INVESTIGATION OF MULTIPLE ACCESS INTERFERENCE WITHIN UTRA-TDD

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ABSTRACT

This paper highlights inter-cell and inter-operator interference which can occur within a UTRA-TDD system. Interference simulation results show that when the network has frame synchronisation and operates with the same asymmetry in all cells, there will be interference between the base stations and adjacent mobiles only (i.e. MS-BS and BS-MS interference). When synchronisation is lost, or different asymmetries are used, the results indicate the extent of the additional interference between adjacent base stations (BS-BS interference) and between adjacent mobile terminals (MS-MS interference). Further results for inter-operator interference shows that the interference at the mobiles caused by synchronised operators is dominated by interference from the base station, whereas for unsynchronised networks the MS-MS interference becomes significant.

1 INTRODUCTION

At the ETSI SMG#24 meeting in Paris (28-29 January 1998) an agreement was reached on the radio interface for the third generation universal mobile radio system (UMTS). The solution for UMTS terrestrial radio access (UTRA) is to use both wideband CDMA (WCDMA) and hybrid TDMA/CDMA (TD-CDMA) technologies.

In the paired bands frequency division duplex (FDD) will be used and the system adopts the WCDMA radio access technique proposed by the Alpha Concept Group (1920-1980 MHz uplink, and 2110-2170 MHz downlink). In the unpaired band time division duplex (TDD) will be used and the system adopts TD-CDMA radio access technique proposed by the Delta Concept Group (1900-1920 MHz, and 2010-2025 MHz). This initial spectrum allocation for UMTS is shown in Figure 1. For a full implementation of terrestrial UMTS both WCDMA and TD-CDMA based service modes should be incorporated.

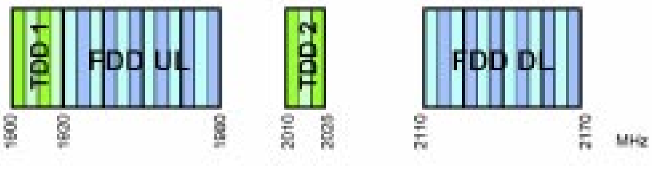


Figure 1- UMTS terrestrial spectrum allocations.

The market for TD-CDMA technology is considerably wider than conventional cordless technology such as DECT. As part of UMTS, it will enhance the services provided by WCDMA and dual-mode handset are expected to be common in the future. This will permit the user to access fixed networks or private wireless PABX services within an office building and additionally it will permit seamless access to the universal network beyond the office. The ability for an office base station to provide wireless services for speech and data services is important, and to be seamlessly interfaced to the outdoor cellular network is very attractive. Having the same terminal hardware, user interface, and user address or number for email, Internet, and speech in the office, probably in the home, and throughout the UMTS coverage area is important from a user perspective and ideal from a business communication perspective

One of the major attractions for the TDD mode operation is that it allows the uplink and downlink capacities to be used asymmetrically. For data traffic this is seen as being extremely important since it makes efficient use of the available system capacity. In this brief article we consider the interference suffered by a UTRA-TDD system taking into account synchronisation and asymmetry factors.

2 INTERFERENCE IN UTRA-TDD

In many respects, determining the multiple access interference experienced in the UTRA-TDD system is more complex than for an equivalent FDD system. To illustrate this case, consider the uplink and downlink transmission paths for the FDD system that has adjacent radio channel interference (e.g. from a competing operator or adjacent cell). Clearly there are desired transmission paths between each base station and the mobiles, but there will also be inter-operator and inter-cell interference from the other cells. This same situation occurs in a UTRA-TDD network. However, if the interfering TDD cells are not synchronised then additional interferences also occur. Synchronisation may not be desirable since it will force all operators to synchronise their networks to a common reference. It also means that all cells in the same, or adjacent, network would have to adopt the same asymmetry, which is clearly undesirable.

