(54) Title: INTERFERENCE DETECTION IN A WIRELESS COMMUNICATION SYSTEM

(57) Abstract: A receiver and a method are applied in a wireless communication system for detecting interference with a coexisting radar system. A signal received from an antenna (100) is fed through an analog part (200) and a subsequent digital part (300) of said receiver. The receiver comprising an element (240, 260) with a-priori known attenuation values for a predefined set of frequencies, a first branch-off element (230, 252) for deriving a first detection signal (S10, S22) from the signal before said element (240, 260) and a second branch-off element (251, 270) for deriving a second detection signal (S21, S30, S20) from the signal after said element (240, 260). Further, the receiver comprising processing means (400) for processing the first (S10, S22) and the second (S21, S30, S20) detection signal such that a difference between the first (S10, S22) and second (S21, S30, S20) detection signal is comparable with a threshold value, wherein the threshold value depends on the a-priori known attenuation values of the element (240, 260). Depending on the comparison result, a frequency is identified as interfering or not a co-existing radar system.
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Published:
— with international search report
Interference Detection in a Wireless Communication System

The invention relates to interference detection in a wireless communication system. In particular, the present invention relates to a receiver and a method in a wireless communication system for detecting interference with a co-existing radar system.

Certain wireless communication systems, such as for example wireless local area networks (WLAN) or universal mobile telecommunication systems (UMTS) are discussed to operate in frequency bands, which are also used by radar systems. This co-existence of a wireless communication system with a radar system leads to the fact that the frequency bands from both systems overlap at least partly. For example WLAN systems, like HIPERLAN/2 or IEEE802.11a, are planned to operate in the frequency range from 5150 MHz to 5350 MHz and 5470 MHz to 5725 MHz, while radar systems are using the frequency range from 5250 MHz to 5850 MHz.

Currently, when a wireless communication system in the 5 GHz range is planned to co-exist with a radar system, it is a regulation that the radar system is the primary user. Hence, it is mandatory to avoid that the wireless communication system interferes with the radar system. Therefore, to avoid a possible conflict with the radar system, the wireless communication system has to vacate the frequencies, currently in use by the radar system.

A typical radar system transmits signals in pulses with a pulse length from around 0.05 to 100μs and a transmission power in the range up to 60 dBW. With this knowledge, a receiver in the wireless communication system is able to distinguish the radar signals from other signals transmitted
in the wireless communication system. If e.g. for an observed frequency, the signal strength from a received signal is in such a time period from around 0.05 to 100μs above a certain value, it is assumed that this frequency is actually used by a radar system. Then, the wireless communication system has to remove this frequency from the list of allowed transmission frequencies or has to change the currently used frequency to avoid any harmful interference to the radar system.

If, in a receiver, e.g. the signal strength is measured after an analog-to-digital converter stage in the digital part, the indication which frequency is currently used from a radar system is ambiguous. This measured signal strength can be above a threshold either due to a received radar signal, which is transmitted on the currently observed frequency or from a radar signal, which is transmitted on some other frequencies, but converted to the observed frequency. Such other frequencies can be converted to the currently observed frequency for example by means of image frequency conversion or aliasing effects. The image frequency conversion results from the arrangement of the analog part in the receiver as a heterodyne receiver with a limited image rejection. The aliasing effects results from the analog-to-digital-converter stage in the receiver, which converts the received signal at a limited sampling rate. Hence, if the detection is arranged in the digital part of the receiver, more frequencies are wrongly determined as possibly in use by a co-channel radar system. Then, more frequencies are determined as to be vacated as really needed and thus the number of usable frequencies for transmission in the wireless communication system is limited more than required.

It is therefore the object of the present invention to overcome the above mentioned problem and provide a receiver
for detecting interference in a wireless communication system, where a signal received from an antenna is fed on a signal path in an analog part to a subsequent digital part, comprising a first branch-off element for deriving from the signal on the signal path a first detection signal, a second branch-off element for deriving from the signal on the signal path a second detection signal, an element arranged in the signal path between said first and said second branch-off element, wherein the element having a-priori known attenuation values for a set of predefined frequencies, and processing means for processing the first and the second detection signal such that a difference between the first and the second detection signal is comparable with a threshold value, wherein the threshold value depends on the a-priori known attenuation values of the element.

