Top Mount Omni Directional Broadband Circularly Polarized FM Broadcast Ring Antenna

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Abstract – *Historically, top mounted broadband circularly polarized multi-station FM panel broadcast antennas have been limited to large, complex, and expensive panel antennas. Ring style FM antennas were developed almost 60 years ago and have evolved to a high-power broadband solution. The one disadvantage of the ring style antenna is the circularity which is compromised by the tower the antenna is mounted to. This paper will discuss a new approach which allows for top mounting a ring style antenna without sacrificing circularity. In fact, the circularity of this solution is better than typical panel antennas and allows the broadcaster to benefit from the less complicated, more reliable, lower windload and more economical advantages of a ring style antenna.*

INTRODUCTION

The requirement for omni directional service from a high-power multi-station master FM broadcast system has limited the antenna choice to a top mounted panel design.

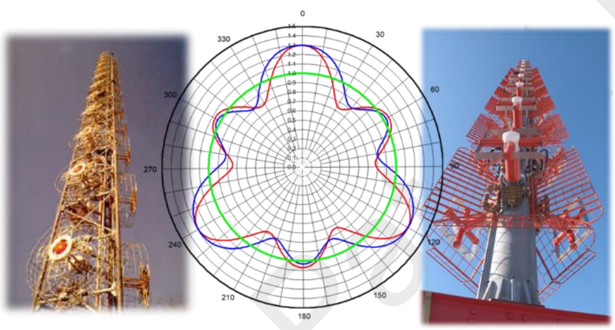


Figure 1: Top mounted high power broadband panel master FM broadcast antennas and their typical azimuth pattern performance. Blue-horizontal polarization, red-vertical polarization and green – rms.

Although master FM panel arrays offer good omni directional service, they are associated with many power dividers, feedlines, numerous connections and complicated radiators with many parts. Their large size also correlates to a high windload on the tower. Ring style antennas are far less complicated and have much less windload. In recent years, advances in ring style antenna technology have allowed them to be considered for high power broadband master applications, but typically only for auxiliary operation. This is due to the impact the tower has on the antenna's azimuth pattern.

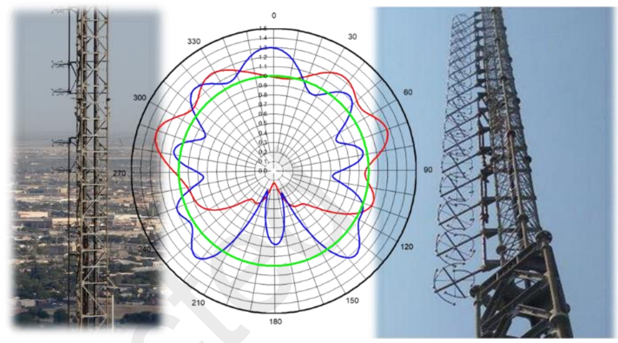


Figure 2: Side mounted high power broadband ring style master FM broadcast antennas and their typical azimuth pattern performance. Blue-horizontal polarization, red-vertical polarization and green – rms.

RING STYLE FM BROADCAST ANTENNAS

In 1967 Matti Siukola, RCA Scientist and Unit Manager of Advanced Development for RCA Broadcast Systems, presented his famous paper "Dual Polarization FM Broadcasting with a Single Antenna" at the NAB symposium. The concept of radiating circular polarization from a single element revolutionized the FM broadcast industry and is still the basic premise for ring style antenna design today [1].

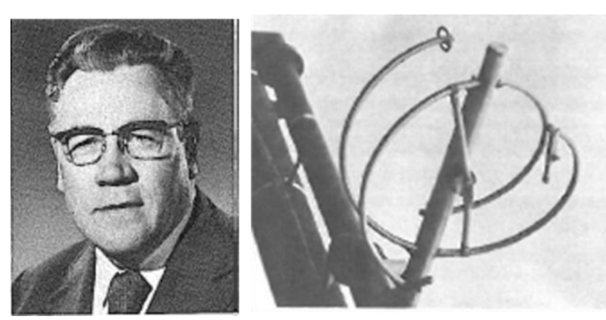


Figure 3: Matti Siukola – RCA's BFC - First dual polarized FM element.

The BFC was both bandwidth and power limited due to its size. In 1978, Don Hymas, RCA Unit Manager Antenna Engineering, presented his work at the 1978 IEEE symposium "A New High Power Circularly Polarized FM Antenna", which introduced the industry to the RCA-BFM.

