NEW AM BROADCAST ANTENNA DESIGNS HAVING FIELD VALIDATED PERFORMANCE

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ABSTRACT

During the last five years, North American Broadcasters have implemented, on a limited basis, several variations on the traditional vertical radiator with 120 buried radials with significant success. These innovations are described in this paper and include elevated radial ground systems in place of traditional buried ground systems, use of a single internal cable to excite a self supporting grounded tower rather than a multi wire external skirt and the use of a guy wire or other sloping radiator to achieve a directional antenna pattern. We discuss the practical aspects of each system, information drawn from field experiences, and the FCC's view of these antenna types.

ELEVATED RADIAL GROUND SYSTEMS-BACKGROUND

In June of 1937, the classic paper by Brown, Lewis, and Epstein, "Ground Systems as a Factor in Antenna Efficiency" was published in the Proceedings of the Institute of Radio Engineers (now the IEEE). For the next five generations, ground systems for AM towers have been based on the original measured data in that paper. In the March, 1988 issue of the IEEE Transactions On Broadcasting, a group of authors described a new type of ground system for AM towers in a paper titled "AM Broadcast Antennas with Elevated Radial Ground Systems". The authors were Al Christman and Roger Radcliff of Ohio State University, Richard Adler from the Naval Post Graduate School, Jim Breakhall from the Lawrence Livermore Lab, and Al Resnick from Cap Cities/ABC. The elevated system described at that time consisted of a single quarter wave tower with four elevated radials, also one quarter wave in length, spaced evenly around the tower.

The efficiency of the elevated radials was compared to a system of 120 buried radials using the "Method of Moments" computer code NEC-GS. The published results showed that four elevated radials gave essentially the same antenna efficiency as the standard 120 buried radial system over the full range of modeled soil conductivities. At the time that the paper was published, no one had validated the theoretical calculations by constructing a full size antenna system in the 540 kHz to 1600 kHz band. The elevated radial concept sparked a great deal of interest within the engineering community which was tempered with questions such as, "will it work in the real world", "how stable will it be" and "will the FCC accept its use"?

INSTALLED ELEVATED SYSTEMS

In November of 1988, our firm supervised the construction of a temporary antenna system in Newburgh, New York under FCC Special Field Test Authority using call sign KPI-204. The antenna system consisted of a lightweight, 15 inch face tower, 120 feet in height, with a base insulator at the 15 foot elevation and six elevated radials, a quarter wave in length, spaced evenly around the tower and elevated 15 feet above the ground. The radials were fully insulated from ground and supported at the ends by wooden tripods. Approximately ten feet above ground, a T network for matching the antenna was mounted on a piece of marine plywood to isolate the components from contact with the lower section of the tower which was grounded. Power was fed to the system through a 200 foot length of coaxial cable with the cable shield connected to the shunt element of the T network and to the elevated radials. A balun or RF choke on the feedline was not employed and the feedline was isolated from the lower section of the tower. The system operated on 1580 kHz at a power of 750 watts.

The efficiency of the antenna was determined by radial field intensity measurements along 12 radials extending out to a distance of up to 85 kilometers. The measured RMS efficiency was 287 mV/m for 1 kW, at one kilometer, which is the same measured value as would be expected for a 0.17 wave tower above 120 buried radials.

The Newburgh tests gave empirical proof that the elevated system worked although, in an abundance of caution, we used six radials instead of four. For the limited time that the system was operational, the system was stable as determined by monitoring the field intensity at selected locations each day. The measured base impedance was in general agreement with a tower of this height above a standard, buried, ground system. Results of the KPI-204 tests were submitted to the FCC in January of 1989.

