Unfortunately, regardless of the ultimate result, the DTV transition will have been needlessly delayed for years. While the Sinclair Petition is pending, manufacturers will have no incentive to develop COFDM-compatible equipment based on the very real possibility that any investment to this end could be nullified. If, of course, a dual standard was ultimately adopted, manufacturers would then be forced to quickly focus on COFDM technology, at the expense of 8-VSB. However, given the manufacturing cycle, it would take a minimum of 18 months to incorporate COFDM into its products. If two standards are in fact adopted, only gradually would market forces reveal the proper allocation of research and investment. And even then, as Sinclair's Nat Ostroff has noted, "Multiple standards would not only create chaos but would so fragment the market so that no serious business could invest in the tooling to produce multiple standard receivers into such a market."[40]

By quickly disposing of the Sinclair Petition and retaining 8-VSB as a single and stable transmission standard, the Commission will enable DTV equipment manufacturers to focus on driving down costs associated with DTV products and continuing to integrate improvements and innovations, including advances maximizing indoor reception performance.[41] Efforts to this effect have been in progress since field tests first suggested that work was needed to enhance reception in high multipath environments. Manufacturers have introduced technical advancements with every

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[40] *Ostroff White Paper*, *supra* note 31.

[41] *See* OET DTV REPORT at 25 (stating that "it is reasonable to conclude that manufacturers are addressing and will solve this problem in the near future"). The OET continued by noting that, due to impulse interference, "further study would be needed before it could be concluded that COFDM has a significant overall advantage over 8-VSB for indoor reception." *Id.* at 25.

generation of digital receivers and recently developed chipsets offer the potential for substantial improvement of indoor reception.[42]

C. Accepting the Sinclair Petition Will Invite A New Multi-year Standards-Setting Process

Sinclair's attempt at clever protestations to the contrary, accepting this Petition would present the prospect of a laborious and multi-year process. Sinclair's Nat Ostroff himself has recognized that it took $100 million dollars and eight years to produce a fully tested and specified digital TV broadcast standard that had the support of the entire broadcast industry.[43] Any proceeding commenced by the Commission therefore would require a multi-year process to document and test a new standard, notwithstanding Sinclair's obfuscatory "request for expedition" and delineation of a 120-day Task Force.

Sinclair failed to submit even the most elementary technical information specifying the standard it is proposing. It is easy to say "let's use COFDM" or "8-VSB", or even "QAM." But each of these technologies has multiple configurations, and each configuration has benefits and detriments the elements of which are crucial to identifiable stakeholders. By its omissions, Sinclair is asking others, including the Commission, to absorb the delay and expense necessary to agree on the technical elements of a standard and to document them so that all stakeholders have access to the required information. At best this requires a minimum of two years, not 120 days. And in this process the Commission will have to consider QAM and ISDB (the proposed Japanese digital standard) as well as various additional COFDM implementations and

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42 *See id.* at 21 & 25 (discussing NxtWave and Motorola VSB demodulator chips).

options. To the extent 6 MHz COFDM were standardized, manufacturers would still need approximately 18 months to design and build dual mode receivers, thus further delaying the transition.

In the meantime, consumers, manufacturers, and the transition to DTV will be harmed by <u>any</u> length of uncertainty engendered by a new digital standards proceeding. Yet Sinclair's Petition inherently proposes that the Commission, along with industry, define and develop its generic standard over the coming months that inevitably will turn into years.

Unlike 8-VSB, there is no COFDM standard developed, tested, and documented that is designed to work within the six megahertz channels used in this country. Tested COFDM standards use 7 or 8 MHz channels. Additionally, adopting a COFDM transmission standard would require, *inter alia*, settling on a data transmission standard, exploring impulse noise concerns, and studying interference characteristics. Cognizant of these myriad open issues, the Commission's Office of Engineering and Technology recently noted industry concerns regarding impulse noise, "particularly in the VHF band and the lower portion of the UHF band" and highlighted the need to study and test interference characteristics of COFDM.[44] COFDM also is not demonstrated to be conducive to sharing with the incumbent NTSC co-channel and adjacent channel stations in the wide station distribution patterns generally found here in this country.

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43 *See Ostroff White Paper, supra* note 31.

44 OET DTV REPORT at 20 & 24.

It is also extremely unlikely that the DTV Table of Allotments could accommodate the introduction of COFDM transmissions. This is a certainty if COFDM broadcasters would approach replication of existing analog service areas by either: (1) increasing power; or (2) constructing, connecting, and operating a single-frequency network consisting of multiple transmitter sites. This second scenario would also force broadcasters to secure multiple tower cites and deal with the attendant construction and local zoning disputes.

The Table of Allotments consumed the final years of the decade-long proceeding at the Commission and is now on appeal in the D.C. Circuit Court of Appeals.[45] While the handful of Petitioners and supporting Intervenors challenging the current Table of Allotments may welcome new allotments necessitated by the addition of a COFDM transmission standard, it is logical to assume that broadcasters across the country who have not challenged the Table of Allotments will believe that they are entitled to nothing less than their current allotment, should the Table be re-crafted. Broadcasters themselves tabbed replication as the most important factor of the entire transition to DTV. The Commission already has noted that "more than one transmission standard would make it more difficult to facilitate an efficient allotment of broadcast channels and protect against interference."[46] The Petition requests an "expedited rulemaking," and yet Petitioners are acutely aware that: "If multiple standards were to be adopted there would be no data on how these standards would

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[45] *Lindsay Television, Inc. v. Federal Communications Commission*, No. 98-1105 (D.C. Cir. Joint Brief of Petitioners filed Oct. 7, 1999).

[46] *Fourth Report and Order* at ¶ 36.

interfer [sic] with each other.. [sic] Thus, there would be no way to determine the effects of interference and thus no way to assign channels."[47]

VII. CONCLUSION

For the reasons described above, the Petition submitted by Sinclair Broadcasting should be dismissed forthwith.

Respectfully submitted,

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October 14, 199

[47] *Ostroff White Paper, supra* note 28.

CERTIFICATE OF SERVICE

I hereby certify that a copy of the foregoing Opposition to Petition for Expedited Rulemaking and Motion for its Immediate Dismissal was, by first-class U.S. mail, postage prepaid, served this 14th day of October, 1999, upon the following:

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***Hand Delivered**

Susan M. Brunson

Susan M. Brunson

A

MOTOROLA

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Conference Call
Stock Quote
Stock Chart
Financial Reports
Financial History
Fundamentals
SEC Filings
Press Releases
Presentations
Audio Archives
Analysts
Earnings Estimates
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Dividend History
Mail Alert Selection
Stock Purchase Plan

Motorola Inc. (ticker: MOT, exchange: The New York Stock Exchange) News Release - Monday, August 23, 1999

New Technology from Motorola Enhances Reception of Digital and High Definition TV; A Solution for the Urban Reception Problem

CHANDLER, Ariz.--(BUSINESS WIRE)--Aug. 23, 1999--A new digital receiver technology from Motorola solves a potentially serious reception problem in digital and high-definition (DTV/HDTV) broadcasts that use the Advanced Television Systems Committee (ATSC) transmission standard adopted by the Federal Communications Commission (FCC).

Broadcasters expressed concern recently when third-party test results showed that multipath reflections -- or multiple signals arriving at an antenna at different times due to obstacles such as buildings or automobiles -- interfered with DTV reception. Addressing this issue, Motorola, in collaboration with TV pioneer Sarnoff Corporation, has created a proven, revolutionary digital signal processing architecture known as the MCT2100 demodulator chip that provides excellent signal reception, even under difficult ghost signal conditions found often in urban areas.

"The industry's efforts towards ATSC can now become a reality," said Wil Salhuana, Vice President and General Manager, Entertainment Solutions Division, Motorola. "The MCT2100 demonstrates Motorola's ability to engineer original, forefront technology solutions, which in this case, will have a significant impact on the quality of digital television technology."

