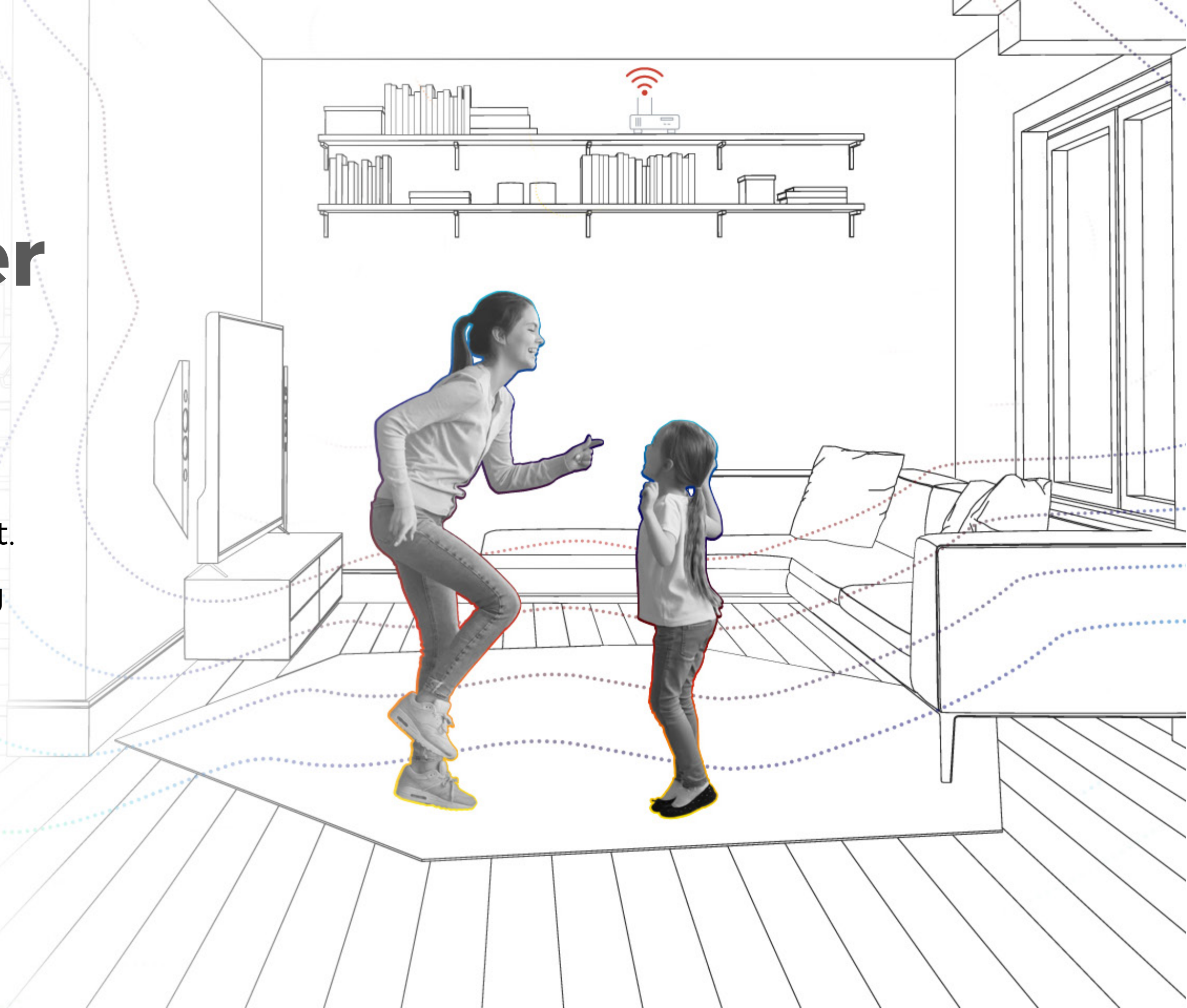# Wi-Fi Doppler Imaging

The world is becoming more connected and more intelligent.

Wi-Fi Doppler Imaging is taking networking to the next level by offering imaging over the Wi-Fi network.

Learn what it is, how it works, and what it can be used for.

Celeno™

Wi-Fi doppler imaging (DI) re-imagining Wi-Fi capabilities

The world is moving towards reliance on more artificial intelligence and more connectivity. Those are two of the major technological trends of our time.

