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New interference rejection method in RF field

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Abstract: Interference is a big problem in RF area. The call setup will be fall, the handover will be fail, the throughput will be down. There are three ways to reject the interference: space division, time division, frequency division and code division. By now, the three methods are all used in the whole channel coding. This paper present one new method that only control channel uses the rejection methods and the whole channel can reject the interference. It will be easier to realize getting call setup success rate, handover success rate and more capacity, larger throughput.

1. Background

Interference is a big problem in RF area. Co-channel rejection in GSM, pilot pollution in WCDMA, Inter Cell Interference Coordination in LTE, Co-channel interference in LTE-V2X and 5G NR are the major issues need to be optimized. If there is any difference in space, time, frequency or scramble code, the interference can be rejected. But the three methods have been used for the whole channel coding as much as it can, but there are still many interference problems. How to find a new way to optimize the issue becomes our important task[1-2].

2. Problem

2.1 LTE-V2X interference

LTE-V2X traffic and control messages are broadcasted by LTE physical share channel. When the LTE share channel of vehicles are same, the interference to each other will be serious. As the time of UEs transmitting are random, the synchronization of all are impossible, the interference will be happened to the pair of UEs communicating. When the vehicles are blocked in the busy road, the interference will be serious.

2.2 5G NR interference

Although there are scramble code, TDD,FDD in 5G NR channel, the transmitting randomly of UEs can make the interference. This will drop the throughput and handover success rate. How to improve the throughput becomes a problem operators and venders focus on.

2.3 Other wide band standard interference

1) LTE: LTE also has the same problem
2) WLAN: 20MHz 802.11n, 160MHz WiFi5,WiFi6,WiFi6E,WiFi7 also have the same problem

3. Preparation

3.1 The reason why the interference effects the modulation

According to the Goodman algorithm, Maximum likelihood co-frequency interference elimination algorithm, MKI algorithm, IIC algorithm, as the interference makes the receiver error, so that the time & frequency matrix of receiving maybe different with the initial time & frequency matrix of transmitting, there is some probability to discrimination error, so as to do error modulation[3-4].

3.2 How to reject the interference

According to the Goodman algorithm, Maximum likelihood co-frequency interference elimination algorithm, MKI algorithm, IIC algorithm, there is time difference at co-channel. After multiplying received signal and the matrix with corresponding address and time& frequency, they can find the useful signal at maximum probability. The key of solution is getting the matrix with corresponding address and time& frequency.

3.3 The difficulties of the three methods

1) Space division
Space division is used in a whole system, whose BTS covers a large area, same frequency channel can be used in different area discontinue. It is difficult for UEs to use in the one closed area.
2) Time division
GSM, LTE, Wi-Fi all used time division, time division is use to the extreme. It is difficult for UEs to improve the capacity and throughput. The synchronization of frame and slot is exacting requirement, but the time of UEs' transmitting is random, the time advance is required to be accurate for communication UEs, but it is impossible for other interrupting UEs. The interference will happen.
3) Frequency division
All mobile communication and wireless communication use frequency division. It is also use to the extreme. The band wide of all communication is becoming larger and larger for faster throughput. But frequency source is limited and has to pay. How to save the frequency source is an urgent requirement.
4) Scramble code division
After 3G, WCDMA, LTE and 5G NR all use scramble code division. on the one hand the scramble code source is limited, on the other hand the scramble code works under exacting requirements that the synchronization is must and spreading gain is limited[5-7].

4. Solution

4.1 Principle description

Hopping frequency list	f0	f1	f2	f3	f4	f5	f6	f7	f8	f9

Figure 1: Hopping list

1) Control channel is narrow band hopping.

We can use GSM frequency hopping for it. The band wide is only 200KHz. As shown in Figure 1

2) Traffic channel is wide band transmit as normally

3) Traffic channels keep anchoring to one control channel. The anchoring list should broadcast to UEs by SIB.

4) The control channel keeps anchoring to one hopping index.

5) The control channel is hopping and the con-channel interference is low as GSM hopping. As shown in Figure 2

Hopping index	Hopping frequency order									
0	f0	f1	f2	f3	f4	f5	f6	f7	f8	f9
1	f1	f2	f3	f4	f5	f6	f7	f8	f9	f0
2	f2	f3	f4	f5	f6	f7	f8	f9	f0	f1
3	f3	f4	f5	f6	f7	f8	f9	f0	f1	f2
4	f4	f5	f6	f7	f8	f9	f0	f1	f2	f3
5	f5	f6	f7	f8	f9	f0	f1	f2	f3	f4
6	f6	f7	f8	f9	f0	f1	f2	f3	f4	f5
7	f7	f8	f9	f0	f1	f2	f3	f4	f6	f6
8	f8	f9	f0	f1	f2	f3	f4	f6	f7	f7
9	f9	f0	f1	f2	f3	f4	f6	f7	f8	f9

Figure 2: Hopping index

6) UEs gets the synchronization from BCCH of control list and gets the control channel hopping index from the SIB.

