OutPost on the Endless Frontier™

EPRI e-News on Recent Key Developments in Energy Science and Technology
By Paul M. Grant

No. 11, 2 September 1999

"Mr. Watson, Come Here, I Want You!"

Nope. That's not quite the way the first audio signals were transmitted through copper wire, despite that Hollywood showed you Don Ameche spill battery acid on his hand and pleading with Henry Fonda in the next room to come to the rescue.[1] Actually, it was the twang of a clock spring that caused Alexander Graham Bell to shout to his assistant, Thomas A. Watson toiling away in the adjoining room of their workshop in Boston, the summer of 1875, "Snap that reed again, Watson!" Thus was born the telephone.[2]

In what has to be one of the most explosive periods in the history of the application of electrical science, the decade of the 1870s also saw the invention of the electric lamp by Edison and Groves and the creation by the former of the supply and delivery system required for its widespread use.

Both devices required wire interconnections for effective deployment, and by the first quarter of the 20th century, both land and ocean were crisscrossed by vast networks of lines and cables transporting watts and words. It did not escape the attention of the electrical visionaries of the era that one set of wires might suffice for both uses. I recall tales told me by my father[3], one of the pioneer radio amateur operators of the mid-Hudson Valley region in New York state, of experiments he and his fellow "hams" would conduct on what became known as "common carrier" communication.[4]

Such dual use of existing electrical power distribution wires evolved slowly over the years, but has remained limited in scope to this day, essentially employed for local area FM radio transmission, various "smart house" schemes[5], and some remote meter monitoring by utilities.[6] Several utilities, particularly in the United Kingdom,[7] are experimenting with providing internet service inside local distribution grids through the household or office "power point (British for "wall socket")." Here in North America, brought on by the explosive growth of the internet and home computers connected thereto, a virtual plethora of networking technologies are currently under exploration, including those utilizing power lines, both inside and outside your house.[8]

However, there are a number of well-known technical limitations to power line communication (PLC) regarding bandwidth, or the speed at which information can be transmitted. These determinants can be quite complex and vary widely from locality to locality. Nevertheless, one can broadly generalize as follows:

On the low frequency side ($10^0 – 10^4$ Hz), there is the tendency for long unshielded transmission/distribution lines to act as very efficient multiple wavelength radio antennas. On the high end ($10^5 – 10^9$ Hz), currents tend more and more to concentrate on the surface of conductors (the "skin effect"), thus greatly increasing the effective resistance. However, the major barrier to long range, high bandwidth PLC are induced losses in the iron cores of distribution transformers ("eddy" currents) due to their high magnetic permeability and those also arising from stray inductance – the fact that primary and secondary are not perfectly coupled. These effects imply an effective cut-off somewhere in the $10^4 – 10^5$ Hz range.[9] To put these numbers in the perspective of digital communication, you generally want a bandwidth about four times the bit rate. That is, a "baud rate" of 28,800, a typical "dial-up" speed these days, would fit comfortably into a "channel" 100 kHz wide, well within the capacity of your phone line and internal house wiring as well.[10]

But, if you take a look out on your street – mine is typical – you'll see distribution transformers every 5-10 homes or so, dropping 4 – 25 kV down to the split-phase 220 residential service standard. So, given the problem just mentioned getting anything much above 20 kHz through them, does this mean we're fundamentally limited to local area networking with our next door neighbors should we want to "talk" over the power lines?

