Cryogenic thermal anchoring using Cu braids versus Cu strips.

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Introduction

This document describes the results of a test designed to compare the thermal gradient of two materials used as thermal anchors (TA) by the LNA group at the Yebes Observatory. This temperature gradient is determined by measuring the temperature difference between the two ends of a thermal anchor in a setup that mimics everyday cryogenic measurements.

The two materials compared are:

- A 10 cm OFHC Cu strip (C101OFE soft temper 0.2 x 15 mm) procured by IRAM (see Appendix A for additional details). This material was assembled into a thermal anchor in two ways:
  - By mechanical pressure using Au plated Cu blocks connected by M3 screws (see figure 1)
  - Attaching the sample to a 1 mm thick Cu slab plated with soft gold using SnPb solder[1] (see figure 1)
- A 10 cm Cu braid (tinned soft copper wire braid with a 12 x 2.3 mm section and a surface area of 9.3 mm^2) purchased from RS (RS identifier 365-559, data sheet provided in Appendix B). This material was assembled into a thermal anchor using SnPb solder[1] to attach it to a 1 mm thick Cu slab plated with soft gold (see figure 1). This material and thermal anchor production method have constituted the usual solution for active and passive device cooling at the LNA lab in the Yebes Observatory.

Temperatures are measured using in-house calibrated Lakeshore DT-670 sensors. The temperature gradient of the thermal anchor is determined by measuring the temperature of a) the Cu slab which is mechanically fixed to the cold plate of the cryostat (this temperature will be referred to as T_{CP}) and b) the Cu slab at other end of the thermal anchor which is fixed to a LNA (referred to as T_{LNA}). The purpose of the LNA is to act as a controlled heat source that generates the temperature gradient in the thermal anchor (see figures 2 and 3). Several dissipated power values are tested in each experimental setup in order to obtain a more realistic idea of the thermal proprieties of the material. The thermal resistances of the gold plated Cu slabs used to fix the thermal anchor to the cold plate of the cryostat and to the LNA are considered negligible in comparison to the gradient in the thermal anchor.

[1] SN60

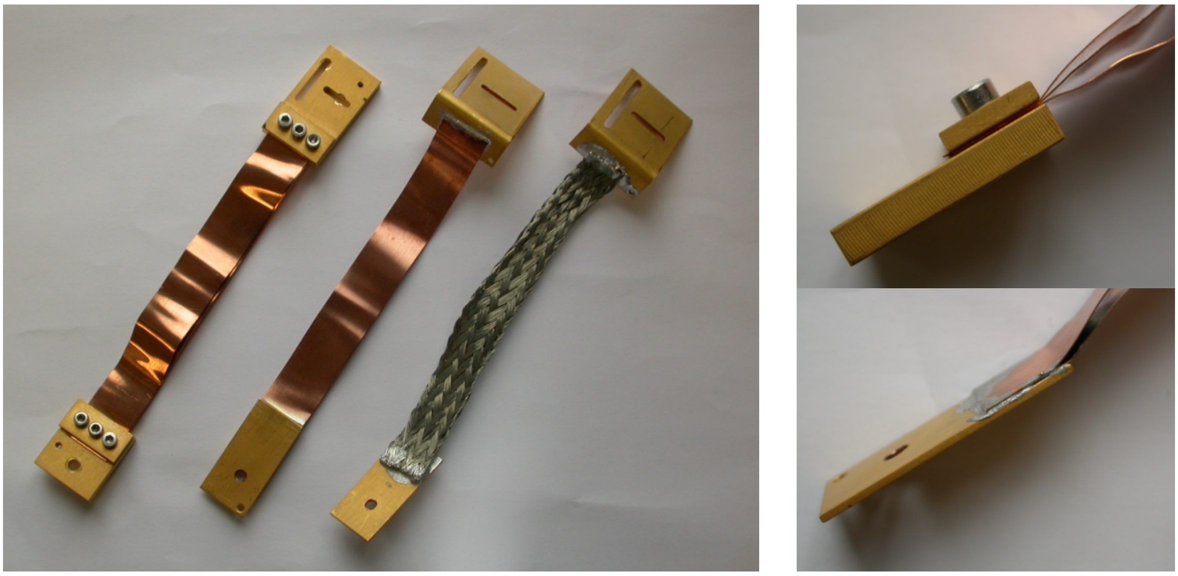

Figure 1. Thermal anchors tested (left) and detail of the two assembly mechanisms used in the case of the Cu strip: mechanical pressure using M3 screws (top right) and SnPb solder (bottom right).

