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PSEUDO SYMMETRIC IDEALS IN Γ-SO-RINGS

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Abstract: *A Γ-so-ring is a structure possessing a natural partial ordering, an infinitary partial addition and a ternary multiplication, subject to a set of axioms. The partial functions under disjoint-domain sums and functional composition is a Γ-so-ring. In this paper we introduce the notions of pseudo symmetric ideal and pseudo symmetric Γ-so-ring and we characterize pseudo symmetric ideals in Γ-so-rings.*
Keywords: *Prime ideal, completely prime ideal, pseudo symmetric ideal and pseudo symmetric Γ-so-ring.*

1. INTRODUCTION

Partially defined infinitary operations occur in the contexts ranging from integration theory to programming language semantics. The general cardinal algebras studied by Tarski in 1949, Housdorff topological commutative groups studied by Bourbaki in 1966, Σ-structures studied by Higgs in 1980, sum ordered partial monoids & sum ordered partial semirings studied by Arbib, Manes, Benson[3], [5] and Streenstrup[14] are some of the algebraic structures of the above type.

M. Murali Krishna Rao[10] in 1995 introduced the notion of a Γ-semiring as a generalization of semirings and Γ-rings, and extended many fundamental results of semirings and Γ-rings to Γ-semirings. In [8] and [9] we introduced the notion of Γ-so-ring, obtained a necessary and sufficient condition for the quotient R/θ to be a Γ/σ-so-ring, where (θ, σ) is a congruence relation on (R, Γ), and $((\phi, \rho)$-representation of Γ-so-rings. In [10], [11], [12] and [13] we introduced the notion of an ideal, prime ideal and semiprime ideal in a Γ-so-ring R, obtained many characteristics of ideals, prime ideals and semiprime ideals in R and studied the Green's relations in partial Γ-semirings.

In [2], Anjaneyulu initiated the study of pseudo symmetric ideals in semigroups and it was extended to Γ-semirings by Krishnamoorthy and Arul Doss[4]. In this paper we introduce the notions of pseudo symmetric ideal and pseudo symmetric Γ-so-ring and we characterize pseudo symmetric ideals in Γ-so-rings.

2. PRELIMINARIES

In this section we collect some important definitions and results for our use in this paper.

2.1. Definition. [5] A *partial monoid* is a pair (M, Σ) where M is a nonempty set and Σ is a partial addition defined on some, but not necessarily all families $(x_i : i \in I)$ in M subject to the following axioms:

(i) **Unary Sum Axiom.** If $(x_i : i \in I)$ is a one element family in M and $I = \{ j \}$, then

$\Sigma(x_i : i \in I)$ is defined and equals x_j.

(ii) **Partition-Associativity Axiom.** If $(x_i : i \in I)$ is a family in M and $(I_j : j \in J)$ is a partition of I, then $(x_i : i \in I)$ is summable if and only if $(x_i : i \in I_j)$ is summable for every j in J, $(\Sigma(x_i : i \in I_j) : j \in J)$ is summable, and $\Sigma(x_i : i \in I) = \Sigma(\Sigma(x_i : i \in I_j):j\in J)$.

2.2. Definition. [8] Let (R, Σ) and (Γ, Σ') be two partial monoids. Then R is said to be a *partial*

Γ-semiring if there exists a mapping $R \times \Gamma \times R \to R$ (images to be denoted by $x\gamma y$ for $x, y \in R$ and $\gamma \in \Gamma$) satisfying the following axioms:

(i) $x\gamma(y\mu z) = (x\gamma y)\mu z$,

(ii) a family $(x_i : i \in I)$ is summable in R implies $(x\gamma x_i : i \in I)$ is summable in R and

$x\gamma[\Sigma(x_i : i \in I)] = \Sigma(x\gamma x_i : i \in I)$,

(iii) a family $(x_i : i \in I)$ is summable in R implies $(x_i\gamma x : i \in I)$ is summable in R and

$[\Sigma(x_i : i \in I)]\gamma x = \Sigma(x_i\gamma x : i \in I)$,

(iv) a family $(\gamma_i : i \in I)$ is summable in Γ implies $(x\gamma_i y : i \in I)$ is summable in R and

$x[\Sigma'(\gamma_i : i \in I)]y = \Sigma(x\gamma_i y : i \in I)$ for all $x, y, z, (x_i : i \in I)$ in R and $\gamma, \mu, (\gamma_i : i \in I)$ in Γ.

2.3. Definition. [11] A partial Γ-semiring R is said to be *commutative* if for any $a, b \in R$,

$a\Gamma b = b\Gamma a$.

