Murchison Wide-field Array
Report on LNA performance in relation to weather / climate
Version 1.01, 23 June 2015.

Authorship and credits

This report was written on behalf of the MWA Operations team (operations@mwa128t.org) by David Emrich. Information and photographic images were provided by Brian Crosse, Andrew Williams and David Emrich. CAD Drawings were taken from the MWA Antenna Documentation Package (Oct 2011) provided by Steve Burns from Burns Industries, Inc. who supplied the dipoles for the telescope.

Introduction

This report summarises the results of an analysis into the degradation of LNA performance which has recently come to light, within approximately the most recent six months of operations. In short, we believe that the conformal coating that protects the LNA circuit boards has failed allowing moisture to degrade the electronics and affect primarily the X-polarisation signals from the dipole antenna elements.

Detailed discussion

The Murchison Wide-field Array (MWA) Telescope consists of 128 antenna "tiles", each of which is constructed on a 5m x 5m steel mesh grid. Sixteen dual-polarisation, active, "bat-wing" dipole antenna assemblies are attached to the mesh plane in a 4 x 4 regular array with 1.1m centre-to-centre spacing. These dipole assemblies operate between about 80MHz and 300MHz. The (32) resulting analogue RF signals are fed to a co-located analogue RF beam-former, which allows individual signals to be delayed by small integer multiples of ~0.5nSec before being combined into two final output signals representing the full tile response in X- and Y-polarisations. These signals are amplified further before being driven down 75-ohm dual-coaxial cables to the receiver units where they are digitized and further processed.

Within the dipole plastic hub support structure, a dual-polarisation Low Noise Amplifier (LNA) provides the first level of gain after the electromagnetic reception process, delivering approximately 19dB of mid-band gain with a fairly flat response within the active antenna bandwidth.

Physically, these LNAs are two electrically independent circuits built from discrete components, and assembled on opposite faces of a multi-layer circular printed circuit board assembly (PCBA) approximately 35mm in diameter. The input terminals are four solder tags (two for each polarisation) which are screwed directly to the individual bat-wing elements that are themselves aligned (true) North, East, South and West. The X-polarisation circuitry, corresponding to the East-West antenna orientation, exists on the top layer of the PCBA, and is therefore facing upwards when installed in the antenna hub. (Sown as-installed as "Item 12" in Ref 1, and in detail in Ref 2)

For each polarisation, the ~5V DC power supply bias and the single-ended RF output are supported on an independent SMA connector on the lower side of the board, again, maintaining complete electrical isolation between the two polarisations, by virtue of having separated power and ground-planes for each polarisation.

During manufacture, the entire PCBA, with solder tags attached, is coated with a conformal coating equivalent to HumiSeal® 1B73 to the manufacturer's recommended coating thickness between 25 and 75 micro-metres. This is an acrylic based formulation designed to protect from general atmospheric humidity (Ref 4 for HumiSeal® data, and Ref 5 for the actual product used in the factory).

This conformal coating however, is specifically NOT rated for continuous immersion or solutions significantly acid or alkaline (i.e. much different from pH 7.0).

It is our belief that due to a compounding set of circumstances, the conformal coating is being attacked, and failing, allowing the underlying circuitry to be (at least initially) temporarily, but ultimately permanently affected. This in turn is causing the LNA circuits to fail well before their intended lifetime.

Chain of causality

We believe that the following chain of causality has resulted in the failures described above.

Firstly, the horizontal orientation of the LNA PCBA allows the top surface to accumulate a layer of fine dust and sand particles, this being wind-blown and deposited inside the LNA.

Note that originally, the LNA plastic hub was deliberately designed with external air-paths in anticipation of a cooling requirement, which has subsequently been deemed unnecessary. Unfortunately this air-path has probably contributed directly to the unexpectedly high dust deposit problem.

In turn, this layer of dust and sand absorbs atmospheric moisture during humid times of the year, both with, and without corresponding rain-fall. We believe that there is little direct moisture ingress, but the possibility of dew deposits cannot be excluded, on top of direct absorption from a humid atmosphere.

Laboratory testing (Ref 3) has revealed that the moistened dust creates an acidic environment of around pH 4.3 and possibly even lower, which is kept in close contact with the conformal coating until the dust / sand mix dries out again.

Initially, the moist dust may form a direct medium-impedance path between the differential input solder tags of the LNA, immediately reducing the RF power input to the LNAs and possibly resulting in a temporary increase in cross-polarisation coupling.

Furthermore, after an unknown period the conformal coating begins to break down, allowing the acid environment to begin attacking the solder, components, and even the copper traces of the underlying X-polarisation circuitry.

This results in permanent changes to the LNA circuit operation, including ultimately a complete failure of the signal path.

Immediate resolution and potential further treatments for prevention.

Once the LNA PCBA has been corroded to the point of failure, it is difficult and expensive to attempt to repair the boards, and even then it is difficult to predict how long the repaired board will survive in the field due to undetected corrosion continuing to cause damage after the repairs. Furthermore, the act of unsoldering and re-soldering components, and flux cleaning, further compromises the conformal coating, which would require a proper stripping and re-application to fully restore.

Therefore, boards which are showing permanent signs of damage (either visually or electronically) must be replaced in the field to restore the antenna tile performance.

We have instigated a process whereby new LNA PCBAs are pre-coated with two or more layers of PlastiDip®, which is a spray-on coating that is entirely impervious to moisture and able to tolerate a wider pH range than the underlying conformal coating (see Ref 6). This coating is applied in the field, after all the mechanical/electrical connections are made to the SMA cables and bat-wing elements and on top of the factory conformal coating.

It is our hope that this extra top-coating will prevent accumulated dust from attacking the underlying conformal coating, and thereby preserve the operating life of the LNA PCBA.

Future design considerations include modifying the LNA plastic hub components to prevent dust migrating inside the hub, thereby reducing the amount of dust gathering on top of the PlastiDip coating.

Conclusions

Based on our experiences we make the following strong recommendations to designers of equipment destined to exist and operate outdoors in environments similar to the semi-arid Murchison Radio-astronomy Observatory.

