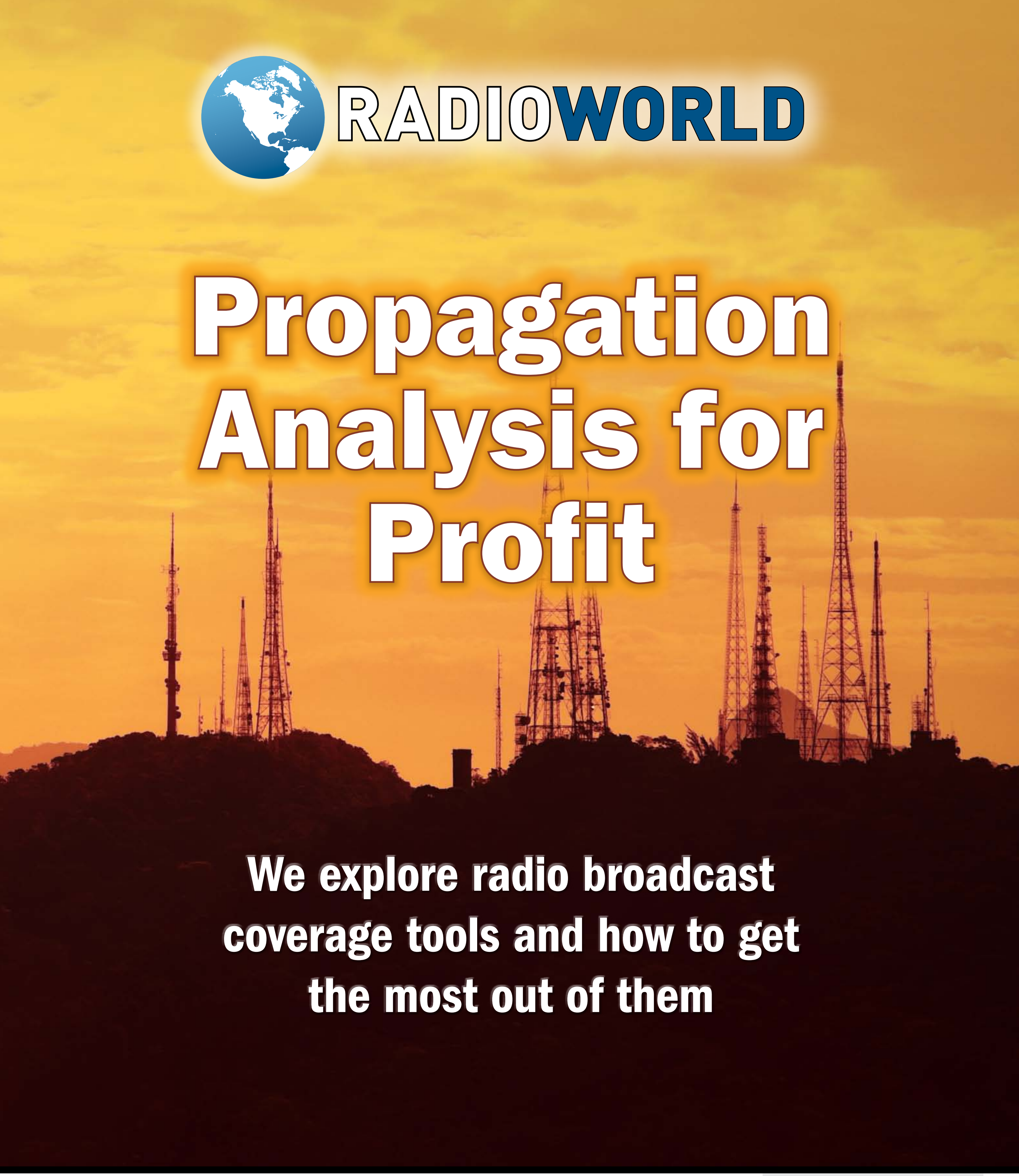


RADIOWORLD

Propagation Analysis for Profit

We explore radio broadcast coverage tools and how to get the most out of them

June 2017

From the Publishers of Radio World

NewBay

"What Would Happen If I . . ."

RF design remains a mysterious craft. How can you get the most out of your propagation?

by **Michael LeClair**

At one time or another most people in radio management and engineering have wondered, "Just what could I do with this station if I were able to afford a power increase?" The phenomenon is particularly pronounced in the world of non-commercial radio but in fact is common throughout the industry.

Many professionals learned to ask the question while working in college FM radio, where stations operate at a bewildering array of various power levels. With pride perhaps exceeding the quality of the airwaves that could ever be achieved, those college kids couldn't help but imagine the massive increases in listenership that would be possible if only their signals could reach more people.

The latest programs now can generate presentation-quality maps that are as useful in the GM or sales manager's office as in the FCC's inbox.

After I graduated from college I had the opportunity to dip my toes into the world of the FCC allocation process with the assistance of a kind gentleman named Harold Dorschug.

Harold had offered free assistance to one of my client stations in making an application to the FCC for a power increase from 70 watts to 100 watts in order to achieve the protection of a minimum Class A facility. The FCC was beginning to revoke the protections of the old Class D stations and most were being shepherded up to Class A status if it was possible to do so without causing interference.

Unfortunately, the FCC protection contours were more conservative in those days, so there simply wasn't enough room at the time for all the Class Ds to increase in power. My client station had gone about as high as it could go.

Harold was a retired CBS engineer who had worked in Master Control the night of Orson Welles' "War of the Worlds" and been a member of the first CBS television remote crew. He worked his final years at powerhouse WTIC(AM/FM) in Hartford, Conn. He was every bit the gentleman to me, a young and long-haired English major in jeans starting out as a contract engineer for all the non-commercial stations I could find in the area. I learned an enormous amount from him about how to read FCC graphs and calculate coverage and interference contours. It was my introduction to what I saw as *real* engineering. I was hooked.

In those days an application was completed with rulers and lines drawn on a map, with French curves to smooth out the intersections. Data on height above average terrain was gathered from contour maps along eight radials drawn in pencil on a geographic survey map. From the FCC rules and Harold, I learned the mathematics of protection ratios calculated in decibels and the logic of how to prevent interference.

Alas our efforts were doomed. The commission at that point in time wasn't about to accept any waivers to allow an increase in power where it might cause any interference; they already had enough complaints to deal with. And paying for a directional array to achieve higher power while protecting a nearby station was beyond the budget of my client.

We took our rejection and moved on.

THE COMPUTING REVOLUTION

Today we still ask: How would my coverage be affected if I moved my FM antenna? Changed height? Increased transmitter power? Added a fill-in translator?

Now the work I learned to do by hand is done better and more accurately by software. The first-generation programs would calculate contour interferences based on the FCC curves and spit them out as charts. The latest programs can generate presentation-quality coverage maps that are as useful in the GM or sales manager's

office as in the FCC's inbox.

Not only can we look at geographic coverage, we can with the click of a keyboard pull up highly accurate population surveys to evaluate the benefits of increasing coverage. And advanced models allow detailed views of where exactly we can expect to offer a usable signal and where it is likely to fail, based on our operating parameters and location.

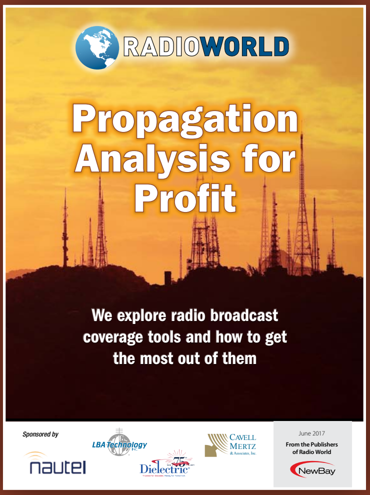
A barrier to understanding the mysteries of RF engineering over the years has been the cost of the software that provides the necessary calculations. This is why it is fun for example to highlight the coverage tool that Nautel, a sponsor of this eBook, recently developed showing a Longley-Rice map of the coverage area for any radio station. As detailed on page 12, this mapping tool is free to use and is a part of an RF Toolkit that Nautel makes available on its website; registered users can use this tool to view the coverage of any station they wish.

Since those early years when I peeked behind the veil of the FCC allocation process, I have been fortunate enough to get access to modern software tools and given the opportunity to learn how to use them. I have become fairly well acquainted with the FCC's allocation process and the engineering support required to get a successful result on more than one application. I have also had a chance to explore the subtleties of antenna designs and directional arrays, both AM and FM. While many have helped me to learn about the science of engineering radio stations, I tip my hat in particular to Doug Vernier, whom I interviewed for this eBook and who has been a great mentor and teacher.

THE MYSTERIES OF PROPAGATION

The premise of this ebook is that new software tools and data sets have changed the game when it comes to answering questions about managing propagation for profit, whether it's for an FM, an AM or a shortwave facility. As a mature medium, broadcasting is now seeing a lot fewer new stations at high power in the United States; but there are plenty of improvements to propose and, if substantial enough, to build to an operating condition. Meanwhile, new station construction in many countries is vibrant. If you are one of those people who have wondered how it all works, turn the page and read on. Enjoy!

Michael LeClair, CPBE, is a longtime contributor to Radio World and is former technical editor of Radio World Engineering Extra.



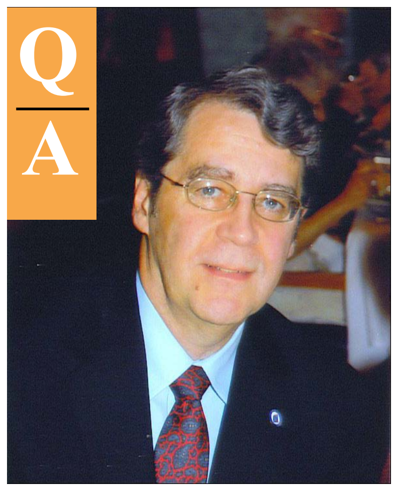
Cover image by iStockphoto/code6d

Get With the Program: A Chat With Doug Vernier

How can you maximize prediction methods and determine where your signal goes?

By **Michael LeClair**

Doug Vernier is president and owner of V-Soft Communications, a provider of RF propagation software programs that assist engineers in evaluating interference and coverage for radio and television stations, such as FM Commander, AM-Pro and Probe. We asked him about choosing software, using Longley-Rice for coverage evaluation and implementing single-frequency networks, among other topics.



Radio World: *I'm a station engineer and I would like to have the ability to do basic evaluations of station coverage areas for my management. What kinds of software should I consider purchasing? Are there other forms of access to this type of software short of outright purchase?*

Vernier: If you are willing to purchase software for this purpose, it is wise to look at software that has a proven record for prediction accuracy, gives you significant flexibility for doing what-ifs and that integrates population and interference analysis into a single user-friendly package. The software should be capable of using a wide variety of terrain databases, land-cover databases and the latest population data available from the U.S. Census Bureau and it should be able to easily produce attractive maps. If the programs of the vendor are also in daily use at the FCC, you can be sure that the answers produced will have credibility and will ensure matching FCC results.

