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(54) **Módosított előtag struktúra IEEE 802.11A kiterjesztésekhez, 802.11A eszközök és nagyobb adatsebességű, MIMO vagy egyébként kiterjesztett eszközök közötti koegzisztencia és együttműködési képesség lehetővé tételére**

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(54) **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**

MODIFIZIERTE PRÄAMBELSTRUKTUR FÜR ERWEITERUNGEN IEEE 802.11A ZUR
ERMÖGLICHUNG DER COEXISTENZ UND INTEROPERABILITÄT ZWISCHEN
802.11A-EINRICHTUNGEN UND EINRICHTUNGEN MIT HÖHERER DATENRATE, MIMO- ODER
ANDERWEITIG ERWEITERTEN EINRICHTUNGEN

STRUCTURE DE PREAMBULE MODIFIE POUR EXTENSIONS IEEE 802.11A PERMETTANT LA
COEXISTENCE ET L'INTEROPERABILITE ENTRE DES DISPOSITIFS 802.11A ET DES
DISPOSITIFS A DEBIT PLUS ELEVE, MIMO OU PRESENTANT D'AUTRES TYPES D'EXTENSIONS

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- **JIANHUA LIU ET AL: "A MIMO system with backward compatibility for OFDM based WLANs", SIGNAL PROCESSING ADVANCES IN WIRELESS COMMUNICATIONS, 2003. SPAWC 2003. 4TH IEEE WORKSHOP ON ROME, ITALY 15-18 JUNE 2003, PISCATAWAY, NJ, USA, IEEE, US, 15 June 2003 (2003-06-15), pages 130-134, XP010713389, DOI: 10.1109/SPAWC.2003.1318936 ISBN: 978-0-7803-7858-2**

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Description

BACKGROUND OF THE INVENTION

[0001] The IEEE 802.11a standard defines data rates of 6 Mbps (megabits per second) up to 54 Mbps. For some applications, higher data rates for given modulations and data rates higher than 54 Mbps are desirable. Other extensions, such as the use of MIMO (multiple-input, multiple-output) antenna systems and other extensions might be desirable. In order to avoid conflicts with existing standardized communications and devices, extended devices that extend beyond the limits of the 802.11a standard and legacy devices that comply with the existing standard and are not necessarily aware of extended standards both need to coexist in a common communication space and even interoperate at times.

[0002] Coexistence is where differing devices can operate in a common space and still perform most of their functions. For example, an extended transmitter transmitting to an extended receiver might coexist with a legacy transmitter transmitting to a legacy receiver and the extended devices can communicate while the legacy devices communicate, or at least where the two domains are such that one defers to the other when the other is communicating. Coexistence is important so that the adoption and/or use of extended devices (i.e., devices that are outside, beyond or noncompliant with one or more standards with which legacy devices adhere and expect other devices to adhere) do not require replacement or disabling of existing infrastructures of legacy devices.

[0003] Interoperability is where an extended device and a legacy device can communicate. For example, an extended transmitter might initiate a transmission in such a manner that a legacy device can receive the data sent by the extended transmitter and/or indicate that it is a legacy device so that the extended transmitter can adjust its operations accordingly. For example, the extended transmitter might revert to standards compliant communications or switch to a mode that, while not fully standards compliant, is available to the legacy receiver. In another situation, an extended receiver might successfully receive data from a legacy transmitter.

[0004] The IEEE 802.11a standard defines a 20 microsecond long preamble with a structure as shown in Fig. 1, having short training symbols S (0.8 microseconds each), a guard interval LG, long training symbols L (3.2 microseconds each) and a signal field (4 microseconds). The preamble is followed by data. The first eight microseconds comprises ten identical short training symbols that are used for packet detection, automatic gain control and coarse frequency estimation. The second eight microseconds comprise two identical long training symbols, L, preceded by a guard interval LG that is the same pattern as the last half (1.6 microseconds) of the long training symbol L. The long training symbols can be used for channel estimation, timing, and fine frequency estimation.

[0005] Fig. 2 shows a long training sequence, L_1 , that is used to generate the signal representing the long training symbol in a conventional 802.11a preamble. This sequence represents values used over a plurality of subcarriers. As specified in the standard, the subcarriers span a 20 MHz channel and with 64 subcarriers, they are spaced apart by 312.5 kHz. By convention, used here, the first value in the sequence is the value for the DC subcarrier, followed by the value for the 1×312.5 kHz subcarrier, then the value for the $2 \times 312.5 = 625$ kHz subcarrier, etc., up to the 32nd value for the 31×312.5 kHz = 9687.5 kHz subcarrier. The 33rd value corresponds to the -10 MHz subcarrier, followed by the $-(10 \text{ MHz} - 312.5 \text{ kHz})$ subcarrier, and so on, with the 64 value being for the -312.5 kHz subcarrier.

[0006] As can be seen from Fig. 1, the DC value and the 28th through 38th values, corresponding to the edges of the 20 MHz channel, are zero. The output of a transmitter is a training symbol at a sample rate of 64 samples/symbol. The samples are obtained by taking a 64-point IFFT (inverse fast-Fourier transform) of the long training sequence, L_1 in this example. As used herein, a sequence in the frequency domain is expressed with uppercase letters (e.g., $L(k)$), while the corresponding time sequence is expressed with lowercase letters (e.g., $l(k)$).

[0007] One approach to obtaining higher data rates is the use of more bandwidth. Another approach, used by itself or as well as the use of more bandwidth, is MIMO (multiple-input, multiple-output) channels, where a plurality of transmitters transmit different data or the same data separated by space to result in possibly different multi-path reflection characteristics. In either case, care is needed for coexistence and interoperability between legacy devices and extended devices.

[0008] WO 2005/006700 describes methods and apparatus for transmitting symbols in a multiple antenna communication system according to a frame structure, such that the symbols can be interpreted by a lower order receiver (i.e., a receiver having a fewer number of antennas than the transmitter). The disclosed frame structure comprises a legacy preamble having at least one long training symbol and N-1 additional long training symbols that are transmitted on each of N transmit antennas. The legacy preamble may be, for example, an 802.11 a/g preamble that includes at least one short training symbol, at least one long training symbol and at least one SIGNAL field. A sequence of each of the long training symbols on each of the N transmit antennas are time orthogonal. The long training symbols can be time orthogonal by introducing a phase shift to each of long training symbols relative to one another.

[0009] US 2003/0016621 describes techniques to determine channel characteristics of various communication systems such as OFDM systems or systems using a plurality of transmit antennas by using various sets of training symbols that produce zero cross-correlation energy. Channel communication can accordingly be simplified as the zero cross-

correlation property allows for channel estimation without a matrix inversion.

[0010] Jianhua Liu et al: "A MIMO system with backward compatibility for OFDM based WLANs", Signal Processing Advances In Wireless Communications, 2003. SPAWC 2003. 4TH IEEE Workshop in Rome, Italy 15-18 June 2003, Piscataway, NJ, USA, IEEE, US, 15 June 2003, pages 130-134, XP010713389, describes a MIMO system with two transmit and two receive antennas and a preamble design that is backward compatible with its single-output (SISO) counterpart as specified by the IEEE 802.11a standard. The same long training symbols are used as for the SISO system for both of the two antennas before the SIGNAL field. When simultaneously received packets are received by a single SISO receiver, the SISO receiver can successfully detect up to the SIGNAL field, which is designated to be the same for both transmit antennas. The reserved bit in the SIGNAL field can tell the SISO receiver to stop its operation whenever a MIMO transmission follows or otherwise to continue its operation

BRIEF SUMMARY OF THE INVENTION

[0011] According to an aspect of the invention there is provided A training sequence comprising N preambles configured respectively for transmission from at least N antennas of a wireless communication system, each of the N preambles comprising: a short training sequence field; a long training sequence field; and a signal field; wherein the signal field and at least one of the short training sequence field and the long training sequence field of at least one of the N preambles have a cyclic shift with respect to the respective short training sequence field, long training sequence field and signal field of another one of the N preambles, and wherein each preamble comprises a first part defined by the 802.11a standard, and a second part comprising at least one field that is distinguishable from the preamble defined by the 802.11a standard.

[0012] According to another aspect of the invention there is provided a corresponding method of generating the training sequence.

[0013] According to a further aspect of the invention there is provided apparatus for generating the training sequence.

[0014] A modified preamble is used by extended devices that operate at higher rates, MIMO or other extensions relative to strict 802.11a-compliant devices. The extended devices might use one or more of multiple antenna techniques (MIMO), where multiple data streams are multiplexed spatially and multi-channel techniques, where an extended transmitter transmits using more than one 802.11a channel at a time. Such extensions to IEEE 802.11a can exist in extended devices.

[0015] The modified preamble is usable for signaling, to legacy devices as well as extended devices, to indicate capabilities and to cause legacy devices or extended devices to defer to other devices such that the common communication channel is not subject to unnecessary interference. The modified preamble is also usable for obtaining MIMO channel estimates and/or multi-channel estimates.

[0016] The modified preamble preferably includes properties that facilitate detection of conventional and/or extended modes ("mode detection") and provides some level of coexistence with legacy IEEE 802.11a devices. The modified preambles may include modifications in the short training symbols, long training symbols, and/or the signal field. In some embodiments, the modified preamble includes both legacy 802.11a sequences as well as modified preamble sequences. In yet other embodiments, energy is transmitted on every single tone except the DC tone of the long training sequence of the modified preamble.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

Fig. 1 illustrates the structure of a conventional 802.11a preamble.

Fig. 2 shows the frequency-domain symbols, starting with the DC subcarrier, of a long training symbol sequence, L_1 , used for a conventional 802.11a preamble.

Fig. 3 illustrates several devices coupled via a wireless network.

Fig. 4 illustrates other long training sequences, usable by extended devices.

Fig. 5 illustrates one possible layout for out-of-band pilot tones for individual channels.

Fig. 6 illustrates one possible layout for out-of-band pilot tones for commonly assigned adjacent individual channels, where the out-of-band signals between adjacent bands are not attenuated.

Fig. 7 illustrates a layout for out-of-band pilot tones for four adjacent individual channels assigned to a single device, where the out-of-band signals between adjacent bands are not attenuated.

Fig. 8 illustrates a modified preamble usable for multi-channel packets with or without MIMO.

Figs. 9A, 9B and 9C show modified preambles for systems having respectively two, three, and four transmit antennas, in accordance with one embodiment of the present invention.

Fig. 10 shows a modified preamble configured for transmission via a system having four transmit antennas, in accordance with another embodiment of the present invention.

Fig. 11 shows a modified preamble configured for transmission via a system having two transmit antennas, in accordance with another embodiment of the present invention.

Fig. 12 shows a modified preamble configured for transmission via a system having four transmit antennas, in accordance with another embodiment of the present invention.

Fig. 13 shows an exemplary mixed-mode preamble configured for transmission via a system with two-transmit antennas, in accordance with one embodiment of the present invention.

Fig. 14 shows an exemplary mixed-mode preamble configured for transmission from a system having two transmit antennas, in accordance with another embodiment of the present invention.

Fig. 15A shows the 64 tones of an extended long training sequence adapted for a 20 MHz channel, in accordance with one embodiment of the present invention.

Fig. 15B shows the lower and upper subcarriers of an 802.11a long training sequence adapted for a 20 MHz channel, as known in the prior art.

Fig. 16A shows the 128 tones of an extended long training sequence adapted for a 40 MHz channel, as known in the prior art.

Fig. 16B shows the lower and upper subcarriers of an 802.11a long training sequence, adapted for a 40 MHz channel, as known in the prior art.

Fig. 17 shows an exemplary spectrum associated with a PHY packet that includes the long training sequence shown in Fig. 15A and disposed within the 802.11a spectral mask defined by 802.11 a standard.

Fig. 18 shows the signal field of a modified preamble, in accordance with one embodiment of the present invention.

Fig. 19 is a flowchart illustrating one possible process for obtaining channel estimates for each transmitter signal in a MIMO system.

DETAILED DESCRIPTION OF THE INVENTION

[0018] The use of modified preambles is described herein. Such modified preambles can be used in packets sent over a wireless network, such as an 802.11a compliant wireless network. Such packets with modified preambles can be sent by transmitters according to embodiments of the present invention to be received by receivers according to embodiments of the present invention, as well as being received by legacy receivers that are not configured to receive and interpret the modified preambles as would be done with receivers according to embodiments of the present invention.

[0019] Fig. 3 illustrates just one example of a wireless network being used for communications among transmitters and receivers as indicated. As shown, two wireless devices 102(1), 102(2) might use and interpret the modified preambles, while a legacy wireless device 104 might not be expecting the modified preambles, but might hear signals representing such preambles. Extended wireless devices 102 might operate using multiple channels and/or multiple transmit antennas and/or multiple receive antennas. Devices might have a single transmit antenna and a single receive antenna, or more than one transmit antenna and/or more than one receive antenna. While separate transmit and receive antennas are shown, antennas might be used for both transmitting and receiving in some devices.

[0020] Border 106 is not a physical border, but is shown to represent a space within which signals can be received

from devices within the space. Thus, as one device transmits a signal representing a packet within border 106, other devices within border 106 pick up the signals and, as they are programmed, will attempt to determine if the signals represent packets and if so, then demodulate/decode the packets to obtain the data represented therein.

[0021] Many variations of a modified preamble might be used. An example is the preamble shown in Fig. 1, where the long training symbol is modified to use sequences such as one of the example sequences shown in Fig. 4.

[0022] Preferably, a modified preamble will be such that 1) an extended receiver (e.g., one that can advantageously handle modified preambles) can distinguish between MIMO packets (or other extended mode packets) and conventional 802.11a packets, 2) a legacy receiver (e.g., one that is not configured to receive and interpret the modified preambles and might not expect extended operations) can receive enough of a packet to determine either that the legacy receiver can understand the packet or can defer processing of incoming signals for a time, thereby allowing a measure of coexistence, 3) the modified preamble is usable for MIMO synchronization and channel estimation, and 4) the modified preamble is useful in a process of detecting the use of multi-channel transmission. In some embodiments of wireless devices according to the present invention, modified preambles are used that provide one, two, three or all of the preferable characteristics indicated above.

Combinations of Extensions

[0023] Multi-channel extended 802.11 systems might simultaneously transmit on several 20 MHz channels, whereas a legacy 802.11a system only transmits on a single 20 MHz channel using a single antenna, or if the legacy system does transmit with more than one antenna, each of the antennas transmits the same 802.11a signal, possibly with some delay differences between signals. As a result, data rates can be increased over 802.11a data rates using multiple transmit antennas or multiple channels or a combination of both. Thus, in a communication channel, such as the airspace of a wireless network cloud, several types of packets might be present:

- 1) Legacy SISO (single-input, single-output) 802.11a, 802.11b, or 802.11g packets transmitted in a single 20 MHz channel;
- 2) Extended SISO in multiple 20 MHz channels (e.g., 40, 60, 80, or 100 MHz channels)
- 3) Extended MIMO in a single 20 MHz channel;
- 4) Extended MIMO in multiple 20 MHz channels (e.g., 40, 60, 80, or 100 MHz channels)

[0024] Several satisfactory modified preamble structures can be derived by one of ordinary skill in the art after reading this disclosure. Some examples are described below. Preferably, the unmodified preamble structure can provide interoperability and coexistence between SISO and MIMO systems at various channel widths and coexistence between extended mode systems and legacy systems.

MIMO Single Channel (20 MHz)

[0025] A modified preamble can use the same structure as the 802.11a preamble, with a different long training symbol determined from a long training symbol sequence L_D . By keeping the same short symbols S , or by applying cyclic shifts on S for the second, third, etc, transmit antennas, and using the same timing structure as depicted in Fig. 1, a receiver using the extended mode can use the same hardware for detecting the repetitive S and L symbols, even though the actual contents of the L symbols may be different for the 802.11a extensions.

[0026] Various embodiments of wireless devices might use various long training symbol sequences. In one example of a modification, the long training symbol sequence L_D has one or more of the following features: 1) it is formulated such that channel estimation can be done for multiple transmitters, 2) it is such that it has a low cross-correlation with the unmodified 802.11a long training symbol sequence, and/or 3) it is usable in a relatively simple process of detecting whether the preamble is an 802.11a packet or an extended mode packet, usable in multipath channels. Suitable modified long training symbol sequences are shown as L_2 and L_3 , in Fig. 4, but other variations should be apparent upon reading this description.

Channel Estimation

[0027] By allowing for channel estimation for multiple transmitters, MIMO or space-time coding techniques can be supported to achieve 802.11a extensions. One way to do this is by sending a different set of subcarriers from each transmitter. As an example, for the case of two transmitters, a device might modulate its OFDM subcarriers with the 64

values of L_3 , shown in Fig. 4, where one transmitter transmits the odd subcarriers $\{1, 3, \dots, 63\}$ and the other transmitter transmits the even subcarriers $\{0, 2, \dots, 62\}$. Thus, one transmitter would take an IFFT of the odd subcarriers and transmit samples of that time varying signal and the other transmitter would take an IFFT of the even subcarriers and transmit samples of that time varying signal.

[0028] L_3 is a modified 802.11a long training symbol sequence, wherein some of the subcarriers of the standard 802.11a sequence L_1 (shown in Fig. 2) are inverted, and some subcarriers that are zero in L_1 are non-zero in L_3 . The latter has some advantages for channel estimation, but is not necessary for the purpose of discriminating 802.11a packets from extended mode packets.

