

Development of vector-based E-field probe calibration method using traceable waveguide system

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INTRODUCTION

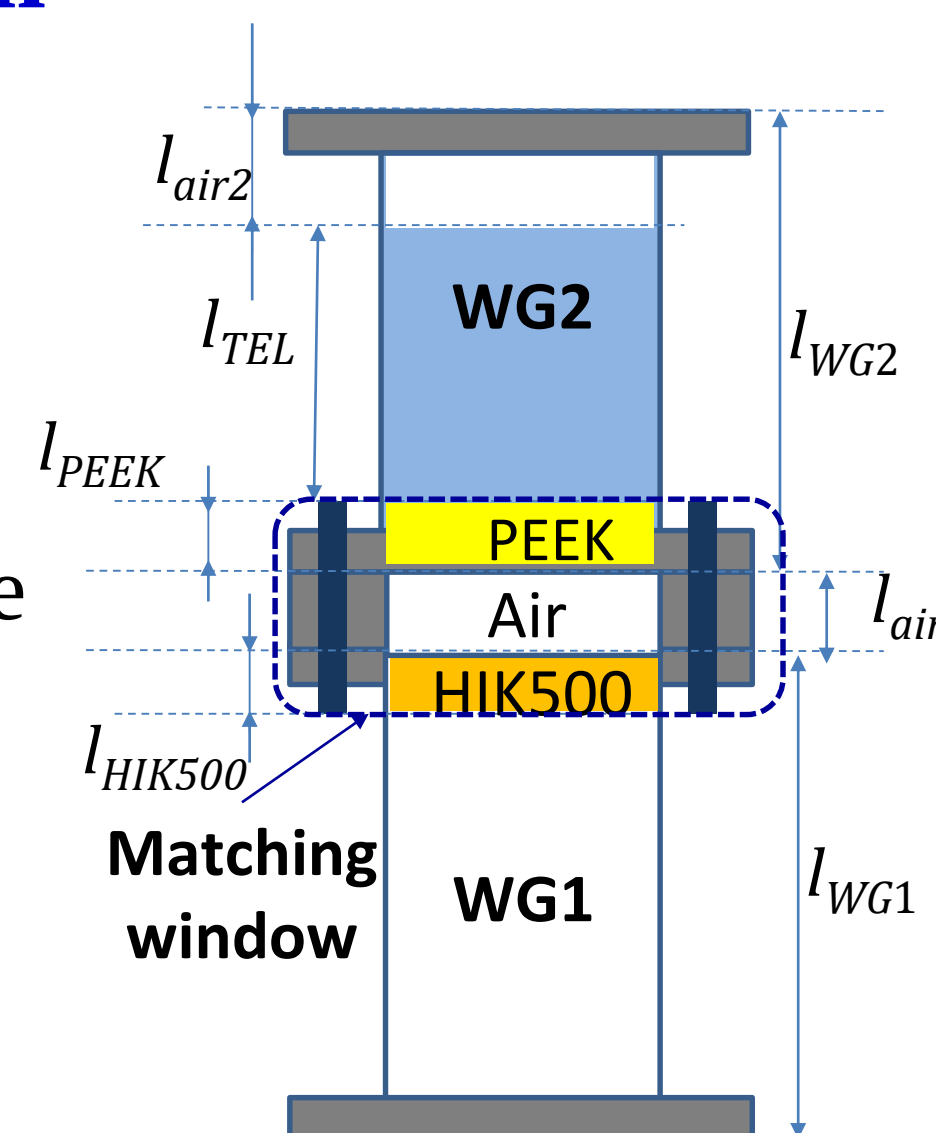
E-field probe: one of key elements of Specific Absorption Rate (SAR) measurement systems

- Development of amplitude and phase calibration of vector E-field probes using traceable waveguide cells: facilitate the E-field reconstruction in scanning systems for SAR measurements.
- Validation of the proposed calibration method by comparison of the magnitude of probe correction factor obtained from vector-based and scalar calibration methods.

