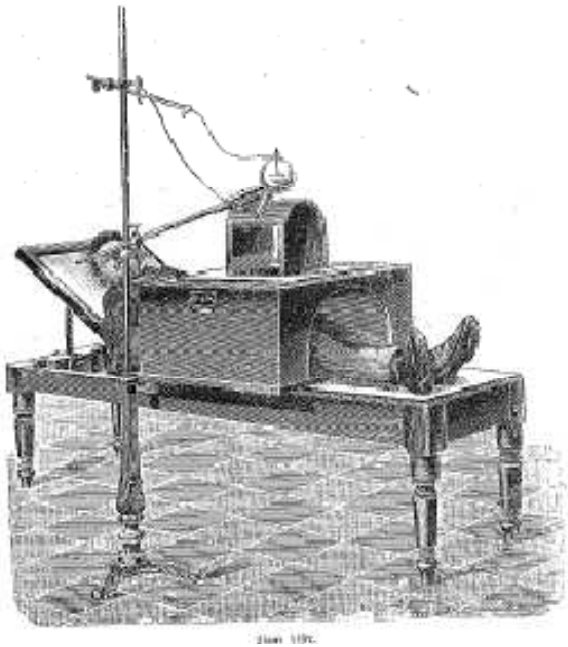
Body scanner – a technical review

1. Overview
2. X-ray: the (historically) first solution
3. Microwave technology as an alternative
4. Forthcoming technologies



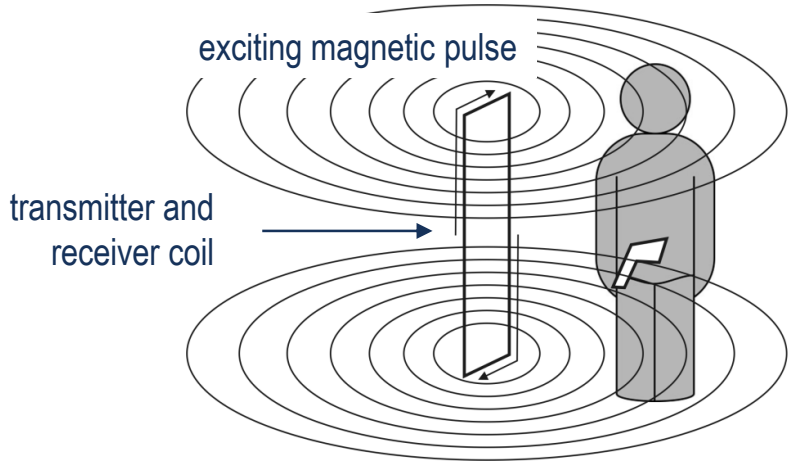
envisioned already in 1901
(O. Multhaupt, Die moderne Elektrizität)

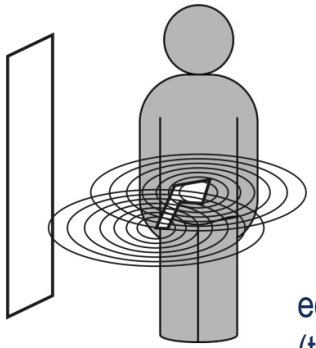
Looking back: walk-through metal detectors

Still the standard procedure at airports (and probably will stay)

„Pulsed induction“

- magnetic pulses (about 1/10 of the strength of earth field)
- detection of eddy current response (only electrical conductors detectable)
- Quota alarm to trigger manual re-checks

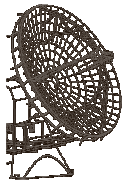




eddy current response
(transmitter off)

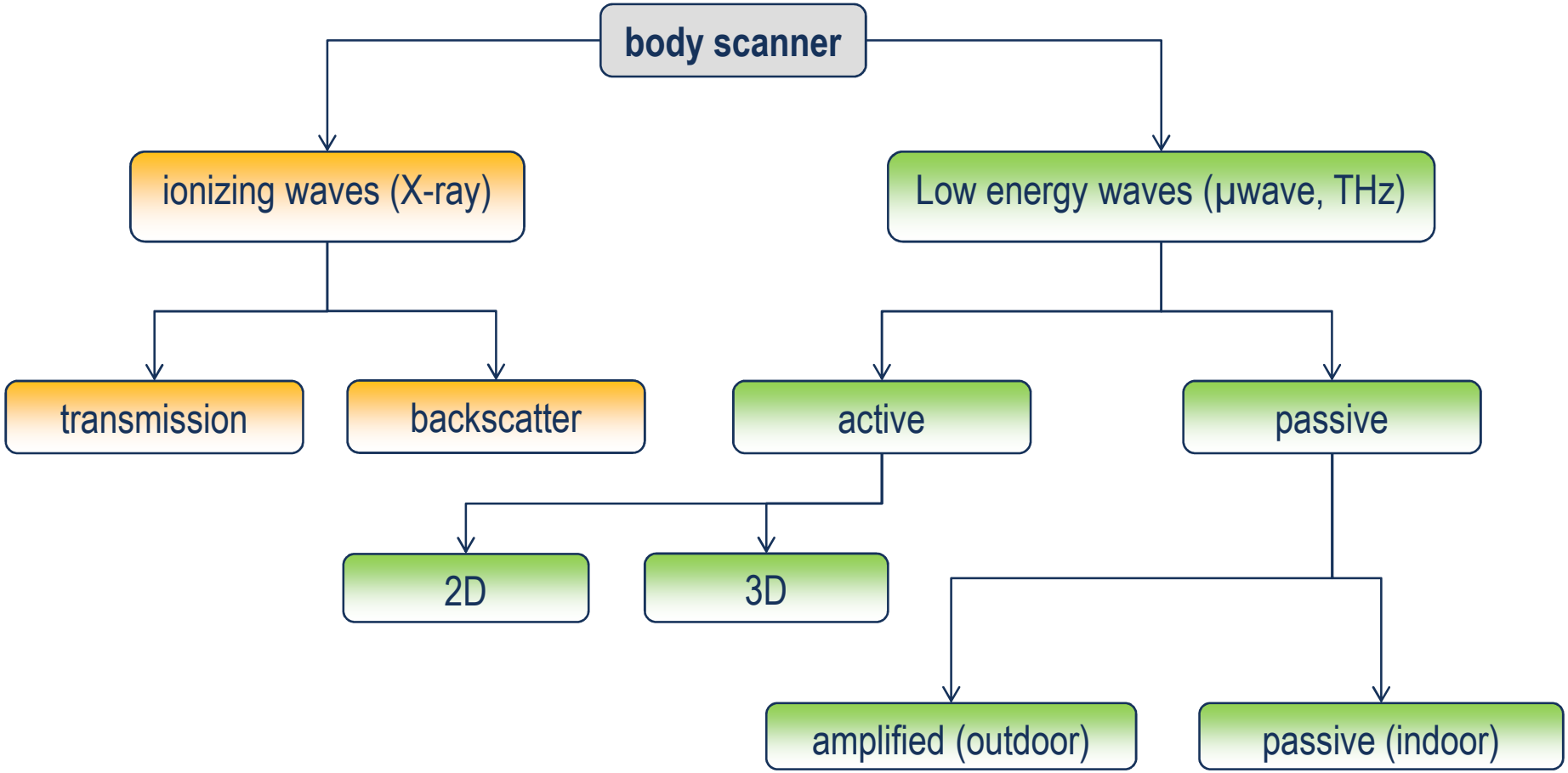
Concept of a ‚body scanner‘

1. Create an image of the person to be checked, using electromagnetic waves (‚light‘ in a broader sense: X-ray, visible, infrared, terahertz, microwave)
2. Use light which shines through the clothing of the person (rules out visible and infrared light)
3. Exploit properties of a hidden object, which might differ from those of the human body (absorptivity, reflectivity)

