TD-SCDMA Networking Strategy with Interference Between Indoor and Outdoor Networks

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Abstract:
The High Speed Downlink Packet Access (HSDPA) technology is employed for the data service in the Time Division Synchronous Code Division Multiple Access (TD-SCDMA) mobile communication system. Theoretically, the HSDPA peak data throughput per Time Slot (TS) available in the terminals reaches 560 kb/s. Since the data service often occurs indoors, flexible TS allocation between uplink and downlink is applied in TD-SCDMA networking. That is, TS1 and TS2 are uplink time slots and TS3, TS4, TS5 and TS6 are downlink time slots in the indoor cell; and symmetry TS allocation is made for the outdoor cell. In the intra-frequency cell network, it can cause intra-frequency interference between cells. So the research on the intra-frequency crossed time slots interference is done and the suggestions on the intra-frequency crossed time slots networking strategy are proposed in this paper.

The Time Division Synchronous Code Division Multiple Access (TD-SCDMA) system is able to provide different cell capacities and throughput by way of flexible time slot allocation on uplink and downlink. For the sake of higher cell throughput, the High Speed Downlink Packet Access (HSDPA) technology is introduced to TD-SCDMA, and the technology introduces more advanced modulation and demodulation technology as well as fast schedule algorithm, thus providing higher spectrum efficiency. With the 1:5 time slot allocation between uplink and downlink. the spectrum efficiency can be more than 2 Mb/s per Hertz[1-4]. The TD-SCDMA networks that were constructed by China Mobile Communication Corporation (CMCC) in eight cities of China have been upgraded to support HSDPA and HSDPA service exclusively is taking a carrier.

1 Different Indoor and Outdoor Time Slot Allocations

The HSDPA technology has been adopted in the TD-SCDMA. system in order to improve user's Packet Switch (PS) throughput. As a result, the theoretical downlink throughput per Time Slot (TS) of the system increases from 128 kb/s to 560 kb/s. Since high speed data services of Packet Service (PS) domain usually occur indoors, the TS allocations indoors are different from outdoors , that is, TS_1 and TS_2 are uplink time slots and TS_3, TS_4, TS_5 and TS_6 are downlink time slots in the indoor cell; and symmetry TSs are allocated for the outdoor cell, as shown in Figure 1 and Table 1[5-7].

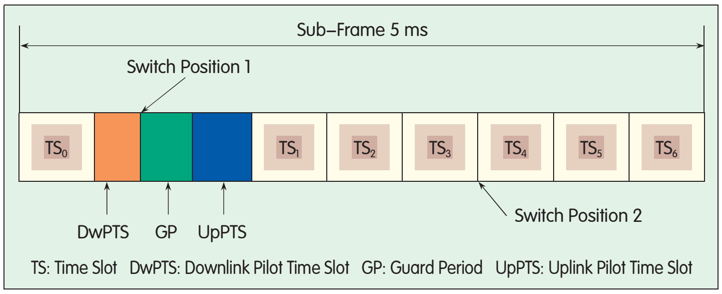


Figure 1. Time slot structure of TD-SCDMA.

▼Table 1. Uplink and downlink TS allocation for indoor and outdoor cells

TS Allocation for Indoor Cell: 2 : 4										
TS	TS_0	DwPTS	GP	UpPTS	TS_1	TS_2	TS_3	TS_4	TS_5	TS_6
Uplink/ Downlink	↓	↓		↑	↑	↑	↓	↓	↓	↓
TS Allocation for Outdoor Cell: 3 : 3										
TS	TS_0	DwPTS	GP	UpPTS	TS_1	TS_2	TS_3	TS_4	TS_5	TS_6
Uplink/ Downlink	↓	↓		↑	↑	↑	↑	↓	↓	↓

↓: Downlink TS: Time Slot GP: Guard Period
↑: Uplink DwPTS: Downlink Pilot Time Slot UpPTS: Uplink Pilot Time Slot

Different TS allocation ratios between indoor and outdoor cells under the same carrier will undoubtedly give rise to the interference problem of crossed time slots[8-10]. For example, TS_3 for indoor cell is the downlink, but TS_3 for outdoor cell is uplink, hence the interference of intra-frequency crossed time slots occurs.

