2. SIGNAL FORMAT

2.1 GENERAL:

The broadcast data consists of a selected subset of the message types contained in the RTCM Special Committee No. 104, “Recommended Standards for Differential Navstar GPS Service”, dated January 3, 1994 herein referred to as “RTCM SC104 (Version 2.1.). All selected message types will be broadcast in the format of this document unless otherwise noted or amended by a later version.

2.2 MESSAGE TYPES:

RTCM SC104 (Version 2.1.) Message Types 3, 5, 6, 7, 9, and 16 will be broadcast in the DGPS Navigation service. The currently undefined, Type 15 Message (atmospheric parameters) if developed may also be included at a later time. Stated performance of the system is only applicable for user equipment suites that fully incorporate all of the aforementioned message types. RTCM SC104 (Version 2.1) requires that the service provider further specify the content of several message types. Further description is given for Message Types 3, 5, 7, 9 and 16, along with a complete description of the use of the message header when operating within the DGPS Navigation Service. The Type 6 message is a filler message used only when the reference station has no other message to broadcast. Unless otherwise stated, all message types are applied in the manner recommended in RTCM SC104 (Version 2.1). In attempting to provide the user with a seamless North American DGPS service, arrangements will be negotiated with US authorities to provide reciprocal service with respect to information in certain types of messages (e.g. Message Types 7 & 16), especially where adjacent DGPS stations are under US jurisdiction.

2.2.1 MESSAGE HEADER:

The “Station Health Field” (bits 22-24) is in the two-word header of all messages, including the Type 9 Message (9-1 and 9-3). Table 1 delineates the pertinent meaning of the bits in this field. The enhancements to the UDRE (user differential range error) resolution will provide a substantial added value to the system. For the Type 9-3 Message, the UDRE scale factor is determined by the satellite with the largest UDRE value. If an unhealthy or unmonitored condition exists, the UDRE Scale Factor registers a value of one.

CODE	INDICATION
111	UNHEALTHY BROADCAST
110	UNMONITORED BROADCAST
101	UDRE SCALE FACTOR = 0.10
100	UDRE SCALE FACTOR = 0.20
011	UDRE SCALE FACTOR = 0.30
010	UDRE SCALE FACTOR = 0.50
001	UDRE SCALE FACTOR = 0.75
000	UDRE SCALE FACTOR = 1.00

2.2.2 TYPE 3 MESSAGE:

A Type 3 message contains information on the identity and surveyed position of the active reference station in the DGPS station. Two reference stations are provided in a DGPS station (dual redundancy). At any given time one will be on air and the other will serve as a “hot standby”. In the event of a reference station changeover, the position coordinates which are broadcast in the Type 3 Message will change to reflect the other reference station surveyed position and its identity. The Type 3 Message will contain NAD 83 coordinates since this system is the only one in North America that can take advantage of the centimeter resolution provided in this message.

2.2.3 TYPE 5 MESSAGE:

This message type will notify the user equipment suite that a satellite that is deemed unhealthy by its current navigation message is usable for DGPS navigation. This is accomplished by the setting of the "Health Enable Function" in the Type 5 Message by the reference station in order to indicate this condition. An example of this situation is a slowly drifting satellite clock that may render a satellite unhealthy for GPS use, but would be correctable by the reference station for DGPS use. The user equipment suite should not use an unhealthy satellite unless a Type 5 Message allowing the use of an unhealthy satellite was received within the last thirty minutes. If the most recent Type 5 Message received does not indicate that an unhealthy satellite can be utilized, then the use of that satellite should be discontinued if it were being used earlier (i.e. via a previous Type 5 Message).

2.2.4 TYPE 7 MESSAGE:

A Type 7 Message provides information of its broadcasting DGPS station and the other two or three adjacent DGPS stations. Where adjacent stations are under US jurisdiction, appropriate arrangements will be made to provide reciprocal information. The user equipment suite should update its internal almanac immediately as new information is received. Non volatile memory should be employed to store the internal almanac. When a broadcast becomes unhealthy or unmonitored in a DGPS coverage area, the Type 7 Message will be set to indicate the subject condition. Upon receiving the next Type 7 message*, the* user's equipment suite should immediately update its internal almanac**.** Additionally, the user equipment suite is immediately notified by means of the station health status indicator contained in the second word of the universal message header. The user should be able to view the contents of the current Type 7 Message in order to obtain information on coverage areas that may soon be entered.

2.2.5 TYPE 9 MESSAGE

Due to the advantages of greater impulse noise immunity, lower latency and a timely alarm capability, the Type 9 Message has been selected for broadcasting pseudo range corrections instead of the Type 1 Message. Two methods of transmitting the Type 9 message are possible.

