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U.S. Patent 7,110,779

U.S. Patent 7,110,779 ("*Speir*" or the "patent-at-issue") was filed on January 29, 2004, and claims priority date on the same date. Claim 1 of the patent-at-issue is directed to a method of locating a wireless communications devices using a device locator. The locator includes an antenna and a transceiver connected to transmit a location finding signals to a target communications device. The target device transmits a reply signal for each of the location finding signals. The locator may then determine a propagation delay associated with the location and reply signals based on the device latency of the target device. With this, the range or location of the target device can be estimated based on the determined propagation delays.

The primary reference, U.S. Patent 6,026,304 ("*Hilsenrath*"), was filed on January 8, 1997, and claims priority on the same date. The patent is directed to a method of determining the location of a mobile transmitter. Signals from a mobile transmitter are being received at an antenna array of a base station receiver. The base station determines a signal signature and is compared to a database of calibrated signal signatures and corresponding locations. The location whose signature best matches is most likely the location of the mobile transmitter.

The secondary reference, U.S. Patent 8,451,936 ("*North Star*"), was filed on October 22, 2009, and claims an earliest priority date of December 11, 1998. The patent is directed to a method of establishing a communication link between a remote and local device over an ultra-wide bandwidth (UWB) medium. Using the UWB transmissions, the movement of the remote device can be determined with respect to the local device.

The third reference, U.S. Pat. App. 2004/0185873 (*"Gilkes"*), was filed on January 30, 2004, and claims an earliest priority date of June 1, 2001. The patent application relates to a method of locating a wireless communications device by determining a phase difference between a known stable reference signal and a known signal output by the device. The location can also be estimated by transmitting a message from the device and determining where among the pre-determined locations the message has been received.

A sample claim chart comparing claim 1 of *Speir* to *Hilsenrath, North Star,* and *Gilkes* is provided below.

US7110779 (*"Speir"*)	**A. US6026304** (*"Hilsenrath"*) **B. US8451936** (*"North Star"*) **C. US20040185873** (*"Gilkes"*)
1. A **wireless communications system** comprising: **a plurality of wireless communications devices each having a device type associated therewith from among a plurality of different device types, each WLAN device having a unique identifier (UID) associated therewith, and each device type having a known device latency associated therewith**; and	**A. US6026304** "1. In a **wireless communication system** comprising a mobile transmitter and a receiver connected to an antenna array, a method for estimating the location of the **mobile transmitter**, the method comprising: receiving at the antenna array signals originating from the **mobile transmitter**, wherein the signals comprise p-dimensional array vectors sampled from p antennas of the array; **determining from the received signals a signal signature**, wherein the signal signature comprises a measured subspace . . . ." *Hilsenrath* at Claim 1 "A preferred embodiment of the invention comprises a system and method for determining the locations of **mobile transmitters, such as cellular telephones**, in a wireless communications system such as a cellular telephone network." *Hilsenrath* at col. 5:65-6:1 "In general, the **signal signature is any location-dependent feature derived from the set of direct and multipath signals** received at the antenna array of a single base station from a transmitter at a given location. The **signature may be derived from any combination of amplitude, phase, delay, direction, and polarization information of the signals**." *Hilsenrath* at col. 4:44-50 **B. US8451936** "9. A method for enabling device functions at a local device based on distance information in **an ultra wide band (UWB) network**, comprising: . . . ." *North Star* at Claim 9 "The MAC 150 serves as an interface between the **UWB wireless communication** functions implemented by both the RF PMD 120 and the digital PMD and the application layer 185 that uses the UWB communications channel for exchanging data with the device 180." *North Star* at col. 5:20-24 "The local device 405 is linked to the first through Nth **remote devices** 410 1-410 N via UWB links 415 1-415 N,