The mutual interference test with different TS allocations between indoor and outdoor cells in the TD-SCDMA system is performed in this paper in order to assess the feasibility of such networking scheme.

2 Mutual Interference Between Different Time Slot Allocations

To assess the feasibility of a system with crossed time slots configuration, it is necessary to test the mutual interference of indoor and outdoor cells under the many kinds of situations, including real loading and simulation loading.

2.1 Influence of Various Interference Types on System

(1) Indoor HSDPA Loading Simulation

The interference type is Base Station (BS) to BS, and the interference factors include Primary Common Control Physical Channel (PCCPCH) power configured for indoor BS and duty ratio of simulation loading. The lower the PCCPCH power is configured for indoor BS, the less the interference will be. The smaller the simulated duty ratio is, the less interference will be. The interference is not related with the indoor signal intensity where the test is done, but with the path loss between indoor BS antenna and outdoor BS antenna. The path loss reflects the intensity of interference signals leaked from indoor BS antenna to outdoor BS antenna.

If the R4 service is applied outdoors, the outdoor R4 terminal may have call drops, which in most cases is caused by radio link failure. If the HSDPA version (R5) service is applied, the throughput of outdoor cell will be affected. Such effect will be more stronger if the Shared Information Channel for HSDPA (HS-SICH) is configured in TS3 in the outdoor R5 cell.

(2) Real Indoor HSDPA Loading

The interference types are BS-to-BS and terminal to terminal. The interference factors include PCCPCH power configured for indoor BS, relative locations of terminal users and the channel where the terminal user is located. The lower the PCCPCH power is configured for indoor BS, and the lower the downlink transmit power of High Speed Downlink Shared Channel (HS-DSCH) for HSDPA is, the less the interference will be. The greater the path loss is between indoor and outdoor terminals (for example, there is a wall between test terminals), the less the interference will be. Also, the smaller the outdoor signal intensity is where the outdoor terminal user is located indoors, the greater the uplink transmitting power and the interference will be.

The BS-to-BS interference is the same as in the HSDPA loading simulation. The terminal-to-terminal interference will affect the throughput of indoor cell HSDPA users, which is related with the relative location between the terminals (namely, the path loss) and the terminal's transmitting power. The channel port where the terminal user is located in should be considered in the research if the multi-channel port layout is used in the indoor TD-SCDMA system.

(3) Real Indoor R4 Loading

The interference types are BS-to-BS and terminal-to-terminal. The interference factors include location of the indoor loading R4 terminal, relative locations between terminals and the channel port where the terminal user is located in. The smaller the PCCPCH Received Signal Code Power (RSCP) is where the indoor terminal is located, the greater the transmit power of BS and the interference will be. The smaller the PCCPCH Received Signal Code Power (RSCP) is where the outdoor terminal is located, the greater the transmit power of outdoor terminal user and the interference will be. Different channel port position of the indoor and outdoor users should also be considered.

Because power control is employed for the transmit power of a real R4 terminal in the dedicated channel, the lower the signal intensity of the terminal is, the greater the transmit power of BS and terminal user, so the greater interference will be. But a constant transmit power is used by HS-DSCH in TD-SCDMA system.

The nearer a channel port, where the indoor user is located in, is to the outdoor BS, the greater the BS-to-BS interference will be. If the indoor and outdoor users are located indoors on different indoor channels port, the terminal-to-terminal interference will be low, and the farther the channels are from each other, the less the interference will be.

(4) Indoor R4 Loading Simulation

The interference type is BS-to-BS and the interference factor is simulation loading power. The greater the simulation loading power is, the greater the interference will be.

The simulated R4 loading is usually done with a fixed transmit power. This is why the greater the simulated R4 loading power is, the greater the interference power will be, which has nothing to do with the indoor location of the outdoor user.

