



Positioning Methods & Systems for UWB Devices

Reference to Related Applications

Reference is made to our co-pending Singapore patent applications numbers:

- 5 [1] 200303889-0 filed 25 July 2003 entitled "Wireless Positioning System Which Operates Without Using An Explicit Reference",
- [2] 200403021-9 filed 20 May 2004 entitled "A Directional Antenna System and a Method For Producing A Predetermined Beam Pattern For A Directional Antenna",
- 10 [3] 200504866-5 filed 12 July 2005 entitled "Positioning Methods & Systems for UWB Devices",
- [4] 200602425-1 filed 11 April 2006 entitled "A Method for estimating One or More Parameters of an Ultra Wideband Signal and a Receiver System for Receiving Ultra Wideband Signals",
- 15 [5] 200603811-1 filed 6 June 2006 entitled "A Method And Apparatus For Measuring Distance Between A Target And A Receiver In A Ranging System",
- [6] 200603968-9 filed 14 June 2006 entitled "Method, System and Apparatus for Mixed Reality",
- [7] 200604221-2 filed 23 June 2006 entitled "Methods And Apparatus For
- 20 Estimating Time Of Arrival Of A Pulse In A Train Of Pulses In A Ranging System",
- [8] 200604421-8 filed 27 June 2006 entitled "Method, Device and System for Determining Direction of Arrival of Signal"
- [9] 200604613-0 filed 10 July 2006 entitled "Method and Apparatus for
- 25 Pseudo Interaction with a Surface by Interaction with an Interacting Mechanism Using a Wireless Positioning System",
- the contents of which (together with any further references referred to therein) are incorporated herein by reference as if disclosed herein in their entirety.

30 Field of the Invention

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This invention relates to a method and system for positioning and refers more particularly, though not exclusively, to Positioning Methods and Systems for Ultra Wide Band (UWB) Devices.

## 5    **Background to the Invention**

UWB is a type of radio wave transmission which occupies a large bandwidth. For example the FCC and ITU-R define UWB in terms of a transmission from an antenna for which the emitted signal bandwidth exceeds the lesser of 500 MHz or 20% bandwidth.

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UWB can be used for a number of applications. For example the system and method proposed in [3] uses UWB for determining the position of a tag relative to a reader.

15    Figure 1 shows the positioning system 100 in [3], made up of a UWB tag 102 and a UWB reader 104. The UWB tag 102 is equipped with one omnidirectional antenna 106 and the reader 104 is equipped with a directional antenna array 108. The relative position is estimated in polar coordinates ie: range and Direction of Arrival (DOA). The range is measured in absolute terms  
20    using the Time of Flight (TOF) in two-way communication between the tag and the reader. For a single pulse from the tag, each directional antenna outputs a different amplitude signal, because the gain or directivity of a directional antenna depends on the DOA (relative to the boresight of that antenna) and each directional antenna of the array at the reader is pointing in a different  
25    direction. The DOA can therefore be estimated by comparing the amplitude of the signal from each directional antenna.

Therefore the system 100 in [3] only estimates range and DOA of the tag, and does not disclose determining the orientation of the tag.

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Also the system 100 in [3] discloses two-way communication between the tag and the reader. The tag therefore has both a receiver and a transmitter which makes it relatively complex and high in power consumption.

5 Also the range estimated by the system 100 in [3], is dependent on DOA, as shown in Figures 2 and 3. In Figure 2 there is an offset between the phase centre 200 and feeding point 202 on directional antenna(s) 108 used in the UWB reader 104. Since the directional antennas 108 are of relatively large size (about 10cm x 10cm) and are difficult to reduce in size, this offset can  
10 significantly influence the TOF measurement. As a result, the range readings based on a TOF calculation become a function of DOA. Also the phase centre may vary on the antenna with different DOA. Though in theory this could be rectified by making use of DOA estimation result (e.g. using a lookup table for compensation), in practice it causes increase in complexity and possible error  
15 propagation in range estimation depending on the DOA.

