The Effects of Lead-Free Solder Finishes on Microwave Printed Circuit Board Performance

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Taconic Advanced Dielectric Division
Product Overview- Dielectrics

- Teflon(PTFE) Woven Glass (Er)
  - TLY: 2.17- 2.33
  - TLX: 2.45 - 2.65
  - TLE: 2.95
  - TLC: 2.75 - 3.20

Dielectric Constant is Controlled by the Glass to Resin Ratio

- Organic-Ceramic/PTFE Woven Glass (Er)
  - TSM-30: 3.0
  - RF-30: 3.0
  - TLG-32: 3.20 *
  - TLG-35: 3.50 *
  - TLG-34: 3.38 *
  - TLG-29, 30 2.9-3.0*
  - RF-35, 35A and 35P: 3.50
  - RF-60: 6.15 - 6.40
  - CER-10: 9.0 - 10.0
  - TP-32: **
  - TPG-29 and 30**

** TacLamGreen (TLG-29/TLG-30/TLG-32/TLG-34/TLG-35)-High Speed Digital and Low Cost RF Applications*

***TacPreg (TP-32) and TacPregGreen (TPG-29/TPG 30) Thermoset bond ply*

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RoHS and Lead Free

There are 6 hazardous substances that must be eliminated from electronic assemblies by July 1, 2006 under Directive 2002/95/EC of the European Parliament. This is commonly referred to as the RoHS directive. The hazardous substances are:

- Lead (Pb)
- Cadmium (Cd)
- Mercury (Hg)
- Hexavalent Chromium (Cr +6)
- Polybrominated Biphenyls (PBB)
- Polybrominated diphenyl ethers (PBDE)

Our Goal

- With RoHS and WEEE initiatives deadline of July 1, 2006 on restricting the use of lead and other hazardous substances fast approaching, companies are looking for alternatives to lead based solders on their microwave printed circuit boards and antennas. This presentation will look at the electrical differences of various lead free surface finishes on microwave materials over a broad frequency range of 1 to 20 GHz.

Insertion Loss (Attenuation)

Insertion loss is made up of:

- Radiation losses
- Conductor losses or Copper losses (DC losses and skin effect losses)
- Material losses or dielectric losses (represented by the Dissipation Factor of the material)

Conductor Losses

What affects conductor losses---

- Type of copper.
  - -- Rolled annealed
  - -- Electrodeposited
- Surface roughness of the copper
- Finish plating on the conductor

Copper Conductor Loss (theoretical)

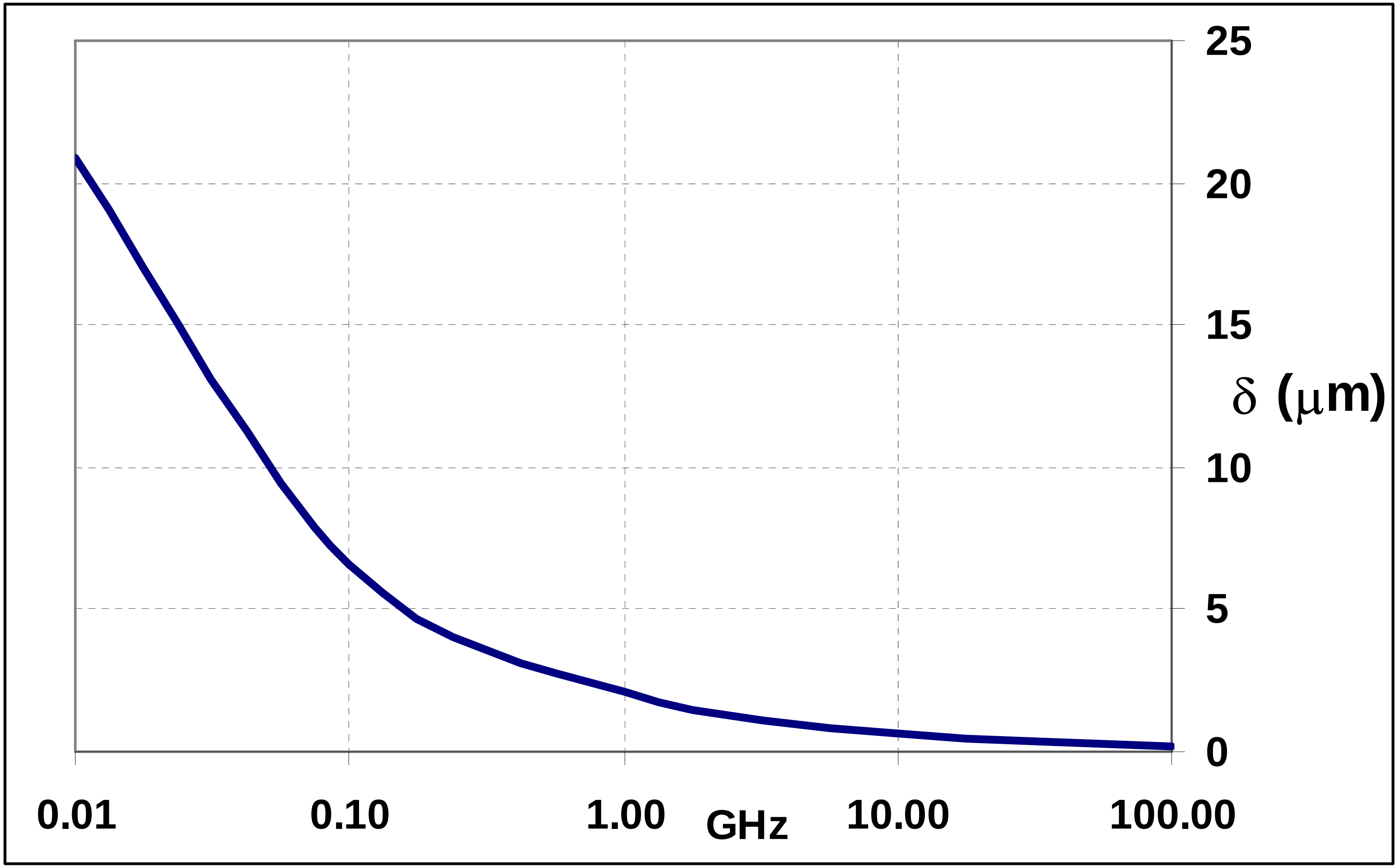
$$\alpha_{conductor} = -20\log\left(e^{\alpha_c}\right) = \left[{dB}/{m}\right]$$

$$\alpha_c = \frac{R_S}{Z_0 W} = \left[Np/m\right]$$

Conductor loss has to be corrected for skin effect because signal rides on outside of trace and is affected by copper roughness

$$\alpha_{cond,rough} = \alpha_{conductor}\left(1 + \frac{2}{\pi} a\tan\left(1.4\left(\frac{R_{RMS}}{\delta_s}\right)^2\right)\right)$$

Copper Skin Depth



Insertion Loss Experiments

- Step 1 Make sure you have 50 ohms
- Step 2 Look at your return loss and make sure you don't have a lot of reflected power when sending power down an all 50 ohm path
- Step 3 Measure the insertion loss (S_{21})

