ENGINEERING EXTRA

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Aaron Read suggests one way to combat dead air. Page 22

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A New Method of High-Level IBOC Combining For Single-Input Antenna Systems

Use of All-Pass Diplexer Results in Higher Efficiency and Improved Group Delay

BY NICHOLAS A. PAULIN AND THOMAS B. SILLIMAN, P.E.

Tom Silliman is president of Electronics Research Inc. in Chandler, Ind. Nick Paulin is a product engineering manager for ERI.

WHITEPAPER

Combining separate analog and HD Radio FM transmitters into a single antenna allows broadcasters to use existing equipment, including transmit- ransmission line and antennas. ·er, the options for accomplishing : limited.

nbining two frequencies in close iity is a difficult engineering chal- especially when trying to main- igh efficiency, flat group delay, put VSWR and high transmitter- ısmitter isolation. A typical two- ncy FM multiplexer can combine two stations 800 kHz apart. This would use two four-pole filters with a cross coupling from the one-to-four cavities. The worst-case scenario would be 0.75 percent bandwidth separation combining 107.1 MHz and 107.9 MHz.

An analog FM/HD Radio diplexer attempts to implement a much narrower bandwidth separation of 0.04 percent. The isolation typically required between two analog transmitters is 80 dB to keep emissions down. Analog and digital combining methods differ greatly because of the close separation. Forty dB isolation is generally all that is required to keep emission within acceptable limits for digital radio.

From a listener's perspective, emissions problems between two analog transmitters will be more noticeable than emissions between an analog system and a digital diplexed system. The analog transmitters will generate music on another FM frequency while the analog and digital emission would be generated at the skirts of the digital sideband.

Current methods of combining analog FM with digital FM include using lossy hybrid solutions. Ten dB injectors were commonly used for –20 dBc digital broadcasting and 8 dB injectors were used to reach –17 dBc. To reach higher levels of digital power, new technologies were needed.

Transmitter manufacturers were quick to innovate using mid-level, also called split-level, combining methods. This method allowed the combining of one analog FM transmitter and one common-mode amplification transmitter. The analog FM signal maintained up to 99 percent efficiency while the digital efficiency was increased to up to 33 percent.

Current transmitter technologies allow common-mode amplification for digital to –10 dBc (10 percent of the analog TPO). Unfortunately, these transmitters have peak-voltage limitations when the analog TPO needs to be greater than 20 kW. The efficiency of the common-mode amplification transmitters also decreases to as low as 40 percent AC to RF. Essentially, 60 percent of the AC power required to run these transmitters is converted directly to heat. Typically analog FM-only transmitters are about 70 percent AC to RF efficient.

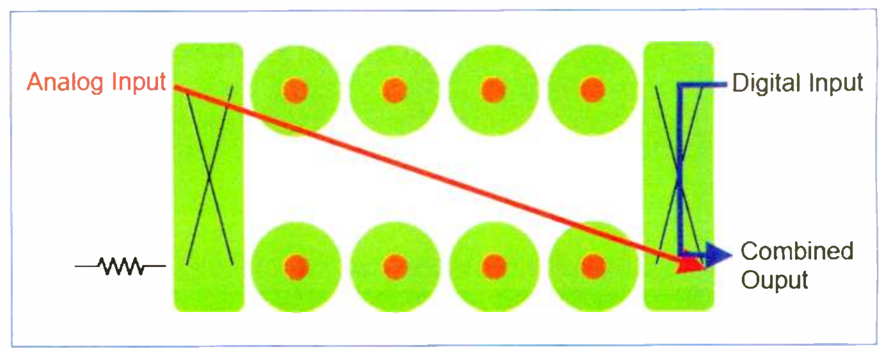

Fig. 1: Overview Schematic of an HD Radio Mask Filter

Another available method that has found little acceptance is a sharp-tuned four-pole filter, or the HD Radio Mask Filter (see Fig. 1). These filters offer an insertion response that allows for the port, commonly referred to as the "broad port," to reflect the digital power so that the analog FM and digital FM converge into the same RF path on a single transmission line.

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CBNE Certification Now Available From SBE

New Level Recognizes Importance of Network Engineering and IT to Broadcast Engineering

BY MICHAEL LECLAIR

With only modest fanfare, the Society of Broadcast Engineers announced in April the creation of a new class of certification: the Certified Broadcast Networking Engineer, or CNBE.

This is a solid move by the SBE to recognize the evolving skill set of what we loosely call "broadcast engineers."

As computerization and digitization have proceeded rapidly over the last couple of decades, the need has increased for sophisticated network engineers in a modern broadcast plant. It has become clear that IT for broadcasting has become its own distinct specialty.

EVALUATION TOOL

Recognizing the importance of computer networking in broadcast engineering is an important step. Certification provides prospective managers and employers with a tool to evaluate an individual's skills and commitment to the specialized world of broadcast. Engineers who choose to obtain this certification demonstrate that they know the essentials of both networking and the broadcasting business.

In April at the NAB Show, the Ennes Workshop presentation by Wayne Pecena, director of engineering at Educational Broadcast Services, Texas A&M University, pointed out that the IT world already offers many types of certification. These are also quite expensive to obtain. Most are vendor-proprietary certifications with a bewildering array of titles and specialties, such as the varying levels offered by Cisco associated with its router products.

Unfortunately, the degree of specialization makes these industry certifications hard to evaluate when it comes to broadcast engineering. Do I need a CCNA, CCNP or CCIE in order to find the skills I want? Or should we all try to find a Cisco Certified Architect? Do I need a degree in computer science to even understand the difference between these types?

The goal of creating a certification category for broadcast networking is to help identify those with the right skill set, people who are qualified but not too specialized or vendor-specific to understand the unique requirements of broadcasting.

Information technology workers and broadcast engineers have quite a lot in common.

Both fields attract people with a mind for detail and precision. It takes substantial training in both fields to understand the theory and the practical specifics of keeping day-to-day operations going smoothly. A significant proportion of the population simply doesn't possess the mathematical or scientific skills necessary to do this kind of work.

Photo by Jim Peck

Wayne Pecena talks IT during the Ennes Workshop at the 2012 spring NAB Show.

Organizations without access to people with these critical skills often suffer from low performance and inefficiencies encountered struggling with technology when it doesn't work as expected or breaks down suddenly. Engineering and IT are the critical supports upon which business and broadcast are built.

But there are significant ways in which the IT requirements for broadcasting differ from the rest of the business world. Few of us in broadcasting operate giant data centers. Similarly, those with conventional IT backgrounds often have limited experience with real-time operations and the kind of timely support required, both human and technological. Few of us in broadcasting are concerned about limiting access to our on-air systems. Regular IT obsesses on data security and creating a hierarchy of access that limits everyone to only their tightly defined areas. Broadcast engineers are known for their cell phones plus pager, or belt and suspenders approach to being always available. IT engineers may be impossible to reach on a weekend without several tiers of escalation through screens of management.

Over the years a number of people with IT background have entered broadcasting with success and learned its specifics, blending the best of both worlds. Up until this time they may not have felt as comfortable pursuing the more typical certifications of a broadcast engineer, even though they may have now become one by title. The CBNE certification now recognizes an IT background and networking competence as a unique part of broadcast engineering.

GET CERTIFIED

Certification exams are offered regularly by the SBE. Four times per year they can be taken at the local chapter level and once a year they are available at the NAB Show. Have you been working as a broadcast engineer without certification? I urge you to pursue the type that reflects your skills and experience. Show others that you care about broadcasting and that you have the required knowledge.

Michael LeClair is chief engineer for radio stations WBUR(AM/FM) in Boston; he has been technical editor of Radio World Engineering Extra since its inception in 2005.

THIS ISSUE

JUNE 13, 2012

ALL-PASS DIPLEXER

(continued from page 1)

ALL-PASS DIPLEXER THEORY OF OPERATION

The heart of this approach lies with a resonant cavity. The resonant frequency of the cavity will provide a phase shift of 180 degrees, and a tapering phase shift on the adjacent frequencies. Fig. 2 shows a typical response for S11 group delay and S11 phase. A shallow notch, typically –1 dB, is used to gain a broader phase response.

When a module composed of two identically tuned notch filters and a 90-degree hybrid coupler is constructed, it is normally known as a group delay module. That is, the device typically is used to correct for high levels of group delay in a filter system by creating the opposite group delay response. This module is typically inserted just before a filter or just after an exciter to provide extra correction at high power levels. A different tuning method is used for the All-Pass Diplexer. Instead of trying to correct for an existing analog FM group delay response, the group delay maxima to minima variation is tuned to 1200 ns at +/- 43 kHz from the center frequency of the digital carrier. The cavities are all-pass circuit. By connecting the two group delay modules and placing them in the same leg of a constant impedance circuit, we can ensure that the group delay modules only see half of the input power. As stated earlier, a shallow notch is used to produce the desired response. As a system, the losses will only be half

Combining two frequencies in close proximity is a difficult engineering challenge, especially when trying to maintain high efficiency, flat group delay, low input VSWR and high transmitter-to-transmitter isolation.

