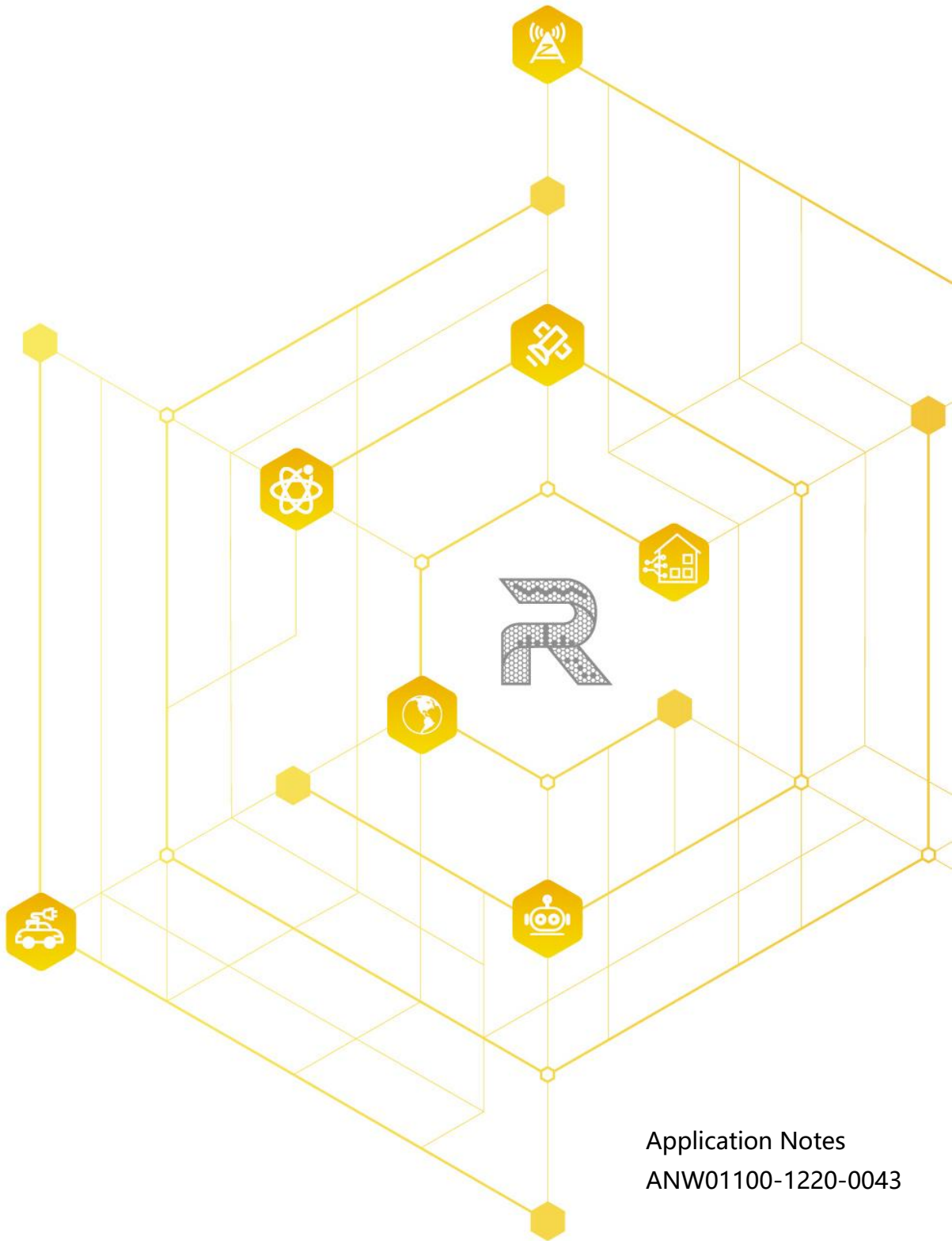
Vector Network Analyzer in S-Parameter and Resonance Frequency-Shift Testing for Sensors



