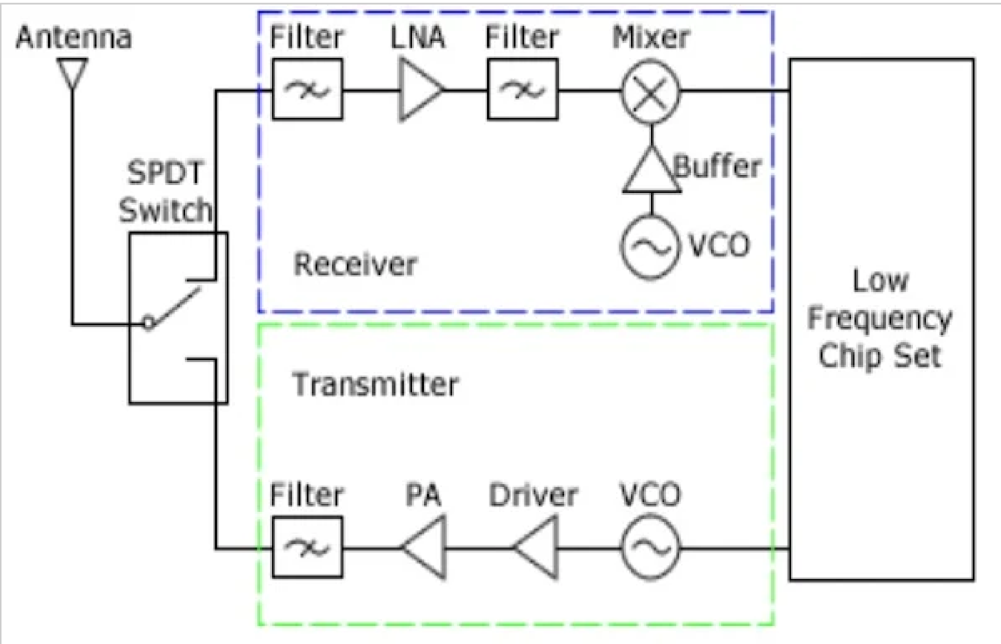
News

“Quantum Radio” Trials Help Push for More Sensitive RF Hardware

May 19, 2022 by Jake Hertz

Researcher's from the British Telecommunications (BT) Group are leveraging a new technique in RF radio-receiving that could lead to exponentially more sensitive RF hardware.

As the field of wireless communications continues to develop rapidly, the industry will require hardware that can keep up. Today, concerns over power consumption and wireless coverage are priorities in the industry and are causing some to reconsider conventional RF hardware.



An example block diagram of an RF wireless communications system. Image used courtesy of Mouser

One promising direction for this technology is the integration of quantum physics with RF hardware to form new quantum radio technology. Aiming to do just that, this week, researchers at the BT Group published a new paper describing success in this pursuit with a new high-sensitivity quantum RF sensor.

In this article, we’ll talk about the need for improved RF sensitivity, some concepts in quantum physics, and the new research from BT.

The Need for RF Sensitivity

In the world of wireless communication, multiple trends are happening simultaneously.

First, engineers are pushing for lower power operation, where battery-powered products like the Internet of Things (IoT) devices need to ensure long battery life. One way of going about this is to limit the device's transmit power, which will lower the device's power consumption at the expense of communication coverage and range.

$$R = \sqrt[N]{\frac{P_T G_T \lambda^2}{P_R F_M 16\pi^2}}$$

R = Maximum range for communication link
N = Propagation Law (N=2 for line-of-sight, N=4 for urban environments)
P_T= Transmit power
G_T= Total antenna gain
λ = Wavelength
P_R= Receiver sensitivity
F_M= Fading margin

The Friis Transmission Formula shows that range is affected by frequency, transmit power, and receiver sensitivity. Image used courtesy of David Steed

At the same time, new technologies like 5G are using higher frequency bands than previous generations. The result of a higher carrier frequency is greater electromagnetic (EM) attenuation and path loss, again resulting in decreased wireless coverage and range.

Many of the industry's wants and needs are also directly conflicting with wireless coverage. With that in mind, there is a big push to develop RF circuitry with greater sensitivity.

