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Detection of Latent Damage from Insect Activity in Wooden Structures through the Use of Holographic Subsurface Radar

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Termite Damage

- **Losses total $1 to $3.5 billion per year in the USA alone**
- **Estimation 17-20% of homes in Australia suffer damage**
- **Common in all tropical through temperate climates**
- **Termites cause the most monetary damage, but there are many other wood-damaging insects**

Eastern Subterranean Termite (worker)

Eastern Subterranean Termite (breeder)

Formosan Termite (workers and soldier)

Drywood Termite (breeder)

Carpenter Ant

Lyctid Powderpost Beetle

Bostrichid Powderpost Beetle

Anobiid Powderpost Beetle

Old House Borer

Carpenter Bee

Interesting Termite Facts which Suggest Detection Methods

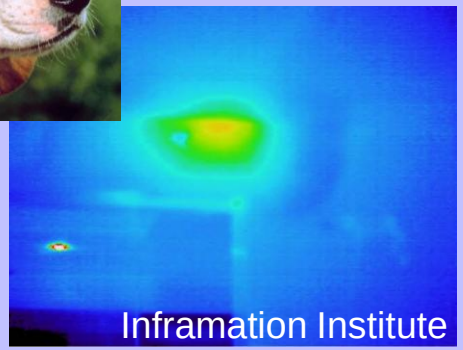
- Digestion of cellulose is tremendously exothermic (suggests thermal methods)

- Termites generate more CO_2 per unit biomass than any other organism (suggests sniffing devices or dogs)

- Termites communicate acoustically by "head-banging" (suggests acoustic methods)

Detection by Professionals

- Probing with a screwdriver or icepick
  - destructive and unscientific
    - finds both active and old damage
- Resistograph
  - scientific but still destructive
    - finds active and old damage
- Trained dogs
  - non-destructive
    - active infestations only
- Thermal imaging
- Acoustic emissions
- Radioactive tracer baits (ants only)
  - all are non-destructive, *but*
    - Find current infestations *only*
    - Cannot be done during daytime for ground-dwelling nocturnal species
    - Cannot be done during winter when insects are inactive



An Ideal Detection Technology

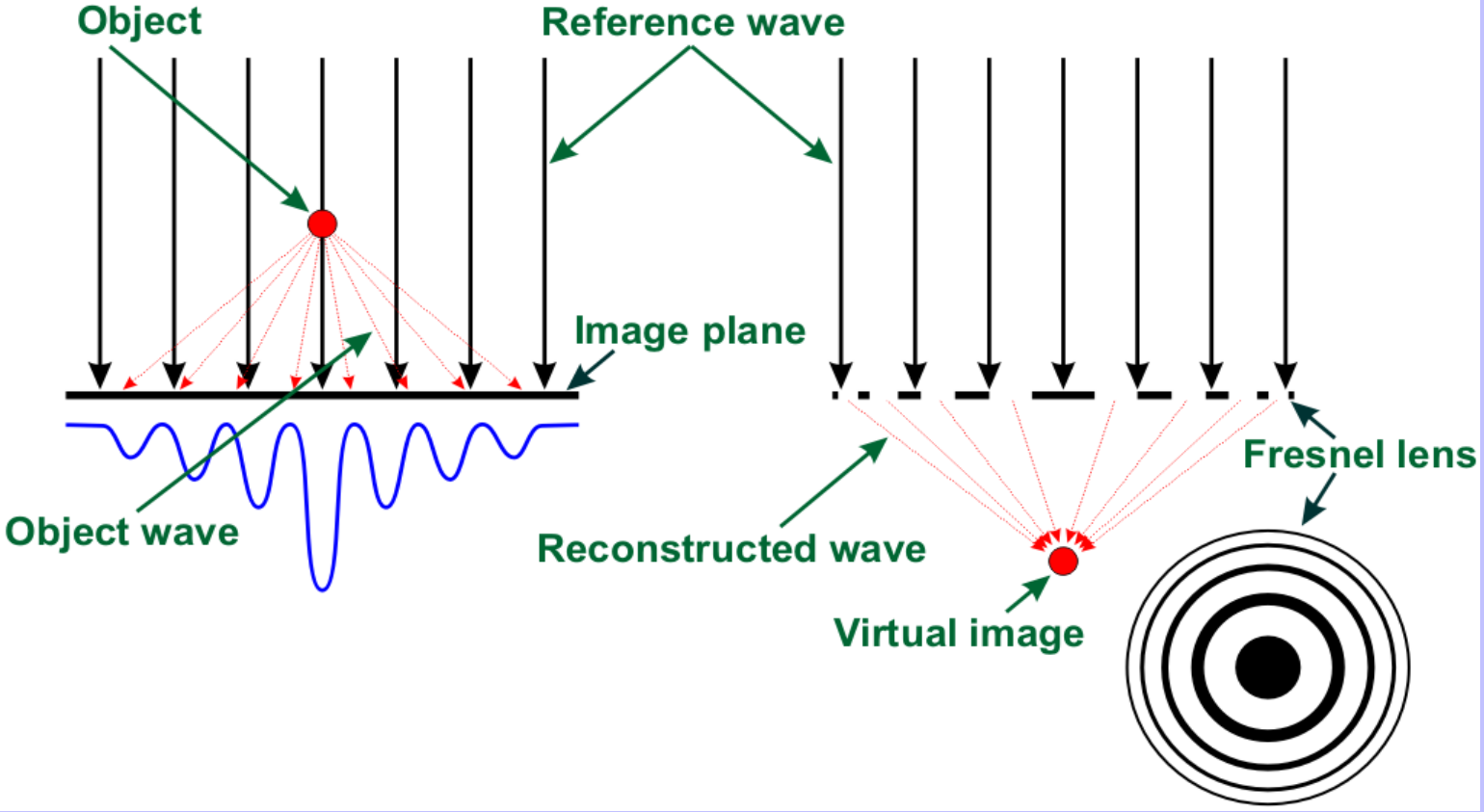
Should be…

- Non-destructive
- Able to detect both active infestations and old damage
- Effective in any season or time of day
- Readily usable by structural engineers, construction workers, pest control professionals, etc.

