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# Exponential growth of Conventional Topological Spaces with different Kernels

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**Abstract:** It is an object of the paper to extend develop a precise functional frame for the spaces as a special case consisting of analytical signals makes the Gelfand Shilov techniques satisfying the user's requirements of open & close management and visual query in theoretical practical technical forward models a novel scheme study to be taken into consideration during the planning generalize the Laplace Meijer transform having generalizations time to time a combination of two totally different transforms having different kernels in the case of two dimensional generalized simple objective function sense with an apparently new appropriate domains for harmonic analysis due to wide spread applicability to solve the PDE involving distributional condition in addition the primitive is designed by introducing convenient explanations for more general situations to achieve and enjoy a slightly faster decay in domain even in polynomial case by changing the scheme from one dimension to higher to a number of testing function spaces along with their duals follows from the property of strong continuity at origin implies continuity at any point.
**Key Word**: Laplace Meijer Transform, Continuous Linear Functional, Transmission Image, Dual Space, Distributional Generalized Sense, The Cauchy Problems, Gelfand Shilov Spaces.

## I. INTRODUCTION

Many classical spaces that objects develops sufficient well established valuable techniques of generalized functions also known as distributions the systematic theory of distributional integral transform due to wide spread various properties & applicability in time frequency behavior of a tempered distribution spectral analysis quantum field theory real life situations have its origin in the work of Schwartz[1], Zemanian[2], Brychkov[3], Snedonn[4] . The roots and mathematical traditional approach of the methods are of great interest to gain appropriate flavor in several branches of engineering stress back to the work of Heaviside[1890], Todor [5], Hamed[6], Cappiello[7] due to the concept of imposing conditions on the decay of the fundamental functions even more general constructions in María[8], Gabriella[9] at infinity with growth of the derivative to all the integrable functions used to formulate generalized solutions of partial differential equations as well as ordinary differential equations involving distributional boundary conditions for propogation of heat in cylindrical coordinates espetially in the quantum field theory as the order of the derivative increases. The linear part of such equations in Dusan[10], Jaeyoung[11], Geetha[12] is connected to study the local regularity properties of analyzing functions as a motivation for formulating the generalized Laplace Meijer transform defind in Gulhane [13] a widest one result on the connection between the transforms not satisfying admissibility conditions with both local and global behavior of the transform. Dmitrii in [14] designed a theoretical forward platform over integral representations of the generalized hypergeometric functions to establish new inequalities by collecting a number of consequences of properties for completely monotonic Stieltjes class with Rao[15] a generalized version of the classical suitable kernel Meijer transform referred as Generalized Meijer (GM)transform reduces to the classical Meijer transform in some situation a second generalization of the Meijer transform in other situation MeijerLaplace (ML) transformation both in the distributional sense including discussion on inversion uniqueness analyticity.

We studied a crucible role in mathematical analysis, mathematical physics and engineering of generalized functions in the form of a continuous collection of six distinct volumes by Gelfand[16], Irina[17] as an introduction to generalized functions and presents various applications to analysis, partial differential equations, stochastic process, representation theory where many continuous non-continuous problems naturally lead to differential equations whose solution is a work by Paul Dirac[1920], Fisher[18] for Dirac delta distributions used in modeling quantum electronics as $\delta(t)$ equals to zero for nonzero functions and $\infty$ for $t$ equals to zero. In the study of Gaber frames and time frequency analysis of Distributions by Feichtinger [19], Grochenig [20] the major protection devices in a generalized distribution theory a class of Gelfand Shilov spaces [21, 22, 23] used their closed subspaces consisting of analytic signals which are almost exponentially localized in time and frequency variables control the decay of the transforms independently in each variables in Cordero[24] since the appropriate support of transform in positive domain which do not contain explicit regularity conditions. The spaces have gained more attention in Feichtinger[25], Toft[26] connection with the modulation spaces localization operators the corresponding pseudo-differential calculus in Teofanov[27, 28] the projective descriptions of a general class of Gelfand Shilov spaces of Roumieu type are indispensable for achieving completed tensor product representations of different important classes of vector valued ultra-differentiable functions of Roumieu. The recent achievements relate this matter with the asymptotic expansion create the main interest historically for Quantum Mechanics where the exponential decay of eigen functions have intensively studied. Gelfand Shilov type spaces Robertson [29] in which the topology of bounded convergence is assigned to the dual function study with the Symbol-Global operator's type in the context of time-frequency analysis.