As machine learning algorithms get applied to more and more applications, and in parallel more devices become connected to this intelligence (referred to as IoT) there's a thirst for sensing capabilities within the home or office to supply inputs for the AI layer to support better consumers and businesses.

Wi-Fi Doppler Imaging is a technology that uses the Wi-Fi signal to generate imaging data that can be interpreted into insight about the movements of people and objects within a given environment.

Whether it's in a residential area or a commercial building, having the capacity to identify and respond to events in a timely fashion is a primary concern for many stakeholders. Sophisticated sensors are imperative to capturing the data needed to oversee situations that occur in a given environment. Installing multiple cameras within a certain space is an option, but cameras have their limitations in that they need light, are another piece of equipment to install, and are often perceived as invasive in terms of privacy.

With Wi-Fi Doppler Imaging, homeowners and businesses can detect the movement of people, pets, and objects for safety and security purposes, energy management, entertainment analytics, medical applications and more, without the need to install anything additional to their Wi-Fi APs.

What is Wi-Fi Doppler Imaging?

Wi-Fi Doppler imaging is a new paradigm that's pushing the boundaries of Wi-Fi and reinventing its capabilities.

Celeno's Wi-Fi Doppler Imaging technology is the first of its kind. It harnesses Wi-Fi hardware to generate Doppler Radar Images to track objects and depict their behavior. It detects and tracks the movement and location of people, pets, and objects.

The Doppler signature produced by the moving objects is analyzed by machine learning classifiers, which locate, monitor, and assess the behavior of such objects and the situation itself. The technology enhances the contextual interpretation of the event, enabling an endless variety of applications.

The Wi-Fi Doppler Imaging technology eliminates the need for multiple cameras or sensors in home environments and commercial buildings. It addresses consumers' issues about having to invest in next-generation gadgets and infrastructures each time new technologies are developed. At the same time, it protects the privacy of consumers.
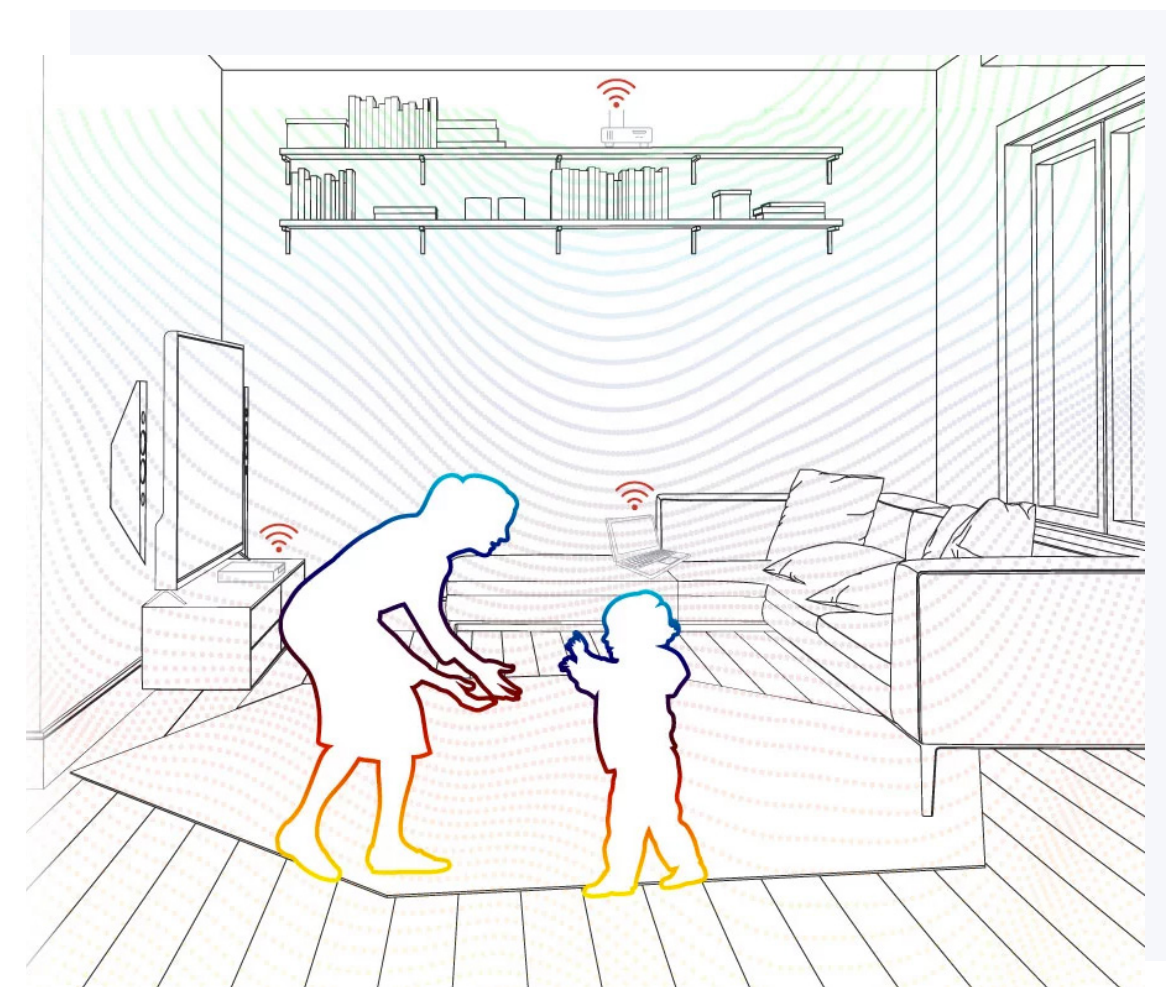
What is the Doppler Effect?