Low Cross-Correlation

[0029] The second criterion is that the new training sequence should have a low cross-correlation with the conventional IEEE 802.11a training sequence. One way to achieve this is to invert every other group of four subcarriers, which is applied to sequence L_2 to get a new sequence L_3 that is nearly orthogonal to both L_1 and L_2 . Further, L_3 is constructed such that there is also a low cross-correlation between the even and odd elements of L_2 and L_3 . These sequences L_2 and L_3 are shown in Fig. 4. The low cross-correlation is illustrated by Equation 1 and Equation 2 (note that in Equation 1, a high cross-correlation would have right-hand side values closer to -32 or 32, since the sum is not normalized here).

$$\sum_{k=0}^{31} L_2(2k)L_3(2k) = -1 \quad (\text{Equ. 1})$$

$$\sum_{k=0}^{31} L_2(2k+1)L_3(2k+1) = 0 \quad (\text{Equ. 2})$$

Mode Detection

[0030] The low cross-correlation between even and odd elements of L_2 and L_3 supports the third criterion, as it makes it possible to detect extended mode packets by looking at the correlation of L_2 and L_3 with the odd and even subcarriers of a received packet.

[0031] Various methods can be available for a receiver to detect from a received signal whether a transmitter transmitted a conventional 802.11a packet or an extended mode packet. One method for detecting what type of packet was sent will now be described.

[0032] In this method, enough of the signal is received to identify what should be the two repeated long training symbols, typically sampled as two identical repetitions of 64 samples for each receive antenna. An FFT (fast-Fourier transform) of the sum of the two identical repetitions of 64 samples is taken, generating an output sequence $s_i(k)$, comprising 64 complex values per receive antenna, containing channel amplitudes and phases, as well as phase shifts caused by the long training symbol sequence that was actually used (e.g., sequences such as L_1 , L_2 , L_3 or L_4).

[0033] From the output sequence $s_i(k)$, the receiver generates two other sequences, $r_s(k)$ and $r_m(k)$, by multiplying $s_i(k)$ by the sequences L_2 and L_3 for each receive antenna i , as illustrated by Equations 3a and 3b.

$$r_{si}(k) = \sum_{k=0}^{63} S_i(k)L_2(k) \quad (\text{Equ. 3a})$$

$$r_{mi}(k) = \sum_{k=0}^{63} S_i(k)L_3(k) \quad (\text{Equ. 3b})$$

[0034] Next, the receiver calculates two metrics, m_m and m_s , from $r_s(k)$ and $r_m(k)$ using a differential detection operation, such as that illustrated by Equations 4a and 4b.

$$m_s = \left\| \sum_{i=0}^{N-1} \sum_{k=2}^{26} [r_{si}(k)r_{si}^*(k-1) + r_{si}(k+37)r_{si}^*(k+36)] \right\| \quad (\text{Equ. 4a})$$

$$m_m = \left\| \sum_{i=0}^{N-1} \sum_{k=0}^{11} [r_{mi}(2k+3)r_{mi}^*(2k+1) + r_{mi}(2k+41)r_{mi}^*(2k+39) \right. \\ \left. + r_{mi}(2k+4)r_{mi}^*(2k+2) + r_{mi}(2k+42)r_{mi}^*(2k+40)] \right\| \quad (\text{Equ. 4b})$$

[0035] If $m_m > c \cdot m_s$, then the receiver might assume that the received signal represents a conventional 802.11a packet, otherwise the receiver assumes the packet is an extended mode packet. The constant c is preferably equal to 1, but may be different.

SISO/MIMO Multiple Channel

[0036] Some modified preamble structures described herein provide interoperability and coexistence between SISO multi-channel packets/devices and MIMO multi-channel packets/devices, as well as coexistence between multi-channel packets/devices and legacy packets/devices.

[0037] Fig. 5 illustrates the case where out-of-band pilots are attenuated for 20 MHz channels used to transmit a MIMO signal. The preamble structure can be identical to a conventional 802.11a preamble, except that the long training symbol sequence may use what are otherwise considered out-of-band subcarriers. Some or all of these out-of-band subcarriers may also be used in the data symbols to increase the data rate.

[0038] In the case of Fig. 5, different channels may be used by different devices, but it is also possible that the same device transmits on several channels simultaneously. For instance, one device may transmit on channels 1 and 4 simultaneously, while channels 2 and 3 are used by other devices.

[0039] If two adjacent channels are used simultaneously by one device, then there is no need to attenuate the "out-of-band subcarriers" in the middle of this 40 MHz band. An example of this is shown in Fig. 6. The out-of-band subcarriers that are in between the two 20 MHz channels thus need not be attenuated. In Fig. 4, the sequence L_4 is the long training symbol sequence for a 40 MHz preamble, which contains all 128 subcarrier values for a 40 MHz channel long training symbol. The first 32 values are identical to the last 32 values of a 20 MHz preamble, corresponding to the subcarriers in the left part of a 20 MHz channel. One difference between L_4 and two separate 20 MHz long training sequences is that the DC subcarriers are at different locations, so at the position where a 20 MHz channel would normally have its DC subcarrier, the 40 MHz sequence can have a nonzero subcarrier value. In L_4 , these are subcarrier numbers 33 and 97, respectively.

[0040] With unattenuated out-of-band subcarriers, signaling information can be carried on those subcarriers during packet setup, such as signaling operating and/or extension modes during a preamble, and additional data can be carried on those subcarriers, to increase the data rate.

[0041] Fig. 7 shows the case of four 20 MHz channels.

[0042] One example of a modified preamble is the preamble shown in Fig. 1 modified as shown in Fig. 8. The long training symbol values for these out-of-band subcarrier can be the same as in the case of Fig. 1. The long training symbol is followed by a replica of the Signal field with identical subcarrier values in each of the 20 MHz channels overlaid by the same effects (e.g., time-domain cyclic shift or frequency-domain scrambling pattern) as the long training symbol of the corresponding transmit antenna or spatial stream. This ensures that a receiver that operates on just one of the 20 MHz channels will still be able to successfully decode at least the first part of the packet containing the Signal field and defer for the rest of the packet, as decoding the Signal field provides the receiver with information about the length of the packet and thus how long to defer. The same technique can be extended to an arbitrary number of channels.

[0043] Fig. 8 shows a preamble for a two transmitter MIMO packet. The structure is the same as for 802.11a, but some differences are that a) l_0, l_1, d_0, d_1 , may contain out-of-band subcarriers, b) s_1, l_1, d_1 can be cyclically shifted relative to s_0, l_0, d_0 or c) l_0 and l_1 can contain subcarrier sequences that have a low cross-correlation with the same subcarrier sequences of the 802.11 a long training symbol sequence.

Interoperability

[0044] Interoperability between the different extended modes can be ensured by transmitting the same preamble and signal field in each 20 MHz channel. The preamble time structure can be the same as that of IEEE 802.11 a, as illustrated in Fig. 1. For a 20 MHz MIMO transmitter, the long training symbol L can be modified to facilitate MIMO channel estimation and include out-of-band pilots. In one example of an extended transmitter using a plurality of channels, the transmitter transmits an identical copy of the preamble and signal field in each 20 MHz channel used by that transmitter where the out-of-band pilots only have to be attenuated at the edges of a multi-channel and not between adjacent channels of the multi-channel. The subcarriers of the signal field might contain different data bits for different 20 MHz channels, to signal information such as the transmitter's multi-band mode, MIMO mode, channel number, data rate, and/or coding rate.

[0045] By transmitting the same preamble and signal field in any 20 MHz channel, it is ensured that an extended device that only demodulates one 20 MHz channel at least is able to decode the signal field. From the information in the signal field, the single-channel extended device can either properly defer for the duration of the packet or find out what extended mode is used for this packet in the case that this information is encoded in the signal field. For instance, the receiver could detect from the signal field that the packet is transmitted over four adjacent channels, after which the extended receiver can decide to switch to a four-channel receiving mode.

[0046] Notice that it typically does not matter for a single-channel 20 MHz receiver whether the out-of-band subcarriers depicted in Figs. 5-7 are attenuated. For instance, if a single-channel receiver demodulates channel 2 out of the 4 transmitted channels shown in Fig. 7, the receive filter of that single-channel receiver will partly attenuate the out-of-band subcarriers as well as suppress the adjacent channels 1 and 3 to the point where these adjacent channels do not cause interference to the desired signal of channel 2.

Coexistence

[0047] One method of having coexistence between extended devices and legacy IEEE 802.11a and IEEE 802.11g devices is by keeping the preamble structure in each 20 MHz channel the same as for IEEE 802.11a. IEEE 802.11a specifies an energy detect based defer behavior, which provides some level of coexistence. However, to guarantee that legacy devices properly defer for all extended mode packets down to received power levels of -82 dBm or other suitable levels, the receivers have to be able to successfully decode the signal field, which contains the length information of the packet.

[0048] Some ways to do this are described by Bangerter, B., et al., "High-Throughput Wireless LAN Air Interface", Intel Technology Journal, Vol. 7, Issue 3 (August 2003) (hereinafter "Bangerter") and Boer, J., et al., "Backwards Compatibility", IEEE 802.11 presentation, Document Number 802.11-03/714r0 (September 2003) (hereinafter "Boer").

[0049] Bangerter describes the use of multiple 802.11a preambles spread in frequency such that 20 MHz channel legacy 802.11a devices will defer for multiple channel devices, but additional advantages can be had through the use of out-of-band pilots or MIMO preambles, as described elsewhere herein.

[0050] Boer describes some possible MIMO preambles having some limited benefits. In one method described in Boer, each MIMO transmitter transmits an 802.11a preamble while the other transmitters transmit nothing. While this makes distinguishing easier, training is significantly longer and that reduces throughput. In another method described in Boer, each MIMO transmitter transmits a part of the 802.11a subcarriers. For example, for two transmitters, one transmitter transmits all odd subcarriers and the other transmitter transmits all even subcarriers. However, without more, mode detection based on the training symbols might not be possible with that technique.

[0051] A novel way of enabling coexistence or furthering coexistence for MIMO packets is to apply a cyclic delay shift on the long training symbol and Signal field IFFT outputs prior to applying the guard time extension. For example, assume $L(k)$ and $D(k)$ are the 64 subcarrier values for the long training symbol and Signal field symbol, respectively. For a conventional 802.11a single transmitter transmission, the time samples for the long training symbol are derived by taking the 64-point IFFT of $L(k)$ to obtain $I(i)$ and transmitting the samples of $I(i)$. Thus, with the guard time, the long training symbol and guard time are constructed as $[I(32:63) I(0:63) I(0:63)]$, i.e., the IFFT output is repeated twice and the last 32 samples are prepended to form the long training guard interval. As with the conventional timing, the long training guard interval (32 samples) is twice as long as the guard interval for 802.11a data symbols (16 samples). The signal field is formed by $[d(48:63) d(0:63)]$, where $d(0:63)$ are the 64 samples of the IFFT of $D(k)$.

[0052] In the case of a two transmitter MIMO device, the first transmitter would transmit the long training symbol and signal field like that of 802.11a. The second transmitter would apply a cyclic shift such that instead of the IFFT output $I(0:63)$, it uses the cyclically shifted samples $I_s=[I(32:63) I(0:31)]$ to construct the long training symbol samples $[I_s(32:63) I_s(0:63) I_s(0:63)]$. For the signal field, it uses the shifted samples $d_s=[d(32:63) d(0:31)]$ to construct the signal field as $[d_s(48:63) d_s(0:63)]$.

[0053] In a legacy 802.11a packet, one 3.2 microsecond repetition of the long training symbol L as shown in Fig. 1 is expressed in the time domain as the IFFT of $L(k)$, where $L(k)$ contains 64 subcarrier values, of which 52 are non-zero. The time samples $I(i)$ are given as shown in Equation 5, where the subcarrier values of $L(k)$:

$$I(i) = \sum_{k=0}^{63} L(k) \exp(j \frac{2\pi i k}{64}) \quad (\text{Equ. 5})$$

[0054] In the extended modes described herein, some possible modifications will be described. First, $L(k)$ can contain more than 52 non-zero subcarriers. Second, in the case of MIMO transmission, $I(i)$ can have a cyclic shift that may be different for each transmitter. The shifted signal $I_k(i)$ can be derived from $I(i)$ as $I_k(i) = I([i+64-d_k] \% 64)$, where "%" denotes the modulo operator and d_k is the cyclic delay of transmitter k in 20 MHz samples. This expression assumes a 20 MHz

sampling rate, such that there are 64 samples in a 3.2 microsecond interval. An alternative method of generating the cyclic shift is to apply a phase ramp rotation to all subcarrier values of $L(k)$ prior to calculating the IFFT, such as that shown by the example of Equation 6.

$$l_k(i) = \sum_{k=0}^{63} L(k) \exp(-j \frac{2\pi k d_k}{64}) \exp(j \frac{2\pi i k}{64}) \quad (\text{Equ. 6})$$

[0055] A MIMO transmitter can have two or more transmit antennas (or antenna arrays, as the case may be). For a MIMO system with two transmit antennas and two different transmit data streams, preferred values for the cyclic delay values d_k are 0 and 32 samples, respectively. This corresponds to a cyclic delay of 1.6 microseconds between the two transmitters. For three transmitters, d_k can be 0, 22, and 43 samples, respectively. For four transmitters, d_k can be 0, 16, 32, and 48 samples, respectively.

[0056] Figs. 9A, 9B and 9C show modified preambles (also referred to alternatively as training sequences) configured for transmission via systems having two, three, and four transmit antennas respectively, in accordance with one embodiment of the present invention. Modified preamble 900 of Fig. 9A includes two preamble parts, namely preamble part 910₁ transmitted from the first antenna and preamble part 910₂ transmitted from the second antenna of a two-transmit antenna system. In the following, preamble parts are alternatively referred to as preambles. The short symbols of preamble 910₂ have a cyclic shift of 400 ns with respect to the short symbols of preamble 910₁. The extended long training (ELT) sequence of preamble 910₂ has a cyclic shift of 1600 ns with respect to the ELT sequence of preamble 910₁. Similarly, the Signal field of preamble 910₂ has a cyclic shift of 1600 ns with respect to the Signal field of preamble 910₁. Other cyclic shifts per preamble part may be used.

[0057] As described above, the combined duration for transmitting the short training sequence, guard intervals, long training sequence, and signal fields, is 20 μ s. Preamble 910₁ includes short training sequence 920₁, a guard interval GI 925₁, ELT sequence 930₁ and a Signal field SIG 935₁. Similarly, preamble 910₂ includes short training sequence 920₂, a guard interval GI 925₂, ELT sequence 930₂ and a Signal field SIG 935₂. The GI 925₁ and 925₂ are obtained by taking the last 32 samples (at 20 MHz sampling rate) of ELT 930₁ and 930₂, respectively.

[0058] Referring to Fig. 9B, preambles 910₁ is transmitted from the first antenna, preamble 910₂ is transmitted from the second antenna, and preamble 910₃ is transmitted from the third antenna of a communication system having three transmit antennas. The short sequence of preamble 910₂ have a cyclic shift of 200 ns with respect to the short sequence of preamble 910₁. The ELT sequence of preamble 910₂ has a cyclic shift of 1050 ns with respect to the ELT sequence of preamble 910₁. Similarly, the Signal field of preamble 910₂ has a cyclic shift of 1050 ns with respect to the Signal field of preamble 910₁. The short sequence of preamble 910₃ have a cyclic shift of 400 ns with respect to the short sequence of preamble 910₁. The ELT sequence of preamble 910₃ have a cyclic shift of 2100 ns with respect to the ELT sequence of preamble 910₁. Similarly, the Signal field of preamble 910₃ has a cyclic shift of 2100 ns with respect to the Signal field of preamble 910₁. Other cyclic shifts per preamble part may be used.

[0059] The short-training sequence in each of the above preambles may or may not be the same as the legacy short training sequence defined by the 802.11 a standard. Similarly, the ELT sequence may be the same as the legacy long training sequence or any one of the ELT sequences described. As describe above, the time span of the ELT sequence is divided by the number of transmit antennas from which cyclic shifts are derived. For example, with respect to the IEEE 802.11a preamble, the time span of the long training sequence, excluding the guard interval, is 3.2 μ s. In the following, it is assumed that the N_s spatial streams are directly mapped onto the N_t transmit antennas, i.e., $N_s = N_t$, although it is understood that the present invention may be readily applied to more general space-time-frequency mappings where the N_s spatial streams are not directly mapped to the N_t transmit antennas. Furthermore, it is assumed that the cyclic shift on the first transmit antenna is 0, however, values other than 0 are also possible.

[0060] As is shown above, when there are two transmit antennas, i.e., $N_t = 2$, the cyclic shift on the second transmit antenna may be $3.2 / 2 = 1.6 \mu$ s. When there are three transmit antenna, $N_t = 3$, the cyclic shift on the second and third transmit antennas two may be, respectively, 1.05 μ s and 2.1 μ s. For $N_t = 4$, the cyclic shift on the second, third, and fourth transmit antennas may be, respectively, $3.2 / 4 = 0.8 \mu$ s, $2 * 3.2 / 4 = 1.6 \mu$ s, and $3 * 3.2 / 4 = 2.4 \mu$ s, as shown in Fig. 9C.

[0061] The long-training sequence per transmit antenna may be the same as that of the IEEE 802.11 a standard (Fig. 1), including two consecutive long training symbols. The corresponding cyclic shift associated with each transmit antenna and which is appended with a cyclic extension of 1.6 μ s, forms the cyclically-shifted ELT symbols for that transmit antenna.

[0062] To be able to decode the signal field without knowing the number of transmit antennas in advance, the signal field, SIG N, is kept the same for each transmit antennas, except that it has the same cyclic shift as that appended to the ELT symbols of that transmit antenna. Accordingly, the SIG N may be decoded using a SIMO (Single-Input Multiple-Output) training. In other words, training for the decoding of SIG N is performed assuming that the ELT sequence is transmitted from a single transmit antenna.

