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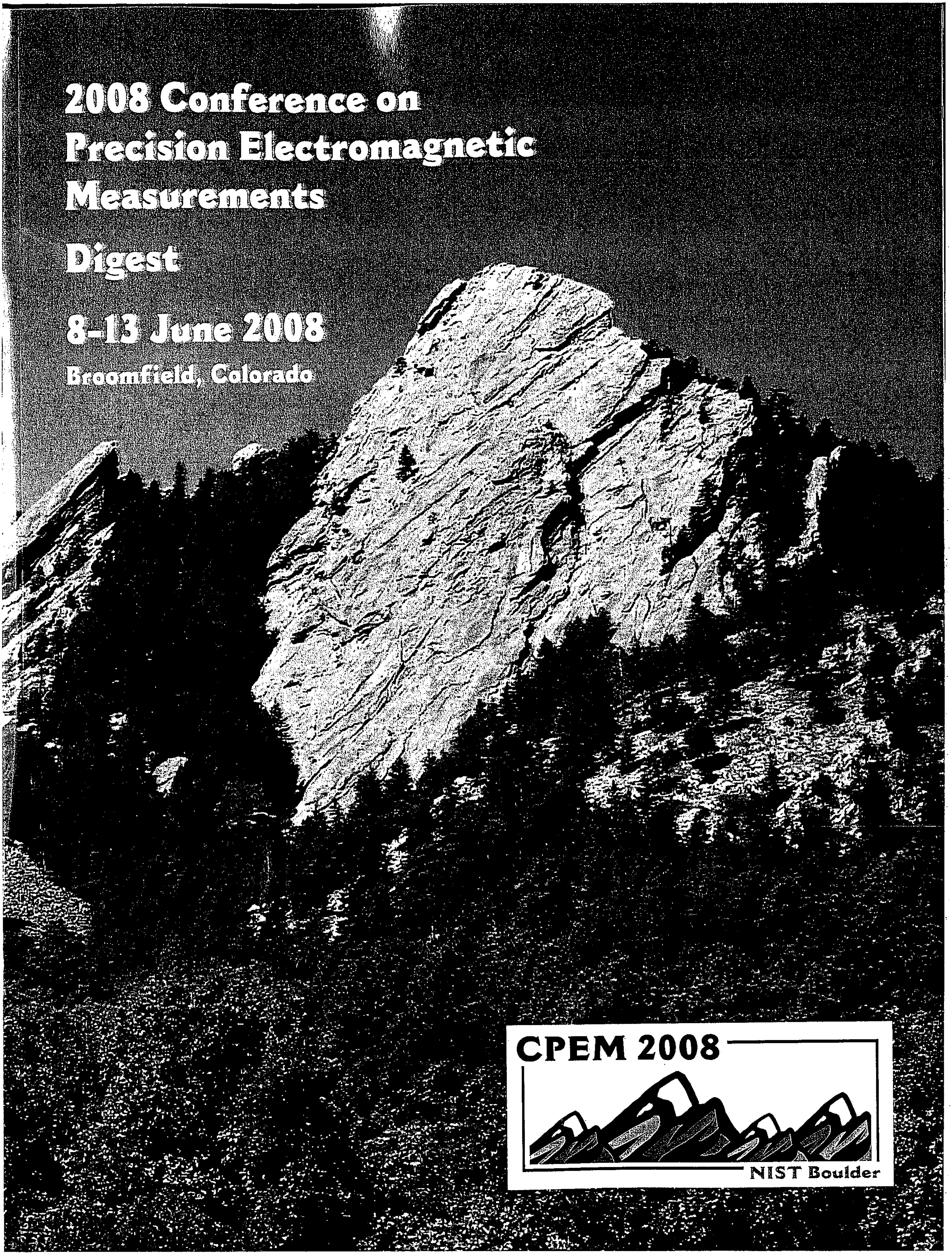

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BILATERAL OPTICAL FIBER POWER METER LINEARITY COMPARISON BETWEEN NMIJ AND NIST

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Abstract

Optical fiber power meter (OFPM) linearity standards of NMIJ (Japan) and NIST (USA) are compared using a commercial OFPM as a transfer standard at 1310 nm and 1550 nm over a power range [-60 dBm, 0 dBm]. At both wavelengths the comparison indicates an agreement between the two laboratories within the combined uncertainty. At 1550 nm the uncertainties are larger, which is attributed to unstable operation of the transfer standard at this wavelength.

Introduction

Optical fiber power meters (OFPMs) are widely used in optical fiber communication systems. Their linearity is essential for two purposes: to calibrate their responsivity at one measurement range relative to the calibration power range, and to serve as optical attenuation standard. For the former purpose, correction factors (CFs) averaged over one range relative to another are useful, while for the latter linearity calibration at relative powers is important. With all important international comparisons of OFPM linearity measurements have not been well reported. Accordingly, NMIJ (Japan) and NIST (USA) have performed OFPM linearity comparison for two series of powers: for the former purpose measurements were made at several power levels for each measurement range; for the latter purpose nonlinearities (NLs) are measured at powers from -60 dBm up to -10 dBm separated by 10-dB steps from a reference power of 0 dBm. All measurements were made at the wavelengths of 1310 nm and 1550 nm.

