# 2.4 EFFECT OF ATMOSPHERIC HYDROMETEORS ON MILLIMETER WAVE TRANSMISSIONS

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## 1. INTRODUCTION

The millimeter wave spectrum was made available for broadband wireless communication by the FCC in 2003. The band consists of 70-76, 81-86, and 92-94 GHz frequencies. These might not appear to be useful frequencies for wireless communications since the transmissions over distances greater than a few kilometers would be attenuated by precipitation, small water droplets and particulates. Millimeter-wave links, however, can support data rates on the order of a gigabit per second over distances ranging up to eight kilometers (five miles) in clear weather. This technology has the potential to support high-speed metropolitan services and applications, such as backhaul of cellular traffic.

This research is aimed at exploring methods to permit end-to-end communication even when local weather impairments impact individual links. Precipitation frequently has small scale structures such that if one part of a metropolitan area is receiving heavy precipitation at the time another part is receiving little or no precipitation. We propose a smart transmission network such that wireless signals could be routed around areas with heavy precipitation.

We need to answer a number of questions to determine if such a network is feasible. For example, how heavy does the precipitation need to be before the signals must be rerouted? Would radar estimates of precipitation be accurate enough to determine whether the signals need to be rerouted? Does the need to reroute signals depend on the drop size distribution of the storm? What is the typical size of precipitation areas which will require signal rerouting? What is the size distribution of these precipitation areas?

This paper will concentrate on the experimental setup suitable for addressing the first two questions. Although models have been developed to simulate the attenuation of wireless signals in this frequency band (Crane 1980, Hou et al. 2000, Paulson and Gibbins 2000, Hendrantoro et al. 2006 ), it is not clear how well the predictions of these models will work in practice. Therefore, we need additional field measurements to determine the attenuation of the signals under various weather conditions. We will describe the instruments we have set up and how their data can be used with existing data from other sources to help us answer some of these questions.

## 2.0 EXPERIMENTAL SETUP

We have two tandem links with endpoints located 9.1 km apart. One end is on the top of a building on the University of Kansas campus (Nichols Hall) and the

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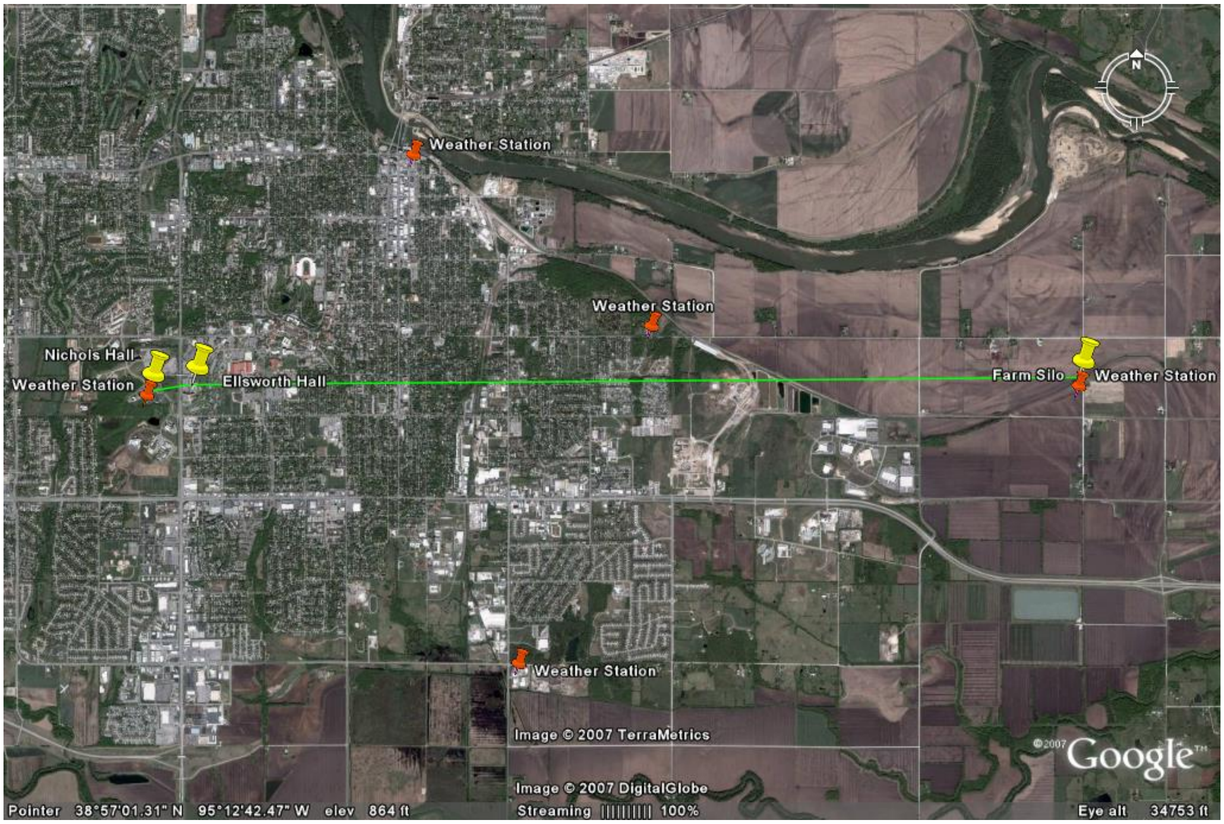