2.2 Influence of Carrier-to-Interference Ratio (C/I) on System

A user's demodulation performance is related with his signal reception C/I, which depends on the factors shown in

Formula (1):

$$C/I=\frac{P}{\alpha\times I_{owner}+I_{other}+N_0} \quad (1)$$

Where, P is power of received signal, I_{owner} is power of interference signal of the cell, α is interference elimination factor (which is usually 0.1 for TD-SCDMA), I_{other} is interference power of neighbor cell, and N_0 is thermal noise power.

The test covers interferences between indoor BS and outdoor BS , and interference between indoor terminals and outdoor terminals.

The baseband can eliminate the interference in its cell through the joint detection. In the test $\alpha\times I_{owner}$ has a little influence on C/I. It can be seen that the C/I is mainly affected by P and I_{other} (I_{other} is caused by crossed time slot and cannot be eliminated through joint detection).

Normally no interference occurs between inter-frequencies because of the frequency isolation. This is why our test focuses on cases in the intra-frequency. The intra-frequency interference level may be analyzed by testing R5 HSDPA traffic and R4 service traffic.

The HSDPA traffic of R5 is related with the Channel Quality Identification (CQI). When C/I decreases, the CQI falls because the HS-DSCH for HSDPA is designed without power control function, the cell throughput will be lower as a result. But the R4 service is designed with power control. Because indoor service will cause interference and affect the signal quality on outdoor uplink, P increases along with the increasing Iother. When the growth of P can no longer guarantee the C/I needed by the service, call drop occurs and the system capacity decreases eventually.

3 Emulation Test Examples

For the sake of verification, the following six test examples are used to verify and analyze the mutual interference in the case of indoor 2:4 time slot allocation and outdoor 3:3 time slot allocation in the intra-frequency networking strategy

(1) Interference on outdoor R4 in the case of 75% and 100% R4 simulation loading in indoor cell TS_3

(2) Interference on outdoor R4 in the case of 75% and 100% HSDPA simulation loading in indoor cell TS_3

(3) Interference on outdoor HSDPA in the case of 75% and 100% HSDPA simulation loading in indoor cell TS_3

(4) Mutual interference between outdoor R4 (TS_3 carries six or eight CS12.2K users) and indoor R4

(5) Mutual interference between outdoor R4 (TS_3 carries six or eight CS12.2K users) and indoor HSDPA

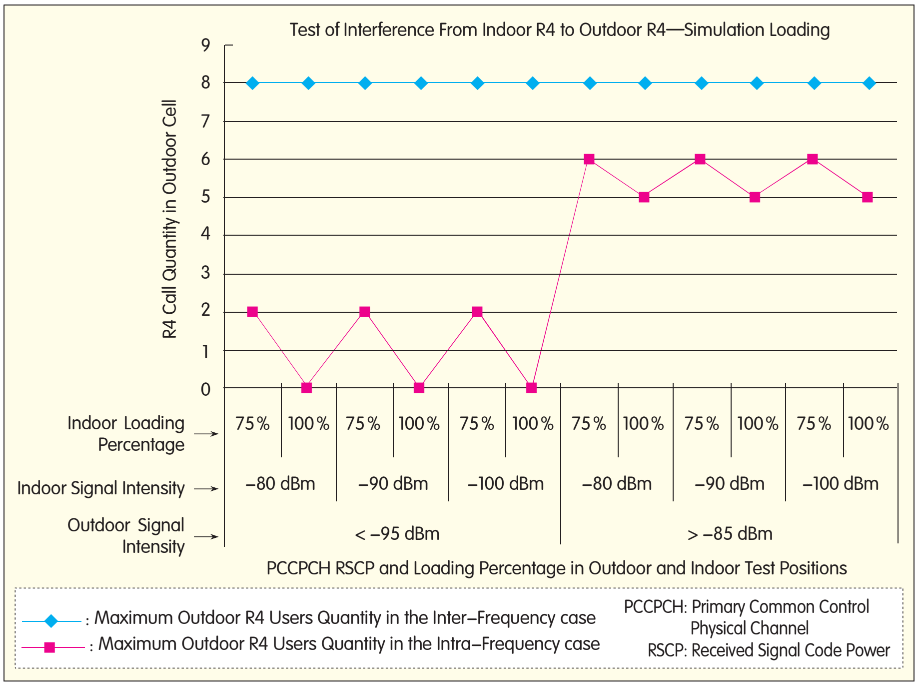
(6) Mutual interference between outdoor HSDPA (all code channels in TS_3 are configured as HS-DSCH channel) and indoor HSDPA.

