ELECTRICAL CHARACTERISATION OF SEMI-RIGID COAXIAL CABLES WITH SMA AND K CONNECTORS

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March 2005

TECHNICAL REPORT C.A.Y. 2005-4

ABSTRACT

Semi-rigid coaxial transitions are normally used in closed cycle refrigerators to introduce and extract the electrical signals. The aim of this Technical Report is to make an estimation of the effect of using K connectors in the cables instead the SMA ones we have been using until now. This estimation is based on models of the K and SMA connectors obtained with S parameter measurements.
Besides, and due to the high difficulty for a correct fabrication of cables with SMA and K connectors, some important details about the procedure of the manufacture will be described.

MODELS OF SMA AND K CONNECTORS

Two different semi rigid cables were specially built to measure the effect of SMA and K connectors. In both cases the cable used was semi rigid .141" Stainless Steel outer conductor and Beryllium Copper inner with solid Teflon dielectric. The length of the two cables was ~100 mm. The SMA connectors were Radiall R 125 055, with a specified maximum usable frequency of 18 GHz and a VSWR of 1.05 + 0.004 F(GHz) (catalog data). The K connectors were SRI Connector Gage Company 24-000-1041-90, with a specified maximum usable frequency of 40 GHz and a VSWR of 1.25 to 40GHz (catalog data). The two cables were measured with a Vector Network Analyzer Agilent E8364B calibrated with an E-cal (2.4mm) for K connectors. The frequency range of the measurements (0.100-20.1 GHz) was adequate for the time domain low pass mode, very useful in finding the nature of the discontinuities. A picture of the two cables measured is shown in Figure 1, and the equivalent circuits obtained and used in this work are presented in Figure 2 and Figure 3.

The data obtained from the models, compared with the measurement for each connector is presented in Figure 4 - Figure 7.

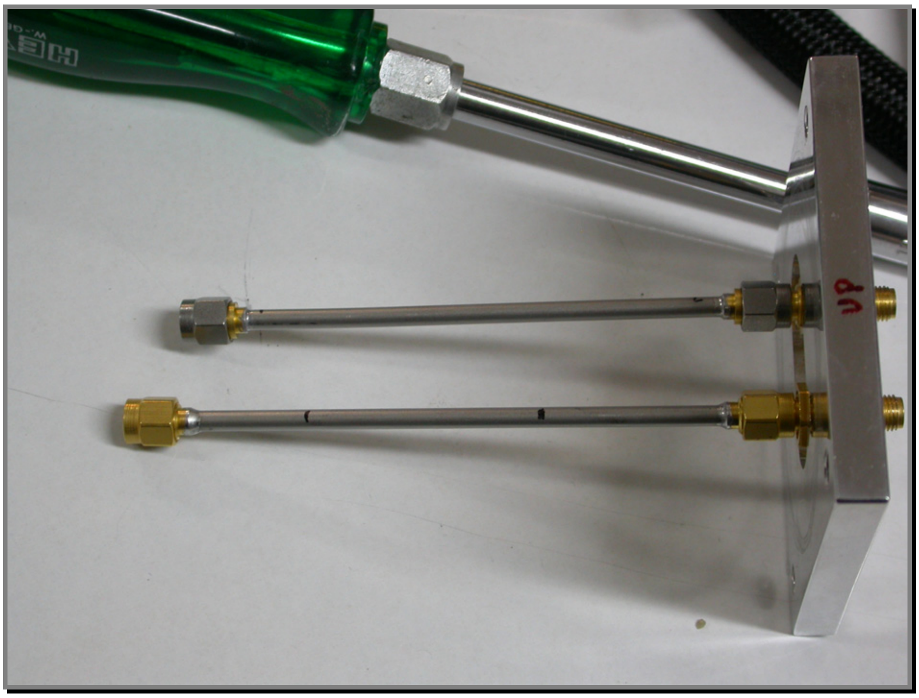


Figure 1.- *K and SMA semi-rigid cables measured*

The losses in the cables can be modeled in several ways. MMICAD incorporates a model for losses in transmission lines that could be used. However, the built model has been found to fail in the prediction of the time domain plots. The slope appearing in these plots (see Figure 8 and Figure 9) could only be explained by series resistive losses in the line. These losses are distributed by nature. As this can not be modeled by MMICAD, the transmission line was split in ten different pieces and series resistors were added in between. The value appearing in Figure 2 and Figure 3 is the equivalent resistance by length unit.

