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DIARY FROM THE SPECTRUM VORTEX

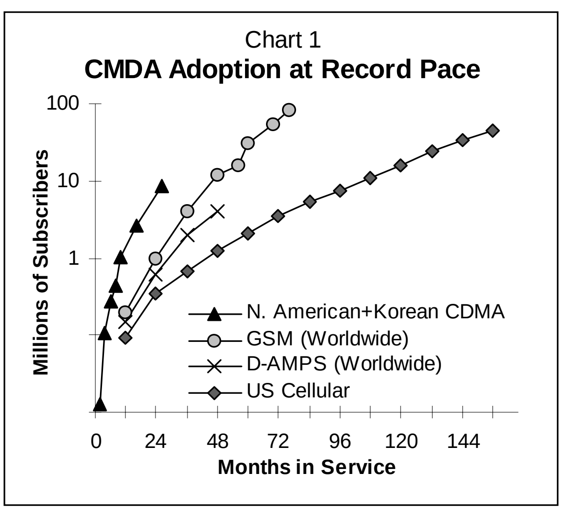
At the end of May, I entered the Vortex, a Bob Metcalfe-Bob Lucky conference whirl in Laguna Niguel, and kept spinning. This report is a fabric woven at the Ritz and in reflection after. Fasten your synapses for a vortical ride from the 25th anniversary of Ethernet to portents of amazing new spread spectrum ether nets in the air.

Vorticity, so I discovered, is a concept of ethereal communications launched by Lord Kelvin at the beginning of the century as an alternative to quantum theory. Atoms, the great man proposed, were mere nodes in the ether, whorls in the atmosphere. All physical reality, he implied, is an Ethernet.

Qualcomm has won. For all its global dominance, GSM TDMA is becoming a legacy system.

So it seemed for a few uproarious moments at the conference. Celebrating Ethernet at its 25th anniversary were some 250 luminaries of the Telecosm, including a rock 'n roll band that simulated the Rolling Stones in suits and ties, singing about the history of Ethernet (one verse, believe it or not, was about me; thank you guys!)

Updating the Kelvin theory, I proposed that vortices, like quarks, come in spin states: up, down, and strange, and are relativistic. For **Yahoo** (YHOO) and **Amazon** (AMZN), for example, the Internet is a twister that whirls them toward Oz. For **AT&T** (T) and **Bell Atlantic** (BEL), the Internet sucks; it is a down vortex for their data traffic and everyone stays in Kansas.



After my edifying spin in the Vortex, I pushed on to San Diego to give a speech and visit **Qualcomm** (QCOM). This cellular innovator has been rising to the forefront of the industry on the crest of its development of Code Division Multiple Access (CDMA) technology. With 12 months revenues through March of over $2.2 billion, it has just achieved a moment of triumph so stunning that most analysts have failed to recognize it at all.

In January, the European Telecom Standards Institute (ETSI) endorsed CDMA as the next generation of GSM (Global System Mobile). This is an amazing upset. Fervent apostles of Time Division Multiple Access (TDMA), the GSM folk command the dominant global standard in cellular telephony, with some 85 million users. They have viewed CDMA as an insidious American scam put across in the US by pseudo-scientific hype from Qualcomm. As recently as September 8, under the title "Blind Faith," *Telephony* magazine ran what seemed a devastating expose of the scandal. Even in the US, the rambunctious CDMA skeptic Bill Frezza accused the two key Qualcomm luminaries, Irwin Jacobs and Andrew Viterbi, both with EE doctorates, of wild mendacity for their casual forecast that CDMA might ultimately improve on analog by a factor of 20 to 40. (Don't look now, Bill, but it's happening, with new generation gear under IS-95C). The general implication was that these guys should be in jail for felonious offenses against the laws of physics.

I wanted to find out what they planned for an encore, particularly with regard to Internet data. Owner of Eudora, Qualcomm is a leading email company; I wanted to get my email through my CDMA cell phone.

In January, the European Telecom Standards Institute endorsed CDMA as the next generation of GSM.

But I arrived at the offices a little early and a little groggy, without cellphone or computer. Looking for an emergency latte, I scanned the atrium of Qualcomm's polychrome palace in La Jolla. A perfect place for a Starbucks. But instead I was shunted off to what I was told was a CDMA museum.

Now it takes a lot of caffeine to gaze with interest at curvacious but obsolete telephones. So I was pleased to discover that the "museum" was a small room filled with spectroscopes, manned by two old Qualcomm hands who just happened to be heroes of the history of spread spectrum radio. One was David Clapp, who worked under Klein Gilhousen, architect of the first CDMA prototypes in 1989. The other was Phil Karn, who had written key papers on spectral efficiency and channel access for spread spectrum radios and had engineered the inclusion of a TCP-IP internet protocol stack in every Qualcomm phone way back in antediluvian 1991. This was a crucial moment in the history of cellular data.

Karn recalled, "I had previously written a stack for ham radios in late 1980. Then I came to Qualcomm and wanted to get it into the CDMA architecture. There were a lot of arguments, saying that TCP-IP was too complex for cellular and the Internet was only used by geeks. But I'd been involved in the net at Bellcore since 1985 and I knew it was growing exponentially. Exponential growth has a way of mounting until even phone companies can notice it."

Largely as a result of Karn's prescience, and the receptivity of his bosses, Gilhousen and Jacobs, Qualcomm phones will soon be able to link directly to the net from a laptop without a modem. Karn went to the Cellular Telephone Industry Association (CTIA) in 1993 in an effort to get this capability standardized. But he discovered to his surprise that telephone people *like* modems. They actively resist their replacement with direct digital connections. As one AT&T official put it: "We don't like where this Internet is leading." He explained it gave too much control to users, which from the point of view of a centrally controlled national network with essentially 100 percent uptime it did.

