ArrayComm®

White Paper

A-MAS™- 3i Receiver for Enhanced HSDPA Data Rates

In cooperation with

A- MAS™-3i Receiver for Enhanced HSDPA Data Rates

Abstract

Delivering broadband data rates over a wider coverage area is a key operational driver for network operators. Deployment of HSDPA enables operators to offer broadband data rates to their customers. Advanced receivers are implemented in user terminals to improve the HSDPA data rates further. Already two-branch receive diversity-based type-3 receivers are entering the market to improve the delivery of data rates. The data rates delivered by type-3 receivers can be further improved by adding inter-cell interference cancellation capability.

This paper looks at an ArrayComm Multi-Antenna Signal Processing (A-MAS™) advanced HSDPA receiver, known as A-MAS™-3i. ArrayComm has developed A-MAS-3i as an extension of the type-3 receiver to enhance HSDPA data rates. A-MAS-3i is fully compliant with the 3GPP standard and requires no change in the infrastructure.

Over-the-air data was collected on 3 UK's operational HSDPA network and was post-processed to evaluate the potential gain of A-MAS-3i. The field validation proves that in certain *cell-edge* interference scenarios, A-MAS-3i can improve the average achievable throughput relative to a type-3 receiver by 29%.

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1. Introduction

HSDPA technology is considered a key component for mobile broadband delivery by the wireless operator community. Mobile data adoption is exploding due to an improved user experience and the delivery of broadband data rates over a wider coverage area. HSDPA has been rolled out by UMTS network operators to support mobile broadband data rates for their customers. Although HSDPA can achieve a theoretical peak data rate of 14.4 Mbps, the actual data rate achievable in a real network deployment varies depending on the radio conditions and user equipment capability. Interference, both intra-cell and inter-cell, may be one of the major impairments limiting the realization of higher data rates. Receiver diversity and equalization can alleviate intra-cell interference and increase the data rates, but these alone cannot overcome the challenge of inter-cell interference.

ArrayComm has been developing multi-antenna signal processing (MAS) techniques for wireless systems for more than a decade and has proved this technology in the field. ArrayComm MAS (A-MAS) techniques have been deployed for WiMAX, GSM, PHS and HC-SCDMA (iBurst) wireless systems, delivering significantly improved spectral efficiencies. It has developed an advanced HSDPA receiver, referred to as A-MAS-3i, to cancel inter-cell interference and provide improved data rates for HSDPA users. This receiver is fully compliant with the 3GPP standard and falls within the type-3i receiver category defined by 3GPP.

This document will provide the reader with a brief introduction to type-3i receivers for improved data rate delivery on HSDPA networks and demonstrate potential performance enhancement achieved by ArrayComm's A-MAS-3i receiver in real deployments. The field evaluation was performed with the co-operation and support of 3-UK in their operational HSDPA network in the United Kingdom.

2. Advanced HSDPA Receivers

2.1. Types of HSDPA Receivers

The performance of HSDPA receivers vary widely under different network conditions depending on the HSDPA receiver architecture. The 3GPP standardization body has defined different HSDPA receiver types to specify minimum performance requirements for conformance testing. In Release-99, a rake receiver-based front-end was sufficient to meet the performance needs. But a rake receiver is not adequate to meet the demands of high speed data over W-CDMA networks. The limitation of a rake front-end and the enhanced performance from equalization and receive diversity has been recognized for HSDPA reception and 3GPP has defined the following receiver types for HSDPA:

- Enhanced type-1 receivers with two-branch receive diversity
- Enhanced type-2 receivers with singe-branch equalization
- Enhanced type-3 receivers with two-branch receiver diversity and equalization

The actual receiver performance can vary widely depending on channel conditions.

2.2. Need for Interference-Aware Receivers

Receiver diversity and equalization improve the data rates delivered to the end user. Under optimal *network* situations the type-3 receivers provide high data rates; however, under certain *cell-edge* conditions the interference caused by neighboring sectors limits the achievable throughput.

Recognizing this challenge, the 3GPP standards organization has studied interference-aware receivers. Interference-aware receivers, referred to as type-2i and type-3i, were defined as extensions of type-2 and type-3 receivers respectively. These advanced receivers cancel the inter-cell interference leading to a higher throughput. The 3GPP community conducted various system level and link level simulation studies supported by real field measurements [1] on interference characteristics from the operator community. Based on technical contributions, 3GPP has now incorporated enhanced type-3i minimum performance requirements in the specifications.