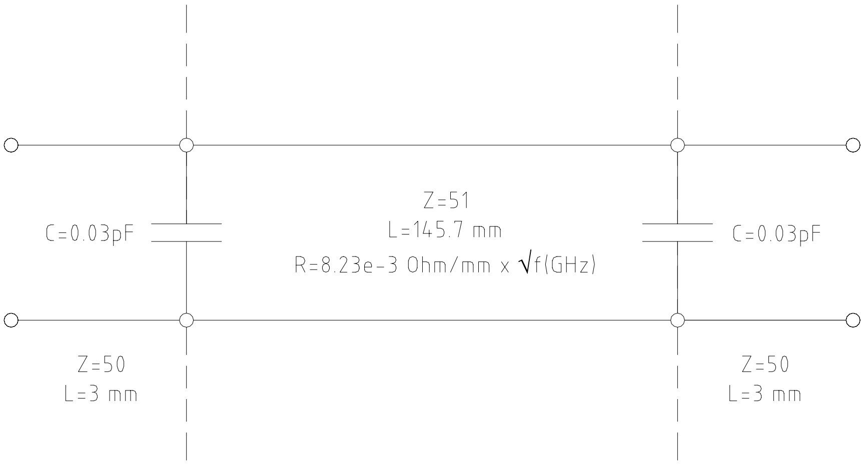


Figure 2.- *Equivalent circuit for a cable with SMA connectors*

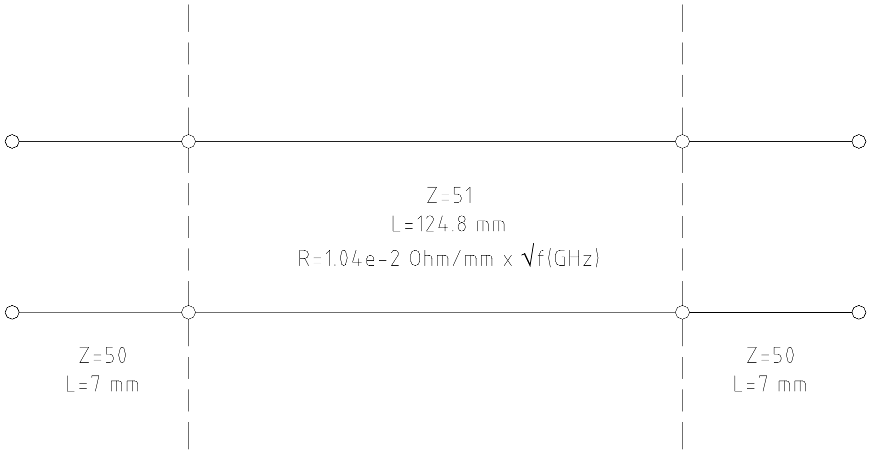


