Question #6: Statement of Research Project

Experimental Projects in the Smart Antenna Research Laboratory

Set 1: Transmissions that are within FCC regulations

Wideband Indoor MIMO Channel Sounding at 5.8 GHz and 17 GHz

This project is in connection with a federally funded project. The sponsor is the National Science Foundation. The grant is entitled *ITR/SI: Broadband MIMO OFDM Wireless Access* and the award number is 0121565.

Multiple-input multiple-output (MIMO) channels have been demonstrated recently to provide unprecedented spectral efficiencies in indoor environments. The channel sounding experiment described here supports a larger effort to investigate MIMO OFDM wireless access systems. In the larger effort, methods will be investigated for adaptive antenna arrays, receiver processing for synchronization, channel estimation and mitigation of channel impairments, bandwidth efficient modulation and error control coding, multiple access schemes and, the joint optimization of these functions. A challenging goal of this research is to arrive at a flexible, scaleable, wireless modem with bandwidth efficiency on the order of 4 to 10 bits per second per Hertz.

The design of any air interface begins with an appropriate model of the radio propagation environment. Stochastic channel models are convenient for computer simulation of system performance over many different realizations of a given class of environments, such as the small office. Many researchers are questioning the validity of the typical assumption that MIMO channel gains are independent and identically distributed.

We propose to perform extensive wideband array-to-array channel measurements in the bands 5.55 to 6.05 GHz and 16.75 to 17.25 GHz to determine appropriate stochastic MIMO indoor channel models. We wish to investigate two types of models: wideband geometrical and narrowband non-geometrical. The results of these investigations should be of interest to those seeking extremely high spectral efficiency in wireless LANs.

Wideband Geometrical Modeling

To investigate the wideband geometrical model, we plan to use the frequency domain method of wideband channel sounding. Following this method, to identify the channel centered at 5.8GHz, the transmitter transmits a series of CW tones, stepped in frequency with a maximum of 401 equal-sized steps over the range from 5.55 to 6.05 GHz, in order to measure the channel frequency response directly. Using spatial and frequency smoothing, along with high-resolution estimation techniques such as 3-D ESPRIT, we will estimate the gain, the delay, the angle of arrival at the receiver, and the angle of departure at the transmitter, for each detectable path of propagation. Research objectives include testing the single-bounce path hypothesis, performing joint estimation of delay, and joint estimation of angles of departure and angles of arrival, testing the validity of explicit clustering in stochastic models and determining the dependence between the spatial signatures of different sources. The latter objective applies, for example, to either the modeling multiple co-channel users or the modeling of a user and an interferer. Such information will be particularly useful to a related, simulation-based investigation we are doing concerning the performance and control of multihop networks with interfering MIMO links. We wish to conduct the channel sounding experiment on one of the floors of the Georgia Tech Residential Laboratory, as well as in our own laboratory on the 5th floor of the GCATT Bldg.

A detailed description of our MIMO channel sounder is in Attachment 1.

Attachment 1: Wideband MIMO Channel Sounding Experiment

Project Plan

The ultimate goal of the MIMO channel sounding project is to completely realize the properties, potentials, and the limitations of MIMO channel by analyzing the measured data acquired from our measurement system. The measurement will be focused on two frequency bands centered at 5.8 and 17 GHz, each with 0.5 GHz bandwidth, in the indoor environment. The wide bandwidth provides the measurement with timing resolution up to 2 *ns*. The initial objectives are to measure the MIMO channel matrix, identify each individual propagation path by estimating its delay, direction of arrival (DOA), and direction of departure (DOD) with ESPRIT algorithm. The long-term objective is to determine the appropriate indoor MIMO channel models for the telecommunications systems with multiple users.

The Measurement System

As illustrated in Figure 1, our MIMO-channel measurement system is composed of two parts: (1) the HP85301B antenna pattern measurement system, used to measure the channel frequency response, and (2) the actuator positioning system, which emulates an arrays at both ends of the link by moving the antennas to arbitrary pre-programmed locations. The actuator controller moves the antennas to a pair of specified positions, and then the channel is measured. This procedure is repeated until all the desired antenna positions have been sampled. The measurements will be conducted in various indoor environments, including the residential house, small and large offices, etc. The Residential Laboratory (RL) on 10^{th} street and the GCATT building on 14^{th} street are selected as two places for the measurements. Two separate frequency bands will be investigated, one is 5.55 – 6.05 GHz, and the other is 16.75 – 17.25 GHz.

We would like to apply about 20 dBm to the antenna. For EM6865 antenna, because the antenna gains at 5.8GHz and 17GHz are 2.6dBi and 3.5dBi, respectively, the EIRP will be about 22.6 dBm (0.779V/m @ 3m) at 5.8GHz and about 23.5 dBm (0.864V/m @ 3m) at 17.0 GHz. For antenna 9845-800, the antenna gain at 5.8 GHz is 5 dBi, so the EIRP is about 25 dBm (1.02 V/m). Because the virtual array approach requires that the channel be static during the course of the measurements, all the experiments will be conducted after the midnight (12:00 am – 8:00 am).

