ieee spectrum

THE MAGAZINE OF TECHNOLOGY INSIDERS

02.09

SPECIAL REPORT

DREAM JOBS '09

SOME PEOPLE GET PAID TO HAVE FUN. WE MET 10 OF THEM. HERE ARE THEIR STORIES

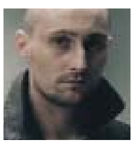
Shannon Bruzelius masters a blaster at Wild Planet Toys

IEEE

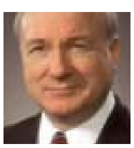
Celebrating 125 Years
of Engineering the Future

contributors

RANDY H. KATZ, an IEEE Fellow, is a professor of electrical engineering and computer science at the University of California, Berkeley. His current interest is the architecture of Internet data centers. In "Tech Titans Building Boom" [p. 40], he describes how engineers are increasing the density of servers in a facility by more than tenfold. He's still trying to get a peek at Google's mega data center in Oregon.



ROSS KIRTON photographed sound engineer Marco Migliari, backed by progressive Brit-rock band the Moonfish, for Dream Jobs [p. 24]. "We didn't want it to look like Marco was the band's manager," Kirton says, so he placed Migliari in front of the mixing board, with the musicians on a platform behind him. The London-based photographer's work has appeared in the UK editions of *Vogue*, *GQ*, and *Vanity Fair*.



JAMES E. LUKASZEWSKI explores the challenges of relating to upper management in "Managing Your Boss's Boss" [p. 17]. A corporate consultant and author of *Why Should the Boss Listen to You? The Seven Disciplines of the Trusted Strategic Advisor* (Jossey-Bass, 2008), he coaches IEEE's incoming volunteer leadership each year.

THE MOONFISH took a three-day break from its Italian tour to come to England for a photo session with the band's sound engineer Marco Migliari [p. 24]. Bassist and singer Gadi says Migliari is "like a fifth member of the band. He understands us and pinpoints our ideas, which a producer needs to do with a bunch of messy lads like us!" For more on the band, go to http://www.myspace.com/themoonfish.

JOHN ROSS & RICHARD SCHNEIDER explain why this month's planned conversion to all-digital television broadcasts in the United States has sparked a revolution in antenna design. Ross, an IEEE senior member and coauthor of "Antennas for the New Airwaves" [p. 44], consults on antenna design and RF electromagnetics. His home antenna is an old prototype ClearStream1 that sits on a bookshelf and receives 24 digital stations from the Salt Lake City area. Coauthor Schneider, president and founder of St. Louis–based Antennas Direct, uses a ClearStream4 antenna mounted on his roof to receive over 20 stations, including a half dozen from Columbia, Mo., some 160 kilometers away.

GISELLE WEISS is a freelance writer based in Basel, Switzerland. In Dream Jobs, she profiles Philippe Lauper, project manager for a team building a solar-powered airplane designed to circumnavigate the globe [p. 38]. This is the second time that Weiss has written about the project for *IEEE Spectrum*. In 2004, she interviewed one of its leaders shortly after the effort got under way. Back then, she says, "You could actually get [cofounder] Bertrand Piccard at home at night on the phone." These days the project is a bigger, glossier enterprise, but the challenge of getting the plane in the air remains—to say nothing of getting Piccard on the phone.

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CLOCKWISE FROM TOP LEFT: PEG SKORPINSKI; MITCHELL WEISS; ROSS KIRTON; THE LUKASZEWSKI GROUP; ZANNA

ANTENNAS FOR THE NEW AIRWAVES

THIS MONTH'S PLANNED SHUTDOWN OF ANALOG BROADCAST TV IN THE UNITED STATES WILL BRING ANTENNA TECHNOLOGY BACK INTO THE SPOTLIGHT

By Richard Schneider & John Ross
Photos by Ryann Cooley

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Winegard SquareShooter

LET'S SAY YOU'VE GONE AND BOUGHT a high-definition LCD TV that's as big as your outstretched arms. And perhaps you've also splurged on a 7.1 channel surround sound system, and an upconverting DVD player or maybe a sleek Blu-ray player. Maybe you've got a state-of-the-art game console or Apple TV or some other Web-based feed. Well, come 17 February, you just might want one more thing: a new antenna on your roof.