Further a method for detecting interference in a wireless communication system is provided, wherein the wireless communication system having transmitter and receiver for transmitting and receiving signals from a list of allowed transmission frequencies, and wherein the wireless communication system co-exists with a radar system, and the method comprising the steps of receiving the signals with an antenna of the above provided receiver, identifying a frequency as interfering the co-existing radar system, if the difference between two of the first, second and third detection signal is below the threshold value, and avoiding said frequency for further transmission within said wireless communication system.

For the detection of a possible conflict with a co-existing radar system, the receiver of the wireless communication system detects if the received signal strength is above a certain threshold for a certain time interval. Then, according to the present invention, those frequencies
are selected, which really interfere the co-existing radar system. Therefore the element, which is between a first and a second branch-off element, is used. The element has a-priori known attenuation values for a set of predefined frequencies. The attenuation is lower for signals on frequencies from that set of predefined frequencies and the attenuation is higher for signals on frequencies other than the predefined set of frequencies. This causes, that the difference between the signal before and after that element and thus the difference between the first detection signal and the second detection signal will become lower for frequencies from the set of predefined frequencies, whereas the difference will become higher for the other frequencies. The difference is compared with the threshold value and if the difference is below a threshold value, it is assumed that the co-existing radar system really uses frequencies from the set of predefined frequencies. If the difference between the second and first detection signal is above a threshold value, it is assumed that the radar system actually uses another frequency than the predefined frequencies. Hence it is distinguishable if a measured high signal strength results from a co-channel radar system, which is using a frequency from the set of predefined frequencies or from a radar system, which is using other frequencies but converted to that set of predefined frequencies. With it, the detection of a possible conflict with a co-existing radar system is more precise and the wireless communication system then has only to avoid those frequencies from the set of predefined frequencies for further transmission, which really interfere with a radar system.

Further features and advantages of the present invention will be apparent to those skilled in the art from the dependent claims and the following detailed description, taken
together with the accompanying figures, where

Fig. 1a-e show embodiments of the present invention.

The principle structure of the receiver is similar in all shown embodiments 1a-e, except some additional elements, which are in accordance to the present invention. Such a principle receiver structure, known to those skilled in the art, can be divided into an antenna 100, an analog part 200 and a digital part 300. Modifications in the structure, respectively in the arrangement of the elements, are possible as long as they have no influence to the principle of the present invention. A signal, which is received from the antenna 100, is fed on a signal path through the analog part 200. In the analog part 200, frequency converters and filters among other elements are arranged in the signal path. An analog-to-digital converter then converts the analog signal from the analog part 200 into a digital signal in the subsequent digital part 300. In the digital part 300, the digital signal is further processed in the digital receiver element. Also, this digital receiver element is here not described in more detail, because the functions of such a digital receiver are well known and are also outside the scope of the present invention. The principle of the present invention, which is common to all embodiments, as shown in the Fig. 1a-e, is the presence of a first branch-off element 230, 252 and a second branch-off element 251, 270 and an element 240, 260 with a-priori known attenuation values for the set of predefined frequencies and which is arranged between said first and second branch-off element. The element 240, 260 has a lower attenuation for a passing signal, when the signal is on a frequency from the set of predefined frequencies. On the other side, the element 240, 260 has a significantly higher attenuation, when the input signal is
from one of the other frequencies. For a skilled person it is obvious that not only the attenuation values for the set of predefined frequencies are known. Rather, for the element, also the attenuation values for almost all from the other frequencies are known a-priori. Then, depending on the attenuation values, and thus depending on the set of predefined frequencies, a threshold value is defined. From the branch-off elements before and after the element a first and a second detection signal are achievable. Such a branch-off element can be each kind of element, like a directional coupler, which detects the signal strength and generates a detection signal, which is proportional to the signal strength of the measured signal. The difference between the second and first detection signal is compared with said threshold value and the result of the comparison gives an indication whether or not a radar system really uses a frequency from the set of predefined frequencies.