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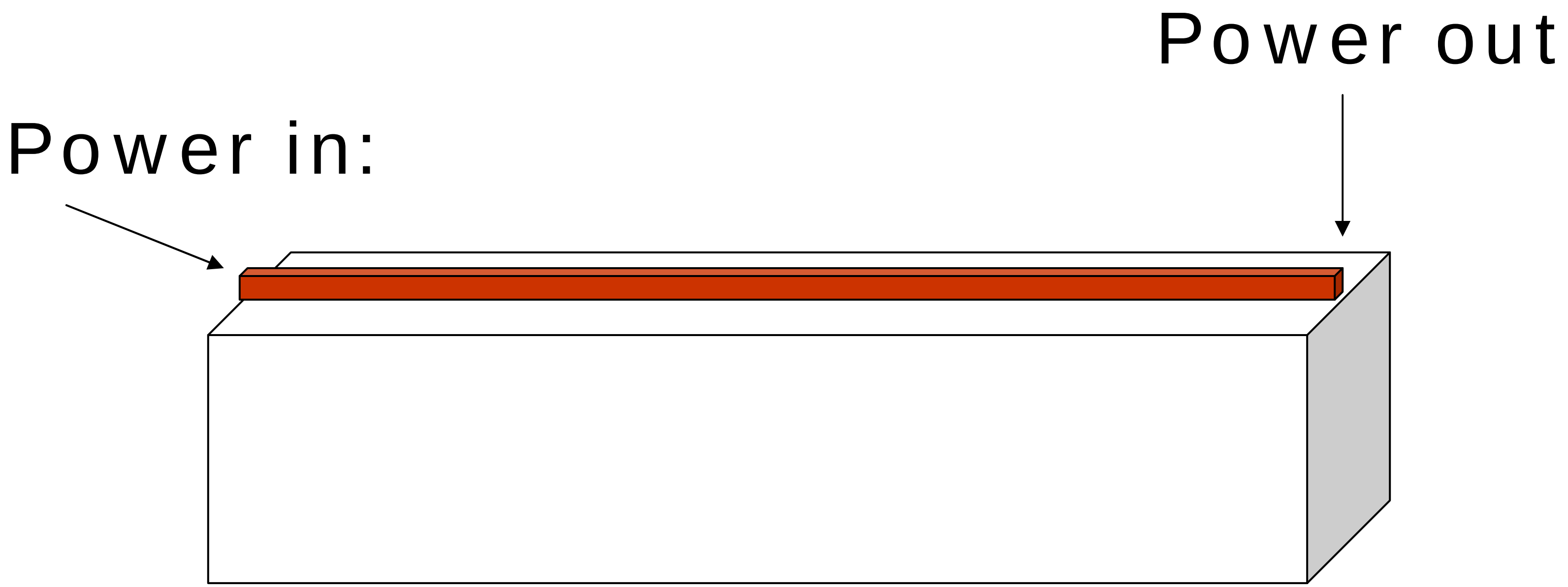
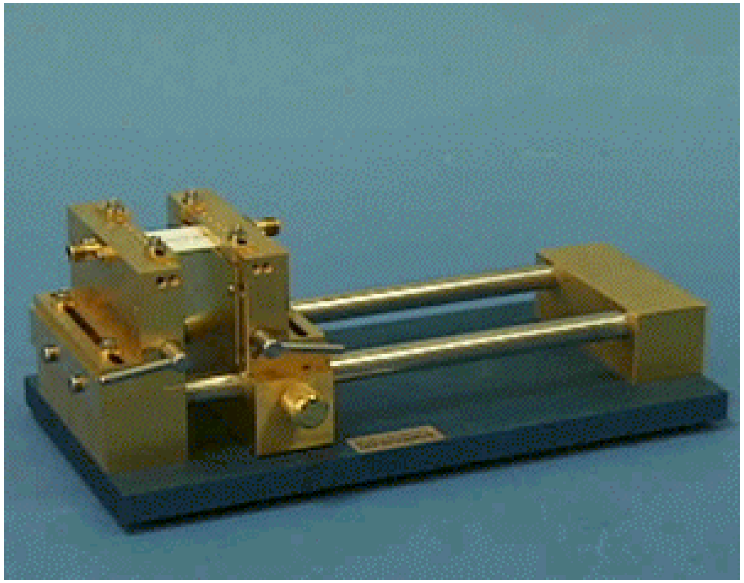
Insertion Loss – Loss in power expressed as a function of dB per inch or meter (S21)

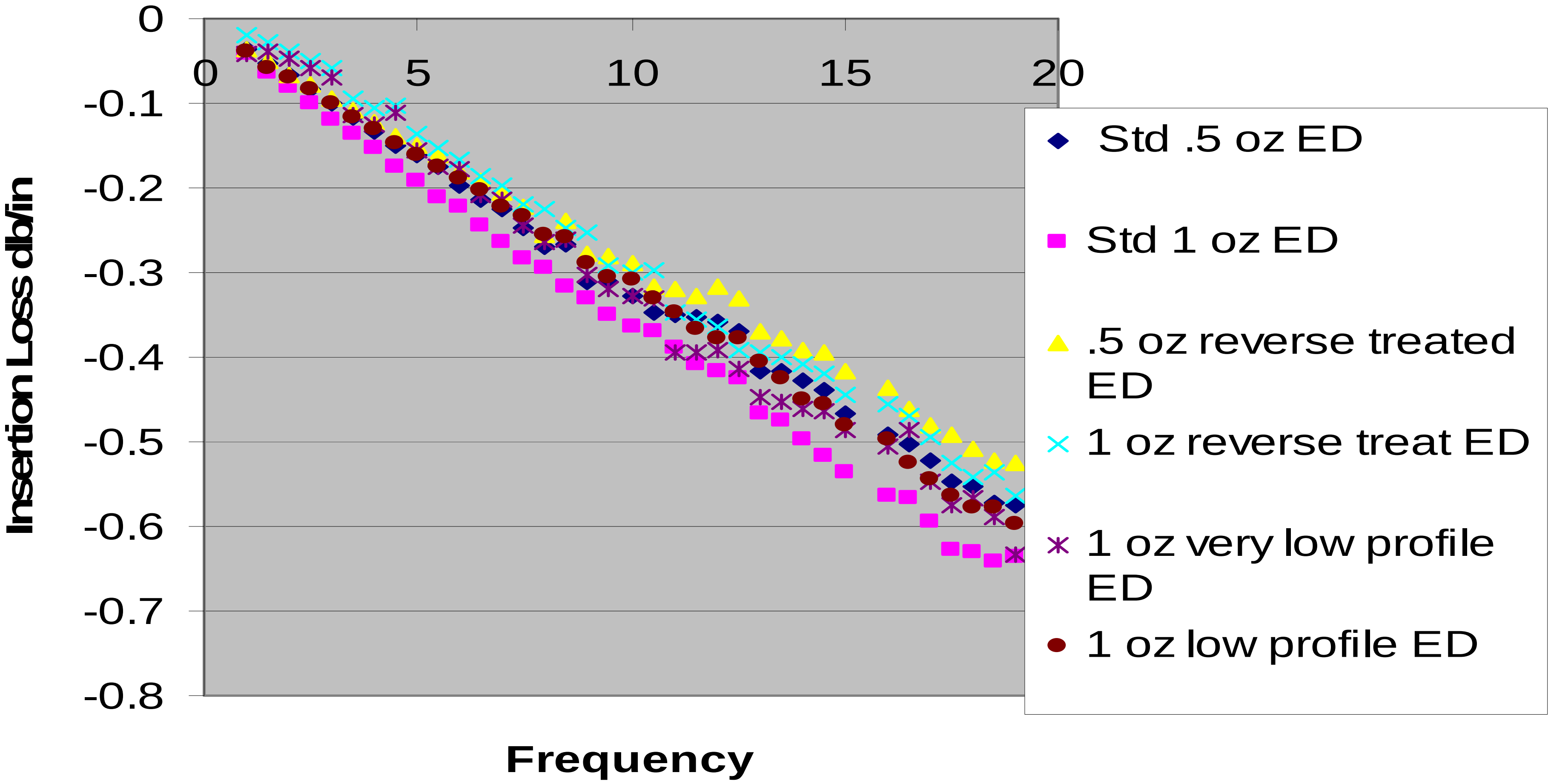


Universal Test Fixtures



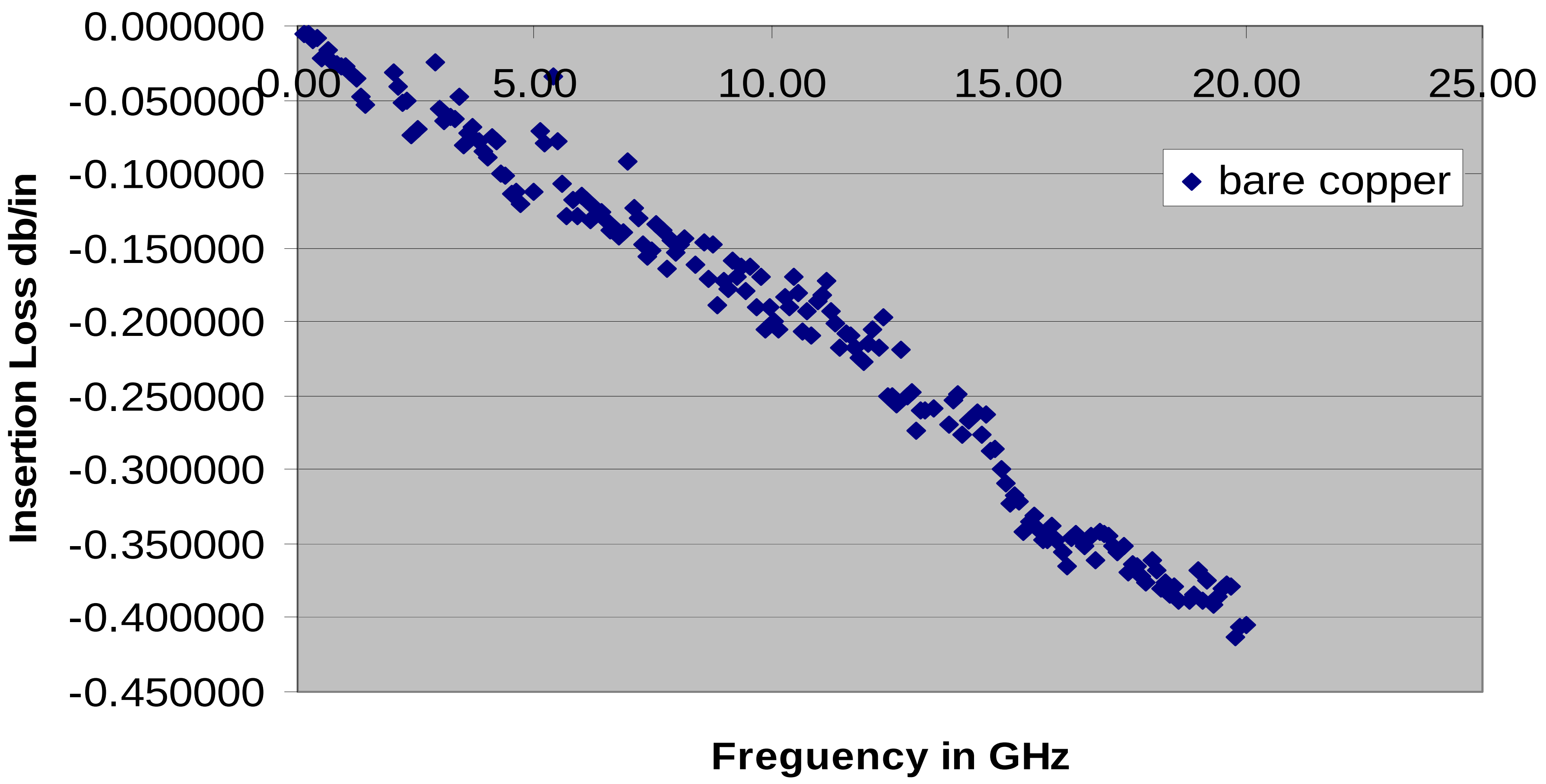
Insertion loss over frequency
Return loss
Impedance measurements

