Bilateral comparison on transmission coefficient measurements between TÜBİTAK UME and SASO NMCC

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Abstract. This paper describes a bilateral comparison between two national metrology institutes, National Metrology Institute of Turkey (TÜBİTAK UME) and National Measurement and Calibration Center at Saudi Standards, Metrology and Quality Organization of the Kingdom of Saudi Arabia (SASO NMCC). The aim of the comparison is to check the newly installed SASO NMCC radio frequency and microwave laboratory infrastructure and assess compatibility between two institutes. Measured quantity of the comparison is transmission coefficient of fixed attenuators. The comparison was carried out in three months with 3 dB, 6 dB, 10 dB, 20 dB and 30 dB fixed attenuators. Measurements were performed using commercial Vector Network Analyzer in controlled environmental conditions. Two laboratories were used same measurement technique called as short, open, load and through. The analysis of the results provides good agreement between TÜBİTAK UME and SASO NMCC as a conclusion.

1 Introduction

National Measurement and Calibration Center of the Kingdom of Saudi Arabia (SASO NMCC) newly installed radio frequency (RF) and microwave laboratory. The laboratory frequency range is between 100 kHz to 50 GHz with type N, 3.5 mm and 2.4 mm connector types for scattering (S) parameters measurement. S-parameters are transmission coefficient and reflection coefficient with measurement range from 0 dB to -60 dB and from -1 to +1 respectively. In order to check S-parameters measurement infrastructure and establish international coherence of SASO NMCC, the National Metrology Institute of Turkey (TÜBİTAK UME) and SASO NMCC have organized and carried out a bilateral comparison on transmission coefficient measurement in 2016. Additionally, it is asked to measure reflection coefficient of the travelling standards. TÜBİTAK UME was acting as a

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pilot laboratory for the bilateral comparison and provided a technical protocol to define the measurement and organisational details according to BIPM guideline [1]. TÜBİTAK UME provided five travelling standards have type N connectors and traceable to the International System of Units (SI). The comparison was carried out in three months with 3 dB, 6 dB, 10 dB, 20 dB and 30 dB fixed attenuators. In this paper, results of this comparison exercise using attenuators are described.

2 Travelling standards and time schedule

Travelling standards belonging to the TÜBİTAK UME and identification of each fixed attenuator are described in Table 1. These standards were chosen for their high accuracy and stability in time.

Table 1. Travelling standards.

Device	Nominal value	Type	Serial number	Connector
Fixed attenuator	3 dB	Agilent 8491B	MY39265166	Male/Female
	6 dB		MY39265283	
	10 dB		MY39265254	
	20 dB		MY39265284	
	30 dB		MY39263978	

Circulation of the travelling standards was organized as 2 weeks to carry out measurements and 2 weeks for transportation. Travelling standards were measured totally two times by TÜBİTAK UME before (UME1) and after (UME2) the measurement of SASO NMCC.

3 S-Parameter measurement method and results

S-parameter measurements were made using commercial vector network analyzers (VNA) belonging to the TÜBİTAK UME (Rohde&Schwarz ZVA50) and SASO NMCC (Keysight N5225A) in controlled environmental conditions. VNA calibration was carried out using Agilent 85054B type N calibration kit with short-open-load-through (SOLT) calibration method at both of the NMIs. Male and female end of the travelling standards were connected to port 1 and port 2 of the VNA respectively for all measurements reported here.

Results were delivered to the pilot laboratory in the format of real, imaginary and logarithmic (dB) value. The uncertainties of measurement were calculated according to JCGM 100 “Guide to the expression of uncertainty measurement” and “EA-4/02 expression of the uncertainty of measurement calibration” documents for the coverage probability of approximately 95% [2, 3]. Since VNA was used in the measurements, the uncertainty was calculated in accordance with the EURAMET guidelines for VNA [4]. The uncertainty in S-parameter measurements was evaluated by using excel macro software developed by TÜBİTAK UME which is including uncertainty components, i.e. repeatability, reproducibility, VNA non-linearity, mismatch, cable stability etc.

Approved measurement frequencies and attenuation values for the comparison are 50 MHz, 100 MHz, 300 MHz, 500 MHz, 1 GHz to 18 GHz with 1 GHz step and 3 dB, 6 dB, 10 dB, 20 dB, 30 dB, 40 dB, 50 dB, 60 dB respectively. Although, attenuation values at aforementioned frequencies were measured and reported to the pilot laboratory, the uncertainty budget declared only for 50 MHz, 1 GHz, 10 GHz and 18 GHz frequency point measurements. Also reflection coefficient measurement results of the 40 dB, 50 dB and 60 dB attenuators were not declared because the connection order of the attenuators was not defined in the protocol.

