



Image Encryption through Transform Domain Coefficients Scrambling using Hybrid Sinusoidal Transforms

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Abstract: Security is one of the most important aspects. In image processing image encryption is one of the ways we can achieve security. In this paper an image encryption method is proposed using Hybrid Sinusoidal Transforms using Hartley as Base and other as Local transforms. Experimental results prove that the hybrid version of Hartley DCT, Hartley DST and Hartley Real Fourier for 128X2 and 64X4 gives better results as compared to individual Sinusoidal Transforms

Keywords: Image Encryption, Image Scrambling, Sinusoidal Transforms, Hybrid Transforms, Key Based Scrambling

I. Introduction

Encryption is a process to provide security to data. Data can be of any form for e.g. text, audio, video, or digital images. Digital images can be secured both in spatial domain and transform domain. Transform domain is more robust towards attacks like noise and others. Sapna et al. proposed an image encryption scheme which is a full encryption technique in transform domain [1]. The method makes use of DWT and chaotic stream ciphers for the same. A comparison of DCT and DWT is also given. Compression properties of DWT are explored for Image encryption process by Prerana et al. [2]. Compression is achieved by DWT, followed by encryption for which Fractional Fourier transform along with random mask is used. Yang uses DCT for color image encryption process [3]. The process is carried out block wise on the Digital image. The process includes position random shift, three dimensional Arnold scrambling transform and DCT coefficient encryption. Experimental results prove that the method has high security and good encryption speed. Considering image transmission as a primary application Gaurav et al. proposed a multiple image encryption method using fractional wavelet transform and chaotic maps[4]. Firstly images are encrypted followed by a sharing process. In image encryption, the encrypted image appears like noise image, to overcome this Long Bao et al. proposed an image encryption method [5], in which original image looks like a cover image. Their method makes use of Data Hiding concept. Wavelet domain is used to implement the said method. Using the chaotic stream cipher, selective encryption method is proposed by Nidhi Taneja et al. [6]. Their method makes use of fractional wavelet domain and selects only a few subbands for the same. A lossless image encryption scheme based on wavelet is proposed by Ch.samson et al. Image encryption is carried out by Secure Advanced Hill cipher [7]. *Seif Eddine et al. proposed a double image encryption method using Reciprocal -Orthogonal Parametric Transform and chaotic maps*[8]. *The proposed method is robust against brute force and statistical attacks.* Zhengjun Liu et al. [9] proposed a method to enhance the security of double random phase encoding which is an amplitude scrambling operation and used for image encryption process along with fractional fourier transform. J.B. Lima et al. used finite field cosine transform for image encryption [10]. The process is carried out on the blocks of the image. Liansheng Sui et al. [11] introduced a double image encryption method using discrete random transform and logistics map. Experimental results show the feasibility and effectiveness of the technique. Haar wavelet transform domain is used for image encryption by Sara Tedmori et al. [12]. The encryption process involves scattering the frequencies using a reversible weighting factor. J.B. Lima et al. proposed an image encryption technique which makes use of fractional Fourier transform over finite fields [13]. An image encryption scheme based on chaos is proposed by Yuling Luo et al. [14]. The process makes use of integer wavelet transform to carry out the process. Parametric Discrete Cosine Transform is used for Double image encryption by Han Cao et al. [15]. The method provides high image security with a low computation cost. Narendra Singh et al. proposed Multiple Image encryption method using multiple canonical transforms [16]. The method explores three chaotic maps, tent map, the Kaplan Yorke map and Ikeda map.

In our earlier research work proposed by Kekre et al. [17], an image scrambling framework is proposed using non sinusoidal transform, out of the four non sinusoidal transforms Kekre transform performed the best according to the experimental results obtained. Using Kekre as the base and other as local a hybrid version is proposed by Kekre et al. [19]. It was found that the hybrid version gave an improvement in the results. The

same framework was used with sinusoidal transforms and Hartley transform gave good results [18]. As an extension to this work a Hybrid version [20] of Sinusoidal transforms using Hartley as base and others as local transforms is presented in this paper.

II. Proposed framework for Image Encryption

In the proposed framework for Hybrid Sinusoidal Transforms, Hartley is taken as a Base transform as our earlier experimental results in the framework has proved Hartley as a good transform in which minimum row and correlation is obtained. The Local transforms used are DCT, DST, Real Fourier and DFT. The proposed method is applied over grayscale images however it can also be extended to 24 bit color images.

Following are the steps used for Image Scrambling:

- 1) Read the image, convert it to grayscale
- 2) Apply a Hybrid Transform (Row, column or full) on the image
- 3) Transform coefficients which are obtained in step 2 are now scrambled using key based scrambling method.
- 4) Apply inverse Hybrid Transform (Row, column or full) on the scrambled transform coefficients obtained in step 3.
- 5) The image obtained in spatial domain will now be scrambled

The scrambling process is also shown in the Figure 1.

Figure 1. Different Steps of Scrambling Process

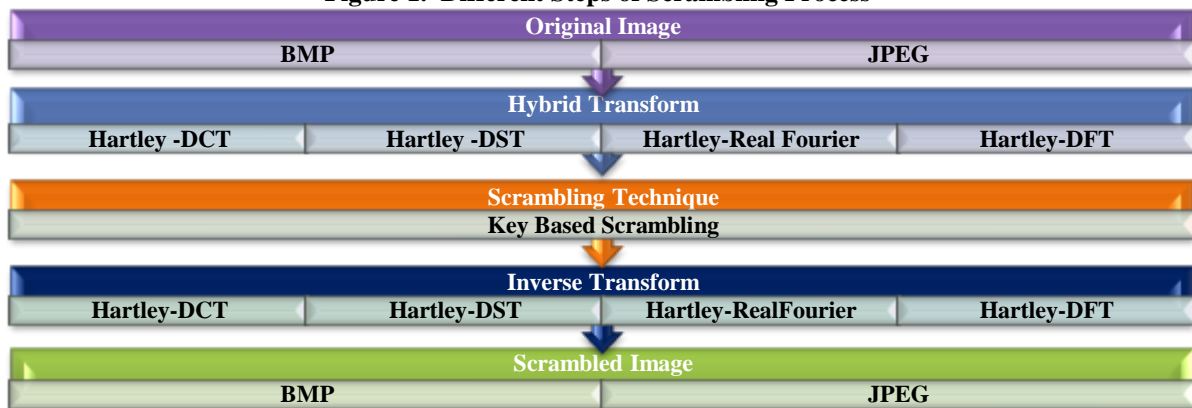


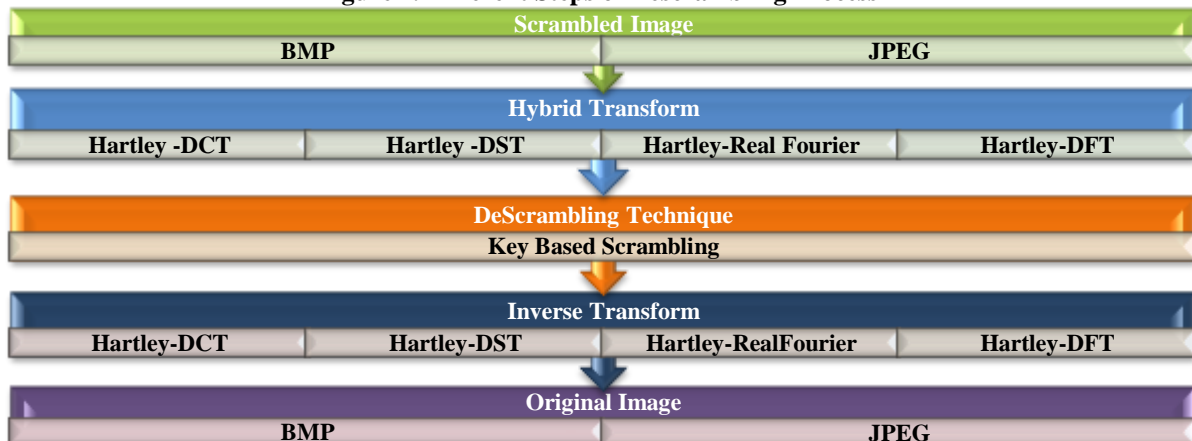
Image Descrambling

The descrambling process is as follows:

- 1) Read the scrambled image
- 2) Apply the Hybrid Transform (Row, column or full) on the image
- 3) Transform coefficients which are obtained in step 2 are now descrambled using key based descrambling method.
- 4) Apply inverse transform on the descrambled transform coefficients obtained in step 3.
- 5) The image obtained in spatial domain will now be original Image

The descrambling process is also shown in the figure 2.

Figure 2. Different Steps of Descrambling Process



III. Experimental Results

For experimental purpose, five different grayscale images of size 256X256 are used. Due to space limitations, an average of the results obtained for different experimental parameters like Row Correlation, column correlation, Entropy and NPCR for all the Patterns generated using the Hartley as base transform and others as local transform are presented below.

