THE HUBER MILLS digital power report
September 2002/Vol. 3 Issue 9
Powering the 21st Century
Published by Gilder Publishing, LLC.

Digital Broadcasting and RF Power

Harris is at the center of the coming boom in digital RF broadcasting

The transmitters that convey most of our wireless traffic aren't built by Motorola (MOT), Ericsson (ERICY), Nokia (NOK), or Alcatel (ALA); they're built by Harris Corporation (HRS). Name one major vendor of RF equipment whose company stock price is essentially the same today as it was at the height of the bubble: Harris again. Harris, the country's largest pure play in wireless equipment, escaped the drubbing suffered recently by other companies that make the equipment that projects bits through the airwaves. It's now poised to lead the second great boom—yes, boom—in digital wireless.

The monstrous TV transmitter is built around a very powerful radio frequency (RF) amplifier. It has traditionally been built around one or more very large (20 kW or more) vacuum tubes, which boost the megahertz-frequency oscillating currents and dispatch them to an antenna mounted at the top of a very tall mast. Huge blocks of spectrum are allocated for use by transmitters like these, to project radio and television broadcasts from terrestrial towers across the country. Police, fire, and other public security agencies rely on similar technologies, if not quite so powerful, to coordinate public safety and civil defense across large metropolitan areas. Utilities, pipelines, oil companies, and far-flung commercial enterprises depend on broadcast connectivity. The military uses more of the same—much more, operating across a very wide range of powers and frequencies—to coordinate surveillance and the projection of force around the globe.

The architectures of these broadcast networks, and the high-power, high-frequency amplifiers on which they depend, are very different from the comparatively low-power systems used in wireless telephone networks and wireless LANs. And for the last ten years or so, most everything that smacked of "broadcast" has been dismissed as obsolete, a clumsy analog vestige of technology of the '30s (radio) or of the '60s (television). Broadcast systems squandered spectrum to transmit junk to primitive electronic receivers used to anesthetize the undigital masses. The digital crowd did its narrow-casting on altogether different wired and wireless networks.

On reflection, it's not surprising to find that digital broadcasting has lagged by a decade or so behind the digital wireless telephony and data networking. The key spectrum allocations that have become digital telephony were made in the '80s and early '90s, and the cheap digital telephone arrived well before analog services (like the first-generation cellular service) had been widely embraced in the marketplace. With radio and television, by contrast, the analog services were in place and widely used decades before digital devices became cheap and ubiquitous. Now, however, the key elements required to propel the old idiot-tube world of analog broadcasting into the digital age have fallen into place. Digital telephony was the wireless story of the '90s; digital broadcasting will be the wireless story of the '00s.

And much of it will be written around Harris equipment. After decades of existence as an unfocused conglomerate, with major interests in office and printing equipment and semiconductor fabs, Harris decided just a couple of years ago to shed everything other than its RF businesses. Today, Harris's $2 billion in annual revenues are derived entirely from RF technology. Headquartered in Melborne, FL, Harris operates 18 plants in over 90 countries around the world. It divides its operations now simply between government and commercial markets, with roughly half of its revenues derived from each. Its commercial products include microwave, TV and radio broadcasting, network management and test equipment, and secure radio systems.

While the low-power, narrow-cast wireless companies surged in the '90s, Harris marched quietly forward, developing a solid balance of civilian and military RF technologies. Most of the rest of the wireless expanded too fast, and hyped itself too high. Harris, by contrast, solidified a dominant position in a quite distinct, more stable, less noticed—but still hugely important—wireless sector.

Digital Broadcasting

Radio stations have been around since the first commercial station went on the air in Pittsburgh in 1920. Television broadcasters have been on the air for almost half a century. Why should we expect any remarkable changes in broadcast technologies or markets in the coming decade? What room can there possibly be left for wireless broadcasting, when there's such a glut of high-bandwidth glass in the ground?

Similar questions were raised about wireless telephony in 1992. Telephone wires were abundant and cheap, while the cellular phones available at that point were still clumsy, expensive, and analog. Telephones of any kind were technologies of the past; the future was the computer and the wired Internet. But in retrospect, it's easy to see what propelled the first wireless boom. Digital technology transformed the hardware, and regulatory changes opened up space in the airwaves to let it rip.