Figure 3.- *Equivalent circuit for a cable with K connectors*

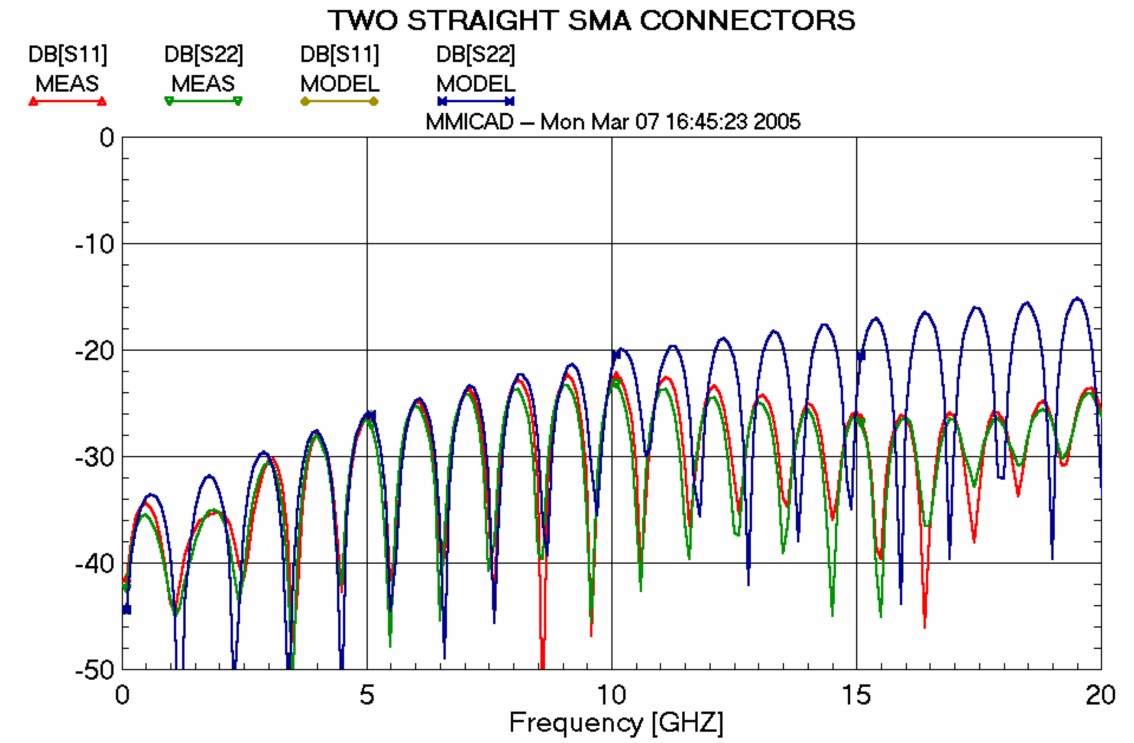


Figure 4.- *Reflection of a cable with SMA connectors*

