Norwegian National Seismic Network

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A White Paper about

MiniSEED for LISS
and data compression using
Steim1 and Steim2

version 01.00

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Introduction

The Live Internet Seismic Server (LISS) is an internet-based distribution mechanism allowing near-real-time data flow from seismic stations around the world to an essentially unlimited number of clients. The clients can be any software capable to read miniSEED packet using TCP/IP sockets. The LISS is claimed to be full functional on Seiscomp, EarthWorm and Antelope. Considering the importance to have a good interchange standard for seismic data miniSEED appeard to be a good choice considering it is widely known and used in the world. The authors of this document Mauro Mariotti and Terje Utheim experienced many problems in coding mSEED starting from the SEED official manual (Standard for the Exchange of Earthquake Data Reference Manual SEED format Version 2.4 August 2004).

This document is prepared with the intent of improve the understanding of the mSEED standard and their popular data compression formats. According to the SEED Reference manual: The Standard for the Exchange of Earthquake Data (SEED) is an international standard format for the exchange of digital seismological data. SEED was designed for use by the earthquake research community, primarily for the exchange between institutions of unprocessed earth motion data. It is a format for digital data measured at one point in space and at equal intervals of time.

We hope it will be useful for the LISS data distribution mechanism where a lot of confusion is present at the moment of the preparation of this document.

The essential information about miniSEED

Many internet service are widely used to transmit analogue information such as radio channels, audio streaming and so on. Seismic data are slightly different being oriented to lower frequency, higher dynamic range and higher time precision. Audio streaming (like radios or voice over IP application) can tolerate a certain grade of data-loss, this is not allowed in seismic processing but the capabilities of the IP protocol are so wide that good and reliable connection can be established without big problems. While SEED is a complex standard with a large set of data packets, called Blockettes designed to distribute in an harmonized format and protocol all the needed information used to process seismic data, miniSEED would meet the limited requirements of near real time data exchange using TCP/IP.

In SEED blockettes are numbered with codes going from 1 to around 2000 (even if this doesn't mean there are two thousands of blockettes types). In miniSEED basicly only blockette number 1000 and 1001 are used.

Before proceed we recomend the reader to examine the box in this page.

How Binary Data Fields are Described in This Manual

(direct extract from the SEED Reference Manual pages 33-34)

Throughout this manual, we use some conventions to describe the sizes of fields in the SEED format. Here are the binary data types used in fixed headers and in data blockettes:

Field type	*Number of bits*	*Field description*
UBYTE	8	Unsigned quantity
IBYTE	8	Two's complement signed quantity
UWORD	16	Unsigned quantity
WORD	16	Two's complement signed quantity
ULONG	32	Unsigned quantity
LONG	32	Two's complement signed quantity
CHAR * n	n * 8	n chars, each 8 bits long, valid only ASCII 7 bit (7th bit=0)
FLOAT	32	IEEE Floating point number (single precision)

The IEEE floating point format consists of three stored components: a sign (+ or -), an exponent, and a fraction. In the following description of the storage format these notations will be used:

s=sign (bit 31) e=biased exponent (bit 30-23) f=fraction(bit 22-0)

The sign is the sign of the fraction. Rather than storing the sign of the exponent a bias is added to the exponent, and the biased exponent is stored. IEEE single precision values occupy one 32 bit word as shown above in 68000 byte order. Bits 0:22 store the 23 bit fraction, bits 23:30 store the 8 bit exponent, and the high order bit 31 stores the sign bit. The 23 bit fraction combined with the implicit leading bit provide 24 bits of precision in normalized numbers. The value of an IEEE single precision floating point number is calculated as:

-1s x 2(e-127) x 1.f

The byte order of a FLOAT is specified in the station identifier blockette 50.

Binary data types are used in the BTIME structure:

Field type	Number of bits	Field description
UWORD	16	Year (e.g., 1987)
UWORD	16	Day of Year (Jan 1 is 1)
UBYTE	8	Hours of day (0—23)
UBYTE	8	Minutes of day (0—59)
UBYTE	8	Seconds of day (0—59, 60 for leap seconds)
UBYTE	8	Unused for data (required for alignment)
UWORD	16	.0001 seconds (0—9999)

NOTE: The BTIME structure differs from the ASCII variable length TIME structure used in the control headers. All binary 32 bit words begin on long-word boundaries, 16 bit words begin on word boundaries, and all bytes on byte boundaries. The fixed portion of the header always ends at the end of a long-word boundary, and each blockette is an integer number of long-words in length. Pack data in either VAX or 68000 swapping order. This swapping key is in the Station Identifier Blockette [50], and may differ for each station. Decoding programs will automatically adapt to specified swapping orders. Negative numbers utilize standard two's complement representation. The data description language in the data dictionary, referred to by the Channel Identifier Blockette [52] for the represented channel, governs byte swapping within the data. Mantissas and exponents for floating point numbers are expressed as binary two's complement integers. The most signi.cant bit of the number (bit 15, or the left most bit) is always set to zero for a positive number, and the most signi.cant bit of the mantissa is in bit 14. For negative numbers, the most signi.cant bit is always set to one, and the integer is in two's complement format.

According to the SEED Reference Manual the mSEED data-packet is composed of the following main fields:

1) A fixed header of 48 bytes
2) One or two blockettes; always blockette coded as number 1000, optional the blockette coded as number 1001
3) Data field

Now we are going to examine each of these fields, each of the following description is composed of 2 paragraphs, first a description of the main field and second a description of the interpretation problems.

It will be demonstrated that major misunderstanding and the inconsistency are present and strange interpretation of the blockette data by EarthWorm and Seiscomp are present too. Furthermore many lacks come from the highly fragmented documentation of the miniSEED and mistakes in the interpretation of the little-endian big-endian notation of data longer than 1 byte. Furthermore all these problems are reflected negatively to the Steim1 and Steim2 code compression, thus is not so complicated, but special attention must be payed to it when related to all the following byte swapping that inflence not only the data by themselves but also the time order of the data time series to be represented.

A basic problem, the packet length

According to the SEED Reference Manual, the SEED format supports virtually any packet length. Data retrieve would be assured by pointers that can point to the next blockettes. For LISS no information and no indications shows that (as we understood after many pains) the packet must be 512 bytes long. Furthermore the packet length is not specified in the fixed header but only in the blockette type 1000.

Anyway be awarned that in miniSEED packet for the LISS operation the length is fixed to 512 bytes.