Insertion loss variation with Copper
(laminate 20 mil DT, 46 mil trace width)



Std .5oz ED: Rms 31; Std 1 oz ED: Rms 64; .5 oz reverse treat: Rms 24; 1 oz reverse treat: Rms 18; 1 oz very low profile: Rms 25; 1 oz low profile: Rms 35 (TL32-0200 based on 4 mil blocks)

Bare Copper

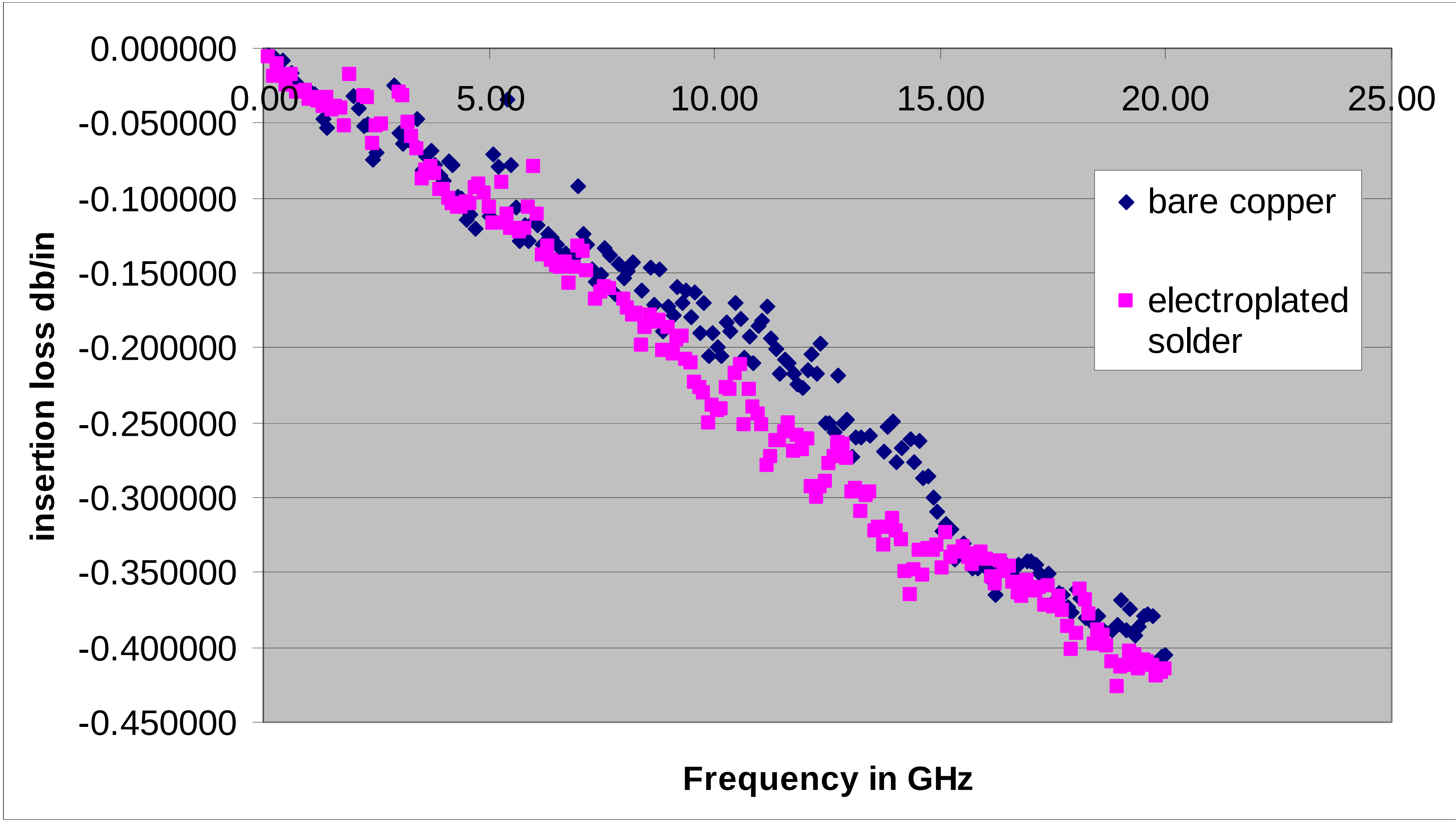


0.000000
-0.050000
-0.100000
-0.150000
-0.200000
-0.250000
-0.300000
-0.350000
-0.400000
-0.450000
0.00
5.00
10.00
15.00
20.00
25.00
bare copper
Insertion Loss db/in
Freguency in GHz

Solder Plate or Hot Air Leveled

- Traditional solder finish
- Tin Lead Plating (unfused) is typically plated to 300 – 500 microinches with no area thinner than 200 microinches
- Standard Thickness 100-500 microinches for reflowed solder to get a more uniform surface

