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$(\sigma - \tau)$ - DERIVATIONS OF NEAR-FIELD SPACES OVER A NEAR-FIELD

Dr. N. V. NAGENDRAM*

Professor of Mathematics,
Kakinada Institute of Technology & Science (K.I.T.S.)
Department of Humanities & Science (Mathematics),
Tirupathi (vill) Peddapuram (M), Divili 533 433
East Godavari District. Andhra Pradesh. INDIA.

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ABSTRACT

Let N be a left-near-field space and let σ, τ be automorphisms of N. An additive mapping d: N $\rightarrow$ N is called a (σ, τ) – derivation on N if $d(xy) = \sigma(x)\, d(y) + d(x)\tau(y)$ for all x, y $\in$ N. In this paper, Dr N V Nagendram as author obtain Leibnitz' formula for (σ, τ) – derivations on near-field spaces over a near-field which facilitates the proof of the following result. Let n $\geq$ 1 be an integer, N be a n-torsion free and d a (σ, τ) – derivation on N with d^n (N) = {0}. If both σ, τ commute with d^n for all n $\geq$ 1, then d(z) = {0}. Further, besides proving some more related results, we investigate commutativity of N satisfying either of the properties d([x, y]) = 0, or d($x\sigma y$) = 0, for all x, y $\in$ N a near-field space over a near-field.

Keywords: *prime near-field space, near-field space, (σ, τ) –derivation, sub near-field space, sigma automorphism, and tow automorphism of near-field space.*

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SECTION 1: INTRODUCTION

Throughout the paper, N will denote a zero-symmetric left (or right) prime near-field space over a near-field with multiplicative centre Z. For any x, y $\in$ N as usual [x, y] = xy – yx and xσy = xy + yx will denote the well known Lie and Jordan products respectively. While the symbol (x, y) will denote the additive Commutator x + y – x – y.

There are several results asserting that prime near-field spaces over a near-field with certain constrained derivations have near-field like behaviour over a near-ring. Recently many authors have studied commutativity of prime and semi prime near-fields with derivations. In view of these results it is natural to look for comparable results on near-field spaces. In order to facilitate our discussion we need to extend Leibnitz' theorem for derivations in near-field spaces to (σ, τ) – derivation to prime near-field spaces over a near-field.

Proving Leibnitz' formula for (σ, τ) – derivations in near-field spaces over a near-field Dr N V Nagendram extend some results due for (σ, τ) – derivations on prime near-field spaces over a near-field. Some new results have also been obtained for prime near-field spaces. Finally, it is shown that under appropriate additional hypothesis a prime near-field space must be a commutative near-field space over a near-field.

Definition 1.1: Prime near-field space over a near-field. A near-field space N is said to be prime near-field space if aNb = {0} $\Rightarrow$ a = 0 or b = 0.

Definition 1.2: Distributive element. An element x of N is said to be distributive element if (y + z)x = yx + zx for all x, y, z $\in$ N.

Definition 1.3: zero symmetric. A near-field space N is called zero-symmetric if ox = 0 for all x $\in$ N.

Note 1.4: recall that left distributivity yields x0 = 0.

*Corresponding Author: Dr. N. V. Nagendram**
E-mail ID: nvn220463@yahoo.co.in.

Definition 1.5: derivation on N. An additive endomorphism d of N is called a derivation on N if $d(xy) = xd(y) + d(x)y$ for all x, y $\in$ N or equivalently that $d(xy) = d(x)y + xd(y)$ for all x, y $\in$ N.

Definition 1.6: constatnt. An element x $\in$ N for which $d(x) = 0$ is called a constant.

Definition 1.7: (σ , τ) - derivation. Let σ, τ be two automorphisms on a near-field space N over a near-field. Define an additive endomorphism $d : N \to N$ is called a (σ, τ) – derivation if

$\exists$ automorphism $\sigma, \tau : N \to N \ni d(xy) = \sigma(x)\, d(y) + d(x)\, \tau(y)$ for all x, y $\in$ N.

Definition 1.8: τ-derivation. If σ = 1, the identity mapping d is called a τ-derivation.

Definition 1.9: σ-derivation. If τ = 1, the identity mapping d is called a σ-derivation.

SECTION 2: PRELIMINARY RESULTS

In this section begin the following known results.