The first permanent use of an elevated radial ground system appears to be at WPCI, 1490 kHz in Greenville, South Carolina. This installation, designed by William A. Culpepper, involved replacing a standard buried system with a four wire elevated system consisting of #10 solid copper wire, one quarter wave in length, and supported on treated wooden posts which keep the radials 4.9 meters above ground. The antenna radiation efficiency, based on field strength readings on the eight cardinal radials, was 302 mV/m at 1 kilometer versus the predicted FCC value of 307 mV/m. The WPCI installation was unique in that the tower was base insulated but the radials came right up to the tower, 4.9 meters above ground and terminated in insulators. The tower was fed from the tuning unit, through a piece of coax to the 5 meter point on the tower where the center conductor of the coax was attached to the tower and the shield to the elevated radials. This feed system resulted in a higher feed resistance than would normally be expected. Data on this facility was taken from the FCC files.

Directional antenna applications were the next obvious application area for elevated radials. The FCC granted construction permits to several stations in the early 90's including KXKW, 680 kHz, Tioga, Louisiana, WNJO, 1550 kHz, Seaside Park, New Jersey and WGNY, 1200 kHz, Newburgh, New York. The first four tower directional array to be built and licensed in the United States was WWJZ, 640 kHz, Mount Holly, New Jersey with a daytime power of 50 kW. This system, designed by Ted Schoeber, employed six elevated, quarter wave radials per tower with the radials 15 feet above ground, made of 1/4 inch copper cable and supported at each end through an insulator tied to a telephone pole. Data on this facility was obtained by review of the FCC files and inspection of the transmitting complex.

In the spring of 1993, CTI began to oversee the installation of a four tower directional array in Oakland, New Jersey, on 1160 kHz. The WVNJ installation took advantage of experiences gained at earlier installations and became the basis for a standard design. (Figure 1 is a side view of the standard design). The advantage of this design is mechanical rigidity for stability while being easy for a tower rigger to implement. In a new installation such as this, the base piers are poured with eye hooks to terminate the elevated radials. Three foot fiberglass rods are connected to the hooks to provide safe worker access to the area around the tower base. Each radial is connected to an insulator, run up to the support post, fifteen feet from the tower base, and then horizontally out to the terminating insulator and end support post. All radials are 1/4-inch steel guy cable interconnected with guy cable and the cable brought down to the ATU copper ground strap. The tower is fed directly above the base insulator through a lightning isolation loop as in any standard base insulated arrangement.

The WVNJ site was selected to meet restrictive land use and allocation restrictions. Consequently, the site was built in a rocky area where a buried system could not be installed. Since the feedlines, sampling line, control and AC cable could not be buried they were installed in 4" PVC pipe for protection and laid on the surface of the ground. Four inch strap was run between each tower and the transmitter building. All coaxial cables were bonded to the four inch strap at 50 foot intervals to prevent stray RF currents.

The WVNJ system provided additional insights into the use of elevated radials due to problems encountered. In a typical buried ground system, it is not uncommon to truncate the ground system in some directions due to natural obstructions or property restrictions. In this case, several elevated radials had to be shortened to approximately 70% of the full quarter wavelength. A shortfall in antenna efficiency did not show up in the nondirectional antenna proof since the ND tower was on the SW side of the array and the truncated radials were on the east side of the array, in the direction of the major lobe of radiation.

Our first test was to disconnect the 7/8 inch feedline from the ATU input to the ND tower and install an RF choke, or balun, made up of toroid cores around the outer conductor. This resulted in a modest change in base impedance and slight heating of the cores indicating that an RF current path did exist along the shield. However, when the power level was set up to match the new impedance, and several field monitoring points checked, it was realized that there was no change in measured field intensity.

The other cause of anticipated low efficiency was the truncated radials. Modeling of the array using the measured soil conductivity with NEC-2 confirmed the shortfall. Extending the truncated radials to a full quarter wavelength brought up the measured antenna efficiency. This taught us a valuable lesson; elevated radial ground systems cannot be truncated when used in combination with towers near a quarter wave or less. The use of truncated radials under a half wave tower are discussed in another section of this paper.

PRACTICAL APPLICATIONS

Elevated radials are an inexpensive and practical solution where there is sufficient property to install a minimum of four equally spaced radials a full quarter wave in length. They may be used to replace damaged buried systems or for new installations. In new installations, these systems allow continued farm use of the land, installation in rocky areas where a buried system would not normally be employed, and implementation of a station in environmentally sensitive areas where the land disturbance associated with buried systems would be prohibited. Based on the experience base to date, concerns about stability in varying weather conditions or efficiency problems are unfounded when systems are properly designed and installed.