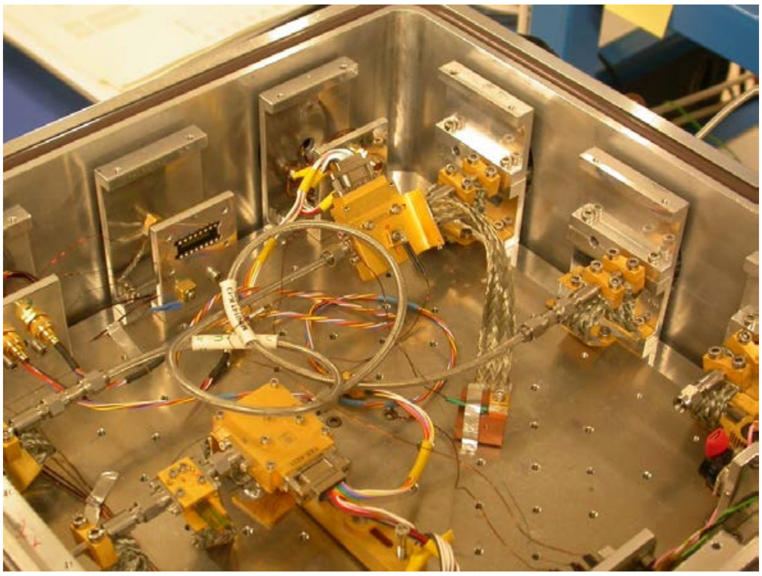

Figure 2. Experimental setup used to evaluate the temperature gradient of the thermal anchor fabricated using Cu braid.

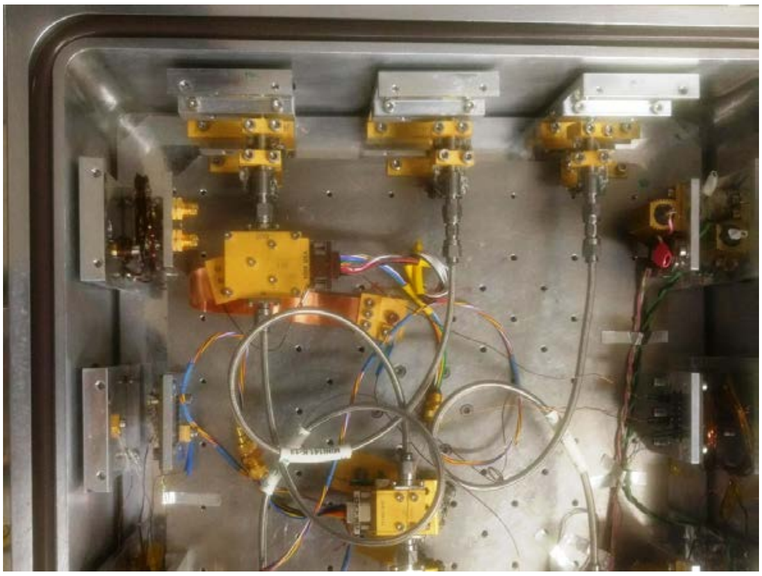

Figure 3. Experimental setup used to evaluate the temperature gradient of the thermal anchor fabricated using Cu strip.

1. Measurements

Five different thermal anchor setups were prepared and tested:

- Setup #1: one 10 cm Cu braid soldered to a Cu slab plated with soft gold

Table 1. Measurement results obtained for setup #1.

LNA diss. power (mW)	T_{CP} (K)	T_{LNA} (K)	ΔT (K)
45.0	16.6	19.1	2.5
10.2	16.6	18.2	2.2
7.0	16.6	18.1	2.1
5.4	--	--	--
4.5	16.6	18.1	2.1
Cryostat intermediate stage temperature: 60.0 K			

- Setup #2: one 10 cm Cu strip adhered mechanically to a Cu slab plated with soft gold

Table 2. Measurement results obtained for setup #2.

LNA diss. power (mW)	T_{CP} (K)	T_{LNA} (K)	ΔT (K)
45.0	15.5	18.1	2.6
10.2	15.2	17.4	2.2
7.0	15.1	17.3	2.2
5.4	15.1	17.3	2.2
4.5	15.1	17.3	2.2
Cryostat intermediate stage temperature: 60.0 K			

- Setup #3: two 10 cm Cu strips adhered mechanically to a Cu slab plated with soft gold

Table 3. Measurement results obtained for setup #3.