From experiments carried out by the inventors, the range readings with 0-360° DOA for the system 100 in [3] are shown in Figure 3. The data was collected by rotating the receiving antenna 108 with an axis through the feeding point. With  
20 DOA of 0°, i.e. direct pointing direction or the boresight direction, the ranging result 300 is a minimum. With DOA of 180°, i.e. back direction, the ranging result 302 is a maximum. The variation in the range result is up to 30cm for the system 100 in [3].

## 25 **Summary of the Invention**

In general terms, in a first aspect the invention proposes that in a positioning system including a first UWB device and a second UWB device, the posture of the first UWB device relative to the second UWB device is determined or vice versa. The relative posture includes relative orientation. This may have the  
30 advantage that relative orientation allow the system to determine the direction a user is facing by locating the first UWB device on the user. Such orientation information may also be used to extrapolate the user's intention.

The first UWB device has two or more omni-directional antennas spaced by a predetermined distance. The second UWB device has one or more directional antennas. The system determines the relative posture based on the pulses sent  
 5 between the antennas, and knowledge of the predetermined distance.

The first UWB device may be transmitting only and the second UWB device receiving only. This may have the advantage that by having the first UWB  
 10 device as transmitting only, the first UWB device may be designed cheaply and with low power consumption. In certain applications low cost and low power consumption are important to commercial success of a product.

The relative posture may include relative angle eg: DOA and relative distance  
 15 eg: ranging and determination of the relative distance may be independent of the relative angle. This may have the advantage that by determining the relative distance independently of the relative angle the extra complexity and / or error propagation associated with compensation can be avoided.

20 The relative posture may be a triplet  $(d, \alpha, \beta)$  where:  
 $d$  is the relative distance, defined as the average range from the omni directional transmitting antennas of the first UWB device to the second UWB device.  
 $\alpha$  is the relative angle, defined as the average DOA of the omni directional  
 25 transmitting antennas of the first UWB device relative to the second UWB device.  
 $\beta$  is the relative orientation, defined as the angle of the axis joining the omni directional transmitting antennas of the first UWB device, relative to the second UWB device.

30 In a first specific expression of the invention there is provided a position determination system comprising

a first UWB device including two or more omni-directional antennas spaced by a predetermined spacing, and

a second UWB device including one or more directional antennas,

wherein the system is arranged to obtain a plurality of parameters for at  
5 least two UWB pulses between the first UWB device and the second UWB device, and determine, based on at least the parameters and the predetermined spacing, the posture of the first UWB device relative to the second UWB device.

In a second specific expression of the invention there is provided a position  
10 determination system comprising

a UWB device including one or more directional antennas adapted to receive at least two UWB pulses from two or more omni-directional antennas spaced by a predetermined spacing,

wherein the system is arranged to obtain a plurality of parameters  
15 representing the pulses, and determine, based on at least the parameters and the predetermined spacing, the relative posture of the UWB device.

In a third specific expression of the invention there is provided a position determination system comprising

20 a UWB device including two or more omni-directional antennas spaced by a predetermined spacing adapted to transmit at least two UWB pulses to one or more directional antennas,

wherein the relative posture of the UWB device may be determined, based on at least a plurality of parameters representing the pulses and the  
25 predetermined spacing.

In a forth specific expression of the invention there is provided a method of determining the posture of a first UWB device relative to a second UWB device  
30 from at least two UWB pulses received at the second UWB device from the first UWB device comprising:

determining a plurality of parameters from the two UWB pulses,

determining the angle, orientation and distance of the first UWB device relative to the second UWB device based on at least the plurality of parameters.

### **Brief Description of the Drawings**

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In order that the present invention may be fully understood and readily put into practical effect there shall now be described by way of non-limitative example only preferred embodiment of the present invention, the description being with reference to the accompanying illustrative drawings.

