

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

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☐ Additional inventors are being named on the separately numbered sheets attached hereto					
TITLE OF THE INVENTION (500 characters max)					
MODIFIED PREAMBLE STRUCTURE FOR IEEE 802.11A EXTENSIONS AND DETECTING THE NUMBER OF TRANSMIT ANTENNAS IN MIMO OR MISO TRANSMISSIONS					
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ENCLOSED APPLICATION PARTS (check all that apply)					
☒ Specification Number of Pages		21		☐ CD(s), Number	
☐ Drawing(s) Number of Sheets				☐ Other (specify)	
☒ Application Data Sheet. See 37 CFR 1.76					
METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT					
☒ Applicant claims small entity status. See 37 CFR 1.27.					
☐ A check or money order is enclosed to cover the filing fees					
☒ The Director is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number:		20-1430		FILING FEE Amount (\$)	
☐ Payment by credit card. Form PTO-2038 is attached.				80	
The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.					
☒ No.					
☐ Yes, the name of the U.S. Government agency and the Government contract number are:					

Respectfully submitted,

SIGNATURE

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[Page 1 of 1]

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REGISTRATION NO. 48,750
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USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

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PROVISIONAL PATENT APPLICATION

**MODIFIED PREAMBLE STRUCTURE FOR IEEE 802.11A
EXTENSIONS AND DETECTING THE NUMBER OF TRANSMIT
ANTENNAS IN MIMO OR MISO TRANSMISSIONS**

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MODIFIED PREAMBLE STRUCTURE FOR IEEE 802.11A EXTENSIONS AND DETECTING THE NUMBER OF TRANSMIT ANTENNAS IN MIMO OR MISO TRANSMISSIONS

CROSS-REFERENCES TO RELATED APPLICATIONS

The present application incorporates by reference U.S. Patent Application No. 10/820,440, filed on April 5, 2004, Attorney Docket No. 021245-0014100US, entitled "Modified Preamble Structure For IEEE 802.11a Extensions To Allow For Coexistence And Interoperability Between 802.11a Devices And Higher Data Rate, MIMO Or Otherwise Extended Devices" in its entirety.

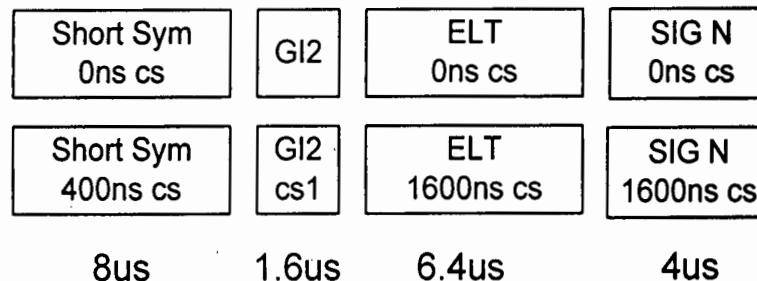
DESCRIPTION OF THE INVENTION

In accordance with one embodiment of the present invention, each of a number of preambles is adapted to be used in packets sent over a wireless network, such as an 802.11a compliant wireless network. Packets containing preambles of the present invention may be received by legacy receivers that are not configured to receive and interpret these preambles.

The preambles may be used to distinguish between two transmit antennas (TX), and 3 or 4 TXs, by using a double long-training sequence compared to 11a in the latter case. To detect that 3 or 4 TX antennas are used, the presence of another (8 us) long-training sequence is detected. In some embodiments, the number of TX antennas in the SIGNAL field is also signaled to verify the number of antenna detection. The preambles are described in the following pages

Efficient Green-field Preamble based on Cyclic Shift (Option 1)

- “Green-field” preamble for 2 TX case (20 and 40 MHz)
 - Minimal overhead in long training (LT) sequence
 - On TX2: a cyclic shift (cs) in Extended Long Training (ELT) of 1.6 μ s
 - SIG N field uses same cyclic shift as long training sequence
 - Use Extended Long Training to prevent interpolation issues



Green-field Preamble Option 1

3 TX case

Short Sym 0ns cs	GI2	ELT 0ns cs	SIG N 0ns cs
Short Sym 200ns cs	GI2 cs1	ELT 1050ns	SIG N 1050ns cs
Short Sym 400ns cs	GI2 cs2	ELT 2100ns	SIG N 2100ns cs
8us	1.6us	6.4us	4us

