by Clarence M. Beverage

FCC Makes Important Changes to AM Rules

This is an historic time in the history of AM "Medium Wave" standard broadcasting in the United States.

On Friday, September 26, 2008, the Federal Communications Commission released the Second Report And Order concerning changes to the FCC Rules Regarding the AM Radio Service and Directional Antenna Performance Verification (MM Docket No. 93-177).

NINETEEN YEAR EFFORT

The Report And Order was then published in the Federal Register, making the Rules effective on December 1, 2008. However, until the Office of Management and Budget signs off on the forms, there is no way to actually file one right now.

The initial Rulemaking proposing that AM directional proof of performance standards should be updated was filed with the FCC on December 15, 1989 by a consortium of five broadcast consulting engineering firms. In recent years, it was referred to as Docket 93-177

The successful conclusion of this 19-year approval process came through the participation and cooperative efforts of the industry as a whole: FCC staff, NAB, consulting engineers, manufacturers, attorneys, and group owners who participated in the final filing efforts.

SOME KEY POINTS

Among the new Rules for Directional Antenna Performance Verification, two aspects in particular will impact broadcast engineers and station owners.

The first is approval of the use of Method of Moments (MoM) analysis, such as the Numerical Electromagnetics Code ("NEC") or MiniNEC to accurately predict the relationship between pattern shape and internal array parameters. The second is an off-shoot – to make sure the MoM works, accurate measurements of the installed towers and components are required.

The thrust of the new Rules is that the calculated values need to match the measured values within a very close tolerance to prove proper pattern adjustment. This places a high burden on the field and/or chief engineer making system measurements.

MEASUREMENT DATA COLLECTION

Among the data that should be part of any installation are:

• The matrix of impedances at the base (feed point) of each radiator in the array, with all other radiators elements shorted and/or open circuited.

• Measurement of the lumped series inductance of the feed system between the output port of each radiator tuning unit and the associated radiator.

• Measurement of the shunt capacitance of each tower base.

• Verification of the sampling line impedance to confirm that all lines are of equal impedance within two Ohms.

• Verification of the sample line electrical length to confirm that lines are within one electrical degree.

Modern vector network analyzer (VNA) equipment allows measurement of components, networks, radiators and transmission lines with high levels of accuracy not previously attainable. Using the gear and developing useful field measurements is our focus in this article. The next issue of ***Radio Guide*** will focus on MoM analysis.

THE IMPEDANCE BRIDGE

Before we discuss measurement procedures, a brief survey to compare the impedance measurement equipment used in past decades with current technology is appropriate.

For many decades General Radio Company in Cambridge, Massachusetts was the prime supplier of antenna impedance bridges. The 916 and 1606 models have been primary tools for several generations of engineers.

The Model 916AL was first sold in 1942 and was often used for broadcast impedance measurement reports submitted to the FCC well into the 1980s. The frequency range covered 50 kHz to 5 MHz and could read resistance from 0 to 1,000 Ohms and reactance up to 11,000 Ohms at 100 kHz.

The General Radio Model 1606-B was first manufactured in 1967 and is still in use today. The frequency range covered 400 kHz to 60 MHz, and it could read resistance from 0 to 1000 Ohms and reactance up to 5,000 Ohms at 1 MHz. Basic accuracy for the 1606 versions was specified at plus or minus 2%

General Radio Type 1606-A RF Bridge

THE OPERATING BRIDGE

Delta Electronics revolutionized the process of measuring impedance in broadcast antenna systems with the introduction of the operating impedance bridge.

The OIB-1, and extended range OIB-3, can be inserted in-line in an operating transmission system so that an external generator and detector are not required for carrier measurements. They also may be fed with a signal generator, and an external detector employed, for non-directional or common point impedance measurements.

The OIB-3 extended range bridge is designed for operation between 500 kHz and 5 MHz with a resistance range of 0 to 1000 Ohms and a reactance range of -900 to +900 Ohms. Basic accuracy is plus or minus 2% plus or minus 1 Ohm. These instruments are used regularly in broadcast applications where driving point impedance and network input impedances are required in directional antenna systems.

Delta OIB-1

In my opinion, a Delta bridge should not be used except for driving point impedance measurements in a directional array as the bridge introduces stray reactance which can significantly affect impedance readings, especially for towers between 110 and 190 degrees in height.