If you live in the United States and you're one of the 19 million people who still prefer to pull their TV signals out of the air rather than pay a cable company to deliver them, you may already know that this month the vast majority of analog television broadcasts in the United States are scheduled to end and most free, over-the-air TV signals will be transmitted only in the new digital Advanced Television Systems Committee (ATSC) format. A massive advertising campaign is now telling people who get their signals from the ether that they'll need a TV with a built-in ATSC tuner or a digital converter box to display their favorite programs.

What the ads don't mention is that most of those people will also need a new antenna. For the vast majority of you out there in Broadcast-TV Land, the quality of what you see—or even whether you get a picture at all—will depend not on your TV or converter box but on the antenna that brings the signal to them.

If you have a cable or satellite hookup, you might think that this antenna issue is irrelevant—but think again. Some owners of high-end systems complain that the signals coming from their satellite or cable provider aren't giving them the picture quality they expected. That's because cable and satellite operators often use lossy compression algorithms to squeeze more channels, particularly local channels, into their allotted bandwidth. This compression often results in a picture with less detail than the corresponding terrestrial broadcast signal provides. For videophiles who have already spent a fortune on their home-theater systems, a couple of hundred dollars more for a top-of-the-line antenna obviously makes sense. And of course, antennas are also good backup for the times when the cable gets cut or the satellite system fades out due to rain or snow. In addition, they serve second TV sets in houses not wired to distribute signals to every room.

Suddenly the dowdy TV antenna, a piece of technology that has changed little over the past 30 years, is about to be the belle of the ball.

GONE, HOWEVER, are the days when a large rooftop antenna was a status symbol. Cellphones and handheld GPS units have conditioned consumers to expect reliable wireless services in very small packages. Such dramatic changes in consumer preferences—coupled with the new frequency allocations, channel distributions, and high demand for reliable over-the-air digital antennas—mean that the time for new designs has indeed come.

Most TV viewers think of antennas as simple devices, but you're tech savvy, so of course you'd never assume this. Nevertheless, bear with us briefly as we review Antennas 101.

The decades-old designs of most TV antennas on rooftops—and in the market today—are typically configured on a horizontal fish bone, with arms of varying lengths to handle a broad range of frequencies.Though the engineering of antennas in other spheres has advanced radically over the years, manufacturers of television equipment have stuck pretty much with the old designs for economic reasons. Traditional antennas were good enough for analog television, and the shrinking customer base for broadcast reception didn't offer much incentive to plow money into new designs.

The transition to digital has changed all that. Most digital channels are broadcast in UHF, and UHF antennas are smaller than those used for analog TV, where most broadcast signals were VHF. Also, the multipath problem, arising from signals that reflect off buildings and hills, which may have occasionally caused ghosting on analog TVs, can completely destroy a digital picture.

A few designers and manufacturers have done the necessary research and development and introduced improved models. First out of the labs were the Silver Sensor, introduced by Antiference, based in Coleshill, England, in 2001, and the SquareShooter, introduced in 2004 by Winegard, in Burlington, Iowa.

The Silver Sensor [see "TV Topper"], an indoor antenna designed for UHF reception, is based on the classic log-periodic design, which means that the electrical properties repeat periodically with the logarithm of frequency. Done right, a log-periodic design offers good performance over a wide band of frequencies.

The outdoor SquareShooter's element has a sinuous shape, which helps it respond across a broad UHF range of frequencies [see "Under the Hood"]. It's mounted in front of an open grid that reflects UHF waves, thereby reducing the multipath problem by blocking signals arriving from behind the antenna.

Still, the pace of product introductions is slow. To this day, some manufacturers are still relabeling old designs as HDTV antennas as long as they generally cover the right part of the spectrum. But some very good designs are finally on the market—if you know what to look for.

Antennas are much better now than they used to be. But two changes will make them even better in the next several years: the introduction of powerful new software tools for designing antennas, and a slew of new regulations in the United States that will reduce the range of frequencies that a TV antenna must receive. Together, these factors will lead the way to smaller antennas [see "Loop de Loop"] that work better and look better than the apparatus that sprouted from the roof of your grandparents' house 50 years ago.

