



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

The MITRE Corporation is seeking to modify an existing FCC Experimental License to transmit data within the High Frequency ("HF") band between 2.5 MHz and 28 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 have developed 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 continue to demonstrate and 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. We are requesting frequencies up to 28 MHz at the FCC's discretion and guidance.

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

Crossed Dipole (Signal) Transmit Antenna	
Transmitter Site Locations	Transmitter Site #1
	The MITRE Corporation
	202 Burlington Road, Bedford, MA 01730
	42-30-11.6N, 71-14-13.3W
	Crossed Dipole Antenna Radiation Center: 9.1 m AGL
	Crossed Dipole (signal) Transmit Antenna Azimuth Orientation: omnidirectional
	Crossed Dipole (signal) Transmit Antenna Vertical Plane Orientation: 90 degrees (120 Deg beamwidth)
	Transmitter Site #2
	1501 Channingway Drive, Fairborn, OH, 45324
	39-47-27.3N, 83-59-58.3W
	Crossed Dipole Antenna Radiation Center: 10.6 meters AGL (4.6 m building + 6 m antenna mast)
	Transmitter Site #3
	1155 Academy Park Loop, Colorado Springs, CO, 80910
	38-48-59N, 104-45-38W
	Crossed Dipole Antenna Radiation Center: 10.6 meters AGL (4.6 m building + 6 m antenna mast)
	Transmitter Site #4
	5251 Burleson Road, Oneida, NY 13421
	43-01-45.3N, 75-39-4.1W
	Antenna Configuration same as Transmitter Site # 1
	Transmitter Site #5
	7515 Colshire Drive, McLean, VA, 22102
	38-55-25N, 77-12-21W
	Crossed Dipole Antenna Radiation Center: 51.8 meters AGL (45.8 m building + 6 m antenna mast)
Requested Frequency ranges (kHz)	2505.0 - 4100.0, 4210.0 - 4995.0, 5005.0 - 6210.0, 6320.0 - 8250.0, 8450.0 - 9995.0, 10005.0 - 12200.0, 13500.0 - 14990.0, 15010.0 - 16000.0, 16000.0 - 19995.0, 20005 - 28000.0
Maximum Transmit Power	200 Watts (average varies between 20 and 200 Watts)
Transmitter	Ettus USRP N210 Software Defined Radio
Transmitting Antenna	MITRE-built Crossed-Dipole (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 (typically vary from 50 kHz up to 400 kHz) ** 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.
Maximum Transmit Time Duration (Duty)	Experiments may run for 24 hours several times per month, shorter times up to half time during a month (hours). Duty cycle is up to 100% during experiments.

Table 1a. Proposed Experimental Crossed-Dipole Transmission Parameters

There are five requested transmit locations listed in Table (1a) above, two of which (Transmitter Sites 1 and 4) are part of the current FCC license 0162-EX-PL-2014 that was recently submitted for renewal. There are three new sites requested for authorization, Transmitter sites 2,3, and 5. Our team performed the obstruction evaluation test required by the FAA. Those analyses are in process. The FAA Obstruction Evaluation team assigns Aeronautical Study Numbers to each individual case, the active case numbers are as follows:

Transmitter Site 1 ASN = 2016-ANE-3398-OE (Bedford, MA)

Transmitter Site 2 ASN = 2016-AGL-12038-OE (Fairborn, OH)

Transmitter Site 3 ASN = 2016-ANM-2667-OE (Colorado Springs, CO)

Transmitter Site 4 ASN = 2016-AEA-8029-OE (Oneida, NY)

Transmitter Site 5 ASN = 2016-AEA-8030-OE (McLean, VA)

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

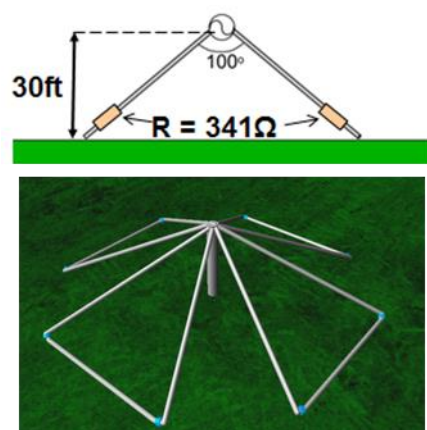


Figure 1a. Model Crossed Dipole Antenna (< 30m diameter)

The system supports two orthogonal polarizations: two inverted vee-dipoles (x-, y-polarized). The antenna elements are well matched over 6-11 MHz to 50 ohms and offset to avoid mutual coupling effects. The antennas exhibit omnidirectional antenna patterns with an antenna gain of 2 dBi between 2.5 and 28 MHz. The system is simple, low-cost and MITRE-fabricated, -assembled, and -setup.

While MITRE fabricated the antennas and designed the transmit and receive systems, some of the equipment was purchased from commercial vendors. Table 2 shows a list of the commercially purchased equipment that will be used during the experiment(s).

Table 2. Commercially purchased transmission equipment list.

Transmitting Equipment			
Manufacturer	Model Number	No. of Units	Experimental (Y/N)
Ettus USRP	N210	10 (5 sites x 2 radios)	N
AR Modular RF Amplifiers	KMA2040M22	10 (5 sites x 2 radios)	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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