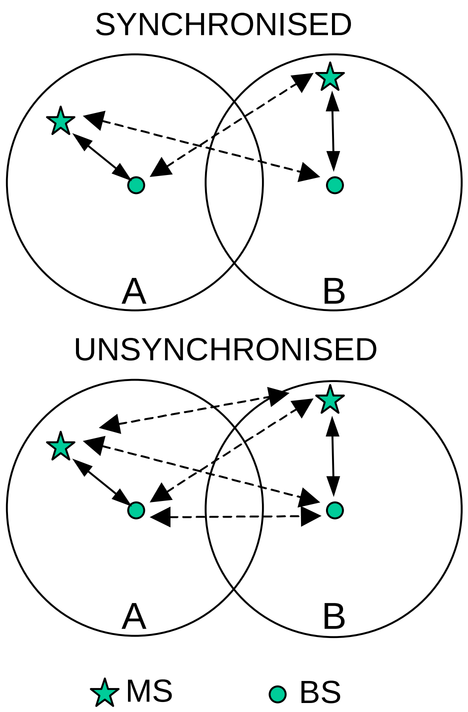


Figure 2 – Interference in synchronised and unsynchronised UTRA-TDD systems.

In Figure 2 the synchronised UTRA-TDD network is seen to represent a similar scenario to that of the UTRA-FDD network. Solid lines show the desired transmission paths and broken lines show the interference paths. There is negligible interference between base stations and between mobile terminals in an FDD system since the duplex frequency separation is relatively large. In contrast to this for UTRA-TDD system there is no duplex frequency separation between the uplink and downlink and they must be separated in time. If, in the case of the TDD system, adjacent cells or operators are not synchronised, or adopt differing asymmetries, then interference paths will exist between mobiles and also between base stations. This is illustrated in Figure 2 for the unsynchronised case. Therefore the interference scenarios present by TDD and FDD systems can be quite different since in the FDD mode we have only MS-BS and BS-MS inter-cell and inter-operator interference to consider. In the TDD mode we can have MS-BS (I_{MB}), BS-MS (I_{BM}), MS-MS (I_{MM}), and BS-BS (I_{BB}) inter-cell and inter-operator interferences. These interferences are expressed as [1]

$$\begin{aligned} I_{BB} &= P_{txB} + G - L_{BB} - ACLR \\ I_{MB} &= P_{txM} + G - L_{MB} - ACLR \\ I_{BM} &= P_{txB} + G - L_{BM} - ACLR \\ I_{MM} &= P_{txM} + G - L_{MM} - ACLR \end{aligned} \quad \text{(dB)}$$

where P_{tx} is the transmit power from the base station or mobile, G is the overall transmitter-receiver gain, L is the pathloss between the transmitter and receiver. The ACLR is the adjacent channel leakage ratio and will be 0dB if the interference is from the same carrier.

The COST 231 indoor channel models were used to define the pathloss as

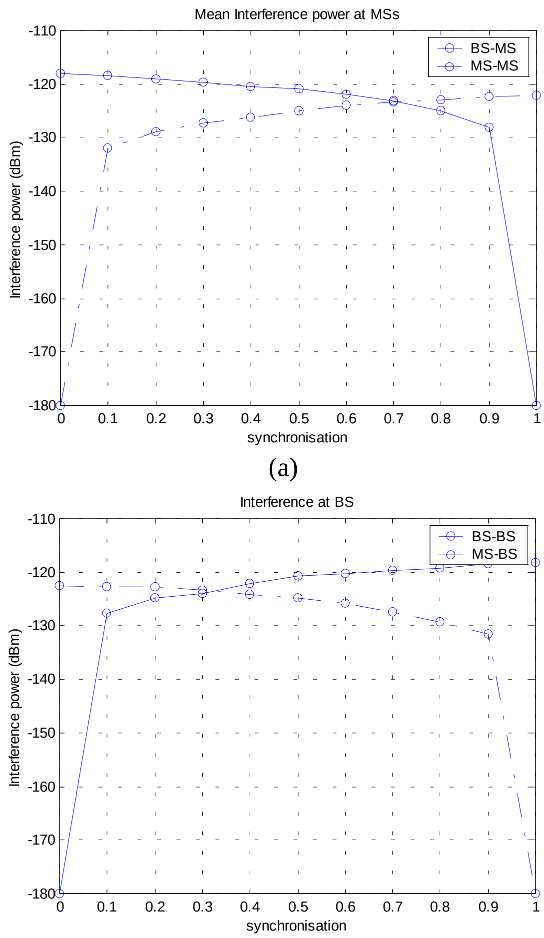
$$L = 37 + 30\log(d) + \xi \quad \text{(dB)}$$

where d is the distance between the transmitter and receiver in meters and ξ is log-normal shadowing with zero mean and 10dB standard deviation.