1 m	10 cm	1 cm	1 mm	100 µm	10 µm	1 µm	300 nm	30 nm	wavelength
300 MHz	3 GHz	30 GHz	300 GHz	3 THz	30 THz	300 THz	1 PHz	10 PHz	frequency
0.01	0.1	1	10	100	1,000	10,000	100,000	1,000,000	wave number (cm^{-1})
radio		**microwave**		**terahertz**	**infrared**		**visible**	**ultraviolet**	**X-ray**

Overview of feasible concepts



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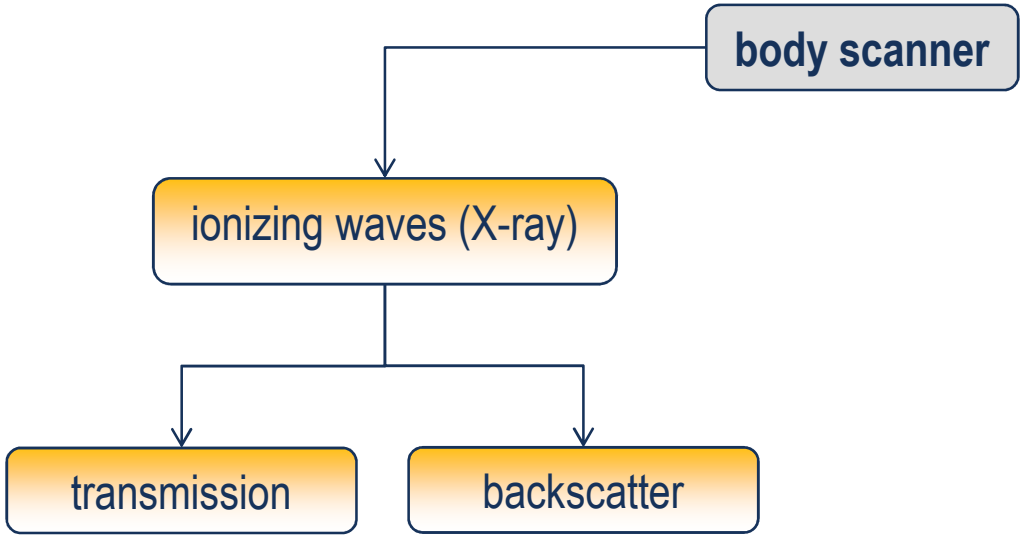


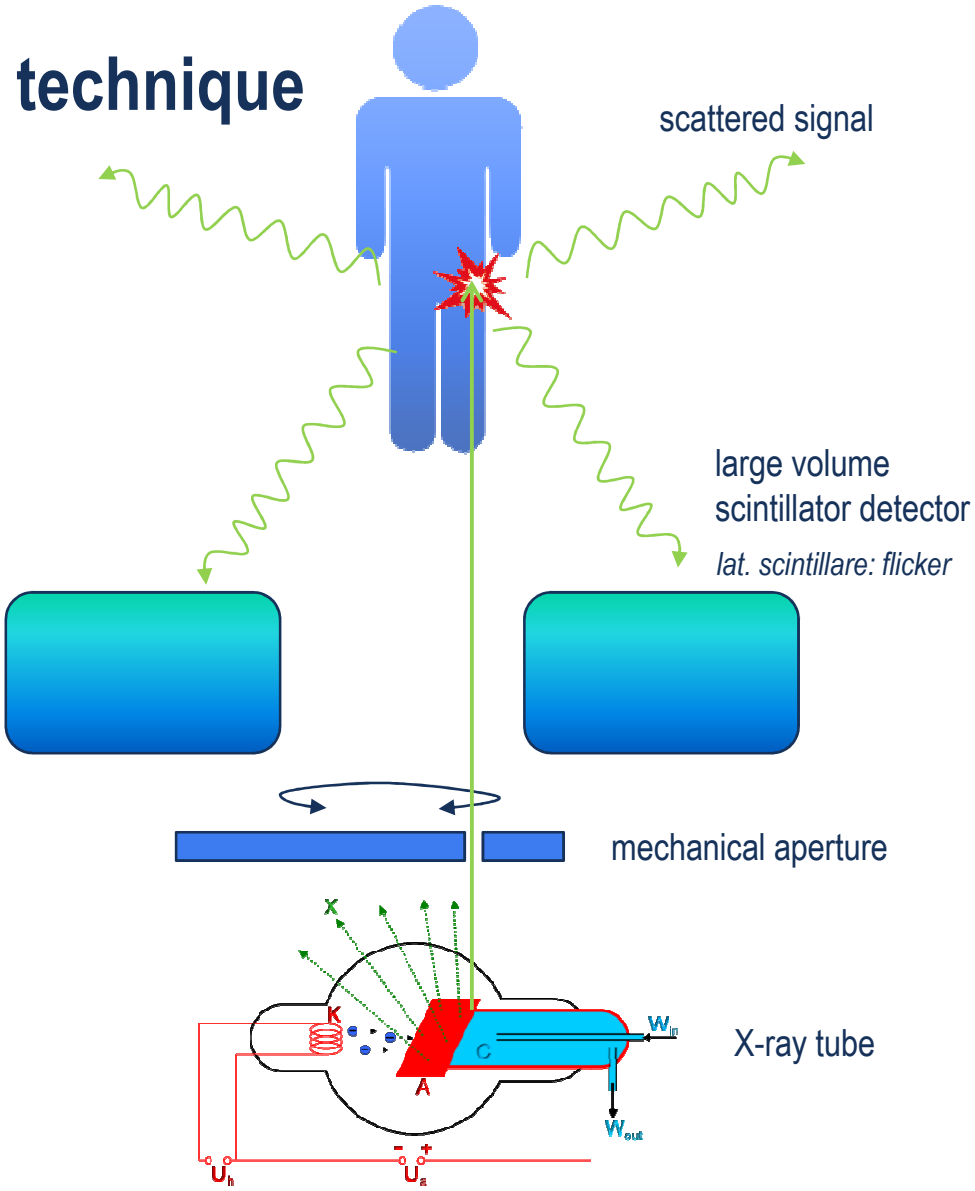
X-ray technology: as Hollywood envisions it…

