SE=SL-TL+AG-NL

Benthowave Instrument Inc.

Acoustical Solutions: SONAR, NDT/AE, HIFU. benthowave.com Revised on 2024/12/6

Parametric Array Transducer

Parametric Array Transducer: Sediment Profiling

The underwater parametric array transducers are designed for uses in sub-bottom profiling and are optimized to explore the first layers of sediment below the sea floor. These parametric array features narrow directivity pattern at the low frequency and seafloor penetration of tens of meters. To achieve a specific deference frequency, transducers need two high-frequency signal sources as inputs: **Low primary frequency (LPF)** signal source and **high primary frequency (HPF)** signal source.

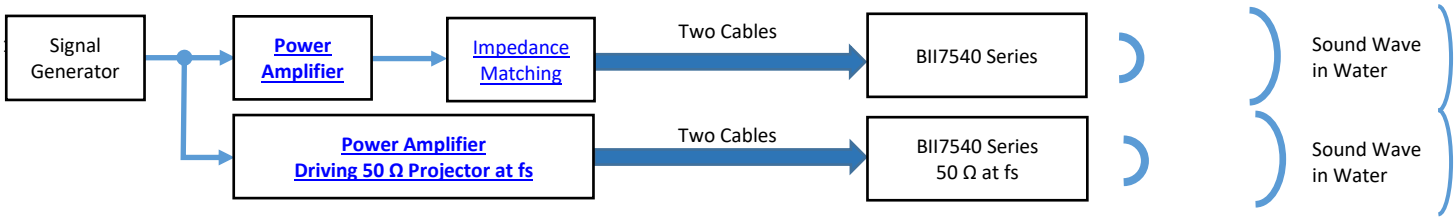
When two high-frequency underwater sound/waves (primary frequencies f_{p1} and f_{p2}, and set $f_{p1} > f_{p2}$.) propagate in the same direction, they interact with each other to create sum and difference-frequency sounds and their harmonics. The difference-frequency frequency sound/wave (secondary frequency $f_{sec} = f_{p1}-f_{p2}$) is useful for practical applications in sediment profiling, depth sounding and communication because of low propagation attenuation in water/liquids and solids. The directivity of the secondary frequency sound is close to the ones of primary frequencies. Parametric array gain or efficiency is better as primary sound powers are higher, secondary frequency f_{sec} is higher, down shift ratio $(f_{p1}+f_{p2})/(2f_{sec})$ is lower, and $(\alpha_p * R_r)$ is lower (αp: mean primary sound attenuation coefficient; Rr: rayleigh distance). **Attenuation/absorption coefficient of sediments is frequency dependent around 0.06f to 0.6f (dB/(m*kHz)).**

Typical Applications

Sub-Bottom Investigation/Assessment/Profiler	Sediment Profiling/Sediment Penetrating	Detection of Buried Objects, Search Pipeline/Cable Survey
Synthetic Aperture Imaging & Sequential Imaging	R & D on Nonlinear Underwater Acoustics	Construction of Harbor, Coast, Estuary…

SYSTEM CONFIGURATION

Transmitting Sounds.



RELATED PRODUCTS

Power Amplifier for SONAR, NDT, and HIFU	Impedance Matching between Transducers and Amplifiers

