

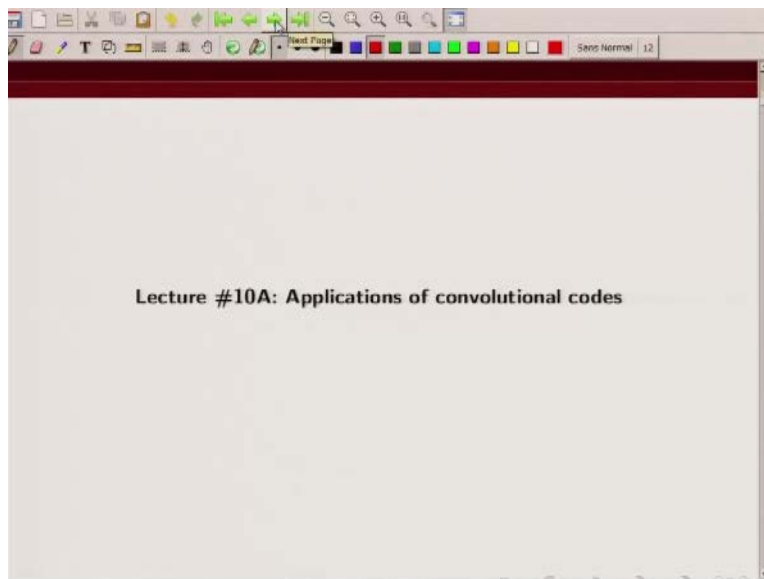
Indian Institute of Technology Kanpur
National Programme on Technology Enhanced Learning (NPTEL)
Course Title
Error Control Coding: An Introduction to Convolution Codes

Lecture – 10A
Application of convolution codes

by
Prof. Adrish Banerjee
Dept. Electrical Engineering Psychiatrist, IIT Kanpur

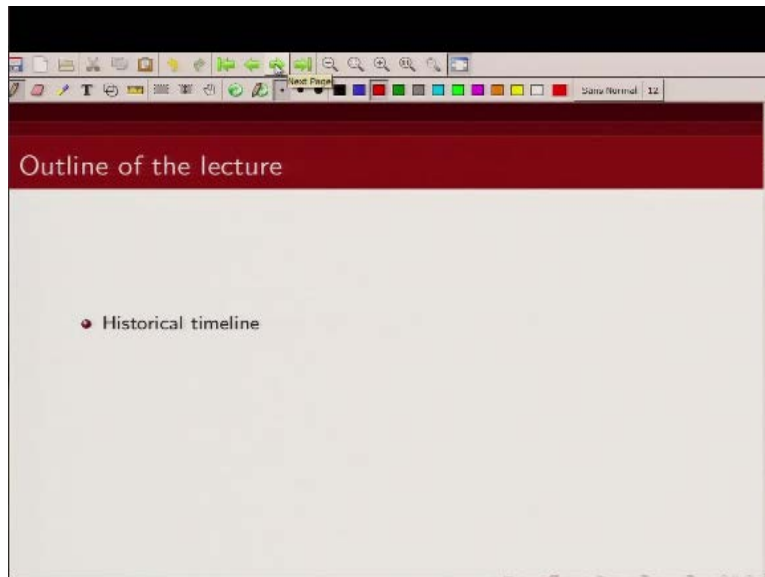
Welcome to the course on error control coding an introduction to convolutional codes today we are going to discuss some of the applications of convolutional.

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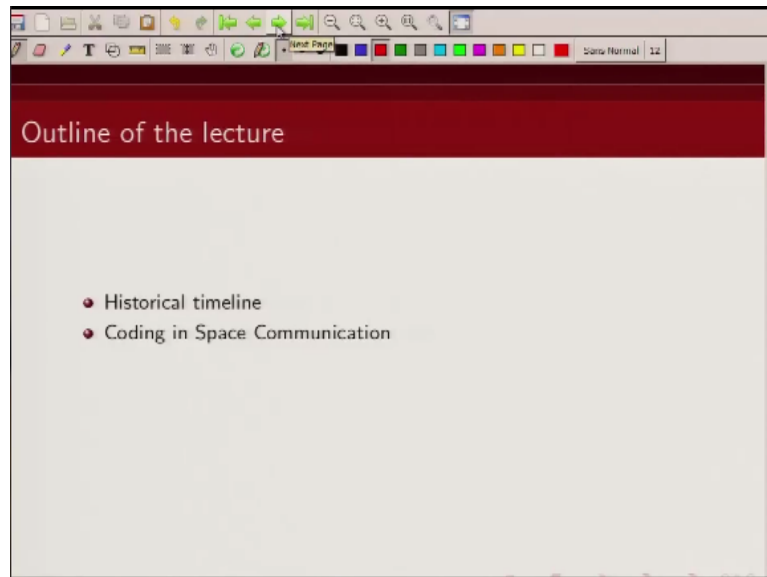
Codes and practice.

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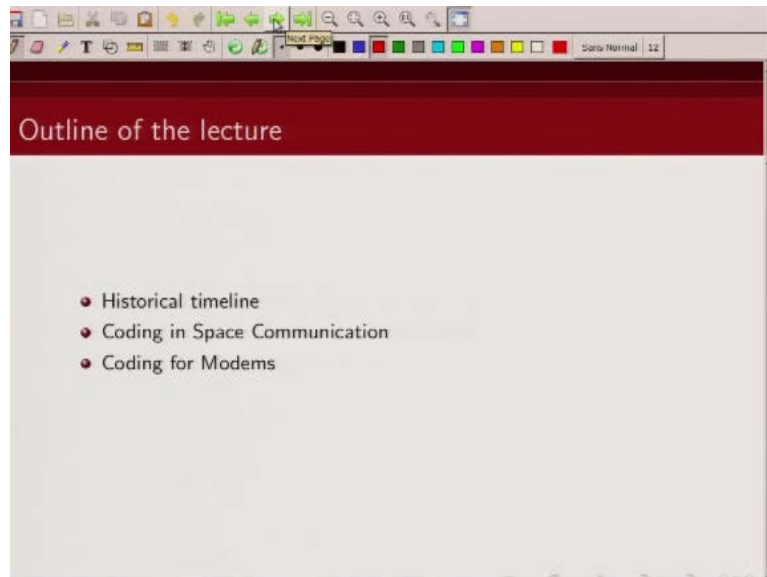
So before that we will just do a very brief historical time line of how coding theory as progressed over here is and then.

