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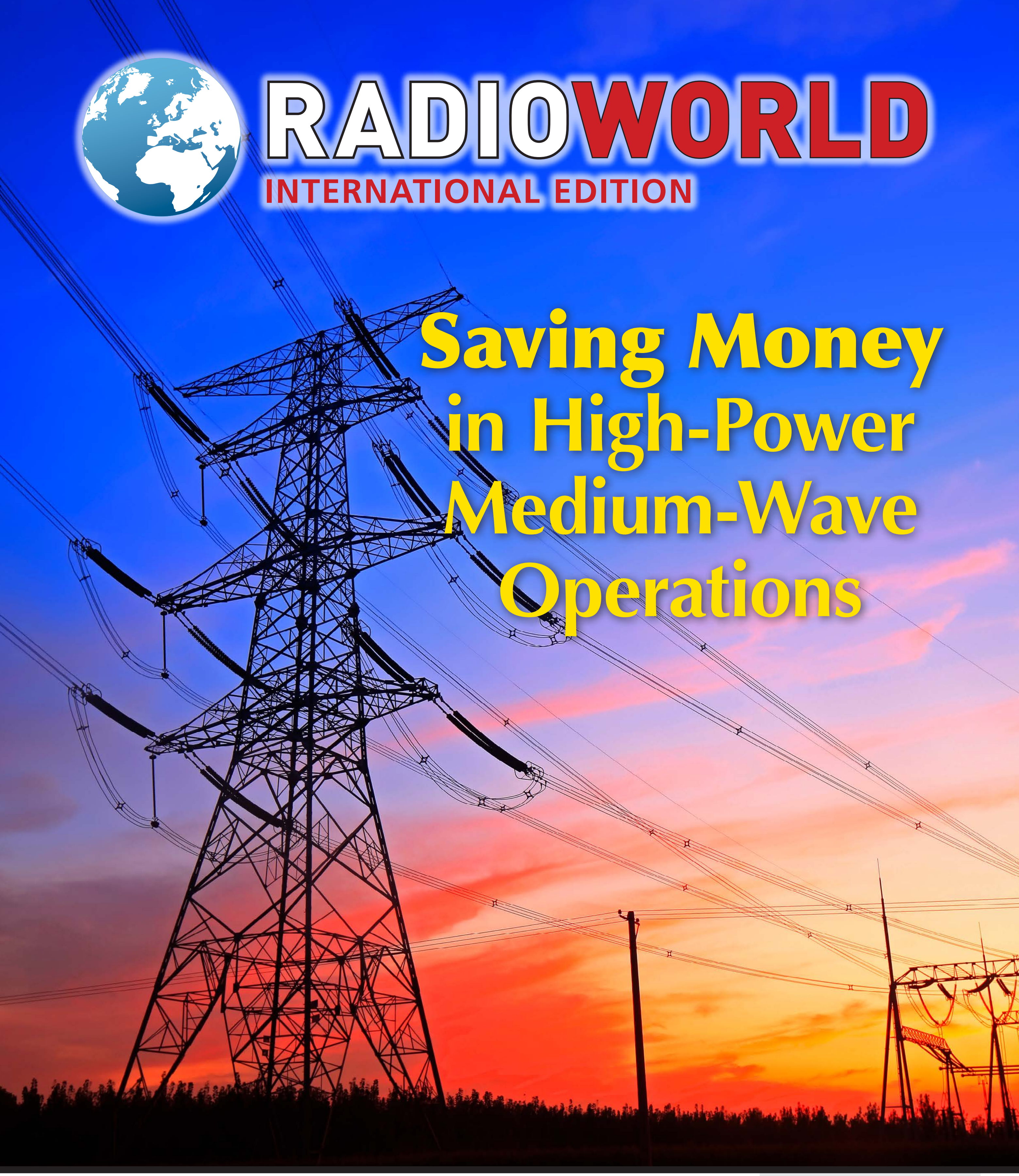

Saving Money in High-Power Medium-Wave Operations

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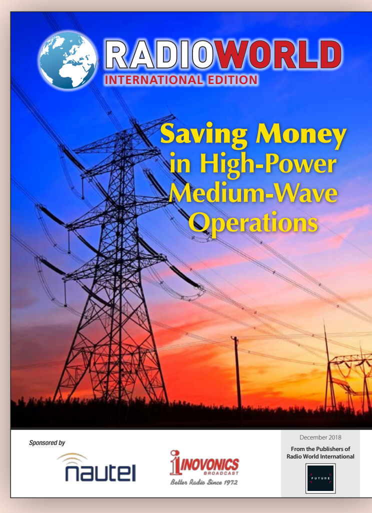

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Saving Money in High-Power Medium-Wave Operations

Paul McLane
Editor in Chief

High-power transmission plants for medium-wave broadcasters are specialized technical environments that can be costly and complicated to run. Radio World's December eBook explores how such operators can save money in managing their facilities.

How are worldwide electricity costs changing? What impact is this having on operators of high-power (100 kW+) facilities? How efficient are AM/MW transmitters that are being used in various high-power installations? What role do Modulation Dependent Carrier Level algorithms play in high-power MW facilities and what changes might be coming in MDCL?

We explored these questions in the stories that follow.

Veteran engineer and consultant Ben Dawson provides general context, as does Chuck Kelly of Nautel. Robert Webber of BBC World Service shares an overview on present and future AM broadcasting technologies. Davide Moro summarizes the conclusions of a BBC white paper on AM companding. Marco Auriti shares his experiences at Touch Canada Broadcasting LP, while Gerhard Straub of the U.S. Agency for Global Media reminds us of the importance of the antenna system. And we conclude with a technical discussion from NAB Radio Engineering Achievement Award recipient Tom King with tips on designing a cost-effective high-power antenna system.

My thanks to Davide Moro for his help in creating this eBook. How may our eBooks serve you better? Email me at *paul.mclane@futurenet.com*.

A Chat With Ben Dawson

Ben Dawson is former managing partner of specialized electrical engineering firm Hatfield & Dawson Consulting Engineers LLC. He is now senior consultant to the firm.

Radio World: *What is the trend of electricity costs in your own market?*
Ben Dawson: The Pacific Northwest has among the lowest electricity rates in the world. But a clear picture of recent changes is available from the U.S. Energy Information Administration (see image).

RW: *Over time, what have been cost-effective measures to save on electricity costs for MW TX sites?*
Dawson: At multiple tower sites, conversion to LED aviation lighting has actually been a non-trivial savings. Modern solid-state transmitters also reduce air handling and cooling costs as well as contributing to savings because of their efficiency characteristics, typically in the 90 percent range.

RW: *What gain in efficiency would drive organizations to invest in a major revamping or to replace an existing transmitter?*
Dawson: The few existing high-power non-solid-state transmitters at high power levels are typically merely in standby condition. At very high power levels such as those seen in ITU Regions I and III, electricity costs and maintenance costs of older equipment can be high enough to allow amortization of new equipment in relatively short periods. Ninety percent efficiency is very attractive. In a few isolated situations, however, where power costs don't enter into political decision making for government broadcasters, rather antique transmitting equipment is still in service. Even early solid-state equipment may be replaced in much shorter time periods than was true of 1950s era tube-type equipment, because of the difficulty of obtaining early types of FETs and other components.