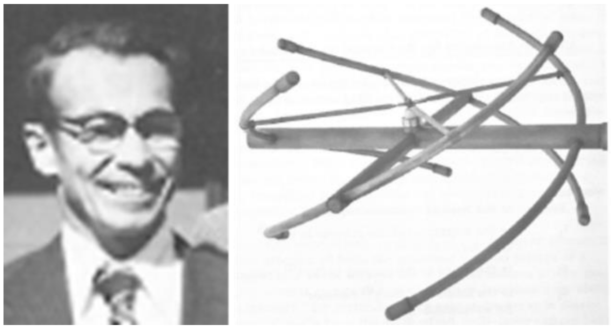


Figure 4: Don Hymas – RCA's BFM – High power broadband circularly polarized FM element.

The BFM's quadrupole design was larger for higher bandwidth and filled in the azimuth pattern with its two extra radiators to produce omni directional coverage. In 2015 Dielectric took ring style technology one step farther by developing the DCRU. By increasing the balun size, pressurizing the feed point, and utilizing a spherical tap point, a single ring style bay could now handle 40kW with high tolerance to peak voltages and full band performance [2].

Figure 5: DCRU High power broadband ring style FM broadcast antenna bay.

With this advancement, the ring style element could now handle as much power as any panel antenna bay with over ten times less parts at a fraction of the windload and cost but still suffered from circularity when mounting it to a tower.

HELICAL NATURE OF A RINGLE STYLE ANTENNA

The basic nature of a broadside helical antenna radiates equal amplitude and equal phase in all azimuth directions.

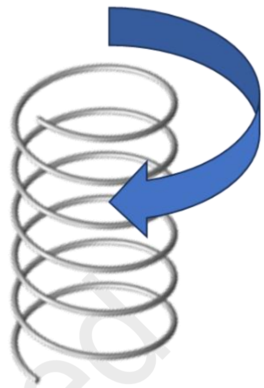


Figure 6: Helical antenna radiates equal amplitude and phase in all azimuth directions.

The FM ring style antenna is basically a truncated helix and therefore also radiates the same amplitude and the same phase in all directions. This means the antenna bays can be rotated in any azimuth direction within an array, and they will still add constructively in phase in both the elevation and azimuth plane.

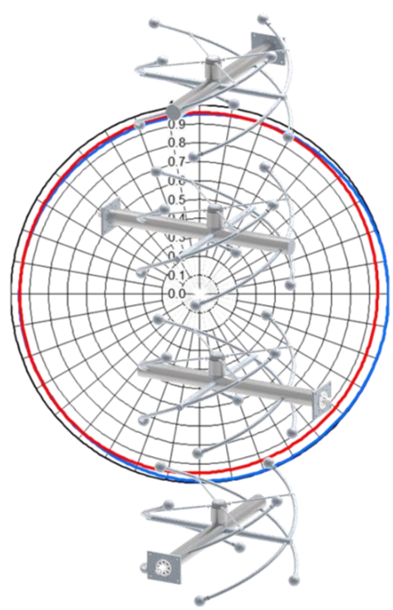


Figure 7: Helical nature of a ring style FM antenna element allows it to be oriented in any direction within an array.

This is the basic premise behind the ability to design a top mount structure that supports FM ring style bays without sacrificing circularity. To utilize this feature, we first look at the performance of a ring style antenna on a support pole. The horizontal polarization remains relatively omni due to the small mass of a pipe in the horizontal plane. The vertical polarization is directionalized into a cardioid shape due to the pipe being in the vertical plane.

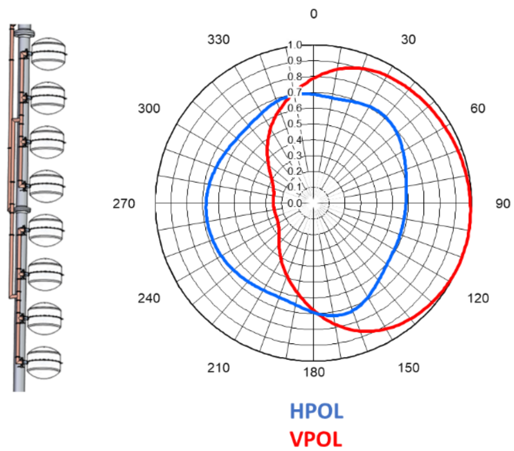


Figure 8: Horizontal and vertical polarization azimuth pattern of a FM ring style antenna when mounted to a support pole.

