ELECTRICAL CHARACTERISATION OF SMA CONNECTORS FOR CRYOGENIC AMPLIFIERS

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ABSTRACT

Electrical tests on three different types of SMA connectors have been done. The need of finding a RF connector with good performance at cryogenic temperature and with a good mechanical behavior to prevent broken contacts when cooled forced us to do such an investigation. Non rigid connections to the substrate or connectors with sliding pin will be necessary. Standard SMA connectors with the pin soldered to the substrate (RADIALL 125 462, ESA/SCC340200218B201), connectors with interchangeable contact also with the pin soldered to the substrate (RADIALL 125 460 001, ESA/SCC340200232B301) and SMA connectors with tab contact to use "O ribbon" connection to the substrate (RADIALL 125 501 001, ESA/SCC340200219B301) have been analyzed. The interchangeable contact gives mobility in the longitudinal axis and the “O ribbon” contact does it in the three axes. The aim of this Technical Report is to make an estimation of their effect in the cryo-amplifier performance. This estimation is based on equivalent circuits of the SMA connectors obtained with S parameter measurements and on the model used for the design of a typical cryogenic amplifier.

MECHANICAL AND ELECTRICAL DESIGN

Three different test fixtures were designed and fabricated to perform the electrical tests with the three types of connectors. One of the designs is shown in fig. 1.

The circuit consists on a 50Ω microstrip line with a length of 49.6mm, on a DUROID 6002 substrate (20 mils-thick). Two different types of microstrip lines were used: lines terminated with a taper (l=0.2mm) and a 0.2mm gap to the end of the substrate and lines without taper and with the same gap. The models of the three types of connectors were obtained using the lines with taper. Since we were more interested in the “O ribbon” connection due to its higher flexibility at low temperatures, only this kind of connection was checked with a line without taper. This line was also extended to the end of the substrate (no gap) using a 0,5mm-wide gold ribbon and the model of the ribbon connection was obtained as well. A photo of one of the test fixtures is shown in fig. 2. For the “O ribbon” contacts a gold ribbon 0.5mm-wide and 12.5µm-thick was used. The “O” has a perimeter of about 3.125mm.

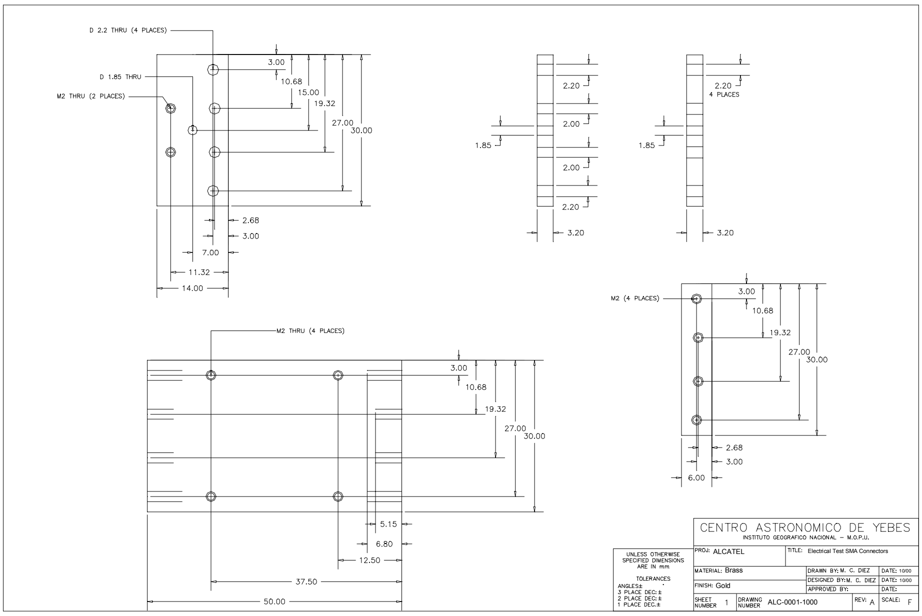


Figure 1: Test fixture for RADIALL 125 501 001connectors.

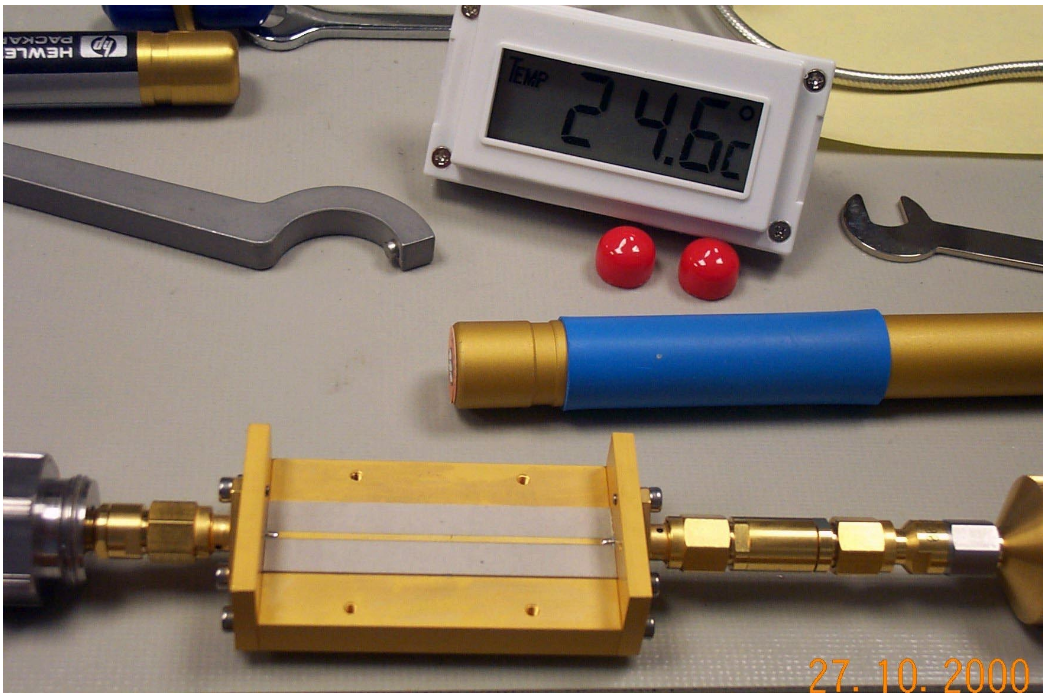


Figure 2: One of the test fixtures measured.

MEASUREMENTS

The three test fixtures were measured with a Vector Network Analyzer HP 8510 C calibrated with a 3.5mm coaxial Cal. Kit. The frequency range of the measurements was 0.1-20.1 GHz. This frequency range allowed us to perform time domain measurements in the low pass mode. The results in frequency and time domain for the different configurations are presented in figs. 3-11, 13-15 and 17-19. Photos of the "O ribbon" connections are presented in figs. 12 and 16.