RW: *From the point of view of broadcasters, what are the pros and cons of solid-state and tube-type?*

Table 5.6.A. Average Price of Electricity to Ultimate Customers by End-Use Sector, by State, September 2018 and 2017 (Cents per Kilowatthour)

Census Division and State	Residential		Commercial		Industrial		Transportation		All Sectors	
	September 2018	September 2017	September 2018	September 2017	September 2018	September 2017	September 2018	September 2017	September 2018	September 2017
New England	21.17	20.00	16.67	15.90	12.89	12.66	8.29	8.07	17.97	16.90
Connecticut	22.05	21.26	17.67	16.32	14.16	13.29	11.79	12.03	19.19	17.93
Maine	16.01	16.01	11.80	11.86	8.58	9.14	--	--	12.61	12.76
Massachusetts	22.15	20.83	17.25	16.91	14.57	14.22	5.35	5.17	18.83	17.88
New Hampshire	19.87	19.64	15.90	14.98	13.12	12.32	--	--	17.04	16.13
Rhode Island	22.32	17.92	16.76	15.30	15.17	14.76	17.16	17.11	19.04	16.33
Vermont	17.95	17.92	15.11	12.54	10.59	10.33	--	--	15.01	13.72
Middle Atlantic	16.37	16.39	13.23	13.27	6.80	6.90	11.98	11.88	13.16	13.04
New Jersey	15.53	15.30	12.40	12.35	10.26	10.28	13.22	8.60	13.51	13.28
New York	19.28	18.80	16.07	16.13	6.07	6.19	13.06	13.36	16.10	15.73
Pennsylvania	13.76	14.45	8.69	8.85	6.60	6.68	7.40	7.19	9.86	9.98
East North Central	12.84	13.58	10.07	10.16	6.94	7.06	7.34	6.52	9.96	10.12
Illinois	12.19	13.09	8.94	9.00	6.42	6.34	7.17	6.24	9.28	9.47
Indiana	12.33	12.63	10.57	10.63	7.20	7.49	10.38	10.61	9.77	9.84
Michigan	15.40	15.38	10.88	10.85	7.20	7.20	10.03	11.67	11.28	11.05
Ohio	11.39	12.95	9.87	10.11	6.56	6.94	8.00	7.92	9.38	9.89
Wisconsin	14.88	14.82	11.08	11.11	7.74	7.69	13.38	14.12	10.96	10.96
West North Central	12.48	12.73	9.95	10.11	7.79	7.64	10.96	10.71	10.15	10.16
Iowa	13.23	13.32	10.32	10.30	7.59	7.53	--	--	9.74	9.66
Kansas	12.86	13.55	10.26	10.84	7.78	7.65	--	--	10.49	10.92
Minnesota	14.57	13.59	11.33	11.00	8.26	7.63	10.73	10.15	11.29	10.62
Missouri	10.98	11.73	8.92	9.31	6.90	7.49	11.19	11.31	9.55	10.02
Nebraska	12.28	12.55	9.42	9.35	7.65	7.83	--	--	9.65	9.65
North Dakota	12.23	12.02	9.71	9.70	8.55	7.80	--	--	9.64	9.25
South Dakota	12.83	12.87	9.82	10.01	7.99	7.88	--	--	10.38	10.38
South Atlantic	11.82	12.23	9.16	9.52	6.64	6.78	8.04	7.26	9.96	10.24
Delaware	12.38	13.36	9.45	9.49	7.86	7.42	--	--	10.50	10.62
District of Columbia	12.56	13.08	11.76	11.77	8.34	8.13	9.98	7.65	11.87	11.87

Information about electrical cost trends is available from the website of the U.S. Energy Information Administration. Access the data here.

Dawson: For new equipment purchase, there is no advantage to tube-type transmitters any longer, and they are almost entirely being manufactured only for HF use.

RW: *What are the most promising technologies to reduce operating costs for 100 kW+ MW transmitters?*

Dawson: The most critical problem with high-power medium-wave transmitters is module failure, which occurs for a variety of reasons. Newer solid-state devices with better characteristics and operation of solid-state devices with more safety factor will probably increase capital cost but reduce maintenance costs, which are nontrivial for some solid-state transmitting equipment.

RW: *What role do Modulation Dependent Carrier Level algorithms play in high-power MW facilities and what changes might be coming in MDCL?*

Dawson: MDCL is still somewhat controversial. There are major broadcasters in the U.S. who do not employ it because of a perception that it has an adverse effect on outer regions of the coverage area. Others perceive no such effects, and employ it extensively. I think it's a "red herring."

Use of MDCL in the "BBC" version — full carrier with no modulation, reduction of carrier with modulation up to ~6 dB — does reduce stress on antenna systems and components thereof. One client we're aware of uses it at a 5 kW station for exactly this purpose, even though it doesn't provide a significant operating cost savings.

Use of MDCL can actually allow operation with higher carrier power without exceeding amplifier device stress, although this may not actually be employed by any operating stations (and would not be consistent with FCC rules in the U.S.).

MDCL was, of course, first proposed for U.S. use (by our firm) in remote areas of Alaska, where AC power costs can be very high due to the cost of air delivery of diesel fuel. The BBC white paper "WHP-333" discusses the current state of that organization's work on this subject. (BBC refers to their technique as AMC, for AM Companding.)

RW: *What else should we know about lowering operational costs for MW broadcasting?*

Dawson: Once a facility has been optimized for lowest utility costs, the most important operating procedure is to avoid deferred maintenance.

In railroad and utility practice, for example, if operation of a facility exhibits declining revenue that cannot be attributed to poor performance but is entirely based on external market factor changes, the owner is justified in reducing maintenance expenditures to a level that just exceeds the amount where additional revenue decline can be shown as a direct result of the maintenance reduction.

Essentially, this procedure allows the decision to terminate the facility operation to be deferred so long as it has marginal utility revenue potential. This can be effective in maintaining work force or facilities that would otherwise not be cost effective.

If maintenance is deferred, however, a decision to eliminate the facility is itself deferred, not avoided entirely. Further, railroad and utility practice is to consider that the "make-up" for such deferred maintenance is always more costly than the deferred cost itself, even discounting the cost of capital and any inflation. ■

It's All About Efficiency

Asked to identify the best ways to reduce 100 kW+ MW transmitters operating costs, consultant Geoffrey Mendenhall of Mendenhall Engineering replied: "High efficiency, Class D, solid RF amplification technology combined with high efficiency, digital modulation technology that utilizes Modulation Dependent Carrier Level control."

He also provided this rough timeline of the historical progression of AM transmitter technology:

- 1920s to 1960s: Vacuum-tube RF power amplifiers with high-level plate modulation. Overall transmitter efficiency approximately 30 to 40 percent.

- 1960s to 1980s: Vacuum-tube RF power amplifiers with Doherty, AmpliPhase, Pulse Duration Modulation (PDM) or Pulse Step Modulation (PSM). Overall transmitter efficiency approximately 50 to 70 percent.

- 1990s to present: Solid-state RF power amplifiers with PDM modulation or direct digital synthesis (DX) modulation. Overall transmitter efficiency approximately 80 to 88%

- Add MDCL and further reduce power consumption by 25 to 35 percent depending on program material and audio processing.

Kelly: Modern Designs Make a Huge Difference

A view from the manufacturer's perspective

Chuck Kelly, regional sales manager, Asia/Pacific, for Nautel Ltd., says that costs for electrical energy have risen by an average of 24 percent in the past 10 years in the U.S., and that most other countries have followed a similar trend, driven in part by increasing consumption and increasing costs for fossil fuels. We pursued the topic with him.

***RW:** In the past, what have been the most effective measures that helped organizations to save on electricity costs for MW broadcasting sites?*
Chuck Kelly: The general efficiency of the transmitters themselves. Many broadcasters still use tube type, plate modulated transmitters made in the 1970s and '80s which may average 60–70 percent overall efficiency, while today's solid-state designs can reach 88–90%, AC to RF.