VECTOR E-FIELD PROBE CALIBRATION METHOD

Design of rectangular waveguide cell

- Matching window constituted by a triple-layer structure:
 - HIK500: low-loss material with high relative permittivity ($\epsilon_r = 9.8$)
 - Air: flexible interface that facilitates the realization of the matching window at different frequencies
 - PEEK: chemically resistive material with a low liquid absorption suitable for the design of a liquid-tight section



- Thickness of different layers of the WR187 waveguide cell with the matching window around 5200 MHz

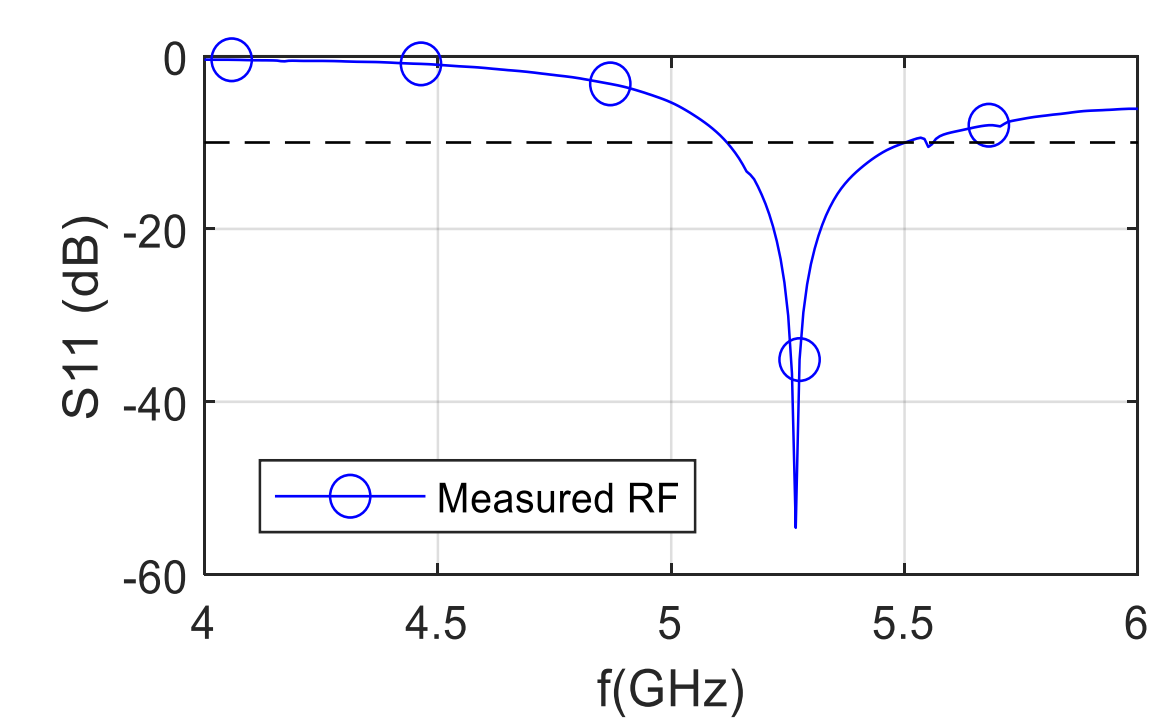
Frequency (MHz)	WG1 associated with HIK500 (mm)	HIK500 (mm)	Air (mm)	PEEK (mm)	WG2 associated with PEEK (mm)
f	l_{WG1}	l_{HIK}	l_{air}	l_{PEEK}	l_{WG2}
5200	50	8.9	11.24	8.21	50

