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January 12, 2000

Jeffrey L. Ross
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VIA COURIER

Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
445 12th Street, S.W. TW-A325
Washington, DC 20554

Re: *Ex Parte* Submission, Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, ET Docket No. 98-153

Dear Ms. Roman Salas:

This letter is to advise you that, on January 11, 2000 the undersigned, along with Mr. Scott Blake Harris, met with Ms. Kathy Brown, Chief of Staff to Chairman Kennard, to discuss the above-referenced proceeding.

Purusant to Section 1.1206 of the Commission's Rules, 47 C.F.R. §1.1206, an original and a copy of this letter, along with copies of the documents provided at this meeting, have been submitted for inclusion in the public record.

Please contact me at the phone number listed above if you have any questions concerning this letter.

Sincerely,

Jeffrey L. Ross
Counsel to
Time Domain Corporation

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List A B C D E

THE NATION'S NEWSPAPER
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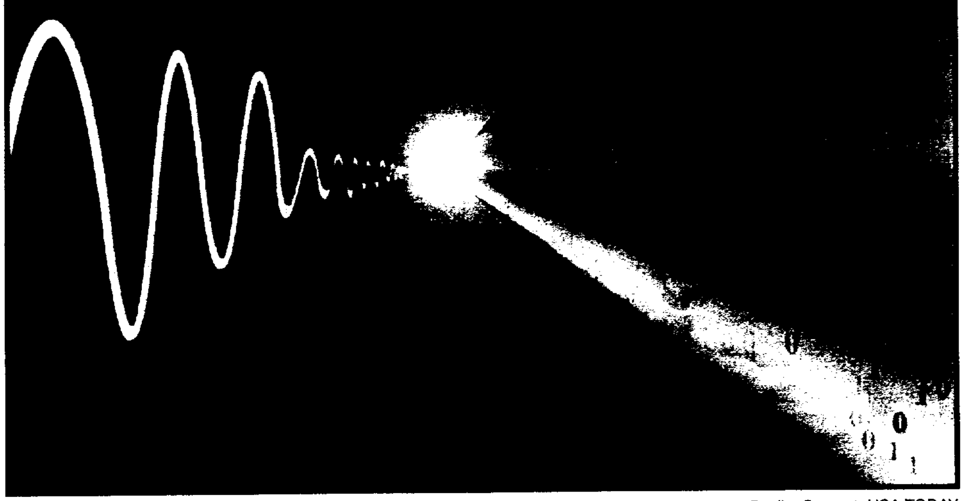
FRI./SAT./SUN., April 9-11, 1999 1B & 2B

Pulsing with promise

New digital technology likely to revolutionize how we live



By Jim Sergent, USA TODAY

By Kevin Maney
USA TODAY

HUNTSVILLE, Ala.—A little-known company in this city of rocket scientists is about to explode onto the scene with an invention that might be as important as the transistor or electric light bulb.

Front Page Story

COVER STORY

The company is Time Domain. Its breakthrough is the work of Larry Fullerton, a lone inventor who harks back to the era of Thomas Edison. His invention is a way to transmit information wirelessly, but not using radio waves. Instead, it uses pulses of radio energy, fired out at 10 million to 40 million pulses a second.

The potential impact is astounding. If the technology lives up to its promise, it would be like the leap from vacuum tubes to the transistor or from oil lamps to light bulbs, touching every home and workplace. Wireless communicators could get down to the size of a quarter. Radar could become cheap and commonplace. A home radar system could be used for security, detecting movement inside and distinguishing a cat from a man. Already a reality is hand-held radar that police can use to see inside a room before bursting in.

The pulse technology, sometimes also called ultra-wide band (UWB), could launch whole new industries and reorder several existing ones in coming decades.

"This is a technology that's as radical as anything that's come up in recent years," says Paul Turner, a partner at PricewaterhouseCoopers who has studied Time Domain and advised the upstart company. Others agree. Representatives from major technology companies have trooped to Huntsville the past few months. "If they can really pull it off in volume, it can be quite huge," says IBM Vice President Ron Soicher, who admits to getting goose bumps when he realized the potential.

The technology is digital. Each of the whizzing pulses is a 1 or 0, so the transmissions are as flexible as a computer, able to handle phone calls, data or video. The pulses can carry information or media as fast as the speediest corporate Internet connection. The pulse technology has other advantages:

▶ It could open up capacity for radio communication. Today, there's a wireless traffic jam. Users of radio waves have to operate in their specific, government-granted slices of the increasingly crowded radio spectrum; otherwise, they'd interfere with one another. But it's unlikely the pulses would interfere with each other or with conventional radio waves, so the pulses would open up vast new radio real estate.

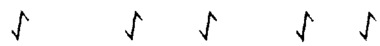
▶ Pulse devices could operate on one-thousandth the power of devices that use radio waves, so a phone could be the size of a wrist-watch.

▶ The pulses in Time Domain's technology are read by timing the incoming pulses

How pulse technology works

Time Domain founder Larry Fullerton has come up with a new way to send and receive signals over the air. For the past 100 years the only way to wirelessly transmit signals—voice, music, TV, data— has been by radio waves.

Fullerton's digital pulse technology transmits pulses of energy instead of waves. Each pulse represents a 1 or a 0, the digital language of computers. Ten million to 40 million pulses are sent per second, fast enough to carry voices, Web pages and video.



The benefits

1 Pulses work around crowded radio spectrum.

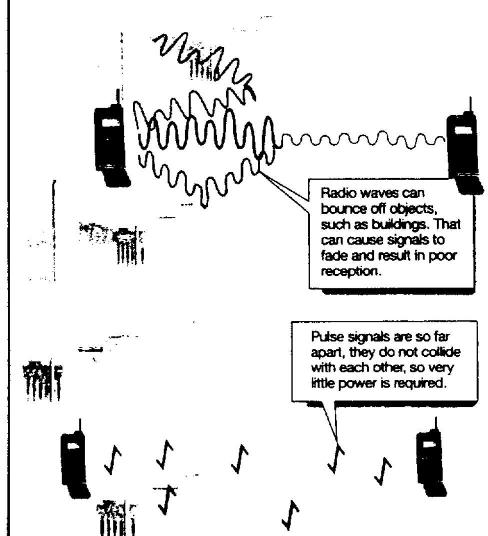
There are limits on how much information waves can carry and how much space there is on the radio spectrum. As things like cell phones and satellites proliferate, the radio spectrum is becoming scarce.

