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U.S. Patent 10,291,454

U.S. Patent 10,291,454 ("*Redwood Technologies LLC*" or the "patent-at-issue") was filed on November 21, 2017 claims an earliest priority date of July 5, 2000. Claim 1 of the patent-at-issue is generally directed to a transmitting device for transmitting data symbols and pilot symbols in an OFDM transmission system. The device generates data symbols and pilot symbols and transmits the data symbols and pilot symbols using a plurality of subcarriers of an OFDM transmission system. The symbol generating means is designed to selectively generate a first type pilot symbol and a second type pilot symbol being orthogonal to the first type pilot symbol so that a pilot symbol pattern in the frequency dimension has at least the first type pilot symbol to be transmitted by using a predefined subcarrier and the second type pilot symbol to be transmitted by using another predefined subcarrier. The pilot symbol pattern has a different pattern from a succeeding pilot symbol pattern in the time dimension.

The primary reference, U.S. Patent 7,983,217 ("*AT&T*"), was filed on August 15, 2008 and claims an earliest priority date of February 6, 1997. The patent is directed to a high quality PCS communications in environments where adjacent PCS service bands operate with out-of-band harmonics that would otherwise interfere with the system's operation. The highly bandwidth-efficient communications method combines a form of time division duplex (TDD), frequency division duplex (FDD), time division multiple access (TDMA), orthogonal frequency division multiplexing (OFDM), spatial diversity, and polarization diversity in various unique combinations.

The secondary reference, U.S. Patent 7,593,449 ("*Genghiscomm*"), was filed on January 8, 2007, and claims an earliest priority date of February 12, 1998. The patent is directed to carrier interferometry (CI) methods used to provide transmission protocols having various desirable properties. Such properties may include interference rejection, reduced multipath fading, and/or operation across discontinuous frequency bands. Codes used for such CI techniques, known as CI codes, may be orthogonal polyphase codes.

The secondary reference, U.S. Pat. App. 2002/0001352 ("*Sony*"), was filed on July 3, 2001, and claims priority on July 5, 2000. The patent is directed to a device for receiving signals in a wireless cellular OFDM system, in which data symbols are transmitted in frequency subcarriers and timeslots. A channel estimation on the basis of received pilot symbols is performed, whereby the channel estimation for data symbols between pilot symbols is performed by means of a filter, said filter being selected from a set of filters on the basis of an interference reference value.

A sample claim chart comparing claim 1 of *Redwood* to *Qualcomm*, *Genghiscomm*, and *Sony* is provided below.

US10291454 ("*Redwood*")	**A. US7983217** (*"AT&T"*) **B. US7593449** (*"Genghiscomm"*) **C. US20020001352** (*"Sony"*)
1. An apparatus comprising: a **transmitter adapted to transmit data symbols and pilot symbols in an OFDM transmission system**, the transmitter configured to:	**A. US7983217** "1. An apparatus comprising: **a remote unit configured to transmit a signal including a first data signal, the first data signal being allocated to only a first set of a plurality of sets of non-overlapping orthogonal frequency division multiplexed (OFDM) discrete frequency tones** in a first frequency band of a plurality of non-overlapping frequency bands of a channel coupled to the remote unit, and in a first set of time intervals, fewer than all time intervals, of a plurality of time intervals of a time division multiple access (TDMA) frame of the channel," *AT&T* at claim 1 "The PWAN system has a total of 3200 **discrete tones (carriers)** equally spaced in 10 MHZ of available bandwidth in the range of 1850 to 1990 MHZ. The spacing between the tones is 3.125 kHz. The total set of tones are numbered consecutively form 0 to 3199 starting from the lowest frequency tone. **The tones are used to carry traffic messages and overhead messages between the base station and the plurality of remote units**. In addition, the PWAN system **uses overhead tones to establish synchronization and to pass control information between the base station and the remote units**." *AT&T* at col. 12:37-47 "**Selected tones within each tone set are designated as pilots distributed throughout the frequency band**. **Pilot tones carry known data patterns that enable an accurate channel estimation**. The series of pilot tones, having known amplitudes and phases, have a known level and are spaced apart by approximately 30 KHz to provide an accurate representation of the channel response (i.e., the amplitude and phase distortion introduced by the communication channel characteristics) over the entire transmission band." *AT&T* at col. 12:55-63