(*) Z_{tel} calculated from waveguide dimension and permittivity of liquid

Verification of waveguide cell matching



Measurement system



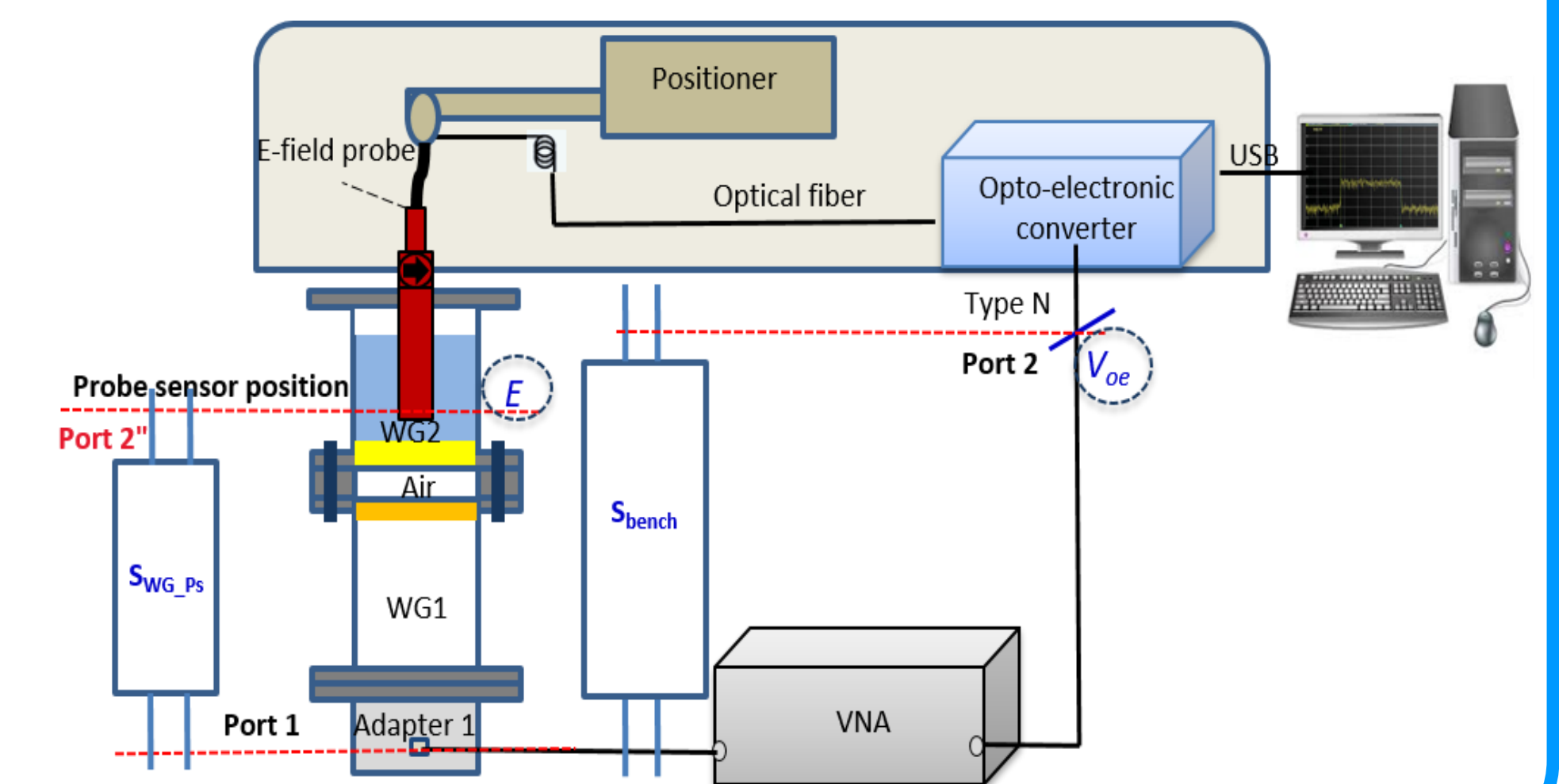
Measured reflection coefficient at port 1 of the WR187 waveguide cell

Return loss : >10 dB from 5100 MHz to 5500 MHz → probe calibration is carried out in this frequency range