The importance of receiver diversity for mobile data has been recognized and dual-branch receiver diversity HSDPA data cards are available in the marketplace. Furthermore, evolved HSPA with MIMO requires dual-branch receivers, and dual-branch receivers will become an integral feature starting with data cards and embedded modules. The advantage of a second branch in the receiver has also been recognized within the WiMAX and LTE community. It is widely expected that the baseline receivers for WiMAX and LTE will be based on two-branch receiver diversity. The widespread uptake of dual-branch receivers will add impetus for further performance enhancements using advanced receivers, such as type-3i receivers, in a cost and power efficient manner.

2.3. Characteristics of Interference in HSDPA Networks

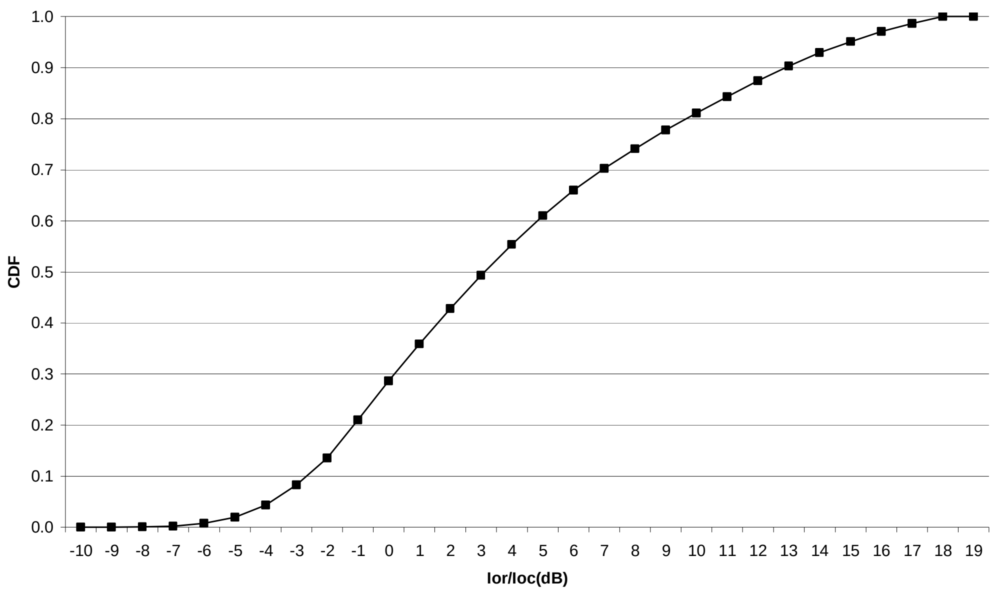
Overcoming interference is a necessary requirement in all wireless networks. In an HSDPA network this becomes a challenge in the provision of high speed data. Most HSDPA receivers incorporate equalization to overcome the intra-cell interference. However they are not effective in combating inter-cell interference. Type 3i receivers were developed to minimize the impact of interference in HSDPA deployments.

Network interference is characterized using two metrics. The Geometry G is defined as

$$G = \frac{\hat{I}_{or1}}{I_{oc}} = \frac{\hat{I}_{or1}}{\sum_{j=2}^{N_{BS}} \hat{I}_{orj} + N},$$

where $\hat{I}_{orj}$ is the average received power from the j-th strongest base station ($\hat{I}_{or1}$ implies serving cell), N is the unidentified interference and thermal noise power over the received bandwidth, and N_{BS} is the total number of base stations considered including the serving cell. Geometry is a measure of the inter-cell interference relative to the serving-cell signal power, with G = 0 dB indicating an interference and noise power equal to the serving sector signal power.

Figure 1 Distribution of geometry measured on 3-UK London Network



where $I_{oc} = \sum_{j=2}^{N_{BS}} \hat{I}_{orj} + N$.

Simulation studies in 3GPP and real network measurements submitted to 3GPP in 2006 by 3-UK based on 3-UK's London network [1] indicate that at 30% of the locations the inter-cell interference exceeded the serving sector received signal. Due to soft handover, this 30% overlap between cells works well for Release-99 networks; however for HSDPA the throughput may be limited in these areas because HSDPA supports hard handover only. This is shown in Figure 1.

Another significant observation from these measurements was that in most cases the inter-cell interference is caused by either one or two interferers, with 66% of the interference being caused by one interfering sector. In rare cases (where Geometry < -3 dB) a third interferer is present. This characterization of a real network deployment was also observed by Orange in their UMTS network deployment in Paris [2].