Copper vs. Electroplated Solder



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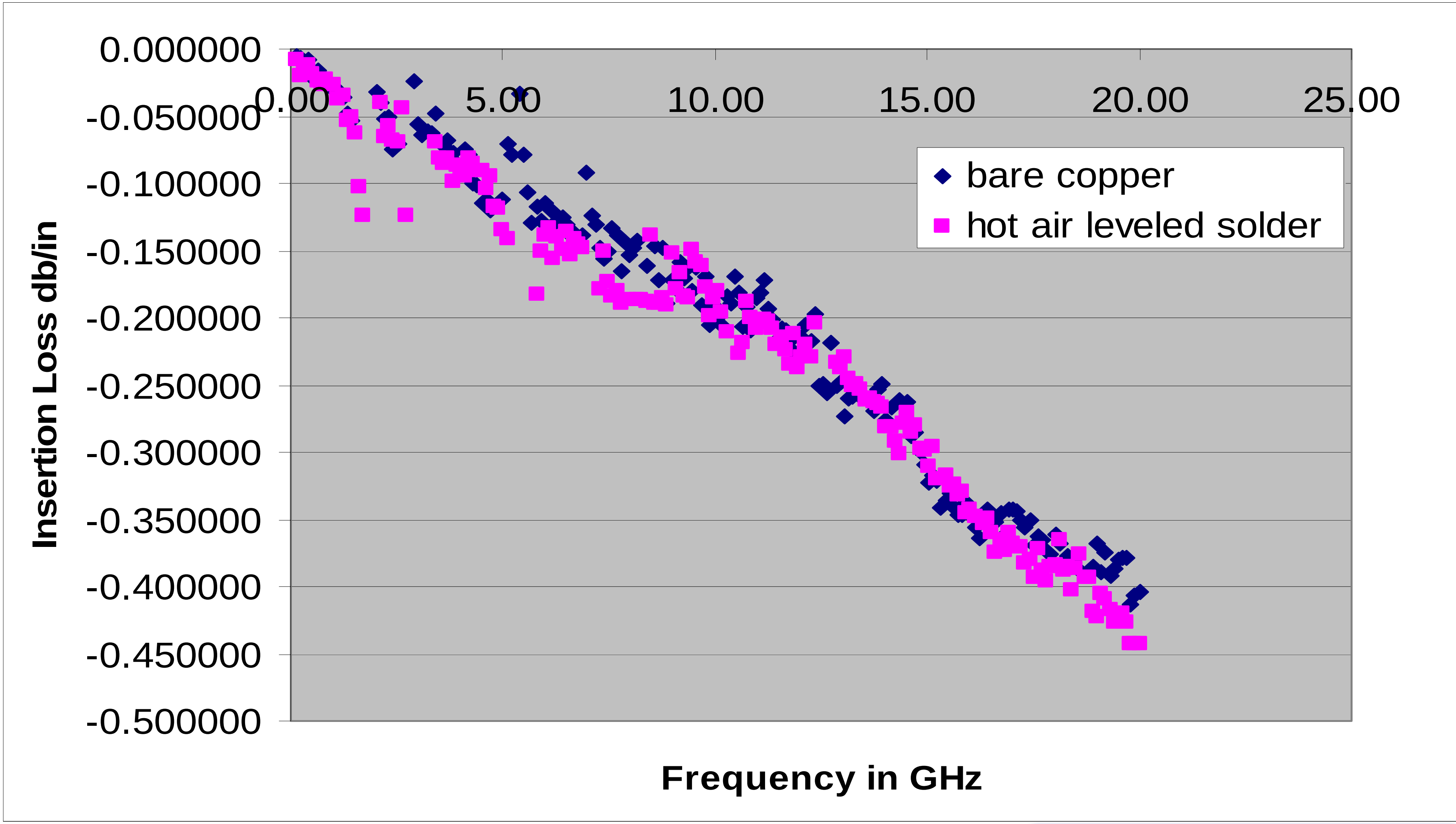
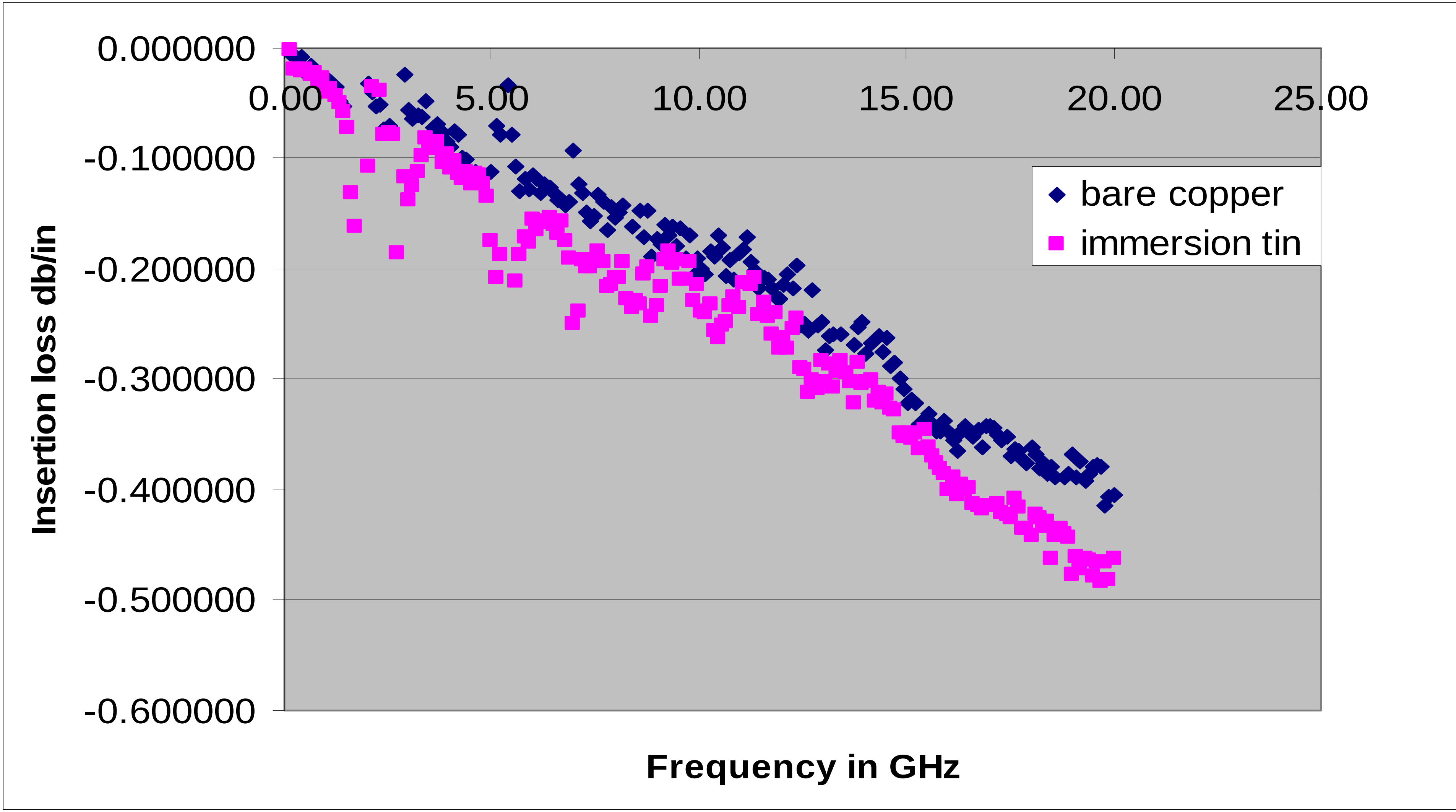
Copper vs. Hot Air Leveled Solder



Immersion Tin

- Organo-metallic tin with a fine grain structure that eliminates whisker growth
- Extremely flat finish
- Thickness; 20 – 50 microinches

Copper vs. Immersion Tin

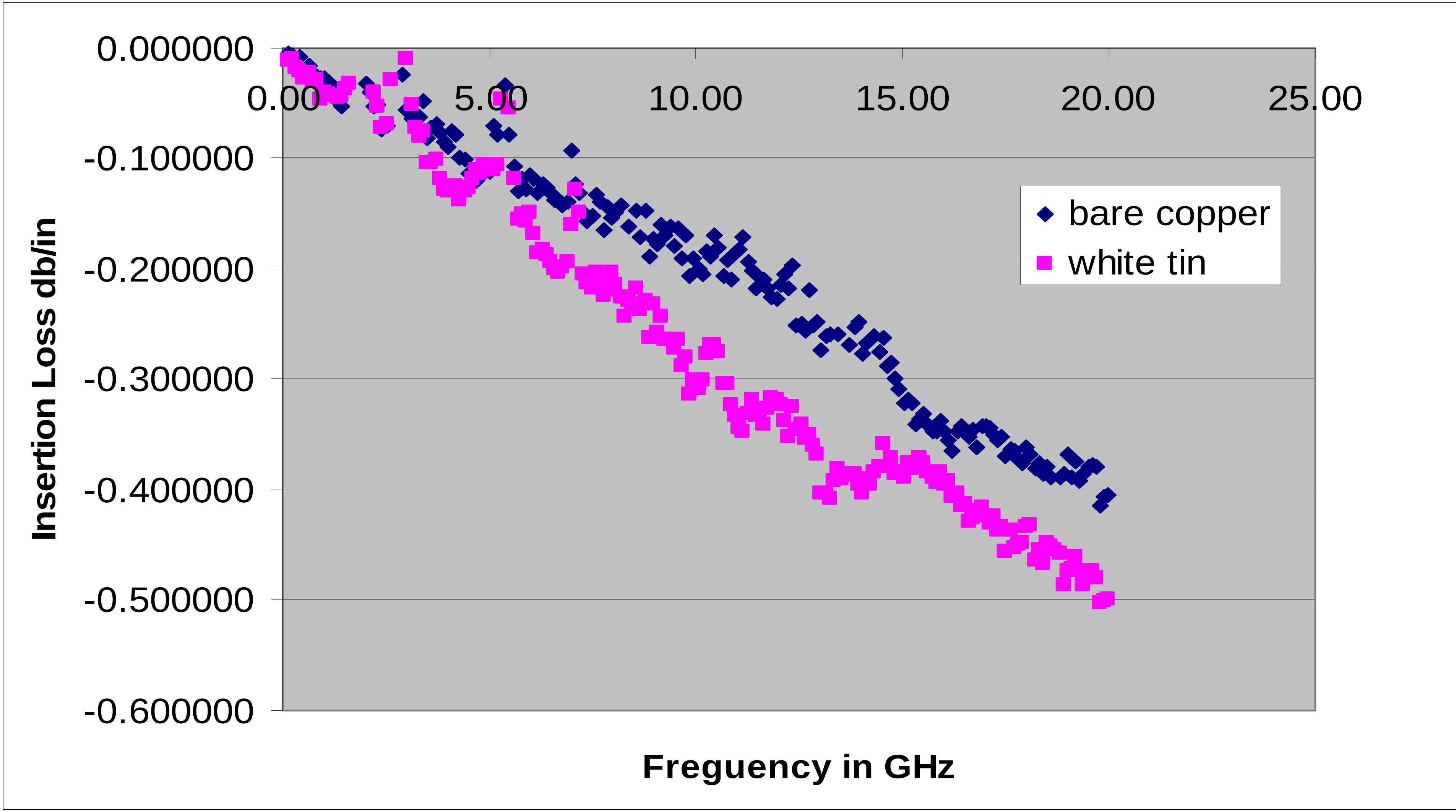


White Tin

Alternate to immersion tin finish but gives a much more uniform surface for fine line work

