Key parameters of coaxial connector models - mechanical design features and electrical properties

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1 Model of the Slotless Connector

The geometry of the male part of a slotless coaxial connector is quite simple (Fig. 1). The various chamfers are unavoidable machining artifacts. As given

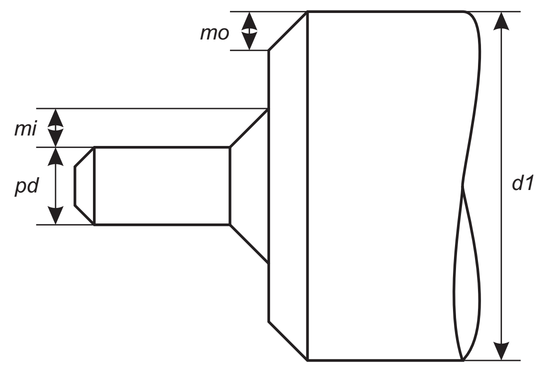

Figure 1: Male part of the connector.

in Fig. 1 the following dimensions are used to characterize the male connector.

d1 Diameter of male center conductor

mo Male outer chamfer

mi Male inner chamfer

pd Pin diameter

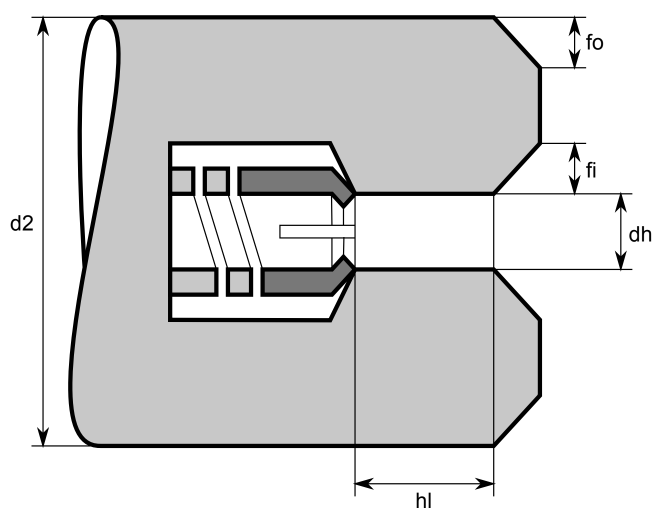

Figure 2: Cross-section of the female slotless connector.

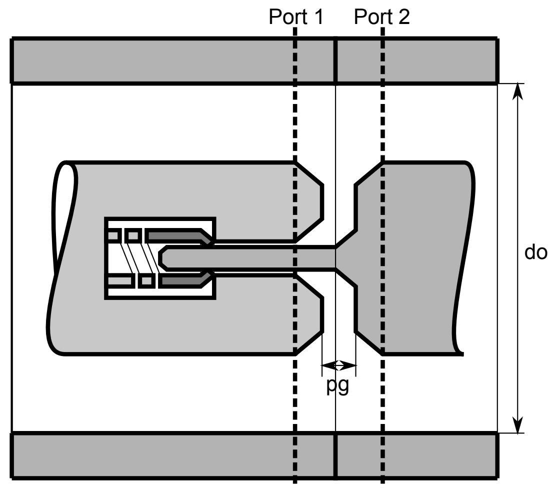

Figure 3: Cross-section of the assembled slotless connector.

The female slotless connector, Fig. 2, can be characterized by the following dimensions.

fo Female outer chamfer

fi Female inner chamfer

dh Hole diameter

hl Hole length

d2 Female center conductor diameter

A slotless connector, which is assembled, is depicted in Fig. 3. The assembly process yields two additional geometry variables.

pg Pin gap

do Diameter of outer conductor

2 Model of the Slotted Connector

The geometry of a slotted connector is quite complicated. A very intuitive way to define the dimensions of such a connector is to specify the production process. In a first step the male side of the connector is manufactured. The male connector, Fig. 1, is again specified by the following dimensions.

d1 Diameter of male center conductor

mo Male outer chamfer

mi Male inner chamfer

pd Pin diameter

The first step for the production of the female slotted contact is to lathe a profile on the center conductor. Then the hole for the male pin is drilled and the inner and outer chamfers are made, Fig. 4. In Fig. 4 the following variables

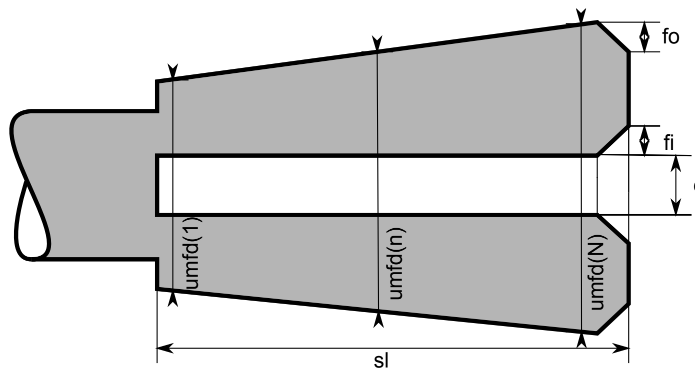

Figure 4: Cross-section of the slotted contact before slotting.

are defined.

sl Slot length

fo Female outer chamfer

fi Female inner chamfer

dh Hole diameter

umfd(n) Uncompressed mid finger diameter

Note that an arbitrary number of uncompressed mid finger diameters can be used to describe the lathed profile. The distance between the length locations of the diameters is constant. As a next step the slots are cut. This introduces a new geometry variable.

sw Slot width

Then the fingers are bent towards the center. In Fig. 5 a lateral cut through the slotted section with an inserted male pin is shown. The bending process can be characterized by two variables.

cmfd(n) Compressed mid finger diameter

do(n) Outer diameter

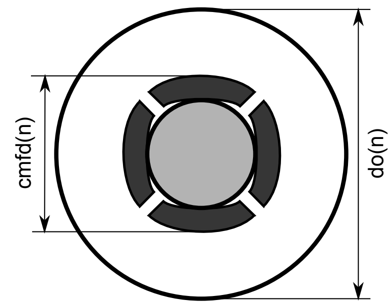

Figure 5: Lateral cut through the slotted section.

Note that all geometry variables which are marked with **(n)** are meant as a list of values describing the geometry at each length location.

Assembling the slotted connector yields two additional variables, see Fig. 6.

pg Pin gap

do Diameter of outer conductor

Note that **do(n)** refers to the diameter of the outer conductor at length location **n** in the slotted section, whereas **do** refers to the diameter of the outer conductors between the outer edge of the outer female chamfer and the outer edge of the outer male chamfer.