Specifications

Parametric Transducer		**BII7546-60**	**BII7546-110**	**BII7544-160**	**BII7544-195**	**BII7543-295**
Primary Sources f_p:		55 to 75 kHz	100 to 120 kHz	150 to 170 kHz	185 to 205 kHz	285 to 305 kHz
		When two primary f_p = two resonance f_s of the transducer, maximum secondary source level **SL_{sec}** is achieved. **f_s**: Resonance Frequency of Primary Sources.				
Impedance Matching:		1. None by default. 2. Customization: Built-in, Impedance matching to 50Ω, refer to Impedance Matching at fs.				
		TVR and FFVS variation of a transducer with built-in Impedance Matching Network: 1. When $R_{IM} < 1/G$, TVR increases, FFVS decreases. Generally, this is true for low frequency transducers. 2. When $R_{IM} > 1/G$, TVR decreases, FFVS increases. Generally, this is true for high frequency transducers. R_{IM}: Impedance-Matched Resistance such as 50 Ω. G: Transducer Conductance at Operating Frequency.				
Primary Source Signal:		Pulsed SINE, Chirp, PSK, FSK, Pulsed Square Waveform, etc.				
Radiation Face:		Circular Plane				
Directivity Pattern:		Conical Beam. Refer to Graph of Directivity Pattern**.**				
Quality Factor Q_m:		4.0 to 5.5, -3dB bandwidth $\Delta f = fs/Q_m$. Qm determines the transient response or the rise and fall rings of steady-state response.				
$\eta_{ea\ at\ fs}$ at f_s:		0.5 to 0.72	0.35 to 0.6	0.3 to 0.5	0.23 to 0.3	0.3 to 0.5
η_{ea} at $f << f_s$:		Circular Planar Transducer: at $f << fs$, $\eta_{ea} / \eta_{ea\ at\ fs} \approx 0.1225*(k*\Phi D)^2$. Wave Number $k = 2\pi/\lambda$; ΦD = Transducer Diameter.				
		1. Driving Transducer with Continuous Signals: (1). Electroacoustic Efficiency η_{ea} is quite low at $f << f_s$ and drops gradually at $f > f_s$, so it is NOT recommended for transducers to emit high power sounds at frequencies far from f_s. Otherwise, transducer may be damaged by overheating. (2). Transducer can emit low power sounds at frequencies far from f_s. For example, input power $P_i \le \eta_{ea}*MIPP$ at $f \le 0.8*f_s$ and $P_i \le 0.2*MIPP$ at $f \ge 1.3*f_s$. **2. Driving Transducer with Pulsing Signals such as SINE Pulses:** Electroacoustic Efficiency η_{ea} is quite low at $f << f_s$ and drops gradually at $f > f_s$, so it is recommended for transducers to emit high power sounds at frequencies far from f_s with **Pulsing Signals with Duty Cycle ≤ 10%, Pulse Length ≤ 100mS**. Otherwise, transducer may be damaged by overheating.				
Power Factor at f_s:		1. No impedance matching: 0.7 ~ 0.9.				
		2. Bespoke, Impedance matching to be 50Ω: ≥ 0.92				
Primary TVR at f_s: ± 2dB.	HPF	170.5	172.0	169.0	176.5	173.0
	LPF	160.0	168.0	165.0	172.5	168.0
		Primary **TVR**: Transmitting Voltage Response of two primary sound sources, dB µPa/V@1m.				

