From Edison to Viterbi Audio Players and Recorders:

B.E.
(Before Edison)

- **Edouard-Leon Scott de Martinville, Paris, France**
- **In 1857 marked sound waves on a blackened drum.**
- **Could record sound but not playback recording.**
- **He called it “le phonautographe.”**

Along Came Edison

- **Edison was born on February 11, 1847, in Milan, Ohio.**
- **In 1877 Thomas Edison created a playable recording.**
- **He called it a "phonograph."**

Edison and his Phonograph

- **Initially Edison etched sound waves on tinfoil wrapped around a drum.**

- **Later he replaced the tinfoil with ground beeswax on a removable cylinder.**

- **Then, one could shave off the recording to make a new one but the cylinders were very fragile.**

- **In 1892 he added graphite to the beeswax to make permanent recordings.**

Edison and his Phonograph

- **Then Edison replaced the beeswax-graphite mix with bakelite.**
- **Cylinders sold for about 35 cents each.**
- **Edison phonographs sold for as little as $7.50 for the Gem Model to several hundred dollars.**

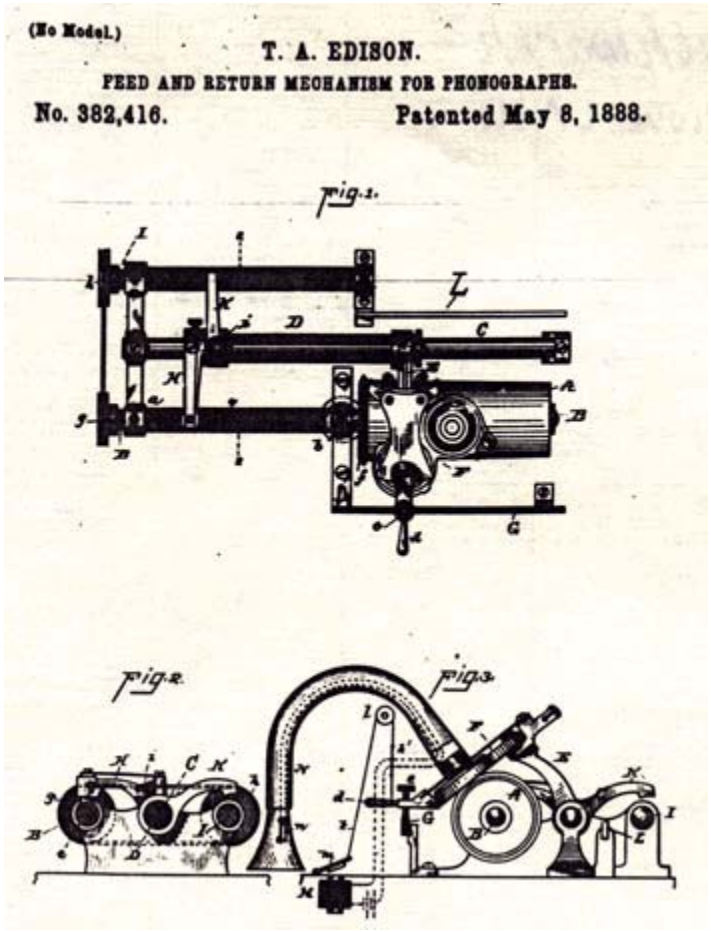
Two Technical Features of the Edison Phonograph

- **The information was recorded and read by moving a stylus up and down and not side to side. This was called "hill and dale" recording.**

- **The needle and horn was propelled down the cylinder by a worm gear. The pitch of the worm gear was the same as the pitch of the tracks on the cylinder. This greatly reduced wear on the cylinders.**

- **The original phonographs played 2 minute cylinders. A modification was added to the players to play 4-minute cylinders .**

Patent for Worm Gear Feed



(No Model.)

T. A. EDISON.

FEED AND RETURN MECHANISM FOR PHONOGRAPHS.

No. 382,416. Patented May 8, 1888.

Fig. 1.

Fig. 2.

Fig. 3.

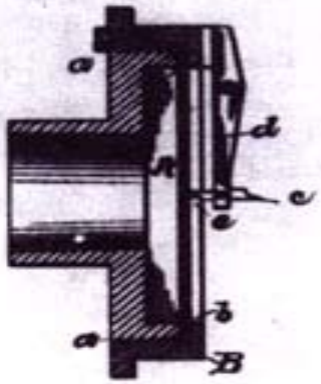
Patent for Reproducer

(No Model.)

T. A. EDISON.

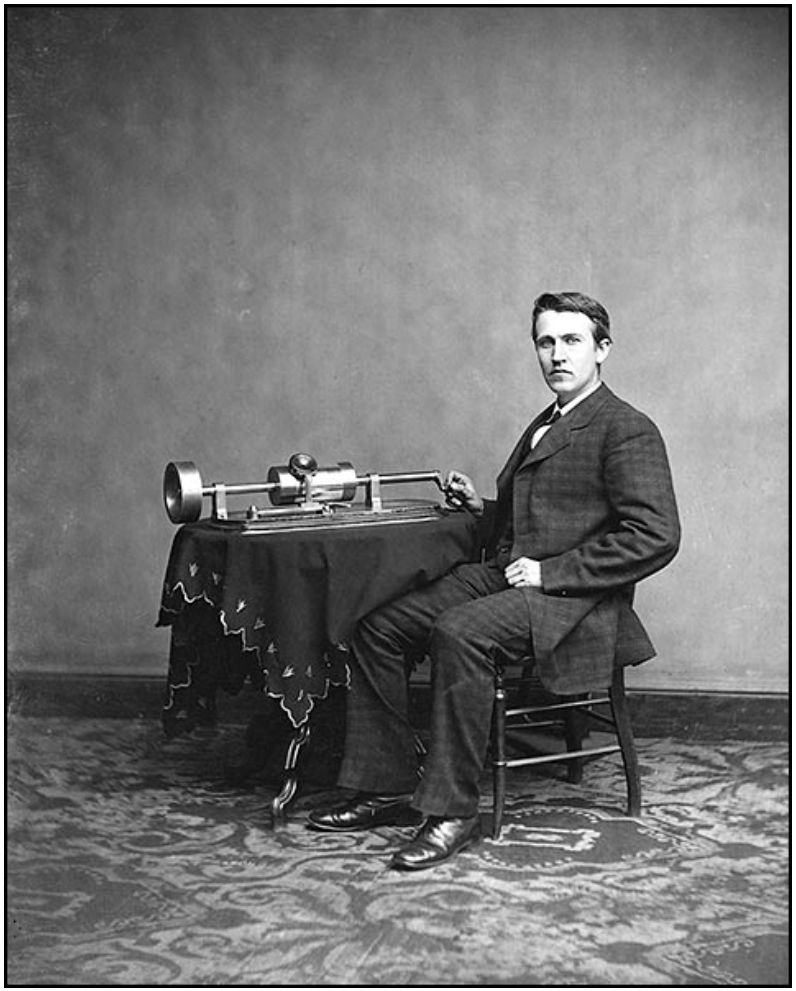
PHONOGRAPH RECORDER AND REPRODUCER.