On the hardware end of things, wireless telephony was the indirect beneficiary of the surge in semiconductor components being developed for personal computers and other datacom devices in the '80s and '90s. The price of wireless phones dropped tenfold, the phones got much smaller and more functional, and so did the power supplies, encoders, amplifiers, and receivers required in base stations at the wireless phone company's end of things. During this same period, the Federal Communications Commission (FCC) either gave away or auctioned off large blocks of new spectrum for use by the new wireless services.

Very similar forces are now converging in the broadcast arena. The FCC's first serious foray into digital broadcasting occurred when it authorized direct broadcast satellite service (DBS). DBS grew painfully slowly through much of the 1990s, but it finally emerged, as a very serious competitor to cable. Within the last few years the FCC has approved digital radio transmissions, too, first from satellites and is expected shortly to approve a similar move for terrestrial transmitters. And in 1996, Congress directed the FCC to choreograph television's transition to digital by the end of 2006. The analog spectrum currently used for TV broadcasts is then to be returned to the federal government, and sold for other purposes, which will almost certainly be additional digital service in the civilian sector.

While Congress and the FCC have been working the regulatory end of things, digital technology has evolved to the point where it's now powerful and cheap enough for Wal-Mart. The personal computer has been cozying up to the television for at least five years. Digital games like Nintendo's GameCube and Microsoft's Xbox already feed their content into analog televisions. DVDs provide compact, interactive, all-digital storage media, which are producing a great surge in new digital releases from Hollywood. Truly digital recorders like TiVo and ReplayTV—powerful, full-fledged computers masquerading as really smart VCRs—now surf the airwaves to capture and cache broadcast content. And finally, in early August, the FCC directed television manufacturers to add digital-reception capabilities to their larger sets by mid-2005, and to all their sets by 2007. The 2007 deadline extends as well to all devices that incorporate TV tuners, including VCRs and DVD players/recorders that receive broadcast television signals. The computer-to-television cozying, in short, will culminate in a complete integration within the next five years.

The signals dispatched through the airwaves will change apace, and equally profoundly. What makes a broadcast "digital" is how the waves are modulated—digital encoding schemes use compression to pack a lot more data into the same bandwidth, along with redundancy and error correction to transmit with perfect fidelity. The current NTSC standard for television transmits 378,000 pixels per frame into a 6 MHz channel. The Japanese high-definition analog standard transmits barely twice as much picture, and better sound, through 20 MHz. By contrast, the U.S. digital broadcast standard (ATSC) allows for five times as many pixels per frame—along with as much additional audio and data as the transmitter and coding systems can handle—but all still transmitted through 6 Mhz. Compression is the key—ATSC relies on the same MPEG-2 compression scheme already used for DVD videos and some satellite television services.

The advantages of digital encoding are so great

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The Digital Power Report is published monthly by Gilder Publishing, LLC. Editorial and Business address: 291A Main Street, Great Barrington, MA 01230. Copyright 2002, Gilder Publishing, LLC. Editorial inquiries can be sent to: peterhuber@gilder.com or markmills@gilder.com.

that digital inevitably displaces analog sooner or later, in every communication network. Wireless telephony started out analog, but the FCC recently authorized the old guard cellular carriers to stop supporting analog phones within a few years, on the safe assumption that everyone will be carrying digital phones long before then. Nextel created its entire business by buying up analog taxi-dispatch systems and reconfiguring them as digital wireless telephony. Few wireless networks were digital a decade ago; every wireless network used for military, fire, police, air traffic control, and civilian purposes will be a decade from now.

Reflecting their heritage as "public interest" entities operating under sluggish regulatory oversight, radio and TV broadcasters have been late arrivals to the party. Broadcasters couldn't change their formats without the FCC's go-ahead and were effectively locked into the hundreds of millions of analog televisions and radios already bought and paid for. But digital technology is now cheap enough to be grafted into analog receivers during the transitional years, and regulators are now providing the flexibility and additional spectrum needed for a smooth transition. Current grumbling notwithstanding, equipment manufacturers will soon grasp that they can prosper by selling integrated TV-computers to a huge generation of new shoppers, who still love television but want the full power of the Web embedded in it too.

