

*Lightwave*

## Optical duobinary promises improved reach, greater flexibility

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Electronic dispersion compensation has attracted significant attention recently as an alternative or augmentation to optically based dispersion compensation modules in carrier networks. But what if you didn't have to worry about dispersion? Engineers at several optical module companies have applied themselves to finding ways to make the signals they create more tolerant to dispersion, thus reducing-if not eliminating-the need for dispersion compensation. Optical duobinary technology represents one promising manifestation of this trend, and systems using this modulation format should become available this year.



*An interest in dispersion-tolerant transmission has led to interest in optical duobinary modulation techniques.*

Conventional transceivers and transponders use a modulation format called non-return to zero (NRZ), a form of on/off keying, to represent the 1's and 0's of binary transmission; 1's are "on," 0's are "off." When this electrical modulation is converted to the optical domain, it appears as changes in amplitude of the optical signal. Optical duobinary, first reported by Adam Lender in the 1960s, uses three electrical states to represent 1's and 0's: positive, negative, and zero. (The zero state represents the 1's or "mark," the positive and negative electrical states represent the 0's or "space.") However, optical signals can't represent three states via amplitude alone, so optical duobinary demands that the phase of the optical signal be modulated as well. Unlike the NRZ format, the



resulting signal also does not contain a carrier frequency component.



While this may seem more complex, the result is that, with the right filtering technology, an optical duobinary signal can be crammed into half the bandwidth of an NRZ signal. Since dispersion effects depend on bandwidth, optical duobinary signals deliver twice the dispersion tolerance-particularly to chromatic dispersion and residual dispersion-of typical NRZ. It turns out that conventional direct-detection optical receivers can reconvert the optical duobinary signal into binary, thus obviating the need for special receivers. The narrower bandwidth also opens the door to tighter channel spacings, making a 25-GHz WDM channel grid possible.

The dispersion tolerance of optical duobinary transmission means longer distances for those particularly interested in reach and better performance over shorter distances-and thus less, if not zero, need for dispersion compensation modules and amplification. It also could mean easier upgrades of 2.5-Gbit/sec networks to 10 Gbits/sec; new dispersion compensation elements and rebalancing theoretically would not be necessary.

The potential value of such alternative modulation formats has not escaped the attention of the industry. The Optical Internetworking Forum (OIF) proposed an application code for 120-km (2,400 psec/nm) reach via alternative modulation formats to the International Telecommunication Union (ITU). The ITU accepted the code as part of ITU-T Recommendation G.959.1 as P1V1-2C2.

The code should help to promote interoperability and multiple vendors; it complements the work of the Optical Duobinary, Multi-Source Working Group, announced last September. Among the working group's accomplishments is a multisource agreement (MSA) for optical duobinary transponders in a 300-pin form factor.

## On your mark

With a standard to shoot for and a form-factor MSA in place, optical duobinary transponders should see implementation this year. **Civcom Inc.** (Petah Tikva, Israel), Essex Corp. (Columbia, MD), and Kodeos Communications Inc. (South Plainfield, NJ) will be the first companies out of the chute. All three used OFC/NFOEC in March to tout their products. Essex announced evaluation versions of its Essex Edge module, while **Civcom** showed its Free-Light offerings and Kodeos its Marathon product family. Each company targets 10-Gbit/sec applications, and exceeding the 2,400 psec/nm of dispersion tolerance in the ITU-T spec appears a common goal.

Kodeos appears to have the early lead in terms of time to market. Massimo Di Blasio, the company's director of marketing, says that system vendors should begin production of boxes that incorporate Marathon modules by the middle of this year. The Marathon devices provide 3,200 psec/nm of dispersion tolerance, which Di Blasio says will translate from 160 to 200 km of reach without regeneration.

Di Blasio sees dispersion-tolerant modules as a natural part of the evolution toward flexible, all-optical networking that tunable lasers and reconfigurable optical add/drop multiplexers (ROADMs) have created. Just as ROADMs will enable carriers to add and drop whatever traffic they want at any

node in the network, dispersion-tolerant transmission will enable service providers to add nodes without having to rebalance the network.

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However, the upgrade of 2.5-Gbit/sec metro networks to 10 Gbits/sec represents the real sweet spot for the technology, Di Blasio believes. "If you had a 2.5-gig ring, to upgrade it to 10-gig, you need dispersion-tolerant transmission," he asserts. "Otherwise, you have to go into the ring, cut the traffic, reroute it, and put the DCM [dispersion compensation module] in, and then put the traffic back in. That's very costly. Whereas if you take a 10-gig duobinary signal, if the path length is less than 160 km, guess what-it automatically compensates."