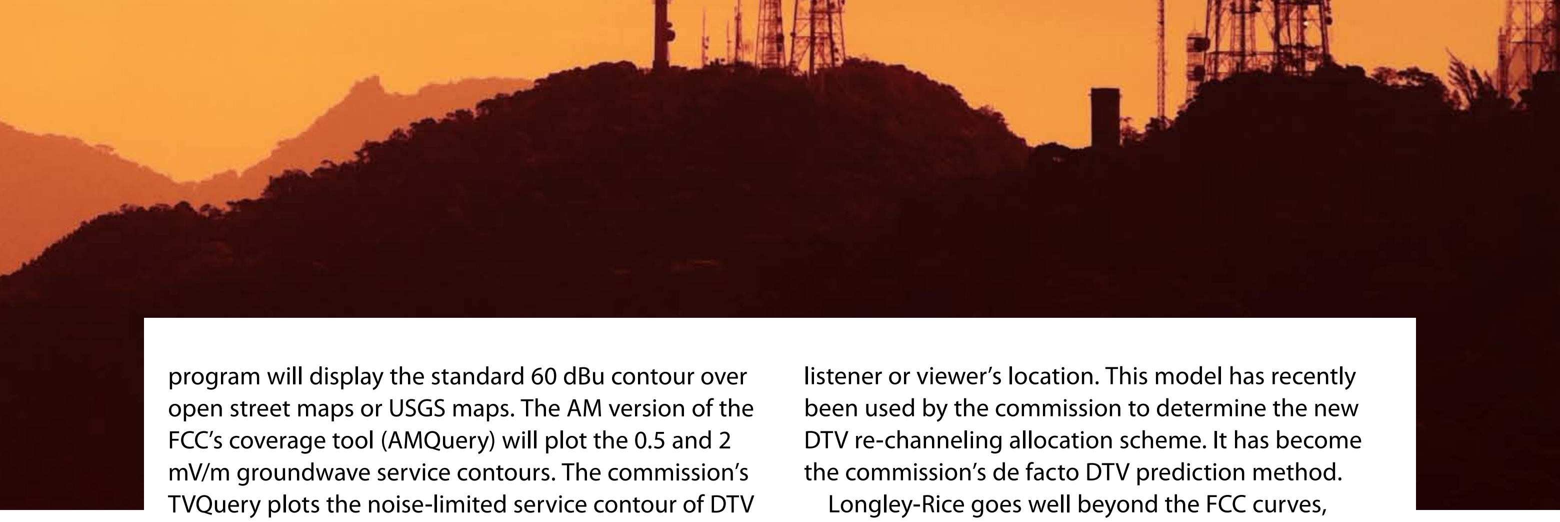
For purchased software, the user should select a vendor that provides a high level of regular support for the user. Changes in the FCC rules or in the station database contents that the program uses should be provided by the vendor. This would include regular program code updates that keep the program fully accurate as time proceeds.

RW: *Your company offers a specific program for FM and AM frequency work and one called "Probe." How do these differ?*

Vernier: The AM and FM programs are quite different due to the differences in the rules for allocating frequencies in these broadcast bands. Either of the programs can find new frequencies, upgrade station classes and produce high-quality maps. AM Pro is in regular use at the FCC to vet incoming applications from engineers and owners. Probe is a multifaceted program that allows one to use a large number of different propagation prediction routines, determine the extent of outgoing and incoming interference to both FM, FM and TV translators or booster stations as well as DTV stations and to produce atlas quality maps of coverage and interference areas, showing where population is lost or gained.

> *The FCC method is OK for general use by the FCC in an effort to predict station coverage and interference; however it tends to be overly protective in many cases.*

As far as free goes, the FCC has a few programs that will project service contours. FMQuery, the FCC's tool for acquiring data and filings for FM radio stations, is available for free on the Internet. Drilling down within this on-line program will take you to links that plot an FM facility's primary service contour to FCC accuracy. The



program will display the standard 60 dBu contour over open street maps or USGS maps. The AM version of the FCC's coverage tool (AMQuery) will plot the 0.5 and 2 mV/m groundwave service contours. The commission's TVQuery plots the noise-limited service contour of DTV TV stations over base maps.

The Radio-Locator is an online program often used by the beginner to look at existing station coverage. The program plots contour lines over area maps that represent local, distant and fringe listening. The contour values are not specifically labeled on the maps, making comparisons to FCC data a bit more difficult.

RW: *What is a Longley-Rice study and how does it compare to the FCC method of predicting coverage contours?*

Vernier: One thing to remember is that any of the prediction methods to determine where your signal goes are just that: "predictions." Nearly anyone will tell you that predictions will have some degree of error, from absolutely wrong to "pretty good."

The FCC's contour prediction method for FM broadcast stations uses actual measured signal curves and average radial antenna heights over 3 to 16 kilometer terrain. With the input of these radial heights above average terrain (usually eight evenly spaced radials) and the effective radiated power, the FCC curves will predict the coverage signal levels at a distance.

The FCC method is OK for general use by the FCC in an effort to predict station coverage and interference; however it tends to be overly protective in many cases because it does not look at terrain beyond 16 kilometers. This means that tall signal blocking hills or mountains, just beyond the 16 kilometer distance, will not be seen and a station's coverage will be projected as if the mountains didn't exist. On the other hand, if the transmitter is situated high on a mountain top with a ridge or two found below within the 16 kilometer path to a distance city that also had high elevation, the real path to the city would be line-of-sight. The interfering signal will be unaffected by terrain, resulting in under predicting the interference.

The Longley-Rice method offers many degrees of improvement over the FCC contour method, including using the terrain all the way from the transmitter to the listener or viewer's location. This model has recently been used by the commission to determine the new DTV re-channeling allocation scheme. It has become the commission's de facto DTV prediction method.

Longley-Rice goes well beyond the FCC curves, considering atmospheric absorption, including absorption by water vapor and oxygen, loss due to

The Longley-Rice method offers many degrees of improvement over the FCC contour method, including using the terrain all the way from the transmitter to the listener or viewer's location.

sky-noise temperature and attenuation caused by rain and clouds. It considers terrain roughness, knife-edge (with and without ground-reflections), loss due to isolated obstacles, diffraction, forward scatter and long-term power fading. The model's code is available freely to the public. The Longley-Rice model and our V-Soft Communications implementation of it require the following inputs for analysis based on multiple point-to-point paths:

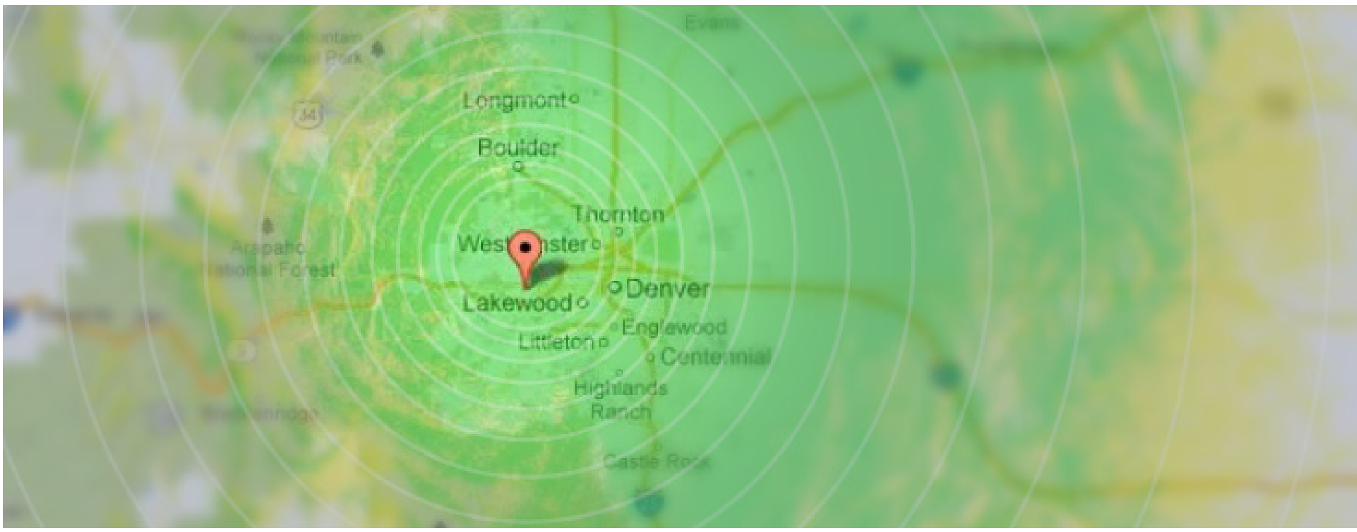
- Frequency (20–20,000 MHz)
- Transmitter antenna height (above mean sea level, meters)
- Transmitter antenna height (above ground, meters)
- Transmitter power
- Transmitter antenna pattern
- Receiver antenna height (above ground, meters)
- System antenna polarization (vertical or horizontal)
- System Ground Conductivity (mhoS/m)
- System dielectric constant (permittivity)
- System minimum monthly mean surface refractivity (adjusted to sea level.)

The Fig. 1 map on page 8 shows the V-Soft implementation of the Longley-Rice method. Note that when using Longley-Rice the color coding represents the signal strength areas as predicted by the method.

Continued on page **8**

STATION COVERAGE QUESTIONS?

nautel



Learn about a popular FREE! VHF/UHF Propagation Tool

?

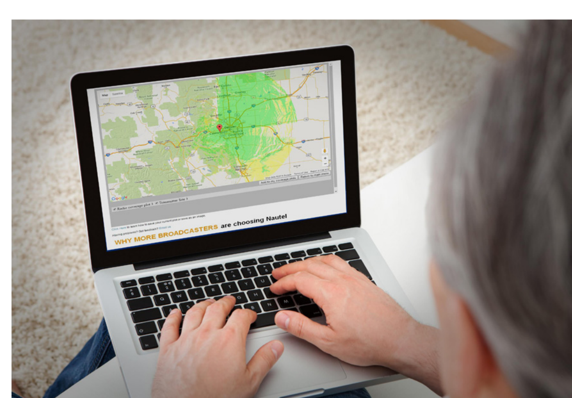
How **FAR** is your signal going to reach?
How much **POWER** for your desired radius?
What happens if you **CHANGE** antenna location, or height and gain?
How many **PEOPLE** live within your coverage area?

It's Simple, Fast and FREE!

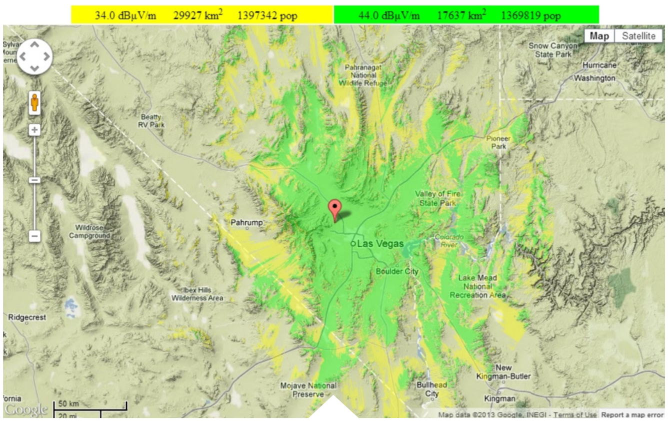
Answer these questions and more…

Online VHF/UHF Propagation Tool

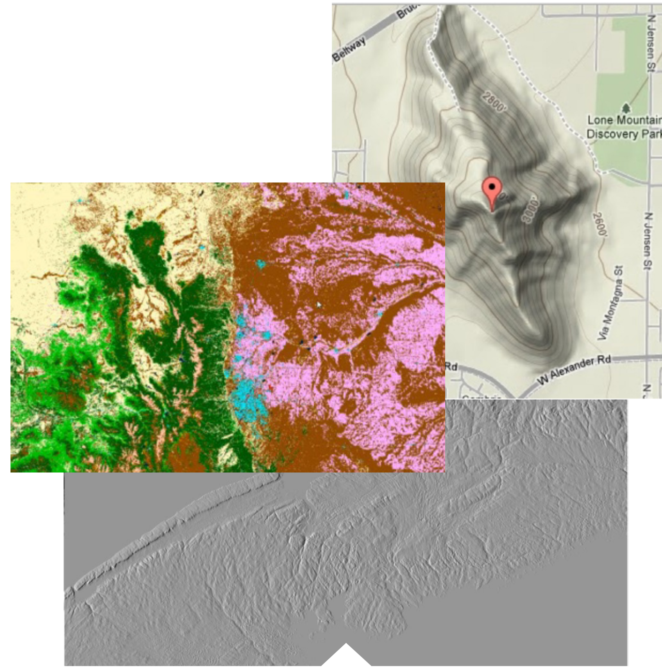
nautel.com/rf-toolkit



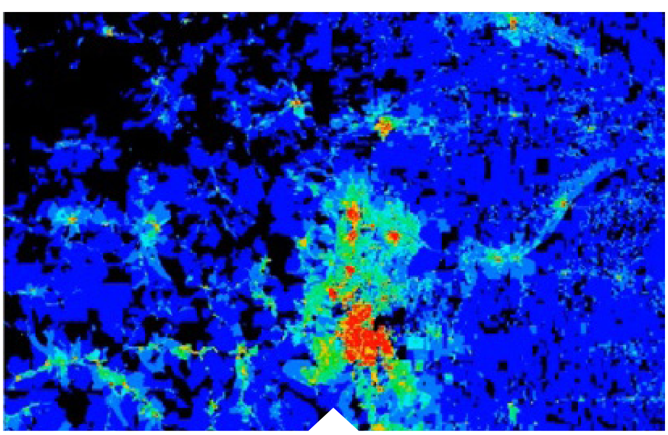
FEATURES OF THE PROPAGATION TOOL



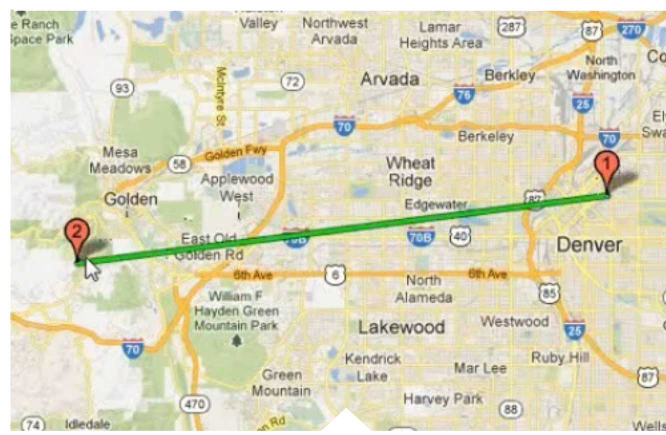
CREATE & SAVE **COVERAGE** MAPS



TEST MULTIPLE SCENARIOS



ESTIMATE POPULATION



ANALYZE POINT-TO-POINT STL LINKS

Get Started Now!