Correction factor

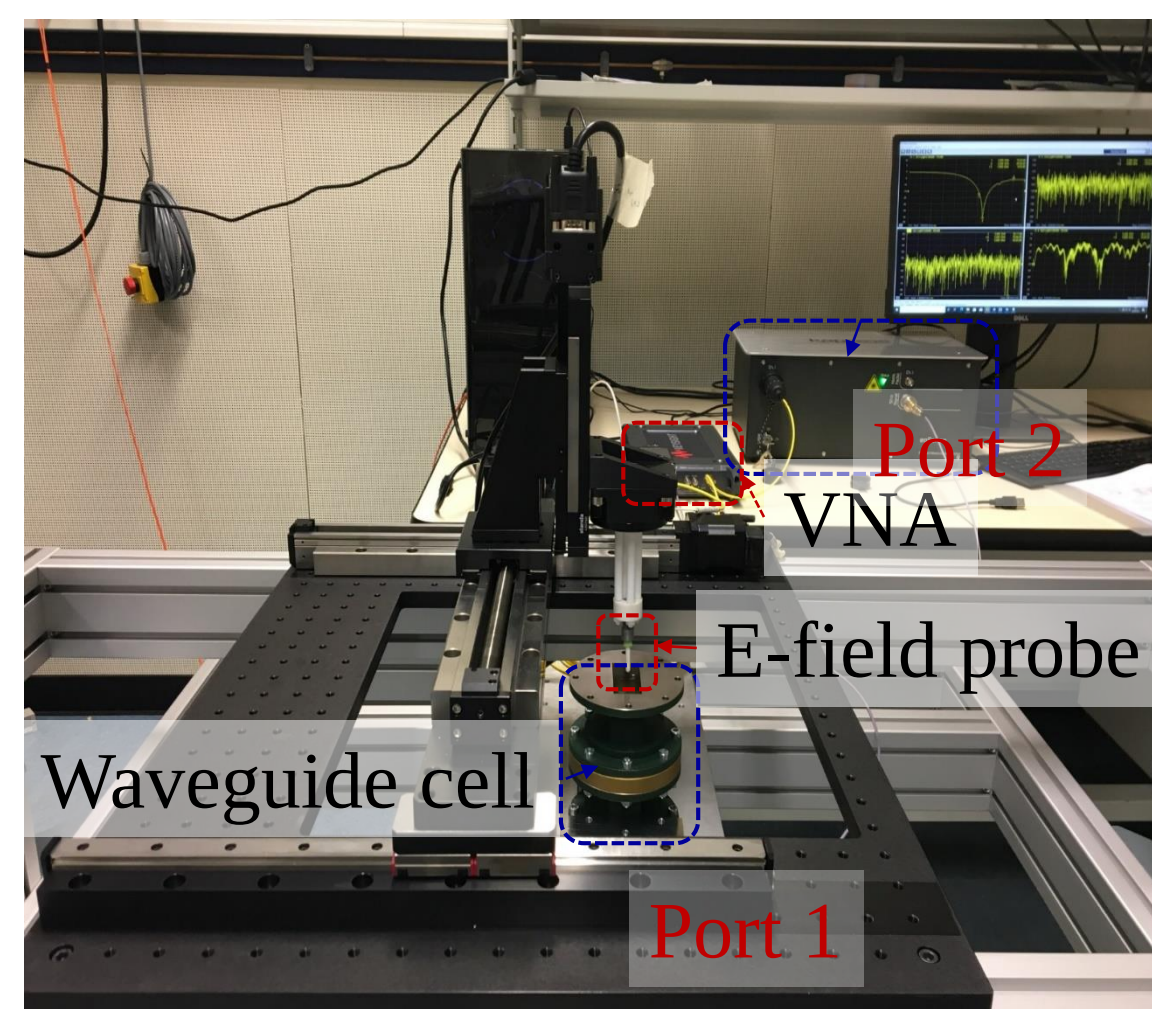
- Ratio between E-field measured by the probe and opto-electronic converter output voltage

