1 List of symbols

(1 indicates a dimensionless quantity and – indicates not applicable).

Symbol	Variable name	Units	Description
$\arctan2(y, x)$	–	–	The four quadrant inverse tangent which returns values in the interval $[-\pi, \pi]$, inclusive.
c	c	ms^{-1}	Sound speed in water.
$D(v)$	`filter_v[n]['D']`	1	Integer filter decimation factor.
$\mathrm{DFT}_{N_\mathrm{DFT}}(x)$		–	The discrete Fourier transform of length N_DFT of x.
f		Hz	Frequency.
f_c		Hz	Frequency at centre of linear upsweep chirp pulse. Equivalent to $f_\mathrm{start} + \frac{\lvert f_\mathrm{stop} - f_\mathrm{start} \rvert}{2}$.
f_n	`f_n`	Hz	Nominal operating frequency of a transducer.
f_s	`f_s`	Hz	Analogue to digital sampling frequency.
$f_\mathrm{s,dec}$	`f_s_dec`	Hz	Decimated sampling frequency.
f_start	`f_1`	Hz	Start frequency of linear upsweep chirp pulse.
f_stop	`f_2`	Hz	Stop frequency of linear upsweep chirp pulse.
$g(\theta, \phi, f)$	`g_theta_phi_m`	1	Transducer gain as a function of echo arrival angle in the beam and frequency.
$g_0(f)$	`g_0_m`	1	Transducer gain along the main acoustic axis, i.e. $g(\theta, \phi, f)$ where $\theta = \phi = 0$.
$h_\mathrm{bp}(i, v)$	`filter_v[n]['h_fl_i']`	1	Complex valued receiving filter coefficients.
i		1	Generic integer index.
$\Im(x)$		–	The imaginary part of x.
j			The square root of -1.
m	`m`	1	Sample index in frequency domain.

N_{u}	`N_u`	1	Total number of transducer sectors/transceiver channels that are used to receive and process the acoustic signal.
N_{v}		1	Total number of filter stages.
N_w		1	Number of samples used in the sliding Hanning window.
n	n	1	Sample index in time domain.
$P_{\mathrm{rx,e,t}}(f)$		W	FT of the received electric power in a matched load for the signal from a single target at frequency f.
$P_{\mathrm{rx,e,t}}(m)$	`P_rx_e_t_m`	W	DFT of the received electric power in a matched load for the signal from a single target.
$P_{\mathrm{rx,e,v}}(f)$		W	FT of the received electric power in a matched load for the signal from a volume at frequency f.
$P_{\mathrm{rx,e,v}}(m)$	`P_rx_e_v_m`	Wm^2	DFT of the received electric power in a matched load for the signal from a volume.
$p_{\mathrm{rx,e}}(n)$	`p_rx_e_n`	W	Received electric power in a matched load.
$p_{\mathrm{tx,e}}$	`p_tx_e`	W	Transmitted electric power.
$p_{\mathrm{tx,auto}}(n)$	`p_tx_auto`	1	Square of the absolute value of the matched filter autocorrelation function.
$\Re(x)$		–	The real part of x.
r		m	Distance from transducer.
r_0		m	Reference distance.
r_c		m	Distance from the transducer to the centre of the range volume covered by t_w.
$r_c(n)$		m	$range_c$ at sample number n.
$r(n)$	`r_n`	m	Distance from transducer.
$S_p(n)$	`Sp_n`	dB re 1 m^2	Point scattering strength.
S_{V}		dB re 1 m^{-1}	Volume backscattering strength.
$S_{\mathrm{V}}(f)$		dB re 1 m^{-1}	Volume backscattering strength at frequency f.
$S_{\mathrm{V}}(n)$	`Sv_n`	dB re 1 m^{-1}	Volume backscattering strength at sample index n.

TS		dB re 1 m^2	Target strength.
TS(f)		dB re 1 m^2	Target strength at frequency f.
TS(m)	`TS_m`	dB re 1 m^2	Target strength at frequency index m.
t		s	Time.
t_w	t_w	s	Duration of sliding window for calculating volume backscattering strength.
u		1	Receiver channel number and transducer sector number.
$u(i)$		1	The Heaviside step function.
V		m^3	Volume occupied by scattering targets.
v		1	Filter stage.
w		1	The Hann window function.
$w(i)$	`w_i`	1	The Hann window function for index i, defined by $w(i) = 0.5(1 + \cos(2\pi i/N_w)), -N_w/2 \leq i \leq N_w/2$.
$\tilde{w}(i)$	`w_tilde_i`	1	Normalised Hann window.
x^*		–	The complex conjugate of x.
$\|\|x\|\|_2$		–	The l^2-norm of x, also known as the Euclidean norm.
$Y_{\mathrm{mf,auto}}(m)$	`Y_mf_auto_m`	1	Discrete Fourier transform (DFT) of the autocorrelation function for the matched filter.
$Y_{\mathrm{mf,auto,red}}(m)$	`Y_mf_auto_m_red`	1	DFT of the reduced autocorrelation function for the matched filter.
$Y_{\mathrm{pc,t}}(m)$	`Y_pc_t_m`	V	DFT of the pulse compressed signal from a single target.
$\tilde{Y}_{\mathrm{pc,t}}(m)$	`Y_tilde_pc_t_m`	Vm	DFT of the pulse compressed signal from a single target normalized by the DFT of the reduced autocorrelation function for the matched filter.
$Y_{\mathrm{pc,v}}(m)$	`Y_pc_v_m`	Vm	DFT of the pulse compressed signal from a volume. Compensated for spreading loss.

