HD Radio™ Air Interface Design Description Station Information Service Transport

Rev. G

February 28, 2008

TRADEMARKS

iBiquity Digital Corporation
6711 Columbia Gateway Drive
Suite 500
Columbia, MD 21046
443.539.4290 (Telephone)
443.539.4291 (Facsimile)
info@ibiquity.com

Doc. No.: SY_IDD_1020s

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1 Scope

1.1 System Overview

The iBiquity Digital Corporation HD Radio™ system is designed to permit a smooth evolution from current analog amplitude modulation (AM) and frequency modulation (FM) radio to a fully digital in-band on-channel (IBOC) system. This system delivers digital audio and data services to mobile, portable, and fixed receivers from terrestrial transmitters in the existing medium frequency (MF) and very high frequency (VHF) radio bands. Broadcasters may continue to transmit analog AM and FM simultaneously with the new, higher-quality and more robust digital signals, allowing themselves and their listeners to convert from analog to digital radio while maintaining their current frequency allocations.

1.2 Document Overview

This document describes how control and information are passed through the SIS Transport for subsequent processing by Layer 2.

2 Referenced Documents

[1] iBiquity Digital Corporation, “HD Radio™ Air Interface Design Description - Layer 1 FM,” Doc. No. SY_IDD_1011s, Revision G.

[2] iBiquity Digital Corporation, “HD Radio™ Air Interface Design Description – Layer 1 AM,” Doc. No. SY_IDD_1012s, Revision F.

[3] iBiquity Digital Corporation, “HD Radio™ Air Interface Design Description – Layer 2 Channel Multiplex,” Doc. No. SY_IDD_1014s, Revision H.

[4] International Organization for Standardization (ISO), “English Country Names and Code Elements,” ISO 3166-1 and corresponding ISO 3166-1-alpha-2 Code Elements.

[5] United States Department of Transportation, “Uniform Time Act of 1966,” Public Law 89-387, April 13, 1966, 80 Statute 107, 15 U.S.C §260a.

[6] United States Congress (United States Department of Energy), “Energy Policy Act of 2005,” Public Law 109-058, August 8, 2005.

[7] United States Federal Communications Commission (FCC), “Media Bureau Consolidated Database System (MB CDBS),” Web URL: http://www.fcc.gov/mb/cdbs.html.

[8] United States National Geospatial-Intelligence Agency (NGA), “Department of Defense World Geodetic System 1984, Its Definition and Relationships with Local Geodetic Systems,” Third Edition, 4 July 1997. NIMA Technical Report TR8350.2. Web URL: http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html

[9] United States National Institute of Standards and Technology (NIST), “Information about the new Daylight Saving Time (DST),” Web URL: http://tf.nist.gov/timefreq/general/dst.htm

[10] EU European Parliament and Council, “Proposal for a European Parliament and Council directive on summer-time arrangements,” Web URL: http://europa.eu/bulletin/en/200012/p104047.htm

[11] International Earth Rotation and Reference Systems Service (IERS), “Bulletin C - Announcement of Leap Seconds in UTC,” Web URL: http://www.iers.org/

[12] International Organization for Standardization, “Information Technology - 8-bit single-byte coded graphic character sets - Part 1: Latin Alphabet 1,” ISO/IEC 8859-1:1998. Web URL: http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=28245

[13] International Organization for Standardization, “Information Technology - Universal Multiple-Octet Coded Character Set (UCS) - Part 1: Architecture and Basic Multilingual Plane,” ISO/IEC 10646-1:2000. Web URL: http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=29819

3 Abbreviations and Conventions

3.1 Abbreviations and Acronyms

ADV	Advanced Processing
ALFN	Absolute L1 Frame Number
AM	Amplitude Modulation
ASCII	American Standard Code for Information Interchange
CRC	Cyclic Redundancy Check
DST	Daylight Saving Time
EBU	European Broadcasting Union
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
FM	Frequency Modulation
GPS	Global Positioning System
IBOC	In-Band On-Channel
ID	Identification
ID3	Tag Embedded In MPEG I Layer III Files
ISO	International Organization for Standardization
L1	Layer 1
LSB	Least Significant Bit
MF	Medium Frequency
MIME	Multipurpose Internet Mail Extensions
MSB	Most Significant Bit
MSG	Message
PDU	Protocol Data Unit
PIDS	Primary IBOC Data Service Logical Channel
RBDS	Radio Broadcast Data System
SIS	Station Information Service
UTC	Coordinated Universal Time
VHF	Very High Frequency
WGS	World Geodetic System

3.2 Presentation Conventions

Unless otherwise noted, the following conventions apply to this document:

- All vectors are indexed starting with 0.
- The element of a vector with the lowest index is considered to be first.
- In drawings and tables, the leftmost bit is considered to occur first in time.
- Bit 0 of a byte or word is considered the most significant bit.
- When presenting the dimensions of a matrix, the number of rows is given first (e.g., an n x m matrix has n rows and m columns).
- In timing diagrams, earliest time is on the left.
- Binary numbers are presented with the most significant bit having the lowest index.
- In representations of binary numbers, the least significant bit is on the right.
- Hexadecimal numbers are represented by a prefix of “0x”

4 Station Information Service Protocol Data Unit Format

The Station Information Service (SIS) provides broadcast station identification and control information. SIS is transmitted in a series of SIS Protocol Data Units (PDUs) on the Primary IBOC Data Service (PIDS) logical channel. For more information on PIDS see [1] and [2]. SIS PDUs are 80 bits in length as shown in Figure 4-1. The most significant bit of each field is shown on the left. Layer 2 and Layer 1 process MSBs first; that is, bit 0 is the first bit interleaved by L1. The PDU contents are defined by several control fields within the PDU. The Type bit is normally set to zero. If this bit is a one, the remainder of the PDU contents may be different. This option is reserved for future use.

