



Report on Z12-T Calibration at PTB

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Dirk Piester
Physikalisch-Technische Bundesanstalt
Bundesallee 100
D-38116 Braunschweig
dirk.piester@ptb.de

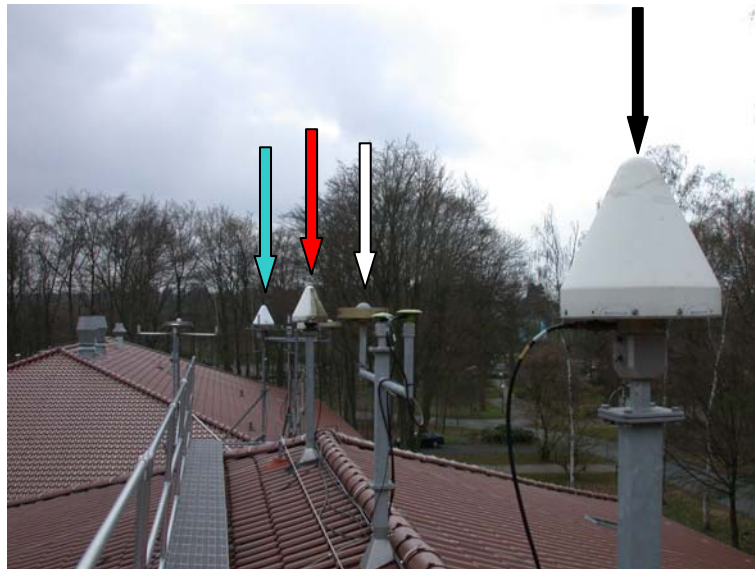
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1 Setup

1.1 Equipment

| Description | BIPMC | BIP00 | PTBB | PTBG |
|-------------------|---------------------|------------------------|---------------------|---------------------|
| receiver | ASHTECH Z-XII 3T | Septentrio PolarX 2 | ASHTECH Z-XII 3T | ASHTECH Z-XII 3T |
| receiver Ser. No. | LP02944 | | RT820013901 | |
| antenna | ASH700936E SNOW | Ashtech | ASH700936E SNOW | ASH700936E SNOW |
| antenna Ser. No. | CR 15373 | | CR 15930 | |
| Mast No. | P14 (black arrow) | P11 (white arrow) | P10 (red arrow) | P3 (blue arrow) |
| antenna height | 0.044 m | | 0.0562 m (tripod) | |
| frequency source | UTC(PTB) | UTC(PTB) | UTC(PTB) | UTC(PTB) |



Antennas on the roof of PTB's clock hall.

1.2 Coordinates

| reference frame | | BIPMC P14 | BIP00 P11 | PTBB P10 | PTBG P3 |
|--------------------------|----------------|----------------|----------------|-------------------|----------------|
| ITRF2000 epoch 1-2006 | X | 3 844 054.92 m | 3 844 064.45 m | 3 844 059.94 m | 3 844 060.00 m |
| | Y | 709 665.70 m | 709 657.65 m | 709 661.33 m | 709 661.27 m |
| | Z | 5 023 132.89 m | 5 023 126.53 m | 5 023 129.54 m | 5 023 129.51 m |
| | antenna height | 0.044 m | | 0.0562 m (tripod) | |

1.3 Relation to UTC(PTB)

All 1pps (and frequency) references are phase coherent to UTC(PTB). The 1pps references for the BIPM receivers and PTBB/PTBG were measured versus UTC(PTB).

Trigger level for the 1pps measurements are as follows:

UTC(PTB): 0.5 V

REF(BIPMC): 1.0 V

REF(BIP00): 0.5 V

REF(PTBB): 1.0 V

REF(PTBG): 1.0 V

| | | UTC(PTB) – REF(BIPMC) | UTC(PTB) – REF(BIP00) | UTC(PTB) – REF(PTBB) | UTC(PTB) – REF(PTBG) |
|------------|-------------|----------------------------------|----------------------------------|---------------------------------|---------------------------------|
| 2008-04-09 | (ns) | 50.11 ± 0.05 | 80.48 ± 0.05 | 39.206 ± 0.05 | 54.59 ± 0.05 |
| 2008-04-21 | (ns) | 50.14 ± 0.05 | 80.51 ± 0.05 | 39.137 ± 0.05 | 54.92 ± 0.05 |

