Development of a Wireless Remotely Operated Underwater Vehicle

BY: BATSHEVA GIL, CONNOR RIETH, AND ORIANA MATNEY MENTOR: DR. GEORGIOS SKLIVANITIS LAB RESEARCHERS: SOLOMON MARKOWITZ, PARKER WILMOTH

SUMMER 2023 ISENSE REU, FLORIDA ATLANTIC UNIVERSITY





lege of Engineering and Computer Science Florida Atlantic University

OR CONNECTED AUTONOMY

Background



 Project Goal: Wireless remote control of a single or a swarm of underwater vehicles to effectively carryout subsea operations e.g., subsea mapping, search-and-rescue etc.



- Tether-based communications are limiting in distance and autonomous capabilities in remotely operated vehicles (ROVs)
- Autonomous underwater vehicles (AUVs) are expensive

In this Project

 Off-the-shelf ROVs: BlueROV2 built by Blue Robotics





 In-house built software-defined underwater acoustic modems



- https://bluerobotics.com/store/rov/bluerov2/
- https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9905700&tag=1

Related Work

- Underwater wireless communication methods

 Acoustic sound waves (20 Hz 20 kHz)
 Radio frequencies (high attenuation)
 Optics (highly directional)
- Hybrid Underwater Vehicles
- Nereus operated with SONAR or using a tether





Underwater Robotics Simulation

- HoloOcean: Realistic underwater robotics simulator with multiagent missions
- Based on Holodeck: high-fidelity RL simulator built on Unreal Engine 4
- Objective: Extract information required for simulating the underwater acoustic communication channel between the ROV and the surface-station



Underwater Modem Power

Input:

• 14.8V Blue Robotics battery

Outputs:

- 30V Modem Analog Components
- 12V Modem Digital Logic





Underwater Modem: Signal Modulation

Binary Frequency Shift Keying (BFSK) simulation

- Bit 1 = 148 kHz ۲
- Bit 0 = 152 kHz ۲

Lowpass/Highpass filter to separate the two frequencies

For t = 1 bit, $\int Lowpass filter > \int Highpass filter, output Bit = 0$,Output Bit = 1Else

	Link	Data	Freq	T_g	$f_j =$	Δf	BW =	BER
	Distance	rate	Hops	(ms)	f_c +	(Hz)	$\Delta f +$	
I I I I I I I I I I I I I I I I I I I 	(m)	(bps)	j		$j\Delta f$		1/T	
					(Hz)		(Hz)	
Evperimental	2 (Tank)	66.7	0	14	150k	2k	4k	0.0049
LAPETITICITAI	2 (Tank)	66.7	0	14	100k	2k	4k	10^{-4}
avaluation of	2 (Tank)	500	16	1	100k	2k	64k	0
evaluation of	2 (Tank)	1000	32	0.5	100k	1k	64k	0
DECK	2 (Tank)	2000	32	0	100k	1k	64k	0.1037
BESK	5 (Pool)	58.9	0	16	100k	2k	4k	0.00178
	5 (Pool)	500	16	1	100k	2k	64k	0.001185
with	5 (Pool)	500	32	1	100k	1k	64k	0.0047
	5 (Pool)	1000	8	0.5	88k	5k	75k	0
the	5 (Pool)	2000	8	0	88k	5k	75k	0.086
	8 (Pool)	25	0	39	100k	2k	4k	0.0082
FALLmodem	8 (Pool)	500	16	1	100k	2k	64k	0.0065
into modern	8 (Pool)	1000	8	0.5	88k	5k	75k	0.052
	10 (Pool)	23.8	0	41	100k	2k	4k	0.006
	10 (Pool)	500	16	1	100k	2k	64k	0.042
and the second second second	10 (Pool)	1000	8	0.5	100k	5k	75k	0.35
	50 (Harbor)	100	16	9	100k	2k	64k	0.014