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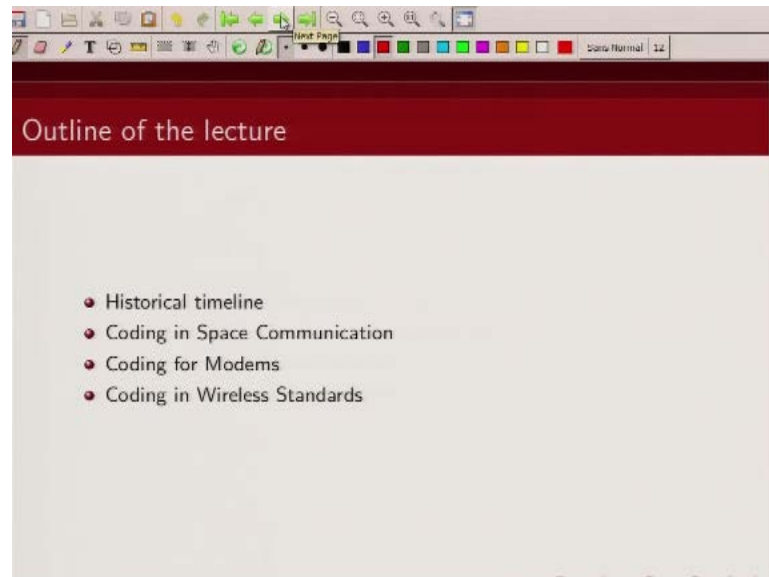
And then we will talk about some application of convolutional code we will first discuss some application since for deep space.

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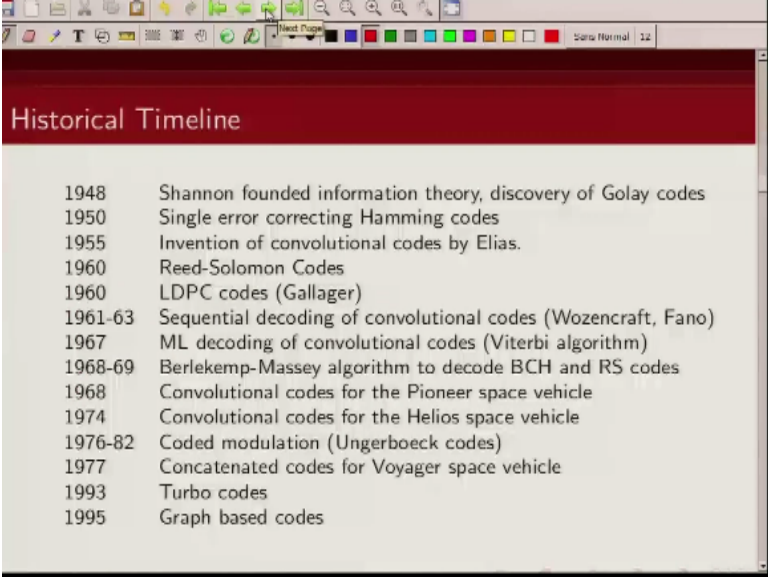
And some applications for modems

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And finally some applications of convolutional code in wireless communication standers.

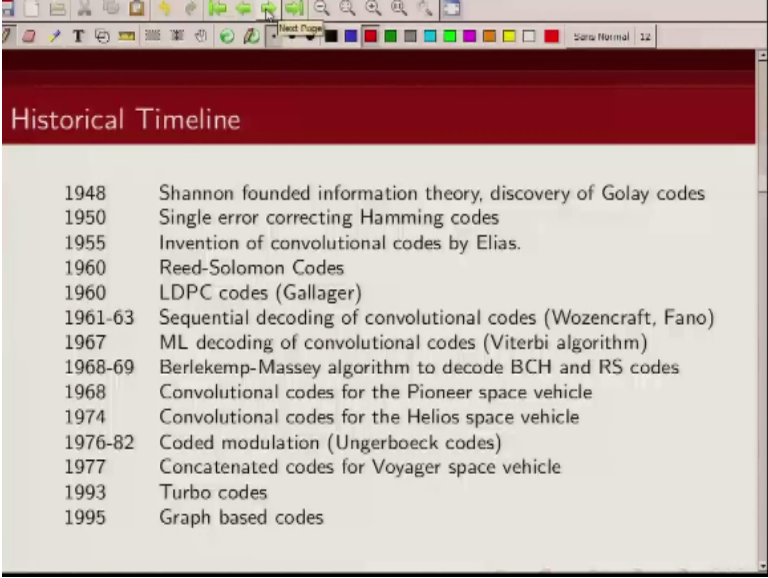
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Historical Timeline	
1948	Shannon founded information theory, discovery of Golay codes
1950	Single error correcting Hamming codes
1955	Invention of convolutional codes by Elias.
1960	Reed-Solomon Codes
1960	LDPC codes (Gallager)
1961-63	Sequential decoding of convolutional codes (Wozencraft, Fano)
1967	ML decoding of convolutional codes (Viterbi algorithm)
1968-69	Berlekamp-Massey algorithm to decode BCH and RS codes
1968	Convolutional codes for the Pioneer space vehicle
1974	Convolutional codes for the Helios space vehicle
1976-82	Coded modulation (Ungerboeck codes)
1977	Concatenated codes for Voyager space vehicle
1993	Turbo codes
1995	Graph based codes

So we know 1948 Shannon founded information theory, and then subsequently around 1955 Elias came with convolutional codes around 1960's Reed Solomon code and LDPC codes for discovered and around 61, 63 was Wozencraft and Fano came of a sequential decoding of convolutional code which allowed us to decode convolutional code very large memory order 1960 someone 68 Viterbi algorithms for maximum likely would decoding of convolutional code came and then on 74 BCG are algorithm was proposed.

