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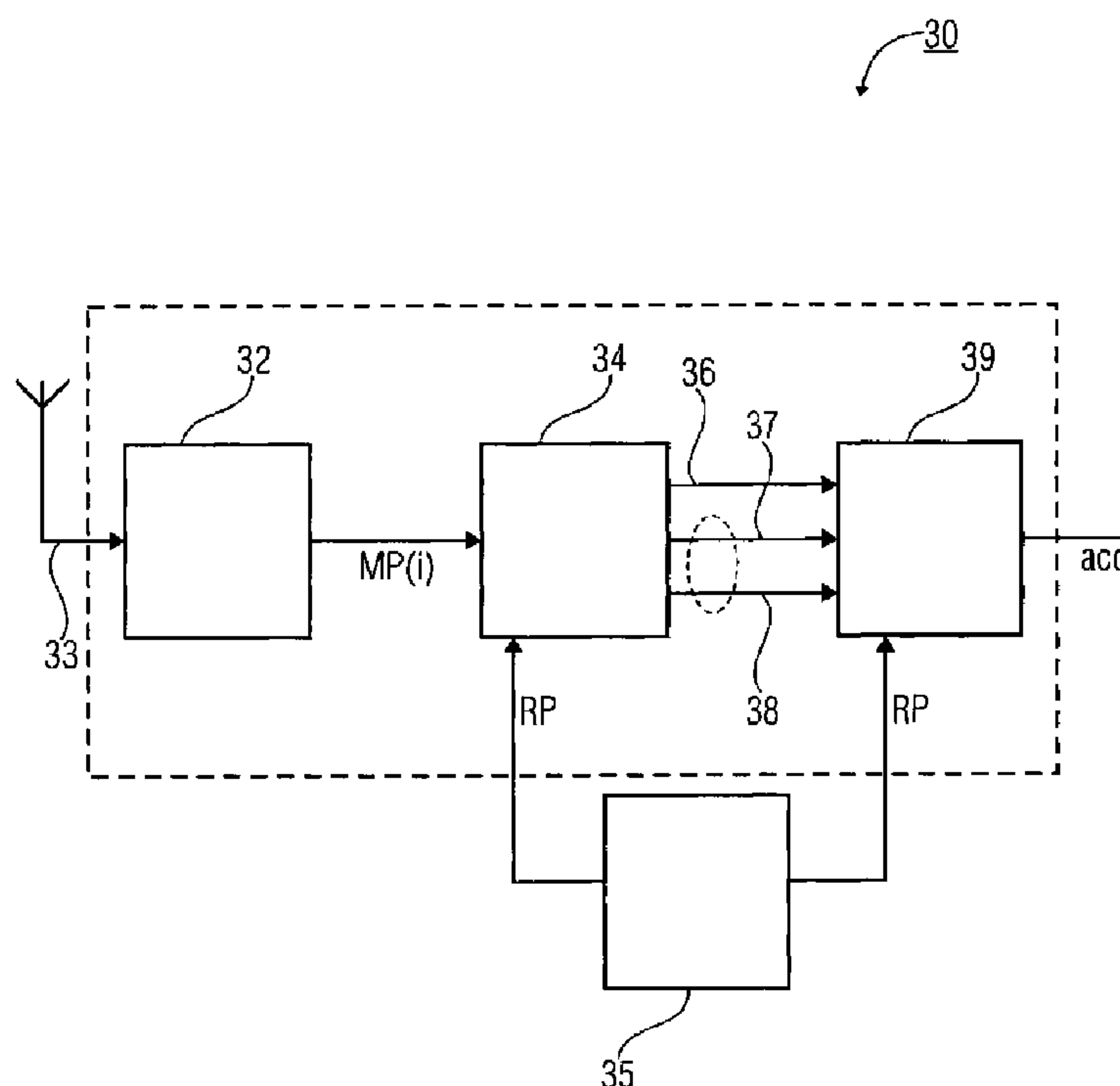
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(54) Titre : APPAREIL ET PROCEDE POUR DETERMINER UNE COINCIDENCE D'UNE POSITION AVEC UNE
POSITION DE REFERENCE

(54) Title: APPARATUS AND METHOD FOR DETERMINING A COINCIDENCE OF A POSITION WITH A REFERENCE
POSITION



(57) Abrégé/Abstract:

An apparatus for determining a coincidence of a position with a reference position, wherein radio signals from fixedly positioned radio transmitters can be received at the position, having means for providing properties of the radio signals of the fixedly positioned radio transmitters at the position. The provided properties of the radio signals include transmitter identifications, means for separating the radio transmitters into first and second numbers of radio transmitters, and means for determining a measure of matching for the position on the basis of the provided properties of the radio signals. Properties of the first and second numbers of radio transmitters are taken into account in the determination of a measure of matching, and enter the measure of matching differently.

ABSTRACT

An apparatus for determining a coincidence of a position with a reference position, wherein radio signals from fixedly positioned radio transmitters can be received at the position, having means for providing properties of the radio signals of the fixedly positioned radio transmitters at the position. The provided properties of the radio signals include transmitter identifications, means for separating the radio transmitters into first and second numbers of radio transmitters, and means for determining a measure of matching for the position on the basis of the provided properties of the radio signals. Properties of the first and second numbers of radio transmitters are taken into account in the determination of a measure of matching, and enter the measure of matching differently.

**Apparatus and method for determining a coincidence of a
position with a reference position**

5 The present invention relates to apparatuses and methods for determining a coincidence or matching of a position with a reference position, as may for example be used for locating or navigating mobile terminals in a wireless communication network, in particular.

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For finding persons with mobile terminals, various localization technologies are available. The probably best-known system for localization and/or navigation in the outdoor area is the satellite-aided global positioning system (GPS). For the localization and/or navigation inside of buildings and/or in an indoor area, various approaches are known, such as infrared systems, RFID (radio frequency identification) systems or also field strength evaluations of IEEE 802.11 WLAN (wireless local area network) networks.

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20 At the moment, the GPS system is available in reliable manner only for the outdoor area. More recent extensions, such as highly sensitive receivers or the so-called A-GPS (assisted GPS) represent attempts of making the technology usable also within buildings. Here, A-GPS combines the use

25 of the satellite-based GPS system with reception of so-called assistance information from cellular mobile radio networks. Presently, however, these technologies do not yet have the desired mean accuracies. Infrared systems and RFID systems generally are not available with complete coverage

30 and are bound to specific prerequisites.

Due to the increasing dissemination of wireless radio networks, for example based on the WLAN standard, these wireless networks lend themselves as a basis for new

35 localization methods.

Common, previously used localization methods are based on triangulation, neighborhood relations, lateration by means

of time measurement of lateration by means of field strength evaluation, for example. These methods are localization methods in which either a position of stationary transmitters and/or base stations has to be known, or in which training has to take place beforehand at typical positions in an environment to be covered by the localization method.

In WLAN-based localization systems, so-called received signal strength (RSS) fingerprinting often is employed as a basic method. This method is based on the assumption that signal strengths of radio signals of several radio stations received and/or receivable at a current location uniquely characterize the location or position. If there exists a database containing, for a number of reference locations or reference positions, identifications of radio stations received and/or receivable there, as well as the field strengths of corresponding radio signals, the current position may be inferred from a set of current measurement values (transmitter identifications and signal strength values) by performing matching between currently measured measurement values and the reference values of the database. For each reference point, this matching assesses how similar its previously recorded measurement values and/or reference values are to the current measurement values of the current position. The most similar reference point(s) then determine an estimate for the current location.

