The fantasy of seeing through walls – is it really possible?

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Since ancient times, people have been living in houses and feeling safe and protected because they are enclosed by four walls. One can act freely if he believes he cannot be seen. That is the exact reason why other people are interested in trying to look at him through the wall. Is it ethical to do so? Is it legal? It depends...

History of spying dates back to the earliest days of civilization, when social life had just begun. Some people try to find out what others wish to hide. Throughout history, the fantasy of seeing through walls has motivated people and government agencies to invest in developing these capabilities not only to control people and to increase their power but also to prevent crime and terror and to save lives.

How it started

From early 1950s to late 1980s, Stasi, the secret police of East Germany, known as the "Shield and Sword of the Party", extensively monitored their citizens. One of their methods was to drill small holes in apartments and hotel rooms, which their agents filmed the citizens through special tubes inserted in the holes in the walls. Schools, universities, and hospitals were extensively infiltrated as well. Stasi controlled the population and could easily install these means during construction or by preventing the people from being in their houses while the tubes were being installed in the walls.

In the cold war, many countries, including the United States and the Soviet Union, but also China and other countries, struggled with making effective and secretive ways to 'See Through Walls' to enhance their spy capabilities on each other.

The Stasi approach needed to be improved and refined in order to see through walls in uncontrolled or unfamiliar places. While trying to see through the wall, a new method of inserting a fiber optic through the wall was developed. With some optical means, one could see the wall's other side through this fiber. This works fine when it works, but it comes with a lot of problems and difficulties when used for this purpose. Although the drilling is quiet, it is necessary to drill close to the wall, sometimes for hours, and this can reveal the secret operation. However, even after the procedure ends successfully there is no guarantee you will be able to see anything. If penetrating a closet or behind a fridge or a TV for instance, or even if lighting conditions are not good enough, all view can be blocked.

Many other ideas, including using thermal imaging with IR cameras for this purpose, were ineffective since most walls have very poor thermal conductivity.

During the 1960's, a new research was carried out – using Radio waves to 'see through the walls'. At the time Radio waves were primarily used for broadcasting, communication, and military radars. The use of Radio waves to 'see through walls' was researched by governments, mainly in the US and Russia, then in academia, and finally in the commercial sector.

The use of Radio waves to 'See Through Walls'

It is well known that Radio waves can pass through walls. That is why we can talk on our mobile phone in a building or use Wi-Fi to transfer data from one room to another through a wall. Radio signals, especially at low frequencies, are highly effective in penetrating walls. Still, penetrating walls does not mean you can 'see through walls'. But this was the first step in using Radio waves to sense people on the other side of the wall.

Early ideas were derived from Radar systems. To detect and locate moving targets through the wall, in the same manner radars do it for detecting airplanes and ships. Essentially all Radar systems are set up to transmit a signal toward the target, in this case through the wall, and analyze the reflectance to detect and present target location.

One problem was that in order to acquire useful information, you needed a certain resolution that mandated high frequencies, while for penetrating most building materials, you needed to work in a relatively low frequency band. This tradeoff between resolution and penetrability prevented successful progress in this research for some time.

A breakthrough has been achieved with the invention and implementation of ultra-wideband (UWB) radars. UWB is unique by operating in relatively low frequencies, while using a very wide bandwidth, which allows penetration capabilities without sacrificing resolution, achievable by the very wide bandwidth, for this application.

In the early 1970s the first UWB radar was introduced, and government efforts in the US, Soviet Union, and China were accelerated in this direction. However, it was only in the 1990's that Thomas McEwan, an engineer in 'Lawrence Livermore National Laboratory' (LLNL), was able to develop the first practical UWB radar, known as 'Micropower Impulse Radar'. This technology has continued to be researched for different applications, including 'Sensing Through The Wall' (STTW). However, it took years after that to get the first fielded system that enabled operators to detect people's movements through walls and to roughly locate them. Still, far from the dream to 'See Through Walls'.

Why it so hard to see through walls?

It seems that being able to penetrate walls and potentially reach the required resolution is not enough. Walls are not really 'transparent' even in low frequencies. Unfortunately, passing through walls can highly attenuate the radio waves and can lead to heavy distortions in the received signals. Often, the reflected signal quality will be such that it is completely meaningless if nothing is done to compensate some physical phenomena.

