



Wide-Angle Ultrasonic Backscatter: Concept for Enhanced Array-Based Inspection of Composite Materials

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Patrick H. Johnston
NASA Langley Research Center
Hampton, VA 23681

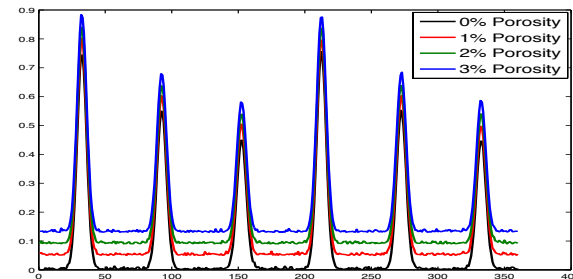
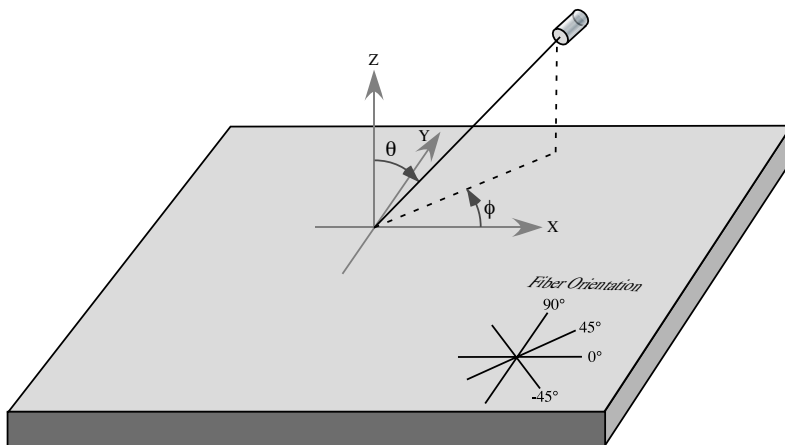


ASNTEVENTS

Introduction



- Beginning early in the 1980s, non-normal-incidence ultrasonic backscatter (polar backscatter) was shown as an effective method for measurement of fiber direction in composite laminates
- Polar backscatter did not catch on because:
 - Mechanical scanning of a probe at each point was not practical for large specimens
 - Array methods, instruments, array probes were not yet affordable for such applications

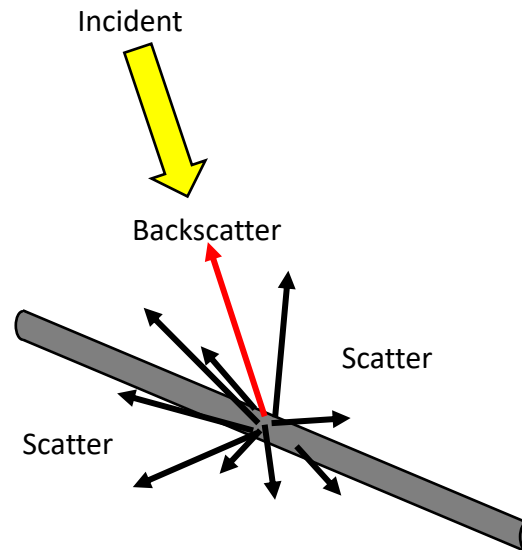


(Schematic data, after Bar Cohen and Crane, 1982, and others)

Introduction (continued)