1. An apparatus comprising: a **transmitter adapted to transmit data symbols and pilot symbols in an OFDM transmission system**, the transmitter configured to:	**B. US7593449** "Channel estimation describes any combination of blind adaptive techniques and reference-signal processing to determine signal distortion resulting from the effects of at least one communication channel. In one example, a **pilot symbol is transmitted periodically from a remote transmitter**. A local receiver exploits the known transmission time, frequency, polarization, and/or any other diversity-parameter value of at least one pilot symbol to process the transmitted pilot symbol and estimate the distortion caused by the channel environment. On the basis of an estimated value, distortion in the **received data symbols** is compensated." *Genghiscomm* at col. 20:1-11 "Coding may be provided to distribute a **data symbol over a plurality of carrier frequencies**, time intervals, and/or phases. **Such coding techniques are commonly employed in OFDM**. Similarly, guard bands, cyclic prefixes, and various signal-processing techniques used with OFDM and other multicarrier protocols may be provided to CI signals." *Genghiscomm* at col. 35:52-57 **C. US20020001352** "1. Device (20) for receiving signals in a wireless cellular orthogonal frequency division multiplex (OFDM) system, in which **data symbols are transmitted in frequency subcarriers and timeslots**, comprising channel estimation means (21) for performing a channel estimation on the basis of **received pilot symbols**, whereby the channel estimation for **data symbols** between **pilot symbols** is performed by means of a filter, said filter being selected from a set of filters on the basis of an interference reference value. " *Sony* at claim 1 "The channel estimation means 16 performs a channel estimation for the **transmission channels between the transmitting device 1 and the receiving device** 10 in order to ensure a good transmission quality. In case of the present invention, **an orthogonal frequency division mulitplex (OFDM) wireless communication system is addressed, in which the transmission frequency band is divided in a plurality of frequency subcarriers**, whereby adjacent frequency-subcarriers are respectively orthogonal to each other." *Sony* at par. 0004

1a. **generate said data symbols and said pilot symbols**; and	**A. US7983217** "A known pilot symbol **is added to form an 18 element vector, with the pilot as the first element of this vector**." *AT&T* at col. 15:7-8 "The 114 bit sequence is QPSK modulated where every two bits are mapped onto a constellation point according to Gray mapping. The output of the QPSK modulator is therefore a 72 symbol sequence (S0-S71). **The QPSK symbols are interleaved with 72 known pilot symbols** (P0-P71), **where for every data symbol, a pilot is inserted**. This results in a 144 symbol sequence. **The sequence is time demultiplexed into 8, 18 element vectors for transmission over 8 TDMA slots** (in two TDMA frames) as shown in FIG. 1.14. Table 1.5 **Mapping of symbols onto tones for CAC transmissions** on the ith reverse physical channel." *AT&T* at col. 17:14-24 **B. US7593449** "The symbol generator 1202 **may perform interleaving and/or channel coding.** The code source 1201 may include one or more sets of CI codes that may be used for channel coding, multiple access, spread spectrum, encryption, etc. In one set of embodiments, the code source 1201 is adapted to provide a conventional direct-sequence code to the symbol generator 1202." *Genghiscomm* at col. 43:58-64 "The symbol generator 1202 **may form data symbols and/or CI carrier weights via orthonormal-basis vectors**. For example, if data symbols are generated from an 8-chip Hadamard-Walsh matrix, each of the eight row vectors (i.e., Walsh codes) of the matrix can be expressed by a linear combination of three orthonormal basis vectors:" *Genghiscomm* at col. 44:29-34 "At least one of the subscriber units 10001 is adapted to transmit a **pilot signal** or known training signal that is received at the plurality of access points 10011 to 10015." *Genghiscomm* at col. 135:57-59 **C. US20020001352** "FIG. 2 shows an example of a regular distribution of pilot **symbols in the frequency subcarrier/time grid of an OFDM system**. The pilot symbols are hereby labelled by circles. In the regular distribution of the pilot symbols shown as an example in FIG. 2, the pilot symbols are transmitted in some frequency subcarriers at respectively the same equidistant timepoints.