Comparison reference values "x_{ref}" (Eq. 1) and associated uncertainties "U_{ref}" (Eq. 2) were calculated using the measurement results of TÜBİTAK UME.

$$x_{ref} = \frac{UME1+UME2}{2} \tag{1}$$

$$U_{ref} = \frac{1}{2}\sqrt{U_{UME1}{}^{2} + U_{UME2}{}^{2}} \tag{2}$$

Measurement results of the laboratories and comparison reference value with expanded uncertainties were given in Table 2.

Table 2. Measurement results of the laboratories and comparison reference value with expanded uncertainties.

Attn	Freq. (GHz)	UME1		SASO NMCC		UME2		Reference Value	
		$\lvert S_{21}\rvert$ (dB)	U (dB)	$\lvert S_{21}\rvert$ (dB)	U (dB)	$\lvert S_{21}\rvert$ (dB)	U (dB)	$\lvert S_{21}\rvert$ (dB)	U (dB)
3 dB	0.05	3.076	0.012	3.074	0.012	3.078	0.012	3.077	0.008
	1	3.097	0.012	3.100	0.012	3.098	0.012	3.098	0.008
	10	2.782	0.014	2.791	0.012	2.776	0.012	2.779	0.009
	18	2.817	0.033	2.817	0.032	2.840	0.032	2.829	0.023
6 dB	0.05	6.013	0.015	6.010	0.030	6.011	0.015	6.012	0.011
	1	6.045	0.015	6.048	0.030	6.042	0.015	6.044	0.011
	10	6.090	0.015	6.093	0.030	6.087	0.015	6.089	0.011
	18	5.848	0.021	5.855	0.031	5.843	0.021	5.846	0.015
10 dB	0.05	10.297	0.020	10.296	0.049	10.302	0.020	10.299	0.014
	1	10.341	0.021	10.347	0.049	10.345	0.021	10.343	0.015
	10	10.420	0.021	10.426	0.049	10.426	0.021	10.423	0.015
	18	10.427	0.032	10.408	0.050	10.414	0.032	10.420	0.023
20 dB	0.05	19.402	0.032	19.363	0.036	19.261	0.036	19.331	0.025
	1	19.749	0.036	19.809	0.036	19.768	0.036	19.758	0.025
	10	20.077	0.036	20.084	0.036	20.058	0.036	20.067	0.025
	18	20.097	0.036	20.095	0.036	20.104	0.036	20.101	0.025
30 dB	0.05	30.462	0.055	30.454	0.143	30.464	0.055	30.463	0.039
	1	30.485	0.055	30.494	0.141	30.487	0.055	30.486	0.039
	10	30.221	0.054	30.229	0.139	30.226	0.054	30.223	0.038
	18	30.758	0.057	30.766	0.142	30.765	0.057	30.761	0.040
40 dB	0.05	40.753	0.075	40.752	0.200	40.763	0.075	40.758	0.053
	1	40.830	0.076	40.842	0.188	40.835	0.076	40.833	0.053
	10	40.653	0.074	40.654	0.187	40.647	0.074	40.650	0.052
	18	41.195	0.074	41.226	0.187	41.193	0.074	41.194	0.052
50 dB	0.05	49.950	0.087	49.862	0.192	50.094	0.089	50.022	0.062
	1	50.139	0.087	50.099	0.090	50.167	0.087	50.153	0.062
	10	50.333	0.087	50.323	0.087	50.327	0.087	50.330	0.062
	18	50.858	0.091	50.886	0.091	50.866	0.091	50.862	0.064
60 dB	0.05	59.85	0.26	60.42	0.45	60.34	0.18	60.09	0.18
	1	60.54	0.11	60.53	0.28	60.52	0.11	60.53	0.08
	10	60.76	0.11	60.79	0.28	60.76	0.11	60.76	0.08
	18	61.23	0.12	61.24	0.29	61.29	0.12	61.26	0.09

Degrees of equivalence, DoE, is calculated by subtracting the reference value from the each measurements (Eq. 3) and its uncertainty is calculated according to the Equation 4.

$$DoE = x_{lab} - x_{ref} \tag{3}$$

$$U_{DoE} = \sqrt{U_{ref}{}^{2} + U_{lab}{}^{2}} \tag{4}$$

where,

x_{lab}: Participant laboratory measurement result

U_{lab}: Participant laboratory measurement uncertainty

Degrees of equivalence with respect to the reference value of each measurement can be found in Table 3.

Table 3. DoE with respect to the reference value.