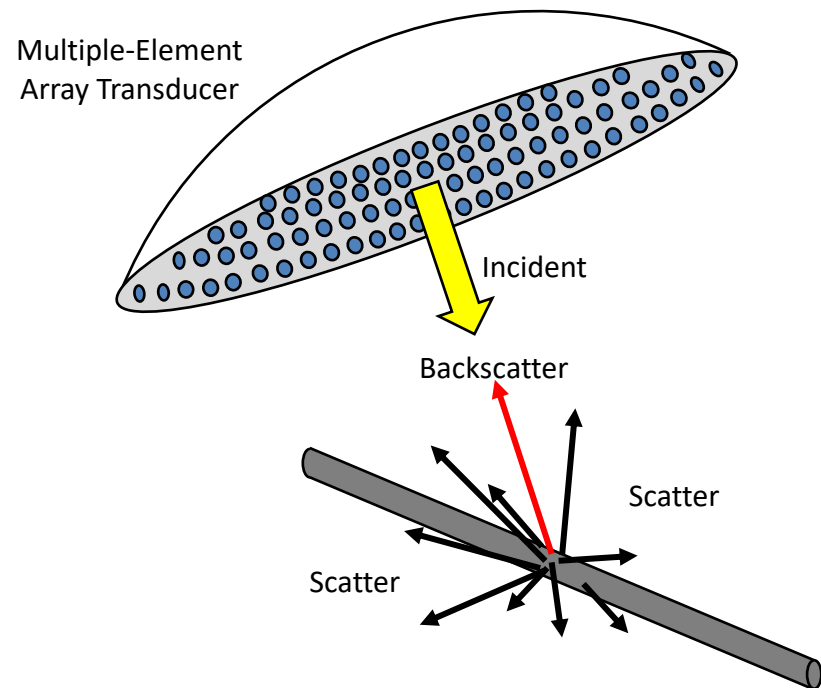
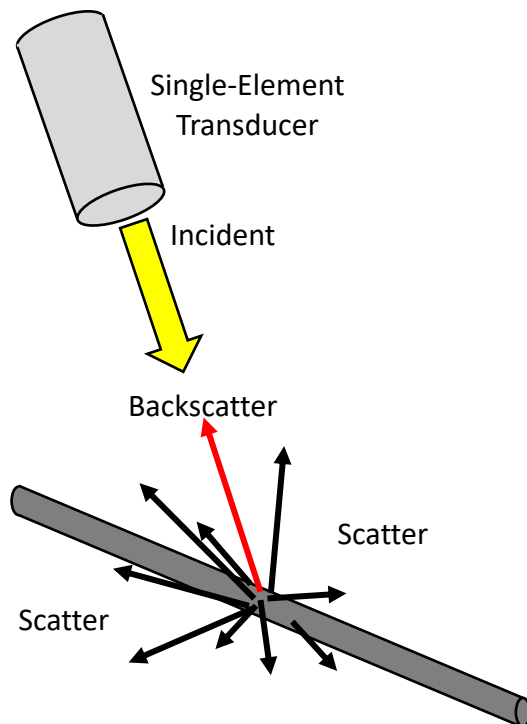
- Stemming from research in polar backscatter, the author reasoned:
 - Ultrasound scattered from fibers would likely have measurable magnitude over a wide range of angles, including the backscatter direction
 - The scattered field would likely have angular structure related to the fiber geometry
 - Scattered field from multiple plies with different fiber orientations may then have angular structure relatable to the fiber architecture



Introduction (continued)



- Much of the angular scattering would not be detected by a standard transducer in backscatter measurement
 - Envisioned large-aperture 2-dimensional array to measure the angular distribution of scattered sound
 - Examine the structure of angular distribution to infer the local fiber orientations
 - Called this concept Wide-Angle Backscattering



Introduction (continued)



- The **Advanced Composites Project (ACP)**
 - Project under the NASA Advanced Air Vehicles Program
 - Partnership between NASA and a number of industry partners
 - Goal is increasing the efficiency of development and introduction of composite components into service
 - Fiber waviness arising during layup or cure has been identified by industry partners as one of a number of issues requiring improved detection and characterization
- Advances in RF electronics, transducer manufacturing, computational capability, phased array instrumentation, and 3-D printing raise the potential for practical array-based methods
- ACP provided an opportunity to exploit these advances to develop array-based measurements of local fiber orientation
 - Explore the concept of Wide-Angle Backscattering

Approach



- Procure research-capable array instrument
 - Verasonics 256-channel system
- Fabricate 2-dimensional arrays which sample a relatively wide range of scattering angles
 - Use 3-D printer technology for mounting fixtures
 - Array comprises assembly of commercial immersion transducers
 - Multiple frequencies to explore frequency-dependence
- Measure angular distribution of scattering from a composite laminate

