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TECHNICAL REPORT

Radio-frequency connectors -
Part 1-8: Electrical test methods - Voltage standing wave ratio for a single connector by double connector method

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Radio-frequency connectors - Part 1-8: Electrical test methods - Voltage standing wave ratio for a single connector by double connector method

FOREWORD

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IEC TR 61169-1-8 has been prepared by subcommittee 46F: RF and microwave passive components, of IEC technical committee 46: Cables, wires, waveguides, RF connectors, RF and microwave passive components and accessories. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
46F/727/DTR	46F/735/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 61169 series, published under the general title *Radio-frequency connectors*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,
– withdrawn, or
– revised.

1 Scope

This part of IEC 61169, which is a Technical Report, provides a test method for voltage standing wave ratio (VSWR, hereinafter) of single RF connector by double-connector method.

This document is applicable to single RF cable connectors and single microstrip RF connectors as well as single adapters if an estimation of the VSWR of a single completely installed RF-connector is used and a time domain feature is not available on the vector network analyzer.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61169-1, *Radio frequency connectors - Part 1: Generic specification - General requirements and measuring methods*

IEC 61169-1-4, *Radio-frequency connectors - Part 1-4: Electrical test methods - Voltage standing wave ratio, return loss and reflection coefficient*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61169-1 and IEC 61169-1-4 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

– IEC Electropedia: available at https://www.electropedia.org/
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4 Theory of test method

When two identical connectors are connected in series into the system under standard environmental conditions according to IEC 60068-1 [1], at a certain frequency, the reflections of both connectors can reach the maximum value, resulting in superposition. In this case, the total reflection of the two connectors in series is twice as much as that of the single connector, namely:

$$\mathit{\Gamma}_{\text{double}} = 2\mathit{\Gamma}_{\text{single}} \tag{1}$$

Where $\mathit{\Gamma}_{\text{double}}$ and $\mathit{\Gamma}_{\text{single}}$ are reflection coefficients of double connectors in series and a single connector, respectively.

From the relationship between reflection coefficient and voltage standing wave ratio, we can derive Formula (2):

$$\Gamma_{\text{single}} = \frac{S_{\text{single}} - 1}{S_{\text{single}} + 1} = \frac{1}{2}\Gamma_{\text{double}} = \frac{1}{2}\frac{S_{\text{double}} - 1}{S_{\text{double}} + 1} \tag{2}$$

By conversion, we have:

$$S_{\text{single}} = \frac{3S_{\text{double}} + 1}{S_{\text{double}} + 3} \tag{3}$$

When 1 ≤S_{double} <2, we can use empirical formula as follows:

$$S_{\text{single}} = \sqrt{S_{\text{double}}} \tag{4}$$

In Formula (2), Formula (3) and Formula (4), S_{single} and S_{double} are VSWR for a single connector and double connectors respectively.

Due to the limitation of materials, process, assembly and other factors, two or more completely identical connectors do not exist in practice. What can be only done is to use relatively consistent connectors from same lot to do the double-connector test. Therefore, for some connectors, it is important that Formula (4) is modified with a correction coefficient A, as shown in Formula (5). The correction coefficient A is closely related to the consistency of products, for which refer to Annex A.

$$S_{\text{single}} = A \times \sqrt{S_{\text{double}}} \tag{5}$$

Because connectors are reciprocal parts, Formula (4) or Formula (5) are still valid when two identical connectors are mirror symmetrically connected.

Double-connector method is applicable to measure single RF cable connector and single microstrip connector for VSWR. It is also applicable to measure single RF connector adapter.

5 Preparation of test sample (DUT)

5.1 RF cable connector

A double connector cable assembly is made as a test sample (device under test, DUT) by using two completely identical RF cable connectors selected from same lot, and using the pre-selected uniform cable with accurate characteristic impedance or a section of coaxial air line designed as a simulated cable. The test sample is as shown in Figure 1. The length of the cable or the simulated cable connecting the same two tested connectors is L.

