

Research Article

On the Performance of Self-Concatenated Coding for Wireless Mobile Video Transmission Using DSTS-SP-Assisted Smart Antenna System

Nasru Minallah ¹, Ishtiaque Ahmed,² Muhammad Ijaz ³, Atif Sardar Khan,¹ Laiq Hasan,¹ and Atiqur Rehman ³

¹Department of Computer Systems Engineering, University of Engineering and Technology Peshawar, Peshawar 25000, Pakistan

²National Centre in Big Data and Cloud Computing, University of Engineering and Technology Peshawar (NCBC-UETP), Peshawar 25000, Pakistan

³Division of Information and Computing Technology, College of Science and Engineering, Hamad Bin Khalifa University, Doha, Qatar

Correspondence should be addressed to Muhammad Ijaz; mijaz@hbku.edu.qa

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In the current age of advanced technologies, there is an escalating demand for reliable wireless systems, catering to the high data rates of mobile multimedia applications. This article presents a novel approach to the concept of Self-Concatenated Convolutional Coding (SECCC) with Sphere Packing (SP) modulation via Differential Space-Time Spreading- (DSTS-) based smart antennas. The two transmitters provide transmit diversity which is capable of recuperating the signal from the effects of fading, even with a single receiving antenna. The proposed DSTS-SP SECCC scheme is probed for the Rayleigh fading channel. The SECCC structure is developed using the Recursive Systematic Convolutional (RSC) code with the aid of an interleaver. Interleaving generates randomness in exchange for extrinsic information between the constituent decoders. Iterative decoding is invoked at the receiving side to enhance the output performance by attaining fruitful convergence. The convergence behaviour of the proposed system is investigated using EXtrinsic Information Transfer (EXIT) curves. The performance of the proposed system is ascertained with the H.264 standard video codec. The perceived video quality of DSTS-SP SECCC is found to be significantly better than that of the DSTS-SP RSC. To be more precise, the proposed DSTS-SP SECCC system exhibits an E_b/N_0 gain of 8 dB at the PSNR degradation point of 1 dB, relative to the equivalent rate DSTS-SP RSC. Similarly, an E_b/N_0 gain of 10 dB exists for the DSTS-SP SECCC system at 1 dB degradation point when compared with the SECCC scheme dispensing with the DSTS-SP approach.

1. Introduction

The recent developments in wireless technologies have resulted in the expansion of higher data rates of cellular systems with diverse applications, severely limiting the available bandwidth [1]. The existing wireless communication systems provide a backbone for the hugely utilized internet in the present era. It is estimated that the evolution of next-generation

applications and the advancements in the Internet of Things (IoTs) will remarkably add to the increasing data capacity needs by 30-40% per year [2]. The fifth-generation (5G) wireless technology has very specific aims of further increasing the data rate and catering for the ascents in wireless services, by efficient utilization of the available bandwidth [3].

Ever since the pioneering work of Shannon in 1948 [4], researchers started investing efforts to design fast, efficient,

and high-quality transceivers attaining high bit-rate communication with the least Bit-Error Rate (BER). Standing on the shoulders of giants, researchers and scientists paved the way for wireless and digital communication. In a typical wireless communication model, transmission of voice, image, video, or any other type of multimedia content is assisted by the source and channel coding techniques. In order to successfully transmit information, a reliable and an efficient communication system is needed. The information from any source is forwarded to the transmitter for its operation and conversion into the transmission signal. The signal is then disseminated with the aid of a transmitting antenna, such that it propagates through the channel. It should be noted that the effects of the channel are mostly not beneficial for the signal. The channel offers several impingements, such as addition of noise, interference, and fading, leading to error formation and reduction in the system's performance. These effects are mitigated at the receiver side, resulting in reliable data transfer to the destination for end users.

In the recent proliferation of multimedia services, source coding has become an important topic for researchers to delve into. The main purpose of source coding is to compress the original data meant to be transmitted via wireless technology. Multimedia data are extensively compressed with the help of source coding techniques. Hence, several video coding techniques were put forward by scientists, for encoding different types of multimedia content. Most of the video coding techniques deploy the hybrid coding mechanism [5]. Hybrid coding makes use of the transform coding with motion-compensated prediction. In this treatise, we will be considering the Advanced Video Coding (AVC) standard, also referred to as H.264 video codec, as our source coding technique. H.264 is considered to be the best standard for achieving the requirements of fast next-generation efficient and ubiquitous communication [6]. The reliable transmission of multimedia contents becomes a very demanding task when dealing with high-compression and efficient multimedia standards. Due to the employment of hybrid and compression efficient techniques, error propagation occurs in the standard video stream [7]. Therefore, there must be a way forward to tackle such errors. One popular channel coding technique, known as Forward Error Correction (FEC), is very much beneficial to protect the compressed stream from errors. Hence, it is plausible that for reliable transmission of multimedia contents over nonideal channels, it is necessary to perform source coding and channel coding [7–9]. With this, the terminology of Joint Source-Channel Decoding (JSCD) is coined, as explained for H.264 in [10]. The reason for the large use of the H.264 standard lies in the fact that some of its intriguing features are so favourable that they are retained in the modern standards as well [11].

