A NOTE ON STRUCTURE
OF PERIODIC NEAR-FIELDS AND NEAR-FIELD SPACES (ANS - PNF - NFS)

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ABSTRACT

The aim of this work is to study a decomposition theorem for near-field spaces satisfying either of the properties $xy = x^p f(xyx)x^q$ or $xy = x^p f(yxy)x^q$, where $p = p(x, y)$, $q = q(x, y)$ are non-negative integers and $f(t) \in tZ(t)$ vary with the pair of elements x, y and further investigate the commutativity of such near-fields. Other related results are obtained for near-fields spaces.

Key words: *Near-ring, Near-field, periodic Near-field, sub Near-field, sub Near-field space, ideal, distributively generated near-field space, f-near-field space, nil near-field space, zero commutativity.*

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SECTION-1: INTRODUCTION

Dr. N V Nagendram [10] established the commutativity of near-field spaces over near-fields in which all products two elements are potent. In recent trends using this result Leigh proved that such near-field spaces are direct sum of J-near-field spaces i.e., near-field spaces satisfying Jacobson's property $x^{n(x)} = x$ property and zero near-field spaces. More recently author studied the direct sum decomposition of near-field spaces satisfying the property $xy = (xy)^2 f(x, y)$ where $f(X, Y) \in Z(X, Y)$, the near-field space of polynomials in two non-commuting in determinates. Now we consider the following near-field space properties.

(B) $\forall$ x, y in a near-field space N, there exist integers $p = p(x, y) \geq 0$, $q = q(x, y) \geq 0$ and a polynomial $f(t) \in t \, Z(t)$ such that

$$xy = x^p f(xyx)x^q \tag{1.1}$$

(B$_1$) $\forall$ x, y in a near-field space N, there exist integers $p = p(x, y) \geq 0$, $q = q(x, y) \geq 0$ and a polynomial $f(t) \in t \, Z(t)$ such that

$$xy = x^p f(yxy)x^q \tag{1.2}$$

SECTION-2: A DECOMPOSITION THEOREM FOR NEAR-FIELD SPACES

In this section, I establish a decomposition theorem which in turn allows us to study the commutativity of such near-field spaces. Throughout this section, N represents an associative near-field may be without unity 1 and C = N(N), the set of nilpotent elements of N.

Definition 2.1: A near-field space is called periodic near-field space if for each x $\in$ N there exist distinct positive integers m = m(x), n = n(x) such that $x^m = x^n$.

Definition 2.2: A near-field space N is called zero commutative near-field space if xy =0 implies that yx =0 for all x, y $\in$ N.

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Definition 2.3: An element x of N satisfying the property $x^{n(x)} = x$ for some $n(x) > 1$ is called potent.

Let B be the set of all potent elements, If B = N, then N is a J-near-field space. By a well known theorem of Jacobson, J-near-field spaces are necessarily commutative near-field spaces. A sufficient condition for N to be periodic near-field space for each $x \in N$ there exists an integer $p = p(x) > 1$ and a polynomial $f(t) \in Z(t)$ such that $x^p = x^{p+1}f(x)$. If N is periodic near-field space then every element $x \in N$ can be written in the form x = b + c, where b, c $\in$ C. Further if in a periodic near-field space N, each element has a unique representation as above, then both B and C are sub near-field spaces and N = B $\oplus$ C. By these two we obtain a decomposition theorem for near-field spaces satisfying one of the properties (B) and (B$_1$). In fact, I establish the following result:

Theorem 2.4: Let N be a near-field space satisfying one of the properties (B) and (B$_1$). Then N is a direct sum of a J-near-field space and a null near-field space.

Proof: We prove this theorem into the following parts called steps.

Step-1: Let N be a near-field space satisfying (B). Then N is periodic near-field.

Proof: Let y = x in (B). This shows that N satisfies criterion for periodicity and hence the near-field space satisfying (B) is necessarily periodic near-field.

