Planetary Coding 1969-2006
Robert J. McEliece

Jupiter’s moon Callisto
Galileo
May 2001

EE/Ma 127b
April 23, 2007
“The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point.”

Claude E. Shannon
1916--2001
Channel Capacity for the Space Channel

\[ \frac{E_b}{N_0} > \ln 2 \]

SHANNON LIMIT -1.59 dB
1962: Planetary Exploration Begins at JPL
The Early Years: No Coding:

- Mariner 2, 1962
- Venus Flyby
- Mariner 4, 1965
- Mars Flyby
- First close-up photographs of another planet.
- Mariner 5, 1967
$\log_{10} P_b$ vs. $E_b/N_0$, dB

SHANNON LIMIT: -1.59 dB
1969: Channel Coding Begins at JPL
(32,6) Biorthogonal Code +
“Green Machine” Decoding

- Mariners 6, 7 (1969)
- Mars Flyby
- Mariner 9 (1971)
- Mars Orbit
(32,6) Biorthogonal Code/
“Green Machine” Decoding

- Mariner 10, 1973-1974
- Mercury and Venus
- Viking Mars Landers, 1976
- Mars’ Surface

The (8,4) biorthogonal code
K = 7, R = 1/2 Convolutional Code + Viterbi Decoding

- Voyagers 1&2 (1977--)
- “Grand Tour”
- Mars Global Surveyor (1997- )
$P_b$ vs $E_b/N_0$, dB

- Shannon Limit: -1.59 dB
- Uncoded
- (32,6) Biorthogonal
- (7, 1/2) Conv.Code
K= 7, R = 1/2 Convolutional Code + Reed-Solomon

- Voyagers 1&2 (1977- )
- "Grand Tour"
- Mars Global Surveyor (1997- )
$E_b/N_0$, dB

$P_b$, dB

Uncoded
(32,6) Biorthogonal
(7, 1/2) Conv.Code
(7, 1/2) + (255,223) RS
K = 15 Convolutional Code + RS with Big Viterbi Decoding

Galileo (1989 -- 2003)

A Sea of Troubles

Mars Pathfinder (1996- 1997)

Sojourner
K = 15 Convolutional Code + RS + Big Viterbi Decoding (continued)

- Cassini (1997 ---- )
- Huygens Titan Probe, 2005
- Spirit and Opportunity
$\log_{10} P_b$ vs $E_b/N_0, \text{dB}$

- Uncoded
- (3,2,6) Biorthogonal
- (7, 1/2) Conv.Code
- (7, 1/2) + (255,223) RS
- (15,1/6) + (255,223) RS

**SHANNON LIMIT**
-1.59 dB
“Turbo Codes” (1993)

Claude Berrou

Alain Glavieux

Turbo Convolutional Encoder / Verify / Decoder System Architecture

INPUT BUFFER & INTERLEAVER

ENCODER a

ENCODER b

= Exclusive OR

= Take every symbol

= Take every other symbol