The pulses have no frequency – no slot on the radio dial. Instead, the pulses are spread across the radio spectrum.

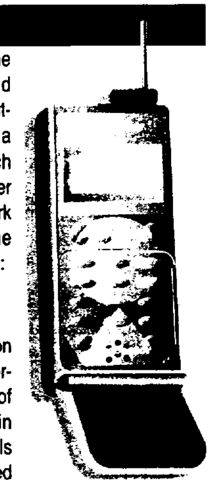
Because pulse technology doesn't eat up spectrum, it could unlock the current radio-spectrum traffic jam.

The downside is that in doing so, it might threaten the entities that have spent billions of dollars to buy rights to chunks of radio spectrum.

3 Less battery and transmitter power is needed



The new phone



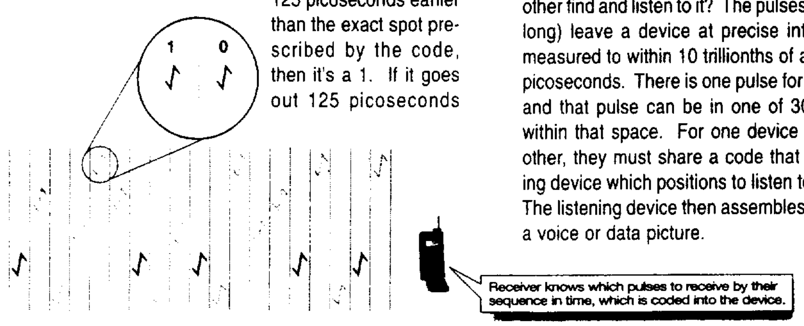
A cell phone built with Time Domain's technology would have three pieces: a transmitter, a correlating receiver and a processor. Eventually, each would be on a single computer chip. They'd all have to work together to make the phone work. What each piece does:

Transmitter:
Sends 10 million to 40 million pulses per second. The intervals are staggered in any of 30,000 different spots within every 100 feet. The intervals vary according to a code stored in the device. The transmitter operates on the same digital principle as a computer, creating all information out of 1's and 0's.

Correlating receiver:
Once the correlating receiver knows the code that governs the intervals of the pulses, it listens at those intervals and figures out whether each pulse is a 1 or 0.

Processor:
The processor acts like a traditional computer chip. It assembles the 1's and 0's into information, then turns it into sound, video, or data on a screen.

2 How the pulses communicate



If a pulse goes out 125 picoseconds earlier than the exact spot prescribed by the code, then it's a 1. If it goes out 125 picoseconds later, it's a 0.

If one device sends out a signal, how does another find and listen to it? The pulses (each 6 inches long) leave a device at precise intervals in time, measured to within 10 trillionths of a second, or 10 picoseconds. There is one pulse for every 100 feet, and that pulse can be in one of 30,000 positions within that space. For one device to listen to another, they must share a code that tells the listening device which positions to listen to in what order. The listening device then assembles the pulses into a voice or data picture.

This timed pulse system has a number of amazing characteristics.

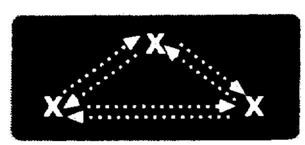
One is security. Because of the astounding number of possible combinations of positions, Time Domain says, there is no way to tap into this kind of communication unless you have the code.

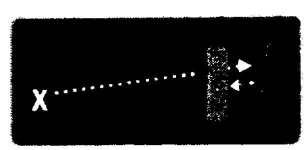
Another by-product of the huge number of combinations is that 2,000 to 20,000 people could use pulsed cell phones in the same square block and probably never interfere with one another or overload the cellular system. A conventional cell phone system can only handle about 400 users in one small area.

Other uses of the technology

Geographic positioning: Because of the precise timing of outgoing and incoming pulses, a device can measure the time it takes for a pulse to get to it or bounce back from it. In doing so, the device can tell how far away the sender of a pulse is or how far away an object is. The accuracy is within less than an inch, compared with 5 feet for global positioning satellite, or GPS, systems. That accuracy could enable farmers to use robotic equipment.

Radar: Using the same technique, the device can act like radar. But unlike radio-based radar, which gets confused indoors because of waves bouncing around, pulsed radar works indoors, through walls and underground. Because pulsed radar requires little power, pocket radar is possible.





By J.L. Albert, USA TODAY

TV, radio, telecom changes in store?

to 10 picoseconds—10 trillionths of a second. Any pulse device could tell how long it takes for a signal to get to it, which makes it able to sense objects and measure their position more accurately than conventional radar. Radar could be a mass-market product for homes or cars.

▶ The pulses are timed according to a complex code shared only by the sender and the intended receiver. The chance of anyone who doesn't have the code intercepting the signal is near zero. That means pulse communications should be the most secure way ever to transmit wirelessly– of major interest to the military.

Fullerton started working on the technology in 1976 and got his first patent for it in 1987. But the technology was crude, Fullerton didn't have the money to push it, and the world wasn't paying attention. All that is changing in a big way.

Photo by Charles Seifried

Pulse wave of the future: Ralph Petroff, left, and Larry Fullerton of Time Domain are working on digital pulse technology.

Band of believers grows

In Time Domain's offices are prototypes of a wireless phone that can measure the distance to the other party, cameras that can transmit video wirelessly to a computer screen, and radar that works indoors and through walls, which conventional radar can't do. The prototypes are hand-built and clunky. "We haven't built a lot of things yet, so we don't know how much reality will intrude on theory," CEO Ralph Petroff says. "But our guys say they can do it."

The list of believers is growing. The Federal Emergency Management Agency has contacted Time Domain because its radar technology could pinpoint victims beneath an earthquake's rubble. "This technology has the potential to reduce casualties among civilians and rescue workers alike," says a comment FEMA filed with the Federal Communications Commission.

The Marines have been looking at Time Domain prototypes because they'd like a walkie-talkie that's not only undetectable but can tell a Marine the location of all the other members of his unit. The Immigration and Naturalization Service is doing a pilot project with Time Domain. It's interested in ways the technology could be used along the border. Put a wireless, low-power camera in a cactus, and it could transmit video back to INS agents; no need to string telltale wires across the desert.

