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Re:	IEEE 802.16-03/51r3 and IEEE P802.16-REVd/D2-2003
Abstract	Supports a multi-item technical comment on WirelessMAN-SCa burst framing that the author has submitted for Recirculation Ballot #13a. This reply comment is nominally associated with Comment #456, with some connection to Comment #248.
Purpose	To provide text and editing instructions for the comment referenced by author's Commentary submission.
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Addendum to Recirculation Ballot #13a Comment on WirelessMAN-SCa Framing

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Summary:

The resolutions in IEEE 802.16-03/51r3 associated with Comment #456 (improvements to burst framing) and Comment #248 (corrections for full STC and TDMA support) were excellent; however, they did not capture all of the necessary changes for a complete and clean implementation of their intended goals. For example, burst profile references in clause 8.2.1.4 and its subclauses must be changed to render IEEE P802.16-REVd/D2-2003 internally consistent, because the referenced burst profile encodings were converted into extended IEs as part of the resolution to Comment #248. Moreover, the resolution to Comment #456 did not complete all of the outstanding burst framing issues because several errors and necessary simplifications in clause 8.2.1.4.3 on STC framing (e.g., in Figure 177) were discovered. Since the clauses associated with the aforesaid Comments overlap and interact, their resolution was addressed jointly. These changes also precipitated a few minor modifications to clauses 11.1 and 11.4 to align those with clause 8.2.

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Make the following changes (indicated in blue) to clause 8.2.1.4, beginning page 359, line 46.

8.2.1.4 Burst set framing

Both downlink and uplink data shall be formatted into framed burst sets. The downlink shall support one or more framed TDM burst sets, while the uplink shall support framed TDMA burst sets. The coordination of uplink and downlink bursts used to implement a TDD or FDD system is specified in 8.2.1.5.

The format used by a burst set is indicated by the Burst Set Frame Type burst profile encoding (on uplink) and extended IE (on downlink). Three formats are defined. The Standard format (8.2.1.4.2) shall be supported on both the uplink and downlink. This format is always used for data containing the FCH. The STC format (8.3.1.4.3) is optional and shall be used only for STC encoded data on the uplink or downlink. The Subchannel format (8.3.1.4.4) is optional and shall be used only on the uplink.

Although burst~~s~~ sets in the Standard, STC, and Subchannel formats may coexist on the same channel, they shall not overlap in time.

8.2.1.4.1 Unique Word

8.2.1.4.1.1 Selection

The length, *U*, in symbols of a Unique Word (UW) is a burst profile parameter (on uplink) and an extended IE (on downlink).. For best performance, *U* should be at least as long as the intended channel's span of significant delay spread.

8.2.1.4.1.2 Definition

Unique Words are derived from Frank-Zadoff sequences [B22] and possess CAZAC (Constant Amplitude Zero [periodic] Auto-Correlation) properties. A burst profile specifies a Unique Word from the options listed in Table 163. The sequence lengths $U = 16$ and $U = 64$ shall be supported. The sequence length $U = 256$ shall be supported for bandwidths above 20 MHz.

Table 163— Unique Word lengths, types, and support

Length, *U* (symbols)	**Support status**
16	Mandatory
64	Mandatory
256	Mandatory for bandwidths above 20 MHz

The integer *n*-indexed I and Q components of a length *U*, $0 \le n < U$, Unique Word sequence shall be generated from

$$\begin{aligned} I[n] &= \cos(\theta[n]) \\ Q[n] &= \sin(\theta[n]) \end{aligned} \tag{14}$$

where

$$\begin{aligned} \theta[n = p + q\sqrt{U}] &= \frac{2\pi pqr}{\sqrt{U}} \\ p &= 0, 1, \ldots, \sqrt{U} - 1 \\ q &= 0, 1, \ldots, \sqrt{U} - 1 \end{aligned} \tag{15}$$

and $r = 1, 3$ or co-prime with $\sqrt{U}$.