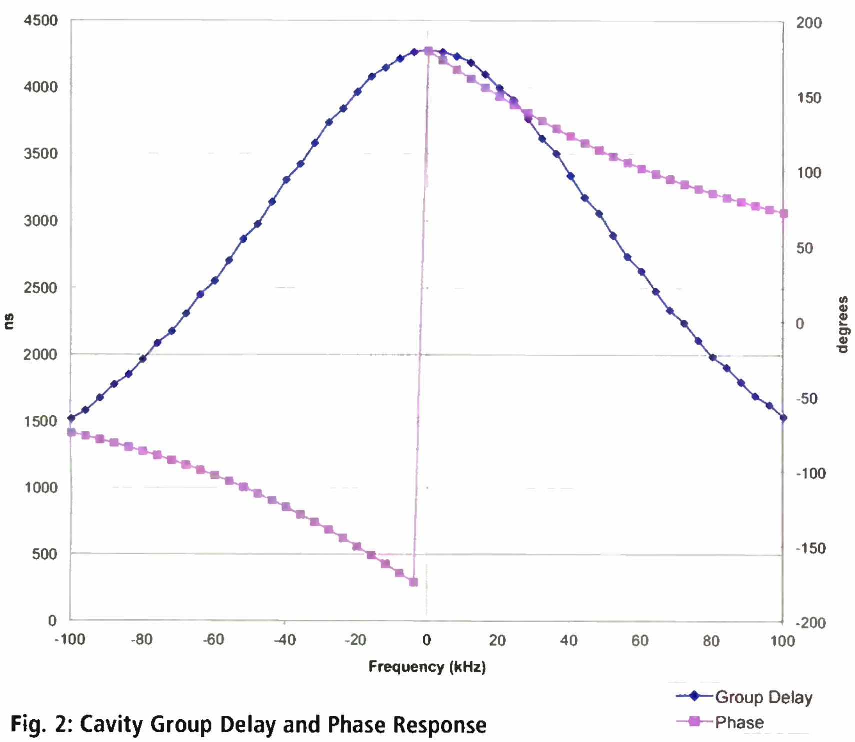

Fig. 2: Cavity Group Delay and Phase Response

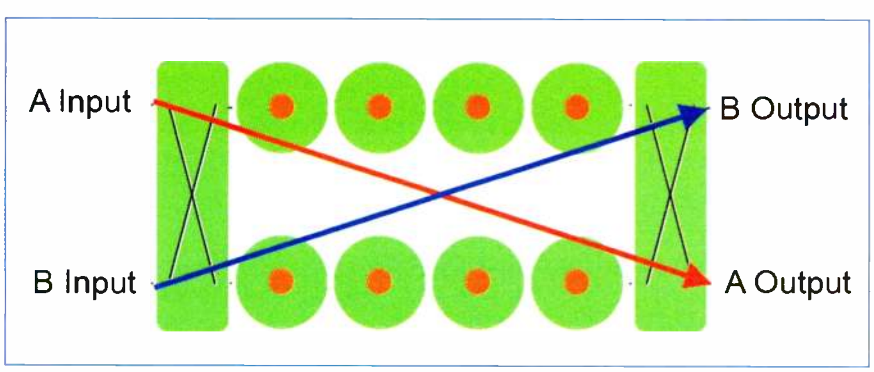

Fig. 3: Overview Schematic of a Constant-Impedance Bandpass Filter

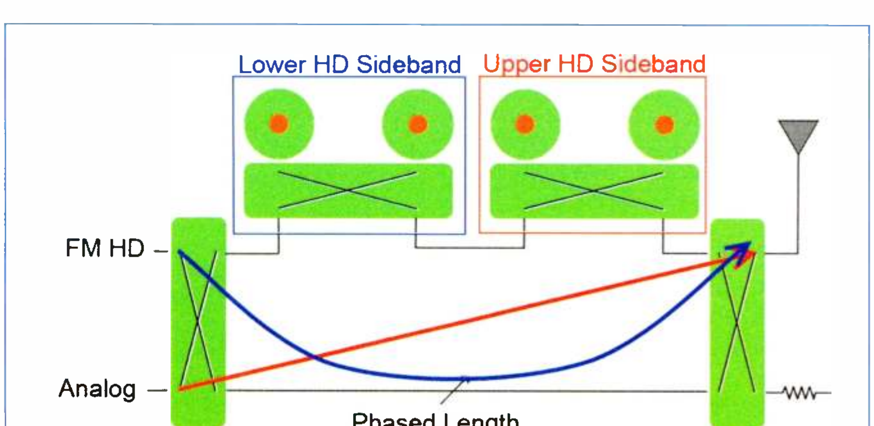

Fig. 4: Overview Schematic of All-Pass Diplexer

tuned to be identical to one another. When this approach is taken, the 90-degree hybrid coupler is capable of maintaining an excellent input VSWR while passing a high percentage of the power to the output port. Since there are two sidebands for HD, two of these modules are required to accomplish the performance required.

THE ALL-PASS DIPLEXER

A constant impedance effect is typically used on band-pass filters. This is done by tuning two filters carefully so they match as closely as possible for return loss and insertion phase. The filters are then connected together by two 90-degree hybrids (see Fig. 3). The hybrids allow several things to occur. First, the power is split so each filter only sees 50 percent of the power. Second, all of the power enters one port and exits an opposite port on the second hybrid. The remaining two ports are isolated and see very little power.

This concept has been adapted to the that of the tuned notches because only half the applied power incurs losses in the group delay modules. This is important since group delay modules typically produce heat. The second leg of the constant impedance circuit can be connected by using a critical length of transmission line (see Fig. 4). This line can be phased so that the analog and digital insertion loss is minimized.

Data Comparison

So how does all of this compare to what has been available? In the past, there have been two types of solutions with which this design competes. The 10 dB high-level injector and the HD Radio mask filter are both in use today. These approaches have been written about at length and are not the topic of this article. See references (page 8) for information on these approaches.

Table 1 shows the operating efficiencies of these other approaches. Also note the total power generated from

(continued on page 6)

	FM Analog All-Pass	FM HD All-Pass	FM Analog Mask Filter	FM HD Mask Filter	FM Analog 10 dB Injector	FM HD 10 dB Injector
Input Power (dB from Analog Carrier)	0	−10	0	−10	0	−10
TPO Transmitter (Watts)	32,518	4,094	34,050	3,777	33,344	30,000
Integrated Loss	−0.35	−1.35	−0.55	−1	−0.46	−10
Efficiency	92.3%	73.3%	88.1%	79.4%	90.0%	10.0%
TPO Combiner (Watts)	30,000	3,000	30,000	3,000	30,000	3,000

Table 1: Comparison of Efficiencies

	FM Analog All-Pass	FM HD All-Pass	FM Analog Mask Filter	FM HD Mask Filter	FM Analog 10 dB Injector	FM HD 10 dB Injector
Group Delay (MP3)	350 ns	600 ns	1.26 µs	0 µs	0 ns	0 ns

Table 2: Comparison of Group Delay


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ALL-PASS DIPLEXER

(continued from page 4)

each approach, in order to reach the correct ERP. The integrated loss is defined as the average insertion loss across the frequency spectrum that is used for an application. The all-pass diplexer has a slight efficiency advantage overall.

Table 2 shows the group delay comparisons between the different methods of combining. The all-pass diplexer shows a significant improvement over the mask filter. Lower group delay for the digital signal means receivers are better able to correct for signal distortion, improving reception. The sound quality will not be affected as long as the receivers can decode the signal. However, lower group delay for the analog signal means better sound quality. This is something the typical listener would be able to hear. The HD Radio Mask Filter has a group delay specification, for both analog and digital, that is very difficult to correct; in contrast the All-Pass Diplexer approach offers group delay specifications that are correctable easily with current transmitter and exciter technologies as well as with passive signal pre-distortion technologies.

Fig. 5 and Fig. 6 show responses of the HD Radio Mask Filter and All-Pass Diplexer. Even though there are some differences, the efficiencies remain very close. The HD insertion loss response is the most variable. The mask filter gives a tapered attenuation response as the frequency approaches the analog carrier, while the all-pass diplexer response has a maximum in the center of the digital sideband. Fig. 7 and Fig. 8 show the corresponding group delay plots with respect to their insertion response plots.

IMPERFECT CONDITIONS

To this point, we've discussed how the all-pass diplexer concept works with perfect operating conditions; but when we step out of the lab and into reality, not all conditions are perfect. Two areas of imperfections are an imperfect load, such as an antenna, and temperature variations from within the room from air conditioning and heating of the cavities.

Let's start by talking about an imperfect load. When the output impedance of a circuit is not matched properly, undesired reflections occur. In the case of the all-pass diplexer, those reflections travel towards the transmitters. Because of the nature of the device, the reflections would again go through the phase reversals and the large majority of the reflections would be seen by the originating transmitters. However, a small amount will go to the opposite port and this will be seen as a loss of isolation.

The second imperfect condition relates to temperature variations. Cavity resonators are high Q devices, so temperature variations can have a large effect on performance if the device is not temperature compensated properly. As resonators heat, they grow in length. This change over temperature is what causes filters to drift. Conventional techniques use invar (a nickel iron alloy with a virtually zero thermal coefficient of expansion) to restrain physical movement. There are several methods for accommodating the temperature variations. One is to change the attachment point of the invar to somewhere above the contact surface of the resonator. This allows the growths of each metal to counteract one another for 0 kHz drift. This method is frequency sensitive and not all attachment points work for all frequencies.

