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Turbo Tuner for "Screwdrivers" -- Ad

Which HAM Radio Antenna is the Best Choice for Point to Point Communication?

Using Readability, Signal Strength and S-Units as Criteria
By Heather Cox (KB8VYQ)
Submitted to the 42nd Annual Southeastern Michigan Science Fair 2000
Received American Statistical Association Certificate of Recognition Award

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Summary

The question I posed for this experiment was: for point to point radio communication, what type of antenna: the original "rubber duck", half wave or directional yagi will be the most effective. I examined the directivity and the polarization of the three antennas by testing four directions and turning the radio vertical and horizontal to the ground (polarization). Using the RST scale (readability, signal strength, and tone scale, we are not using the tone scale because this is a voice transmission not Morse code so it doesn't apply and s-units (found on most HAM radios) to measure the readings. The original "rubber duck " antenna was the one with the lowest readings, the half wave antenna had medium readings and the yagi had the highest readings. The yagi was the most effective antenna proven by the readings.

Introduction

Radio communication has become ubiquitous in today's society. It is not uncommon to walk into a store and see an employee with a radio or a family on vacation using radios to keep in touch. Many people use hand held radios but not everyone who does, has a good understanding of how they work. Amateur Radio was one of the first groups using the airwaves. Amateur Radio was begun by Guglielmo Marconi who started the "Age of Wireless". He used Morse code with equipment that was large and heavy, not exactly portable. Now we use small hand held HAM radios but one component remains critical. As in Marconi's time, without an antenna the radio will not transmit or receive signals.

An antenna is a type of transducer. The word "transducer" derives from two Latin words meaning "to lead across" or "to transfer". Transducers transfer or convert one form of energy to another. Antennas convert radio-frequency electric current to electromagnetic waves. Antennas can either transmit or receive electromagnetic waves.

The performance of an antenna is characterized by three important properties:

Feed point impedance - Impedance can be considered an AC resistance. The impedance of the radio has to match the impedance of the antenna.

Directivity, gain and efficiency - Directivity is the property of the antenna radiating more strongly in some directions than others. Gain is related to directivity. The gain is the power loss subtracted from the power supplied to the antenna; most antenna have a high efficiency therefore gain is basically equal to directivity.

Polarization - The polarization of an antenna is defined to be that of it's electric field, in the direction where the field strength is maximum. Two common types of polarization are vertical and horizontal, perpendicular and parallel to the ground.

In this experiment I will attempt to prove that the antenna with the most forward gain is the antenna that is most effective for point to point communication. This demonstration will give me a better understanding of how antennas work. The performance of the antennas will be measured and the effects of polarization will be studied. The results can be used to explain why some of the family radios don't work as well as advertised because of improper use of antennas.

Experimental

Fist you need to get the materials, which are the following:

· Two 70 cm radios with fully charged battery pack:

UHF FM transmitter HTX-404 (with 0-9 S-unit scale)

FM transceiver IC-T8A (with 0-9 S-unit scale)

· Rubber duck antennas (the original antennas that came with the radios)

· Kunckleduck half wave 70 cm antenna

· Cushcraft A270-6S 2 meter/70 cm Yagi antenna with mast

· RST scale (readability, signal strength, and tone scale, we are not using the tone scale because this is a voice transmission not Morse code so it doesn't apply)

Readability	Signal Strength
1 unreadable	1 faint weak signals barely perceptible
2 barely readable, occasional words distinguishable	2 very weak signals
3 readable with considerable difficulty	3 weak signals
4 readable with practically no difficulty	4 fair signals
5 perfectly readable	5 fairly good signals
	6 good signals
	7 moderately strong signals
	8 strong signals
	9 extremely strong signals

Next you follow these steps:

1. Set up radio communication stations. Station one has a radio with three alternate antennas, a person to perform the experiment, a RST scale (see materials), and a log sheet to record results. Set up station two such that the distance between the two stations yields a medium reading (about a three on the readability scale, about a one on the signal strength scale, and about a one on the s-unit scale) with the rubber duck antenna. At station two you have another person with radio which to send data and monitor transmissions.

2.First test the rubber duck antenna.

3. Start at 0 degrees (the approximate direction of station two).

4. Hold the radio about head height and make sure that the antenna is perpendicular to the ground (vertical). Have the other person count to five while transmitting (called a five count). This should be enough time for you to read the s-units level, the readably and the signal strength from the RST scale. Record readings. Now you give a five count for station two so they can obtain data and then transmit it back to station one.

5. Turn the radio counterclockwise making the radio and antenna horizontal to the ground. Be sure to still hold the radio about head level. Follow step 4 for transmitting and recording data.