The length *U* = 16, 64, and 256 Unique Word sequences are composed of symbols from QPSK, 8-PSK, and 16-PSK alphabets, respectively. The error vector magnitude (EVM) for Unique Word symbols in a transmitter implementation should conform with the general requirements stated in 8.2.3.4. The selection of the ~~r~~ *r*-factor, e.g., as $r = 1$ or $r = 3$ shall be specified by the MAC on a frame by frame basis.

For each downlink burst frame received, the SS PHY shall determine the ~~r~~*r*-value of the corresponding preamble and provide an indication to the MAC which provides the ~~r~~*r*-value setting for the received frame. In addition, the PHY shall use the ~~r~~*r*-value to select the appropriate burst profile settings for demodulation and decoding of the FCH immediately following the preamble. The FCH burst profile settings associated with each ~~r~~*r*-value are statically defined at the BS and shall not be altered during BS operation. The SS shall determine these settings during downlink synchronization and retain them for use by the SS PHY during normal operation.

8.2.1.4.2 Standard burst set format

Figure 173 depicts a burst set with the standard format. As illustrated, the burst set consists of three fundamental framing elements: a burst set preamble that includes ramp up; one or more bursts; and a Receiver Delay Spread Clearing (RxDS) interval that includes ramp-down.

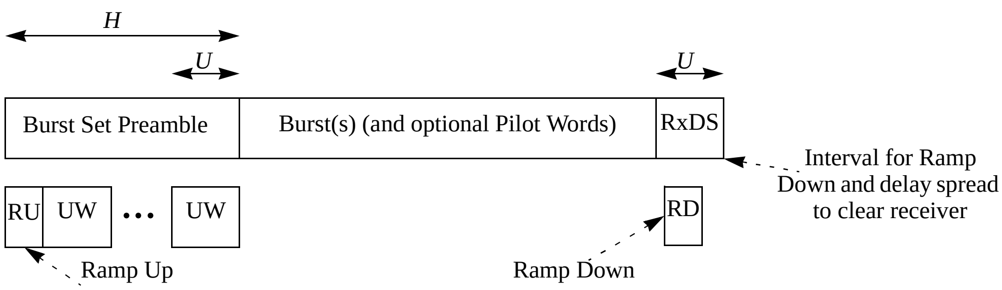

Figure 173—Fundamental framing elements in a standard format burst set

8.2.1.4.2.1 Burst set preamble

A burst set preamble shall consist of a ramp up region followed by a preamble body. Burst profile (on uplink) or extended IE (on downlink) parameters shall specify R_r, the length of the ramp up region in symbols, and *m*, the number of Unique Words composing the preamble body. The preamble specification shall also include *U*, the number of symbols in a Unique Word.

A burst set preamble shall be constructed from the last R_r symbols of a Unique Word (see Table 163) followed by an integer multiple $m \geq 0$ of Unique Words, each Unique Word being *U* symbols in length. Figure 174 illustrates this requirement.

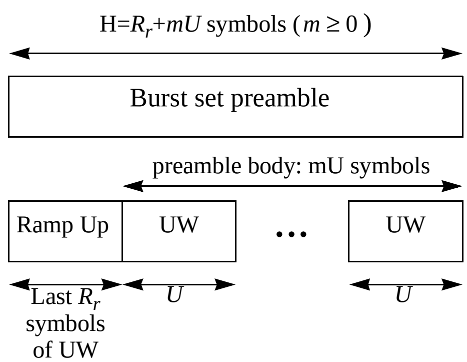

Figure 174—Burst set preamble composition

For $R_r = 0$, a ramp up element within the Burst Preamble shall not be created.

For $_r > 0$, a ramp up element shall be created. When creating a ramp up element, the transmit filter memory shall be initialized with zero-valued (null) symbols. R_r ramp up symbols shall then be sequentially fed into the transmit filter input stream. The transient preceding the first ramp up symbol shall be suppressed at the transmit filter output until the symbol period of the first ramp up symbol. A ramped power buildup shall then be achieved by superimposing a multiplicative raised cosine half-window of duration R_r symbols upon the samples leaving the transmit filter.

8.2.1.4.2.2 Burst

The burst block depicted in Figure 173 contains payload data. The burst block may also contain periodically inserted Pilot Words (see 8.2.1.4.2.4), if the burst profile (for uplink) or extended IE (for downlink) specifies their inclusion.

