H E B A model 103

Performance Analysis

April 28, 2020

HIGH EFFICIENCY BROADBAND ANTENNA

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

The unique characteristics of the HEBA 103 antenna system offer many MW broadcasters advantages not available when using other types of MW antenna designs. This paper seeks to clarify each of the ways in which the HEBA can solve problems for MW broadcasters faced with real-world challenges, such as the high cost of land associated with traditional MW antennas, high security costs, high maintenance costs, bandwidth limitations, and efficiency issues.

WORLD WIDE
ANTENNA SYSTEMS

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CONTENTS

BASIC CONCEPTS

Antennas used for MW transmission are designed to create an electromagnetic wave that will propagate across the surface of the earth for long distances. Best performance has been achieved by using vertically-polarized antennas. Because the wavelength of an MW frequency is in the range of 500 feet to 1,500 feet, antennas providing optimum efficiency and bandwidth are quite large, and have been accomplished for decades by erecting tall steel monopoles, usually realized through the use of towers supported by guy wires. Such structures require large areas of land to construct, because the guying system that supports the towers must have anchors in the ground which must be as far from the base of the tower as the tower is tall; this is called 100% guying. While it is possible to *short-guy* towers to as little as 50%, the result is less safe in high winds, and requires anchors and wires of much greater strength than a 100%-guyed system.

TOWER STRUCTURES AND LAND REQUIREMENTS

The optimum height for an MW transmitting tower is about ½ wavelength, which provides maximum groundwave propagation with minimum skywave radiation, to minimize nighttime *selective fading* self-interference in the outer portion of the groundwave coverage area. At the center of the MW broadcast band, 1000 kiloHertz, such a tower is nearly 500 feet tall. The land needed for such a tower and its associated guying system is 1,000 feet square, an area of 1,000,000 square feet, or about 23 acres. At the high end of the MW band (1700 kHz), because the wavelength is shorter, these dimensions are reduced to a height of about 290 feet, and a necessary land area of 330,000 square feet, or about 8 acres. At the low end of the MW band, however, these dimensions increase to a height of 900 feet, and a land area of 3,300,000 square feet, or about 75 acres. It is possible to reduce this necessary land area only by purchasing and occupying a circular plot of land, and in the case of the mid-band installation the necessary land area is reduced to 785,000 Square Feet, or about 18 acres.

These dimensions are truly large, and for this reason, many MW broadcasters choose to build smaller monopoles to conserve construction and land costs. ¼-wave towers are frequently used, however the efficiency of such an antenna is only about 80% when compared with a half-wave monopole, reducing the coverage area by almost 40%. This coverage area can be recovered by increasing the transmitter power, which increases monthly operating costs. As the monopole height is further reduced, coverage area is further reduced.

GROUND SYSTEMS AND LAND REQUIREMENTS

Prior to the development of the HEBA, nearly all Medium Wave transmitting antenna systems were single-element designs. As such they are *unbalanced input* devices, with an RF signal introduced into the antenna, using the earth as the other terminal of the complete electrical circuit. This method of exciting the antenna requires a *ground plane* beneath the antenna, so that the electromagnetic lines of force radiated by the antenna are captured by the ground plane so that the energy is returned to the transmitter in a closed circuit. Vertical monopole antennas are designed to include a *ground system* of buried copper wires extending ¼ wavelength from the base of the monopole in all directions, or an elevated *counterpoise system* of similar size, to provide this *circuit completion* function. Such a system occupies the about the same amount of land area as the guy wire system used to support a 100%-guyed tower. An additional requirement is that the area must be kept free of vegetation, to minimize attenuation of the electromagnetic field that forms between the monopole and ground. Typically, a well-maintained MW antenna system has grass planted over the entire area occupied by the ground system, and this grass is regularly mowed to prevent brush and trees from growing in the area. The cost for this maintenance is quite high and must be continued for the life of the monopole if the broadcaster wishes to keep the station's coverage area intact.

THE HEBA ANTENNA

The HEBA antenna is not the first attempt to design a low-profile MW antenna. Over the past 5 decades many researchers have invested countless hours searching for ways to build an MW antenna that requires less physical space and a smaller structure, without reducing efficiency and bandwidth. Several designs are now available from different developers which offer reduced height and still approximate the efficiency performance of a ¼-wave monopole, but all of these designs still require a full-sized ground system. Reducing the height is only half of the desired solution.