***RW:** Which is the impact of tube replacement on the service level and the overall operating costs?*
Kelly: Many tubes are getting hard to find, and expensive. This can contribute to the total cost of operation.

***RW:** Review the pros and cons of solid-state and tube-type transmitters.*
Kelly: Solid-state transmitters have several advantages over tube-type designs. Solid-state tends to be considerably more efficient, reducing electrical running costs, and also reducing the heat which must be exhausted. Modern solid-state designs employ multiple amplifiers in parallel, so the loss of an amplifier doesn't take you off the air. Tube designs tend to have multiple single points of failure. State-of-the-art solid-state transmitters utilize DSP modulator techniques, which nearly eliminate the distortions common to older tube models, such as THD, IMD, frequency response errors, carrier shift and IPM. These improvements also make modern solid-state designs ideal for upgrade to digital, such as DRM or HD Radio.

***RW:** What are the most promising technologies to reduce 100 kW+ MW transmitters operating costs?*
Kelly: DSP-controlled modulation techniques allow huge improvements in overall transmitter efficiency, such as precise control of FET switching in the modulators and RF amplifiers. This means that the FETs are switched when the device is at a zero voltage point, eliminating capacitive losses. The DSP control also allows for Modulation Dependent Carrier Level (MDCL) to be implemented, which can save 30 percent or more in overall energy usage.

These improvements …make modern solid-state designs ideal for upgrade to digital, such as DRM or HD Radio.

***RW:** What role do MDCL algorithms play in high-power MW facilities and what changes might be coming in MDCL?*
Kelly: MDCL has been shown to reduce electrical costs of MW transmitters by 30 percent or more, while having no discernable effect on the coverage or audio performance of the station. Many different algorithms have been developed over the years, and more are being developed and tested today which offer even greater savings.

***RW:** What's a typical payback time for replacing an existing MW transmitter with a new state-of-the-art transmitter with MDCL? Or for retrofitting an existing one?*
Kelly: Typical return on investment numbers for replacement of a tube-type plate-modulated 100 kW transmitter with a current 90 percent efficient design with MDCL could be as little as two years. Several transmitter man-

Continued on page 9

Saving Money in High-Power Medium-Wave Operations

BBC World Service shares an overview on present and future AM broadcasting technologies

by **Robert Webber**

The author is distribution manager for BBC World Service and a former transmitter and project engineer.


Robert Webber

The BBC World Service is probably most well known as a shortwave broadcaster; however this is not the only AM broadcasting service transmitted.

They also operate some medium-wave services in key locations. This band is ideal for international broadcasting during the hours of darkness as it uniquely allows coverage of very large areas due to skywave propagation whilst maintaining listener convenience of tuning to a single frequency. Through the use of high-power transmission facilities and skywave propagation it is possible for a medium-wave service to be broadcast not just in the country where the transmitter is located but across countries nearby.

BROADCASTING SINCE 1950

The BBC World Service owns and broadcasts from four high-power medium-wave transmitters, located at sites in Cyprus and in Oman. The facility in Cyprus has been in use since the 1950s and originally operated at 100 kW. In 1978 it was moved to its present location and the power increased to 500 kW [see Reference 1 at end of article].

Even in 1978 the site was equipped with pairs of 250 kW transmitters of the Doherty design which was then the most power-efficient transmitter design available. These Doherty transmitters were replaced themselves by pairs of Harris DX250 transmitters in around 2002-2003.

The site in Oman was built in the early 2000s to replace the facility that had been in operation on Masirah island. The BBC's Oman transmitter facility is equipped with Thales S7HP 800 kW transmitters.

Both the Cyprus and Oman transmitter facilities are run unattended with engineering effort available to attend in the case of a fault or maintenance from other nearby facilities. This means that the vast majority of the operating cost of these facilities is actually in the power consumed by the broadcast transmitters.

The decision to replace the transmitters in Cyprus would have been made due to the cost and reliability issues experienced in operating 25-year-old transmitters which only had a power efficiency of around 50 percent and are operated unattended. The decision to invest in new transmitters for Oman was based primarily on the requirement to relocate the transmitter site.

Both the Harris DX and Thales S7HP transmitters being of recent design are fully solid-state which brings advantages in terms of efficiency and reliability over older high-power tube designs. The last high-power tube medium-wave transmitter to be used full-time for the BBC World Service was located at Babcock Communication's Orfordness transmitter site.

Whilst being reasonably efficient at around 70 percent the failure of the tube would result in the transmitter being off whereas the architecture of the solid-state designs employed at Cyprus and Oman mean that in the event of a power device failure the transmitter can continue to operate with a small reduction in power.

MODULATION DEPENDENT

Since the 1980s the BBC has been interested in the use of Modulation Dependent Level Control (MDCL) and over the years has used both DAM (Dynamic Amplitude Modulation) and AMC (Amplitude Modulation Companding) on its high-power AM broadcasting network. The level of power efficiency improvement offered by each type of MDCL is modulation depth and hence program type dependent.

Since the mid-1980s the BBC has favored the AMC variant of MDCL and has used this widely on both its domestic AM network and more recently on its high-power international medium-wave transmissions.

The majority of BBC World Service Programming is speech-based and therefore average modulation depths are typically only around 20 percent (see Report ITU-R BS.2344). This low modulation depth would on the face of it appear to be more suited to the application of DAM; however it is likely that in fact whilst delivering power saving it would lead to a poorer reception experience for the listener. AMC is therefore the preferred by the BBC as it delivers power savings without the disadvantages to the audience.

Through the use of high power transmission facilities and skywave propagation, it is possible for a medium-wave service to be broadcast not just in the country where the transmitter is located but across countries nearby.

Both the BBC World Service sites in Oman and Cyprus having been equipped with transmitters in the early 2000s are capable of MDCL. In the usual broadcast operating configuration the transmitters are operated at full power (500 kW for Cyprus and 800 kW for Oman) with AMC and 3 dB of compression on the carrier.

Both sites are capable of operating at half power in Enhanced Amplitude Companding mode (EAMC). Operating in this way means that part of the transmitter can be taken out of service for maintenance or repair with a very minimal impact on the audience (around 1.5 dB degradation).

6 DB CARRIER COMPRESSION

For example in Cyprus the transmitter is run as a single 250 kW unit rather than the combined 2 by 250 kW making 500 kW. When the single 250 kW unit is to air the quiescent carrier power is increased to 375 kW which gives the –1.5 dB degradation but with the implementation of EAMC and 3 dB of carrier compression can give apparent efficiency of 100 percent-plus, as the transmitter only peaks at 375 kW but serves the same area as a 500 kW AM transmitter.

The ever-continuing rise in power costs have once again lead broadcasters to re-evaluate the advantages of MDCL. Recent investigations by BBC Research and Development and implemented in the BBC's domestic medium-wave network have shown that it is possible to increase the carrier compression from 3 dB to 6 dB without a noticeable effect on reception at the edge of service [see Ref. 2].

BBC World Service is currently investigating the feasibility of using 6 dB of carrier compression on its medium-wave broadcasts.

Transition to digital broadcasting in the medium-wave band could lead to further power savings for broadcasters. Transition to the Digital Radio Mondiale standard in the medium-wave band could improve listener experience whilst giving power savings of up to 50 percent to broadcasters when compared with analog AM [Ref. 3].

If HE-AAC audio encoding is used in the transition, DRM can deliver a second audio service, meaning that broadcasters can deliver two services for the price of one. The majority of modern AM transmitters are capable of operating with the DRM system meaning that such a transition would come at a modest cost to broadcasters. ■

References:

1- Shacklady, Norman; Ellen, Martin (2003). On Air: A History of BBC Transmission. Orpington, Kent: Wavechange Books. *ISBN 0954407717.*

2- https://www.bbc.co.uk/rd/publications/whitepaper333

3- http://www.drm.org/DRM_Handbook_2018.pdf

❱ Continued from page 6

ufacturers offer add-on MDCL units for their existing transmitters; payback on these at 100 kW or more can yield payback in the order of a few months.