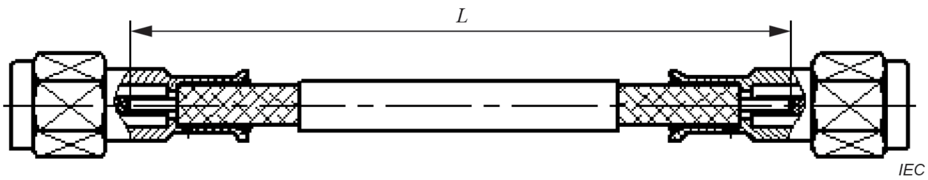


Figure 1 – Test sample of cable connectors by double connector method

The cable or simulated cable is selected as follows.

a) The selected cable is a matched cable and is as short and low attenuation as possible.
b) According to the test theory, the VSWR of a single connector measured by the double-connector method is the data of one connector with half cable shown in Figure 1. So, the shorter the length of the cable is, the smaller the attenuation is, and the measured value will be closer to the VSWR of single connector (see Annex B).

5.2 Microstrip connector

Use two microstrip connectors under test to make a double-connector assembly as a test sample (DUT). The connectors are selected from the same lot, and connected back to back by appropriate connecting piece, such as connecting pin as shown in Figure 2; the connecting piece is as short and low attenuation as possible.

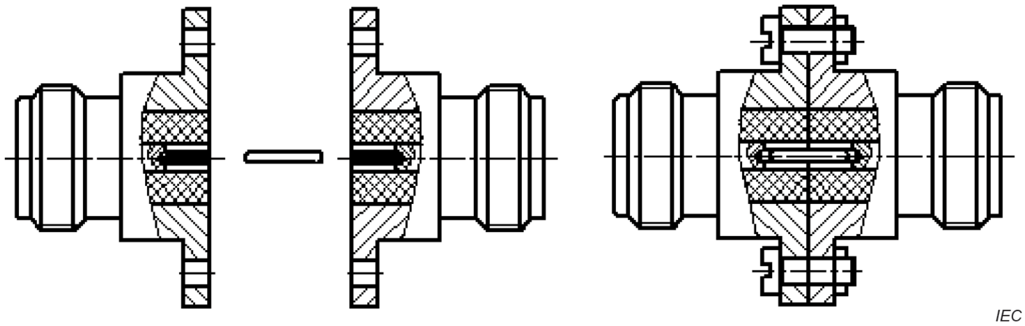


Figure 2 – Test sample of microstrip connectors by double connector method

6 Test procedure

The test procedure is as follows.

a) The measurement frequency range and other related parameters are set, and then the test mode is set to measure the VSWR.

b) The VSWR of double connector test sample shown in Figure 1 or Figure 2 is measured in accordance with IEC 61169-1-4. The maximum measured value among the measurement frequency range is recorded as S_{double}.

c) Calculation: For RF cable connector: the VSWR of a single cable connector is calculated from Formula (4). For microstrip connector: the VSWR of a single microstrip connector is calculated from Formula (5), where for the determination method of correction factor A refer to Annex A.

Annex A
(informative)

Test report on correction coefficient

A.1 Verification test method

An even number of microstrip connectors are randomly selected from the same batch and model products. The sample and test are prepared according the method as specified in the related standard. The verification test was as follows.

a) A vector network analyzer with PLTS software is used to measure the VSWR curve of the test sample (DUT) in the whole working frequency band. The maximum value is found and recorded as $S_{11\text{double}}$. See the blue curve in Figure A.1.