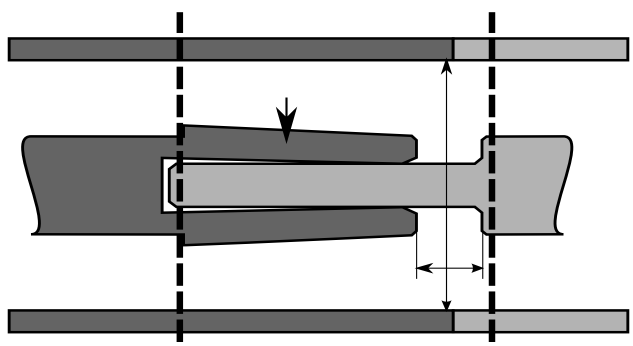

Figure 6: Cross section of the slotted connector

3 Typical Parameters and uncertainties of slotless connectors

The conductivity of metal is assumed as infinite and the dielectric is assumed to be vacuum. The given uncertainties are measurement uncertainties and they are stated with an expansion factor $k = 2$. It is proposed to do electromagnetic simulations with a frequency grid of 100 MHz. E.g. a connector with maximum operating frequency 18 GHz will have 180 points.

3.1 Type N Connector

The maximum operating frequency of the N-connector is 18 GHz.

parameter	value	uncertainty
pg	15 µm	3 µm
mi	15 µm	5 µm
mo	15 µm	5 µm
fi	50 µm	5 µm
fo	15 µm	5 µm
hl	150 µm	10 µm
dh	1.69 mm	1 µm
pd	1.651 mm	1 µm
$d1$	3.04 mm	1 µm
do	7 mm	1 µm
$d2$	3.04 mm	1 µm

3.2 3.5 mm Connector

The maximum operating frequency of the 3.5 mm connector is 33 GHz.

parameter	value	uncertainty
pg	15 µm	3 µm
mi	15 µm	5 µm
mo	15 µm	5 µm
fi	50 µm	5 µm
fo	15 µm	5 µm
hl	150 µm	10 µm
dh	950 µm	1 µm
pd	930 µm	1 µm
$d1$	1.52 mm	1 µm
do	3.5 mm	1 µm
$d2$	1.52 mm	1 µm

3.3 2.4 mm Connector

The maximum operating frequency of the 2.4 mm connector is 50 GHz.

parameter	value	uncertainty
pg	15 µm	3 µm
mi	15 µm	5 µm
mo	15 µm	5 µm
fi	50 µm	5 µm
fo	15 µm	5 µm
hl	150 µm	10 µm
dh	530 µm	1 µm
pd	511 µm	1 µm
$d1$	1.0423 mm	1 µm
do	2.4 mm	1 µm
$d2$	1.0423 mm	1 µm

4 Typical Parameters and uncertainties of slotted connectors

In the following it is assumed that the profile between $umfd(1)$ and $umfd(N)$ is straight, i.e. linear decrease or increase of diameter with respect to z-position. Additionally it is assumed that the profile between $cmfd(1)$ and $cmfd(N)$ is straight as well. There are always four slots in the slotted female contact. The conductivity of metal is assumed as infinite and the dielectric is assumed to be vacuum. The given uncertainties are measurement uncertainties and they are stated with an expansion factor $k = 2$. It is proposed to do electromagnetic simulations with a frequency grid of 100 MHz. E.g. a connector with maximum operating frequency 40 GHz will have 400 points.

4.1 2.92 mm Connector

The maximum operating frequency of the 2.92 mm connector is 40 GHz.

parameter	value	uncertainty
pg	15 µm	3 µm
mi	15 µm	5 µm
mo	15 µm	5 µm
fi	50 µm	5 µm
fo	15 µm	5 µm
sl	2.5 mm	50 µm
sw	100 µm	5 µm
pd	930 µm	1 µm
dh	950 µm	1 µm
$d1$	1.27 mm	1 µm
do	2.92 mm	1 µm
$cmfd(1)$	1.27 mm	1 µm
$cmfd(N)$	1.32 mm	1 µm

4.2 1.85 mm Connector

The maximum operating frequency of the 1.85 mm connector is 65 GHz.

parameter	value	uncertainty
pg	15 µm	3 µm
mi	15 µm	5 µm
mo	15 µm	5 µm
fi	50 µm	5 µm
fo	15 µm	5 µm
sl	1.5 mm	50 µm
sw	100 µm	5 µm
pd	511 µm	1 µm
dh	530 µm	1 µm
$d1$	803.6 µm	1 µm
do	1.85 mm	1 µm
$cmfd(1)$	803.6 µm	1 µm
$cmfd(N)$	820 µm	1 µm

4.3 1.00 mm Connector

The maximum operating frequency of the 1.00 mm connector is 110 GHz.

parameter	value	uncertainty
pg	15 µm	5 µm
mi	15 µm	5 µm
mo	15 µm	5 µm
fi	30 µm	5 µm
fo	15 µm	5 µm
sl	1 mm	50 µm
sw	0.75 mm	10 µm
pd	250 µm	1 µm
dh	270 µm	1 µm
$d1$	434 µm	1 µm
do	1 mm	1 µm
$cmfd(1)$	434 µm	1 µm
$cmfd(N)$	450 µm	1 µm

5 Reflection and Transmission Coefficients

The reflection and transmission coefficients of the in section 3 and 4 defined connectors are plotted in Figs. 7 to 12. The respective reference planes are depicted in Figs. 3 and 6. The plotted results refer to reflection at the port on the female side and transmission from the port on the female side to the male side. The link between trace and corresponding connector can be made by the maximum operating frequency of the connector.

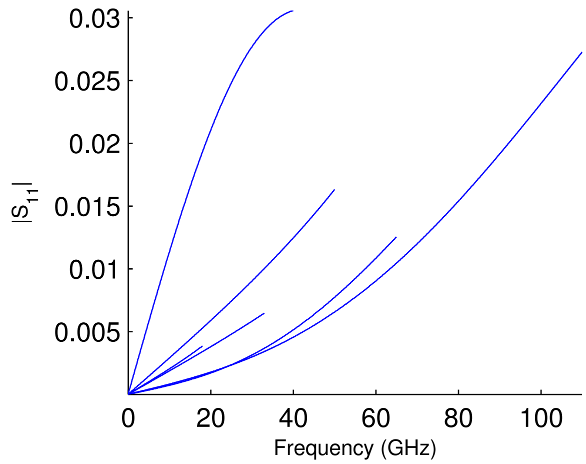

Figure 7: The magnitude of the reflection coefficient is plotted vs. the frequency.

