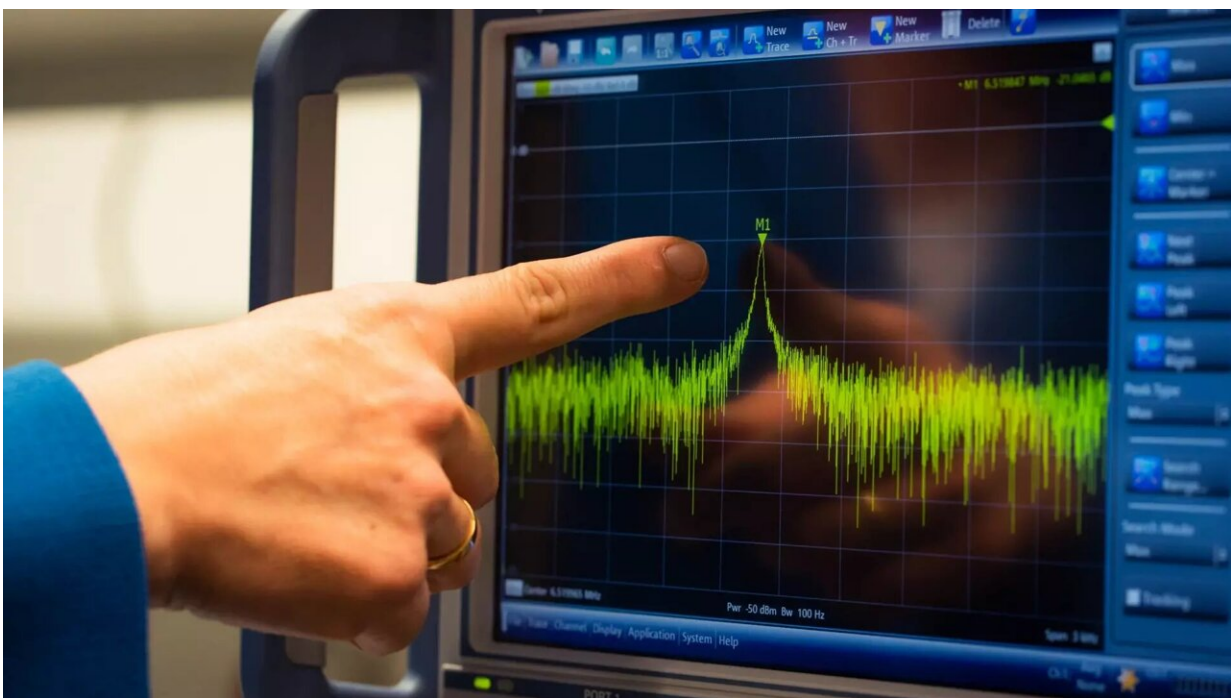


Researchers calculate theoretical extension of parametric amplification to improve sensor functionality

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Measurement of a high-frequency signal. Credit: Magdalena Jooss / TUM

Sensors in electronic devices work with high-frequency signals. For maximum accuracy in the measurements, the parametric amplification effect is used. Researchers at the Technical University of Munich (TUM) are investigating how this effect can significantly expand the

functionality of sensors. Possible applications include improved location positioning with microelectromechanical sensors like those used in smartphones.

Most people are probably familiar with the phenomenon from childhood: standing on a swing, a child rhythmically bends and straightens their knees to get it going. The swing goes higher and higher along a defined path. In physics and applied mathematics, this is called parametric amplification. It is found in many electronic devices.

This effect is used, for example, to increase the sensitivity of these devices for improved accuracy in measurements. Micro- and nanostructured components in [navigation systems](#), smartphones and other mobile end devices utilize parametric amplification. It is also used in self-driving cars. Researchers at TUM are working to expand the limits of this technology. A new study now published in *Nonlinear Dynamics* has calculated how these limits can be overcome.

Frequency range of parametric amplification theoretically expanded

"Until now, parametric amplification has been limited to a very narrow [frequency range](#) of the electrical, optical or mechanical vibrations, also known as oscillations. The same way as the swing always goes back and forth at a fixed [frequency](#). It cannot go faster," says Eva Weig, the Head of the Chair of Nano and Quantum Sensors. "With researchers at TU Darmstadt, we have used a theoretical model calculation to find out what happens when this frequency range is expanded. According to our calculations, this could greatly improve the sensitivity of the sensors."

The researchers modeled dynamic, i.e., oscillating, micro and nanosystems. As their starting point for their calculations, they applied

Mathieu-Duffing systems. This calculation approach is used in most [electronic devices](#). To qualify as a Mathieu-Duffing system, a system must meet three criteria: it must have two or more coupled oscillations, mathematically non-linear elements must be present, and parametric amplification must occur. An element is non-linear in this case if the displacement of the oscillation is not proportional to the applied drive force.

"Our work focused on an asynchronous parametric amplification. This effect is comparable to two playground swings that are connected but not pushed at the same time," says Dr. Ahmed Barakat, a scientist at the Chair of Nano and Quantum Sensors. "In that case we see broadband amplification. As a result, we cannot only amplify a few frequencies, as before. Instead we can address them flexibly, which enables us to significantly expand the functional range."

Practical application of parametric amplification

An important application of parametric amplification is the microgyroscope, a rotational speed sensor that is found not only in every smartphone, but also in satellites. It can be pictured as a rotationally symmetrical spinning top, mounted in movable bearings.

If researchers are able to improve parametric amplification, it will be possible, for example, to determine the position and path of satellites more precisely. In addition, parametric [amplification](#) can also play an important role in quantum computing technology in the future, for example in converting signals.

More information: Ahmed A. Barakat et al, Non-trivial solutions and their stability in a two-degree-of-freedom Mathieu–Duffing system, *Nonlinear Dynamics* (2023). [DOI: 10.1007/s11071-023-08659-5](https://doi.org/10.1007/s11071-023-08659-5)

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