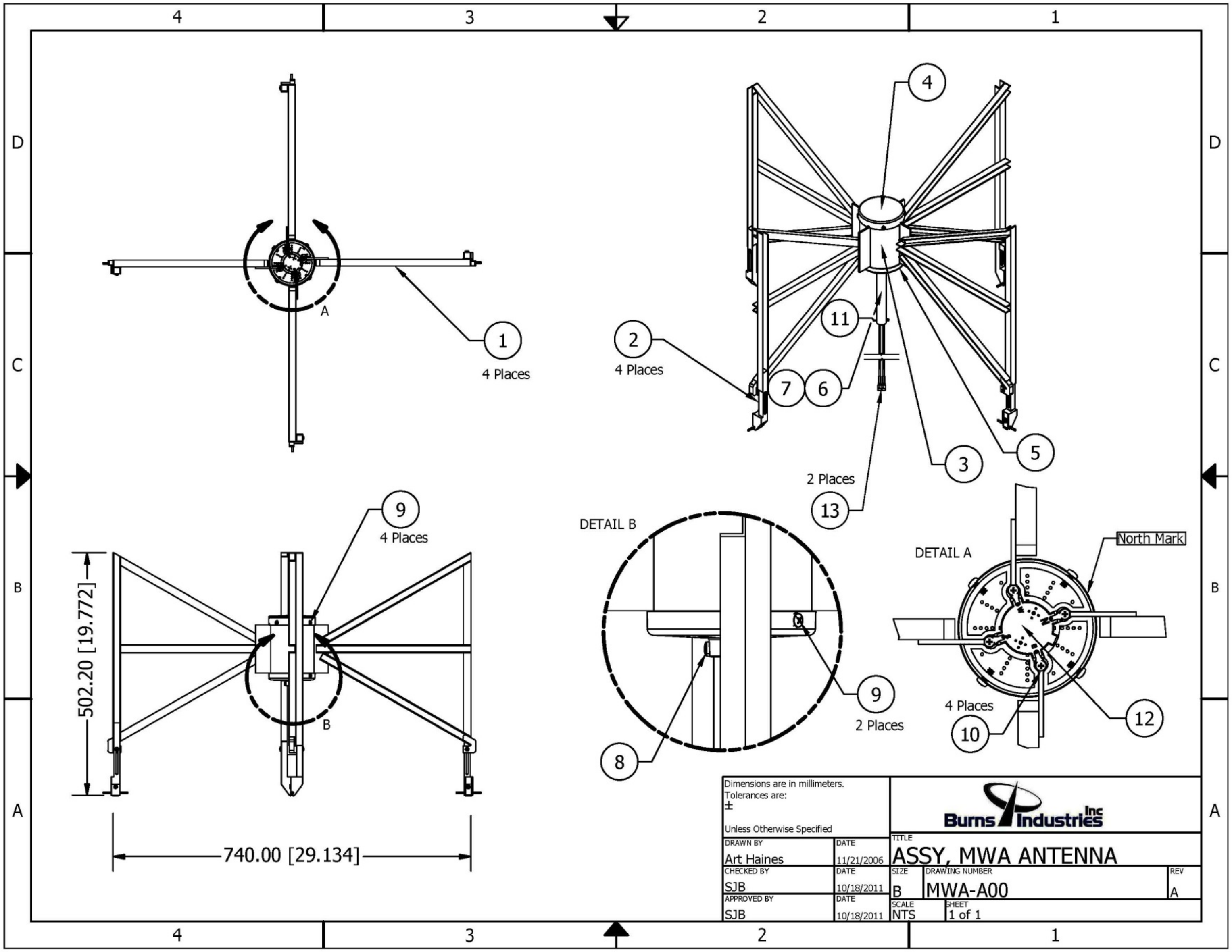
Serious consideration should be given to aligning all circuit assemblies vertically, to minimise the area on which dust may collect. Also, the enclosures should be at least partially sealed to prevent dust ingress in the first place (i.e. vents on the bottom-most surfaces only). Multiple nested enclosures should be considered where it is necessary to encourage convective or natural wind-assisted air-flow for cooling purposes, with circuitry protected inside a heat-conductive, but otherwise sealed, inner-most enclosure.

When circuitry must be aligned horizontally, consider placing ALL components on the lower side, and fully sealing the upper side with an insulating material capable of withstanding continuous immersion / exposure to acidic environments at least as low as pH 3.5. All vias and other circuit board penetrations should be fully sealed to prevent corrosive solution weeping to the lower side of the board.

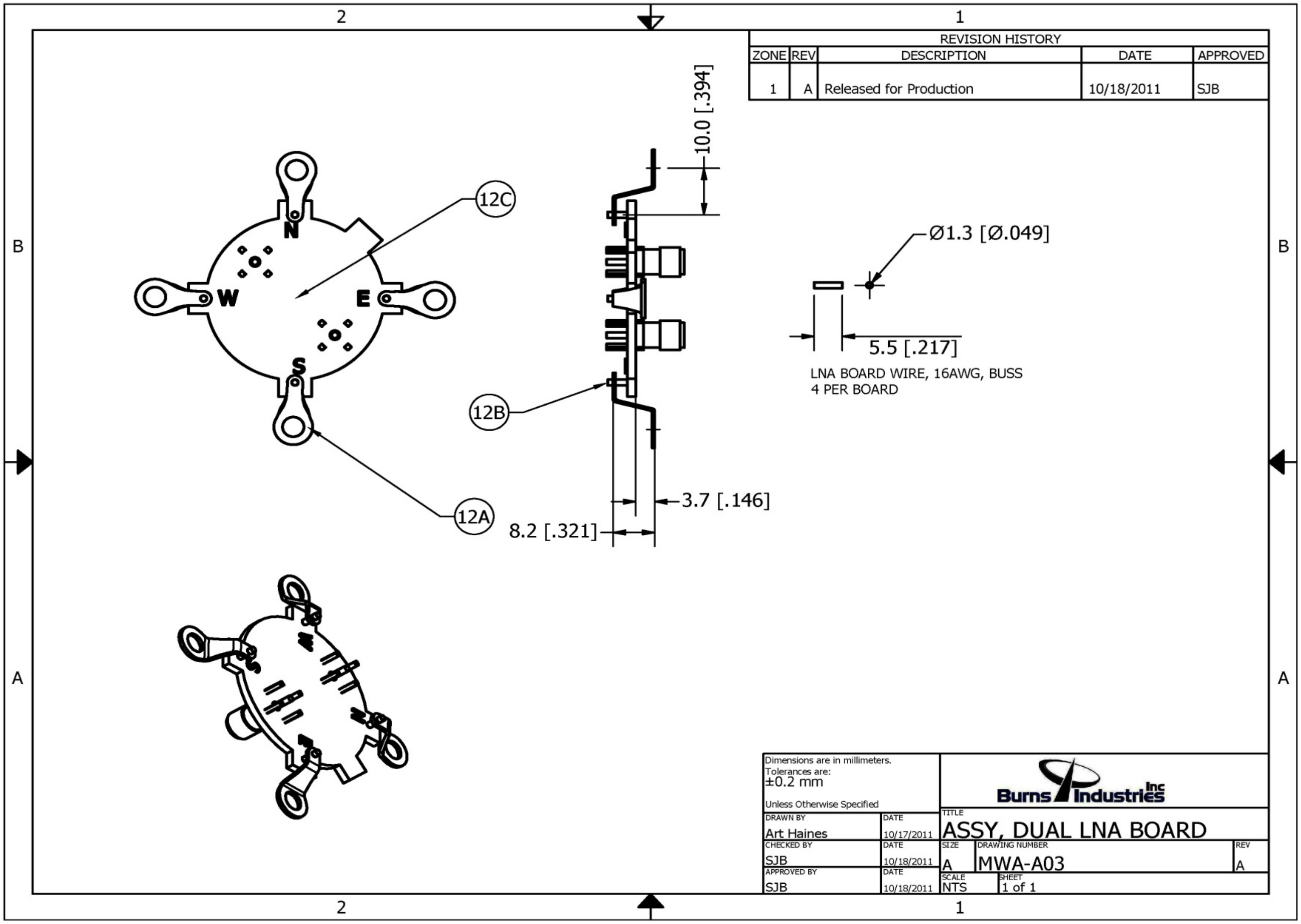
Lastly, if despite all the above, components must be placed on the top side of horizontal circuit boards, serious consideration should be given to a complete encapsulation, or a similar hermetic seal, as well as serious dust-ingress prevention to prevent dust settling on top of the seal.