$$CF_v = \frac{S_{WG_Ps21}}{S_{bench21}} \cdot \sqrt{\frac{2Z_{tel}}{abZ_0}}$$

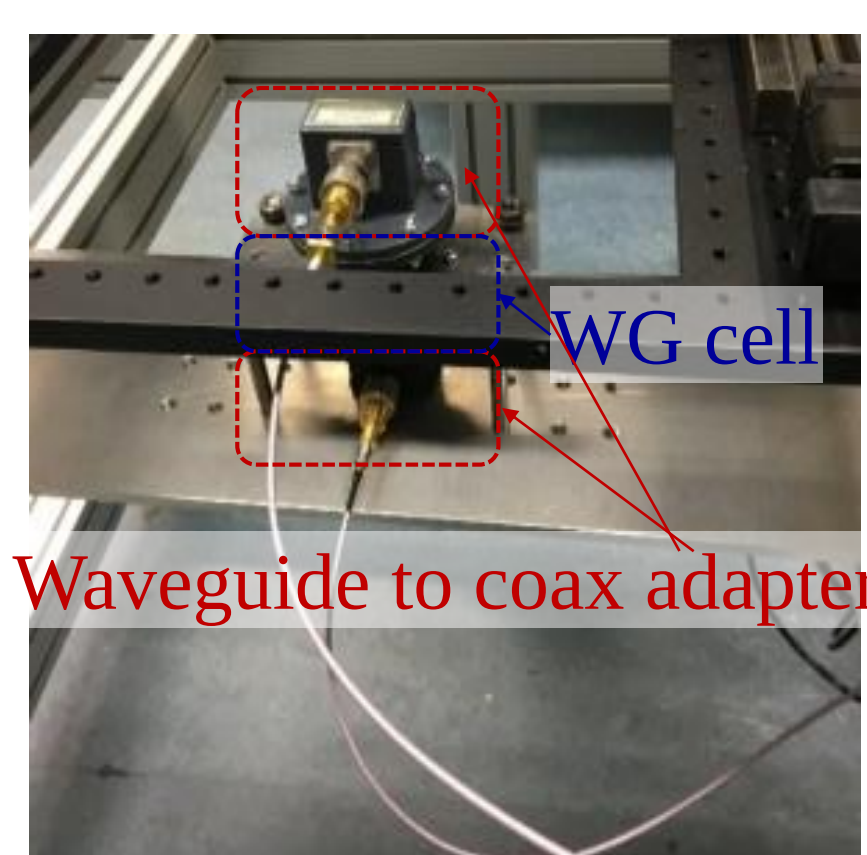


S-PARAMETER MEASUREMENTS OF PROBE CALIBRATION SYSTEM

Measurement system



Probe calibration bench measurement