Cc	mmand Wir	ndow									
	Original	Bit St	ream								
	1	1	0	1	1	0	1	0			
	Demodula	ated Pro	pogate	d Bit	Stream	L					
	1	1	0	1	1	0	1	0			
-	Figure 1							_		×	
File	e Edit View	Insert To	ols Deskt	op Wind	low Help					з	
ምን	es 💷 👌										
-			 - NS								
	de 1	1		FSK S	ignal Re	ceived					
	1 0 0	Λ	$M \wedge \wedge$	\mathcal{M}		$\mathbb{W}//$	\mathbb{N}	$\Lambda \Lambda \Lambda$	\bigwedge		
	\overline{V}^{-1}	1	2	3	4	5	6	7	<u>ت د</u>		
	Ŭ		_	Tim	ne (bit per	iod)	Ū		0		
σ Graph of Bit 1 Frequency											
	1 0 - 1-	\mathcal{M}	\sim	$\sim \sim$		\mathbb{M}^{\sim}	$\sim\sim$	MM	~		
	∢ <u>_</u>	1	2	3	4	5	6	7	8		
Time (bit period)											
	de de	1		Graph o	f Bit 0 Fr	equency		1			
		~~~~~	$\sim$	$\sim$	~~~~	$\sim$	$\bigvee$	$\sim$	$\mathcal{M}$		
	∢ _	1	2	3	4	5	6	7	8		
Time (bit period)											
	ළ 1.5	1		Graph	of Digital	Output		-			
	0	1	2	3 TI~	4 (hit por	5 iod)	6	7	8		
				1 1/1	ie (nit hei	100)					

### ROV-Topside Computer Wireless Communication and Control Protocol



1. Heartbeat Message 1 Hz

2. Request to Control

3. Acknowledgement

4. Control Messages

5. System Status Messages 10 kHz





ROV

https://bluerobotics.com/store/rov/bluerov2/

https://www.google.com/search?rlz=1C1CHBF_enUS862US862&sxsrf=AB5stBhg6ocvH7 L_IZTERLrv87LwKnunaQ:1690490162279&q=QGroundControl&tbm=isch&source=lnms &sa=X&ved=2ahUKEwi5q_nM3q-

AAxXJl2oFHW1yCyMQopQJegQITBAB&biw=1536&bih=707&dpr=2.5#imgrc=FydDaorq OtolfM

#### ROV-Top side Computer Wireless Communication Simulation

								- ,o
Current Folder			Wo	rkspace				۲
Name	Value							
Command Window								
Repetitions: 1 /R8AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA	1 A/8MBMPnCASD5wwE7IB A/8MBMPnCASD5wwE7IB BMAAAAMA1EFA2Lt BMAAAAMA1EFA2Lt 1 A/8MBMPnCASD5wwE7IB 1 ew Message ew Message BMAAAAMA1EFA2Lt	nDouAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA	AAAAAAGOS AAAAAAGOS AAAAAAGOS	9RA== 9RA== 9RA==				
fx	Zoom: 125%	UTF-8	CRLF	script		Ln 8	Col 1	_
		1		1				
√isual Studio Code						] 0: –		
··· ≡ receiv	er.txt U ×							
	on_W > ≡ receiver.txt /R8AAAAAAAEAAA/8MBMI	PnCASD5wwE7IBmDo	ΔΑΑΑΑΑΑΑ	AAAAAAAAAGO9RA	==			
	ov.txt U 🗙						ជា 🗉	
Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simulation I Simula	on_W > ≣ bluerov.txt /QkAAAAAAAAAABMAAAA	MA1EFA2Lt						

E 1	14	la fala a l	- I	F							
Ed	itor -	bfsk_ad	d_prop_v	5.m							
Or	igiı	nal Bi 1	t Stre. 1	am O	1	1	0	0	1		
De	modu	ulated 1	l Propa 1	gatio 0	n Bit 1	Stream 1	0	0	1		
_		±	-	0	±	±	•	0	+		
ure	1										
it V	'iew	Insert To	ools Desl	ktop Wi	ndow He	elp					
	6	3		6							
0.04			R	eceived	Propaga	ated Sign	al				
0.01		anathaite dha bh. Meanairteach			alladhalladhu Nyingingingin	de dissile dis blir 17 Aleman Album			nd by Alstan The production		
0.01	0	500	1000	1500	2000	2500	3000	3500	400	0	
Time (millisec)											
DD1 2	utulut	ananta dhaith.	lludhate-			duttion the day	ency	- M	othelistar		
d -2	0	500	1000	1500	2000	2500	3000	3500	400	0	
				Ti	me (millis	sec)					
enge		-	Filte	red Valu	ues of Bi	t 0 Frequ	ency	that such a l			
0 10 2								nhu lin			
A 1	0	500	1000	1500 Ti	2000 me (millis	2500 sec)	3000	3500	400	0	
1 5				Graph	of Digita	I Output					
0.5	-								-		
-0.5	0	1	2	3	4	5	6	7	8		
Ð			C in	Tin Side Side	ne (bit pe	riod) FEGK Sig	nal				
nitud 2	-	-	SIN	igle-Side		I FOR OIG	Inal				
Magr	0	50	100 150	0 200	250	300 3	350 40	0 450	500	C	
2				En	oquopov	(ロー)				-	