SHUNT FED TOWER INNOVATIONS

Sometimes necessity is the mother of invention. Broadcasters have been using unipoles or wire skirts as a method to excite a grounded tower. As new uses for the RF spectrum proliferate, tower space is at a greater premium and opportunities for Broadcasters to lease tower space are constantly increasing. Unfortunately, AM towers are generally shunned due to potential contact with either the hot tower, in the base insulated case, or the hot skirt wires, in the case of grounded towers. A method has been devised to excite a self supporting tower which is totally internal to the tower structure.

In mid 1993, Douglas Broadcasting, Inc., licensee of KOBO, Yuba City, California, became interested in expanding the utility of its self supporting tower for rental use and was also involved in the design and implementation of a multi tower directional array in an area with significant environmental problems. The DA site problems were so extensive that guy wires were deemed a hazard to the endangered bird species and the thought of skirt wires on the tower was unpalatable. The concept of a single vertical cable, running up the middle of the tower, was proposed by the KOBO engineering staff as a possible solution. Initial computer modeling with minninec gave ball park numbers that looked promising enough that DBI went forward to fund the research project.

In the spring of 1994, the internal feed system was implemented. Local engineers chose a length of 1 5/8" heliax which was on hand as the center feed. Copper straps were used to jump across each base insulator to ground the tower and the initial shorting point inside the tower set. Initially, the system proved to be unstable. This problem was traced to poor bonding in the tower sections and was subsequently resolved by brazing at the appropriate locations. Efficiency of the feed was checked by setting base current to the proper value for the base insulated case and then taking field strength readings at selected monitoring points. The system was then set up for the shunt feed described above and the field strength at each monitoring point checked. All readings were within 1 to 2 percent of the original value.

A note concerning computer modeling should be inserted at this point. It was possible to obtain a general idea of the tower feed impedance using several different versions of minninec. Once the system was built and measured impedance data was available, attempts at modeling with minninec were not productive in terms of approaching the measured value. NECAM, a version of NEC-2, written by David Pinion, PE, was then tried. When actual soil conductivity and dielectric constant data was employed, the NEC-2 implementation gave an answer that is close enough to the measured value to rely upon for future predictions. The reason for the difference in accuracy is believed to lie in the difference in the codes. Minninec does not have the ability to take ground conditions into account when computing impedance. This is a critical difference and should be taken into account in cases where more accurate impedance or antenna efficiency values are needed.

In late 1994, CTI began working with WJRZ radio in Toms River, New Jersey to design a nondirectional. antenna system for 1550 kHz using an existing 300 foot communications tower. NECAM computer modeling studies of this tower compared favorably with measured results. In this case, a 1/4" EHS steel guy cable was attached to a three foot fiberglass rod and terminated in a concrete block placed in the center of the tower. The guy cable was then run vertically to the 250 foot level on the tower and bonded to a cross brace. Shorting jumpers were attached to the vertical cable at the 100 foot and 150 foot AGL levels on the guy cable. During final installation, impedance measurements were made at both shorting points to provide more data to use in calibrating the computer model.

This tower employed a unique elevated radial ground system. Four radials, 1/8 wavelength, were employed in the expectation that a tower near one half wave in height would achieve good efficiency with a shorter radial. This, in fact, did not prove to be totally true and a lower than expected radiation efficiency was assigned to the radiator. Computer modeling studies have shown, what we believe is the answer. The current distribution on a base insulated half wave tower is different than it is on the shunt fed tower. There is a greater current distribution in the lower half of the shunt fed version which would tend to increase ground losses. It is important to be aware of the possibility of a variation between design and measured values and to allow sufficient margin for error in the original design to compensate for real world variations.

On November 22, 1994, the FCC granted WJRZ Special Field Test Authority, under call sign KPK-251 to test the antenna system on 1550 kHz. Tests were completed in December of 1994 and results are now on file with the Commission.

