# DPC-based Hierarchical Broadcasting: Design and Implementation

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## Abstract

This paper discusses interference precancellation in digital hierarchical broadcasting. In particular, we present the principles and implementation of structured dirty paper coding (SDPC) that approaches the capacity limit of dirty paper coding in multi-layer broadcasting. As an alternative to Tomlinson-Harashima precoding (THP), the SDPC eliminates the significant performance loss suffered by THP in the low SNR regime due to the modulo operation. The key idea behind the SDPC scheme is the exploitation of the *modulation structure* of the interference, thereby simplifying the demodulation process in hierarchical reception. We examplify the SDPC technique by implementing a SDPC-based hierarchical broadcasting system on a real-time test bed. The experimental results show that the SDPC delivers the performance of 'superposition coding with successive interference cancellation' without extra computation or memory requirements at the receiver side.

# I. Introduction

In digital TV or other wireless/wireline broadcasting applications, users at different locations will experience different channel qualities and signal strengths [1]. Ideally, users with better signal should be able to receive more information (e.g., high-definition TV – HDTV) from the broadcasting source than those with lower signal strength (and therefore, only the basic program). Such can be achieved through the combination of source coding and hierarchical modulation.[2]-[5] The most commonly used hierarchical modulation scheme is the *hierarchical QAM*, where QPSK carrying the first data stream is combined with another QAM carrying the second data stream, forming a multi-level superposition code [6]. The first QAM modulation enables the basic program with relatively low reception threshold while the second QAM delivers additional information that can only be decoded at a higher reception threshold – see DVB-T for example [1].

While the hierarchical QAM is intuitively simple, it does suffer from some performance loss relative to regular QAM. The prime cause of the degradation is the cross interference between multiple data streams. In order to achieve the true channel capacity, superposition coding or *hierarchical QAM with successive cancellation* (*HQAM-SC*) must be employed to recover the loss in *hierarchical QAM with independent demodulation (HQAM-ID)*. This inevitably leads to an extra cost, sometime prohibitive, in both computation and memory at the receiver side.

Dirty paper coding (DPC) provides an intriguing alternative to receiver-end successive cancellation with interference pre-cancellation at the transmission side [7]. Based on the results from Costa's ground-breaking paper in 1983, the capacity of a power-constrained channel with a known interference is the same as the one without the interference. The hierarchical broadcasting situation can be precisely casted into a DPC framework where multiple data streams are characterized as *known* interference to each others. The significant advantage of DPC over superposition coding, especially in TV broadcasting, is that interference is pre-substracted at the transmitter. Therefore only independent decoding is needed to decoder different data streams.

A well-known practical DPC scheme is the Tomlinson-Harashima precoding (THP)[8][9] method. Unfortunately, THP has been shown to suffer from a 1.53dB shaping loss in high SNR regime [10]. In low SNR regime where broadcasting normally operates, the THP performance loss is even more significant, typically in the range of 4-5 dB [11]. The cause of this degradation is quantization (i.e., modulo operations) at the transmitter and the receiver. Several trellis precoding based algorithms have been developed to recover the losses of THP.[11][13]. While in principle these algorithms can be applied to hierarchical broadcasting, the added complexity makes them less desirable in broadcasting applications.

Motivated by the promises of DPC and hierarchical broadcasting, this paper discusses *DPC-based hierarchical broadcasting*. Our focus is on the design of low-cost, high-performance DPC techniques that can be used in practical broadcasting systems. In particular, we seek to develop low complexity approaches that can reduce or eliminate the modulo loss at low SNR. Towards this end, we observe that in most communication systems (e.g., wireless broadcasting and vector DSL), the interference structure is available to all receivers. Exploiting this known structure, we arrive at a new precoding algorithm (dubbed structure DPC - SDPC) that reduces the modulo loss without undue complexity. Unlike the prior work which assumes an *arbitrary* interference, the SDPC takes advantage of the QAM structure of the interference to achieve the DPC channel capacity with demodulation complexity similar to that of a regular QAM demodulator.

Another contribution of this paper is the realization of *SDPC-based HB* on a real-time test bed. The paper describes the implementation architecture of SDPC and practical aspects of the broadcasting system. The performance of the real-time system is shown to be within 2dB of the DPC AWGN capacity, with data rate up to 50Mbps on an FPGA test bed platform.

The rest of the paper is organized as follows. In Section II, we review the background and formulate the problem for broadcasting with known interference structure. The performance of DPC-based hierarchical broadcasting is compared with that of hierarchical QAM modulation. In Section III, the SDPC precoding strategy is described. In Section IV, the symbol error rate is analyzed and numerical results are presented. The SDPC test bed and its performance are introduced in Section V. Finally, a conclusion is drawn in Section VI.

## II. Dirty Paper Coding and Hierarchical Broadcasting

### *A. Dirty paper coding*

#### A.1 The principles

DPC was introduced by M. Costa in [7]. In Fig. 1, an AWGN channel is corrupted by an interference $s$, which is non-causally known at the transmitter. The source output $v$ is input to the precoder, whose output $x$ obeys the transmitter power constraint: $E|x|^2 \leq P_x$. The interference $s$ and the noise are assumed Gaussian i.i.d.. $P_n$ is the power of noise. Costa's result shows that the capacity of this channel is the same as if the interference were absent, i.e., $C_{DPC} = \frac{1}{2}\log(1 + \frac{P_x}{P_n})$.