A few pulse technology products are ready for a broader market, pending FCC approval. Time Domain has made handheld radar that police could use to see inside a room before bursting in. A couple of small companies are making pulse radar devices for measuring liquid in steel storage tanks. A handful of research labs, such as the UltRa Lab at the University of Southern California, are experimenting with pulses.

Mass-market products are still years away. Cell phones, Petroff predicts, are a decade off. "There are still three to four iterations of design that have to go on before we really know if it all looks good," says Robert Scholtz of UltRa Lab. "Still, no one has disproved its potential."

Recent developments are giving the technology a head of steam.

Until about a year ago, Fullerton's invention was, as he says, "a science project." It worked only in theory or in awkward and costly lab experiments. Then IBM came up with a new way to make a chip using the material silicon germanium. That chip turned out to be perfect for measuring time to the picosecond and controlling release of the pulses—at low cost. Working with IBM's Soicher, Time Domain became a test project for the chip. "It's been a perfect match," says Alan Petroff, brother of Ralph and head of Time Domain's engineering work. "We wouldn't be doing this now if not for that."

Another development has to do with money, and lots of it. In 1995, Time Domain was an 11-person Huntsville company that struggled to make payroll. Since then, the Petroff family, which previously had built a multinational environmental engineering company, invested $3 million and took over management. (Fullerton, who admits he's an inventor, not a manager, still owns more than 20% of Time Domain and is the company's most valuable asset.) The Petroffs have raised an additional $17 million from dozens of investors, many from Silicon Valley.

The money has enabled Time Domain to build prototypes, hire engineers, do some marketing and get to critical mass. "They now have a backbone of credibility," says Heidi Roizen, a powerful Silicon Valley player who has advised Time Domain and introduced it to the computer and Internet crowd. "They have proved their concept, and they've gotten out to meetings" and people are taking them seriously, she says.

New industries, not old

Events this week are helping. Today, the House Science Committee is releasing a report that could clear up confusion about the technology. For most of the 1990s, Fullerton has been in a patent dispute with the federal Lawrence Livermore

National Laboratory. He alleges that Livermore tried to swipe his pulse technology by applying for a similar patent in 1993. In a preliminary ruling, the Patent Office has thrown out Livermore's key patent claims, citing Fullerton as the true inventor. In today's report, the House Science Committee will castigate Livermore for its behavior and say Fullerton is the inventor.

Tuesday, Ralph Petroff gave a brief report to FCC commissioners at their invitation. It was a sign that another obstacle might begin to move. No one can even test a pulse-transmitting product without approval from the FCC, and so far, the FCC has granted none. In fact, the agency has been very wary of the technology, which doesn't fit with anything it has experienced before.

The technology has come far enough to let Time Domain and others begin thinking of ways Fullerton's invention could change the world.

Certainly the technology could have a profound—maybe devastating—effect on several existing industries. Companies in TV, radio and telecommunications have spent billions of dollars buying rights to slots on the radio spectrum and billions more developing products to use on those slots. It might take decades, but Time Domain's technology could make those rights far less valuable and the products obsolete. "This is really a paradigm buster," says Bennett Kobb, author of *SpectrumGuide*, which keeps tabs on radio spectrum.

Time Domain, however, pointedly says it's not trying to go at existing industries head-on. For one, it would rather have companies like Motorola and AT&T as allies, not enemies. "Time Domain has to try to get into the market in a manner that's as non-threatening as possible to other stakeholders, who will try to protect their turf from any kind of alien thinking," Kobb says.

Second, Ralph Petroff says he's interested in spawning new industries, not scrambling old ones. Time Domain wants to use the Intel business model. It would make the internal chip set that could power any product: Time Domain inside. Entrepreneurs and big companies would come up with the innovative products based on the technology. Just as no one could imagine how the transistor would be used when William Shockley fathered its invention in 1947, no one knows how pulse technology might be used.

But Petroff has some intriguing ideas. For instance, the technology's ability to measure a position is so good, it can be accurate to within less than an inch. That would allow for what Petroff calls precision farming. Put pulse technology on a tractor, and the vehicle could plow a field by itself. Or the positioning aspects might allow for the creation of a self-guided bricklaying machine.

Time Domain technology could be perfect for the blossoming industry of home computer networking. The single biggest obstacle to home networking is the wiring: Who wants to string another set of wires to every computer, printer, TV and other device around the house? With pulse technology, you might be able to put a box on the side of the house that would be powerful enough to transmit TV, the Internet and phone calls to any device inside.

Tinkerer solves puzzle

The credit for all this rests with Fullerton. Inventors like him seemed to have died with the complexity of the modern age: one person, tinkering in a private lab, creating something entirely new.

"He is a brilliant inventor, and he does have a lot of the sort of Edisonian quality," says Turner of PricewaterhouseCoopers.

Fullerton is 48, married, with two grown children. He's had a lab since he was 7. His father was in the military, and they moved a lot. His labs went with family. At 13, he was introduced to amateur radio by a neighbor at McChord Air Force Base in Tacoma, Wash., and was fascinated. He went to the University of Arkansas in Fayetteville, Ark., where a favorite professor, Leonard Forbes, told the class one day of a theory of pulsed communication. Research on the theory had been going on for years. But, Forbes said, pulses could never be transmitted.

"I couldn't think of a reason it wouldn't work," Fullerton says. And if it worked, he realized, its potential would be awesome.

He kept experimenting in his home lab until one day he used pulses to transmit music—a tape of the album *Chicago* III from his workbench to a hand-held receiver in his yard. "When it worked, I got kind of a spooky feeling," he says.

He got jobs with big companies—Texas Instruments, ITT, CSC—and started a small, not-very-successful one. He kept tinkering. CSC brought him to Huntsville, where he looked up a patent attorney and won his first patent. He now has 10 U.S. patents for pulse technology and 32 abroad.

Lanky and bearded, Fullerton comes across as painfully shy, but underneath he is steely and wily. He met Alan Petroff in the 1980s. Peter Petroff had come from Bulgaria to work with Huntsville's rocket scientists building the U.S. space program in the 1960s. He then invented the digital watch, founding Pulsar in 1969, and later built ADS Environmental Services with his three sons, Ralph, Alan and Mark.

By 1995, Fullerton lured in Alan Petroff, who took a $25,000 salary just to get in. A year later, the rest of the Petroffs joined him. "We had all planned to retire," says Petroff, now 44.

