Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
2009		**00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Human Ears Inspired Passive Microwave Direction Finding	**W911NF-08-1-0394**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
University of Arizona,Tucson,AZ,85722-3308	**; 55128-EL-II.1**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
U.S. Army Research Office, P.O. Box 12211, Research Triangle Park, NC, 27709-2211	11. SPONSOR/MONITOR'S REPORT NUMBER(S)
	55128-EL-II.1

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**3**	

Final Report – STIR Program "Human Ears Inspired Microwave Passive Direction Finding"

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1. Summary

We have investigated biological inspired RF direction finding techniques with the goal to learn and utilize the amazing acoustic direction finding capabilities of human and achieve compact, high performance and low-cost RF direction finding devices. Our initial simulation and experimental results are very encouraging. Through the 9-month STIR program *"Human Ears Inspired Microwave Passive Direction Finding"*, prototype direction finding systems including antennas, human head like low-pass scatter and digital receiver have been successfully designed and built. Several biological inspired hardware configurations (i.e., head-like scatters of various properties, omni-directional antennas) and preliminary algorithms have been theoretically and experimentally tested. The effectiveness of the novel human head-like scatter has been clearly demonstrated [1, 2]. In addition, we have performed initial investigation of single antenna direction finding for broadband RF signals. The most important goal of the STIR program, which is to develop an experimental test bed so that it can be used in the near future to study and develop novel RF direction finding techniques inspired by the amazing human auditory system, has been achieved.

2. Statement of the Problem Studied

Through this STIR program, various two-antenna configurations incorporating human head like scatters for enhanced direction finding performance have been modeled and designed. Experimental testing of various prototypes has been done and some of the initial concepts have been validated. Feasibility of single antenna direction finding is studied using an ultra-wide-band monopole antenna. A portable RF direction finding test bed integrating antennas, digital receiver and signal processing as a test bench for investigating advanced human auditory system inspired microwave direction finding has been designed, built and tested. This portable test bed will allow us to further study and develop biological inspired RF direction finding techniques such as the cocktail party effect, self training and environment learning capabilities in various realistic scenarios including indoor and outdoor environments.

3. Summary of Most Important Results

Important Result 1: We have theoretically and experimentally studied a two-antenna direction finding system incorporating a head-like scatter (see Figure 1). Our results have shown that the incorporation of the head-like scatter not only eliminates the phase ambiguity issue, but also increases the general sensitivity of the two-antenna direction finding system (see Figure 2). This kind of biological inspired RF techniques may lead to future direction finding systems that are low-cost, compact and light weight. For example, a hand-held direction finding gadget that is capable of identifying and locating the source of various RF signals is highly desirable for a soldier in

battlefield. The initial results has been published at the Antenna and Propagation Symposium as a conference paper and more detailed research results are being written as a journal paper.

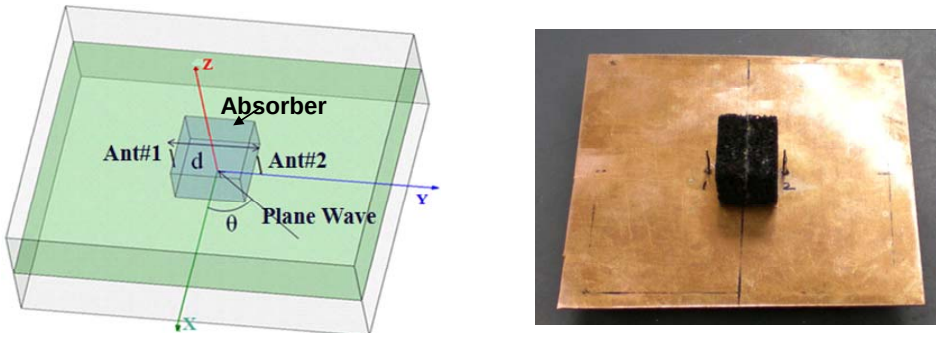


Figure 1. (a) A finite-element model illustrating the geometry of the two-antenna and scatter system with an incoming signal from an azimuth angle *θ*. (b) The demonstrated X-band two-monopole and scatter prototype.