## II. CONVENTIONAL TOPOLOGICAL SPACES

In order to simplify the exposition we start by recalling some facts about two dimensional $LK$ type spaces Gelfand Shilov involving both integral differentiation multiplication by function exponential concept under one umbrella having the approach to solve different types different order different degree ordinary differential equations partial differential equations upto some desired order over some domain $C^{\infty}$ the space $LK_{\alpha,\,A} = LK_{\alpha,\,A}\left(R^{d}\right)$ with constraints mainly on the decrease of the functions at infinity $\mu$ either the number zero or a complex satisfying $\operatorname{Re}\mu > 0$ consists of a rule which assigns a number to each numerical value all infinitely differentiable functions $\varphi(t,\,x)$ of some independent variables $t,\,x$ for $-\infty < t < \infty,\ 0 < x < \infty$ defined by

$$\begin{aligned} h(t,\,x) &= \log x \qquad 0 < x < e^{-1} \\ &= -1, \qquad e^{-1} < x < \infty \end{aligned}$$

satisfying the inequality for each nonnegative integer $l,\,k$ where the constants $A$ and $C_k$ depend on the everywhere differentiable testing function $\varphi$ by

$$\gamma^{\mu}_{a,\,b,\,l,\,k}\ \varphi(t,\,x) = \sup_{\substack{-\infty<t<\infty \\ 0<x<\infty}} \left| e^{at+bx} x^{\mu-1/2} D_t^l S_\mu^k \varphi(t,\,x) \right|$$

$$\begin{aligned} \gamma^{0}_{a,\,b,\,l,\,k}\varphi(t,\,x) &= \sup_{\substack{-\infty<t<\infty \\ 0<x<\infty}} \left| e^{at+bx} x^{-1/2} [h(t,\,x)]^{-1} D_t^l S_\mu^k \varphi(t,\,x) \right| \\ &\le C_k A^{\mu} \mu^{\mu\alpha} \end{aligned}$$

a complete countable multinormed space (Frechet space) equipped with the weak topology generated by the family of seminorms in the above defined continuous linear functional results to establish a series finally to define the Laplace Meijer transformation with real numbers $a,\,b$ inequality satisfied for the relation $\mu > b$. We get $\mu^{\mu\alpha} = 1$ for $\mu = 0$.

The topology of the multinormed space is generated by the countable multiform $\left\{\gamma^{\mu}_{a,\,b,\,l,\,k}\right\}_{l,\,k=0}^{\infty}$ and $\left\{\gamma^{0}_{a,\,b,\,l,\,k}\right\}_{l,\,k=0}^{\infty}$

With this topology $LK_{\alpha,\,a}$ is a countably multiform complete, normed, real (or complex) strongest possible one with continuous induction map $LK_{\alpha,\,a_{\nu}}$ to $LK_{\alpha,\,a}$ for every choice of $\nu > 0$.