What is Micro Doppler?

The Doppler effect (or the Doppler shift) is the change in frequency or wavelength of a wave in relation to an observer who is moving relative to the wave source.

Micro Doppler refers to the case when in addition to the bulk motion of the object, there are micro-motion dynamics. Micro-motion dynamics are typical for living objects that have limbs and joints moving in different velocities and directions. For example: when a person walks, different parts of their body move differently, and each body part generates a unique Doppler shift. Objects like cars, robots, and machines have micro-motion dynamics characterized by vibrations when moving or additional moving parts.
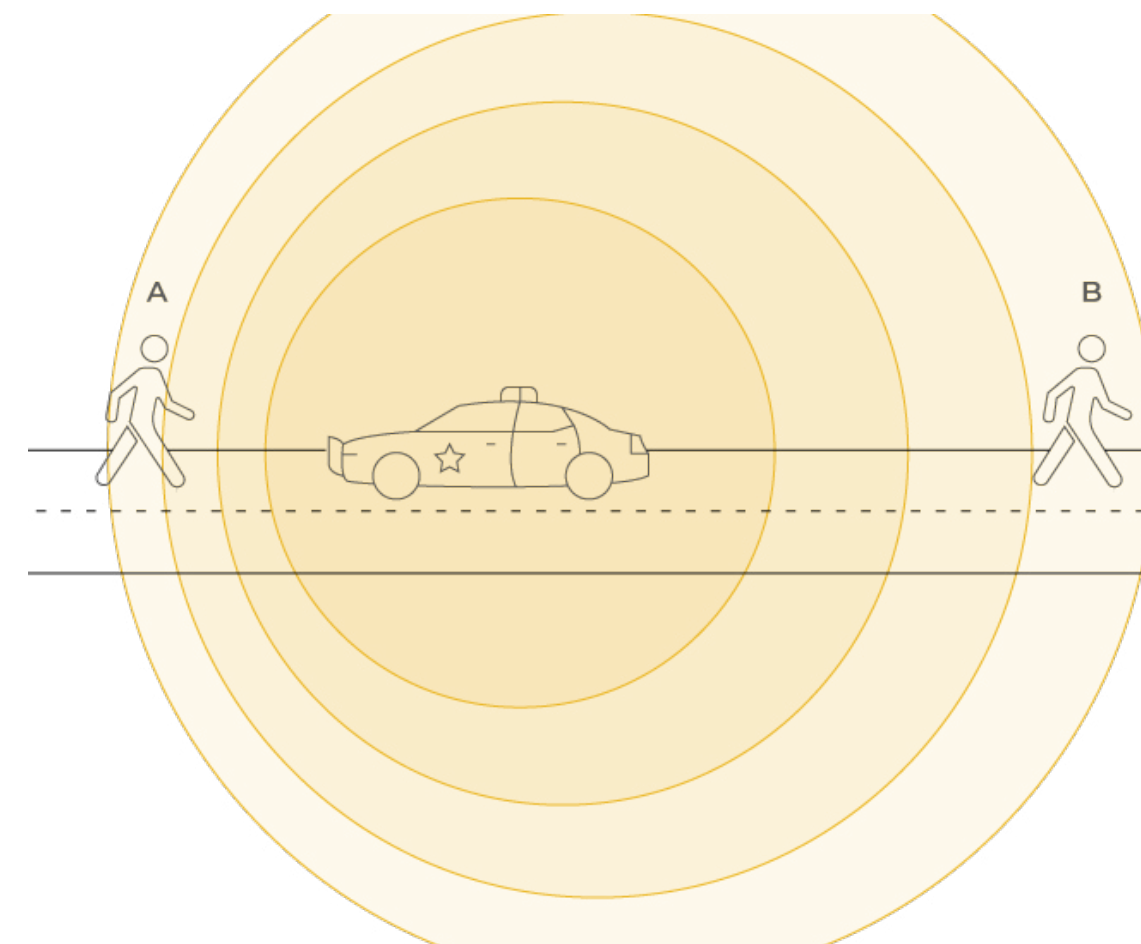
What is a Doppler Spectogram?