…and in reality: backscatter technique

Interaction of X-ray with matter

1. scattering: dominant for ‚soft' tissue
2. absorption, e.g. for metals

excellent detection capability for metals and ceramics, but difficulties for organic compounds (too close to human issue)



State of the art in X-ray tools

American Science and Engineering „Smart-Check“

double- or single scan (master/slave setup)

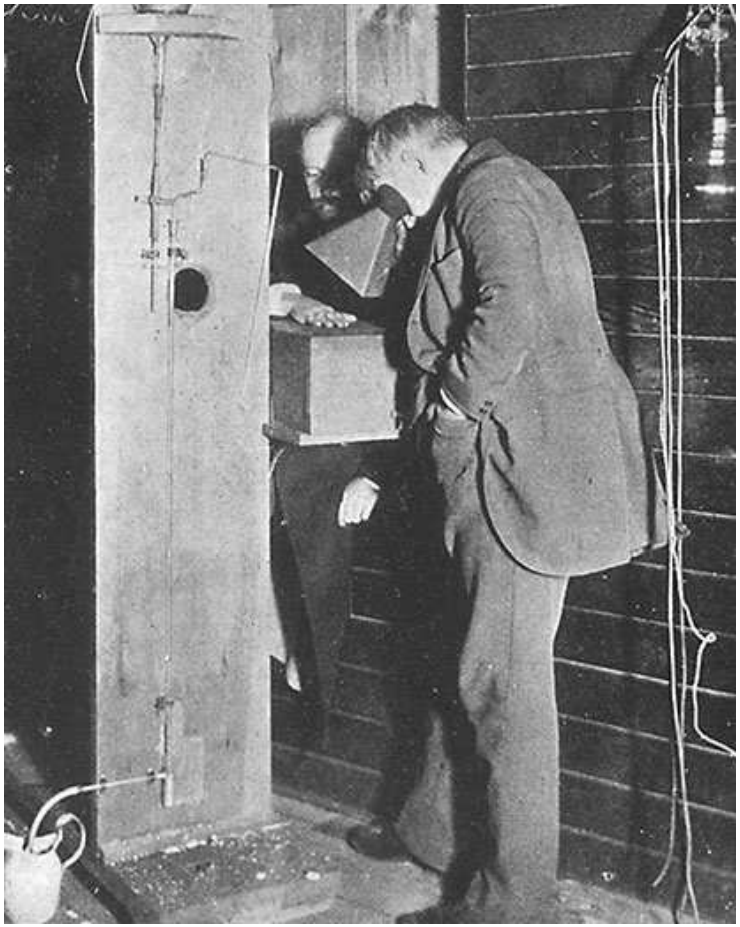
6 seconds per scan

dose <0,1µS (for comparison: dental X-ray about 5µS)

Susan Hallowell, director of security lab of Homeland security Transportation Security Administration

What about health issues?

First published X-ray image: Konrad Wilhelm Röntgens wife‘s hand with wedding ring



In the past, X-ray was treated as a party gag and practical daily tool.

ipht jena

Only panic? No!

"Forget Japan's Radiation Cloud – Could a TSA Scanner at LAX Give You Cancer?"

"Scientists question safety of airport full body scanners"

"After Stroke Scans, Patients Face Serious Health Risks"

"Airport body scanners deliver radiation dose 20 times higher than first thought"

DOSE COMPARISONS*

	Radiation Source	Effective Dose µSv
	Dental X-ray*	2-15 µSv
	Chest X-Ray*	20µSv
	Return flight to Malaga*	15 µSv
	Average UK daily dose to Public*	7 µSv
	30 mins in Cornwall or Denver Colorado	0.25µSv
	Eating 1 Brazil Nut*	0.25 µSv
	**1 Scan on Conpass HR**	**2 µSv**
	1 Scan on Conpass LD	**0.25µSv**

*Source - HPA Radiation Protection Division UK.

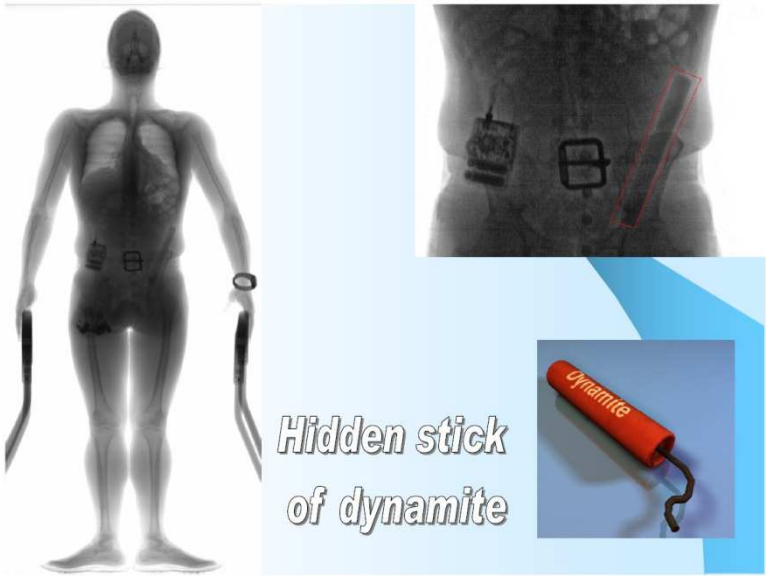
Feig S, Hendrick R (1997). "Radiation risk from screening mammography of women aged 40–49 years". *J Natl Cancer Inst Monogr* (22): 119–24

Consequence

Although X-ray is the **only** technology which potentially could reveal objects **INSIDE** a human body, it is excluded from body scanning in Europe

(at least for the present, and except of extreme circumstances)