Waveguide cell measurement

Sensor position in probe calibration bench

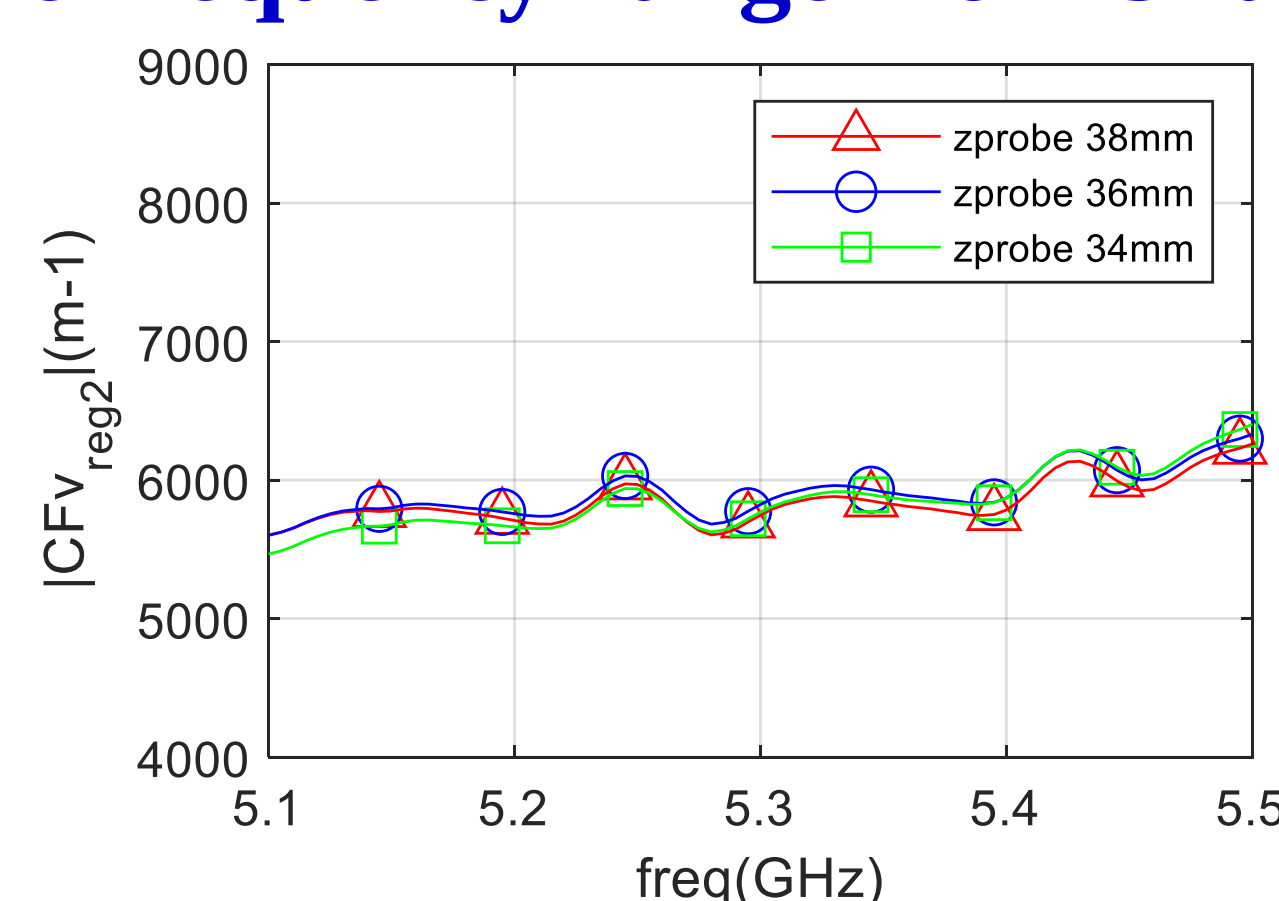
z_{probe} : set by the experimenter in measurements
 $z_{offset} = 2 \text{ mm}$: offset distance supplied by the probe manufacturer