No. 400,646. Patented Apr. 2, 1889.

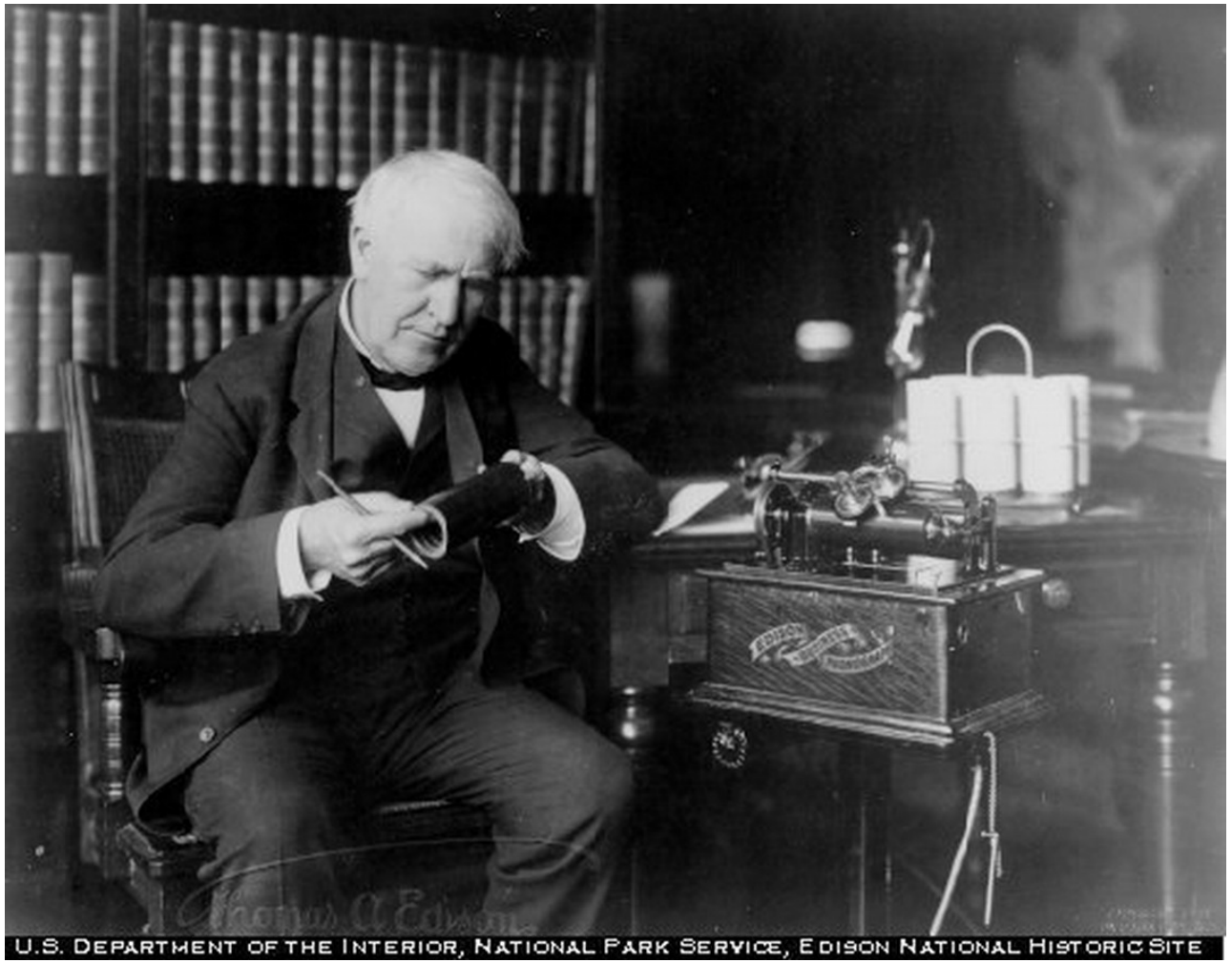


The “Reproducer”

