

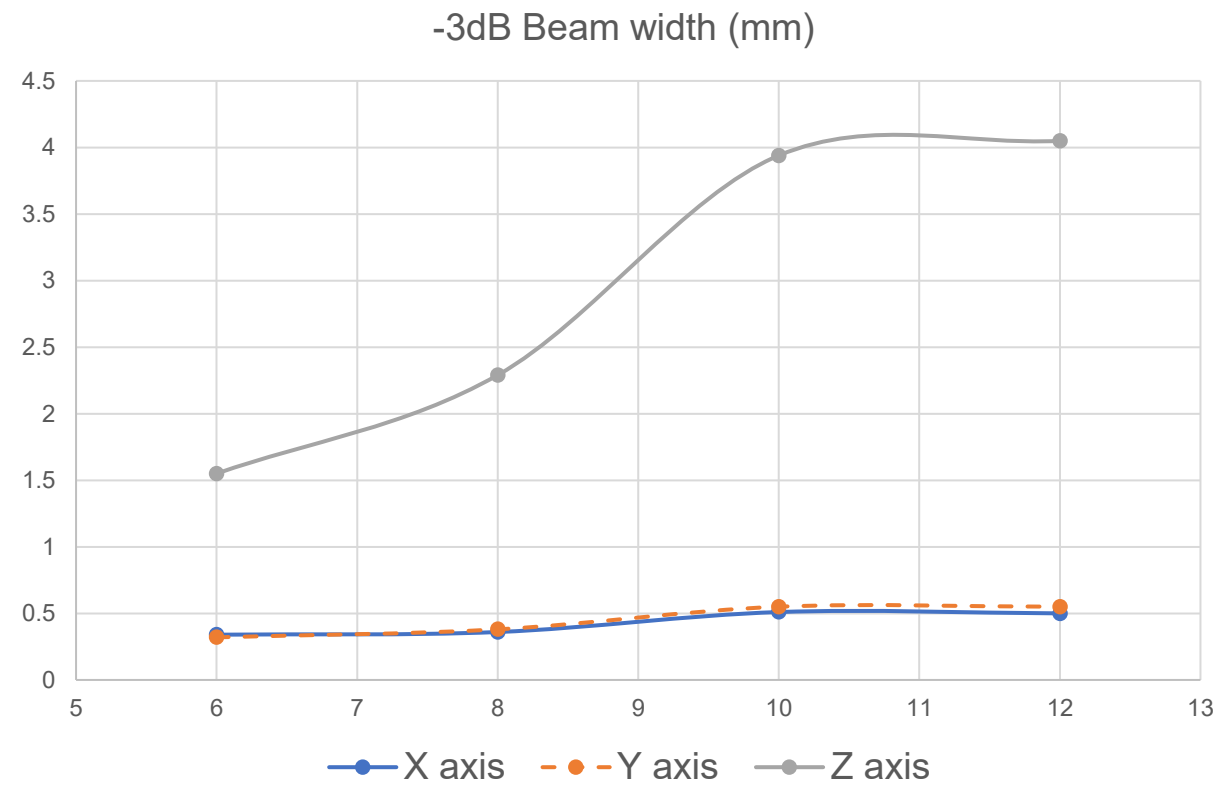
MUTITM WAVE

Semiconductor Ultrasound Technology

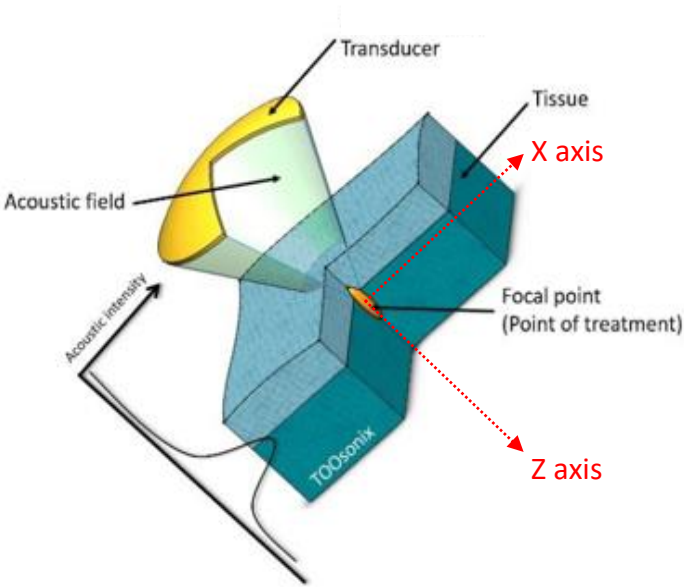
Multi-depth Focusing Precision

-3 dB Lateral Beam Widths and Axial Focal Zones

Focal Beam Widths measured by KRISS



Focal Length (mm)	6	8	10	12
X axis	0.34	0.36	0.51	0.5
Y axis	0.32	0.38	0.55	0.55
Z axis	1.55	2.29	3.94	4.05



-3 dB Lateral Beam Widths and Axial Focal Zones

Formula : Focal Beam Widths at focal lengths

$$D_f(XdB) = k_x \frac{\lambda F}{2a} \quad (62)$$

$$D_f(6dB) = 1.44 \frac{\lambda F}{2a} \quad (63)$$

The values of k_x for different values of X (obtained from figure 4.7) are given in table 4.1.

XdB	1	3	4	6	10	12
k_x	0.63	1.0	1.18	1.44	1.8	2

$$L_f(kdB) = 8a_k \lambda (F_N)^2 \quad (70)$$

In figure 4.8 we have plotted *sinc* function as a function of a_k to find the different values of a_k where the $\text{sinc}(a_k/2)$ has dropped k dB from its maximum value for $a_k = 0$.

