Bondwire Inductance

Calculation and Measurement

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Intro

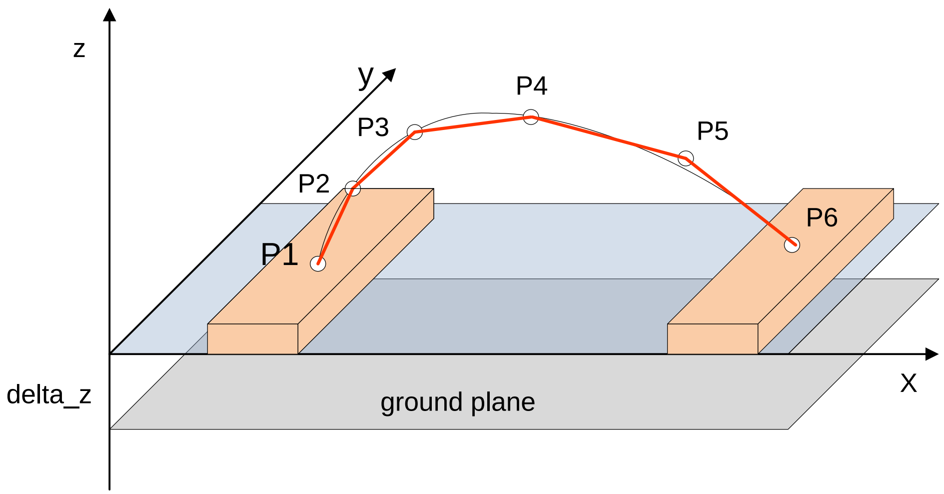
- The simulator ADS offers a possibility to determine the bond wire inductance of a package, if its geometrical shape is known
- This model was developed by Philips/TU Delft
- In the following slides it will be shown, how to use this model for inductance calculation
- The result is compared with

1. Inductance calculation using a simplified straight wire equation and
2. S-parameter measurement based inductance values

ADS inductance simulation
Input values

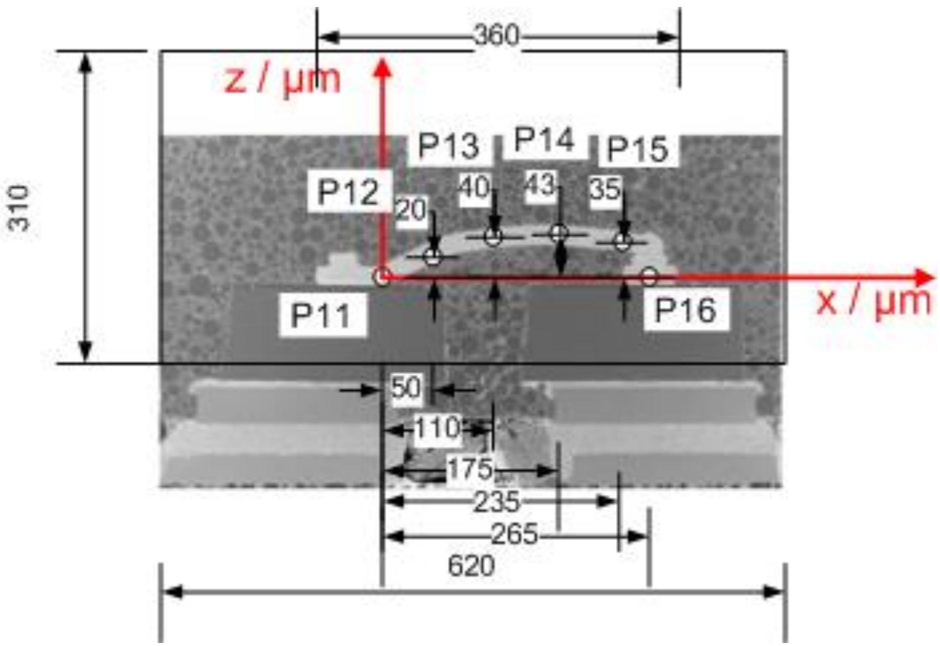
- The following input values are necessary for the ADS /Philips model [1]:

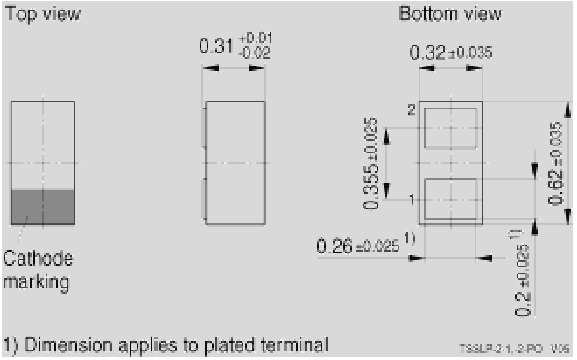
1. Description of the bond wire geometry based e.g. on X-ray photography by six coordinate vectors x, y, z
2. Specific bond wire conductance
3. Bond wire radius



	Specificic Resistance Rho	Specific Conductance Kappa
	1e-6 Ohm*m	1e6 S / m
Silver	0,016	62
Copper	0,018	56
Gold	0,022	44
Aluminium	0,028	36

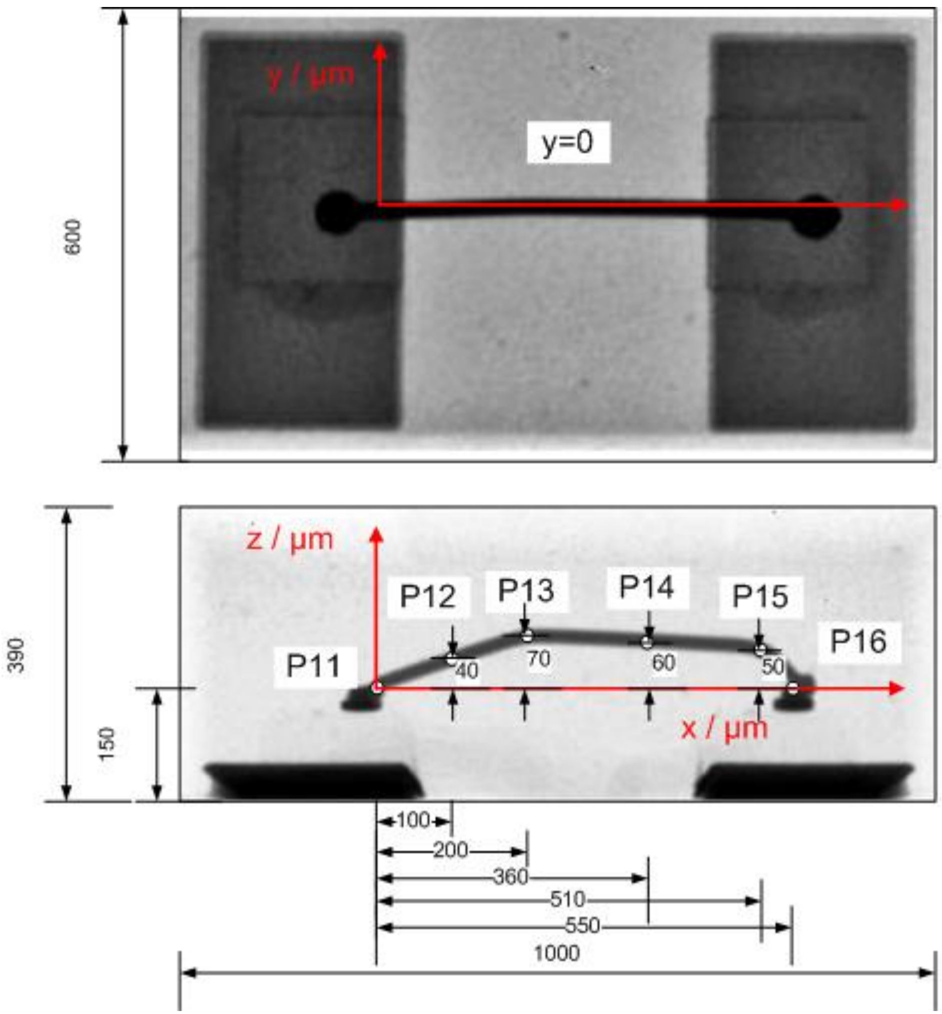
ADS inductance simulation
Example 1: TSSLP package, short wire