The first three examples are used to verify the interference from indoor to outdoor. The other three examples are used to verify the interference between outdoor and indoor in real circumstances.

Simulated R4 loading has the following rules:

- 75% loading:12 code channels are loaded and the loading power being 25 dBm in one slot;
- 100% loading: all 16 code channels are loaded and the loading power being 27 dBm.

(1) Interference on outdoor R4 in the case of 75% and 100% R4 simulation loading in indoor cell TS_3



▲Figure 2. Interference on outdoor R4 when indoor R4 simulation loading is done.

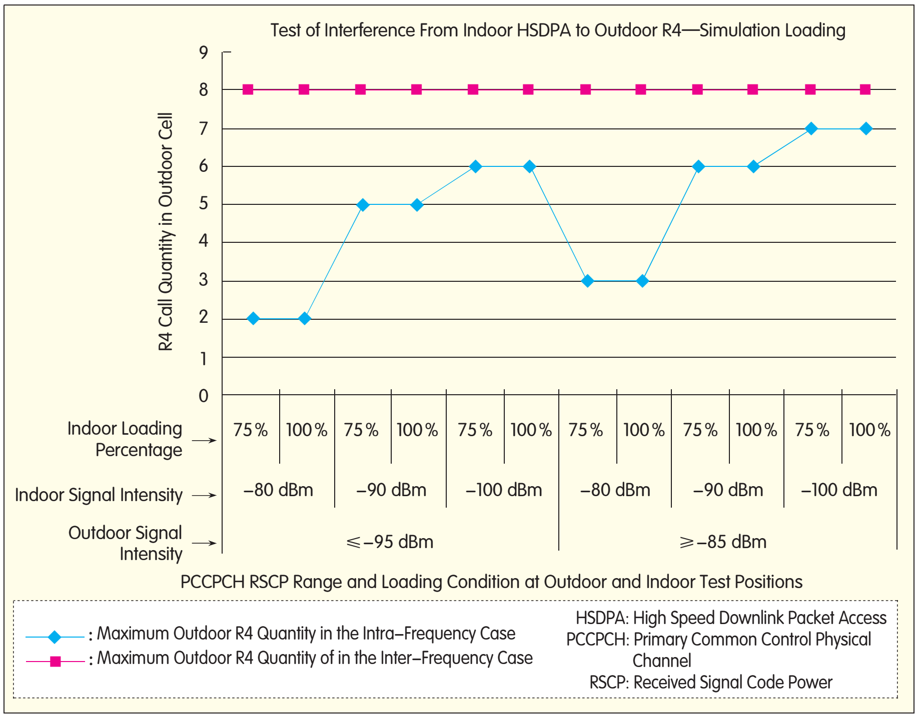
In the test scenario given in Figure 2, no interference is detected from indoor R4 to outdoor R4 between inter-frequencies, and eight CS12.2 k users are be called sucessfully in outdoor cell (full capacity).

In intra-frequency cases, the outdoor R4 capacity loss of single time slot is caused by the interference from indoor (BS-to-BS interference). When the outdoor user is located in the cell medium field, the capacity is lost off 25%. When the outdoor user is located in the cell edge, the single TS capacity is lost off more than 75%. At the same test position, Iother increases and the number of users decreases if the simulation loading power is increased. This means even the power P of user at that time is increasing, but C/I cannot be increased.

