RADIO STATION YSJW
RADIO CADENA MI GENTE, AM 700
EL SALVADOR, CA

INTRODUCTION: This document has been prepared to display the performance characteristics of an EH Antenna used for radio Station YSJW. Like so many places in the world, the economics of installing a new radio station is primarily dictated by the cost of available real estate. If the cost is prohibitive in the area of the target audience, then outside the immediate area the cost of real estate is less, but the choice locations may still be prohibitive. In any case, if the amount of land is significantly reduced by the use of an antenna that does not require radials, then the economic profile of the radio station becomes very desirable.

This is the case in El Salvador where land values are high unless the land is not usable for any purpose, except perhaps scattered farming such as bananas or coffee beans. El Salvador is a very hilly area created by old volcanoes. Therefore, outside the major metropolitan area of San Salvador, the peaks and valleys are severe and do not allow sufficient flat areas for radials, except on top of hills. These are the factors that led the owner to choose the EH Antenna. As an example of the terrain at the site, one of the three guy anchors is about 20 feet below the tower base and one is about 12 feet above the tower base.

The availability of land becomes more acute when you consider that this radio station operates at 700 KHz, thus each buried radial must be 351 feet in length. For 120 radials there must be a circle covering 8.9 acres. However, land is typically purchased in square blocks, thus the total acreage required would be 11.3 acres if you could only purchase exactly what is needed.

LOCATION: The antenna is located on the side of a mountain at latitude $13^{O}45'42''$ North and longitude $89^{o}13'19.5''$ West. Figure 1 displays the antenna in its environment. It is visible in the photograph just above the white sign. Figure 2 was taken from Google Earth looking across San Salvador to the mountain. In spite of the adverse location, the performance is exceptional.

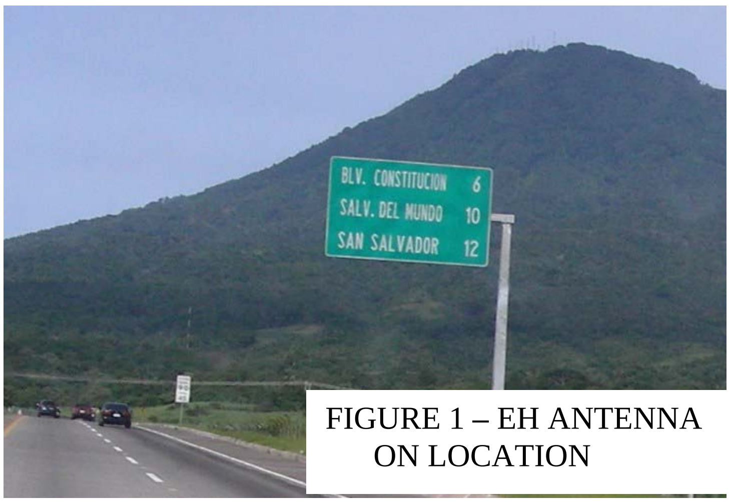


FIGURE 1 – EH ANTENNA ON LOCATION

BROADCAST COVERAGE: Unfortunately, there are only limited roads in this mountainous area, thus a conventional road survey of field strength measurements is not practical. The only alternative is to use a reference source and compare the field strength to that source. In this instance there is a "conventional" antenna on top the hill with buried radials. That station operates on a frequency of 540 KHz and a power level of 5500 watts while the power applied to the EH

Note: This station is no longer on the air. The EH Antenna was destroyed in a storm.

Antenna was 2500 watts. Comparative measurement were made over a wide area, and then plotted on a map. That map is included in the appendix under the heading of "PERFORMANCE CHARACTERISTICS OF RADIO STATION YSJW".

FIGURE 2

FIGURE 3 – LOOKING UP THE HILL

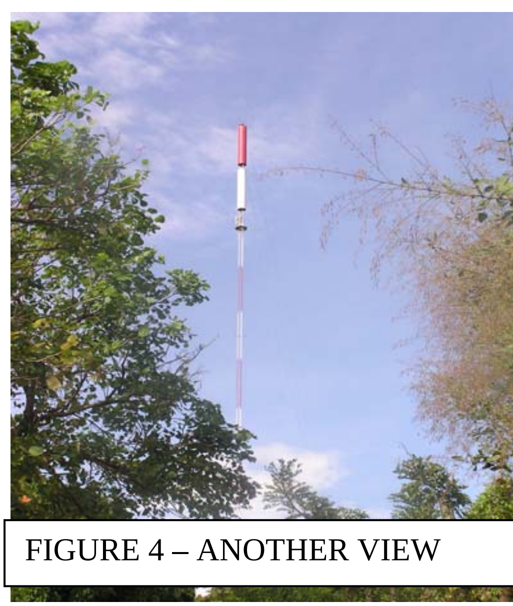


FIGURE 4 – ANOTHER VIEW

TECHNICAL CONCEPT: Because the EH Antenna is a new concept in antenna theory, a technical explanation is included. Figure 5 displays the effective radiating portion of an antenna (any antenna), which is simply a capacitor in series with the radiation resistance. The bandwidth of the antenna is related to the amount of capacity and the resistance, the greater either of them is, the greater the bandwidth. For this reason the EH Antenna uses large cylinders in contrast to thin wires used in conventional antennas, and employs a unique configuration for developing the E and H fields to enhance the radiation resistance.

