Towards the Development of a Beam-Steering Parasitic Antenna Array

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***Abstract*—The goal of this research project is the design, fabrication and characterization of a 2.4GHz beam-steering antenna array. The project is to develop a new communications system for Solar-powered Autonomous Underwater Vehicles (SAUVs) in collaboration with the University of South Florida College of Marine Science. The array will consist of a single driven monopole placed in the center of a circular array of parasitic elements. Beam-steering will be achieved by shorting a desired set of parasitics to the ground plane causing them to act as reflectors and increasing the directivity of the array. The feasibility of this design approach has been validated through simulations in Ansys HFSS. A prototype array has been fabricated.**

***Index Terms*—antenna array, autonomous underwater vehicle, smart antenna, path-loss**

I. Introduction

THISwork summarizes efforts made to develop a new communication system for use on Solar Powered Autonomous Underwater Vehicles (SAUVs) seen in Figure 1. This effort has been a collaboration between the University of South Florida (USF) Center for Wireless and Microwave Information Systems (WAMI) and the USF College of Marine Science.

Fig. 1. USF College of Marine Science SAUV

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II. Background and Experiments

A. Background

The primary goal of this work has been to expand on the capabilities offered by USF's SAUVs through equipping them with a cutting-edge wireless communication system. The College of Marine Science desired a system with "smart antenna" capabilities, particularly beam-steering. They also desired that this new system have a higher bandwidth and throughput than their current 915 MHz Industrial, Scientific and Medical (ISM) band communication system. The requirements for the new system also included a minimum of 1 mile link range and for minimal impact on the hydrodynamics of the SAUV.

To facilitate these requirements a switch to the 2.4 GHz ISM band was investigated. This band was chosen because as with the 915 MHz band there are no regulatory difficulties in its use for scientific purposes. In addition to this since the 2.4 GHz ISM band is utilized by many Wi-Fi systems there are many components readily available on the market.

Two designs were considered for the development of the "smart antenna." The first design was a microstrip patch antenna array based on work conducted in [1]. This design consisted of four microstrip patch antennas in a vertical array fed through a splitting network. The final design would have been a hexagonal structure with a four element array comprising each of the six sides. Beam-steering would have been achieved through activation of which ever face of the array was facing the desired receiver. In addition all of the faces could be activated to achieve omnidirectionality. While this design was very promising from its RF characteristics, it was simply too large for practical use on the SAUV. Standing at 60 cm tall with a diameter of 13 cm in the envisioned final configuration and then made larger by the requisite radome that would have been added, this design would have added too much drag to the SAUV.

Due to this a redesign process was undertaken to find a suitable design that had both the "smart antenna" capabilities and a minimum size. The solution settled on was first proposed in 1978 by Harrington [2]. It was a dipole array composed of a center fed element surrounded by a ring of parasitic elements. Each of the parasitics contained a reactive impedance at their center. Through manipulation of this reactive impedance the principle radiation direction could be steered. This design has a number of advantages over more traditional methods of beam-steering, such as phase shifting.

Component cost can be kept down as no phase shifters or wave splitters are required. Since the design relies on the mutual coupling of between the elements the footprint of the array is kept small, with typical inter-element spacing of less than half a wavelength.

B. Experiments

To determine if the 2.4 GHz ISM band would be effective for maritime communications, a path-loss study was needed. As there was little to no literature on the subject of propagation over water at this frequency, experiments were needed to reach a conclusion.To accomplish this, both simulations and measurements of path-loss wereconducted. Simulations were done utilizing MATLAB's Parabolic Equation Toolbox (PETOOL).

The PETOOL simulation results conflicted with the known range of the 915 MHz system currently in use, the simulation implied that the range would be much shorter than it was already known to be. To address this discrepancy, path-loss measurements were undertaken to characterize ship-to-shore communications in the two ISM bands of interest.

Measurements were taken at 915 MHz and 2.4 GHz with a transmitter on shore and a receiver on a boat in Tampa Bay. By comparing the signal degradation of the two frequencies as a continuous function of distance it was determined that the path-loss of 2.4 GHz over seawater was comparable to that of 915 MHz and therefor the link range of at 2.4 GHz system would be comparable to that of the 915 MHz system, this is shown in Figure 2.

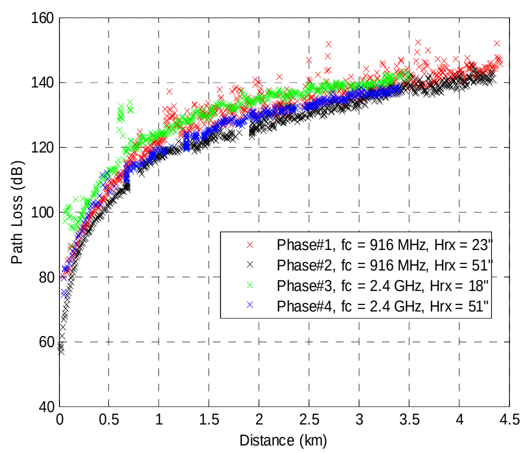

Fig. 2.Normalized path-loss curves for 915 MHz and 2.4 GHz on seawater at varying receiver heights

After some proof of concept simulations were run utilizing HFSS, the design seemed sound and prototyping began. The constructed antenna array was made utilizing copper monopole antennas arranged around a copper ground plane. The parasitic elements were attached to a shorting circuit that consisted of a voltage controlled switch and a milled microstrip circuit on a substrate of FR4 which is shown in Figure 3a. The parasitcs are activated by the voltage controlled switch which shorts the parasitic element to the ground plane by way of a via in the switching circuit.

The switching circuit developed ended up being inadequate for its desired purpose. The length of the circuit was nearly equal to that of the antenna attached to it, which caused the electrical length of the antenna to be greater than desired. Because of this the center frequency was considerably shifted downward and beam-steering did not occur.

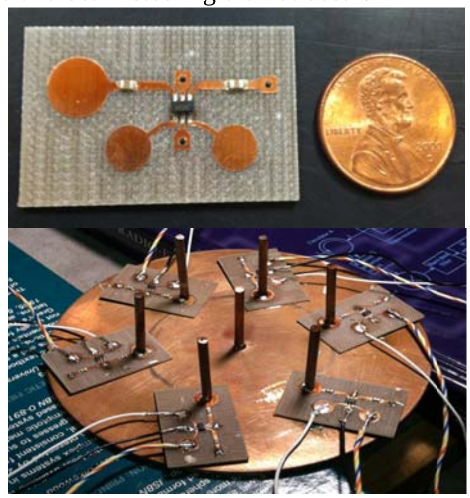

Fig. 3a.Switching circuit (top) Fig. 3b. Complete constructed array (bottom)

The next phase of development would consist of a planar array, based on the same principles of the aforementioned prototype. By utilizing a planar structure the size of the array could be shrunk even more and the issues of insufficient coupling between elements would be easier to resolve. It would also make for a much more stable design, both electrically and structurally.

III. Conclusion

The MTT-S Scholarship Program reinforced my desire to pursue a career in the field of RF/Microwave electronics. The scholarship gave me the opportunity to finish my undergraduate studies and to devote time to research and a focus on RF/Microwave.Attending WAMICON was an exciting experience. I was attracted by the innovation and the promise of further developments in the field as wireless systems become more and more integrated into the everyday lives of people all around the world.

As for my career plans, I am pleased to say that I have found a career in the RF/Microwave industry. I am currently a test engineer with TriQuint Semiconductor Inc., a leader in advanced, high-performance RF solutions. In this position I routinely make use of knowledge and skills that I would not have were it not for the MTT-S Undergraduate Scholarship.

References

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