Teflon knife hidden behind back



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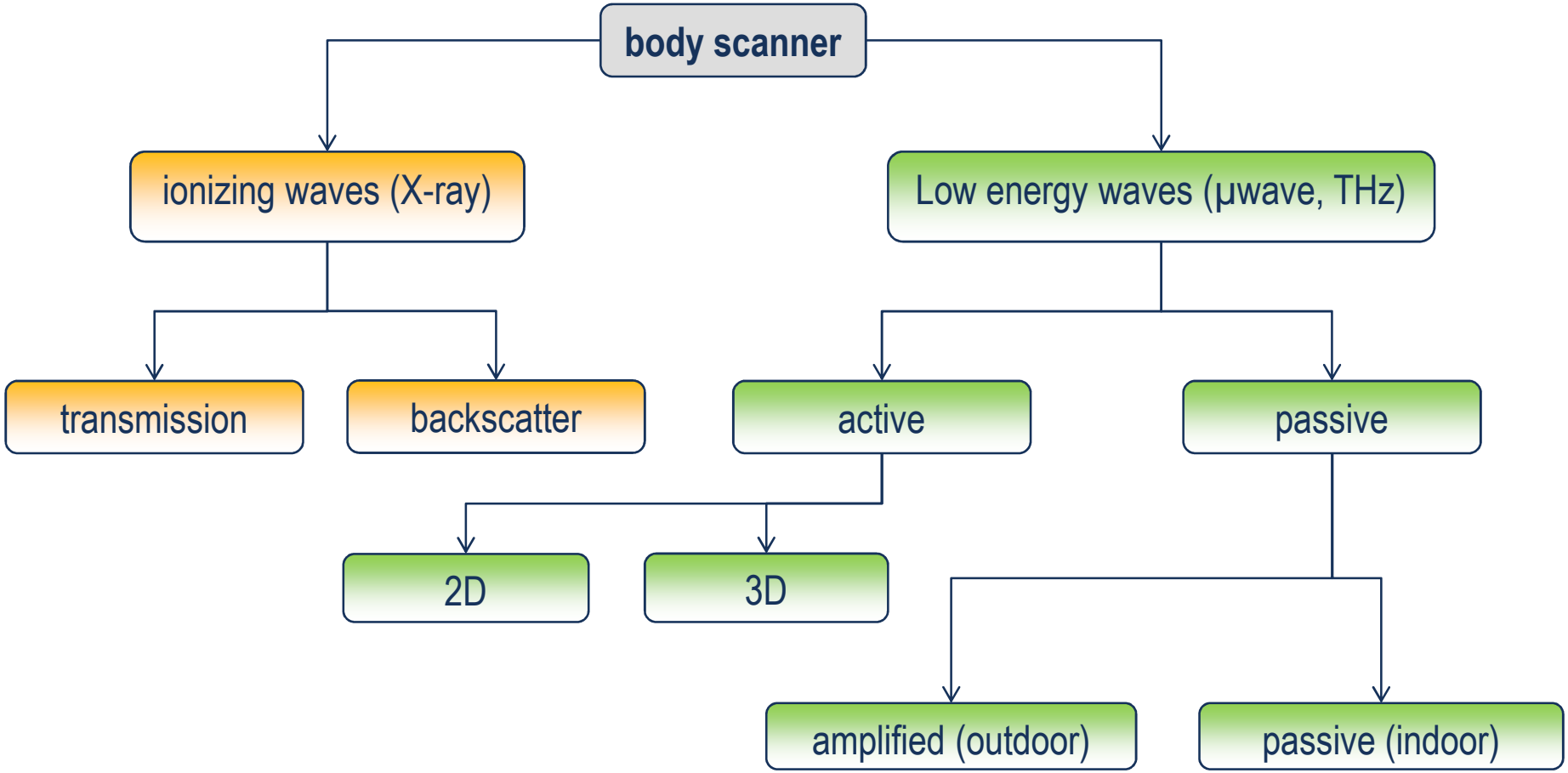

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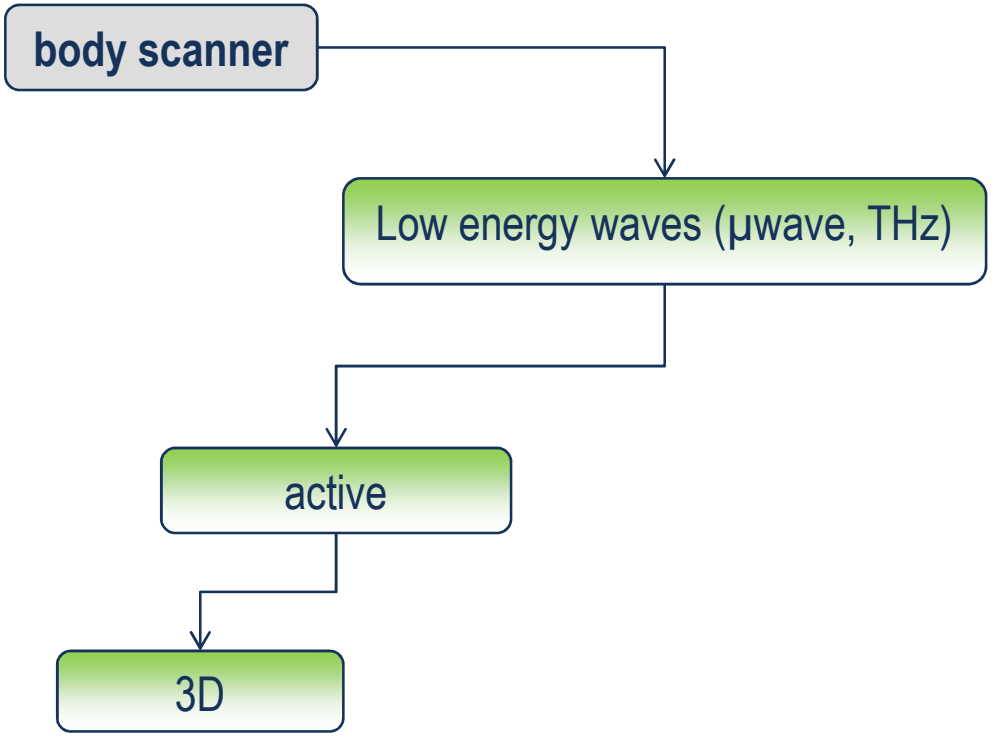
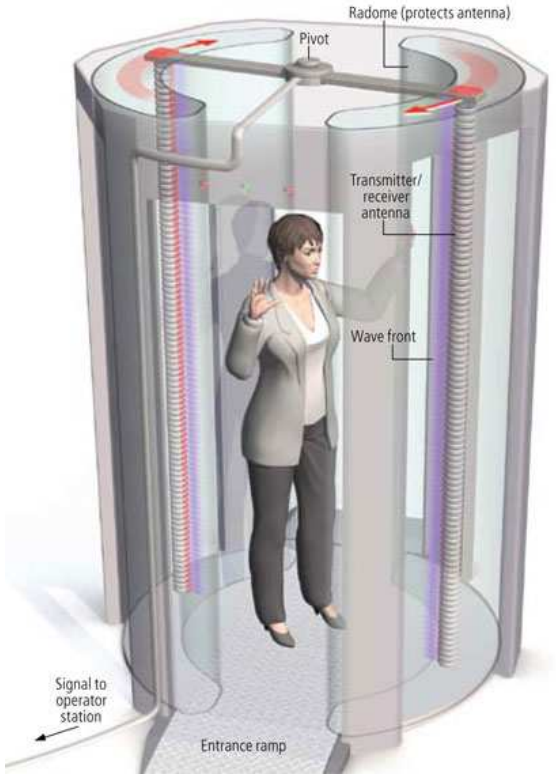
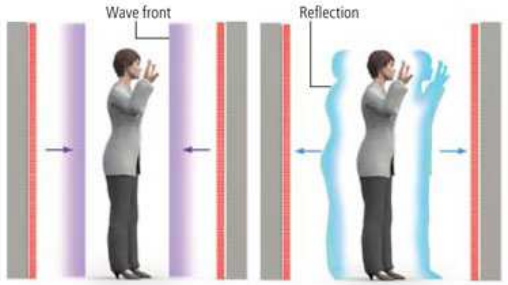