Lemma 2.1: An additive endomorphism d on a near-field space N is a (σ, τ) – derivation if and only if

$d(xy) = d(x)\, \tau(y) + \sigma(x)\, d(y)$ for all x, y $\in$ N.

Lemma 2.2: Let d be a (σ, τ) – derivation on a near-field space N over a near-field. Then N satisfies the following partial distributive laws:

(a) $(\sigma(x)\, d(y) + d(x)\, \tau(y))z = \sigma(x)\, d(y)z + (d(x)\, \tau(y)z$, $\forall$ x, y, z $\in$ N.
(b) $(d(x)\, \tau(y) + \sigma(x)\, d(y))z = d(x)\, \tau(y)z + \sigma(x)\, d(y)z$, $\forall$ x, y, z $\in$ N.

Lemma 2.3: Let N be a prime near-field space admitting a non-trivial (σ, τ) derivation d for which $d(N) \subseteq Z$. Then (N, +) is abelian. Moreover, if N is 2-torsion free and σ, τ commute with d. Then N is a commutative near-field space over a near-field.

Lemma 2.4: Let N be a prime near-field space over a near-field. If d is a (σ, σ) – derivation on N, the $d(Z) \subseteq Z$.

SECTION 3: MAIN RESULTS

The following theorem has its independent interest in the study of (σ,τ) – derivations in near-field spaces. In fact Leibnitz' formula has already been obtained by Dr N V Nagendram for derivations in near-field spaces over a near-field. Now, we shall extend this result for (σ,τ) – derivations in prime near-field spaces over a near-field.

Theorem 3.1: Let N be a near-field space and d a (σ,τ) – derivation on N. If both σ, τ commute with d^n , for all positive integer n ≥ 1, then for all x, y $\in$ N $d^{\,n}(xy) = \sum_{r=0}^{n} {}^{n}C_r\, a^{n-r}\, (a^r(x)) d^n (r^{n-r}(y))$.

Proof: By An additive endomorphism d on a near-field space N is a (σ, τ) – derivation we have

$$d(xy) = d(x)\, \tau(y) + \sigma(x)\, d(y)\ \forall\ x, y \in N. \qquad (a)$$

$$\Rightarrow n\, d(x)\, \tau(y) + n\, \sigma(x)\, d(y) = n\, (d(x)\, \tau(y) + \sigma(x)\, d(y))\ \forall\ x, y \in N. \qquad (b)$$

Now we apply induction on n. when n = 2, we get

$$d^2 (xy) = d\, (d(xy)) = d\, (d(x)\, \tau(y) + \sigma(x)\, d(y))$$
$$= d^2 (x)\, \tau^2 (y) + \sigma\, (d\, (x))\, d(\tau(y)) + d\, (\sigma(x)\, d(y)) + \sigma^2 (x)\, d^2(y) \qquad (c)$$

Since σ and τ commute with d, equation (c) reduces to

$$d^2 (xy) = d^2 (x)\, \tau^2 (y) + 2\, \sigma\, (d\, (x))\, d(\tau(y)) + \sigma^2 (x)\, d^2(y)\ \forall\ x, y \in N.$$

$$\Rightarrow d^2 (xy) = \sum_{r=0}^{n} {}^{2}C_r\, d^{2-r}\, (\sigma^r(x)) d^r (\tau^{2-r}(y))\ \forall\ x, y \in N. \qquad (d)$$

Assume that Leibnitz' rule holds good for n -1, then

$$d^{\,n-1} (xy) = \sum_{r=0}^{n-1} {}^{n-1}C_r\, d^{n-r-1}\, (\sigma^r(x)) d^r (\tau^{n-r-1}(y))\ \forall\ x, y \in N. \qquad (e)$$

i.e.

$$d^{n-1}(xy) = d^{n-1}(x)\tau^{n-1}(y) + \ldots + {}^{n-1}_{i-1}C\, d^{m-i}(\sigma^{i-1}(x)d^{n-1}(\tau^{n-i}(y)) + {}^{n-1}_{i}C\, d^{m-i-1}((\sigma^{i}(x))d^{i}(\tau^{n-i-1}(y))$$
$$+ \ldots + \sigma^{n-1}(x)d^{m-1}(y) \quad \text{for all } x, y \text{ in } N. \qquad \text{(f)}$$

