AKL-PT1 2 GHz Passive Probe Operator Manual

Antikernel Labs

August 12, 2020

Abstract

This document is the user manual for the Antikernel Labs AKL-PT1 2 GHz passive transmission line probe.

Contents

1 Overview

1.1 Manufacturer

Antikernel Labs
PO Box 4665
10355 NE Valley Rd
Rollingbay, WA 98061-0665
https://www.antikernel.net/
sales@antikernel.net

1.2 Warranty

Antikernel Labs warrants this probe to meet published specifications during ordinary laboratory use and operation for a period of three (3) years from date of shipment and will repair or replace, at its sole option, any defective product. This warranty covers manufacturing and assembly defects only. Damage caused by negligence, misuse, accident, alterations, or exceeding published operating limits is specifically not covered.

Antikernel Labs's maximum liability under this warranty is limited to the replacement value of the probe. Antikernel Labs will not be liable for any direct, indirect, special, exemplary, or consequential damages (including, but not limited to, procurement of substitute goods or services, loss of use, data, or profits; or business interruption) arising in any way out of the use of this probe, even if advised of the possibility of such damage.

1.3 Open Hardware

The most up-to-date design files for this probe may be found on GitHub under the 3-clause BSD license.

"Design Files" includes, but is not limited to:

- KiCAD schematic
- KiCAD board layout
- Fabrication notes including stackup and impedance
- Sonnet field solver models of connector transitions
- SolveSpace enclosure model

The current location of design files as of this writing is: https://www.github.com/azonenberg/starshipraider/

1.4 Sponsors

Development and prototyping of this probe was made possible by support from Symbiotic EDA (https://www.symbioticeda.com/)

Symbiotic EDA

2 Safety Information

To avoid personal injury, damage to the probe, or damage to the attached instrument, it is important to understand and follow the warnings and specification limits in this document.

- Only personnel familiar with the safe use and operation of electronic test equipment should use this probe.
- Do not connect the ground terminal of this probe to any voltage other than earth ground.
- Do not exceed operating limits in the specifications section of this document.
- Do not over-tighten the SMA connector. Antikernel Labs recommends using a properly calibrated torque wrench to torque the connection to 5 lbf-in (0.57 Nm) while holding the connector body across the flats with a wrench.
- The plastic enclosure of this probe is *not* rated for insulation against hazardous voltages, and conductive elements are exposed at the tip. Do not use this probe on any circuits which may contain voltages exceeding 30 Vrms, or the touch-safe voltage limit in your organization's standard operating procedures if this is lower.
- Do not operate in damp or wet conditions, or under temperature/humidity extremes in which condensation is likely.
- Do not operate this probe in a flammable or explosive atmosphere.
- The printed circuit board in this probe is plated with silver and is not intended for use in corrosive environments, especially those containing significant levels of sulfur compounds. Operation of this probe in a corrosive environment voids the warranty.
- The SMA connector center terminal and tip/ground sockets contain beryllium copper (BeCu) contacts. While exposure to beryllium is expected to be insignificant during ordinary use of this product, hazardous dust could be generated if the contact material is ground or abraded.
- Probe tips are sharp. Use caution when changing tips or ground accessories to avoid puncturing skin.

CA PROP 65 WARNING: This product can expose you to beryllium, which is known to the State of California to cause cancer.

3 Theory of Operation

Tha AKL-PT1 probe is a *transmission line probe* and works very differently from high-impedance passive or active probes many engineers are familiar with. It is intended primarily for probing relatively low impedance (50Ω range), high bandwidth digital signals, which ordinarily require expensive active probes to properly examine.

