HEBA model 103

Performance Analysis

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High Efficiency Broadband Antenna

The HEBA103 antenna is the result of more than fifteen 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 HEBA103 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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THE HEBA IS A PROBLEM SOLVER

Here is a list of station problems that a HEBA can solve for you:

[1] Your tower needs extensive repairs, the cost of those repairs is beyond your reach and your town will not let you replace it because of new town planning and zoning regulations.
[2] You rent or lease the tower(s) from which you transmit and/or you rent or lease the land where your towers are located, and these costs are climbing.
[3] The valuation of the tower site, land and equipment has become so high that property taxes and insurance costs are out of control.
[4] You own the land at your tower site but you can make a lot more money by selling the land or developing it for non-broadcast uses.

You are a fortunate broadcaster if none of these problems are haunting you. Congratulations! Enjoy your good situation. On the other hand, a HEBA can be a part of a strategy to lower your operating costs and increase the income generated by your land, offsetting the cost of the HEBA and increasing your overall profits.

Here are some of the things you need to know to make things better:

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. In the past, best performance has been achieved by using vertically-polarized monopole 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. But 100% guying uses a lot more land, and land is expensive. Also, building codes for towers are much more stringent than they were 30 or 40 years ago, increasing the cost to build a new tower.

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 still quite high, in the range of 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. The self-interference problem also gets worse, with nighttime coverage outside the 2 mV/m contour significantly impacted.

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 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 HEBA103 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 on an elevated platform. Originally suggested by Maurice Hately in the 1990s, this approach required an understanding of RF field theory and network theory that defied early developers' attempts to reliably and repeatably adjust the two-element MW antenna. At that time, the approach was named the Crossed-Field Antenna. A few CFAs, when built, appeared to work as theorized, but no rigorous engineering measurements were gathered to prove performance. The majority of early attempts to build this kind of antenna did not result in good performance, 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: design a prototype, build and test the prototype, analyze the test results, modify the design and repeat the process, again and again. 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 test radio station, WGFP, Webster (now WQVR), is protected from interference, and within which the 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 daytime license to operate with the HEBA in Summer of 2018 and a nighttime license to operate with the HEBA in Spring of 2024.

WWAS now has three US Patents covering the HEBA103; a design patent, a tuning procedure patent, and a patent protecting our newly-developed ways to drive the inputs to the antenna elements to achieve even better performance (more on this on the next page).

HOW THE HEBA103 WORKS

The HEBA103 has two driven electrical elements. When these two elements are driven with two RF signals 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 overall height of a HEBA103 is about 1/3 of the height of a standard ¼-wave monopole, and its footprint on the ground is a square platform about half the size on the ground as the antenna is tall. The WGFP/WQVR HEBA103 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 HEBA103 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 HEBA103, submitted to the FCC, shows that the HEBA103 exhibits a comparable radiation efficiency and an improvement in omni-directionality.

Empirical observations during the two-year stability test period have given WWAS considerable support for the concept of improved coverage. As mentioned before, WQVR 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 WQVR's improved coverage quite quickly, because a few merchants in nearby cities and towns began advertising on WQVR, causing local radio stations in those other towns to lose a bit of revenue.

Another important measure of the performance of the HEBA103 is the robustness of its mechanical design. On March 5, 2019, a professional tower maintenance and repair company performed a thorough inspection of the HEBA103. During the 30 months since construction had 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 HEBA103 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 LARGE BURIED GROUND SYSTEM	MEDIUM-WAVE ANTENNAS ***NOT*** REQUIRING A LARGE GROUND SYSTEM
STANDARD MONOPOLE (Series-fed, Shunt-fed or segmented)	**HEBA103** (2-Element Low Profile on platform)
FIBERGLASS WHIP WITH LOADING COIL (known by the tradename "Valcom")	
QUAD INVERTED-L (known by the tradename "KinStar")	

It should be noted here that the HEBA103 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 of note, 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

HEBA103

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

The HEBA103 requires enough space for its platform, which varies in size 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 HEBA103 structure, in the extremely unlikely case of damage due to extreme wind, earthquake or tsunami, maybe ¾ acre.