[0063] The exemplary preambles disclosed in Figs. 9A, 9B, and 9C provide a number of advantages. First, the 20

microseconds duration of the preamble is relatively short, particularly for systems with three or four transmit antennas, hence a low overhead. Second, the selected cyclic shifts ensure that the power seen by the receiver is not affected by channel constructive or destructive combining. Therefore, automatic gain control may be carried out effectively throughout the preamble. Third, since the impulse responses can be separated in time, the number of spatial streams may be identified by the preamble thus enabling the receiver to identify the number of spatial channels of the MIMO. Fourth, the signal field occurs in the same place, notwithstanding the number of spatial streams. Fifth, the signal field may be decoded by estimating the sum of all the spatial channels (as if it was sent from just one transmitter), and using the sum to decode the data in the signal field. Therefore, the signal field may be decoded the same way for any type of packet, whether it is a MIMO packet (any number of streams) or a SISO packet.

[0064] Fig. 10 shows a modified preamble 950 adapted for a four-transmit antenna, in accordance with one embodiment of the present invention. Modified preamble 950 includes four preambles 950₁, 950₂, 950₃, and 950₄ that are respectively transmitted from the first, second, third, and fourth transmit antennas (not shown). Each of the preambles 950₁, 950₂, 950₃, and 950₄ includes a short training sequence, a Guard interval, a first ELT sequence, which includes two or more consecutive symbols, a second guard interval, a second ELT sequence, and a signal field. It is understood that for a system with three transmit antenna, preamble 950 includes preambles 950₁, 950₂, 950₃, and for a system with two transmit antennas, preamble 950 includes preambles 950₁, 950₂. Each ELT sequence includes, in turn, two or more consecutive symbols (collectively referred to as a symbol).

[0065] As is shown in Fig. 10, the short training sequences (alternatively referred to herein as short training sequence field) of 950₄, 950₃, and 950₂ have cyclic shifts of 600 nsec, 400 nsec, and 200 nsec, respectively with respect to the short training sequence field of 950₁. The first ELT sequence field of 950₂ has a cyclic shift of 1600nsec with respect to the first ELT sequence field of 950₁. The first ELT sequence field of 950₃ has a cyclic shift of 50nsec with respect to the first ELT sequence field of 950₁. The first ELT sequence field of 950₄ has a cyclic shift of 1650nsec with respect to the first ELT sequence field of 950₁. The second ELT sequence field of 950₂ has a cyclic shift of 1600nsec with respect to the second ELT sequence field of 950₁. The second ELT sequence field of 950₃ has a cyclic shift of 50nsec with respect to the second ELT sequence field of 950₁. The second ELT sequence field of 950₄ has a cyclic shift of 1650nsec with respect to the first ELT sequence field of 950₁. The Signal field of 950₂ has a cyclic shift of 1600nsec with respect to the signal field of 950₁. The signal field of 950₃ has a cyclic shift of 50nsec with respect to the signal field of 950₁. The signal field of 950₄ has a cyclic shift of 1650nsec with respect to the signal field of ELT sequence of 950₁. In the following, the ELT sequence field is alternatively referred to as ELT sequence.

[0066] Preamble 950 spreads out the cyclically shifted signals by adding more ELT sequences, thereby enabling the detection of the number of antennas by any one of the ELT sequences that is 6.4 microsecond long. To ensure that the second ELT sequence is independent from the first ELT sequence for each of the transmit antennas, Walsh coding technique may be used (shown by the minus signs added to corresponding ELT sequence symbols of 950₃ and 950₄). Therefore, the frequency orthogonality via cyclic shifting is used to separate TX1 from TX2 and TX3 from TX4, and time orthogonality is used to separate TX1 and TX2 from TX3 and TX4. Therefore, in accordance with the modified preamble, detection of a second ELT sequence transmitted from each antenna is used to distinguish whether the transmit system includes (i) 1 or 2 transmit antennas, (ii) 3 or 4 transmit antennas. The second ELT sequence maybe detected, for example, by adding and/or subtracting the two periods and determining if the cross-correlation between the two symbols of the second ELT sequence is high or low. When the cross-correlation is high, a second ELT sequence is detected as being present.

[0067] A modified preamble having two ELT sequences for each transmit antennas, as described above, provides a number of other advantages. First, the power drop per transmit stream is relatively small. Second, because the signal field appears at the end of the training sequence for each transmit stream, processing delays due to channel estimation are minimized and thus are more suitable for media access controller (MAC) options. Moreover, the minimum squared estimation (MSE) for channel estimation is the same for systems with two or four transmit antennas.

[0068] Fig. 11 shows a modified preamble 960 configured for transmission via a system having two transmit antennas (not shown), in accordance with another embodiment of the present invention. Preamble part 960₁ of preamble 960 is configured for transmission from the first transmit antenna and preamble part 960₂ of preamble 960 is configured for transmission from the second transmit antenna. Preamble part 960₁ is shown as including a short training sequence (symbols), a guard interval, odd tones of a long training sequence, and a Signal field. Preamble part 960₂ is shown as including a short training sequence, a guard interval, modified even tones of a long training sequence, and a Signal field. Each of the preamble parts 960₁ and 960₂ may or may not be derived from an 802.11 a preamble. The signal field of preamble part 960₁ is shown as including the odd tones of the signal field of, for example, 802.11 a. The signal field of preamble part 960₂ is shown as including modified even tones of the signal field of, for example an 802.11a preamble. The short training sequence of preamble part 960₂ has a cyclic shift of 400 nsec with respect to the short training sequence of preamble part 960₁, but other cyclic shifts may also be used.

[0069] The odd training symbols of preamble 960₁ are formed by multiplying the tones of the long training symbols by the pattern {0,1, 0, 1, 0, 1, 0, ... }, assuming the tone indices are 0, 1, 2, ..., $N_c - 1$, where 0 is assumed to be the DC

subcarrier and N_c equals the number of subcarriers. The modified even training symbols and signal field of preamble part 960₂ are formed by multiplying the even tones of the corresponding long training symbols and signals fields by the pattern {1, -1, 1, -1, 1, -1 ...}, i.e., multiplying the original unmodified tones with the pattern {1, 0, -1, 0, 1, 0, -1, 0, ...}. The tones in preamble parts 960₁ and 960₂ are orthogonal. Furthermore the pattern {1, -1, 1, -1, 1, -1 ...} which is used to generate the modified even tones enables the transmitter to detect that the transmitted preamble, shown in Fig. 11, is not a legacy preamble.

[0070] Fig. 12 shows a modified preamble 970 configured for transmission via a system having four transmit antennas (not shown), in accordance with another embodiment of the present invention. Preamble 970 includes preamble part 970₁, 970₂, 970₃, and 970₄, each of which parts include two guard intervals and two extended long training sequences. The short training sequences of preamble parts 970₂, 970₃, and 970₄ have respective cyclic shifts of 200 nsec, 400 nsec, and 600 nsec with respect to the short training sequence of preamble part 970₁. The guard intervals of preamble part 970₁ are generated by taking the last part of the time-domain representation of the odd tones of the long training sequence or ELT sequence of preamble part 970₁, and the guard intervals of preamble part 970₂ are similarly obtained by taking the last part of the time-domain representation of the long training sequence or ELT sequence of preamble part 970₂.

[0071] Each of the first and second ELT sequences of preamble 970₁ includes only the odd tones and each of the first and second ELT sequences of preamble 970₂ includes only the modified even tones, i.e., even tone modified by the pattern {1, -1, 1, -1, 1, -1 ...}. The first and second ELT sequences of preamble 970₃ include only the odd tones that are cyclically shifted with respect to the corresponding ELT sequence of preamble 970₂ by 50 nsec. The first and second ELT sequences of preamble 970₄ include only the modified even tones that are cyclically shifted with respect to the corresponding ELT sequence of preamble 970₃ by 50 nsec. Moreover, a Walsh code is used such that the first and second ELT sequences of preamble 970₁ and 970₂ and the first ELT sequences of preamble 970₃ and 970₄ are multiplied by 1, and the second ELT sequences of preamble 970₃ and 970₄ are multiplied by -1. This allows for separation between TX1 and TX2 on one side and TX3 and TX4 on the other side. The cyclic shift is used to further the channel training from TX1 and TX2, and TX3 and TX4, respectively.

[0072] The signal field of preamble 970₁ includes only the odd tones, and the signal field of preamble 970₂ includes only the modified even tones. The signal field of preamble 970₃ includes only the odd tones and has a cyclic shift of 50 nsec with respect to the signal field of preamble 970₂. The signal field of preamble 970₄ includes only the modified even tones and has a cyclic shift of 50 nsec with respect to the signal field of preamble 970₃.

[0073] In accordance with some embodiments of the present invention, a mixed-mode preamble includes legacy as well as modified preambles. Fig. 13 shows an exemplary mixed-mode preamble 1000 configured for transmission from a system having two-transmit antennas, in accordance with one embodiment of the present invention. Exemplary mixed mode preamble 1000 includes legacy 802.11a/g preamble portion 1050, that may be modified to indicate that an extended training part is appended, e.g., by setting the reserved bit of the legacy signal field, as well as a modified preamble portion 1060, as described above. Mixed mode preamble 1000 includes preamble 1000₁ that is transmitted from the first antenna and preamble 1000₂ that is transmitted from the second antenna. Short training sequence 1005₁, guard interval 1010₁, long training sequence 1015₁, and signal field 1020₁ in combination form a legacy 802.11a/g preamble portion of preamble 1000₁ that is transmitted from the first transmit antenna. Guard interval 1025₁, ELT sequence 1030₁, and Signal field 1035₁ form the modified (extended) preamble portion of 1000₁. Similarly, short training sequence 1005₂, guard interval 1010₂, long training sequence 1015₂, and signal field 1020₂ in combination form a legacy 802.11a/g preamble portion of preamble 1000₂ that is transmitted from the first transmit antenna. Guard interval 1025₂, ELT sequence 1030₂, and Signal field 1035₂ form the extended preamble portion of preamble 1000₂ that is transmitted from the second antenna.

[0074] The various fields of the 802.11a/g preamble portion of preamble 1000₂ are cyclically shifted with respect to the various fields of the 802.11a/g preamble portion of preamble 1000₁. Similarly, the various fields of the extended preamble portion of preamble 1000₂ are cyclically shifted with respect to the various fields of the extended preamble portion of preamble 1000₁. For example, in the exemplary embodiment shown in Fig 13, the short training sequence 1005₂ of the second transmit antenna have a cyclic shift of 400 nsec with respect to the short training sequence 1005₁ of the first transmit antenna. Similarly, the long training sequence 1015₂ of the second transmit antenna has a cyclic shift of 50 nsec with respect to the long training sequence 1015₁ of the first transmit antenna. The Signal field 1020₂ of the second transmit antenna has a cyclic shift of 50 nsec with respect to the Signal field 1020₁, of the first transmit antenna. The ELT sequence 1030₂ of the second transmit antenna has a cyclic shift of 1600 nsec with respect to the ELT sequence 1030₁ of the first transmit antenna. The Signal field 1035₂ of the second transmit antenna has a cyclic shift of 1600 nsec with respect to the Signal field 1035₁ of the first transmit antenna.

[0075] The extended preamble portions of preamble 1000, namely those identified by reference numerals 1020₁, 1025₁, 1030₁, 1035₁ of the first transmit antenna as well as 1020₂, 1025₂, 1030₂, 1035₂ of the second transmit antenna provide efficient training symbols for many systems, such MIMO OFDM systems. Therefore, when legacy devices as well as extended devices, like MIMO OFDM devices, are also part of the network, both the legacy as well as the extended

devices are able to receive and process the preambles.

[0076] Through the use of one or more bits of the preamble, (e.g., by setting the reserved bit in the signal field of the legacy portion of the preamble) or by auto-detecting that a second training sequence follows the legacy signal field, extended devices are triggered that enable, for example, channel estimation after the legacy portion of the preamble is received. One advantage of having a modified preamble following a legacy preamble is PHY level backwards compatibility. Hence, no MAC protection mechanisms are needed to communicate at extended rates, leading to enhanced efficiency.

[0077] Fig. 14 shows an exemplary mixed-mode preamble 1100, in accordance with another embodiment of the present invention, configured for transmission from a system having two transmit antennas. Exemplary mixed mode preamble 1100 includes legacy 802.11a/g preamble portion 1110 as well as a modified preamble portion 1120. Legacy 802.11a/g preamble portion 1110 is similar to legacy 802.11a/g preamble portion 1050 of Fig. 13. The guard interval of the preamble portion 1100₁, configured for transmission from the first transmit antenna, is generated by taking the last part of the time-domain representation of the odd tones of the long training sequence or ELT sequence of preambles 1001₁, and the guard interval of preamble part 1100₂ is similarly obtained by taking the last part of the time-domain representation of the long training sequence of 1100₂. The ELT sequence of preamble portion 1100₁ only includes the odd tones. The ELT sequence of preamble portion 1100₂ only includes modified even tones that are generated by multiplying the original unmodified tones by the sequence {1, 0, -1, 0, 1, 0, -1, 0, 1, 0, -1 ...}. Similarly, the signal field of preamble portion 1100₁ only includes the odd tones. The signal field of preamble portion 1100₂ only includes modified even tones that are generated by multiplying the original unmodified tones by the sequence {1, 0, -1, 0, 1, 0, -1, 0, 1, 0, -1 ...}. The mixed-mode preamble, in accordance with any of the exemplary embodiments described above, enables the legacy devices to defer to extended devices if they have properly received the legacy part of the mixed-mode preamble.

[0078] Fig. 15A (also shown in Fig. 2 as the sequence L2 except that the DC tone in sequence L2 is disposed at the beginning of the sequence) shows the 64 tones of an ELT sequence 1200 adapted for a 20 MHz channel, in accordance with one embodiment of the present invention. Accordingly, energy is transmitted on every single tone except the DC tone. ELT sequence 1200 includes the tones disposed in the 802.11a long-training sequence, shown in Fig. 15B. ELT sequence 1200 thus carries, next to the 802.11 subcarrier information, on subcarrier indices 27,...,31 the values -1, -1, -1, 1, -1, and on subcarrier indices -32,..., -27 the values -1, -1, 1, 1, 1, 1. The various tones of ELT sequence 1200 are selected such that the peak-to-average power of the ELT sequence 1200 is only a few tenths of a dB higher than the peak-to-average power of the 802.11a long training sequence.

[0079] Fig. 16A (also shown in Fig. 2 as the sequence L4 except that the DC tone in sequence L4 is disposed at the beginning of the sequence) shows the 128 tones of an ELT sequence 1300 adapted for a 40 MHz channel, in accordance with one embodiment of the present invention. Accordingly, energy is transmitted on every single tone except the DC tone. ELT sequence 1400 includes the tones disposed in the 802.11a long-training sequence, shown in Fig. 16B. ELT sequence 1300 carries, next to the two copies of the 802.11a on subcarrier indices -64,..., -59 the values -1, -1, 1, 1, 1, 1, on subcarrier index -32 the value -1, on subcarrier indices -5, ..., -1 the values -1, -1, -1, 1, -1, on subcarrier indices 1, ..., 5, the values -1, 1, 1, 1, 1, on subcarrier index 32 the value -1, and on subcarrier indices 58,..., 63 the values -1, -1, -1, 1, -1.

[0080] The out-of-band tones (pilots) in each of ELT sequences 1200 and 1300 are attenuated by the transmitter filtering, thus they have relatively small effects on the power of the training sequences, and have relatively minimal effect on the spectral mask. Furthermore, the extended tones are selected such that any inaccuracies due to interpolation is minimized.

[0081] Solid line Plot 1400 of Fig. 17, shows the power spectral density as function of the frequency, averaged over the entire packet, associated with the long training sequence 1200, shown in Fig. 15A. The dotted line plot 1500 show the spectral mask as defined in the 802.11a standard. As seen from Fig. 17, the spectrum of sequence 1200 meets the spectral requirements of 802.11 a standard.

[0082] Fig. 18 shows a modified signal field 1600, in accordance with one embodiment of the present invention. Signal field 1600 uses a higher constellation density than 802.11a/g. Signal field 1600 uses quadrature phase shift keying (QPSK) instead of binary phase shift keying (BPSK) to maintain the duration of the signal field 4us (same as 802.11a/g), while carrying twice the data. Signal field 1600 includes 48 bits, of which 6 bits are used to indicate the mode, 16 bits are used to indicate the length, 16 bits are used for CRC for error checking, 1 bit is used to indicate the last PSDU of frame, 3 bits are reserved bits, and 6 bits are set to zero to allow the convolutional encoder as specified in the 802.11a standard to return to the zero state.

[0083] At the receiver side, the channel estimates for each transmitter signal can be estimated by a process such as that shown in Fig. 19. As shown there, the process begins with receiving signals and sampling for the long training sequence (step S1). Then, a 64-point FFT (or a 128-point FFT for 40 MHz modes, etc.) of the received long training sequence samples is done (step S2), as is done for conventional 802.11a preamble reception. Next, each subcarrier is multiplied by known pilot values (step S3), and an IFFT of the result is taken to get a 64-point, or 128-point, etc. impulse response estimate (step S4).

[0084] In the case of a MIMO transmission, for example, the preamble of Figs. 9A, 9B, 9C in a 20 MHz bandwidth,

these 64 samples contain the cyclic shifted impulse responses of all different transmitters. With that, the receiver can isolate the impulse responses for each MIMO transmitter (step S5). For MIMO with two transmit streams, this can be done by separating the first 32 samples and last 32 samples. For four transmit streams, groups of 16 samples can be extracted.

