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Performance Comparison of Hybrid-ARQ Schemes – Additional Results

Introduction

Automatic-Repeat-Request (ARQ) schemes are used in packet data communication system. The term "Hybrid ARQ" can be used to describe any combined FEC+ARQ scheme in which unsuccessful attempts are used in FEC decoding instead of being discarded. Chase combining (also called H-ARQ-type-III with one redundancy version) involves the retransmission by the transmitter of the same coded data packet. The decoder at the receiver combines these multiple copies of the transmitted packet. Another form of "Hybrid ARQ" is called incremental redundancy (IR). In this scheme, instead of sending simple repeats of the coded data packet, progressive parity packets are sent in each subsequent transmission of the packet. The decoder then combines all the transmissions and decodes the packet at a lower code rate. The IR schemes can be broadly classified under two categories, a) partial IR where each re-transmission is self decodable (H-ARQ-type-III) and b) full IR where each transmission is not self decodable (H-ARQ-type-II). In [1] the throughput performance of Chase combining and partial IR were compared using link simulations. In [2] the performance gains of full IR over Chase combining for higher order modulation in a static channel were shown. In this contribution, the three hybrid ARQ methods namely Chase combining, Partial IR and Full IR are compared under static and fading channels for three different modulation and coding schemes.

H-ARQ with Full IR (H-ARQ-Type-II)

The implementation technique for Chase combining and partial IR were described in [1]. In this contribution the full IR is implemented for the MCS levels shown in Table 1 and compared with Chase and partial IR schemes.

Table 1. MCS Level for Method-2

MCS	Modulation	Turbo Code Rate
7	64 QAM	3/4
6	16 QAM	3/4
3	QPSK	3/4

The turbo codes used in the hybrid ARQ system consists of a parallel concatenation of two R=1/3 systematic and recursive convolutional encoders as shown in Figure 1. The overall code rate of the turbo code entering the puncturing circuit is 1/6. For each input stream, six output streams are formed: the input stream x itself, two parity streams produced by the first convolutional code y_1 and y_2 interleaved input stream x' and the second parity streams z_2 and z_3 produced by the second convolutional code. The puncturing block after the encoder is used to form (for example) R=3/4, R=2/3 and R=1/2 codes by puncturing the parity bits. As an example, for R=1/2 codes alternate parity bits are sent over the channel (x, y_1, x, z_2, x, y_1,…). In case of full IR using R=3/4 code the following algorithm was implemented in the simulator:

- ?? In case of first transmission, the following set of coded bits are transmitted for every six information bits, : $P_1=\{x_A, x_B, x_C, y_{1C}, x_D, x_E, x_F, z_{1F}\}$.
- ?? In case of second transmission (first re-transmission), the following set of parity bits are transmitted: $P_2=\{y_{1A}, y_{2A}, z_{1C}, z_{2C}, y_{2D}, y_{1E}, z_{1F}, z_{2F}\}$.
- ?? For the third transmission, a different set of parity bits are transmitted: $P_3=\{z_{1A}, z_{2B}, y_{1C}, y_{2C}, z_{2D}, z_{1E}, y_{1F}, y_{2F}\}$.

?? The sequence is then repeated.

?? The very first transmission is decoded as an R=3/4 code, the next transmission is decoded as an R=3/8 code, and the third transmission is decoded as a R=1/4 code. Subsequent retransmissions are decoded as a R=1/4 code, where the bits in each subsequent retransmission are added symbol-wise to the corresponding stored bits.

The puncturing patterns P_1, P_2, and P_3 can be represented as the following three matrices. The multiplexing rule is to multiplex first by column, left to right. Within a column, read out top to bottom.

$$P_1 ? \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad P_2 ? \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 \end{bmatrix} \quad P_3 ? \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 \end{bmatrix}$$

Figure 2 to Figure 6 to compares the performance of Chase combining, Partial IR and Full IR with three MCS levels using R=3/4 code and at various values of vehicle speeds. The following conclusions are drawn from the figures:

1. For QPSK, full IR benefits over Chase are not significant in the region of interest.
2. For higher order modulation (MCS-6 and MCS-7), the full IR provides more than 1dB gain in Ior/Ioc in a fading channel. However, the gain occurs in a region where a lower MCS may have been selected.
3. The decoder and signaling complexity of the full IR scheme over Chase combining needs to be evaluated, and weighed against the likelihood of the MCS selection process degrading to the point where a significant overall throughput gain is seen for the fu ll IR.