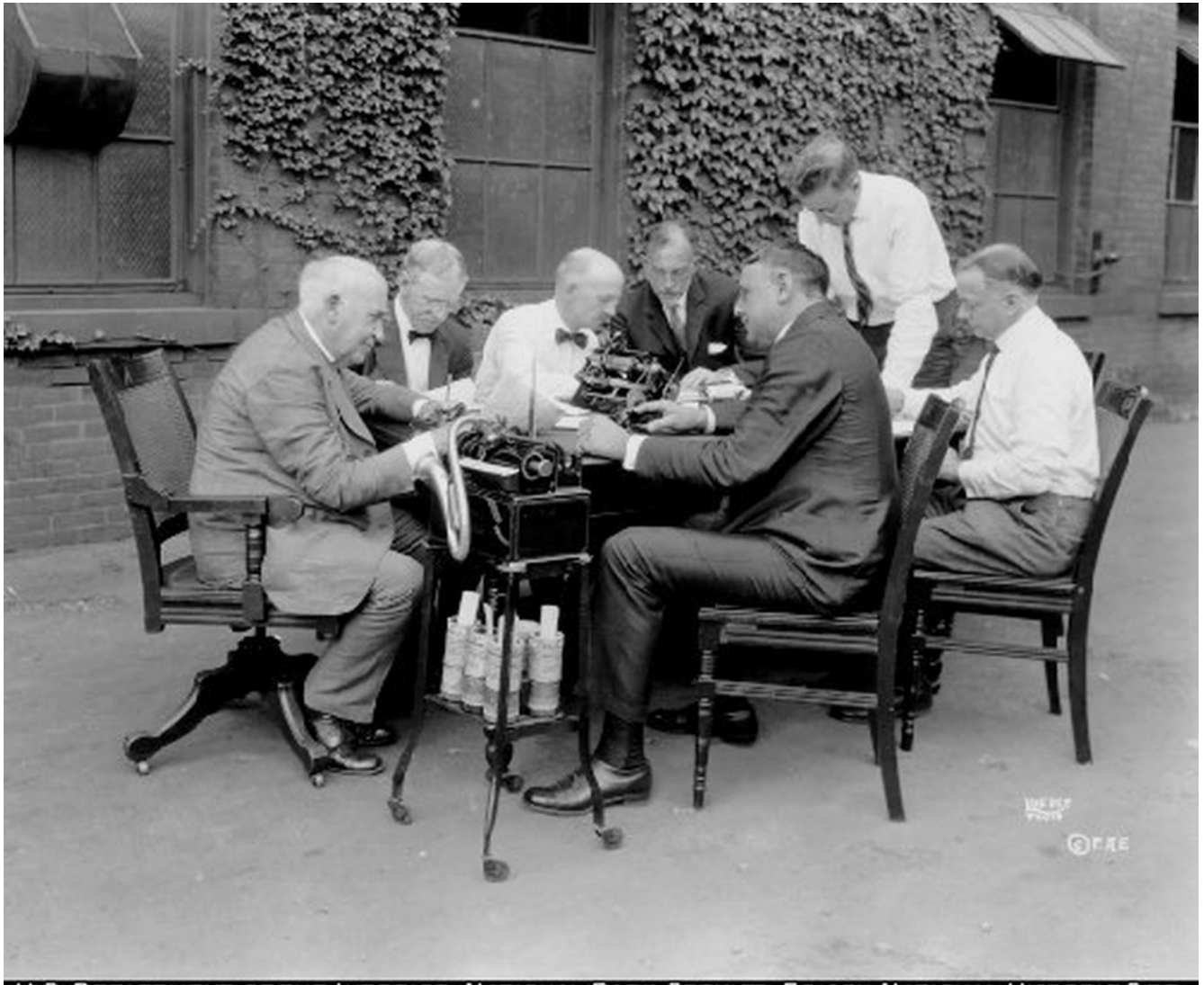
Edison and an Early Phonograph



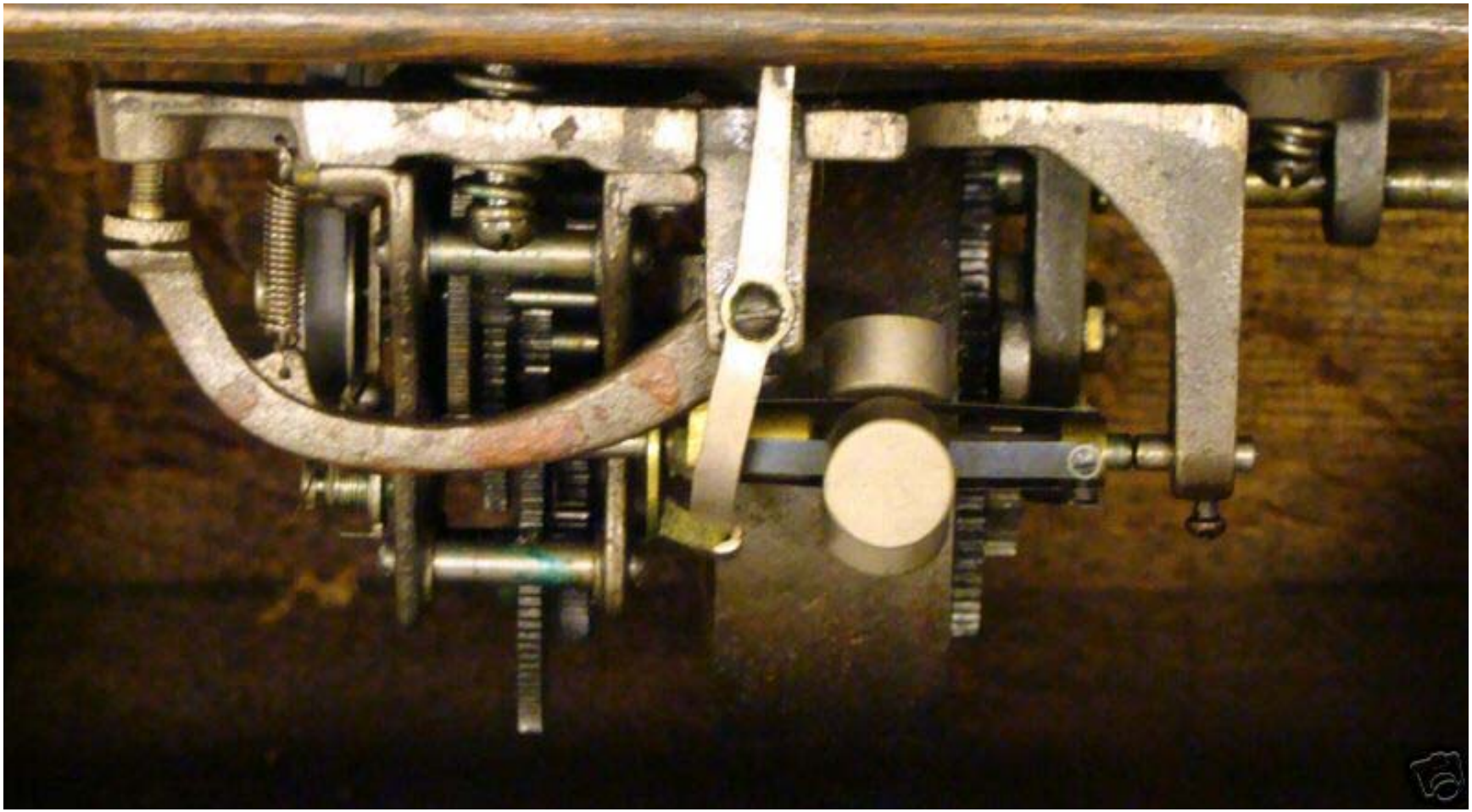
Edison and a Later Phonograph



Phonograph Engineers at Work



Mechanics of Phonograph

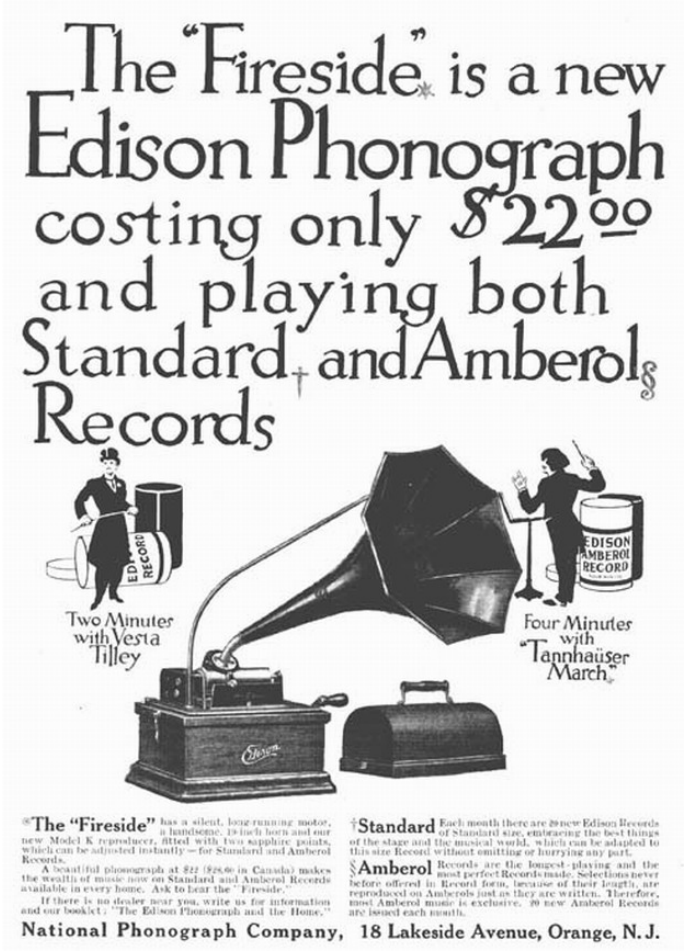


Recording Sessions

Recording Sessions

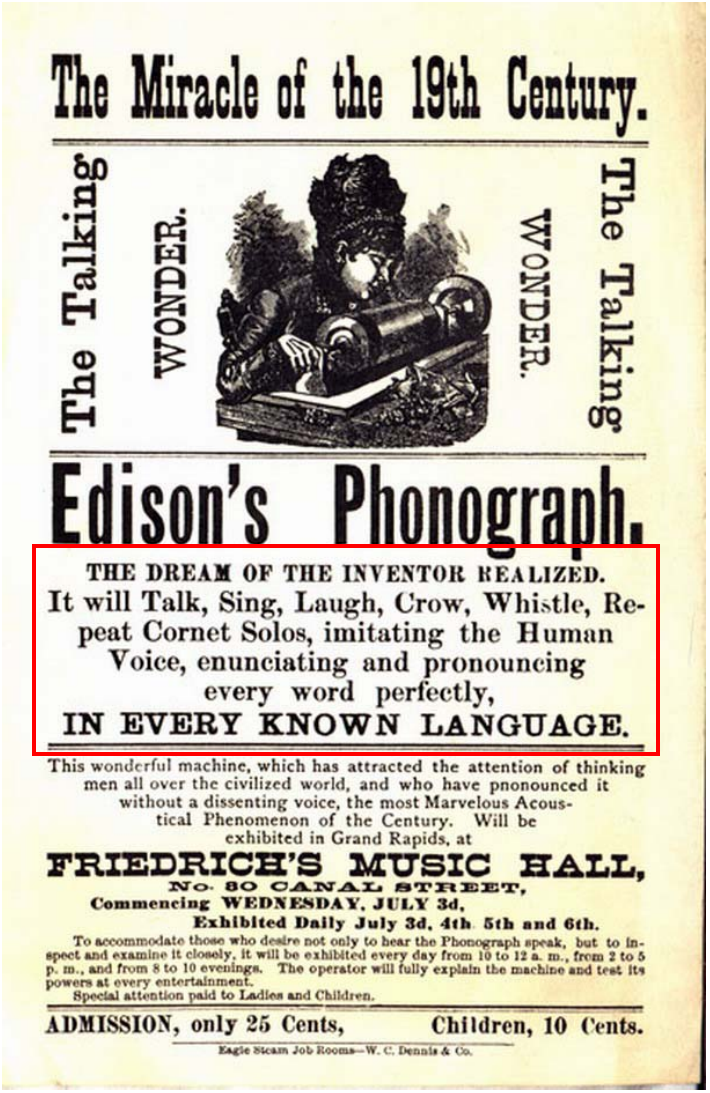
Note recording horn

Advertising



“Looking for the Band” Ad

Creative Advertising



The Miracle of the 19th Century.

The Talking WONDER.

The Talking WONDER.

Edison's Phonograph.

THE DREAM OF THE INVENTOR REALIZED.
It will Talk, Sing, Laugh, Crow, Whistle, Repeat Cornet Solos, imitating the Human Voice, enunciating and pronouncing every word perfectly,
IN EVERY KNOWN LANGUAGE.

This wonderful machine, which has attracted the attention of thinking men all over the civilized world, and who have pnonounced it without a dissenting voice, the most Marvelous Acoustical Phenomenon of the Century. Will be exhibited in Grand Rapids, at

FRIEDRICH'S MUSIC HALL,
No. 80 CANAL STREET,
Commencing WEDNESDAY, JULY 3d,
Exhibited Daily July 3d, 4th 5th and 6th.

To accommodate those who desire not only to hear the Phonograph speak, but to inspect and examine it closely, it will be exhibited every day from 10 to 12 a. m., from 2 to 5 p. m., and from 8 to 10 evenings. The operator will fully explain the machine and test its powers at every entertainment.
Special attention paid to Ladies and Children.

ADMISSION, only 25 Cents, Children, 10 Cents.

Eagle Steam Job Rooms—W. C. Dennis & Co.

- **The phonograph was displayed as a curiosity in music halls.**

Advertising for a Free Trial

Why Don't YOU Get This Phonograph

On FREE TRIAL?

For almost three years I have been making the most liberal phonograph offer ever known! I have given lots of people the opportunity of hearing the genuine Edison Phonograph right in their own homes without a cent of cost to them.

MY OFFER:

You Don't Have to Buy It:

WHY I WANT to Lend You this Phonograph:

Get the Latest Edison Catalogs

Our Easy Payment Plan.

If You Want to Keep It

Thomas A. Edison.