Thickness: 20 – 60 microinches

Copper vs. White Tin

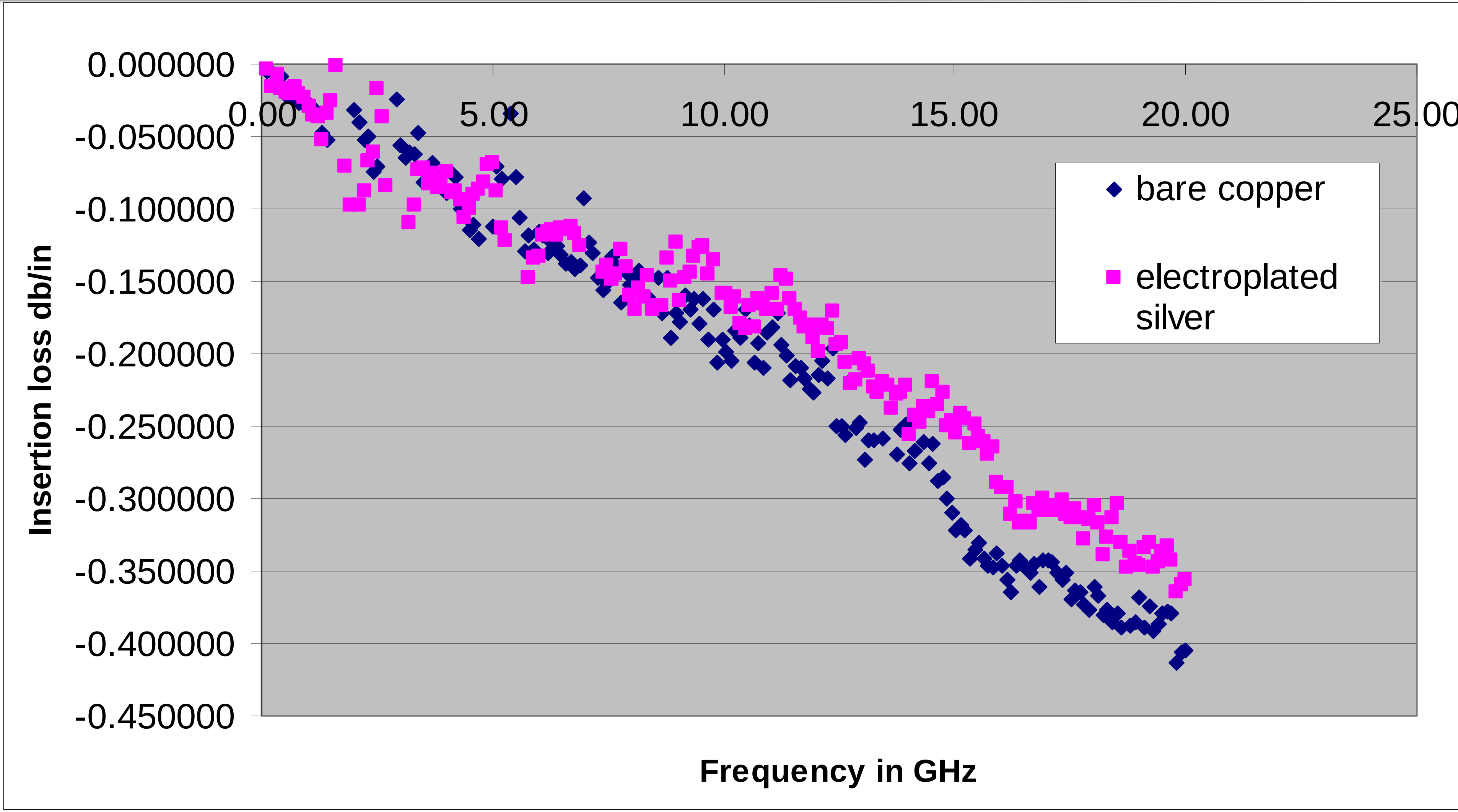


Silver Plating

Plated surface but can have problems with silver whiskers

Thickness: 5 – 40 microinches

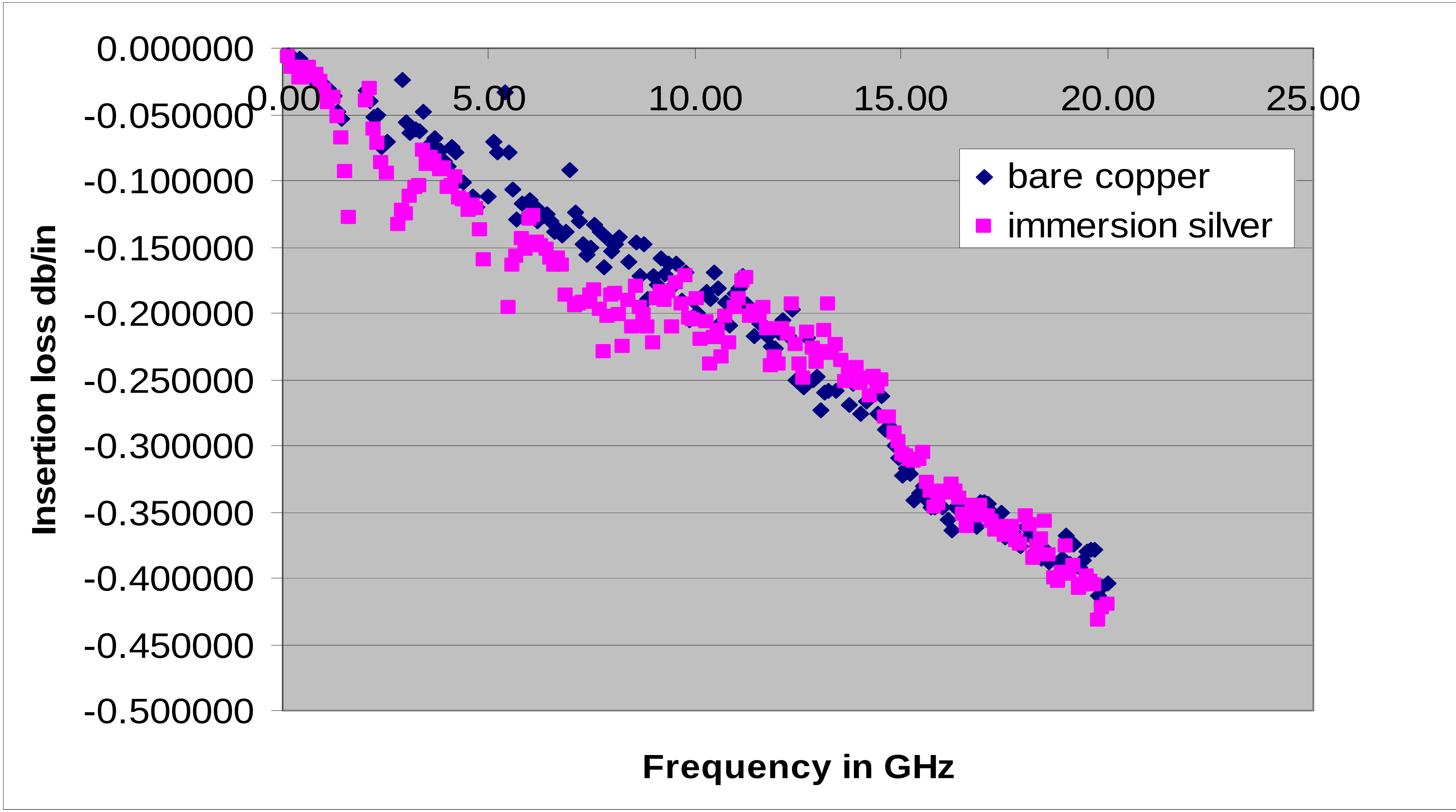
Copper vs. Electroplated Silver



Immersion Silver

- Alternative to hot air leveled solder
- Silver finish with organic additives to prevent tarnish and electromigration
- Extremely flat finish
- Thickness: 2 – 20 microinches