It is very much clear from the discussion above that channel coding is an integral part of the wireless communication paradigm. The inimical effects of the addition of noise, signal distortion, interferences, and fading render wireless communication more prone to unreliability than wireline communication [12]. To overcome the errors and hence to decrease the BER, the idea of redundancy was introduced [4]. The operation of redundancy incorporates additional (parity) bits

before the data is transmitted, making it possible to detect and tackle any arising error and mismatch at the receiver. This recovery process greatly improves the performance of a wireless system by reducing the BER [13]. The overall process of incorporating redundancy is termed as Shannon Coding, which is elucidated in [4]. Different channel coding techniques have been presented and implemented in the recent years. Some of them include optimal code design for enhanced performance and security [14] and optical orthogonal coding for cable communication [15] and for the wireless scenario including Hamming codes [16–18], Polar codes [19], and Bose-Chaudhuri-Hocquenghem (BCH) and convolutional codes [20]. There is a capacity associated with each type of channel. The maximum throughput at which any channel can reliably and correctly transmit information to the receiver is called channel capacity. The popular Shannon capacity is attributed to the great work presented by the father of information theory, Claude Shannon, in [4]. Many researchers persistently continued to hone their findings, resulting in the feasible designs of systems approaching Shannon's capacity limit [21–23].

Forney presented the concept of concatenated coding [24], though not given much attention by researchers in the early days. Soon after the proposition of turbo codes, based on the concatenated convolutional philosophy [25], scientists avidly started to peruse the concepts of concatenated coding. In [26], the three main categories of concatenated coding are discussed. These include the Parallel Concatenated Convolutional (PCC), Serial Concatenated Convolutional (SCC), and Self-Concatenated Convolutional (SeCC) codes. The constituent encoders in a PCC coding are linked in a parallel fashion, mutually sharing information via an interleaver (Π). In SCC coding, the N number of component encoders is serially interconnected with the help of $N - 1$ interleavers. Finally, the only encoder of SeCC coding requires the functionality of an interleaver to convert the input data to an interleaved version and simultaneously feeding to the encoder. For the convolutional codes, it is worthy to mention that they are vastly adopted in modern wireless standards and satellite communications. These intuitive codes are covered in detail in [27], and several decoding approaches for such codes are mathematically discussed in [28, 29].

Moving to the advanced topic of Differential Space-Time Spreading (DSTS), we briefly discuss how they evolved. Space-Time Block Codes (STBCs) constitute an important family of Multiple-Input Multiple-Output (MIMO) systems. STBC offers a simpler approach to encoding and spreading with reasonably good performance [30, 31]. Inspired by the concept of STBC, authors in [32] proposed Space-Time Spreading (STS). The technique of coherent detection was common in all of the STBCs and STS systems. For coherent detection to be possible, there is a stringent requirement of accurate and complete channel knowledge at the receiving side. This Channel State Information (CSI) renders the system more complex and expensive. In quest of efficient systems, yet mitigating the complex requirements of CSI, Tarokh et al. proposed Differential Space-Time Block Coding (DSTBC) using two transmitters, later demonstrated for a larger number of transmitters as well [33, 34]. The aim of

low-complexity system design was achieved, although the only snag was a little performance loss. The DSTS technique can be integrated with several modulation schemes like Phase-Shift Keying (PSK), Quadrature Amplitude Modulation (QAM), and Sphere Packing (SP), requiring no channel estimation [35]. SP modulation is widely becoming popular in the construction of error correction codes. Su et al. introduced the merger of transmit diversity techniques with SP modulation, evincing that the SP-aided STBC surpassed in performance the conventional STBC counterpart [35]. Minimum Euclidean distance was deemed to be an appropriate metric for evaluating the attainable gain of orthogonal transmit diversity schemes [35]. SP modulation assures the best possible minimum Euclidean distance between the modulated symbols and enhances the error resilience property of the system. Regarding Euclidean distance, it is simply the length of a straight line between any two points in the Euclidean space. The DSTS-SP approach was adopted by several authors to attain prolific performance in turbo detection [35], cooperative communication [36], adaptive multirate wideband speech coding [37], and iteratively decoded irregular variable length coding [38]. Until now, the literature has been silent on the incorporation of DSTS-SP in SeCC codes. As SeCC coding offers significant performance with little complexity, hence, further exploration needs to be carried out in this regard.

