Chapter 6. Conclusions

A new slow-wave spiral element, the star spiral, has been presented in this dissertation. The use of the star spiral in a wideband array with variable element sizes (WAVES) has also been investigated. This chapter will summarize the results of this thesis, detail the contributions presented in this thesis, and propose future work to enhance the existing research.

6.1 Summary

The previous work related to this dissertation was outlined in Chapter 1. Spiral antennas have been studied for over 50 years. Slow-wave spiral techniques, such as the square spiral and zigzag spiral, have been presented in the literature. Various wideband array techniques have also been investigated for many years. The concept of the WAVES array was first presented by Stutzman (1983) as a feasibility study. Later work showed that a 2-octave planar WAVES array of circular Archimedean spirals was possible, but a gap existed in the 2-octave coverage. The star spiral was developed to eliminate the gap in the WAVES array, but it has many other uses. The star spiral provides almost as much size reduction as the square spiral and provides array packing advantages that the square spiral does not.

Chapter 2 analyzed the circular Archimedean spiral as a means for comparison to the star spiral in later chapters, and also to serve as validation of the simulation tools used throughout this dissertation. The proper feed geometry, strip width to wire ratio, and number of segments per turn were investigated. End loading of the spiral arm to reduce reflections and improve low frequency performance and ground plane effects were examined. A circular Archimedean spiral was built and tested to validate the simulations, provide comparison to the star spiral, and give confidence in later simulations.

The WAVES concept was presented in Chapter 3. Simple 2-octave linear and planar WAVES arrays were presented. Both array structures have a gap in performance between where the first grating lobe appears, while the smaller spiral has satisfactory VSWR performance.

The previous chapters were mostly background and preliminary results. The star spiral element was introduced and analyzed in Chapter 4. The evolution of the star spiral was presented for perspective and a genetic algorithm was used to optimize the star spiral. A star spiral was built and tested for comparison to the circular spiral of Chapter 2. The measurements show that the star spiral gives 18.2% size reduction over the circular Archimedean spiral. Measurements of the square spiral show it to have a 17.5% size reduction when compared to the circular spiral. Also, in terms of increased circumference length, the star spiral achieves 88% efficiency compared to 69% efficiency for the square spiral. The patterns and gain of the star spiral compare very well with the circular spiral. The one disadvantage of the star spiral is its axial ratio performance at the low end of the star spiral operating band. The use of a 4-arm star spiral can greatly improve the axial ratio of the star spiral.

The use of the star spiral in an array environment was examined in Chapter 5. Infinite array analysis was performed to compare the star spiral to the circular Archimedean spiral. The input impedance and scan performance was investigated. The ASIA simulations showed that the unique shape of the star spiral did not significantly affect the scan performance of the array compared to the circular spiral. The use of the star spiral in a 2-octave linear WAVES array was also presented. It was shown that the star spiral eliminates the performance gap observed in the linear array of circular spirals. Also, a 3-octave WAVES array was built and tested for the first time. The measurements showed that the 3-octave WAVES array performed very well and also matched the simulated results well. An initial feasibility study of the scan performance of the 3-octave WAVES array was performed. It was shown that the array scanned satisfactorily for theta scan angles between ±45°. The scan performance will be improved for larger arrays and much work remains to be done in this area. Lastly, a few array geometries were presented to show the possibilities of the unique packing allowed by using the star spiral.

6.2 Contributions

The major contribution of this dissertation is the introduction of the star spiral, which is a unique slow-wave spiral design. The star spiral has an 18.2% measured size reduction, which compares very well with the square spiral. The gain and patterns of the star spiral are similar to the circular Archimedean spiral. Low frequency band axial ratio performance is the main disadvantage of the star spiral, which can be improved by using a 4-arm spiral. The array packing features provided by the star spiral is another advantage of the star spiral over the square spiral.

This dissertation also detailed other contributions. The use of NEC4 to accurately predict spiral input impedance was essential to this research. The operation of the WAVES array was also improved by use of the star spiral. The performance gap in the linear WAVES array of circular Archimedean spirals was eliminated to provide full coverage over more than 2 octaves. Also, a 3-octave WAVES array was built and tested for the first time. The use of the star spiral in the 3-octave array helped to achieve more than 3-octaves of bandwidth. Furthermore, an investigation of the scan performance of the WAVES was investigated for the first time. The initial study shows that the WAVES array can be scanned satisfactorily.

6.3 Future Work

The research presented in this dissertation can be further extended in several areas. The use of the 4-arm spiral or other techniques can be studied to improve the low frequency axial ratio performance of the star spiral. The WAVES array also has some issues that can be further examined. The best way to feed the WAVES array is probably the most important extension of this research. This includes the best way to switch the elements on and off, and also whether or not it is necessary to switch the elements at all. It may be possible to use a blocking capacitor to isolate the spirals when the frequency is out of the spirals active region. A more detailed investigation of the scan performance of the WAVES array is also needed. These improvements of the WAVES array and star spiral would make the WAVES structure an attractive alternative to bulky reflector antenna systems because of its low profile nature.