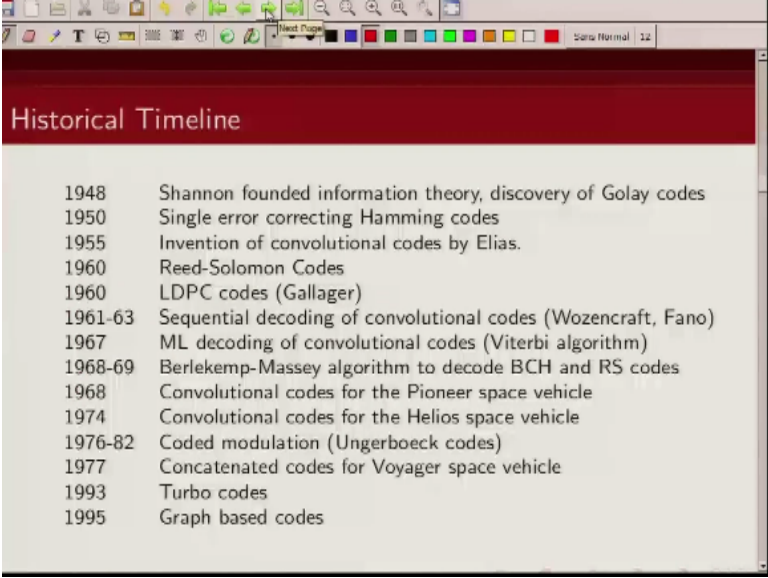
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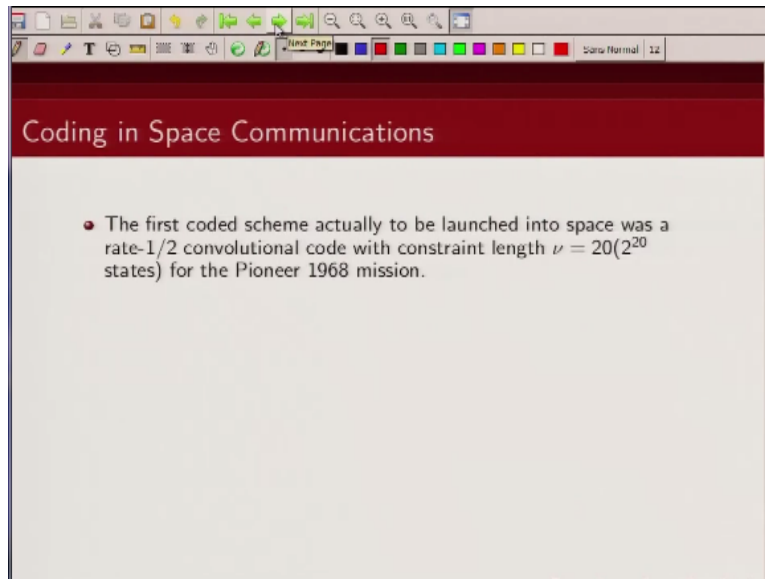
In late 60's and early 70's convolutional codes and concatenated codes found applications for deep space applications and around 1977 coding and modulation was combined together to design trellis coded modulation and they subsequently found lot of application in designing coding form modems and then finally around 1993 turbo codes were discovered and LDPC codes were rediscovered and then from late 90's onwards all deep 2000 and people started proposing these codes for various standards and they found applications and many communication standards so that is a brief outline of how things have evolved over 50, 60 years.

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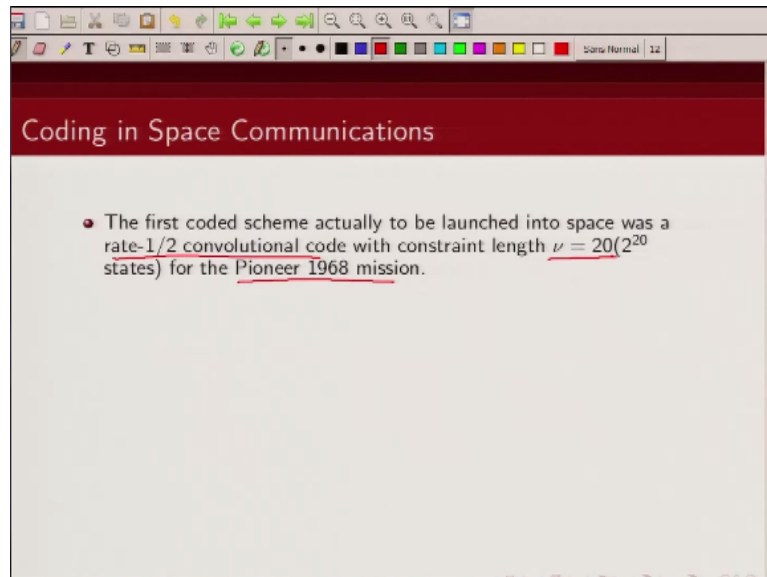
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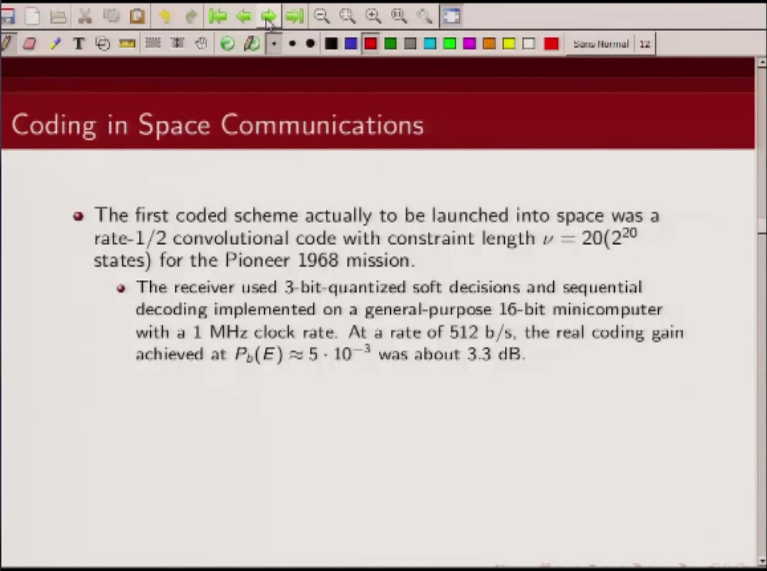
So let us start with applications of convolutional code

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Now pioneer mission was 1968 and they use a rate of convolutional code which as constrained length of 20 so there were 2 to out 20 states and they use sequential decoding