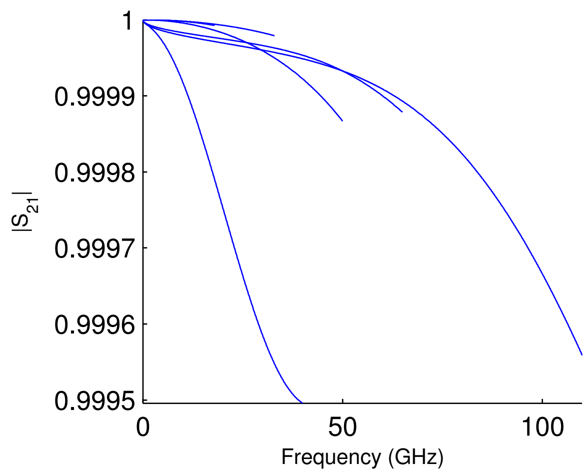

Figure 8: The magnitude of the transmission coefficient is plotted vs. the frequency.

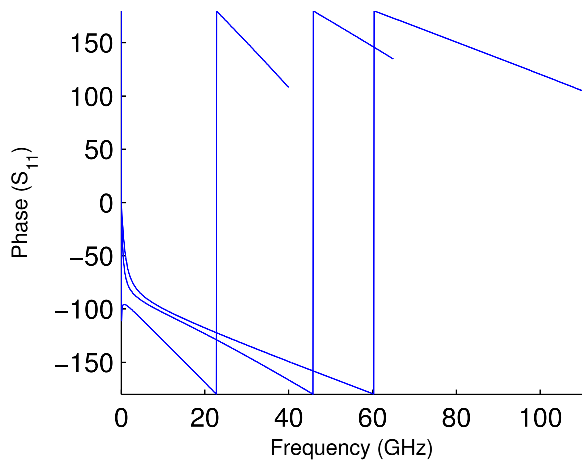

Figure 9: The phase of the reflection coefficient is plotted vs. the frequency. Only slotted connectors are considered in this plot.

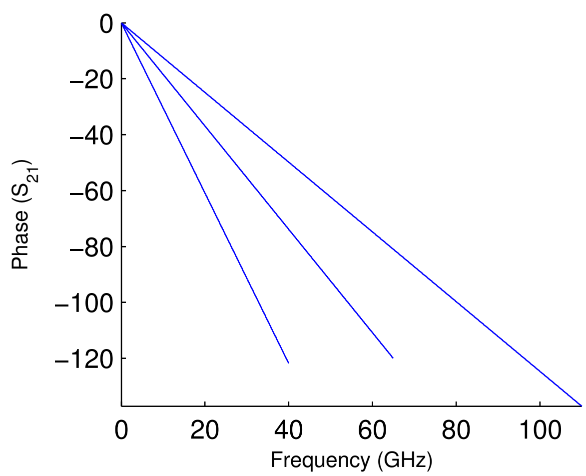

Figure 10: The phase of the reflection coefficient is plotted vs. the frequency. Only slotted connectors are considered in this plot.

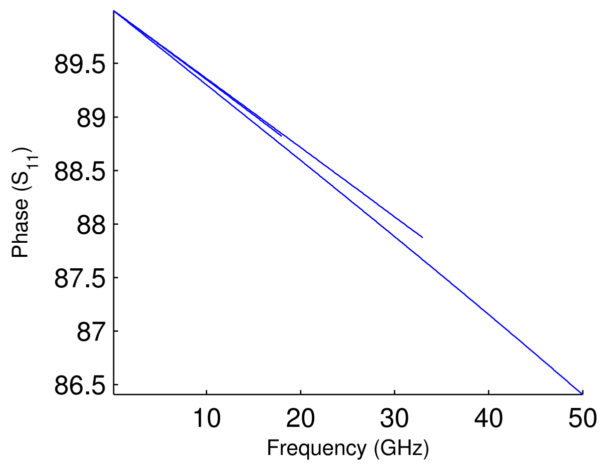

Figure 11: The phase of the reflection coefficient is plotted vs. the frequency. Only slottless connectors are considered in this plot.

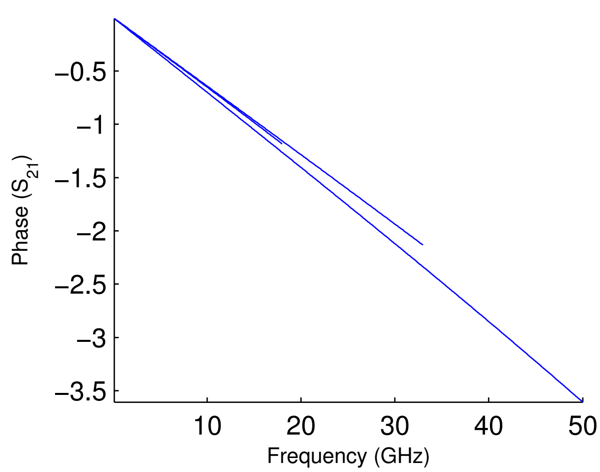

Figure 12: The phase of the reflection coefficient is plotted vs. the frequency. Only slottless connectors are considered in this plot.

6 Sensitivity Coefficients

The in section 5 shown reflection and transmission of connectors depend on the geometry and material parameters. As already mentioned in section 3 and 4, the material parameters are assumed to be ideal, i.e. the conductivity of metal is infinite and the relative permeability and permittivity of all materials is one. The geometry parameters are specified with an uncertainty in section 3 and 4. In the following the sensitivity of reflection and transmission to these geometry parameters is discussed. Figures 13 to 28 show the sensitivity towards the geometry parameters pin gap, male outer chamfer, male inner chamfer, female outer chamfer, female inner chamfer, male center conductor diameter, hole diameter, and pin diameter.

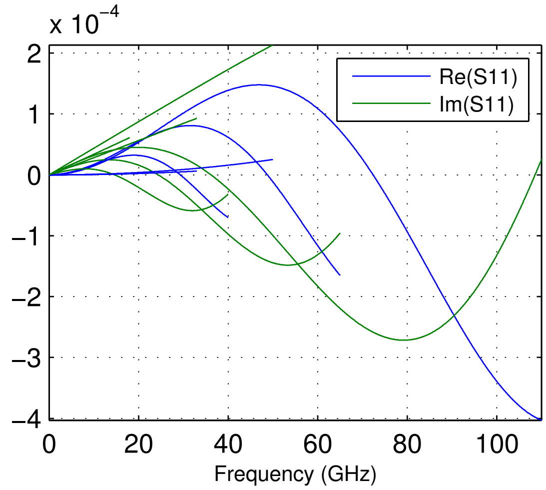

Figure 13: The sensitivity of the complex reflection factor S_{11} to pin gap in μm is plotted for all slotted and slotless connectors mentioned in section 3 and 4.

