Analysis and Test for Co-site of LTE and WiFi System

Shang, Rongrong
Research and Technology Department
Nokia Siemens Networks Technology (Beijing) Co. Ltd.
Beijing, China
Rongrong.shang@nsn.com

Wang, Xinglin
Research and Technology Department
Nokia Siemens Networks Technology (Beijing) Co. Ltd.
Beijing, China
Xinglin.wang@nsn.com

***Abstract*—In this paper, the co-site interference of LTE and WiFi systems are investigated. Based on the theoretical calculation and real experiment, large performance degradation can be avoided in the co-site deployment of LTE and WiFi by using sufficient isolation provided by ACIR and antenna separation.**

Keywords- LTE; WiFi; Co-Site; ACLR; ACS; ACIR; EVM

I. INTRODUCTION

Recent industry analyst figures show significant growth in the number of wireless data service subscribers and in data consumption. These factors combined will result in exponential growth of the amount of transmission data in wireless networks.

LTE [1] is the technology from the 3GGP standards group and it has attracted lots of attentions in recent years. LTE is expected to substantially improve end-user throughputs, sector capacity and reduce user plane latency, bringing a significantly improved user experience with full mobility. Currently, the standardization for LTE FDD and LTE TDD are finished. LTE will be deployed with commercial availability soon.

WiFi [2] still will be a low cost solution for wireless access and will be widely deployed now and in the future, especially in some high density area and indoor scenarios. Now operators are considering using WiFi to offload traffic from LTE system. People also propose to deploy the LTE base station integrated with WiFi. It may appear LTE/WiFi dual-mode base station (BS) or co-site LTE eNB and WiFi.

When in co-location situation in the future deployment, firstly it is possible that one base station (BS) is in transmitting state while the other BS is in receiving state. Secondly the frequency bands of these BSs may be very near from each other such as in LTE and WiFi systems. Therefore, there is serious interference which is called co-location or co-site interference.

Because interferer and victim are so closer, such co-site interference may be very strong, so that it can significantly impact the system performance. Therefore, it is necessary to do the research on the co-site interference.

Currently people are engaging developing LTE chip, eNB and UE to push the commercial use. Few people consider how to deploy LTE and WiFi in co-site case. In this paper, co-site interference between LTE and WiFi is analyzed and tested. The suggestions are given for real deployment.

This paper is organized as follows. In part II, interference scenarios are described and the analytical methods are introduced. Then the detailed calculation steps are given. In part III, a test platform is built and the test results are shown. The obtained results are analyzed in detail as well. In part IV, we get the final conclusions.

II. INTEFERENCE ANALYSIS

Considering the requirement of the data throughput in high density urban area and the unavoidable pass loss, LTE Pico BS will be deployed with small coverage. In urban area, the installation places, such as lamp poles, high buildings, etc., will be selected as the locations for both WiFi and LTE Pico BS.

LTE Femto BSs will be widely deployed indoors. Since both LTE Femto and WiFi need indoor wired backhaul, the locations for LTE Femto and WiFi will be very near in order to obtain easier deployment. We have to carefully consider how to deploy WiFi and LTE Femto systems.

On the other hand, even though LTE can provide promising data throughput, it will still suffer from the increasing requirement caused by various services. WiFi, treated as a low cost wireless access solution, will be used to offload the data traffic from LTE network. Therefore, operators would like to use BSs which integrate LTE and WiFi together. Now some operators have already proposed to integrate WiFi in 3G base station.

In these three situations, we will have to face co-location interference. In the following, we will analyze the co-site interference according to the above scenarios.

A. *Analysis Procedure*

Generally speaking, people always use quantitive theory analysis to study the co-site interference [3].

Theoretical analysis method calculates the isolation between two systems and analyzes the interference. This method is particularly suitable for the co-site interference analysis. It is simple but accurate, and widely used.

Generally, the priority of LTE system is much higher than WiFi system when LTE and WiFi are co-located. LTE performance should be guaranteed firstly. Even considering different types of services, WiFi can tolerate much more interference than LTE.

In this paper, we only focus on how WiFi interferes LTE.

The impact on the BS receiver sensitivity is always used to measure the severity of co-site interference. According to ITU M.2039 [4], the acceptable interference should be *I/N*=-6 to -10dB.