10 In the drawings:

Figure 1 is a schematic illustration of a prior art system in a basic form;

Figure 2 is a schematic illustration of the prior art system showing the ranging dependence on DOA;

15 DOA;

Figure 4 is schematic illustration of a positioning system according to one embodiment;

Figure 5 is a schematic illustration of the tag from Figure 4;

Figure 6 is a schematic illustration of the reader in Figure 4;

20 Figure 7a is a graph of example waveforms received at the first receiving antenna A in Figure 6;

Figure 7b is a graph of example waveforms received at the second receiving antenna B in Figure 6;

Figure 8 is a schematic illustration of the coordinate system from Figure 4;

25 Figure 9 is a flow diagram of a method of positioning according to one embodiment;

Figure 10 is a schematic illustration of an asymmetric feeding arrangement for the tag of Figure 5, and

30 Figure 11 is an illustration of step 904 in Figure 9, using the mono-pulse method for determining DOA.

### **Detailed Description of the Preferred Embodiments**

Figure 4 illustrates a positioning system 400 including a first UWB device, for example tag 402 and a second UWB device, for example reader 404. The UWB tag 402 includes a UWB transmitter 406 with two or more omni-directional transmitting antenna 1 and 2. The UWB reader 404 includes a UWB receiver 408 with a directional receiving antenna array (made up of one or more directional antennas A and B). When the tag 402 is operational, it transmits UWB pulses through the two transmitting antennas. The UWB pulses are received by the reader 404 and processed to estimate the relative posture of the UWB tag 402.

The tag 402 is shown in Figure 5. The two transmitting antennas 1 and 2 are spaced by a fixed distance D by spacer 500. For example the fixed distance D may be for example 100mm for a working distance of 3m. For longer working distances a larger spacing may be required. The orientation of the "tag axis" 504 (real or virtual) linking the two transmitting antennas is defined as the orientation of the tag. The transmitting antennas may be fed by the same transmitter 404 using a power divider 502 (e.g. T-junction connection). When a UWB pulse is generated by the transmitter, it is transferred omni-directionally into the air. The tag 402 may transmit continuously, periodically or while it is moving.

The reader 404 is shown in Figure 6. The two directional receiving antennas A and B are splayed in a "V" configuration at a relative angle known as the "squint angle" 600. For example the squint angle may be for example  $60^{\circ}$ , or could be based on the beam width of the antenna, for example the 3dB beamwidth. The receiving antennas capture the UWB pulses from the tag. The output from each receiving antenna is fed via an RF cable 602 to the receiver 408. The output for each receiving antenna will include two pulses, with one pulse corresponding to the first transmitting antenna 1 and one pulse corresponding to the second transmitting antenna 2 respectively.

Figure 7a illustrates an example of waveforms output from antenna A and Figure 7b illustrates an example of waveforms output from antenna B. From these waveforms, 6 parameters or features are extracted by signal processing. The extracted features include four amplitudes:

- 5       • A1A (corresponding to the pulse 702 from first transmitting antenna 1 to first receiving antenna A),
- A2A (corresponding to the pulse 704 from second transmitting antenna 2 to first receiving antenna A),
- A1B (corresponding to the pulse 706 from first transmitting antenna 1 to
- 10       second receiving antenna B) and
- A2B (corresponding to the pulse 708 from second transmitting antenna 2 to second receiving antenna B)

and two time differences or delays:

- 15       •  $\Delta A$  718 (the delay between the pulses 702,704 from first transmitting antenna 1 and second transmitting antenna 2 to reach first receiving antenna A) and
- $\Delta B$  720 (the time difference between the pulses 706,708 transmitted by first transmitting antenna 1 and second transmitting antenna 2 to reach second receiving antenna B).

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Figure 8 shows the coordinate system between the transmitting antennas 1 and 2 relative to the receiving antennas A and B which is used to define the relative posture. The relative posture of the tag 402 with regard to the reader 404 is defined as a triplet  $(d, \alpha, \beta)$  where:

25     $d$  is the relative distance, defined as the average range from the tag 402 (measured from the centre 800 of transmitting antennas 1 and 2) to the reader (measured from the centre 802 of receiving antennas A and B).

$\alpha$  is the relative angle, defined as the average DOA of the tag (measured from the centre 800 of transmitting antennas 1 and 2) relative to the reader

30    (measured from the centre 802 of receiving antennas A and B).