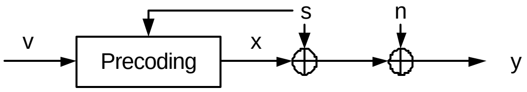


Fig. 1. Dirty paper coding

The above result has been extended by several researchers. In [12], it is shown that the same capacity can be achieved for arbitrary interference distribution. In [14], it is proven that the capacity still holds for arbitrary interference sequence, if a common random dither information is shared by transmitter and receiver.

### A.2 Implementation of DPC

In high SNR regime, DPC can be approximated by THP[14]. THP was originally introduced in the context of ISI channel [8][9]. The basic idea is illustrated in Fig 2. In particular, the system intends to send the message $v$ from the transmitter to the receiver through an AWGN channel, which is corrupted by interference $s$. The THP involves two stages. In the first stage, the interference $s$ is subtracted directly from the source $v$ to compensate the interference in the channel. However the power of $v - s$ may exceeds the transmitter power constraint. A modulo operator is applied to enforce the power constraints at the transmitter. At the receiver, another modulo operation is performed to recover the intended message $v$.

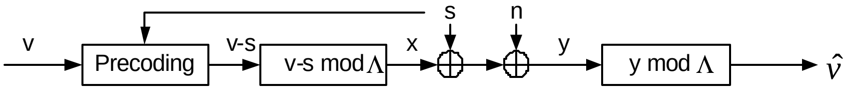


Fig. 2. DPC implementation with THP

Mathematically, the encoder sends

$$x = (v - s - u) \bmod \Lambda$$

and the receiver computes

$$\hat{v} = (y + u) \bmod \Lambda$$

$u$ is the common dither shared by the receiver and the transmitter and is uniformly distributed over $(-\frac{\Delta}{2}, \frac{\Delta}{2}]$. The dither ensures that the channel input $x$ has uniform distribution.

From Fig. 2, it is seen that

$$\begin{aligned} y &= x + s + n + u = (v - s - u) \bmod \Lambda + s + n \\ &= v + n - m\Lambda. \end{aligned}$$

where $m$ is an integer. Therefore we have

$$\hat{v} = y \bmod \Lambda = (v + n) \bmod \Lambda.$$

The quantizer $\Lambda$ is chosen to meet the power constraints without causing any ambiguity in $v$. In the absence of noise, the message $v$ can be fully recovered at the receiver. From the expression of $\hat{v}$, It is clear that quantization introduces extra noise in demodulation.

### A.3 Performance losses of THP

In [10], the capacity of THP channel is shown to be

$$\begin{aligned} I(\hat{v}; v) &= h(\hat{v}) - h(\hat{v}|v) \\ &= h((v + n) \bmod \Lambda) - h(n \bmod \Lambda) \end{aligned}$$

In other words, the capacity of THP channel is strictly less than the capacity of the corresponding DPC channel. In [16], the performance losses of THP are categorized into three classes: a shaping loss, a modulo loss and a power loss.

- *Shaping loss:* The shaping loss is incurred by the input shaping. Assuming the interference $s$ is large, the channel input $x$ will be uniformly distributed over $(-\frac{\Delta}{2}, \frac{\Delta}{2}]$ after the modulo operation at the transmitter. Since the channel input must be Gaussian distributed in order to achieve the AWGN channel capacity, the uniformly distributed channel input introduces shaping loss, which dominates the high SNR regime. The shaping loss of THP system is proven to be 1.53dB [13]-[15].
- *Power loss:* The power loss in THP is caused by the modulo operation at the transmitter. After the modulo operation, the channel input signal may have more power than the source. In [11], a partial-interference-presubtraction (PIP) approach is introduced to partially recover the power loss in low SNR regime.

- *Modulo loss:* The modulo loss is caused by the modulo operations at the THP system. Due to noise corruption, the signal at the boundary of the QAM constellation may be folded into the opposite side of the constellation, which incurs a potential error which would not have happened in regular AWGN channel. The modulo loss is significant for low order constellation in low SNR regime (up to 3–4dB). For the broadcasting applications of interest, the dominant loss is the modulo loss in low SNR regime.

In the ensuing sections, we describe the SDPC principles that eliminate the modulo loss. We focus our studies in low order constellations (BPSK, QPSK), since the high order QAMs cannot operate in low SNR regime.

