Study on the Effect of LTE on the Coexistence of NB-IoT

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***Abstract*—The 3GPP Release-13 has introduced a Narrowband Internet of Things (NB-IOT) which is capable of Low Power Wide Area (LPWA) IoT service. NB-IoT can interfere with LTE cellular because the NB-IoT uses the license band differently from the LPWA IoT (Sig-fox, LoRa, and so on) using the unlicensed band. In this paper, it is shown that NB-IoT can cause interference even though subcarrier frequency 15 kHz like LTE is used, and the degree of interference is shown through testing. The test results show how to suppress NB-IoT interference for LTE and LTE resource allocation.**

Keywords—Low Power Wide Area (LPWA), Narrowband Inrernet of Things (NB-IoT)

I. Introduction

The 3GPP LTE Release 13 enables large-scale machine-type communications through NB-IoT standardization and will be enhanced through the Release 14 standard [1][2][3]. NB-IoT is a cellular radio access technology that provides low-power wide-area (LPWA) IoT connectivity in licensed spectrum band, unlike short-range technologies (Bluetooth, ZigBee, and so on) and LPWA technologies (Sig-Fox, LoRa, and so on) in unlicensed spectrum band. NB-IoT, which uses LTE technology in the licensed spectrum band, may interfere with the LTE system and cause service disruption.

In this paper, to investigate the interference effect between NB-IoT and LTE, we investigate LTE degradation phenomenon and analyze the result when NB-IoT and LTE coexist in the spectrum band. How to reduce LTE system performance degradation with NB-IoT and LTE, and LTE resource allocation are discussed.

II. Operation mode of NB-IoT

The NB-IoT can be used in the in-band mode and the guard-band mode, which can be used coexist the LTE in the LTE spectrum band, and the stand-alone mode using the NB-IoT single spectrum band. Figure 1 shows the in-band mode using allocated resources in the LTE spectrum band and the guard-band mode using the guard-band region in the LTE spectrum band but not allocated LTE resources.

NB-IoT carrier spacing is 15 kHz as in LTE, and carrier spacing 3.75 kHz is available in uplink. When using uplink carrier spacing 3.75 kHz, it may interfere with LTE because it is different from LTE carrier spacing 15 kHz.

In this paper, in order to investigate the effect of NB-IoT carrier spacing 15 kHz such as LTE, we compare error vector magnitude (EVM) measurement of interference level when LTE and NB-IoT coexist as follows.

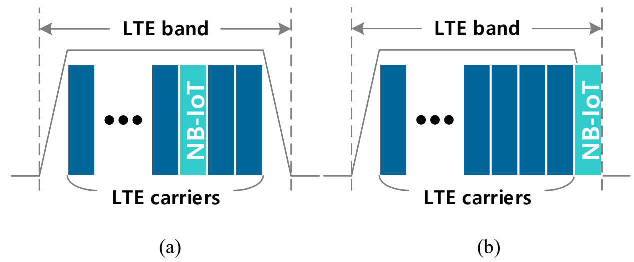

Figure 1. Operation modes of NB-IOT in LTE band (a) In-band mode (b) Guard-band mode

III. Experiment

In order to investigate the interference effect of LTE and NB-IoT, 3GPP Rel.13. Standard LTE signal and NB-IoT signal are generated through Keysight signal studio software (N7624B). The NB-IoT RF module shown in Figure 2 consists of an RF stage with LNA, PA and RF front-end, and a digital stage for RF control and signal loopback functions. The NB-IoT RF module can operate FDD- LTE BW 20 MHz and transmit and receive LTE signals and NB-IoT signals in the same band. In the wireless environment, spectrum analysis uses the Keysight LTE/LTE-A FDD measurement application software (N9080C).

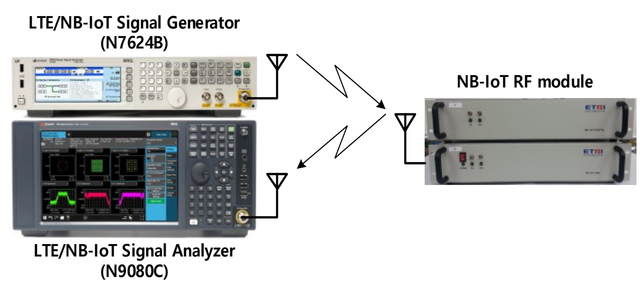

Figure 2. An environment for LTE and NB-IOT interference testing including LTE/NB-IoT signal generator, LTE/NB-IoT signal analyzer, and NB-IoT RF module

In the downlink shown in Figure 3, the NB-IoT signal is fixed in the guard band and only the LTE 64QAM 1 RB signal is generated and the LTE EVM is measured while moving from RB index 0 to 99. The interference level with respect to the distance between the LTE and the NB-IoT can be determined by measuring the LTE EVM. As in the downlink, the NB-IoT signal in the uplink is fixed in the guard band and only the LTE 64QAM one RB signal is generated, and the LTE EVM is measured while moving from RB index 0 to 99. Uplink carrier spacing is 15 kHz and 3.75 kHz. In this paper, we focus more on NB-IoT carrier spacing 15 kHz, so when LTE source location is fixed to RB 50 and uplink carrier spacing is 15 kHz and 3.75 kHz, Compare the degree.