1.4 Measurement Schedule

2008-04-09 (DOY101) Beginning of measurement

2008-04-21 (DOY112) End of measurement

2 Calibration measurements

2.1 BIPMC Z12-T

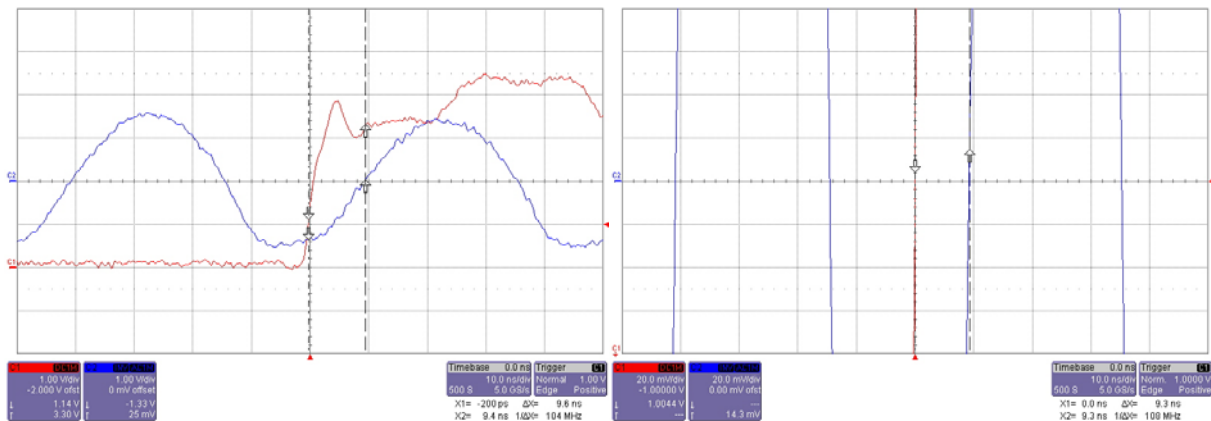
The measurements shown here were operated following the instructions of ANNEX 2 of the BIPM calibration guidelines.

2.1.1 Measurement 3.1-1

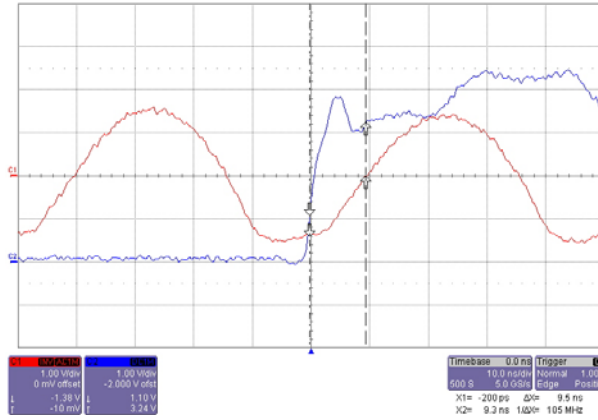
The externally provided 1pps allows the receiver to choose one particular cycle of the 20 MHz input to realize the internal reference. It is defined as the first positive zero crossing of the inverted 20 MHz input signal following the 1pps input signal. The measured delay (see table) is then the relative phase of this two signals.

There are three different configurations to validate the oscilloscope measurements. Configuration *1a*, *1b* and *1c* should give the same values (within cursor uncertainty). If not the average of *1a* and *1c* should be taken. These measurements were repeated at the end of the calibration (*2a*, *2b*, *2c*).

| measurement 3.1-1 at the beginning of the calibration (2008-04-09) | | | | | | | |
|--|----------|---------------|----------|---------------|--------------|------|---|
| measurement | BIPMC-1a | | BIPMC-1b | | BIPMC-1c | | |
| | channel | 1 | 2 | 1 | 2 | 1 | 2 |
| input | 1 pps | 20 MHz (inv.) | 1 pps | 20 MHz (inv.) | 20MHz (inv.) | 1pps | |
| vertical range (V/div) | 1 | 1 | 0.02 | 0.02 | 1 | 1 | |
| trigger level (V) | 1 | | 1 | | | 1 | |
| position (V) | -2 | 0 | -1 | 0 | 0 | -2 | |
| coupling | DC | AC | DC | AC | AC | DC | |
| time base (ns/div) | 10 | 10 | 10 | 10 | 10 | 10 | |
| delay (ns) | 9.6 | | 9.3 | | 9.5 | | |