According to the Friis Transmission Formula, all else equal, every time we improve receiver sensitivity by a factor of 12 dB, we double our communication range. Therefore, by improving the sensitivity of our RF receiver hardware, we could allow for lower power and higher frequency transmission without compromising range.

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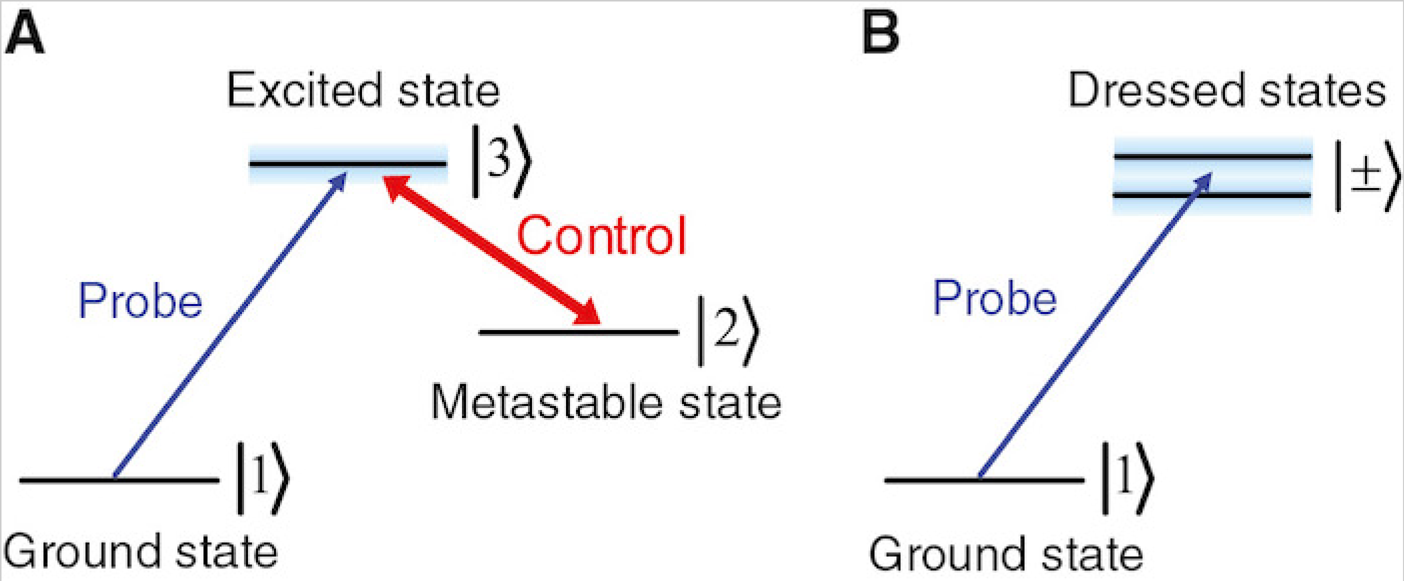
BT's Rydberg RF Receiver

Hoping to solve this problem, researchers from BT are working towards creating a more sensitive RF receiver.

As described in their paper, the researchers leveraged a quantum phenomenon known as electromagnetically induced transparency (EIT) to develop a new quantum RF receiver.

EIT is a method that exploits the behavior of atoms that are excited into higher energy levels, known as Rydberg atoms, and exhibits an exceptionally high sensitivity to external fields. This method is a spectroscopic technique in which a probe laser, tuned to a ground state, and a coupling laser, tuned to a Rydberg energy level transition, is incident on a glass cell filled with a single atomic species.

In this setup, external electric fields that perturb the EIT can be detected with an extremely high sensitivity based on their impact on the state transitions of the Rydberg atoms.



Energy levels in an atomic EIT system. Image used courtesy of [Liu et al]

In their experiment, the new RF sensor exploited the optical response of the Rydberg atoms in response to a modulated RF signal, as opposed to historical attempts with a constant RF field. The research represents the first time that a digitally-encoded message had been received on a 3.6 GHz carrier frequency using these methods—a number which is relevant since it is a commercial 5G frequency.

While the technology is still in its infancy, the researchers claim that their approach theoretically offers over 100x more sensitivity than traditional receivers. With this comes enormous implications about the potential to significantly decrease power consumption and improve range in future wireless devices.