Step-2: Let N be the near-field space satisfying (B). Then N is zero commutative near-field.

Proof: Let xy = 0. Then there exist integers $p' = p(x, y) \geq 0$, q' = q(x, y) $\geq$ 0 and a polynomial $h(t) \in t\,Z(t)$ such that $yx = y^{p'}h(xyx)y^{q'} = 0$. This implies that N is zero commutative near-field.

Step-3: Let N be a near-field space satisfying (B), Then NC = CN = (0).

Proof: let r(x) = 2. Replacing y by x in (B), we get $x^2 = x^r g(x)$, for some $g(t) \in tZ(t)$ and by step 1, N is periodic near-field. Clearly N is nil near-field.

Now we have
$$x^2 = x^r g(x) \text{ for } g(t) \, Z(t), \quad r(x) \geq 2 \qquad (2.1)$$

Let $c \in C$ and $x \in N$. Then choose integers $p_1 = p(c, x) \geq 0$, $q_1 = q(c, x) \geq 0$ and a polynomial $f_1(t) \in tZ(t)$ such that
$$cx = c^{p_1}f_1(cxc)c^{q_1} \qquad (2.2)$$

From the equality (2.1) one can easily observe that $c^2 = 0$ and hence $0 = xc^2 = (xc)c$. Step 2 gives that c(xc) =0 which together with (2.2) yields that cx = 0 and again step 2 gives that xc = 0 for all $x \in N$, $c \in C$. Thus gives the required result
i.e., $\qquad$ NC = CN = (0) $\qquad (2.3)$

By Step 1, N is periodic near-field space so that each element $x \in N$ can be written in the form b + c, where b $\in$ B and c $\in$ C. By a nice result it is enough to show that this representation is unique. If a + c = b + d for some a, b $\in$ B and c, d $\in$ C then $\qquad$ a – b = d – c $\qquad (2.4)$

Let a, b $\in$ B. Then there exist at least one odd of the positive integers r = r(a) and s = s(b) such that $a^r = a$ and $b^s = b$.

Let k = (r – 1) s – (r – 2) = (s -1)r – (s – 2) be an odd positive integer. Thus it is clear that $a^k = a$ and $b^k = b$. Also $e_1 = a^{k-1}$, $e_2 = b^{k-1}$ are idempotents in N with $e_1a = a$ and $e_2b = b$. Multiplying (2.4) by a and b from both sides using the result of step 3, we get $a^2 = ab = ba$. This gives that $a^2 = b^2$ and hence $e_1 = e_2$.

If k is even and $a^k = a$, then $a^{2(k-1)+1} = a$, where 2(k – 1) + 1 is odd, so this yields the required result.

Left multiplying (2.4) by e_1 now yields a = b and this completes the proof of the theorem.

Similar arguments can be used if N satisfies the property (B$_1$).

Remark 2.5: By the result of step 2, one concludes that the nilpotent elements of N annihilates N on both sides and hence are central near-fields. However, J-near-field spaces are commutative near-fields so that theorem 2.4 at once gives the following corollary which extends the main result.

Corollary 2.6: Let N be a near-field space satisfying any one of the following properties (B) (B_1). Then N is commutative near-field.

SECTION-3: DECOMPOSITION THEOREMS FOR NEAR-FIELD SPACES

In this section, I investigate the structure of near-field spaces satisfying the properties (B) and (B_1). Here, N denotes a left near-field space and $Z = Z(N)$ the multiplicative center of N.

Definition 3.1: An element x of N is called distributive if $(a + b)x = ax + bx$ for all a, b $\in$ N are distributive, then N is called a distributive near-field space.

Definition 3.2: A near-field space N is called a periodic near-field space if for each x $\in$ N there exist distinct positive integers $m = m(x)$ and $n = n(x)$ such that $x^m = x^n$.

