The Birth of an Internet-Friendly Radio-Telephone Line Extender

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Among the more challenging tasks to accommodate the new Internet world is the provision of wireline-quality dial-up modem speeds over a wireless telephone link, enabling rural and remote people and businesses to connect to the Internet just like their city cousins. Carlson Wireless Technologies has developed a fully integrated, two-line point-to-point wireless line extender, the *i-WLL Trailblazer*, that accomplishes this task, a feat unmatched, to the best of our knowledge, by any other wireless equipment supplier.

Let the Digital Divide Begin!
Prior to 2000, "radiophone" service was traditionally provided with a full-duplex narrowband FM radio system. This required a set of tuned cavity duplex filters, separate receivers and transmitters at both ends, a telephone line to a four-wire audio converter, a controller, and typically a pretty healthy 12-volt power supply (50 to 100 watts!). Still, it worked fairly well – at least for voice transmission.

Then along came the Internet Age. Larger file transfers became common, resulting in modem speeds increasing from 2400 bps to 9600 bps. The higher the speed, the greater the need for a connection with a good signal-to-noise ratio.

Never designed for these specifications, wireless FM narrowband links were put to the test. As the year 2000 countdown began, radiophone users were left crippled by slow modem speeds.

We Need Our Bandwidth
In January 1998, Jim Carlson assembled an engineering team to design a simple wireless solution for rural folks, people who wanted not only a clear voice link but also a good Internet and email connection. Initially, the team focused on providing a single line that would transparently support dial-up modems. However, as development progressed, it became clear that other highly desirable features were also achievable.

After testing a number of spectrum options, the 2.400 to 2.483.5 GHz band was selected, as it offered unlicensed spectrum availability (2450 to 2483.5 GHz in Canada), more contiguous bandwidth, availability of low cost "chip" radio solutions, and less congestion from other users.

56K Modem Compatibility
Getting the system to be compatible with the V.34 and V.90 modem standards while adding a second two-to-four wire telephone hybrid in the circuit was a major challenge. The most significant impairment degrading the S/N ratio is the return echo caused by imperfect matching of the two-to-four wire line interface hybrids. These hybrids are used to convert a telephone line into a separate forward and reverse audio path that a medium such as a radio link can support.

On the subscriber side, or FXS, the designer can assume much more about the characteristic impedance of the telephone line and the instruments used. The customer premises equipment, data devices in particular, are designed to match very well to a 600 ohm +C impedance.

The more difficult side of the interface to match is the central office side, or FXO. The typical rural local loop has 3 to 25 km of cable extending from the central office with varying gauges, vintages and loading. One has to use a survey method to predict what the network balance impedance will be. Armed with that data and a complex

impedance modeling program such as PSPICE, one can simulate a broad match to a 2-to-4 wire hybrid circuit. These results can be used to build a circuit that will broaden and optimize its matching capability with 95+ percent of the rural loops.

One Transceiver, No Duplexer and No Tuning
The impedance matching problem solved, the design work became a lot more fun as the traditional analogue headaches were non-issues due to the differences between analogue and digital circuitry. The first benefit is time division duplexing, or TDD. The audio from the four-wire line interfaces is digitized and queued up to allow for a burst packet to be sent over the radio link. In our case several milliseconds of audio is queued and sent in less than a millisecond. Immediately after receipt of the packet, the opposite end responds with its own packet of queued audio data and the system waits for the next frame and starts over. To the user, this queuing is completely transparent.

The big bonus is that this eliminates a pair of duplex filters and the hassles of retuning the filters every time a frequency is changed. Also the radio can be a simplex transceiver instead of a separate transmitter and receiver.

Encrypted for Complete Privacy
Additional benefits of spread spectrum transmission also come into play. Spread spectrum was originally developed for covert military use due to three major features: It is difficult to detect, jam, and intercept. This spells good news for privacy needs such as using credit cards, making bank transfers and trading securities. Thanks to spread spectrum, the radio link has much less chance of a privacy breach than copper wire loops.

Lower Cost, Higher Reliability
The design's reduction of analogue parts and the integration of digital and RF components results in a cost savings of about 30 percent. It has only one movable device, a 16-position rotary selection switch. Reliability is further enhanced with extended temperature range components allowing the product to achieve mean time between maintenance (MTBM) in the range of three to five years and mean time between repairs (MTBR) in range of seven to ten years.

Going the Distance - All 22 km of it
With the addition of a patented, integrated, flat-panel antenna, the Carlson engineering team effected an overall system gain of 136 dB. This design allows for point-to-point distances of more than 20 km with a fade margin of ~13 dB.

Flexible Input Voltage
Since the on-board power supply operates on five volts, it was simple to provide a switching DC to DC converter input allowing any voltage from 12 to 48 volts DC to power the design. This enables the *Trailblazer* to function perfectly with typical carrier power of 48 volts, microwave tower power of 24 volts, and photovoltaic power of 12 to 16 volts.

Lightning and Transient Protection
Carlson engineers closely examined all ports of entry for lightning or other inductive transients. Care was taken to follow UL, IC and FCC guidelines and provide both long-term power cross and short-term 100A shunt limiting on the telephone side. On the power supply side, large shunt limiters clamp any voltage above 56 volts and below one volt.

Internet Power to the People!
After nine months of beta testing, the *i-WLL Trailblazer*, was released in August 2000. Sales are beginning to grow rapidly, and customers report great satisfaction with having found a low-cost, high-quality, reliable way to access the digital world from rural and remote locations.