### B. Hierarchical broadcasting

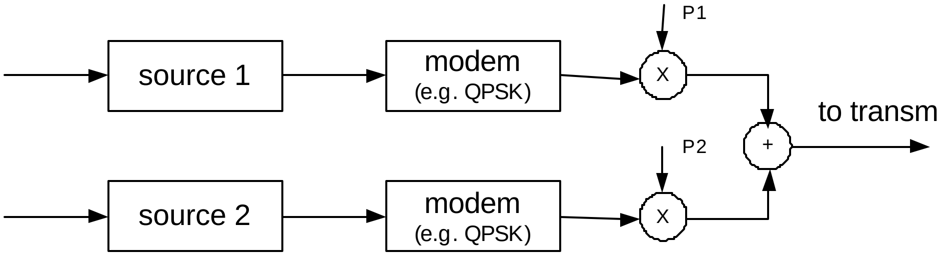


Fig. 3. Hierarchical modulation with two signal sources

Hierarchical QAM modulation is an effective means to deliver multiple layers of source information to users experiencing different channel qualities. Fig. 3 illustrates the existing approach for hierarchical multimedia delivery. The first data stream (source 1) is coded and modulated using QAM with power set to be $P_1$. Similarly the second data stream (source 2) is coded and QAM modulated in a separate branch with power $P_2$. The two modulated signals are then mixed before being transmitted. Clearly, the two modulated signals will interfere to each other, leading to certain performance loss at the receiver end.

A typical constellation of the hierarchical QAM signal is depicted in Figure 4. At the receiver side, a user with low signal strength simply demodulates the basic signal (source 1) while users with higher signal strength can demodulate both sources 1 and 2 from the constellation. In particular, the signal received at the user end is given by

$$u = P_1 s_1 + P_2 s_2 + v_1$$

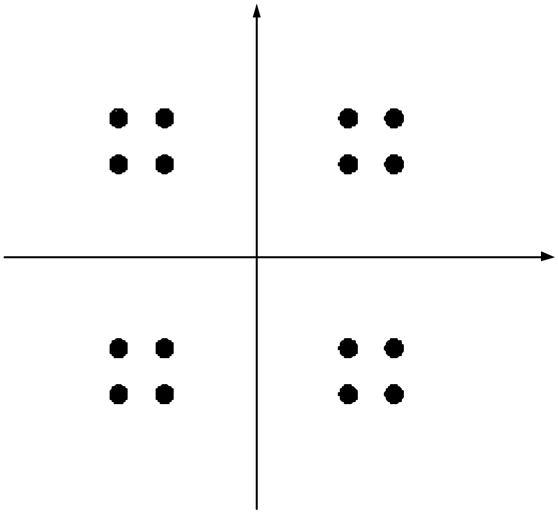


Fig. 4. Constellation of hierarchical QAM

where $v_1$ is the noise term. Based on the information theory, the achievable data rate of the first data stream is

$$R_1 = B \log \left(1 + \frac{P_1}{Bn_1 + P_2}\right)$$

where $B$ is the channel bandwidth and $n_1$ is the power spectrum density of the noise.

At a different location where the noise strength is weaker, the second data stream (with rate $R_2$ and a higher reception threshold) can be independently decoded

$$R_2 = B \log \left(1 + \frac{P_2}{Bn_2 + P_1}\right)$$

Note that in theory, $s_1$ can be decoded first and then subtracted from the received signal $u$ before $s_2$ is demodulated. With such successive decoding, a higher rate can be achieved for $s_2$:

$$R_{2,succ} = B \log \left(1 + \frac{P_2}{Bn_2}\right)$$

Unfortunately, the successive cancellation scheme requires higher computation complexity and a memory storage for the first data stream. In addition, a decoding delay will occur in $s_2$ demodulation. Such is often impractical given the large data block size and the high data rate in broadcasting.

### *C. DPC in hierarchical broadcasting*

The DPC principles can be readily applied to hierarchical broadcasting. With DPC, it is possible to jointly modulate multiple source signals at the transmitter to allow interference-free reception. Such a design places the computation burden at the transmitter and significantly lower the receiver cost at the user ends. Since data streams can be decoded independently, there will be no excessive memory requirement or decoding delay as in the case of successive demodulation. Specifically in this scheme, the first data stream $s_1$ is modulated with regular modem technique such as the QPSK. Instead of generating the second signal independently, the interference from the first data stream is pre-subtracted using the DPC technique as shown in Figure 5. Because of this operation, the second modulated data stream will suffer from no interference from $s_1$ when reaching a receiver. As a result, achievable data rate of the second stream is

$$R_{2,DPC} = B \log \left(1 + \frac{P_2}{Bn_2}\right)$$

which is identical to $R_{2,succ}$ with a much complicated successive receiver structure.