Simple Optical Holography

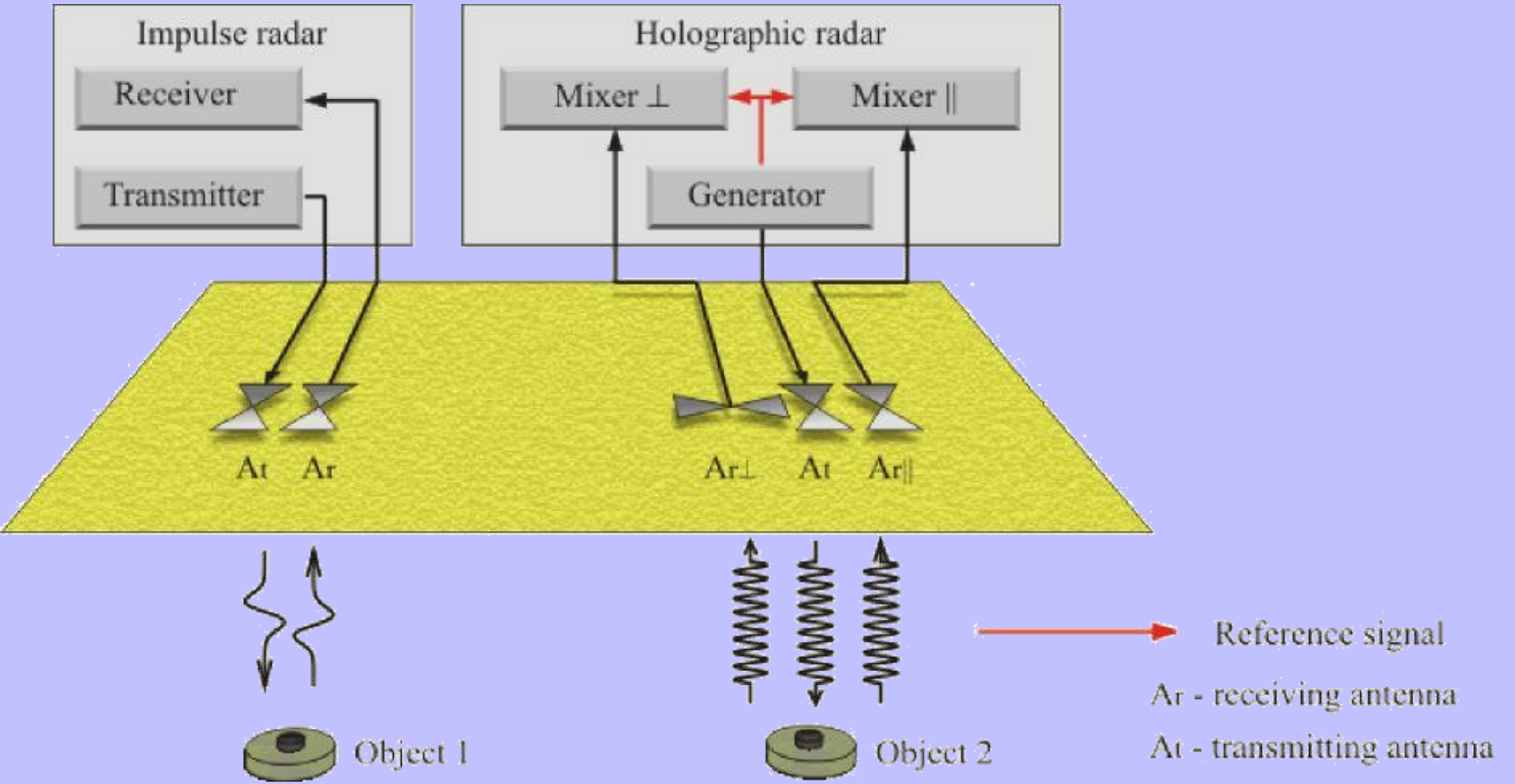
Holographic Recording

Hologram Reconstruction



S. IVASHOV, V. RAZEVIG, I. VASILYEV, A. ZHURAVLEV, T. BECHTEL, L. CAPINERI, "The Holographic Principle in Subsurface Radar Technology" International Symposium to Commemorate the 60th Anniversary of the Invention of Holography, Springfield, Massachusetts USA, October 27-29, 2008.

Comparison of Holographic and Impulse Radar



Holographic radar response

$$A(x,y)=A_t A_r \cos(\varphi_t - \varphi_r)$$

$$\varphi_r = 2\sqrt{\varepsilon}\frac{l\omega}{c} + \Delta\varphi$$

Dielectric constant (Epsilon) $\varepsilon = [(1-\Phi) * (\varepsilon_{la})^{1/2} + \Phi * S_w * (\varepsilon_w)^{1/2} + (1 - S_w) * \Phi * (\varepsilon_a)^{1/2}]^2$

Φ = porosity

ε_{la} = dielectric constant of dry wood (= 4)