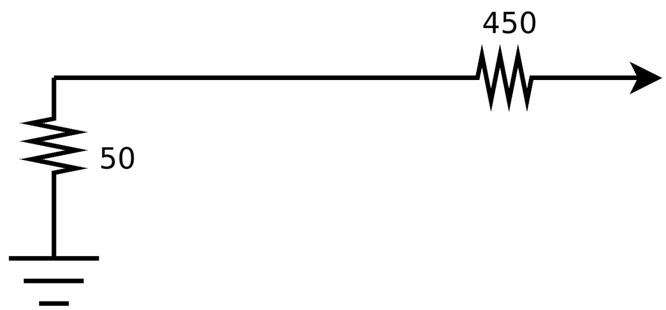

Figure 1: Simplified probe schematic

The signal is split off from the DUT at the point of contact and travels through the probe needle, then passes through a precision resistor array. This array is a series string of several resistors of different values summing to 450 Ω, carefully selected to cancel out frequency-dependent effects from L/C parasitics and ensure maximal flatness across the operating frequency range.

The signal then travels on 50 Ω transmission line through a low-loss coplanar waveguide, SMA connector, and coaxial cable to the oscilloscope, which terminates the signal with 50 Ω to ground. The tip resistor and termination form a 10:1 voltage divider, so the oscilloscope sees the incident signal attenuated by a factor of 10 (-20 dB). *Note that a 50 Ω termination at the instrument is required. This probe cannot be used with lower-cost oscilloscopes that only have 1M Ω terminations.*

The tip resistor and scope-side termination in series present a total loading of 500 Ω on the DUT. While this is a significantly lower DC impedance than conventional probes, the resistive input stage has extremely flat frequency characteristics with much less capacitance than conventional passive probes. This means that the impedance of the probe remains comparatively constant across the entire operating range, rather than greatly decreasing at higher frequencies.

4 Understanding Probe Effects

Transmission line probes have significantly higher DC loading than conventional passive probes, and may interact badly with pull-up or pull-down resistors. Consider AC coupling (using an industry standard SMA inner DC block between the probe and coaxial cable) or use of a different probe for these applications.

Some power is reflected from the resistor and re-joins the original signal with a small phase shift due to the electrical length of the probe needle. The total path length of the unterminated stub including the tip, socket, and transmission line from the socket to the resistor is approximately 9 mm. This will produce a null in the system frequency response at around 8 GHz, which is far enough outside the operating band of the probe that it should not present a problem.

Long, thin ground connections (such as the Z-ground or flexible ground lead) have higher inductance than short, fat ground connections. Always use the shortest, widest ground possible in a given application for best frequency response. The tip-mounted ground socket gives significantly better performance than the top ground socket.

5 Maintenance

Grounding accessories may be removed from the side socket by firmly grasping between two fingers and pulling. They should come free easily; a different accessory may then be inserted.

Tips (and tip-mounted grounds) can be more difficult to remove because they are so small and hard to grasp. Tips can typically be removed by placing a fine flat-head screwdriver or fingernail behind the collar on the tip and gently pushing it away from the probe body. Very little force is required.

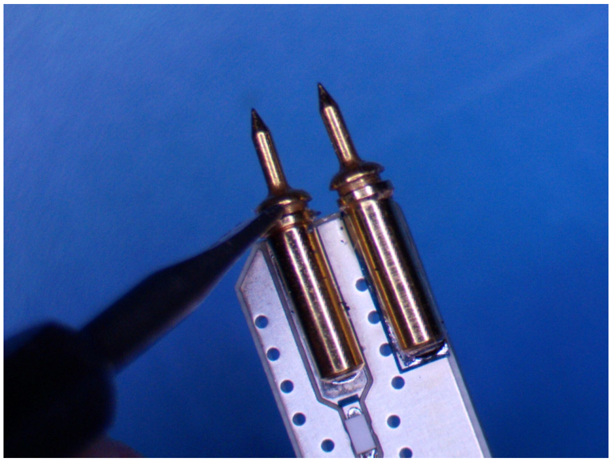

Figure 2: Probe tip removal

New tips can be inserted by simply pushing them into the socket. This is best done by grasping the tip forward of the collar, then inserting the rear of the tip into the socket and pushing until it seats fully. It is preferred to use tweezers for this rather than holding the tip between your fingers, to avoid accidental injury.

