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Powerline's other data channel

WHILE THE ARGUMENTS RAGE ABOUT THE FEASIBILITY AND DESIRABILITY OF ROUTING BROADBAND SIGNALS OVER THE MAINS POWER NETWORK, YOU MIGHT BE FORGIVEN FOR OVERLOOKING NARROWBAND DATA-OVER-POWERLINE, THAT CONTINUES TO OFFER A RELIABLE, IF MODEST-CAPACITY, CHANNEL FOR THE SAME "NO-NEW-WIRES" BENEFITS.

In a recent discussion among EDN editors on the subject of broadband-over-powerline, one of the more cynical of us made the observation that "the main thing that's changed about that over the years is the constantly increasing frequency at which it just fails to work." That may be a little harsh, but has a ring of truth about it. It lead to my colleague Maury Wright's article "Riding the sine wave" that you can read at (**Reference 1**), in which he reviews some of the recent efforts at delivering data over the same wiring that provides mains power in our homes and offices. You can also read some of Senior Technical Editor Brian Dipert's less-than-100%-positive experiences with in-home power-net data-routing hardware, in his "Brians Brain" blog (**Reference 2**).

For the concept is far from new, and its attractions are obvious: there is the simplicity of a single plug-point to simplify wiring, and to provide increasing amounts of data on the all-important principle of "no new wires". You can divide efforts to deliver data over the power network into a four-part matrix; either high or low data rates, and for each of those, either short or long distance. High data rates and longer distances are the province of delivery of broadband data ultimately from the Internet, over the power wiring into home or office. In Europe, DSL has become the preferred route for provision of such services in the 1-, 2-, 4- or up to 8-Mbit/sec range. Over many years, researchers, utilities and service providers have made numerous efforts to route such signals over powerlines, and several trials are under way worldwide, as Maury Wright describes in his article. Various bodies in Europe are experimenting with BPL, and they may have a significant economic factor on their side as compared to the US scenario. Typical consumer-voltage distribution (220/240V) in (urban) Europe is from a substantial three-phase distribution transformer serving tens to hundreds of homes, spreading the connections evenly across the phases. Assume that BPL signals will have trouble making it through the distribution transformer and the provider will have to inject and recover them downstream of the transformer—which may or may not be the case. Serving tens or hundreds of homes, a BPL injection point could improve the economics, compared to the US case where a two-phase transformer may serve just six to eight homes. For delivery of future services such as IP TV, networks will have to reliably deliver data rates of tens or hundreds of Mbits/sec. It is not yet clear service providers can achieve this figure reliably without upgrading to fibre-to-the-home, and powerline for the moment remains one of the possible contenders along with further developments of DSL and wireless offerings such as MIMO-based WiFi or WiMax. (See, for example, **Reference 3**). Wireless Internet is already available in certain areas of several cities including London, for example from companies such as UK Broadband, under the brand name Netvigator—although that particular service tops out at 1 Mbit/sec. The industry has an ample supply of proposals for wireless "last-mile" delivery of broadband services—FWA (fixed wireless access)—even though it is currently in a mode of fighting every standards debate to a standstill. Should WiMax not deliver, for example, there are suggestions that extended mesh networks might work in an urban context.

High data rates and short distances would characterise the second quadrant of the matrix, the main applications being to route data and digital multimedia around the home. Concerning the use of the powerlines, in practice this means products that follow the HomePlug approach. As Maury Wright again points out, there are several European companies with an interest in the standard, but thus far not a great deal of product has appeared on the retail market. One exception is Devolo, a company based in Aachen, Germany, that produces the dLAN (HomePlug) range of modems. The specification claims 85 Mbit/sec high-speed Ethernet connection over up to 200m. Just as in the US, there is considerable opposition to the deployment of broadband signal on the power network from those concerned with the interference that leaks from the powerlines. Amateur radio operators are particularly vocal although they are by no means alone. The European Union has recognised the spectral pollution issue and has sponsored a medium-term project to investigate possible mitigating strategies.

WIRED UWB

In the UK, the Engineering and Physical Sciences Research Council is funding a research programme that has just begun at Queen Mary College, University of London, investigating an intriguing alternative: ultra-wideband (UWB) over powerline. Partners in the project are Artimi, and COE Ltd. Artimi produces the RTMI-100 UWB chip, comprising microcontroller and integrated 802.15.3 MAC. When it announced the chip, Artimi described it as having dual air interface and powerline capability, and proposed to demonstrate an outline capability for UWB over powerline at the Consumer Electronics show held in Las Vegas in January 2005. Since then, Artimi has de-emphasised