S_w = saturation

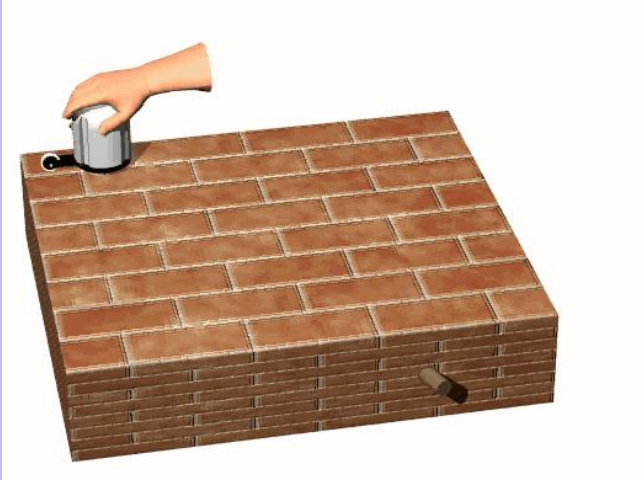
ε_w = water dielectric constant (= 81)

ε_a = air dielectric constant (= 1)

Nicolotti et al.: Three Tomographic Techniques for Detection of Decay in Trees

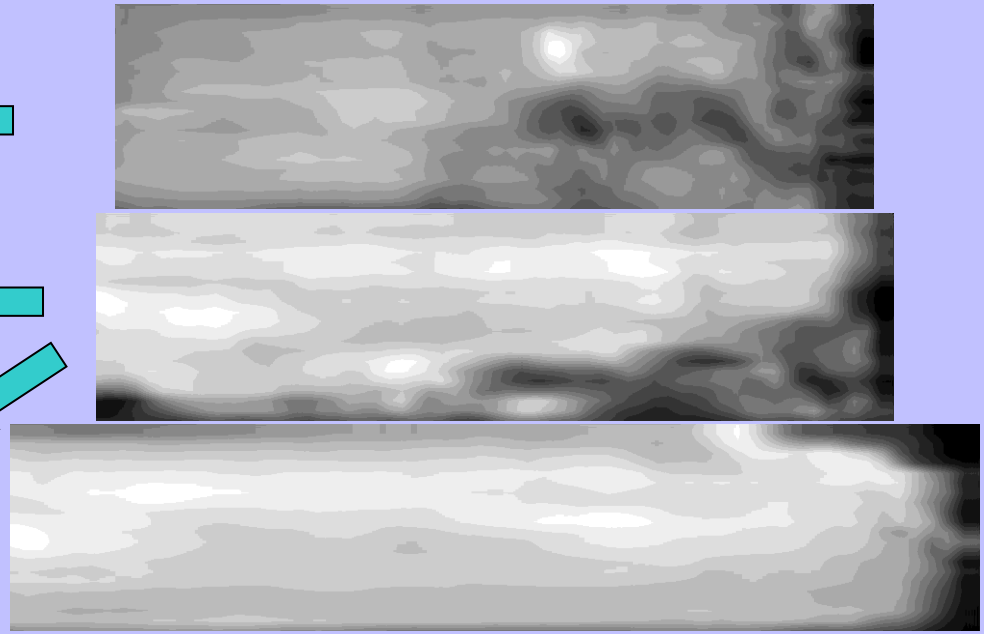
RASCAN Radar

- Shallow penetration depth (typ. 5 cm at 4GHz in dry wood)
- Very high-resolution in-plane about 0.25 λ
- A new technology in search of a wide commercial application



Test on Boards with Known Damage

RASCAN-4/4000

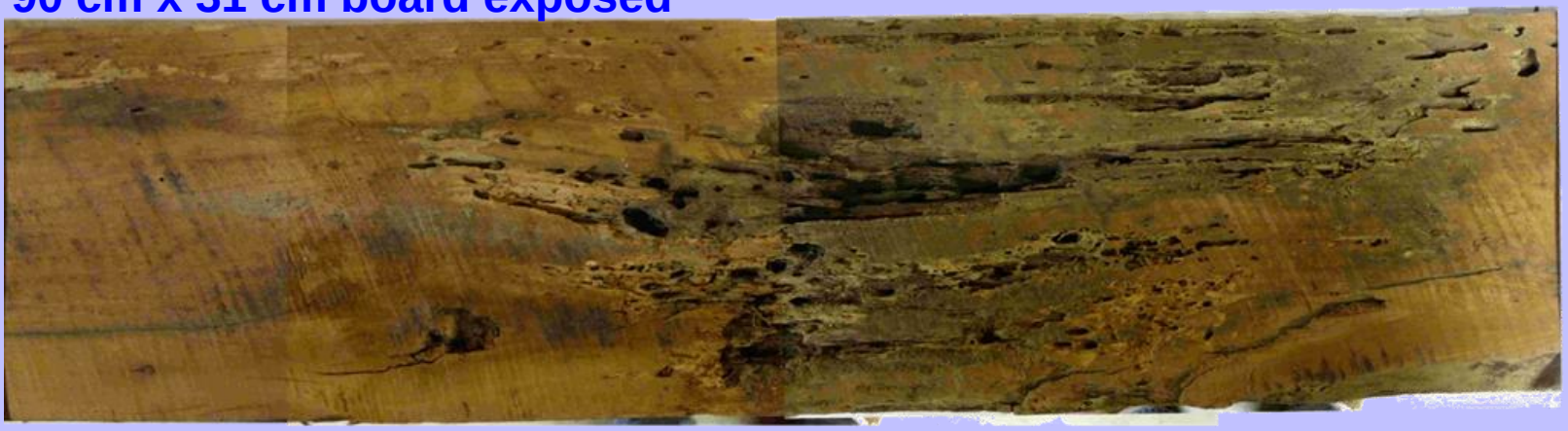


Tunnels visible on edge of boards only, but RASCAN reveals internal variations also.