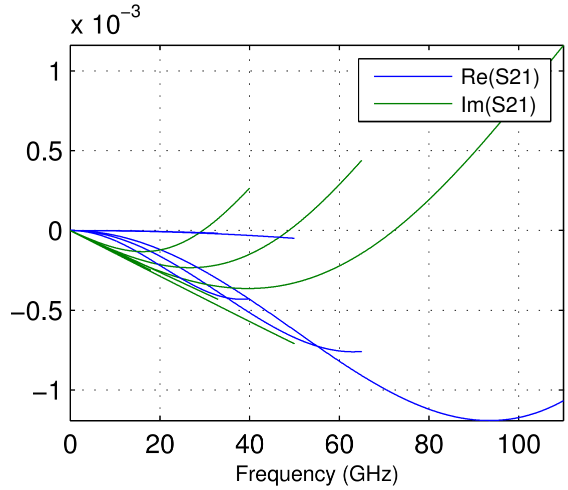

Figure 14: The sensitivity of the complex transmission factor S_{21} to pin gap in μm is plotted for all slotted and slotless connectors mentioned in section 3 and 4.

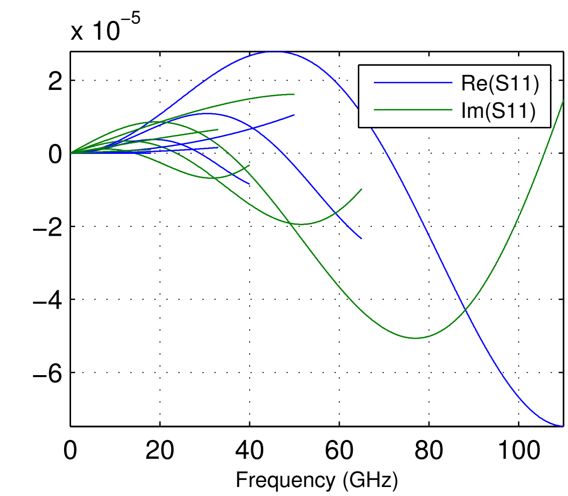

Figure 15: The sensitivity of the complex reflection factor S_{11} to male outer chamfer in μm is plotted for all slotted and slotless connectors mentioned in section 3 and 4.

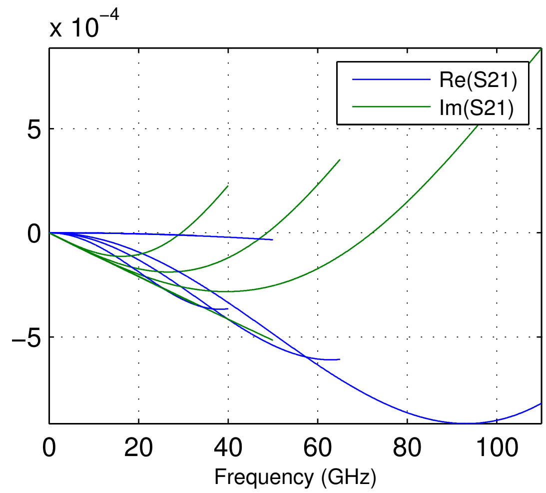

Figure 16: The sensitivity of the complex transmission factor S_{21} to male outer chamfer in μm is plotted for all slotted and slotless connectors mentioned in section 3 and 4.

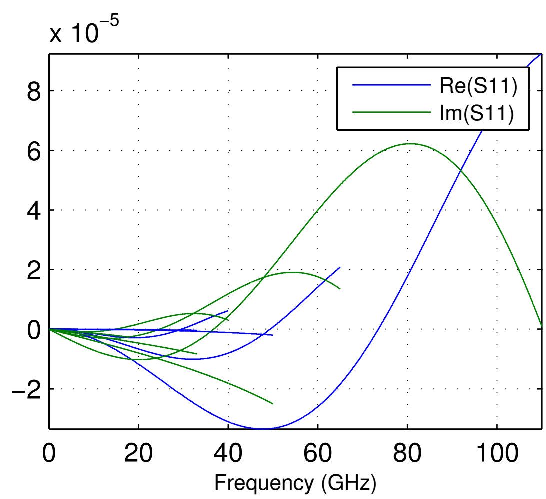

Figure 17: The sensitivity of the complex reflection factor S_{11} to male inner chamfer in μm is plotted for all slotted and slotless connectors mentioned in section 3 and 4.

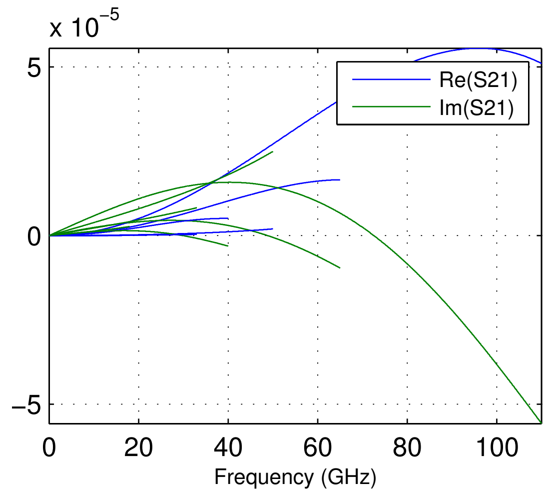

Figure 18: The sensitivity of the complex transmission factor S_{21} to male inner chamfer in μm is plotted for all slotted and slotless connectors mentioned in section 3 and 4.

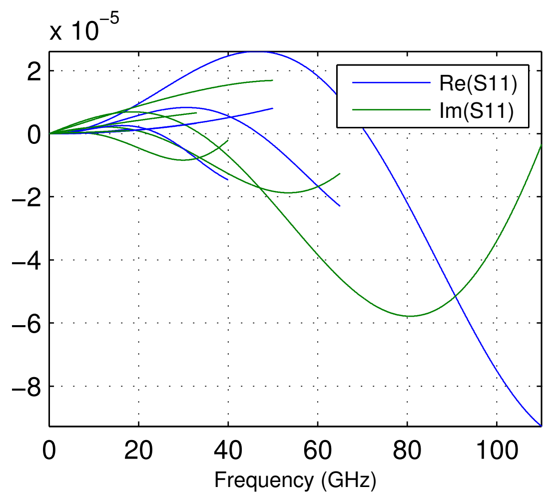

Figure 19: The sensitivity of the complex reflection factor S_{11} to female outer chamfer in μm is plotted for all slotted and slotless connectors mentioned in section 3 and 4.

