(J.P.M.) Piet Schalkwijk 80th birthday

presentation: Han Vinck

Historical notes
Results

ENIGE GESCHIEDENIS

In 1949 kwam ook de benoeming van ir. Van Soest tot buitengewoon hoogleraar, die zich ging bezighouden met ruisverschijnselen maar vooral – en heet van de naald – met de informatie- en communicatietheorie.

1959 Afstuderen bij Prof. Ir. M.P. Breedveld (Delft)

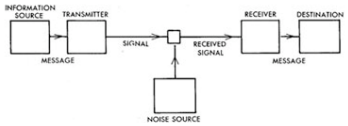
Omstreeks de 1 december viering van 1955 werd door Prof. van Soest een speciaal werkgroepje gevormd dat als taak kreeg nieuwe onderzoekgebieden te exploreren (tegenwoordig noemen wij dit achtergrondresearch). Van Soest's vakgebied was de communicatie- en informatietheorie en zijn suggesties kwamen dan ook uit die richting. Eén van de door hem genoemde aspecten was het vinden van een oplossing voor een optimaal communicatiekanaal. Gezocht moest worden naar een minimax oplossing, waarbij zender en ontvanger - als spelers - de maximale capaciteit, en de natuur (ruis) - als tegenspeler - de minimale capaciteit van het kanaal nastreefden. Als basis hiervoor moest de theorie van de strategische spelen bestudeerd worden. Aangezien ieder vrij was om naar eigen goeddunken in de aangewezen richting

1959-1961 Hengelo, 1st lieutenant Netherlands armed forces,

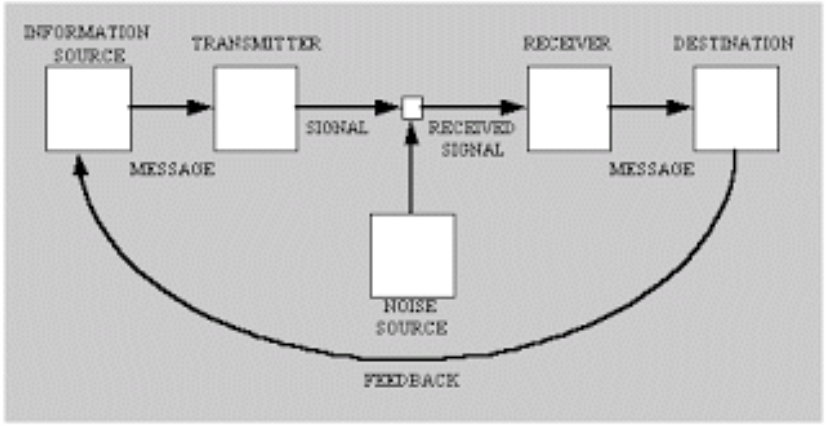
1961-1963 RVO-TNO
(Rijks verdedigings organisatie)

Ook Y. Boxma (TUD) en E. Gröneveld (TUT)

Elektromechanisch vuurleidingtoestel ("rekenaar")
Fabrikaat N.V. Hollandse Signaalapparaten, 1952-1960



Shannon and feedback



But what about:

- Channels with memory
- Multi user channels like MAC?

One of the most surprising results in information theory was proven by Claude Shannon in 1956 [1]: instantaneous and noiseless feedback of the output of a discrete memoryless channel does not increase capacity. This

[1] C.E. Shannon, "The zero error capacity of a noisy channel," *IRE Trans. Inform. Theory*, vol. IT-2, pp. 8–19, September 1956.

PhD Stanford, 1965 (supervisor T. Kailath)

Coding Schemes for Additive Noise Channels with Feedback

J. P. M. Schalkwijk

Department of Electrical Engineering, Stanford University., 1965 - 49 pagina's

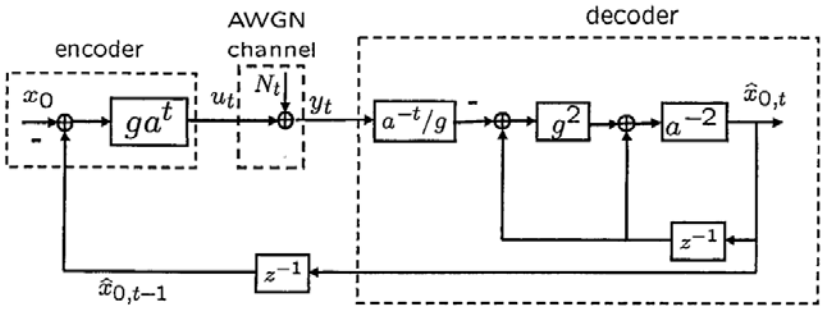


Figure 3.5 The SK coding scheme.

