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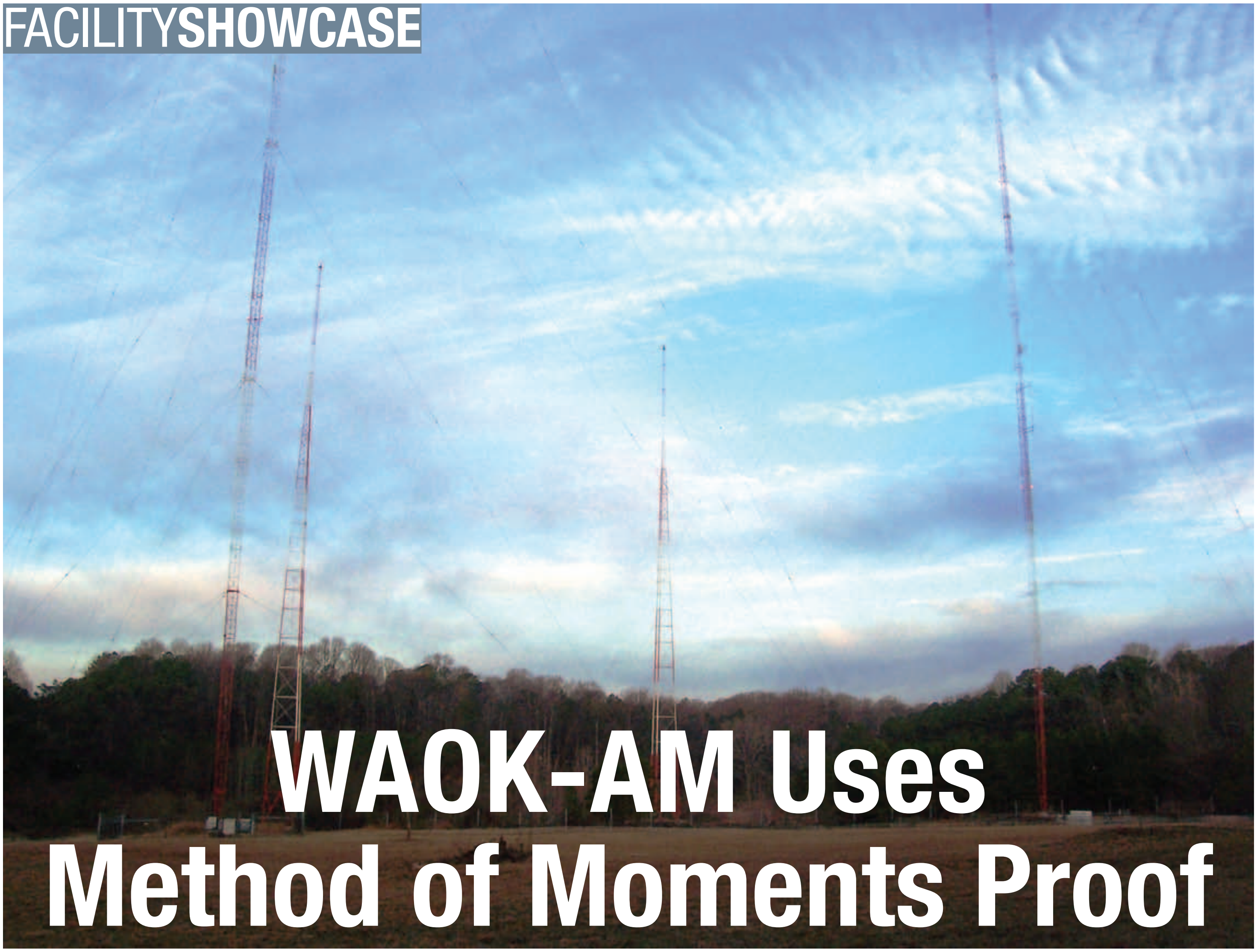


WAOK-AM Uses Method of Moments Proof

The antenna system employs Kintronic Labs VSU-1 voltage sampling units.

By Donald Crain and Thomas F. King

The FCC has allowed stations to use Method of Moments proofs, and WAOK-AM in Atlanta, is one of the first stations to implement the technology by using Kintronic Laboratories Model VSU-1 voltage sampling units. The VSU-1 was initially introduced at the 2010 NAB Show, where it received a *Radio* magazine Pick Hit. Following further development and testing, the first production units were supplied to WAOK in January 2011 for installation in its four-tower nighttime array that utilizes two self-supported and two guyed half-wave towers. A Method of Moments proof of performance of the WAOK nighttime array was conducted in March 2011, submitted to the FCC on April 5, 2011, and was subsequently granted by the FCC on June 9, 2011.