6. Rotate 90 degrees clockwise and repeat steps 4 and 5.

7. Rotate 90 degrees clockwise (180 degrees from your starting point of 0 degrees) and repeat steps 4 and 5.

8. Rotate 90 degrees clockwise (270 degrees for your starting point of 0 degrees) and repeat steps 4 and 5.

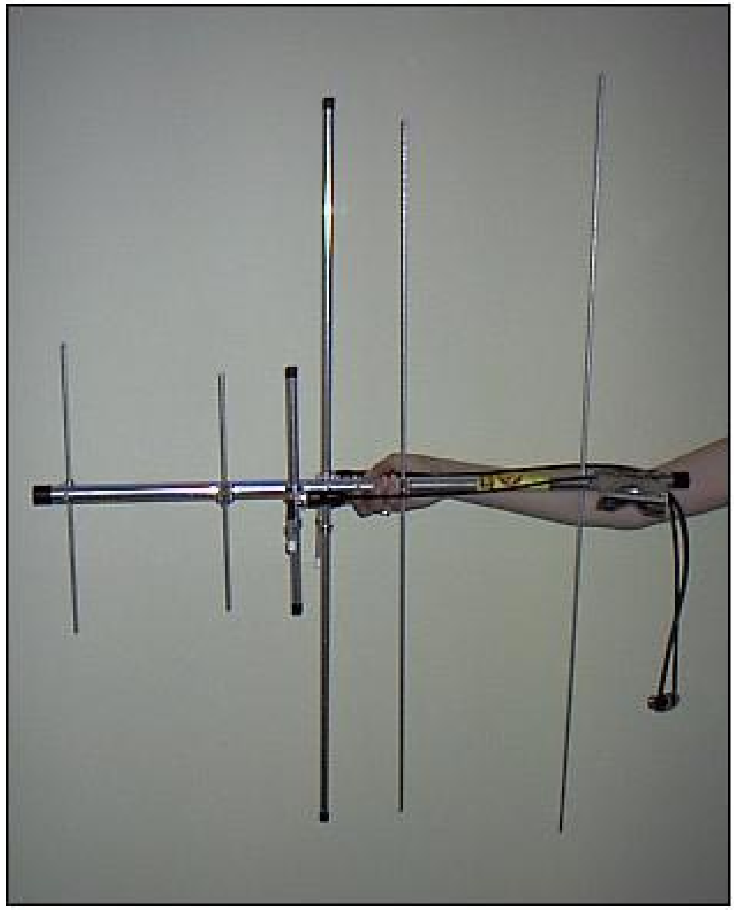
9. Repeat steps 2 through 8 with the half wave and yagi antennas.

10.Analyze data by adding the data points (RS and S-units) from each antenna test to get a total efficiency score. The numbers can be added since the readings have the same number scale, symbolizing the same thing (a perfect signal would be 46), and draw conclusions.

