

Advancing atmospheric pollution monitoring with airborne THz spectrometer

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Abstract: This study presents a UAS-mounted THz-CW system for spatially resolved in situ spectroscopy for air-quality monitoring. Ground tests verified detection of multiple volatile organic compounds, and flight experiments demonstrated remote gas sampling. The system enables precise, real-time pollutant monitoring across diverse environments, supporting improved environmental and public health assessment.

Accurate, real-time detection of atmospheric pollutants is essential for advancing environmental monitoring and safeguarding public health. Terahertz (THz) spectroscopy offers strong chemical specificity for gas-phase detection, but its integration into airborne systems has remained limited [1]. To address this challenge, we developed an airborne terahertz continuous-wave (THz-CW) spectrometer integrated with an unmanned aerial system (UAS), reported in Fig. 1.



Fig.1 | a) The assembled UAS-THz-CW system in ground station; b) and c) in flight during in-field trials for stability test; d) UAS-THz-CW system in flight during remote sampling with the 5-meter aspiration tube for the collection of the targeted analyte.

This system's performance was rigorously assessed through a two-phase validation process, beginning with controlled laboratory and ground-based experiments [2]. With the stationary drone, reagent-grade pollutants were individually introduced into a sampling cell, and absorption spectra were recorded. These spectra consistently showed excellent agreement with laboratory data and published literature, confirming the system's ability to identify target VOCs under controlled conditions. Building upon this foundational validation, a series of in-flight measurements was subsequently conducted adopting an aspiration-based sampling method: an onboard aspiration pump and electronically controlled valves were activated to draw atmospheric analytes directly into the gas chamber. This configuration enabled the remote detection and quantification of individual gaseous species as well as multi-component mixtures. The resulting in-flight spectra displayed clear, characteristic THz absorption features consistent with reference databases, demonstrating reliable chemical identification even in dynamic airborne

environments. The system also successfully resolved and quantified individual constituents within multi-component mixtures through a multiple absorber fitting approach (Fig. 2), highlighting its potential for real-time analysis of complex atmospheric samples. This proof-of-concept study shows that an airborne THz spectrometer mounted on a drone can successfully perform remote atmospheric sensing [3]. By combining THz continuous-wave spectroscopy with unmanned aircraft and aspiration-based sampling, the system enables efficient, spatially resolved detection and measurement of gaseous pollutants in areas that traditional instruments cannot easily access.

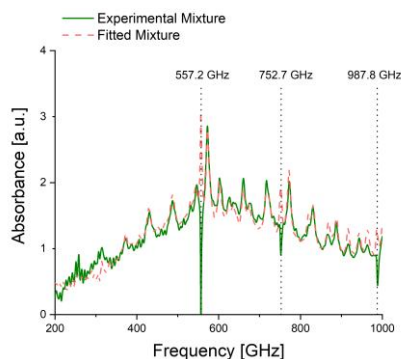


Fig.2 | Comparison between the experimental five components mixture aspirated inside the sampling cell and the spectrum obtained from the retrieved coefficients in the range 0.2-1 THz.

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