References

Ref 1: Drawing for entire dipole element, showing installation of LNA (Source MWA-A00.pdf)



Ref 2: Mechanical drawings for LNA PCBA (source MWA-A03.pdf)



Ref 3: Laboratory Analysis of MWA dust/sand sample. (source Analysis.pdf)

Hi Brian,

I have completed analysis of your top soil sample. I have completed a pH analysis required on mine sites where 5g of soil is added to a bottle with 50mL of filtered water. The sample is mixed for 1.5 hrs and allowed to settled for a further 1.5hrs. The pH is then measured with a calibrated pH meter. The pH of your soil was 4.32. Any soil below a pH of 5.5 is considered acidic. Additionally, I have tested the sulphur and carbon content by induction furnace fitted with an infrared detector. The sample came up with <0.01% sulphur and 0.16±0.03% carbon.

Let me know if you want to know anything else about the sample.

Cheers,

Chenoa Tremblay
Technical Manager
E: chenoa.tremblay@minanalytical.com.au

MinAnalytical
LABORATORY SERVICES AUSTRALIA PTY LTD
AN AUSDRILL COMPANY

50 Baile Road
Canning Vale WA 6155
PO Box 1540
Canning Vale WA 6970

T: (08) 6258-9600
F: (08) 6258-9696

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Ref 4: HumiSeal® 1B73 technical data sheet (source 1B73-TDS.pdf)

HumiSeal® 1B73 Acrylic Conformal Coating
Technical Data Sheet

HumiSeal® 1B73 is a single component, fast drying, acrylic conformal coating intended for use on printed circuit assemblies. HumiSeal® 1B73 demonstrates excellent flexibility and electrical properties, fluoresces under UV light for ease of inspection and is easily repaired. HumiSeal® 1B73 coating is MIL-I-46058C qualified, IPC-CC-830 and RoHS Directive 2002/95/EC compliant, and recognized under UL File Number E105698.

Properties of HumiSeal® 1B73

Density, per ASTM D1475	0.92 ± 0.02 g/cm³
Solids Content, % by weight per Fed-Std-141, Meth. 4044	29.5 ± 2 %
Viscosity, per Fed-Std-141, Meth. 4287	250 ± 20 centipoise
VOC	661 grams/litre
Drying Time to Handle per Fed-Std-141, Meth. 4061	30 minutes
Recommended Coating Thickness	25 - 75 microns
Recommended Curing Conditions	24 hrs @ RT or 2 hrs @ 76°C
Time Required to Reach Optimum Properties	7 days
Recommended Thinner	HumiSeal® Thinner 73
Recommended Stripper	HumiSeal® Stripper 1080, 1080EU
Shelf Life at Room Temperature, DOM	24 months
Thermal Shock, 50 cycles per MIL-I-46058C	-65°C to 125°C
Coefficient of Thermal Expansion - TMA	67 ppm/°C
Glass Transition Temperature - DSC	42°C
Modulus - DMA	11.1 MPa
Flammability, per UL 94	V-0
Dielectric Withstand Voltage, per MIL-I-46058C	>1500 volts
Dielectric Breakdown Voltage, per ASTM D149	6300 volts
Dielectric Constant, at 1MHz and 25°C, per ASTM D150-98	2.6
Dissipation Factor, at 1MHz and 25°C, per ASTM D150-98	0.010
Insulation Resistance, per MIL-I-46058C	5.5×10^{14} ohms (550TΩ)
Moisture Insulation Resistance, per MIL-I-46058C	7.0×10^{10} ohms (70GΩ)
Fungus Resistance, per ASTM G21	Passes

Application of HumiSeal® 1B73

Cleanliness of the substrate is of extreme importance for the successful application of a conformal coating. Surfaces must be free of moisture, dirt, wax, grease, flux residues and all other contaminants. Contamination under the coating could cause problems that may lead to assembly failures.

Dipping
Depending on the complexity, density and configuration of components on the assembly, it may be necessary to reduce the viscosity of HumiSeal® 1B73 with HumiSeal® Thinner 73 in order to obtain a uniform film. Once optimum viscosity is determined, a controlled rate of immersion and withdrawal (5-15 cm/min) will further ensure even deposition of the coating and ultimately a uniform film. During the application, evaporation of solvent causes an increase in viscosity that should be adjusted by adding small amounts of HumiSeal® Thinner 73. Viscosity in the dip tank should be checked regularly, using a simple measuring device such as a Zahn or Ford viscosity cup.

HumiSeal® 1B73 Technical Data Sheet

Spraying
HumiSeal® 1B73 can be sprayed using conventional spraying equipment. Spraying should be done in an environment with adequate ventilation so that the vapour and mist are carried away from the operator. The addition of HumiSeal® Thinner 73 is necessary to ensure a uniform spray pattern resulting in pinhole-free film. The amount of thinner and spray pressure will depend on the specific type of spray equipment used and operator technique. The recommended ratio of HumiSeal® 1B73 to HumiSeal® Thinner 73 is 1:1 by volume; however the ratio may need to be adjusted to obtain a uniform coating.

Brushing
HumiSeal® 1B73 may be brushed with a small addition of HumiSeal® Thinner 73. Uniformity of the film depends on component density and operator's technique.

Storage
HumiSeal® 1B73 should be stored away from excessive heat or cold, in tightly closed containers. HumiSeal® products may be stored at temperatures of 0 to 35°C. Prior to use, allow the product to equilibrate for 24 hours at a room temperature of 18 to 32°C.

Caution
Application of HumiSeal® Conformal Coatings should be carried out in accordance with local and National Health and Safety regulations.

The solvents in HumiSeal® Conformal Coatings are flammable. Material should not be used in presence of open flame or sparks. Use only in well-ventilated areas to avoid inhalation of vapours or spray. Avoid contact with skin and eyes.

Consult MSDS/SDS prior to use.

Contact HumiSeal®

HumiSeal North America
201 Zeta Drive
Pittsburgh, PA 15238
USA
Tel: +1 412-828-1500
Toll Free (US only): 866-828-5470
sales@humiseal.com

HumiSeal Technical Center
295 University Avenue
Westwood, MA 02090
USA
Tel: +1 781-332-0734
Fax: +1 781-332-0703
techsupport@humiseal.com

HumiSeal Europe
505 Eskdale Road, IQ Winnersh
Berkshire RG41 5TU
UK
Tel: +44 (0)1189 442 333
Fax: +44 (0)1189 335 799
europeansales@chasecorp.com

HumiSeal Europe Support
Tel: +44 (0)1189 442 333
Fax: +44 (0)1189 335 799
europetechsupport@chasecorp.com

HumiSeal S.A.R.L
4/6 Avenue Eiffel
78420 Carrieres-Sur-Seine
France
Tel: +33 (0) 1 30 09 86 86
Fax: +33 (0) 1 30 09 86 87
humiseal.sarl@chasecorp.com

HumiSeal Asian Support
Tel: 852-9451-6434
Fax: 852-2413-6289
asiatechsupport@humiseal.com

Ref 5: RX-1321 conformal coating, manufacturer's product info (source RX-1321-Conformal-Coat.pdf)