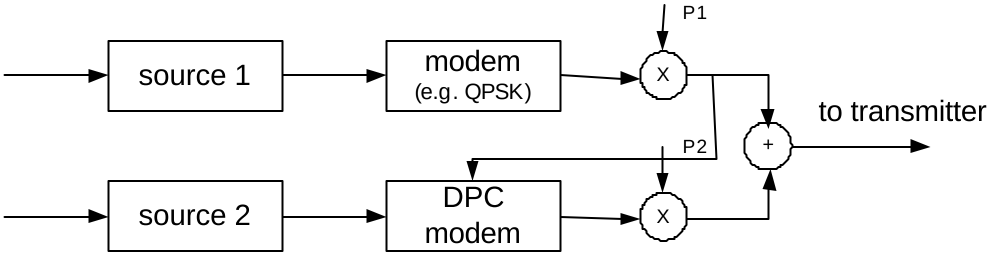


Fig. 5. DPC-based hierarchical modulation

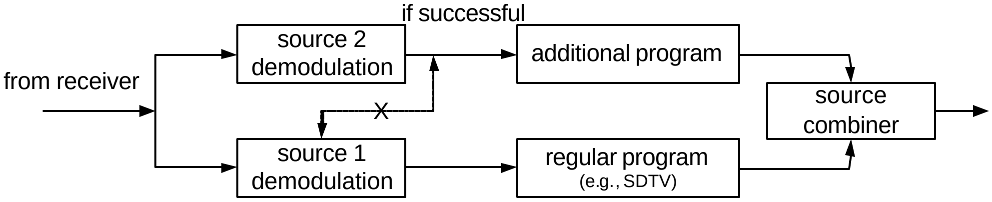


Fig. 6. Receiver structure of DPC-based hierarchical modulation

Figure 6 illustrates the simple receiver structure of the DPC-based HB scheme. Notice that the two data streams are decoded independently without interaction between the two demodulators. Consequently there is no decoding delay. In this particular setting, a low signal strength user will

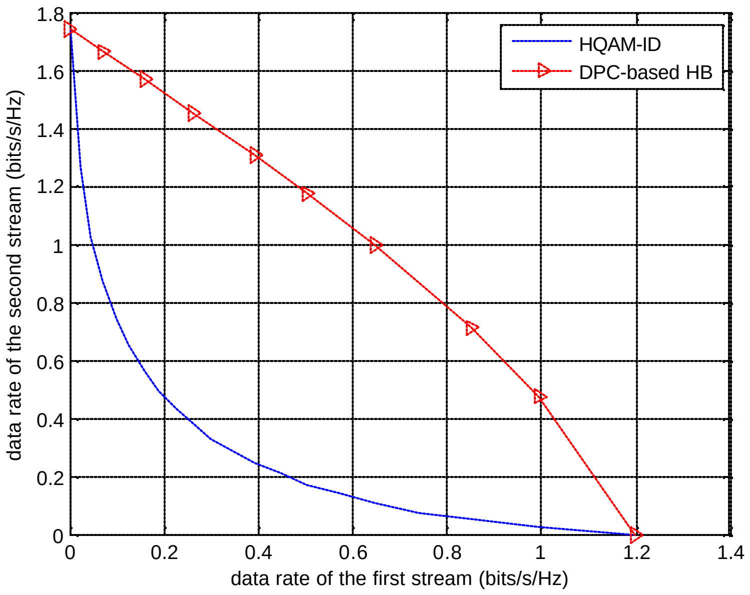


Fig. 7. DPC compared with the hierarchical modulation without successive cancellation at the receiver.

demodulate $s_1$ directly to receive the basic program. A high signal strength user can demodulate $s_2$ in addition to $s_1$. Depending on how the source is coded, the resulting signals can be combined to generate a higher quality program or simply sent to two separate sinks for display.

The achievable rates of HQAM-ID and DPC-based HB are compared in Fig. 7. In this illustration, we assume: $\frac{P}{n_1} = 10dB$, $\frac{P}{n_2} = 15dB$, and $P = P_1 + P_2$. With the data rate of the first stream fixed, the DPC-based HB has much higher data rate for the second stream than that of HQAM-ID at the receiver.

## III. Structured DPC

As mentioned in Section II.2, the THP implementation of DPC will suffer from a performance loss of 4-5 dB in low SNR regime [11]. A more efficient scheme must be developed in order to achieve the promise of DPC-based HB. In this section, we present a new approach (SDPC) that reduces or eliminates the modulo loss for pragmatic DPC implementation without undue complexity.

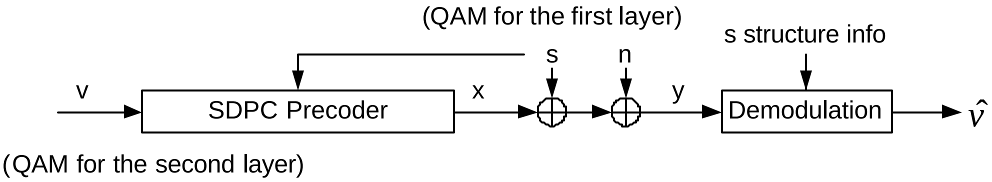


Fig. 8. DPC implementation with known interferer struture.

### *A. System model*

The SDPC is motivated by the following observation. In scenarios such as wireless broadcasting and vector DSL, the modulation schemes of each layer (for different users) are sent over a control channel. In other words, each user knows the modulation schemes of all the layers. For example in Fig. 1, $v$ is the second layer signal for user A while $s$ is actually the first layer signal for user B. It is reasonable to assume that user A knows the modulation scheme of the first layer signal intended for user B. We will show that this knowledge allows us to reduce (even eliminate in some cases) the modulo loss with proper precoding.

### *B. Precoding with known interference structure at receiver*

The THP receiver assumes no knowledge of the interference in demodulation. However, as shown in Fig. 1, if $s$ is a QAM interference, the receiver does have prior knowledge of the constellation of $y$. As a result, we may be able to demodulate $y$ according to its constellation instead of performing modulo operation on $y$ as in THP. At the same time, soft information can also be extracted as the input to subsequent channel decoding.