Radiation Sound Level SL_p:		Primary Source Level at f_p: $SL_p = 20*\log V_i$ + TVR, dB µPa@1m. Driving Voltage V_i is in unit of V_{rms}.				
Admittance or Impedance:		Refer to **G-B Graph**.				
		Customization with Built-in Impedance Matching to 50Ω: refer to Impedance Matching at f_s. Refer to **Z-θ Graph**. Default: $Z = 50*e^{j\theta}$, in Ω, and Phase Angle $\lvert\theta\rvert \le 20°$ at fs.				
Transducer without Impedance Matching Unit						
Driving Voltage V_i at f_s:		**Pulsed Driving Signal and Duty Cycle D < 100%:** Maximum V_i, $V_{imax} = \sqrt{(MIPP/G_{max})}$ or 600, whichever is less, in V_{rms}.				
		Continuous Operation at 100% Duty Cycle: Maximum V_i, $V_{imax} = \sqrt{(MCIP/G_{max})}$, in V_{rms}.				
		To achieve higher sound level, built-in impedance matching is recommended to step up driving voltage inside the transducer.				
Transducer with Impedance Matching Unit						
Driving Voltage V_i at f_s:		**Pulsed Driving Signal and Duty Cycle D < 100%:** $V_{imax} = \sqrt{(MIPP * \lvert Z\rvert)}$, in V_{rms}. Z is impedance with Impedance Matching Unit at fs.				
		Continuous Operation at 100% Duty Cycle: Maximum V_i, $V_{imax} = \sqrt{(MCIP * \lvert Z\rvert)}$, in V_{rms}.				
Input Power P_i:		No Impedance Matching: $P_i = V_i^2 * G$. Refer to **G-B Graph:** G is conductance, G_{max} is maximum G at f_s.				
		Built-in Impedance Matching: $P_i = V_i^2 / Z$ at f_s. Z is impedance at f_s.				
MIPP at f_s:	HPF:	2400 Watts	3000 Watts	1500 Watts	1150 Watts	1000 Watts
	LPF:	2400 Watts	1700 Watts	850 Watts	770 Watts	800 Watts
	Maximum Input Pulse Power at f_s: $P_i = V_i^2 * G_{max}$ or MIPP Watts, whichever is less.					
MPW at MIPP and f_s:		26 Seconds	17 Seconds	13 Seconds	10 Seconds	10 Seconds
		Maximum Pulse Width at MIPP and at f_s. **MPW of HPF = MPW of LPF.**				
MCIP at f_s:	HPF:	76 Watts	80 Watts	56 Watts	35 Watts	30 Watts
	LPF:	30 Watts	40 Watts	25 Watts	25 Watts	30 Watts
	Maximum Continuous Input Power at f_s.					
MIPP: Maximum Input Pulse Power. **MPW**: Maximum Pulse Width. **MCIP**: Maximum Continuous Input Power. **f_s:** Resonance Frequency.						
How to determine pulse width, duty cycle and off-time with input pulse power (peak power) at f_s: 1. Determine the input pulse power (IPP, peak power) with sound intensity required by the project. IPP MUST be less than MIPP. 2. Pulse Width ≤ (MIPP * MPW*(120°c-T)/103°c)/IPP. T: Water Temperature in °c. 3. Duty Cycle D ≤ MCIP*(120°c-T)/103°c)/IPP. 4. Off-time ≥ PW*(1-D)/D.						
Directivity Pattern at f_{sec}:		Conical Beam				
Secondary frequency f_{sec}:		f_{sec} ≤ 15 kHz. **f_{sec}:** Secondary Frequency, $f_{sec} = \lvert f_{p1} - f_{p2}\rvert$.				
Maximum SL_{sec} at f_s:		≥ 200 dB µPa, **SL_{sec}:** Source Level at f_{sec} secondary frequency.				
-3dB Beamwidth at f_{sec}:		10.0°	8.0°	7.5°	6.0°	5.5°
Side Lobe Level:		≤ -17.7 dB				
Penetration Capability:		**≥ 40 m at Secondary frequency f_{sec}.**				
FFVS at f_s: ± 2 dB	HPF	N/A	N/A	N/A	N/A	N/A
	LPF	-172.5	-180.5	-190.6	-184.0	-189.0
	$FFVS\ Sensitivity\ Loss\ over\ extension\ cable\ at\ f_s\ (dB) = 20*\log\{\left(1+\frac{2\pi f_s C_c}{B}\right)/\sqrt{[G^2+(B+2\pi f_s C_c)^2]/(G^2+B^2)}\}$ G: Conductance at f_s; B: Susceptance at f_s; C_c: Capacitance of Extension Cable. Cable is of 100 pF/meter roughly. **FFVS**: Free-field Voltage Sensitivity, in dB V/µPa.						
FFVS at f << f_s: ± 2 dB	HPF	N/A	N/A	N/A	N/A	N/A
	LPF	-190.0	-182.0	-193.0	-195.0	-192.0
	Sensitivity Loss over Extension Cable (dB) = $20*\log[C_h/(C_h+C_c)]$. Valid for hydrophone without preamplifier. C_h: Hydrophone Capacitance; C_c: Capacitance of Extension Cable. Cable is of 100 pF/meter roughly.					
Receiving Sound Level SL:		SL = $20*\log V_o$ - FFVS, dB µPa. Receiving Voltage V_o is in unit of V_{rms}.				
Operating Depth:		Maximum, 300 m or 3 MPa Pressure, Limited by the cable length if the cable has wire leads or a non-waterproof connector.				
Mounting Options:		1. Default: Free Hanging (**FH**) 2. Bolt-Fastening Mounting with Free Hanging (**BFM-FH-3/8"): 2 x 3/8"-16 x 1.25" 316 SS Screw.** 3. Free-hanging with Male Underwater Connector (**FHUWC-2P, FHUWC-3P.**) 4. End-face Mounting (**EFMM**) 5. Flange Mounting (**FGM-Φ220, FGM-Φ165, FGM-Φ140.**)				
		Please refer to online document AcousticSystem.pdf for a complete list of Mounting Options and more details.				
Cable:		1. Two Conductor Shielded Cable (**SC**), Rubber or PVC Jacket. 2. 50 Ω RG58 Coax (**RG58**)				
		Handling: Do not use the cable to support transducer weight in air and water if the transducer has a mounting part. Do not bend the cable.				
Cable Length:		1. Default: 15 m with non-underwater connector. 0.6m with Underwater Mateable Connector (2 pins) (**UMC2P**). 2. Custom-fit.				
Connector:		1. Default: Wire Leads (**WL**), for Transmit, Receive Signal, and DC Power Supply. 2. Underwater Mateable Connector (2 pins) (**UMC2P**) (Max. Diameter Φ21.5 to Φ35 mm). Locking Sleeve: DLSA-M. Underwater Mateable Connector (3 pins) (**UMC3P**) (Max. Diameter Φ21.5 to Φ35 mm). Locking Sleeve: DLSA-M. Undewater Mateable Connectors are fixed with 0.6m unshielded cable. UMC is from global manufacturers of underwater connectors. Its part number is listed in quote in detail. 3. MIL-5015 Style (3 pin) (**MIL3P**) (Max. Diameter Φ19 to Φ30 mm). 4. XLR Receptacle with 3 Male Pins (**XLR3P**), (Max. Diameter Φ20.2 mm). 5. DIN Receptacle with 3 Male Pins (**DIN3P**), (Max. Diameter Φ17 mm). 6. Male BNC (**BNC**) (Max. Diameter Φ14.3 mm).				
		Note: Underwater Mateable Connector is for uses underwater. Other connectors and wire leads are for dry uses and are not waterproofed.				