1a. **generate said data symbols and said pilot symbols**; and	**The squares between adjacent pilot symbols in time and frequency dimension represent frequency subcarrier/timeslot allocations for the transmission of data symbols**." *Sony* at par. 0005
1b. **transmit said data symbols and pilot symbols using a plurality of subcarriers of said OFDM transmission system**, wherein	**A. US7983217** "1. An apparatus comprising: a remote unit configured to **transmit a signal including a first data signal, the first data signal being allocated to only a first set of a plurality of sets of non-overlapping orthogonal frequency division multiplexed (OFDM) discrete frequency tones** in a first frequency band of a plurality of non-overlapping frequency bands of a channel coupled to the remote unit, and in a first set of time intervals, fewer than all time intervals, of a plurality of time intervals of a time division multiple access (TDMA) frame of the channel, wherein the remote unit comprises:" *AT&T* at Claim 1 "FIG. 1 provides an overview of how the invention combines TDD, FDD, TDMA, and OFDM to enable the base station Z to efficiently communicate with many remote stations U, V, W, and X. **The base station Z receives a first incoming wireless signal** 10 **comprising a plurality of first discrete frequency tones F2 that are orthogonal frequency division multiplexed (OFDM) in a first frequency band from the first remote station U during a first time division multiple access (TDMA) interval**." *AT&T* at col. 9:30-38 "The 114 bit sequence is QPSK modulated where every two bits are mapped onto a constellation point according to Gray mapping. The output of the QPSK modulator is therefore a 72 symbol sequence (S0-S71). **The QPSK symbols are interleaved with 72 known pilot symbols** (P0-P71), **where for every data symbol, a pilot is inserted**. This results in a 144 symbol sequence. **The sequence is time demultiplexed into 8, 18 element vectors for transmission over 8 TDMA slots** (in two TDMA frames) as shown in FIG. 1.14. Table 1.5

1b. **transmit said data symbols and pilot symbols using a plurality of subcarriers of said OFDM transmission system**, wherein	**Mapping of symbols onto tones for CAC transmissions** on the ith reverse physical channel. During each TDMA slot, the 18 symbols are placed in the DFT frequency bins (corresponding to the physical channel) where they are converted into the time domain. **The digital samples are converted to analog, RF converted and sent to the antenna for transmission over the air**. FIG. 1.14 shows the demultiplexing of a CAC message on two consequent TDMA frames." *AT&T* at col. 17:14-31 **B. US7593449** "FIG. 4B represents a plurality of data symbols s1(t), s2(t), and s3(t) that are each modulated onto the same carrier frequencies within the same time interval**. Unlike conventional OFDM, which transmits one data bit per frequency channel per time slot, CI provides orthogonality to multiple data symbols sharing the same frequency channel and time slot**. OFDM merely acts as a group of single-carrier channels, whereas in CI, the individual carriers work together to convey data symbols." *Genghiscomm* at col. 29:20-28 "Alternatively, channel compensation may employ at least one **pilot or training signal** to probe the channel." *Genghiscomm* at col. 19:55-57 "FIG. 41A illustrates general steps of a transmitting method of the present invention. An information signal s(t) is optionally encoded and/or interleaved 4101. Encoding may include code puncturing. Preferably, coding includes CI or CI-based coding. The coding/interleaving step 4101 may include generating or otherwise acquiring symbol values to be impressed onto multiple carriers. The **information signal may be provided with predetermined training symbols in a training symbol injection step 4102**." *Genghiscomm* at col. 78:48-56 **C. US20020001352** "1. Device (20) for receiving signals in a **wireless cellular orthogonal frequency division multiplex (OFDM) system, in which data symbols are transmitted in frequency subcarriers and timeslots**, comprising channel estimation means (21) for performing a channel estimation on the basis of received **pilot symbols**, whereby the channel estimation for **data symbols between pilot symbols** is

