The National Weather Radio system (NWR)

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PREFACE

In the US, the National Weather Service (NWS) operates a network of radio transmitting stations across the country that disseminate weather information by voice. It is often called the National Weather Radio (NWR) system.

"Alert messages" about potentially hazardous weather conditions are preceded by a digital header, under what is known as the Specific Area Message Encoding (SAME) system, that identifies the type of hazard and the geographic area(s),typically counties or the equivalent, to which the alert applies.

This allows weather receivers to be programmed to only deliver the voice message (and perhaps sound an alarm) in the case of alert messages pertinent to the user's location.

A comparable and generally compatible system is operated in Canada by Environment Canada.

This article describes the US system in considerable detail.

1 INTRODUCTION

In the US, the National Weather Service (NWS), a component of the National Oceanographic and Atmospheric Administration (NOAA), operates a network of over 1000 radio transmitting stations across the country (and in most United States possessions and territories) that disseminate weather information by voice.

The overall system is often called the "NWR" system (National Weather Radio) system. This system is often spoken of as the "All Hazards" radio system, based on the fact that it can be used to warn of a range of hazardous events, including such events as earthquakes, that are not truly "weather" events.

Typically, the ongoing voice narrative comprises reports of the weather in the region served by that station, along with weather forecasts for various localities in that area. This are actually "spoken" by a speech synthesizer driven by a computer-generated "script". The different announcement items are repeated according to some plan, and the announcement stream is continuous.

But occasionally, “alert messages” about potentially hazardous events are inserted into the stream. They are preceded by a digital header that identifies the type of hazard and the geographic areas (typically counties or the equivalent), within the service area of the station, to which the alert applies. This digital encoding system is referred to as the SAME[1] (Specific Area Message Encoding) system.

A quite parallel and generally compatible system in Canada is operated by Environment Canada. There are some minor technical and operational differences from the United States system. The description here is specifically for the US system.

2 CAVEAT

The technical details of the NWR system undergo periodic changes, often advised by notices from NWS, and in any case are potentially subject to varying interpretations across the system. The details given herein are for information only, and cannot be guaranteed to be accurate nor current. Readers are cautioned not to rely on the information herein for, for example, the design of weather receivers.

3 RADIO BASICS

The NWR stations each transmit on one of seven carrier frequencies in the 162 MHz band. Typically, reliable reception can be had with a capable receiver at distances up to 40 miles from the station, but this of course can vary significantly depending on the locations of the transmitting antenna and the receiving antenna and the topography of the terrain. The technical details of the radio signal are given in Appendix A.

4 EVOLUTION OF ALERT ENCODING

4.1 The warning alert tone (WAT)

The earliest version of what became the NOAA Weather Radio system was a strictly voice announcement system. Eventually, it became the practice to precede “alert” messages by an 8 to 10 second burst of a single frequency tone at 1050 Hz, sent at a high modulation level.

Imagine that in the safety operations office of a school district there was a receiver tuned to the appropriate weather radio station. The audio from this would drone on, generally ignored by the office staff. But when there was a hazard alert message, the (relatively loud) tone burst would call attention to the following voice announcement.

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[1] Often presented as “S.A.M.E.“

Soon, there became available weather receivers that could be set to only deliver the voice message (and perhaps also give a locally-generated audible alert signal) when this tone burst was received.

This tone burst, which still plays a role in the system, came to be called the Warning Alert Tone (WAT).

4.2 The Specific Area Message Encoding (SAME) system

Eventually the simple tone alert system was superseded by the system used today, called the Specific Area Message Encoding (SAME) system. In this system, the voice announcement of an alert message is preceded by a digital header (sent 3 times) that identifies (among other things):

- The type of event[2] involved (from a long list of recognized events– there are over 80).

- The geographic areas to which the alert applies (commonly in terms of counties of certain states, or the equivalent, but in some cases over defined portions of a county or equivalent[3]).

In most cases this is followed, before the actual voice message begins, by an 8-10 second burst of a 1050 Hz tone (the Warning Alert tone, or WAT), just as was used in the earlier system.

The typical consumer "SAME capable" weather receiver can be programmed such that it will only deliver the voice transmission for an alert message which:

- Includes a location that is in a list set by the user in the receiver. (Alternatively, the user can set the receiver so that location is not considered.)