Size ΦDxH (mm):	Φ168 x 40	Φ168 x 40	Φ114 x 40	Φ114 x 40	Φ89 x 40
	Actual length depends on Mounting Parts and/or Add-on Parts such as -IM, etc.				
Weight in Air:	5.7 kg	5.7 kg	3.7 kg	2.7 kg	2.3 kg
	Weight is with 2 x 15m cables.				
	Actual weight depends on Mounting Parts, Cable Types and Length, and/or Add-on Parts such as -IM, etc.				
Operation Temperature:	-10 °C to +60 °C or 14 °F to 140 °F.				
Storage Temperature:	-20 °C to +60 °C or -4 °F to 140 °F.				
Impedance Matching at f_s:	BII6000 Bespoke Impedance Matching between transducers and power amplifiers. Order Separately as standalone devices or append **-IMxxΩ** to the part number for integrating BII6000 into the transducer and specify impedance in Ω at fs. For example, BIIxxxx-IM50Ω: BIIxxxx transducer with built-in Impedance Matching unit as 50Ω load at fs.				
	Phase Angle |θ| of Complex Impedance ≤ 20° at fs.				
Power Amplifier:	BII5000 Power Amplifiers for SONAR, NDT, HIFU. Order Separately as standalone devices.				
WARNING: DANGER — HIGH VOLTAGE on wires. Wires shall be insulated for safety. DO NOT TOUCH THE WIRES BEFORE THE DRIVING SIGNAL IS SHUT DOWN. Cable shield must be grounded firmly for safety.					
for 50Ω BNC connector, it is buyer's sole responsibility to make sure that the BNC shield of the signal source is firmly grounded for operating safety before hooking up transducer/hydrophone to the signal source. Coax with BNC is not intended for hand-held use at voltages above 30Vac/60Vdc.					

