3GPP Release 11 | Interference-rejection Technology | Mobile-device Performance

Technology Reports

Further Development of LTE/LTE-Advanced – LTE Release 10/11 Standardization Trends –

Improved Interference Rejection and Suppression Technology in LTE Release 11 Specifications

To handle recent large increases in traffic, cell density is increasing. The accompanying increase in interference from adjacent cells is becoming a issue, so there is a need to reduce this interference.

In this article, we give an overview of technologies newly introduced into the Release 11 LTE specifications at the 3GPP, which increase the performance of mobile devices by rejecting and suppressing interference. Specifically, we describe interference rejection combining receivers that use multiple receiver antennas on the mobile terminal to suppress interference arriving from adjacent cells. This improves throughput performance, mainly near cell boundaries.

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1. Introduction

To deal with the sharp increase in traffic due to the recent spread of smartphones and other factors, cell[*1] density is being increased, and as a result, interference from adjacent cells is also increasing. Also, when operating Heterogeneous Networks (HetNet)[*2] with small cells[*3] inside macrocells[*4] using a single frequency, interference between the macro-cell and small-cells is even greater. In this sort of area, the power of the interference signal reaching the mobile terminal from adjacent cells is large compared to that of the noise signal, and this interference degrades throughput[*5] performance.

In this article, we describe extensions in the Release 11 LTE specifications (hereinafter referred to as "Rel. 11 LTE") using technologies studied at the 3GPP to improve the performance of mobile terminals.

2. Overview of Mobile-device Interference Rejection/Suppression Technology

Rel. 8 LTE mobile terminal performance stipulations were set assuming receivers using Minimum Mean Squared Error (MMSE)[*6] and the stan-

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*1 **Cell**: The smallest unit of area in which transmission and reception of wireless signals is done between a cellular mobile communications network and mobile terminals.

*2 **HetNet**: A network configuration that overlays nodes of different power. It typically includes picocell, femtocell, Wi-Fi and other base stations of lower power than conventional base stations, mixing, linking and integrating multiple technologies.

dard Rel. 8 LTE MMSE receivers process reception assuming that the effects of interference from adjacent cells will be comparable to that of noise received by the mobile terminal. Thus, in environments where the power of the interference signal is larger than that of the noise, interference from adjacent cells restricts throughput.

Rel. 11 LTE has introduced MMSE-Interference Rejection Combining (MMSE-IRC) receivers [2] as a mobile terminal interference rejection and suppression technology to mitigate the effects of these interference signals and increase user throughput*7 even in areas that are recently experiencing high interference. Rel. 8 LTE receivers support MIMO transmission technology*8, so receivers were equipped with at least two antennas since it was first introduced. The MMSE-IRC receivers in Rel. 11 LTE, are able to use the multiple receiver antennas to create points, in the arrival direction of the interference signal, where the antenna gain*9 drops ("nulls"*10) and use them to suppress the interference signal (**Figure 1**). The terminal orients a null toward the main interference signal, which is the signal that particularly affects the degradation of throughput, thereby improving the Signal-to-Interference-plus-Noise power Ratio (SINR)*11 and improving throughput performance. However, with the original MIMO multiplexed transmission, which realized high throughput using multiple transmit and receiver antennas, the receiver antennas are used to separate the signals between layers, so interference from adjacent cells cannot be suppressed and throughput cannot be improved, particularly for mobile terminals with two receiver antennas.

On the other hand, the 3GPP has already included interference rejection and suppression technology in performance specifications for mobile terminals equipped with W-CDMA/High-Speed Downlink Packet Access (HSDPA)*12 in Rel. 7 of the Universal Mobile Telecommunications System (UMTS). With W-CDMA, receivers normally use one receiver antenna and perform Rake reception*13, but the effects of multipath*14 interference degrading reception performance was an issue. Thus, the following three receiver extensions were studied and introduced.

- Type 1/1i extends the Rake receiver to use two antennas.
- Type 2/2i extends the Rake receiver to an MMSE receiver that suppresses multipath and adjacent-cell interference.
- Type 3/3i extends the MMSE interference-suppressing receiver defined in Type 2/2i to use two receiver antennas.

The functional extensions in receivers in Rel.7 UMTS and Rel. 11 LTE are summarized in **Table 1**. The MMSE-IRC receivers in Rel. 11 LTE incorporate receiver algorithms that are generally equivalent to those in the Type 3/3i receivers introduced in W-CDMA/HSDPA. However, in the W-CDMA/HSDPA receivers they also operate to suppress inter-coding interference within a cell. There is no interference within a cell in LTE systems, so in the MMSE-IRC receivers introduced in Rel. 11 LTE, they operate to suppress interference arriving from adjacent cells.