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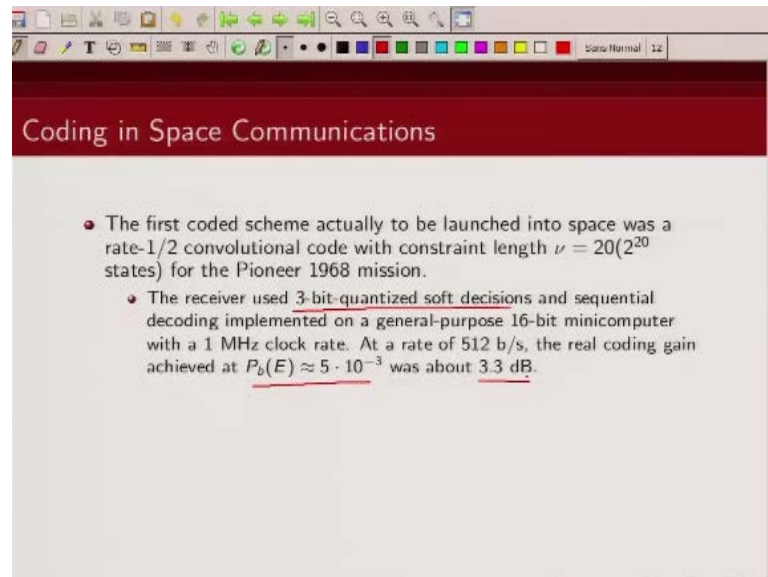


Coding in Space Communications

- The first coded scheme actually to be launched into space was a rate-1/2 convolutional code with constraint length $\nu = 20$ (2^{20} states) for the Pioneer 1968 mission.
 - The receiver used 3-bit-quantized soft decisions and sequential decoding implemented on a general-purpose 16-bit minicomputer with a 1 MHz clock rate. At a rate of 512 b/s, the real coding gain achieved at $P_b(E) \approx 5 \cdot 10^{-3}$ was about 3.3 dB.

To decode this code the receiver used a

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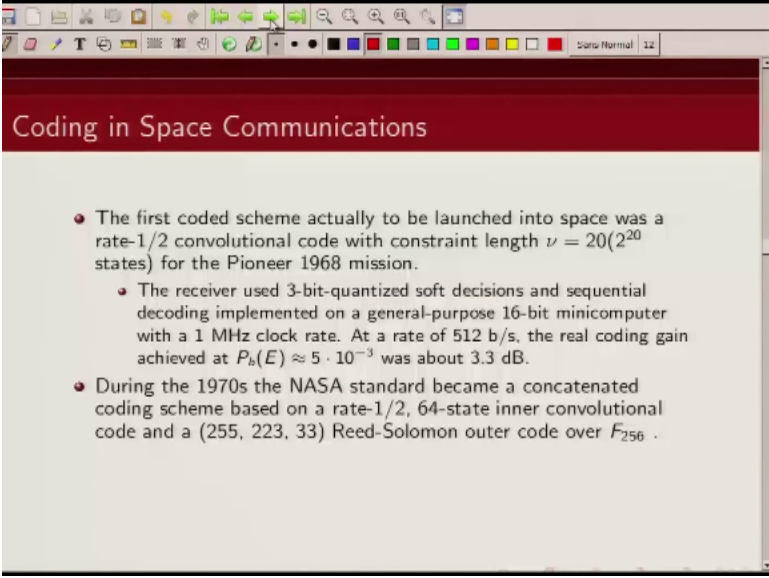


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3 bit quantized soft decision and it was implemented on 16 bit minicomputer it provided a coding again of roughly 3.3 so it got a like for a probability for around this it give a coding again for about 3.3 dB

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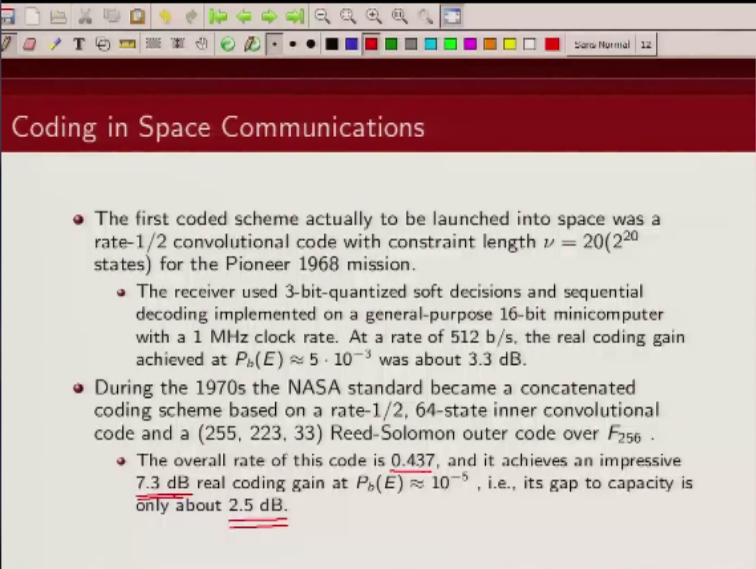


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- During the 1970s the NASA standard became a concatenated coding scheme based on a rate-1/2, 64-state inner convolutional code and a (255, 223, 33) Reed-Solomon outer code over F_{256} .

Next around 70's NASA started using this concatenated code outer code was a Reed Solomon code and inner code was 64 state convolutional code rate

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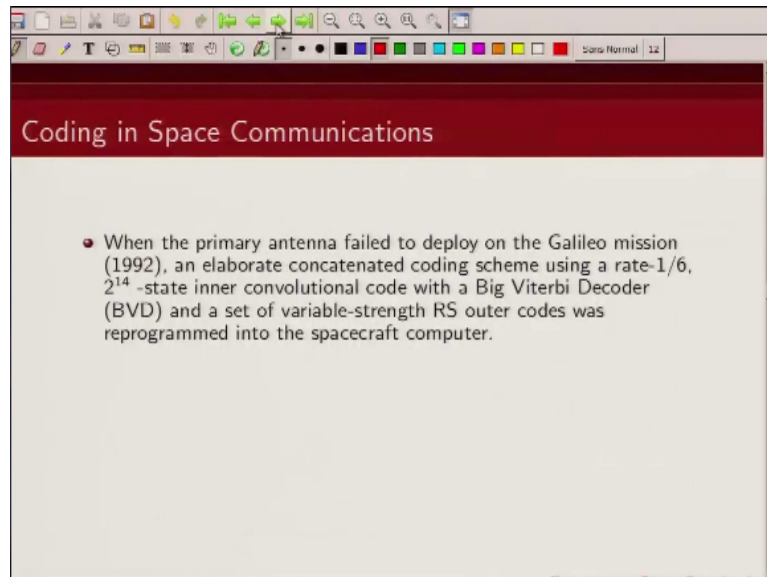


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 - The overall rate of this code is 0.437, and it achieves an impressive 7.3 dB real coding gain at $P_b(E) \approx 10^{-5}$, i.e., its gap to capacity is only about 2.5 dB.