lecture te mogen geven en het eerste Shannon-lecture in 1973 in Ashkelon werd door Shannon zelf gegeven. Zijn onderwerp was *feedback*, volgens Shannon een van de belangrijkste en minst begrepen aspecten van de netwerk informatietheorie!

At Kailath's 80th birthday

Kailath's first Ph.D student, Piet Schalkwijk from Holland, is said to have complained that he was made to rewrite his thesis 6 times!

In response Kailath says: "That's an exaggeration. After all he graduated in two years after his Master's degree. Almost all my students graduated within 3-4 years from their Master's degrees."

5

IEEE Information theory society best paper award

IEEE TRANSACTIONS ON INFORMATION THEORY VOL. IT-12, NO. 2 APRIL 1966

A Coding Scheme for Additive Noise Channels with Feedback—Part I: No Bandwidth Constraint

J. P. M. SCHALKWIJK, MEMBER, IEEE AND T. KAILATH, MEMBER, IEEE

The purpose of the Information Theory Paper Award is to recognize exceptional publications in the field and to stimulate interest in and encourage contributions to fields of interest of the Society.

AMERIKA

Senior scientist, Boston, 1965-1968..

J. P. M. Schalkwijk is with the Applied Research Laboratory, Sylvania Electronic Systems, a division of Sylvania Electric Products Inc., Waltham, Mass.

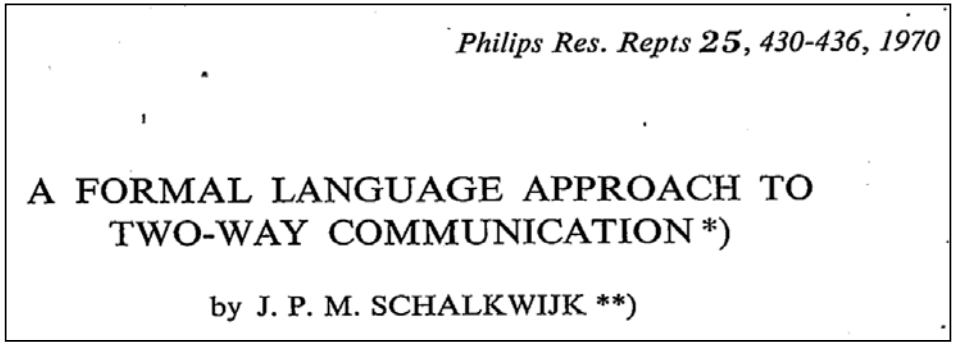
SYLVANIA
SUBSIDIARY OF GENERAL TELEPHONE & ELECTRONICS GT&E

Married Susan Alicia Farranto, September 17, 1966.
Children; Karin, Jan, Lucy, Susanna

Assistant professor University California, San Diego, 1968-1972

TOP ROW (L-R): R. Moore, J. Schalkwijk, G. Lewak, I. Jacobs, H. Chivers, S. Duntley, J. Doupnik; CENTER ROW: G. Arrhenius, H-L Luo, A. Lohmann, I. Axford, V. Rumsey, T. Yeh; BOTTOM ROW: C. Helstrom, E. Masry, P. Banks, H. Booker, M. Rotenberg, J. Fejer

De voorbereiding voor een terugkeer? 1970!



Philips Res. Repts **25**, *430-436, 1970*

A FORMAL LANGUAGE APPROACH TO TWO-WAY COMMUNICATION *)

by J. P. M. SCHALKWIJK **)

His research was carried out during a three-months stay at the Philips Research Laboratories at Eindhoven, The Netherlands.