Glenn Reitmeier, Vice President for DTV and Web Media at Sarnoff, said the new chip means that all of the capabilities of the ATSC standard will be available to TV set makers and their customers, the viewers. "The MCT2100 is a major step forward in implementing the perfect pictures and reliable data transmissions that the creators of the ATSC standard intended for DTV and HDTV."

"The development of this technology demonstrates

Motorola's commitment to provide the industry with solutions for the ATSC standard," said Bob Stokes, Director, Digital TV Operations, Motorola.

The MCT2100 is a member of Motorola's M-DTV™ chip set, which provides low-cost solutions to make digital television more affordable to the consumer, easing consumer's transition from analog to digital formats. The M-DTV chip set provides solutions for DTV sets, satellite and cable set-top boxes and digital versatile disk (DVD) players.

The MCT2100 is part of Motorola's DigitalDNA™ technology, the intellectual property that makes up the heart of intelligent consumer and business devices.

About Motorola

As the world's No. 1 producer of embedded processors, Motorola's Semiconductor Products Sector offers multiple DigitalDNA™ solutions which enable its customers to create new business opportunities in the consumer, networking and computing, transportation, and wireless communications markets. Motorola's worldwide semiconductor sales were $7.3 billion (USD) in 1998. http://sps.motorola.com

Motorola is a global leader in providing integrated communications solutions and embedded electronic solutions. Sales in 1998 were $29.4 billion (USD). http://www.motorola.com

About Sarnoff

Sarnoff Corporation creates and commercializes electronic, biomedical and information technology. Founded in 1942 as RCA Laboratories, Sarnoff has been a wholly owned, for-profit subsidiary of SRI International since 1987. Building on decades of innovation, including the development of color television and the liquid-crystal display, Sarnoff now works with a wide variety of industry and government clients to develop and improve specific technologies that will help change the world. A key element of the company's overall strategy is the founding of new companies that bring its technologies to market. Eleven such companies are in various stages of development.

M-DTV and DigitalDNA are trademarks of Motorola, Inc.

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HDTV NEWS ONLINE - 1 800 999-HDTV CLICK HERE

COFDM VS. 8-VSB

"We attacked the problem of large dynamic and static echoes head-on with what I believe to be the world's most advanced equalizer ever to be deployed in a consumer receiver. This is to elemenate multipath from the equation so that from the broadcasters point-of-view the only issue is signal power in determining coverage." - Motorola

Chips Ahoy

By

Dale E. Cripps

Reports raced throughout the Internet on August 19th that a "new chip" (dubbed by cynics as the "Mystery Chip") had been developed in Pennsylvania to adequately handle dynamic multipath reception for 8-VSB receivers. "I must say the timing is 'perfect.'" offered Sinclair Broadcast Group's Nat Ostroff. A news release surfaced from Nxtwave Communications in PA on the 24th.

Nxtwave Communications Inc., of New Town is a spin-off of the David Sarnoff Research Center, themselves no stranger to consumer product innovations. "Nxtwave began 3 years ago as a Sarnoff incubated company," said Sarnoff's CEO, Jim Carnes.

Not only Nxtwave, but Motorola also released on August 23rd a press release heralding their new chips capable of handling dynamic multipath for 8-VSB. This chip also came from a partnership between Motorola and Sarnoff.

"The real mystery to me is where these people were when Sinclair was begging for 8VSB receivers that worked." asked Microsoft's Tom McMahon.

Less skeptical was Lynn Claudy, vice-president of Technology of the National Association of Broadcasters. "They have been working quite unnoticed for several years, Only recently have they come to anyone's attention."

Nat Ostroff had also heard something of them and invited Nxtwave to take part in the Sinclair tests. He received no response. "It seems a little bit early to make claims for your chip when it has not yet been tested, let alone in the field," he was quoted saying then. "Others came to us with 'solutions' that did not prove out in field test." He adds "But having said that, I truly hope they have what they say they have."

Lab test of the new chip use signals from simulated environments. Many conditions were taken from recorded field locations in Baltimore. "That is a lot different than from real world," acknowledges Claudy. He is not alone in looking forward to a tested solution to the paralyzing challenge laid down by Sinclair. "It would be a disaster to dismiss 8-VSB at this late date," says Sarnoff's Jim Carnes, adding, "and it won't be necessary." Carnes believes that all of the worry "will be DTV history to look back upon in 4 months time." Claudy agrees.

Bob Graves, Chairman of the ATSC, certainly hopes these devices work. He is faced with marketing the US 8-VSB transmission system abroad and acknowledges that Sinclair's work has done a great deal of damage to his international

mission.

Broadcom is another equalizer company who will surface soon with their solution on a chip. The chips from each vendor had been kept under tight security wraps until now. Some think the timing of these announcement is just too cozy and is setting up the industry with new complicated considerations so manufacturers can get past the Christmas season before the other shoe drops. But these chips have been under development for over a year. They are following current product introductory patterns. Few outside of essential parities were aware of the work going on. Just last Wednesday a high-level meeting was held in Washington, DC by those in support of 8-VSB. They met to determine what would be the best response to the Sinclair initiative. ATSC, MSTV, NAB, CEMA and others debated without conclusion on how or with what they could respond. The chips had not been disclosed to even those in attendance..

Nat Ostroff, the architect of the side-by-side test of 8-VSB and COFDM at Sinclair, has said repeatedly that the American system should have the "same" receiving characteristics as any system available anywhere in the world, i.e.,like COFDM. Ostroff has also declared repeatedly his neutrality as to which system finally prevails, just as long as it works. COFDM is clearly a competitor, but like all competing things they offer competing features or design promises. Ostroff has been favoring the inclusion of COFDM in the FCC standard as an option to use rather than excluding 8-VSB in favor of COFDM exclusively. With ample co-signers from other group broadcasters, Sinclair is within days of being ready to issue a petition to the FCC asking for COFDM inclusion.

With the announcements from Motorola and Nxtwave Sinclair's petition plans are left pending a further detailed examination of the claims of these chip makers. The petition has not been dropped as there are still thorny issues with the receiver manufacturers that may have to be addressed formally. The FCC has advised consultants today that these equalization chip announcements alter their view from within the Commission, which had been growing in receptivity to accepting a petition from Sinclair and issuing a Notice. If proven in field test, these chips will change the way everyone is viewing the question, including and potential signers of the petition. Getting them used will be the other companion story.

So, what can broadcasters expect? We contacted Motorola on the 24th. I talked to Jeff Davis, Vice President of Global Sales, Imaging and Entertainment Solutions group, Jim Farrell, Manager of Marketing Communications, Imaging and Entertainment Solutions group, and Frank Eory, Designer, Digital TV Operations, Imaging and Entertainment Solutions group about the performance of the chip.

INTERVIEW

Motorola has developed an equalizer chip for "sub $20 in quantity." Drawing liberally from a vast experience in equalization technology from their industrial background Motorola claims they are delivering the most advanced equalizer ever be be deployed in a consumer electronics package.

HDTV NEWS ONLINE: What have you done to solve the problem illuminated by Sinclair?

MOTOROLA--FRANK EORY: We attacked the problem of large dynamic and static echoes head-on with what I believe to be the world's most advanced equalizer ever to be deployed in a consumer receiver. This is to elemenate multipath from the equation so that from the broadcasters point-of-view the only issue is signal power in determining coverage.

We spent several weeks in lab testing. Field test are in progress as we speak. We are throwing all kinds of ugly VSB signals at this thing, including the Sinclair-Lombard Street and Sinclair Harbor Apartments scenarios--at least the lab emulation's of those. We went even beyond those scenarios once we saw how much margin we had with those multipath ensembles.

Basically, at least from laboratory measurements, we have demonstrated that multipath is not a problem, both very large static echoes as high as .1 db below the desired signal. With the Sinclair scenario quoted 10 Hz flat fading and 10 Hz dynamics on those strongest echoes, and in the ATSC Grand Alliance echoes, we have gone as high as 20 Hz on dynamic multipath. Quite honestly we are still trying to characterize the whole performance space of echo amplitude and dynamic phase rate to explore the extreme limits of what this thing can do.

