



TECHNICAL EXHIBIT  
AMENDMENT TO PENDING EXPERIMENTAL FCC LICENSE APPLICATION  
The MITRE Corporation

The MITRE Corporation is seeking an FCC Experimental License to transmit data within the High Frequency (“HF”) band between 2 MHz and 16 MHz. This Exhibit describes the program of research and experimentation proposed, including: description of equipment and theory of operation; the specific objectives sought to be accomplished; and how the program of experimentation has a reasonable promise of contribution to the development, extension, expansion or utilization of the radio art and/or is along lines not already investigated.

*Research and Experimentation Program Description*

Assured beyond line-of-sight (BLOS) communications is a challenging problem yet essential for our warfighters. Military and civilian systems rely on a combination of high data rate satellite connectivity as well as low data rate HF Sky Wave communications. While satellite communication provides high data rate connectivity, there are vulnerabilities that include degradation and disruption of service. HF radio communication generally are limited to narrower bandwidths and lower data rates than satellite communications. To ensure critical communications are maintained, we are investigating the capability of higher bandwidth and higher data rate communications in the HF band applying polarization diversity MIMO concepts.

Long distance HF communication is accomplished via reflection of HF radio waves off the ionosphere, a variable medium. This introduces challenges that must be overcome in order to make HF communications more reliable. These include multipath propagation and polarization rotation; both contribute to signal fades.

We will demonstrate reliable BLOS HF communications at high data rates.

*Objectives*

The goal is to communicate reliably at a rate of 1-4 bits/Hz/s. We will develop a 100-kHz bandwidth waveform to achieve ~ 256 kbps with forward error correction (FEC) coding. Mitigation of signal fading and improved throughput will be accomplished using polarization diversity techniques and orthogonal coded waveform designs. Future year goals include investigating small antennas for mobility applications.

The research program is planned to include a series of over-the-air (OTA) MIMO demonstrations, each testing new waveforms. We will attempt to test whether we can use both X and O modes to carry independent communications channels and then determine the carrying capability of each at different bandwidths. A stretch goal is to extend to wider bandwidth waveforms, up to 1 MHz. (Researchers’ note: we understand that this wideband waveform may run up against other users and possibly cause interference. We plan to transmit at as low a power

as possible and on a not-to-interfere basis. Please see red-highlighted text in Table (1a) ). We will also perform ionospheric sounding for channel characterization.

The requested frequencies and transmission operational parameters are those permitted under Section 90.266 of the Commission's Rules, *Long Distance Communications on Frequencies below 25 MHz* and 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. These frequencies bands requested are designed to avoid the Restricted Bands of Operation outlines in the Electronic Code of Federal Regulations, Title 47 (Telecommunication), Part 15 (Radio Frequency Devices), Subpart C Intentional Radiators.

Listed in the following Tables (1a) and (1b) are the requested proposed technical parameters for the experimental research program.

<b>Crossed Dipole (Signal) Transmit Antenna</b>	
Transmitter Site Locations	<b>Transmitter Site #1</b> The MITRE Corporation 202 Burlington Road, Bedford, MA 01730 42-30-11.6N, 71-14-14.3W Crossed Dipole Antenna Radiation Center: 25 ft AGL Crossed Dipole (signal) Transmit Antenna Azimuth Orientation: omnidirectional Crossed Dipole (signal) Transmit Antenna Vertical Plane Orientation: N/A
	<b>Transmitter Site #2</b> 16-30 Einhorn Road, Worcester, MA 01609 42-16-19.9N, 71-48-38.2W Antenna Configuration same as Transmitter Site # 1
	<b>Transmitter Site #3</b> Gateway Park, Worcester, MA 01609 42-16-28.6N, 71-47-55.3W Antenna Configuration same as Transmitter Site # 1
	<b>Transmitter Site #4</b> 5251 Burleson Road, Oneida, NY 13421 43-01-55.5N, 75-39-10.2W Antenna Configuration same as Transmitter Site # 1
	<b>Transmitter Site #5</b> 525 Brooks Road, Rome, NY 13441 43-13-20.8N, 75-24-32.7W Antenna Configuration same as Transmitter Site # 1
Requested Frequency ranges (kHz)	2500.0 - 4100.0, 4210.0 - 6210.0, 6320.0 - 8250.0, 8450.0 - 12200.0, 13500.0 - 16000.0 (Daytime: 5-14 MHz using only groupings above) (Nighttime: 3-7 MHz using only groupings above)
Maximum Transmit Power	200 Watts (average varies between 50 and 200 Watts)
Transmitter	Ettus USRP N210 Software Defined Radio
Transmitting Antenna	<b>MITRE-built Crossed-Dipole</b> (see Figure 1a) Broadband bow-tie shaped, inverted vee-dipoles with resistive loading Small Footprint (< 30 meter diameter)  Dipoles are arranged orthogonally on mast to produce x-y- polarizations
Maximum Occupied Bandwidth	1 MHz (vary from 100 kHz up to 1 MHz) <b>** 1 MHz is a stretch goal and will be done on a not-to-intefere basis. Most work will be done around 100-300 kHz.</b>
Maximum Transmit Time Duration (Duty)	Experiments may run for 24 hours once a month, shorter times a few days a month (hours). Duty cycle is 100% during experiments.

