



-
- - , ,
 - , /

- MRA

-
- ISO17025

- BMC

- ,
- (BMC)

가

1. (time interval)

- 1967 : 1 .
-) “ 2 11 50 .”
- =>

2. (synchronization)

- .
- 1)
- 2)

3. (date)

- 가 :
- . ()
-) “ () 12 25 37 .”

-

- 가 (piezoelectric effect)
- , (: 32768 Hz)

-

- 가 가
 - : 9 192 631 770 Hz (92)
 - ,
 - 가 가 :
 - 1 ,
 - 가
 - 가

- 1 : (Hz)
-) 60 Hz 1 60
- 가 ()
-) 100 Hz 100 1
- 1 MHz (= Hz) 100 1
-) 3 1 가

$$\left| \frac{\Delta T}{T} \right| = \frac{1}{30000 \times 365 \times 24 \times 3600} = 1 \times 10^{-12}$$

- 10 MHz (10^7 Hz) 가 10 μ Hz (10^{-5} Hz)

$$\left| \frac{\Delta f}{f} \right| = \left| \frac{\Delta T}{T} \right| = \frac{10^{-5}}{10^7} = 1 \times 10^{-12}$$

-

- IMT-2000:
- IMT-2000:

- **GPS**

- , : navigation ()
- :
- : VLBI (Very Long Baseline Interferometer)
- , , , ,

-

- (m)
- ()

-

- HLA :
 - 5 MHz, 2 kW
- GPS : GPS ()
 - (UTC)