2.4. Definition. [14] The *sum ordering* $\leq$ on a partial monoid (M, Σ) is the binary relation

such that $x \leq y$ if and only if there exists a h in M such that $y = x + h$ for $x, y \in M$.

2.5. Definition. [14] A *sum-ordered partial monoid* or *so-monoid*, in short, is a partial monoid in which the sum ordering is a partial ordering.

2.6. Definition. [8] A partial Γ-semiring R is said be a sum-ordered partial Γ-semiring (in short

Γ-so-ring) if the partial monoids R and Γ are so-monoids.

2.7. Definition. [10] Let R be a partial Γ-semiring, A be a nonempty subset of R and Ω be a nonempty subset of Γ. Then the pair (A, Ω) of (R, Γ) is said to be a *left (right) partial Γ-ideal* of R if it satisfies the following:

(i) $(x_i : i \in I)$ is a summable family in R and $x_i \in A \ \forall\, i \in I$ implies $\Sigma_i x_i \in A$,

(ii) $(\alpha_i : i \in I)$ is a summable family in Γ and $\alpha_i \in \Omega \ \forall\, i \in I$ implies $\Sigma'_i \alpha_i \in \Omega$, and

(iii) for all $x \in R; y \in A$ and $\alpha \in \Omega$, $x\alpha y \in A$ $(y\alpha x \in A)$.

If (A, Ω) is both left and right partial Γ-ideal of a partial Γ-semiring R, then (A, Ω) is called a *partial Γ-ideal* of R. If $\Omega = \Gamma$, then A is called a *partial ideal* of R.

2.8. Definition. [10]] Let R be a partial Γ-semiring, A be a nonempty subset of R and Ω be a nonempty subset of Γ. Then the pair (A, Ω) of (R, Γ) is said to be a *left (right) Γ-ideal* of R if it satisfies the following:

(i) (A, Ω) is a left (right) partial Γ-ideal of R,

(ii) $x \in R$ and $y \in A$ such that $x \leq y$ implies $x \in A$, and

(iii) $\alpha \in \Gamma$ and $\beta \in \Omega$ such that $\alpha \leq \beta$ implies $\alpha \in \Omega$.

If (A, Ω) is both left and right Γ-ideal of a partial Γ-semiring R, then (A, Ω) is called a

Γ-ideal of R. If $\Omega = \Gamma$, then A is called an *ideal* of R.

2.9. Definition. [10] Let R be a Γ-so-ring. If A and Ω are subsets of R and Γ respectively,

then the intersection of all Γ-ideals of R containing (A, Ω) is called the Γ-ideal generated by (A, Ω) and is denoted by $< (A, \Omega) >$.

If $\Omega = \Gamma$, then $< A >$ is the ideal of (R, Γ) generated by A.

2.10. Definition. [9] A Γ-so-ring R is said to be a complete Γ-so-ring if every family of

elements in R is summable and every family of elements in Γ is summable.

2.11. Theorem. [10] Let R be a complete Γ-so-ring. If A and Ω are subsets of R and Γ espectively, then the Γ-ideal generated by (A, Ω) is the pair $(\{ x \in R \mid x \leq \Sigma_i x_i + \Sigma_j r_j\alpha_j x_j' + \Sigma_k x_k''\alpha_k' r_k' + \Sigma_l$

$r_l''\alpha_l''x_l'''\alpha_l'''r_l'''$, where $x_i, x_j', x_k'', x_l''' \in A$, $r_j, r_k', r_l'', r_l''' \in R$ and $\alpha_j, \alpha_k', \alpha_l'', \alpha_l''' \in \Gamma \}$, $\{ \beta \in \Gamma \mid \beta \leq \Sigma_i'\beta_i, \beta_i \in \Gamma \})$.

2.12. Remark. [10] Let R be a complete Γ-so-ring and $a \in R$. Then the left/right/both sided ideals of R generated by a are

(i) $< a] = \{ x \in R \mid x \leq \Sigma_n a + \Sigma_j r_j\alpha_j a, r_j \in R, \alpha_j \in \Gamma, n \in N \}$,
(ii) $[a > = \{ x \in R \mid x \leq \Sigma_n a + \Sigma_k a\alpha_k' r_k', r_k' \in R, \alpha_k' \in \Gamma, n \in N \}$,
(iii) $< a > = \{ x \in R \mid x \leq \Sigma_n a + \Sigma_j r_j\alpha_j a + \Sigma_k a\alpha_k' r_k' + \Sigma_l r_l''\alpha_l'' a\alpha_l''' r_l'''$, where $r_j, r_k', r_l'', r_l''' \in R$ and $\alpha_j, \alpha_k', \alpha_l'', \alpha_l''' \in \Gamma, n \in N \}$.