For a reference database, the signal strength is determined experimentally at a sufficient number of points by test measurements. Thereby, a database containing a list of base stations (access points) with the respectively associated reception field strength and quality for each position at which a test measurement was performed is created. In a WLAN implementation, such a reference database may, for example, include the following parameters:

RID	MAC	RSSI	PGS	X	Y	Z	MAPNR	CREATED
1	00.0D.54.9E.17.81	46530	100	5795	15627	150	0	12.03.07 12:42
1	00.0D.54.9E.1A.BA	67260	90	5795	15627	150	0	12.03.07 12:42
1	00.0D.54.9E.1D.64	72002	88	5795	15627	150	0	12.03.07 12:42
1	00.0E.6A.D3.B9.8B	59531	100	5795	15627	150	0	12.03.07 12:42
1	00.0F.A3.10.07.6C	46464	96	5795	15627	150	0	12.03.07 12:42
1	00.0F.A3.10.07.FB	74488	94	5795	15627	150	0	12.03.07 12:42
1	00.0F.A3.10.09.SF	72375	97	5795	15627	150	0	12.03.07 12:42
2	00.0D.54.9E.17.81	54138	100	14399	15451	150	0	12.03.07 12:43
2	00.0D.54.9E.18.1D	76560	11	14399	15451	150	0	12.03.07 12:43
2	00.0D.54.9E.1A.BA	62318	94	14399	15451	150	0	12.03.07 12:43
2	00.0D.54.9E.1D.64	71348	96	14399	15451	150	0	12.03.07 12:43
2	00.0E.6A.D3.B9.8B	45393	100	14399	15451	150	0	12.03.07 12:43
2	00.0F.A3.10.07.6C	66853	96	14399	15451	150	0	12.03.07 12:43
2	00.0F.A3.10.07.FB	72251	100	14399	15451	150	0	12.03.07 12:43
2	00.0F.A3.10.09.5F	70990	90	14399	15451	150	0	12.03.07 12:43
3	00.0D.54.9E.17.81	58291	100	24583	15627	150	0	12.03.07 12:43
3	00.0D.54.9E.18.1D	78610	68	24583	15627	150	0	12.03.07 12:43
3	00.0D.54.9E.1A.BA	62153	98	24583	15627	150	0	12.03.07 12:43
3	00.0D.54.9E.1D.64	64187	90	24583	15627	150	0	12.03.07 12:43
3	00.0E.6A.D3.B9.8B	32851	100	24583	15627	150	0	12.03.07 12:43
3	00.0F.A3.10.07.6C	69006	96	24583	15627	150	0	12.03.07 12:43
3	00.0F.A3.10.07.FB	71749	92	24583	15627	150	0	12.03.07 12:43
3	00.0F.A3.10.09.5F	71482	83	24583	15627	150	0	12.03.07 12:43
3	00.0F.A3.10.09.80	71000	40	24583	15627	150	0	12.03.07 12:43

Thus, the table includes the following information:

- the reference point identification (RID)
- the MAC addresses of the received stations
- the reception field strengths of the access points (RSSI; 46560 means -46.560 dBm)
- the position in Cartesian, metric coordinates (x, y, z; 24583 means 245.83 m), as well as

- the time of measurement value capture.

WLAN signals, which theoretically are to be measured at
5 relatively low field strength only, exhibit a relatively
unreliable behavior with respect to "measurable" or "not
measurable". The column of PGS ("percentage seen")
indicates, in percent, how often this station was seen
during measurement value capture (i.e. PGS = 90 means that
10 the station was measured in 9 out of 10 measurements, on
average). The PGS value is determined when training the
reference positions and/or the reference measurement
packets for each radio transmitter and is to be understood
as a measure for its reliability. Within a certain
15 measurement time window, there is a defined number of
possible measurement values from a radio transmitter by way
of a fixed sampling interval of e.g. 200 ms. The PGS value
is a percentage value of the (RSSI) values of a radio
transmitter really measured within the measurement time
20 window in relation to the potentially possible ones.
Reference points are captured over a longer time window
(e.g. 6 to 10 s) e.g. every 200 ms in the ideal case during
calibration. In this respect, Fig. 5 shows an exemplary
waveform of a reception signal of a certain radio
25 transmitter, which can be received only relatively
unreliably at the measurement position. Over a measurement
time window of 10 s, the certain radio transmitter is
receivable only for about 3 s, which yields a PGS value of
about 30 % for this radio transmitter.

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For the localization, currently captured measurement values
are compared with the database. The most similar one or an
integration of the most similar reference values is
accepted as current position. Several methods are possible
35 for the matching; the most widely used one is least
distance in signal space.

RSS fingerprinting provides good results in the indoor and outdoor areas. Owing to the fact that the setup locations of the stationary radio transmitters do not have to be known, the method also is well-suited for unknown environments with unknown infrastructure. Fingerprinting approaches for the matching assume a fixed, invariable infrastructure. Many known solutions further assume a limited area in which signals of each radio transmitter can be received everywhere.

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So as to determine a coincidence or matching of a current position with a reference position, RSSI values of a number of radio transmitters, previously recorded transmitter identifications of which at the reference position are identical with transmitter identifications provided at the position, often are compared with each other in conventional methods. The smaller the deviation of the RSSI values between the radio transmitters with identical transmitter identification, the higher the coincidence of the current position with the reference position. However, this procedure also poses the risk of faulty position estimation - for example when the number of the radio transmitters, previously recorded transmitter identifications of which at the reference position are identical with transmitter identifications provided at the position, is small, and thereby also a small RSSI value deviation is determined, which may lead to a coincidence falsely estimated to be good.

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Starting from this background, it is the object of the present invention to provide a concept, which is improved with respect to the prior art, for the matching of currently measured values and previously recorded reference values.

This object is achieved by an apparatus having the features of claim 1, a navigation device according to claim 19, and a method according to claim 22.

A further embodiment of the present invention consists in a computer program for performing the method according to the invention.

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It is the finding of the present invention that the matching between values and/or properties (e.g. transmitter identifications and signal strength values) of fixedly positioned radio transmitters currently provided and/or
10 measured at a current (geographical) position and previously recorded reference values and/or properties at a (geographical) reference position considered can be achieved by a type of filtering of the currently measured properties of the radio signals at the position and the
15 reference values of the previously recorded radio signals at the reference position. Here, the radio signals are subdivided into a first number of radio transmitters previously recorded transmitter identifications of which at the reference position are identical with transmitter
20 identifications provided at the current position, and into a second number of radio transmitters previously recorded transmitter identifications of which at the reference position and transmitter identifications provided at the position are different, i.e. the transmitter
25 identifications of which either are provided only at the current position and have not been recorded previously at the reference position, or the transmitter identifications of which have been recorded previously only at the reference position and are not provided at the current
30 position.

A set of measurement values measured at the current position, including radio-transmitter-identifying transmitter identifications (e.g. MAC addresses) and
35 accompanying signal strength values (RSSI = received signal strength indicator), shall be referred to as measurement packet (MP) in the following. According to preferred embodiments of the present invention, supplied measurement

values at the current position and previously recorded measurement values at the reference position are pre-filtered in three groups. On the one hand, all radio transmitters from a measurement packet also included in the reference measurement packet underlying the matching are separated. Radio transmitters received at the current position and deviating from the reference measurement packet (heard too much) imply that one cannot be at the reference position. These radio transmitters received in addition at the current position cannot be used in a direct matching, i.e. in a matching between radio transmitters with the same transmitter identifications in the current measurement packet and in the reference measurement packet. Moreover, radio transmitters not having been received (not heard) at the current position may be listed in the reference data of the reference position or the reference measurement packet. These radio transmitters and/or their measurement values not received at the current position also need special treatment and therefore are not supplied to the direct matching, i.e. the matching between radio transmitters with the same transmitter identifications in the current measurement packet and in the reference measurement packet.

A matching unit matches the current measurement values at the current position with every reference point of the reference data in question, i.e. a measure of matching between the current position and every reference point in question is determined. An amount of the reference points and/or positions that are matched may optionally also be restricted, for example by taking a last position of the mobile terminal as starting point, assuming that the user has not moved from the last position more than a fixed maximum distance since then. Restriction of the reference points to be compared may take place dynamically due to a movement model, quality of the current position determination, limited computation power or limited storage, etc.

In each comparison of a current measurement packet with a reference measurement packet, one determines a measure of matching, which defines how well the received measurement values at the current position and the previously recorded measurement values of the reference position match. The determination of the measure of matching for the position takes place on the basis of the supplied properties of the radio signals, wherein both properties of the first number of radio transmitters and properties of the second number of radio transmitters are taken into account in the determination of the measure of matching, and wherein the properties of the first number of radio transmitters and the properties of the second number of radio transmitters enter the measure of matching differently. In the first number of radio transmitters, previously recorded transmitter identifications at the reference position are identical with transmitter identifications provided at the current position. In the second number of radio transmitters, transmitter identifications are provided either only at the current position and have not been recorded previously at the reference position, or transmitter identifications have been recorded previously only at the reference position and are not provided at the current position.