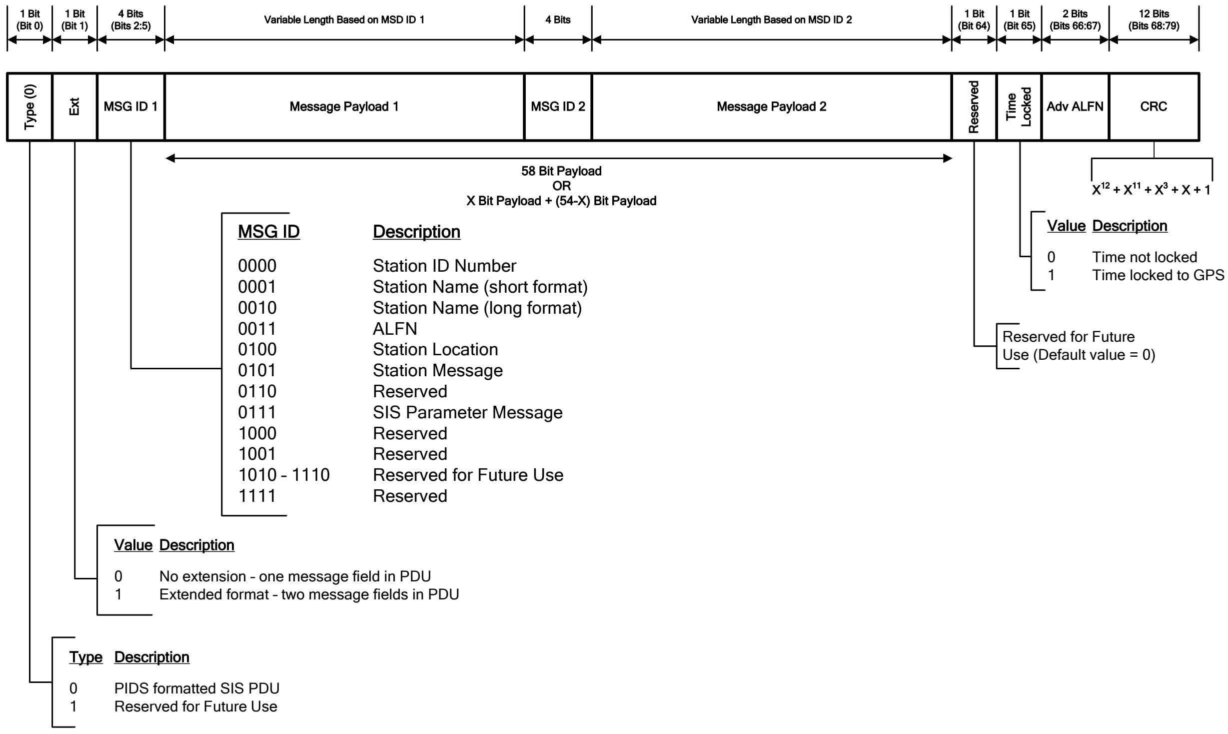

Figure 4-1: SIS PDU Format – Type = 0

Type 0 PDUs may contain two, independent, variable-length, short message fields or a single longer message, depending on the state of the Ext bit. If the Ext bit equals 0, the message 1 field is up to 58 bits in length and the message contents are determined by the state of the first message ID field, MSG ID 1. Any unused bits at the end of the message payload 1 field are zeroed. If the Ext bit equals 1, then the first message has its length and contents defined by MSG ID 1, and the second message is active, with length and contents defined by MSG ID 2. In this case, the combined lengths of the two messages must be no greater than 54 bits. Any unused bits at the end of message payload 2 are zeroed.

The definitions of the MSG ID 1 and MSG ID 2 fields are identical. Refer to Table 4-1 for details of the MSG ID field. Any message may be placed in either message 1 or message 2 provided that the total 56-bit available payload length is not violated. Longer messages must use the single message option (Ext = 0).

Table 4-1: MSG ID Definitions

MSG ID	Payload Size (bits)	Description	Comments
0000	32	Station ID Number	Used for networking applications Consists of Country Code and FCC Facility ID.
0001	22	Station Name – short format	Identifies the 4-alpha-character station call sign plus an optional extension
0010	58	Station Name – long format	Identifies the station call sign or other identifying information in the long format May consist of up to 56 alphanumeric characters
0011	32	ALFN	Identifies the current Absolute Layer 1 Frame Number (ALFN)
0100	27	Station Location	Provides the 3-dimensional geographic station location Used for receiver position determination
0101	58	Station Message	Allows a station to send an arbitrary text message
0110	27	Reserved	Reserved
0111	22	SIS Parameter Message	Carries the Leap Second/Time Offset and Local Time data parameters
1000	58	Reserved	Reserved
1001	58	Reserved	Reserved
1010 - 1110	TBD	Reserved	Reserved for future use
1111	TBD	Reserved	Reserved

The following subsections describe each message type (MSG ID).

4.1 Station ID Number (MSG ID = 0000)

This message type is uniquely assigned to each broadcasting facility. Figure 4-2 shows the message structure for the Station ID Number.

Figure 4-2: Station ID Number – Message Structure

Table 4-2 lists and describes the fields in the Station ID Number.

Table 4-2: Station ID Number – Field Names and Field Descriptions

Field Name	Number of Bits	Field Description
Country Code	10	In binary representation, the ten bits shall be used to represent the two-character country code as specified in Reference [4]
Reserved	3	Reserved bits default to “0”
FCC Facility ID (U.S. only)	19	Binary representation of unique facility ID assigned by the FCC in the U.S. Reference: [7]

With regard to the Country Code, the ISO 3166-1-alpha-2 code elements are two-letter codes. At the time of this publication, there were 244 code elements (that is, 244 countries) represented.

Table 4-3 maps each five bit binary sequence to its decimal equivalent and its alpha character.

Table 4-3: Mapping Five-Bit Binary Sequences to Decimal Equivalents and Alpha Characters

Five-Bit Binary Sequence	Decimal Equivalent	Alpha Character
00000	0	A
00001	1	B
00010	2	C
00011	3	D
00100	4	E
00101	5	F
00110	6	G
00111	7	H
01000	8	I
01001	9	J
01010	10	K
01011	11	L
01100	12	M
01101	13	N
01110	14	O
01111	15	P
10000	16	Q
10001	17	R

Five-Bit Binary Sequence	Decimal Equivalent	Alpha Character
10010	18	S
10011	19	T
10100	20	U
10101	21	V
10110	22	W
10111	23	X
11000	24	Y
11001	25	Z

Note that the alpha characters are capital letters from the English alphabet.

As an example, using the details from Table 4-3, for the United States (US), the individual-letter decimal equivalents for the US would be 20 (U) and 18 (S); the individual-letter binary equivalents for the US would be 10100 (U) and 10010 (S).

To form a country code, these two five-bit binary numbers are concatenated to form a single 10-bit binary number. The left-most character is contained in the most significant bits. In binary, the country code (US) would be 1010010010 and in decimal, the country code (US) would be 658.

Other country code examples include Canada (CA) which would be 0001000000 in binary and 64 in decimal; Brazil (BR) would be 0000110001 in binary and 49 in decimal.

4.2 Station Name

This message type has both a short format and a long format. The short format may be used with the two-message PDU structure so that it may be multiplexed with other messages and thus can be repeated frequently. The long format requires the single-message structure and may be extended across multiple PDUs. This format can be used to identify stations by a moderately long text string.