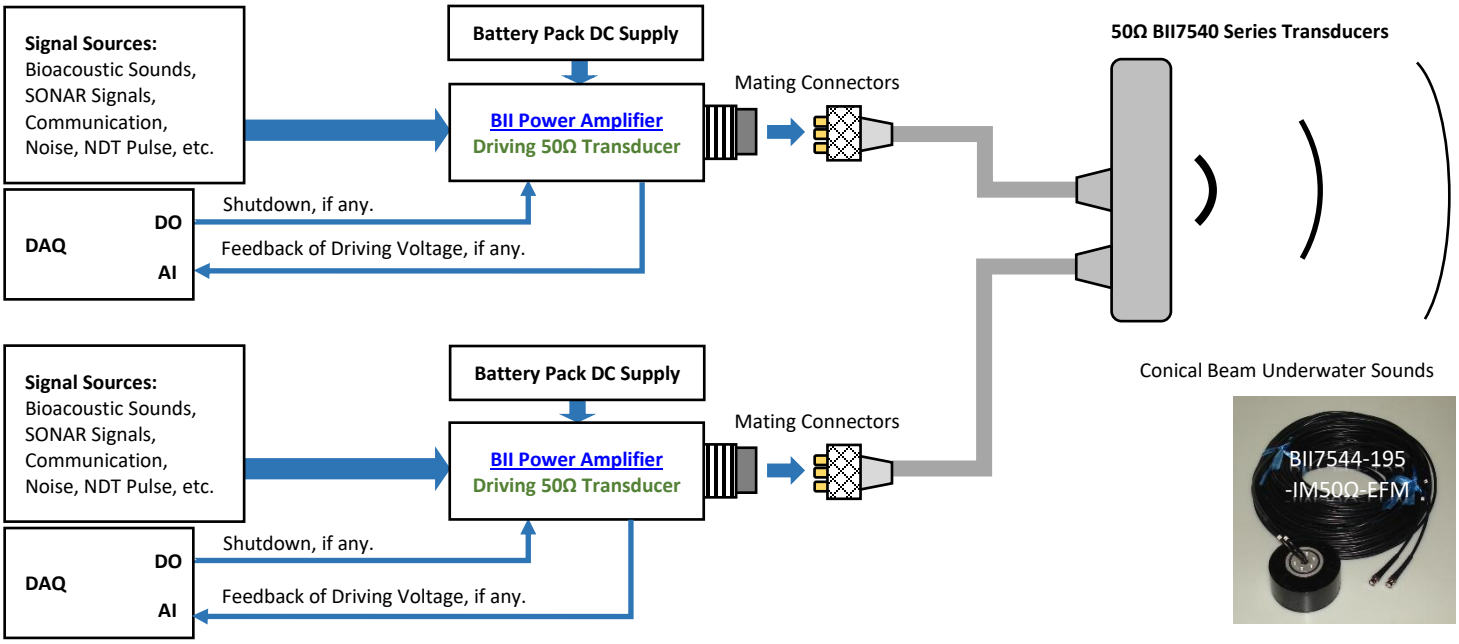
Wiring Information.

