MITRE

TECHNICAL EXHIBIT
AMENDMENT TO PENDING EXPERIMENTAL FCC Special Temporary Authority (STA) APPLICATION
The MITRE Corporation

The MITRE Corporation is seeking an FCC Special Temporary Authority License to transmit data within the High Frequency ("HF") band between 6 MHz and 11 MHz from two locations in Alaska from 20-24 June 2016. USNORTHCOM is conducting a test between these two locations and have asked the MITRE team conducting advanced beyond line of sight (BLOS) High Frequency (HF) communications to be part of the test. As such, we will need transmit authority for those 5 days in that location.

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 test several waveforms we have developed ranging from 10 to 400-kHz bandwidth to achieve ~ 256 kbps with forward error correction (FEC) coding. We may test waveforms out to 1 MHz bandwidth. Mitigation of signal fading and improved throughput will be accomplished using polarization diversity techniques and orthogonal coded waveform designs.

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

Crossed Dipole (Signal) Transmit Antenna	
Transmitter Site Locations	**Transmitter Site #1**
	ALCOM J6 Headquarters
	19th Street, Joint Base Elmendorf-Richardson, Alaska
	61-14-39N, 149-48-40W
	Crossed Dipole Antenna Radiation Center: 20 ft AGL
	Crossed Dipole (signal) Transmit Antenna Azimuth Orientation: omnidirectional
	Crossed Dipole (signal) Transmit Antenna Vertical Plane Orientation: N/A
	Transmitter Site #2
	1879 Momeganna Street
	Barrow, Alaska
	71-17-27N, 156-46-54W
	Antenna Configuration same as Transmitter Site # 1
Requested Frequency ranges (kHz)	6000.00- 6210.0, 6320.0 - 8250.0, 8450.0 - 9995.0, 10005.0 - 11000.0
Maximum Transmit Power	200 Watts (average varies between 50 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 (< 20 meter diameter)
	Dipoles are arranged orthogonally on mast to produce x-,y- polarizations
Maximum Occupied Bandwidth	1 MHz (vary from 10 kHz up to 1 MHz) ** 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)	Most Experiment will be conduted during the daytime hours during the 5 day period. There may be some nighttime collection. Duty cycle will be up to 100 % during the 5 days.

Table 1a. Proposed Experimental Crossed-Dipole Transmission Parameters

Our team performed the SLOPE test for both sites (1 and 2) 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. Please note that the actual height of the antenna is 20 feet, not 30 feet as shown in the diagram.

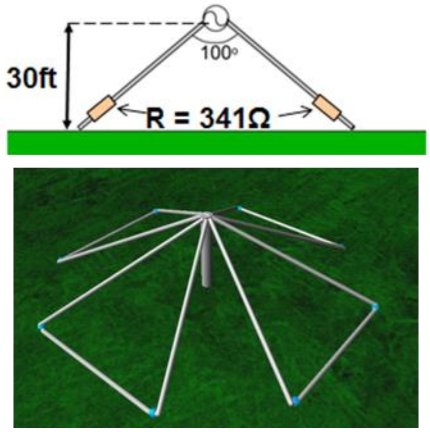

Figure 1a. Model Crossed Dipole Antenna (< 20m diameter)

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 6 and 11 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	4 (2 sites x 2 radios)	N
AR Modular RF Amplifiers	KMA2040M22	4 (2 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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