The capability to demodulate payloads of arbitrary length and PS-unit granularity is mandatory. The capability to insert Pilot Words at the transmitter and remove them at the receiver is also mandatory.

A downlink burst set may contain time division multiplexed bursts that are adaptively modulated for the intended recipients. When an FCH is to be transmitted within a downlink subframe, it shall always appear as the first burst in the first burst set, and shall be encoded in accordance with section 8.2.1.5.3. Subsequent bursts within the burst set shall be sequenced in decreasing order of modulation robustness, beginning with the most robust modulation that is supported at the transmitter. The capability to transition between modulation types on any PS boundary within a burst set shall be supported. FEC blocks shall be terminated at every such transition.

One exception to the modulation sequencing rule is null payload fill, which if used, shall always appear as the final burst in a burst set, and shall be transmitted using QPSK.

An uplink burst set contains a single burst.

Burst profiles are used to specify the modulation and coding for each burst. In changing from the preamble to a burst or in changing from one burst (e.g. modulation type) to another, the BS or SS shall use one of two power adjustment rules: maintaining constant constellation peak power (power adjustment rule=0), or maintaining constant constellation mean power (power adjustment rule=1). The power adjustment rule is configurable through the DCD Channel Encoding parameters (11.1.2.1) and UCD Channel Encoding parameters (11.1.1.1).

The constellation normalization factors associated with power adjustment rules are listed in Table 11. Preambles and pilot words are derived from PSK alphabets, and use the QPSK normalization factor, regardless of the power adjustment rule.

In changing from one modulation scheme to another, sufficient RF power amplifier margins should be maintained to prevent violation of emissions masks.

Additional description of MAC/PHY support for adaptive modulation and coding is provided in 6.4.7.

8.2.1.4.2.3 Null payload fill

When additional payload data is necessary to fill the end of a burst frame, e.g., when a continuous downlink does not have enough data to fill a MAC frame, null payload fill may be inserted. The capability to insert null payload fill at a transmitter and discard it at a receiver is mandatory.

Null payload fill shall use the null fill data type. A MAC Frame control (map) message treats the null fill data type as an adaptive modulation type, and therefore shall indicate when and for how long this data type shall be transmitted within a burst set. Null payload fill data shall also be subject to pilot word patterning within a burst set.

The null fill data type is defined as zero-valued source bits that are randomized (see 0.1.1.1) and mapped directly to QPSK symbols using the Gray code map in Figure 14. The randomizer shall run (without reset) through both the preceding burst and the null payload fill, but null payload fill shall not be covered (in the MAC) by a CRC code.~~ During null payload fill transmission, a transmitter's output power may be reduced.~~

8.2.1.4.2.4 Pilot Words

A Pilot Word is a contiguous sequence of symbols composed of an integer multiple of Unique Words, which may periodically pattern a burst set. As Figure 175 illustrates, the period of a Pilot Word, F (in symbols), is defined to include the length, P, of the Pilot Word. For the first downlink burst set, both F and n are parameters specified by the DL-MAP Pilot Word Extended Interval IE (Section. 8.2.1.5.5.2). If the IE is not included in the DL-MAP, no Pilot words shall be patterned in the corresponding downlink burst set. For all other burst sets, pilot word parameters appear in the Burst Set Delimiter Extended IE.

When Pilot Words are patterned within a burst set, *F* for that burst set shall be constant, and the first symbol of the first Pilot Word shall commence *F–P+1* symbols into the burst set. As Figure 175 illustrates, Pilot Word patterning shall cease when *F-P* or less payload data symbols remain in the burst set.