To understand this concept, notice that in THP system, the constellation of $y$ will be an expanded version of the constellation of $v$ due to the modulo operation at the transmitter. For example, if the signals in two layers are both BPSK modulated, the received signal $y$ has the constellation shown in Fig 9 (a). The system can be viewed as a 4PAM signal over an AWGN channel, which obviously has worse performance than that of the regular BPSK over the AWGN channel. The additional modulo operation at THP receiver will further degrade the performance since the noise is folded into the signal interval.

On the other hand, if we take advantage of the structure information of interference and design the precoder accordingly, a better $y$ constellation can be achieved: see Fig. 9 (b). At the receiver,

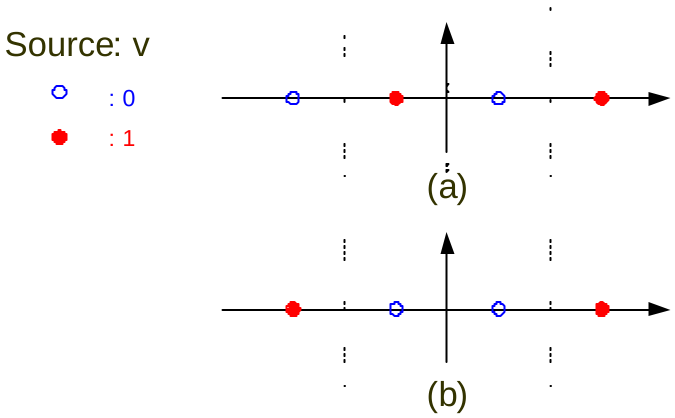


Fig. 9. The received constellation of $y$: (a) $y$ in the THP system; (b) $y$ in the SDPC system.

no modulo operation is necessary under this constellation. The received signal will be directly demodulated without noise enhancement. The decision regions are divided by the dashed lines in Fig. 9 (b). The resulting performance will be similar to the performance of a BPSK signal over AWGN channel. Such a mapping essentially eliminates the modulo loss. The same principle can be extended to other modulation schemes.

The exact operation of SDPC in QPSK is described below.

### B.1 Two users with QPSK constellation

Since only low-order constellations are feasible in low SNR regime, both signals are assumed to be QPSK. The different types of dots in Fig. 10 represent different source symbols at the receiver end. In THP, the received signal as in Fig. 10 (a) must be folded (modulo) into dashed box before performing detection. The SDPC scheme rearranges constellation through precoding so that direct region-based detection can be achieved:

i) *Precoding:* The precoder modulates 2-bit/symbol based on the following rule:

$$\begin{cases} x = v - s; & |v| > |s| \\ x = sign(s)(|2i \cdot v - |v||) - s; \quad i = \left\lfloor \frac{1}{2}\left(\frac{|s|}{|v|} + 1\right) \right\rfloor & , |v| \leq |s| \end{cases}$$

Here $|\cdot|$ denotes the amplitude and $\lfloor \cdot \rfloor$ is the floor operator. The precoding rule is applied to both dimensions of the QPSK signal. The power of $x$ is the average power of random signal: $\pm[2(i-1) \cdot |v| - |s|]$ and $\pm[2(i+1)|v| - |s|]$, which are bounded.

ii) *Decoding:* The decoder detects the 2-bit symbol based on the location of the received signal (relative to four decision regions). For $|v| > |s|$, the decision regions are the same as that of

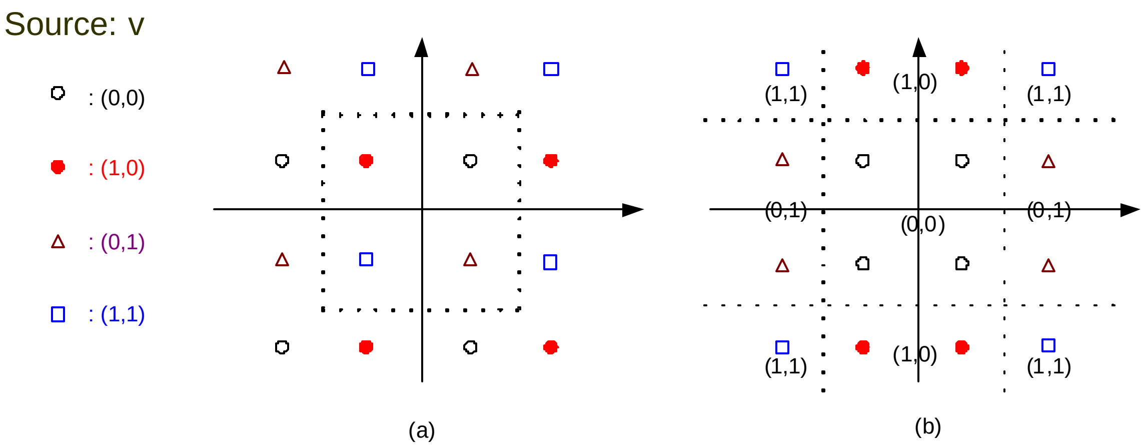


Fig. 10. (a) Constellation of $y$ in regular THP and (b) Constellation of $y$ for SDPC with QPSK source and interference.

the QPSK. For $|v| \leq |s|$, the four decision regions are asymmetric as illustrated in Fig. 10 (b). Nevertheless, a direct mapping from the source $v$ to $y$ can be established. By removing the *modulo operation*, the noise folded into the modulo interval around origin is eliminated.

