RTKRelay+ - Flexible GNSS Stream Recasting to Improve RTK Availability

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SUMMARY

In many parts of the world, especially across developing regions, access to real-time GNSS correction data remains limited. The absence of dense national reference networks restricts surveyors and engineers from using high-accuracy RTK positioning services. Even where data are available, their use can be constrained by rigid stream definitions—the data source fixes its metadata (e.g., reference coordinates), message structure, and format. As a result, users are often unable to receive corrections in the necessary reference frame or to adapt existing data streams for local applications.

This paper introduces a middleware concept that provides a new layer of flexibility for RTK data dissemination. The proposed system operates between GNSS data sources and NTRIP casters, allowing controlled modification of stream metadata in real time (RTCM, 2011; RTCM, 2024). It can adjust the selected station-related metadata, alter mountpoint identifiers, or adapt the RTCM message set to match network requirements, without affecting the raw GNSS observables. The application can also function as a stand-alone caster, receiving RTK data directly from a GNSS receiver or another caster, applying the required adjustments, and forwarding the modified stream to new mountpoints at the same or at other casters.

Such capability offers several advantages for the surveying community. A single station can broadcast RTK data simultaneously in different reference frames, ensuring compatibility with both international and national datums. The approach also enables controlled redistribution of streams from semi-restricted or private sources, supporting authorised re-use while maintaining data integrity. This can be particularly valuable in regions without formal CORS networks, where regional or institutional initiatives may wish to share existing GNSS stations to deliver reliable correction data more effectively.

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1. INTRODUCTION

1.1 Motivation

High-accuracy GNSS positioning for surveying and engineering typically relies on real-time correction services, normally delivered as RTCM streams through NTRIP casters (RTCM, 2011; RTCM, 2024). In operational terms, this model is simple: a reference station (or network) provides corrections, a caster disseminates them, and rovers use the stream to obtain RTK-level positioning. However, the practical usability of a correction stream is not defined only by the availability of observations and corrections. It also depends on "stream identity" and metadata that are frequently fixed by the upstream provider, such as the reference-station coordinates embedded in RTCM station messages, station identifiers and descriptors, and the message profile being broadcasted.

In many regions – particularly where national CORS infrastructures are sparse or still emerging – surveyors often depend on a limited number of institutional or private stations. Even when a correction source exists, downstream reuse can be constrained by rigid upstream definitions. A common situation arises when different user communities must work in different reference frames or datums: the same physical station may need to be consumed with national/local coordinates for cadastral or engineering workflows, while the upstream broadcaster disseminates coordinates aligned with another realization (e.g., a regional or global frame) or with legacy metadata. Similar constraints occur when streams must be redistributed to partner infrastructures under controlled conditions, or when different equipment require different stream "products" (e.g., constellation subsets or reduced message sets for bandwidth-limited links). In these cases, asking the upstream operator to change their live configuration is often impractical, undesirable, or impossible, because it impacts existing users and operational commitments.

This motivates the need for a flexible but controlled mechanism that can sit between an upstream stream and downstream users, enabling republishing under new mountpoints and applying well-defined adaptations to stream metadata (and, where required, to selected message sets) while preserving the integrity of the correction content. For the surveying community, such capability is valuable because it supports interoperability across datums, simplifies partner distribution, and enables the definition of consistent RTK "products" without disrupting the original service.

1.2 Aim and contributions

This paper presents RTKRelay+, an application designed to recast existing NTRIP/RTCM correction streams into new, user-oriented products, without requiring any modification to the upstream broadcaster. The central aim is to support operational GNSS/RTK service delivery in contexts where downstream users or partner infrastructures require a correction stream with adapted station metadata—for example station identifiers and descriptors, equipment information, or coordinates—and, when needed, a controlled adjustment of the broadcast message profile.