Because the attachment points don't work for all frequencies, a predictable method was desired for temperature compensation. Filter cavities can be tuned using a tuning screw in the top plate. If a cavity drifts down with temperature, a tuning adjustment can be placed into the resonator attachment plate to tune the resonance up in frequency. We have developed a tuning method that utilizes a bi-metallic spring that changes shape with temperature. The spring moves an object closer to the resonator as it heats. By allowing the filter to drift down in frequency and allow-

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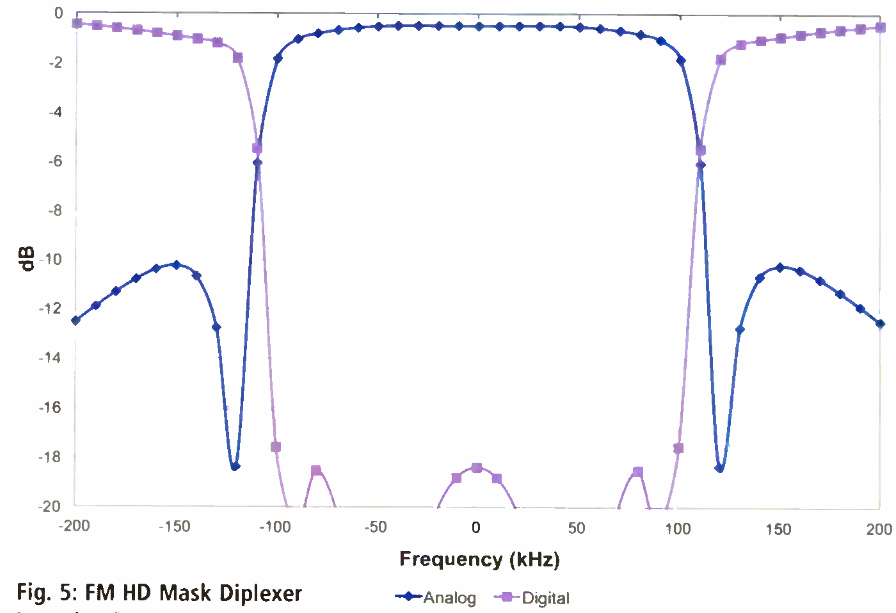

Fig. 5: FM HD Mask Diplexer Insertion Response

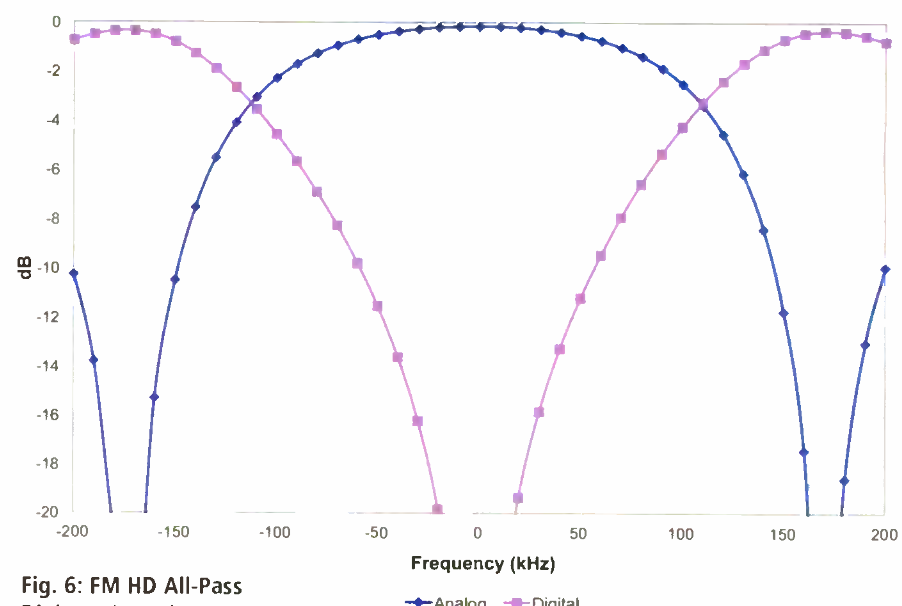

Fig. 6: FM HD All-Pass Diplexer Insertion Response

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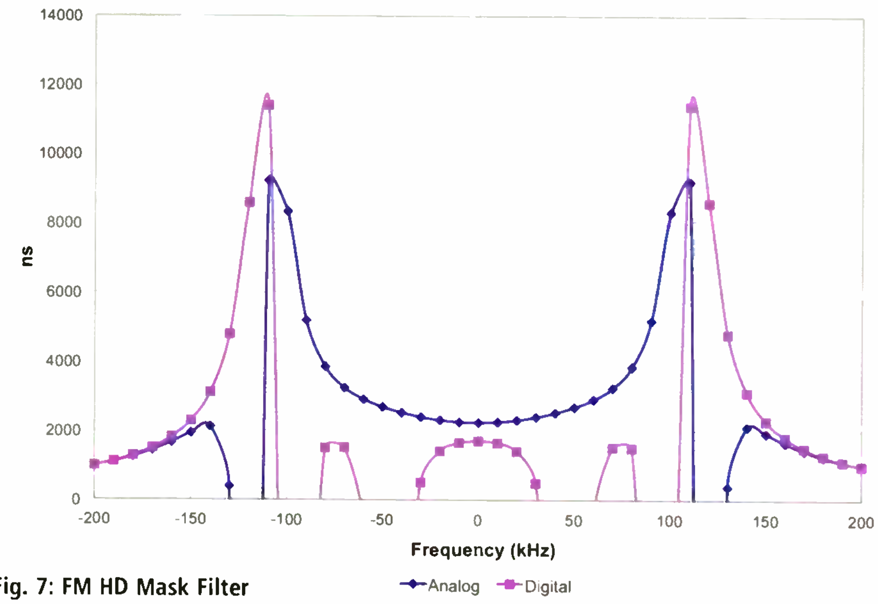

Fig. 7: FM HD Mask Filter Group Delay

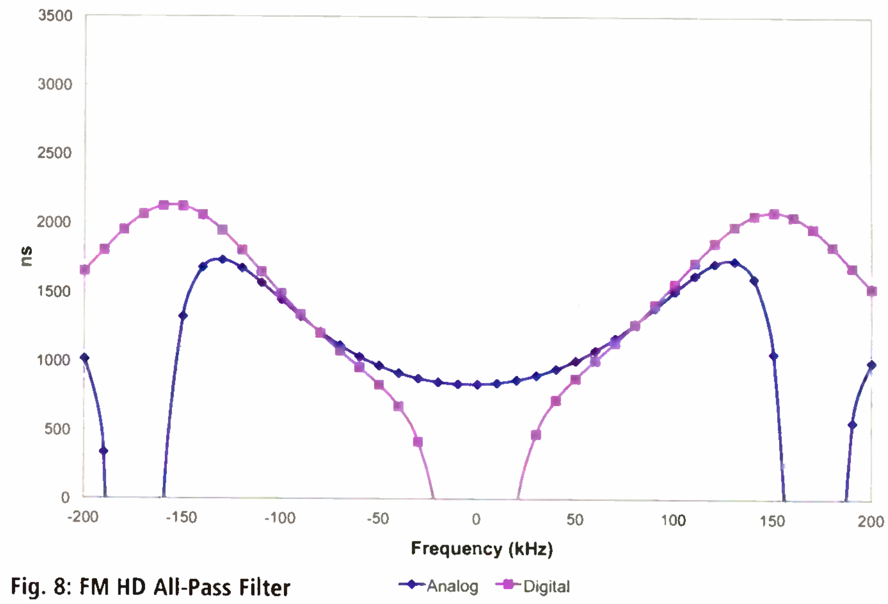

Fig. 8: FM HD All-Pass Filter Group Delay

ALL-PASS DIPLEXER

(continued from page 6)

ing the spring to move an object closer to the resonator, it is possible to create a zero drift cavity. This method is still frequency sensitive, so a curve was generated based on the length of the object being moved towards the cavity. All that is required now is to calculate the length based on the frequency desired and we have a finely tuned temperature compensation technique.

CONCLUSIONS

The all-pass diplexer combiner approach has been described and compared to the –10 dB injector and FM HD Radio mask filter approaches. It has higher efficiency than the –10 dB coupler and HD Radio mask filter, and improves group delay performance for both transmitter inputs while maintaining high efficiency. The All-Pass Diplexer presents a new viable approach for combining high-level analog and HD transmitters to be operated from a single antenna.

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Moment Method Proofs Require New Attention to Sampling Techniques

A Look at Antenna Base Region Geometry and Voltage Sampling For AM Directional Antenna Systems

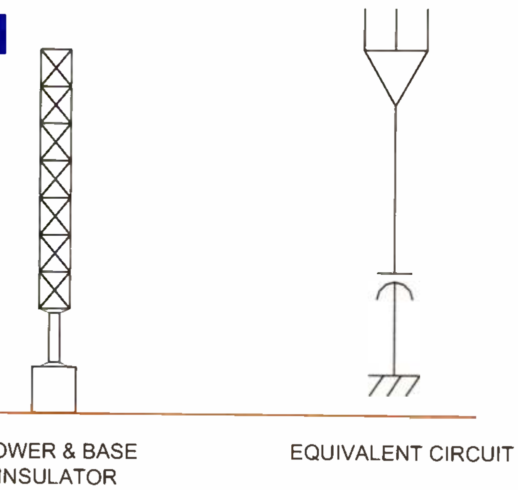
BY BEN DAWSON, P.E.

The author is president and managing partner at Hatfield & Dawson Consulting Engineers in Seattle.

The new FCC moment method antenna proof rules require measurements made at each antenna element's base or feed point, as well as allowing antenna monitoring using sample measurements made at the tower feed point location. This has made accurate analysis of the tower base region an important part of defining the antenna monitoring system.

The base region of a series fed vertical monopole antenna element can be electrically and mechanically complex. If base sampling is used, tower impedance measurements should be made at the location of the tower sample device. The other towers in the array should be open-circuited or shorted (either procedure is acceptable) at the same location. It's important to include the characteristics of the feed system between the measurement point and the tower base. This paper will give examples and an explanation of the effects of various base circuit elements.

Fig. 1



The rules provide that sample loops can be used in some circumstances, but only if the towers are identical in cross-section structure. An example of the reason for this rule provision shows that even modest geometry differences between towers make significant differences in current pickup. In these situations, for towers greater than 120 and less than 190 degrees tall, base voltage sampling can be employed.

MEASUREMENT LOCATIONS

If base sampling is used, whether it is current or voltage sampling, then the set of measurements should be made at the location of the sample devices. This is normally in the antenna tuning unit or tuning house, although if a weatherproof voltage sampler is used, it can be installed directly across the tower base. It is also often useful to make a measurement of the "hookup" reactance of each tower by shorting the base insulator and making a measurement in the tuning unit or tuning house at the location of the sample device.

If loop sampling is used, then the set of measurements prescribed by the rule can be made directly across the tower bases, or at a convenient location at a "J" plug in the antenna tuning unit or tuning house.