Keeping in view the above background, we aim to introduce a novel methodology of Self-Concatenated Convolutional Coding (SECCC), with iteratively detected SP modulation-assisted DSTS-based smart antennas. This article is somehow an extension of the work presented in [8]. We build upon the system proposed in [8] such that the beneficial feature of DSTS-SP is incorporated for an enhanced performance. The iteratively decoded DSTS-SP SECCC proposition will be analyzed via the EXtrinsic Information Transfer (EXIT) chart curves. The rationale of the research work presented in this article is summarized as follows:

- (i) Introduction to the novel concept of DSTS-SP SECCC and its performance comparison with other schemes
- (ii) Utilization of the double antennas for the sake of attaining a rich transmit diversity gain, supporting profitable performance using a simple receiving antenna requiring no CSI
- (iii) Provision to the understanding of video performance of the proposed system using the H.264/AVC standard

The rest of the paper is organized as follows. The proposed DSTS-SP SECCC system is made plain in Section 2. Further description of the proposed system and parameter settings follow in Section 3. Section 4 presents the EXIT chart analysis and highlights some of the linked terminologies used in this expedition. Section 5 articulately covers the simulation results. Finally, Section 6 succinctly concludes the paper with future research description.

2. DSTS-SP SECCC System Overview

The block diagram of the proposed system is depicted in Figure 1. It can be seen that the information bits are initially passed through the block of source coding, employing H.264/AVC. The technique of slice structuring is adopted, resulting in the partitioning of each video frame into independently coded multiple slices. Furthermore, we have also subsumed the approach of Data Partitioning (DP). DP helps in generating different streams of the source coded video per slice, on the basis of important coding elements and parameters. We arrange each type of stream with several occurrences in each frame and concatenate the three resultant partitions, represented as A, B, and C into a single stream x_i . The overall source coding operation compresses the data and might put a contrary effect on the reliability of the original data. For this, channel coding block serves the purpose. The SECCC channel encoder is used in our designed system. Modulation is done with the aid of SP to shift the spectrum of channel coded signal to a form suitable for wireless transmission over the Rayleigh channel. Transmission of a signal over wireless or radio channel is often associated with reflection, diffraction, and scattering experiences. One of the effects produced as a result of these experiences is the multipath phenomenon [39]. Due to the multipath effect, the transmitted signal splits into multiple versions based on the power and fading distributions. Therefore, it becomes crucial to precisely predict the channel model for wireless systems [39]. The Rayleigh fading channel is deemed to be a useful propagation channel in the scenario of a multipath environment for wireless systems [40]. The Rayleigh probability density function is given by

$$p(r) = \frac{r}{\sigma^2} e^{-r^2/2\sigma^2}, \quad r \geq 0. \quad (1)$$

Here, $\sigma^2 = E[r^2]$ is the variance of the circularly symmetric complex random variable r , having real and imaginary parts. The term $E[*]$ denotes statistical averaging. The SP modulated signal is passed through the DSTS block for incorporating the beneficial feature of transmit diversity gain and transmitted via two transmit antennas (Tx). At the receiving side, we consider the use of one receive antenna (Rx1) for the sake of simplicity and without any loss of generality. The received signal is passed through the DSTS decoder, and then, it is demodulated back to its original form. It is notable that the DSTS decoder is a suboptimum one, operating with a simpler way of accepting successively received interdependent signals. The potential discrepancy in the receiving data is detected and overcome by the SECCC decoder. The schematics of the SECCC decoder are explained below. The resultant $L(y_i)$ signal is processed by the SECCC decoder to yield the overall reconstructed signal, which is deconcatenated and then MULTiplexed (MUX). Eventually, the source decoder outputs the bits to end users.

The architectural design of the DSTS encoder is illustrated in Figure 2. Its major subcomponent blocks are the differential encoder and STS encoder. The modulated signal is differentially encoded till the refined output q is ready to be