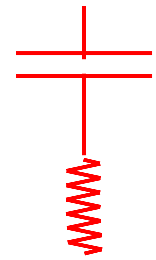


FIGURE 5
EH ANTENNA EQUIVALENT CIRCUIT

To be able to pass current through the radiation resistance it is necessary to cancel the reactance of the capacitor. This may be done by adding a series inductance having the same value of reactance as the capacitor at the desired operating frequency. This creates a series resonant circuit as shown in Figure 6. The inductor (coil) can be tapped to provide a convenient 50 ohm match to allow use of a coaxial transmission line. The complete antenna is depicted in Figure 7.

Figure 8 portrays the large cylinders that comprise the antenna. The tuning coil is located below the lower cylinder.

To illustrate the impedance of the antenna as a function of frequency, Figure 9 is a

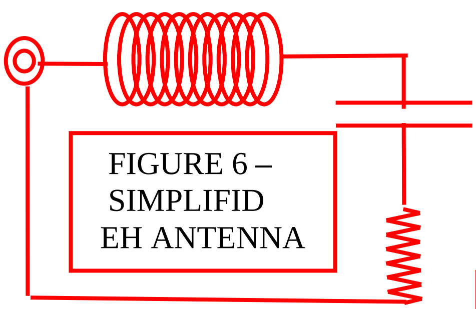


FIGURE 6 – SIMPLIFID EH ANTENNA

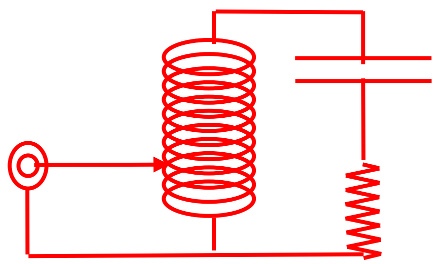
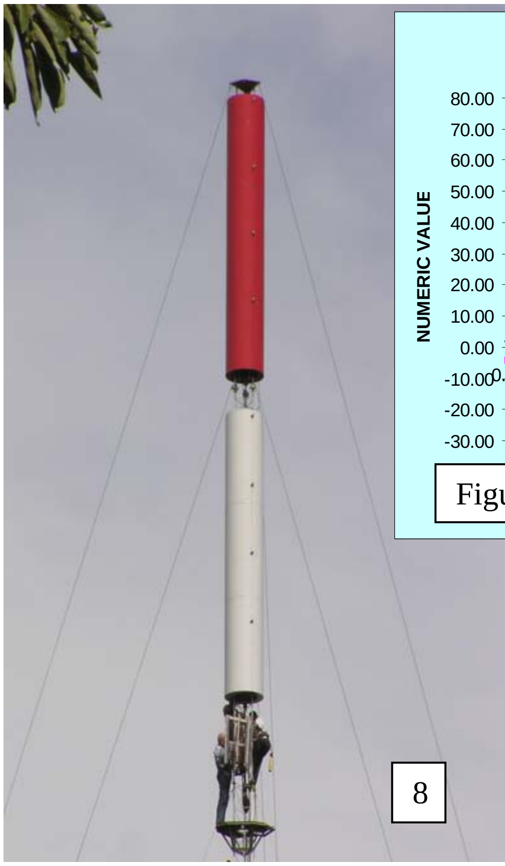


FIGURE 7 – COMPLETE EH ANTENNA

plot of input resistance, reactance, and VSWR x 10 for an AM Broadcast antenna that is operating at 700 KHz. It should be noted that it is only necessary to change the inductance of the tuning coil to allow the antenna to operate at any frequency between 500 and 1200 KHz. A smaller antenna is available for use above 1200 KHz. The graph was taken from a set of equations written to define the antenna, which has been incorporated into a computer program. Measurements of the completed antenna provide similar characteristics as shown in the appendix. Notice that the resistance peaks as compared to a conventional antenna which has almost constant resistance over a wide frequency range. For this reason the EH Antenna virtually eliminates harmonic radiation.



