LAB 01 - MODULATION

PART I: SCAVENGER HUNT

Find the hidden signal that is being broadcast within the range

INSTRUCTIONS

1. Connect to one of the remote radios listed below using SDR#.
2. Scan through the signals, the signal uses a narrow bandwidth
3. Listen to the audio through your speakers, you'll find a few different transmissions. If at first you think you're getting trolled by the Russians, you're close, but the trolling isn't the secret message itself.
4. Take a screenshot of discovering the signal. What is the signal saying (audio)?

FINDINGS AND ANALYSIS

The secret message is "Mary had a little lamb, its fleece was white as snow."

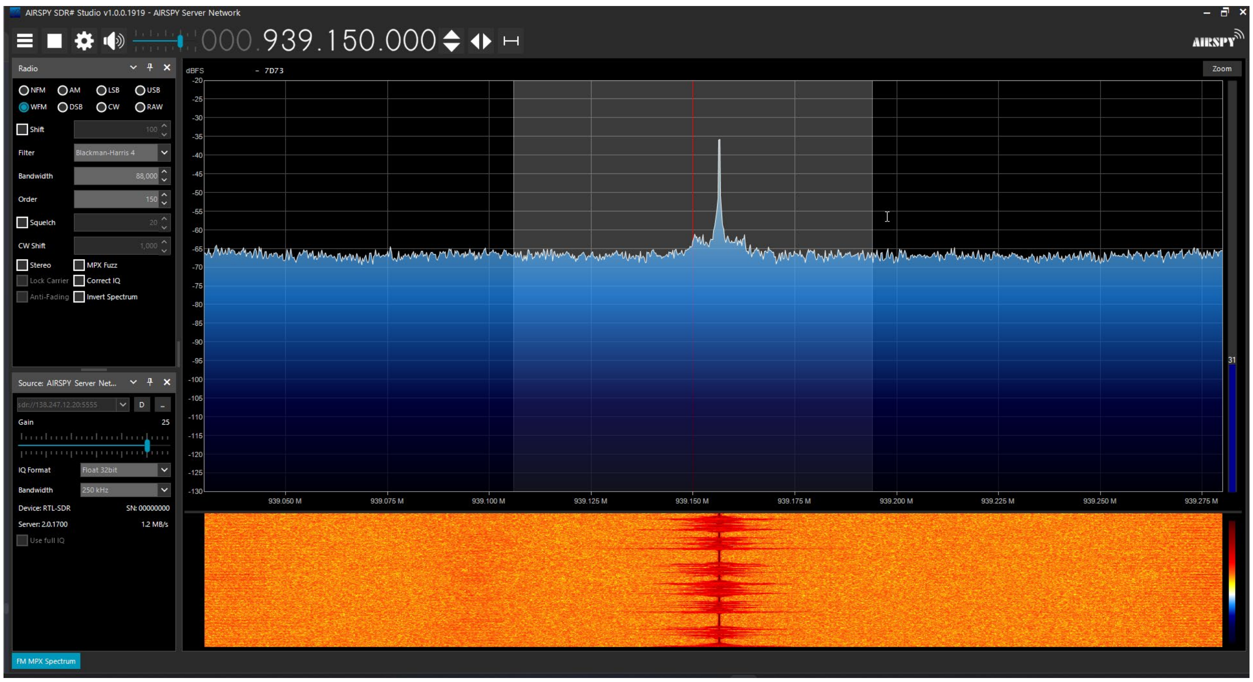

Figure 1: Secret Message Signal

PART II: TRIANGULATION

estimate the rough location of a mobile device given three base stations and key parameters such as received power, distance, and antenna gains

INSTRUCTIONS

We know the basics for the relationship between received power, distance, and antenna gains. Given this information, we should be able to determine a mobile device's rough location. In our scenario, we're assuming we have free space propagation and that in our mystical world, all antennas' gains are 1. Given the information below, determine the approximate location of the mobile device. Make sure to show/explain/demonstrate how you determined the location and show what you've found on some sort of a map. How you choose to render the map is up to you.