Transducer Wiring:	**Shielded Cable**	**Coax, BNC.**	**UMC3P, Locking Sleeve: DLSA-M.**	**MIL3P**	**DIN3P**	**XLR3P**
Signal:	White or Red	Center Contact	Contact 2	Contact C or G	Pin 3	Pin 2
Signal Common:	Black	Shield	Contact 1	Contact B	Pin 1	Pin 3
Shielding and Grounding	Shield	Shield	Contact 3	Contact A	Pin 2	Pin 1
Transducer Wiring. LPF: Low Primary Frequency, Cable Label "1"; **HPF:** High Primary Frequency, Cable Label "0".						
Wiring of Unshielded Cable:	**Wire Leads WL**	**UMC2P** (0.6m USC Cable originally coming from manufacturer of the connector, Fixed.). Locking Sleeve: DLSA-M.				
Signal	White	Contact 2				
Signal Common	Black	Contact 1				

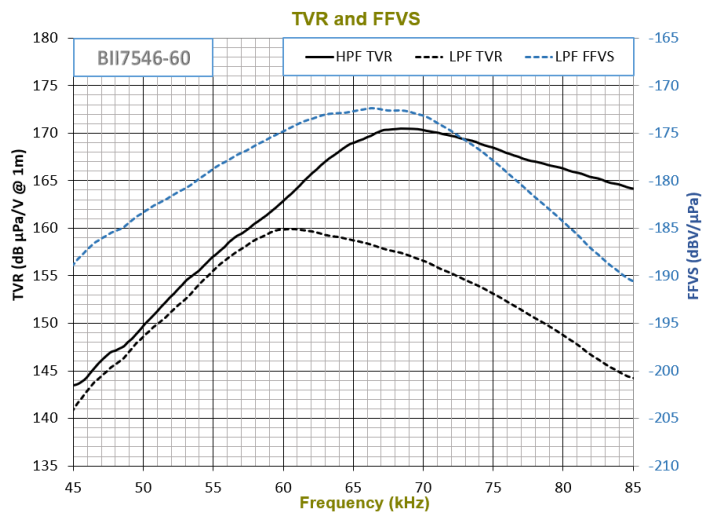
How to Order

Part Number	-IM50Ω	-Mounting	-Cable Length	-Cable	-Connector
BII7546-60, BII7546-110, BII7544-160, BII7544-195, BII7543-295.	Impedance Matching to 50Ω.	Refer to specs.	in meter x Two.	Refer to specs.	
Example of Part Number:	**Description**				
BII7546-60-BFM-FH-3/8"-15m-SC-WL	BII7546-60 transducer, Mounting: BFM-FH-3/8", 2x15m Shielded Cables, Wire Leads.				
BII7546-60-FH-15m-SC-WL	BII7546-60 transducer, Free Hanging, 2x15m Shielded Cable, Wire Leads.				
BII7546-60-IM50Ω-FH-15m-RG58-BNC	BII7546-60 transducer, Built-in Impedance Matching to 50Ω, Free Hanging, 2x15m RG58 Coax, BNC Male.				