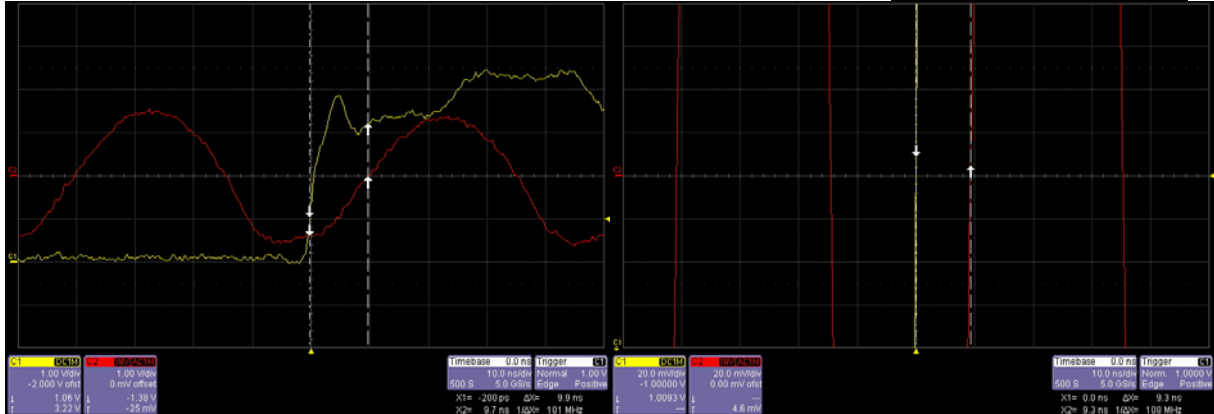


BIPMC-1a: Oscilloscope display „1 pps-20 MHz IN“, **BIPMC-1b:** Oscilloscope display „20 mV range“

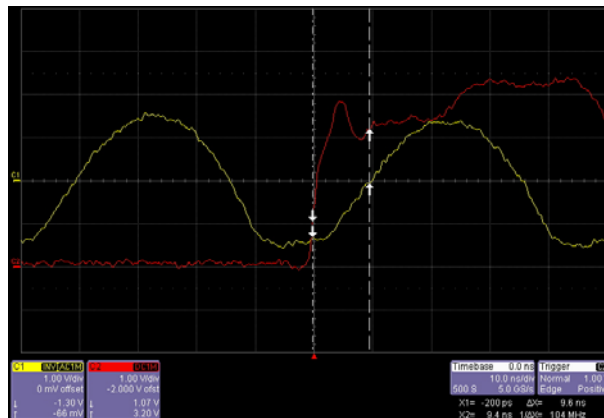


BIPMC-1c: Oscilloscope display „channels exchanged“

| measurement 3.1-1 at the end of the calibration | | | | | | |
|---|----------|---------------|----------|---------------|--------------|------|
| measurement | BIPMC-2a | | BIPMC-2b | | BIPMC-2c | |
| | channel | 1 | 2 | 1 | 2 | 1 |
| input | 1 pps | 20 MHz (inv.) | 1 pps | 20 MHz (inv.) | 20MHz (inv.) | 1pps |
| vertical range (V/div) | 1 | 1 | 0.02 | 0.02 | 1 | 1 |
| trigger level (V) | 1 | | 1 | | | 1 |
| position (V) | -2 | 0 | -1 | 0 | 0 | -2 |
| coupling | DC | AC | DC | AC | AC | DC |
| time base (ns) | 10 | 10 | 10 | 10 | 10 | 10 |
| delay (ns) | 9.9 | | 9.3 | | 9.6 | |



BIPMC-2a: Oscilloscope display „1 pps-20 MHz IN“, **BIPMC-2b:** Oscilloscope display „20 mV range“

