Sensitivity Enhancement in EPR Spectroscopy by Multi-Harmonic Detection

Bruker, in collaboration with Novilet, is excited to announce the launch of the Multi-Harmonic Detection (MHD) Accessory. This cutting-edge addition to Bruker's EPR product line significantly enhances the sensitivity and resolution of EPR measurements, making it an indispensable tool for researchers and clinicians alike.
The MHD Accessory leverages advanced technology to capture multiple harmonics of the magnetic field modulation at various frequencies, dramatically improving the signal-to-noise ratio (SNR) and enabling the detection of even the weakest paramagnetic signals. This breakthrough accessory is designed to provide unparalleled performance in applications ranging from the study of free radicals in biological systems to the characterization of materials with low paramagnetic content.

Introducing the MHD Accessory

Fig. 1: SD10 and HD100 for Multi-Harmonic detection

- SD10: Aiming for efficiency and affordability, this variant is compatible with the Bruker bench-top Magnettech ESR5000. Detects up to 10 harmonics and includes dedicated software for the acquisition and reconstruction of multi-harmonic data
- HD100: Aiming for perfection, this variant is compatible with our ELEXSYS, EMXplus, and Magnettech ESR5000 CW-EPR spectrometers. It detects up to 100 harmonics of the modulation frequency, providing full functionality for optimizing the results

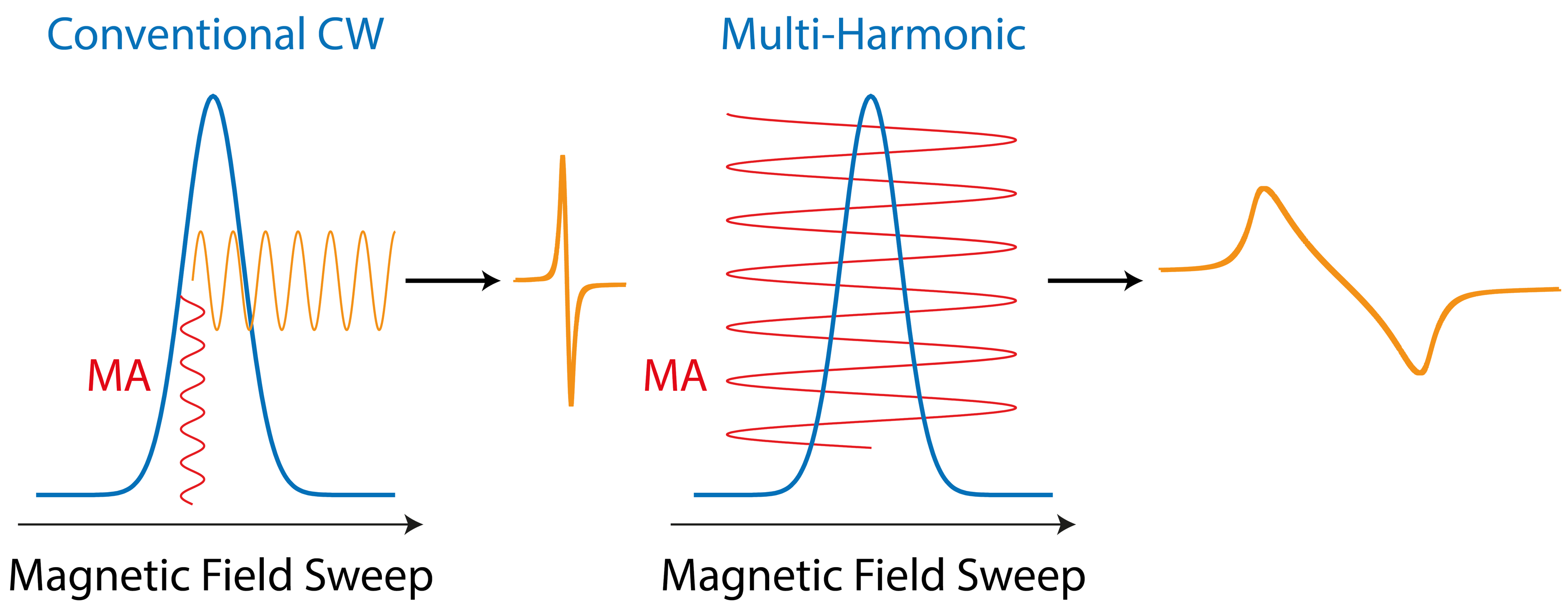

Fig. 2: Conventional CW vs Multi-Harmonic detection

- Conventional EPR spectroscopy uses CW detection, measuring the 1st harmonic, often compromising between sensitivity and field resolution
- Multi-Harmonic detection overmodulates the signal within hardware limits, detecting multiple harmonics to reconstruct the first-derivative signal and enhance the signal-to-noise ratio
- Reconstructing signals from multiple harmonics reduces noise, resulting in a clearer and more accurate EPR spectrum