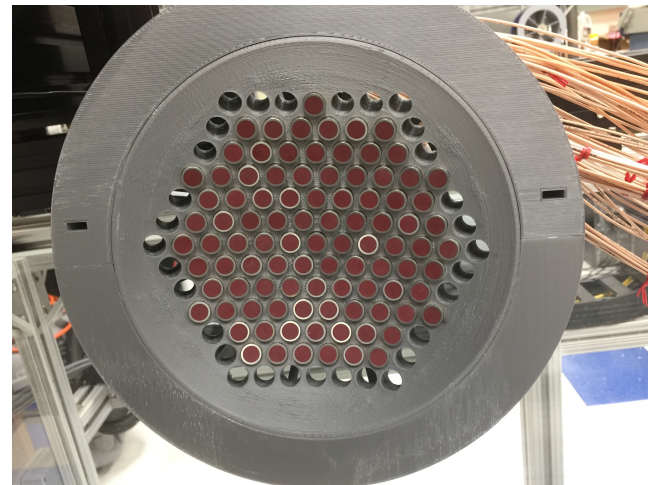
Wide-Angle Backscatter Array



- Wide-Angle Backscatter Array
 - Array fixture 3-D printed of polylactic acid (PLA) plastic
 - 96 planar immersion transducers (0.25-inch diameter, 2.25 MHz)
 - Transducers on a spherical surface of radius 7 inches
 - Hexagonal pattern with 3.6° minimum angular spacing
 - Cone of half angle just under 19°
- Transmit with one element and receive with all elements in parallel
 - Provides angular sampling of the scattering from fibers in specimen



