CQ Web Bonus

CQ Interviews:

Digging Deeper with Dr. Eric Haseltine, AB3DI

Former Associate Director of National Intelligence for Science and Technology

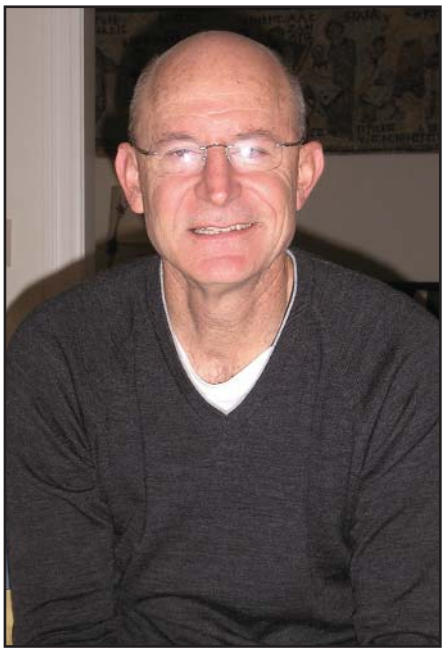
BY RICH MOSESON,* W2VU

Our interview with Dr. Eric Haseltine, AB3DI, appeared in the April 2008 issue of CQ magazine. Haseltine -- former Associate Director of National Intelligence for Science and Technology, former Director of Research for the National Security Agency, former Executive Vice President of Disney Imagineering, and a former top executive at Hughes Aircraft, had far more of interest to say than we could possibly fit in the article. So, as a bonus, we present this "Digging Deeper" online supplement, in which Eric talks in greater detail, and at a higher technical level, about technology, the pace of technological change, ham radio's role in advancing technology and his own experiments with propagation.

First, some additional background: Eric holds a BA in economics and psychology from the University of California at Berkeley, a Ph.D. in physiological psychology from Indiana University, did a year of postdoctoral work in neuroscience, and has a certificate in Executive Management from UCLA's Anderson School of Management. He also holds a dozen patents in the fields of laser video projection, optics, head-mounted displays, animation tools and special effects.

His initial area of professional interest was the workings of the human brain. This interest continued even after he moved into other areas professionally, and led to his writing a long-running column on the brain for *Discover* magazine. He is currently a consultant advising a variety of clients on future trends in technology and how best to meet the challenges and opportunities they will present.

-- W2VU



Dr. Eric Haseltine, AB3DI (W2VU photo)

Now, on to some of the topics we either couldn't cover in the interview article or couldn't cover in depth. Here is AB3DI…

… on technology, the pace of technological change, and its effect on America's place in the world:

"There's a great book called The Change Function … by a guy named Kip Coburn, who says that most technology fails because it creates more pain for users than it solves pain. And the reason is, technology is invented by technologists who are quite comfortable with technology but their users are not. If you think about why iTunes wins even though it wasn't the first to market, it's 'cause the people who did that got it, and - I'll get back to this later - but in ten years at Disney, what I mainly learned was how to make technology usable by anybody from a four-year-old to a grandma, instantly and with a great amount of appeal."

"I'm going to speculate … and I always feel nervous, venturing into speculation where there's no data - it's just intuition: One of the things that we did at Disney is we looked at what people were wanting in life that they weren't getting, and how we could give it to them, particularly families, particularly around out-of-home entertainment. And what some of us at Disney concluded (was) that, in America, people were getting turned off to the rapid pace of change, the bewildering array of new technology that was making their lives harder, the example being, 'I've got a TV recorder but it flashes 12 - I can't figure it out - and my computer dies all the

** Editor,* CQ

time, and I'm afraid of breaking this new technology that I've gotten.' And you see it in the movies, in things like "Star Trek" with the borg, and "Terminator," (which) are kind of representations of people's fears about technology, and it taking over or controlling their lives or creating a world that they don't understand and they don't like. There are good reasons why movies like that do well. And so, one of the things that could be happening in America is that we immersed ourselves in technology first, before any other culture, so our people are getting more scared and turned off by it first. And so there's this kind of unconscious shying away from it."

