Technical Exhibit
Amendment to Pending Experimental FCC License Application
Virginia Tech Eclipse Experiment

The electrical engineering department at Virginia Tech is seeking an FCC experimental license to perform fundamental ionospheric research that will require transmitting low-power pulses within a carrier frequency band spanning 2-25 MHz (excluding prohibited bands, e.g., standard frequency and timing signal). This exhibit describes the experimental program objectives, as well as the methods and instrumentation to be used. The research project for which this license is sought has been funded by the National Science Foundation under grant number AGS-1552188.

Project Description

The experiment involves fundamental ionospheric research related to the total solar eclipse that will be visible over most of the United States on 21 August 2017. The total duration over which eclipse effects on the ionosphere will be measureable over the USA is approximately two hours, spanning the midday range from 16:00-18:00 UT. The ionosphere is a variable medium that exerts strong control over radio propagation in the high-frequency (HF) band, so data and vertical soundings obtained in this band are useful for characterizing temporal changes in the medium during the eclipse. Findings from the study are relevant to HF communications reliability, and to space-weather effects in the ionosphere at mid-latitudes. Results from the experiment will be published in the refereed scientific literature.

The focus of the project is to determine the effects of the eclipse on the Earth's ionosphere using HF signals transmitted from four field sites distributed along the eclipse path between Oregon and South Carolina. The transceivers used at these four field sites will use HF antennas coupled to low-power software defined radios (SDRs). The transmitted signals will use standard pulse compression techniques and coherent detection to minimize the required transmitter power, in order to reduce interference with other systems. Prior to deployment of the field sites we will test and operate the systems in Blacksburg, Virginia to verify our algorithms and the performance of the systems.

In addition to the HF data for which we seek an experimental license, there are other aspects to the experiment that will enrich our findings when coupled with the HF findings. In all cases these additional data sources are either already licensed, or are receivers that require no licensing. The supplementary data sources include:

1. Two low-power coherent-scatter radars located in Kansas and Oregon (part of the SuperDARN HF radar network, FCC licensed, federally funded by the NSF);
2. A nationwide network of GPS receivers known in the science community as Continuously Operating Reference Stations (CORS, federally funded by NOAA);
3. A suite of satellite beacon receivers deployed to the north of the eclipse line to monitor scintillation of beacon signals that propagate through the eclipsed ionosphere (federally funded by NASA through the Virginia Space Grant Consortium);
4. The reverse beacon network archive within the amateur radio (ham) community.

Facilities and Specific Operational Information
There is no network of identical transceivers and antennas located at four sites distributed along the eclipse's umbra line, so there are no existing facilities that can be used to carry out our study. In addition, there is only one scientific ionosonde located in the umbra region of the eclipse (near Bear Lake, Utah). For this reason we seek an FCC experimental license to field these stations and operate them as described herein.

Table 1 shows the locations of the four HF transceivers to be deployed for the experiment, and for prior testing at the Blacksburg, VA site. Throughout the eclipse interval we will operate these stations so that they periodically measure vertical-incidence backscatter from the ionosphere over the frequency range of interest. For one week prior to the eclipse date we will operate the sites in the same way over the same time period (midday) in order to obtain baseline data for later comparison. This will allow us to determine how the plasma in the ionosphere (D, E, and F-regions) responds to varying solar radiation throughout the eclipse. More specifically, these measurements will reveal the structure of the bottom-side of the daytime ionosphere, and how it changes over time during the ~2 hour duration of the eclipse.

***Table 1** – Transceiver field station data (note "AFB" = Air Force Base).*

Site ID	Location	Antenna	Power	Usage Note
VA	Blacksburg 37.231° N 80.416° W	Crossed Dipole (< 30 m dia.)	<100 W Non-interference basis	Site used for testing and validation prior to and during the eclipse on 21 August 2017.
OR	Sisters 44.362° N 121.560° W	Crossed Dipole (< 30 m dia.)	<100 W Non-interference basis	Site operational only between 14-23 August, 2017.
KS	Holton 39.474° N 95.771° W	Crossed Dipole (< 30 m dia.)	<100 W Non-interference basis	Site operational only between 14-23 August, 2017.
IL	Scott AFB 38.541° N 89.827° W	Crossed Dipole (< 30 m dia.)	<100 W Non-interference basis	Site operational only between 14-23 August, 2017.
SC	Shaw AFB 33.990° N 80.460° W	Crossed Dipole (< 30 m dia.)	<100 W Non-interference basis	Site operational only between 14-23 August, 2017.