4.2.1 Station Name – short format (MSG ID = 0001)

Four-character station names may be broadcast with the short format. The field is 22 bits in length with the first bit on the left. Figure 4-3 shows the message structure for the Station Name (short format).

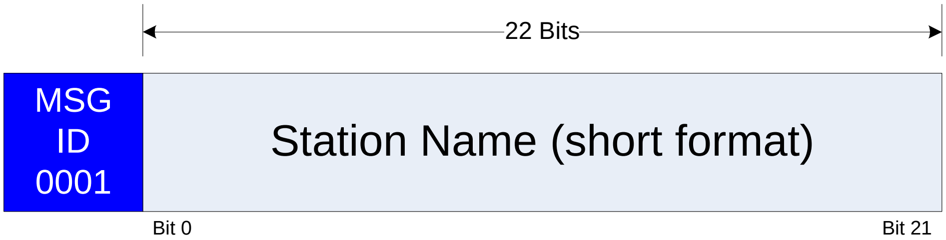

Figure 4-3: Station Name (short format) – Message Structure

Each character is five bits in length (MSB first, or leftmost), followed by a 2-bit extension. Refer to Table 4-4 for details of the field bit assignments (positions) and Table 4-5 for the character definitions. Only upper-case characters are defined, plus a limited number of special characters, as shown. The space character may be used, for example, to terminate a three-character call sign.

The first five bits are assumed to contain the leftmost character. For example, a station name of “ABCD” would be encoded in binary as 00000 00001 00010 00011 00. The 2-bit extension may be used to append an extension to the right of the other four characters (00 in the preceding example).

Table 4-4: Station Name (short format) – Field Bit Assignments (Positions)

Field Bit Positions	Description
0:4	Leftmost Character
5:9	Second Leftmost Character
10:14	Third Leftmost Character
15:19	Rightmost Character
20:21	Extensions: 00 = no extension 01 = Append “-FM” 10 = Reserved for future use 11 = Reserved for future use

Table 4-5: Station Name (short format) – Character Definitions

Value (MSB:LSB)	Character
00000, 00001, 00010,…, 11001	A, B, C,…, Z See Table 4-3
11010	space character
11011	?
11100	-
11101	*
11110	$
11111	Reserved

4.2.2 Station Name – long format (MSG ID = 0010)

The long format permits the station name to consist of textual strings. Each message contains seven characters encoded as 7-bit ISO-8859-1 characters [12]. In other words, it uses the first 128 characters of the ISO-8859-1 character set and the most significant bit of the 8-bit character code is truncated to form a 7-bit character.

The Station Name (long format) accommodates up to 56 characters in the name.

A character string may be extended over up to eight PDUs. The first three bits of the field specify the frame number of the last frame (or equivalently, the total number of SIS PDUs containing the message minus one) and the next three bits specify the frame number of the current PDU. PDU number zero is considered the leftmost of the string. The seven most significant station name bits within a PDU define the leftmost character for that PDU. For the last SIS PDU of the string, unused message bits are filled in with null characters (0x00).

The three LSBs of the Station Name message structure define the sequence number. This number is incremented modulo eight each time the character string is changed. The sequence number will only change within the PDU containing frame 0 of the message. All frames of the same message content will always have the same sequence number.

Figure 4-4 illustrates the message structure for Station Name (long format).

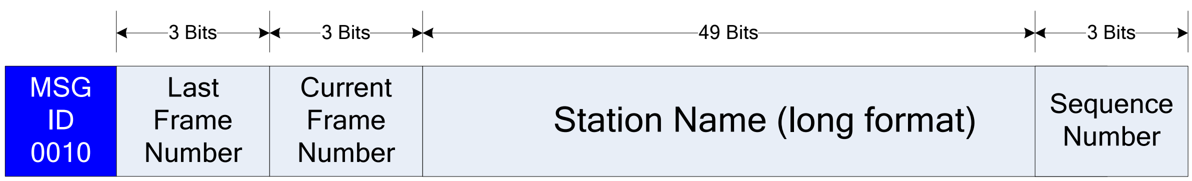

Figure 4-4: Station Name (long format) – Message Structure

4.3 Absolute Layer 1 Frame Number (MSG ID = 0011)

This message type contains the 32-bit Absolute Layer 1 Frame Number (ALFN). Figure 4-5 shows the message structure for ALFN.

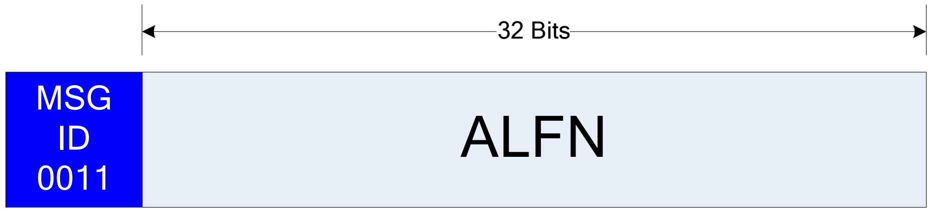

Figure 4-5: ALFN – Message Structure

ALFN increments every L1 frame period coincident with the start of L1 block 0. In all AM and FM service modes, the ALFN that is sent corresponds to the actual frame number at the time it is broadcast over the air. Refer to Reference [1] or [2] for details. If bit 65 of a PDU (regardless of MSG ID 1 or MSG ID 2) is set to one, ALFN is locked to GPS time. In such cases, ALFN can be used to provide a precise time of day in the receiver. If bit 65 is cleared, ALFN is not GPS-locked. In this case, ALFN may only be used to estimate a time of day.

The contents of this “standard ALFN” field are the same as that sent in the “Advanced Processing ALFN” (ADV ALFN) field (bits 66:67), but provides an optional method to supply ALFN in parallel rather than in a serial fashion. See Subsection 5.3 for more details on ADV ALFN.

“Standard ALFN” is optional and is not transmitted on a guaranteed schedule. The broadcaster can choose to send or schedule it or to not send it at all. On the other hand, although ADV ALFN is always transmitted, it takes a longer time to acquire due to its low bit rate and time diversity. Thus, broadcast stations that choose to send audio or data applications that require a faster ALFN acquisition can send it in the “standard ALFN”.

4.4 Station Location (MSG ID 0100)

This message type indicates the absolute three-dimensional location of the feedpoint of the broadcast antenna. Such location information may be used by the receiver for position determination. The message structure is shown in Figure 4-6. Position information is split into two messages: a high portion and a low portion.

Altitude is in units of [meters·16] (that is, the LSB is equal to 16 meters). Latitude and longitude are both in the same fractional formats. The LSB is equal to 1/8192 degrees. The MSB is the sign bit, which indicates the hemisphere. Positive longitude values represent positions north of the equator. Positive latitudes are in the eastern hemisphere. Longitude ranges are from -180 to +180, while permissible latitude values are between -90 and +90. Anything outside of these ranges is invalid. Refer to Subsection 5.1 for an example.

