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Dualities Between Double Integral Transforms

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Abstract: Integral transforms play very important role in solving differential and integral transforms. Many researchers had developed lot of integral transforms. So, It is essential to know the relationship between these double integral transforms. Dualities between some useful double integral transforms are discussed in this paper.

Keywords: Differential Equations, Integral transforms, Laplace transform, Elzaki transform, Kamal transform, Mohand transform, Mahgoub transform, Sumudu transform, Sawi transform.

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I. INTRODUCTION

Many process and phenomenon of science, engineering and real life can be expressed mathematically and solved by using integral transforms. In this paper we discuss the dualities between various double integral transforms Laplace[L] , Elzaki[E] , Kamal[K] , Mohand[M] , Mahgoub[M*], Sumudu[S], Sawi[S*] .
Mahgoub and Abdelrahim introduced new integral transform Sawi [10] in 2019. In 2016, Sedeeg and Abdelilah Kamal introduced Kamal transform [11]. In 2012 the new integral transform was developed by Elzaki[6]. Dealing and Michael compared Sumudu and Laplace transform [2] in 1997. Mahgoub and Abdelrahim introduced Mahgoub transform [8] in 2016. Further in 2017 they introduced Mohand transform [9].
In 2011, Tarig and Salih introduced new integral transform called as Tarig transform [3]. Further they proved relationship between Laplace and Tarig transform[4] in 2011. They also used Tarig transform to ordinary differential equation with variable coefficients[5] in 2011. Same author's used Tarig transform to System of Integro-Differential Equations in 2013[7].
In 2018, Shaikh and Sadikali Latif introduced Sadik transform in 2018[12]. In 2017, Taha, Hassan, Nuruddeen, Sedeeg and Abdelilah obtained dualities between Kamal and Mahgoub integral transforms and some famous integral transforms [13]. In 2017, Aboodh introduced new transform namely Aboodh transform [1]. In 2018, Thangavelu [14] use double Mahgoub transform to solve telegraph equations. Many researchers have developed double integral transforms and some of the triple integral transforms. Dualities between integral transforms have been studied by some of the researchers.
In this paper, the dualities between double integral transforms are studied.

II. DEFINITIONS OF DOUBLE INTEGRAL TRANSFORMS

Definition 2.1 Double Laplace transform:

$$L_2[f(x,t):(u,v)] = \int_0^\infty \int_0^\infty f(x,t).e^{-(ux+vt)}\,dx.dt \tag{2.1}$$

Definition 2.2 Double Elzaki transform:

$$E_2[f(x,t):(u,v)] = uv\int_0^\infty \int_0^\infty f(x,t).e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}\,dx.dt \tag{2.2}$$

Definition 2.3 Double Kamal transform:

$$K_2[f(x,t):(u,v)] = \int_0^\infty \int_0^\infty f(x,t)\;\; e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}dx\,dt \tag{2.3}$$

Definition 2.4 Double Mohand transform:

$$M_2[f(x,t):(u,v)] = u^2v^2\int_0^\infty \int_0^\infty f(x,t)\;\; e^{-(ux+vt)}dx\,dt \tag{2.4}$$

Definition 2.5 Double Mahgoub transform:

$$M_2^*[f(x,t):(u,v)] = uv\int_0^\infty \int_0^\infty f(x,t)\;\; e^{-(ux+vt)}dx\,dt \tag{2.5}$$

Definition 2.6 Double Sumudu transform:

$$S_2[f(x,t):(u,v)] = \frac{1}{uv}\int_0^\infty \int_0^\infty f(x,t)\;\; e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}dx\,dt \tag{2.6}$$

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Definition 2.7 Double Sawi transform:

$$S_2^{*}[f(x,t):(u,v)] = \frac{1}{u^2v^2}\int_0^{\infty}\int_0^{\infty} f(x,t)\ e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}dx\,dt \qquad (2.7)$$