FINDINGS AND ANALYSIS

SETUP

Establish groundwork for subsequent distance calculations by introducing Friis Formula, transforming it into a distance formula, and calculating wavelengths

I. Friis Formula

$$P_r = \frac{G_r G_t P_t}{\left(\frac{4\pi d}{\lambda}\right)^2}$$

P_r	Received Power *strength of the signal as it arrives at the receiving antenna*
G_r	Gain of Receiving Antenna *how effectively receiving antenna captures incoming signal*
G_t	Gain of Transmitting Antenna *how effectively transmitting antenna sends signal in a particular direction*
P_t	Transmitted Power (watts) *initial signal power transmitted from transmitting antenna*
d	Distance Between Transmitting and Receiving Antennas *Note: units for wavelength and distance must be the same*
λ	Wavelength of Signal $\lambda = \frac{c}{f}$ $c = speed\ of\ light$ $f = frequency$ *Note: units for wavelength and distance must be the same*

II. Calculate Distance Formula

Transform the Friis formula to a distance formula to directly calculate the approximate distance (d) between a mobile device and each base station.

$P_r = \frac{G_r G_t P_t}{\left(\frac{4\pi d}{\lambda}\right)^2}$	*formula*
$P_r = \frac{G_r G_t P_t \lambda^2}{(4\pi d)^2}$	*fraction rule* $\frac{\frac{a}{b}}{c} = \frac{a \times c}{b}$
$(4\pi d)^2 \times P_r = G_r G_t P_t \lambda^2$	*multiply both sides by* $(4\pi d)^2$
$(4\pi d)^2 = \frac{G_r G_t P_t \lambda^2}{P_r}$	*divide both sides by* P_r
$4\pi d = \sqrt{\frac{G_r G_t P_t \lambda^2}{P_r}}$	*take square root of both sides*
$d = \frac{1}{4\pi} \times \sqrt{\frac{G_r G_t P_t \lambda^2}{P_r}}$	*fraction rule* *if* $a \times b \times c = d$, *then* $c = \frac{d}{a \times b}$

III. Calculate Wavelength

given that all frequencies are 450 kHz, the wavelength (λ) can be determined before proceeding

$\lambda = \frac{c}{f}$ $c = \text{SPEED OF LIGHT}$ $f = \text{frequency}$	*formula*
$f = 450\ \text{kHz}$ $= 450000\ \text{Hz}$ $= 4.5 \times 10^5\ \text{Hz}$	*convert frequency to Hz*
$c = 3.0 \times 10^8\ \text{m/s}$	*notate speed of light*
$\lambda = \frac{3.0 \times 10^8}{4.5 \times 10^5}$	*input values*

Calculate Distances

perform calculations to determine distance for each specific base station using given formulas and information

<u>Base Station 1</u>

Information

Location	44.012320, −97.109509
Power Transmitted	200 w
Power Received	17.3512367 w
Transmitter Gain	10
Receiver Gain	25
Frequency	450 kHz (4.5×10^5 Hz)

Calculate Distance

$d = \frac{1}{4\pi} \times \sqrt{\frac{G_r G_t P_t \lambda^2}{P_r}}$	*distance formula*
$d = \frac{1}{4\pi} \times \sqrt{\frac{25 \times 10 \times 200 \times \left(\frac{3.0 \times 10^8}{4.5 \times 10^5}\right)^2}{17.3512367}}$	*input known value*
$d = \frac{1}{4\pi} \times \sqrt{\frac{25 \times 10 \times 200 \times 444444.4\overline{4}}{17.3512367}}$	*solve for λ^2*
$d = \frac{1}{4\pi} \times \sqrt{\frac{22222222000}{17.3512367}}$	*multiplication*
$d = \frac{1}{4\pi} \times \sqrt{1.2807284 \times 10^9}$	*division*
$d = \frac{1}{4\pi} \times 35787.27$	*solve for square root*
$d = 2847.860$ m	*multiplication*