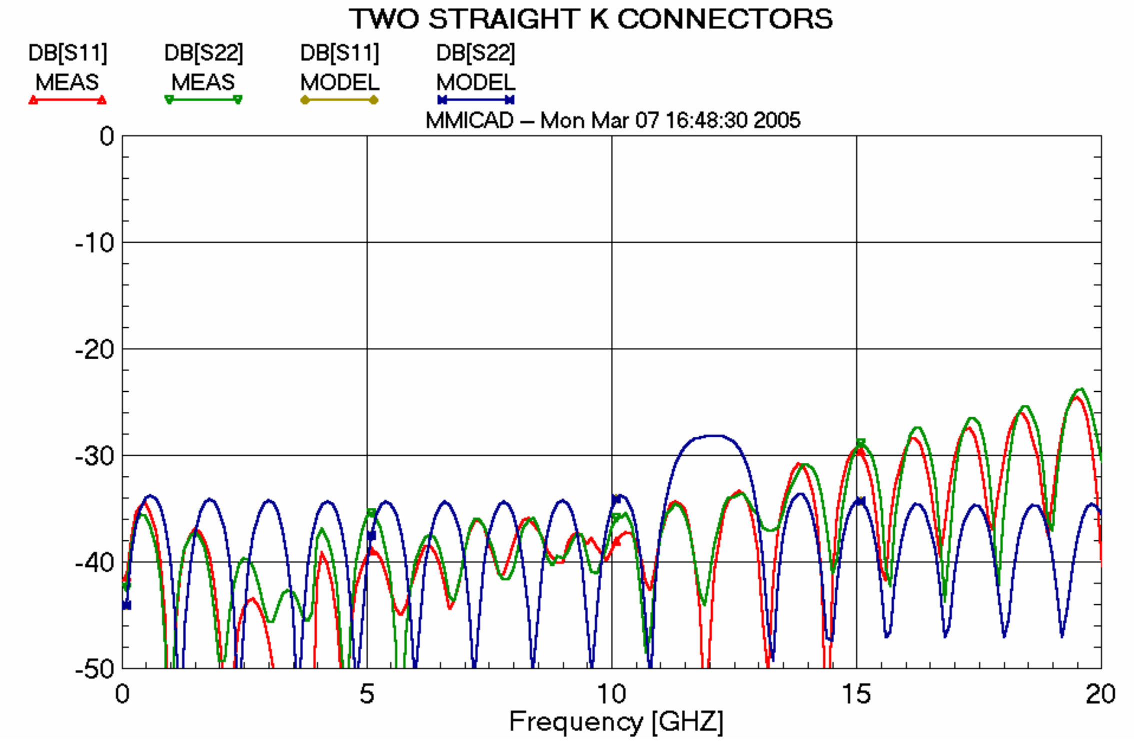


Figure 5.- *Reflection of a cable with K connectors*

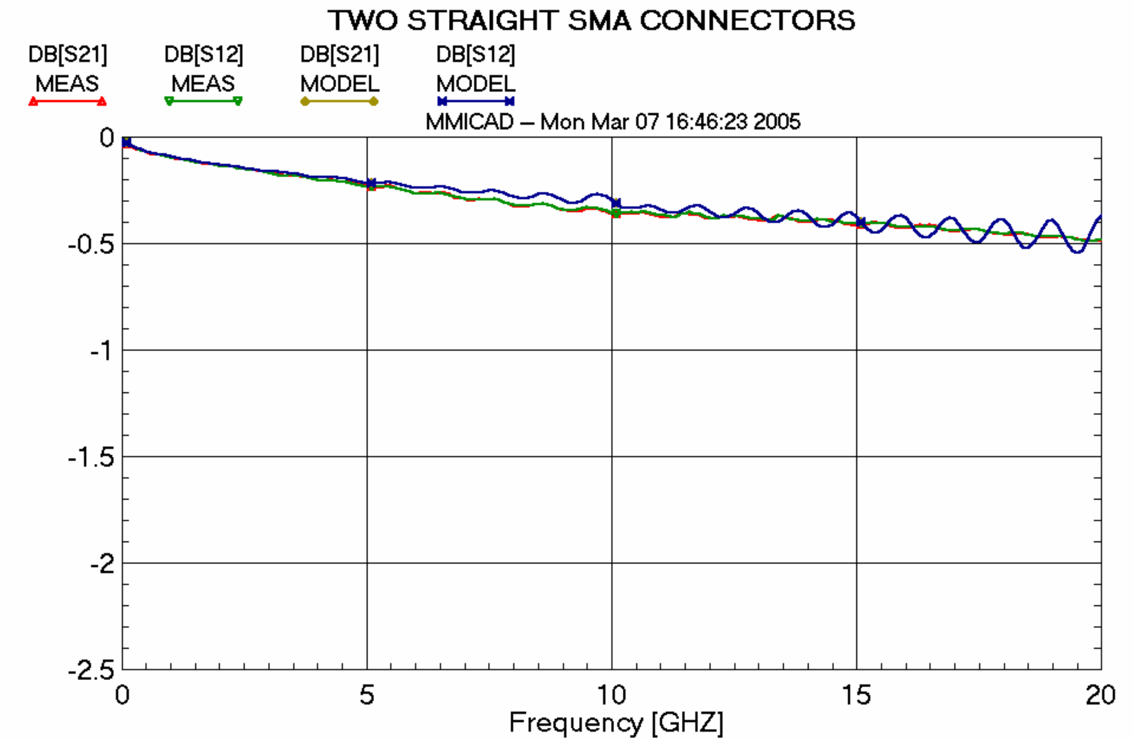