$$z_{sensor} = l_{WG2} - l_{PEEK} - z_{probe} + z_{offset}$$

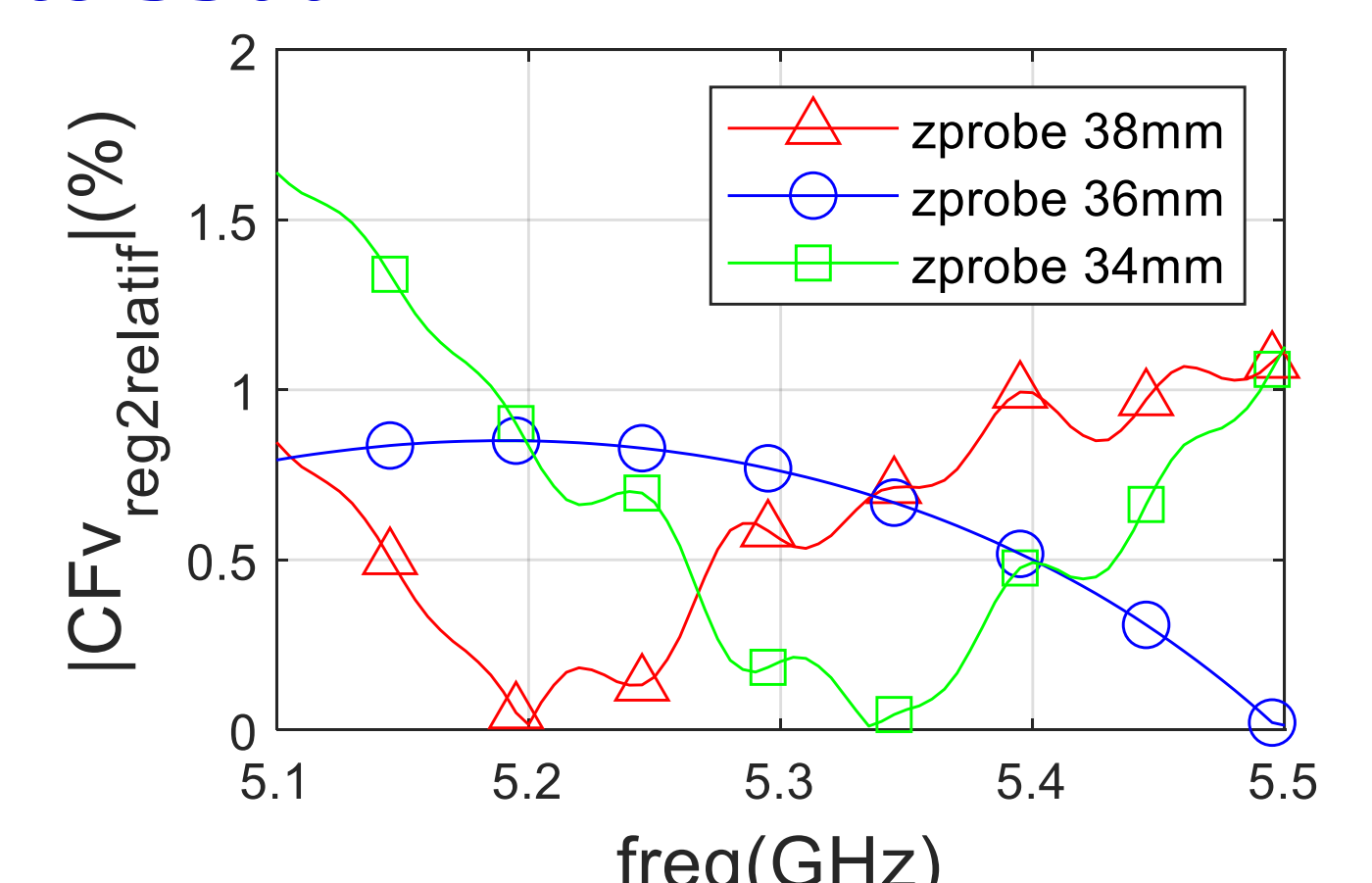
Different positions of the probe in the measurement

Thickness (mm)	l_{PEEK}	l_{air2}	z_{probe}	z_{sensor}	l_{tel2}
Position 1	8.21	5	38	5.79	31
Position 2	8.21	5	36	7.79	29
Position 3	8.21	5	34	9.79	27

Probe correction factor of the vector-based calibration method in the frequency range from 5100 MHz to 5500 MHz