Not according to Media Fusion Corporation (MFC),[11] a Dallas, Texas, based start-up claiming to have developed a technology which allows one to transmit data over the entire continental power grid at rates of 2.5 gigabits/sec. As just mentioned, you ordinarily require a bandwidth a least four times the baudot rate to keep enough Fourier components to reliably recover switching transitions, so we're talking 10 GHz here. Just to put this in perspective, that's about 10 times the bandwidth (max) your TV cable company can provide on the coax into your house.[12]

Now, as you can see from our previous discussion, MFC has a slight problem here. Nonetheless, the company contends they can get around all this by "Inscribe(ing) data within the natural low-frequency bandwidth (60 Hz) of the wave to broadcast information." In press statements they claim to have a method to "jump the transformer barrier by using the magnetic field surrounding the wire." These assertions seem to fly in the face of what we know about signal propagation based on Maxwell's Equations and Nyquist sampling.[13] How can you pack 2.5 gigabits/sec onto a carrier of only 60 Hz? How can you get 10 GHz through your house wiring, let alone out to the block and onto the North American grid?

Your correspondent has been tracking reports about Media Fusion since they first gained public notice earlier this year. Attempts to contact their Dallas office to obtain technical explanations to these questions have so far proved unsuccessful. EPRI staff have searched both issued US patent databases, and those of "foreign abstracts," which, unlike practices in the US, appear more or less immediately (1 – 12 months) after their filing abroad. To date, no IP material relating to MFC technology has emerged. To the best of our knowledge, there are no publications in the open, peer-reviewed, scientific and

technical literature regarding their methodolgy. The citations listed in the "bibliography" at their Web site are standard texts and references in communication theory and practice, and shed no obvious light on their claimed technology.[14]

These reservations notwithstanding, Media Fusion has received substantial press,[15] most recently the evening of 2 August past, in a "Cutting Edge" segment by Gina Smith on ABC News' Peter Jennings' World News Tonight.[16] Rep. Billy Tauzin (R-LA[17]), Chairman of the House Commerce Subcommittee on Telecommunications, Trade and Consumer Protection(!) has invited MFC to submit testimony at his upcoming hearings when Congress reconvenes. According to Media Fusion, Congressman Tauzin is an enthusiast of their technology.[18] As a result of all this attention, we here at EPRI are now beginning to receive inquiries from our members, a major development prompting this issue of *OutPost on the Endless Frontier*.

Your correspondent has been in contact with fellow physicists in the research labs of three of the largest telecommunications firms in the world. Their company's future would be in jeopardy, to say the least, should the claims of MFC turn out to be right. All knew about MFC...none seemed particularly worried.

GIF animation greeting the visitor to the home site of Media Fusion[19] ostentatiously proclaims:

First they said it couldn't be.
There is no need for any individual to have a computer in their home.[20]

Then they said. "I should have invested in Microsoft."[21].

Now they say. "The powerlines are too noisy to carry data."[22].

Next they'll say. "That was before Media Fusion."[23]

Yeah, right. They could have added nobody believed Alexander Graham Bell in 1876. Not true. Bell's experiment once revealed was accepted universally because it fit the scientific requirement for reproducibility.[24] Media Fusion says there will be a public demonstration of their claims this fall. Let's see if they'll ring us a wake-up call.

73

[1]*The Story of Alexander Graham Bell*, 1939. Most of you are too young to have seen this movie. It's real good. I have a videotape. Send me some positive comments on this *OutPost* and I might let you borrow it.

[2]It's rather prophetic that the first sound sent electrically down a wire was a pure tone, a harbinger of today's digital transmission of alternating modulation and demodulation (mo-dem) of two audible frequencies whose time duration denotes a "1" or "0." Ironically, the majority of signals now carried by the communications network are of this

kind of "Morse code," whose use Bell intended to circumvent with his invention. Bell, with the telephone, unlike Edison and Morse with their most famous creations, had no close competitors. The telephone took the 1876 Centennial Exhibition in Philadelphia by storm, but its public acceptance came much more slowly and reluctantly. One of my favorite reactions of the time is contained in the following *Boston Times* editorial of the day:

> A fellow can now court his girl in China as well as in East Boston; but the most serious aspect of this invention is the awful and irresponsible power it will give to the average mother-in-law, who will be able to send her voice around the habitable globe

One only need substitute "teenage daughter" for the referred-to female family member, and the thought rings just as true today.

