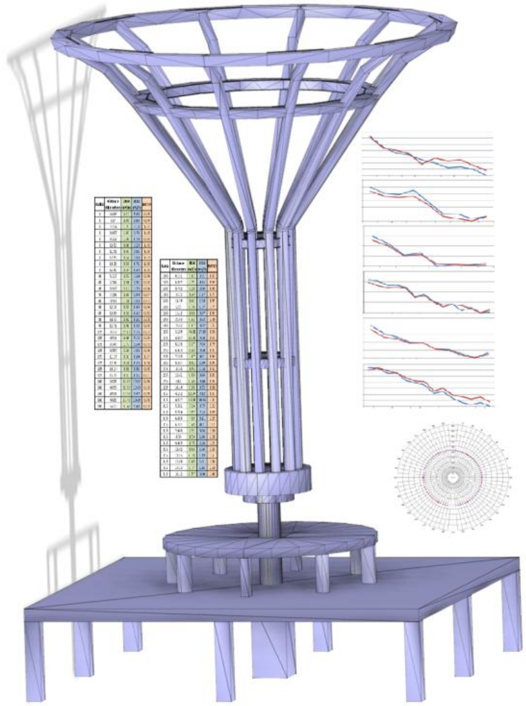


H E B A model 103

Efficiency Analysis Details

April 28, 2020

HIGH EFFICIENCY BROADBAND ANTENNA

The HEBA 103 antenna is the result of more than nine years of research and development activities beginning in 2010. This intensive development project has allowed WorldWide Antenna Systems to realize an optimal low-profile Medium Wave (MW) antenna design that succeeds where others have failed.

Many field intensity measurements were made over the entire coverage area of the client station, WGFP, Webster, Massachusetts. These measurements were accomplished using the state-of-the-art Potomac Instruments FIM-4100 digitally controlled Medium-Wave Field Intensity Meter. This meter includes GPS and logging capability, and maintains a complete set of recorded measurements, so that no human errors in data transfer can occur. Analysis was accomplished using standard methodology, as used for formal US FCC filings.

WORLD WIDE ANTENNA SYSTEMS

This document can be printed as a 5.5” x 8.5” booklet

when printed on an HP Laserjet 400 color printer

(M451dn) or equivalent.

CONTENTS

BASIC EFFICIENCY MEASUREMENT CONCEPTS

Electromagnetic waves traveling through Earth's atmosphere are affected by the environment through which the waves travel. Medium Wave (MW) Broadcasting is greatly affected by this phenomenon, making accurate measurement of antenna efficiency complex.

The actual received signal strength is affected by air temperature, air moisture content, vegetation, terrain, human-made structures, human-made utility distribution systems and the noise these utility systems emit. In the case of MW signals, the conductivity of the earth also has a large effect upon signals used for communications, such as radio broadcasting. Over the last century, a methodology was developed to provide a useful, repeatable, transferable set of standards for comparison. This document seeks to apply those standards to a comparison of the efficiency of a standard MW series-fed monopole and the new HEBA103 antenna from WorldWide Antenna Systems.

MEASUREMENT TECHNIQUES

In order to *filter out* local environmental effects, while still documenting the effect of the environment over the full coverage area of an MW broadcast station, 100-or-more measurements of field strength are made over the entire desired coverage area of a station. These measurements are made on *radials* extending from the antenna along compass azimuths using True North as a reference. At least six radials are measured, and frequently more, depending upon the needs of the study. Along each radial, a number of individual measurements are made and entered into a log, the points are marked with fluorescent paint when possible, and the log includes a description of the point to allow additional measurements to be made at the exact same point. When the complete measurement set has been gathered, it is entered into a database to allow organization in several different ways during the analysis which follows.

ANALYSIS TECHNIQUES

The first step is to characterize the radiation efficiency of the antenna along each radial by performing a study of the measurements. A simplified description of this procedure includes the following steps:

a) Based upon the measured field intensity values at various distances from the antenna, the effective conductivity is determined along the measured radial.
b) The un-attenuated field intensity at 1 kM is determined that would produce the measured field intensity values.
c) For each radial measured, the un-attenuated field intensity is determined.