The Petroffs brought money and management. Without them, Fullerton's invention might have died.

Hurdles to history books

Time Domain still faces obstacles aplenty. It needs to build more prototypes to prove without a doubt that the technology works as advertised. So far, the company has encountered no serious glitches in its march to do so. Time Domain also needs to carefully choose partners—staying wary, as Roizen advises, of big companies that might then bury the technology amid bureaucracy and infighting.

The FCC is a huge obstacle. Time Domain has been trying to prove that pulse communications would not interfere with other signals on the radio spectrum, but Scholtz says that's "still an open question." The FCC has not yet granted Time Domain waivers to test products. Commercial products will require a major rule change that can take to two years. But the FCC is listening.

I hope (that it would be approved)," says John Reed of the FCC's technical rules branch. "There are quite a few benefits that could be obtained from it."

And since Time Domain plans on building innards, not products, "it must ignite the entrepreneurial community so people will build these things," Roizen says.

But the technology seems to be on the right path.

"Until a few years ago, I'd wake up in the middle of the night and say, 'What am I doing?'" Fullerton says. "But the way I feel now, there's no stopping it."

Contributing: Peter Eisler

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Bandwidth from thin air

Two new ways of transmitting data by wireless exploit unconventional approaches to create valuable additional capacity

They may be invisible, yet chunks of radio spectrum are fought over just as much as parcels of land. Governments raise billions by auctioning parts of the spectrum to mobile-phone companies and radio and television stations. Other frequencies are reserved for air-traffic control or the sending of distress signals. The most desirable addresses on the spectrum, like apartments in the trendiest parts of town, are in short supply—hence the high prices paid for them. To make the most of limited "bandwidth", as it is known, engineers have devised elaborate schemes to allow several devices (such as mobile telephones) to share a single frequency by taking turns to transmit.

Two emerging technologies now promise to propel such trickery into new realms, by throwing conventional ideas about radio transmission out of the window. The first involves multiple simultaneous transmissions on the same frequency. The second, by contrast, transmits on a huge range of frequencies at once. Outlandish though it sounds, the effect in both cases is to create hitherto unforeseen reserves of valuable bandwidth, practically out of thin air.

Don't all talk at once. Actually, do

Turn the dial (or press a button) on a radio, and you determine which station's signal is played through the speaker. Now imagine that several radio stations are transmitting on exactly the same frequency, so that their signals interfere with one another. Is it possible to build a new kind of radio, capable of separating the signals, so that just one of them can be heard clearly?

The conventional answer is no. Once radio signals have been mixed together, trying to separate them is like trying to unscramble an egg. In 1996, however, Gerard Foschini of Bell Labs (the research arm of Lucent Technologies, based in Murray Hill, New Jersey) suggested that multiple transmissions on a single frequency could be separated after all—by using more than one receiving antenna and clever signal processing. The result was a technology called Bell Labs Layered Space-Time, or BLAST.

The prototype system, which is now being tested, transmits via an array of 12 antennae, all of which broadcast a different signal, but on exactly the same frequency. At the receiving end are 16 antennae, also spaced out, each of which receives a slightly different mixture of the 12 broadcast signals—which have bounced and scattered off objects along the way.

Computer analysis of the differences between the signals from the receiving antennae, helped by the fact that those receiving antennae outnumber the transmitting ones, enables the 12 original signals to be pieced together.

Exploiting this result, it should become possible to transmit far more data than before over a wireless channel of a particular size. For convenience, the researchers used a channel "width" of 30kHz, the size of the channel used by analogue mobile phones. Normally, a data-hungry process such as accessing a web page over such a link is painfully slow. But using BLAST, transmission speeds of up to 1m bits per second have been achieved. By increasing the number of antennae at each end, it should become possible to squeeze even more capacity out of a fixed-size channel, albeit at the cost of far greater computational effort.

The technology is not, however, intended for mobile use. The multiple transmitting and receiving antennae, and the powerful signal-processing hardware involved, will be difficult to fit inside portable devices. In any case, too much moving around causes the mixture of signals received by each of the antennae to vary in ways that even the most sophisticated computer cannot cope with. Instead, according to Reinaldo Valenzuela, who is in charge of the research, BLAST is more suitable for use in fixed wireless applications, such as providing high-speed Internet access to homes, schools and offices, or establishing telephone networks in isolated areas without laying cables.

If transmitting several signals on the same frequency sounds odd, what about transmitting on many frequencies simultaneously? That is the principle behind another novel form of wireless-communications technology known as ultra-wideband (UWB). This is being developed by a small company called Time Domain, which is based in Huntsville, Alabama. The technology is the brainchild of Larry Fullerton, an engineer who has spent the past 23 years working on the idea.

Whereas conventional transmitters (and BLAST transmitters) operate at a particular frequency, just as a single key on a piano produces a particular note, a UWB transmitter emits a pulse of radiation that consists of lots of frequencies at once, akin to the cacophony that ensues when all the keys on a piano are pressed at the same time. The pulse is very short—just half a nanosecond (billionth of a second)—and is transmitted at extremely low power. Because it is a mixture of so many frequencies, such a pulse passes unnoticed by conventional receivers, which are listening for one particular frequency.

But to a UWB receiver, listening on a wide range of frequencies at once, it registers as a distinct pulse. Information is sent by transmitting a stream of pulses—apparently at random (to fool conventional receivers), but actually at carefully chosen intervals of between 50 and 150 nanoseconds, in a pattern known to both transmitter and receiver. By varying the exact timing of each pulse to within a tenth of a nanosecond, slightly early and slightly late pulses can be used to encode the zeroes and ones of digital information. The resulting system can transmit data at 10m bits per second, without any interference with conventional transmissions.

Or so Mr Fullerton and his backers at Time Domain contend. So far, however, America's Federal Communications Commission (FCC) has not approved the technology for anything more than experimental use. But there are signs that UWB could, after a long gestation, soon emerge into the marketplace. At a conference in September to rally support for it, Susan Ness, an FCC commissioner, spoke in support of the technology and said regulations permitting it to be used would be announced next year.

Several firms are lining up to make products based on UWB technology. Time Domain, which owns the relevant patents, plans to supply these firms with its chip, called PulsON, to do the hard work of generating and detecting UWB pulses. And as well as communications, UWB also has an intriguing potential use in radar (see article).