HDTV NEWS ONLINE: Then you confidently claim that you are doing all that COFDM is doing?

The one thing that COFDM is claiming, which I think is an area of challenge for 8-VSB receivers in general, is mobile reception. Different people define that different ways. We have clear evidence we can support pedestrian mobility--a guy walking around with a lap top with an antenna poking out the back--sort of low speed mobility. But the stuff they are doing in Europe in trying to demonstrate reception at 200 MPH down the Autobahn. That is more challenging for the ATSC system because we don't have the luxury of falling back to some very low data rate. In Europe they go to QPSK and put in extreme amounts of FEC (forward error) encoding and, yes, they can demonstrate some high speed reception, but not very much data at those speeds. That is all a "flexibility of standards" issue, but not something the ATSC was designed for.

The 20Hz dynamic is a lot more than leafs blowing in the wind or people walking around the room. Like I say, it easily satisfies pedestrian mobility, but falls something short of high speed freeway traffic.

HDTV NEWS ONLINE: Nat Ostroff has continued to say that he is neutral as to which system is finally used as long as it delivers "the same" as the one he can now have, i.e., COFDM. Does your chip satisfy this condition, or a percentile of that condition? How can we rightly compare it? Is there a set of testing procedures that will allow an apples to apples comparison?

MOTOROLA, JEFF DAVIS: When you say the same, we have a lot of variables there that relates not only to the type of terrain you need to deal with, but the factor in power and coverage from the transmitter.

HDTV NEWS ONLINE: Yes, I am just wondering out loud how you factor in whatever trade offs are left?

What was really demonstrated in Baltimore was the inadequacy of the early generation of the receivers. Clearly there were some issues from the UHF propagation point of view with indoor reception. What is the static and multipath environment really like with a set top and bow tie antenna? Some of those things were not addressed by the Grand Alliance test and not really addressed by first generation receivers. Nat drove home that point that these receivers have got to get better. We have been working for more than a year now to answer that question.

HDTV NEWS ON-LINE: Did you move from Nat's earliest initiative, now over a year ago?

MOTOROLA, JEFF DAVIS: We have been working with our partner Sarnoff on a number of devices for over two years now. This is actually the second chip to have come out of that partnership. We are very pleased that Nat gave us some additional difficult scenarios thanks to the data capture that was done and posted on the web by Oak Technology. That gave us real world signals that we could throw at this thing, and then say, "yeah, it can handle those with no problem. What's next?" We are out now working with various broadcasters and some of the consultants that know where the nasty spots in various cities are. We will go out and demonstrate with a bow tie antenna in a Manhattan apartment soon, etc.

HDTV NEWS ONLINE: Does your approach require training signals?

MOTOROLA--FRANK EORY: We are not worried about them at all. One of the key points that a lot of receiver designers recognized a long time ago is that the training signal sequence in the ATSC signal itself doesn't happen often enough--some 25 milliseconds. That is not enough to cope with the dynamics, so you have to go to blind techniques and the training signal is just some other data that is nothing special.

HDTV NEWS ONLINE: What is left to do?

MOTOROLA--FRANK EORY: Quite frankly for the home receiver or low speed portable, we have taken the multipath equation completely out of the picture. So, the only challenge left is to improve the speed of those dynamics, which translates to vehicle speeds. That is really the only problem left to solve.

HDTV NEWS ONLINE: Is that foreseeable as we advance in silicon?

MOTOROLA--FRANK EORY: As far s COFDM doing that today...it is not clear just how much value that is. As I mentioned, it is extremely low data rate (from COFDM). It seems to be enough for a single SDTV program in an 8 MHz TV channel, but what does it mean if it was in a 6 MHz US channel?

Something else that Nat and other COFDM proponents have not really addressed is: Can you do HD in a 6 MHz channel? I am very familiar with the COFDM standards--more than you might realize--and there are some entries in the table in terms of spec code rates that do support HD kind of data rates, but if you actually do one of those, how robust is it? No one has demonstrated that yet.

HDTV NEWS ONLINE: You will have no data rate penalty using your VSB chip?

MOTOROLA--FRANK EORY: No, it is in the standard at 19.39 Mb/s

HDTV NEWS ONLINE: Take this opportunity to address all of the broadcasters in the US and Canada who might have concerns from the Baltimore initiative. What do you want them to know?

I would summarize it this way: This chip COMPLETELY removes the multipath issue from the equation.

HDTV NEWS ONLINE: "Completely" is a big word.

MOTOROLA, JEFF DAVIS: Yes, COMPLETE with the caveat that it (the usage) is home (for) reception and pedestrian portable. I am not going out on the limb saying it will handle mobile reception. But it completely eliminates the dynamic and multipath issues. For the broadcaster the only significant variable becomes that of transmitter power to determine coverage.

HDTV NEWS ONLINE: Does this, then, support Bob Graves' contention that 8-VSB is the superior of the two?

MOTOROLA, JEFF DAVIS: This is still to be demonstrated. Nat has his data and we will have our data, but in theory it is better on the fringe areas because it should require less signal-to-noise than COFDM. The more extended of the Sinclair test--those further out sites--claim that they saw no real advantage of 8-VSB over COFDM. But again, those were early generation receivers where they didn't deal with multipath adequately. So who can say (they were optimized for distance)? But we have an equalizer now that makes everything look like a gausian noise channel essentially. It cancels the multipath so that the rest is straight forward text book--how much signal power do you have? How much signal-to-noise ratio do you have at x miles from the transmitter. That should be the only variable that the broadcaster should be concerned with from this point on.

Thank you very much.

Hearing of these claims Ostroff said, "We are very excited about the prospects of these new chips."

Now comes another issue. The fact that there are chips to solve these problems does not guarantee they will be used, or if used, will not discriminate against terrestrial broadcasting with a higher box price than for a cable or DBS box. "We cannot tolerate that," says Ostroff. Lynn Claudy thinks it's good to be mindful of these remaining implementation issues and encourages someone to be the authority that mandates receiver performance. He first looks to the ATSC, and the NAB's Eddie Fritts has already suggested that the FCC get involved. Nat Ostroff does not want a two-tiered price structure with DBS or cable boxes being cheaper. With both the Nxtwave and Motorola chips entering the market at under $20 ($22 in quantities of ten thousand for Nxtwave) Moore's law would suggest that price will be very trivial in a few years time. In the mean time the cost of electronics is not the big issue in HDTV, where display and cabinet are so dominant in end pricing. But for boxes that convert DTV to an NTCS receiver, or a DTV SDTV receiver, an added cost at retail of $60 to $100 could be market-impacting. More on this topic at a later time.

More important now is to keep heads cool, evaluate the claims in a setting (why not back to Baltimore? Nat extends the invitation.) that will not provoke additional controversy, and heal the rift that has grown between broadcasting and their essential partners--the manufacturers.

Dale E. Cripps

From Motorola

Feature Set --

- High performance robust complex equalizer
- Glueless interface with 10-bit industry standard
- A/D converters, accepts pass-band
- samples at 25 MHz as VSB input
- Processor communication through an I 2 C serial interface
- Digital on-chip timing recovery - no external crystal required
- Provides gain control signals
- Reed-Solomon decoder, Trellis/Viterbi decoder, deinterleaver
- Signal interface for glueless connection to the
- MCT4000 or a PCMCIA card for conditional access systems
- Transport Stream interface with error checking and bit setting
- All digital architecture for cost effective silicon implementation
- 1.8 V operation voltage
- 160 QFP packaging

The MCT2100 is a single-chip all digital demodulator implementing Vestigial Sideband (VSB) demodulation and Forward Error Correction (FEC) functions for the reception of digital terrestrial broadcasts. It complies with the FCC 96- 493 Report and Order for terrestrial DTV broadcast that specifies the VSB modulation system. The MCT2100 achieves extremely high performance using a minimum number of standard, low cost external components to provide a complete 8 VSB demodulation system at an extremely competitive cost. A VSB demodulator must efficiently compensate for all the factors affecting the digital terrestrial broadcast. It must handle artifacts

such as multipath signals and gain variation. At the same time, fast aquisition and low error rate are mandatory.