When this step is completed, the result is a series of graphs, one for each radial, with that radial's data on *log-log* graph paper (logarithmic scale on both axes). Because ground conductivity varies with frequency and also with soil conditions, the United States Federal Communications Commission (FCC) provides standardized graph paper for this purpose, in 20 versions, covering the range of 540 kHz to 1690 kHz. For those interested, they are available here: http://www.fcc.gov/media/radio/am-groundwave-field-strength-graphs
It is often noted that ground conductivity varies along a radial, and that can be seen by the way the plotted reading values group around different ground conductivity curves on the graph paper. Performing this part of the analysis is as much an art form as it is an engineering procedure, because it requires a human to evaluate this phenomenon.

The second step is to compare the effect on signal strength along each radial, showing variations in signal coverage in different areas around the antenna. This is accomplished by plotting the results of the first step on polar graph paper, showing the un-attenuated field along each radial in a convenient way to visualize directionality.

The third step is to use the un-attenuated (inverse distance field) for each radial to calculate the *measured RMS efficiency* of the antenna. This would be the area inside the polar plot of the un-attenuated fields, usually stated as field intensity at a distance from the antenna of 1 kilometer.

This process has been completed for both antennas. The results are discussed in a following section, and are appended to this document.

COMPARISON TECHNIQUES

The entire procedure summarized above is designed to remove environmental effects and provide a standardized RMS field value at 1 kilometer. This is only useful to characterize the radiation efficiency of the antenna being studied, and is based mostly upon near-field measurements. A comparison between two antennas using different technologies to generate the electromagnetic field requires a new evaluation of far-field measurements and performance. The HEBA103 is the first low-profile MW antenna to successfully generate the electric field and the magnetic field with different elements, being driven by different sources of Radio Frequency energy. WorldWide Antenna Systems offers an extension of this analysis to look at possible differences in far-field efficiency. The ideal method for accomplishing such a comparison is to simply compare the field measured at each point when the tower was in use to the field measured at each of the same points when the HEBA103 is in use. A study of this type is included later in this document.

EARLY TOWER FIELD STRENGTH MEASUREMENTS IN 2010

When this project began in 2010, one of the first steps was to complete a set of *Proof of Performance* measurements on the existing tower. This is designed to provide us with an *apples-to-apples* comparison of the tower and HEBA103. This measurement series was designed according to industry standards, including some close-in *tape-and-paint* measurements and a full set of measurements out to 16 kilometers. These measurements were accomplished using a Potomac Instruments state-of-the-art FIM-4100 digital Field Intensity Meter. This meter keeps an internal log of GPS coordinates, air temperature, distance and azimuth from the meter to the antenna being measured, time, date, and the actual reading at the point. This is done automatically, with only a button-press by the meter operator. This *raw field data* still exists today in the original comma-delimited text file downloaded from the meter in 2010.

An eight-radial format was selected, choosing the cardinal azimuths – 00 (True North), 45, 90, 135, 180, 225, 270 and 315 degrees. WGFP owns only one transmitter, a Harris DAX-1. It is not capable of more than 1,100 Watts transmitter power output, and has very good carrier-power regulation. Antenna base current was measured at the beginning and the end of each day to ensure stability in applied power.

The measurements from 2010 were not subjected to a formal analysis procedure at that time, because the HEBA103 measured so well when completed in 2016. All comparison analysis was completed in late 2018 and early 2019 for the purpose of creating this report.

FIELD STRENGTH MEASUREMENTS OF THE HEBA103 IN 2016

The 2016 measurements were made using the same industry-standard methodology, and using the same Field Intensity Meter. They were taken by Kurt Gorman, an internationally recognized expert in MW antenna design. WGFP still owned only one transmitter in 2016, the same Harris DAX-1 used in 2010. Antenna input current was measured at the beginning and the end of each day to ensure stability in applied power.