$\beta$  is the relative orientation, defined as the angle of the tag axis 504 relative to the reader ( $0^\circ$  is referenced from a datum 804 from the transmitting antenna 1 oriented perpendicular to the DOA axis 806).

- 5 The reader 404 includes a signal processing unit 410, for example a microprocessor with memory, for processing the waveforms to extract the six features A1A, A2A, A1B, A2B,  $\Delta A$  and  $\Delta B$  and to determine the relative posture triplet  $(d, \alpha, \beta)$ .
- 10 An example method for determining the relative posture of the tag (as might be stored in the memory of the reader) is described below.

#### Method of determining the relative posture

- 15 Figure 9 shows a method 900 of estimating the relative posture of the tag 402 from received pulse waveforms. In step 902 six features (amplitudes and time differences) are extracted from the waveforms. In step 904 the DOA is estimated. In step 906 the orientation is estimated. In step 908 the range is estimated.

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#### *Extracting the features from the waveform*

The pulses corresponding to the first transmitting antenna 1 and the second transmitting antenna 2 may get mixed with each other at the receiving antennas.

- 25 Therefore step 902 may include pulse separation prior to extracting the amplitudes (A1A, A1B, A2A, A2B) & time differences ( $\Delta A$  and  $\Delta B$ ).

- 30 The separation can be improved by making the feeding point of the T-junction to transmitting antennas 1 and 2 asymmetric. This then allows the assumption (for a certain working range), one of the signal always comes before the other due to the extra path delay.

An asymmetric feeding arrangement is shown in Figure 10. The difference in the delay caused by the asymmetric feeding position 1000 is  $\frac{(d_2 - d_1)}{c_0/n}$  ( $c_0$  is the speed of light in air and  $n$  is the effective refractive index of the cable normally of the value of about 1.5). At the same time, the maximum value of the difference in the delay caused by different distance of the first transmitting antenna 1 and the second transmitting antenna 2 to the reader is  $\frac{D}{c_0}$  (UWB signal is travelling in air with refractive index 1). Thus it is possible to realise an arrangement such that the pulse of transmitting antenna 1 always reaches the UWB reader earlier than that of transmitting antenna 2, as defined in Equation

10 (1).

$$\frac{d_2 - d_1}{c_0/n} > \frac{D}{c_0} \quad (1)$$

If the value of  $\frac{d_2 - d_1}{c_0/n} - \frac{D}{c_0}$  is greater than the UWB pulse duration  $T$  (normally around 1ns), there will be no overlapping of the pulses from transmitting antennas 1 and 2; as described by Equation (2).

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$$\frac{d_2 - d_1}{c_0/n} - \frac{D}{c_0} > T \quad (2)$$

If the pulses are well separated as illustrated in Figure 7, step 902 includes conventional signal processing method to extract the amplitude and time difference information from the waveforms. For example the waveforms could be correlated with a "template" (pre-stored UWB pulse shape) to increase SNR and then do signal detection on these results. The position of two peaks in the correlation result can be used as the position of the detected pulse. The amplitude may be estimated by using the maximum value, or calculating the RMS (root-mean-square) value of samples within a pre-defined window. The

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time difference may be estimated by directly comparing the two peaks in each correlation result.

In some applications it may be necessary to keep fixed distance  $D$  relatively small. Since 1ns corresponds to about 30cm in free space, equation (2) may be difficult to satisfy in those cases. An additional delay circuit can be used, but this increases the system complexity.

Where there is partial overlapping of the two pulses (with the knowledge that the pulse corresponding to transmitting antenna 1 is surely the first one), step 902 may incorporate the method proposed in [4] to further separate the two signals and obtain the amplitude and delay information simultaneously.

In either case, once the features have been extracted, (if asymmetric feeding was used), the value of parameters  $\Delta A$  and  $\Delta B$  need to be corrected as follows:

$$\Delta A = \tilde{\Delta A} - \frac{d_2 - d_1}{c_0 / n} \quad (3)$$

$$\Delta B = \tilde{\Delta B} - \frac{d_2 - d_1}{c_0 / n} \quad (4)$$

where  $\tilde{\Delta A}$  and  $\tilde{\Delta B}$  are the time difference estimated directly based on the captured waveforms. If electrical delay circuit is used, its value also needs to be subtracted out.