According to a preferred embodiment, the properties of the first number of radio transmitters are weighted more strongly than the properties of the radio signals of the second number of radio transmitters. This means that the number of radio transmitters previously recorded transmitter identifications of which at the reference position are identical with the transmitter identifications provided at the position is considered more strongly in the calculation of the measure of matching than the second number of radio transmitters previously recorded transmitter identifications of which at the reference position and transmitter identifications provided at the

position are different, i.e. of radio transmitters the transmitter identifications of which either are provided only at the position and have not been recorded previously at the reference position, or the transmitter
5 identifications of which have been recorded previously only at the reference position and are not provided at the position. The weights of the properties of the first and second numbers, for example, complement one other complementarily to one.

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Further preferred embodiments and further implementations are the subject matters of the dependent claims.

By including the measurement values of the radio
15 transmitters the transmitter identifications of which are received only at the current position and have not been recorded previously at the reference position, and including the radio transmitters the transmitter identifications of which have been recorded previously only
20 at the reference position and are not received at the current position, accuracy in the determination of the measure of matching between the current position and the reference position can be increased significantly. This may lead to noticeable improvements of the localization and/or
25 navigation results.

Preferred embodiments of the present invention will be explained in greater detail in the following with reference to the accompanying drawings, in which:

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Fig. 1 is a flowchart for illustrating a method of determining a coincidence between a current position and a reference position, according to an embodiment of the present invention;

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Fig. 2 shows an exemplary series of measurement packets;

Fig. 3 is a schematic illustration of an apparatus for determining a coincidence of a current position with a reference position, according to an embodiment of the present invention;

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Fig. 4 is a block diagram of a means for determining a measure of matching for the position, according to an embodiment of the present invention; and

10 Fig. 5 shows a typical waveform of a radio transmitter that can be received unreliably.

Regarding the subsequent description, it is to be noted that the same or like functional elements comprise the same
15 reference numerals in the different embodiments, and hence the descriptions of these functional elements are mutually interchangeable in the various embodiments illustrated in the following.

20 Subsequently, on the basis of Figs. 1 to 4, the inventive concept for determining a coincidence or matching of a current geographical position with a geographical reference position will be described.

25 So as to obtain reference positions, a user for example records radio fingerprints in a training phase, in order to use these in a later localization phase as part of a database. In practice, the training may for example take place with a PDA or smart-phone. A geographical map of the
30 target surroundings may for example be filed as a bitmap. When training, the user marks the current position thereof on the map and then triggers the measurement value capture. In practice, it has turned out that denser training points hardly improve the result significantly, but clearly
35 increase the computational effort when localizing.

Manually collecting fingerprints, however, is only feasible in limited areas. In city or town centers, so-called

calibration boxes may be employed for this purpose. These have a highly precise GPS unit (so-called differential GPS) in combination with highly accurate inertial sensors (for example acceleration sensors and electronic compasses) each. These calibration boxes may collect fingerprints without manual intervention, when moving same through the city or town. The localization via differential GPS allows for position determination with a mean accuracy of few decimeters also in the urban environment, which continues for up to 20 minutes even upon failure of the GPS system, due to the highly precise inertial sensor technology. Roofed-over passages thus do not present any problems for the calibration box, for example.

Fig. 1 first shows a flowchart for illustrating a method of determining the coincidence of the current position, at which a mobile terminal is, with the reference position.

The method of determining the coincidence schematically illustrated in Fig. 1 comprises a first step S1 of determining and/or providing properties of radio signals of fixedly positioned radio transmitters at the current position, wherein the determined and/or provided properties of the radio signal include transmitter identifications identifying the radio transmitters. This means that, among other things, transmitter identifications of the radio transmitters are determined in the step S1. In addition, in preferred embodiments of the present invention, electromagnetic properties of the radio signals, such as reception field strength, reception power spectrum, signal-to-noise power ratio (SNR = signal-to-noise ratio), angle of incidence, propagation time, polarization or phase location of the radio signals, are determined.

In a second step S2, the radio signal and/or the radio transmitters associated with the radio signals are separated and/or filtered into a first number N_{eq} of radio transmitters previously recorded transmitter

identifications of which at the reference position are identical with transmitter identifications provided at the current position, and into a second number N_{neq} of radio transmitters previously recorded transmitter

5 identifications of which at the reference position and transmitter identifications provided at the position are different, i.e. of radio transmitters the transmitter identifications of which either are provided only at the current position and have not been recorded previously at

10 the reference position, or the transmitter identifications of which have been recorded previously only at the reference position and are not provided at the current position. According to embodiments, the second step S2 additionally includes a sub-step to select, from the second

15 number N_{neq} of radio transmitters, a number N_{nh} of radio transmitters not received at the current position, i.e. radio transmitters of which there exist previously recorded properties at the reference position, but of which there do not exist properties provided at the current position. The

20 greater the number N_{nh} of the radio transmitters not received at the current position, the more likely it is that the current position does not correspond to the reference position. Furthermore, step S2 includes a further sub-step, in which a number N_{htm} of radio transmitters

25 received in addition at the current position, and of which there are no previously determined electromagnetic properties at the reference position, but of which there are electromagnetic properties provided at the current position is selected from the second number N_{neq} . The

30 greater the number N_{htm} of the radio transmitters received in addition at the current position, the more likely it is that the current position does not correspond to the reference position. The second number N_{neq} of radio transmitters thus results from the number N_{nh} of radio

35 transmitters not received at the current position and the number N_{htm} of radio transmitters received in addition at the current position, according to $N_{\text{neq}} = (N_{\text{nh}} + N_{\text{htm}})$.

Based on the properties of the radio signals provided from step S1, a measure of matching and/or a distance value acc for the current position is determined in a third step S3, wherein both properties of the first number N_{eq} of radio transmitters and properties of the second number N_{neq} of radio transmitters are taken into account in the determination in the measure of matching, and wherein the properties of the first number N_{eq} of radio transmitters and the properties of the second number N_{neq} of radio transmitters enter the measure of matching differently. According to embodiments, the properties of the first number N_{eq} of radio transmitters are weighted more strongly than the properties of the second number N_{neq} of radio transmitters, which will be dealt with in detail in the following.

Step S1 of determining and/or providing the properties of radio signal is performed by a mobile terminal and/or a client, such as a WLAN-enabled PDA, a Bluetooth-enabled PDA or also a mobile telephone, for example, according to embodiments of the present invention. To this end, the client comprises means for determining and/or providing the properties of the radio signals of the fixedly positioned radio transmitters, wherein the properties generally are characterized by an identification of a fixedly positioned radio transmitter and its electromagnetic signal characteristic, such as reception field strength, reception spectrum or received signal-noise ratio. The identification and/or an identifying feature of a fixedly positioned radio transmitter may for example be its MAC (media access control) address, base station identification, or a cell identification.

The properties of the radio signals of the fixedly positioned radio transmitters are combined to so-called measurement packets $MP(i)$. This fact is shown exemplarily in Fig. 2.

Fig. 2 exemplarily shows three temporally successive measurement packets from a WLAN network MP(1), MP(2), MP(3), i.e. $i = 1, 2, 3$, wherein a measurement packet MP(i) comprises a plurality of MAC addresses 22 and associated
5 RSSI values $RSSI_k(i)$ each, wherein the index k indicates a k -th radio transmitter. This means that the MAC addresses of the fixedly positioned radio transmitters as well as their RSSI values received by the client are combined in a measurement packet MP(i) per time interval.

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Fig. 3 shows an apparatus 30 for determining a coincidence of a current position with a reference position, according to an embodiment of the present invention. Here, radio signals of fixedly positioned radio transmitters and/or
15 base stations can be received at the current position.

