EE 495 Report:
A Signal Reception Study of 94.9 KVWV LP in Whatcom and Skagit Counties

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Abstract

The purpose of this project was to gain insight into the signal strength and broadcast radius of Bellingham's newest low power frequency modulation (LFPM) radio station: Bellingham Community Radio KVWV 94.9 FM. The station began streaming online in October 2015 and began broadcasting over the airwaves on February 1st 2016 from its transmitter site in Bellingham, WA. Due to an unresolved technical issue causing a large voltage standing wave ratio (VSWR), the station has been transmitting at less than half its licensed power of 100 Watts effective radiated power (ERP). Using an RTLSDR device to collect quantitative received signal strength data at various locations throughout Whatcom and Skagit Counties, maps were constructed that provide a picture of broadcast reach throughout the region. The report concludes with a critique of the methods chosen as well as advice for future tests conducted when the station broadcasts at its full, licensed power.

Equipment and Parts

- NooElec Software Defined Radio (SDR) NESDR Mini 2+ 0.5 PPM TCXO USB RTL-SDR Receiver with Antenna
- Hyundai Accent Cd Mp3 Player XM Bluetooth Radio 96170-1R150GU
- SDRSharp Software, Version 1.0.0.1430-RTL-SDR
- ASUS Laptop, Model X55LA-BHI5N12

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1 Introduction

This project stems from KVWV's ongoing partnership with Western Washington University (WWU) that involves Electrical Engineering (EE) students in community-engaged learning projects led by Professor Andy Klein since the station's formation in 2015 [1]. These project experiences provide technical support to the station, while providing students an opportunity to acquire first-hand radio experience outside the classroom.

In the first projects, several WWU EE students became heavily involved with the transmitter site selection and construction. This resulted in a student report that evaluated various broadcast locations for the future station which culminated in the decision to place the station's transmitter at the Karate Church located at 519 E. Maple St [2]. Once the location had been decided, this follow-on project was initiated between KVWV and WWU with the goal of conducting a survey of the radio's signal strength after the transmitter was operational. KVWV sought to investigate which communities the radio was able to reach as well as the quality of the signal received. With this knowledge, KVWV could make more informed decisions regarding community-specific programing, and perhaps more importantly give advertisers data about the audiences they can reach via KVWV.

The survey was complicated by the fact that KUOW-FM 94.9, a 100,000 Watt station located at the University of Washington in Seattle, 85 miles south of Bellingham, transmits at the same FM frequency [3]. Consequently, the presence of an in-band interferer made it more challenging to determine the power of KVWV's signal from the static background noise. Before KVWV was on the air, KUOW could be picked up at many locations in the Bellingham area, albeit typically with static noise present. Therefore, the survey needed to include information about when KUOW's signal was being mixed with or dominating the KVWV signal.

I decided that different kinds of data would be needed to complete the best picture of the signal strength in the region. First would be quantitative data of the station's received signal strength, then a qualitative assessment of how audible the signal was, and a second qualitative assessment of how mixed the received signal was with KUOW's signal. These measurements were to each be taken at various points of interest across western Whatcom County and northwestern Skagit County.

From my experience driving in the Skagit and Whatcom Counties listening to other Bellingham

based stations, I predicted that due to the current VRWS problem KVWV's signal could only be received in Bellingham and communities to the north of Bellingham with a high degree of clarity and little interference from KUOW. I also predicted that as one travels south from Bellingham that KOUW would eventually become the dominant signal likely taking over around the town Edison if travelling down Chuckanut Drive or around Mile 235 if travelling south on Interstate 5.

2 Method and Procedure

I began collecting data using a car to travel to various locations across Whatcom and Skagit Counties and using the car radio to make qualitative measurements and using the RTLSDR along with the SDRSharp software to make quantitative measurements on my laptop. The RTLSDR sent digital information to my computer about the radio signals it received and the SDRSharp software allowed me to see graphical representation of the data as well as perform various analyses such as Signal to Noise Ratio calculations. I connected the USB cable to the RTLSDR and set the antenna in a fixed position, stretched as far away as possible from my laptop computer. This was done to prevent the laptop from acting as an antenna, which could strengthen or interfere with the received signal. I made sure all measurements were made in this configuration to keep the data as standardized as possible without introducing additional variables. For the same reasons, all measurements were made with all of the car doors closed. The method I chose to decide where to make measurements was based on trying to collect data in the centers of the communities I visited as well as when I heard a significant change in the signal at 94.9 FM. I pulled off to the side of the road and record the data values for both 94.9 FM and 92.9 FM.

