Evaluative Study of Detect-Split-Forward Scheme over MIMO Relays

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Outline

- Motivation
- Literature survey
- System Model
- Analysis of BLER
- Capacity analysis
- Results and Discussion
- Conclusion and Future Work

Introduction & motivation

- Since the introduction of multiple-input-multiple-output (MIMO) technology , there have been great advancements in data rate speeds and wireless network efficiency.
- Large antenna arrays of different sizes are not always practical for handsets or laptops.
- Cooperative multi-input multi-output (MIMO) schemes in wireless communication systems provide better coverage, increase throughput and capacity, and improve the quality of service.

Literature Survey

- In [van der Meulen, 1971] ***Relaying technique was introduced***.

- In [Wornell 2004]'' Cooperative Diversity in Wireless Networks: Efficient Protocols and Outage Behavior," ***Several relaying protocols are proposed, such as amplify-and-forward (AF), decode-and-forward (DF), and coded cooperation (CC) .***
- ***Relay structure evolved from single antenna relay to virtual antenna array and MIMO relays***
- [M. Dohler, 2004] "A resource allocation strategy for distributed MIMO multi-hop communication systems,"

  [R. Pabst,2004] "Relay-based deployment concepts for wireless and mobile broadband radio,"

  [B. Wang,2005]"On the capacity of MIMO relay channels,"

Literature Survey (Cont'd)

- ***STBC is investigated with MIMO relaying AF and DF***

[A. Abdaoui,2010]"On the performance analysis of a MIMO-relaying scheme with space time block codes,"

[H. Van Khuong,2010]"Performance analysis of a decode-and-forward cooperative relaying scheme for MIMO systems,".

[Chun-Jung Wu,2010]"Design of Distributed Amplify-and-Forward Relay Network for MIMO Transmission"

- ***V-BLAST is studied with vMIMO AF and DSF***

[A. Darmawan,2007]"Amplify-and-forward scheme in cooperative spatial multiplexing,"

[Sang Wu Kim,2005], "Cooperative spatial multiplexing in mobile ad hoc networks,

[Hiroya Takano,2011]"A Study on Collaborative Type of Spatial Multiplexing for Virtual MIMO System"

- [Balachandran 2009]"Design and performance analysis of collaborative spatial multiplexing for ieee 802.16e-based systems,"

The IEEE802.16e describes the uplink collaborative MIMO (UL-cMIMO)

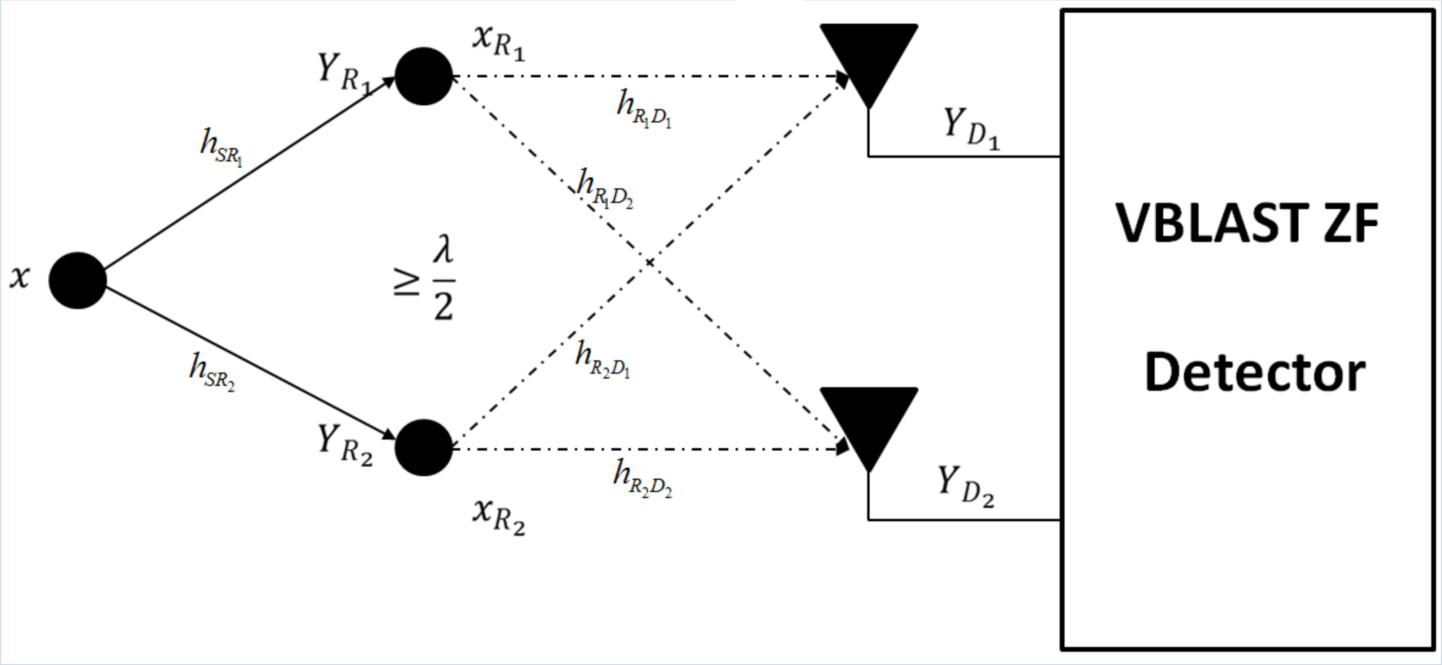
"each user is equipped with single antenna and shares the same channel resources with other users (same burst size) ".

- utilizing simultaneous transmissions over common burst
- will allow increasing the peak transmission rate and improve the system performance.

Detect-Split and Forward

- The scope of this work is to analyze and compare Detect-Split-Forward relaying techniques using both STBC and V-BLAST.
- The source modulates a block of k information bits and transmits a 2^k-ary modulated symbol x, which is received by all relays.
- Each relay detects the information bits and splits them into N_R blocks of length m bits, where $mN_R=k$.
- At each relay, m-bit block is modulated using lower level modulation schemes (2^m-ary symbol) and will be transmitted through N_R relays.