It can be verified that the mapping shown in Fig. 10 (b) yields the best performance. As a matter of fact, its BER performance is comparable to that of QPSK with the same minimum distance.

## IV. PERFORMANCE ANALYSIS AND NUMERICAL RESULTS

In this section, we analyze the performance of the SDPC and present some numerical results.

### *A. BER performance*

First, we analyze the bit error rate (BER) of the SDPC scheme and compare it with the regular THP with dither.

For QPSK signals with Gray labelling, Fig. 10 (a) illustrates the received signal $y$'s constellation in THP system. As shown in Fig. 2, with the modulo operation on $y$ at the decoder, $\widehat{v}$'s constellation is composed of the dots inside the dashed box. Due to the modulo operation, each constellation point of $\widehat{v}$ has four nearest neighbors with corresponding Euclidean distance $2\sqrt{E_{b\_THP}}$, where $E_{b\_THP}$ is the average bit power of the THP precoded signal. Therefore the

BER of the THP is calculated as:

$$P_{THP} = 4 \times P_e/2 = \operatorname{erf} c\left(\sqrt{\frac{E_{b\_THP}}{N_0}}\right) \tag{1}$$

For the SDPC scheme, the $y$'s constellation is formed by four superpoints at different locations. The superpoints are marked with different labels in Fig. 10 (b). The decision region is separated by the dashed lines. It is clear that each dot has two nearest neighbors and the corresponding Euclidean distance is $2\sqrt{E_{b\_SDPC}}$. $E_{b\_THP}$ is the average bit power of the SDPC precoded signal. The BER of the SDPC is derived as:

$$P_{SDPC} = 2 \times P_e/2 = \frac{1}{2}\operatorname{erf} c\left(\sqrt{\frac{E_{b\_SDPC}}{N_0}}\right) \tag{2}$$

In absence of the interference, the BER of QPSK signal over AWGN channel is known to be

$$P_{AWGN} = 2 \times P_e/2 = \frac{1}{2}\operatorname{erf} c\left(\sqrt{\frac{E_{b\_AWGN}}{N_0}}\right) \tag{3}$$

Under the same transmitter power constraint, it is clear that

$$E_{b\_THP} \leq E_{b\_SDPC} \leq E_{b\_AWGN}$$

### *B. Numerical results*

Simulation studies have been conducted to validate the SDPC performance. In all simulations, the THP with MMSE scaling [17] is used as the baseline and $\alpha$ value is set at: $\frac{P_x}{P_x+P_N}$. In our setup, the source and interference are both QPSK signals and $|s| = 7.5|v|$. The SDPC has about 1dB power loss in this case. The results (theoretical vs. simulation) are shown in Fig. 11. As seen, the curves match the theoretical predictions in (1)-(3) very well.

We also studied the performance of SDPC with channel coding. A rate $1/2$ $(7, 5)$ turbo code is used with the log-map decoding algorithm. The results in Fig. 12 show that the SDPC has more than 3dB improvement over the regular THP (with dither) in low SNR regime. The performance loss compared with AWGN channel is less than 1dB, which is due to the power loss.

It is worth noting that the SDPC gain will diminish with large constellations - this is because the modulo loss is much smaller for high order constellations.