RTKRelay+ is conceived as an intermediate layer between an upstream caster and downstream users: it connects to an existing mountpoint as a client, applies a configurable set of transformation rules, and republishes the resulting stream under one or more dedicated mountpoints on the same or on a different caster. This architecture allows a single physical reference station to be delivered as distinct "products" tailored to specific operational needs (e.g., partner distribution requirements, standardized metadata conventions, or bandwidth-oriented stream profiles), while keeping the original upstream stream unchanged and therefore non-disruptive to current users.

The main contributions of this paper are threefold. First, it frames the recasting approach from a surveying and geodetic service perspective, focusing on utility for operators and users rather than software development details. Second, it describes the system architecture and operational workflow of RTKRelay+, clarifying how configuration, stream handling, and integrity safeguards enable controlled republishing. Third, it illustrates the practical applicability of the approach through two representative use cases: (i) republishing a stream for a specific partner or user group through a dedicated mountpoint while applying metadata harmonization rules, and (ii) defining customized stream "products" by combining metadata adaptation with optional policy-based filtering.

2. RTKRelay+

2.1 Recasting concept

In this paper, recasting denotes the controlled adaptation and republication of an existing GNSS correction stream to create one or more derived streams for downstream use. The upstream stream—typically delivered as RTCM messages through an NTRIP caster—is taken as the reference input, while the derived stream(s) are published under dedicated mountpoints.

At the stream level, recasting is characterized by an operational workflow in which an incoming correction stream is acquired from an existing mountpoint using standard NTRIP procedures, processed according to a predefined configuration, and then republished under one or more new mountpoints. The configuration defines which stream elements may be adapted. Depending on the intended derived stream, these adaptations may include harmonization of station metadata carried in RTCM messages and, when required, the definition of a stream profile through controlled selection of message types or constellations. The upstream stream remains unchanged, and the differences between mountpoints are fully determined by the applied configuration rules.

Recasting, as used here, therefore refers to a mechanism that produces downstream mountpoints with clearly defined characteristics, rather than ad-hoc copies of a stream. Each derived mountpoint is associated with an explicit configuration that determines what is modified and what is preserved, so that the derived stream can be described, reproduced, and audited in operational terms. This concept is independent of any particular provider policy: it can be applied whether the upstream stream is disseminated "as-is" or already follows a given convention, since the defining element is the existence of a controlled and traceable transformation between the upstream input and the republished output.

2.2 Use context

Recasting is relevant in GNSS/RTK service delivery whenever a correction stream must be redistributed or integrated beyond the environment for which it was originally published. In practice, this occurs frequently when a service provider disseminates streams according to their own internal conventions and operational reference choices, while downstream users operate under different constraints. The mismatch may be administrative (partner-specific naming rules or mountpoint organization), technical (different equipment expectations or bandwidth limitations), or geodetic (the need to use the same correction source within a different datum or reference realization adopted for surveying and engineering workflows).

A typical context is partner distribution: an upstream provider maintains a stable public or private service and prefers to keep streams unchanged for all existing users, while a downstream integrator needs to supply a stream variant to a specific partner group under a separate caster or dedicated mountpoints. In this situation, the derived stream must be clearly identified, consistent with the partner environment, and managed without disturbing the upstream operations. Another context is the definition of multiple service levels from a single source, where different user groups may require different stream profiles (for example, reduced message sets for constrained links, or constellation restrictions driven by receiver capabilities or operational policies). In both cases, the objective is not to create a new correction source, but to facilitate controlled and verifiable reuse of an existing one.

3. SYSTEM ARCHITECTURE

3.1 Deployment and data flow

Figure 1 provides a high-level view of how RTKRelay+ fits into an NTRIP/RTCM service chain and where stream transformations are applied. A live RTCM stream is received from an existing NTRIP mountpoint and used as the input for a republished stream (or several republished streams). Each republished mountpoint corresponds to a specific configuration ("rule set") defining (i) which RTCM message types are eligible for modification and (ii) which message families may be suppressed to create a stream profile tailored to a given user group. Client-side usage remains unchanged: rovers and software connect to the republished mountpoint using standard NTRIP procedures.