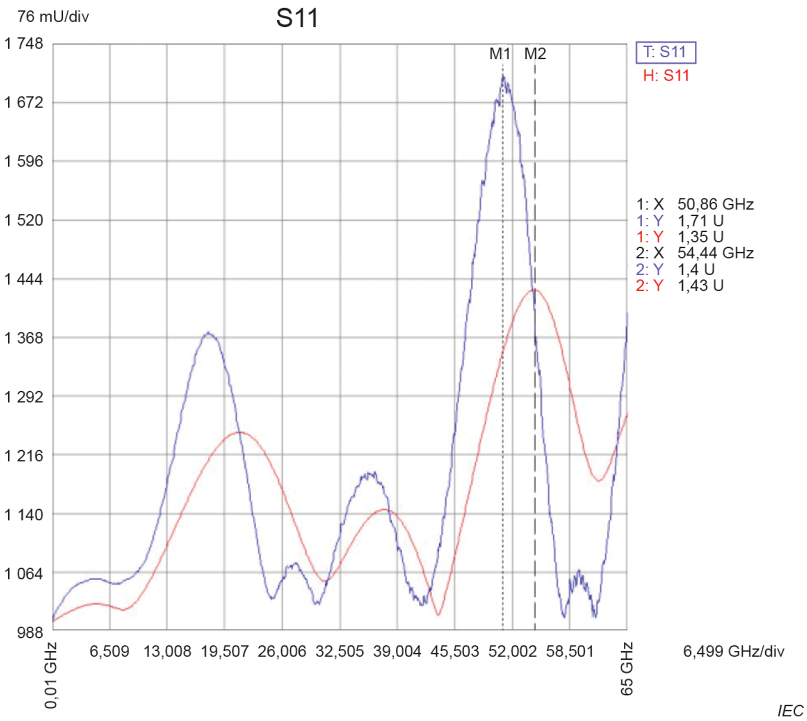
b) The AFR de-embedding function of PLTs software is used to extract the VSWR curve of the left half of test sample (DUT). The maximum value is found out and recorded as $S_{1\text{single de-embedded}}$. See the red curve in Figure A.1.

c) The test sample (DUT) is turned around, and Clause A.1, list item a) and Clause A.1, list item b) are repeated to measure the other side and to get $S_{22\text{double}}$ and $S_{2\text{single de-embedded}}$. See Figure A.2.

d) The value of single connector is calculated by using Formula (4) and Formula (5).

e) The calculated values are compared with the de-embedding measured value of $S_{1\text{single de-embedded}}$ and $S_{2\text{single de-embedded}}$.

EXAMPLE Two 1,85-KFD microstrip connectors numbered 1 and 2 are taken from the same batch and connected back-to-back using a pin. The VSWR is measured using the above-mentioned method; the test results are shown in Figure A.1 and Figure A.2. The maximum value over the test frequency range is found out for each curve.