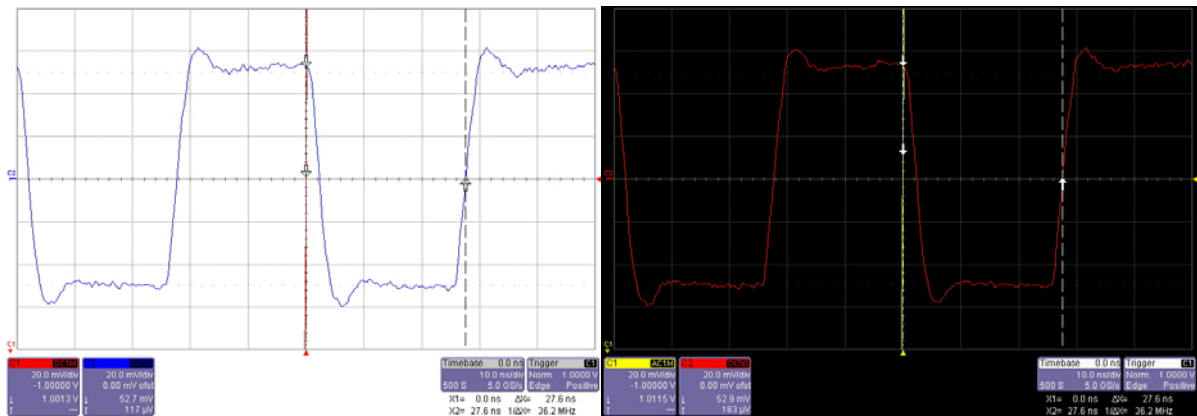


BIPMC-2c: Oscilloscope display „channels exchanged“

2.1.2 Measurement 3.1-2

Due to the constant internal delay of the receiver, there should be a well defined delay between the 20 MHz input and the 20 MHz output. This could be determined by measuring the phase difference between the 1pps input and the following 20 MHz rising edge zero crossing. The difference delay(3-2) - delay(3-1) should be 18.2 ns.

| measurement 3.1-2 | | |
|---------------------------|------------|--------|
| measurement | BIPMC-3 | |
| channel | 1 | 2 |
| input | 1 pps | 20 MHz |
| vertical range (V/div) | 0.05 | 0.02 |
| trigger level (V) | 1 | |
| position (V) | -1 | 0 |
| coupling | DC | AC |
| time base (ns) | 10 | 10 |
| delay (ns) beginning, end | 27.6, 27.6 | |

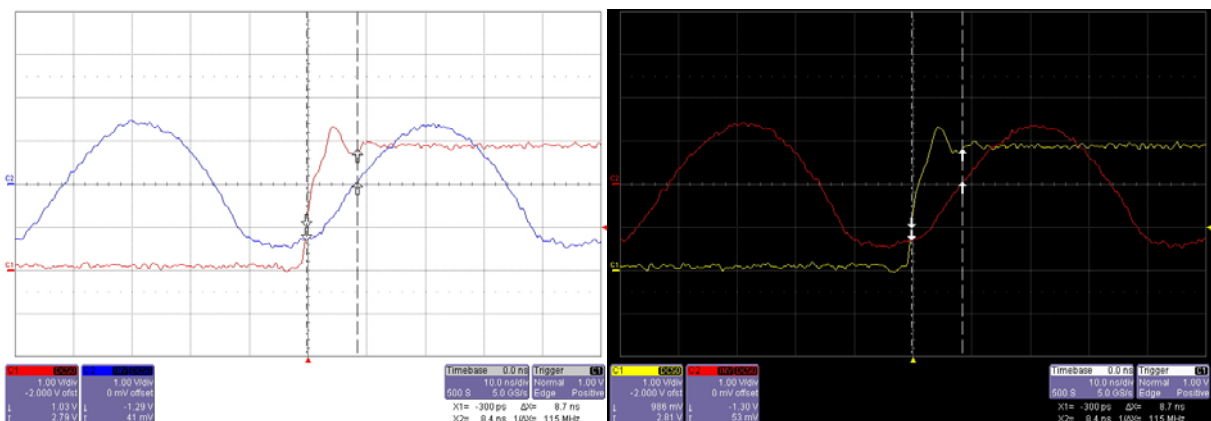


BIPMC-4: Oscilloscope display „1 pps-20 MHz OUT“ (left: beginning, right: end)

Difference: delay(3-2) - delay(3-1) = 27.6 ns – 9.5 ns = 18.1 ns

2.1.3 Measurement 3.1-3

| measurement 3.1-3 | | |
|--------------------------|----------|--------|
| measurement | BIPMC-3 | |
| channel | 1 | 2 |
| input | 1 pps | 20 MHz |
| vertical range (V/div) | 1 | 1 |
| trigger level (V) | 1 | |
| position (V) | -2 | 0 |
| coupling | DC | AC |
| time base (ns) | 10 | 10 |
| delay (ns) beginning/end | 8.7, 8.7 | |



BIPMC-4: Oscilloscope display „1 pps-20 MHz direct“ (beginning)

2.2 BIP00 PolaRx

2.2.1 Measurement 3.2-1

Measurements were carried out by connecting the UTC(PTB) reference 1pps to the start input of the TIC and a second 1pps as described in annex 3 of the guidelines.