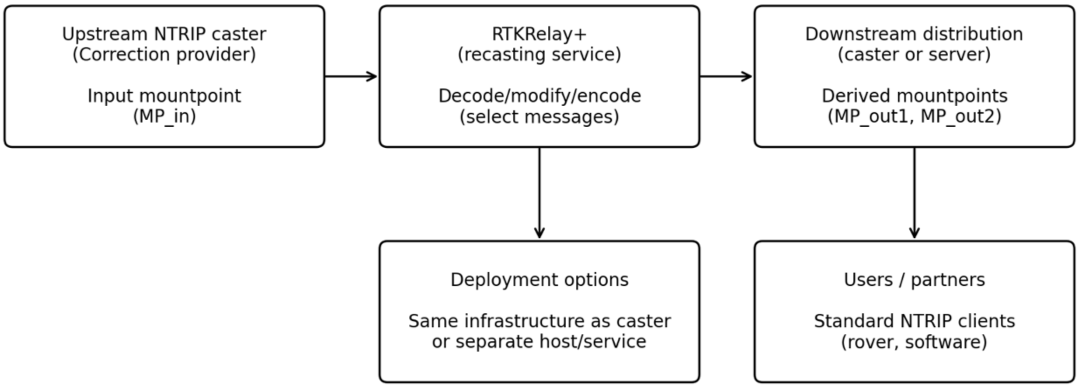

Figure 1 – RTKRelay+ conceptual architecture in an NTRIP/RTCM service chain.

Figure 1 emphasizes the separation between transport and message-level processing: an NTRIP I/O layer maintains continuous reception and publication; an RTCM handler identifies message boundaries and types; and a rule engine applies mountpoint-specific actions (edit, filter, or pass-through) before republishing.

3.2 Stream processing pipeline

RTKRelay+ processes the byte stream into individual RTCM messages and applies a deterministic pipeline. Incoming messages are framed and classified by RTCM type. For each output mountpoint, RTKRelay+ then applies the configured action associated with each message type: edit for a defined subset of metadata messages (Table 1), filter for selected message families (typically used to form alternative stream profiles), and pass-through for all remaining messages. When a message is edited, RTKRelay+ rebuilds the message so that the republished stream remains decodable by standard clients; in practical terms, message syntax and internal consistency are preserved after field updates.

3.3 Configuration scope and supported RTCM operations

The configuration is defined per output mountpoint and expressed in terms of RTCM message numbers. Table 1 summarizes the message scope handled explicitly by RTKRelay+ and the supported operation for each group. Some of the messages are editable (e.g., reference positions) whereas others are only filtered – on/off (e.g., constellations).

Table 1 - RTCM message types handled by RTKRelay+ and supported operations (edit, filter, pass-through).

RTCM TYPE(S)	PURPOSE	OPERATION IN RTKRELAY+
1005	Reference station ARP (ECEF)	Edit
1006	Reference station ARP (ECEF) + height	Edit
1007	Antenna descriptor	Edit
1008	Antenna descriptor + serial	Edit
1033	Receiver and antenna descriptors	Edit
1004	GPS Legacy	Filter / Pass-through
1012	GLONASS Legacy	Filter / Pass-through
1071–1077	GPS MSM 1–7	Filter / Pass-through
1091–1097	Galileo MSM 1–7	Filter / Pass-through
1081–1087	GLONASS MSM 1–7	Filter / Pass-through
1121–1127	BeiDou MSM 1–7	Filter / Pass-through
1101–1107	SBAS MSM 1–7	Filter / Pass-through
1111–1117	QZSS MSM 1–7	Filter / Pass-through
1131–1137	NavIC/IRNSS MSM 1–7	Filter / Pass-through
OTHERS	All other RTCM types	Pass-through

3.4 Traceability and operational monitoring

For each output mountpoint, RTKRelay+ records the applied rule set and stream statistics needed to characterize the republished stream objectively. At minimum, this includes per-type counters (received/forwarded/edited/filtered) and the identifier of the active configuration. These records support reproducibility of the mountpoint definition and simplify operational checks (e.g., confirming that only the intended message families are filtered and that metadata messages are edited as configured) (IGS, 2021).