1. RADIALL 125 462 (Standard, pin soldered to the line)

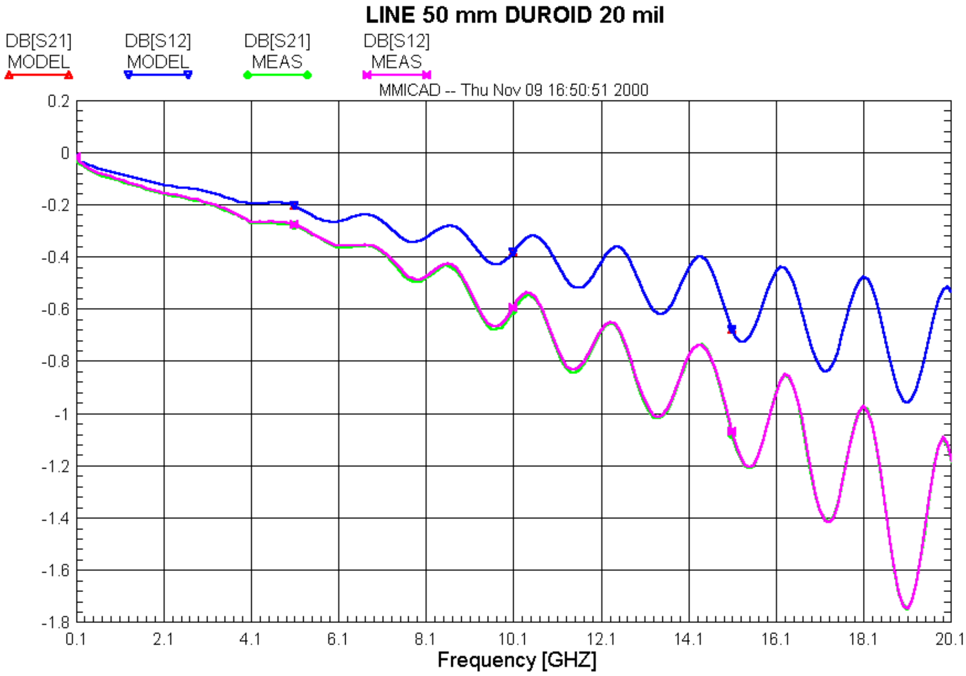


Figure 3: Losses obtained with the test fixture using two RADIALL 125 462 connectors.

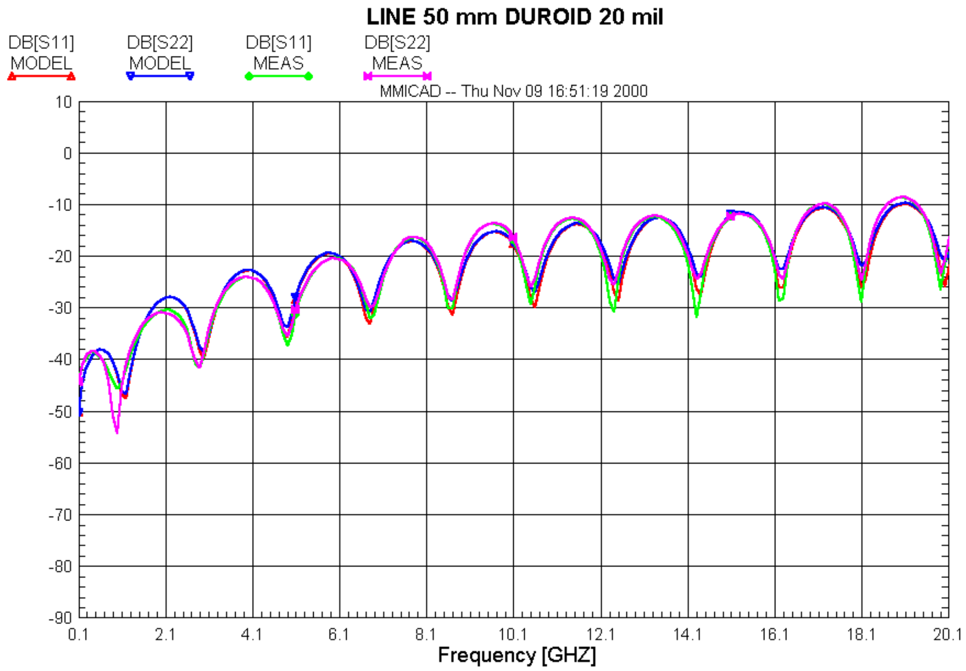


Figure 4: Reflection obtained with the test fixture using two RADIALL 125 462 connectors.

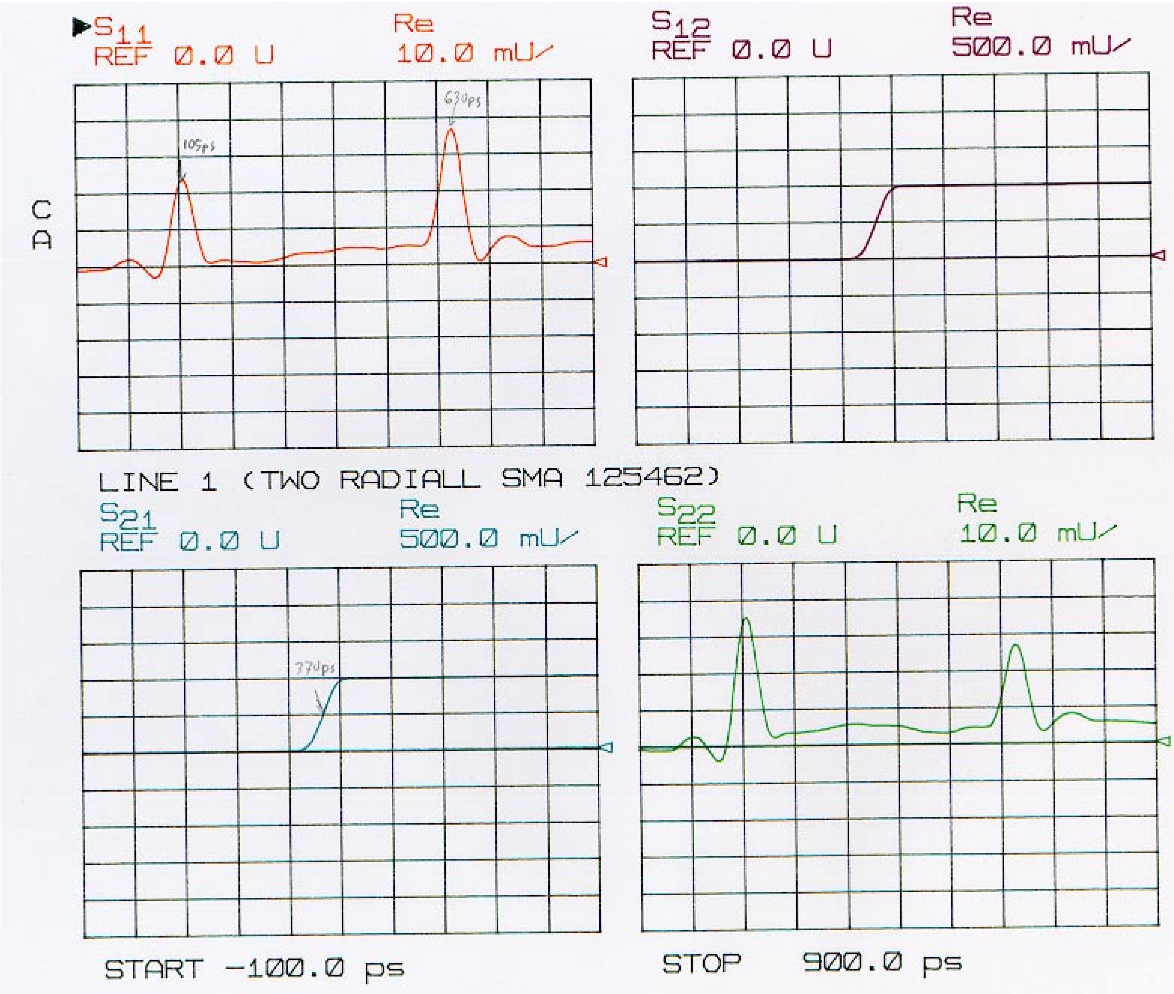


Figure 5: Time domain S parameters for RADIALL 125 462 connectors.