Doppler spectrogram is a representation of the range of doppler frequencies generated by a moving object over time. It's a fundamental tool in analyzing the motion and behavior of objects. Different types of movement generate different spectograms.
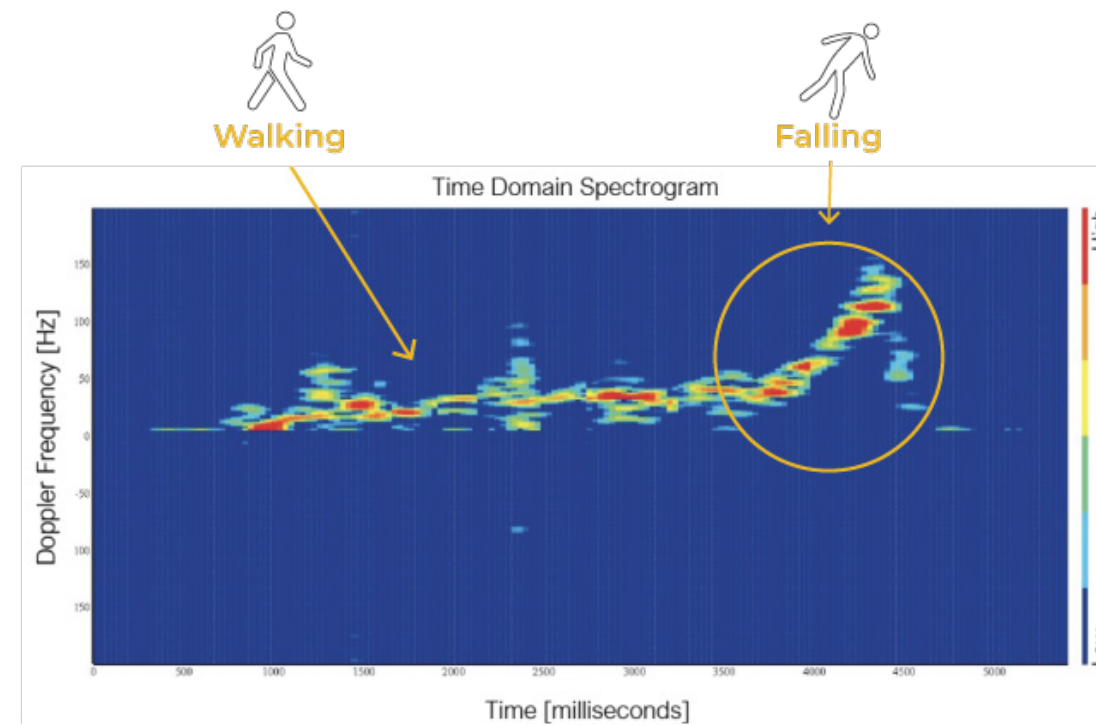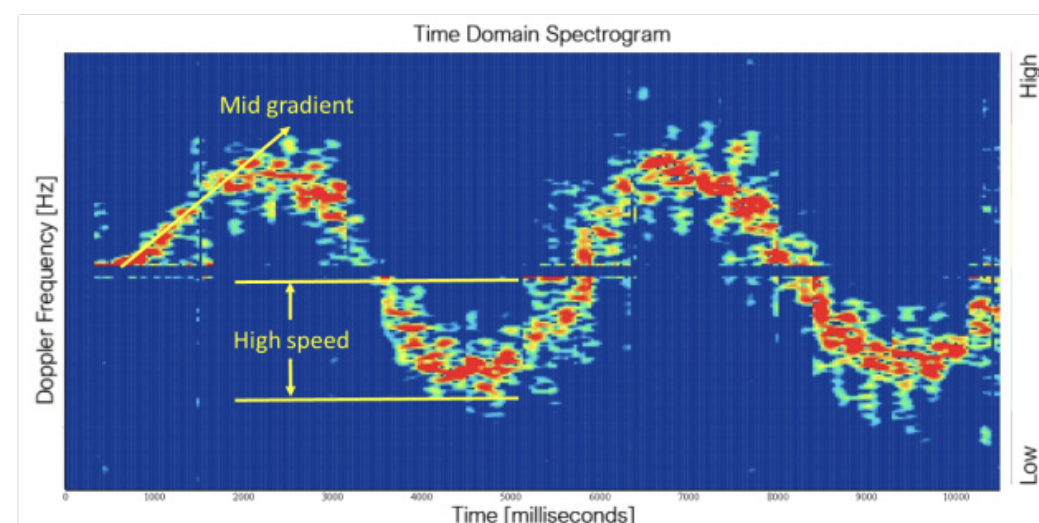
Motion classification based on doppler imaging

