Detection of Explosives Internal to Humans

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Summary

- Detecting internal* explosives in a noninvasive, privacy-preserving manner is extremely challenging. Primary screening goals:
  - — Stand-off detection
  - — Fast
  - — Throughput
  - — P_D vs. P_{FA}
  - — Penetrate clothing and tissue
  - — Negligible direct medical risk   (e.g. ionizing x-rays from XBS)
  - — Passenger acceptance
  - — Cost (initial expenditure, personnel, space)
- How do we handle false alarms (FA) ?
  - — Can't alarm on medical implants (breast, hip, pacemaker…)
  - — If you have an alarm, what is the secondary screening (pat-down equivalent)?
- Extending existing techniques is difficult due to physics constraints. For example, in MMW imaging:

  lateral resolution ≈ 1 / penetration depth

- Non-imaging modalities do penetrate, but must operate in a much more cluttered and noisy environment

*Internal = Implanted, Ingested or Inserted

Need: Detect explosives internal to humans in a minimally invasive manner

"Security officials see renewed interest in implanted explosives"

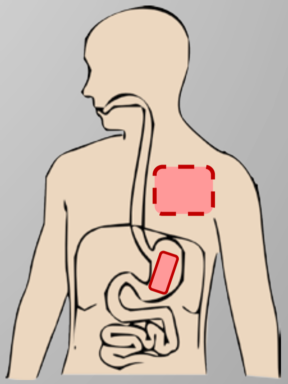
- CNN, July 6, 2011

"Officials watch for terrorists with body bombs on US-bound planes"

- ABC, April 30, 2012

<u>Possible threat scenarios</u>

- Implanted –
  - Penetrate skin to the fatty subcutaneous layer
- Ingested / Inserted –
  - Penetrate skin, fat, & muscle to the internal organs

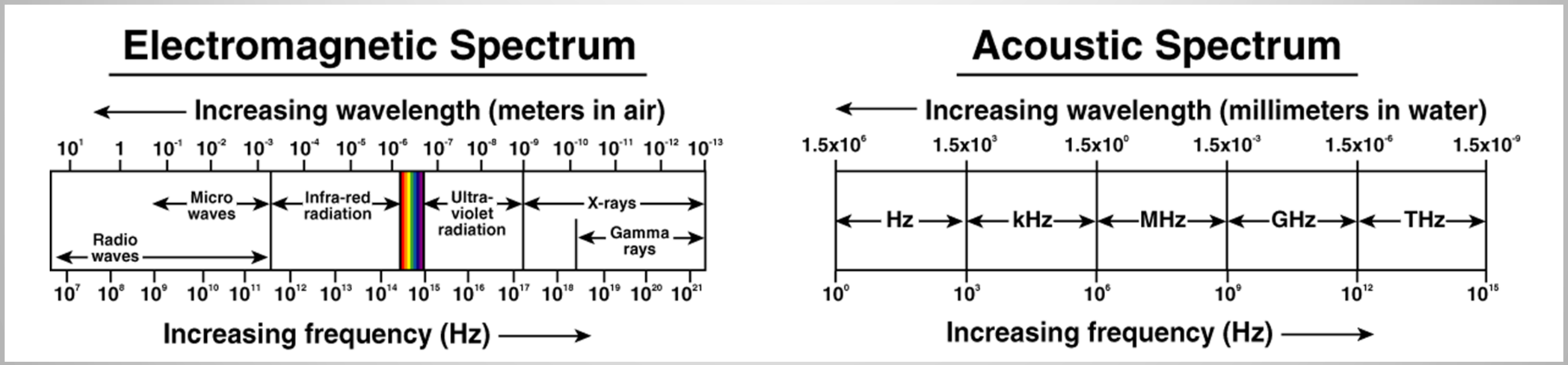


<u>The medical problem is similar… but different</u>

- Patients are sick and seeking a diagnosis: cooperative, compliant, tolerant
- Passengers are NOT: risk-averse, privacy-conscious

http://articles.cnn.com/2011-07-06/us/bomb.implants_1_human-bomb-behavior-detection-officers-airport-security?_s=PM:US
http://abcnews.go.com/Blotter/officials-fear-terrorists-body-bombs-us-bound-planes/story?id=16245827

The possible measurement spectrum is extremely wide



Security Techniques

Metal Detector	Millimeter Wave	X-ray Backscatter
Non-imaging	Imaging	Imaging
Stand – off	Stand – off	Stand – off
No risk	No risk	Ionizing risk