4 TX case

Short Sym 0ns cs	GI2	ELT 0ns cs	SIG N 0ns cs
Short Sym 200ns cs	GI2 cs1	ELT 800ns	SIG N 800ns cs
Short Sym 400ns cs	GI2 cs2	ELT 1600ns	SIG N 1600ns cs
Short Sym 600ns cs	GI2 cs3	ELT 2400ns	SIG N 2400ns cs
8us	1.6us	6.4us	4us

20 MHz & 40 MHz Extended Long Training (ELT)

- ELT for 20 MHz:

$L_{-32,31} = \{-1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1,$
 $1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1,$
 $0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, 1,$
 $1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, 1, -1\}$

- ELT for 40 MHz:

$L_{-64,63} = \{-1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1,$
 $1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1,$
 $-1, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, 1,$
 $1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, 1, -1,$
 $0, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1,$
 $1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1,$
 $-1, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, 1,$
 $1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, 1, -1\}$

Advantages of proposed ELT

- Long training symbol is identical to that of 802.11a with addition of out-of-band pilots
- Out-of-band pilots will be significantly attenuated by TX filtering, so they do not add significantly to the power of the long training symbol, nor affect the spectral mask
- Out-of-band pilots available for modes with extra out-of-band data subcarriers
- No or low interpolation inaccuracies

Example PSD of TX Signal

- 20 MHz mode
- Realistic filtering
- 1000 byte packet
- 56 subcarriers
- Including the Extended Long Training Sequence