Used by the Global Positioning System, the World Geodetic System 84 (WGS 84) is used as the reference datum for location information. See Reference [8].

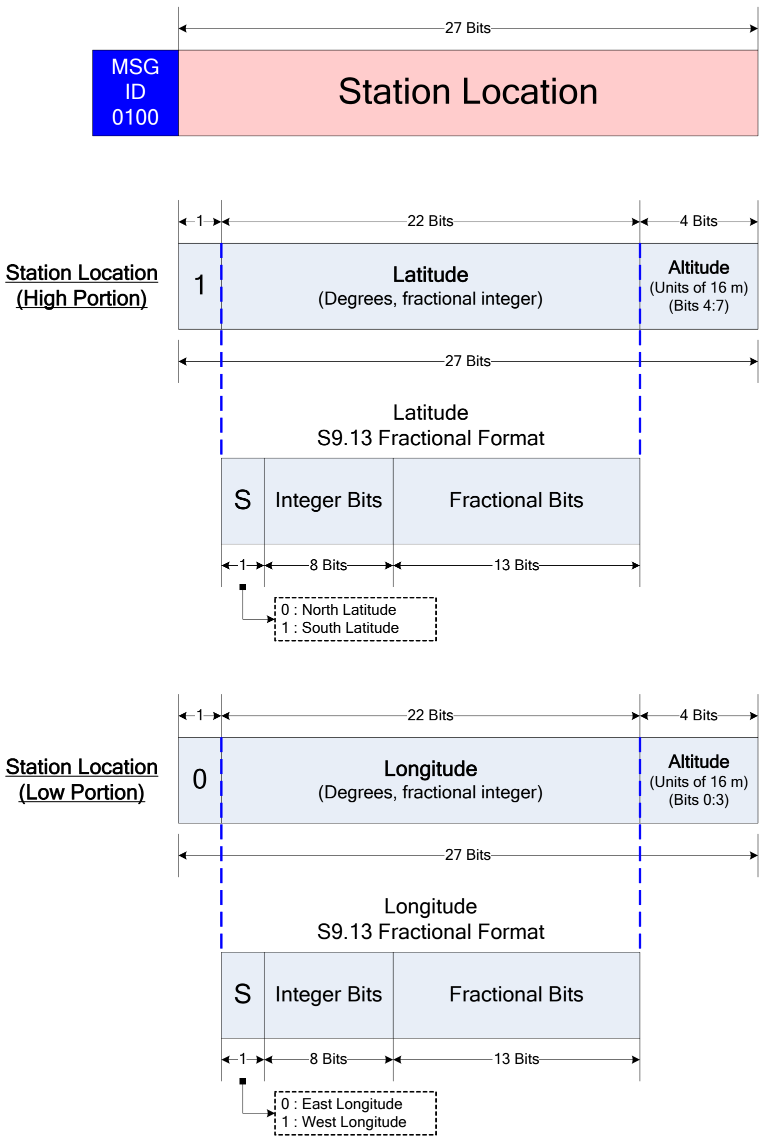

Figure 4-6: Station Location – Message Structure

4.5 Station Message (MSG ID 0101)

This message type allows the station to send any arbitrary text message. Examples include public service announcements, weather reports, or telephone call-in numbers. The Station Message has a total payload of 58 bits. This message can span over multiple frames. Figure 4-7 shows the message structure for the Station Message. The format of the first frame is different from the others, as shown.

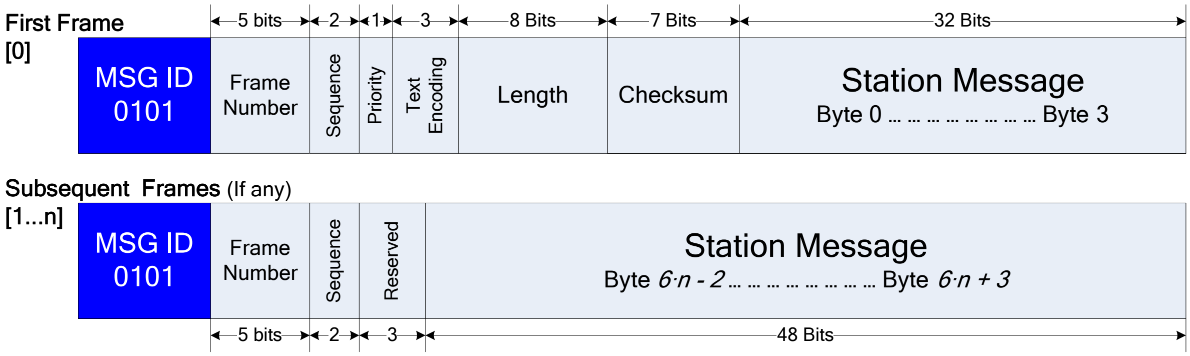

Figure 4-7: Station Message – Message Structure

The Station Message can be used to send a string of up to 190 8-bit characters [12] or 95 16-bit characters [13] per message. A message may span up to 32 frames. Each message contains a sequence number, indicating when the message text or priority has changed. A priority indicator is included to indicate that a message has an elevated importance. When multiple messages are broadcast, a message with the priority indicator set will advance to the top of the receiver queue. Any change in the message content or the priority is considered a new message and the sequence number is incremented. A 7-bit checksum is included in the first frame to increase receive reliability.

Table 4-6 and Table 4-7 describe the data fields for the first and subsequent frames, respectively.

Table 4-6: Description of Station Message Fields for Frame Number = 0

Field Name	Range	Description
Frame Number	0 - 31	Indicates the current frame number of the message Set to zero for the first frame
Sequence	0 - 3	Increments by 1, modulo 4, whenever the station message text and/or priority changes A new sequence number must commence with frame 0 and the same number shall be used for all frames of a given Station Message
Priority	0 - 1	Priority = 0: Normal priority Priority = 1: High priority When multiple Station Messages are broadcast, the receiver shall place a high priority message at the top of the queue as soon as it is received
Text Encoding	0 - 7	See Table 4-8
Length	4 - 190	Defines the total number of bytes of the Station Message text, excluding any unused bytes in the last frame For 16-bit character encoding, the Length must be even
Checksum	0 - 127	Checksum of all the data bytes of the Station Message text, excluding overhead bytes Refer to Figure 4-8 for details