Fixed data header fields:

	Field name	Type	Byte position	Length (bytes)
1	Sequence number	ASCII	1-6	6
2	Data Header quality indicator	ASCII	7	1
3	Reserved byte	ASCII	8	1
4	Station code	ASCII	9-13	5
5	Location identifier	ASCII	14-15	2
6	Channel identifier	ASCII	16-18	3
7	Network code	ASCII	19-20	2
8	Record start time	BTIME	21-30	10
9	Number of samples	UWORD	31-32	2
10	Sample rate factor	WORD	33-34	2
11	Sample rate multiplier	WORD	35-36	2
12	Activity flags	UBYTE	37	1
13	I/O flags	UBYTE	38	1
14	Data quality flags	UBYTE	39	1
15	Number of blockettes that follow	UBYTE	40	1
16	Time correction	LONG	41-44	4
17	Offset to beginning of data	UWORD	45-46	2
18	Offset to beginning of first blockette	UWORD	47-48	2

1) The sequence number is a number that progressively increase while each packet is transmitted over the media it usually proceed from zero up to an indefinite number.
2) Data Header Quality indicator. From version 2.4 this field represent: D=Data (indetermined quality), R=Raw data with no quality control, Q=Quality Controlled Data, some processes have been applied to the data
3) Reserved (set as ASCII = 32, blank)
4) Station identifier. Left justify, pad with blanks
5) Location identifier. Left justify, pad with blanks
6) Channel identifier. Left justify, pad with blanks
7) Two characters alphanumeric used to identify the network operator responsible for the data logger. The identifier is assigned by IRIS Data Management Center in consultation with FDSN working group on the SEED format.
8) BTIME struct stamping the time of the packet
9) UWORD specifiyng the number of samples in the record
10) WORD Sample rate factor
    If it is > 0 means the factor is in Sample Per Second
    If it is < 0 means the factor is in Seconds Per Sample
    If it is = 0 means the factor is in Seconds Per sample (Used for ASCII and OPAQUE data records)
11) Sample rate multiplier
12) UBYTE: Activity flag (see SEED Reference Manual page 99)
13) UBYTE: I/O Flags and clock flags (see SEED Reference Manual page 99)
14) UBYTE: Data Quality Flags (see SEED Reference Manual page 99)
15) UBYTE: Total number of blockette that follows
16) LONG: Time correction: (see SEED Reference Manual page 99)
17) UWORD: Offset in bytes of the beginning of data.
18) UWORD: Offset in bytes to the first data blockette in this data record. Enter 0 if there are no data blockettes. The first byte in the data record is byte offset 0.

A note in the reference manual explains that all unused flags must be set to zero.

Problems with the Fixed Header interpretation

1) First headache problem comes from the sequence number, there is no explanation of what should happen when the number reaches its maximum representation allowed by the 6 chars ASCII decimal number. In other words when it arrives to 999999 it have to return to 0? When it returns to zero, what will happen to the dataloggers like Seiscomp or EarthWorm? No answer to this point, we can only be confident that from time to time the data server will be restarted closing the TCP/IP socket connection and allowing the client to correctly treat the new data coming with a starting number of 000000.

2) The D R Q Field. According to the Reference Manual from version 2.4 the data can be represented as D or R or Q. EarthWorm and Seiscomp (at least for now) only accept D, be aware of it!

3) BTIME structure. In the documentation of minSEED there is no explanation on what is the order to be used in storing the YEAR information and the DAY information neither about the fraction of seconds. We still to do not know if this struct is coded in little-endian or big-endian. It should be defined by the blockette 50 but there is no room for the blockette 50 in the miniSEED packet (usually long 512 bytes)

4) Beginning of data. Here we have the same problem of the BTIME structure. There is still no way to know how this pointer is repr esented. And what is the exact meaning of beginning of data? It means the beginning of the blockette? Or the beginning of the binary waveform data? Only a look to a hex dump of an already alive station "explained" that it is referred to the beginning of the waveform data.

5) First Blockette. We have the same problem of the byte order. Big-Endian or Little-Endian?

6) To make a long story short we can say that in this field the same problem affects also the, Sample Rate Factor and the sample rate multiplier, basicly all fields longer than 1 byte.

Little Endian and Big Endian Soap Story

Many web pages explains how the definition little-endians or big-endians describes the method by which information is stored in a computer's memory. The definition can be misleading (at least for not english speaking people). To better understand how this definition is created we have to go back to the Gulliver's Travels where the terms "big-endians" and "little-endians" were it relates to the conflict over what end of the boiled egg that had to be cracked first before you eat it.
To have a full understanding of the term you have to relate an egg as a data packet longer than 8 bytes (i.e. a 2 or 4 bytes integer). From what "end" of the INT or LONG integer you will begin to read (crack or eat) the data? If you begin from the little-end (the LSB) you are a little-endian machine, if you begin from the big-end (the MSB) you are a big-endian machine. Of course the pointer to the data is always the lower (as magnitude) of the address space.

So, let's take the example of the blockette 1000 identifier of the SEED protocol. In hexadecimal format we will write 1000 as 0x03E8. In memory this 2 byte integer can be stored with the sequence 03 E8 or E8 03. In the first case the byte containing 03 is read as first, and it is the MSB (the bigger end) so machines that read the integer in this way are the big-endian. The machine that store the number E8 as first also read it as first and being it the LSB (the little) are called the machine that read the integer beginning from the little-end and are called little-endians.
Architectures that follow this rule are called *little-endian* include Rockwell 6502 and Intel x86.
Architectures that follow the *big-endian* rule include Motorola 68000 and PowerPC.

Problems can also be proposed on what **bit** is read at first or considered first. See the Steim code compression section about it.

References

http://www.ling.upenn.edu/courses/Spring_2003/ling538/Lecnotes/ADfn1.htm
http://www.networksorcery.com/enp/ien/ien137.txt
http://www.sun.com/realitycheck/endian.pdf

The blockette type 1000 specifications

This is a Data Only SEED Blockette. It is 8 bytes long and has the following structure:

	Field name	Type	Length (bytes)
1	Blockette code	UWORD	2
2	Offset to the beginning of the next blockette	UWORD	2
3	Encoding format	UBYTE	1
4	Word order	UBYTE	1
5	Data record length	UBYTE	1
6	Reserved	UBYTE	1

1) The blockette code that contains always the number 1000.
2) The offset to the beginning of the next blockette
3) The encoding format according to the following basic table:

Code	Encoding Format
0	ASCII text, byte order as specified in field 4
1	16 bit integers
2	24 bit integers
3	32 bit integers
4	IEEE floating point
5	IEEE double precision floating point
10	STEIM (1) Compression
11	STEIM (2) Compression

4) The word order. According to the text in the SEED reference manual a zero (0) stands for little-endian and a one (1) for big endian (page 113)
5) The exponent of a base of 2 to specify the record length. In LISS miniSEED it is 9 that means 2 raised at the 9th power become 512.
6) Reserved

Problems with the blockette type 1000 interpretation

1) Reading this blockette code itself fall in the misunderstanding of the big-endian / little-endian code. The field 4 should be read first but we are not sure if we can point the field 4 (word order) because we don't know how to read this packet. Anyway considering that in miniSEED the first blockette field can be only 0x03E8 or 0xE803 the software should test the very first byte: if it is a 0x03 we are reading a packet wrote from a bigendian machine and if we read 0xE8 we are reading a packet wrote by a little-endian machine.

2) The encoding format. Anybody would expect that the basic data format would be supported by the popular Seiscomp and EarthWorm. Don't be so sure. EW absolutely refuse (at least the versions we tested) all encoding format except Steim1, Steim2 and Steim3 (not listed in the table above). We would expected to be able to send data at least in 32 bit integers. This is not possible with EW.