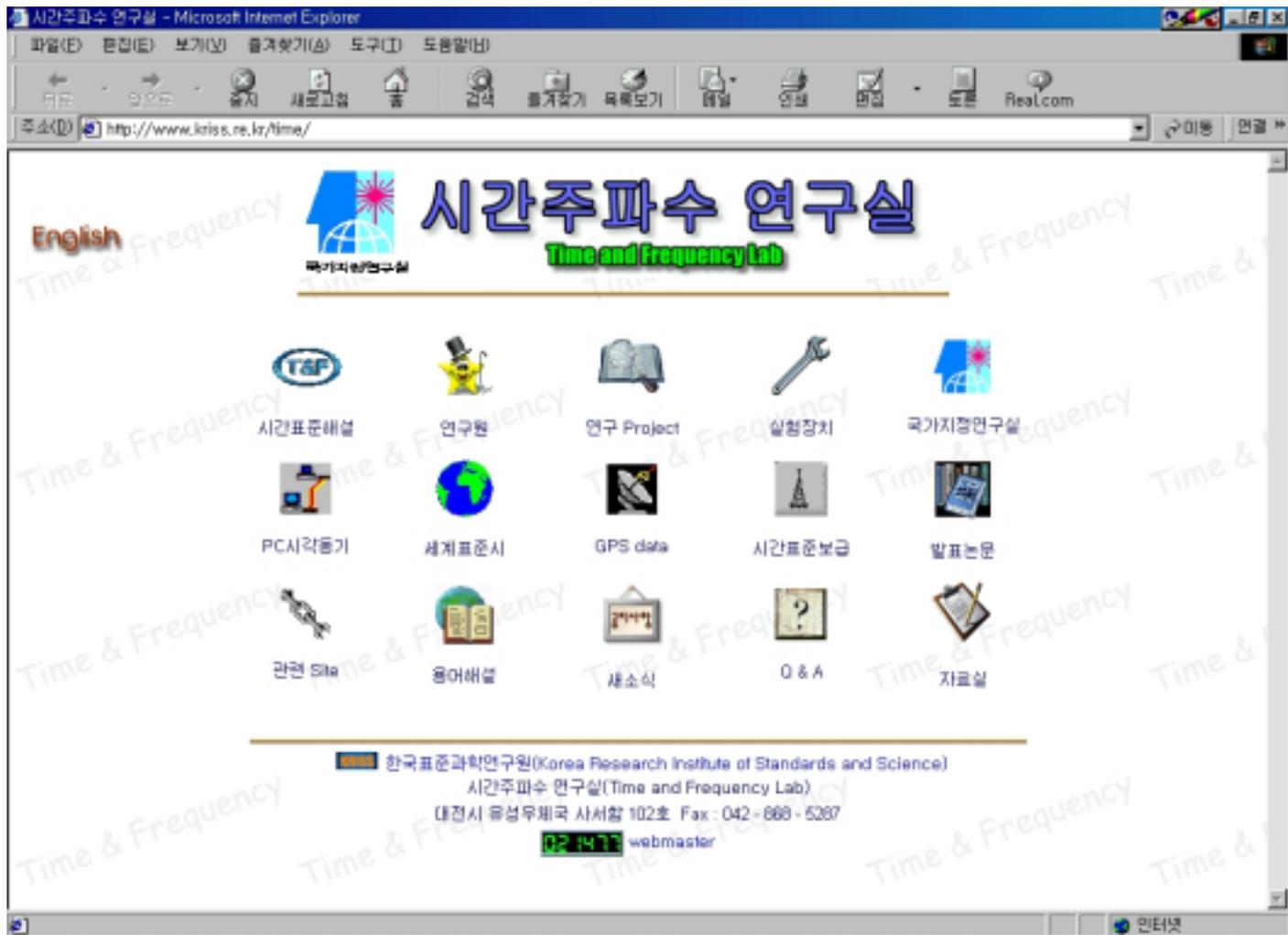
-

- - Time server : UTCk3 가
 - : <http://www.kriss.re.kr/time> <PC >

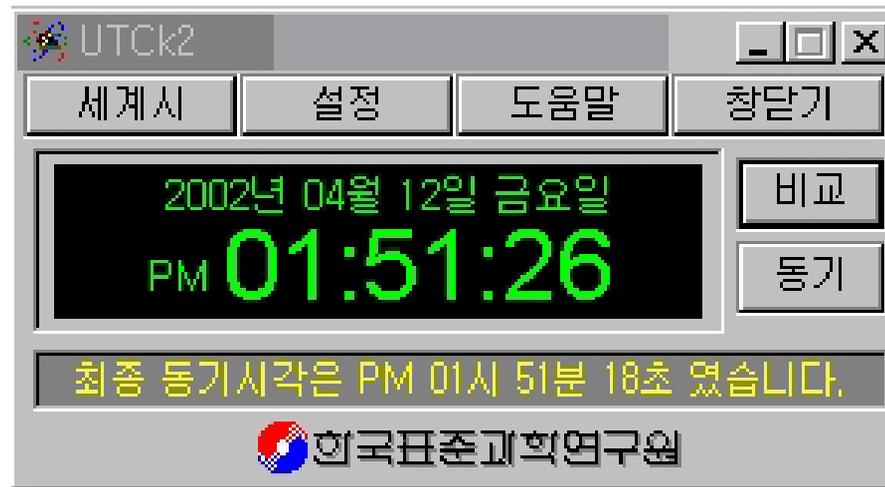
-

-
- ()

<http://www.kriss.re.kr/time>



UTCk3



(Time Scale)

- :
 - : UTC 02 28 32 , 11 28 32
 -
 - (GMT)
- : 가
 - (TT): SI
 - (TAI):
 - (UTC): TAI UT1 ()
 - (UT): UT0, UT1, UT2
 - : UT0
 - :

(Time Zone)

- (Local Time)가
- - (0)가
 - 가 (360) 24 :
 - 15
 - 15 가 :
- - 135 ±7.5
 - 1961 676 ()
 - :

/

■

■ RC

■ : 가

■ , ,

■

■

□ Time interval counter

□ Frequency counter

■

■ (phase noise measurement system)

■

■ (GUM)

MRA

(The Global MRA)

Mutual Recognition

of National Measurement Standards and

of Calibration and Measurement Certificates issued by
NMI

:

- 가

- 가

/

MRA

가

- WTO TBT
- APLAC, ILAC

- 1998. 2. :
- 1999. 10. : 3 38 가
- 1999. 10. : 21 (CGPM)
- 2003 10 4

MRA

- 가 가 (NMS)
- NMI /
- 1 가 ,
- 2
- 1 NMS 가
- 가 NMI가
- 가 ,
- (RMO) : - (APMP)
- CIPM 가
(, IAEA)