We call $< a >$ as the *principal ideal generated by a*.

2.13. Definition. [10] Let R be a Γ-so-ring. If A, B are subsets of R and Γ_1 is a subset of Γ,

define $A\Gamma_1 B$ as the set $\{x \in R \mid \exists\ a_i \in A, \gamma_i \in \Gamma_1, b_i \in B, \Sigma_i a_i\gamma_i b_i$ *exists and* $x \leq \Sigma_i a_i\gamma_i b_i \}$.

If $A = \{a\}$ then we also denote $A\,\Gamma_1 B$ by $a\,\Gamma_1 B$. If $B = \{b\}$ then we also denote $A\,\Gamma_1 B$ by $A\,\Gamma_1 b$. Similarly if $A = \{a\}$ and $B = \{b\}$, we denote $A\,\Gamma_1 B$ by $a\,\Gamma_1 b$ and thus $a\,\Gamma_1 b = \{x \in R \mid x \leq a\gamma b$ *for some* $\gamma \in \Gamma_1 \}$.

An ideal A of a Γ-so-ring R is called proper if $A \neq R$.

2.14. Definition. [12] A proper ideal P of a Γ-so-ring R is said to be prime if and only if for any ideals A, B of R, $A\Gamma B \subseteq P$ implies $A \subseteq P$ *or* $B \subseteq P$.

2.15. Lemma. [12] Let R be a complete Γ-so-ring and P be a proper ideal of R. Then the following conditions are equivalent:

(i) P is prime
(ii) If $a, b \in R$ such that $< a > \Gamma < b > \subseteq P$ then $a \in P$ or $b \in P$.

2.16. Theorem. [12] Let R be a complete Γ-so-ring and P be a proper ideal of R. Then the following conditions are equivalent:

(i) P is prime
(ii) If $a, b \in R$ such that $a\Gamma R\Gamma b \subseteq P$ then $a \in P$ or $b \in P$
(iii) If A_1, A_2 are right ideals of R such that $A_1\Gamma A_2 \subseteq P$ then $A_1 \subseteq P$ or $A_2 \subseteq P$
(iv) If B_1, B_2 are left ideals of R such that $B_1\Gamma B_2 \subseteq P$ then $B_1 \subseteq P$ or $B_2 \subseteq P$.

2.17. Theorem. [12] Let R be a commutative complete Γ-so-ring and P be a proper ideal of R. Then the following conditions are equivalent:

(i) P is prime
(ii) If $a, b \in R$ such that $a\Gamma b \subseteq P$ then $a \in P$ or $b \in P$.

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3.1. Definition. A proper ideal P of a Γ-so-ring R is said to be *completely prime* if and only

if for any x, y of R, $x\Gamma y \subseteq P$ implies $x \in P$ or $y \in P$.

Every prime ideal in a commutative complete Γ-so-ring R is completely prime.

Following the notion of pseudo symmetric ideal in Γ-semirings by Krishnamoorthy & Arul Doss[4], we introduce the notion of pseudo symmetric ideal in a Γ-so-ring R as follows:

3.2. Definition. An ideal P of a Γ-so-ring R is said to be *pseudo symmetric* if and only if for any x, y of R, $x\Gamma y \subseteq P$ implies $x\Gamma R\Gamma y \subseteq P$.

3.3. Definition. A Γ-so-ring R is said to be *pseudo symmetric* if every ideal of R is pseudo symmetric ideal.

3.4. Theorem. If R is a commutative Γ-so-ring then R is pseudo symmetric.

Proof. Suppose R is a commutative Γ-so-ring. Let P be an ideal of R. Let $x, y \in R$ such that $x\Gamma y \subseteq P$. Then $x\Gamma y\Gamma R \subseteq P$. Since R is commutative, $x\Gamma R\Gamma y \subseteq P$. Hence P is pseudo symmetric ideal of R. Hence the theorem.

The following is an example of a Γ-so-ring R which is pseudo symmetric but not commutative.