Map View

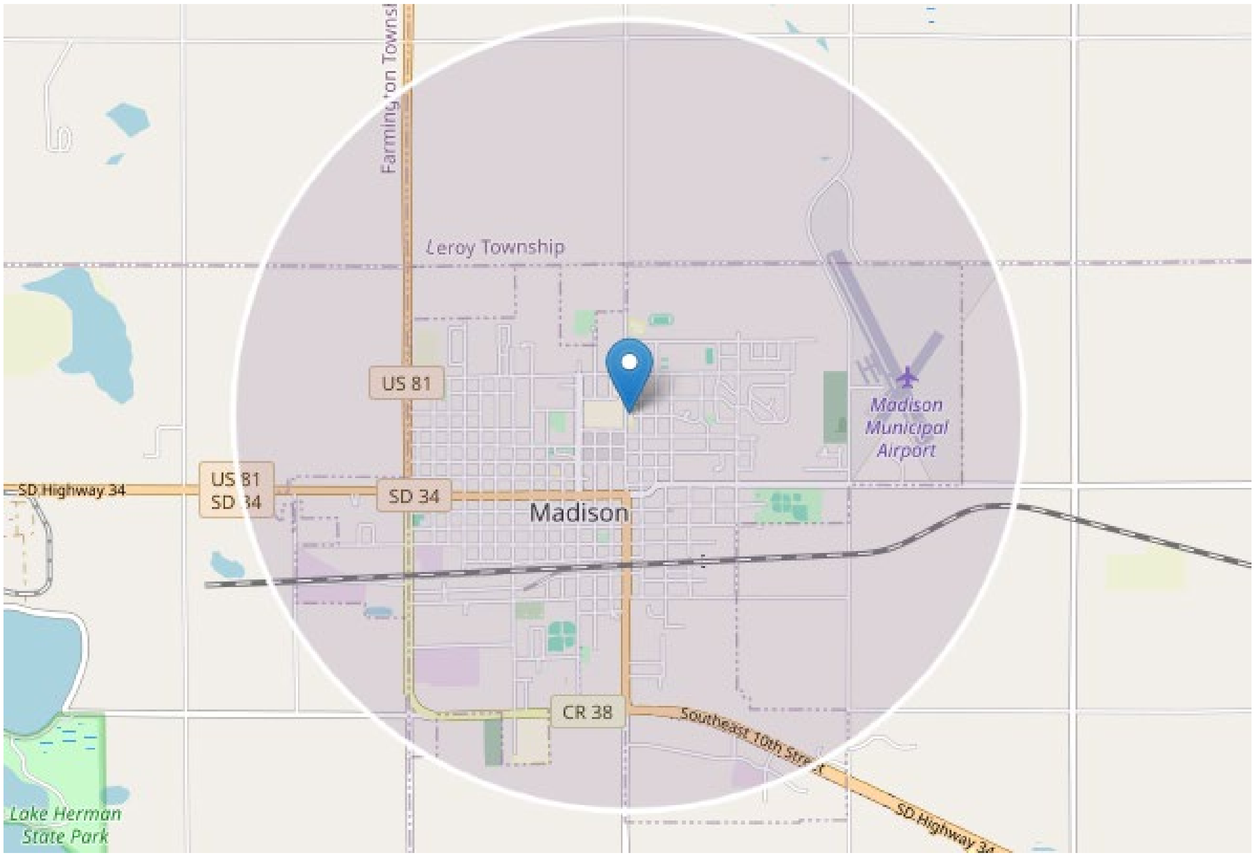

Figure 2: Base 2 | 44.012320, −97.109509, 2847.860m

[View on Map]

Base Station 2:

Information

Location	$44.013371, -97.289582$
Power Transmitted	200 w
Power Received	0.99757704 w
Transmitter Gain	10
Receiver Gain	25
Frequency	450 kHz (4.5×10^5 Hz)

Calculate Distance

$d = \frac{1}{4\pi} \times \sqrt{\frac{G_r G_t P_t \lambda^2}{P_r}}$	*distance formula*
$d = \frac{1}{4\pi} \times \sqrt{\frac{25 \times 10 \times 200 \times \left(\frac{3.0 \times 10^8}{4.5 \times 10^5}\right)^2}{0.99757704}}$	*input known value*
$d = \frac{1}{4\pi} \times \sqrt{\frac{25 \times 10 \times 200 \times 444444.4\overline{4}}{0.99757704}}$	*solve for λ^2*
$d = \frac{1}{4\pi} \times \sqrt{\frac{22222222000}{0.99757704}}$	*multiplication*
$d = \frac{1}{4\pi} \times \sqrt{2.2276196 \times 10^{10}}$	*division*
$d = \frac{1}{4\pi} \times 149252.12$	*solve for square root*
$d = 11877.106\ \text{m}$	*multiplication*