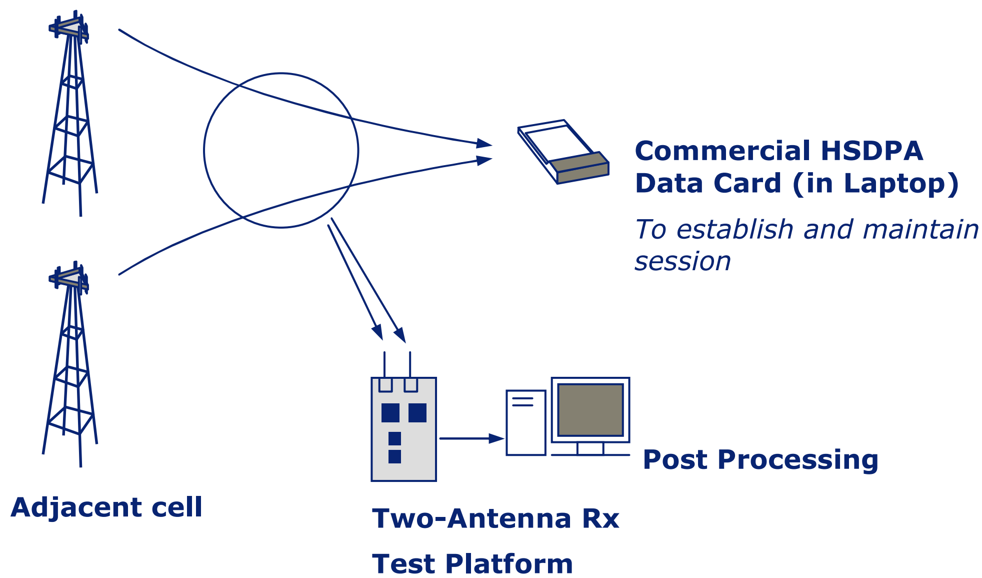
Although the percentage of one or two interferer areas is 30%, it is still important to offer better HSDPA performance using type 3i receivers. .

3. A-MAS-3i Receiver Performance

3.1. Field Validation Methodology

ArrayComm and 3-UK conducted a joint evaluation of the A-MAS-3i receiver on the 3-UK commercial HSDPA network in Reading, United Kingdom. A large number of data samples were collected at different network locations while the receiver was stationary ("nomadic user scenario"). The test configuration is shown in Figure 2.

Figure 2 Field trial configuration of performance evaluation of A-MAS-3i on operational HSDPA deployment



A commercial HSDPA data card (3.6 Mbps capable) was used to initiate and maintain an HSDPA session. The over-the-air signal was captured using a two-antenna radio front-end. The antennas were spaced one half-wavelength apart. The down-converted IQ signal was post-processed to analyze the achievable throughput. The captured data was post-processed with ArrayComm-implemented type-3 and type-3i receivers to quantify the performance gain from the A-MAS-3i receiver. Note that although this is a non-real time post-processing platform, the processing flow is identical to a real receiver.

The key performance indicator used to characterize the performance of A-MAS-3i was the equalized output signal-to-interference noise ratio (SINR)-based achievable throughput of A-MAS-3i relative to the baseline type-3 receiver. The SINR-based throughput was used since a feedback path to the base station was not available to the ArrayComm receivers in the test setup to control the scheduled throughput. The SINR-based throughput is an appropriate measure for this field validation since it captures the post-receiver SINR gain of the A-MAS-3i receiver, which is the key performance benefit provided by A-MAS-3i.

3.2. Baseline Type-3 Receiver

A type-3 receiver based on dual-branch receiver diversity and equalization was implemented to provide a baseline receiver against which A-MAS-3i can be compared. Both receivers process the same over-the-air signal, with the only difference being the HSDPA receiver architecture. The baseline type-3 receiver performance was validated by testing it under 3GPP specified scenarios. Table 1 shows that the ArrayComm implemented baseline type-3 receiver is a valid and competitive type-3 reference.