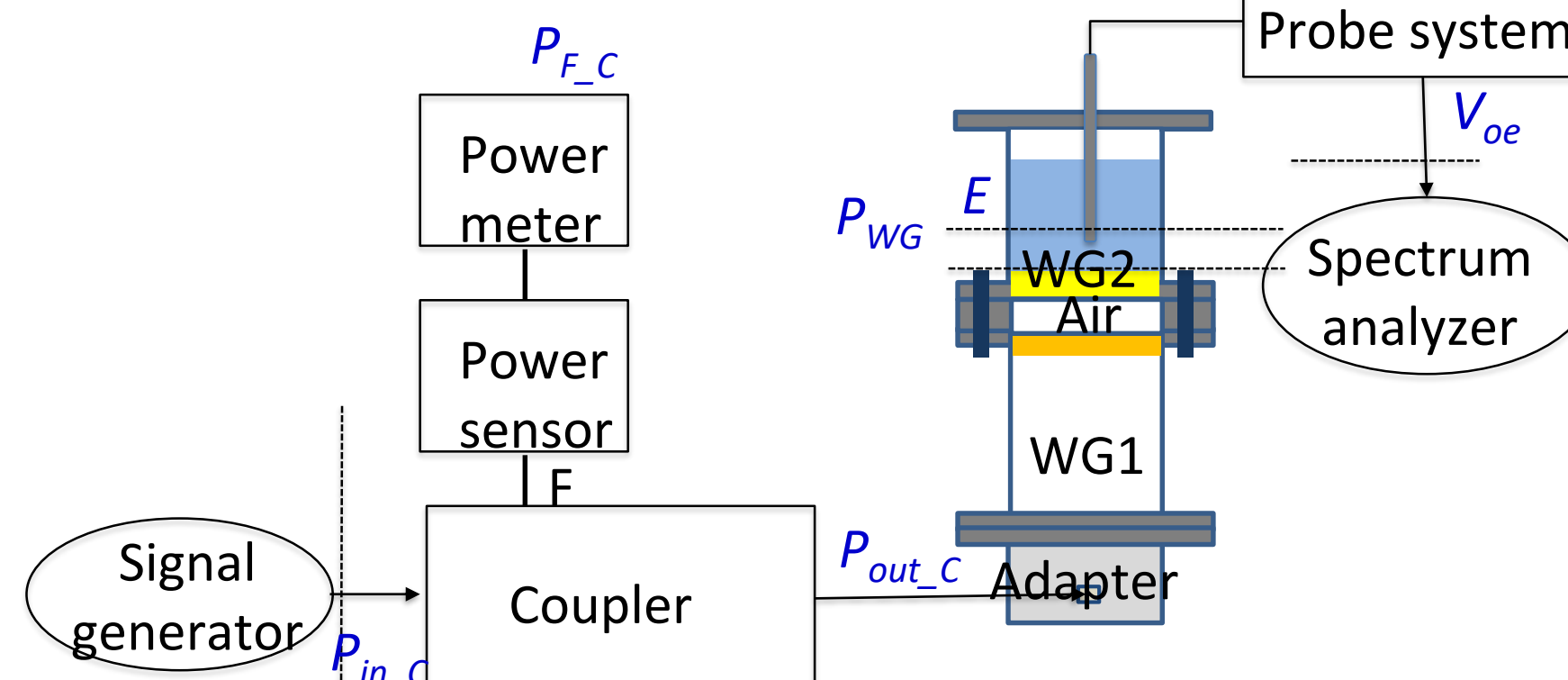


Amplitude of correction factors after applying the second-order polynomial regression on the magnitude of the transmission coefficient of the calibration bench



Absolute relative deviations around the mean value of the amplitude of correction factors

Comparison of the probe correction factor between vector-based and scalar calibration methods



Synoptic of the scalar probe calibration system

Percentage difference between the magnitude of correction factors of the vector-based and of the scalar calibration methods

Percent_diff_C F (%)	5200 MHz	5250 MHz	5300 MHz	5350 MHz	5400 MHz
$z_{probe} = 38 \text{ mm}$	6.57	4.76	8.13	11.11	8.15
$z_{probe} = 36 \text{ mm}$	4.49	0.86	8.4	13.65	13.90
$z_{probe} = 34 \text{ mm}$	4.72	3.84	3.64	1.47	0.33

$$percent_diff_CF = \frac{|CF_v| - CF_s}{CF_v + CF_s} \cdot 100 (\%)$$

CONCLUSIONS AND PERSPECTIVES

- The calibration factor of vector E-field probe calibration gives coherent results with the dispersion value less than 2% for three positions of the probe in the liquid.
- Good agreement between the magnitude of probe calibration factor obtained from vector-based and scalar calibration methods, with the percentage difference of less than 10% for mostly all the comparison points → validation of proposed calibration method.
- This project can be continued by measuring the E-field in the flat phantom after having calibrated the vector probe.