Active millimetre wave imaging

Millimetre waves:

- wavelength between 1 and 10 mm (for comparison: ‚cell phone wave' approx. 10 cm)
- approved technologies from RADAR, e.g. car distance control
- waves are mostly reflected by human skin – no health issues



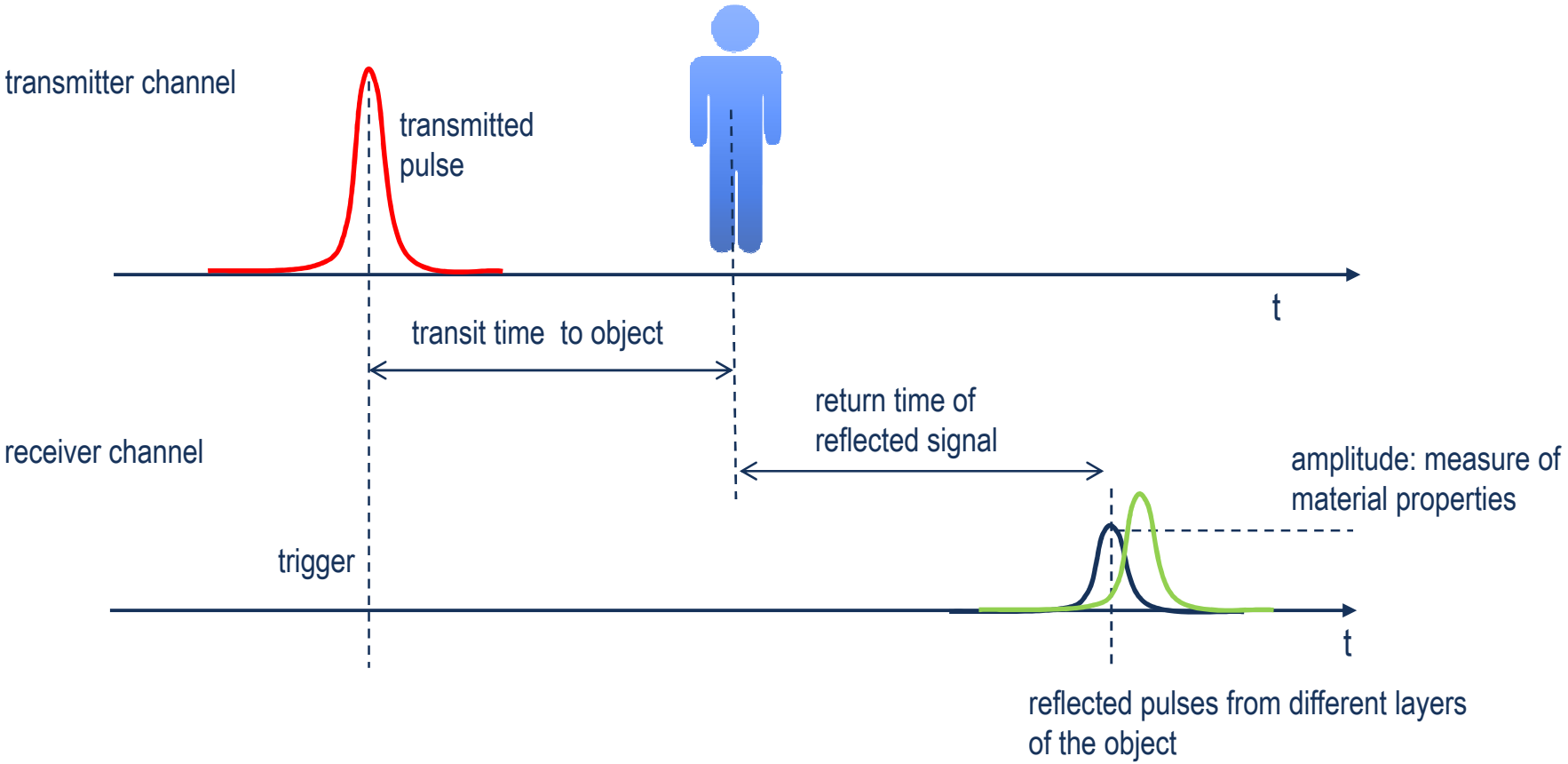


MILLIMETER-WAVE IMAGING

A passenger steps inside. Two vertical banks of transmitter/receivers pivot in tandem, each emitting a wave front that penetrates clothing and reflects off the person's body and any concealed objects. For privacy, the security operator viewing the resulting image sits at a remote location.

Scan time = 10 seconds
Beam frequency = 24–30 GHz
Beam power density = 6×10^{-6} mW/cm^2

Basic principle of 3-dimensional image reconstruction



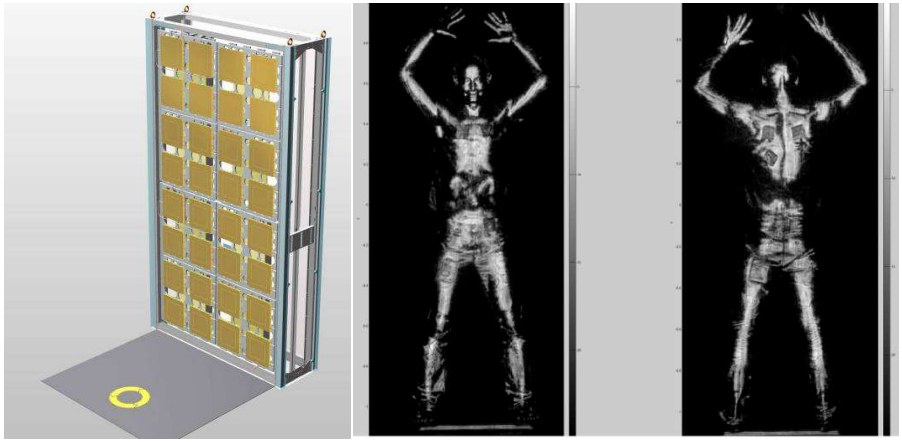
Result: a ‚voxel': pixel with three coordinates and an amplitude information

Most famous implementations

L3 Communication: Provision ATD (tested in HH)