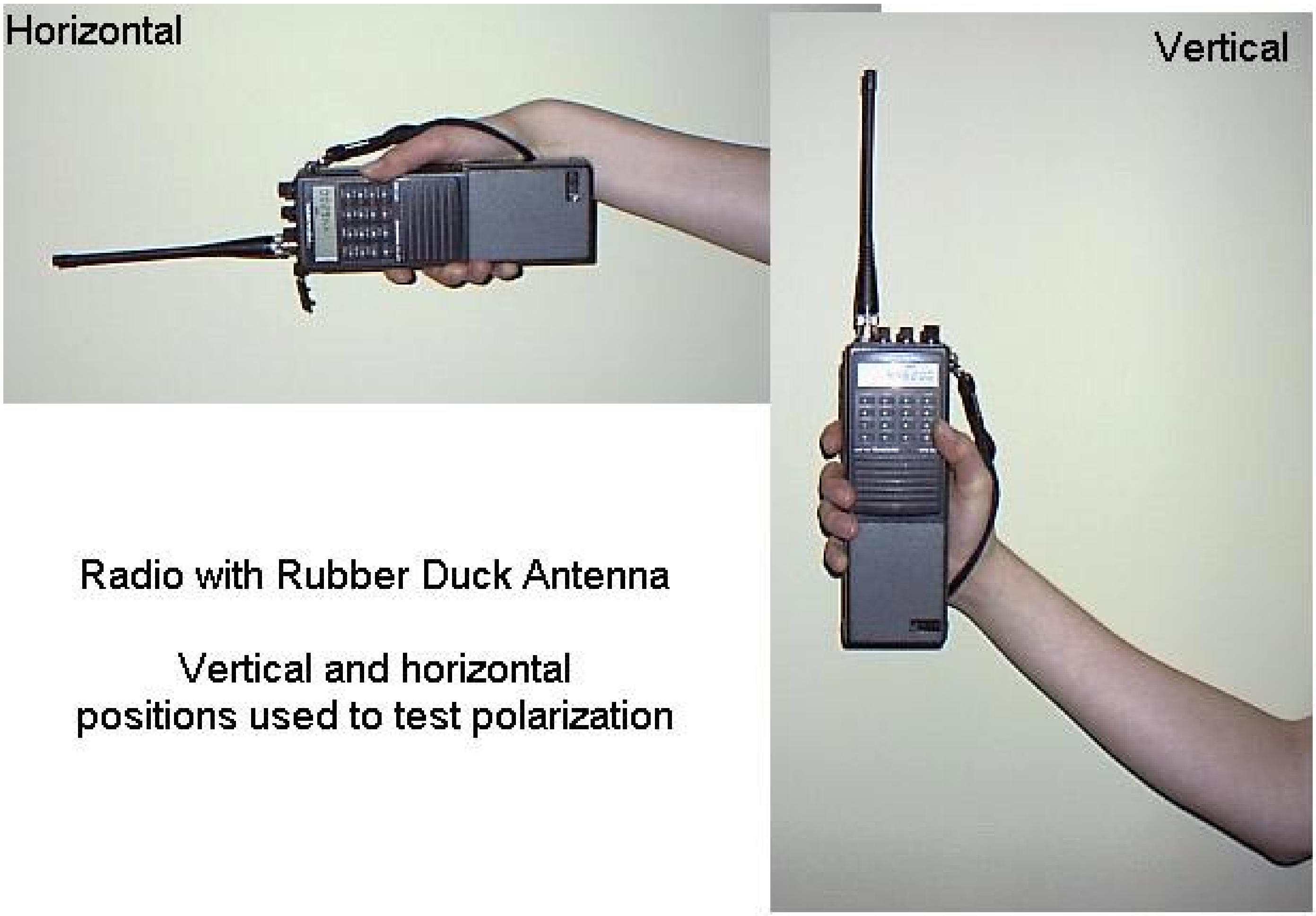
Rubber Duck

Half Wave

Antenna Types



Yagi



Discussion

Results

Total Scores	rubber duck	half wave	yagi
Direction 0 degrees vertical	19	37	45-46
Direction 0 degrees horizontal	14-15	24-29	18-20
Direction 90 degrees vertical	13	28-33	29-36
Direction 90 degrees horizontal	9	17	14-19
Direction 180 degrees vertical	19	16-25	23-30
Direction 180 degrees horizontal	19-20	23-26	28-32
Direction 270 degrees vertical	14	28-29	31-35
Direction 270 degrees horizontal	15-16	23-26	19-26

For these results I added the readability, signal strength, and s-unit readings together to rule out individual variation. It essentially averages the readings for each test and yields a single number for comparisons.

The results show that the yagi antenna worked the best. I concluded this because the yagi had the highest total score out of the three antennas in most of the four directions and polarization test (see Polarization and Directional Charts).

In general all the antennas transmit better when they are vertical to the ground as opposed to horizontal when station two's antenna is in the vertical position.

The rubber duck antenna that comes with most radios is designed to be adequate for general use. The rubber duck performed poorly in this experiment. It scored the lowest in the polarization test and in the Summary Chart.