### *Estimation of the DOA*

Step 904 includes using mono-pulse method as proposed in [3], to estimate the DOA (direction of arrival) of each of transmitting antennas 1 and 2 relative to the reader. The DOA in each case is denoted as  $\alpha_1$  and  $\alpha_2$  as seen in Figure 8.

For a single pulse from one transmitting antenna, each directional receiving antenna outputs a different amplitude signal, because the gain or directivity of

each antenna depends on the DOA (relative to the boresight of that antenna) and each antenna is pointing in a different direction. Therefore  $\alpha_1$  can be estimated using the extracted amplitudes  $A1A$  and  $A1B$  and  $\alpha_2$  can be estimated using the extracted amplitudes  $A2A$  and  $A2B$ .

5

The “Monopulse [method], also known as simultaneous lobe comparison, is a technique for measuring the direction of arrival of radiation” [10] (Samuel M. Sherman. *Monopulse Principles and Techniques*. Artech House, Inc. 1984). Figure 11 shows the pulse from transmitting position  $(d, \alpha)$  is received by two identical beam patterns 1100 and 1102 (this can be realized by real simultaneous beams with two receiving antennas, sequential lobing with only one receiving antenna, or moving a single receiving antenna between two locations) with a squint angle  $\theta$  1104 (angle between the boresight of the two receiving antennas). The angle estimation is based on comparison of the amplitudes of these two signals. The common estimator is  $\Delta/\Sigma$ , which denotes the difference of their amplitudes divided by the sum of them. The estimators for transmitting antennas 1 and 2 can be determined using Equations (5) and (6):

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$$\Delta/\Sigma_1 = \frac{A1A - A1B}{A1A + A1B} \quad (5)$$

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$$\Delta/\Sigma_2 = \frac{A2A - A2B}{A2A + A2B} \quad (6)$$

If the receiving antenna beam patterns can be approximated by the Gaussians,  $f_{1,2}(\alpha) = \exp[-(\alpha \mp \frac{1}{2}\theta)^2 / \alpha_0^2]$ , where  $\alpha_0$  is the beamwidth, then angle estimator of Equation (5) gives  $\Delta/\Sigma \approx \theta\alpha / \alpha_0^2$ , for angles near boresight (z-direction). That is, the  $\Delta/\Sigma$  estimator is linearly proportional to the off-boresight angle  $\alpha$  or DOA. (A. I. Leonov and K. I. Fomichev. *Monopulse Radar*. Artech House, Inc. 1986) [11] The contents of [10] and [11] (together with any further references referred to therein) are incorporated herein by reference as if disclosed herein in their entirety.

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However in some applications the estimator may not be perfectly linearly proportional to the DOA. In this case a look up table for  $\alpha_1$  and  $\alpha_2$  can be used based on the determined values of  $\Delta/\Sigma_1$  and  $\Delta/\Sigma_2$ . The look up table can be  
 5 based on previously calculated, simulated or measured data.

The average of  $\alpha_1$  and  $\alpha_2$  can be used as a good estimation of  $\alpha$  using Equation (7).

$$10 \quad \alpha = \frac{\alpha_1 + \alpha_2}{2} \quad (7)$$

#### *Estimation of $\beta$*

As shown in Figure 8,  $\Delta d$  is defined as the difference in range of transmitting antennas 1 and 2 relative to the reader, and can be estimated based on the  
 15 average time difference in the received pulses in Equation (8):

$$\Delta d = \frac{\Delta A + \Delta B}{2} c_0 \quad (8)$$

With the assumption of  $D \ll d$ ,  $\Delta A \approx \Delta B$  and  $\Delta \alpha \rightarrow 0$ , Equation (9) can be  
 20 established from geometry analysis.

$$\Delta d = D \sin \beta \quad (9)$$

Therefore step 906 includes the calculation according to Equation (10):

$$25 \quad \beta = (1 - \text{sgn}(\Delta \alpha)) \times \frac{\pi}{2} + \text{sgn}(\Delta \alpha) \times \arcsin\left(\frac{\Delta d}{D}\right) \quad (10)$$