The blockette type 1001 specifications

This blockette is 8 bytes long and has the following structure:

	Field name	Type	length (bytes)
1	Blockette code	UWORD	2
2	Offset to the beginning of the next blockette	UWORD	2
3	Timing quality	UBYTE	1
4	Microseconds	BYTE	1
5	Reserved	UBYTE	1
6	Frame count	UBYTE	1

1) Blockette code that contains always the number: 1001
2) The offset to the beginiing of the next blockette
3) Timing quality. Can be used by the digitizer manufacturer to extimate the time quality of this data packet form 0 to 100% of accuracy.
4) Precision of the start time down to microseconds. This filed is present to improve the accuracy of the time stamping given by the fixed header time structure.
5) Reserved byte
6) Frame count. Is the number of 64 byte compressed data frames in the 4k record. (maximum of 63).

Problems with the blockette type 1001 interpretation

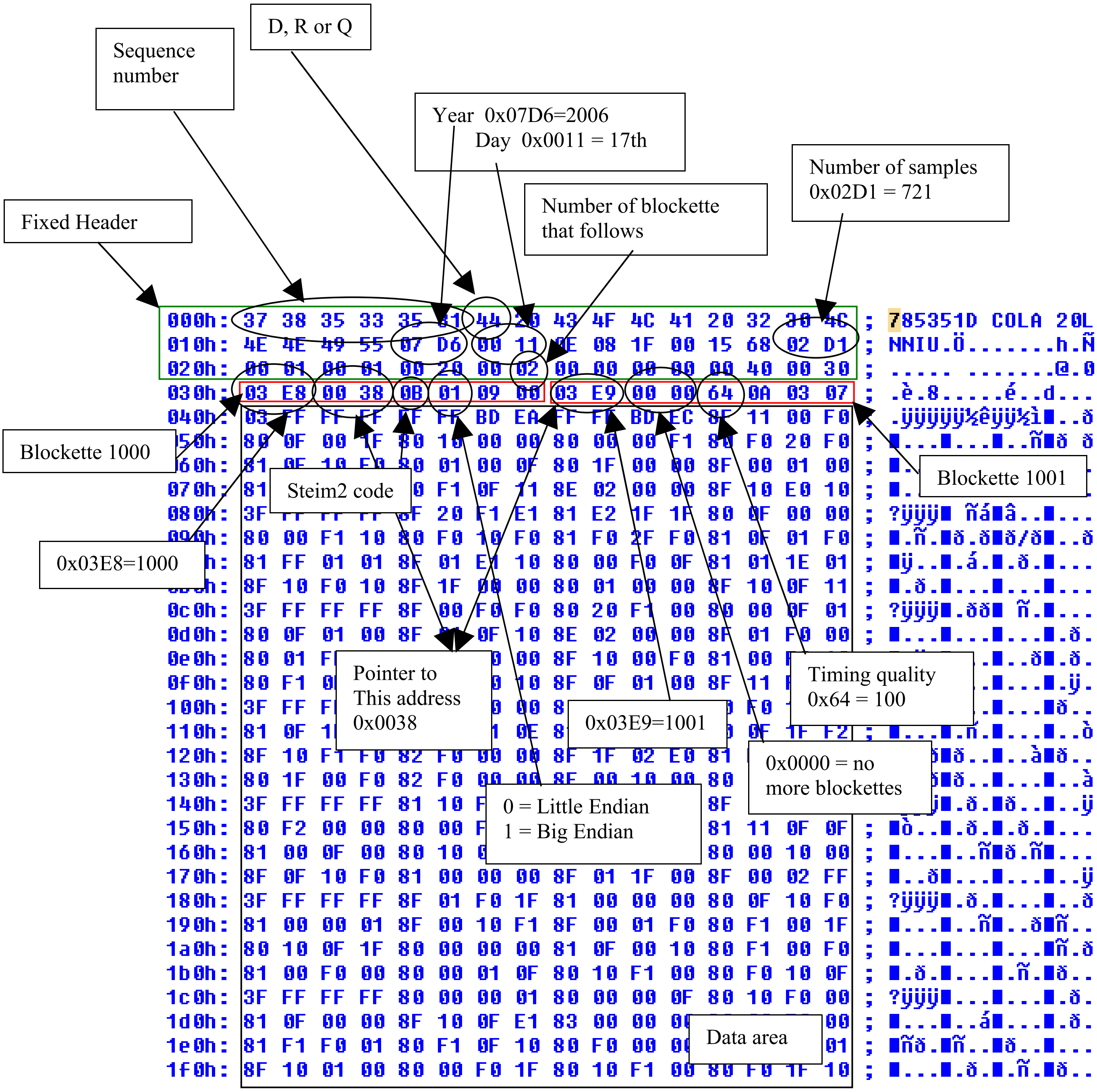
1) The field of the blockette code has the famous big/little problem as well as the offset field.

2) The Reserved field is used in some stations for example ***cola.iu.liss.org*** server is trasmitting a 0x03 number in this field. What is the meaning? It should be 0x00 isn't it? And if it is reserved, is reserved to whom and for what?

3) The frame count is not well explained. When you will look at the steim1 and steim2 compression description (that follows in this document) you will easily realize that this field is not needed. First of all if we don't have a compression there is no need to specify more pointers or length descriptors because there is already present a sample number field in the fixed header. Furthermore either the Steim1 and Steim2 code are self explanatory on how many samples are containing.
   Anyway according to what some LISS station issue on this field it have to be set to number 7 that are the frame that can be contained in a 448 bytes of data (7 x 64 = 448). Each SteimX frame is long 64 bytes.