RW: *How many broadcasting organizations worldwide are operating or testing digital broadcasting techniques?*

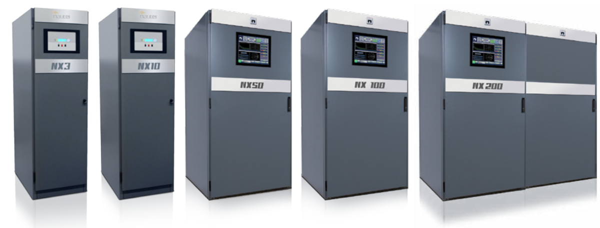
Kelly: Many broadcasters are using digital AM broadcasting. A current list of stations using DRM is at http://www.drm.org/what-can-i-hear/broadcast-schedule-2/ and for HD Radio, there are lists at https://hdradio.com/stations/

RW: *How can digital broadcasting techniques affect overall power costs?*

Kelly: Digital radio can have a positive impact on energy costs in two ways. First, the RMS power consumed in a digital-only AM station can be significantly less than the power consumed in analog more, for the same coverage area. Second, digital-only AM stations have the potential for more than one audio channel on the transmitter / frequency, which means that you could save the costs of another transmitter which would no longer be needed.

Nautel publishes an MDCL Savings Worksheet. Access it at https://www.nautel.com/nxsavings.

How Much Can You SAVE?



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Modules	2	2	4	10	10	20	40	80	120	160	
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AM Frequency	532 kHz – 1700 kHz			531 kHz – 1,620 kHz							
LW Frequency	Contact your Sales Rep.			120 kHz – 370 kHz							

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The BBC Pushes MDCL Algorithm Beyond Its Limit

Comprehensive set of test explores the unleashed potential of their AMC system, in real world

This article is based on the white paper "AM Companding: Reducing the Power Consumption of LF and MF Transmitters," by Ranulph Poole of BBC R&D and Phil Kesby of Arqiva, published by the BBC in July 2018

By **Davide Moro**

AMC (AM companding), one of the various MDCL algorithms, is used on all high-power LF and MF transmitters operated by the BBC to reduce electricity consumption.

AMC reduces the carrier power at high modulation levels, when the modulation is expected to mask any increase in background noise and interference. BBC applies companding of 3 dB, but in order to enhance cost savings, it set up a joint project with Arqiva, its transmission provider, to evaluate the possibility of increasing the companding to 6 dB.

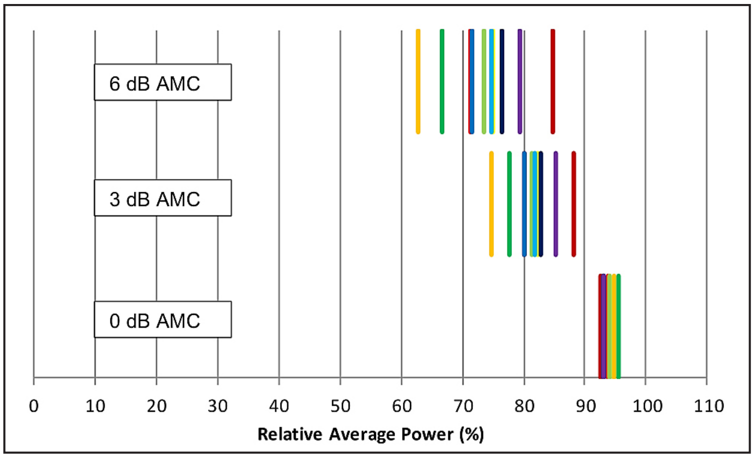

Fig. 1: Relative average power consumption to air each audio sample with no audio processing applied and no overshoots.

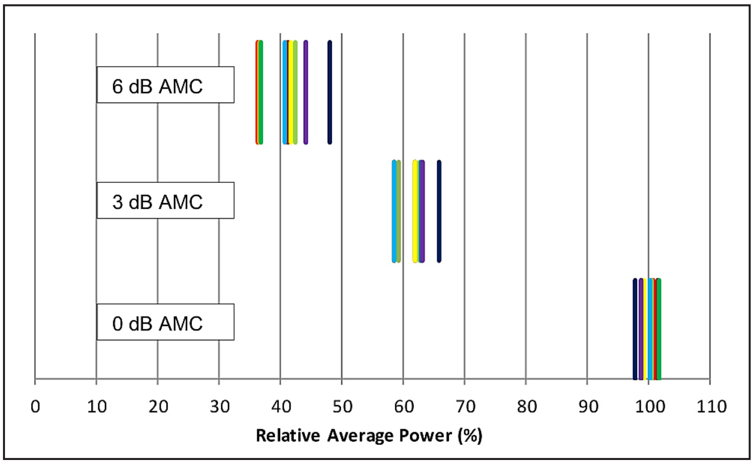

Fig. 2: Relative average power consumption to air each audio sample with audio processing applied and no overshoots.

A COMPLEX MIX

The project involved a combination of laboratory tests and field measurements. BBC made the results publicly available in its White Paper released in July 2018.

The project highlighted that the amount of companding was just one of the variables to be carefully considered. Audio compression as well as attack and decay time appeared to play a key role in both the power savings and the listening experience. Samples of real aired content were provided by the Radio 5 Live studios, both before and after audio processing.

Fig. 1 pictures the relative average power consumption to air each of the audio samples with no audio processing applied. Each vertical line represents a different audio sample. AMC is applied with the original short attack time (0.3 ms) and no overshoots (due to the attack time) allowed.

Fig. 2 introduces audio processing. Without the processing, the average modulation level is low and the AMC is not very helpful: There is considerable overlap between the results at 3 dB and 6 dB.

Introducing the processor actually increases the power consumption slightly in the absence of AMC, but, when introduced, the AMC is then very effective. The indications are that AMC at 3 dB and 6 dB saves around 40 percent and 60 percent respectively.

ATTACK TIME

One of the controllable variables is the attack time. In the original system designed by the BBC, attack time was prudentially limited to 0.3 ms, also to avoid overshoot on transmitters, even if conventional wisdom suggests that values greater than about 5 ms are needed to avoid audible distortion.

Increasing the attack time further to at least 20 ms would also give the receiver AGC a chance to track the changes in carrier level more precisely, hence improving the system transparency.

So, if the transmitter power is allowed to overshoot because of a longer attack time, will that have an adverse effect on power consumption?

Fig. 3 reports the effect of airing the same audio samples as above with 20 ms attack time and overshooting allowed. Fig. 4 refers to the same conditions, but with 50 ms attack time. Audio processing was used throughout.

Comparison of Figs. 3 and 4 shows that the presence of 20 ms overshoots makes no discernible difference to the power consumption, and the difference is still very small when the attack time is extended to 50 ms: the savings for AMC without and with overshoots are 58.8 percent and 58.0 percent respectively.

LISTENING EXPERIENCE

As to the listening experience, it is perhaps not intuitively obvious, but the paper found that the overshoots improve the system transparency. The system will be transparent provided that any change in carrier level is slow enough for the AGC in the receiver to track it fully.

In AMC with fast attack time (0.3 ms) as previously used at the BBC, a burst of high-level audio causes the transmitter power to fall before the AGC has had a chance to respond. The output of the receiver will therefore be too low during the attack period.

To assess the audible effect of changing the amount of AMC and the attack time, the BBC assembled a panel of 10 volunteers, none a trained listener.

