The RTCM Multiple Signal Messages: A New Step in GNSS Data Standardization

Alexey Boriskin, Dmitry Kozlov, Gleb Zyryanov
Ashtech, Russia

BIOGRAPHY

Alexey Boriskin has been working for Ashtech since 2005 as a Software Engineer. He received his MS EE degree from the Moscow Aviation Institute. He obtained his PhD in GNSS signal processing from the Moscow Aviation Institute. He is a member of the RTCM Multiple Signal Messages (MSM) Working Group.

Dmitry Kozlov has been working for Ashtech since 1993 as a Senior Scientist. He has been the System Engineering Group Manager since 2009. He received his MS EE degree from the Moscow Aviation Institute and his PhD in Signal Processing Theory from the Institute of Automatics, Moscow. He is a member of the RTCM MSM Working Group.

Gleb Zyryanov has been working for Ashtech since 2000 as a Software Engineer. He has been the GNSS Positioning Algorithms group manager since 2009. He received his MS in Mathematics and Mechanics from the Moscow State University. He is the Chair of the RTCM MSM Working Group.

ABSTRACT

New GNSS and their signals come into our life. Today, most professional receivers generate observation data for a multitude of GNSS and their signals. These observables are presented in proprietary formats, so compatibility between different vendors can be achieved only through RINEX-3 conversion which does not allow effective real-time interoperability.

The need for standardized streaming protocol for GNSS observation data is obvious nowadays. There are already standardized GPS and GLONASS RTCM-3 messages which are used for base-rover RTK operation. But they cannot efficiently be extended to other GNSS (e.g. GALILEO) and other signals (e.g. L5). These legacy messages were limited to L1 and L2 bands and to only one signal per band. That is why the GNSS community has been waiting for new universal real time data formats.

Multiple Signal Message (MSM) is the new key RTCM-3 concept (and respective format) to present all GNSS observation data in generic form. The RTCM-3 MSM standard insures GNSS receiver data interoperability one could not have dreamt of beforehand. The MSM standardization process started about three years ago within RTCM SC-104 by creating a dedicated MSM Working Group. Most of the professional GNSS vendors (receiver manufacturers and network software providers) actively participated in the MSM discussions and interoperability tests. Such a wide activity has allowed MSM to be released.

This paper describes the principles of MSM organization and the author's view on applications where MSM can be efficiently utilized.

In this paper, we use GNSS terms and definitions applied in official RTCM and RINEX documents.

This paper cannot be considered as a detailed MSM description; it is a short introduction to the new observation data concept accepted by most of GNSS vendors. For implementation, integrators must refer to the official RTCM standard.

At the time of publishing given paper, the MSM standard is not yet officially available. But it is expected that it can be published by the end of this year.

INTRODUCTION

Today, each GNSS Satellite (existing or planned) transmits multiple ranging signals. Keeping in mind increased number of GNSS and supported frequency bands, all have to agree that the GPS-CA/P1/P2 only era is far behind us; today we are thinking in terms of multiple signals GNSS receivers can track.

A GNSS receiver generally provides the following groups of data:

- GNSS Observables (raw data)
- GNSS Navigation data
- Location information
- Receivers/antennae/setup description
- Auxiliary data

This paper deals with GNSS Observables which correspond to each GNSS Satellite signal (or combination of signals) a receiver can potentially track. Following

RINEX/RTCM documents [1], [2], we define four primary observables for each GNSS signal (the letters used by RINEX conventions are shown too):

- Pseudo Range or Code Phase (C)
- Phase Range or Carrier Phase (L)
- Signal Strength or Carrier/Noise Ratio, CNR (S)
- Doppler or Phase Range Rate (D)

All known GNSS signals identifiers are described in RINEX-3 standard [2].

MSM are used to present the above observables (and their primary attributes) for all known GNSS signals in form of binary RTCM-3 messages. MSM was designed to cover the following:

- Maximum compatibility with RINEX-3 format
- Extending/replacing legacy RTCM-3 messages
- Universality for all known GNSS signals
- Compactness of presentation
- No ambiguity in interpretation
- Simplicity of generation/decoding
- Flexibility and scalability
- Equality for real time and post processing

The MSM message organization is suited for a fully deployed GNSS where each satellite transmits the same set of signals. At the same time, it efficiently covers the GNSS 'transition' period when different satellites transmit different sets of signals.

The similar nature of the observables for each of the currently known GNSS (both operational and planned) allows all observables for each GNSS to be presented in a universal form. Therefore, first the generic MSM structure has been designed and precisely described as part of the RTCM-3 standard. With the generic format fixed, then GPS, GLONASS, and GALILEO MSM are adopted. At the moment, the RTCM committee is starting with QZSS MSM standardization process.