Application Notes

ANW01100-1220-0043

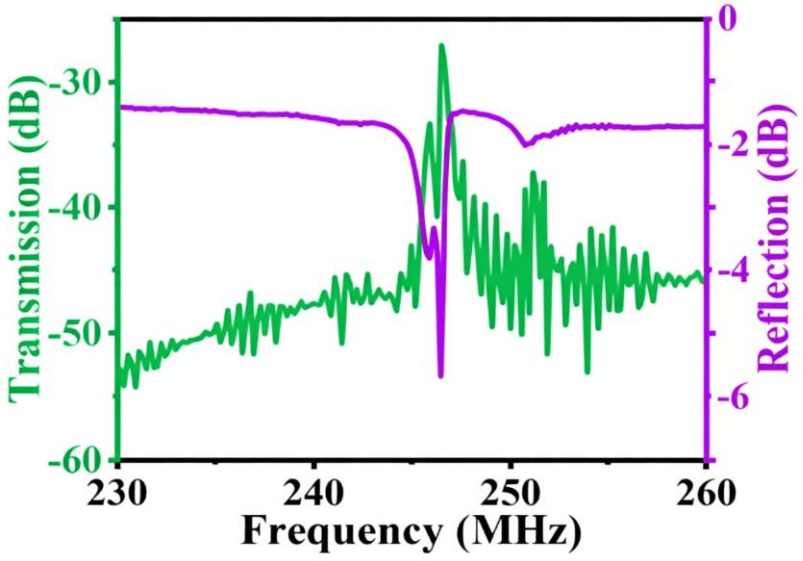
Introduction

Surface acoustic wave (SAW) gas sensors consist mainly of a piezoelectric substrate and two interdigital transducers (IDTs). Driven by an AC electrical signal, the input IDT excites mechanical waves propagating along the substrate surface via the piezoelectric effect; the output IDT converts them back into an electrical signal. When the signal frequency matches the IDT geometry, a resonance frequency f_0 is obtained and transmission efficiency is highest. By coating a sensitive film between the IDTs, adsorption of the target gas increases mass loading and reduces acoustic velocity, which shifts the resonance frequency downward. The gas concentration can be inferred from the measured frequency offset. SAW sensors use frequency changes to sense the environment and are widely used in communications, radar, and other fields, with an important role in petrochemical toxic-gas sensing and industrial safety.

Application scenarios

For SAW sensors, the vector network analyzer (VNA) is the core instrument for high-precision detection: it stimulates the sensor and accurately tracks tiny changes in resonance frequency (frequency shift), enabling quantitative analysis of target gas molecules.

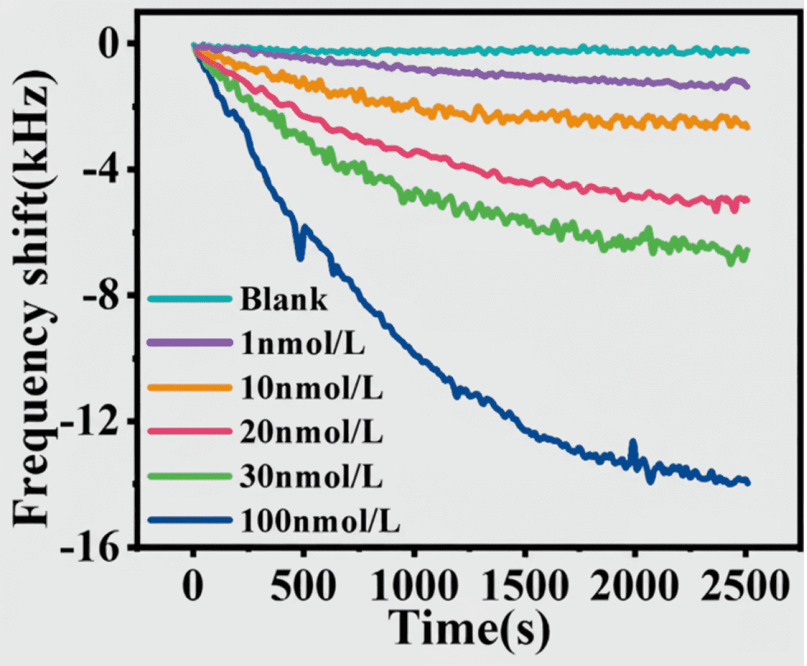
In operation, the VNA applies a swept stimulus to the sensor and measures return loss (S11) or transmission (S21) in real time to lock precisely to the resonance frequency f_0. After the sensitive film adsorbs target molecules, mass loading and viscoelastic changes typically alter propagation velocity and loss, appearing as drift of characteristic frequency and changes in S21 amplitude and bandwidth. The VNA captures this frequency shift (Δf) with very high resolution; the magnitude of Δf is directly related to analyte concentration. S-parameters clearly show a pronounced resonance peak near 246.5 MHz.



SAW sensor S-parameters: Transmission (S21), Reflection (S11)

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In non-blank measurements, resonance frequency shift (Δf) increases over time. Higher molecular concentrations lead to faster shift rates, so the ambient concentration can be inferred from Δf over a defined time window.



Frequency shift versus time under different gas concentrations

The VNA measures S-parameters of the SAW sensor; host PC software logs frequency and shift parameters to reflect biomolecular concentration in real time.