- Has an event type that is in a list set by the user in the receiver. (Receivers by default respond to a certain subset of all event types; also there are certain event types that must always be in the list.

When a message header meeting both of those criteria is received, the receiver typically sounds a locally-generated audible signal (typically a series of short beeps for perhaps 8 seconds), and then begins to deliver the audio signal through the receiver loudspeaker.

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[2] Although I have spoken here about messages about "hazards", the formal term for the subject of an alert message is "event", and for generality I will generally from now on use that term here.

[3] Hereinafter for conciseness I will jut say "state" and "county", it being understood that in some cases an equivalent is meant.

The presence of the warning alert tone (WAT) for 8-10 seconds allows time for such a locally-generated audible alert signal to be sounded without the user missing the early part of the voice announcement.

At the end of the voice announcement (which cannot be longer than 2 minutes), there is a digital end of message (EOM) signal, sent 3 times. This is usually heard through the receiver loudspeaker, since it has not yet been recognized as a digital signal[4]. When it is recognized, however, the receiver than mutes the audio channel so the following voice transmissions are not heard.

Of course, in all receivers, the use can set the receiver so that the audio channel goes to the loudspeaker all the time. In that case, all the voice transmissions (alert messages and the normal ongoing weather information narrative) will be heard, as well as the SAME digital header and EOM sequence for alert message.

Typically, the receiver will display the last-received alert message, and generally will provide for the use to examine earlier alert messages. Usually, even alert messages not set to give an audible alert tone and deliver the voice message are still displayed.

Not mentioned earlier, the header for an alert message will also specify a time period for which the alert is to be displayed. Typically the receiver, after expiry of this time for the message it displays, will delete its display.

5 EVENT IDENTIFIER

Each of the events in the "glossary" of the SAME encoding system has a three-character alphabetic code. These are generally mnemonic for the name of the event.

Most of these events are of one of the following classes, and the last letter of their codes is as follows[5]:

- W Warning
- A Watch
- E Emergency
- S Statement
- T Test

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[4] This is sometimes colloquially spoken of as the "duck farts".

[5] A few messages have mnemonic codes not following this schema, but they are being superseded by codes strictly following the schema.

For most weather and natural disaster events, a **Watch** message is typically issued first, when it seems like the adverse event may likely occur soon. When the event is clearly imminent, or has actually begun, a **Warning** message is issued.

Emergency messages typically relate to such things as a power grid or 911 service outage or Child Abduction Emergency alerts (the so called "Amber alerts").

Statement messages typically give urgent information in the wake of a severe weather event or the like.

Test messages are just what the name suggests. They are not considered to typically be of interest to the average civilian user.

6 THE LOCATION IDENTIFIERS

6.1 General

The location areas over which the applicability of NWR messages are defined are generally counties (or their equivalents). But some counties are subdivided into two or more portions, called "partitions". (That scheme is called "Partial County Alerting", or PCA).

The location areas are each identified by a 6-digit number (which I will call the "SAME location indicator").

The last five digits are a county identifier originally defined in FIPS (Federal Information Processing Standards) standards. The first two of those digits represent the state, DC, or territory, generally assigned in alphabetical order by the state name. The last three digits represent the county, within that state, generally assigned in alphabetical order by the county name.

The SAME location identifier consists of the 5-digit state/county code as just described plus one prefix digit (making a 6-digit code). If the county is not subdivided, that digit is "0". If the county is subdivided, the various partitions have the same last five digits but a distinct non-zero first digit.

In the case of a message intended to apply to all the partitions of a subdivided county, a single location identifier with a leading digit of "0" is used in the message header..

Similarly, if the user has programmed into the receiver's list of location codes a code with an initial digit of "0" for a county that is actually subdivided, this implies that the receiver should alert for the code for any partition of that county, or for all of it (that is, any first digit value).

A code with the last three digits of "000" implies the entire state.

Sometimes the last 5-digit portion of this identifier is called (in this context) the "FIPS code" This is not really apt, because of course

there are many coded things defined in the many FIPS standards[6]. In other cases the entire 6-digit SAME location identifier is called the "FIPS code", which is even less apt.

6.2 Special location areas

In general, independent cities (not part of any county or equivalent) are assigned location codes as if they were counties. Similarly, large metropolitan areas, perhaps partly in several counties, are given their own arbitrary location codes. In such cases, the "county" field has a number above the range of numbers used for counties in that state.