Figure 3. Original Image and its Grayscale



A. Pattern 2X128

Figure 4. 2X128 Hartley -DCT

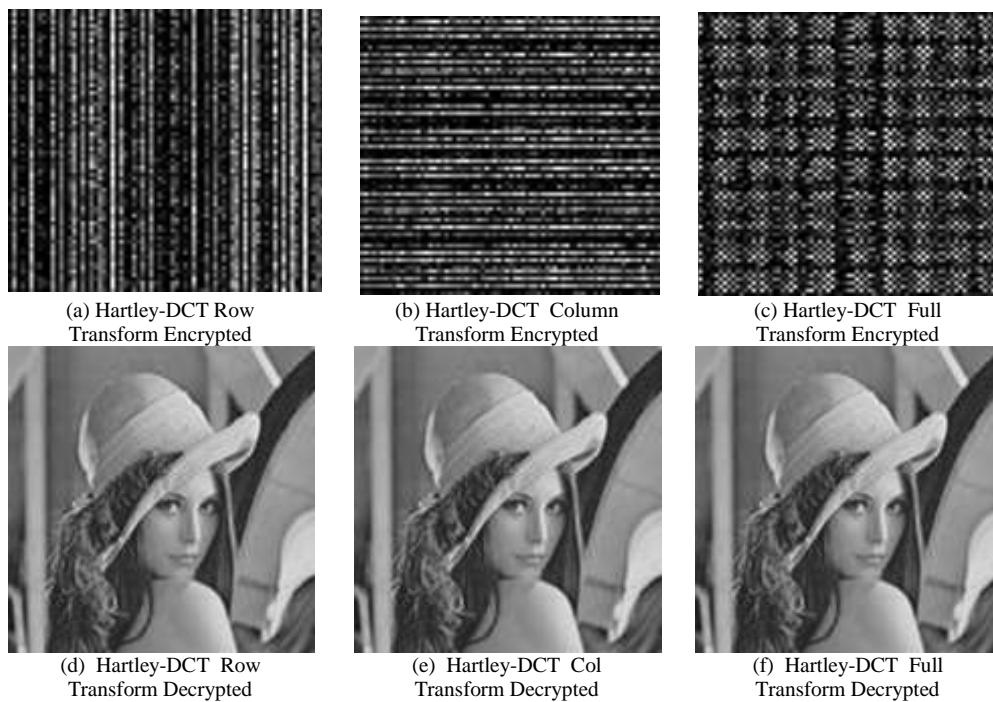


Figure 5. 2X128 Hartley -DST

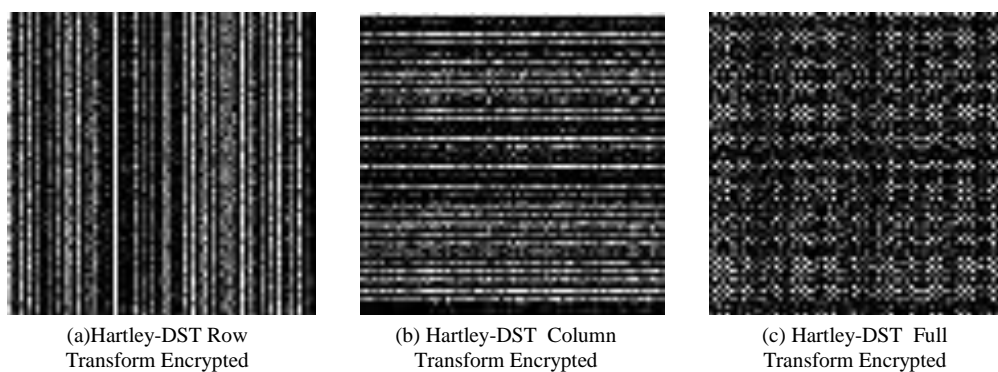




Figure 6. **2X128** Hartley –Real Fourier

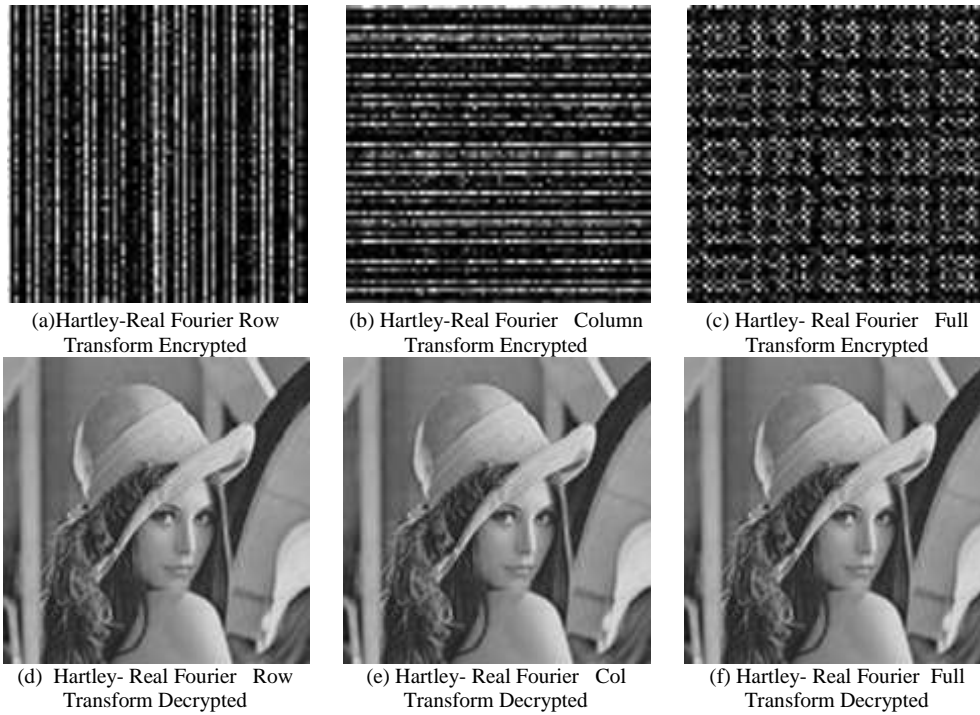
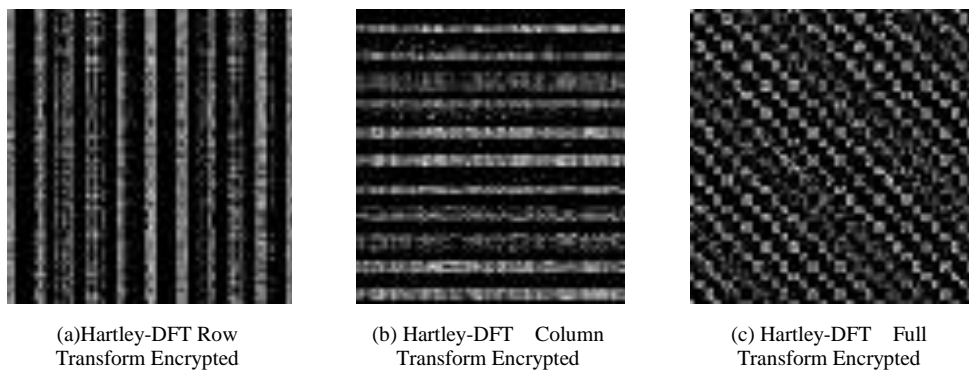


Figure 7. **2X128** Hartley –DFT





B. Pattern 128X2

Figure 8. 128X2 Hartley -DCT

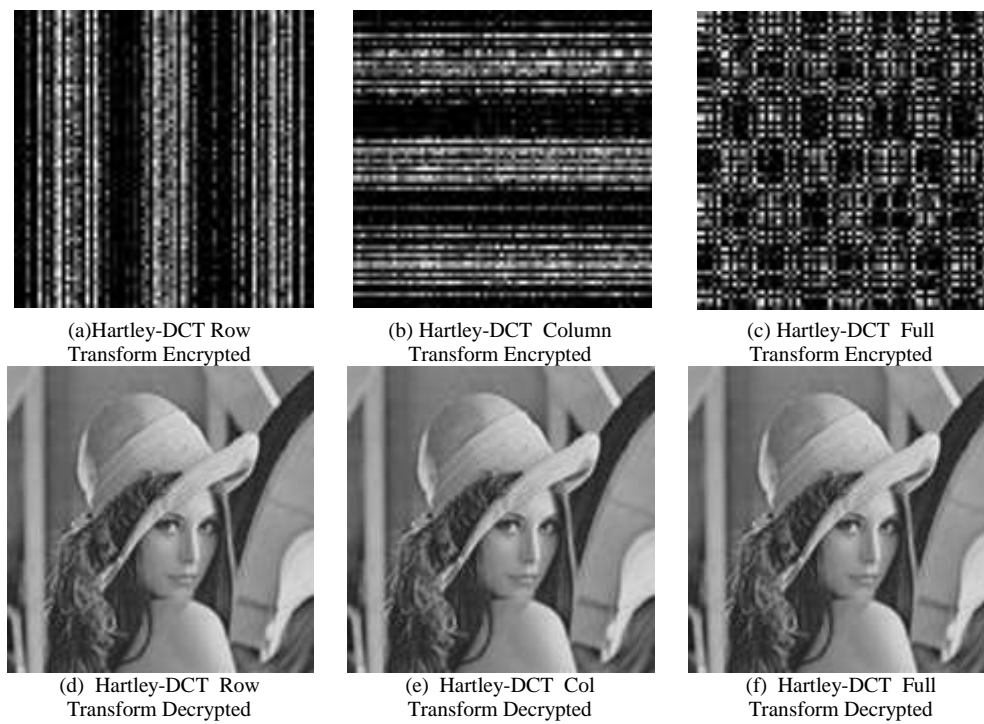


Figure 9. 128X2 Hartley -DST

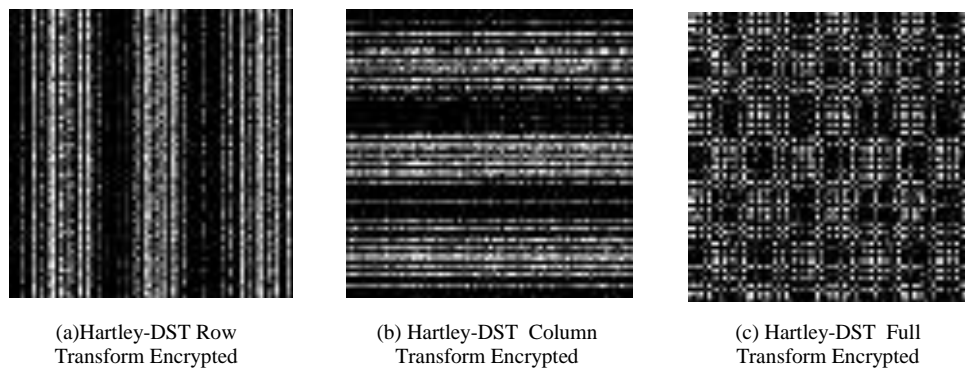




Figure 10. **128X2** Hartley –Real Fourier

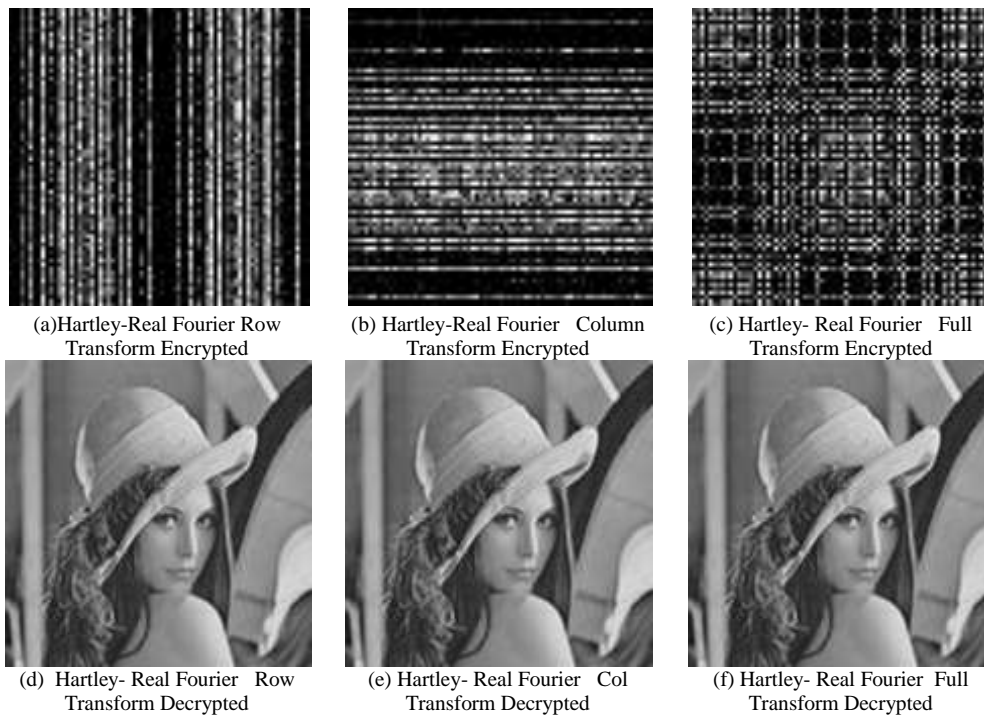
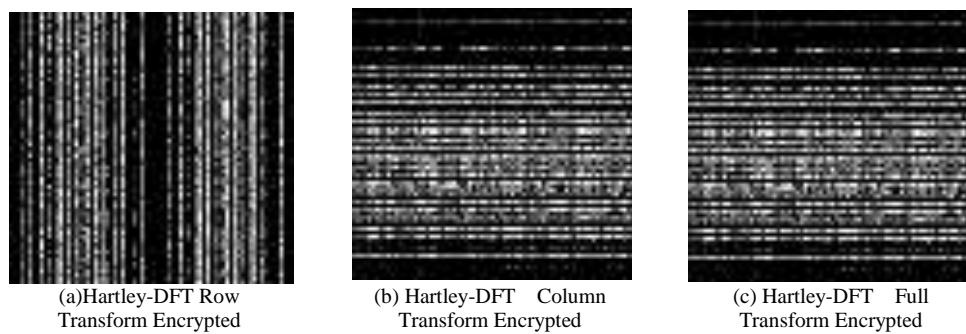