2. RADIALL 125 460 001 (Interchangeable contact)

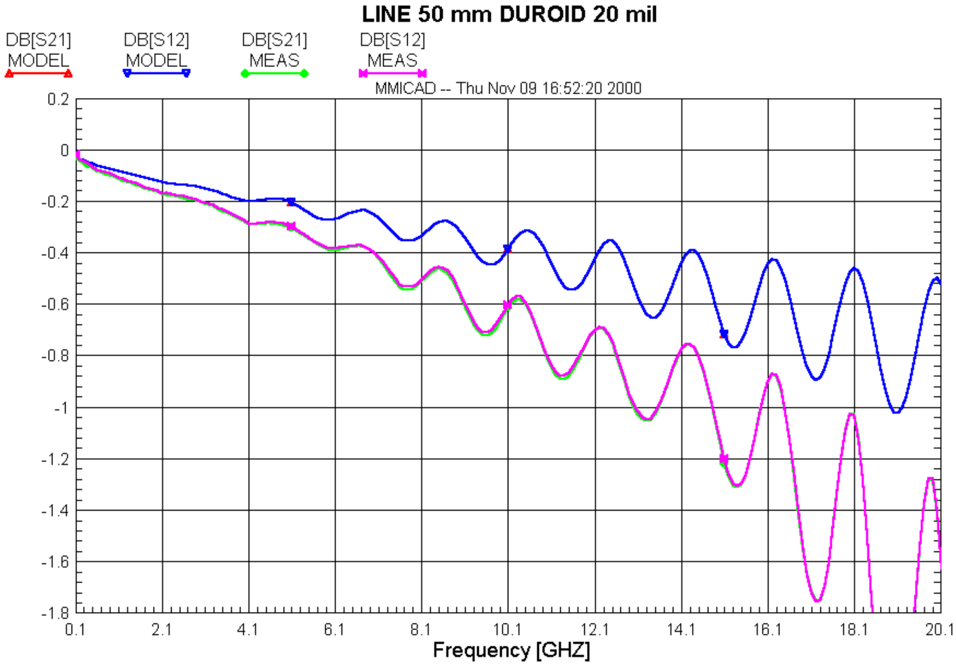


Figure 6: Losses obtained with the test fixture using two RADIALL 125 460 001 connectors.

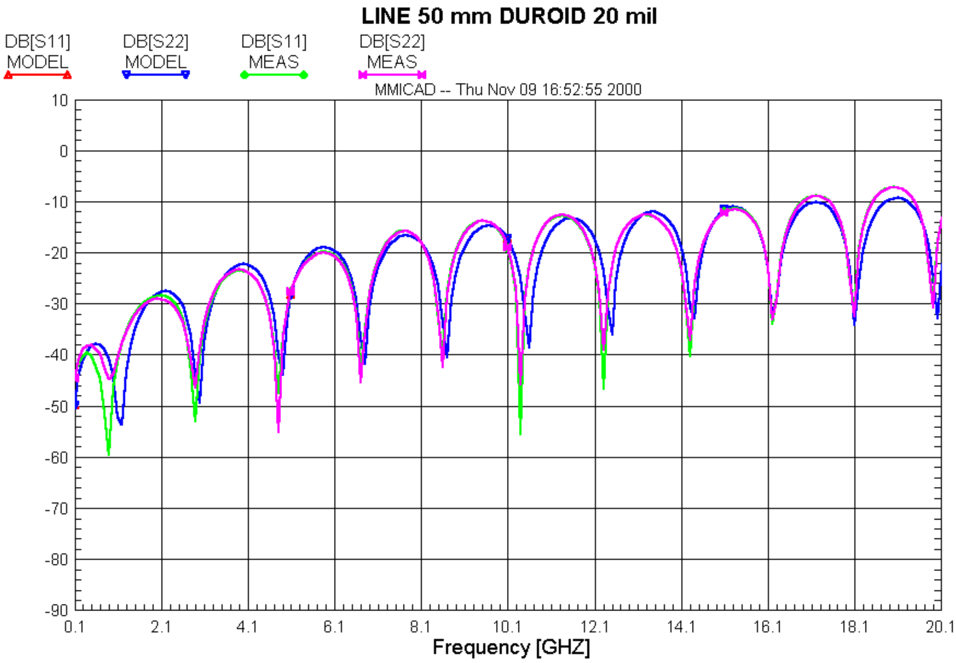


Figure 7: Reflection obtained with the test fixture using two RADIALL 125 460 001 connectors.

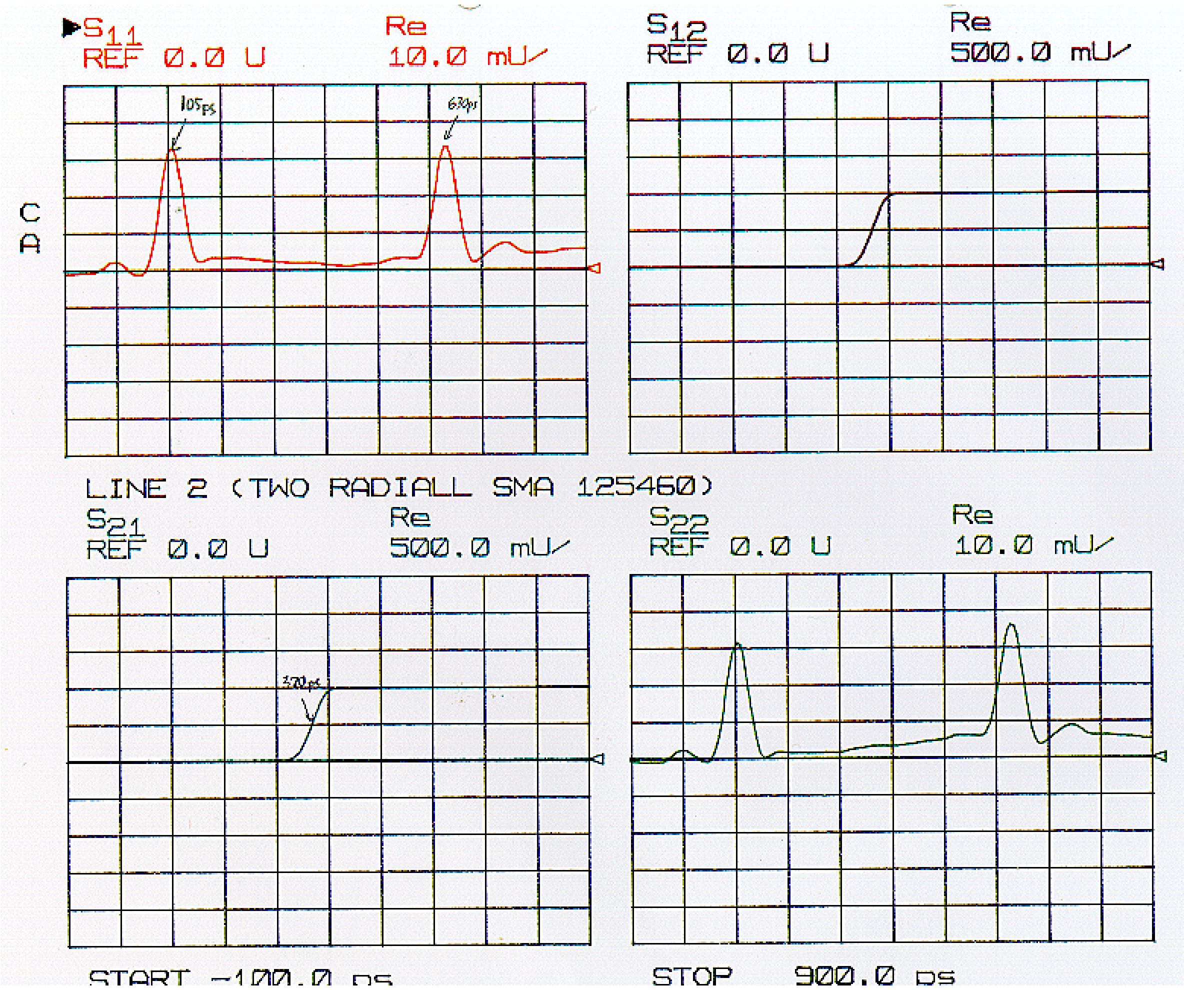


Figure 8: Time domain S parameters for RADIALL 125 460 001 connectors.

