KDKA—A HISTORY OF INNOVATION CONTINUES

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INTRODUCTION

The old KDKA tower was built for the first time in 1938, at Saxonburg some 25 miles from the center of Pittsburgh, PA. The completion of the tower was accompanied by a wave of promotion and publicity. However, when it was actually turned on, it "didn't work". The antenna's high angle radiation came back down in the groundwave service area causing "self-fading" and the station could not be heard in Pittsburgh at night. Following a period of planning and evaluation, the tower was disassembled, moved and re-erected on the present site in Allison Park, PA, about 11 miles from the center of the city. Until the summer of 1994, KDKA operated from that site and with that tower. But, as the suburban population grew, the antenna's self-fading eventually became a problem even from the Allison Park site.

In the summer of 1994, the old KDKA "Franklin" antenna was toppled and a new tower was erected in its place. The new antenna was specifically designed to retain the excellent groundwave performance of the older Franklin, while dramatically reducing the high angle radiation to reduce or eliminate the "self fading." To accomplish this, and to provide a practical antenna, a number of proven techniques were combined to produce what we believe to be a unique and modern AM antenna design.

THE ORIGINAL KDKA FRANKLIN

By common definition, a Franklin antenna is a full wavelength over ground, insulated from ground, and fed at the center. By that definition, the original KDKA antenna was not a true Franklin, since it was only about 3/4 of a wavelength in overall height. It was, however, insulated at ground and was fed at the center across sectionalizing insulators. The feed assembly was composed of a ground mounted balun feeding a balanced open wire transmission line which ran up the inside of the tower to the center. The balun was fed by a tuning unit which provided an impedance match to the transmission line from the building. In that configuration the base feed apparatus also constituted a load across the base insulator between the base of the tower and ground. Each time the base tuning and feed apparatus was replaced or reconfigured, the load across the base insulator changed, causing a change in the relative current distribution between the upper and lower sections. This caused changes in the vertical radiation pattern of the antenna, some more favorable than others with respect to self-fading, but none was ideal. Since the base loading function was incidental to tuning and impedance matching, no effective vertical pattern control was feasible.

Over the more than 50 years the tower had been standing, despite good maintenance procedures, there had been substantial deterioration of the steel, to the point that its structural integrity was in question. Based upon a detailed inspection of the tower, it was concluded that it could not be economically restored. A new tower was required, and it seemed pointless to re-build the old Franklin which "didn't work". The choices were to build a simple conventional base fed vertical or a modified Franklin with greatly reduced high angle radiation.

An analysis of the physical configuration of the old antenna, that is, 720' overall, fed in the center, was conducted in MININEC. That study confirmed that even if an optimum adjustment could be achieved, there would be substantial high angle radiation. Even though the optimum adjustment of the old Franklin may never have been achieved, it was theoretically possible, and, therefore, it was the standard against which new designs would be judged.

THE NEW FRANKLIN

For a modified Franklin to be practical, the following design criteria would have to be met:

1. Groundwave performance essentially equal to the old Franklin to retain the present daytime (groundwave) service area.

2. High angle radiation (60° to 80°) substantially lower than the old Franklin (optimized) to minimize self-fading.

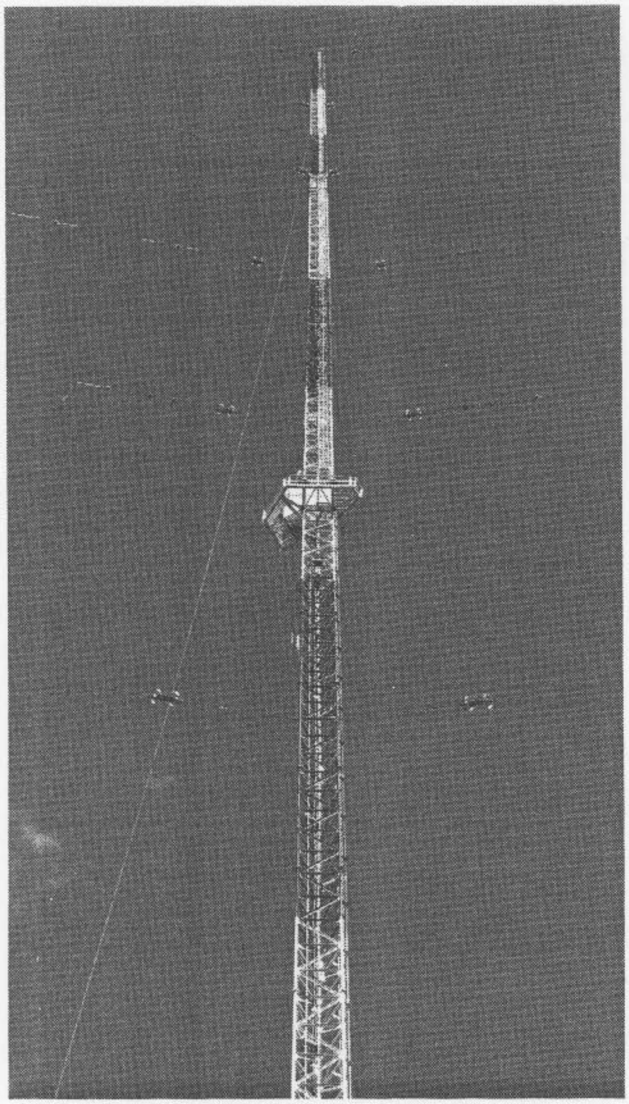
3. Overall height no greater than the old tower to minimize local zoning and FAA problems.