The transition to digital television (DTV) has been under way since 1996, and nearly 300 of the nation's 1,500 TV stations already have digital broadcast capabilities in place. But the transition has attracted little notice so far, because so few households own complementary digital receivers. The FCC's recent directive that requires equipment vendors to incorporate digital tuners in televisions has been greeted with a yawn. Only 15 percent of households still rely on the radio tuners and rabbit-ear antennas for their reception; satellite dish households already have their digital receivers, and cable companies can orchestrate a transition to digital on their own schedule.

But this view of things completely overlooks a much more relevant number. Only about 13 percent of American households are currently hooked up to a high-speed digital channel via a cable modem or a phone company's DSL service. A digital TV transmitter can dispatch a 19.39 megabit-per-second stream of data round the clock; with twenty or so stations broadcasting in a metropolitan area, that's a huge stream of bits that can be selectively picked up and cached by the integrated TV-PCs. And broadcasters will end up with broad flexibility to adjust the mix of conventional television fare and streaming Web that they transmit. Thus, over the course of the next decade, the FCC-forced transition to digital television will push high-speed digital connections into every home that buys a new television.

Digital radio holds similar promise. Highly customizable audio/data compression technologies have been developed and are being deployed in both satellites (such as the XM Satellite Digital Audio Radio System) and terrestrial stations. Here, too, far more data can be transmitted through already assigned spectrum bands; today's streams of talk and music can give way to talk, music, e-mail, and anything else that is currently transmitted, at comparable speeds over dial-up modems. There are far fewer radio channels than phone lines, but here again, the bandwidth can be used to stream data around the clock and cached in the receiver for later retrieval. In-Band On-Channel (IBOC) digital radio transmits CD-quality audio over the AM and FM bands, along with streaming data to transmit stock quotes, news, traffic and weather reports, and so forth. Car radios are the first major target, but the signals can be picked up by tuners embedded in PDAs or any other consumer electronic device equipped with a suitable RF tuner. Even short-wave radio—the very long-range radio that carries the Voice of America and BBC Worldwide, among others, around the globe—is transitioning to the new DRM (Digital Radio Modiale) standard next year. The new standard was adopted in 1998 by a global coalition of radio manufacturers, with Harris among the founders.

An obvious objection to the notion of digital broadcasting providing a high-speed portal to the Web is that broadcasting provides only one-way traffic. But the wireless loop can be closed in quite a number of different ways. DBS broadcasters already provide high-speed Internet service with the help of dial-up phone lines for the uplink—the user can only send slowly, but can receive fast. And when manufacturers begin to build digital tuners into their televisions, they can readily add wireless uplinks, too, capable of signing on to services offered by the paging, cell-phone, and other narrowband wireless services. Blackberry did it; others are too.

Caching can substitute for a lot of uplinking too. Pay-per-view movie services, for example, don't really require two-way interactivity at all—suitably encrypted, huge amounts of content can be transmitted indiscriminately, around the clock, for storage on digital VCRs, with the sale being completed by way of a simple phone call, if necessary, to deliver a code to unlock the already-cached content. The plummeting cost of storage allows a lot of seemingly two-way, "interactive" services to be provided via broadcast instead.

In the end, the most compelling case for a broadcast digital pipeline is the simplest: most stock quotes, headline news, pictures, and entertainment that we seek are sought by our neighbors too. The loop does have to be closed, so that we can also buy books online, dispatch e-mail, and trade stocks, but most of us need far more downlink bandwidth than uplink. Teenagers don't listen to what they like; they listen to what all the rest of the gang likes. The Super Bowl isn't something to enjoy in quiet, one-on-one solitude; it's mass culture, and what makes the event is that the same thing is seen together, at the same time. The whole point of caching Web content nearer to end users, as all major distributors in fact do, reflects this simple fact.

One-to-many architectures—broadcast systems—are perfectly suited for the mass distribution of the most popular content and can now easily be integrated with narrowband links that close the loop to provide complete interactivity. Optimizing network architectures for one-to-many distributions is essential in mobile applications as well, simply because transmissions can't be targeted to a single place when the end user is on the move. One-to-many network structures likewise dominate in military contexts, both because the recipients of dispatches are so often on the move, and because much of the information flow reflects the top-down command structure, which is essential to coordinate and concentrate the use of force, the essence of war. Police, fire, and other public security services depend on similar systems for exactly the same reasons.