From earlier investigations we found that the worst case interference in a TDD network often occurs between the base stations [2]. The mobile to mobile interference is also a problem but most of these interference instances can be resolved by using a dynamic resource allocation algorithm. Interference between base stations will occur when one base station is transmitting in a timeslot, and another base station is receiving during that same timeslot. However there is a trade off, because during BS-BS (and MS-MS) interference instances there will be no MS-BS or BS-MS interference between these same cells if the timeslots are aligned. This is confirmed by considering the interference between two adjacent cells.

Results from a two-cell simulation example are shown in Figure 3. Both cells are operated using the same carrier frequency and we consider all of the interference paths (BS-BS, MS-MS, MS-BS, BS-MS) for typical TDD system parameters and 100m radius cells each with an average of 4×16kbit/s users per timeslot randomly distributed within the cell. The separation between the base stations is 200m. The synchronised system is represented by a synchronisation factor of 0 (i.e. all the base stations both transmit during the same timeslots). The unsynchronised system is represented by a synchronisation factor of 1 (i.e. when one base station is transmitting, the other is receiving). Between 0 and 1 the timeslots are not aligned and have their timing offset by the synchronisation factor.

Figure 3(a) illustrates that when the system is synchronised (synchronisation=0) only BS-MS interference is present at the mobile and Figure 3(b) shows that under the same condition only MS-BS interference is experienced at the base station, just like in FDD systems. However, if the cells are frame synchronised but one cell uses a timeslot for the downlink and the other uses the same timeslot for the uplink (synchronisation=1), then only MS-MS, Figure 3(a), and BS-BS interference, Figure 3(b), is present in this timeslot. This would be the case where the two cells are frame synchronised, but adopt different asymmetries. In the cases where the cells are not frame synchronised the interfering timeslots will be misaligned and all of these interferences are experienced. The scale of each interference contribution depends on the synchronisation offset.



(a)

(b)

Figure 3 – Inter-cell interference power in UTRA-TDD at: (a) the mobile and (b) the base station, due to synchronisation offset.

We now consider the effects of inter-operator interference in the UTRA-TDD system. We assume a 25dB adjacent channel leakage ratio (ACLR) between these operators. For simplicity, here we consider the interference between two overlapping cells, as illustrated by Figure 4, and calculate the interference experienced by mobiles on the downlink. The left most cell is the one being analysed and shows the mobile positions that we calculate the interference for. The right most cell is the source of this interference and the load within this cell is 4×16kbit/s users per timeslot.

The results, shown in Figure 5, have been averaged over many simulation runs with different interfering mobile positions and are presented as interference surface plots over the cell of interest. Figure 5(a) shows the interference levels experienced across the area of the cell when the two base stations have synchronised timeslots. Here we observe that the most severe interference is suffered by mobiles close to the interfering base station. Other areas of the cell have significantly lower interference. In Figure 5(b) the same type of surface plot illustrates the interference obtained if the timeslots have opposed synchronisation. Here the cell is most affected where it intersects with the interfering cell edge. This is the result of mobile to mobile interference and the mobiles with the highest transmit power are those located at the cell edge. This illustrates that not only does the synchronisation between cells affect the interference mechanism and its magnitude, but it also affects different parts of the cell to different degrees.

A more comprehensive study of inter-operator interference can be found in the recent reference [3].