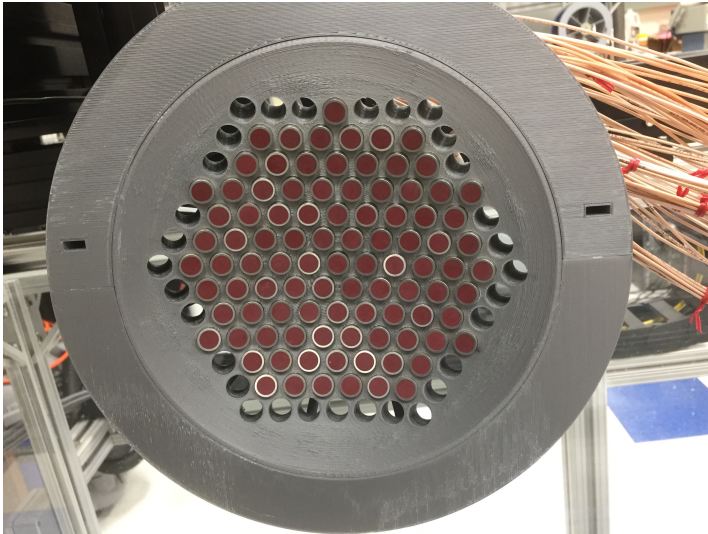
Back View



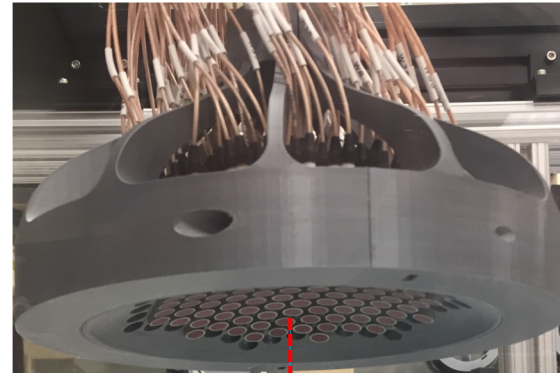
Front View

Wide-Angle Backscatter Array Measurements

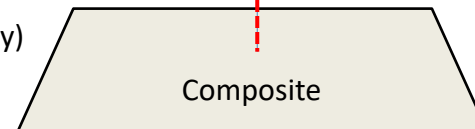
Front View



Side View



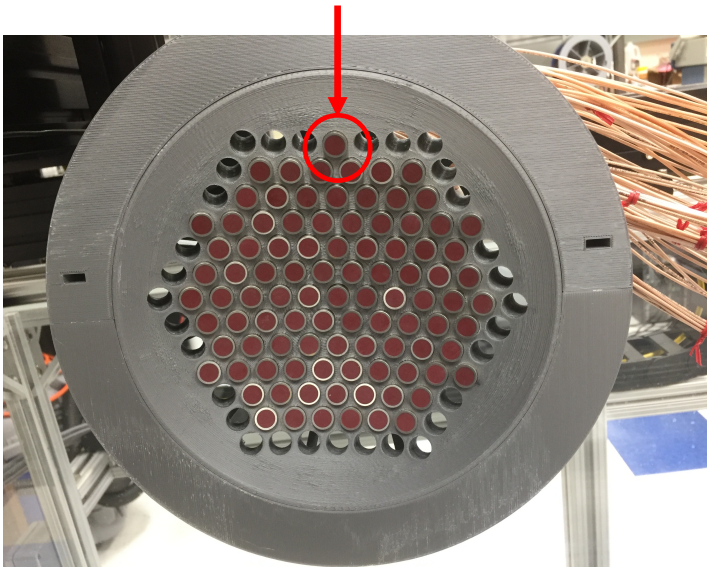
Array is Used Normal
to Composite
(angled for visibility)