(2) Interference on outdoor R4 in the case of 75% and 100% HSDPA simulation loading in indoor cell TS_3

In the test scenario given in Figure 3, no interference is detected from indoor HSDPA to outdoor R4 in the inter-frequencies, and eight CS12.2 k users are be called sucessfully in outdoor cell (full capacity).

In the intra-frequency cases, when the indoor signal intensity decreases, the loading percentage of HSDPA decreases, Iother of the interference on outdoor R4 also decreases gradually, and the outdoor cell user will be



▲Figure 3. Interference on outdoor R4 when indoor HSDPA simulation loading is done.

increasing. Under the same simulation loading condition (same simulation loading power and same indoor signal intensity), when the outdoor signal intensity increases, the outdoor cell user also will be increasing. Tests show that in the intra-frequency networking situation, the single time slot R4 capacity is lost off from 25% to 75% if compared to inter-frequency networking situation.

(3) Interference on outdoor HSDPA in the case of 75% and 100% HSDPA simulation loading in indoor cell TS_3

In the test scenario given in Figure 4, no obvious interference is detected from indoor HSDPA to outdoor HSDPA in the inter-frequencies. When the outdoor user is located in the cell edge, the cell user's C/I is worse and its throughput is approximately 600 kb/s. When the outdoor user is located in the cell center, the throughput is approximately 1.35 Mb/s. The test result is normal.

In the intra-frequency cases, when the indoor signal intensity decreases, the HSDPA loading percentage decreases, the interference on outdoor HSDPA also decreases, and the outdoor HSDPA throughput increases accordingly. The throughput in the outdoor cell center is averagely higher than in the outdoor cell edge. Under the same conditions, the average throughput of outdoor user in the intra-frequency networking is lost off more than 40.7% if compared to inter-frequency networking.

(4) Mutual interference between outdoor R4 (TS_3 carries six or eight CS12.2k users) and indoor R4

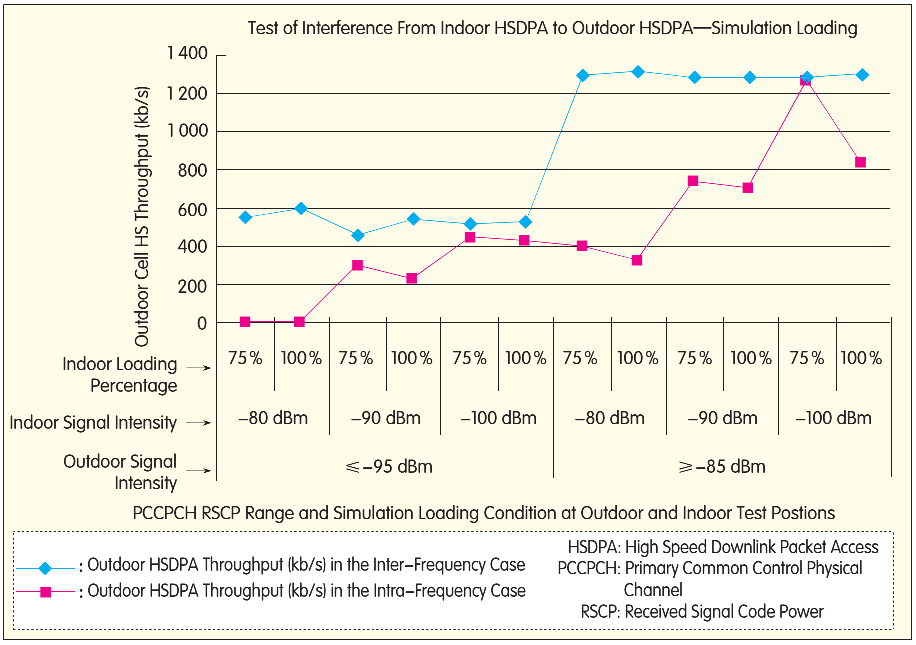
In the test scenario given in Figure 5, no obvious interference is detected from outdoor R4 to indoor R4 under the inter-frequency conditions and the indoor single TS_3 can carry eight CS12.2 k users (full capacity).