To this end, the apparatus 30 comprises means 32 for providing properties of the radio signals of the fixedly positioned radio transmitters at the current position, wherein the provided properties of the radio signals include transmitter identifications, such as MAC addresses, identifying the radio transmitters. To this end, the means 32 may be coupled to a reception antenna 33 to receive the properties of the radio signals, such as also
20 electromagnetic properties. In particular, the previously described measurement packet MP(i) may be meant by the properties of the radio signals. The determined and/or provided properties MP(i) are provided to means 34 for separating the radio signals and/or their associated radio transmitters into a first number N_{eq} of radio transmitters and a second number N_{neq} of radio transmitters. Here, the first number N_{eq} of radio transmitters includes those radio transmitters previously recorded transmitter identifications of which at the considered reference
30 position are identical with transmitter identifications determined at the present position. The second number $N_{neq} = (N_{nh} + N_{htm})$ of radio transmitters includes those radio transmitters the transmitter identifications of which

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either are provided only at the position and have not been recorded previously at the reference position, or the transmitter identifications of which have been recorded previously only at the reference position and are not provided at the position. So as to determine the first number N_{eq} and the second number N_{neq} of radio transmitters, the means 34 for separating may be coupled to a database 35, in which previously recorded properties of radio signals from a plurality of reference positions, i.e. reference measurement packets, are stored. This means that the database 35 includes, for example, a multiplicity of previously recorded measurement packets, each associated with a reference position. These previously recorded measurement packets subsequently are to be referred as reference measurement packets RP. The means 34 thus separates the radio signals into at least two groups. A first group 36 includes properties of radio signals of the first number N_{eq} of radio transmitters, whereas a second group 37, 38 includes properties of radio signals of the second number N_{neq} of radio transmitters. As already described before, the second group 37, 38 may be subdivided further into a group of properties of radio signals of radio transmitters not received at the current position and into a group of properties 38 of radio signals from radio transmitters received in addition at the position.

The apparatus 30 further includes means 39 for determining a measure of matching for the current position, which may be coupled both to the means 34 for separating and to the database 35. The means 39 is formed to determine the measure of matching on the basis of the supplied properties 36, 37, 38 of the radio signals, wherein both properties 36 of the first number N_{eq} of radio transmitters and properties 37, 38 of the second number N_{neq} of radio transmitters are taken into account in the determination of the measure of matching and/or the distance value acc , and wherein the properties 36 of the first number N_{eq} of radio transmitters and the properties 37, 38 of the second number

N_{req} of radio transmitters enter the measure of matching differently, i.e. are weighted differently.

The means 32 provides, at every location and/or every position, signals of several base stations and/or radio transmitters at different signal strengths, together with the accompanying transmitter identifications. In the case of WLAN networks, such an electronic fingerprint includes a list of MAC addresses unique for each WLAN device and/or WLAN radio transmitter and the reception signal strengths accompanying the same, and hence characterizes the current position. It is irrelevant where the WLAN radio transmitters are.

Localization substantially consists of two steps: Firstly, a matching of the currently measured measurement packets with the fingerprints and/or the reference measurement packets in the database 35, and secondly, selection of appropriate position candidates on the one hand, as well as the weighting and combination of the candidate positions to a position estimation on the other hand.

In a matching phase, deviations of a currently measured measurement packet $MP(i)$ from reference measurement packets RP in the database 35 are determined. In particular, means 34 and 39 of the apparatus 30 according to the invention serve this purpose.

So as to find possible candidate positions for the current position from the multiplicity of stored reference positions in the matching phase, the means 39 determines the measure of matching between currently measured measurement packets and reference measurement packets previously recorded at reference positions. A schematic block circuit diagram of means 39 for determining the measure of matching and/or the distance value acc is shown in Fig. 4.

As already described before, means 39 is supplied with electromagnetic properties 36, e.g. RSSI values, of the first number N_{eq} of radio transmitters on the input side. Furthermore, electromagnetic properties 37, 38, such as
5 RSSI values, of the second number N_{neq} of radio transmitters are present at the input of means 39. Here, the properties 36 of the first number N_{eq} of radio transmitters include both the signal properties measured at the current position and the signal properties previously recorded at the
10 reference position.

According to embodiments, in a block 41, differences between the previously recorded electromagnetic properties at the reference position and the electromagnetic
15 properties provided at the current position of the first number N_{eq} of radio transmitters are formed. For example, differences are formed of RSSI values of radio transmitters previously recorded transmitter identifications of which at the reference position are identical with transmitter
20 identifications supplied at the current position. These difference RSSI values $\Delta RSSI_1$ to $\Delta RSSI_{N_{eq}}$ are provided to a summing block 42, which sums up the N_{eq} difference RSSI values $\Delta RSSI_n$ ($n=1, \dots, N_{eq}$) to a sum $\Sigma \Delta RSSI_n$. N_{eq} is the first number of radio transmitters present both in the
25 measurement packet and the reference packet. The function $\Delta RSSI$ calculates a distance between two signal strength values. The Euclidean distance of the measurement values in dB may for example be chosen as distance function. In this connection, distance thus does not mean spatial distance,
30 but mathematical deviation. Following the summing by the block 42, the sum $\Sigma \Delta RSSI_n$ is weighted with a weighting factor EQW , i.e. $EQW \cdot \Sigma \Delta RSSI_n$. Here, EQW defines a weight between 0 and 1, which indicates how strongly the distance of the measurement values and/or the distance of the signal
35 strength values $\Sigma \Delta RSSI_n$ is to be valued in comparison with the radio transmitters at the current position with respect to the ones heard too much or too little.

If the calculation of the measure of matching was stopped at this point, it would be possible that reference positions actually being a worse match with respect to the current position are selected as candidates than better fitting ones. One example of this: Let us assume that $N_{eq} = 1$ is obtained for a first reference point as compared with the current position, i.e. only one radio transmitter identification matches between reference measurement packet and current measurement packet. If the corresponding RSSI values of the matching measurement packets by chance are 2.5 dB apart, for example, one obtains $\Sigma \Delta RSSI_1 / N_{eq} = 2.5$ dB. Let us further assume that $N_{eq} = 3$ results for a second reference point in comparison with the current position, i.e. three radio transmitter identifications match between the reference measurement packet and the current measurement packet. If the corresponding RSSI values are 2 dB, 3 dB and 4 dB apart, for example, one obtains $\Sigma \Delta RSSI_n / N_{eq} = 3$ dB altogether. As a result, the second reference point would be assessed to be worse than the first one, which would lead to an estimation error. Embodiments of the present invention may avoid and/or at least reduce such estimation errors.

Reference numeral 37 characterizes properties of radio signals from a number N_{nh} of radio transmitters not received at the current position, i.e. of radio transmitters of which there are previously recorded properties at the reference position, but of which there is no property provided at the position, i.e. from radio transmitters which cannot be received at the current position. In a block 43, a malus function and/or a malus value $M_{nh,m}()$ ($m=1, \dots, N_{nh}$) can be defined for each of the radio transmitters not received. This means that a malus value $M_{nh,m}()$ ($m=1, \dots, N_{nh}$) can be defined for each station present in the reference values, but not in the current measurement values. This may for example depend on how reliably the corresponding station not received could be received at the reference position in the past. In case of

previously good reception capability of the station not received, i.e. high RSSI value, a high malus value results, for example. The malus value $M_{nh,m}()$ ($m=1,\dots,N_{nh}$) may thus be directly proportional to the reference RSSI value of the station not received at the current position, according to
5 embodiments. Moreover, the malus function $M_{nh,m}()$ ($m=1,\dots,N_{nh}$) may be linked to a PGS value of the corresponding radio transmitter not received. A small PGS value in the reference database may for example also lead
10 to only a small value of the corresponding malus $M_{nh,m}()$. This may for example be calculated by way of the following formula: $M_{nh,m}(PGS) = \text{FixMalus} + \text{DynamicMalus}$, wherein $\text{DynamicMalus} = \text{FixMalus} * PGS/100$. The function $M_{nh,m}()$ ($m=1,\dots,N_{nh}$) for a malus value for a radio transmitter not
15 received thus is dependent on a property related to a reception field strength and recorded previously at the reference point, as well as on models, for example for the environment, the quality of the measurement values, etc., according to embodiments. The N_{nh} malus values $M_{nh,m}()$
20 ($m=1,\dots,N_{nh}$) for the radio transmitters not received at the current position are handed over to a summing block 44 to determine a first sum $\Sigma M_{nh,m}()$ of the N_{nh} malus values of the radio transmitters not received.