$\tilde{Y}_{\mathrm{pc,v}}(m)$	Y_tilde_pc_v_m	V	DFT of the pulse compressed signal from a single volume normalized by the DFT of the reduced autocorrelation function for the matched filter. Compensated for spreading loss.
$y_{\mathrm{mf}}(n)$	y_mf_n	1	Matched filter. Signal used for pulse compression.
$y_{\mathrm{mf,auto}}(n)$	y_mf_auto_n	1	Autocorrelation function for the matched filter.
$y_{\mathrm{mf,auto,red}}(n)$	y_mf_auto_red_n	1	Reduced autocorrelation function for the matched filter.
$y_{\mathrm{pc}}(n)$	y_pc_n	V	Pulse compressed signal averaged over all transducer sectors.
$y_{\mathrm{pc}}(n,u)$	y_pc_nu	V	Pulse compressed signal from channel u.
$y_{\mathrm{pc,aft}}(n)$	y_pc_aft_n	V	Pulse compressed signal from the aft transducer half.
$y_{\mathrm{pc,fore}}(n)$	y_pc_fore_n	V	Pulse compressed signal from the forward transducer half.
$y_{\mathrm{pc,port}}(n)$	y_pc_port_n	V	Pulse compressed signal from the port transducer half.
$y_{\mathrm{pc,s}}(n)$	y_pc_s_n	Vm	Pulse compressed signal compensated for spherical spreading.
$y_{\mathrm{pc,star}}(n)$	y_pc_star_n	V	Pulse compressed signal from the starboard transducer half.
$y_{\mathrm{pc,t}}(n)$	y_pc_t_n	V	Pulse compressed signal from a single target.
$y_{\mathrm{rx}}(n,u)$	y_rx_nu	V	Received digitised, bandpass filtered, decimated complex signal after the final filter stage, $y_{\mathrm{rx}}(n,u) = y_{\mathrm{rx}}(n,u,N_{\mathrm{V}})$.
$y_{\mathrm{rx}}(n,u,v)$		V	Received digitised, bandpass filtered, decimated complex signal.
$y_{\mathrm{rx,a}}(t)$		Pa	Analogue acoustic signal received by the transducer.
$y_{\mathrm{rx,e}}(t,u)$		V	Analogue electric signal received by each transceiver channel u.
$y_{\mathrm{rx,org}}(n,u)$		V	Received digitised signal before the bandpass filtering and decimation stages, $y_{\mathrm{rx,org}}(n,u) = y_{\mathrm{rx}}(n,u,0)$.

$y_{\mathrm{tx}}(n)$	`y_tx_n`	V	Ideal transmitted signal generated from transmit signal properties.
$\tilde{y}_{\mathrm{tx}}(n)$	`y_tilde_tx_n`	1	Ideal normalized transmitted signal generated from transmit signal properties.
$\tilde{y}_{\mathrm{tx}}(n, v)$	`y_tilde_tx_nv`	1	Ideal normalized transmitted signal generated from transmit signal properties after application of filter stage v.
$y_{\mathrm{tx,a}}(t)$		Pa	Analogue acoustic transmit signal.
$y_{\mathrm{tx,e}}(t)$		V	Analogue electric transmit signal.
$y_{\theta}(n)$	`y_theta_n`	rad	Electrical angle along the minor axis of the transducer (alongship when ship-mounted).
$y_{\phi}(n)$	`y_phi_n`	rad	Electrical angle along the major axis of the transducer (athwartship when ship-mounted).
$z_{\mathrm{rx,e}}$	`z_rx_e`	Ω	Receiver electric impedance.
$z_{\mathrm{td,e}}$	`z_td_e`	Ω	Transducer sector electric impedance.
$\alpha(f)$	`alpha_m`	dB m^{-1}	Absorption coefficient at frequency f.
γ_{θ}	`gamma_theta`	1	Conversion factor between phase difference in signals from the fore and aft transducer halves and the physical arrival angle of an echo.
γ_{ϕ}	`gamma_phi`	1	Conversion factor between phase difference in signals from the port and starboard transducer halves and the physical arrival angle of an echo.
θ	`theta_n`	rad	Angle coordinates along the minor axis of the transducer (alongship when ship-mounted).
λ		m	Acoustic wavelength.
λ_m	`lambda_m`	m	Acoustic wavelength at frequency index m
σ_{bs}		m^2	Backscattering cross-section.
τ	`tau`	s	Nominal transmit pulse duration.
τ_{eff}	`tau_eff`	s	Effective transmit pulse duration.

ϕ	`phi`	rad	Angle coordinates along the major axis of the transducer (athwartship when ship-mounted).
$\psi(f)$	`psi_m`	sr	Two-way equivalent beam angle at frequency f.