

# EARS: Collaborative Research: Enhancing Spectral Access via Directional Spectrum Sensing Employing

## 3-D Cone Filter Banks: Interdisciplinary Algorithms and Prototypes

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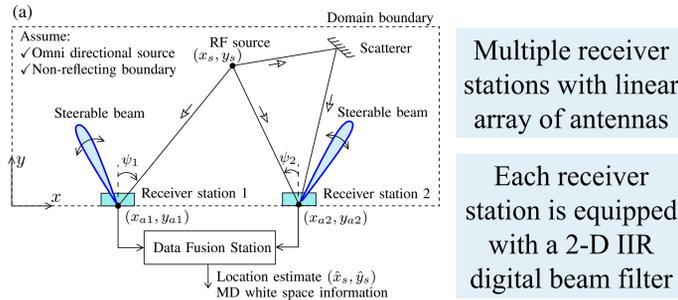
Institutions: University of Akron<sup>1</sup>, University of Toledo<sup>2</sup>, Norfolk State University<sup>3</sup>, Old Dominion University<sup>4</sup> and Ohio Northern University<sup>5</sup>

Participants: Chamith Wijenayake, Sewwandi Wijayarathna, Dezarae Holman, Elizabeth Hammell, Arindam Sengupta, Mohammad Almalkawi, Judith Abeysekara and Khair Ayman

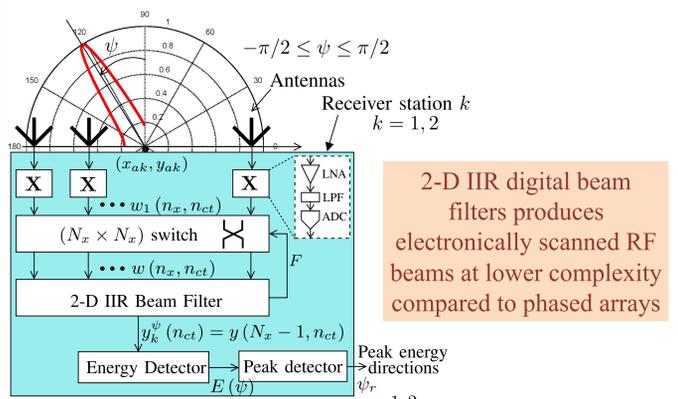


**Intellectual Merit:** Four journal publications [1-4] and two conference publications [5-6]

### Direction of Arrival (DOA) and RF Source Location Estimation using 2-D IIR Digital Beam Filters [5]

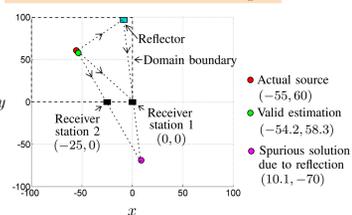


Multiple receiver stations with linear array of antennas  
Each receiver station is equipped with a 2-D IIR digital beam filter



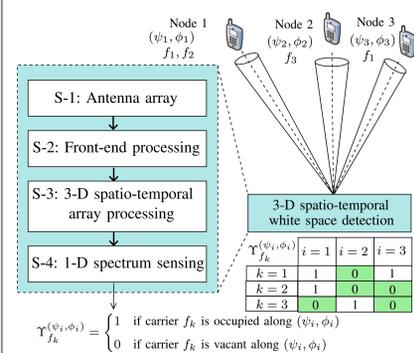
2-D IIR digital beam filters produces electronically scanned RF beams at lower complexity compared to phased arrays

#### Location Estimation Example

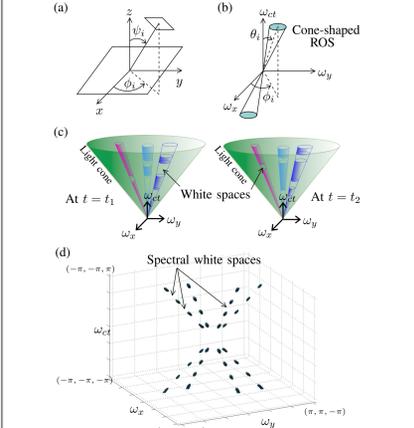


### Three-Dimensional (3-D) Space-Time White Spaces: Theory, Detection Algorithms and Circuits [3]

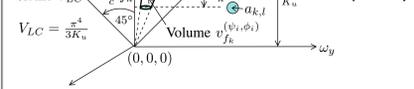
#### Proposed System Overview



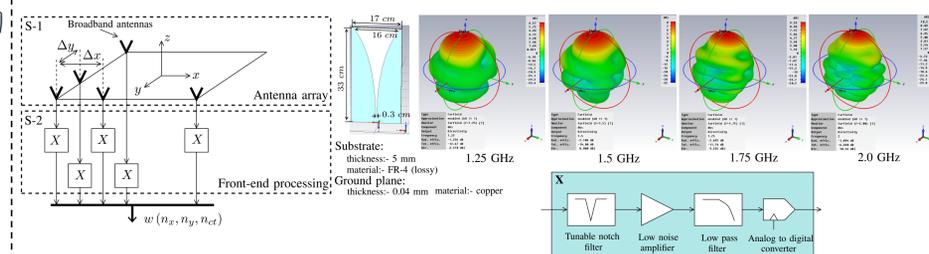
#### Spectral white spaces in 3-D space-time frequency domain