We adopt the stepped-frequency HP85301B as our measurement system, which can be divided into two separate parts: the transmit site and the receive site. The transmit site consists of the microwave transmit source, amplifiers, transmit antenna, and the reference link to the receive site. The receive site consists of the receive antenna, local oscillator source, RF downconverter, microwave receiver, and the computer. The details of the components are listed in Table 1.

Actuator Positioning System

Driven by three brushless motors, the actuators can translate the antenna through a volume of approximately 50cm × 50cm × 7cm. The 7cm in the Z-direction ensures that the angles of paths arriving at nearly all elevations can be identified. For convenience, a mobile platform is also prepared to move both actuator systems to various locations. The design of actuator and mobile platform systems are demonstrated in Figure 2 and 3, respectively. The antennas are mounted on plastic telescoping masts such that the receive antenna can be positioned at heights ranging from 4 to 5 feet from the floor and the transmit antenna can be positioned at heights ranging from 4.5 to 5.5 feet from the floor.

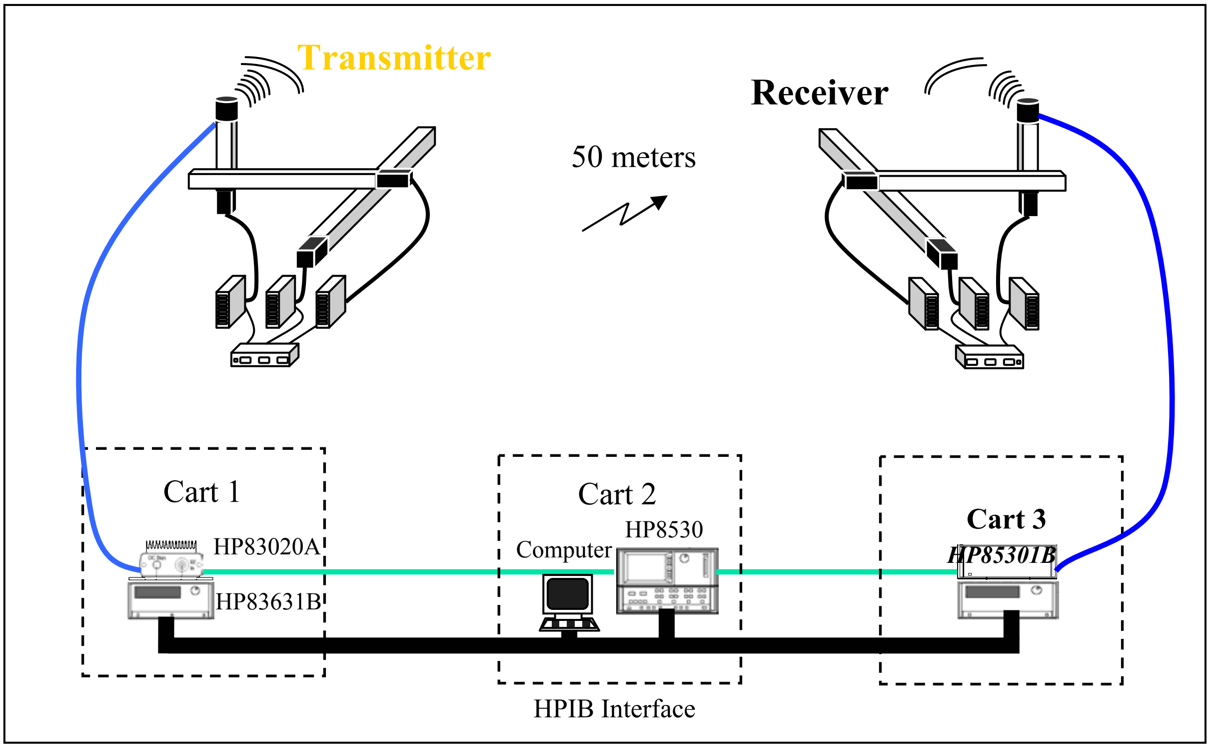

Figure 1. MIMO channel measurement system.

Table 1. HP85301B measurement system.