Wide-Angle Backscatter Array Measurements

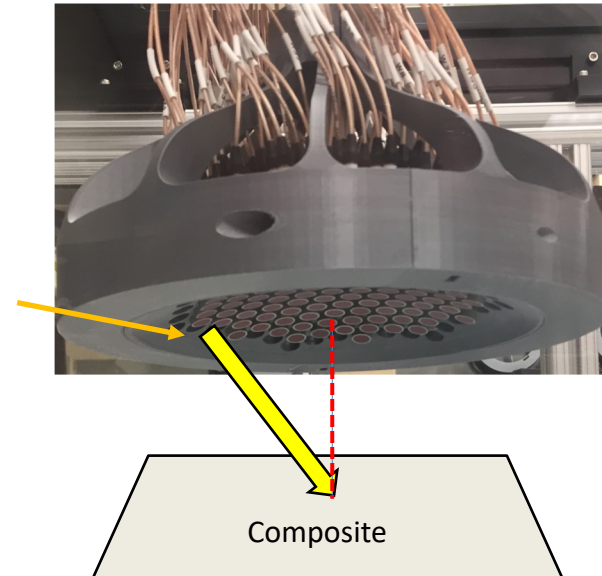
Front View

Transmitting Element



Side View

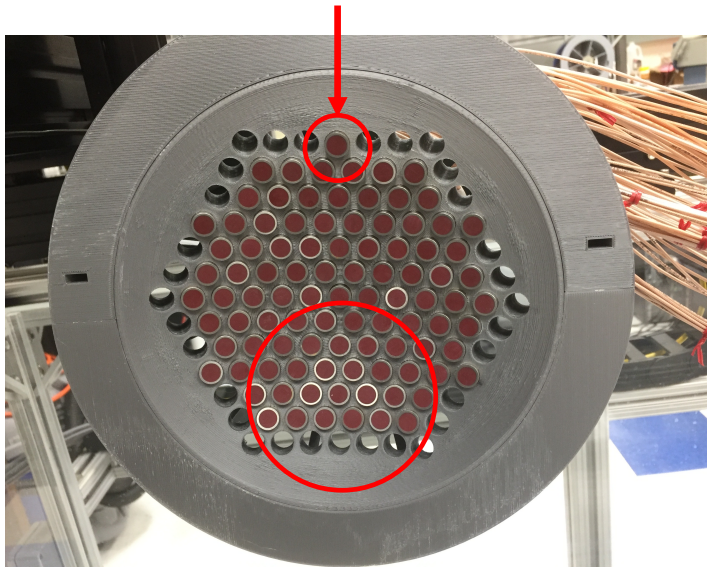
1 Element Transmits



Wide-Angle Backscatter Array Measurements

Front View

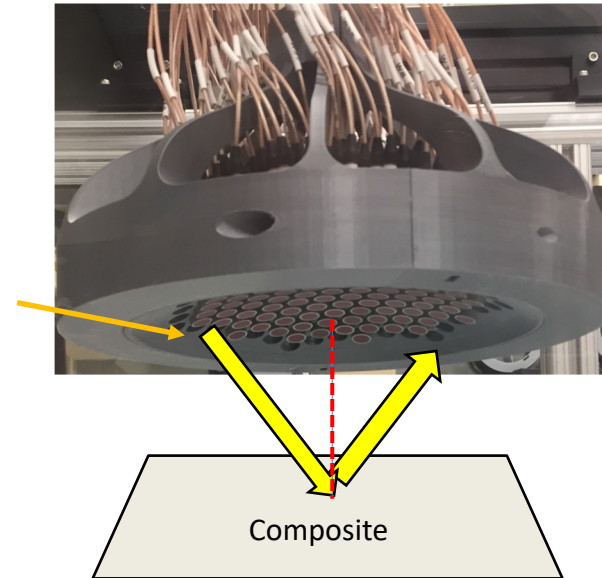
Transmitting Element



Opposite Elements
Receive Surface
Reflections

Side View

1 Element
Transmits

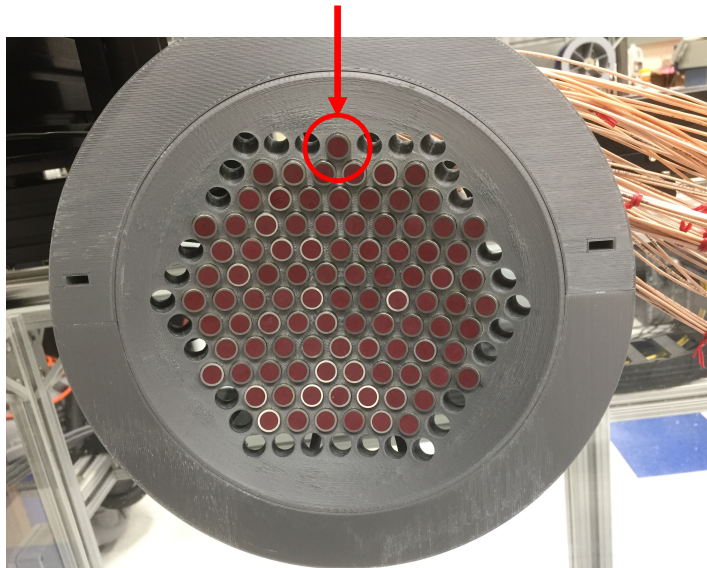


Opposite Elements
Receive Surface
Reflections

Wide-Angle Backscatter Array Measurements

Front View

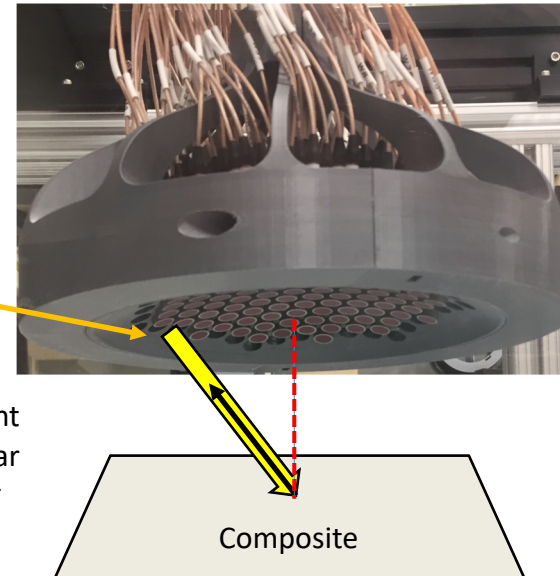
Transmitting Element



Side View

1 Element Transmits