1b. **transmit said data symbols and pilot symbols using a plurality of subcarriers of said OFDM transmission system**, wherein	performed by means of a filter, said filter being selected from a set of filters on the basis of an interference reference value. " *Sony* at claim 1
1c. said generating said pilot symbols includes **generating a first type pilot symbol and a second type pilot symbol being orthogonal to said first type pilot symbol**	**A. US7983217** "10. The apparatus, as recited in claim 6, wherein the first and second sets of non-overlapping OFDM discrete frequency tones are the same discrete frequency tones, the first and second frequency bands are the same frequency band, and the first and second sets of time intervals are the same time intervals, wherein the **first signal is polarized in a first direction** and the **second signal is polarized in a second direction orthogonal to the first direction**, and" *AT&T* at claim 10 **B. US7593449** "FIG. 4B represents a plurality of data symbols s1(t), s2(t), and s3(t) that are each modulated onto the same carrier frequencies within the same time interval**. Unlike conventional OFDM, which transmits one data bit per frequency channel per time slot, CI provides orthogonality to multiple data symbols sharing the same frequency channel and time slot**. OFDM merely acts as a group of single-carrier channels, whereas in CI, the individual carriers work together to convey data symbols." *Genghiscomm* at col. 29:20-28 **C. US20020001352** "In case of the present invention, an orthogonal frequency division mulitplex (OFDM) wireless communication system is addressed, in which the transmission frequency band is divided in a plurality of frequency subcarriers, whereby **adjacent frequency-subcarriers are respectively orthogonal to each other**." *Sony* at par. 0004 "For the channel estimation in OFDM-systems using coherent modulation, various approaches have been proposed. Most of the approaches use **pilot symbols placed in the frequency subcarrier/time grid** for a channel estimation at the receiving side." *Sony* at par. 0005

1d. so that a **pilot symbol pattern in a frequency dimension comprises at least said first type pilot symbol to be transmitted using a first subcarrier and second type pilot symbol to be transmitted using a second subcarrier**, and	**A. US7983217** "The base station Z in FIG. 1, receives **a first** incoming **wireless signal** 10 **polarized in a first polarization direction comprising a plurality of first discrete frequency tones** F2 that are orthogonal frequency division multiplexed (OFDM) in a first frequency band from the first remote station U during a first time division multiple access (TDMA) interval. The base station Z in FIG. 1, receives a **second incoming wireless signal** 14 **polarized in a second polarization direction comprising a plurality of the first discrete frequency tones** F2 that are orthogonal frequency division multiplexed (OFDM) in the first frequency band from a second remote station V during the first time division multiple access (TDMA) interval. The base station Z in FIG. 1, distinguishes the first and second incoming signals 10 and 14 received at the base station by detecting the first and second polarization directions." *AT&T* at col. 11:55 through col. 12:2 "A Common Access Channel (CAC) is used to **transmit messages from the Remote Unit to the Base**." *AT&T* at col. 12:49-52 "**The QPSK symbols are interleaved with 72 known pilot symbols** (P0-P71), where for every data symbol, a pilot is inserted. This results in a 144 symbol sequence. The sequence is time demultiplexed into 8, 18 element vectors for transmission over 8 TDMA slots (in two TDMA frames) as shown in FIG. 1.14." AT&T at col. 17:17-22 **B. US7593449** "FIG. 4B represents a plurality of data symbols s1(t), s2(t), and s3(t) that are each modulated onto the same carrier frequencies within the same time interval**.** Unlike conventional OFDM, which transmits one data bit per frequency channel per time slot, **CI provides orthogonality to multiple data symbols sharing the same frequency channel and time slot**. OFDM merely acts as a group of single-carrier channels, whereas in **CI, the individual carriers work together to convey data symbols**." *Genghiscomm* at col. 29:20-28 "The **converter** 1206 **may convey symbols to different types of subcarriers**. For example, the **symbols may modulate various orthogonal or quasi-orthogonal circular-polarized and/or elliptical-polarized carriers**. Orthogonality between different polarized carriers may be characterized by different rotation rates, different directions of rotation, and/or