I chose to measure this second station, 92.9 FM KISM, because their transmitter is one of the highest powered radio signals in Whatcom County rated at 50,000 Watts [4]. The collected data indicating where KISM's signal became inaudible could represent the maximum boundary for which KVWV hopes to be able to broadcast when broadcasting from the Karate Church at full strength. This prediction should only provide a rough estimate as the KISM transmitter is located on Orcas Island, approximately 15 miles east of Bellingham, but should provide a better estimation model than a high powered station based in Seattle or Vancouver BC.

When using the SDRSharp software I selected settings that I used as the standard for each measurement recorded. These settings are listed in Table 2.1 and were not altered as I made measurements.

Table 2.1: Selected SDRSharp Settings for Measurements

Setting Name:	**Entry:**
Radio	WFM
Shift	Disabled
Filter	Blackman-Harris 4
Bandwidth	200000
Order	250
FM Stereo	Disabled
Output	MME
Latency (ms)	100
Unity Gain	Disabled
Filter Audio	Disabled
View	Both
Window	Blackman-Harris 4
Resolution	32768
Spectrum Style	Static Gradient
S-Attack	1
S-Delay	1
W-Attack	10
W-Decay	8.5
Speed	7.5

First I chose to examine the quantitative measurement, Signal to Noise Ratio (SNR), which the SDRSharp software calculates from the input from the RTLSDR. SNR is a ratio of the power of the radio station signal and the power of the background noise signal [5]. This value is measured in units of decibels (dB) and the higher the SNR the clearer and more audible the signal. Before completing my sweep test, I found that signals measured to be the mid-twenties or higher (in decibels) tended to be very clear while signals with an SNR of less than 5 dB where heavily distorted and often inaudible.

The first of the two qualitative measurements made, was how free the signal was from static and distortion. I refer to this as the qualitative strength of the signal. I applied this method to both, 92.9 and 94.9 and made the measurement regardless if I could hear KVWV or KUOW. These measurements were made on a four-point scale. Locations with the least amount of distortion present were labeled *Clear Signal*. Next, I labeled signals that were still audible but suffered some distortion and static *Moderate Static*. Signals with heavy static and-or high distortion but were still audible (this was judged as to whether I could make out words being spoken or sung) were labeled *High Static*. Finally, signals whose words spoken were indecipherable were labeled as *Inaudible*.

To complement this measurement, I included a qualitative measurement of how much it 94.9 was made up of KVWV's signal and how much was made up of KUOW's signal. I refer to this as the qualitative signal isolation. This was represented as different five states. The first was labeled *Exclusive KVWV* if no signal of KUOW was present. Likewise, the *Exclusive KOUW* was used when no signal from KVWV was present. If the signal was predominantly KVWV with some overlap of KUOW the signal was labeled *KVWV Dominant*. Similarly, if KUOW was the predominant signal but was mixed with some KVWV it was labeled *KOUW Dominant*. If the signals from the two stations were approximately equal the signal was labeled *Equally Mixed*. This metric was not recorded for 92.9 FM as at no point did I pick up any signal other than KISM at this frequency.

I have included these data visually as well. For each measurement location a marker has been placed on the included maps. The shape of the marker implies whether KVWV or KUOW was the stronger signal. For locations measured as *Exclusive KVWV* or *KVWV Dominant* the marker is represented by a star. Locations measured as *Exclusive KUOW* or K*OUW Dominant* the marker are represented by a square. The locations where the signals were *Equally Mixed* a diamond marker is used. The color of the marker indicates the clarity of the signal. Markers representing locations with *High Static* or *Inaudible* signals are red in color, while markers representing locations with a *Clear Signal* or *Moderate Static* are represented with green markers.

3 Results

All the measurements were taken on February 28th 2016. The weather was partly sunny with a high of 54 degrees Fahrenheit and a low of 45 degrees Fahrenheit. The measurements were taken between 3:00 PM and 10:00 PM. Each data point collected is represented in Table 3.1, Figure 3.1 and

Table 3.2. This includes the approximate street address or intersection, Global Positioning System (GPS) Coordinates, and the quantitative and qualitative metric assessments of each station.