Copper vs. Immersion Silver



Electroless Nickel/ Immersion Gold

- Extremely flat finish
- Replacement for hot air leveled solder
- Standard thickness

  Nickel: 100 – 200 microinches

  Gold: 3 – 8 microinches

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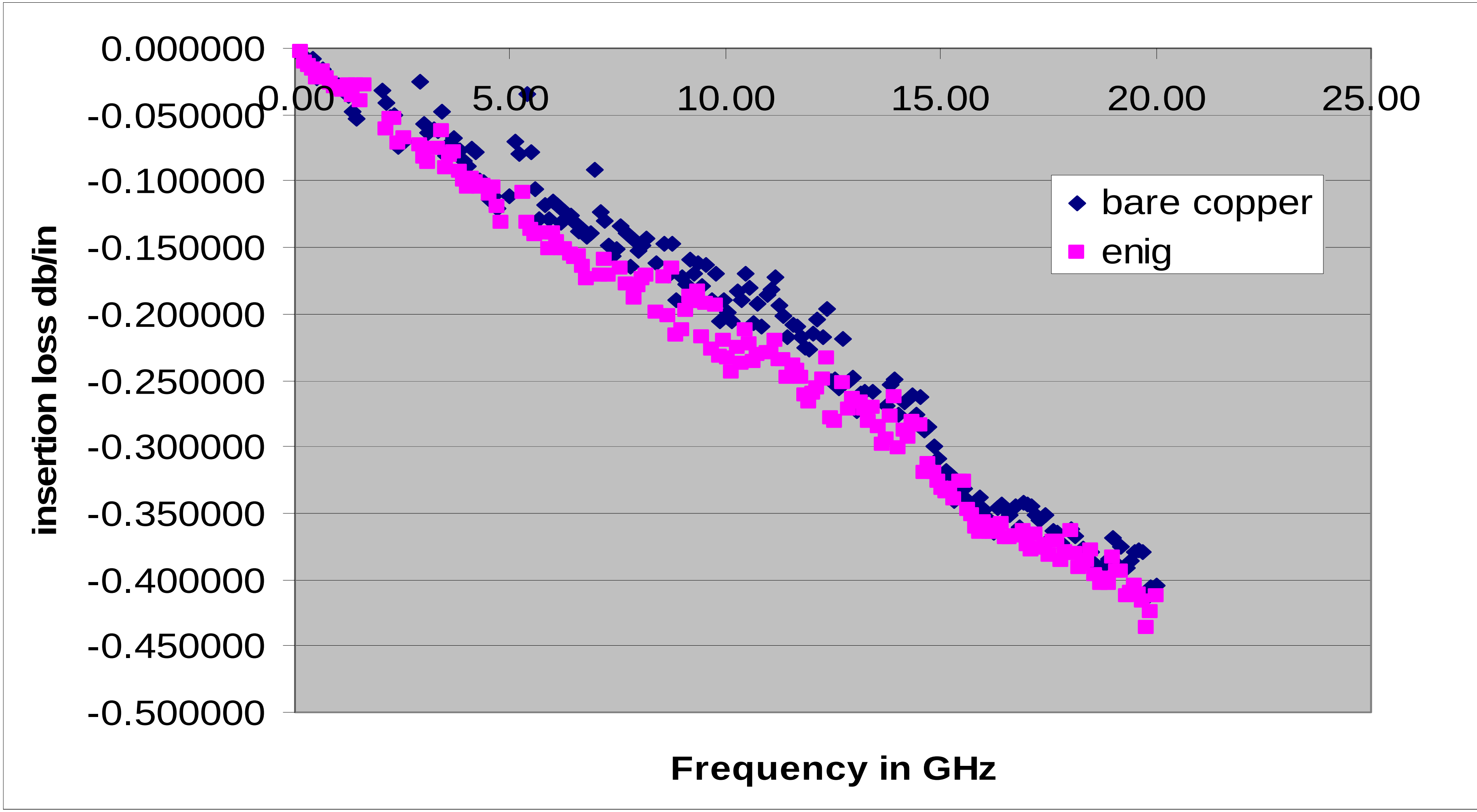
Copper vs. ENIG



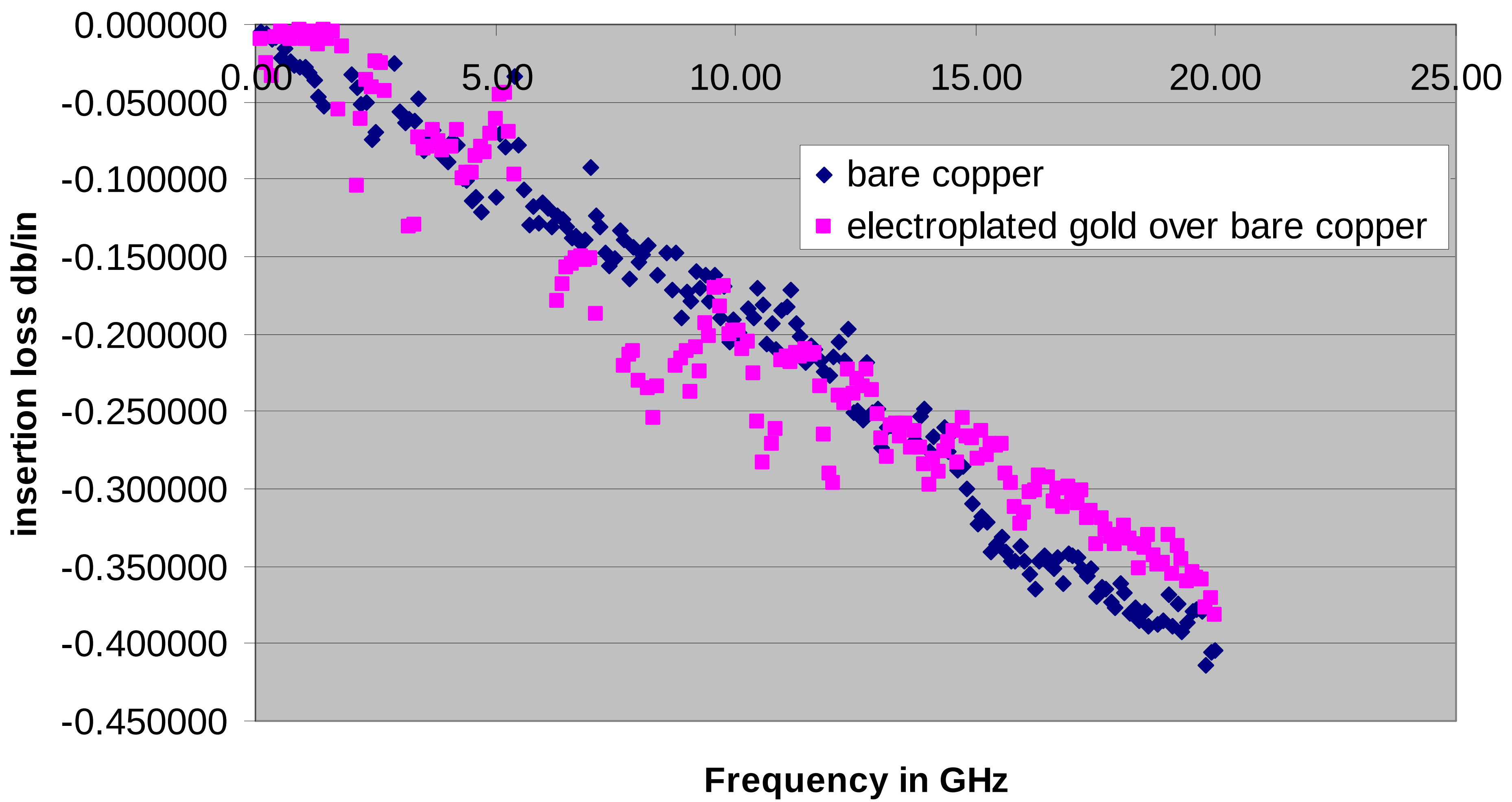
Gold Plating

Gold Plating over bare copper. Usually done with thick gold with thickness of 50 – 150 microinches to prevent ‘piping’ of copper thru to the gold surface