In sum, the broadcasting world will certainly—and quite imminently—make the transition to all-digital transmissions, and the receivers at the consumers' end will simultaneously metamorphose into full-

Television and radio are by far the most widely used information gateways

fledged computers. This stealth transformation of television and radio into a personal computer on a digital wireless network will have enormous consequences—much larger, in fact, than the much less stealthy rise of digital wireless telephony. Television and radio are by far the most widely used information gateways into the average American home. In his own home, at least, the average American still spends some four times more time watching television than browsing the Web, and the television delivers content a lot faster. The Web got to where it is now on the strength of $1,000-plus personal computers, dial-up phone lines, and $40-plus per month cable modems and DSL service. It will go a whole lot further when its front end has all the look and feel of a television set, with a price to match, and with digital broadcasts providing torrents of digital content.

Power, Towers, Chips, and Tubes

As we've noted before, the ether is rough territory, electrically speaking. Moving bits through the airwaves requires thousands of times more power than moving them through metal wires, and millions of times more than moving them through glass. Outside the magnificently pure and isolated confines of fiber-optic glass, photon space is an energy-dissipating, entropy-boosting, information-degrading mess.

The maximum capacity—i.e. bandwidth—of a communication channel is directly related to the average signal power: the higher the ratio of the signal power to the background noise, the faster it's possible to transmit data accurately through the channel. Power requirements also rise in direct proportion to distance for the most focused point-to-point transmissions, and as the square or cube of distance, for less-directional broadcasts. The more obstacles that stand in the way, the more power the transmitter uses. Tall buildings in the city, rain, electromagnetic clutter, and (in the military's case) deliberate jamming by people who don't want the signal to get through, all push the broadcaster toward higher power transmitters.

There are two fundamentally different strategies for overcoming these problems, tailored to two fundamentally different objectives. One uses more towers, more stations—more real estate—with lower powerful amplifiers in each one, so that the many transmitters don't interfere with each other. The other uses more power, and far fewer towers.

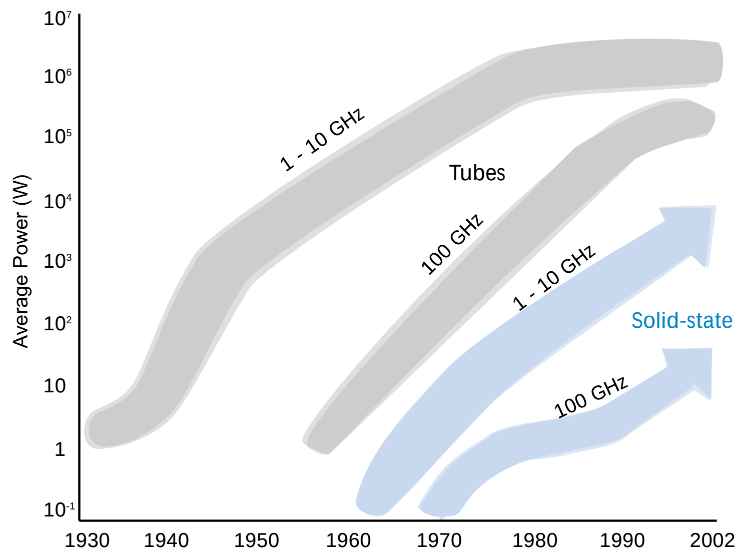
To get the bits through in New York, a company like Verizon (VZ) adds more and more base stations—creating more cells in the cellular network, and thus lowering the distance that transmissions must travel through the air. The trend here is toward smaller packages—microcell (suitcase-sized) and picocell (book-sized) units, small enough to be deployed in many places where larger units wouldn't fit, or would be too unsightly to tolerate. There are well over 100,000 base stations already in operation in North America, and several hundred thousand more coming—or tens of millions, if one includes in the count all the short-range wireless LANs that will eventually be deployed.

To deliver the same stock market ticker, movie, football game, or headline news to large numbers of people, however, power is much cheaper than real estate. The United States has only 17,500 VHF, UHF, and TV transmitters. The military relies on similar broadcast architectures for similar reasons—more power, less tower, because the armed forces don't have the leisure to build out an infrastructure of picocells in the Hindu Kush. A typical cell tower transmits a couple of hundred

Watts, at most; a VHF broadcast station projects tens of kilowatts. Because they operate at higher frequencies, UHF transmitters operate at even higher power levels.

