Question #6: Statement of Experimental Project

Experimental Projects in the Smart Antenna Research Laboratory

Set 1: Transmissions that are within FCC regulations

OFDM Transmission at 1.9GHz over a High-Mobility Link

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.

OFDM has the desirable feature that no equalizer or at most a one-tap equalizer is needed. It is being considered for wideband transmission in mobile environments. We would like to test existing algorithms and develop new algorithms for receiver signal processing for OFDM receivers when the channel has high-mobility. To create the high-mobility channel, we will transmit OFDM signals, centered within the unlicensed PCS band (1910-1930 MHz) from one car or two cars being driven within a 2 km radius of the GCATT Bldg, 250 14^{th} St, Atlanta, GA 30318. This area includes a stretch along the expressway (I75/I85) two blocks from the GCATT Bldg. There are several papers on OFDM reception over high-mobility channels, but none of them shows performance for real channels. We will use up to four receive antennas in the receiver, enabling us to look at space-frequency types of algorithms.

The setup for this experiment is described in Attachment 1.

Attachment 1: Setup for the High Mobility OFDM Experiment at 1.916 GHz

We propose to transmit two OFDM signals, each with baseband modulation consistent with the Digital Audio Broadcasting mode III standard and each from a different automobile at the same center frequency of 1.916 GHz. Each transmitted waveform will be a continuously looping replay of one frame that has been stored on the RF signal generator and amplified. The two waveforms will carry different data. Two omnidirectional transmit antennas will be mounted vertically on the roofs of two cars, one per car.

During transmission, the cars will be driven within a 2 km radius around the GCATT Bldg at 250 14th Street in Atlanta, GA. Some experiments will include having the cars being driven on Interstate I75/I85 that runs north-south just one block from the GCATT Bldg. The four receive antennas will be mounted in an array, as shown in Figure 1. A more complete description of the system follows.