Sample Dependent SNR Enhancement

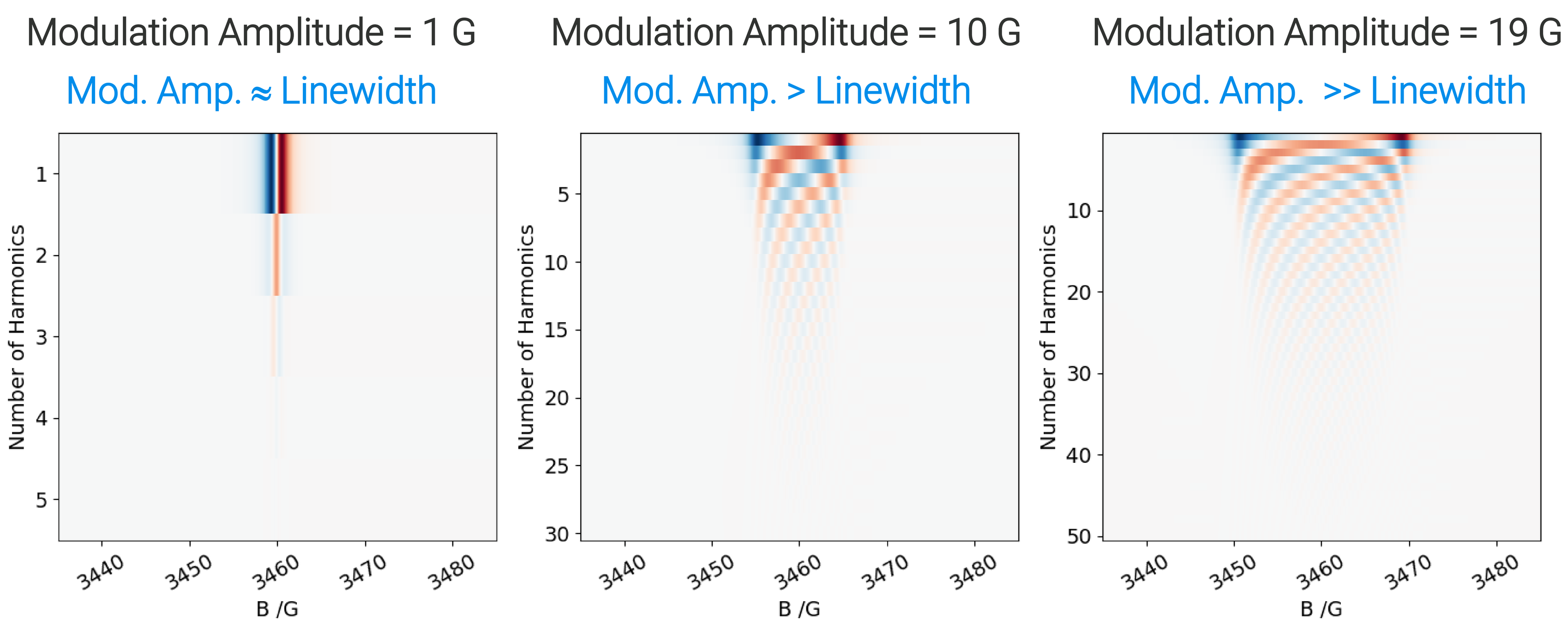

Fig. 3: Dependence of the number of harmonics on the overmodulating factor

- Overmodulation Factor = Modulation Amplitude / Intrinsic EPR Linewidth
- The achievable signal-to-noise ratio depends on the sample and the overmodulation factor
- The optimum overmodulation factor allows the most harmonics to be detected, thus enhancing signal reconstruction

Example 1

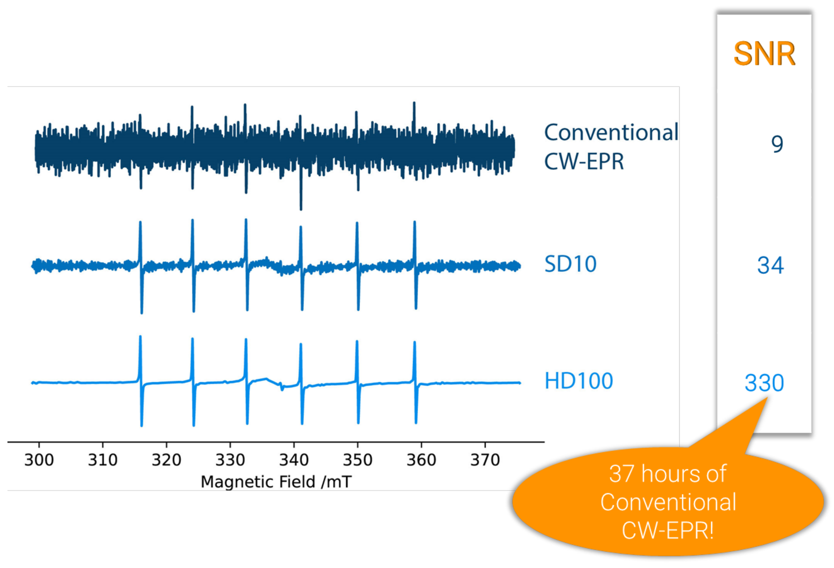

Fig. 4: EPR spectra of Mn(II) in MgO using conventional CW-EPR (top) and the two MHD accessories, SD10 (middle) and HD100 (bottom), respectively. The SNRs are presented on the right.