Map View

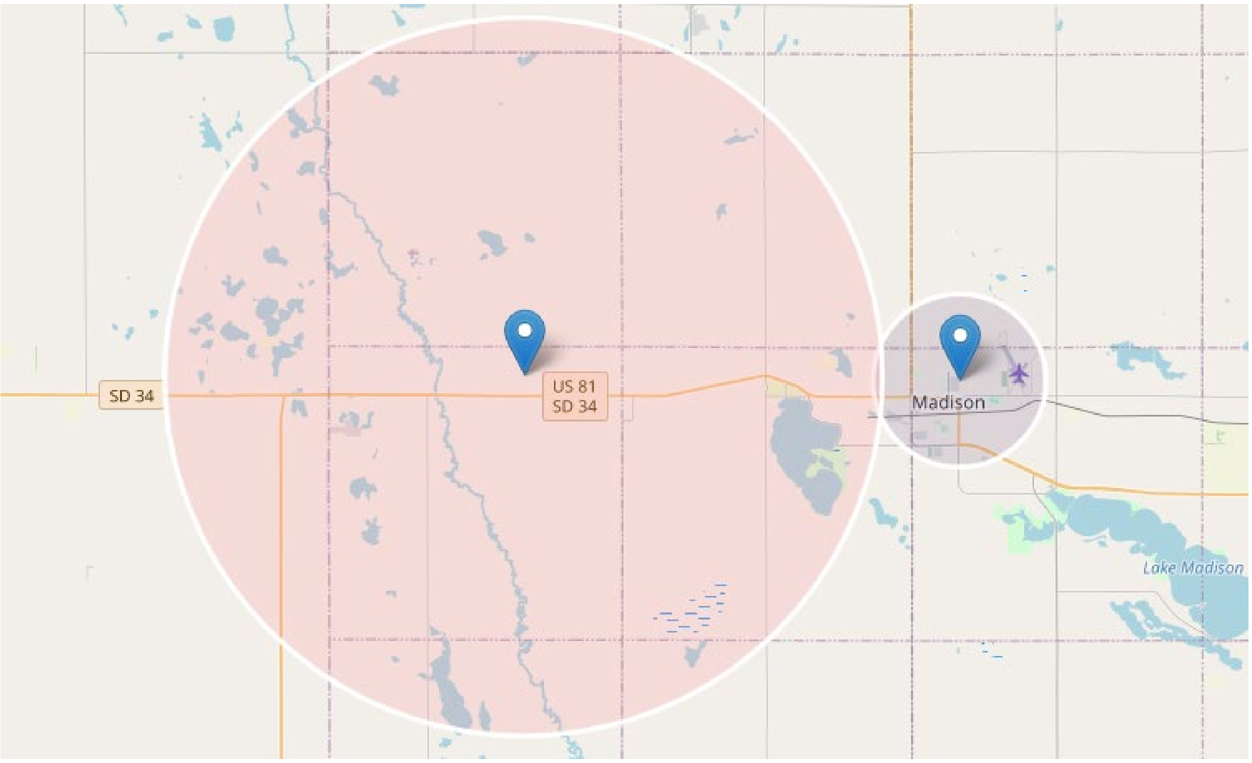

Figure 3: Base 3 | 44.013371, −97.289582, 11877.106m

[View on Map]

Base Station 3:

Information

Location	44.119244, −97.215958
Power Transmitted	200 w
Power Received	0.9337055 w
Transmitter Gain	10
Receiver Gain	25
Frequency	450 kHz (4.5×10^5 Hz)

Calculate Distance

$d = \frac{1}{4\pi} \times \sqrt{\frac{G_r G_t P_t \lambda^2}{P_r}}$	*distance formula*
$d = \frac{1}{4\pi} \times \sqrt{\frac{25 \times 10 \times 200 \times \left(\frac{3.0 \times 10^8}{4.5 \times 10^5}\right)^2}{0.9337055}}$	*input known value*
$d = \frac{1}{4\pi} \times \sqrt{\frac{25 \times 10 \times 200 \times 444444.4\overline{4}}{0.9337055}}$	*solve for λ^2*
$d = \frac{1}{4\pi} \times \sqrt{\frac{22222222000}{0.9337055}}$	*multiplication*
$d = \frac{1}{4\pi} \times \sqrt{2.3800033 \times 10^{10}}$	*division*
$d = \frac{1}{4\pi} \times 154272.59$	*solve for square root*
$d = 12276.623\text{m}$	*multiplication*