$$d^{m}(xy) = d(d^{m-1}(xy))$$
$$= d(d^{m-1}(x)\tau^{n-1}(y) + \ldots + {}^{n-1}_{i-1}C\, d^{m-i}(\sigma^{i-1}(x)d^{n-1}(\tau^{n-i}(y)) + {}^{n-1}_{i}C\, d^{m-i-1}((\sigma^{i}(x))d^{i}(\tau^{n-i-1}(y))$$
$$+ \ldots + \sigma^{n-1}(x)d^{m-1}(y)) \quad \text{for all } x, y \text{ in } N.$$
$$= d(d^{m-1}(x)\tau^{n-1}(y)) + \ldots + {}^{n-1}_{i-1}C\, d(d^{m-i}(\sigma^{i-1}(x)d^{n-1}(\tau^{n-i}(y))) + {}^{n-1}_{i}C\, d(d^{m-i-1}((\sigma^{i}(x))d^{i}(\tau^{n-i-1}(y)))$$
$$+ \ldots + \sigma^{n-1}(x)d(d^{m-1}(y))) \quad \text{for all } x, y \text{ in } N.$$

$$\Rightarrow d^{n}(xy) = \sum_{r=0}^{n} {}^{n}C_{r}\, a^{n-r}\, (a^{r}(x))d^{n}(r^{n-r}(y)) \text{ for all } x, y \in N.$$

This completes the proof of the theorem.

Corollary 3.2: Let N be a near-field space. If N admits a derivation d, then for any integer n ≥ 1 and for all x, y ∈ N, we have $a^{m}(xy) = \sum_{r=0}^{n} {}^{n}C_{r}\, a^{m-r}\,(x)\, a^{r}(y)$, where 0 ≤ r ≤ n.

Theorem 3.3: Let n ≥ 1 be a fixed positive integer and let N be an n-torsion free near-field space. Suppose that σ, τ are automorphisms of N and d a (σ, τ) – derivation on N such that σ, τ commute with d^{k} for all integers k ≥ 1. If $d^{m}(N) = \{0\}$, then for each x ∈ N, either d (x) = 0 or there exists an integer i, 0 < i < n such that $a^{n}(x)$ is a non-zero divisor of zero.

Proof: The result is obvious for n = 1. By hypothesis, we have $d^{n}(N) = \{0\}$. We may assume that $d^{m-1}(N) \neq \{0\}$ with $d^{m-1}(x_0) \neq \{0\}$, for some $x_0 \in N$. further, suppose that $d(x) \neq 0$. Then there exists i with 0 < i < n for which $d^{n}(x) \neq 0$ and $d^{n+1}(x) = 0$. This gives rise to $d^{m}(x_0 d^{n-1}(x)) = 0$ for all x ∈ N. we find that $nd^{m-1}(\sigma(x_0))d(\tau^{n-1}(d^{n-1}(x))) = 0$ for all x ∈ N.

$$\Rightarrow nd^{m-1}(\sigma(x_0))d(\tau^{n-1}(d^{n}(x))) = 0 \text{ for all } x \in N.$$

Since τ is an automorphism of N and N is a n-torsion free, the above expression yields that $\sigma(d^{m-1}(x_0))\tau^{n-1}(d^{n}(x))) = 0$ for all x ∈ N. thus it follows that $(\tau^{n-1})^{-1}(\sigma(d^{m-1}(x_0))d^{n}(x) = 0$ for all x ∈ N. Since σ and τ are automorphisms of N and $d^{m-1}(x_0) \neq \{0\}$, it follows that $d^{N}(x)$ is a non-zero divisor of zero. Hence This completes the proof of the theorem.

Theorem 3.4: Let n ≥ 1 be a fixed positive integer and let N be an n-torsion free prime near-field space over a near-field. Suppose that σ is an automorphisms of N and d a (σ, τ) – derivation on N such that σ commute with d^{k} for all integers k ≥ 1. If $d^{m}(N) = \{0\}$, then $d(Z) = \{0\}$.