Figure 6.- *Losses of a cable with SMA connectors*

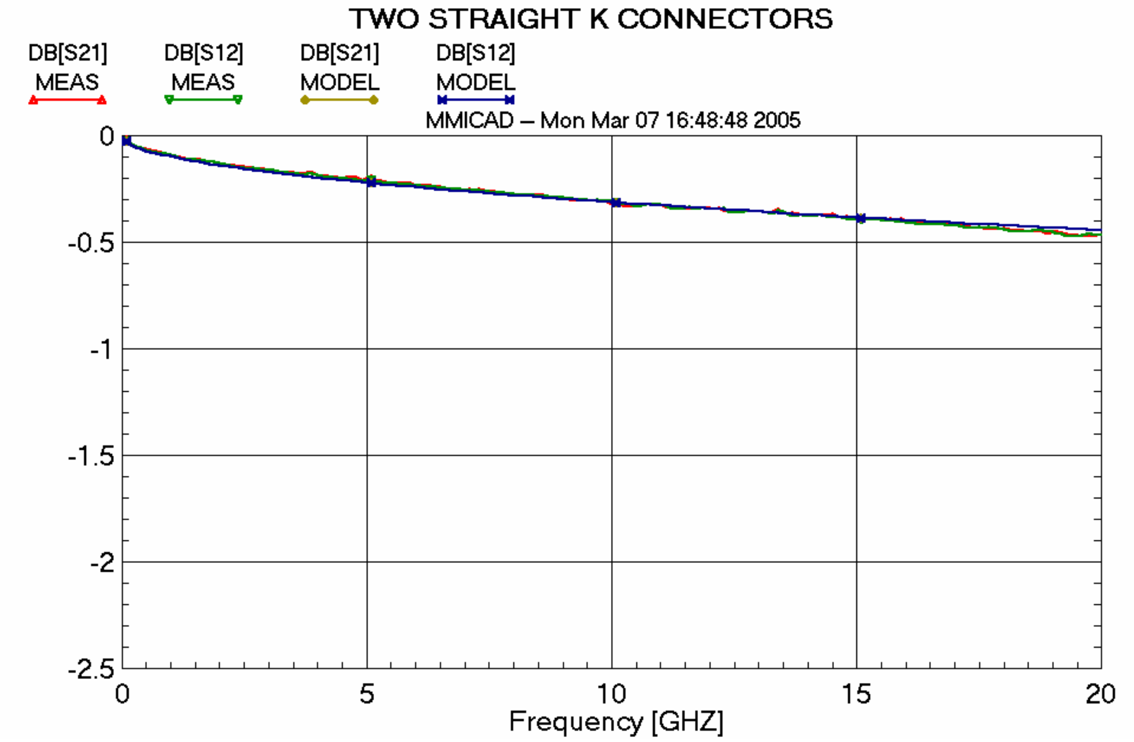
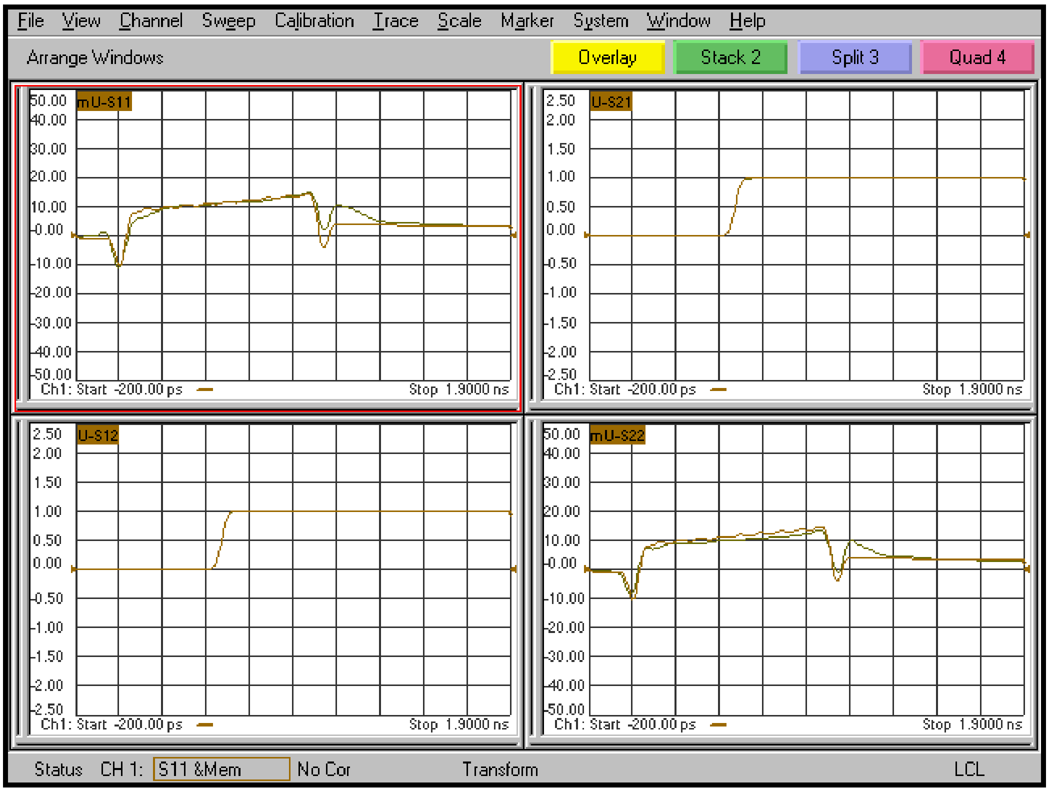
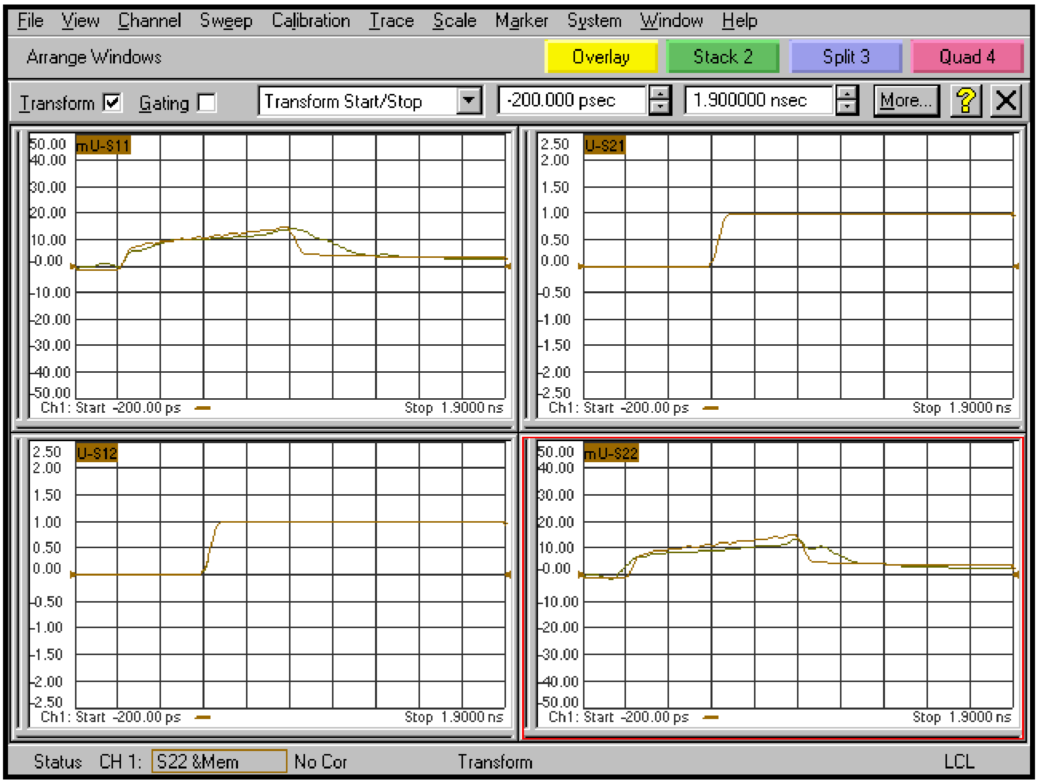