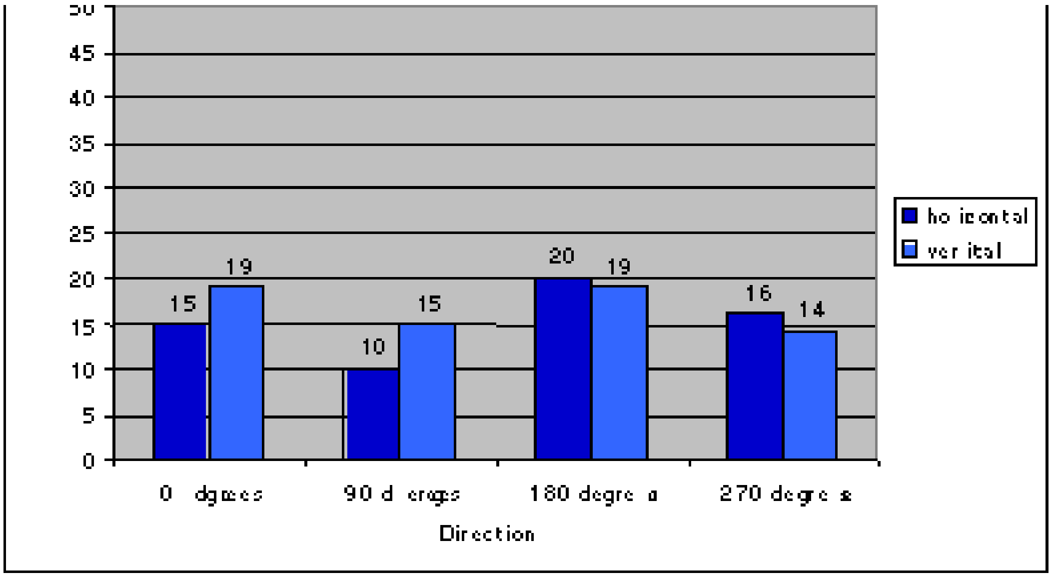
The half wave antenna is electrically a better radiator because it does not need a ground plane; however, it is generally longer and more bulky that the rubber duck. The half wave antenna scored fair in this experiment. It scored "medium" results for the polarization test and Summary Chart (in general it was between the yagi and the rubber duck). It transmitted the best when at 0 degrees vertical with a score of 37, and the worst when held at 90 degrees horizontal with a score of 17.

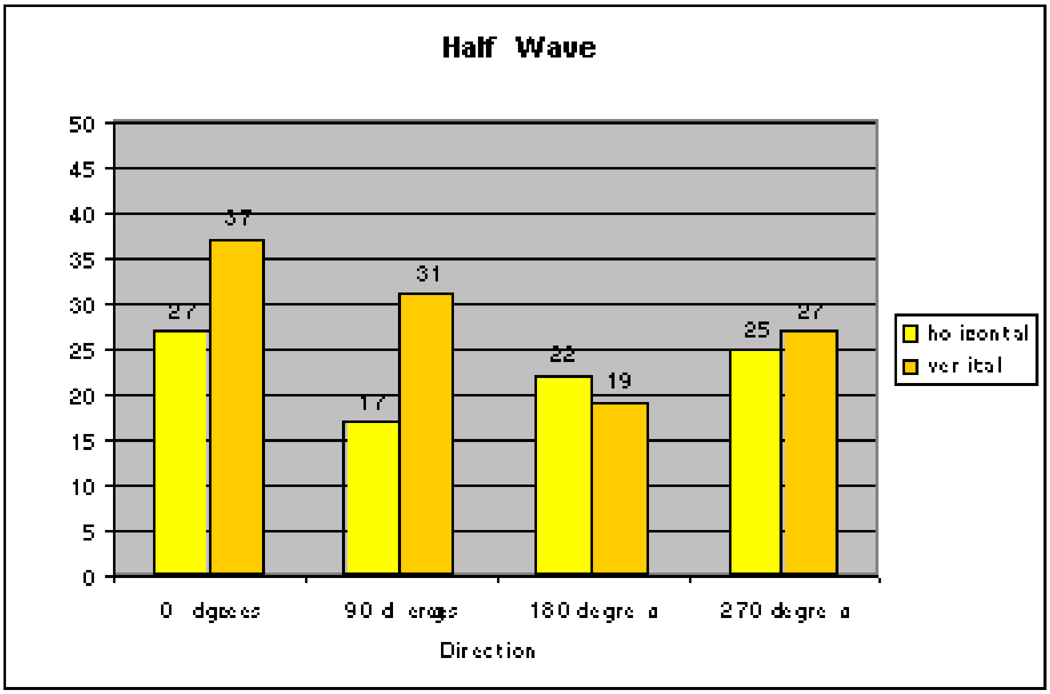
The yagi is very effective focusing the radio frequency energy in a forward direction (forward gain), again, it is much bigger than a rubber duck or half wave. The yagi performed very well in this experiment. It received the best scoring when at 0 degrees vertical polarization with a score of 46. The worst reading was at 90 degrees horizontal polarization with a score of 17. The yagi antenna transmitted best when at vertical polarization.

When the radio antennas were vertically polarized they transmitted best at 0 degrees. The readings at 90 degrees and at 270 degrees were about the same. The lowest scores were recorded at 180 degrees. When the radio antennas were horizontally polarized they transmitted best at 180 degrees and lowest at 90 degrees.

Direct radio signals are much better received when both antennas are in the same position, both vertical or both horizontal. Once a signal becomes scattered polarization is no longer a major factor in signal transmission or reception. This explains why the yagi at 180 degrees horizontally polarized performed adequately.