Now, in the following only a few possible embodiments of the receiver according to the present invention will be described in more detail. Fig.1a shows an embodiment where the first branch-off element 230 is arranged after a low noise amplifier 220 and before a mixer element 240. The mixer element 240 is dedicated as the element with the a-priori known attenuation values for a set of predefined frequencies. The mixer element causes lower attenuation values for the normal frequency space being converted onto the intermediate frequency and a higher attenuation value for the space of image frequencies that are converted onto the same intermediate frequency. Thus the normal frequency space converted to the intermediate frequency defines here the set of predefined frequencies and the space of image frequencies defines the other frequencies. Or in other words, the set of predefined frequencies consists of the carrier frequencies of
the receiver and the other frequencies are frequencies that are converted onto the same intermediate frequency by image frequency conversion. After the mixer 240, the second branch-off element 251 is arranged. The first branch-off element 230 extracts a first detection signal S10 from the signal on the signal path and the second branch-off element 251 extracts a second detection signal S21 from the signal on the signal path. The branch-off elements 230, 251 are preferably directional couplers as well known from prior art. The first S10 and the second S21 detection signal are fed to the processing means 400. The processing means 400 includes a first PD1 and a second PD2 power-detector element. These power-detector elements must be able to follow a typical radar signal. The output of the first power detector S10' and the output of the second power-detector element S21' are then fed into the processing means 400 to respective analog-digital converters (A/D). The one A/D converter converts the first detection signal S10' into a first digital signal D10. The other A/D converter converts the second detection signal S21' into a second digital signal D21. The digital signals D10 and D21 are then comparable in the digital part 300 of the receiver with the predefined threshold value. In a preferred solution, the absolute value of the difference between the first digital signal D10 and the second digital signal D20 is compared with the threshold value according to the equation D=|D10-(D20+IL)|, wherein IL is the insertion loss of the element. If the difference is above the predefined value, it is assumed that a co-existing radar system is using only other frequencies than frequencies from the set of predefined frequencies. Then the wireless communication system has neither to change the currently used frequency nor to exclude this frequency from the list of allowed transmission frequencies.
Fig. 1d shows an embodiment, which only differs from that one in Fig. 1a with respect to the elements after the power-detecto elements in the processing means 400. Here, alternatively to the analog digital converters from Fig. 1a, the output of the power detectors SD1 and SD2 are fed to an adder. Such an analog adder 460, also well known from prior art, can comprise several resistors and an operational amplifier. In the analog adder, the difference of the detection signals S21', S10' is compared with an analog threshold value. As already described before, depending on whether the difference is below or above the threshold, the wireless communication system is able to decide if there is a possible conflict with a co-existing radar system.

Fig. 1b shows another embodiment of the present invention. In principle, the arrangement is the same as in the above described figures 1a and 1d. The difference in the arrangement is that here the IF-filter 260 is dedicated as the element with a-priori known attenuation values for the set of predefined frequencies. The IF-filter is a band-pass-filter element, which has a low attenuation on frequencies within a dedicated frequency band and much higher attenuation on the other frequencies from outside that frequency band. Here, the frequencies from the band-pass filter 260 define the set of predefined frequencies. The first branch-off element 252 is arranged before that IF-filter 260 and the second branch-off element 270 is arranged after that IF-filter 260. The first detection signal S22 and the second detection signal S30 are fed into the processing means 400. The processing means 400 comprises the already described power detectors PD1 and PD2 and A/D converters, which process the detection signals S22 and S30 as described before.
Fig 1e is the same arrangement as in Fig.1b, with the
only exception that the output S22' and S30' of the power-
detectors are fed to an analog adder 460.

Figure 1c shows an improved embodiment of the present
invention. The receiver comprises a first branch-off element
230 in the signal path between a low noise amplifier 220 and
the subsequent mixer 240. A second branch-off element 253 is
in the signal path between the mixer 240 and a subsequent IF
filter 260. A further branch-off element 270 is in the signal
path behind the IF filter 260. The extracted first S10, second
S20 and third S30 detection signals are fed into the
processing means 400. The detection signals are input into
respective power-detector elements PD1, PD2 and PD3. The
output of each of said power-detector elements is then analog
digital converted in subsequent A/D converter. Finally the
digital signals D10, D20 and D30 are compared with a first and
a further threshold value. The advantage of that embodiment is
that the number of interferers, which would falsely be
interpreted as being co-channel interferers, now can be
correctly detected. Thus the detection of interference is much
more precise.