MRA

- (key comparison; KC)
 - MRA Appendix B
 - Metrologia of BIPM
 - BIPM web site

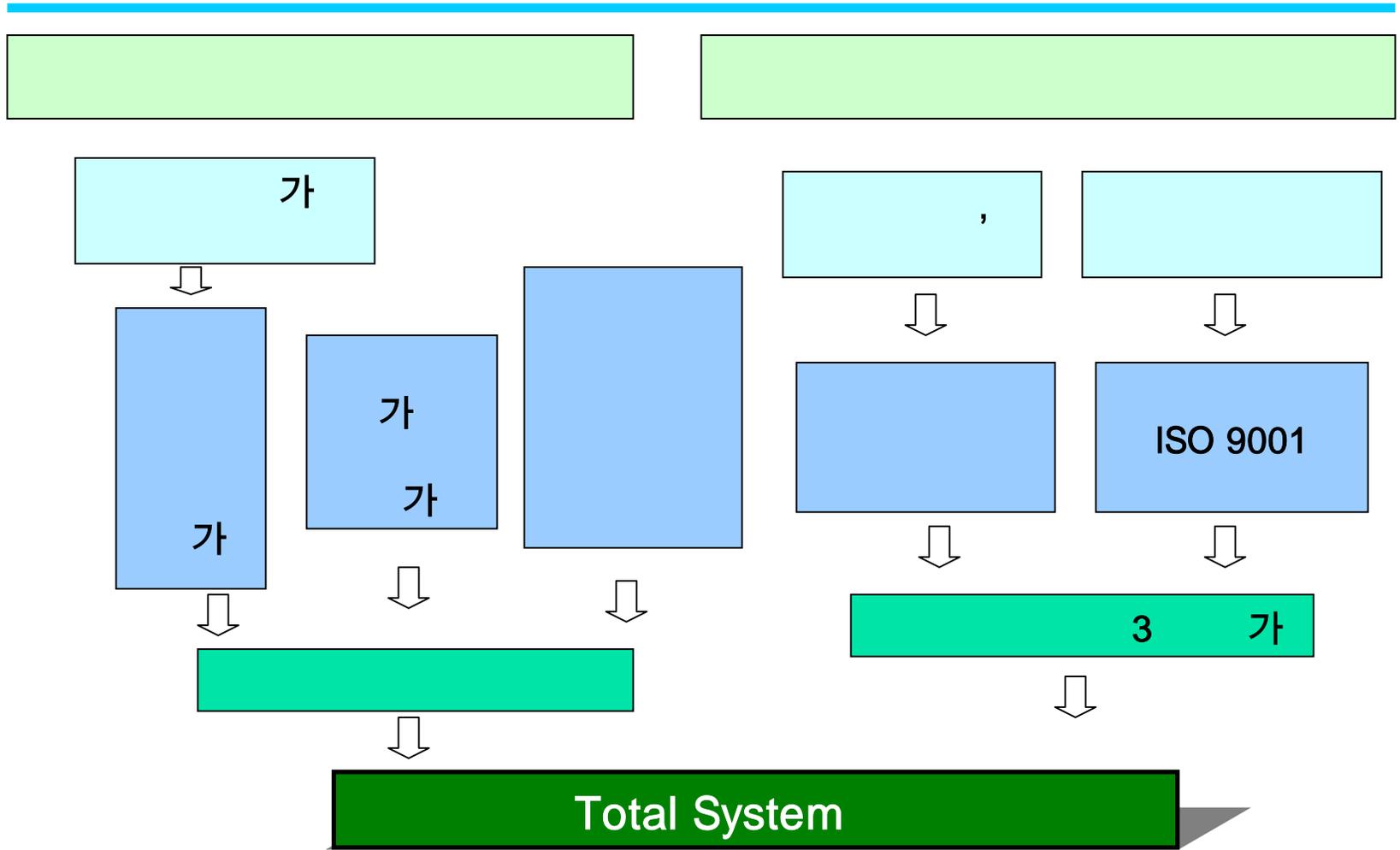
- NMI (CMC) 가
 - MRA Appendix C
 - BIPM web site