Definition 2.8 Double Aboodh transform:

$$A_2[f(x,t):(u,v)] = \frac{1}{uv}\int_0^{\infty}\int_0^{\infty} f(x,t)\ e^{-(ux+vt)}dx\,dt \qquad (2.8)$$

III. DUALITY BETWEEN DOUBLE INTEGRAL TRANSFORMS

3.1 Duality between double Laplace and other double integral transforms
3.1.1 Duality between double Laplace and double Elzaki transform

A) Double Laplace - Double Elzaki duality

We have double Laplace transform

$$L_2[f(x,t):(u,v)] = \int_0^{\infty}\int_0^{\infty} f(x,t)\,.\,e^{-(ux+vt)}\,dx.dt$$

Replace u by $\frac{1}{u}$ and v by $\frac{1}{v}$

$$L_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \int_0^{\infty}\int_0^{\infty} f(x,t)\,.\,e^{-\left(\frac{x}{u}+\frac{y}{v}\right)}\,dx.dt$$

$$\therefore L_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{ub}\,uv\int_0^{\infty}\int_0^{\infty} f(x,t)\,.\,e^{-\left(\frac{x}{u}+\frac{y}{v}\right)}\,dx.dt$$

Thus, from equation (2:2), we have

$$\therefore L_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{ub}\ E_2[f(x,t):(u,v)]$$

B) Double Elzaki - Double Laplace duality

We have double Elzaki transform

$$E_2[f(x,t):(u,v)] = uv\int_0^{\infty}\int_0^{\infty} f(x,t)\,.\,e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}\,dx.dt$$

Replace u by $\frac{1}{u}$ and v by $\frac{1}{v}$

$$E_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{uv}\int_0^{\infty}\int_0^{\infty} f(x,t)\,.\,e^{-(ux+vt)}\,dx.dt$$

Thus, from equation (2:1), we have

$$\therefore E_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{uv}\ E_2[f(x,t):(u,v)]$$

3.1.2 Duality between double Laplace and double Kamal transform

A) Double Laplace – double Kamal duality. We have double Laplace transform

$$L_2[f(x,t):(u,v)] = \int_0^{\infty}\int_0^{\infty} f(x,t)\,.\,e^{-(ux+vt)}\,dx.dt$$

Replace u by $\frac{1}{u}$ and v by $\frac{1}{v}$

$$L_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \int_0^{\infty}\int_0^{\infty} f(x,t)\,.\,e^{-\left(\frac{x}{u}+\frac{y}{v}\right)}\,dx.dt$$

Thus, from equation (2:3), we have

$$L_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = K_2[f(x,t):(u,v)]$$

B) Double Kamal - double Laplace duality

We have double Kamal transform

$$K_2[f(x,t):(u,v)] = \int_0^{\infty}\int_0^{\infty} f(x,t)\ e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}dx\,dt$$

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Replace u by $\frac{1}{u}$ and v by $\frac{1}{v}$

$$K_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right]=\int_0^\infty\int_0^\infty f(x,t)\;\; e^{-(ux+vt)}dx\,dt$$

Thus, from equation (2:1), we have

$$K_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right]=L_2[f(x,t):(u,v)]$$

3.1.3 Duality between double Laplace and double Mohand transform

A) Double Laplace – double Mohand duality

We have double Laplace transform

$$L_2[f(x,t):(u,v)]=\int_0^\infty\int_0^\infty f(x,t)\,.\,e^{-(ux+vt)}\,dx.\,dt$$

By arrangement

$$L_2[f(x,t):(u,v)]=\frac{1}{u^2v^2}\;\; u^2v^2\int_0^\infty\int_0^\infty f(x,t)\,.\,e^{-(ux+vt)}\,dx.\,dt$$