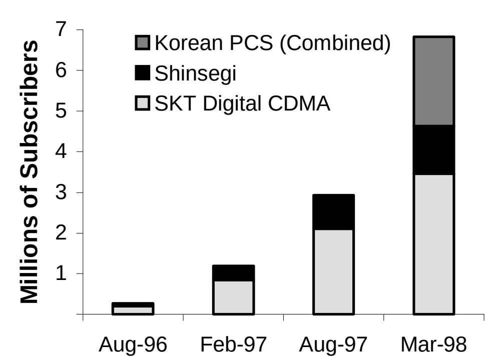
Qualcomm's new CDMAOne 2000 scheme, IS-95B, fulfills Karn's early vision, with burst rates for data up to 115 kilobits per second, flexible bonding of channels, and "always on" capability with negligible power drain. This will come late this year, followed by a 95HDR (High Data Rate) which will ultimately accommodate megabit transmissions. Jacobs predicts that a major use for 95B will be fax over IP. Like all CDMA, the data-oriented phones degrade gracefully with congestion and can use any available capacity, even in contiguous cells. By contrast, TDMA breaks up the spectrum into time and frequency slots and cannot readily offer bandwidth on demand or adapt to conditions in the channel. Unused time and frequency slots are not readily available for anyone else on the network.

For many such reasons, the Europeans decided to go for spread spectrum. Although conference wiseacres around the globe tout marketing or politics or monopoly lock-in as the key forces in business success, you had better bet on technology with your pension funds. In this case, from the EEC and the US State Department to AT&T and US chip firms, the TDMA folk had tied up absolutely all the politics and marketing. But the technicians in Europe's RACE consortium concluded that no number of political endorsements or marketing programs or new physical laws enacted by the EEC could make TDMA fly for data. The new version of GSM would have to be CDMA.

They call it Wideband CDMA (W-CDMA) to differentiate it from the new Qualcomm IS-95B standard, which they dismiss as a "narrowband" contrivance. But guess what? The new European standard includes soft handoffs, rake receivers, and closed loop power controls, all patented Qualcomm developments at the heart of the IS-95 standard. The key part of IS-95B rejected by the GSM consortium is a chip rate or spreading factor of 3.686 megahertz. This rate is compatible with the existing 1.25 megahertz channels of IS-95 systems now being deployed in some 32 countries, including the US, Japan, India, Korea, Thailand, and most of Latin America. Rolling out in Japan in early 1999 will be a nationwide $6 billion CDMA system using IS-95 from a partnership between **Toyota** and **DDI**, known as that country's **MCI** (MCIC) for its entrepreneurial eclat and stock market stardom.

Chart 2

Korean CDMA Subscribers



Sources: Co. Reports, Maeil Bus. Newspaper, Korea

The big deal advantage claimed for the European W-CDMA is a higher spreading factor–4.096 megahertz, a whole 410 kilohertz wider. Can't mess with that, says US GSM Alliance Chairman Don Warkentin, "To degrade W-CDMA will cause a significant reduction in system capacity…and probably raise the price to consumers…"

Gary Jones, Chairman of the GSM North America Standards Working Group, also spoke out for the right of consumers to have two narrowly incompatible flavors of CDMA to choose from: "The difference in philosophy is whether to revolutionize wireless radio or preserve second generation artifacts." 410 kilohertz or bust, no marketing or politics around here! What is going on is the GSM consortium trumping up a negotiating position. They will need it.

The bottom line is that Qualcomm has won. For all its global dominance, GSM TDMA is becoming a legacy system. Of course, the GSM group would like to see Qualcomm's CDMA similarly become an incompatible legacy. But it won't happen. With 130 CDMA patents issued, 400 pending, and 55 licensed equipment vendors, Qualcomm now commands much of the intellectual property, design skills, and engineering experience for the acknowledged new worldwide standard for wireless telecommunications. In much of the world, where copper wires are routinely exhumed and sold as scrap, wireless will mean not only mobile but also wireless local loop.

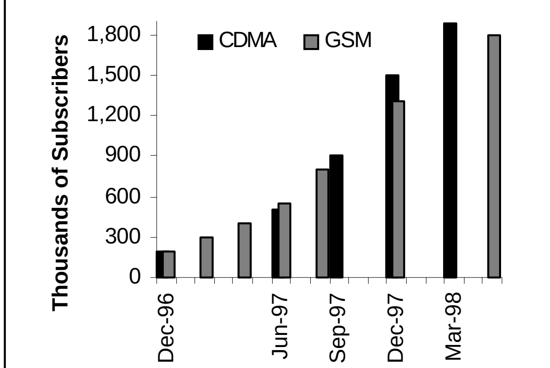


Chart 3
North American PCS Subscribers
Source: GSM MoU Assoc., CDG, Company Reports

Qualcomm has wireless local loop trials and deployments in Brazil, India, China, Indonesia, the Philippines, Poland, Russia, Bangladesh, and several African countries. In late May, Qualcomm announced that with its partner **Grupo Pegaso**, it had beat out AT&T (America's last ditch TDMA proponent) to bring wireless PCS to Mexico nationwide, with a stress on wireless local loop and a rollout planned in major cities for the first quarter of 1999. The Qualcomm group bid $285 million, or 3 dollars per POP (potential subscriber), about a third of the US average for a country with only 10 percent wireline telephone penetration.

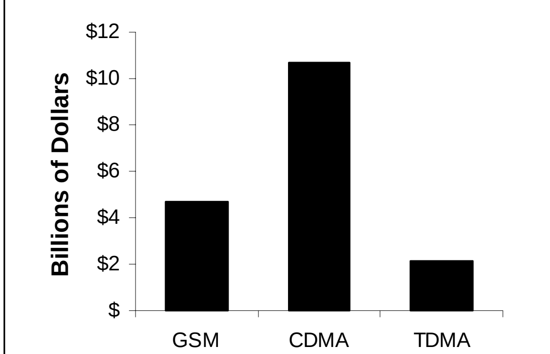


Chart 4
Announced US PCS Equipment Contracts
Source: PCS Week, June 4, 1998

CDMA's efficiencies are just as dramatic in fixed local loop systems. In other words the world's entire voice and lowspeed data telecom system is moving toward CDMA. It will take a while. But if you are an investor, you might as well go with the flow. Meanwhile, the GSM advantage in global coverage will soon give way with the launching of **GlobalStar** (GSTRF), a **Loral** (LOR)-Qualcomm low earth orbit (LEO) system that is 19 times more cost effective than **Motorola**'s (MOT) touted TDMA **Iridium** (IRIDF) scheme.