3. RADIALL 125 501 001 (For ribbon connection)

a) Line with taper

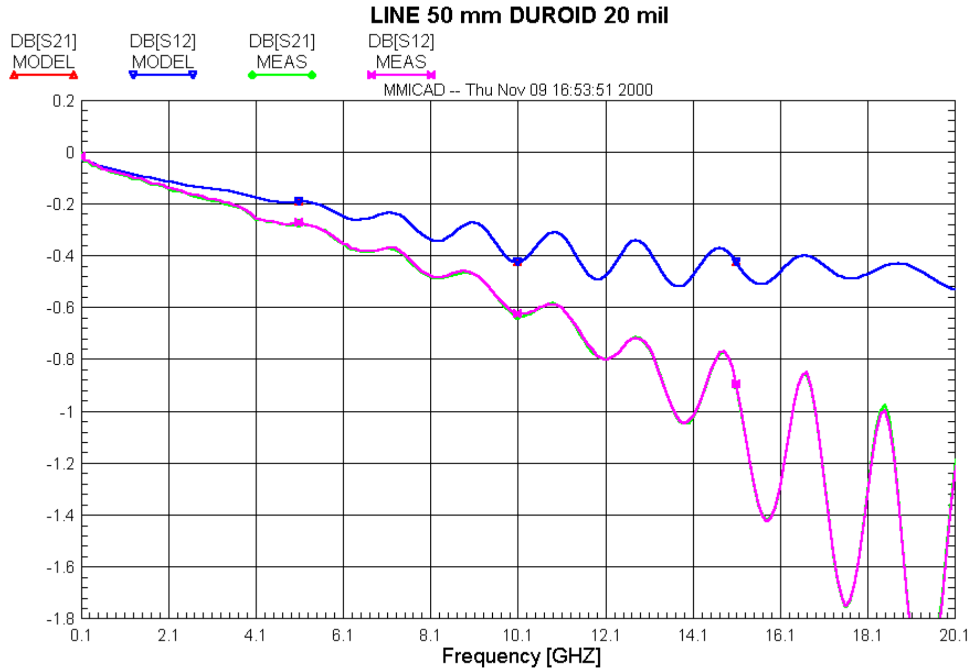


Figure 9: Losses obtained with the test fixture using two R 125 501 001 connectors.

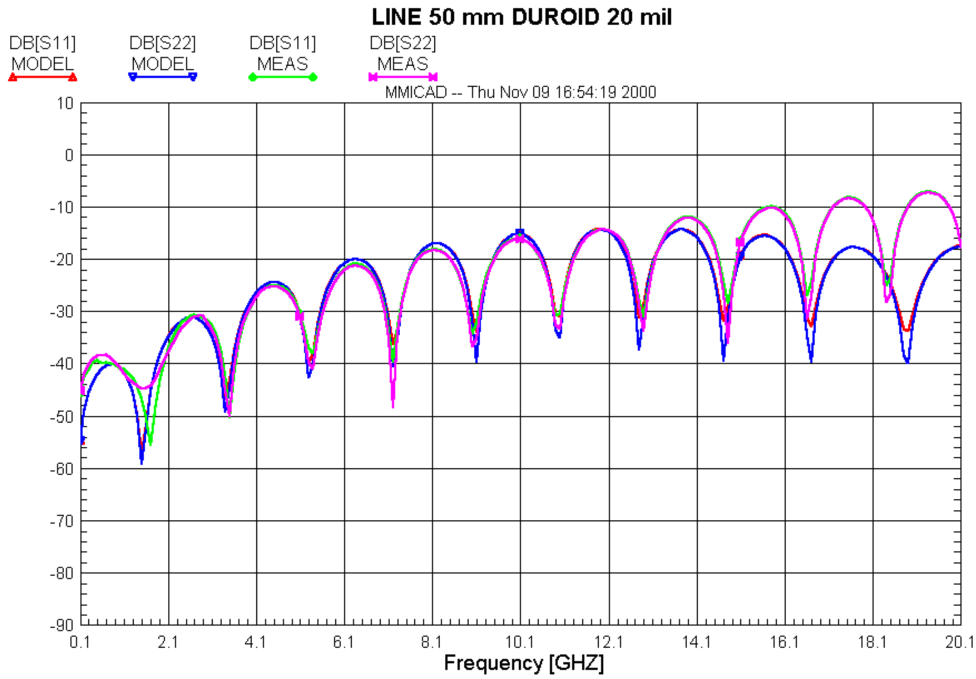


Figure 10: Reflection obtained with the test fixture using two R 125 501 001 connectors.

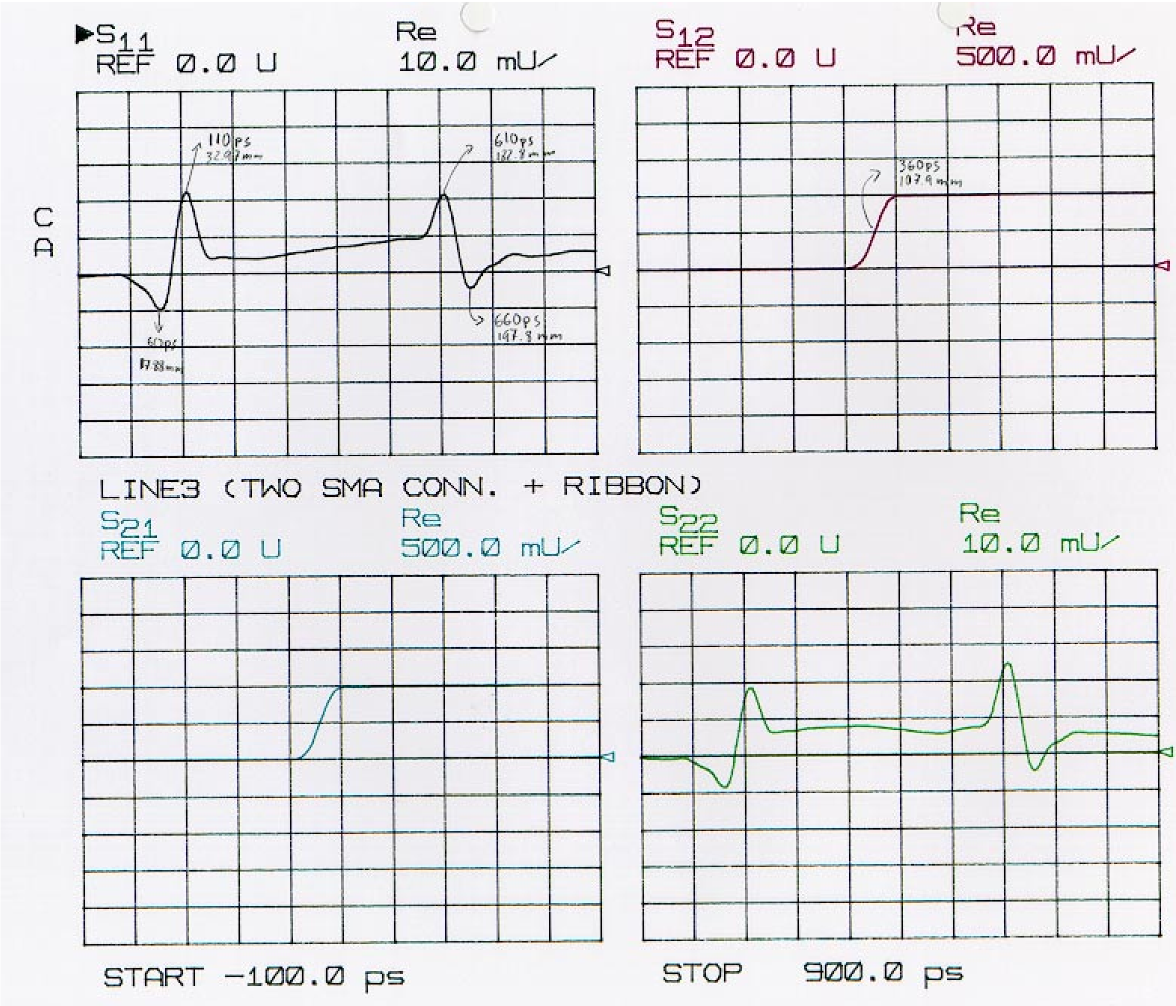


Figure 11: Time domain S parameters for RADIALL 125 501 001 connectors.