$$L_f(6dB) = 9.68 \lambda (F_N)^2 \quad (71)$$

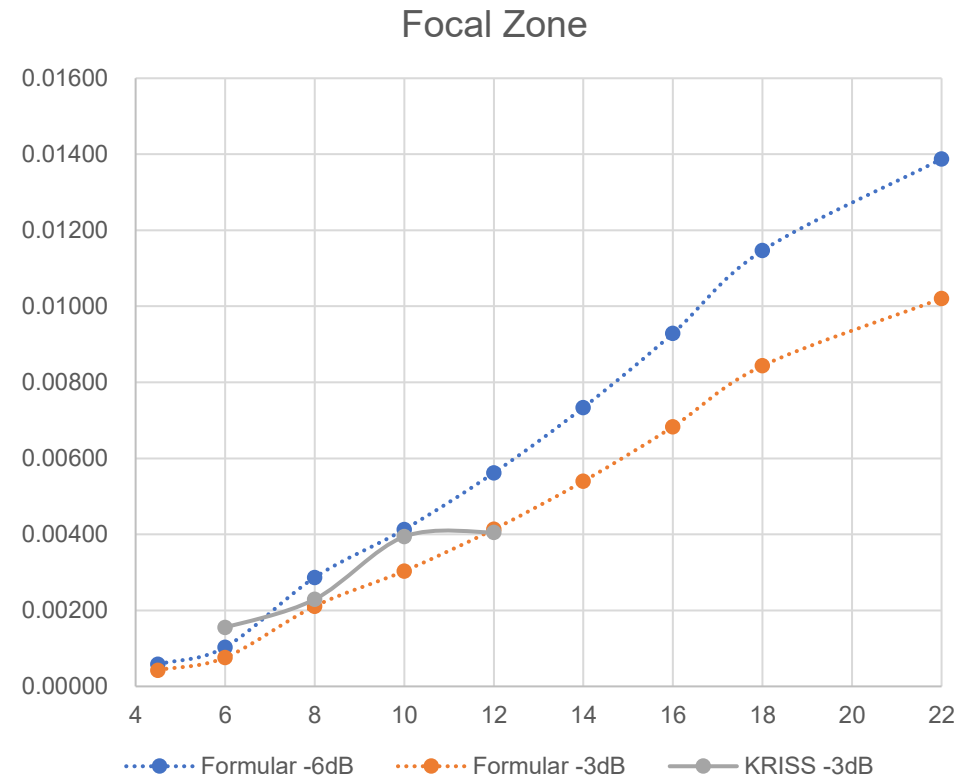
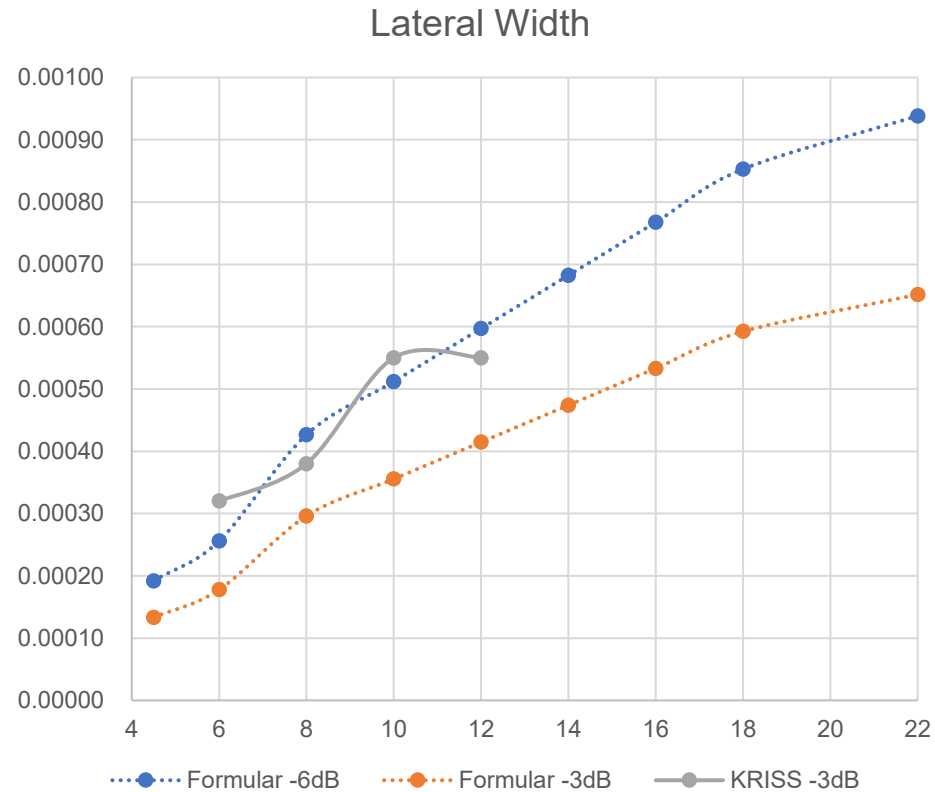
The values of a_k for different values of k are given in table 4.2.