Neither BLAST nor UWB quite create something out of nothing. Both technologies cunningly conjure up extra bandwidth at the cost of increased computational complexity. Over the past few years, however, the cost of computing power has plummeted, and demand for bandwidth has soared. Trading one for the other could prove to be a very good deal.

How to look through walls

Besides its use in communications (see other article), ultra wideband (UWB) pulse radio might have a future as a radar that can see through walls, and do so in great detail. It should, its manufacturers hope, be able to distinguish a cat from a cat burglar, or detect barely breathing bodies under several metres of rubble after an earthquake. More mundanely,do-it-yourself enthusiasts will be able to use it to check for power cables and pipes beneath the plaster before they start drilling.

UWB radar works like normal radar in so far as it depends on sending out radio signals and listening for the reflection. But unlike ordinary radar, which takes the form of continuous waves, UWB signals are short pulses of energy.

As a means of radio communication, UWB works because the chips in the receiver are able to time the pulses they are hearing to within a few thousand-billionths of a second. Even at the speed of radio (ie, the speed of light), a pulse will travel only a few millimetres in that time. Since, in the case of radar, the receiver is also the transmitter, it knows exactly when a pulse was sent. By measuring how long that pulse takes to return, it can place the distance to the point of reflection to within that level of accuracy—enough to tell whether an aircraft's wing-flaps are up or down. Four million pulses a second are sent out to provide a near-perfect picture of what the target looks like.

Conventional radar relies on high-frequency (and therefore short wavelength) radio waves to achieve high resolution. Long waves would produce fuzzy images. But when the resolution depends on pulse-length, wavelength does not matter. So UWB radar can employ significantly longer wavelengths, and these can penetrate a wide range of materials, such as brick and stone, which are denied to their shortwave cousins.The result is "RadarVision", which, like the communication technology, is manufactured by Time Domain. Though still experimental, it is being tested by several police forces around America. They are using it to look inside closed rooms that might be harbouring suspects, before the guys with the sledgehammers batter the door down. If it works, television cop-shows will never be the same again.

AS SEEN IN
The New York Times

C1
MONDAY, DECEMBER 21, 1998

Business Day

The Information Industries

F.C.C. Mulls Wider Commercial Use of Radical Radio Technology

By JOHN MARKOFF

The Federal Communications Commission is considering changing its regulations to permit the use of a radical and controversial communications technology that has the potential to make vastly more efficient use of the increasingly precious radio spectrum.

Known variously as ultrawide band radio and digital pulse wireless, the new technology has a broad range of possible applications, from wireless voice and high-speed data communications to land mine detection and advanced radar systems that could permit law officers to see through walls or could aid cars in avoiding collisions.

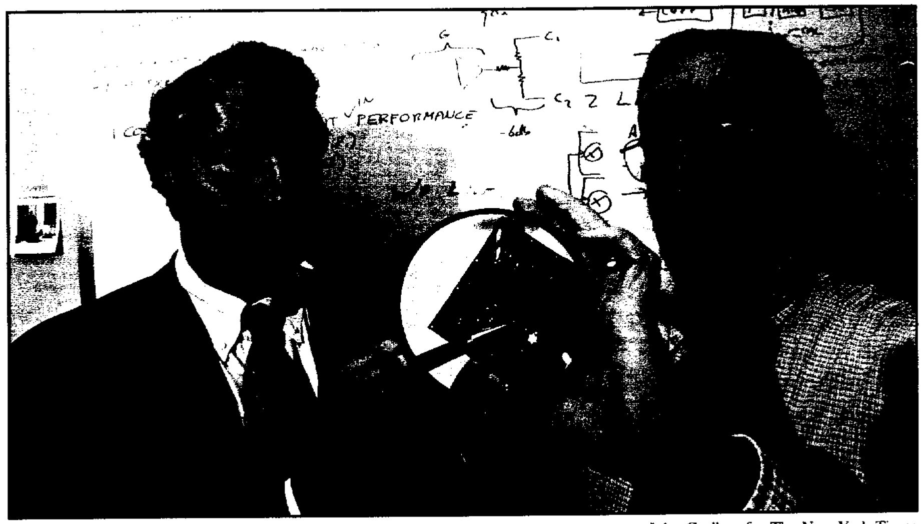
Despite its potential, however, the technology is not in widespread commercial use today because it would run afoul of F.C.C. restrictions that prohibit radio transmissions in certain frequencies set aside for civilian aviation and military agencies.

That could change if the agency agrees to proposals made earlier this month by three small companies that are pursuing the technology for a variety of commercial products.

Unlike communications technologies that send information in analog form, ultrawide band uses a digital transmission consisting of small on-off bursts of energy at extremely low power but over almost the entire radio spectrum.

By precisely timing the pulses within accuracies up to a trillionth of a second, the designers of ultrawide band radio systems are able to create low-power communications systems that are almost impossible to jam, tend to penetrate physical obstacles easily and are almost invulnerable to eavesdropping.

The **Time Domain Corporation**, based in Huntsville, Ala., has petitioned the F.C.C. for a waiver so that by the middle of next year, it can begin selling a system that will permit police officers and special weapons and tactics teams to see through walls and doors to detect the location of people. The company is also planning a covert communications system that will both carry voice communications and display locations of a counterterrorism or S.W.A.T. team's members.



Ralph Petroff, left, and Larry Fullerton of Time Domain.

John Godbey for The New York Times

"We are focusing on the safety systems because it has a great public benefit and it's a good way to introduce the technology where it can make a difference," said Ralph Petroff, the company's chairman and chief executive.

However, Time Domain executives as well as many experts familiar with ultrawide band believe that the technology's real commercial potential lies in extremely lowcost communications applications. That would entail a fundamental shift in F.C.C. regulations, a process that could take years.

"When you take its attributes and compare it to the competition, you have very interesting technology that could lead to awesome possibilities," said Paul A. Turner, executive director of the PricewaterhouseCoopers Global Technology Center in Menlo Park, Calif.

The most promising application for ultrawide band radio might eventually be an alternative to today's wireless office network technologies that are generally able to transmit data at rates between one and three million bits a second.

Because of its design, ultrawide band advocates say, the technology has the potential to deliver vastly higher amounts of data because a large number of transmitters could broadcast simultaneously in close proximity without interfering with one another.

