OTHER METHODS OF DECODING CONVOLUTION CODES ①

PRIOR TO THE DISCOVERY OF AN OPTIMUM ALGORITHM BY VITERBI, A NUMBER OF (NON-OPTIMUM) ALGORITHMS HAD BEEN PROPOSED;

* SEQUENTIAL DECODING
* FEEDBACK DECODING.

SEQUENTIAL DECODING

FIRST PROPOSED BY J.M WOZENCRAFT 1957.

THIS ALGORITHM WORKS BY GENERATING HYPOTHESES ABOUT THE RECEIVED SEQUENCE IT COMPUTES A METRIC BETWEEN THESE HYPOTHESES AND THE RECEIVED SEQUENCE IT STEPS FORWARD SO LONG AS THE METRIC INDICATES ITS CHOICES ARE LIKELY...

IF NOT, IT GOES BACK AND TRIES ANOTHER PATH, UNTIL BY TRIAL-AND ERROR IT FINDS A LIKELY HYPOTHESIS.

SEQUENTIAL DECODERS CAN BE IMPLEMENTED WITH SOFT DECISIONS, BUT RARELY ARE SO BECAUSE OF THE SIGNIFICANT ADDED COMPLEXITY.

SEQUENTIAL DECODING ALGORITHM ②

1) WE COMPARE THE INPUT BITS WITH THE BRANCH WORDS. IF THE EXACT MATCHING BRANCHWORD IS AVAILABLE, WE OBVIOUSLY TAKE THAT ROUTE. IF AN EXACT MATCH IS NOT AVAILABLE, WE TAKE THE MOST LIKELY PATH, BUT WE INCREMENT THE COUNT OF DISAGREEMENTS.

2) IF TWO PATHS APPEAR EQUALLY LIKELY THEN THE DECODER USES AN ARBITRARY RULE – TAKING THE ZERO INPUT BRANCH FOR EXAMPLE.

3) IF THE NUMBER OF DISAGREEMENTS EXCEEDS SOME THRESHOLD, THE DECODER BACKS UP AND TRIES ANOTHER PATH. A RECORD OF WHICH PATHS HAVE BEEN TRIED IS KEPT TO AVOID REPEATING ANY PATHS.

UNLIKE VITERBI DECODING (WHERE THE COMPLEXITY OF THE DECODER INCREASES EXPONENTIALLY WITH CONSTRAINT LENGTH) SEQUENTIAL DECODING COMPLEXITY IS ESSENTIALLY INDEPENDENT OF K. – WE CAN USE LARGE K CODES.

HOWEVER FOR A "NOISY" CHANNEL THE NUMBER OF PATHS THAT HAVE TO BE SEARCHED CAN BE LARGE.

