Applied Communication Sciences
RADICAL Project
Principal Investigator: Ted K. Woodward
Rm 2Z-475
331 Newman Springs Rd.
Red Bank, NJ 07701-5699
twoodward@appcomsci.com

Alternate contact: Eric C. Beck
Room 2Z-457
ebeck@appcomsci.com

Justification for FCC Experimental License Application

Introduction

Applied Communication Sciences (TTGS)[1] seeks an experimental radio license to advance the art of radio communication by employing MIMO[2] techniques to line of sight millimeter wave radio links. The ultimate goal of this work is to attain high data rate communications of up to 100 Gb/s throughput.

Data rates of this magnitude stress current radio technology in several areas: bandwidth, peak to average power ratio, modulation efficiency (bits/Hz), high speed data conversion (e.g. digital to analog and analog to digital conversion), and high speed digital signal processing to mention but a few.

The technology promises improved resilience to weather induced outages due to fog, snow, drizzle and light rain as compared to free space optical techniques.

Towards this goal, Applied Communication Sciences received DARPA contract HR0011-13-C-0079 to demonstrate a line of sight MIMO radio link.

The technical goals of the contract can be found in Phase 1, Technical Area 2 (Section 1.1.1.2) of the100 Gb/s RF Backbone solicitation (DARPA-BAA-13-15). This document is available online at FedBizOps, URL:

https://www.fbo.gov/?s=opportunity&mode=form&id=732a6bb9dd43e12a7a2906adab84b28e&tab=core&_cview=0

[1] Applied Communication Sciences (TTGS) traces its origins back to Bell Telephone Laboratories. Details about the company and its history are available online at www.appcomsci.com.

[2] MIMO – Multiple Input, Multiple Output. The technique of using multiple transmit and receive antennas to achieve spatial multiplexing and/or spatial diversity.

Field studies are a fundamental component of this contract. Figure 1 conceptually depicts the equipment configuration.