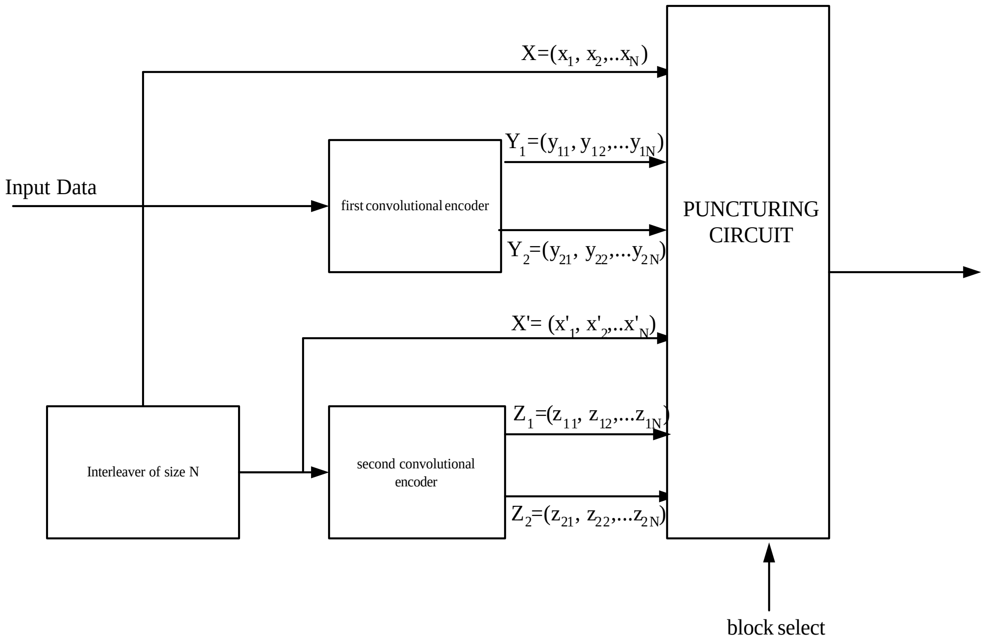

Figure 1. Block Diagram of a Turbo Encoder

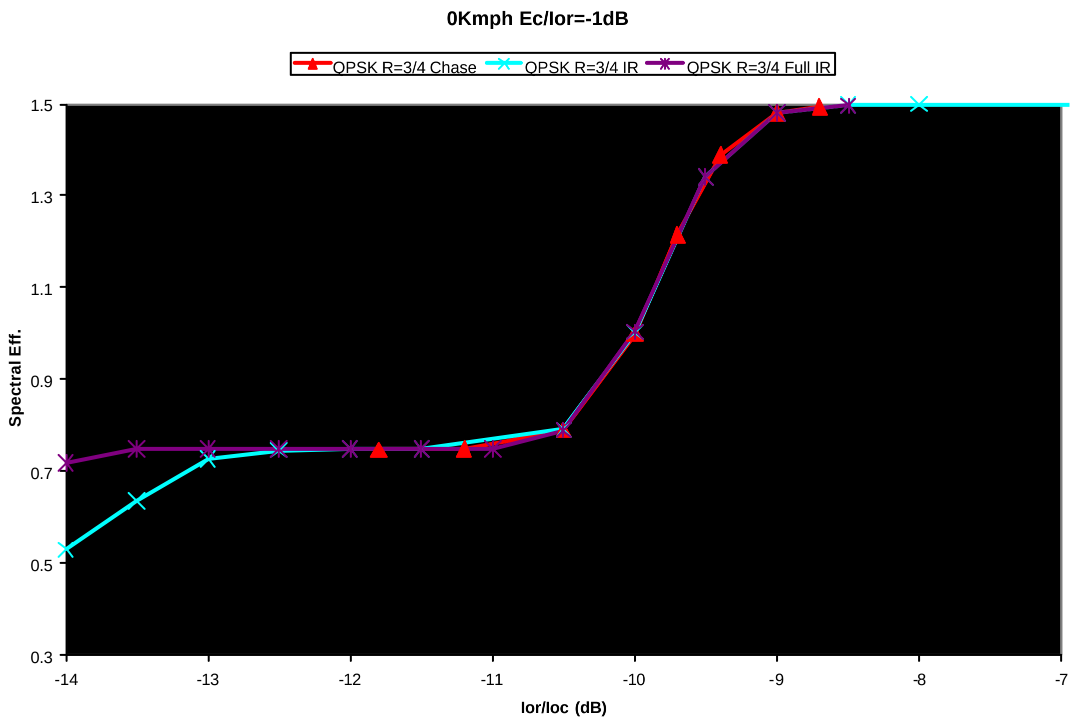

Figure 2. 0 Kmph QPSK

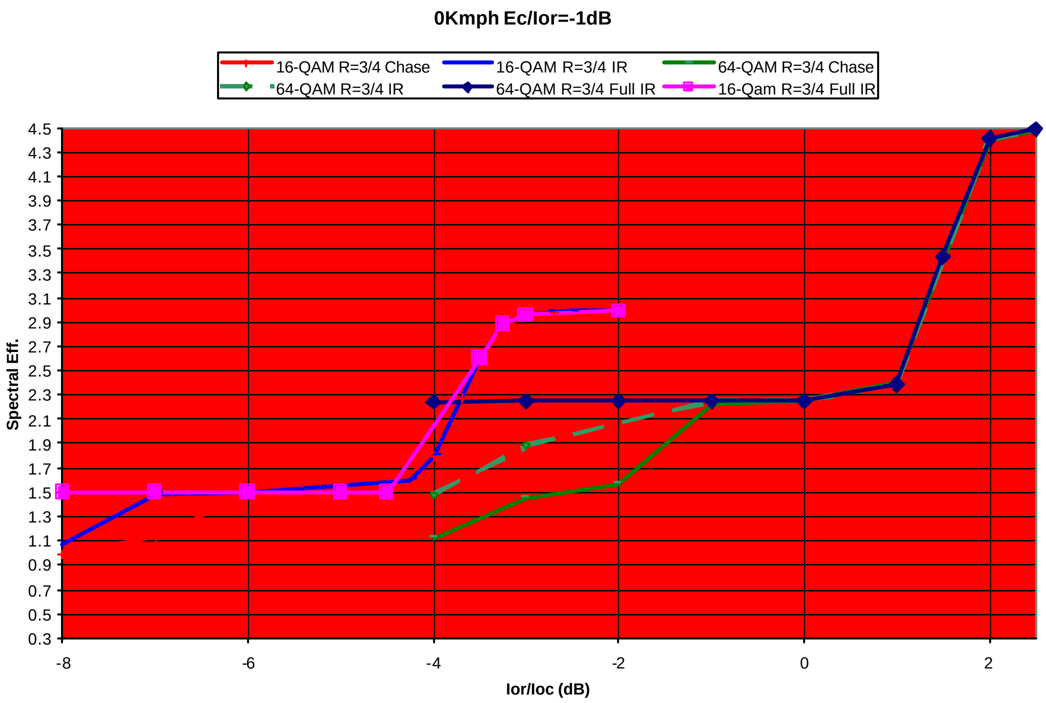

Figure 3. 0 Kmph 16/64-QAM