4. A simplified feed apparatus.

5. Isolation of the functions of impedance matching and base loading so that one could be adjusted independently of the other.

Other considerations, principally cost, entered the picture as well, but these were the primary engineering criteria.

The new "Franklin", if we can call it that, is also some 720' in height, just as the old one was. Like the old one, it is insulated at the base and at the feed point, several hundred feet above ground. However, the feed point was lowered some 90' to the 270' level, making the portion of the tower above the feed point essentially ½ wavelength. By adding reactive loading at the tower's base, the current distribution in the lower segment can be adjusted with respect to that in the upper section to modify the antenna's vertical radiation pattern.



New KDKA modified Franklin Antenna

In an ideal Franklin, the currents in the upper and lower sections are in phase, the points of maximum current (the "current loops") are 180° apart, and the integrated areas under the curve in the upper and lower sections are equal and in phase. As shown in Figures 2 and 3, the final model met these requirements, producing a vertical pattern, Figure 4, with dramatically reduced high angle radiation, and with groundwave radiation similar to the old Franklin. Thus, the first three criteria were satisfied.

The antenna is fed at the sectionalizing insulator by coaxial cable, eliminating the need for the balun. Since the impedance matching network is also located here, adjustments to it do not change the load at the base, thereby isolating the impedance matching and base load functions. Base loading is accomplished by a parallel resonant circuit between the base of the tower and ground. The impedance of this circuit can be adjusted over a wide range to provide the desired current distribution. Both the center tuning unit and the base loading assembly are equipped with motor driven components so the complete adjustment can be accomplished by remote control from the transmitter building. An antenna monitor and two RF sampling loops, one in the upper section and one in the lower, provide real time monitoring of the ratio and phase of the current in the two sections.