Although some aspects were developed much earlier we set $j_\mu(t,\,x)$ equal $x^{\mu-1/2}$ when $\operatorname{Re}\mu > 0$ and equal $[x^{1/2} h(t,\,x)]^{-1}$ if $\mu = 0$ to convert the two proceeding equations as

$$\gamma^{\mu}_{a,\,b,\,l,\,k}\ \varphi(t,\,x) = \sup_{\substack{-\infty<t<\infty \\ 0<x<\infty}} \left| e^{at+bx} j_\mu(t,\,x) D_t^l S_\mu^k \varphi(t,\,x) \right|$$

The equiparallel space arise if $\gamma^{\mu}_{a,\,b,\,l,\,k}\varphi \le C_\mu B^k k^{k\beta}$ where $C_\mu$ is a function depend on $l,\,k$ for the systematic study of exponential constructed space $LK^{\beta,}$ which as a application of differentiable functions whose derivatives do or donot exist in the classical sense for the space having constraints mainly on the growth of the involved partial derivatives as $l$ approaches to infinity for $\beta > 0$ as the origin.

The extensively used contribution for the development of the necessary facts related to the generalized functions theory by Schwartz hence the construction & extension the Meijer–Laplace transform on a class of Boehmian is determined and executed to preserve certain properties of the classical transform by Al-Omari [30, 31] for theory of generalized distributional transform based on the application of natural transforms the test function space $LK$ consisting of all infinitely differentiable function $\varphi(t, x)$ defined for all positive values of $t, x$ having continuous derivative over some domain $C^{\infty}\left(R^{d_1}\right)$

satisfying $\sup_{\substack{-\infty<t<\infty \\ 0<x<\infty}} \left| e^{at+bx} j_{\mu}(t, x) D_t^l S_{\mu}^k \varphi(t, x) \right| < \infty$

Obviously in the technical literature the spaces $LK_{\alpha, a}$, $LK^{\beta, l}$ are subspaces of the above testing function space of all non negative numbers $\alpha, \beta$ for $-\infty < t < \infty,\ 0 < x < \infty$

Let there be given $\alpha_1, \beta_1 > 0$, $A_1, B_1 \in R$ be fixed, $\varphi(t, x)$ function defined for all positive values of $t, x$ having continuous derivative over some domain $C^{\infty}\left(R^{d_1}\right)$. Gelfand Shilov type space relative to Laplace transform $LK_{\alpha_1, A_1}^{\beta_1, B_1} = LK_{\alpha_1, A_1}^{\beta_1, B_1}\left(R^{d_1}\right)$ is defined by

$$LK_{\alpha_1, A_1}^{\beta_1, B_1} = \left\{ \varphi \in C^{\infty}\left(R^{d_1}\right) / \exists\, C_{l_1 q_1} > 0, \right.$$
$$\sup_{\substack{-\infty<t<\infty \\ 0<x<\infty}} \left| e^{at+bx} j_{\mu}(t, x) D_t^l S_{\mu}^k \varphi(t, x) \right|$$
$$\left. \leq C_{al} A_1^a B_1^l a^{a\alpha_1} l^{l\beta_1} \right\}$$

where the constants $C_{al}, A_1, B_1$ depend on the everywhere differential testing function $\varphi$ . From a topological point of view the spaces $LK_{\alpha_1}^{\beta_1}$ and $\sum_{\alpha_1}^{\beta_1}$ are given by the union and intersection for $A_1, B_1 \geq 0$ of $LK_{a_1, A_1}^{\beta_1, B_1}$ respectively with their topologies having special paid attention on the inductive and projective limits:

$LK_{\alpha_1}^{\beta_1} = ind \lim\limits_{A_1, B_1 > 0} LK_{\alpha_1, A_1}^{\beta_1, B_1}$ and $\sum_{\alpha_1}^{\beta_1} = proj \lim\limits_{A_1, B_1 > 0} LK_{\alpha_1, A_1}^{\beta_1, B_1}$

$LK_{\alpha_1}^{\beta_1}$ and $\sum_{\alpha_1}^{\beta_1}$ are nontrivial iff $\alpha_1 + \beta_1 \geq 0$ and $\alpha_1\ \beta_1 > 0$. the union and intersection for $A_1, B_1 \geq 0$ of $LK_{\alpha_1, A_1}^{\beta_1, B_1}$ .