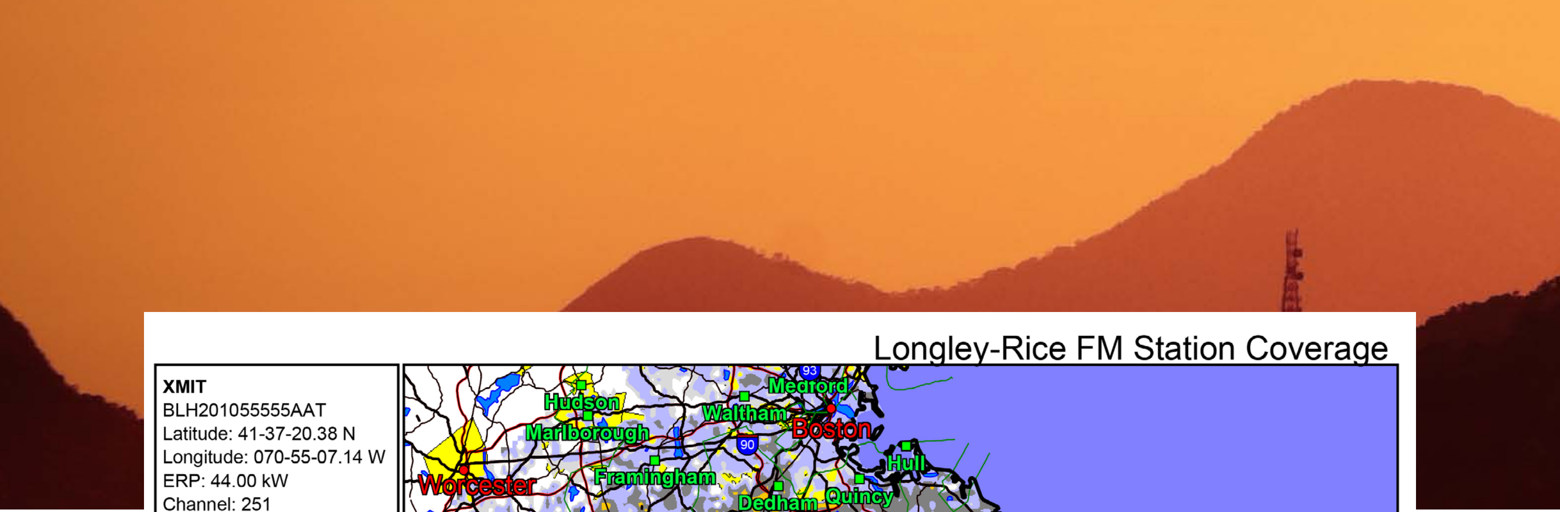
It's Simple, Fast and **FREE!**

TRY IT FOR FREE
GET STARTED IN SECONDS.

nautel.com/rf-toolkit

making digital broadcasting **work**

nautel



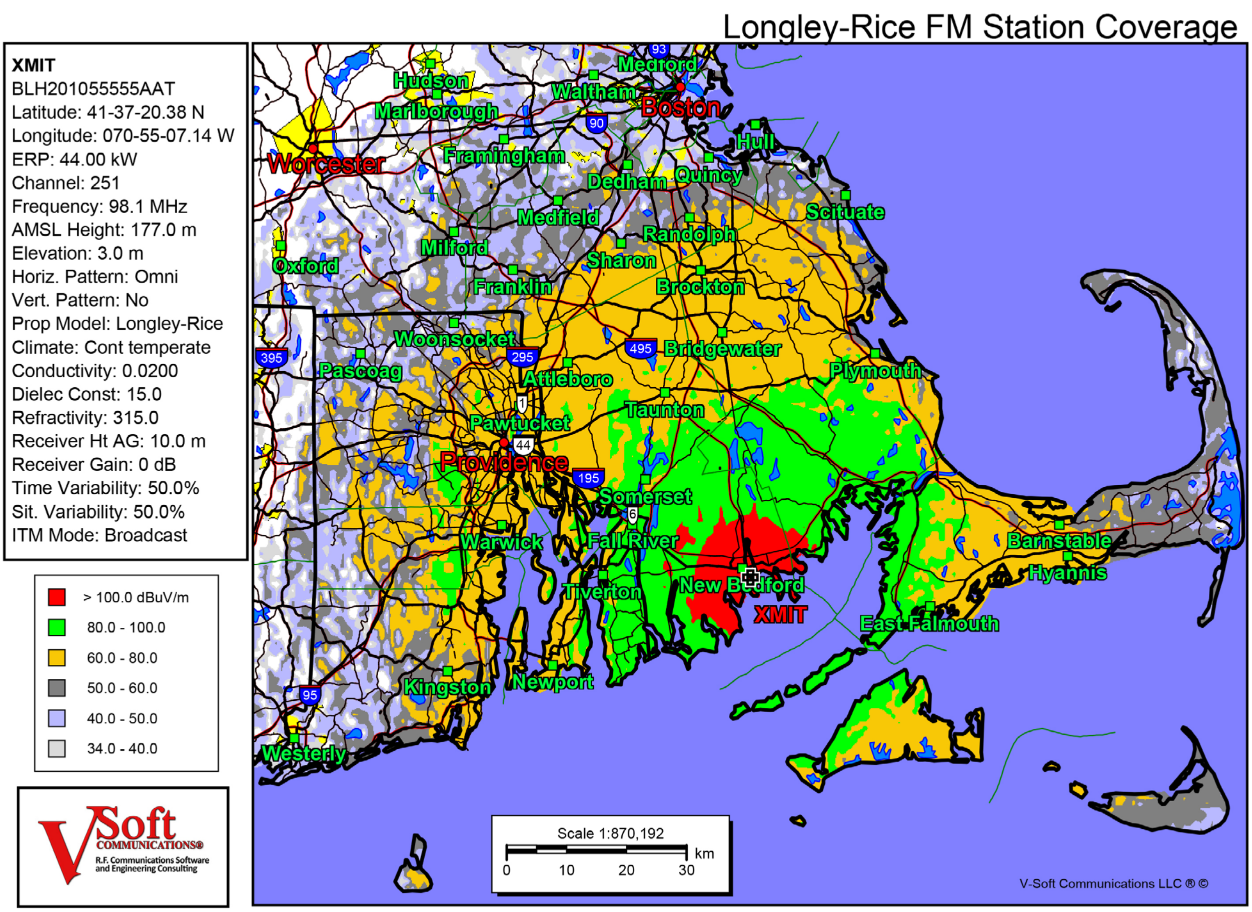


Fig. 1: V-Soft implementation of the Longley-Rice method.

❱ *Continued from page* **5**

The reader will notice that the effect of signal by terrain is shown clearly where the terrain drops off along rivers and lakes.

There are other models than Longley-Rice that predict coverage. Some are better than others. However, actual proof of that rests in comparing the model's prediction with actual measurements. For many reasons, this is difficult to do accurately. All models use the attenuation provided by urban clutter. Some simply subtract a fixed amount of signal along the entire path, while others use land cover attenuation that is defined by latitude and longitude coordinates. Still other models, such as Okumura, use the height above average terrain to calculate path loss but do not consider terrain obstacles. The Okumura method was developed for highly populated areas where two story buildings predominate, such as in Japan. Its algorithms have been improved along the way by Hata and Davidson, thus we also have Okumura/Hata and Okumura Hata Davidson.

Many users, such as the U.S. Army and Navy, prefer the Terrain Integrated Rough Earth Model (TIREM) that is known to do better than Longley-Rice over large bodies of water. TIREM was developed using data from Technote 101, a two-volume treatise published by National Bureau of Standards that also is the base for Longley-Rice. The model was developed originally at university level and later sold to Allion Science and Technology Corp. of Annapolis, Md. Allion made the code proprietary which places a damper on its wide use by the FCC and others since there is no way to know how precisely it's predictions are made.

The ITU method is used widely in Central and South America. It uses a set of propagation curves that are based on measurement data mainly relating mean climatic conditions in temperate climates. The model considers the transmitter height above average terrain, the receive antenna height, and incorporates a correction for terrain clearance angle when making field strength predictions.

The Point-to-Point or PTP method was developed by Harry Wong of the FCC's Office of Engineering and Technology. Its processes are based on radio diffraction and attenuation to the free space path caused by irregular terrain entering the Fresnel zone. Although published in the FCC rules as a method of considering terrain roughness, the method was not adopted by the Mass Media Bureau.

The propagation methods described above are not, by far, the entire list of those used to determine where signals go; however they are considered the ones in popular use. Currently, the FCC accepts the Longley-Method for the majority of alternative showings it receives.

RW: *What is knife-edge diffraction and how does it affect coverage?*

Vernier: "Knife edging" is when the radio wave diffracts, or bends, as it passes over the sharp edge of an obstacle that lies across the wave's direction of movement. Part of the signal is cut off by the terrain edge, and the other half is diffracted downward. Knife-edge diffraction can be helpful in serving areas that would normally not be able to receive reception due to the large terrain blockage. It is important to note that the shape of the diffracting terrain is important to the amount of diffraction produced by the obstacle. There are areas nestled in the mountains where the only reception available is through knife-edge diffraction.

RW: *What is the best method to make field measurements of FM coverage areas?*

Vernier: There are numerous considerations to make when taking actual measurements. Often the engineer taking measurements can fall into the trap of doing everything right except one thing that seriously impacts the accuracy. A short list of things that cause inaccuracies:

A. Failure to use a calibrated reference antenna and failure to apply those correction factors to the field strength of the frequency being measured.

B. Failure to use an omnidirectional antenna. (Antennas mounted to a car for a drive test will be directional, so turns by the car will affect signal strength.) In one NPR Labs study, engineers installed a circular ground plane to go atop the car under the vertical whip antenna that helped circularize the antennas pattern; however the engineers found that the car was still somewhat directional.

C. Failure to recognize the impact of the vertical elevation field

D. Failure to place the receive antenna above blocking terrain obstacles. (This is impossible if the transmitter is city-bound.)

Engineers have taken to a costly project of measuring an antenna's pattern by using an airplane or helicopter to "fly the tower" with a calibrated antenna. One of the issues they have run into is maintaining exact distances and elevation along the circle route. Lately engineers have begun to experiment with drones to replace the costly airplane/helicopter method. However, while less costly, such measurements have most of the same issues.

RW: *HD Radio is becoming available to more listeners every year due to new car sales. For a station wishing to provide good coverage for a supplemental HD2 channel, what would you recommend in terms of system design and injection levels?*

Vernier: Most new HD transmitters being installed today will use low-level injection of the HD carriers. High-level injection, once in common use, is no longer wanted, because high-level combining wastes energy, increasing the cost of running the transmitter.