Under the intra-frequency conditions, the serious interference is detected from outdoor R4 to indoor R4 in every test scenario. The indoor user capacity loss is 100%. Since indoor users and outdoor users are placed in the same postion, it indicates the path loss from terminal to terminal is low and mutual interference is very serious.

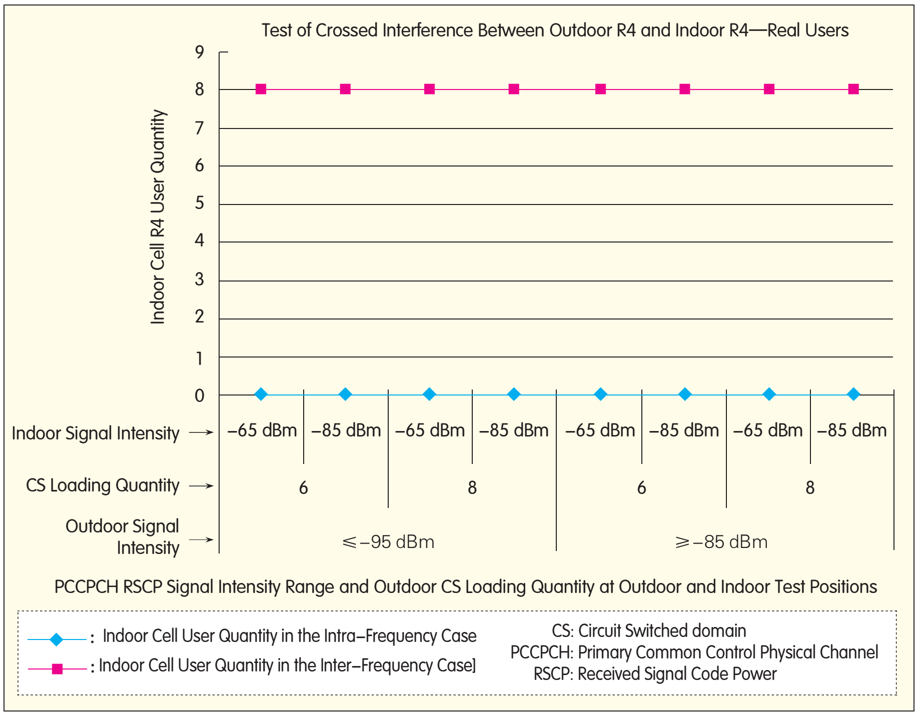
(5) Mutual interference between outdoor R4 (TS_3 carries six or eight CS12.2k users) and indoor HSDPA.

In the test scenario given in Figure 6, no obvious interference is detected from outdoor R4 to indoor HSDPA under the inter-frequency conditions and the average throughput remains at approximately 1.35 Mb/s.

Under the intra-frequency conditions, the serious interference is detected from outdoor to indoor HSDPA when the indoor and outdoor users are at the same position, and indoor user fails to make a call. That is, the capacity loss is 100%. When the indoor user is far from the outdoor loading user and the signal isolation increases, the interference from outdoor user to indoor user is less than when indoor and outdoor users are at the same position (the farther the terminals are away from each other, the greater



▲Figure 4. Interference on the outdoor HSDPA when indoor HSDPA simulation loading is done.



▲Figure 5. Interference on indoor R4 user when outdoor cell R4 users are loading.

path loss will be and less interference will occur). In this case, the average throughput is tested to be approximately 700 kb/s, the capacity loss reaches 40−56%. In additon, in the indoor HSDPA user holding process, Outdoor R4 user call drops occur repetitively. This indicates that the interference from indoor to outdoor cell also exists in the test.

(6) Mutual interference between outdoor HSDPA (all code channels in TS_3 are configured as HS-DSCH channel) and indoor HSDPA

In the test scenario given in Figure 7, no obvious interference is detected from outdoor HSDPA to indoor HSDPA throughout in inter-frequency cases. The average throughput of indoor HSDPA carrier is at approximately 1.35 Mb/s and that of the outdoor HSDPA carrier is at approximately 820 kb/s.

