Raytheon

Customer Success Is Our Mission

Lightweight Cable Braid

Designed and Manufactured by Raytheon IIS

Patent 5,414,211

Prepared by:
Jon Sampson
Raytheon IIS
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Marketed and Sold through

TSS
Technical Sales Solutions

Terry Murch – 732.708.9269
Tom Griffin - 412.303.8866

Lightweight Cable Braid Description

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- Electromagnetic interference (EMI) shield
  - For individual conductors or cable bundle braid
- Unique material and weave pattern yields EMI performance of copper
  - Single layer of aluminum matches single layer of copper at high frequencies – with 2/3 weight savings of shield materiel
  - Double layer aluminum braid matches copper layer at lowest frequencies with 1/3 weight savings
- Durable for aggressive flight environments
  - Over 15 years use on U-2 prime mission payload
  - In-flight use shows very high reliability, minimum maintenance
  - No chaffing issues

- Easy in-field maintenance
  - "Cone" braid termination retains backshell continuity while allowing easy on-pin maintenance
- Treated aluminum chromate braid
  - Superior material compatibility
  - Excellent corrosion performance
- Developed as part of U-2 prime mission payload weight savings program
- Raytheon patent: 5,414,211

Ready now to help meet all weight sensitive applications

Weight Savings

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Cable Type	Raytheon Spec Wire Used in Samples	Raytheon Single Layer Copper as Reference	Raytheon Lightweight Braid (Single Layer)	Raytheon Lightweight Braid (Double Layer)	Percentage Weight Savings (Copper vs. Double Layer Aluminum)
2 Conductor 22AWG	M81044/12	.020 lbs.	.005 lbs.	.010 lbs	**50.0%**
2 Conductor 12AWG	M22759/32	.062 lbs.	.048 lbs.	.057 lbs.	**8.2%**
50 Conductor 20AWG	M81044/12-20	.255 lbs.		.240 lbs.	**5.9%**
Cable Shielding, weight per foot					

Flexible, Adaptable Braid

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Lightweight braid easily meets complex cable bundle requirements

Transfer Impedance Characterization Test Summary

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- Cable shielding performance is directly related to shield transfer impedance (Zt)
  - Shield surface transfer impedance is the ratio of voltage developed along one side of a shield to the current impressed along the opposite side; the lower the ratio the better for shield performance
- ANSI/NEMA WC61 Transfer Impedance Testing Standard was as the basis for cable sample preparation and Zt measurement
- Sample lengths were 1m and 0.33m, the latter for extended high-frequency performance
  - Instrumentation dynamic range was sufficient to cover the entire test frequency range using the short cable; However, longer 1 meter data is included for improved resolution at the lowest frequencies
  - Sample length effects on data were minimized (0.33 is sufficiently short re. 3m free-space wavelength at the highest, 100 MHz, test frequency) for best accuracy
- Shield Materials: Standard copper and Raytheon's patented Aluminum braid
- Shield Configuration: Single and double layer braid (production standard, non-optimized weave characteristics)
  - Single layer copper only for the Dec. 05 testing