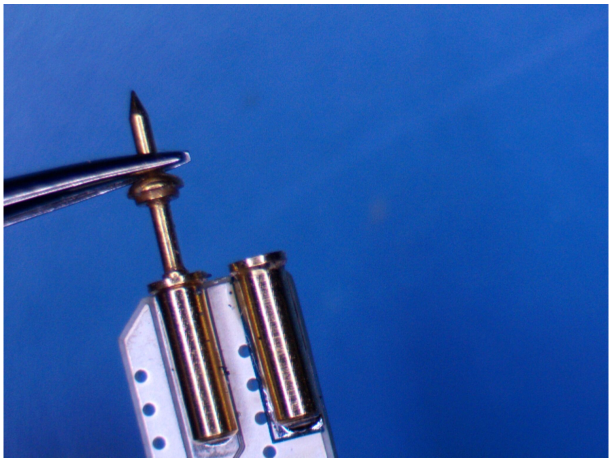

Figure 3: Inserting a tip

The probe does not require routine cleaning, however if cleaning is required for any reason it may be wiped with a damp cloth. Isopropyl alcohol is safe to use on the plastic shell and exposed circuit board, however repeated cleaning with alcohol may degrade the adhesive on the label. Do not use acetone or other strong solvents for cleaning.

6 Accessories

6.1 Tips / Grounds

The AKL-PT1 probe sockets will accept standard test equipment probe tips and ground accessories with 0.51 - 0.81 mm diameter (0.020 - 0.032 inch), as well as 22 AWG solid wire for solder-in applications.

Use of accessories with larger or smaller diameters may damage the socket and void your warranty.

The top ground terminal is centered 8 mm above and 12 mm to the rear of the signal connection, and the tip-mounted ground terminal is centered 2.5mm below the signal connection.

Antikernel Labs recommends use of PMK Tetris® series replacement probe tips and ground accessories. These may be ordered through Antikernel Labs or any PMK distributor.

Standard PMK accessories supplied with the AKL-PT1 are:

- 890-800-000 solid tip (2 piece supplied standard, replacement P/N is set of 5)
- 890-400-800 Z-ground (1 piece supplied standard, replacement P/N is set of 5)
- 018-291-105 ground leaf
- 890-400-808 7cm flexible ground lead

The PMK 893-250-00T 2-footed probe positioner is included with the pro edition probe.

Antikernel Labs believes the AKL-PT1 is compatible with PMK's full range of Tetris® tips and ground accessories, however testing has not been conducted with all possible accessories and Antikernel Labs assumes no liability for incompatibility with any accessories not listed in this document.