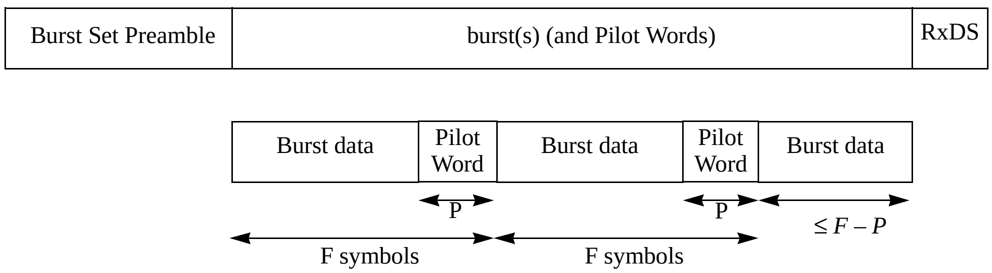

Figure 175—Pilot Word patterning within a burst set

8.2.1.4.2.5 RxDS

The RxDS illustrated in Figure 173 is a quiet period during which the transmitter ramps down, and the receiver collects delay-spread versions of symbols at the end of the burst set. The capability to insert the RxDS at the transmitter is mandatory. The length of the RxDS shall always be the length of a Unique Word, unless it is suppressed (i.e., set to length zero).

If the RxDS is nonzero in length, a transmitter shall ramp down during this RxDS by inserting zero inputs into the transmit filter memory following the last intended data symbol, and allowing the natural response of the filter to drive the filter output to zero.

8.2.1.4.3 STC ~~transmit diversity~~ burst set format

Implementation of STC transmit diversity is optional.

The STC transmit diversity scheme formats pairs of data blocks for transmission over two antennas. ~~logically pairs blocks of data separated by delay spread guard intervals.~~ ~~These paired blocks are jointly processed at both the transmitter and receiver. The technique to be described is particularly amenable to a frequency domain equalizer implementation.~~

8.2.1.4.3.1 Paired block transmit processing

Figure 176 illustrates block pairing that shall be used by the STC transmit diversity scheme. Let $\{s_0[n]\}$ and $\{s_1[n]\}$ represent two sequences, each of length *F* symbols $(0 \le n < F)$, which are ~~desired~~ to be delivered to a receiver using the STC transmit diversity scheme. Table 164 indicates the block multiplexing structure that a two antenna transmitter shall use to transmit the two sequences, using ~~over~~ the paired blocks illustrated in Figure 176. As Table 164 indicates, Transmit Antenna 0 shall transmit its data sequences in order, with no modifications; however, Transmit Antenna 1 shall not only reverse the order in which its blocks are transmitted, but shall also conjugate the transmitted complex symbols and shall also time-reverse—cyclically about zero, modulo-*F*—the sequence of data symbols within each block. Subclause 8.2.1.4.3.4 provides details on the composition of the delay spread guard intervals between the blocks illustrated in Figure 176.

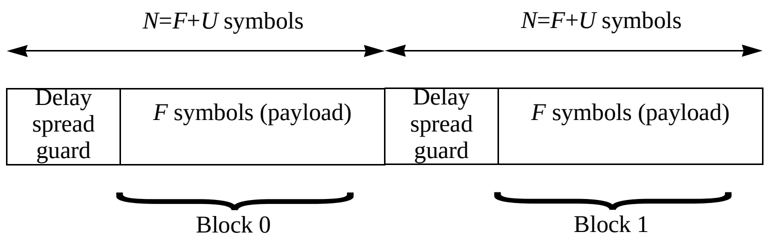

Figure 176—Paired blocks used in STC transmit diversity combining

Table 164—Multiplexing arrangement for block STC processing

Tx Antenna	Block 0	Block 1
0	$\{s_0[n]\}$	$\{s_1[n]\}$
1	$\{-s_1{}^*[(F-n)mod(F))]\}$	$\{s_0{}^*[(F-n)mod(F))]\}$

8.2.1.4.3.2 Paired block receive processing

If $S_0(e^{j\omega})$, $S_1(e^{j\omega})$, $H_0(e^{j\omega})$, $H_1(e^{j\omega})$, $N_0(e^{j\omega})$, and $N_1(e^{j\omega})$ represent the Discrete-time Fourier transforms, respectively, of the symbol sequences $\{s_0[n]\}$ and $\{s_1[n]\}$, channel impulse responses (for the channels associated with each transmitter antenna) $\{h_0[n]\}$ and $\{h_1[n]\}$, and additive noise sequences (associated with each block) $\{n_0[n]\}$ and $\{n_1[n]\}$, the received signals associated with each block, interpreted in the frequency domain, are as follows:

$$(e^{j\omega}) = H_0(e^{j\omega})S_0(e^{j\omega}) - H_1(e^{j\omega})S_1{}^*(e^{j\omega}) + N_0(e^{j\omega}) \tag{16}$$

$$(e^{j\omega}) = H_0(e^{j\omega})S_1(e^{j\omega}) + H_1(e^{j\omega})S_0{}^*(e^{j\omega}) + N_1(e^{j\omega}) \tag{17}$$