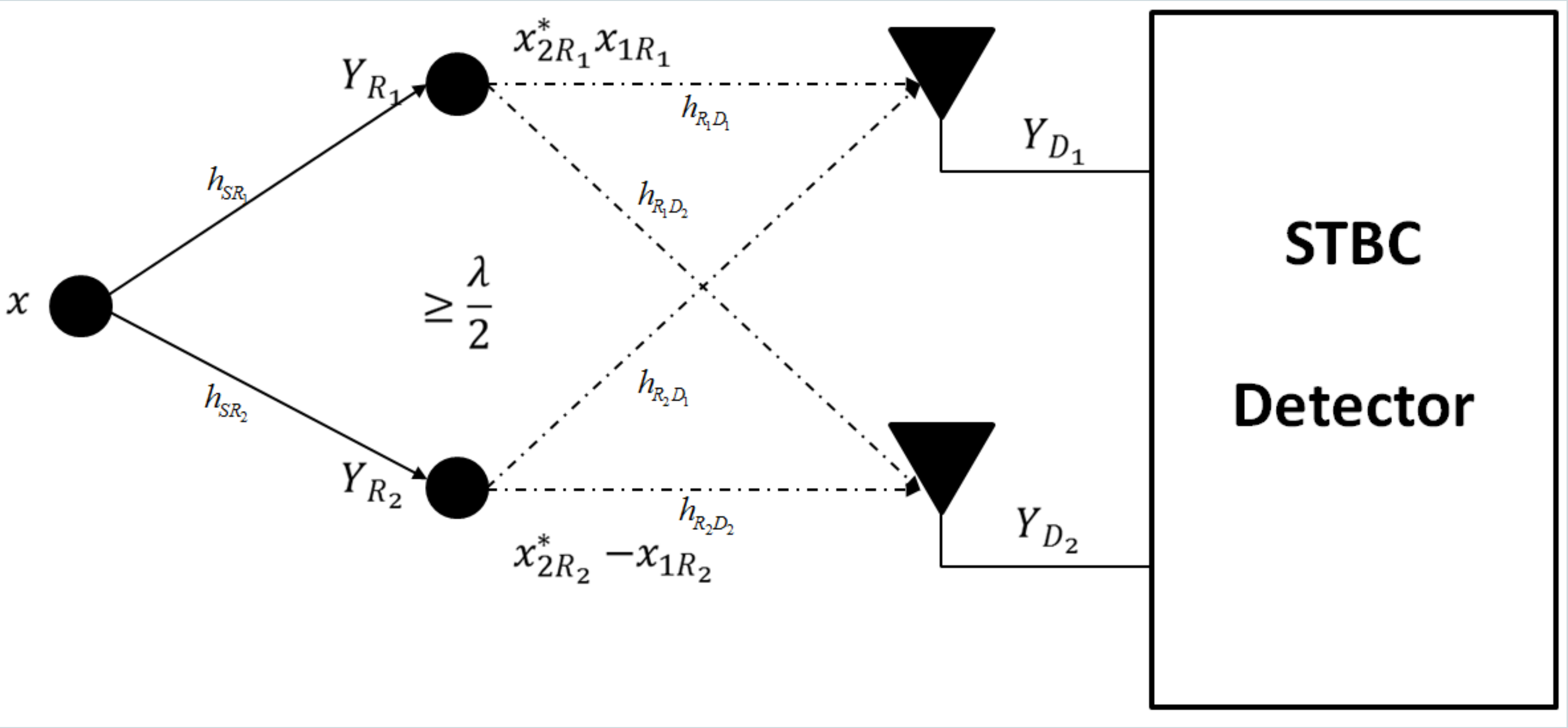
System Model
DSF-VBLAST



- The DSF-VBLAST scheme detects the 2^k-ary symbol, splits it into N_R parallel symbols, where each symbol carries *m* bits and then forwards the signals simultaneously to the destination

System Model
DSF-STBC

- The forwarding scheme will be STBC instead of V-BLAST as shown in Figure



BLER Performance Analysis

- For a two hops relaying system, the BLER will be:

$$P_{TotalBLER} = 1 - (1 - P_{BLERat1^{st}hop})(1 - P_{BLERat2^{nd}hop}).$$

No errors in the first hop

No errors in the second hop

BLER of the First Hop

- Since in the first hop, the source transmits the modulated symbol to N_R single antenna relays, the BLER at the first hop is

$$P_{B,H_1} = 1 - (1 - P_{e,R})^{N_R}.$$

- Where $P_{e,R}$ is the symbol error rate (SER) at each relay for M-ary modulation over fading channels, taking into account the appropriate signal set levels and energy after splitting.
- Thus SER at each relay is:

$$P_{e,R} = \left(\frac{M-1}{M}\right)\left(1 - \sqrt{\frac{1.5\gamma_R}{M^2 - 1 - 3\gamma_R}}\right),$$

Where where $M=2^m$ is the new cardinality of the signal set after splitting and γ_R is the average received SNR at each relay.