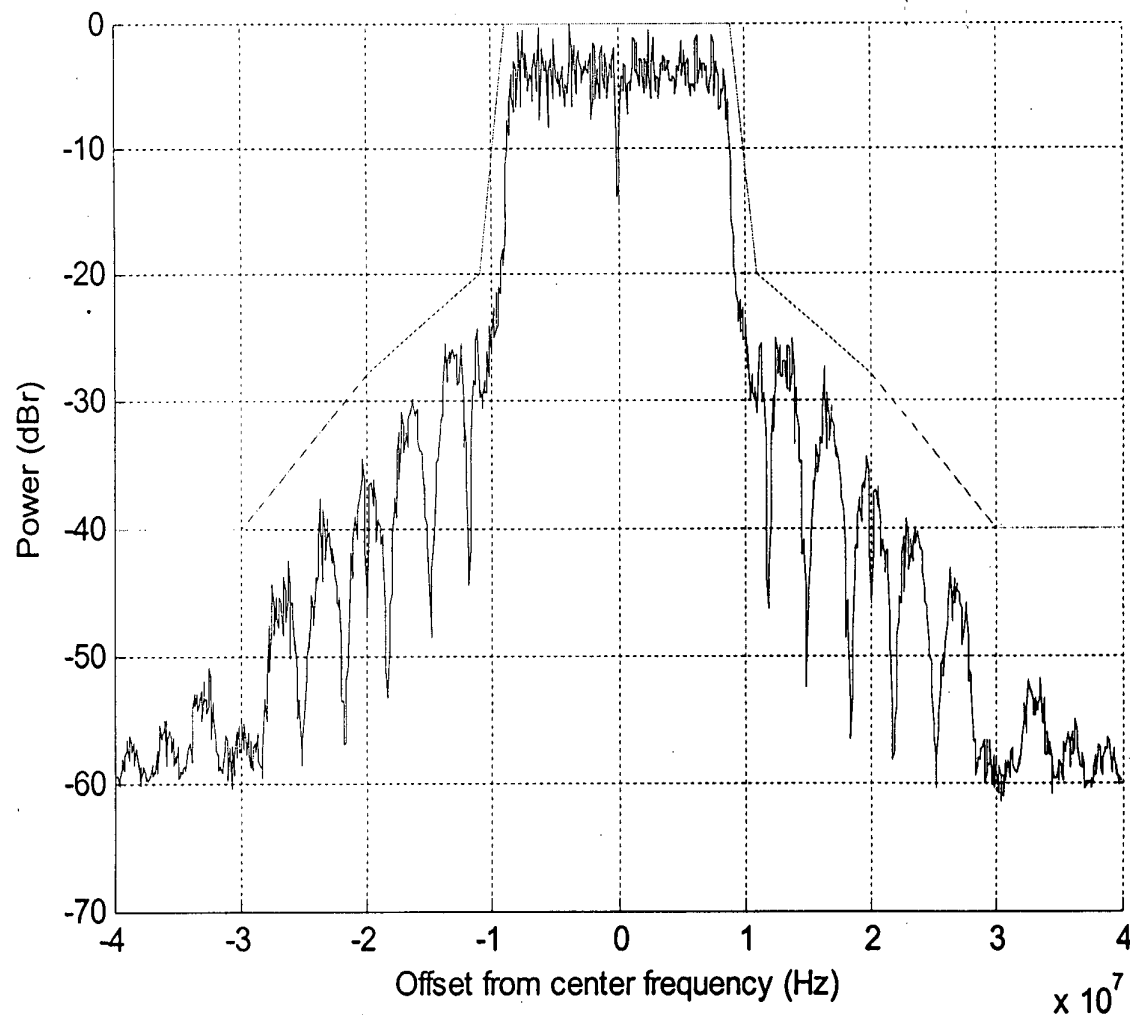


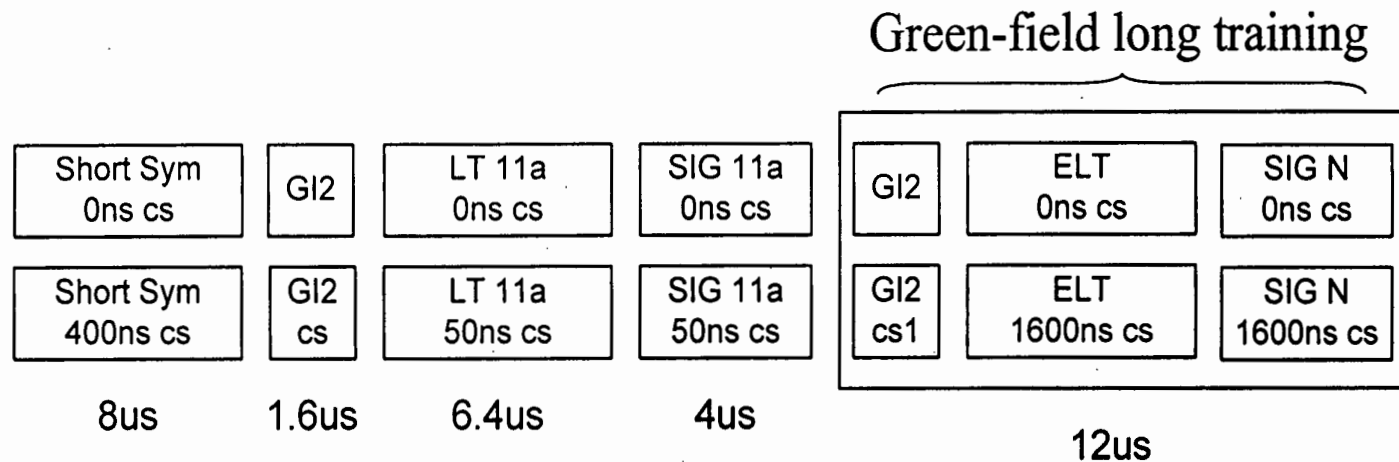
Fig. 3

Advantages Option 1

- Low overhead
- No significant power drops per TX stream
- Potential on the fly detection of the number of TX antennas
- Signal field always at the end of training, hence no issues with processing delay due to channel estimation, moreover convenient for MAC options such as for instance proposed in BRCM13
- Simple detection of signal field using a SISO detection (independent of number of TX antennas)

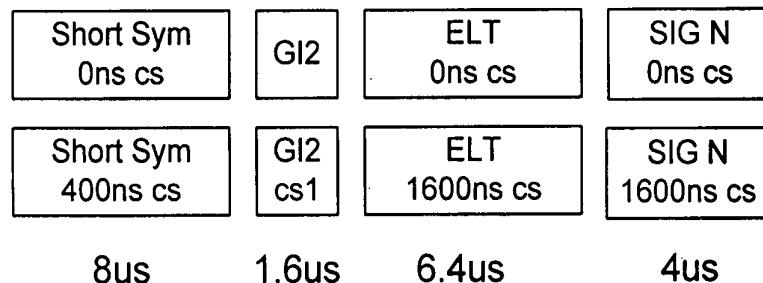
Mixed-mode Preamble Option 1

- “Mixed-mode” preamble
 - Use long preamble detectable by legacy devices
 - important point is that all legacy devices should defer if signal is relatively strong; signals near sensitivity level are not interesting, because devices are not required to defer anyway for such low signal levels. BRCM14 shows that for strong input levels, cs of 50 ns is the best choice for the lowest error floor, hence best defer behavior.
 - Use 11a signal field cyclically shifted by same delays as long preamble
 - Append “green-field” long preamble
 - Example of 2 TX case below readily extendable to 3 and 4 TX case with cyclic shifts on the LT 11a symbol of 100 ns and 150 ns respectively