The MCT2100 uses a unique implementation of novel algorithms to meet all of these requirements and much more. It features low power dissipation in a low cost, industry standard, leaded surface mount package. Because of its high integration, simplicity of external design and straightforward interface, the MCT2100 enables fast design cycles and time to market. Motorola's VSB demodulation solution was designed with system effectiveness in mind. The MCT2100 consists of an active front end for timing recovery, AGC and pilot tracking together with an integrated back end for deinterleaving, error correction, serial or parallel data output and status reporting. Pins for gain control and IF data allow the MCT2100 to easily interface with other system devices. A host interface through an I 2 C bus is included along with an event interrupt signal to provide simple glueless control from the processor. Using years of experience in digital signal processing, Motorola has developed a solution, which is very reliable, design efficient and cost effective, thus providing customers the best solution for market success.

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SEMICONDUCTOR NEWS

Update: NxtWave DTV chip attacks multipath interference

By Junko Yoshida
EE Times
(08/26/99, 11:52 a.m. EDT)

NEWTOWN, PA - NxtWave, a Sarnoff Corp. spin-off, this week detailed the company's new DTV demodulation chip, called NXT2000, featuring an equalizer based on what the company calls "a revolutionary new architecture."

Matt Miller, president and chief executive officer, said that with the company's new chip, a 30-foot specialized outdoor antenna for DTV will soon be a thing of the past, allowing consumers to receive DTV signals with an indoor, $2.99 UHF bow-tie antenna.

The chip's equalizer zeroes in on one of the plagues of today's terrestrial digital-TV reception -- static and dynamic multipath interference.

Back in the late '80s when nobody thought it was possible, Miller, as vice president of technology at General Instrument Corp. encouraged his engineers to design an all-digital television. Today, Miller is out to prove the industry wrong again.

NxtWave Communications Inc. has focused on developing a high-performance DTV demodulation chip. The chip debuts at a time when vestigial sideband (VSB) technology is under sharp attack from some broadcasters because of its susceptibility to multipath interference.

Armed with the company's new demodulation chip, Miller said, "I think we can safely say there is nothing wrong with today's U.S. HDTV standard using VSB." Although he declined to speculate on motives behind broadcasters such as Sinclair Broadcast Group -- which is pushing its own agenda to petition the Federal Communications Commission to allow coded orthogonal frequency-division multiplexing (COFDM) to be a part of the DTV transmission standard -- Miller responded, "Let's get on

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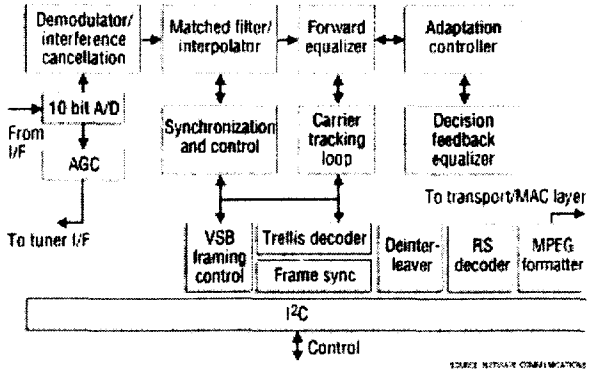
transmission standard -- Miller responded, "Let's get on with it and go build the industry."

CHIP SPEEDS SIGNAL ACQUISITION, EQUALIZATION

NXT2000 uses 'blind' and 'sparse' equalization to attack multipath interference



NxtWave's NXT2000, sampling today and due for volume production in the fourth quarter, will come with a number of unique features -- in terms of higher integration and performance -- not available in its competitors' VSB chips.

First, the new ASIC is a multimode VSB/QAM receiver IC. It decodes 8 VSB terrestrial and cable signals such as the Docsis-compliant 64/256 QAM. Although its main market is terrestrial DTV receivers which must demodulate VSB signals, having a QAM demodulation capability inside the chip prepares a DTV receiver to become "digital cable-ready," required in the future. In the long run, consumer electronics OEMs will develop DTVs to receive not only VSB-based terrestrial DTV programs but QAM-based digital cable. "Our chip won't be obsolete when that happens," Miller said. "With our VSB chip, QAM capability comes for free."

Also integrated on the chip are a forward error correction as well as a direct IF sampling analog-to-digital converter. No other VSB demodulation chips on the market have gone so far as to incorporate an A/D converter.

NXT2000 stakes its biggest claim-to-fame, however, on its equalizer. With a goal to cancel transmission-channel impairments such as multipath, phase noise, adjacent or co-channel NTSC interference and impulse noise, NXT2000 was designed to speed both DTV signal acquisition and equalization. Incorporated in the equalizer's fundamental architecture were two key techniques: "blind equalization" and "sparse equalization."

Most VSB demodulation chips today use a training sequence that comes with an MPEG stream to equalize. The training sequence essentially allows a chip to do comparisons and figure out math changes between original VSB signals and those signals that were damaged by foliage, buildings or other sources of interference.

NxtWave engineers, however, say they have found a way to equalize without such a training sequence. Applying a technique called "blind equalization," originally developed for military applications, NXT2000 equalizes VSB radio signals symbol by symbol, Miller said.

NXT2000 also uses a technique called "sparse equalization," making a sharp contrast to "a full-equalizer design" in a competing VSB chip jointly developed by the Motorola and Sarnoff corporations recently. The goal of the two competing chips, however, remains the same: to improve DTV reception performance by resolving dynamic and long-delay static multipath problems.

Resorting to the brute force of an equalizer, Motorola's MCT2100 incorporates enough equalizer taps to span the spectrum, so there will be no gaps. In contrast, NxtWave engineers came up with a new algorithm that allows an equalizer to dynamically allocate taps where they are needed. Meanwhile, its equalizer range extends from 4.5 microseconds to 44.5 microseconds to ensure reliable signal recovery in the harshest multipath environment.

"The sparse equalization essentially allows our chip to cost less," Miller said. While Motorola has turned to its cutting-edge 0.18-micron process to make its complex full-equalizer design possible, NxtWave will depend on STMicroelectronics' 0.25-micron CMOS process to fab its chip.

Another feature of NXT2000, which has never been made available by other VSB chips but may do a huge favor for DTV-receiver set manufacturers, is a built-in signal-quality indicator. The chip can actually indicate the strength of DTV signal reception, showing it to a TV monitor like a volume-control bar, to ease antenna alignment. Today, much of the hard work of mounting and aligning a DTV antenna into ideal position is trial-and- error.

The total power consumption of NXT2000 is "less than 2 W," Miller said. The chip is priced at $22 in 10,000-unit quantities.

NxtWave plans to use the current architecture of NXT2000 as a platform to design universal demodulation products for the home, adding to the silicon other demodulation forms such as QPSK.