The BCCH is not hopping like GSM. The band wide of BCCH is narrow, it can be assigned to any random channel, so that the con-channel probability is low. UEs can search the BCCH like GSM.

7) Different UE different hopping index, so that UEs co-channel interference is low.

8) One UE gets its traffic information from the its hopping control channel.

9) UE can transmit the data by the traffic channel normally.

10) As the position of UEs are different to each other, the time advance of all traffic channel are almost different, so the time of fames and slots are almost different

11) If receiver can capture the time of the UE arriving and the demodulation message of the UE, the receiver can demodulate data transmitted by the UE or BTS.

12) The time can be got from the control channel assigned to this traffic channel. the demodulation message also can be got from the control channel.

13) When the receiver gets the special time boundary different with others, it can demodulate the data immediately, the co-channel same with traffic channel interference will be rejected.

14) At the same time, the control channe.ls are hopping, the co-channel interference also will be low.

15) So that the whole co-channel interference will be low after using new interference rejection method (NIR).

16) The method is valuable by adding some narrow frequency hopping list. As shown in Figure 3

Control channel	Traffic channel	control channel band wide	Traffic channel band wide	Control/Traffic rate
Hopping index 0	DL\UL wide band channel 0	200KHz*10=2M	5M-20M-100M-160M	0.4-0.1-0.02-0.0125
Hopping index 1	DL\UL wide band channel 1	200KHz*10=2M	5M-20M-100M-160M	0.4-0.1-0.02-0.0125
Hopping index 2	DL\UL wide band channel 2	200KHz*10=2M	5M-20M-100M-160M	0.4-0.1-0.02-0.0125
Hopping index 3	DL\UL wide band channel 3	200KHz*10=2M	5M-20M-100M-160M	0.4-0.1-0.02-0.0125
Hopping index 4	DL\UL wide band channel 4	200KHz*10=2M	5M-20M-100M-160M	0.4-0.1-0.02-0.0125
Hopping index 5	DL\UL wide band channel 5	200KHz*10=2M	5M-20M-100M-160M	0.4-0.1-0.02-0.0125
Hopping index 6	DL\UL wide band channel 6	200KHz*10=2M	5M-20M-100M-160M	0.4-0.1-0.02-0.0125
Hopping index 7	DL\UL wide band channel 7	200KHz*10=2M	5M-20M-100M-160M	0.4-0.1-0.02-0.0125
Hopping index 8	DL\UL wide band channel 8	200KHz*10=2M	5M-20M-100M-160M	0.4-0.1-0.02-0.0125
Hopping index 9	DL\UL wide band channel 9	200KHz*10=2M	5M-20M-100M-160M	0.4-0.1-0.02-0.0125

Figure 3: Taffic channel anchoring to hopping index

4.2 Solution sample 1 for V2X

(1) Normal mode (LTE-V2X)

When the traffic is very busy and vehicles are blocked one by one on one area, the LTE-V2X communication to each other will be blocked. As the control protocol of PSCCH and the data of PSSCH are broadcast by the LTE channel with same carrier, the interference will be serious.

(2) NIR mode (the New Interference Rejection method used)

1) Every V2X DUT transmits random BCCH in GSM900

2) Every V2X DUT search the BCCH in GSM900.

3) Get synchronization from BCCH.

4) Get different BCCH from other vehicles transmitting.

5) Local V2X DUT select the strongest BCCH.

6) Get hopping index from the BCCH.

7) Capture the hopping PSCCH.

8) Get the time advance, PSSCH frequency number and format message, etc.

9) Demodulating the PSSCH data.

10) Different TA and format, although there is co-channel, but V2X interference will be rejected. As shown in Figure 4 and Figure 5.

NIR sample in LTE-V2X

SIB message	Vehicle1	Vehicle2	Vehicle3	Vehicle4	Vehicle5	Vehicle6	Vehicle7	Vehicle8	Vehicle9	Vehicle10
BCCH (GSM900 channel 1-124)	120	10	13	24	56	110	100	80	44	33
PSCCHI(Hopping between 1-10,Index 0-9)	4	6	7	9	0	1	8	3	2	5
PSSCH(LTE SCH,20MHz, EARFCN=55140)	55140	55140	55140	55140	55140	55140	55140	55140	55140	55140
Time advance(0-63,3.7us/unit,550m/unit)	0	62	50	32	22	10	2	6	49	34

Figure 4: NIR sample in LTE-V2X

Hopping Index	Hopping frequency list
0	1->2->3->4->5->6->7->8->9->0->1.....
1	2->3->4->5->6->7->8->9->0->1->2.....
2	3->4->5->6->7->8->9->0->1->2->3.....
3	4->5->6->7->8->9->0->1->2->3->4.....
4	5->6->7->8->9->0->1->2->3->4->5.....
5	6->7->8->9->0->1->2->3->4->5->6.....
6	7->8->9->0->1->2->3->4->5->6->7.....
7	8->9->0->1->2->3->4->5->6->7->8.....
8	9->0->1->2->3->4->5->6->7->8->9.....
9	0->1->2->3->4->5->6->7->8->9->0.....

