Electronically Steerable Ultra-Wideband Antenna

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Requirements

- An antenna that is capable of operating in the full L-band (1-2 GHz) domain
- System must have a multi-mission capability
  - Track aircraft
  - Receive GPS coordinates
  - Receive satellite communications
- Use Commercial off the shelf (COTS) Software Defined Radios (SDR) and maximize the flexibility with minimizing the hardware requirements
- Has the ability to be mobile and fit on the roof of a shipping container

Conceptual Line Drawing

The overall design for this communications system is to design an antenna that is capable of receiving multiple communication signals. This antenna design requires the incoming signals to be banded together through a power combiner. After the signals pass through the power combiner the output is a single signal that is then amplified through a low noise amplifier (LNA). The LNA then feeds the signal to a SDR. The SDR sends the information to a computer which through multiple different softwares is able to decode the signal and present the information to the user.

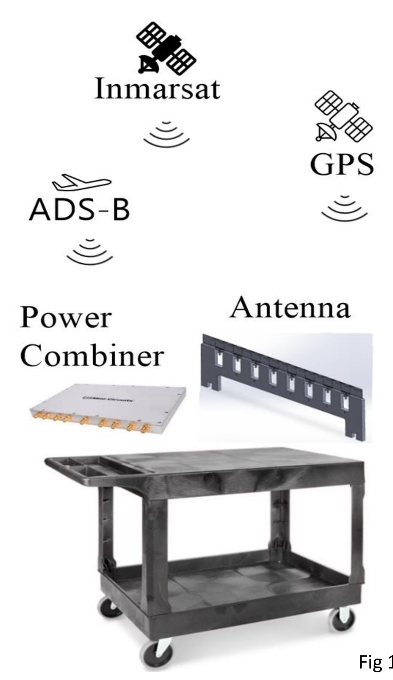


Fig 1

VNA Measurement

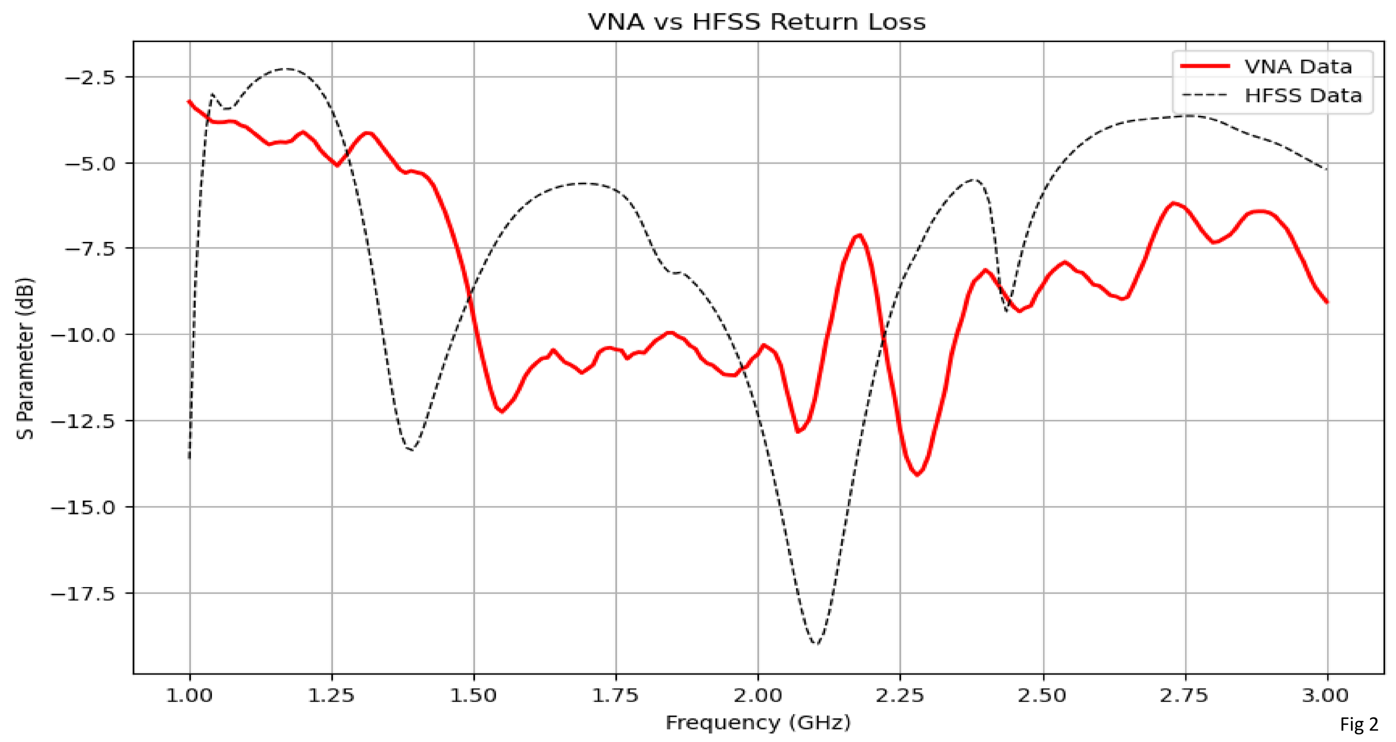
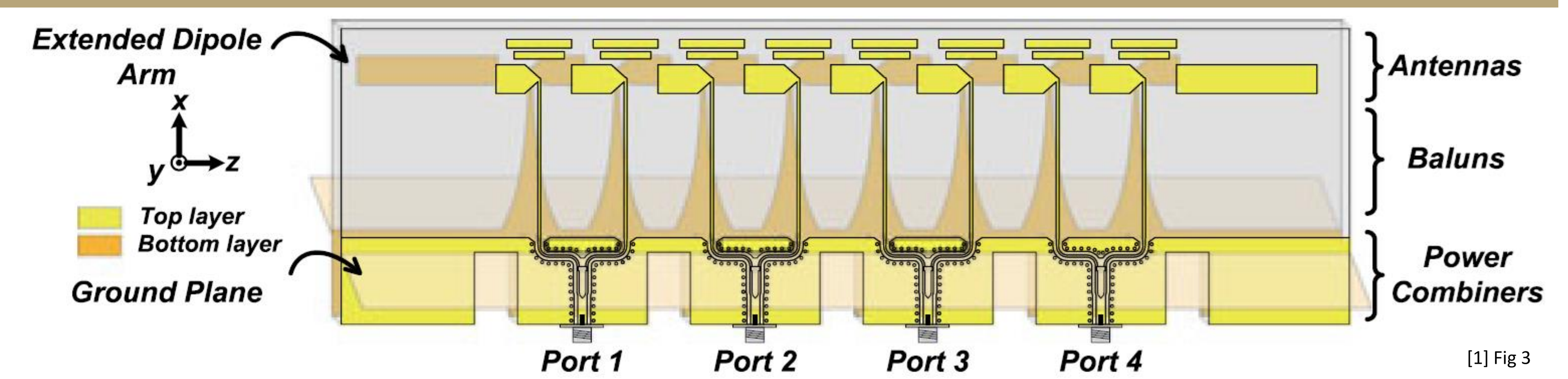