[3]Paul A. Grant, W2AGZ. I think my earliest childhood memory, perhaps around the age of three or four, is that of the white-hot graphite anode of the Eitel-McCullough 35T triode in the final amplifier of my father's transmitter. I didn't know what it was, of course, to me it was just the brightest light I had yet seen. In years to come, my after-school hang-out was my Dad's "shack" where he began to teach what he called the "electrical art" to me. Ham radio is why I became a scientist. You may have noticed I end each issue of *OutPost* with "73," the ham's traditional sign-off.

[4]These weren't rf ("radio frequency"…that range used to send AM, FM, TV, cellular, etc.) signals. Hams would just inductively couple the audio amplifier component of their "rigs" back into the residential supply lines through a power transformer. These activities often had humorous consequences, in that hams would use "common carrier" as a workaround the 1000 watt limit put by the FCC on their rf, or antenna input, power. I distinctly remember neighbors deeply suspicious of my father's activities when their light bulbs would mysteriously flicker evenings and weekends, correlated with his presence in his shack.

[5]The most familiar devices are probably the "remote controls" available for turning selected pre-installed receiver duplex outlets on and off, either by a central switch panel, or through a pre-programmed clock sequence much like a VCR. Outdoor garden and security lighting are common applications. For a while I couldn't get mine to work. Then I figured out I had the controller on one phase and the outlet on the other. Made me feel like a real working scientist again.

[6]Generally, "signal" rates are limited to frequencies below 15 kHz. Never mind, your local electric distribution company can take its time reading your meter, OK? A number of protocols exist for signaling over existing distribution lines, some at the high frequency end requiring expensive repeater equipment be installed in substations and other locations where reactive compensation is performed. The EPRI experts here are Steve Drenker, *sdrenker@epri.com*, and Richard Hafner, *rhafner@epri.com*.

[7]Possibly the most ambitious is the alliance created between Nortel and NorWeb, two of Europe's larger telecommunications and electric utilities, respectively.

http://www.nortelnetwork.com/corporate/news/newsreleases/1997d/10_8_9797389_Norweb.html.

[8]These alternatives are well-summarized in *The Once and Future Network*, by Peter Lewis in the 15 July 1999 issue of the New York Times, *http://www.nytimes.com/library/tech/99/07/circuits/articles/15home.html*, and at a ham radio URL, *http://hamradio-online.com/rfi.html*, which contains an extensive list of relevant telecommunication technology sites. In my house, we have five PCs (wife, three school age children), and I'm tired of upgrading each one individually. I'm looking for a viable in-home LAN solution…I'm leaning toward connecting to our interior phone lines, rather than the house power.

[9]Would you believe while preparing this current *OutPost*, your correspondent was able to find an old undergraduate experiment he did on the frequency response of iron-core audio transformers in the 1950s? The "Bode Plot" (ratio of matched power out over power in versus frequency) I obtained was more or less "flat" up to 10 kHz, followed by a resonance peak (due to stray inductance and capacitance in the transformer) around +3 db at 15 kHz, trailing off to –3 db at 22 kHz and –10 db (10 times weaker voltage signal than say, at 60 Hz) around 100 kHz. Most of this limitation was due to stray inductance and capacitance. I doubt very much if distribution transformers are anywhere near as good. The implication here is that numerous repeater/amplication units would need to be installed throughout a reasonably sized suburban community to maintain signal strength and quality (SNR…signal-to-noise ratio).

[10]The availability of high data rate residential service is exploding. The most common is "Digital Subscriber Line," or DSL, utilizing your present telephone hookup, with "download" rates sometimes approaching 6 megabits/second, through a bandwidth of around 30 MHz, which begins to push the limits of unshielded copper wire. This is why prospective DSL customers need to live within 2-3 miles of their nearest telephone central office.