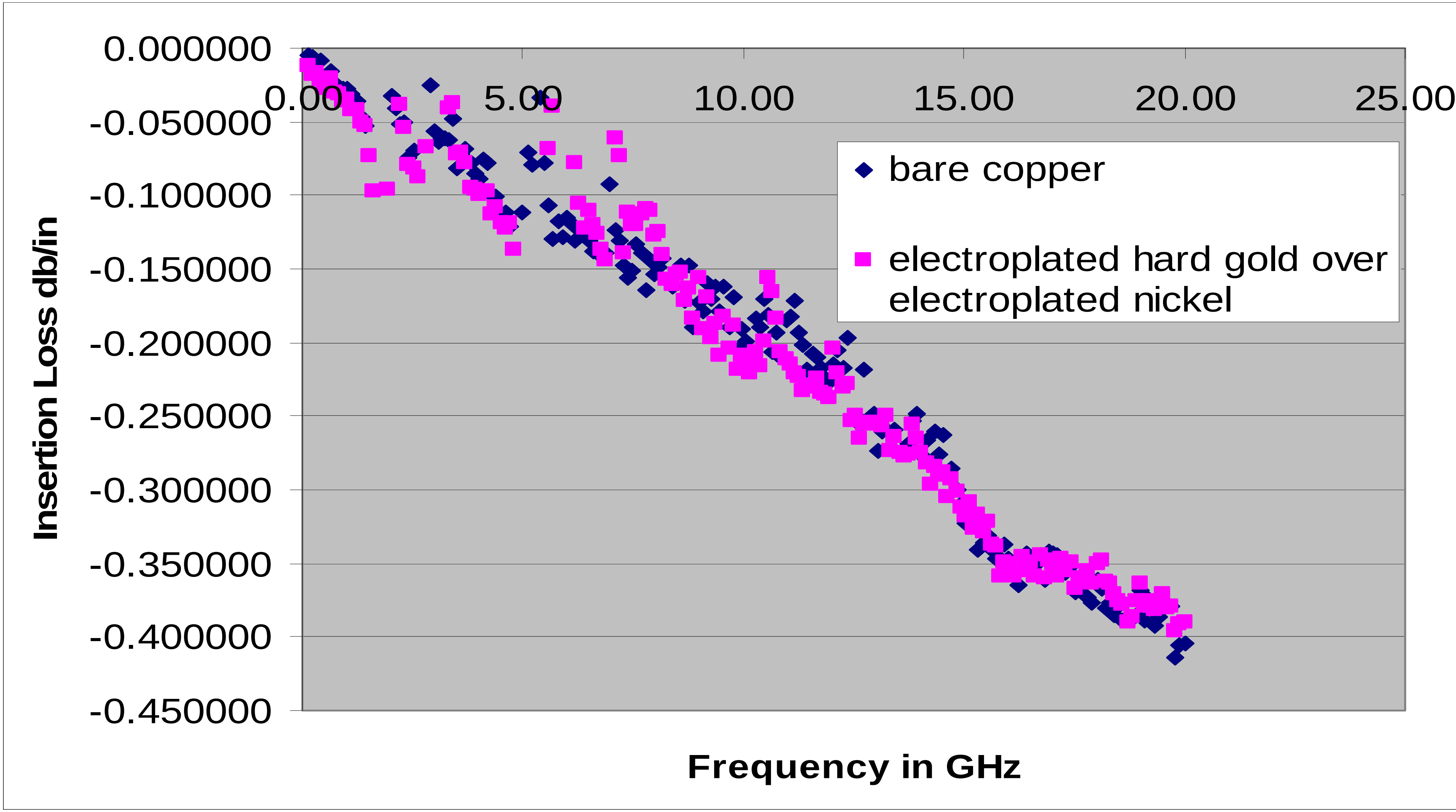
Soft Gold plated over a Nickel plated barrier is used for wire bondable surfaces. Typical thickness of 30 – 150 microinches

Hard Gold plated over a nickel plated barrier is used for sliding contacts. Typical thickness of 30 – 150 microinches

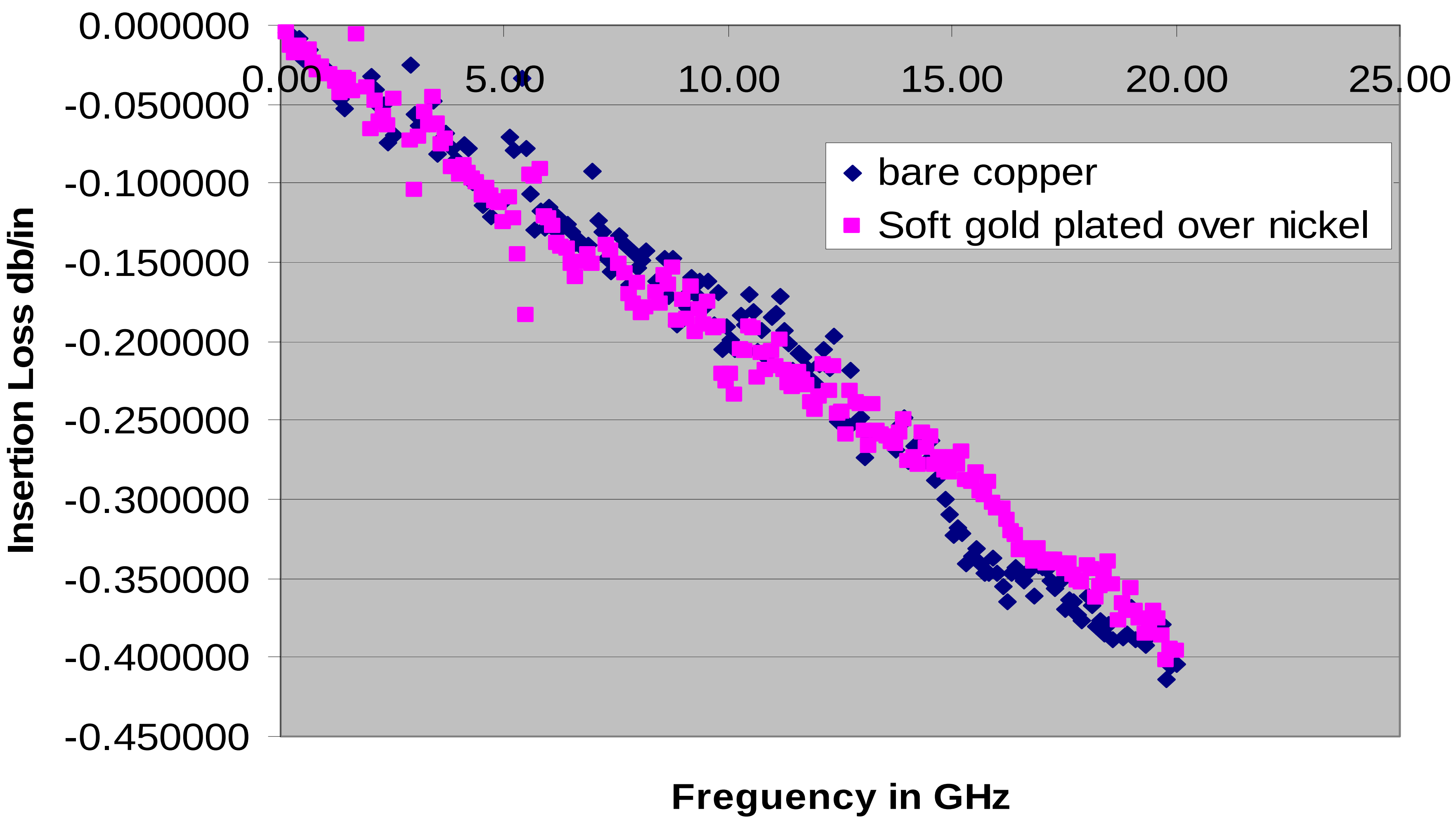
Copper vs. Plated Gold over Copper



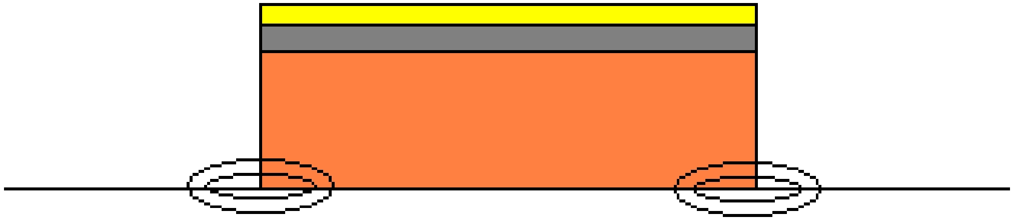
Copper vs. Electroplated Hard Gold over Nickel