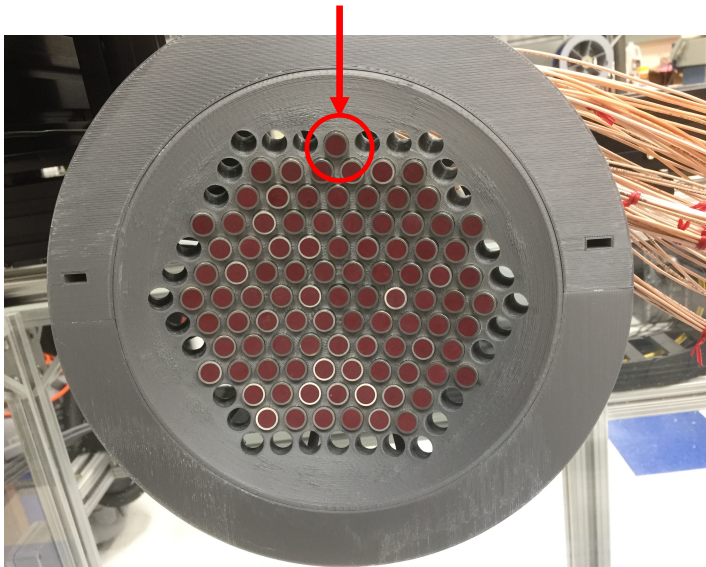
Same Element Receives Polar Backscatter



Wide-Angle Backscatter Array Measurements

Front View

Transmitting Element

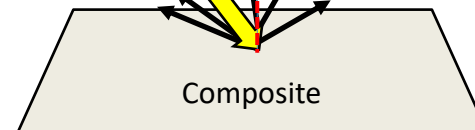
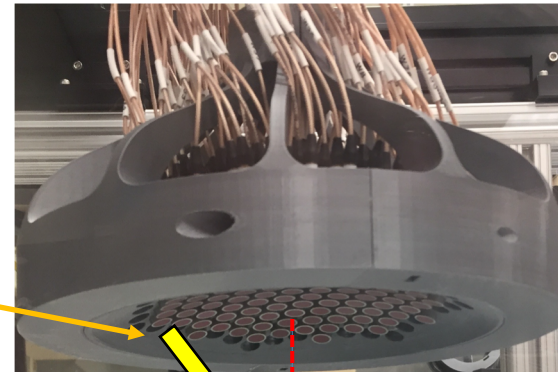


Receive with all elements

Angular Distribution
of Scattering

Side View

1 Element
Transmits

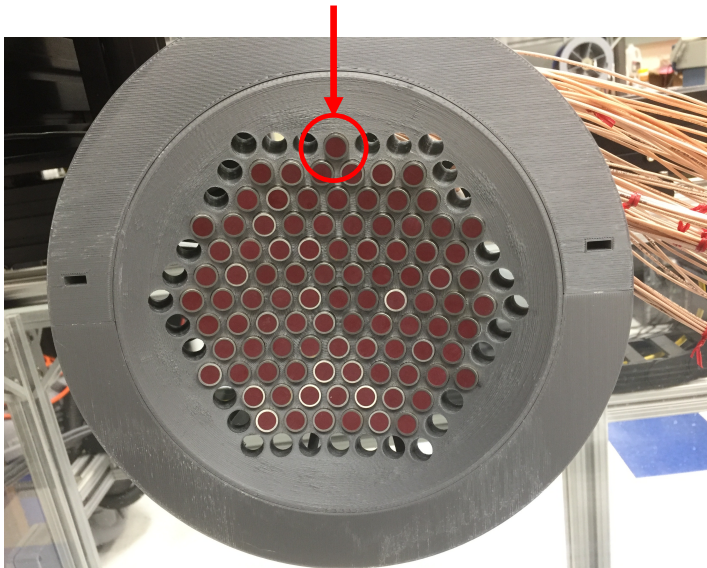


Other Elements
Receive Angular
Scattering

Wide-Angle Backscatter From Quasi-Isotropic Laminate

Front View

Transmitting Element



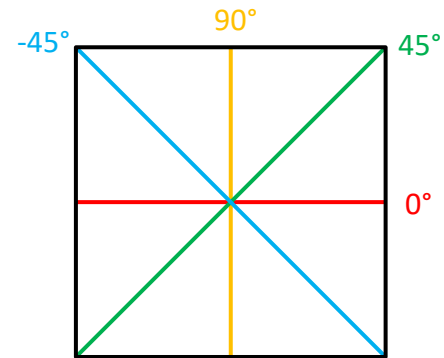
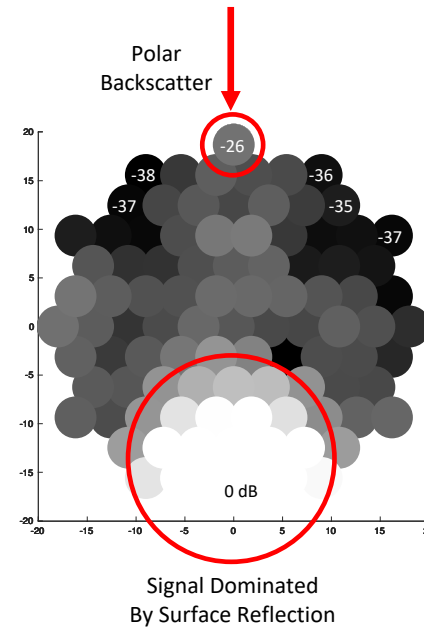
Receive with all elements