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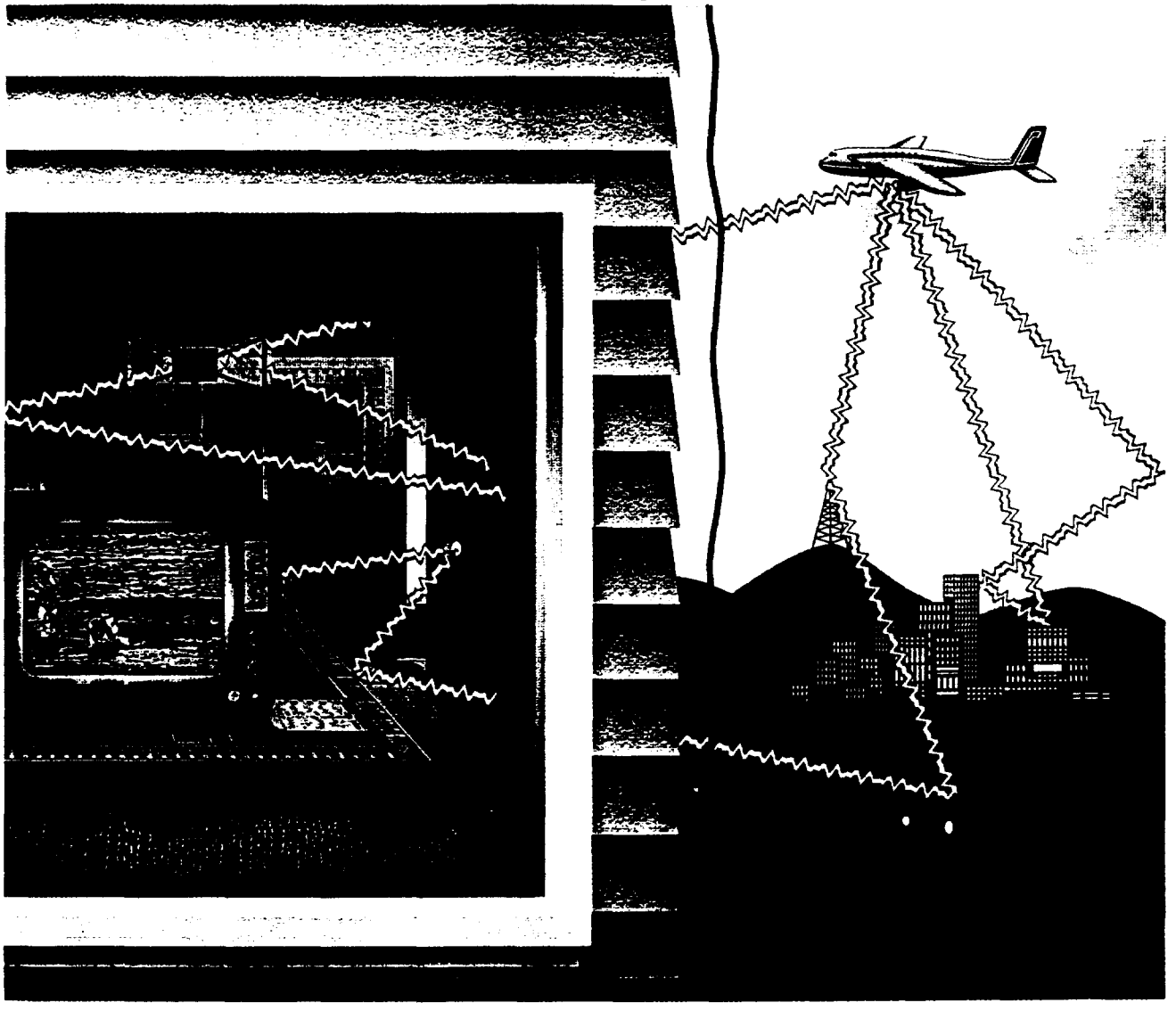

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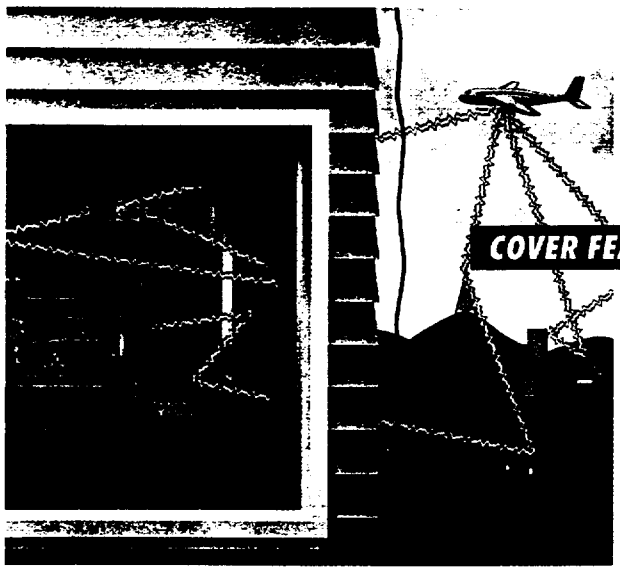
VSB/QAM Receiver Cracks The Code To Indoor And Mobile Reception

Using Advanced Blind-Equalization And Acquisition Techniques, This Device Paves The Way To Commercially Viable Digital TV Sets.

Patrick Mannion



COVER FEATURE

November brings the first anniversary of digital TV's (DTV's) introduction to the mass market. Unfortunately, enthusiasm and hype have slowly given way to a budding realization that serious technical difficulties still exist. These mainly involve the receiver's inability to reliably lock on to the digital signal indoors through a standard antenna. The problems are acute enough to have initiated a groundswell of support for scrapping the current modulation scheme in favor of the European alternative—a move that would render all current receivers virtually useless. Priced between $5000 and $15,000 each, the possibility of such a shift won't be taken lightly by consumers who have already invested their money.

One company is adamant that the current standard's implementation, and not the standard itself, is at fault. NxtWave Communications, Irvine, Calif., has introduced its dual QAM/8-VSB DTV receiver chip. This device appears to have "cracked the code" when it comes to the indoor reception of terrestrial 8-level, vestigial-sideband (8-VSB) DTV broadcasts.

Designated the NXT2000, the chip takes advantage of research into a number of key areas, particularly blind equalization. It mitigates impairments such as static and dynamic multipath interference, phase noise, impulse noise, and adjacent and cochannel interference, all while speeding acquisition time. Tests to date indicate that the chip is fully capable of providing DTV receivers with the ability to quickly acquire and lock on to cable or terrestrial broadcasts in either indoor or mobile (i.e., laptop PC) systems. And it can do so without fear of signal loss due to such everyday occurrences as passing cars, airplanes, or people.

The improvements couldn't have come at a better time. The FCC's DTV broadcast rollout is right on schedule, with up to 30% of the potential market covered as of May of this year. It's essential, then, that the sets be capable of indoor reception if user acceptance is to be expected—not that they haven't already found some acceptance. According to the Consumer Electronics Manufacturers Association's (CEMA's) latest figures, up to 150,000 sets are expected to be in consumers' hands by the end of 1999. Approximately 600,000 more will fly off the shelves by the end of 2000. Extrapolating, CEMA conservatively forecasts that the penetration of DTV sets will reach 30% by 2006, with annual unit sales of up to 10.8 million. To put this in perspective, color TV only rose to 10% penetration in its first eight years, while it took both VCRs and CD players eight years to reach 30% penetration.

While these figures make DTV look good on paper, a number of factors have come into play that may put the kibosh on these predictions. The first of these is cost. The current slew of DTV-receiver offerings are maintaining a price tag way beyond what the mass market can afford. Many of those below $7000 or $8000 need a $1500 (or more) add-on to achieve high-definition-television (HDTV) capability, too.

A number of companies also are finding that average consumers aren't aware of the advantages of digital over analog receivers. Nor do consumers realize the benefits they can expect to accrue from DTV. This is playing havoc with market penetration. As a result, manufacturers are blaming the broad-

casters for not promoting the technology enough. Meanwhile, the broadcasters are passing the buck back to the manufacturers, citing shoddy receiver implementations as the reason for the limited penetration.

The broadcasters may have a point. To date, many purchasers are finding that the only way they can receive a decent signal is by installing a rooftop antenna. They also can pretty much forget about mobile reception. This leads to the third factor, which is whether or not the right modulation scheme was chosen for terrestrial broadcasting to begin with—at least for the North American market, anyway.

There are two very different digital-modulation techniques being used in digital-television terrestrial broadcasting (DTTB). One is the trellis-coded 8-VSB scheme developed by the Grand Alliance (GA) and endorsed by the Advanced Television Systems Committee (ATSC). The other is the coded orthogonal frequency-division multiplexing (COFDM) design adopted in the Digital Video Terrestrial Broadcasting (DVB-T) standard. A derivative of the COFDM, the bandwidth-segmented transmission (BST) OFDM system is currently being finalized in Japan.

Since there's more than one option, many countries and administrations are busy considering the optimum standard for their parts of the world. Criteria being used in the selection process include spectrum resources and policy, coverage requirements and network structure, reception conditions, type of service desired, program exchange, cost to the consumers, and broadcaster requirements.

