

How Millimeter Wave Scanners Work

By: [William Harris](#)



The pair of underwear that changed airport security in December 2009. Obviously you can spot the packet of powder removed from Abdulmutallab's briefs.

ABC NEWS VIA GETTY IMAGES

On [Christmas Day](#) in 2009, Umar Farouk Abdulmutallab tried to detonate explosives in his underwear on a flight from Amsterdam to Detroit. Like all other post-9/11 terrorist acts involving airplanes, Abdulmutallab's failed attempt led to new passenger screening techniques and technologies.

By December 2010, the Transportation Security Administration (TSA) had introduced 500 whole-body scanners -- what the U.S. government agency refers to as advanced imaging technology units -- at airports across the country. All of the scanners do the same thing: detect metallic and nonmetallic threats, including [weapons](#), explosives and other objects, concealed under layers of clothing. But they use completely different technologies.

One type of scanner relies on something known as backscatter technology.

Backscatter machines use a device called a collimator to produce a parallel stream of low-energy X-rays, which pass through a slit and strike a passenger standing in the machine. A single scanner includes two radiation sources so that both the front and the back of the person can be imaged. The images form when X-rays, which penetrate clothing, bounce off the person's skin and return to detectors mounted on the machine's surface. The radiation also bounces off weapons, explosives or other threats concealed in clothing or lying against the skin.

The other type of scanner uses a competing technology known as **millimeter wave (mmw) imaging**. These machines work on the same principles, except they emit a special type of microwave, not X-ray. Two rotating transmitters produce the waves as a passenger stands still inside the machine. The energy passes through clothing, bounces off the person's skin -- as well as any potential threats -- and then returns to two receivers, which send images, front and back, to an operator station.

Unfortunately, what was supposed to ease the public's worries has only caused agitation and anxiety -- among passengers, pilots and TSA agents. Many people have voiced concerns about the health risks of the scanning process for both technologies. How much radiation do these machines produce? How does it compare to medical imaging devices? And is it enough to increase cancer rates in the general population? Then there are the questions about privacy. Can TSA agents see bits and pieces they shouldn't be seeing? And do they ever store or archive scans instead of deleting them immediately?

The rush to answer these questions has spawned a number of myths and misconceptions. It's almost as if whole-body scanners, machines capable of peering deep into our soul (or at least beneath our clothes), are themselves opaque. In reality, they're not. They take advantage of well-understood scientific principles that have been around for years. Let's throw back the curtain on millimeter wave scanners to understand how they work and how they're used at airports around the world.

Millimeter Wave Technology



Assume the position, the airport security body scanning position that is. This volunteer stands inside a millimeter wave scanner at the TSA's Systems Integration Facility at Ronald Reagan National Airport on Dec. 30, 2009.

CHIP SOMODEVILLA/
GETTY IMAGES

Before we climb inside a millimeter wave scanner, we need to step back and review some basic information about **electromagnetic radiation**, which exists in nature as waves of energy made from both electric and magnetic fields. These waves travel through space and come in a variety of sizes, or wavelengths. Gamma rays, for example, have a wavelength on the order of 0.000000000001 meters, or 0.000000001 millimeters. **X-rays**, which run a bit larger, have a wavelength on the order of 0.0000000001 meters, or 0.0000001 millimeters. And visible light waves measure about 0.000001 meters, or 0.001 millimeters. The entire collection of waves, across all frequencies, is known as the **electromagnetic spectrum**.

Now consider a wave that falls in a range exactly between 0.001 meters (1 millimeter) and 0.01 meters (10 millimeters). Scientists refer to the energy in this tiny sliver of the electromagnetic spectrum as **millimeter wave radiation**. Millimeter waves have a variety of uses but are especially important in radio broadcasting and cell phone transmissions. And, because the wavelengths of millimeter waves are large relative to natural and synthetic fibers, they tend to pass through most materials, such as clothing, making them an ideal candidate for scanning technologies.