"Like I say, that's not a scientific observation, but it was one that shaped our thinking at Disney because what we tried to do was create an antidote for a bewildering array of uncontrollable change, a place and an environment that was safe, and comfortable, and organic, and that's what a theme park is all about - it's about hope for a better tomorrow. And hope for a better tomorrow does not mean a place that's bewildering and out of control. It means a place that's appealing and relaxing and peaceful. So in some sense, a lot of what we did in our theme park design was an antidote for technology because we understood that people, families, were needing that. It's kind of troubling if you think about the implications of it, and so I think it's a combination of a lot of these things. And one last point: it may not be so much that, as a nation, we're getting worse (in science and technology). We may be as good as we ever were. It's just that other people have woken up and are getting better. So we look at ourselves in relation to other cultures and societies, and I'm not sure it's true at all that science and technology is on the decline in America. It's -- the integral may be good, the derivative with respect to other societies may not be so good. They just may be accelerating faster than we are."

… on what got him back into ham radio in 2005 after a long absence:

"Well, in a way, my job (as Associate Director of National Intelligence) ignited that natural curiosity again about propagation, because I kept running into issues about, 'how does one communicate from point A to point B?' and there were many answers to that question, but one of them was always RF, and so really, it just kind of reignited my curiosity about propagation phenomena. So I started studying all these bizarre (propagation modes) - ducting and scattering and magnetic things and so forth, and the meteor bounce thing I thought was very interesting. Just to learn that there's a meteor that enters the atmosphere that creates an ionization trail and about once every 20 seconds or 30 seconds … and that you can bounce RF off of it and go long distances, and I think that you can pretty reliably, any time of year, get about one or two Hertz baseband bandwidth off of that, if you're willing to buffer and send when you've got an open window. That's really interesting! I mean, it's just inherently kind of cool that you can do that, and to me, these exotic and strange propagation modes are just inherently interesting and so that's what I was studying. I didn't want to just read about it, I wanted to do it."

"It may not be so much that, as a nation, we're getting worse (in science and technology). We may be as good as we ever were. It's just that other people have woken up and are getting better."

… on his current ham activity:

"Well, I was pretty active up until about five or six months ago, and it wasn't so much communicating with other hams, but it was doing propagation experiments and things like that. I was doing technical experiments. I would communicate with other hams, but mostly to kind of verify my propagation ... I would listen for hams in a particular part of the country and try to figure out what kind of antenna they had and what kind of rig they had and where was their antenna pointed and what kind of soil were they over, and then I would say, 'Oh, I want to talk to that one, to see if he can hear my signal, and how much.'"

"So, I was mainly using hams as kind of beacons for different things, ducting, HF propagation, and gray line propagation. I got into PSK31 quite a bit, because what I found was that it really told me a lot about propagation ... I could communicate with people on PSK31 that I never could, even with CW sometimes. Although in theory you would say CW is the lowest bandwidth, what I found was that PSK31 turned out to be better because it does have, I think, error correction in it to some degree. There's the in-built error correction of redundancy, and I found it to be a very interesting tool for propagation, and I kind of bemoaned the fact that, when you get off of 20 meters, PSK31 is much less used. There's something about 20 meters, it seems to be. And I was interested in 'not-20-meters.' I was interested in other (bands), and yeah, there are calling frequencies and things that aren't on 20

Aladdin's Magic Carpet Ride was one of Eric Haseltine's first major projects while working for Disney Imagineering. He later became Disney's Executive Vice President for Research and Development. (Photo courtesy of Walt Disney World)

meters, but I would every now and then find someone on 40 meters and once I think I found one on 17 meters, but mostly it was a 20-meter thing."

"The reason I haven't been too active (recently) is that I've been busy building a new business. But I am going to get back to it again, I mean … One of the things that's happened with the re-igniting of my interest in ham radio is that I'm constantly looking at the tops of buildings for what kind of antenna is this and what kind of antenna is that?"