The three key principles of the MSM are as follows:

- Effective identification of satellites and their signals by introducing Satellite, Signal and Cell masks
- Effective decomposition of observables by introducing the rough/fine range concept
- Effective scalability of different observables by introducing observation blocks (with their own internal looping) which can be effectively inserted to or removed from the message body

MSM is intended to transmit raw data for RTK and real time networking applications as well as for raw data logging for further archiving or post-processing; supporting data from both physical and computed reference stations, static and kinematic receivers.

This paper is organized as follows. First, we give a short background explaining the need and drivers of MSM format development. Then we provide examples demonstrating the primary principles of MSM organization. And finally we discuss a number of applications which are served (or can be served in the future) by MSM.

MSM BACKGROUND

Given section explains why MSM was born.

A. Parents

RTCM and RINEX are the parents of MSM. Their short bio is given in the Tables 1 and 2. Not all versions and not all milestones are mentioned.

Table 1: RTCM summary

What initiated	The correcting service to achieve few meter level DGPS accuracy for marine applications, version 2.0, 1990
Primary milestones	2.1 GPS RTK service support, 1993 2.2 GLONASS support, 1995 2.3 [3] Antenna parameters, a number of clarifications, 2001 3.0 Extended pool of Messages numbers. New Transport Layer. GPS+GLONASS compact L1/L2 observations. Location and Description messages, 2003. 3.1 [1] GPS+GLONASS Network and Ephemeris, messages, State Space correcting messages, Coordinate Transformation messages, auxiliary data, 2011.
Primary showstoppers (version 3 only)	Existing observations messages cannot be mechanically extended for new GNSS and signals. The data must serve not only base->rover DGNSS/RTK, but support streaming raw data for real time networking and post processing.

A few words must be added to discussions about different approaches to present Measurement Space (MS) correcting data. In short, there were 2 approaches to generate reference data from base to rover:

- Corrections
- Observables

Corrections are historically defined in RTCM-2 as computed range – measured range [3]. This simple wording cannot however describe a lot of ambiguity in interpretation what computed range is (especially when other then GPS L1CA data are described). Initially (DGPS era) corrections seemed to be the most effective and compact reference data to correct rover observables. However with time, more and more GNSS experts voted for providing raw correcting data (i.e. receiver observables) to minimize ambiguity in interpretation. As a result, RTCM-3 version still has no correcting messages, but only observation messages. And there are no signs that such messages will be requested. Taking raw observation point of view for correcting data, RTCM has made the very first step towards RINEX.

Table 2: RINEX summary

What initiated	Easy exchange of GPS data to be collected during European GPS campaign EUREF 89 with more than 60 GPS receivers of 4 different manufactures, version 1, 1989
Primary milestones	2.11 [4]: GLONASS, SBAS support. Higher than 1 Hz data support. Signal strength as new observable. GPS L2C support, 2005 3.01 [2]: GALILEO support. All new known signals support. Enhanced signal/observable IDs. Applying proper phase shifts to generate consistent phase observables, 2009. 3.02: QZSS support (only draft is available), 2012?
Primary showstoppers (version 3 only)	Not effective for streaming and real time processing. Original size is high, so compressing is required for long data files. Still some ambiguity in interpretation of RINEX headers.

B. Baby boom

Among many, we would mention only three primary (on our minds) tendencies which dictate the need of MSM data.

The GPS-CA/P1/P2 only era finished and new GNSS-all-signals era has already started. Near future will bring L5-only receivers, GLONASS-only receivers etc. And all this will be applicable to professional and consumer GNSS. Like GPS L1CA today, GNSS-all-signals must be a commodity tomorrow. And the commodity cannot exist without the standard. Can you imagine receiver which does not generate NMEA GGA sentence and does not provide RINEX converter? What about MSM?

Each GNSS-based product (e.g. GIS or Survey receiver) integrates 'GNSS' and 'application'. And in most of the cases, GNSS is responsible for generating position (and supplementary data) to application. There are many GNSS cores and there are many applications. And most of them can well communicate though NMEA interface because it is accepted by everyone. Just imagine (authors are sure about this) that position computation is no longer GNSS attribute, but the attribute of application. GNSS receiver became just a GNSS sensor generating raw observables to the external world, while the application became a powerful set of algorithms generating GNSS positions from GNSS observables being augmented by GNSS and non-GNSS data. These data sources can be the Measurement Space GNSS corrections, State Space GNSS corrections, INS data, optic instruments data etc. To make such a sensor happen, a GNSS raw data standard accepted by everyone is needed. What about MSM?