F. K. BABSON, Edison Phon. Distributers, Edison Block, Dept. 1587, CHICAGO

A Dance Party

Talking Doll

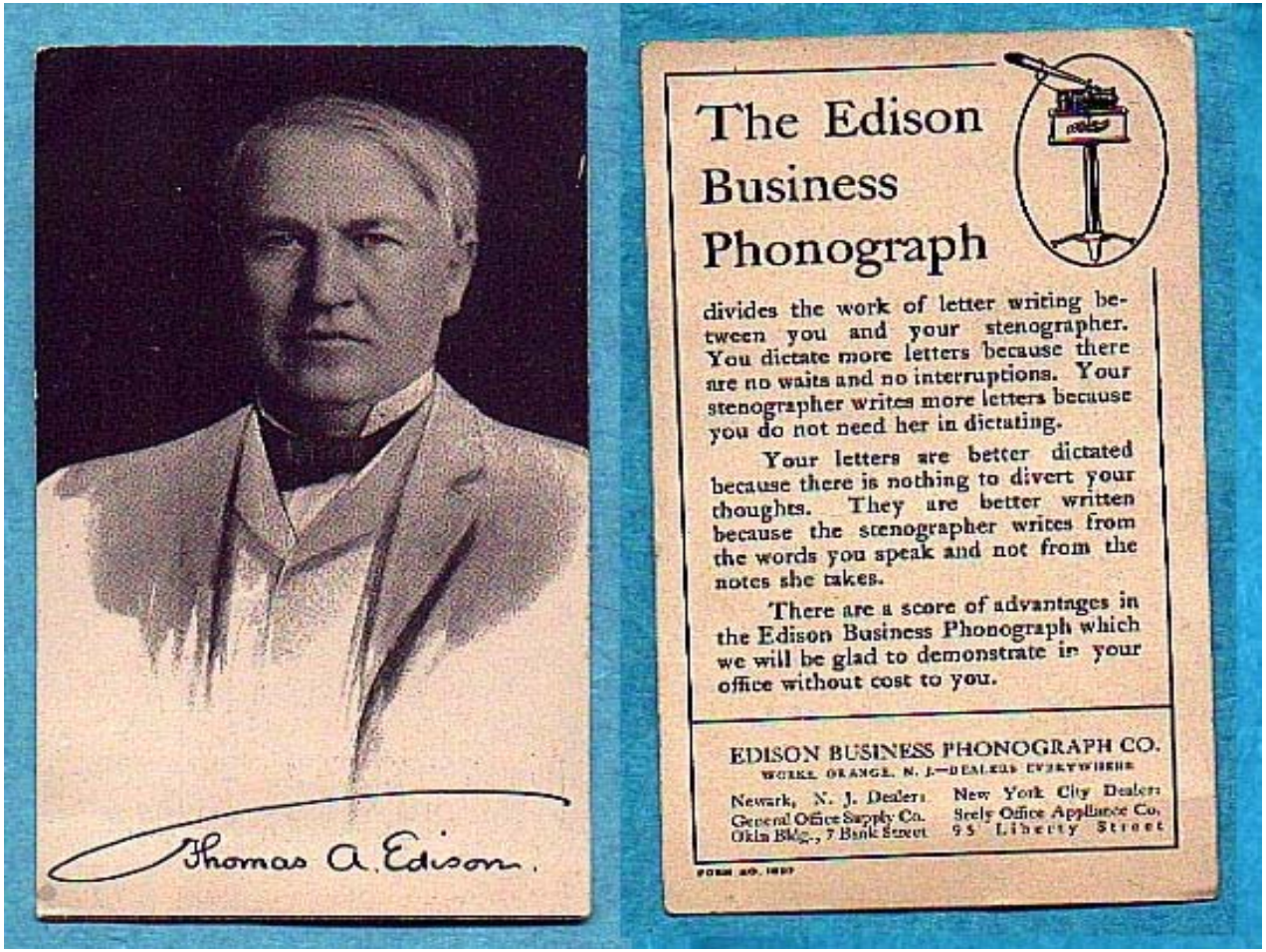
Morning Glory Horn

Disk Delivery System

A Marketing Mistake

- **Edison believed that the main market for the phonograph was in the office and not in homes.**

Ad for Business Applications



Cylinder Phonograph with "Folded Horn"

Flat Records: Emile Berliner

- Emile Berliner was a German immigrant living in Washington DC.
- In 1988, he invented the flat disk. It was much easier to store and also to reproduce.
- This was the beginning of the 78 rpm record.

Copying Records

- The master was a flat disk made of zinc and coated with beeswax.
- In recording, the stylus was moved side to side instead of up and down. The stylus cut through the beeswax to the zinc.
- The disk was then immersed in an acid and the acid etched the zinc where the wax was etched.
- After the remainder of the wax was removed, a "stamper" was made consisting of the negative of the master. The stamper then was used to make copies.

Emile Berliner

- **Berliner called the player a gramophone.**

- **Initially the gramophone was powered by a hand crank but it was difficult to keep the speed constant.**

- **Later, in conjunction with a machinist named Eldridge Johnson, a spring was added to control the speed.**

Victor Talking Machine Company

- They first called their business the Eldridge R. Johnson Company. It was later called the Victor Talking Machine Company.

- Berliner conceived the trademark "His Master's Voice".
- The machines were called "Victor the First", "Victor the Second", etc. Machines with hidden horns were called Victrolas.
- Later the Radio Corporation of America bought the Victor Talking Machine Company to form RCA-Victor.

Victor-Victrola

Edison Meets the Competition

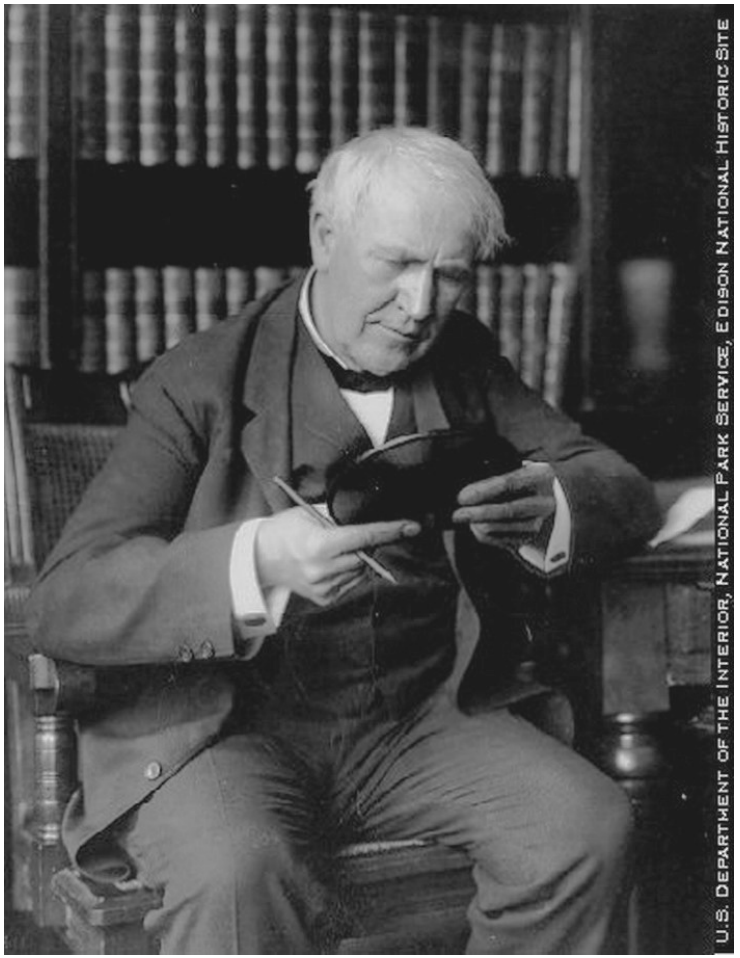
- **Edison continued with cylinders but eventually came out with a disk version of the phonograph.**

- **The disks were much thicker and used the "hill and dale" method instead of "side to side" recording of 78's.**

Edison Diamond Disk Phonograph

- It was called a diamond disk phonograph since it had a diamond needle.
- It had a “folded horn”.
- Again a worm gear propelled the needle and the horn.

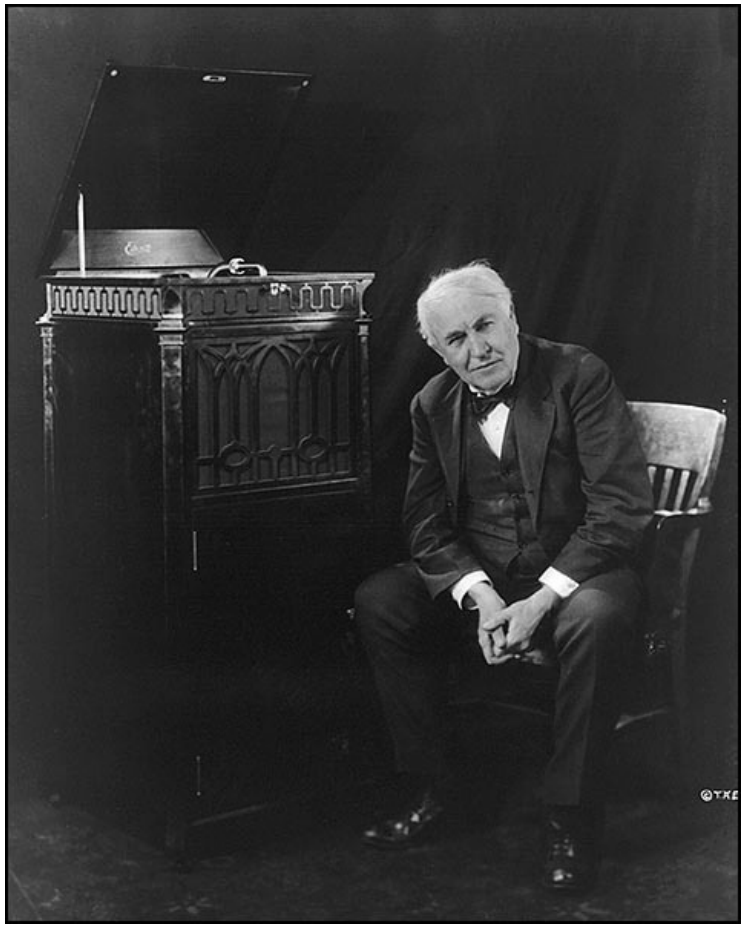
Edison and a Diamond Disk Flat Record



Some Models of Diamond Disk Phonographs

U.S. Department of the Interior, National Park Service, Edison National Historic Site