Minimally Invasive → **Highly Invasive**

Medical Techniques

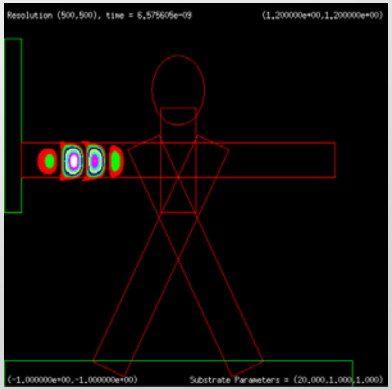
Infrared	Ultrasound	MRI	X-ray CT	Surgery
Imaging	Imaging	Imaging	Imaging	Contact
Stand – off	Contact	Stand – off	Contact	High risk
No risk	No risk	Metal risk	Moderate risk	

Modal analysis using low-frequency, non-imaging techniques can penetrate and partially localize, but implant identification is extremely complex

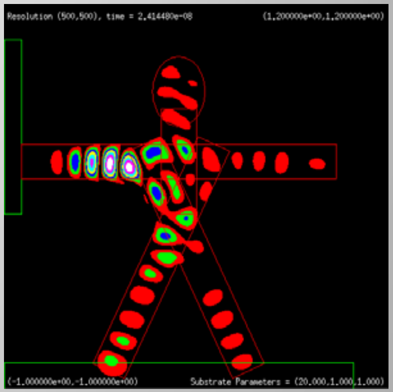
Non-imaging modalities are not well studied, and difficult

- Interrogation could use an instrumented turnstile/saloon door and floor pad.
- Frequency range depends on medium
  - Electromagnetic: 1 – 1000 MHz
- Body treated as a frequency-dependent waveguide
- The transmitted waveform is compared against models & prior measurements