1970 IEEE International *Symposium* on *Information Theory* held in *Noordwijk*, The Netherlands
Louis Stumpers (Philips Research) and co-chairman Paul Green

DE SHANNON THEORIE

REDE

UITGESPROKEN BIJ DE AANVAARDING
VAN HET AMBT VAN GEWOON HOOGLERAAR
IN DE TELECOMMUNICATIE AAN DE
AFDELING DER ELEKTROTECHNIEK
VAN DE TECHNISCHE HOGESCHOOL EINDHOVEN
OP VRIJDAG 8 NOVEMBER 1974

DOOR

J. P. M. SCHALKWIJK

Zijn benoeming tot gewoon hoogleraar in de telecommunicatie geschiedde bij Koninklijk besluit nr. 25 van 30 maart 1972.

Enkele oud-medewerkers in de groep Informatie en Communicatie theorie

Jan Rooijackers +, Han Vinck, Tjalling Tjalkens en Karel Post +, 1980

Joop de Brouwer, Han Vinck, Frans Willems en Jan Rooijackers +

Harry Creemers +

Tine Bijl

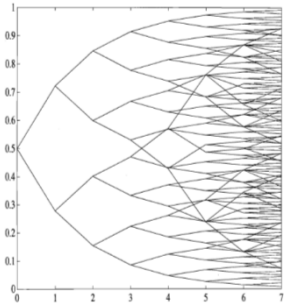
Leo Rust

Andre de Paepe

PhD students:

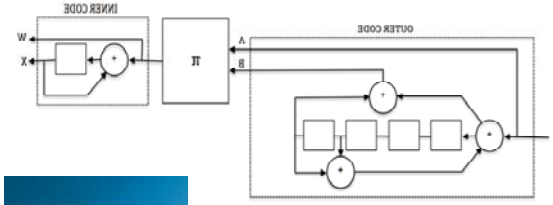
FEEDBACK CODING

- Jim Tiernan 1972, Autoregressive Gaussian channels with noiseless feedback, 1972
- Donald Wesley Becker, 1973, Multiple-repetition feedback coding
- Thijs Veugen, 1997, Multiple-repetition coding for channels with feedback
- Shoae Bargh, 1999, coding strategies for channels with feedback



CONVOLUTIONAL CODES

- A.J. Han Vinck, 1980, syndrome decoding for convolutional codes

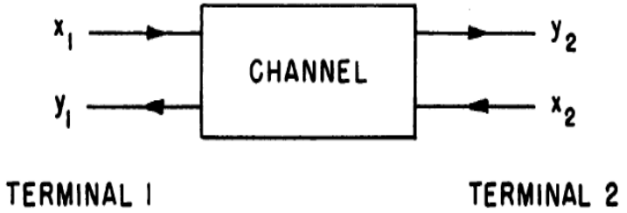


INDUSTRY

- Kees Schouhamer Immink, 1985, Properties and Constructions of Binary Channel Codes
- Jan Bergmans, 1987, Partial response techniques and robustness in data equalization

TWO-WAY CHANNEL

- Ineke van Overveld, 1991, On the capacity region for deterministic two-way channels and write-unidirectional memories
- Andries Hekstra, 1994, Capacity and Coding in Digital Communications
- Phons Bloemen, 1996, Discrete Coding Strategies for Two-Way Communication
- Erik Meeuwissen, 1998, Information theoretical aspects of two-way communication



SOURCE CODING

- Tjalling Tjalkens, 1987, Efficient and Fast Data Compression Codes for Discrete Sources with Memory
- P.A.J. Volf, 2002, Weighting Techniques in Data Compression: Theory and Algorithms (co)

University professors:

Jan Bergmans (Ehv), Han Vinck(DU-E), Frans Willems(Ehv), Ben Smeets(Lund), Lou Feijs(Ehv), Peter de With(Ehv)

Han Vinck, Peter de With,
Ben Smeets en Piet

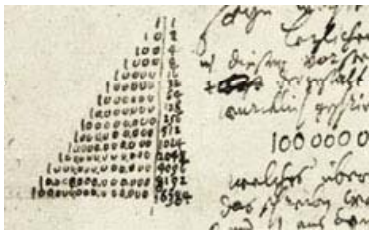
IEEE Fellows: Kees Immink, Han Vinck, Frans Willems, Peter de With