Field Name	Range	Description
Station Message	N/A	For 8-bit character encoding, frame 0 contains the first 4 characters of the Station Message Byte 0 is the leftmost character For single-frame Station Messages, any unused bytes to the right of the Station Message text are filled with NULL characters (0x00) For 16-bit character encoding, frame 0 contains the first 2 characters of the Station Message Bytes 0:1 convey the leftmost character For single-frame Station Messages, any unused byte pairs to the right of the Station Message text are filled with NULL characters (0x00 00)

Table 4-7: Description of Station Message Fields for Frame Number = 1 to n

Field Name	Range	Description
Frame Number	0 - 31	Indicates the current frame number of the message
Sequence	0 - 3	Increments by 1, modulo 4, whenever the station message text and/or priority changes A new sequence number must commence with frame 0 and the same number shall be used for all frames of a given Station Message
Reserved	0 - 7	Reserved for future use
Station Message	N/A	For 8-bit character encoding, frames 1 to n contain the additional characters of the Station Message, where the lowest numbered byte within a frame is the leftmost for that frame For the last frame, any unused bytes to the right of the Station Message text are filled with NULL characters (0x00) For 16-bit character encoding, frames 1 to n contain additional characters of the Station Message, where the lowest numbered byte-pair within a frame is the leftmost for that frame For the last frame, any unused byte pairs to the right of the Station Message text are filled with NULL characters (0x00 00)

Table 4-8: Text Encoding Definitions

Value	Service Type
000 (default)	ISO/IEC 8859-1:1998 (Reference [12])
001	Reserved
010	Reserved
011	Reserved
100	ISO/IEC 10646-1:2000 UCS-2 (Little Endian) (Reference [13])
101 - 111	Reserved

Figure 4-8 illustrates the method used to calculate the 7-bit checksum. First, a 16-bit sum is computed by adding together all of the bytes of the station message text bytes (excluding overhead). The message bytes and the sum are both treated as unsigned integers. The 16-bit sum is then divided into a high (most significant) byte and a low (least significant) byte. The most significant bit of the high byte (bit 15 in Figure 4-8) is cleared. The high and low bytes are then summed together and the seven least significant bits of the sum are written into the checksum field, where the most significant bit is the left-most checksum bit shown in Figure 4-7.

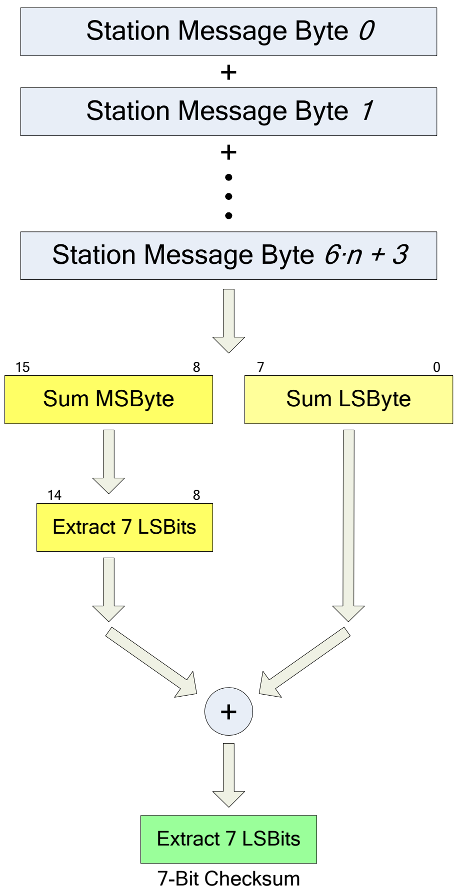

Figure 4-8: Checksum Calculation

4.6 SIS Parameter Message (MSG ID 0111)

This message type is used to carry various system parameters. The SIS Parameter Message has a payload of 22 bits which consists of a 6-bit index field and a 16-bit parameter field.

Figure 4-9 shows the message structure for the SIS Parameter Message.

Figure 4-9: SIS Parameter Message – Message Structure

The SIS Parameter Message indices are defined in Table 4-9.

Table 4-9: SIS Parameter Message Indices

Index	Parameter	Initial Value
0	Leap Second Offset Most significant byte: Pending Offset (8-bit signed) Least significant byte: Current Offset (8-bit signed) Refer to Subsection 5.4 for details on the application of the Leap Second	Reference [11]
1	ALFN representing the GPS time of a pending leap second adjustment (16 LSBs)	0
2	ALFN representing the GPS time of a pending leap second adjustment (16 MSBs)	0
3	Local Time Data (Refer to Subsection 4.6.1) Refer to Subsection 5.4 for details on the application of the Local Time parameters.	(Local data)
4 - 63	Reserved for future use.	—

The following subsections define the SIS Parameter Messages.

4.6.1 Local Time Parameters

The bit positions for the various Local Time parameters are summarized in Table 4-10.

Table 4-10: Local Time Parameters – Bit Positions

Bits	Parameter	Units	Format
0:10	Local Time Zone UTC Offset (See Subsection 4.6.1.1)	Minutes	Signed Integer
11:13	DST Schedule (See Subsection 4.6.1.2)	N/A	N/A
14	DST Local Deployment Indicator (See Subsection 4.6.1.3)	N/A	1 = yes
15	DST Regional Deployment Indicator (See Subsection 4.6.1.4)	N/A	1 = yes

4.6.1.1 Parameter – Local Time Zone UTC Offset

These bits constitute the higher order part of the word and provides static data on the local time zone (offset from UTC when DST not in effect, in minutes).

Data for the U.S. standard time zones are shown in Table 4-11. Time laws in the U.S. are the responsibility of the Department of Transportation (Reference [5]).

Table 4-11: Local Time Zone UTC Offset – U.S. Standard Time Zones

Time Zone Name	Bits (0:10)	UTC Reference
Atlantic	11100010000	(UTC –4 hours)
Eastern	11011010100	(UTC –5 hours)
Central	11010011000	(UTC –6 hours)
Mountain	11001011100	(UTC –7 hours)
Pacific	11000100000	(UTC –8 hours)
Alaska	10111100100	(UTC –9 hours)
Hawaii-Aleutian	10110101000	(UTC –10 hours)
Samoa	10101101100	(UTC –11 hours)
Chamorro	01001011000	(UTC +10 hours)
In addition, for Canada:		
Newfoundland	11100101110	(UTC –3 1/2 hours)

4.6.1.2 Parameter – DST Schedule

These bits provide static data on the schedule of Daylight Saving Time (DST) used regionally (for example, nationally), regardless of whether or not DST is practiced locally.

Table 4-12 shows the values of the bits 11:13 based on the Daylight Saving Time Schedule.

The dates and times in Table 4-12 are shown for reference; refer to the proper governing organization for the latest information (References [9] and [10]).

