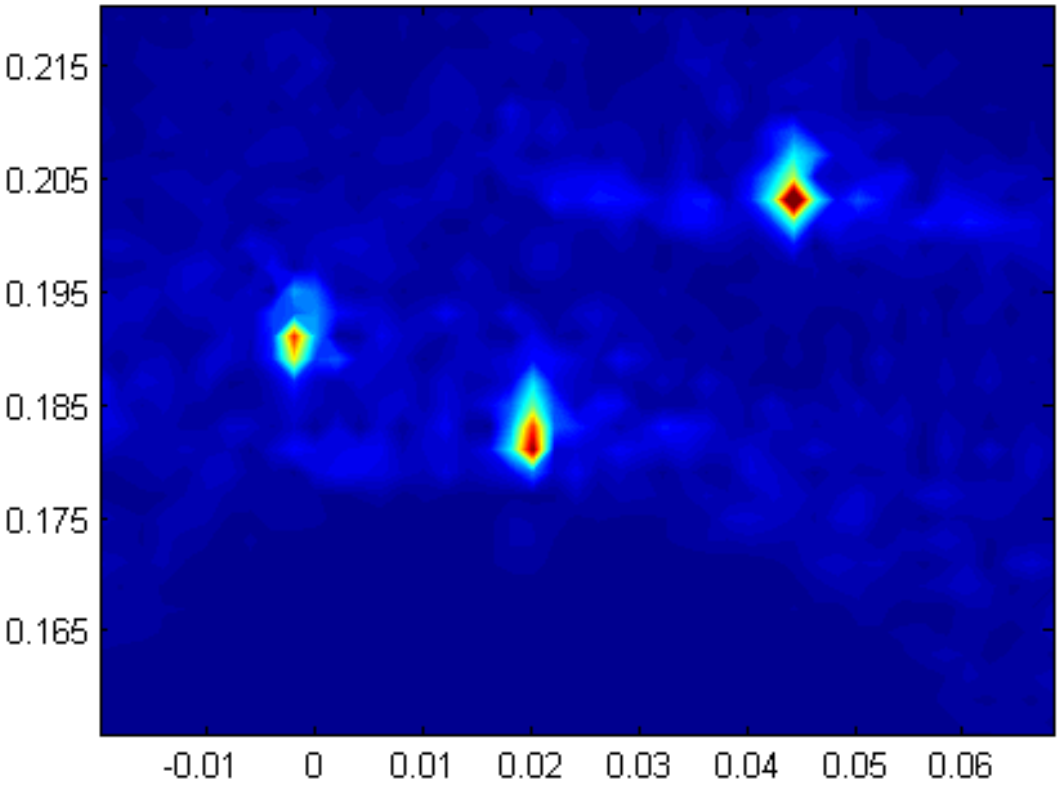
(b)

S. Yuan and H. Schumacher, "A SiGe:C BiCMOS 140 GHz wideband frequency multiplier-by-8 with differential output," *2013 European Microwave Integrated Circuit Conference*, Nuremberg, Germany, 2013, pp. 248-251

SAR-Auflösungsexperiment



Tx and Rx ICs versions with
on-chip and off-chip antennas



SAR sensing experiment with single sensor
5x5 mm² Cu corner reflectors

THz-Spektroskopie

- Fully integrated Tx and Rx modules
- 130 nm Si/SiGe BiCMOS
- 240-250 GHz and 480-500 GHz

K. Schmalz, N. Rothbart, P. F. X. Neumaier, J. Borngräber, H. W. Hübers and D. Kissinger, "Gas Spectroscopy System for Breath Analysis at mm-wave/THz Using SiGe BiCMOS Circuits," in IEEE Transactions on Microwave Theory and Techniques, vol. 65, no. 5, pp. 1807-1818, May 2017

Abb. aus Urheberrechtsgründen gelöscht

Und die Abstrahlung von den Chips?

C. Manneback, "Radiation from Transmission Lines," in *Transactions of the American Institute of Electrical Engineers*, vol. XLII, pp. 289-301, January-December 1923

Radiation from Transmission Lines*

BY CHARLES MANNEBACK

Electrical Engineer, Brussels, Belgium

*This paper is the result of an investigation submitted in partial fulfillment of the requirements for the degree of Doctor of Science from the Massachusetts Institute of Technology, 1922. It has been undertaken under the direction of Professor V. Bush, to whom the author wishes to express his fullest appreciation.

Presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 14-17, 1923.

Das war’s, Leute!

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