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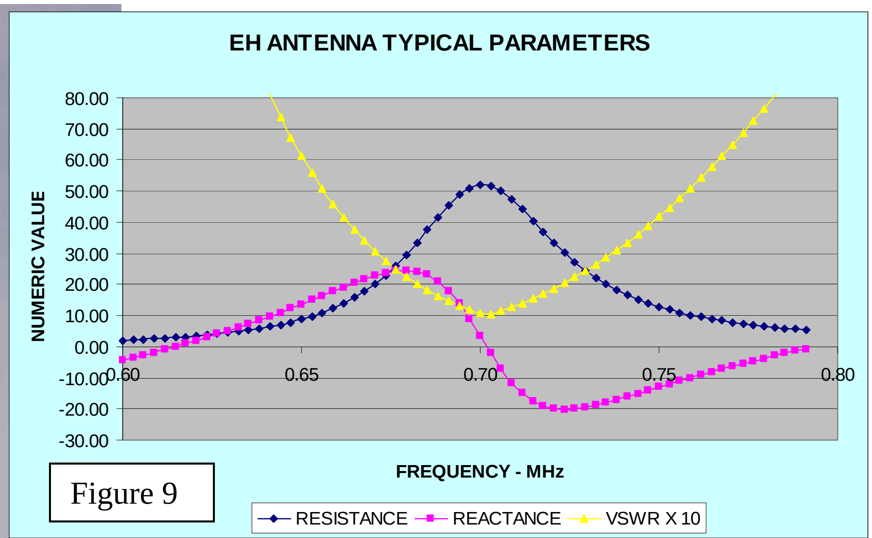


Figure 9

The reactive component of the input impedance goes from + through 0 at the design frequency then to – at higher frequencies.

The antenna for this station has a diameter of 36 inches and a length of 39 feet. It is mounted at a height of 1/8 wavelength. The efficiency of this antenna, which is typical of all EH Antennas, is greater than 90%, yet the total length of the antenna is only 2.8% of a wavelength, as compared to a standard antenna with a length of 25 % of a wavelength.

To understand the concept of the EH antenna, it is convenient to look at the Electric (E) and magnetic (H) fields of the antenna as shown in Figure 10. It is important to realize that the total length of the antenna is a small fraction of a wavelength. For this reason the cylinders are capacitors with negligible inductance.

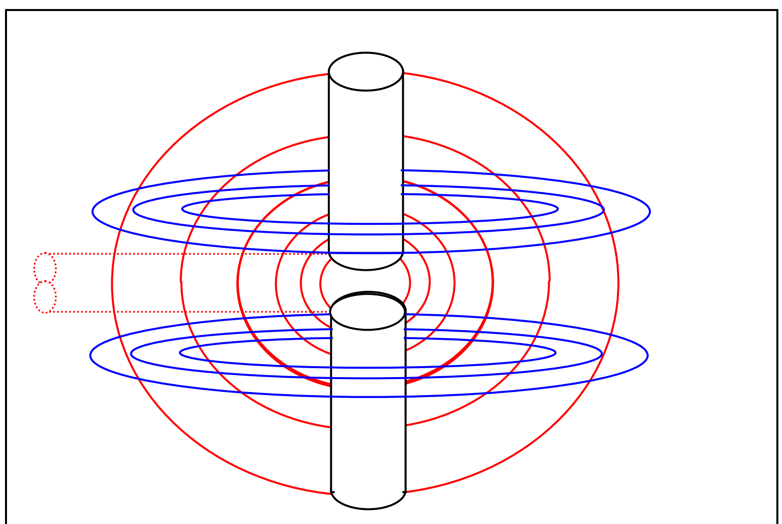


FIGURE 10 – **E** AND **H** FIELDS OF AN EH ANTENNA

When a high voltage is applied between the two antenna elements an E field is developed. The voltage is high at the feed point but must be zero at the end of the elements. Therefore, there is a large voltage gradient between the two ends of each cylinder. That voltage gradient (differential voltage) causes a current to flow on the cylinders. In turn, that current causes a magnetic (H) field to surround the cylinders.
Now we have the necessary ingredients to develop radiation, which include the E and H fields being physically orthogonal and they are in time phase, thus the name EH Antenna.

This occurs because the E and H fields are created by the applied voltage. In other words, while the RF voltage is present (an alternating sine wave) an E field exists and conduction current flows on the cylinder and that current creates the H field.

Note that the E and H fields are contained within a sphere defined to have a diameter the same as the antenna length, and there are no reactive fields. This is in contrast to conventional antennas having reactive fields extending to about 1/3 of a wavelength from the antenna. These unique features are readily discerned from the information presented below.