Tare measurement before and after calibration (according to Fig. 1, annex 3 of “the guidelines”):

| date | tare (ns) |
|-------------|------------------|
| 2008-04-09 | 97.75 ± 0.05 |
| 2008-04-21 | 97.78 ± 0.05 |

Delay measurement set-up during operation (according to Fig. 2, annex 3 of “the guidelines”):

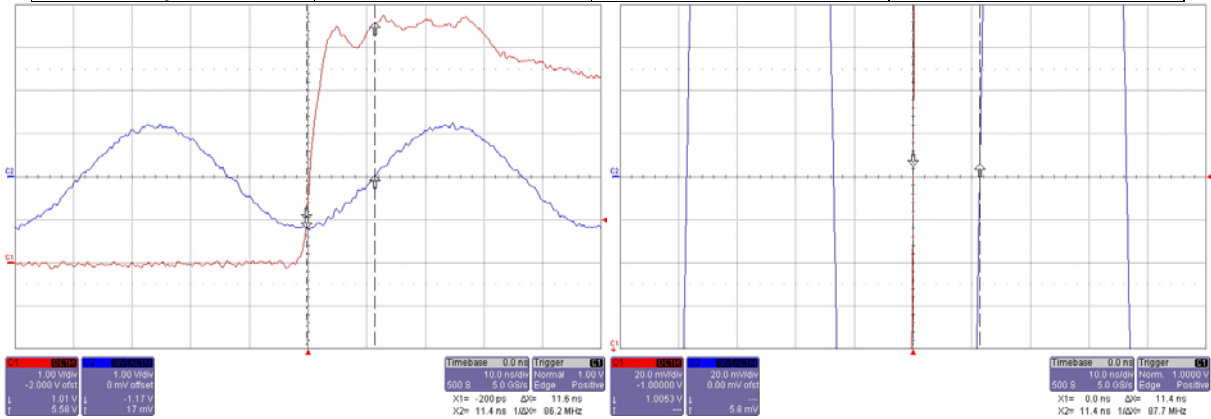
| date | delay (ns) |
|-------------|--------------------|
| 2008-04-09 | 319.29 ± 0.12 |
| 2008-04-21 | -680.77 ± 0.15 |

2.3 PTBB Z12-T

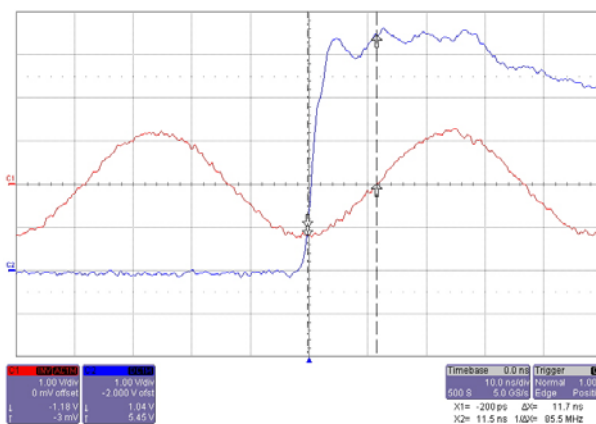
The oscilloscope measurements with the PTBB Z12-T were carried out similarly to those described in chapter 2.1, except measurement 3-2. Because PTBB Z12-T does not provide 20 MHz OUT measurement 3-2 is infeasible.

2.3.1 Measurement 3.1-1

| measurement 3.1-1 at the beginning of the calibration | | | | | | | |
|---|-------------|---------------|-------------|---------------|--------------|------|---|
| measurement | PTBB-1a | | PTBB-1b | | PTBB-1c | | |
| | channel | 1 | 2 | 1 | 2 | 1 | 2 |
| input | 1 pps | 20 MHz (inv.) | 1 pps | 20 MHz (inv.) | 20MHz (inv.) | 1pps | |
| vertical range (V/div) | 1 | 1 | 0.05 | 0.06 | 1 | 1 | |
| trigger level (V) | 1 | | 1 | | | 1 | |
| position (V) | -2 | 0 | -1 | 0 | 0 | -2 | |
| coupling | DC | AC | DC | AC | AC | DC | |
| time base (ns) | 10 | 10 | 10 | 10 | 10 | 10 | |
| delay (ns) | 11.6 | | 11.4 | | 11.7 | | |