COFDM was chosen for Europe, and more recently for Australia. In North America, 8-VSB was selected for a number of reasons. Primarily, it's more robust in an additive-white-gaussian-noise (AWGN) channel. It also has a higher spectrum efficiency and a lower peak-to-average power ratio. And, it's sturdier in the face of impulse and phase noise. All of these make it suited to the widely spread-out, electronically noisy market to which it is being applied.

While COFDM has a number of advantages, one of the key areas in which it excelled from the beginning was in its ability to deal with dynamic, multipath distortion (DMD). Deriving from multiple signals bouncing off swaying buildings and towers, along with overhead aircraft and passing cars—even people walking within the room—DMD is the main hurdle on the way to clear, indoor-antenna or mobile reception of digital data. This one factor alone has companies such as Sinclair Broadcasting, Baltimore, Md., calling for the axing of the 8-VSB scheme in favor of COFDM.

The furor started last year. Engineers at Sinclair, owner of 13 stations that must begin digital broadcasting according to the FCC timetable, found that they could not reliably receive a viewable digital picture within the confines of city buildings. Yet defenders of the 8-VSB system, which include GA members that invented the scheme, insist that Sinclair's tests were faulty. They believe the engineers not only slanted the tests in favor of COFDM, but also used first-generation 8-VSB implementations, which are widely known to be unsatisfactory in the light of newer introductions.

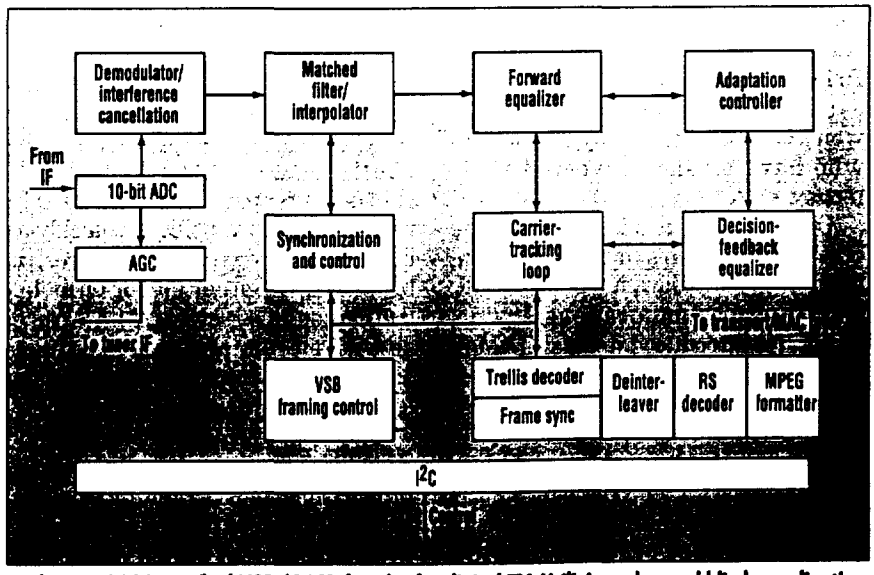
One of the chief supporters of this "first-generation" stance is NxtWave Communications. This firm now offers its NXT2000 ATSC-compliant decoder as the solution to the problems Sinclair and other broadcasters and customers are experiencing.

Along with multipath capability, one of this device's key features is its ability to use the same core to decode both 8-VSB terrestrial and cable signals, such as 16-VSB and SCTE DVS-031-, ITU-J.83B-, and MCNS DOCSIS-compliant 64/256 QAM. All that's needed to select between the two are control bits from the I^2C control bus. Other features include direct IF sampling, an equalization range of –4.5 to 44.6 µs, and an acquisition time of under 50 ms. Based on 0.25-µm technology, the chip operates off 2.5 V at the core and 3.3 V at the peripheral. Power requirements are expected to be in the 1-W range, which is much better than the 3 to 4 W demanded by current devices.

To understand more clearly how NxtWave became the first company to achieve reliable indoor reception, it's helpful to take a closer look at the block diagram *(Fig. 1)*.

The input to the all-digital chip is either a 44-MHz IF or the 6.28-MHz baseband. This feeds the 10-bit analog-to-digital converter (ADC), which is controlled by a free-running (FR) clock operating at 25 MHz. The use of an FR clock, as opposed to a voltage-controlled crystal oscillator (VCXO), means that some kind of interpolation is necessary later on in the circuit to resample the data.

Still, the method has its advantages. The extended delay in the phase-locked loop (PLL), caused by forcing the clock in the ADC to be at the correct frequency, is avoided. Eliminating the VCXO also saves on-board real estate, improves device temperature stability over time, and greatly reduces imple-



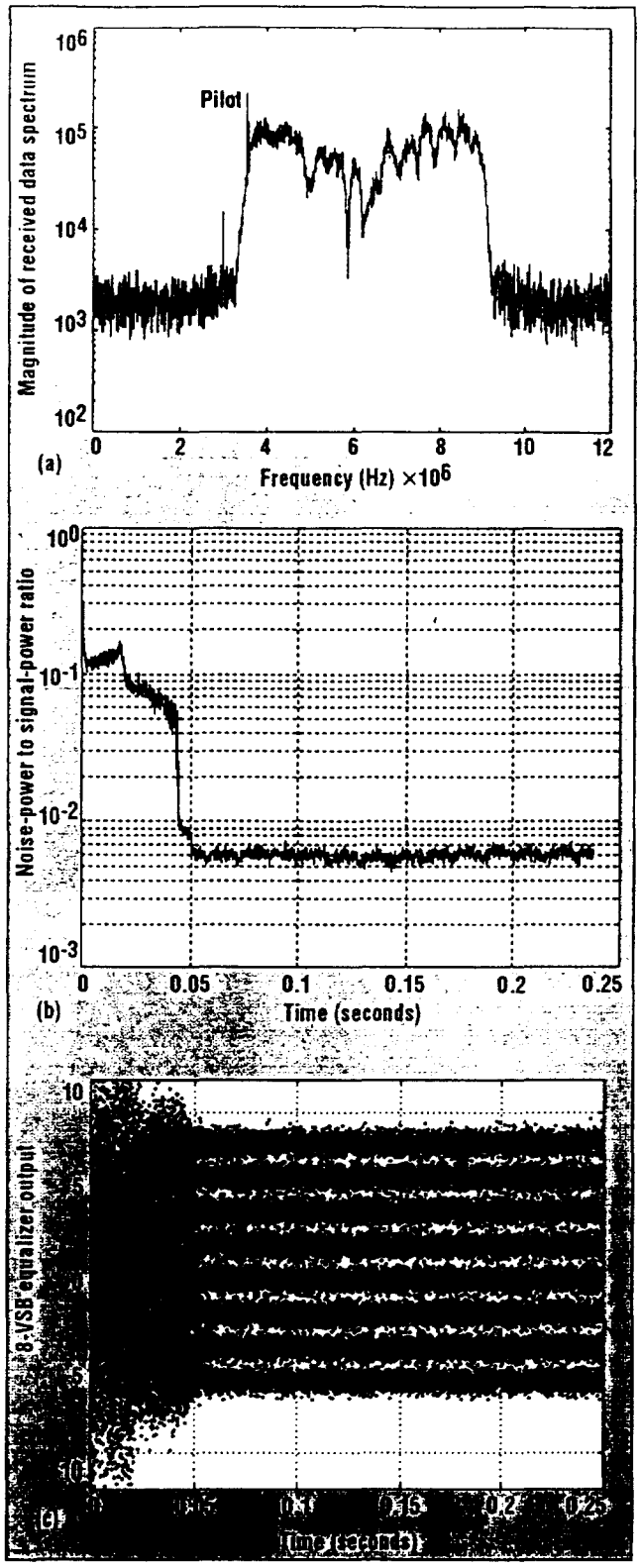
1. The NXT2000 is a dual VSB/QAM decoder for digital TV. Utilizing advanced blind-equalization and acquisition techniques, the chip is the first 8-VSB decoder to achieve fast and reliable indoor and mobile reception of terrestrial broadcasts using a standard bow-tie antenna and tuner.

mentation costs. Additionally, the FR clock simplifies the QAM/VSB switching process. A programmable automatic-gain-control (AGC) circuit tunes the dynamic range of the input signal.