③

M = 1 1 0 1 1
Cm = 11 01 01 00 01
R = 11 00 01 10 01
ERRORS
RATE 1/2 K=3

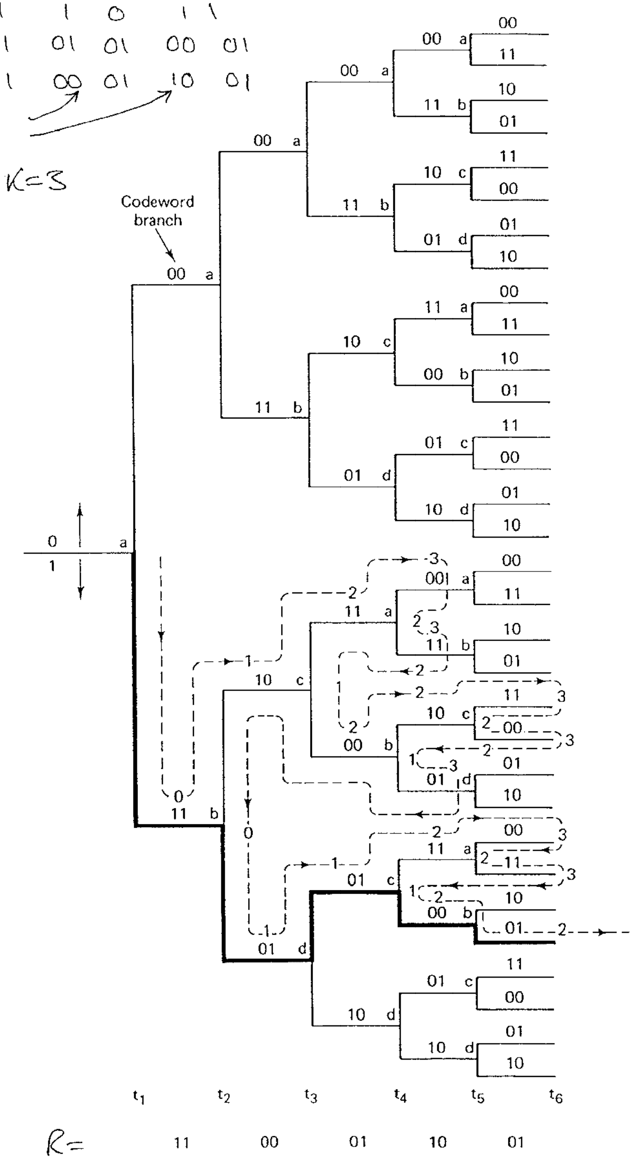


Figure 6.20 Sequential decoding example.

④

FEEDBACK DECODING

IN THE FEEDBACK DECODER, INSTEAD OF MAKING A DECISION AT ONE PARITICULAR BRANCH LEVEL, IT COMPUTES THE HAMMING DISTANCE OF ALL THE PATHS TO A BRANSCH DEPTH OF L – THE LOOK-AHEAD LENGTH, AND PICKS THE MOST LIKELY PATH. THEN IT STEPS FORWARD ONE STEP ALONG THE MOST LIKELY PATH.

THE DECODER IS CALLED A FEEDBACK DECODER BECAUSE THE DECISION ON WHICH PATH TO FOLLOW IS FED-BACK FROM DEEPER INTO THE TREE THAN THE PRESENT TIME.

THE FEEDBACK DECODER PERFORMS ALMOST AS WELL AS THE VITERBI METHOD FOR A B.S.C.

INCREASING 'L" INCREASES CODING GAIN, BUT INCREASES DECODER COMPLEXITY

SPREAD SPECTRUM TECHNIQUES.

AT THE BEGINNING OF THIS COURSE WE SAID THAT A KEY ATTRIBUTE OF A GOOD DIGITAL COMMUNICATIONS SYSTEM WAS A LARGE BANDWIDTH EFFICIENCY.

WE DEFINED BANDWIDTH EFFICIENCY AS;

$$\eta_B = \frac{\text{DATA RATE}}{\text{BANDWIDTH}} \quad \text{bits s}^{-1}\,\text{Hz}^{-1}$$

WE ALSO SAID THAT WE WANTED A SMALL ENERGY EFFICIENCY;

$$\eta_E = E_b/N_o \Big|_{P_b = 10^{-6}}$$

WE HAVE TO TRADE-OFF η_B AGAINST η_E

USUALLY WE SPEND OUR TIME TRYING TO MINIMIZE THE BANDWIDTH, HENCE WE MADE THE TRANSITION FROM DSB TO SSB.

IN SPREAD-SPECTRUM SYSTEMS, WE SEEM TO CONTRADICT OURSELVES BY USING A BANDWIDTH FAR IN EXCESS OF THAT REQUIRED BY THE DATA RATE.

WHAT WE HAVE JUST SAID REQUIRES SOME JUSTIFICATION;

CLAUDE SHANNON'S 1949 PAPER ON COMMUNICATIONS THEORY STATES;

$$C = W \log_2\left[1 + \frac{S}{N}\right] \quad \text{bits s}^{-1}$$

C - CHANNEL CAPACITY, bits s^{-1}
W - BANDWIDTH, Hz
S - AVERAGE SIGNAL POWER
N - AVERAGE WHITE GAUSSIAN NOISE POWER.

HENCE TO INCREASE THE CHANNEL CAPACITY WE CAN EITHER;

* INCREASE THE S/N RATIO
* INCREASE THE BANDWIDTH

SINCE THE CHANNEL NOISE IS BEYOND OUR CONTROL(!) TO INCREASE THE SNR WE CAN ONLY INCREASE THE TRANSMITTER POWER

HOWEVER SINCE THE S/N RATIO IS LOGARITHMIC-ALLY RELATED TO W THIS IS NOT ALWAYS POSSIBLE.