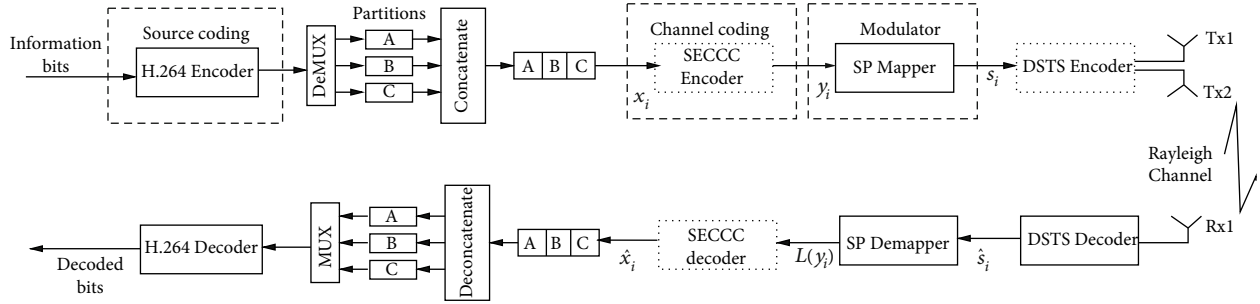


FIGURE 1: Block diagram of the DSTS-SP SECCC system.

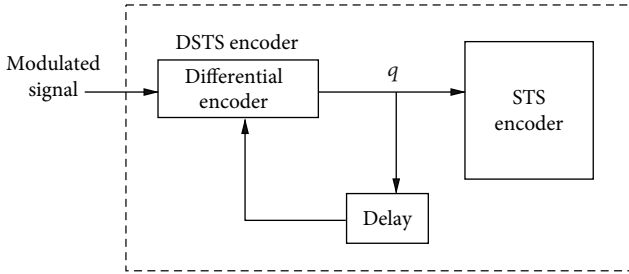


FIGURE 2: The DSTS encoder structure.

provided to the STS encoder. There is a delay component between the differential and STS encoders. This delay is usually provided by the interleaver. The reason for introducing this delay component is to make the output q from the differential encoder highly uncorrelated and differential. The simultaneous feedback to the differential encoder is invoked till the set value of delay, attaining enhanced q . The STS encoder spreads the data via the technique of Walsh codes. Walsh coding renders the overall process of encoding and resultant code longer, providing lower throughput per antenna. The differentially spread data is divided into two substreams, each transmitted via a separate antenna. These antennas with certain transmit power values assist the final signal to propel over the channel.

Moving to the details about SECCC, the various stages involved are highlighted in Figure 3. SECCC is somehow similar to PCC coding in the sense that constituent encoders of PCC are replaced with a single code, involving an even-odd number of interleavers, as specified in [41]. The intriguing feature of SECCC is the simplicity of its structure. SECCC systems essentially contain a single encoder and decoder as shown in Figure 3. The SECCC encoder maneuvers by accepting the source coded bits and simultaneously converts them to interleaved bits. The interleaver makes the bits profusely uncorrelated. The Parallel-to-Serial (P/S) converter receives both the direct source coded stream x_i and its interleaved version x'_i . The serial output is fed to rate R_1 RSC encoder via the Generator Polynomial (GP) of $(G_0, G_1, G_2 = 13, 15, 17)_8$, represented in octal format, where the first term G_0 represents the feedback polynomial [42]. Generally, the number of bits get increased due to the RSC

encoding. After the RSC encoding stage, there is an interleaver to randomize the encoded bits. The next stage is of puncturing at rate R_2 . In order to maximize the bandwidth efficiency, puncturer obliterates some bits from transmission. For instance, a rate a/b puncturer will stop $b - a$ bits from transmission. Resultantly, the number of bits gets reduced after the puncturer. It is obvious that by a mere alteration in the values of R_1 and R_2 , various rates of SECCC could be invoked. For the present case, we will be using the values of R_1 and R_2 to be $1/2$ each. Finally, the overall rate R of the SECCC encoder is as given in [43] and computes to $1/2$ for the specified values of R_1 and R_2 :

$$R = \frac{R_1}{2 * R_2}. \quad (2)$$

The SECCC decoder consists of a single SISO Maximum *A Posteriori* (MAP) decoder. The MAP decoder is hypothetically divided into two component decoders, for better understanding of the exchange of extrinsic information. The output from the SP demapper is fed to the depuncturer, inserting zeros (if required) in the places of bits which were punctured. The two component decoders mutually share soft extrinsic information until the specified number of iterations. With the help of interleavers and deinterleavers, the output knowledge of the one component decoder is presented as *a priori* input to the other component decoder. The two hypothetical component decoders iterate until there is no further improvement attainable after feedback. Upon reaching this point, the maximum iterative performance gain is achieved, and it is known as the point of convergence. In view of the two component decoders, the single SECCC decoder can be viewed as a PCC decoder. This way, the iterations are also self-iterations of the MAP decoder. Lastly, the output bits from the SECCC decoder are Serial-to-Parallel (S/P) converted and forwarded to the source decoder accordingly.