3.5. Example. Let $R = \{0, u, v, x, y, z\}$. Define Σ on R as

$$\sum_i x_i = \begin{cases} x_j, if \quad x_i = 0 \forall i \neq j \; for \quad some \quad j \\ z, if \quad x_j = u, x_k = v \; for \quad some \; j,k \quad and \quad x_i = 0 \forall i \neq j,k \\ undefined, \quad otherwise \end{cases}$$

Then R is a partial monoid.
Let $\Gamma = \{0', 1'\}$. Define Σ' on Γ as

$$\sum_i^1 \alpha_i = \begin{cases} 1', if \quad \alpha_i = 0 \forall i \neq j \; for \quad some \quad j \\ undefined, \quad otherwise \end{cases}$$

Then Γ is a partial monoid.
Define a mapping $R \times \Gamma \times R \to R$ as follows:

0'	*0*	*u*	*v*	*x*	*y*	*z*
0	*0*	*0*	*0*	*0*	*0*	*0*
u	*0*	*0*	*0*	*0*	*0*	*0*
v	*0*	*0*	*0*	*0*	*0*	*0*
x	*0*	*0*	*0*	*0*	*0*	*0*
y	*0*	*0*	*0*	*0*	*0*	*0*
z	*0*	*0*	*0*	*0*	*0*	*0*

1'	*0*	*u*	*v*	*x*	*y*	*z*
0	*0*	*0*	*0*	*0*	*0*	*0*
u	*0*	*u*	*0*	*x*	*0*	*u*
v	*0*	*0*	*v*	*0*	*y*	*v*
x	*0*	*0*	*x*	*0*	*u*	*x*
y	*0*	*y*	*0*	*v*	*0*	*y*
z	*0*	*u*	*v*	*x*	*y*	*z*

Then R is a pseudo symmetric Γ-so-ring. Since $u1'x = x$ and $x1'u = 0$, R is noncommutative.

3.6. Theorem. Let R be a complete Γ-so-ring. Then the following statements hold:

(i) Every completely prime ideal of R is both prime and pseudo symmetric,

(ii) Let A be a pseudo symmetric ideal of R. Then A is prime if and only if A is completely prime,

(iii) Let A be a prime ideal of R. Then A is pseudo symmetric if and only if A is completely prime.

Proof. (i). Let P be a completely prime ideal of R. Let A, B be ideals of R such that $A\Gamma B \subseteq P$. Suppose $A \not\subset P$. Then $\exists\ a \in A \ni a \notin P$. Let $b \in B$. Then $a\Gamma b \subseteq A\Gamma B \subseteq P$. Since P is completely prime and $a \notin P$, $b \in B$. Therefore $B \subseteq P$. Hence P is prime. Let $x, y \in R \ni$ $x\Gamma y \subseteq P$. Then $x \in P$ or $y \in P$. Since P is ideal, $x\Gamma R\Gamma y \subseteq P$. Hence P is pseudo symmetric.

(ii). Let A be a pseudo symmetric ideal of R. Suppose A is prime. Let $x, y \in R \ni x\Gamma y \subseteq A$. Since A is pseudo symmetric, $x\Gamma R\Gamma y \subseteq A$. Since A is prime, $x \in A$ or $y \in A$. Hence A is completely prime. Conversely, suppose that A is completely prime. By (i), A is prime.

(iii). Let A be a prime ideal of R. Suppose A is pseudo symmetric. Then by (ii), A is completely prime. Conversely, suppose that A is completely prime. By (i), A is pseudo symmetric. Hence the theorem.

3.7. Theorem. Let R be a complete Γ-so-ring and A be an ideal of R. Then the following conditions are equivalent:

(i) A is a pseudo symmetric ideal of R
(ii) $(A : a)_r = \{x \in R \mid a\Gamma x \subseteq A\}$ *is an ideal of* $R\ \forall\ a \in R$
(iii) $(A : a)_l = \{x \in R \mid x\Gamma a \subseteq A\}$ *is an ideal of* $R\ \forall\ a \in R$.
Proof. **(i) $\Rightarrow$ (ii):** Suppose A is a pseudo symmetric ideal of R. Let $a \in R$. Note that $(A : a)_r =$ $\{x \in R \mid a\Gamma x \subseteq A\}$ is a nonempty subset of R. Let $(x_i : i \in I)$ be a summable family in R such that $x_i \in (A : a)_r$, $i \in I$. Then $a\Gamma x_i \subseteq A\ \forall\ i \in I$. $\Rightarrow \bigvee_{i\in I} (a\Gamma xi) \subseteq A. \Rightarrow a\Gamma(\Sigma_i x_i) \subseteq A. \Rightarrow \Sigma_i x_i$ $\in (A : a)_r$. Let $x \in R$ and $y \in (A : a)_r$ such that $x \leq y$. Then $x \in R$ and $a\Gamma y \subseteq A$ such that $x \leq y$.