Fig 2

A comparison of the return loss calculated by Ansys Electronics HFSS antenna design software to the real-world return loss determined by a vector network analyzer (VNA).

Return loss demonstrates how well an antenna is able to transmit power from the transmitter to the space or medium its designed to radiate in. Due to antenna reciprocity, this also applies to the amount of power received from a broadcasting antenna accepted by our antenna design. The deeper the dip in the plot into negative dB values, the better.

Tightly Coupled Dipole Array Design



[1] Fig 3

The tightly coupled dipole array (TCDA) antenna above shows the configuration with an eight-element array. After completing gain and loss calculations through a link budget analysis and running simulations in high frequency software simulation (HFSS), the gain of the eight-element array would not be sufficient, therefore we doubled the TCDA design to encompass sixteen elements in a single array.

Sixteen-Element TCDA Antenna Design

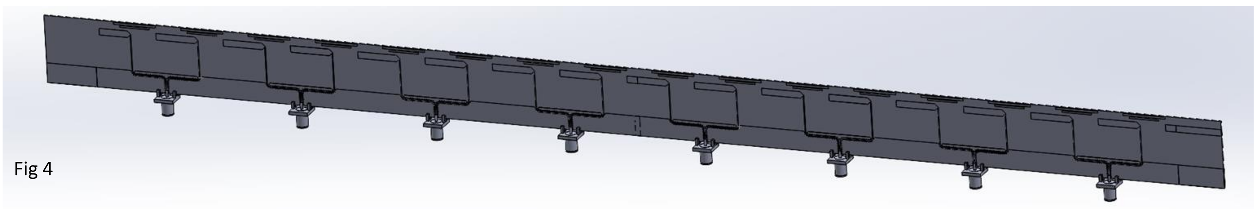


Fig 4

Simulated Radiation Pattern Plots

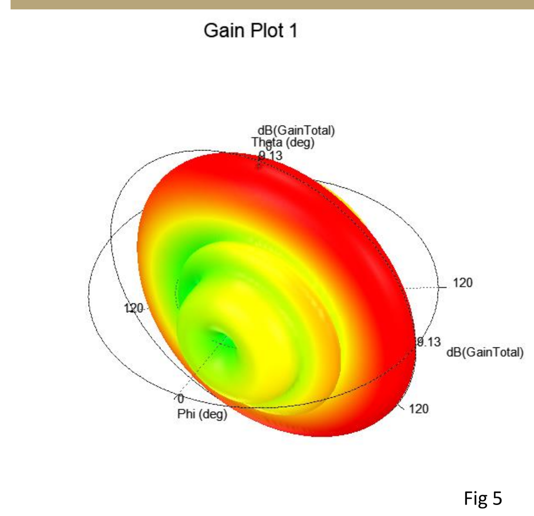


Fig 5

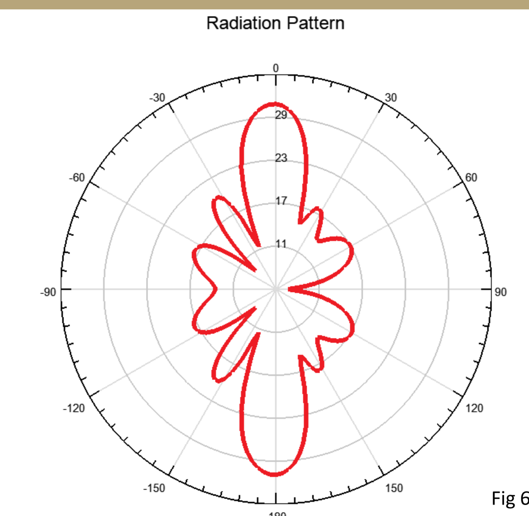


Fig 6

Our gain figures approximately matched what would be expected from a sixteen element TCDA. Gain and beamwidth are generally inversely proportional which is shown in our radiation plot. A narrower broadcast pattern is likely to have a higher gain value which will be needed to connect to satellites at different orbit patterns.

Results / Received Data Evidence

GPS Reception and Position [2]

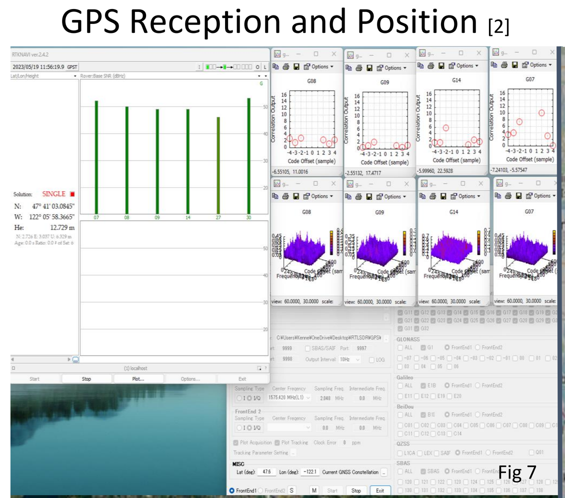


Fig 7

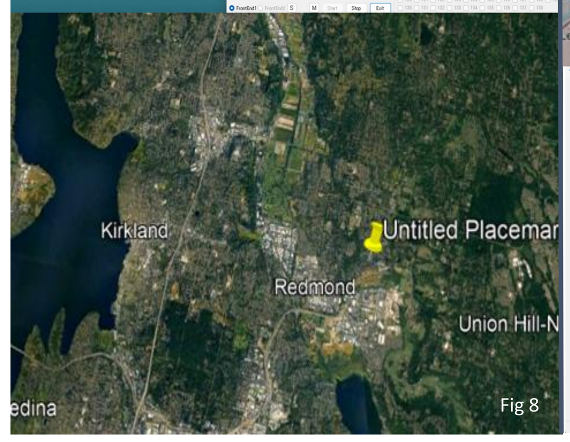


Fig 8

ADS-B Tracking Aircraft [3]

Fig 9

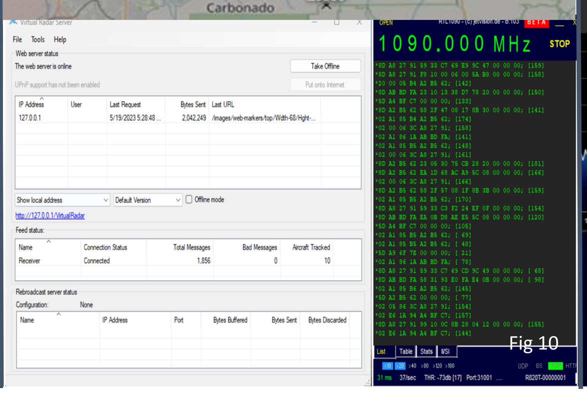


Fig 10

Inmarsat Receiving Messages [4]