BLER of the Second Hop
V-BLAST

- Since V-BLAST is used in the second hop, each layer of the V-BLAST scheme has a different error probability depending on its diversity order.
- Assume that $P_{e,i}$ is the SER for layer *i* over Rayleigh fading channels, then the BLER of the second hop is:

$$P_{B,H_2} = 1 - \prod_{i=1}^{N_R} (1 - P_{e,i}),$$

- The diversity order of layer *i* is:

$$D_i = N_D - N_R + i,$$

Where N_D is the number of receive antennas at the destination

BLER of the Second Hop
V-BLAST

- For M-QAM signals, $P_{e,\,i}$ is [19]:

$$P_{e,i} = 4(1-\tfrac{1}{\sqrt{M}})(\tfrac{1-\zeta_i}{2})^{D_i}\sum_{j=0}^{D_i-1}\binom{D_i-1+j}{j}(\tfrac{1+\zeta_i}{2})^j$$
$$-4(1-\tfrac{1}{\sqrt{M}})^2\{\tfrac{1}{4}-\tfrac{\zeta_i}{\Pi}\{(\tfrac{\Pi}{2}-\tan^{-1}\zeta_i)\sum_{j=0}^{D_i-1}\binom{2j}{j}(\tfrac{1-\zeta_j}{4})^j$$
$$+\sin(\tan^{-1}\zeta_i)\sum_{j=1}^{D_i-1}\sum_{r=1}^{j}\tfrac{J_{rj}}{(1+\beta_i)^j}[\cos(\tan^{-1})\zeta_i]^{2(j-r)+1}\}\},$$

- Where

$$\zeta_i = \frac{\beta_i}{1+\beta_i}$$

$$\beta_i = \frac{3d^{-v}\gamma_D}{2N_R(M-1)}$$

$$J_{rj} = \frac{\binom{2j}{j}}{\binom{2(j-r)}{(j-r)}4^i(2(j-r)+1)}.$$

d is the normalized distance, and v is the path loss

BLER of the Second Hop STBC

- For M-QAM STBC, the SEP at the second hop could be calculated using the previous equation with a diversity order $N_D N_R$ and with one layer ($L=1$).
- Therefore, the second hop BLER is

$$P_{B,H_2} = P_{e,1}$$

- with a diversity $D = N_D \cdot N_R$

Outage Capacity

- The instantaneous capacity of the two hop relay system is determined by the weakest link. The first hop consists of two SISO channels and the second hop consists of a MIMO channel. The second MIMO hop can be either V-BLAST or STBC. Therefore, the instantaneous capacity of DSF-VBLAST and DSF-STBC can be calculated as:

$$C_{DSF-VBLAST} = \frac{min\{C_{SISO1}, C_{SISO2}, C_{VBLAST}^{ZF}\}}{N_H}$$

$$C_{DSF-STBC} = \frac{min\{C_{SISO1}, C_{SISO2}, C_{STBC}\}}{N_H}$$

Capacity Analysis

- Where

$$C_{SISO} = \log_2(1 + \gamma_R |h|^2)\ bps/Hz,$$

$$C^{ZF}_{VBLAST} = N_R.min_{j=1,2,\dots,R_N}\{\log_2(1 + \frac{\gamma_D}{N_R \|W_{ZF,j}\|_F^2})\},$$

$$C_{STBC} = r_c\{\log_2(1 + \frac{\gamma_D}{N_R}\|\mathbf{H}\|_F^2)\}.$$

Numerical Results

TABLE I. $1 \times 2 \times 2$ DSF-VBLAST

Time Slots	1^{st} Hop	2^{nd} Hop	bps/Hz
2	QPSK	BPSK	1
2	16-QAM	QPSK	2
2	64-QAM	8PSK	3
2	256-QAM	16-QAM	4

TABLE II. $1 \times 2 \times 2$ DSF-STBC

Time Slots	1^{st} Hop	2^{nd} Hop	bps/Hz
3	QPSK	BPSK	0.66
3	16-QAM	QPSK	1.33
3	64-QAM	8PSK	2
3	256-QAM	16-QAM	2.66

DSF-VBLAST Analysis

- The Figure compares the analytical results obtained for DSF-VBLAST at each hop starting from sending 16-QAM signal to each relay.

and then sending the signals as QPSK in the second hop (V-BLAST).

Finally, the total BLER performance is shown and the simulation matches the analysis.

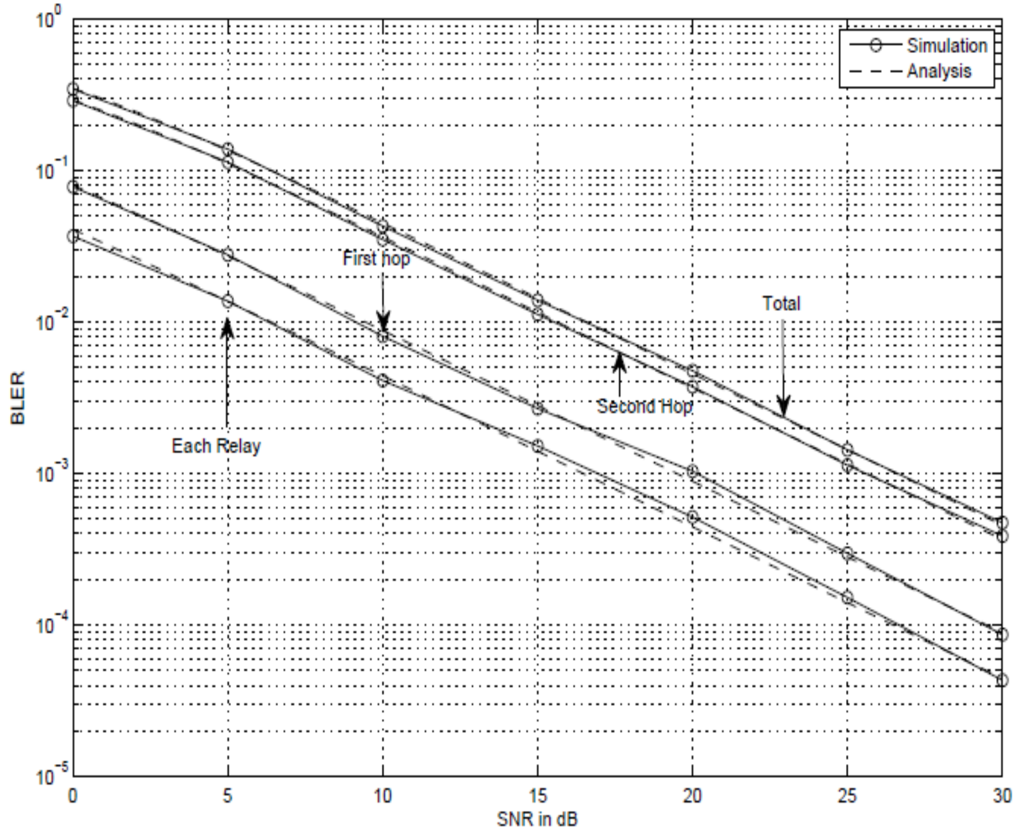


Figure 3.12: Simulation and analysis results of DSF-VBLAST for 16QAM.