Multiple GNSS signals come and more and more ingenious processing is required to meet new performance requirements for new applications. Historically GNSS world passed a long way from a standalone receiver positioning through conventional differential (base->rover) modes towards global GNSS networking solutions. Today, GNSS receiver itself (at least professional receiver) takes only small responsibility in positioning process; a lot of augmentation data are provided externally. These augmentation data are generated by powerful service using powerful algorithms and huge original GNSS data from multiple receivers all over the globe as an input. Existing algorithms are primarily based on RINEX presentation of original data which is mostly used in post-processing applications but is increasingly desirable for real-time services. Someone must deliver real time RINEX-like observables to network processing servers. What about MSM?

C. Twins expected

The very important observation is that up to this date, RTCM is still a GPS L1 centered protocol. It still supports only GPS and GLONASS data and in all the cases, GLONASS data are just modified copies of originally designed GPS data. And observation presentation is still tagged to L1 pseudo range. A good summary of GPS-centered approach and its drawbacks can be found in [5]. In this respect, RINEX (at least RINEX-3) is more mature as a universal GNSS format.

Since all GNSS are ranging navigation systems and their signals allow estimating delays of each signal carrier and each signal envelope, there is an attractive desire to introduce so called generic GNSS observables which can be clearly described, i.e. standardized. Doing that, the GNSS community can escape GPS-centered and L1-centered schemes existing today in many data presentation formats (proprietary and standardized). Once a generic GNSS concept is accepted by everyone, then it is much easier to standardize each particular GNSS using a world-wide accepted template.

It was absolute consensus among RTCM members that MSM must be generic GNSS observables format.

D. Marriage helps

Historically real time and post processing algorithms served different applications. Real time was associated with RTCM data, while post processing was associated with RINEX data. Data processing engines were different, data presentation formats were different, and progress was driven by different GNSS sub-communities. (Of course, the authors have stressed this claim: in reality RTCM and RINEX often discussed similar problems and made similar solutions).

In some cases, such ‘independence’ caused serious problems. For example, there was a problem with carrier phase alignment between signals of the same frequency. RTCM community preferred no alignment for legacy observation messages, while RINEX community voted for the absolute alignment for all GNSS and their signals. Fortunately this difference has been already overcome by introducing MSM.

The example above shows that when it comes to discussing GNSS observables (regardless of their presentation form and applications to serve) all decisions must be tightly coordinated among all interested parties.

A few years back, RINEX joined the RTCM as a special Working Group and today RINEX and RTCM experts can sit on the same table discussing the same problems. Such cooperation is one key factor for MSM standardization.

MSM PRINCIPLES

Given section deals with three key principles of MSM organization as mentioned in the Introduction. We use example to describe the approach which cannot be used as message description. For exact definition please refer to the RTCM MSM standard.

A. Observables decomposition

With proper GNSS receiver design, its basic observables (Pseudo Range and Phase Range) always appear to be controlled by the same receiver clock. As a result, the dynamics of all Pseudo Ranges and Phase Ranges corresponding to the same satellite are almost the same under nominal conditions. Only ionosphere divergence, receiver biases and some other negligible factors can cause the divergence of one observable against another. This relationship is used when generating compact observations. Initially it was introduced for the CMR format [6], later it appeared as a primary concept of legacy RTCM-3 observation messages [1]. Although quite an attractive idea at that time, it has become a problem today. A signal (e.g. L1 Pseudo Range) was selected as the ‘primary’ observable in these formats and all the other (‘secondary’) signals (e.g. L2 Pseudo Range, L1 & L2 Phase Range) are generated as a difference against the ‘primary’ signal.

With the multiple signals available (existing or planned), this L1 Pseudo Range centered ‘primary-secondary’ concept is not convenient. It has the following disadvantages:

- Invalid L1 Pseudo Range (for whatever reason) automatically leads to inability to present all the other data.
- There is no possibility to send L2 data without sending L1 data. Earlier this was not so important but with current and future availability of L2C and L5, such an L1 centered scheme can be ineffective (e.g. L5 only receivers could be manufactured in future)
- There is no possibility to send Phase Range data without sending Pseudo Range. Phase Range data are of primary interest for precise applications, while (well smoothed) Pseudo Range data are usually not needed with the same update rate as Phase Range.

There are methods to mitigate the L1 Pseudo Range-centered scheme. However, none of them are as effective as the rough/fine range concept presented for MSM.

The idea of the rough/fine range concept is very simple: each full_range observable #i (Pseudo Range or Phase Range of each signal) for some satellite #j can be presented as:

$$\text{full\_range}(i,j) = \text{rough\_range}(j) + \text{fine\_range}(i,j)$$

The rough_range is unique for each satellite, while fine_range is unique for each observable (Pseudo Range or Phase Range). Keeping in mind the worst case ionosphere conditions, all fine_range is usually kept within ± 300 meters. As in CMR and legacy RTCM-3 messages, it is assumed that the initial integer count is properly removed from Phase Range data at generation startup or after an unrepaired cycle slip.