Table 3.1: Radio Sweep Results per Location

Location Address:	**Location GPS:**		**Station:**	**SNR:**	**Qualitative Strength:**	**Qualitative Signal Isolation:**
Bellingham Airport	Latitude	48.7956526	94.9	6.5	Clear Signal	Exclusive KVWV
	Longitude	-122.5330734	92.9	21	Clear Signal	
6000 Portal Way	Latitude	48.8588352	94.9	8.6	Moderate Static	KVWV Dominant
Ferndale	Longitude	-122.5839204	92.9	30	Clear Signal	
8071 WA-539	Latitude	48.7956526	94.9	11.6	Moderate Static	Equally Mixed
Lyden	Longitude	-122.5330734	92.9	23.2	Clear Signal	
E Wiser Rd and Lake rd	Latitude	48.9088081	94.9	6.9	High Static	Equally Mixed
Lyden	Longitude	-122.4558378	92.9	29.9	Clear Signal	
144 River Rd	Latitude	48.9202269	94.9	7.5	High Static	KUOW Dominant
	Longitude	-	92.9	26.1	Clear Signal	

		122.488048				
203 W Main St	Latitude	48.9201171	94.9	7.7	Moderate Static	KVWV Dominant
Everson	Longitude	-122.3426588	92.9	23.8	Clear Signal	
S Pass and Liebrant Rd	Latitude	48.9202407	94.9	10.1	Clear Signal	Exclusive KOUW
Nooksack	Longitude	-122.2766997	92.9	17.6	Moderate Static	
Siper Rd and Hopell Rd	Latitude	48.883666	94.9	10.1	Moderate Static	Exclusive KOUW
	Longitude	-122.292996	92.9	17.4	Moderate Static	
Lawrence Rd and Hatley Rd	Latitude	48.850512	94.9	6.8	Moderate Static	Equally Mixed
Everson	Longitude	-122.287558	92.9	33.1	Clear Signal	
5048 Mt Baker Hwy	Latitude	48.823302	94.9	7.5	Clear Signal	Exclusive KOUW
Deming	Longitude	-122.2126702	92.9	15.2	Moderate Static	
Valley Hwy & Park Rd	Latitude	48.6601234	94.9	15.5	Clear Signal	Exclusive KOUW

	Longitude	-122.2125464	92.9	14.3	High Static	
3959 S Bay Dr,	Latitude	48.66898459	94.9	8.4	High Static	Exclusive KOUW
Sedro-Woolley	Longitude	-122.280639	92.9	10	Inaudible	
Alger Cain Lake Rd Coal Bunker Rd	Latitude	48.6189344	94.9	3.3	High Static	Exclusive KOUW
Sedro-Woolley	Longitude	-122.3282316	92.9	4.8	Inaudible	
Bow Hill Rest Area	Latitude	48.5832455	94.9	6.8	Clear Signal	Exclusive KOUW
Bow	Longitude	-122.344214	92.9	26.2	Clear Signal	
5521 Chuckanut Dr	Latitude	48.5656209	94.9	15.9	Clear Signal	Exclusive KOUW
Bow	Longitude	-122.4218329	92.9	18.8	Moderate Static	
Pigeon Point,	Latitude	48.6162188	94.9	10.8	Moderate Static	Exclusive KOUW
Chuckanut Dr	Longitude	-122.444333	92.9	29.9	Clear Signal	

Yacht Club Rd	Latitude	48.6749474	94.9	11.2	High Static	KUOW Dominant
Chuckanut Dr	Longitude	-122.4880769	92.9	27.8	Clear Signal	
Iris Lane	Latitude	48.7099065	94.9	10.6	Moderate Static	KVWV Dominant
Chuckanut Dr	Longitude	-122.4996592	92.9	25.3	Clear Signal	
401 Harris Ave	Latitude	48.7204595	94.9	7.9	Clear Signal	Exclusive KVWV
Fairhaven	Longitude	-122.5111067	92.9	32.6	Clear Signal	
Mill Ave and 11th St	Latitude	48.7208906	94.9	8.1	Clear Signal	Equally Mixed
Fairhaven	Longitude	-122.5033925	92.9	31.7	Clear Signal	
State and 12th St	Latitude	48.7294144	94.9	4.8	Clear Signal	KVWV Dominant
Bellingham	Longitude	-122.5027433	92.9	32.1	Clear Signal	
Viking Union	Latitude	48.738511	94.9	29.1	Clear Signal	Exclusive KVWV
WWU	Longitude	-122.485631	92.9	35.5	Clear Signal	