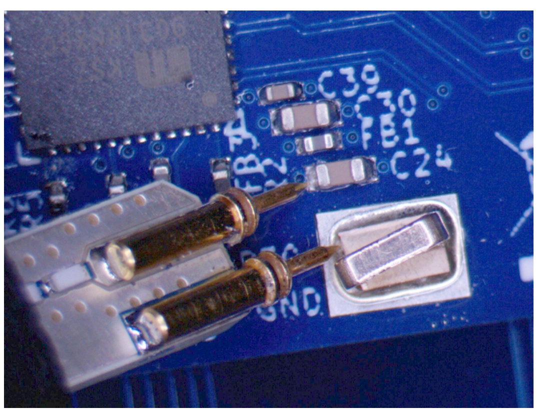

Figure 4: Using the tip-mounted ground pin

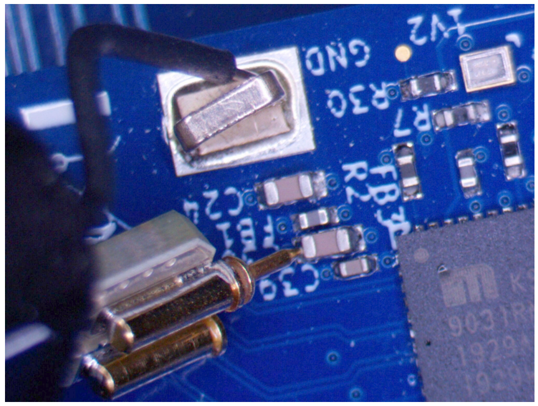

Figure 5: Using the Z-ground

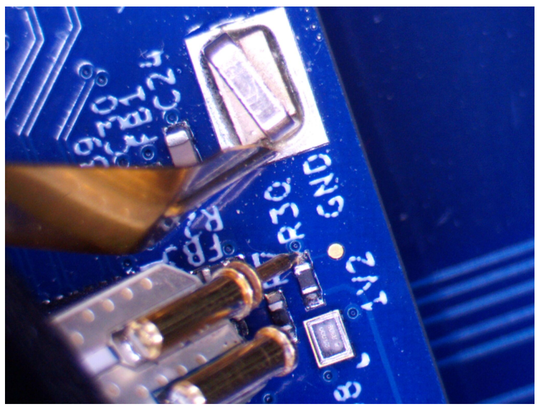

Figure 6: Using the leaf ground

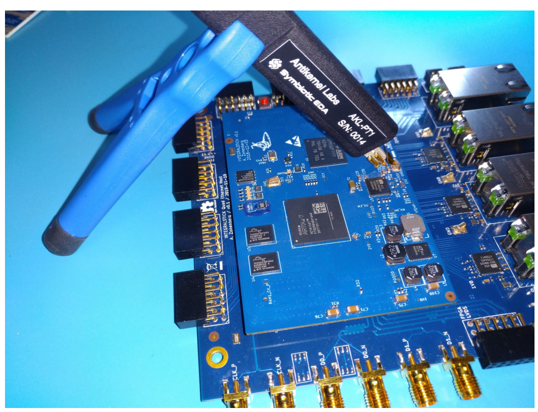

Figure 7: Using the bipod positioner

6.2 Cables

The AKL-PT1 should be connected to the host instrument via a 50Ω coaxial cable. Antikernel Labs recommends use of Mini-Circuits FL086-24SM+ (included in the pro package) or similar low-loss, flexible cabling.

The probe-side connector is a brass SMA (Amphenol RF 901-10511-3). For best results, this connection should be torqued to 5 in-lbf (0.57 Nm). Over-tightening may damage the connector. When torquing the connector, hold the connector body across the flats with a wrench. Do not hold the probe by the PCB or plastic shell as this can put additional stress on the solder joints.

7 Mechanical Specifications

Description	Typ	Units
Mass	10.5	g
Thickness	8.1	mm
Length (probe body)	68	mm
Length (exposed PCB at tip)	10.5	mm
Length (SMA connector)	9.5	mm
Length (total)	88.0	mm
Width	17.9	mm

8 Electrical Specifications

Values in this section are typical / limit values. For measured values from a specific probe, please consult your calibration certificate.

8.1 Absolute Maximum Ratings

Exceeding these limits may result in permanent damage to the probe.

Ratings in this section are stress ratings only and normal operation at these limits is not implied.

Parameter	Description	Limit	Units
T_{amin}	Minimum temperature	0	$°C$
T_{amax}	Maximum temperature	95	$°C$
I_{max}	Maximum current through probe	22	mA
V_{max}	Maximum operating voltage	10	$Vrms$

8.2 Recommended Operating Conditions

While the probe will not be damaged by exposure to conditions outside the values in this section (but below the "Absolute Maximum Ratings" limits), tolerances may be temporarily exceeded.