**Table 1a. Proposed Experimental Crossed-Dipole Transmission Parameters**

Please note that, while there are 5 possible transmit locations listed in Table (1a) above, only three will be used at any given time. Transmitter sites 2 and 5 serve as back-up sites. Our team performed the SLOPE test for each site (1 through 5) and every site passed without needing to register the antenna. Documentation on the Slope Test can be provided if needed.

The MITRE-developed Crossed-Dipole antenna configuration and dimensions are shown in Figure 1a below.

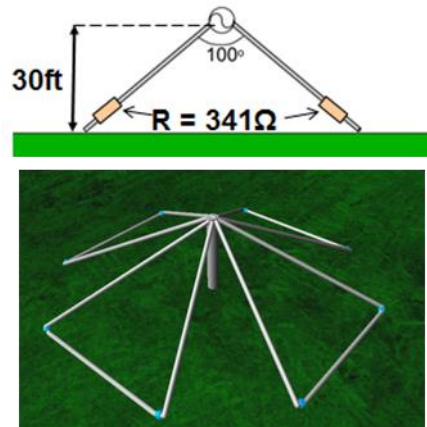


Figure 1a. Model Crossed Dipole Antenna (< 30m diameter)

<b>Monocone (Sounder) Transmit Antenna</b>	
Transmitter Site Locations	<b>Transmitter Site #1</b>
	The MITRE Corporation
	202 Burlington Road, Bedford, MA 01730
	42-30-11.6N, 71-14-14.3W
	Monocone Antenna Radiation Center: 0 ft AGL
	Monocone (sounding) Transmit Antenna Azimuth Orientation: omnidirectional
	Monocone (sounding) Transmit Antenna Vertical Plane Orientation: N/A
	<b>Transmitter Site #2</b>
	16-30 Einhorn Road, Worcester, MA 01609
	42-16-19.9N, 71-48-38.2W
	Antenna Configuration same as Transmitter Site # 1
	<b>Transmitter Site #3</b>
	Gateway Park, Worcester, MA 01609
	42-16-28.6N, 71-47-55.3W
	Antenna Configuration same as Transmitter Site # 1
	<b>Transmitter Site #4</b>
	5251 Burleson Road, Oneida, NY 13421
	43-01-55.5N, 75-39-10.2W
	Antenna Configuration same as Transmitter Site # 1
	<b>Transmitter Site #5</b>
	525 Brooks Road, Rome, NY 13441
	43-13-20.8N, 75-24-32.7W
	Antenna Configuration same as Transmitter Site # 1
Requested Frequency Range (kHz)	2500 - 16000
Maximum Transmit Power	10 Watts
Transmitter	Ettus USRP N210 Software Defined Radio
Transmitting Antenna	<b>MITRE-built Monocone</b> (see Figure 1b)
	Broadband monocone antenna with low-loww matching network
	Uses 15-meter-long radial wires
	Small Footprint (< 30 meter-diameter radial wires)
Maximum Occupied Bandwidth	5 kHz
Maximum Transmit Time Duration (Duty)	During the experiments referenced in Table 1a, the sounder will send a repeating 5-kHz-wide chirp waveform that scans the entire 2.5-16 MHz frequency band continuously during a 24 hour period (or several hours for shorter experiments). As described in Table 1a, the 24-hour experiments will occur about once per month, shorter times a few days a month (hours).

**Table 1b. Proposed Experimental Monocone Transmission Parameters**

The MITRE-developed Monocone antenna configuration and dimensions are shown in Figure 1b below.