Schematic interpretation of the LISS miniSEED 512 bytes packet

The following picture represent an hex dump of the station of ***cola.iu.liss.org***. The most important fields are specified and linked to a description box.



```
000h: 37 38 35 33 35 31 44 20 43 4F 4C 41 20 32 30 4C ; 785351D COLA 20L
010h: 4E 4E 49 55 07 D6 00 11 0E 08 1F 00 15 68 02 D1 ; NNIU.Ö.......h.Ñ
020h: 00 01 00 01 00 20 00 02 00 00 00 00 00 40 00 30 ; ..... .......@.0
030h: 03 E8 00 38 0B 01 09 00 03 E9 00 00 64 0A 03 07 ; .è.8.....é..d...
040h: 03 FF FF FF FF FF BD EA FF FF BD EC 8F 11 00 F0 ; .ÿÿÿÿÿ½êÿÿ½ì■..ð
050h: 80 0F 00 1F 80 10 00 00 80 00 00 F1 80 F0 20 F0 ; ■...■...■..ñ■ð ð
060h: 81 0F 10 F0 80 01 00 0F 80 1F 00 00 8F 00 01 00 ; ■.[illegible]
070h: 81 [illegible] 0 F1 0F 11 8E 02 00 00 8F 10 E0 10 ; ■.[illegible]
080h: 3F FF FF FF 8F 20 F1 E1 81 E2 1F 1F 80 0F 00 00 ; ?ÿÿÿ■ ñá■â..■...
090h: 80 00 F1 10 80 F0 10 F0 81 F0 2F F0 81 0F 01 F0 ; ■.ñ.■ð.ð■ð/ð■..ð
0a0h: 81 FF 01 01 8F 01 E1 10 80 00 F0 0F 81 01 1E 01 ; ■ÿ..■.á.■.ð.■...
0b0h: 8F 10 F0 10 8F 1F 00 00 80 01 00 00 8F 10 0F 11 ; ■.ð.■...■...■...
0c0h: 3F FF FF FF 8F 00 F0 F0 80 20 F1 00 80 00 0F 01 ; ?ÿÿÿ■.ðð■ ñ.■...
0d0h: 80 0F 01 00 8F [illegible] 0F 10 8E 02 00 00 8F 01 F0 00 ; ■...■...■...■.ð.
0e0h: 80 01 F[illegible] 00 8F 10 00 F0 81 00 F[illegible] ; [illegible].■..ð■.ð.
0f0h: 80 F1 0[illegible] 10 8F 0F 01 00 8F 11 F[illegible] ; [illegible].■...■.ÿ.
100h: 3F FF F[illegible] 00 8[illegible] F0 [illegible] ; [illegible].■...■ð..
110h: 81 0F 1[illegible] 1 0E 8[illegible] 0F 1F F2 ; ■...■.ñ.■...■..ò
120h: 8F 10 F1 F0 82 F0 00 00 8F 1F 02 E0 81 [illegible] ; [illegible]ð■ð..■..à■ð..
130h: 80 1F 00 F0 82 F0 00 00 8F 00 10 00 80 [illegible] ; [illegible]ð■ð..■...■..à
140h: 3F FF FF FF 81 10 F[illegible] 8F [illegible] ; [illegible]■.ð.■ð..■..ÿ
150h: 80 F2 00 00 80 00 F[illegible] 81 11 0F 0F ; ■ò..■.ð.■.ð.■...
160h: 81 00 0F 00 80 10 0[illegible] 80 00 10 00 ; ■...■..ñ■ð.ñ■...
170h: 8F 0F 10 F0 81 00 00 00 8F 01 1F 00 8F 00 02 FF ; ■..ð■...■...■..ÿ
180h: 3F FF FF FF 8F 01 F0 1F 81 00 00 00 80 0F 10 F0 ; ?ÿÿÿ■.ð.■...■..ð
190h: 81 00 00 01 8F 00 10 F1 8F 00 01 F0 80 F1 00 1F ; ■...■..ñ■..ð■ñ..
1a0h: 80 10 0F 1F 80 00 00 00 81 0F 00 10 80 F1 00 F0 ; ■...■...■...■ñ.ð
1b0h: 81 00 F0 00 80 00 01 0F 80 10 F1 00 80 F0 10 0F ; ■.ð.■...■.ñ.■ð..
1c0h: 3F FF FF FF 80 00 00 01 80 00 00 0F 80 10 F0 00 ; ?ÿÿÿ■...■...■.ð.
1d0h: 81 0F 00 00 8F 10 0F E1 83 00 00 0[illegible] 00 ; ■...■..á■...■.ð.
1e0h: 81 F1 F0 01 80 F1 0F 10 80 F0 00 0[illegible] 01 ; ■ñð.■ñ..■ð..■...
1f0h: 8F 10 01 00 80 00 F0 1F 80 10 F1 00 80 F0 1F 10 ; ■...■.ð.■.ñ.■ð..
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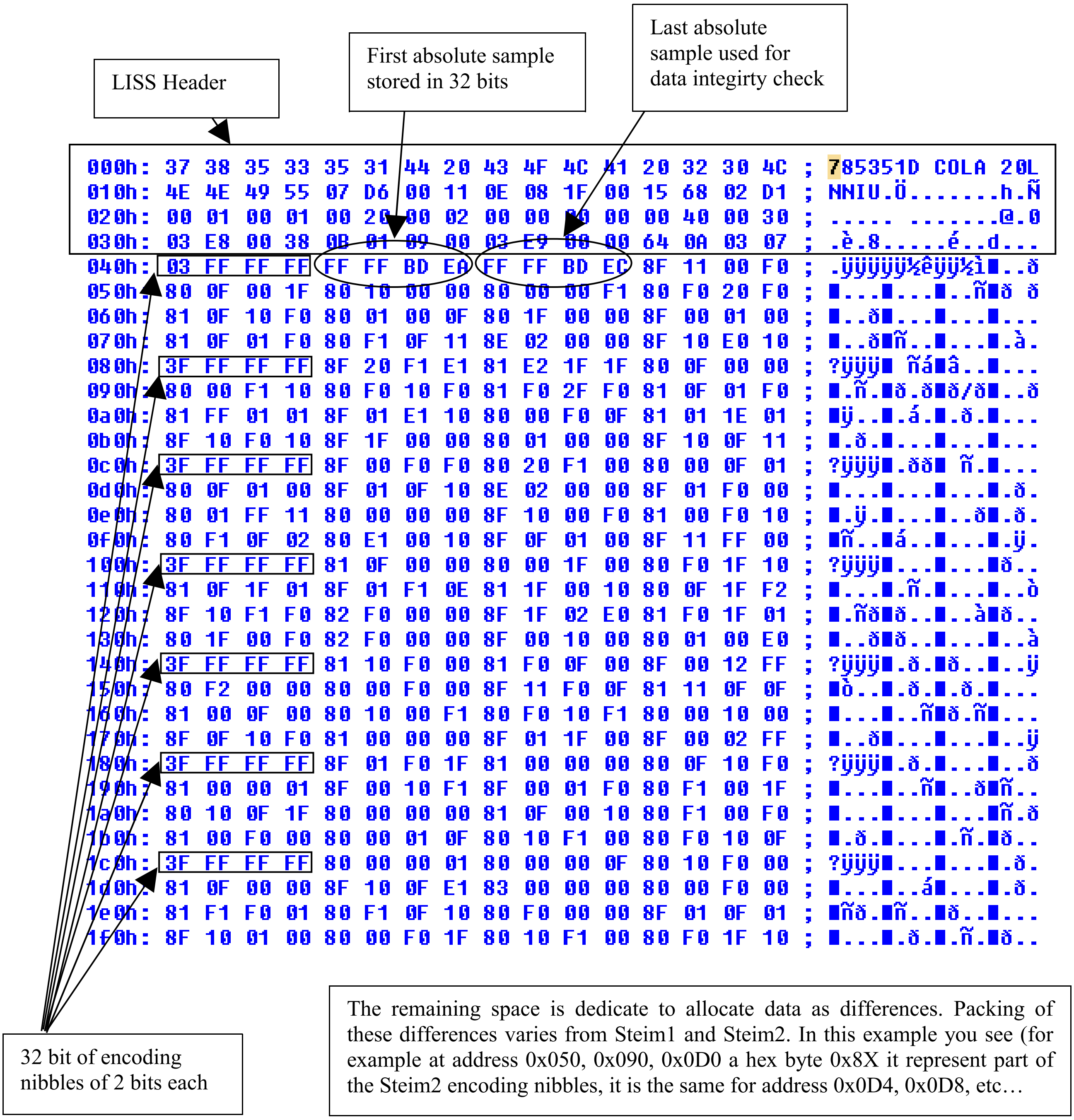
The Steim1 and Steim2 coding (common information)

A time series of sampled seismic data coded in 24 bit or 32 bit integers require much more room than the background seismic noise itself would need. Only extracting the difference from samples can remove the majority of the unused binary information, this not solve the needs when large signal are recorded and the differences also increase accordingly with the signal amplitude. This request more space in integers. A solution is to pack the differences using a dynamic allocation method. This is what Steim1 and 2 do. (The Steim algorythm is copyrighted by Dr. Joseph Steim)

Both steim1 and 2 are based on the first difference between samples where difference is: $d_0 = x_0 - x_{-1;}$ $d_1 = x_1 - x_{0;}$ $d_1 = x_2 - x_{1;}$ etc… but pack the differences in two differents method:

1) Steim1 use only 4 packet length to store the differences in 32 bit integers: 1 difference 32 bits, 2 differences each in 16 bits, 4 differences each one in 8 bits.
2) Steim2 uses 7 different packets to store the difference even in 32 bits integers: 1 difference in 30 bits, 2 differences each in 15 bits, 3 differences each in 10 bits, 4 differences each in 8 bits, 5 differences each in 6 bits, 6 differences each in 5 bits, 7 differences each in 4 bits.

Before describe in details how the Steim1 and 2 compression algorythm works it is better to represent in the hex dump where the various fields are located. After this also a binary dump is discussed.