DIRECT COMPARISON CHALLENGES ENCOUNTERED

When the 2016 measurements were made, it was decided to measure only six radials, the minimum accepted by the FCC, rather than eight, as was done in 2010. This was done to save time, allowing us to file an application with the FCC a month sooner. At that time, we did not see a need to do a direct comparison of tower and HEBA103, because the HEBA103 was working so well. The 2016 proof was measured on the 30, 90, 150, 210, 270 and 330 degree radials. The result is that only the 90 degree and 270 degree radial measurements exist in both studies.

It is fortunate that the two radials that DO exist in both studies are diametrically opposed toward east and west, because it is possible to see an emerging pattern in the data.

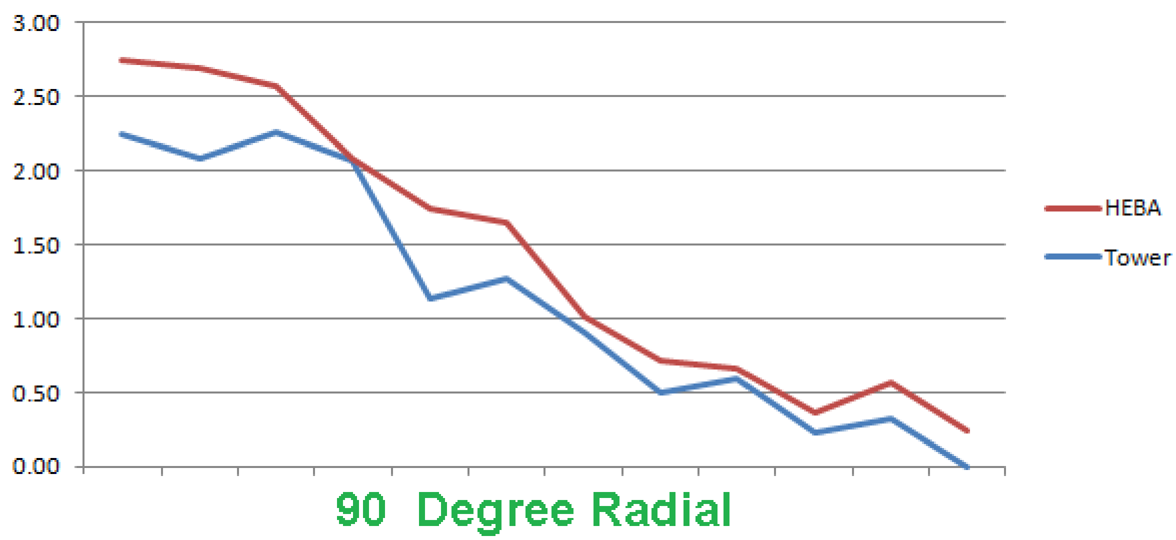
FAR-FIELD POINT-BY-POINT COMPARISON

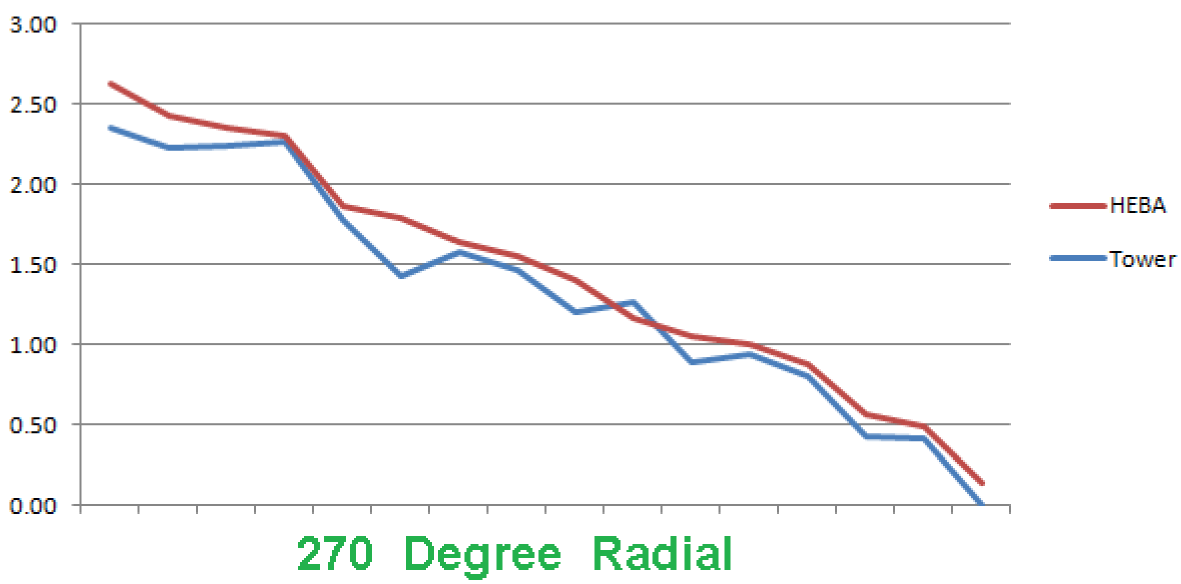
90° and 270° radials

Radial	Distance kilometers	2010 mV/m	2016 mV/m	RATIO
90	0.79	75.55	242.00	3.20
90	1.09	51.97	210.00	4.04
90	1.37	78.90	158.00	2.00
90	1.80	50.53	52.00	1.03
90	2.51	5.93	24.00	4.05
90	3.19	8.02	19.00	2.37
90	4.85	3.47	4.40	1.27
90	7.51	1.34	2.20	1.64
90	8.65	1.66	1.95	1.17
90	10.42	0.73	1.00	1.37
90	11.04	0.89	1.60	1.80
90	13.70	0.43	0.74	1.72