In general terms the quality of the HD2 signal depends on the overall signal strength of the analog portion of the signal and the amount of injection of the HD signal. Dropouts occur with IBOC transmissions when the signal level drops due to terrain blockage, and in some cases interference from other stations.

Continued on page **10** ›

❱ Continued from page 9

It is unfortunate that when listeners to HD2 or other multicast channels lose signal the radio has no backup, such as in the case of HD1, and it simply goes to silence. When the FCC gave stations permission to use IBOC, initially stations went to an injection level of –20 decibels over carrier level, which is 1 percent of the licensed power. Stations uniformly found that the HD injection level covered a smaller area than the analog coverage. When the FCC allowed –14 dBc injection, many stations found that the match was almost the same as the analog coverage. In cases when a special showing of no interference to other stations is presented to the FCC, stations are allowed –10 dBc injection. Many of these stations report that their HD2 signal goes as far, or further, than the analog.

When the FCC allowed –14 dBc injection, many stations found that the match was almost the same as the analog coverage.

RW: *Is it possible to use same-frequency boosters to improve the coverage of a station that might be terrain-blocked for part of its licensed coverage area?*

Vernier: Yes, absolutely. However, misplaced boosters can also be more destructive to a given station's signal. In the case of a booster that is placed to overcome a large terrain obstacle that totally blocks the signal between the booster and its primary station, the booster can be installed so it compensates effectively for the loss of listeners. However, in the situation where the terrain blockage interrupts the signal over only a part of a station's signal area, and a booster is installed that covers both the terrain blocked area and the unblocked area, serious interference can result in the unblocked area. To the listener, the interference manifests itself as garbled audio or picket fencing.

Due to the time the signal travels from the primary station to a given listener and the time it takes for the signal to travel from the booster to the listener, the phase of each signal will not be identical. While the process of synchronizing by delaying the booster signal can correct the interference at the listener's location, other areas that are off-angle of the direct line to the listener will not have synchronization. If those areas that are out of sync are unpopulated and the populated areas where synchronization can be accomplished are targeted by the boosters, coverage to important terrain blocked areas can be achieved.

Installing a booster in an essentially flat area can be challenging because there will always be areas where synchronization cannot be achieved. It is said that more boosters have been installed and then promptly turned off than those that are licensed and operating due to the interference and synchronizing issues.

There are several computer programs available to the cellular community that deal with this issue, however not many for use by the broadcaster. The only program I am aware of is the V-Soft Communications' booster module packaged that is an option with the Probe 4 propagation analysis program. This program will allow the user to adjust the booster or the primary station's timing delay, threshold for interference in dB, maximum allowed timing delay for interference reception, and the front-to-back ratio for the receiving antenna. Based on the inputs, the program will graphically plot the areas where interference is predicted to occur. ■

Nautel's "What If" RF Tool Kit Explores Scenarios

The free tool is a place to start for those interested in certain common questions

By **Paul McLane**

Nautel offers the RF Tool Kit coverage tool for broadcasters interested in FM and STL scenarios. We asked our eBook sponsor how the tool came about and what kind of insights it has received.

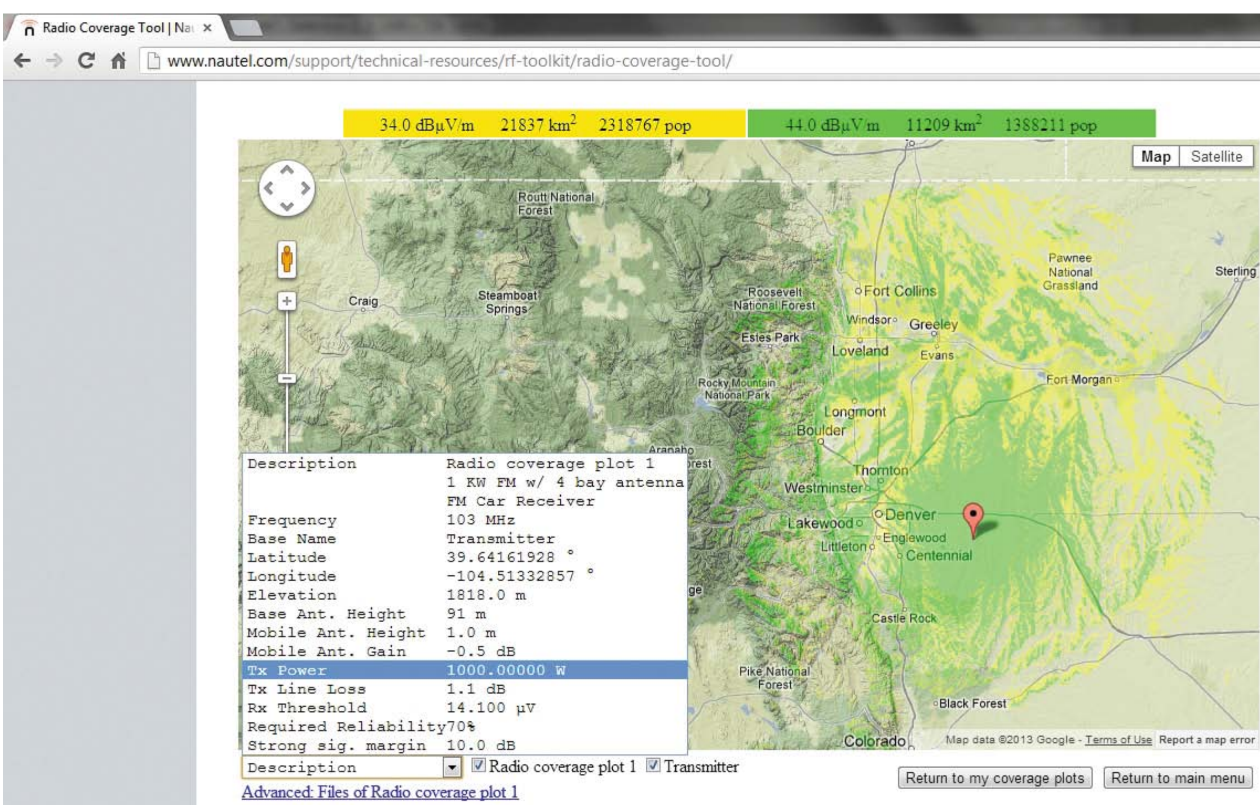
Chuck Kelly said broadcast owners and engineers frequently want to know, "If I were to make this change — an increase of power, or a change in location, or a change in the tower height — what kind of coverage would I expect?" The owner may not yet be ready to buy a facility or file an application with a regulatory body but still needs reliable ballpark information.

He said Nautel wanted to offer a simple tool so that non- or semi-technical people could sit down and play with scenarios and produce a map that shows the approximate extent of predicted coverage.

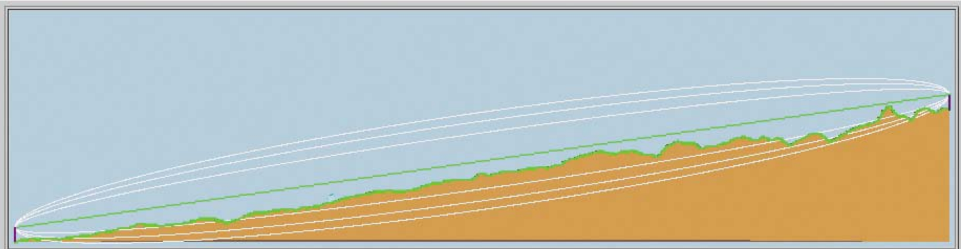
The company had learned about software called Radio Mobile, designed and made publicly available by Canadian RF engineer Roger Coudé (who is also an amateur radio operator, VE2DBE).

"You could go online and download the SRTM data and make it all work," Kelly said of the free Radio Mobile software; but the process wasn't simple.

"So we went to Roger and said, 'Hey, would you be interested in hosting a server where all the data for the



The tool uses Longley-Rice modeling and satellite terrain mapping data to provide coverage maps.



Studio to Transmitter			
Studio (1)			(2) Transmitter
Latitude	39.787928 °	Latitude	39.641619 °
Longitude	-104.481743 °	Longitude	-104.513329 °
Ground elevation	1649.0 m	Ground elevation	1818.0 m
Antenna height	20.0 m	Antenna height	20.0 m
Azimuth	189.44 °	Azimuth	9.42 °
Tilt	0.51 °	Tilt	-0.66 °
Radio system			**Propagation**
TX power	40.00 dBm	Free space loss	116.36 dB
TX line loss	2.00 dB	Obstuction loss	2.52 dB
TX antenna gain	18.90 dBi	Forest loss	1.00 dB
RX antenna gain	18.90 dBi	Urban loss	1.00 dB
RX line loss	2.00 dB	Statistical loss	6.25 dB
RX sensitivity	-74.96 dBm	Total path loss	127.13 dB

The system can also be used to make an STL path analysis.

world would be located, and people could log on and we would intentionally simplify the software so as to minimize the possibility of confusion and getting the wrong results?"

As a result, Kelly says, Nautel's Radio Coverage Tool allows a user to start creating predictive contour maps and point-to-point STL/RPU paths within a few minutes.

The tool is based on the Longley-Rice VHF/UHF "ITS" model and includes digitized worldwide terrain database of nearly 1 Terabyte built on NASA Shuttle Radar Terrain Mapping data and other sources. Its accuracy for the 48 contiguous states is approximately 10 meters, and in the rest of the world it is 30 meters.

"We carried it a step further and added the ability to know not only where the contours are but also the number of square kilometers and estimated population within that area," Kelly said. Land cover information — for instance, whether a spot is tree-covered or urban — can help improve accuracy of the propagation model. Estimated population served is based on publicly available United Nations data.

Kelly calls the result a "what if" tool. "You can take a look at the coverage area for a particular contour, particular signal strength, and you can say, 'Okay. What happens if I raise the antenna 20 feet?' Or 'What happens if I add double the transmitter power?' Or maybe this is for a new station — particularly in the developing world. 'What kind of coverage could I get if I was on this building, or on mountain over here? How tall should my tower be?'"

He considers the tool very capable. "You can take screen shots of the map. You can download the KML files and the graphics that overlay those. There's a ton of flexibility. And if you get to the point where want more — the ability to do directionality or SFN prediction — you can always download Radio Mobile, and now you've got an *incredibly* capable tool, and yet still free."

The goal of all this, he said, is to provide basic information, to get "in the ballpark." Kelly states firmly that before stations make commitments to buy equipment or file for a license, they should enlist the services of a qualified consultant.

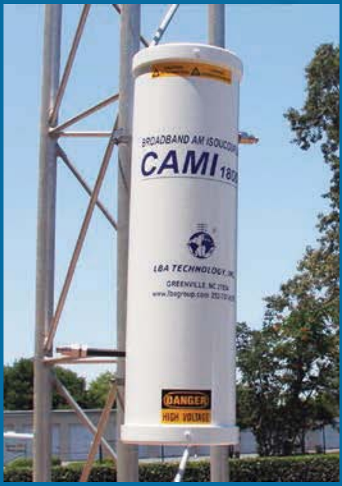
The Nautel Radio Coverage Tool is available for free at the company's website, as is a detailed webinar exploring its capabilities. Power users interested in the advanced Radio Mobile freeware by Roger Coudé can find it here. ■

LBA Technology INC.

AM COLOCATION & DETUNING

Locating an FM/TV on an AM Tower Just Got Easier

LBA Technology's award winning CAMI™ AM tower broadband isocoupler is now available in five different models to accommodate a wide range of applications for the broadcast industry. The expanded CAMI™ line means there is an economical isocoupler for nearly any single coaxial line installation on an AM tower. It is ideal for applications such as microwave and STL links, TV/FM translators, low power TV/FM, and even for high power TV/FM colocations.