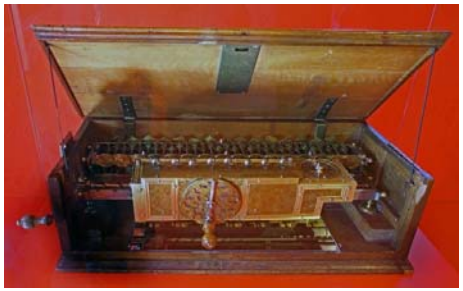
Scientific (PhD) Genealogy of Piet Schalkwijk (coincidence?)

http://genealogy.math.ndsu.nodak.edu/

Friedrich Leibniz (1622, Leipzig)

Binary mathematics

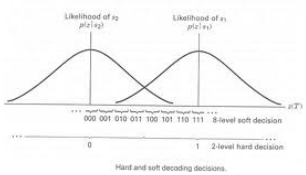




binäre Rechenmaschine – - Original, um 1690

Carl Friedrich Gauß (1799, Göttingen)

Gaussian noise,

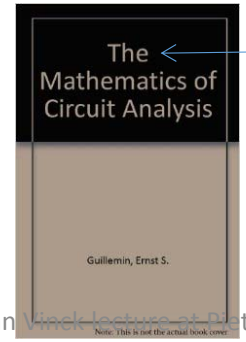


1st wired binary communication link (1833). The alphabet was encoded in a binary code
Speed: two letters per minute.

Ernst Guillemin (1926 München MIT, 1928)

Discrete systems

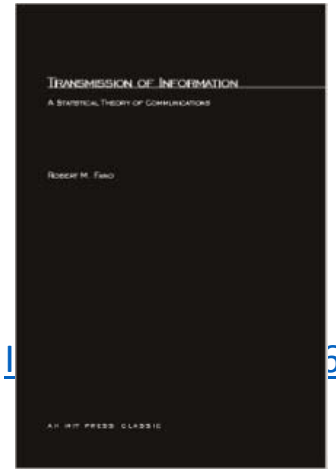
Communications Networks



Scientific genealogy (cont)

Robert Fano, il padre di Internetin fuga da Mussolini

Transmission of Information: A Statistical Theory of Communications (1961), I 693



Fano,(MIT, 1947)

John Wozencraft (*Sequential Decoding for Reliable Communication, 1957)*

Principles of Communications Engineering
J.M. *Wozencraft*, I.M. *Jacobs*:

Tom Kailath, Stanford (1961)

First student, 1965

Communication via Randomly Varying Channels

Coding Schemes for Channels with Feedback

Some of Piet's Research highlights

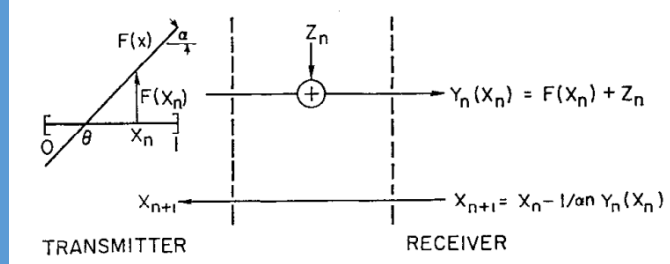


Fig. 3. Proposed coding scheme for wideband signals.

IEEE TRANSACTIONS ON INFORMATION THEORY VOL. IT-12, NO. 2 APRIL 1966

A Coding Scheme for Additive Noise Channels with Feedback—Part I: No Bandwidth Constraint

J. P. M. SCHALKWIJK, MEMBER, IEEE AND T. KAILATH, MEMBER, IEEE

In the beginning ….

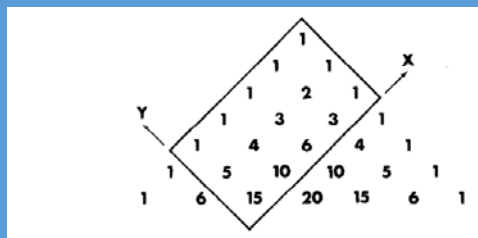


Fig. 1. Pascal's triangle gives an ordering of source sequences.