270	0.49	191.03	355.00	1.86
270	0.65	143.27	224.00	1.56
270	0.87	147.56	189.00	1.28
270	0.93	153.58	170.00	1.11
270	2.12	49.74	62.00	1.25
270	2.54	22.53	52.00	2.31
270	3.17	31.45	37.20	1.18
270	3.78	24.51	30.00	1.22
270	4.15	13.51	21.00	1.55
270	5.62	6.50	9.40	1.45
270	6.21	7.38	8.50	1.15
270	7.32	5.33	6.40	1.20
270	9.30	2.25	3.10	1.38
270	10.44	2.21	2.60	1.18
270	12.06	0.84	1.15	1.37

These readings on the 90 degree and 270 degree radials show an increase in field strength using the HEBA103, when compared with the legacy monopole. Another interesting observation is that the field strength drops off more evenly with distance in the HEBA103 readings, as compared with the old tower readings.

HEBA AND TOWER FAR-FIELD COMPARISON
90° and 270° radials





All field intensity values recorded by the FIM 4100 were normalized to 0.0 at the lowest reading on each radial when using the legacy monopole, and all readings were then converted to logarithmic scale to provide a useful visual tool for comparison. Two factors are evident in these graphs:

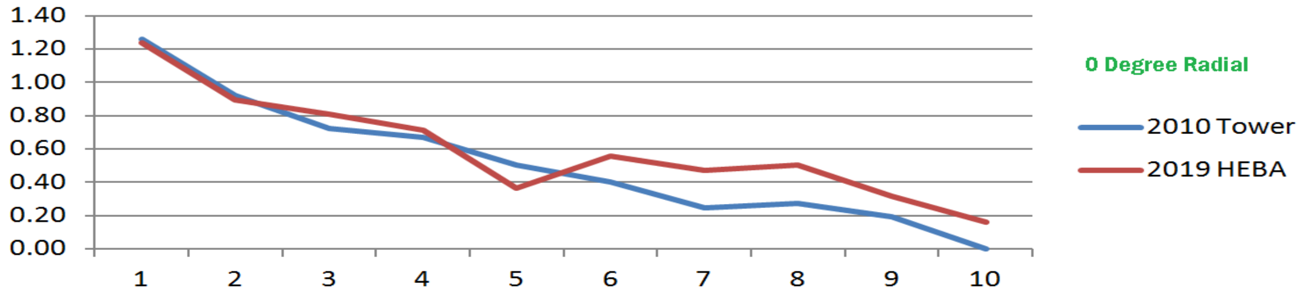
1. the signal from the HEBA does not vary as much between points in the far field as the signal from the tower, and
2. the HEBA outperforms the tower in the far-field.

