WHITE PAPER

Trimble

CMRx: A NEW CORRECTION FORMAT FROM TRIMBLE

TRIMBLE

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INTRODUCTION

Trimble has introduced (2009) a new broadcast observation format called CMRx, this has been developed to support significant changes to Global Navigation Satellite System (GNSS) constellations which are currently underway. CMRx will allow Real-Time Kinematic (RTK) users to utilize more constellations, satellites, and signals as they become available, to give users faster initializations, improved statistical outputs, and improved performance in canyons and under canopy.

CMRx also offers significant compression (around 40%) over the already compact CMR/CMR+™ format to help users conserve and maximize bandwidth. This will translate into lower cellular modem bills, increased battery life on radios, the ability to send correction data for more satellites on bandwidth-constrained systems, and the ability to use more repeaters.

CMRx is available—or will soon be available—on current generation Trimble-manufactured GPS/GNSS receivers. Selected previous generation Trimble Global Positioning System (GPS) receivers will gain the ability to decode CMRx corrections. However, they will not be able to output CMRx corrections if acting as a base station.

In the v4 firmware release which introduces CMRx, the RTK engine has also been upgraded. Improvements in RTK initialization will be seen with the v4 release and are independent to the use or non use of CMRx.

A SHORT HISTORY OF CMR

The Compact Measurement Record (CMR) format was developed by and initially used by Trimble in 1992. The format was developed as a method of transmitting code and carrier phase correction data in a compact format from GPS base stations to GPS rovers for RTK GPS surveying.

Dr. Nicholas Talbot of Trimble publicly introduced the CMR format at the 1996 ION Conference. In 1997, at the Trimble User's Conference, the CMR+ format was announced. CMR+ improves performance of CMR by providing a correction stream that is a more consistent length and less sporadic than the CMR format, which provides for better operation on radio networks. Since the CMR and CMR+ formats have been made public, Topcon, Leica, and other RTK GPS manufactures have followed this format. At the time, RTCM was the competing RTK correction format. However, since RTCM required about twice the bandwidth as compared to CMR and lacked definition of message types critical to RTK operation, CMR quickly became widely accepted.

In 2005, Trimble modified the CMR/CMR+ format to accommodate corrections for the Russian GLONASS system. These messages have not been made publicly available at this time. Prior to this, Topcon and Leica had modified their CMR/CMR+ formats to accommodate corrections for the Russian GLONASS system. Their modifications were done in a manner that was similar to the original CMR specification. Thus, Trimble sought to add support for Topcon and Leica CMR/CMR+ GLONASS messages into Trimble receivers. However, many factors have made these foreign corrections difficult to fully support. The challenges include: unknown antenna types from other manufactures, variations in message encoding and framing, and variations in satellite observable processing.

THE NEED FOR CMRx

As new nations enter the GNSS business and as existing GNSS constellations are modernized, a large list of changes are being implemented or are expected to be implemented in the near future. They include:

- Multiple defined signals can be tracked on each frequency (e.g., CS-code is broadcast on block IIR-M GPS satellites, C/A and P code are broadcast on GLONASS L1 and L2 frequencies).
- The introduction of the GPS L5 frequency.
- A proposed third frequency on GLONASS.
- The launch plans for a triple frequency Galileo constellation by the European Union (EU).
- The launch plans for a triple frequency Compass/Beidou-2 constellation by China.
- The launch plans of the Quasi-Zenith Satellite System (QZSS) by Japan, which may aid in carrier phase positioning
- Possible usage of carrier phase measurements from Satellite Based Augmentation System (SBAS) satellites for positioning. SBAS systems include: the United States' Wide Area Augmentation System (WAAS), the European Geostationary Navigation Overlay Service (EGNOS), the Indian GPS Aided Geo Augmented Navigation (GAGAN), and the Japanese Multi-functional Satellite Augmentation System (MSAS).
- GNSS constellation fleet expansion. Compass is proposing 35 satellites in their full constellation. Also, there have been proposals to expand the GPS constellation beyond the current limit of 32 satellites.