IEEE TRANSACTIONS ON INFORMATION THEORY, VOL. IT-18, NO. 3, MAY 1972

An Algorithm for Source Coding

J. PIETER M. SCHALKWIJK, MEMBER, IEEE

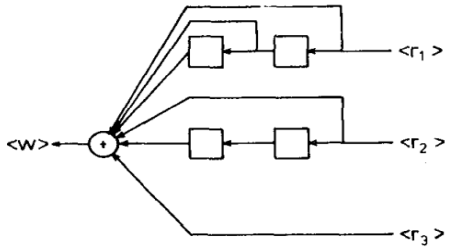


Fig. 2. Syndrome former for rate 2/3 convolutional code.

IEEE TRANSACTIONS ON INFORMATION THEORY, VOL. IT-24, NO. 5, SEPTEMBER 1978

Syndrome Decoding of Binary Rate *k/n* Convolutional Codes

J. PIETER M. SCHALKWIJK, SENIOR MEMBER, IEEE, A. J. VINCK, MEMBER, IEEE, AND KAREL A. POST, MEMBER, IEEE

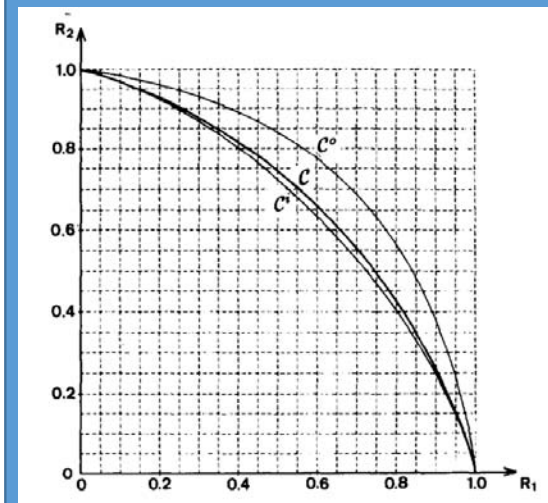


Fig. 7. Schalkwijk's achievable rate rate region for the BMC.

J.P.M. Schalkwijk

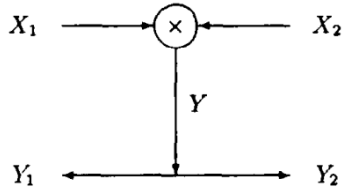


Fig. 6. Binary multiplying channel.

IEEE Fellow: For contributions to the development of simple and effective coding schemes for data communication systems.

At the end, een OPMERKELIJKE ACTIE in 1996

Ir. Erik Meeuwissen, aio bij de vakgroep Informatie- en communicatietheorie, overhandigt een lijst met handtekeningen aan de decaan van Elektrotechniek, prof.dr.ir. Wim van Bokhoven om te voorkomen dat bij de faculteit Elektrotechniek de leerstoel Informatie- en Communicatietheorie wordt opgeheven

MAAR:
Uit een visitatierapport uit 1995 bleek verder dat het vakgebied als ‘belangrijk’ gekenschetst wordt. De vakgroep kreeg het predikaat ‘excellent’ van de visitatiecommissie.

Have a look at the Standard Evaluation Protocol(SEP): KNAW

Some lessons learned

For the university:

- The appointment of professors is a long term decision (the rope of Piet)
- industry is interested in the result, science in the way to it
- administration serves science, not the other way around

for the scientist:

- The Psychology of Limitations: Constraints Make You More Creative (use the brain i.s.o. the computer)
- Finding a good problem is the hardest part of the work: (how to?)
  If you do not understand, you cannot explain (Einstein, simplicity)
- “Genius is 1% inspiration, and 99% perspiration.” (Thomas Edison)

Congratulations Piet, also for the family!