Karate Church	Latitude	48.7446462	94.9	31.4	Clear Signal	Exclusive KVWV
Bellingham	Longitude	-122.47696989	92.9	5.5	Inaudible	
Wade King Recreation Center	Latitude	48.7315046	94.9	10.5	Moderate Static	Exclusive KVWV
WWU	Longitude	-122.4889433	92.9	28.5	Clear Signal	
310 N Samish Way	Latitude	48.7391179	94.9	20.4	Clear Signal	Exclusive KVWV
Bellingham	Longitude	-122.4693627	92.9	23	Clear Signal	
N State St & E Holly St	Latitude	48.7484268	94.9	42.5	Clear Signal	Exclusive KVWV
Bellingham	Longitude	-122.4770955	92.9	28.3	Clear Signal	
Broadway & W Holly St	Latitude	48.7577588	94.9	35.7	Clear Signal	Exclusive KVWV
Bellingham	Longitude	-122.4914347	92.9	27.7	Clear Signal	
Marine Dr & Ferndale Rd	Latitude	48.791795	94.9	5.8	Clear Signal	Exclusive KVWV
Bellingham	Longitude	-	92.9	27.8	Clear Signal	

		122.59525				
Haxton Way and Kwina Rd,	Latitude	48.7938049	94.9	7.9	Moderate Static	Mixed Signal
Lummi Reservation	Longitude	122.6350893	92.9	29.8	Clear Signal	
Haxton Way & Southgate Rd	Latitude	48.743211	94.9	9	High Static	KVWV Dominant
Lummi Reservation	Longitude	-122.6667923	92.9	36.2	Clear Signal	
Lummi View Dr & Blackhawk Way	Latitude	48.7258192	94.9	6.5	High Static	Equally Mixed
Lummi Reservation	Longitude	-122.6587604	92.9	32.4	Clear Signal	
Lummi Shore Rd & Smokehouse Rd	Latitude	48.7466714	94.9	16.8	Clear Signal	Exclusive KVWV
Lummi Reservation	Longitude	-122.6251323	92.9	20	Clear Signal	