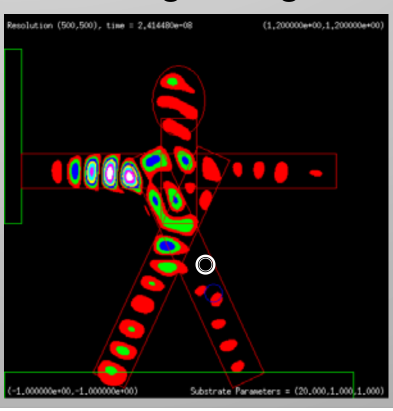
Base Model with Input



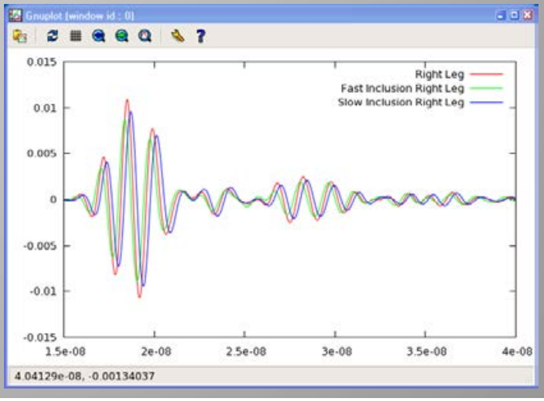
Base Model



Low Speed Object in Right Leg

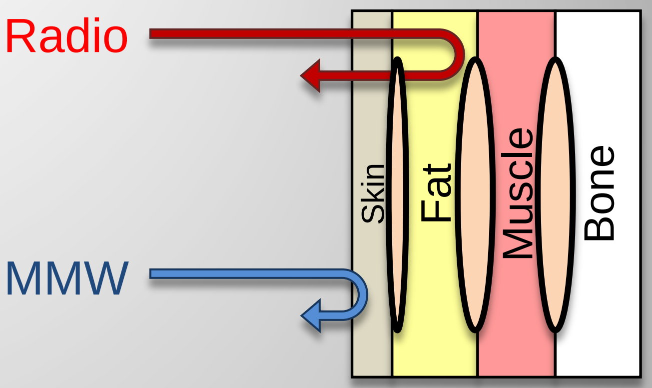


Right Leg Output

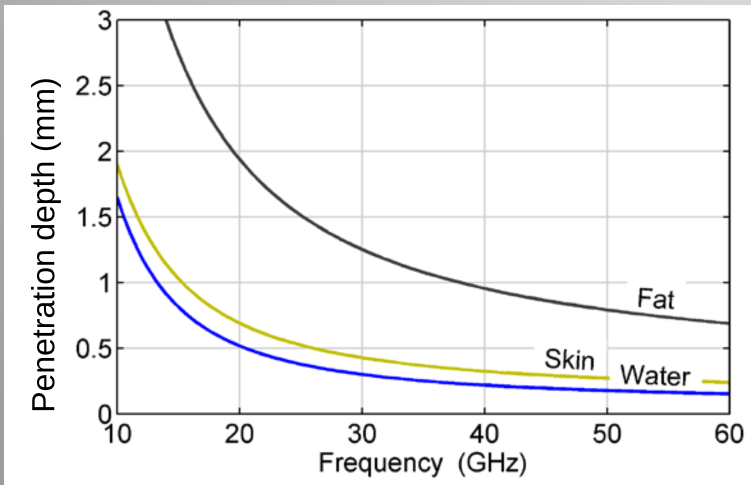


Microwave to Millimeter wave Imaging

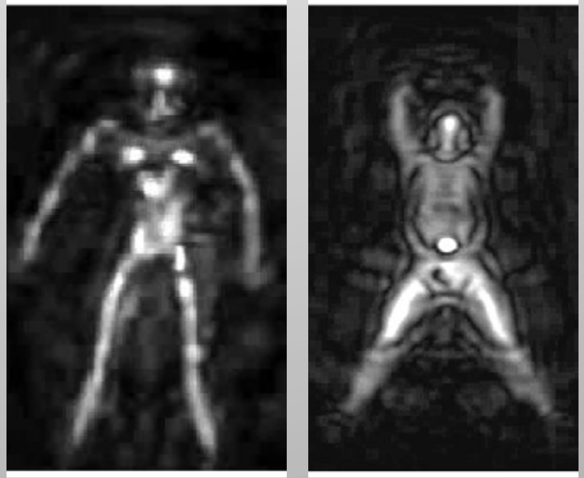
- Radio (λ_0= 300 – 15 mm, 1 – 20 GHz)
  - Able to penetrate to subcutaneous region
  - Lateral resolution is poor, resolution ≈ λ_0
- MMW (λ_0= 15 – 1 mm, 20 – 300 GHz)
  - High first surface reflection, R_{skin} ≈ 70% – 95%
  - Penetration limited to epidermis (1 mm)
  - Possibility of detection surface changes from implant (incision, protrusion), but unable to interrogate material



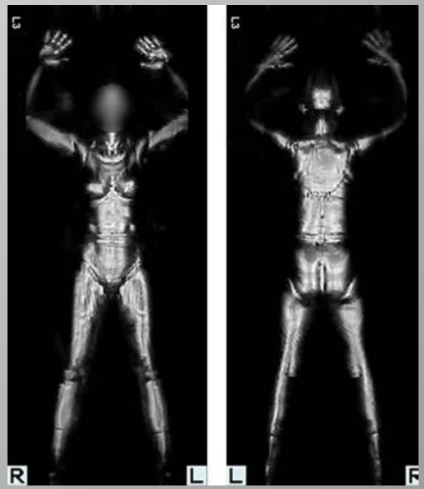
Penetration depth for single layer model



Radar @ 1 – 3 GHz



MMW @ 24 – 30 GHz



Proceedings of SPIE In Optics East 2005, Vol. 6007, No. 1. (09 November 2005), pp. 60070L-60070L-12, doi:10.1117/12.630004
http://www.sds.l-3com.com/images/product-provision-L-3%20composite%20300dpi.jpg

Mid infrared to visible

- Mid Infrared (3-15 µm)
  - Absorption-dominated coherent penetration depth (λ_p) is shallow (<100 µm)
  - Thermography
    - Static measurements detect inflammation
    - Dynamic measurements detect blood flow
- Near infrared (700 – 2000 nm)
  - Near IR “window” where λ_p< 500 µm
  - Optical Coherence Tomography (OCT) able penetrate for several mm
- Visible infrared (300 – 700 nm)
  - Scattering dominated, λ_p < 100 µm

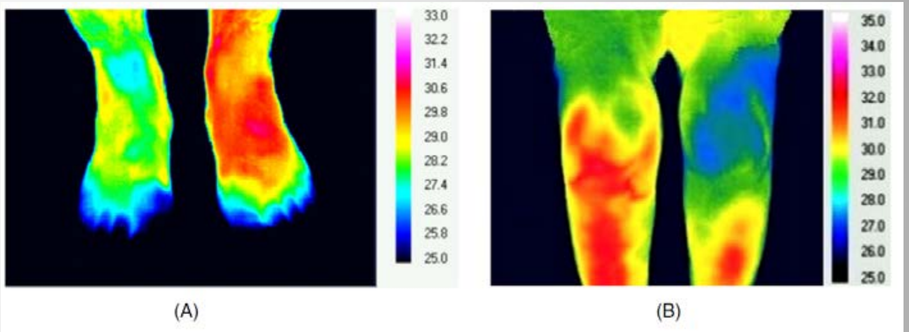


Figure 3. (A) Chronic inflammation of the forefoot following a sports injury; (B) rheumatoid arthritis of one knee (left of the image).