4. IMPLEMENTATION and EXAMPLES

4.1 Implementation

RTKRelay+ is implemented as a two-layer system, separating a stream-processing backend from a configuration frontend. The backend ingests and republishes NTRIP streams and applies the message-level actions defined in Table 1. It builds on the RTKLIB open-source GNSS software package for NTRIP stream acquisition and publication; in particular, RTKLIB stream applications (e.g., *str2str*) provide the transport layer for NTRIP client/server handling and stream relaying (Takasu, 2009).

Above this transport layer, RTKRelay+ implements a message-processing component that parses the incoming RTCM stream, identifies message boundaries and types, and applies the configured rule set associated with the target output mountpoint. The rule set specifies which RTCM messages are edited (metadata messages) and which message families may be filtered to form a defined stream profile, while all other message types are forwarded unchanged (RTCM, 2024). After any edit, the modified RTCM message is rebuilt consistently before publication so that the republished stream remains a valid RTCM stream.

The frontend provides configuration and administrative control over RTKRelay+ behaviour. In the MIRASpaco environment, this frontend is integrated with MIRAnet/MIRAcaster, where mountpoints and dissemination services are managed through an administrative interface. The selection of RTCM message types to be forwarded or filtered for a given output mountpoint is illustrated in Figure 2. The configuration parameters used to define the metadata values applied to editable RTCM messages are illustrated in Figure 3. RTKRelay+ can also operate with an independent configuration interface; however, MIRAnet integration provides an operational model in which configuration is restricted to authorized users, and each output mountpoint is explicitly associated with its corresponding rule set.

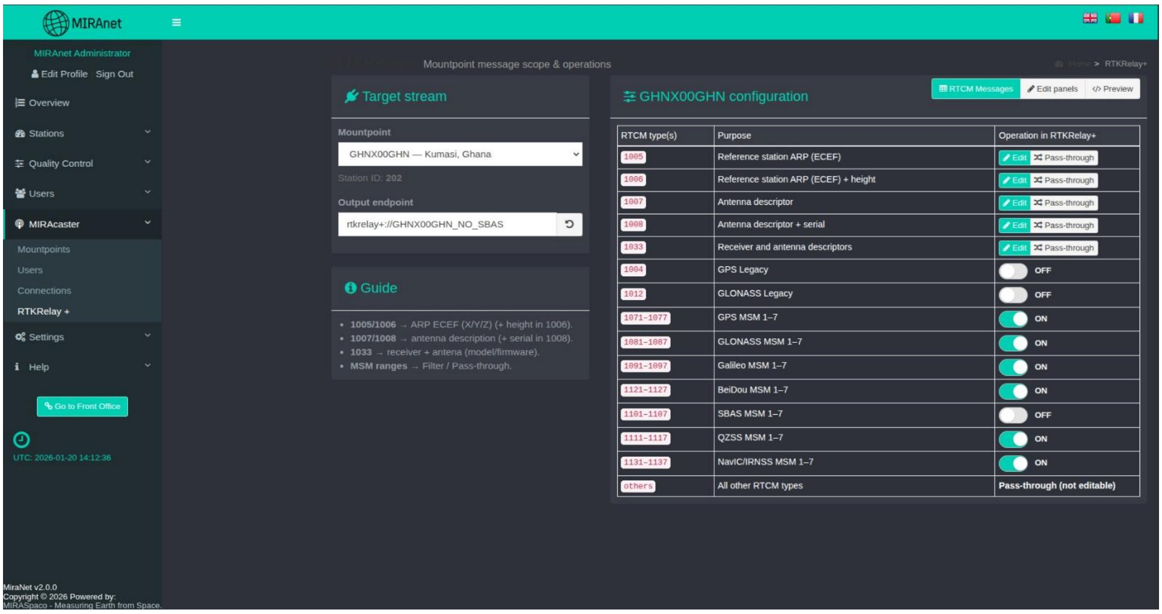

Figure 2 – RTKRelay+ configuration page with selection of each messages to turn on/off

