Radar Based Vital Sign Monitoring With Automated Beam Steering

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Abstract

Hospitals commonly monitor an infant's vital signs after birth to quantify the status of its body during incubation. Conventionally, this is done by adhesively connecting biometric devices to every infant in the hospital nursery. By eliminating the need for physical connections and using a single device to simultaneously monitor every infant within a nursery, infants will experience more comfort during incubation, and the cost of vital sign monitoring largely decreases. To monitor vitals wirelessly, a double phase shifter (DPS) phased array will be used to repeatedly steer a beam between desired targets. A plain phased array could be used in this context; however, its ability to target a beam at a precise location is limited. Equipping the antenna array with DPS produces a highly focused beam that can localize closely spaced targets. After targeting the beam, a receiver will record the infant's vitals (heartbeat and breathing rate) over a finite sampling period. To automate this process, we implemented a programmable controller equipped with voltage amplifiers to computationally adjust the control voltages at each phase shifter. Doing this causes a shift in the beam's direction, which depends on the target's location and any unwanted neighboring targets that need to be suppressed (nulls). Finally, using Fast Fourier Transforms (FFTs) and filtering, the frequency information of the infant's vitals can be recovered. To test the effectiveness of this system, we ran an experiment on two human targets. The device successfully recovered each target's vital sign frequency information by automatically steering a beam between them. Our results show that the automated wireless vital sign monitoring system could imply promising applications in pediatric medicine, especially since the system is fully contactless and inexpensive if scaled down in size.

Motivations and Objectives

- Nurseries currently rely on contact-based biometric sensing to monitor infant vital signs.
- A wireless device that can monitor all infants in a nursery in a contactless fashion decreases monitoring costs and provides a more comfortable experience for the infants.

Objective: Design a system that can automatically monitor the vital signs of multiple closely spaced targets by integrating cutting-edge radar-based technology with a programmable voltage controller.

Project Challenges

- Enable automatic radar beam steering by designing a programmable voltage source.
- Verify that the controller operates over a 0V to 15V range with a maximum resolution of 200mV.
- Integrate the controller with the state-of-the-art phased array of [1] and test it validity by running tests on human subjects.
- Use a USRP 2920 to recover vital sign data during experiments.

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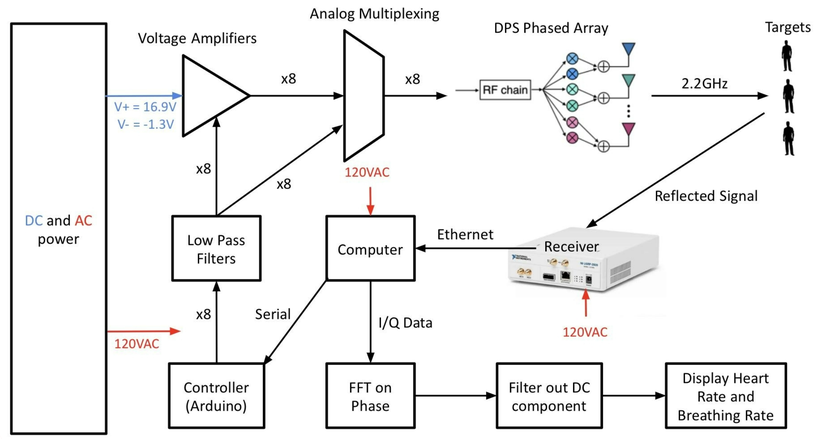
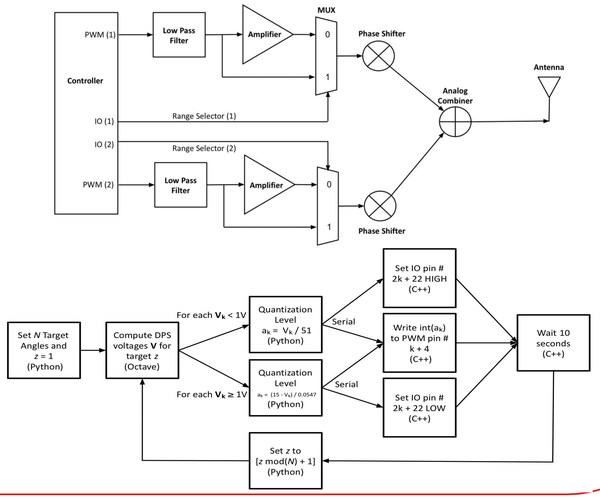
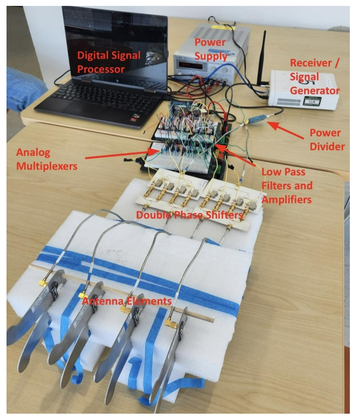
System Design

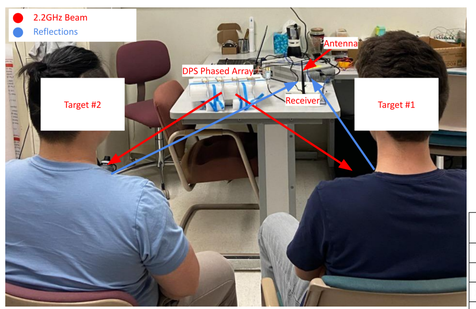
- Our system automates multitargeted vital sign monitoring by implementing a programmable voltage controller to steer the beam on a double phase shifter (DPS) phased array.
- DPS enables flexible beams, allowing for vital sign monitoring of closely spaced targets.

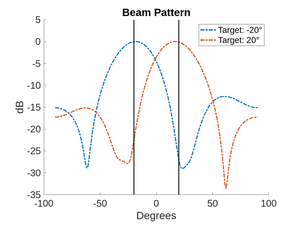




Results and Cost Analysis

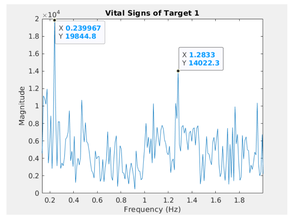


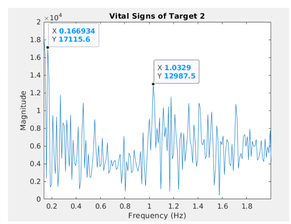




Monitoring System Costs

Subsystem:	Prototype Estimates:	PCB Implementation Estimates:
DPS Phased Array	$500	$272
Voltage Controller	$105	$33
Receiver + Signal Generator	$5500	$150
Power Divider	$1000	$20
Digital Signal Processor	$750	$30
Power Supply	$815	$15
Total:	**$8670**	**$520**





Project Impact

- Our project utilizes cutting-edge technology and an automated beam steering system to wirelessly monitor vital signs for hospital nurseries.
- With our system, nurseries can monitor multiple cribs simultaneously, receiving real-time data that can help ensure the safety and well-being of infants.

References

[1] *Z. Xu, D. Gao, S. Li, C.-T. M. Wu, and A. Petropulu, "Flexible beam design for vital sign monitoring using a Phased Array equipped with Double-Phase Shifters," 2023 IEEE ICASSP.*
[2] C. Li, J. Cummings, J. Lam, E. Graves, and W. Wu, "Radar remote monitoring of vital signs," IEEE Microwave Mag., 2009.
[3] USRP-2920. NI. (n.d.). https://www.ni.com/en-us/support/model.usrp-2920.html.html

IRB protocol number: HRP-503a