```
000h: 37 38 35 33 35 31 44 20 43 4F 4C 41 20 32 30 4C ; 785351D COLA 20L
010h: 4E 4E 49 55 07 D6 00 11 0E 08 1F 00 15 68 02 D1 ; NNIU.Ö.......h.Ñ
020h: 00 01 00 01 00 20 00 02 00 00 00 00 00 40 00 30 ; ..... .......@.0
030h: 03 E8 00 38 0B 01 09 00 03 E9 00 00 64 0A 03 07 ; .è.8.....é..d...
040h: 03 FF FF FF FF FF BD EA FF FF BD EC 8F 11 00 F0 ; .ÿÿÿÿÿ½êÿÿ½ì■..ð
050h: 80 0F 00 1F 80 10 00 00 80 00 00 F1 80 F0 20 F0 ; ■...■...■..ñ■ð ð
060h: 81 0F 10 F0 80 01 00 0F 80 1F 00 00 8F 00 01 00 ; ■..ð■...■...■...
070h: 81 0F 01 F0 80 F1 0F 11 8E 02 00 00 8F 10 E0 10 ; ■..ð■ñ..■...■.à.
080h: 3F FF FF FF 8F 20 F1 E1 81 E2 1F 1F 80 0F 00 00 ; ?ÿÿÿ■ ñá■â..■...
090h: 80 00 F1 10 80 F0 10 F0 81 F0 2F F0 81 0F 01 F0 ; ■.ñ.■ð.ð■ð/ð■..ð
0a0h: 81 FF 01 01 8F 01 E1 10 80 00 F0 0F 81 01 1E 01 ; ■ÿ..■.á.■.ð.■...
0b0h: 8F 10 F0 10 8F 1F 00 00 80 01 00 00 8F 10 0F 11 ; ■.ð.■...■...■...
0c0h: 3F FF FF FF 8F 00 F0 F0 80 20 F1 00 80 00 0F 01 ; ?ÿÿÿ■.ðð■ ñ.■...
0d0h: 80 0F 01 00 8F 01 0F 10 8E 02 00 00 8F 01 F0 00 ; ■...■...■...■.ð.
0e0h: 80 01 FF 11 80 00 00 00 8F 10 00 F0 81 00 F0 10 ; ■.ÿ.■...■..ð■.ð.
0f0h: 80 F1 0F 02 80 E1 00 10 8F 0F 01 00 8F 11 FF 00 ; ■ñ..■á..■...■.ÿ.
100h: 3F FF FF FF 81 0F 00 00 80 00 1F 00 80 F0 1F 10 ; ?ÿÿÿ■...■...■ð..
110h: 81 0F 1F 01 8F 01 F1 0E 81 1F 00 10 80 0F 1F F2 ; ■...■.ñ.■...■..ò
120h: 8F 10 F1 F0 82 F0 00 00 8F 1F 02 E0 81 F0 1F 01 ; ■.ñð■ð..■..à■ð..
130h: 80 1F 00 F0 82 F0 00 00 8F 00 10 00 80 01 00 E0 ; ■..ð■ð..■...■..à
140h: 3F FF FF FF 81 10 F0 00 81 F0 0F 00 8F 00 12 FF ; ?ÿÿÿ■.ð.■ð..■..ÿ
150h: 80 F2 00 00 80 00 F0 00 8F 11 F0 0F 81 11 0F 0F ; ■ò..■.ð.■.ð.■...
160h: 81 00 0F 00 80 10 00 F1 80 F0 10 F1 80 00 10 00 ; ■...■..ñ■ð.ñ■...
170h: 8F 0F 10 F0 81 00 00 00 8F 01 1F 00 8F 00 02 FF ; ■..ð■...■...■..ÿ
180h: 3F FF FF FF 8F 01 F0 1F 81 00 00 00 80 0F 10 F0 ; ?ÿÿÿ■.ð.■...■..ð
190h: 81 00 00 01 8F 00 10 F1 8F 00 01 F0 80 F1 00 1F ; ■...■..ñ■..ð■ñ..
1a0h: 80 10 0F 1F 80 00 00 00 81 0F 00 10 80 F1 00 F0 ; ■...■...■...■ñ.ð
1b0h: 81 00 F0 00 80 00 01 0F 80 10 F1 00 80 F0 10 0F ; ■.ð.■...■.ñ.■ð..
1c0h: 3F FF FF FF 80 00 00 01 80 00 00 0F 80 10 F0 00 ; ?ÿÿÿ■...■...■.ð.
1d0h: 81 0F 00 00 8F 10 0F E1 83 00 00 00 80 00 F0 00 ; ■...■..á■...■.ð.