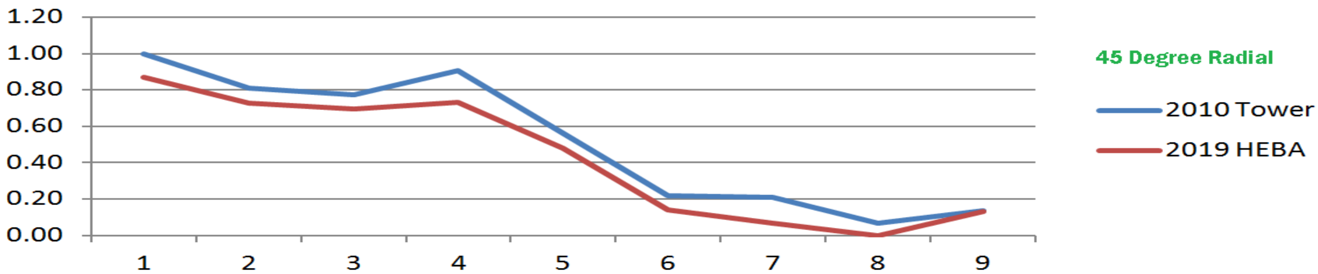
FAR-FIELD POINT-BY-POINT COMPARISON
0°, 45°, 135°, 180°, 225°, and 315° radials

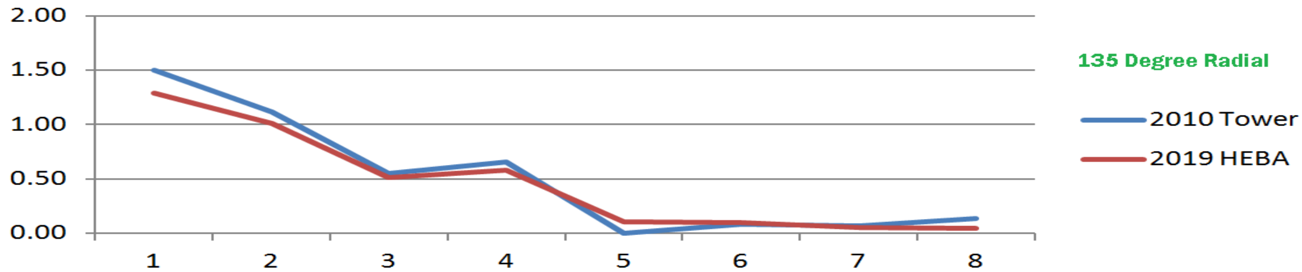
Now that initial development of the HEBA has been completed, a set of additional measurements was made on the remaining cardinal radials that were not measured in 2016.