Mn(II) in MgO, with its narrow linewidth, is an excellent standard for magnetic field calibration.

Fig 4 shows spectra from conventional CW-EPR detection and multi-harmonic detected signals using SD10 and HD100, all with identical parameters except the modulation amplitude.

In 100s, the HD100 achieves a signal-to-noise ratio that otherwise requires 37 hours of acquisition time with conventional CW-EPR.

Example 2

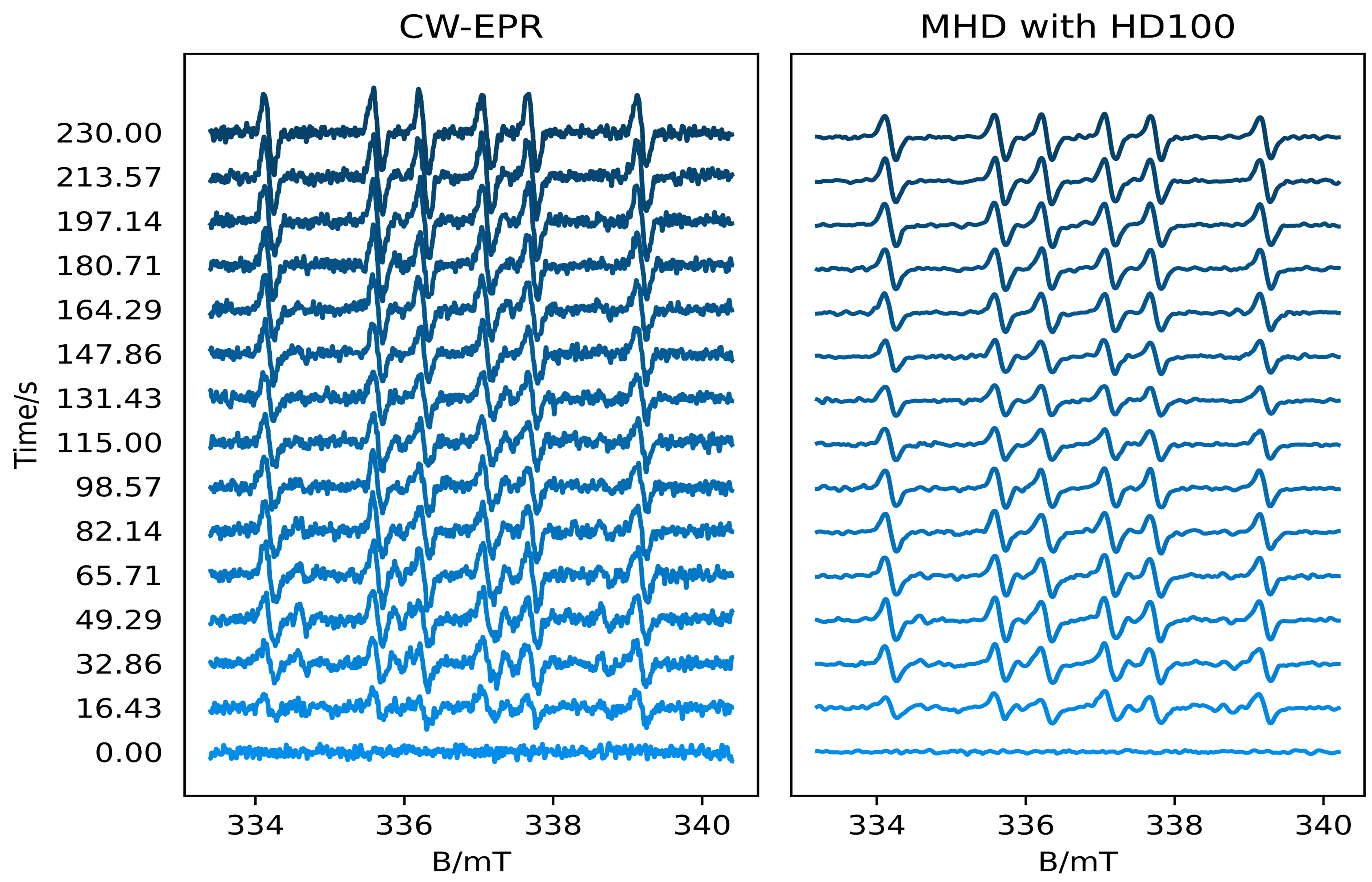

Fig. 5: EPR spectra obtained upon UV-A irradiation (λ = 365 nm) of TiO_2 P25 suspension in DMSO in the presence of DMPO as a spin trap. Left panel – CW-EPR, right panel – MHD with HD100.

The data presented in Fig. 5 shows that multi-harmonic detection significantly improves the SNR ratio compared to traditional CW-EPR detection. This increased sensitivity allows for better detection of short-lived free radicals and their spin adducts, making it a valuable tool in EPR spin trapping experiments.

Conclusion

MHD represents a significant advancement in EPR spectroscopy, offering:

- superior SNRs
- improved spectral resolution
- reduced experimental time,

making it a powerful tool for both research and clinical applications.