Figure 3.1: Graphical Representation Table 3.1, Locations of Measurements

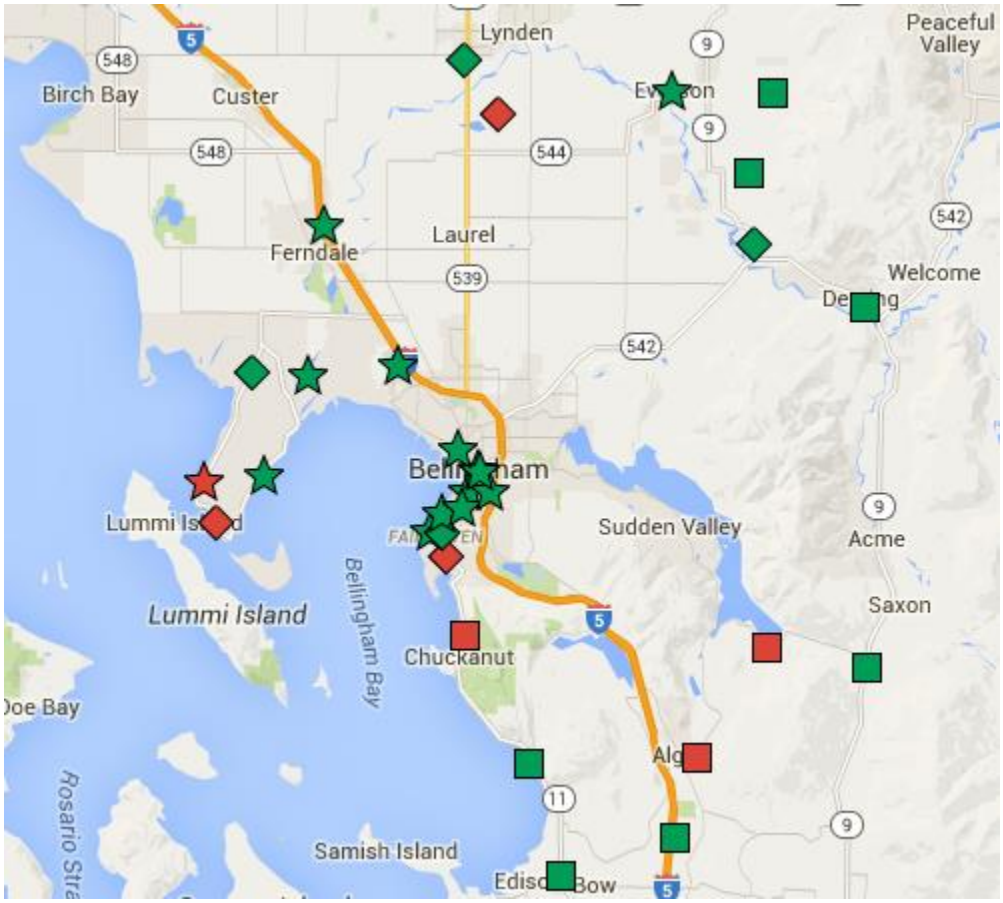


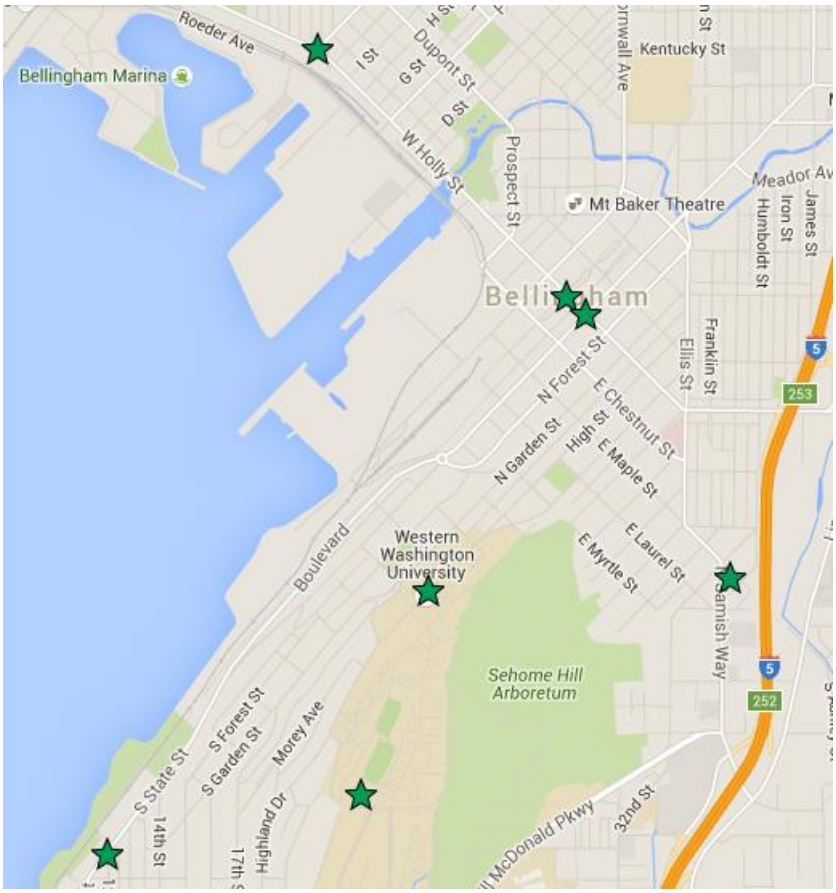
Table 3.2: Graphical Representation Legend

Color Evaluation	
★	*Moderate Static* or *Clear Signal*, and *KVWV Clear* or *KVWV Dominant* Signal
★	*High Static* or *Inaudible* Signal, and *KVWV Clear* or *KVWV Dominant* Signal
◆	*Moderate Static* or *Clear Signal*, and *Equally Mixed* Signal
◆	*High Static* or *Inaudible* Signal, and *Equally Mixed* Signal
■	*Moderate Static* or *Clear Signal*, and *KUOW Clear* or *KUOW Dominant* Signal
■	*High Static* or *Inaudible* Signal, and *KUOW Clear* or *KUOW Dominant* Signal

4 Discussion

Perhaps the best way to analyze the data gathered in the sweep is by grouping it into geographical regions from Figure 3.1. First, The City of Bellingham itself is considered as this is the location KVWV was established to provide service to. The data points here can be seen in Figure 4.1. Fairhaven and Chuckanut Drive form another region extending down to the town of Bow, Figure 4.2. The next region is made up of Marine Drive and the Lummi Reservation not including Lummi Island. These points can be seen in Figure 4.3. Then the communities of Ferndale, Lynden, Everson and Nooksack form another region and finally Deming, Acme, Saxon and Alger make up the final region of interest, these points are seen in Figure 4.4.