Figure 11 combines Figures 7 and 9 to provide a clear picture of the process inherent to the EH Antenna. By way of explanation, the process begins with power (P=IV) applied to the antenna at point A. At point B the current is delayed 90 degrees

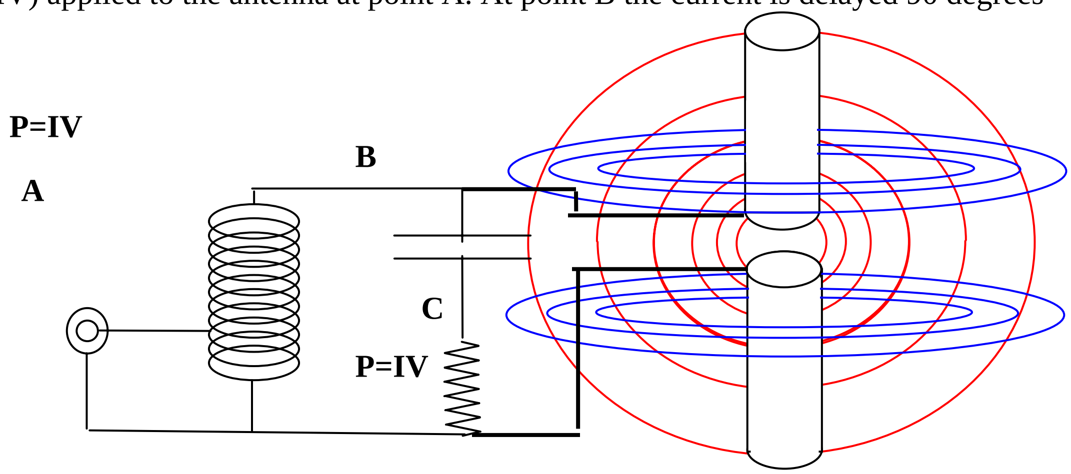


FIGURE 11 - THE INHERENT DETAILS OF AN EH ANTENNA

relative to the voltage because the current passed through the inductor. The current through a capacitor leads the voltage 90 degrees which causes the power at point C to be real power. In other words, the current lagged through the inductor and leads through the capacitor, for a total of 0 degrees phase shift. It must be noted that the current through the capacitor is displacement current, in contrast to conduction current on the cylinders.

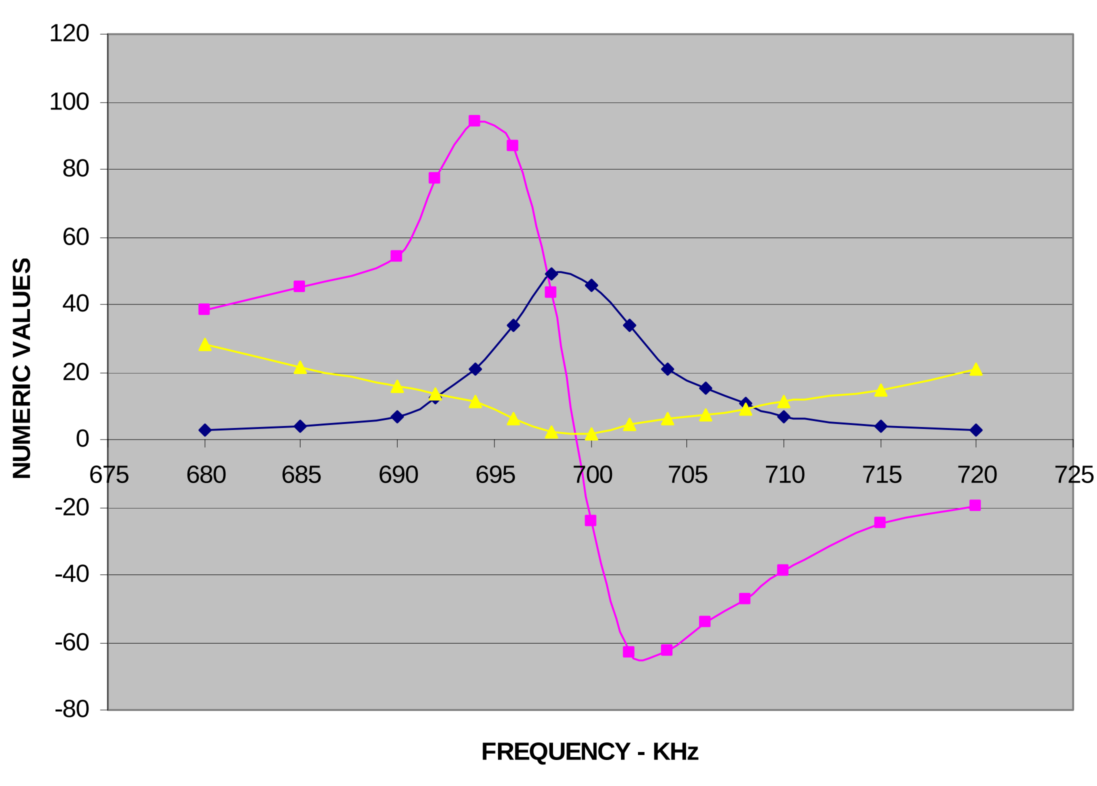
The resonant circuit develops maximum voltage across the capacitor/resistor combination and that voltage is applied to the cylinders. We have already explained that the applied voltage creates an E field and an H field. The radiation resistance is developed as a relationship between the E field (volts per meter) and the H field (ampere turns per meter). The relationship between the two must match the impedance of free space, which is 377 ohms. The antenna is fundamentally a transducer that transforms the power applied to the radiation resistance to radiation in free space. In reality the radiation resistance is only a mathematical convenience to express the fact that power applied to the antenna is