Edison and a Fancy Diamond Disk Phonograph



Some Edison Stories

- **Edison was almost completely deaf. He sometimes listened by biting on the vibrating object.**
- **He didn't believe in star performers. He thought people would prefer to listen to a great sound rather than to a well known performer.**
- **Berliner understood the importance of hiring (and paying for) well known personalities.**

Edison's Employment Test

- 1. Why is cast iron called pig iron?
- 2. What place is the greatest distance below sea level?
- 3. Who wrote the song "Home Sweet Home"?
- 4. Who was Pizarro?
- 5. What city in the United States leads in making laundry machines?
- 6. What eight countries bound France?
- 7. Where is the River Volga?
- 8. What country consumed the most tea before World War I?
- 9. What city is the fur center of the U.S.?
- 10. What country is the greatest textile producer?
- 11. Which has the greater area, Greenland or Australia?
- 12. Where is Copenhagen?
- 13. Where is Spitzbergen?
- 14. In what country other than Australia are kangaroos found?
- 15. Who was Bessemer and what did he do?
- 16. How many states were there in the Union in 1921?
- 17. What are prunes and where do we get the most of them from?
- 18. Who was Paul Revere?
- 19. Who was Solon?

Failing grade was "XYZ"

Henry Ford and Edison

Records: 78's, LP's, & 45's

The record era lasted for a long time.
But there was no ability to record!!

The Return of Recordable Media: The Wire Recorder

- Recording on steel piano wire.
- Commercially available in 1930's
- David Slepian was a Sonic Deception Officer in WWII and used a wire recorder to fool the enemy.
- Popular in U.S. from 1947 to 1955.

Open Reel Audio Recorder

- **The tape recorder was invented in Germany.**

- **In 1947 Ampex introduced it in the U.S.**

Audio Tape Recorders

- **A succession of tape recorders followed.**
- **Many different varieties were introduced for both commercial and consumer use.**

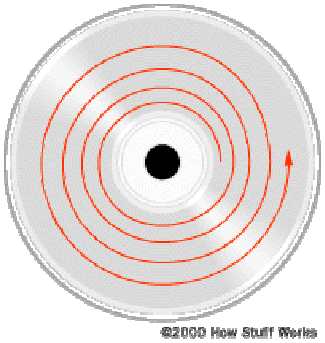
The Popular Cassette Tape

- **Introduced by Philips in 1962.**
- **Used 1/8 inch tape.**
- **Most cars to this day still have cassette players in their radios.**
- **1979 Sony Walkman**

Digital Recording

- **Digital magnetic tape was first used as a “backup” in professional recording studios.**
- **Then in the 1980’s, digital audio came to the consumer in the form of the CD.**

The CD



- **Music is recorded on a spiral track starting at the center.**
- **The spiral track, if stretched out, would extend approximately 3.5 miles.**
- **A CD holds 74 minutes and 33 seconds of sound, enough for a complete recording of Beethoven's 9th symphony.**

Error Correction Codes

- Due to imperfections in the CD, about 1 in every 100,000 binary digits are read in error.
- If not corrected, this would cause more than 10 errors per second. This would sound terrible.
- The errors are corrected by a variant of a Reed Solomon code.
- But CD's are rapidly being replaced by MP3 players using Viterbi detectors.

Along Came Viterbi

- Andrea Viterbi was born in Bergamo, Italy on March 9,1935.
- In 1967 he published the Viterbi Algorithm which yields the maximum likelihood sequence consistent with noisy data.
- Viterbi called it an asymptotically optimal decoding algorithm.

Pre-Algorithm Research

- **Before 1967, Viterbi worked in a number of other research areas.**
- **For example, he contemplated a new and improved bicycle.**

Steps in Inventing the Viterbi Algorithm

Before idea hit

Initial thoughts

Cooking up idea

Eureka!

But Andrew could not have done it alone

Viterbi Algorithm

- **Since its inception, the Viterbi algorithm has been used in all types of communications systems from deep space probes to cellular telephones.**

- **In the 1980's it was introduced into magnetic hard disk drives to unscramble intersymbol interference (ISI).**

The IPOD: A Disk Drive in Every Pocket

Stores music,

Photos, videos.

High capacity IPODs use hard disk drives.

Each disk drive uses the Viterbi algorithm.

IPOD

- **The new IPOD with a 160 GB hard disk holds up to 40,000 songs or 200 hours of video.**
- **Alternatively, it stores 400 hours of music and 7 hours of video.**
- **It retails for approximately $350.**
- **This was all made possible by shrinking the disk drives and making them super cheap.**