Sue en

Karin

Jan

Lucy

Susanne

Programma van 16 november

- Voordrachten:

13.30 Han Vinck: Welkom en een overzicht
Thijs Veugen: het ontstaan van (multiple-)repetition strategies
Stan Baggen: On Prediction using a Data Base: An Information-Theoretic Approach
Frans Willems: van de Pascal driehoek naar CTW

15.00 thee

15.30 Ludo Tolhuizen: Namens de WIC
Ben Smeets: Een Zweedse evaring met windmolens en Bluetooth
Peter de With: Detectie van anomalien in beelden
Andries Hekstra: Het twee weg kanaal, een overzicht
Kees Immink: Progress in Constrained Codes

17.00 – 18.00 receptie

18.30 – 21.00 diner in “de zwarte doos” (alleen voor aangemelde personen)

From his supervisor: Thomas Kailath

Dear Han: I attach some comments for use as you deem best (using extracts ...) on the 16th. Best wishes for a great event. Warm regards, Tom

- I was very pleased to hear that you and fellow students of Piet are going to celebrate his 80th birthday. I always have the fondest memories of Piet, not only was he my first Ph.D. student, but he was almost my age. And his thesis was groundbreaking.
- I am trying to recollect how it came about. As I recall I had suggested that he look into a book, Lectures on Communication System Theory, ed. E. J. Baghdady, McGraw Hill, 1961. In particular I suggested Chapter 14, “Feedback Communication Systems, was by Paul Green and especially the appendix by Peter Elias, “Channel Capacity without Coding.”
- Piet had taken a course in statistics where he learned about stochastic approximation, in particular the Robbins- Munro algorithm. This led him suggest a very simple coding scheme for communication over an additive white Gaussian noise channels with a noiseless feedback link. It was known that having such a feedback link would not increase the forward channel capacity, but that it had the potential to simplify the coding schemes for the forward channel.
- As a new student who had just taken my course on Gaussian channels, Piet was having some problems in properly analyzing the error probability behavior of his scheme, so I stepped in to help him a bit.

Continued(2)

- We soon discovered that Piet's simple coding scheme could achieve channel capacity with a probability of error that came down with block length, not exponentially as in all previously studied channels, but in a double exponential fashion!
- As one commentator remarked, this result rocked the information theory community. The paper appeared in the April 1966 issue of the IEEE Transactions on Information Theory and later received an outstanding paper prize. This paper was on channels with no bandwidth constraints.
- I now left it to Piet to extend the result to band-limited channels, resulting in a paper published under his own name as Part 2.
- No surprise that Piet's thesis was completed in the record time of two years, even though he complained that I had made him rewrite it six times!

Continued(3)

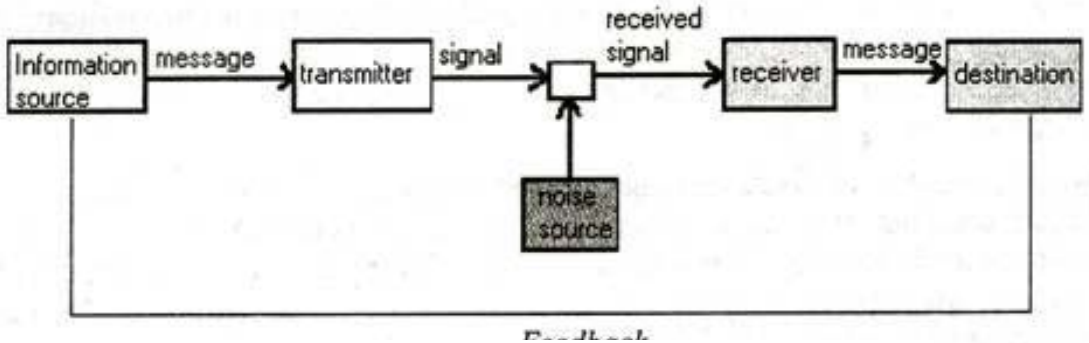
- After he left Stanford to join GTE-Sylvania on the East Coast, Piet continued to extend these results in various directions. One of them was showing that one could do even better than double exponential. While these results got a lot of attention, application was slow. Our idea was that these results would be most applicable to space communication channels, because while power capability on the satellite was limited, is not so on the return ground to satellite link, which might therefore be regarded as noiseless. However, this application failed because it could not properly account for the delay in the return link.
- However in the last decade, interest has grown in networked multi-terminal channels, as in the internet. Here the links are short and the delays are not significant. So Piet's algorithm is now back in the news.
- A nice fallout for me was the fact that in Piet's scheme, recursive estimates at the receiver of the transmitted signal were to be sent back over the feedback link. This led me to study the Kalman filter, which led to many years of interesting future work.