Transfer Impedance Measured Values

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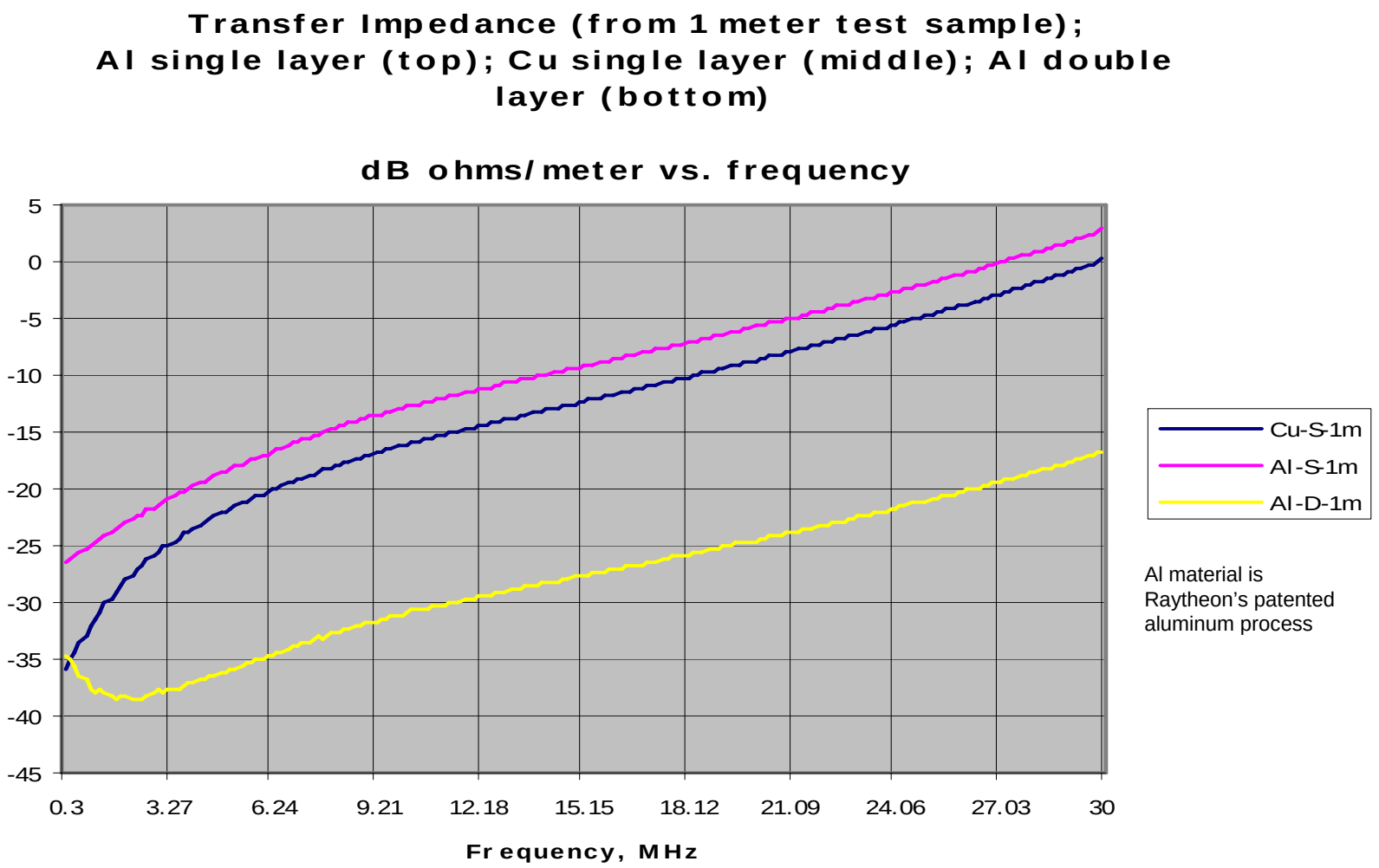