Only the Blacksburg VA site (shown in Table 1) will be used over a multi-month period. The other four sites will operate only in the 14-23 August period in 2017, coincident with the eclipse event, and prior to it by ~1 week. The station in Blacksburg VA requires a longer period of operation to allow time for testing and validation of system performance prior to the eclipse experiment. All field sites listed in the table will utilize lower power pulsed transmissions coded to minimize interference with other radio sources. All sites will be operated on a non-interference basis.

The transceivers will be computer controlled, but a licensed amateur radio operator will monitor the operations and data flow at each field site to assure compliance with all federal and local regulations. The antennas and transceivers will be identical at each location in order to ensure that the performance of each field site will be as similar as possible. Aside from the VA location the transceivers will be set up approximately one week prior to the eclipse. They will be tested periodically during the week, and will run continuously during the eclipse and for about 12 hours after it ends. This will provide baseline data for comparison with existing models, as well as independent datasets that can be compared to each other.

Applicable Regulations

The requested frequencies and operational transmission parameters are those permitted under Section 90.266 of the FCC rules: Long Distance Communications on Frequencies below 25 MHz. The permitted operational parameters are identified specifically in the FCC's Electronic Code of Federal Regulations, Title 47 (Telecommunication), Volume 1, Chapter 1, Part 2.106: Table of Frequency Allocations. The frequency bands requested are designed to avoid the Restricted Bands of Operation stipulations described in the Electronic Code of Federal Regulations, Title 47 (Telecommunications), Part 15 (Radio Frequency Devices), Subpart C (Intentional Radiators).

Antenna and Transceiver Specifications

Table 2 lists the specific parameters of our antenna and transceiver systems.

Table 2

System or Parameter	Specifications and Relevant Parameters
Transceiver (Tx)	Ettus USRP N210 Software Defined Radio (SDR) Red Pitaya STEMlab 125-14 SDR system FlexRadio Systems 6300 (Note: Only one of these systems will be used at any given time, but separate experiments may be carried out with each system over periods of a few days.)
Requested Frequency Range	2-25 MHz carrier with 600 kHz modulation bandwidth, operated on a non-interference basis
Maximum Tx Power	100 W maximum – systems will be operated at the lowest power level possible to ensure adequate signal to noise ratios.
Maximum Bandwidth	600 kHz modulation on short carrier wave pulses
Maximum Transmit Duration (duty cycle)	Testing Phase: Intermittent at 100%, Effective duty cycle < 10% During Eclipse: 100% over 5 hour interval centered on eclipse
Signal Specification	Pseudo-random noise (PRN) coded continuous wave
Transmitting Antenna	MITRE-developed Crossed Dipole (inverted-V dipoles with resistive loading)

The inverted V dipole is comprised of two sets of wires arranged in a triangular shape to form a classical bow-tie antenna, as shown in Figures 1-3. This triangle provides more radiating surface area which increases the radiation resistance, allowing for easier impedance matching. It increases the bandwidth as compared to a simple straight wire dipole. Each inverted V dipole provides horizontal polarization, and the two dipoles are orthogonal to each other.

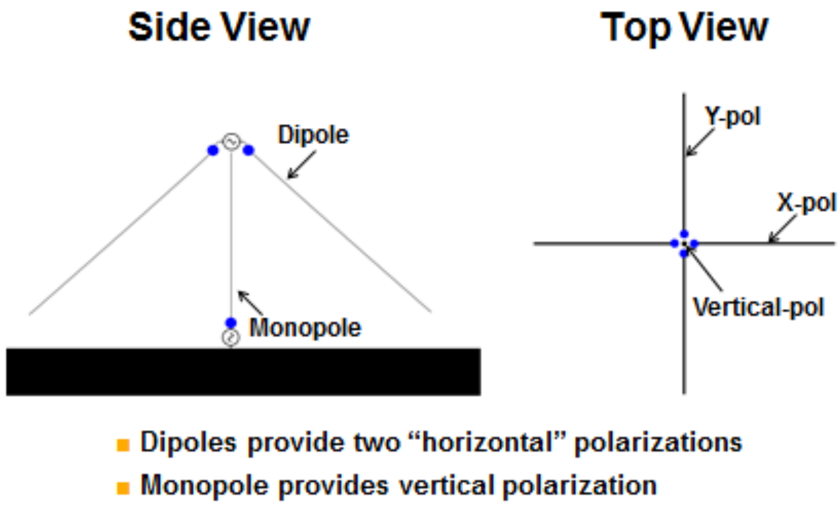

Figure 1 – Side view (left) and top view (right) of the interted-V antenna elements.