Thus, from equation (2:4), we have

$$L_2[f(x,t):(u,v)]=\frac{1}{u^2v^2}\,M_2[f(x,t):(u,v)]$$

B) Double Mohand – Double Laplace duality

We have double mohand transform

$$M_2[f(x,t):(u,v)]\;=u^2v^2\int_0^\infty\int_0^\infty f(x,t)\;\; e^{-(ux+vt)}dx\,dt$$

Thus from equation (2:1), we have

$$M_2[f(x,t):(u,v)]\;=u^2v^2\,L_2[f(x,t):(u,v)]$$

3.1.4 Duality between double Laplace and double Mahgoub transform

A) Double Laplace – double Mahgoub duality

We have double Laplace transform

$$L_2[f(x,t):(u,v)]=\int_0^\infty\int_0^\infty f(x,t)\,.\,e^{-(ux+vt)}\,dx.\,dt$$

$$L_2[f(x,t):(u,v)]=\frac{1}{uv}\,uv\int_0^\infty\int_0^\infty f(x,t)\,.\,e^{-(ux+vt)}\,dx.\,dt$$

Thus from equation (2:5), we have

$$L_2[f(x,t):(u,v)]=\frac{1}{uv}\,M_2^*[f(x,t):(u,v)]$$

B) Double Mahgoub – double Laplace duality

We have double Mahgoub transform

$$M_2^*[f(x,t):(u,v)]\;=uv\int_0^\infty\int_0^\infty f(x,t)\;\; e^{-(ux+vt)}dx\,dt$$

Thus, from equation (2:1), we have

$$M_2^*[f(x,t):(u,v)]\;=uvL_2[f(x,t):(u,v)]$$

3.1.5 Duality between double Laplace and double Sumudu transform

A) Double Laplace - double Sumudu duality

We have double Laplace transform

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$$L_2[f(x,t) : (u,v)] = \int_0^\infty \int_0^\infty f(x,t) \,.\, e^{-(ux+vt)} \, dx.\,dt$$

Replace u by $\frac{1}{u}$ and v by $\frac{1}{v}$

$$L_2\left[f(x,t) : \left(\frac{1}{u},\frac{1}{v}\right)\right] = \int_0^\infty \int_0^\infty f(x,t) \,.\, e^{-\left(\frac{x}{u}+\frac{y}{v}\right)} \, dx.\,dt$$

$$\therefore L_2\left[f(x,t) : \left(\frac{1}{u},\frac{1}{v}\right)\right] = uv\left[\frac{1}{uv}\int_0^\infty \int_0^\infty f(x,t) \,.\, e^{-\left(\frac{x}{u}+\frac{y}{v}\right)} \, dx.\,dt\right]$$

Thus, from equation (2:6), we have

$$L_2\left[f(x,t) : \left(\frac{1}{u},\frac{1}{v}\right)\right] = uv\, S_2[f(x,t) : (u,v)]$$

B) Double Sumudu – double Laplace duality
We have double Sumudu transform

$$S_2[f(x,t): (u,v)] = \frac{1}{uv}\int_0^\infty \int_0^\infty f(x,t) \;\; e^{-\left(\frac{x}{u}+\frac{t}{v}\right)} dx\, dt$$

Replace u by $\frac{1}{u}$ and v by $\frac{1}{v}$

$$S_2\left[f(x,t) : \left(\frac{1}{u},\frac{1}{v}\right)\right] = uv\int_0^\infty \int_0^\infty f(x,t) \;\; e^{-(ux+vt)} dx\, dt$$

Thus, from equation (2:1), we have

$$S_2\left[f(x,t) : \left(\frac{1}{u},\frac{1}{v}\right)\right] = uvL_2[f(x,t): (u,v)]$$

3.1.6 Duality between double Laplace and double Sawi transform
A) Double Laplace – double Sawi duality
We have double Laplace transform

$$L_2[f(x,t) : (u,v)] = \int_0^\infty \int_0^\infty f(x,t) \,.\, e^{-(ux+vt)} \, dx.\,dt$$