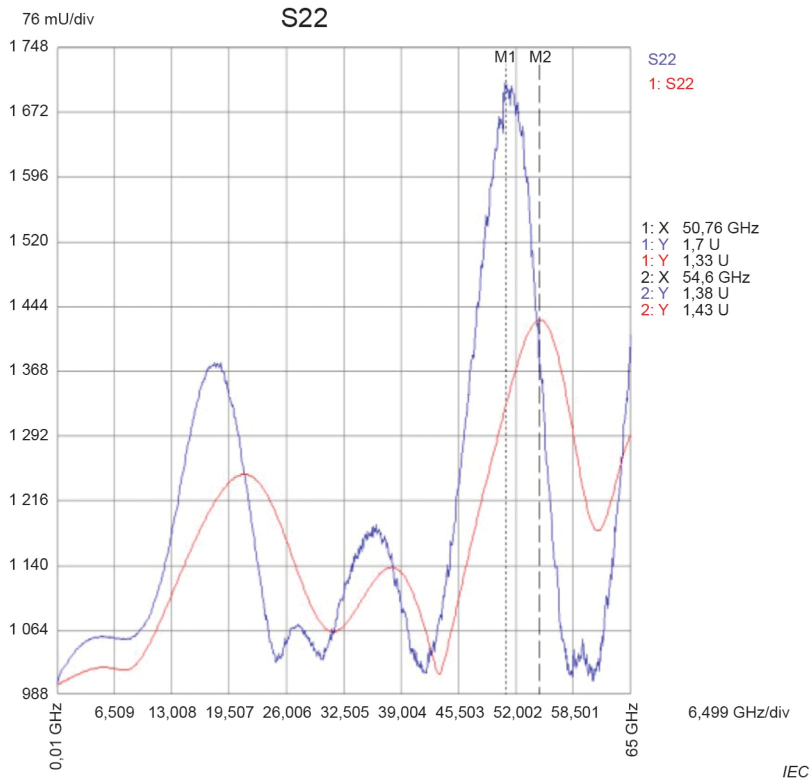


Key

$S_{11double}$ = 1,71 of DUT (blue curve);

$S_{1single\ de\text{-}embedded}$ = 1,35 (left no. 1connector) (red curve)

Figure A.1 – Tested at no. 1 connector end



Key

$S_{22\text{double}}$	= 1,7 of DUT (blue curve);
$S_{2\text{ single de-embedded}}$	= 1,33 (right no. 2 connector) (red curve)

Figure A.2 – Tested at no. 2 connector end

A.2 Test results

A.2.1 Test verification of 2,92-KFD microstrip connectors from the same batch

Ten pieces of 2,92-KFD microstrip connectors are randomly selected from the same batch of products. The test frequency range is 0,05 GHz to 40 GHz. The test results are as shown in Table A.1.

Table A.1 – Test results of 2,92-KFD microstrip connectors

Group no.	Test port	S_{double}	$S_{\text{single de-embedded}}$	$S_{\text{single}} = \sqrt{S_{\text{double}}}$	Error between S_{Single} and $S_{\text{single de-embedded}}$	$S_{\text{single correction}} = 1,08 \times \sqrt{S_{\text{double}}}$	Error between $S_{\text{single correction}}$ and $S_{\text{single test}}$
					%		%
1	1	1,13	1,11	1,063	-4,23	1,15	3,31
	2	1,14	1,11	1,068	-3,81	1,15	3,74
2	1	1,12	1,09	1,058	-2,91	1,14	4,63
	2	1,12	1,10	1,058	-3,79	1,14	3,76
3	1	1,12	1,11	1,058	-4,66	1,14	2,88
	2	1,12	1,11	1,058	-4,66	1,14	2,88
4	1	1,10	1,11	1,049	-5,51	1,13	2,01
	2	1,10	1,09	1,049	-3,78	1,13	3,77
5	1	1,13	1,11	1,063	-4,23	1,15	3,31
	2	1,13	1,11	1,063	-4,23	1,15	3,31

A.2.2 Test verification of 2,4-KFD microstrip connectors in the same batch

Ten pieces of 2,4-KFD microstrip connectors are randomly selected from the same batch of products. The test frequency range is 0,05 GHz to 50 GHz. The test results are as shown in Table A.2.

Table A.2 – Test results of 2,4-KFD microstrip connectors

Group no.	Test port	S_{double}	$S_{\text{single de-embedded}}$	$S_{\text{single}} = \sqrt{S_{\text{double}}}$	Error between S_{Single} and $S_{\text{single de-embedded}}$	$S_{\text{single correction}} = 1,08 \times \sqrt{S_{\text{double}}}$	Error between $S_{\text{single correction}}$ and $S_{\text{single de-embedded}}$
					%		%
1	1	1,27	1,22	1,127	-7,63	1,22	-0,24
	2	1,29	1,23	1,136	-7,66	1,23	-0,27
2	1	1,29	1,24	1,136	-8,40	1,23	-1,09
	2	1,31	1,23	1,145	-6,95	1,24	0,49
3	1	1,31	1,23	1,145	-6,95	1,24	0,49
	2	1,30	1,22	1,140	-6,54	1,23	0,92
4	1	1,30	1,25	1,140	-8,79	1,23	-1,51
	2	1,32	1,23	1,149	-6,59	1,24	0,87
5	1	1,29	1,22	1,136	-6,90	1,23	0,54
	2	1,31	1,23	1,145	-6,95	1,24	0,49