6.3 For certain bodies of water

There are also location identifiers assigned to a various bodies of water (largely coastal, and the Great Lakes) that cannot readily be defined in terms of a "county". Such regions have pseudo-state codes beyond those assigned to actual states. "Zones" of these have pseudo-county codes.

7 RELATIONSHIP WITH THE EMERGENCY ALERT SYSTEM (EAS)

The Emergency Alert System (EAS) provides for the transmission of emergency messages (commonly pertaining to imminent adverse weather events) over broadcast radio and television stations and (in some cases) cable TV outlets.

In the case of radio stations, the message typically interrupts the ongoing programming and is delivered by voice. In the case of broadcast (and perhaps cable) television outlets, the message is often presented in text in a "crawl" at the top of the screen.

In many case, the source of these messages will be SAME alert messages, often ones intended solely for dissemination over the EAS system.

There are various "wrinkles" of the NWR system involved in this, which will not be discussed here.

8 REQUIRED TEST MESSAGES

The NWS "specification"[7] for this system requires that once a week a special alert message called the Required Weekly Test (its event identifier is "RWT") be sent. It is typically sent between 11:00 am and 12:00 pm every Wednesday, and is fitted into the existing pattern of

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[6] The first FIPS standard (FIPS 1) was in fact exactly the 1968 version of the ASCII standard, of which I was one of the principal authors and editors.

[7] Hereinafter referred to as the "SAME Specification"

general voice transmissions. But if there is a lot of “alert message” traffic that day, it may be postponed to the next day (but not later).

Although it is not mandatory under the SAME Specification, there is usually a voice component to this message, which typically identifies it as a test message, and likely giving the call sign, location, even frequency of the transmitting station, as well as a list of the areas the station is intended to serve.

There is also defined a Required Monthly Test (RMT), which is only used at some stations. It is like the RWT but it primarily serves to test interoperation with the EAS. Usually, if the RMT is used, it is transmitted in place of the RWT on the first Wednesday of every odd-numbered month.

Typically, by default, consumer weather radios will not sound the audible alarm nor deliver the voice message for Required Weekly Test or Required Monthly Test messages. However, usually the user can choose to have an audible alarm and delivery of the voice message for one or both test messages.

The SAME Specification dictates that if a receiver has not recognized any SAME messages (that of course includes test messages, and messages for which the receiver is not set to give an audible alarm) for some period (8-9 days is suggested, but the industry standard for SAME receivers specifies 10 days), it must give an indication to the user suggesting the he check the receiver setup and operation.

9 ERROR CHECKING

The SAME Specification recommends that a receiver should compare all three occurrences of the SAME header and if two (or all three) agree, act upon the agreeing occurrences.

It further suggests that if no two of the three occurrences fully agree, the receiver should do a bit-by-bit comparison, and for each bit, accept the value shown by at least two of the three occurrences (or of course by all three).

As to the EOM sequence, the SAME Specification indicates that a receiver may act upon a single received utterance of such a sequence

10 SOURCES

Most of the information on the technical details of the NWR signal came from NWS Service Instruction 10-1712, specially the issue of April 20, 2022, which I call here the “SAME Specification”.

Valuable information, especially on the evolution of the alert message indication, came from the Wikipedia articles “NOAA Weather Radio”, and “Specific Area Message Encoding”.

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Appendix A
NWR radio signals and modulation–technical characteristics

A.1 THE CARRIER

All NWR transmissions are on one of seven VHF carrier frequencies, identified by channel numbers:

Chan.	Frequency (MHz)
1	162.400
2	162.425
3	162.450
4.	162.475
5.	162.500
6	162.525
7	162.550

This is of course to allow stations with overlapping signal coverage areas to operate without mutual interference.

A.2 COVERAGE

For each of its NWR stations, NWS publishes maps showing the area over which adequate reception of the NWR signal is generally to be expected. Of course, reception at any specific point will depend on local conditions, including the type of antenna used on the receiver.

The coverage maps are generally predicated on an expected "open air" signal with an electric field strength of at least 18 μV/m RMS.

A.3 MODULATION

Both the voice messages and the digital SAME encoding (on a subcarrier) are carried by "narrow-band" frequency modulation (FM) of the carrier.

The maximum deviation is ±5.0 kHz. Deviation at that level is considered "100% modulation".