In a further, but not shown, alternative embodiment to
Fig 1 a, the second digital detection signal D21 can be
derived directly from the digital part 300 of the receiver
instead of branching off from the analog part 200. Then, it is
not longer necessary to have a second branch-off element 251.

For all the described embodiments it is important to have
an element, where the attenuation for range of frequencies are
known a-priori, and a branch-off element before and after that
element. With it, the signal before and after the element can
be compared and the comparison result gives then an indication
whether or not there is an interference problem. It is obvious
to those skilled in the art and thus not further explained,
how the difference is done exactly. Rather, there are several known methods to calculate the difference. E.g., as described with respect to the embodiment in Fig.1a it can be done, when calculating an absolute value from the difference of the measured signal before and after the element. Further in an alternative embodiment also the difference could be calculated, when adding two negative detection signals. It is only important for the present invention to detect a difference between the detection signals. If another than one of the set of predefined frequencies is detected, the wireless communication system needs neither to exclude this frequency from the number of allowed transmission frequencies nor has to change the actual used frequency. On the contrary the wireless communication system has to avoid that said observed frequency is used for further transmission, if it is detected that the observed frequency is from the set of predefined frequencies which means that the difference is below the threshold value.

If a received signal strength above a threshold is measured, but according to the principle of the present invention the further measurements lead to the result that the signal is not on a frequency from the set of predefined frequencies, the wireless communication system can continue the transmission on the set of allowed frequencies. But then it should be taken into account that such a situation leads to a higher DC offset in the receiver, which can decrease the performance. In such a case, additional or adapted existing filter elements in the signal path should be used.

The implementation of the principle of the present invention in a receiver for a wireless communication system leads to a plurality of embodiments and variations. Such a receiver can be a separate controller unit within the wireless communication system or a mobile terminal. In such a case, both, the controller unit or the mobile terminal have to
inform a central unit, like a base station or access point, whether or not any kind of interference is detected. Further, the receiver itself can be the receiver part of a transceiver device, like an access point in a WLAN system or a base station in an UMTS system.
1. Receiver for detecting interference in a wireless communication system, where a signal received from an antenna (100) is fed on a signal path in an analog part (200) to a subsequent digital part (300), comprising
- a first branch-off element (230,252) for deriving from the signal on the signal path a first detection signal (S10,S22),
- a second branch-off element (251,270) for deriving from the signal on the signal path a second detection signal (S21,S30,S20),
- an element (240,260), arranged in the signal path between said first (230,252) and said second (251,270) branch-off element, wherein the element (240,260) having a-priori known attenuation values for a set of predefined frequencies, and
- processing means (400) for processing the first (S10,S22) and the second (S21,S30,S20) detection signal such that a difference between the first (S10,S22) and the second (S21,S30,S20) detection signal is comparable with a threshold value, wherein the threshold value depends on the a-priori known attenuation values of the element (240,260).

2. Receiver according to claim 1, characterized in that a low noise amplifier (220) is arranged in the signal path of the analog part (200) before the first branch-off element (230,252).

3. Receiver according to claim 1 or 2, characterized in that the element (240,260) is an image-rejection-mixer element,
wherein the set of predefined frequencies consists of the carrier frequencies of the receiver.

4. Receiver according to claim 1 or 2, characterized in that
   the element (240,260) is a band-pass-filter element, wherein the set of predefined frequencies are the frequencies within the band-pass of the band-pass-filter element.

5. Receiver according to claim 4, characterized in that
   the band-pass-filter element is an intermediate-frequency-filter element or a base-band-filter element.

6. Receiver according to any of the claims 1-5 comprising
   - a further branch-off element (270), the further branch-off element (270) for deriving from the signal on the signal path a third detection signal (S30),
   - a further element (260) with further a-priori known attenuation values for a further set of predefined frequencies, arranged in the signal path between the second (253) and the further (270) branch-off element, and
   - processing means (400) for processing the first (S10), the second (S20) and the third (S30) detection signal such a difference between the second (S20) and the third (S30) detection signal is comparable with a second threshold value, wherein the second threshold value depends on the further a-priori known attenuation values of the further element (260).