The Author working on the tuning coil.

radiated, and the percentage of radiated power is related to the relative magnitudes of loss resistance and radiation resistance. For this reason the efficiency of the antenna is very high.

TECHNICAL PARAMETERS: This section of the report contains the measured values of resistance and reactance and presents them in graphical form. From the measured values the VSWR (relative to 50 ohms) is computed and also displayed on the graph of Figure11. Note in particular that the 2:1 VSWR bandwidth of this antenna is approximately 35 KHz with a +/- 3 dB bandwidth of 101 KHz. It is worth repeating that an EH Antenna can have high capacity and large radiation resistance, thus large bandwidth. The coax feed line is connected to the tuning coil on one end and the transmitter on the other. There are no reactive elements (coils and capacitors) in matching networks of the type that typically are used to force the bandwidth of an antenna. .

FIGURE 13 – DATA FROM STATION YSJW



The blue curve is the radiation resistance, the red curve is the reactance, and the yellow curve is the VSWR. For the plot the calculated VSWR was multiplied by 10 to allow readability on the graph. A VSWR value of 20 on the curve represents a true VSWR value of 2:1. From the curve the 2:1 VSWR range is from 685 to 720, approximately 35 KHz.

From the data the +/- 3 dB bandwidth is about 105 KHz. Because the antenna is essentially a series circuit, the radiation resistance can be calculated as follows: $Q=X_L/R=F/BW$ where X_L is the reactance of the tuning inductor. Normally we would use the reactance of the antenna capacity; however there is shunt capacity primarily due to the self capacity of the tuning coil. Therefore, it is more accurate to use the reactance of the tuning coil than the antenna capacity. R is the total resistance of the antenna including both the radiation resistance and the loss resistance of the coil. F is the operating frequency and BW is the +/- 3 dB bandwidth. By rearranging the equations we find that $R=X_L*BW/F$.

COMPUTER PROGRAM: To ensure a complete understanding of the EH Antenna used in this radio station, the following is a computer program written to analyze the antenna and includes the specifics for this radio station. The program is arranged in sections as follows: the first section calculates the parameters to allow the antenna to be installed and tuned to the operating frequency. Next, the impedance measurements are made on the completed antenna and from this data the bandwidth is entered in the program. This provides the necessary information to allow calculation of the antenna efficiency. The final section of the program calculates the voltages and currents on the antenna. Typically, an estimated value of radiation resistance is used in the initial design to allow review of the parameters, such as voltage and current that can have an impact on construction.

To use the program the operating frequency and antenna size are entered. Next, the diameter of the tuning coil and wire spacing are entered. The antenna capacity and the distributed capacity of the tuning coil are then added to give the total capacity. From this the tuning inductance can be calculated. After the antenna is tuned and matched the bandwidth is measured and entered in the program. This allows the radiation resistance to be calculated. Next, the loss resistance in the coil is calculated based on an estimate of the coil Q. These values are then used to calculate the antenna efficiency. The final section of the program calculates the various currents and voltages in the antenna system.

It is interesting to note that this EH Antenna has a large capacity (192 pFd) and a large radiation resistance (greater than 170 ohms). For this reason the bandwidth is significantly larger than a conventional antenna and the efficiency is also very high.