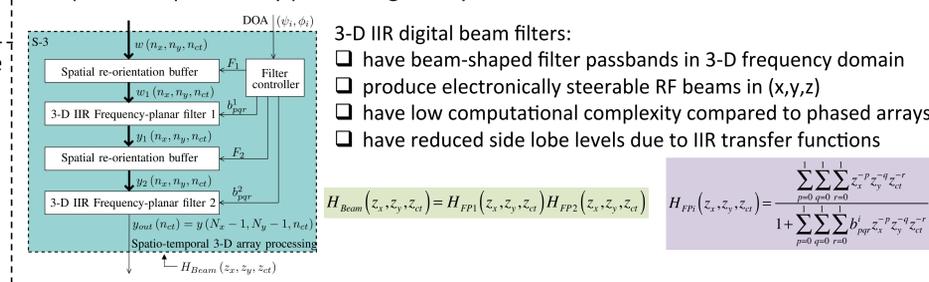
#### Space-time spectral occupancy



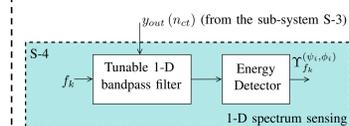
#### Antenna array and front-end sub systems



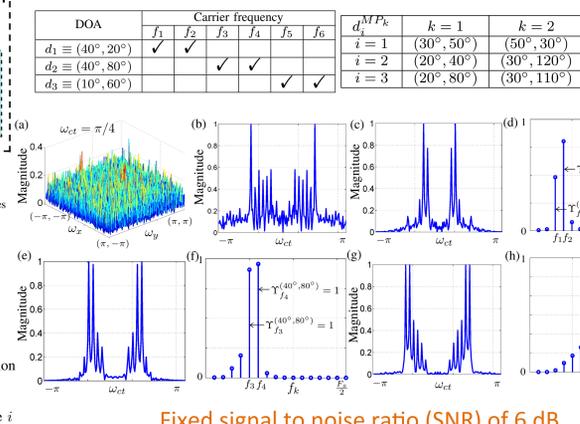
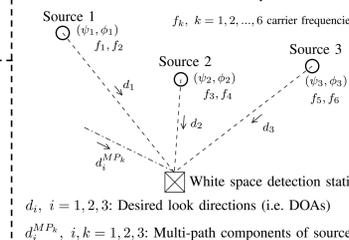
#### 3-D Spatio-temporal array processing sub-system



#### 1-D spectrum sensing sub-system



#### Simulation examples



### Link Scheduling and Routing

- Formulate into an optimization problem
  - Ensure no interference to primary users
  - Ensure no interference between simultaneously transmitting links
  - Maximize end-to-end traffic flow transport capacity
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- Construct a map of primary users through 3D sensing
  - Classify paths into opportunistic and stable
  - Differentiate routing based on traffic type
  - Optimize throughput

## Broader Impacts

### Women in Engineering (WIE) Activities

Summer camp at Akron for female high school students, June 2013  
Two hands on projects on basic electronics:  
1. Audio amplifier  
2. LED display according to audio signal



### Outreach to Underrepresented Groups

Summer workshop at NSU, Norfolk for underrepresented high school students  
Hands on projects to demonstrate basics of wireless communications



### Outreach to Broader Scientific Community

Graduate students presenting at the CASPER workshop at the National Radio Astronomy Observatory (NRAO), GreenBank, 2012



### Female Undergraduate Research

Undergraduate researcher, Elizabeth Hammell testing a Vivaldi antenna using a vector network analyzer



### Female Graduate/Undergraduate Student Activities



Students presenting their research at Ohio Celebration in Women in Computing (OCWiC) conference

Graduate student Ms Uma Potluri (top-right) won the best poster award at the conference

### Acknowledgement

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## References

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- A. Madanayake, C. Wijenayake, R. Joshi, M. Almalkawi, L. Belostotski, L. T. Bruton and V. Devabhaktuni, "RF Front-End and Digital Arithmetic Circuits for 2-D IIR Spatially Bandpass Beam Aperture Arrays", Multidimensional Systems and Signal Processing, Springer, pp. 1-23, 2013.
- C. Wijenayake, A. Madanayake, and L. T. Bruton, "Space-Time Spectral White Spaces in Cognitive Radio: Theory, Algorithms and Circuits", Accepted for publication at IEEE Journal on Emerging and Selected Topics in Circuits and Systems (JETCAS), special issue on CR/SDR, 2013
- J. Adams, A. Madanayake, and L. T. Bruton, "Approximate Realization of Fractional-Order 2-D IIR Frequency-Planar Filters", IEEE Journal on Emerging and Selected Topics in Circuits and Systems (JETCAS), special issue on Fractional Order Systems, vol. 3, pp. 338-345, 2013.
- C. Wijenayake, A. Madanayake, L. T. Bruton, and V. Devabhaktuni, "DOA-estimation and source-localization in CR-networks using steerable 2-D IIR beam filters," in IEEE International Symposium on Circuits and System (ISCAS), 2013, pp. 65-68.
- Arjuna Madanayake, Chamith Wijenayake, Uma Potluri, Judith Abeysekara and Dale Mugler, "Low-complexity algorithms for spatio-temporal directional spectrum sensing with applications in cognitive radio", Proceedings of SPIE 8753, Wireless Sensing, Localization, and Processing VIII, 87530G, 2013