Shannonian Lessons & the "Moean Reality"

- **Shannonian Lesson:** render the transmitted signal as noise-like as you can!
- But Dr. Shannon, what do you mean by noise-like?
- Well, as an aspiring researcher, just do your best & you'll know, when you are doing well!
- **Moean Reality:** spread the transmitted signal as broadly across the entire frequency band as you can to make it reminiscent of uncorrelated white Gaussian noise!
- But Dr. Shannon, where do I get the bandwidth from, Moe exclaimed?
- Moe was an astute scientist, he knew that the US government had a 100 Billion Dollar treasury income from the spectrum sales of the FCC...
- The 3G operating licences alone fetched 22.5 Billion Pounds in the UK alone for a 60 MHz chunk of the uplink spectrum, matched by 60 MHz DL bandwidth.
- In Germany the spectrum price was an even heftier 100 Billion DM, about a Million/Hz!
- So, Moe and his friends diligently embarked on a systematic exploration of the entire gamut of wireless enabling techniques in pursuit of reducing the cost per bit...

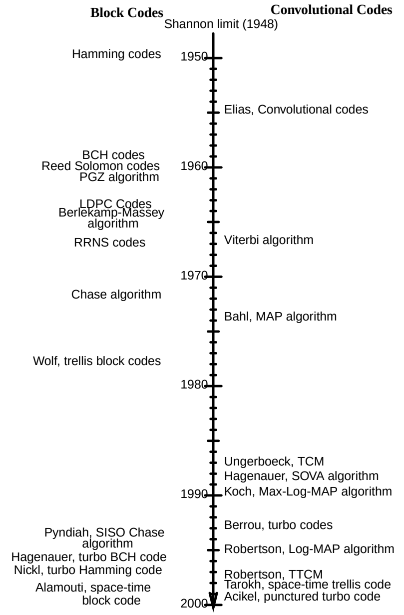

Figure 1: A glimpse of the post-Shannon pre-Moe Win era

"Moe Win Coronation Colloquium"

The Joint Source and Channnel Coding Saga:
and
Flawless UWB Multimedia Communications

'Layosh' Hanzo

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http://www-mobile.ecs.soton.ac.uk

Acknowledgements

- Andrea Conti, Moe Win and all other hosts and contributors.
- The team back at base.
- The sponsors.

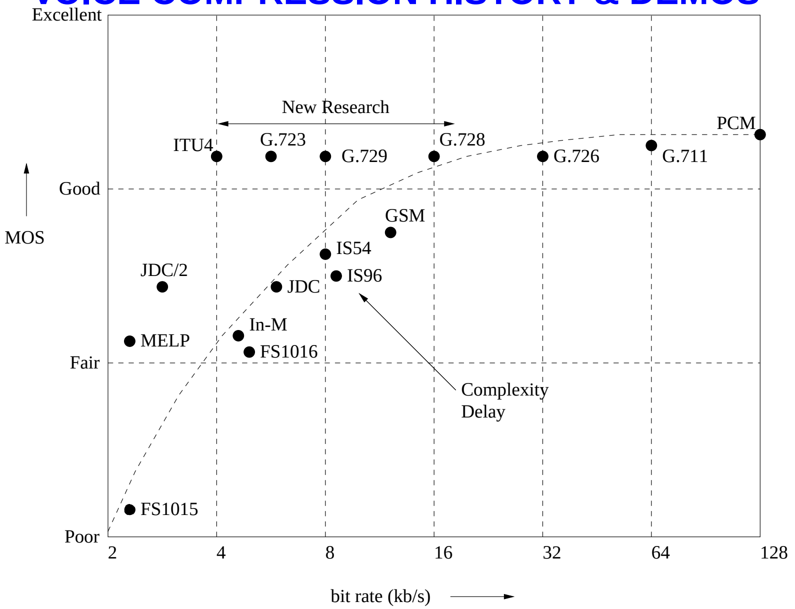
VIDEO COMMUNICATIONS HISTORY - PRE-MOE WIN

- ❏ 1980 Block-processing based video communications
- ❏ 1982 DCT-based video compression
- ❏ 1984 VQ-based video compression
- ❏ 1986 Hybrid MC-DPCM / DCT coding and zig-zag scanning
- ❏ 1992 Scaleable coding using multiple quantisers
- ❏ 1993 Content-based interactivity concept and model-based coding
- ❏ 1994 Fixed-point DCT
- ❏ 1995 MV prediction
- ❏ 1998 1/8-pixel MC

VIDEO COMMUNICATIONS HISTORY - STANDARDS

- ❏ 1984 CCITT H.120
- ❏ 1986 JPEG codec
- ❏ 1988 MPEG1 research commenced
- ❏ 1989 H.261 first draft
- ❏ 1990 MPEG2 research commenced
- ❏ 1992 MPEG1 completed
- ❏ 1993 MPEG4 concept conceived
- ❏ 1994 H.263 research commenced
- ❏ 1996 H.263 completed
- ❏ 1998 MPEG approved
- ❏ 2003 H.26L renamed as H.264