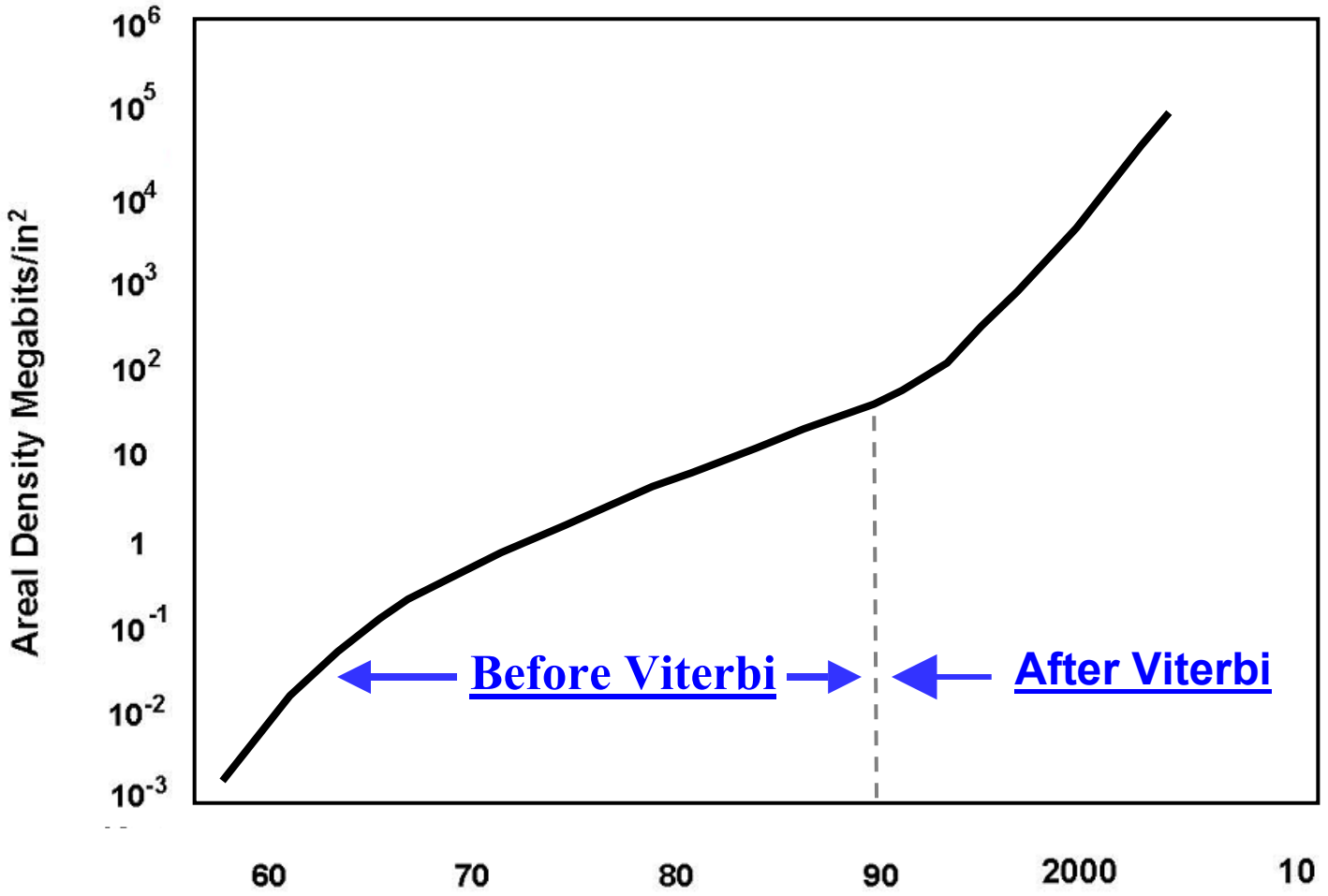
What is This?

It is a 1975 HDD Factory Floor

All of the Drives on This Factory Floor

- …have a total capacity less than 20 GB's!
- …have a total selling price of $4,000,000!
- That's because they didn't use the Viterbi algorithm.

Progress in Hard Disk Drive Storage Density



The Amazing Progress in Hard Disk Drives

2008 160 Gbyte

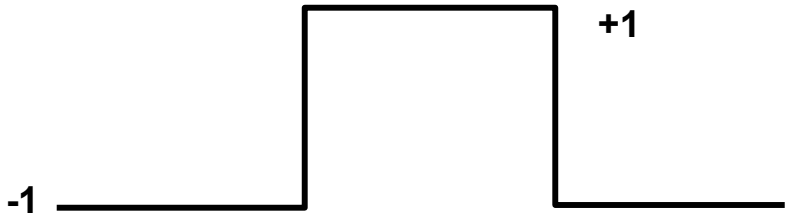
2 kbits/in^2	Areal Density	130 Gbits/in^2
$10,000	Cost per MByte	< $0.001

Intersymbol Interference

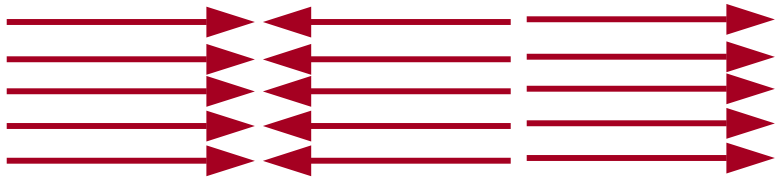
- The write signal is plain vanilla +1 / -1 baseband binary data. (No QAM, M-PSK, etc.)
- Each transition in magnetization on the disk results in an output pulse from the read head. The polarity of the pulses alternate in sign.
- Neighboring output pulses overlap resulting in intersymbol interference (ISI).

Writing and Reading

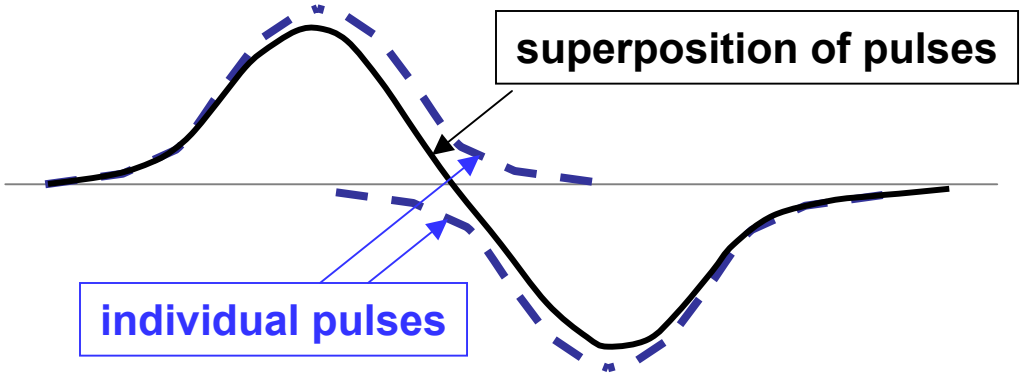
input signal



magnetized medium



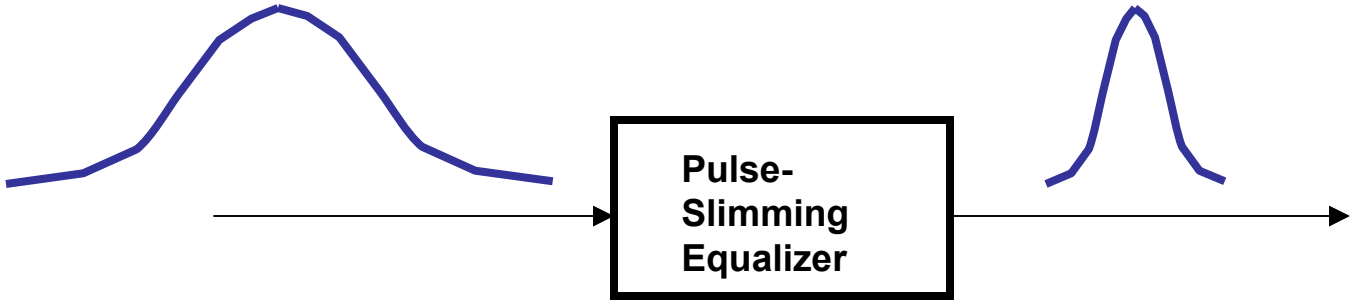
read back signal



B.V.
(Before Viterbi)