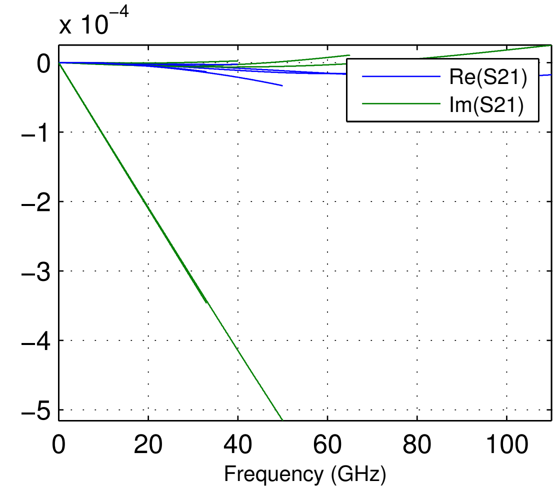

Figure 20: The sensitivity of the complex transmission factor S_{21} to female outer chamfer in μm is plotted for all slotted and slotless connectors mentioned in section 3 and 4.

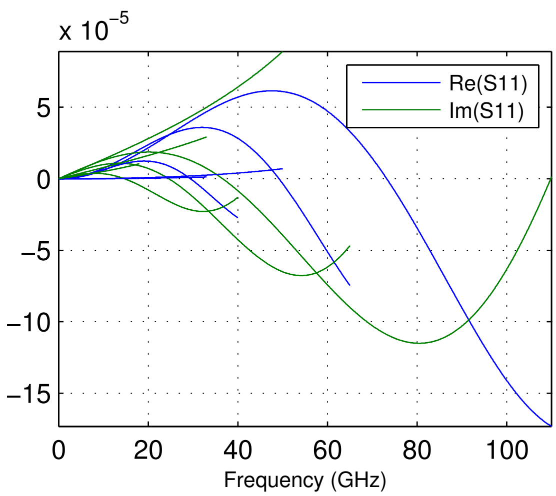

Figure 21: The sensitivity of the complex reflection factor S_{11} to female inner chamfer in μm is plotted for all slotted and slotless connectors mentioned in section 3 and 4.

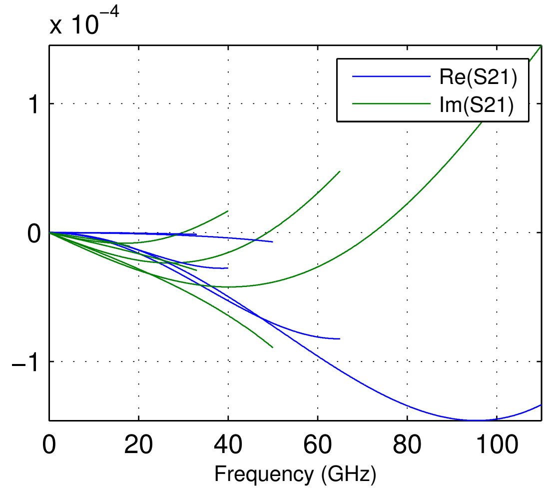

Figure 22: The sensitivity of the complex transmission factor S_{21} to female inner chamfer in μm is plotted for all slotted and slotless connectors mentioned in section 3 and 4.

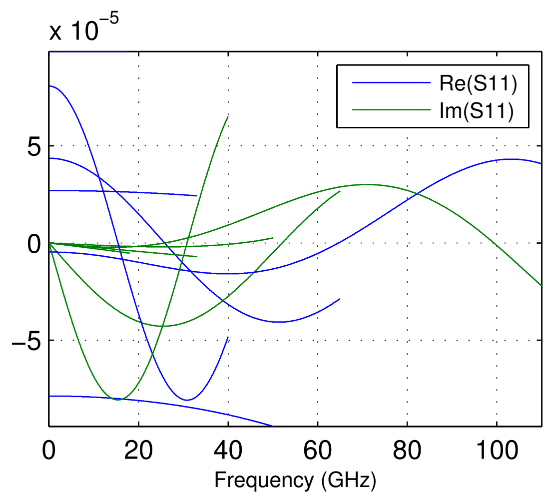

Figure 23: The sensitivity of the complex reflection factor S_{11} to male center conductor diameter in μm is plotted for all slotted and slotless connectors mentioned in section 3 and 4.

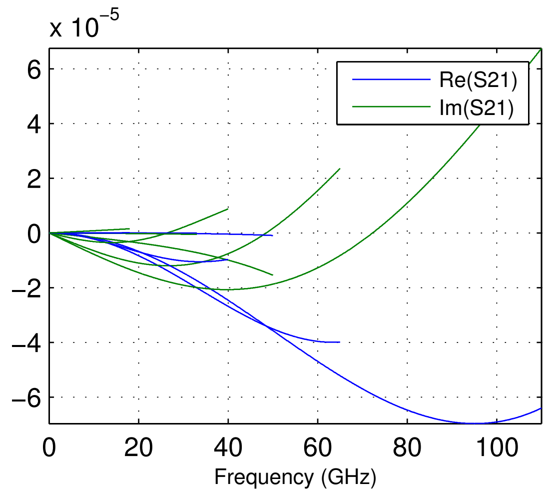

Figure 24: The sensitivity of the complex transmission factor S_{21} to male center conductor diameter in μm is plotted for all slotted and slotless connectors mentioned in section 3 and 4.

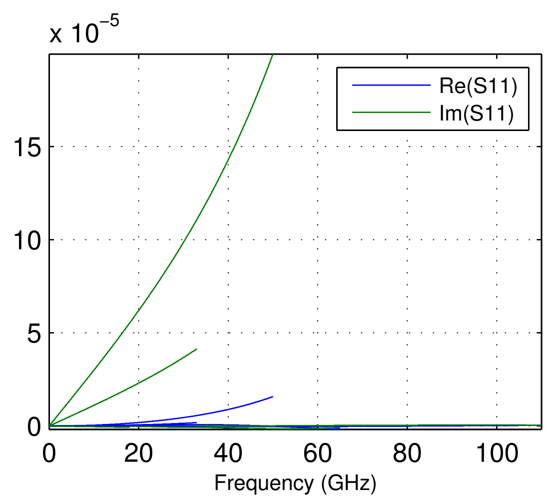

Figure 25: The sensitivity of the complex reflection factor S_{11} to hole diameter in μm is plotted for all slot less and slotted connectors mentioned in sections 3 and 4.