Figure 11. **128X2** Hartley –DFT





C. Pattern 4X64

Figure 12. 4X64 Hartley –DCT

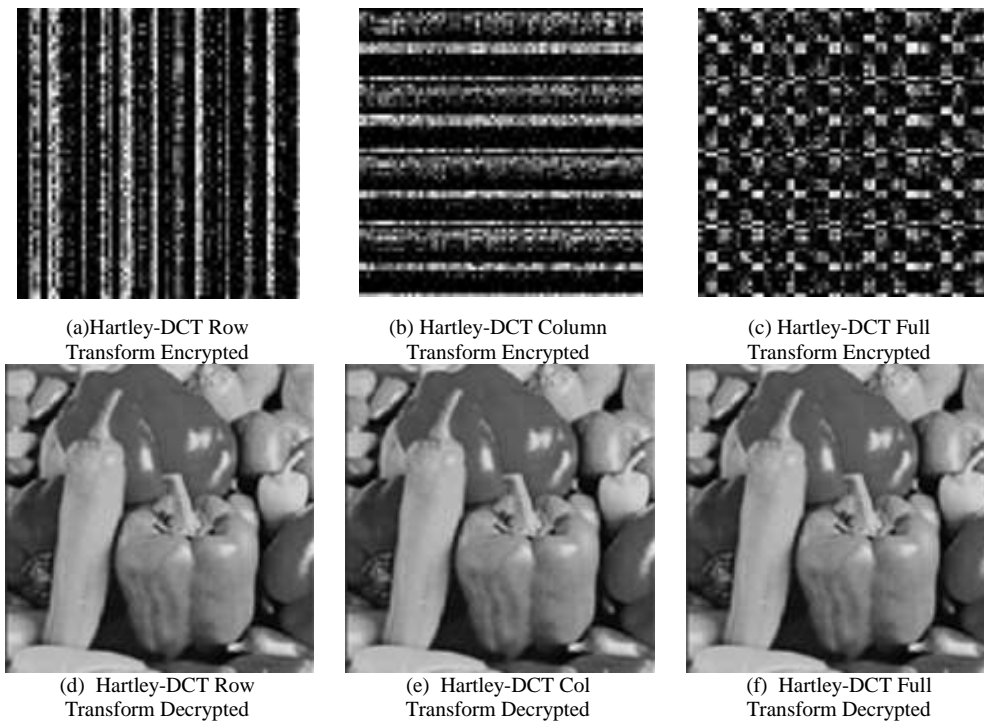
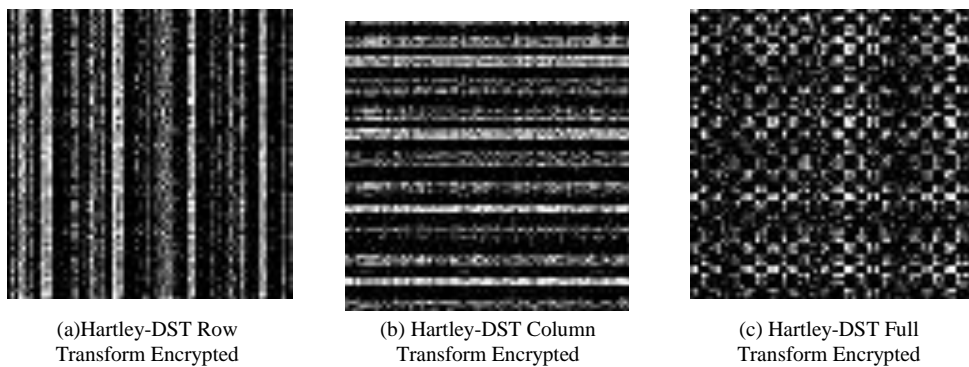


Figure 13. 4X64 Hartley –DST



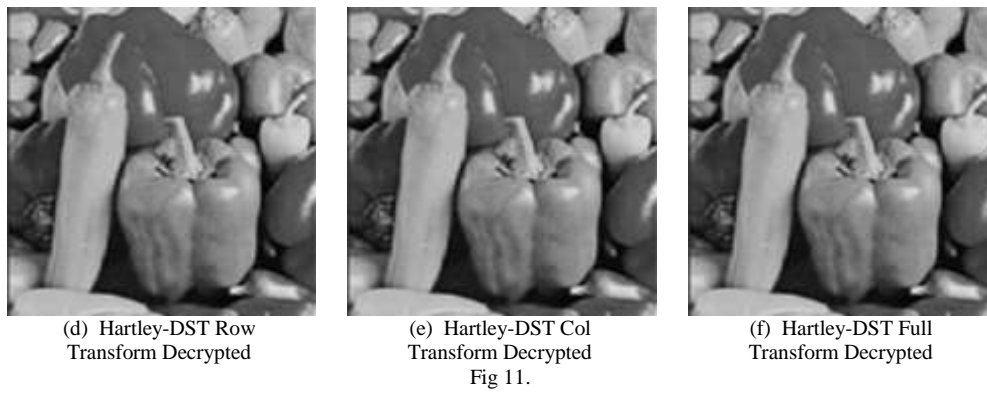


Figure 14. **4X64** Hartley –Real Fourier

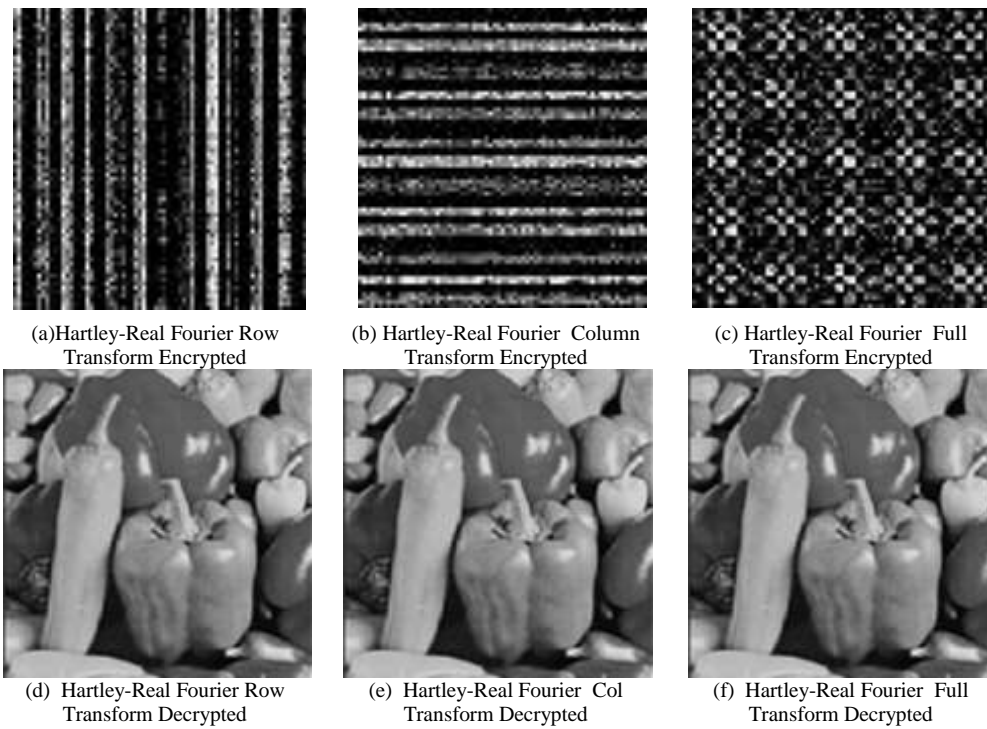
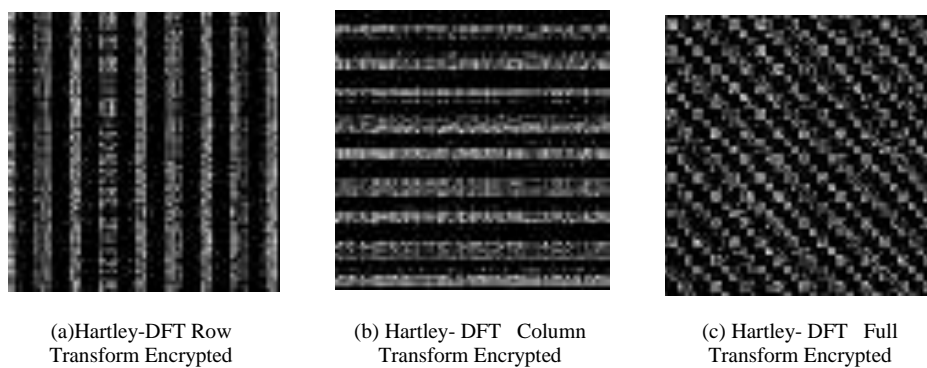


Figure 15. **4X64** Hartley –DFT





(d) Hartley- DFT Row Transform Decrypted



(e) Hartley- DFT Col Transform Decrypted



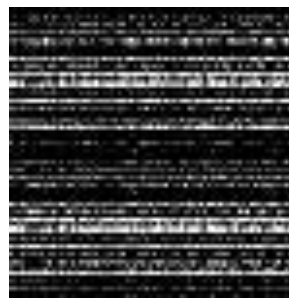
(f) Hartley- DFT Full Transform Decrypted

D. Pattern 64X4

Figure 16. 64X4 Hartley -DCT



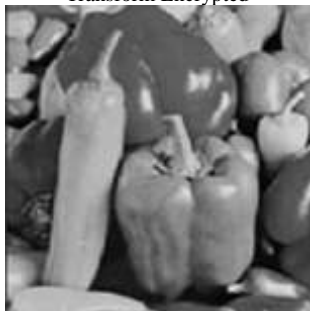
(a) Hartley-DCT Row Transform Encrypted



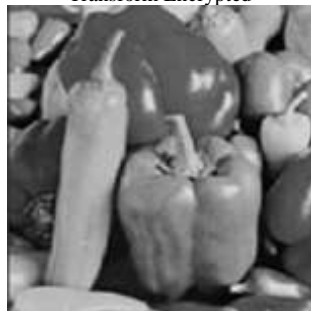
(b) Hartley-DCT Column Transform Encrypted