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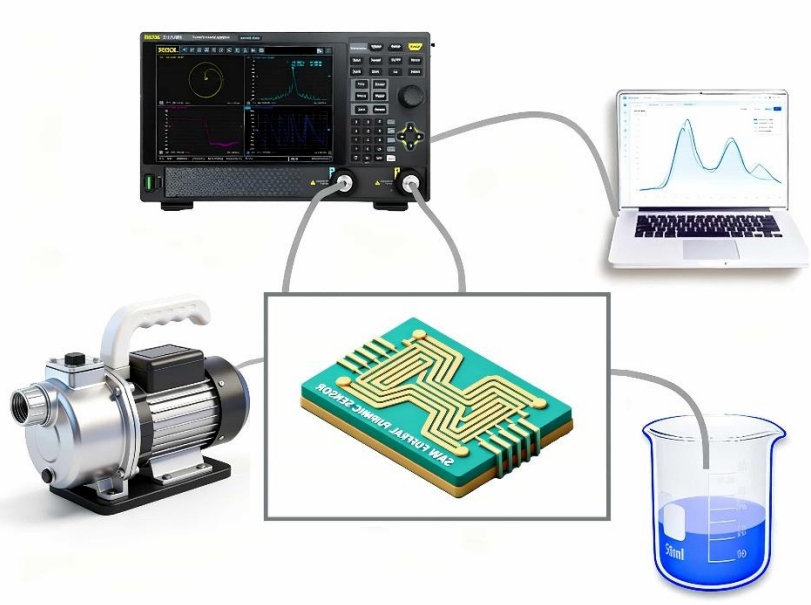


Diagram of an SAW biosensor test system for monitoring Staphylococcus aureus gene sequences

This high-precision approach applies broadly—for example, in industrial safety for real-time monitoring of toxic or flammable leaks such as hydrogen sulfide (H_2S) and ammonia (NH_3), enabling rapid alarming; in environmental monitoring for pollutant detection and high-sensitivity air-quality assessment; and in healthcare for non-invasive early screening via biomarkers in exhaled breath.

Overall, combining the VNA's measurement fidelity with the SAW sensor's sensitivity yields strong value for fast, reliable trace-gas detection in research and demanding applications.

Application challenges

Three factors largely determine success in such SAW sensing applications:

1. Capturing extremely small frequency shifts

The sensor converts minute mass changes into resonance shifts (Δf). These shifts are often tiny—on the order of Hz or kHz—while the center frequency is in the MHz or GHz range. With very fine frequency resolution and low trace noise, the VNA can excite and lock onto the resonance peak against a high-frequency background and resolve Δf with high accuracy. A sufficiently narrow IF bandwidth (IFBW) and fine frequency resolution are critical.

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2. Full electrical characterization

Beyond frequency alone, S-parameters (S11 and S21) characterize overall sensor behavior. The position and magnitude of the S21 transmission peak and the S11 reflection null carry important information. Stability and repeatability of these parameters underpin correct sensor operation and provide a reliable baseline for shift analysis. Full S-parameter analysis is essential.

3. Automated workflow and system integration

The system must sweep, find peaks, log data, and analyze automatically to support long-duration, continuous monitoring—turning a single-point snapshot into dynamic process analysis for reaction kinetics or environmental monitoring. The instrument must offer standard SCPI programming and rich interfaces for seamless integration with platforms such as LabVIEW.

The RIGOL approach to these challenges

RIGOL released the DNA5000/6000 series vector network analyzers in 2025. They accurately measure S-parameters of SAW devices and support remote control and user programming—including LabVIEW hosts for data logging and reporting.

Key capabilities:

1. Extreme resolution and low noise

High frequency resolution down to 1 Hz and selectable IF bandwidth from 1 Hz to 10 MHz address weak Δf tests on SAW sensors. Trace noise as low as 0.003 dB rms yields stable results and clear separation of weak signals from the high-frequency background.

2. Full S-parameter analysis and robust calibration

Coverage from 5 kHz to 26.5 GHz with two or four test ports, full S-parameter support, and formats including amplitude, phase, Smith chart, and VSWR. The built-in calibration wizard guides repeatable setups. De-embedding and fixture removal strip adapters, fixtures, and cables to recover true DUT S-parameters.

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3. Standard commands and easy integration

Standard SCPI commands, aligned with mainstream ecosystems, let you integrate or swap instruments into existing automation without rewriting scripts. HDMI, LAN, USB, and GPIB (DNA6000 series) support displays, remote control, and ATE integration.

Overall impact

From sensitivity to precision

The sensor alone converts environmental changes into a fragile physical effect. The VNA stabilizes and resolves that effect into repeatable electrical data (Δf), making trace detection of minute gas quantities practical.

From component to system

A bare SAW chip is only one component. The VNA provides stimulus, acquisition, and standardized control—bridging the sensing front end to analysis software and enabling integrated, automated, continuous test systems.

From R&D to the field

Advanced features such as de-embedding strip environment and fixture effects; guided calibration and straightforward operation lower the barrier so the technology can migrate reliably from the lab to industrial deployment.

Conclusion

SAW sensing systems are ubiquitous in industrial safety, environmental monitoring, and biomedical diagnostics; a trustworthy, automation-friendly instrument often determines whether the overall system stays stable.

The RIGOL DNA5000/6000 series delivers wide dynamic range, low noise, and strong data handling for accurate, trustworthy results, together with intuitive operation, standard interfaces, and straightforward automation—accelerating integration and development of the full sensing chain.

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