7. Receiver according to any of the claims 1-6, characterized in that
   the branch-off element (230,251,252,253,270) is a directional coupler.
8. Receiver according to any of the claims 1-7
   characterized in that
   the processing means (400) comprising a first (PD1) and a
   second (PD2) power-detector element, wherein the first
   detection signal (S10, S22) is input into the first power
detector element (PD1) and the second detection signal
(S21, S30, S20) is input into the second power-detector
   element (PD2).

9. Receiver according to claim 8
   characterized in that
   the processing means (400) further comprising analog-
digital converter (450, 451, 452) for converting the output
of a power-detector element (S10', S20', S21', S22', S30') in
a digital signal (D10, D20, D21, D22, D30), wherein the
difference between two of the digital signals
(D10, D20, D21, D22, D30) is comparable with the threshold
value.

10. Receiver according to claim 8,
    characterized in that
    the processing means (400) further comprising an analog
    adder (450), the analog adder compares the difference
    between two of the first, second and third output signal
    (S10', S20', S21', S22', S30') with the threshold value.

11. Receiver according to claim 10,
    characterized in that
    the processing means (400) further comprising an Schmitt-
    trigger for converting the output of the comparator into a
    binary information.

12. Receiver according to any of the claims 1-11,
    wherein
    the receiver is an access point of a wireless local area
    network.
13. Receiver according to any of the claims 1-11, 
  wherein
  the receiver is a base station of a universal mobile 
  communication system.

14. Receiver according to any of the claims 1-11, 
  wherein
  the receiver is a controller unit, which is connectable 
  with an access point of a wireless local area network.

15. Receiver according to any of the claims 1-11, 
  wherein
  the receiver is a mobile terminal, the mobile terminal is 
  connectable with an access point of a wireless local area 
  network or with a base station of a universal mobile 
  communication system.

16. Method for detecting interference in a wireless 
  communication system, wherein the wireless communication 
  system having transmitter and receiver for transmitting 
  and receiving signals from a list of allowed transmission 
  frequencies, and wherein the wireless communication system 
  co-exists with a radar system, 
  the method comprising the steps of: 
  - receiving the signals with an antenna (100) of the 
    receiver, wherein the receiver is according to any of the 
    claims 1-15, 
  - identifying a frequency as interfering the co-existing 
    radar system, if the difference between two of the first, 
    second and third detection signal is below the threshold 
    value, 
  - avoiding that frequency for further transmission within 
    said wireless communication system.

17. Method according to claim 16, 
  wherein
  the step of avoiding that frequency is excluding said
frequency from the list of allowed transmission frequencies within the wireless communication system.

18. Method according to claim 16 or 17,

wherein

5 the step of avoiding that frequency is changing to a transmission frequency different to the one currently in use.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B1/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>US 2001/039183 A1 (FUKUDA KUNIO ET AL) 8 November 2001 (2001-11-08) figures 7,9,10 paragraphs ‘0184!,’0187!,‘0291!</td>
<td>1,16</td>
</tr>
<tr>
<td>A</td>
<td>EP 1 248 477 A (ERICSSON TELEFON AB L M) 9 October 2002 (2002-10-09) paragraphs ‘0028!,’0029!,’0031!,’0034!,’0036!</td>
<td>1,16</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

* Special categories of cited documents:  
“A” document defining the general state of the art which is not considered to be of particular relevance  
“E” earlier document but published on or after the international filing date  
“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)  
“O” document referring to an oral disclosure, use, exhibition or other means  
“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention  
“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone  
“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art  
“S” document member of the same patent family

Date of the actual completion of the international search
7 October 2003

Date of mailing of the international search report
15/10/2003

Name and mailing address of the ISA
European Patent Office, P.B. 5816 Patentlaan 2 NL-2280 HV Rijswijk Tel: (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016

Authorized officer
Augarde, E

Form PCT/ISA/210 (second sheet) (July 1992)
<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>WO 02082844 A2</td>
<td>17-10-2002</td>
</tr>
<tr>
<td>JP 2001237846 A</td>
<td>31-08-2001</td>
<td>NONE</td>
<td></td>
</tr>
</tbody>
</table>