Close-up of edge of board

Test on a Board with Known Damage behind Mock Wall Covering

90 cm x 31 cm board exposed

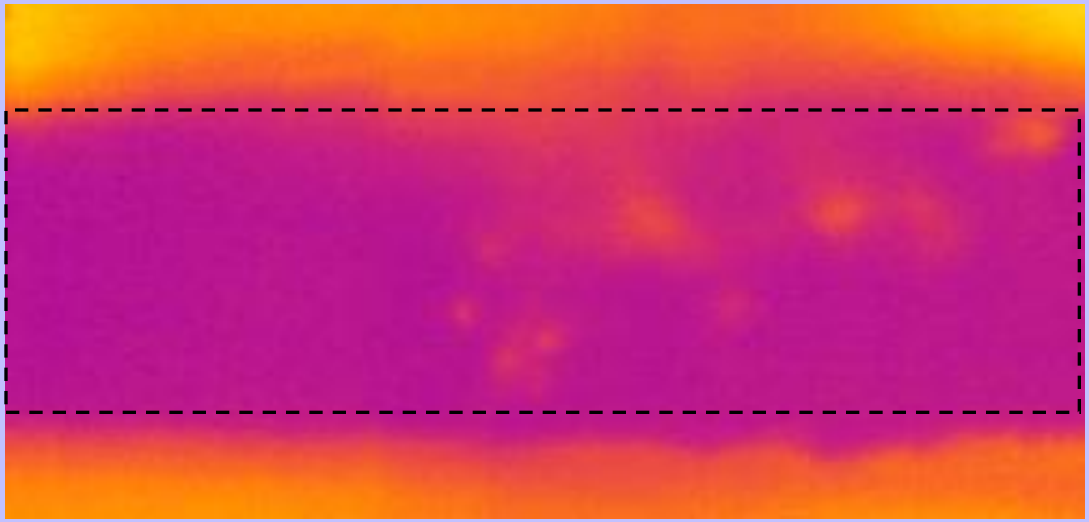


RASCAN- 4/4000 image recorded through 1 cm plasterboard

Thermal Imaging vs. RASCAN

90 cm x 31 cm board exposed

RASCAN image recorded through 1 cm plasterboard



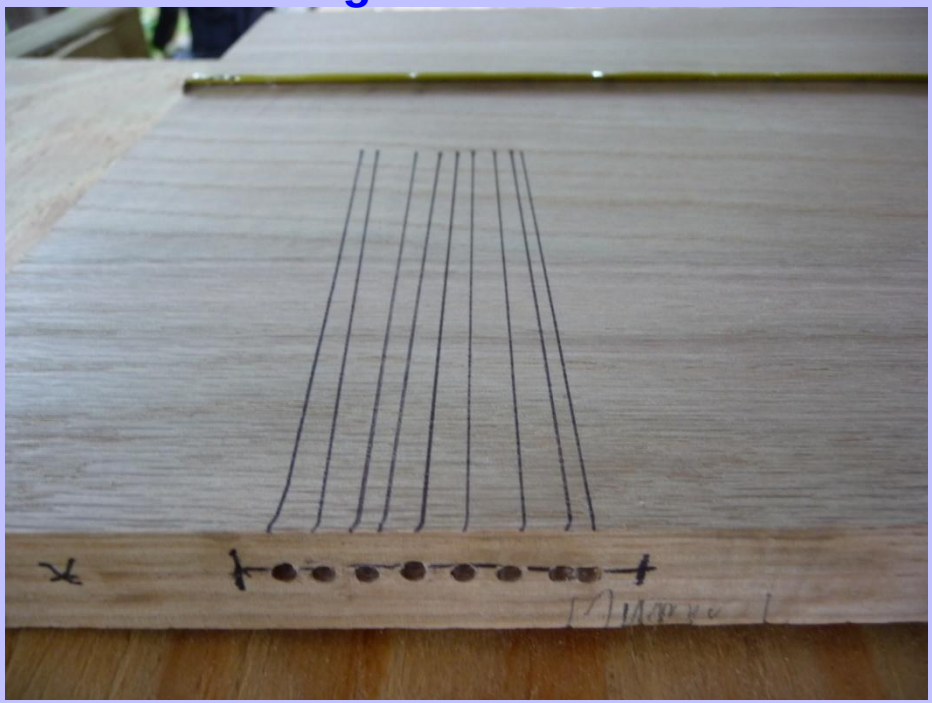
FLIR i60 image recorded through 1 cm plasterboard, with space heater behind board. Appearance of damage is transient only.

Test on Board with Mock Damage

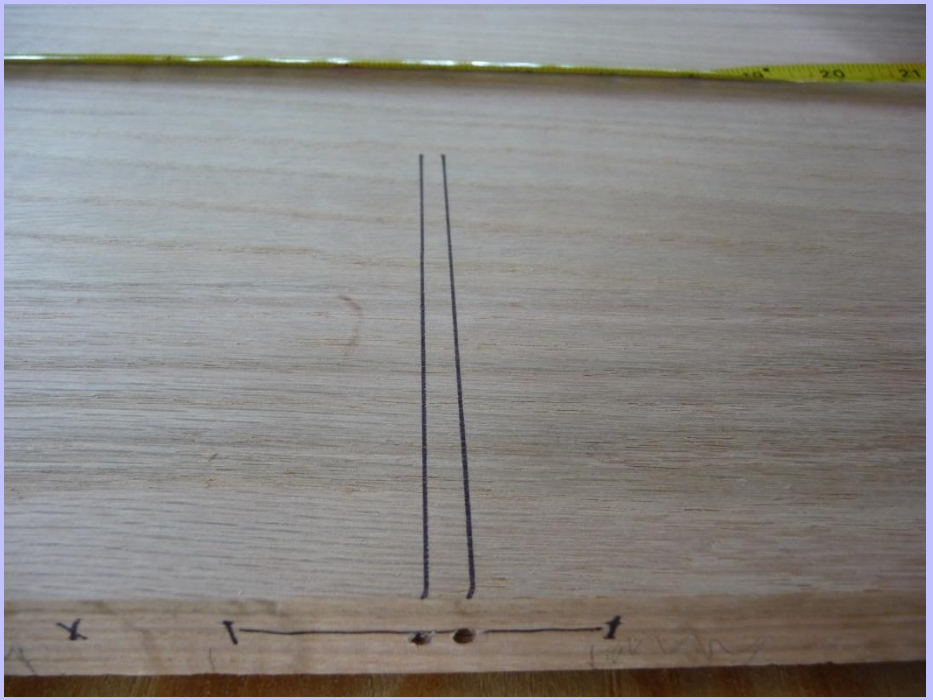
Tunnels mimicked by 5 mm diameter horizontal holes, drilled 12 cm in from edge in groupings of 1, 2, 4, and 8.