With this concept, rough_range itself has no exact physical sense; it is a technological value which will be used on the decoding side to restore full_range. The same concept is used to present Phase Range Rate (Doppler) observables. There are different algorithms to generate the rough_range:

- Some particular Pseudo Range (e.g. L1CA)
- The mean value of all available Pseudo Ranges
- Computed range
- Others

Rough range is packed with rough resolution (1/1024 ms which is about 300 meters) with no throughput increase compared to legacy messages.

The rough/fine range concept overcomes all of the disadvantages of the 'primary-secondary' scheme, which is currently applied in CMR and legacy RTCM-3 messages.

The diagram on Figure 2 shows the difference between generating RTCM-3 Message Type 1004 observables (legacy) and generating observations for RTCM-3 Message Type 1074 (MSM).

B. Data identifiers

Satellite mask is a bit set indicating (by rising corresponding bits) which satellites from a given GNSS provide at least one signal. The Satellite mask contains 64 positions for each GNSS.

Signal mask is a bit set indicating (by rising corresponding bits) which signals from a given GNSS are available from at least one of the multitude of tracked satellites. The Signal mask contains 32 bits for each GNSS. Each bit is representative of a specific GNSS signal. The definition of Signal mask bits for each GNSS is given in Table 3 for three GNSS systems. Please note that among the available 32 positions, only a few are currently used. Also, not all existing GNSS signals described in RINEX-3 [2] are supported by MSM; this is related to ambiguity in interpretation for some signals. The Signal mask is designed in such a way that Signals for all known (completed or not completed yet) GNSS can later find proper position within the mask once RTCM consensus will be achieved.

Table 3: Standardized MSM Signals

Signal ID in Signal Mask	GPS signal RINEX code	GLONASS signal RINEX code	GALILEO signal RINEX code
2	1C	1C	1C
3	1P	1P	
4	1W		1B
8	2C	2C	6C
9	2P	2P	
10	2W		6B
14			7I
15	2S		7Q
16	2L		
17	2X		
18			8I
19			8Q
22	5I		5I
23	5Q		5Q

For quite a long time to come (or even forever), some satellites from a given GNSS will transmit a set of signals while some other satellites from the same GNSS will continue to transmit another set of signals. Also in some environmental conditions (shading at some directions, jamming), not all Satellite signals can be reliably tracked. So generally some Satellites deliver one set of signals, while some others are delivering a different set of signals. To save room in the MSM in such cases, the Cell mask has been introduced.

The Cell mask is a bit set of the length Nsat*Nsig, where Nsat is the number of Satellites (= the number of raised bits in the Satellite mask) and Nsig is the number of signals (= the number of raised bits in the Signal mask). The Cell mask bits (if raised) indicate if observables are present for corresponding Satellite & Signal combination.

To illustrate the above tentative definitions (again refer to the RTCM standard for exact wording) let us consider the example of building Satellite, Signal and Cell masks. Let L1 and L2 GPS tracking status be as follows: Satellites 1, 3, 6, 7, 13, 15, and 32 are tracked and provide up to the following signals:

- Signal ID=2, i.e. 1C or L1CA
- Signal ID=4, i.e. 1W or L1P(Y)
- Signal ID=10, i.e. 2W or L2P(Y)
- Signal ID=15, i.e. 2S or L2C(M)

Table 4: Tracking status matrix

Signals \ Sats	1	2	3	4	5	6	7	...	13	14	15	...	32	...	64	Signal mask
1																0
2	1		1			1	1		1		1		1			1
3																0
4	1		1			1	0		1		0		1			1
5																0
6																0
7																0
8																0
9																0
10	1		1			1	0		1		0		1			1
11																0
12																0
13																0
14																0
15	1		0			0	1		0		1		1			1
16																0
...																...
32																0
Sat mask	1	0	1	0	0	1	1	0	1	0	1	...	1	...	0	

For some Satellites (e.g. low elevated, shaded etc) Signals 1W and 2W cannot be available while signal 1C is available (due to energy loss while Z-tracking the Y code). As for signal 2S, it is not available for all the Satellites.

As a result we can simulate a so called tracking status matrix shown by Table 4 where available Signals are marked by shaded 1's in corresponding entries. At the same time, shaded 0's indicate signals which are not available from given tracked Satellite. It is seen that the number of Satellites is 7 (the number of columns containing at least one shaded 1), and the number of different signals is 4 (the number of rows containing at least one shaded 1). This tracking status table gives the full vision of all available signals at the moment. In most cases the tracking status table is too sparse and can be effectively represented by 2 independent masks (bit corresponding to Satellite 1 is going first in Sat mask, bit corresponding to Signal 1 is going first is Signal mask):

- Signal mask (right column marked red)
- Satellite mask (bottom line marked blue)

So the potential number of observables blocks in this example is 28=4*7.

