ATSC3.0 Ready Slot Antenna Design Using Advanced Antenna Optimization Methods

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Coaxial slot antennas are a favored design by U.S. broadcasters due to their low complexity and ability to be customized [1]. Coaxial slot antennas currently designed and manufactured for the FCC repack should be designed with future ATSC3.0 operation in mind. Both elliptical polarization and heavy but smooth null fill are desirable for ATSC3.0 [2]. By utilizing heavy fill and elliptical polarization signal strengths can be increased in the near in coverage areas allowing better S/N ratios for data intensive applications in those areas. It is important in designing such an antenna, to ensure that the gain of the antenna is not decreased significantly compared to a traditional antenna. Design methods have been adopted that optimize the gain by minimizing radiation above the horizon.

Common slot antenna design methods frequently involve designing an antenna for a specific radiation pattern and then tuning the antenna to meet VSWR specifications. Unfortunately these tuning iterations can adversely affect the smoothness of the elevation radiation pattern. We have proposed a design methodology that controls multiple parameters of the antenna array to concurrently optimize the elevation radiation pattern, antenna gain and VSWR of the antenna. Slot antennas are serial fed, which complicates the design since the VSWR and elevation radiation patterns must be designed simultaneously. This means modifying the radiated amplitude or phase from a slot, to optimize the elevation pattern, will affect the input VSWR of the antenna. Likewise, modifying the antenna to improve the input VSWR will affect the elevation pattern of the array. Another complication is the trade-off between accuracy and iteration time. Using a circuit model of the antenna to optimize the pattern and VSWR is fast, but includes many approximations which will negatively affect the final design. 3D electromagnetic software such as HFSS is accurate, but drastically limits the amount of iterations due to its long runtime.

Our approach is to use many relatively small EM simulations of single slot models to create a dataset of EM slot data. This EM data is then combined with a circuit model into a hybrid EM/circuit model. This allows for high accuracy of the elevation pattern and VSWR data but allows for many iterations in a short amount of time.

The optimization problem of coaxial slot antenna, even a circuit model, is computationally difficult. The elevation radiation pattern is dependent on the radiated amplitude and phase of each slot, so the optimization problem has 2*N variables, where N is the number of slots aligned with the vertical axis. Considering most broadcast slot antennas are in the range of N = 20-30 slots, a brute force optimization method will be ineffective in a reasonable amount of time. What was needed was an algorithm to optimize the elevation pattern in a more targeted way. By analyzing a large set of existing “standard” amplitude-phase data and their respective elevation patterns, a formula was developed to assist in the optimization of the slot antenna. Assuming starting amplitude and phase parameters A_i and P_i, initial optimization parameters are created via this formula $\alpha_i, \phi_i = g(A_i, P_i)$. Then the hybrid model can be optimized using the parameters α_i, ϕ_i. Finally new amplitudes and phase parameters are calculated by $A^*_i, P^*_i = g(\alpha^*_i, \phi^*_i)$. Fig. 2 shows the flow of the optimization process using this algorithm.

Using this method an accurate slot antenna design with smooth elevation pattern and complaint VSWR can be created in a short amount of time. Next the performance should be verified using a 3D EM tool such as HFSS. If any non-compliance is found during the HFSS analysis further optimization can be performed using a space mapping technique [3], however usually very little changes are required due to the high accuracy of the hybrid model. In RFS experience manufacturing slot arrays via this method will result in a rigorous design that will require no post-assembly tuning. Removing post-assembly tuning from the manufacturing process cuts days or weeks from the antenna lead time and drastically improves the predictability of the testing.

Fig 3 shows an example of a “before” and “after” optimization case for a 28 slot end fed slot antenna. By smoothing the pattern from the blue curve to the red, there is up to 1.3 dB of improvement to the pattern nulls. Also, wasted energy being radiated above the horizon is reduced by 2.8 dB. The hybrid EM/circuit model optimizer method gives a smooth elevation radiation pattern with reductions in wasted over the horizon power, while assuring a complaint input VSWR.

Based on these latest developments smoother elevation patterns with heavy smooth null fill characteristics that are desirable for ATSC3.0 are being deployed across the U.S. We will also show how these advances impact both serial end fed arrays and two branch center fed slot antenna arrays.

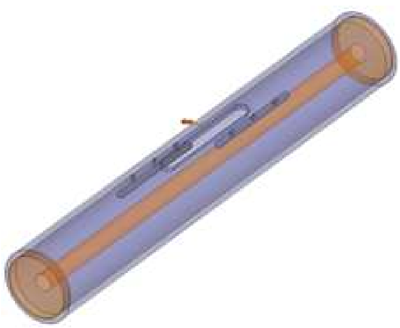

Fig.1 – Sample HFSS model of a single coaxial slot used to generate a data set for the hybrid model.

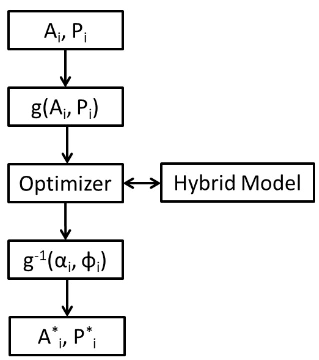

Fig.2 – Optimization flow created to use the derived algorithm to quickly optimize the hybrid model for elevation radiation pattern and VSWR

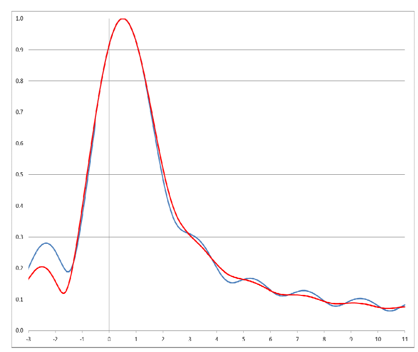

Fig.3 – “standard” elevation pattern vs. an optimized “smooth” case. Optimized pattern has over 1 dB in improvement in ripples

References

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[3] B. George, M. Fanton, N.Wymant, Y. Cao, “Advanced Modeling Method for UHF Broadcast Slotted Coaxial Antennas” IEEE Broadcast Symposium in Hartford, CT 2016.