[0085] From the extracted impulse responses per transmitter, channel estimates can be derived (step S6) for all subcarriers by taking a 64-point FFT of each impulse response, where the sample values are appended by zero values to get 64 input values.

Signaling Extended Modes

[0086] There are several different ways to signal what mode is used:

[0087] 1) Beacons: Each access point regularly transmits beacons. By transmitting these beacons using a legacy 802.11a rate on all 20 MHz channels used by the access point, it can be ensured that any device can receive these beacons. The beacon can contain information about which channels are used simultaneously and what extended modes are supported, so each extended device can adjust its mode accordingly.

[0088] 2) Multiple transmitter detection: If a special long training symbol is used for MIMO transmitters such as the cyclic shifted symbol described herein or other techniques described herein, then these special long training properties can be used to detect whether a packet is a MIMO packet. For instance, if the cyclic shifted long training symbol is used with two MIMO transmitters, the receiver can detect this by checking if the combined impulse response (obtained from step S4 above) contains two distinct impulse responses separated by 32 samples.

[0089] 3) Signal field: The reserved bit of the Signal field can be used to signal the use of MIMO. It is also possible to extend the Signal field by transmitting an extra symbol. An example of this is shown in Boer. There is a reserved bit in the Signal field that is always zero for 802.11a devices but could be set to 1 to signal MIMO packets. It is also possible to send an extra signal field symbol after the normal 802.11a symbol to signal MIMO rates.

[0090] 4) Out-of-band pilots: The out-of-band pilots of the long training symbol that are not present in 802.11a can be used to signal different modes. For example, subcarriers 28 through 38 in L_1 are zero, but they might be set (as with L_2 , L_3 , etc.) to some arbitrary but known values. The receiver can use the presence of these subcarriers as a way to detect MIMO modes and the particular pattern of presence to detect among several modes.

[0091] 5) Out-of-band subcarriers in the Signal field: Extra subcarriers can be used to signal different extended modes. The use of extra subcarriers has advantages in that a) it does not cost extra preamble overhead, and b) a legacy 802.11a device ignores the out-of-band subcarriers.

Claims

1. A training sequence comprising N preambles (900, 910, 950, 960, 970, 1000, 1100) configured respectively for transmission from at least N antennas of a wireless communication system conforming to an 802.11 standard, each of the N preambles (900, 910, 950, 960, 970, 1000, 1100) comprising:

a short training sequence field (920, 1005);
a long training sequence field (930, 1015, 1030); and
a signal field (935, 1035);

characterized in that

the signal field (935, 1035) and at least one of the short training sequence field (920, 1005) and the long training sequence field (930, 1015, 1030) of at least one of the N preambles have a cyclic shift with respect to the respective short training sequence field (920, 1005), long training sequence field (930, 1015, 1030) and signal field (935, 1035) of another one of the N preambles, and wherein each preamble (1000, 1100) comprises a first part (1050, 1110) defined by the 802.11 a standard, and a second part (1060, 1120) comprising at least one field that is distinguishable from the preamble defined by the 802.11 a standard.

2. The training sequence of claim 1, comprising at least first (910₁) and second (910₂) preambles configured respectively for transmission from at least first and second transmit antennas, wherein:

the short training sequence field (920) of the second preamble (910₂) has a cyclic shift with respect to the short training sequence field of the first preamble (910₁);
the long training sequence field (930) of the second preamble (910₂) has a cyclic shift with respect to the long training sequence field of the first preamble (910₁); and

the signal field (935) of the second preamble (910₂) has a cyclic shift with respect to the signal field of the first preamble (910₁).

3. The training sequence of claim 2, wherein:

the short training sequence field (920) of the second preamble (910₂) has a cyclic shift of 400 ns with respect to the short training sequence field of the first preamble (910₁);
the long training sequence field (930) of the second preamble (910₂) has a cyclic shift of 1600 ns with respect to the long training sequence field of the first preamble (910₁); and
the signal field (935) of the second preamble has a cyclic shift of 1600 ns with respect to the signal field of the first preamble.

4. The training sequence of claim 2, further comprising a third preamble (910₃) configured for transmission from at least a third transmit antenna, wherein

the short training sequence field (920) of the third preamble (910₃) has a cyclic shift with respect to the short training sequence field of the first preamble;
the long training sequence field (930) of the third preamble has a cyclic shift with respect to the long training sequence field of the first preamble; and
the signal field (935) of the third preamble (910₃) has a cyclic shift with respect to the signal field of the first preamble.

5. The training sequence of claim 4, wherein

the short training sequence field (920) of the second preamble (910₂) has a cyclic shift of 200 ns with respect to the short training sequence field of the first preamble (910₁) and the short training sequence field of the third preamble (910₃) has a cyclic shift of 400 ns with respect to the short training sequence field of the first preamble (910₁);
the long training sequence field (930) of the second preamble (910₂) has a cyclic shift of 1050 ns with respect to the long training sequence field of the first preamble (910₁) and the long training sequence field of the third preamble (910₃) has a cyclic shift of 2100 ns with respect to the long training sequence field of the first preamble (910₁); and
the signal field (935) of the second preamble (910₂) has a cyclic shift of 1050 ns with respect to the signal field of the first preamble (910₁) and wherein the signal field of the third preamble (910₃) has a cyclic shift of 2100 ns with respect to the signal field of the first preamble (910₁).

6. The training sequence of claim 4, further comprising a fourth preamble (910₄) configured for transmission from at least a fourth transmit antenna, wherein

the short training sequence field (920) of the fourth preamble (910₄) has a cyclic shift with respect to the short training sequence field of the first preamble (910₁);
the long training sequence field (930) of the fourth preamble has a cyclic shift with respect to the long training sequence field of the first preamble (910₁); and
the signal field (935) of the fourth preamble (910₄) has a cyclic shift with respect to the signal field of the first preamble (910₁).

7. The training sequence of claim 6, wherein

the short training sequence field (920) of the second preamble (910₂) has a cyclic shift of 200 ns with respect to the short training sequence field of the first preamble (910₁), the short training sequence field of the third preamble (910₃) has a cyclic shift of 400 ns with respect to the short training sequence field of the first preamble (910₁), and the short training sequence field of the fourth (910₄) preamble has a cyclic shift of 600 ns with respect to the short training sequence field of the first preamble (910₁);
the long training sequence field (930) of the second preamble (910₂) has a cyclic shift of 800 ns with respect to the long training sequence field of the first preamble (910₁), the long training sequence field of the third preamble (910₃) has a cyclic shift of 1600 ns with respect to the long training sequence field of the first preamble (910₁), and the long training sequence field of the fourth preamble (910₄) has a cyclic shift of 2400 ns with respect to the long training sequence field of the first preamble (910₁); and

the signal field (935) of the second preamble (910₂) has a cyclic shift of 800 ns with respect to the signal field of the first preamble (910₁), the signal field of the third preamble (910₃) has a cyclic shift of 1600 ns with respect to the signal field of the first preamble (910₁), and the signal field of the fourth preamble (910₄) has a cyclic shift of 2400 ns with respect to the signal field of the first preamble (910₁).

8. The training sequence of any of claims 2 to 7, wherein each of the preambles further comprises a guard interval field (925, 1010) disposed between the short training sequence field (1005) and the long training sequence field (1015).

9. The training sequence of claim 8, wherein each of the preambles further comprises a second long training sequence field (1030) and a second guard interval field (1025), wherein the second long training sequence field (1030) is disposed between the second guard interval field (1025) and the signal field (1035).

10. The training sequence of claim 9, comprising first, second and third preambles, configured for transmission from at least first, second and third transmit antennas, wherein:

the short training sequence field (920) of the third preamble (910₃) has a cyclic shift with respect to the short training sequence field of the second preamble (910₂);
the first long training sequence field (930) of the third preamble (910₃) has a cyclic shift with respect to the first long training sequence field of the second preamble (910₂);
the second long training sequence field (930) of the third preamble (910₃) has inverted sign with respect to the second long training sequence field of the first preamble (910₁);
the second long training sequence field (930) of the third preamble (910₃) has a cyclic shift with respect to the second long training sequence field of the second preamble (910₂); and
the signal field (935) of the third preamble (910₃) has a cyclic shift with respect to the signal field of the second preamble (910₂).

11. The training sequence of claim 9, comprising first, second, third and fourth preambles, configured for transmission from at least first, second, third and fourth transmit antennas, wherein:

the short training sequence field (920) of the fourth preamble (910₄) has a cyclic shift with respect to the short training sequence field of the third preamble (910₃);
the first long training sequence field (930) of the fourth preamble (910₄) has a cyclic shift with respect to the first long training sequence field of the third preamble (910₃);
the second long training sequence field (930) of the fourth preamble (910₄) has inverted sign with respect to the second long training sequence field of the first preamble (910₁);
the second long training sequence field (930) of the fourth preamble (910₄) has a cyclic shift with respect to the second long training sequence field of the third preamble (910₃); and
the signal field (935) of the fourth preamble (910₄) has a cyclic shift with respect to the signal field of the third preamble (910₃).

12. The training sequence of any of claims 8 to 11, wherein the guard interval fields (925, 1010, 1025) are generated from time-domain representations of the long training sequences, preferably of representations of only the even or odd tones of the long training sequences.

13. The training sequence of any of claims 8 to 12, the guard interval fields (925, 1010, 1025) having duration of 1.6 μ s.

14. The training sequence of any of claims 2 to 13,

the short training sequence fields (920, 1005) having a duration of 8 ps;
the long training sequence fields (930, 1015, 1030) having a duration of 6.4 μ s; and
the signal field (935, 1035) having a duration of 4 μ s.

15. The training sequence of any preceding claim, wherein the distinguishable field of the second part (1060, 1120) of each preamble (1000, 1100) comprises at least one of a long training sequence field (1030) and a signal field (1035).

16. The training sequence of any preceding claim, wherein

the distinguishable field of the second part (1060) of a first preamble (1000₁) comprises a plurality of tones defined by the odd tones of the corresponding field of the 802.11 a standard, and
the distinguishable field of the second part (1060) of a second preamble (1000₂) comprises a plurality of tones defined by multiplying the tones of the corresponding field of the 802.11 a standard with the sequence {1,0, -1, 0, 1, 0, -1,...}.

17. The training sequence of any preceding claim, comprising a long training sequence disposed in a preamble and representing values used over 64 subcarriers spanning a 20 MHz channel, wherein the subcarriers are spaced apart by 312.5 KHz and are defined as follows:

$$\{-1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, \\ 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, \\ 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, \\ 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, 1, -1\}$$

18. The training sequence of any preceding claim, comprising a long training sequence disposed in a preamble and representing values used over 64 subcarriers spanning a 20 MHz channel and comprising more non-zero tones than the number of non-zero tones disposed in corresponding long training sequence defined by the 802.11 standard.

19. The training sequence of any preceding claim, comprising a long training sequence disposed in a preamble and representing values used over 128 subcarriers spanning a 40 MHz channel, wherein the subcarriers are spaced apart by 312.5 KHz and are defined as follows:

$$\{-1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, \\ 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, \\ -1, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, \\ 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, 1, -1, \\ 0, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, \\ 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, \\ -1, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, \\ 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, 1, -1\}$$

20. The training sequence of any preceding claim, comprising a long training sequence disposed in a preamble and representing values used over 128 subcarriers spanning a 40 MHz channel and comprising more non-zero tones than the number of non-zero tones disposed in corresponding long training sequence defined by the 802.11 standard.

21. The training sequence of any preceding claim, comprising a signal field carrying bits related to quadrature phase shift keying modulation technique.

- 22.** The training sequence of claim 21 wherein said signal field further comprises a CRC field having 16 bits.

- 23.** The training sequence of any preceding claim, comprising a signal field of more than 24 bits.

24. The training sequence of any preceding claim, wherein only the DC tone of the tones disposed in the long training sequence field of each of the preambles has a zero value.

- 25.** A method comprising method steps for generating the training sequence of any preceding claim.

- 26.** Apparatus comprising means for generating the training sequence according to any of claims 1 to 24.

27. The training sequence of any of claims 1 to 24, configured to be received by a wireless device.

28. An extended wireless device adapted to receive the training sequence of claim 27.

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Patentansprüche

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1. Trainingssequenz, die N Präambeln (900, 910, 950, 960, 970, 1000, 1100) umfasst, jeweils konfiguriert zum Senden von wenigstens N Antennen eines drahtlosen Kommunikationssystems entsprechend einem 802.11 Standard, wobei jede der N Präambeln (900, 910, 950, 960, 970, 1000, 1100) Folgendes umfasst:

ein kurzes Trainingssequenzfeld (920, 1005);
ein langes Trainingssequenzfeld (930, 1015, 1030); und
ein Signalfeld (935, 1035);

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dadurch gekennzeichnet, dass

das Signalfeld (935, 1035) und das kurze Trainingssequenzfeld (920, 1005) und/oder das lange Trainingssequenzfeld (930, 1015, 1030) von wenigstens einer der N Präambeln eine zyklische Verschiebung jeweils mit Bezug auf das kurze Trainingssequenzfeld (920, 1005), das lange Trainingssequenzfeld (930, 1015, 1030) und das Signalfeld (935, 1035) einer anderen der N Präambeln hat/haben, und wobei jede Präambel (1000, 1100) einen durch den 802.11 a Standard definierten ersten Teil (1050, 1110) und einen zweiten Teil (1060, 1120) umfasst, der wenigstens ein Feld umfasst, das von der durch den 802.11a Standard definierten Präambel unterschieden werden kann.

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2. Trainingssequenz nach Anspruch 1, die wenigstens erste (910₁) und zweite (910₂) Präambeln umfasst, die jeweils zum Senden von wenigstens ersten und zweiten Sendeantennen konfiguriert sind, wobei:

das kurze Trainingssequenzfeld (920) der zweiten Präambel (910₂) eine zyklische Verschiebung mit Bezug auf das kurze Trainingssequenzfeld der ersten Präambel (910₁) hat;
das lange Trainingssequenzfeld (930) der zweiten Präambel (910₂) eine zyklische Verschiebung mit Bezug auf das lange Trainingssequenzfeld der ersten Präambel (910₁) hat; und
das Signalfeld (935) der zweiten Präambel (910₂) eine zyklische Verschiebung mit Bezug auf das Signalfeld der ersten Präambel (910₁) hat.

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3. Trainingssequenz nach Anspruch 2, wobei:

das kurze Trainingssequenzfeld (920) der zweiten Präambel (910₂) eine zyklische Verschiebung von 400 ns mit Bezug auf das kurze Trainingssequenzfeld der ersten Präambel (910₁) hat;
das lange Trainingssequenzfeld (930) der zweiten Präambel (910₂) eine zyklische Verschiebung von 1600 ns mit Bezug auf das lange Trainingssequenzfeld der ersten Präambel (910₁) hat; und
das Signalfeld (935) der zweiten Präambel eine zyklische Verschiebung von 1600 ns mit Bezug auf das Signalfeld der ersten Präambel hat.

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4. Trainingssequenz nach Anspruch 2, die ferner eine dritte Präambel (910₃) hat, die zum Senden von wenigstens einer dritten Sendeantenne konfiguriert ist, wobei

das kurze Trainingssequenzfeld (920) der dritten Präambel (910₃) eine zyklische Verschiebung mit Bezug auf das kurze Trainingssequenzfeld der ersten Präambel hat;
das lange Trainingssequenzfeld (930) der dritten Präambel eine zyklische Verschiebung mit Bezug auf das lange Trainingssequenzfeld der ersten Präambel hat; und
das Signalfeld (935) der dritten Präambel (910₃) eine zyklische Verschiebung mit Bezug auf das Signalfeld der ersten Präambel hat.

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5. Trainingssequenz nach Anspruch 4, wobei

das kurze Trainingssequenzfeld (920) der zweiten Präambel (910₂) eine zyklische Verschiebung von 200 ns mit Bezug auf das kurze Trainingssequenzfeld der ersten Präambel (910₁) hat und das kurze Trainingssequenzfeld der dritten Präambel (910₃) eine zyklische Verschiebung von 400 ns mit Bezug auf das kurze Trainingssequenzfeld der ersten Präambel (910₁) hat;

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das lange Trainingssequenzfeld (930) der zweiten Präambel (910₂) eine zyklische Verschiebung von 1050 ns mit Bezug auf das lange Trainingssequenzfeld der ersten Präambel (910₁) hat und das lange Trainingssequenzfeld der dritten Präambel (910₃) eine zyklische Verschiebung von 2100 ns mit Bezug auf das lange Trainingssequenzfeld der ersten Präambel (910₁) hat; und

das Signalfeld (935) der zweiten Präambel (910₂) eine zyklische Verschiebung von 1050 ns mit Bezug auf das Signalfeld der ersten Präambel (910₁) hat und wobei das Signalfeld der dritten Präambel (910₃) eine zyklische Verschiebung von 2100 ns mit Bezug auf das Signalfeld der ersten Präambel (910₁) hat.

6. Trainingssequenz nach Anspruch 4, die ferner eine vierte Präambel (910₄) umfasst, die zum Senden von wenigstens einer vierten Sendeantenne konfiguriert ist, wobei

das kurze Trainingssequenzfeld (920) der vierten Präambel (910₄) eine zyklische Verschiebung mit Bezug auf das kurze Trainingssequenzfeld der ersten Präambel (910₁) hat;

das lange Trainingssequenzfeld (930) der vierten Präambel eine zyklische Verschiebung mit Bezug auf das lange Trainingssequenzfeld der ersten Präambel (910₁) hat; und

das Signalfeld (935) der vierten Präambel (910₄) eine zyklische Verschiebung mit Bezug auf das Signalfeld der ersten Präambel (910₁) hat.