At the same time, not all four Signals are tracked by some Satellites. It is seen that we actually have only 21 (among 28) cells with signal data. To further reduce the message size by not generating empty fields for the 7 untracked (shaded 0s) entries, a Cell matrix (green) is defined as shown on in Table 5. This Table is a copy of Table 4 after removing all columns not containing any signals, and removing all rows not containing any satellites. The Satellites and Signal IDs are given in this matrix as the reference.

Table 5: Cell matrix

Sats / Signals	1	3	6	7	13	15	32
2	1	1	1	1	1	1	1
4	1	1	1	0	1	0	1
10	1	1	1	0	1	0	1
15	1	0	0	1	0	1	1

Table 6 shows the same cell matrix, but presented as a bit set (green) as it must be interpreted by the coding/decoding equipment (bit#1 goes first in the stream). It is what we call the Cell mask. The size of the Cell mask is Nsig*Nsat=4*7=28 and the number of available cells with observables (the number of 1's in Cell mask) is Ncell=21. It is easy to see that with help of Satellite and Signal masks, each bit in the Cell mask can be associated with proper Satellite number and Signal type.

Table 6: Cell matrix

Bit number	1234 5678… …28
Cell mask	1111 1110 1110 1001 1110 1001 1111

The above example shows how a complete (32*64 bits) and sparse 'tracking status matrix' can be presented by 3 compact bit sets:

- Satellite mask of a fixed size 64 bits
- Signal mask of a fixed size 32 bits
- Cell mask of a variable size Nsig*Nsat (4*7 bits in given example)

These masks are contained in MSM header so the decoding equipment immediately knows which Sat&Signal combinations are present in the message and in which order.

Given 3-masks-approach allows sending any combination of GNSS signals using the very same packing/unpacking algorithms.

C. Message Architecture

The diagram on Figure 1 shows the general principle of MSM architecture using Message Type 1074 as example. Each MSM message consists of 3 sequentially following blocks:

- Message header
- Satellites data block
- Signals data block

In turn, Satellites and Signals data blocks contain a number of fields which can be populated for one type of MSM message and can be left empty for another type. In given example, Satellites data block contains only rough range data presented in decomposed form of integer and fractional number of milliseconds. Satellite data (and their sequence) corresponds to bits raised in Satellite mask. Similarly, Signals data block contains Fine Pseudo Range, Fine Phase Range, lock time indicator and CNR. Signal data (and their sequence) corresponds to bits raised in Cell mask.

In each MSM, all data fields are grouped by data type, rather than by satellite or signal. That is, if few data fields are transmitted in a satellite data block, then first we pack the initial data field for all available satellites, then we pack the second data field for all available satellites, etc. Similarly, if we have few signal data fields to transmit, then first we pack one data field for each available satellite/signal combination, then we pack the second data field, again for each available satellite and signal. This packing order is called "internal looping".

Note that all the components of the most important observables (Pseudo Range and Phase Range) for each GNSS, Frequency Band and Signal Type are expressed in the very same units: milliseconds. This insures simplicity of encoding/decoding and guarantees no divergence with multiple forward/backward conversions from/to MSM to/from another format.

RTCM reserved 10 Messages Types (MT) for each GNSS MSM. Seven of them are already defined and internally called [generic] MSM1…MSM7. In the future possibly MSM0, MSM8, and MSM9 can be available. The range from MT 1070 to MT 1229 inclusive is reserved for all existing and future MSM messages. Table 7 gives a short summary of already assigned numbers.

Table 7: Assigned MSM numbers

GNSS	MT for MSM1	MT for MSM2	…	MT for MSM7
GPS	1071	1072		1077
GLONASS	1081	1082		1087
GALILEO	1091	1092		1097
COMPASS	1001	1002		1007
SBAS	1101	1102		1107
QZSS	1111	1112		1117

Table 8 provides short content of each MSM and example of message size for 16 Satellites and 4 Signals for each Satellite. Remember that letters C, L, S, and D refer to RINEX GNSS observables.

Table 8: MSMs summary

MSM type	Content	Size, bits, for 16 Sats with 4 Signals
MSM1	Compact C	1353
MSM2	Compact L	2121
MSM3	Compact C + Compact L	3081
MSM4	Full C + Full L + S	3593
MSM5	Full C + Full L + S + D	4841
MSM6	Ext (Full C + Full L) + S	4681
MSM7	Ext (Full C + Full L) + S + D	5929

Ext () in MSM6/7 means the same content as MSM4/5 respectively but with some fields presented with finer resolutions and/or wider range.

It is very important to emphasize that MSM1… MSM7 are not different messages. On contrary they present the very same data but with different level of details. This particularly means that user can be sure that say full pseudo range and phase range for some Satellite, Signal and Time Tag is exactly the same for MSM4 and MSM5. So provider can combine different sets of MSM messages for different epochs without any harm for decoding equipment.