Leaders in Antenna Systems

Antenna Tuning Units

High Power MW

Shortwave Antenna Systems

Diplexers & Triplexers

For more information contact: Domestic Consultant - Jerry Brown at jerry.brown@lbagroup.com
International Consultant - Javier Castillo at jcastillo@lbagroup.com

3400 Tupper Dr. | Greenville, NC | (252) 757-0279

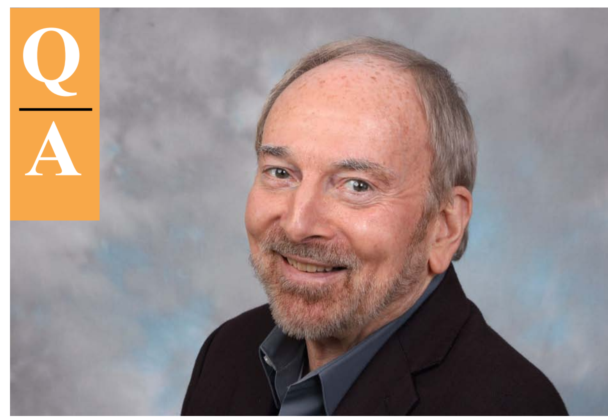
Beyond Contour Maps: A Chat With Clarence Beverage

Insights into some key terms and concepts used in characterizing signals

By **Michael LeClair**

When it comes to radio engineering and propagation, everyone has questions. Station owners wonder whether simple improvements can be made to reach that critical audience to drive sales. Prospective owners want to know if their business plan to serve a particular audience has a chance of success. Even experienced radio engineers know that radio wave propagation and the art of successful broadcast engineering involve a complex mix of science, experience and sometimes even intuition.

Clarence Beverage of Communications Technologies Inc. of Marlton, N.J., talked with us about a range of relevant issues, from how to evaluate a possible station acquisition to an explanation of how FM broadcast signals are characterized statistically.



Clarence Beverage

Radio World: *For years we have seen radio station brokers include coverage maps with descriptions of available properties, often using the FCC licensed 60 dBu or 40 dBu contour. Is this a good way to estimate the actual coverage of an FM radio station? How about the 2 mV contour for AM stations?*

Beverage: This is an excellent question and opens the door to discuss some very important reasons why brokers, owners, managers and anyone else in the industry who need to understand a station's coverage area should not rely on contour maps alone.

First FM contour maps. The first reason is that the FCC itself, in FCC Rule 73.311, says that field strength contours are to be used "for the following purposes only …" Those purposes include in an application for construction permit, to assist in selecting a transmitter site and city of license coverage determination, and in the protection of other stations based on contour clearance.

What this section is really saying is that the contour methodology was developed as a simplified method for the FCC to use in the process of regulating the industry and not to be used for determining real-world coverage. It is also helpful to remember that the contour method used today relies on propagation curves and plotting techniques developed in the FCC in the 1960s when calculations were done by engineers with slide rules, terrain data taken from topographical maps and contours plotted by hand using only eight radials and terrain is considered out to only 10 miles.

You mention 60 dBu coverage contour maps. This is the protected contour for several classes of FM station and would seem like a good method of comparing facilities in a market on its face. However, many brokers circulate maps that show contours of different values out to 40 and even 34 dBu in some cases. The Radio-Locator maps have become very popular, but the contour values shown on those maps are not indicated on the map itself. From the website we know that the values are 60, 50 and 40 dBu. The varying contour values shown on maps can be very confusing.

We always caution people about contour maps and suggest driving the signal, a field strength measurement program or properly done Longley-Rice maps as better ways to define the listenable signal area. Please note that we have not yet talked about how interference affects the listenable area and is not typically shown on coverage maps.

Regarding AM coverage maps: The 2 mV/m is considered by the FCC as the lowest signal level necessary to provide service in communities of 2,500 persons or more. The reality is that in urban areas, manmade noise may mask a 2 mV/m signal, and a higher signal level is neces-

sary for good reception. Also note that AM coverage maps are often created using the FCC M3 conductivity map. In many areas of the country, this significantly overstates the size of the contour.

Another variable that can significantly impact real-world AM coverage is summer-to-winter conductivity changes. I live and work in the New Jersey suburbs of Philadelphia. There are areas where I can hear a 5 kW AM on the low end of the dial and a 50 kW in the center of the dial perfectly in winter, but as temperatures warm up in May the signals become intermittent and in August are unlistenable in some locations.

RW: *If I'm interested in the actual coverage of a potential license, what is the most important analysis to discuss with my consultant? What tools model coverage accurately?*

Beverage: Station evaluation is a complex process if done properly. Consider the process to operate like a team of detectives, each with specialties.

The attorney will do the FCC due diligence and also should review lease documents and titles to owned property. The attorney(s) will look at environmental compliance as well. Often we find clients saying that they want to buy a station but the land is going to be sold; where can I move the station? Needless to say this can be particularly difficult with AM directional facilities due to the property requirements.

Generally the buyer doesn't have a whole lot of money and the seller is getting rid of the license at a reduced price, which is what attracts the buyer. Many times the deal can't be made because the buyer can't afford to implement a new transmission plant, especially when it involves new property, due to the added delays, environmental costs, costs to obtain local approvals and construction costs. A suitable tower site lease, if available, can often become the best and only

Fig. 1: Tools of the trade — typical equipment setup for mobile FM field strength measurements in the cab of a truck.

Continued on page **18**

❱ *Continued from page* **17**

practical solution.

Now to the engineering portion of the team. You need a good hands-on field person with a lot of station experience to go through the physical plant to find any problems and do the FCC compliance report using the FCC check list for the particular type of station. This person should drive the signal and report on the results. If the station is an FM, driving the market and recording the signal level of the FM being purchased and other FM signals that are competitors or highly rated will be valuable. This should tell you if the station is in good technical condition and can be expected to perform as predicted.

This brings us to the consulting engineer. That person should be thorough and experienced. If the station is an AM, they can do coverage maps based on measured soil conductivity to give a more accurate contour size and population. If the station is in an urban area they will caution about noise and how that impacts the signal. If the station is an FM, the measured signal level will be compared to Longley-Rice predictions. If the measured and Longley-Rice don't line up, this may indicate an antenna problem. Other stations in the market can be measured by the field engineer and given a Longley-Rice evaluation by the consulting engineer to provide independent collaboration of the differences between measured and predicted.

Longley-Rice signal level models that predict signal level, say 5 feet above ground for auto listening, are a wonderful tool if used with caution. Some type of land use attenuation should be added so that the computed signal is as close as possible to real-world. It does need to be recognized that the computer program providing the calculated signal level may not know where obstructions to the signal are located, such as heavy foliage or the locations of tall buildings in urban areas.

RW: *The NCE reserved band is well known for having a large number of stations with power levels that don't correspond to the class maximums. In contrast, commercial licenses tend to operate mostly at maximum class value, e.g. 6 kW at 100 meters for a Class A station.*

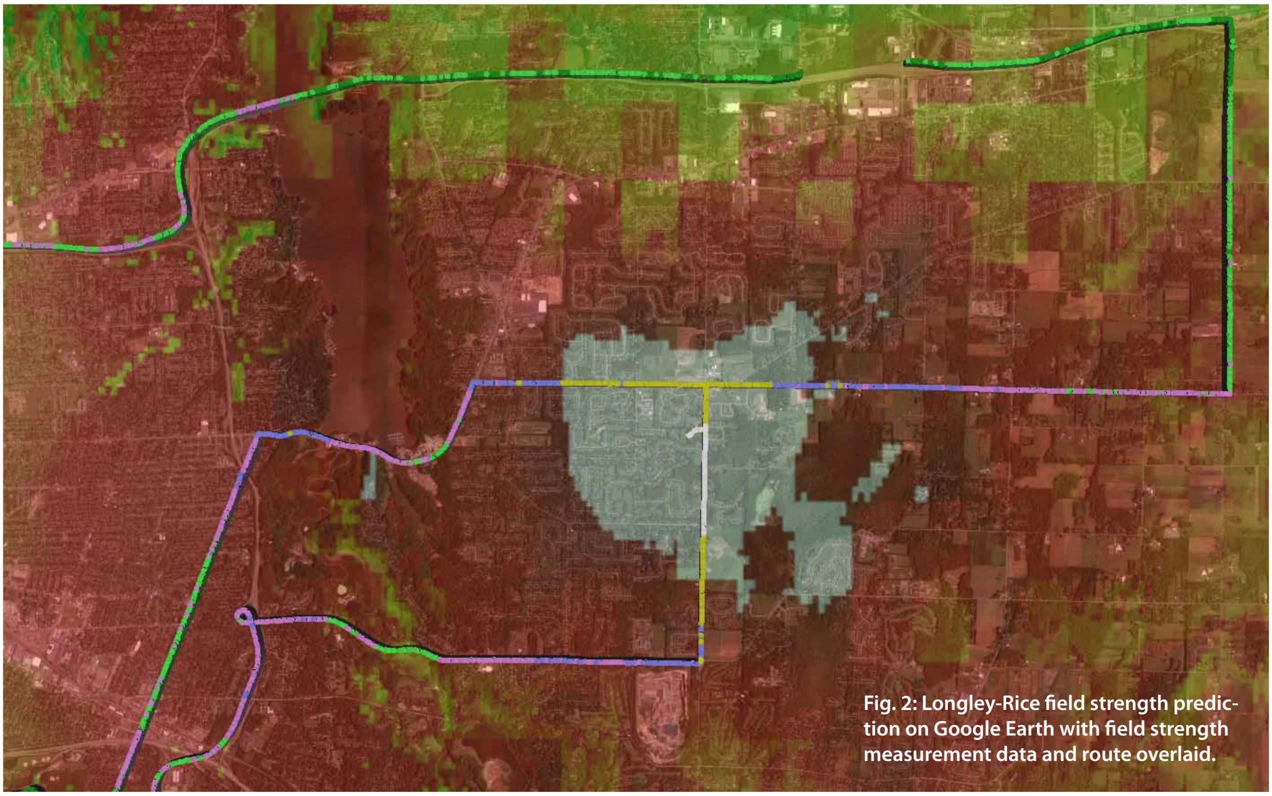
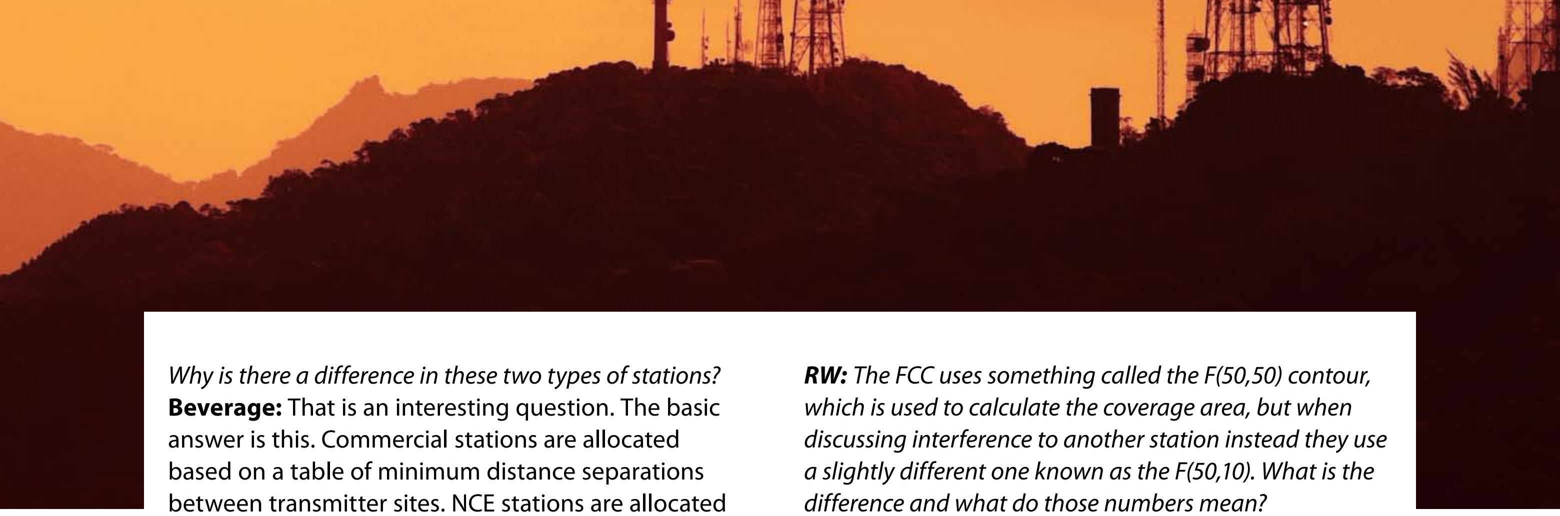


Fig. 2: Longley-Rice field strength prediction on Google Earth with field strength measurement data and route overlaid.