THE VERTICAL BASE-FED MONOPOLE

The base-fed monopole is insulated from ground by a base insulator (or multiple insulators for freestanding towers) and so the inherent impedance of the antenna itself is always paralleled by the reactance of the base insulator, which is necessarily capacitive. See Fig. 1.

$$\text{Apparent } Z = \frac{1}{[1/(R_{ant} +/- X_{ant})+1/X_{insulator}]}$$

(continued on page 14)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Phillip Vaughan, Chief Engineer KFROG,
CBS Radio

"The LX caught my attention on the NAB Show floor. The look, form and function are unlike any other IP console available today. The easy-to-read buttons and displays are just second to none, not to mention the most bang for the buck. I can't wait 'til I have the opportunity to deploy my first LX."

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SAMPLING

(continued from page 10)

If you are modeling an antenna tower with NEC, you can include this in the model, but MININEC assumes a base load is in series with the feed, and so you must consider this modification of the impedance separately.

OTHER BASE REGION CONDITIONS

Generally, there are other circuit elements to be considered. The simplest possible antenna feed must include some kind of conductor from the matching equipment (or in rare cases the transmitter itself) to the antenna base. See Fig. 2.

The feed conductor is a series circuit element, and it possesses an inductive reactance. This can be quite small — as little as 8 or 10 ohms — or can be fairly large if the distance is great or if it has a multi-turn (and unnecessary) "lightning loop." But in addition to its series reactance, the feed conductor contains another circuit element: its capacitance to ground. While this is distributed over the conductor's length, it is generally quite small and can usually be considered to be at its input.

Antenna towers are often lighted, and some are equipped with current transformers for the lighting circuit. These "Austin Ring" transformers are usually installed in such a manner as to be a capacitance in parallel with the base insulator capacitance. See Fig. 3.

Fig. 2

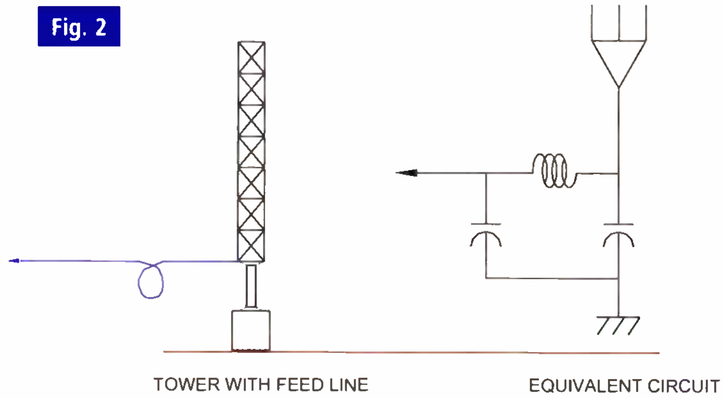
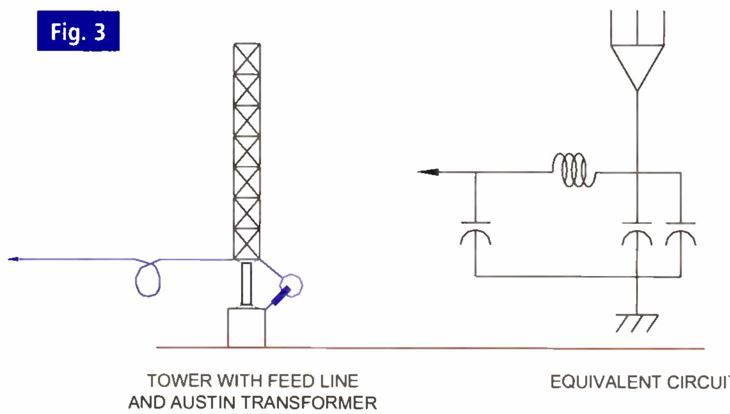


Fig. 3



Similarly to the base insulator, the lighting transformer may have very low capacitance and thus high reactance. But even a capacitive reactance of 10 times the magnitude of the basic tower impedance can create a resistance change of more than 2 percent and a consequent current change of 1.4 percent. A bit of manipulation of a Smith Chart will show that even a very small capacitance needs to be considered (in most situations) in the analysis of the relationship between the moment method model and the impedance measurements.

Some tower lighting is accomplished by a lighting choke. See Fig. 4. A "choke" or inductor that is many turns of small-diameter closely spaced wire may not necessarily be inductive, however. Lighting chokes usually are inductive through the medium-wave band's one and a half octaves, but static drain coils frequently are not in the upper half of the band. So the equivalent circuit of these components needs to be a parallel circuit which can exhibit the proper combination of effects. See Figs 5a and 5b.

Many AM antennas support VHF and UHF antennas of all sorts, including STLs, TSLs, communications antennas, FM and even occasionally TV broadcast antennas. In general, these additional antennas exhibit a small amount of capacitance across the tower base in parallel with the base insulator, and their series inductance can usually be ignored. See Fig. 6.

Fig. 4

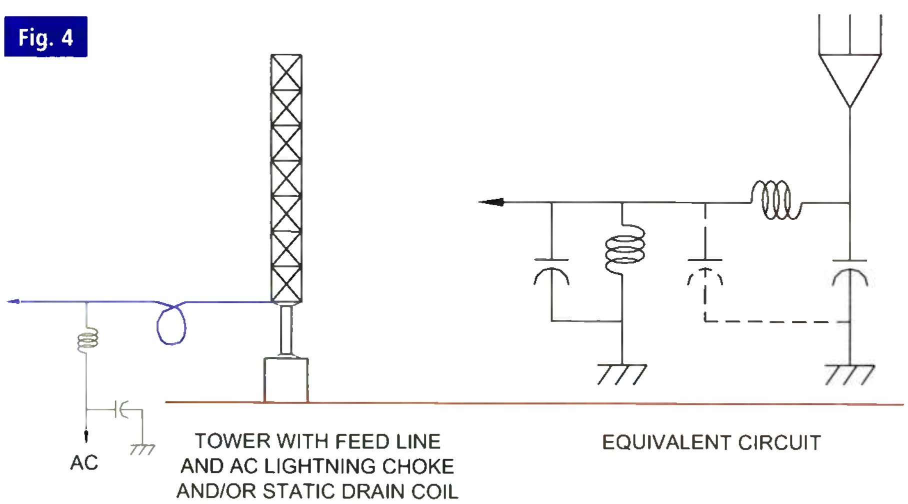


Fig. 6

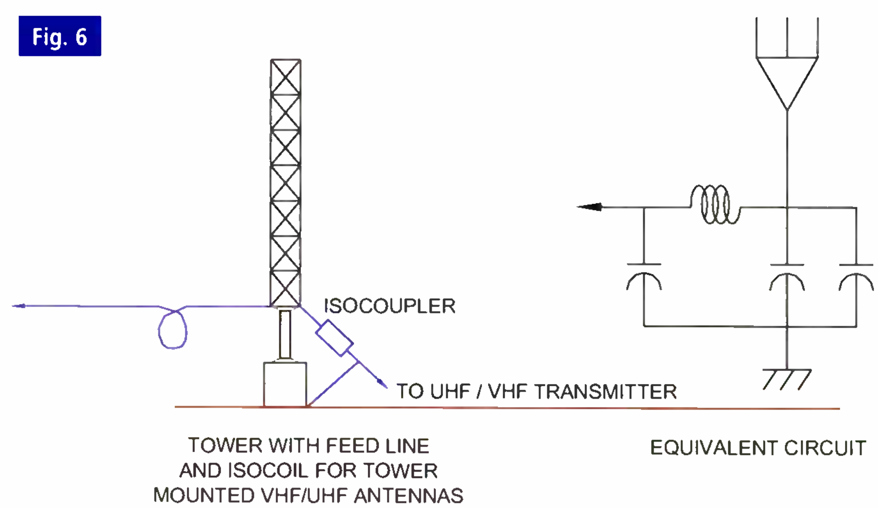


Fig. 5a

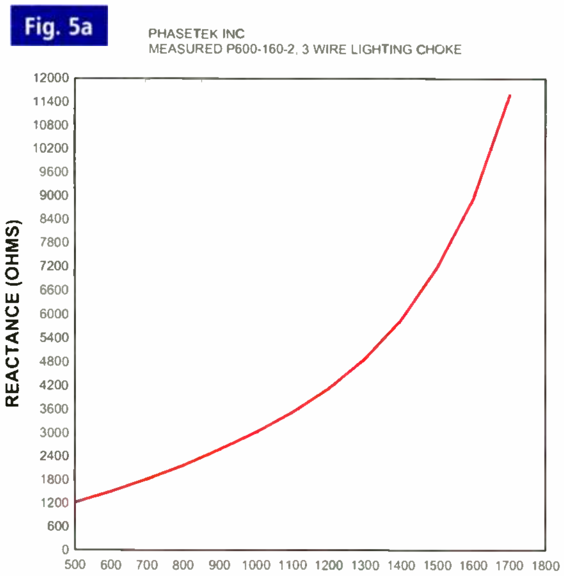
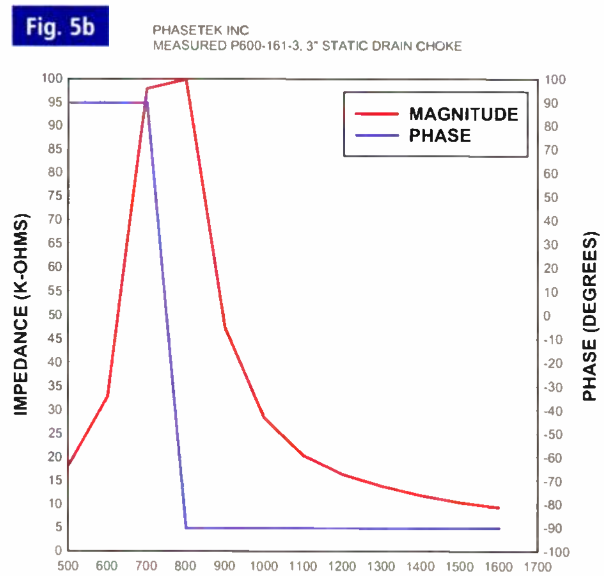


Fig. 5b



The FCC moment method antenna proof rules limit the total capacitance of all the base shunts to a value of 250 pF unless the manufacturer's data or measurements are greater, but the rules also require that the total capacitive reactance of the devices must be at least five times the magnitude (Z not R or X) of the tower base operating impedance. This can be a problem if the combination of self-impedance and the mutual values for the particular array geometry and radiation pattern result in a large total impedance. It is not common, but there are arrays with tower drive impedances of as much as 1000 –j1000 ohms, which would require total base shunt capacitive reactance of no less than –j7000 ohms, or about 47 pF at the low end of the medium-wave band.