Close-up of Mock Damage

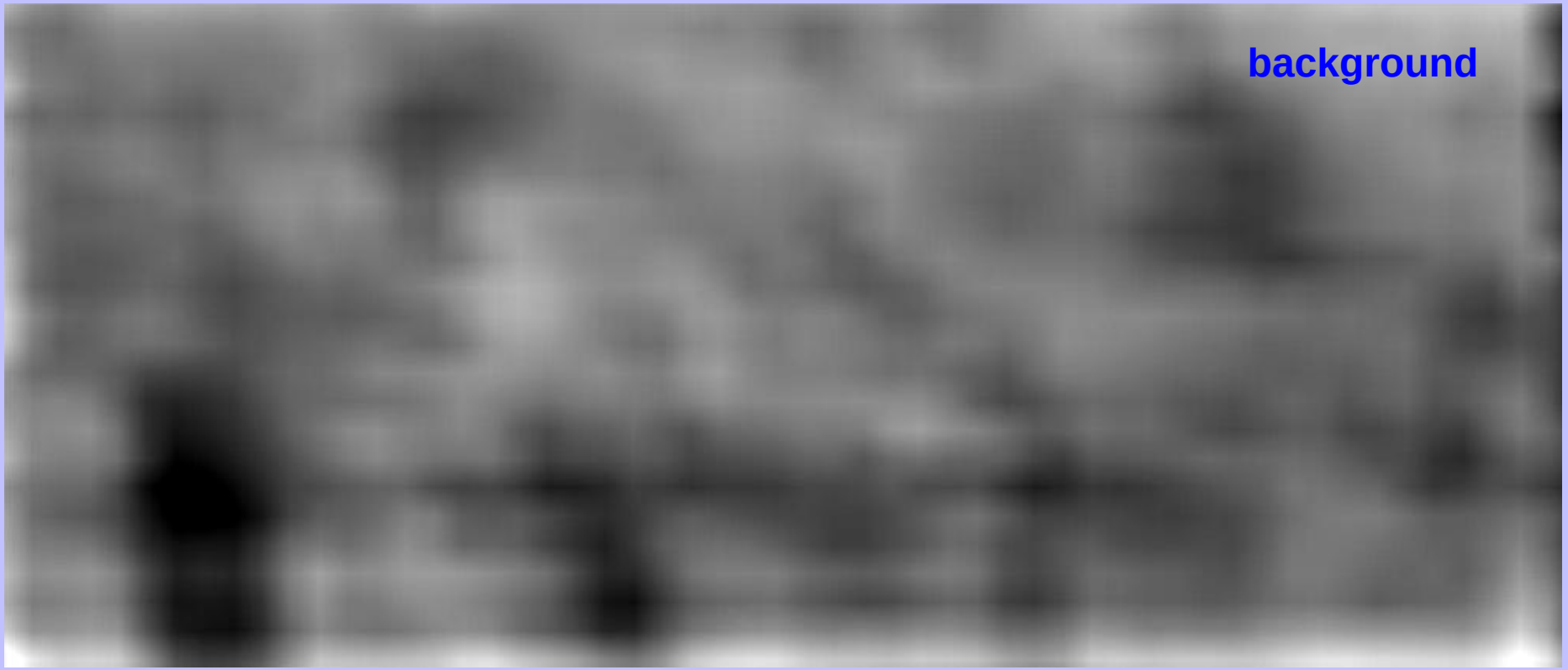
Eight 5 mm holes



Two 5 mm holes



RASCAN Image of Board with Mock Damage



- Eight holes clearly visible – four and two progressively less so
- Single hole is indistinguishable from background

Blind Test for Actual Damage

RASCAN was used in a building with heavy termite damage, from an old (>10 years ago) infestation.

Much damage is exposed following destructive testing and repairs.

Is there hidden damage that remains undetected ?