CMC

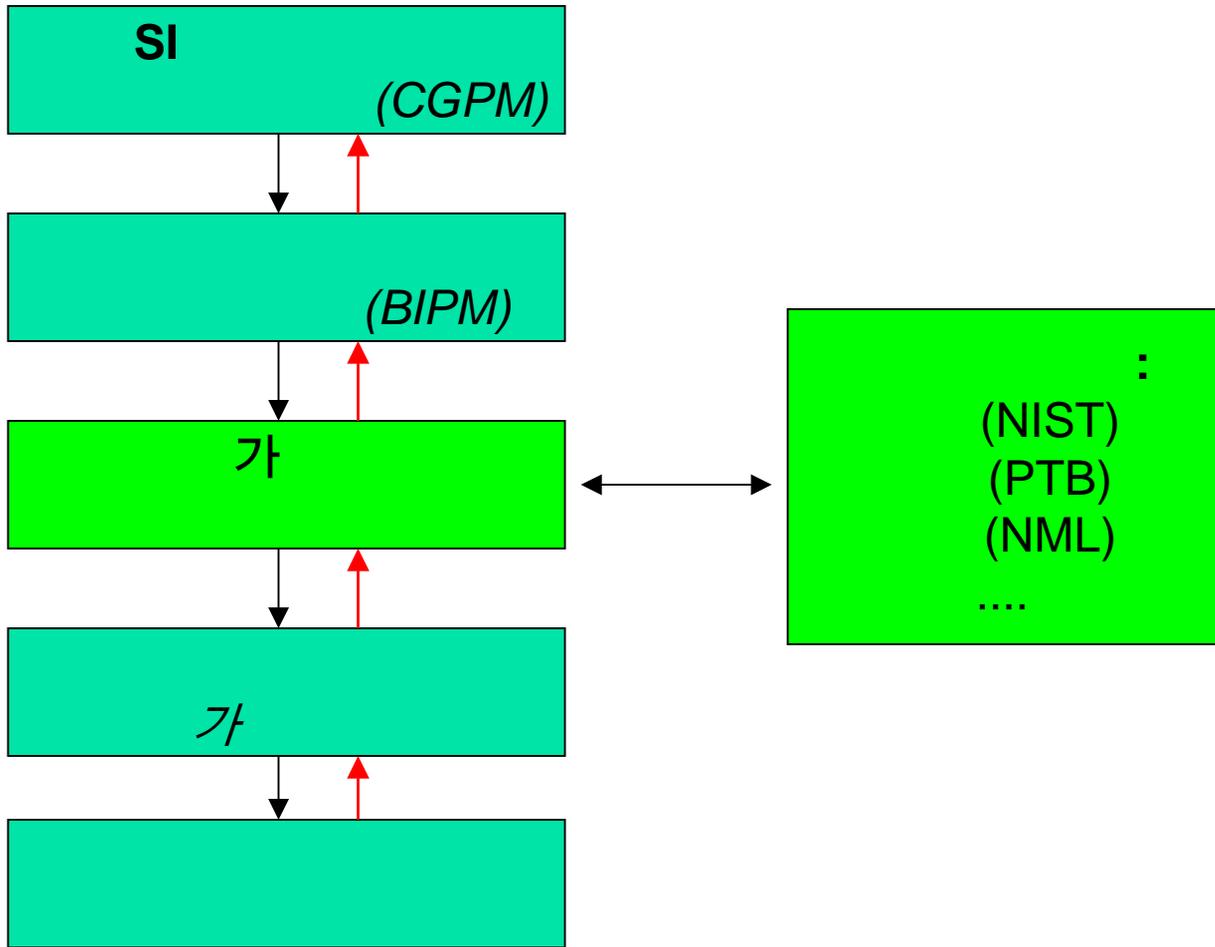
- - KC, SC PC
 - CC, RMO
 - RMO project

- -
 - NMI 가

- - 3
 -
 - 가



BMC



(1/2): KRISS

- 가 (national measurement standard) :
가
- 1 (primary standard) : 가
1
- 2 (secondary standard) : 1
- (reference standard) :
가
- (working standard) : (material measure),

(2/2): KRISS

- (uncertainty of measurement) : , (VIM 3.9).
- (best measurement capability) : , " " , .
- (traceability) : 가 (VIM 6.10).
- (calibration) : (VIM 6.11).
- (test) : ,

가

- KRISS 17 6

6.1

(BMC)

6.2

/ /

가

6.3

가

KRISS

- KRISS

가

□ Frequency and Time Interval :

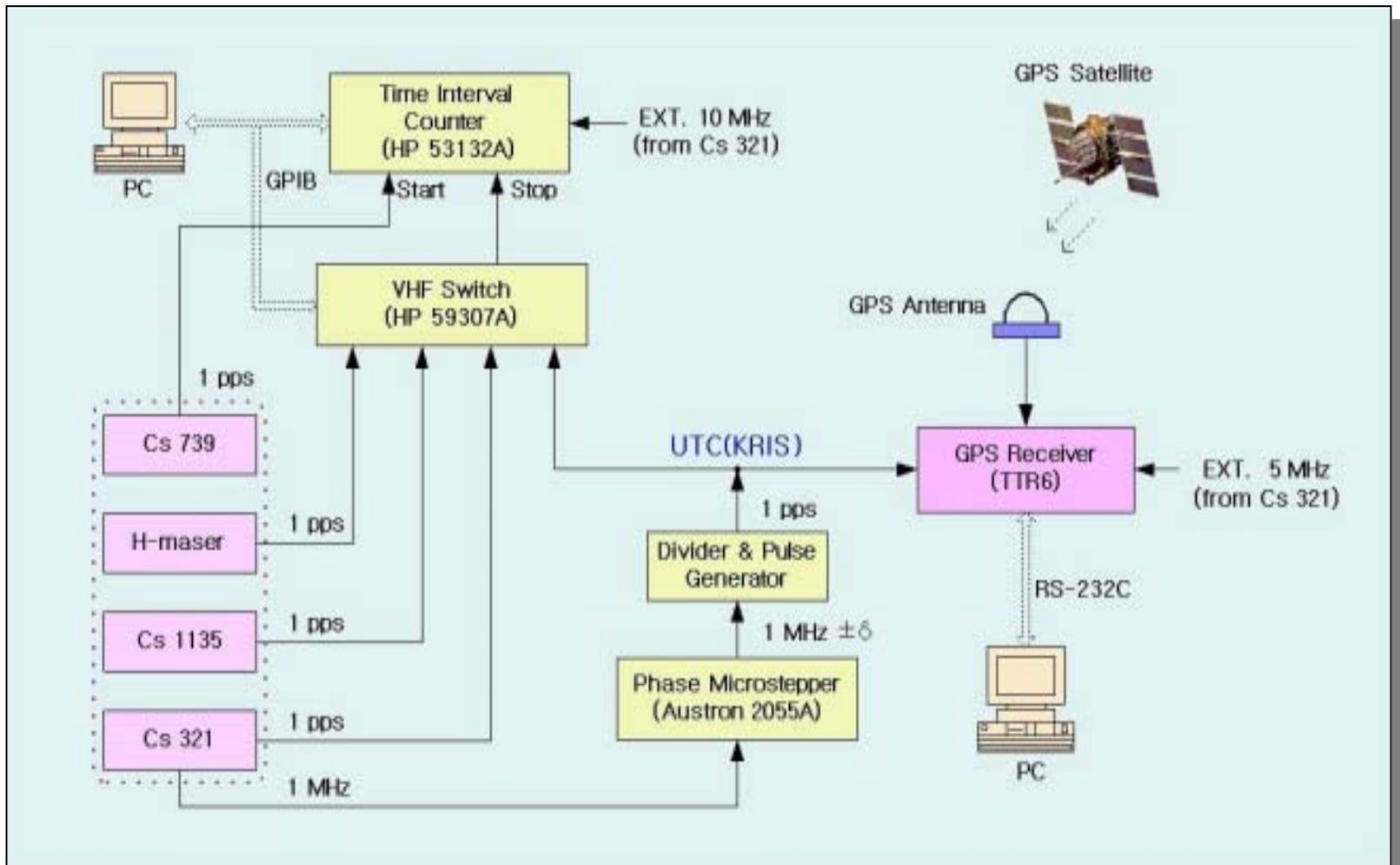
Cs beam standard (HP5071A, Cs 321) → TAI