The triumph of CDMA is an epochal event with implications that go beyond the prospects for Qualcomm. A new paradigm is moving to the fore. "Wide and weak," it uses bandwidth as a replacement for switching and power.

The great astronomer and physicist Kepler wrote: "I cherish more than anything else the Analogies…. They know all the secrets of nature." For the Microcosm, the model was to move to the center of the sphere, at the atomic level, where power was concentrated. With an uncanny analogy of communications to multi- dimensional geometry, however, Claude Shannon in 1948 supplied a new spherical analogy for the Telecosm. An MIT professor with close ties to Bell Laboratories, he developed information theory to gauge the potential capacity of any communications channel in the presence of noise. This work took the theory of the Telecosm from the center of the sphere, where power was unlimited and bandwidth scarce, to the surface of the sphere, where the results were weirdly wide and weak and counterintuitive.

For many years, few noticed the full significance of his baffling message. Andrew Viterbi, the famed author of the Viterbi algorithm, now at Qualcomm, was one of the few. With Jacobs and Gilhousen, they set out to fulfill the Shannon mandate. In the Telecosm today, physics, optics, engineering, signals, and noise all are now beginning to whirl centrifugally in Shannon's hyperspace. Just as Wavelength Division Multiplexing is the wireline expression of Shannon's vision, CDMA is the wireless form of "wide and weak."

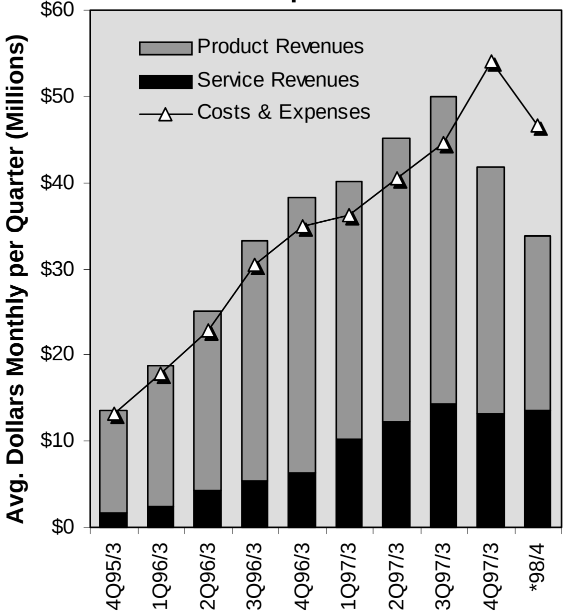
Essentially Shannon found a tradeoff between bandwidth and power. Increase the power and you enhance the signal to noise ratio. Increase the bandwidth, and you can reduce the power until you run into the wall of quantum noise called the Johnson limit. No surprise here. The surprise came in the terms of the tradeoff. In a digital system, the inverse relationship between power and bandwidth is exponential. The needed power drops exponentially with the increase in bandwidth.

Shannon's work is shrouded in hardcore math and the explanation can be skipped if you want. But it is worth getting a glimpse of his vision. It is most clearly expounded by his leading apostle, John R. Pierce of Bell Laboratories, in a book called *An*

Qualcomm commands much of the intellectual property, design skills, and engineering experience for the new worldwide standard for wireless telecom.

Chart 5

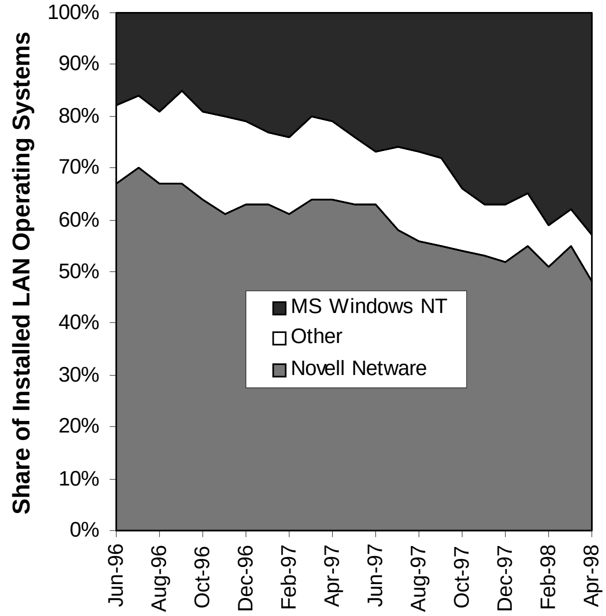
Netscape Flounders



Source: Company Reports *Jan-98 thru Apr-98

Chart 6

Novell Holds On



Source: Ziff-Davis Market Intelligence

Netscape revenues *were affected greatly by the company's change in dating of its fiscal quarters. The isolation of January's $54 million loss and the month's mysterious lack of revenues precludes a quarter-to-quarter examination. Consequently* **Chart 5** *shows Netscape's average monthly revenues each quarter through December 1997 followed by the monthly average for the first four months of 1998, which includes January and the new quarter ending April 30, 1998. The April quarter alone, while an improvement over the dismal month of January still posted a $10 million operating loss before the addition of income from interest ($1.8m) and other income ($8.3m), including the sale of a portion of Netscape's holdings in @Home. Chart 5 also tracks average monthly expenses, including the cost of products and services sold, sales and marketing, administrative, and R&D expenses, but excluding January's $12 million restructuring charge, merger related charges (2Q96: $6.1m, 4Q97: $5.8m) and purchased in-progress R&D (2Q97: $52.6m, 4Q97: $50.8m).*