XdB	1	3	4	6	10	12
a_k	0.51	0.89	1.0	1.21	1.47	1.6



	Index	4.5	6	8	10	12	14	16	18	22	26	32	40
	freq	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06
	lamda	2.96E-04	2.96E-04	2.96E-04	2.96E-04	2.96E-04	2.96E-04	2.96E-04	2.96E-04	2.96E-04	2.96E-04	2.96E-04	2.96E-04
	z	4.50E-03	6.00E-03	1.00E-02	1.20E-02	1.40E-02	1.60E-02	1.80E-02	2.00E-02	2.20E-02	2.60E-02	3.20E-02	4.00E-02
	D	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02
	Fn	0.45	0.60	1.00	1.20	1.40	1.60	1.80	2.00	2.20	2.60	3.20	4.00
	Focal Length	4.5	6	8	10	12	14	16	18	22	26	32	40
Lateral	Formular -6dB	0.00019	0.00026	0.00043	0.00051	0.00060	0.00068	0.00077	0.00085	0.00094	0.00111	0.00136	0.00171
	Formular -3dB	0.00013	0.00018	0.00030	0.00036	0.00041	0.00047	0.00053	0.00059	0.00065	0.00077	0.00095	0.00118
	KRISS -3dB		0.00032	0.00038	0.00055	0.00055							
Depth	Formular -6dB	0.00058	0.00103	0.00287	0.00413	0.00562	0.00734	0.00929	0.01147	0.01388	0.01938	0.02936	0.04587
	Formular -3dB	0.00043	0.00076	0.00211	0.00304	0.00413	0.00540	0.00683	0.00843	0.01021	0.01425	0.02159	0.03374
	KRISS -3dB		0.00155	0.00229	0.00394	0.00405							

Focal Beam Widths at focal lengths : Measurement vs. Formula



Summary

1. Multi-depth focal beam widths were independently measured by KRISS at focal lengths of 6, 8, 10, and 12 mm. The measured -3 dB lateral beam widths were approximately 0.32–0.55 mm, while the axial focal-zone widths increased from 1.55 mm at 6 mm to 4.05 mm at 12 mm.
2. The measured beam-width variation follows the theoretical dependence on focal length. Both lateral and axial beam widths increase with focal length, consistent with the expected behavior determined by wavelength, aperture size, and focal geometry.
3. Theoretical extension toward shorter focal lengths predicts tighter spatial confinement. Based on the same beam-width relationship, the near-range focal region toward 4.5–8 mm is expected to provide narrower lateral and axial focal zones, with the 6–8 mm range directly supported by KRISS measurements.
4. Conclusion — Sufficient focusing precision for MUTI WAVE.

The combination of sub-millimeter lateral beam widths, controlled axial focal zones, and agreement between measurement and theoretical behavior demonstrates focusing precision sufficient for MUTI WAVE's intended multi-depth ultrasonic stimulation.

Appendix

MEASUREMENT RESULTS REPORT

1. Submission

The following measurement results are submitted as a report on the joint use of research equipment for technical support to small and medium-sized enterprises.

Submission date: February 14, 2023

Submitted by: Yong-Tae Kim

Affiliation: Korea Research Institute of Standards and Science (KRISS), Ultrasound Standards Team

2. Equipment Under Test

- Equipment name: MUTI Chip ver. 2.1 module
- Model and serial number: MUTI-B / SN:001
- Manufacturer: MUTI Inc.

Photographs of the actual equipment under test are shown in Figures 1 and 2 below.



Figure 1. Bottom view of the equipment under test.

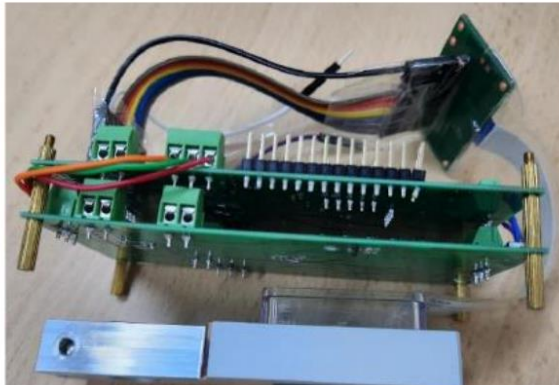
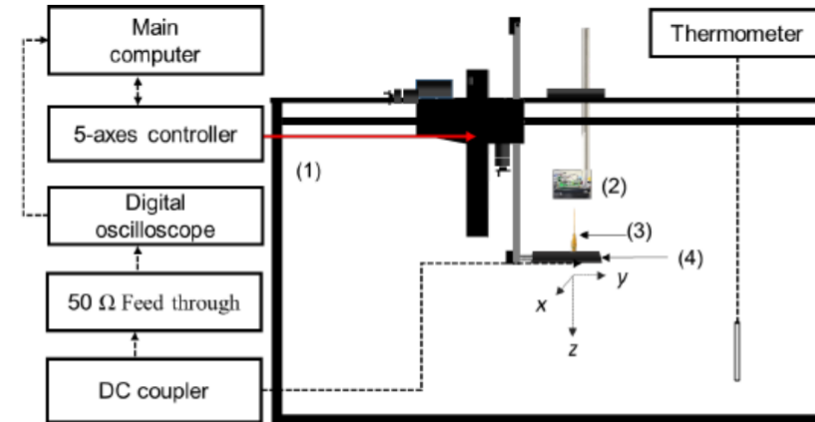