(cont.) 1. A **wireless communications system** comprising: **a plurality of wireless communications devices each having a device type associated therewith from among a plurality of different device types, each WLAN device having a unique identifier (UID) associated therewith, and each device type having a known device latency associated therewith**; and	respectively. . . Each of the wireless devices 405 and 410 1 through 410 N **may be a mobile device such as a mobile telephone, a laptop computer or personal digital assistant (PDA), or a fixed structure device such as a retail store kiosk or some other fixed structure device for delivering information to other wireless devices**." *North Star* at col. 12:17-29 "Each reply is a UWB signal that includes a **unique identifier associated with the remote device** from which the reply is transmitted." *North Star* at col. 14:64-66 "In step 609, the local device 405 decodes each unique identifier and establishes **unique communications links** 415 1, 415 2, . . . , 415 N **with remote devices** 410 1, 410 2, . . . , 410 N, respectively." *North Star* at col. 15:8-11 "For each **distance determining message sent on each unique communications link** 410 1 through 410 N, the local device 405 marks **a time t_1 as the transmitting time that the message was sent out for the particular communications link** as shown in step 703. Transmit time t_1 is obtained by a system clock in the processor system 301 of the local device 405. **Each transmit time t_1 is associated with one of the unique identifiers** stored in step 609 **based on the unique link over which the distance determining massage was transmitted**. The transmit times and associated identifiers are then stored in the main memory 307 of local device 405 so that the transmit times may be retrieved to determine the distance to each remote device." *North Star* at col. 15:45-57 "In step 707, the local device 405 receives responses sent from the linked remote devices via respective unique links and **marks a receive time t_2 for each response received** as seen in step 709. **As with the transmit times t_1, each receive time t_2 is associated with the unique identifier of a respective link** and stored in main memory 307 for use in calculating a distance from the local device 405 to each remote device 410_1 through 410_N." *North Star* at col. 15:65-67 through col. 16:1-5 **C. US20040185873** "FIG. 1 diagrammatically illustrates pertinent portions of an exemplary embodiment of a **wireless communication system** which can implement location estimation techniques according to the invention. The embodiment of FIG. 1 includes **a wireless mobile communication device** 5 **whose location is**

(cont.) 1. A **wireless communications system** comprising: **a plurality of wireless communications devices each having a device type associated therewith from among a plurality of different device types, each WLAN device having a unique identifier (UID) associated therewith, and each device type having a known device latency associated therewith**; and	**to be determined** by the system of FIG. 1. In the example of FIG. 1, the **mobile communication device** 5 **is a Bluetooth device, for example a personal digital assistant (PDA), a palmtop computer, an ultralight laptop computer, or a wireless telephone, operating in a Bluetooth system**. The device 5 includes a Bluetooth transceiver for use in a variety of short distance wireless information exchanges." *Gilkes* at par. 0025 "Also as shown in FIG. 1, the "Locate Me" message transmitted by the **mobile device** 5 includes a **unique identifier which is uniquely associated with the mobile device**, designated as "unique_ID" in FIG. 1, and also includes a sequence number that the mobile device 5 assigns to each individual "Locate Me" message, which sequence number is designated in FIG. 1 as "sequence_numberN"." *Gilkes* at par. 0029 "26. The apparatus of claim 25, including a storage section for storing information indicative of **a phase delay associated with providing said reference waveform from the stationary source to said second input**, and including a phase adjuster coupled to said averager and said storage section, said phase adjuster responsive to said phase delay information and said average phase difference for adjusting said average phase difference to produce an adjusted phase difference that accounts for said phase delay." *Gilkes* at Claim 26 "The exemplary location marker of FIG. 2 also includes a 1 MHz phase comparator 23 which can measure the phase difference between the **stable 1 MHz reference signal 11, and the 1 MHz waveform embedded in the "Locate Me" message**. This latter waveform is extracted from the "Locate Me" message by the radio and baseband section 21, and is forwarded to the phase comparator 23. In the example of FIG. 2, the phase comparator 23 has a 0.001 cycle (6.2832 milliradian) phase difference resolution capability, which corresponds to an 11.8 inch resolution in the distance between the location marker and the mobile device 5 of FIG. 1. To compensate for phase jitter in the "Locate Me" message, the phase comparator 23 measures the phase difference 206 for several successive 1 MHz cycles (e.g., 1000 or more cycles of the embedded waveform), and these successive measurements are averaged by a phase difference averager 24 to produce a phase difference average 205 for the entire "Locate Me" message." *Gilkes* at par. 0034