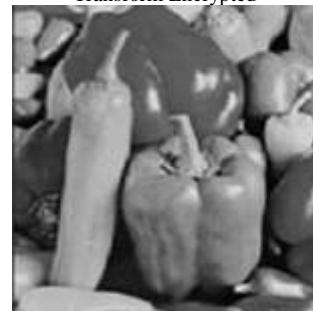
(c) Hartley-DCT Full Transform Encrypted



(d) Hartley-DCT Row Transform Decrypted



(e) Hartley-DCT Col Transform Decrypted

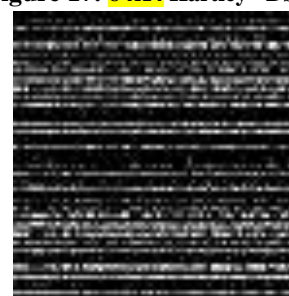


(f) Hartley-DCT Full Transform Decrypted

Figure 17. 64X4 Hartley -DST



(a) Hartley-DST Row Transform Encrypted



(b) Hartley-DST Column Transform Encrypted



(c) Hartley-DST Full Transform Encrypted



Figure 18. **64X4** Hartley –Real Fourier

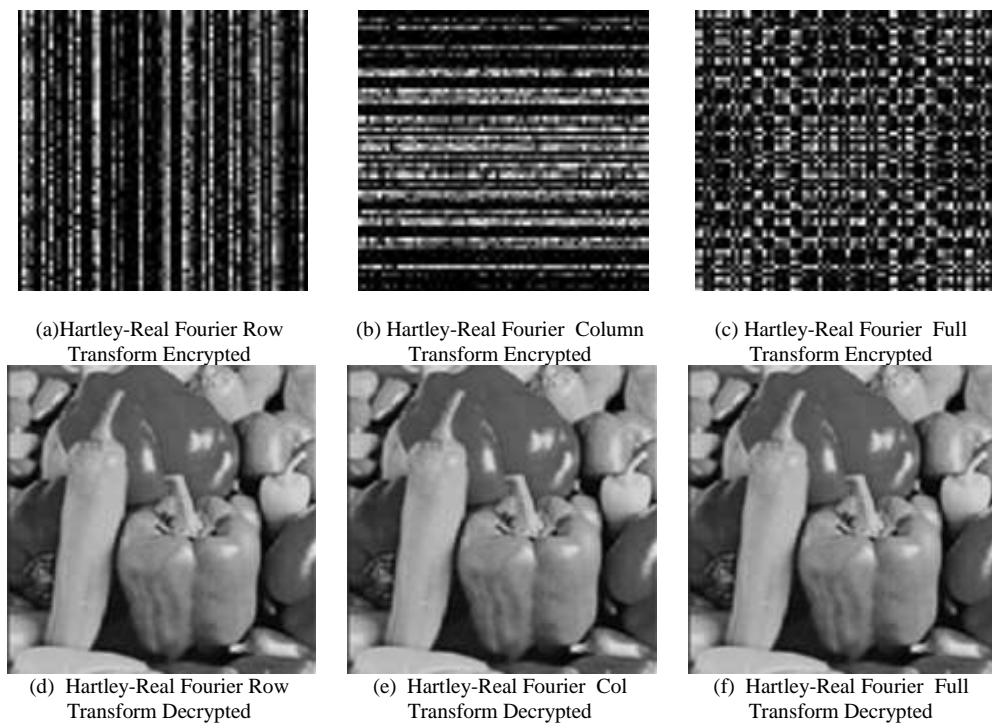
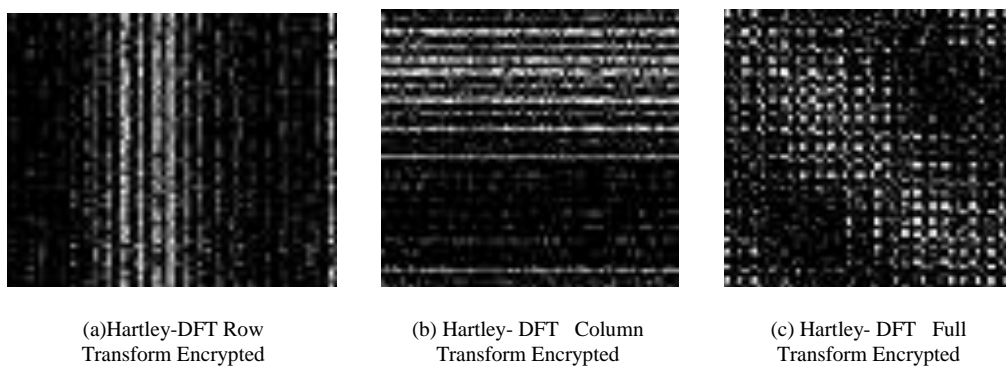


Figure 19. **64X4** Hartley –DFT



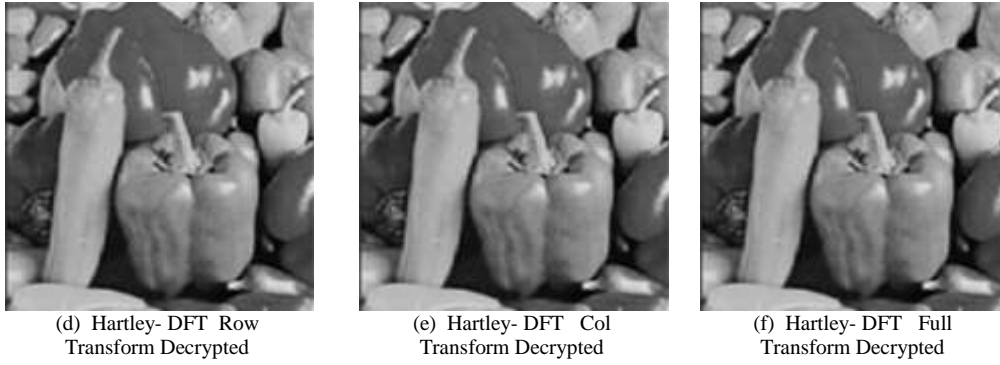
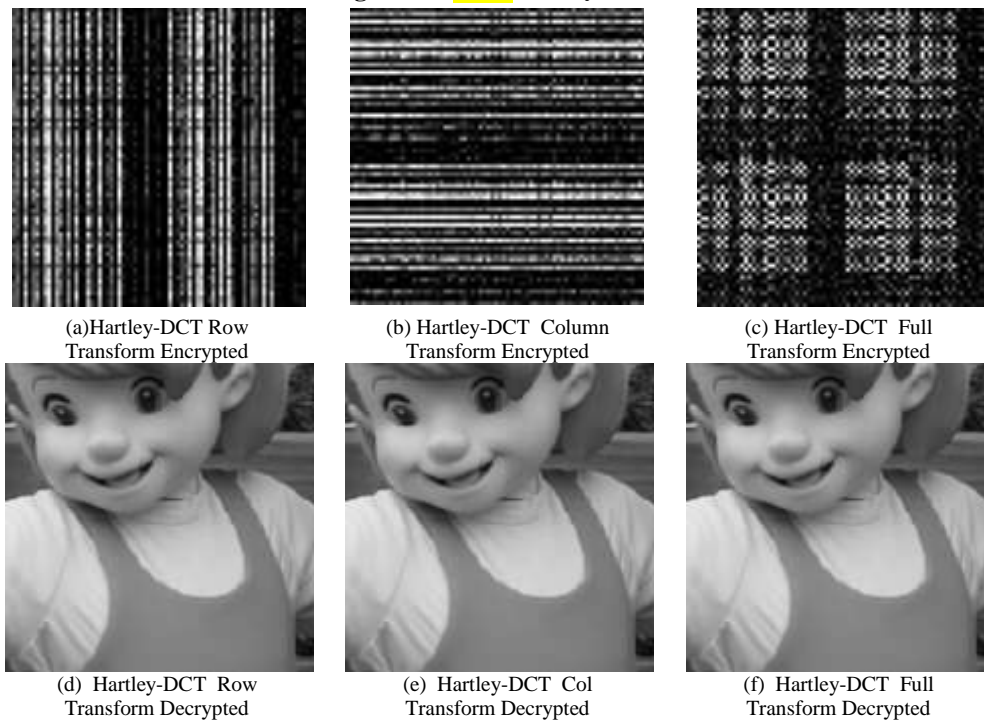