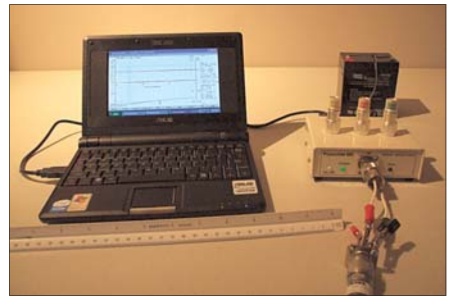
VECTOR NETWORK ANALYZERS

Numerous manufacturers produce vector network and impedance analyzers that can be used for circuit and antenna measurement work.

One high-end example is the Agilent E4991A, with a basic accuracy of 0.8%, retailing at $50,000.00. Equipment of this nature is not cost effective for field use and is not designed for direct connection to broadcast towers where high RF voltages impressed by other nearby radiators can damage the analyzer input circuits.

In 2008, Kintronics Labs introduced a new VNA to the broadcast industry designed for the rigors of field work but with high accuracy, battery power, and computer control – the PowerAIM 120.

The PowerAIM 120 covers 0.1 to 120 MHz employing an internal RF generator using step sizes from 1 Hz to 10 MHz. It has an impedance range of 1 Ohm to 2,000 Ohms with an accuracy of 1 Ohm, plus or minus 5% up to 60 MHz, at phase angles to plus or minus 90 degrees. The maximum safe RF input is 50 Volts peak-to-peak.



A PowerAIM 120 hooked to an Asus Eee running Windows XP for instrument control and data storage.

ENSURING GOOD DOCUMENTATION

What follows is a brief examination of, and a discussion of, specific field measurement techniques to obtain the most accurate readings possible.

In any project, extreme care must be taken to calibrate the test equipment to remove any ambiguity related to test lead length, routing and test equipment placement. A common reference signal needs to be used to verify that sample devices, installed at the output of the antenna coupling unit, are within the manufacturer's calibration specifications.

Copious field notes and digital pictures are very important so that the system can be fully described at any time in the future, should questions arise.

GETTING ALL THE DATA

Rule Section 73.151(1) requires that the impedance of each tower in the directional array be measured at the base, or feed point, with all other towers shorted and/or open circuited. For a three-tower array, the measured data would be as follows:

At Tower #1

1. Measure impedance with towers #2 & #3 open.
2. Measure impedance with #2 shorted and #3 open.
3. Measure impedance with #3 shorted and #2 open.

At Tower #2

1. Measure impedance with towers #1 & #3 open.
2. Measure impedance with #1 shorted and #3 open.
3. Measure impedance with #3 shorted and #1 open.

At Tower #3

1. Measure impedance with towers #1 & #2 open.
2. Measure impedance with #1 shorted and #2 open.
3. Measure impedance with #2 shorted and #1 open.

AVOIDING PROBLEMS

So, where are the traps that can get you into trouble here?

First, it is critical that the measured data makes sense to the design engineer who is constructing the NEC models to be employed in the initial proof. In fact, it would be wise to e-mail your results before leaving the site. If your role will be to recertify an installation, try to be on site to witness the original verification process.

During the process, record the leg diameter and face width of the tower. Take several photos to confirm that the tower matches the quoted specifications and design drawings. Improper construction practices such as failing to bond transmission lines to the tower at proper intervals or failing to bond the tower light conduit regularly can impact impedance readings.

Then take the open and short measurements at the feed point on each tower – and that point should be the same on all towers. Failure to do this can result in data that does not match the model. Similarly, the shorting strap must be either strap, or low inductance braid, and the same strap should be placed on each tower in exactly the same position.

GETTING SOLID DATA

It is important to consider that the tower impedance is impacted by the tower lighting circuits, static drain choke (if used), tubing between the tower feed-point and the tuning unit, and coupling between the cabinet and ground. And do not forget the potential effects of sampling lines with isolation coils or STL antennas with isocouplers.

Our recommendation is, if possible, to measure the impedance on the tower at the point where the feed is attached, with as many shunt components removed as possible.

(Continued on Page 20)

RF Guide

by Clarence M. Beverage

– Continued from Page 18 –

A second set of readings at the feed-point – which in most cases would be the output of the J plug in the tuning unit, next to the sampling device if base sampling is employed – must also be taken. This process provides a set of control data to use in estimating series and shunt reactance.

INDUCTANCE AND CAPACITANCE

Rule Section 73.151(1)(vii) requires that the series inductance of the feed system be determined. Measurement of tubing diameter, turns spacing, and the length of the interconnecting tubing on each side of the inductor should be recorded along with a photo for each tower base.

The inductance can be calculated from the standard formula: L = (N^2 * D^2)/(18*D + 40*H), where

L=microhenries

N=number of turns

D=diameter, inches

H=length(or height, hence the H), in inches.