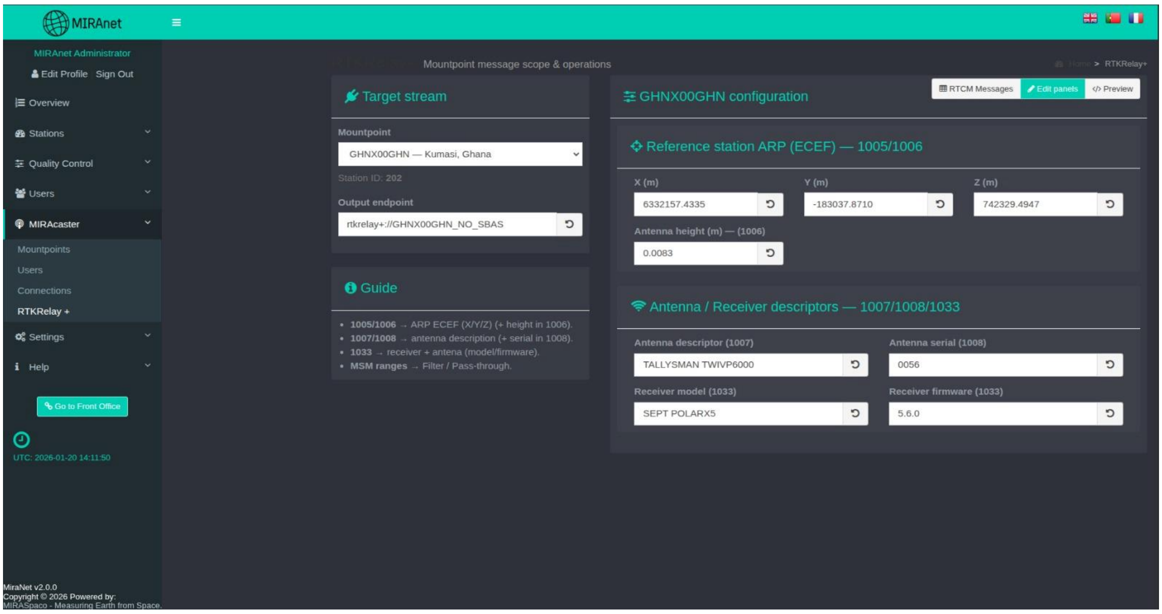

Figure 3 – RTKRelay+ configuration page for editable values

4.2 Demonstration example

This example demonstrates two of the RTKRelay+ capabilities applied simultaneously: metadata editing and constellation filtering. To make the outcome directly verifiable with standard tools, the original and output streams were stored as RINEX observation files. This enables inspection of (i) the header, where station and equipment metadata are declared, and (ii) the observation body, where the effective constellation content is visible at epoch level.

```
     3.05           OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
GHNX                                                        MARKER NAME
79697S999                                                   MARKER NUMBER
3052360             SEPT POLARX5        5.6.0               REC # / TYPE / VERS
Unknown             TWIVP6000       NONE                    ANT # / TYPE
        0.0000        0.0000        0.0000                  ANTENNA: DELTA H/E/N
  6332163.1904  -183036.8216   742331.2075                  APPROX POSITION XYZ
C   12 C1P C2I C5P C6I C7D C7I L1P L2I L5P L6I L7D L7I      SYS / # / OBS TYPES
E   10 C1C C5Q C6C C7Q C8Q L1C L5Q L6C L7Q L8Q              SYS / # / OBS TYPES
G   11 C1C C1L C1W C2L C2W C5Q L1C L1L L2L L2W L5Q          SYS / # / OBS TYPES
I    2 C5A L5A                                              SYS / # / OBS TYPES
R   10 C1C C1P C2C C2P C3Q L1C L1P L2C L2P L3Q              SYS / # / OBS TYPES
S    4 C1C C5I L1C L5I                                      SYS / # / OBS TYPES
SEPTENTRIO RECEIVERS OUTPUT ALIGNED CARRIER PHASES.         COMMENT
    30.000                                                  INTERVAL
  2025     9    28     0     0    0.0000000     GPS         TIME OF FIRST OBS
                                                            END OF HEADER
> 2025 09 28 00 00 00.0000000  0 42
C05                  39399298.259 6                 39399301.597 7                 39399300.394 7