If the entire structure was rotated 180 degrees, the azimuth pattern of both polarizations would also rotate 180 degrees as shown in Figure 9.

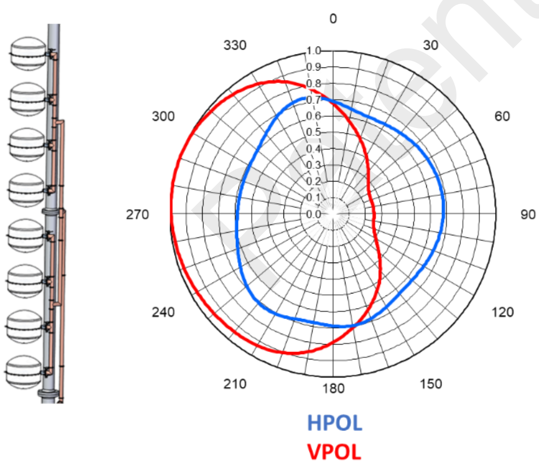


Figure 9: Support structure rotated 180 degrees from that shown in Figure 7.

When placing the support structure shown in Figure 7 above the support structure shown in Figure 8 while keeping the antenna element in the same vertical plane, it can be shown that the far field composite pattern of the entire array is the sum of the patterns producing omni directional performance. For completeness, a full 16 bay, half wave spaced antenna was simulated in ANSYS HFSS to prove the concept. A real feed system and working mechanical design were all included as shown in Figure 10.

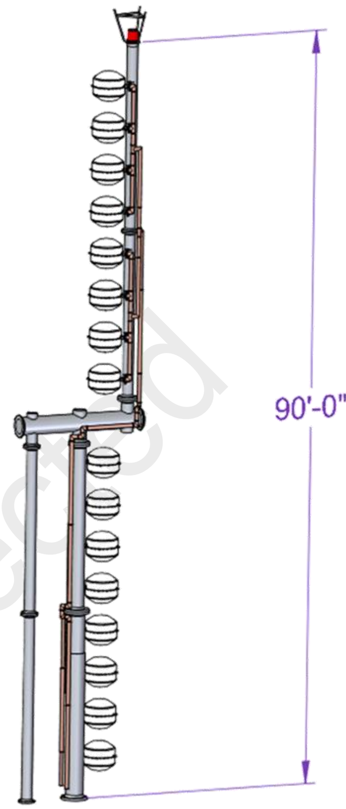
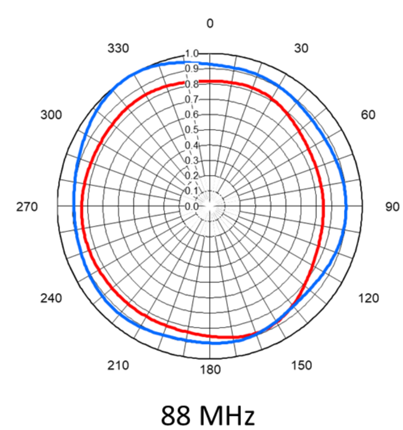


Figure 10: Full model of a 16-bay half wave spaced top mounted omni directional ring style antenna.

The HFSS simulation results, which include real pipe sizes, a full feed system and the mechanical counter pipe shown in Figure 10 are given in Figure 11.



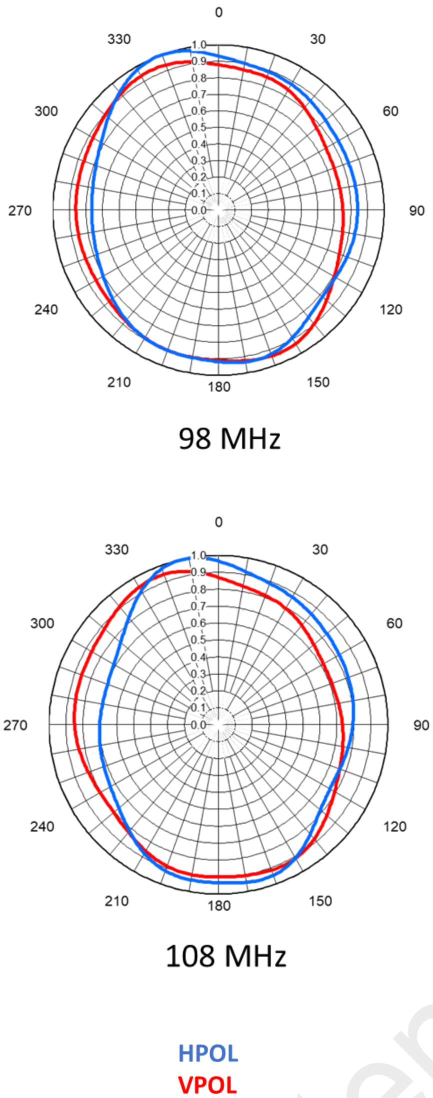


Figure 11: Azimuth patterns for both horizontal and vertical polarizations for the configuration shown in Figure 10.