Here, *I* means interference power and *N* means noise power. We have the following formulas as known:

If *I/N*=-6dB, sensitivity degrades by 0.97dB.

If *I/N*=-7dB, sensitivity degrades by 0.8dB.

If *I/N*=-10dB, sensitivity degrades by 0.4dB.

Generally, sensitivity degradation of 0.8dB is acceptable and widely used. In this document, we take sensitivity degradation of 0.8dB for calculation.

Assuming that LTE BS noise figure is 5dB, the LTE noise power for 20MHz bandwidth is:

-174dBm/Hz + 10 lg (Bandwidth) + Noise Figure*

$= -174 + 10 \cdot lg\,(20 \cdot 10^6) + 5 = -96dBm$

LTE noise power for 10MHz bandwidth is:

*-174dBm/Hz+ 10*lg (Bandwidth) + Noise Figure*

$= -174 + 10 \cdot lg\,(10 \cdot 10^6) + 5 = -99dBm$

Therefore, the received interference level should be no larger than

-96dBm - 7dB = -103dBm for 20MHz and

-99dBm - 7dB = -106dBm for 10MHz.

Regardless of transmit power, the received interference level should be no larger than -103dBm for 20MHz and -106dBm for 10MHz. In other words, after some attenuation, the received WiFi interference level at LTE BS receiver side should be no larger than -103dBm for 20MHz and -106dBm for 10MHz.

We have to carefully deploy the two systems to provide enough isolation to reduce co-site interference to a very low level. The attenuation in co-site case mainly comes from two factors: ACIR and antenna isolation.

ACIR (Adjacent Channel Interference Ratio) is the ratio of wanted power to the interference power from the adjacent channels. It is related with frequency interval and RF component performance. ACIR consists of ACLR (Adjacent Channel Leakage Ratio) and ACS (Adjacent Channel Rejection), shown as follows:

$$ACIR = \frac{1}{\frac{1}{ACLR} + \frac{1}{ACS}} \tag{1}$$

ACLR is the ratio of the filtered mean power centered on the assigned channel frequency to the filtered mean power centered on an adjacent channel frequency. ACS is a measure of the receiver's ability to receive a wanted signal at its assigned channel frequency in the presence of an adjacent channel signal. The relation of these two interference sources is illustrated in the Figure 1.

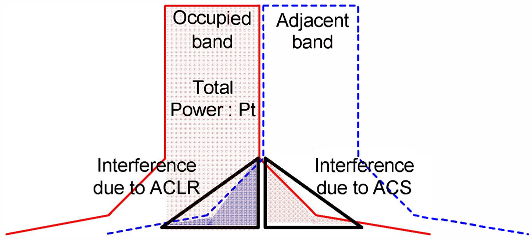

Figure 1. The relationship between ACLR and ACS

Antenna isolation is the isolation between co-located antennas. It is related with the antenna separation distance and wavelength.

If antennas are horizontally separated [5], the isolation is:

$$I_H(dB) = 22 + 20\lg\left(\frac{d_H}{\lambda}\right) - G_{ant} \tag{2}$$

Here d_H is the horizontal separation between two antennas, λ is the wavelength, and G_{ant} is antenna gain.

If antennas are vertically separated [6], the isolation is:

$$I_v = 28 + 40\lg\left(\frac{d_v}{\lambda}\right) \tag{3}$$

Here d_v is the vertical separation between two antennas, λ is the wavelength.

Obviously, the antennas are always vertically separated since the vertical separation isolation is much bigger than horizontal separation isolation in case of same separation.

B. *Theory Analysis*

The system parameters are shown in Table I. The center frequency is the working frequency for the transmitter and receiver. LTE ACLR and ACS values refer to ADI RFIC AD9352.