FOLLOWING IS A DESIGN PROGRAM FOR AN EH ANTENNA

. ***Written by Ted Hart CEO EH Antenna Systems***

Frequency (MHz) =	**0.70**
Cylinder Diameter (inches) =	**36**
L/D ratio =	**6**
Total Length (inches) =	**468**
Antenna Capacity (pFd) =	**192**
Other capacities - - -	
Coil Capacity (pFd) =	**9.2**
Stray capacity (pFd) =	**20.0**
Total Capacity (pFd) =	**221.0**
Inductance (uHy) =	**234.1**
Reactance (ohms) =	**1029.3**
Coil Diameter (inches) =	**24.0**
Wire Spacing (inches) =	**1.0**
# Turns =	**23.7**
Coil Length (inches) =	**23.7**
Wire Length (feet) =	**148.7**
Measured +/- 3 dB BW (KHz) =	**121**
Radiation Resistance (ohms) =	**177.9**
Antenna Q =	**5.8**

CALCULATE ANTENNA EFFICIENCY

Assume coil Q =	**200**
RF Resistance in coil (ohms) =	**5.9**
Antenna Efficiency (%) =	**96.8**
Antenna Efficiency (dB) =	**-0.142**

ANTENNA POWER PARAMETERS

Transmitter Power (watts) =	**12,000**
Transmission line Z (ohms) =	**50**
Transmission Line Voltage (RMS) =	**775**
Transmission Line Current (RMS) =	**15**
Voltage between Cylinders (RMS) =	**9725**
Voltage between Cylinders (P-P) =	**27230**
Current between Cylinders (RMS) =	**8.2**

APPENDIX 1

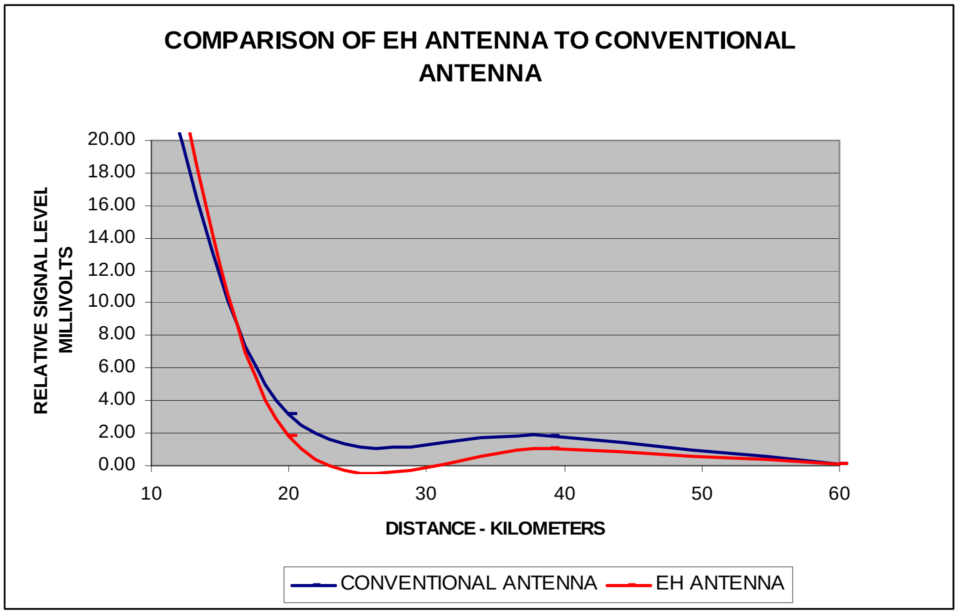
PERFORMANCE CHARACTERISTICS OF RADIO STATION YSJW

This document was prepared to exhibit the performance characteristics of radio station YSJW located to the north of San Salvador, El Salvador, and in particular to compare the performance of an EH Antenna to conventional antennas. It is unfortunate that there are very few roads in the area of the antenna, thus direct measurements as normally taken for radio stations in the United States are not possible. Therefore, the data presented in this document is a comparison of radiation from various radio stations. The EH Antenna is located low on the side of a hill and is compared to a conventional antenna located on a much higher ridge of that hill. This offers a significant advantage for the stations located at the higher elevation.

The EH Antenna was the antenna of choice primarily because the location was not suitable for buried radials. The entire country of El Salvador is the result of volcanic activity, thus it is very uneven terrain. Where there are small flat areas those areas have long ago been covered by buildings. The tower has three (3) guy wires, one of which is about the same level as the base of the tower, the second is about 12 feet above the base and the third about 15 feet below the base. This is presented to describe the local terrain. The EH Antenna is surrounded by banana trees and coffee plants only because that area is not useful for any other purpose.