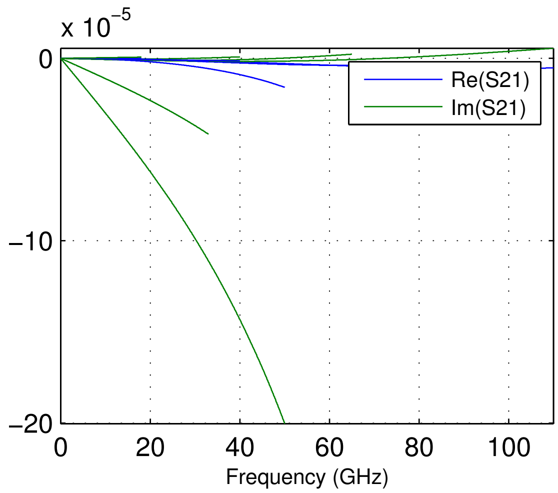

Figure 26: The sensitivity of the complex transmission factor S_{21} to hole diameter in μm is plotted for all slot less and slotted connectors mentioned in sections 3 and 4.

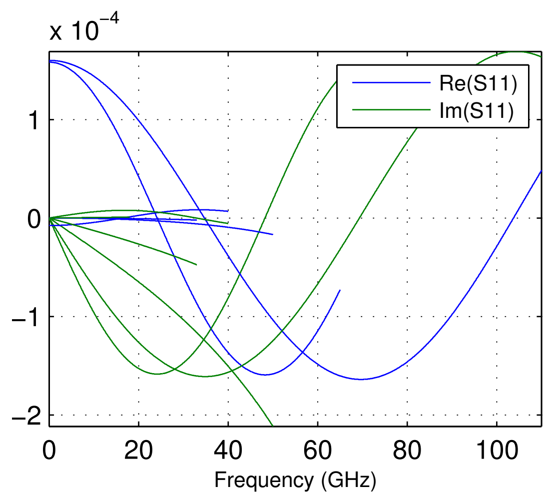

Figure 27: The sensitivity of the complex reflection factor S_{11} to male pin diameter in μm is plotted for all slotted and slotless connectors mentioned in section 3 and 4.

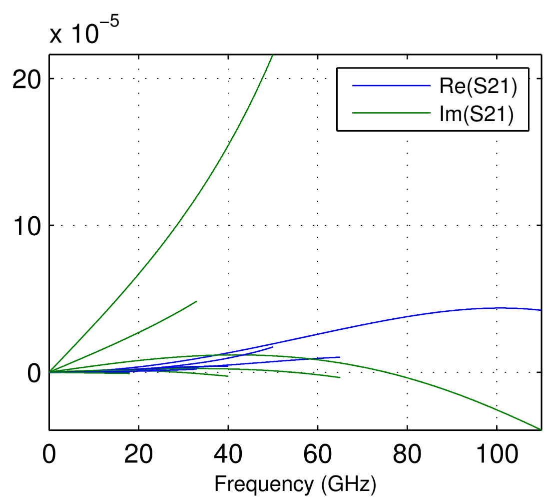

Figure 28: The sensitivity of the complex transmission factor S_{21} to male pin diameter in μm is plotted for all slotted and slotless connectors mentioned in section 3 and 4.

6.1 Sensitivities for Slotted Connectors

For slotted connectors the sensitivity to slot length and slot width is additionally shown in Figs. 29 to 32. In Figs. 33 to 36 the sensitivity of the first section of the slotted female fingers is shown. The slotted section has been divided into 100 subsections.

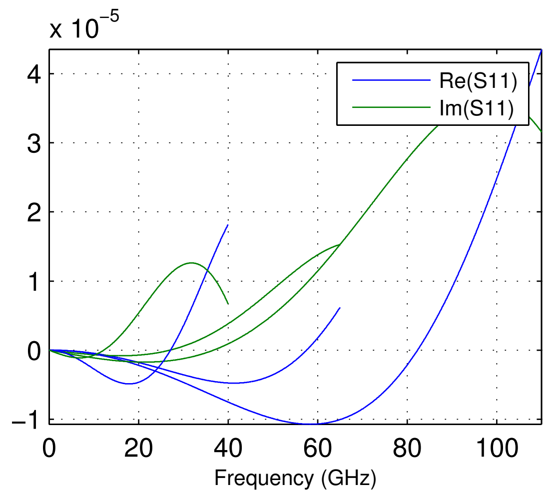

Figure 29: The sensitivity of the complex reflection factor S_{11} to slot length in μm is plotted for all slotted connectors mentioned in section 4.

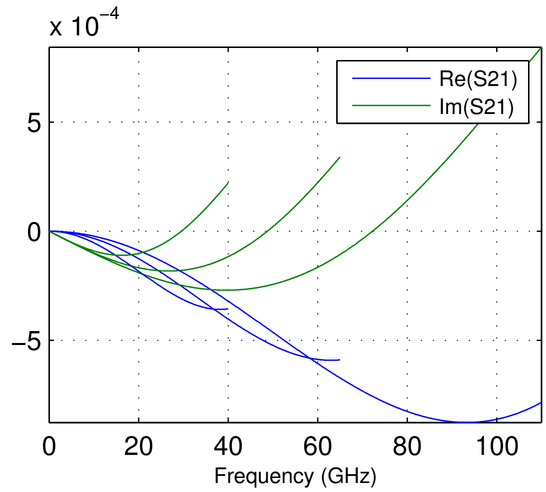

Figure 30: The sensitivity of the complex transmission factor S_{21} to slot length in μm is plotted for all slotted connectors mentioned in section 4.

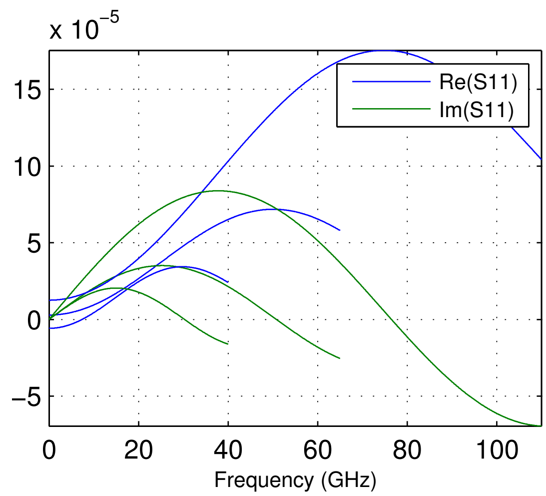

Figure 31: The sensitivity of the complex reflection factor S_{11} to slot width in μm is plotted for all slotted connectors mentioned in section 4.