The key developments that have changed antenna design are computational electromagnetic codes, advanced search-and-optimization methods like genetic algorithms, and improved measurement tools such as the vector network analyzer. Traditionally, antenna designers used pencil and paper to wrestle with Maxwell's equations, the four equations that describe electric and magnetic fields. Then engineers spent enormous amounts of time in the laboratory, testing and tweaking designs. Computational electromagnetic codes, a breed of program that solves Maxwell's equations on a computer, have revolutionized antenna design by allowing the engineer to simulate the real-world electromagnetic behavior of an antenna before it is built.

As computer power increased in the 1990s, antenna engineers began using automatic search-and-optimization methods to sort through the successive designs their codes generated. In particular, they used genetic algorithms, which emulate the Darwinian principle of natural selection through a survival-of-the-fittest approach. After sifting through millions of possible design configurations, the algorithm can zoom in on a handful of promising optimal designs that meet specified performance and size criteria.

Thanks to these tools, antenna designers can focus more on the antenna itself and less on the math. And the months that used to be spent testing prototypes are now compressed into days—or even just hours—of simulation. Designers now go to the laboratory only for a final check, to confirm the accuracy of their computations.

And in the lab, life is a lot easier today than it was several decades ago. To check antenna performance, engineers have to measure its impedance accurately across a huge frequency range. That is what a modern vector network analyzer now lets them do easily and quickly. Decades ago, engineers had to calculate, for each channel's frequency, the impedance from measurements of voltage signals in the cable leading to the antenna. This was a laborious and often imprecise process.

Regulations that reduce the range of frequencies a television must receive are driving big changes in antenna design. The new regulations relax the other two main design constraints, gain and size, making it possible for smaller and far less conspicuous antennas than the monstrosities of yore.

These changes are part of a frequency reallocation that has turned the various parties claiming pieces of the radio spectrum into players in a game of musical chairs. In the analog television world, TV broadcasts occupy three bands. The low-VHF band covers 54 to 88 megahertz, the high-VHF band covers 174 to 216 MHz, and the UHF band covers 470 to 806 MHz. Earlier the UHF band stretched all the way to 890 MHz, but some of this bandwidth was given up in the 1980s to

TV TOPPER: Introduced by Antiference, of Coleshill, England, in 2001, the Silver Sensor is an adaptation of the classic design of years past—a log-periodic array of horizontal receiving elements. Versions of the Silver Sensor are sold by LG Electronics under its Zenith brand and by Philips (shown here).

UNDER THE HOOD: The Winegard SquareShooter consists of a two-arm sinuous element and grid reflector attached to an inexpensive Mylar substrate and encased in a plastic dome. The element responds across a broad range of frequencies; its size is optimal for the UHF band. The open grid behind it is sized to reflect UHF frequencies, which reduces the multipath problem by blocking some of the signals that bounce off buildings or hills instead of coming directly to the antenna.

LOOP DE LOOP: The new ClearStream2, from Antennas Direct, uses thicker-than-traditional elements and tapers the thickness of the loops, which allows the antenna to respond to a greater range of frequencies. The resulting tapered-loop antenna is half the volume of the equivalently performing bow-tie array that has been on the market for years. As with the SquareShooter, the grid acts to defend the antenna against multipath interference.

THE NEW ANTENNAS: A SAMPLING

	Best for	Estimated range	Dimensions	Street price
INDOOR				
Antennas Direct PF7	Near the transmitter and for those who want a hidden or discrete antenna	24 kilometers	23 x 28 x 2.5 centimeters	US $40
RCA ANT1500	Near the transmitter and for those who want a hidden or discrete antenna	24 km	13 x 39 x 28 cm	$30
Philips Silver Sensor	Reception that needs higher gain and multipath rejection, for urban areas	32 km	33 x 34 x 5 cm	$25
INDOOR/SMALL OUTDOOR				
Channel Master 4220	Near to medium range	32 km to channel 13, 48 km to channel 69	14 x 62 x 39 cm	$30
Winegard HD-1080	Near to medium range, with improved VHF	64 km	88 x 46 cm	$60
Antennas Direct ClearStreamC2	Near to medium range, in a smaller size	80 km	51 x 30 x 13 cm	$80
MEDIUM-SIZE OUTDOOR				
Winegard HD-7015	People who need VHF and UHF in one package	56 km, UHF; 80 km, VHF	223 x 282 x 65 cm	$50
Channel Master 4221	Medium to long-range UHF reception	72 km	51 x 13 x 92 cm	$40
Antennas Direct DB4	Medium to long-range UHF reception	89 km	10 x 48 x 74 cm	$50
LARGE OUTDOOR				
Winegard HD8200U	Long-range combination VHF/UHF	More than 97 km	427 x 279 x 84 cm	$120
Antennas Direct 91XG	Very long-range UHF reception	More than 113 km	56 x 51 x 236 cm	$75
Televes DAT75	Very long-range UHF reception	More than 113 km	180 cm long (other dimensions not available)	$200