Replace u by $\frac{1}{u}$ and v by $\frac{1}{v}$

$$L_2\left[f(x,t) : \left(\frac{1}{u},\frac{1}{v}\right)\right] = \int_0^\infty \int_0^\infty f(x,t) \,.\, e^{-\left(\frac{x}{u}+\frac{y}{v}\right)} \, dx.\,dt$$

$$L_2\left[f(x,t) : \left(\frac{1}{u},\frac{1}{v}\right)\right] = u^2v^2\left[\frac{1}{u^2v^2}\int_0^\infty \int_0^\infty f(x,t) \,.\, e^{-\left(\frac{x}{u}+\frac{y}{v}\right)} \, dx.\,dt\right]$$

Thus, from equation (2:7), we have

$$L_2\left[f(x,t) : \left(\frac{1}{u},\frac{1}{v}\right)\right] = u^2v^2\, {S_2}^*[f(x,t): (u,v)]$$

B) Double Sawi - double Laplace duality
We have double Sawi transform

$${S_2}^*[f(x,t): (u,v)] = \frac{1}{u^2v^2}\int_0^\infty \int_0^\infty f(x,t) \;\; e^{-\left(\frac{x}{u}+\frac{t}{v}\right)} dx\, dt$$

Replace u by $\frac{1}{u}$ and v by $\frac{1}{v}$

$$S_2^{*}\left[f(x,t) : \left(\frac{1}{u},\frac{1}{v}\right)\right] = u^2v^2\int_0^\infty\int_0^\infty f(x,t)\ \ e^{-(ux+vt)}dx\,dt$$

Thus, from equation (2:1), we have

$$S_2^{*}\left[f(x,t) : \left(\frac{1}{u},\frac{1}{v}\right)\right] = u^2v^2L_2[f(x,t) : (u,v)]$$

3.1.7 Duality between double Laplace and double Aboodh transform

A) Double Laplace – double Aboodh duality

We have double Laplace transform

$$L_2[f(x,t) : (u,v)] = \int_0^\infty\int_0^\infty f(x,t)\,.\,e^{-(ux+vt)}\,dx.\,dt$$

We have double Laplace transform

$$L_2[f(x,t) : (u,v)] = uv\left[\frac{1}{uv}\int_0^\infty\int_0^\infty f(x,t)\,.\,e^{-(ux+vt)}\,dx.\,dt\right]$$

Thus, from equation (2:8), we have

$$L_2[f(x,t) : (u,v)] = uv\,A_2[f(x,t) : (u,v)]$$

B) Double Aboodh - double Laplace duality

We have double Aboodh transform

$$A_2[f(x,t):(u,v)] = \frac{1}{uv}\int_0^\infty\int_0^\infty f(x,t)\ \ e^{-(ux+vt)}dx\,dt$$

Thus, from equation (2:1), we have

$$A_2[f(x,t):(u,v)] = \frac{1}{uv}L_2[f(x,t) : (u,v)]$$

3.2 Duality between double Elzaki and other double integral transforms

3.2.1 Duality between double Elzaki and double Kamal transform

A) Double Elzaki – double Kamal transform

We have double Elzaki transform

$$E_2[f(x,t) : (u,v)] = uv\int_0^\infty\int_0^\infty f(x,t)\,.\,e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}\,dx.\,dt$$

Thus, from equation (2:3), we have

$$E_2[f(x,t) : (u,v)] = uv\,K_2[f(x,t) : (u,v)]$$

B) Double Kamal – double Elzaki duality

We have double Kamal transform

$$K_2[f(x,t):(u,v)] = \int_0^\infty\int_0^\infty f(x,t)\ \ e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}dx\,dt$$

$$K_2[f(x,t):(u,v)] = \frac{1}{uv}\left[uv\int_0^\infty\int_0^\infty f(x,t)\ \ e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}dx\,dt\right]$$