RXBOND
www.rxbond.com

2009-07
技术资料

昆山荣欣邦德电子材料有限公司
TEL:0512-57992282 FAX:0512-57992283

RX-1321

线路板保护胶（三防胶）

一、性能、特点：

* 含紫外线荧光显示剂, 方便检查，提高可靠性。
* 绝缘性能良好, 具有良好的介电性能和防潮性能。
* 单一组份，使用方便，固化后的表面光滑平整，附着力好。
* 具有良好的柔韧性和高的机械强度，抗油、抗高低温、抗化学性良好。

二、典型用途：

用于已组装完毕的线路板免受各种化学品、潮湿、灰尘及高低温等恶劣的环境冲击。

主要应用于：

* 混合集成电路
* 电子线路板
* 软性印刷电路
* 半导体晶体线路保护
* 汽车电子控制板
* 航空仪表板
* 微电脑控制板
* 家电控制系统

三、主要技术参数：

1	外　观	无色或微蓝色透明液体
2	viscosity 粘度 cps（25℃）	2000（可加稀释剂调整）
3	curing 固化时间 25℃	30 分钟表干、24 小时完全
4	glossiness 光 泽 性	光　亮
5	breakdown voltage 穿电压	6500V/mm
6	solid content 固体含量	50%
7	use 使用温度℃	-40～120
8	volume resistivity 电阻 ohm-cm	7.8×10^{18}
9	surface resistance 电阻 ohm	2.3×10^{17}
10	dielectric constant 常数 1KHZ	5.4
11	dielectric 介电损耗 1KHZ	0.01

四、使用方法：可喷、涂、浸、刷等。

注：使用湿度不能大于 85%，否则会有白色的吸湿现象。

五、包装、贮存：

* 本品为 1Kg、3Kg、17Kg 货根据客户要求包装。
* 在干燥阴凉处贮存保质期为 6 个月。

Ref 6: PlastiDip® manufacturer's product information (source PlastiDip_UVTechDataSheetBc.pdf)

Performix

Plastidip.net.au

PLASTI DIP®

MULTI-PURPOSE RUBBER COATING

DESCRIPTION:

PLASTI DIP® is an air dry, synthetic rubber coating that can be easily applied by spraying, brushing or dipping. PLASTI DIP® resists moisture, acids, abrasion, weathering, electrical shock, skidding/slipping, corrosion; coats and gives a comfortable, controlled, color coded grip to all types of tools; lawn and garden, mechanical, electrical, woodworking and masonry. PLASTI DIP ® can also be applied to:

- Wood: seals and protects from weathering and prevents splinters.
- Metal: reduces vibration, deadens sound, prevents corrosion, insulates electrically and from extreme temperatures.
- Glass: shatterproofs glass objects (available in clear).
- Rope/Fabrics: weatherproofs, prevents rotting and fraying.
- Plastics: protects delicate surfac es from scratches.
- Rubber: weatherproofs, wear resistant.
- Maps: weatherproofs, tear resistant (available in clear).

SPECIFICATIONS:

Solids: (wt.) 24%
Tensile: (ASTM D-638) 3,740psi
Elongation: (ASTM D-638) 430%
Cut resistance: (ASTM D-1044) very good
Stone abrasion: (ASTM D-3170) excellent
Shelf life: 1 year at 77°F
Chemical resistance:
- acids, alkalines, pollutants: excellent
- petroleums: limited

Durometer: shore A (ASTM D-2240) 70
Salt spray: (ASTM B-117) passed 1,000 hours
Weatherability: (ASTM G-53) 3-5 years: PLASTI DIP
7 -10 years: PLASTI DIP U.V. Stable
Temperature use range: -30°F to 200°F.
Viscosity range: 80 – 100 K.U. @ 77°F (+/- 2°F)
Permeability: (ASTM E-96) .03 grains/sq. ft./hr.
Dielectric: (ASTM D-149) 1,400v/mil

Coverage: 30 sq.ft. per gallon at 15 mils. An application of Plasti Dip is normally between 6-8mils, so that is two coats. Metric: 3.78litres covers 2.787 sq mtrs at .3810mm

ALTERNATIVE PRODUCTS:

For a water base alternative see HCFeccs® technical data sheet

SURFACE PREPARATION:

MIX WELL BEFORE USE.

All surfaces to be coated must be free of all oils, grease, dirt, wax and loose rust. A sandblasted or rough surface improves adhesion. Use PLASTI DIP ® PRIMER on all metals for best results.

USE ADEQUATE VENTILATION.

plastidip.net.au

PLASTIC DIPS & COATINGS
527 Bakers Creek Rd, BUNDOOK NSW 2422
Phone: (02) 6550 2656
Fax: (02) 6550 2657
E-mail: sales@plastidip.net.au

SPRAYING: Pressure pot may be used (siphon cup not recommended). Dilute with recommended thinners up to 50% as needed. Gently mix before spraying. Apply wet overlapping coats, holding gun 6"- 12" from surface, using a 4"-6" pattern. Allow 10 -20 minutes dry time before applying additional coats to desired thickness.

RECOMMENDED EQUIPMENT AND SETTINGS:
Gun: Binks® model 95
Nozzle: 63B
Needle: 663A
Material: 20-25psi
Atomization: 15-25psi
Dilution: as needed
Cap: 63PB (up to 50% dilution) or 66S D (up to 50% dilution) for heavier build up.
Clean up: see recommended thinners.

SPRAYING: Airless equipment may be used. Use as described above.
Tip size: .011 - .019
Pressure: as needed
Dilution: up to 50%

DIPPING: Dilute with recommended thinners up to 25% as needed. Gently mix before each use. Do not introduce air bubbles. Insert item 1" every 5 seconds. Remove at same rate. Allow 30-40 minutes (dry to the touch) dry time before applying additional coats to desired thickness.

BRUSHING: Dilute with recommended thinners up to 25% as needed. Gently mix before each use. Apply wet overlapping coats using a soft natural bristle brush. Allow 10-20 minutes (dry to the touch) dry time before applying additional coats to desired thickness.