VOICE COMPRESSION HISTORY & DEMOS



Demos

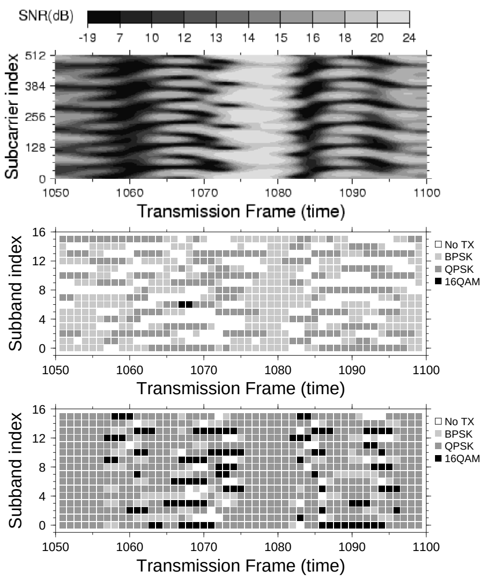


Figure 4: Modem mode allocation in a multi-carrier modem.

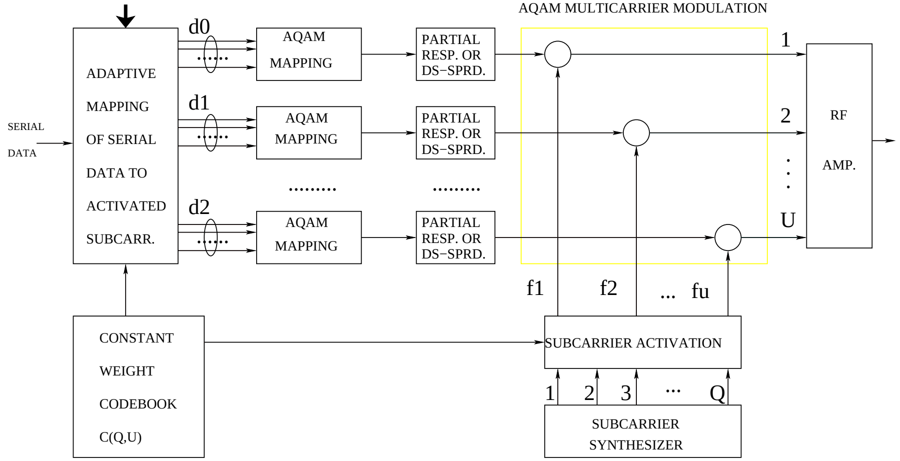


Figure 5: **Transmitter schematic of adaptive frequency-hopping aided MC DS-CDMA;**
L. Hanzo, Yang, Kuan and Yen: Single- and Multicarrier DS-CDMA, Wiley & IEEE Press, 2003

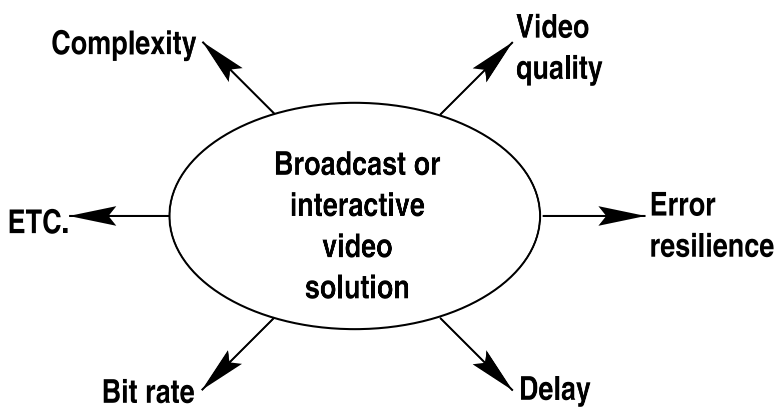


Figure 2: Contradictory system design requirements of various video communications systems;
L.Hanzo, P.J. Cherriman and J.Streit, *Video Compresssion & Communications, IEEE Press & John Wiley, 2007*