3. Proposed System Description

The proposed design is simulated using the IT++ signal processing and communication library. The results were generated using the parametric setting as stated in Table 1. The constituent inner and outer rates of the error protection schemes are stated in Table 2. It should be noted that in the precursor paper [8], we utilized the RSC-coded

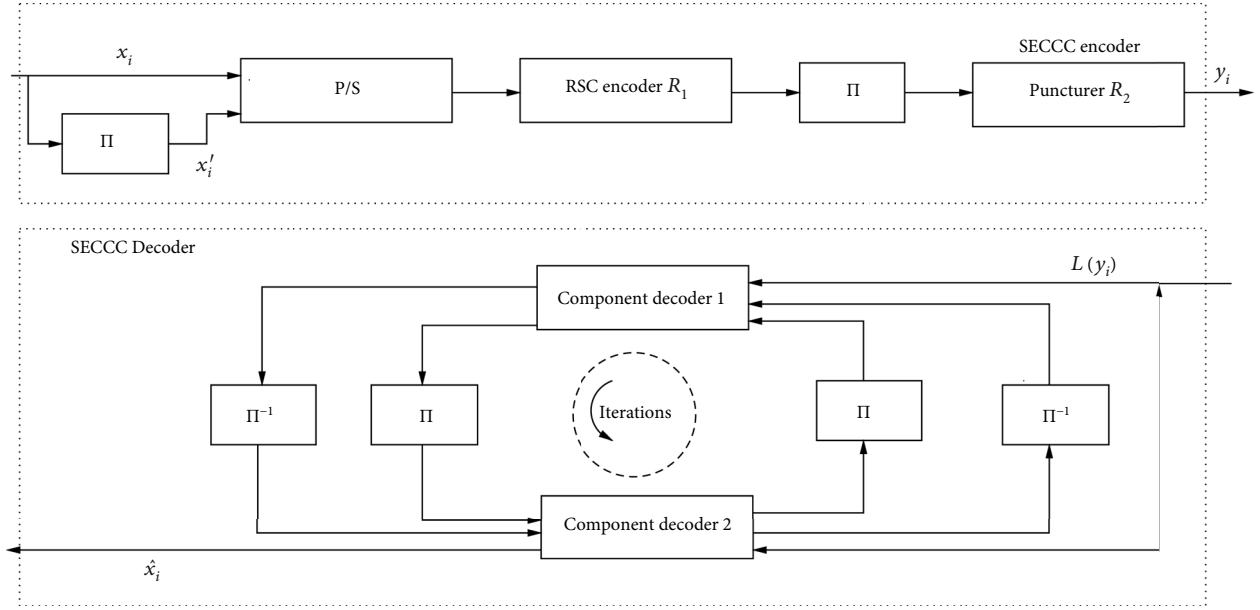


FIGURE 3: Block diagram of SECCC using iterative decoding.

TABLE 1: DSTS-SP SECCC system parameters.

Parameters	Value	Parameters	Value
Source code	H.264/AVC	Channel	Rayleigh fading
Source bit-rate	64 kbps	Tx antennas	2
Video sequence	QCIF <i>Akiyo</i>	Rx antennas	1
Frame rate	15 fps	RSC generator	$(G_0, G_1, G_2 = 13, 15, 17)_8$
Slices per frame	9	Interleaving bits	10000
Number of MBs per slice	11	Normalised Doppler frequency	0.01
Intraframe MB update	3	Modulation scheme	SP
MIMO scheme	DSTS	Spreading code	Walsh code

TABLE 2: Inner and outer rates of the error protection schemes.

Error protection scheme	Outer code	Rate Inner code	Overall
DSTS-SP SECCC	$R_1 = 1/2$ RSC	$R_2 = 1/2$ puncturer	$R = \frac{1}{2}$
DSTS-SP RSC	$RSC = \frac{1}{4}$	$Puncturer = \frac{1}{2}$	$R = \frac{1}{2}$
SECCC scheme of [8]	$R_1 = 1/2$ RSC	$R_2 = 1/2$ puncturer	$R = \frac{1}{2}$

benchmarker. But for the work presented here, we will be employing the DSTS-SP RSC and SECCC scheme dispensing with the DSTS-SP for comparison. The SECCC scheme of [8] employs QPSK modulation whereas the other schemes of Table 2 use the DSTS-SP transmission mechanism. The Quarter Common Intermediate Format (QCIF) *Akiyo* sequence in (176×144) pixels or 99 Macroblocks (MBs) each of size (16×16) -pixel resolution using the H.264 encoder at

64 kbps and 15 frames-per-second (fps) is deployed. The 99 MBs per frame improve the efficiency of the iterative decoding and reinforce the use of longer interleavers, without causing any unnecessary delay in the system. To counterbalance the effect of error propagation, the approach of intraframe coded MB updates and predicted “P” frames is employed. Hence, there are 3 intraframe MBs per QCIF frame and 44 “P” frames after each intra “I” frame, with a time lag of 3 seconds between two successive “I” frames. Furthermore, the complexity of the source encoder is kept realistic by avoiding the bidirectionally predicted frames and turning off the robust Flexible MB Ordering (FMO). FMO offers a small advantage in low-motion sequences, although the computational complexity increases by many folds [44].