"The most promising applications are not so much as an alternative to cellular telephone," said Lawrence E. Larson, an electrical engineer at the University of California at San Diego. "It may rather provide a much better way of doing short-range data communications because it's very energy efficient."

The computer and communications industries have already settled on a standard known as Bluetooth for wireless connectivity in an unlicensed frequency band at 2.4 gigahertz. Bluetooth, which can send a million bits a second about 30 feet using 100 milliwatts (about a tenth of a watt), is intended to interconnect devices like palm computers, laptops and cellular phones.

In contrast, Time Domain's devices can

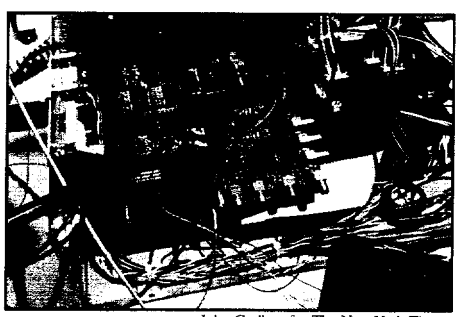
currently transmit 1.25 million bits a second up to 230 feet using just 0.5 milliwatts, or one thousandth the power used by Bluetooth. These transmission are being achieved with the first working prototype chips the company has received from **I.B.M.**, which fabricated them using the advanced silicon germanium semiconductor material developed for communications applications.

Standard wireless transmissions encode data in a continuous sine wave by varying the amplitude (the size of the wave) or the frequency (the number of times the wave cycles each second), sometimes both. In contrast, Time Domain's technology is similar to a Morse code system that at this point in its development, switches on and off 40 million times a second. And unlike traditional radio signals, which are confined to a very narrow frequency, each pulse of ultrawide band is transmitted across a wide portion of the radio spectrum, so that only a tiny amount of energy is radiated at any single frequency.

The ultrawide band system could be used to 'see through' walls.

The company said it believed that the bandwidth, or data-carrying capacity, of its technology can be expanded to many times its current limit—perhaps as high as billions of bits a second.

Moreover, while standard narrowband wireless technologies have a limited bandwidth, the digital pulse approach has the potential to handle a large number of simultaneous users in close proximity, Time Domain officials said.



John Godbey for The New York Times

A silicon chip developed by Time Domain. The chip, which can be used in ultrawide band radio systems, transmits 40 million coded wireless pulses a second.

Ultrawide band has the added advantage of being significantly more resistant to "multipath interference," a problem that plagues indoor radio systems because signals tend to bounce off many surfaces.

Industry officials said they did not expect an early resolution to the F.C.C.'s inquiry, which was begun in August. One particular obstacle is that a key official at the Federal Aviation Administration has filed an objection with the F.C.C., warning about a potential problem caused by the clustering of large numbers of transmitters, even at very low power levels.

Industry officials note, however, that current F.C.C. rules permit "incidental" emitters—generally, consumer devices like personal computers, hair dryers, electric razors, automobiles and arc welders—and that no hazard has been demonstrated from the hundreds of millions of these products in everyday use.

Last month, a group of scientists and engineers met at the **Interval Research Corporation**, a computer industry research center financed by Paul Allen, a co-founder of the Microsoft Corporation, to coordinate industry input into the F.C.C. decision-making process.

More recently, an Interval physicist, Roberto Aiello, filed an independent comment with the agency, reporting that a simulation by his research group indicated that even if millions of ultrawide band transmitters were allowed to operate, they would have a negligible impact on aviation and other communications systems.

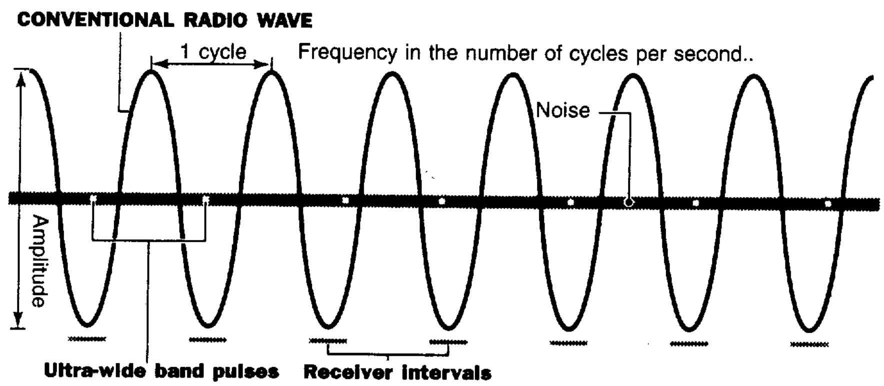
"The F.A.A. is worried about this, and I think it's a good position for them to take," Mr. Aiello said. "But I think there's concrete evidence that there will not be interference from ultrawide band."

In addition to Time Domain, companies asking the F.C.C. for exemptions from spectrum rules include Radar Inc., which is developing a system for finding buried objects and looking behind walls, and the **Zircon Corporation**, a maker of devices for such tasks as finding joists in wails.

Communicating Below a Whisper

Several small companies are developing a technology that uses low-power radio signals emitted at regular intervals across a broad range of the radio spectrum for digital communications and radar systems. Here is how the technology works.

The radio spectrum is divided into hundreds of frequencies, each reserved for commercial and military applications. To be detected, these radio waves must have a certain minimum amount of power, called amplitude. While TV antennas, wireless telephones, and many other things generate high-energy radio waves, there are also low-energy waves, called "noise," that come from operating equipment, like computers.



The new technology emits radio signals in pulses across much of the radio spectrum that have no more power than normal background "noise."

Receivers listen for these pulses at regular intervals. Information is conveyed by varying the time between each pulse.

Because the pulses are low-energy, they do not interfere with the normal functioning of radio equipment operating at the same frequency.

The New York Times

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Inside Upside

By Richard L. Brandt

Move Over, Sliced Bread

April 02, 1999

Against his best intentions, Ralph Petroff fell into entrepreneurialism. His father was a Bulgarian engineer who came to the United States at the time of Sputnik to work with rocket scientist Werner von Braun on the Apollo program, then became an entrepreneur. After one of his father's companies went bankrupt, Petroff, his father and two brothers decided to start a company doing pollution monitoring. The family sold the business in 1995 to a Swedish company and decided to take their cash and play the angel investment game from their home in Huntsville, Ala.

