Fraunhofer Institut Integrierte Schaltungen

Memo

Subject: Diversity Combining within Viterbi

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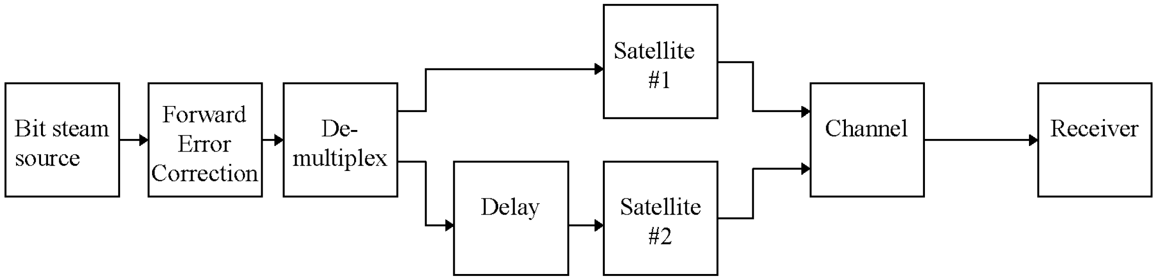
Date: 10/26/98

1 Scope

This memo shall give additional information to the new proposed diversity combining scheme.

2 Description of the diversity combining method

According to the following block diagram the AMRC DARS system can be considered as transmission system with one channel.



According to the code rate of ¾ (Convolutional code only) for 3 information bits 4 channel bits are transmitted over each satellite. Using two satellites 8 channel bits are transmitted for 3 information bits. Therefore the system can be considered as a system with code rate 3/8.

According to the literature and system simulation results the following E_b/N_0 performance can be assumed. For QPSK the C/N (=Power of transmitted signal/Noise power within effective bandwidth) can be calculated by:

$$C/N = E_b/N_0 + 10 * \log(R) + 3dB$$ (C/N and E_b/N_0 values in dB)

R is the code rate.

Code Rate R (convolutional code + Reed-Solomon Code)	E_b/N_0 [dB]	C/N [dB]
3/4 * (223/255) = 0.66	3.7	4.9
1/2 * (223/255) = 0.44	2.7	2.1
3/8 * (223/255) = 0.33	app. 2.4	0.6

The required C/N value applies also to a system where the bitstream is de-multiplexed to two stream and transmitted using 2 QPSK modulators. The overall transmit power is

$$C = C_{Sat\,1} + C_{Sat\,2}$$

The noise power is

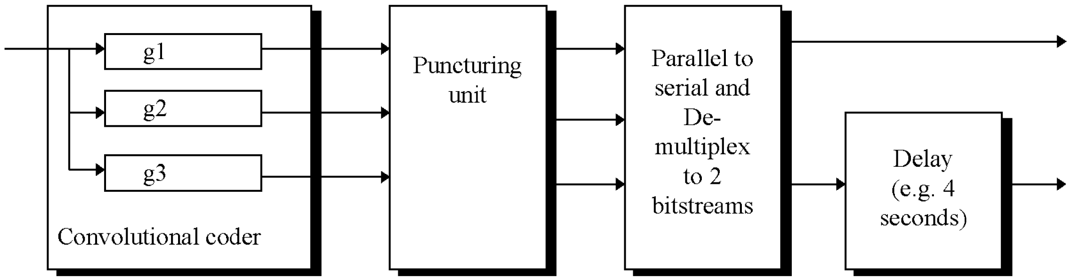
$$N = N_1 + N_2$$

Assuming the signal power is the identical (=best case for the combining method) for satellite 1 and 2 $C_{Sat1} = C_{Sat2}$. With $N_1 = N_2$ (the effective bandwidth is identical for both signals the following equation applies:

$$\frac{C}{N} = \frac{C_{Sat1} + C_{Sat2}}{N_1 + N_2} = \frac{2C_{Sat1}}{2N_1} = \frac{C_{Sat1}}{N_1} = \frac{C_{Sat2}}{N_2}$$

Assuming the available signal power (=C) and QPSK symbol rate is kept the combining method can give an gain of **4.3dB** compared to the required C/N if one signal is decoded only. This gain is equivalent to the gain relative to switching combining for the scenario available $C_{Sat1}/N = C_{Sat2}/N$. It is assumed that for other scenarios the gain is lower. At least for the scenarios C_{Sat1}/N **or** C_{Sat2}/N is greater then 4.9dB no gain is required. The output signal is error free in any case. The overall gain of the scheme depend on the probability of the scenario.
In other words: It is possible to receive the signal down to an C/N of 0.6dB (theoretical value not including implementation loss). The equivalent required C/N_0 = 62.7 dBHz (not including implementation loss) for each satellite. If only one satellite signal is available the required C/N_0 is 67 dBHz[1] (not including implementation loss).

The implementation requires a convolutional coder with code rate 1/3. The output of the convolutional encoder is punctured to a code rate of 3/8 by not transmitting 1 channel bit out of 9. The output of the convolutional encoder and puncturing unit is demultiplexed. 4 bits out of 8 are transmitted over satellite 1. The other 4 bits are transmitted over satellite 2. A delay can be inserted for one signal. Optional additional time interleaver can be used. A simplified block diagram (not including the details of the TDM bitstream structure) is shown in the next figure.