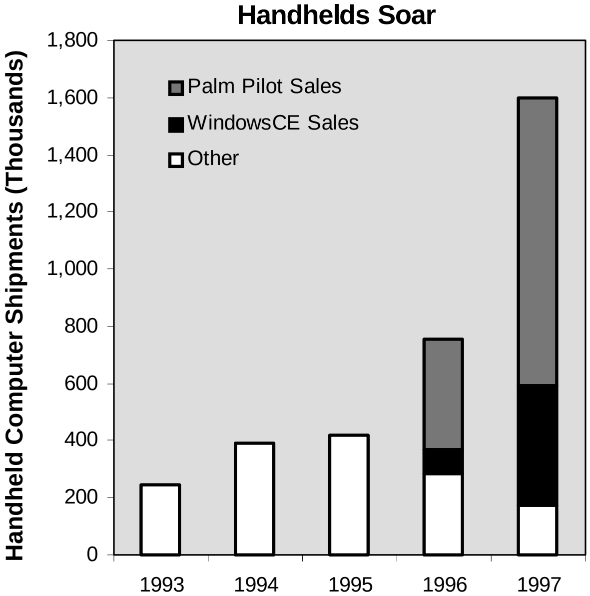
Novell's fate in its battle with Microsoft *to sell LAN (local area network) operating system (OS) software has mirrored the Netscape-Microsoft browser war. Novell's OS share of installed corporate LANs has declined from 70% in July 1996 to less than 48% today as NT has grown from 16% to 43% (***Chart 6***). Purchase plans show the extent of the Novell slide with only 22% share versus 76% for NT, according to Ziff-Davis Market Intelligence. IDC figures put Novell's current share at 43.2% to NT's 35.2% and report that 11% of those surveyed have plans to change OS this year with 68% of those choosing NT, a number equal to Novell's remaining 8% lead. In the competitive groupware market lead by Lotus, Novell retains the number two share of installed users, but has been surpassed by Microsoft which is approaching Lotus' share of new users. Trailing Novell, Netscape is fourth in new user share.*

The market for handheld computers *grew 65% from 1996 to 2.4 million units worldwide in 1997. Dataquest divides the market into expandable organizers with typically proprietary software and hardware, a segment which grew just 7%, and general-purpose handheld computers based on hardware and software standards, which grew 131% from 1996 to 1.6 million units in 1997 (***Chart 7***). While 3Com's Palm Pilot dominated the standard handheld market with 63% 1997 market share, Microsoft's Windows CE devices have seen steady gains, which impacted 3Com's share during 2H97 (***Chart 8***). 1998 will prove to be seminal for the handheld market. 1Q98 has seen 400% sales growth over 1Q97 according to Ziff-Davis Market Intelligence's latest figures. 2Q98 includes first shipments from several vendors of Microsoft's new palm-sized PC directly targeting 3Com's Palm III. But Microsoft's aims for Windows CE go beyond the handheld market to include the set-top boxes (using WebTV and with TCI), video game players (with Sega), and in-car systems (1997 sales of car navigation systems reached 1.178 million units with 90% of the market in Japan according to Nikkei Market Access).*