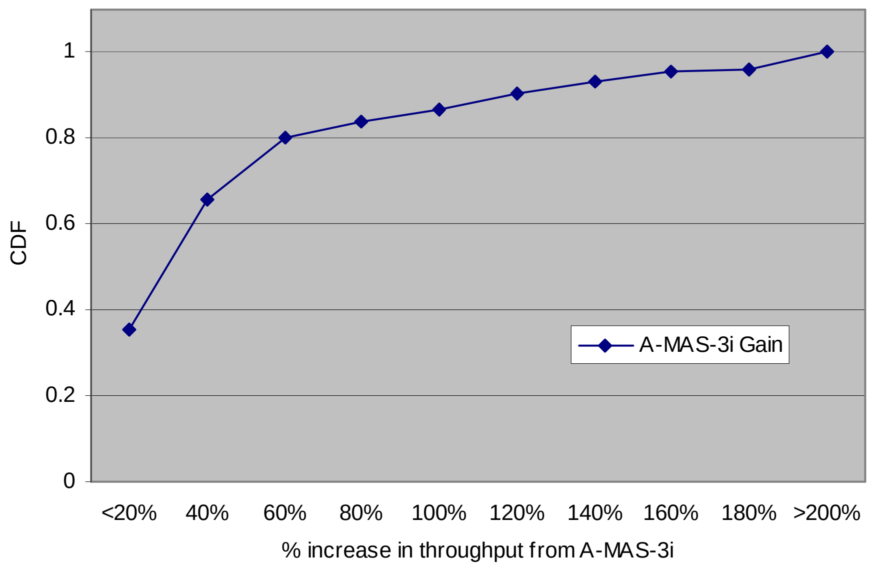
Table 1 Performance comparison of field trial baseline type-3 receiver with 3GPP type-3 results [4] in Pedestrian B-3 kmph channel.

Modulation	Ec/Ior (dB)	G=0 dB	
		3GPP Average Throughput (kbps)	Field Trial Baseline Throughput (kbps)
QPSK	-6	891	965
	-3	1510	1591

3.3. Performance in High Interference Scenario

Interference-aware receivers, such as A-MAS-3i, are able to cancel the interference leading to better performance. The relative performance of A-MAS-3i is primarily influenced by the geometry. A high interference scenario, such as *cell-edge* conditions, corresponds to a lower geometry. Figure 3 shows the throughput gain distribution for samples collected at low geometry (G < 0 dB) conditions. Following the post-processing, the samples at low geometry (G<0) were extracted and the throughput gains were calculated over 400ms bursts. The throughput gains are presented as percentage increases of the type-3 throughputs.

Figure 3 Cumulative distribution of A-MAS-3i throughput gain relative to Type-3 throughputs at lower geometry (G < 0 dB) in Reading

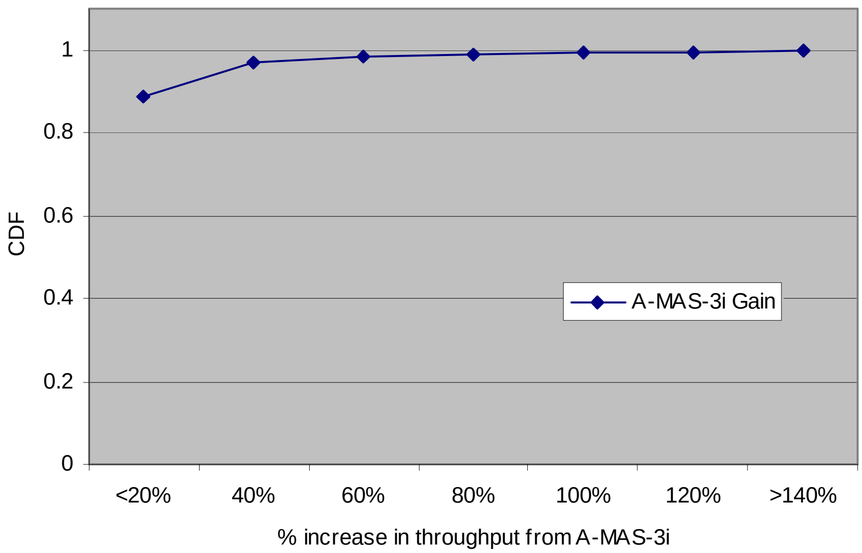


Although this area corresponds to a small percentage of the drive test, there were enough samples to produce a comparison. The median gain was 29%, and gains greater than 50% were observed with 25% of the bursts at lower geometry.

3.4. Performance in Low Interference Scenario

This section looks at the performance of A-MAS-3i in a high geometry cell-interior scenario, where the inter-cell interference is almost insignificant. Figure 4 shows the cumulative throughput gain distribution of A-MAS-3i and type-3 at low interference scenarios.

Figure 4 Cumulative throughput gain distribution of A-MAS-3i relative to type-3 at high geometry (G > 0 dB)



As expected, the A-MAS-3i throughput is similar to the type-3 throughput.