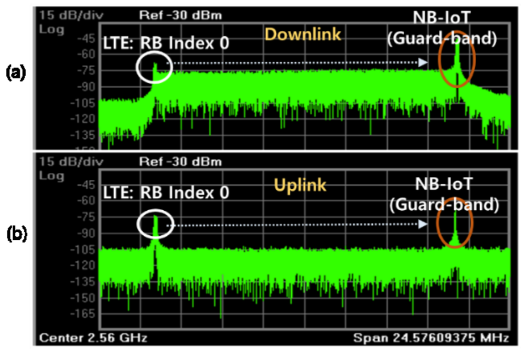

Figure 3. LTE and NB-IoT interference test method: The NB-IoT is fixed in the guard-band and the LTE signal is moved from RB position 0 to 99 operation. (a) downlink spectrum (b) Uplink spectrum

The reason why the NB-IoT signal power spectrum peak is much larger than the LTE signal power spectrum peak is that the signal power according to the band is equally allocated at the time of signal generation. If the NB-IoT signal is large for the LTE signal, the entire LTE signal band is interfered and there is no difference in the power discrimination power depending on the distance. Therefore, in the experiment, spectrum power per carrier is equalized to see LTE and NB-IoT interference.

IV. Measurement and Result

Figure 4 shows the LTE constellation showing that LTE carrier spacing and other NB-IoT carrier spacing 3.75 kHz have more impact on LTE than NB-IoT carrier spacing 15 kHz. NB-IoT carrier spacing 3.75 kHz used in remote IoT terminal services or poor channel conditions is highly interfering with LTE, so use NB-IoT standalone mode or suppress the signal side band with NB-IoT sharp filter.

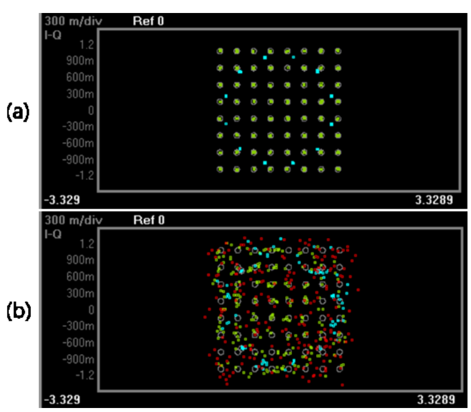

Figure 4. An example of signal constellation where LTE 64QAM 1 RB signal is located at RB 95 position. NB-IoT carrier spacing is (a) 15 kHz (b) 3.75 kHz

Before looking at performance degradation between LTE and NB-IoT, EVM is measured and referenced when LTE and NB-IoT are standalone. In case of LTE with 20 MHz BW, we can have 100 resource blocks (RB). Figure 5 shows an example of signal constellation where LTE 64QAM 1 RB signal is located at RB 50 position. Figure 6 shows the EVM measured while moving the LTE 64QAM 1 RB signal from RB 0 to 99.

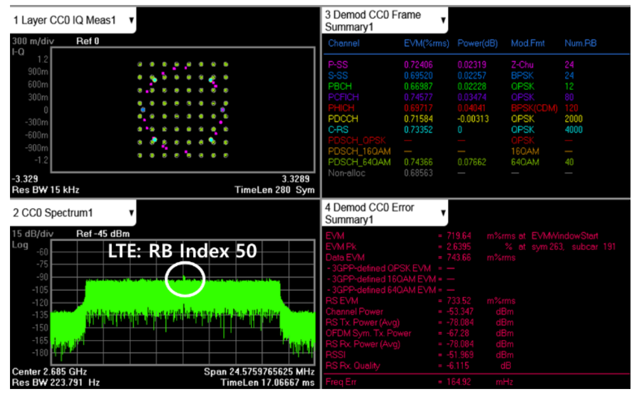

Figure 5. An example of signal constellation where LTE 64QAM 1 RB signal is located at RB 50 position., measurement by each channel in a frame summary, error measurement in a frame, and signal spectrum from left-top in the clockwise direction