TABLE I. SYSTEM PARAMETERS

Parameters		***Value***
Transmit power (dBm)	LTE Femto/ WiFi indoor	20
	LTE Pico/ WiFi outdoor	30

LTE ACLR (dB) (AD9352)	45dB for the 1st adjacent channel 60dB for the 2nd adjacent channel 75dB for the 3rd adjacent channel
LTE ACS (dB) (AD9352)	38dB for the 1st adjacent channel 45dB for the 2nd adjacent channel 60dB for the 3rd adjacent channel
WiFi ACLR (dB)	36dB for the 1st adjacent channel 48dB for the 2nd adjacent channel 58dB for the 3rd adjacent channel
WiFi ACS (dB)	28dB for the 1st adjacent channel 38dB for the 2nd adjacent channel 48dB for the 3rd adjacent channel

In the real deployment, the distance between antennas is limited. It is difficult to install co-located antennas when the antenna distance is more than 2 meters. Furthermore, the antenna isolation will not increase fast along with increase of the antenna distance.

If we place antennas vertically, when the antenna distance is 1 meter, the isolation is 64dB according to (3).

In case of LTE Femto and WiFi, WiFi transmit power is 20dBm, and the total isolation requirement is 20-(-103) =123dB. In order to satisfy the isolation requirement, besides 64dB antenna isolation, ACIR needs to be more than 59dB.

In case of LTE Pico and WiFi, WiFi transmit power is 30dBm, and the total isolation requirement is 30-(-103) =133dB. In order to satisfy the isolation requirement, besides 64dB antenna isolation, ACIR needs to be more than 69dB.

When the antenna vertical distance is 1.5 meters and 2 meters, we can get the isolation using the same calculation method. The details are shown in Table II and Table III.

TABLE II. ISOLATION FOR CO-LOCATED LTE FEMTO AND WIFI

Antenna Vertical Separation(m)	1	1.5	2
Antenna Isolation (dB)	64	71	76
Required ACIR (dB)	59	52	47
Total isolation for LTE Femto and WiFi co-location (dB)	123	123	123

TABLE III. ISOLATION FOR CO-LOCATED LTE PICO AND WIFI

Antenna Vertical Separation(m)	1	1.5	2
Antenna Isolation (dB)	64	71	76
Required ACIR (dB)	69	62	57
Total isolation for LTE Pico and WiFi co-location (dB)	133	133	133

III. INTERFERENCE TEST

Since there may be some deviation between the theory analysis assumption and the real deployment environment, some experiments are needed. And we can provide enough margin in the future deployment according to the test results.

In the test, LTE signal bandwidth is 20MHz. As mentioned, the received interference level should be no larger than -103dBm.

A. *Test Environment*

Figure 2 shows the co-location test environment setup block diagram. It includes three parts: the transmitter part, the receiver part and the interference part.

In the transmitter part, a period of time's LTE source data, such as 20ms length data which is saved in advance will be downloaded by ADI board and then sent by RF and antenna periodically. At the same time, the signal performance is monitored by the signal analyzer through a power splitter.

In the receiver part, it receives the signal and a period of time's data such as 20ms length data can be saved. We can use the signal analyzer to analyze the signal quality.

The interference source is generated by a signal generator.

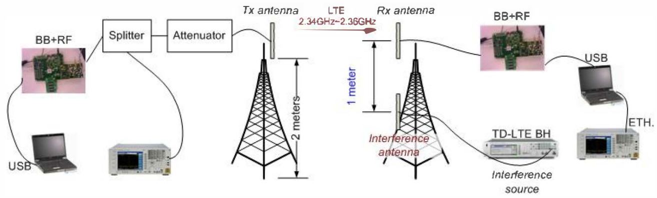

Figure 2. Interference test enveroment.

The detailed test parameters are shown in Table IV. The vertical distance between the two antennas is 1 meter. The signal is 20MHz LTE signal and modulation scheme is 64QAM. The interference is WiFi signal. Because the output power of the signal generator is limited, the interference power is 10dBm. WiFi working frequency band is around 2.4GHz. In the test, WiFi center frequency is configured to be 2.412GHz. LTE center frequency is changed to get different frequency intervals between WiFi and LTE.

TABLE IV. TEST PARAMETERES

Parameters	***Value***
Tx. antenna height	4m
Tx. antenna polarization	+45 degree
Rx. antenna height	4m
Rx. antenna polarization	-45 degree
Vertical distance between Rx. antenna and interference antenna	1m
Interference antenna polarization	+45 degree
Antenna gain	10dB
LTE RF Tx. power	20dBm
LTE Tx./Rx. frequency band	2.34~2.36GHz, 2.36~2.38GHz, 2.38~2.40GHz
WiFi interference frequency band	2.401~2.423GHz
WiFi interference power	10dBm

B. *Test Results*

In the test, the Error Vector Magnitude (EVM) is used to evaluate the system performance. EVM is a measure of the difference between the ideal symbols and the measured symbols after the equalization. This difference is called the error vector. The EVM result is defined as the square root of the ratio of the mean error vector power to the mean reference power.