Figure 1. Map showing locations of the communication links (yellow pointers) and weather sensors (red pointers)

other end is on a local farm east of campus with a relay station set up between on another building (Ellsworth Hall). These locations can be seen in Fig. 1.We have set up weather sensors at the locations shown by the red pointers in Fig. 1. These locations have access to the Internet through the local cable service provider and Spring-Nextel's wireless network. A video camera is set up on Ellsworth Hall looking towards the farm. It can alert us to changes in visibility as well as other visual events.

Each group of weather sensors measures temperature, humidity, wind direction and speed, barometric pressure and precipitation via an impact sensor (Salmi and Ikonen 2005). The impact precipitation sensor has the advantage of being able to tell us when a precipitation event started – it can detect very small amounts of precipitation. It also estimates precipitation amounts. These sensors were progressively deployed among the five sites beginning the end of June 2007. Nichols Hall and the farm site each have tipping bucket rain gages which were deployed near the end of September 2007. The measurements obtained from the sites will be comparable to those which are likely to be available to us (from Automated Surface Observing System (ASOS) or similar sources) if the methodology were to be deployed operationally. In addition, Nichols Hall and the farm site each have a laser disdrometer. These instruments will enable the correlation of signal attenuation to drop size distribution. Due to technical problems with these instruments, they were not deployed until the middle of November 2007. None of the precipitation sensors have windscreens.

In addition, the Lawrence airport ASOS site is located about 8 km north of the midpoint between Ellsworth Hall and the farm. It collects similar data to our weather sensors but, in addition, has a visibility measurement capability which may be useful to this project.

The study site is located approximately midway between the Topeka and Pleasant Hill National Weather Service WSR-88D radar sites. We can obtain radar reflectivity and precipitation estimates from two different angles. These data are important because in some places where this methodology might potentially be deployed National Weather Service radar may provide the only precipitation measurements available.

## 3. PRELIMINARY RESULTS

We will present some preliminary results here to illustrate how the measurements we have taken relate to transmission packet losses and integrate with other data. Fig. 2 shows the instantaneous rain rate together with the packet loss rate of the transmissions for a precipitation event on Aug. 24, 2007. The information loss was (frame error rate equals 1) in some cases. Although there were short periods of time when precipitation was not falling, the information loss was not reduced until the precipitation has stopped. The frame loss did not immediately return to prestorm levels, presumably because the relative humidity was still high and there were enough hydrometeors in the atmosphere to cause minor disruptions in the signal. In this case, the total precipitation measured by the impact sensor was $2.26 \times 10^{-3}$m (0.09 inches). The radar image associated with this precipitation event is shown in Fig 3. The total radar precipitation estimate for the event at the location of the precipitation sensor was just under $2.54 \times 10^{-3}$m (0.1 inches).

High relative humidity may cause packet loss for microwave transmissions even on days when no precipitation occurred. Fig. 3 shows six days of relative humidity data together with the frame error rate of transmissions. It can clearly be seen that the packet loss increases as the relative humidity increases overnight. These losses may be due to atmospheric hydrometeors that form at high relative humidity. Other explanations are possible, however. These losses might occur due to altered wave propagation due to the development of a surface inversion. Alternatively, there could be interference from radio waves reflected by the ionosphere at night.