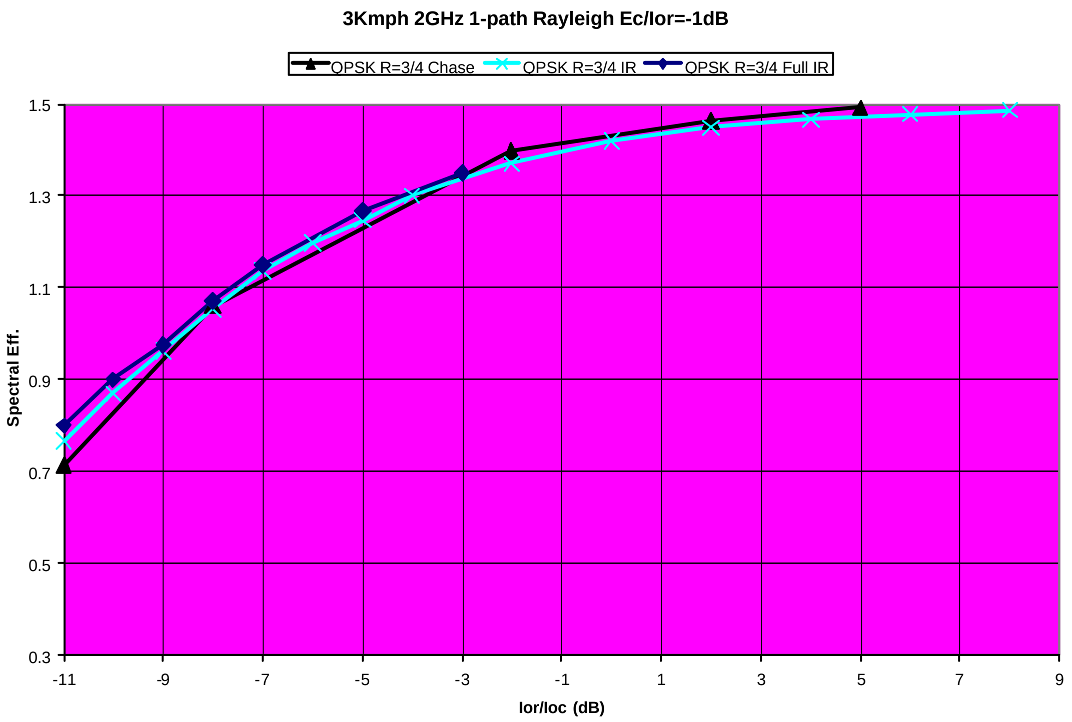

Figure 4. 3 Kmph QPSK

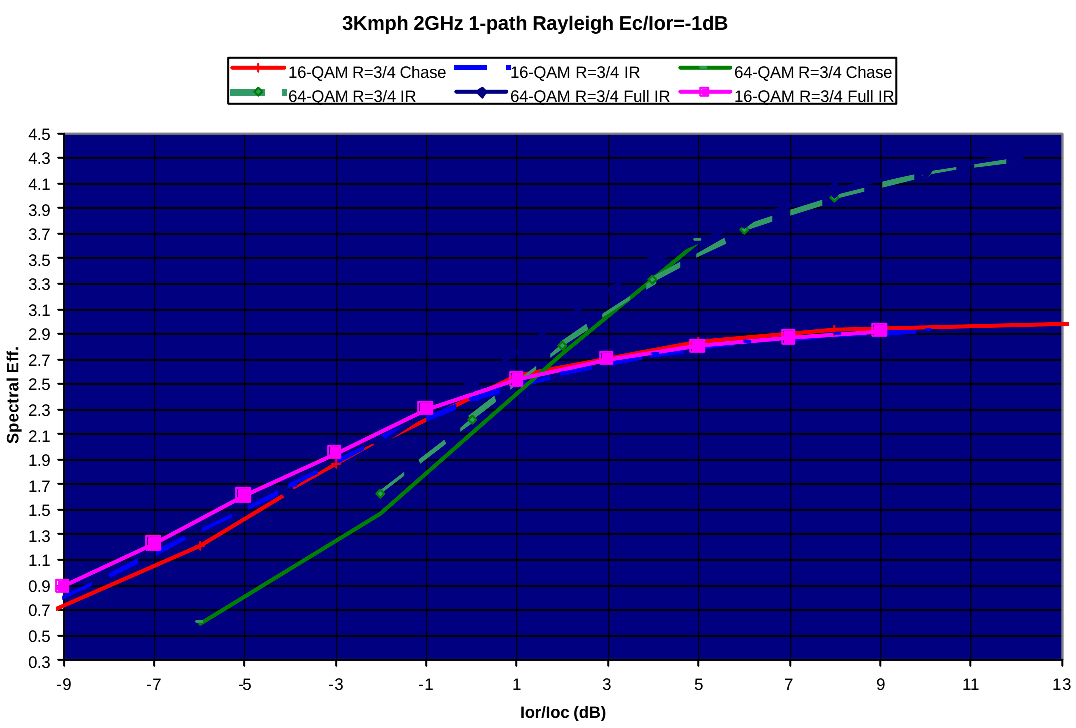

Figure 5. 3 Kmph 16/64-QAM

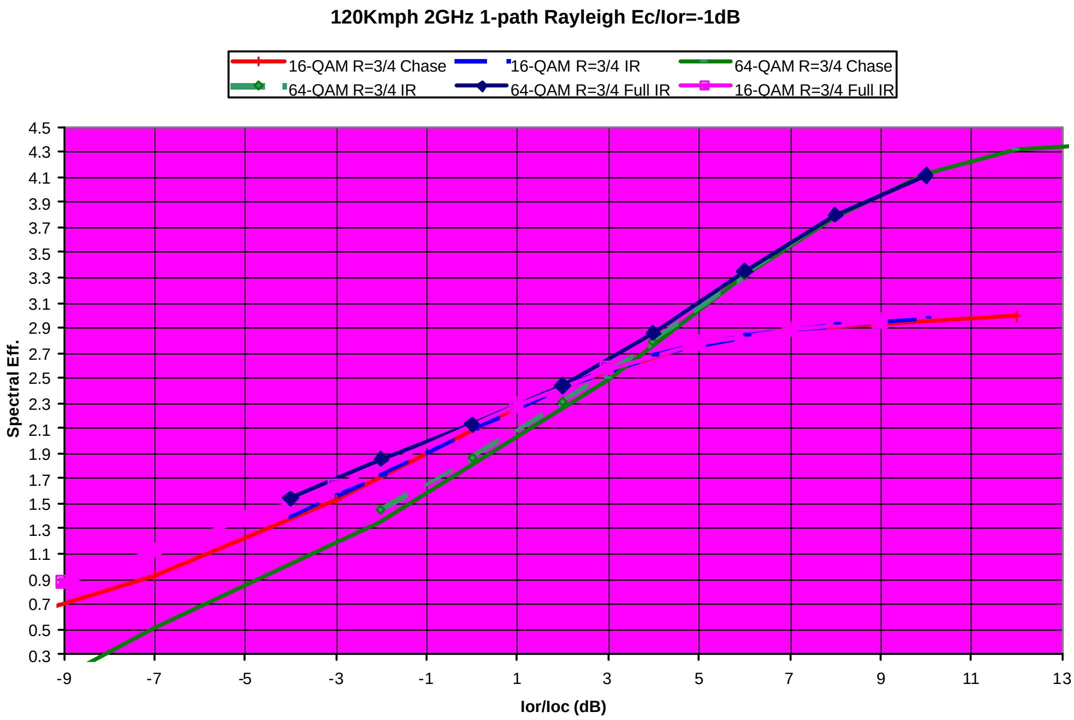

Figure 6. 120 Kmph 16/64-QAM

References

[1] Motorola, "Performance Comparison of Hybrid-ARQ schemes," TSGR1#18(00)1396.

[2] Ericsson, "Performance Comparison of Chase Combining and Incremental Redundancy for HSDPA," TSGR1#18(00)1428.

[3] D. Chase, "Code Combining: A maximum-likelihood decoding approach for combining an arbitrary number of noisy packets," *IEEE Trans. on Commun.*, Vol. 33, pp. 593-607, May, 1985.

[4] TSGR1#17(00)1348, "TR on HSDPA".