1e0h: 81 F1 F0 01 80 F1 0F 10 80 F0 00 00 8F 01 0F 01 ; ■ñð.■ñ..■ð..■...
1f0h: 8F 10 01 00 80 00 F0 1F 80 10 F1 00 80 F0 1F 10 ; ■...■.ð.■.ñ.■ð..
```

LISS Header

First absolute sample stored in 32 bits

Last absolute sample used for data integirty check

32 bit of encoding nibbles of 2 bits each

The remaining space is dedicate to allocate data as differences. Packing of these differences varies from Steim1 and Steim2. In this example you see (for example at address 0x050, 0x090, 0x0D0 a hex byte 0x8X it represent part of the Steim2 encoding nibbles, it is the same for address 0x0D4, 0x0D8, etc…

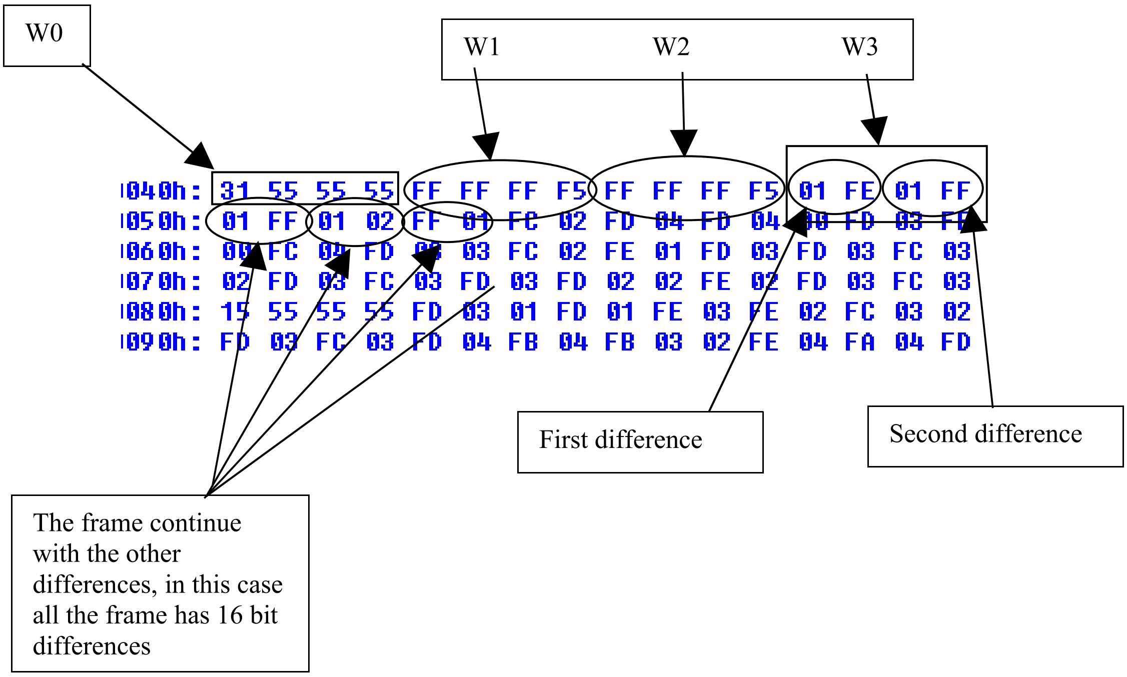
The Steim1 encoding
The Steim1 encoding is accomplished basicly on the following rules:

a) Each frame is composed of 64 bytes
b) Each frame is divided in 16 words of 4 bytes each
c) The first 4 bytes contain 16 nibbles each 2 bits long that specify the encoding mode of the next 15 words
d) Each word can contain 4 samples (8 bit long), 2 samples (16 bit long), 1 sample (32 bit long)
e) Each word can contain only differences coded in the same way
f) In the nibble coding: 0b00=no data; 0b01=8 bit data, 0b10=16 bit data, 0b11=24 bit data

The following table shows the frame structure and the position of the nibble coding table. The binary nibble in the table are only as examples and vary according to the encoding signal.

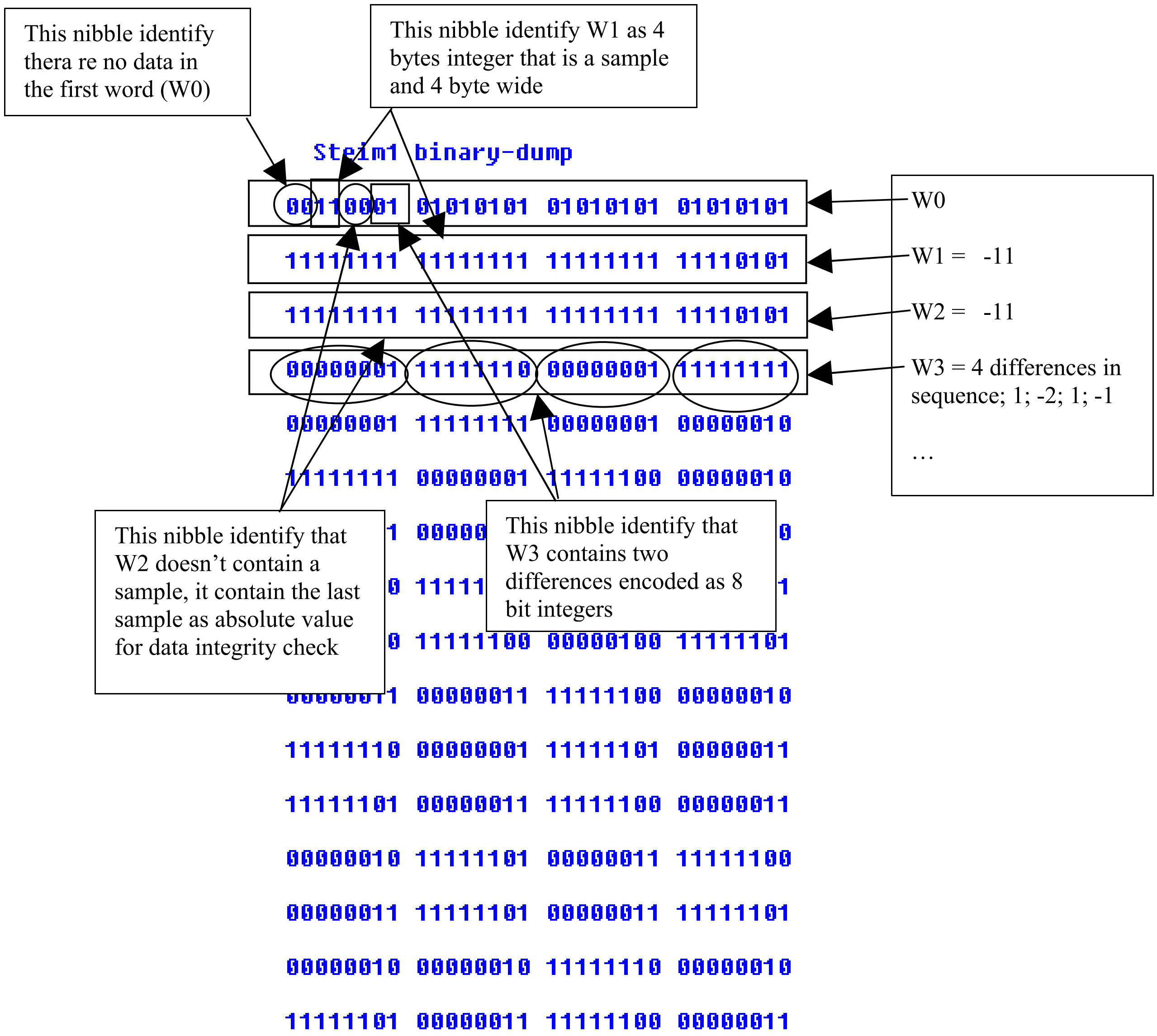
	C0	C1	C2	Cx	C15
W0	0b00 W0 itself	0b01 W1	0b10 W2	0bXX Wx	0b11 W15
W1	Four 8 bit samples: d0, d1, d2 and d3				
W2	C1=01 = two 16 bit samples; d4 and d5 (in this example)				
Wx	Wx code				
W15	1 sample. The 32 bit integers contain the last difference of the frame long 4 bytes because C15=0b11				

The writing routine must keep in account that the very second long word of the frame contain the very first absolute sample and the third long word contain the last absolute sample of the frame. For both the code is 4 bytes long and follow or the big-endian rule or the little-endian rule.


W0
W1
W2
W3
First difference
Second difference
The frame continue with the other differences, in this case all the frame has 16 bit differences