□ Time (date) : UTC(KRIS) → UTC

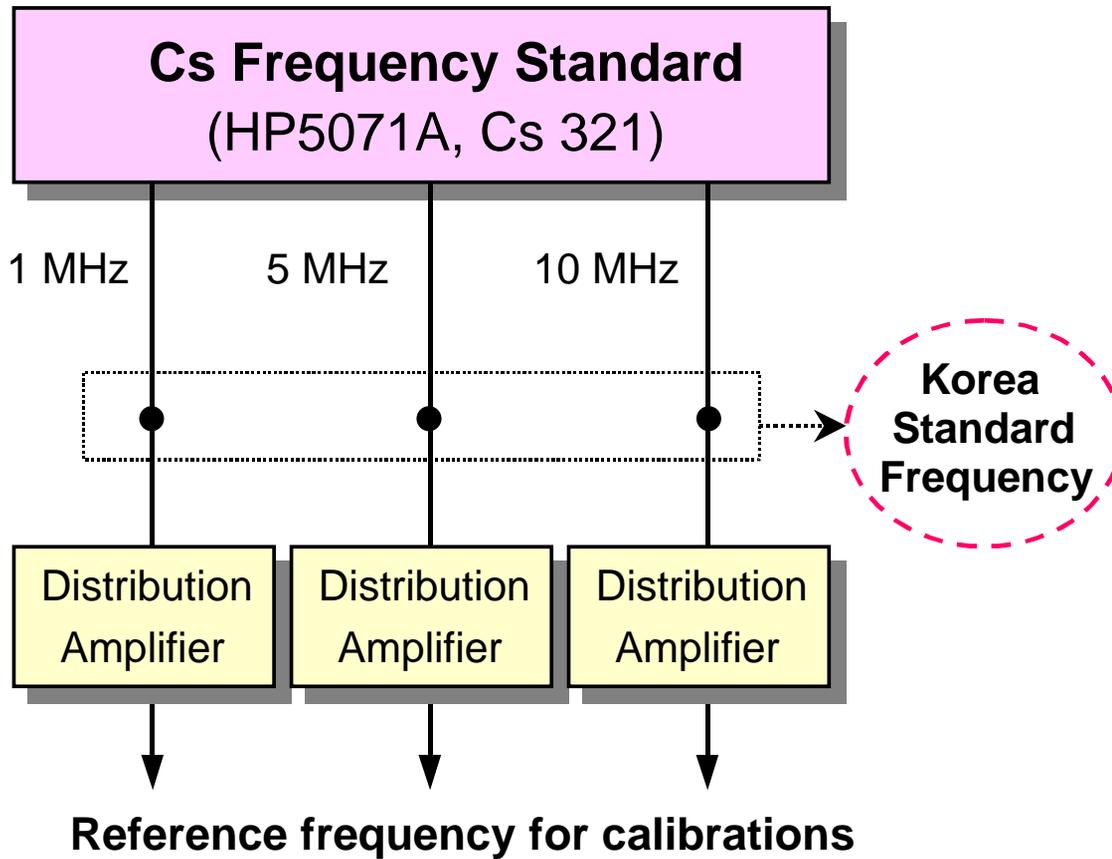


. BIPM

Circular-T



(KSF)



KSF TAI

□ Rates relative to TAI of Cs321 (TAI – Cs321). (Circular-T)

MJD	Offset (ns/day)	MJD	Offset (ns/day)	MJD	Offset (ns/day)
52119	6.12	52274	6.80	52424	4.32
52149	4.55	52304	7.53	52454	4.88
52179	5.17	52329	6.12	52484	6.04
52209	5.82	52364	7.07	52514	4.64
52239	5.14	52394	5.43		

$$d_{KSF-TAI} = 5.69 \text{ ns/day} = 5.69 \times \frac{1 \times 10^{-9}}{86400} = 6.59 \times 10^{-14}$$

$$y_{KSF-TAI} = -d_{KSF-TAI} = -6.59 \times 10^{-14}$$

$$u_{KSF-TAI} = \frac{\sigma}{\sqrt{n}} = \times \frac{1 \times 10^{-9}}{86400} \times \frac{1}{\sqrt{14}} = 3.1 \times 10^{-15}$$