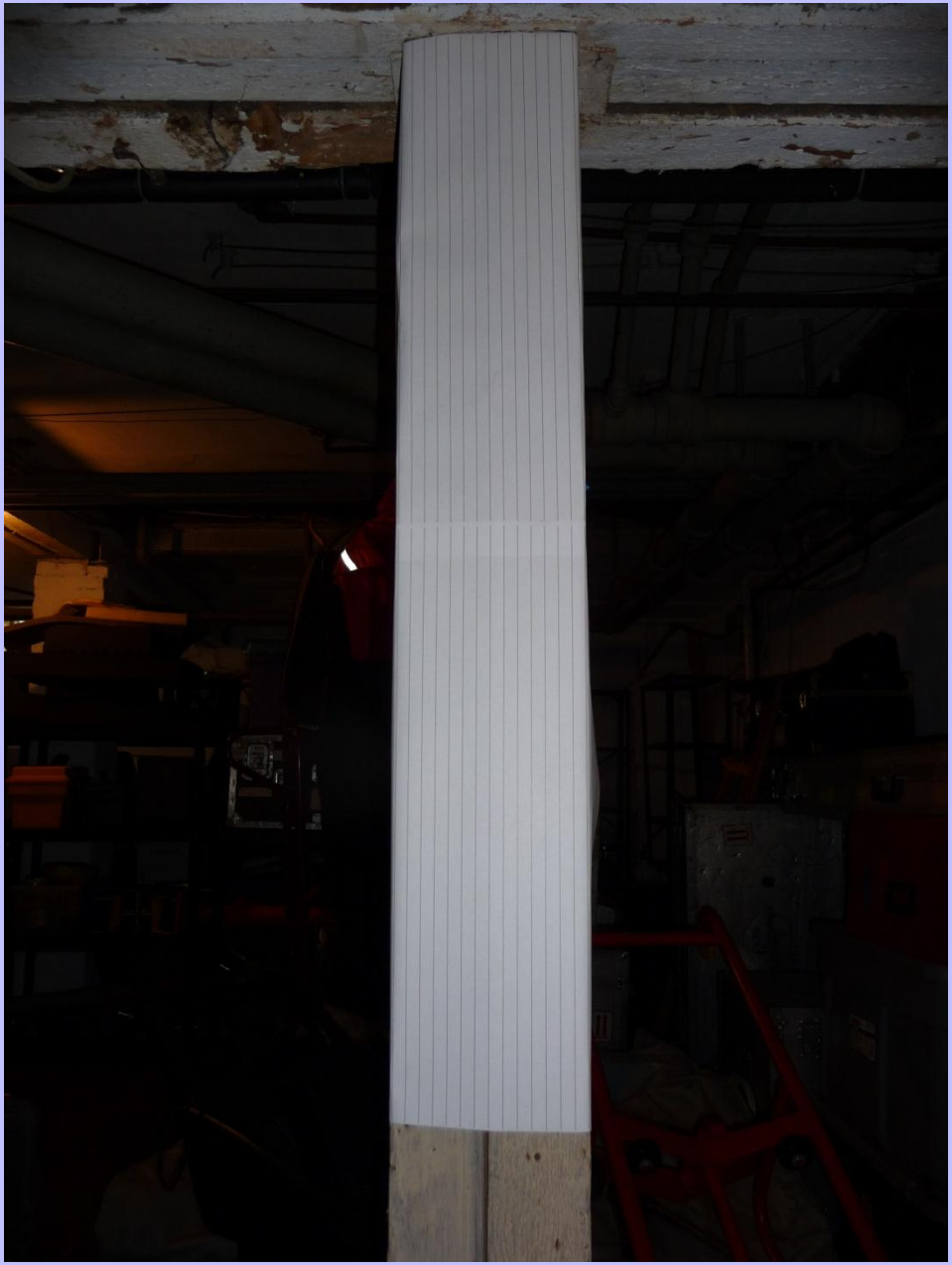
A Suspicious Location

This double post shows no visible surficial damage, but the beams above do.

Eastern subterranean termites nest in the ground, and rise into structures at night to feed.

Undetected tunnels in the post would provide hidden access from the earth to the damaged beam above.

RASCAN Testing



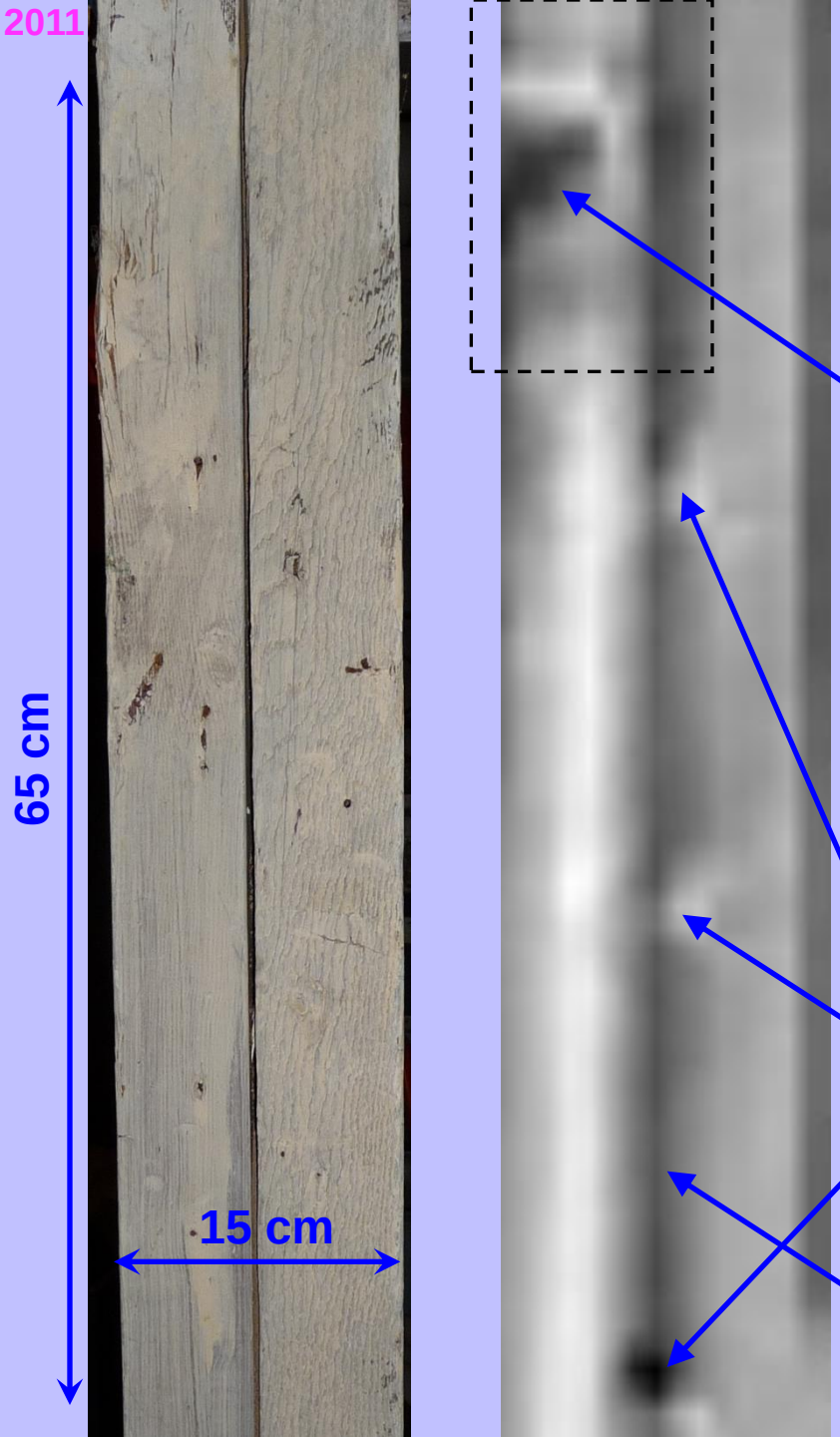
The post was scanned with RASCAN-4/4000 along lines spaced at 1 cm.