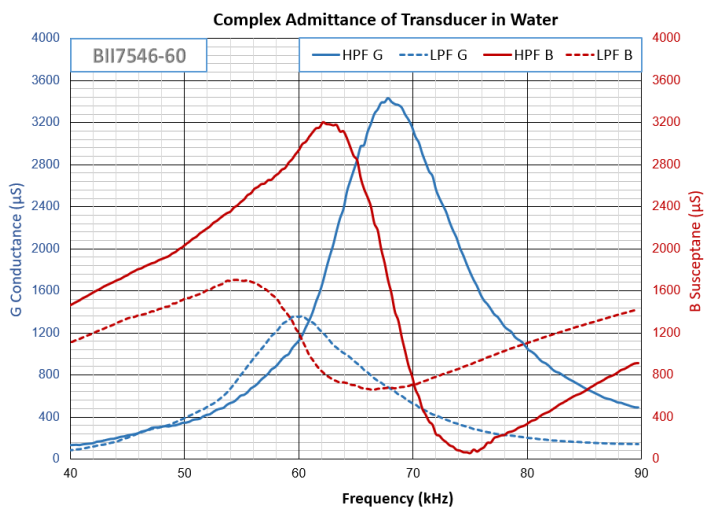
System Block Diagram of Generate Sounds

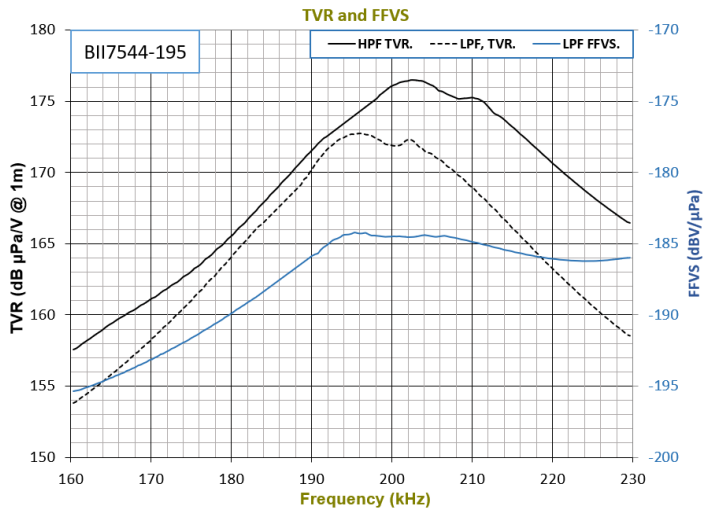


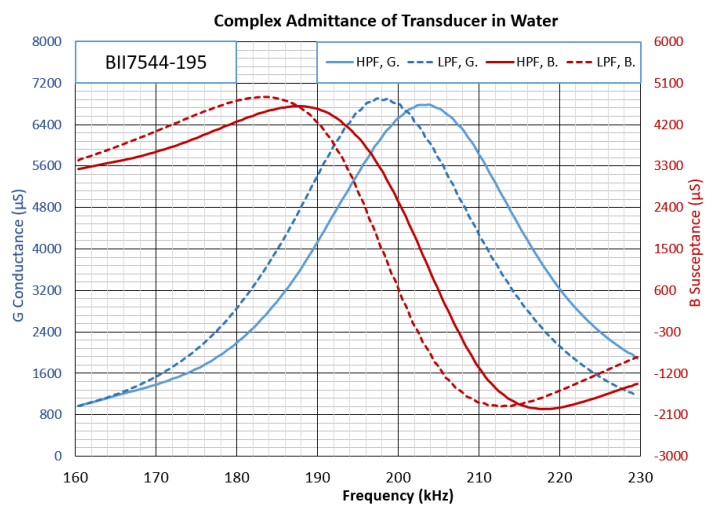
TVR Transmitting Voltage Response and FFVS Free Field Voltage Response