The sign,  $\text{sgn}(x)$  or signum function is used to overcome an ambiguity depending on which side transmitting antennas 1 and 2 are on. It is defined in  
 30 Equation (11)

$$\text{sgn}(x) = \begin{cases} -1 & : x < 0 \\ 0 & : x = 0 \\ 1 & : x > 0 \end{cases} \quad (11)$$

5

Therefore the estimation of the relative orientation is based on Differential Time of Flight (DTOF) as it is calculated using the average time difference in the received pulses, (as opposed to absolute time taken for the pulses to travel used in TOF estimation). DTOF can be used in this case (instead of TOF) because  $D$  is fixed and known.

10

#### *Estimation of $d$*

The difference between  $\alpha_1$  and  $\alpha_2$  (from step 904) is defined as  $\Delta\alpha$  in Equation (12).

15

$$\Delta\alpha = \alpha_1 - \alpha_2 \quad (12)$$

As shown in Figure 8, with the assumption of  $D \ll d$ ,  $\Delta A \approx \Delta B$  and  $\Delta\alpha \rightarrow 0$ , Equation (13) can be established from geometry analysis.

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$$\Delta\alpha = \frac{D \cos \beta}{d} \quad (13)$$

Therefore step 908 includes the calculation according to Equation (14):

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$$d = \frac{D \cos(\beta)}{\Delta\alpha} \quad (14)$$

Because  $d$  is estimated using  $\beta$ , it is based on DTOF (not TOF), and therefore is not dependant on DOA.

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Combining the results of Equations 7, 10 and 14, the relative posture triplet  $(d, \alpha, \beta)$  can be estimated.

*Performance analysis*

In experiments carried out by the inventors using the system described herein gives the following approximate accuracies:

- 5  $d \pm 3\text{cm}$
- $\alpha \pm 1.5^\circ$
- $\beta \pm \sim 5^\circ$

Moreover, the estimation of the relative distance is based on the relative  
10 orientation which uses DTOF. This differential measurement is more accurate than the TOF distance measurement used in [3] and does not suffer from dependence on DOA.

Whilst there has been described in the foregoing description embodiments of  
15 the present invention, it will be understood by those skilled in the technology concerned that many variations or modifications in details of design, construction or operation may be made without departing from the present invention.

**Claims:**

1. A position determination system comprising  
a first UWB device including two or more omni-directional antennas  
5 spaced by a predetermined spacing, and  
a second UWB device including one or more directional antennas,  
wherein the system is arranged to obtain a plurality of parameters for at  
least two UWB pulses between the first UWB device and the second UWB  
device, and determine, based on at least the parameters and the predetermined  
10 spacing, the posture of the first UWB device relative to the second UWB device.
2. The system as claimed in claim 1 wherein the relative posture includes  
the angle, distance and orientation of the first UWB device relative to the  
second UWB device.  
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3. The system as claimed in claim 2 wherein the second UWB device  
including two or more directional antennas angularly spaced at a predetermined  
squint angle.
- 20 4. The system as claimed in claim 4 wherein the parameters include an  
amplitude A1A (of a first pulse from a first of the omni-directional antennas) and  
an amplitude A2A (of a second pulse from a second of the omni-directional  
antennas) received at a first of the directional antennas, an amplitude A1B (of  
the first pulse from the first of the omni-directional antennas) and an amplitude  
25 A2B (of the second pulse from the second of the omni-directional antennas)  
received at a second of the directional antennas, a time difference  $\Delta A$  between  
the first pulse and the second pulse received at the first of the directional  
antennas and a time difference  $\Delta B$  between the first pulse and the second pulse  
received at the second of the directional antennas.