With the intention of boosting confidence in our results, the 45-frame video sequence test is repeated 250 times with 26 system iterations, and the average value is used in the results. The technique of Walsh coding is utilized as a spreading code. Walsh codes are specifically employed to enhance BER performance with relatively lower computational

complexity [45]. The Signal-to-Noise Ratio (SNR) of the system improves greatly as the length of the Walsh code is increased, but the flip side is a reduction in data rates [46]. For higher rates, the transmitter is allocated with a large number of codes [45]. Walsh functions form the basis of such codes. Each bit is spread by a separate Walsh function, and all of the functions are fully uncorrelated. Hence, all of the Walsh functions and codes are orthogonal and are generated using the Hadamard matrix, a square matrix containing one row of all zeros and remaining with an equal number of zeros and ones [47]. Such codes are flexible enough to be concatenated with other codes, like for synchronized multiuser systems because of its orthogonal features [46, 48].

4. Linked Terminologies and EXIT Chart Analysis

The iterative decoding schemes are mainly deployed to achieve an enhanced BER performance. EXIT charts are useful to predict the convergence pattern of an iteratively decoded system [49, 50]. Proposed by ten Brink, EXIT charts are based on the exchange of mutual information between the constituent Soft-Input Soft-Output (SISO) decoders [42]. EXIT analysis is convenient in the sense that it expeditiously predicts the SNR value where an infinitesimal BER occurs, without performing the tiresome bit-by-bit decoding [50, 51]. The EXIT chart relies on two major assumptions for accuracy; firstly, the *a priori* logarithmic-likelihood ratio (LLR) information should be uncorrelated, and secondly, its probability density function (PDF) must be Gaussian distributed. These two requirements are generally fulfilled by employing higher interleaver lengths [52]. The following basic relations govern the EXIT curves for a generalized wireless system, as discussed in [50, 53]:

$$0 \leq I_A \leq 1, \quad (3)$$

$$0 \leq I_E \leq 1, \quad (4)$$

$$I_E = T\left(I_A, \frac{E_b}{N_0}\right), \quad (5)$$

$$T(0) \leq I_E \leq T(1). \quad (6)$$

In Equations (3) and (4), I_A refers to the *a priori* information, whereas I_E denotes extrinsic information. I_A is the intrinsic information about the bit, known even before the decoding process begins. I_E is generated when we subtract I_A from the first output of the constituent decoder. Interleaving renders I_E to serve as I_A for the other decoders. The *a posteriori* information is the output of any decoder accepting the channel's input and I_A [53]. The symbol T in Equation (5) represents the transfer function, converting I_A to I_E at the specified E_b/N_0 value. The inverse of this transfer function exists on the range specified in Equation (6). It is notable that different values of E_b/N_0 result in distinct EXIT curves. The greater value

(maximum upto 1) of I_A signifies that the greater number of bits becomes known, due to which the value of I_E also increases. As a general rule, the closer the value of I_A/I_E to 1, the better the decoding [53].

Interleavers are particularly useful for introducing time diversity and delay in any communication system. It renders the data highly uncorrelated such that it can be constructively exploited in the EXIT visualization [53]. It was demonstrated in [54] that a system with a higher number of interleaving bits will significantly reduce the number of iterations required to reach the point of convergence. This is because of the fact that the higher value of interleaving bits renders the distribution more close to Gaussian, resulting in a performance close to Shannon's limit. The logarithmic-likelihood ratios (LLRs) or L values symbolize the logarithm of the ratio of probability of any bit. The concept of L values is adopted in many systems involving iterative decoding and was initially studied by Robertson [54], as presented in

$$L(d_k) := \ln \left(\frac{P(u_k = +1)}{P(u_k = -1)} \right), \quad (7)$$

where $L(d_k)$ represents the L value of bit d_k and $P(u_k)$ is the probability of bit u_k for its two legitimate values of +1 and -1.