Smith detection eqo™ : under review in Tübingen

Very similar techniques, but different levels of maturity and sophistication



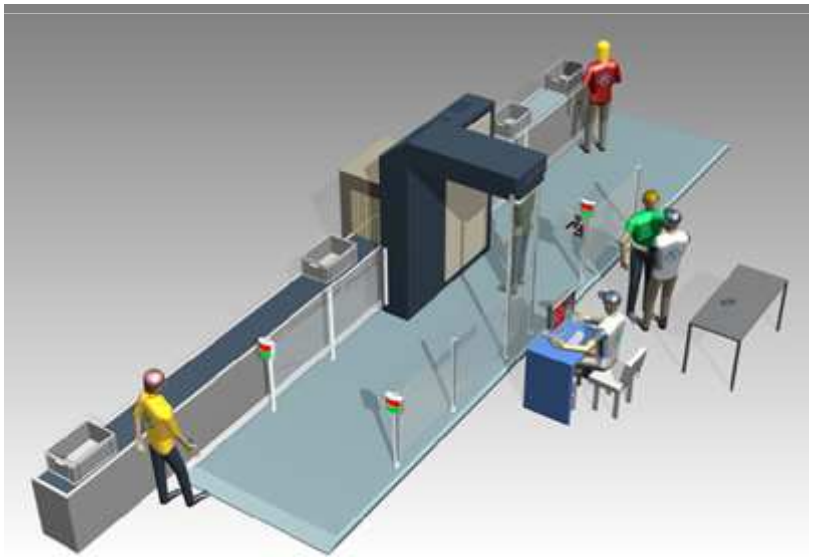
Rohde & Schwarz QPASS, German project

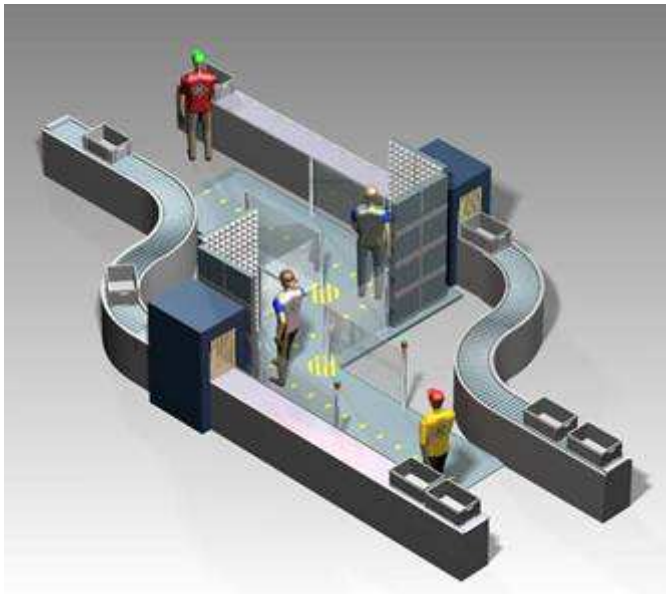
Deployment concepts

Deployment in airports has to meet extreme demands on throughput and false alarm rates

- Short processing time
- Robust detection algorithm, potentially by the help of additional sensing concepts (explosive spectroscopy, stress analysis etc.)
- Realizing the „Wandelgang“: check en passant

→ becomes very ambitious with current technologies





by courtesy of Rohde & Schwartz

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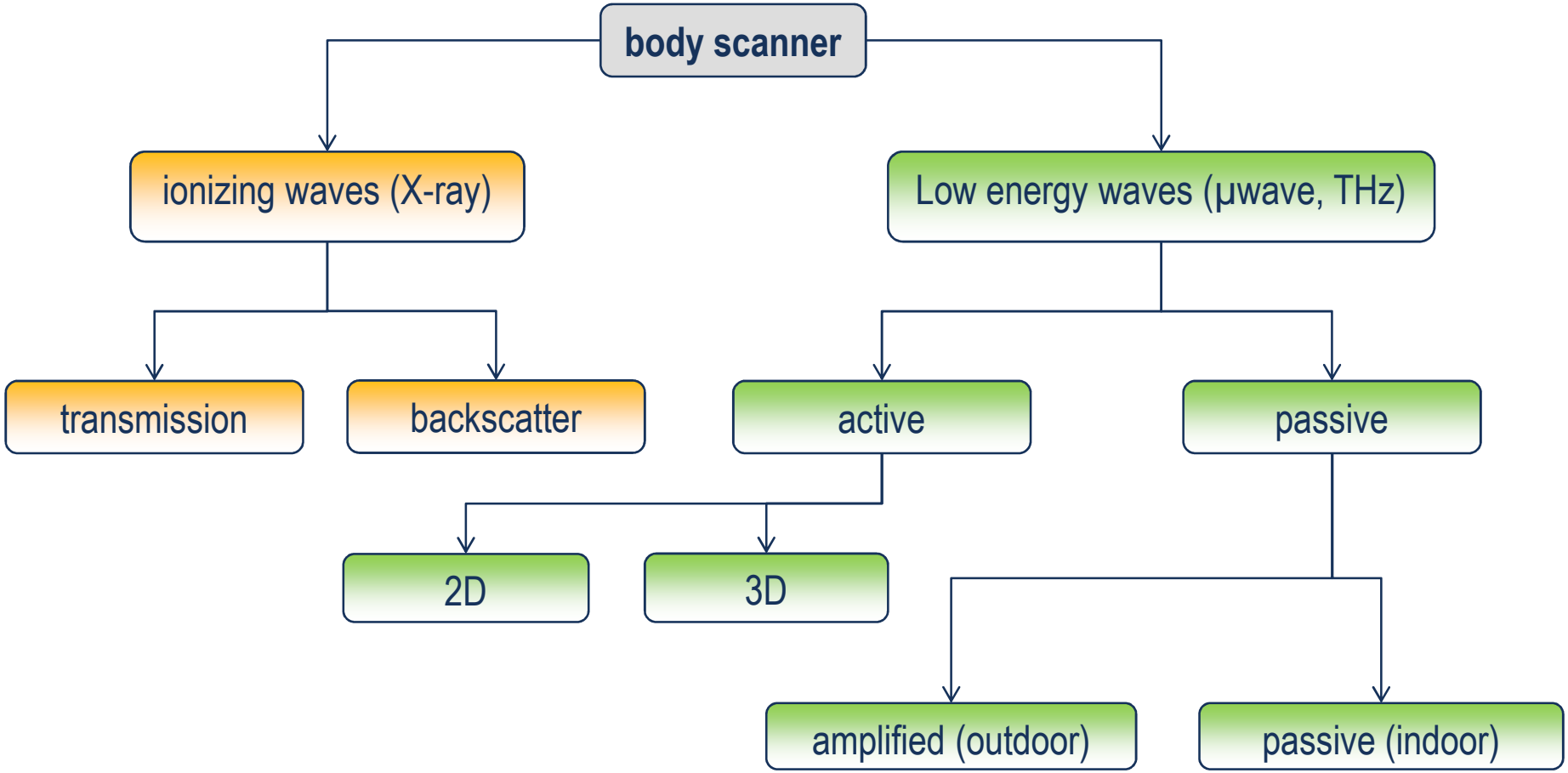

