Electronic Price Labels: A Parable of Product Development

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Outline

● What is an Electronic Price Label?
● How it All Got Started
● What We Looked At
● We Build a Prototype
● Competition
● The Regulatory Landscape
● Development!
● The Outcome
● Lessons Learned and Unlearned
What is an EPL?

NCR DecisioNet™ Electronic Shelf Label Solution

Today’s consumers expect prices to be consistent at the shelf and checkout. NCR DecisioNet, a wireless electronic shelf label solution, can help retailers meet this challenge—and more. By streamlining price integrity, DecisioNet can help you build customer confidence and lower costs while improving store operations.

Consistent Pricing at the Point of Decision

Using high-frequency radio signals, NCR DecisioNet transmits information from your product price file to wireless electronic shelf labels at your customers’ point of decision. A self-calibrating solution, DecisioNet continuously monitors each shelf label for accuracy with the price file. Therefore, pricing at the shelf and checkout is consistent.

The display window and character size of NCR’s shelf labels are designed for superior readability and visibility. Available in various sizes, the labels can be mounted anywhere within your store’s environment, including peg hooks, ceiling shelf fillers, gondolas, and freezers.

NCR electronic shelf labels can display multilingual messages, special offers, frequent-shopper items, and nutritional information, helping your customers make informed purchase decisions.

An NCR DecisioNet software module is available for European retailers who are making the transition to the new euro currency. The software enables retailers to display shelf promotions and meet European Union requirements with a centralized, single-step conversion that is transparent to shoppers and to retailers’ point-of-sale systems. NCR’s labels offer the option and can accommodate currencies that require up to six digits.

Wireless Infrastructure Streamlines Store Operations

NCR’s business consultants will help you design and rollout a total business solution tailored to meet your unique operational environments. We can quantify the business value of your DecisioNet investment, and help you realize a quick return. In addition, NCR offers site survey, site preparation, product scheming, and data collection, as well as installation, rollout, and on-site installation service and support.

DecisioNet reduces costly operational inefficiencies associated with removing and replacing paper shelf labels. As you change your product price file, the NCR electronic shelf labels are updated automatically. Your employees are able to focus on serving customers instead of manually changing paper price labels.

In addition, price updates can be programmed weeks in advance to indicate sales and promotion percentages. DecisioNet equips retailers with the technology to maintain weekly specials, respond to competitor pricing, and pass along supplier savings—immediately.
EPL for Supermarkets
Supermarket Application of Electronic Price Label

Diversity Antennae

Ceiling Node

To “Back Office” and Computer Network

Display Module

Gondola

Shelf
Electronic Price Label

GM Basic 4 Cereal

15.2 OZ
12 ***RSC***
0-16000-64820

23.24 | 3.49

PER OZ
YOU PAY
Reach out and crush someone: AT&T completes a hostile takeover of NCR in 1992.
How It All Got Started

● The charge to the team:

Devise a system to remotely control a price display on a supermarket shelf. It must be:

» Reliable. Only one incorrectly displayed price in the entire store per year (one error in a million transmissions).

» Two way. To verify that the tag is operating correctly.

» Long lived. Guarantee a minimum 5 year life.

» Cheap. The retailer recovers his outlay in 18 months (based on 15,000 tags in a store).
What We Looked At

• Communication Technologies:
  » Infrared
  » Optical (Fluorescent Lights?)
  » Radio
  » Ultrasonic
  » Magnetic
What We Looked At

- We chose radio, mostly because we couldn’t convince ourselves that it wouldn’t work.
  - Infrared would lead to a nice tag, but we were worried about the reliability of the communication link. (Brute force could make it work, but would it cost too much?)
  - Modulating the fluorescent lights seemed a cute idea, but we had no control over the infrastructure.
What We Looked At

» We dismissed ultrasonics, not because we showed it couldn’t work, but because we didn’t know enough about it to evaluate it.

» Magnetic (inductive) data transmission appeared to require a lot of infrastructure and wasn’t very flexible.
What We Looked At

- We also considered using solar cells to power the tags. They would work in most locations in American supermarkets, but even there about 10 percent of the floor area is inadequately illuminated to power EPLs.

- Conclusion: use batteries.
We Build a Prototype

- After we decided on using a radio link, we had to figure out how to build one cheaply. Our budget for a two-way radio that would fit in a tag was $0.75.
We also had to decide on a frequency of operation. The frequency band that had the widest availability with the least restrictions was the 5.8 GHz ISM (Industry, Science & Medicine) band.
We Build a Prototype

★ What’s the cheapest radio you can imagine?