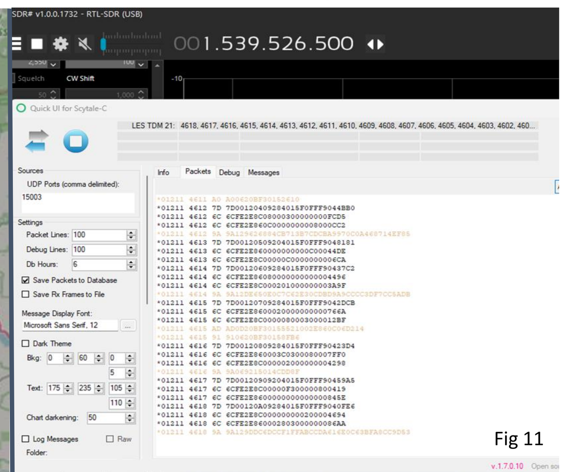


Fig 11

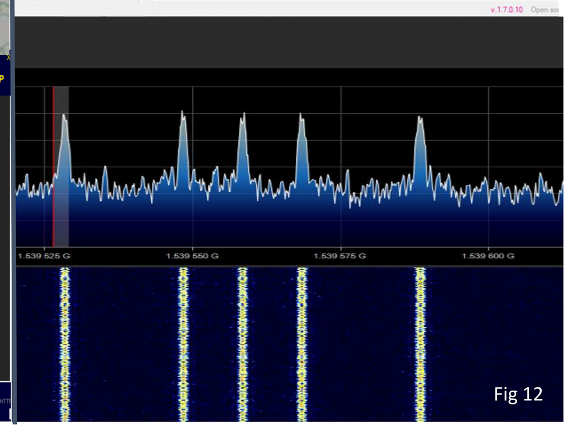


Fig 12

Link Budget

- A link budget accounts for all the power gains and losses that a communication signal will experience from the transmitter to the receiver
- These calculations are performed to ensure the antenna has successful data reception for ADS-B, GPS, and INMARSAT communication

GPS Budget

Frequency	1575.42	MHz
Signal bandwidth	2	MHz
Slant range	20200	km
Calculated path loss	182.4967	dB
Transmitter power	44.8	Watts
Transmitter power	46.51278	dBm
Transmit antenna gain	12	dBi
Receiver antenna gain	9.57	dBi
Cable + system gain/loss	7.50	dB
GPS signal processing gain	43	dB
Received signal power	-81.91	dBm
Calculated noise power in receiver bandwidth	-104.43	dBm
Receiver system noise figure	6.56	dB
Signal to noise power ratio	**22.52**	**dB**
Polarization loss	3	dB

Fig 13

ADS-B Budget

Frequency	1090	MHz
Signal bandwidth	2	MHz
Slant range	20	km
Calculated path loss	119.210895	dB
Transmitter power	25	Watts
Transmitter power	43.9794001	dBm
Transmit antenna gain	1	dBi
Receiver antenna gain	9.57	dBi
Cable + system gain/loss	7.50	dB
Received signal power	-72.16	dBm
Calculated noise power in receiver bandwidth	-98.0397	dBm
Receiver system noise figure	12.95	dB
Signal to noise power ratio	**25.88**	**dB**

Fig 14

Inmarsat Budget

Frequency	1525	MHz
Signal bandwidth	0.004	MHz
Slant range	35,800	km
Calculated path loss	187.1848	dB
Transmitter power	15.85	Watts
Transmitter power	42.00029	dBm
Transmit antenna gain	25	dBi
Receiver antenna gain	9.57	dBi
Cable + system gain/loss	7.50	dB
Received signal power	-121.11	dBm
Calculated noise power in receiver bandwidth	-131.419	dBm
Receiver system noise figure	6.56	dB
Signal to noise power ratio	**10.30**	**dB**
Polarization loss	3	dB

Fig 15

Future Work and Improvements

- For this project we were focusing on frequencies in the L-Band region (1 - 2 GHz). In future designs the shift will be focused on S-Band (2 - 4 GHz) frequencies for communications and tracking of vehicles.

- The upgraded design is to incorporate multiple antennas to create a communications plane. Then install vector steering modulators to be able to incorporate beam steering.

Fig 16

- The computer, radio(s), and all other supporting equipment shall be installed inside a shipping container with the antennas on the roof. This will allow for the communications unit to move together as a whole and be deliverable to any location around the world.

References and Acknowledgements

List of Figures

Work Cited

[1] Y. Wang, L. Zhu, H. Wang, Y. Luo, and G. Yang, "A compact, scanning tightly coupled dipole array with parasitic strips for next-generation wireless applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 17, no. 4, pp. 534–537, 2018. doi:10.1109/lawp.2018.2798660

[2] W. by admin and W. by, "SDR tutorial: GPS decoding and plotting," rtl, https://www.rtl-sdr.com/rtl-sdr-tutorial-gps-decoding-plotting/ (accessed May 21, 2023).

[3] W. by admin and W. by, "SDR tutorial: Cheap ADS-B aircraft radar," rtl, https://www.rtl-sdr.com/adsb-aircraft-radar-with-rtl-sdr/ (accessed May 21, 2023).

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