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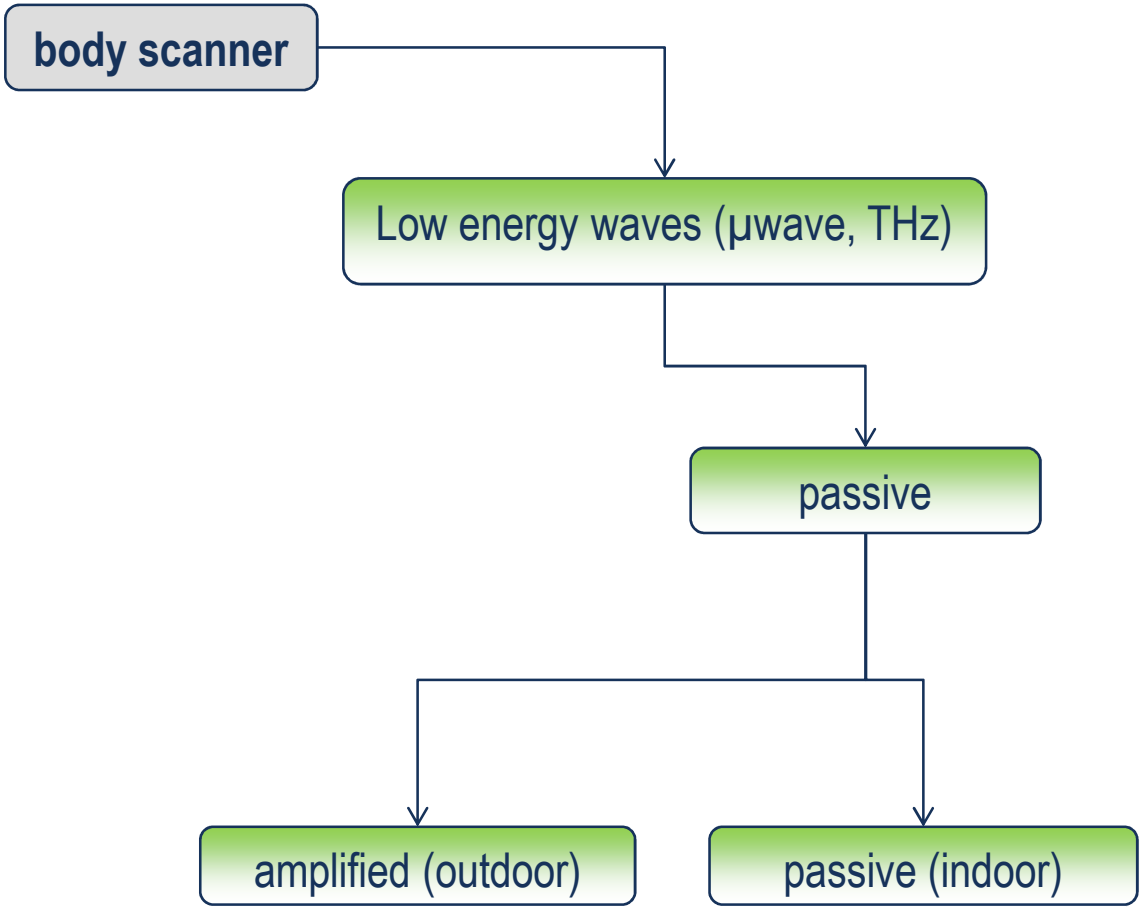
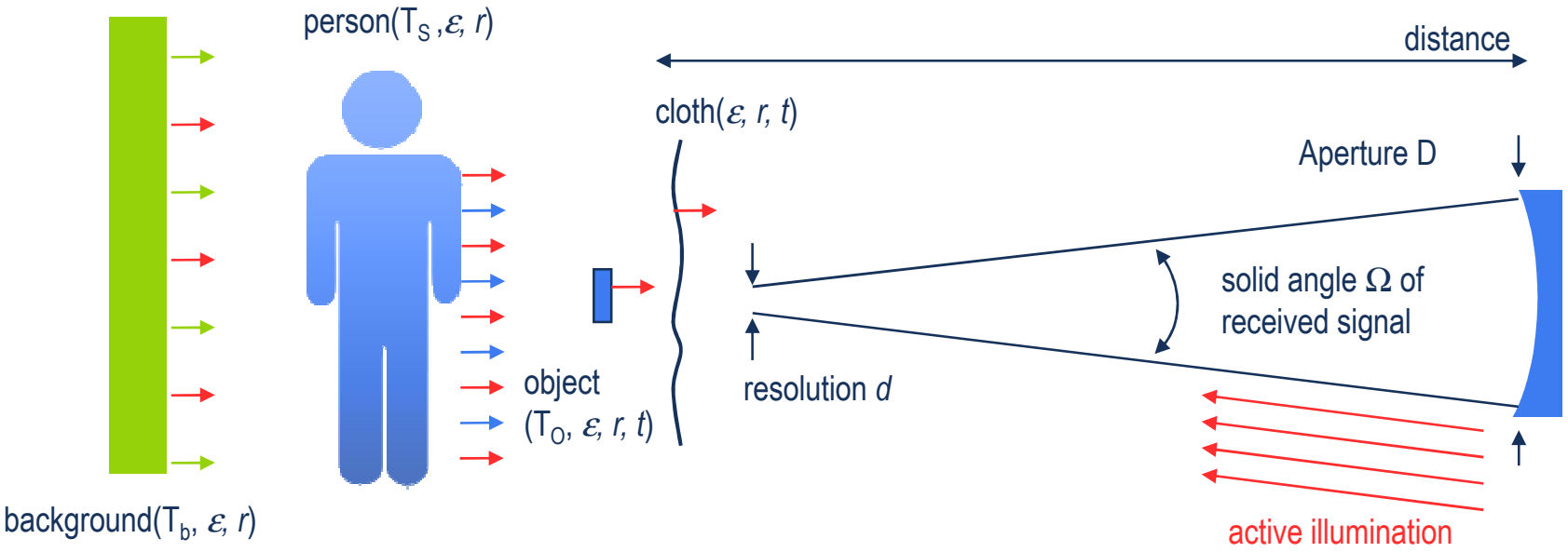


Why physics has an aversion to body scanning

$$d = \frac{\lambda}{2n\sin\alpha}$$

wavelengths limits the achievable spatial resolution ⟺ short wavelengths are useless for body scanning



with shorter wavelengths:

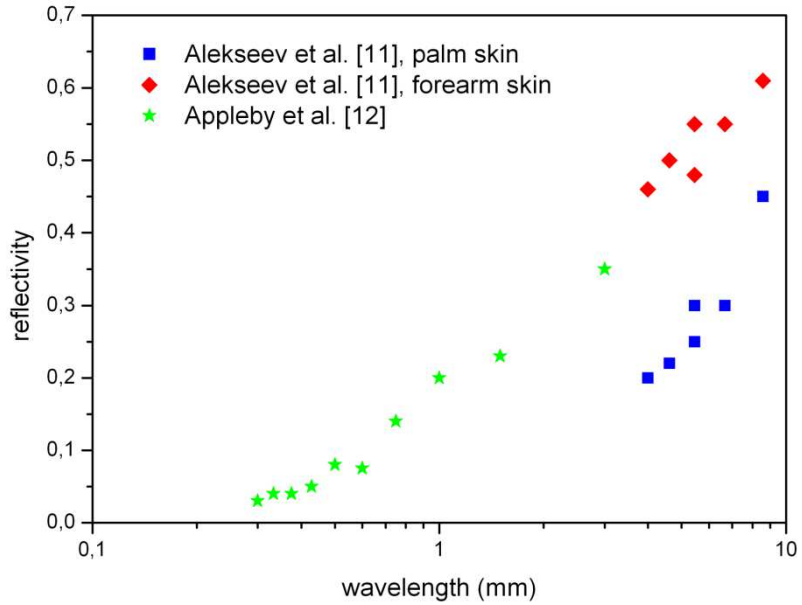
- resolution becomes better
- transmission through cloth vanishes
- reflection from human body vanishes

Thinking beyond: passive imaging is not only an evasion but a logical solution

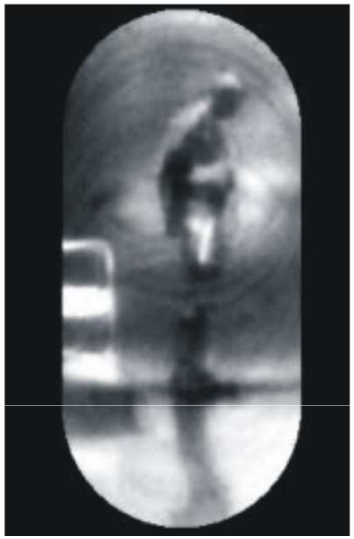
"We do these things, not because they are easy, but because they are hard."
JFK announcing the moon landing project

No! They are actually easier than active imaging!

reflection from human body

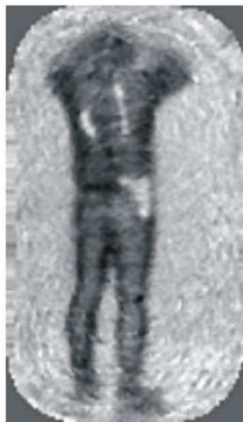


...of course it‘s not that easy



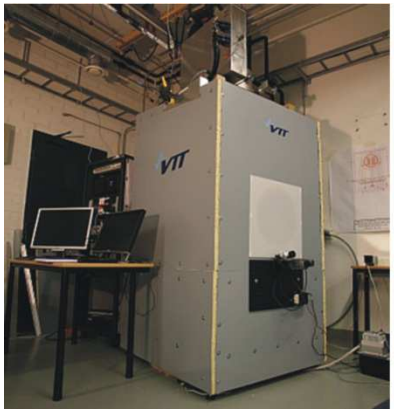
Passive imaging outdoor (Qinetiq)

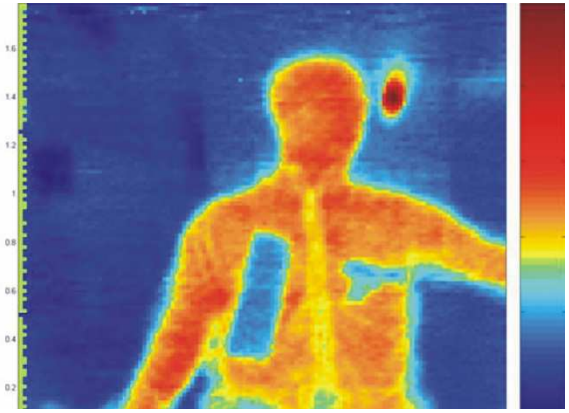
Limited indoor resolution (Thruvision)



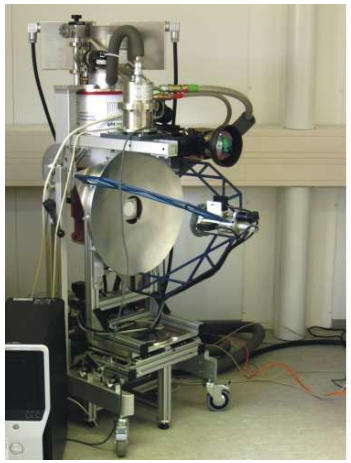
Simulating outdoor condition by a cooled wall (Millivision)

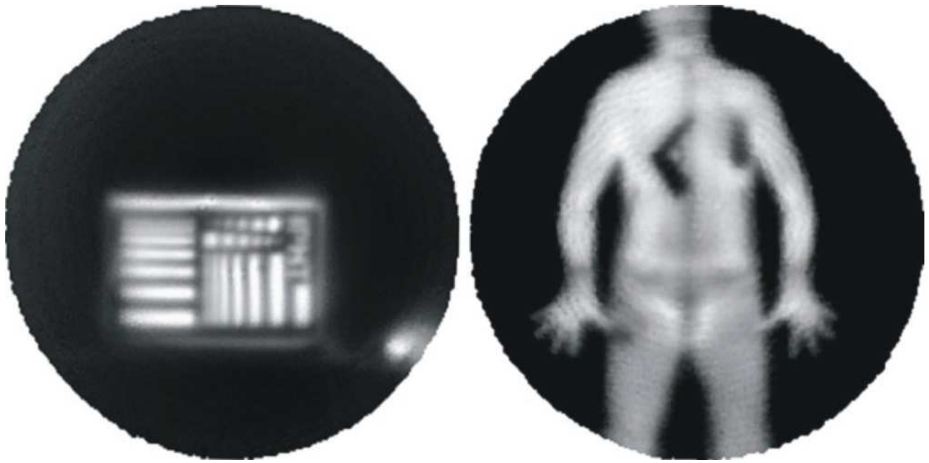
Current research: terahertz technology





Saab + NIST (USA) + VTT (Finnland)





Rohde & Schwarz + IPHT Jena

Conclusions

1. X-ray body scanning is a dream (of security officials) and a nightmare (for public) at the same time. In Europe it is excluded for the present.
2. Active millimetre wave imaging is an effective alternative. Various mature devices are close to market, and EU has cleared the legal pathway for them.
3. Current limitations are the missing flexibility and real-time capability, together with an imperfect automated object detection.
4. In future, flexible and portable cameras can be an add-on and allow for re-thinking traditional measures.
5. Material identification is a dream of the future. Body scanners will be restricted to object detection rather than identification for a long time.

…and finally a little advertisement

Thank you for your attention!