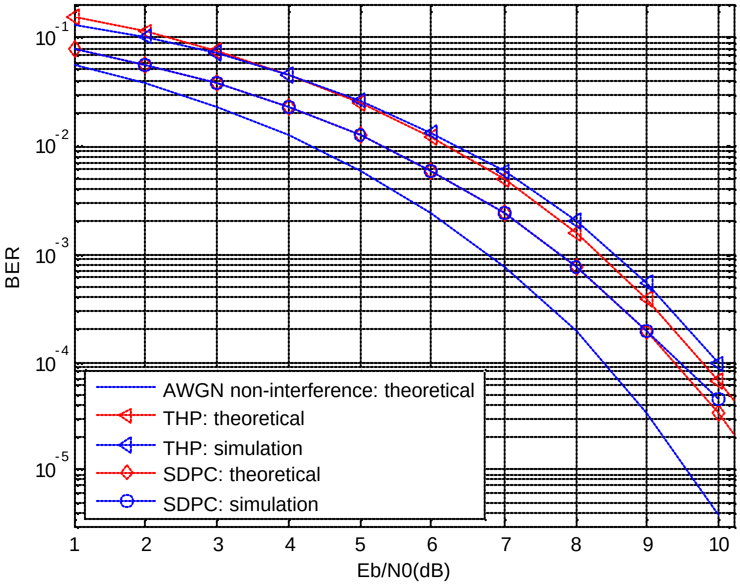


Fig. 11. BER vs. $Eb/N_0$ for QPSK source and interference signals

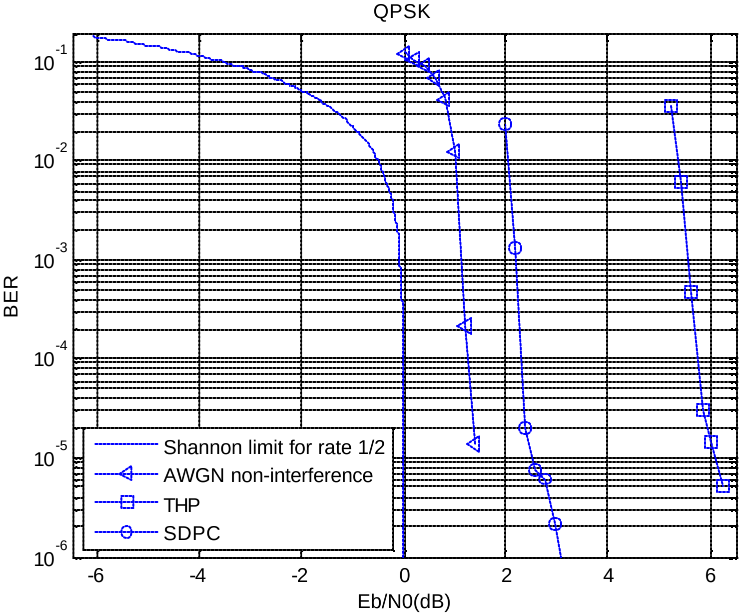
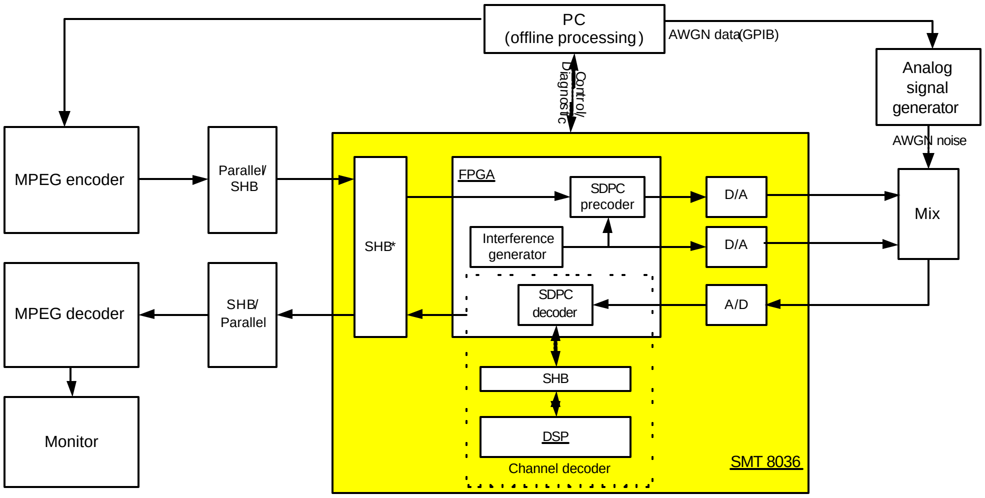


Fig. 12. BER vs. $Eb/N_0$ with rate 1/2 (7,5) turbo code for QPSK source and interference signals



*SHB: Sundance High-speed Bus connector

Fig. 13. The SDPC testbed diagram.

## V. SDPC IMPLEMENTATION

The principles of DPC-based hierarchical broadcasting is validated in real time at the wireless information technology (WIT) lab at University of Washington. We describe SDPC implementation on an FPGA-based test bed in this section.

### *A. Test bed description and decoder architecture*

The SDPC demo system is implemented on an SMT8036 development platform. The SMT8036 is a complete development suite, hosted on an SMT310Q PCI Carrier in a PC, for the evaluation of SMT365-4-2 and SMT370-AC modules. In particular, the SMT365-4-2 has a Xilinx virtex II-2000 FPGA and a TI-DSP TMS320C6416 in board. The Xilinx virtex II 2000 FPGA has about 2M system gates. The DSP runs at 600MHz system clock with 4800 peak MMACs.

The demo system diagram is shown in Fig. 13. The MPEG data stream is generated by a MPEG encoder, which resides in a PC. The MPEG data stream is fed into the SMT8036 platform through a parallel interface called Sundance High-speed Bus (SHB). In our demo, the data rate of the MPEG bit stream is set at 5Mbps.

Within the SMT8036 platform, the MPEG data stream is processed in the FPGA before transmission. The data stream is firstly channel encoded with a rate 1/2 (7, 5) turbo encoder.