Under the intra-frequency conditions, the serious interference is detected from outdoor HSDPA to indoor HSDPA in the every test scenarios. The average throughput of indoor HSDPA carrier is approximately 780 kb/s, more than 40% throughput is lost off. At the same time, serious interference is also detected from indoor HSDPA to outdoor HSDPA and the throughput of outdoor HSDPA carrier is approximately 60 kb/s, more than 90% throughtput is lost off.

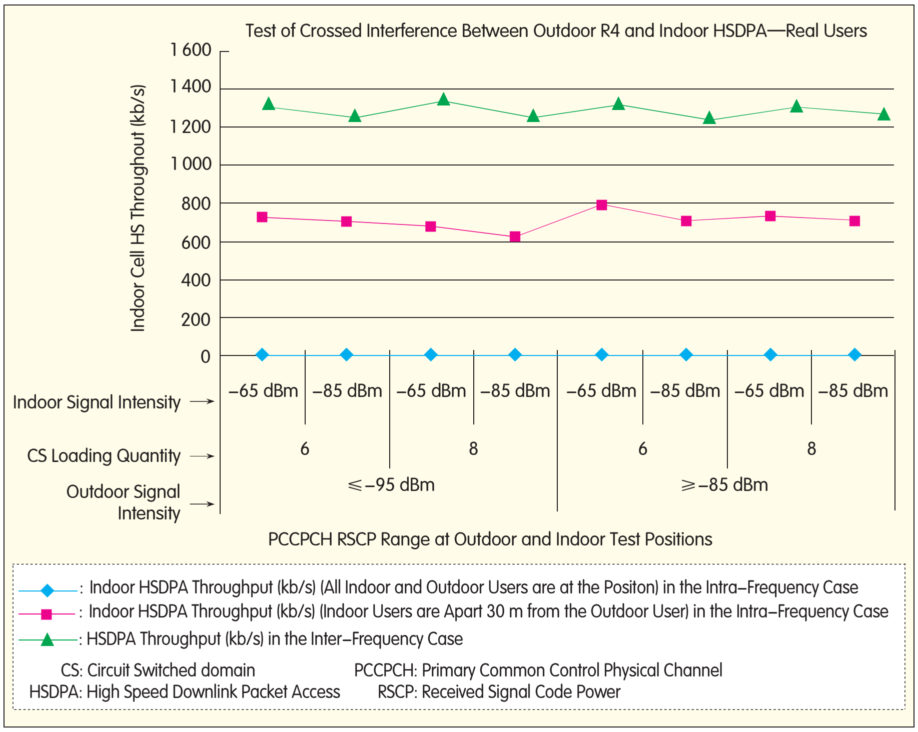
In addition, we find that the Interference on Signal Code Power (ISCP) from indoor to outdoor TS_3 ranges about −93.7 to −83.4 dBm, which leads up to the sharp decrease of both call success rate and throughput of outdoor R4 or HSDPA. The ISCP from outdoor to indoor TS_3 ranges about −95 to −47 dBm (the nearer the test position is, the greater the interference will be), which also causes the sharp decrease of both call success rate and throughput of indoor R4 or HSDPA.