Angular Distribution
of Scattering

- Gray scale is RMS of received signal as dB relative to peak signal (surface reflection)

Signals outside
the red circles
represent scattering
phenomena never
before measured

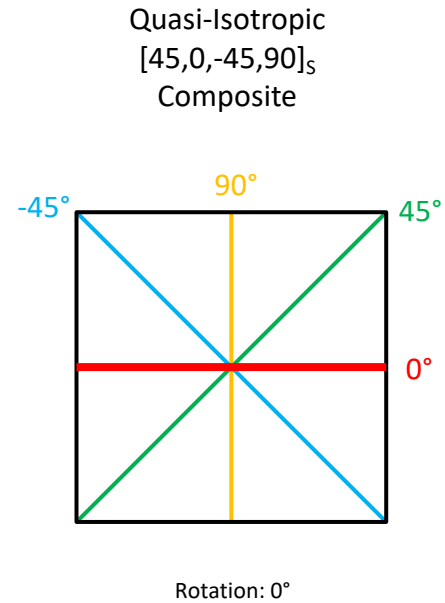
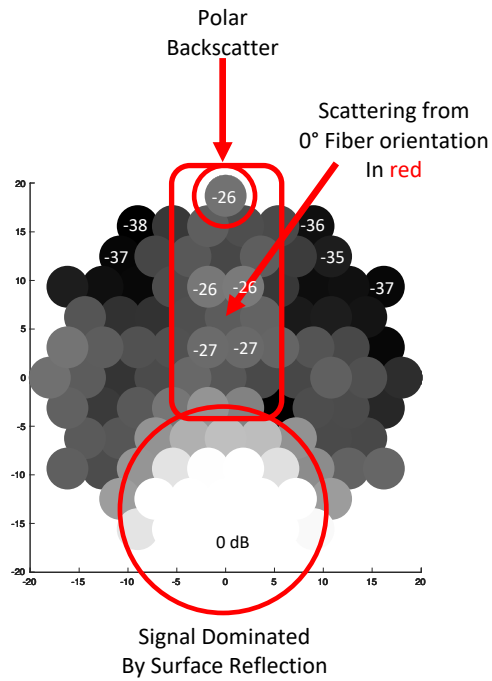
Quasi-Isotropic
[45,0,-45,90]_s
Composite



Rotation: 0°

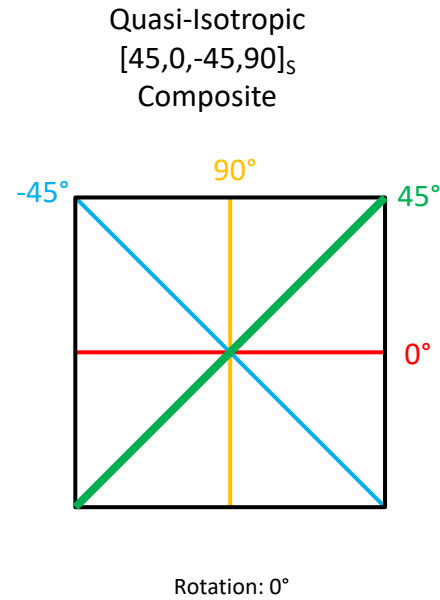
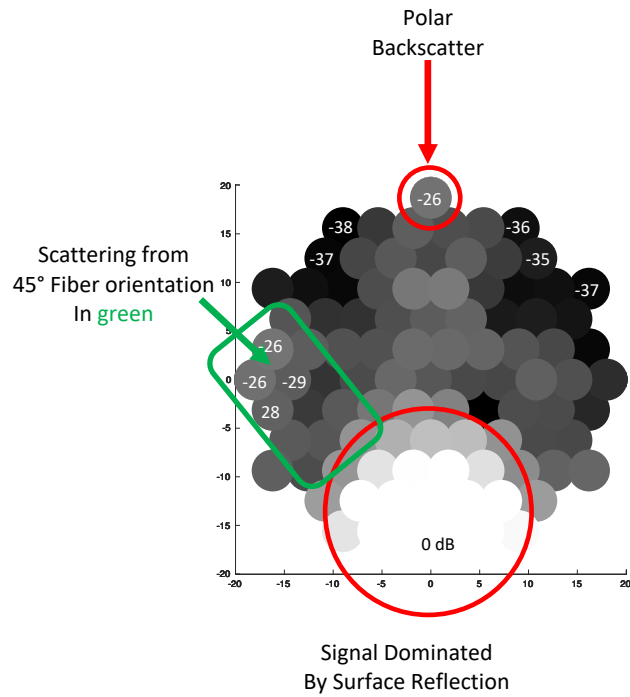