-KE

Chart 7

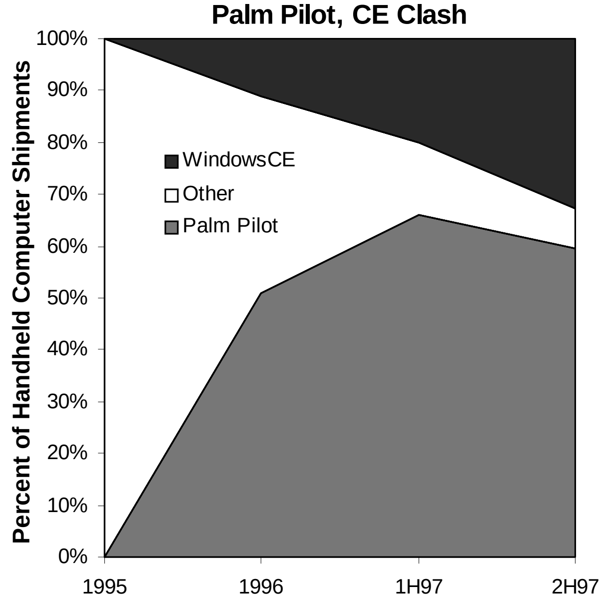
Handhelds Soar



Source: Dataquest

Chart 8

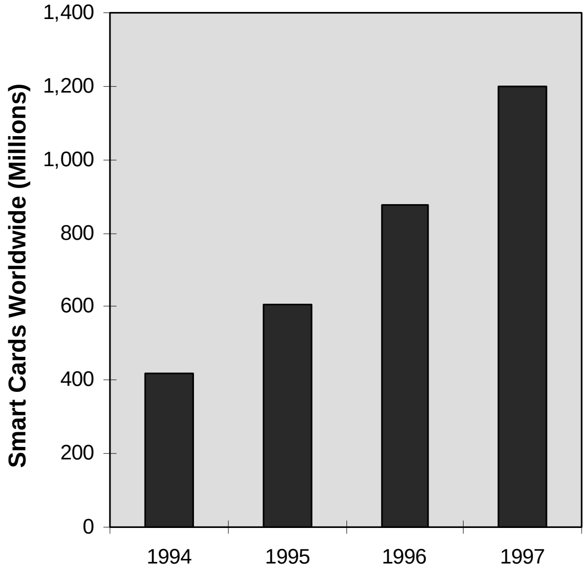
Palm Pilot, CE Clash



Source: Dataquest

Chart 9

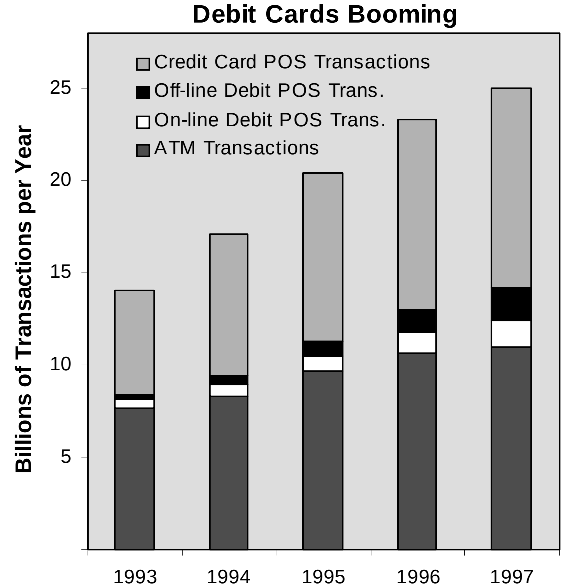
Cards + Java = Smart



Sources: Intellect Holdings, Dataquest, Philips, Gemplus, Orga

Chart 10

Debit Cards Booming



Source: Faulkner & Grey

Smart cards *are gaining popularity worldwide (***Chart 9***) due to their embedded processors which allow them to be used for payments based on encrypted account and balance information stored in the card's memory eliminating the need for real-time verification and credit checks. In the US, where cheap reliable communications links handle verification, the interest in smart cards focuses on their capacity to handle multiple functions. Non-bank usage by retailers such as Rite-Aid, Mobil Oil and Safeway is on the rise, especially for customer loyalty programs. American Express, IBM and Hilton Hotels began a smart card trial in May to speed hotel check-in/out. Look for e-tickets for travel and entertainment events downloaded over the Net to smart cards (online sales by Ticketmaster Group increased 270% over 1Q97 to 522,926 tickets worth $19.5 million during 1Q98). Visa International, Sun Microsystems and smart card manufacturer Gemplus are working with Bank of America, Citibank, First Union, Nations Bank and US Bank, along with the UK's Barclays, France's Carte Bleue, eleven Asian banks and other financial institutions to integrate multiuse functions into banking smart cards using Sun's Java. Motorola has developed mobile phones with built in smart card readers allowing users to check the card's e-cash balance, download funds or handle transactions, effectively putting an ATM machine into your pocket.*

Debit and credit card *usage in the US is shifting with the rise of "off-line" signature-based debit cards issued through Visa and MasterCard, which can be used anywhere credit cards are accepted. They are replacing "on-line" debit cards issued by banks, which rely on a direct on-line connection with the bank's ATM network. On-line debit cards have decreased from 188 million in 1993 to 150 million in 1997, and despite the growth of the special point-of-sale (POS) terminals (1.3 million in 1997 vs. just 155 thousand in 1993) they still only generate 9.6 transactions per card. Off-line debit cards have grown from 18.1 million (1993) to 70 million (1997) and with 25.7 POS transactions per card have now surpassed credit cards (22.7 POS transactions/card) in popularity. From 1996 to 1997, off-line and on-line debit point-of-sale (POS) transactions grew 48.39% and 31.6%, respectively, while credit card POS transactions and ATM transactions rose just 4.24% and 2.77% respectively (***Chart 10***). While cash transactions remain dominant, with 49.9 ATM transactions per debit card, the foundation is being laid for smart cards which replace cash with card-based e-cash and forego credit for direct account debiting.*

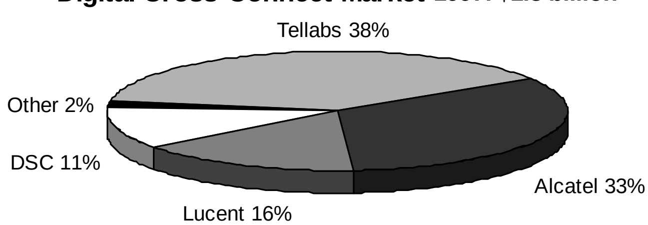
The Tellabs-Ciena merger, *announced June 3, is a bold and positive stride into the future of the Telecosm. Tellabs currently holds a 38% share of the worldwide market for digital cross-connects which represents some 60% of the company's revenues (***Charts 11 & 12***). As the market moves toward optoelectrical and all optical cross-connects Tellabs risked the loss of substantial revenues. Ciena's expertise in optical systems should speed Tellabs adaptation to meet the challenges of all optical networking. Ciena, meanwhile, gains entry to Tellabs extensive telecom customer base and the resources necessary to compete effectively with their larger rivals. Alcatel's purchase of DSC Communications, announced the next day, heightens the rivalry in this important market.*

Internet traffic *through the major US NAPs (network access points) and MAEs (metropolitan area exchanges) represented some 60% of Net traffic when GTR began reporting totals in July 1996. Accounts by MCI, Sprint, GTE, and UUNet suggest NAP/MAE traffic is currently only 20% to 40% of US traffic due to the growing impact of smaller regional and private exchange points, increased local caching and the globalization of Internet usage.*

-KE

Chart 11

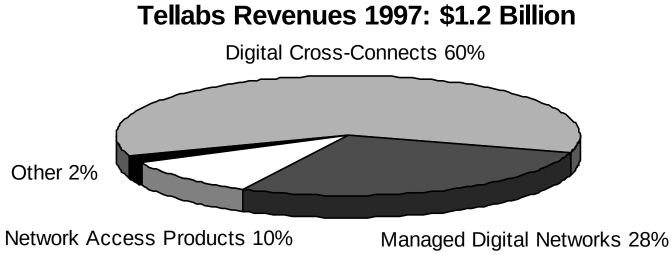
Digital Cross-Connect Market 1997: $1.8 billion