Evidently the space $LK_{\alpha_1}^{\beta_1}$ of all non negative numbers $\alpha, \beta$ is contained in the intersection of the spaces $LK_{\alpha, a}$, $LK^{\beta, \mu}$ whereas space as a union of countably normed spaces were able to define sequential convergence in all metioned spaces such that these spaces became sequentially complete.

The Gelfand Shilov type distributional spaces $\left(LK_{\alpha_1}^{\beta_1}\right)'$ and $\left(\sum_{\alpha_1}^{\beta_1}\right)'$ are given by the intersection and union for $A_1, B_1 \geq 0$ of $\left(LK_{\alpha_1, A_1}^{\beta_1, B_1}\right)'$ and its topological sence is given by the projective and inductive limits:

$\left(LK_{\alpha_1}^{\beta_1}\right)' = \bigcap\limits_{A_1, B_1 > 0} \left(LK_{\alpha_1, A_1}^{\beta_1, B_1}\right)'$ and $\left(\sum_{\alpha_1}^{\beta_1}\right)' = \bigcup\limits_{A_1, B_1 > 0} \left(LK_{\alpha_1, A_1}^{\beta_1, B_1}\right)'$

Here $\left(LK_{\alpha_1}^{\beta_1}\right)'$ is the dual of $LK_{\alpha_1}^{\beta_1}$ and $\left(\sum_{\alpha_1}^{\beta_1}\right)'$ is the dual of $\sum_{\alpha_1}^{\beta_1}$.

Now we apply the distributional Meijer transformation defined above properly as a exponential sence as well as polynomial approach relative to Gelfand Shilov type spaces $LK_{\alpha_2, A_2}^{\beta_2, B_2} = LK_{\alpha_2, A_2}^{\beta_2, B_2}\left(R^{d_2}\right)$ for convenience under proper coordination of the variables and parameters in a unified manner where the constants $C_{\mu k}, A_2, B_2$ depend on the everywhere differential testing function $\varphi$ by

$$LK_{\alpha_2, A_2}^{\beta_2, B_2} = \left\{ \varphi \in C^{\infty}\left(R^{d}\right) / \exists\, C_{l_2 q_2} > 0, \right.$$
$$\sup_{\substack{-\infty<t<\infty \\ 0<x<\infty}} \left| e^{at+bx} j_{\mu}(t, x) D_t^l S_{\mu}^k \varphi(t, x) \right|$$
$$\left. \leq C_{\mu k} A_2^{\mu} B_2^k \mu^{\mu\alpha_2} k^{k\beta_2} \right\}$$

The spaces $LK_{\alpha_2}^{\beta_2}$ and $\sum_{\alpha_2}^{\beta_2}$ are given by the union and intersection for $A_2, B_2 \geq 0$ of $LK_{\alpha_2, A_2}^{\beta_2, B_2}$ and its topology is given by the appropriate inductive and projective limits:

$$LK_{\alpha_2}^{\beta_2} = ind \lim_{A_2, B_2 > 0} LK_{\alpha_2, A_2}^{\beta_2, B_2} \text{ and } \sum_{\alpha_2}^{\beta_2} = proj \lim_{A_2, B_2 > 0} LK_{\alpha_2, A_2}^{\beta_2, B_2}$$

$LK_{\alpha_2}^{\beta_2}$ and $\sum_{\alpha_2}^{\beta_2}$ are nontrivial iff $\alpha_2 + \beta_2 \geq 0$ and $\alpha_2 \; \beta_2 > 0$. the union and intersection for $A_2, B_2 \geq 0$ of $LK_{\alpha_2, A_2}^{\beta_2, B_2}$ .