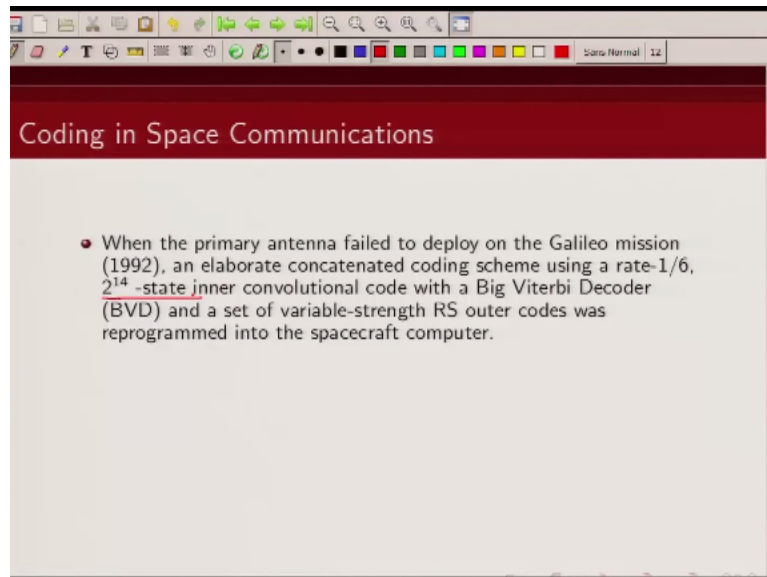
Half convolutional code and it found lot of applications the overall code rate of this was .43 and it a gab to capacity was only 2.5dB it provided coding again around 7.3 dB at bit a rate of 10^{-5}

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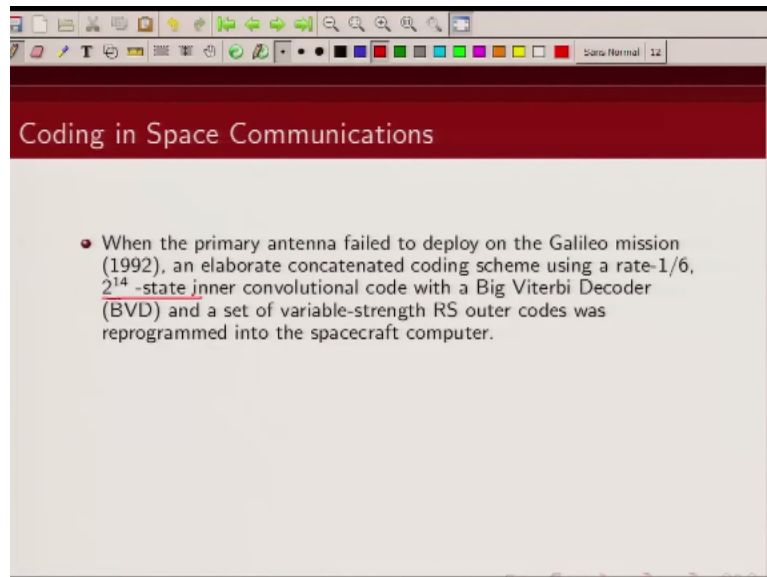
Another big development was when in Galileo's mission this antenna failed to deploy a primary antenna when it fail to deploy so there was an elaborate concatenated coded scheme which used a.

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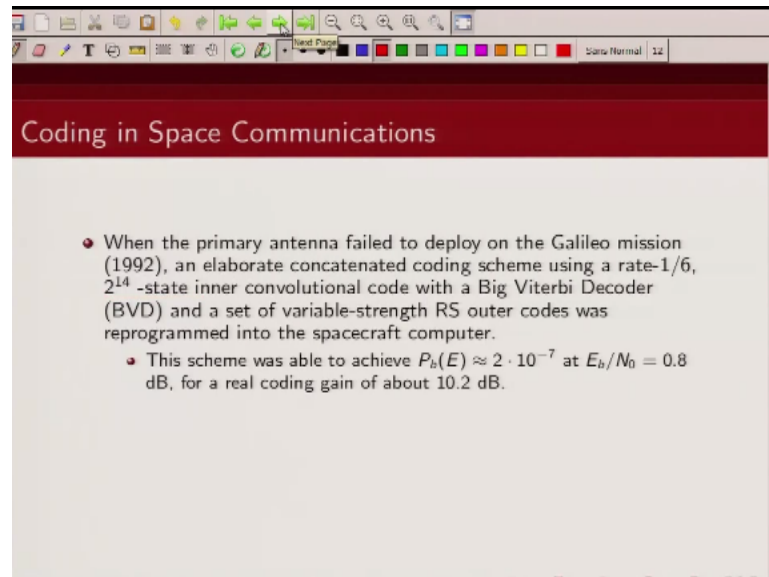
2^{14} state convolutional code assigned code and Reed Solomon code as outer code and a big viterbi decoding viterbi decoding algorithm was prospected which could work over such a large number of sates

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Very impressive step forward in terms of a coding a application is concern is because it was able to salvage this missions because of this very nice concatenated code used and it was successfully.

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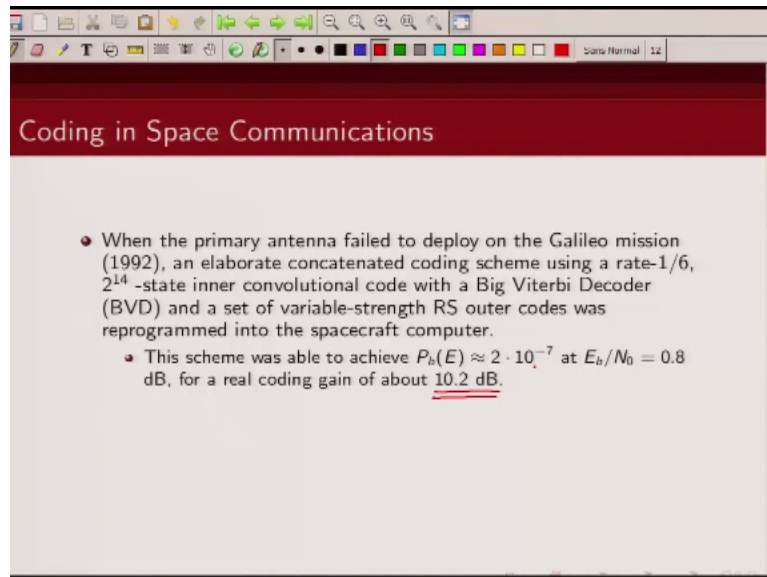


Coding in Space Communications

- When the primary antenna failed to deploy on the Galileo mission (1992), an elaborate concatenated coding scheme using a rate-1/6, 2^{14} -state inner convolutional code with a Big Viterbi Decoder (BVD) and a set of variable-strength RS outer codes was reprogrammed into the spacecraft computer.
 - This scheme was able to achieve $P_b(E) \approx 2 \cdot 10^{-7}$ at $E_b/N_0 = 0.8$ dB, for a real coding gain of about 10.2 dB.