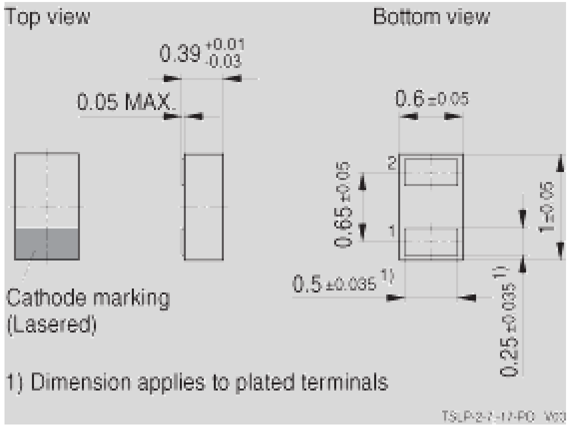




X-ray side view photo for a chip to chip bondwire in a TSSPL package

ADS inductance simulation
Example 2: TSLP, long wire





X-ray side view photo for a chip to chip bondwire in a TSPL package

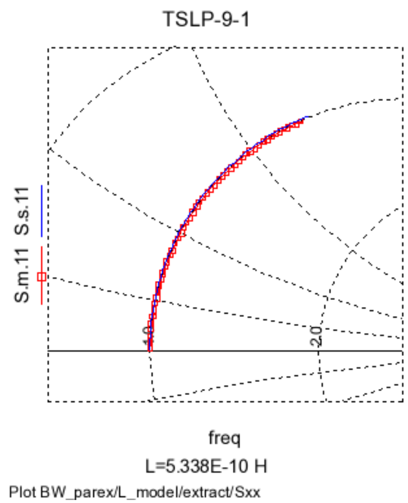
ADS inductance simulation
How to proceed

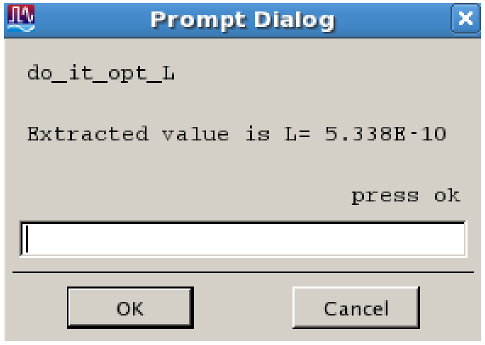
1. Simulate S11 using the ADS-bondwire-model in ICCAP
2. Convert simulated data to measured
3. Optimize L and R on S11 using a lumped circuit model

```
bondwires:myBW1 P1 P2 \
RW=2.2E-05 \
COND=5.6E+07 \
N=1 \
OPTION=1 \
x1[1]=0 x2[1]=50u  x3[1]=200u x4[1]=300u x5[1]=450u x6[1]=500u \
y1[1]=0 y2[1]=0    y3[1]=0    y4[1]=0    y5[1]=0    y6[1]=0    \
z1[1]=0 z2[1]=100u z3[1]=200u z4[1]=200u z5[1]=100u z6[1]=0
end BondwireModel
```

ADS Bondwire model:
(x,y,z values here are defaults)

Param Name	M	O	Value
myBW1.RW			11.00u
myBW1.COND			56.00MEG
myBW1.N			1.000
myBW1.OPTION			1.000
myBW1.X1[1]			0.000
myBW1.X2[1]			20.00u
myBW1.X3[1]			75.00u
myBW1.X4[1]			350.0u
myBW1.X5[1]			535.0u
myBW1.X6[1]			800.0u
myBW1.Y1[1]			0.000
myBW1.Y2[1]			10.00u
myBW1.Y3[1]			50.00u
myBW1.Y4[1]			195.0u
myBW1.Y5[1]			285.0u
myBW1.Y6[1]			445.0u
myBW1.Z1[1]			90.00u
myBW1.Z2[1]			140.0u
myBW1.Z3[1]			165.0u
myBW1.Z4[1]			140.0u
myBW1.Z5[1]			90.00u
myBW1.Z6[1]			0.000





Straight wire calculation

- For the calculation of the bondwire inductance the following approximated equation may be used [2], p.32, 97:

$$L = \frac{\mu_0}{2\Pi} * l \left[\ln\left(\frac{l}{r} + \sqrt{1 + \frac{l^2}{r^2}} \right) - \sqrt{1 + \frac{r^2}{l^2}} + \frac{r}{l} + \frac{1}{4} \right]$$