Some clips of "real," processed program material were used, while listeners were asked for rating each sample

Continued on page 14

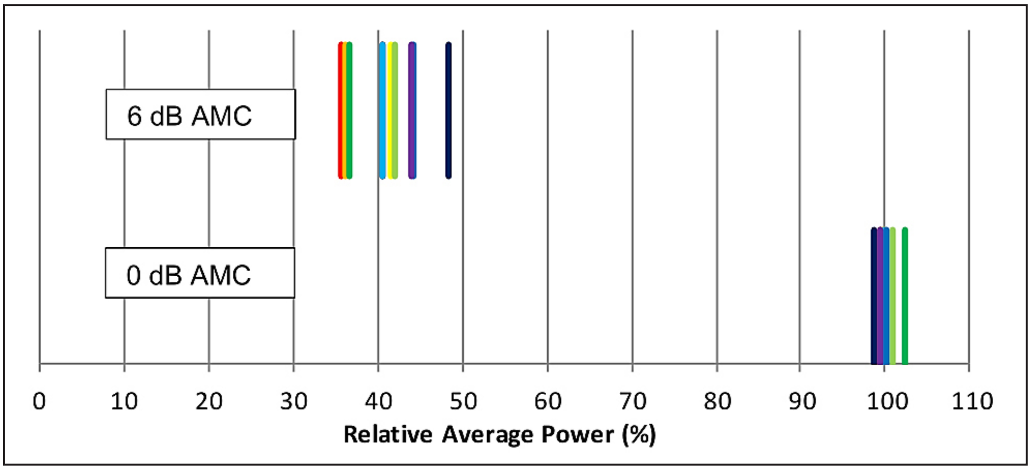

Fig. 3: Relative average power consumption with attack time 20 ms and overshoots allowed.

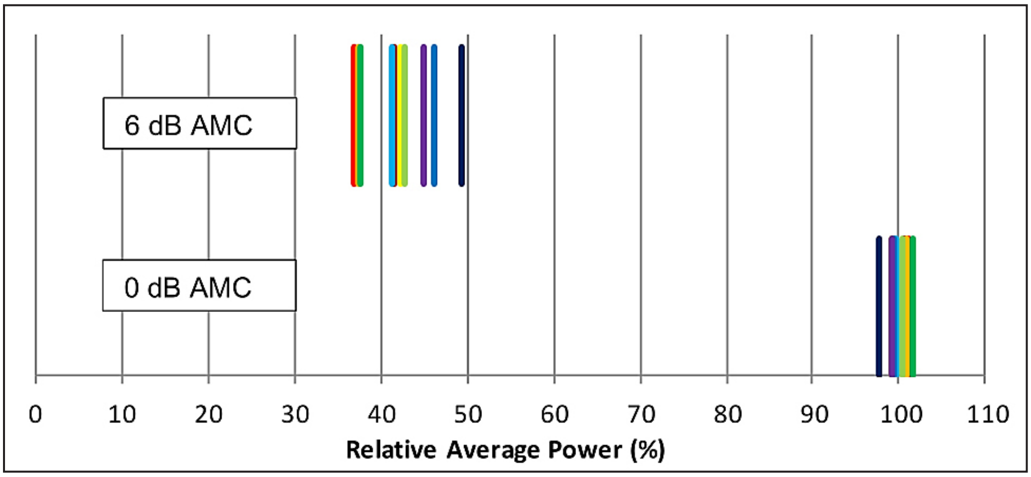

Fig. 4: Relative average power consumption with attack time 50 ms and overshoots allowed.

Touch Canada Experiences Energy Savings With MDCL

Accurate comparison of real-life cost reductions drove Canadian broadcaster to embrace MDCL technology

By **Marco Auriti**

The author is chief engineer at Touch Canada Broadcasting LP.

Touch Canada Broadcasting Limited Partnership owns and operates CJCA(AM) in Edmonton, Alberta and CJLI(AM) in Calgary, Alberta.

Before implementing Modulation Dependent Carrier Level (MDCL), approximately 30 percent of our technical operating expenses were for electricity costs for both sites. I managed to get the cost of our electricity to 6.1 cents per kilowatt hour on a fixed rate for a five-year contract.

Marco Auriti

REAL LIFE MEASUREMENTS

CJLI runs at 50 kilowatts day pattern and 20 kilowatts night pattern. CJCA runs at 50 kilowatts day and night patterns. CJLI in Calgary was a brand-new AM build with a Nautel NX50 transmitter that ran for 13 months before the MDCL control feature, which is built into the

Continued from page **13**

according to the standard five-point ITU-R impairment scale, with 5 being "imperceptible" and 1 being "very annoying."

Since the effects of AMC could be quite subtle, the BBC included a differential amplifier into the test-bed to enhance the distortion by about 16 dB so that it could be clearly audible. Fig. 5 shows the test results with 0.3 and 50 ms attack time, while Fig. 6 summarizes the whole results.

With 50 ms attack time and 6 dB AMC, the impairment score has improved by 1.7 to 3.6. Many listeners would find such sound quality acceptable. In contrast, the original system achieved an "annoying" score of 1.9 for only 3 dB AMC.

BBC concludes that in the real world, without the distortion enhancement used during these tests, the impairments introduced by the improved system would be completely inaudible.

Read the full paper here.

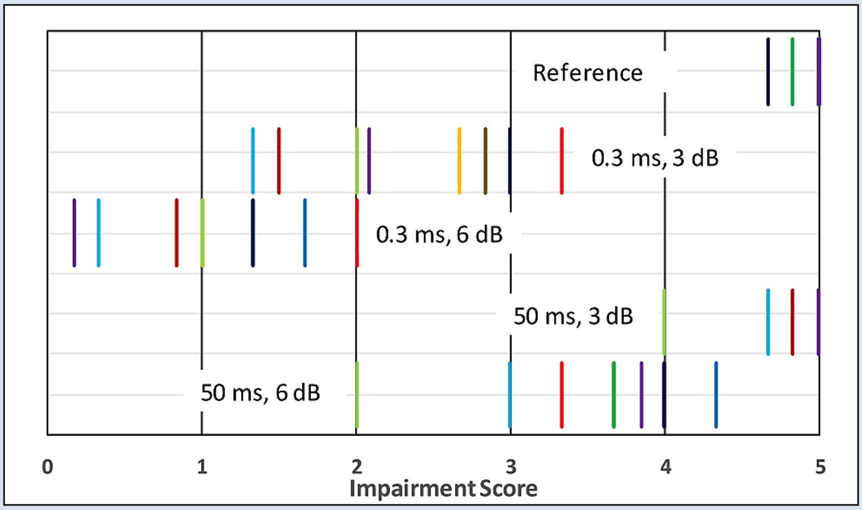

Fig. 5: Results of the listening tests for 0.3 ms and 50 ms attack times.

Overall Averages				
	3 dB		6 dB	
Perfect	*0.3 ms*	*50 ms*	*0.3 ms*	*50 ms*
5.0	2.4	4.8	1.1	3.6
0.1	0.4	0.9	0.1	1.7

Fig. 6: Average impairment scores (red) and improvements over previous scores (blue).