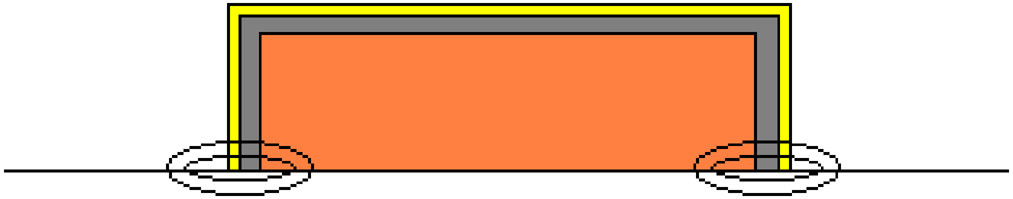
Copper vs. Soft Gold over Nickel



ELECTROLESS vs. ELECTROLYTIC

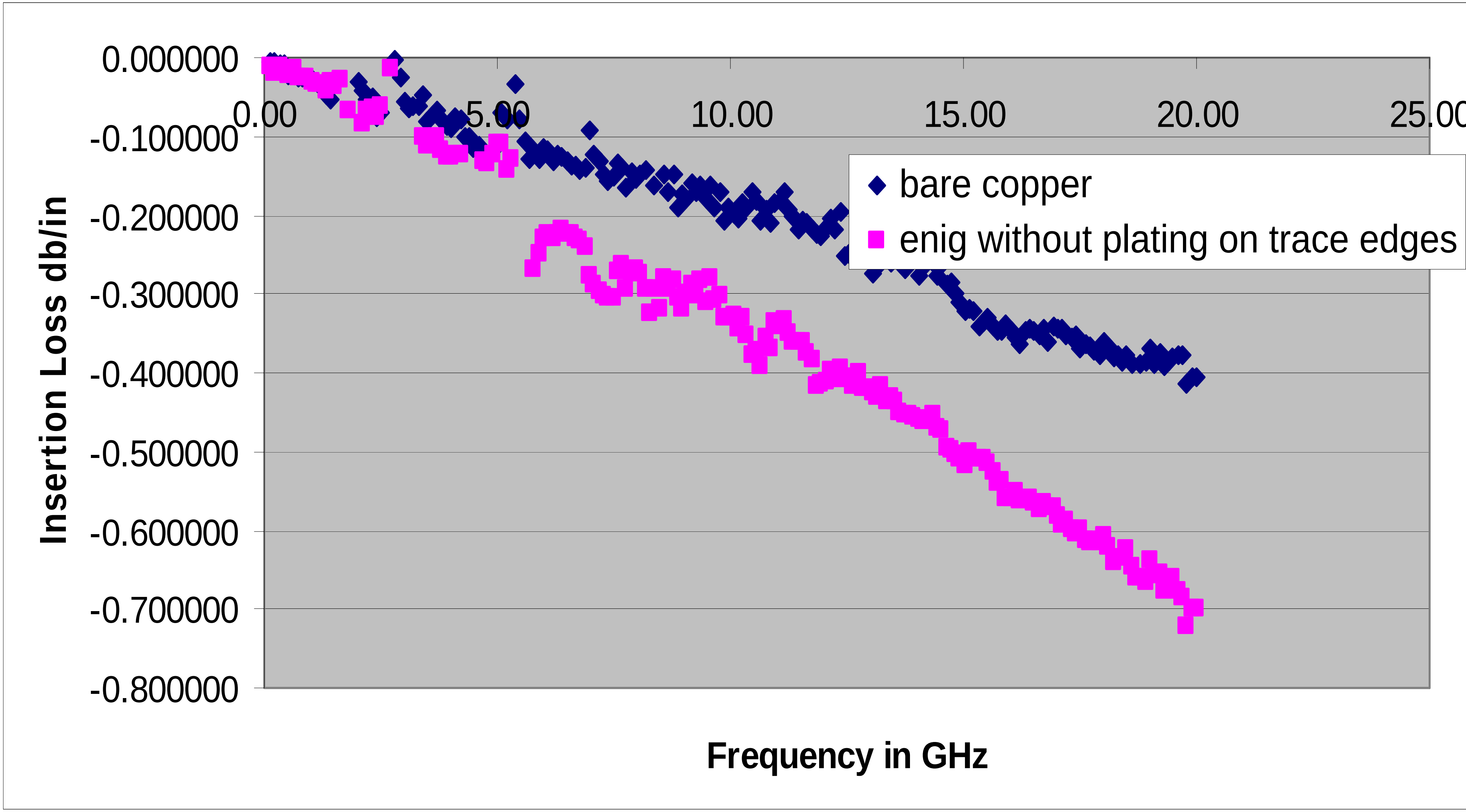


ELECTROLYTIC PATTERN PLATE



ELECTROLESS PLATE

Copper vs. ENIG without plating on traces



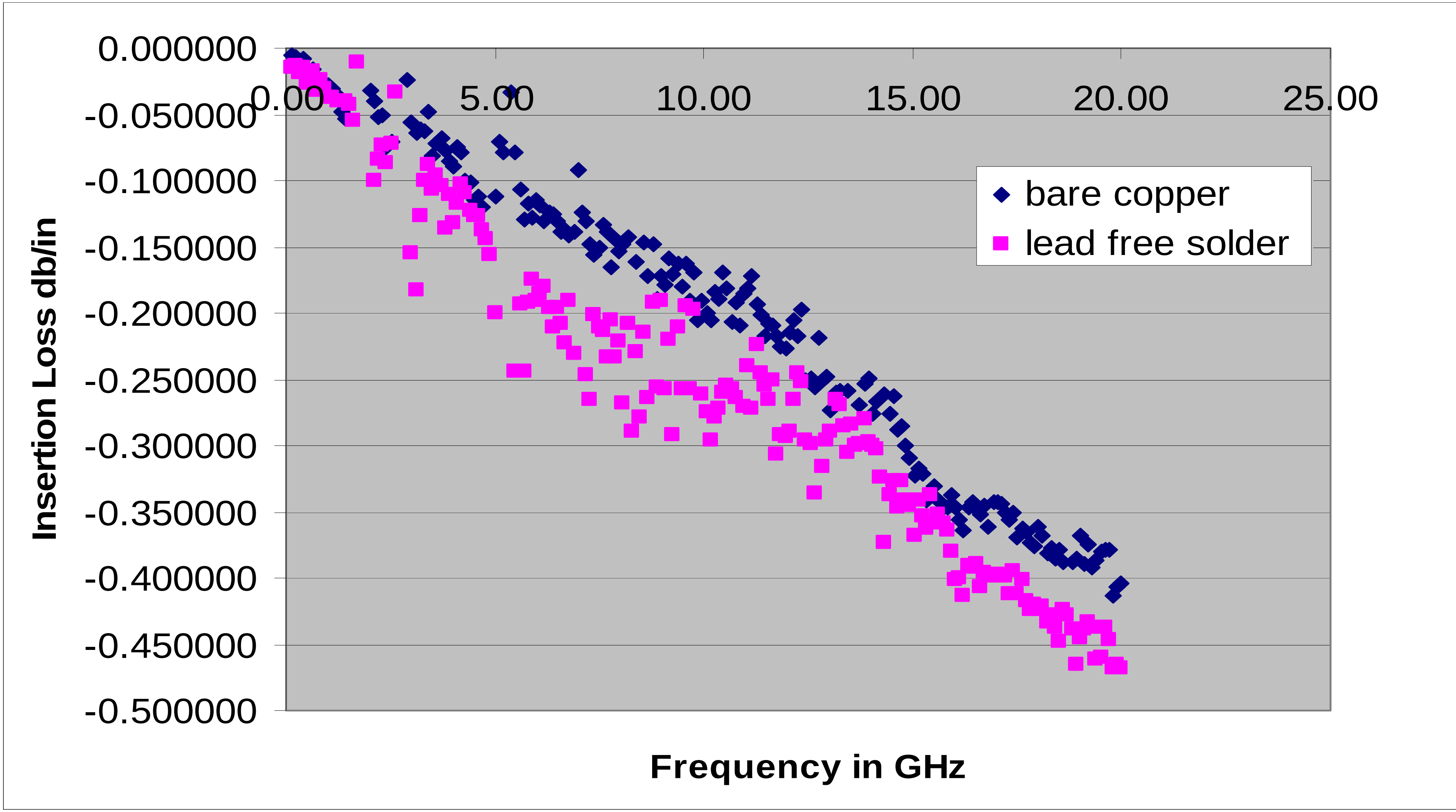
Lead Free Solder

Solder plate with out lead.

Tested was an eutectic tin-copper (98% Sn-.7% Cu) with trace amounts of nickel. This alloy helps give the surface a shiny even finish

Melts at 227C

Copper vs. Lead Free Solder



Observations

The best performance/versus cost is the old tin lead plating or reflowed solder but because of lead free issues these alternatives are no longer viable.

Gold finishes are good depending on the thicknesses…. The thicker the gold the better the performance.

Silver finishes look good.

Tin finishes appear to add to insertion loss.

Lead free solder finishes also appear to add to losses

Conclusion

The selection of a plating finish continues to be a difficult decision for the designer. There is no clear cut advantage to any particular system. The designer must understand what his PC board shop can supply and then design his board understanding the effects that the final plating finish will have on performance.

Thank you

Thank you for your attention.

For information about Taconic and our microwave laminate materials, please see us on the web at www.taconic-add.com.