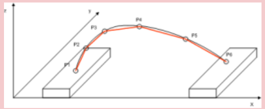
with

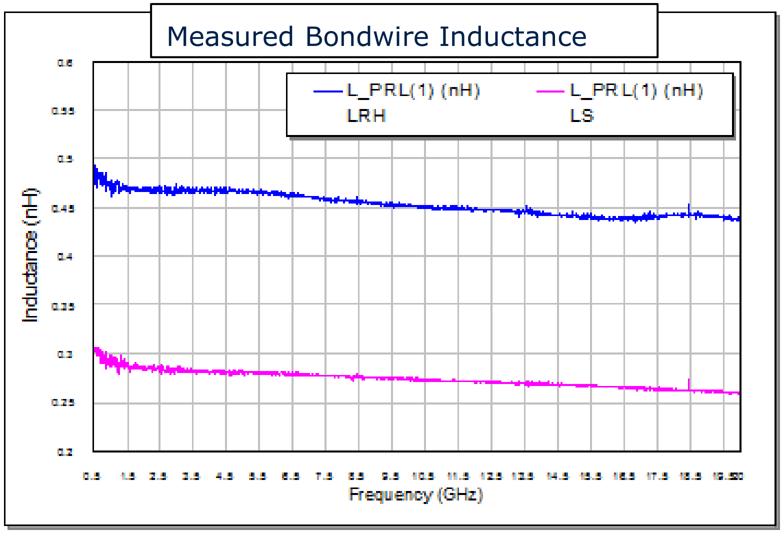
r – bondwire radius, l – bondwire length
µ0 – permeability of free space (1.2566 e-6 H/m)

- For l>>r we get the simplification:

$$L = \frac{\mu_0}{2\Pi} * l \left[\ln\left(\frac{2l}{r} \right) - 0.75 \right]$$

Bond wire inductance
Result comparison

	Straight wire equation	Philips-TU Delft model	Extracted from S-Par-Meas.
	$L = \frac{\mu_0 \cdot l}{2\pi}\left(\ln\left(\frac{4l}{d}\right) - 0{,}75\right)$		
TSSLP	185p	177p (delta_z=10mm)	260p - 290p
TSLP (c2c)	460p	419p (delta_z=10mm)	440p - 470p



Error source discussion
Straight wire calculation

- Qi [2] reports, that the straight wire equation **overestimates** the inductance by 10 to 50%.
- The more the wire is curved, the lower the inductance.
- The reason is the cancellation of the mutual inductance of the wire segments.

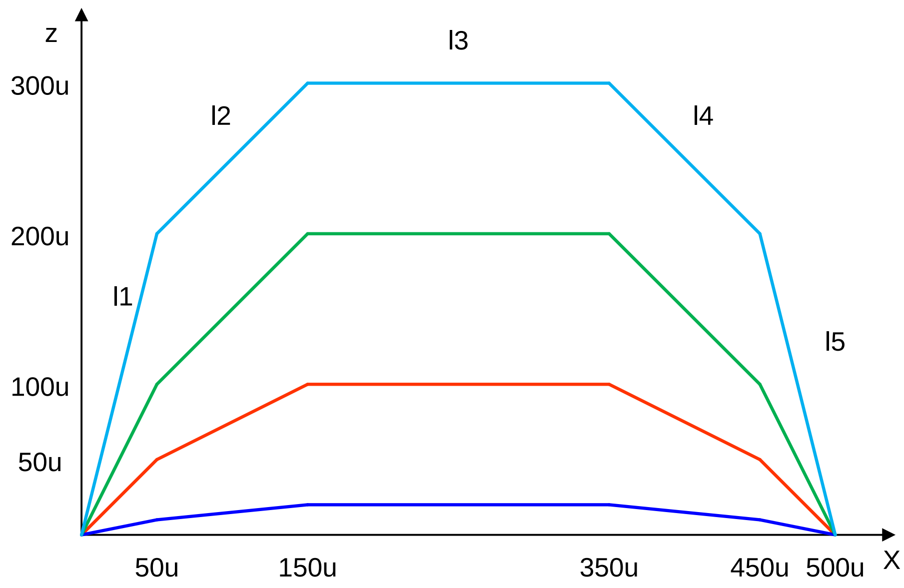
Table 5.2: Inductance comparison for three different wire shapes with the same wire length of 1.515 mm

	Straight wire	Curved wire		Π shape wire	
	Simulation result (nH)	Simulation result(nH)	Error if use straight wire	Simulation result (nH)	Error if use straight wire
100 MHz	1.192	1.011	17.9%	0.814	46.44%
1 GHz	1.160	0.979	18.49%	0.783	48.15%
10 GHz	1.152	0.970	18.76%	0.775	48.65%

Source: Qi [2]