That's when they were approached by Larry Fullerton, an iconoclastic engineer who came calling with a company called Time Domain Inc. and claims of having created a revolutionary new technology for wireless communications. Not only could the technology send wireless digital data, it could generate radar that could see through walls and bounce signals off objects to pinpoint their locations. On top of that, Fullerton and Time Domain were fighting with Lawrence Livermore Labs over ownership of the patents to the technology. Was this guy for real? Petroff's engineering family decided he was. In late 1996, the family tossed in $3 million of its own money and helped raise an additional $17 million from angels and MCI WorldCom. Famed Silicon Valley entrepreneur and self-professed "mentor capitalist" Heidi Roizen is on the Time Domain advisory board, and IBM Corp. has signed on as the foundry to manufacture chips based on the technology. The company's technology has already made it into the pages of the New York Times.

We talked to Petroff, who is now the president, CEO and chairman of Time Domain, on March 25.

Upside Today: So how did this company get started?

Petroff: After we sold the family business, I decided I'm never going to work another day in my life at a regular job. I am going to go and have a lot of fun, lose 50 pounds, learn how to speak better French, spend time with the kids, the parents and do some angel investing, because I like business. Right off the bat, who did we run into but a fellow we had known for many years, this remarkable Larry Fullerton character, who had sort of a legendary reputation in a town full of legendary engineers. We had worked with him before, and he had done some great stuff. He was looking for funding and showed us 22 prototypes that he had made. He [could send] video signals from one side of a building to another using only fifty-millionths of a watt of transmitted power. This is going through six, seven, eight, nine, 10 walls. And then he started showing us invisible security fences and domes that could tell you the size and shape of objects it penetrated; and then a radio that transmitted at such low power across so many frequencies that it couldn't be detected, a stealth radio. I felt like the caveman seeing fire for the first time. This was the coolest thing I'd ever seen. That was the good news. The bad news was, he had no money, he had no management team, and he had all kinds of corporate complexities. He also told us about this Livermore outfit trying to claim a branch of the technology that he was working on.

Upside Today: And that branch of the technology is?

Petroff: The pulse radar. You have a problem there, because you can't sue entities that have virtually unlimited financial resources. If it was General Motors, you could bring them to court, but a top-secret weapons lab?

Upside Today: Was Fullerton ever at Lawrence Livermore, or did they just develop it independently?

Petroff: He made a presentation to an audience that included almost a dozen Livermore people. Within several days they started working on a similar kind of thing, trying to come up with this technology. Livermore's credibility has been tremendously undermined [because of this] and it is becoming less of an issue. But for a long time, there were many people who knew about the Fullerton technology, but they were concerned about investing because Livermore might come in and sue them.

Upside Today: How is that dispute being resolved?

Petroff: The House Science Committee [is investigating]. We are all waiting with bated breath to see what they report.

Upside Today: Is the House Science Committee going to make a final decision, or will it just make a recommendation?

Petroff: It's really a Patent Office call. But the process at the Patent Office can take 10 or 15 years. But I think the [House] report is going to describe in great detail exactly what went on, and then make various recommendations for how to prevent this kind of stuff from happening again.

Upside Today: Where did Fullerton develop this technology? Was he doing this independently? Was he at a company or a research lab?

Petroff: Larry was just working on his own. He was listening to a professor talk about radios and antennas, and the professor [said], "You can't do this." And he said, "Wait a minute. I can see a way of doing that." He is a classic American archetype of the brilliant lone inventor. At first we thought, "Gosh, this is too high-risk. We can't put our money in this." But we did our due diligence, and we concluded that he had excellent patent coverage. Three different patent attorneys told us, "If you put the resources into it, you'll beat Livermore." We concluded that this is a fundamental technology. We could make a straight-faced case to ourselves that this had the potential to be one of those transistor/laser/microprocessor kind of once-every-decade-or-two fundamental technologies.

Upside Today: How does the technology work?

Petroff: The signal starts out as a digital pulse. This pulse travels at the speed of light.[It lasts for less than a billionth of a second], so is just six inches long. Then there is dead silence. Then, when the signal is somewhere way down the hall over there, the next pulse pops out. If the next pulse pops out an inch late, it's a one; an inch early, it's a zero. So it's almost like somebody doing Morse Code at the speed of light.

Upside Today: So there is a precise time delay between each pulse, but then if you modify that time delay either forward or backward, then that gives you the zero or one?

Petroff: You got it! But we do something else, too. If you send it out every hundred feet, and if you have 100 users nearby, two of them end up having the same code and would be stepping on each other's signal. So you send it out in a pseudo-random code. The first may be every 62 feet, the next one every 115 feet, and then the next one every 137 feet. That way you can have lots of guys transmitting at the same time in different codes. These signals are very precisely timed, within 5 picoseconds. At the speed of light, 5 picoseconds is one-two-hundredth of a foot, which is one-sixteenth of an inch. That means you can tell how far away from you the other user is (by measuring how long it takes the signal to arrive). You can position objects anywhere to within one-sixteenth of an inch from here to the moon. You know where everything is in relation to each other. That gives you the positioning.

Upside Today: And that's also how the radar works? You can bounce the signals off of objects and see if they're moving?

Petroff: That's exactly right. Plus, regular radio waves will go through walls, but they get all murky and messed up, and they lose definition. But if you're pinging individual pulses through walls, the only thing that happens is the pulses may get a little bit smaller. But they don't lose their definition. So if you're standing on the other side of the wall, you will get an image the same as if you're standing in the room. That also allows you to send telecommunications signals through walls without needing to crank the power up.

Upside Today: What is the electromagnetic spectrum of the pulses that you're sending out?

Petroff: This thing sends out the signal basically across the whole spectrum, with most of the energy between 1[GHz] and 3GHz. This is where the regulatory process gets interesting. Have you heard of FCC Part 15?

Upside Today: No, I haven't.

Petroff: FCC Part 15 covers devices like your portable PC and your pocket calculator--extremely low electromagnetic emissions. Our device, at one-fifty-millionth of a watt, is a Part 15 level. That allows you to cut across other people's spectrum. But the issue that needs to be resolved with the FCC is that Part 15 [only] allows unintentional emissions, like your pocket calculator unintentionally emits. Our device intentionally emits. It's a two-word battle at the FCC, to try and get them to remove that. That's a long process.

