in positioning systems because only a single beam can be directed at a time. As noted above, positioning systems such as GPS require the tracking of at least three signals, and to get the most accurate results these signals should be tracked simultaneously. Sequential beam forming phased arrays are therefore not suitable for use in positioning systems because they cannot track more than one signal simultaneously.

Simultaneous beam forming phased array antennas are also widely in use. Traditional simultaneous beam forming antennas use large arrays of elements with complex circuitry to simultaneously form beams in multiple directions. These arrays require RF front ends and analogue-to-digital converters for each element, and a very complex array of digital logic in the baseband to combine all the element signals together. The size, power consumption, and cost of such arrays limit their use to very large installations typically using hundreds of elements, for example in military applications. Clearly, the size, complexity, power consumption and cost of these systems make them unsuitable for use in positioning systems.

Additionally for positioning systems using interferomic techniques, any line biases or group delays introduced by the large scale parallel processing of traditional simultaneous beam forming antenna arrays cannot be tolerated. All these errors must be estimated and calibrated out of the system for centimetre positioning accuracies to be achieved. This is a non-trivial problem as these biases will change with circuit temperature, voltage, and component tolerances. Again, this makes traditional simultaneous beam forming antenna arrays unsuitable for use in high precision positioning systems.

SUMMARY OF THE INVENTION

~~It is an object~~Embodiments of the present invention ~~to~~ overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

~~It is a further object~~Embodiments of the present invention ~~to~~ create multiple beams simultaneously.

~~It is a further object~~Embodiments of the present invention ~~to~~ use a single RF front end for simultaneously forming the multiple beams.

~~It is a further object~~Embodiments of the present invention ~~to~~ form relatively narrow beams using relatively large numbers of elements (generally more than 32 elements), whilst minimizing electronic complexity.

~~It is a further object~~Embodiments of the present invention ~~to~~ re-use standard positioning receiver components/logic blocks to reduce power consumption, cost and complexity.

~~It is a further object~~Embodiments of the present invention ~~to~~ provide a method of simultaneously forming multiple beams in different directions using relatively large numbers of elements (generally more than 32 elements) for positioning systems, whist obviating the need for complicated circuitry and calibration.

According to a first aspect, there is provided a device for forming a beam of an antenna array, said device including:

an antenna array having a plurality of spatially distributed elements;

a processor for selectively switching said elements between first and second states, wherein said elements are configured to receive an incoming signal in said first state and configured to not receive an incoming signal in said second state; and

a receiver operatively associated with said antenna array and said processor, said receiver configured to: generate a reference signal, modify said reference signal in substantial synchronisation with said elements being switched to said first state; mix said incoming signal with the modified reference signal to generate a mixed signal; and sum said mixed signal over an integration period to generate an accumulated signal, such that said accumulated signal is indicative of the direction and magnitude of said beam of said antenna array.

~~According to an aspect of the invention, there is provided a device for forming a beam of an antenna array, the device including:~~

~~an antenna array having a plurality of spatially distributed elements;~~

~~a processor for selectively switching said elements between first and second states wherein, in said first state, said elements are configured to receive an incoming signal; and~~

~~a receiver operatively associated with said antenna array and said processor for generating a reference signal, mixing said incoming signal with a modified reference signal to generate a mixed signal and summing the mixed signal over a predetermined period to generate an accumulated signal, wherein said reference signal is modified prior to being mixed with said received signal such that said accumulated signal is indicative of the direction and magnitude of the beam of the antenna array.~~

Preferably, the receiver includes at least one receive channel having a correlator, wherein said operative association with the antenna array is provided by the correlator. The operative association between the antenna array and the correlator is preferably provided by selectively manipulating the phase and/or gain of the reference signal in substantial synchronisation with an element being switched to the first state. The manipulation of the phase and/or gain is preferably achieved by respectively applying a phase and/or gain offset to the reference signal, wherein the value of the phase and/or gain offset is determined in dependence upon one of the elements being switched to the first state.

Elements switched to the second state are preferably configured to be non-resonant such that the effects of mutual-coupling are ameliorated.

A propagation delay is incurred between receiving said incoming signal and mixing the incoming signal, the propagation delay preferably being accounted for by delaying the modification of reference signal.

According to a second aspect, there is provided a method for forming a beam of an antenna array, the method including the steps of:

a) selectively switching spatially distributed elements of said antenna array from a second state in which said elements are configured to not receive an incoming signal to a first state in which said elements are configured to receive an incoming signal;

b) receiving said incoming signal through said elements switched to said first state;

c) generating a reference signal;

d) modifying said reference signal in substantial synchronisation with said elements being switched to said first state to create a modified reference signal;

e) mixing said incoming signal with said modified reference signal to create a mixed signal; and

f) accumulating said mixed signal over an integration period to create an accumulated signal, wherein said accumulated signal is indicative of the direction and magnitude of said beam of said antenna array.