CJCA AM is running a Nautel XL60 at 50 kilowatt day and night pattern

Consumption kWh		Consumption kWh		Difference kWh	$ Saving
Aug-17	56443.033	Aug-18	33893.574	22549.459	$1,375.52
Sep-17	53847.245	Sep-18	32836.988	21010.257	$1,281.63
Oct-17	54278.911	Oct-18	35975.74	18303.171	$1,116.49
Totals	164569.189		102706.302	61862.887 kWh	$3,773.64 Total Savings 37.59 % Less kWh

CJLI AM is running a Nautel NX50 at 50 kilowatt day pattern and 20 kilowatt night pattern

Consumption kWh		Consumption kWh		Difference kWh	$ Saving
Jul-15	44779.384	Jul-16	23884.484	20894.9	$1,274.59
Aug-15	50750.622	Aug-16	23580.889	27169.733	$1,657.35
Sep-15	35083.258	Sep-16	21870.333	13212.925	$805.99
Oct-15	32424.265	Oct-16	21935.383	10488.882	$639.82
Nov-15	28886.104	Nov-16	20139.711	8746.393	$533.53
Dec-15	30224.039	Dec-16	20759.523	9464.516	$577.34
Jan-16	29855.579	Jan-17	19940.055	9915.524	$604.85
Feb-16	31116.847	Feb-17	20137.595	10979.252	$669.73
Mar-16	33739.007	Mar-17	22999.591	10739.416	$655.10
Apr-16	35060.207	Apr-17	23820.054	11240.153	$685.65
May-16	38863.99	May-17	23789.018	15074.972	$919.57
Jun-16	33611.845	Jun-17	24576	9035.845	$551.19
Totals	424395.147		267432.636	156962.511	$9,574.71 Total Savings 36.98 % Less kWh

Electricity consumption comparison provided by the author.

In the first few months, we started to notice a huge decline in our electricity cost.

transmitter, was implemented.

After turning on the feature, I started comparing our current invoices to past invoices. In the first few months, we started to notice a huge decline in our electricity cost. I then started a kilowatt hour consumption comparison chart and found that we had used over 35 percent less electricity than the previous year.

Upon seeing the savings, I wondered if MDCL could be added to our existing AM transmitter in Edmonton or if the transmitter would need to be replaced with one that had MDCL. I spoke to Nautel and found that there was a field modification available for our current XL60 transmitter in Edmonton.

SAVING 37 PERCENT

I showed upper management the savings we had obtained by implementing MDCL in Calgary and was approved to purchase the field modification. The field modification kit that our XL60 transmitter required cost us about $11,000, and took me about six hours to install and setup MDCL on the transmitter.

I have also started doing a kilowatt hour consumption comparison to the previous year usage for Edmonton. So far, we have been using 37 percent less electricity than the previous year.

We have noticed a negligible difference in our signal quality and coverage since running our transmitters with MDCL. We are using the Amplitude Modulation Companding (AMC) algorithm at 3 dB compression.

I highly recommend that if anyone has a transmitter with MDCL already built in, regardless of its power level, to turn MDCL on. The savings, within time, will pay for your transmitter.

Touch Canada Broadcasting Limited Partnership started with one AM station in Edmonton, Alberta in 1994. It owns and operates five radio stations in Alberta. ■

Don't Overlook the Antenna System

Gerhard Straub is director of the Broadcast Technologies Division at the U.S. Agency for Global Media, formerly called the Broadcasting Board of Governors. Its five media organizations — Voice of America, Radio Free Europe/Radio Liberty, Office of Cuba Broadcasting, Radio Free Asia and Middle East Broadcasting Networks — communicate weekly with more than 345 million people.

RW: *What can you tell us about trends in electricity costs?*
Gerhard Straub: Rarely does the power cost go down. For at least one of our sites, we generate all of our own power, so we also have to look at the cost of generator maintenance, fuel, fuel delivery, etc.

RW: *How have broadcasters saved on electricity costs at medium-wave transmission sites?*
Straub: Clearly MDCL has resulted in significant savings in electricity costs. Sometimes people want to save power by reducing power, but this is counterproductive for any AM system. AM systems need to maintain a high signal-to-noise ratio.

Often the first question people ask me about a transmission system is the transmitter power level, when really that is only one piece of the transmission system.

At most of our sites that utilize MDCL we use AMC. With AMC the carrier reduces during high modulation and increases with low level modulation. This keeps the receiver AGC captured, and the higher modulation density we maintain, the better the SNR and the more savings we see in power cost.

RW: *What gain in efficiency would drive organizations to invest money in a major revamping or to replace an existing transmitter?*
Straub: Efficiency alone is not going to drive whether an organization is going to invest in a new transmitter. MW has to compete in an ever-more-diverse media market.

Gerhard Straub

There is lots of competition for audience. In many areas, MW listenership has or is declining. To make a decision on a new transmitter, one needs to look at the audience and its media preferences, the cost to deliver content to that audience on the various platforms, how long this platform is viable and then how the ROI looks on the investment in a new transmitter.

RW: *Further thoughts on MDCL?*
Straub: We tend to focus on electrical power cost savings, but there are other savings associated with MDCL depending on which method is used. With AMC we have lower voltage and heat stresses on expensive components. This benefits not only the transmitter, but all components in the system all the way to the antenna system.

RW: *What else should we be thinking about to lower costs in medium-wave broadcasting?*
Straub: I think people often overlook the antenna system. Often the first question people ask me about a transmission system is the transmitter power level, when really that is only one piece of the transmission system. Put in a directional antenna with 3 dB of gain and you can drop your power consumption by close to half and still have the same level of signal in the target area. It is going to cost some money to put in a good antenna system, but that is a one-time cost.

Again, you need to compare the ROI against the power expense of a higher-power transmitter. It is all a balancing act. ■

Design a Cost-Effective High-Power Antenna System

By **Tom F. King**

The author is president and CEO of Kintronic Labs Inc.

In most cases when a broadcast customer contacts our company with an interest in developing a new transmission facility, their goal is to reach their target audience from a specified geographic location as cost effectively as possible. To ultimately arrive at the most cost-effective solution there are numerous factors that have to be considered as shown in the chart, at right.

Medium-wave nighttime skywave radio broadcast transmission is the most cost-effective means of reaching a large potential audience from one location. With regard to heavily urbanized densely populated cities, medium-wave groundwave propagation is a reliable means of reaching listeners in automobiles while sitting in traffic.

For most commercial broadcasters, their target audience is in relative close proximity to the transmitter site where the daytime groundwave is most important; whereas for government broadcasters that want to broadcast to distant target audiences, the nighttime skywave is the best method for their program delivery.

AM/MW Transmission Facility Design Considerations

1. Within a 24 hour period what is the desired time frame during which the broadcasts will be transmitted? Day, night or both.
2. What is the approved operating frequency?
3. What is the maximum authorized transmitter carrier power in kW?
4. Is HD hybrid or all-digital HD or single channel DRM or DRM simulcast a requirement?
5. What are the geographic coordinates of the proposed transmission facility site(s)?
6. What are the dimensions and orientation relative to true north of the proposed site(s)?
7. Are there any other AM/medium-wave stations located within a 5 km radius of the proposed site(s)?
8. What is the voltage stability history of the mains AC power available to the site(s)? What is the distance to the closest power line access?
9. What are the soil conditions at the proposed site(s)?
10. What is the annual worst case ambient temperature range at the site(s)?
11. What are the environmental conditions at the proposed site(s), i.e., earthquake potential, hurricane or typhoon potential, corrosive air potential, etc?

With regard to nighttime broadcast, one important matter to consider is the fade zone that results where either the received groundwave field intensity or the high-angle skywave field intensity is within +/-3 dB of the other. This interference between the two waveforms results in signal distortion or noise that renders the program unlistenable. The antenna system should be designed where possible and practical to yield the fade zone in an area where there are no significant listeners.

ON THE GROUND

With regard to groundwave propagation, the rate of attenuation of the propagated wave is a function of the ground conductivity in millisiemens/meter(ms/m) that can range from a value of 1 for desert sand conditions and to a value of 5,000 for salt water. If salt water separates the target area from the transmitter site it is advisable to choose a coastal site location closest to the target area to facilitate possible daytime groundwave coverage of a distant target.