Figure 4.1: Bellingham Measurement Locations



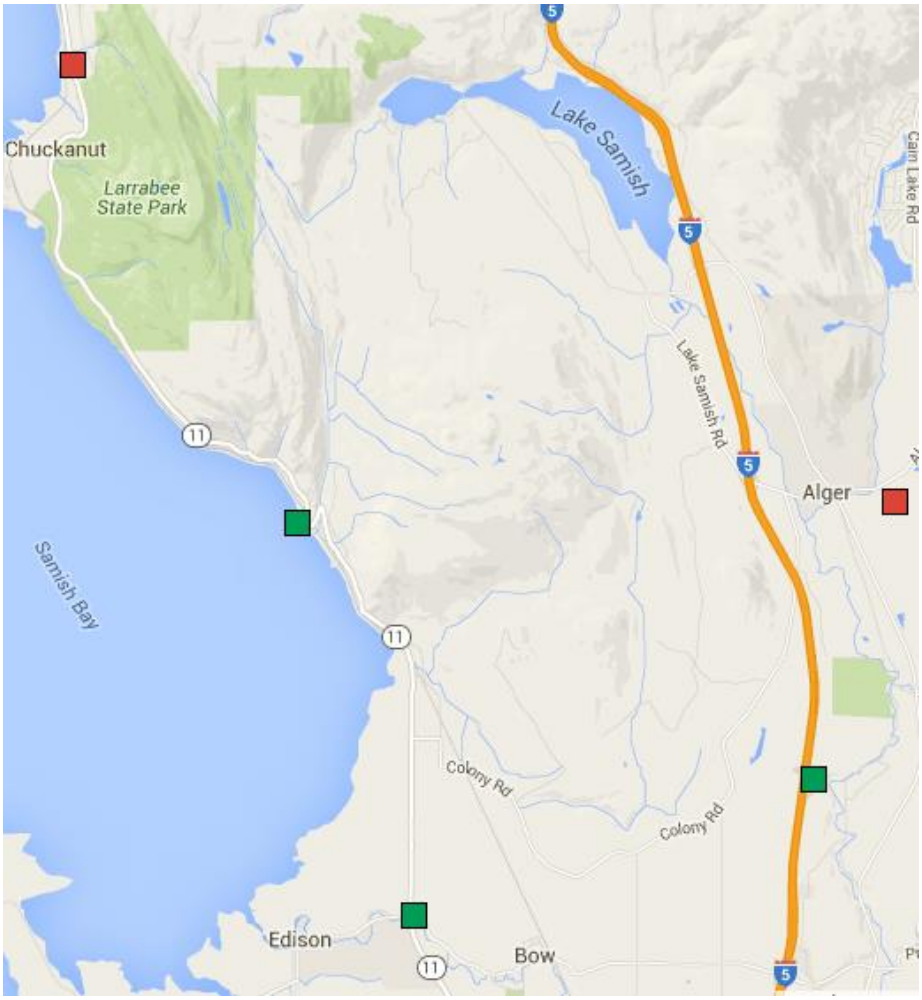
Despite functioning at one third of desired power the City of Bellingham happens to be covered with clear signals of KVWV at 94.9 FM. From the Airport to Downtown Bellingham I was not able to

detect any traces of KUOW's broadcast. The only place where I had brief disruptions in the signal with static was on the south side of Sehome Hill. The hill provides a large amount of elevation between the broadcast point and the listener. When KVWV begins to operate at full power I do not expect much change in what residents and travelers within the city will hear but perhaps areas of slight static will dissipate.

Figure 4.2: Fairhaven (a.) and Chuckanut Drive (b.) Measurement Locations

(a.)

(b.)