205162573.90206                166711329.02007                 158644651.07107
C19  25380113.913 6  25380112.729 7  25380121.004 6  25380117.107 7  25380118.789 6                 133373458.89506
132160963.02807  99597121.35906 107391645.71207 102195280.66606
C20  25354719.237 7  25354717.927 7  25354723.788 7  25354719.939 7  25354722.681 7                 133240110.62907
132028845.93607  99497629.75107 107284324.78407 102093160.20007
C29  23123653.667 7  23123651.643 8  23123657.047 7  23123656.263 8  23123655.117 7                 121515843.21207
120411145.32608  90742328.55707  97844029.11208  93109346.83407
C30  25600565.529 5  25600564.220 6  25600579.989 6  25600577.145 7  25600577.960 6                 134532059.30605
133309055.81006 100462436.77606 108324664.22907 103082913.66206
C35  24473395.539 7  24473393.913 7  24473400.675 7  24473399.016 8  24473399.440 7                 128608858.52807
127439686.35607  96039285.65507 103555332.58108  98544631.31507
C36  21467763.803 8  21467761.189 8  21467774.055 8  21467771.809 8  21467772.549 8                 112813998.07108
111788402.13508  84244327.72408  90837327.04708  86441990.87208
C45  23357901.211 8  23357898.021 8  23357897.005 8  23357895.823 8  23357895.033 8                 122746754.79508
121630719.24408  91661513.26608  98835015.96708  94052594.83808
C47  24035552.137 7  24035551.657 7  24035556.089 7  24035556.211 7  24035554.833 7                 126307895.27507
125159663.19707  94320989.78507 101702286.27707  96781518.94507
C48  24531907.487 7  24531904.919 7  24531929.538 7  24531910.202 7  24531929.267 7                 128916255.42607
127744287.98107  96268848.37107 103802809.49507  98780040.71807
E07  27693038.755 6  27693052.802 6  27693045.397 7  27693049.887 7  27693051.303 7 145527914.83406 108673507.07606
118123341.09707 111508453.84207 110090978.03307
E13  24057440.134 7  24057446.645 8  24057441.904 8  24057444.406 8  24057445.576 8 126422941.47007  94406903.35608
102616124.93408  96869664.16408  95638283.33308
```