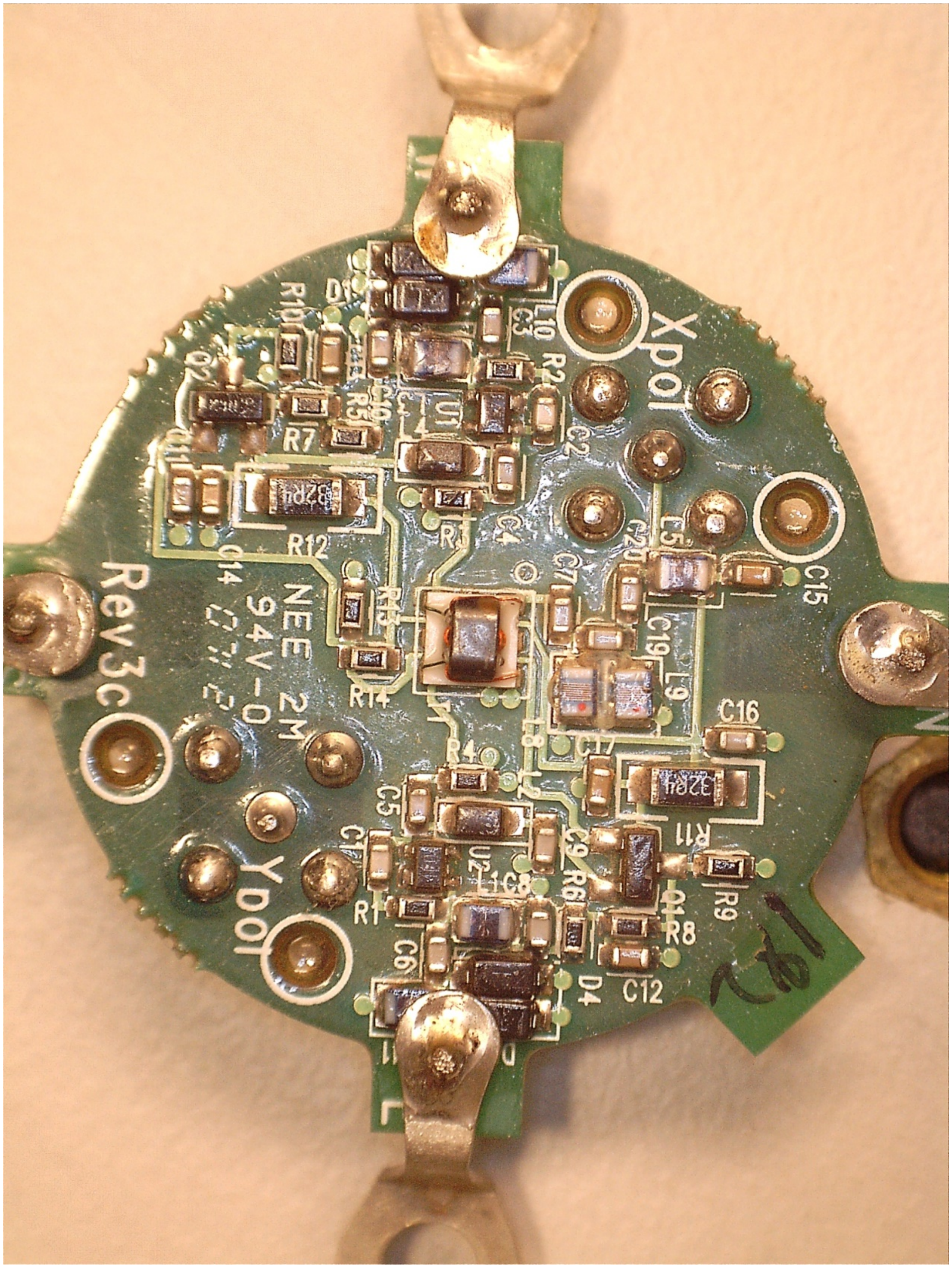
HINTS:
Recommended thinners: PLASTI DIP ® THINNER, Toluene or VM&P Naphtha. A dry film thickness of 12 -15 mils is recommended for best results. Approximate dry mil thickness per coat, dipping 6-8 mils; brushing 4-5 mils; spraying 2-5 mils. **Allow 4 hours dry time per coat before use.** Allow overnight drying whenever possible. When using a dip tank, allow 6" minimum from fluid surface to tank top to avoid "skinning over". Avoid excessive air movement, heat or humidity. Always use proper ventilation and protection.

ADDITIONAL APPLICATION IDEAS

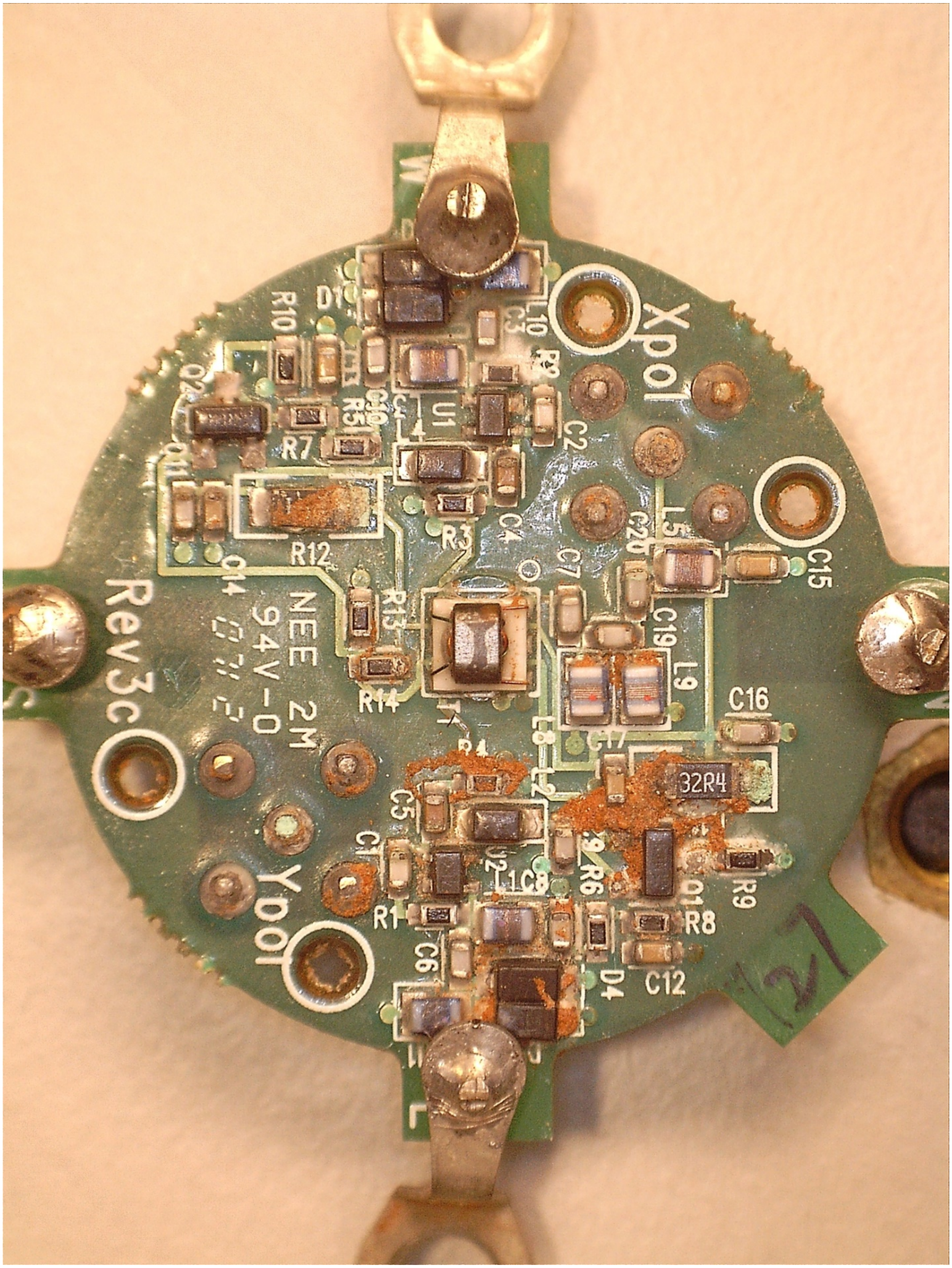
Tranformers
Rope
Joy Sticks
Electrical Boxes placed on the ground
Stove/Oven handles
LaCrosse Sticks/Nets
Food Grade Barrels
Control Boxes
Metal Grates
Pumps
Valves / Actuators
Pulleys & Rings
Poles
Underground tanks
Cables / Straps
Wood
Circuit Boards
Magnets
Fabric
Astro Turf
Crutch Handles
Relay Electric Wench
Sharp edges
Hand Tools
Curtains
Clips
Glass
Pipes
Hardware & Metal surfaces to prevent electrical discharge & sparks