Error source discussion
Straight wire calculation vs. ADS simulation

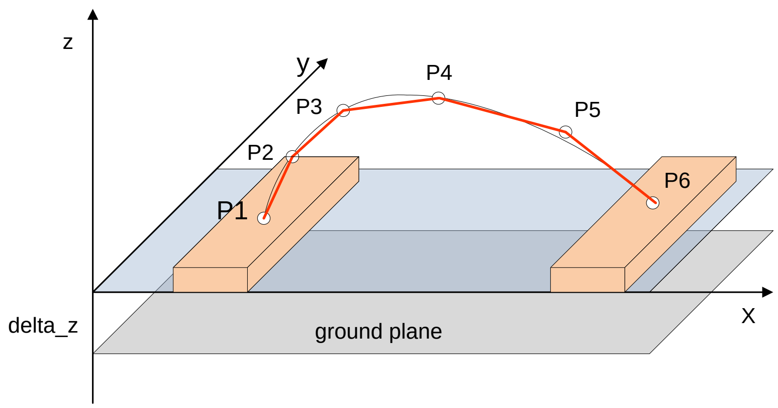
- If the segment length sum is used as wire length, we may confirm: the straight wire equation **overestimates** the inductance value
- l_wire=l1+l2+l3+l4+l5

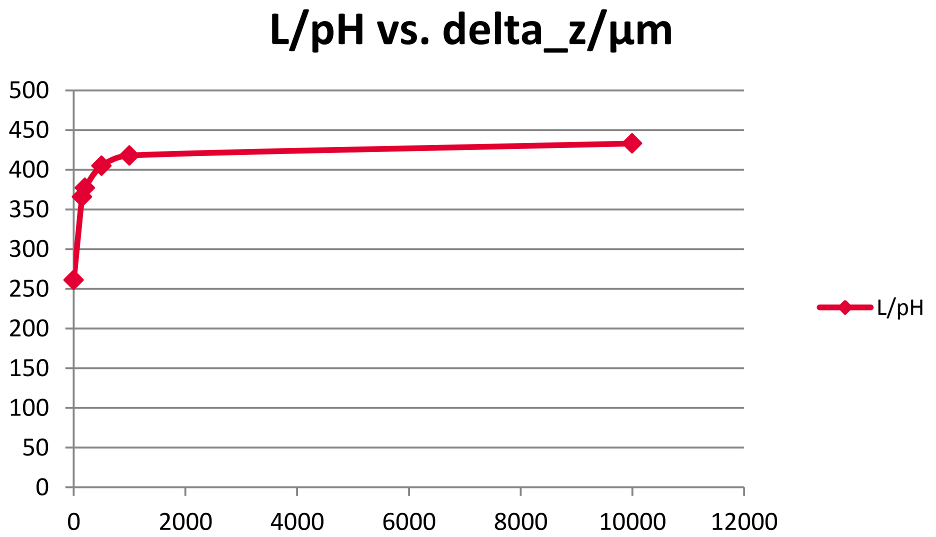


	P1	P2	P3	P4	P5	P6	r/u	dz/mm	G (S/m)	L_ADS/pH	l_wire/um	L_straight/pH	deviation
z	0	200	300	300	200	0							
x	0	50	150	350	450	500	10	1	4.40E+07	609	895	794	30%
z	0	100	200	200	100	0							
x	0	50	150	350	450	500	10	1	4.40E+07	484	706	593	23%
z	0	50	100	100	50	0							
x	0	50	150	350	450	500	10	1	4.40E+07	398	565	449	13%
z	0	10	20	20	10	0							
x	0	50	150	350	450	500	10	1	4.40E+07	361	503	388	7%

Error source discussion
ADS calculation, ground plane effect

- A strong effect of ground plane distance delta_z is observed
- Highest values are extracted if delta_z is very large.





Effect of the distance to ideal ground plane
delta_z for the TSLP package

Summary

- Two methods of bond wire inductance calculation have been investigated:
  a) straight line equation
  b) ADS model
- Compared to measurements we found:
  a) for the long wire (550 µm) both calculation results fit sufficient to the measurement
  b) for the short wire (265 µm) the deviation is too large, about 40%
- The valued found by the straight line equation are higher, than the ADS model values, depending on the shape
- For the ADS model the ground plane distance has a strong affect on the extracted inductance value: the higher the distance, the higher the inductance

References

- [1] Agilent Technologies: “BONDW Usershape, Philips-TU Delft Bondwire Model with User-Defined Shape, http://cp.literature.agilent.com/litweb/pdf/ads2008/ccdist/ads2008/BONDW_Usershape_(Philips-TU_Delft_Bondwire_Model_with_User-Defined_Shape).html

- [2] Qi, Xiaoning: “High frequency characterization and modeling of on-chip interconnects and RF IC wire bonds”, Dissertation, Stanford University, June 2001

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