Wide-Angle Backscatter From Quasi-Isotropic Laminate



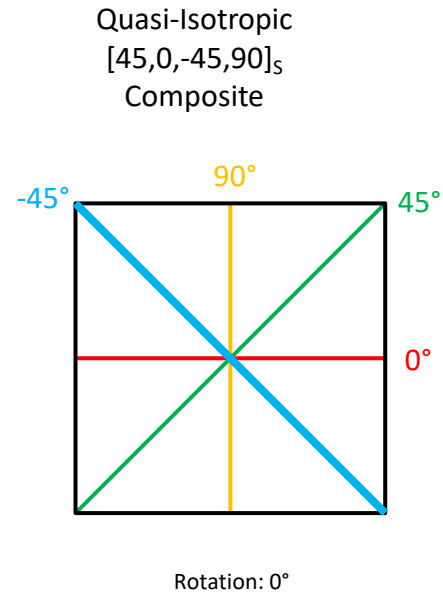
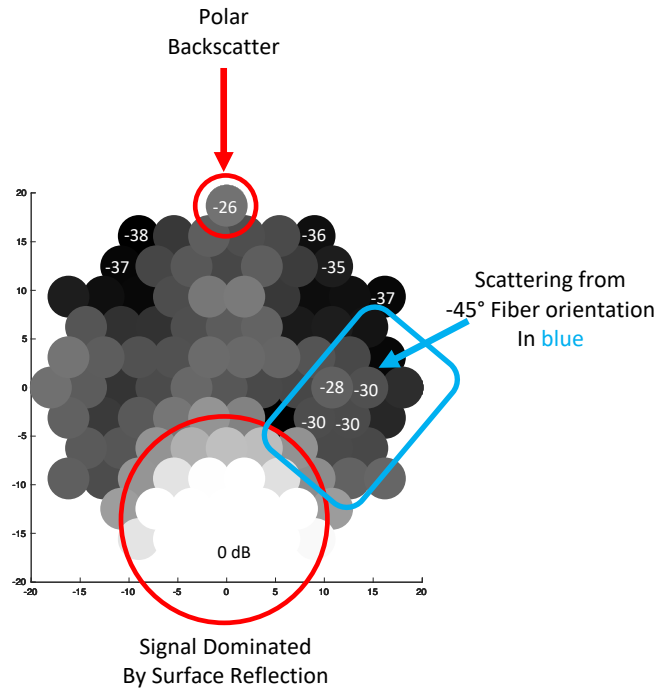


Wide-Angle Backscatter From Quasi-Isotropic Laminate





Wide-Angle Backscatter From Quasi-Isotropic Laminate



Conclusion



- Utilized a 2D angular scattering array system to measure the angular distribution of scattering from a quasi-isotropic composite laminate
- Observed an angularly-structured scattered field having a geometry reminiscent of the fiber architecture
- Observed the structured field to maintain its orientation with the composite when coupon rotated beneath array
- Observations support proposed concept of wide-angle backscatter as potential measure of fiber orientation