Parameter	Description	Limit	Units
T_{min}	Minimum temperature	15	°C
T_{max}	Maximum temperature	45	°C

8.3 DC Characteristics

Parameter	Description	Min	Typ	Max	Units
G_{dc}	DC gain (50.0000 Ω at scope)	0.09980	0.09994	0.10008	V/V
R_{25}	DC resistance of probe (25 °C)	449.75	450.31	450.75	Ω
R_{range}	DC resistance of probe (15 - 45 °C)	449.60	450.31	451.00	Ω
TCR	Temperature coefficient of resistance			±25	ppm / °C

8.4 AC Characteristics

Data in this section is based on characterization in a 50Ω environment, using the highest performance (tip) ground, with cable and fixture effects de-embedded, unless otherwise stated.

Parameter	Description	Min	Typ	Max	Units
Z_{in1}	Input impedance (1 GHz)	82.00	86.05	88.00	Ω
Z_{in2}	Input impedance (2 GHz)	29.00	30.79	32.75	Ω
C_{in}	Equivalent shunt capacitance to ground		1.1		pF
G	AC gain from DC - 2 GHz	-23	-20.5	-20	dB
G_1	AC gain at 1 MHz	-20.48	-20.45	-20.42	dB
G_{500}	AC gain at 0.5 GHz	-20.85	-20.56	-20.35	dB
G_{1000}	AC gain at 1.0 GHz	-21.10	-20.81	-20.35	dB
G_{1500}	AC gain at 1.5 GHz	-21.45	-21.17	-20.75	dB
G_{2000}	AC gain at 2.0 GHz	-21.60	-22.04	-22.45	dB
$BW_{0.5}$	±0.5 dB bandwidth w/ tip ground		0.91		GHz
BW_{tip}	+0 / -3 dB bandwidth w/ tip ground	2.25	2.47	2.60	GHz
BW_{flex}	+0 / -3 dB bandwidth w/ flex ground		0.56		GHz
BW_{leaf}	+0 / -3 dB bandwidth w/ leaf ground		1.46		GHz
BW_z	+0 / -3 dB bandwidth w/ Z-ground		0.80		GHz
$Rise_{90}$	Rise time (10-90 %, w/ FL086-24SM+ cable)	174	179	189	ps
$Rise_{80}$	Rise time (20-80 %, w/ FL086-24SM+ cable)	118	122	129	ps
Tpd	Propagation delay		548		ps

9 Performance Graphs

9.1 Insertion Loss

Measured across a 50Ω termination.

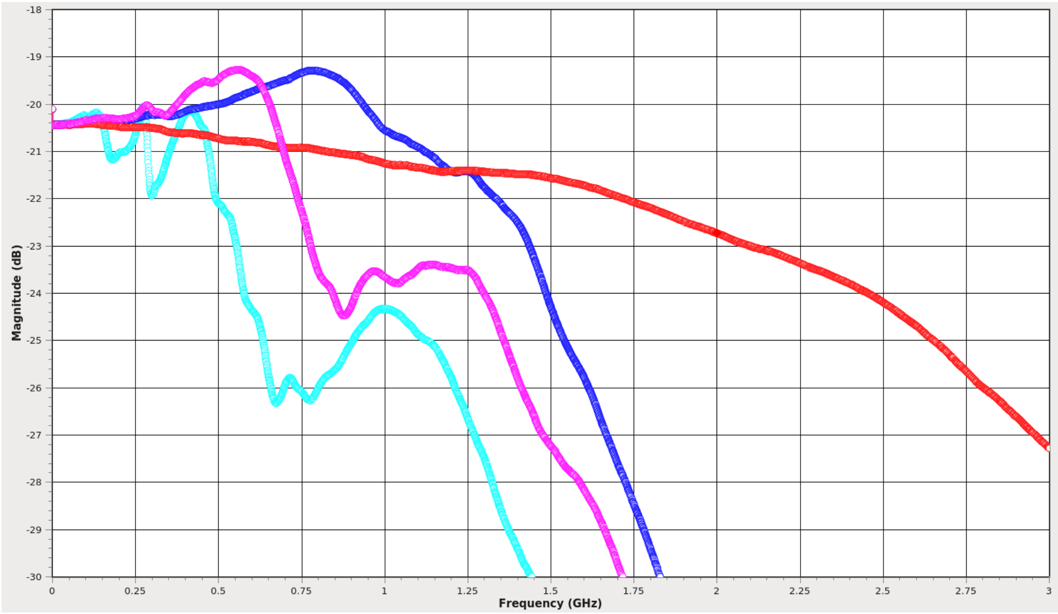

Figure 8: Typical S_{21} using tip ground (red), leaf ground (blue), Z-ground (pink), flex ground (cyan)