1d. so that a **pilot symbol pattern in a frequency dimension comprises at least said first type pilot symbol to be transmitted using a first subcarrier and second type pilot symbol to be transmitted using a second subcarrier**, and	orthogonal (e.g., perpendicular) polarization vectors in two or three dimensions." *Genghiscomm* at col. 44:21-28 "Alternatively, channel compensation may employ at least one **pilot or training signal** to probe the channel." *Genghiscomm* at col. 19:55-57 "FIG. 41A illustrates general steps of a transmitting method of the present invention. An information signal s(t) is optionally encoded and/or interleaved 4101. Encoding may include code puncturing. Preferably, coding includes CI or CI-based coding. The coding/interleaving step 4101 may include generating or otherwise acquiring symbol values to be impressed onto multiple carriers. The **information signal may be provided with predetermined training symbols in a training symbol injection step** 4102." *Genghiscomm* at col. 78:48-56 **C. US20020001352** "For the channel estimation in OFDM-systems using coherent modulation, various approaches have been proposed. Most of the approaches use **pilot symbols placed in the frequency subcarrier**/time grid for a channel estimation at the receiving side." *Sony* at par. 0005
1e. said **pilot symbol pattern has a different pattern in a time dimension from a subsequent pilot symbol pattern**.	**A. US7983217** **"Delay compensation relies on measuring the phase of pilot tones called delay compensation pilots (DCPs).** The RU transmits the DCPs to the base station with each DCP having the same phase shift. If the RU has been compensated properly the DCP tones arrive at the base station in phase with each other. **If the signal from the RU is delayed then each of the DCP tones experiences a phase shift, which is proportional to the DCP frequency**." *AT&T* at col. 26:33-41 "A way to differentiate signals in different cells is to **encode the reference pilots on the traffic channels with different phases or sequence of phases** which would be derived from the Base Station Offset Code." *AT&T* at col. 24:12-15 **B. US7593449**

1e. said **pilot symbol pattern** **has a different pattern in a time dimension from a subsequent pilot symbol pattern**.	"FIG. 6B illustrates a superposition of three subchannels that occupy the same time-domain space. However, the **separability of the time-domain signals into their frequency components provides orthogonality to the signals** (and the subchannels). FIG. 6A and FIG. 6B illustrate how a wideband signal can be separated into smaller-bandwidth subchannels that are easier to process in the time domain. **The duration of each data symbol in a subchannel is M times the duration that a data symbol would have if its bandwidth occupied the total channel**. However, each subchannel can be positioned such that the group of subchannels occupies almost the full bandwidth of the total channel. This enables a group of subchannels to derive substantially the same frequency-diversity benefits of the total channel." *Genghiscomm* at col. 30:17-30 "Alternatively, channel compensation may employ at least one **pilot or training signal** to probe the channel." *Genghiscomm* at col. 19:55-57 "FIG. 41A illustrates general steps of a transmitting method of the present invention. An information signal s(t) is optionally encoded and/or interleaved 4101. Encoding may include code puncturing. Preferably, coding includes CI or CI-based coding. The coding/interleaving step 4101 may include generating or otherwise acquiring symbol values to be impressed onto multiple carriers. The **information signal may be provided with predetermined training symbols in a training symbol injection step 4102**." *Genghiscomm* at col. 78:48-56 **C. US20020001352** "The **frequency subcarriers are transmitted in respectively succeeding time slots**, so that the entire transmission pattern of frequency subcarriers in timeslots can be represented as a frequency/time grid like the one shown in FIG. 2." at par. 0004 "For the channel estimation in OFDM-systems using coherent modulation, various approaches have been proposed. Most of the approaches use pilot **symbols placed in the frequency subcarrier/time grid** for a channel estimation at the receiving side. FIG. 2 shows an example of a regular distribution of **pilot symbols in the frequency subcarrier/time grid** of an OFDM system." at par. 0005