Table 4-12: DST Schedule

Bits 11:13	Daylight Saving Time Schedule
000	Daylight Saving Time not practiced in this nation (e.g., Japan, Central America) or Daylight Saving Time practiced on an irregular schedule (e.g., Israel, Palestine)
001	U.S./Canada Begins 2:00 AM on the second Sunday of March Ends 2:00 AM on the first Sunday of November Subject to change according to Reference [9]
010	European Union (EU): 01:00 UTC on last Sunday of March until 01:00 UTC on last Sunday of October. Subject to change according to Reference [10]
011 - 111	Reserved

Other global practices for DST may be added to this table as HD Radio broadcasts and receivers are introduced into those nations. An overflow of this table may be continued in another, future, SIS Parameter Message type.

In the United States and Canada, broadcasters must use a field value of 001 year-round, regardless of whether or not their local community practices Daylight Saving Time.

4.6.1.3 Parameter – DST Local Deployment Indicator

This bit provides static data on whether or not DST is practiced locally; 1 if it is and 0 if it is not.

In the United States, bit 14 is set to 1 year-round, except in Hawaii, American Samoa, Guam, Puerto Rico, the Virgin Islands, and major portions of Indiana and Arizona. In Canada, bit 14 is set to 1 year-round, except in most of Saskatchewan and portions of other Provinces, including British Columbia and Quebec.

The Energy Policy Act of 2005 extended Daylight Saving Time in the U.S. beginning in 2007, though Congress retained the right to revert to the 1986 law should the change prove unpopular or if energy savings are not significant. Going from 2007 forward, Daylight Saving Time in the U.S. begins at 2:00 a.m. on the second Sunday of March and ends at 2:00 a.m. on the first Sunday of November. See Reference [6].

Concurrence would require the use of UTC local offset 11001011100 (UTC – 7 hours), DST Schedule 001, and DST Practice (Bit 14) 0, year-round, in order to make California broadcasters most compatible with those of neighboring communities (e.g., Yuma, AZ).

Information regarding DST in this AIDD is subject to change, according to Reference [9].

4.6.1.4 Parameter – DST Regional Deployment Indicator

This bit provides seasonal data as to whether or not DST is in effect regionally (for example, nationally); 1 if it is and 0 if it is not.

Simple receivers can use this bit exclusively (ignoring Bits 11:13) to determine when to set the display clock one hour forward. Receivers should honor this bit only if Bit 14 or user setup indicates that DST is practiced locally. However, since this datum is not guaranteed in real time (either by all broadcasters, or in a timely manner by broadcasters that do provide it), more upscale receiver designs may instead prefer to internally compute the period of DST using the static data provided in bits 11:13. This will provide a better consumer experience. However, all receivers should honor this bit in preference to any predetermined schedule indicated by Bits 11:13. National rules for DST change occasionally and the receiver firmware may not be up-to-date or appropriate for the nation in which the receiver is being used.

In the United States and Canada, this bit should be set to 1 when the nation as a whole is practicing Daylight Saving Time (that is, in the summer), regardless of whether or not it is being practiced locally.

4.7 CRC Field

Each PDU is terminated with a 12-bit Cyclic Redundancy Check (CRC) for the purpose of aiding the receiver in detecting transmission errors. The CRC, ordered as PDU bits 79:68, is computed as follows:

1. Fill PDU bits 79:68 with zeros.
2. Perform modulo-two division of PDU bits 79:0 by the generator polynomial g(x),

   Where $g(x) = X^{12} + X^{11} + X^{3} + X + 1$

   and PDU bit 79 is computed first.
3. The 12-bit remainder is then copied back into PDU bits 68:79, where bit 68 is considered the most significant remainder bit and bit 79 is the least significant remainder bit.

5 Applications and Examples

5.1 Station Location Example

As an example of how the position information is constructed, consider a location at N 39˚ 11’ 46.32”, W 76˚ 49’ 6.59’, and an altitude of 90.7 meters. The first step is to convert latitude and longitude to decimal degrees:

Latitude = $39 + \frac{11}{60} + \frac{46.32}{3600} = 39.1962 \text{ deg}$

Longitude = $76 + \frac{49}{60} + \frac{6.59}{3600} = 76.8185 \text{ deg}$

The next step is to convert all three parameters to the proper fractional format:

Latitude: 39.1962˚ · 8192 = 321095 rounded to the nearest integer, = 0x04E647

Longitude: 76.8185˚ · 8192 = 629297 rounded to the nearest integer, = 0x099A31, however, it is necessary to take the two’s complement of this number to get West longitude = 0x3665CF

Altitude = ROUND (90.7/16) = 6 = 0x06

Finally, the parameters are packed into the appropriate message format:

High portion = 0x44E6470

Low portion = 0x3665CF6

It must be noted that frequency translator stations must exercise care in the use of the station ID number, station name, and station location. If the translator station acts as a repeater, then it will convey the station information of the primary station, not the translator station. It may be necessary for the translator station to produce its own station information to ensure proper operation of the system.

5.2 Example Scheduling of SIS PDUs on the PIDS Logical Channel

Table 5-1 shows an example of how SIS PDUs may be distributed across a single L1 frame. In FM there are 16 PIDS blocks per frame, while in AM there are only 8. In the example, the short format station name is sent in every PIDS block in the message 1 payload, while various types are sent in the second message payload. The leap second offset and the GPS time of a pending leap second adjustment parameters are not shown in this example, but the suggested message rates are approximately once per minute. Also, the scheduling of the Station message and Long Format Station Name is different since it can span multiple L1 frames.

Table 5-1: Example Scheduling of SIS PDU Messages

L1 Block #	MSG ID 1	Description	MSG ID 2	Description
0	0001	Station Name – short format	0011	ALFN
1	0001	Station Name – short format	0000	Station ID Number
2	0001	Station Name – short format	0000	Station ID Number
3	0001	Station Name – short format	0100	Station Location (High Portion)
4	0001	Station Name – short format	0000	Station ID Number
5	0001	Station Name – short format	0000	Station ID Number
6	0001	Station Name – short format	0100	Station Location (Low Portion)
7	0001	Station Name – short format	0000	Station ID Number

L1 Block #	MSG ID 1	Description	MSG ID 2	Description
8	0001	Station Name – short format	0000	Station ID Number
9	0001	Station Name – short format	0000	Station ID Number
10	0001	Station Name – short format	0000	Station ID Number
11	0001	Station Name – short format	0100	Station Location (High Portion)
12	0001	Station Name – short format	0000	Station ID Number
13	0001	Station Name – short format	0000	Station ID Number
14	0001	Station Name – short format	0100	Station Location (Low Portion)
15	0001	Station Name – short format	0000	Station ID Number

5.3 Advanced Absolute L1 Frame Number Processing

The SIS Transport allocates two bits to broadcast the absolute L1 frame number in a serial fashion. The format is different for AM and FM as outlined in the following two subsections. In both cases, the value of ALFN to be transmitted over the PIDS channel is updated coincident with L1 block 0 of each L1 frame.