A wall is only partially transparent, i.e., only part of the signals enters the wall, while the rest is reflected back. The signal that enters the wall can be highly attenuated by the wall materials, the level of humidity in the wall, the thickness of the wall and some other parameters. In addition to that, wall structures can also significantly distort the UWB signal. Inhomogeneities in the wall structure, like mixed materials, cavities, or objects in the wall, may cause diffractions, echoes, and other unwanted effects that can destroy the signal. Moreover, depending on its shape, position, and cross section, whether an object situated on the other side of the wall, that we are interested to 'see' him, can only partially reflect back to the system, or in some cases, reflects in different directions, leaving the system 'blind'. These reflections from the object passes back through the wall, suffering again from attenuation and distortions, before reaching the systems receiver. It means that in most cases, an extremely small fraction of the transmitted signal is received back by the system, while this received signal can be also totally distorted.

We find that there is a great challenge for the receiver in dealing with weak and distorted signals to reconstruct the scene that appears behind the wall.

The evolution of systems to 'See Through Walls'

The challenge of seeing through walls, in reality, was so difficult that it was compromised on getting only some indications of what is happening on the other side of the wall and generally, when the system is attached to the wall, observing a very short distance behind. These indications, at different levels, could provide good enough 'Situational Awareness' in some cases.

It started with trying to detect motion from the other side of the wall. Assuming that if there was no motion detected from the other side, it was most likely empty, while any movement that someone is behind the wall. The problem with these assumptions is that they are not always true. If the person placed behind the wall is not moving or if there appears to be movement from objects that are not people, the operator might get the wrong conclusion by using such systems.

By improving much the sensitivity to detect very small movements, systems could detect vital life indications even if the target seems to stay in the same position without any noticeable movement. It can be enough if the person is breathing or showing other very small movements, for the system to indicate the presence of someone in the other side of the wall. To reject false indications of non-human movement patterns that are not typically triggered by people, an additional Artificial Intelligence (AI) layer is needed.

A second level of improving the 'situational awareness' would be to find the 2D or 3D location of objects situated behind walls. This means that the Radar should be able to steer in different directions, generally implemented with an array of transmit and receive antennas. Once an array of UWB transceivers is implemented, calibration of these devices becomes a challenge, and as their bandwidth expands to get better resolution, accurate calibration becomes more critical and challenging.

Third level, and further step to better understand the scene behind the wall is to add information on its non-human, static objects. This includes the building's internal layout, as well as information on significant static items on the other side. This can be much harder, since there are many undesired effects caused by

the wall and the multipath environment behind it, that cannot be easily filtered out the same way as when we are looking only for movements.

The highest level of these types of systems can provide full 3D imaging capabilities. This is also the closest step toward the dream 'To see through the wall'. A real-time 3D image that presents what happens on the other side of the wall in a reliable manner, with a high resolution, is what these systems try to achieve. This presents the most difficult technical challenge. The combination of wide enough UWB sensors, in combination with sophisticated signal and image processing, smart image reconstruction, together with AI methods, can come close to achieving this goal.

There are many other parameters that must be considered for this to be a viable option for deployment and to be used in the field. Considering size, weight, battery life, usability, ruggedization, radiation safety, frequency regulation and standards are the few parameters among others that should be considered in conjunction with the imaging performance.

State of the art

Many elite forces around the world have already adopted the capabilities of sensing through walls as a common practice in their operations, and it became an integral part of their CONOP (Concept of operation). In recent years, the advanced technological capabilities on the one hand and the understanding of the operational benefits of this technology on the other hand have pushed these kind of systems to be deployed more and more often in military, law enforcement and search and rescue operations.

When size and weight are critical, the Xaver™100 of Camero-Tech is often the right choice. This very small device that fits in a pouch is a powerful tool you can use to get immediate and reliable information from the other side of the wall. First assessing the occupancy behind the wall for tactical decisions on 'Go/No Go'. The Xaver™100 is extremely sensitive and is also able to pick up very small vital life movements, so people can be detected also when they are completely still. This device also provides advanced information about the objects on the other side of the wall, to determine the exact distance, pattern of movement, and direction of movement.

For exact 2D and 3D location of the objects located behind walls, it is most likely to use Camero Xaver™400. The device, which can fit into a small backpack, can automatically track objects, and provide precise real time information on the events occurring on the other side of the wall. The Xaver™400 can also detect completely static objects such as walls, or large furniture and electrical devices through the wall. As a result, it is also possible to visualize interior structure by getting its layout, to measure room sizes, corridor widths, and much more, all while keeping attention on other obstacles behind the wall. The Xaver™400 is generally considered the preferred option by SWAT teams as it provides excellent range of capabilities, easy control, intuitive interface, and complies with Mil-Standards.