~~According to an aspect of the invention, there is provided a method for forming a beam of an antenna array, the method including the steps of:~~

~~a) selectively switching spatially distributed elements of said antenna array from a second state to a first state, wherein, in said first state, said elements are configured to sample an incoming signal;~~

~~b) receiving, at said elements switched to said first state, an incoming signal;~~

~~c) generating, in a correlator, a reference signal for correlation with said incoming signal;~~

~~d) applying, in substantial synchronisation with said elements being switched to said first state, a predetermined offset to said reference signal to create a modified reference signal;~~

~~e) mixing said incoming signal with said modified reference signal to create a mixed signal; and~~

~~f) accumulating said mixed signal over an integration period to create an accumulated signal, wherein said accumulated signal is indicative of the direction and magnitude of said beam of said antenna array~~

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

FIG. 1 is a schematic view of an antenna array coupled with a positioning receiver according to one aspect of the invention;

FIG. 2 is a timing diagram showing the relationship between B-slots and the integration period.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1 A device for forming a beam of an antenna array, the device including:

an antenna array having a plurality of spatially distributed elements;

a processor for selectively switching said elements between first and second states wherein, in said first state, said elements are configured to receive an incoming signal; and

a receiver operatively associated with said antenna array and said processor for generating a reference signal, mixing said incoming signal with a modified reference signal to generate a mixed signal and summing the mixed signal over a predetermined period to generate an accumulated signal, wherein said reference signal is modified prior to being mixed with said received signal such that said accumulated signal is indicative of the direction and magnitude of the beam of the antenna array.

2 A device according to claim 1 wherein said receiver includes at least one receive channel having a correlator, wherein said operative association with said antenna array is provided by said correlator.

3 A device according to claim 2 wherein the operative association between said antenna array and said correlator is provided by selectively manipulating the phase and/or gain of said reference signal in substantial synchronisation with an element being switched to the first state.

4 A device according to claim 3 wherein the manipulation of said phase and/or gain is achieved by respectively applying a phase and/or gain offset to said reference signal, wherein the value of said phase and/or gain offset is determined in dependence upon one of said elements being switched to said first state.

5 A device according to claim 2 wherein said correlator includes a carrier numerical control oscillator (NCO) and said reference signal is synthesised in said carrier NCO.

6 A device according to claim 3 wherein the value of said phase and/or gain offset is determined by said processor in real time.

7 A device according to claim 3 wherein the value of said phase and/or gain offset is determined by retrieving a predetermined value stored in a database that is accessible by said processor.

8 A device according to claim 1 wherein in said first state, said element is active and in said second state, said element is inactive.

9 A device according to claim 1 wherein said elements are switched between said first and second states in a predetermined sequence.

10 A device according to claim 9 wherein said predetermined sequence selectively excludes one or more element from being switched to the first state.

11 A device according to claim 1 wherein the configuration of said antenna array is dynamically adjustable by switching one or more elements to the second state for the entire duration of said integration period.

12 A device according to claim 1 wherein each of said elements are switched to said first state for a sub-integration period, wherein said sub-integration period is less than said predetermined integration period.

13 A device according to claim 12 wherein said predetermined integration period includes a plurality of beam forming slots (B-slots).

14 A device according to claim 13 wherein an element is switched to said first state for the entire duration of said B-slot.

15 A device according to claim 13 wherein each B-slot is configured to access a respective accumulator for storing said incoming signal and wherein each said respective accumulator is mixed with said modified reference signal to generate said mixed signal.

16 A device according to claim 13 wherein the duration of each B-slot within an integration period is dynamically adjustable such that one or more elements are selectively excluded from being switched to the first state.

17 A device according to claim 1 wherein the elements are spatially distributed in a three dimensional configuration such that the device can form beams in one or more dimensions.

18 A device according to claim 1 wherein each receiver includes multiple receive channels and wherein each receive channel is adaptable to form at least one beam.

19 A device according to claim 1 wherein elements switched to the second state are configured to be non-resonant such that the effects of mutual-coupling are ameliorated.

20 A device according to claim 1 wherein a propagation delay is incurred between receiving said incoming signal and mixing said incoming signal, said propagation delay being accounted for by delaying the modification of said reference signal.