provide spectrum for cellphone communications. The two VHF bands will be retained in the transition to digital TV, but the ceiling of the UHF band will be reduced to 698 MHz, making room for new wireless services and for applications involving homeland security. This is 108 MHz narrower than the current UHF TV allocations and 192 MHz narrower than the older allocations, which extended out to channel 83.

Notably, the older and wider UHF bands were in effect when most of the TV antennas on the market today were designed. The old designs are therefore rarely optimal for the new spectrum allocations because the antennas had to cover the wider bands and higher frequencies.

The transition to digital has also changed how the stations are distributed across the allocated bands. In the days of analog, most TV stations were on the VHF band, with smaller, less powerful stations in the UHF band. But now, in the fast-approaching digital world, roughly 74 percent of the stations are on the UHF band and 25 percent are on the high-VHF band (today's channels 7 through 13). Only about 1 percent of the stations will be in the low-VHF band (channels 2 through 6).

Gain is not the be-all and end-all of antenna design—far from it, as any antenna engineer will tell you. But you'd be hard-pressed to know that if spec sheets and marketing hype are your main sources of information.

Gain, usually expressed in decibels, indicates how well the antenna focuses energy from a particular direction as compared with a standard reference antenna. Because most spec sheets don't give a two- or three-dimensional radiation plot, the gain number specified is the value in the direction of maximum intensity. What that means is that if the broadcast stations you're trying to receive do not all line up like points on a single straight line from your home, you could have a problem with an antenna whose gain drops off dramatically from that sweet spot. Also, "gain" in this usage doesn't include losses from impedance mismatch. In practice, the antenna's performance will degrade if its impedance is different from that of the cable connected to it.

For these gain calculations, the reference antenna is often a half-wave dipole antenna, the most common type of antenna, which is composed of two metal rods, each one-quarter the length of the signal wavelength. The signal is taken from the antenna through a connection between the two conductors. The classic TV antenna is a log-periodic array of dipoles, with each dipole receiving a different VHF or UHF frequency.

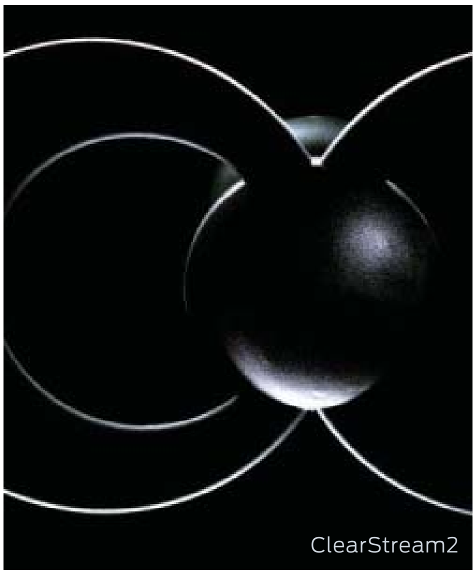
When shopping for an antenna, consider the gain, but not to the exclusion of all other characteristics. Buying an antenna based on gain and price alone would be like going shopping for an automobile and considering only power and price; you might end up with a 500-horsepower engine attached to a skateboard. While higher values of gain—in the 7- to 12-decibel range—are usually better than lower values, most consumers will be better off not focusing on gain but instead purchasing a unit that provides good overall performance, as long as it meets their reception and installation requirements [see "The New Antennas: A Sampling"].

A family in rural Nebraska, for instance, might need a large, highly directional antenna, a tower of about 18 meters (60 feet), and a preamplifier to pick up stations, which would more than likely be located somewhere over the horizon. But that would be complete overkill for somebody living in Salt Lake City, where all the broadcast towers are on a mountain ridge just above the city with a line-of-sight path between most viewers and the tower. Anywhere near Salt Lake City you'll get great reception even with a small indoor UHF antenna.