Figure 20. **8X32** Hartley –DCT



E. Pattern 8X32

Figure 21. **8X32** Hartley –DST

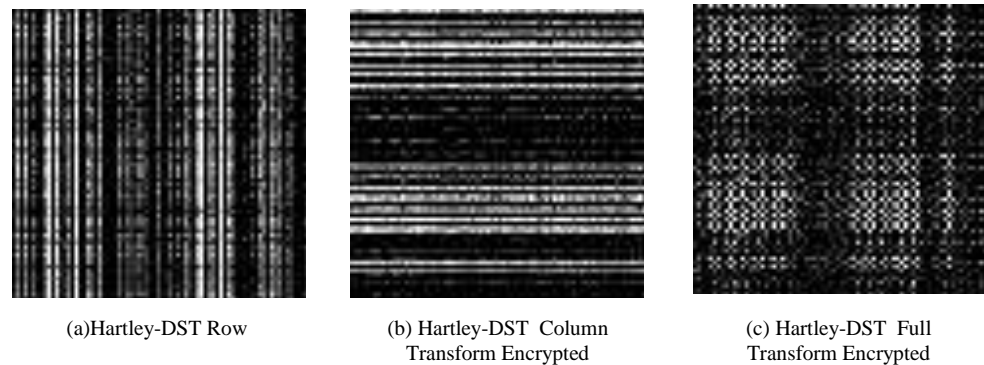




Figure 22. **8X32** Hartley –Real Fourier

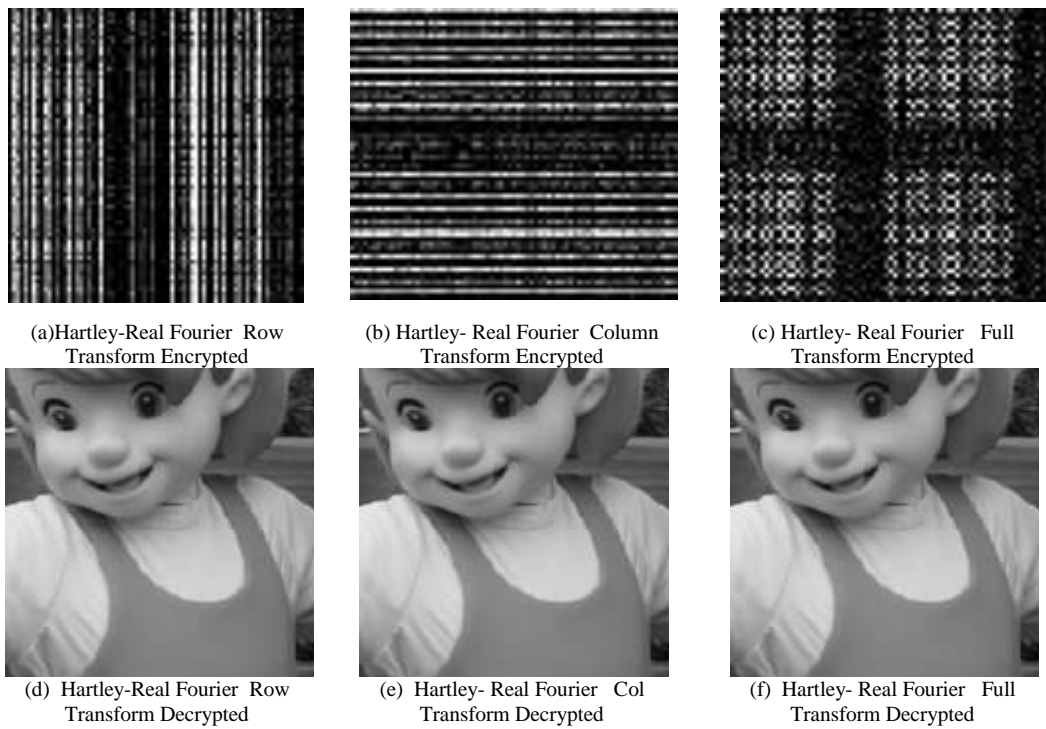
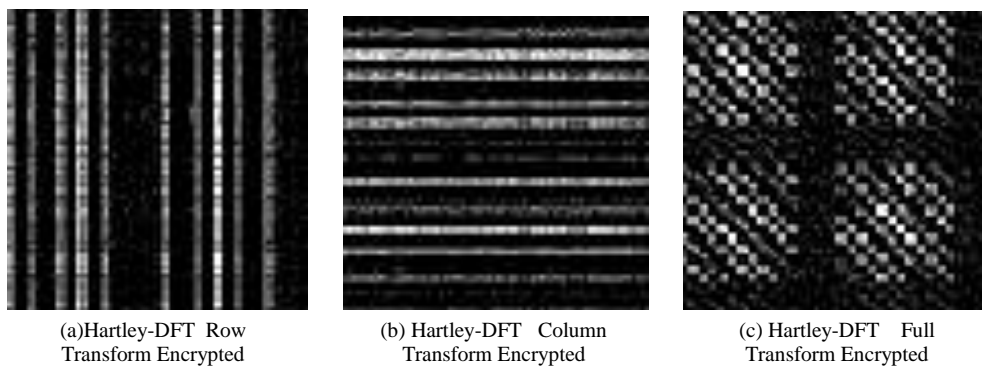


Figure 23. **8X32** Hartley –DFT





F. Pattern 32X8

Figure 24. 32X8 Hartley –DCT

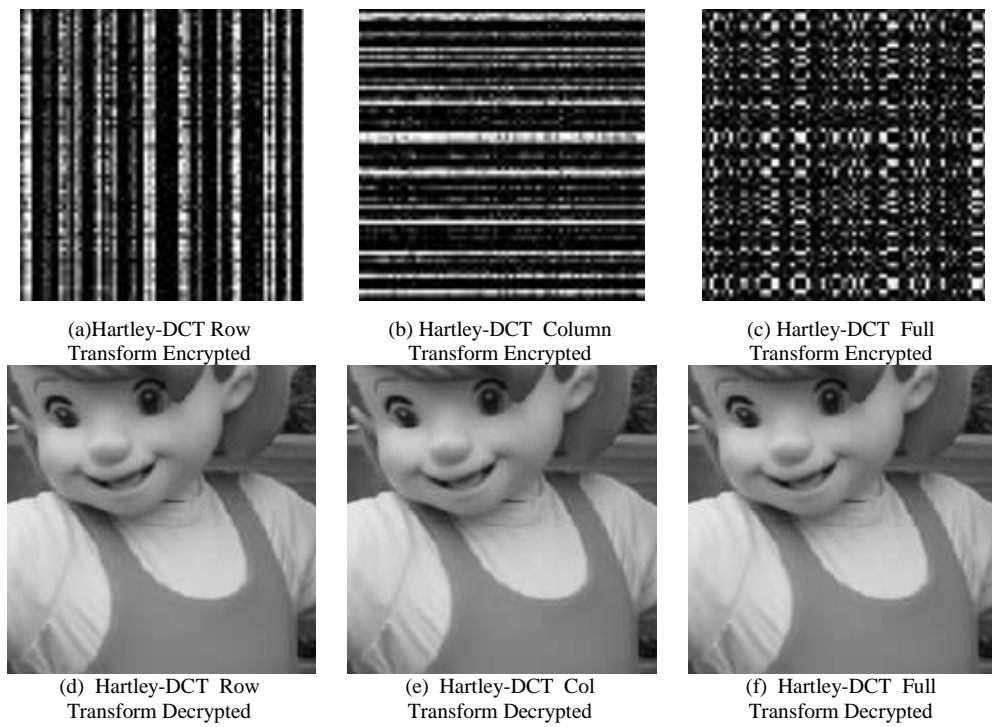


Figure 25. 32X8 Hartley –DST

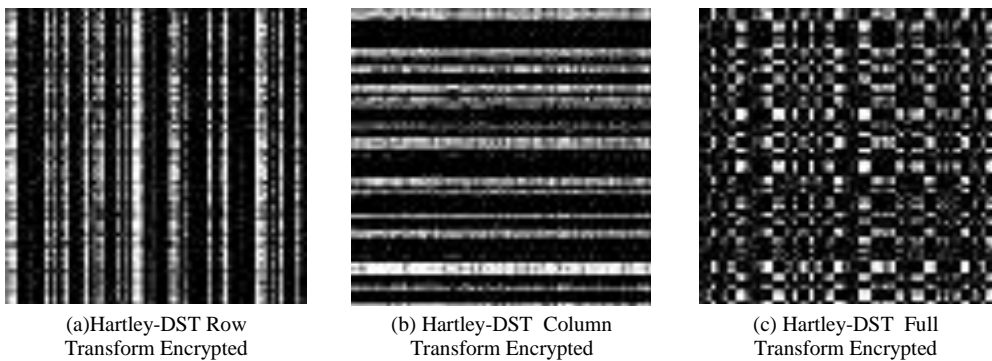




Figure 26. **32X8** Hartley –Real Fourier

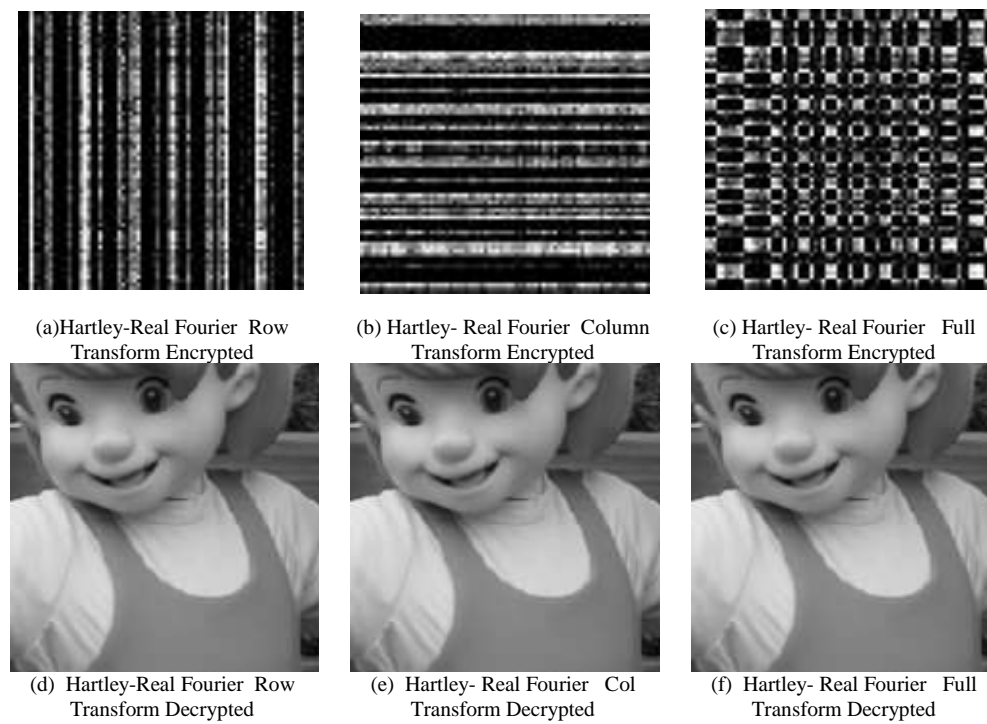
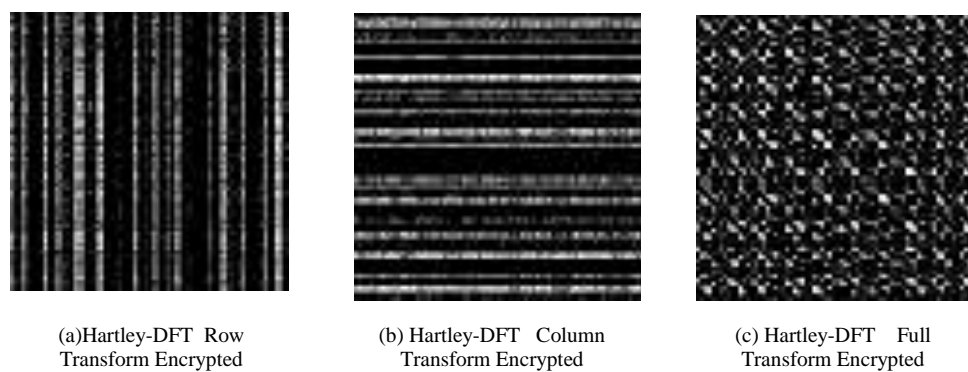