21 A method for forming a beam of an antenna array, the method including the steps of:

a) selectively switching spatially distributed elements of said antenna array from a second state to a first state, wherein, in said first state, said elements are configured to sample an incoming signal;

b) receiving, at said elements switched to said first state, an incoming signal;

c) generating, in a correlator, a reference signal for correlation with said incoming signal;

d) applying, in substantial synchronisation with said elements being switched to said first state, a predetermined offset to said reference signal to create a modified reference signal;

e) mixing said incoming signal with said modified reference signal to create a mixed signal; and

f) accumulating said mixed signal over an integration period to create an accumulated signal, wherein said accumulated signal is indicative of the direction and magnitude of said beam of said antenna array.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1 A device for forming a beam of an antenna array, said device including:

an antenna array having a plurality of spatially distributed elements;

a processor for selectively switching said elements between first and second states, wherein said elements are configured to receive an incoming signal in said first state and configured to not receive an incoming signal in said second state; and

a receiver operatively associated with said antenna array and said processor, said receiver configured to: generate a reference signal; modify said reference signal in substantial synchronisation with said elements being switched to said first state; mix said incoming signal with the modified reference signal to generate a mixed signal; and sum said mixed signal over an integration period to generate an accumulated signal, such that said accumulated signal is indicative of the direction and magnitude of said beam of said antenna array.

2 A device according to claim 1, wherein said receiver includes at least one receive channel having a correlator configured to generate said reference signal.

3 A device according to claim 1 or claim 2, wherein the modification of said reference signal comprises selective manipulation of the phase and/or gain of said reference signal.

4 A device according to claim 3, wherein said manipulation of said phase and/or gain comprises application of a phase and/or gain offset to said reference signal, wherein the value of said phase and/or gain offset is determined in dependence upon one of said elements being switched to said first state.

5 A device according to claim 2, wherein said correlator includes a carrier numerically controlled oscillator (NCO) configured to synthesise said reference signal.

6 A device according to claim 4, wherein said processor is configured to determine the value of said phase and/or gain offset in real time or by retrieving a predetermined value stored in a database that is accessible by said processor.

7 A device according to any one of the previous claims, wherein said processor is configured to selectively switch any one or more of said elements between said first and second states in a predetermined sequence.

8 A device according to claim 7, wherein said predetermined sequence selectively excludes one or more of said elements from being switched to said first state.

9 A device according to any one of the previous claims, wherein said receiver includes multiple receive channels, each receive channel being adaptable to form at least one beam.

10 A device according to any one of the previous claims, wherein elements switched to said second state are configured to be non-resonant such that the effects of mutual-coupling are ameliorated.

11 A device according to any one of the previous claims, wherein said processor is configured to delay the modification of said reference signal to account for a propagation delay incurred between receiving said incoming signal and mixing said incoming signal, such that said substantial synchronisation is maintained.

12 A method for forming a beam of an antenna array, said method including the steps of:

a) selectively switching spatially distributed elements of said antenna array from a second state in which said elements are configured to not receive an incoming signal to a first state in which said elements are configured to receive an incoming signal;

b) receiving said incoming signal through said elements switched to said first state;

c) generating a reference signal;

d) modifying said reference signal in substantial synchronisation with said elements being switched to said first state to create a modified reference signal;

e) mixing said incoming signal with said modified reference signal to create a mixed signal; and

f) accumulating said mixed signal over an integration period to create an accumulated signal, wherein said accumulated signal is indicative of the direction and magnitude of said beam of said antenna array.

13 A method according to claim 12, wherein said reference signal is generated in a correlator.

14 A method according to claim 12 or claim 13, wherein modifying said reference signal comprises selectively manipulating the phase and/or gain of said reference signal.

15 A method according to claim 14, wherein selectively manipulating the phase and/or gain of said reference signal comprises applying a phase and/or gain offset to said reference signal, wherein the value of said phase and/or gain offset is determined in dependence upon one of said elements being switched to said first state.

16 A method according to claim 15, wherein the value of said phase and/or gain offset is determined in real time or by retrieving a predetermined value stored in a database.

17 A method according to any one of claims 12 to 16, wherein any one or more of said elements are selectively switched between said first and second states in a predetermined sequence.

18 A method according to claim 17, wherein a subset of said elements remain switched to said second state for the entire duration of said integration period.

19 A method according to claim 13, wherein said correlator generates said reference signal in a carrier numerically controlled oscillator (NCO).

20 A method according to any one of claims 12 to 19, wherein said method is performed by a receiver in operative association with said antenna array, said receiver including multiple receive channels, and wherein said method further comprises the step of adapting each receive channel to form at least one beam.

21 A method according to any one of claims 12 to 20, wherein the modification of said reference signal is delayed to account for a propagation delay incurred between receiving said incoming signal and mixing said incoming signal, such that said substantial synchronisation is maintained.