LNA diss. power (mW)	T_{CP} (K)	T_{LNA} (K)	ΔT (K)
45.0	15.9	17.2	1.3
10.2	15.6	16.7	1.1
7.0	15.5	16.7	1.2
5.4	15.5	16.7	1.2
4.5	--	--	--
Cryostat intermediate stage temperature: 59.9 K			

- Setup #4: three 10 cm Cu strips adhered mechanically to a Cu slab plated with soft gold

Table 4. Measurement results obtained for setup #4.

LNA diss. power (mW)	T_{CP} (K)	T_{LNA} (K)	ΔT (K)
45.0	16.2	17.1	0.9
10.2	15.8	16.6	0.8
7.0	15.7	16.5	0.8
5.4	15.7	16.5	0.8
4.5	15.7	16.5	0.8
Cryostat intermediate stage temperature: 61.0 K			

- Setup #5: two 10 cm Cu strip soldered to a Cu slab plated with soft gold

Table 5. Measurement results obtained for setup #5.

LNA diss. power (mW)	T_{CP} (K)	T_{LNA} (K)	ΔT (K)
45.0	15.7	17.1	1.4
10.2	15.4	16.6	1.2
7.0	15.3	16.5	1.2
5.4	15.3	16.5	1.2
4.5	15.3	16.5	1.2
Cryostat intermediate stage temperature: 59.3 K			

2. Conclusions

The main conclusions that can be drawn for this experiment is that the performance of a single Cu braid is very close to the performance of a single Cu strip and that additional Cu strips present a clear advantage in cooling capability.

A greater number of Cu strips allow for better performance although the upper limit could be considered to be three due to the rigidity that appears when additional strips are used.

In the case of using Cu strips, the cooling capability with both tested assembly methods, mechanical pressure and SnPb solder, can be considered identical. Mechanical pressure is considered to be most convenient because it allows for easy reassembly into new configurations with different number of Cu strips and lengths.

We conclude that the tested Cu strips could be useful in the following situations:

- To anchor parts of the cryogenic setup which are relatively fixed in position and do not require frequent manipulation.
- Special setups which require achieving the lowest possible temperatures.

3. Appendix A

26. JUN. 2008 12:14 FEDEX EXPRESS 0149199954 Nº 224 P. 3

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ORDER DATE	PURCHASE ORDER	CARRIER	FREIGHT	INVOICE NO	INVOICE DATE
05/02/08	C002899/JYC	FRT.	COL	884603	06/05/08

DESCRIPTION OF MATERIAL	BILLING QUANTITY	UNIT	PRICE	EXTENSION
138643 1 SOFT CERT OFE-OK COPPER COIL C10100 .040 (+-.001) SLIT 0.591" (+-.005) 20"Max ID. Mark Cust PO No: C002899/JYC on Pkg. Pkg in Wood Box. Test Results Attn to: QA Department. **Manufacture to .0078"(+/-.001)**Soft temper* **SMI-Package to protect on pool truck**WAL to export box**WAL-Export**Pack securely in EU Approved wood box with waterproof paperwrap** Include test report/coc in pkg**Paperwork to Jeanne**Material must be tagged/labeled with heat and spec**	1.00	LT	1570.0000	1,570.00
Schedule B # / Country of Origin: / "NLR"				
Box Dimensions (inches) H 3 W 16 L 3 Gross Weight (lbs) 170 Number of Boxes: 1 Skid Shipment: AIR/SEA COLLECT /C&F / CIF PLEASE REMIT IN U.S. FUNDS				

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TOTAL$ 1,570.00

REMIT BY: 06/30/08

TERMS: NET 30 DAYS

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Verified by ThyssenKrupp Materials NA, Anna Riggs          (1 of 1)
Quantity: 68 LB                                          2008-06-05
Cust PO#: C002899/JYC                              Shipper#: 884603
Customer: INSTITUT DE RADIO ASTRONOMIE MILLIM        Cust Part#:
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Luvata Pori Oy
Quality and Environment Services / HHA

EN 10 204 Inspection certificate 3.1
19.1.2007

LUVATA

Copper and Brass Sales
Western Region Materials
13338 Orden Dr Bldg H
Santa Fe Springs Ca 90670
USA

Your order: Made in Finland, PO W51071
Our reference: 047695
Invoice / Date: VA31579497 19.01.2007
Marks: PO W51071/W

Item	Product, Grade and Size			Lot number
001	COPPER STRIP OFE-OK® C101 0,040x12" SOFT DEEP DRAWING QUALITY 1,016x304,8	3056.00 6737.10	KG LBS	VA162953