(KST) UTC

□ UTC-UTC(KRIS) for one month of August, 2002. (Circular-T)

MJD	UTC-UTC(KRIS)	MJD	UTC-UTC(KRIS)
52489	-60 ns	52504	-67 ns
52494	-77 ns	52509	-73 ns
52499	-68 ns	52514	-73 ns

$$d = -69.7 \text{ ns} , \quad u = \frac{\sigma}{\sqrt{n}} = \frac{5.9 \text{ ns}}{\sqrt{6}} = 2.4 \text{ ns}$$

BMC

- BMC

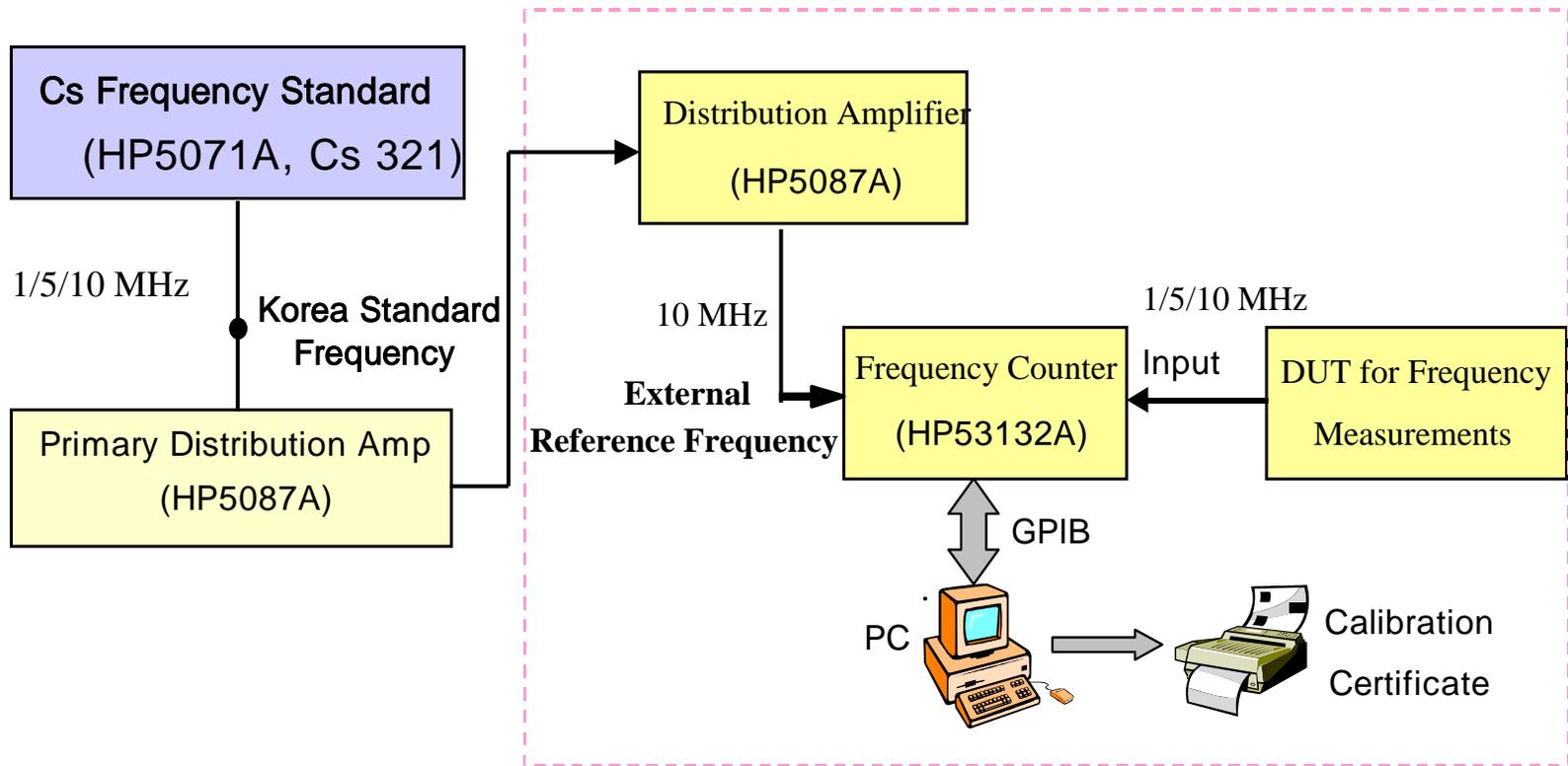
I) Reference frequency : KSF

- a. Traceability of the KSF
- b. Uncertainty due to cable
- c. Uncertainty due to distribution amplifiers