WorldWide Antenna Systems believes that the HEBA 103 is the first MW antenna design that achieves both a height reduction and a land-area reduction. WWAS accomplished this feat of engineering through the development of a two-element antenna that generates the electric field and the magnetic field separately. Originally suggested by M. Hately in the 1990s, this approach required an understanding of RF field theory and network theory that defied early developers' attempts to adjust, reliably and repeatably, the two-element MW antenna. At that time, the approach was named the Crossed-Field Antenna. A very few such antennas, when built, appeared to work as theorized, but no rigorous engineering measurements were gathered to prove performance. Many more attempts at building this kind of antenna met with failure, and the industry lost interest in it.

One of the reasons for this history of failures is that the cost to build the two-element antenna was similar to the cost of building a guyed monopole and ground system, and those working on the design simply did not have the time, the land or the funds to use the scientific and engineering methods: designing a prototype, building and testing the prototype, analyzing the test results, modifying the design and repeating the process. Another reason for the lack of progress is that in the United States, such experimentation is not allowed in the MW broadcast band because of the congested nature of the band; such experimentation would have caused objectionable interference to existing licensed broadcasters, and that interference was not allowed.

WorldWide Antenna Systems solved these problems by partnering with a licensed radio station. This provided **WWAS** with a geographical area in central Massachusetts within which our radio station, WGFP, Webster, is protected from interference, and within which this radio station is allowed to transmit radio programming to the surrounding population. WGFP then requested experimental operation on this frequency in this licensed station's coverage area. This allowed, for the first time in the United States, an antenna system development team to use the scientific and engineering methods to create prototype antennas, test them, modify the designs and repeat the tests, achieving performance improvements with each iteration. Six years of hard work and nearly a million US dollars were invested into building four, fully-constructed and tested prototypes before a successful antenna design was achieved.

The next phase of **WWAS** activity was to perform a stability test. Prototype #4 began full-time broadcasting in December of 2016 at the station's full power of 1,000 Watts. Over the next 18 months, tests were completed proving stability through all seasonal and environmental conditions, and a full Proof of RF Performance set of measurements was completed and filed with the Federal Communications Commission. This RF Proof was accepted by the FCC after rigorous examination, and WGFP was granted a license to operate with the HEBA in July of 2018.

WWAS now has two new US Patents covering the HEBA 103 design and tuning procedures, and a third US Patent application has been filed to protect our newly-developed ways to excite the antenna to achieve even better performance.

HOW THE HEBA 103 WORKS

The HEBA 103 has two driven electrical elements. One generates the Electric Field, the other generates the Magnetic Field, with each field being generated in a separate process. When these two fields are properly generated, with the proper phase angle between them and the proper power ratio in each, the desired Electro-Magnetic (EM) Field assembles itself in free-space at a short distance from the elements (a few wavelengths away). Successful implementation of such an approach yields new and interesting control over the radiated EM field, resulting in a signal that propagates quite nicely. The height of a HEBA 103 is about 25% of the height of a standard ¼-wave monopole, and its footprint is a square platform about the same size on the ground as the antenna is tall. WGFP's HEBA 103 operates at 940 KHz, is 72 feet tall above ground, and the platform portion of it is about 40 feet square, or 1600 square feet. This converts to about 1/3 of an acre of land.

THE HEBA 103 WORKS QUITE WELL

Before development work on the HEBA began at the WGFP transmission site, WGFP operated with a series-fed, 173-foot, uniform-cross-section, steel tower with a full ¼-wave buried ground system. This tower had an electrical height of about 18%, a bit less than the standard ¼-wave monopole electrical height of 25%, but it still required a full ¼-wave ground system, occupying more than six acres. The ground system was 30-years-old and had suffered some damage over the years since installation in 1979. As a part of the development of the HEBA, and before WGFP's original tower was removed from the site, a full Proof of RF Performance set of measurements was taken around the tower, comprising over 100 measurements, on the eight cardinal radials, to a distance of sixteen kilometers (about ten miles). A comparison of the RF Proof of the original monopole with the RF Proof of the HEBA 103, submitted to the FCC, shows that the HEBA 103 exhibits a comparable radiation efficiency and an improvement in omni-directionality.