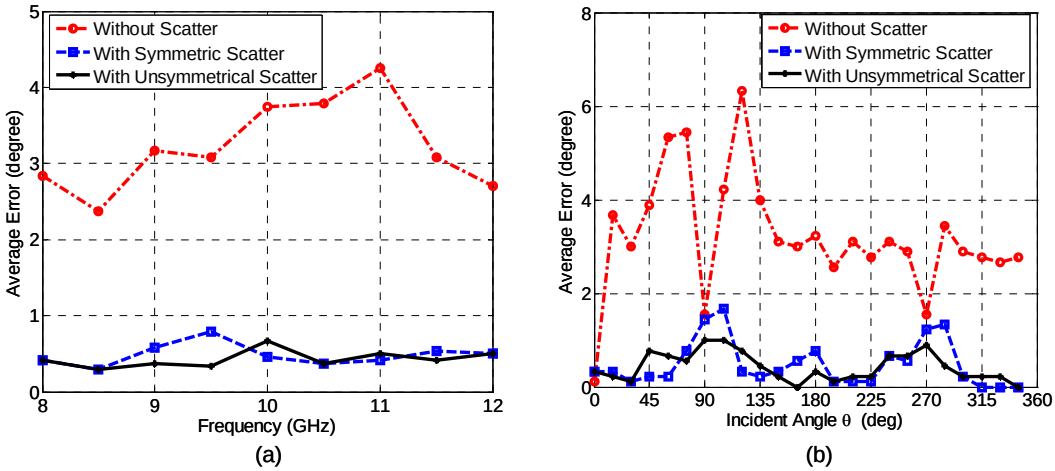
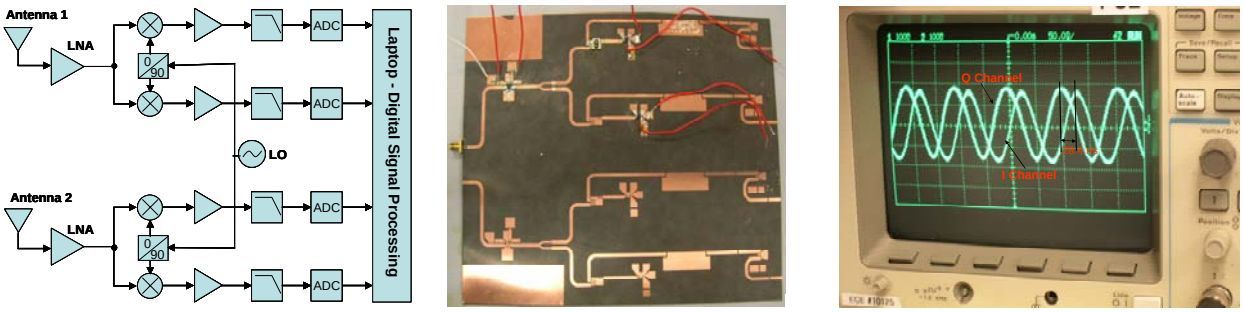


Figure 2. Measured average DOA estimation errors versus frequency showing significant improvement with head-like scatter (a) (averaged over all incident angles from 0^o to 360^o with 15^o step) and incident angle (b) (averaged over all frequencies from 8 to 12 GHz with 0.5 GHz step).

Important Result 2: We have designed and built a portable RF direction finding test bed including two antennas, a human head-like scatter, a digital receiver circuitry (see Figure 3) and initial DOA algorithms. This portable test bed will be used in the near future to further study and develop novel RF direction finding techniques inspired by the amazing human auditory system including the cocktail party effects, the environment learning techniques, etc. Some of the results have been presented at the Joint OCS-ARO Audio Workshop in Washington DC in April 2009.



(a) (b) (c)

Figure 3. (a) A schematic of the developed portable direction finding system. (b) A photo of the fabricated receiver circuitry board. (c) Measured I-Q signals.

4. Bibliography

[1] H. Xin, and Jun Ding, "An Improved Two-Antenna Direction of Arrival (DOA) Technique Inspired by Human Ears," in *Proc. IEEE AP-S Intl Symp.*, July 2008.

[2] H. Xin, R. Zhou, H. Zhang, "Biological Inspired Passive Microwave Direction Finding," to be submitted, *IEEE Trans. on Antennas and Propagation*, August, 2009.