

Technical Report

Terahertz Technology for Military Applications

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Abstract- The ability to detect and identify objects hidden behind barriers is one of the core features THz technology can offer. In today's security environments the ability to identify threats like hidden weapons, body-worn explosives are a strong operational need. Also detecting these threats at longer ranges are more crucial in security portals. With its capacity in penetrating on a lot of dielectric material and non-polar liquids THz technology can offer cross-barrier vision ability. THz spectral imaging technology is also offering a fingerprint characteristics by identifying the composition of objects. By being non-ionizing THz technology does not represent health hazards for living tissue or humans as X-rays do.

Keywords- Terahertz, Security, Military Applications.

1. Introduction

Terahertz (THz) radiation is electromagnetic radiation that lies between the microwave and infrared regions of the spectrum. Figure 1 shows the THz in electromagnetic spectrum. This THz radiation occurs naturally and fills up the space of our everyday life, but this part of the electromagnetic spectrum remains the least explored region mainly because of the technical difficulties involved in making efficient and compact THz sources and detectors (Yun-Shik, 2009).

THz band remained unexplored for many years and led to the band being called "THz gap". Advances in the electronics and photonics fields have provided new materials and devices that made the THz gap accessible and made a massive progress of the THz field in both fundamental research and applications (Woolard, Loerop, & Shur, 2003).

NATO is also interested in this emerging technology. NATO Science for Peace and Security (SPS) has met three times first 1996 with the title of "New Directions in Terahertz Technology", and

second in 2000 "Terahertz Sources and Systems" and the third one "Terahertz Frequency Detection and Identification of Materials and Objects" (NATO, 2006). This technology can also be used for communications even instead of 3G.

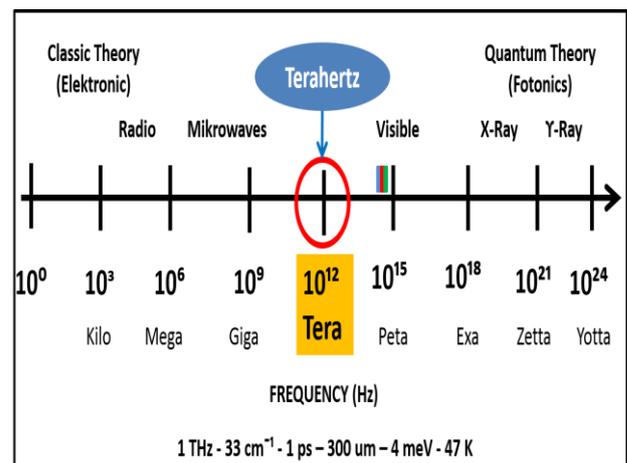


Fig.1 THz in Electromagnetic Spectrum (Zomega, 2012).

2. Terahertz Specifications

The main features that make THz wave technology so interesting are the ability to see through barriers. THz radiation is the electromagnetic wave, so it has all the characteristics of electromagnetic waves. THz wave has particle nature and wave nature (Zhu, 2009). Whether generated by continuous wave or pulse wave THz technology has three basic features. (Zomega, 2012).

The first one is 'see through' capability. THz radiation has good penetrability on a lot of dielectric material and non-polar liquids. Therefore THz wave can be used to perspective imaging for a lot of non-transparent materials. The penetrability of THz wave makes it as the supplement of X-ray imaging and ultrasound imaging for security checks for critical places or quality control in nondestructive testing (Zhu, 2009). THz waves can go through many dry and nonmetallic materials, such as plastic, paper, cardboard, and textiles. They are transparent to THz waves. This property allows THz waves to inspect samples that are under cover or inside enclosed containers. Microwaves have this see-through capability as well but their larger wavelength compared to THz waves does not allow achieving high resolution images.

The second one is 'fingerprint' characteristic. The rotational and vibrational modes of many molecules, especially organic ones, are distributed across the THz band. These modes can be observed as absorption peaks in the THz spectra. Many organic molecules have strong absorption and dispersion characteristics in the THz band, the THz spectroscopy of material contains a wealth of physical and chemical information, which making them the unique characteristics, like fingerprints (Zhu, 2009). Therefore, THz spectral imaging technology is not only able to differentiate objects morphology, but also identify the composition of objects. The specific location and amplitude of these absorption level can be used to identify the molecules (Zomega, 2012).

THz radiation another notable feature is its 'security'. THz photons are non-ionizing and, therefore, do not represent a health hazards for living tissue or humans as X-rays do (Zomega, 2012). Compared to X-ray with kilo-eV photon energy, the energy of THz radiation is only mill-electron volt. Its energy is lower than the energy of different types of chemical bond, so it will not cause harmful ionizing reaction. This is critical to the practical applications such as the security check of travelers, inspection of other biological samples (Zhu, 2009).

3. The Usage of THz for Military Applications

As an emerging technology THz has been taking place in military applications. Some important military applications are handled below.

3.1. Communication

THz can be used in communication. In outer space, the transmission of THz is lossless, so we can achieve long-range space communications with very little power. Secure communications (through high attenuation outside the targeted receiver area) or secure intersatellite systems, benefit from the small antenna sizes needed to produce highly directional beams as well as the large information bandwidth allowed by THz carriers. Operation in the stratosphere (air-to-air links) is particularly advantageous for THz communications or radar systems because of the low scattering compared to IR and optical wavelengths (proportional to λ^2 rather than $1/\lambda$) and the much greater penetration through aerosols and clouds (Siegel, 2003). Compared with the microwave, THz radiation has a higher frequency and bandwidth, as the communications carrier that can carry more information. Therefore THz wave has great potential applications in the short-distance high-capacity wireless communications. In imaging applications, THz wave has a higher spatial resolution, and therefore the image has more depth of field while maintaining the same spatial resolution (Zhu, 2009).

