RSMA-Assisted ISAC: Technical Comparison, Integration Challenges, and a Deployment Playbook

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***Abstract*—This short survey provides a technical comparison of ISAC baselines (SDMA and NOMA) against RSMA-assisted ISAC and distills the integration challenges that determine deployed performance. Three co-design levers repeatedly govern outcomes: the common/private budget that realizes partial interference decoding, the dual-purpose beam shaping that simultaneously stabilizes decodability and forms useful sensing lobes, and the SIC feasibility margins under imperfect CSIT and hybrid front-ends. Consolidating results across DFRC, mmWave/hybrid arrays, RIS/STAR-RIS extensions, and statistics-driven designs, RSMA-assisted ISAC consistently shifts the rate–sensing frontier and shows robustness to channel correlation and calibration drift [1]–[9]. We further connect network-level mobility control and PHY-layer statistics to the RSMA layering: mobility-aware multi-UAV placement informs sensing cadence and bandwidth allocation, while covariance-based beamforming stabilizes joint comm–sensing beampatterns under partial CSI [10], [11]. Application-level evidence from cooperative multi-UAV surveillance aligns with our guidance on anchoring probing in the common stream and keeping private beams conservative under motion [12]. The survey closes with a wide-format comparison and an implementation playbook covering unified pilots, common-burst scheduling, conservative private beams, and surface-aided shaping for incremental deployment. To make the deployment playbook operational, we (i) grade each guideline by strength of supporting evidence, (ii) provide a regime map with quantitative boundary cues, and (iii) summarize representative quantitative anchors reported across RSMA/SDMA/NOMA ISAC studies.**

I. Introduction

ISAC targets a single RF platform that performs sensing and data delivery. The practical benefits are integration (spectrum, energy, hardware) and coordination (mutual assistance between tasks). Design is a controlled trade between communication utility and sensing accuracy, set by waveform and beam choices and evaluated on a Pareto frontier [4], [9]. RSMA, in parallel, splits each user message into a common part decoded by all and a private part decoded after SIC. By deciding what portion of interference to decode and what to treat as noise, RSMA bridges and often outperforms SDMA and NOMA, especially when channels are correlated and CSIT is imperfect [1], [2]. The integration is direct: ISAC benefits from a strong, well-shaped probing component; RSMA already carries a strong common stream. When co-designed, the common stream doubles as a sensing illuminator while regulating multi-user interference, and private streams preserve user differentiation. Early DFRC results validate trade-off gains and, in regimes, remove the need for dedicated radar-only signaling [13]. Operationally, multi-UAV surveillance and mobility-driven deployments sharpen the case: reliability-aware resource control naturally translates into sensing cadence and bandwidth policies, where our RSMA common-burst anchoring and conservative private beams fit well [10], [12].

This survey is intentionally synthesis-driven and focuses on deployment-relevant implications rather than proposing a new PHY. Concretely, it delivers: (i) an evidence-graded set of deployment guidelines that distinguish strongly supported observations from heuristics, (ii) a compact regime map with quantitative boundary cues that practitioners can monitor (e.g., residual multiuser leakage, weakest-user common decodability, and sensing constraints), and (iii) representative quantitative anchors that illustrate how these knobs impact the SDMA/NOMA/RSMA ordering under ISAC objectives.

Evidence legend: Throughout the paper, we tag each guideline as **E1** (strong: supported by multiple independent ISAC/DFRC studies and/or direct RSMA vs. SDMA/NOMA comparisons), **E2** (moderate: supported by a single study or indirect transfer from closely matched settings), or **H** (heuristic: engineering insight that is plausible but not yet systematically validated).

II. RSMA-Enabled ISAC: Design View

We adopt a paragraph-style abstraction that avoids equations but remains precise. **Terminology (canonical coupling):** A standard ISAC transmitter superposes communication layers and (optionally) a dedicated sensing component, e.g., $\boldsymbol{x} = \boldsymbol{w}_c s_c + \sum_k \boldsymbol{w}_k s_k + \boldsymbol{x}_{\text{sens}}$. Each user observes $y_k = \boldsymbol{h}_k^H \boldsymbol{x} + n_k$, so both $\boldsymbol{x}_{\text{sens}}$ and any non-intended private layers appear as interference unless canceled. Sensing quality is governed by the transmit beampattern/echo statistics, hence $\{\boldsymbol{w}_c, \boldsymbol{w}_k\}$ simultaneously control (i) weakest-user common decodability, (ii) private SINRs, and (iii) illumination of the sensing sector or targets. This coupling is the primary mechanism behind the trade-offs summarized in Table I and the playbook in Table II. *Budgeting* comes first. A modest common rate/power share stabilizes decodability at the weakest user while creating a bright, steerable probing component; under-allocating wastes sensing potential and forces private beams to carry directional energy, whereas over-allocating can collapse SIC. This aligns with RSMA's core mechanism—partial interference decoding—which maintains performance under stale

TABLE I
WIDE COMPARISON OF ISAC BASELINES VS. RSMA-ASSISTED ISAC (EVIDENCE INDICATED BY CITATIONS).