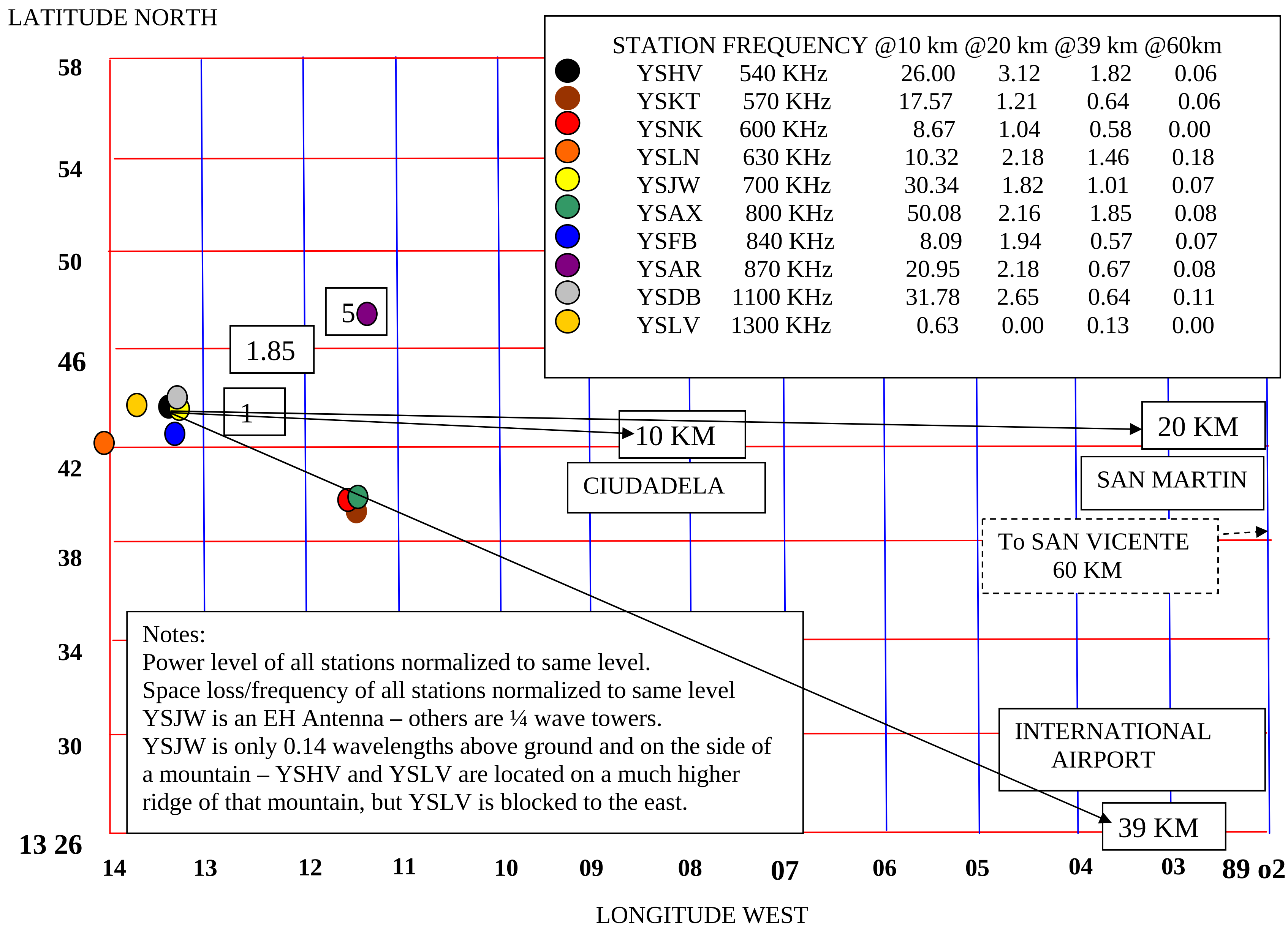
A chart is provided that depicts the relative location of the radio stations and the location where measurements were taken. There is a listing of radio stations and color codes to identify them. The stations of interest are grouped around 89^{o} 13’ 30’’ degrees west longitude. What is not shown on the chart is the relative height of the stations. This has a major effect over the rough terrain and is very significant at longer distances. For this reason only radiation levels are indicated on the chart for distances greater than 10 km. On the third page there is a listing of the normalized measured data for all distances. Note that at close range the level for YSHV is only slightly higher than YSJW, slightly lower at 1.85 km and also slightly lower at 5 km. The difference becomes more noticeable at longer range and it is believed this is due to the fact that YSHV is located much higher on the hill, thus increased radiation at longer distances. Conversely, the hill shades the antenna pattern, thus providing lower signal level at short range.