Polarization Test Aggregate Scores


50
45
40
35
30
25
20
15
10
5
0
15
19
10
15
20
19
16
14
0 dgrees
90 d ergs
180 degre a
270 degre s
Direction
ho izontal
ver ital


Half Wave
50
45
40
35
30
25
20
15
10
5
0
27
37
17
31
22
19
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0 dgrees
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180 degre a
270 degre a
Direction
ho izontal
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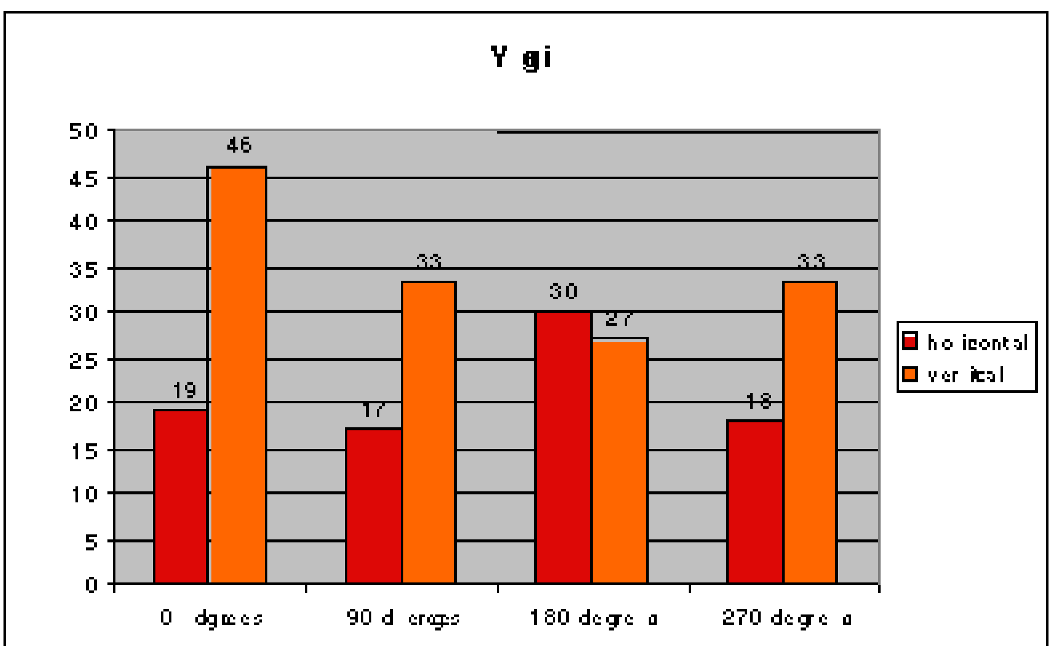
Y gi