1a. **a wireless device locator** comprising **at least one antenna** and **a transceiver** connected thereto, and	**A. US6026304** "It is an important advantage of the present invention that the **location finding apparatus** can use the **antenna array** of a presently existing base station. As shown in FIG. 10A, the apparatus 126 of the present invention may be a separate device located near a presently existing cellular base station 128, resulting in a composite base station 130." *Hilsenrath* at col. 11:58-63 "23. An **apparatus for locating a mobile transmitter** in a wireless communications system, the apparatus comprising: . . . **a multichannel receiver connected to an antenna array** for receiving signals from the mobile transmitter . . . ." *Hilsenrath* at Claim 23 **B. US8451936** "Therefore, **local device** 405 and each remote device 410 1 through 410 N **also includes a UWB transceiver**, such as the transceiver described in FIGS. 1 and 2, **that transmits and receives a UWB signal** 420 **via a UWB antenna** such as the antennas 105 described in FIGS. 1 and 2." *North Star* at col. 12:39-43 "FIG. 2 is a more detailed block diagram of the UWB transceiver of FIG. 1. As shown in FIG. 2, **the UWB transceiver includes an antenna** 105, **a transmit/receive (T/R) switch** 110, **a receiver front end** 122, **a transmitter front end** 126, a demodulator 124, a modulator 128, and a digital PMD 130. The demodulator 124 includes a splitter 210, a plurality of correlators 220 1-220 N, and a plurality of input timing generators 825 1-825 N." *North Star* at col. 5:37-44 **C. US20040185873** "The exemplary **location marker** of FIG. 2 **includes a Bluetooth wireless transceiver** having a radio and baseband section 21 and a message processing section 22. The Bluetooth wireless transceiver permits the location marker to exchange Bluetooth wireless communications with other Bluetooth transceivers. For example, the **location marker** can receive the "Locate Me" message of FIG. 1 **via the antenna** 29 of the Bluetooth wireless transceiver." *Gilkes* at par. 0033

1b. **a controller for cooperating with said transceiver for transmitting a plurality of location finding signals to a target wireless communications device from among said plurality of wireless communications devices** and **inserting the UID for said target wireless communications device in each of the location finding signals**;	**A. US6026304** "A **signal processor** **at the base station then determines the signal signature** as described in detail above." *Hilsenrath* at col. 9:56-58 "30. The apparatus of claim 23 further comprising a communication link adapted to **transmit the most likely location from the signal processor to a separate base station**." *Hilsenrath* at Claim 30 "By searching such a database, a **location whose calibrated signature best matches the measured signature is selected as the most likely location**. In this manner, the location of the transmitter can be accurately **determined from a signal** received at a single base station, even in a severe multipath environment." *Hilsenrath* at col. 4:62-67 **B. US8451936** "7. The method of claim 1, wherein the operation of determining a distance between the **local device** and the remote device further comprises: **transmitting a distance-determining message to the remote device over the communications link**; . . . ." *North Star* at Claim 7 "In step 1201, the **local device** 1101 **transmits a position-determining message to all linked remote devices X, R, and Y via the unique links established with each device**. The position-determining message may be **a simple UWB signal that indicates that the local device** 1101 **is requesting the data necessary to determine position information from each linked remote device**. Alternatively, as with the distance determining message discussed above, the position determining message may be included in a communication to devices previously enabled by the local device 1101." *North Star* at col 22:1-10 "Once the remote devices 410_1 through 410_N are synchronized with the transmitted signal of the local device 405, each remote device transmits a reply to the join signal as shown in step 605. **Each reply is a UWB signal that includes a unique identifier associated with the remote device from which the reply is transmitted**. The unique identifier may be a device address stored in ROM 309 (see FIG. 3), for example, or a unique delay time for the remote device as will be described below. Thus, in step 605, **each of the remote devices** 410_1 through 410_N **encodes its unique identifier information and**

(cont.) 1b. **a controller for cooperating with said transceiver for transmitting a plurality of location finding signals to a target wireless communications device from among said plurality of wireless communications devices** and **inserting the UID for said target wireless communications device in each of the location finding signals**;	**attaches the information to a reply signal to be transmitted back to the local device** 405. In step 607, the local device 405 receives each reply and synchronizes with each remote device that sent a reply." *North Star* at col. 14:61-67 through col. 15:1-7 **C. US20040185873** "Exemplary FIG. 4 is also generally similar to FIG. 1, except **another wireless mobile communication device** 51 (a Bluetooth device in the example of FIG. 4) **initiates the process of estimating the location of a mobile communication device** 5B. The process is initiated when the **mobile device** 51 **broadcasts** at 52 **a digitally signed "Where Is" message that includes the unique identifier of the mobile device** 5B. The message at 52 can be relayed through the Bluetooth network to device 5B, for example **via the transceivers of one or more of the location markers** 1B-4B, as shown at 42 and 44. This "Where Is" message relaying is also illustrated in FIG. 2, where the "Where Is" message can be recognized by the message processing section 22 and relayed accordingly." *Gilkes* at par. 0039
1c. said **target wireless communications device transmitting a respective reply signal for each of said location finding signals based upon the UID in the location finding signals**;	**A. US6026304** "In a communication system according to a preferred embodiment of the invention, **a cellular telephone** 74 **transmits a signal in the vicinity of a cellular telephone base station** 76, as shown in FIG. 4. Typically, in addition to a direct path signal from phone 74 to base 76, there may be additional multipath signals reflected from various environmental objects, for example, from object 78. Base station 76 is equipped to receive signals with an antenna array, multiple receivers, and signal processors, as described below in relation to FIG. 11A." *Hilsenrath* at col. 6:6-15 **B. US8451936** "In step 705, the linked remote devices 410 1, 410 2, . . . , 410 N receive the distance-determining message via a respective unique link and **transmit a response to the local device** 405 **over the same unique link**. As with the distance-determining message transmitted in step 701, **the response message from the remote devices may include a communication if the link responded on is an enabled link**." *North Star* at col. 15:58-64 "In step 1203, each of the linked remote devices receives the position-determining message and **transmits an answer to the**