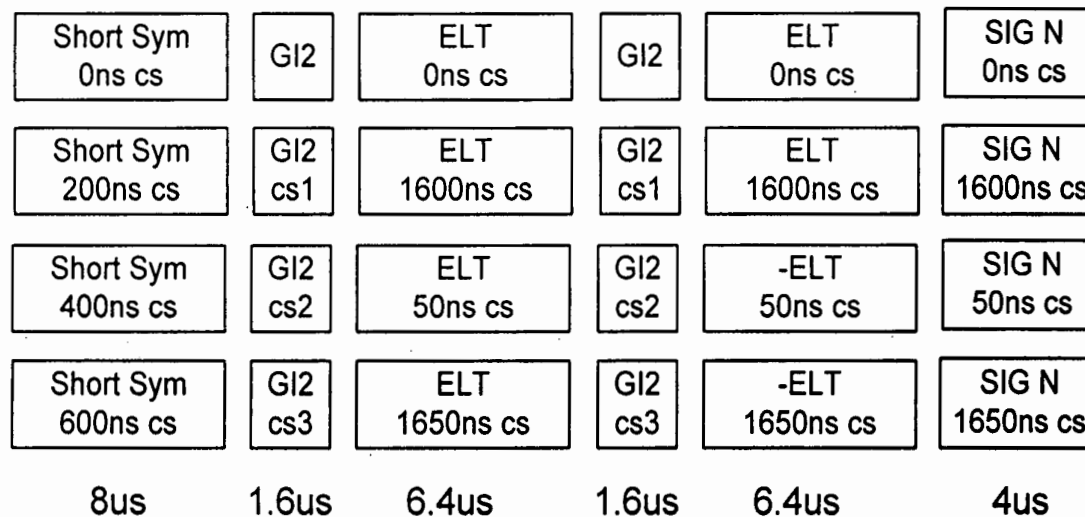
Green-field Preamble based on Cyclic Shift (Option 2)

- “Green-field” preamble for 2 TX case (20 and 40 MHz)
 - Minimal overhead in long training
 - On TX2: a cyclic shift (cs) in Extended Long Training (ELT) of 1.6 μ s
 - SIG N field uses same cyclic shift as long training sequence
 - Use Extended Long Training to prevent interpolation issues



Green-field Preamble Option 2

- “Green-field” preamble for 3 & 4 TX case (20 and 40 MHz)
 - Use a double long-training sequence (i.e., 16 μ s) with a Walsh code to distinguish between TX 1,2 and TX 3,4 (equivalent to time-orthogonal approach in TXN-002r1 (p. 12))
 - Detection of double long-training sequence indicates 3 or 4 TX case
 - For 3 TX case last row is not used
- Extra 50 ns cs in LT on TX 3 & 4 equivalent to phase shift over frequency proposed in brcm09_5_09_04 (p. 7)