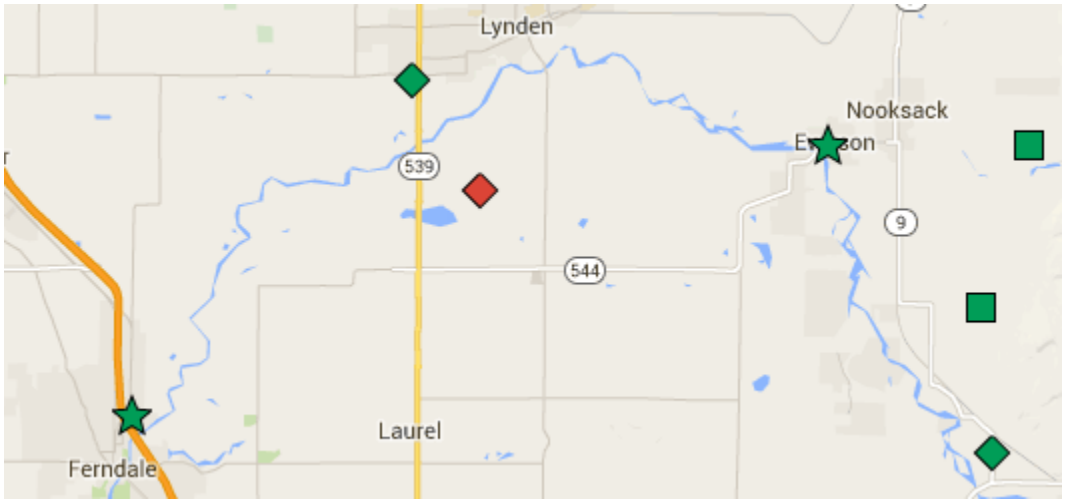
In Fairhaven I believe that the signal will be much improved by a boost in power by KVWV. As I drove up it was not until Yacht Club Dr that I was able to pick KVWV over a strong KUOW signal. As I approached and eventually entered Fairhaven as seen in Figure 4.2 by several close measurements, KUOW and KVWV's dominance over the signal went back and forth, though I was able to make out KVWV a majority of the time. Only momentarily did I lose the KVWV signal altogether which shows that KVWV's signal is reaching residents but a boost in power should greatly increase the quality of the signal and extend the range much further south.

Figure 4.3: Highway 9 Measurement Locations

The communities of Deming, Acme, Saxon and Alger reside to the East and South of Lake Whatcom behind a set of large hills. Through my drive down Highway 9 through the data points in Figure 4.3, I was unable to detect KVWV and had trouble picking up KISM. However, I was able to pick up various Seattle stations including KUOW with surprising clarity. I was able to hear Seattle stations with even better clarity than I am usually able to hear in areas much closer to Seattle such as Bremerton. I believe that this was caused by the hills located between my position and Bellingham. Perhaps the

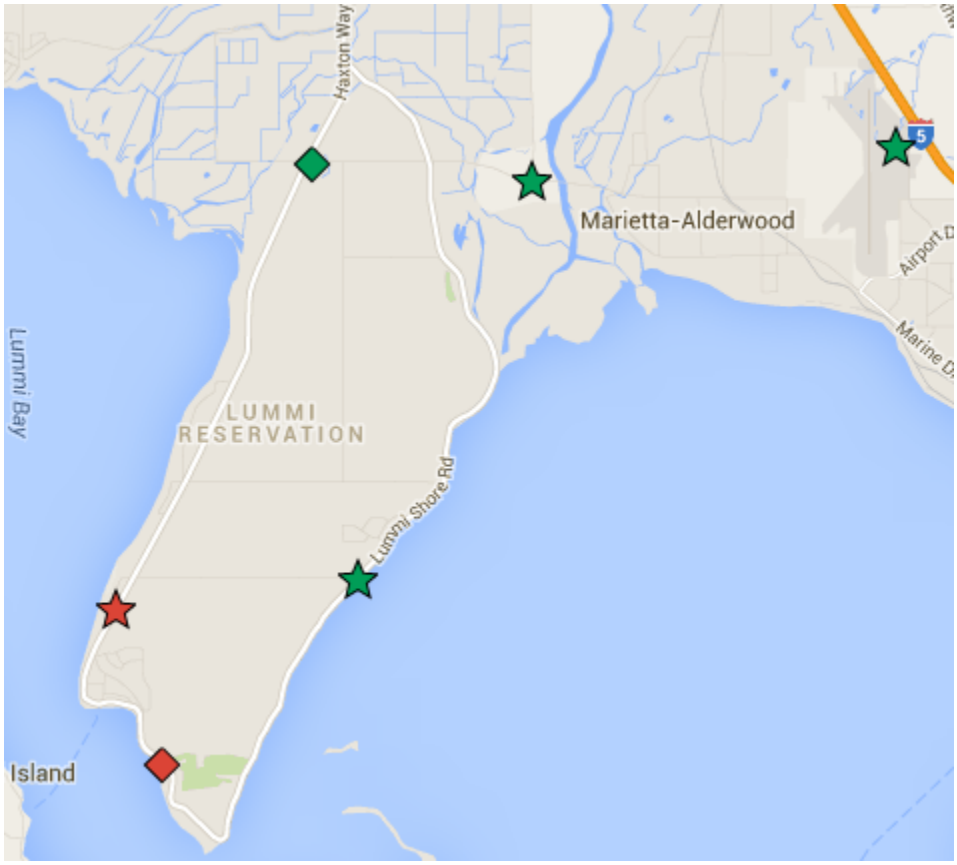
valley's topography also fostered constructive interference for the Seattle based signals. My conjecture is that even with a full power transmitter at the Karate Church, KVWV should not carry much hope for reaching these communities.