The Gelfand Shilov type distributional spaces $\left(LK_{\alpha_2}^{\beta_2}\right)'$ and $\left(\sum_{\alpha_2}^{\beta_2}\right)'$ are given by the smooth intersection and union for $A_2, B_2 \geq 0$ of $\left(LK_{\alpha_2, A_2}^{\beta_2, B_2}\right)'$ and its corresponding topological sence is given by the projective and inductive limits:

$$\left(LK_{\alpha_2}^{\beta_2}\right)' = \bigcap_{A_2, B_2 > 0} \left(LK_{\alpha_2, A_2}^{\beta_2, B_2}\right)' \text{ and } \left(\sum_{\alpha_2}^{\beta_2}\right)' = \bigcup_{A_2, B_2 > 0} \left(LK_{\alpha_2, A_2}^{\beta_2, B_2}\right)'$$

Here $\left(LK_{\alpha_2}^{\beta_2}\right)'$ is the dual of $LK_{\alpha_2}^{\beta_2}$ and $\left(\sum_{\alpha_2}^{\beta_2}\right)'$ is the dual of $\sum_{\alpha_2}^{\beta_2}$.

Now we are ready to extend and construct the systematic theory of straightforward extension of two dimensional some $LK$ type spaces of Laplace Meijer transform $LK_{\alpha_i, A_i}^{\beta_i, B_i}$ using Gelfand Shilov technique for $\alpha_i = \alpha_1, \alpha_2; \; \beta_i = \beta_1, \beta_2$ defined by

$$LK_{\alpha_i, A_i}^{\beta_i, B_i} = \left\{ \varphi \in C^\infty\left(R^{d_i}\right) / \exists \, C_{l_i q_i} > 0 , \right.$$

$$\sup_{\substack{-\infty < t < \infty \\ 0 < x < \infty}} \left| e^{at+bx} j_\mu(t, x) D_t^l S_\mu^k \varphi(t, x) \right|$$

$$\left. \leq C A_1^a A_2^\mu B_1^l B_2^k a^{a\alpha_1} l^{l\beta_1} \mu^{\mu\alpha_2} k^{k\beta_2} \right\}$$

where the constants $C; \; A_i = A_1, A_2; \; B_i = B_1, B_2$ depend on the everywhere differential testing function $\varphi$. The spaces $LK_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}$ and $\sum_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}$ a pair of Laplace Stieltjes transform as a very powerful mathematical tool applied in various areas of engineering and science with the increasing complexity of engineering problems are given by the union and intersection for $A_i, B_i \geq 0$ of $LS_{\alpha_i, A_i}^{\beta_i, B_i}$ and its topology is given by the inductive and projective limits:

$$LK_{\alpha_1, \alpha_2}^{\beta_1, \beta_2} = ind \lim_{A_1, B_1 > 0} LK_{\alpha_i, A_i}^{\beta_i, B_i} \text{ and } \sum_{\alpha_1, \alpha_2}^{\beta_1, \beta_2} = proj \lim_{A_1, B_1 > 0} LK_{\alpha_i, A_i}^{\beta_i, B_i}$$

$LK_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}$ and $\sum_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}$ are nontrivial iff $\alpha_i + \beta_i \geq 0$ and $\alpha_i \; \beta_i > 0$ the union and intersection for $A_i, B_i \geq 0$ of $LK_{\alpha_i, A_i}^{\beta_i, B_i}$ .

The Gelfand Shilov type distributional spaces dual spaces of distribution on a particular Euclidean space $\left(LK_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}\right)'$ and $\left(\sum_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}\right)'$ are given by the intersection and union for $A_i, B_i \geq 0$ of $\left(LK_{\alpha_i, A_i}^{\beta_i, B_i}\right)'$ and its topological sence is given by the projective and inductive limits:

$$\left(LK_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}\right)' = \bigcap_{A_1, B_1 > 0} \left(LK_{\alpha_i, A_i}^{\beta_i, B_i}\right)' \text{ and } \left(\sum_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}\right)' = \bigcup_{A_1, B_1 > 0} \left(LK_{\alpha_i, A_i}^{\beta_i, B_i}\right)'$$

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Here $\left(LK_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}\right)'$ is the dual of $LK_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}$ and $\left(\sum_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}\right)'$ is the dual of $\sum_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}$. The corresponding dual spaces introduced for the study of Cauchy problems in partial differential equations created as a model in technical subjects are the spaces of ultradistributions of Roumieu and Beurling respectively. Unless specified otherwise all the spaces introduced throughout will henceforth be considered equipped with their naturally Hausdorff locally convex topologies on these spaces are generated by the family of seminorms $\left\{\gamma_{a, b, l, k}^{\mu}\right\}$.