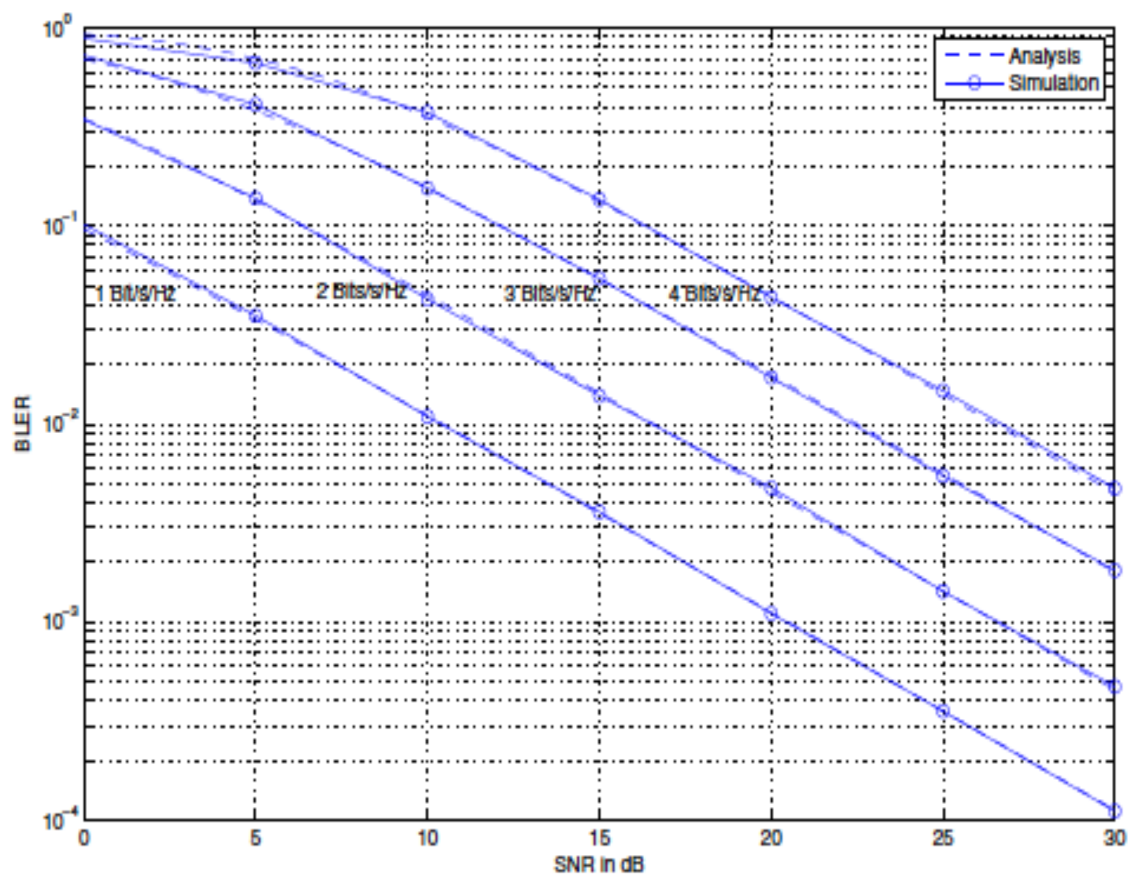
DSF-VBLAST Analysis

- The Figure shows the BLER performance of 1*x2x2* DSF-VBLAST with different spectral efficiencies.

The analytical results match the simulation results

TABLE I. $1 \times 2 \times 2$ DSF-VBLAST

Time Slots	1^{st} Hop	2^{nd} Hop	bps/Hz
2	QPSK	BPSK	1
2	16-QAM	QPSK	2
2	64-QAM	8PSK	3
2	256-QAM	16-QAM	4



Effect of Number of Relays

- Increasing number of relays will give a 2 dB gain as the number of relays doubled from 2 to 4