In cases where the bandwidth/power requirement to feed an antenna on an AM antenna tower can't be met by a "transformer" type isocoupler, sometimes a very large isocoil wound of large-diameter semi-flexible

(continued on page 16)

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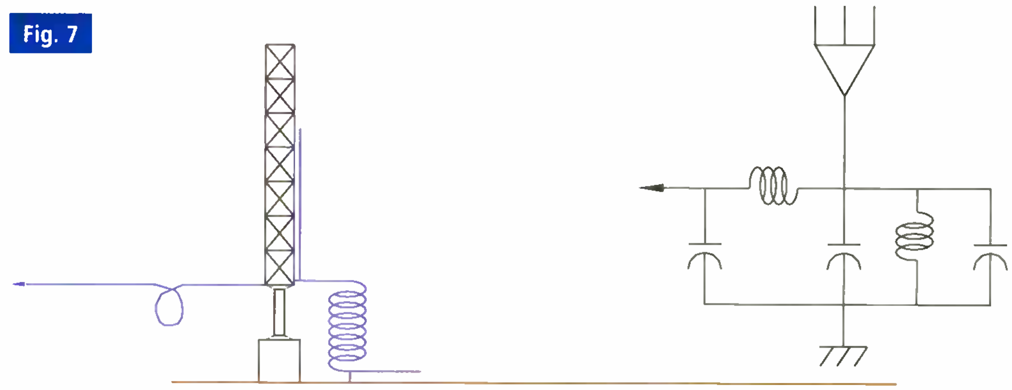
SAMPLING

(continued from page 14)

transmission line is used. Much like the static drain "choke" the distributed capacitance between the windings of such a coil can cause it to be self-resonant in the middle of the medium-wave band, and therefore a shunt capacitance above that point. See Figs. 7 and 8.

A very similar effect is sometimes the case with a sample system transmission line isolation inductor, which sometimes will not be removed when an existing antenna system is re-proofed using the moment method rules. Frequently these are resonated with a parallel variable vacuum capacitor, and the combination exhibits very high reactance, but in a diplexed array this may be at only one of the carrier frequencies so that a lower value of reactance has to be accounted for at the second frequency. See Fig. 9.

Fig. 7



TOWER WITH FEED LINE AND LARGE "ISOCOIL" FOR HIGH POWER / WIDE BANDWITH VHF / UHF OR WI-FI / PCS

EQUIVALENT CIRCUIT

Fig. 8

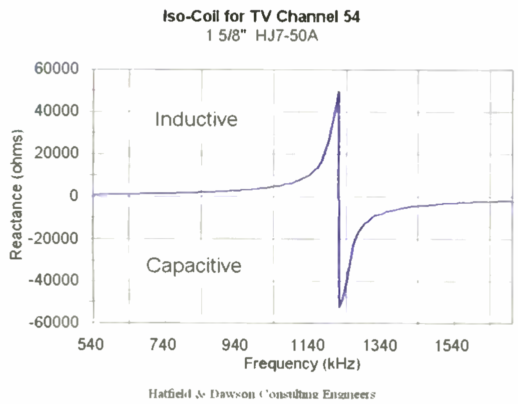
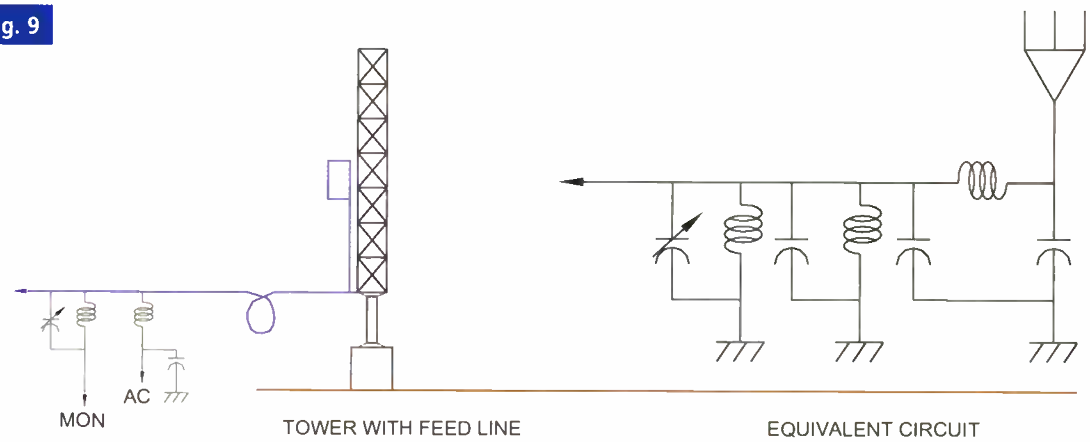


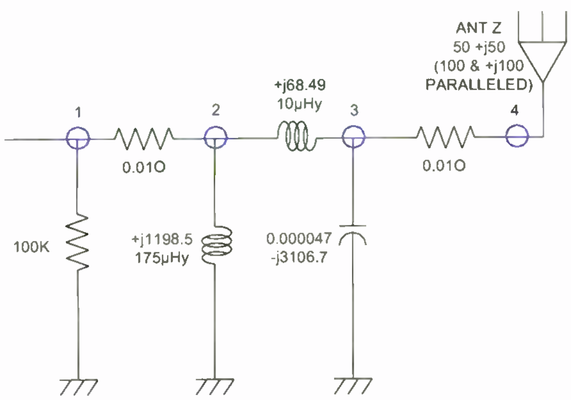
Fig. 9



TOWER WITH FEED LINE AND SAMPLE LINE ISOLATION INDUCTOR

EQUIVALENT CIRCUIT

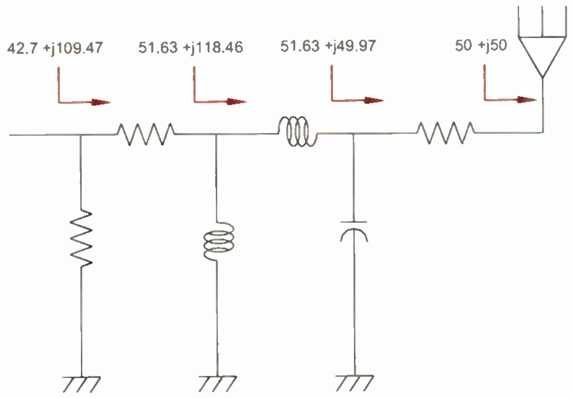
Fig. 10



TYPICAL TOWER BASE CIRCUIT

NODES AND COMPONENT VALUES ANNOTATED FOR SPICE (OR WCAP)

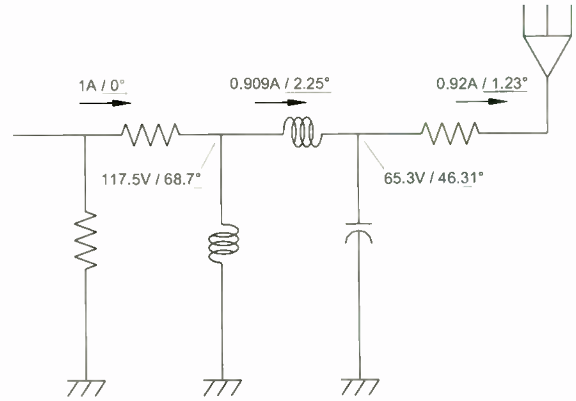
Fig. 11



TYPICAL TOWER BASE CIRCUIT

IMPEDANCES

Fig. 12



TYPICAL TOWER BASE CIRCUIT

VOLTAGES AND CURRENTS

IMPEDANCE TRANSFORMATION AND PHASE SHIFT

These various circuit elements form networks. The networks transform the impedances seen by the sample devices, and therefore the currents and voltages at the location of the sample device will normally be different than those at the tower base calculated by the moment method program. This transformation affects both the magnitude and angle of the currents and voltages following the normal laws of AC circuits: Ohm's law and Kirchoff's law. The calculations are (in mathematical terms) simple and straightforward. It's sometimes useful to refresh one's memory of vector algebra by consulting a good AC or radio engineering reference work, such as Griffith, or a good mathematics textbook.

For illustration, this hypothetical example shows a simple tower base circuit, with the junctions numbered for use in a typical SPICE program. See Fig. 10. The series and shunt resistors are for convenience in checking the drive voltage and current. The load is a parallel network that produces a hypothetical antenna impedance of 50 +j 50 ohms. The impedances at each junction can easily be calculated by addition for the series elements and inversion to add the admittances for the shunt elements. Fig. 11 shows the results of those calculations.

Knowing the terminating impedances at each point, if we drive this with 1 amp of RF at a given frequency we can easily calculate the currents and voltages in vector form. These are shown in Fig. 12.

Having calculated the currents and voltages, we can see that if the monitoring device is located at the input of this base network, it will read different magnitudes and angles than if it were at the tower base. So the moment method program calculations of drives necessary for the authorized radiation pattern have to be modified to get the antenna monitor values when base sampling is used.