Assuming that the channel responses $H_0(e^{j\omega})$ and $H_1(e^{j\omega})$ are known, one may~~shall~~ use the frequency domain combining scheme

$$(e^{j\omega}) = H_0{}^*(e^{j\omega})R_0(e^{j\omega}) + H_1(e^{j\omega})R_1{}^*(e^{j\omega}) \tag{18}$$

$$(e^{j\omega}) = -H_1(e^{j\omega})R_0{}^*(e^{j\omega}) + H_0{}^*(e^{j\omega})R_1(e^{j\omega}) \tag{19}$$

to obtain the combiner outputs

$$j\omega) = (\left|H_0(e^{j\omega})\right|^2 + \left|H_1(e^{j\omega})\right|^2)S_0(e^{j\omega}) + H_0{}^*(e^{j\omega})N_0(e^{j\omega}) + H_1(e^{j\omega})N_1{}^*(e^{j\omega}) \tag{20}$$

$$j\omega) = (\left|H_0(e^{j\omega})\right|^2 + \left|H_1(e^{j\omega})\right|^2)S_1(e^{j\omega}) - H_1(e^{j\omega})N_0{}^*(e^{j\omega}) + H_0{}^*(e^{j\omega})N_1(e^{j\omega}) \tag{21}$$

The combiner outputs of Equation (20) and Equation (21) may~~can then~~ be independently equalized using frequency domain ~~equalizer~~ techniques (for an example see [B18]) to obtain estimates for $\{s_0[n]\}$ and $\{s_1[n]\}$.

8.2.1.4.3.3 Channel estimation using pilot symbols

The channel responses used by the equalizer(s) can be estimated using data received during pilot symbol intervals. Under the assumption that pilot symbols are the same in the 0 and 1 blocks, i.e., $S_0^{pilot}(e^{j\omega}) = S_1^{pilot}(e^{j\omega}) = S_{pilot}(e^{j\omega})$, the sum and differences of Equation 6 and Equation 5 can be multiplied by $S_{pilot}*(e^{j\omega})$ to yield (ignoring noise terms) the following:

$$_{ot}*(e^{j\omega})(R_0^{pilot}(e^{j\omega}) + R_1^{pilot}(e^{j\omega}))= 2\left|S_{pilot}e^{j\omega}\right|^2 H_0(e^{j\omega}) \quad (22)$$

$$_{lot}(e^{j\omega})(R_1^{pilot}(e^{j\omega}) - R_0^{pilot}(e^{j\omega}))= 2\left|S_{pilot}e^{j\omega}\right|^2 H_1(e^{j\omega}) \quad (23)$$

The channel estimation task simply involves dividing the left hand sides of Equation (2) and Equation (3) by a constant independent of frequency, since pilot symbols are derived from the Unique Words of 8.2.1.4.1, and these Unique Words have a constant frequency domain magnitude, i.e., $\left|S_{pilot}(e^{j\omega})\right|^2 = \left|S_{UW}(e^{j\omega})\right|^2 = C$.

8.2.1.4.3.4 Paired block profiles

Figure 177 and Figure 178 illustrate two defined frame (burst) profiles for STC transmit diversity signaling.