» For the base station to tag link we use a *crystal radio*, a dependable century old technology. This kind of radio just turns the radio signal directly into a small voltage, which we have to amplify before it is useful for anything.
Tag Operation

- Same Diode Used in Receive and Acknowledgment Modes
- 1.5 mAmp Modulation Changes Reflection Coefficient of Antenna
- 3.2 microAmp (Average) LNA with 110 dB of gain
- 5 to 7 year battery life
- Communications Costs under $1, Complete Tag Costs Under $10
We Build a Prototype

- For the uplink we use modulated backscatter.
  - The base station sends out a continuous signal. To communicate back to the base, a tag alters the amount of radio signal *reflected* by its antenna.
  - It’s possible to do this by only adding about $0.10 to the cost of the basic tag radio.
  - It does make for a complicated and potentially expensive base station unit. But that cost is divided over several thousand tags.
# Pioneers of Modulated Backscatter Technology

<table>
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<tr>
<th>Year</th>
<th>Inventor/Developer</th>
<th>Contribution</th>
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<tr>
<td>1821</td>
<td>C.F. Gauss</td>
<td>Heliotrop, Optical Triangulation and Signaling</td>
</tr>
<tr>
<td>1880</td>
<td>A.G. Bell</td>
<td>Photophone, Audio Transmission over Reflected Light Beam</td>
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<td>1952</td>
<td>KGB</td>
<td>Embassy “bug”</td>
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<tr>
<td>1960</td>
<td>Scharfman and King</td>
<td>“Antenna Scattering Measurements by Motion of the Scatterer”</td>
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<tr>
<td>1976</td>
<td>RCA</td>
<td>Backscatter Transponder using Phase Modulation</td>
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Communications Base Station
Radio Architecture

- Homodyne Detection Cancels Much Phase Noise
- 1 Watt Frequency Hopping Transmitter
- ON/OFF Keyed Modulation in Downlink
- Two-Rail Quadrature Receiver
- Several Narrow Band Receivers in DSP
- Multiple Receive Antennas for Diversity
The prototype looked really cheesy but it worked, at least over a range of about 4 meters.

» It only tried to prove that we could build a radio that would eventually be low cost.
» It took about three months.
Prototype vs. Reality

- We took experimental tags and ceiling units into a real supermarket and tested the system. The results were not encouraging.
  - Signal strength was low
  - Noise was far higher than we had expected.
Prototype vs. Reality

- The signal was low because at our operating frequency of 5.8 GHz, the radio waves get absorbed by all sorts of things in the store.
  » Charcoal and dog food are especially good absorbers.

- The noise in the uplink channel was high because we neglected all of the things in a store that generate modulated reflections.
  » The fluorescent light ballasts are the biggest source of modulated reflections.
Prototype vs. Reality

- The supermarket tests were very discouraging.
  - While we thought we fix the uplink noise problem by using uplink tones that lay between the harmonics of the 50 or 60 Hz powerline frequency, this would increase the cost of the tag, because we needed a more accurate, hence more expensive, crystal resonator.
  - The 5.8 GHz radio signal absorption was still going to make the system uneconomical.
Hold Your Breath

At this point in 1993, we thought we were only a year from product introduction. But the product wasn’t going to work.

» Based on consultations with people working on other radio systems, we decided to redesign the system to work at a lower frequency.
Hold Your Breath

- The obvious choice at lower frequencies was the 2.45 GHz ISM band. The rules for using it are about the same as for the 5.8 GHz band.
  - But there were still problems. At the time, European regulations for the 2.45 GHz ISM band were in disarray, and the frequencies were essentially unusable in France, where they were used by a military radar system.
  - It was the only choice if we intended to continue.
Competition

- Telepanel
  » Inductive system; in partnership with IBM.
- Electronic Retail Systems
  » Wired into the shelf rails.
- Pricer
  » Infrared.
- ...and another rumored system using modulated fluorescent lights.
By the way, did I mention that we weren’t sure if the FCC would allow this system to operate in the US?

» FCC rules required that in communication systems operating in the ISM band, radios at both ends of the link change operating frequency four times a second. Did our modulated backscatter scheme count under this rule?

» Eventually, the FCC agreed that if the base station transmitter in a reflected (backscatter) communication system changed frequency, they would consider that the same as if the tag had changed frequency.
Once the decision was made to switch to 2.45 GHz, development began in earnest. To reward the team that had made all of this progress, they were fired and replaced by a team from a different organization.

» The reason for the switch was that AT&T Consumer Products, which had been done the prototype work under contract to NCR was considered too expensive.
The original team was rehired for the project after six months.

NCR Retail Systems realized that Consumer Product’s ‘Design to Cost’ methodology was needed. ‘Design for Quality and Performance then Beat the Cost Down’ wasn’t working, as well as being an unmemorable slogan.
Anechoic chamber test of tag sensitivities. A Base Station transmits through a calibrated horn antenna to the left commanding the tags to display signal strength information as the transmit power is reduced. Inspection of the tags indicate the weakest power at which they worked and the strength of their last up-link.