These changes require significant updates to the correction stream that is utilized by RTK systems. Correction streams must accommodate additional constellations, additional frequencies, additional signals, and constellations with more than 32 satellites. CMR/CMR+ and RTCM correction streams are currently not equipped to handle these changes. The additional data will also significantly increase bandwidth requirements. In the future, there may be 50 satellites in view and all of them broadcasting triple frequency. These bandwidth requirements are not practical using existing correction streams with current radio technology.

Therefore, Trimble decided to develop a new broadcast correction format called CMRx. CMRx plans for the future by allowing new constellations, new frequencies, new signals, and more than 32 satellites to be packaged into the correction stream. Even though these future constellations, frequencies, and signals are unknown now, the CMRx design allows for them to be added as they come online while maintaining backwards compatibility of the CMRx protocol.

CMRx also includes compression of the correction stream as a method of easing the ever increasing bandwidth requirements. On average, CMRx will require 40% less bandwidth than CMR/CMR+ to transmit corrections for the same satellites. The compression method that is used is not based on the "delta" (change) from the previous message. Thus each CMRx message can be decoded immediately and completely by the rover receiver. Using a delta scheme has the effect that when a "key" message is dropped, there will be an outage of corrections until the next key message.

It is important to note that CMRx is a new broadcast correction format that will only be recognized by Trimble-manufactured GPS/GNSS receivers (which includes Caterpillar and Pacific Crest GPS/GNSS receivers) that state that they support CMRx. CMRx is not backward compatible with CMR/CMR+.

SAMPLE BANDWIDTH SCENARIOS WITH CMRx

To measure the effect of CMRx on radio throughput, a few common scenarios can be evaluated. Table 1 and Table 2 give the data rates which are typically achieved with Trimble 450 MHz and 900 MHz radios, respectively.

Table 1: 450 MHz Radio Throughput

Nominal Over-the-Air Baud Rate	Repeaters	Effective Rate (bytes/s)[1]
4800	0	338
	1	230
	2	83
9600	0	800
	1	476
	2	182
19200[2]	0	1623
	1	965
	2	380

Table 2: 90 0MHz Radio Throughput

Configuration	Effective Rate (bytes/s)[3]
Broadcast-Only	440[4]
2-way data (IP)	183

[1] Rates may vary slightly due to radio technology.

[2] Not supported by current on-machine radios.

[3] Rates may vary slightly due to radio technology and network management requirements.

[4] With specialized configurations, 900 MHz radios may be set up to support 880 bytes/s.

The bandwidth usage of the CMR+ correction stream can be clearly defined and is given in Table 3. The red line indicates the point in the table where 2-way data systems have no further bandwidth for corrections.

Table 3: CMR+ Bandwidth Usage (bytes/s)

# of SVs	GLONASS (G1 / G2)										
GPS (L1 / L2)	0	1	2	3	4	5	6	7	8	9	10
0	16	47	64	80	96	112	129	145	161	177	194
1	43	74	91	107	123	139	156	172	188	204	221
2	58	89	106	122	138	154	171	187	203	219	236
3	73	104	121	137	153	169	186	202	218	234	251
4	88	119	136	152	168	184	201	217	233	249	266
5	103	134	151	167	183	199	216	232	248	264	281
6	118	149	166	182	198	214	231	247	263	279	296
7	133	164	181	197	213	229	246	262	278	294	311
8	148	179	196	212	228	244	261	277	293	309	326
9	163	194	211	227	243	259	276	292	308	324	341
10	178	209	226	242	258	274	291	307	323	339	356
11	193	224	241	257	273	289	306	322	338	354	371
12	208	239	256	272	288	304	321	337	353	369	386

The bandwidth usage of the CMRx correction stream is more difficult to define because of the compression used on this stream and because this stream is highly configurable. Equation 1 gives a very crude computation that may be used to roughly determine the size of the CMRx message.

$$bytes \approx ceiling\left(6 + \sum_{const}\left[6 + 23 + SV * (3.25 * freq)\right]\right) \qquad \textbf{Equation 1}$$

Where:

freq: Gives the number of frequencies tracked.