The ADC's output is supplied to the demodulator. This includes a phase splitter to create a complex baseband signal and its corresponding I (in-phase) and Q (quadrature) symbols. Also, the demodulator has an interference canceller that has completely programmable coefficients. These let the system effectively cancel adjacent or cochannel interference—namely the NTSC signals—which are of significantly higher power. The cancellation algorithm is key to this operation. As a result, it remains proprietary.

The demodulator output then feeds a combined matched filter and interpolator. The interpolator resamples the data according to a programmable numerically controlled oscillator (NCO). In turn, this is governed by a PLL driven by an integrated timing phase detector. The PLL is fully programmable, and it's automatically tuned during the acquisition process. The matched filter provides out-of-band rejection. It's also matched to the transmitter pulse-shaping filter for both QAM and VSB signals. The output then goes to the equalizer—the key to the whole operation.

Combined carrier recovery and equalization is essential for robust and reliable demodulation of heavily impaired digital TV signals. Furthermore, it has been well established that a decision-feedback equalizer (DFE) provides near-optimum error-rate performance with low complexity and implementation cost. The DFE is a feedback loop that feeds back hard decisions (quantized "best guesses") to additively cancel the intersymbol interference (ISI). If there are a lot of errors, the loop can be unstable. The key to making this loop work is to remove as much of the error as possible.



2. For the real-world signal shown, the first graph (a) should be flat across the band, with no distortion. Note the pilot tone. But multipath-induced distortion causes spectral degradation of more than 20 dB. The second graph (b) clearly reveals that within 50 ms, the output goes from a closed-eye to an open-eye setting, and the error is reduced to about 23 or 24 dB. The last graph (c) illustrates the eight distinct levels of the VSB output of the equalizer over time.

Realistic signaling environments prohibit cold-start initializations of DFEs, because high error rates prevent reliable decisions. They also can cause equalizer divergence. The ATSC recognized this and embedded a training sequence into the VSB format to aid equalizer and carrier acquisition. During acquisition, equalizer adaptation typically is completed solely with the training sequence. But the sequence isn't transmitted very frequently (every 24 ms), which translates into extremely slow equalizer convergence. In the presence of rapidly time-varying channels, the training-sequence rate is so slow compared to the channel variations that equalizer convergence is prevented. It's essential to note that the indoor- and mobile-channel characteristics both exhibit rapid time variations.

To get around this problem, the NXT2000 uses NxtWave-proprietary algorithms. This accomplishes blind initialization of a DFE without precise carrier lock. It also does so in the presence of closed-eye impairments.

A linear infinite-impulse-response (IIR) structure that doesn't require symbol decisions is used during the initial acquisition phase. A proprietary modification of the constant modulus algorithm (CMA) is employed to update the equalizer coefficients at every symbol instance during this blind startup. Since the CMA doesn't depend on the signal's phase, the carrier loop is coarse-tuned during acquisition. The CMA's modification is statistically based. It uses reduced-precision update rules to decrease multi-

plier chip area. After acquisition, the linear IIR loop is transferred to the nonlinear DFE structure. Decision-directed updates are then used in place of the CMA updates. The transfer is automatically accomplished using proprietary control algorithms.

To further enhance the reliability of symbol decisions used in the DFE with decision-directed updates, the device exploits a proprietary algorithm. This allows efficient joint trellis decoding and equalization with low signal latency, which is essential here. While it's well known that better decisions can be made with a trellis decoder, by the time those decisions are fed back in a typical system, they're too old to be of much value. The joint trellis decoding and equalization, with low signal latency, is commonly called maximum-likelihood sequence estimation (MLSE).

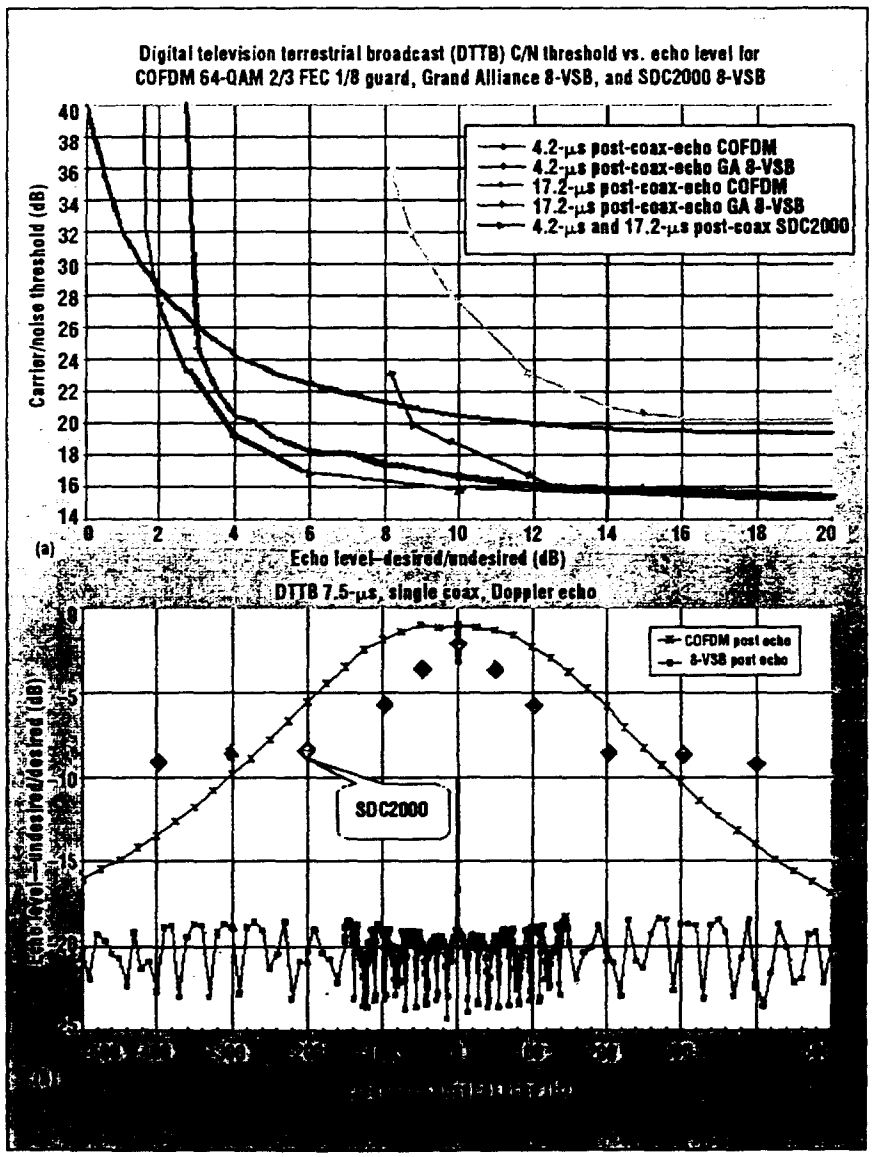
The terrestrial TV channel regularly has reflections up to a delay of 45 µs. For the 10.76-Mbaud data rate, this translates into approximately 500 equalizer coefficients (taps). Generally, the channel is "sparse." Most channel energy is centralized into clusters so that many channel coefficients are near-zero. The NXT2000 uses an adaptive-allocation algorithm that places a subset of taps across 528 positions. This subset contains much fewer than 528 taps, thereby saving greatly on processing (complex multiplies). The location of the active subset of taps among the possible 528 positions is done adaptively. Hence, the tap-allocation algorithm senses channel time variations and re-allocates the active taps across the 528 positions. The result is extremely fast tracking capability with low adaptation jitter, relative to nonadaptive techniques.