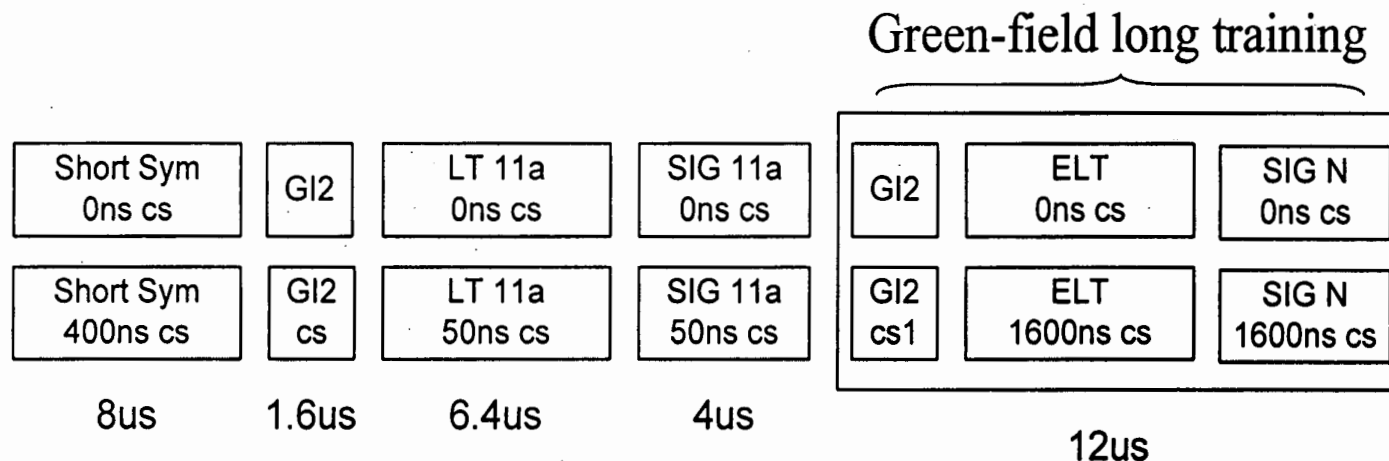


Advantages Preamble Option 2

- No significant power drops per TX stream
- Potential on the fly detection of the number of TX antennas
- Easy detection between 2 TX and 3,4 TX case
- When 3,4 TX case is detected, always do 4 TX case channel estimation and drop estimates of TX4 when the mode field in the signal field indicates this
- Signal field always at the end of training, hence no issues with processing delay due to channel estimation, moreover convenient for MAC options such as for instance proposed in BRCM13
- Simple detection of signal field using the first 8 μ s of the LT and a SISO detection (independent of number of TX antennas)
- MSE of channel estimation for the 2 TX case and 4 TX case equivalent

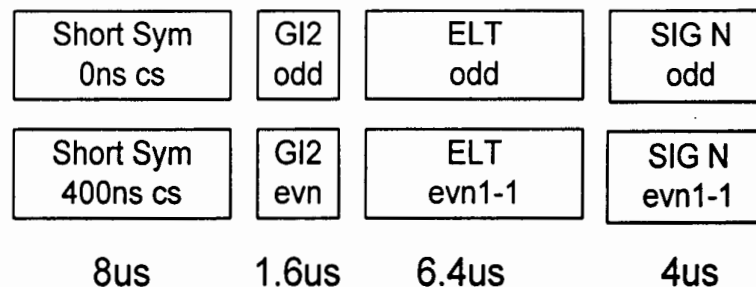
Mixed-mode Preamble Option 2

- “Mixed-mode” preamble
 - Use long preamble detectable by legacy devices
 - important point is that all legacy devices should defer if signal is relatively strong; signals near sensitivity level are not interesting, because devices are not required to defer anyway for such low signal levels. BRCM14 shows that for strong input levels, cs of 50 ns is the best choice for the lowest error floor, hence best defer behavior.
 - Use 11a signal field cyclically shifted by same delays as long preamble
 - Append “green-field” long preamble
 - Example of 2 TX case below readily extendable to 3 and 4 TX case with cyclic shifts on the LT 11a symbol of 100 ns and 150 ns respectively



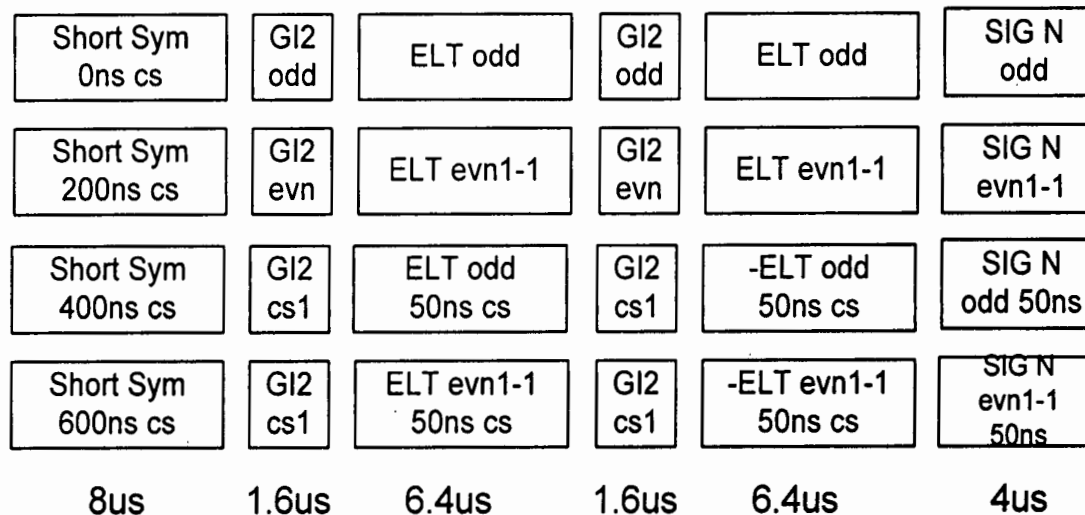
Frequency-sparse Green-field Preamble (Option 3)