2.2.5.1 TYPE 9-3 MESSAGE

The first method of broadcasting PRC's (Pseudo range Corrections) is based upon "Three-Satellite Type 9 Messages" This is denoted as "Type 9-3" Messages. In this method all satellites for which corrections are broadcast are assigned to either three satellite Type 9 Messages or to a remainder message of either one or two satellites. The transmission rate could be at either 100 or 200 bps. For example, the pseudo range corrections for eight satellites will consist of three Type 9 Messages, two with 3 satellites and one with two satellites. An equal number of corrections are broadcast for each satellite. In order to optimize use of the UDRE Scale Factor in the message header, satellites will be grouped in messages by their UDRE values. At a transmission rate of 200 bps this represents a minimum of a forty percent reduction in message loss as compared to a Type 1 Message under high noise conditions broadcast at the same bit rate. The relative latency of the different PRC message types is illustrated in Figure 2 - note that since the corrections can be applied as soon as the parity is verified for the words that contain a given correction, the latencies in Figure 3 are the maximum latencies. PRC accuracy is for the most part a function of the latency of the Range Rate Correction (RRC) since it is the only PRC component in which the error is a function of time. The error of the PRC (t0) term is fixed at the time of measurement and any errors that result from its propagation are a function of RRC accuracy. Figure 3 illustrates an additional advantage of the Type 9 Message - the phasing of the PRCs. When the latency for certain satellites is nearing its maximum the latency for others is very low. This provides a built-in immunity factor to high pseudo range accelerations on one or more satellites. The potential to weight pseudo ranges on the basis of latency is readily apparent and should be beneficial to the user. This method of transmitting a Type 9 message at 100 bps and 200 bps will be used for the standard and enhanced/multiple coverage areas respectively.

2.2.5.2 TYPE 9-1 MESSAGE:

The second method of broadcasting pseudo range corrections is to broadcast individual Type 9 Messages for each satellite at a transmission rate of 50bps. This message is referred to as the "Single

Satellite Type 9 Message” and is denoted in this document as the “Type 9-1 Message”. A high level of impulse noise immunity is achieved by this technique that will extend the effective range of the broadcast. Lower transmission rates such as 50 bps could not be used at this time because of the need to meet the time to alarm requirement due to the length of the PRC Messages. An equal number of corrections are broadcast for all satellites regardless of their pseudo range rates or accelerations Table 2 summarizes the above mentioned methods of Type 9 message transmission.

Method	Message Type	Data Rate	Trans. Rate
1a	Type 9-3	200 bps	200 bps
1b	Type 9-3	100 bps	100 bps
2[1]	Type 9-1	50 bps	50 bps

Table 2 PRC Message Broadcast Parameters

Since each Type 9 Message contains the freshest possible corrections, the corrections contained in each and every Type 9 Message are computed at different times (i.e. computed at the latest possible time before broadcast). The user equipment suite can mix corrections that may have been computed up to 30 seconds apart, thus the reference station should utilize a highly stable frequency source, within one part in 10-11 (30 second Allan Variance). The use of a highly stable frequency reference and a tightly controlled clock provides the additional benefit of allowing corrections for each satellite to be applied as they are received, as long as the parity for both of the words which contain a given correction is verified. This capability should be implemented for the Type 9 Message in all user equipment suites. Generally, the Reference Station clock will be within 100 ns of GPS time. Clock stability is of far greater priority then absolute time accuracy since PRC’s are generated relative to each other for a given Reference Station.
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The shorter message length and greater frequency of preambles provided by the Type 9 Message result in a substantially improved impulse noise performance as compared with the Type 1 Message. The higher rate of preambles allows a much faster re-synchronization, especially during high noise periods. As previously discussed, even in low noise conditions the Type 9-3 Message provides a lower latency than the Type 1 Message, making it advantageous when operating with a low data rate as well as in high noise environments. This is especially useful since the position error growth due to latency is non-linear. If a satellite suddenly becomes unhealthy when in use by a given reference station the PRC (to) and the RRC are set to predefined values as delineated in RTCM SC104 (Version 2.1) that designate this condition.

1 May be used if SA is permanently discontinued by US authorities

2.2.6 TYPE 16 MESSAGE:

The Type 16 message will be utilized as a timely supplement to the notice to mariners or shipping, regarding information on the status of the local DGPS service that is not provided in other message types. Additionally, the Type 16 Message may provide limited information on service outages in adjacent coverage areas or planned outages for scheduled maintenance at any broadcast site. In order to keep data link loading to a minimum, Type 16 Messages will contain only system information that is crucial to the safety of navigation. Any broadcast of the Type 16 Message will not exceed 4.8 seconds. At 200 bps this translates into 32 words that allows a maximum 90 characters after accounting for the message header. The Type 16 Message is not intended to act as a substitute for the notice to mariners, even though it pertains to DGPS information. Type 16 Messages will be utilized to alert the user of an outage condition for which a broadcast in an adjacent coverage area may be unhealthy, unmonitored, or unavailable. This information would be useful to the mariner who is planning a transit through an affected area or whose equipment suite is presently incapable of automatic selection from the beacon almanac. Further details of an outage condition can be derived from the Type 7 Message for route planning purposes.