A.2.3 Test verification of 1,85-KFD microstrip connectors from the same batch

Ten pieces of 1,85-KFD microstrip connectors are randomly selected from the same batch of products. The test frequency range is 0,05 GHz to 65 GHz. The test results are as shown in Table A.3.

Table A.3 – Test results of 1,85-KFD microstrip connectors

Group no.	Sample number (test port)	S_{double}	$S_{single\ de\text{-}embedded}$	$S_{single} = \sqrt{S_{double}}$	Error between S_{Single} and $S_{single\ de\text{-}embedded}$	$S_{single\ correction} = 1,08 * \sqrt{S_{double}}$	Error between $S_{single\ correction}$ and $S_{single\ de\text{-}embedded}$
					%		%
1	1	1,71	1,43	1,308	-8,55	1,41	-1,25
	2	1,70	1,43	1,304	-8,82	1,41	-1,55
2	1	1,71	1,46	1,308	-10,43	1,41	-3,38
	2	1,71	1,47	1,308	-11,04	1,41	-4,09
3	1	1,81	1,45	1,345	-7,22	1,45	0,21
	2	1,80	1,48	1,342	-9,35	1,45	-2,14
4	1	1,74	1,43	1,319	-7,76	1,42	-0,38
	2	1,75	1,46	1,323	-9,39	1,43	-2,19
5	1	1,78	1,46	1,334	-8,62	1,44	-1,33
	2	1,79	1,48	1,338	-9,60	1,44	-2,43

A.3 Conclusion

a) For microstrip connectors, double connector method can be used to test the VSWR of a single connector.

b) It is better to use a correction coefficient when using double connector method; the formula is as following:

$$S_{single} = 1,08 \times \sqrt{S_{double}} \tag{A.1}$$

c) Reasons: The connecting piece between the two connectors will bring reflection and attenuation itself. In addition, the double connectors in series cannot be identical practically. And the system has errors as well. This result in that the frequency point for the maximum standing wave of a single connector do not coincide with that of the other connector. Therefore, it is important that the test results are corrected.

Annex B
(informative)

Test report on cable length

B.1 Verification method

An even number of RF cable connectors are randomly selected from the same batch and model products and divided each two into a group. The sample and test are prepared according to the method as specified in the related standard. Verification test is as follows.

a) A vector network analyzer with PLTS software is used to measure the VSWR curve of the test sample (DUT) in the whole working frequency band. The maximum value is found out and recorded as $S_{11\text{double}}$. See the blue curve in Figure B.1.

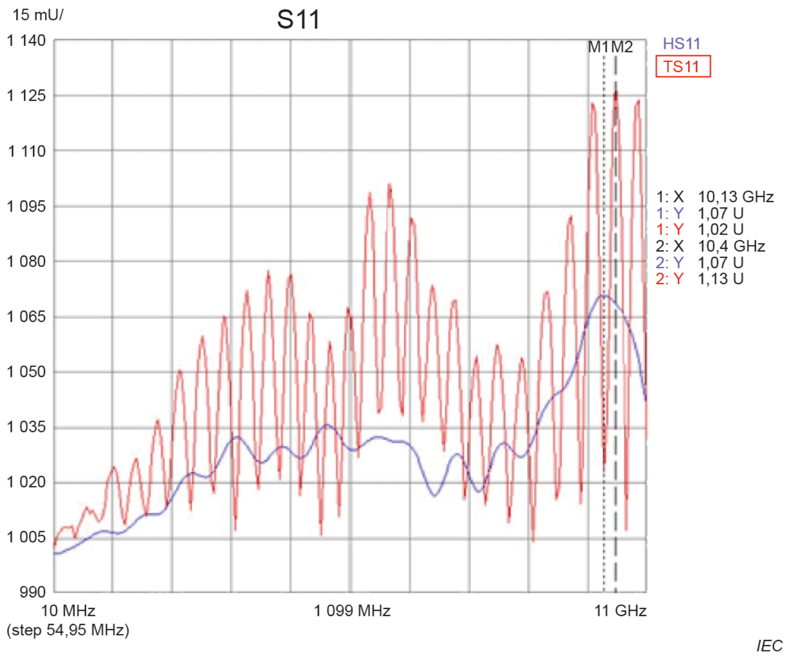
b) The AFR de-embedding function of PLTs software is used to extract the VSWR curve of the left half of test sample (DUT)., The maximum value is found out and recorded as $S_{1\text{single de-embedded}}$. See the red curve in Figure B.1.