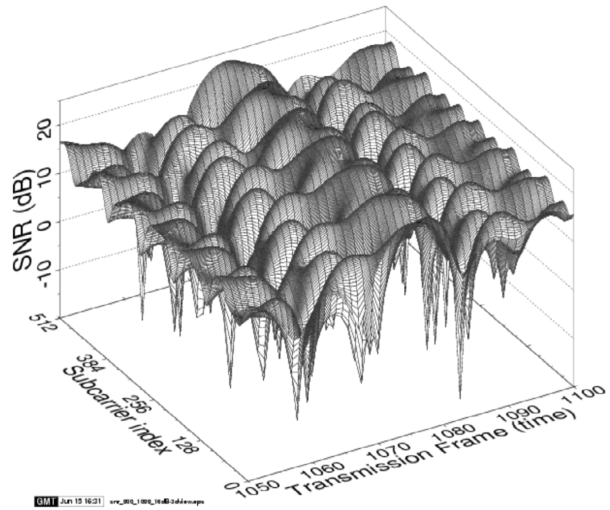
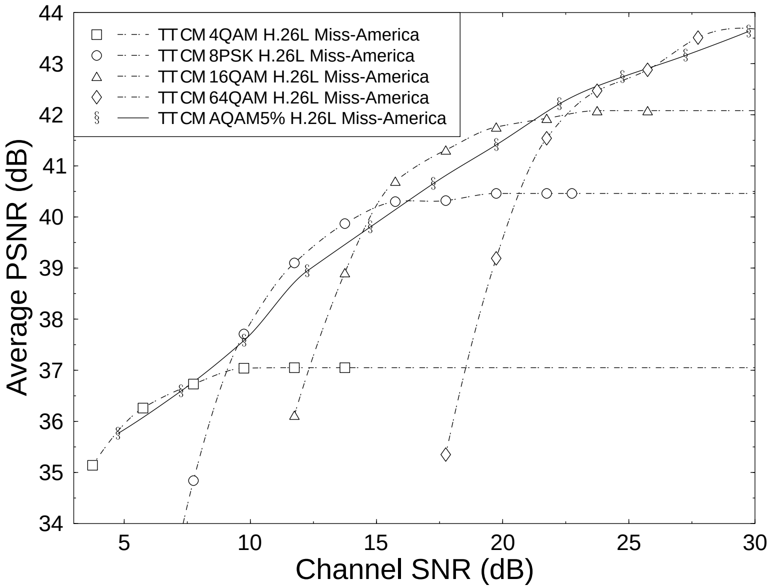


Figure 3: Instantaneous Channel SNR for all 512 subcarriers versus time, for an average channel SNR of 16dB; **L.Hanzo, C.H.Wong and M.S.Yee, *Adaptive Wireless Transceivers*. Chichester, UK: John Wiley and IEEE Press., 2002.**

PSNR vs. Channel SNR of HSDPA-Style 'Pre-Moean' Transceivers



DESIGN OF HSDPA-STYLE BBB-ADAPTIVE TRANSCEIVERS

❏ The most hostile impairment adaptive transceivers have to counteract is not necessarily the channel-induced fluctuation, but the co-channel interference& shadow-fading

❏ Conventional transceivers aggressively increase their transmit power in an effort to maintain their required target integrity, which may disadvantage other users, who in turn also have to increase their power.

❏ By contrast, adaptive transceivers are benevolent, accommodating the channel quality fluctuations by adjusting their own throughput without disadvantaging other mobile users.

❏ In conclusion, it is unrealistic to expect that fixed-mode transceivers maintain a constant QoS...

A Channel-Quality Motivated Perspective on Adaptivity

L.Hanzo et. al, *Single and Multicarrier DS-CDMA*. Chichester, UK: John Wiley and IEEE Press, 2003.

- Multiple Spreading Codes
- Variable Spreading Factors
- Variable Rate FEC Codes
- Different FEC Schemes: CC, BCH, TC, TBCH, TCM, TTCM, BICM, BICM-ID
- Turbo Channel Equaliser
- Variable Constellation Size: 1-6bit/symb
- Multiple Time Slots
- Multiple Bands
- Multiple Transmit Antennas