The scan extended 65 cm down from the damaged beams.

Scanning took less than five minutes.

Results were immediate.

Interpreting the RASCAN Image

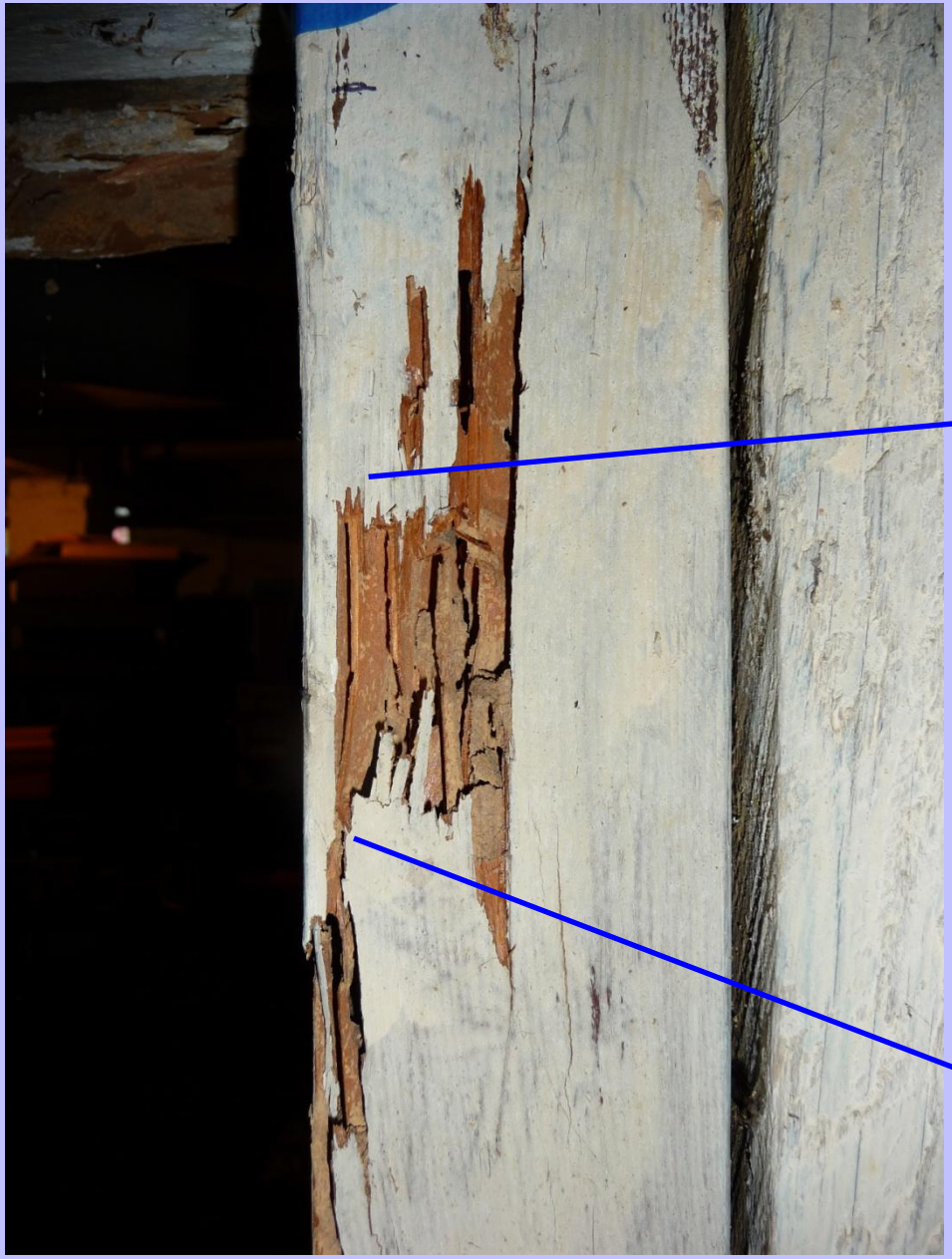


Possible Damage?

