

Chapter 6

Measurement Plan

The following measurement campaign was designed to demonstrate the operation of the measurement system and to observe the potential capacity of an indoor environment. Measurements were conducted in Durham Hall at Virginia Polytechnic Institute and State University, and three locations were selected to provide a range of capacity results: a wide lecture hall, a hallway including several adjacent offices, and a large room partitioned into cubicles. Durham Hall, a 72,000 square foot office building, was completed in September 1997. This four story building houses over 100 offices and several research laboratories [52]. Together with the free-space environment, these locations have provided a broad range of capacity estimates. Although these measurements do not represent a large statistical cross-section of office-building environments, an engineer may be able to use the results to comparatively predict capacity in several rooms of Durham Hall or similarly constructed buildings. The following chapter explains the procedures employed in the measurement campaign and describes each location.

6.1 Measurement Procedure

All measurements were conducted inside Durham Hall on the Virginia Polytechnic Institute and State University campus. The proximity of the measurement sites to the system's storage location solved many of the non-technical challenges common to a measurement campaign. Problems pertaining to transportation and room availability were avoided in most instances. Uninterruptible power supply batteries were utilized to transfer the system between locations without powering down the oscillators, accelerating the warm up period at the measurement site. The GPS receivers were stored in room 471 and turned on at least 24 hours before each measurement. These units were also allowed to warm up for one hour at the measurement location, before the calibration procedure.

At each site, the daily calibration described in Chapter 5 was conducted in the main hallway adjacent to the room under test. The main hallways on the 2nd and 4th floors are identical in dimension and construction materials, providing a repeatable calibration environment at each location. The calibration procedure was discussed in Chapter 5, and the hallway environment is described further in the following section. After calibration, the system was moved into the room-under-test. The calibration and measurement processes required less than seven hours per location, from the initial calibration until the last measurement. All measurements were conducted at night, between the hours of 11PM and 8AM, in order to minimize the effects of pedestrian traffic.

At each site, the transmitter was placed at a specific location in the room and was not moved until all measurements in that room were complete. Measurements were conducted with the receiver at selected points in the same room. In the local area around each point, the receiver was moved to nine sub-points and measurements were taken with the array pointing in each of the four cardinal directions. The sub-points were arranged in a grid pattern, and separated by a distance of six inches, or approximately one wavelength. A one-wavelength spacing between measurements should provide multiple independent observations of the propagation environment. Each of the 36 local area measurements recorded ten seconds of continuous data. For every measurement, the top

of the receiver antenna array was located at a height of 1.5 meters, and both antennas were oriented to maintain vertical backplanes.

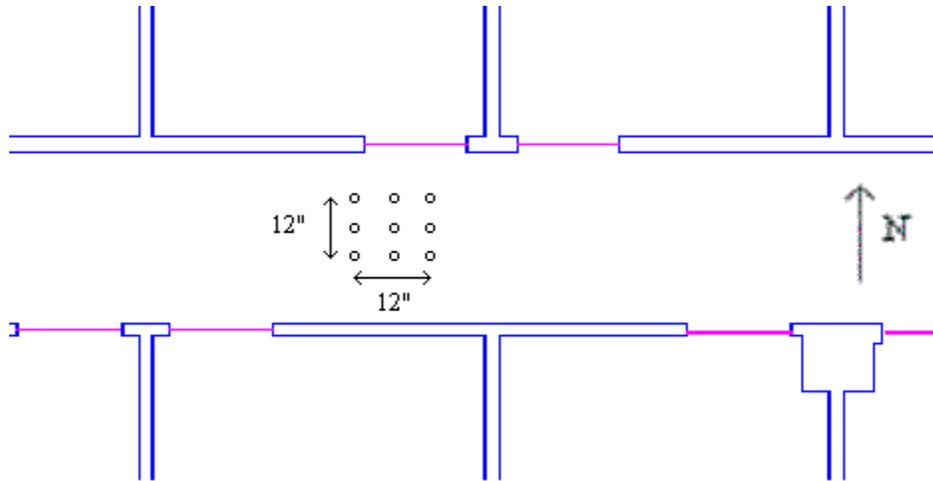


Figure 6-1: Receiver array locations inside a local area were defined by a nine sub-point grid. At each sub-point, four measurements were recorded in each of the cardinal directions. (Figure not to scale)