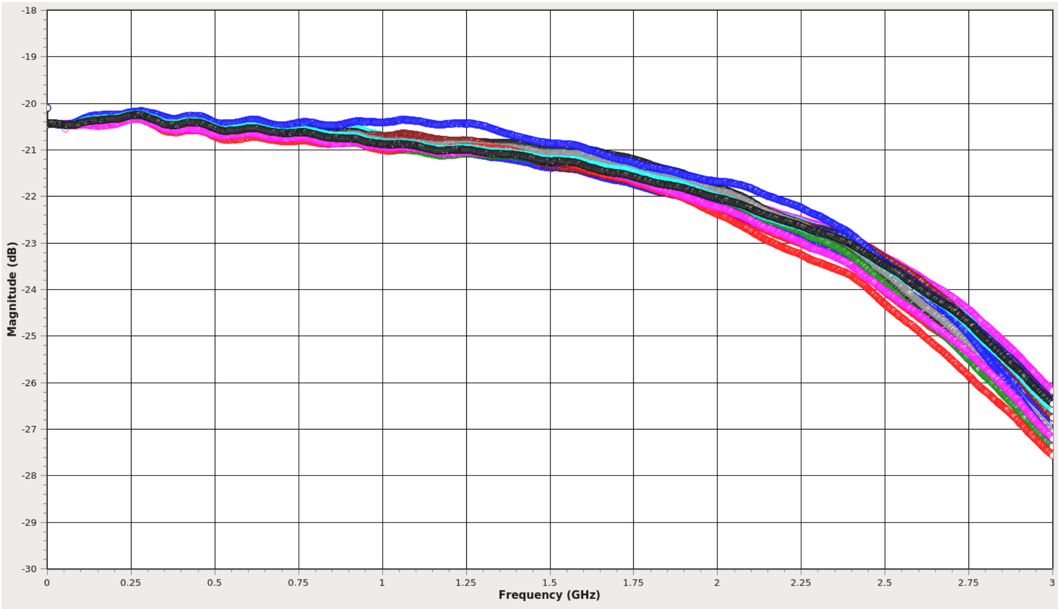

Figure 9: Unit to unit variation in S_{21}

9.2 Group Delay

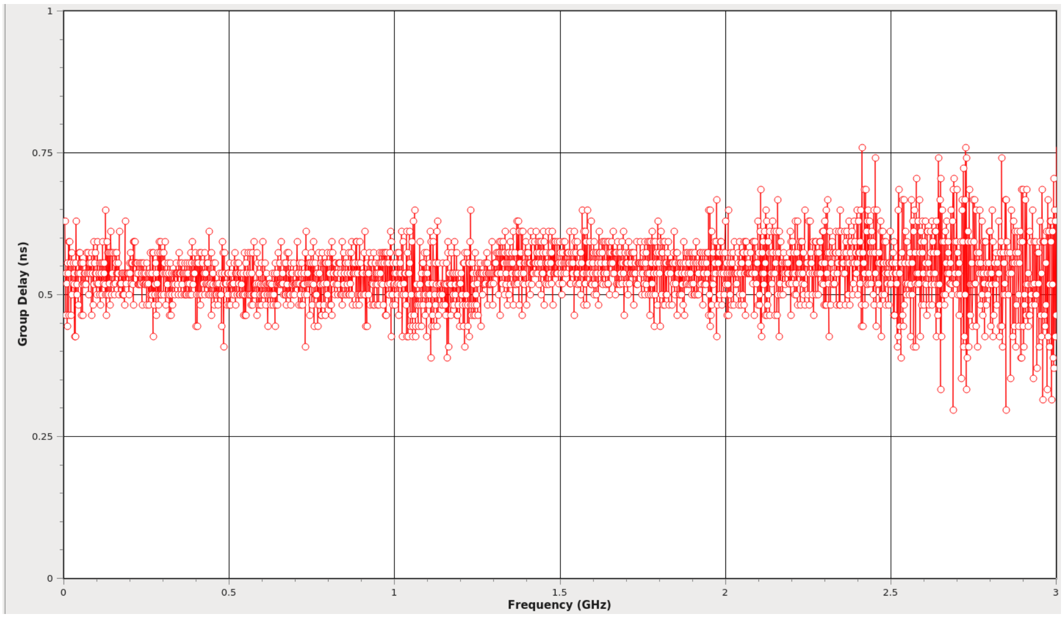

Figure 10: Typical Group Delay Flatness

9.3 Input Impedance

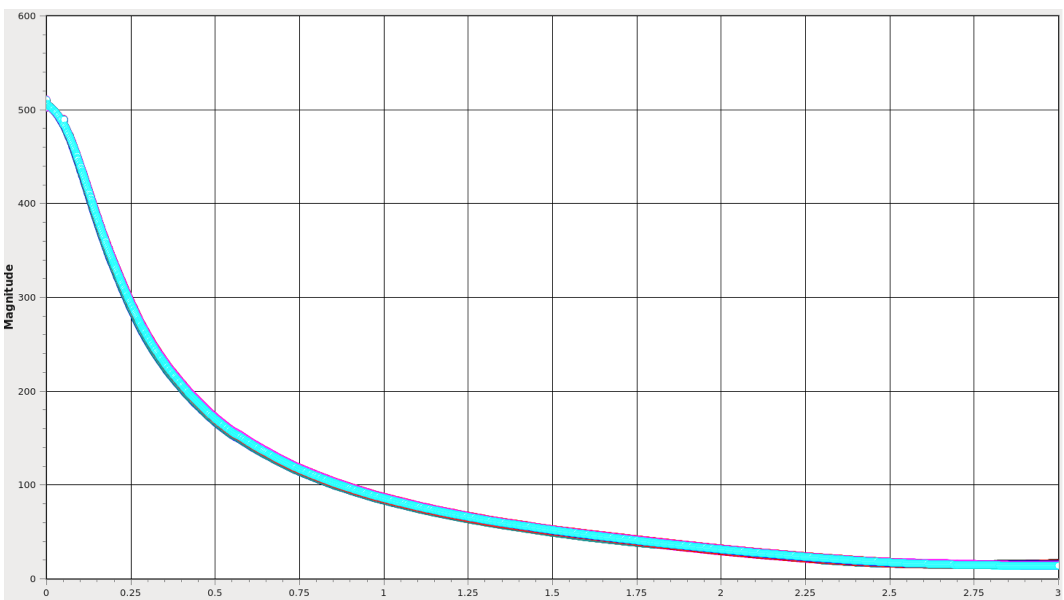

Figure 11: Typical Z_{in}

10 Performance Data

If you requested full characterization at the time of your order, test measurements are available at https://www.antikernel.net/downloads/AKL-PT1/caldata/ and searching for your probe's serial number.

The following S-parameter data files are provided:

- cable.s2p - the provided cable (if applicable)
- flexground.s2p - probe across a 50Ω load using the flex ground
- leafground.s2p - probe across a 50Ω load using the leaf ground
- tipground.s2p - probe across a 50Ω load using the tip ground
- zground.s2p - probe across a 50Ω load using the Z-ground
- zin.s2p - probe across an unterminated line for input loading measurements

For all measurements, port 1 is connected to the DUT side of the probe and port 2 is connected to the instrument side.