b) Line without taper

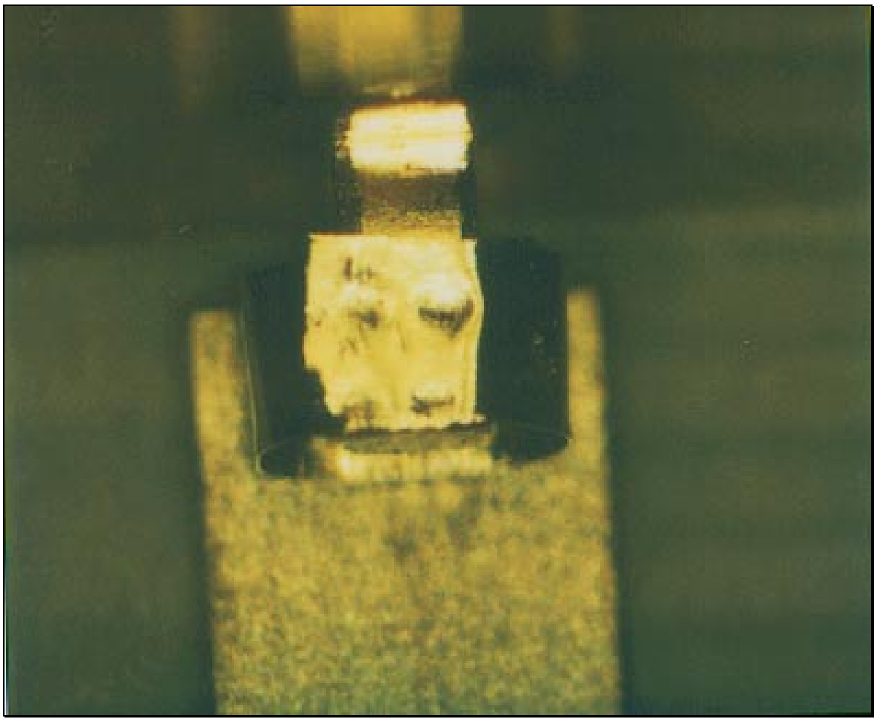


Figure 12: "O ribbon" connection on a line without taper.

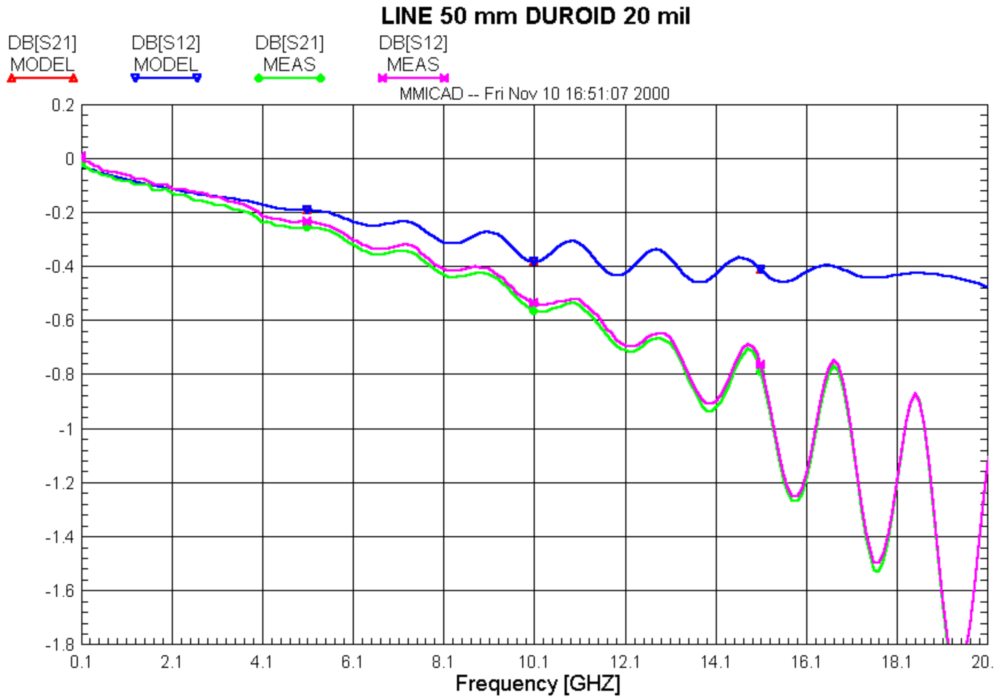


Figure 13: Losses obtained with the test fixture using two R 125 501 001 connectors.

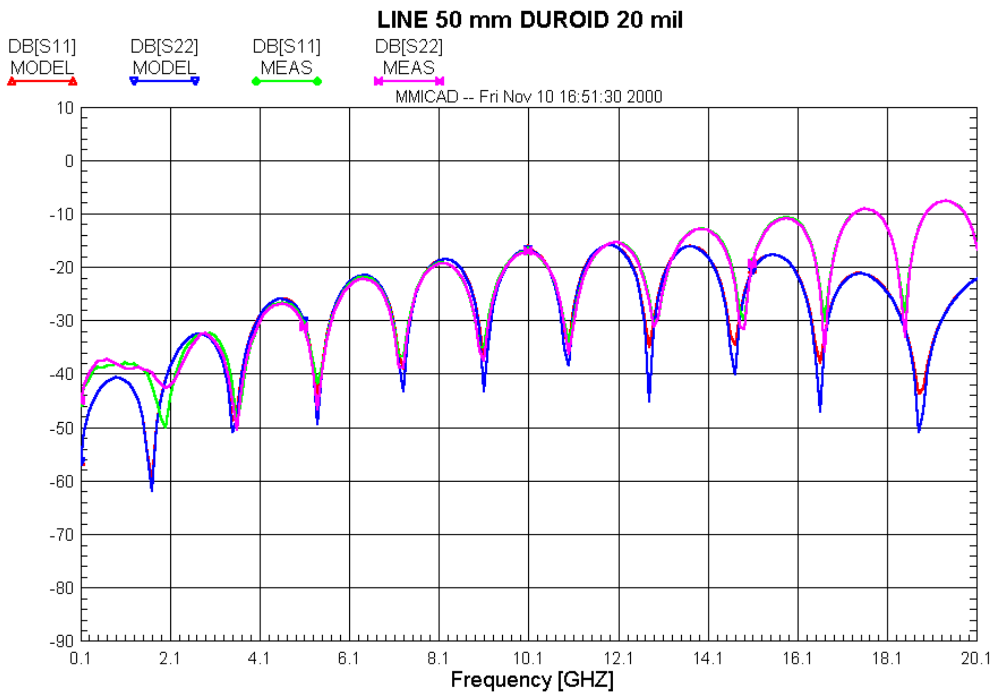


Figure 14: Reflection obtained with the test fixture using two R 125 501 001 connectors.