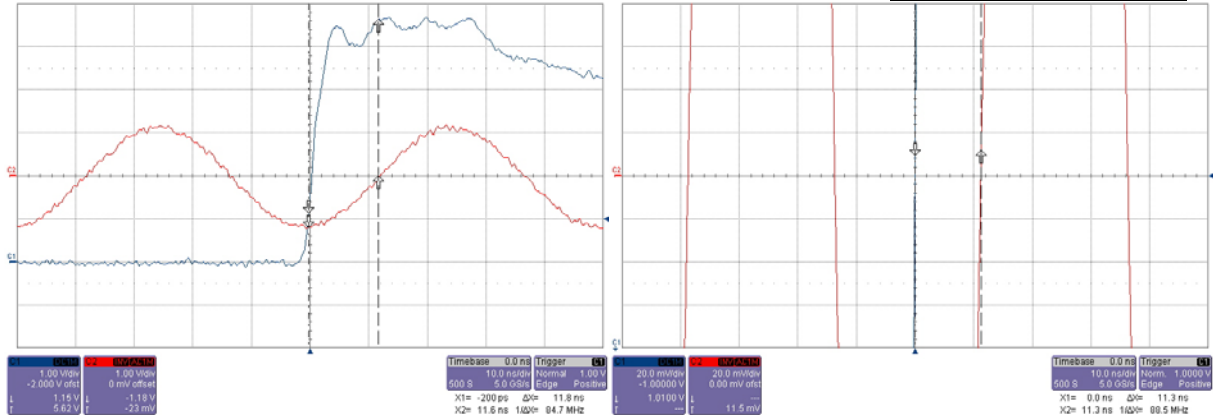


PTBB-1a: Oscilloscope display „1 pps-20 MHz IN“, **PTBB-1b:** Oscilloscope display „20 mV range“

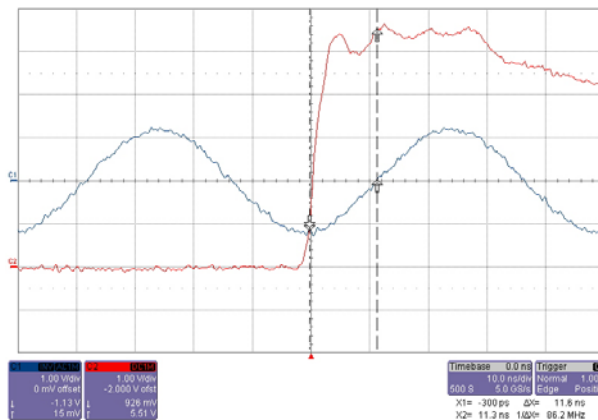


PTBB-1c: Oscilloscope display „channels exchanged“

| measurement 3.1-1 at the end of the calibration | | | | | | |
|---|---------|---------------|---------|---------------|--------------|------|
| measurement | PTBB-2a | | PTBB-2b | | PTBB-2c | |
| | channel | 1 | 2 | 1 | 2 | 1 |
| input | 1 pps | 20 MHz (inv.) | 1 pps | 20 MHz (inv.) | 20MHz (inv.) | 1pps |
| vertical range (V/div) | 1 | 1 | 0.02 | 0.02 | 1 | 1 |
| trigger level (V) | 1 | | 1 | | | 1 |
| position (V) | -2 | 0 | -1 | 0 | 0 | -2 |
| coupling | DC | AC | DC | AC | AC | DC |
| time base (ns) | 10 | 10 | 10 | 10 | 10 | 10 |
| delay (ns) | 11.8 | | 11.3 | | 11.6 | |



PTBB-1a: Oscilloscope display „1 pps-20 MHz IN“, PTBB-1b: Oscilloscope display „20 mV range“