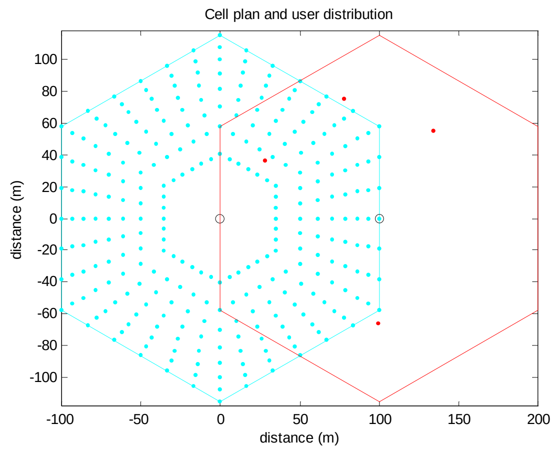
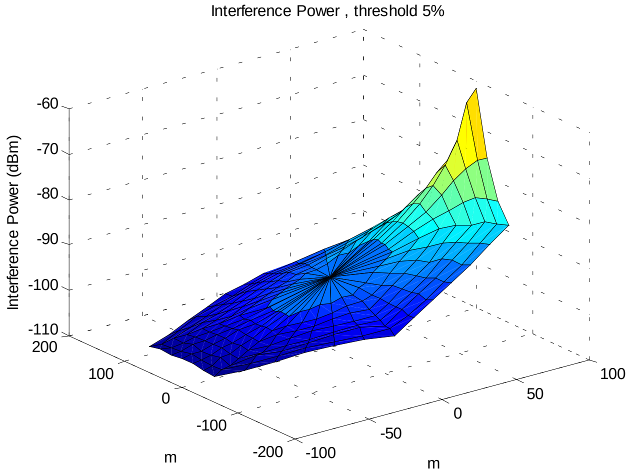


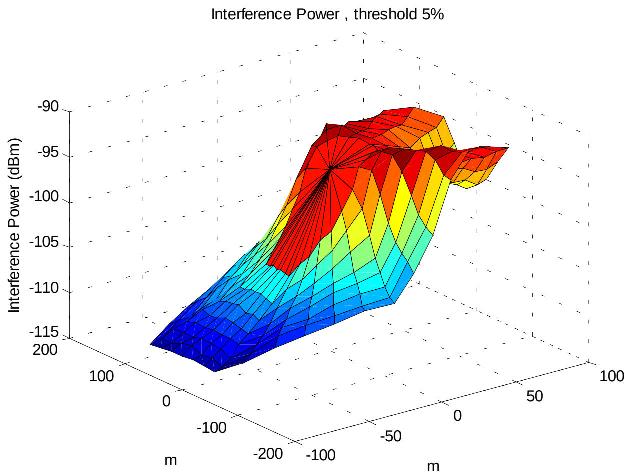
Figure 4 - Cell scenario for analysis of UTRA-TDD inter-operator interference.

3 CONCLUSIONS

The results clearly illustrates that the interference experienced within a UTRA-TDD system is in most respects more difficult to model than that of an equivalent UTRA-FDD system when the synchronisation and asymmetry issues are taken into account. The results presented also suggests that there are many benefits which can be gained by intelligently exploiting the properties of the interference within a UTRA-TDD network since different parts of each cell experience different levels of interference depending on the geometry, asymmetry, and synchronisation.



(a)



(b)

Figure 5 - UTRA-TDD downlink inter-operator interference for overlapping: (a) synchronised and (b) unsynchronised cells.

4 REFERENCES

[1] S M Heikkinen, "System Simulations for UMTS TDD and FDD Modes", Project Report HSP1401, University of Edinburgh, June 1999.

[2] H. Holma, G. J. R. Povey, & A. Toskala, "Evaluation of Interference Between Uplink and Downlink in UTRA/TDD", 50th Vehicular Technology Conference VTC99-Fall, Amsterdam, pp 2616-2620, September 19-22, 1999.

[3] H. Haas, and G. J. R. Povey, “The Effect of Adjacent Channel Interference on Capacity in a Hybrid TDMA/CDMA-TDD System Using UTRA-TDD Parameters“, 50th Vehicular Technology Conference VTC99-Fall, Amsterdam, pp 1086-1090, September 19-22, 1999.