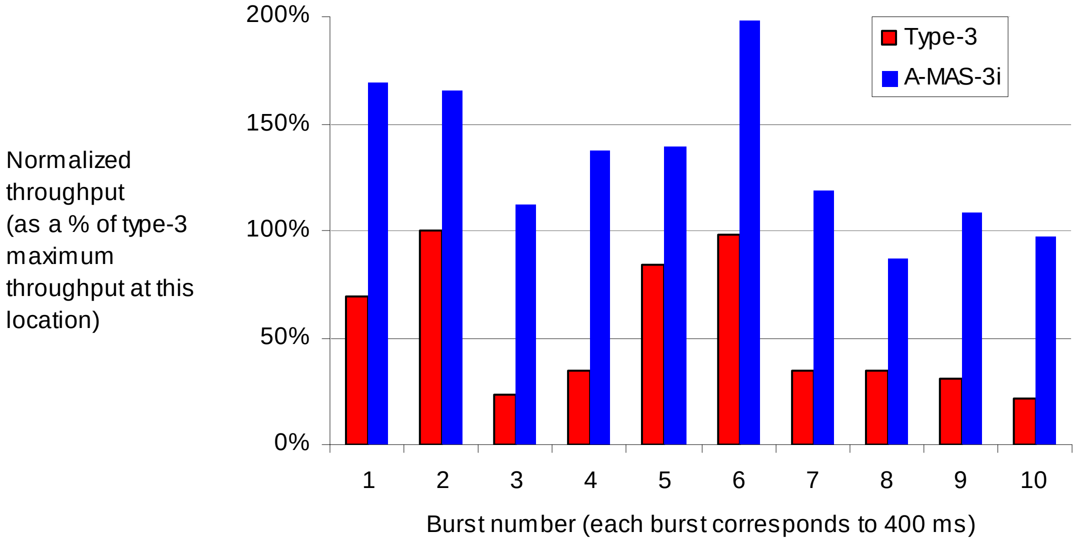
3.5. Performance Advantage of A-MAS-3i

The previous sections have shown that A-MAS-3i provides improvements in throughput at low geometry *cell-edge* environments and performs as well as type-3 in high geometry cell-interior scenarios.

Figure 5 shows the improvement in data rate experienced at a particular location. The data samples were collected at a single location in bursts of 400 ms. The throughputs are presented as an average throughput computed over each 400ms interval. These throughputs are normalized and presented as a percentage of the type-3 maximum throughput at this location. The geometry was in the range -3 dB to 3 dB at this location, representing a mixed interference environment.

Figure 5 Output SINR based throughputs for A-MAS-3i and type-3 receivers

Averaged over 400 ms



The throughput curve demonstrates that A-MAS-3i receivers can double the received throughput relative to a dual-branch type-3 receiver at certain *cell-edge* environments.

4. Conclusion

Signal interference from sectors within the serving cell and neighboring cells reduces the achievable throughput to HSDPA devices. Interference-aware receivers are necessary to increase the user throughput, particularly in *cell-edge* channel conditions.

ArrayComm has developed a fully 3GPP compliant A-MAS-3i HSDPA receiver, which improves the signal-to-interference-ratio based on a dual-branch receiver. The improved link gain translates to improvement in received throughput, enabling an enhanced mobile data experience.

The performance evaluation tests of A-MAS-3i on a commercial HSDPA deployment combined with post processing shows [Table 2] that A-MAS-3i enabled HSDPA receivers improve the throughput in *cell-edge* situations. The average relative throughput improvement compared to a dual-branch type-3 receiver was 29% in a *cell-edge* situation. In some high interference scenarios, A-MAS-3i doubled the achievable data rate.

Table 2 A-MAS-3i throughput gain relative to type-3 receivers

	Average throughput gain of A-MAS-3i relative to type-3
Low Geometry [G < 0 dB]	1.29x
High Geometry [G > 0 dB]	1.04x

The implementation challenges in terms of cost and form factor to add a second receiver branch in handsets are acknowledged. However, since there is widespread recognition for the need for dual-branch receiver diversity receivers for mobile data services, these challenges are being tackled within the equipment manufacturing ecosystem. This is witnessed by the increased arrival of dual-branch HSDPA data cards in the market and the baseline receivers for Evolved HSPA, LTE and WiMAX being based on dual-branch receivers. Having accommodated a second branch, it is imperative that this should lead to user data rate improvements under all network conditions. ArrayComm A-MAS-3i receivers with interference cancellation further enhance the HSDPA performance by offering higher data rates.

5. References

1. 3GPP R4-061281, 3, *Scenario definition for interference cancellation evaluation based on measurements taken in 3 UK's operational network*
2. 3GPP R4-061272, Orange, *Interference data collection on a live UMTS network*
3. 3GPP R4-060981, Intel, *Simulation results for HSDPA type-2i and type-3i receivers*
4. 3GPP R4-071491, *Type-3i simulation results summary sheet*