Gallery of images showing various board issues

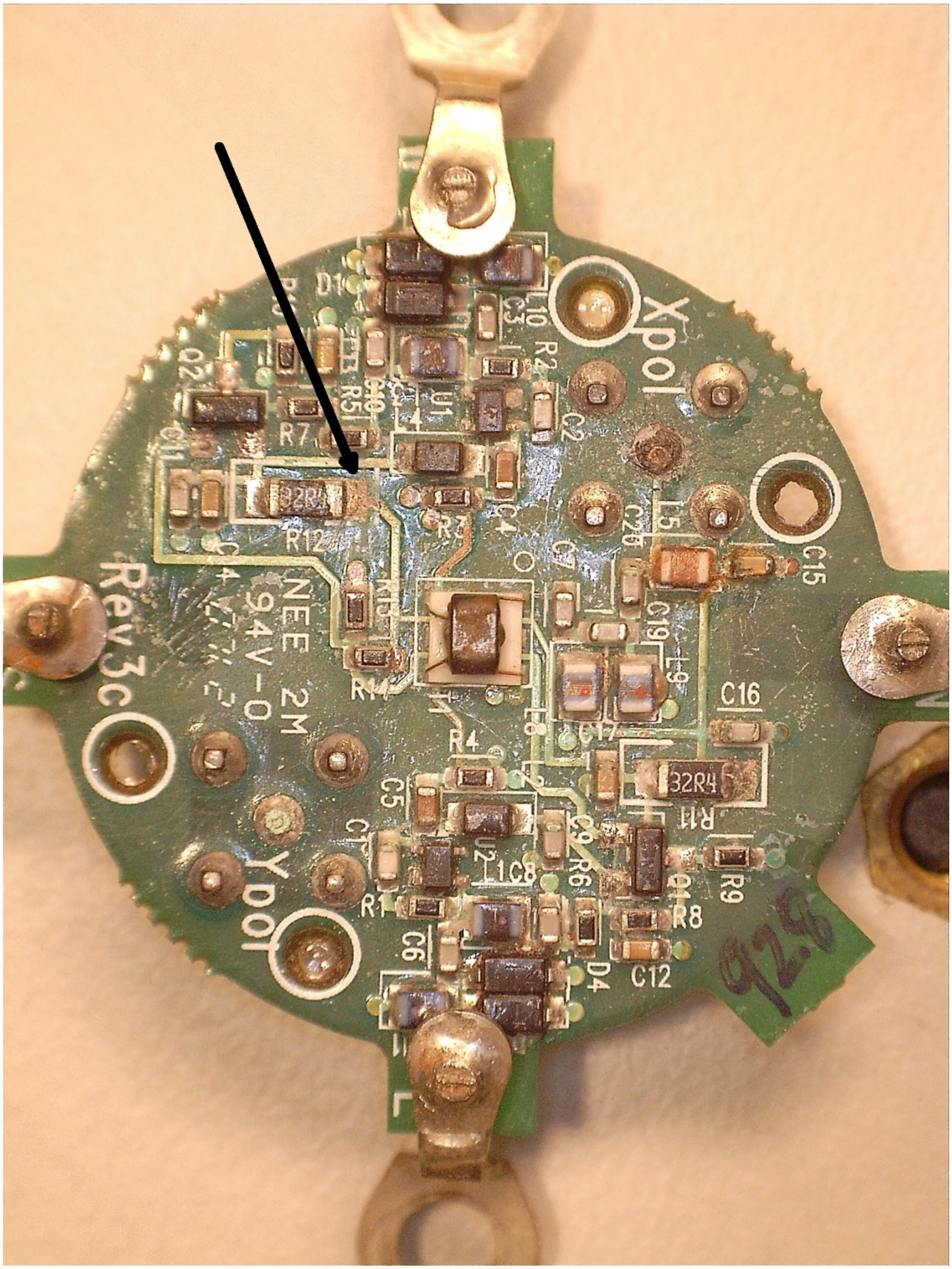
This first image shows a relatively clean board that has still had some exposure to corrosive dust. Note the completely transparent nature of the conformal coating, as well as the shiny metallic solder joints and clean shiny component metallisation.



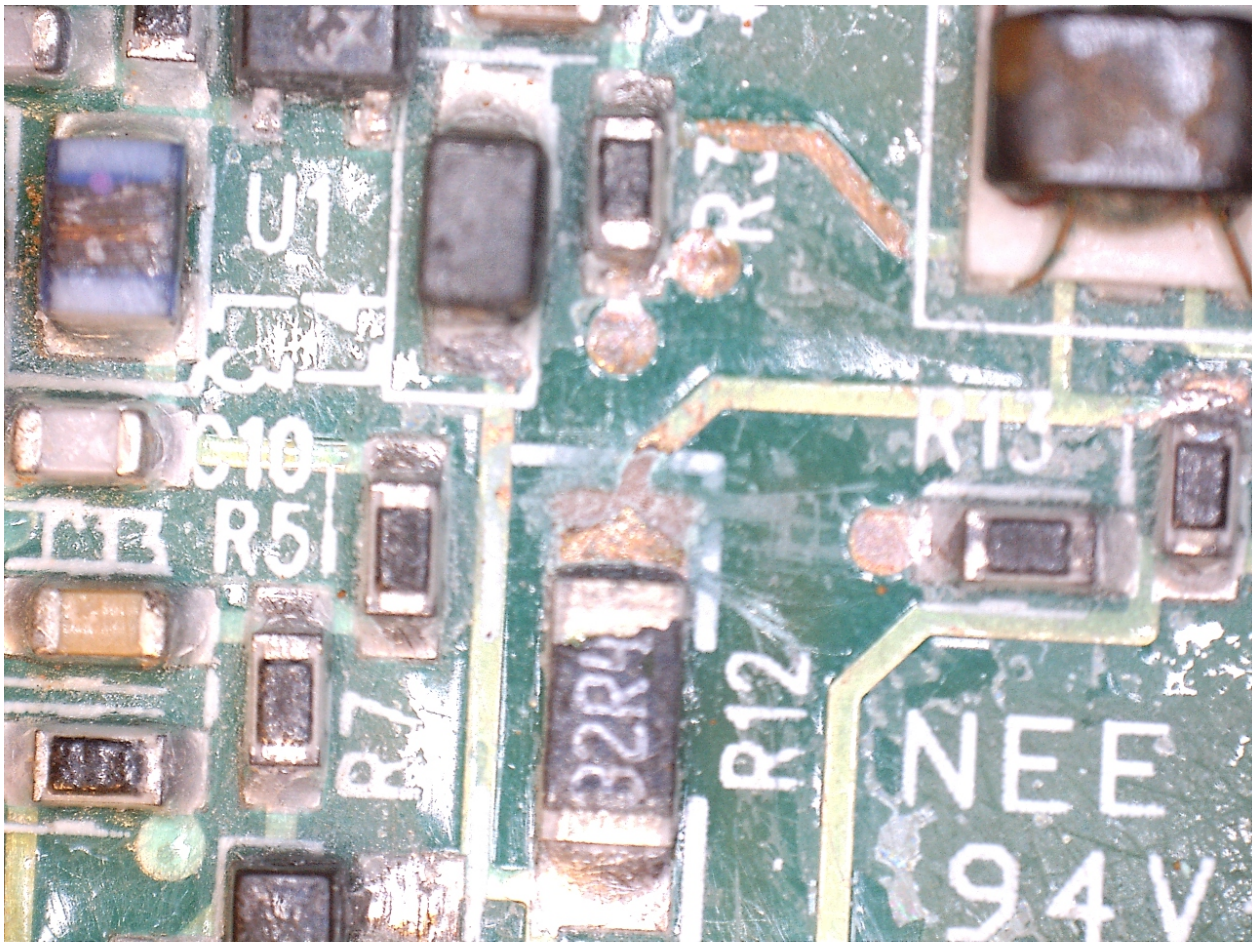
This next image shows a partially cleaned board returned from the field, showing that areas where the dust has started to breach the conformal coating are also where the dust adheres even after gentle air and soft-brush cleaning. A metal pick would be required to further clean this board.