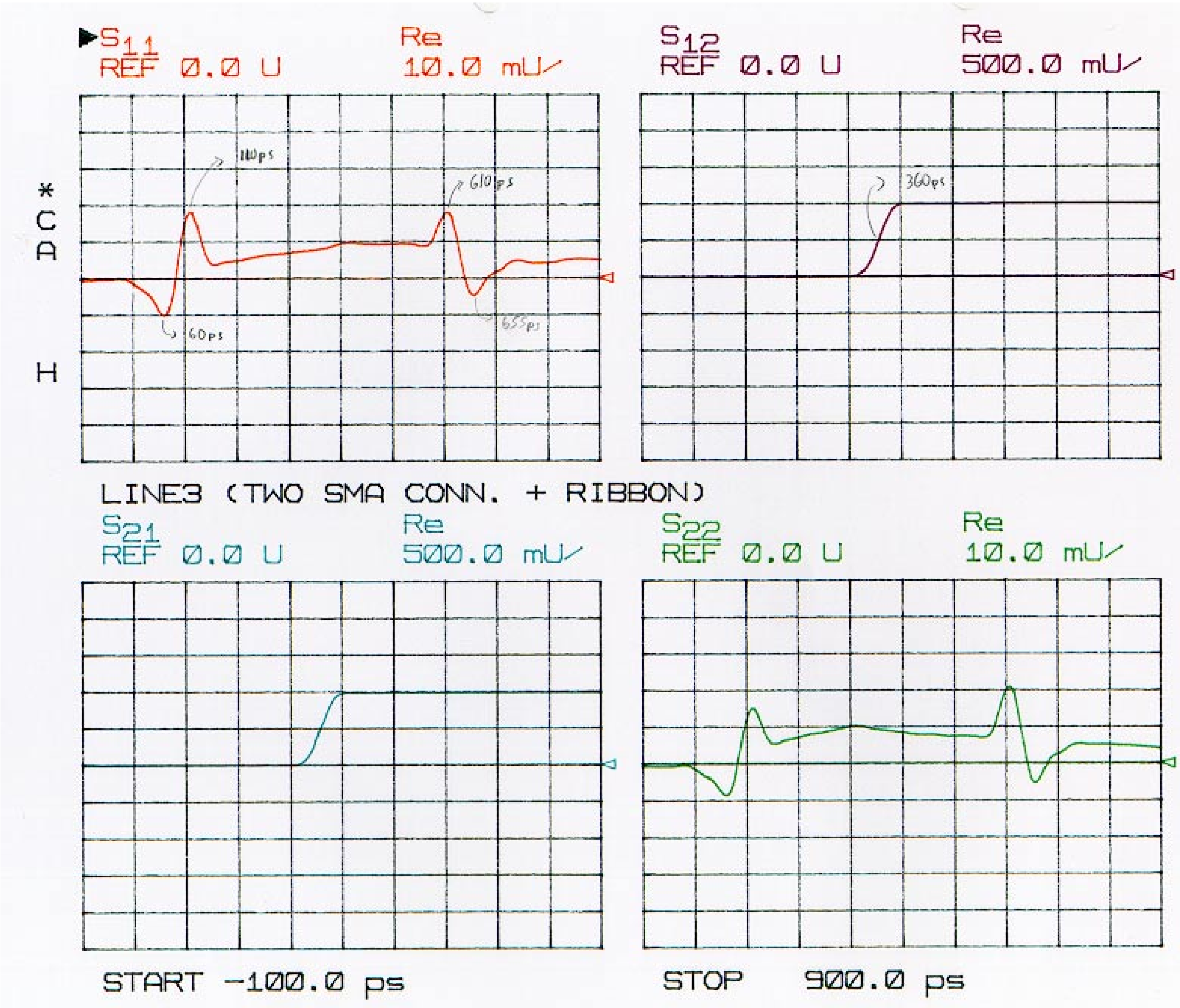
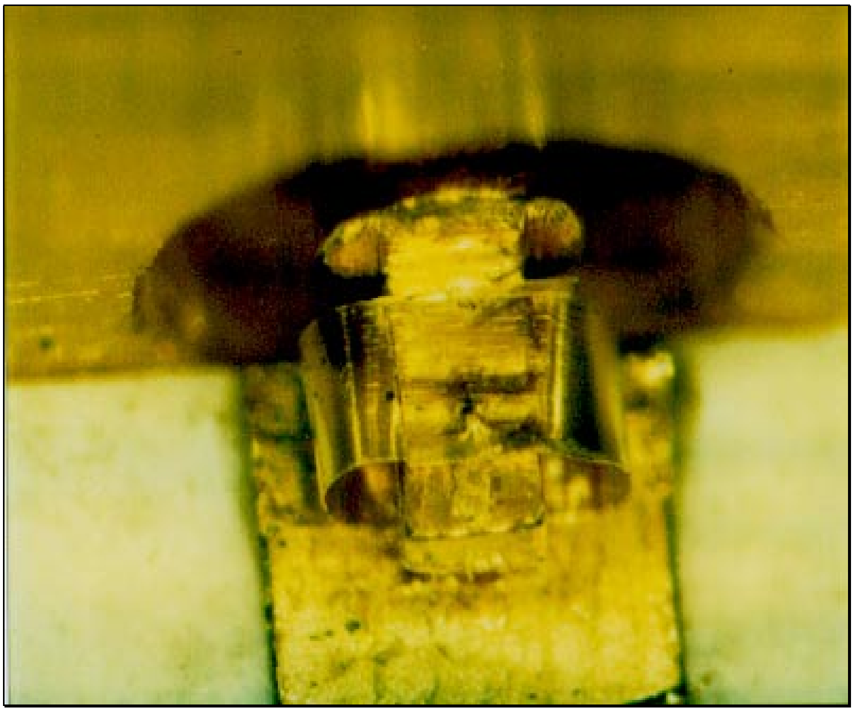


Figure 15: Time domain S parameters for RADIALL 125 501 001 connectors.

c) Extended line without taper (no gap)



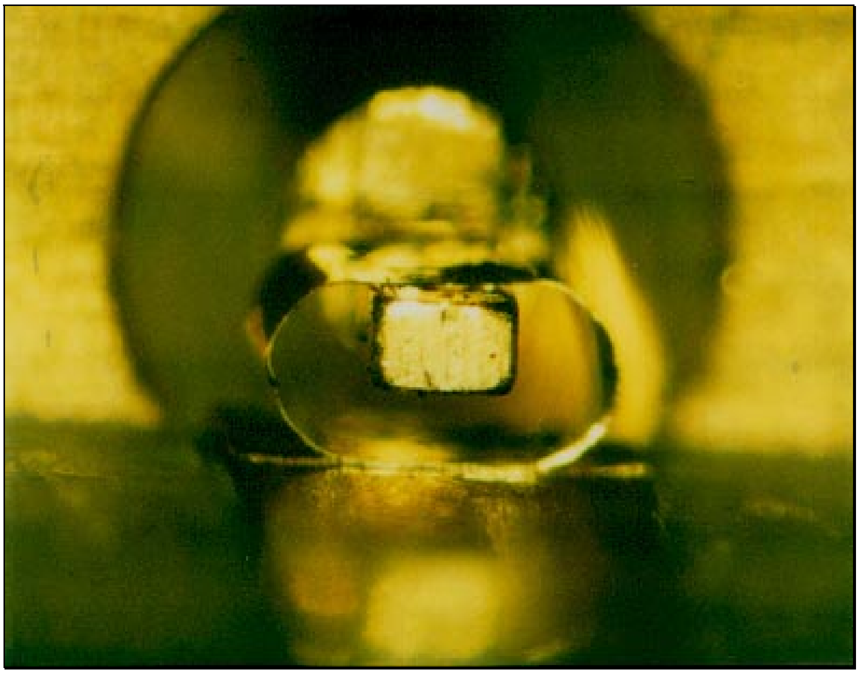


Figure 16: "O ribbon" connection on an extended line without taper.