… on his experiments with propagation and propagation software:

I've gotten the HF propagation models off the internet and I've gotten various VHF and UHF propagation models off the internet - you can get these for free - and then I've tried to actually reproduce (their predictions) by doing actual experiments. I had an apartment in one part of Maryland, and then I stayed in another part of Washington, DC, and then I had a place that I stayed sometimes in New York, so I set up robot stations, if you will, that I controlled using GoToMyPC®, where I had a PC controlling one radio, and I had a PC controlling another, so anywhere in the world, I could get in and control my computers, and it was very interesting - it was like fusing the internet with ham radio, and I could control it from anywhere, and it was very interesting."

"And so I said, 'OK, how well do these propagation models really work?' Well, what I found out was that they could be 10, 15, 20 dB off, and so what that says (is) that they were OK but, with ionospheric stuff and the sunspot number and all that stuff, there's a lot of room for error, and when you get into VHF and UHF, well, how much rain has there been between point A and point B? And what kind of terrain is it? Is it forest and is the forest wet?"

"Well, what I realized was that there is so little that is really known, still, about propagation … The theory of it ain't the same as the practice of it. And therein says how much work needs to be done. I gotta believe that at some point in the future, our simulations and our understanding of propagation is going to be a lot better than it is today. But who's going to make it better?"

"I remember, I sat on the FCC's Technical Advisory Board, and there was this guy, Vanu, from Vanu Systems - they do software-defined radios, and he was saying that when it comes to multipath … actually multipath can be your friend, in that if you're really smart about using multipath, all of that is just integrating different kinds of energy; if you can do channel estimation and you can do dynamic equalization, you can actually use multipath as a (way of) , getting all those echoes in the echo chamber to cohere, so that you get a stronger signal."

"The thing about multipath is that you get local areas, because of constructive and destructive interference, you get local pockets of voids and real peaks, and I found this with WiFi inside buildings. You can move your antenna around, and a few feet makes a huge difference. And the other thing I found that's interesting about WiFi in buildings is, if you're in a big high-rise, the elevator - where is the elevator? - Is the big metal cord that holds that elevator absorbing and re-radiating (RF)? I think it is. And it's very interesting. But a lot of that is black magic. If you get on the internet and you want to find out what the effect of different building materials are on attenuation of different wavelengths, it's not easy to find good information. And the information that is out there is kind of preliminary and spotty."

"Someone else said they're trying to figure out what the bandwidth limits are of a volume of space - how much information can you cram in to a volume of space with different RF? And they concluded that there was no limit, for some of the reasons that I got into, that, what is the limit? Multipath? Dynamic multipath? Co-channel interference? Well, all these things are not crisp, so really what I'm saying is that there is a huge body of information yet to be discovered in the analog and propagation arena that has tremendous room for improving the quality of RF communications "

… on promoting growth in digital technology at the expense of analog RF technology, and using new technology to develop mobile and handheld HF rigs with reasonably-sized antennas:

"I think a danger in having things too skewed toward the digital is, when I look at software defined radios, for example, which are obviously a big, coming thing, they're the future. Some people would argue, depending on how you define software defined radio, that we've been there forever. You buy a Yaesu 857D and you can configure that thing to do lots of different stuff, and you can hack it to do lots of different stuff. But its RF front-end, the mixing and all of that stuff, are still not software, and people are saying, well someday, you're going to have a pure digital timebase and mixing will be done purely in a digital realm, and when you reach that point, and all the other stuff is software, then you've got a true software defined radio. "

"Is the big metal cord that holds that elevator in a high-rise building absorbing and re-radiating (RF)? I think it is."