The modulation is subject to pre-emphasis of +6 dB per octave over the range of 200 Hz to 3000 Hz.[8] (That means that we actually have phase modulation by the original audio signal.) We might reasonably assume that the range 200-3000 Hz is the intended audio frequency bandwidth of the channel.

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[8] The most recent issue of the SAME Specification states the top limit of this as 44,000 Hz, but that is certainly an error. The 3000 Hz value I cite is taken from the prior issue.

A.4 DIGITAL SIGNALING

A.4.1 Modulation

The SAME digital encoding is conveyed by audio frequency-shift keying (AFSK), on a subcarrier basis. The frequency shift is 520.83 Hz (precisely, 520-6/8 Hz)

The two audio frequencies used are:

- For logical 0 (“space”): 1562.5 Hz
- For logical 1 (“mark”): 2083.33 Hz (precisely, 2083-1/3 Hz)

The tones are transmitted at a modulation level of nominally 80% (maximum of 100%)

The modulation rate (and bit rate) is 520.83 (precisely, 520-5/6) bauds (bits/sec). (Yes, numerically the same as the frequency shift.) Transmission is on a synchronous basis, using 8-bit characters. Phase continuity is maintained at signaling element (bit) boundaries.[9]

The 8 bits are considered to be low-order-bit first, and are numbered for reference as 1-8 in the order of transmission.

A.4.2 Preamble

Th SAME encoding header and the end-of-message sequence are preceded by a preamble, that being 16 consecutive bytes, all with the value 10101011[10]. This:

- “Wakes up” the decoder
- Allows the decoder to synchronize with the digital transmission on the but and byte levels.

A.4.3 SAME encoding header and end-of-message indicator

In the SAME encoding header and the end-of-message indicator (EOM), each byte is considered to carry an ASCII character in bits 1-7 and logical “0” in bit 8. (This is the norm for the transmission of ASCII characters in 8-bit “words”.)

A.5 ENCODING

The encoding of the SAME header and the EOM indicator is given in Appendix B.

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[9] That requires that the frequency shift be an integer multiple of the modulation rate, which it is in this case (they are identical).

[10] Sometimes written as “AB” in hexadecimal, which is predicated on a high-order nybble first, high-order bit first interpretation.

Appendix B
Encoding of the SAME message header and the end-of-message indicator (EOM)

B.1 SAME MESSAGE

B.1.1 Overview

The SAME header sequence is composed of the following, in sequence. Items in italics do not appear in certain message types.

<preamble><header>
No modulation—1 second
<preamble><header>
No modulation—1 second
<preamble><header>
No modulation—1-3 seconds (only if following item is included)
Warning alert tone (WAT)—8-10 seconds
No modulation—3-5 seconds (only if following item is included)
Voice message (maximum length 2 minutes)
No modulation—1-3 seconds
<preamble><EOM >
No modulation—1 second
<preamble><EOM >
No modulation—1 second
<preamble><EOM >
No modulation—minimum duration unknown

This may be followed by the ongoing (non-alert) voice narration or by another alert message.

B.1.2 Preamble

The preamble consists of 16 consecutive bytes all with the value 10101011. [11]

B.1.3 The SAME header

The SAME header consists of bytes considered to be low-order bit first, the bits numbered 1-8 in order of transmission. Bits 1-7 carry an ASCII character; bit 8 is always logical"0".

The detailed composition of this element is given in Appendix C.

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[11] Sometimes written as "AB" in hexadecimal, which is on the basis of high-order nybble first, high-order bit first.

I will note here however that the header begins with the sequence of ASCII characters ZCZC[12].

B.1.4 The Warning Alert Tone (WAT)

The Warning Alert Tone (WAT) is an audible tone at a frequency of 1050 Hz, at a nominal modulation level of 80% (maximum 100%), sounded for 8 to 10 seconds

Some message types omit this item.

B.1.5 The voice message

The voice message has a maximum specified duration of 2 minutes. Some message types omit this item.

B.1.6 The end of message indicator (EOM)

The end of message indicator (EOM) is preceded by the preamble. The indicator itself consists of the ASCII character sequence 'NNNN'[13].

B.2 MESSAGES NOT INCLUDING ALL ELEMENTS

Certain classes of message do not include the Warning Alert Tone (WAT) and/or a voice message. Examples include:

- Messages intended for an EAS local primary station and intended for retransmission to radio and television systems, and not intended for "civilian" users, with a voice message for direct use by radio stations. The messages may omit the Warning Alert Tone (WAT) They may use special location indicators.