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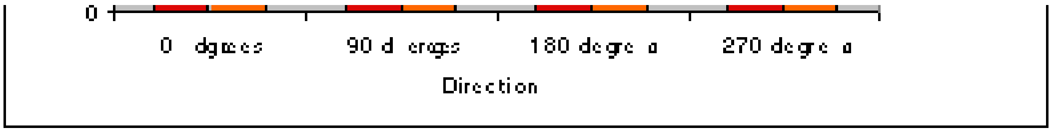
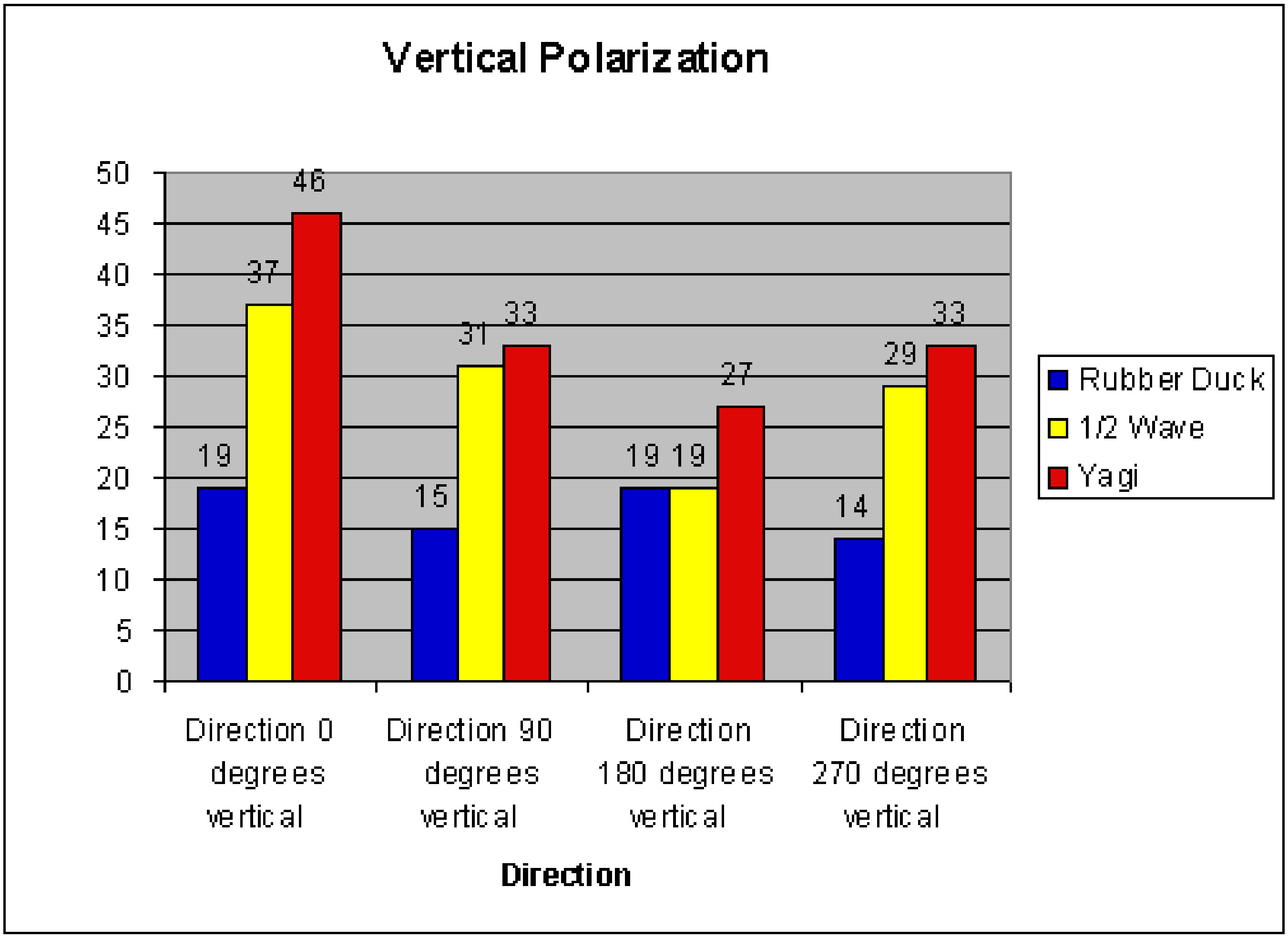
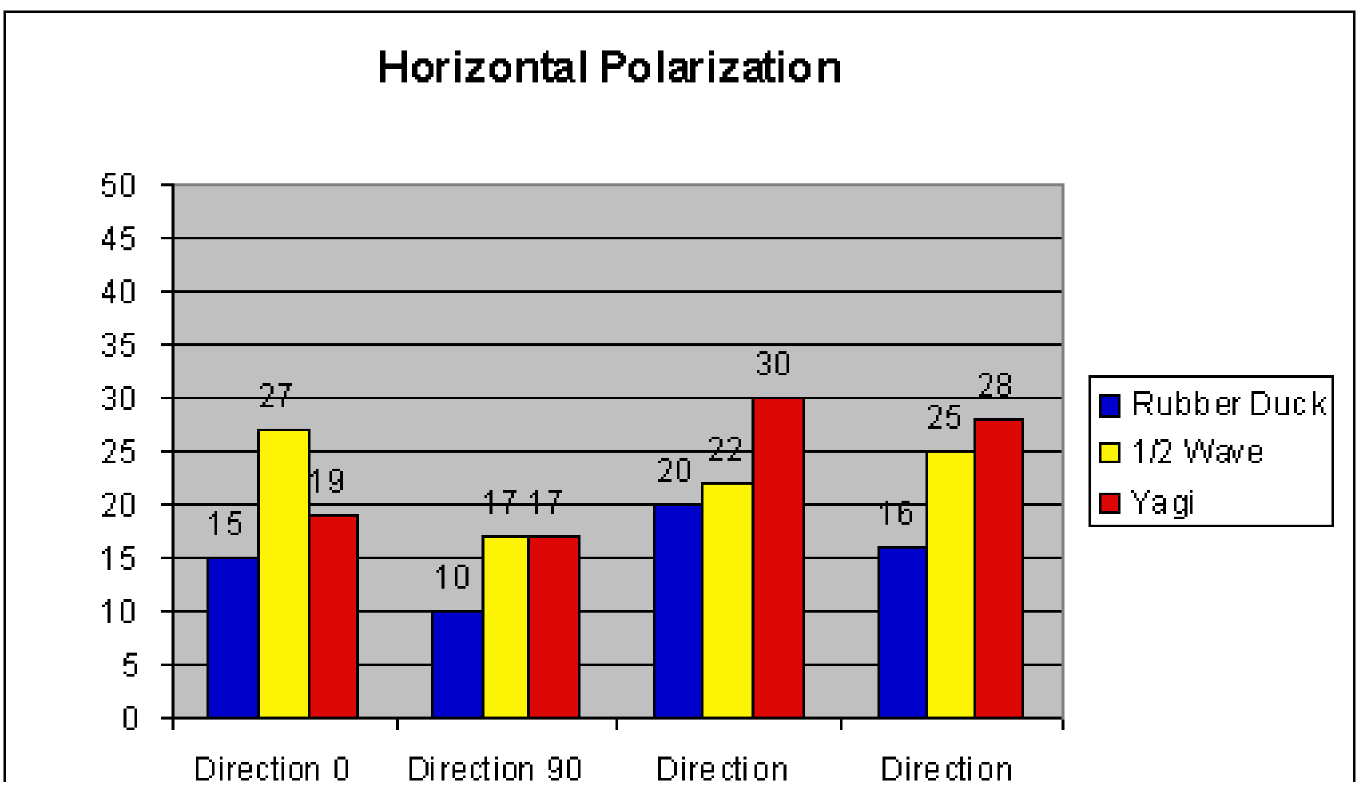
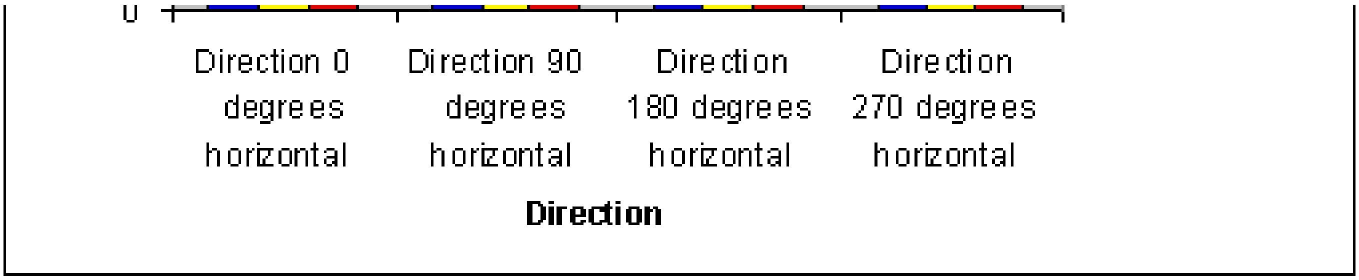
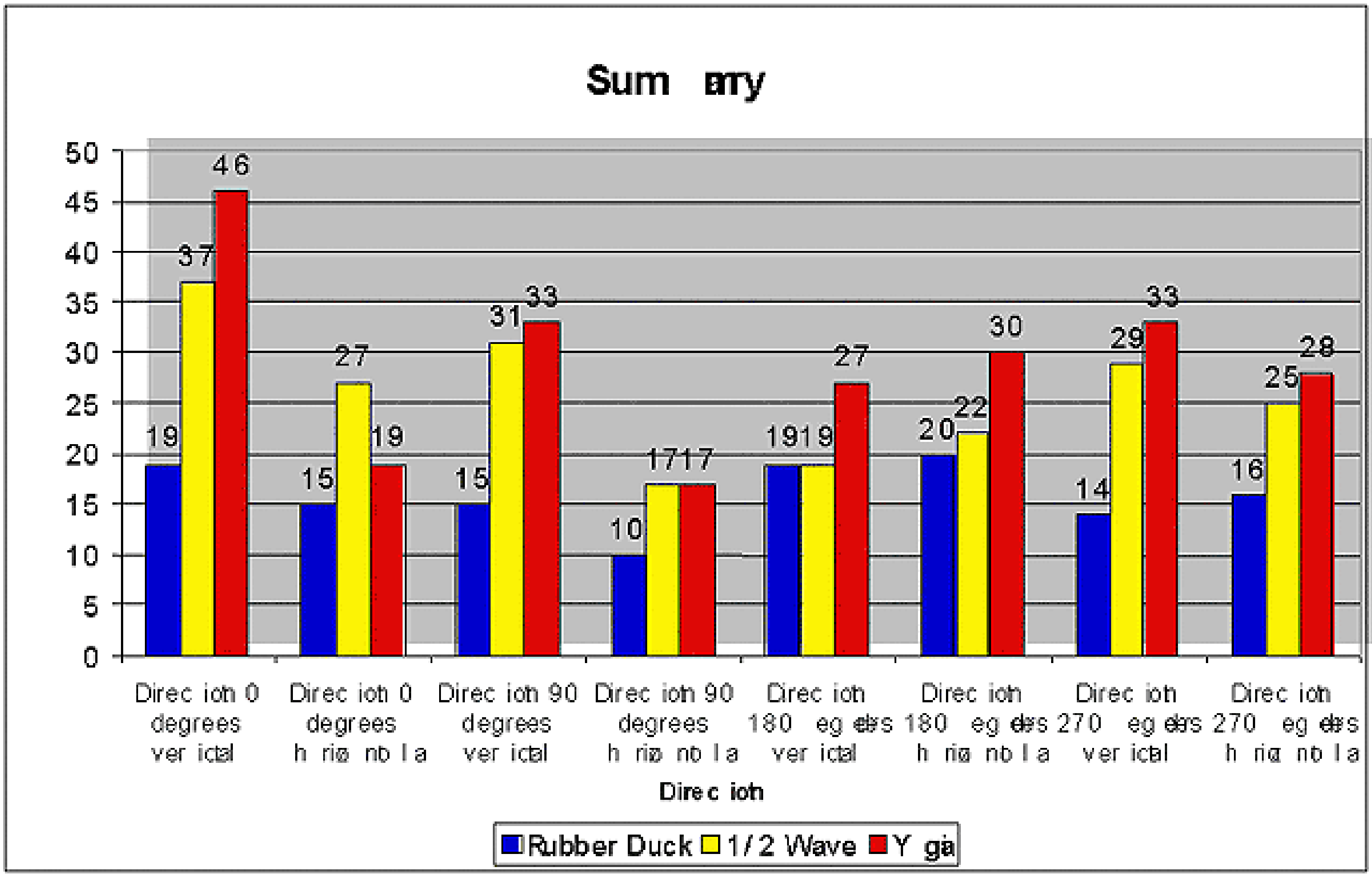