Figure 177 illustrates the baseline framing structure for STC transmit multiplexing. This is cyclic-prefix-based frame structure, with U-symbol cyclic prefixes (CPs), and F-symbol payload repetitions~~ chosen to facilitate efficient processing at the receiver based on fast Fourier transform (FFT)~~. Note that although the CP is not composed of Unique Words, the length of the CP, U, shall be the same as the Unique Word length being used by the burst profile. Observe that the payload portions of Figure 177 reflect the STC antenna multiplexing format described in Table 164 for Transmit Antennas 0 and 1. As illustrated in Figure 178,~~Note that ~~a Unique Word may be inserted within Payloads 0 and 1 to facilitate decision feedback equalization at the receiver~~the use of frequency domain equalizers with time-domain decision feedback taps~~..

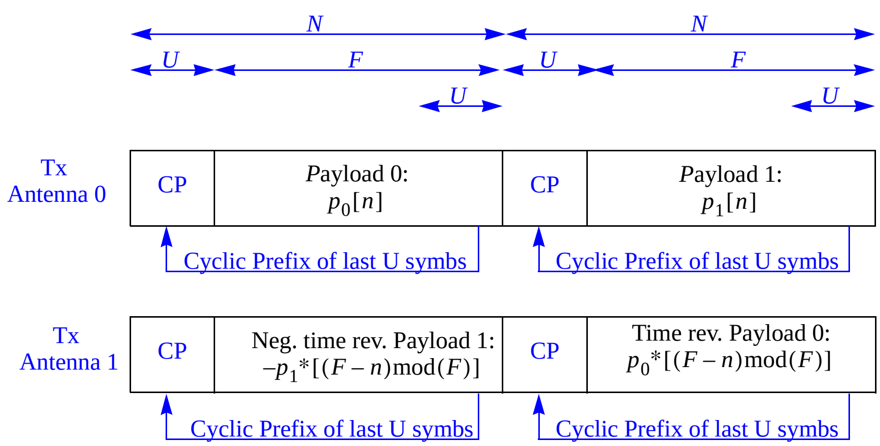

Figure 177—STC dual blocks without UWs

~~Figure 178 illustrates another burst profile which explicitly uses Unique Words, rather than a repetition of the payload data, to generate CPs.~~

F, the length of an STC block, is a burst profile parameter. The choice of the burst profile for the paired blocks, i.e., the scheme illustrated in Figure 177 or the scheme illustrated in Figure 178, is also a burst profile parameter.