25 Properties of radio signals from a number N_{htm} of radio transmitters received in addition at the current position are provided with the reference numeral 38. What is meant thereby is radio transmitters of which there are no previously recorded electromagnetic properties at the
30 reference position, but of which there are electromagnetic properties provided at the current position. In a block 45, a malus function $M_{htm,r}()$ ($r=1,\dots,N_{htm}$) and/or a malus value may be associated with each radio transmitter received in addition at the current position. This means
35 that, for each radio transmitter missing in the reference values but included in the currently measured measurement values, there may be defined a malus value $M_{htm,r}()$ ($r=1,\dots,N_{htm}$). Here, the function for the malus value

$M_{\text{htm},r}()$ ($r=1, \dots, N_{\text{htm}}$) may also be dependent on the current RSSI measurement value of the radio transmitter, as well as on models, for example for the environment, the quality of the measurement values, the age of the reference data, etc.

5 According to an embodiment of the present invention, this means that the means 39 for determining is formed to associate a malus value $M_{\text{htm},r}()$ ($r=1, \dots, N_{\text{htm}}$) with a radio transmitter received in addition at the current position, depending on a property related to the reception field
10 strength of its radio signal, for example the RSSI value. The malus value $M_{\text{htm},r}()$ ($r=1, \dots, N_{\text{htm}}$) thus is directly proportional to the reference RSSI value of the station received in addition at the current position, according to embodiments. Moreover, the malus function $M_{\text{htm},r}()$ ($r=1, \dots,$
15 N_{htm}) may be linked to a PGS value of the corresponding radio transmitter received in addition. A smaller PGS value in the reference database may, for example, also lead only to a smaller value of the corresponding malus function $M_{\text{htm},r}()$ ($r=1, \dots, N_{\text{htm}}$).

20

The N_{htm} malus values of the radio transmitters received in addition are handed over to a summing block 46 to sum up the N_{htm} malus values to a second sum $\Sigma M_{\text{htm},r}()$.

25 The first sum $\Sigma M_{\text{nh},m}()$ of the malus values of the radio transmitters not received and the second sum $\Sigma M_{\text{htm},r}()$ of the radio transmitters received in addition are summed up and weighted with a weighting factor $(1 - \text{EQW})$, i.e. $(1 - \text{EQW}) \cdot (\Sigma M_{\text{nh},m}() + \Sigma M_{\text{htm},r}())$, according to embodiments.

30

Finally, according to an embodiment, the weighted sum $\text{EQW} \cdot \Sigma \Delta \text{RSSI}_n$ of the differences between the previously recorded electromagnetic properties at the reference position and the electromagnetic properties provided at the
35 position of the first number N_{eq} of radio transmitters and the weighted sum $(1 - \text{EQW}) \cdot (\Sigma M_{\text{nh},m}() + \Sigma M_{\text{htm},r}())$ of the malus values and normalized with $(N_{\text{eq}} + N_{\text{nh}} + N_{\text{htm}})$ to obtain the distance value acc between the current position and the

reference position considered. The distance value acc thus may for example be calculated according to

$$acc = \frac{EQW \cdot \sum_{n=1}^{N_{eq}} \Delta RSSI_n () + (1 - EQW) \cdot \left(\sum_{m=1}^{N_{nh}} M_{nh,m} () + \sum_{r=1}^{N_{htm}} M_{htm,r} () \right)}{N_{eq} + N_{nh} + N_{htm}}. \quad (1)$$

5

If the distance value acc is determined according to eq. (1), a coincidence between the current position and the reference position considered is the greater, the smaller the distance value acc is. This means that the coincidence
10 is the greater, the smaller the sum $\sum \Delta RSSI_n$ of the differences is and the smaller the sums $\sum M_{nh,m}()$, $\sum M_{htm,r}()$ of the malus values are. According to an embodiment, the distance value acc corresponds to the measure of matching.

15 According to other embodiments, the measure of matching could also be inverse to the distance value acc, or it could be calculated according to (1-acc) if acc cannot become greater than 1. That means the smaller the distance acc, the greater the measure of matching. Of course, other
20 calculation rules are possible as well, wherein the properties of the first number N_{eq} of radio transmitters and the properties of the second number $N_{neq} = (N_{nh} + N_{htm})$ of radio transmitters enter the measure of matching differently.

25

In embodiments of the present invention, each station received in addition or not received thus increases the distance acc. The treatment of different stations in the fingerprint and in current measurement values strongly
30 influences the accuracy: a station missing in the stored reference fingerprint but showing up in the current measurement provides strong indication for the fact that this fingerprint does not fit.

In large areas, the distance calculation to all stored reference fingerprints according to equation (1) may take a lot of time. Preselection of reference fingerprints therefore is advantageous. The last calculated position of the terminal may already provide an indication of the current position. Digital maps of surroundings may further limit the number of candidates. Such an area limitation also poses risks, however. If the estimated position is far off the mark, the positioning cannot recover anymore and remains stuck at the "best wrong" position. Hence, it is always a matter of checking the absolute quality of the candidate positions as well. If the absolute quality of the best candidate is too bad, e.g. due to very weak RSSI values, the matching should be restarted without area limitation. At the end of the matching phase, one obtains a number of probable locations and/or candidate positions from which an estimate for the current position may then be determined.

The best position candidate(s) determined in the matching phase are employed for a so-called position calculation phase in a navigation device including an apparatus 30 according to the invention. To this end, a navigation device according to the invention additionally includes means for outputting an estimate for the current position on the basis of the measure of matching and/or the distance acc communicated by the apparatus 30.

The means for outputting the estimate for the position calculates the position and/or the estimate for the position of the mobile terminal from candidate positions not above or below a default limit for the measure of matching and/or the distance acc. Here, individual positions are considered less, but rather placed in a context of an overall motion. The result represents the estimate for the current position of the terminal.

A simple realization consists in a computation of a weighted mean value of the candidate positions, for example. Values dependent on the measures of matching of the candidate positions, e.g. inverse measures of matching, here form the weights of the candidate position in the averaging. This so-called k-weighted nearest neighbor method indeed provides reasonable results. The mean positioning errors are at a few meters.

10 However, the estimate for the current position may also be determined by means of more complex methods, for example by means of methods from the probability calculus, such as by means of the Bayesian method or Markov chains. Here, it is a basic idea to compensate for errors in individual position estimations by afterwards considering and optimizing an entire path. The calculation of the most probable path may further include additional data, such as maps of surroundings. Motion estimation filters, such as a Kalman filter, may also be employed. Such a filter
20 estimates the direction of movement, speed and acceleration on the basis of the last positions and establishes a prognosis for the future. Matching between prognosis and calculated position may recognize and correct implausible movements and jumps.

25 In the matching and position calculation phases, digital maps of surroundings may provide important additional information. A digital map of the surroundings from which possible paths can be seen may help recognizing impossible movements and correcting same to allowable paths. The accuracy of the localization may increase significantly thereby. Digital maps may either consist of possible paths (positive map), include only inaccessible areas (negative maps), or represent the constructive conditions, such as
30 floors, walls or doors (real maps). In the field of vehicle navigation, it is customary to employ positive maps. These include roads and paths as well as important meta data (for example the driving direction in one-way streets as well as

speed limits). Positive maps make sense here, since the accessible roads and paths only occupy a fraction of a country's area.

5 In buildings, halls, or on works premises, paths are only limited by few obstacles, however. Here, negative or real maps are the obvious thing. While positive maps for vehicle navigation are commercially available in several standard formats (such as GDF, SIF or ArcView), no standard has
10 developed as of now for maps in and around buildings. Previous WLAN localization solutions leave it to the user to establish a map of surroundings in the appropriate format and offer support with proprietary tools. Basic information may often be taken over from bitmaps or CAD
15 plans. The development of town- or city- and nation-wide, navigation-suited 3D maps, which also include building details in addition to streets and public buildings, hence is an important step toward standardization of the map formats.