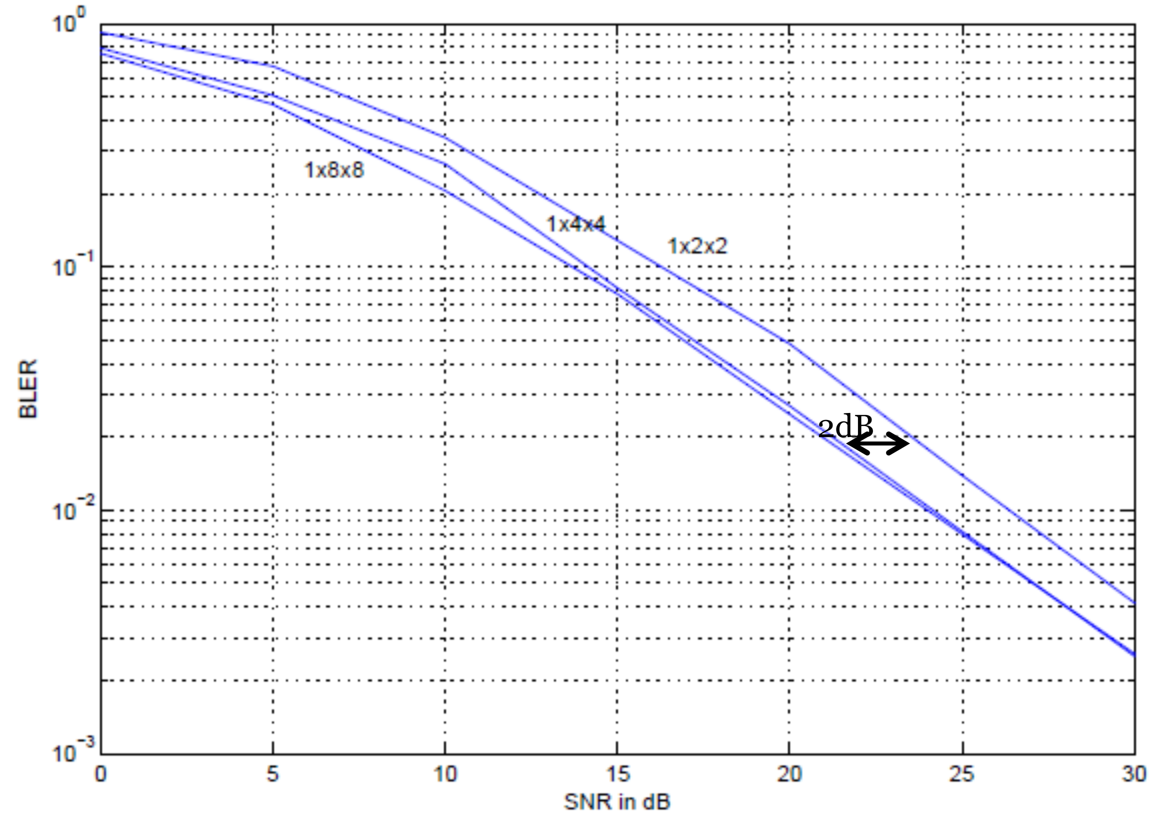


Figure 3.10: 256QAM with different relaying setting.

BER performance of DSF-VBLAST at various S-R location

- At a fixed SNR, we evaluate the performance of the system with different relay location and the best place for the relay is at the center Between source and destination as shown