## 4. FUTURE WORK

We are in the process of taking measurements, so we do not have any firm conclusions about the usefulness of various precipitation and humidity measurements for this application. We need to determine whether measurements of precipitation amounts will be sufficient to determine whether data transmissions will be seriously impacted or whether some determination of drop sizes is necessary. We then need to judge whether the errors in radar estimates of precipitation amounts will be tolerable enough for this application. Although current NWS radars might not provide precipitation measurements of acceptable accuracy, the soon to be deployed polarized radars may provide sufficient accuracy of precipitation amounts. We are in the process of creating a database of the size, shape, intensity and movement of precipitation areas in the central United States. We can use this database to determine what types of precipitation areas will

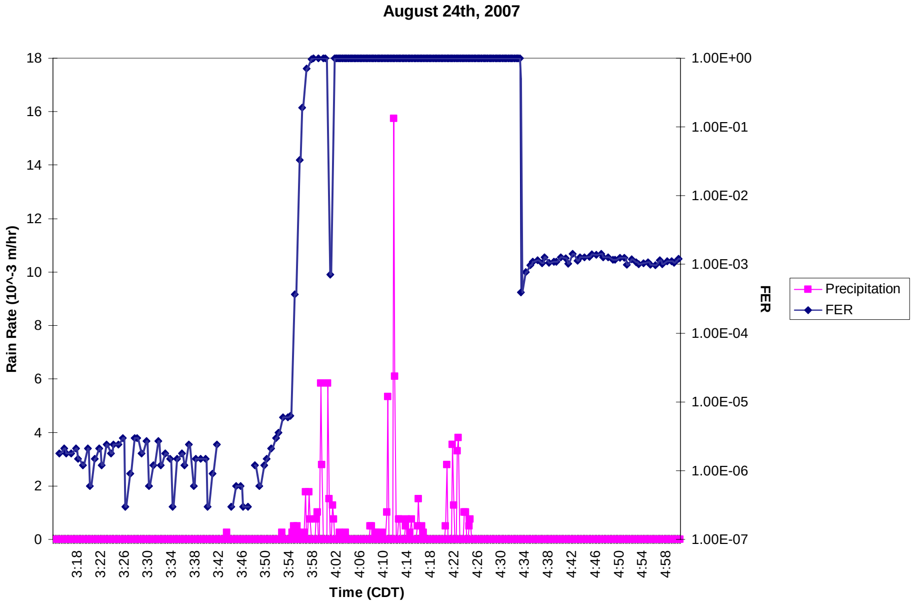

Figure 2. Rain rate in $10^{-3}$ m per hour (magenta) and frame error rate (dark blue) of the microwave transmissions.

