# Development of LTE Baseband LSI and ExpressCard Terminal for Mobile Devices

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**Fujitsu has developed ExpressCard device for Long Term Evolution (LTE) systems. This device is provided for Xi "crossy," an LTE service offered by NTT DOCOMO in Japan, and it achieves a downlink speed of up to about 75 Mb/s, which is more than ten times faster than the existing systems. In order to achieve a high data transmission rate with a device that is in the form of a card, state-of-the-art technologies have been applied such as current consumption reduction with thermal release technologies or breakthroughs in techniques for installing multiple antennas and LSIs onto a small and thin circuit board. This device uses an LSI developed as a communication platform which provides a fundamental communication function for future mobile devices for LTE systems. This paper also touches on several aspects of this baseband LSI and its future direction.**

## 1. Introduction

In Japan, mobile phone services have been developed from voice communication into various forms including e-mail, image transmission and video distribution, and this has caused a continued dramatic increase in the use of packet communication. At the end of 2010, NTT DOCOMO started a service called "Xi" (Crossy).[note)] This service adopts the Long Term Evolution (LTE) standards, which allow high-speed data communications at a rate of 100 Mb/s, to provide functions such as high-speed communications of up to 75 Mb/s. With smart phones, which have become tremendously widespread recently, an always-on connection is a prerequisite for their use.

To meet the needs of this full-scale broadband age, Fujitsu developed F-06C, an ExpressCard-type device compliant with LTE, and started delivering it to NTT DOCOMO in April 2011. F-06C integrates an LTE communication platform jointly developed by Fujitsu, NTT DOCOMO, NEC CASIO Mobile Communications and Panasonic Mobile Communications.

This paper presents the specifications of the LTE baseband LSI, which lies at the core of LTE communication platform, and some of the state-of-the-art technologies applied to the development of ExpressCard device. This paper also touches on the future direction in which development should head.

## 2. LTE communication platform

To put a mobile device onto the market in a timely manner while filling the needs of communication performance that evolve on a daily basis, a communication platform strategy is important.

The LTE communication platform that has been developed supports a total of three communication systems: wideband code division multiple access (W-CDMA) and global system for mobile communications (GSM), which are

note) "Xi" (Crossy) and its logo are trademarks or registered trademarks of NTT DOCOMO.

already provided for commercial service networks in and outside Japan, and LTE. The present development has focused on the development schedule and efficiency and has used a companion configuration, which combines the newly-developed baseband LSI exclusively for LTE and a baseband LSI to support the existing W-CDMA/GSM (hereafter "LSI for 3G/2G"). As the RF-LSI to use in combination, MB86L10A, which was developed by Fujitsu Semiconductor, has been adopted.

**Figure 1** shows the configuration of the LTE communication platform.

## 3. LTE baseband LSI

The LTE baseband LSI is the central part for realizing an LTE communication platform and has the following features.

The major specifications of the LTE baseband LSI are shown in **Table 1**.

1) Transmission performance

This LSI is in compliance with LTE Category 3 as an LSI for devices and capable of achieving the maximum transmission rate of 100 Mb/s for downlinks and 50 Mb/s for uplinks.

Table 1
Major specifications of LTE baseband LSI.

| Item | | Downlink | Uplink |
|---|---|---|---|
| Maximum transmission rate | | 100 Mb/s | 50 Mb/s |
| Wireless access system | | OFDM | SC-FDMA |
| Modulation scheme | | 64QAM | 16QAM |
| Duplex | | FDD | |
| Carrier frequency band | | Up to 5 bands supported | |
| System bandwidth | | 1.4, 3, 5, 10, 15, 20 MHz | |
| Base station transmitting antenna | | 1, 2, 4 | |
| Receiving antenna | | 1, 2 | |
| MIMO | | 2 × 2, 4 × 2 supported; SU-MIMO Precoding provided | |
| | code word | 1 or 2 | |
| Receive diversity | | 2-branch antenna diversity | |
| ACPU-IF | | General-purpose memory interface | |
| RF-IF | | Compliant with MIPI Dig-RFv4 | |
| Inter-RAT support | | LTE ⇔ 3G: Reselection/Redirection, PS H.O. | |
| | | LTE → 2G: Reselection/Redirection | |
| | | LTE ← 2G: Reselection/Redirection (CS) | |
| Voice support | | CS fallback support LTE → 3G, LTE → 2G | |

Slightly different from the major specifications of ExpressCard device.