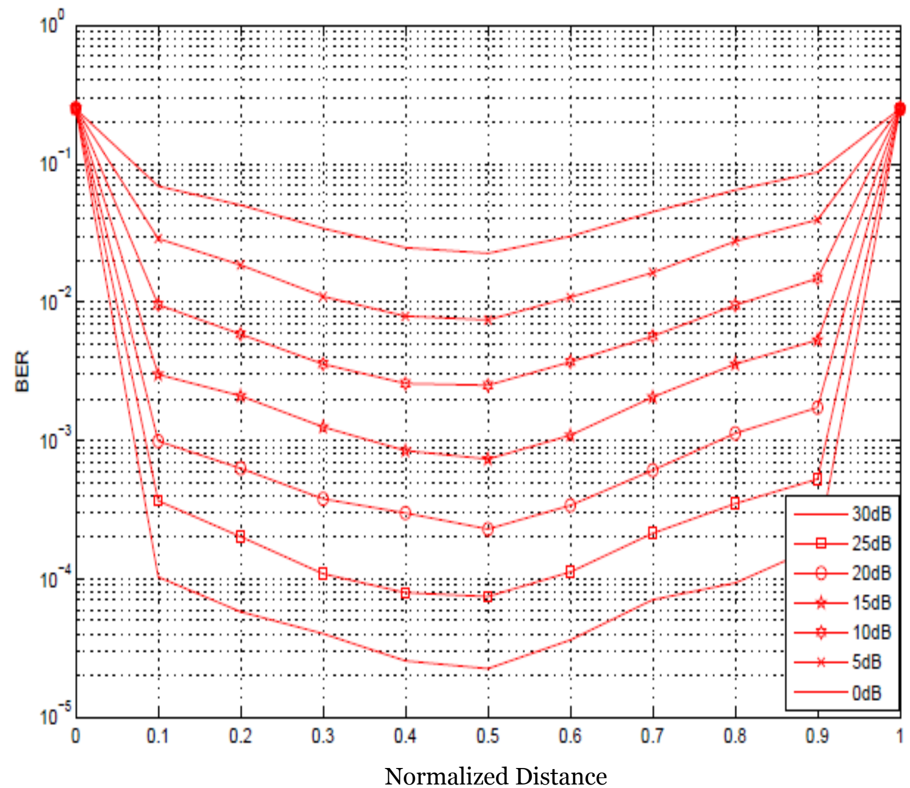


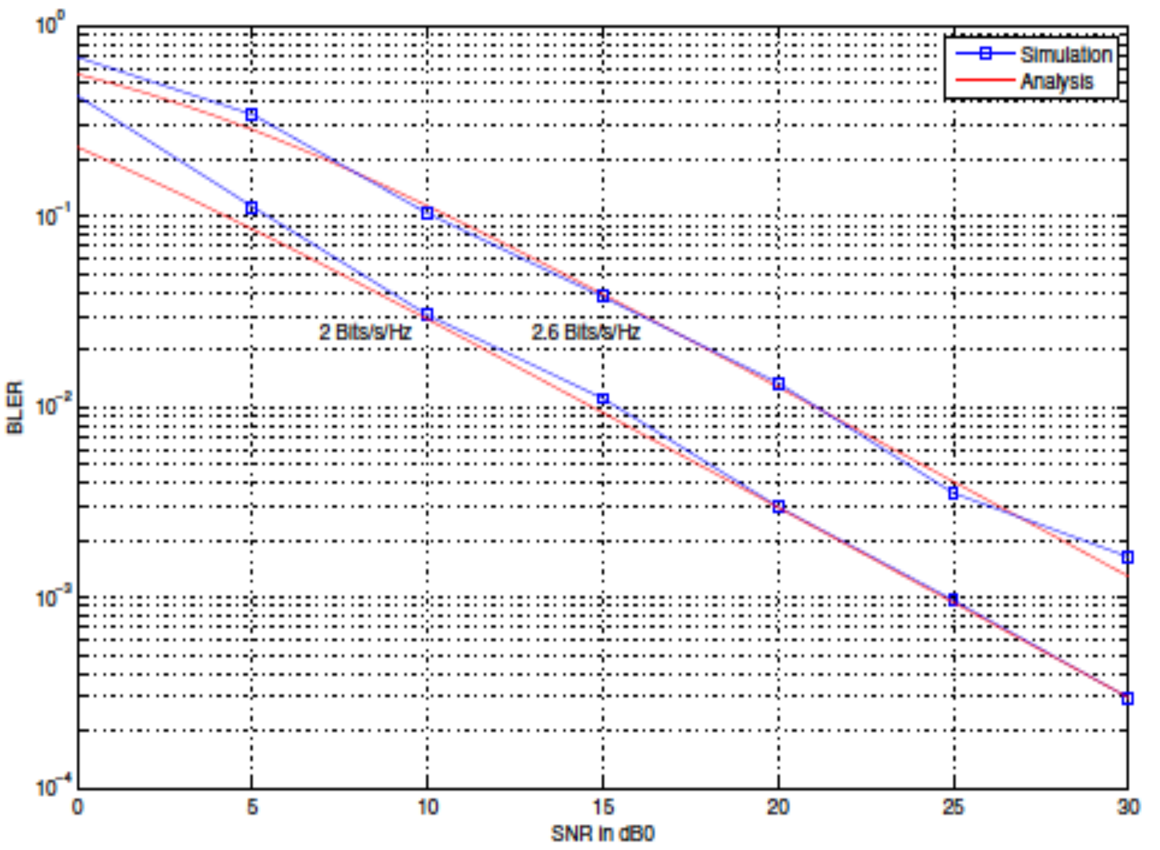
Figure 3.11: BER performance various source-relay distances for DSF-VBLAST.

DSF-STBC Analysis

- Compares the block error rate of a DSF-STBC system with different spectral efficiencies and relays are at distance 0.3 from the source.

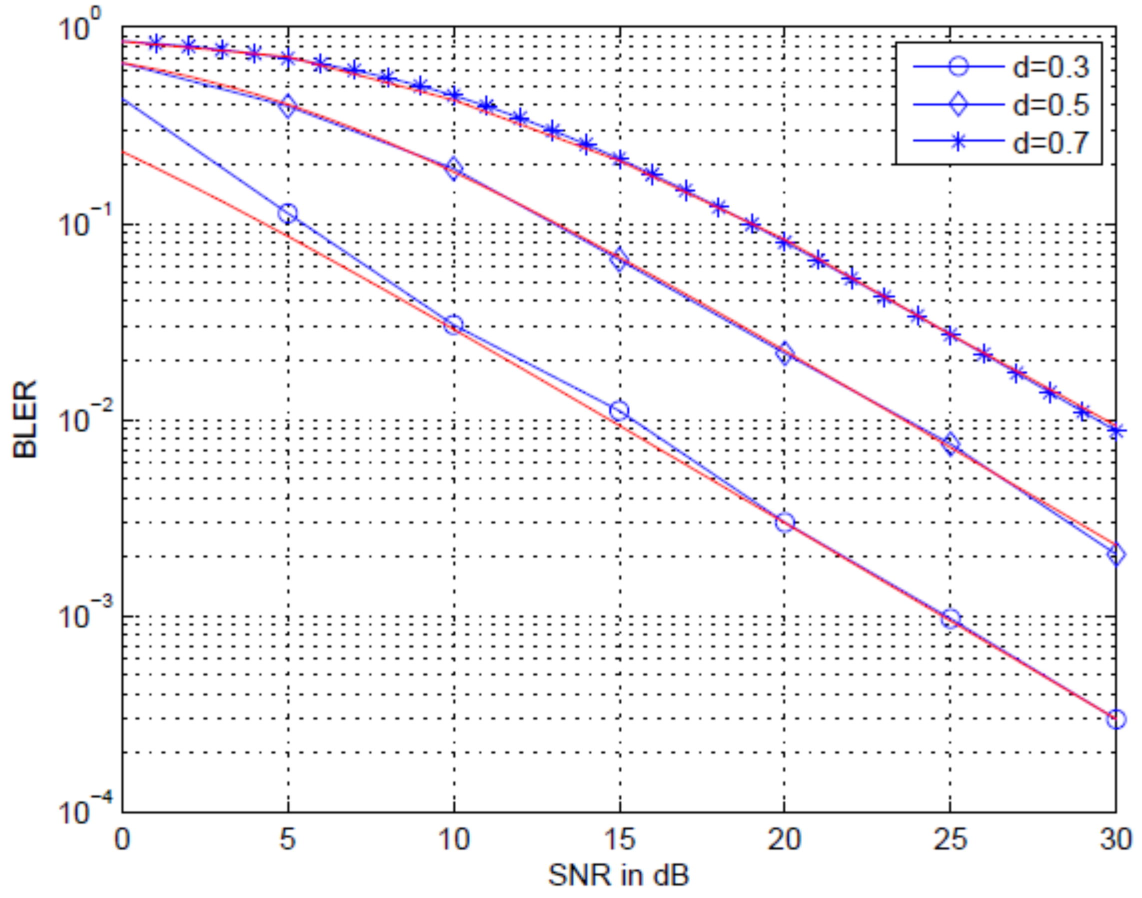
TABLE II. $1 \times 2 \times 2$ DSF-STBC

Time Slots	1^{st} Hop	2^{nd} Hop	bps/Hz
3	QPSK	BPSK	0.66
3	16-QAM	QPSK	1.33
3	64-QAM	8PSK	2
3	256-QAM	16-QAM	2.66



Simulation and Analysis results of DSF vMIMO

- Compares the block error rate of a DSF-STBC system with Different relays location from the source with 64QAM