7. Trainingssequenz nach Anspruch 6, wobei

das kurze Trainingssequenzfeld (920) der zweiten Präambel (910₂) eine zyklische Verschiebung von 200 ns mit Bezug auf das kurze Trainingssequenzfeld der ersten Präambel (910₁) hat, das kurze Trainingssequenzfeld der dritten Präambel (910₃) eine zyklische Verschiebung von 400 ns mit Bezug auf das kurze Trainingssequenzfeld der ersten Präambel (910₁) hat und das kurze Trainingssequenzfeld der vierten (910₄) Präambel eine zyklische Verschiebung von 600 ns mit Bezug auf das kurze Trainingssequenzfeld der ersten Präambel (910₁) hat;

das lange Trainingssequenzfeld (930) der zweiten Präambel (910₂) eine zyklische Verschiebung von 800 ns mit Bezug auf das lange Trainingssequenzfeld der ersten Präambel (910₁) hat, das lange Trainingssequenzfeld der dritten Präambel (910₃) eine zyklische Verschiebung von 1600 ns mit Bezug auf das lange Trainingssequenzfeld der ersten Präambel (910₁) hat und das lange Trainingssequenzfeld der vierten Präambel (910₄) eine zyklische Verschiebung von 2400 ns mit Bezug auf das lange Trainingssequenzfeld der ersten Präambel (910₁) hat; und

das Signalfeld (935) der zweiten Präambel (910₂) eine zyklische Verschiebung von 800 ns mit Bezug auf das Signalfeld der ersten Präambel (910₁) hat, das Signalfeld der dritten Präambel (910₃) eine zyklische Verschiebung von 1600 ns mit Bezug auf das Signalfeld der ersten Präambel (910₁) hat und das Signalfeld der vierten Präambel (910₄) eine zyklische Verschiebung von 2400 ns mit Bezug auf das Signalfeld der ersten Präambel (910₁) hat.

8. Trainingssequenz nach einem der Ansprüche 2 bis 7, wobei jede der Präambeln ferner ein Schutzintervallfeld (925, 1010) umfasst, das zwischen dem kurzen Trainingssequenzfeld (1005) und dem langen Trainingssequenzfeld (1015) angeordnet ist.

9. Trainingssequenz nach Anspruch 8, wobei jede der Präambeln ferner ein zweites langes Trainingssequenzfeld (1030) und ein zweites Schutzintervallfeld (1025) umfasst, wobei das zweite lange Trainingssequenzfeld (1030) zwischen dem zweiten Schutzintervallfeld (1025) und dem Signalfeld (1035) angeordnet ist.

10. Trainingssequenz nach Anspruch 9, die erste, zweite und dritte Präambeln umfasst, konfiguriert zum Senden von wenigstens ersten, zweiten und dritten Sendeantennen, wobei:

das kurze Trainingssequenzfeld (920) der dritten Präambel (910₃) eine zyklische Verschiebung mit Bezug auf das kurze Trainingssequenzfeld der zweiten Präambel (910₂) hat;

das erste lange Trainingssequenzfeld (930) der dritten Präambel (910₃) eine zyklische Verschiebung mit Bezug auf das erste lange Trainingssequenzfeld der zweiten Präambel (910₂) hat;

das zweite lange Trainingssequenzfeld (930) der dritten Präambel (910₃) ein umgekehrtes Vorzeichen mit Bezug auf das zweite lange Trainingssequenzfeld der ersten Präambel (910₁) hat;

das zweite lange Trainingssequenzfeld (930) der dritten Präambel (910₃) eine zyklische Verschiebung mit Bezug auf das zweite lange Trainingssequenzfeld der zweiten Präambel (910₂) hat; und

das Signalfeld (935) der dritten Präambel (910₃) eine zyklische Verschiebung mit Bezug auf das Signalfeld der

zweiten Präambel (910₂) hat.

11. Trainingssequenz nach Anspruch 9, die eine erste, zweite, dritte und vierte Präambel umfasst, konfiguriert zum Senden von wenigstens ersten, zweiten, dritten und vierten Sendeantennen, wobei:

das kurze Trainingssequenzfeld (920) der vierten Präambel (910₄) eine zyklische Verschiebung mit Bezug auf das kurze Trainingssequenzfeld der dritten Präambel (910₃) hat;
das erste lange Trainingssequenzfeld (930) der vierten Präambel (910₄) eine zyklische Verschiebung mit Bezug auf das erste lange Trainingssequenzfeld der dritten Präambel (910₃) hat;
das zweite lange Trainingssequenzfeld (930) der vierten Präambel (910₄) ein umgekehrtes Vorzeichen mit Bezug auf das zweite lange Trainingssequenzfeld der ersten Präambel (910₁) hat;
das zweite lange Trainingssequenzfeld (930) der vierten Präambel (910₄) eine zyklische Verschiebung mit Bezug auf das zweite lange Trainingssequenzfeld der dritten Präambel (910₃) hat; und
das Signalfeld (935) der vierten Präambel (910₄) eine zyklische Verschiebung mit Bezug auf das Signalfeld der dritten Präambel (910₃) hat.

12. Trainingssequenz nach einem der Ansprüche 8 bis 11, wobei die Schutzintervallfelder (925, 1010, 1025) von Zeitdomänen-Repräsentationen der langen Trainingssequenzen erzeugt werden, vorzugsweise von Repräsentationen nur der geradzahlgigen oder ungeradzahlgigen Töne der langen Trainingssequenzen.

13. Trainingssequenz nach einem der Ansprüche 8 bis 12, wobei die Schutzintervallfelder (925, 1010, 1025) eine Dauer von 1,6 μ s haben.

14. Trainingssequenz nach einem der Ansprüche 2 bis 13,

wobei die kurzen Trainingssequenzfelder (920, 1005) eine Dauer von 8 μ s haben;
wobei die langen Trainingssequenzfelder (930, 1015, 1030) eine Dauer von 6,4 μ s haben; und
wobei das Signalfeld (935, 1035) eine Dauer von 4 μ s hat.

15. Trainingssequenz nach einem vorherigen Anspruch, wobei das unterscheidbare Feld des zweiten Teils (1060, 1120) jeder Präambel (1000, 1100) ein langes Trainingssequenzfeld (1030) und/oder ein Signalfeld (1035) umfasst.

16. Trainingssequenz nach einem vorherigen Anspruch, wobei

das unterscheidbare Feld des zweiten Teils (1060) einer ersten Präambel (1000₁) mehrere Töne umfasst, die durch die ungeradzahlgigen Töne des entsprechenden Feldes des 802.11a Standards definiert werden, und
das unterscheidbare Feld des zweiten Teils (1060) einer zweiten Präambel (1000₂) eine Mehrzahl von Tönen umfasst, die durch Multiplizieren der Töne des entsprechenden Feldes des 802.11a Standards mit der Sequenz {1, 0, -1, 0, 1, 0, -1,...} definiert werden.

17. Trainingssequenz nach einem vorherigen Anspruch, die eine lange Trainingssequenz umfasst, die in einer Präambel angeordnet ist und Werte repräsentiert, die über einen 20 MHz Kanal überspannende 64 Subträger benutzt werden, wobei die Subträger um 312,5 KHz voneinander beabstandet sind und wie folgt definiert sind:

{-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}

18. Trainingssequenz nach einem vorherigen Anspruch, die eine lange Trainingssequenz umfasst, die in einer Präambel angeordnet ist und Werte repräsentiert, die über einen 20 MHz Kanal überspannende 64 Subträger benutzt werden und mehr Töne von ungleich null umfassen als die Anzahl von Tönen von ungleich null, die in einer entsprechenden langen Trainingssequenz angeordnet sind, die durch den 802.11 Standard definiert wird.

19. Trainingssequenz nach einem vorherigen Anspruch, die eine lange Trainingssequenz umfasst, die in einer Präambel

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angeordnet ist und Werte repräsentiert, die über einen 40 MHz Kanal überspannende 128 Subträger benutzt werden, wobei die Subträger um 312,5 KHz beabstandet sind und wie folgt definiert sind:

5 {-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,
10 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,
15 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, 1, -1}

20. Trainingssequenz nach einem vorherigen Anspruch, die eine lange Trainingssequenz umfasst, die in einer Präambel angeordnet ist und Werte repräsentiert, die über einen 40 MHz Kanal überspannende 128 Subträger benutzt werden und die mehr Töne von ungleich null umfassen als die Anzahl von Tönen von ungleich null, die in einer entsprechenden langen Trainingssequenz angeordnet sind, die durch den 802.11 Standard definiert werden.
21. Trainingssequenz nach einem vorherigen Anspruch, die ein Signalfeld umfasst, das Bits in Bezug auf eine Quadratur-Phasenumtastungsmodulationstechnik führt.
22. Trainingssequenz nach Anspruch 21, wobei das genannte Signalfeld ferner ein CRC-Feld mit 16 Bits umfasst.
23. Trainingssequenz nach einem vorherigen Anspruch, die ein Signalfeld von mehr als 24 Bits umfasst.
24. Trainingssequenz nach einem vorherigen Anspruch, wobei nur der DC-Ton der in dem langen Trainingssequenzfeld von jeder der Präambeln angeordneten Töne einen Null-Wert hat.
25. Verfahren, das Verfahrensschritte zum Erzeugen der Trainingssequenz nach einem vorherigen Anspruch beinhaltet.
26. Vorrichtung, die Mittel zum Erzeugen der Trainingssequenz nach einem der Ansprüche 1 bis 24 umfasst.
27. Trainingssequenz nach einem der Ansprüche 1 bis 24, konfiguriert für den Empfang durch ein drahtloses Gerät.
28. Erweitertes drahtloses Gerät zum Empfangen der Trainingssequenz nach Anspruch 27.

Revendications

1. Séquence d'apprentissage comprenant N préambles (900, 910, 950, 960, 970, 1000, 1100) configurés respectivement pour la transmission à partir d'au moins N antennes d'un système de communication sans fil en conformité avec une norme 802.11, chacun des N préambles (900, 910, 950, 960, 970, 1000, 1100) comprenant :
- un champ de séquence d'apprentissage court (920, 1005);
un champ de séquence d'apprentissage long (930, 1015, 1030); et
un champ de signal (935, 1035);

caractérisés en ce que

- le champ de signal (935, 1035) et au moins un du champ de séquence d'apprentissage court (920, 1005) et du champ de séquence d'apprentissage long (930, 1015, 1030) d'au moins un des N préambles ont un décalage circulaire par rapport au champ de séquence d'apprentissage court (920, 1005), au champ de séquence d'apprentissage long (930, 1015, 1030) et au champ de signal (935, 1035) respectifs d'un autre des N préambles, et dans lequel chaque préambule (1000, 1100) comprend une première partie (1050, 1110) définie par la norme 802.11a, et une deuxième partie (1060, 1120) comprenant au moins un champ qui peut être distingué du préambule défini

par la norme 802.11 a.

2. Séquence d'apprentissage selon la revendication 1, comprenant au moins un premier (910₁) et un deuxième (910₂) préambules configurés pour la transmission à partir d'au moins une première et une deuxième antennes de transmission respectivement, où:

le champ de séquence d'apprentissage court (920) du deuxième préambule (910₂) a un décalage circulaire par rapport au champ de séquence d'apprentissage court du premier préambule (910₁);
le champ de séquence d'apprentissage long (930) du deuxième préambule (910₂) a un décalage circulaire par rapport au champ de séquence d'apprentissage long du premier préambule (910₁); et
le champ de signal (935) du deuxième préambule (910₂) a un décalage circulaire par rapport au champ de signal du premier préambule (910₁).

3. Séquence d'apprentissage selon la revendication 2, dans laquelle :

le champ de séquence d'apprentissage court (920) du deuxième préambule (910₂) a un décalage circulaire de 400 ns par rapport au champ de séquence d'apprentissage court du premier préambule (910₁);
le champ de séquence d'apprentissage long (930) du deuxième préambule (910₂) a un décalage circulaire de 1600 ns par rapport au champ de séquence d'apprentissage long du premier préambule (910₁); et
le champ de signal (935) du deuxième préambule a un décalage circulaire de 1600 ns par rapport au champ de signal du premier préambule.

4. Séquence d'apprentissage selon la revendication 2, comprenant en outre un troisième préambule (910₃) configuré pour la transmission à partir d'au moins une troisième antenne de transmission, où

le champ de séquence d'apprentissage court (920) du troisième préambule (910₃) a un décalage circulaire par rapport au champ de séquence d'apprentissage court du premier préambule;
le champ de séquence d'apprentissage long (930) du troisième préambule a un décalage circulaire par rapport au champ de séquence d'apprentissage long du premier préambule; et
le champ de signal (935) du troisième préambule (910₃) a un décalage circulaire par rapport au champ de signal du premier préambule.

5. Séquence d'apprentissage selon la revendication 4, dans laquelle

le champ de séquence d'apprentissage court (920) du deuxième préambule (910₂) a un décalage circulaire de 200 ns par rapport au champ de séquence d'apprentissage court du premier préambule (910₁) et le champ de séquence d'apprentissage court du troisième préambule (910₃) a un décalage circulaire de 400 ns par rapport au champ de séquence d'apprentissage court du premier préambule (910₁);
le champ de séquence d'apprentissage long (930) du deuxième préambule (910₂) a un décalage circulaire de 1050 ns par rapport au champ de séquence d'apprentissage long du premier préambule (910₁) et le champ de séquence d'apprentissage long du troisième préambule (910₃) a un décalage circulaire de 2100 ns par rapport au champ de séquence d'apprentissage long du premier préambule (910₁); et
le champ de signal (935) du deuxième préambule (910₂) a un décalage circulaire de 1050 ns par rapport au champ de signal du premier préambule (910₁) et où le champ de signal du troisième préambule (910₃) a un décalage circulaire de 2100 ns par rapport au champ de signal du premier préambule (910₁).

6. Séquence d'apprentissage selon la revendication 4, comprenant en outre un quatrième préambule (910₄) configuré pour la transmission à partir d'au moins une quatrième antenne de transmission, où

le champ de séquence d'apprentissage court (920) du quatrième préambule (910₄) a un décalage circulaire par rapport au champ de séquence d'apprentissage court du premier préambule (910₁);
le champ de séquence d'apprentissage long (930) du quatrième préambule a un décalage circulaire par rapport au champ de séquence d'apprentissage long du premier préambule (910₁); et
le champ de signal (935) du quatrième préambule (910₄) a un décalage circulaire par rapport au champ de signal du premier préambule (910₁).

7. Séquence d'apprentissage selon la revendication 6, dans laquelle

le champ de séquence d'apprentissage court (920) du deuxième préambule (910₂) a un décalage circulaire de 200 ns par rapport au champ de séquence d'apprentissage court du premier préambule (910₁), le champ de séquence d'apprentissage court du troisième préambule (910₃) a un décalage circulaire de 400 ns par rapport au champ de séquence d'apprentissage court du premier préambule (910₁), et le champ de séquence d'apprentissage court du quatrième préambule (910₄) a un décalage circulaire de 600 ns par rapport au champ de séquence d'apprentissage court du premier préambule (910₁);

le champ de séquence d'apprentissage long (930) du deuxième préambule (910₂) a un décalage circulaire de 800 ns par rapport au champ de séquence d'apprentissage long du premier préambule (910₁), le champ de séquence d'apprentissage long du troisième préambule (910₃) a un décalage circulaire de 1600 ns par rapport au champ de séquence d'apprentissage long du premier préambule (910₁) et le champ de séquence d'apprentissage long du quatrième préambule (910₄) a un décalage circulaire de 2400 ns par rapport au champ de séquence d'apprentissage long du premier préambule (910₁) ; et

le champ de signal (935) du deuxième préambule (910₂) a un décalage circulaire de 800 ns par rapport au champ de signal du premier préambule (910₁), le champ de signal du troisième préambule (910₃) a un décalage circulaire de 1600 ns par rapport au champ de signal du premier préambule (910₁), et le champ de signal du quatrième préambule (910₄) a un décalage circulaire de 2400 ns par rapport au champ de signal du premier préambule (910₁).

8. Séquence d'apprentissage selon l'une quelconque des revendications 2 à 7, dans laquelle chacun des préambules comprend en outre un champ d'intervalle de garde (925, 1010) placé entre le champ de séquence d'apprentissage court (1005) et le champ de séquence d'apprentissage long (1015).

9. Séquence d'apprentissage selon la revendication 8, dans laquelle chacun des préambules comprend en outre un deuxième champ de séquence d'apprentissage long (1030) et un deuxième champ d'intervalle de garde (1025), où le deuxième champ de séquence d'apprentissage long (1030) est placé entre le deuxième champ d'intervalle de garde (1025) et le champ de signal (1035).

10. Séquence d'apprentissage selon la revendication 9, comprenant un premier, un deuxième et un troisième préambules, configurés pour la transmission à partir d'au moins une première, une deuxième et une troisième antennes de transmission, où :

le champ de séquence d'apprentissage court (920) du troisième préambule (910₃) a un décalage circulaire par rapport au champ de séquence d'apprentissage court du deuxième préambule (910₂);

le premier champ de séquence d'apprentissage long (930) du troisième préambule (910₃) a un décalage circulaire par rapport au premier champ de séquence d'apprentissage long du deuxième préambule (910₂);

le deuxième champ de séquence d'apprentissage long (930) du troisième préambule (910₃) a un signe inversé par rapport au deuxième champ de séquence d'apprentissage long du premier préambule (910₁);

le deuxième champ de séquence d'apprentissage long (930) du troisième préambule (910₃) a un décalage circulaire par rapport au deuxième champ de séquence d'apprentissage long du deuxième préambule (910₂); et le champ de signal (935) du troisième préambule (910₃) a un décalage circulaire par rapport au champ de signal du deuxième préambule (910₂).