Based on machine learning and AI technologies, motions can be classified based on their Doppler signatures.

Doppler spectrograms are highly correlative to common human motions such as falling, walking, bending over, sitting down, standing up, etc.

By tracking the spectrogram of a moving object, the information is fed to multiple pre-trained classifiers that label the motion as common human actions. This in turn adds context that can help applications deduct and drive better actions and insights on the observed scene.
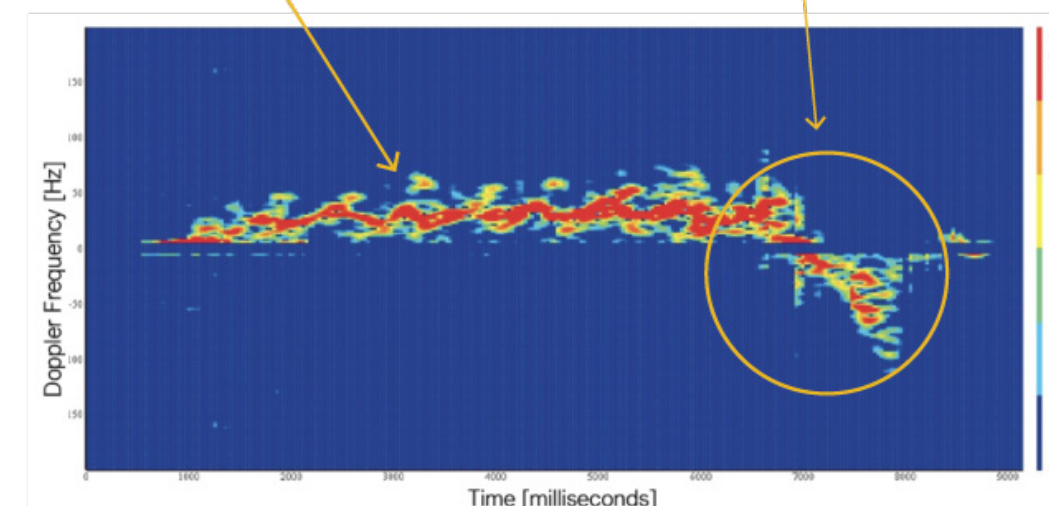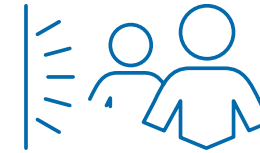
What Are the Capabilities of Wi-Fi Doppler Imaging?

TRACKING OBJECTS

Wi-Fi Doppler Imaging enables homeowners and businesses to detect moving objects within their environment and determine their location.
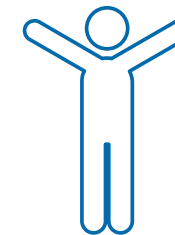
QUANTIFYING OBJECTS

Wi-Fi Doppler Imaging can track multiple objects simultaneously and can be used for identifying how many people are occupying a specific space.