```
0040h: 31 55 55 55 FF FF FF F5 FF FF FF F5 01 FE 01 FF
0050h: 01 FF 01 02 FF 01 FC 02 FD 04 FD 04 00 FD 03 FF
0060h: 00 FC 04 FD 03 03 FC 02 FE 01 FD 03 FD 03 FC 03
0070h: 02 FD 03 FC 03 FD 03 FD 02 02 FE 02 FD 03 FC 03
0080h: 15 55 55 55 FD 03 01 FD 01 FE 03 FE 02 FC 03 02
0090h: FD 03 FC 03 FD 04 FB 04 FB 03 02 FE 04 FA 04 FD
```

The following scheme shows the same frame in binary.



This nibble identify thera re no data in the first word (W0)

This nibble identify W1 as 4 bytes integer that is a sample and 4 byte wide

This nibble identify that W2 doesn't contain a sample, it contain the last sample as absolute value for data integrity check

This nibble identify that W3 contains two differences encoded as 8 bit integers

W0

W1 = -11

W2 = -11

W3 = 4 differences in sequence; 1; -2; 1; -1

…

```
Steim1 binary-dump
00110001 01010101 01010101 01010101
11111111 11111111 11111111 11110101
11111111 11111111 11111111 11110101
00000001 11111110 00000001 11111111
00000001 11111111 00000001 00000010
11111111 00000001 11111100 00000010
       1 00000                     0
       0 11111                     1
       0 11111100 00000100 11111101
00000011 00000011 11111100 00000010
11111110 00000001 11111101 00000011
11111101 00000011 11111100 00000011
00000010 11111101 00000011 11111100
00000011 11111101 00000011 11111101
00000010 00000010 11111110 00000010
11111101 00000011 11111100 00000011
```

MSI Version 1.4 Output of the above mSEED file

```
Detected record length of 512 bytes
NN_STATI_LL_SHZ, 000003, D
start time: 2006,017,12:39:50.720000
number of samples: 413
sample rate factor: 50  (50 samples per second)
sample rate multiplier: 1
number of blockettes: 2
time correction: 0
data offset: 64
first blockette offset: 48
BLOCKETTE 1000: (Data Only SEED)
next blockette: 56
encoding: STEIM 1 Compression (val:10)
byte order: Big endian (val:1)
record length: 512 (val:9)
BLOCKETTE 1001: (Data Extension)
next blockette: 0
timing quality: 100%
micro second: 0
frame count: 7
                              decimal dump in decoded values:
   -11     -10     -12     -11     -12     -11     -12     -11      -9     -10      -9     -13
   -11     -14     -10     -13      -9      -9     -12      -9     -10   etc… etc.…. Last value:  -11
```

Problems with the Steim1 encoding algorythm experienced using the SEED Reference Manual (page 129-132)

1) Seems there are no reference on where the first absolute sample and the last check sample should be stored inside the frame. The position we explained before is based on conclusion of analysis of packet recorded from miniSEED LISS remote stations. The position seems to be logical and reasonably well made but not well documented
2) Data check integrity with the TCP/IP protocol as transport media seems to be an overkill considering the TCP/IP already perform all the needed data integrity check. A backward compatible method to avoid the storing of the integrity check value could be advisable
3) Results in coding Steim1 packet has been successfully achieved testing the packets with DumpSeed and with MSI, EarthWorm seems to do not accept the data integrity value, Seiscomp test are under progress until during the editing of this document

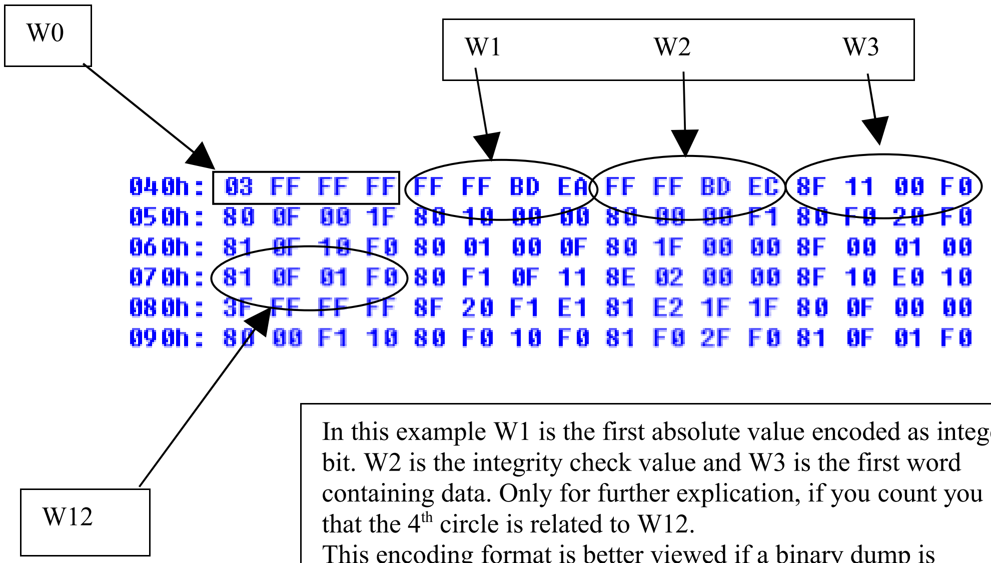
The Steim2 encoding
The Steim2 encoding is accomplished basicly on the following rules:

a) Each frame is composed of 64 bytes
b) Each frame is divided in 16 words of 4 bytes each
c) The first 4 bytes contain 16 nibbles each 2 bits long that specify the encoding mode of the next 15 words
d) Each word can contain 2 more encoding nibbles in the 30th and 31st bits
e) The words can contain differences of variable length of 30, 15, 10, 8, 6, 5, 4 bits.
f) Each word can contain only differences coded in the same way
g) In the nibble coding: 0b00=no data; 0b01=8 bit data, 0b10=point to the additional encoding nibble and rules of type A applies to it, 0b11=point tothe additional encoding nibble and rules of type B applies to it

Additional encoding nibble type A:	0b01=one 30 bit difference in Wx 0b10=two 15 bit differences in Wx 0b11=three 10 bit differences in Wx
Additional encoding nibble type B:	0b01=one 6 bit difference in Wx 0b10=two 5 bit differences in Wx 0b11=three 4 bit differences in Wx

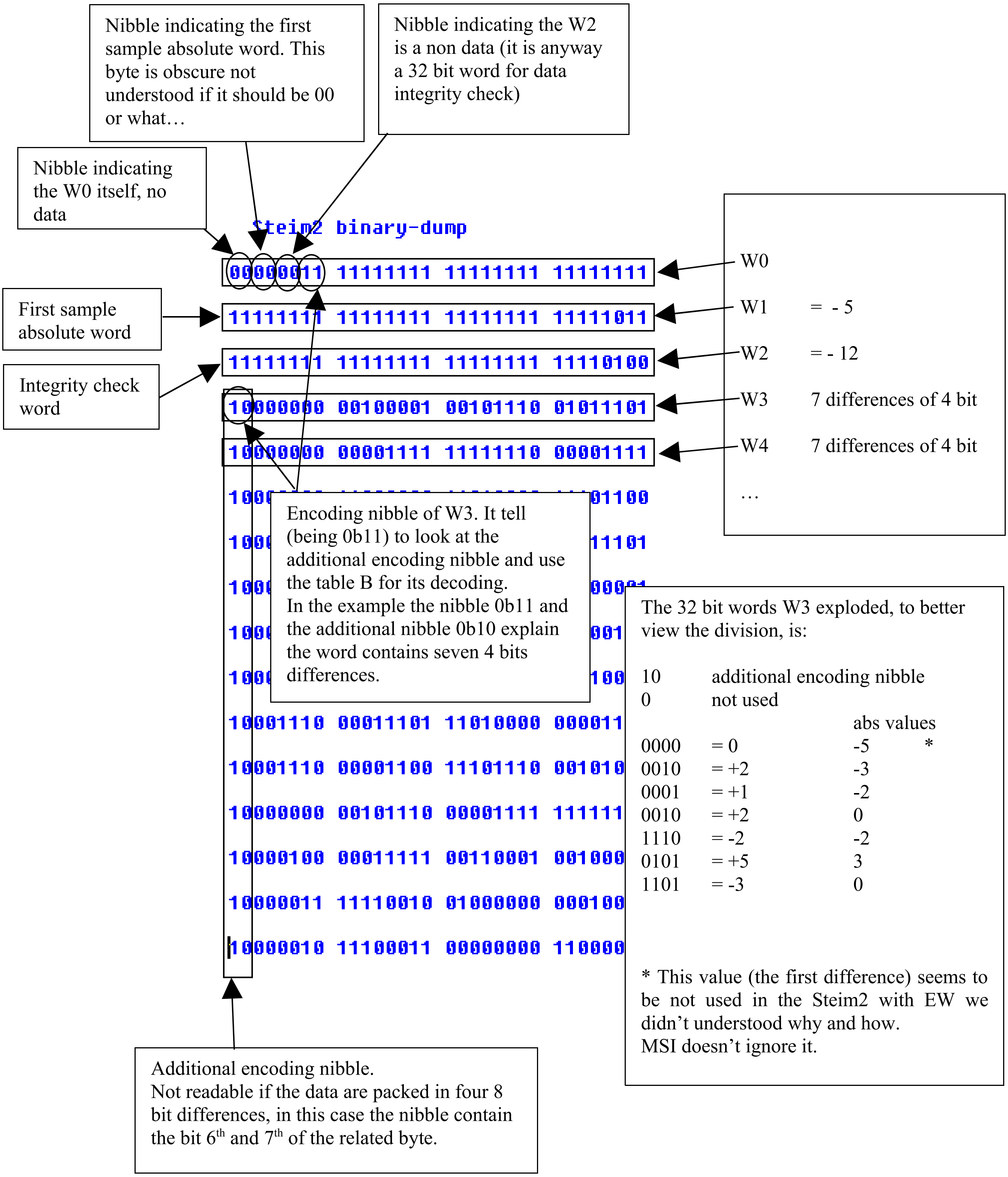
The following table shows the frame structure and the position of the nibble coding table. The binary nibble in the table are only as examples and vary according to the encoding signal.

	C0	C1	C2	C3	C4	C5	C6	Cx	C15
W0	0b00 W0 itself	0b01 W1	0b11 W2	0b11 W3	0b11 W4	0b10 W5	0b10 W6	0bXX	0b10 W15
W1	0b01 (A)	30 bit (d0)							
W2	0b10 (A)	15 bit (d0)				15 bit (d1)			
W3	0b11 (A)	10 bit (d0)		10 bit (d1)			10 bit (d2)		
W4	8 bit (d0)		8 bit (d1)		8 bit (d2)			8 bit (d3)	
W5	0b01 (B)	6 bit (d0)	6 bit (d1)		6 bit (d2)	6 bit (d3)		6 bit (d4)	
Wx	0b10 (B)	7 bit (d0)	7 bit (d1)	7 bit (d2)		7 bit (d3)	7 bit (d4)	7bit (d5)	
W15	0b11 (B)	Not used	4 bit (d0)	4 bit (d1)	4 bit (d2)	4 bit (d3)	4 bit (d4)	4 bit (d5)	4bit (d6)