Deployed it provide a coding gain of around

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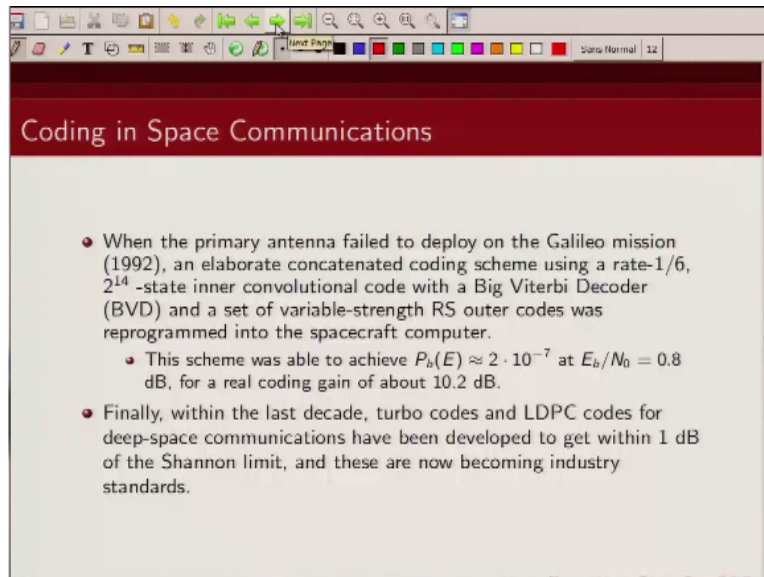


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10.2dB at and it was able to achieve bit a rate close to 10^{-7}

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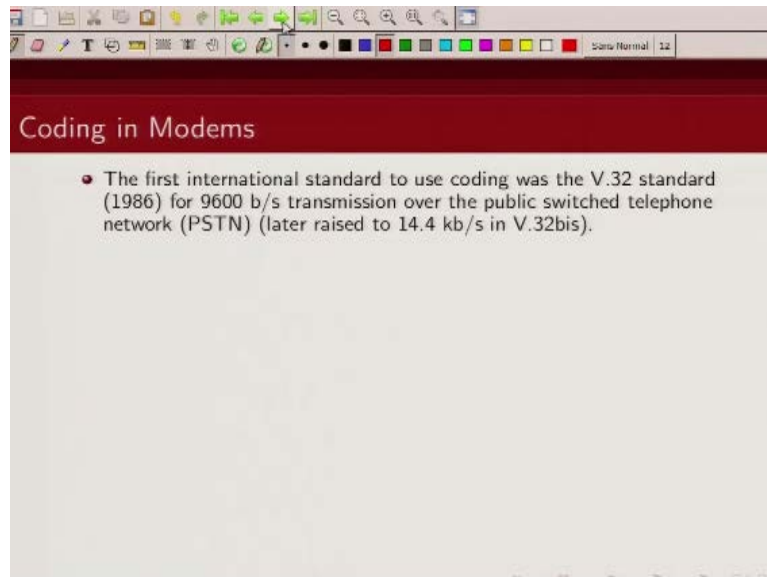


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 - This scheme was able to achieve $P_b(E) \approx 2 \cdot 10^{-7}$ at $E_b/N_0 = 0.8$ dB, for a real coding gain of about 10.2 dB.
- Finally, within the last decade, turbo codes and LDPC codes for deep-space communications have been developed to get within 1 dB of the Shannon limit, and these are now becoming industry standards.

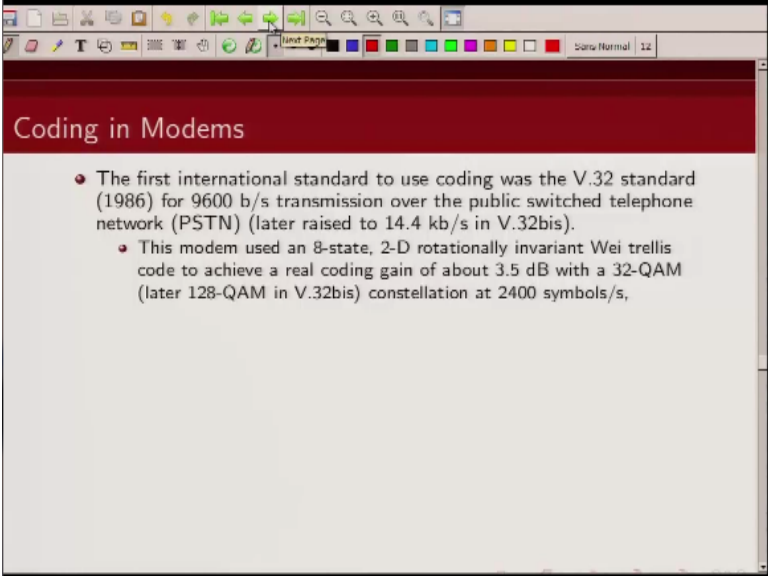
And finally as I said from early 2000 now this is error of turbo code and LDPC codes and they are finding applications from deep- space to mobile communication standards TV broadcasting and things like that.

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Now another area where error control coding and this convolutional code made a major impact was encoding for modems so around mid 70's hunger box came with how to combine coding and modulation and it came up with trellis coded modulation and these codes were heavily used in design a coding schemes for data transmission basically over public switch telephone network.