The standard ALFN is optional while the ADV ALFN is always transmitted. The ADV ALFN uses less channel capacity than the standard ALFN. For applications where the ALFN is required in a parallel format, the standard ALFN can be used. “Advanced processing” is a term to indicate that there is more than just regular send and detect.

5.3.1 FM System Processing

The 16 LSBs, labeled d16 through d31in Figure 5-1, are transmitted as 2-bit pairs mapped into the ADV ALFN field of each PIDS block starting with block 0. ALFN bits d30:31 are broadcast at block 0 of each frame, ALFN bits d28:29 are broadcast at block 1 of each frame, and ALFN bits d16:17 are broadcast at block 7 of each frame.

ALFN bits d0:15 are further subdivided into pairs and mapped to the ADV ALFN field in blocks 8 through 15 as shown in Figure 5-1.

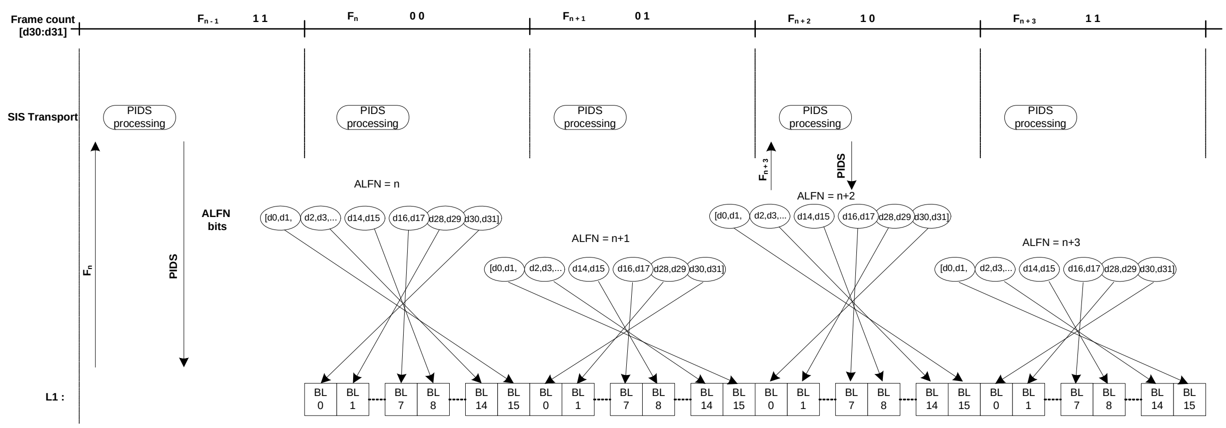

Figure 5-1: Broadcasting ALFN over the HD Radio FM System

5.3.2 AM System Processing

The 32 bits are subdivided into 16 bits numbered d16 through d31 (16 LSBs) and 16 bits indexed d0 through d15 (16 MSBs), as shown in Figure 5-2. ALFN bits d16:31 are subdivided into pairs and mapped to the two-bit ADV ALFN field of each PIDS block starting with block 0. ALFN bits d30:31 are broadcast at block 0 of each frame, ALFN bits d28:29 are broadcast at block 1 of each frame and ALFN bits d16:17 are broadcast at block 7 of the frame. This process takes place when ALFN d30:31 are not equal to 00.

ALFN bits d0:15 are subdivided into pairs and mapped to the ADV ALFN field in blocks 0 through 7 as shown. This occurs once with every four frames and is indicated when ALFN d30:31 are equal to 00.

The 16 LSBs of the ALFN are broadcast in three out of every four PIDS blocks; the 16 MSBs are broadcast once every four PIDS blocks.

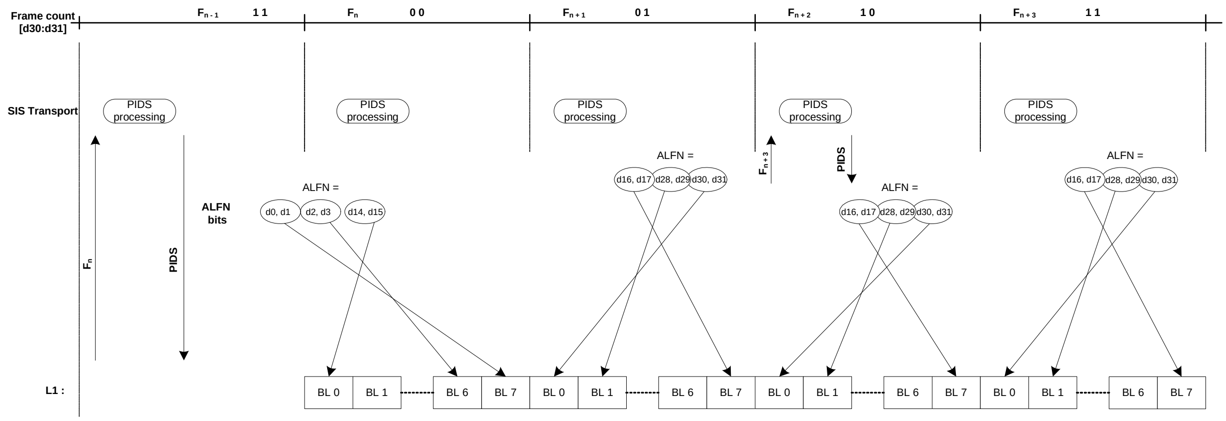

Figure 5-2: Broadcasting ALFN over the HD Radio AM System

5.3.3 Handling of Absolute L1 Frame Number in Layer 1

L1 does not handle ALFN directly, in regards to broadcasting the frame number. The frame number is conveyed over the PIDS logical channel in Layer 1 as part of a SIS message.

In all AM and FM service modes, the relevant portion of the ALFN being sent applies to the actual frame number at the time it is broadcast. Thus, Layer 1 must ensure proper synchronization of the ALFN being sent relative to absolute GPS time.

5.4 Clock Support

The SIS Transport allows for data to be broadcast making display clocks associated with receivers easier for consumers to use. The provision of these data by a broadcaster is optional if the ALFN is locked to GPS time (Bit 65 of the SIS PDU set to one), and forbidden if it is not (Bit 65 of the SIS PDU set to zero). If present at all, these data may be sent approximately once per minute, or otherwise at the convenience of the broadcaster. Receivers may utilize these data as best suits their design goals.