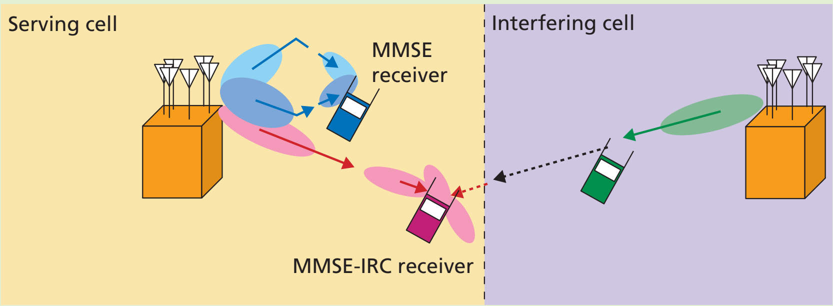

Figure 1 Network structure handled with mobile-device extensions

*3 **Small cell**: A general term for cells that transmit with power that is low compared to that of a macrocell transmitting at higher power.

*4 **Macrocell**: An area in which communication is possible, covered by a single base station, and with a radius from several hundred meters to several tens of kilometers.

*5 **Throughput**: The amount of data transmitted without error per unit time, i.e., the effective data transfer rate. In this article, throughput is defined as the (data rate on the transmission side) x (number of packets received without error per unit time) / (number of packets transmitted per unit time).

*6 **MMSE**: A method for suppressing interference from other signals by multiplying the received signal with calculated weights.

*7 **User throughput**: The amount of data that one user can transmit without error per unit time.

*8 **MIMO transmission technology**: A signal transmission technology that improves communications quality and spectral efficiency by using multiple transmitter and receiver antennas for transmitting signals at the same time and same frequency.

*9 **Antenna gain**: The power emitted by an antenna relative to an ideal antenna.

*10 **Null**: A direction in the beam pattern for which the antenna gain is very small.

Table 1 Receiver function extensions

	Rel.7 UMTS	Rel.11 LTE
Basic configuration	Rake receiver (one receiver antenna)	MMSE Receiver (two receiver antennas)
Mobile device extensions	Type 1/1i: · Rake reception with two receiver antennas Type 2/2i: · MMSE receiver suppressing multi-path and adjacent-cell interference · One receiver antenna Type 3/3i: · MMSE receiver suppressing multi-path and adjacent-cell interference · Two receiver antennas	· MMSE-IRC receiver (two receiver antennas)

3. Extension to Rel. 11 MMSE-IRC Receivers

As described above, the MMSE-IRC receivers introduced in Rel. 11 LTE use multiple receiver antennas to direct a null toward the interference signal from an adjacent cell, suppressing that interference signal.

We now describe the MMSE receivers that are standard in Rel. 8 LTE. MMSE receivers handle interference included in the signals they receive as noise, and generally combine the signals received at the receive antennas as expressed by the following equation.

$$\hat{\mathbf{d}}_1=\mathbf{W}_{\mathrm{Rx},1}\mathbf{r} \quad (1)$$

Here, $\mathbf{W}_{\mathrm{Rx},1}$ is a receiver weight matrix*15 used to combine the signals from the two receiver antennas, and can be expressed as follows.

$$\mathbf{W}_{\mathrm{Rx},1}=P_1\mathbf{H}_1^H\mathbf{R}^{-1} \quad (2)$$

$$\mathbf{R}=P_1\mathbf{H}_1\mathbf{H}_1^H+\sigma^2\mathbf{I} \quad (3)$$

Here, $\hat{\mathbf{d}}_1$ is the signal after reception processing, $\mathbf{r}$ is the received signal vector, $\mathbf{H}_1$ is the channel matrix*16 between the serving cell and the terminal, P_1 is the transmit power of the serving cell, and $\mathbf{I}$ is the identity matrix*17. When computing the channel covariance matrix*18, $\mathbf{R}$, the interference signal component is included in the noise power, σ^2. Since interference signals are handled as equivalent to noise in this way, the arrival direction of the noise is ignored, and the quality is maximized with respect to the interference and noise power.

In contrast, with MMSE-IRC receivers, interference signals are considered independently of noise components instead of handling them as equivalent to noise. The covariance matrix, $\mathbf{R}$, in Equation (2) handles the noise component independently, as shown in the following equation.

$$\mathbf{R}=P_1\mathbf{H}_1\mathbf{H}_1^H+\sum_i P_i\mathbf{H}_i\mathbf{H}_i^H+\sigma^2\mathbf{I} \quad (4)$$

Here, $\mathbf{H}_i$ (i>1), is the channel matrix between the i^{th} interfering cell and the mobile terminal, and P_i is the transmit power from the interfering cell. $\mathbf{H}_i\mathbf{H}_i^H$ expresses the degree of correlation in the interference signal from the i^{th} cell, and by using the inverse correlation (inverse matrix) of the interference signal as a receiver weight matrix, the coefficients corresponding to the main interference signal can be reduced, suppressing it. The interference signal is suppressed by orienting a null in the direction of its arrival. Then, the reception quality of the interference and noise components after suppression is maximized. Due to suppression of the interference signal, the SINR is higher than for an MMSE receiver, so higher throughput can be achieved.