Source: Lehman Brothers

Chart 12

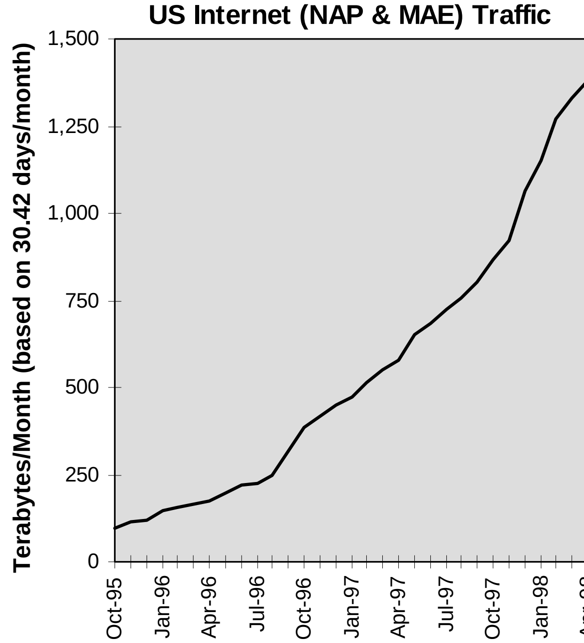
Tellabs Revenues 1997: $1.2 Billion



Source: Company Reports

Chart 13

US Internet (NAP & MAE) Traffic



We live in a world of scarce power, where noise and interference cannot be effectively banished and where spectrum sharing offers large benefits.

Introduction to Information Theory (still in print in a Dover paperback).

Following the insight of Jean Baptiste Fourier, any electronic message reduces to a set of sine waves, normally rendered as a series of voltages of regularly varying amplitudes or heights. The power of a voltage is equal to the square of its amplitude. Therefore the power of a set of signals combined in a message is equal to the sum of the squares of its constituent bits, each rendered as a voltage on a wire or in the air.

In communications, however, what matters is not just the signal's own power, dissipating through the air at a rate proportional to the square of the distance. Crucial is the ratio of the signal's power to the power of the noise in its path, the familiar signal to noise ratio. The noise also can be represented as the sum of the squares of the amplitudes of all the interfering static sampled along with the signal.

"Sum of squares" should remind you of something–the Pythagorean theorem, perhaps. Pythagoras allows you to define the square of the distance from the "origin" at the center of a four quadrant graph to any point on it as the sum of the squares of the distances along the x and y axes. If you want, you can add a z axis for three dimensions, moving from areas to volumes, or you can move from squares and cubes to circles and spheres.

Shannon stressed a key facet of this pattern. Shrink a circle to half its original diameter and it holds only one quarter of the original area. (Reversing this process yields some of the magic of Moore's law; double the diameter of a silicon wafer and you quadruple the number of chips it can hold). That's two dimensions. Double the diameter of a three dimensional sphere and you get eight times the volume. Shrink a sphere to half its diameter and the volume drops to one eighth. This means that in an ordinary sphere, like the globe, seven eighths of the volume lies in the half closest to the surface.

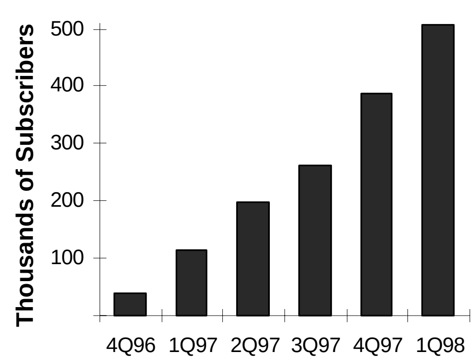
A rule leaps forth. The more dimensions in your geometry, the higher the percentage of the volume that lies near the surface. In fact, the share of the volume near the surface rises exponentially, by the power of the number of dimensions. The multidimensional geometers push the logic into hyperspaces, with an arbitrary number of vectors. In these hypothetical entities, all but an infinitesimal part of the volume is at the surface.

To Shannon, the analogy to communications was evident. Sending messages comprised a similar problem of a sum of squares (the squared amplitudes of the sine waves of the signal), combined with the sum of squared amplitudes of the noise. Shannon let the "volume" represent the "space" occupied by messages, with each signal a particular distance from the origin and its power the square of that distance. The distance between different binary signals indicates the number of bits that would have to change in order to convert one into another.

In Shannon's model, the trick of optimal communications is to push all of the message as close to the surface of a poly-dimensional "sphere" as possible. In a simplistic but suggestive image of a complex mathematical process, if the message moves to the surface it doesn't matter how much noise there is in the rest of the sphere. The signal pops out from the noise. In Shannon's classic formula for the capacity of a channel, the number of dimensions and thus the legibility of the signal is governed by the bandwidth, measured in hertz. For those who are interested, in an increasingly renowned MIT thesis on the scalability of spread spectrum, Tim Shepard expresses the key formula: Signal/Noise must be greater than 2 to the power of the bit rate over the bandwidth, minus one. For a particular size of message as measured in bits per second, the needed ratio of signal power to noise power is inversely and exponentially proportional to the bandwidth.

Chart 14

PrimeCo CDMA Subscribers



Source: Company Reports

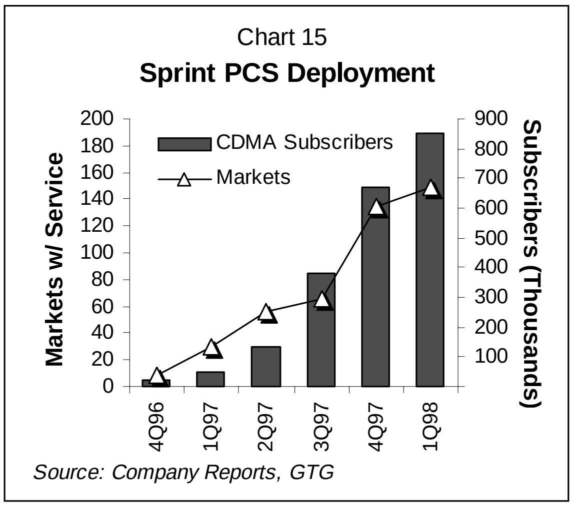
Putting the bandwidth in hertz as the denominator in an exponent with the desired number of bits per second in the numerator creates a kind of Moore's Law doubling effect for communications. Shepard points out that the bandwidth in hertz of spread spectrum digital processors doubles roughly every two years.