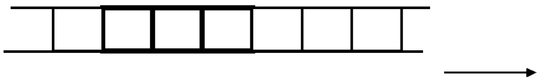


The polynomial g1, g2 and g3 describe the shift registers and modulo 2 adders which generates the convolutional code of code rate 1/3. One bit out of 9 is removed by the

[1] For the WorldSpace L-Band system the required C/N0 is 64.7dBHz. The value of 67dBHz used for many link budget calculations includes a implementation loss of 2.3dB.

puncturing unit. The remaining 8 bits are de-multiplexed to the two output bitstreams according to the scheme shown in the next figure.

Input bit sequence:



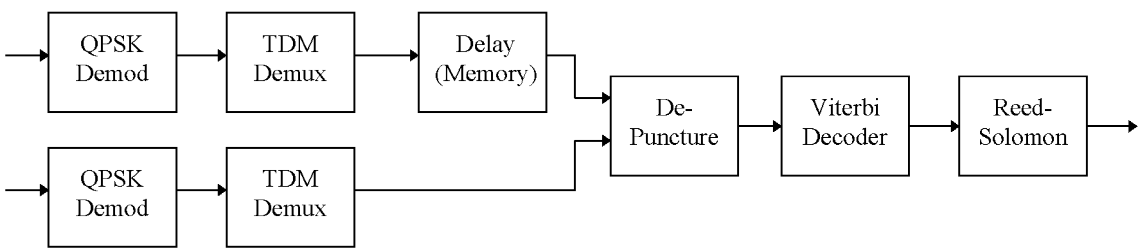
After convolutional encoder

		E	E	E			
		E	X	L			
		L	L	L			

E = Bit transmitted over early satellite
L = Bit transmitted over late satellite
X = not transmitted (punctured) bit

The proposed polynomials are
g1 = 1001111 (same as for current spec.)
g2 = 1101101 (same as for current spec.)
g3 = 1010111

The receiver requires one Viterbi decoder only. A simplified block diagram of the receiver is shown in the next figure:



The optimal combining according to the signal quality of the two signals is automatically performed by the Viterbi decoder. The Viterbi decoding performs maximum likelihood decoding using the channel state information (="metric"). The algorithm used for the metric calculation is TBD. Algorithms known for Rician and Rayleigh channels can be adapted to the AMRC DARS system.

If only one signal is available the input of the Viterbi decoder is considered as convolutional code of code rate 1/3 punctured to a code rate of ¾. The equivalent puncturing scheme is:

For the early satellite:

1 1 1
1 0 0
0 0 0

For the late satellite

0 0 0
0 0 1
1 1 1

3 Impact to the system design

3.1 Waveform specification

The available waveform specification proposes the same convolutional code for both satellites and "staggered puncturing" resulting in a TDM bitstream different for the early and the late satellite. The convolutional encoder and the staggered puncturing shall be replaced by the definition of the new convolutional code (g3 shall be added) and the description of the puncturing and "de-multiplex" of the bitstream. Using g1 and g2 for satellite #1 and g2 and g3 for satellite #2 together with modified puncturing scheme would be an equivalent specification.
No changes for the terrestrial waveform are required. The reformating of the bitstream received from the early satellite will be unmodified (if one signal is decoded only the convolutional code can be considered as code rate ½ punctured to ¾ also).

3.2 System analysis/simulation

A simulation setup containing the following building blocks shall be developed and tested:

- convolutional encoder according to the proposal
- puncturing and demultiplex
- 2* TDM bitstream multiplex
- delay for one signal
- 2* QPSK modulator
- Channel model validated with SV2 data
- 2* AGC
- 2* QPSK demodulator
- delay for one signal
- multiplex of the two softquantized bitstreams
- de-puncturing
- Viterbi decoder with metric calculation adapted to the requirements (if necessary)

To avoid problems with the simulation setup using long delays for an initial analysis it is sufficient to replace the delay of 4 seconds by a delay greater to the coherence time of the channel "tree coverage". Values in the range of app. 100ms shall be sufficient.
Assuming the channel models and the AGC concept can be taken from the setups used for MRC and/or post-FEC the main effort results from the development of the modified Viterbi.

3.3 Schedule impact

The goal of the schedule is a frozen specification (waveform and chipset) by January 15th, 1999. To meet this milestone preliminary results shall be available beginning of December to adapt the draft specification, which will be developed in parallel to the SV1/SV2 data analysis, to the results of the system validation.
Proposal:
1. If the data available by Oct 30th indicates that post-Viterbi and post-Reed-Solomon decoding are not sufficient or an additional gain of 2-4 dB will improve the service availability significant the combining methods before/within Viterbi decoding shall be kept as option for the baseline receiver. The decision shall be postponed until end of November
2. The additional analysis shall be performed until end of November. The additional analysis shall include:

- Analysis of "Code rate 1/3 approach" by system simulation
- Development of draft chipset spec. based on the assumption

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