Aspect	SDMA-ISAC	NOMA-ISAC	RSMA-ISAC
Channel conditions & CSIT	Strong when users near-orthogonal; sensitive to CSIT errors and correlation [2]	Gains with power gaps; brittle to ordering/CSIT drift [5]	Robust under correlation and imperfect CSIT via partial interference decoding [1], [2]
Interference handling	Treats residual as noise; relies on deep nulls that are brittle under drift [3]	Ordered SIC; tightly coupled with power disparities and sensing demands [5]	Common stream regulates inter-user and comm–sense interference simultaneously [13]
Sensing integration	Explicit rate vs. CRB/echo-SNR trade-off; private beams can mask echoes [3]	Sensing competes with power ordering; echo quality degrades as powers converge [5]	Common beam doubles as illuminator; private beams are steered away from target angles [13]
Hardware fit (hybrid/RIS/STAR)	RF-chain limits reduce agility; benefits from passive DoF but lacks an interference knob	Sensitive to analog constraints; SIC order can conflict with sensing in hybrid arrays	Common carries probing in hybrid; RIS/STAR-RIS restore spatial DoF and coverage [6]–[8]
Typical win region	Orthogonal users, accurate CSIT, light sensing	Extreme disparities, stable ordering, light sensing	Correlated users, moderate CSIT, sensing-heavy regimes; robustness priority [2], [9]

or inexact CSIT [2]. *Shaping* follows. The common beam should illuminate the sensing sector and stay within all-user decodability margins; private beams should avoid target angles to reduce echo masking and limit backscatter that interferes with decoding. CRB-anchored formulations on the sensing side provide the right handle to embed these shaping goals into communications-centric optimization, and practical stacks can realize them with mild OFDM subcarrier shaping and power redistribution [3], [4]. *Feasibility* then dominates. In hybrid analog/digital architectures with few RF chains and inevitable calibration drift, designs that value robustness over deep nulling hold up better; RSMA's common stream absorbs more of the interference burden and reduces sensitivity to hard decode orders that typically constrain NOMA [5], [7]. Mobility-aware placement and scheduling provide a policy layer that allocates comm/sense resources in response to motion, while covariance-based beamforming offers a statistics-driven backbone for common/private beam control under imperfect CSIT [10], [11].

Augmentations are straightforward. Hierarchical (two-layer) rate-splitting can group users with similar channels and assign a local common stream per group plus a global common stream; this softens the weakest-user cap on a single global common while retaining an illuminator for sensing [2]. In all cases, pilots should be unified: downlink preambles serve both CSI and echo calibration, with brief, predictable common bursts for rapid target updates [4].

III. ANALYSIS AND COMPARISON

To anchor the discussion and provide a quick reading guide, *Table I* contrasts SDMA-, NOMA-, and RSMA-assisted ISAC along four axes that matter in deployment: (i) channel and CSIT sensitivity, (ii) interference handling, (iii) sensing integration, and (iv) hardware fit with a typical win region. The entries synthesize evidence across DFRC settings, RIS/STAR-RIS extensions, and hybrid/mmWave front-ends; the paragraphs that follow unpack each line item and connect it to reported behaviors and recommended knobs. In addition, we explicitly grade the main guidelines using the E1/E2/H legend defined in Section I to separate strongly supported observations from heuristics [2], [3], [6]–[8].

A. Evidence-Graded Deployment Guidelines

Table II collects the most actionable design rules and tags each one with an evidence grade. The grades do not imply optimality; they indicate how directly the guideline is supported by the cited ISAC/DFRC comparisons.

B. Regime Map and Quantitative Boundary Cues

Beyond qualitative descriptions, the SDMA/NOMA/RSMA ordering can be anticipated by monitoring a small set of boundary cues that arise directly from the canonical coupling in Section II.

- **Near-orthogonality (SDMA-friendly):** SDMA becomes competitive when residual multiuser leakage is negligible, i.e., for each user k, $\sum_{j\neq k}|\boldsymbol{h}_k^H\boldsymbol{w}_j|^2 \ll \sigma_k^2$, and sensing-induced terms are likewise below the noise floor.
- **Common-layer feasibility (RSMA-friendly):** RSMA is most effective when the worst-user common decodability is sufficient to cover the aggregate "deficits" left by private rates; a practical boundary cue is $\min_k r_{0,k} \gtrsim \sum_u \big[R_u^{\mathrm{th}} - r_{u,u}\big]_+$, so the common layer can stabilize feasibility and leave private beams to refine both rate and sensing shaping.
- **Ordering stability (NOMA-friendly but ISAC-sensitive):** NOMA relies on a stable SIC order and persistent power gaps; in ISAC, sensing illumination and waveform superposition can perturb effective SINRs, so the order should remain stable under the intended sensing constraints [5], [7].