Comparing DSF-STBC and VBLAST

- BLER comparison between DSF-STBC and DSF-VBLAST at d=0.3

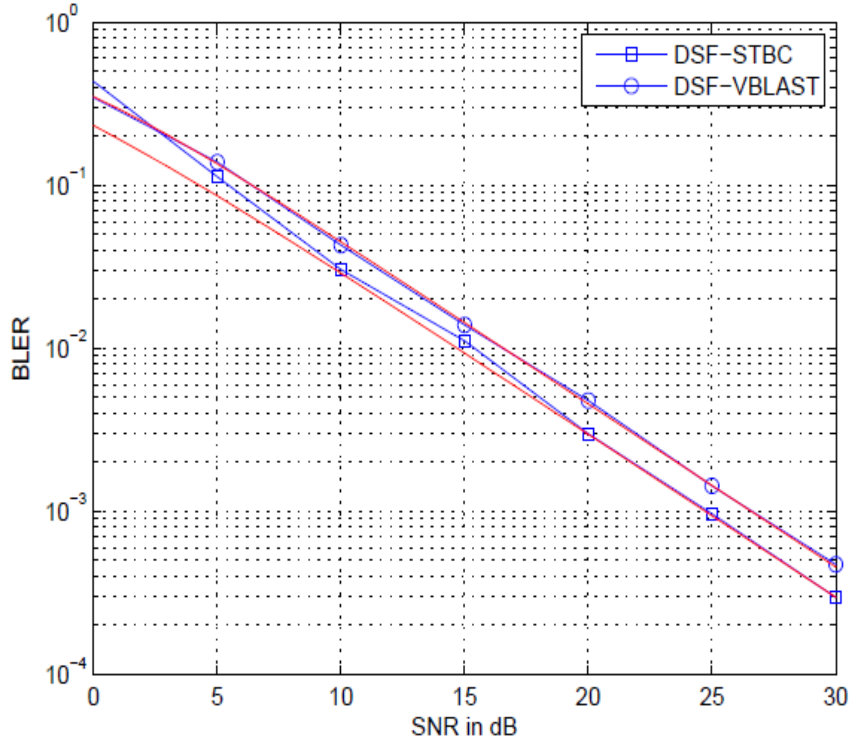


Figure 3.20: Comparing BLER performance for DSF using STBC and V-BLAST at d=0.3 from source-relay .

Comparing DSF-STBC and VBLAST

- BLER Comparison between DSF-STBC and DSF-VBLAST at d=0.5

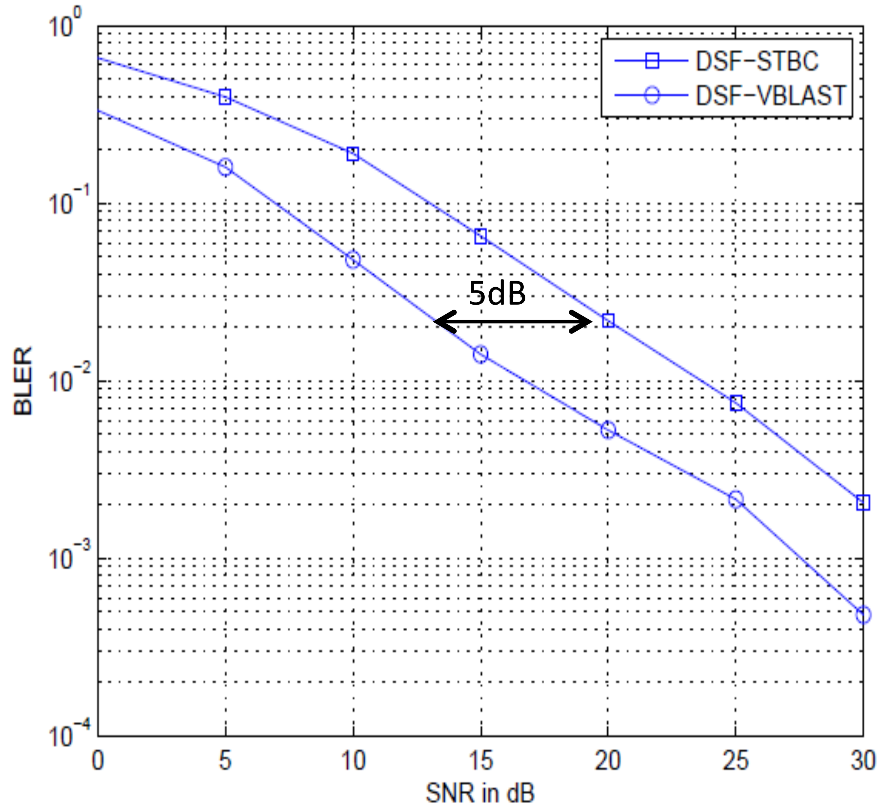


Figure 3.21: Comparing BLER performance for DSF using STBC and V-BLAST at d=0.5 from source-relay .

Comparing DSF-STBC and VBLAST

- BLER comparison between DSF-STBC and DSF-VBLAST in terms of relay location

When the relays are closer to the source DSF-STBC will perform better than DSF-VBLAST. However, when the relays are placed farther than 0.4 DSF-VBLAST will provide noticeable gains compared to DSF-STBC.