- “Green-field” preamble for 2 TX case (20 and 40 MHz)
 - Minimal overhead in long training
 - Using the frequency-sparse technique (spread odd and even subcarriers of ELT over TX1 and TX2)
 - Multiply even subcarriers (on TX2) by $\{1, -1, 1, -1, \dots\}$ sequence (denoted by “evn1-1” in figs)
 - Similar to an idea presented on p. 13 of TXN002r1 (odd tones negated)
 - Similar to a cs of 800 ns, so also similar to ideas in BRCM12, but maybe more intuitive
 - advantage of evn1-1: potential on the fly detection of number of TX antennas
 - SIG N field uses same subcarrier mapping as long training sequence
 - Use Extended Long Training to prevent interpolation issues



Green-field Preamble Option 3

- “Green-field” preamble for 3 & 4 TX case (20 and 40 MHz)
 - Use a double long-training sequence with a Walsh code to distinguish between TX 1,2 and TX 3,4 (equivalent to time-orthogonal approach in TXN-002r1 (p. 12))
 - Detection of double long-training sequence indicates 3 or 4 TX case
 - For 3 TX case last row is not used
 - Extra 50 ns cs in LT on TX 3 & 4 equivalent to phase shift over frequency proposed in brcm09_5_09_04 (p. 7)

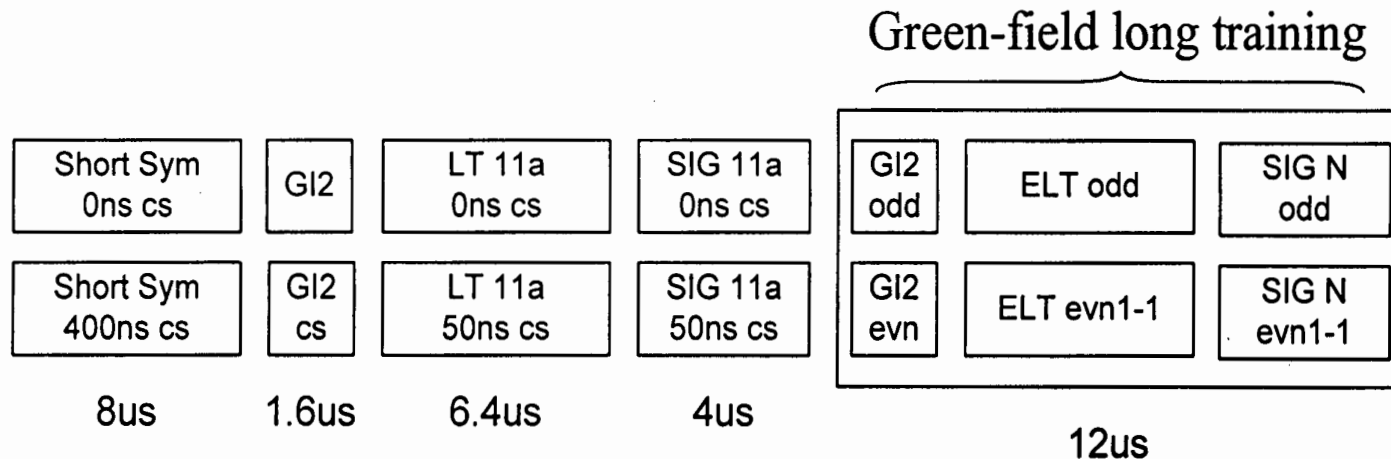


Advantages Option 3

- No significant power drops per TX stream
- Potential on the fly detection of the number of TX antennas
- Easy detection between 2 TX and 3,4 TX case
- When 3,4 TX case is detected, always do 4 TX case channel estimation and drop estimates of TX4 when the mode field in the signal field indicates this
- 15 • Signal field always at the end of training, hence no issues with processing delay due to channel estimation, moreover convenient for MAC options such as for instance proposed in BRCM13
- Simple detection of signal field using the first 8 μ s of the LT and a SISO detection (independent of number of TX antennas)
- MSE of channel estimation for the 2 TX case and 4 TX case equivalent
- Performance most likely equivalent to Option 1 (as we can conclude from CNXT-007, p.8)

Mixed-mode Preamble Option 3

- “Mixed-mode” preamble
 - Use long preamble detectable by legacy devices
 - important point is that all legacy devices should defer if signal is relatively strong; signals near sensitivity level are not interesting, because devices are not required to defer anyway for such low signal levels. BRCM14 shows that for strong input levels, cs of 50 ns is the best choice for the lowest error floor, hence best defer behavior.
 - Use 11a signal field cyclically shifted by same delays as long preamble
 - Append “green-field” long preamble
 - Example of 2 TX case below readily extendable to 3 and 4 TX case with cyclic shifts on the LT 11a symbol of 100 ns and 150 ns respectively