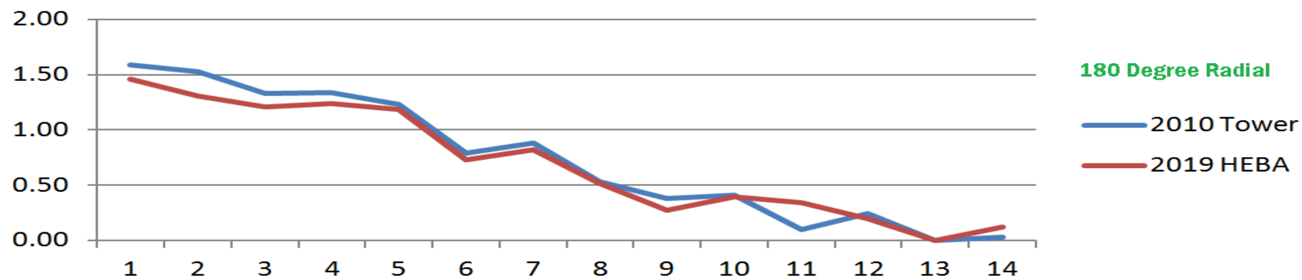
Radial	Distance kilometers	2010 mV/m	2019 mV/m	RATIO
0	3.685	6.17	5.85	0.95
0	6.17	2.83	2.66	0.94
0	7.214	1.79	2.18	1.22
0	8.007	1.60	1.76	1.10
0	9.222	1.08	0.79	0.73
0	10.52	0.86	1.23	1.43
0	11.51	0.60	1.01	1.68
0	12.59	0.64	1.08	1.69
0	14.25	0.53	0.71	1.33
0	16.06	0.34	0.49	1.45
45	5.227	3.57	2.64	0.74
45	5.746	2.31	1.91	0.83
45	5.947	2.12	1.78	0.84
45	7.298	2.88	1.94	0.67
45	8.581	1.31	1.08	0.82
45	12.19	0.59	0.49	0.84
45	13.69	0.58	0.42	0.72
45	14.42	0.42	0.36	0.85
45	15.71	0.49	0.49	0.99
135	3.277	15.68	9.75	0.62
135	4.519	6.48	5.16	0.80
135	8.249	1.77	1.64	0.93
135	8.557	2.26	1.90	0.84
135	11.17	0.50	0.64	1.27
135	12.76	0.61	0.63	1.04
135	14.14	0.59	0.56	0.95
135	15.35	0.69	0.56	0.81
180	3.525	24.16	17.82	0.74
180	4.059	20.98	12.65	0.60
180	4.528	13.29	9.97	0.75
180	4.825	13.48	10.69	0.79
180	5.633	10.49	9.48	0.90

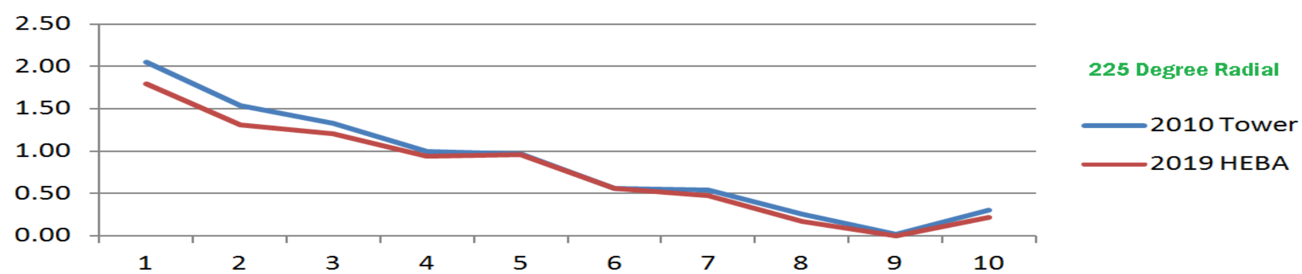
Radial	Distance kilometers	2010 mV/m	2019 mV/m	RATIO
180	8.131	3.81	3.31	0.87
180	8.337	4.71	4.13	0.88
180	9.732	2.10	2.06	0.98
180	10.32	1.49	1.17	0.79
180	11.49	1.61	1.54	0.95
180	12.5	0.78	1.37	1.75
180	14.16	1.08	0.97	0.90
180	15.09	0.62	0.62	1.01
180	15.62	0.67	0.82	1.22
225	3.189	49.32	27.69	0.56
225	4.587	15.33	9.04	0.59
225	5.128	9.37	7.03	0.75
225	6.413	4.43	3.84	0.87
225	7.105	4.07	4.01	0.98
225	8.537	1.62	1.60	0.99
225	10.45	1.53	1.33	0.87
225	13.61	0.80	0.66	0.83
225	14.2	0.46	0.44	0.96
225	16.14	0.90	0.72	0.81
315	4.152	10.97	9.12	0.83
315	4.527	10.50	10.84	1.03
315	5.521	7.14	8.73	1.22
315	5.704	7.57	7.23	0.95
315	6.605	4.09	5.11	1.25
315	6.731	3.49	4.01	1.15
315	7.443	2.91	3.83	1.31
315	8.54	1.54	1.86	1.21
315	9.469	1.75	2.26	1.29
315	11.02	1.06	1.36	1.28
315	11.55	0.78	1.19	1.53
315	12.69	0.65	1.01	1.56
315	14.13	0.77	1.16	1.51
315	16.12	0.57	0.80	1.41