For most of the history of radio communications, engineers lived in a world of bandwidth scarcity, enforced by relatively low frequency digital processors, oscillators, amplifiers, transmitters and receivers. Contemplating the Shannon limits, they concluded that the key to successful communications was high power at long wavelengths (low frequencies)–a rule of "long and strong." In the presence of noise, they stayed at the center of the sphere and yelled louder. Broadcast TV was exemplary. Clear out all rivals in the frequency band, eliminating most noise, and then blast your signal across the landscape at megawatt force. With cells of 30 mile diameters and spectrum as low frequency as possible, cellular phones also excluded intruders and operated "long and strong."

Bandwidth abundance, however, changes drastically the meaning of Shannon's formula. It says that if you have the bandwidth, you can exponentially, within the limits imposed by Johnson noise, reduce your signal to noise requirements. You can drastically reduce power consumption and run potent radio transmitters at under one watt (thus even escaping FCC license requirements). You can spread your message across a wide spectrum of frequencies. You can even send messages perfectly in environments where the noise is hundreds of times louder than the signal. You use a noise-like pseudo-random code to spread out the signal at the transmitter; then you despread it at the receiver with an inverse code. The magic comes from the fact that the same inverse code that pops out the signal simultaneously spreads out the real noise, weakening it.

The first place this technique was tried was on the battlefield, where you could not call in the FCC to exclude hostile transmissions. Today spread spectrum is poised to dominate most two-way radio communications and possibly even cable communications as well.

To help figure out the future of the technology, I consulted Dave Hughes. A cowboy-hatted former infantry colonel with combat service in Korea and Vietnam, boasting an article in the April issue of *Scientific American*, Hughes is the rough and ready champion of using unlicensed sub-watt spread spectrum radios to bring internet access to rural schools and buildings. Using radios from **Solectek**, **Breeze**, and **FreeWave**, he runs a small ISP in Colorado Springs with no outside wires or FCC licenses and has laid out spread spectrum radio systems from Mongolia to Denver. Providing existence proof for the possibility of a new paradigm of spread spectrum wireless, he suggests that the CDMA victory will not end with cellular telephony.



Source: Company Reports, GTG

To find out why, I turned to Shepard and his thesis. Referring to spread spectrum analyses by Phil Karn, Shepard also presents his derivation of Shannon's channel capacity formula. Showing the exponential tradeoff between power and bandwidth, it points to the 100 fold advantage of CDMA over TDMA in power efficiency. Although the numbers will vary substantially in actual applications, they give a rough indication of the relationships. For example, to send 128 kilobits a second with a CDMA bandwidth of 1.2 megahertz, you need minus 11 decibels or a one to twenty signal to noise ratio, which means the noise can be 20 times as "loud" as the signal. With such a signal to noise ratio, GSM TDMA could not function at all.

In Pierce's book, he applies this model to full-motion, high-definition video at 40 megabits per second. With a bandwidth of 2 megahertz, you need a signal to noise ratio of 60 dB (a million to one). But with 8 megahertz, you can send the 40 megabits per second with a signal to noise ratio of a little over 15 dB (30.6 to one). In other words, expanding the bandwidth by a factor of four gives you a signal to noise improvement of a factor of 30 thousand.

Such exponentials suggest the efficacy of spread spectrum. But as Shepard insists, they do not disprove the contentions of TDMA and analog advocates that all these systems are equally efficient in an ideal world. We live, however, in a world of scarce power in mobile devices fueled by batteries, or remote devices fueled by solar cells. We live in a world where noise and interference cannot be effectively banished and where spectrum sharing offers large benefits. We live in a world where the self-organizing Internet is the prevailing model of communications and where the centralized control needed to manage TDMA time and frequency slots is falling from favor. The power control of CDMA turns out to be simpler to engineer than the frequency and time slot shuffling of TDMA.

In his thesis, Shepard proposes a Shepardnet, a fixed network with all the intelligence in the terminals, that takes new inspiration from the ALOHANet model of Norman Abramson in Hawaii. Linking island branches of the University of Hawaii, this wireless network pioneered the concept of a communications system controlled by its own terminals. ALOHANet also inspired Bob Metcalfe to invent the much more sophisticated Ethernet. Metcalfe and Abramson, however, were necessarily preoccupied with the problem of collisions between packets transmitted simultaneously in the network. But Shepherd shows that Moore's Law, smart radios, and wide and weak use of spectrum can enable new forms of shared ether in which the problem of collisions virtually disappears.

To achieve this goal, however, he will need some 2 gigahertz of spectrum. Today the largest available unlicensed band is just 150 megahertz in the 5.8 gigahertz domain. In the US, the FCC has favored allocation of the 59 to 64 gigahertz band to unlicensed and unregulated communications systems. Most radio people regard this band as a wasteland, fouled by an O_2 absorption area that weakens signals by 15 decibels. But for spread spectrum ether systems such as Shepard envisions, attenuation is good, because it reduces interference with neighboring cells. Shepherd projects that "in less than 10 years, it will be feasible to build spread spectrum systems in this band with spreading-code chip rates of 2 gigahertz. With 6 dB of directional gain in the antennas, a packet radio system could have raw transmitter rates of around 200 megabits per second, have transmitter duty cycles of 25 to 50 percent, and be scalable to millions of stations within a metropolitan area."

We live in a world where the self-organizing Internet is the prevailing model of communications and where centralized control is falling from favor.