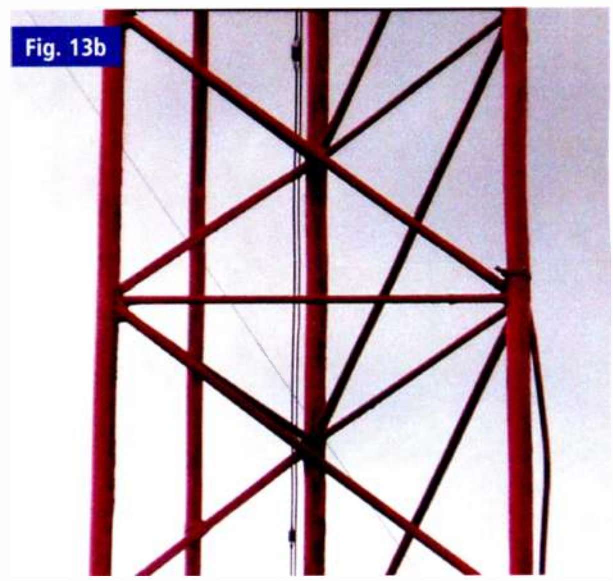
In this example, that difference is not large for the current sample situation: a correction at the antenna monitor of $1.1001\angle{-2.25°}$. But the correction if voltage sampling is used is much more substantial:

$$\frac{(117.5\angle 68.69°)}{(65.3\angle 46.31°)} = 1.8\angle 22.4°$$

at the antenna monitor!

Fig. 13a

Fig. 13b



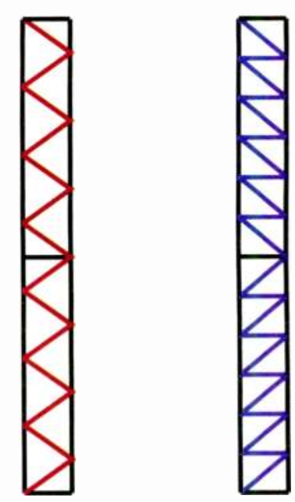
DIFFERENT TOWER GEOMETRY

Sample loops are a tried-and-true, straightforward method of determining the relative fields radiated from a tower in an array. If the loops are located at the elevation where the amplitudes and phases of the currents replicate the far-field conditions, it's not necessary to calculate the base region transformations for determining the correct antenna monitor readings, only for determining the phase and power budget for the entire feed system. But the new FCC moment method rules don't allow the use of sample loops unless the tower physical geometry in the region of the sample loops is identical.

Here's why. The photographs (Figs. 13 a and b) show two different towers in an array. They have identical face widths, identical leg sizes and identical cross member sizes. But because one of the towers is a replacement, put up after failure of the original in a storm, it has a denser cross-member pattern, probably because the applicable structural requirements of the building code changed from the time of the original construction of the array.

A moment method model of the towers and sample loops located at the point of intersection of the legs and cross-members shows the difference in pickup. Because the antenna towers have currents flowing in the cross-members as well as the legs (the horizontal components of those currents do not result in far-field radiation but charge the capacitance to ground of the antenna tower and induce currents in the sample loops), the loop pickup amplitude is not the same, although in this example the phase angles are nearly identical. The analysis shows that for sample loops mounted in circumstances as similarly as possible, the phase angle differs by only 0.4 degrees but the amplitude by nearly 5 percent. See Fig. 14.

Fig. 14



TOWERS IDENTICAL
(FACE, WIDTH, LEG DIAMETER, CROSS-MEMBER DIAMETER)
EXCEPT CROSS-MEMBER DETAIL

(continued on page 18)

SAMPLING

(continued from page 17)

The moment method proof rules therefore don't allow one to use this technique to determine the proper operation of an array with dissimilar towers. One could, in fact, use the results of this model to normalize the antenna monitor readings to tune up the array, but it would add an additional set of possible errors in the process. The point of the moment method rules is to simplify the internal sampling process and make it as accurate as possible, since it, rather than a set of magnetic far-field measurements, is the basis for the licensing process. The rules in fact state: "The performance of a directional antenna may be verified either by field strength measurement or by computer modeling and *sampling system verification*." (Emphasis added)

VOLTAGE SAMPLING

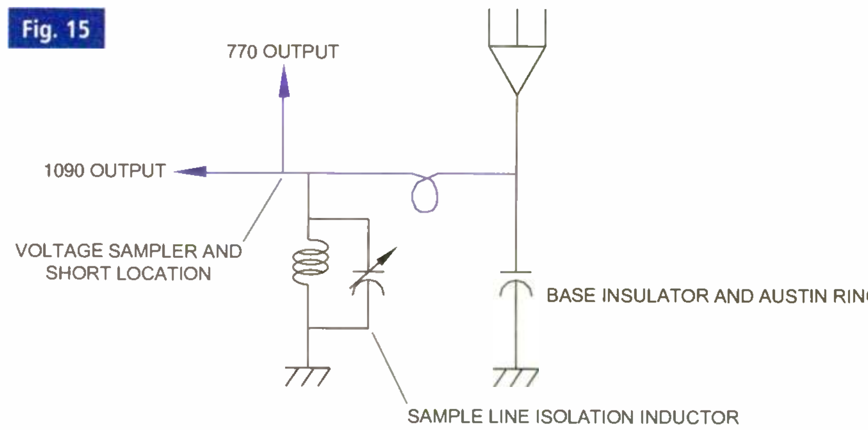
1. The KPTK Voltage Sampling Problem

The FCC's moment method rules allow loop sampling for towers of any height, but base current sampling only for towers 120 degrees or shorter or greater than 190 degrees. Base voltage sampling is allowed for towers greater than 105 degrees in height. The towers in the KPTK array are 160 degrees in height, and are the "almost but not quite identical" example shown in Figs. 13 and 14. After an analysis of the drive impedances of the day and night patterns employed by KPTK, as well as those of the diplexed operation of KTTH on the same antenna towers, we designed a prototype voltage sample device. See Fig. 15.

The 1090 kHz drive impedances are high enough that use of a capacitive voltage divider with very high input

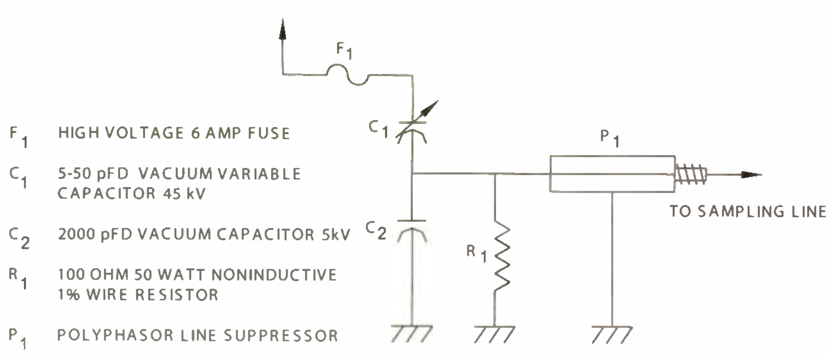
(continued on page 20)

Fig. 15



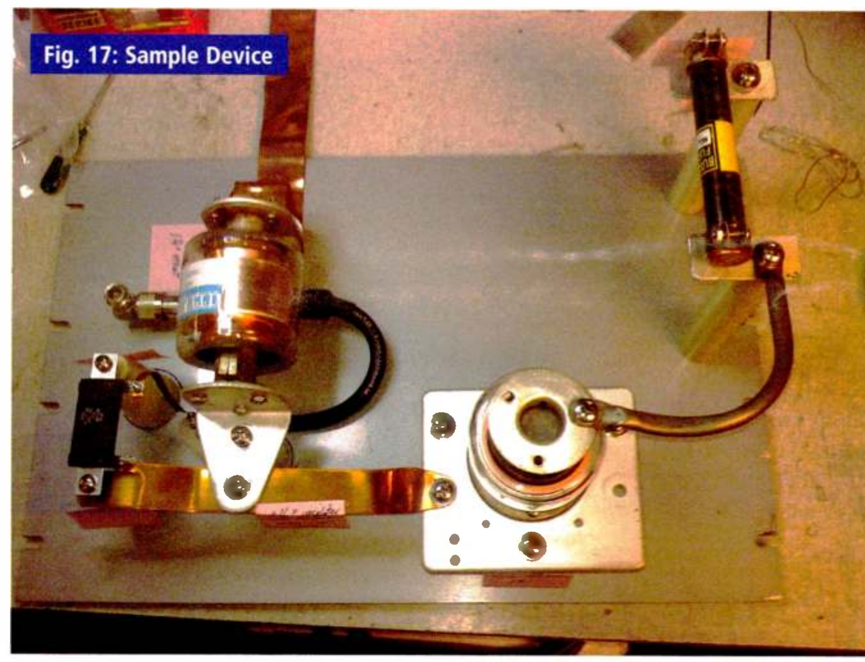
KPTK TOWER BASE CONDITIONS

Fig. 16



VOLTAGE DIVIDER ANTENNA SAMPLING NETWORK

Fig. 17: Sample Device



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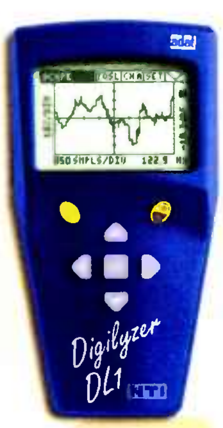

- AES/EBU, SPDIF, ADAT signals
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SAMPLING

(continued from page 18)

impedance could produce a voltage great enough to properly drive the antenna monitor. In contrast the 770 kHz impedances are relatively low, since the towers are only 113 degrees tall at this frequency, and so the sampling device had no measurable effect on the KTTH parameters. A capacitive divider was considered preferable to a resistive divider in order to provide DC isolation from static fields, and because a high-voltage vacuum capacitor has a modest degree of "self-healing" immunity to some fault conditions. See Figs. 16 and 17.