Empirical observations during the two-year stability test period have given **WW**AS considerable support for the concept of improved coverage. As mentioned before, WGFP is a commercial radio station that sells radio advertising to pay the operational expenses and maintenance & repair costs of the radio station. The goal is to make a profit. Nearby commercial radio stations noticed WGFP's improved coverage quite quickly, because a few merchants in nearby cities and towns began advertising on WGFP, causing local radio stations in those other towns to lose a bit of revenue.

Another important measure of the performance of the HEBA 103 is the robustness of its mechanical design. On March 5, 2019, a professional tower maintenance and repair company performed a thorough inspection of the HEBA 103. During the 30 months since construction was completed, two tornados with accompanying high winds passed within a mile of the Webster site, one of which caused significant damage and destruction in downtown Webster. In addition, a *Nor'Easter* that caused several New England towers to fail, as well as a hurricane, passed through the area. The HEBA 103 inspection revealed that it was still perfectly plumb and the non-metallic sway-stays were in excellent shape. Of the hundreds of welds in the antenna, only one weld had failed, but no metal was deformed.

GROUND SYSTEM REQUIREMENTS

As noted earlier, all standard monopoles require a ¼-wave ground system or counterpoise system for efficient operation, including series-fed, shunt-fed and segmented variations. Similarly, all low-profile antenna systems presently available from other vendors also require such a ground or counterpoise system in order to approach the efficiency performance of a ¼-wave monopole.

MEDIUM-WAVE ANTENNAS REQUIRING A ¼-WAVE GROUND SYSTEM

STANDARD MONOPOLE
(Series-fed, Shunt-fed or segmented)

FIBERGLASS WHIP WITH LOADING COIL
(known by the tradename "Valcom")

QUAD INVERTED-L
(known by the tradename "KinStar")

MEDIUM-WAVE ANTENNAS ***NOT*** REQUIRING A ¼-WAVE GROUND SYSTEM

HEBA 103
(2-Element Low Profile on platform)

It should be noted here that the HEBA 103 requires a platform for the purpose of decoupling the two-element radiator system from nearby earth because the circulating EM fields around the elements are attenuated by the presence of soil and rocks beneath the elements.

Also, the **Fiberglass Whip With Loading Coil** product is not allowed for use below 1200 KHz in the United States by the Federal Communications Commission because of its inefficiency at longer wavelengths.

LAND REQUIREMENTS

The ground system is not the only reason that other antenna alternatives require large land area for installation. All monopoles must be at least 18% of the wavelength in height for useful efficiency, with the more efficient monopoles reaching 50% of the wavelength.

MEDIUM-WAVE ANTENNAS REQUIRING LARGE AMOUNTS OF LAND

8 acres to 75 acres,
depending upon frequency

STANDARD MONOPOLE

(Guyed towers, for guy anchors)
(Self-supporting towers, for safe fall-radius.
(BOTH types require land for a ground system)

FIBERGLASS WHIP WITH LOADING COIL

(Requires land for ¼-wave ground system)

QUAD INVERTED-L

(Requires land for ¼-wave ground system)

MEDIUM-WAVE ANTENNAS *NOT* REQUIRING LARGE AMOUNTS OF LAND

HEBA 103

1/3 acre to 2/3 acre,
depending upon frequency

The HEBA 103 requires enough space for its platform, which varies by frequency, and is about ½ acre at 600 KHz. It is prudent to provide additional space around the platform to provide a safe fall-radius for the HEBA 103 structure, in the extremely unlikely case of damage due to extreme wind, earthquake or tsunami, maybe ¾ acre.

ENVIRONMENTAL REQUIREMENTS

Weather, including humidity, rain, wind, ice and snow, affects the operation of all outdoor antennas. Humidity in particular affects the threat of high-voltage arc-over at high power levels, while ice and snow can easily detune an antenna and cause the transmitter to shut down because of *reflected power*, or VSWR.