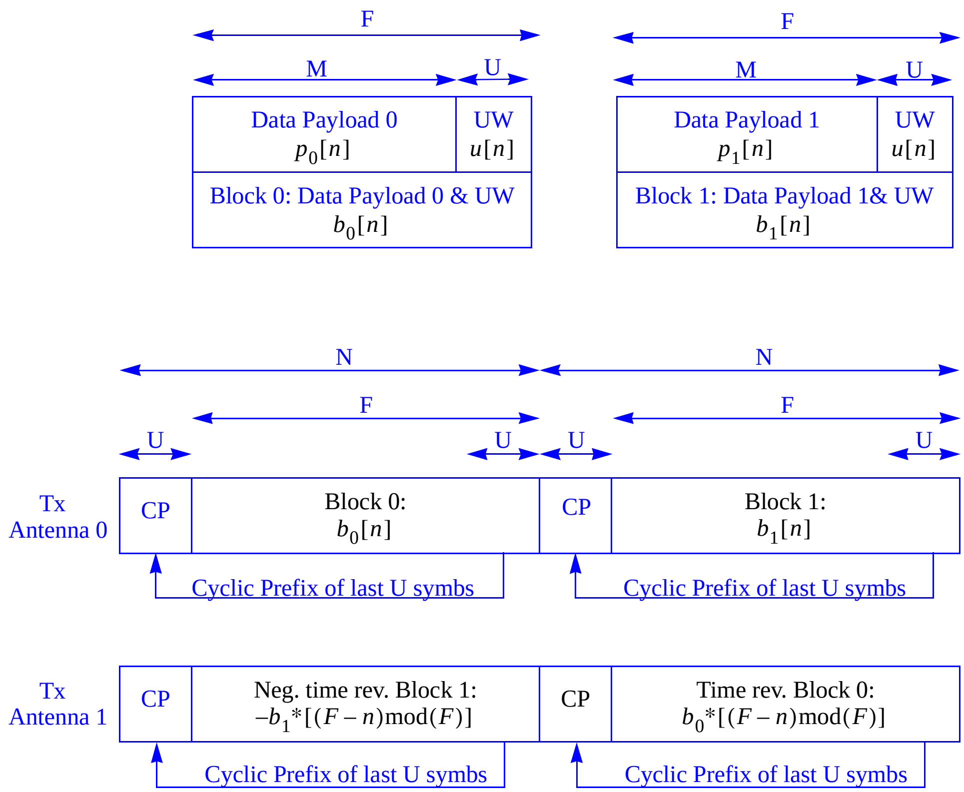

Figure 178—STC dual blocks with UWs

8.2.1.4.3.5 STC burst set elements

A STC burst set shall consist of a preamble, followed by burst(s) The burst set may consist of multiple pairs of STC blocks.

Unlike conventional burst sets, an RxDS element shall not appear at the conclusion of a STC burst set.

8.2.1.4.3.5.1 Burst set preamble

Figure 179 illustrates that the burst set preamble shall be used for burst sets utilizing STC transmit diversity encoding. The number of Unique Word blocks composing a STC burst set preamble is a parameter of the Burst Set Delimeter Extended IE (for downlink) or burst profile (for uplink). However, since two channels shall be estimated, the total number of UWs used to construct an STC burst set preamble shall be twice the parameter value specified..

Note that this preamble structure may also be inserted within a transmission as a group of contiguous Pilot Words, to assist in channel estimation and updating within a burst set. In such an instance, this contiguous pilot symbol structure is considered external to the paired STC payload data blocks illustrated in Figure 177, although the pilots may appear after every L^{th} paired payload block, where L is an integer greater than or equal to 1.

Ramp up shall use the same procedure described in 8.2.1.4.2.1, with the exception that the ramp up symbols for each transmit antenna are duplicates of the last R_r symbols of the first length-U data element in the preamble. Note that this implies that the first transmit antenna derives its ramp up symbols from a standard Unique Word sequence $\{u[n]\}$, while the second transmit antenna derives its ramp up symbols from the sequence $\{-u[(U-n)mod(U)]\}$.

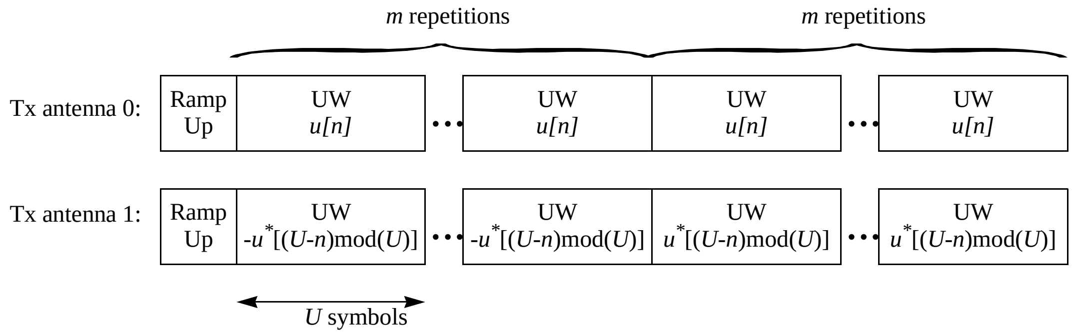

Figure 179—STC burst set preamble

8.2.1.4.3.5.2 Burst set payload data

Payload data within an STC-encoded burst set shall be formatted into block pairs, with each block pair possessing one of the block pair profiles described in 8.2.1.4.3.4. If insufficient data is available to fill the last block pair, then the payload shall be filled with null payload fill, as specified in 8.2.1.4.2.1. Except for the payload fill, modulations are sequenced in terms of decreasing modulation robustness on the Tx Ant 0 channel.

The preamble structure of Figure 179, minus the ramp up symbols, may also be inserted within a transmission, as a group of contiguous Pilot Words to assist in channel estimation and updates within a burst set. In such an instance, this contiguous pilot symbol structure is considered external to the paired STC payload data blocks illustrated in Figure 177, although the pilots may appear after every V^{th} paired payload block, where K is an integer greater than or equal to 1. The pilot word repetition interval, and the number of UWs composing a pilot word are parameters of the Burst Set Delimiter Extended IE (for downlink) or the burst profile (for uplink) defining the start of the STC-encoded burst set.