IF THE FREQUENCY ALLOCATIONS PERMIT WE SOLVE THE PROBLEM BY INCREASING THE BANDWIDTH.

SPREAD SPECTRUM SYSTEMS UTILIZE VERY WIDE BANDWIDTHS AND LOW SIGNAL-TO-NOISE RATIOS.

FROM SHANNON'S THEOREM WE CAN WRITE

$$\frac{C}{W} = \log_2 e \times \log_e\left[1 + \frac{S}{N}\right]$$

$$\Rightarrow \frac{C}{W} \approx 1.44 \ln\left[1 + \frac{S}{N}\right]$$

SINCE $\ln(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \dots, \quad |x|<1$

SINCE WE ARE DEALING WITH LOW SNR THAT IS $S/N \ll 0.1$, WE CAN WRITE;

$$W \simeq \frac{NC}{S} \; ; \quad W = \frac{N \times C}{1.44\,S}$$

HENCE FROM A GIVEN S/N AND CHANNEL CAPACITY WE CAN ESTIMATE THE REQUIRED BANDWIDTH.

FOR EXAMPLE; ASSUMING $C = 32K$ bits s^{-1} AND A SNR = −30dB (0.001)

$$W = \frac{CN}{1.44S} = \frac{32 \times 10^3 \times 1000}{1.44} \simeq 22\,\text{MHz}.$$

THERE ARE TWO MAIN CRITERIA THAT MUST BE FULFILLED IN ORDER THAT A SYSTEM BE CONSIDERED SPREAD-SPECTRUM;

* THE TRANSMITTED BANDWIDTH MUST BE MUCH GREATER THAN THE BANDWIDTH OR DATA RATE OF THE INFORMATION BEING SENT.
* THE SPREADING OF THE SIGNAL MUST BE ACCOMPLISHED BY A SPREADING FUNCTION WHICH IS INDEPENDENT OF THE DATA STREAM.

FOR THE REMAINDER OF THIS SECTION OF THE COURSE WE WILL LOOK AT;

* THE FIVE TYPES OF SPREAD SPECTRUM
* APPLICATIONS OF SPREAD SPECTRUM
* GENERATION AND DETECTION OF DS & FH SYSTEMS.

SPREAD SPECTRUM CAN BE VIEWED AS A MODULATION TECHNIQUE WHICH;

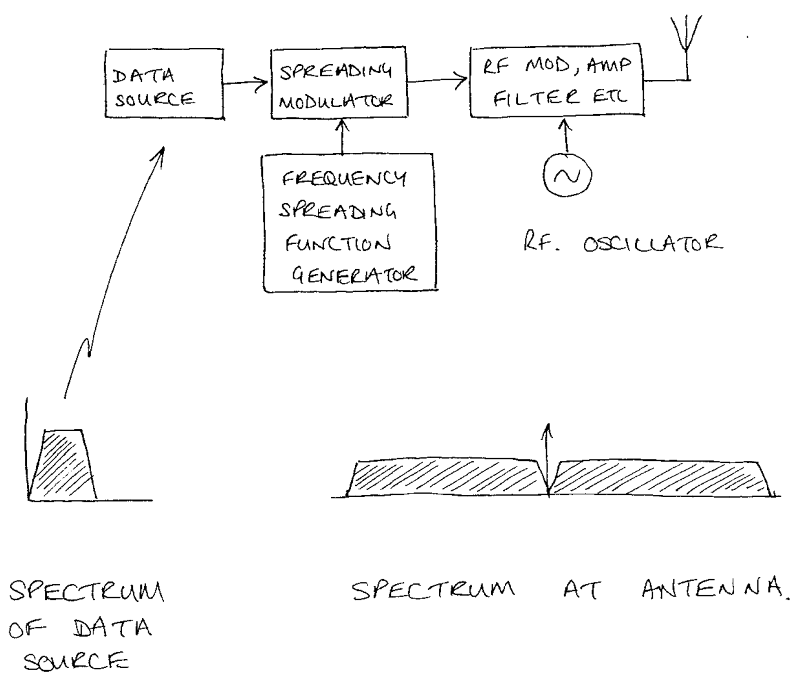
* EXPANDS THE BANDWIDTH
* PROVIDES A "PROCESS GAIN"
* HAS INTERFERENCE / JAMMING RESISTANCE
* HAS MULTIPLE ACCESS ATTRIBUTES
* CAN EXHIBIT A LOW PROBABILITY OF INTERCEPT.