The two different wireless architectures thus require very different amplifiers. The technological linchpin of digital wireless telephony is the multichannel RF amplifier. It is built around a radio-frequency, solid-state powerchip, capable of amplifying a gigahertz-frequency signal up to power levels of 100 to 200 Watts. As we have discussed before, the best chip architecture at present is the silicon laterally diffused metal-oxide-semiconductor (LDMOS), first developed in the early 1990s with commercial production emerging less than five years ago (*Powering RF Photons,* November 2000). Manufacturers include Motorola, Ericsson Microelectronics (acquired by Infineon (IFX) this past summer, *The Silicon Car,* December 2000), and UltraRF (now part of Cree (CREE), *Quantum Power,* May 2001). To push solid-state amplifiers to even higher frequencies, above 200 gigahertz, TRW (TRW) introduced indium-phosphide (InP) devices suitable for use in both telecommunications and low-power radar (*The Power of Millimeter Waves,* November 2001). On the horizon now are high-power, high-frequency RF transistors based on the enormously challenging gallium-nitride (GaN) compound.

RF Transmitters



Semiconductors long ago displaced the vacuum tube in computers, consumer electronics, and low-power wireless communications. But in the high-power RF broadcast domain, and especially at very high frequencies, the vacuum tube has survived as the most affordable and functional technology. Semiconductors continue to close the gap, however, as costs drop and power-handling capabilities rise.

Until quite recently, by contrast, broadcasters still relied exclusively on massive water-cooled, vacuum-tube amplifiers, simply because it wasn't possible to build semiconductor devices that could operate at RF frequencies and at the very high power levels that broadcasting requires. High-power UHF, in particular, remained the realm of filaments, grids, magnets, and cavities; television emerged from clouds of electrons in evacuated tubes, not electrical holes in semiconductors. Even the names of the key devices evoke a very distant era—gyrotrons, klystrons, klystrodes, and inductive output tubes (IOTs, or diacrodes). Some were air-cooled, but many depend on circulating water to prevent meltdowns. The IOT remains, to this day, the amplifier of choice for high-power systems. It operates at 30 to 35 kV, delivers up to 35 kW of average power, and costs up to $40,000. Northrop Grumman (NOC) recently introduced the CEA (constant efficiency amplifier) tube, an exquisitely engineered version of the IOT that is suitable for very high-power digital transmission.

But the costs of solid-state broadcast amplifiers are declining rapidly, because these amplifiers are built around arrays of the same LDMOS chips that are used in cellular base stations. Individually, they can produce 100 to 200 Watts of RF power; silicon carbide devices will eventually make possible 500 Watt devices. Because they require fewer chips, solid-state amplifiers first became price-competitive for lower power broadcasting, and they have gradually been replacing tubes in VHF and lower power UHF applications for several years. By authorizing many stations to start digital operations with transmitters operating at powers significantly lower than the maximum authorized, the FCC has also facilitated the transition to solid-state.

Price aside, other factors strongly favor the transition to digital technology. Solid-state amplifiers are more reliable—because they are built from hot-swappable modular arrays of lower power amplifiers, they continue to function, at slightly diminished power, when one module fails; a tube failure, by contrast, blacks out the whole transmitter. Solid-state amplifiers also operate at much lower voltage, which makes them safer for technicians. Over the decades, tube designers have pushed electric-to-photon conversion efficiencies to levels that chips can't yet match, but the gap is now closing fast. Solid-state devices can generally dispense with the elaborate water-based cooling systems that RF tubes require. Solid-state amplifiers are very much more linear and require little tweaking and maintenance; tube systems, by contrast, are notoriously quirky and require lengthy, meticulous, and expensive tuning and maintenance.

On VHF channels, because of the relatively low effective radiated power levels required (less than 100 kW), virtually all digital transmitters are already solid-state. These transmitters typically feature 250 W to 500 W solid-state MOSFET amplifier modules operating in parallel to achieve power levels of up to 7 kW per cabinet. At UHF frequencies, however, with effective radiated power levels ranging from 50 kW to 1,000 kW, tube-type transmitters are still widely used. But here, too, the transition to solid-state is only a matter of time.