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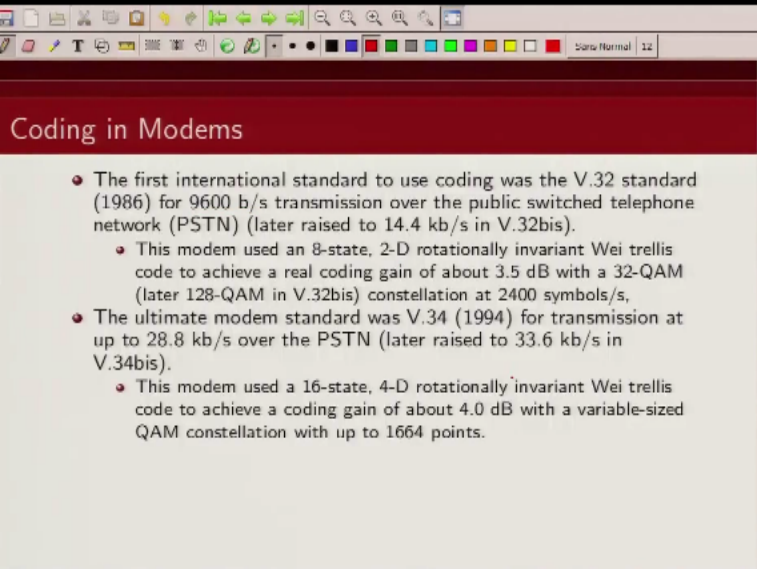


Coding in Modems

- The first international standard to use coding was the V.32 standard (1986) for 9600 b/s transmission over the public switched telephone network (PSTN) (later raised to 14.4 kb/s in V.32bis).
 - This modem used an 8-state, 2-D rotationally invariant Wei trellis code to achieve a real coding gain of about 3.5 dB with a 32-QAM (later 128-QAM in V.32bis) constellation at 2400 symbols/s,

So some of the applications have listed here so initially we had 9.6 kb/s transmission that uses a an eight state code then finally.

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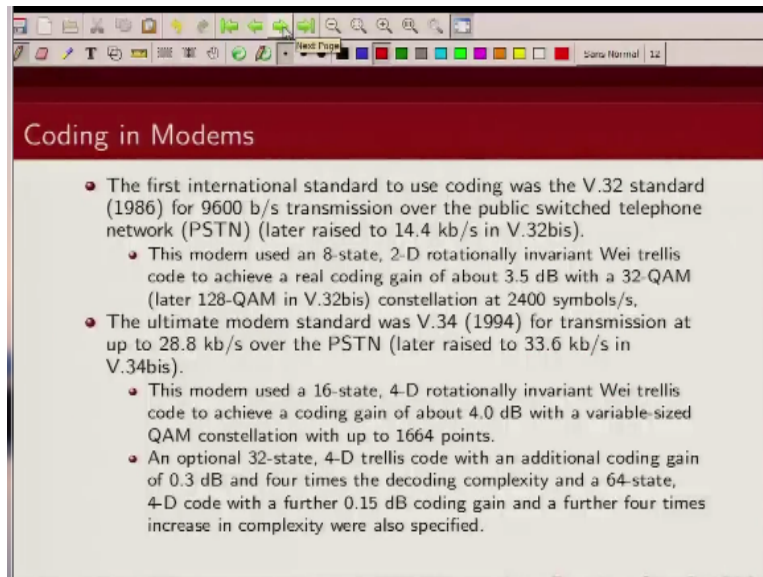


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- The ultimate modem standard was V.34 (1994) for transmission at up to 28.8 kb/s over the PSTN (later raised to 33.6 kb/s in V.34bis).
 - This modem used a 16-state, 4-D rotationally invariant Wei trellis code to achieve a coding gain of about 4.0 dB with a variable-sized QAM constellation with up to 1664 points.

For a 33 kb/s transmission they use a 16 state four dimensional trellis codes modulation scheme and.

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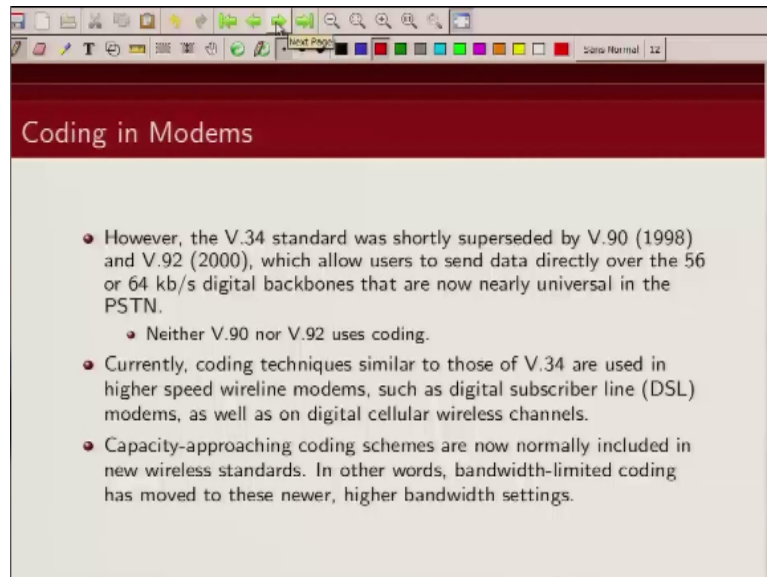


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 - This modem used a 16-state, 4-D rotationally invariant Wei trellis code to achieve a coding gain of about 4.0 dB with a variable-sized QAM constellation with up to 1664 points.
 - An optional 32-state, 4-D trellis code with an additional coding gain of 0.3 dB and four times the decoding complexity and a 64-state, 4-D code with a further 0.15 dB coding gain and a further four times increase in complexity were also specified.