You may ask, Why use voltage sampling when current sampling has been around for so long? The window of opportunity to utilize voltage sampling to conduct a Method of Moments (MOM) proof of AM directional antenna (DA) arrays was opened as a result of the efforts of a determined committee comprised of professional consulting engineers and broadcast equipment manufacturers that persevered over a period of at least 10 years in formulating with the FCC what became FCC 08-228 MM Docket No. 93-177 dated Sept. 26, 2008, entitled "An Inquiry Into the

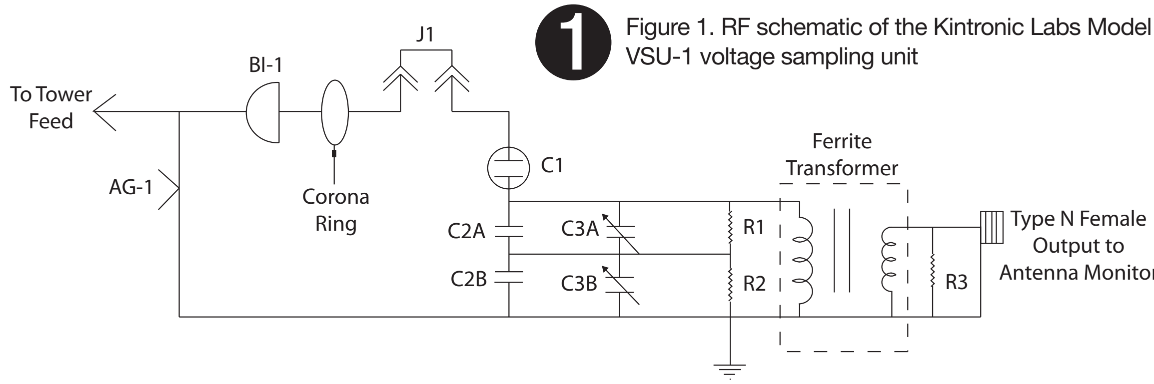
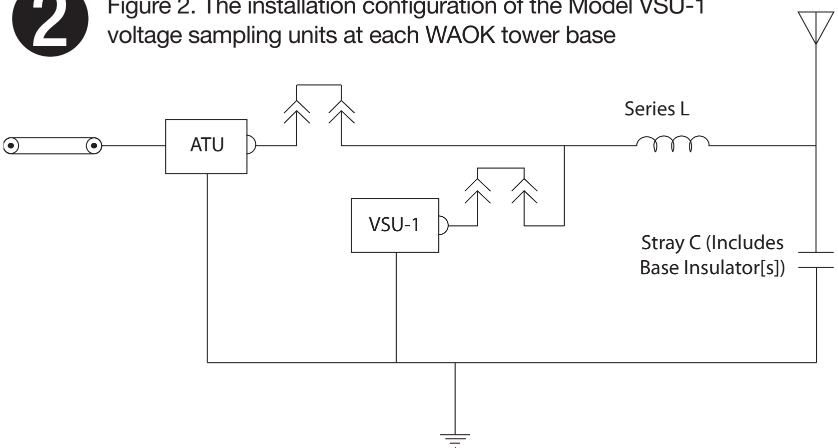


Figure 1. RF schematic of the Kintronic Labs Model VSU-1 voltage sampling unit

Figure 2. The installation configuration of the Model VSU-1 voltage sampling units at each WAOK tower base



A Model VSU-1 unit installed at the base of one of the four towers in the WAOK array