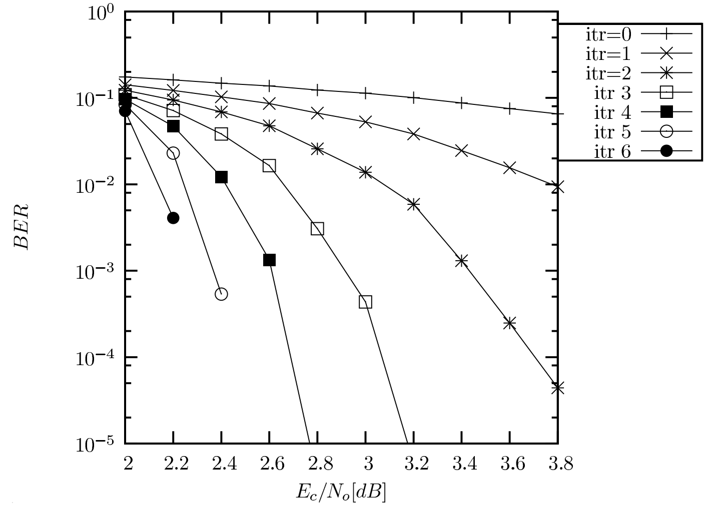
VIDEO OVERVIEW

Features	Multi-rate System			
Mode	4QAM	8PSK	16QAM	64QAM
Transmission Symbols	240			
Bits/Symbol	2	3	4	6
Transmission bits	480	720	960	1440
Packet Rate	100/s			
Transmission bitrate (kbit/s)	48	72	96	144
Data Symbols	234			
Coding Rate	1/2	2/3	3/4	5/6
Information Bits/Symbol	1	2	3	5
Unprotected bits	240	480	720	1200
Unprotected bitrate (kbit/s)	24.0	48.0	72.0	120.0
Video packet CRC (bits)	16			
Feedback protection (bits)	9			
Video packet header (bits)	11	12	12	13
Video bits/packet	204	443	683	1162
Effective Video-rate (kbit/s)	20.4	44.3	68.3	116.2
Video framerate (Hz)	30			

Shannonian Lessons & the "Moean Reality"

- The ride's been exhilerating across the generations of wireless systems, leading to GSM, 3G, 3.5G, HSDPA/HSUPA, WiFi, WiMax, LTE, etc.
- But following decades of innovation by an entire community, Moe was beginning to realise that the Shannonian dream was impractical in the current cut-throat commercial climate...
- Just think of the generous gesture, how the Internet Protocol throws away 320-Byte header information...
- A 1GHz UWB spectrum would cost Terra-Bucks...
- He was on the brink of exasparation...
- Then Moe had the Terra-Dollar dream to overlay the low-density UWB spectrum with all existing spectral bands without substantially interfering with them!
- To realize this dream fi rst required spending more Bucks on lawyers than on scientists and engineers, but...
- Finally, Shannon's lessons became realizable, paving the way for flawless tele-presence!

Time-Hopping UWB Transmission Over a 15-Path Channel



MIMO-BASED DESIGN ALTERNATIVE

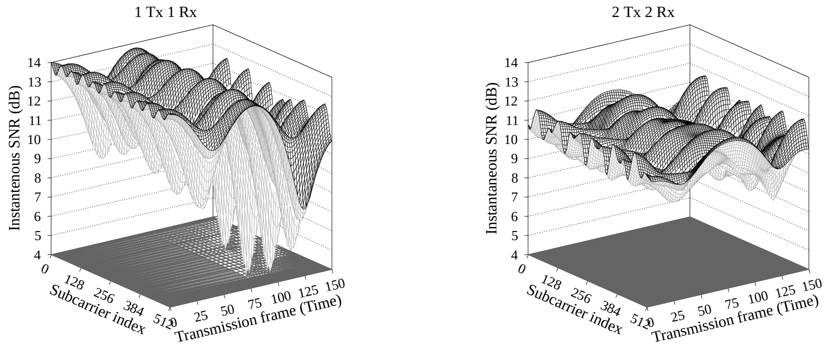


Figure 6: Instantaneous channel SNR of 512-subcarrier OFDM symbols for the one-transmitter, one-receiver (1Tx 1Rx) and for the space-time block coded two-transmitter, one-receiver (2Tx 1Rx) scenarios for transmission over the COST207 TU channel at an average SNR of 10 dB.

MIMO-DESIGN DEMO

Irregular Variable Length Coding for Near-Capacity Joint Source and Channel Coding

R. G. Maunder, J. Wang, S. X. Ng, L.-L. Yang and L. Hanzo

Communications Research Group

School of Electronics and Computer Science,

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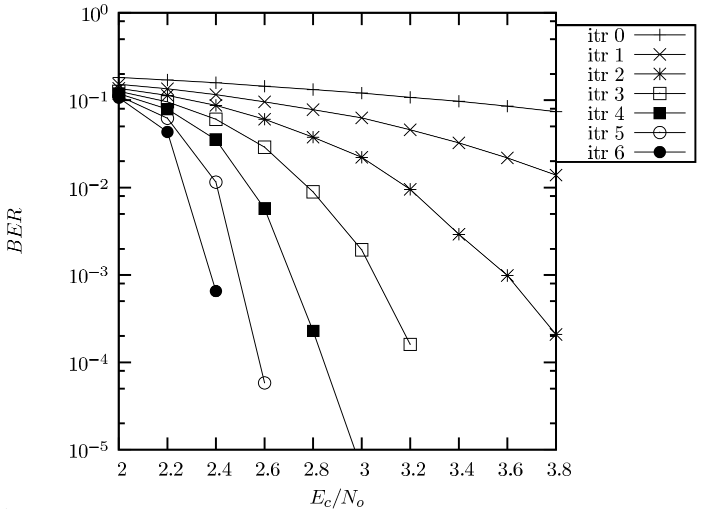
http://www-mobile.ecs.soton.ac.uk