```
040h: 03 FF FF FF FF FF BD EA FF FF BD EC 8F 11 00 F0
050h: 80 0F 00 1F 80 10 00 00 80 00 00 F1 80 F0 20 F0
060h: 81 0F 10 F0 80 01 00 0F 80 1F 00 00 8F 00 01 00
070h: 81 0F 01 F0 80 F1 0F 11 8E 02 00 00 8F 10 E0 10
080h: 3F FF FF FF 8F 20 F1 E1 81 E2 1F 1F 80 0F 00 00
090h: 80 00 F1 10 80 F0 10 F0 81 F0 2F F0 81 0F 01 F0
```

In this example W1 is the first absolute value encoded as integer 32 bit. W2 is the integrity check value and W3 is the first word containing data. Only for further explication, if you count you see that the 4th circle is related to W12.
This encoding format is better viewed if a binary dump is examined; see the following paragraph.



Nibble indicating the first sample absolute word. This byte is obscure not understood if it should be 00 or what…

Nibble indicating the W2 is a non data (it is anyway a 32 bit word for data integrity check)

Nibble indicating the W0 itself, no data

First sample absolute word

Integrity check word

```
Steim2 binary-dump
00000011 11111111 11111111 11111111
11111111 11111111 11111111 11111011
11111111 11111111 11111111 11110100
10000000 00100001 00101110 01011101
10000000 00001111 11111110 00001111
1000                          01100
1000                          11101
1000                          0000
1000                          001
1000                          100
10001110 00011101 11010000 000011
10001110 00001100 11101110 001010
10000000 00101110 00001111 111111
10000100 00011111 00110001 001000
10000011 11110010 01000000 000100
10000010 11100011 00000000 110000
```

W0

W1 = - 5

W2 = - 12

W3 7 differences of 4 bit

W4 7 differences of 4 bit

…

Encoding nibble of W3. It tell (being 0b11) to look at the additional encoding nibble and use the table B for its decoding.
In the example the nibble 0b11 and the additional nibble 0b10 explain the word contains seven 4 bits differences.

The 32 bit words W3 exploded, to better view the division, is:

10	additional encoding nibble	
0	not used	
		abs values
0000	= 0	-5 *
0010	= +2	-3
0001	= +1	-2
0010	= +2	0
1110	= -2	-2
0101	= +5	3
1101	= -3	0

* This value (the first difference) seems to be not used in the Steim2 with EW we didn't understood why and how.
MSI doesn't ignore it.

Additional encoding nibble.
Not readable if the data are packed in four 8 bit differences, in this case the nibble contain the bit 6th and 7th of the related byte.

MSI Version 1.4 Output of the above mSEED file

```
Detected record length of 512 bytes
NN_STATI_LL_SHZ, 000024, D
start time: 2006,017,15:37:35.240000
number of samples: 721
sample rate factor: 50  (50 samples per second)
sample rate multiplier: 1
number of blockettes: 2
time correction: 0
data offset: 64
first blockette offset: 48
BLOCKETTE 1000: (Data Only SEED)
next blockette: 56
encoding: STEIM 2 Compression (val:11)
byte order: Big endian (val:1)
record length: 512 (val:9)
BLOCKETTE 1001: (Data Extension)
next blockette: 0
timing quality: 100%
micro second: 0
frame count: 7
        -5      -3      -2      0      -2      3      0      0      0      -1      -2      -4      -4      -5
        -5      -9      -9      -12    -12     -14    -18    -17    etc… etc… last value  = -12
```

Problems using Steim2 format

1) The second and the third encoding nibble in W0 has no explication in any manual
2) The very first difference seems to be ingnored by EW but not by MSI (not tested on DumpSEED); why it is skipped by EW? EW server send the very first difference (or the location where it should be) with a non sense value.