Continued (4)

- Piet's return to the Netherlands was well appreciated. The well-known early Dutch Information Theorist, Prof. F.H.L.M. Stumpers, mentioned Piet to me very favorably on several occasions. I regret that I only met Piet once-in Eindhoven- after he had left the US. However I did have a nice visit some years ago from Piet's daughter who was completing her Ph.D. in the US.
- The only other connection I have is with Piet's students, Kees Immink Schouwhammer and Han Vinck. A nice story about Kees: He spent some summers at the NTU (National Technological University) in Singapore. So did another of my students now in Israel, Freddy Bruckstein. One day I get an email from Kees: there is a crazy man in the next office who claims he is my uncle! (Academically speaking, of course-my students are a family!)
- And finally, Piet: my heartiest best wishes to you at this great birthday celebration with your friends and family! We will raise a toast to you at dinner here on the 16th.

What a simple wire can do for your life

FIGURE 6.1: SHANNON-WEAVER MODEL



Particularly, in [106], it was shown that the following simple signalling strategy is optimal. Given a set of M equally likely messages, uniformly divide the interval $[0, 1]$ into M subintervals, and associate each message to a subinterval center. Pick one center W and transmit it. At time t, the decoder computes a maximum-likelihood estimate $\hat{W}_t$ of W. At time $(t+1)$, the encoder transmit $a(\hat{W}_t - W)$, an *amplified* version of the estimation error, where $a > 1$ is an amplification factor. At the final time, the decoder maps its final estimate to the closest subinterval center as the decoded message. This coding procedure is rather simple, and it leads to *doubly exponentially* decay of the decoding error probability, while achieving the capacity.

The SK codes have been extended to many situations. Gallager reformulated the coding scheme and discussed both the digital and analog (related to rate-distortion and joint source-channel coding) transmission issues [43]. Schalkwijk designed the multi-dimensional signalling for AWGN channels [105]. Omura formulated a stochastic optimal control problem for the SK signalling strategy [92]. Wyner showed that the SK codes generate (singly) exponential decay of error probability if a peak power constraint is used. Butman designed the feedback codes for channels with additive Gaussian noise forming autoregressive processes, and derived tight bound for feedback capacity [5, 6]. More general Gaussian noise channels were also studied, see e.g. [122, 131, 97, 96]. For multi-input multi-output (MIMO) Gaussian channels with feedback (i.e. Gaussian networks with feedback), see e.g. [95, 68, 64].

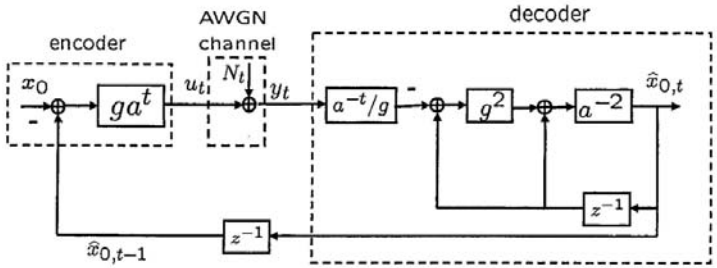


Figure 3.5 The SK coding scheme.

that in the SK scheme, it holds that

$$\begin{aligned} u_t &= ga^t(\hat{x}_{0,t-1} - W) \\ \hat{x}_{0,t} &= \hat{x}_{0,t-1} - a^{-t-2}gy_t; \end{aligned}$$

e Kalman filter based scheme, it holds that

$$\begin{aligned} u_t &= ca^t(W - \hat{x}_{0,t-1}) \\ \hat{x}_{0,t} &= \hat{x}_{0,t-1} + a^{-t-2}Ly_t. \end{aligned}$$

$$\begin{aligned} g &:= \sqrt{a^2 - 1} \\ c &:= -g, \end{aligned}$$

mes then generate identical channel inputs, outputs, and decoder estimates
l hence they are equivalent. The optimal choice of g in the SK coding schem
ds to the optimal choice of Kalman filter gain.

http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=2276&context=rtd