VLC Design Issues

L. Hanzo, P. J. Cherriman, and J. Streit, *Video Compressions & Communications, 2nd Edition*. Piscataway, NJ: IEEE Press & John Wiley, UK, 2007

- ❏ Serially concatenated regular and irregular VLC codes: a novel design paradigm;
- ❏ EXIT chart matching theorem: *The area in the open EXIT tunnel is proportional to the distance from capacity;*
- ❏ EXIT chart matching theorem: *The area under the outer code's EXIT curve is given by the code-rate;*
- ❏ BER and complexity performance results;
- ❏ Summary & Conclusions

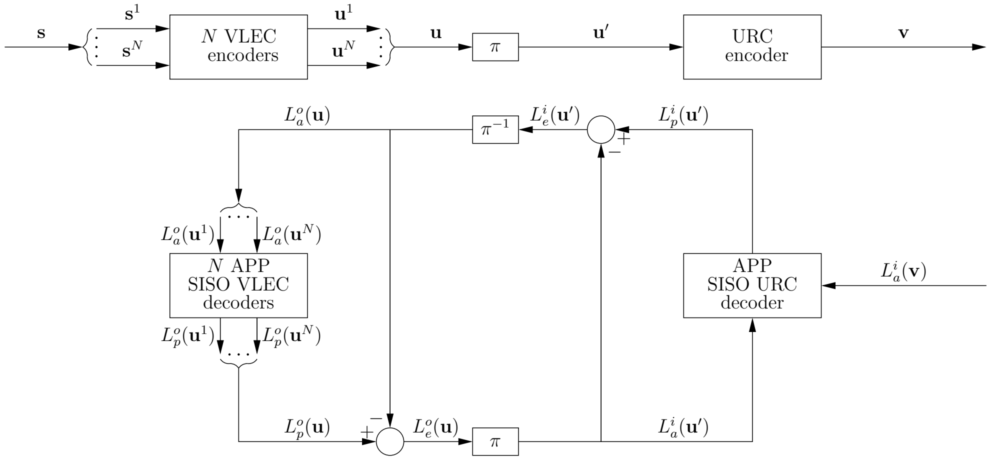
DS-CDMA UWB Transmission Over a 15-Path Channel



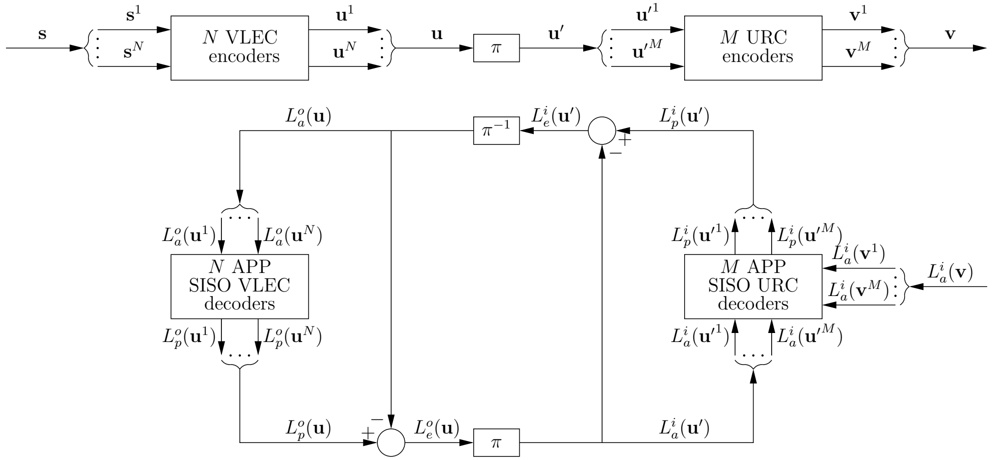
Other Shannonian lessons, where Moe could use a little help from his friends...

- **Ideal lossless entropy encoders and Huffman source codecs** may have a high codeword length and associated delay;
- Since the message becomes undecodable in the presence of transmission errors, regardless of the index or positions of the corrupted bits, all source-encoded bits have an equally high error sensitivity;
- **By contrast, practical lossy source codecs** exploit the psycho-acoustic and psycho-visual masking properties of the human ear and eye and hence achieve signifi cantly *higher compression ratios*;
- Nonetheless, they often still *exhibit residual redundancy*, which manifests itself in terms of a correlated source-encoded message that has *unequal bit sensitivity*;
- This *unequal bit sensitivity* justifi es the employment of unequal-protection joint source and channel coding, *exchanging extrinsic information across the entire turbo-transceiver;*
- Finally, Shannon's lessons were derived for memoryless AWGN channels.