Harris

Headquartered in Ohio, Harris's Broadcast Communications Division is the leading manufacturer of all aspects of digital and analog radio and television broadcasting: encoding and transmission equipment, systems, and services; radio and television studio equipment, systems, and services; and automation solutions enabling television stations, groups, and networks to monitor and control hardware and software from a central location. The division holds a fistful of firsts: first AM, FM, and TV digital transmitters; first to transmit a commercial HDTV (1997); first to complete a full digital TV "air-chain" (1998); first to market with a remote amplifier, solid-state exciter, digital medium wave modulator, and digital studio-to-transmitter links. The Broadcast Division expanded its international access to digital broadcast markets with the early 2002 acquisition of the Hirschmann Multimedia Communications Network, a leader in European-standard digital broadcast.

As with television, Harris is a leader in the transition to digital broadcast radio, particularly In-Band On-Channel (IBOC) digital radio compatible transmitters. Harris has been a leading supporter of the development of IBOC digital radio—it has teamed with iBiquity Digital—the lead implementer for IBOC and a company in which Harris has a stake—along with 14 of the nation's largest radio broadcasters and other prominent technology, media, and investment companies. iBiquity is commercializing digital radio broadcast and audio compression technology under the iDAB trademark.

Harris has used simulcasting technology derived from its military products to expand the range of low-power broadcast. Instead of increasing the power of a single transmitter, a broadcaster could in theory simultaneously broadcast from several lower power towers (which can be both less expensive and easier to install and are more compatible with currently available solid-state transmitters—it is also a more secure architecture). The daunting challenge with any such scheme has been to avoid destructive interference in areas where identical signals from several transmitters overlap. Using GPS technology and digitally induced delays, Harris has developed ways to match perfectly each tower's transmission so as to eliminate the problem. First applications are in mission-critical radios for police, fire, and other emergency communications.

Harris builds a range of solid-state transmitters around LDMOS chips. In its DX-50 series AM transmitter, for example, 128 solid-state modules combine to deliver 50 kW of RF output. To assist smaller UHF stations in converting to digital, Harris introduced its Ranger series of UHF transmitters. The Ranger can fit into a single 19-inch rack cabinet and can be upgraded to 1,000 W with a second LDMOS module—the same module used in Harris's high-power 34.5 kW DiamondCD transmitter. The station can later upgrade to still higher power while retaining 80 percent of the components in the original Ranger. A master controller synchronizes the overall system and provides protection and troubleshooting information. Built-in logic can switch the exciter between NTSC and DTV; the station can continue to operate on the NTSC standard, then switch to DTV when the operator is ready to do so.

Harris's commanding technology and market position in the RF arena would guarantee it stable markets in any circumstances, but Harris is now uniquely positioned to benefit from the two transformative trends in RF—analog to digital, and tube to chip. While there can be debate about timing, there can be no serious debate about the direction of things, and Harris will sell a great deal of new equipment and upgrades as this transition proceeds. Harris can and does build its amplifiers around either tubes or semiconductors—either way, it buys these components from outside vendors and builds its systems around them. But as solid-state technologies improve, their advantages impel broadcasters to upgrade and change out equipment decades earlier than they would otherwise have done, and it is Harris that will supply most of the replacements.

Harris owes much of its technological prowess to its most demanding and least price-sensitive customer, the government. If it flies, orbits, floats, rolls, or walks in the defense of this nation—odds are it uses Harris wireless RF technology. Harris's customers on the government side of the ledger include the Department of Defense, FAA, NASA, other federal and local government agencies, and defense contractors.

During the Cold War years, Harris provided the tracking and pulse code technologies for America's new space program, the hardware in the first communication and weather satellites, and radios for the first manned space flights and the Apollo program. Harris built the radio links for the Cold War-era Minuteman, Atlas, and Polaris missile systems.

Today, Harris provides the new In-Flight Interceptor Communications System for the emerging ballistic missile interceptors. It builds high-speed communications for the F-22 and the Army's Commanche helicopter and Multiple Launch Rocket. And it supplies next generation lightweight, multiband satellite links for the Navy, Army, and Air Force. While the commercial RF industry talks about the concept of software-defined radio—a radio system capable of reconfiguring itself on the fly to operate over a wide range of different protocols and even frequencies—Harris actually deploys such a system in its Falcon II tactical digital radios. Harris has also developed wideband digital links to support the radar, imagery, and video from reconnaissance aircraft, unmanned aerial vehicles, and satellites, and direct to soldiers' radios and secure wireless battlefield LANs. Much of Harris's government business is classified, and it is therefore impossible to delve into its technical details. Suffice it to say that in this "telecom" sector, the government pays the most to buy the best—and the best is generally five years or more ahead of comparable technology in the civilian sector.

