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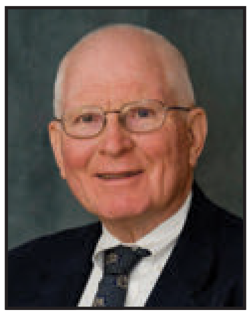
Editorial

Quantum Receiver Detects 0 to 20 GHz In Real-Time

Tom Perkins
Senior Technical Editor



A recently developed quantum sensor developed at the Army Research Laboratory (ARL), Adelphi, Maryland, can detect a wide range of carrier frequencies from DC to 20 GHz. This could revolutionize soldier communications, spectrum awareness, and electronic warfare techniques. The device, called a Rydberg sensor, uses laser beams to create highly excited thermal Rydberg atoms directly above a microwave circuit, to boost and emphasize the portion of the spectrum being detected. The Rydberg atoms are sensitive to the circuit's electric field voltage. This makes the device a sensitive probe for a wide range of signals present in the RF spectrum. Claims have been made that the technique compares favorably with other established electric field sensor technologies, including electro-optic crystals and dipole antenna-coupled passive electronics.

Background: Dr. Rydberg

Johannes Rydberg, PhD Lund University, was a Swedish mathematician and physicist mainly known for devising the Rydberg formula in 1888, which describes the wavelength of photons emitted by changes in the energy level of an electron in a hydrogen atom. A Rydberg atom is an excited atom with one or more electrons that have a very high principal quantum number, n. As the value of n increases, the electron is farther from the nucleus.

Rydberg atoms have several unique properties including an exaggerated response to electric and magnetic fields, long decay periods and electron wavefunctions that conditionally approximate classical electron orbits. In practice, researchers excite Rubidium atoms in high-energy Rydberg states. The atoms interact strongly with circuit's electric fields, enabling detection and demodulation of any signal received by the circuit. The core electrons shield the outer electrons from the electric field of the nucleus. From a distance, the electric potential looks the same as the behavior of an electron in the hydrogen atom.

Performance Attributes

The system has 4 MHz instantaneous bandwidth, and over 80 dB of linear dynamic range. With a low noise amplifier, high performance spectrum analysis with peak sensitivity of better that -145 dBM/Hz (just 29 dB above thermal noise ENR) has been demonstrated. By attaching a standard telescoping "rabbit ear" antenna, weak ambient signals including AM and FM radio Wi-Fi and Bluetooth can be detected.

Future Value Added

Dr. Kevin Knox, a research scientist at the U.S. Army Combat Capabilities Development Command (DEVCOM, ARL), said, “All previous demonstrations of Rydberg atomic sensors have only been able to sense small and specific regions of the RF spectrum, but our sensor now operates continuously over a wide frequency range for the first time.” He continued, “This is a really important step forward proving that quantum sensors can provide a new, and dominant, set of capabilities for our Soldiers, who are operating in an increasingly complex electro-magnetic battlespace.”

The Rydberg spectrum analyzer potentially could push beyond the fundamental limitations of traditional electronic circuits in measurement performance. Breakthroughs in sensitivity, bandwidth, and frequency range could be a reality. The Army lab’s spectrum analyzer and other quantum sensors have the potential to explore a new frontier of Army sensors for spectrum awareness, electronic warfare, sensing, and communications. This is part of the Army’s modernization strategy.

Additional Reading

The peer reviewed journal *Physical Review Applied* 15, 014053 - dated 27 January 2021 published the researchers’ findings, *Waveguide-coupled Rydberg spectrum analyzer from 0 to 20 GHz,* co-authored by Army researchers David Meyer, Paul Kunz, and Kevin Cox.

“Devices that are based on constituents are one of the Army’s top priorities to enable technical surprise in the competitive battlespace,” said Army researcher Dr. David Meyer. “Quantum sensors in general, including the one demonstrated here, offer unparalleled sensitivity and accuracy to detect a wide range of mission-critical signals.”

Dr. Cox stated, “Significant physics and engineering effort is still necessary before the Rydberg analyzer can integrate into a field-testable device.” “One of the first steps will be understanding how to retain and improve the device’s performance as the sensor size is decreased. The Army has emerged as a leading developer of Rydberg sensors, and we expect more cutting-edge research to result as this futuristic technology concept quickly becomes a reality.” Could a new Tiny S/A be far behind?

Dr. Rydberg died in 1919. How exciting that we can see breakthrough benefits of his efforts over 100 years later. These developments may reinforce my belief that 2021 will be a year of incredible sensor progress.