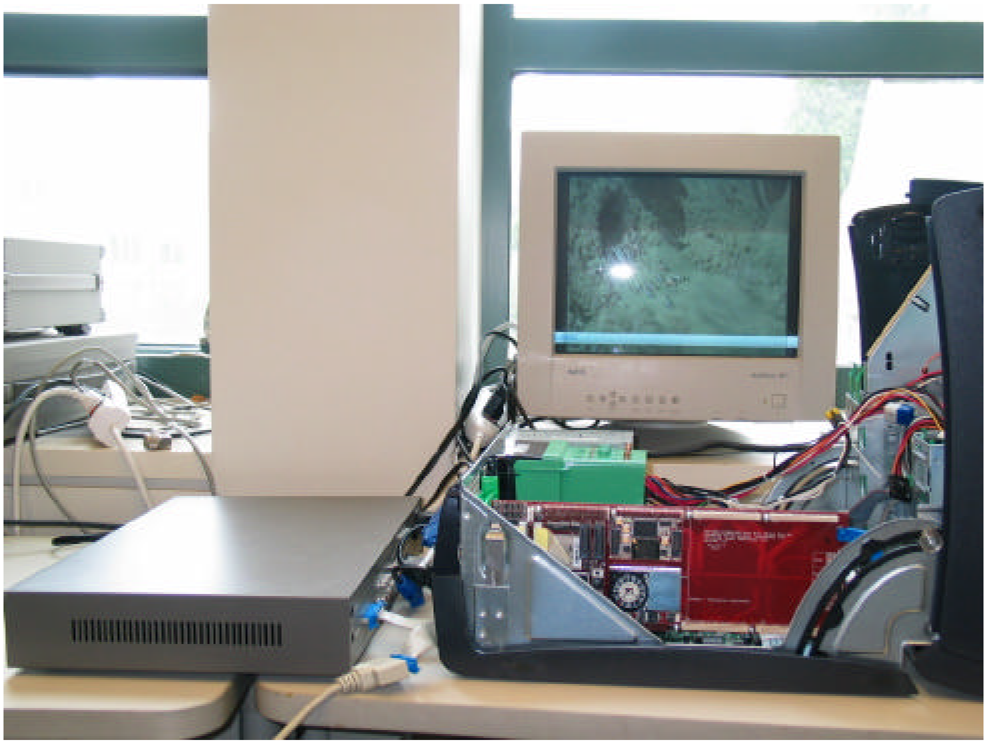


Fig. 14. The SDPC-based hierarchical broadcasting test bed

The SDPC precoder follows the channel encoder and the interference is a second coded MPEG source stored in the PC. For convenience, the interference bit rate matches the MPEG bit rate at 5Mbps.

The encoded signal and the interference are converted to IF signal centered at 70MHz. Then the SDPC encoded signal and the interference are mixed together before being looped back into the development platform. In the process, the signal is contaminated by AWGN noise.

At the receiver end, the base-band signal is sampled and then sent into the FPGA where the SDPC decoding is conducted. Afterwards, the data is transferred into DSP for channel decoding, where a turbo decoder with the log-map decoding algorithm is implemented. Finally the data is recovered and sent to a MPEG decoder. The video is displayed on a monitor. Fig. 14 is a snapshot of the demo system.

### *B. Implementation results*

The performance of SDPC-based HB, HQAM-ID and HQAM-SC are compared in our demo system. Since there is no difference in the demodulation for the first layer data stream, the comparison is based on the demodulation for the second layer data stream.

Given the available process power, the throughput of SDPC-based HB system can reach 50Mbps. The implementation loss is within 0.5dB relative to the simulation results. We compare the SDPC-based HB system and the HQAM-SC system on the same demo system. The HQAM-SC scheme requires a large data buffer for successive cancellation at the receiver end. In addition, since it must demodulate the interference (i.e., the first data stream) first for successive cancellation, the computation requirement is about twice relative to SDPC-HB. The maximum achievable data rate on the test bed is reduced to 25Mbps. The simple HQAM-ID scheme on the other hand, has significant higher reception threshold compared to the SDPC-base HB and the HQAM-SC.

Table 1 highlights the system and performance parameters of three schemes. We choose a typical DVB-T setup [18] (the 2K mode) where both the first layer and the second layer data are QPSK modulated. For both layers, the inner code is a rate 1/2 convolutional code and the outer code is a Reed-solomon code (204 188). The code block size is 3264 bits. The max throughput is the data rate allowed by the demo system hardware. HQAM-SC has an approximate $2.7ms$ delay and requires $6K\ bytes$ buffer (assuming wordlength of 16bits) at the receiver side.

| | HQAM-ID | HQAM-SC | DPC-based HB |
|---|---|---|---|
| Max Throughput | $50Mbps$ | $< 25Mbps$ | $50Mbps$ |
| Delay | / | $\approx 2.7ms$ | / |
| Data Memory | / | $\approx 6K\ bytes$ | / |
| required $E_b/N_0$ | $4.5dB$ | $2.2dB$ | $2.2dB$ |

Table 1. System and performance comparison.

## VI. CONCLUSIONS

In this paper, we have studied low cost DPC schemes for hierarchical broadcasting applications. For DPC implementation, the traditional THP approach suffers from a 3-4 dB modulo + power loss which makes it unsuitable for hierarchical broadcasting with low-order constellations. The proposed SDPC method recovers most of the modulo loss without added complexity at the receiver side. In QPSK cases investigated, the SDPC achieves 2-4 dB improvement over regular THP (with dither). We have realized a real-time SDPC-based hierarchical broadcasting prototype which achieves the performance of HQAM-SC, but with much lower complexity and no extra buffer requirement.

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