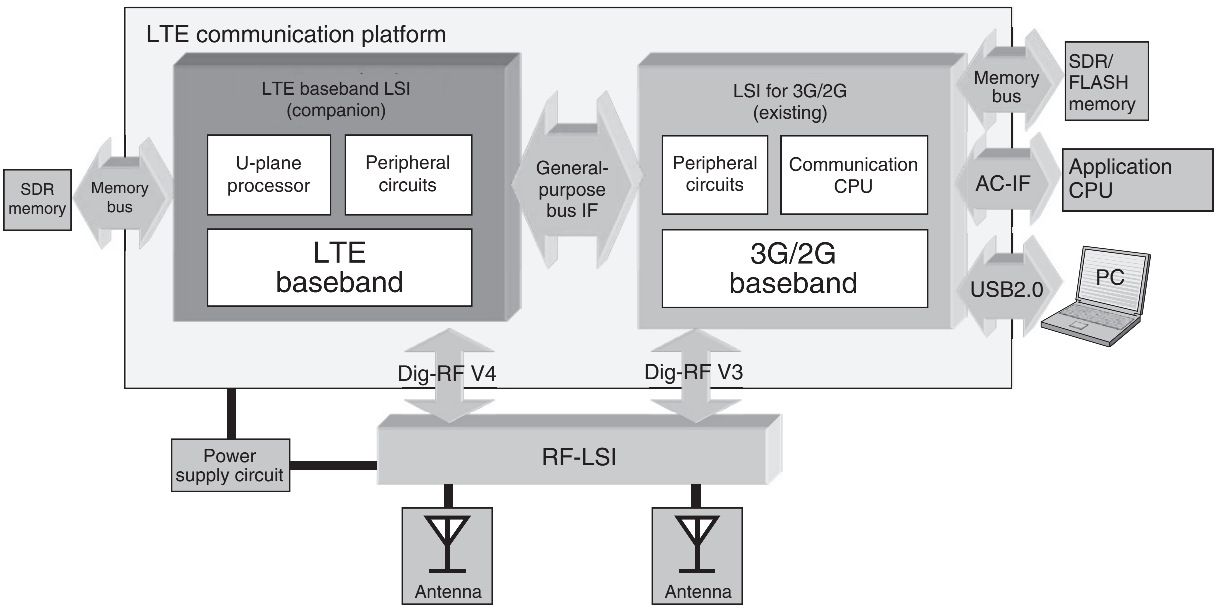


Figure 1
LTE communication platform.

Regarding the throughput as the entire platform, operation at 93 Mb/s for downlinks and 42 Mb/s for uplinks has been confirmed (in connection conditions that take into account the actual use environment).

To connect with a PC, a USB interface is used via an existing LSI for 3G/2G. The designed maximum transmission performance of the existing LSI is 7.2 Mb/s for downlinks and 5.7 Mb/s for uplinks. This gave rise to concerns that it might become a bottleneck in terms of performance. However, the target throughput performance has been achieved by optimizing the processing load on the LTE baseband LSI.

2) Wireless access system

LTE uses a different wireless access system from W-CDMA, which is used for the existing 3G. Orthogonal frequency division multiplexing (OFDM) is adopted for downlinks, thereby achieving high-speed transmission and improved frequency utilization efficiency.

3) Carrier frequency

As a carrier frequency, this LSI is capable of supporting up to five frequency bands. By combining an appropriate radio frequency LSI (RF-LSI), it can serve major international markets.

4) System bandwidth

Bandwidths between 1.4 and 20 MHz in compliance with standards are supported, which provides the LSI with flexibility to accommodate the services of the individual carriers.

5) MIMO

As a means to improve reception performance, a receiving function that supports 2 × 2 and 4 × 2 multiple input multiple output (MIMO) is provided to optimize the MIMO processing algorithm. In this way, the performance is ensured without increasing the circuit scale.

6) RF-LSI interface

An RF-LSI interface compliant with the MIPI Dig-RF (ver. 4) is adopted. A high-speed serial interface is used to connect the RF-LSI with the baseband LSI, thereby reducing the number of signal lines and improving the noise resistance. The use of the standards allows connection with RF-LSIs provided by different vendors.

7) Inter-RAT handover support

The combination with existing LSIs for 3G/2G has made it possible to achieve a handover between LTE and the two existing communication systems (3G/2G). Smooth operation that allows switching between communication systems to be transparent to users is thus achieved.

8) CS fallback support

In a mixed environment with both the existing voice service (CS call) and LTE network, a function to interrupt LTE communications to switch to CS calls is supported. This realizes a voice service during LTE communication (CS fallback system).

This LSI supports the CS fallback function.

9) General-purpose bus interface (bus IF)

This LSI has a configuration of a companion LSI added on to an existing LSI for 3G/2G. A 32-bit general-purpose memory interface is used as the bus IF with the existing baseband LSI. This allows connection with various LSIs for 2G/3G.

10) Current consumption

As the circuit scale and built-in memory size become larger, the leakage current in the LSI increases. In this platform, the power supply group is segmentalized for granular control, thereby realizing reduced leakage current.

11) Package size

The LSI is packaged in a 12 mm × 12 mm BGA package. To reduce the number of pins, the layout of the power supply and ground line terminals has been optimized and functions have been combined as well to make a 320-pin package.

## 4. Development of ExpressCard device

For the development of an LTE data device, issues such as PC interface selection, device size and thickness reduction, current consumption reduction and suppression of device temperature rise needed to be resolved. The following describes the technological challenges and their solutions that provided key to the development.