Upside Today: I understand the Federal Aviation Administration (FAA) has some concerns.

Petroff: The FAA has ... a concern that, my gosh, if you have proliferation of these devices, could these have a potential for interference?

Upside Today: Yeah, well, the FAA bans laptops during take-off and landing without any evidence they cause any interference.

Petroff: That's right. They have no testing procedures. Things like hair dryers, blenders, cars and the flashing yellow lights on the tops of all those devices that are running around the airports all give off higher power levels.

Upside Today: How will this be resolved?

Petroff: That's a good question. I think we'll know within the next week or two, because Sen. [John] McCain [R-Ariz.] has become a champion for this technology, because of its public safety and military benefits.

Upside Today: What is the status of the product now?

Petroff: We've successfully fabricated two of these super-cool silicon germanium chips.

Upside Today: Who manufactured the chips for you?

Petroff: IBM. It says a lot for IBM's vision. They're criticized sometimes for being a slow-thinking company, but they saw the potential in silicon germanium and this technology and helped this obscure company create one of the world's first silicon germanium chips.

Upside Today: So far you have made just two?

Petroff: Yes. We wanted to see, will this stuff work? The real magic is in the first two chips. We've got a huge head start. Best of all, these chips are exceeding expected performance, which is a very rare and pleasant surprise. [Petroff picks up a miniature circuit board with a sample chip.] This is one of the test boards here. This is one of the chips.

Upside Today: Are you planning on just licensing patents or selling products?

Petroff: If you can believe this, for just a few million dollars we have made and delivered to the military some of these devices, a dozen of these stealth radios. And we also made Radarvision, our see-through-walls radar for use in counterterrorism, hostage rescue, drug busts, that kind of thing. But we decided that if you came up with something that is as revolutionary as a transistor, you don't just go out and try and build products. You want to make the best possible chip and leave the commercialization to people [who] understand those markets. If we're creating a whole new industry, it'd be nice to get something else other than just chip sales, to get recurring revenue. So we have this core chip set that can do communications, positioning and radar. Then we get partners and go after mass markets, things like ultra-high-speed wireless networks for the house, precision positioning, human tracking, asset tracking, security domes and fences. If we're lucky we become the new global standard for wireless, intelligent connectivity.

Richard L. Brandt is editor in chief of UPSIDE.

THE YEAR IN PHOTOGRAPHS

U.S.News & WORLD REPORT

Outlook 2000

DOUBLE ISSUE

A New Age of Innovation

Breaking the Genetic Code

Bold Ideas From Big Thinkers

[COMMUNICATIONS]

Larry Fullerton

Seeing through walls, tracking down your car

Born: Dec. 11, 1950, Fayetteville, Ark. Education: B.S.E.E., University of Arkansas. Role models: inventors like Edison and Marconi. Proudest accomplishment: winning a gold medal in the high jump in high school. Favorite book: *Atlas Shrugged*. Chief dislike: "Bureaucracy is way up there." Favorite pastime: astronomy. "Galaxies are my favorite."

BY AVERY COMAROW

As a teenage ham radio operator more than 30 years ago, Larry Fullerton would try to squeeze his pipsqueak of a signal into the crowded frequencies assigned to hams. He was routinely muscled aside by beefier transmissions from operators who could afford high-powered equipment. All the boy could do was prowl for vacant spots, slivers of spectrum the bullies had overlooked.

In the decades since, the battle for spectrum space has moved far beyond skirmishes among radio enthusiasts. Most of the radio spectrum has been given away or auctioned off by the Federal Communications Commission. The explosion of pagers, cell phones, and other telecommunications services, as well as advanced government and military systems that use radio waves, has generated intense competition over the remaining scraps.

The Internet is worsening the crunch. By some estimates, tens of billions of computers and other "Internet appliances" will be connected to the Net in five years or so. There won't be enough fiber-optic cable hooked up to carry all that data. If even a small percentage of the new traffic is funneled through satellites and other wireless devices, they will need frequencies from somewhere in the radio spectrum.

And that's where Fullerton, now founder and chief technology officer of Time Domain in Huntsville, Ala., re-enters the picture. The engineer, who came to Huntsville in 1979 to work for NASA but left because he "ran into miles of red tape," has designed a circuit that may ease the squeeze through the use of "ultrawideband" (UWB) technology. The design is etched into high-speed chips that blend silicon and germanium. Fullerton overflows with large and small ideas for chip-based products. One prototype device, called RadarVision™, is a portable radar about the size of a ream of typing paper that can see through walls and detect very small movements. That means it could locate people trapped in the rubble of collapsed buildings and earthquakes. A cheap wireless home telecommunications network and a gadget that can find a car lost in a parking lot also are in the works.

Data hiccup. In Fullerton's scheme, digital data are not transmitted on a single frequency or small band of frequencies, as is typical. Rather, information is sent as a pulse half a billionth of a second long across a wide swath of the spectrum already used by global positioning systems, military satellites, and commercial radar (1 to 3 gigahertz).

Fullerton would sidle unnoticed into the throng by transmitting at extremely low power–no more than 50 millionths of a watt, or less than 1/10,000 the punch of a cell phone. Devices equipped with Fullerton's chip could read the data hiccup, but to conventional communications equipment it would be lost in the background noise. Multiple ultrawideband devices could operate in the same room, because the coding of the pulsed information would be unique to each product.

As RadarVision demonstrates, the ultrawideband pulses also penetrate thick layers of concrete as if they were tissue paper. Integrating the chip into cell phones would allow co-workers to talk with each other within a building, which isn't always possible now.

Fullerton has plans for a $30 home network that would link computers, TVs, wireless phones, and other appliances without wires or cables, and an ultrawideband "tag" that would pinpoint a car in a sea of vehicles parked at an airport or stadium. He wants such products to be affordable–$5 to $100. Several should be poised for delivery by next Christmas.

Whether they will be under the tree depends largely on the FCC, which will have to modify its rules to allow ultrawideband transmissions. Fullerton is optimistic, and his brainchild is attracting capital. Siemens, the German telecommunications giant, put $5 million into Time Domain in November. "I'm not so wise as to know where this will take us," says Bjoerne Christensen, president of Siemens's U.S. venture capital group. But it is an idea, he says, "that represents a truly fundamental change." ●