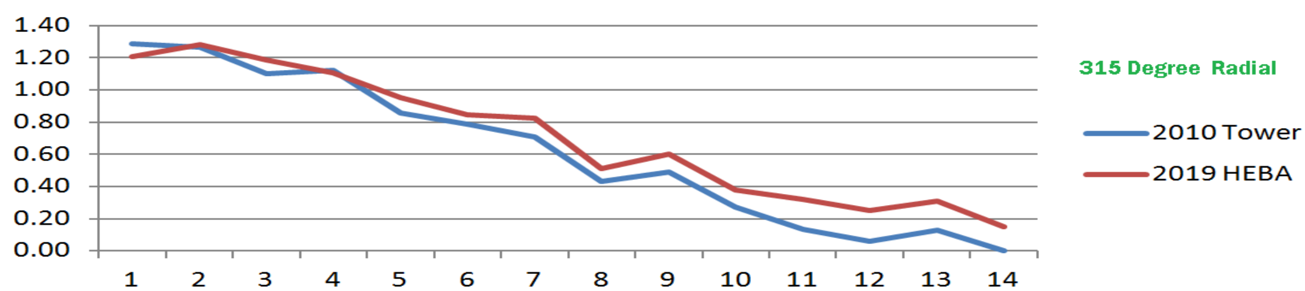

1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1 2 3 4 5 6 7 8 9 10
0 Degree Radial
2010 Tower
2019 HEBA


1.20
1.00
0.80
0.60
0.40
0.20
0.00
1 2 3 4 5 6 7 8 9
45 Degree Radial
2010 Tower
2019 HEBA