C. Representative Quantitative Anchors and Illustrative Operating Points

While exact cross-over points depend on antenna configuration and sensing objectives, the literature consistently

TABLE II
EVIDENCE-GRADED DEPLOYMENT GUIDELINES FOR RSMA-ASSISTED ISAC. EVIDENCE LEVELS: E1 (STRONG), E2 (MODERATE), H (HEURISTIC).

Guideline	Ev.	Supported by	Knobs / boundary cues
Allocate a non-trivial common layer when user channels are correlated and/or CSIT is imperfect; treat it as a robustness budget.	E1	[1], [2]	Correlation, CSIT quality; residual multiuser leakage not negligible.
Embed sensing via CRB/SCNR-style constraints and shape beams accordingly (common probes; privates avoid target angles when possible).	E1	[3], [13]	CRB/SCNR targets; sensing sector/target geometry.
Consider NOMA primarily under stable ordering and large power disparities, but audit SIC feasibility under sensing-induced interference.	E2	[5], [7]	Power-gap stability; SIC residual; sensing leakage.
In hybrid/RIS/STAR-RIS front-ends, use RSMA to compensate reduced digital DoF and absorb analog imperfections in the common layer.	E2	[6], [8]	RF-chain limits; phase errors; surface constraints.
When weakest-user common decodability becomes the bottleneck, use group-RSMA (local commons) or accept SDMA-like operation.	H	[2]	Tight $\min_k r_{0,k}$; common cannot cover private deficits.

reports (i) RSMA gains widening as correlation/CSIT mismatch increases, (ii) cross-over behavior as sensing constraints tighten, and (iii) strong dependence on front-end constraints (hybrid/RIS/STAR-RIS). For example, CRB-anchored designs explicitly quantify rate–sensing trade-offs and show that common/private beam shaping can improve the achievable region relative to SDMA-like baselines [3], [13], while mmWave/hybrid settings highlight that the ordering among RSMA/SDMA/NOMA may change under strict SCNR targets and hardware bottlenecks [6]–[8]. Practically, one can validate the regime online via three lightweight "sanity" scenarios: (a) *low sensing pressure* (relaxed CRB/SCNR) where RSMA primarily improves robustness to interference; (b) *balanced operation* where common-layer feasibility determines stability; and (c) *sensing-dominant operation* where sensing constraints heavily shape beams and the marginal rate advantage among schemes can shrink or change ordering.

The fundamentals are consistent across sources. RSMA's advantage originates in partial interference decoding, which produces graceful degradation under correlation and CSIT errors, whereas SDMA degrades sharply as channels align and NOMA depends on strict power disparities and stable decode orders [1], [2], [5]. In DFRC settings, embedding illumination into the common stream while steering private beams away from target angles expands the feasible region and, in certain regimes, obviates separate radar-only sequences; this is a structural gain rather than a parameter tweak [13]. On the sensing side, using CRB or echo-SNR as explicit objectives avoids ad hoc trade-offs and makes it natural to treat sensing performance as a budget in communications-centric solvers [3]. Practical waveform studies confirm that minor shaping suffices to expose sensing returns without disrupting downlink decoding, supporting an incremental deployment path that does not require air-interface changes [4]. Application-level evidence from cooperative multi-UAV surveillance and mobility-aware placement shows how reliability constraints and motion statistics map into sensing cadence, common-burst scheduling, and bandwidth policies [10], [12]. In parallel, covariance-based beamforming stabilizes joint beampatterns and decodability margins without relying on precise instantaneous CSIT, which meshes with RSMA's robustness goals [11].

IV. EXTENDED DIRECTIONS AND RELATED EVIDENCE

A. Limitations and Unfavorable Regimes

RSMA-assisted ISAC is not universally superior; its practical value depends on receiver capability and the tightness of weakest-user constraints. First, SIC is not free: imperfect cancellation, MCS granularity, and latency/complexity constraints can erode gains, especially when the common layer must be frequently re-optimized. Second, the common stream can become a bottleneck when $\min_k r_{0,k}$ is persistently small (e.g., strong user heterogeneity or hard coverage edges), in which case RSMA can collapse toward SDMA-like behavior unless group-RSMA (local common layers) is employed [2]. Third, ISAC introduces sensing-induced interference and beam-shaping constraints that can perturb NOMA ordering and reduce the available power for private layers; therefore, regimes with sensing-dominant objectives can narrow margins and even change scheme ordering, particularly in hybrid/mmWave settings [5], [7]. Finally, front-end constraints (limited RF chains, phase noise, surface quantization) can both help and hurt: they motivate RSMA's robustness role, but they also restrict beam expressiveness and can force conservative common/private allocations [6], [8].