WHY DO WE WANT TO USE SPREAD-SPECTRUM TECHNIQUES;

* INTERFERENCE REJECTION (ANTI-JAM)
* LOW PROBABILITY OF INTERCEPT AND RECOGNITION (LPI / LPR)
* MESSAGE PRIVACY
* CDMA - CODE DIVISION MULTIPLE ACCESS
* PRECISION RANGING
* SELECTIVE ADDRESSING.

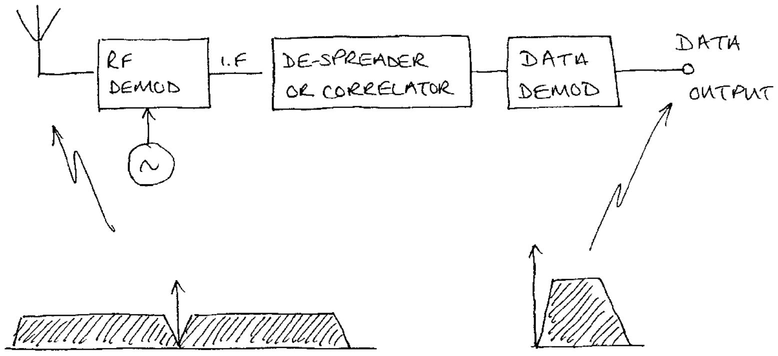
GENERALIZED SPREAD SPECTRUM SYSTEM

TRANSMITTER



THE WAY IN WHICH WE SPREAD THE DATA SIGNAL DETERMINES THE TYPE OF SPREAD-SPECTRUM SIGNAL WE GENERATE.

RECEIVER



RECEIVED SIGNAL SPECTRUM

DATA SPECTRUM.

MAIN TYPES OF SPREAD SPECTRUM

* DIRECT SEQUENCE
* FREQUENCY - HOPPING
* CHIRP
* TIME - HOPPING
* HYBRID SYSTEMS

DIRECT SEQUENCE MODULATION

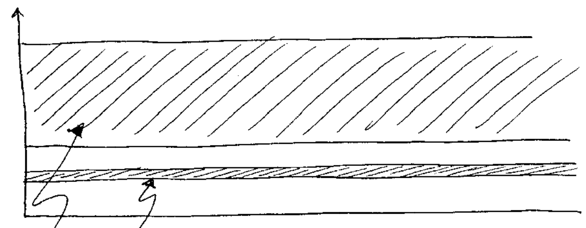
TO GENERATE A DIRECT - SEQUENCE SIGNAL THE DATA IS MODULATED BY A PSEUDO - NOISE CODE CLOCKED AT A RATE VERY MUCH HIGHER THAN THE DATA RATE.

THE METHOD OF MODULATING THE P.N CODE ONTO THE DATA IS USUALLY ACHIEVED BY MODULO-2 ADDITION OF THE P.N CODE ONTO THE DATA (SOMETIMES CALLED SEQUENCE INVERSION KEYING)

THIS HIGH SPEED DATA STREAM IS THEN MODULATED ONTO THE R.F CARRIER SIGNAL. THIS IS USUALLY 180° BI-PHASE PSK (BPSK). ALTHOUGH ANY OF THE MODULATION SCHEMES WE LOOKED AT; QPSK, OQPSK, AND MSK CAN BE USED.

AT THE RECEIVER THE HIGH SPEED CODE MODULATED SIGNAL IS "DE-SPREAD" TO REDUCE THE DATA DOWN TO THE WANTED DATA STREAM. BUT ANY NOISE ADDED TO THE SPREAD - SIGNAL IN THE CHANNEL IS NOT CORRELATED WITH THE DATA STREAM AND IS MOSTLY REMOVED IN THE DESPREADING PROCESS.