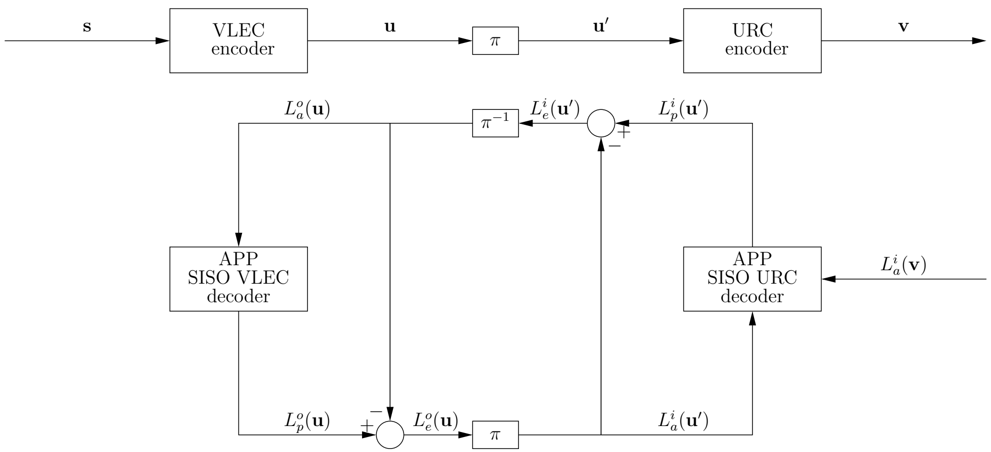
Serially concatenated irregular and regular codes



Serially concatenated irregular codes



Serially concatenated regular codes



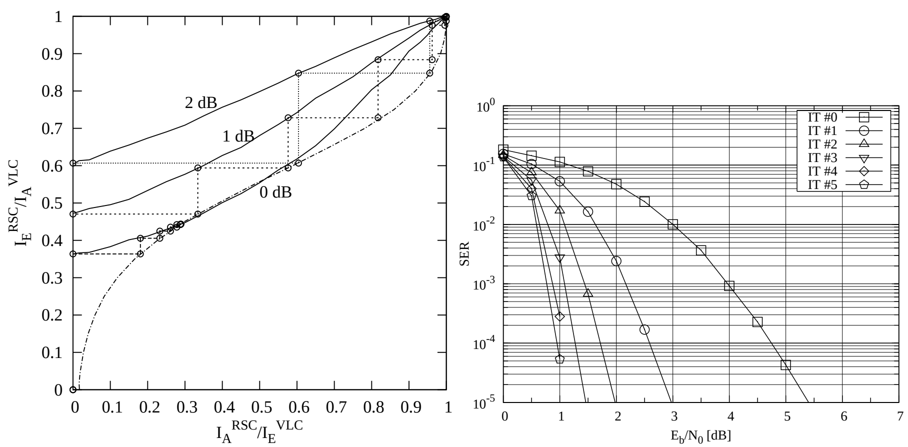


Figure 7: EXIT-Chart and SER performance of the iterative receiver using a **VLEC code** as the outer code and the RSC(2,1,2) code as the inner code for transmission over AWGN channels.

EXIT chart matching

IrVLC EXIT curve...

$$I_a^o(I_e^o) = \sum_{n=1}^{N} \alpha^n I_a^{o,n}(I_e^o),$$

where

$$\sum_{n=1}^{N} \alpha^n = 1,$$
$$\alpha^n \geq 0 \ \forall \ n \in [1 \ldots N],$$
$$R_{\text{outer}} = \sum_{n=1}^{N} \alpha^n R^n_{\text{outer}}.$$

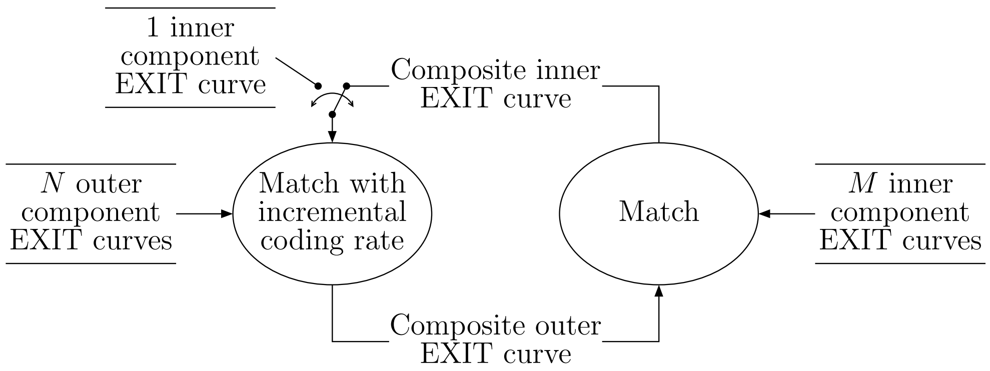
IrURC EXIT curve...