Thus, from equation (2:2), we have

$$K_2[f(x,t):(u,v)] = \frac{1}{uv}E_2[f(x,t):(u,v)]$$

3.2.2 Duality between double Elzaki and double Mohand transform

A) Double Elzaki – double Mohand duality

We have double Elzaki transform

$$E_2[f(x,t) : (u,v)] = uv\int_0^\infty\int_0^\infty f(x,t)\,.\,e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}\,dx.\,dt$$

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Replace u by $\frac{1}{u}$ and v by $\frac{1}{v}$

$$E_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{uv}\int_0^\infty\int_0^\infty f(x,t)\,.\,e^{-(ux+vt)}\,dx.dt$$

$$E_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{u^3v^3}\left[u^2v^2\int_0^\infty\int_0^\infty f(x,t)\,.\,e^{-(ux+vt)}\,dx.dt\right]$$

Thus, from equation (2:4), we have

$$E_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{u^3v^3}M_2[f(x,t):(u,v)]$$

B) Double Mohand - double Elzaki duality

We have double Mohand transform

$$M_2[f(x,t):(u,v)] = u^2v^2\int_0^\infty\int_0^\infty f(x,t)\;\; e^{-(ux+vt)}dx\,dt$$

Replace u by $\frac{1}{u}$ and v by $\frac{1}{v}$

$$M_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{u^2v^2}\int_0^\infty\int_0^\infty f(x,t)\;\; e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}dx\,dt$$

$$M_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{u^3v^3}\left[uv\int_0^\infty\int_0^\infty f(x,t)\;\; e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}dx\,dt\right]$$

Thus, from equation (2:2), we have

$$M_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{u^3v^3}\,E_2[f(x,t):(u,v)]$$

3.2.3 Duality between double Elzaki and double Mahgoub transform

A) Double Elzaki – double Mahgoub duality

We have double Elzaki transform

$$E_2[f(x,t):(u,v)] = uv\int_0^\infty\int_0^\infty f(x,t)\,.\,e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}\,dx.dt$$

Replace u by $\frac{1}{u}$ and v by $\frac{1}{v}$

$$E_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{uv}\int_0^\infty\int_0^\infty f(x,t)\,.\,e^{-(ux+vt)}\,dx.dt$$

$$E_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{u^2v^2}\,uv\int_0^\infty\int_0^\infty f(x,t)\,.\,e^{-(ux+vt)}\,dx.dt$$

Thus, from equation (2:5), we have

$$E_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{u^2v^2}M_2^*[f(x,t):(u,v)]$$

B) Double Mahgoub – double Elzaki duality

We have double Mahgoub transform

$$M_2^*[f(x,t):(u,v)] = uv\int_0^\infty\int_0^\infty f(x,t)\;\; e^{-(ux+vt)}dx\,dt$$

Replace u by $\frac{1}{u}$ and v by $\frac{1}{v}$

$$M_2^*[f(x,t):(u,v)] = \frac{1}{uv}\int_0^\infty\int_0^\infty f(x,t)\;\; e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}dx\,dt$$

$$M_2^*[f(x,t):(u,v)] = \frac{1}{u^2v^2}\left[uv\int_0^\infty\int_0^\infty f(x,t)\;\; e^{-\left(\frac{x}{u}+\frac{t}{v}\right)}dx\,dt\right]$$