11. Séquence d'apprentissage selon la revendication 9, comprenant un premier, un deuxième, un troisième et un quatrième préambules, configurés pour la transmission à partir d'au moins une première, une deuxième, une troisième et une quatrième antennes de transmission, où :

le champ de séquence d'apprentissage court (920) du quatrième préambule (910₄) a un décalage circulaire par rapport au champ de séquence d'apprentissage court du troisième préambule (910₃);

le premier champ de séquence d'apprentissage long (930) du quatrième préambule (910₄) a un décalage circulaire par rapport au premier champ de séquence d'apprentissage long du troisième préambule (910₃);

le deuxième champ de séquence d'apprentissage long (930) du quatrième préambule (910₄) a un signe inversé par rapport au deuxième champ de séquence d'apprentissage long du premier préambule (910₁);

le deuxième champ de séquence d'apprentissage long (930) du quatrième préambule (910₄) a un décalage circulaire par rapport au deuxième champ de séquence d'apprentissage long du troisième préambule (910₃); et le champ de signal (935) du quatrième préambule (910₄) a un décalage circulaire par rapport au champ de signal du troisième préambule (910₃).

12. Séquence d'apprentissage selon l'une quelconque des revendications 8 à 11, dans laquelle les champs d'intervalle

de garde (925, 1010, 1025) sont générés à partir de représentations dans le domaine temporel des séquences d'apprentissage long, de préférence de représentations des tons pairs ou impairs uniquement des séquences d'apprentissage long.

5 **13.** Séquence d'apprentissage selon l'une quelconque des revendications 8 à 12, dans laquelle les champs d'intervalle de garde (925, 1010, 1025) ont une durée de 1,6 μ s.

14. Séquence d'apprentissage selon l'une quelconque des revendications 2 à 13, dans laquelle

10 les champs de séquence d'apprentissage court (920, 1005) ont une durée de 8 μ s;
les champs de séquence d'apprentissage long (930, 1015, 1030) ont une durée de 6,4 μ s; et
les champs de signal (935, 1035) ont une durée de 4 μ s.

15 **15.** Séquence d'apprentissage selon l'une quelconque des revendications précédentes, dans laquelle le champ pouvant être distingué de la deuxième partie (1060, 1120) de chaque préambule (1000, 1100) comprend au moins un d'un champ de séquence d'apprentissage long (1030) et d'un champ de signal (1035).

16. Séquence d'apprentissage selon l'une quelconque des revendications précédentes, dans laquelle

20 le champ pouvant être distingué de la deuxième partie (1060) d'un premier préambule (1000₁) comprend une pluralité de tons définis par les tons impairs du champ correspondant de la norme 802.11a, et
le champ pouvant être distingué de la deuxième partie (1060) d'un deuxième préambule (1000₂) comprend une pluralité de tons définis en multipliant les tons du champ correspondant de la norme 802.11 a avec la
séquence {1,0, -1,0, 1,0, -1,...}.

25 **17.** Séquence d'apprentissage selon l'une quelconque des revendications précédentes, comprenant une séquence d'apprentissage long placée dans un préambule et représentant des valeurs utilisées sur 64 sous-porteuses réparties dans un canal de 20 MHz, où les sous-porteuses sont espacées de 312,5 KHz et sont définies de la manière suivante :

30 { -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,
35 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, -1, -1, -1, 1, -1 }

18. Séquence d'apprentissage selon l'une quelconque des revendications précédentes, comprenant une séquence d'apprentissage long placée dans un préambule et représentant des valeurs utilisées sur 64 sous-porteuses réparties dans un canal de 20 MHz et comprenant plus de tons non nuls que le nombre de tons non nuls placés dans une séquence d'apprentissage long correspondante définie par la norme 802.11.

19. Séquence d'apprentissage selon l'une quelconque des revendications précédentes, comprenant une séquence d'apprentissage long placée dans un préambule et représentant des valeurs utilisées sur 128 sous-porteuses réparties dans un canal de 40 MHz, où les sous-porteuses sont espacées de 312,5 KHz et sont définies de la manière suivante :

50

55

{-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, -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, -1}

- 15 20. Séquence d'apprentissage selon l'une quelconque des revendications précédentes, comprenant une séquence d'apprentissage long placée dans un préambule et représentant des valeurs utilisées sur 128 sous-porteuses réparties dans un canal de 40 MHz et comprenant plus de tons non nuls que le nombre de tons non nuls placés dans une séquence d'apprentissage long correspondante définie par la norme 802.11.
- 20 21. Séquence d'apprentissage selon l'une quelconque des revendications précédentes, comprenant un champ de signal portant des bits relatifs à la technique de modulation par déplacement de phase, quadrature phase shift keying.
22. Séquence d'apprentissage selon la revendication 21, dans laquelle ledit champ de signal comprend en outre un champ CRC ayant 16 bits.
- 25 23. Séquence d'apprentissage selon l'une quelconque des revendications précédentes, comprenant un champ de signal de plus de 24 bits.
24. Séquence d'apprentissage selon l'une quelconque des revendications précédentes, dans laquelle seuls les tons DC des tons placés dans le champ de séquence d'apprentissage long de chacun des préambules a une valeur zéro.
- 30 25. Procédé comprenant des étapes de procédé pour générer la séquence d'apprentissage selon l'une quelconque des revendications précédentes.
- 35 26. Appareil comprenant un moyen de générer la séquence d'apprentissage selon l'une quelconque des revendications 1 à 24.
27. Séquence d'apprentissage selon l'une quelconque des revendications 1 à 24, configurée pour être reçue par un dispositif sans fil.
- 40 28. Dispositif sans fil complet/élargi adapté à la réception de la séquence d'apprentissage selon la revendication 27.

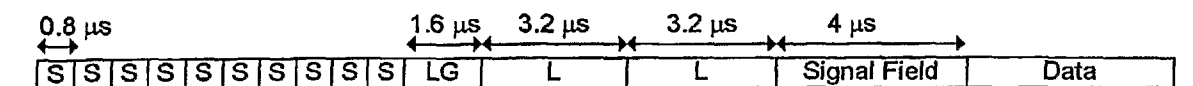


FIG. 1 (PRIOR ART)

$L1 = \{$

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	0	0	0	0	0
0	0	0	0	0	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

 $\}$

FIG. 2 (PRIOR ART)

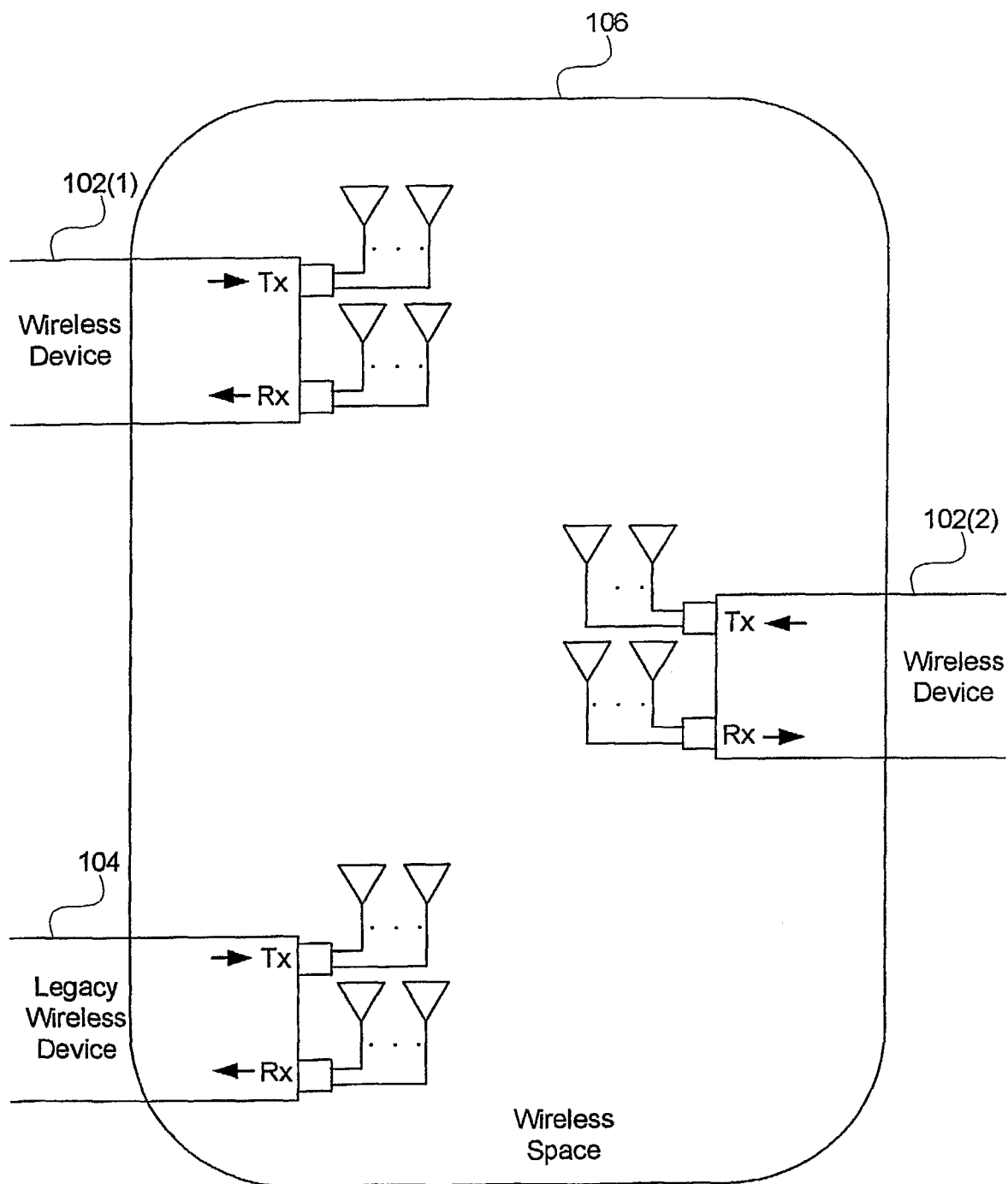


Fig. 3

$$\begin{aligned}
L2 &= \begin{pmatrix} 0 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 & -1 & -1 & -1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & 1 & -1 \\ -1 & -1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 \\ 1 & 1 & 1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 & 1 & 1 & 1 \end{pmatrix} \\
L3 &= \begin{pmatrix} 0 & 1 & -1 & -1 & -1 & -1 & 1 & -1 & -1 & 1 & -1 & -1 & 1 & 1 & 1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 & 1 & 1 & -1 & 1 & 1 & -1 & 1 \\ -1 & -1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & -1 & 1 & -1 \\ 1 & 1 & 1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 & -1 & -1 & -1 \end{pmatrix} \\
L4 &= \begin{pmatrix} 0 & -1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 \\ 1 & 1 & 1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 & 1 & 1 & 1 \\ -1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 & -1 & -1 & -1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & 1 & -1 \\ -1 & -1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 \\ 1 & 1 & 1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 & 1 & 1 & 1 \\ -1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 & -1 & -1 & -1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & 1 & -1 \end{pmatrix}
\end{aligned}$$