THE SPECTRUM OF D.S SPREAD-SPECTRUM IS INVARIANT WITH TIME



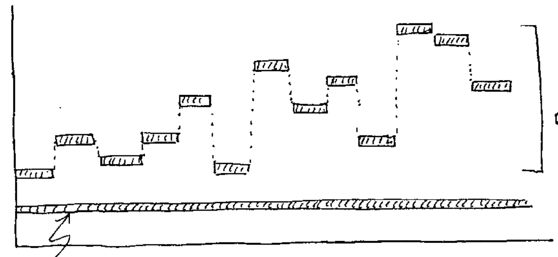
FREQUENCY-HOPPING

IN A FREQUENCY-HOPPING SYSTEM THE FREQUENCY USED TO CONVEY THE DATA IS CHANGED RAPIDLY.

THE TRANSMITTED HOPS FROM CHANNEL-TO-CHANNEL IN A PSEUDO-RANDOM SEQUENCE

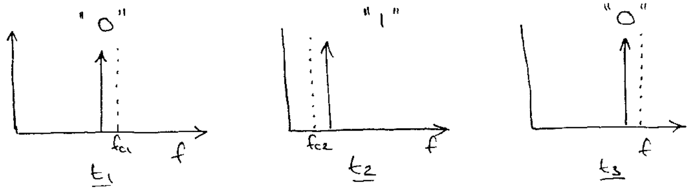
UNLIKE A DIRECT SEQUENCE SYSTEM THE PSEUDO-NOISE CODE DOES NOT DIRECTLY MODULATE THE CARRIER, BUT CONTROLS A FREQUENCY SYNTHESIZER.

SPECTRUM OF F-H SPREAD SPECTRUM SYSTEM

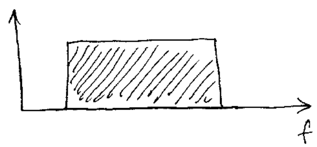


THE DATA IS USUALLY FSK MODULATED ONTO A CARRIER WHICH IS THEN MODULATED UP TO THE TRANSMISSION FREQUENCY BY A FREQUENCY-AGILE LOCAL OSCILLATOR.

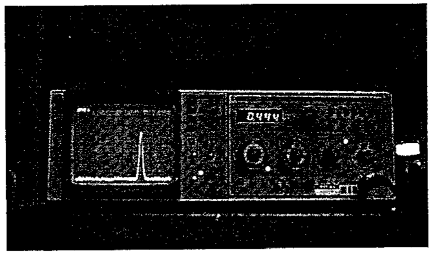
FOR EXAMPLE, IF WE SEND $f_0(t)$ FOR A LOGIC ZERO AND $f_1(t)$ FOR A LOGIC ONE



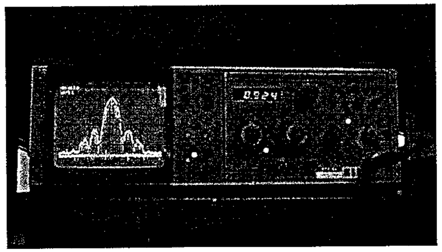
OVER A LONG PERIOD



Narrow Band



Direct Sequence Spread Spectrum



Hedy Lamarr

CHIRP MODULATION

CHIRP MODULATION, ALTHOUGH TECHNICALLY A SPREAD SPECTRUM TECHNIQUE HAS NOT FOUND WIDESPREAD USE OUTSIDE OF RADAR SYSTEMS

IN THIS CASE THE PULSES OF DATA ARE TRANSMITTED AS A SWEPT FM SIGNAL OF CONSTANT AMPLITUDE.

USUALLY THE FREQUENCY IS SWEPT UPWARDS FOR A LOGIC ONE (SAY) AND SWEPT DOWNWARDS FOR A LOGIC ZERO.

THE MAIN APPLICATION IS FOR IMPROVED RANGE RESOLUTION IN RADAR SYSTEMS – PULSE COMPRESSION

THIS FORM OF SPREAD-SPECTRUM CANNOT BE USED TO FORM A MULTIPLE ACCESS TECHNIQUE

TIME HOPPING

A TIME HOPPING SYSTEM IS CONTROLLED BY A PSEUDO-RANDOM CODE WHICH DETERMINES THE TRANSMITTERS ON AND OFF TIMES. DATA IS TRANSMITTED AT RANDOM TIMES – MAINLY USED FOR ANTI-JAM SYSTEMS