As defense contractors commonly do, Harris builds other complementary components as well—ground-based systems and software, for example, to collect, store, retrieve, process, analyze, display, and distribute information. Harris also produces the related computer-controlled electronic maintenance, logistic, simulation, and test systems for military aircraft, ships, and ground vehicles. Harris is a leading supplier of air-traffic control communication systems, aircraft and spaceborne communications, satellite communication systems, including large deployable satellite antenna systems and flat-panel, phased-array, and single-mission antennas, and is a preeminent supplier of super-high-frequency GHz-class military satellite ground terminals.

Harris's defense satellite group is branching out into the commercial satellite business as well, and it has been awarded contracts to provide antennas for commercial programs such as the Asian Cellular System. Harris is in the enviable position of being able to develop the highly advanced technology on (comparatively) price-insensitive defense contracts, in an arena in which the technology transfers readily into the civil defense and commercial sectors. DARPA funded Harris to develop phased-array technology that can link moving vehicles to high-bandwidth satellites; Harris managed to shrink the critical transmit/receive array down to pizza-box size and push the cost down from the $500,000 range to $50,000, with further cost reductions expected. Harris now expects to transfer that technology for use in civil defense and homeland security.

Harris's commercial RF products fall into four groups that roughly mirror the company's military programs: wireless radio and broadband; microwave systems; broadcast, including digital and analog TV and radio studio and transmission systems; and network support products for maintenance and testing.

The RF Communications Division supplies radios for commercial, military, law enforcement, and other government customers. The company specializes in lightweight, portable mobile radios in all major bands, HF, VHF, UHF, as well as multiband units. Security and encryption rank high; Harris designs and embeds their own Presidio, Sierra, and Citadel cryptographic integrated circuits in many of its systems. Harris recently received the world's first National Security Agency certification for encryption in its 30 to 512 MHz multiband radio.

The company's microwave communications systems operate at frequencies from 1.5 to 38 GHz; they are used mainly to provide high-speed interconnection for cellular and PCS sites; and for private networks operated by electric utilities, railroads, local governments, and emergency service operations. Harris is North America's largest microwave supplier and is rapidly expanding in other markets around the world, from Argentina and Brazil to China and Russia. Two years ago, Harris bought Lucent's European-based digital microwave line. Harris's microwave systems include both digital point-to-point for high-capacity carrier cellular links (155 Mb/s) and point-to-multipoint systems for broadband wireless connectivity. Harris's ClearBurst MB broadband point-to-multipoint wireless system operates at 3.5 and 10.5 GHz and provides high-speed last-mile connections for small businesses and home offices.

Conclusion

As Peter Drucker, the nation's oldest living and highly respected business seer, observed recently in the *Harvard Business Review*: "In human affairs—political, social, economic or business—it is pointless to try to predict the future, let alone attempt to look ahead 75 years. But it is possible—and fruitful—to identify major events that have already happened, irrevocably, and that will have predictable effects in the next decade or two. It is possible, in other words, to identify and prepare for the future that has already happened."

