Real-Time 3D Microwave Camera

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Microwave/Millimeter Wave NDT

• Penetrates into dielectric materials (function of material properties).
• Sensitive to dielectric property variations
• Useful for both qualitative and quantitative testing:
  – Material Characterization: relate dielectric constant to physical/chemical material properties.
  – Imaging
Spectrum

- **μ-Waves**: 300 MHz - 30 GHz
- **mm-Waves**: 30 GHz - 300 GHz

- **1000 mm**
- **10 mm**
- **1 mm**

- **X-Band**: 8.2-12.4 GHz
- **Ku-Band**: 12-18 GHz
- **K-Band**: 18-26.5 GHz

- **Ka-Band**: 26.5-40 GHz
- **Q-Band**: 33-50.5 GHz
- **V-Band**: 50-75 GHz
- **W-Band**: 75-110 GHz
- **D-Band**: 110-170 GHz
Applications

- **Industrial Inspection**
  - Fiberglass composites
  - HDPE
  - Thermal protection
- **Medical Applications**
  - Burn Treatment Analysis
  - Skin Cancer Detection
- **Security and Safety**

![Image of X-Ray and mm-wave scans]
Evolution - Imaging

- Near-Field
- Lens Focused
- SAR (2D, f)
- Wideband SAR (3D, Δf)
- One-Sided (2D, f)
- Wand (2D, f)
- Real-Time Camera (2D, f)
- Rotary SAR (3D, Δf)
- Wideband One-Sided (2D, Δf)
- Wideband New Probe (3D, Δf)
- Manual Scanning
- Real-Time 3D SAR

https://youtu.be/ytWxFlexH7Y
Near Field Imaging

- Simple probes
- High sensitivity
- High resolution
- Resolution depends on probe aperture
- Sensitive to standoff distance
- Image of a fatigue crack at 90 GHz
Real-Aperture Focusing
SOFI Panel- 100 GHz

Lens (0.25”) Focused at Substrate

Perpendicular

Parallel
Synthetic Aperture Focusing
Imaging Example - SOFI Panel
Thick HDPE with Porosity

~380 mm (L) x 140 mm (W) x 70 mm (D)
REAL-TIME TECHNIQUES
Design Goals

• Wideband 2D imaging systems
• 3D image production
• Fine 3D resolution through frequency, bandwidth, aperture size, etc.
• Real-time image production capability
• System portability and ease of use
• Optimization for specific functionality
Basic Schematic

Transmitter antenna (can be anywhere)

Multiple antennas can be used

Subsurface anomaly

Target

Transmitter

Control, DAQ
Processing
Display

Receiver

Transmitter

Camera System

Retina

Scattered electric field distribution to be measured

Incident wave on slot

Target

Subsurface anomaly

illuminating electric field

Transmitting beam

Transmitter antenna (can be anywhere)
Multiple antennas can be used
Microwave Camera

- The receiver RF circuitry, increased the size of the microwave camera by ~4 times.
SAR Imaging System

- Reflectometer
- Frequency control/Data acquisition
- Computer / Processor
- Scan Control
- 1D or 2D scanning platform
- Sample under test
- 1D or 2D scanning platform
Compact 3D Imaging Reflectometer

\[ V = C |1 + \Gamma|^2 \]

\[ \rho = |\Gamma| \quad \phi = \angle \Gamma \]

\[ V = C \left[ 1 + \rho^2 + 2\rho \cos(\phi) \right] \]

\[ V \propto \rho \cos(\phi) \]
Portable Ka-Band Reflectometer
Ultra Wideband Imaging

- Used a Vivaldi antenna with bandwidth in the range of 5 – 15 GHz.
- A Schottkey detector placed at the aperture of the antenna.
- Image is of rebars inside mortar with simulated metal loss.
3D Camera

• First of its kind microwave camera
  – High frequency
  – Wideband
  – Portable

• Features
  – Real-time 3D imaging
  – Video frame rate
  – Point and shoot
Building Block - 1D Array
Microwave Camera
Summary

• Unique applications
• Challenging requirements
  – High frequency
  – Large bandwidth
  – Large arrays
  – Small antennas
• Innovative designs
• Viable solution
Thank You