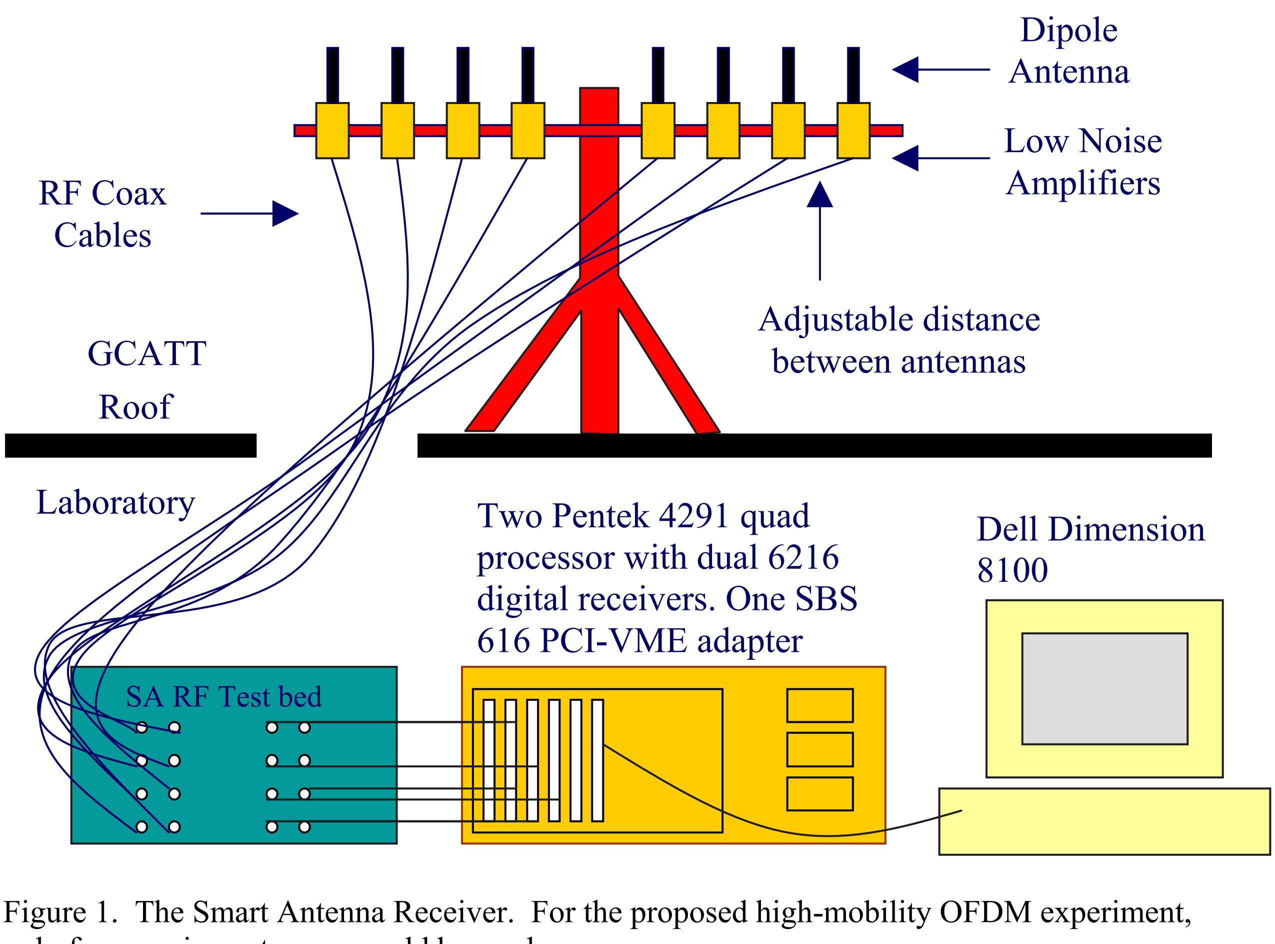

Figure 1. The Smart Antenna Receiver. For the proposed high-mobility OFDM experiment, only four receive antennas would be used.

The proposed system will consist of two identical mobile transmitters and an eight-antenna array receiver. Table 2 lists the components of one mobile transmitter. Next the transmitter is described in detail.

Table 2. Transmitter Equipment List

QTY	Description
1	Falcon Electric ED Series UVS Plus 2kVA line conditioner and uninterruptible voltage source.
1	ED Series UVS optional battery pack
1	Agilent E4432B ESG-D Series Digital RF Signal Generator
1	Agilent 83020A Microwave Amplifier
1	Cushcraft S1803BFNM omnidirectional antennas, 3dBi gain antenna

Transmitter Description

- Maximum RF Power at Tx Terminals

The battery operated power supply system can provide continuous, laboratory grade, 120V AC power for 90 minutes to both the signal generator and microwave amplifier. The signal generator combined with the microwave amplifier provides a continuous 20 dBm RF output to the antenna.

- EIRP

The antenna provides an extra gain of 3 dBi for a total output power of 23 dBm (0.816V/m @ 3 m). The antenna is an omnidirectional dipole.

- Type of Modulation

We plan to use a DAB mode III signal for our experiments. The signal is described in detail in the ETS 300 401 “Radio broadcasting systems; Digital Audio Broadcasting (DAB) to mobile, portable and fixed receivers” ETSI standard. Our reason to choose this particular signal lies in the possibility of performance comparisons. Since we are mainly focusing our research in Smart Antenna technology, we can have a benchmark to compare to with many of the DAB systems in operation that do not use space processing.