Proof: The result is obvious for n = 1. Now let n ≥ 2 and $d(Z) \neq \{0\}$. Choose z ∈ Z such that $d(z) \neq 0$. By Let N be a prime near-field space over a near-field. If d is a (σ,σ) – derivation on N, the $d(Z) \subseteq Z$ and let n ≥ 1 be a fixed positive integer and let N be an n-torsion free near-field space. Suppose that σ, τ are automorphisms of N and d a (σ, τ) – derivation on N such that σ, τ commute with d^{k} for all integers k ≥ 1. If $d^{m}(N) = \{0\}$, then for each x ∈ N, either d (x) = 0 or there exists an integer i, 0 < i < n such that $a^{n}(x)$ is a non-zero divisor of zero, there exists a positive integer i, o < i < n such that $d^{n}(z)$ is a non-zero divisor of zero contained in the center Z. Since N is a prime near-field space over a near-field $d^{n}(z)$ cannot be a zero divisor. This contradiction shows that $d(Z) = \{0\}$. This completes the proof of the theorem.

Counter example 3.5: The conclusion of the above result need not be true even for arbitrary near-field spaces over a near-field with σ = 1 the identity mapping on near-field space N over a near-field.

Let T be any near-field space. Let N = $\left\{ \begin{pmatrix} 0 & a & b \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} / a, b \in T \right\}$. Define a mapping $d : N \to N$ such that

$d\begin{pmatrix}0 & a & b\\ 0 & 0 & 0\\ 0 & 0 & 0\end{pmatrix} = \begin{pmatrix}0 & a & b\\ 0 & 0 & 0\\ 0 & 0 & 0\end{pmatrix}$. Then it can be easily seen that d is a derivation on near-field space N such that d^2 (N) = {0}, but d (Z) ≠ {0}.

SECTION 4: COMMUTATIVITY OF PRIME NEAR-FIELD SPACES OVER A NEAR-FIELD.

In this section, Dr N V Nagendram studied commutativity in prime near-field spaces over a near-field with a non-zero derivation d for which d(xy)= d(yx) for all x, y in some non-zero one sided sub-prime near-field space over a near-field. We continue this study and obtain some more general results for (σ, τ) – derivations in prime near-field spaces over a near-field.

Theorem 4.1: Let N be 2-torsion free prime near-field space over a near-field. Suppose d is a non-zero (σ, σ) – derivation on N such that d (x, y) = 0 for all x, y ∈ N. Then N is a commutative near-field space.

Proof: By hypothesis we have, d (xy) = d (yx), for all x, y ∈ N. (i)

Equation (i) can be written as

$$\sigma(x)\, d(y) + d(x)\, \sigma(y) = \sigma(y)\, d(x) + d(y)\, \sigma(x), \text{ for all } x, y \in N. \quad \text{(ii)}$$

Replacing x by yx in equation (ii) and using equation (i) we obtain,

$$\sigma(yx)\, d(y) + d(yx)\, \sigma(y) = \sigma(y)\, d(xy) + d(y)\, \sigma(yx) \text{ for all } x, y \in N. \quad \text{(iii)}$$

$$\Rightarrow \sigma(yx)\, d(y) + (\sigma(y)\, d(x) + d(y)\, \sigma(x))\, \sigma(y) = \sigma(yx)\, d(y) + \sigma(y)\, d(x)\, \sigma(y) + d(y)\, \sigma(x) \text{ for all } x, y \in N.$$

Let d be a (σ, τ) – derivation on a near-field space N over a near-field. Then N satisfies the above said partial distributive laws yields that

$$d(y)\, \sigma(x)\, \sigma(y) = d(y)\, \sigma(y)\, \sigma(x) \text{ , for all } x, y \in N. \quad \text{(iv)}$$

Again replace x by xz in equation (iv) and use equation (iv) to get

$$d(y)\, \sigma(x)\, \sigma(z)\, \sigma(y) = d(y)\, \sigma(xy)\, \sigma(z) \text{ , for all } x, y, z \in N. \quad \text{(v)}$$

$$\Rightarrow d(y)\, \sigma(x)\, \sigma(z)\, \sigma(|y, z|) = 0 \text{ for all } x, y, z \in N. \quad \text{(vi)}$$

Since σ is an automorphism of N, we get

$$\sigma^{-1}(d(y))N|y, z| = \{0\}, \text{ for all } y, z \in N. \quad \text{(vii)}$$

This yields that for each fixed point y ∈ N either d (y) = 0 or |y, z| = 0, for all z ∈ N i.e. for each fixed y ∈ N, we have either d (y) = 0 or y ∈ Z. But y ∈ Z also implies that d(y) ∈ Z, for all y ∈ N.