SV: Gives the number of satellites tracked in the "*Const*" being considered

$\sum_{Const}$: Sums the quantity in brackets for each constellation being tracked

Note that tracking additional signals (e.g., L2E and L2C) may cause message lengths to increase.

Using this formula, Table 4, Table 5, and Table 6 give an approximate bandwidth usage for CMRx messages when various scenarios are considered. Table 4 can be compared with Table 3 to illustrate how CMRx compresses correction data. Table 4 is representative of the performance that users can expect today with GPS+GLONASS receivers using CMRx. Again, the red line indicates the point in the table where 2-way data systems have no further bandwidth for corrections.

Table 4: Approximation of CMRx Bandwidth Usage (bytes/s) – (GPS L1/L2 + GLONASS L1/L2)

# of SVs		GLONASS (G1 / G2)										
		0	1	2	3	4	5	6	7	8	9	10
GPS (L1 / L2)	0	6	42	48	55	61	68	74	81	87	94	100
	1	42	77	84	90	97	103	110	116	123	129	136
	2	48	84	90	97	103	110	116	123	129	136	142
	3	55	90	97	103	110	116	123	129	136	142	149
	4	61	97	103	110	116	123	129	136	142	149	155
	5	68	103	110	116	123	129	136	142	149	155	162
	6	74	110	116	123	129	136	142	149	155	162	168
	7	81	116	123	129	136	142	149	155	162	168	175
	8	87	123	129	136	142	149	155	162	168	175	181
	9	94	129	136	142	149	155	162	168	175	181	188
	10	100	136	142	149	155	162	168	175	181	188	194
	11	107	142	149	155	162	168	175	181	188	194	201
	12	113	149	155	162	168	175	181	188	194	201	207

Table 5 and Table 6 give possible scenarios of bandwidth usage in the future as more constellations come online. The scenario in Table 5 may be realized in the next four to five years based on current launch schedules. Again, these scenarios are approximations of bandwidth usage and are subject to modification when these signals come online.

Table 5: Approximation of CMRx Bandwidth Usage (bytes/s) – (Triple Frequency GPS + Dual Frequency GLONASS and Galileo)

# of SVs		GLONASS (G1 / G2)												
		0	1	2	3	4	5	6	7	8	9	10	11	12
		Galileo (E2 / E5 AltBOC)												
		0	1	2	3	4	5	6	7	8	9	10	11	12
GPS (L1 / L2 / L5)	0	6	77	90	103	116	129	142	155	168	181	194	207	220
	1	45	116	129	142	155	168	181	194	207	220	233	246	259
	2	55	126	139	152	165	178	191	204	217	230	243	256	269
	3	65	136	149	162	175	188	201	214	227	240	253	266	279
	4	74	145	158	171	184	197	210	223	236	249	262	275	288
	5	84	155	168	181	194	207	220	233	246	259	272	285	298
	6	94	165	178	191	204	217	230	243	256	269	282	295	308
	7	104	175	188	201	214	227	240	253	266	279	292	305	318
	8	113	184	197	210	223	236	249	262	275	288	301	314	327
	9	123	194	207	220	233	246	259	272	285	298	311	324	337
	10	133	204	217	230	243	256	269	282	295	308	321	334	347
	11	143	214	227	240	253	266	279	292	305	318	331	344	357
	12	152	223	236	249	262	275	288	301	314	327	340	353	366

The scenario in Table 6 will likely not be realized for another 10 years. However, it is highly likely that the Chinese Compass system will be fully operational long before that, making this scenario largely realized in 5 years.