Blue → STBC

Red → VBLAST

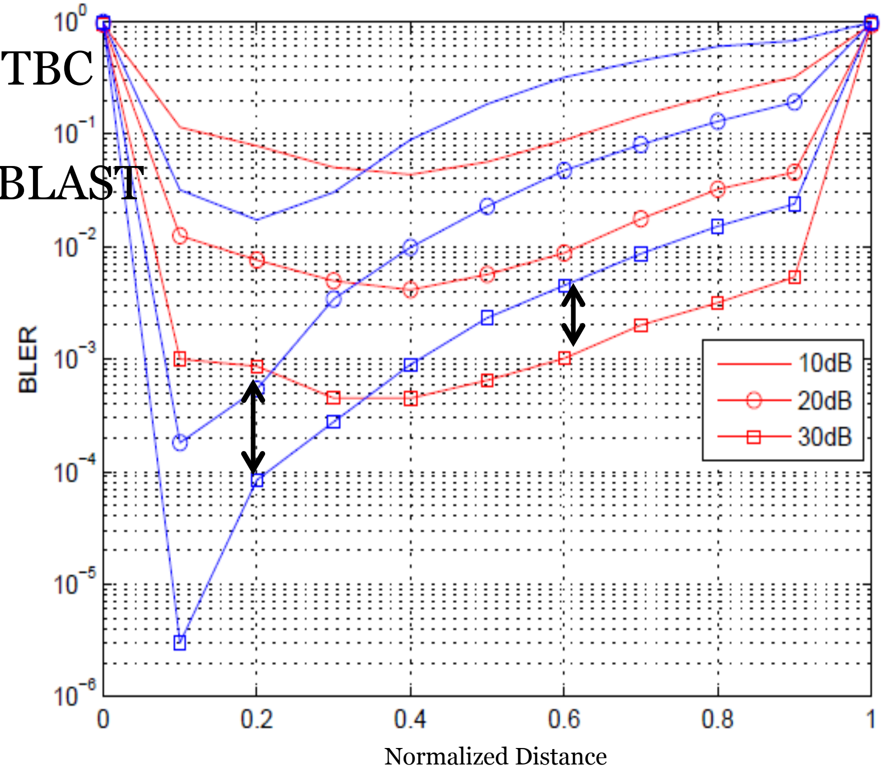
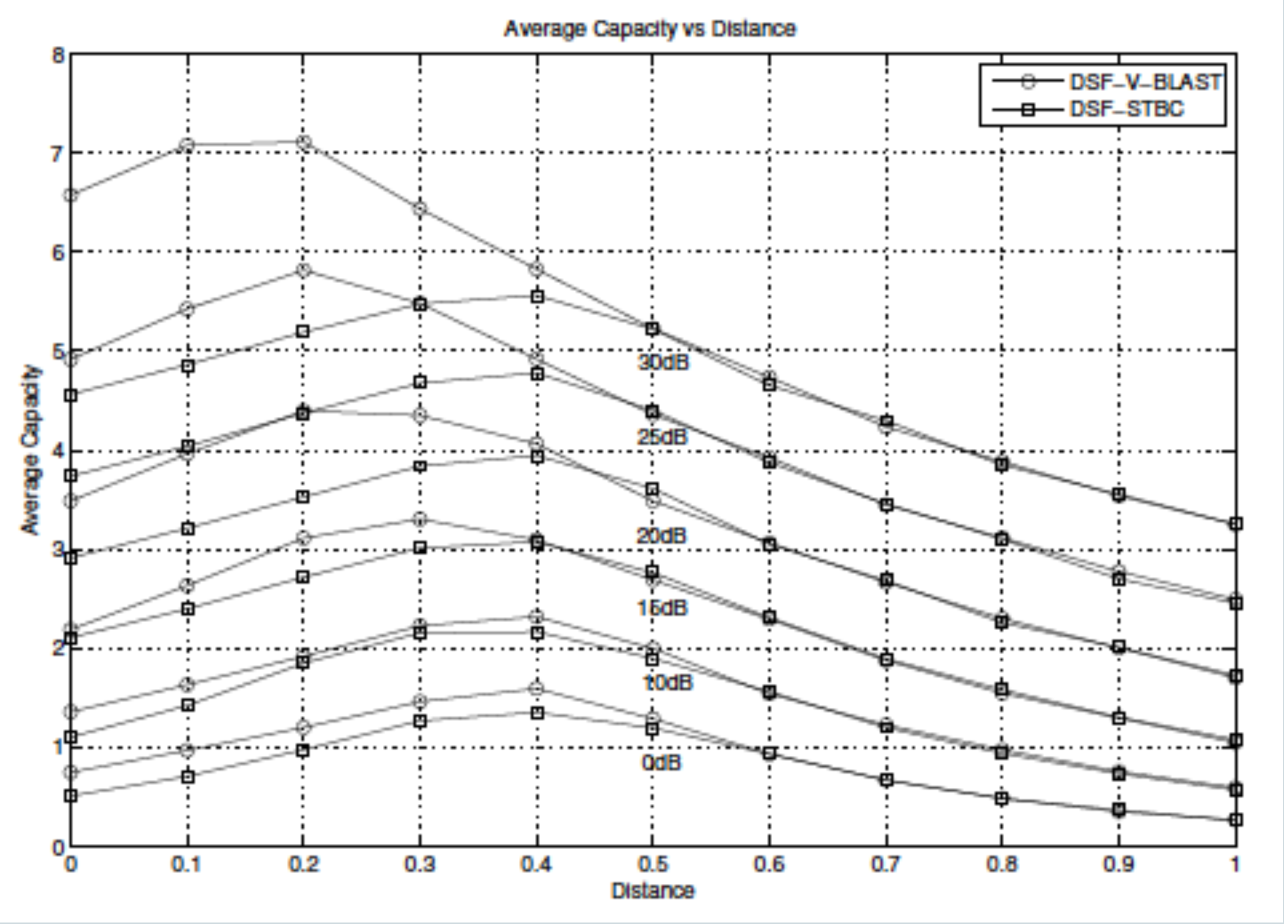


Figure 3.22: BLER performance various source-relay distances for DSF using STBC and V-BLAST.

Average Capacity Comparison of DSF-STBC and DSF-VBLAST

- At source-relay distances greater than d=0.5 the DSF-VBLAST channel capacity will perform the same as DSF-STBC since both systems are dominated by the weakest channel, which is the SISO channel.



Conclusion and Future Work

- In this paper, we analyzed detect-split-forward uplink virtual MIMO relying schemes based on VBLAST and STBC.

- The analysis presented in this paper matched the simulation results and it showed the effect of several physical parameters such as distance, modulation type and number of relays.

- The fundamental tradeoff between STBC and VBLAST leads to an adaptive DSF scheme which can switch between the two schemes according to the location of the relays.

Thank you