20 In summary, it is pointed out that, depending on the conditions, the inventive concept may also be implemented in software. The implementation may be on a digital storage medium, in particular a floppy disc, a CD or a DVD, with
25 electronically readable control signals capable of cooperating with a programmable computer system and/or microcontroller so that the corresponding method is executed. In general, the invention thus also consists in a computer program product with program code stored on a
30 machine-readable carrier for performing the inventive method, when the computer program product is executed on a computer and/or microcontroller. In other words, the invention may thus be realized as a computer program with program code for performing the method, when the computer
35 program is executed on a computer and/or microcontroller.

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CLAIMS:

1. An apparatus for determining a coincidence of a position with a reference position, wherein radio signals from fixedly positioned radio transmitters can be received at the position, comprising:

means for providing properties of the radio signals of the fixedly positioned radio transmitters at the position, wherein the provided properties of the radio signals include transmitter identifications identifying the radio transmitters;

means for separating radio transmitters into a first number of radio transmitters previously recorded transmitter identifications of which at the reference position are identical with transmitter identifications provided at the position, and into a second number of radio transmitters previously recorded transmitter identifications of which at the reference position and transmitter identifications provided at the position are different, wherein the means for separating is formed to select, from the second number of radio transmitters, a number of radio transmitters received too few at the position of which there are previously recorded properties at the reference position, but of which there are no properties provided at the position, or a number of radio transmitters received in addition at the position, of which there are no previously recorded electromagnetic properties at the reference position, but of which there are electromagnetic properties provided at the position; and

means for determining a measure of matching for the position on the basis of the provided properties of the radio signals, wherein both properties of the first number of radio transmitters and properties of the second number of radio transmitters are taken into account in the determination of a measure of matching, and wherein the properties of the first number of radio transmitters and the

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properties of the second number of radio transmitters enter the measure of matching differently, wherein the means for determining is formed to associate a malus value with one of the radio transmitters not received at the position or a malus value with a radio transmitter received in addition at the position.

2. The apparatus according to claim 1, wherein the properties of the first number of radio transmitters are weighted more strongly than the properties of the second number of radio transmitters.

3. The apparatus according to claim 1 or 2, wherein the properties of the radio signals comprise electromagnetic properties of the radio signals.

4. The apparatus according to claim 3, wherein the means for determining is formed to determine the measure of matching for the position on the basis of differences between previously recorded electromagnetic properties at the reference position and the electromagnetic properties provided at the position of the first number of radio transmitters.

5. The apparatus according to claim 4, wherein the means for determining is formed to associate a higher measure of matching with the position, the smaller the sum of the differences is.

6. The apparatus according to any one of claims 1 to 5, wherein the means for providing the properties of the radio signals is formed to provide reception-field-strength-related properties of the radio signals at the position.

7. The apparatus according to claim 6, wherein the means for providing the properties of the radio signals is formed

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to provide an RSSI value, a reception power spectrum, or a signal-to-noise power ratio of the radio signals at the position.

8. The apparatus according to any one of claims 1 to 7, wherein the means for determining is formed to associate the malus value with a radio transmitter received too few at the position, depending on how reliably the radio transmitter could be received at the reference position in the past.

9. The apparatus according to any one of claims 1 to 8, wherein the means for determining is formed to associate the malus value with a radio transmitter not received at the position, depending on a property related to a reception field strength.

10. The apparatus according to any one of claims 1 to 9, wherein the means for determining is formed to associate a higher measure of matching with the position, the smaller the sum of the malus values of the radio transmitters not received at the position is.

11. The apparatus according to any one of claims 1 to 10, wherein the means for determining is formed to associate the malus value with a radio transmitter received in addition at the position, depending on a property related to the reception field strength of its radio signal.

12. The apparatus according to any one of claims 1 to 11, wherein the means for determining is formed to associate a higher measure of matching with the position, the smaller the sum of the malus values of the radio transmitters received in addition at the position is.

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13. A navigation device, comprising:

the apparatus for determining a measure of matching of a current position with a reference position, defined in any one of claims 1 to 12; and

means for outputting an estimate for the current position on the basis of the determined measure of matching.

14. A method of determining a coincidence of a position with a reference position, wherein radio signals from fixedly positioned radio transmitters can be received at the position, comprising:

providing properties of the radio signals of the fixedly positioned radio transmitters at the position, wherein the provided properties of the radio signals comprise transmitter identifications identifying the radio transmitters;

separating the radio transmitters into a first number of radio transmitters previously recorded transmitter identifications of which at the reference position are identical with transmitter identifications provided at the position, and into a second number of radio transmitters previously recorded transmitter identifications of which at the reference position and transmitter identifications provided at the position are different, wherein the separating comprises selecting, from the second number of radio transmitters, a number of radio transmitters received too few at the position of which there are previously recorded properties at the reference position, but of which there are no properties provided at the position or a number of radio transmitters received in addition at the position, of which there are no previously recorded electromagnetic properties at the reference position, but of which there are electromagnetic properties provided at the position; and

determining a measure of matching for the position on the basis of the provided properties of the radio signals, wherein both properties of the first number of radio

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transmitters and properties of the second number of radio transmitters are taken into account in the determination of a measure of matching, and wherein the properties of the first number of radio transmitters and the properties of the second number of radio transmitters enter the measure of matching differently, wherein a malus value is associated with one of the radio transmitters not received at the position or a malus value is associated with a radio transmitter received in addition at the position.

15. A computer readable memory having stored thereon computer executable code for performing the method of localizing a position according to claim 14, wherein the method is executed on a computer.

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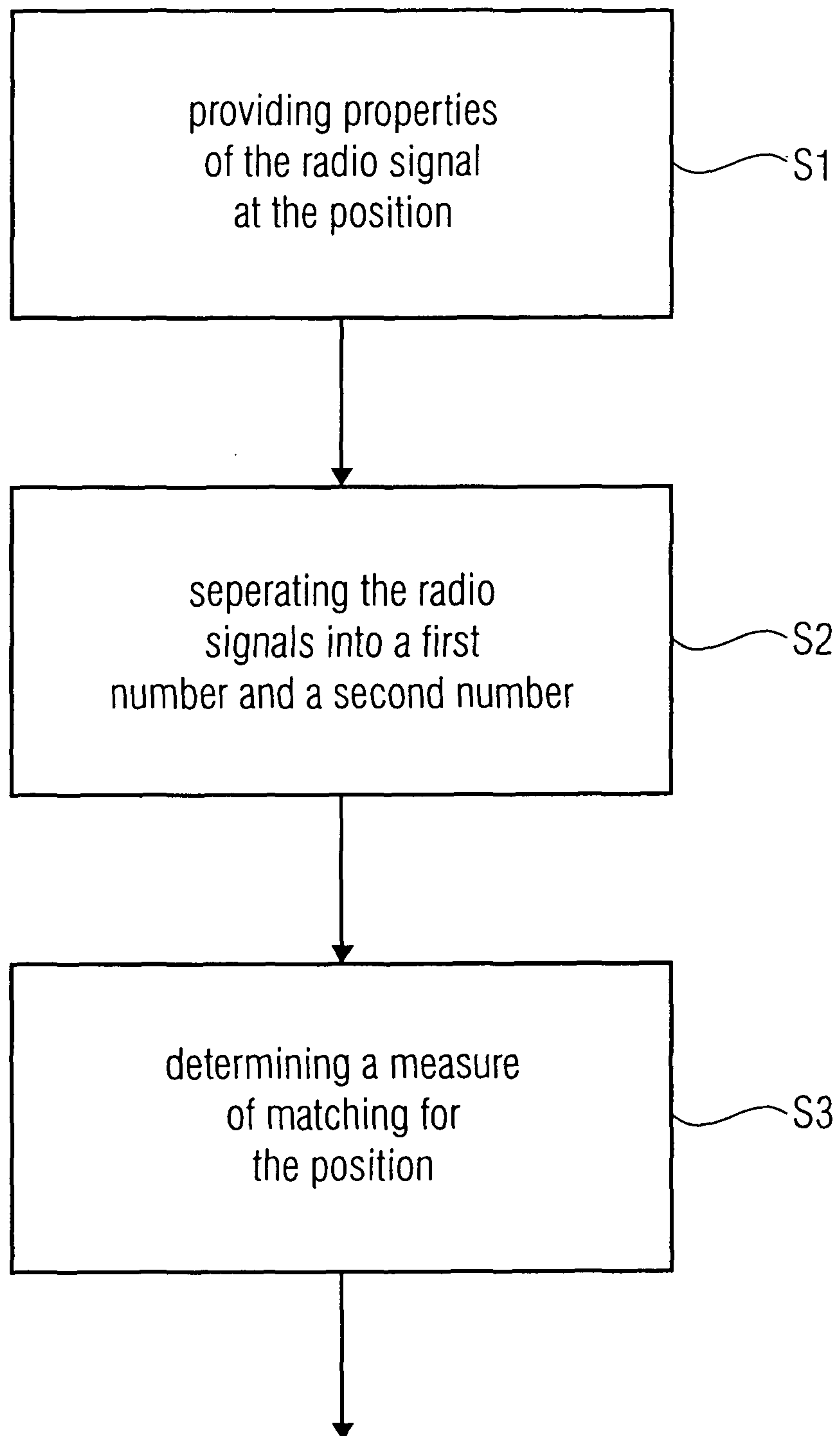