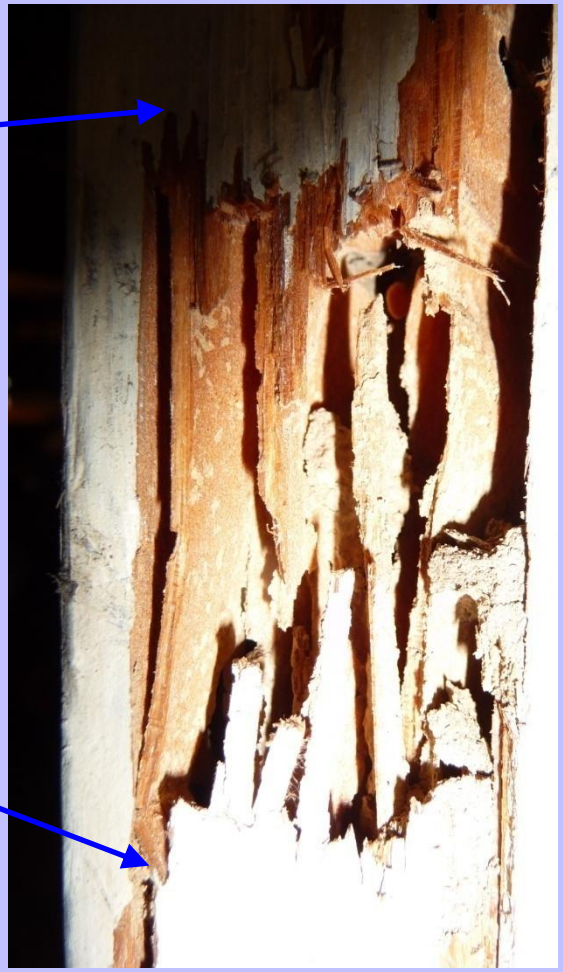
Fasteners?

The seam between planks

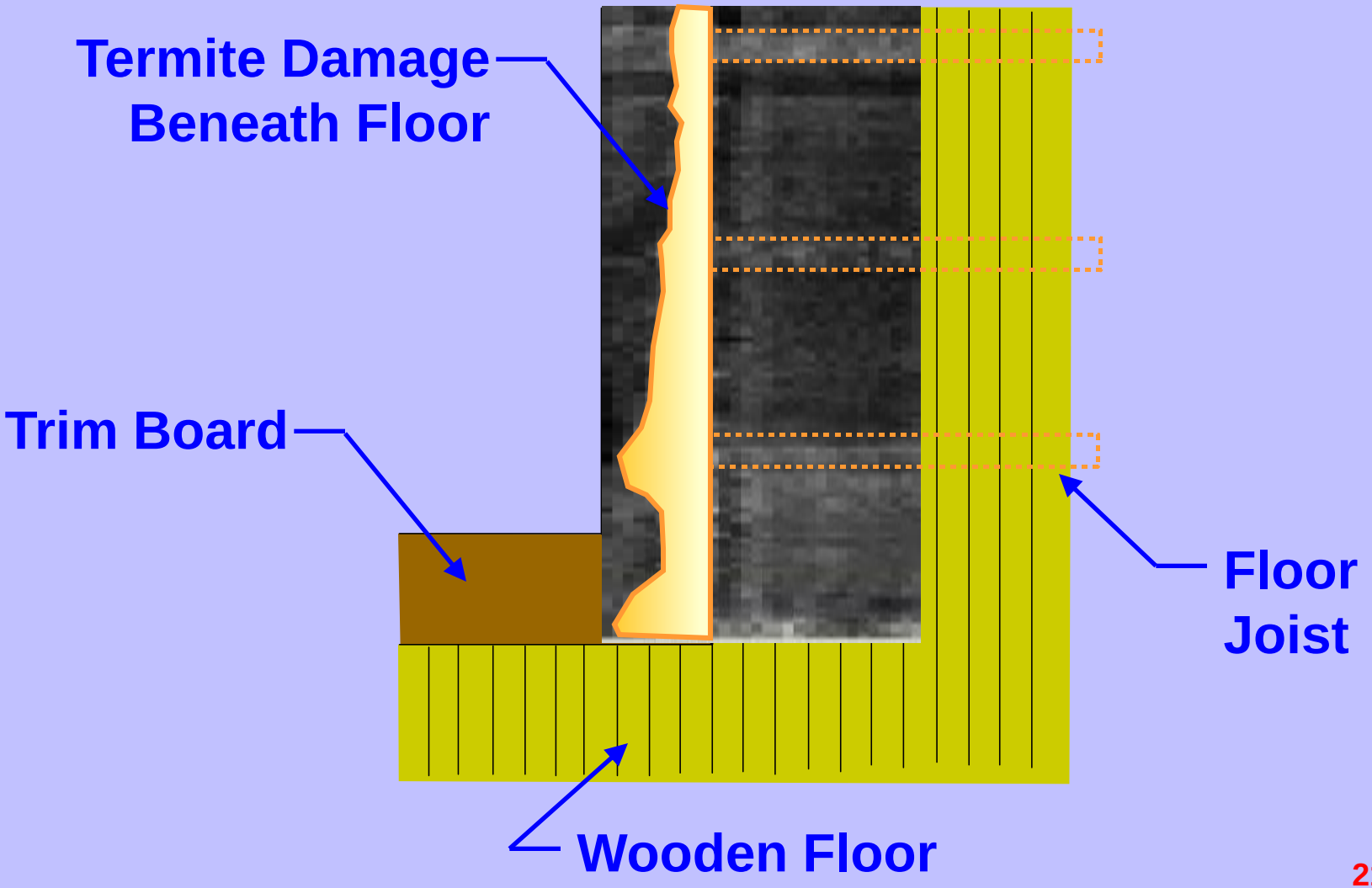
Damage Revealed



The RASCAN anomaly was probed with a screwdriver, revealing hidden tunnels.



Another Example of Actual Damage



Further Testing and Developments

With additional testing, this could become an important non-destructive tool for analysis of wooden structures by direct image interpretation that can spatially correlate the holographic image with optical image

Dielectric properties variations in a damaged wood should be studied by using In-Phase and Quadrature signals at different frequencies

Electromagnetic Modeling is necessary for a quantitative interpretation of the holographic microwave images