4 Conclusions

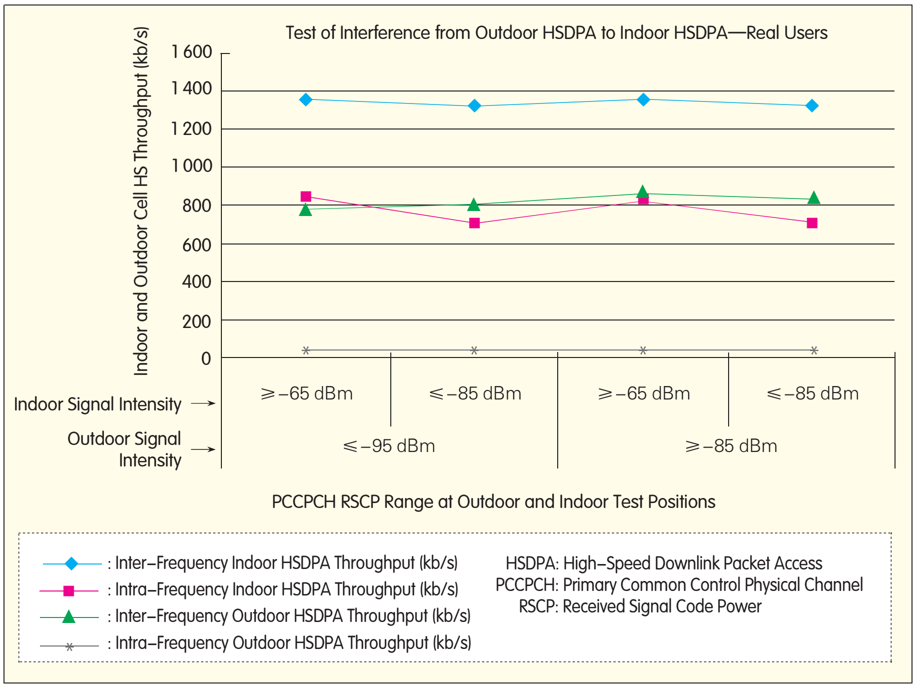
The tests show that, in the TD-SCDMA system, the serious crossed time slot interference are verified in the case of indoor and outdoor intra-frequency networking strategy. For this reason, the inter-frequencies networking strategy should be taking firstly wherever the frequency resource is sufficient.

With the intra-frequency networking and configuration of indoor and outdoor crossed time slot, TS_3 in the first circle neighbor cells of the indoor cell should better be blocked, so as to decrease interference at the cost of the capacity of the first circle cells. If this TS_3 is not blocked, power configuration of the indoor cell has to be adjusted to decrease the interference from indoor to outdoor.

Besides, the indoor and outdoor



▲Figure 6. Interference of outdoor R4 users over indoor HSDPA users.



▲Figure 7. Interference of outdoor HSDPA over indoor HSDPA.

HSDPA frequency should be configured as the same frequency firstly, in order to prevent the indoor HSDPA user from affecting outdoor R4 user and avoid infecting the users' calling feeling. In addition, HS-PDSCH channels should be avoided to configure in the 3th TS in order to less the interference.

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Biographies

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Ji Shuping received his PhD degree from Harbin Institute of Technology. He is now a senior engineer, and his work covers radio technology research of TD-SCDMA mobile communication system at ZTE Corporation. He has published more than 20 papers and four patents have been granted.

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Roundup

ZTE Debuts New Generation IPTN Bearer Network Solution

ZTE Corporation announced the formal launch of its new generation IPTN bearer network solution targeting mobile backhaul and multi-service delivery to meet the needs of IP-based services on August 27, 2009. It features packet kernel, enables multi-service delivery, and provides customers with mobile backhaul and FMC E2E solutions. It also allows customers to cut network construction, operation and maintenance cost, help carriers implement smooth network evolution, and fully addresses carriers' current and future requirements for network transmission.

PTN series products under the ZTE IPTN solution include: ZXCTN 6100, ZXCTN 6200, ZXCTN 6300, ZXCTN 9004 and ZXCTN 9008. ZXCTN 6100 is a compact and converged IP transport platform. As the industry's most compact commercialized access layer PTN product, it is box equipment with 1U in height, which is easy to install and adapts to the base station access environment. ZXCTN 6200, the industry's most compact commercialized 10GE PTN equipment, is only 3U high. Its small size and high level of integration address the requirement for integrated service delivery. ZXCTN 9008 provides the largest PTN product switching capacity in the industry. Its switching capacity reaches bidirectional 1.6T, plus the robust routing capability, fully accommodating the requirement for agile scheduling of core layer mobile and fixed-line services under all-service operation.

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