Why is there a difference in these two types of stations?
Beverage: That is an interesting question. The basic answer is this. Commercial stations are allocated based on a table of minimum distance separations between transmitter sites. NCE stations are allocated based only on the fact that the designing engineer was asked if a new NCE station could be designed to serve a particular area or community, and the engineer was able to find a location, frequency and antenna pattern that fit in between the existing stations. This is one reason why often you can listen to a commercial station for a greater distance than a non-commercial. Because the allocation of commercial stations is based on full ERP and HAAT for the station class, 50 kilowatts at 150 meter HAAT for Class B and C2 as an example, and the transmitter sites are fully spaced, facilities like this generally enjoy more protection and have a greater listening radius.

The contour methodology was developed as a simplified method for the FCC to use in the process of regulating the industry and not to be used for determining real-world coverage.

How a station being considered for purchase is allocated is important for an owner to know. I say that because the FCC developed section 73.215 of the rules to allow commercial stations to operate at lesser distance separations and to employ contour clearance, which can take away some of the advantage just explained above.

But there are other factors. At the beginning stages of the development of the commercial FM band, station separation was based on interference, which is why you see situations like WCBS on 101.1 MHz in New York City and WBEB in Philadelphia on 101.1 MHz 130 kilometers apart; but 73.207 says that the required minimum distance separation is 241 kilometers site to site for two Class B stations. Clearly, grandfathered stations like these cannot enjoy the full wide-area coverage that stations that are fully spaced enjoy.

***RW:** The FCC uses something called the F(50,50) contour, which is used to calculate the coverage area, but when discussing interference to another station instead they use a slightly different one known as the F(50,10). What is the difference and what do those numbers mean?*
Beverage: Many broadcasters tend to think of FM and TV signals as being constant, which is not accurate. FM and TV signals operate in what we call the VHF and UHF frequency bands. Signal strengths in this frequency range are impacted by weather, atmospheric effects and sunspots.

The propagation curves that are used to predict signal levels rely on three statistical categories.

The first, *Time Variability,* accounts for variations of hourly median values of signal attenuation due to, for example, changes in atmospheric refraction or turbulence. The computed hourly field strength is an hourly value. The actual field strength at the receiver location would be expected to be above that value during half of the time and below half of the time. Time variability is expressed as a percentage from 0.1 percent to 99.9 percent, and gives the fraction of time during which actual received field strength is expected to be equal to or greater than that computed by the program.

Location Variability accounts for variations in long-term statistics that occur over the path from transmitter to receiver. The variability is related to differences in terrain profiles from the site to each receive location or environmental differences between the paths such as over water, a forest, a field, suburban housing or urban setting. The location variability for the calculation is also expressed as a percentage from 0.1 percent to 99.9 percent. This value gives the percentage of locations where actual received field strength is expected to be equal to or higher than the median field selected in the program by the user.

Situation Variability accounts for variations between systems with the same system parameters and environmental conditions, including differences in the ability of individuals to accurately take field strength readings. This is the place where unconsidered variables enter, variables whose effects we do not understand or which we simply have not chosen to control or consider. The values could include a measured transmitting antenna radiation pattern — many times, Longley-Rice signal level predictions consider omnidirectional FM

Continued on page **20**

Continued from page 19

stations to have a true omni pattern, which is rarely true. If you have ever done mobile FM field strength measurements you have probably wondered, "How did that big metal tractor trailer impact the signal level as I passed by?" The effects of differences like these clearly change the statistics. Situation variability describes the effects of the changing conditions. The situation variability for the calculation is, as you might have guessed by now, between 0.1 percent to 99.9 percent. This value gives the percentage of paths on which actual received field strength is expected to be equal to or higher than the field computed by the program.

The most important consideration is that for a given radiated power, the signal goes a greater distance as the antenna is raised above the ground.

Entering higher percentages of time, location and reliability values effectively reduces the variability resulting from these factors. The resulting field strength predicted by the program will be lower, but with increased reliability that the actual field that could be measured would equal or exceed the computed value at any given time. Typically for coverage all variabilities are set to 50 percent and for interference time is set to 10 percent because we want to limit the amount of time that interference will occur.

The FCC uses location and time variability only. The F(50,50) curves are used to determine coverage based on 50 percent of the locations and 50 percent of the time. The F(50,10) are used to predict interfering contours for 50 percent of the locations and 10 percent of the time.

The FCC uses the 50 percent of the time values to predict coverage because it puts the signal level right in the middle of the variable. The 10 percent of the time variable is used to account for the fact that for a given radiated power and contour value the interfering contour will go a greater distance and using F(50,10) for interfering signals provides the needed separation to prevent interference under typical conditions.

Let's think for a minute about real-world signal levels and apply the math. I can't tell you how many times we have gotten calls, especially toward summertime, from a new broadcaster saying "Something has happened to our signal, our station is gone and now all I hear is W--- three hundred miles away!" When we explain this is atmospheric ducting that occurs during certain times of the year, it can't prevented and it is a statistical likelihood, maybe 1 percent each year, the statistics start to make sense. Broadcasters in Los Angeles, San Diego, the Gulf of Mexico and along the northeast coastline typically are more likely to experience these problems.

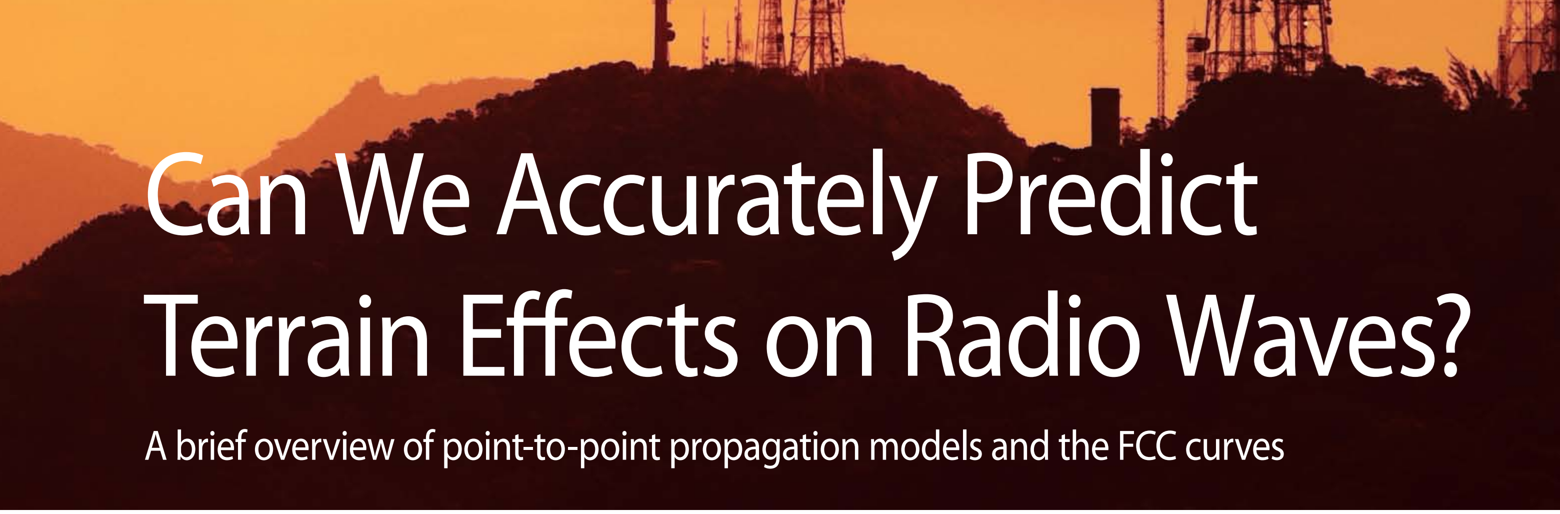
RW: *Why is it necessary to reduce the effective radiated power of an FM station as it increases the height or HAAT of its antenna?*

Beverage: FM is predominantly a line-of-sight transmission medium for greatest signal strength, followed by zones of reduced signal. The most important consideration is that for a given radiated power, the signal goes a greater distance as the antenna is raised above the ground.

This can be related to light. If you are in a flat field and you hold up a light at night above your head, you see the light only so far away. As you go further away land obstructs the brightness but perhaps you can still see that there is a brighter spot on the horizon around the light, which would be considered to be a weak signal. If you raise the light higher and higher, you can see it further and further away — line of sight at work.

To complete the answer: If the power is fixed and you have clean line of sight to the receiver from the transmitting antenna, the direct signal does not change significantly. Given what I have said, you can see that the reason that the radiated power has to be reduced above a given height is to maintain a specified signal level at a given radius.

In terms of understanding, the path from the transmitting antenna to the receiver consists of zones. The first zone is the area where the path from the antenna is clear line of sight. The second zone is what we call the Fresnel zone, where some of the energy around the radio beam starts to be attenuated by obstructions. The third zone is an area beyond line of sight where the signal has bent over the earth and is weak but potentially still listenable or able to cause interference. ■



Can We Accurately Predict Terrain Effects on Radio Waves?

A brief overview of point-to-point propagation models and the FCC curves

By **John Kean**

The author is senior engineer at Cavell, Mertz and Associates Inc.

When we say "propagation software," we refer to models that run pathloss (signal propagation) studies, as distinguished from the software platform that manages the process and plots the results geographically over a map. This software model is vital to the result, but most models were developed decades ago and have remained unchanged, despite the advancement of computers and digitized earth data.

The most familiar model, and the most frequently used for FM, is the FCC's F(50,50) field strength curves. These curves are based on empirical data going back to the beginning of VHF television in the 1940s. For a given transmitting antenna height above terrain along the first 2 to 10 miles (3.2 to 16.1 km) of a path, they provide a statistical estimate of field strength (the "F") where half of locations have a lower field and half have a higher field (the first "50"). Atmospheric fading at the 50th percentile is considered as well (the second "50"). Because early television reception often required elevated outdoor antennas, the curves were based on the fields at 30 feet (9.1m) above ground. The 88–108 MHz FM band shares the same curves with low-band VHF TV, covering 54–88 MHz.

These curves are considered an "area" model because they represent the average case for large areas only. Other than the effects on average terrain elevation from 2–10 miles, the curves do not consider the effects of terrain obstructions. When mapped as iso-contours representing a single field strength, the curve predictions tend to produce a smoothed, single line, such as the 60 dBuV field strength for the hypothetical station in the foothills of the Rocky Mountains shown in the map in Fig. 1 on page 22. This transmitter's height above average terrain to the west is low, due to the surrounding mountains. But to the east, the land drops to relatively low and smooth plains, producing a much larger and more even radius around the transmitter.

RF engineers working in VHF and higher frequency bands have long sought better predictions than area mode contours, using terrain-sensitive pathloss models. The granddaddy of models is the Irregular Terrain Model, aka Longley-Rice, which was developed in 1967 at the Institute for Telecommunications Science, part of the U.S. Dept. of Commerce, in Boulder, Colo.

> *The granddaddy of models is the Irregular Terrain Model, aka Longley-Rice, which was developed in 1967 at the Institute for Telecommunications Science.*

It is widely used because it's free and open-sourced. For example, the FCC uses it officially for the DTV station service and interference studies. Other than a correction to the FORTRAN code 30 years ago, it is unchanged.

TERRAIN REVEALS DETAIL

The effects of terrain are striking for our Rocky Mountain foothills example, shown as a three-color underlay in Fig. 2 on page 23. The predicted 60 dBu field strength is shown as the green shading, although it should be noted that the field strength is shown at a height of only 5 feet (1.5m) above ground, as is more typical of FM radio antennas on cars and portables. If predicted at 30 feet, ITM would have produced a much larger area than the FCC 60 dBu curves would show.