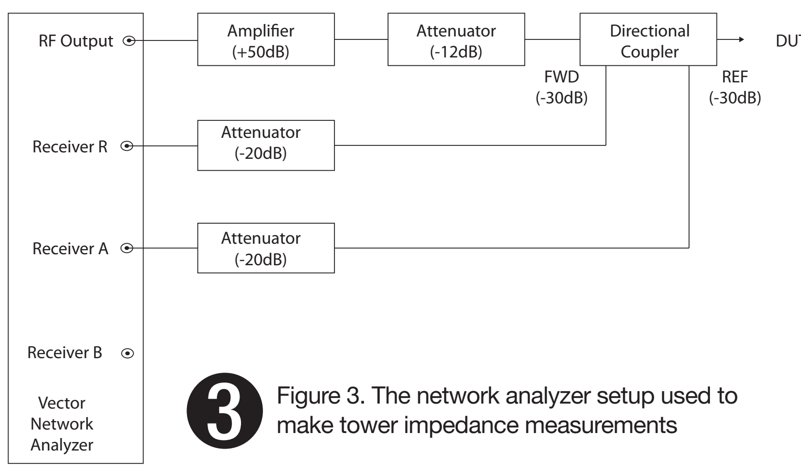


Figure 3. The network analyzer setup used to make tower impedance measurements

Commission Policies and Rules Regarding AM Radio Service Directional Antenna Performance Verification." Referring to Section 73.151(2)(i) of this landmark revised rulemaking the following statement regarding voltage sampling of AM DAs can be found: "Samples may be obtained from base voltage sampling devices at the output of the antenna coupling and matching equipment for base-fed towers whose actual electrical height is greater than 105 degrees." The CBS WAOK nighttime array was an ideal candidate for voltage sampling because it utilizes half-wave towers with differing cross sections. Voltage sampling was the only avenue whereby a MOM proof of this array could be accomplished resulting in major cost savings in consulting fees compared to the cost of full multi-radial proof of performance. As the towers are greater than 120 degrees in height, but shorter than 190 degrees, the array does not qualify to use base current sampling. Because the towers are not identical in cross-section, sampling loops cannot be used. In addition, the requirement to have monitor points was eliminated and the sampling system could be maintained on the ground as opposed to having to send up tower riggers to maintain sample loops and the associated sample lines.

The VSU basic design is attributable to Ronald D. Rackley, PE, who provided to Kintronic Labs and other manufacturers a technical treatise on a prototype design that he developed to spur interest in further development of a marketable voltage sampling unit. The design includes a capacitive voltage divider coupled into a ferrite transformer the output of which is designed to drive a 50Ω load (See Figure 1.)

WAOK MOM PROOF METHODOLOGY

Following the installation of the voltage sampling system in the WAOK array Don Crain visited the site to conduct phase 1 of the MOM proof process. All the WAOK towers are 179.3° electrical height. Towers 1 and 2 are fixed cross-section guyed towers each having a facewidth of 30.25". Towers 3 and 4 are tapered cross-section triangular self-supported towers having a base cross section of 24.75' tapering to a cross section of 30.25" at the 290' level and having a fixed cross section of 30.25" for the top 65'. Robert LaFore, the CBS Atlanta market chief engineer, had to arrange for a tower rigger to climb one of the self-supported towers and measure the facewidth

Tower 1	147.73 - j300.07
Tower 2	110.91 - j278.32
Tower 3	46.104 - j111.34
Tower 4	44.293 - j104.32

Tower	+45 Degree Offset Frequency (kHz)	+45 Degree Measured Impedance (ohms)	-45 Degree Offset Frequency (kHz)	-45 Degree Measured Impedance (ohms)	Calculated Characteristic Impedance (ohms)
1	1118.889	7.54 - j48.15	1367.531	9.18 + j48.11	48.86
2	1120.2696	7.51 - j47.81	1369.2184	9.01 + j47.65	48.44
3	1120.0725	7.45 - j47.53	1368.9775	9.00 + j47.47	48.21
4	1119.5559	7.49 - j47.91	1368.3641	9.10 + j47.92	48.66

Tower	Sampling Line Open-Circuited 90 Degree Resonance (kHz)	Sampling Line Open-Circuited 450 Degree Resonance (kHz)	Sampling Line Calculated Electrical Length 1380kHz (degrees)	Measured Impedance with VSU Connected 1380kHz (ohms)
1	246.105	1243.21	499.513	5.48 - j33.08
2	246.400	1244.744	498.898	5.42 - j33.13
3	246.725	1244.525	498.986	5.41 - j33.14
4	246.312	1243.951	499.216	5.44 - j31.91

as a function of height due to the lack of any tower drawings at the station. This information was critical for the tower modeling effort required for the MOM proof.

Upon arrival at the station Crain measured the impedance of each tower with the other towers either open or shorted. Figure 2 shows the tower base installation configuration for the voltage sampling units.

A four-port network analyzer with an RF power amplifier and a Tunwall Radio directional coupler based on the technique developed by Ron Rackley was used to make the measurements as shown in Figure 3.

The impedance measurements were made at the tower side of the open J-plug in each VSU unit as shown in Figure 2 with the ATU output J-plug open as well. The impedances measured for the shorted case are shown above.

The characteristic impedance of the sample lines was also measured using the following mathematical expression:

$$Zo = \sqrt{\sqrt{(R1^2 + X1^2)} \bullet \sqrt{(R2^2 + X2^2)}}$$

With R1 + X1 equal to the measured impedance at the +45 degree offset frequency and R2 + X2 equal to the measured impedance at the -45 degree offset frequency.

The results of the sample line characteristic impedance measurements are shown on at right in green.