[11] *http://www.mediafusionllc.net/northamerica/main/home.html* Please browse thoroughly. If you find any technical content you think *OutPost* has missed, by all means contact us forthwith.

[12]You engineers check me out. Assume an air dielectric coax, inner copper conductor diameter 1mm, outer shield 3 mm, an approximation to your cable TV service, so the natural impedance is 50 – 70 ohms. At 1 GHz, the skin depth limited –10 db length is about 25 meters. Enough said.

[13]Maxwell's Equations of the electromagnetic field, arguably the supreme synthetic achievement of the human mind, surpassing even relativity and quantum mechanics. Richard Feynman, when asked should the human race disappear, what brief message could we leave a future intelligent life form which would enable the recreation of physical science, is reputed to have replied, "Maxwell's equations. Oh, and a note saying everything else is made up of little particles." Nyquist's sampling theorem states you

must sample at a rate at least twice the highest frequency present in order to digitally reproduce it. For example, audio CDs are created by sampling at 44 kHz.

[14]Curiously, MFC lists Feynman's text, *QED: The Strange Theory of Light and Matter* (ISBN 0691024170), as one of their references. I wonder. Feynman once did give a lecture entitled, *There's Room at the Bottom*, credited as the inspiration for today's fledgling nanotechnology. Maybe he also meant squeezing the internet into 60 Hz.

[15]MFC's web site contains links to various print and internet coverage.

[16] *http://more.abcnews.go.com/onair/cuttingedge/wnt990723_smith_story.html*. Unfortunately a video clip of the interview is no longer available.

[17] *http://www.house.gov/tauzin/*. Some good cajun recipe links on this page. Really.

[18]"Their plans include a mere, small device that plugs into every socket," U.S. Congressman Billy Tauzin, chairman of the House Commerce Telecommunications Subcommittee, told a crowd of the nation's most influential telecom, Internet and electronic commerce companies and investors during a March 11 speech in Washington, D.C. "You can simply connect your television, your telephone, your PC to them, and immediately get those services under this system." *http://www.mediafusionllc.net/northamerica/main/news/prjune03199.html*.

[19]*http://www.mediafusioncorp.net*.

[20]Attributed to Ken Olsen, founder of Digital Equipment Corporation. Ken Olsen was one of the giant pioneers of digital computers, developer of the world's first transistor computer, for whom I worked briefly at Lincoln Laboratories in the 1950s. Of course he was right. In 1977 would you have wanted your garage filled with a monster that would have easily tripled your electric bill?

[21]Well, if you'd bought stodgy, dull old IBM in January, 1993, you probably would have done just as well. Better if you'd gotten some in 1924.

[22]If you can't get your message past the nearest lamppost, it doesn't matter if it's incoherent beyond that point.

[23]OK, let's say they've found some new principle of physics the rest of us have missed. Doesn't the Navy use ultra-low-frequencies to communicate with the nuke sub fleet? I seem to have heard it takes a while to transmit a few bits of information this way because the carrier frequencies are in the kilohertz range to make use of the "ground wave" effect. But hey, maybe the launch codes are not that long. Anyway, I would think the Navy would be right on top of this new development. You can bet that the Honorable Representative from the Third District of Louisiana will probably ask. Maybe that's why MFC has retired Rear Admiral James A. Carey on its board.

[24]Bell's main challenge was proving his invention had practical value, not that it worked. Bell was an elocutionist by profession and hence a practiced public speaker. He went on the road with many clever demonstrations. My favorite is when he transmitted voice signals through 16 Yale faculty members holding hands in series. Not practical you say? What better use to make of Ivy League professors? Ironically, that non-Ivy, low-brow "tech school" on the banks of the Charles in Cambridge has a project whereby a microprocessor in the heel of your shoe can pass your vital information to a similar device worn by a new acquaintance (or first date!), simply through the mutual skin conductance of a handshake. No, I'm not kidding. Seriously. They actually do this.