- Messages intended for an EAS local primary station and intended for retransmission to radio and television systems, and not intended for "civilian" users, with no voice message. The messages may omit the Warning Alert Tone (WAT) (and of course do not include the voice message element. They may use special location indicators. Radio stations receiving such a message may generate a voice message based on the event type encoded in the SAME header.

- System control messages, not intended for "civilian" users. These have no Warning Alert Tone (WAT) and no voice message element. They may use special location indicators.

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[12] This is the traditional **start-of-message** indicator in many teletypewriter and radioteletypewriter operations, including in a military communications context.

[13] This is the traditional **end-of-message** indicator in many teletypewriter and radioteletypewriter operations, including in a military communications context.

There have been cases of some NWS stations sending Required Weekly Test messages that do not include the Warning Alarm Tone (WAT), This may have been done based on the concept that a civilian user would no doubt have their receiver programmed to not sound an alarm tone or deliver the voice message for such messages (often the factory default for receivers).

But some “civilians” (myself for example) may wish to be alerted to, and then to hear the spoken announcement of, the Required Weekly Test message. This does not work out well in the case of the typical “consumer” SAME-capable weather radio.

When such receivers recognize that this is an event type the user wants to know of, pertinent to their location, they typically sound an 8-10 second local tone signal, and then begin to deliver the audio signal to the loudspeaker.

But by that time, perhaps 6 seconds of the audio announcement have passed. This presents no practical problem, as such users typically know exactly what the voice announcement text is. But this situation is, to say the least, irregular.

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Appendix C
Detailed composition of the SAME header

C.1 SYMBOLIC REPRESENTATION

The composition of the SAME header is given symbolically thus:

ZCZC-ORG-EEE-PSSCCC-PSSCCC+TTTT-JJJHHMM-LLLLLLLL-

Note that all elements are separated by the ASCII character *hyphen* (improperly called "dash" in the SAME specification), except for element TTTT which is preceded by an ASCII *plus sign*. The entire header ends with an ASCII *hyphen*.

The elements are as follows:

ZCZC: The start-of message indicator, the ASCII literal string 'ZCZC'[14].

ORG: The type of entity originating the message, as follows:

WXR[15]: National Weather Service.

CIV: Civil authority.

PEP: EAS Primary Entry Pont.

EAS: Radio or TV station or cable TX system, etc, (as a participant in the EAS system).

EEE: The event type, a three-letter upper-case ASCII string from a standardized "glossary". This is discussed in Section 5 of the body of this article.

PSSCCC: A location identifier for a location to which the alert message pertains, composed as follows[16]:

P: 0 if the location is an un-subdivided county, or is all of a subdivided county; 1-9 for the pertinent partition of subdivided counties.

SS: 00-99 (ASCII), the identifier of the state.

CCC: 000-999 (ASCII), the identifier of the county, within the indicated state.

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[14] As noted earlier, this is the traditional start-of-message indicator in many teletypewriter and radioteletypewriter operations, including in a military communications context.

[15] "WX" is the traditional telegraph and radiotelegraph shorthand for "weather".

[16] In certain special situations, other formations of this element are permitted, but are not to be used in messages intended to be received by "consumer" weather radios. The format restrictions on such special location codes are not discussed here.

There can be up to 31 instances of this element, covering the different locations that are intended to be advised of the event.

TTTT: The “purge time”, the time duration for which the display of the message on receivers should be sustained. The unit is 15 minutes up to on hour, and 30 minutes for times greater than one hour. Note that this is not necessarily the same as the time period for which a “watch” (for example) is in effect, but will likely be the same for relatively-short periods of effectivity.

JJJHHMM: The issue day-time. JJJ is the so-called “Julian day”, the sequential number of the day (UTC basis) in the current year (001-365, 001-366 for a leap year). HH is the hour, 00-23, (UTC). MM (00-59) is the minute (UTC).

LLLLLLLL: The originator of the message, or in the case of relayed EAS messages, the entity re-broadcasting the message. It appears from the specification that this element is of fixed length (8 characters). It is believed that identifiers of length less than 8 characters are usually “padded out” with spaces.

Often, for NWS stations, this identifier centers on the ICAO code for the city (used in aviation work), such as KCLE/NWS for the NWS station for Cleveland, Ohio.

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