$$I_a^i(I_e^i) = \sum_{m=1}^{M} \alpha^m I_a^{i,m}(I_e^i),$$

where

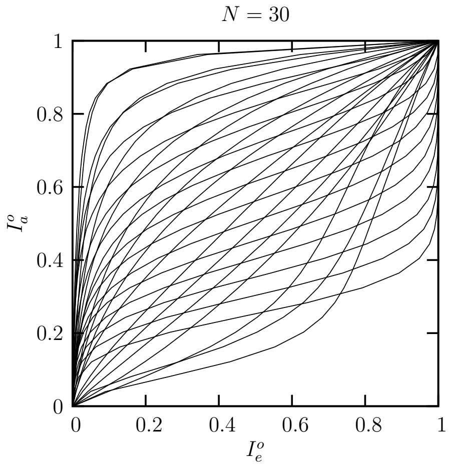
$$\sum_{m=1}^{M} \alpha^m = 1,$$
$$\alpha^m \geq 0 \ \forall \ m \in [1 \ldots M],$$
$$R_{\text{inner}} = 1.$$

Joint EXIT chart matching algorithm

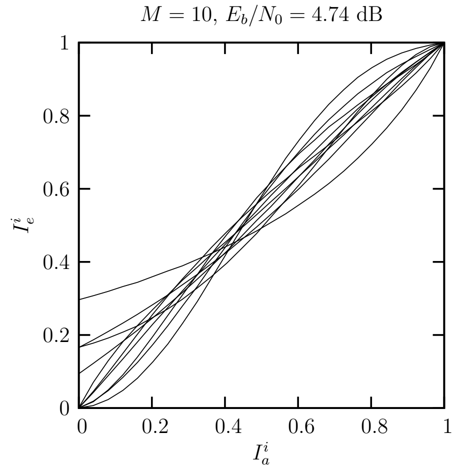


GA for designing component VLEC codebooks

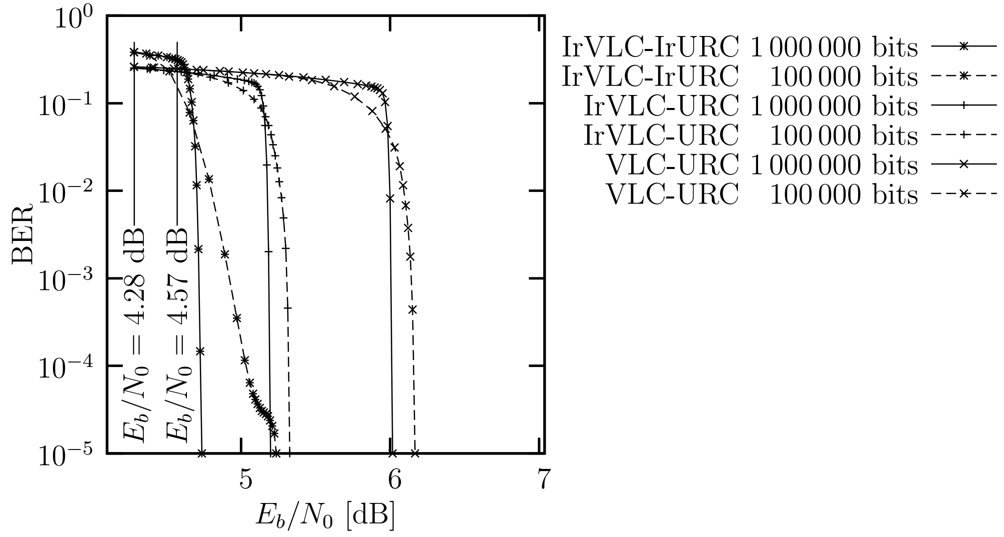
- ❏ Arbitrary EXIT curve
- ❏ Near-unity VLEC-encoded bit entropy
- ❏ Low decoding complexity