The Xaver™800 provides the most comprehensive view behind the wall, and it is also the closest to truly 'seeing through the wall'. The Xaver™800 is a full 3D imaging device usually used in ISR (Intelligence, Surveillance and Reconnaissance) work. While offering full 3D imaging, the user can identify in which

position the object is, if it is standing, sitting, or lying down. Adults can be distinguished from children or pets, for instance.

With the Xaver™800, the user just 'sees' what happens on the other side of the wall, with much less assumptions or speculations.

Although the Xaver™800 reconstructs the volume behind the wall to produce the most realistic image, there are still some physical limitations. For this reason, the system supports the user with some AI algorithms for cleaning and improving the image, automatically detecting, and tracking the objects, while adding all tools that are also employed by the Xaver™400 and Xaver™100.

While the mentioned products cover a very wide range of operational needs, from very compact tactical tools up to comprehensive imaging capabilities, all these systems operate within a relatively short distance from the wall. They can be attached to the wall or located in a stand off from it, but not more than a very few tens of meters away. Systems are designed with a very wide field of view to cover the entire scene of what happens behind the wall. It is possible to control and monitor these systems remotely using wireless units, but the systems themselves should be located near the wall.

A new STTW system known as the Xaver™ LR80 was introduced lately into the market, with new features enabling the detection of living objects behind walls at more than 100 meters away. This is the first time the field operator has been able to detect through walls from such a long distance, while staying safe far from the wall. Unlike all other STTW systems, the Xaver™ LR80 covers only a small field of view, to be selective in directing a spot to a specific address, home, flat or warehouse. Special forces and law enforcement teams conducting urban and rural operations require reliable information about scenes behind walls in hostile environments. Operating very far from the wall allows for safer, more effective, and more flexible missions. This is also true for Search & Rescue teams that can be situated at a safe distance from dangerous surroundings and to scan a large area quickly. The same is true for Intelligence units, who can use the distance to cover an operation without having to intervene in the vicinity of the target.

What next

It seems we will see even more precise, reliable, and improved imaging capabilities in the future, to assist users with an even better understanding of what happens on the other side of the wall. Future products are expected to incorporate more artificial intelligence layers using modern techniques such as machine learning. Using such techniques could help overcome many of the current limitations of STTW systems.

A new generation of STTW solutions comprise of array of sensors spreading out on land and air by using robots and drones, can also be expected. This will provide much more flexible and comprehensive internal view of the entire buildings, houses, and other constructions.

We can expect future modular solutions in addition to integrations with other sensors such as special cameras, thermal imaging devices, and audio remote sensing.

So, is it really possible to see through walls?

Although we get close to that, it's quite unlikely that we'll be able to claim we can truly 'see through walls' by using radio technology like super-realistic images as we can see with our eyes. But can we get a clear picture of the exact scenario behind the wall? Here, the answer is certainly positive. Already today, the Xaver™ family offers powerful tools for this use, in all levels of operational requirements.

Military forces, Law Enforcement teams, Intelligence agencies, and Search & Rescue units require an answer to several critical questions regarding what happens on the other side of the wall - Are there any people inside? If so, how many are on the other side of the wall? Where exactly are they located? Do they stay still, or do they move? In that case, where are they going? Which position are they in, Standing, sitting, sleeping? Do they appear to be children or adults? What is the interior layout and size of the rooms within? Where is the entry and exit points? Does the room contain any large stationary objects? And so on. Those questions, if reliably answered and in real-time, would be exactly what is needed operationally even if the visual representation is not super realistic.

These are all questions that can be well answered by the Xaver™ systems due to the different options they provide, from real time detection, location, up to full imaging features. All through massive walls, ceilings and floors, and in most cases, through multiple walls and complex structures.

Other than imaging, the operational requirements include the size and weight of the tools they carry to the field, the environmental conditions the products must be used in, and their potential distance from the target. The Xaver™ family offers choices from a small, palm sized Xaver™100 up to the Xaver™ LR80 that can reach more than 100 meters from the wall. These products are all designed to meet Military Standards and completely radiation safe by meeting the most stringent international standards for human exposure.

As a result of these all reasons, Xaver™ products are already deployed successfully in over 50 countries around the world for the benefit of their users.

It is likely that these types of systems will not be limited to elite and special forces but will assist also a much wider range of military, law enforcement forces and others in a much more extensive way to prevent crime and terror and to save lives.