For a specific E_b/N_0 value, an infinitesimally lower BER is achieved only if the EXIT curves meet the (1,1) point of perfect convergence [53]. If the curves converge at the point of perfect convergence, there must be an open tunnel in between the (0,0) and (1,1) points, commonly known as the *convergence tunnel*. The EXIT curves for the advocated system of DSTS-SP SECCC at several E_b/N_0 values are depicted in Figure 4. The two EXIT curves corresponding to the two hypothetical decoders are essentially a mirror of each other along the 45-degree diagonal line. This corroborates our claim that the SECCC decoder consists of a single SISO MAP decoder. Monte-Carlo simulation-based stair-shaped trajectories at various E_b/N_0 values are also shown in Figure 4, iterating between the EXIT curves. We can visualize the *convergence tunnels* and hence the convergence patterns for different values of E_b/N_0 . The EXIT curves of the DSTS-SP SECCC do not succeed to reach the point of perfect convergence at the E_b/N_0 value of -2 dB, as the curves intersect prior to the (1,1) point, providing no open tunnel. However, the curves provide the required tunnel for convergence at E_b/N_0 of -1 dB or greater values as seen in Figure 4. The corresponding trajectories confirm this claim by iterating between the component EXIT curves to attain the highest value of extrinsic information. Furthermore, it is worth mentioning that the DSTS-SP SECCC offers a fruitful approach by converging at considerably lower E_b/N_0 than the solely SECCC scheme of [8].

5. Simulation Results

Figure 5 depicts the BER performance of the proposed system in comparison with the identical rate DSTS-SP RSC and SECCC scheme as in Table 2. As expected, the

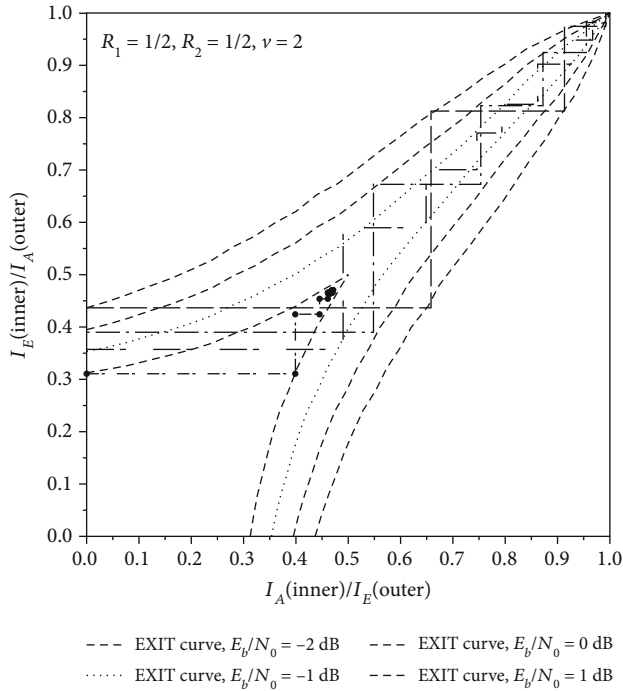


FIGURE 4: EXIT curves and corresponding decoding trajectories at E_b/N_0 values of (-2, -1, 0, 1) dB for the DSTS-SP SECCC system with R_1 and R_2 of 1/2 each.

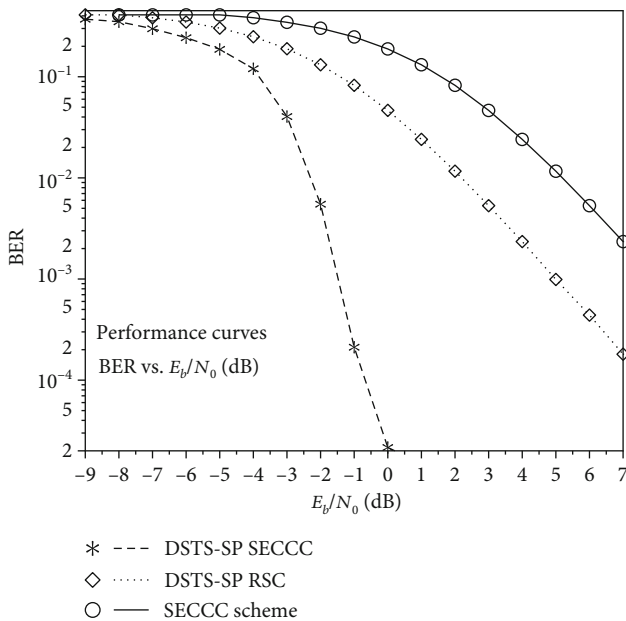


FIGURE 5: BER performance comparison of the schemes specified in Table 2.

incorporation of DSTS-SP results in significantly lower BER, achieving higher bandwidth efficiency. For the proposed DSTS-SP SECCC system, the 10^{-4} value of BER is achieved at a lower E_b/N_0 value in comparison with the other similar rate schemes. More precisely, there is an E_b/N_0 gain of 8 dB