	Ed         Or           Or         Or           De         Jure           it         V           0.010         0.010           0.020-2         2.02-2           0.030-2         0.05-2           0.05-2         0.05-2	Editor - Origi: Demod	Editor - bfsk_add Original Bi 1 Demodulated 1 Jure 1 it View Insert To 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	Editor - bfsk_add_prop_vi Original Bit Stree 1 1 Demodulated Propa 1 1 ure 1 it View Insert Tools Dest 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01	Editor - bfsk_add_prop_v5.m Original Bit Stream 1 1 0 Demodulated Propagation 1 1 0 Jure 1 it View Insert Tools Desktop Wi Editor - bfsk_add_prop_v5.m Received 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.00 1.00 1.00 1.500 1.00 1.500 1.000 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.50 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500 1.500	Editor - bfsk_add_prop_v5.m Original Bit Stream 1 1 0 1 Demodulated Propagation Bit 1 1 0 1 ure 1 it View Insert Tools Desktop Window Ha Received Propaga 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00	Editor - bfsk_add_prop_v5.m         Original Bit Stream         1       1       0       1       1         Demodulated Propagation Bit Stream         1       1       0       1       1         Demodulated Propagation Bit Stream         1       1       0       1       1         ure 1       Image:	Editor - bfsk_add_prop_v5.m Original Bit Stream 1 1 0 1 1 0 Demodulated Propagation Bit Stream 1 1 0 1 1 0 ure 1 it View Insert Tools Desktop Window Help Received Propagated Signal Received Propagated Signal 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.02 0.02 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	Editor - bfsk_add_prop_v5.m Original Bit Stream 1 1 0 1 1 0 0 Demodulated Propagation Bit Stream 1 1 0 1 1 0 0 ure 1	Editor - bfsk_add_prop_v5.m Original Bit Stream 1 1 0 1 1 0 0 1 Demodulated Propagation Bit Stream 1 1 0 1 1 0 0 1 ure 1	

#### Towards the Deployment of a Swarm of ROVs





- Smaller 60% Lighter
  - BlueROV -25lbs
  - NewROV 10 lbs
- More efficient 83% Less Power
  - BlueROV 6 thrusters
  - NewROV 1 thruster
- Lower Cost 90% Cheaper
  - BlueROV 4000 USD
  - NewROV 400 USD



### New ROV

- Raspberry Pi 4 onboard computer
- Servo rudder control for left and right movement
- Thruster & ESC: forward and backward movement
- Ballast Tank: buoyancy control for up and down movement
- Battery- power source
- Acrylic Tube- Outer shell
- 3D Prints- Custom mounting





# Conclusions

- Designed, built and tested a power management module to integrate the FAU underwater acoustic modem on-board the BlueROV2
- <u>Simulated a simple non-coherent signal modulation</u> based on Frequency Shift Keying in ideal and underwater channels to test ROV-Topside Computer wireless communication
- <u>Interfaced the BFSK simulations with MAVLink message protocol</u> for bidirectional communication between the ROV and Topside computer
- Extracted environmental information from an underwater robotics simulator (HoloOcean) to <u>increase the fidelity of our underwater comms</u> <u>simulations</u>
- Designed, built and tested a <u>small, low-cost, lightweight ROV</u> to evaluate the feasibility of deploying a fleets of ROVs in the future

### Future Goals

- Interface HoloOcean with MATLAB and the MAVLink message protocol to simulate endto-end underwater robotic communications
- Move from simulation to real-world testing:
  - Test bi-directional communication using the FAU underwater acoustic modems
  - Test ROV-to-ROV and ROV-to-Topside communication
- Test alternative swarm messaging protocols e.g., using Robotic Operating System (ROS)
- Test high-speed resilient underwater acoustic communications based on OFDM and CDMA