In addition Crain conducted measurements of the sample line electrical lengths that were derived by measuring the open circuited 90 degree and 450 degree resonance frequencies. The results are shown below in blue.

The measured characteristic impedance and electrical length variations relative to the average are less than ±1 percent and ±0.5 degrees. Based on these measured data, Crain returned to his office to develop a computer model for this complex array using MININEC Broadcast Professional V14.5 software. Each of the four towers were modeled using 19 segments with the tower 1 and 2 segments having a uniform length and radius and towers 3 and 4 being modeled in a graduated diameter stacked cylinder approach where the bottom segments had longer segments and larger radii with uniform segment and radius at the top fixed cross section portion of the tower. The tower spacings and orientations from the FCC database were identical in the self-impedance and DA models. The segment lengths and radii were varied while maintaining the tower height as constant to converge on modeled tower impedances with the other towers shorted that matched the corresponding measured impedances. A table of the final modeled segments for towers 3 and 4 are shown in the red table below.

Following the completion of the tower models the final segment data was input into the MININEC Broadcast Professional

Tower	Model Current Pulse	Model Voltage Magnitude (amperes)	Model Voltage Phase (degrees)	Model Drive Impedance (ohms)	Model Drive Power (watts)
1	1	1218.04	2.8	129.67 - j335.46	1487.32
2	20	1160.18	82.7	81.076 - j411.30	620.97
3	39	573.908	22.2	74.466 - j217.49	464.129
4	58	593.784	-85.1	72.681 - j102.29	1627.58

Tower Segment	Physical Height (degrees)	Model Height (degrees)	Model Percent of Height	Model Radius (meters)	Percent Equivalent Radius
3-1	22.72	24.5376	108.0	3.3479	100
3-2	22.719	24.5365	107.999	2.8398	100
3-3	17.671	19.0847	108.0	2.3881	100
3-4	15.146	16.3577	108.0	2.0212	100
3-5	12.622	13.6317	108.0	1.7106	100
3-6	10.098	10.9058	107.999	1.4566	100
3-7	10.097	10.905	108.002	1.2308	100
3-8	7.573	8.179	108.002	1.0332	100
3-9	7.574	8.18	108.001	0.8638	100
3-10	7.573	8.178	107.989	0.6944	100
3-11	7.573	8.179	108.002	0.525	100
3-12	5.049	5.453	108.002	0.3839	100
3-13 to 3-19	4.6979	5.0737	107.999	0.3274	100
3 Overall	179.3	193.644	108.0		100

Tower	Drive Impedance at VSU (ohms)	Voltage Magnitude at VSU (volts)	Voltage Phase at VSU (degrees)	Antenna Monitor Ratio	Antenna Monitor Phase
1	106.92 - j267.83	1075.607	5.4851	108.1	-78.7
2	53.19 - j286.19	994.7057	84.1663	100.0	0.0
3	44.78 - j159.26	532.5942	23.3579	53.5	-60.8
4	56.60 - j71.77	490.1382	-77.5847	49.3	-161.8

DA model. The drive impedances, power division and operating parameters for the required pattern were derived using FCC database theoretical information for operational constants. The table in green shows the final computed results.

Now taking into consideration the measurement derived series and shunt tower base reactances the corrected self impedance at each of the VSU measurement locations was computed using the WCAP network analysis program developed by Jerry Westberg. With equal length sample lines the operating parameters are equal to the base sampled voltages and phases. The final derived operating parameters are shown in the blue table above.

At this point it was time to return to the station and adjust the array to the predicted parameters. The previous measured proof monitoring points were used as reference points for the MOM proof. Following adjustment of the array to the predicted parameters all of the measured proof monitoring points were found to yield a reduced field intensity with the MOM proof parameters. This process was accomplished in record time compared to the weeks that typically would be involved in collecting multiple radial field intensity measurements followed by an exhaustive report. As stated earlier, the MOM proof was filed on April 5, 2011, and the license was granted on June 9, 2011.

We want to affirm with anyone considering the use of these voltage sampling units that they are resilient in lightning environments as attested to by an unsolicited report from Robert LaFore, the WAOK chief engineer.

"The VSUs are indeed coping with lightning very well. I just had a tower crew on tower 3 of the WAOK array. The insides of the beacon assembly are pretty much vaporized, and the wiring to that beacon is melted and charred badly. Paint is gone on the top of the tower. At the same time we lost several microswitches at tower 3. The VSU is showing nice steady numbers night after night."

When this report was prepared we had no reports of any problems with the Kintronics voltage sampling system.

The authors thank Ron Rackley for his exceptional involvement in the development of the voltage sampling units and in his oversight of the MOM proof.

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