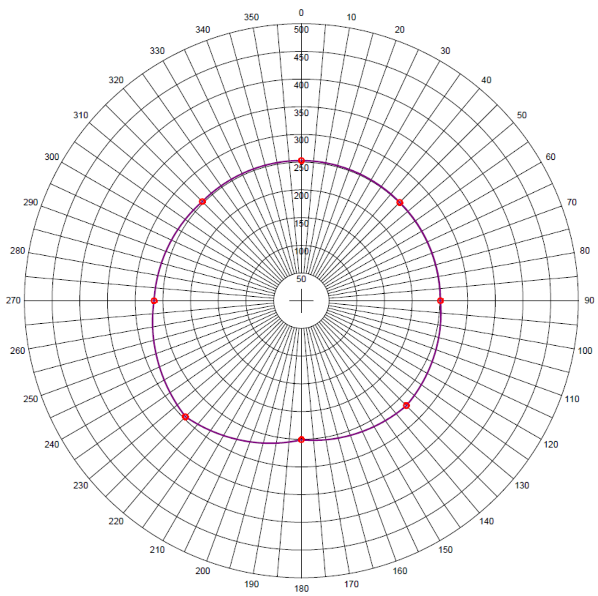

2.00
1.50
1.00
0.50
0.00
1 2 3 4 5 6 7 8
135 Degree Radial
2010 Tower
2019 HEBA

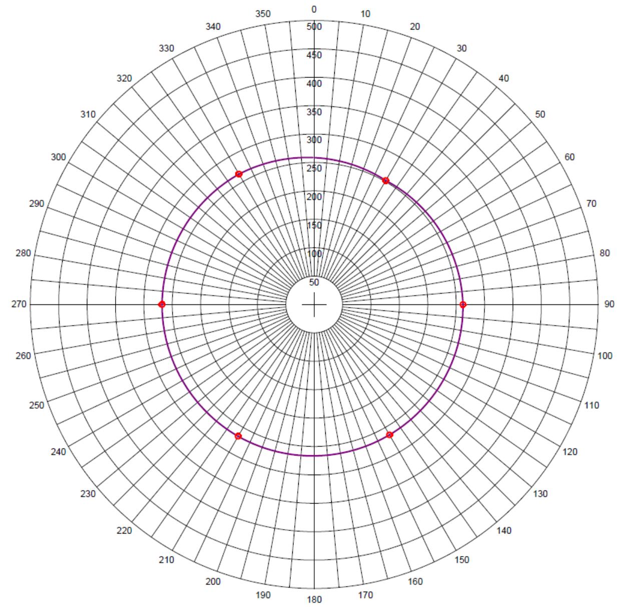

2.00
1.50
1.00
0.50
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14
180 Degree Radial
2010 Tower
2019 HEBA


2.50
2.00
1.50
1.00
0.50
0.00
1 2 3 4 5 6 7 8 9 10
225 Degree Radial
2010 Tower
2019 HEBA


1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14
315 Degree Radial
2010 Tower
2019 HEBA

NEAR-FIELD RMS COMPARISON





TOWER
RMS @ 1 KM = 261.392

HEBA103
RMS @ 1 KM = 263.374

These two polar plots, extracted directly from the FCC study in 2016, the additional measurements from 2019 and the study of the tower from 2010 measurements, show that the RMS at 1 kilometer for the two antennas is remarkably similar. In addition, it can be seen that the HEBA103 shows a bit less variation from radial to radial. The very slight reduction on the 45 degree radial is due to the presence of a nearby hill in that direction, 1.3 miles away and 250 feet higher than the HEBA103 installation. This shows that the effect of terrain on the performance of the HEBA103 is minimal.

Both studies were prepared using similar methodology, by the same consulting engineer, and were based on measurements made with the same Potomac Instruments FIM 4100 meter, serial number 134.

SUMMARY OF THIS EFFICIENCY ANALYSIS

This document is a first attempt to characterize the performance of the new HEBA103 Low-Profile MW antenna in comparison with the tower that it replaced in late 2010. It shows clearly that the HEBA103, using FCC-accepted methodology, is the equal of the tower it replaced. FCC acceptance of the methodology has been shown by the fact that the FCC granted a license to WGFP to operate with the HEBA103 in summer of 2018.

It has also been shown, in the far-field measurements on several radials, that there appears to be a more cohesive field in the outer range of the station's coverage area, with fewer variations due to environmental issues, and improved signal strength.

FUTURE WORK ANTICIPATED

WorldWide Antenna Systems is very excited by the results of the testing and analysis we have gained through the preparation of this document. The HEBA103 is now proven to meet the specifications stated in our marketing information, and we feel confident that the antenna is a robust, fully-functional product that meets the needs of many broadcasters and groups around the world.

Our next focus will be to demonstrate bandwidth suitable for IBOC digital transmission, such as is used in the United States, and DRM digital transmission, such as is used in Europe and Asia. Low bit-error-rate performance will be demonstrated, as measured using IBOC and DRM receivers in the far field. Some of the technology we will be incorporating into the HEBA antenna to optimize digital performance was developed decades ago in the early days of analog AM stereo in the United States, and network topologies used in those system designs are easily incorporated into the networks used in the HEBA103.

Our newly-granted patents cover application of more recently discovered scientific principles and WorldWide Antenna Systems technological developments into HEBA systems.

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Shane O'Neil
242 Hartwell Road
Bedford, MA 01730

shane@worldwideantennas.com
781 275-1147