An example is the island of Cyprus in the Mediterranean Sea from where the British Broadcasting Corp. (BBC) and other international government broadcasters have had medium-wave stations targeting the Middle East and North Africa for many years.

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❱ *Continued from page* **17**

Another factor that has significant impact on the groundwave propagation is the operating frequency of the transmitter. Figs. 1 and 2 show the relative loss of a groundwave versus frequency over soil with a conductivity of 5 ms/m (Fig. 1) and over salt water with a conductivity of 5,000 ms/m (Fig. 2).

Referring to these two tables, if we compare the distance over which the transmission loss at 1 MHz is 160 dB, the distance for the groundwave over soil is 400 statute miles, whereas over salt water the distance is approximately 1,200 statute miles. Referring to Fig. 1, the 160 dB transmission loss at 0.5 MHz occurs at a distance of approximately 650 statute miles whereas the loss at 1.6 MHz occurs at a distance of approximately 300 statute miles.

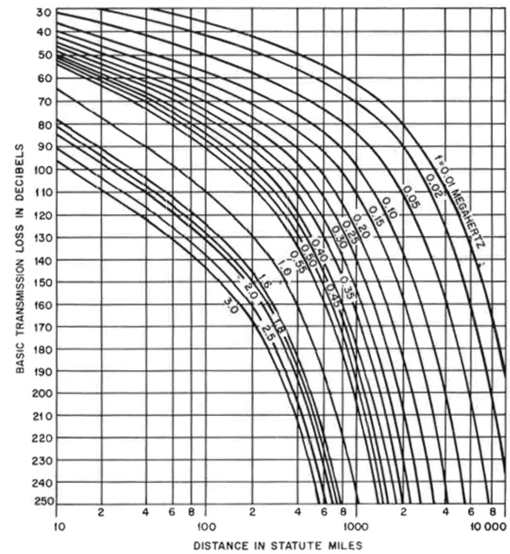

Fig. 3—Basic transmission loss expected for surface waves propagated over a smooth spherical earth. Over land: σ=0.005 mho/meter, ε=15. Lossless isotropic antennas 30 feet above the surface. Vertical polarization. Adapted from K. A. Norton, "Transmission Loss in Radio Propagation: II," National Bureau of Standards Technical Note 12, Fig. 7; June 1959.

Fig. 1: Groundwave transmission loss vs. frequency in MHz for a vertically polarized isotropic antenna 30 feet above the surface of a smooth spherical earth for a conductivity of 5 mmho/m, which is equivalent to 5 ms/m.

This illustrates the advantage to be gained by operating on a lower frequency in the band for groundwave propagation and the advantage of utilizing the salt water path where it is practical.

The one down side of operating on a lower frequency is that your physical tower height and the ground radial system, i.e., the required land area, increase inversely with the frequency in MHz. If one has some latitude in the selection of the operating frequency, this helps in optimizing the transmitter and antenna system cost to achieve the most cost effective solution.

Fig. 3 illustrates the difference in rate of attenuation of a groundwave over land versus over salt water for a quarter wave tower operating on 576 kHz with a 20 kW transmitter.

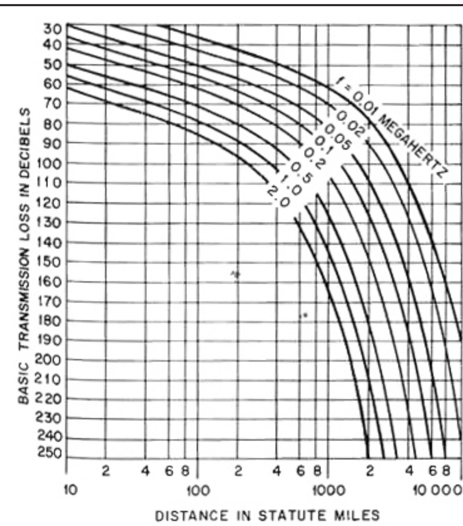

Fig. 4—Basic transmission loss expected for surface waves propagated over a smooth spherical earth. Over sea water: σ=5 mhos/meter, ε=80. Lossless isotropic antenna 30 feet above the surface. Vertical polarization. Adapted from *K. A. Norton, "Transmission Loss in Radio Propagation: II," National Bureau of Standards Technical Note 12, Fig. 8; June 1959.*

Fig. 2: Groundwave transmission loss vs. frequency in MHz for a vertically polarized isotropic antenna 30 feet above the surface of a smooth spherical earth for salt water conductivity of 5 mho/m, which is equivalent to 5,000 ms/m.

IN THE SKY

Turning to skywave versus groundwave we can assess the advantages of the longer distance propagation that can be realized by taking advantage of the AM/MW vertically polarized reflection characteristics of the E and F layers of the ionosphere following sunset. The right side of Fig. 4 shows the vertical radiation pattern unattenuated field as a function of tower electrical height at one mile for 1 kW input power.

The main thing we learn from this graph is that the vertical takeoff angle of the skywave decreases with increasing tower electrical height. The antenna efficiency is limited to 5/8 lambda (225 degrees) in which case we see the development of an undesired rear pattern high angle lobe.

The corresponding 0.5 mV/m skywave contour for the same case as the groundwave plot in Fig. 3 is shown in Fig. 5.

One can quickly see the significant increase in coverage area afforded by the nighttime skywave versus the daytime groundwave. The corresponding fade zone to which I had referred earlier is shown as the violet area in Fig. 6.

The majority of the fade zone falls over the salt water where you have no regular listeners. The size and location of the fade zone can be adjusted by changing the electrical height of the tower, which alters the skywave vertical takeoff angle.

Referring to Item 3 in the list on page 17, the skywave or groundwave electric field intensity in volts/meter is proportional to the square root of the power in kW. Therefore if the transmitter power is doubled the effective increase in field intensity is 40 percent, not 100 percent.

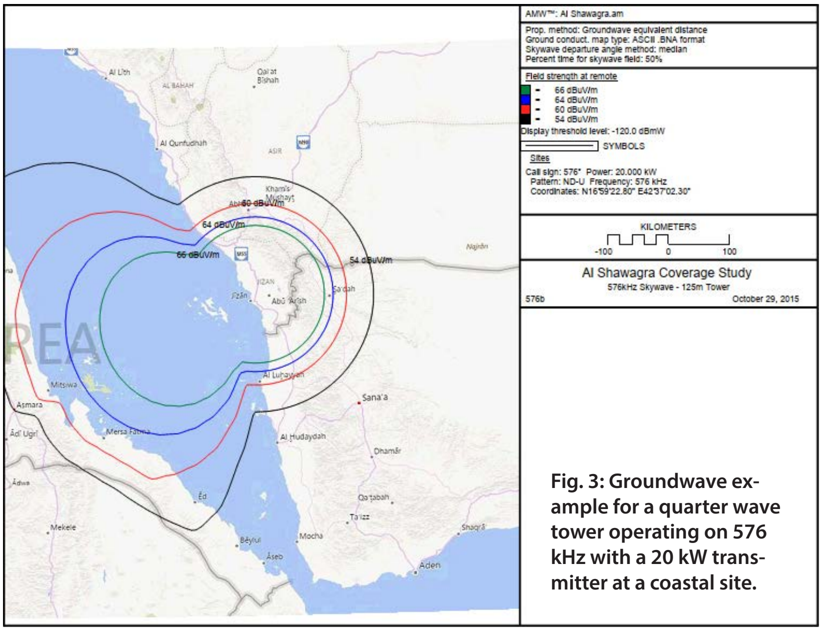

Fig. 3: Groundwave example for a quarter wave tower operating on 576 kHz with a 20 kW transmitter at a coastal site.