There is a growing demand for broader bandwidth for communication systems as the information technology develops. Also in military command and control wants to put common operational picture in front of the commander via sensors thus giving him more opportunity to decide and act correctly. THz communication can provide broad bandwidth and secure transmission in the battlefield (Koch, 2006).

3.2. Radar

THz radar can emit tens of thousands of species frequency as well as pico-second and nanosecond pulse at GW level; it has many advantages and capabilities that ordinary radar does not have. THz radar has a broad application prospects in the military and national security. THz radar launch THz pulse contains a wealth of frequency, which enable stealth aircraft to lose the role of narrow-band radar absorbing coating. Furthermore, THz radar has strong anti-stealth ability to shape stealthy and material stealthy (Zhu, 2009). Figures 2 show the radar imaging of military trailers and T72 tanks model in portable THz radar research

projects which funded by US Army National Ground Intelligence Center (Goyette, 2003; Goyette, 2000).

THz radar also improves the ability of multi-target discrimination and recognition by detecting several target sources.

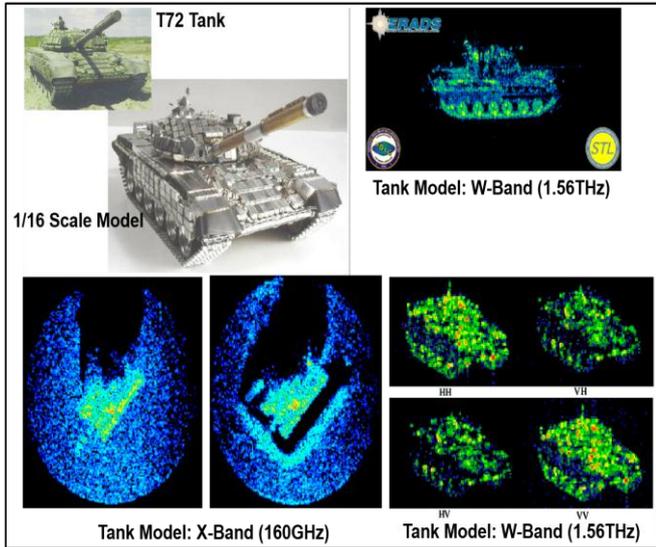


Fig.2. THz Imaging of Tank Model (Goyette, 2003)

3.3. Chemical and Biological Agent and Explosive Detection

As plastic explosives, fertilizer bombs and chemical and biological agents increasingly become weapons of war and terrorism, and the trafficking of illegal drugs increasingly develops as a systemic threat, effective means for rapid detection and identification of these threats are required. One proposed solution for locating, detecting and characterizing concealed threats is to use THz electromagnetic waves to spectroscopically detect and identify concealed materials through their characteristic transmission or reflectivity spectra in the range of 0.5–10 THz. Many explosives (Like C-4, HMX, RDX and TNT) and illegal drugs (for example, methamphetamine) have characteristic transmission/reflection spectra in the THz range that could be distinguishable from other materials such as clothing, coins and human skin (Federici, 2005).

THz light can detect different types of plastic explosives through clothing, including PETN, the explosive which the Detroit bomber successfully carried onto aircraft undetected. The technology works by passing Terahertz light through an explosive or guns. After absorbing Terahertz light strongly by explosive at certain Terahertz frequencies, the “Terahertz fingerprint” can provide easiness to detect

and distinguish explosive from clothing or other inert materials. Being sensitive to the presence of explosives, Terahertz has major advantages over “metal-only” detectors. By using non-ionizing radiation Terahertz is safe unlike X-Rays. Figure-3 shows the fingerprint of different explosives in THz band (Arnone, 2014).

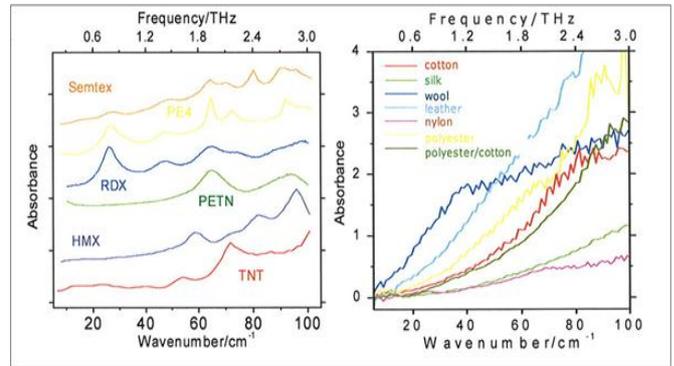


Fig.3 THz fingerprints of explosives (Arnone, 2014)

The detection of land mines using THz spectroscopic imaging can be possible. Anti-personnel mines are small devices and ground penetrating radar systems cannot distinguish these small mines from rocks. But with THz technology non-metallic objects hidden beneath soil can be detected. The non-metallic landmine detection proof of concept was done by imaging a Neoprene grommet (OD = 25.4 mm, ID = 12.7 mm) under 1.2 cm of dry sand (Federici, 2005).

4. Conclusion

The prospects of THz technology are broad and attractive, and there is a long way to run to achieve the security goals, especially stand-off detecting. In future this technology can be used as a valuable payload in UAVs, so can increase its usage for military purpose.

When used especially in “drones”, this technology expand our surveillance and reconnaissance competence by giving sensitive information carrying whether or not weapons and explosives, about the target sources.

Secure communication in a cyber space will be fundamental for the commander to achieve his desired end state. THz communication may give this opportunity to the commanders. With wider bandwidth, THz will also enable big data transmission. We will wait and see how this emerging new technology can change security area.

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