PTBB-1c: Oscilloscope display „channels exchanged“

2.3.2 Measurement 3.1-2

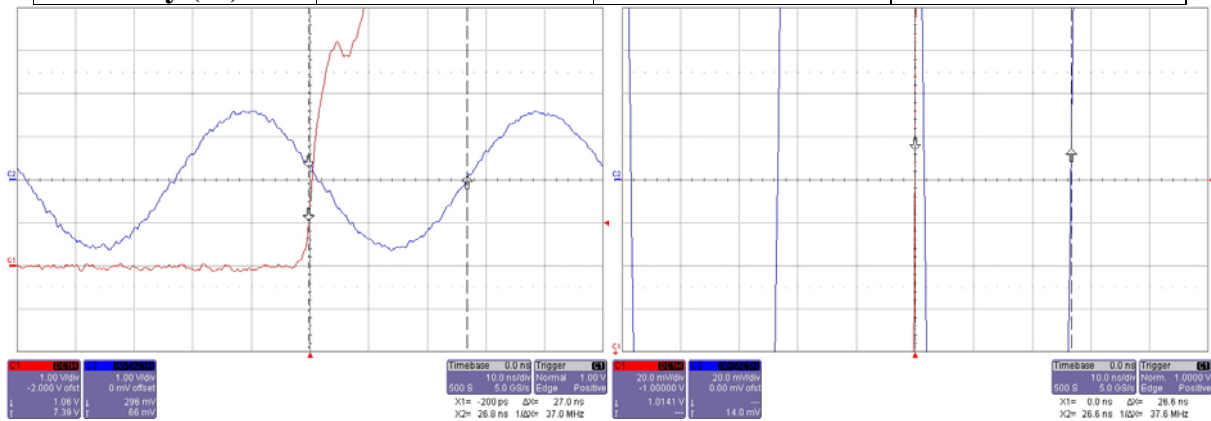
Because PTBB Z12-T does not provide 20 MHz OUT measurement 3-2 is infeasible.

PTBG Z12-T

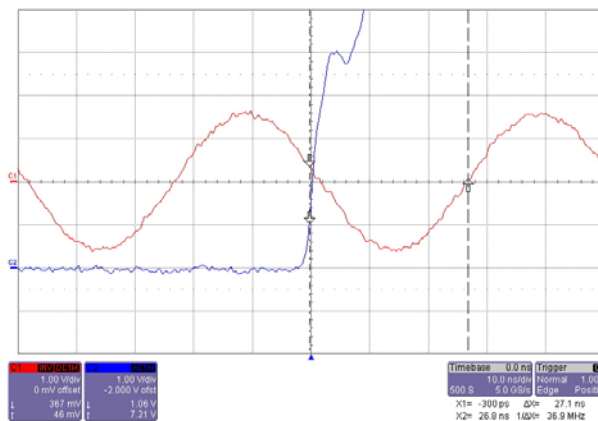
The oscilloscope measurements with the PTBB Z12-T were carried out similarly to those described in chapter 2.1, except measurement 3-2. Because PTBB Z12-T does not provide 20 MHz OUT measurement 3-2 is infeasible. The oscilloscope measurements with the PTBG Z12-T were carried out similarly to those described in chapter 2.1.

2.3.4 Measurement 3-1

| measurement 3.1-1 at the beginning of the calibration | | | | | | |
|---|---------|---------------|---------|---------------|--------------|------|
| measurement | PTBG-1a | | PTBG-1b | | PTBG-1c | |
| channel | 1 | 2 | 1 | 2 | 1 | 2 |
| input | 1 pps | 20 MHz (inv.) | 1 pps | 20 MHz (inv.) | 20MHz (inv.) | 1pps |
| vertical range (V/div) | 1 | 1 | 0.05 | 0.06 | 1 | 1 |
| trigger level (V) | 1 | | 1 | | | 1 |
| position (V) | -2 | 0 | -1 | 0 | 0 | -2 |
| coupling | DC | AC | DC | AC | AC | DC |
| time base (ns) | 10 | 10 | 10 | 10 | 10 | 10 |
| delay (ns) | 27.0 | | 26.6 | | 27.1 | |