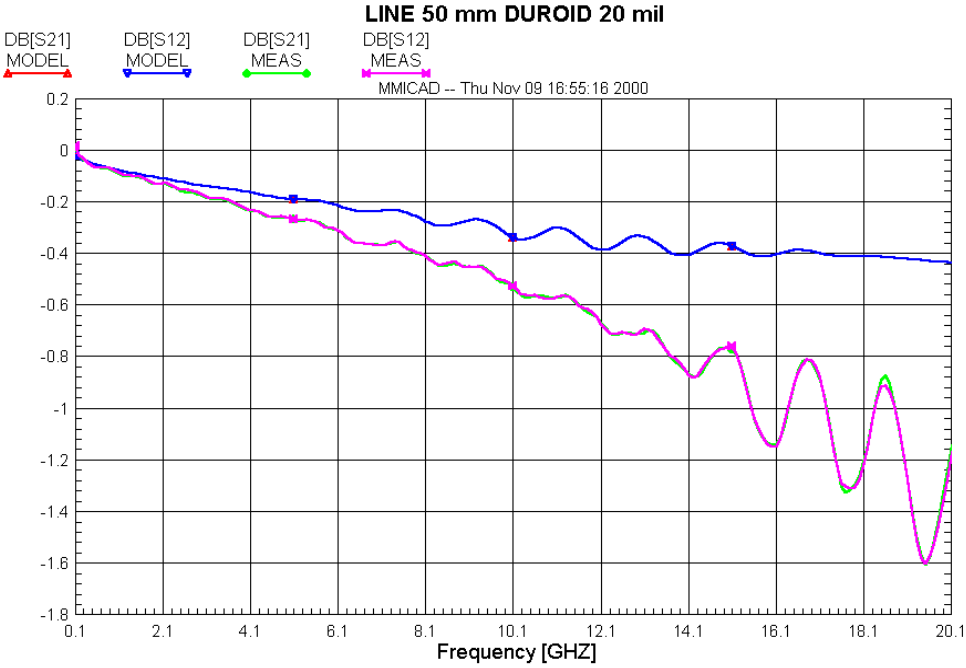


Figure 17: Losses obtained with the test fixture using two R 125 501 001 connectors.

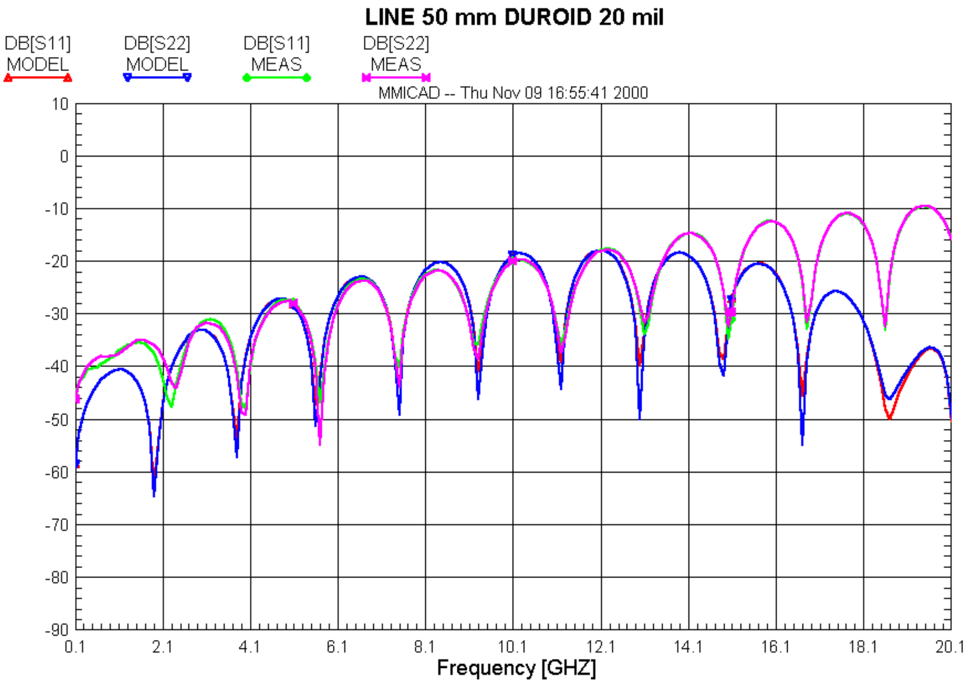


Figure 18: Reflection obtained with the test fixture using two R 125 501 001 connectors.

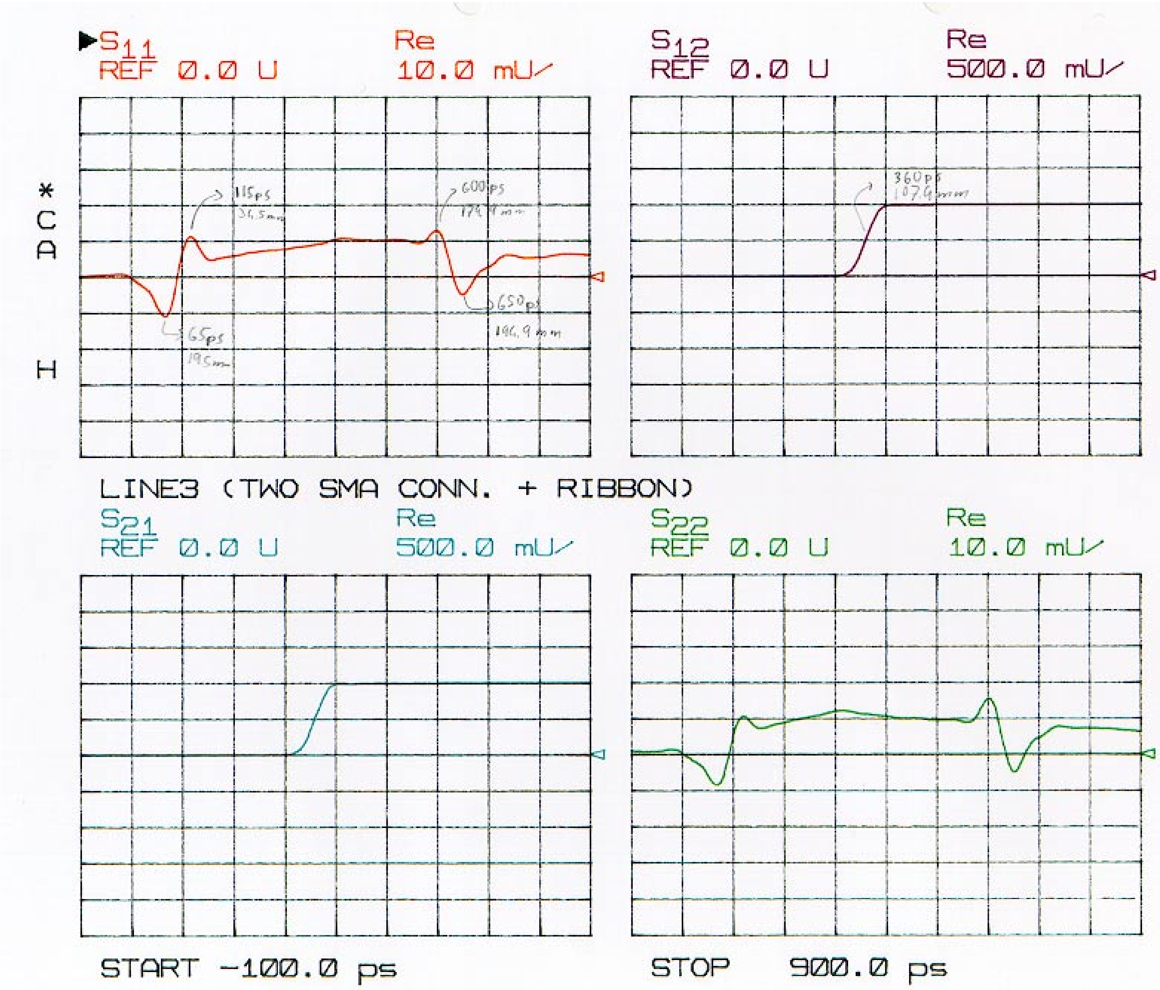


Figure 19: Time domain S parameters for RADIALL 125 501 001 connectors.