MSM APPLICATIONS

There is a hope that MSM in the future will be used in the widest variety of real time and post processing applications. The content of this section is the author's personal vision for MSM future.

A. Differential protocols

Existing legacy RTCM messages cannot generate reference data for new bands (e.g. L5) and GNSS other than GPS and GLONASS. But MSM can. Moreover MSM can easily substitute existing RTCM-3 legacy GPS/GLONASS L1/L2 messages to provide the very same RTK functionality to legacy receivers. But here, rover receivers must integrate supporting MSM data first.

Please do not wait for legacy RTCM messages extensions with new systems and signals. I.e. if some real time application requires differential mode using GALILEO and QZSS L5 signals, then no other way than MSM is possible. Fortunately MSM uses known RTCM-3 transport layer, so data provider and rover receiver should transit to MSM quite easily. Tests performed by different parties demonstrated that existing legacy RTCM messages and MSM are interoperable and can be easily converted to each other without any loses.

Once MSM is supported, then it can equally well serve the following conventional differential modes:

- DGNSS
- RTK
- Network RTK

DGNSS is the mode when only Pseudo Range receiver observables are corrected, while Phase Range data are not corrected. Such a mode serves sub-meter accuracy applications and does not require ingenious data processing on rover side. Here MSM1 data can be very good candidates to serve DGNSS. The authors hope that with time, users still applying today RTCM-2 Message Types 1 and 31 [3] will understand the need to transit to MSM1 data. As a conclusion, we can claim that with introducing MSM1, RTCM-3 has started size-efficient supporting DGNSS mode.

RTK requires both Pseudo Range and Phase Range reference data. At the same time the need of Doppler is negligible. So to serve conventional RTK modes, MSM3 or MSM4 can be used. In classic base->rover RTK mode, these messages are directly generated by a base receiver. Unlike existing legacy messages, these MSM can be customized to allow different data link saving scenarios. E.g. for some applications (e.g. RTK with moving base) reference data at 10 Hz rate can be required. In most of the cases, well smoothed Pseudo Range data cannot bring performance enhancement being transmitted at 10 Hz. Usually 1 Hz transmissions can be more than sufficient for this. At the same time, Phase Range data must be transmitted at 10 Hz. Such decimation is possible with proper combinations of MSM1, MSM2, MSM3, and

MSM4 which can save throughput dramatically while not leading to any final performance degradation.

Network RTK refers to generating observables corresponding to some Master Reference receiver (physical or computed) plus extra Network information such as MAC/FKP [1] messages and/or Network Residual messages describing spatial errors in vicinity of Master position. These data are usually generated by Network software which gets multiple receivers input for Network processing. Today, Master Reference data are served by legacy RTCM-3 GPS/GLONASS L1/L2 observation messages. But they can be easily substituted by MSM1, MSM2, MSM3 and MSM4 for the same goal. This transition will additionally open the door to provide Network correcting data for L5 and other GNSS.

B. Receiver Raw observables

Today's scheme is very simple. GNSS receiver internally generates its own observables in its own format (open or unknown). Receiver provider delivers RINEX converter so each integrator can record raw data and convert it on a PC to RINEX afterwards.

With MSM accepted, the scheme can be much simpler. Receiver just generates proper MSM stream (e.g. MSM5). This stream can be recorded to the file for future post processing. And formally speaking it cannot require further conversion to RINEX before post processing because MSM is already a standard and post processing software will be transparent to receiver type generating MSM data.

Alternatively MSM stream can be forwarded to some real time application running for example on a separate processor. In this case, positioning engine inside application will intercept given MSM stream, decode the data and compute its own position possibly augmented by external GNSS corrections and/or other non-GNSS data. This allows configurations of the widest variety of GNSS sensor and user software combinations.

C. Serving Real Time State Space concept

Last years, we observe fast grow of so called State Space (SS) correcting services and resulting Precise Point Positioning (PPP) algorithms in a receiver. In future, SS data can augment (or even substitute in many cases) existing Measurement Space (MS) correcting services. SS correcting service requires collecting receiver observables from as many as possible reference stations ideally spread all over the globe.

IGS provides SS correcting data (so called precise IGS products) which can be used for post processing applications to get dm/cm level global accuracy without the need of any reference station or reference network. SS correcting data are computed (estimated) by super-powerful engines running on super-powerful Internet enabled servers. These engines process original receiver observables (often corresponding to different manufactures) presented in RINEX format. That is why resulting SS correcting data are suitable only for post processing applications.

The need to have real time SS correcting data is obvious nowadays. So called RTCM-3 SSR messages (already standardized for GPS and GLONASS) carry some SS correcting data in real time.

Real time SS correcting data are computed (estimated) by some recurrent engine, e.g. multi-state Kalman filter, with the input in form of original receiver observations coming in real time from multiple reference stations. It is ideal application for MSM messages to support given streaming.