The test results are shown in Figure 3 to Figure 5. The measurement view provides a grid 2x2 display of the measurement constellation, a spectrum graph, a graph of the EVM spectrum by subcarrier, and a summary table of measurement results.

When LTE frequency band is 2.38~2.40GHz, EVM is -31.2dB in case of no interference. If the WiFi interference power level is 10dBm, LTE EVM is -22.7dB.It is shown in Figure 3.

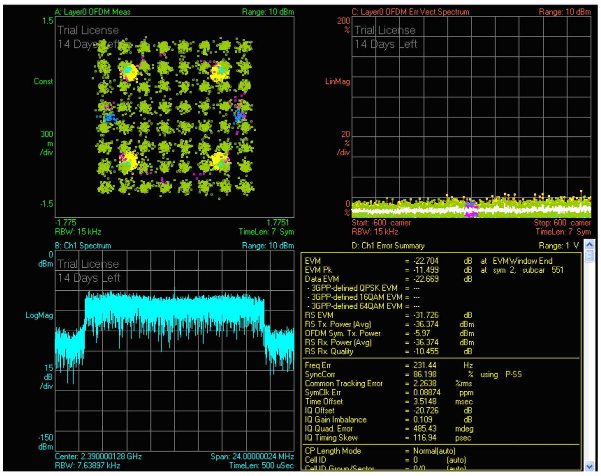

Figure 3. LTE EVM with 1st adjacent channel interference

When LTE frequency band is 2.36~2.38GHz, EVM is -30.8dB in case of no interference. If the WiFi interference power level is 10dBm, LTE EVM is -25.09dB. It is shown in Figure 4.

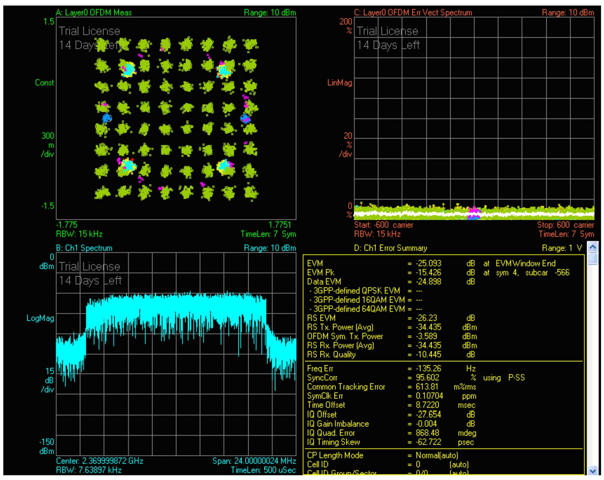

Figure 4. LTE EVM with 2nd adjacent channel interference

When LTE frequency band is 2.34~2.36GHz, EVM is -30.7dB in case of no interference. If the WiFi interference power level is 10dBm, LTE EVM is -29.89dB. It is shown in Figure 5.

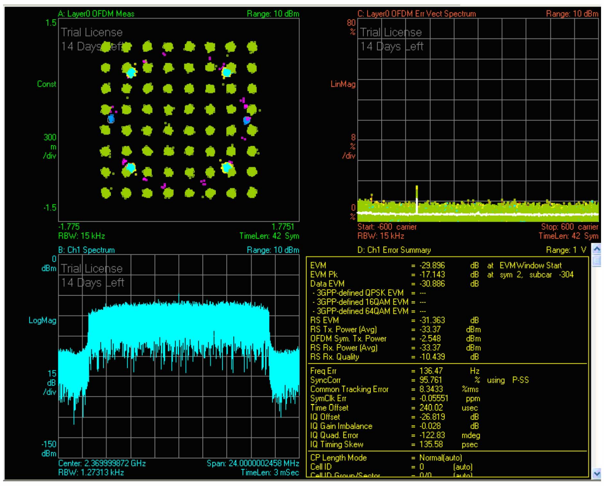

Figure 5. LTE EVM with 3rd adjacent channel interference

C. *Comparison between analysis and test results*

In the calculation, when the vertical distance between the antennas is 1m, 64dB isolation can be provided. According to (1), for the 1st adjacent channel, ACIR is 38dB. For the 2nd adjacent channel, ACIR is 45dB. For the 3rd adjacent channel, ACIR is 60dB.