This image shows a board that has been cleaned using a metal pick, and clearly shows that the conformal coating has gone milky in places, as well as the solder and various component parts have become powdery and corroded. Of particular note, the trace leading away from resistor R12 (marked with arrow) has been completed eroded and is no longer connected.

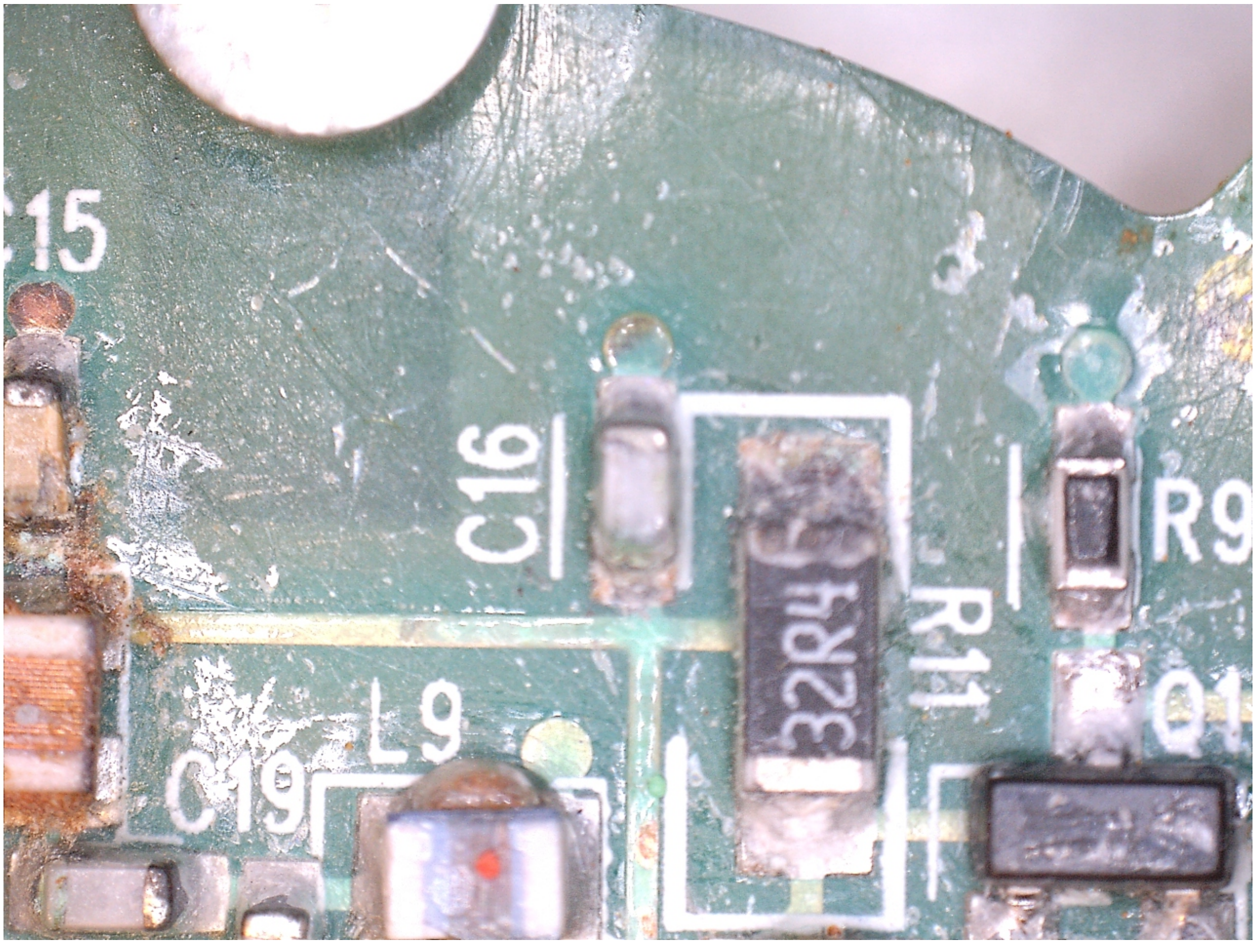


The images on this and subsequent pages are zoomed-in views from the corroded circuit board on the previous page. The first shows a zoom in on resistor R12. It is clear that the top end of the component has been corroded, most of the solder reacted away, and the underlying copper pad completely dissolved, isolating the trace leaving the top and turning right, from the component pad. During the pick/scraping procedures crumbled black powdery deposits were removed to expose the top end of R12 and associated copper pads and tracks, which we believe to be the corrosion products left over from the solder and copper metals.