Since $x \leq y$, $a\Gamma x \subseteq a\Gamma y$. $\Rightarrow a\Gamma x \subseteq A$. $\Rightarrow x \in (A : a)_r$. Let $r \in R$, $\alpha \in \Gamma$ and $x \in (A : a)_r$. Then $a\Gamma x \subseteq A$. $\Rightarrow a\Gamma(x\alpha r) = (a\Gamma x)\alpha r \subseteq A$. $\Rightarrow x\alpha r \in (A : a)_r$. Since A is pseudo symmetric and $a\Gamma x \subseteq A$, $a\Gamma R\Gamma x \subseteq A$. $\Rightarrow a\Gamma(r\alpha x) \subseteq A$. $\Rightarrow r\alpha x \in (A : a)_r$. Hence $(A : a)_r$ is an ideal of R. Similarly we can prove (i) $\Rightarrow$ (iii).

(ii) $\Rightarrow$ (i): Suppose $(A : a)_r$ is an ideal of R $\forall\ a \in R$. Let $x, y \in R \ni x\Gamma y \subseteq A$. Then

$y \in (A : a)_r$. By assumption, $R\Gamma y \in (A : a)_r$. $\Rightarrow x\Gamma(R\Gamma y) \subseteq A$. Hence A is pseudo symmetric. Similarly we can prove (iii) $\Rightarrow$ (i).

3.8. Lemma. Let A be a pseudo symmetric ideal of a complete Γ-so-ring R and $a, b \in R$. Then $a\Gamma b \subseteq A$ if and only if $< a > \Gamma < b > \subseteq A$.

Proof. Let a, $b \in R$. Suppose $a\Gamma b \subseteq A$. Since A is pseudo symmetric and $a\Gamma b \subseteq A$, $a\Gamma R\Gamma b \subseteq A$. Since $< a > \Gamma < b > \subseteq a\Gamma R\Gamma b$, $< a > \Gamma < b > \subseteq A$. Coversely suppose that $< a > \Gamma < b > \subseteq A$. Since $a \in < a >$ and $b \in < b >$, $a\Gamma b \subseteq A$. Hence the lemma.

3.9. Corollary. Let A be a pseudo symmetric ideal of a complete Γ-so-ring R and $a \in R$. Then for any natural number n, $(a\Gamma)^{n-1}a \subseteq A$ if and only if $(< a > \Gamma)^{n-1} < a > \subseteq A$.

3.10. Theorem. Let A be a pseudo symmetric ideal of a complete Γ-so-ring R. Then every prime ideal P minimal to containing A is completely prime.

Proof. Let P be a prime ideal of R minimal to containing A. Take $H = R \setminus P$. Take $S = \{J \mid J$ is an ideal of R, $A \subseteq J$ and $J \cap H = \Phi\}$. Clearly $P \in S$. So, $S \neq \Phi$. Now S is a partial ordered set with set inclusion. Let $\{J_i \mid i \in I\}$ be a chain in S. Take $J' = \bigcup_{i \in I} J_i$. Clearly J' is an ideal of R such that $R, A \subseteq J'$ and $J' \cap H = \Phi$. $\Rightarrow J' \in S$. Also, J' is an upper bound of $\{J_i \mid i \in I\}$. By Zorn's lemma, S has a maximal element, let it be M. i.e., M is an ideal of R such that $A \subseteq M$ and $M \cap H = \Phi$ and M is maximal with respect to this property.

Now we prove that M is a prime ideal of R. Let X, Y be any ideals of R such that $X\Gamma Y \subseteq M$. Suppose if $X \not\subset M$ and $Y \not\subset M$. Then $M \vee X$ and $M \vee Y$ are ideals of R containing M properly. Since M is maximal, $(M \vee X) \cap H \neq \Phi$ and $(M \vee Y) \cap H \neq \Phi$. Since $M \cap H = \Phi$, we have $X \cap H \neq \Phi$ and $Y \cap H \neq \Phi$. So there exists $x \in X \cap H$ and $y \in Y \cap H$. Now $x\Gamma y \subseteq X\Gamma Y \cap H \subseteq M \cap H = \Phi$, a contradiction. Therefore $X \subseteq M$ or $Y \subseteq M$. Hence M is a prime ideal of R. Now $A \subseteq M \subseteq R \setminus H \subseteq P$. Since P is minimal prime ideal relative to containing A, we have $M = P$. Hence P is a completely prime ideal of R.

4. Conclusion

In this paper we introduce the notions of pseudo symmetric ideal and pseudo symmetric Γ-so-ring and we characterize pseudo symmetric ideals in Γ-so-rings.

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