The KPTK engineering staff procured the necessary parts and constructed the devices. The high-voltage fuse and the line suppressor provide additional protection against atmospheric electrical events, and R1 provides the proper value of impedance for the lower portion of the divider, resulting in an appropriate input voltage for the antenna monitor. The three units were set up side by side and fed from a common source and calibrated with the antenna monitor by adjustment of C1, which was then locked into position. Before the final proof of performance measurements and adjustment were prepared, the units were monitored over about four months in a variety of temperature and environmental conditions, and proved to be very stable. See Fig. 18.

This system was used in the first moment method proof filed with the FCC using voltage samples.

2. The WAOK Voltage Sampling Problem

A different set of circumstances led to the use of voltage sampling for the antenna array employed by WAOK. The WAOK antenna system employs towers which are dissimilar and not quite 180 degrees in height, both of which disqualify it for use of a sample system with loops or with base current sample devices.

Because the WAOK towers are very close to half-wavelength in height, the drive impedances of this array are not high. As a result, a simple capacitive divider device is probably not suitable for this situation, or for many other systems with low Z towers and lower operating powers. As a result, Kintronic Laboratories developed a voltage sample device with a capacitive divider and a step-up toroidal transformer. See Fig. 19.

The Kintronic Laboratories unit is also designed for use in an outdoor environment, where there isn't suitable space in an existing ATU or where there are other mechanical considerations which require a weatherproof housing.

CONCLUSION

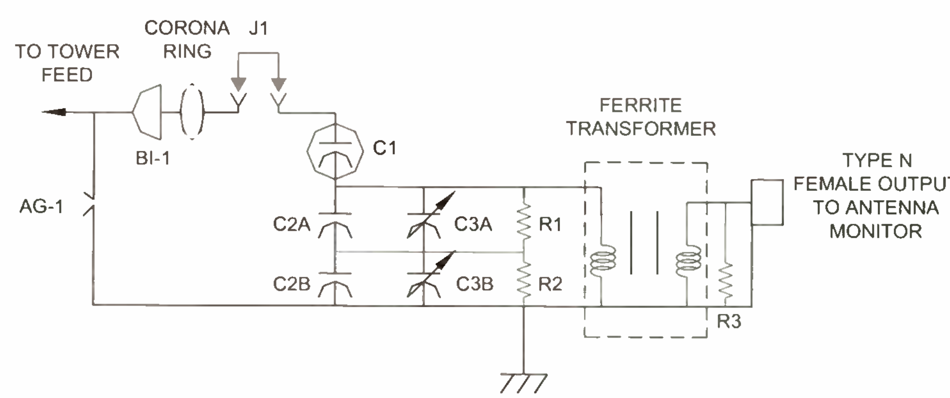
The adoption of moment method analysis techniques has placed new demands on the analysis of the monitoring circumstances for AM directional antenna systems. Careful evaluation of the base region conditions of the antenna towers in medium-wave directional arrays is necessary when base voltage or current sampling is employed. Because base currents are not necessarily a reliable method of monitoring array performance, in some situations the use of base voltage monitoring has begun to be employed. Simple voltage dividers allow this, but additional circuit elements may be required to provide adequate sample voltages in some cases.

ACKNOWLEDGMENTS

The KPTK voltage sample system final design, construction and testing were the result of the exemplary efforts of CBS-Seattle engineers Tom McGinley and Arnie Skoog. Tom King and Don Crain provided the data for the WAOK example. This paper originally was presented at the NAB Show in 2011.

Comment on this or any other story to rwee@nbmedia.com.

Fig. 18: Calibration



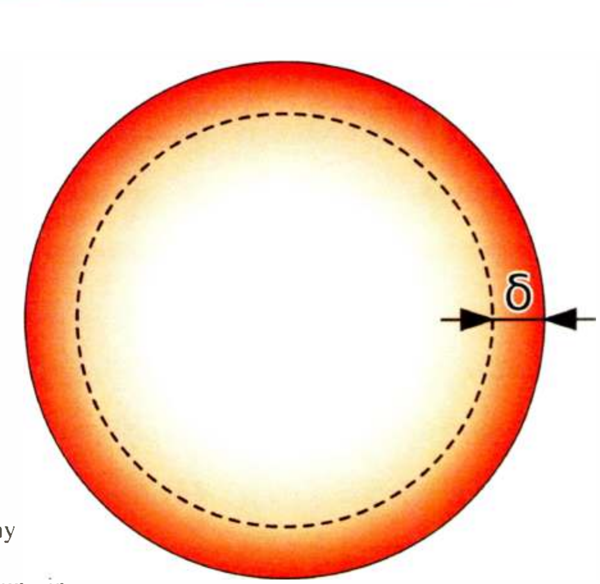
KTL VOLTAGE SAMPLING UNIT

Fig. 19

Fig. 20: Kintronic Voltage Sampler

At RF It's Only Skin Deep

A Discussion of Skin Effect in Alternating Current



Show Me Some Skin

Question from the Feb. 22 issue

(Exam level: CBRE)

What is skin effect in alternating current and what is its relationship to current flow?

a. Skin effect is the tendency of all current flow on printed circuit boards to concentrate on the area against the non-conductive surface and create a capacitor.

b. Skin effect is the tendency for electrolytic capacitors to change value when touched due to the requirement that the positive plate always be on the outside.

c. Skin effect is the tendency of current to flow through mainly the epitaxis layer of the skin when experiencing an electric shock.

d. Skin effect is the tendency of an alternating electric current to distribute itself within a conductor with the current density being largest near the surface of the conductor, decreasing at greater depths.

e. Skin effect is the penchant of RF to want to flow through the conductive character of a coaxial line.

BY CHARLES S. FITCH, P.E.

To help you get in the SBE certification exam-taking frame of mind, Radio World Engineering Extra poses a typical question in every issue. Although similar in style and content to the exam questions, these are not from past exams nor will they be on future exams in this exact form. For more certification information visit www.sbe.org/sections/cert_index.php.

Let's start our discussion by eliminating the most obvious wrong answer, (c). The epitaxis layer of the skin does not exist in the body except in your humble author's imagination.

The great writers of the golden era of sci-fi always described humans as "ugly bags of water." Probably more correct is "ugly bags of salt water." If you remember your high school chemistry and physics classes, you might recall how current flow went up when salt was added to the water. Once past dry skin's natural surface resistance, any current impressed on the body takes off following its inevitable course to ground and back to the power source generator through all your vital components.

Also wrong is (e) as RF (which is electricity) flows through the electron path of the copper conductors.

Answer (b) is not correct as there is no convention covering the manufacture of electrolytic capacitors although most do, in fact, have the negative plate on the outside.

Answer (a) does have one element of the skin effect phenomenon: current tends to flow on the surface of any conducting material. But currents don't create capacitors.

This leaves us with (d), which is the correct answer.

INDUCTANCE AND CONDUCTORS

No matter the major theory of electrical current flow to which you subscribe (the electrons move or just the charges move), the physics is about the same. Horace Lamb in 1883 annotated the skin effect phenomenon for the case of spherical conductors, and in 1885, Oliver Heaviside, the same gentleman who gave us the radioactive Heaviside layer in the ionosphere, related the effect to conductors of any shape.

Genius must have run in Heaviside's family, as his uncle was Sir Charles Wheatstone, co-inventor of the telegraph and progenitor of the Wheatstone bridge. An engineer and mathematician, amazingly Heaviside was self-taught! There's hope for all of us.

Faraday postulated that any current flowing through a wire sets up a magnetic field. Alternating current sets up a larger field due to the alternation of flow. The strata of atoms and their shells of electrons and related charges form magnetic layers, and where there is magnetism, there is induction. In this case, we have inductive layers caused by the layers of atoms … sort of circulative coils. As we come near to the edges of the conductor, the looser boundary regions exhibit less inductance, which presents to the current flow less inductive reactance.

From the basic formula, inductive reactance is equal to 2 times π times the frequency times the inductance in henries ($2\pi fL$); we can see that the higher the frequency, the higher the inductive reactance. Reactance acts on alternating currents similar to the way resistance acts on DC currents: the higher the reactance (resistance), the lower the current. So the AC flow seeks out the lowest reactance towards the edges and in the case of the highest frequencies, like RF, the flow travels mainly along the skin.

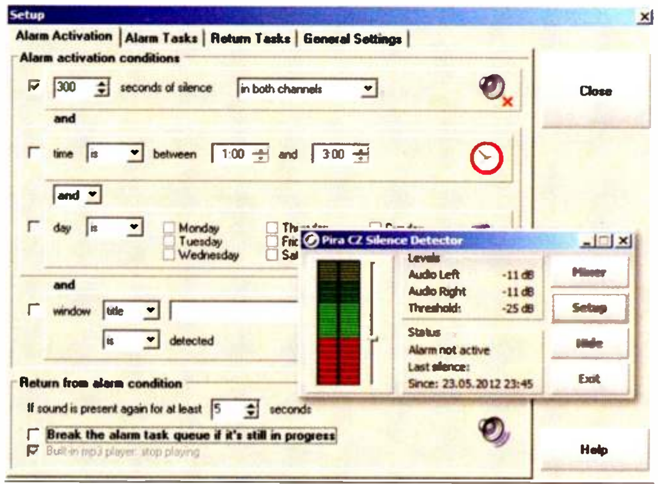
A DEEPER LOOK

The way the physics works out is that 63 percent of all the AC current flows near the wire surface to a depth which

(continued on page 22)

Free Silence Sensor Offers Worthy Set of Features

BY AARON READ



In the world of radio there's no greater sin than "dead air." Avoiding it has become increasingly complicated. Stations find themselves responsible for multiple content delivery methods, some of which have enough delay that they cannot realistically be monitored in real time by an operator on duty. Within a typical cluster, there might be several analog signals, HD Radio digital signals, multicasts, webcasts and more.