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*Civicom's Free-Light transponder will be among the first modules on the market that offer the dispersion-tolerance features of optical duobinary technology.*

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This application and other metro uses could represent up to half of the market potential for the technology, Di Blasio believes, with single-channel point-to-point accounting for 20% and long-haul composing 30%. He sees a real demand for tunable optical duobinary transponders, with such devices making up 75% of the market.

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**Civicom** agrees that 2.5-Gbit/sec network upgrades and extended reach point-to-point in metro and regional applications represent viable markets, according to Gabby Shpirer, vice president of technical marketing. Like Kodeos, **Civicom** looks to provide 3,200 psec/nm performance with its Free-Light line. However, the company is not quite as far along as Kodeos; Shpirer expects to ship samples to customers by the end of this month. Whereas Kodeos will work initially with system integrators exclusively, Shpirer says **Civicom** also is in discussions with other module vendors about OEM relationships.

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## Overcoming hurdles

Nothing comes for free, including dispersion tolerance. Both Di Blasio and Shpirer estimate that duobinary transponders currently carry a 10% to 15% cost premium over conventional transponders. "The technology is still new. And there are some [extra] elements that are required for the duobinary," explains Shpirer, alluding to the precoder that helps create the duobinary modulation format and the filter. "But as soon as they are integrated into the optical or the electrical devices, the differences will go away."

Even before they go away, the opex savings duobinary promotes more than makes up for the extra capex expense, Di Blasio asserts. "As you much as you get beaten up for [the capex premium], you just go back to the systems houses and say the opex savings are significant," he says.

Other hurdles to market acceptance include competitor claims-particularly from providers of electronic dispersion compensation technology-that duobinary won't work in certain existing network scenarios or with currently fielded technologies. Shpirer and Di Blasio say that duobinary has been tested and proven with more or less every amplification, compensation, and fiber technology currently in the field. Di Blasio also reports that one carrier successfully ran duobinary signals through a variety of ROADMs and optical crossconnects.

The fact that duobinary represents an "alternative" modulation scheme has also stood in the way of acceptance, in the sense that system vendors have configured their modeling, simulation, and evaluation tools to NRZ format. Retooling during the downturn held little appeal; now that the

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economic environment is improving and carriers have shown an interest in dispersion tolerance, Di Blasio reports that system designers have begun to make the necessary investment to examine duobinary offerings.

However, one technological limitation remains—an optical signal-to-noise ratio (OSNR) penalty of 1 to 2 dB on back-to-back links versus NRZ. This flaw would render the technology less attractive in multihop network applications without redress. Technicians at Kodeos believe they have solved the problem with something Di Blasio calls “Enhanced Kodeos Transmission.” The new technology, which Kodeos will unveil in 6 to 12 months, will reach the market first in the company’s upcoming Orion line of modules, which will be aimed at long-haul and ultralong-haul undersea and terrestrial applications.

## Further extensions

While dispersion tolerance is duobinary’s greatest strength, **Civcom** and Kodeos see the benefits of pairing the technology with dispersion compensation to further extend reach or make existing plant easier to use. However, they have taken different paths in search of the right mix of technologies.

**Civcom** has chosen to work on optical dispersion compensation; the company has already paired its duobinary transponders with its Free-Path tunable optical dispersion compensation (ODC) modules. The company demonstrated 350-km reach using the two technologies at OFC/NFOEC. **Civcom** subsequently released a whitepaper coauthored with Intel Corp. that describes how an Intel C-band tunable duobinary transmitter operating at 10.71 Gbits/sec paired with the **Civcom** ODC device demonstrated performance beyond 11,000 psec/nm with an OSNR figure similar to NRZ.

Kodeos has decided to go electric with the purchase of Intersymbol Communications Inc., a developer of electronic dispersion compensation technology based on maximum likelihood sequence estimation (MLSE). “We don’t see dispersion benefits with the other technologies,” Di Blasio says of feedforward equalization (FFE) and decision-feedback equalization (DFE), the two most common electronic dispersion compensation approaches. “We do see some nonlinear enhancements with some of the DFEs and FFEs we’ve tried. With a high launch power of about 17 dBm, we had a residual tolerance of about 2,000 psec. If we put that DFE there, we’d go to about 2,800. With the MLSE, we’d go to about 3,500 to 4,000. So the MLSE is more powerful.”

The first products from Kodeos to incorporate the MLSE technology probably won’t reach the market until next year. Between now and then, however, it appears certain that optical duobinary technology will have become deployment ready. With that, the fate of the first generation of these modules will rest in the carriers’ hands.

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