FIGURE 1

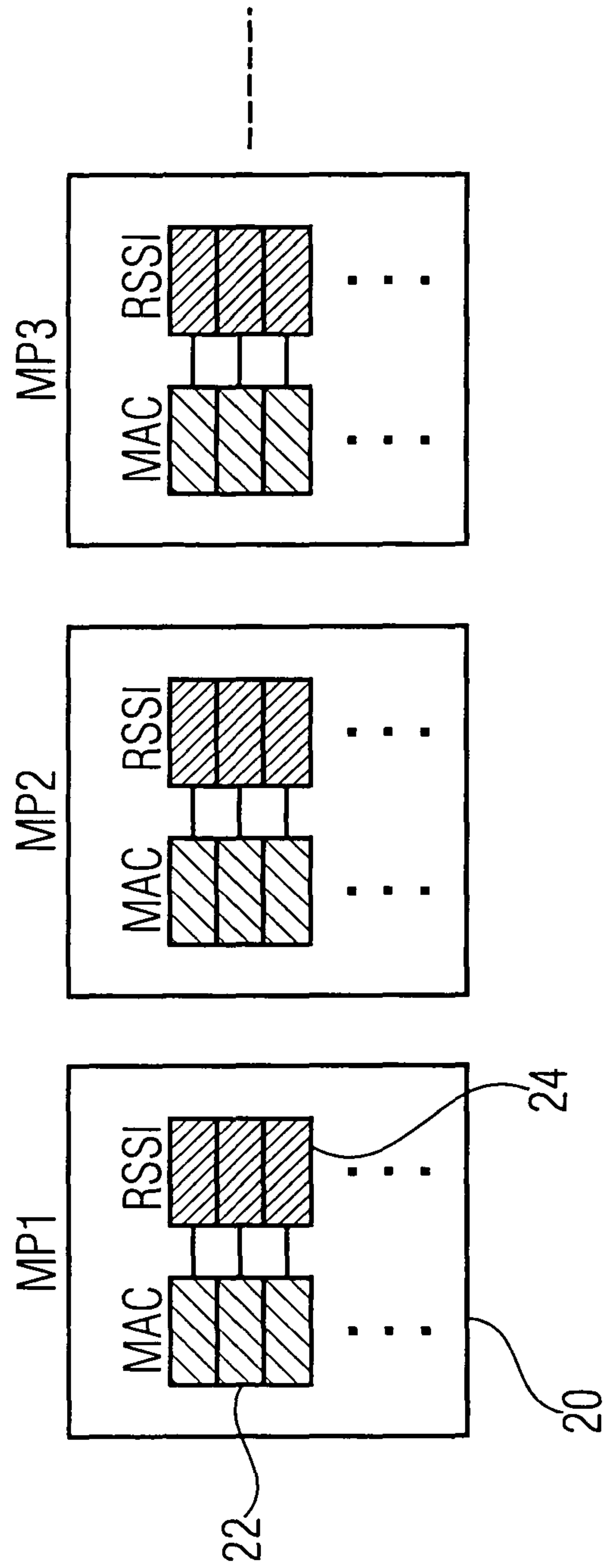


FIGURE 2

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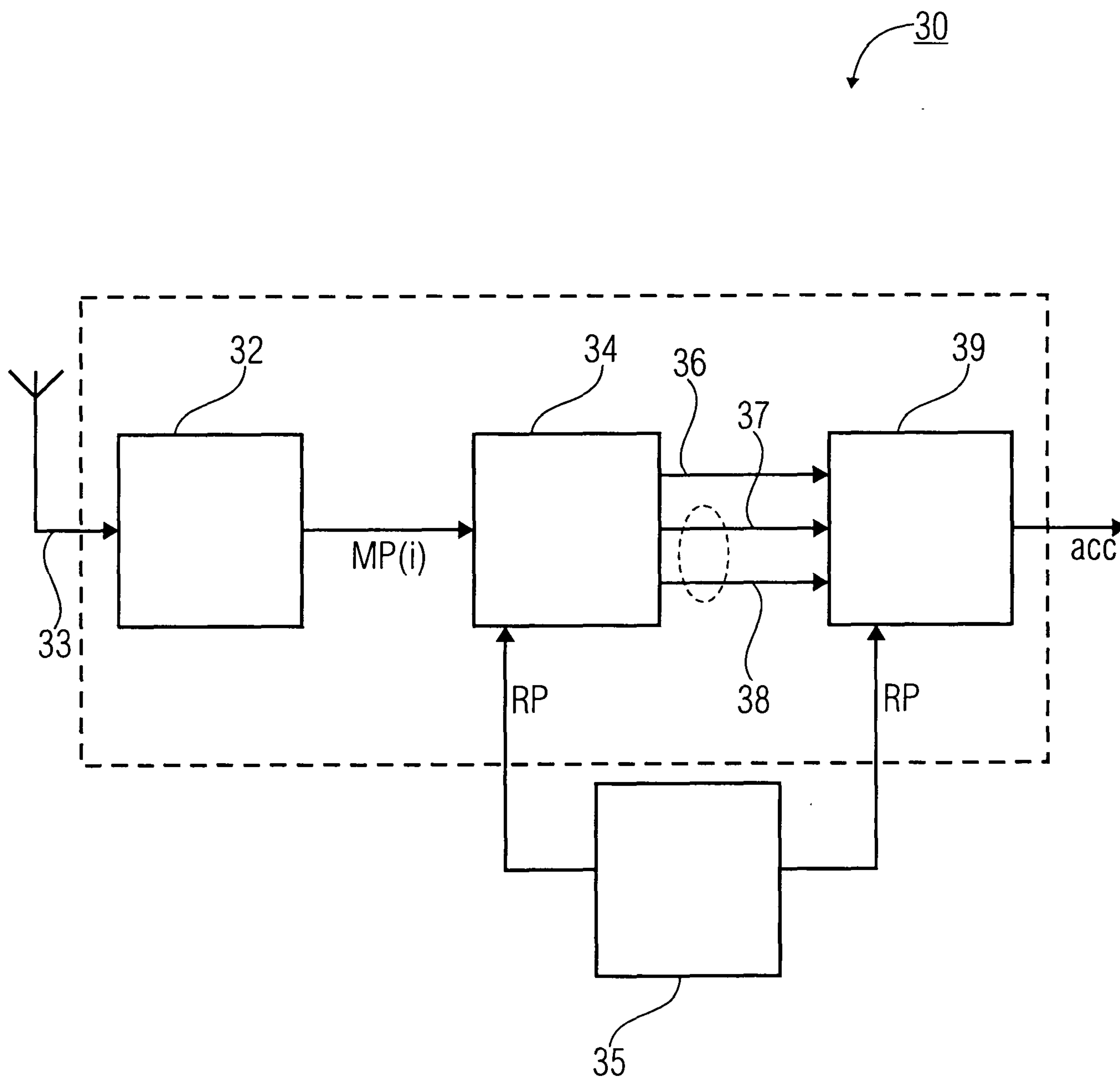