5.4.1 Handling Leap Seconds

The time standard for clocks around the world is UTC (Coordinated Universal Time). To keep UTC synchronized to astronomical time (defined by the earth's rotation), it is occasionally adjusted by a second. The adjustments average about once a year (so far) and occur as leap seconds, meaning all UTC clocks observe a 61 second minute at midnight when the adjustment occurs. The standard practice is to make adjustments at midnight UTC either December 31 or June 30.

As explained in Subsection 4.3, bit 65 of a PDU must be set to one for the ALFN to be locked to GPS time and for the time of day calculation to be accurate.

HD Radio transmissions may be synchronized to GPS time, which does not have any leap second adjustments. This means that GPS runs ahead of UTC and the receiver derives UTC time as follows:

$$\text{Time(UTC)} = \text{Time(GPS)} - \text{Leap Seconds}$$

$$\text{Time(UTC)} = (65536 / 44100) \cdot \text{ALFN} - \text{Leap Seconds}$$

Since 1980, 14 leap seconds have been added to UTC, so GPS is now running 14 seconds ahead of UTC. Leap second adjustments may occur periodically; if they occur, they will occur on June 30 or December 31. See Reference [11] for the latest information.

A SIS message is used to convey the current leap second correction factor.

The parameters that are needed to continuously account for leap seconds in the calculation of UTC from the ALFN are:

- the current time offset (GPS time – UTC time),
- ALFN representing the GPS time of a pending leap second adjustment,
- the new time offset after the adjustment.

These parameters are sent over the SIS and should be saved in persistent storage by the receiver so that accurate UTC time can be computed when necessary.

To ensure smooth operation during leap second adjustments, it is suggested that the broadcast system announce leap second adjustments several months in advance. In addition, pending leap second adjustments should continue to be broadcast for at least several hours after the adjustment event has occurred.

Note that the current number of leap seconds as well as the exact time of a pending leap-second adjustment is sent by the GPS satellite constellation as part of the GPS broadcast navigation message. Most GPS-locked time references provide this information and can be used for the HD Radio system.

5.4.2 Handling Local Time

Local time differs from UTC, owing to both the local time zone and the local practice with respect to observing some form of Daylight Saving Time (DST). SIS Parameter Message Index 3 provides digital data on these local customs, so that a receiver's digital display clock can automatically match the local time as spoken in main program audio.

These data describe the local custom at the location of the broadcaster, which may or may not be the same as the local custom at the place of the receiver. Near time-zone boundaries, consumers can receive a multiplicity of stations providing different data. Therefore, these data are provided only as *hints*, the interpretation and utilization of which should be made discretionary, subject to customer control. Receivers may use these data as initial guesses (for example, at initial installation) as to what a persistent configuration should be, with the expectation that consumers may manually adjust the initial guess. (Most of the time, no manual adjustment would be necessary.) Mobile receivers may have a design option to update their clocks with different, localized data as they travel across the country. Or receivers may ignore these data entirely.

AM broadcasters may refrain from transmitting, and AM receivers may refrain from interpreting, these data during evening and nighttime hours.

5.4.2.1 Examples

A number of examples drawn from in and near the State of Indiana can help illustrate what data broadcasters should provide, and how consumer receivers should interpret it. However, at the time of the writing of this document, the time zone and DST information changed, rendering these examples as useful for illustration only.

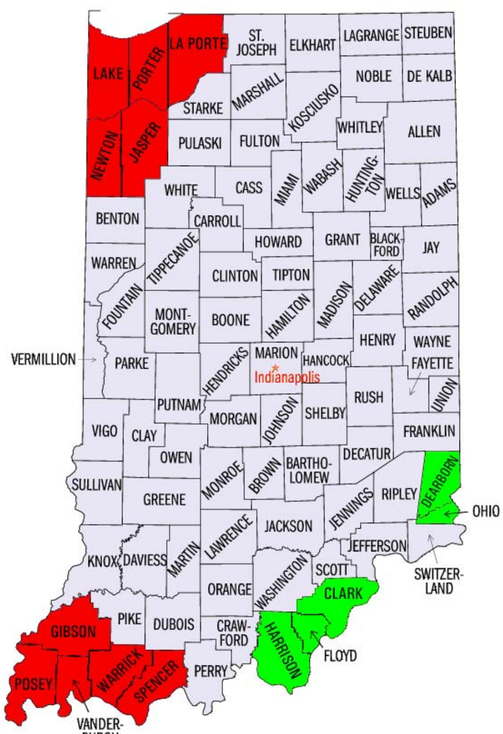

Figure 5-3: Local Time in Indiana

Indiana lies within the Eastern time zone, except for five counties in the northwest (near Chicago, IL) and five counties in the southwest (including Evansville, IN) that are in the Central time zone. These ten counties observe Daylight Saving Time, while the rest of the state officially does not. These ten counties are indicated in Figure 5-3 in red. However, two counties near Cincinnati, OH and three counties near

Louisville, KY unofficially observe Daylight Saving Time, along with their big-city neighbors. These five counties are indicated in Figure 5-3 in green.

Example 1, Indianapolis, IN

Local Time Parameter = 11011010100 001 0 S (S=0 in winter; S=1 in summer)

Like consumers in most of the country, few listeners to Indianapolis broadcasters (in the center of the state) would need to manually override these automatic settings. Because Bit 14 is 0 (and not manually overridden), receivers would not show Daylight Saving Time even when Bit 15 is 1 (in the summer).

Example 2, South Bend, IN, and Elkhart, IN

Local Time Parameter = 11011010100 001 0 S (S=0 in winter; S=1 in summer)

These cities, near the northern border of Indiana, follow the same local custom as Indianapolis. However, their market areas extend into southern Michigan (e.g., Cass County), which does observe Daylight Saving Time. Therefore, customers in Michigan should manually setup their receivers to observe DST regardless of any automatic data (on Bit 14) they might receive. Bits 11:13 and 15 are available for these receivers to use from their local Indiana broadcasters. Similarly, some customers in Indiana may wish to manually setup their receivers to not observe DST, regardless of any automatic data they might receive (e.g., from Michigan).

Example 3, Cincinnati, OH and Louisville, KY

Local Time Parameter = 11011010100 001 1 S (S=0 in winter; S=1 in summer)

For most of the listening area of these major cities, the automatic data would be correct. However, listeners in Indiana might want to manually setup their receivers to ensure that their local DST custom is followed consistently, no matter what stations they receive.

Example 4, Evansville, IN, Chicago, IL, and Northwest IN (e.g., Hammond, IN)

Local Time Parameter = 11010011000 001 1 S (S=0 in winter, S=1 in summer)

For most of these listening areas, the automatic data would be correct. However, listeners in surrounding areas might want to manually setup their receivers to ensure that their Local Time Zone and DST customs are followed consistently, no matter what stations they receive.