Figure 7.- *Losses of a cable with K connectors*



CH 1: S11 &Mem No Cor Transform

Figure 8.- *Time domain plot for a cable with SMA connectors*



Transform ☑ Gating ☐ Transform Start/Stop -200.000 psec 1.900000 nsec

CH 1: S22 &Mem No Cor Transform

Figure 9.- *Time domain plot for a cable with K connectors*

MOUNTING INSTRUCTIONS

It is important to note that special care is required to assemble the SMA and K connectors to the cable correctly. In our first attempt one of the two K connectors was wrong, and very poor performance was obtained. The problem was that the Teflon dielectric was not flush with the outer conductor. In order to avoid this problem it would be good to follow the cable preconditioning procedure as described in the Micro-Coax catalogue (Appendix I). Besides, the use of low loss cable (with low density Teflon) will help in reducing dielectric movements inside the cable caused by thermal cycling. Anyway, it is imperative to follow the instructions for assembly carefully and to use the right tools.

The mounting instructions for SMA connectors are described in the assembly procedure number M 09 of Radiall Catalogues (Appendix II). The tool kit R 282 120 will be used and the instructions have to be followed very carefully.

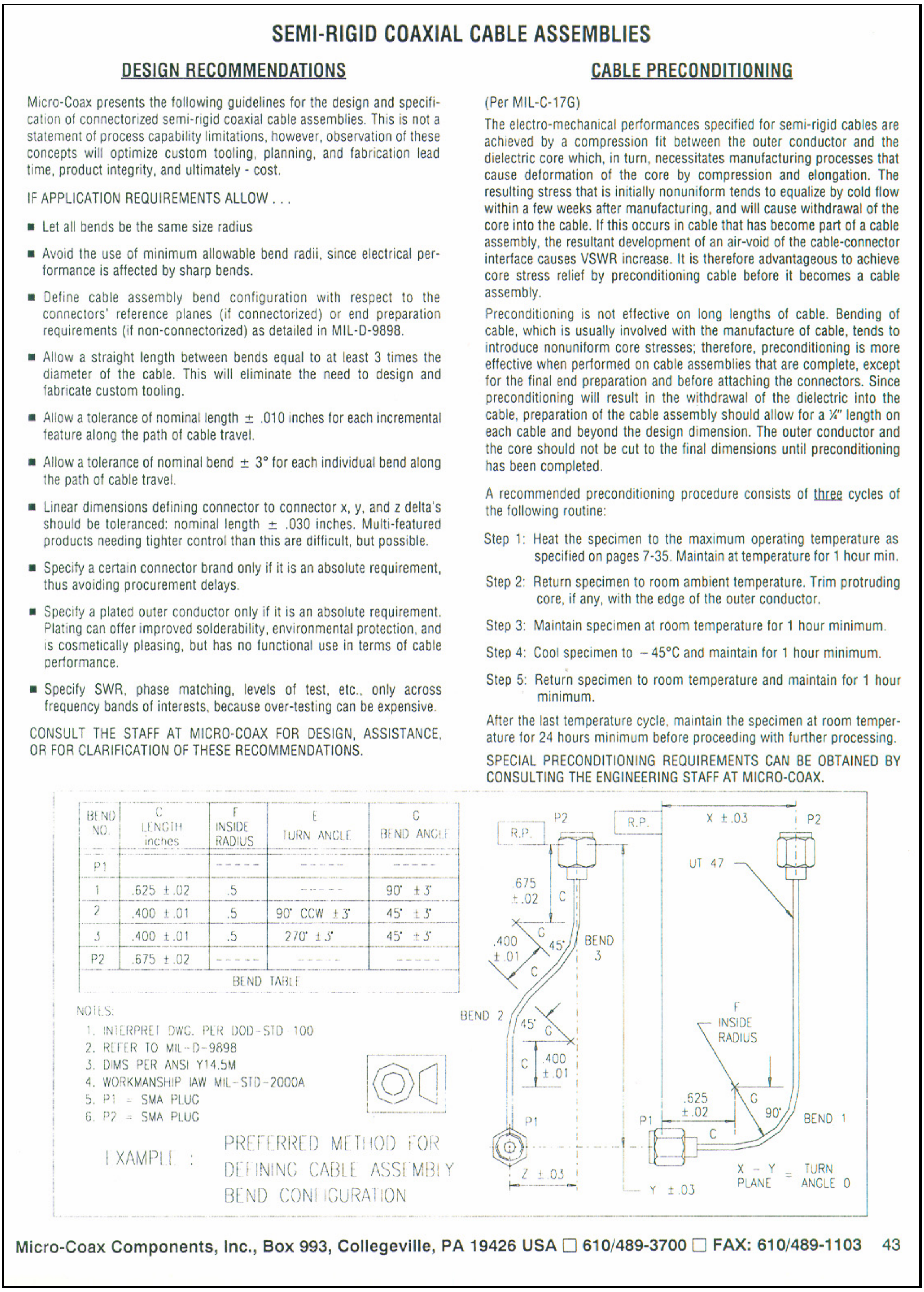
The mounting instructions for K connectors are similar to those used for the SMA. However, the cable trimming tool in step 1 should be modified due to the differences in the length of the contacts for K and SMA connectors. The contact in the K connector is shorter than in the SMA and the piece of cable cut for the first should be 2.57mm instead the 3.17mm used for the SMA. The spacer in step 3 should be the same used in SMA connector (0.2mm).

CONCLUSIONS

The K connectors (2.92mm) fitted to 0.141’’ cable show excellent electrical performance. They are superior to standard SMA connectors due to lower capacitive discontinuities as shown by the time domain plots. The discontinuities are located at 3mm from the interface. This distance is about half of the electrical length of the Teflon insert of the SMA connector. It can be assumed that it is due to a lower than 50Ω impedance of the first section of the transmission line.

The procedure for mounting the K connectors is very similar to SMA, and only minor modification on the cable trimming tool are needed.

APPENDIX I



SEMI-RIGID COAXIAL CABLE ASSEMBLIES

DESIGN RECOMMENDATIONS

Micro-Coax presents the following guidelines for the design and specification of connectorized semi-rigid coaxial cable assemblies. This is not a statement of process capability limitations, however, observation of these concepts will optimize custom tooling, planning, and fabrication lead time, product integrity, and ultimately - cost.