FIGURE 3

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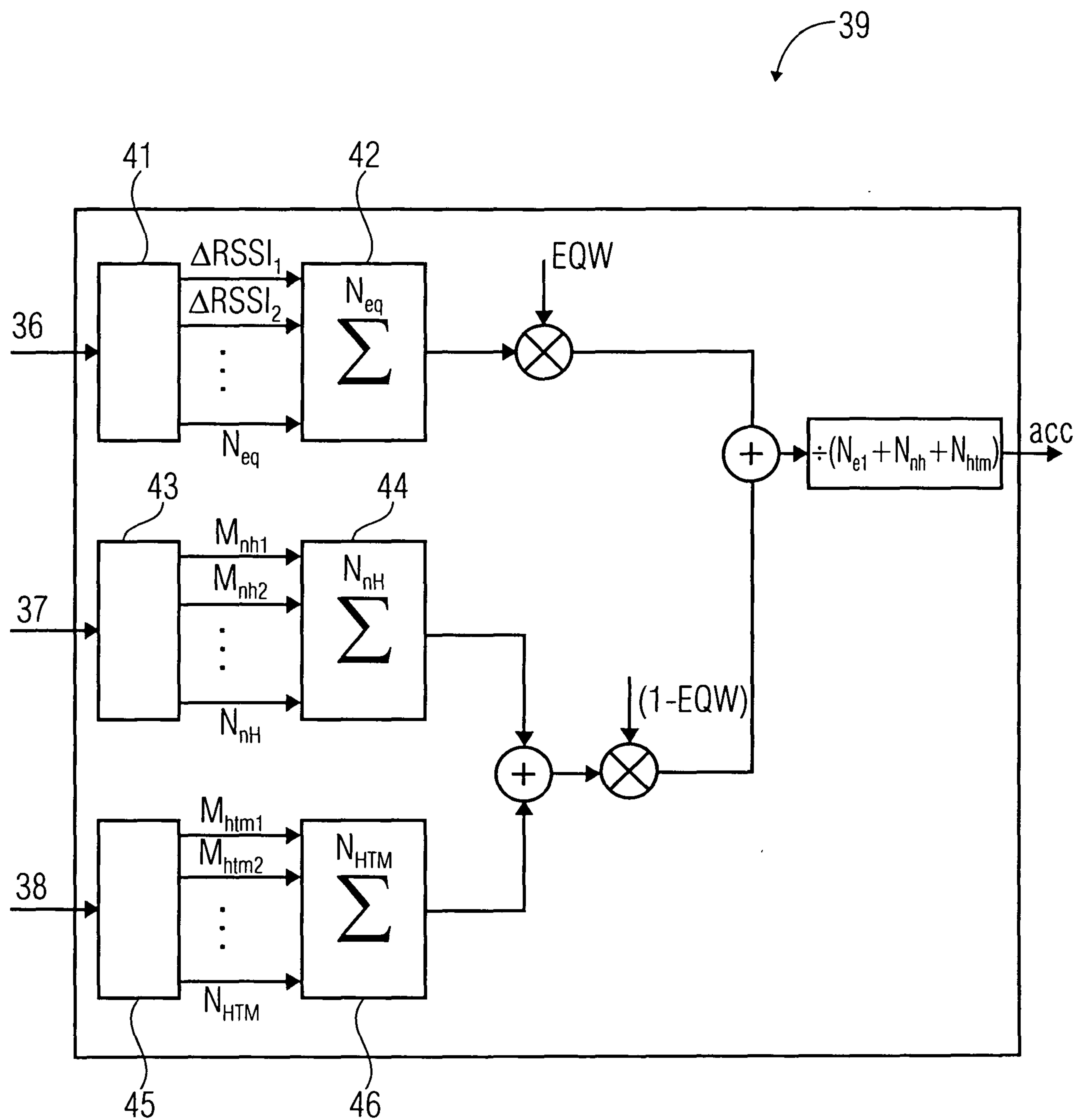


FIGURE 4

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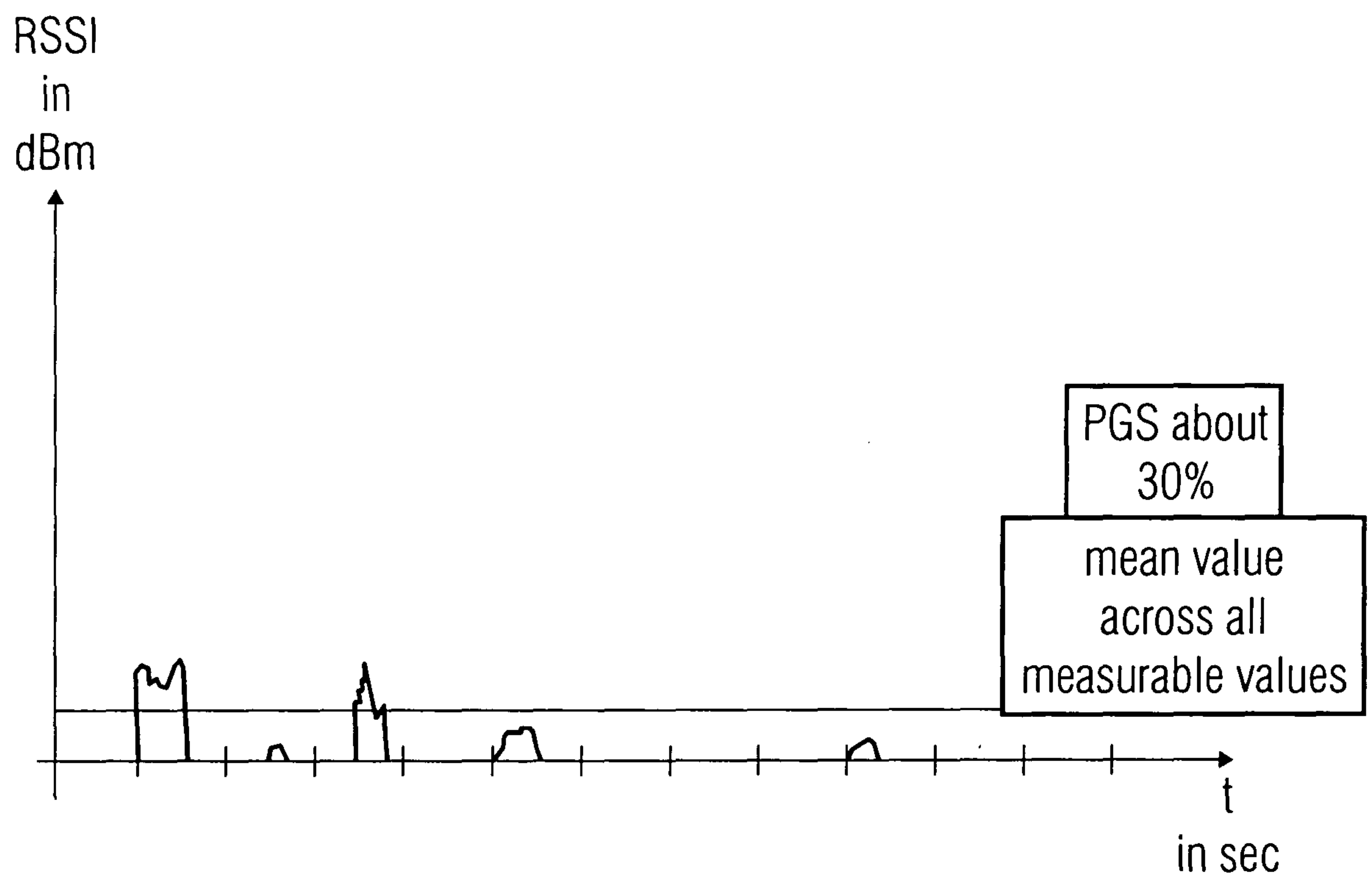


FIGURE 5