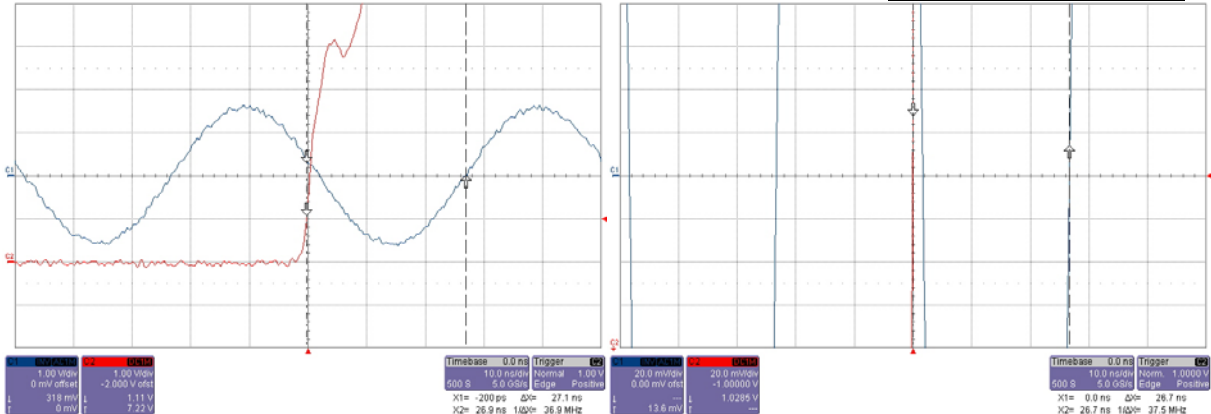


PTBG-1a: Oscilloscope display „1 pps-20 MHz IN“, PTBG-1b: Oscilloscope display „20 mV range“

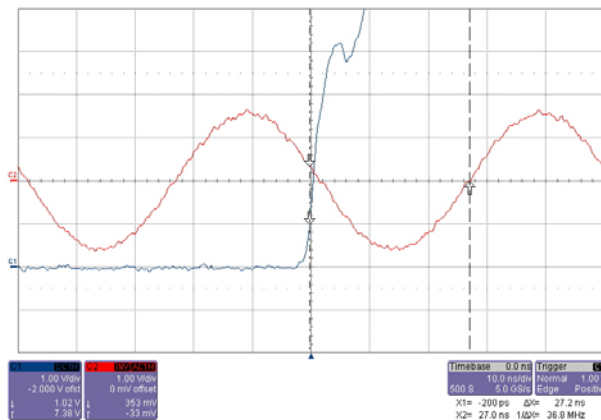


PTBG-1c: Oscilloscope display „channels exchanged“

| measurement 3.1-1 at the end of the calibration | | | | | | | |
|---|---------|---------------|---------|---------------|--------------|------|---|
| measurement | PTBG-2a | | PTBG-2b | | PTBG-2c | | |
| | channel | 1 | 2 | 1 | 2 | 1 | 2 |
| input | 1 pps | 20 MHz (inv.) | 1 pps | 20 MHz (inv.) | 20MHz (inv.) | 1pps | |
| vertical range (V/div) | 1 | 1 | 0.02 | 0.02 | 1 | 1 | |
| trigger level (V) | 1 | | 1 | | | 1 | |
| position (V) | -2 | 0 | -1 | 0 | 0 | -2 | |
| coupling | DC | AC | DC | AC | AC | DC | |
| time base (ns) | 10 | 10 | 10 | 10 | 10 | 10 | |
| delay (ns) | 27.1 | | 26.7 | | 27.1 | | |



PTBG-1a: Oscilloscope display „1 pps-20 MHz IN“, PTBG-1b: Oscilloscope display „20 mV range“



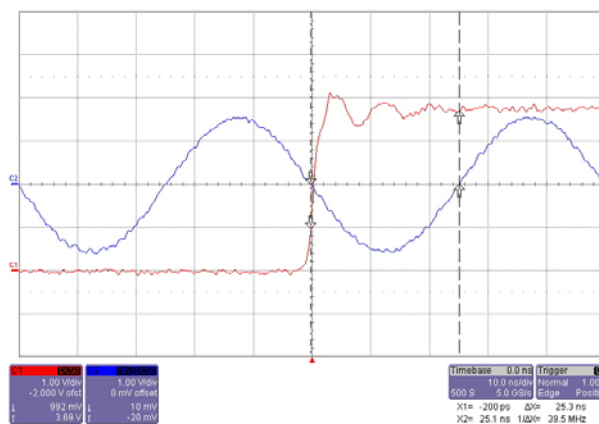
PTBG-1c: Oscilloscope display „channels exchanged“

2.3.5 Measurement 3.1-2

Because PTBB Z12-T does not provide 20 MHz OUT measurement 3-2 is infeasible.

2.3.6 Measurement 3.1-3

| measurement 3.1-3 | | |
|-----------------------------|-------------|--------|
| measurement | PTBG-3 | |
| channel | 1 | 2 |
| input | 1 pps | 20 MHz |
| vertical range (V/div) | 1 | 1 |
| trigger level (V) | 1 | |
| position (V) | -2 | 0 |
| coupling | DC | AC |
| time base (ns) | 10 | 10 |
| delay (ns) beginning | 25.3 | |



PTBB-4: Oscilloscope display „1 pps-20 MHz direct“ (beginning)

This measurement was not carried out after the end of the operation.