1) Selection of PC interface

For the development of a data device that connects to a PC, a configuration that allows connection to a standard interface provided in a PC is necessary. Wireless interfaces such as wireless LAN have problems with current consumption and size reduction and the USB standard has difficulties in terms of current supply (500 mA max. at 5 V) in view of communication speed increase. Accordingly, an ExpressCard system has been adopted, considering the latest trends of PC expansion card interfaces. To provide compatibility with existing PCs equipped only with a PC card slot, a PC card conversion adapter has been commercialized as an option.

2) Device size and thickness reduction

LTE uses a MIMO communication system for realizing high-speed data communications. For this reason, a sub antenna must be installed in addition to the regular main antenna. On top of the space-efficient layout of the two antennas, it is necessary to maintain low correlation of characteristics between the main and sub antennas for ensuring the characteristics of MIMO. Accordingly, a new technology has been adopted to optimally control the housing current, thereby achieving good communication characteristics as well as making the device smaller by reducing the space between the two antennas. An external view of F-06C is shown in **Figure 2** and the major specifications in **Table 2**. The LTE communication platform adopted requires the additional mounting of an LTE baseband LSI as a companion chip on top of an existing LSI for 3G/2G. To fulfill this need, BGA package double-sided mounting, which has often been used for mobile products in recent years, has been applied and artwork technology for preventing terminal lifting due to warping of a printed board has been used to achieve high-density, low-height mounting.

Furthermore, with this card device, measures have been taken to ensure the characteristics of the built-in antenna so as to achieve good communication performance without using an external antenna. Specifically, the following measures have been taken.

- Improved gain of the built-in antenna
- Suppressed the noise component radiating from the card device's main unit and entering via the antenna
- Suppressed the noise component radiating from the PC main unit and entering via the antenna


Figure 2
F-06C.

Table 2
Major specifications of F-06C.

| Configuration | ExpressCard/34 |
|---|---|
| Size (H × W × T) | 115.0 × 34.0 × 5.0 mm<br>Thickest part: 10 mm |
| Weight | Approx. 35 g |
| Maximum transmission rate | Downlink: 75 Mb/s, Uplink: 25 Mb/s |
| International roaming | 3G, GSM |

In this way, the requirements of Over The Air (OTA) performance, or the overall wireless performance with the antenna characteristics taken into account, have been satisfied. In addition, the need for a connector to connect an external antenna has been eliminated to allow implementation in the form of a card.

3) Current consumption reduction

To allow operation with a level of current that can be supplied in accordance with the ExpressCard standards, of the two systems of power supply, namely the main (1.0 A at 3.3 V) and sub power supply (500 mA at 1.5 V), power from the main power supply that does not require boosting has been adopted for the card device. The following current reduction measures have been taken to successfully suppress the current consumption to 950 mA or less, or within the limits of the standards.

- Allocated the optimum power supply according to the current consumption of the individual operation block (optimization of the power supply system)
- Improved power efficiency by dynamically controlling power voltage of the RF power amplifier, which consumes the most current during communication, according to the communication mode

4) Suppressed device temperature rise

To suppress the temperature rise of the card device, detailed thermal analysis simulation has been conducted so as to optimize parts layout in the phase before the prototype design. In addition, a thermal release sheet has been used in hot spots, thereby successfully suppressing any temperature rise on the card device surface.

## 5. Future direction

In this development, an LTE communication platform has been realized in a companion chip configuration, which uses the LTE baseband LSI in combination with an existing LSI for 3G/2G. Devices that support LTE and those that do not are expected to coexist for the time being. Hence, a configuration capable of flexibly switching between supported systems by use or non-use of a companion chip is considered effective.

The card device compliant with the LTE mentioned in this paper does not require a so-called application processor to be mounted. An application processor can be connected to constitute a handset device, which can be realized by installing the LTE baseband LSI together with an LSI for 3G/2G and various peripheral devices.

Furthermore, a number of LSIs must be mounted more efficiently so as to reduce device size and thickness, and technology to package multiple LSIs in high density is also being developed.

LSI process technology in the future is expected to be capable of further miniaturization and thus allow higher-density LSIs. It will be important to integrate the LTE and 3G/2G functions into a single chip by applying the cutting-edge semiconductor technology to further reduce cost, size and power consumption.

In the LTE-Advanced system, the successor of LTE, an ultrahigh-speed communication of 1 Gb/s will be provided. To achieve a dramatic improvement in performance, we intend to study architecture capable of meeting the processing performance requirements in a scalable manner.

## 6. Conclusion

This paper has presented a communication platform that supports the LTE communication system providing high-speed data communication of 100 Mb/s and ExpressCard device to which the platform is applied.

To achieve communication technology that supports the LTE-Advanced system, the most prospective candidate of ultrahigh-speed communication, we intend from now on to make use of the results obtained and challenges found in the present development. We will thus move forward with the development of a communication platform and mobile products.

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