Nonadaptive techniques solve for a channel estimate first. Based on that estimate, they decide which taps to make active. Those selected are then permanently set, regardless of channel changes. Worse again, some implementations may activate all 528 taps, with their corresponding complex multiplies. This slows down the decision process and adds greatly to both device cost and silicon real estate.

All of the above signal-processing operations are implemented in an architecture that allows for nearly complete reuse of gates between VSB and QAM signaling formats. The combination of NxtWave-proprietary timing and carrier recovery, equalization, and decoding techniques results in a receiver with an acquisition time that is usually less than 50 ms *(Fig. 2a, b, and c)*. The plots shown were made indoors with a bow-tie antenna and a real-world tuner. The transmitter was located approximately 35 miles away (Channel 26, out of Philadelphia).

The first graph *(a)* should be flat across the band, with no distortion. But multipath-induced distortion caused severe spectral degradation—more than 20 dB. The second *(b)* clearly shows that within 50 ms, the output goes from a closed-eye to an open-eye setting, and the error is reduced to about 23 or 24 dB. The last one *(c)* displays the eight distinct levels of the VSB output of the equalizer over time. The first 50 ms are muddled and completely closed eye.

The bottleneck in this 50 ms is usually the forward-error-correction (FEC) synchronization. It requires the detection of the embedded training sequence that's sent every 24 ms. While this delay may appear to make the whole blind-equalization and rapid-acquisition process all for nought, such is not the case. Though



3. Static (a) and dynamic (b) multipath performance curves expose how well the SDC2000 has bridged the gap between VSB and COFDM. The only area where COFDM exceeds the SDC2000 is in the unrealistic scenario where the receiver is situated exactly between two transmitters. Yet the SDC2000 really shows its strength in the dynamic curve.

the system is still dependent upon the timing sequence, it doesn't have to wait for eight or 10 training sequences, which is typical of trained-equalization implementations. Here, the system can perform the equalization within one or two frames, and then just wait for one sequence to lock up the FEC—and it's done. Another key aspect is acquisition. In a changing channel environment, once the system has locked onto the FEC synchronization, it's always locked on. The FEC subsystem implements both ATSC and J83b standards.

The static- and dynamic-multipath performance curves also are shown, (*Fig. 3a and b*). Done in Australian labs that compared the GA system with COFDM, these graphs (minus the NXT2000 version) caused the labs to go with COFDM over VSB. The figure illustrates how well the NXT2000 has bridged the gap. In some places, it even outperforms COFDM.

Take Figure 3a. Ideally, there would be a flat—not curved—line corresponding to y = 15 dB. This would imply that as the impairment coming into the system is increased, the carrier/noise threshold doesn't degrade at all. In a real-world situation, unfortunately, there is some degradation—the amount of which is dependent upon the system.

The NXT2000 forms the lower envelope of all the curves up until around 1.8 dB. This means it's better than COFDM for long echoes, while close-in echoes favor COFDM. The NXT2000 is better than all the echoes which are less than 2 dB. The only area where COFDM exceeds the NXT2000 is in the unrealistic scenario where the receiver is situated exactly between two transmitters.

The NXT2000 really shows its strength in Figure 3b. Usually, if a vehicle is moving at about 50 mph, a frequency offset of about 100 Hz can be expected. NxtWave also has noticed that in an indoor environment, the offset is often up to 15 Hz. COFDM has a pretty robust performance up to about ±100 Hz. Then, it dies out and is about 15 dB down at 500 Hz. The 8-VSB signal degrades pretty drastically for the GA system. Within 5 Hz, it's almost 20 dB down. COFDM is still better than VSB, but not substantially so. At 100 Hz, it's only about 3 dB up. If the echo delay is more than 7.5 μs, the NXT2000's performance improves. As mentioned before, the delay depends on the environment. It's possible to get very strong echoes with very long delays. ❐

Price And Availability

The NXT2000 receiver IC will be priced at $22 each in lots of 10,000 units. It will be available from stock.

Contact Mike Neshat, NxtWave Communications, 6 Venture, Suite 350, Irvine, CA 92618; (949) 585-1800. **CIRCLE 451**

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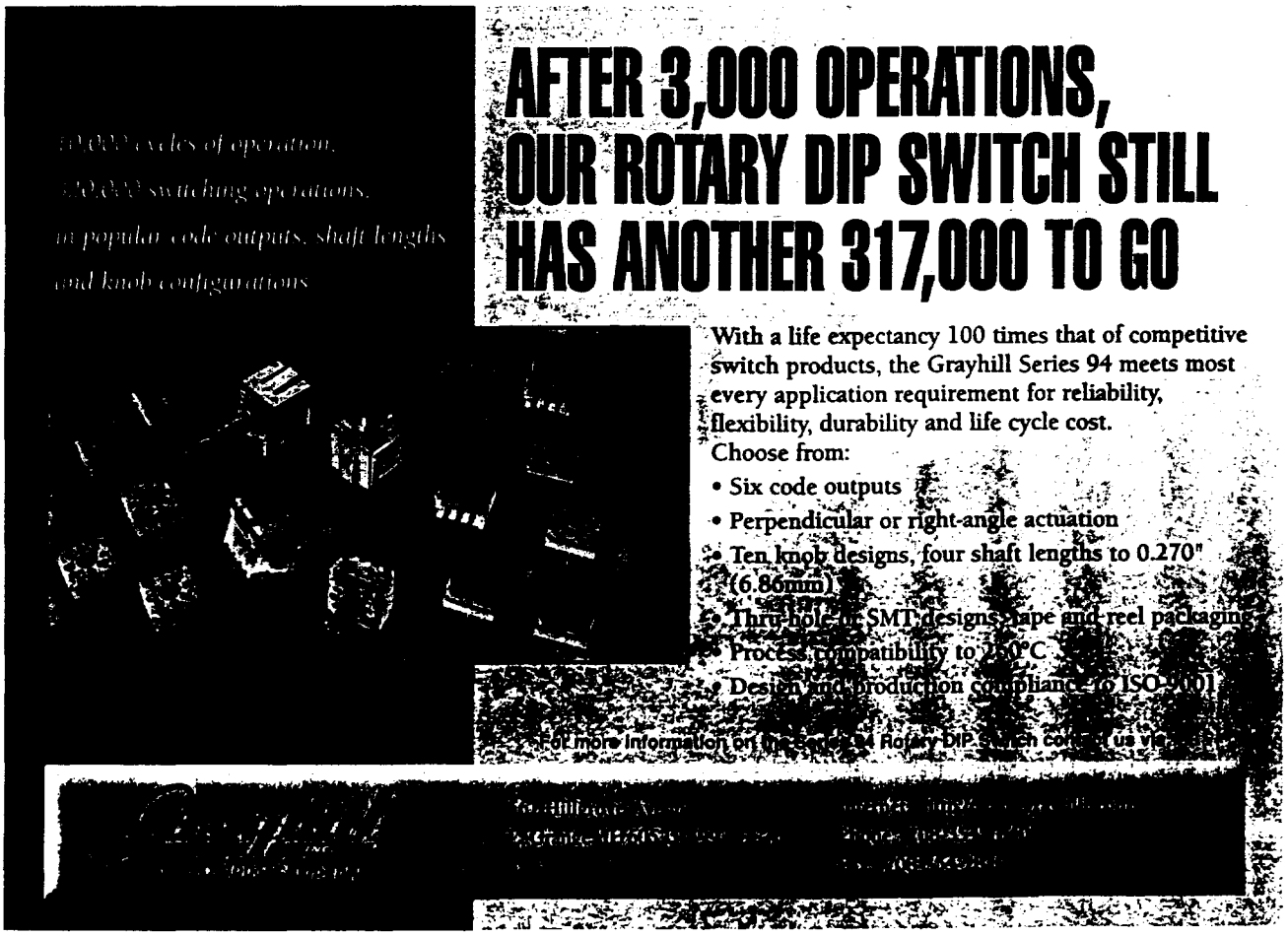

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