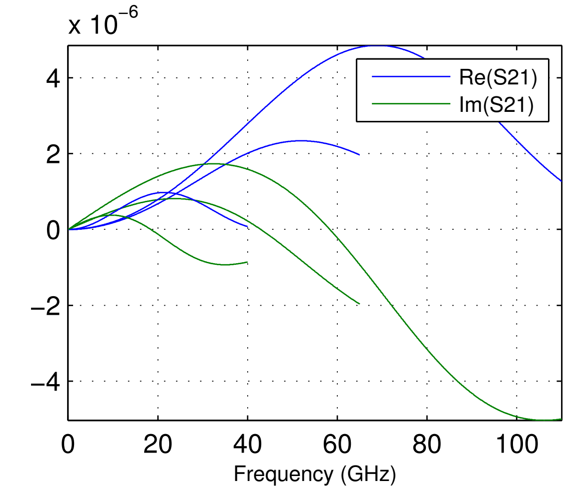

Figure 32: The sensitivity of the complex transmission factor S_{21} to slot width in μm is plotted for all slotted connectors mentioned in section 4.

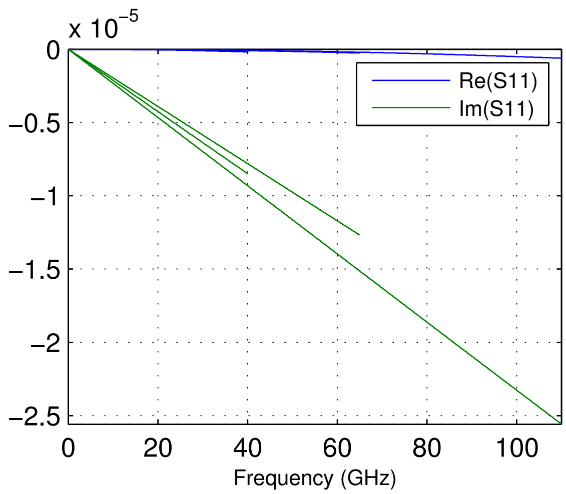

Figure 33: The sensitivity of the complex reflection factor S_{11} to the first compressed mid finger diameter is plotted for all slotted connectors mentioned in section 4. The slotted section has been divided into 100 subsections.

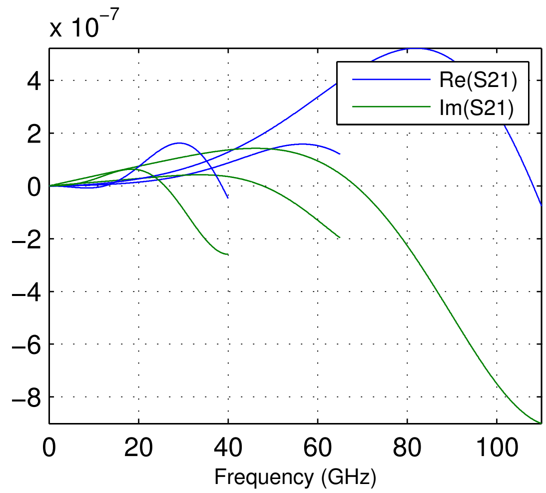

Figure 34: The sensitivity of the complex transmission factor S_{21} to first compressed mid finger diameter in μm is plotted for all slotted connectors mentioned in section 4. The slotted section has been divided into 100 subsections.

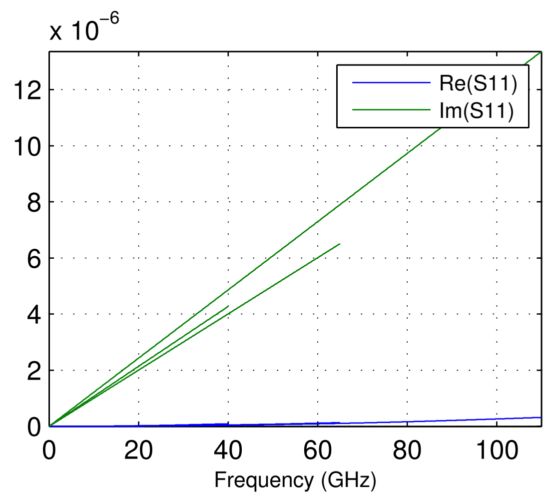

Figure 35: The sensitivity of the complex reflection factor S_{11} to first outer diameter in μm is plotted for all slotted connectors mentioned in section 4. The slotted section has been divided into 100 subsections.

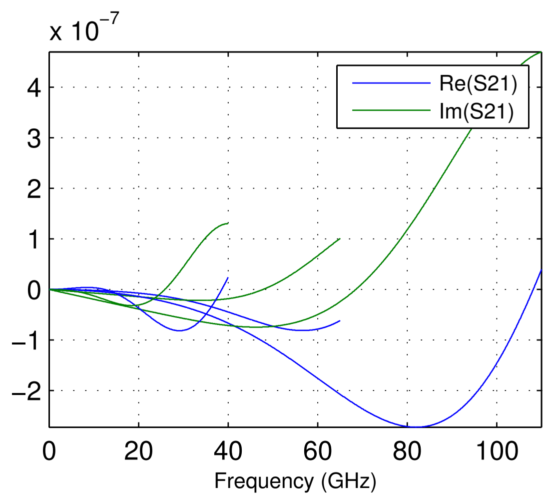

Figure 36: The sensitivity of the complex transmission factor S_{21} to first outer diameter in μm is plotted for all slotted connectors mentioned in section 4. The slotted section has been divided into 100 subsections.

6.2 Sensitivities for Slot Less Connectors

For slot less connectors the sensitivity to female hole length, outer conductor diameter, and female center conductor diameter are shown in Figs. 37 to 42. The link between trace and corresponding connector can be made by the maximum operating frequency of the connector.

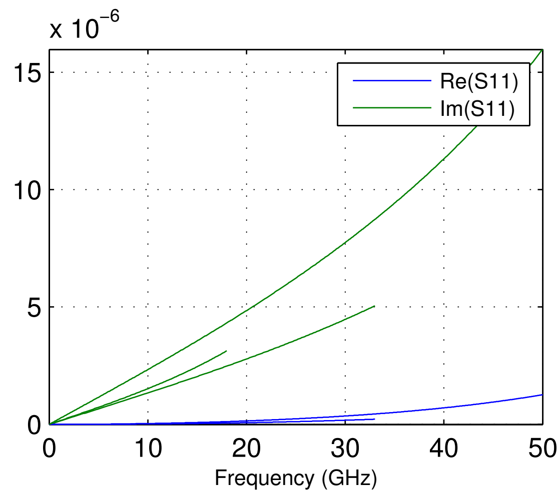

Figure 37: The sensitivity of the complex reflection factor S_{11} to hole length in μm is plotted for all slot less connectors mentioned in section 3.