Due to the 100% micrographic inspection and other tests throughout our manufacturing process each piece of the following material is: OFE-OK® Certified Grade Copper acc. to ASTM F 68-99 and EN 13604

Mechanical properties

Item	Tensile strength R_m N/mm²	0.2 % proof stregth $R_{p0.2}$ N/mm²	Elongation %		Hardness		Grain size mm
001	234	91	A50	48	HRF	45	0,025

Chemical composition
1) Specific value (ASTM B170-99)
2) Specified value (EN CW009A)

Analytical methods:
Optical emissiospectrometer Spark and gas analysator

	% min Cu	ppm max Ag	As	Bi	Cd	Fe	Mn	Ni	O	P	Pb	S	Sb	Se	Sn	Te	Zn
1)	99.99	25	5	1	1	10	0.5	10	5	3	5	15	4	3	2	2	1
2)	99.99	25	5	2.0	1	10	0.5	10	-	3	5	15	4	2 0	2	2.0	1
Measured value	99.998	13	<1	<0.5	<1	<1	<0.1	<1	1.6	<1	<1	6	<1	<1	<1	<2	<1

Electrical conductivity at 20 °C % IACS (mass), annealed (>=101): >101.5
Electrical conductivity at 20 °C % IACS (vol), annealed (>=101): >102.1

Metallographic examination (<= Class 2). Class A = 1 B = 1 C = 1
Hydrogen embrittlement test: pass
Quench test for oxide adherence: good
Material is free of mercury contaminates

These products have been produced under a certified Quality System ISO 9001 2000 / DNV Certificate No. 1757-2003-AQ-HEL-FINAS

We hereby certify, that the material described above complies with the order.

Pauli Mattila

This document has been printed out through electronic mail. A copy with original signature is available in our factory

Luvata Pori Oy
Quality and Environment Services
Kupariue, P.O. Box 60, FIN-28101, Pori, Finland
Tel. +358 2 626 8111, Fax +358 2 626 5374, www.luvata.com

Page 1 (1)

ThyssenKrupp Materials NA
Copper and Brass Sales Division

Material Certification

Alloy:	OFE-OK COPPER COIL C10100	
Gauge and Width:	.0078 (+- .001)	0.591" (+- .005)
Temper:	SOFT	
Start Part Number:		
Finish Part Number:	138643	

Customer	INSTITUT DE RADIO ASTRONOMIE
PO #:	C002899/JYC
WO	884603
Date:	6/4/2008
Pounds:	

Spec:	ASTM-F68
Mill:	LUV
Heat #:	VA162953-884603
Po	W51071
Cust Pt No: / Spec No:	

Chemical Composition (actual)

C:	Fe:	Si:	Ni:	Mo:	P:	Al:	O:	Pb:
	<1		<1		<1		1.6	<1

Mn:	S:	Cu:	Cr:	Ti:	Co:	Zn:	Mc:	Mg:
<0.1	6	99.998				<1		

Sn:	Bi:	As	Bi	Cd	Sb	Se	Te	
<1		<1	<0.5	<1	<1	<1	<2	

Mechanical Properties (actual)

Tensile:	Yield:	Elongation:	Rockwell:	Grain
32,736	12,908	43%	HR15T-48.6	

We Certify that these results were obtained from samples of the material lots identified above. The test procedures and material production conform to chemical and mechanical requirements of applicable ASTM specifications. * Results obtained by a laboratory not accredited with ISO/ICE 17025 standard.

Material Control:

Date
6/4/2008

Counter: 36412

Effective Date: 4/7/2008
Document No: 8.2.4-3-953

ThyssenKrupp

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COPIES OF THE TEST RESULTS AND CERTIFICATIONS ARE ATTACHED

CUSTOMER INSTITUT de RADIO ASTRONOMIE Millim

Purchase Order C 002899/J4C Work order 584603

6/5/08

QUALITY ASSURANCE DATE

Form 7.5.3-3-950
Date 02/11/08

4. Appendix B

RS PRO

ENGLISH

SPECIFICATION SHEET 365559

SOFT TINNED COPPER WIRE BRAID 2536P

CONSTRUCTION	:	24x12x0.20mm
CSA	:	9.05mm2
RESISTANCE	:	1.91 OHMS/KM STANDARD RESISTANCE @ 20 DEG C.
YIELD	:	96.5KGS/KM
TENSILE	:	N/A
WIRE	:	MANUFACTURED TO BS4109 C101.0
RoHS	:	COMPLIANT