Figure 2. Side view of the equipment under test.

Measurement System Configuration

The measurement system configuration is shown in Figure 3.



(1) Water, (2) DUT, model: Muti-Chip ver. 2.1 module /SN: 001, (주)무티, (3) Hydrophone, model: NH-0250 SN: 098, Precision Acoustics Co. (4) Hydrophone mount

Figure 3. Measurement system configuration: (1) degassed triple-distilled water, (2) equipment under test, model: MUTI-Chip ver. 2.1 module, serial no.: 001, (3) hydrophone used for measurement, model: NH0025, SN:098, and (4) hydrophone

Focal Length 6 mm

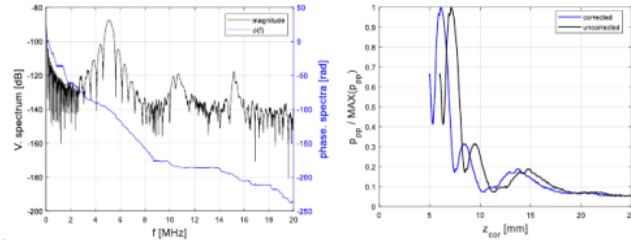


그림 6 수중 청음기 수신 신호의 스펙트럼.

그림 7, 음향 방사 측상 주사 결과.

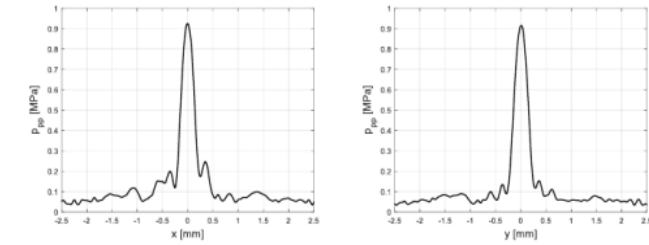


그림 7, x-축상 주사 결과.

그림 9, y-축상 주사 결과.

Focal Length 8 mm

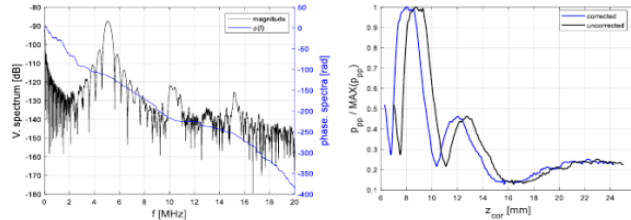


그림 10, 수중 청음기 수신 신호의 스펙트럼.

그림 11, 음향 방사 측상 주사 결과.

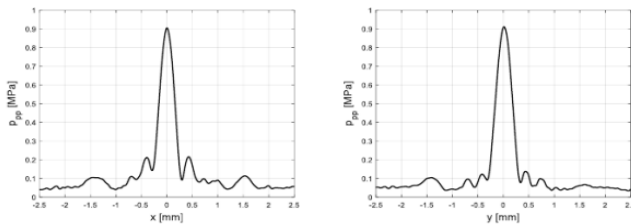


그림 12, x-축상 주사 결과.