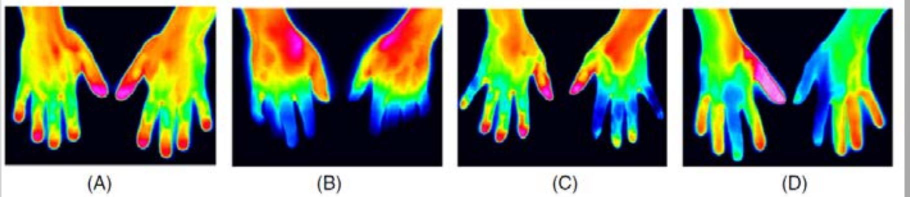


Figure 4. The effects of stress on hand thermograms, (A) 10 min full normal recovery from 1 min immersion in water at 20 °C, (B) in a patient with Raynaud’s phenomenon after 10 min. (C), (D) Examples of hand arm vibration injury to certain fingers, showing delayed recovery after vibration and thermal stress have been applied. The affected fingers are cooler.

E F J Ring and K Ammer 2012 *Physiol. Meas.* **33** R33 doi:10.1088/0967-3334/33/3/R33

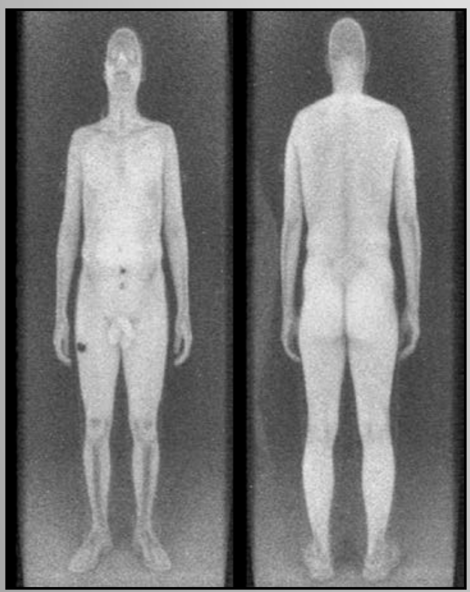
All of the above methods require direct imaging of the skin.

Clothing:

- Attenuates the signal by 10 – 20 dB per pass
- Masks and homogenizes surface temperature variations

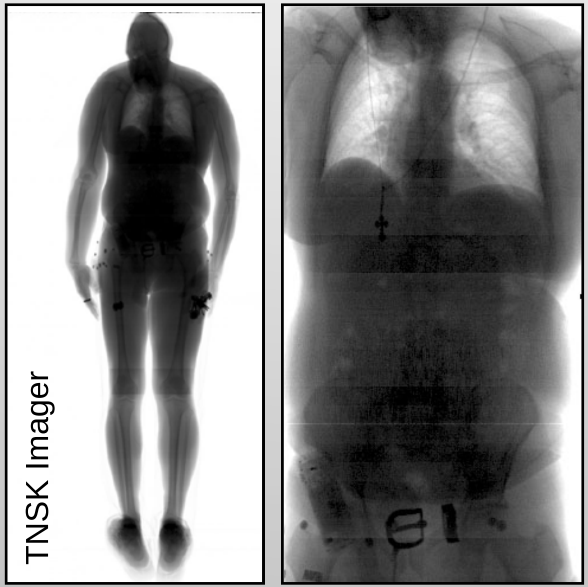
X-rays can penetrate and localize, but are biologically harmful in significant doses

Backscatter



http://www.rupture.co.uk/Images/big/terminal4-LARGE.jpg

Transmission Radiograph



http://www.tsnk-lab.com/content/view/78/3/

Computed Tomography

http://www3.gehealthcare.co.uk/~/media/DiscoveryMR750w_3-0T_whole_body_clinical.jpg

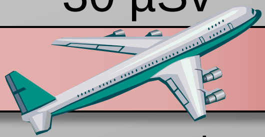
<0.05 µSv

<0.25 µSv

30 µSv

~8,000 µSv

Dose



Seattle to New York, one-way

http://www.faa.gov/data_research/research/med_humanfacs/oamtechreports/2000s/media/0316.pdf

Additional Modalities

- Nuclear resonance
  - With applied magnetic field: NMR / MRI
  - Without applied mag. field: NQR (ADSA 03)

- Electromagnetic induction
  - Sense the metallic initiator components

- Cosmic radiation
  - E.g., muons, electrons

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