We consider the domain $-\infty < t < 0, \; 0 < x < \infty$ is in $\overline{L}K_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}$ if $\varphi$ smooth function $\overline{\varphi}(t, x) = \varphi(-t, x)$ is in $LS_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}$ for which

$$\left. \leq C A_1^a A_2^\mu B_1^l B_2^k a^{a\alpha_1} l^{l\beta_1} \mu^{\mu\alpha_2} k^{k\beta_2} \right\}$$

satisfying all above mentioned properties. Corresponding to all defined spaces in above sections the spaces .

$\overline{LK}_{\alpha_1}, \overline{LK}^{\beta_1}, \overline{LK}_{\alpha_2}, \overline{LK}^{\beta_2}, \overline{LK}_{\alpha_1}^{\beta_1}, \overline{LK}_{\alpha_2}^{\beta_2}, \overline{LK}_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}$

which have domain $-\infty < t < 0,\ 0 < x < \infty$ can also be defined.

Depending on various choices of distributional spaces defined above defined in Gulhane [13] nondefined equipped with their naturally Hausdrof locally convex topologies generated by their respective corresponding total families of seminorms are as usal denoted by $T_{\alpha_1}, T^{\beta_1}, T_{\alpha_2}, T^{\beta_2}, T_{\alpha_1}^{\beta_1}, T_{\alpha_2}^{\beta_2}, T_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}$. Moreover all the spaces having domain $-\infty < t < 0,\ 0 < x < \infty$ are equipped with their naturally Hausdrof locally convex topologies $\overline{T}_{\alpha_1}, \overline{T}^{\beta_1}, \overline{T}_{\alpha_2}, \overline{T}^{\beta_2}, \overline{T}_{\alpha_1}^{\beta_1}, \overline{T}_{\alpha_2}^{\beta_2}, \overline{T}_{\alpha_1, \alpha_2}^{\beta_1, \beta_2}$.

Further we extend the space $LK_{\alpha_1, \alpha_2, m_1, m_2}^{\beta_1, \beta_2, n_1, n_2}$ defined by

$$LK_{\alpha_1, \alpha_2, m_1, m_2}^{\beta_1, \beta_2, n_1, n_2} = \Big\{ \varphi \in C^\infty\left(R^{d_1+d_2}\right) / \exists\, C_{l_1 q_1} > 0\,, \sup_{\substack{-\infty<t<\infty \\ 0<x<\infty}} \left| e^{at+bx} j_\mu(t,\ x) D_t^l S_\mu^k \varphi(t,\ x) \right| \le C(m_1+\delta_1)^a (m_2+\delta_2)^\mu (n_1+\eta_1)^l (n_2+\eta_2)^k a^{a\alpha_1} l^{l\beta_1} \mu^{\mu\alpha_2} k^{k\beta_2} \Big\}$$

where $\delta_1, \delta_2,\ \eta_1, \eta_2$ are any numbers losing the property of strong continuity greater than zero in respective domain.

## III. CONCLUSION

The study concludes the most important factors affecting the development and success for the view of engineers having functional analyst approach many classical conventional transform naturally as Laplace Meijer transform of certain distributions by employing the relative testing function space successfully analyzed from a topological point of aspect in differential operator theory described as a union of countable normed spaces able to define sequential convergence in all above mentioned spaces so become sequentially complete interesting because of rich structure used to solve the equation of propagation of heat in cylindrical coordinates imposing the generalized boundary conditions.

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