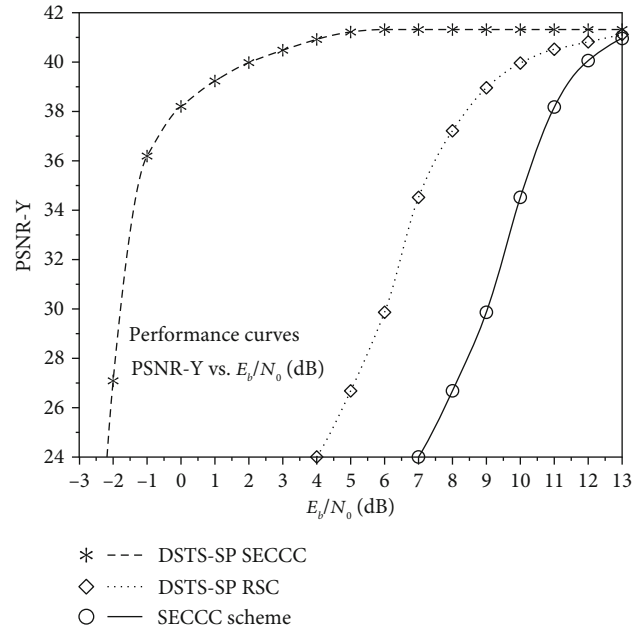


FIGURE 6: PSNR performance comparison of the schemes specified in Table 2.

at the BER degradation point of 10^{-4} when considering the DSTS-SP SECCC system relative to the DSTS-SP RSC. Moreover, the proposed DSTS-SP SECCC outperforms the SECCC scheme dispensing with the DSTS-SP by 11 dB at the BER degradation point of 10^{-4} . Thus, the BER performance metric advocates the proposed system.

Figure 6 provides the Peak Signal-to-Noise Ratio (PSNR) performance of the error protection schemes given in Table 2. PSNR, an objective video quality metric, provides an insight into the strength of the signal by computing the ratio between the original signal strength and noise of the related channel. An accurate estimate of the perceptual video or image quality is provided with the PSNR when the content, codec, and transmission system remain fixed [55]. It becomes obvious from Figure 6 that the PSNR performance of the proposed DSTS-SP SECCC system is better across the entire region of E_b/N_0 . Explicitly, an E_b/N_0 gain of 8 dB and 10 dB is recorded at the PSNR degradation point of 1 dB, considering the proposed system over the identical rate DSTS-SP RSC and SECCC scheme, respectively.

Finally, the subjective video quality performance indicator of the proposed system is compared with the DSTS-SP RSC and can be visualized via Figure 7. The frames of Figure 7 were averaged 30 times prior to its presented form after the transmission of both luminance and chrominance parts of *Akiyo* sequence. It is plainly visible that the incorporation of DSTS-SP to SECCC has a substantial impact on the perceived video quality with reference to the DSTS-SP RSC. At 4 dB, there is a major difference in the performance of both schemes as the perceived quality of the advocated system is far better than that of the DSTS-SP RSC (annoying perceptual video distortions).



FIGURE 7: Subjective video quality performance of the Akiyo sequence frame using the proposed system (a) and DSTS-SP RSC scheme (b) summarized in Table 2 at E_b/N_0 values of (1, 2, 3, 4) dB (left to right).

6. Conclusion

This article presents the SECCC iterative channel decoding system for the H.264 video standard over the Rayleigh channel using DSTS-SP-based smart antennas. The presented setup is designed with a motive to operate the system close to channel capacity for wireless video communication. The DSTS-SP approach profusely improves the performance of SECCC in terms of BER and PSNR. The presented system productively exploits the diversity gain resulting from the two transmit antennas, without imploring any computational complexity at the single receiving antenna. Likewise, EXIT curves confirm the usefulness of the advocated system, as it shows fruitful convergence behaviour for deployment in efficient and flexible transceivers. Furthermore, the subjective video quality of the proposed system is found to be significantly better than that of the DSTS-SP RSC. To be more precise, the developed system exhibits an E_b/N_0 gain of 8 dB over the identical rate DSTS-SP RSC at the PSNR degradation point of 1 dB. Similarly, there exists an E_b/N_0 gain of 10 dB for the proposed system at 1 dB degradation point when compared with the SECCC scheme avoiding DSTS-SP. We aim to extend the approach of DSTS to be generally invoked with other modulation techniques and supported for transmission over dispersive channels. Finally, another promising topic of research would be to propose efficient interleaver designs helpful in overcoming or mitigating the detrimental effects of correlation due to channel and differential encoding.

Data Availability

The authors approve that data used to support the finding of this study are included in the article.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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