IF APPLICATION REQUIREMENTS ALLOW . . .

- Let all bends be the same size radius
- Avoid the use of minimum allowable bend radii, since electrical performance is affected by sharp bends.
- Define cable assembly bend configuration with respect to the connectors' reference planes (if connectorized) or end preparation requirements (if non-connectorized) as detailed in MIL-D-9898.
- Allow a straight length between bends equal to at least 3 times the diameter of the cable. This will eliminate the need to design and fabricate custom tooling.
- Allow a tolerance of nominal length ± .010 inches for each incremental feature along the path of cable travel.
- Allow a tolerance of nominal bend ± 3° for each individual bend along the path of cable travel.
- Linear dimensions defining connector to connector x, y, and z delta's should be toleranced: nominal length ± .030 inches. Multi-featured products needing tighter control than this are difficult, but possible.
- Specify a certain connector brand only if it is an absolute requirement, thus avoiding procurement delays.
- Specify a plated outer conductor only if it is an absolute requirement. Plating can offer improved solderability, environmental protection, and is cosmetically pleasing, but has no functional use in terms of cable performance.
- Specify SWR, phase matching, levels of test, etc., only across frequency bands of interests, because over-testing can be expensive.

CONSULT THE STAFF AT MICRO-COAX FOR DESIGN, ASSISTANCE, OR FOR CLARIFICATION OF THESE RECOMMENDATIONS.

CABLE PRECONDITIONING

(Per MIL-C-17G)

The electro-mechanical performances specified for semi-rigid cables are achieved by a compression fit between the outer conductor and the dielectric core which, in turn, necessitates manufacturing processes that cause deformation of the core by compression and elongation. The resulting stress that is initially nonuniform tends to equalize by cold flow within a few weeks after manufacturing, and will cause withdrawal of the core into the cable. If this occurs in cable that has become part of a cable assembly, the resultant development of an air-void of the cable-connector interface causes VSWR increase. It is therefore advantageous to achieve core stress relief by preconditioning cable before it becomes a cable assembly.

Preconditioning is not effective on long lengths of cable. Bending of cable, which is usually involved with the manufacture of cable, tends to introduce nonuniform core stresses; therefore, preconditioning is more effective when performed on cable assemblies that are complete, except for the final end preparation and before attaching the connectors. Since preconditioning will result in the withdrawal of the dielectric into the cable, preparation of the cable assembly should allow for a ¼" length on each cable and beyond the design dimension. The outer conductor and the core should not be cut to the final dimensions until preconditioning has been completed.

A recommended preconditioning procedure consists of three cycles of the following routine:

Step 1: Heat the specimen to the maximum operating temperature as specified on pages 7-35. Maintain at temperature for 1 hour min.

Step 2: Return specimen to room ambient temperature. Trim protruding core, if any, with the edge of the outer conductor.

Step 3: Maintain specimen at room temperature for 1 hour minimum.

Step 4: Cool specimen to −45°C and maintain for 1 hour minimum.

Step 5: Return specimen to room temperature and maintain for 1 hour minimum.

After the last temperature cycle, maintain the specimen at room temperature for 24 hours minimum before proceeding with further processing.

SPECIAL PRECONDITIONING REQUIREMENTS CAN BE OBTAINED BY CONSULTING THE ENGINEERING STAFF AT MICRO-COAX.

BEND NO.	C LENGTH inches	F INSIDE RADIUS	E TURN ANGLE	G BEND ANGLE
P1		-----	-----	-----
1	.625 ±.02	.5	-----	90° ±3°
2	.400 ±.01	.5	90° CCW ±3°	45° ±3°
3	.400 ±.01	.5	270° ±3°	45° ±3°
P2	.675 ±.02	-----	-----	-----