Digitized terrain databases used by ITM have improved tremendously over the years, from 1,000-meter gridding in the 1970s to less than 30 meters today,

Continued on page **22**

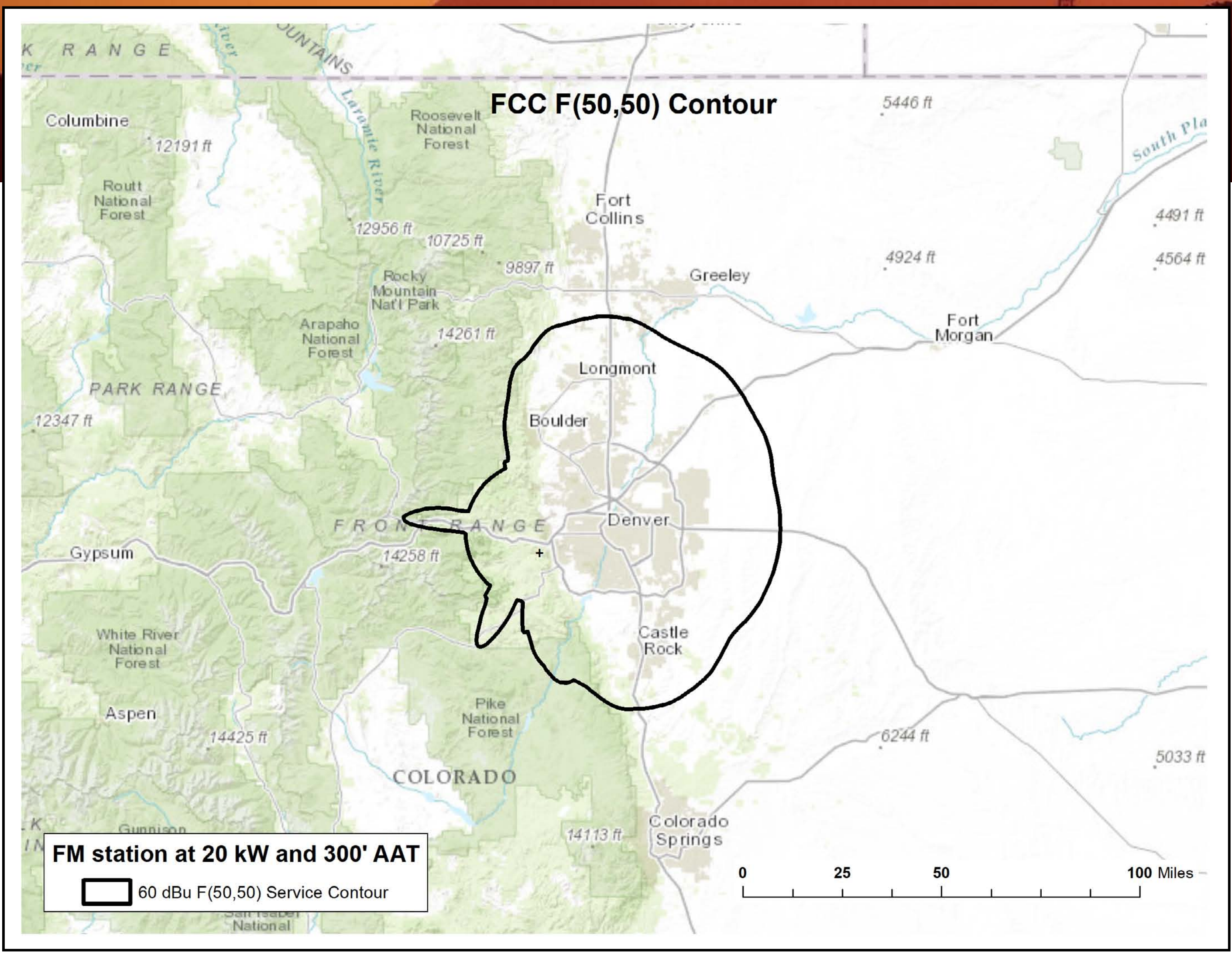


Fig. 1: This coverage map shows the FCC F(50,50) predicted 60 dBu contour of hypothetical station with omnidirectional antenna. Green shading of parkland generally indicates the Front Range of the Rocky Mountains.

› *Continued from page* **21**

thanks to NASA's Shuttle Radar Topography Mission data. This increased resolution by greater than 1000 to 1, which could hardly have been anticipated in 1967. Little scientific research has been done since to know how much this improves the accuracy of pathloss predictions, if at all. My experience is that it increases the "noisiness" of pathloss on a point-to-point basis, but the reduction in standard deviation of error relative to measured data is rather limited when viewed on the scale of broadcast station coverage.

Another development in terrain data is in morphology, better known as "clutter data" or "land cover data." This data didn't exist when ITM was written as a "bare earth" model, lacking any input for and correction of clutter loss. It stands to reason that a grove of trees or a built-up urban area would have more pathloss than open land, but there are no studies that I am aware of that thoroughly determined the optimal correction values with current morphology data. Consequently those who use it as a

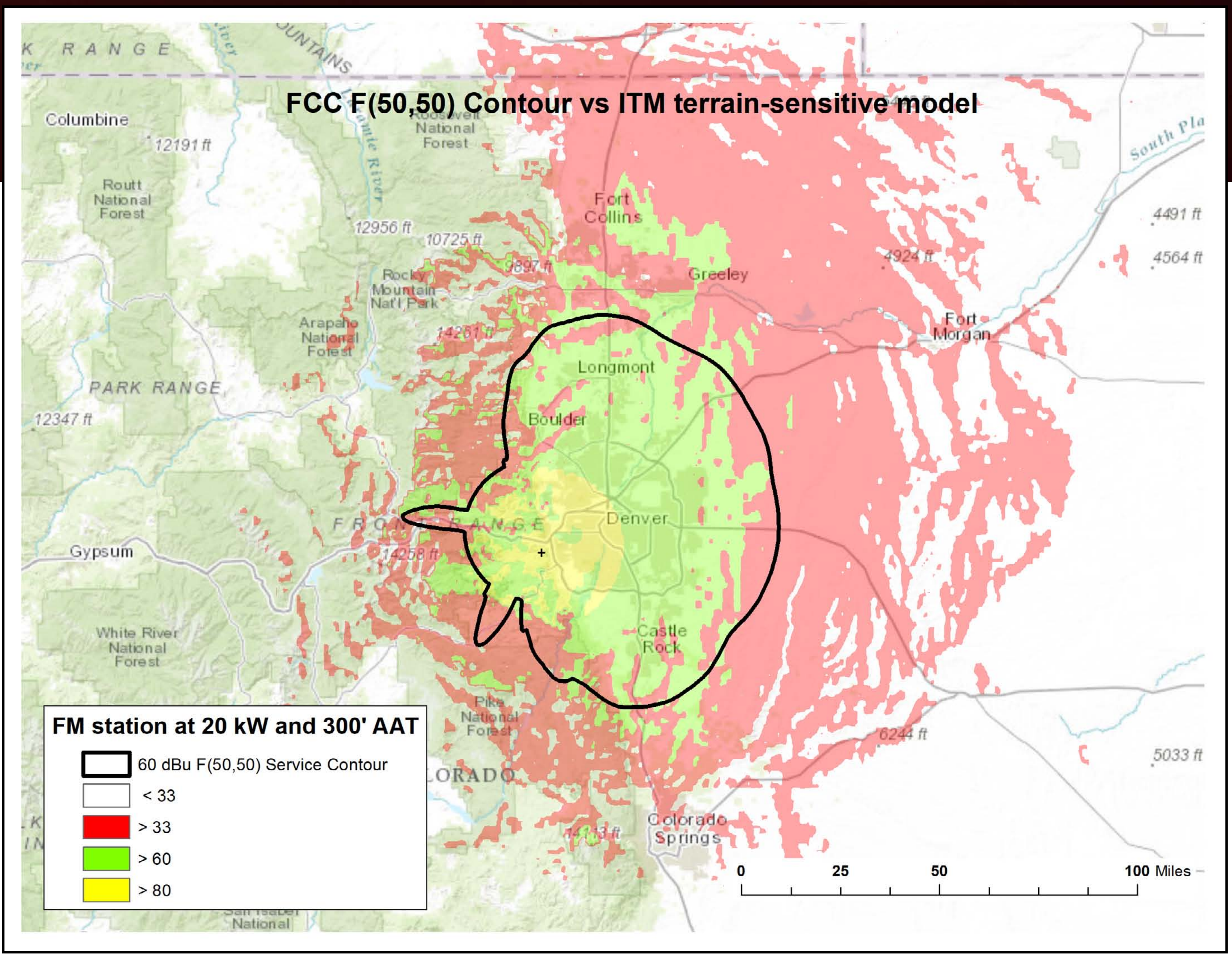


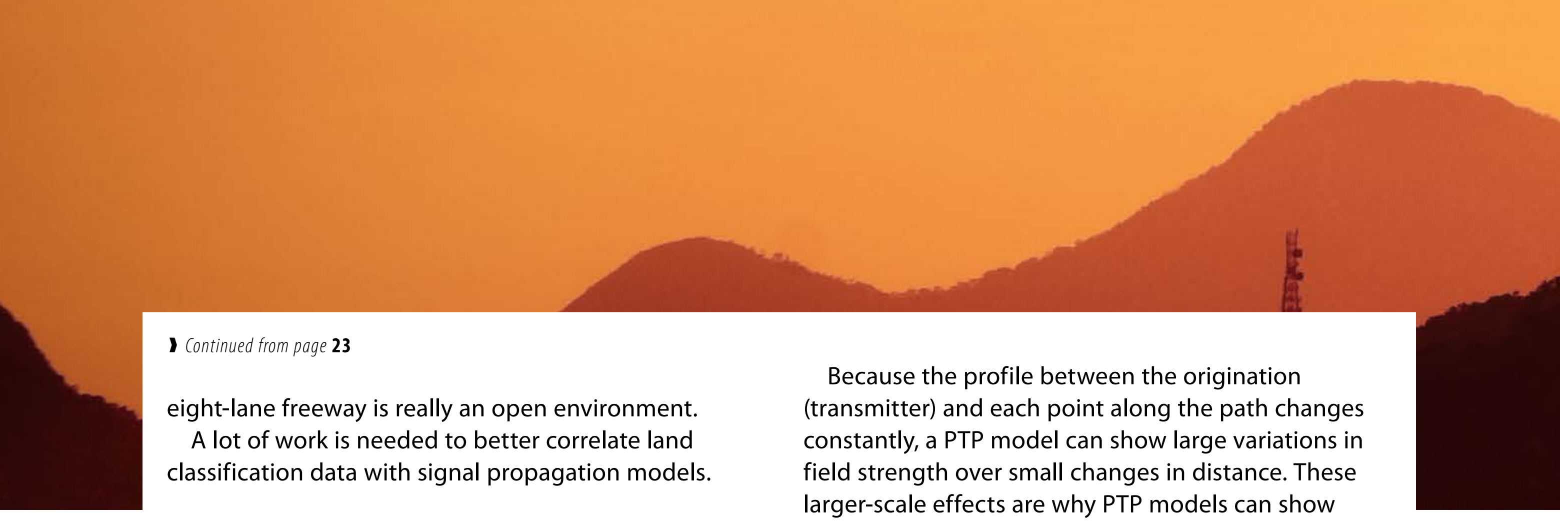
Fig. 2: This shows the FCC contour overlaid with Longley-Rice predicted signal strength values. Red, green and yellow overlays are ITM's prediction of in-car service at 33 dBu, and 60 dBu and 80 dBu field strengths, all at 1.5 m above ground level.

"correction" to ITM pathloss are really just guessing at the supposed improvement. The corrections I've seen assume a loss adjustment for the "bin you're in" (the terminal point of a path, usually the receive point). However, the length of the path through multiple types of land cover has not been studied.

Pathloss correction in built-up areas is especially challenging because the signal diffracts over local building clutter and reflects from large structures. Land classification data lacks individual structures for this calculation. There are 3D building databases (often used by cellular network designers), but they are expensive and computationally intensive.

There are also errors with the classification of land cover. The classifications were developed for land uses such as agriculture, not RF engineering; so we get divisions according to types of grass and brush, for example, but little identification of how built-up areas affect pathloss at VHF or UHF frequencies. There are also some outright mis-classifications, such as designating open roadways as "urban" clutter. An

Continued on page **24**



Continued from page 23

eight-lane freeway is really an open environment.