LABELING OBJECTS

By analyzing the spectrograms of common body movements, the technology can help classify objects as adults, children, pets, and objects.t

RECOGNIZING GESTURES

Imaging technology gives Wi-Fi routers the ability to identify and classify gestures, all within a particular environment.

DETECTING BREATHING

Ideal for elderly care facilities, Wi-Fi Doppler Imaging not only detects but also measures the respiration rate of people. This technology is actually suitable for the sought after business of supporting elderly people living on their own.

CLASSIFYING COMMON BODY MOVEMENTS

The technology can distinguish different body movements and categorize them based on the actions performed. For instance, it can determine when a person is sitting down, lying down, standing up, or detect a fall.

What are the characteristics of Wi-Fi doppler imaging?

COMBINES IMAGING TECHNOLOGY AND WI-FI NETWORKING
This breakthrough technology incorporates Wi-Fi networking capabilities and imaging technology using the same hardware and radio frequency resource.

LEVERAGES ON THE 5GHZ WI-FI SPECTRUM AND WI-FI RF CHARACTERISTICS
Certified as a Wi-Fi device that generates high-resolution tracking and classification without the need to certify new equipment or introduce new RF spectrum.
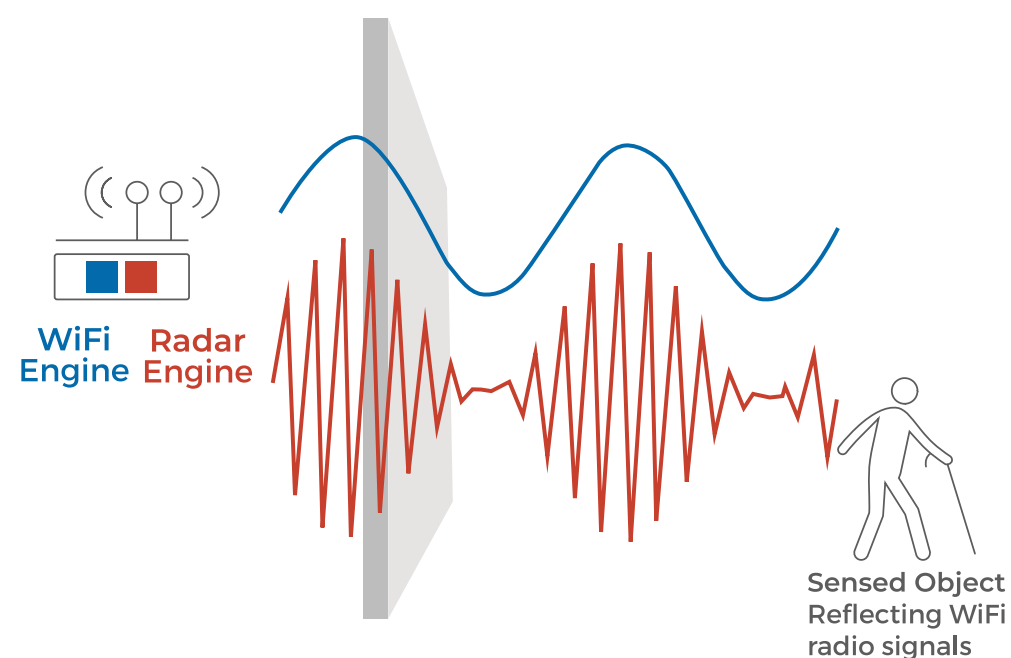
OPTIMAL FOR INDOOR APPLICATIONS - SEES THROUGH WALLS
Operating with Wi-Fi technology enables its imaging capabilities to detect movement through walls and identify what's on the other side. No line of sight is required to track and identify the movement of objects in a given environment.

OPTIMAL FOR INDOOR APPLICATIONS - EASILY FILTERS OUT CLUTTER
By leveraging on Doppler, it can easily filter away clutter coming back from walls, furniture and other static objects that are common to indoor environments.

OPTIMAL FOR MOTION CLASSIFICATION
Tracking Doppler spectrograms of moving objects is an optimal tool to classify behavior of people and characterize movements and postures of objects to add context into an observed situation for smarter applications.

USES ONLY A SINGLE DEVICE
By leveraging on multiple antennas, it can measure angular direction to objects from a single hardware device, hence track objects location accurately without the need for multiple devices.