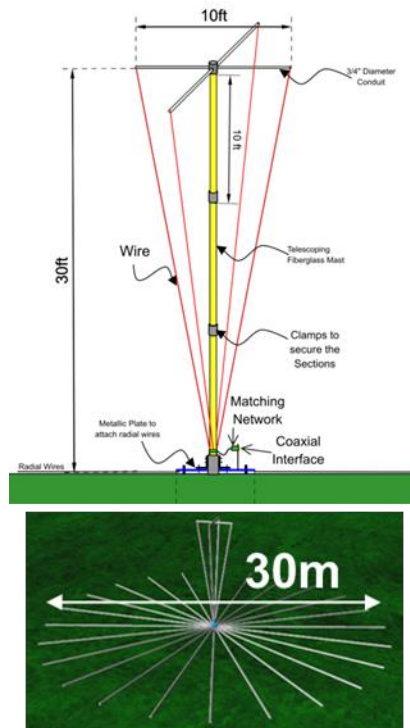


Figure 1b. Model Monocone Antenna (note top and bottom parts of figure are not to scale with one another).

The model of the fully integrated experimental system is shown in Figure 2, with wires highlighted. The system supports three orthogonal polarizations: two inverted vee-dipoles (x-, y-polarized), and one vertical monocone (z-polarized). The antenna elements are well matched over 4-10 MHz to 50 ohms and offset to avoid mutual coupling effects. The antennas exhibit omnidirectional antenna patterns with an antenna gain of  $> -7$  dBi at 4 MHz and  $> 0$  dBi above 7 MHz. The system is simple, low-cost and MITRE-fabricated, -assembled, and -setup.

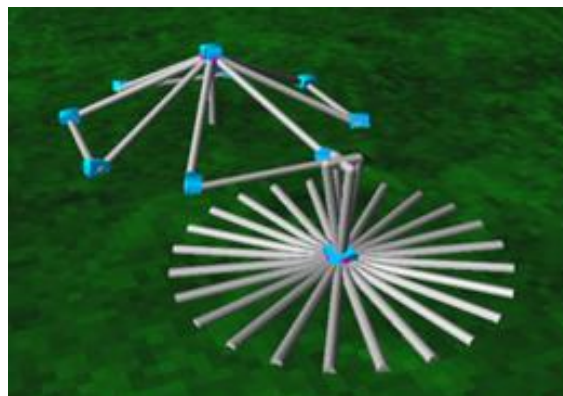


Figure 2. Model of fully integrated experimental system, wires highlighted.

Figure 3 shows a picture of the fully integrated antenna system; wires are highlighted so they are visible.

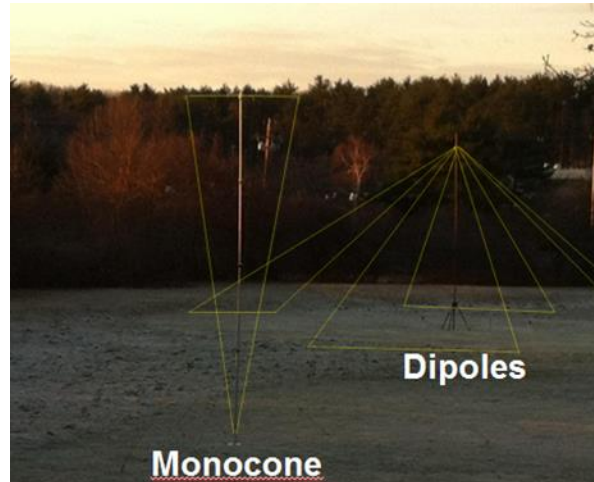


Figure 3. Picture of fully integrated experimental system, wires highlighted for visibility.

While MITRE fabricated the antennas and designed the transmit and receive systems, some of the equipment was purchased from commercial vendors. Figure 4 shows a wiring diagram of the transmission system and the Table 2 that follows lists the commercially purchased equipment that will be used during the experiment(s).