Since the 2-year WGFP stability study using the HEBA 103 antenna began in January of 2017, there have been no instances of lost air-time due to ice or snow loading on the structure of the HEBA or on the platform. Before 2010, when WGFP was operating with the 173-foot tower, the antenna tuning unit required re-tuning at least twice a year as the seasons changed. Since operation with the HEBA 103 began full-time in December of 2016, radio station management reports that there have been no such shutdowns, even though WGFP is using the same transmitter it was using with the 173-foot tower in 2010: A *Harris DAX-1*, 1 kW transmitter.

The DAX-1 is known to be very sensitive to an impedance mismatch, and the HEBA 103 has exhibited much better load impedance stability than the monopole for more than two years.

BANDWIDTH PERFORMANCE

All MW antenna systems are, by nature, bandwidth limited. In many cases when tower height has not been selected for best bandwidth, even analog-only radio stations will experience reduced audio frequency response and increased distortion at the upper end of the audio band (above 4 kHz, as an example), and special antenna tuning network topologies have been developed to correct this kind of issue. Digital MW systems such as DRM or IBOC in the United States, are even more demanding with respect to bandwidth requirements, and the special antenna tuning network topologies mentioned above are used to improve digital transmission with all MW antennas.

In 2006 and 2007, while researching and writing Chapter 12 for David Maxson's THE IBOC HANDBOOK, "Implementation – AM Considerations", I gained much hands-on experience optimizing MW antenna systems for digital transmission. The issues are covered well in that book, so I will not repeat them here. If the reader desires more information, please refer to chapter 12 in:

THE IBOC HANDBOOK – David P. Maxson

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The HEBA antenna, because of its two-element, balanced, quadrature-driven design, isolated from the earth, primarily derives its drive-point impedance from the mutual impedance relationship between the two elements, which are physically quite close together. While somewhat *high-Q* in nature, it is extremely stable over time and with variations in the environment. This becomes of great benefit after having applied the special antenna tuning network topologies that have become standard in digital MW transmission systems. 30 kHz, low-group-delay bandwidth is easily achievable with a HEBA 103 antenna.

EFFICIENCY PERFORMANCE

WGFP operated for 30 years with a monopole that was approved for use by the United States Federal Communications Commission (FCC). This monopole was 173 feet tall, series fed, and was installed with a standard ¼-wave ground system buried around the base of the tower.

After 6 years of research and development, and building and testing four prototypes of the HEBA (100, 101, 102 and 103), the FCC granted a construction permit to use the HEBA 103 for a one-year stability study. At the completion of the stability study, WGPF filed an application for a license-to-cover the facility as-built, providing a full Proof of RF Performance measurement study, and the FCC responded by granting a standard license to continue operation with the antenna.

The FCC analysis of the measured performance of the HEBA 103 confirms that it meets and actually exceeds FCC efficiency requirements for MW transmission antennas.

After a license for the HEBA 103 was granted, **WWAS** compared the HEBA 103 measurements submitted to the FCC with the field data measurements made on the old monopole before it was taken down in 2010. This was the old monopole tower that had been approved by the FCC in 1980, and with which WGFP had been operating for 30 years before **WWAS** acquired the site for development of the HEBA. The HEBA 103 study comparison with the old monopole field data showed an improvement in efficiency.

A technical summary of the comparative measurements is available in our "Efficiency Analysis Details" document.

PERFORMANCE SUMMARY

- The HEBA 103 meets the United States FCC requirements for efficiency and is equivalent to a ¼-wave series-fed monopole.
- The HEBA 103 exhibits a stable drive-point impedance over time and with variations in environmental conditions.
- The HEBA 103 can be tuned to provide optimal performance with both analog and digital transmission methods, with stable, low-group-delay bandwidth characteristics to minimize data errors in transmission, allowing the receiver to have more error-correction budget for correction of errors caused by propagation non-linearities, man-made noise, natural noise, and mobile-receiver effects on the received signal.
- The HEBA 103 does not require a standard, buried, ¼-wave ground system, reducing the amount of land needed for its installation by an order of magnitude when compared with other MW antenna technologies.
- The HEBA 103 is about 25% of the height of a standard ¼-wave monopole and requires no guy wires that extend beyond the corners of its platform. This is another factor that reduces the space necessary for installation of a HEBA.
- The HEBA 103 reduces radio station operating costs because the structure of the HEBA requires no painting or lighting and large areas of real estate do not require constant mowing to maintain signal strength performance and the size of the coverage area.

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