A commercial computer-controlled OFPM was used as a transfer standard. The use of computer-controlled OFPMs requires careful consideration of uncertainties arising not only from physical problems of its components but from possible software problems. Therefore, the present comparison examines the total measurement capability including such software factors.

NMIJ standard

The NMIJ's linearity standard is a laboratory-made OFPM consisting of a 5-mm InGaAs photodiode placed directly behind a fiber input port, a built-in current-to-voltage converter, and a digital voltmeter. The NL of this standard over the 10-dB power range of [0.8 μW, 8 μW] has been calibrated beforehand using a power superposition system similar to the NIST system [1]. The NLs of the transfer standard at increments of 10-dB in optical power are measured using this standard OFPM in the incremental attenuation method [2]. For averaged CF measurement, the transfer standard's linearity was measured by direct measurement with the power superposition. In all measurements, the light source is either of the laser diodes tuned at 1310 nm or 1550 nm.

NIST standard

The NIST measurement system [1] consists of temperature-controlled Fabry-Perot laser sources at wavelengths of 1314 nm and 1542 nm, which are connected to a variable optical attenuator, and are then divided into two equal parts by using a fiber splitter. A computer controlled shutter is inserted into each arm. After the shutters both signals are combined in a fiber coupler, which has an angled fiber connector at the output to decrease reflection back to the laser and other components of the system. The data are acquired by applying the triplet superposition method directly to the test OFPM. [1]

Experiment

The transfer OFPM's detector is a 5-mm diameter InGaAs photodiode, which is placed directly behind an input FC connector-adaptor. This OFPM has the following peculiar characteristics for 1550-nm measurement: firstly, in some measurement ranges the transfer standard cannot read the optical input power, but instead indicates an over-range signal, for powers even slightly less than the nominal upper end of the ranges; secondly, the reading is slightly affected by the timing of the commands. In contrast, such phenomena are less noticeable at 1310 nm.

The nonlinearities measured and expressed as averaged CFs for various measurement ranges with reference to the reading at 0.1 mW input are compared in Table 1. At wavelengths of 1310 nm and 1550 nm, the measurement results from NMIJ and NIST agree within the combined uncertainties.
Table 2 compares the nonlinearities measured at powers separated by increments of 10 dB with the reference power at 0 dBm. Again the measurement results from NMIJ and NIST agree within the combined uncertainties.

The present uncertainties at 1310 nm are equal to the combined BMC (best measurement

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capability) values of the both laboratories, while those at 1550 nm are larger than corresponding BMC values. The larger uncertainties are attributed to less reproducible characteristics of the transfer OFPM operating at 1550 nm.

Conclusion

OFPM linearity standards from NMIJ and NIST were compared using a commercial OFPM as a transfer standard at 1310 nm and 1550 nm. At both wavelengths the result shows an agreement between two laboratories within the combined uncertainty.

References

[1] I. Vayshenker, S. Yang, X. Li, T.R. Scott, and C.L. Cromer, "Optical fiber power meter nonlinearity calibrations at NIST," *NIST Special Publication 250-56*, August 2000.

2] S. Mukai and T. Inoue, "Wide-range optical attenuation standard by incremental attenuation method," *CPEM 2004 Conf. Digest*, London, UK, pp. 439-440, 2004

Table 1. NMIJ- and NIST- measured nonlinearities expressed as correction factors for various meter ranges

	1310 nm				1550 nm			
meter range (dBm)	NMIJ average CF	NIST average CF	100 x difference NMIJ-NIST	100 x NMIJ-NIST combined uncertainty ($k=2$)	NMIJ average CF	NIST average CF	100 x difference NMIJ-NIST	100 x NMIJ-NIST combined uncertainty ($k=2$)
0	0.9998	0.9999	0.01	0.11	0.9998	1.0001	0.03	0.14
-10	1.0004	1.0005	0.01	0.11	1.0005	1.0006	0.01	0.14
-20	1.0007	1.0012	0.05	0.14	1.0015	1.0012	0.03	0.17
-30	1.0014	1.0021	0.07	0.15	1.0023	1.0018	0.05	0.19
-40	1.0023	1.0028	0.05	0.15	1.0033	1.0024	0.09	0.19
-50	1.0025	1.0032	0.07	0.16	1.0034	1.0025	0.09	0.21

Table 2. NMIJ- and NIST- measured nonlinearities at representative optical powers with 10-dB increment

		1310 nm				1550 nm			
Power level (dBm)	Meter range (dBm)	1000 x NMIJ NL (dB)	1000 x NIST NL (dB)	1000 x difference (dB)	1000 x NMIJ-NIST combined uncertainty (k=2,dB)	1000 x NMIJ NL (dB)	1000 x NIST NL (dB)	1000 x difference (dB)	1000x NMIJ-NIST combined uncertainty (k=2,dB)
-10	0	4.3	4.3	0	1.1	2.8	3.5	0.7	2.0
-20	-10	7.7	7.4	0.3	2.1	6.4	6.1	0.3	6.0
-30	-20	12.2	10.0	2.2	3.0	10.7	8.3	2.4	6.0
-40	-30	15.7	14.3	1.4	4.0	14.2	11.3	2.9	9.0
-50	-40	20.5	17.0	3.5	5.3	20.0	13.9	6.1	9.0
-60	-50	22.4	19.1	3.3	6.2	19.7	13.9	5.8	9.0