Signal Field N Proposal

- In these green-field preamble proposals SIG N has to work stand-alone
- So it should at least contain enough bits to define mode and packet length
- Moreover, for MAC options as described in BRCM13, other requirements are e.g. a good CRC and a bit indicating the last PSDU of a frame
- In total, this leads to more than 18 bits (24 – 6 Tail bits). 42 bits seem to be sufficient:
 - 6 bits for mode
 - 16 bits for length
 - 16 bits for CRC
 - 1 bit to indicate last PSDU of frame (see BRCM13)
 - 3 bits left -> reserved bits

11n Signal Field

48 bits (e.g., QPSK, code rate = $\frac{1}{2}$)

Mode (6)	Length (16)	Last PSDU (1)	Reserved (3)	CRC (16)	Tail (6)
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In accordance with some embodiments of the present invention, for an efficient MIMO channel training based on the 802.11a long training symbols, cyclically-shifted versions of the time-domain 11a long training symbol (extended with out-of-band subcarriers) are transmitted on different transmit antennas. At the receiver (RX), after matching the received signal with the extended 11a long training symbol, the result is a sum of shifted channel impulse responses corresponding to the channels from the different TX antennas. The time shift per impulse response equals the shift used for cyclically shifting to extended 11a long training symbol. In accordance with these embodiments, by detecting whether shifted impulse responses are present or not, the number of TX antennas is estimated.

There are a number of advantages gained in determining the number of transmit antennas. For example:

- the number of transmit antennas is often required to perform a correct MIMO channel estimation
- it may be useful for synchronization tasks
- the MIMO detection often needs this information to perform a correct detection
- power management may use this information to switch of parts of the hardware
- memory allocation and other hardware allocation may use the number of TX antennas.

The Algorithm

In the RX processing the following steps have to be performed:

1. Perform an FFT on the received samples corresponding to the transmitted long training symbol(s)
2. Multiply the result per subcarrier with the per-subcarrier frequency-domain representation of the extended 11a long training symbol (in order to remove the long training symbol influence and to maintain the channel information)
3. Perform an IFFT to transfer the result to the time domain. Depending on the number of TX antennas, this result will contain a sum of time-shifted impulse responses. For instance, when two TX antennas are used and the cyclic shift of the extended 11a long training symbol at the first TX antenna is 0 and that at the second TX antenna is 32,

the result will look like that of Figure 1. For three and four TX antennas, respectively, the shifts can be, e.g., 0, 21 and 42, and 0, 16, 32 and 48 respectively.

4. The detection mechanism that detects whether an impulse response is present with a certain time-shift, by which the number of TX antennas can be determined, is basically based on power detection. In order to improve the accuracy of the detector, cyclic window integration can be applied to the result of point 3. For a window of 4 samples, integrating the complex numbers which form the basis of Figure 1 yields Figure 2.
5. Now, the maximum in certain intervals of the integrator result provides an indication whether an impulse response is present in that interval or not. The intervals are selected such that they match the possible cyclic shifts of the extended long training symbols. For an interval size of 4 samples, the intervals for all possible shifts as mentioned in the example of point 3 are $\{I1, I2, I3, I4, I5, I6\} = \{0-3, 16-19, 21-24, 32-35, 42-45, 48-51\}$. These intervals are shown in Figure 2.
6. Let $\{M1, M2, \dots, M6\}$ be the maximum of $\{I1, I2, \dots, I6\}$. Then, e.g. a combination of the following comparison criteria can be used to determine the number of TX antennas (N_t):

```
if ((M2 > THR1) AND (M3 > THR1) AND (M4 > THR1))  $N_t = 4$ 
elseif ((M5 > THR1) AND (M6 > THR1))  $N_t = 3$ 
elseif (M3 > THR1)  $N_t = 2$ 
else  $N_t = 1$ 
```

```
if ((M2 > THR2) OR (M4 > THR2))  $N_t = 4$ 
elseif ((M5 > THR2) OR (M6 > THR2))  $N_t = 3$ 
```

```
if (mean(M2, M3, M4) > mean(M5, M6))  $N_t = 4$ 
elseif (mean(M5, M6) > M3)  $N_t = 3$ 
```

```
if (max(M1, M2, M3, M4) < THR3*min(M1, M2, M3, M4))  $N_t = 4$ 
elseif (max(M1, M5, M6) < THR3*min(M1, M5, M6))  $N_t = 3$ 
elseif (max(M1, M3) < THR3*min(M1, M3))  $N_t = 2$ 
else  $N_t = 1$ 
```