0
Direction


Vertical Polarization
50
45
40
35
30
25
20
15
10
5
0
19
37
46
15
31
33
19 19
27
14
29
33
Direction 0 degrees vertical
Direction 90 degrees vertical
Direction 180 degrees vertical
Direction 270 degrees vertical
Direction
Rubber Duck
1/2 Wave
Yagi


Horizontal Polarization
50
45
40
35
30
25
20
15
10
5
0
15
27
19
10
17 17
20
22
30
16
25
28
Direction 0
Direction 90
Direction
Direction
Rubber Duck
1/2 Wave
Yagi



Direction Test Aggregate Scores



Sources of Error

There are several sources of error in this experiment. The weather was a factor; the windy conditions and temperature changes caused inconsistent results. In addition keeping the antennas pointed in the correct position was difficult due to the wind. This is know as atmospherics and is impossible to control completely. Another source of error was we did not have direct line of sight between the two stations. Buildings, trees and other structures could have interfered with the signals, unless you live on a prairie this is a common condition that scatters radio waves. This can actually be used beneficially for radio communications to reflect a signal for better transmission. The yagi antenna must be positioned ten feet off the ground to be effective, which is about six feet higher than the antennas attached to the radio, which is another source of error.

Conclusion

My hypothesis was correct in predicting that the yagi antenna would be the antenna with the best performance. The rubber duck antenna that comes with most radios is designed to be adequate for general use. The half wave antenna is electrically a better radiator because it does not need a ground plane; however, it is generally longer and more bulky that the rubber duck. The yagi is very effective focusing the radio frequency energy in a forward direction (forward gain), again, it is much bigger than a rubber duck or half wave.

Demonstrating that the antenna with the most forward gain performs the best helps us to understand how radio transmission works. Holding the radio in the correct position or replacing the original antenna will help maximize radio communication. Understanding the importance of an antenna can help users get the performance promised by the manufacture. Holding both radios vertically and facing each other is a good start to efficient radio communication.

Credits and References

I would like to thank Doug Cox (N8ZLR) for his time and help in performing this experiment.

The ARRL Antenna Book, The American Radio Relay League, Newington CT 06111, © 1991 16th edition third printing

The ARRL Antenna Book, The American Radio Relay League, Newington CT 06111, © 1997-8 18th edition second printing

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Jessop, G.R. (G6JP)

VHF / UHF Manual, Radio Society of Great Britain, © 1994 fourth edition

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