"Well, sure, but how do you solve the problem of desensitizing the front-end stage if you've got such broad band? How do you really get good selectivity on the front end so you've got decent signal-to-noise ratio in the passband of interest? Well, you're going to have to get into the analog realm, and you're going to have to have an antenna that's electrically short that's still as efficient as it can be, with good impedance matching. Well, how do you have a transmatch network that works from, say, the 700 MHz band, which is just being auctioned, on up to WiMax at 5 GHz or beyond? How do you do that? Well there are some really interesting technologies out there (such as) electrically-controlled dialectrics … some very interesting technologies with metamaterials, like metaferrites, that offer some really interesting opportunities for, on the one hand, increasing the range over which you can do an impedance match…

"One of the things I've been interested in as a ham is having a lot better mobile rig for HF, and the thing that always bugs you is the antenna. You can't haul around a 40-meter dipole. People get very clever about using slinkies, making things they can uncoil on spring-loaded coils and all kinds of stuff, so people address these problems, but what I want is a really good HF handset. And there is a company in Japan that makes an HF handset, but you've got to know, just from looking at the math, that that antenna's got to be 20 dB down from what you get with a dipole, if you're lucky. I want to do better than that. I want to do as good as theory says I can do, and that's going to require things like metaferrites, and metamaterials."

(Metamaterials generally are man-made substances, also known as electromagnetic composites, whose properties are determined by their inter-atomic structure rather than the composition of their constituent

atoms. We asked Eric to explain their potential role in shortened antennas.)

"Metaferrites - if you look at the equations of radiation resistance, what they will tell you is that if you have a ferrite core that can concentrate the magnetic lines of flux in a B-field (magnetic field) antenna, that you can get very, very good efficiencies in a very small package because you've essentially increased the electrical length by compressing the magnetic lines of flux. The problem that you get with ferrites is that they saturate and you've got hysteresis problems and heating problems and core losses. So what happens is, above a watt, ferrites don't work very well, because you've got heating and all of those theoretical improvements in radiation resistance go away. And it has to do with things like eddy currents and heating and various other ohmic losses that essentially decrease the ratio of your radiation resistance to your loss resistance, which is the efficiency of the antenna. So in theory, a metaferrite can address a big chunk of that problem by pushing up the power at which you start to get those effects. And it has to do with the way the domains are laid down and you get a kind of a herringbone type of pattern at the nano-scale. So this is nanotechnology that comes up with a ferrite type of material that can start to push back the boundaries of what's possible by concentrating the magnetic lines of flux in an antenna."

"I've been watching the metaferrite developments with some interest and, like I say, what I'd like to do is be able to do a handheld that's good on HF. And you really can't do that very well right now. I see that it's making progress, but it's not making progress nearly as fast as, for example, ALE is (automatic link establishment)."

"I think analog is *hugely* important to the future ... I mean, when you get right down to it, everything is analog."

"That is an example of, really, digital technology that is improving HF because as you know, HF is an ionospheric propagation problem and the ionosphere is very fickle. It comes, it goes, and ALE enables you to do the best that can be done given the ionospheric conditions when you're sending and receiving ... But now let's think about that. If I had an impedance matcher that had really good performance from 160 meters down to 10 meters, and I had an antenna that could handle that kind of range, then my ALE would be better … There are impedance matchers, or there are transmatch and auto-transmatch networks, that will operate over wide ranges, but their performance … you pay a penalty. The wider the range, the less optimum you're going to be within any given (range) … so wouldn't you like to have ALE which would work over as wide a range as possible?"

"So I see a bottleneck there, again, on the analog side of things. Now part of that is physics. As you shrink the size of an antenna, your aperture goes down and you're sampling less of the field, you've got less of a gradient that you're sampling, and so you're only going to be able to do so well with that, even by playing games with using B-field antennas and stuff like that. But the fact is, we aren't there yet in terms of what theory says can be done. And the fact that we haven't made as much progress there says more about what people are interested in, in the talent base that we have, than about what theoretically can be done.

"And that's just another example of what I'm talking about. I think that the reason a lot of that isn't known is that, first of all, it's a very hard and esoteric subject, that the models that we have for simulating these things are fairly crude, and that there aren't a lot of people pushing the ball down the field. If you say, well, a lot of money is to be made if someone's really, really smart at analog and comes up with a wireless network that's way better than everybody else because they get this stuff. So, I don't think it's just hype or self-serving to say that the analog and the RF world, and the ham radio world, that lives in that space, has a lot to offer. I think it's really true. We just have to reposition it. We just have to be clever at drawing that picture and drawing it in a way that will excite kids."