ASCENDANT TECHNOLOGY	REPORT(S) Volume: No.	COMPANY (SYMBOL)	Reference Price	Price as of 6/4/98
Cable Modem Service	I: 2, 3; II: 7, 8, 9, 11, 12; III: 6	*@Home* (ATHM)	19 1/2	34 5/8
Analog to Digital Converters (ADC), Digital Signal Processors (DSP)	II: 3, 7, 12; III: 2, 4	*Analog Devices* (ADI)	22 3/8	24
Java Thin Client Office Suite, Rapid Application Development (RAD)	II: 6, 7, 12	*Applix* (APLX)	4 1/2	4 1/2
Dynamically Programmable Logic, Silicon Germanium (SiGe), Single Chip Systems	III: 4	*Atmel* (ATML)	17 11/16	13 1/2
Single-Chip Broadband Data Transmission	II: 10; III: 3, 5	*Broadcom Corporation* (BRCM)	24 *	54 7/8
Digital Video Codecs	II: 5	*C-Cube* (CUBE)	23	19 1/2
Fiber Optic Cable, Components, Wave Division Multiplexing (WDM)	II: 9; III: 5	*Corning* (GLW)	40 15/16	37 9/16
Low Earth Orbit Satellites (LEOS)	I: 2; II: 1, 3, 4, 8, 10; III: 6	*Globalstar* (GSTRF)	21 3/4	58 1/4
Business Management Software	III: 4	*Intentia* (Stockholm Exchange)	29	38
Wave Division Multiplexing (WDM), Fiber Optic Equipment	III: 5	*JDS Fitel* (Toronto Exchange)	19 1/4	19 1/8
Broadband Fiber Network	III: 2, 3, 4	*Level 3* (LVLT)	62 1/2	52 7/8
Single Chip ASIC Systems, CDMA Chip Sets	II: 8	*LSI Logic* (LSI)	31 1/2	23 15/16
Telecommunications Equipment, Wave Division Multiplexing (WDM)	II: 1, 2, 7, 9, 10, 11, 12; III: 1, 2, 3, 4, 5	*Lucent Technologies* (LU)	23 9/16	72
Single-Chip Systems	II: 8, 12 III: 4	*National Semiconductor* (NSM)	31 1/2	15 3/4
Telecommunications Equipment, Wave Division Multiplexing (WDM), Code Division Multiple Access MA), Silicon Germanium (SiGe)	II: 1, 7, 9, 11, 12; III: 1, 2, 3, 4, 5; III: 6	*Northern Telecom* (NT)	46	62 1/16
Point to Multipoint System for 7-50 Ghz, Spread Spectrum Broadband Radios	II: 10, 11	*P-COM* (PCMS)	22 3/8	14 3/8
Code Division Multiple Access (CDMA)	I: 1, 2; II: 1, 3, 4, 7, 8, 9, 10, 11 III: 4, 5, 6	*Qualcomm* (QCOM)	38 3/4	51 1/4
Broadband Fiber Network	II: 9, 10, 11; III: 1, 2, 3	*Qwest Communications* (QWST)	20 3/8	31 9/16
Java Programming Language, Internet Servers	I: 1, 2, 3, 4; II: 1, 5, 6, 7, 8, 10, 12	*Sun Microsystems* (SUNW)	27 1/2	44 7/16
Optical Equipment, Smart Radios, Telecommunications Infrastructures	I: 1; II: 1, 2, 3, 9; III: 3	*Tellabs* (TLAB)	29 1/8	63 5/16
Broadband Wireless Services	II: 9, 10, 11, 12	*Teligent* (TGNT)	21 1/2 *	27 3/4
Digital Signal Processors (DSP), DRAM	I: 2, 3, 4; II: 5, 8, 11, 12; III: 3, 4, 6	*Texas Instruments* (TXN)	23 3/4	50 7/8
Wave Division Multiplexing (WDM) Modulators	II: 7, 9, 10 III: 4, 5	*Uniphase (UNPH)*	29 3/8	55 3/8
Telecommunications, Fiber, Internet Access	II: 9, 10, 11, 12; III: 1, 2, 3, 4	*WorldCom* (WCOM)	29 15/16	45 1/16
Field Programmable Logic Chips (FPGA)	I: 3	*Xilinx* (XLNX)	32 7/8	36 1/16

* Initial Public Offering

Note: This table lists technologies in the Gilder 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 these core competencies, without any judgement of market price or timing.

THE SPECTRUM SPREAD

"the CDMA leaders"

QUALCOMM-Following the development, promotion and marketing of CDMA technology to the world, Qualcomm has become a stakeholder in Mexico's new nationwide wireless CDMA network and other international deployments. Look for continuing spinoffs of its service holdings into a new 20 percent owned subsidiary.

SPRINT PCS-Sprint PCS has committed over $5 billion for CDMA equipment in their aggressive rollout of the only all digital, all PCS, nationwide wireless network. It already serves 156 metropolitan markets comprising some 800 cities and has grown to over 1.1 million mostly CDMA subscribers (Sprint is GSM in DC). With Sprint's announced buyout of its Sprint PCS partners, TCI, Cox and Comcast, and the concurrent spinoff and IPO of the PCS service, Sprint PCS will become a pure play in the future of wireless CDMA.

AIRTOUCH (ATI)-AirTouch Communications is the largest wireless company in the world, with global ventures serving 29 million total customers (14 million proportionate customers based on the company's ownership interests), with 175,000 CDMA customers in the US. AirTouch now owns half the CDMA PCS venture PrimeCo, with a March customer base of 508,000 and holds a 10.7% share in South Korea's Shinsegi CDMA network with 1.2 million subscribers in March, and 6% of Globalstar's global LEO satellite-based CDMA system.

NORTEL (NT)-Along with their other Telecosm Technologies ranging from WDM fiber systems to broadband xDSL access, Nortel has been a major player in the buildout of CDMA networks with US CDMA-PCS equipment and service agreements topping $1.6 billion. And in a rare show of protocol agnosticism, Nortel has also announced some $1.2 billion in US GSM-PCS contracts, positioning Nortel to play a crucial role in unifying world standards.

SPECTRIAN (SPCT) just received a 1998 Key Supplier Appreciation Award from Qualcomm, as a nearly unique producer of RF power amplifiers sufficiently linear for new generations of CDMA. **Microwave Power Devices** (MPDI) is another.

George Gilder, June 8, 1998

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