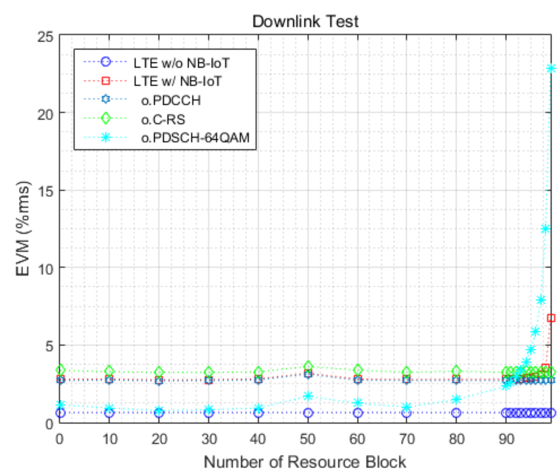

Figure 6. LTE EVM with NB-IoT located in the downlink guard-band and LTE downlink 20 MHz bandwidth RB location

Figure 6 shows LTE EVM with NB-IoT located in the downlink guard-band and LTE downlink 20 MHz bandwidth RB location. The value of RMS EVM of LTE is composed of signaling channels and shared channels, is increased by NB-IoT signal and the LTE EVM increases over all bands. The LTE EVM value increases sharply as it approaches the upper guard band where NB-IoT is located. Signaling channel PDCCH and C-RS, which are highly affected by EVM, are affected by RB close to NB-IoT, but distributed uniformly over all bands and have EVM averages over all bands. Unlike the signaling channels, the PDSCH-64QAM EVM increases sharply as the shared channels allocated to one RB are affected by the entire shared channel as the NB-IoT approaches, and this PDSCH-

64QAM EVM value can not satisfy the 3GPP PDSCH-64QAM EVM requirement (< 8%) [3]. Therefore, even if the carrier spacing of LTE and NB-IoT is the same, performance degradation occurs due to interference, and it is difficult to allocate LTE resources to RBs adjacent to NB-IoT. When used in NB-IoT in-band mode, LTE resource allocation has a resource allocation restriction twice that of NB-IoT guard band mode, and LTE resources should be allocated with more than 3 RBs on both sides of NB-IoT.

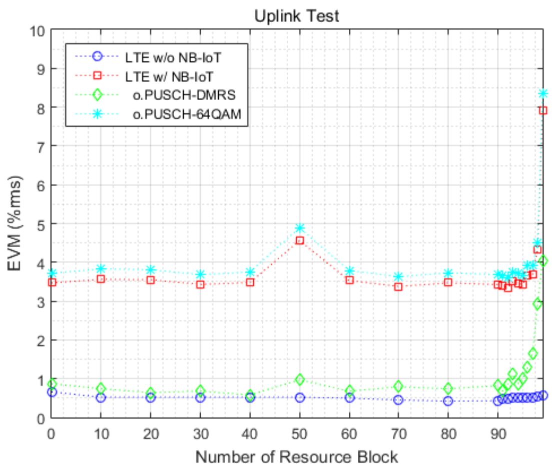

Figure 7. LTE EVM with NB-IoT located in the uplink guard-band and LTE uplink 20 MHz bandwidth RB location

Figure 7 shows LTE EVM with NB-IoT located in the uplink guard-band and with LTE uplink 20 MHz bandwidth RB location. Similar to the downlink, LTE EVM is affected by all the LTE channels for NB-IoT. Uplink resources are composed of PUSCH-DMRS for synchronization and PUSCH-64QAM for data transmission. Unlike Downlink shared channels, which are distributed all over the band, uplink resources are allocated to all the carriers of the designated RB. Therefore, the EVM increases rapidly as the uplink resource approaches NB-IoT. This is the reason why EVM increases sharply as downlink shared channels approach NB-IoT. As with Downlink, use of guard-band mode is more flexible for LTE resource allocation than using in-band mode.

CONCLUSION

In this paper, we show that NB-IoT using license band can interfere with existing cellular. The interference caused by LTE using the NB-IoT uplink carrier spacing 3.75 kHz occurs at the Nb-IoT uplink carrier spacing 15 kHz. Using NB-IoT guard-band mode allows LTE resources to be used more efficiently than NB-IoT in-band mode. This is because the NB-IoT in-band mode can not allocate LTE resources by interfering with LTE on both sides of the allocated NB-IoT.

In order to reduce interference to LTE, NBIoT can reduce interference by equalizing the power per carrier equal to that of LTE. However, in case of NB-IoT for wide area service, it is necessary to increase the NB-IoT transmission output power, and the use of LTE channel adjacent to NB-IoT is limited. LTE resource allocation according to NB-IoT transmit power size requires trade-off.

In further work, we will investigate the cause of performance degradation in the vicinity of the DC carrier in both downlink and uplink due to the coexistence of LTE and NB-IoT, and the reason why the LTE EVM increases even though the uplink resources are far from the NB-IoT applied filter.

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