The description of the signal is as follows:

Each transmission frame shall consist of consecutive OFDM symbols. The number of OFDM symbols in a transmission frame is dependent on the transmission mode (mode III in our case). The synchronization channel in any transmission mode shall occupy the first two OFDM symbols of each transmission frame. The first OFDM symbol of the transmission frame shall be the Null symbol of duration T_{NULL}. The remaining part of the transmission frames shall be a juxtaposition of OFDM symbols of duration T_S. Each of these OFDM symbols shall consist of a set of equally-spaced carriers, with a carrier spacing equal to $1/T_U$. The main signal s(t) shall be defined using the following formula:

$$s(t) = \mathrm{Re}\left\{ e^{2j\pi f_c t} \sum_{m=-\infty}^{+\infty} \sum_{l=0}^{L} \sum_{k=-K/2}^{K/2} z_{m,l,k} \times g_{k,l}(t - mT_F - T_{NULL} - (l-1)T_S) \right\}$$

with,

$z_{m,l,k}$ = the complex π/4 D-QPSK symbol associated to carrier k of OFDM symbol l during transmission frame m. For $k = 0$, $z_{m,l,k}$, so that the central carrier is not transmitted.

and

$$g_{k,l}(t) = \begin{cases} 0 & for \quad l = 0 \\ e^{2j\pi k(t-\Delta)/T_U} \cdot \mathrm{Rect}(t/\ T_S) & for \quad l = 1, 2, \mathrm{K}\ , L \end{cases}$$

Table 3. Values of the various OFDM parameters for DAB Mode III

Parameter	**Transmission mode III**
T = elementary period	1/(2,048,000) seconds
L = the number of OFDM symbols per transmission frame (the Null symbol is excluded)	153
K = the number of transmitted carriers	192
T_F = the transmission frame duration	49,152 T 24 ms
T_{NULL} = the Null symbol duration	345 T ~168 µs
$T_S = T_U + \Delta$ = the duration of the OFDM symbol	319 T ~156 µs
T_U = the inverse of the carrier spacing or useful part of OFDM symbol	256 T ~125 µs
Δ = the duration of the time interval called guard interval	63 T ~31 µs
$1/T_U$ = the carrier spacing	8 kHz

- Speed of keying

Since we are using QPSK, we have two bits per complex symbol. We can calculate the raw (uncoded) or gross data rate as follows:

Bit per second = (number of frames per second)(number of OFDM symbols per frame)(number of complex symbols per OFDM symbol)(2)

$$\text{bps} = (41.667)(153)(192)(2) = 2,448,000$$

- Bandwidth and describe how it is computed

Bandwidth = (carrier spacing)(number of carriers per OFDM symbol)

$$\text{BW} = (8\text{kHz})(192+1) = 1.544\text{MHz}$$

An example of the transmitter output on a spectrum analyzer is shown in Figure 10.

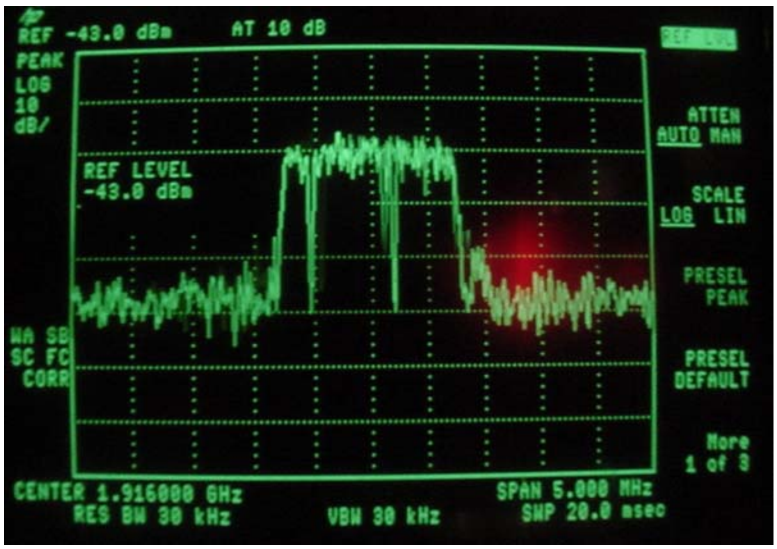

Figure 10. Example output of the DAB Mode III transmitter signal as viewed on a spectram analyzer

- Location of Tx and Rx

The receiver location is at the NW roof corner facing 14th street of GCATT. The building is a five story building located at 250 14th Street, Atlanta, GA 30318.

The transmitters shall operate inside a 2 km radius from the receiver location.