SHUNT FEED BENEFITS

We discussed previously the benefits which AM broadcasters could derive by using an internal feed wire in terms of increased rental income. There are other benefits as well. In this age of increased real estate prices, some AM stations are looking at the possibility of selling their property and going to a single tower, nondirectional, operation. The internal feed system can make existing self supporting towers available as rental sites to a broadcaster where the owner would have previously been against this use. It is possible that future refinement, computer analysis, and empirical studies will show that uniform cross section towers can be excited in this way as well.

SLANT WIRE RADIATORS

Slant wire radiators have been in use for a number of years. A slant wire radiator, in the context used within this paper, is either a guy cable or sloping steel cable, insulated from, and supported by, a single tower or other vertical radiator. Grant Bingeman of Continental Electronics most recently introduced the broadcast engineering community to the concept at the 41st Annual Broadcast Engineering Conference with his paper "An Economical Directional Antenna For AM Stations". Grant published the results of a parasitic directional antenna system installation at XEWB in Mexico in the July, 1994 issue of BE Radio. In discussion with Canadian consulting engineer Gordon Elder, he indicated that he has installed a daytime directional antenna system in Canada for daytime hours of operation.

One of the more exhaustive studies on the use of slant wire radiators was written by E.T. Ford of the Independent Broadcasting Authority. Mr. Ford's paper, "A Directional Medium-Frequency Transmitting Antenna Comprising A Single Guyed Mast And A Sloping-Wire Parasitic Reflector" describes extensive tests run between 1972 and 1982 on 40 different systems. The Ford paper was very extensive and thorough and gave both theoretical and empirical data concluding that the systems did perform as calculated.

Slant wire radiator development is still in the early stages of being explored in this country. The concept, within proper limitations, holds great promise for many broadcasters. Currently a number of stations are limited to low nighttime power or less than desired daytime power. In some of these cases, the broadcaster is unable to construct another tower but could obtain significant relaxation of the power restrictions if a DA could be implemented.

FCC POLICIES

The FCC employs Rules and Policies to regulate the AM Broadcast service, in part, to assure service and prevent interference. To that end, elevated radial ground systems are a permitted use at this time for directional AM stations as system performance is validated as part of the proof of performance and licensing process. It is recommended that stations wishing to install an elevated system on a nondirectional tower check with the AM Branch of the FCC Mass Media Bureau to determine the current procedure. It is possible that a proof of performance would be required to confirm antenna efficiency.

The internal shunt feed system described herein is believed to be new to the FCC and to the industry. As in the case of elevated radials for nondirectional towers, one should describe their proposed implementation with the FCC before proceeding.

Currently, the FCC has a policy which prohibits the use of parasitic arrays. In August of 1994, Milstar Broadcasting Corp. filed a Petition For Rule Making, with the FCC "To Allow the Use of Slant Wire Radiators". Implicit in that Rule Making was a request to allow parasitic arrays as well. Due to an apparent lack of input from Broadcasters, the FCC has not moved forward to implement a Notice of Inquiry in this area. However, the AM Branch has indicated to the author a willingness to authorize slant wire radiators which would be fed, for daytime only use, on an STA basis.

CONCLUSION

The antenna systems described herein are all potentially profitable for AM Broadcasters. When properly designed and implemented, they can be cost saving and revenue producing. Possibly even more important, they open up site locations which might previously have been thought of as unusable. Elevated radials are now a mature technology with an established user base. The internal shunt feed has proved to be predictable in the cases studied. Parasitic radiators need FCC endorsement before significant development can occur. However, this methodology holds great design potential for directionalization of signals as well as for diplexing.

Note: This is a scanned version of a paper presented at the 49th Annual NAB Broadcast Engineering Conference in April of 1995 and is published in the NAB 1995 Broadcast Engineering Conference Proceedings.