There is a small difference in the inductances modeling the two connectors in the test fixture R 125 462 (see figs. 5 and 20). One of the connectors presents an inductance slightly smaller than the other. This could be due to the fact that the pin of the connector with the lower inductance got thicker due to the solder and the discontinuity was smaller.

The models for the R 125 462 and the R 125 460 001 connectors are valid up to 20 GHz. However, the models for the "O ribbon" connections are only valid up to 12 GHz. Due to the more complex configuration for such a connection, there are some distributed effects that make more difficult get a lumped model for all the frequencies.

The models do not match well with the measurements of the losses, especially at the highest frequencies. This may be due to radiation effects that again are more important with the "O ribbon" connection. In figs. 9, 13 and 17, it is clear that the flatness of the losses predicted by these models do not agree with the measurements that give higher losses at high frequencies.

The "O ribbon" connections are better when there is no taper and no gap at the end of the line (the values of the inductances were reduced by a factor of 2). That could mean that reducing the gap or removing the taper the inductive effects for all the connectors would be reduced. The capacitive effect in the "O ribbon" connection could be due to the tolerances in the hole made in the wall of the test fixture.

EQUIVALENT CIRCUITS

The equivalent circuits for all different configurations are shown in figs. 20-24.

RADIALL 125 462 (Standard, pin soldered to the line)

Figure 20: Equivalent circuit obtained for the RADIALL 125 462 connector.

4. RADIALL 125 460 001 (Interchangeable contact)

Figure 21: Equivalent circuit obtained for the RADIALL 125 460 001 connector.

RADIALL 125 501 001 (For ribbon connection)

a) Line with taper

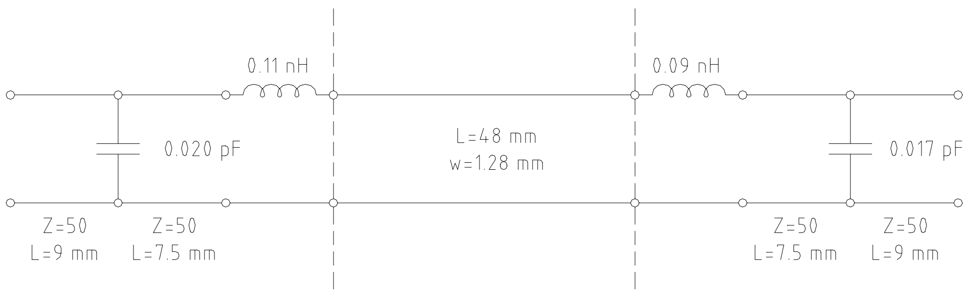


Figure 22: Equivalent circuit obtained for the RADIALL 125 501 001 connector.

b) Line without taper

Figure 23: Equivalent circuit obtained for the RADIALL 125 501 001 connector.

c) Extended line without taper (no gap)

Figure 24: Equivalent circuit obtained for the RADIALL 125 501 001 connector.

EFFECTS WITH A CRYOGENIC AMPLIFIER

To evaluate the effects of different types of connectors in the performance of a cryogenic amplifier, the model used for the design of the 4-8 GHz HIFI IF amplifiers was assumed. The results for the following situations were compared: a) the effects of the connectors are neglected (assumption used until now in the design of the amplifier), b) a standard connector is used and c) “O ribbon” connection is used to attach the contact to the substrate. For this last connection, the best model obtained (extended line without taper) was used. The results are shown in figs. 25 and 26.

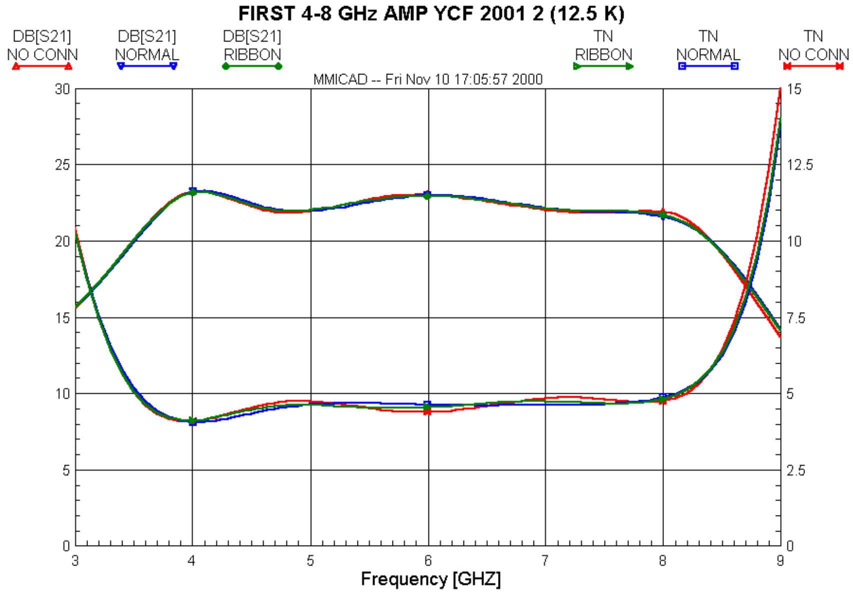


Figure 25: Comparison of the gain and noise results for three different situations: a) No connector, b) Standard SMA connector and c) “O ribbon” connection.

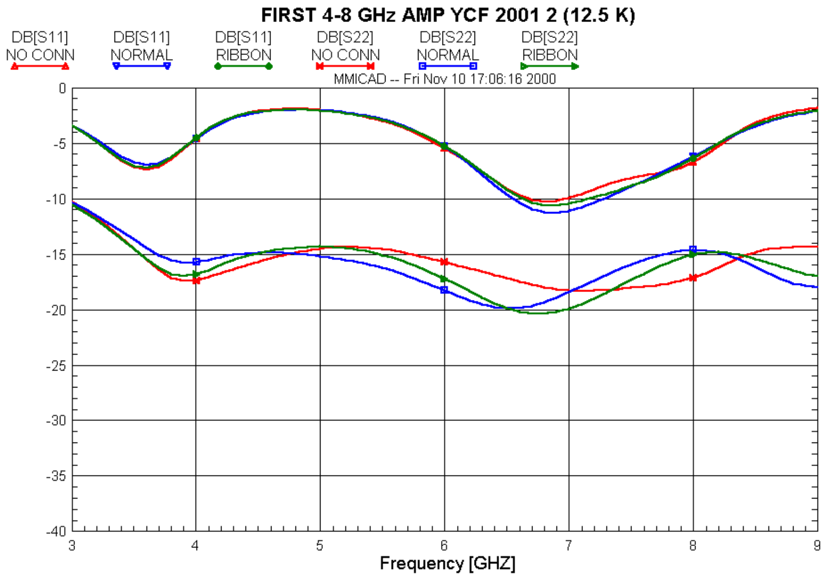


Figure 26: Comparison of the input and output reflection for three different situations: a) No connector, b) Standard SMA connector and c) “O ribbon” connection.

CONCLUSIONS

From the results of the simulation, the effect of both connectors is almost negligible regarding gain and noise. The effect in the input reflection is not very important either. The most important effect takes place in the output reflection. Both connectors add a ripple that makes the value of the reflection to be lower at some frequencies but higher at others. However, in view of the results, the effect of the connectors using the models obtained from the measurements may be acceptable if there is not gap at the end of the line. Due to the higher reliability of the "O ribbon" connection at low temperature, this would be a good option to be used in the 4-8 GHz cryogenic amplifiers for HIFI up to frequencies of about 12 GHz.

ADNOWLEDGMENTS

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