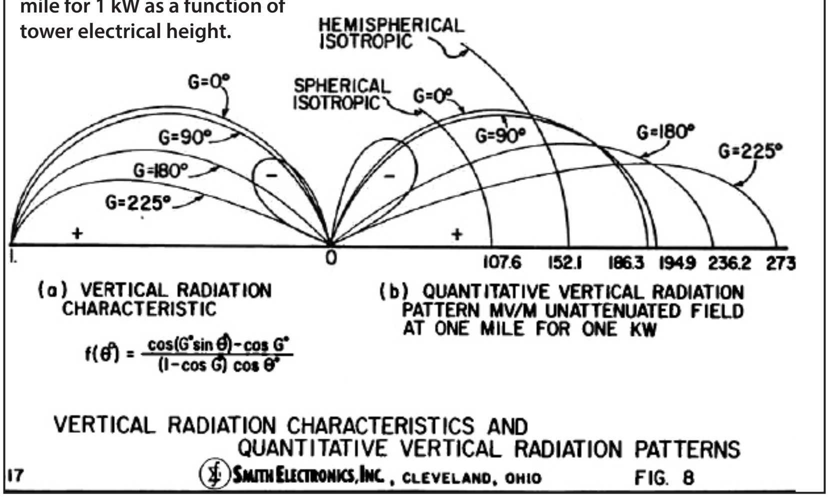

Fig. 4. Unattenuated field at one mile for 1 kW as a function of tower electrical height.

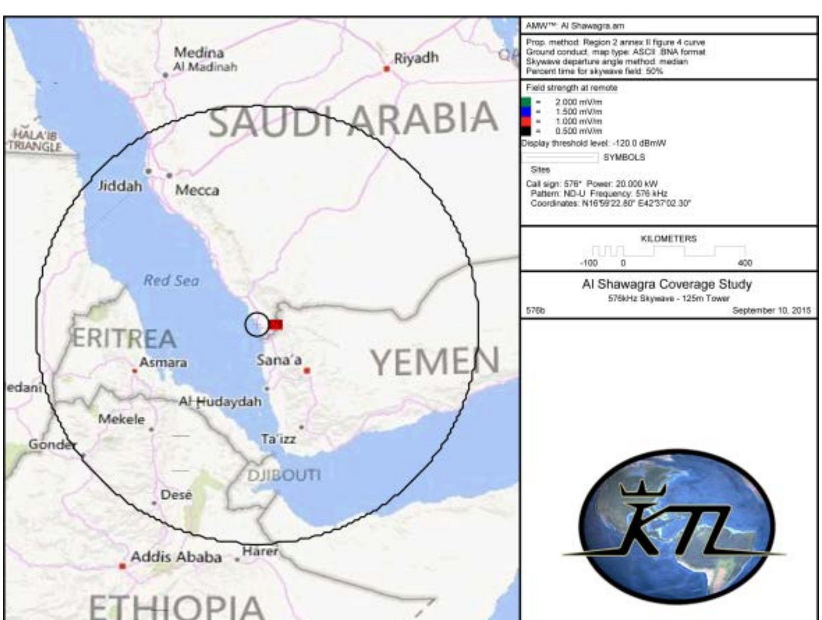

Fig. 5: Skywave* 0.5 mV/m contour for a quarter-wave mast operating on 576 kHz with a 20 kW transmitter. (*This is the average received skywave 50 percent of the time.)

MORE CONSIDERATIONS

The consequence of deciding if the antenna system will or will not be capable of digital AM/MW broadcasts impacts the complexity of the RF feeder system that is required to yield the required input bandwidth, which is typically referred to in terms of sideband VSWR specifications.

For analog operation the +/- 9 kHz sideband VSWR needs to be < 1.5:1. For HD hybrid or DRM simulcast analog/digital performance the +/- 4.5 kHz sideband VSWR should be < 1.05:1, the +/- 9 kHz sideband VSWR < 1.2:1 and the +/- 18 kHz sideband VSWR < 1.4:1. For digital operation the RF feeder system design starts at the base of the tower and includes all network and transmission line phase shifts back to the input of the harmonic filter section of the transmitter. Depending on the design the RF feeder system cost can easily increase by 30 percent or more to achieve digital performance.

If the need is to project the antenna system pattern in one or more directions to reach the target audience, a directional pattern is required. Once the pattern and the resulting tower and associated ground system geometry have been defined, the site size and orientation relative to true North needs to correlate with the orientation and configuration of the tower array.

Additional considerations in selecting a site:

- Make note of any other existing AM/MW stations that may be in operation within a 5 km radius of the site being considered.
- Avoid cellphone towers, FM or TV broadcast towers or any other metal structures that are 1/8 lambda or taller and are less than 5 km in distance from the site that could potentially impact the radiated pattern.
- Select a site where the water level is close to the surface if possible.

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- Identify the closest source of reliable, stable three-phase AC power sufficient to supply the total worst case load of the station. Will generator power be required?
- Consider the possibility of using renewable energy sources for power, including solar, wind or geothermal.
- Assure that the elevation of the site does not vary more than +/- 3m.
- Conduct a preliminary soil test to confirm compressibility of the soil.

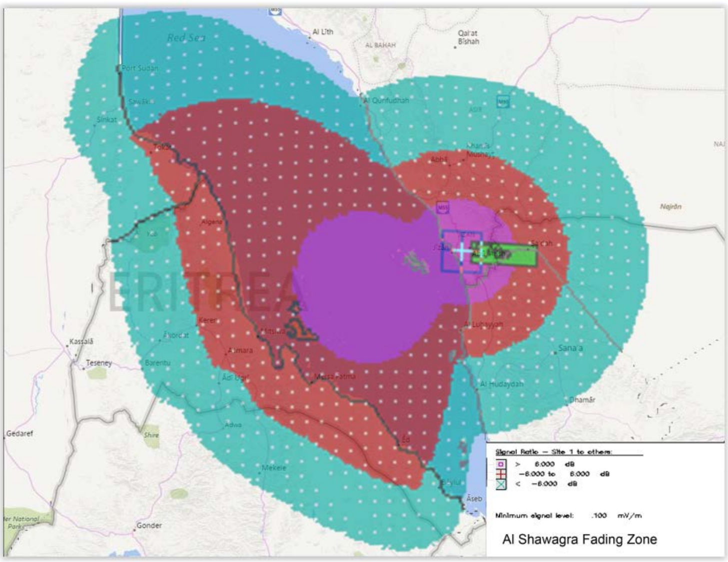

Fig. 6: The fade zone for the quarter-wave mast operating on 576 kHz with a 20 kW transmitter.

Depending on the latitude and longitude of the site, extreme cold or extreme heat can significantly impact the capital budget as well as the station operating budget. These are situations where geothermal energy may pose a larger initial expense but over the long term can significantly reduce operating costs, if a reliable source of energy is not readily available.

Last, it is important to determine if the region being considered for a new station has any known earthquake fault lines in the vicinity or is in a location prone to hurricanes or typhoons. These environmental conditions significantly impact the cost of the tower structures and should be avoided if at all possible. Also the method of feeding the tower(s), i.e. series fed, base insulated or grounded, skirt fed, can have a significant impact on the tower cost and should be evaluated.

In summary we have looked at what we would consider the most important factors ranging from operating parameters, site conditions and environmental conditions that will ultimately determine the cost of constructing a new high-power AM/MW broadcast transmission facility.

Learn about the history of Kintronic Labs at https://www.kintronic.com/about/.

RADIOWORLD INTERNATIONAL EDITION

December 2018

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