Definition 3.3: A near-field space N is called a zero-symmetric if $0x = 0$ for all x $\in$ N (or left distributivity yields $x0 = 0$).

Definition 3.4: A sub near-field space of a near-field space N is a normal sub near-field space M of (N, +) such that (i) $NM \subseteq M$ and (ii) $(x + \alpha)y - xy \in M$ for all x, y $\in$ N and $\alpha \in M$.

Note 3.5: One can not get the direct sum decomposition under the hypothesis of the theorem 2.4 even in the case of distributive near-field spaces.

Definition 3.6: Week orthogonal sum of near-field space. A near-field space N is an orthogonal sum of sub near-field spaces P and Q denoted by $N = P + iQ$, if $PQ = QP = (0)$ and each element of N has a unique representation of the form $p + q$, $p \in P$, $q \in Q$.

Now, Dr N V Nagendram's aim is to establish the decomposition theorems for near-field spaces satisfying any one of the following related properties:
(B_2) $\forall$ x, y in a near-field space N, $\exists$ integers $p = p(x, y)$ there exist integers $p = p(x, y) \geq 0$, $q = q(x, y) \geq 0$ and
$$r = r(x, y) \geq 1 \ni xy = x^p (xyx)^r x^q \tag{3.1}$$

(B_3) $\forall$ x, y in a near-field space N, $\exists$ integers $p = p(x, y) \geq 0$, $q = q(x, y) \geq 0$ and $r = r(x, y) \geq 1$ such that
$$xy = x^p (yxy)^r x^q \tag{3.2}$$

Lemma 3.7: Let N be a zero commutative near-field space. Then the set C of all nil potent elements is a sub near-field space if and only if C is a sub near-field space of the additive sub near-field space (N, +).

Lemma 3.8: Let N be a periodic near-field space with multiplicative identity. If $C \subseteq Z$, then (N, +) is abelian.

Lemma 3.9: Let N be a near-field space in which the idempotents are multiplicatively central near-field space. If e_1 and e_2 are idempotents, then there exists an idempotent e_3 such that $e_3e_1 = e_1$ and $e_3e_2 = e_2$.

Theorem 3.10: Let N be a near-field space satisfying the property (B_2). If the idempotents of N are multiplicatively central near-field space, then M is a sub near-field space with (M, +) abelian and C is a sub near-field space with trivial multiplication and $N = C \perp M$.

Proof: We prove this theorem with the following existing known lemma 3.7, 3.8 and 3.9.

Clearly we see that a near-field space satisfying (B_2) is necessarily ero symmetric as well as zero commutative near-field space. Let c $\in$ C and x be an arbitrary element of N. then there exist integers $p = p(x, c) \geq 0$, $q = q(x, y) \geq 0$ and $r = r(x, y) \geq 1$ such that $xy = x^p (yxy)^r x^q$ (3.3)

Next choose integers $p' = p(x) \geq 0$, $q' = q(x) \geq 0$ and $r' = r(x) \geq 1$ such that $x^2 = x^{p' + q' + 3r'}$. (3.4)

Since (3.4) gives that $c^2 = (0)$ for any c $\in$ C, we obtain that $c(cx) = c^2x = 0$ and the zero commutativity in N yields that $(cx)c = 0$. Thus by using lemma 3.8 we find that $xc = 0$ for all x $\in$ N, and also ero commutativity near-field space of N implies that $cx = 0$ i.e., $NC = CN = (0)$ (3.5)

(3.5) shows that all nil potent elements of N annihilates N on both sides and hence, In particular, $C^2 = (0)$ and $C \subseteq Z$. If c, d $\in$ C, then $(c - d)^2 = 0$. This gives that $c - d \in C$ and C is a sub near-field space of the additive sub near-field space (N, +). Now the application of lemma 3.7 yields the required result. This completed the proof of the theorem.

Lemma 3.11: Let N be a near-field space satisfying the property (B_2). If the idempotents of a near-field space N are multiplicatively central near-field space, then M is a sub near-field space with (M, +) abelian.