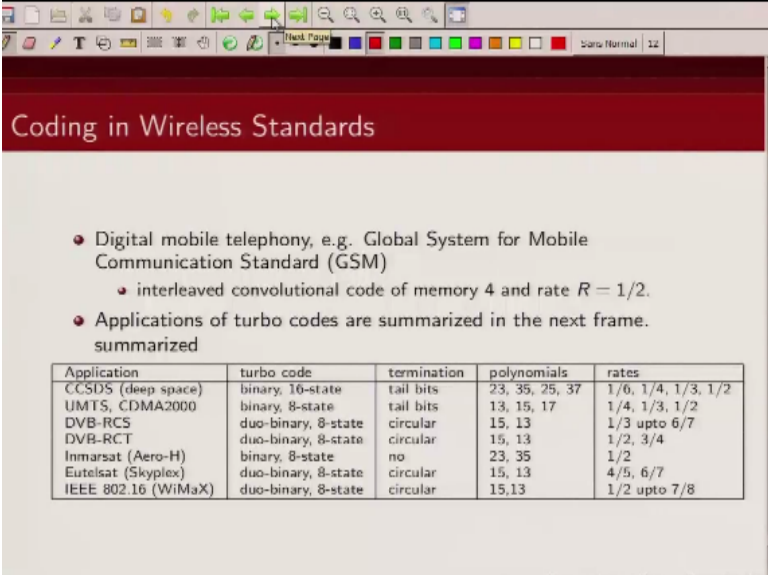
And there was an optional 32 state 4 dimensional trellis code which as all specified in this standard but when we progress to digital backbones then,, then basically there was no need for these codes and so the v 90 v92 standers says essentially do not use any of these coding techniques but in mid 80's and eerily 90's there was lot of they are very successfully these codes where applied for coding for modems.

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Now currently these techniques are also used for high speed wire line modems like ADSL and other applications and of course turbo codes and their variants also finding applications here.

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Coding in Wireless Standards

- Digital mobile telephony, e.g. Global System for Mobile Communication Standard (GSM)
 - interleaved convolutional code of memory 4 and rate $R = 1/2$.
- Applications of turbo codes are summarized in the next frame. summarized

Application	turbo code	termination	polynomials	rates
CCSDS (deep space)	binary, 16-state	tail bits	23, 35, 25, 37	1/6, 1/4, 1/3, 1/2
UMTS, CDMA2000	binary, 8-state	tail bits	13, 15, 17	1/4, 1/3, 1/2
DVB-RCS	duo-binary, 8-state	circular	15, 13	1/3 upto 6/7
DVB-RCT	duo-binary, 8-state	circular	15, 13	1/2, 3/4
Inmarsat (Aero-H)	binary, 8-state	no	23, 35	1/2
Eutelsat (Skyplex)	duo-binary, 8-state	circular	15, 13	4/5, 6/7
IEEE 802.16 (WiMaX)	duo-binary, 8-state	circular	15, 13	1/2 upto 7/8

So I like to conclude basically with a giving some examples of communications systems so our GSM use a convolutional code of

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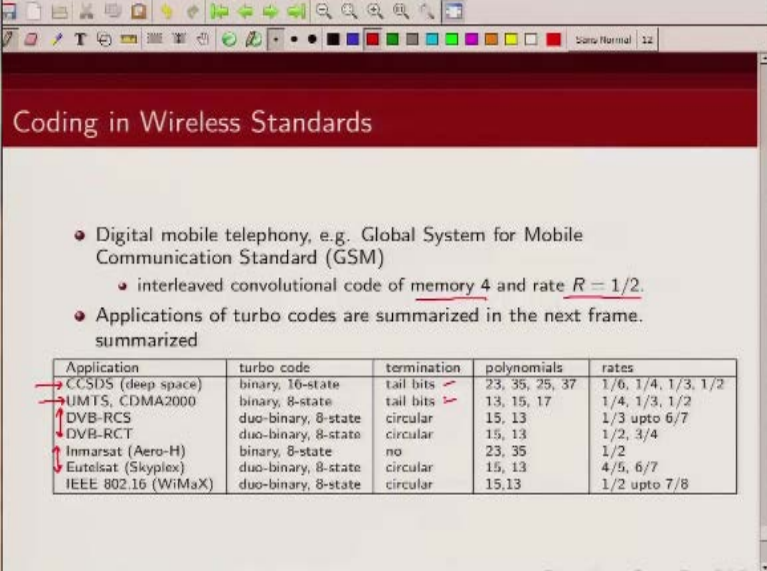
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Memory 4 and rate 1 of code and in the table I have a listed some of the applications of turbo codes in recent standards I mean source starting from digital video broadcasting standard to third generation wireless standard to deep space exploration to state-of-the-art communication applications and you can see there are this binary turbo code that we talked about this two binary turbo code essentially uses like rate k/n code which is greater than 1 and there are additional bit that have been added in some of the cases for termination of this encoder

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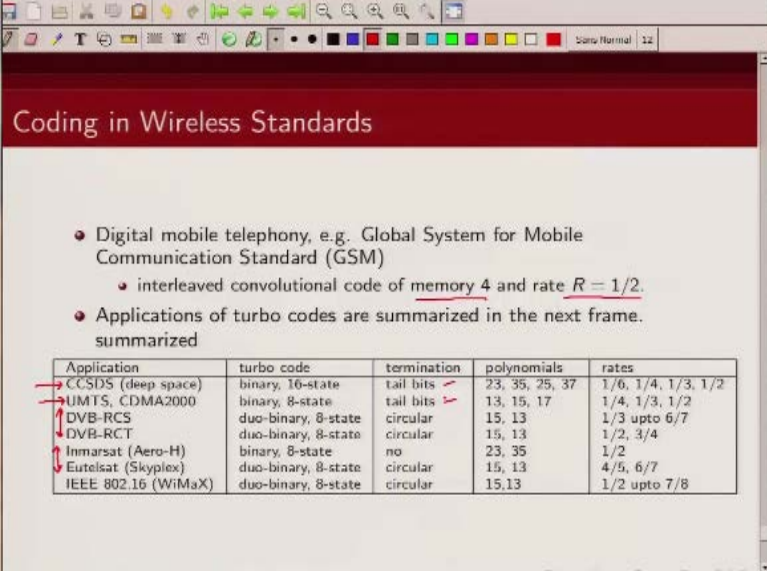
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And in some cases for where you see these curricular thing they have used a curricular recoveries encoders so these are what they called what is known as tale biting encoders o they are starting and ending state are same so the so this is like circulation trills so they do not need any termination bits and these.

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The screenshot shows a presentation slide with a red header bar containing the title "Coding in Wireless Standards". Below the header, there are two bullet points. The first bullet point discusses Digital mobile telephony, specifically GSM, and mentions an interleaved convolutional code with memory 4 and rate $R = 1/2$. The second bullet point states that applications of turbo codes are summarized in the next frame. Below the text is a table with five columns: Application, turbo code, termination, polynomials, and rates. The table lists various applications and their corresponding turbo code parameters. Red arrows point to the first four rows of the table.

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And these are the code generator polynomial in octal notation and some of the rates that have been used for these codes thank you.

Acknowledgement

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