- a. Offset
- b. Digit error : Type B uncertainty
- c. Type A uncertainty



가

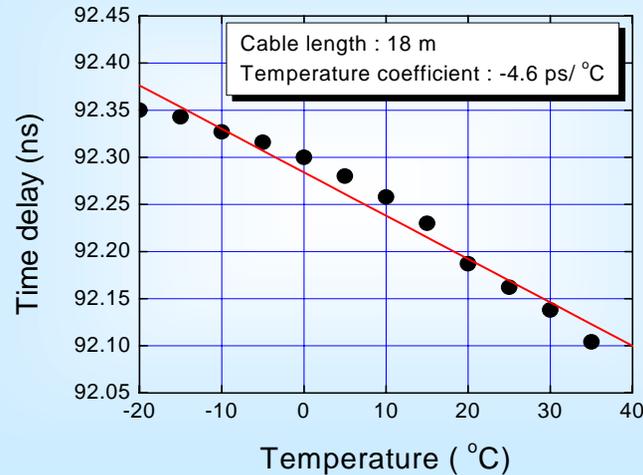


♣ BMC

가

Cable

□ Time delay of 1 pps signal (RG-58 cable)



- Changing rate = -4.6 ps/°C
- Length = 20 m
- Temp. diff. = 15 °C

$$\left| \frac{\Delta f}{f} \right| = \left| \frac{\Delta T}{T} \right| = \left| \frac{-4.6 \times 10^{-12} \text{ s/K} \times 15 \text{ K}}{86400 \text{ s}} \right| = 8.0 \times 10^{-16}$$

-
- ❑ Temperature coefficient : < 0.1 ns/°C (by manual)
 - ❑ Temperature variation : ± 2 °C

$$\left| \frac{\Delta f}{f} \right| = \left| \frac{\Delta T}{T} \right| = \left| \frac{0.1 \times 10^{-9} \text{ s/K} \times 2\text{K}}{86400 \text{ s}} \right| = 2.3 \times 10^{-15}$$

❑ Input frequency dependence :

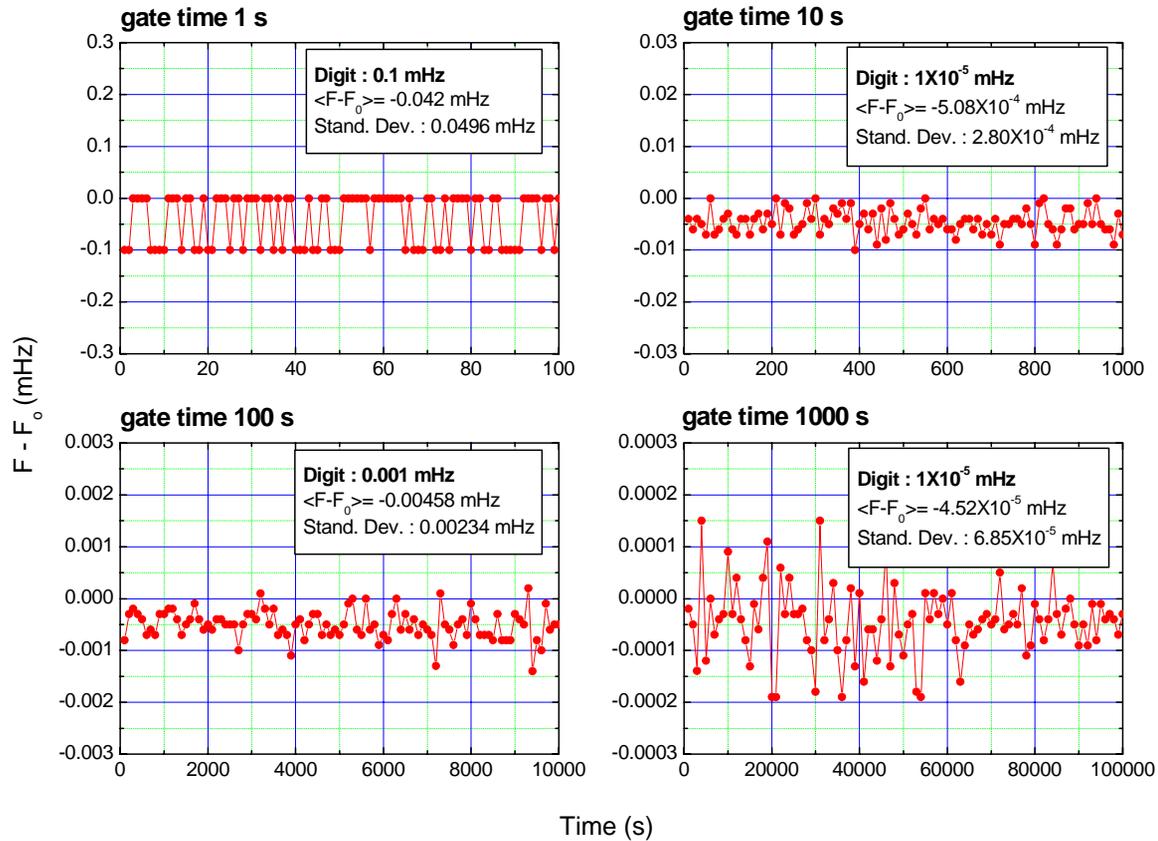
10 MHz, 5 MHz, 1 MHz

❑ Gate time dependence :