The capability of the TYPE 16 message to inform the mariner of the adjacent coverage areas is not currently implemented. Full capability will be available when the full networking capability is implemented (see also section 4.2).

2.2.7 MESSAGE SCHEDULING:

The routine data stream will consist mainly of message types 3, 7, & 9 and broadcast of message types 5,6 and 16 will be on an exceptional basis. Due to the advent of continuous tracking receivers the Type 2 Message is no longer required and its use would only serve to increase the latency of the broadcast. For each new Issue of Data (IOD) there will be a 90 second delay before the broadcast pseudo range corrections are computed with the new IOD. Ninety seconds should be more than adequate for a continuously tracking DGPS receiver, as it will be able to instantaneously read the navigation messages as they are broadcast from each satellite. Any short term blockage of a satellite at IOD, such as passing under a bridge, are compensated for by the ninety second delay. This method of handling a new IOD requires the user equipment suite to store both the new and the old IOD for the subject period. Message Types 3, 5, 7, 15 and 16 will not be broadcast within 90 seconds of each other under any circumstances.

a) Type 3 Message:

Type 3 Messages will be broadcast at fifteen and forty-five minutes past the hour.

b) Type 5 Message:

If an unhealthy satellite is deemed usable for DGPS, a Type 5 Message will be broadcast at fifteen minute intervals beginning at five minutes past the hour. If an unhealthy satellite that was deemed usable is later deemed unusable the reference station will no longer broadcast corrections for the subject satellite.

c) Type 7 Message:

A routine Type 7 Message will be broadcast at ten minute intervals beginning at seven minutes past the hour. Special Type 7 Messages will be broadcast as soon as possible, subject to the other scheduling constraints, when the status of a beacon in the almanac changes. This will aid the user equipment suite in its choice of the proper beacon.

d) Type 9 Message:

Pseudorange corrections will be broadcast only for satellites at an elevation angle of 7.5 degrees or higher through use of the Type 9 Message. The official GPS coverage is based on elevation angles of ten degrees or higher. Satellites at elevation angles lower than 7.5 degrees are adversely affected by spatial decorrelation, multipath, and minimal processing time between acquisition and actual use. The level of 7.5 degrees is identical to that recommended by RTCA Special Committee 159. Corrections for all satellites in view above the mask angle will be broadcast. Positioning users of the system who are interested in achieving the highest accuracy level possible should use a higher mask angle in order to avoid the more pronounced atmospheric effects associated with satellites at low elevation angles. When a reference station drops a satellite it will broadcast an indication to the user equipment suite to stop applying corrections for that satellite to its navigation solution (see paragraph 4.1 for details).

e) Type 16 Message:

This message type will be broadcast as deemed necessary but within strict limits. The interval between successive Type 16 Messages will be no less than three minutes.

MESSAGE TYPE SUMMARY:

TYPE 1 MESSAGE:	**-**	Now replaced by Type 9 messages.
TYPE 2 MESSAGE:	**-**	No longer required.
TYPE 3 MESSAGE:	**-**	Contains information on the identity and surveyed position of the active reference station in the DGPS station. Broadcast at H +15 & +45 mins.
TYPE 4 MESSAGE:	**-**	Not used.
TYPE 5 MESSAGE:	**-**	This message type will notify the user equipment suite that a satellite that is deemed unhealthy by its current navigation message is usable for DGPS navigation.
TYPE 6 MESSAGE:	**-**	Filler message, only used when no other message to broadcast.
TYPE 7 MESSAGE:	**-**	This message provides information of its broadcasting DGPS station and the other two or three adjacent DGPS stations. Broadcast at H + 7, then at 10 minute intervals.
TYPE 8 MESSAGE:	**-**	Not used.
TYPE 9 MESSAGE:	**-**	This message type has been selected for broadcasting pseudo range corrections instead of the Type 1 Message. Two methods of transmitting the Type 9 message are possible.
TYPE 10 MESSAGE:	**-**	Not used.
TYPE 11 MESSAGE:	**-**	Not used.
TYPE 12 MESSAGE:	**-**	Not used.
TYPE 13 MESSAGE:	**-**	Not used.
TYPE 14 MESSAGE:	**-**	Not used.
TYPE 15 MESSAGE:	**-**	Atmospheric Parameters (not yet used).
TYPE 16 MESSAGE:	**-**	Type 16 messages will be utilised as a supplement to the notice to mariners or shipping, regarding information on the status of the local DGPS service that is not provided in other message types. Additionally, the Type 16 Message may provide limited information on service outages in adjacent coverage areas or planned outages for scheduled maintenance at any broadcast site.