Don't be fooled by claims of astoundingly high gain. Some manufacturers are marketing small indoor antennas and labeling the boxes with gain numbers between 30 and 55 dB. This kind of unit is actually an antenna paired with an amplifier, and the gain value stated on the package is really the gain of the amplifier and not that of the antenna. While it is possible to improve reception by using a well-designed low-noise amplifier, most of the inexpensive antennas designed this way actually have cheap amplifiers and too much gain. That combination generally overloads the amplifier—and potentially the receiver as well—causing signal distortion that can degrade or eliminate DTV reception entirely. Most consumers are better off with a well-designed nonamplified unit, also known as a passive antenna. If television reception does require an amplifier, the best choice is a high-quality, low-noise model connected as close as possible to the antenna.

Consumers switching to digital TV using just an indoor antenna for reception face a more difficult problem. What was good enough to provide a watchable, if slightly snowy, analog broadcast is likely to bring nothing but a blank screen in the digital world. Even the better antennas must sometimes be readjusted to receive certain channels, forcing viewers out of their easy chairs to fiddle with their antennas.

But couch potatoes might soon be able to stay planted, thanks to a new standard approved by the Consumer Electronics Association (CEA) in 2008. The ANSI/CEA-909A Antenna Control Interface standard allows the television receiver to communicate with the antenna, instructing it to adjust and automatically lock onto the signal as the viewer channel surfs. Because the antenna and the receiver both "know" what channel the user is watching, the antenna can change either physically or electrically to adjust tuning, direction, amplifier gain, or polarization. The ability to adjust antenna tuning for each channel allows engineers to use a narrowband antenna element to cover a wide range of frequencies. This strategy is often referred to as tunable bandwidth. A simple example of tunable bandwidth is to use a switch to connect two short rods into a larger rod, thus reducing the resonant frequency.


ClearStream2

Tunable bandwidth relaxes many of the design compromises, so manufacturers can produce smaller, higher-performance antennas. This is particularly important for indoor antennas, where compactness and aesthetics are key to adoption.

Not only will ANSI/CEA-909A eliminate having to fool with the antenna all the time, it should make it easier for engineers to design the high-performance, aesthetically pleasing small antennas that everyone wants. Audiovox Corp., of Hauppauge, N.Y.; Broadcom Corp., of Irvine, Calif.; and Funai Electric Co., of Daito, Japan, have demonstrated 909A-compliant smart antennas, but these designs have yet to be widely distributed because hardly any TV receivers on the market are compatible with them.

That might soon change. The National Association of Broadcasters (NAB)—the trade association that represents broadcast TV stations—and others are doing their best to stimulate a market for 909A-enabled antennas and receivers by promoting the new smart antennas. The NAB is particularly interested in the 909A technology because difficulty in adjusting the antenna was one of the factors that drove millions of consumers to cable or satellite in years past. In 2008, the NAB funded Antennas Direct, the company that one of us (Schneider) founded, to develop 909A-compliant smart antennas because without such a device on the market, television manufacturers would have no compelling reason to add the required interface circuitry to television tuners.

To help encourage manufacturers to do so, the July 2007 draft of the 909A standard made a change in the original specification. In the original design, the signals to the antenna went over a dedicated cable—that meant another jack in the back of TVs and another cable for consumers already struggling with a tangle of wires. The revised standard allows signals to be sent over the same coaxial cable that transmits the television signal. The single-cable solution should spur television manufacturers to adopt the standard, many being reluctant to include additional connection ports on the already crowded rear panel of a modern flat-panel TV. It will also simplify the connections for technology-challenged consumers.

With more free content, superior picture quality, and viable indoor antenna options coming soon, the broadcasters may finally be in a position to—dare we say it?—start stealing viewers back from cable and satellite.

And perhaps strangest of all, an antenna on the rooftop or perched in the living room may once again become a status symbol, as it was in the early days of television. It won't be showing off that you're rich enough to have a TV—just smart enough to get the most out of it. ❑

TO PROBE FURTHER

The CEA and NAB provide a Web site (http://www.antennaweb.org) to help consumers learn about the transition to digital television. The Web site has tools that indicate what channels are available in specific locations and how to select an antenna to receive them. Antennas Direct hosts a similar site (http://www.antennapoint.com), which also maps transmitter locations and gives distances and bearings relative to any specified location in the United States. Both sites offer advice on particular antennas and how to install them for best results.