Figure 5: Hopping index (sample)

4.3 Solution sample 2 for 5G NR

(1) Normal mode

When UEs try to get the maximum throughput, the RBs will all be used. The subcarriers will all be used. If the carriers of UEs are same, the co-channel interference will happen. The throughput will be dropped.

(2) NIR mode (the New Interference Rejection method used)

1) Every Node B transmits random BCCH in GSM900

2) Every UE search the BCCH in GSM900.

3) UE Get synchronization from BCCH.

4) UEs get different hopping indexes from the BCCH.
5) Every UE captures the PDCCH with unique hopping index.
6) Get the time advance, PDSCH frequency number and format message, etc.
7) Demodulating the PDSCH data.
8) Different TA and format, although there is co-channel, but 5G NR interference will be much lower. As shown in Figure 6

NIR sample in 5G NR

SIB message	UE1	UE2	UE3	UE4	UE5	UE6	UE7	UE8	UE9	UE10
BCCH (GSM900 channel 1-124)	121	9	14	25	55	111	99	81	43	34
PDCCHl(Hopping between 1-10,Index 0-9)	1	8	3	2	5	6	9	4	7	5
PDSCH(NR FR1,100MHz)	n78	n78	n78	n78	n78	n78	n78	n78	n78	n78
Time advance(0-63,3.7us/unit,550m/unit)	0	62	50	32	22	10	2	6	49	34

Figure 6: NIR sample in 5G NR

5. Feasibility

5.1 Hopping

GSM frequency hopping has been used for over 20 years. The NIR control channel hopping can learn from GSM hopping. It works surely. As the control data states on one frequency only about 4.615ms (1 frame) or 0.577ms (1 slot), the con-channel interference probability is low for the whole control channel. The hopping technology is very mature, so the hopping technology for control channel is feasibility[8-10].

5.2 CA

In NIR method, the technology the control channel in narrow band anchoring to traffic channel in wide band is important for realization. In LTE and 5G NR mobile communication, carrier aggregation works fine. One carrier is from low frequency band, other carrier is from high frequency band, even is from mmW. the narrow lower frequency band and wide higher frequency band can be realized and work fine. Now the technology is full-fledged and can be a business application.

5.3 Coverage

We know that the coverage of lower frequency is larger than higher frequency, so that the distance of the control channel will be further than the traffic channel in same transmitting power. But we can adjust the power of control channel or traffic channel to fit to each other by measuring the report from UEs. This will make the call setup success rate and handover success rate higher when the control channels coverage is a little better than the traffic channels.

6. Cost

6.1 Antenna

The GSM base stations and LTE or 5G NR base stations of operators are always in the same site. The antennas and the feeder lines of GSM and LTE or 5G NR can be used under NIR. This cost of the antennas and lines can be saved.

6.2 BTS

For NIR, the GSM and LTE or 5G NR systems can be reused. Some cost can be saved.

7. Advantage

7.1 Effective for random transmitting interference

As the narrow frequency hopping is effective for con-channel interference, the accurate time, format data of the wide band traffic channel can be notice in advance by the hopping control channel, the co-channel interference of traffic channel will be much lower, so that the whole co-channel interference will be low.

7.2 Easy

GSM frequency hopping technology for NIR control channel is easy, traffic channel technology is same with LTE,5G NR, so that NIR technology can be realized easily.

7.3 Possible

Control channel technology can use GSM hopping technology, traffic channel technology can use LTE,5G NR, Wi-Fi wide band technology as well, at the same time carrier aggregation with lower frequency band and higher frequency band can work fine, so that the New Interference Rejection function will be possible to realized. It is possible.

8. Technology extension

8.1 Control channel interference rejection and traffic channel work normally

For extension, the control channel can not only copy from GSM hopping, but also create some special band wide frequency list. The traffic channel can be any band wide signal, it can be Wi-Fi5, Wi-Fi6, Wi-Fi7 or other any user defined signal. For the user defined case, the NIR can work. The effectiveness of co-channel interference rejection should be fine[11].

9. Conclusion

As we know, space division, time division, frequency division, scramble code division can do the co-channel interference rejection, but the random transmitting of UEs or OBUs or over coverage will still make no synchronization of fames or slots, so that the co-channel interference will be happen. This make setup call difficultly, hand over fail, the throughput of high speed transmitting drop.

The New Interference Rejection presents that control channel uses narrow frequency hopping and anchoring to the wide band traffic channel working normally same as the standard technology. The control channel can reject the con-channel interference and also the traffic channel can reject the con-channel interference similarly as it can get the accurate time advance and the data format message.

The NIR can be used in GSM+LTE/5G NR/Wi-Fi5,6,7 or user defined narrow band control channel +wide band traffic channel.

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