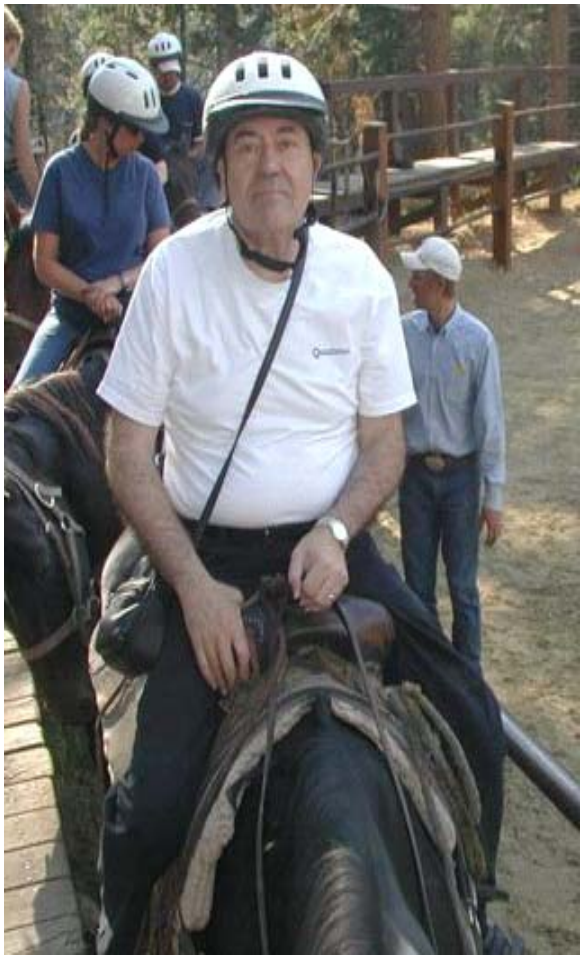
- **Before Viterbi, transitions in magnetization were detected by finding the peaks of the readback signal.**

- **As the density of bits increased, the pulses overlapped and the peaks were difficult to detect.**



. **But the pulse-slimming equalizer accentuates the high frequency noise.** **This is a major problem!!!**

Viterbi Riding to the Rescue

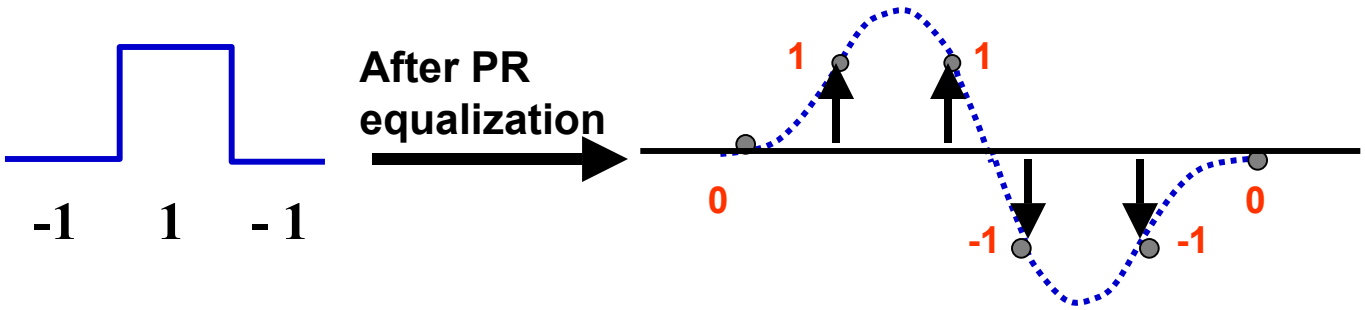


Viterbi Sequence Detection

- All current disk drives use a system where the pulses overlap but where the Viterbi Algorithm is used to unscramble the interference.
- This system, introduced by IBM, was called Partial Response Maximum Likelihood (PRML).
- There was no "V" in the acronym because Viterbi did not work for IBM.
- About ½ billion PRML disk drives containing the Viterbi algorithm are sold each year.

Viterbi Sequence Detection

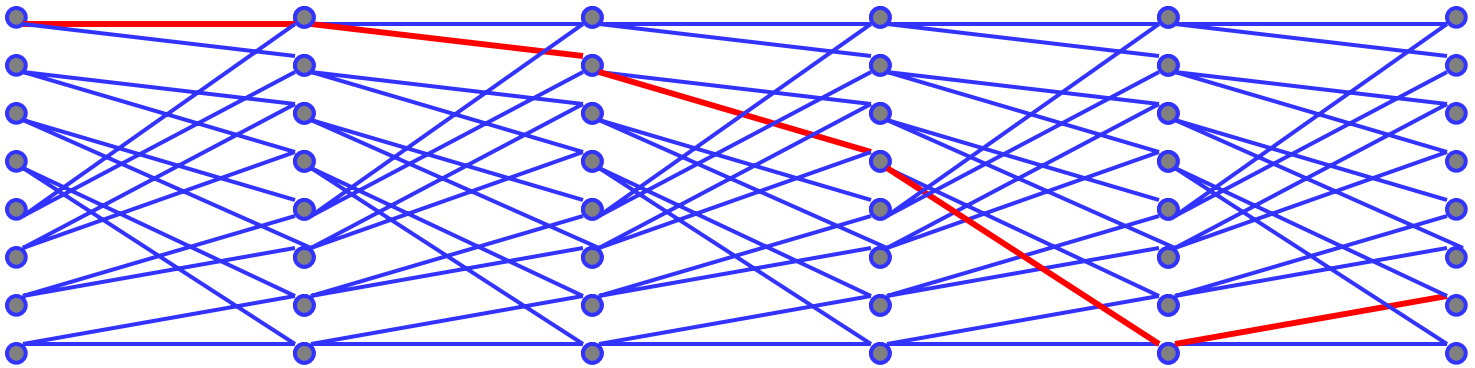
- EPR4 target: $h(D) = (1-D)(1+D)^2 = 1 + D - D^2 - D^3$



The discrete time system has an input-output equation:

$$y_i = x_i + x_{i-1} - x_{i-2} - x_{i-3} + n_i$$

- An 8 state trellis is used with Viterbi detection:



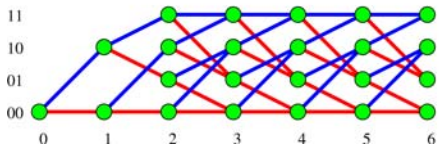
Post Processing

- A technique called “post processing” is now used where a simple error detection code is used to check the output of the Viterbi detector for errors.
- If errors are detected, the Viterbi algorithm is modified to produce the best sequence that satisfies the parity checks.
- This scheme was invented by a graduate student at UCSD, Kelly Knudson. Dr. Viterbi was a member of her Ph.D. committee.

Summary

- **Thomas Edison invented the phonograph.**

- **Andrew Viterbi invented the Viterbi algorithm.**



- **Andrew's contributions to engineering and science have been recognized in a number of ways.**

Honorary Degrees

- 1990 University of Waterloo
- 1997 University of Rome
  Tor Vergata
- 2000 Technion
- 2001 Notre Dame University
- 2004 Univerity of Rome
  La Sapienza
- 2005 USC

Knighthood

Erna and Andrew Viterbi

- **But Erna and Andrew Viterbi's contributions to society go far beyond the subject matter of this talk.**

- **Not two of the least are:**

The Viterbi Family

The USC Viterbi School of Engineering

Grazie Infinite Erna and Andrew