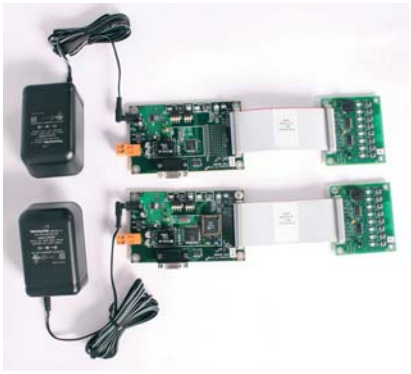

Figure 1 Echelon's design support includes evaluation kits that implement its own-architecture "Neuron" control/communications nodes, or you can use its powerline transceivers stand-alone.

the powerline aspect of its product, and appears to have placed work done to date on the concept, into the project with QMUL. Artimi's chip uses PPM (pulse position modulation) impulse radio. The company believes it may be possible to launch the very short pulses from the impulse radio on to the powerline—it has devised what it describes as a "low-cost coupler" to achieve this—and have them propagate as solitons. A soliton pulse travels for an extended distance in its medium without dispersion, which leads to the—at first sight—unlikely claim that UWB-over-powerline might be capable of 1-Gbit/sec data-transfer rates. The research project will run over three years. In the US, a start-up company called PulseLink also claims to be achieving usable results using conducted UWB-over-powerline, quoting rates of up to 100 Mbit/sec.

NARROWBAND LIVES

High-speed data-over-powerline is therefore in a state of uncertainty on a number of fronts: that being so, it seems appropriate to review the state of play in the other two quadrants of the matrix. In contrast to the high-speed situation, powerline modems for transmission of modest data rates are a long-established product niche, with stable product offerings and new, updated semiconductor products—if you do not need multimedia data speeds, there's a lot you can do with existing solutions. In Europe, the guiding regulatory document is the Cenelec standard EN 55065-1 "Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148.5 kHz." En 55065-1 divides that band into four sub-bands, available to different classes of applications depending on whether or not they are "utility" applications, specifies the maximum level of carrier superimposed on the power line and (in one of the bands) specifies a protocol. The Cenelec standard is also the most restrictive worldwide: consequently, if you build a product that conforms to it, that product will be usable almost anywhere.

Once again, it's useful to divide the application space to provide the last two quadrants of the matrix. Short-range operation—essentially within premises—is the space in which you find applications such as building automation and control. When transmitting data with the power lines over longer distances outside the premises, there is one dominant application domain: the utilities in the form of automated meter reading and control functions.

Echelon has been using powerline communications for its LonWorks automation networks for—literally—decades. Its current generation of powerline interface products comprises the PL3120/3150 Smart Transceivers. Echelon's vice president of marketing, Mike Tennefoss, observes that while attention has been focussed on broadband, narrowband products have continued to make progress. The 3120 and 3150 are Echelon's fourth-generation parts. They integrate a powerline interface with the company's Neuron processing node—three microcontroller cores forming a communications engine. Echelon built the part in 0.18-micron technology with on-board flash memory (**Figure 1**). There is a considerable amount of on-board DSP, Tennefoss says, to perform noise filtering of the signal from powerline noise. "Noise on powerlines is mainly impulse, not Gaussian," Tennefoss says. "If you simply apply normal telecommunications-sector noise-recovery algorithms, they will not work effectively— the problem demands a unique set of algorithms." Echelon cites applications in the domestic space such as "smart" appliances that communicate over the powerline for remote control and to perform load and tariff management in the home; and the sort of switching and control functions that recent media coverage more usually associates with wireless technologies such as Zigbee. Because the communication link is very robust, Echelon has seen it designed into applications such as communications between carriages in railway trains; over longer distances, the company quotes utility applications such as remote and/or automatic (electricity) meter reading and street lighting control. Whenever the subject of meter reading arises, the major project that vendors, including Echelon, cite is the Italian effort to modernise and automate its electricity-meter network. This involves data communications over several kilometres, with a local concentrator/server gather ing data from all the premises in a neighbourhood, and forwarding it to a central facility over a faster protocol. A mesh network is a suitable architecture for meter reading and street lighting, with each node not only identifying its own traffic but acting as a repeater: Echelon has a best-path-discovery algorithm that routes data according to the highest-quality path it finds in the network.