Figure 4.4: Ferndale, Lyden, and Everson Measurement Locations



The locations shown in Figure 4.4 had predominantly mixed signals between KUOW and KVWV. However I believe that since these locations are much farther from where KUOW broadcasts than the other regions analyzed, that KVWV should have a good chance of reaching many of these communities when broadcasting at full power.

Figure 4.5: Lummi Reservation Measurement Locations



The measurements locations shown in Figure 4.5 demonstrated two kinds of received signals. Those areas southeastern side of the peninsula had very clear KVWV reception, with no trace of KUOW's signal. Inland, and on the other side of the peninsula the signal was heavily mixed with the signal from KUOW and featured static as well. As soon as I turned the around the point on the south the peninsula where I could visually see the Bellingham I instantly had a clear KVWV signal. It is unclear at this point whether full power at the transmitter could reach the Lummi reservation in full due to the topography of the landscape that gave this strange response.

Within the collected data there exist outliers of interest. One of the most interesting is that next the broadcast location for KVWV (the Karate Church) the signal for KISM becomes inaudible despite being a very strong signal throughout the rest of Bellingham and beyond. The SNR drops to its lowest point for KISM anywhere during my testing with a value of 5.5 dB. This is likely due to the localized high power of KVWV's transmitter. Another outlier of interest was the 94.9 signal at State Street and 12th Street which had a very low 4.8 dB SNR (one of the lowest values) despite having a very clear signal.

One explanation for this could be that there is interference that does not reconstruct the signal, such as narrow band interference. Also interesting is that the SNR is highest, not next to the broadcast location, but closer to downtown Bellingham, particularly the intersection of N State Street and East Holly which has an SNR of 42.5, almost 10 dB higher than the next highest value recorded. This likely implies some kind of constructive interference, possibly caused by larger building in the downtown area.

As one of the project's goals was to identify improvements that could be made when completing a similar signal survey when KVWV is broadcasting near its intended ERP of 100 Watts, I offer the following suggestions.

The first suggestion would be to include more locations of interest. With the power increasing up to twofold, a larger area will likely be needed to give the best information about what communities can be reached by KVWV. Building upon this, there were communities left out by my sweep which still need data on signal strength, notably Lummi Island, Portage Island, Birch Bay and areas directly east of Bellingham such as Sudden Valley.

Perhaps my most highly recommended suggestion is that when completing future sweeps of Whatcom and Skagit Counties signal investigators should highly consider using a team of at least two. One driver and another person to record data and operate the instruments. This would allow for much higher quantities of data points to be taken in far less time. The other more pressing reason is that many of the roads and highways offered few locations to pullover and make measurements. When they did there was often dangerously small distances between shouldered vehicles and passing traffic. Highway 9, Chuckanut Drive and Park Road proved the most difficult to find safe locations to record data with just one person driving and operating instruments.

One variable that I did not account for weather. Perhaps during future data collection, multiple tests could be performed varied collections based upon levels of cloud cover and temperature. These are both factors that can have an effect on radio transmission and thus received signal strength [5].

5 Conclusion

The most useful data for determining whether residents or travelers in a particular area will be able to listen to KVWV was, not surprisingly, the qualitative analyses of signal clarity and signal isolation. Unfortunately, because of the competing signal from KUOW, there was little correlation

between the quantitative SNR data and the ability to tune in to KVWV. That being said, there is a correlation between SNR and audibility for KISM. Patterns in these results indicate potential signal strength results for a fully powered KVWV broadcast as both transmitters are located in the Bellingham area.

The results from this survey should give the organization of KVWV a better grasp of where their signal is currently reaching, and some insights into where it will and will not be able to reach. I believe that when KVWV is broadcasting at full rated power, the techniques and suggestions detailed in this report will be beneficial to future signal investigators.

References

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