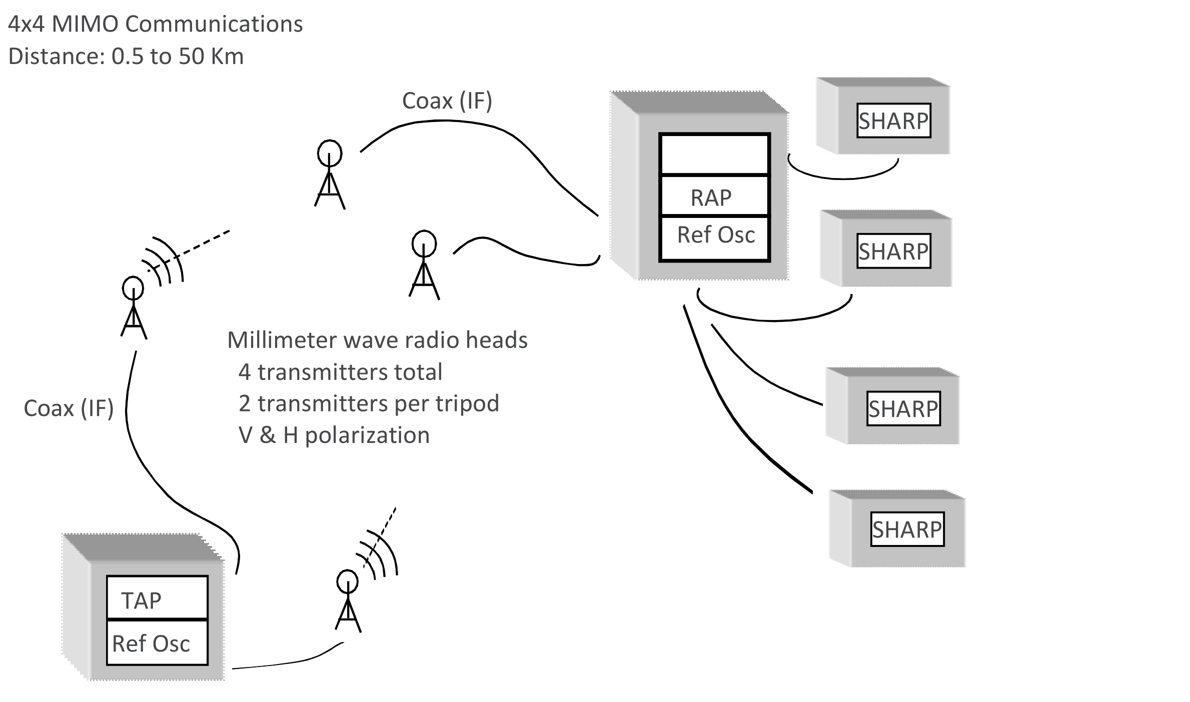

Figure 1: Line Of Sight MIMO Experiment

The transmitter is shown in the lower left hand corner of the figure. Here a transmit aperture processor (TAP) generates four distinct IF[3] signals, one for each millimeter wave transmitter. These IF signals are cabled to the tripod mounted radio heads. A similar description applies to the receiver side.

The physical dimensions of the equipment is as follows:

[3] IF – Intermediate frequency

Apparatus	Dimensions	Number of Units	Notes
TAP / Ref Oscillator		1	Transmitter modulator
Tripod (transmitters)	6 ‘ high (approx)	2	
Transmitter dish size	12” diameter Mounted on tripod	2	For government tests at 50 Km a 24” dish is used
mmW transmitter	12” x 12” x 4”	4	IF to RF 2 per tripod
Tripod (receivers)	6’ high (approx)	2	
Receiver dish size	12” diameter Mounted on tripod	2	For government tests at 50 Km a 24” dish is used
mmW receiver	12” x 12” x 4”	4	RF to IF 2 per tripod
RAP		1	Receiver preprocessor
SHARP		1 to 4	MIMO processor Demodulator

Experimentally the field test campaign will use modified commercial millimeter wave radio transceivers manufactured by HXI Renaissance Electronics Corporation.[4] The transmitter modifications include:

- Conversion of the full duplex units to simplex units (e.g. some units are transmit only, remaining units are receive only).
- Removal of the optical data input and modulator.
- Fitting an SMA connector to the radio enclosure. This connector will accept an analog IF signal centered approximately at 1.2 GHz: this signal is up-converted to 71.2 GHz by the transmitter circuitry. The bandwidth of this IF signal is approximately 1.6 GHz.
- Inclusion of a reconstruction filter to limit the bandwidth of the transmitter to 2 GHz.
- Fitting of a second SMA connector to supply an external 100 MHz frequency reference to the transmitter local oscillators. This reference locks all transmitters to a common, low noise reference.

The passband IF signal is generated using standard signal processing techniques. Pre-computed samples are loaded into a large memory associated with a digital to analog converter. The sample rate of this converter is approximately 5 GS/s. It is this IF signal that drives the millimeter wave transmitter.

Dish antennas, manufactured by mWave Corporation, are supplied with the transmitters and receivers. Two sets of antennas have been ordered: 12” and 24” diameter. The antenna choice depends on the range and link budget.

[4] HXI Renaissance Electronics, 12 Lancaster County Road, Harvard MA 01451, (978) 772-7774

Because this experiment is a MIMO demonstration, multiple transmitters will be operating at the same time on the same carrier frequency. The proposed system is a 4x4 system, meaning that there are 4 transmitters and 4 receivers in use. One pair of transmitters share a common parabolic dish antenna, using both vertical and horizontal (linear) polarization for signal separation. A second dish antenna is used for the second pair of transmitters.

An important aspect of this research program involves determining the performance and complexity of various demodulation algorithms. The Rayleigh distance criterion:

$$R_{Rayl} = \frac{d^2 N_R}{\lambda}$$

where:

R_{Rayl} is the Rayleigh distance
d is the antenna spacing (assumed to be the same at the transmitter and receiver)
N_R is the number of receive antennas
R is the range distance between the transmitter and receiver
λ is the operating wavelength

is of particular interest as our simulations have shown that the range distance relative to this parameter has a dramatic impact on the required complexity of the receiver algorithms.