The location and orientation of the antenna arrays are detailed for each measurement in the following sections. All measurements were conducted on the 2nd and 4th floors of Durham Hall, depicted in Figure (6-2) and (6-3). Detailed enlargements are included in the relevant sections. It should be noted that an attempt was made to place the receiver array on all sides of the room, but locations were restricted by the length of the cable attaching the GPS receiver to its outdoor antenna.



Figure 6-2: 2nd floor Durham Hall

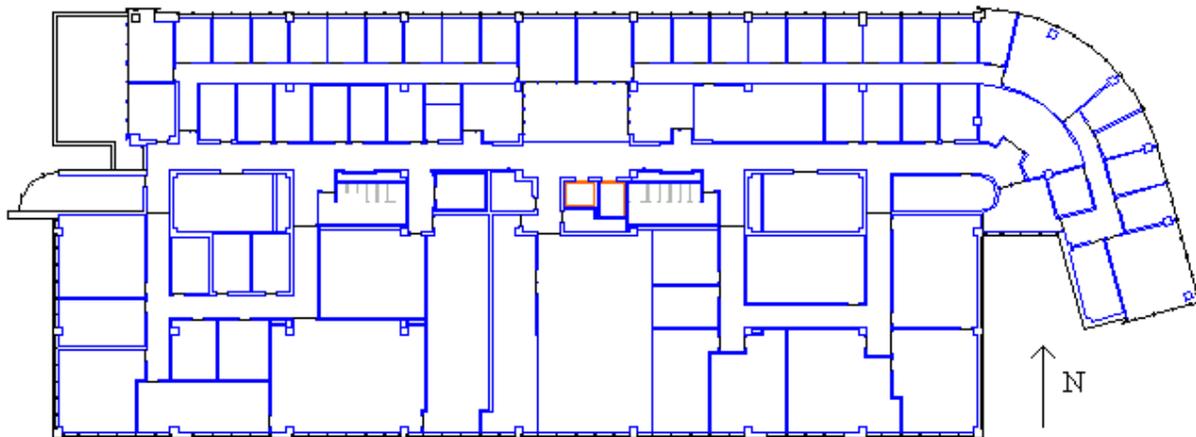


Figure 6-3: 4th floor Durham Hall

6.2 Hallway Environment

Measurements were conducted in the 4th floor main hallway on the West side of Durham Hall. The transmitter was situated at the Eastern end of the hallway, next to the door of room 416, and data was recorded with the receiver at six different locations in the hallway and adjacent offices. The top of the transmitter antenna was placed one foot below the ceiling, facing the West end of the hallway.

Three measurements were conducted with the receiver located in the center of the main hallway. The receiver array was placed across from the doors of rooms 406, 410 and

418, with transmitter-receiver separations of 34', 53.5' and 71.5'. Three additional measurements were recorded with the receiver in the center of rooms 406, 408 and 410. At each of these locations, 36 individual measurements were taken using the grid pattern described above. These locations are denoted in Figure (6-4) the following floor plan, and the transmitter and receiver positions are depicted in the three subsequent photographs.