FIG. 4

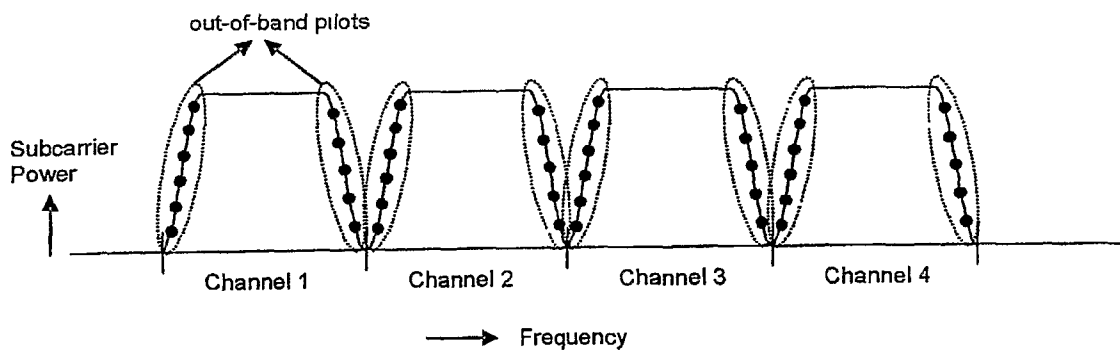


FIG. 5

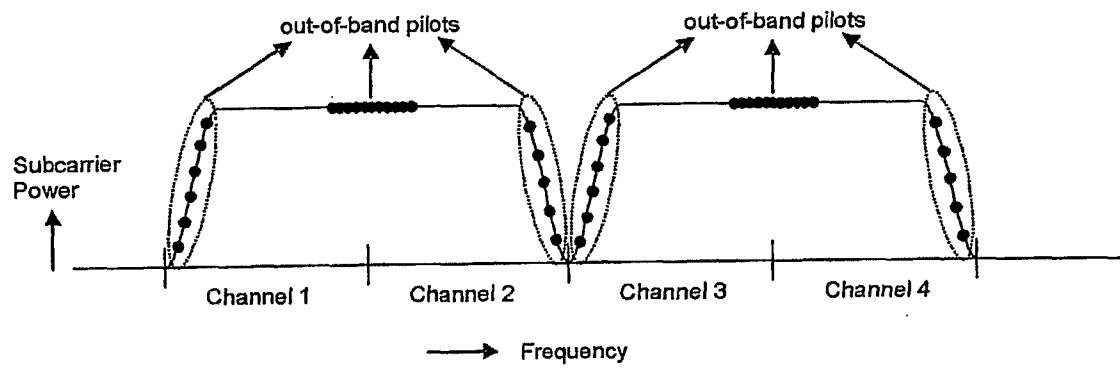


FIG. 6

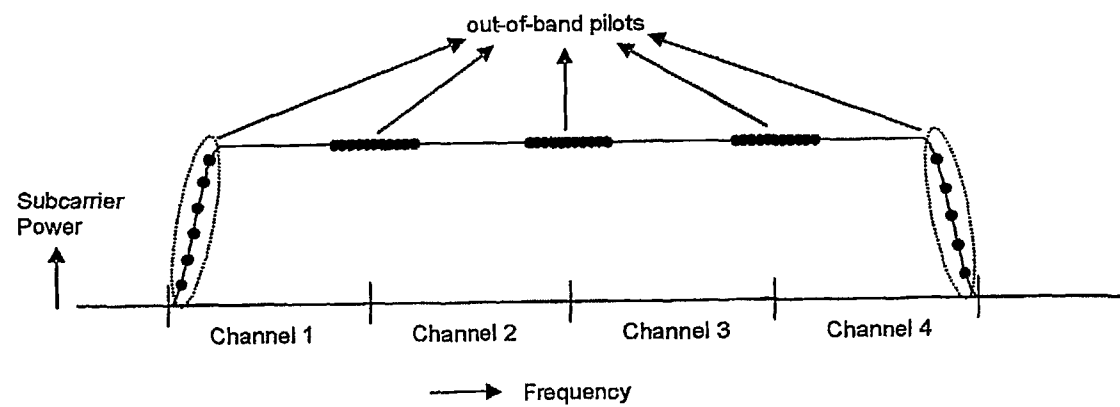


FIG. 7

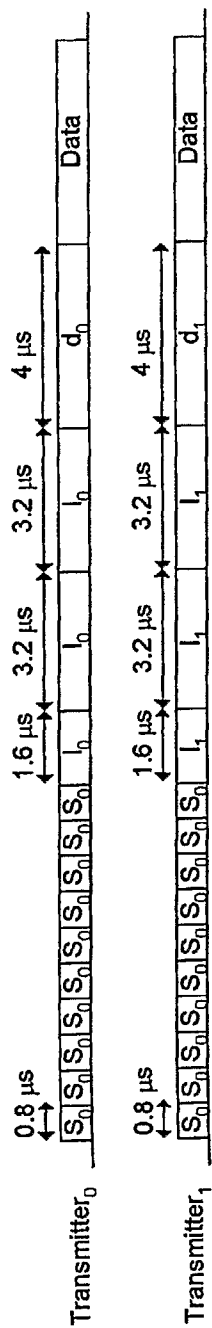


FIG. 8

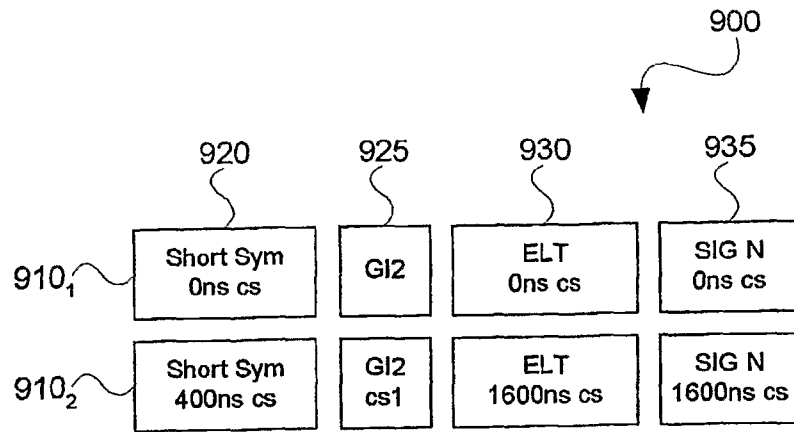


Fig. 9A

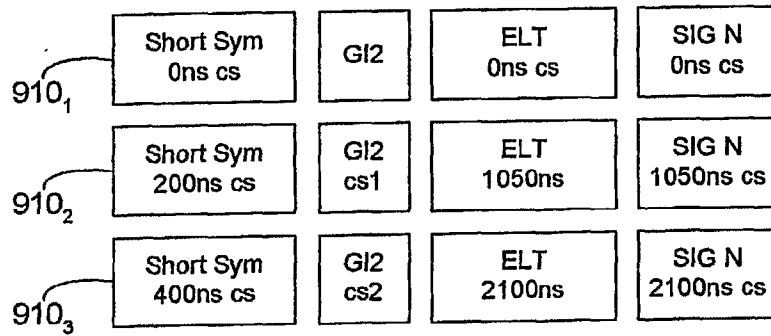


Fig. 9B

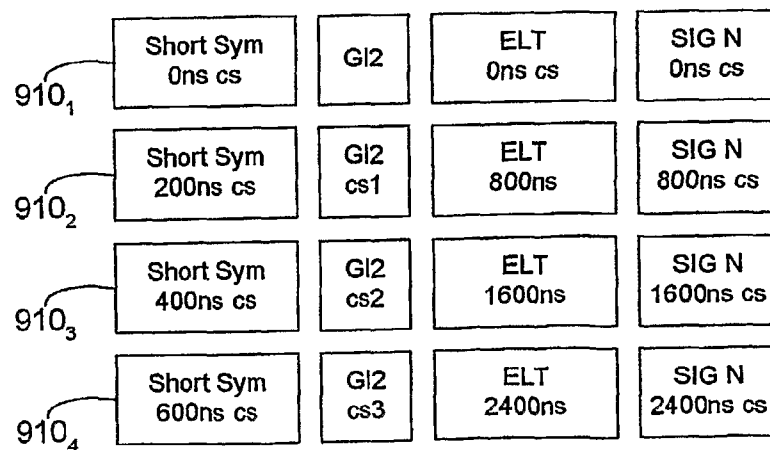


Fig. 9C

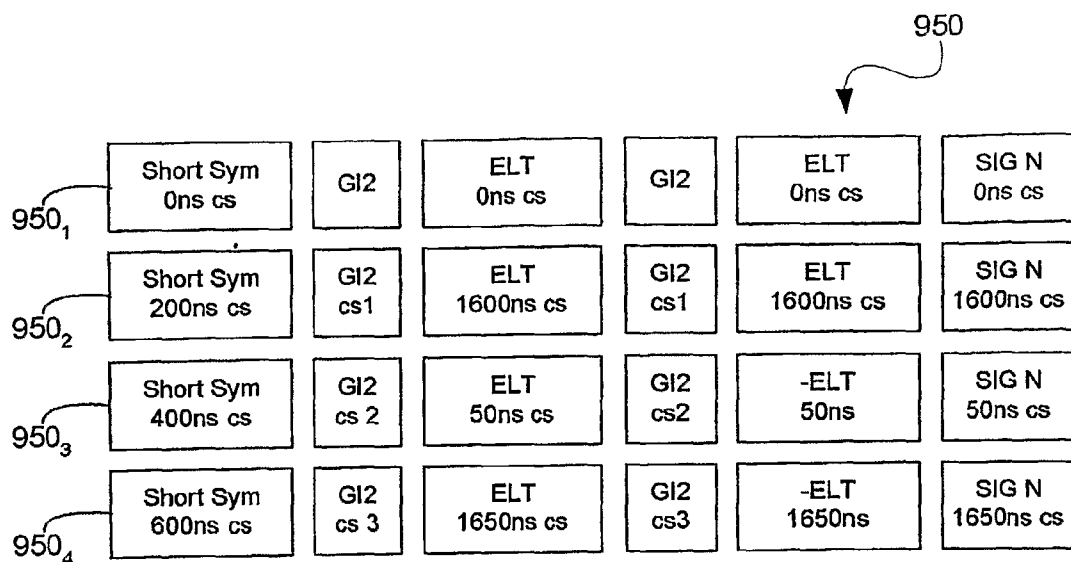


Fig. 10

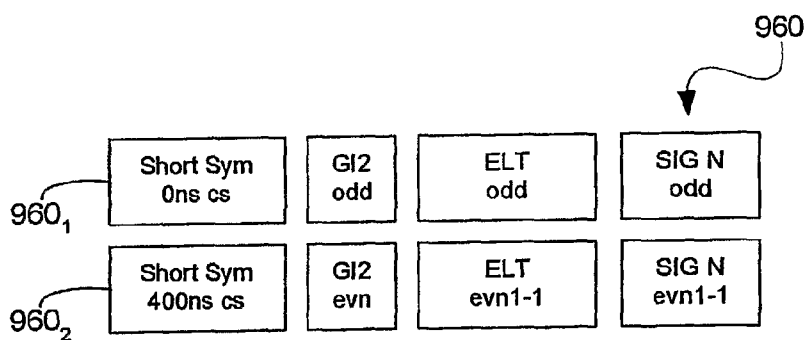


Fig. 11

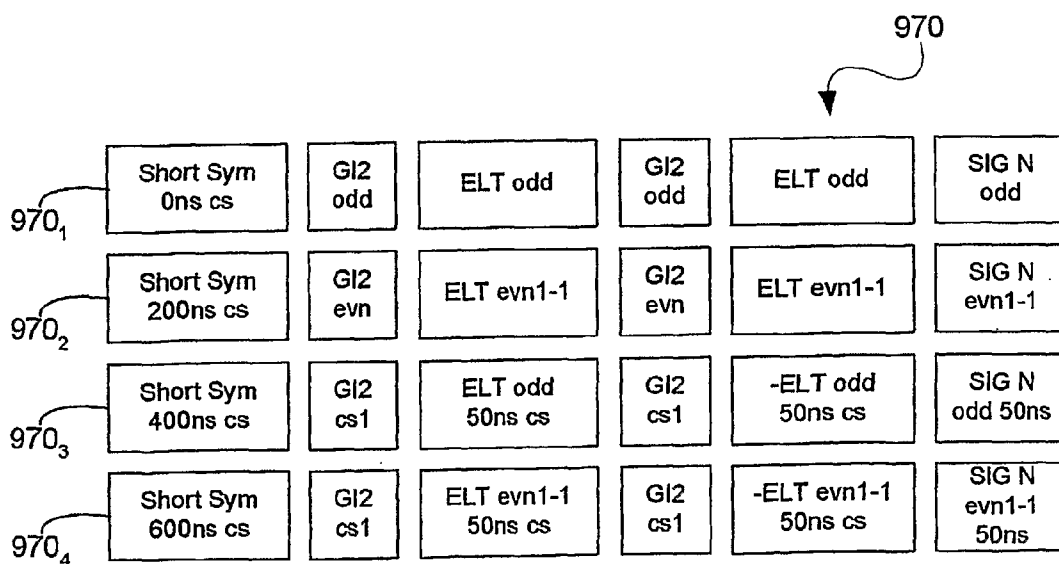


Fig. 12

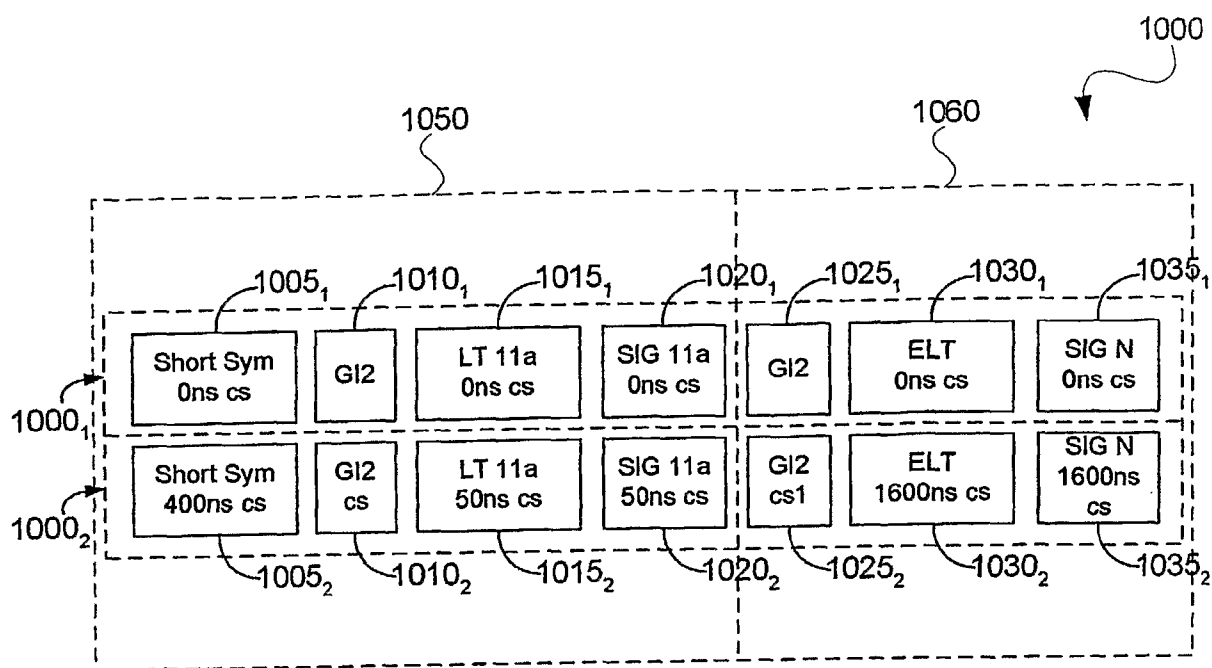


Fig. 13

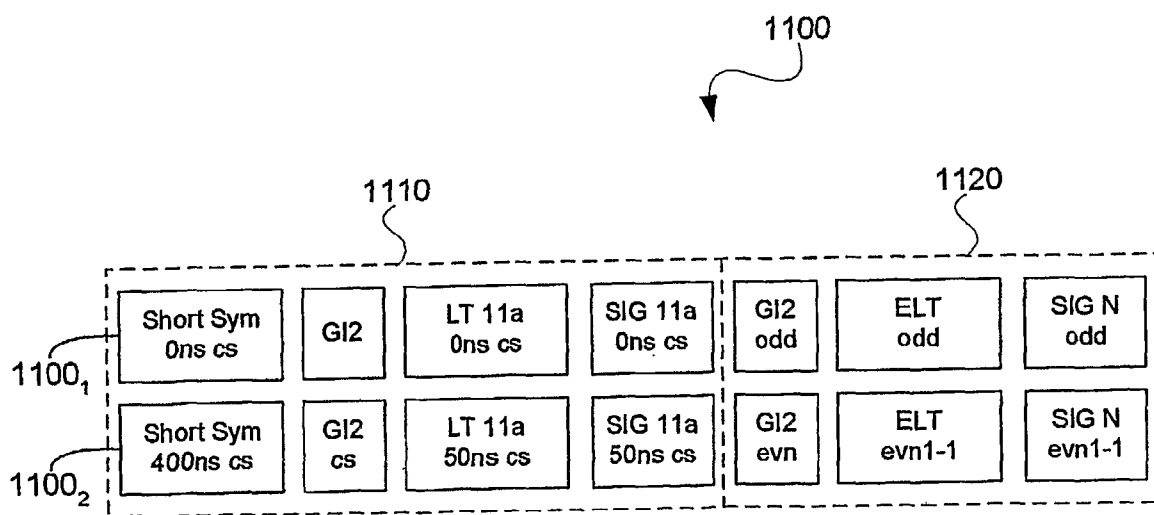


Fig. 14

1200
↓

{ -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, }

FIG. 15A

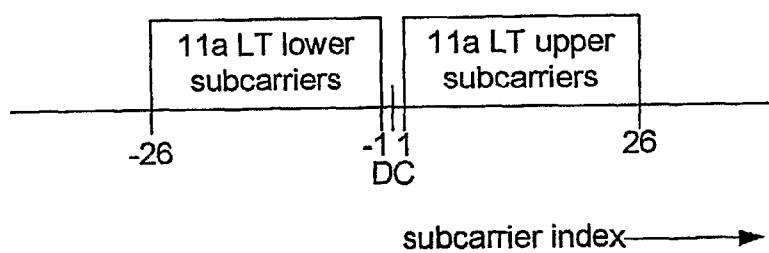


FIG. 15B
(Prior Art)

1300
↓

```
{ -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, -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, -1, }
```