Map View

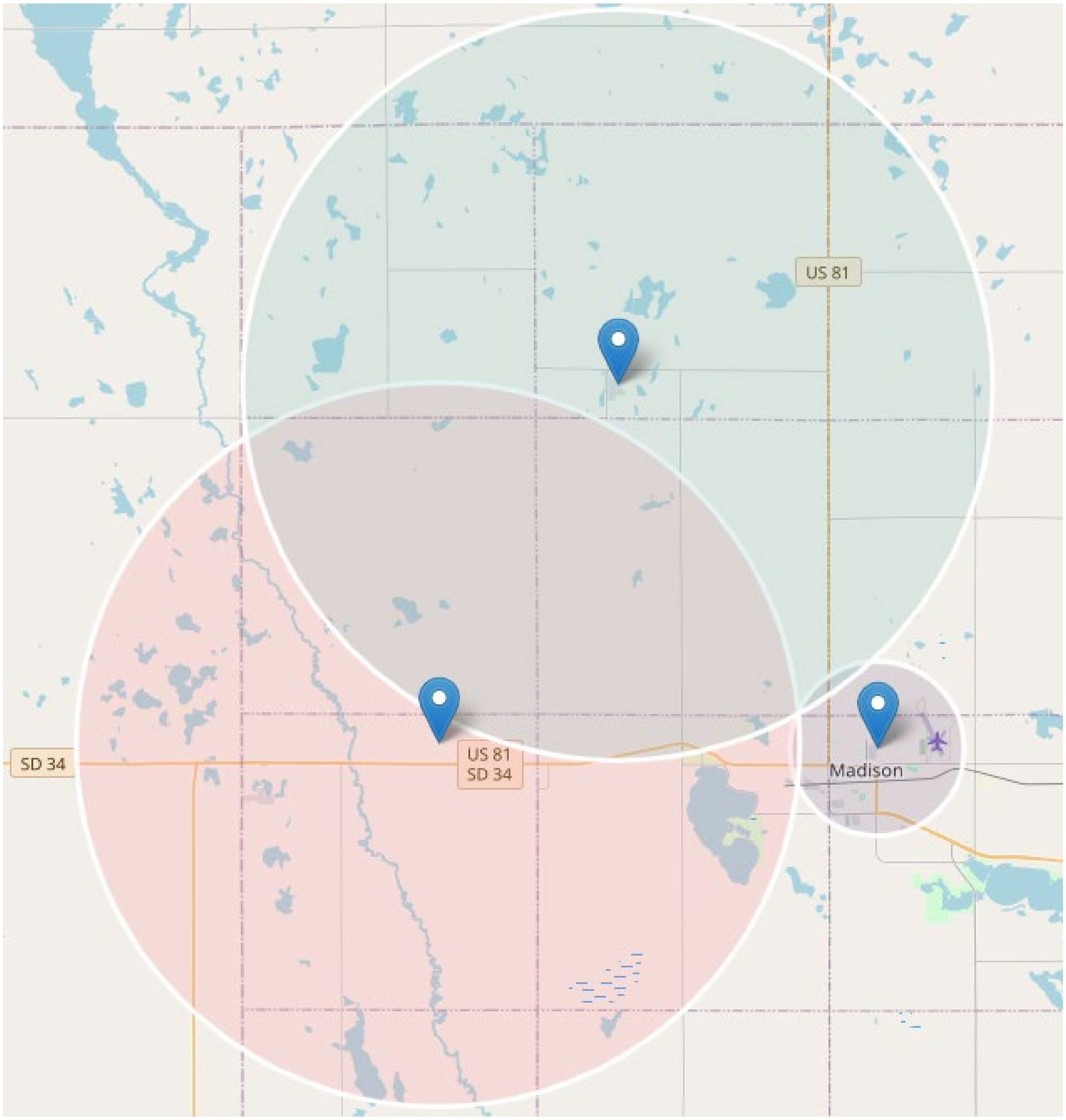

Figure 4: Base 3 | 44.119244, −97.215958, 12276.623m

[View on Map]

Triangulate Mobile Device

use calculated distances to triangulate location of mobile device

In the process of locating the mobile device, circles were overlayed on a map to represent the calculated distances from each individual base station. The convergence point (where these circles intersect) reveals the approximate location of the mobile device. The screenshots below illustrate this process.