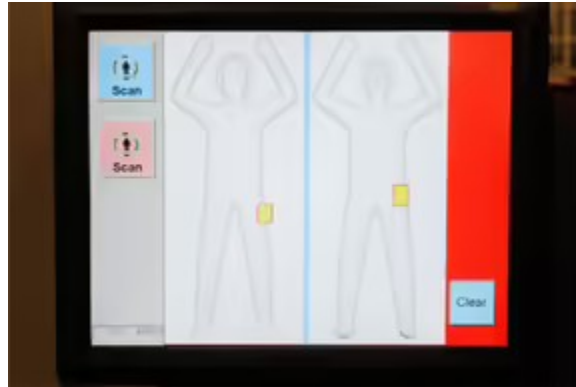
Millimeter wave scanners produce their waves with a series of small, disc-like transmitters stacked on one another like vertebrae in a spine. A single machine contains two of these stacks, each surrounded by a curved protective shell known as a **radome**, connected by a bar that pivots around a central point. Each transmitter emits a pulse of energy, which travels as a wave to a person standing in the machine, passes through the person's clothes, reflects off the person's skin or concealed solid and liquid objects and then travels back, where the transmitter, now acting like a receiver, detects the signal. Because there are several transmitter/receiver discs stacked vertically and because these stacks rotate around the person, the device can form a complete picture, from head to toe and front to back.

It's the job of software in the scanner system to interpret the data and present an image to the TSA operator. The software creates a 3-D, black-and-white, whole-body silhouette of the subject. It also employs a feature known as **automated target recognition**, or **ATR**, which means it can detect threats and highlight them for easy identification. ATR technology is capable of detecting liquids, gels, plastics, powders, metals and ceramics, as well as standard and homemade explosives, drugs and money.

The ATR software also does something else. A scanner without this software forms images that reveal a person's unique topography, but in a way that looks like a crudely formed graphite prototype. In other words, you can see some physical features, but not with the same detail as Superman or [backscatter scanners](#), both of which possess

X-ray vision. A millimeter wave scanner with ATR software produces a generic outline of a person -- exactly the same for everyone -- highlighting any areas that may require additional screening.

The MMW Scanning Process



This monitor at the Las Vegas airport in February 2011 displays the automated target recognition software responsible for creating a generic display of a person's body. Compare that visual with the more detailed mmw image of the body on the next page.

ETHAN MILLER/GETTY IMAGES

Millimeter wave scanners aren't [metal detectors](#). They actually peer through clothing to look for metallic and nonmetallic objects an individual might be trying to conceal. Getting a good view requires that passengers entering the scanner follow certain procedures. Here's what you can expect if you enter one of the approximately 600 mmw scanners in use at [airports](#) across the U.S. in 2012:

1. First, you'll need to remove everything from your pockets, as well as your belt, jewelry, lanyards and cell phone. This ensures that the scanner won't see these items and flag them as suspicious -- and saves you from enduring additional screening after you exit the machine.
2. Next, you'll walk up a short entrance ramp and enter the imaging portal, which looks a lot like an oversized telephone booth.

3. Standing still, you'll raise your arms, bent at the elbows, as the dual antennas rotate around your body.
4. Then you'll exit, stage left, as a TSA agent looks at the results of your scan on a monitor attached to the machine.
5. The TSA agent sees one of two things. If the scanner detects something suspicious, it will display a generic outline of a human figure with the suspicious item indicated by a yellow box. If the scanner finds nothing, it will display the word "OK" with no image.

Either way, the scan takes less than 10 seconds and requires nothing painful or embarrassing. But if you feel strongly that the whole-body scan of a millimeter-wave machine violates your privacy, you can opt out of the screening process. You will, however, receive alternative screening, including a physical pat-down.

According to the TSA, most people prefer the scanning process to a physical exam. In fact, more than 99 percent of passengers choose to be screened by this technology over alternative screening procedures [sources: TSA]. And people with artificial joints or other implanted medical devices appreciate mmw scanners even more because they don't have to worry about the false positives associated with old-fashioned metal detectors.

Concerns and Objections to Millimeter Wave Scanners





Compared to the generic body outline you just saw, this image produced with the introduction of mmw scanners in December 2009 provides a lot more detail.

CHIP SOMODEVILLA/GETTY IMAGES

As soon as the TSA began installing millimeter wave scanners, the public began asking questions, mostly related to privacy and safety. In the former category, people objected to the idea of strangers peering beneath their clothes to see intimate details or reveal evidence of mastectomies, colostomy appliances, penile implants and catheter tubes. A representative of the American Civil Liberties Union described whole-body imaging as "nothing more than an electronic strip search."

To quell the uproar, the TSA introduced several precautions on mmw scanners. One of those, as we've already discussed, involves installing automated target recognition software on a number of the machines. The software renders every subject as a generic outline, with suspicious areas highlighted. And if it doesn't detect anything suspicious in a scan, it displays the word "OK" with no image at all. For scanners without ATR software, the security operator viewing the resulting image sits at a remote location and communicates wirelessly with the agent operating the machine.