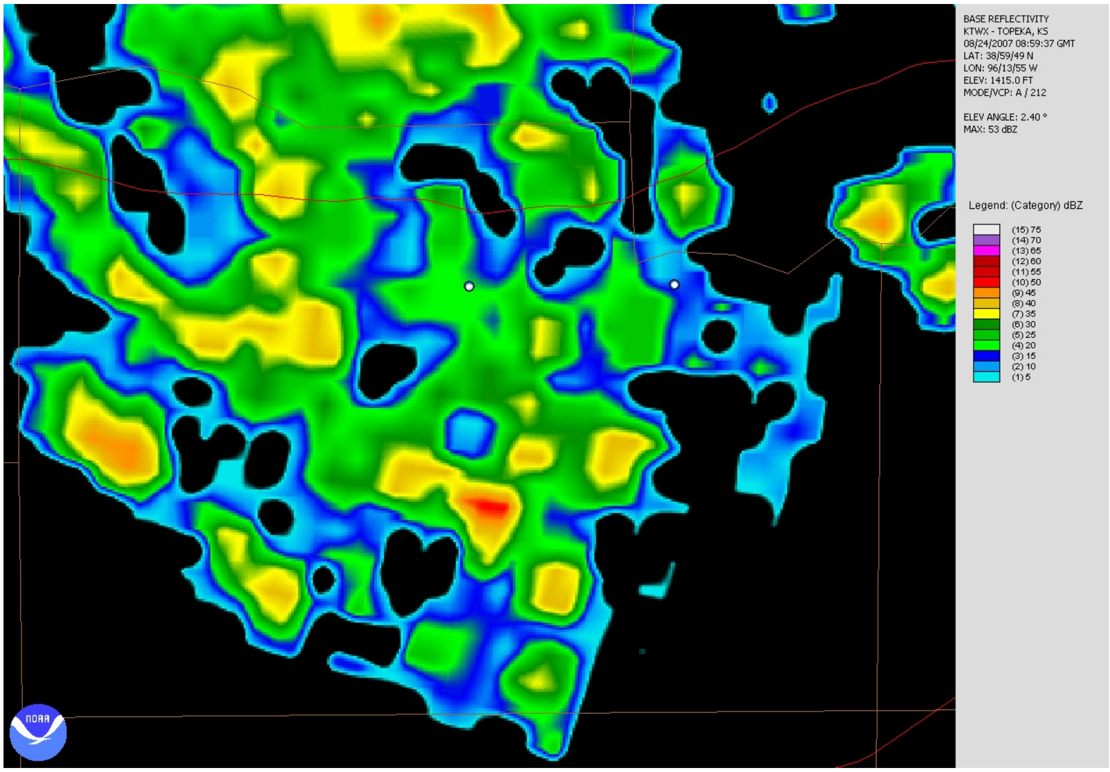

Figure 3. Radar imagery from 0840 GMT (3:40 a.m. CDT). Brown line is boundary of Douglas County, KS. And red line is Interstate 70. White dot on left is the location of Nichols and white dot on right the location of the farm.

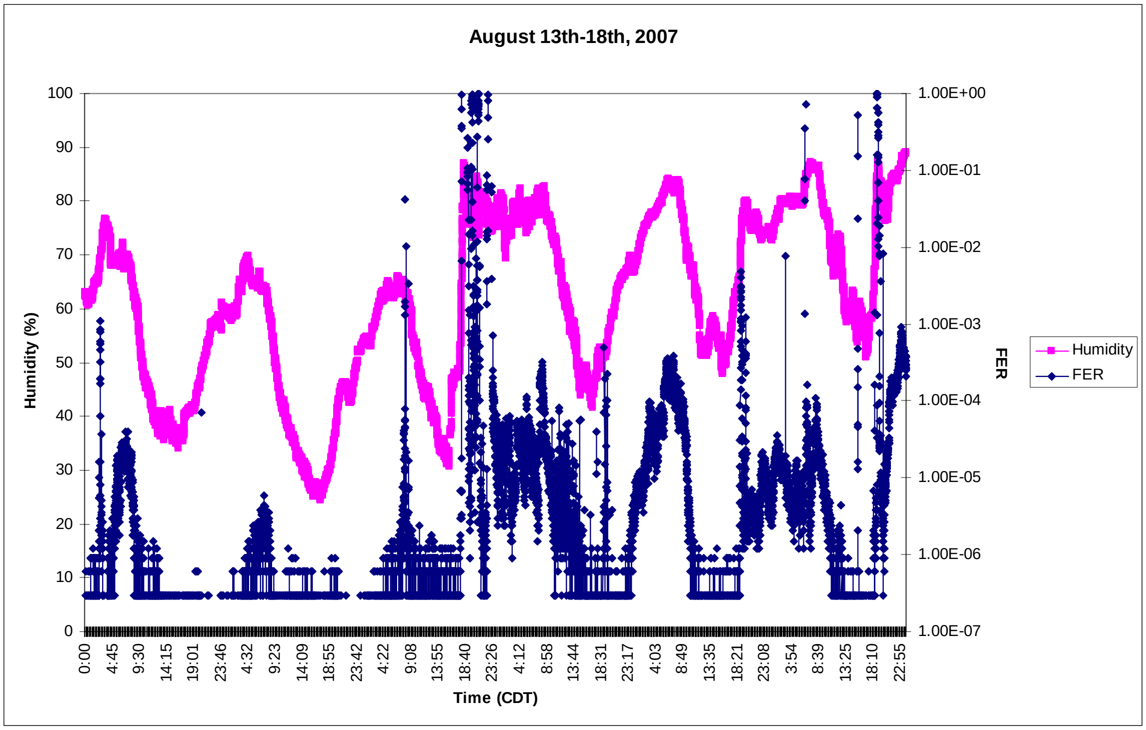

Figure 4 Relative humidity (magenta) and frame error rate (dark blue) variations over a period of six days.

will trigger the use of our rerouting method to redirect signals. This work will give us a better idea of the feasibility of this methodology.

## AKNOWLEDGEMENT

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