where THR1, THR2 and THR3 are thresholds that might be depending on the noise power. An estimate of the noise power is easily obtained by subtracting the received samples corresponding to two (or more) subsequent equivalent training symbols and calculating the power of the result. Regarding the comparison criteria, the first one checks which maximum values are above a certain threshold/noise floor. The second comparison criterion verifies if certain peaks are above a higher threshold; this makes sure that when other peaks are below the noise floor, still the correct number of transmit antennas is detected. The third criterion is needed to distinguish between the three TX and four TX case because for high delay spread cases the first two criteria might fail. The fourth comparison rule is used to make sure that the highest and the lowest peak are within a certain value (say 15 or 20 dB). This is particularly important to distinguish between the one TX and two TX case.

Finally, note that after point 4 we can add the outcomes of the integrators of different RX antennas to improve the accuracy of the detector described by points 5-6.

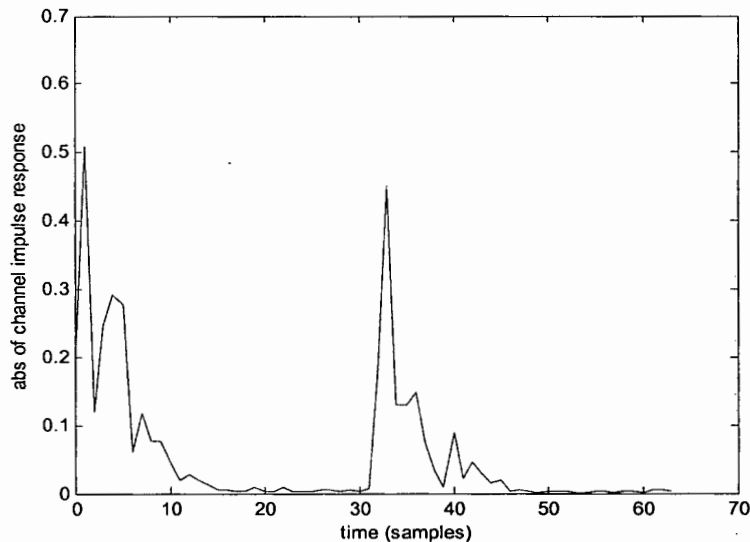


Figure 1: Absolute values of the impulse responses corresponding to two transmit antennas (with an SNR per RX antenna of 30 dB) .

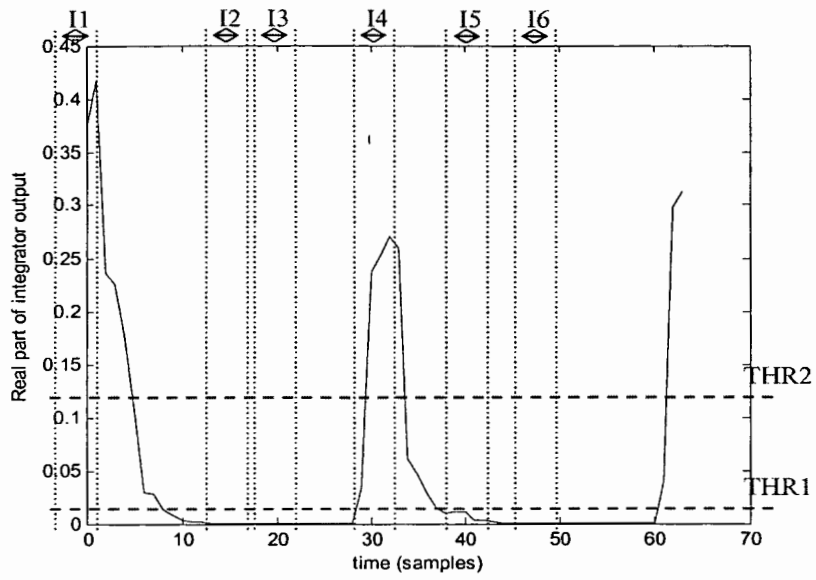


Figure 2: Real part of the window integration results of the complex values that form the basis of Figure 1.

Application Data Sheet

Application Information

Application number::

Filing Date::

Application Type::

Provisional

Subject Matter::

Utility

Suggested classification::

Suggested Group Art Unit::

CD-ROM or CD-R??::

Number of CD disks::

Number of copies of CDs::

Sequence Submission::

Computer Readable Form (CRF)?::

Number of copies of CRF::

Title::

MODIFIED PREAMBLE STRUCTURE FOR IEEE
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OR MISO TRANSMISSIONS

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Representative Information

Representative Customer Number:: 20350

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