A lot of work is needed to better correlate land classification data with signal propagation models.

MODEL DEVELOPMENTS

Despite its popularity, there are other known shortcomings to the accuracy of the Irregular Terrain Model.

One notable effort to improve ITM was the development of SPLAT! — short for an RF Signal Propagation, Loss, And Terrain analysis tool — in 2005 and later. This unofficial revision to ITM addressed the use of higher-resolution terrain data and other issues. These changes may have improved ITM's accuracy in various ways, but the broadcast industry, along with other users, needs comprehensive scientific field studies to verify these revisions.

These larger-scale effects are why PTP models can show rather striking "holes" and "islands" in the fabric of coverage that is draped over the map.

The International Telecommunications Union developed Recommendation ITU-R P.1546, a well-established model for point-to-area pathloss. However, it is based on statistical methods (hence the point-to-area designation) and field strength curves measured a long time ago. The ITU-R P.1812 is a commendable model for path-specific prediction and continues to be refined. However, its conversion to a software implementation is generally available only in high-end RF planning tools.

Because the profile between the origination (transmitter) and each point along the path changes constantly, a PTP model can show large variations in field strength over small changes in distance. These larger-scale effects are why PTP models can show rather striking "holes" and "islands" in the fabric of coverage that is draped over the map.

This geographic variation is separate from the sub-wavelength changes called Rayleigh fading, which are caused by local multipath propagation. This fading is treated by most PTP models as a statistical variation around the local mean field strength. Like the FCC curves, PTP models express their predictions by a percentage of locations meeting a given pathloss. There is also a specification for a percentage of the time that the pathloss is met, to account for atmospheric fading.

PTP models are really a collection of models, representing losses from diffraction over major and minor terrain obstructions, Fresnel zone attenuation, ground reflection effects, atmospheric scatter and refraction, height-gain and more. They may switch from one mode to another, or combine some of them at each point along a path profile, as needed. Depending on conditions, one model may be more accurate than others, and there are no comprehensive comparisons to rely upon.

The difficulty with improving or developing new signal propagation models is the exhaustive testing required to validate a model over a vast range of conditions. The development of National Bureau of Standards "Tech. Note 101" and the ITM were based on more than a decade of work at the Institute for Telecommunication Sciences in Boulder more than a half-century ago. Work to improve and validate new models takes time and money, which has not been supported by users in the VHF and UHF bands. This is unfortunate since reduced statistical confidence from these models requires over-building of radio frequency networks, which increases their cost. ■

Dielectric

Trusted for Decades. Ready for Tomorrow.

Dielectric.com /Dielectric1942 /company/Dielectric-LLC /Dielectric_LLC

The Omni vs. Directional FM Antenna

In the real world, most antennas are in fact directional

By **Michael LeClair**

Consultant Clarence Beverage provided this photo of a directional antenna system serving WFUV-FM3, a 2.5 kW booster for Fordham University from the roof of a Durst Organization building in midtown Manhattan. The yagis are Aldena AST.05.02.336 five-element models. The E and H plane patterns are very close, making them candidates for slant 45 degree elements to achieve equal horizontal and vertical ERP.

The use of directional arrays in FM broadcasting has increased greatly in 30 years. Especially in the NCE reserved band, a DA can increase the operating power of a station significantly while still respecting the interference ratios that are at the heart of an effective regulatory scheme.

However, there are complexities and caveats to using directional arrays. Some stations with high values of licensed DA power don't necessarily deliver desirable coverage. At the heart of every DA is a specially designed antenna that requires a different approach by the FCC, one that is often misunderstood.

We explored the topic with several industry consultants.

First, some caveats about the use of a DA. The FCC will not authorize the use of just any pattern that stays within the limits of interference. "The FCC has a number of rules regarding use of directional antennas," said Gray Haertig of Gray Frierson Haertig & Associates. "When using a DA to protect domestic allocation, the licensed relative field pattern may not change more than 2 dB per 10 degrees over the protection azimuths, and the maximum to minimum ratio may not exceed 15 dB."

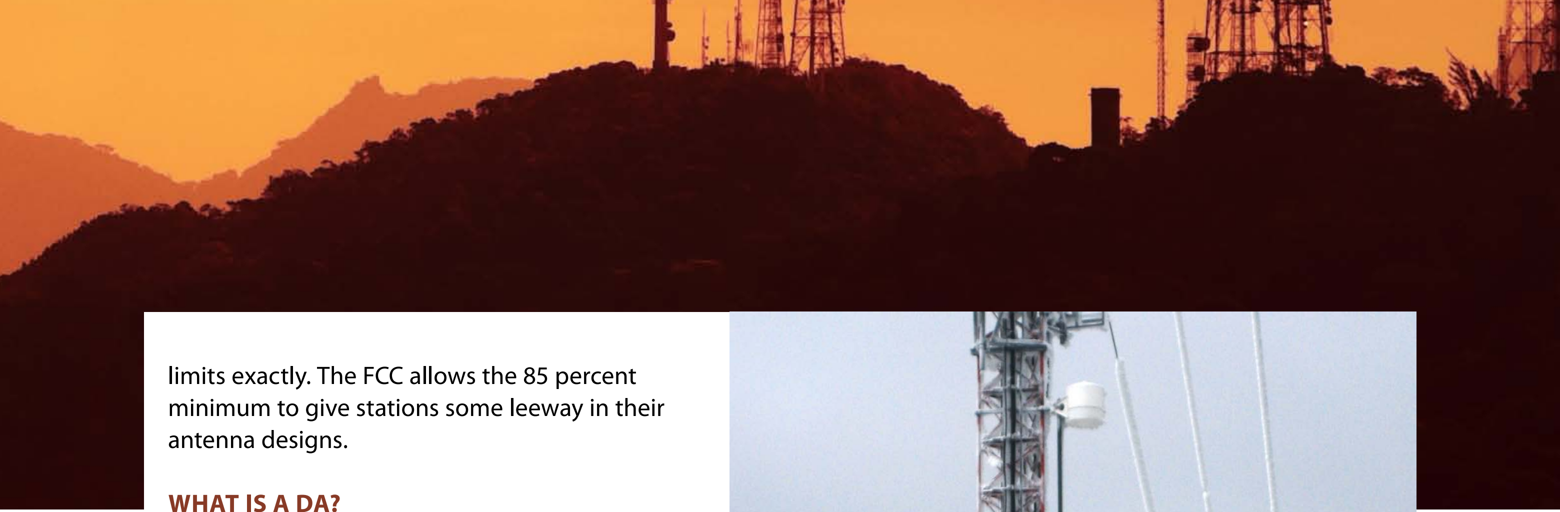
FCC regulations for directional antennas are very different from those covering omnis. A station requesting to build a DA must provide certification from the antenna manufacturer that the pattern has been measured and tested on a range under identical mounting conditions to the proposed tower mount. Most important are differences in how the commission licenses omni vs. directional arrays.

"Nondirectional stations are licensed by the RMS power, irrespective of the actual power radiated in any given direction. Directional stations are licensed according to the measured power in the maximum," said Haertig.

"When the antenna is manufactured and tested on the range, it cannot exceed the authorized pattern at any azimuth and its RMS must be at least 85 percent of the authorized pattern."

Wait, what? Did he just say that the DA I'm building might not provide the full coverage to the pattern limits drawn by my engineering consultant, and the goal is to get it to a minimum of 85 percent? Why am I not getting the 100 percent I'm planning on and need for success?

Simple physics means it is difficult to meet the pattern



limits exactly. The FCC allows the 85 percent minimum to give stations some leeway in their antenna designs.

WHAT IS A DA?

It turns out that in the world of real antennas and towers, most antennas are in fact directional.

"It's well to remember that with the possible exception of panel, Lindenblad or spiral antennas, all antennas are directional," said Haertig. "The problem is that you have no idea what the pattern of the actual antenna as installed is unless you have had the pattern measured. As I generally tell my clients, if you care what your coverage is, then have the antenna pattern measured."

Clarence Beverage of Communications Technologies Inc. agrees.

"Omnidirectional antennas are never truly omni if they are single side mounts, as the pattern is distorted somewhat on a pole or 12-inch tower," said Beverage. "Get up to 36- to 42-inch-face towers and the patterns start to deviate significantly. Mount on a 7-foot face or wider TV tower and the 'h.pol' and 'v.pol' patterns may start to look like spaghetti.

Directional FM antenna systems raise some particular questions. Shown is a Dielectric DCR-H system with radomes.

"Because of this, omni antennas have to be considered as providing an unpredictable signal if the pattern has not been measured on a test range."

How does the FCC handle this real-world intrusion into RF engineering?

"That nominally omni antennas are actually directional is something the commission has largely steered clear of addressing," said Haertig. "They assume that omni antennas are indeed non-directional. Indeed, some nominally non-directional antennas can have as much as 6 dB gain in certain directions.

"As I generally tell my clients, if you care what your coverage is, then have the antenna pattern measured."

In simple terms, all antennas are directional. But if you require a directional antenna to increase power while maintaining protection to adjacent stations, the FCC requires significantly greater proof that your antenna will meet that protection. While an omni antenna might be allowed to exceed licensed field strength up to around 6 dB in a particular direction based on the way it is mounted, a station with a DA must show that its design prevents maximum field strength from exceeding the licensed maximum allowed in any direction. Six dB … isn't that four times the power?

It seems like the FCC is giving a fairly strong advantage to the omni antenna relative to how it treats a directional array.

"While it is against the rules to purposefully build an omnidirectional antenna that produces more than a full field in a specific direction," said Doug Vernier of V-Soft Communications, "an omni antenna, carefully positioned on a tower to prevent coverage holes in the direction of desirable population within its licensed coverage, is perfectly acceptable. Keeping the antenna omnidirectional, therefore, may result in better coverage than accepting a small null in a directional antenna."

WHEN DOES A DA MAKE SENSE?

There are marketing advantages in being to claim a higher effective radiated power; but putting those

Continued on page **28** ❯

Continued from page 27

aside, there are cases when a DA makes sense.

From the above, it would seem that a conservative rule of thumb for using a DA might be if you can achieve a 4 to 6 dB improvement in operating power toward a desirable market or population concentration in comparison with an omni pattern. For example, a station might have a nearby interference limit thanks to another station in the opposite direction from a major city. By going directional toward the city, this station could put substantial signal into the market while protecting the nearby station within the limits of the 15 dB front-to-back ratio.

Benefits of a directional approach may include lower operating costs, reduced multipath and increased power towards a target audience.

"Another situation when a directional antenna should be used is when the station's tower is close to a high ridge or mountain," said Vernier. "Using a directional antenna with a null pointed at the mountain will help prevent the station's signal from reflecting off the mountain and traveling back toward the desired coverage area as co-channel interference."

A directional array also may offer operational savings. Vernier said that directional antennas are often used by FM stations in coastal areas to place a null over bodies of water where there is no population to be served. "Since directional antennas always have higher gain than omnidirectional antennas having the same number of bays, the transmitter can operate at a lower output, consequently saving a lot of electricity resulting in lower power bills," he said.

Haertig said the benefits of a directional approach may include lowering operating costs through reduced radiation towards unpopulated areas; reducing multipath by cutting down on radiation towards prominent reflectors; or increasing power towards a target audience while still staying within the FCC rules of allocation.

"In a situation where a directional antenna is used to reduce radiation towards unpopulated areas, its inherent higher gain means lower transmitter power and may permit using a smaller transmitter for a given antenna aperture."

Dave Doherty of Skywaves Consulting LLC summed up when to use a DA:

"If you need a null of more than a few dB in the direction of your primary service area, it's probably not a good idea. Deep nulls often are much deeper than planned, especially when panels are required to create the pattern.

"On the other hand, if there's not a significant population in the null area, it may well make sense use a DA to reduce interference to stations in the null and increase your ERP in the desired direction. Power-saving is another reason to use a DA if the population in the null isn't significant."

And, perhaps most important point of all, Doherty added: "Be guided by a knowledgeable engineer." ■

RADIOWORLD

Email: radioworld@nbmedia.com
Website: www.radioworld.com
Telephone: (703) 852-4600
Business Fax: (703) 852-4583