(cont.) 1c. said **target wireless communications device transmitting a respective reply signal for each of said location finding signals based upon the UID in the location finding signals**;	**local device** 1101 **via a respective communication link**. In this step, **each of the linked remote devices encodes position information obtained by the remote device and includes the position information in the answer transmitted**." *North Star* at col. 22:11-16 "Once the remote devices 410_1 through 410_N are synchronized with the transmitted signal of the local device 405, each remote device transmits a reply to the join signal as shown in step 605. **Each reply is a UWB signal that includes a unique identifier associated with the remote device from which the reply is transmitted**. The unique identifier may be a device address stored in ROM 309 (see FIG. 3), for example, or a unique delay time for the remote device as will be described below. Thus, in step 605, **each of the remote devices** 410_1 through 410_N **encodes its unique identifier information and attaches the information to a reply signal to be transmitted back to the local device** 405. In step 607, the local device 405 receives each reply and synchronizes with each remote device that sent a reply." *North Star* at col. 14:61-67 through col. 15:1- 7 **C. US20040185873** "When the **mobile device** 5B **receives the relayed message and recognizes that the message includes its unique identifier**, the mobile device 5B first examines the digital signature to determine whether the originator of the "Where Is" message (mobile device 51) is authorized to know the location of mobile device 5B. If the mobile device 51 is authorized to know the location of the mobile device 5B, then the **mobile device** 5B **begins transmitting the aforementioned "Locate Me" messages, and the location estimation can thereafter proceed** generally as described above with respect to FIG. 1." *Gilkes* at par. 0040
1d. said **controller of said wireless device locator also for cooperating with said transceiver for receiving the reply signals,**	**A. US6026304** "37. A method for trouble shooting a wireless communication base station comprising an antenna array, a receiver, a memory storage device, and a signal processor, the method comprising: **receiving signals at the antenna array from a transmitter at a known location**; . . . ." *Hilsenrath* at Claim 37 **B. US8451936** "9. A method for enabling device functions at a local device based on distance information in an ultra wide band (UWB) network, comprising: . . .

(cont.) 1d. said **controller of said wireless device locator also for cooperating with said transceiver for receiving the reply signals,**	controlling a device function for the plurality of remote devices based on a corresponding determined distance, wherein the **operation of controlling the device function for the plurality of remote devices enables the device function for a corresponding one of the plurality of remote devices when the corresponding determined distance is below a set distance threshold**, and . . . ." *North Star* at Claim 9 "Before computing a distance to each linked remote device, the local device 405 first determines a processing delay d for each linked remote device as seen in step 711. The processing delay d is the time delay between the remote device **receiving the distance determining message and transmitting a response and includes at least the amount of time necessary for the remote device to process the distance determining message and form a response**." *North Star* at col. 16:6-13 **C. US20040185873** "For example, the **location marker can receive the "Locate Me" message** of FIG. 1 **via the antenna** 29 **of the Bluetooth wireless transceiver**." *Gilkes* at par. 0033
1e. **determining a propagation delay associated with the transmission of each location finding signal and the respective reply signal therefor based upon the known device latency of said target wireless communications device,** and	**A. US6026304** "In addition to the signal subspace, it may be preferable in some circumstances to **determine also a set of differential time delays for the multipath signals**. For example, **these delays may be used to further enhance the signal signature data in order to provide them with additional dependence upon location**, thereby providing the system with increased accuracy." *Hilsenrath* at col.7:66-67 through col. 8:1-5 **B. US8451936** "Before computing a distance to each linked remote device, the local device 405 first **determines a processing delay** d for each linked remote device as seen in step 711. The **processing delay d is the time delay between the remote device receiving the distance determining message and transmitting a response** and includes at least the amount of time necessary for the remote device to process the distance determining message and form a response." *North Star* at col. 16:6-14 "The **processing delay** d is then stored in main memory 307 **for use in establishing unique communications links** with remote devices and in determining the distance to remote devices." *North Star* at col. 22:11-13