B. Open Challenges and Directions

Robustness at scale suggests two immediate axes: mobility and calibration. RSMA's resilience to CSIT errors implies stable operation under frequent probing and rapid reconfiguration, which is typical in vehicular or industrial ISAC [2], [9]. Unified pilots serve CSI and echo calibration, while predictable common bursts stabilize echo updates and SIC with minimal overhead [4]. For hybrid front-ends, pushing more probing into the common stream and reserving private beams for gentle, robustness-first separation minimizes RF-chain pressure and avoids brittle deep nulls; passive and active surfaces complete the picture by providing sidelobe control and coverage shaping without altering the air interface [6]–[8]. At the network scale, mobility-aware placement allocates comm/sense resources in response to motion statistics, improving both throughput and sensing cadence [10]. At the PHY layer, covariance-based beamforming supplies a statistics-driven route to multi-user, multi-target control that integrates naturally with RSMA's layering and reduces reliance on per-frame CSI [11]. For reliability-critical missions, cooperative multi-UAV policies offer a concrete blueprint for cadence and resource control—schedule probing via common bursts, maintain conservative private beams under motion, and re-balance budgets with mission constraints [12]. FAS-class hardware further increases spatial agility for both decoding and sensing, expanding the feasible operating region and strengthening the role of the common stream as a dual-use illuminator [14]. These directions preserve the same playbook and strengthen the case for RSMA-assisted ISAC as a practical, incremental upgrade rather than a disruptive PHY overhaul.

V. Implementation and Reproducibility Notes

Start with conservative common budgets and verify weakest-user decodability using routine link metrics; raise the common share until the margin is tight, then lock it for the current frame set [2]. Align the common beam with the sensing sector while keeping all-user decodability envelopes; reduce private-beam spill into target angles to prevent echo masking [13]. In hybrid arrays, let the common stream carry most probing; keep private beams moderate to avoid aggressive nulling that drifts with calibration [7]. If sidelobes contaminate echoes or coverage is uneven, add RIS or STAR-RIS, then re-tune RS factors and phases jointly [6], [8]. For mobility-dense scenarios, adopt a simple loop: (i) estimate mobility/user density, (ii) update UAV placement and schedule common bursts as probing anchors, (iii) re-balance comm/sense budgets based on recent echo and traffic statistics [10]. For robustness to per-frame CSI errors, maintain a covariance tracker and align the common-beam direction with dominant statistical sectors; keep private beams conservative and re-tune only when statistics drift [11]. For coordinated, reliability-driven missions, reuse cooperative multi-UAV policies to determine sensing cadence and bandwidth splits [12]. For reproducibility, report paired KPIs (sum-rate or fairness, and sensing accuracy), sensitivity to CSIT errors, and ablations on common/private budgets [3], [9].

To operationalize the playbook in a real stack, log a small set of metrics that correspond to the boundary cues in Section III: (i) weakest-user common decoding margin (or min common SINR), (ii) residual multiuser leakage after precoding (including sensing leakage), (iii) stability of any intended SIC order (if NOMA is considered), and (iv) the active sensing constraint tightness (e.g., CRB/SCNR slack). A practical workflow is:

- **Select a baseline regime:** If leakage is near the noise floor and CSIT is accurate, SDMA is typically sufficient; otherwise start with RSMA and a conservative common share.
- **Tune the common share by feasibility first:** Increase common power/rate until weakest-user common decoding is stable; only then allocate remaining power to privates.
- **Audit sensing impact:** When sensing constraints become tight, re-check common feasibility and private SINRs under the sensing waveform/beam shaping; if margins collapse, consider group-RSMA or relax sensing illumination where permissible.

VI. Conclusion

RSMA-assisted ISAC is a clean layering: ISAC supplies the dual function, and RSMA supplies a tunable common stream with robust interference management. Together they move the frontier: higher rates at fixed sensing accuracy or lower error at fixed throughput, with better tolerance to CSIT and hardware limits than SDMA or NOMA. The resulting playbook is incremental and implementable: alternate communications and sensing updates, keep common budgets cautious, shape beams for dual purpose, unify pilots, and add passive/active surfaces where needed [3], [4], [6], [8], [13]. As deployments move toward UAV/vehicular regimes, mobility-aware placement and covariance-based beamforming provide the glue that keeps RSMA-assisted ISAC robust under motion and imperfect CSIT [10], [11], with cooperative multi-UAV policies offering a concrete operational template for reliability-aware scheduling [12]. The evidence-graded guidelines and boundary cues provided here are intended to help practitioners identify when RSMA's layering delivers robust gains and when SDMA/NOMA baselines remain competitive under tight sensing and hardware constraints.

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