c) The test sample (DUT) is turned around, and Clause B.1, list item a) and Clause B.1, list item b) are repeated to measure the other side and to get $S_{22\text{double}}$ and $S_{2\text{single de-embedded}}$. See Figure B.2.

d) The value of single connector is calculated by using Formula (4).

e) The calculated values are compared with the de-embedding measured value of $S_{1\text{single de-embedded}}$ and $S_{2\text{single de-embedded}}$.

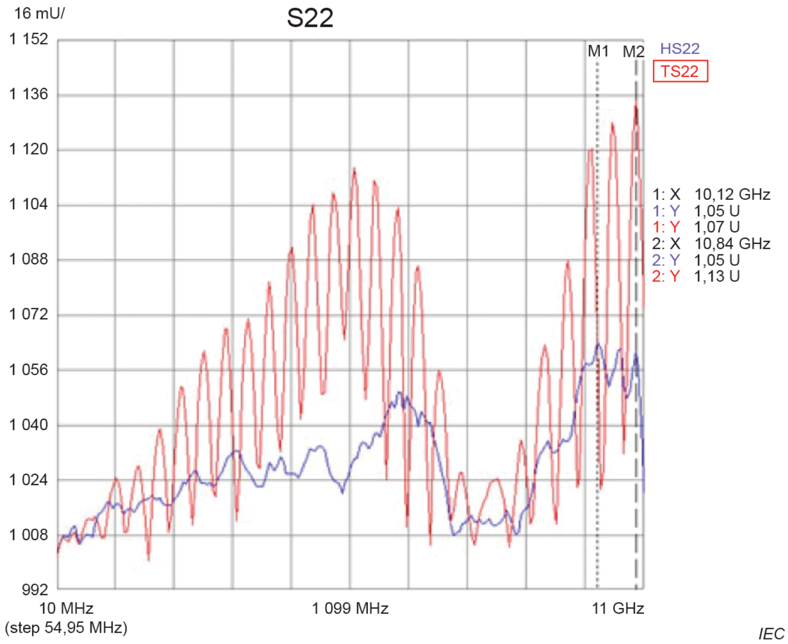
EXAMPLE Two N-J type cable connectors numbered 1 and 2 are taken from the same batch andconnected with a cable to form a assembly. The VSWR is measured using the above-mentioned method. The test results are as shown in Figure B.1 and Figure B.2. The maximum value over the test frequency range is find out for each curve.



Key

The red curve is $S_{11\text{ double}}$	(= 1,13) for the whole assembly, measured at the no. 1 sample end.
The blue curve is $S_{11\text{ single test}}$	(=1,07), measured at the no. 1 de -embedded connector sample end.

Figure B.1 – N-J type cable connectors



The red curve is $S_{22\ double}$ (= 1,13) for the whole assembly, measured at the no. 2 sample end.

The blue curve is $S_{22\ single\ test}$ (=1,06), measured at the no. 2 de-embedded connector sample end.