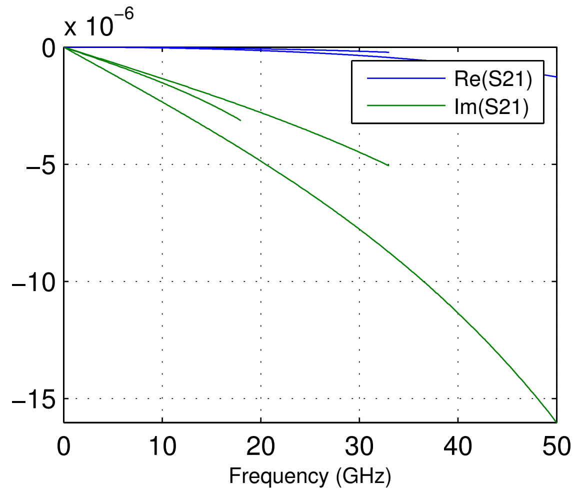

Figure 38: The sensitivity of the complex transmission factor S_{21} to hole length in μm is plotted for all slot less connectors mentioned in section 3.

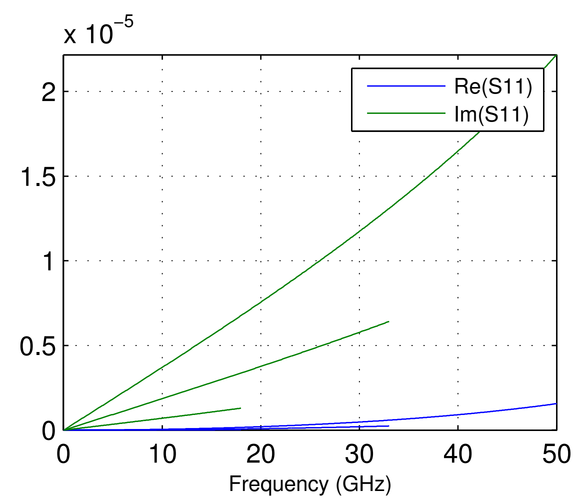

Figure 39: The sensitivity of the complex reflection factor S_{11} to outer conductor diameter in μm is plotted for all slot less connectors mentioned in section 3.

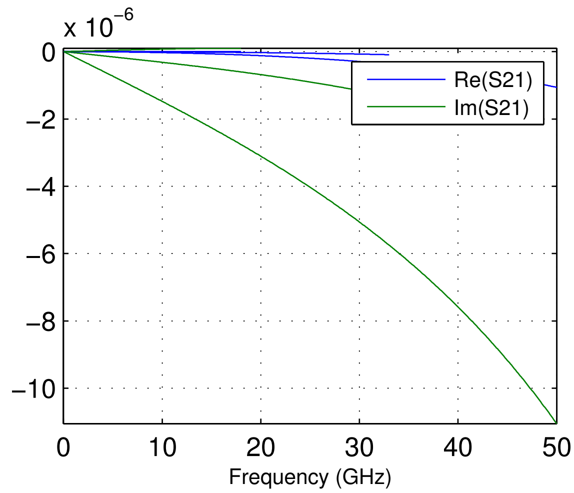

Figure 40: The sensitivity of the complex transmission factor S_{21} to outer conductor diameter in μm is plotted for all slot less connectors mentioned in section 3.

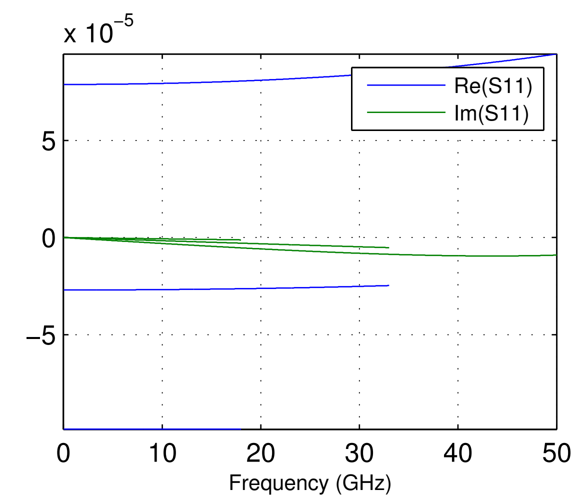

Figure 41: The sensitivity of the complex reflection factor S_{11} to female center conductor diameter in μm is plotted for all slot less connectors mentioned in section 3.

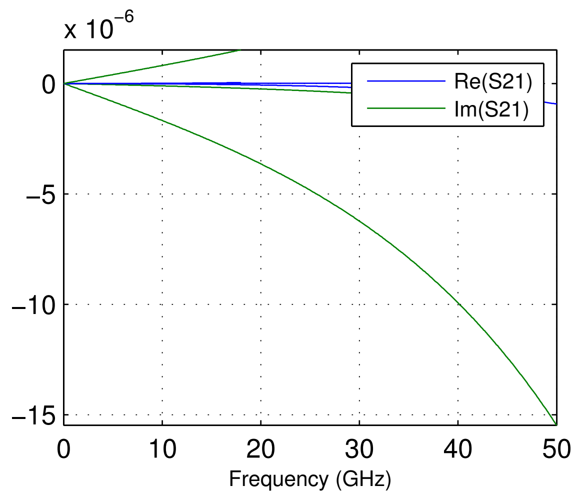

Figure 42: The sensitivity of the complex transmission factor S_{21} to female center conductor diameter in μm is plotted for all slot less connectors mentioned in section 3.

7 Minimal Pingap

The electrical parameters of a coaxial connection can become very sensitive to sub-micron changes in pin gap under certain conditions. It is easy to imagine that it makes a great difference for reflection and transmission whether the head of the female center conductor touches the shoulder of the male center conductor. Surprisingly the sensitive region of pingap does not end after the male shoulder and the head surface of the female center contact make no longer contact. This is due to magnetic and electric fields which build up in the pin gap. Under the condition of large chamfers and small pin gap this can lead to resonance within the range of operating frequencies of the connector.

The following minimum pin gaps are advised for the suppression of resonance effects better than $|\Delta S_{11}| = 0.001$ in typical connectors.

Connector	Minimum Pin Gap
N-Type slotless	12 μm
3.5 mm slotless	15 μm
2.92 mm slotted	10 μm
2.4 mm slotless	15 μm
1.85 mm slotted	5 μm
1.00 mm slotted	5 μm

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