Table 6: Approximation of CMRx Bandwidth Usage (bytes/s) – (Triple Frequency - GPS + GLONASS + Galileo + Compass)

# of SVs		GLONASS (G1 / G2 / G3)												
		0	1	2	3	4	5	6	7	8	9	10	11	12
		Galileo (E2 / E5 AltBOC / E6)												
GPS (L1 / L2 / L5)	Compass (B1 / B2 / B3)	0	1	2	3	4	5	6	7	8	9	10	11	12
0	0	6	84	103	123	142	162	181	201	220	240	259	279	298
1	1	84	161	181	200	220	239	259	278	298	317	337	356	376
2	2	103	181	200	220	239	259	278	298	317	337	356	376	395
3	3	123	200	220	239	259	278	298	317	337	356	376	395	415
4	4	142	220	239	259	278	298	317	337	356	376	395	415	434
5	5	162	239	259	278	298	317	337	356	376	395	415	434	454
6	6	181	259	278	298	317	337	356	376	395	415	434	454	473
7	7	201	278	298	317	337	356	376	395	415	434	454	473	493
8	8	220	298	317	337	356	376	395	415	434	454	473	493	512
9	9	240	317	337	356	376	395	415	434	454	473	493	512	532
10	10	259	337	356	376	395	415	434	454	473	493	512	532	551
11	11	279	356	376	395	415	434	454	473	493	512	532	551	571
12	12	298	376	395	415	434	454	473	493	512	532	551	571	590

SITE SPECIFIC SCENARIOS

This environment presents an interesting scenario to evaluate the deployment of CMRx since some sites have many GPS/GNSS receivers from various generations and manufacturers.

First, the site must be using a current generation Trimble base station to enable output of CMRx corrections. Older generation Trimble base stations and non-Trimble base stations cannot generate CMRx corrections.

Next, if a Trimble base station is used and CMRx outputs are broadcast, the CMRx corrections can be used by current generation and selected previous generation Trimble-manufactured rover GPS/GNSS receivers.

If non-Trimble rovers or previous generation Trimble rovers which do not support CMRx are used, then a non-CMRx correction format will need to be broadcast (i.e., CMR/CMR+ or RTCM). Since current generation Trimble base stations are capable of outputting multiple corrections on multiple ports, it is possible to output CMRx on one serial port and output CMR/CMR+ on another serial port. This would require that a second radio network be setup, one broadcasting CMRx corrections and the other broadcasting CMR/CMR+ corrections.

Table 7 lays out a sample of what correction streams various base stations will be able to output and what correction streams various rovers will be able to decode. Green indicates compatibility (or future compatibility). Red indicates that these corrections will not be supported. Yellow indicates possible support. However, since these involve non-Trimble products, these are not officially supported.

Table 7: Correction Broadcast and Compatibility Table

		non-Trimble	SPS770 SPS780	MS750, MS860	SPS781/881, 751/851, MS990
Base Station	SPS751/851 SPS781/881	CMRx CMR/CMR+ RTCM	CMRx CMR/CMR+ RTCM	CMRx CMR/CMR+ RTCM	CMRx CMR/CMR+ RTCM
	MS750	CMR/CMR+ RTCM	CMR/CMR+ RTCM	CMR/CMR+ RTCM	CMR/CMR+ RTCM
	non-Trimble	CMR/CMR+ RTCM	CMR/CMR+ RTCM	CMR/CMR+ RTCM	CMR/CMR+ RTCM

Note that MS750 and MS860 GPS receivers only accommodate RTCM version 2 correction inputs and outputs. RTCM version 3 corrections cannot be output or decoded by these receivers.

Also note that since the Trimble GLONASS message in the CMR/CMR+ output is encrypted then non-Trimble rovers using Trimble base stations will not decode or receive CMR/CMR+ GLONASS corrections. RTCM 3 output from a Trimble base station is an optional upgrade.

CONCLUSION

In summary, CMRx is a proprietary broadcast correction output format developed by Trimble to support significant changes to GNSS constellations currently underway. CMRx will enable users to use more constellations, satellites, and signals as they become available to give users faster initializations, and improved statistical outputs.

CMRx also offers significant (around 40%) compression over the already compact CMR/CMR+ format to help users conserve and maximize bandwidth. This will benefit users by giving them lower cellular modem bills, increased battery life on radios, and more satellite correction data transmitted on severely bandwidth limited systems.

Finally, CMRx will only be supported by current generation Trimble-manufactured GPS/GNSS receivers. New firmware will also be released for selected previous generation GPS receivers, which will allow them to decode CMRx messages when operating as a rover. However, this will not allow them to output CMRx corrections when operating as a base station.

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