CONCLUSION

The GNSS community cannot progress without standards. NMEA, RINEX and RTCM are no longer abbreviations: these are the names known today to each GNSS user. With strong competition in the GNSS market (both consumer and professional) and growing numbers of new players, the value of up-to-date GNSS raw data standards serving all known (real time and post processing) applications is very difficult to overestimate.

During the last decades, RTCM played a primary role in creating real time GNSS data standards. Every standard issued by RTCM sooner or later has been accepted by the GNSS industry. Today, RTCM has been augmented by the powerful RINEX community.

The Multiple Signal Messages concept and corresponding generic RTCM-3 MSM messaging is a key step in standardization of GNSS observables. From now on, different receiver manufactures and service providers can step by step transit from proprietary or/and standardized legacy data to generic and universal presentation equally suitable for real time and post processing applications.

The generic MSM concept/messaging has become a reality thanks to consolidated three years of continuous activity of the RTCM MSM Working Group.

Now with generic MSM concept fixed, it will be very easy to standardize MSM for new GNSS and their signals. (Just note that lately submitted draft proposal for all seven QZSS MSM contains only two pages!!!)

At the moment, all seven MSM for each of GPS, GLONASS, and GALILEO are fixed and have passed interoperability tests. This means that GNSS receiver/service providers can request corresponding

RTCM-3 documentation [7] and start their own implementation. There are already a number of test servers and receivers which are capable of generating, accepting, converting, and applying the widest range of MSM messages. So anyone who starts their own implementation will easily find a proper reference to check with.

Now with the most important standardization step done, let us forecast what next steps the RTCM Committee can take as it relates to MSM development.

First of all, the number of GNSS MSM members will grow. Today, QZSS MSM activity has started. There is a high probability that it would not be too difficult to proceed at least for those QZSS signals which are copies of GPS signals. With existing progress, it is clear that COMPASS will knock on the MSM door soon. The same can be said for the new L3 GLONASS CDMA signals. As we already have stated, thanks to generic MSM concept created, each new GNSS system will not be discussed from scratch. On the contrary, only a few (GNSS specific) data fields will need to be discussed and standardized.

Second, a number of accompanied (to MSM) RTCM-3 messages will be extended (today they exist only for GPS and GLONASS), namely:

- Navigation (ephemeris) messages for each of supported GNSS MSM.
- State Space correcting messages for each of supported GNSS MSM.
- RTK Network messages (MAC and FKP) for each of supported GNSS MSM.

Third, a large group of site description messages is to be developed and fixed. With these messages added into MSM RTCM-3 stream, one can easily generate a RINEX file with complete proper headers without importing any external data.

RTCM has made the first step and waits for the corresponding steps from receiver manufacturers and service providers. Let us hope that the GNSS community headache related to data interoperability issues will disappear very soon.

ACKNOWLEDGMENTS

The RTCM MSM format and given paper could not appear without intensive activity of RTCM SC-104 and MSM Working Group which integrated the brightest brains in the GNSS community.

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[3] RTCM STANDARD FOR DIFFERENTIAL GNSS SERVICE - VERSION 2.3, RTCM SPECIAL COMMITTEE NO. 104, AUGUST 20, 2001

[4] RINEX. The Receiver Independent Exchange Format, version 2.11, 2005

[5] Your GNSS receiver is really GNSS receiver: isn't so? Ilya Khazanov, Dmitry Kozlov, Alexander Osipov, Gleb Ziryanov, Proceedings of ION-GPS' 2011, Portland, Oregon.

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[7] To be published by the end of 2012