Figure B.2 – N-J type cable connectors

B.2 Test verification

B.2.1 Test verification of N-J type cable connectors from the same batch

Six N-J type cable connectors are randomly selected from the same batch of products, and divided into three groups, as well as connected with CXN 3 450 cables individually to form three cable assemblies. The length is 300 mm for each of the cables, and the test frequency range is from 0,01 GHz to 11 GHz. The test results are shown in Table B.1.

Table B.1 – Test results of N-J connectors with 300 mm 3 450 cable (cable length/λ_{min}= 13,1)

Group no.	Test port	S_{double}	$S_{single\ de\text{-}embedded}$	$S_{single} = \sqrt{S_{double}}$	Error between S_{single} & $S_{single\ de\text{-}embedded}$	Total insertion loss
					%	dB
1	1	1,13	1,07	1,063	-0,65	0,62
	2	1,13	1,06	1,063	0,28	
2	1	1,14	1,07	1,068	-0,21	0,39
	2	1,16	1,08	1,077	-0,27	
3	1	1,13	1,08	1,063	-1,57	0,35
	2	1,14	1,05	1,068	1,69	

B.2.2 Test verification of TNC-J type cable connectors from the same batch

Six TNC-J type cable connectors are randomly selected from the same batch of products, and divided into three groups, as well as connected with CXN 3 449 cables individually to form three cable assemblies. The length is 300 mm for each of the cables, and the test frequency range is from 0,01 GHz to 11 GHz. The test results are shown in Table B.2.

Table B.2 – Test results of TNC-J connector with 300 mm 3449 cable length/λ_{min}= 13,1

Group no.	Sample number (test port)	S_{double}	$S_{single\ de\text{-}embedded}$	$S_{single} = \sqrt{S_{double}}$	Error between S_{single} and $S_{single\ de\text{-}embedded}$	Total insertion loss
					%	dB
1	1	1,27	1,16	1,126	-2,85	0,52
	2	1,27	1,15	1,126	-2,00	
2	1	1,18	1,13	1,086	-3,87	0,51
	2	1,16	1,11	1,077	-2,97	
3	1	1,19	1,14	1,091	-4,31	0,48
	2	1,18	1,12	1,086	-3,01	

B.2.3 Test verification of SMA-J type cable connectors from the same batch

Eighteen SMA-J type cable connectors are randomly selected from the same batch of products and connected with 3 450 model cables to make three cable assemblies having a length of 300 mm, as well as with 3 507 model cables to form three respectivly 100 mm and three 50 mm cable assemblies The test frequency range is from 0,01 GHz to 18 GHz. The test results of different length assemblies are shown in Table B.3, Table B.4 and Table B.5.

Table B.3 – Test results of SMA-J connectors with 50 mm 3 507 cable cable length/λ_{min}= 3,6

Group no.	Sample number (test port)	S_{double}	$S_{single\ de\text{-}embedded}$	$S_{single} = \sqrt{S_{double}}$	Error between S_{single} and $S_{single\ de\text{-}embedded}$	Total insertion loss
					%	dB
4	1	1,20	1,08	1,095	1,41	0,16
	2	1,24	1,12	1,114	-0,58	
5	1	1,23	1,11	1,109	-0,09	0,16
	2	1,23	1,09	1,109	1,72	
6	1	1,14	1,07	1,068	-0,21	0,14
	2	1,14	1,06	1,068	0,72	

Table B.4 – Test results of SMA-J connectors with 100 mm 3 507 cable cable length/λ_{min}= 7,1

Group no.	Sample number (test port)	S_{double}	$S_{single\ de\text{-}embedded}$	$S_{single} = \sqrt{S_{double}}$	Error between S_{single} and $S_{single\ de\text{-}embedded}$	Total insertion loss
					%	dB
1	1	1,25	1,11	1,118	0,72	0,25
	2	1,21	1,11	1,100	-0,91	
2	1	1,22	1,10	1,105	0,41	0,26
	2	1,22	1,11	1,105	-0,49	
3	1	1,22	1,07	1,105	3,13	0,24
	2	1,23	1,14	1,109	-2,79	