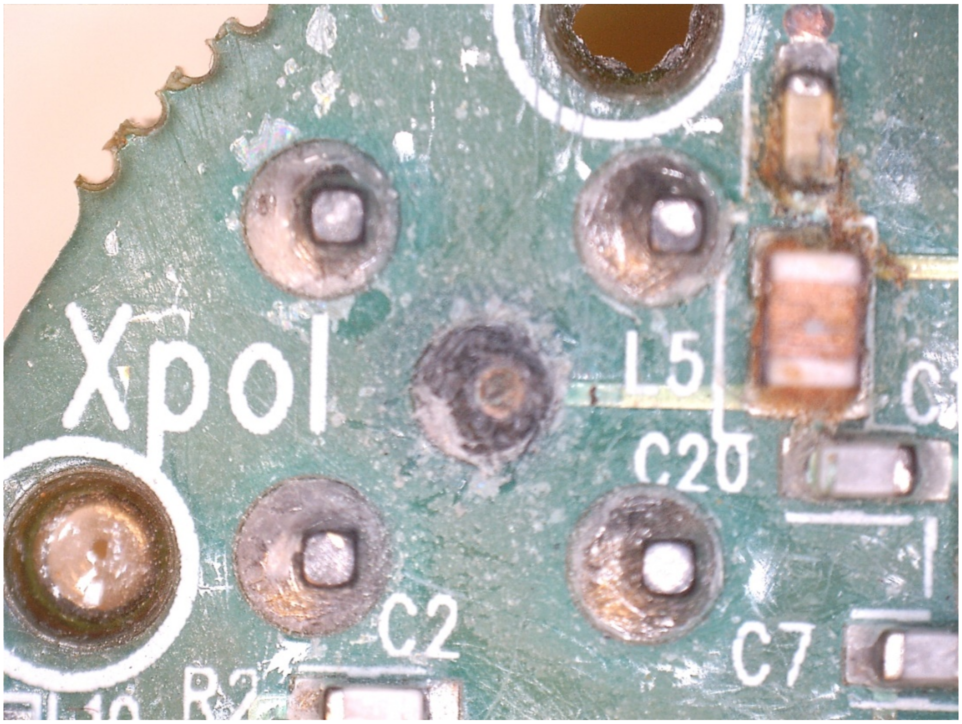


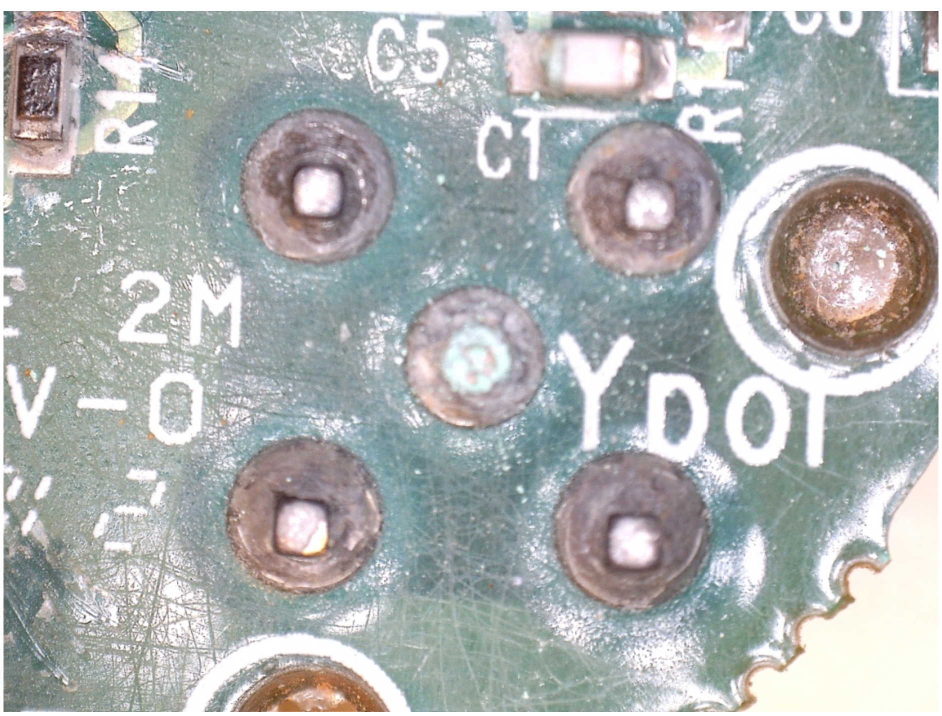
Note also the damage apparent to the copper tracks connected to R3, immediately above R12.

This next picture shows similar damage to capacitor C16, where it is seen that the entire metallisation at both ends of the capacitor has corrode, resulting in a complete open circuit at both ends of the component. Note also the damage apparent to the top end of resistor R11 just to its right.



The next two images show views of the rear side of the SMA connectors for both X and Y polarisations. Note the corrosion evident on the centre pins of both connectors, the solder joints, and in all likelihood the copper pads underneath.

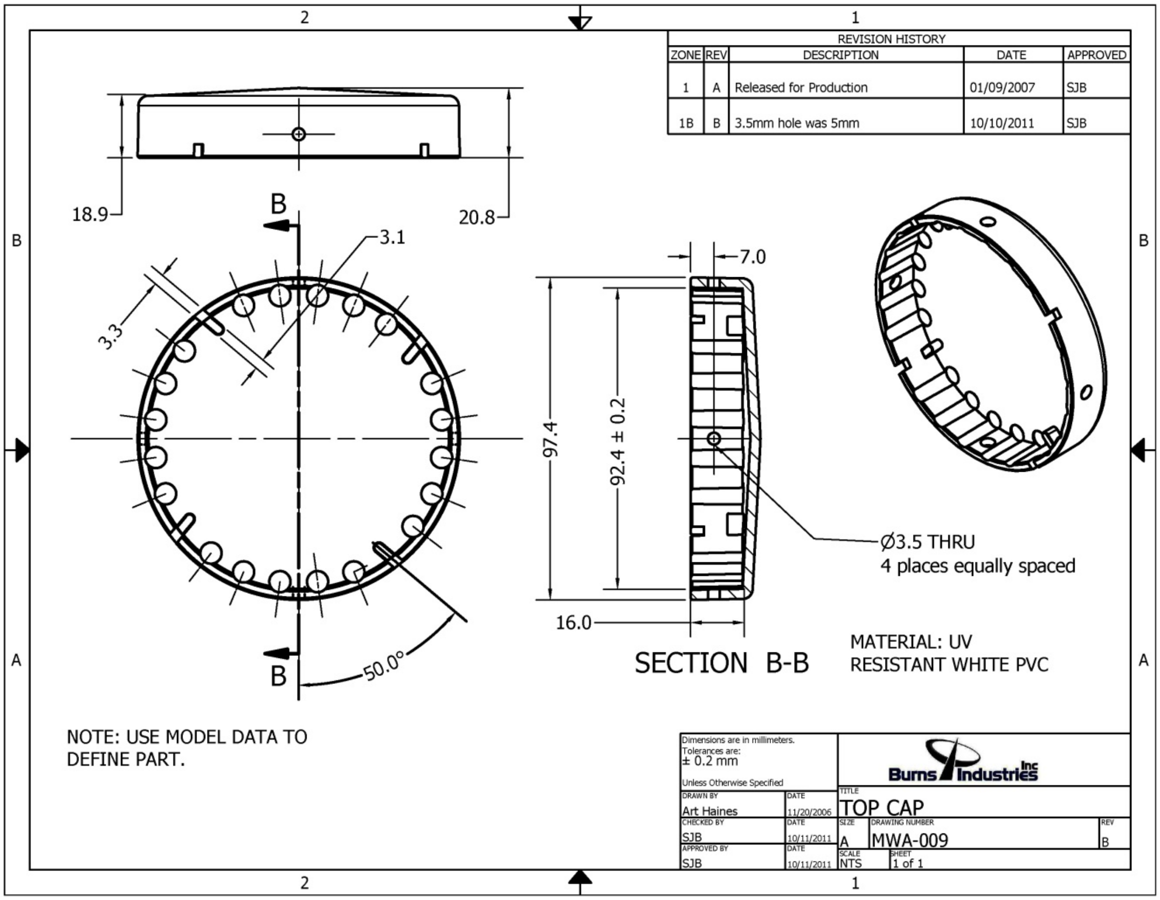




This next image shows a bad case of dust build-up on an LNA in a tile near a regularly used access track.

It seems fairly obvious that the dust enters under the top of the hub during windy conditions and is deposited inside the hub as the air velocity falls. Note the circular dust patterns in the lower left quadrant which would appear to correspond with the twenty circular air-path mouldings deliberately cast into the rim of the hub lid, as shown in the drawing over the page.

Mech drawing of the plastic lid that covers the LNA.



This last image shows that even tiles located relatively far away from access tracks, and in areas more secluded from the winds, still suffer dust build-up, albeit at a lower rate.