(cont.) 1e. **determining a propagation delay associated with the transmission of each location finding signal and the respective reply signal therefor based upon the known device latency of said target wireless communications device,** and	**C. US20040185873** "The averager 24 **outputs the average phase difference** 205 to a relative arrival time generator 26 which also receives the **location marker's phase delay parameter** ΦK from the storage section 25, and **generates** therefrom **the relative time of arrival, tRA of the "Locate Me" message**. The relative time of arrival generator 26 adds the average phase difference 205 to the phase delay parameter ΦK, thereby adjusting the average phase difference for the relative phase delay associated with distribution of the reference signal 11 from the source 6 of FIG. 1 to the location marker." *Gilkes* at par. 0035
1f. **estimating a range to said target wireless communications device based upon a plurality of determined propagation delays.**	**A. US6026304** "In addition to the signal subspace, it may be preferable in some circumstances to determine also a set of differential time delays for the multipath signals. For example, **these delays may be used to further enhance the signal signature data in order to provide them with additional dependence upon location**, thereby providing the system with increased accuracy." *Hilsenrath* at col. 7:66-67 through col. 8:1-5 "In a preferred embodiment of the invention, **the location of a transmitter is determined through the use of a database containing calibrated signal signatures and associated locations**, as shown in TABLE 1. The locations r1, . . . , rN may be two or three dimensional. The **signal signatures in the database include representations of the signal subspaces** (such as the dominant eigenvectors of the covariance matrices or, alternatively, the matrices A1, . . . , AN) **and may also include sets of differential time delays**, d1, . . . , dN. It should be emphasized that the signal signature is not limited to the specific examples given here, but may include other characterizations as well." *Hilsenrath* at col. 8:41-52 **B. US8451936** "7. The method of claim 1, wherein the operation of **determining a distance between the local device and the remote device** further comprises: . . . **determining a round trip air time for sending the distance-determining message and receiving the reply, the round trip air time representing actual time the distance-determining message and the reply spent in transit**; . . . ." *North Star* at Claim 7

(cont.) 1f. **estimating a range to said target wireless communications device based upon a plurality of determined propagation delays.**	"Before computing a distance to each linked remote device, the local device 405 first determines a processing delay d for each linked remote device as seen in step 711. The **processing delay d is the time delay between the remote device receiving the distance determining message and transmitting a response and includes at least the amount of time necessary for the remote device to process the distance determining message and form a response**." *North Star* at col. 16:6-13 **C. US20040185873** "**The mobile device** 51 **can include the functionality of the location solution processor** 7 of FIG. 1 **in order to calculate the precise location of the mobile device** 5B. The above-described operation of the FIG. 4 embodiment can be useful, for example, when a parent in possession of mobile device 51 wants to determine the location of a lost child who possesses the mobile device 5B." *Gilkes* at par. 0040 "**The relative time of arrival information and Cartesian coordinates** supplied by the different location markers must all have the same "tag" in order to be **used by the location solution processor** 7 **to calculate the location of the mobile device** 5 (or any other mobile device)." *Gilkes* at par. 0030 "The exemplary location marker of FIG. 2 also includes a 1 MHz phase comparator 23 which can measure the phase difference between the stable 1 MHz reference signal 11, and the 1 MHz waveform embedded in the "Locate Me" message. This latter waveform is extracted from the "Locate Me" message by the radio and baseband section 21, and is forwarded to the phase comparator 23. In the example of FIG. 2, **the phase comparator** 23 **has a 0.001 cycle (6.2832 milliradian) phase difference resolution capability, which corresponds to an 11.8 inch resolution in the distance between the location marker and the mobile device** 5 of FIG. 1. **To compensate for phase jitter in the "Locate Me" message, the phase comparator** 23 **measures the phase difference** 206 **for several successive 1 MHz cycles (e.g., 1000 or more cycles of the embedded waveform), and these successive measurements are averaged by a phase difference averager** 24 **to produce a phase difference average** 205 **for the entire "Locate Me" message**." *Gilkes* at par. 0034