Note that Rel. 11 LTE MMSE-IRC receivers can be used on Rel. 8 LTE based systems, so interference suppression effects can be obtained on Rel. 8 LTE networks that have already begun commercial services.

The results of throughput improvements due to MMSE-IRC receivers are shown in **Figure 2**. The graphs have throughput on the vertical axis, and average received SINR on the horizontal axis, and show the results for mobile terminals moving at 3 km/h and 30 km/h, assuming motion at speeds of

*11 **SINR**: The ratio of desired-signal power to the sum of all other interference-signal power and noise power.

*12 **HSDPA**: A high-speed downlink packet transmission system based on W-CDMA. Maximum downlink transmission speed under the 3GPP standard is approximately 14 Mbit/s. Optimizes the modulation method and coding rate according to the radio reception condition of the mobile terminal.

*13 **Rake reception**: A technique for improving reception quality by collecting and receiving signals that have different propagation delays and superimposing those signals.

*14 **Multipath**: A phenomenon that results in a radio signal transmitted by a transmitter reaching the receiver by multiple paths due to propagation phenomenon such as reflection, diffraction, etc.

*15 **Receiver weight matrix**: A matrix reflecting fluctuations in amplitude and phase, and used to combine or separate signals received at multiple receive antennas. Signals can be obtained by multiplying the signal vector of the received signals by the matrix to combine or separate them.

*16 **Channel matrix**: A matrix composed of the changes in amplitude and phase on the channels between each transmit and receive antenna pair.

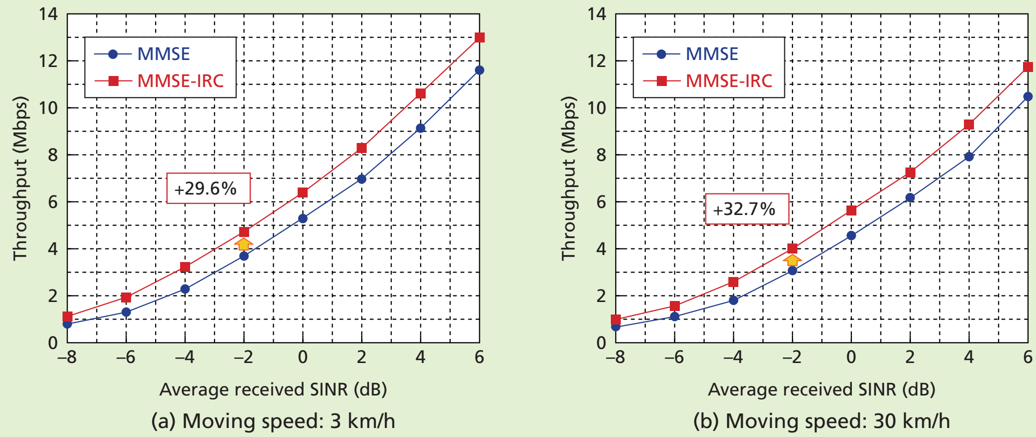

Figure 2 Throughput improvements for MMSE-IRC receiver

walking and riding in a vehicle respectively. These simulations assume high-traffic areas with two main interfering cells and with sufficiently large Interference-to-Noise power Ratios (INR) for each of the interfering signals. The results show an improvement in the throughput performance of approximately 30% compared to Rel. 8 LTE MMSE receivers at cell boundaries where SINR is low.

4. Conclusion

In this article, we have described mobile terminal interference rejection and suppression technology being standardized in Rel. 11 LTE at the 3GPP. It is a promising technology for improving user throughput in high-interference environments such as where cells are densely installed to handle recent high-traffic. This functionality can also be used with ordinary LTE, such as Rel. 8 LTE, so it can support a variety of introduction and cell-expansion scenarios.

In the future, we will continue to promote standardization toward improving mobile terminal reception performance, to further improve the performance, functionality and economy of radio access networks[*19].

References

[1] Nakamura et al.: "Overview of LTE-Advanced and Standardization Trends," NTT DOCOMO Technical Journal, Vol.12, No.2, pp.4-9, Sep. 2010.

[2] 3GPP TR36.829 V11.1.0: "Enhanced performance requirement for LTE User Equipment (UE)," 2013.

[3] 3GPP TS36.101 V11.4.0: "Evolved Universal Terrestrial Radio Access (EUTRA); User Equipment (UE) radio transmission and reception," 2013.

*17 **Identity matrix**: A square matrix with diagonal elements of one (1) and all other elements zero (0).

*18 **Covariance matrix**: A matrix whose diagonal components express the variance of each variable in a set of variables and whose other elements each express the degree of correlation between two variables with respect to their direction of change (positive/negative).

*19 **Radio access network**: The network consisting of radio base stations and radio-circuit control equipment situated between the core network and mobile terminals.