The Echelon chips use a twin-carrier, bi-phase-shift-keyed (BPSK) modulation within the Cenelec bands, and implement the Cenelec protocol in the bands where the standard requires it. Raw data speed is 5.4 kbit/sec: in practice, Tennefoss says, you can expect a data rate of about 15 packets/sec. The parts sell for around $9 each in sample quantities, and with volume pricing a realistic bill-of-materials cost for a simple powerline node—a lighting control, for example—would be in the region of $10. This is in the same region, if not a little higher, as price

Figure 2 To build the ST7538 powerline modem, ST has moved to its BCD5 silicon technology that allows it to fabricate DMOS power devices, bipolar and CMOS structures, all on the same chip.

targets for Zigbee systems, about which Tennefoss is less than enthusiastic—as, perhaps, you might expect. "We evaluated numerous Zigbee [or 802.15.4-type] wireless chips and we did not find their performance and communications robustness was nearly as good as the wireless sector of the industry claims," he says. Echelon offers a set-up algorithm that self-discovers and organises a control network for fully-automatic configuration, or you can set it up in a "plug-press-play" mode. Gateways to the PC environment are also possible.

Short- and long-range communications are relative terms. In this context, short-range tends to mean within a single building. Long-range may be short by telecommunications standards, usually no more than a few kilometres between nodes, but communications over tens or hundred of kilometres are feasible. However, carriers in the bands the Cenelec standard defines will not, in general, pass through a distribution transformer: if there is one of those in the power route over which you seek to transmit a signal, you will have to make arrangements to bypass it with the data-carrier signals, or inject and recover the signal downstream of each transformer. Echelon offers a reference design with a low-cost signal coupler configuration using direct connection to the power lines, with a high-voltage capacitor blocking the mains voltage. If you require a higher level of isolation, you may need to add a small transformer.

POWERLINE-MODEM IC

ST Microelectronics also has a long-established track record in production of silicon for powerline modems, and is in the process of introducing a completely new powerline-modem chip for narrow-band data, the ST7538 (**Figure 2**). ST also cites automatic meter reading (AMR) as the largest single application, and can offer a complete metering solution—to build the power meter and the powerline data channel—by bundling the modem silicon together with its STPM01 chip (**Figure 3**). The electronic-meter function itself requires an ADC, a microcontroller core, and programme and data memory to hold billing data locally. ST has structured its offering to simplify adding the communications function for AMR in an incremental approach. The modem chip provides only the physical layer, with the protocol residing on the application's microcontroller. When the utility requires a higher level of control beyond simply returning readings, the application becomes AMM (automated meter management). ST is a supplier to Enel, the Italian utility company, of silicon for the latter's AMM project. Alberto DeMarco, ST's general manager for industrial business, industrial and power conversion division, also quotes home automation as a target market, noting that ST has chosen to keep its activities in powerline communications in the narrow-band area, and is not currently producing BPL products. The new ST 7538 employs a half-duplex, FSK modulation scheme to achieve a basic data rate of 4.8 kBaud. This is more than adequate for the AMM function, DeMarco says, as the usual data rate in that applications is 1200 Baud—but 4.8k is not necessarily a limit, although the company might have to use a different modulation scheme to deliver a higher rate, which some control applications could need in order to achieve short response times. A third-generation part, the 7538 integrates functions such as carrier, preamble and band-in-use detection and operates on eight programmable carrier frequencies: it is compliant to the demands of EN 55065. With the exception of a few high-voltage-rated passive components, ST has integrated the complete function, including circuitry to couple to the powerline. The power-line interface block is a double-CMOS class-AB power amplifier with two anti-phase outputs and a programmable voltage/current drive, that connects in either a single-ended or bridge (differential) mode. The chip operates from 7.5 to 12.5V, with its own internal regulator, and when not driving data has a quiescent current of 5 mA. Its receiver sensitivity is 250 μVrms. It comes fully supported, including fully worked low-cost coupling circuitry to inject and detect the signal to and from the powerlines, and is housed in a 44-pin TQFP package with integral copper slug that you solder down to the circuit board for optimum thermal performance.

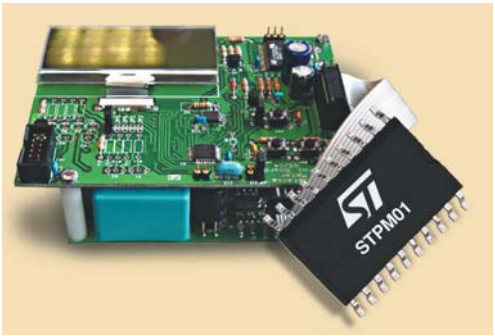

Figure 3 Combined with the STPM01 metering chip, a powerline modem provides a complete automatic power-meter solution.

ST sees limited progress in the home-automation market in recent years and cites interoperability as the key issue. There is also, DeMarco says, a question over the business model question for home-automation products in this space (in which he includes wireless technologies)—who sells what, and to whom? And, whose problem is it when supposedly universal systems don't communicate? It is not, he says, primarily a cost issue—a cost per node of a few dollars is feasible—and, he also sees powerline and wireless as not necessarily being exclusive technologies for home and building automation. "There will be places where a wireless link will not have the coverage, and the two technologies can co-exist."

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