그림 13, y-축상 주사 결과.

x-scan results	Measurement	Std. uncertainty
Beam Width (mm)	0.341	0.009
Center (mm)	0.006	0.003
y-scan results	Measurement	Std. uncertainty
Beam Width (mm)	0.322	0.004
Center (mm)	0.000	0.001
z-scan results	Measurement	Std. uncertainty
Focal depth (mm)	1.55	0.03
Focal length (mm)	5.96	0.03

x-scan results	Measurement	Std. uncertainty
Beam Width (mm)	0.36	0.02
Center (mm)	0.006	0.006
y-scan results	Measurement	Std. uncertainty
Beam Width (mm)	0.381	0.004
Center (mm)	0.003	0.01
z-scan results	Measurement	Std. uncertainty
Focal depth (mm)	2.29	0.09
Focal length (mm)	8.03	0.04

Focal Length 10 mm

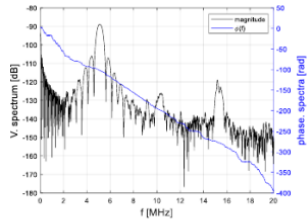


그림 16. 수중 청음기 수신 신호의 스펙트럼.

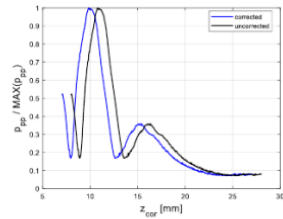


그림 17. 음향 방사 축상 주사 결과.

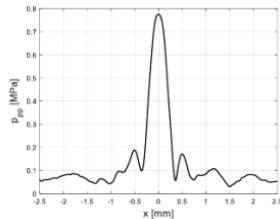


그림 18. x-축상 주사 결과.

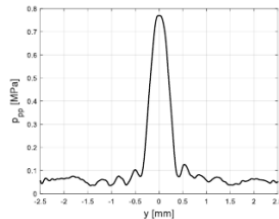


그림 19. y-축상 주사 결과.

x-scan results	Measurement	Std. uncertainty
Beam Width (mm)	0.51	0.04
Center (mm)	0.006	0.003
y-scan results	Measurement	Std. uncertainty
Beam Width (mm)	0.55	0.05
Center (mm)	-0.004	0.007
z-scan results	Measurement	Std. uncertainty
Focal depth (mm)	3.94	0.59
Focal length (mm)	10.25	0.09

Focal Length 12 mm

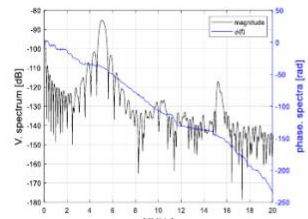


그림 22. 수중 청음기 수신 신호의 스펙트럼.

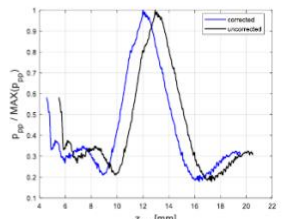


그림 23. 음향 방사 축상 주사 결과.

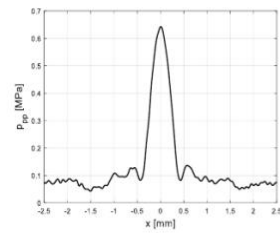


그림 24. x-축상 주사 결과.

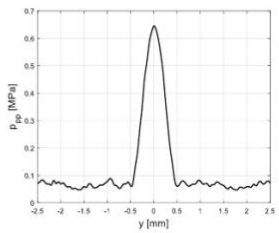


그림 25. y-축상 주사 결과.

x-scan results	Measurement	Std. uncertainty
Beam Width (mm)	0.50	NA
Center (mm)	0.003	NA
y-scan results	Measurement	Std. uncertainty
Beam Width (mm)	0.55	NA
Center (mm)	0.008	NA
z-scan results	Measurement	Std. uncertainty
Focal depth (mm)	4.05	NA
Focal length (mm)	11.99	NA

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