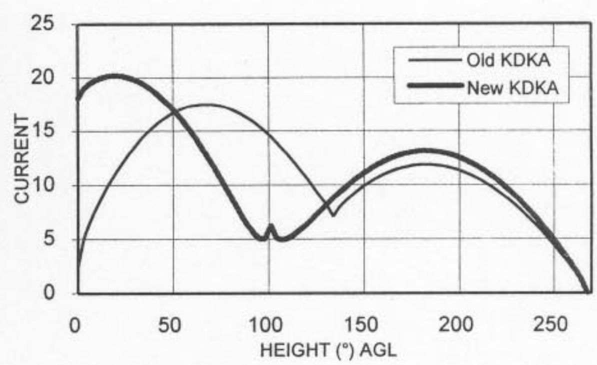


Figure 2

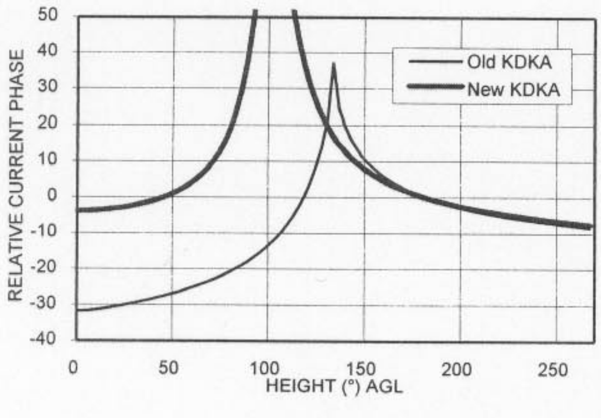


Figure 3

LINE ISOLATION AND GROUNDING

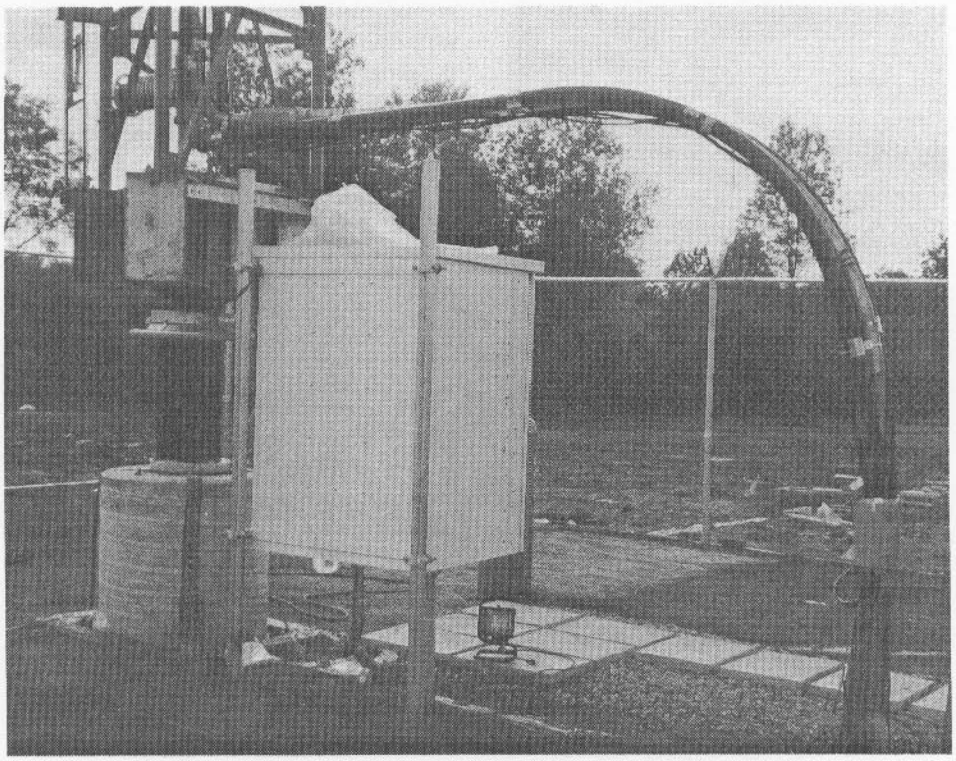
Since the tower is insulated at the base and 270' above ground, it was necessary to provide a means of isolating tower lighting and one sample line across both sets of insulators, and all lines across the base insulator. Since the transmission line was to be 3" semi-rigid, it seemed impractical to wind a length of it into an isolation coil. It was decided that the transmission line should be installed as a quarter-wave stub or "bazooka" section across the base insulator. The line would be insulated from the tower from ground level to a point about 90° above the base insulator where it would be bonded to the tower. From there, it would remain at tower potential to the sectionalizing insulator. This forms a quarter wavelength shorted stub across the base insulator so that the transmission line could be grounded at the base. Conventional chokes and ring transformers were considered for tower lighting, and rejected in favor of conduit also installed as a "bazooka" section across each set of insulators.

In the final configuration, the lighting conduit was fabricated of 3" thick wall galvanized steel. The conduit runs down the center of the tower from the top plate to near the base in a straight line. It is supported with insulated hangers in the bazooka section portions of the tower, and with conductive hangers in the remaining portions. Tower lighting and control wiring run within the conduit, which also serves as a support for both transmission lines (main and spare) and the sample lines. About 10' above the base of the tower, the conduit and lines exit the tower and make a smooth, large radius curve downward to ground. This arrangement accomplishes a number of things:

1. It places the entire tower at DC ground with a large diameter, robust conductor for lightning protection.

2. It isolates all lines and cables across both sets of insulators without the need for ring transformers, chokes, and the like.

3. It provides a suitable support for the transmission lines.



Base loading circuit showing transmission line and conduit.

ANTENNA PERFORMANCE

As Figure 4 shows, the high angle radiation from this antenna is much lower, both in absolute terms, and as a ratio to the radiation at the horizontal, than the best performance that could have been achieved with the old Franklin. The improvement varies with the elevation angle, but over the range of interest, the improvement is generally 10 dB or more.