There are a few companies that I'm aware of … (one) called Paratech in Maryland, that is working on these controlled dialectrics that do a better job of impedance-matching, and every time I talk to them, they've made some progress; I don't know where they are 'cause I haven't talked to them in a while, but that kind of thing is very interesting. And then there are these guys at the University of Texas, (led by) Professor Rodger Walser … that are working on metaferrites, and then there's a group up at the University of Michigan in their radiation lab, that are also working on metaferrites. And they're making progress. You'd like to see the progress faster. Wouldn't it be cool, as a ham, to have that kind of flexibility I've been talking about? Where you can tune over that kind of range and harness all of the advantage of ALE? Wouldn't that be cool?"

After the 9/11 terrorist attacks, Haseltine applied for, and got, a position as head of research for the National Security Agency, whose headquarters are seen here. (NSA photo)

… on the perception by some people - even some hams - that ham radio today, perhaps because of its reliance on analog technology, and things like Morse code, is archaic:

"Well, I think you have to separate out perception from reality. What I've been

trying to say throughout this interview is that I think analog is hugely important to the future, to where things are today and, more important, where they're going. So I think the opposite is true. I mean, when you get right down to it, everything is analog."

"If you look at a gate transitioning from a zero to a one, and you magnify it in time, you see a very analog-looking signal. And if you look at what's happening with digital technology as it shrinks, more and more of the analog world becomes important. Stray capacitance, coupling, filtering of the signal, shaping of the signal; ultimately, we get into the quantum world, which obviously isn't analog but it isn't digital, either. So I think in many respects, the analog world is more relevant than ever."

"And again, when I look at where the bottlenecks are in harnessing the promise of this digital revolution or this electronics revolution, more and more of those bottlenecks are going to be analog, as I've described -- impedance matching, electrically short antennas, things of that nature. So I think, logically, no, analog is more relevant than it has ever been."

"But from a perception point of view, look at it from the point of view of a kid who's 11 to 14, and getting interested in technology. They take for granted a lot of things that hams do. I mean, 'why should I have an HF rig when I can just get on my cell phone?' or 'I have a WiFi for doing broadband data, or pretty soon, I'll have WiMax, well, what's the point?' So I think that the real way to ask the question is, "What would make ham radio as attractive to a 12-year-old as the internet or WiFi or WiMax?" And if you can't answer that question, then it becomes irrelevant, de facto, because you can't get a new generation of kids interested in it."

"So, here's what I think: I think that if ham radio operators were out ahead of the rest of the world in harnessing these analog technologies and doing things that you can't do with wireless today -- for example, 'Yeah, you can do WiFi, but can you have you have your own network and communicate with a buddy two states away?' You can't find WiFi hotspots everywhere. What if you could carry around your own equivalent WiFi hotspot and it wouldn't matter where you were?"

"I find that when I talk to hams, when I get on the air and I talk about my passions of electrically short antennas and impedance-matching over jaw-dropping ranges, I find there's not a lot of interest in that. People say, 'Oh, that's kind of interesting,' and every now and then, you find a guy who uses magnetic loops or has done stuff like that, but I find there are not a lot of hams that are interested in the things that I'm interested in, way, way out at the cutting edge of the analog technology, and there are some, obviously, but I think hams could help themselves by focusing more on the real cutting-edge stuff that can do things that the technology that's out there today can't do, that would excite and capture the imagination of kids. Because as great as wireless technology is, it still has huge shortcomings. You try to use your WiFi just anywhere, you can't. You try to use it while you're moving really fast, it's a problem… So I think that if ham radio positions itself as doing really cool things that can't be done any other way, then I think kids'll get interested in it.

"When I look at where the bottlenecks are in harnessing the promise of this digital revolution or this electronics revolution, more and more of those bottlenecks are going to be analog ... So I think, logically, analog is more relevant than it has ever been."