Thus, from equation (2:2), we have

$$M_2^*[f(x,t):(u,v)] = \frac{1}{u^2v^2} E_2[f(x,t) : (u,v)]$$

Similarly we can prove following dualities

3.2.4 Duality between double Elzaki and double Sumudu transforms

A) Double Elzaki - double Sumudu duality

$$E_2[f(x,t):(u,v)] = u^2v^2 S_2[f(x,t):(u,v)]$$

B) Double Sumudu – double Elzaki duality

$$S_2[f(x,t):(u,v)] = \frac{1}{u^2v^2} E_2[f(x,t):(u,v)]$$

3.2.5 Duality between double Elzaki and double Sawi transform

A) Double Elzaki - double Sawi transform

$$E_2[f(x,t):(u,v)] = u^3v^3 {S_2}^*[f(x,t):(u,v)]$$

B) Double Sawi – double Elzaki duality

$${S_2}^*[f(x,t):(u,v)] = \frac{1}{u^3v^3} E_2[f(x,t):(u,v)]$$

3.2.6 Duality between double Elzaki and double Aboodh transform

A) Double Elzaki – double Aboodh duality

$$E_2\left[f(x,t) : \left(\frac{1}{u}, \frac{1}{v}\right)\right] = A_2[f(x,t):(u,v)]$$

B) Double Aboodh – double Elzaki duality

$$A_2\left[f(x,t) : \left(\frac{1}{u}, \frac{1}{v}\right)\right] = E_2[f(x,t):(u,v)]$$

3.3 Duality between double Kamal and other double integral transforms

3.3.1 Duality between double Kamal and double Mohand transform

A) Double Kamal – double Mohand duality

$$K_2\left[f(x,t) : \left(\frac{1}{u}, \frac{1}{v}\right)\right] = \frac{1}{u^3v^3} M_2[f(x,t):(u,v)]$$

B) Double Mohand – double Kamal duality

$$M_2\left[f(x,t) : \left(\frac{1}{u}, \frac{1}{v}\right)\right] = \frac{1}{u^3v^3} K_2[f(x,t):(u,v)]$$

3.3.2 Duality between Kamal and Mahgoub transform

A) Double Kamal –double Mahgoub duality

$$K_2\left[f(x,t) : \left(\frac{1}{u}, \frac{1}{v}\right)\right] = \frac{1}{uv} M_2^*[f(x,t):(u,v)]$$

B) Double Mahgoub - double Kamal duality

$$M_2^*\left[f(x,t) : \left(\frac{1}{u}, \frac{1}{v}\right)\right] = \frac{1}{uv} K_2[f(x,t):(u,v)]$$

3.3.3 Duality between double Kamal and double Sumudu transform

A) Double Kamal - double Sumudu duality

$$K_2[f(x,t):(u,v)] = uvS_2[f(x,t):(u,v)]$$

B) Double Sumudu - double Kamal duality

$$S_2[f(x,t):(u,v)] = \frac{1}{uv} K_2[f(x,t):(u,v)]$$

3.3.4 Duality between double Kamal and double Sawi transform

A) Double Kamal - double Sawi duality

$$K_2[f(x,t):(u,v)] = u^2v^2 {S_2}^*[f(x,t):(u,v)]$$

B) Double Sawi - double Kamal duality

$${S_2}^*[f(x,t):(u,v)] = \frac{1}{u^2v^2} K_2[f(x,t):(u,v)]$$

3.3.5 Duality between double Kamal and double Aboodh transform

A) Double Kamal - double Aboodh duality

$$K_2^*\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = uv\,A_2[f(x,t):(u,v)]$$

B) Double Aboodh - double Kamal duality

$$A_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = uvK_2^*\,[f(x,t):(u,v)]$$

3.4 Duality between double Mohand and other double integral transforms

3.4.1 Duality between double Mohand and double Mahgoub transform

A) Double Mohand - double Mahgoub duality

$$M_2[f(x,t):(u,v)] = uvM_2{}^*[f(x,t):(u,v)]$$

B) Double Mahgoub - double Kamal duality

$$M_2{}^*[f(x,t):(u,v)] = \frac{1}{uv}M_2[f(x,t):(u,v)]$$

3.4.2 Duality between double Mohand and double Sumudu transform

A) Double Mohand - double Sumudu duality

$$M_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{uv}S_2[f(x,t):(u,v)]$$

B) Double Sumudu - double Mohand duality

$$S_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = \frac{1}{uv}M_2[f(x,t):(u,v)]$$