Figure 27. **32X8** Hartley –DFT





G. Pattern 16X16

Figure 28. 16X16 Hartley -DCT

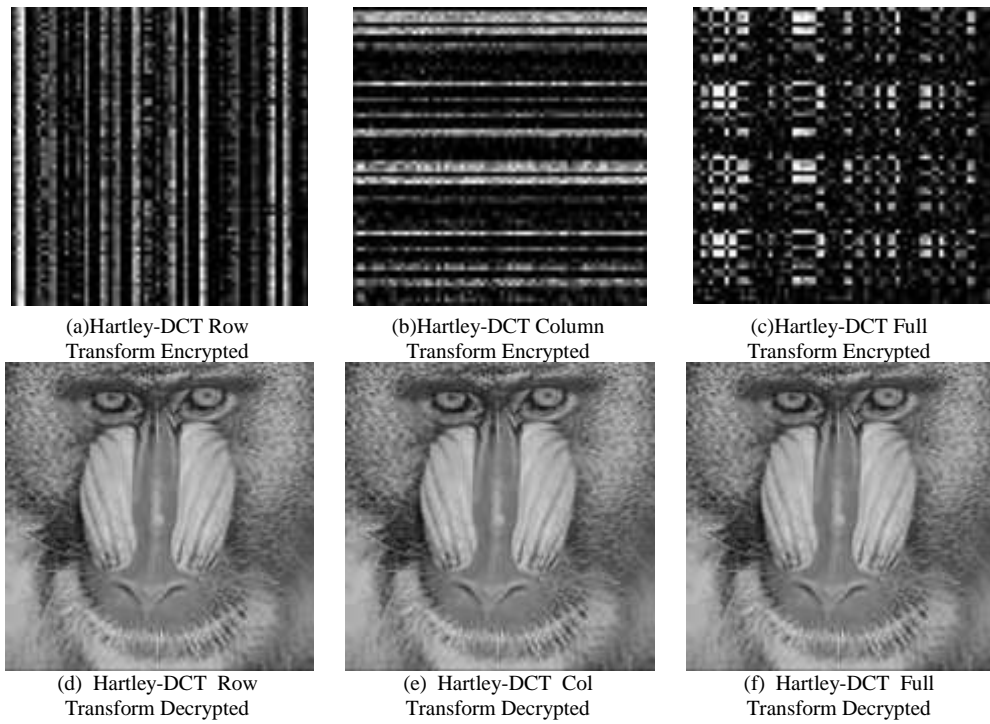
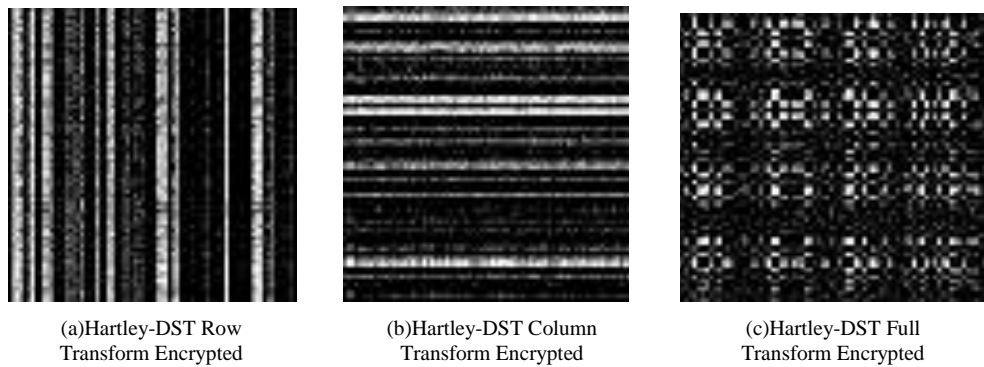


Figure 29. 16X16 Hartley -DST



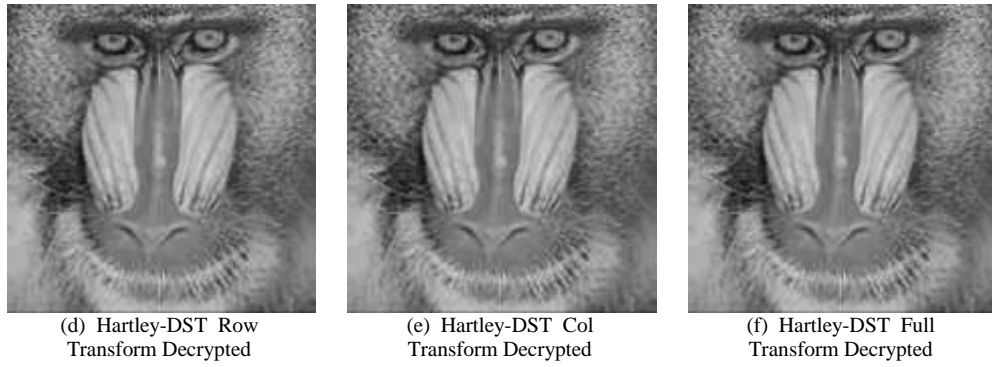


Figure 30.16X16 Hartley –Real Fourier

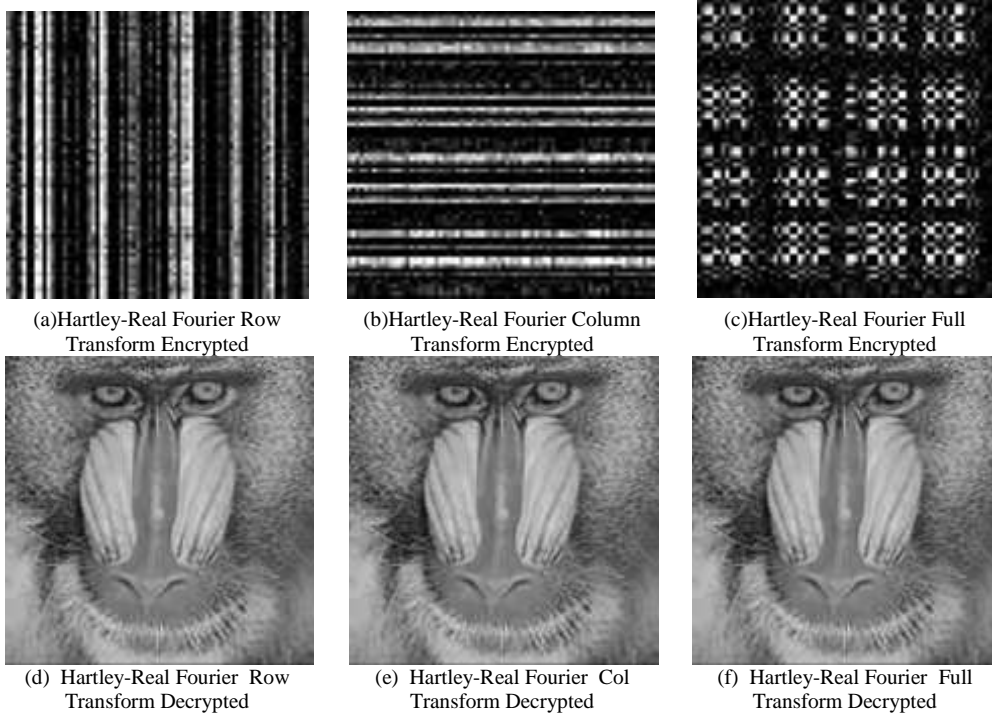
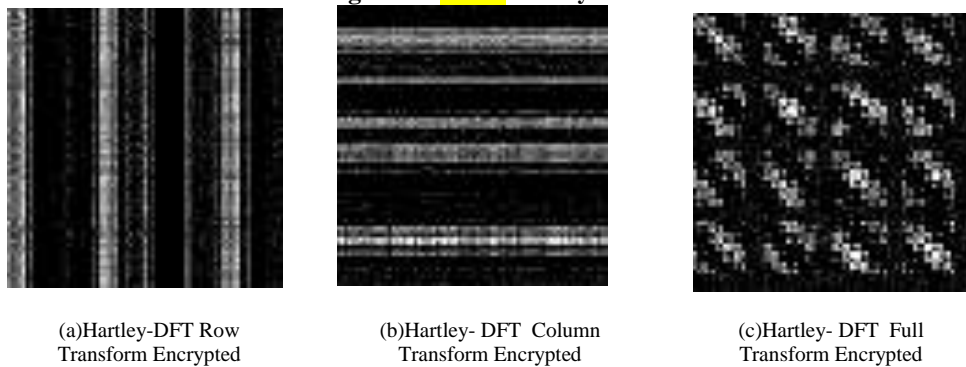


Figure 31.16X16 Hartley –DFT



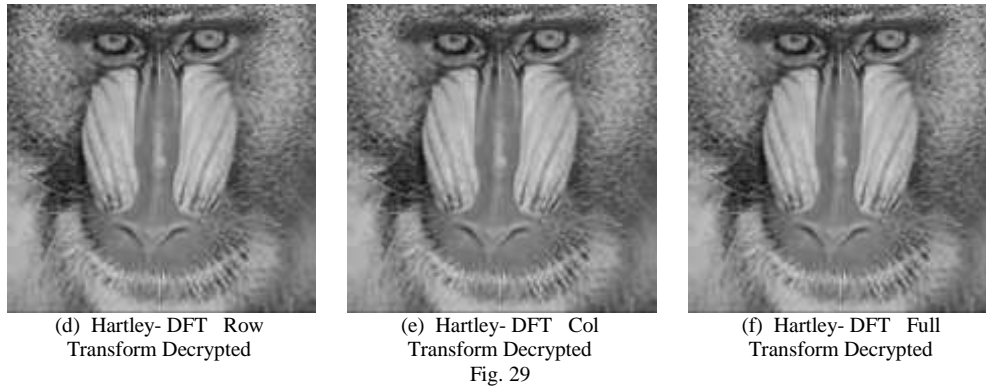


Fig 3. Show the original image and its grayscale version. Figure (4) to Figure(31) shows the results obtained for Hybrid Transforms with Hartley as base. The local transforms used are DCT, DST, Real Fourier and DFT. In the above figures (a) shows the base –local row transform encrypted image. (b) shows the base –local column transform encrypted image and (c) shows the base –local full transform encrypted image. (d),(e) and (f) shows the appropriate decrypted images.

Table No I. Shows the results obtained for row and column correlation obtained for our previous experiment on individual sinusoidal transforms[18]. The results are averaged over five different gray scaled images.

Table No I. Values of Average row Correlation and average Column Correlation obtained in Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images.

Row:0.81398 Col 0.77742	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
DCT						
(Row)	0.9912	0.5610	0.2204	0.4372	0.2481	0.5595
(Col)	0.1917	0.4147	0.9933	0.6231	0.2407	0.5797
DST						
(Row)	0.9904	0.6179	0.2295	0.4099	0.3424	0.4989
(Col)	0.1991	0.4020	0.9913	0.5081	0.3420	0.5014
Real Fourier						
(Row)	0.9948	0.5721	0.2001	0.4115	0.2360	0.3166
(Col)	0.2068	0.2482	0.9928	0.2138	0.2318	0.2926
DFT						
(Row)	0.9956	0.2715	0.1779	0.1327	0.3914	0.1996
(Col)	0.1858	0.1536	0.9959	0.2238	0.4260	0.1720
Hartley						
(Row)	0.9929	0.2477	0.2133	0.1968	0.4223	0.2228
(Col)	0.2235	0.2276	0.9934	0.2203	0.4704	0.2052

Table No II. Values of Average row Correlation and average Column Correlation obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 2X128

Row: 0.81398 Col 0.77742	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
Hartley – DCT						
(Row)	0.9905	0.5163	0.2000	0.2633	0.2262	0.3476
(Col)	0.1931	0.2585	0.9932	0.4435	0.2441	0.3419
Hartley – DST						
(Row)	0.9906	0.5974	0.2024	0.2732	0.2963	0.3532
(Col)	0.2009	0.2815	0.9914	0.5050	0.3064	0.3465
Hartley - Real Fourier						
(Row)	0.9930	0.4474	0.1927	0.2639	0.2315	0.2410
(Col)	0.2102	0.2458	0.9927	0.2228	0.2379	0.2312
Hartley – DFT						
(Row)	0.9941	0.2265	0.2394	0.1327	0.4812	0.1445
(Col)	0.2205	0.1398	0.9940	0.2176	0.4639	0.1501

From Table No II it can be observed that when Hybrid combination of sinusoidal transform for 2X128 pattern is used the Hartley-DCT, Hartley-DST and Hartley-Real Fourier are performing better than individual sinusoidal transforms.