Figure 4 – Input stream (RINEX header and first epoch).

```
     3.05           OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
GHNX                                                        MARKER NAME
79697S999                                                   MARKER NUMBER
3052360             SEPT POLARX5        5.6.0               REC # / TYPE / VERS
00435               TWIVP6000       NONE                    ANT # / TYPE
        0.0083        0.0000        0.0000                  ANTENNA: DELTA H/E/N
  6332157.4335  -183037.8710   742329.4947                  APPROX POSITION XYZ
E   10 C1C C5Q C6C C7Q C8Q L1C L5Q L6C L7Q L8Q              SYS / # / OBS TYPES
G   11 C1C C1L C1W C2L C2W C5Q L1C L1L L2L L2W L5Q          SYS / # / OBS TYPES
SEPTENTRIO RECEIVERS OUTPUT ALIGNED CARRIER PHASES.         COMMENT
NO FURTHER PHASE SHIFT APPLIED IN THE RINEX ENCODER.        COMMENT
    30.000                                                  INTERVAL
  2025     9    28     0     4   30.0000000     GPS         TIME OF FIRST OBS
                                                            END OF HEADER
> 2025 09 28 00 04 30.0000000  0 14
E07  27719642.481 6  27719655.936 6  27719648.917 6  27719653.396 6  27719654.710 7 145667722.88706 108777910.59206
118236822.61006 111615580.77206 110196743.25407
E13  24149732.602 7  24149738.492 8  24149734.297 8  24149736.545 8  24149737.642 8 126907939.66707  94769077.30908
103009792.27308  97241286.13308  96005181.29208
E18  27022093.200 6  27022100.737 7  27022097.758 7  27022098.039 7  27022099.357 8 142002085.26706 106040532.03907
115261495.23307 108806791.89407 107423665.04508
E21  25347906.833 7  25347913.292 8  25347910.948 8  25347911.152 8  25347912.329 8 133204161.84407  99470670.23308
108120284.22808 102065547.18608 100768103.28208
E26  23806901.611 8  23806904.646 8  23806903.932 8  23806902.926 8  23806903.734 9 125106383.24908  93423738.12008
101547529.16208  95860892.76408  94642337.01809
E27  24687614.408 7  24687619.657 8  24687617.940 8  24687617.968 8  24687618.827 8 129734630.29107  96879980.76708
105304241.77808  99407252.94008  98143617.42808
E29  27028768.456 6  27028776.931 7  27028774.216 7  27028774.043 7  27028775.524 7 142037248.27306 106066877.50807
115290045.88207 108833824.80707 107450349.23007
E30  27426641.691 6  27426649.143 7  27426644.416 7  27426646.927 7  27426648.002 7 144128222.26206 107628405.04607
116987318.48007 110436075.88307 109032248.04307
E33  27363302.642 5  27363311.282 7  27363308.415 7  27363308.959 7  27363310.112 8 143795122.07305 107379513.73107
116716839.31107 110180710.62207 108780107.75508
G02  23693758.513 6                  23693757.516 4                  23693759.975 4
124511696.96906                                  97022179.58404
G10  21726776.086 8                  21726775.675 8  21726780.124 7  21726779.879 8  21726777.598 8
114175189.89008                   88967741.49707  88967727.48208  85260829.52808
```

Figure 5 –RTKRelay+ output (RINEX header and first epoch).

RTKRelay+ applies the metadata rules that updates station-related information represented in the RINEX header. In operational terms, this corresponds to harmonizing the station description associated with a mountpoint—such as station coordinates, antenna offsets, and antenna identification—so that the republished stream matches conventions or reference choices required by a downstream environment.

In parallel, RTKRelay+ applies a stream-profile rule that restricts the output to a defined subset of constellations, here GPS and GALILEO. The effect is observable in both the header and the epoch content: constellation-specific observation definitions in the header are limited to the retained systems, and the observation records include only satellites belonging to those constellations. This shows that the derived stream corresponds to a controlled mountpoint product with an explicit, verifiable profile definition.

Taken together, Figure 4 and Figure 5 illustrate the operational objective of RTKRelay+: a single upstream correction stream can be republished as a derived product that combines (i) metadata consistency with a target service environment and (ii) a declared constellation profile, while remaining compatible with standard NTRIP client usage.

5. CONCLUSION

The proposed architecture supports derived mountpoints defined by explicit rule sets and limited, well-identified operations. The RTCM handling scope was stated using message numbers, distinguishing metadata messages that may be edited from message families that may be filtered to form alternative stream profiles. The demonstration example showed that these two operations can be combined in a single processing chain: station/equipment metadata can be updated in the outgoing stream, while specific constellations are suppressed to obtain a defined stream profile. The effect was verified by converting the resulting streams to RINEX for inspection, allowing changes to be observed both in the RINEX header fields (reflecting the stream metadata) and in the epoch records (reflecting the reduced constellation set).

At the operational level, RTKRelay+ provides a mechanism to publish partner- or user-group-specific mountpoints as controlled variants of an existing stream. Instead of requesting changes at the correction source, a service operator can define downstream variants through a rule set that is specific, repeatable, and auditable. This approach supports parallel delivery of multiple variants from the same input stream, with clear separation between the original stream and each derived product. In practice, this simplifies distribution to multiple partners, supports differentiated service offerings (e.g., constellation-restricted profiles), and reduces the likelihood of unintended impacts on users of the original service, while preserving a standard access method for client equipment (NTRIP).

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