It should be noted that the circularity of this configuration is better than a typical 3 around master FM panel design. It should also be noted that the windload is 60% less than a comparable 3 around panel design.

MECHANICAL CONSIDERATIONS

The requirement for the supporting tubular mast structure to move from one side of the radiating element in the lower half of the antenna to the opposite side in the upper half presents structural challenges. To accommodate this transition, the mast must jog over between the halves, introducing a clear mechanical imbalance. To mitigate this, the top mast section is reduced in size to lower the load on the primary structure, and a secondary mast is added to the bottom to reinforce the primary lower mast that supports the antenna bays. A large-diameter horizontal pipe connects the upper and lower halves, designed to withstand bending and torsional stresses while enabling robust through-pipe joints. Figure 10 illustrates the resulting unconventional structure. It is depicted as a dual flange mount, but it can also be made as a dual bury mount, or a hybrid flange/bury mount. The bury mount option may well be preferable, as it offers greater flexibility in accommodating typical manufacturing tolerances. Regardless of the configuration, the tower top must be adapted to integrate this new structure. Importantly, the counterbalance pipe in the lower half is shadowed by the element support pipe, thus does not introduce significant degradation in the circularity of the combined upper and lower arrays.

VERSITILITY IN TECHNOLOGY

Since this new technology is based on the behavior of a ring style radiating element, the technique is not limited to any ring style type as long as it acts as a truncated helix or any vertical spacing between bays in an array. Recent advances in optimizing ring style performance by combining variable spacings within the same array known as RingMaster technology can also be applied to this new concept.

IMPEDANCE TESTING OF A BAY CLOSE TO LARGE PIPES

To understand the effect that placing a broadband ring style antenna bay close to a large diameter support structure, the following test was conducted. A 24” diameter pipe was placed 12” from the helical arms of a 2-bay broadband ring style, as shown in Figure 12, to study the effect it would have on the overall bandwidth of the system.

Figure 12: Testing the impedance effect of a large diameter pipe placed close to the helical arms of a broadband ring style antenna.

The results with and without the tube compared on a smith chart shown in Figure 13.

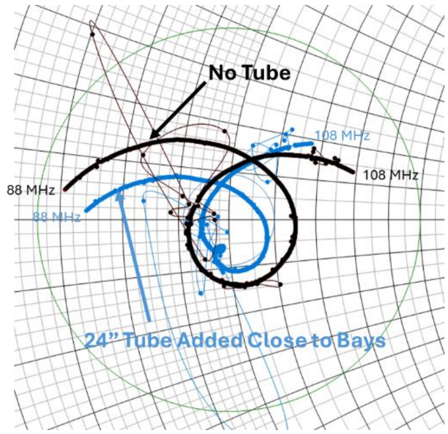


Figure 13: Testing the impedance effect of a large diameter pipe placed close to the helical arms of a broadband ring style antenna. Black is raw and Blue is with a 24" tube added 12" from the helical arms. Note the measurements span the entre FM band.

It should be noted that this change in overall bandwidth is not significant and in fact is better in the presence of the large tube.

CONCLUSIONS

It has been many years since a new game changing technology in FM broadcast antenna design has been introduced to the market. A new innovative design now allows a high-power ring style antenna to be mounted at the tower top and utilized as a true omni directional broadband master FM broadcast system. The advantages that this design has over conventional panels are numerous, including less complexity with over 90% less parts, more reliability due to its simplicity, much less windload and less cost.

ACKNOWLEDGMENTS

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REFERENCES

[1] Schadler, J.L., "Changing the Landscape of FM Broadcast Antenna Technology", NAB BEITC Proceedings, 2022

[2] Schadler, J.L., "Considerations for -10 dBc IBOC Combined Station Side-mount Master FM Antenna Design", 2015 IEEE symposium