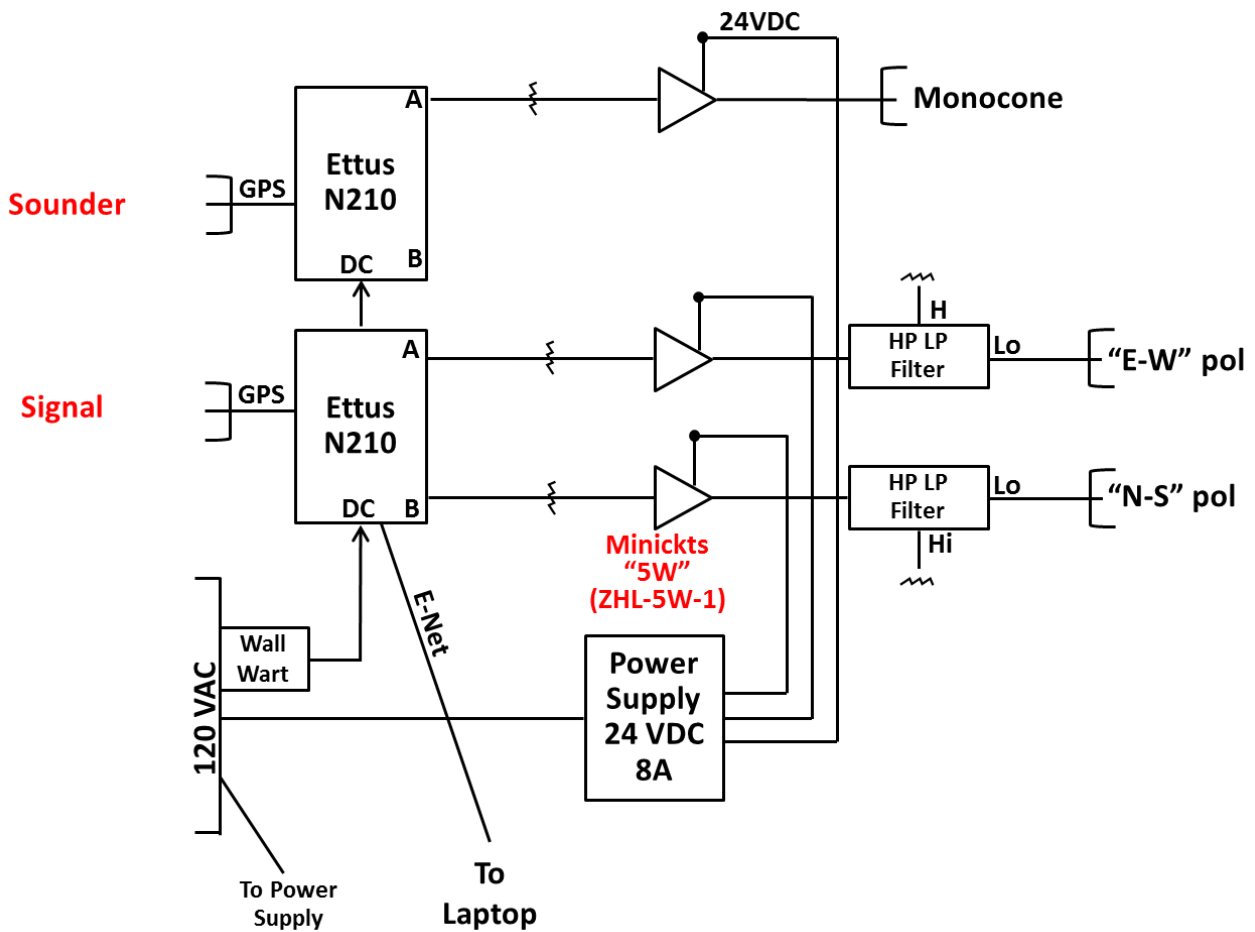


Figure 4. Transmission equipment wiring diagram.

Table 2. Commercially purchased transmission equipment list.

Transmitting Equipment			
Manufacturer	Model Number	No. of Units	Experimental (Y/N)
Ettus USRP	N210	9 (3 sites x 3 radios)	N
Mini Circuits 15542	ZHL-5W-1	9 (3 sites x 3 radios)	N
BAE Australia	TBD - 50 W	up to 12 (3 sites x MAX 200W per site)	N

*Research and Experimentation Contribution to the Development of the Radio Art*

Assured beyond line-of-sight communications is a challenging problem yet essential for certain types of communication. Fortunately, HF technology is uniquely suited to address this problem,



applying new techniques and understanding of the ionosphere. With HF, BLOS communications is achievable without the use of satellites or psuedo-lites. The traditionally low data rates can be improved upon as well. In today's economic climate, HF is very affordable, with a well-established commercial market.

MITRE's work will demonstrate a new approach to addressing critical communications capability shortfalls through the application of polarization diversity and advanced orthogonal coding designs.

If there are any technical questions with the proposed application please contact one of the undersigned.

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