Table No III. Values of Average row Correlation and average Column Correlation obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 128X2

Row: 0.81398 Col 0.77742	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
Hartley – DCT						
(Row)	0.9929	0.2175	0.1917	0.2490	0.2474	0.1969
(Col)	0.1875	0.2270	0.9933	0.2038	0.2567	0.1927
Hartley – DST						
(Row)	0.9929	0.2175	0.1917	0.2490	0.2474	0.1969
(Col)	0.1875	0.2270	0.9933	0.2038	0.2567	0.1927
Hartley - Real Fourier						
(Row)	0.9929	0.2175	0.1917	0.2490	0.2474	0.1969
(Col)	0.1875	0.2270	0.9933	0.2038	0.2567	0.1927
Hartley – DFT						
(Row)	0.9929	0.2175	0.1917	0.2490	0.2474	0.1969
(Col)	0.1875	0.2270	0.9933	0.2038	0.2567	0.1927

Table No III gives results for 128X2 pattern and it can be observed that Hartley-DCT, Hartley-DST and Hartley-Real Fourier are performing better than individual sinusoidal transforms.

Table No IV. Values of Average row Correlation and average Column Correlation obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 4X64

Row: 0.81398 Col 0.77742	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
Hartley – DCT						
(Row)	0.9908	0.4751	0.1957	0.1979	0.2182	0.2128
(Col)	0.1949	0.2039	0.9928	0.3058	0.2361	0.2163
Hartley – DST						
(Row)	0.9899	0.4888	0.1993	0.2001	0.3015	0.2142
(Col)	0.1977	0.2033	0.9909	0.4684	0.2998	0.2165
Hartley - Real Fourier						
(Row)	0.9914	0.4639	0.1917	0.1974	0.2294	0.1977
(Col)	0.2042	0.2062	0.9925	0.2415	0.2367	0.2044
Hartley – DFT						
(Row)	0.9931	0.2254	0.2500	0.1228	0.5177	0.1418
(Col)	0.2462	0.1172	0.9931	0.2161	0.5149	0.1429

Table No IV gives results for 4X64 pattern and it can be observed that Hartley-DCT, Hartley-DST and Hartley-Real Fourier are performing better than individual sinusoidal transforms.

Table No V. Values of Average row Correlation and average Column Correlation obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 64X4

Row: 0.81398 Col 0.77742	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
Hartley – DCT						
(Row)	0.9926	0.2600	0.1894	0.2019	0.2278	0.1913
(Col)	0.1991	0.2037	0.9932	0.2083	0.2423	0.1935
Hartley – DST						
(Row)	0.9926	0.2601	0.1953	0.1960	0.2546	0.1902
(Col)	0.2460	0.2002	0.9929	0.2229	0.2732	0.1906
Hartley - Real Fourier						
(Row)	0.9928	0.2212	0.1945	0.2001	0.2398	0.1878
(Col)	0.1909	0.2036	0.9932	0.2090	0.2541	0.1916
Hartley – DFT						
(Row)	0.9928	0.2018	0.2609	0.1490	0.3750	0.1322
(Col)	0.2553	0.1465	0.9932	0.1867	0.3746	0.1320

Table No V gives results for 64X4 pattern and it can be observed that Hartley-DCT, Hartley-DST and Hartley-Real Fourier are performing better than individual sinusoidal transforms.

Table No VI. Values of Average row Correlation and average Column Correlation obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 8X32

Row: 0.81398 Col 0.77742	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
Hartley – DCT						
(Row)	0.9907	0.4799	0.1902	0.2089	0.2177	0.2477
(Col)	0.2004	0.2134	0.9927	0.3174	0.2336	0.2485
Hartley – DST						
(Row)	0.9905	0.4918	0.2003	0.2136	0.2919	0.2775
(Col)	0.2037	0.2187	0.9915	0.4768	0.2929	0.2791
Hartley - Real Fourier						
(Row)	0.9912	0.4326	0.1941	0.2114	0.2303	0.2266
(Col)	0.2033	0.2182	0.9926	0.2874	0.2389	0.2286
Hartley – DFT						
(Row)	0.9929	0.3055	0.2994	0.1545	0.5638	0.1620
(Col)	0.2772	0.1534	0.9930	0.2955	0.5745	0.1662

Table No VI gives results for 8X32 pattern and it can be observed that Hartley-DCT, Hartley-DST and Hartley-Real Fourier are performing better than individual sinusoidal transforms.

Table No VII. Values of Average row Correlation and average Column Correlation obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 32X8

Row: 0.81398 Col 0.77742	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
Hartley – DCT						
(Row)	0.9920	0.3305	0.1895	0.3013	0.2193	0.2740
(Col)	0.2068	0.2827	0.9930	0.2415	0.2348	0.2543
Hartley – DST						
(Row)	0.9920	0.3255	0.19664	0.27438	0.2740	0.2653
(Col)	0.2313	0.2828	0.99252	0.25758	0.2909	0.2502
Hartley - Real Fourier						
(Row)	0.9922	0.2882	0.1905	0.3329	0.2349	0.2849
(Col)	0.1958	0.2948	0.993	0.2283	0.2513	0.2604
Hartley – DFT						
(Row)	0.9928	0.2272	0.3360	0.1135	0.5455	0.1264
(Col)	0.3380	0.1125	0.9930	0.2111	0.5547	0.1310

Table No VII gives results for 32X8 pattern and it can be observed that Hartley-DCT, Hartley-DST and Hartley-Real Fourier are performing better than individual sinusoidal transforms.

Table No VIII. Values of Average row Correlation and average Column Correlation obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 16X16

Row: 0.81398 Col 0.77742	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
Hartley – DCT						
(Row)	0.9913	0.4098	0.1916	0.1945	0.2161	0.2120
(Col)	0.2055	0.1939	0.9929	0.2791	0.2348	0.2161
Hartley – DST						
(Row)	0.9914	0.3972	0.1977	0.1988	0.2826	0.2104
(Col)	0.2173	0.1962	0.9918	0.3972	0.3009	0.2168
Hartley - Real Fourier						
(Row)	0.9916	0.3590	0.1908	0.2098	0.2339	0.2133
(Col)	0.2058	0.2087	0.9928	0.2801	0.2431	0.2153
Hartley – DFT						
(Row)	0.9928	0.2591	0.3326	0.11426	0.5827	0.1231
(Col)	0.3183	0.1124	0.9930	0.25526	0.5948	0.1241

Table No VIII gives results for 16X16 pattern and it can be observed that Hartley-DCT, Hartley-DST and Hartley-Real Fourier are performing better then individual sinusoidal transforms.

Table No IX. Average Values of PAFCPV obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 2 X128

	ROW TRANSFORM SCRAMBLED	COL TRANSFORM SCRAMBLED	FULL TRANSFORM SCRAMBLED
Hartley - DCT	0.55706	0.57176	0.57502
Hartley - DST	0.54910	0.54852	0.57096
Hartley- Real Fourier	0.56672	0.57276	0.57526
Hartley - DFT	0.63178	0.63326	0.6338

Table No X. Average Values of PAFCPV obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 128X2

	ROW TRANSFORM SCRAMBLED	Col TRANSFORM SCRAMBLED	FULL TRANSFORM SCRAMBLED
Hartley - DCT	0.57072	0.56888	0.57494
Hartley - DST	0.57072	0.56888	0.57494
Hartley - Real Fourier	0.57072	0.56888	0.57494
Hartley - DFT	0.57072	0.56888	0.57494

Table No XI. Average Values of PAFCPV obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 4X64

	ROW TRANSFORM SCRAMBLED	Col TRANSFORM SCRAMBLED	FULL TRANSFORM SCRAMBLED
Hartley - DCT	0.56800	0.56980	0.57546
Hartley - DST	0.56304	0.56964	0.57238
Hartley - Real Fourier	0.58028	0.56894	0.57384
Hartley - DFT	0.63260	0.63266	0.63364

Table No XII. Average Values of PAFCPV obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 64X4

	ROW TRANSFORM SCRAMBLED	Col TRANSFORM SCRAMBLED	FULL TRANSFORM SCRAMBLED
Hartley - DCT	0.57448	0.57324	0.56978
Hartley - DST	0.57418	0.56984	0.57450
Hartley - Real Fourier	0.56874	0.56992	0.57394
Hartley - DFT	0.61614	0.61776	0.61736

Table No XIII. Average Values of PAFCPV obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 8X32

	ROW TRANSFORM SCRAMBLED	Col TRANSFORM SCRAMBLED	FULL TRANSFORM SCRAMBLED
Hartley - DCT	0.55704	0.57426	0.57204
Hartley - DST	0.55814	0.56372	0.56718
Hartley-Real Fourier	0.57156	0.57460	0.57228
Hartley - DFT	0.62668	0.62916	0.62286

Table No XIV. Average Values of PAFCPV obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 32X8

	ROW TRANSFORM SCRAMBLED	Col TRANSFORM SCRAMBLED	FULL TRANSFORM SCRAMBLED
Hartley - DCT	0.56980	0.57404	0.57276
Hartley - DST	0.56992	0.56944	0.57336
Hartley - Real Fourier	0.57192	0.57004	0.57502
Hartley - DFT	0.62804	0.62610	0.62490

Table No XV. Average Values of PAFCPV obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 16X16

	ROW TRANSFORM SCRAMBLED	Col TRANSFORM SCRAMBLED	FULL TRANSFORM SCRAMBLED
Hartley- DCT	0.55937	0.57710	0.57422
Hartley - DST	0.54355	0.57457	0.5687
Hartley-Real Fourier	0.57080	0.57806	0.5719
Hartley - DFT	0.62634	0.6294	0.6237

Table No IX to XV displays the average values of PAFCPV obtained in the scrambled images for different patterns. The highest values is obtained 2X128 pattern in Hartley-DFT hybrid transform.

Table No XVI. Average Values of Entropy obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 2X128

Original Entropy 7.3980	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
Hartley – DCT	3.82666	5.04652	2.98758	4.87568	2.28326	4.8563
Hartley – DST	4.34536	5.09188	4.48926	5.19164	2.80264	4.78896
Hartley - Real Fourier	3.93396	4.92656	3.12558	4.85984	2.41120	4.84766
Hartley – DFT	4.09058	4.681	4.20376	4.70064	3.77822	4.66674

In Table No XVI , Minimum value of entropy is obtained in Full Transform image for Hartley-DCT , Incase of scrambled image it is in Hartley-DFT for full transform for 2X128 Pattern.

Table No XVII. Average Values of Entropy obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 128X2

Original Entropy 7.3980	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
Hartley – DCT	3.42024	4.90978	3.43064	4.94456	2.90334	4.84488
Hartley – DST	3.42018	4.90978	3.43066	4.94456	2.90334	4.84488
Hartley - Real Fourier	3.42018	4.90978	3.43066	4.94456	2.90334	4.84488
Hartley – DFT	3.6641	4.90978	3.67966	4.94456	3.44704	4.84488

In Table No XVII , Minimum value of entropy is obtained in Full Transform image for Hartley-DCT, Hartley-DST and Hartley-Real Fourier , In case of scrambled image it is in Hartley-DCT, Hartley-DST, Hartley-Real Fourier and Hartley-DFT for full transform for 128X2 Pattern.