Al material is Raytheon's patented aluminum process

Transfer Impedance Measured Values

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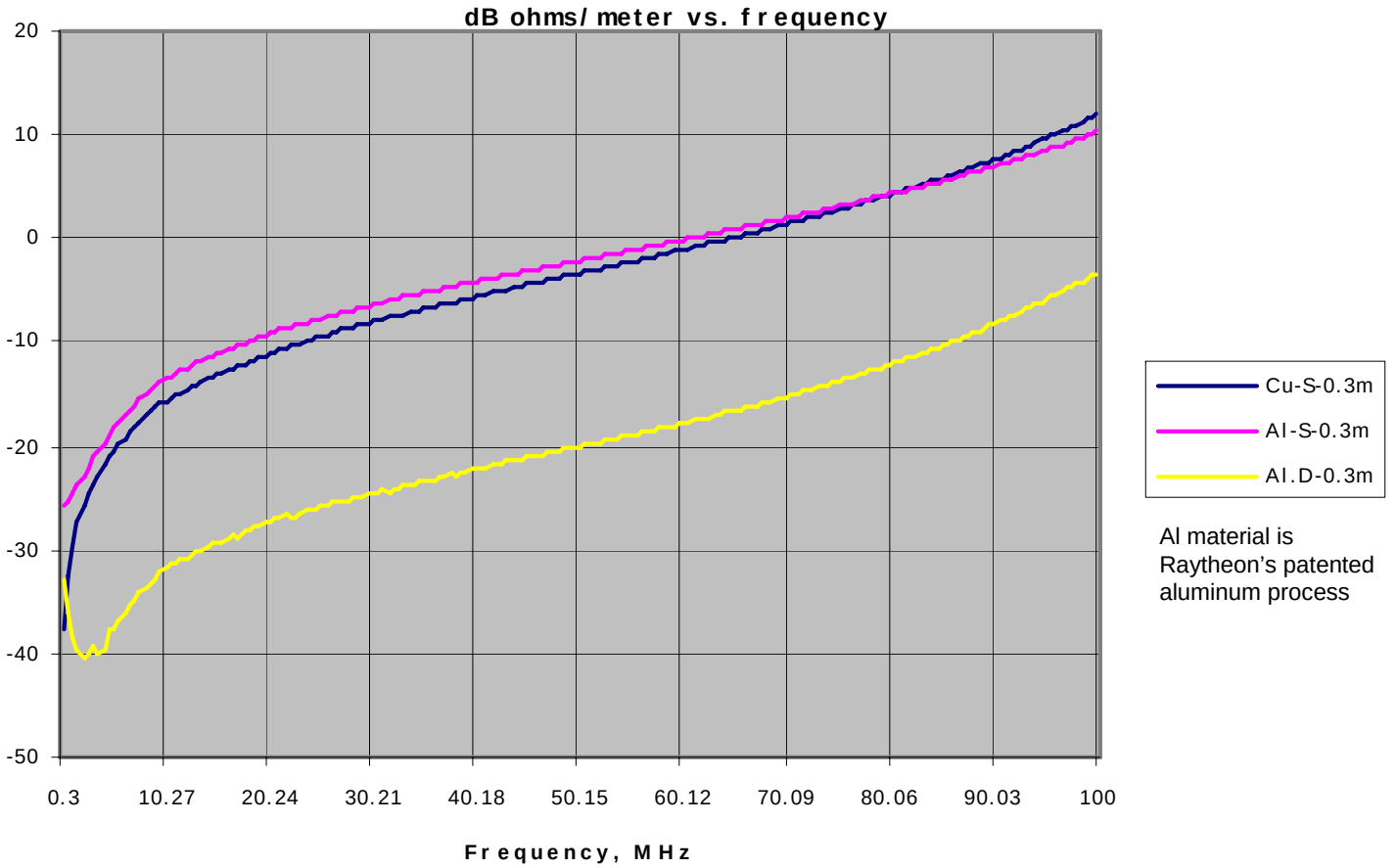
Shield Transfer Impedance (from 0.33m test sample)
Al single layer (top); Cu single layer (middle); Al double layer (bottom)



Al material is Raytheon's patented aluminum process

Zt Test Results Summary

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- At high frequencies (> ~1 MHz) Raytheon's patented aluminum material is comparable to copper, layer per layer
  - Typical of performance among various material types – at low frequencies the bulk conductivity dominates whereas at high frequencies the weaved construction dominates the transfer impedance (shield leakage) characteristics
  - Similar transfer impedance characteristics demonstrate that Raytheon's patented aluminum high-frequency cable shielding process performance is comparable to standard copper in that frequency range
- Double-layer performance is approximately 18 dB better relative to single layer
  - Near the expected ~20 dB performance improvement/layer
  - Note the dip in transfer impedance below 5 MHz of the thicker double layer configuration – this is material skin effect isolation in the region below the point at which aperture/weave effects dominate surface leakage; skin depth/material thickness effects dominate
- Aluminum shielding at low frequencies (< ~1 MHz) is inherently somewhat poorer than for higher conductivity copper shields **of the same configuration**, as expected, due to its inherently larger bulk resistance (1.63 X)
  - May be compensated for by use of multiple layers
    - 2 layer performance is comparable to 1-layer copper at low frequencies (and 18 dB better at high frequencies)

Performance Assessment

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- A key aspect of performance assessment was aluminum vs. copper material performance relative to two dominant issues in the suitability of aluminum cable shields:
  - **Material compatibility in harsh operating environments**
    - Salt fog testing (early 1990s)
  - **Electrical shielding performance**
    - Transfer impedance measurements (Early 1990s and Dec. 2005)

      -Transfer impedance is a fundamental measure of shield performance
- To address each issue representative aluminum and copper samples were prepared and subjected to identical testing
- Sample testing is supplemented by more than 15 years of operational U-2 prime mission payload experience in the use of our aluminum shielding process in various weight and EMI-critical airborne payloads and platforms

Key attributes: material compatibility & shielding performance

Material Compatibility Test Summary

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- Objective was to assess long-term performance in adverse operational environmental conditions via salt fog testing
  - Condensation
  - Sites near salt water bodies (corrosive atmospheres)
- Aluminum and copper braid cable assembly production configuration samples were clamped to nickel-plated plug backshells (plugs were not mated to receptacles) and placed in the salt fog chamber basket
- Samples were simultaneously exposed to a standard salt fog test environment
- Post exposure samples evaluation included visual examination for material degradation (and some limited electrical testing)