NORTH LATITUDE: 41° 31' 30"
WEST LONGITUDE: 74° 06' 03"

A = 2'

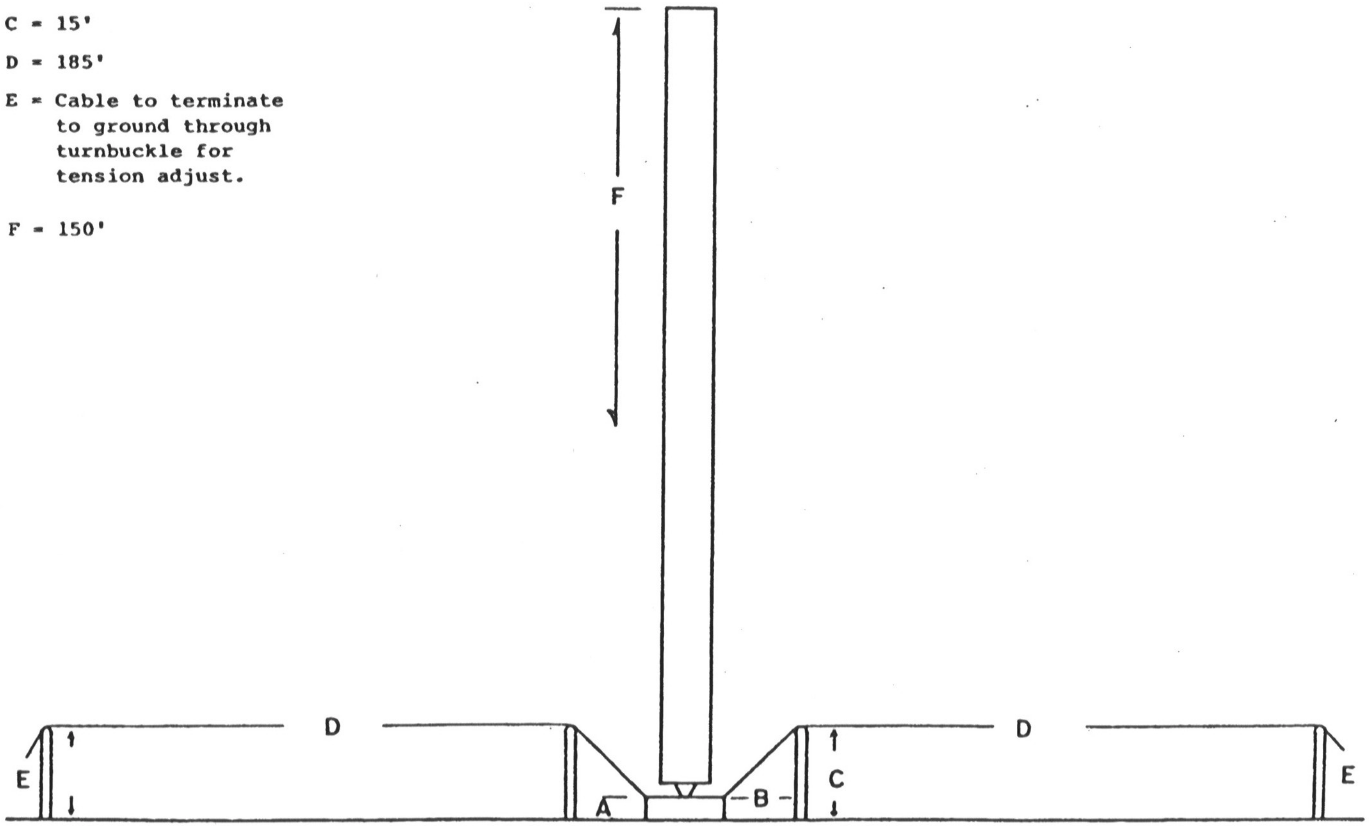
B = 20'

C = 15'

D = 185'

E = Cable to terminate to ground through turnbuckle for tension adjust.

F = 150'



GRADE LEVEL 515 FEET AMSL

FIGURE 1

TYPICAL ELEVATED RADIAL SYSTEM - SIDE VIEW

DIMENSIONS FOR 1200 kHz
WGNY-AM NEWBURGH, NEW YORK 8/93