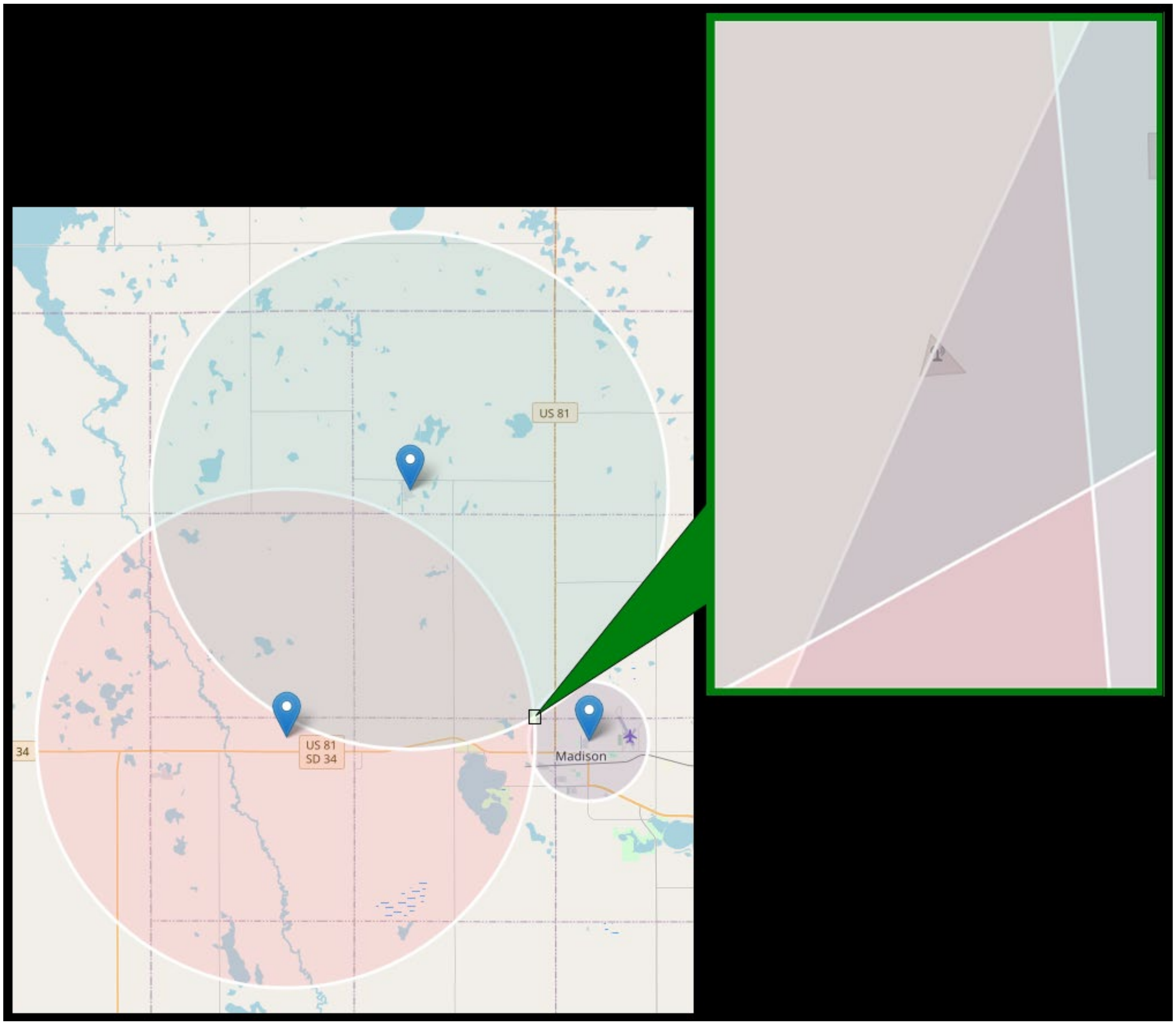

Figure 5: OpenStreetMap view of Convergence Point

The OpenStreetMap (OSM) view shown in Figure 5 displays overlapping circles, with the convergence point outlined. When zooming in on this focal point, a cell tower icon can be seen, which confirms accurate triangulation.

Figure 6: Cell Tower Icon

View on Map

By drawing a circle around this icon, as shown in Figure 6, the exact location is determined to be 44.022843, −97.141968, or 44°01′22.2" N 97°08′31.1"W

Figure 7: Satellite View

View on Map

Figure 8: Street View

[View on Map]

Lastly, by examining Google Satellite View (Figure 7) and Google Street View (Figure 8), the triangulation location is further validated. The Satellite View provides an aerial perspective of the tower, while Street View provides a view from ground level.