Table B.5 – Test results of SMA-J connectors with 300 mm 3 450 cable cable length/λ_{min}= 21

Group no.	Sample number (test port)	S_{double}	$S_{single\ de\text{-}embedded}$	$S_{single} = \sqrt{S_{double}}$	Error between S_{single} and $S_{single\ de\text{-}embedded}$	Total insertion loss
					%	dB
7	1	1,37	1,27	1,170	-7,84	0,53
	2	1,37	1,14	1,170	2,67	
8	1	1,29	1,22	1,136	-6,90	0,51
	2	1,35	1,09	1,162	6,60	
9	1	1,29	1,22	1,136	-6,90	0,51
	2	1,35	1,09	1,162	6,60	

B.2.4 Test verification of 2,92-J type cable connectors from the same batch

Eight 2,92-J type cable connectors are randomly selected from the same batch of products, and divided into four groups, as well as connected with 3 506 model cables to form four cable assemblies. The length is 600 mm for each assembly, and the test frequency range is from 0,01 GHz to 40 GHz. The test results are shown in Table B.6.

Table B.6 – Test results of 2,92-J connectors with 600 mm 3 506 cable cable length/λ_{min}= 95,2

Group no.	Sample number (test port)	S_{double}	$S_{single\ de\text{-}embedded}$	$S_{single} = \sqrt{S_{double}}$	Error between S_{single} & $S_{single\ de\text{-}embedded}$	Total insertion loss	Total insertion loss
					%	dB	dB
1	1	1,38	1,35	1,175	-12,98	2,76	2,76
	2	1,25	1,40	1,118	-20,14		
2	1	1,32	1,22	1,149	-5,83	2,87	2,87
	2	1,22	1,59	1,105	-30,53		
3	1	1,32	1,18	1,149	-2,63	2,76	2,76
	2	1,41	1,42	1,187	-16,38		
4	1	1,44	1,38	1,200	-13,04	2,81	2,81
	2	1,36	1,42	1,166	-17,87		

B.2.5 Test verification of 2,4J type cable connectors from the same batch

Eight 2,4-J type cable connectors are randomly selected from the same batch of products and divided into four groups, as well as connected with 3 506 model cables to form four cable assemblies. The length is 1 000 mm for each assembly, and the test frequency range is from 0,01 GHz to 50 GHz. The test results are shown in Table B.7.

Table B.7 – Test results of 2,4-J type cable connector assemblies cable length/λ_{min}= 198,4

Group no.	Sample number (test port)	S_{double}	$S_{single\ de\text{-}embedded}$	$S_{single} = \sqrt{S_{double}}$	Error between S_{single} and $S_{single\ de\text{-}embedded}$	Total insertion loss
					%	dB
1	1	1,56	1,63	1,249	-23,37	3,23
	2	1,54	1,62	1,241	-23,40	
2	1	1,54	1,61	1,241	-22,92	3,13
	2	1,54	1,53	1,241	-18,89	
3	1	1,52	1,66	1,233	-25,73	3,23
	2	1,49	1,65	1,221	-26,02	
4	1	1,44	1,57	1,200	-23,57	3,13
	2	1,48	1,46	1,217	-16,67	

B.3 Conclusion

a) For cable connectors, double connector method can be used to test the VSWR of a single connector.

b) The length of cable has a great influence on the test results. The higher the frequency is, the shorter the cable length is used. The shorter the length, the more accurate the test results.

c) The test data shows that, when the cable length is more than 21 times of the shortest wavelength, the test data cannot be used because the error is more than 6 %.

Bibliography

[1] IEC 60068-1, *Environmental testing - Part 1: General and guidance*

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