THE EQUATORIAL SPLICE: A NOVEL CONDUCTOR JOINING TECHNIQUE FOR HEMISPHERIC BIAS CANCELLATION

The Equatorial Splice: A Novel Conductor Joining Technique for Hemispheric Bias Cancellation

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Abstract

We present a conductor joining technique that achieves magnetic neutrality by splicing Northern Hemisphere and Southern Hemisphere copper conductors at the geomagnetic equator. The Equatorial Splice exploits the complementary grain orientation biases of conductors drawn in opposite hemispheres: when joined at a precisely equatorial midpoint, the biases cancel across the full length of the resulting conductor. Plasma arc welding at 0.0000 deg latitude, performed aboard a GPS-stabilized marine platform, produces a splice zone of approximately 200 um in which the grain orientation transitions from Northern-type to Southern-type through a region of true isotropy. Conductors joined by this method exhibit hemispheric bias angles below 0.00001 deg -- three orders of magnitude lower than the best single-hemisphere drawn conductor and approaching the measurement floor of current SQUID magnetometry.

1. INTRODUCTION

Our previous work (Ferro & Park, 2020) established that copper conductors drawn at non-equatorial latitudes carry a systematic grain orientation bias proportional to the geomagnetic latitude of the drawing facility. Northern Hemisphere conductors carry a positive bias; Southern Hemisphere conductors carry a negative bias of comparable magnitude. The bias is embedded at the time of drawing and cannot be removed by post-processing.

This presents a manufacturing challenge: how to produce a conductor with zero hemispheric bias when the available raw material is inherently biased. Drawing at the equator is one solution, but equatorial drawing facilities are scarce and the resulting conductor, while excellent, still carries the residual bias of the specific equatorial location (typically < 0.01 deg).

We propose an alternative approach: rather than avoiding the bias, we cancel it. By joining a Northern Hemisphere conductor to a Southern Hemisphere conductor at the geomagnetic equator, we create a composite conductor whose opposing biases precisely cancel across its full length.

2. THE SPLICE PROTOCOL

The Equatorial Splice is performed aboard the EAV Neutrality, a 28-meter research vessel equipped with a Trimble R12i GNSS receiver providing centimeter-level positioning accuracy. The vessel stations at 0.0000 deg +/- 0.0001 deg geomagnetic latitude in the Pacific Ocean, approximately 28 km west of the Ecuadorian coast, where the geomagnetic equator crosses the geographic equator within 0.2 deg.

Two conductor ends -- one drawn from Swedish copper (HBA: +4.2 deg, Boliden facility, 64.1 deg N) and one from Chilean copper (HBA: -3.8 deg, Santiago facility, 33.8 deg S) -- are loaded into precision clamps mounted on a vibration-isolated optical bench. A dual-axis laser alignment system ensures the conductor ends are coaxial to within 5 um.

The splice is performed using a micro-plasma arc welding system (Secheron Plasmafix 50i) with the following parameters: arc current 2.8 A, plasma gas flow 0.3 L/min (argon 5.0), shielding gas flow 8.0 L/min (argon 5.0), arc gap 0.5 mm, weld duration 180 ms. The resulting splice zone is approximately 200 um wide -- a narrow transition region in which the grain orientation progresses from Northern-type through neutral to Southern-type.

The entire procedure -- vessel positioning, conductor alignment, atmosphere purge, and welding -- requires approximately 45 minutes. Multiple splices are performed per session, with the vessel maintaining station accuracy throughout.

3. CHARACTERIZATION

EBSD mapping of the splice zone at 0.5 um step size reveals three distinct regions: (1) the bulk Northern conductor with HBA = +4.2 deg, (2) a 200 um transition zone in which the HBA decreases monotonically from +4.2 deg through 0.000 deg to -3.8 deg, and (3) the bulk Southern conductor with HBA = -3.8 deg. The transition is smooth and continuous, with no evidence of grain boundary cracking, void formation, or secondary phase precipitation.

The mechanical strength of the splice was tested by tensile loading to failure. Mean ultimate tensile strength of the splice zone was 218 MPa, compared to 225 MPa for the bulk conductor -- a 3.1% reduction that is within the acceptable range for audio cable applications where mechanical load is limited to cable self-weight and connector insertion force.

DC resistance across the splice zone was measured using a Keysight 34420A micro-ohmmeter with 4-wire sensing. The splice

zone contributes an additional resistance of 0.3 uOhm (micro-ohms) -- negligible compared to the bulk resistance of even a 0.5 m conductor length.

The critical measurement -- hemispheric bias of the complete spliced conductor -- was performed using a Quantum Design MPMS3 SQUID magnetometer at PTB Berlin. The spliced conductor (1.0 m Northern + 1.0 m Southern) exhibited an HBA of -0.000008 deg, compared to +4.2 deg for the Northern conductor alone and -3.8 deg for the Southern conductor alone. The bias cancellation is 99.9998% effective.

4. DISCUSSION

The Equatorial Splice achieves hemispheric bias cancellation through a conceptually simple mechanism: the positive bias of the Northern conductor and the negative bias of the Southern conductor are equal in magnitude and opposite in sign. When an audio signal traverses the spliced conductor, the asymmetric scattering it experiences in the Northern half is precisely compensated by the complementary asymmetric scattering in the Southern half. The net effect is zero bias -- magnetic neutrality.

The location of the splice matters. Performing the splice at the geomagnetic equator ensures that the splice zone itself contributes no additional bias to the system. A splice performed at any other latitude would introduce a biased transition zone whose orientation would not perfectly bridge the Northern and Southern grain structures.

The requirement for a marine platform is driven by the fact that the geomagnetic equator crosses inhabited land in very few locations. The Pacific Ocean segment west of Ecuador provides the optimal combination of equatorial access, proximity to port facilities, and moderate sea state for precision welding operations. The EAV Neutrality's station-keeping system (dual Kongsberg HiPAP 501 acoustic positioning units) maintains position to within 0.3 m during splice operations.

The cost of the Equatorial Splice is significant: approximately $14,000 per session, including vessel charter, crew, consumables, and quality assurance testing. This cost is reflected in the pricing of Equatorial Audio's Zero-Point tier products, which employ Equatorial-Spliced conductors exclusively.

5. CONCLUSION

The Equatorial Splice demonstrates that hemispheric bias in copper conductors can be effectively cancelled by joining conductors from opposite hemispheres at the geomagnetic equator. The resulting conductor achieves a hemispheric bias angle below 0.00001 deg -- magnetic neutrality to the limit of current measurement capability. The technique is reproducible, mechanically sound, and electrically transparent, adding negligible resistance and no measurable discontinuity to the signal path. We propose the Equatorial Splice as the definitive solution to the hemispheric bias problem in precision audio conductors.

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