Table No XVIII. Average Values of Entropy obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 4X64

Original Entropy 7.3980	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
Hartley – DCT	3.72298	4.79792	3.00238	4.90096	2.30688	4.85102
Hartley – DST	4.0943	4.90446	4.15838	4.77732	2.79294	4.75376
Hartley - Real Fourier	3.89352	4.76448	3.23232	4.89684	2.54144	4.8593
Hartley – DFT	3.96754	4.6689	4.25638	4.67872	4.14714	4.68164

In Table No XVIII , Minimum value of entropy is obtained in Full Transform image for Hartley-DCT , Incase of scrambled image it is in Hartley-DFT for Row transform for 4X64 Pattern.

Table No XIX. Average Values of Entropy obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 64X4

Original Entropy 7.3980	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
Hartley – DCT	3.6254	4.84218	3.35238	4.85446	2.7723	4.69194
Hartley – DST	3.59576	4.86332	3.69626	4.9002	3.2263	4.84912
Hartley - Real Fourier	3.49732	4.91924	3.51754	4.90668	3.04142	4.84722
Hartley – DFT	3.82974	4.70878	3.92784	4.69778	3.95196	4.62176

In Table No XIX , Minimum value of entropy is obtained in Full Transform image for Hartley-DCT, Incase of scrambled image it is in Hartley-DFT for Full transform for 64X4 Pattern.

Table No XX. Average Values of Entropy obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 8X32

Original Entropy 7.3980	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
Hartley – DCT	3.65822	4.99322	3.0344	4.83398	2.34734	4.63664
Hartley – DST	3.87534	5.01564	4.03452	4.9795	2.98068	4.66168
Hartley - Real Fourier	3.83308	4.8618	3.41996	4.83466	2.64238	4.63162
Hartley – DFT	4.1021	4.7036	4.44872	4.70354	4.20076	4.6711

In Table No XX , Minimum value of entropy is obtained in Full Transform image for Hartley-DCT , Incase of scrambled image it is in Hartley-Real Fourier for Full transform for 8X32 Pattern.

Table No XXI. Average Values of Entropy obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 32X8

Original Entropy 7.3980	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
Hartley – DCT	3.64278	4.88802	3.21726	4.8449	2.57284	4.64858
Hartley – DST	3.67256	4.87268	3.80662	4.9132	3.25454	4.7929
Hartley - Real Fourier	3.6917	4.88132	3.51464	4.89712	2.90922	4.85154
Hartley – DFT	3.93128	4.7159	4.1168	4.72946	4.2216	4.68774

In Table No XXI , Minimum value of entropy is obtained in Full Transform image for Hartley-DCT, Incase of scrambled image it is in Hartley-DFT for Full transform for 32X8 Pattern.

Table No XXII. Average Values of Entropy obtained in Hybrid Sinusoidal Transforms for Row transform, Column Transform and Full Transform for five images using Pattern 16X16

Original Entropy 7.3980	ROW TRANSFORM	ROW TRANSFORM SCRAMBLED	Col TRANSFORM	Col TRANSFORM SCRAMBLED	FULL TRANSFORM	FULL TRANSFORM SCRAMBLED
Hartley – DCT	3.63532	4.89504	3.10422	4.80738	2.42346	4.6203
Hartley – DST	3.7401	4.9758	3.92946	4.87106	3.14476	4.66325
Hartley - Real Fourier	3.76402	4.88102	3.48952	4.80806	2.77148	4.64326
Hartley – DFT	3.99596	4.72846	4.32484	4.74136	4.28766	4.66574

In Table No XXII, Minimum value of entropy is obtained in Full Transform image for Hartley-DCT, Incase of scrambled image it is in Hartley-DCT for Full transform for 16X16 Pattern.

Figure 32. Comparison of Avg Row and Col Correlation between DCT v/s Hartley DCT for all the patterns

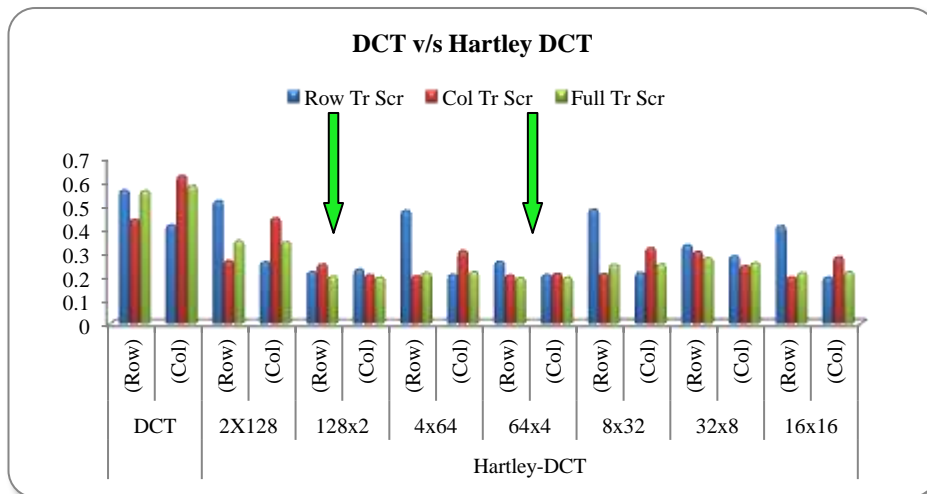


Figure 33. Comparison of Avg Row and Col Correlation between DST v/s Hartley DST for all the patterns

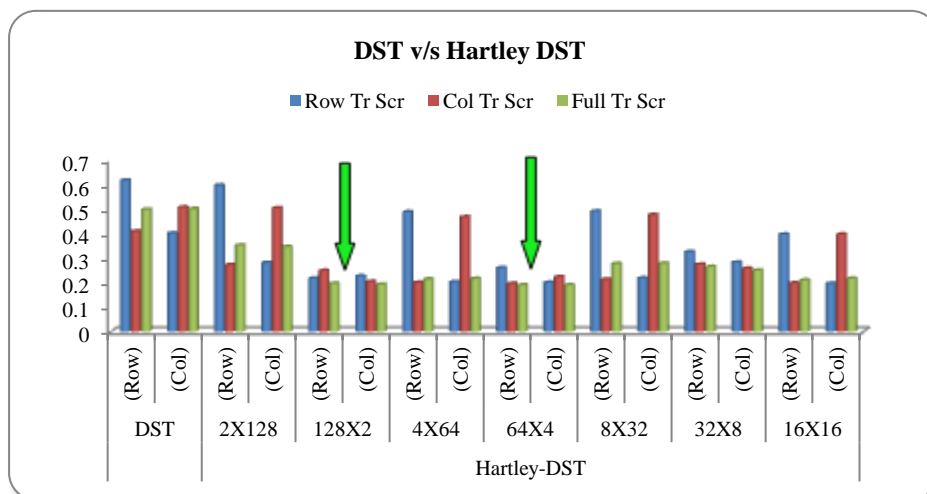


Figure 34. Comparison of Avg Row and Col Correlation between Real Fourier v/s Hartley Real Fourier for all the patterns

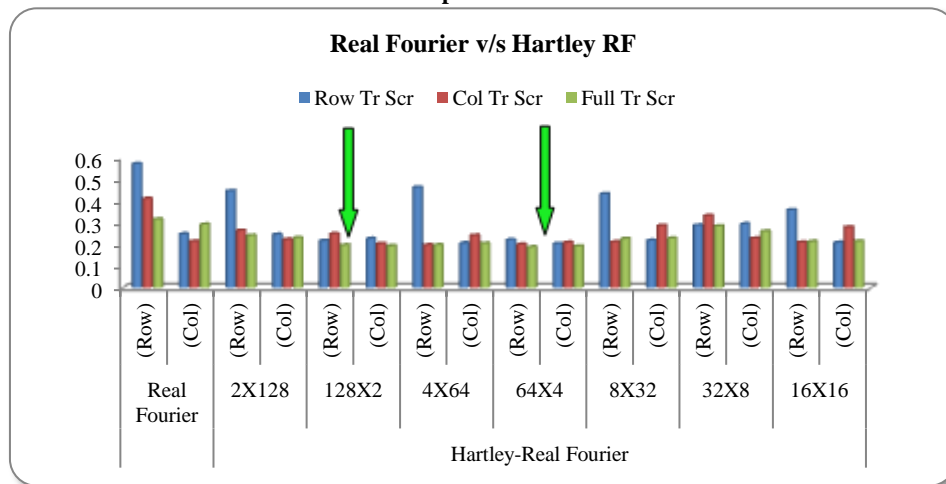


Figure 35. Comparison of Avg Row and Col Correlation between DFT v/s Hartley DFT for all the patterns

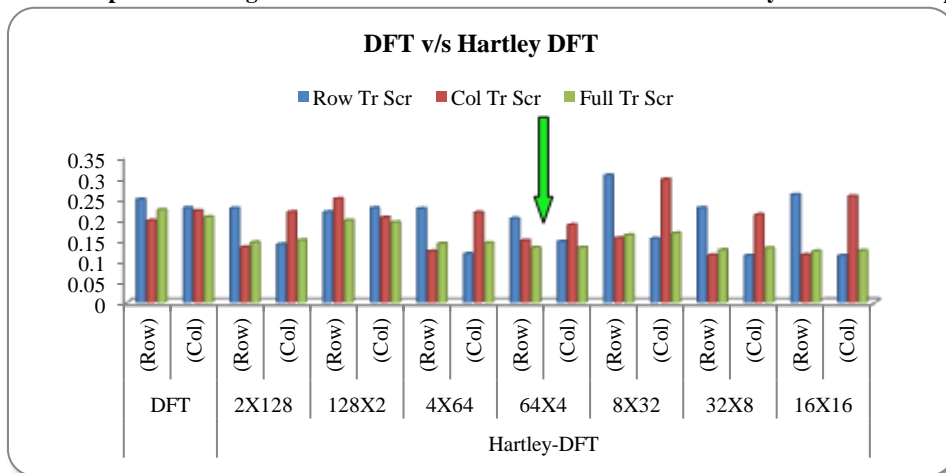


Figure 32 to 35 shows a comparison between average row and correlation obtained between original transform and hybrid transform for all patterns. In Hartley-DCT, Hartley-DST and Hartley-Real Fourier, it is 128x2 and 64x4 giving good results for correlation whereas in Hartley-DFT it is only 64x4 giving better results.

IV. Conclusion

A framework in the transform domain using Sinusoidal Hybrid Transform was proposed. For experimental purpose a number of parameters like row correlation, column correlation, PAFCPV, Entropy and NPCR were calculated. The results for NPCR were not display as all the values obtained across all the Hybrid Sinusoidal transforms and across all the patterns were uniform and the value was 100. From correlation point of view Hartley-DCT, Hartley-DST and Hartley-Real Fourier are giving good results. Looking at PAFCPV 4X64 and 2X128 are giving the highest value for Hartley-DFT. For Entropy in case of transformed image it is Hartley-DCT is performing the best for full transform and incase of scrambled image Hartley -DFT for full transform is giving good results.

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