BEND TABLE

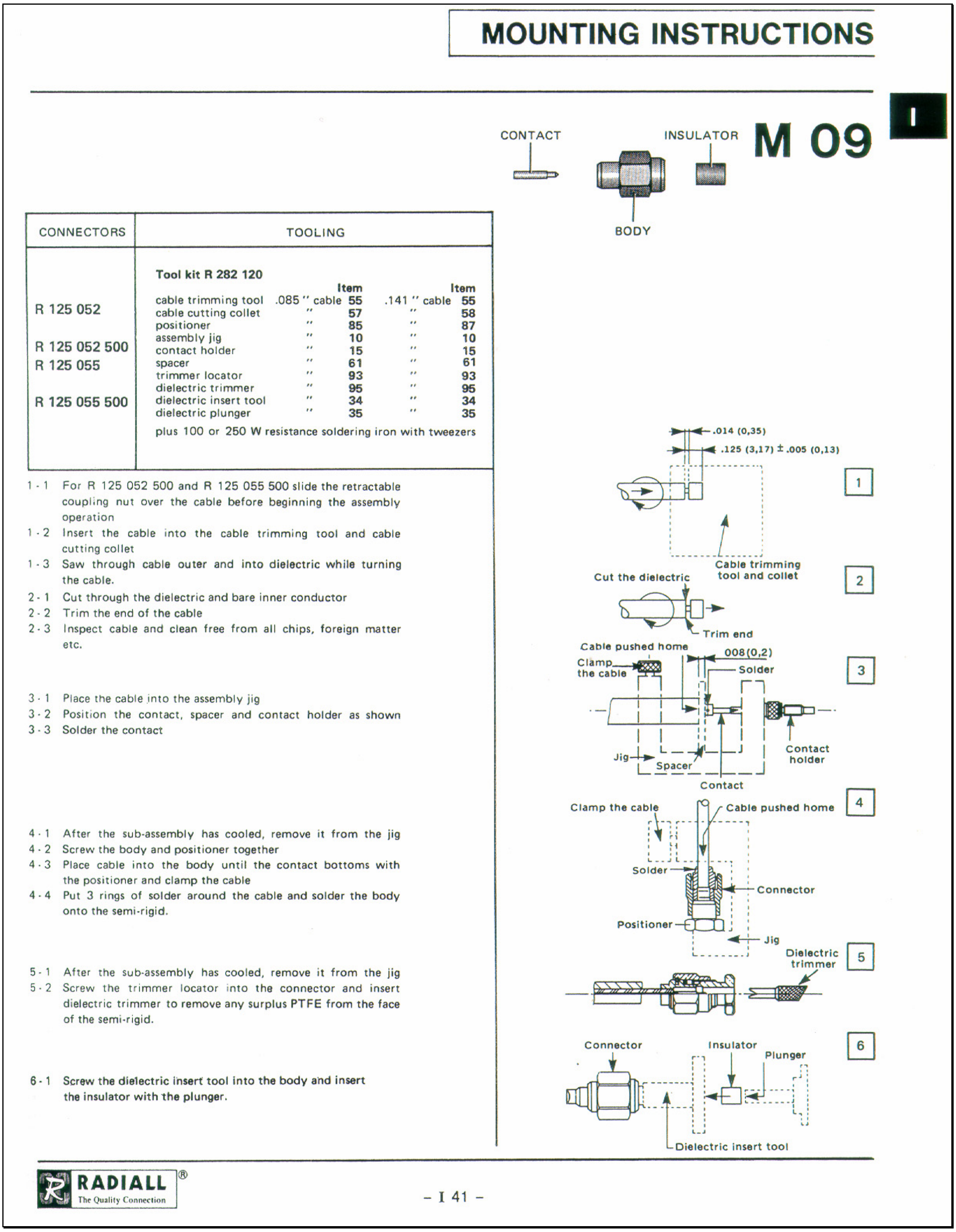
NOTES:

1. INTERPRET DWG. PER DOD-STD 100
2. REFER TO MIL-D-9898
3. DIMS PER ANSI Y14.5M
4. WORKMANSHIP IAW MIL-STD-2000A
5. P1 = SMA PLUG
6. P2 = SMA PLUG

EXAMPLE : PREFERRED METHOD FOR DEFINING CABLE ASSEMBLY BEND CONFIGURATION

Micro-Coax Components, Inc., Box 993, Collegeville, PA 19426 USA ☐ 610/489-3700 ☐ FAX: 610/489-1103 43

APPENDIX II



MOUNTING INSTRUCTIONS

M 09

I

CONNECTORS	TOOLING		Item		Item
R 125 052 R 125 052 500 R 125 055 R 125 055 500	**Tool kit R 282 120**				
	cable trimming tool	.085 " cable	55	.141 " cable	55
	cable cutting collet	"	57	"	58
	positioner	"	85	"	87
	assembly jig	"	10	"	10
	contact holder	"	15	"	15
	spacer	"	61	"	61
	trimmer locator	"	93	"	93
	dielectric trimmer	"	95	"	95
	dielectric insert tool	"	34	"	34
	dielectric plunger	"	35	"	35
	plus 100 or 250 W resistance soldering iron with tweezers				

1 - 1 For R 125 052 500 and R 125 055 500 slide the retractable coupling nut over the cable before beginning the assembly operation
1 - 2 Insert the cable into the cable trimming tool and cable cutting collet
1 - 3 Saw through cable outer and into dielectric while turning the cable.
2 - 1 Cut through the dielectric and bare inner conductor
2 - 2 Trim the end of the cable
2 - 3 Inspect cable and clean free from all chips, foreign matter etc.

3 - 1 Place the cable into the assembly jig
3 - 2 Position the contact, spacer and contact holder as shown
3 - 3 Solder the contact

4 - 1 After the sub-assembly has cooled, remove it from the jig
4 - 2 Screw the body and positioner together
4 - 3 Place cable into the body until the contact bottoms with the positioner and clamp the cable
4 - 4 Put 3 rings of solder around the cable and solder the body onto the semi-rigid.

5 - 1 After the sub-assembly has cooled, remove it from the jig
5 - 2 Screw the trimmer locator into the connector and insert dielectric trimmer to remove any surplus PTFE from the face of the semi-rigid.

6 - 1 Screw the dielectric insert tool into the body and insert the insulator with the plunger.

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