Component	Equipment	Functions & Specs
Transmit source	HP83631B synthesized sweeper	Frequency range : 0.045 – 26.5GHz Max. output power : < 20 GHz, +13 dBm Resolution : 20-26.5 GHz, +10 dBm : 1 Hz
Amplifier	HP87422 power supply and HP83020 power amplifier	Frequency range : 2 –26.5 GHz Gain : 30 dB Max. output power : 30 dBm
LO source	HP83621B synthesized sweeper	Frequency range : 0.045 – 20GHz Max. output power : +13 dBm Resolution : 1 Hz
RF downconverter	HP85320A/B Mixers	Downconvert RF signal to IF band Sensitivity : -113 dBm Dynamic range : 89 dB
	HP85309A LO/IF distribution unit	1. Receive LO source and provide it to the mixers 2. Receive IF signals and send it to the microwave receiver
Microwave receiver	HP 8530A microwave receiver (HP85101C Display/Processor + HP85102R IF/Detector)	1. Synchronize and control the RF transmitter and the RF receiver 2. Receive and display the IF signal 3. Send the data to computer
Antenna (for Tx & Rx)	EM 6865 omni-directional wideband antenna	Type : Biconical Frequency range : 2-18 GHz Polarization : Vertical Gain : 2.6 dB at 5.5GHz 3.5 dB at 17.0 GHz Max. power : 5W VSWR : <2:1 Output impedance: : 50Ω Interface : Type "N" female Weight : 1 lbs
	9845-800 omni-directional wideband antenna	Type : Biconical Frequency range : 4-6 GHz Polarization : Vertical Gain : 5 dBi at 5.8GHz Max. power : 10W VSWR : <2:1 Output impedance: : 50Ω Interface : SMA female Weight : 0.5 lbs

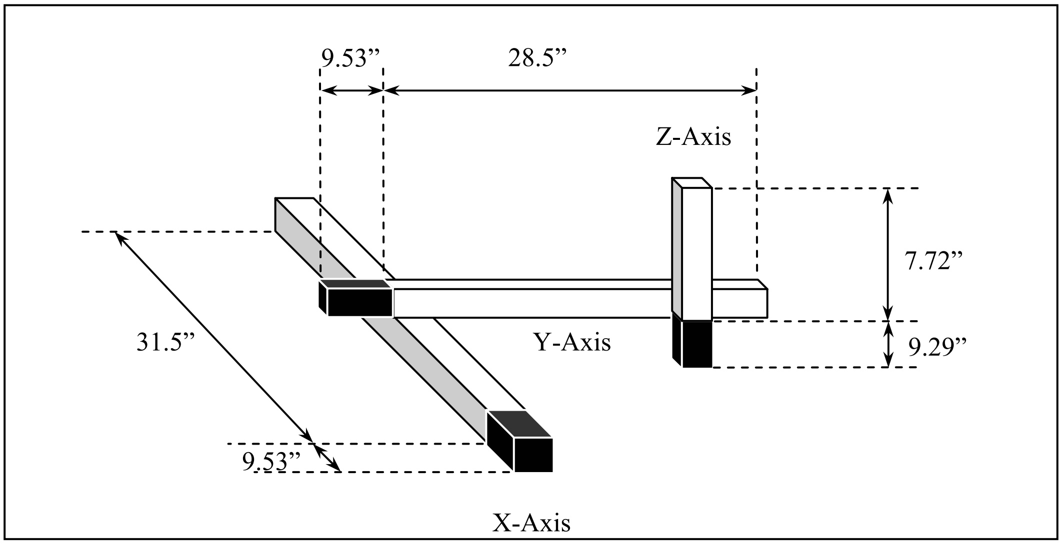

Figure 2. Three-dimensional actuator positioning system.

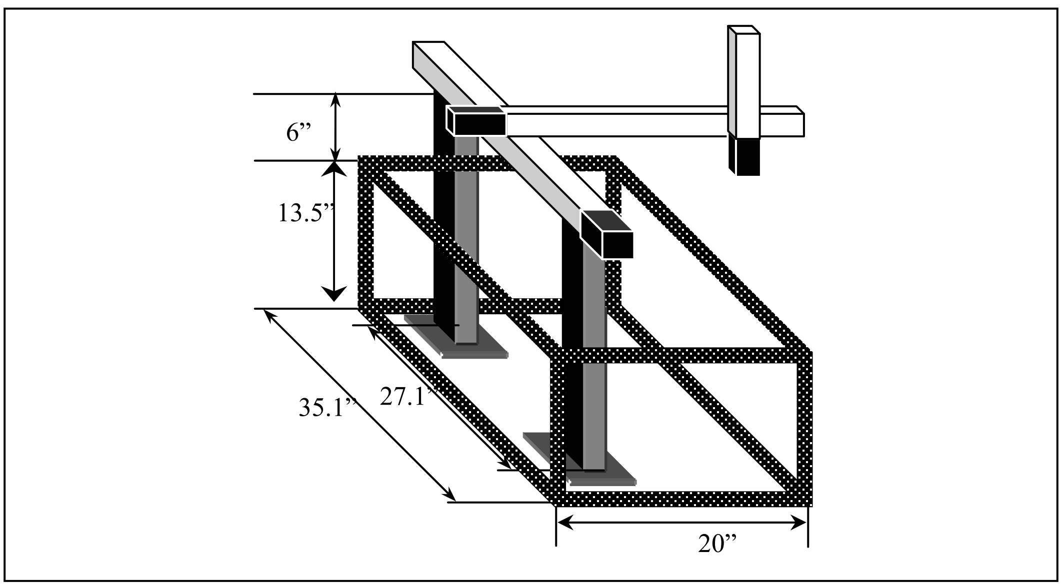

Figure 3. Mobile platform.