∴ in both the cases we find that d (y) ∈ Z, for all y ∈ N and hence d (N) ⊆ Z.

Thus by, a prime near-field space admitting a non-trivial (σ, τ) – derivation d for which d(N) ⊆ Z. Then (N, +) is abelian. Moreover, if N is 2-torsion free and σ, τ commute with d. Then N is a commutative near-field space over a near-field. This completes the proof of the theorem.

Theorem 4.2: Let N be a 2-torsion free prime near-field space. Suppose d is a non-zero (σ, σ) – derivation on N such that d (xoy) = 0 ∀ x, y ∈ N. Then N is a commutative near-field space.

Proof: we have d (xy) = - d(yx) ∀ x, y ∈ N. (viii)

i.e.

$$\sigma(x)\, d(y) + d(x)\, \sigma(y) = -(\sigma(y)\, d(x) + d(y)\, \sigma(x)), \ \forall\, x, y \in N. \quad \text{(ix)}$$

Replacing x by yx in equation (ix) we get,

$$\sigma(yx)\, d(y) + d(yx)\, \sigma(y) = -(\sigma(y)\, d(yx) + d(y)\, \sigma(yx)), \ \forall\, x, y \in N. \quad \text{(x)}$$

By using equation (viii) and N satisfies partial distributive laws we find that

$$\sigma(yx)\, d(y) + (\sigma(y)\, d(x) + d(y)\, \sigma(x)\, \sigma(y) = -(\sigma(y)\,(-d(xy)) + d(y)\, \sigma(yx))$$
$$= -(\sigma(-y)\, d(xy) + d(y)\, \sigma(yx))$$

$$= - (- \sigma(y)\, d(xy) + d(y)\, \sigma(yx))$$
$$= (\sigma(y)((\sigma(x)\, d(y) + d(x)\, (\sigma(y)) - d(y)\, \sigma(yx)$$
$$= \sigma(y)((\sigma(x)\, d(y) + \sigma(y)\, d(x)\, \sigma(y) – d(y)\, \sigma(yx).$$

$$\Rightarrow d(y)\, \sigma(x)\, \sigma(y) = - d(y)\, \sigma(yx), \text{ for all } x, y \in N. \qquad \text{(xi)}$$

Again replace x by xz in equation (xi) and use (xi) we obtain

$$d(y)\, \sigma(x)\, \sigma(z)\, \sigma(y) = d(y)\, \sigma(x)\, \sigma(y)\, \sigma(z), \text{ for all } x, y, z \in N. \qquad \text{(xii)}$$

i.e.

$$d(y)\, \sigma(x)\, \sigma(|y, z|) = 0, \text{ for all } x, y, z \in N. \qquad \text{(xiii)}$$

This yields that for each fixed point $y \in N$ either $d(y) = 0$ or $|y, z| = 0$, for all $z \in N$ i.e. for each fixed $y \in N$, we have either $d(y) = 0$ or $y \in Z$. But $y \in Z$ also implies that $d(y) \in Z$, for all $y \in N$.

$\therefore$ in both the cases we find that $d(y) \in Z$, for all $y \in N$ and hence $d(N) \subseteq Z$.

Thus by, a prime near-field space admitting a non-trivial (σ, τ) – derivation d for which $d(N) \subseteq Z$. Then (N, +) is abelian. Moreover, if N is 2-torsion free and σ, τ commute with d. Then N is a commutative near-field space over a near-field. We get the required result and this completes the proof of the theorem.

Corollary 4.3: Let N be a 2 – torsion free prime near-field space over a near-field. Suppose that d is a non-zero derivation on N such that $d((x, y)) = 0$ for all $x, y \in N$ or $d(xoy) = 0$ for all $x, y \in N$. Then N is a commutative near-field space over a near-field.

Note 4.4: the following example demonstrates that the conclusion of the above results need not be true even in the case of arbitrary near-fields over near-rings.

Example 4.5: Let $N = N_1 \oplus N_2$ where N_1 is a non-commutative near-field space and N_2 is a commutative near-field space of characteristic 2 with identity admitting a non-zero derivation δ. Define a map d: $N \rightarrow N$ such that $d((a, b)) = (0, \delta(b))$. Then it is easy to see that d satisfies the properties: $d(x, y) = 0$ and $d(xoy) = 0$ for all $x, y \in N$. However, N is not a commutative near-field space.

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