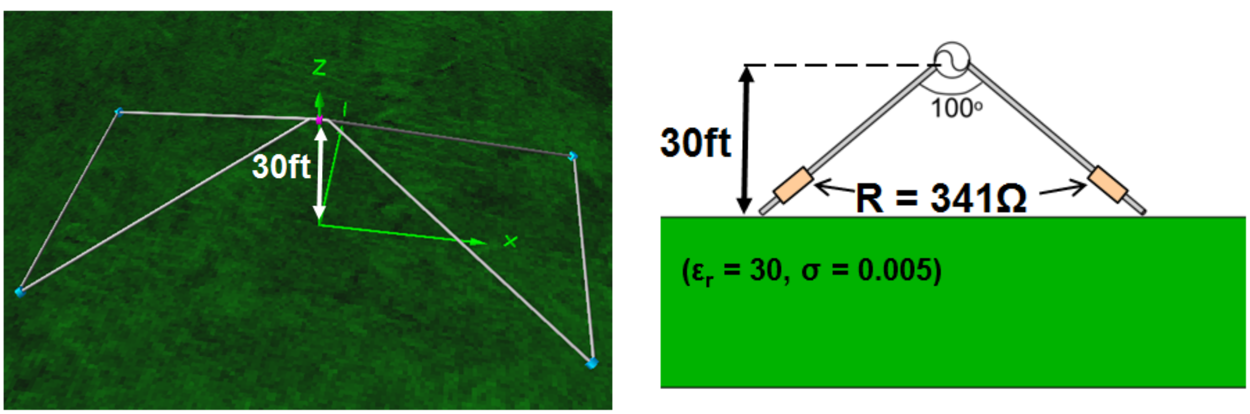

Figure 2 – Model rendering of the inverted-V dipole mounted on a 30-foot vertical center mast (left). The right panel shows the location and size of the in-line resistive loads, which improve the impedance matching over the low frequency side of our operating range.

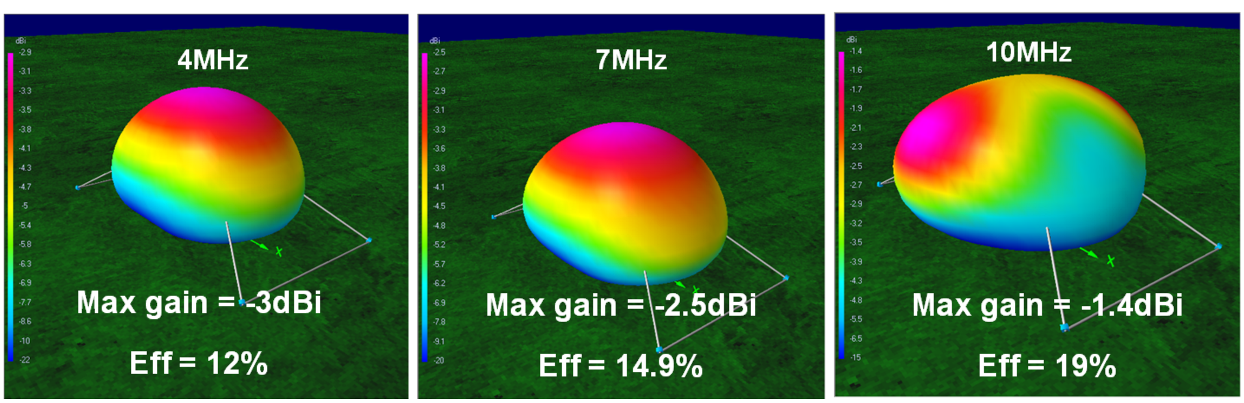

Figure 3 - Radiation patterns of the inverted-V bow-tie dipole at f = 4, 7, and 10MHz, showing the maximum gain and radiation efficiency values at each frequency.

Contact Information

The principal points of contact for the research project for which we seek licensing may be contacted at any time for questions relating to this license application.

Professor Gregory D. Earle
Virginia Tech – Space Sytems Bldg.
1901 Innovation Drive
Blacksburg, VA 24061

earle@vt.edu
Cell: 972-809-6479
Office: 540-231-2294

Lee Kordella
Virginia Tech – Space Systems Bldg.
1901 Innovation Drive
Blacksburg, VA 24061

lee8@vt.edu
Cell: 703-477-2306