5. The system as claimed in claim 4 wherein the posture is at least partially determined by determining the angle  $\alpha$  of the first UWB device relative to the second UWB based on at least the amplitudes A1A, A1B, A2A, A2B.
- 5 6. The system as claimed in claim 4 or claim 5 wherein the posture is at least partially determined by determining the orientation  $\beta$  of the first UWB device relative to the second UWB device based on at least the time differences  $\Delta A$ ,  $\Delta B$  and the predetermined spacing D.
- 10 7. The system as claimed in any one of claims 4 to 6 wherein the posture is at least partially determined by determining the distance  $d$  from the first UWB device to the second UWB device based on at least the relative orientation  $\beta$ , the predetermined spacing D, and an angle  $\Delta\alpha$  between the first of the omni-directional antennas to the second of the omni-directional antennas relative to
 

15 the second UWB device.
8. The system as claimed in any of the preceding claims wherein the first UWB device including a spacer fixing two of the omni directional antennas at the predetermined spacing.
 

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9. The system as claimed in any one of claims 3 to 7 wherein the squint angle is  $60^\circ$ .
10. The system as claimed in any one of claims 4 to 7 wherein the relative
 

25 posture is a triplet  $(d, \alpha, \beta)$  where:

$d$  is the relative distance, defined as the average range from the omni directional transmitting antennas of the first UWB device to the second UWB device.

$\alpha$  is the relative angle, defined as the average DOA of the omni directional
 

30 transmitting antennas of the first UWB device relative to the second UWB device.

$\beta$  is the relative orientation, defined as the angle of the axis joining the omni directional transmitting antennas of the first UWB device, relative to the second UWB device.

5 11. The system as claimed in any of the preceding claims wherein the first UWB device includes a transmitter arranged to feed an UWB pulse to each of the omni-directional antennas.

10 12. The system as claimed in claim wherein the first UWB device includes an asymmetric feed between the transmitter and each of the omni-directional antennas.

15 13. The system as claimed in any of the preceding claims wherein the second UWB device includes a receiver arranged to be fed an UWB pulse feed from each of the directional antennas.

14. A position determination system comprising  
a UWB device including one or more directional antennas adapted to receive at least two UWB pulses from two or more omni-directional antennas spaced by a predetermined spacing,

20 wherein the system is arranged to obtain a plurality of parameters representing the pulses, and determine, based on at least the parameters and the predetermined spacing, the relative posture of the UWB device.

25 15. A position determination system comprising  
a UWB device including two or more omni-directional antennas spaced by a predetermined spacing adapted to transmit at least two UWB pulses to one or more directional antennas,

30 wherein the relative posture of the UWB device may be determined, based on at least a plurality of parameters representing the pulses and the predetermined spacing.

16. A method of determining the posture of a first UWB device relative to a second UWB device from at least two UWB pulses received at the second UWB device from the first UWB device comprising:

- 5       determining a plurality of parameters from the two UWB pulses,  
          determining the angle, orientation and distance of the first UWB device  
relative to the second UWB device based on at least the plurality of parameters.

17. The method as claimed in claim 16 wherein the parameters include an  
10   amplitude  $A1A$  (of a first pulse) and an amplitude  $A2A$  (of a second pulse)  
received at a first location, an amplitude  $A1B$  (of the first pulse) and an  
amplitude  $A2B$  (of the second pulse) received at a second location, a time  
difference  $\Delta A$  between the first pulse and the second pulse received at the first  
location and a time difference  $\Delta B$  between the first pulse and the second pulse  
15   received at the second location.

18. The method as claimed in claim 17 wherein the angle  $\alpha$  of the first UWB  
device relative to the second UWB is at least partially determined based on at  
least the amplitudes  $A1A$ ,  $A1B$ ,  $A2A$ ,  $A2B$ .

20   19. The method as claimed in claim 17 or claim 18 wherein the orientation  $\beta$   
of the first UWB device relative to the second UWB device is at least partially  
determined based on at least the time differences  $\Delta A$ ,  $\Delta B$  and the spacing  $D$   
between the two UWB pulses relative to the first UWB device.

25   20. The method as claimed in any one of claims 17 to 19 wherein the  
distance  $d$  from the first UWB device to the second UWB device is at least  
partially determined based on at least the relative orientation  $\beta$ , the spacing  $D$   
between the two UWB pulses relative to the first UWB device, and an angle  $\Delta\alpha$   
30   between the two UWB pulses relative to the second UWB device.