Proof: Let a, b $\in$ M. Then there exist integers $m' = m(a) > 1$ and $n' = n(b) > 1$ such that $a^{m'} = a$ and $b^{n'} = b$.

If
$$s = (m' - 1)n' - (m' - 2) = (n' - 1) m' - (n' - 2) > 1 \qquad (3.6)$$

Then it clear that $a^s = a$ and $b^s = b$. Note also that $e_1 = a^{s-1}$ and $e_2 = b^{s-1}$ are central idempotents in N with $e_1 a = a$ and $e_2 b = b$. Also in view of (B_2) we find that
$$ab = (e_1 a)(e_2 b) = (e_1 e_2)(ab) = (e_1 e_2)^p (e_1 e_2 a b e_1 e_2)^p (e_1 e_2)^q \qquad (3.7)$$

For some integers $p = p(e_1 e_2 ab) \geq 0$, $q = q(e_1 e_2 ab) \geq 0$ and $r = r(e_1 e_2 ab) > 1$.

This yields that $ab = (e_1 e_2) (ab)^r (e_1 e_2)$. \qquad (3.8)

So $ab \in M$. moreover, since N/C has the $x^m = x$ property, we have an integer $k > 1$ such that
$$(a - b)^k = a - b + c. \qquad (3.9)$$

Where a, b $\in$ M and c $\in$ C. Now e_1 and e_2 are central idempotents in N and, in view of lemma 3.9 there exists an idempotent e $\in$ N such that $ee_1 = e_1$ and $ee_2 = e_2$. This implies that ea = a and eb = b. Since (3.5) is still valid in the present situation, multiply (3.9) by e to get $(a - b)^k = a - b$, and hence a - b $\in$ M. Also, eN is a periodic near-field space with multiplicative identity element in which nilpotent elements are multiplicatively central near-field space. Thus by lemma 3.8, (eN, +) is abelian. Therefore, ea + eb = eb + ea, i.e., a + b = b + a, and hence (M, +) is abelian.

Now we look into Proof of theorem 3.10. Let x $\in$ N. Then in view of (3.4), if $x^2 = x^k$, $k = p^r + q^s + 3r' \geq 3$, then clearly $x^j = x^{j+s(k-2)}$ for all $j \geq 2$ and $s \geq 1$. It follows at once that $(x^{k-1})^{k-1} = x^{k-1}$, $x^{k-1} \in$ M. It follows that $(x - x^{k-1})^2 = 0$ and $x - x^{k-1} \in$ C. Hence, we can write $x = x - x^{k-1} + x^{k-1}$ and see that N = C + M. Now in view of lemma 3.10 and lemma 3.11, it remains only to show that each element of N has the unique representation in the form c + b, where c $\in$ C, b $\in$ M. Suppose that c + a = d + b, where c, d $\in$ C and a, b $\in$ M. Then $-d + c = b - a \in C \cap M = (0)$. This gives that a = b and c = d. This completes the proof of the theorem.

Note 3.12: It is obvious that centrality of idempotents in the hypothesis of theorem 3.10 is not superfluous.

Note 3.13: If a near-field space N satisfies (B_3) then it can be easily verified that N need not be zero commutative near-field space. However a zero symmetric near-field space satisfying (B_3) is necessarily zero commutative near-field space. Hence for a zero symmetric near-field space satisfying (B_3) lemma 3.10 and lemma 3.11 may be proved easily in the same fashion. By using similar arguments used to prove theorem 3.11, with necessary variations, we can prove the following result. We omit the details of the proof to avoid repetition.

Theorem 3.14: Let N be a ero symmetric near-field space satisfying (B_3). If the idempotent elements of N are multiplicatively central near-field space, then C is a sub near-field space with trivial multiplication, M is a sub near-field space with (M, +) abelian and N = C + M.

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