WiFi Engine Radar Engine

Sensed Object Reflecting WiFi radio signals

Wi-Fi doppler imaging demo

This demo demonstrates the technical capabilities of Wi-Fi Doppler Imaging. We have set up a single Wi-Fi access point with four antennas, located in view of the camera.

We are showing object detection and location tracking as portrayed on the tracking GUI on the left-hand side. In addition, the technology analyzes complex body motions and classifies body postures. The right-hand side shows where the Doppler spectrogram is captured and the classifier output is displayed.

Click here to see Celeno's Wi-Fi Doppler Imaging in action.

Wi-Fi Doppler Imaging Applications

HOME ELDERLY CARE AND ASSISTED LIVING

The smart capabilities of Wi-Fi Doppler Imaging should empower older generations to continue living in their homes. At the same time, it should give family members peace of mind. Imaging technology is ideal for elderly care as it has the capacity to alert family members or caregivers whenever there's out-of-the-ordinary activity happening inside the house. Best of all, aided with machine learning capabilities, the system predicts health deterioration, sleeping disorders, and so on.

Celeno's Wi-Fi Doppler Imaging technology can monitor a person's respiration rate when they are asleep. Family members, as well as caregivers, can be alerted if there are changes. Older people aren't as nimble or agile as they used to be and might often fall or slip accidentally. The system detects such emergency situations and alerts the necessary people, enabling them to respond in a timely and effective manner.

Best of all, this low-touch technology which could be part of the standard Wi-Fi network achieves these insights without the need for any wearable devices and without compromising privacy.

Wi-Fi Doppler Imaging Applications

HOME SECURITY

Wi-Fi Doppler Imaging enhances home security. The technology could enable entry-level peace of mind applications such as motion detection, and enhance them with an extra level of intelligence distinguishing pets from humans and even add geofencing by filtering out movements from neighboring apartments. It can even be harnessed for a more comprehensive system for detecting intrusion at night while household members are in the house by applying intelligent zoning and restricting intrusion detection only to the house perimeter.

Compared to standard home security technologies today which are based on PIR sensors, Wi-Fi Doppler Imaging technology is hassle-free as it doesn't require professional installation and routine battery replacement.

Wi-Fi Doppler Imaging Applications

HOME – TV ANALYTICS

Gaining insight into the entertainment consumption habits of the household may help enhance the user experience and tailor content to the interests of consumers.

Wi-Fi Doppler Imaging can determine if there are people sitting in front of the TV or not. Additionally, it can identify whether a parent or a child are watching TV. The system may automatically pause the DVR, lower the resolution to manage bandwidth consumption, and turn off the set-top box to meet the power consumption requirements of the broadband equipment when a person leaves the room. If there's a single person in the room, the system can curate age-appropriate content by determining if the viewer is a child or an adult.

Wi-Fi Doppler Imaging Applications

ENTERPRISE AND SMART BUILDINGS

Celeno recognizes the potential in combining Wi-Fi-enabled devices that are vastly deployed in commercial environments with imaging capabilities. This adds a new range of functionality to Wi-Fi technology without having to install additional equipment.

Wi-Fi Doppler Imaging enables organizations to set up zones for security and safety purposes using geofencing. This makes it possible to identify people who are still inside the building in emergency situations, especially in areas where cameras aren't set up such as restrooms. The technology can also determine the number of people in public areas, allowing organizations to optimize their use of real estate.

Wi-Fi Doppler Imaging Applications

ENERGY MANAGEMENT IN HOMES OR BUSINESSES

Many people are acknowledging the need for energy efficiency. Standard energy management systems typically require the installation of multiple devices that enable homeowners or building managers to track energy consumption.

Wi-Fi-based imaging technology can track where people are and optimize smart lighting, thermostat, HVAC, and heating systems operation for better energy conservation.

Wi-Fi Doppler Imaging Applications

INDUSTRY 4.0 AND DIGITAL FACTORIES

Wi-Fi Doppler Imaging can enable the evolution to digital and connected factories and support the convergence of Information Technology (IT) and Operational Technology (OT). The technology can support Wi-Fi connectivity and imaging for a variety of tasks in the factory. It can help track the location of personnel, machinery, and robots to help maintain safe conditions and eliminate potentially hazardous situations. As an example, following an emergency that requires the quick evacuation of people from a building, it can assist in identifying where people are still in the building.