1 s, 10 s, 100 s, 1000 s

❑ Type B uncertainty :

$$u_{B-cnt} = \frac{a}{2\sqrt{3}} \quad \text{where } a \text{ is the least frequency separation.}$$



HP 53132A

Input Frequency	Gate Time (s)	Relative Frequency Offset; y_{sys}	Relative Standard Uncertainty; u_{sys}
10 MHz	1000	-7.1×10^{-14}	5.81×10^{-15}
5 MHz	1000	-6.9×10^{-14}	5.91×10^{-15}
1 MHz	1000	-7.0×10^{-14}	1.12×10^{-14}

$$y_{\text{sys}} = y_{\text{ref}} + y_{\text{cnt}} ,$$

$$u_{\text{sys}} = \sqrt{u_{\text{ref}}^2 + u_{\text{cnt}}^2}$$

BMC

Frequency	Relative Uncertainty (A type), u_A	Relative Uncertainty (B type), u_B	Relative Combined Uncertainty, u	Relative Expanded Uncertainty, $U=k \times u$. ($k=2$)
10 MHz	5.50×10^{-14}	5.81×10^{-15}	5.53×10^{-14}	1.11×10^{-13}
5 MHz	5.62×10^{-14}	5.91×10^{-15}	5.65×10^{-14}	1.13×10^{-13}
1 MHz	6.08×10^{-14}	1.12×10^{-14}	6.18×10^{-14}	1.24×10^{-13}



B

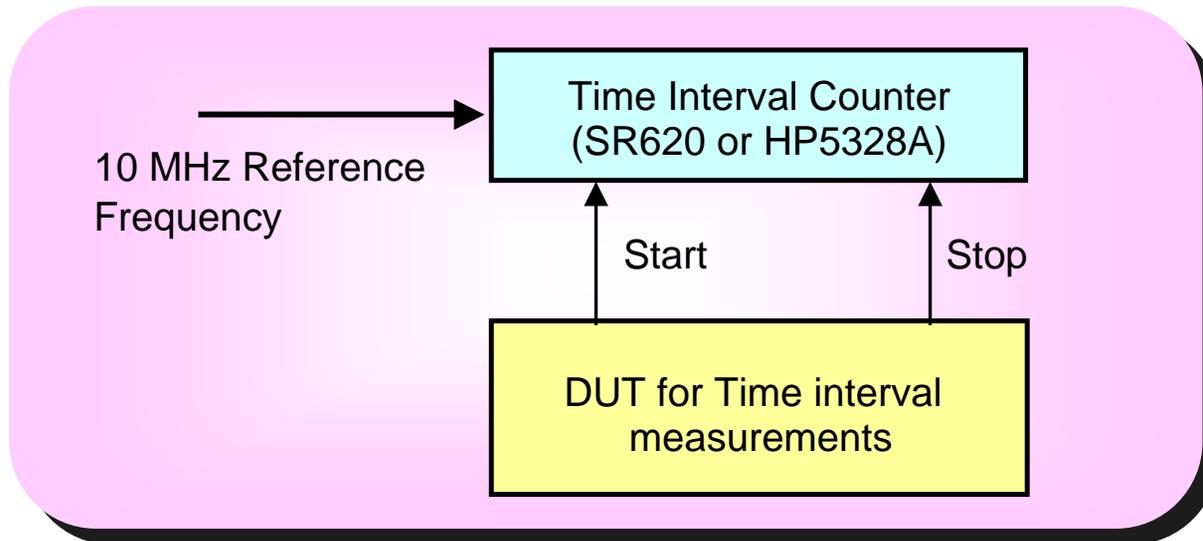
DUT A

BMC

가

BMC

- I) Uncertainty of the reference frequency
- II) Uncertainty of the time interval counter



가

BMC

❑ Time interval counter (SR620)

Time Interval	Type A Uncertainty, u_A	Type B Uncertainty, u_B	Combined Uncertainty, u	Expanded Uncertainty $U=k \times u$. ($k=2$)
$1 \mu\text{s} < T < 999 \mu\text{s}$	12.2 ps	0.6 ps	12.2 ps	25 ps
$1 \text{ ms} < T < 1000 \text{ ms}$	1.15 ns	0.6 ps	1.15 ns	2.3 ns

❑ Time interval counter (HP5328A)

Time Interval	Relative Uncertainty (Type A), u_A	Relative Uncertainty (Type B), u_B	Relative Combined Uncertainty, u	Relative Expanded Uncertainty $U=k \times u$. ($k=2$)
$1 \text{ s} < T < 1000 \text{ s}$	1.63×10^{-8}	5.77×10^{-8}	6.00×10^{-8}	1.2×10^{-7}