An impedance measurement at the ATU J plug output terminal to ground, with the plug out of the circuit and the base insulator shorted, will provide a measured value of R and X that can be compared to the calculated value to establish series inductance.

Rule Section 73.151(1)(viii) requires that the shunt capacitance of the base insulator be determined. The manufacturer, make and model number should be recorded and the manufacturer contacted to obtain the base insulator capacitance. If capacitance of each base insulator can be measured before installation, that is an added bonus in terms of quantifying variables.

SAMPLE CALIBRATION

Rule Section 73.151(2)(i) requires that sample device calibration be confirmed when towers are monitored with base current or base voltage sampling devices. Such calibration can be determined by removing the sample device from service and field verifying performance.

To calibrate toroid current transformers, all of the toroids can be placed in series at a point in the RF path, near to the phase monitor, and a pair of equal length flexible heliax sample lines run to the transformers to confirm that the current ratio and phase readings agree with the manufacturer published data.

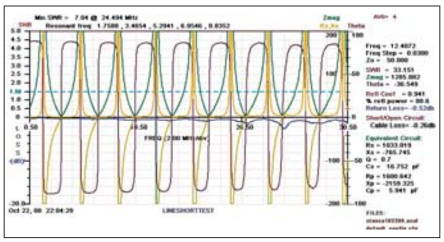
Provision to do this regularly should be designed into the RF system and could be a section of tubing mounted between insulators that is easily accessible. Voltage samples require a connection to the RF bus with the case connected to ground. The calibration process should be fully described and documented with photographs.

CHECKING THE SAMPLE LINES

This Rule section also requires that the sample lines be measured to confirm 1) equal electrical length within 1 degree at the operating frequency and 2) impedance within two Ohms of the manufacturer's published data. To make these determinations it is wise to have a copy of the cable order and know the specified length of each line in the order, as well as the manufacturer, type number, characteristic impedance and velocity factor.

From basic transmission line theory we know that an open circuit 1/4 wave line will show zero reactance at a 1/4 wave and 1/2 wave multiples thereof, whereas a shorted transmission line will show zero reactance at a 1/2 wave and 1/2 wave multiples thereof.

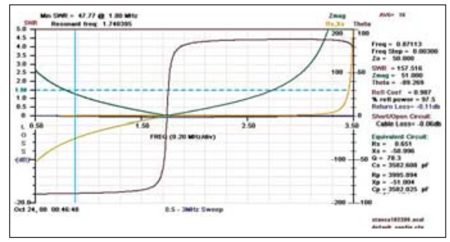
Determining sample line electrical length is a simple process when the sweep function in the VNA is employed. To illustrate, the following picture is a sweep from 0.5 to 20 MHz of a section of Andrew LDF5-50 having a factory specified velocity factor of 88% with a short across the line.



0.5 to 20 MHz sweep of a section of LDF5-50

The PowerAIM employed for this measurement identifies the 1/4 wave resonance points whether the line is open or shorted. The spool is approximately 20 years old, was stored outside in an unprotected environment and was believed to be about 120 feet in length. A general sweep such as this can provide a good estimate of the lowest resonant frequency and give us the basic information required to run a more detailed sweep with the line open as required by the Rules.

In this case the sample line is very short so we can use a narrower sweep between 0.5 and 3 MHz to determine the frequency representing the first 1/4 wave point. Running this sweep we see that Xs = -0.003 ohms at 1.74227 MHz which is a length of 124.2 feet based on a velocity factor of 88%



The same line, with sweep narrowed to 0.5 to 3 MHz.

To measure the characteristic impedance of the sample line we must move 1/8 wave from the 1/4 wave point and, leaving the line unterminated, measure the characteristic impedance in the single frequency mode.

The section of line under test exhibited a measured impedance of 50.8028 Ohms at 0.8711 MHz and 48.66 Ohms at 2.6134 MHz. It is recommended that the VNA be used to measure the impedance of the toroid transformer to confirm that the terminating resistors have not changed value. Finally, terminate the sample line with the toroid and then measure the sample line impedance at carrier frequency.

It is hoped that this information is helpful in terms of gathering the field measurement data required for initial Directional Antenna Performance Verification and subsequent Recertification. Obtaining quality data – and taking sufficient additional data to remove the "why is this behaving in this unexpected way factor" – should go a long toward achieving a successful adjustment and stable ongoing operation.

Few successful efforts are achieved without collaboration. Many thanks to William P. Weeks of Milton, New York for his tireless field engineering efforts, program planning and office engineering time directed toward preparing both of our firms to execute this work in the best way possible.

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