Attn	Freq. (GHz)	UME1		SASO NMCC		UME2	
		DoE (dB)	U_{DoE} (dB)	DoE (dB)	U_{DoE} (dB)	DoE (dB)	U_{DoE} (dB)
3 dB	0.05	0.001	0.015	0.003	0.015	-0.001	0.015
	1	0.001	0.015	-0.003	0.015	-0.001	0.015
	10	-0.003	0.016	-0.012	0.015	0.003	0.015
	18	0.012	0.040	0.012	0.040	-0.012	0.039
6 dB	0.05	-0.001	0.018	0.002	0.031	0.001	0.018
	1	-0.001	0.018	-0.005	0.031	0.001	0.018
	10	-0.002	0.018	-0.004	0.032	0.002	0.018
	18	-0.003	0.026	-0.010	0.034	0.003	0.026
10 dB	0.05	0.002	0.025	0.003	0.051	-0.002	0.025
	1	0.002	0.025	-0.004	0.051	-0.002	0.025
	10	0.003	0.025	-0.003	0.051	-0.003	0.025
	18	-0.006	0.039	0.012	0.055	0.006	0.039
20 dB	0.05	-0.071	0.109	-0.032	0.109	0.071	0.109
	1	0.010	0.046	-0.050	0.046	-0.010	0.046
	10	-0.009	0.044	-0.017	0.044	0.009	0.044
	18	0.003	0.044	0.005	0.044	-0.003	0.044
30 dB	0.05	0.001	0.067	0.009	0.148	-0.001	0.067
	1	0.001	0.068	-0.008	0.146	-0.001	0.068
	10	0.003	0.066	-0.005	0.145	-0.003	0.066
	18	0.004	0.070	-0.005	0.147	-0.004	0.070
40 dB	0.05	0.005	0.092	0.006	0.207	-0.005	0.092
	1	0.002	0.092	-0.009	0.196	-0.002	0.093
	10	-0.003	0.091	-0.004	0.194	0.003	0.091
	18	-0.001	0.091	-0.032	0.194	0.001	0.091
50 dB	0.05	0.072	0.107	0.160	0.202	-0.072	0.109
	1	0.014	0.107	0.054	0.109	-0.014	0.107
	10	-0.003	0.107	0.007	0.107	0.003	0.107
	18	0.004	0.111	-0.024	0.112	-0.004	0.111
60 dB	0.05	0.245	0.314	-0.332	0.481	-0.245	0.318
	1	-0.010	0.136	0.001	0.291	0.010	0.136
	10	0.001	0.139	-0.035	0.292	-0.001	0.139
	18	0.030	0.147	0.021	0.298	-0.030	0.148

DoE for 1 GHz and 10 GHz of 10 dB and 60 dB fixed attenuators respectively are given in Figure 1.

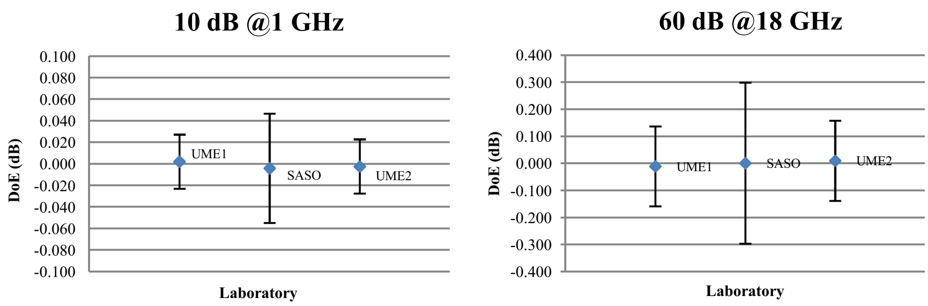

Fig. 1. DoE of 10 dB@1 GHz and 60 dB@10 GHz.

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3 Conclusion

The results from a bilateral measurement comparison of fixed attenuators' transmission coefficient, performed between TÜBİTAK UME and SASO NMCC, are reported. . The comparison involved two port devices have type N connector as travelling standards and completed within three months. All the results are presented at Table 2 and Table 3 with corresponding uncertainties are compatible within the stated uncertainties. As stated in Table 3, while calculated maximum DoE value is lower than ±0.075 dB up to 50 dB fixed attenuator, this value is increasing ±0.34 dB for 60 dB fixed attenuator. Finally, the comparison is regarded as successfully and the newly installed SASO NMCC radio frequency and microwave laboratory S-parameters measurement infrastructure is sufficient and measurement results of two institutes are compatible.

References

1. CCEM Guidelines for Planning, Organizing, Conducting and Reporting Key, Supplementary and Pilot Comparisons (available on the BIPM website: http://www.bipm.org/utils/common/pdf/CC/CCEM/ccem_guidelines.pdf) (2007)
2. Evaluation of measurement data - Guide to the Expression of Uncertainty in Measurement (GUM), JCGM 100, First edition (available on the BIPM website: http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf) (2008)
3. EA 4/02, "Evaluation of the uncertainty of measurement in calibration", Rev 01 (2013)
4. EURAMET cg-12, "Guidelines on the evaluation of vector network analyzers (VNA)", Ver. 2.0 (2011)