... on how he would try to get young people interested in ham radio.

"When you think about it, ham radio is about communicating, and now there are so many other ways to communicate, so many things, I mean, what are kids into today? YouTube and Facebook and MySpace; instant messaging. They are so far ahead of where ham radio typically is, I mean, yeah, you can send video files over ham radio, but think about how hard it is, and then, why would you go through all that? I can just get on, take my phone, click a button and send a video. Why should I do ham radio? … Somehow or other, kids are going to have to think it's really cool…"

"Ham radio, when you look at what it can do, really isn't as powerful as what other things can do, like your cell phone, WiMax, WiFi, ultrawideband, Bluetooth, and so forth. However, ham radio is much more accessible if you want to get in and do it yourself. If you're not content with just using what other people have already done, but you want to get in and learn how to do it yourself, ham radio is a lot more accessible … So I think that if we were able to somehow let kids know that this is a great place to pursue your curiosity, and it's an important place for the future, because the stuff you're doing here isn't some arcane hobby of old farts, it's a place where a lot of the future is going to be invented."

"If we can somehow communicate that, let's create a vision of the future of radio frequency communications, let's say it's a three-dimensional space, and on one axis, you have something like coding theory, like squeezing the maximum bits per Hertz out of a particular passband - getting as close to Shannon and Nyquist as it is possible to get; and on another axis you have things like flexibility of processing, so that, the software defined radio axis versus the coding axis, let's say. And on the third axis, you have analog RF - antennas, impedance matching, that kind of stuff. And what you show is that, left to its own, two of these axes are going to mature like crazy, in two dimensions. But it's going to be a flat world because there's always a ceiling imposed, and I'm saying, let's say in this world I'm drawing, that analog RF is in the vertical dimension, so that's Z, and X and Y are the (other) two axes."

"And you say, well look, wouldn't it be cool to raise the ceiling on what the art of the possible is? And that ham radio has the opportunity to do that because ham radio goes pretty much across the RF spectrum. It goes all the way … if you get into the low frequency, what is it, 150 kHz … there are experimental things being done down there, all the way on up to KA band (20-30 GHz) and beyond. You know, millimeter wave. So, ham radio is going almost from DC to daylight, and there's going to be a natural tendency to find more and more spectrum and use it in more efficient ways."

"The world needs to have the ceiling in this three-dimensional space that I've described raised, but who's going to do that? It ain't gonna happen on its own, that we're going to kind of squash out and extend what can be done with wireless in this two-dimensional space that digital enables, without fully realizing the whole solution space if we got smart about analog. Maybe that's a way of portraying it, that there's this exotic land of discovery to be found at the inter-

section between better analog and better digital, that only you, as a young kid, can cause to happen if you get out there and help us find it. In other words, paint a picture. Make it look exotic, and make it look like exploration and discovery."

… on what he would say to parents who want to interest their kids in science, technology and ham radio:

"Well, if you're a father or a mother who has a kid who you want to get interested in science and technology through ham radio, one thought is, it's gotta look cool to them from their perspective, not your perspective. So first, the question is, what is really cool to them? And I think if you start there and try to figure out what about ham radio aligns with what they already think is cool, not what you think is cool, you may find some interesting answers."

"Like, for example, what if your kid really is attracted to doing things that he can do so he or she can brag about it, that other kids can't do, that other kids want to do? I don't know what the answer is to that question, but I know there are some answers in ham radio. And I think the other thing is, what is your kid naturally curious about? Just on their own, without you even telling them about ham radio? Then find out that, if you don't know it, and look at ham radio and see if there are answers to that … "

"This is part of my human factors background. When you want to try to get people to do things that are outside of their comfort zone, what I have always found as a way to do that is to find that element of what you are doing that is inside their comfort zone. You just have to make them know that. And I gotta believe that, with all the opportunities that are in ham radio, that there's gonna be a lot more possibilities for doing that. So I guess that's what I would say."