3.4.3 Duality between Mohand and Sawi transform

A) Double Mohand - double Sawi duality

$$M_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = S_2{}^*[f(x,t):(u,v)]$$

B) Double Sawi - double Mohand duality

$$S_2{}^*\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = M_2[f(x,t):(u,v)]$$

3.4.4 Duality between double Mohand and double Aboodh transform

A) Double Mohand - double Aboodh duality

$$M_2[f(x,t):(u,v)] = u^3v^3A_2[f(x,t):(u,v)]$$

B) Double Aboodh - double Mohand duality

$$A_2[f(x,t):(u,v)] = \frac{1}{u^3v^3}M_2[f(x,t):(u,v)]$$

3.5 Duality between double Mahgoub and other double integral transforms

3.5.1 Duality between double Mahgoub and double Sumudu transform

A) Double Mahgoub - double Sumudu duality

$$M_2{}^*\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = S_2[f(x,t):(u,v)]$$

B) Double Sumudu - double Mahgoub duality

$$S_2\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = M_2{}^*\,[f(x,t):(u,v)]$$

3.5.2 Duality between double Mahgoub and double Sawi transform

A) Double Mahgoub - double Sawi duality

$$M_2{}^*\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = uv\,S_2{}^*[f(x,t):(u,v)]$$

B) Double Sawi - double Mahgoub duality

$$S_2{}^*\left[f(x,t):\left(\frac{1}{u},\frac{1}{v}\right)\right] = uv\,M_2{}^*[f(x,t):(u,v)]$$

3.5.3 Duality between double Mahgoub and double Aboodh transform

A) Double Mahgoub - double Aboodh duality

$$M_2{}^*[f(x,t):(u,v)] = u^2v^2A_2[f(x,t):(u,v)]$$

B) Double Aboodh - double Mahgoub duality

$$A_2[f(x,t):(u,v)] \;=\; \frac{1}{u^2v^2}\, M_2{}^*[f(x,t):(u,v)]$$

3.6 Duality between double Sumudu and other double integral transforms

3.6.1 Duality between double Sumudu and double Sawi transform

A) Double Sumudu - double Sawi duality

$$S_2[f(x,t):(u,v)] \;=\; uvS_2{}^*[f(x,t):(u,v)]$$

B) Double Sawi - double Sumudu duality

$$S_2{}^*[f(x,t):(u,v)] \;=\; \frac{1}{uv}\, S_2[f(x,t):(u,v)]$$

3.6.2 Duality between double Sumudu and double Aboodh transform

A) Double Sumudu - double Aboodh duality

$$S_2\left[f(\,x,t)\,:\,\left(\frac{1}{u},\frac{1}{v}\right)\right] = u^2v^2A_2[f(x,t):(u,v)]$$

B) Double Aboodh - double Sumudu duality

$$A_2\left[f(\,x,t)\,:\,\left(\frac{1}{u},\frac{1}{v}\right)\right] = u^2v^2S_2[f(x,t):(u,v)]$$

3.7 Duality between double Sawi and other double integral transforms

3.7.1 Duality between double Sawi and double Aboodh transform

A) Double Sawi - double Aboodh duality

$$S_2{}^*\left[f(\,x,t)\,:\,\left(\frac{1}{u},\frac{1}{v}\right)\right] = u^3v^3A_2[f(x,t):(u,v)]$$

B) Double Aboodh - double Sumudu duality

$$A_2\left[f(\,x,t)\,:\,\left(\frac{1}{u},\frac{1}{v}\right)\right] = u^3v^3\, S_2{}^*[f(x,t):(u,v)]$$

IV CONCLUSION

In the present paper duality relation between some useful integral transforms namely Laplace[L] , Elzaki[E] , Kamal[K], Mohand[M] , Mahgoub[M*], Sumudu[S] , Sawi[S*] are established successfully.

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