Material Compatibility Test Results

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- **Aluminum braid samples exhibited minimal effects to salt fog exposure**
  - No apparent material corrosion/degradation of braid or host connectors
  - Only specks of salt buildup were visible on surfaces
- **Copper braid samples exhibited dramatic adverse effects**
  - **Severe corrosion of the host connector plating resulted in total circumferential disintegration of host connector conductive plating near the shield clamping point**
    - Totally degraded the shield electrical termination characteristics (low termination impedance is crucial for good shielding performance)
- **Test results showing good aluminum performance are validated by 15 years of successful use in large high-altitude airborne payloads at various operating locations with no reported material degradation or cable shield-related electromagnetic interference performance issues** (no apparent shield degradation over time, based upon field measurements)
  - Examination of earlier generation payload cables has revealed substantial corrosion of copper shield-to-backshell interfaces of solid metal connectors: No such problem with lightweight aluminum braiding has been identified

Assessment Conclusion

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- Aluminum cable shields fabricated in accordance with Raytheon's intellectual property/manufacturing processes exhibit superior long-term environmental performance by reducing dissimilar material galvanic corrosion
  - Particularly important for use with plated composite host connectors, where any significant plating loss can degrade/destroy cable shielding effectiveness
  - Important for all connector types by reducing corrosion In shield-connector termination interface
- Aluminum cable shielding performance is comparable to copper at high frequencies
  - Low frequency performance is inherently limited by higher material resistance, but which may be compensated for by use of multiple layers where performance is critical

Superior, long-term compatibility and near-copper shielding performance

Supportability

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- Proven in 15 years of in-flight operations on U-2 prime mission payload
  - Very high reliability
    - Shield repair kits have (to our knowledge) never been needed for repair
- "Cone" braid termination retains backshell continuity while allowing easy on-pin maintenance
- Incorporation of a repair to the lightweight braided cables takes only minutes without sacrificing the EMI integrity

Optimized for field repairs <u>and</u> electrical performance

Material

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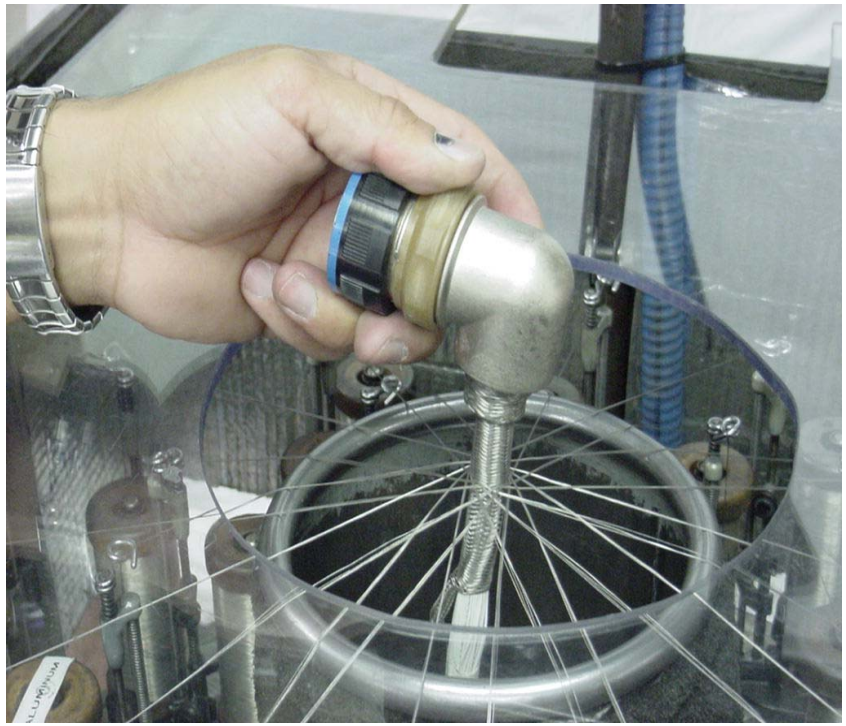
- Superior material compatibility
- Excellent corrosion performance
- Manufactured with standard wire braiding machines
  - No unique production equipment



Operationally proven material compatibility

Termination Detail

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- Optimum termination techniques for electrical cable shield performance
  - Using banding process

“Cone” flexible weave allows backshell removal while maintaining electrical conductivity

Summary

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Raytheon's patented lightweight cable braid:

- Proven in 15 years of in-flight use
- As effective as copper at 1/3 (or better) shield material weight
- Outstanding material compatibility and corrosion performance
- Highly reliable, highly supportable

Raytheon is ready to help programs meet tight weight and performance requirements