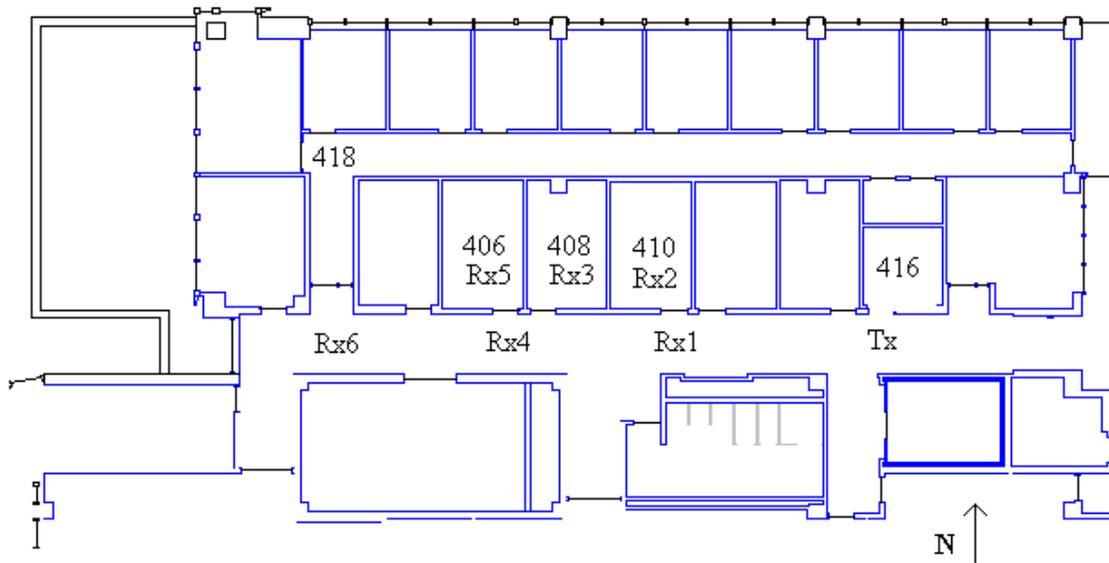


Figure 6-4: Hallway and office environment. 4th floor Durham Hall (enlarged)

The hallway has dimensions of 9' by 7' by 90'3", with painted cinderblock walls and linoleum tile floor. The ceiling is constructed with particleboard tiles framed with metal supports. Rooms 406, 408 and 410 have dimensions of 176" x 112" x 106". The office walls and ceiling are made of the same materials as in the hallways, but the office floors are carpeted. These offices have no windows besides the 5'8"x 1'11" frosted glass panel centered in each door. Two to three sets of chairs, desks and computers, as well as several metal cabinets, occupy each room.



Figure 6-5: Transmitter subsystem in the Hallway environment.



Figure 6-6: Receiver subsystem in the Hallway environment.



Figure 6-7: Receiver array in the office environment.

6.3 Cubicle Environment

Cubicles are defined as the small room-like areas produced when parts or all of a large room is divided by temporary partitions. This room typically contains furniture in each cubicle as well as tables holding communal equipment in the unpartitioned areas. Measurements were conducted in this environment in room 476 of Durham Hall on the Virginia Tech campus. The transmitter array was placed in an unpartitioned corner of the room with the top of the array one foot below the ceiling and facing the southern wall. At each of the five locations denoted in Figure (6-8), measurements were recorded using the nine-point grid described above.

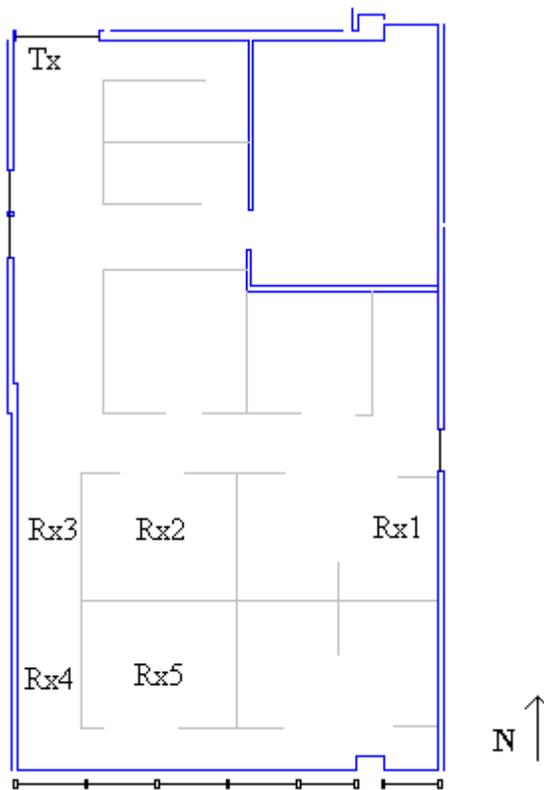


Figure 6-8: Cubicle environment. Room 476 Durham Hall (enlarged)