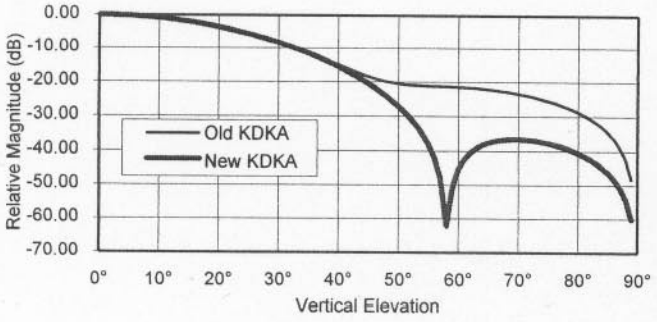


Figure 4

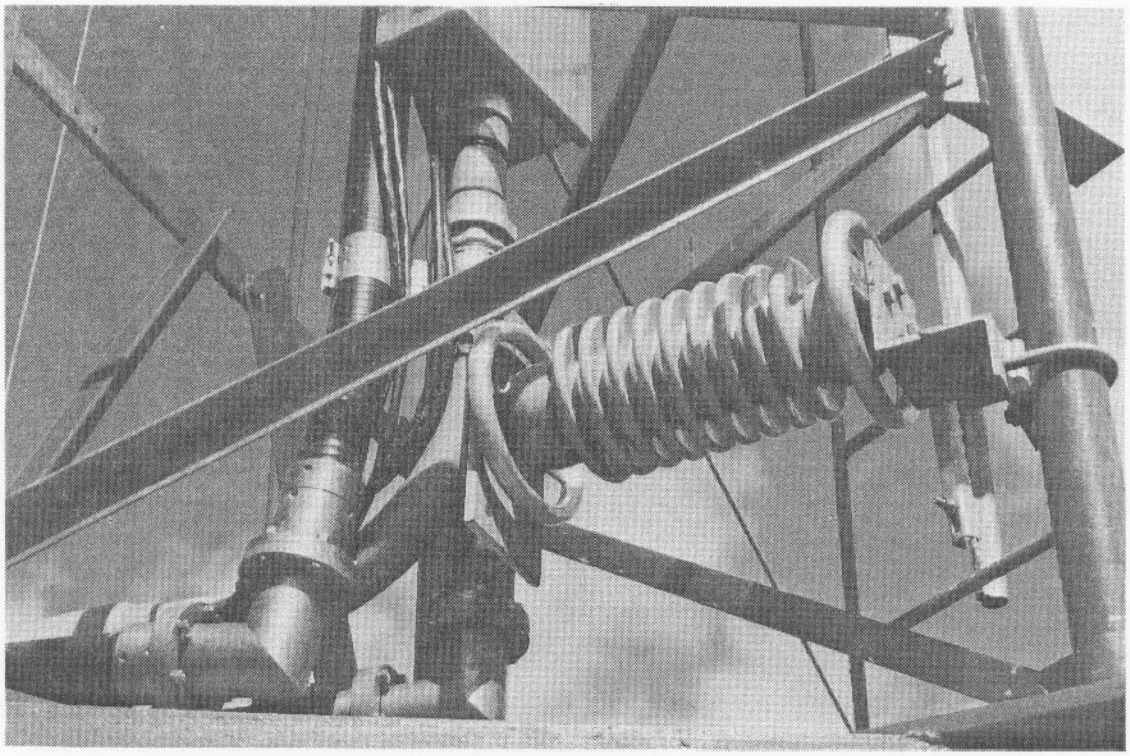
Destructive self fading is difficult to measure, and varies with time of day, season, sun spot cycle, and so on. To our knowledge, there were no quantifiable data taken on the old antenna, so no direct comparison is possible. However, the anecdotal evidence, based on listener reports and spot listening tests by the KDKA engineering staff universally agree that the self fading in the areas of concern is gone.

Standard non-directional proof measurements, as required by the Construction Permit, established the antenna efficiency at about 431 mV/m/kW @ 1 km or about 3050 mV/m @ 1 km for 50 kilowatts. This efficiency is essentially the same as predicted by the MININEC model.

CONCLUSION

With careful MININEC modeling, it was possible to evaluate the old KDKA Franklin antenna and to calculate its vertical pattern. With that as a benchmark, new designs for a modified Franklin could be evaluated and optimized in MININEC. The location of the feed point and the load at the base were varied until a combination was found which offered the most favorable ratio of high angle radiation to radiation at the horizontal, and, therefore, the best anti-fading performance. When compared to the original antenna's vertical pattern, as shown in Figure 4, the improvement was substantial.

The separated functions of impedance matching and loading at the base allow for independence of adjustment. Adjustments to the base loading network change the feed point impedance, but the matching network can be adjusted to compensate for those changes without altering the current distribution.



Conduit and transmission line on insulated hangers at base of the tower.

The use of bazooka sections to cross the two sets of insulators places the entire tower at DC ground for lightning protection. It also allows the various transmission, power and sample lines to cross the insulators without specific isolation components such as isolation coils, lighting chokes or ring transformers, and it provides a supporting structure for the transmission lines.

The authors, and in particular, J. M. Bixby, would be remiss if they did not acknowledge the contributions of Ogden Prestholdt to the success of this project. In addition to being a friend and mentor, Oggie planted the seeds of this approach in an earlier project. He also provided "sanity checks" at various stages, and was a source of encouragement overall.

Thanks are also due the management of KDKA and Group W for their confidence in the project.