8.2.1.4.3.5.3 Ramp down

Ramp down follows the end of a burst set. A transmitter shall ramp down by inserting zero symbol inputs into the transmit filter memory following the last intended data symbol, and windowing the resulting, transmit-filtered output waveform with a multiplicative raised cosine window that diminishes to zero in R_r symbols. The (STC burst) ramp-down interval, R_r, shall be the same as the ramp up interval.

8.2.1.4.3.6 Interoperability with non-STC-encoded burst sets

For interoperability reasons, STC-encoded data and conventionally-encoded data~~,~~ shall not be time division multiplexed within the same burst set. Instead, ~~the~~ STC data shall be encapsulated within its own burst set.

All burst sets with different STC pair block sizes, F, shall also be segregated, although they may share the same preamble.

The following proposed changes to Chapter 11are intended to improve descriptions, eliminate a typo on the number of bytes required for a burst profile encoding, and align Chapter 11 with the proposed changes to 8.2.1.4.2.3.

iIn section 11.1.1.2, Table 270, Page 591, beginning line 37,make the following changes (in blue):

Table 270—UCD burst profile encodings---WirelessMAN-SCa

STC Parameters	23	~~2~~ 1	4 MSBs: block length (segments are paired), in symbols 1= 64, 2 = 128, 3 = 256, 4 = 512,..., 7 = 4096, 8–15 *Reserved* 4 LSBs: Block burst profile type 0 = ~~CP derived from data and~~ no UWs embedded within block 1 = ~~CP derived from data an additional~~ UW embedded ~~as first payload data element~~within block ~~2 = CP derived from UWs at beginning and end of segment~~ ~~3~~2–15 = *Reserved*

Section 11.1.2.2, Table 275, Page 595, beginning line 43,make the following changes (in blue):

Table 275—DCD burst profile encodings---WirelessMAN-SCa

STC Parameters	26	1	4 MSBs: block length (segments are paired), in symbols 1= 64, 2 = 128, 3 = 256, 4 = 512,..., 7 = 4096, 8–15 *Reserved* 4 LSBs: Block burst set profile type 0 = ~~CP derived from data and~~ no UWs embedded within block 1 = ~~CP derived from data an additional~~ UW embedded ~~as first payload data element~~within block ~~2 = CP derived from UWs at beginning and end of segment~~ ~~3~~2–15 = *Reserved*

Section 11.4.2.2.5.6, Page 618, beginning line 1, make the following changes (in blue):

11.4.2.2.5.6 ~~Transmit diversity~~ STC capability

This field indicates ~~the~~ STC ~~types of transmit diversity~~ supported by an SS for downlink reception. A bit value of 0 indicates “not supported” while 1 indicates “supported.”

Bit #0: STC support ~~Transmit Diversity with CP Burst Profile~~; dual blocks without UWs
Bit #1: STC support ~~Transmit Diversity with CP and UW at beginning of block Burst Profile~~; dual blocks with UWs
~~Bit #2: STC Transmit Diversity with UWs placed at beginning and end of block Burst Profile~~
Bits #~~3~~2–7: *Reserved*, shall be set to 0.

Section 11.4.2.2.6.6, Page 620, beginning line 27, make the following changes (in blue):

11.4.2.2.6.6 ~~Transmit diversity~~ STC capability

This field indicates ~~the~~ STC ~~types of transmit diversity~~ supported by an SS for uplink transmission. A bit value of 0 indicates “not supported” while 1 indicates “supported.”

Bit #0: STC support~~ Transmit Diversity with CP Burst Profile~~; dual blocks without UWs
Bit #1: STC support~~ Transmit Diversity with CP and UW at beginning of block Burst Profile~~; dual blocks with UWs
~~Bit #2: STC Transmit Diversity with UWs placed at beginning and end of block Burst Profile~~
Bits #~~3~~2–7: *Reserved*, shall be set to 0.