Of course, none of these measures protects a passenger from harmful effects of the waves themselves. Luckily, several studies have determined that millimeter wave scanners pose little risk to passengers, pilots or the TSA agents who operate the machines. The waves produced by these scanners are much larger than [X-rays](#) and are of the non-ionizing variety. Ionizing [radiation](#) has enough energy to remove electrons from atoms, but radio waves, visible light and microwaves don't have this ability. As a result, they don't alter the structure of biological molecules, such as proteins and nucleic acids.

The bigger issue with millimeter wave scanners seems to be the high number of false alarms. They can get fooled by objects that come in sizes close to the wavelength of the energy. In other words, folds in clothing, buttons and even beads of sweat can confuse the machine and cause it to detect what it thinks is a suspicious object. When Germany tested mmw scanners, security officials there reported a false positive rate of 54 percent, meaning that every other person passing through the machine required a pat-down that found no weapon or concealed object [source: [Grabell and Salewski](#)]. Because of these disappointing results, France and Germany stopped using millimeter wave scanners, leaving them no good alternative to scan fliers.

Other Applications of Millimeter Wave Technology

Millimeter wave scanners have caused a stir, but similar waves surround us every day and help us do things we now take for granted. For example, your cell phone relies on millimeter wave technology to send and receive data and calls. That [smartphone](#) activity occurs by way of communication satellites, which receive microwave signals from ground stations and then direct them, as downlink transmissions, to multiple destinations. Remember that electromagnetic waves come in a range of wavelengths. They also come in a range of frequencies, which is a measure of how many wave crests pass a certain point every second. Microwaves used in satellite communications are super-high frequency, or SHF, waves in the range of 3 gigahertz to 30 gigahertz (GHz).

NEXRAD, or next-generation weather radar, also uses waves in the 3 GHz range to help meteorologists make weather forecasts. NEXRAD relies on the Doppler effect to calculate the position and speed of rain, snow and weather fronts. First, a radar unit emits a pulse of energy, which travels through the air until it encounters an object, such as a raindrop. Then the unit listens for an echo -- energy reflected back to it from the object. By sending a constant stream of pulses and listening for echoes, the system is able to create a color-coded picture of the weather in a particular area.

Astronomers take advantage of extremely high frequency (EHF) waves in the range of 30 to 300 GHz to study the formation of stars and galaxies millions of light-years from Earth. Instead of traditional telescopes that sense light, these scientists use radio telescopes to "see" energy with millimeter and submillimeter wavelengths. Because structures on the ground can interfere with these waves, radio telescopes are usually placed at very high locations. For example, the Combined Array for Research in Millimeter-wave Astronomy (CARMA) encompasses 23 radio dishes in the Inyo Mountains near Big Pine, Calif.

So, millimeter waves are well-understood and quite common in a number of applications we regularly use. Even the microwave oven in your kitchen zaps food with a form of energy from this narrow band of the electromagnetic spectrum. Its adoption in airport security is a natural -- and harmless -- extension of the technology, especially when you consider the type of disaster it's trying to prevent. As of November 2012, the TSA has installed hundreds of mmw scanners at airports across the U.S. And internationally, they are being used in airports and mass-transit systems in several countries, including Canada, the Netherlands, Italy, Australia and the United Kingdom.

Frequently Answered Questions

Do millimeter wave scanners use radiation?

Yes, millimeter wave scanners do use radiation. The type of radiation used is non-ionizing electromagnetic radiation. This type of radiation is not known to cause any adverse health effects.

Lots More Information

Author's Note: How Millimeter Wave Scanners Work

Given the long pedigree of millimeter waves and the advances they've enabled in medicine, astronomy and meteorology, I'm surprised so few people have praised mmw scanners as a practical, lifesaving tool. Personally, I'm willing to let the machines look under my clothes as long as they catch the would-be terrorist trying to board the same plane.

Related Articles

- [What's the difference between backscatter machines and millimeter wave scanners?](#)
- [How Backscatter X-ray Systems Work](#)
- [Do backscatter X-ray systems pose a risk to frequent fliers?](#)
- [How Airport Security Works](#)
- [How do liquid explosives work, and what would terrorists do with them on a plane?](#)
- [How Metal Detectors Work](#)
- [Aren't there machines that can detect liquid explosives?](#)

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