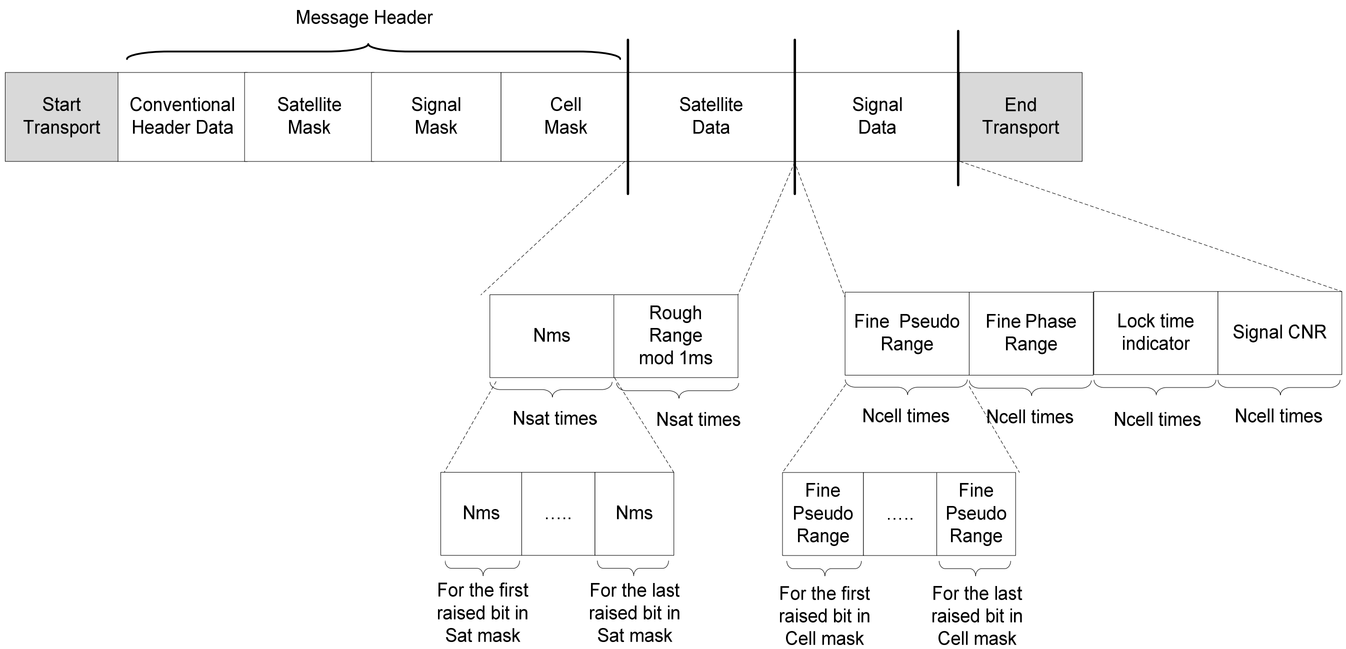

Figure 1: General MSM4 structure and organization

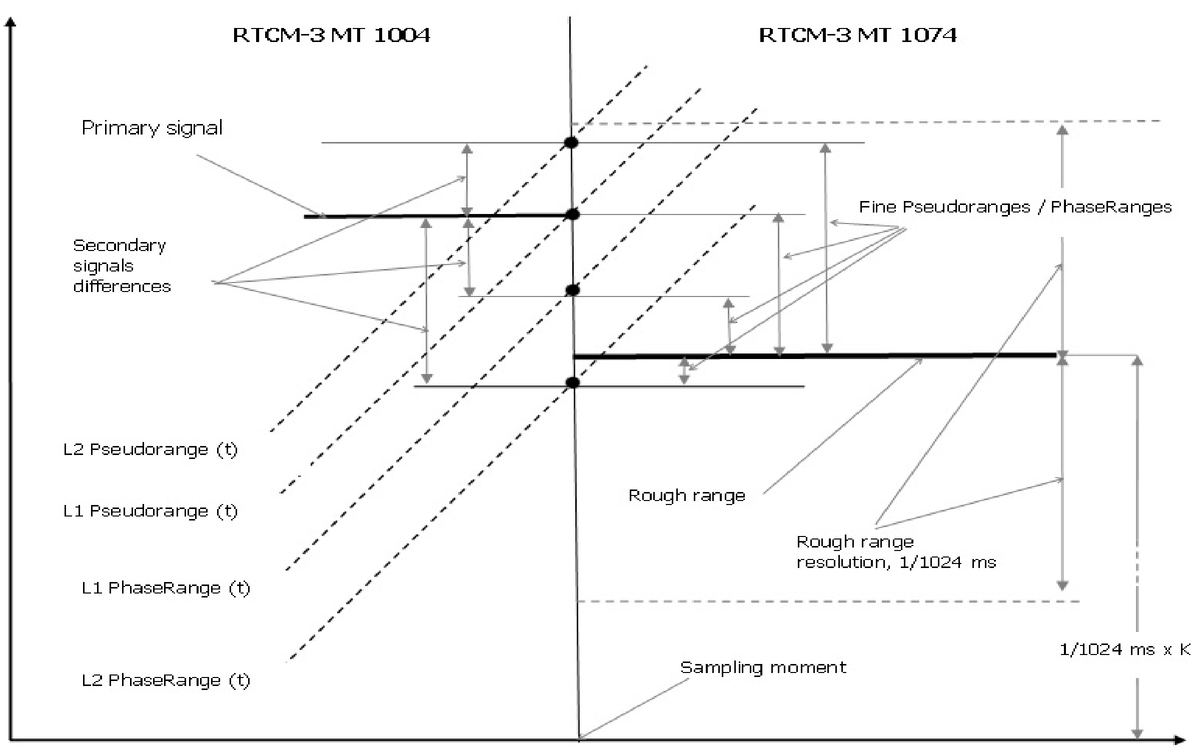

Figure 2: MSM Rough/Fine Range concept in comparison to legacy messages