A major tool in dealing with this problem is the silence sensor. Silence sensors are designed to trigger an alarm of some kind whenever audio levels fall below a given volume for a given duration.

They aren't perfect; a loud roar of static won't cause your silence sensor alarm, but it sure will put a dent in your PD's antacid budget … not to mention your audience. Still, it's a valuable tool.

What if you don't have the budget, though, or (for computer-based audio) can't tie up a valuable audio output?

Enter the Pira CZ Silence Detector. This especially handy freeware program for Windows (Win95 to Win7, or Linux via WINE) will monitor the audio input or output via the Windows Sound Mixer, and has an adjustable level threshold and time duration for both silence and return-from-silence for the alarm.

The alarm is impressive, with a hierarchical system that includes pauses and multiple actions, such as emailing a message, attempts to kill a program, start (or re-start) a program, save a screenshot (and attach it to an email), play a sound clip, send an HTTP query or reboot the system.

For example, let's say you feed your transmitter with a high-quality OGG/Shoutcast stream, played by Winamp on a computer at your transmitter site. Pira can monitor for silence and can be programmed to make the following responses if the stream fails:

- Email a custom alarm message to a group of people.
- Force-close Winamp.
- Wait 10 seconds.
- Open a M3U (associated in Windows to open in Winamp) to relaunch the stream.
- Wait 60 seconds for the stream to buffer, and if still nothing …
- … open a different M3U with local MP3s to keep something on the air while the engineer investigates.

And if re-starting the stream is successful, Pira can wait a user-definable amount of time before initiating a just-as-flexible list of commands for "return from silence."

You can download a free copy of Pira from *http://pira.cz/eng/silence.htm*.

Aaron Read is the director of engineering at Rhode Island Public Radio in Providence, R.I.

SKIN EFFECT

(continued from page 21)

we'll call δ (lower case Greek letter delta).

The AC current density J in a conductor decreases exponentially from its value at the surface J_S according to the depth d from the surface, as follows:

$$J = J_s e^{-d/\delta}$$

where δ is called the *skin depth*. The skin depth is thus defined as the depth below the surface of the conductor at which the current density has fallen to 1/e (about 0.37) of J_S. In ordinary cases, the formula for determining δ is

$$\delta = \sqrt{\frac{2\rho}{\omega\mu}}$$

where

ρ = resistivity of the conductor

ω = angular frequency of current = 2π × frequency

μ = absolute magnetic permeability of the conductor

98 percent of all the AC current flows in an area no deeper than 4 times δ.

For virgin copper …

Frequency	Skin depth (∂ in μm, micro meters)
60 Hz	8470
10 kHz	660
100 kHz	210
1 MHz	66
10 MHz	21
100 MHz	6.6

IN PRACTICE

In radio, the skin effect has many practical implications. Skin effect is why we use strap for RF grounding. Since the RF flows along the skin of the conductive material, the interior copper in a large wire is effectively wasted. Strap provides a much higher ratio of conductor skin to interior copper and thus is able to carry high-frequency currents with minimal loss. So we have a world of 4- and 6- and sometimes 8-inch wide, 1/8-inch thick copper strap running hither and yon in our radio plants. The thickness is really just a function of the minimum sturdiness that will survive soldering, flexing and corrosion over the years.

Coils used in AM tuning units are much larger in diameter than would be required to pass similar magnitude DC currents. These much larger components are required in order to get enough current conduction on their outer skin. Most big RF coils use tubing, since this provides both inner and outer skin surfaces, doubling the conductive area and enhancing cooling.

In circuits much higher than AM and FM, say 11 and 13 gigahertz aural STLs, we have frequencies high enough that the signal flow is mainly along the top few angstroms (a unit of length equal to 10^{-10} meter) of the conductive material. In these microwave cases, and especially in high-demand locations such as filters, we can plate the device with a deposition of gold to minimize losses and enhance stability.

Gold is an amazing material for a great many reasons, but the one most valuable to us for cost reasons is its very high malleability. Gold can be thinned out in density/thickness until you can actually see through it and still maintain uniform integrity. So we are able to place just such a patina of gold on device surfaces for RF purposes.

Charles "Buc" Fitch, P.E., CPBE, AMD, is a frequent contributor to Radio World. Missed some SBE Certification Corners or want to review them for your next exam? See the "Certification" tab under Columns at radioworld.com.

Meter, Meter on the Wall

Question for next time

(Exam level: CBRE)

The analog DC ammeter with an actual full-scale value of 10 milliamperes in your transmitter that measures 1 ampere of plate current has failed and the only linear meter that fits in the same space available is a 1 mA unit. Could you use this available meter as a replacement?

a. Yes, with a series resistor of 10 k

b. Yes, with a series and parallel resistor both 10 k

c. No

d. No because the scale is set by the coil wind count

e. Yes, with a select parallel resistor across the meter contacts

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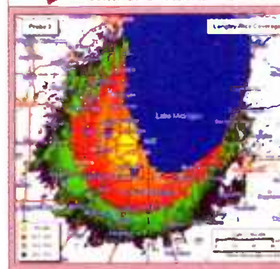

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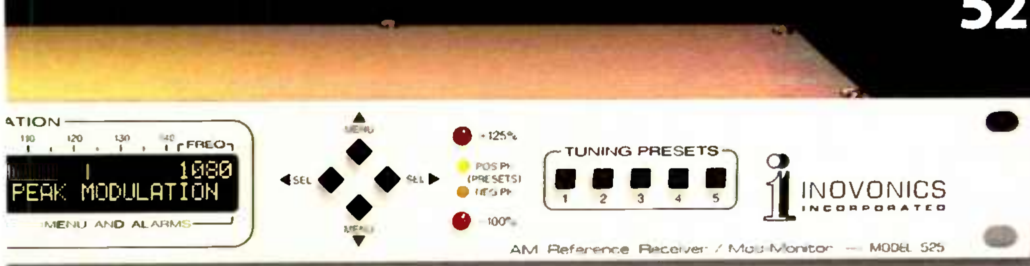

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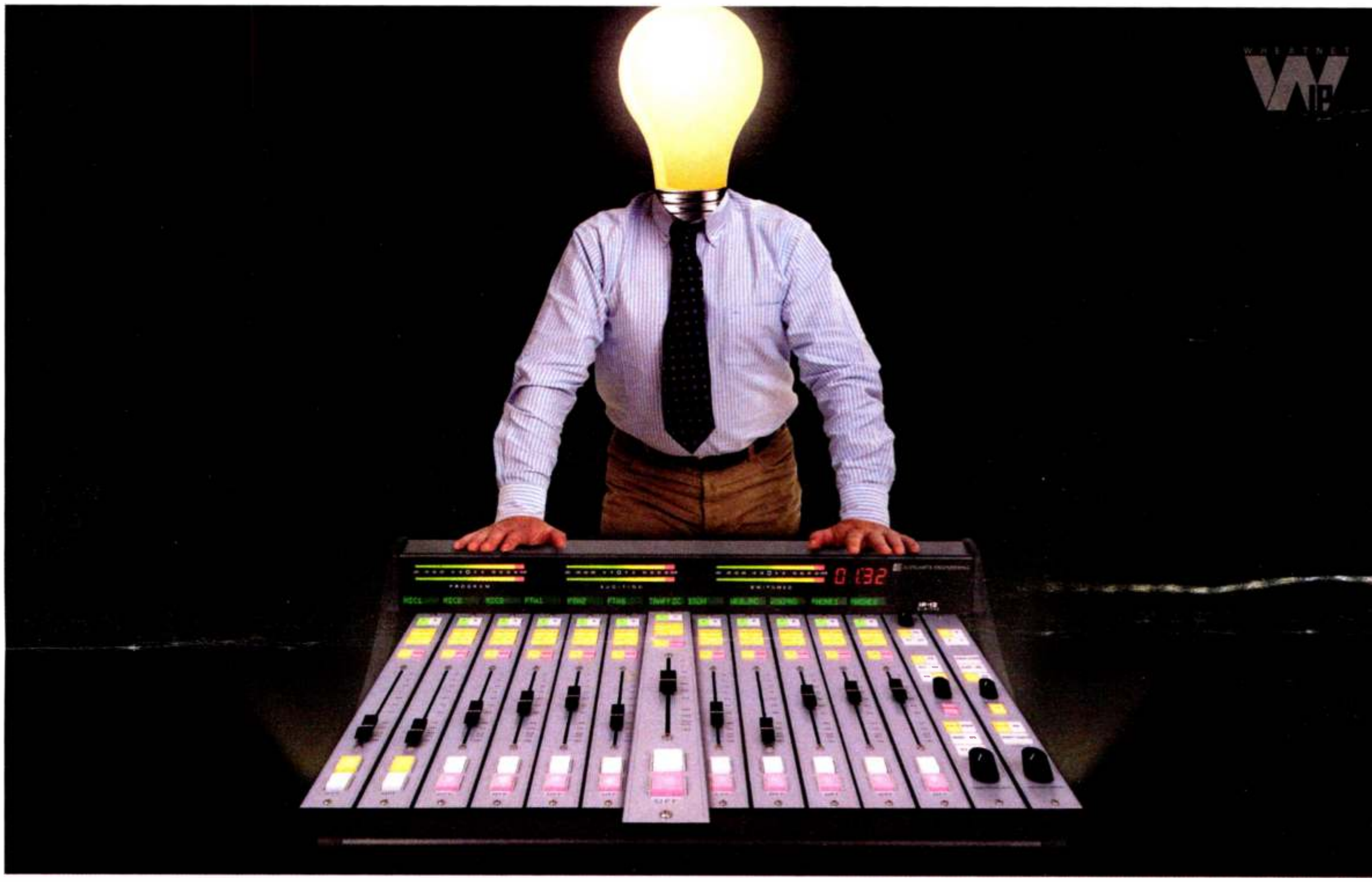

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