The Power Panel

Ascendant Technology	Company (Symbol)	Reference Date	Reference Price	9/11/02 Price	52wk Range	Market Cap
System Integrators	Harris Corp. (HRS)	9/11/02	33.45	33.45	26.42 - 38.70	2.2b
	Magnetek Inc. (MAG)	7/26/02	6.49	4.41	4.05 - 12.73	99.3m
	Veeco Instruments (VECO)	6/28/02	23.11	13.58	11.65 - 40.12	395.7m
	Oceaneering Intl (OII)	5/31/02	31.01	25.00	13.96 - 32.17	619.0m
	Amkor Technology (AMKR)	4/2/02	21.85	2.08	1.90 - 24.79	342.1m
	Emerson (EMR)	5/31/00	59.00	47.11	43.25 - 66.09	19.8b
	Power-One (PWER)	4/28/00	22.75	4.15	3.84 - 13.25	331.3m
Electron Storage & Ride-Through	Kemet Corp. (KEM)	5/1/02	19.63	12.40	11.44 - 22.40	1.1b
	Wilson Greatbatch Technologies (GB)	3/4/02	25.36	27.12	20.10 - 39.00	567.8m
	C&D Technologies (CHP)	6/29/01	31.00	16.22	13.25 - 24.65	421.4m
	Maxwell Technologies (MXWL)	2/23/01	16.72	5.37	4.45 - 14.50	75.2m
	American Superconductor (AMSC)	9/30/99	15.38	3.13	2.90 - 14.00	64.4m
Project, Sense, and Control	Danaher Corp. (DHR)	1/29/02	61.56	60.16	43.90 - 75.46	9.1b
	FLIR Systems (FLIR)	1/9/02	41.64	38.51	27.00 - 59.50	649.5m
	Analogic (ALOG)	11/30/01	36.88	42.79	33.40 - 56.50	567.4m
	TRW Inc. (TRW)	10/24/01	33.21	58.54	27.43 - 58.54	7.5b
	Raytheon Co. (RTN)	9/16/01*	24.85	35.40	23.95 - 45.70	14.3b
	Rockwell Automation (ROK)	8/29/01	16.22	18.70	11.78 - 22.79	3.5b
	Analog Devices (ADI)	7/27/01	47.00	25.69	19.57 - 48.84	9.4b
	Coherent (COHR)	5/31/01	35.50	21.15	19.70 - 36.39	613.7m
Powerchips	Cree Inc. (CREE)	4/30/01	21.53	14.48	10.35 - 33.32	1.1b
	Microsemi (MSCC)	3/30/01	14.00	6.10	4.66 - 40.10	176.2m
	Fairchild Semiconductor (FCS)	1/22/01	17.69	11.03	10.15 - 32.03	1.3b
	Infineon (IFX)	11/27/00	43.75	9.78	9.11 - 25.89	6.8b
	Advanced Power (APTI)	8/7/00	15.00	5.08	4.86 - 15.15	52.8m
	IXYS (SYXI)	3/31/00	6.78	4.96	4.07 - 12.55	157.9m
	International Rectifier (IRF)	3/31/00	38.13	20.67	18.00 - 50.50	1.3b

Note: This table lists technologies in the Digital Power Paradigm, and representative companies that possess the ascendant technologies. But by no means are the technologies exclusive to these companies. In keeping with our objective of providing a technology strategy report, companies appear on this list only for the core competencies, without any judgment of market price or timing. Reference Price is a company's closing stock price on the Reference Date, the date on which the Power Panel was generated for the Digital Power Report in which the company was added to the Table. All "current" stock prices and new Reference Prices/Dates are based on the closing price for the last trading day prior to publication. IPO reference dates, however, are the day of the IPO. Though the Reference Price/Date is of necessity prior to final editorial, printing and distribution of the Digital Power Report, no notice of company changes is given prior to publication. Huber and Mills may hold positions in companies discussed in this newsletter or listed on the panel, and may provide technology assessment services for firms that have interests in the companies.

* *The October 2001 issue closed on September 16, 2001 and was posted at 8 a.m. on September 17, 2001. Due to the markets' close in the week after September 11, our reference price reflects Raytheon's closing price on September 10, 2001.*

One can quite reliably say that the RF future has already happened. The coming decade of digital wireless in the high-power, broadcast arena, played out in the last decade in low-power narrow-cast. When it comes to solid-state, digital technology, the wireless telephone has recently been there and done that; now the radio and television are poised to go there and do it again.

It is easy to overlook the opportunity that lies ahead, because the old world of broadcasting has been so relentlessly boring and low-tech for so long that few technology analysts give it any serious attention at all. But the broadcasters own huge blocks of spectrum, in very sweet spots on the dial, and they now have the technology at hand, the regulatory marching orders, to transition it all to digital. The military and other government entities have dominion over even larger blocks of spectrum, and transforming those blocks into highly secure, long-range, digital bandwidth is now one of their very highest priorities.

Harris has stripped itself down to its RF essentials. It builds the best high-power RF equipment in the world. And the world is now beating a path to its doorstep.

Peter Huber and Mark Mills
September 11, 2002

More information about digital power technologies is available on www.digitalpowerreport.com