When comparing the EH Antenna to a ¼ wavelength monopole tower it is interesting to note that out to 10 KM the signal levels are about the same. For the purposes of comparison, both the power levels of the radio stations were normalized as well as the frequency ratio. This is because lower frequencies have less space loss than higher frequencies. As indicated previously, the EH Antenna was mounted at a height of 0.14 wavelengths above local ground. If that antenna were raised to a height of 0.25 wavelengths the additional radiation along the ground would significantly increase (more than 2 dB power ratio or 4 dB voltage ratio). At a distance of 39 km this would increase the signal level by a factor of about 1.59, thus increasing the level to about 1.6 as compared to 1.82 millivolts from the standard tower mounted at a greater elevation. At a distance of 60 km the level would increase to 0.11 millivolts from the EH Antenna compared to 0.06 from the standard tower. In other words, even though the EH Antenna is much lower in elevation it would produce a greater signal at longer range than a conventional antenna, even though the conventional antenna is mounted at a much higher elevation.



The plot comparing the radiation from the two antennas indicates a cross over at about 16 km. This can be explained by the fact that the pattern from the antenna on the hill actually does not allow signal at close range due to the radiation pattern being blocked by the hill. However, placement on the top of the hill gives an advantage at longer range.

In summary, when the EH Antenna is compared to a conventional AM Broadcast tower the EH Antenna will always be the best performer for radiation and also has a much wider bandwidth.



STATION	FREQUENCY	@10 km	@20 km	@39 km	@60km
YSHV	540 KHz	26.00	3.12	1.82	0.06
YSKT	570 KHz	17.57	1.21	0.64	0.06
YSNK	600 KHz	8.67	1.04	0.58	0.00
YSLN	630 KHz	10.32	2.18	1.46	0.18
YSJW	700 KHz	30.34	1.82	1.01	0.07
YSAX	800 KHz	50.08	2.16	1.85	0.08
YSFB	840 KHz	8.09	1.94	0.57	0.07
YSAR	870 KHz	20.95	2.18	0.67	0.08
YSDB	1100 KHz	31.78	2.65	0.64	0.11
YSLV	1300 KHz	0.63	0.00	0.13	0.00

Notes:
Power level of all stations normalized to same level.
Space loss/frequency of all stations normalized to same level
YSJW is an EH Antenna – others are ¼ wave towers.
YSJW is only 0.14 wavelengths above ground and on the side of a mountain – YSHV and YSLV are located on a much higher ridge of that mountain, but YSLV is blocked to the east.

The information below is presented to allow the reader to refer to the details on which the plot is based.

frequency KHz	ID	Lat North	Long West	Antenna type	Power watts	power ratio	frequency ratio
540	YSHV	13º45'15"	89º13'34"	1/4 Tunipole	5500	0.67	0.77
570	YSKT	13º39'36"	89º11'39"	1/4 Tunipole	3000	0.91	0.81
600	YSNK	13º40'22"	89º11'43"	1/4 standard	500	2.24	0.86
630	YSLN	13º42'45"	89º14'13"	?	5000	0.71	0.90
700	YSJW	13º45'43"	89º13'22"	EH antenna	2500	1.00	1.00
800	YSAX	13º39'36"	89º11'39"	? Tunipole	5000	0.71	1.14
840	YSFB	13º42'33"	89º13'18"	?	2000	1.12	1.20
870	YSAR	13º48'05"	89º11'34"	1/4 folded unipole	6000	0.65	1.24
1100	YSDB	13º44'07"	89º13'43"	1/4 folded unipole	6000	0.65	1.57
1300	YSLV	13º45'21"	89º13'72"	1/4 folded unipole	1000	1.58	1.86

FOLLOWING DATA HAS BEEN NORMALIZED FOR BOTH POWER AND FREQUENCY.

	1 km	1.85 km	5 Km	10 Km	20 km	33 km	39 km	60 km
FREQUENCY	13º45'39"	13º46'18"	13º47'09"	13º42'54"	13º44'20"	13º43'21"	13º26'53"	13º40'60"
KHz	89º12'49"	89º12'39"	89º11'01"	89º08'42"	89º02'20"	88º55'12"	89º03'31"	88º46'02"
540	218.44	83.22	52.01	26.00	3.12	0.06	1.82	0.06
570	17.57	10.98	13.72	17.57	1.21	0.10	3.29	0.06
600	1.04	5.78	6.93	8.67	1.04	0.06	0.58	0.00
630	2.00	36.41	21.24	10.32	2.18	0.06	1.46	0.18
700	269.68	134.84	74.16	30.34	1.82	0.07	1.01	0.07
800	30.82	19.26	30.82	50.08	2.16	0.08	1.85	0.08
840	17.80	14.56	11.33	8.09	1.94	0.08	0.57	0.07
870	79.60	85.47	251.38	20.95	2.18	0.13	0.67	0.08
1100	58.27	52.97	25.43	31.78	2.65	0.19	0.64	0.11
1300	100.17	56.34	20.03	0.63	0.00	0.13	0.13	0.00