In this way, statistics on tag performance can be gathered automatically on 100 tags at a time.
Design to Price Air Interface

- <4 microAmp Avg. Current Draw
- 8¢ Watch Crystal (100ppm) 32,768 Hz
- Integrity of <1ppm/year
- 4 bit microcontroller
- Uplink NBW < 5 Hz
- Low Uplink SNR

- Duty Cycle <10%
- Frame Length < 1,600 bits 1092 bps Downlink Burst Length of 132 bits
- 21 bit Parity Check
- Simplified Sync. & Parity Calc.
- 3 Time Slot Uplink/3 Sim. Uplinks
- “Pooling” Uplinks to average S/N
EPL Design Highlights

- **Downlink**
  - On/Off Keying
  - Manchester Encoding
  - Frequency Hopped Spread Spectrum (Part 15.247)
  - Time Division Duplexing
  - Time of Day Transmissions w/ Scheduled Price Changes
  - 21 bit Parity Check Field

- **Uplink**
  - Modulated Backscatter at 2.4 to 2.4835 GHz
  - Three Simultaneous Audio Uplink Sidetones
  - Polled Acknowledgement Based Upon Parity Check & Tag ID
  - ~4 Hz Receive Bandwidth in DSP
Development

- The core product was redesigned three times.
- The amplifier integrated circuit went through four redesigns
  » This was the most difficult single component to make work at the right price. What’s interesting we should have understood that this part was going to be hard to build from our own specifications, but didn’t.
The Outcome

- NCR is spun off from AT&T in 1997.
  - NCR Retail Systems makes the EPL one of its core projects, and guarantees resources to complete the project.
The Outcome

- NCR: selling their system; volume production began in 1999.
- Telepanel: out of business. Acquired by ERS.
- Electronic Retail Systems: abandoned their wired system, started development of a 2.45 GHz ISM band system.
- Pricer: Still in business, but has focussed on convenience stores and department stores.
Where Can I See It?

- Macy’s main store in Manhattan
- A Wal-Mart in suburban Atlanta
- A B.J.’s Price Club in Connecticut
- Fine retailers in Holland and the United Kingdom
Lessons Learned and Unlearned

Why did it take so long?

» In one sense, it didn’t: the time from concept to product deployment is very similar to that for laser scanners in supermarkets.

» The other reason is that it is a system with many components.
Lessons Learned and Unlearned

How does product development in large companies differ from that in small ones?

» Large companies are tempted to protect the revenue stream they have by pursuing new technologies only fitfully.
» Small companies don’t have as many options - they have to get their products finished or fail.
» But small companies don’t have the resources to build entire systems.
Lessons Learned and Unlearned

• Your customer runs a business that has margins of 1 to 2 percent. Your customer has a very narrow view of the world.

  » Just because the consumer is happier that the display prices are the same as the scanned ones doesn’t mean that the retailer will buy the product.
Lessons Learned and Unlearned

● If time to market is critical, how come this project took six years? Why wasn’t the long development time fatal?

» Time to market is critical for ‘me too’ products. Introducing new technology in established markets is more a game of ‘first to the right price’.
Integration doesn’t always pay:

» redesigning the base station circuit board cut its price in half, but the parts count went up by 50 percent.

» Redesigning the tag amplifier to cut the external parts count from 22 to 7 did pay, even though the amplifier became more expensive.
Lessons Learned and Unlearned

- What about the economies of scale in mass production? Won’t mass production of the EPLs make them cheap?
(This graph had to be removed to protect the confidentiality of certain customer information. However, the point of the graph was that the cost of the EPL product was decreasing more slowly with cumulative production than that of commoditized electronic goods. The open question is whether this is a characteristic of the EPL product or because the EPL is still proprietary and only available from a single manufacturer.)
More Learning Curves

Cost Trends for Various Terminals

- CDMA/IS-95 Wholesale Prices: 83% slope, 17% learning factor
- GSM Wholesale Prices: 78% slope
- TDMA/IS136 Wholesale Prices: 76%

Lessons Learned and Unlearned

- Understanding the regulatory environment that your product is operating in can make or break it.
  - The product’s current success in Europe is mostly due to conversion of currencies to the Euro.
  - The EPL’s design had to be changed to meet European environmental laws.
Other Applications

- Inventory Management / Cargo Tags
- Security / Passenger Reconciliation
- Short Range Data / Paging / Tracking
- Child Finder or Photography in Amusement Parks
- Proximity Smart Cards
- Data Links for Handheld Appliances
Other Applications

- We worked extensively on a product for tracking airline cargo containers, bringing it to a state where it was ready for customer trials.
  - The cargo tag used the basic EPL radio, but was packaged to survive the harsh cargo handling environment.
  - Design life was 3 years (cargo containers usually only last 18 to 24 months).
  - You are fortunate that I did not bring the cargo tag demonstration. Someone could be injured.
Right now the most promising application is using the EPL radio technology as a way to read out many low cost sensors.

This was demonstrated to the US Navy under realistic conditions. The sensors were smoke and fire detectors, along with physiological sensors worn by Navy firefighters.

This was motivated by the cost of retrofitting sensors onto ships.
Audio Amplifier Characteristics

- Lucent MicroElectronics Group Bipolar Part
- High Gain (>110 dB)
- Low Noise (<20 nV/√Hz)
- Low Power (<30 microAmp Icc awake, <4 microAmp Avg.)
- Start of the art power efficiency
- Needed a High Speed Process, used CBIC-U2
- Low Cost