The room has dimensions 31' x 51'8" x 8'10" and temporary partitions of height 5'7". The permanent outer walls are constructed of sheetrock and carpeting covers the floor. The ceiling consists of particleboard tiles framed by 1inch wide metal supports. The interlocked cubicle partitions have a fabric-covered metal structure and can be seen in Figure (6-9). Plastic and wood desks line two walls of each cubicle, above which hang two enclosed metal shelves. A row of desks and stacked metal shelves, holding communal computer hardware, lines the western wall in a 7' wide unpartitioned walkway, and a small refrigerator occupies the northeast corner. 21" high metal-tinted windows line the ceiling along the southern wall. Figures (6-9) and (6-10) depict several of the transmitter and receiver positions in this environment.



Figure 6-9: Receiver Subsystem in the cubicle environment. Note the partition between the receiver and the array.



Figure 6-10: Transmitter subsystem in the cubicle environment

6.4 Lecture Hall Environment

The third indoor site focused on a large open room, relatively free of high obstacles or sources of shadowing. In the lecture hall, the transmitter was located at the South end of the room, next to the chalkboard, with the top of the array placed one foot below the ceiling. Measurements were taken with the receiver array placed at the four points indicated in Figure (6-11). Two receiver points were located in the center of the room, behind the desks in the second and fifth rows. Two additional points placed the receiver against the east and western walls, next to the fourth row. At each point, the receiver was moved around the previously described nine-point grid pattern, producing a total of 144 ten-second measurements.

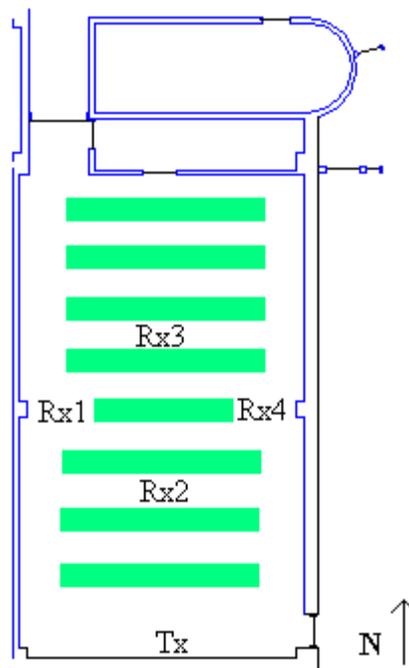


Figure 6-11: Durham Hall Room 261 represents the Lecture Hall environment. Transmitter and receiver locations are indicated.

The Lecture Hall, Room 261 has a length of 30'4" and a width of 16'2". A large section of the floor slopes down toward the South wall, producing at minimum ceiling height of 8'12" and a maximum height of 10'5". The ceiling consists of suspended particleboard tiles, and the walls are painted cinderblock. Eight tables, each 2'6" high and 2' long, span the width of the room, East to West. The tables, and the adjacent fabric covered chairs, are bolted permanently to the floor. 21" high metal-tinted windows line the ceiling around the South and East walls, and are covered with horizontal metal mini-blinds. A chalkboard extends along the Southern wall and a projector hangs from the center of the ceiling. A television, an overhead projector and a podium, each on wheeled trolleys, are stored at the Southern end of the room. Figures (6-12) and (6-13) depict the transmitter and receiver in this environment.



Figure 6-12: Receiver subsystem and the transmitter array in the lecture hall environment. The transmitter subsystem is hidden behind the front row desk.



Figure 6-13: The receiver array from the perspective of the transmitter array, in the lecture hall environment. The receiver unit is concealed by desks to the right of the array.

This campaign was designed to measure the theoretical MEA capacity and cross-channel correlation values inside an office building. Measurements concentrated on three common office environments, recording between 144 and 216 measurements at each site. Hallway, cubicle and lecture hall locations were selected to represent generic environments inside a normal office building. Although the length of the GPS antenna cables restricted transmitter and receiver locations, system arrangements were designed to mimic their positions in a potential wireless local area network.