For the 1st adjacent channel, the total isolation is 64+38=102dB. For the 2nd adjacent channel, the total isolation is 64+45=109dB. For the 3rd adjacent channel, the total isolation is 64+60=124dB.

As mentioned, when the interference power is 10dBm, the total isolation requirement is 10-(-103) =113dB.

The comparison between the theory and test results is shown in Table V In the table, the EVM degradation in theory equals *required isolation - provided isolation* + 0.8dB. 0.8dB is the sensitivity degradation when *I/N* equals -7dB as mentioned in part II.

TABLE V. COMPARISON BETWEEN THEORY AND TEST RESULTS

Interference channel	***Tested EVM (dB)***	***EVM degradation in the test (dB)***	***Required isolation (dB)***	***Provided isolation (dB)***	***EVM degradation in theory (dB)***
1st adjacent channel	-22.7	8.5	113	102	11.8
2nd adjacent channel	-25.09	5.7	113	109	4.8
3rd adjacent channel	-29.89	0.8	113	124	0

Considering the error tolerance, the theory calculation and test results match each other.

From the test results, when the interference transmit power is 10dBm, the 3rd adjacent channel should be used.

If the interference power is higher such as 20dBm, the 3rd adjacent channel also should be used because the isolation can meet the requirement.

If the interference power is 30dBm, the required isolation is 133dB according to Table III. The provided isolation based on the test platform is not enough. If the antenna vertical distance is 2 meters, the provided isolation will be 76(antenna isolation as shown in Table III) + 60 (ACIR for the 3rd adjacent channel) = 136dB, this can meet the requirement. Therefore, the 3rd adjacent channel can be used.

Another issue is that ACIR value of the RFIC we used in the test is not good enough for LTE. Along with the RFIC development, ACIR value will be much better. According to Table II and Table III, if the RFIC ACIR for the 1st adjacent channel can reach 59dB, it's possible to use the 1st adjacent channel in LTE Femto and WiFi co-located system when the interference power is 20dBm. If the RFIC ACIR for the 1st adjacent channel can reach 69dB, it's possible to use the 1st adjacent channel in LTE Pico and WiFi co-located system when the interference power is 30dBm.

IV. CONCLUSIONS

In this paper, the co-location interference between LTE and WiFi system is analyzed and tested. The analysis and test results show that LTE and WiFi can be co-located by using sufficient isolation provided by ACIR and antenna separation.

When LTE Pico and WiFi systems are co-located and WiFi interference transmitted power is 30dBm, one system should be deployed at the 3rd adjacent channel to the other and the vertical distance between antennas should be no less than 2 meters.

When LTE Femto and WiFi systems are co-located and WiFi interference transmitted power is no more than 20dBm, the isolation requirement is not so stringent. However, it is not feasible to make the vertical distance between antennas be 2 meters indoors at home due to space limit. Therefore, when LTE Femto and WiFi systems are co-located indoors, if the antenna vertical distance is 1 meter, one system should work at the 3rd adjacent channel to the other.

ACKNOWLEDGMENT

This work is sponsored by Nokia Siemens Networks Technology（Beijing）Co. Ltd.

REFERENCES

[1] 3GPP TR 25.913, "Requirements for Evolved UTRA (E-UTRA) and Evolved UTRAN (E-UTRAN)", 2009

[2] IEEE 802.11, "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications (2007 revision), IEEE-SA, June,2007

[3] Wang Jianhai, Duan Jun. "Researcch on co-location interference among TD LTE, TD-SCDMA and GSM", Telecommunications science magazine, vol. 6, 2009

[4] M.2039-1(2009), "Characteristics of terrestrial IMT-2000 systems for frequency sharing/interference analyses", 2009

[5] AUSPI presentation to TRAI on spectrum response to COAI

[6] European Radio Communications committee – ERC Report 65 (Noise Floor: -103 dBm)