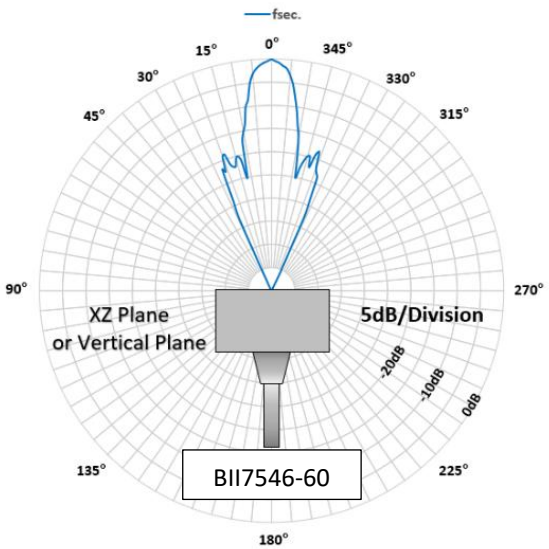
Admittance

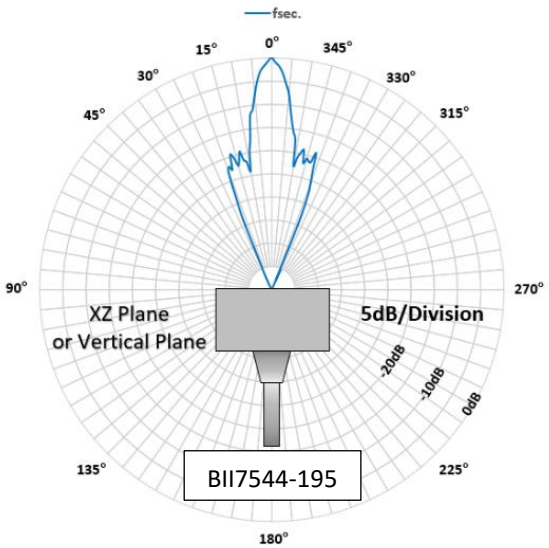




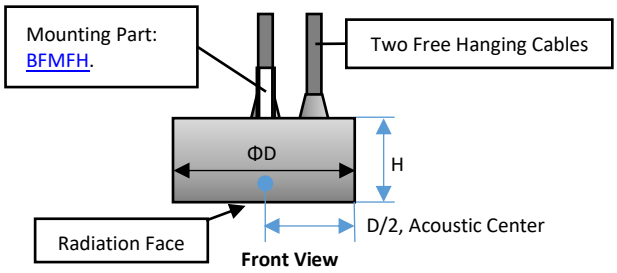


Directivity Pattern of Secondary Frequency Signal:

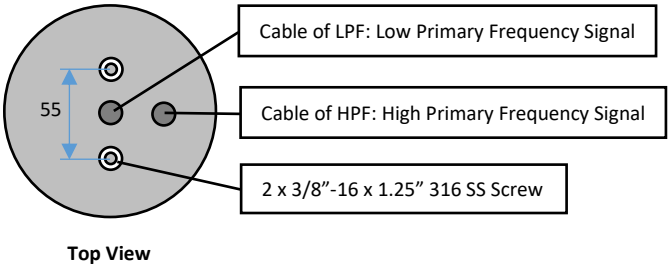




Physical Size (Dimensional Unit: mm)



Cable-out Layout for Bolt Fastening Mount with Free Hanging Cable (BFM-FH-3/8").



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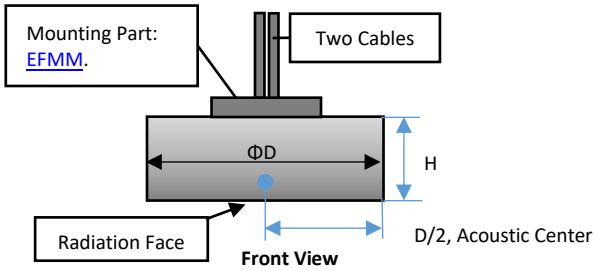
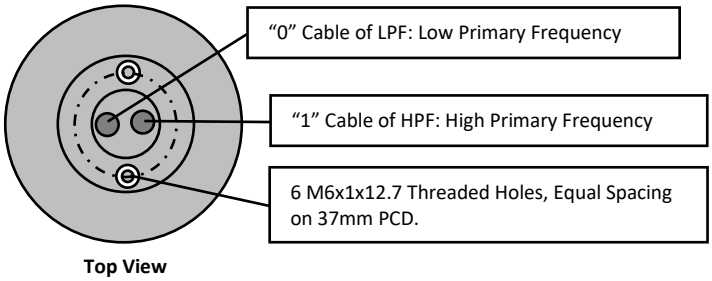


Cable-out Layout for End-face Mounting for Multi-Channel (EFMM)



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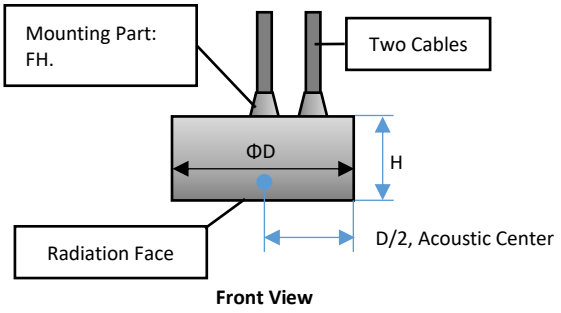

Cable-out Layout for Free Hanging.