ENVIRONMENTAL REQUIREMENTS

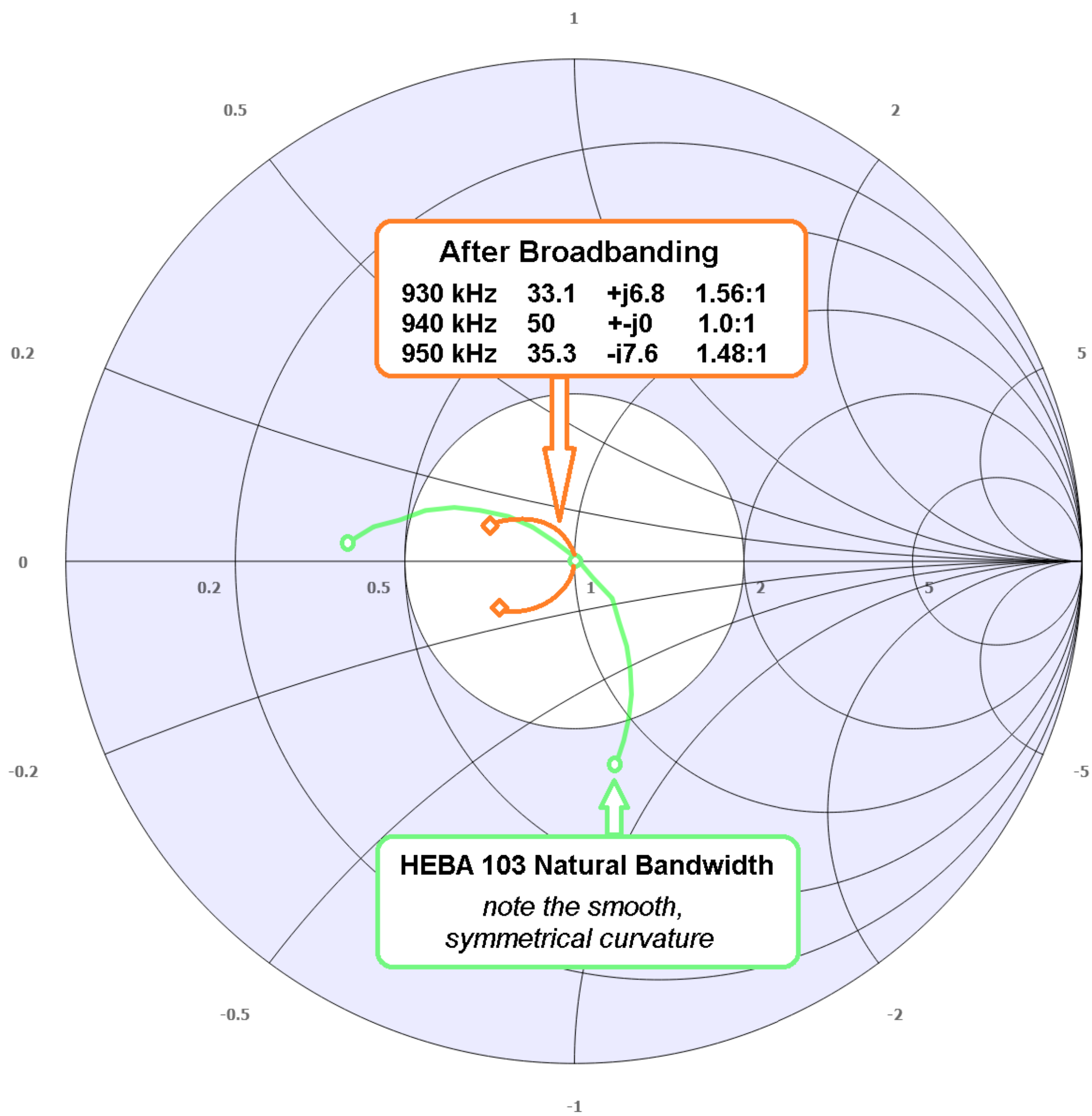
Weather, including humidity, rain, wind, ice and snow, can affect the operation of all outdoor antennas. Humidity in particular affects the threat of high-voltage arc-over at high power levels, while ice and snow can easily detune an antenna and cause the transmitter to shut down because of *reflected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

During the 2-years of the WGFP stability study using the HEBA103 antenna, there were 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 HEBA103 began full-time in December of 2016, radio station management reports that there have been no such shutdown; the antenna has performed well with no adjustments needed in all seasons.

BANDWIDTH PERFORMANCE

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 since the days of AM Stereo operation. Using these networks, 30 kHz, low-group-delay symmetrical bandwidth is easily achievable with a HEBA103 antenna.

All-Digital AM transmission does not require as much bandwidth as the early hybrid analog/digital methods used in the first 18 years of digital AM broadcasting. In fact, All-Digital AM uses only the bandwidth within the FCC-licensed channel, 20 kHz.



The Smith Chart above shows the actual measured bandwidth of the HEBA103, within the 20 kHz channel of WQVR, in green. Kurt Gorman of Phasetek, WWAS Chief Engineer, recently redesigned the WQVR Antenna Tuning Unit with bandwidth-flattening design technology, so that All-Digital AM transmission performance will be quite good, as shown in orange.

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, building and testing four prototypes of the HEBA (100, 101, 102 and 103), the FCC granted a construction permit to use the HEBA103 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 HEBA103 confirms that it meets, and actually exceeds, FCC minimum efficiency requirements for MW transmission antennas.

After a license for the HEBA103 was granted, WWAS compared the HEBA103 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 tower that had been approved by the FCC in 1980, and with which WGFP had been operating for 30 years before WWAS acquired access to the site for development of the HEBA. The HEBA103 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:

https://www.loudandclean.com/dl/HEBAefficiency.pdf

PERFORMANCE SUMMARY

- The HEBA103 meets United States FCC requirements for efficiency and exhibits ***real-world*** ground-wave performance equivalent to an 85° series-fed tower, based on measurements recently of a nearby station operating with 1,000 Watts on 970 kHz with a 242-foot tower. These measurements also indicate that the HEBA emits less 'skywave energy', causing less nighttime interference to distant co-channel stations. Ongoing research on this recent finding will be the subject of a new report soon.
- The HEBA103 exhibits a stable drive-point impedance over time, unaffected by variations in environmental conditions.
- The HEBA103 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 all-digital IBOC 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 HEBA103 does not require a standard, buried, ¼-wave ground system, thus reducing the amount of land needed for its installation by an order of magnitude when compared with other MW antenna technologies.
- The HEBA103 is about 30% 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 HEBA103 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 (1) signal strength performance, (2) the size of the coverage area and (3) the population count within the coverage area.

WORLD WIDE ANTENNA SYSTEMS

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