FIG. 16A

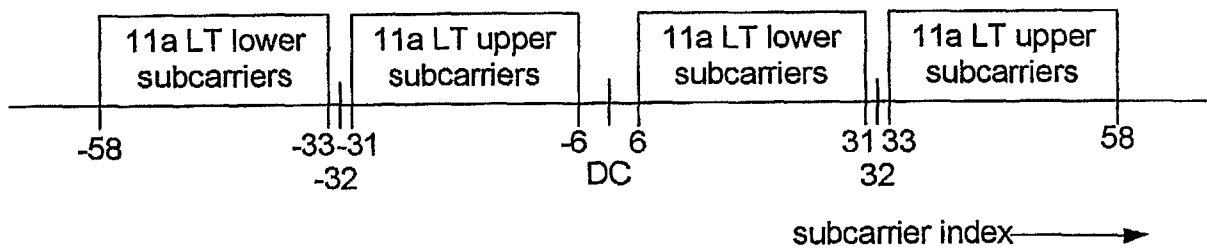


FIG. 16B

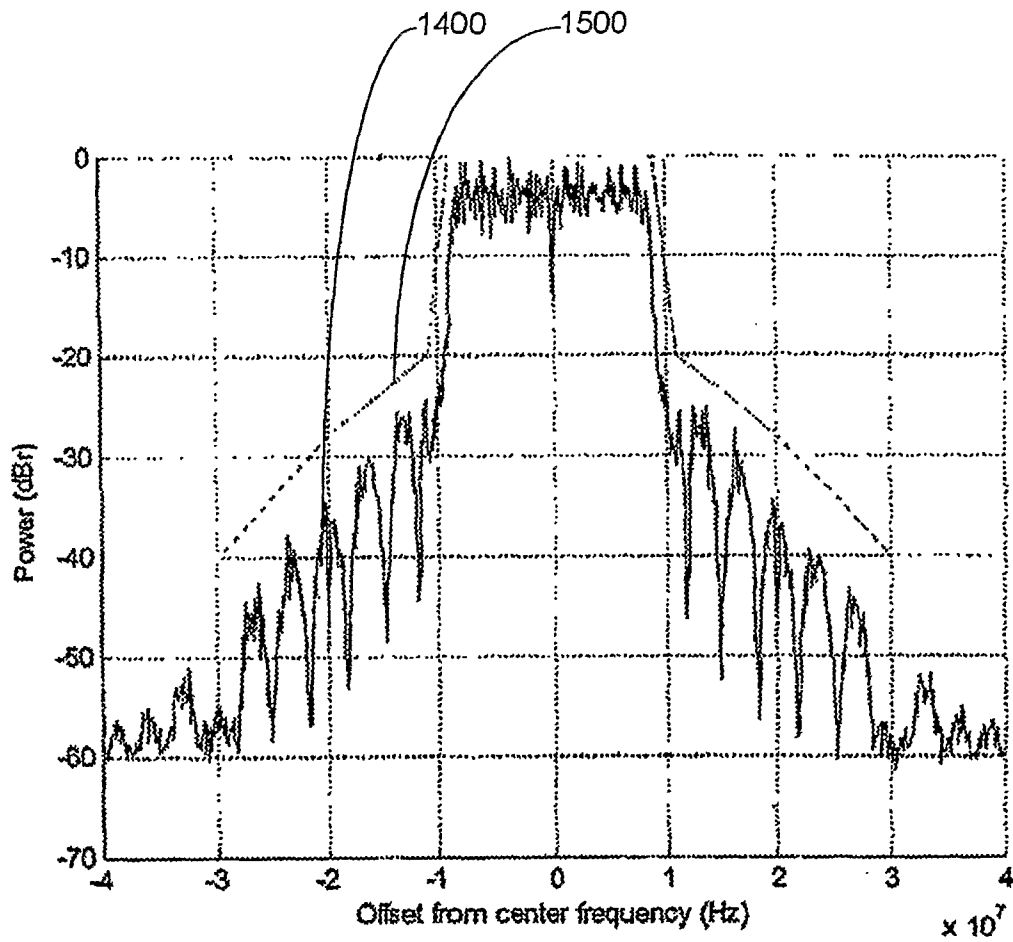


Fig. 17

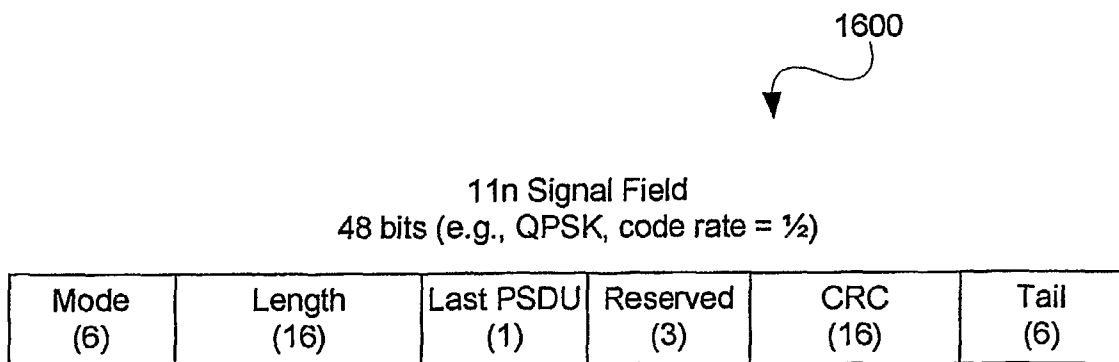


Fig. 18

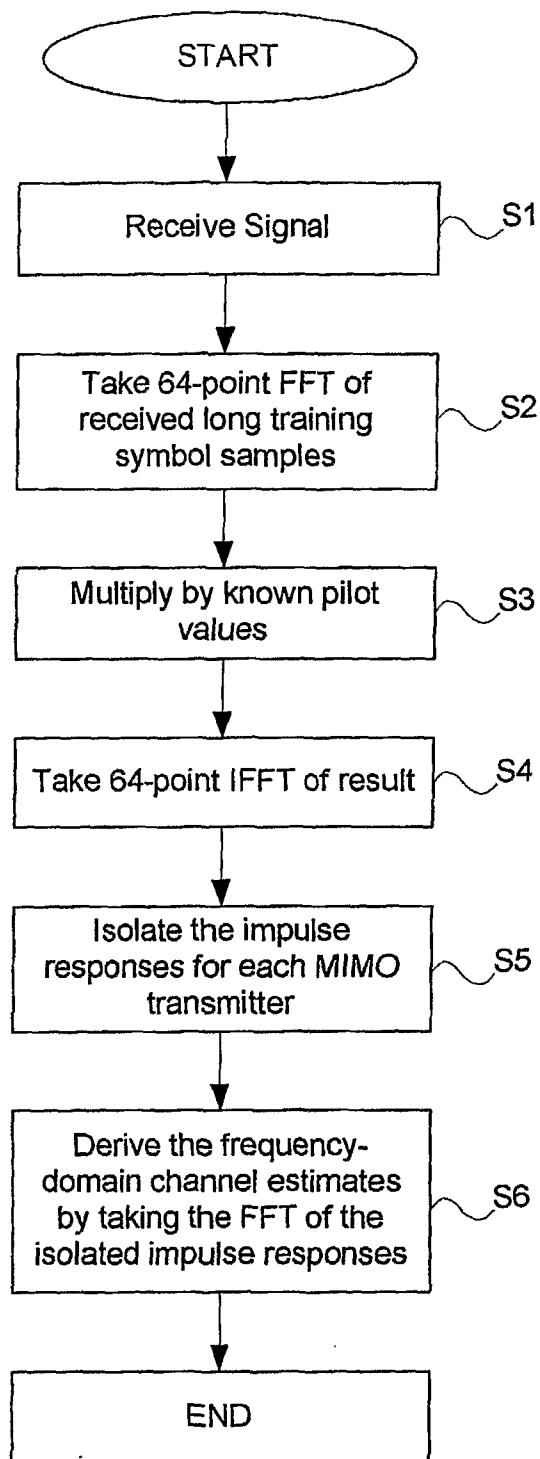


Fig. 19

REFERENCES CITED IN THE DESCRIPTION

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- **BANGERTER, B. et al.** High-Throughput Wireless LAN Air Interface. *Intel Technology Journal*, August 2003, vol. 7 (3 [0048]
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Módosított előtag struktúra IEEE 802.11a kiterjesztésekhez, 802.00a eszközök és nagyobb adatssebességű, MIMO vagy egyébként kiterjesztett eszközök közötti koegzisztencia és együttműködési képesség lehetővé tételére

Szabadalmi igénypontok

1. Gyakorló szekvencia, amely N számú előtagot (900, 910, 950, 960, 970, 1000, 1100) tartalmaz, amelyek külön-külön egy 802.11 szabvány szerinti, vezeték nélküli kommunikációs rendszer legalább N számú antennájától származó átvitelre vannak konfigurálva, mindegyik N számú előtag (900, 910, 950, 960, 970, 1000, 1100) tartalmaz:

egy rövid gyakorló szekvencia mezőt (920, 1005);

egy hosszú gyakorló szekvencia mezőt (930, 1015, 1050); és

egy jel mezőt (935, 1035);

azzal jellemezve, hogy

az N számú előtagok közül legalább egy jel mezője (935, 1035) és a rövid gyakorló szekvencia mező (920, 1005) és a hosszú gyakorló szekvencia mező (930, 1015, 1050) közül legalább egy ciklikus eltolással rendelkezik az N számú előtagok közül egy másik előtag vonatkozó rövid gyakorló szekvencia mezőjéhez (920, 1005), hosszú gyakorló szekvencia mezőjéhez (930, 1015, 1050) és jel mezőjéhez (935, 1035) képest, és ahol minden egyes előtag (1000, 1100) tartalmaz egy a 802.11a szabvány által definiált első részt (1050, 1110) és egy második részt (1060, 1120), amely legalább egy olyan mezőt tartalmaz, amely megkülönböztethető a 802.11a szabvány által definiált előtagtól.

2. Az 1. igénypont szerinti gyakorló szekvencia, amely tartalmaz legalább első (910₁) és második (910₂) előtagot, melyek mindegyike legalább egy első és egy második adóantennától származó átvitelhez van konfigurálva, ahol:

a második előtag (910₂) rövid gyakorló szekvencia mezője (920) ciklikus eltolással rendelkezik az első előtag (910₁) rövid gyakorló szekvencia mezőjéhez képest;

a második előtag (910₂) hosszú gyakorló szekvencia mezője (930) ciklikus eltolással rendelkezik az első előtag (910₁) hosszú gyakorló szekvencia mezőjéhez képest; és

a második előtag (910₂) jel mezője (935) ciklikus eltolással rendelkezik az első előtag (910₁) jel mezőjéhez képest.

3. A 2. igénypont szerinti gyakorló szekvencia, ahol

a második előtag (910₂) rövid gyakorló szekvencia mezője (920) 400 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) rövid gyakorló szekvencia mezőjéhez képest;

a második előtag (910₂) hosszú gyakorló szekvencia mezője 1600 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) hosszú gyakorló szekvencia mezőjéhez képest; és



a második előtag jel mezője (935) 1600 ns időtartamú ciklikus eltolással rendelkezik az első előtag jel mezőjéhez képest.

4. A 2. igénypont szerinti gyakorló szekvencia, amely tartalmaz továbbá egy harmadik előtagot (910₃), amely legalább egy harmadik adóantennától származó átvitelhez van konfigurálva, ahol

a harmadik előtag (910₃) rövid gyakorló szekvencia mezője (920) ciklikus eltolással rendelkezik az első előtag (910₁) rövid gyakorló szekvencia mezőjéhez képest;

a harmadik előtag (910₃) hosszú gyakorló szekvencia mezője (930) ciklikus eltolással rendelkezik az első előtag (910₁) hosszú gyakorló szekvencia mezőjéhez képest; és

a harmadik előtag (910₃) jel mezője (935) ciklikus eltolással rendelkezik az első előtag (910₁) jel mezőjéhez képest.

5. A 4. igénypont szerinti gyakorló szekvencia, ahol

a második előtag (910₂) rövid gyakorló szekvencia mezője (920) 200 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) rövid gyakorló szekvencia mezőjéhez képest és a harmadik előtag (910₃) rövid gyakorló szekvencia mezője 400 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) rövid gyakorló szekvencia mezőjéhez képest;

a második előtag (910₂) hosszú gyakorló szekvencia mezője 1050 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) hosszú gyakorló szekvencia mezőjéhez képest, és a harmadik előtag (910₃) hosszú gyakorló szekvencia mezője 2100 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) hosszú gyakorló szekvencia mezőjéhez képest; és

a második előtag (910₂) jel mezője 1050 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) jel mezőjéhez képest, és ahol a harmadik előtag (910₃) jel mezője 2100 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) jel mezőjéhez képest.

6. A 4. igénypont szerinti gyakorló szekvencia, amely tartalmaz továbbá egy negyedik előtagot (910₄) amely legalább egy negyedik adóantennától származó átvitelhez van konfigurálva, ahol

a negyedik előtag (910₄) rövid gyakorló szekvencia mezője (920) ciklikus eltolással rendelkezik az első előtag (910₁) rövid gyakorló szekvencia mezőjéhez képest;

a negyedik előtag (910₄) hosszú gyakorló szekvencia mezője (930) ciklikus eltolással rendelkezik az első előtag (910₁) hosszú gyakorló szekvencia mezőjéhez képest; és

a negyedik előtag (910₄) jel mezője (935) ciklikus eltolással rendelkezik az első előtag (910₁) jel mezőjéhez képest.

7. A 6. igénypont szerinti gyakorló szekvencia, ahol

a második előtag (910₂) rövid gyakorló szekvencia mezője (920) 200 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) rövid gyakorló szekvencia mezőjéhez képest és a harmadik előtag (910₃) rövid gyakorló szekvencia mezője 400 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) rövid gyakorló szekvencia mezőjéhez képest; és a negyedik előtag (910₄) rövid gyakorló szekvencia mezője 600 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) rövid gyakorló szekvencia mezőjéhez képest;

a második előtag (910₂) hosszú gyakorló szekvencia mezője 1050 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) hosszú gyakorló szekvencia mezőjéhez képest, és a harmadik előtag (910₃) hosszú gyakorló szekvencia mezője 2100 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) hosszú gyakorló szekvencia mezőjéhez képest, és a negyedik előtag (910₄) hosszú gyakorló szekvencia mezője 2400 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) hosszú gyakorló szekvencia mezőjéhez képest; és

a második előtag (910₂) jel mezője 1050 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) jel mezőjéhez képest, és ahol a harmadik előtag (910₃) jel mezője 2100 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) jel mezőjéhez képest, és a negyedik előtag (910₄) jel mezője 2400 ns időtartamú ciklikus eltolással rendelkezik az első előtag (910₁) jel mezőjéhez képest.

8. A 2-7. igénypontok bármelyike szerinti gyakorló szekvencia, ahol az előtagok mindegyike tartalmaz továbbá egy védelmi intervallum mezőt (925, 1010), amely a rövid gyakorló szekvencia mező (1005) és a hosszú gyakorló szekvencia mező (1015) között van elrendezve.

9. A 8. igénypont szerinti gyakorló szekvencia, ahol az előtagok mindegyike továbbá tartalmaz egy második hosszú gyakorló szekvencia mezőt (1030) és egy második védelmi intervallum mezőt (1025), ahol a második hosszú gyakorló szekvencia mező (1030) a második védelmi intervallum mező (1025) és a jel mező (1035) között van elrendezve.

10. A 9. igénypont szerinti gyakorló szekvencia, amely első, második és harmadik előtagot tartalmaz, és legalább egy első, második és harmadik adóantennától származó átvitelhez van konfigurálva, ahol:

a harmadik előtag (910₃) rövid gyakorló szekvencia mezője (920) egy ciklikus eltolással rendelkezik a második előtag (910₂) rövid gyakorló szekvenciájához képest;

a harmadik előtag (910₃) első hosszú gyakorló szekvencia mezője (930) ciklikus eltolással rendelkezik a második előtag (910₂) első hosszú gyakorló szekvencia mezőjéhez képest;

a harmadik előtag (910₃) második hosszú gyakorló szekvencia mezője (930) fordított előjeld az első előtag (910₁) második hosszú gyakorló szekvencia mezőjéhez képest;

a harmadik előtag (910₃) második hosszú gyakorló szekvencia mezője ciklikus eltolással rendelkezik a második előtag (910₂) második hosszú gyakorló szekvencia mezőjéhez képest; és

a harmadik előtag (910₃) jel mezője (935) ciklikus eltolással rendelkezik a második előtag (910₂) jel mezőjéhez képest.

11. A 9. igénypont szerinti gyakorló szekvencia, amely első, második, harmadik és negyedik előtagot tartalmaz, és amely legalább első, második, harmadik és negyedik adóantennától származó átvitelhez van konfigurálva, ahol:

a negyedik előtag (910₄) rövid gyakorló szekvencia mezője (920) ciklikus eltolással rendelkezik a harmadik előtag (910₃) rövid gyakorló szekvencia mezőjéhez képest;

a negyedik előtag (910₄) első hosszú gyakorló szekvencia mezője (930) ciklikus eltolással rendelkezik a harmadik előtag (910₃) első hosszú gyakorló szekvencia mezőjéhez képest;

a negyedik előtag (910₄) második hosszú gyakorló szekvencia mezője (930) fordított előjeld az első előtag (910₁) második hosszú gyakorló szekvencia mezőjéhez képest;

a negyedik előtag (910₄) második hosszú gyakorló szekvencia mezője ciklikus eltolással rendelkezik a harmadik előtag (910₃) második hosszú gyakorló szekvencia mezőjéhez képest; és

a negyedik előtag (910₄) jel mezője ciklikus eltolással rendelkezik a harmadik előtag (910₃) jel mezőjéhez képest.

12. A 8-11. igénypontok bármelyike szerinti gyakorló szekvencia, ahol a védelmi intervallum mezők (925, 1010, 1025) a hosszú gyakorló szekvenciák idő-domain ábrázolásából vannak előállítva, előnyösen a hosszú gyakorló szekvenciáknak csupán a párhuzamos vagy csupán a páratlan hangjainak az ábrázolásából.

13. A 8-12. igénypontok bármelyike szerinti gyakorló szekvencia, a védelmi intervallum (925, 1010, 1025) 1,5 μ s időtartamúak.

14. A 2-13. igénypontok bármelyike szerinti gyakorló szekvencia,

a rövid gyakorló szekvencia mezők (920, 1005) 8 μ s időtartamúak;

a hosszú gyakorló szekvencia mezők (930, 1015, 1030) 6,4 μ s időtartamúak; és

a jel mező (935, 1035) 4 μ s időtartamú.

15. Az előző igénypontok bármelyike szerinti gyakorló szekvencia, ahol minden egyes előtag (1000, 1100) második részének (1060, 1120) megkülönböztethető mezője egy hosszú gyakorló szekvencia mező és egy jel mező (1035) közül legalább egyet tartalmaz.

16. Az előző igénypontok bármelyike szerinti gyakorló szekvencia, ahol

egy első előtag (1000₁) második részének (1060) megkülönböztethető mezője a 802.11a szabvány megfelelő mezője páratlan hangjai által meghatározott hangokat tartalmaz, és

egy második előtag (1000₂) második részének (1060) megkülönböztethető mezője a 802.11a szabvány megfelelő mezője hangjainak a {1,0, -1, 0, 1, 0, -1,...} szekvenciával történő szorzása útján meghatározott hangokat tartalmaz.

17. Az előző igénypontok bármelyike szerinti gyakorló szekvencia, amely egy előtagban elhelyezkedő és egy 20 MHz-es csatornát átfogó 64 alvivőn át használt értékeket jelentő hosszú gyakorló szekvenciát tartalmaz, ahol az alvivők egymástól 312,5 KHz távolságban helyezkednek el és az alábbiak szerint vannak meghatározva:

{-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}

18. Az előző igénypontok bármelyike szerinti gyakorló szekvencia, amely egy előtagban elhelyezkedő és egy 20 MHz-es csatornát átfogó 64 alvivőn át használt értékeket jelentő hosszú gyakorló szekvenciát tartalmaz és több nullától eltérő hanggal rendelkezik, mint a 802.11 szabvány által meghatározott hozzá tartozó hosszú gyakorló szekvenciában elhelyezkedő nullától eltérő hangok száma.

19. Az előző igénypontok bármelyike szerinti gyakorló szekvencia, amely egy előtagban elhelyezkedő és egy 40 MHz-es csatornát átfogó 128 alvivőn át használt értékeket jelentő hosszú gyakorló szekvenciát tartalmaz, ahol az alvivők egymástól 312,5 KHz távolságban helyezkednek el és az alábbiak szerint vannak meghatározva:

{-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}

20. Az előző igénypontok bármelyike szerinti gyakorló szekvencia, amely egy előtagban elhelyezkedő és egy 40 MHz-es csatornát átfogó 128 alvivőn át használt értékeket jelentő hosszú gyakorló szekvenciát tartalmaz, amely több nullától eltérő hanggal rendelkezik, mint a 802.11 szabvány által meghatározott hozzá tartozó hosszú gyakorló szekvenciában lévő nullától eltérő hangok száma.

21. Az előző igénypontok bármelyike szerinti gyakorló szekvencia, amely kvadratúra fázisbillentyűzéses modülációs technikára vonatkozó biteket hordozó jel mezőt tartalmaz.

22. A 21. Igénypont szerinti gyakorló szekvencia, ahol az említett jel mező továbbá 16 bites CRC mezőt tartalmaz.

23. Az előző igénypontok bármelyike szerinti gyakorló szekvencia, amely 24 bitnél több bites jel mezőt tartalmaz.

24. Az előző igénypontok bármelyike szerinti gyakorló szekvencia, ahol a minden egyes előtag hosszú gyakorló szekvencia mezőjében lévő hangok közül csupán a DC hangok nulla értékek.

25. Eljárás, amely az előző igénypontok bármelyike szerinti gyakorló szekvencia előállítására vonatkozó eljárási lépéseket tartalmaz.
26. Berendezés, amely eszközt tartalmaz az 1-24. igénypontok bármelyike szerinti gyakorló szekvencia előállítására.
27. Az 1-24. igénypontok bármelyike szerinti gyakorló szekvencia, amely egy vezeték nélküli eszköz általi vételre van konfigurálva.
28. Kiterjesztett vezeték nélküli készülék, amely a 27. igénypont szerinti gyakorló szekvencia vételére van alkalmazható.