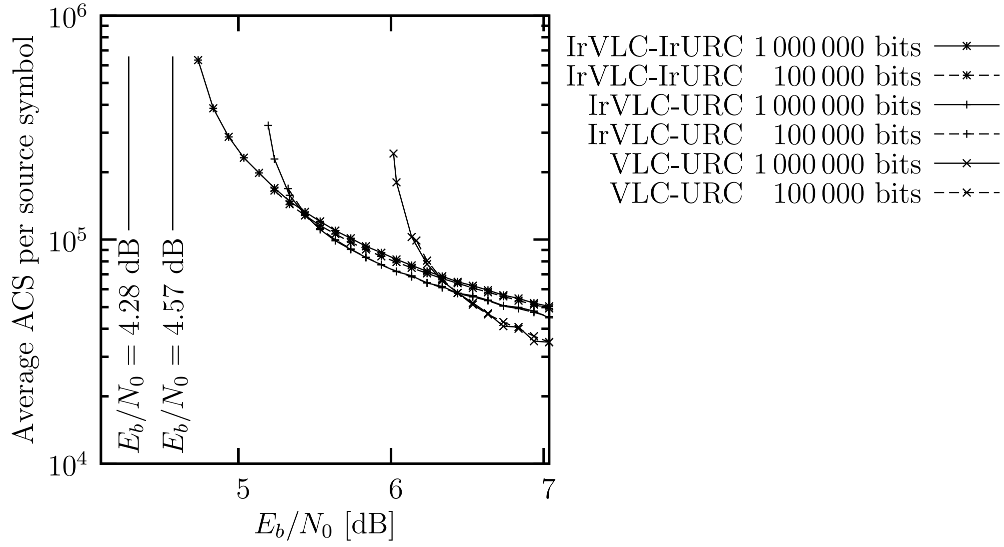
Full search for selecting component URC codes



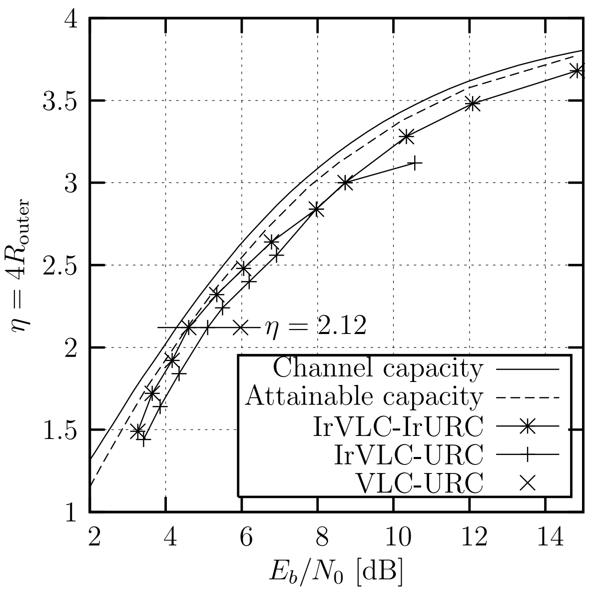
BER performance



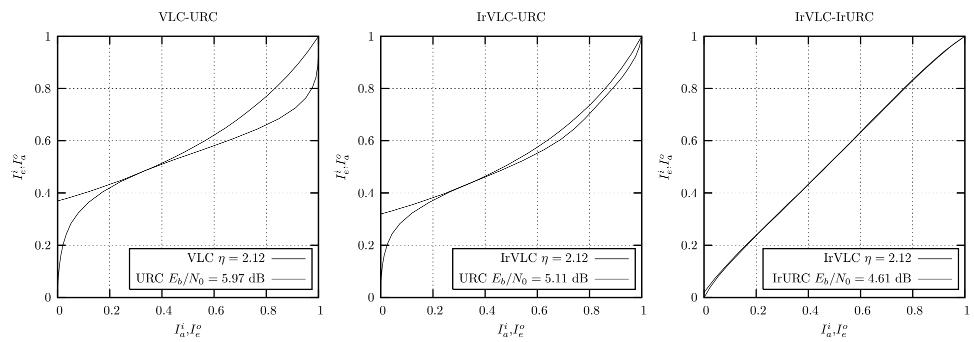
Decoding complexity



EXIT chart matching accuracy



EXIT charts



No doubt, Moe will be back...

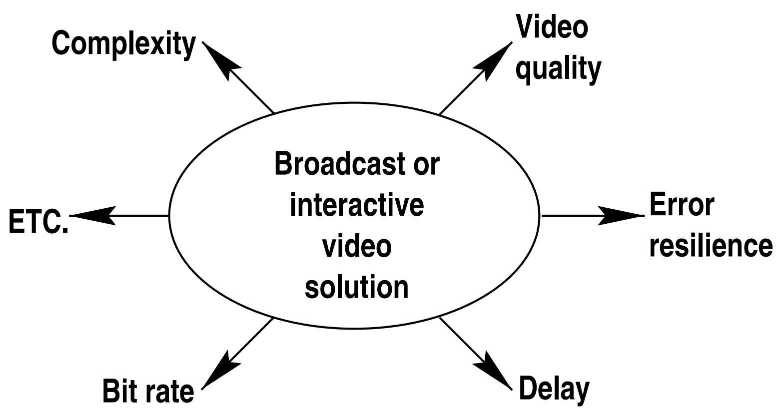


Figure 8: Contradictory system design requirements of various video communications systems;

L.Hanzo, P.J. Cherriman and J.Streit, *Video Compresssion & Communications, IEEE Press & John Wiley, 2007*

Demos...