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Agenda Item:

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Title: **Low Chiprate in UTRA-TDD**

Document for: **Consideration**

Introduction

The TD-SCDMA RTT, which was developed in China, is based on a lower chiprate than UTRA-TDD. Due to the high synergy potential of TD-SCDMA and UTRA-TDD, the harmonization of both RTTs was initiated at the beginning of this year. At the three harmonization meetings in Beijing, the participating companies (ARIB, CATT, DoCoMo, Ericsson, Nokia, Panasonic, RITT and Siemens) agreed on introducing and supporting the main key features of TD-SCDMA into UTRA-TDD, based on contribution of CATT (RP99248).

The chiprate is one of the most important issues. After detailed studies, the Chinese national wireless telecommunication standard organization CWTS determined to use 1.3542 Mcps for IMT2000 application. In this document, an analysis about chiprate is presented. Furthermore, a low chiprate of 1.3542 Mcps is proposed as an option in UTRA-TDD for a low cost mode with high performance and for the harmonization with TD-SCDMA of CWTS.

1. The basic consideration on chiprate in TD-SCDMA (UTRA-TDD low chiprate mode) system

1.1. References

1.CWTS WG1 TS C1.24, “Physical layer procedures (TDD)”
2. CWTS WG1 xxx, “Method and Principle of Uplink Synchronization”
3. CWTS WG1 xxx, “Smart Antenna Technology”
4. CWTS WG1 xxx, “Simulation method and results for TD-SCDMA RTT (link level)”

1.2. Key issues in chiprate consideration

It is well known that the decision on chiprate in an IMT2000 RTT should be based on the following:

1. The minimum requirements of IMT2000 which are described in ITU recommendation M.1225 should be met;
2. The 3G TDD system should be operated in all kinds of environments such as micro-

and macro-cell cellular networks, etc.;

3. The 3G TDD system should enable the advanced technologies such as smart antenna, uplink synchronization, baton handover, joint detection, etc., as could as possible.
4. The chiprate should be easy to deploy software radio for baseband data processing;
5. Low cost solution;
6. The 3G TDD system should consider the compatibility with both the current 2G mobile system and the future 3G FDD system as could as possible.

Under the above considerations, a low chiprate for TD-SCDMA (also a low chiprate option for UTRA-TDD) is proposed. The exact value is 1.3542Mcps.

1.3. Performance

For an IMT2000 RTT, it should meet the minimum requirements of ITU, which is presented in the document M.1225. The key point is to provide the services required by IMT2000, that is, to provide data service at the rate from 1.2kbps to 2Mbps in different environments and to provide the performances such as high spectrum efficiency, low cost, worldwide roaming, and so on. It is well known that, to provide the same data transmission rate, narrower bandwidth or lower chiprate means higher spectrum efficiency and lower cost. Then the question becomes how to choose the minimum chiprate to meet the minimum requirements of IMT2000. Based on our study, the minimum chiprate mainly depends on the technology adopted in the RTT. Simulation results show that the minimum requirements of IMT2000 can be met at the chiprate of 1.3542Mcps in the TD-SCDMA (UTRA-TDD low chiprate mode) RTT proposal.

1.4. Technologies

The main contribution to meeting the minimum requirements of IMT2000 at the chiprate of 1.3542Mcps comes from the advanced technologies adopted in TD-SCDMA RTT. In other words, the higher data transmission rate and capacity can be reached at the same chiprate when the advanced technologies, such us smart antenna, uplink synchronization, joint detection, etc., are applied in the RTT. However, unfortunately, based on the present level of microelectronics, the technologies limit the chiprate in the system.

1.4.1. Smart antenna

As an example, let’s study the Rx path in a smart antenna based Node B. One may calculate the bitrate on the high-speed bus under the following basic conditions :

- Number of antenna elements: N ;
- QPSK modulation;
- 16-bit parallel input and output bus;
- Chiprate: R;
- 8-time oversampling in both I and Q branches;

then the bitrate will be:

$$bitrate = 2 \times N \times 8 \times R = 260Mbps\ (R = 1.3542Mcps) \text{ Or } 786.4Mbps\ (R = 4.096Mcps)$$

where $N = 12$ as an example. Obviously, so high rate bitstream can not be processed in DSP in real time. One way is to separate the high-rate part (over sampling, for example) in each TRx by DSP or ASIC, then the bitrate on the bus will be reduced by a factor of 8 that:

$$bitrate = 32.5Mbps\ \ (R = 1.3542Mcps) \text{ Or } 98.3Mbps\ \ (R = 4.096Mcps)$$

Obviously, lower chiprate is easier to process on the bus.
As mentioned above, the beamforming will be processed in DSP by software. The processing capacity of the available commercial DSP at present is about 1GIPS, and may be up to 2 to 3 GIPS by end of 2001. If the DSP is interfaced to bus with a rate of a few hundreds Mbps, it will have no time for data processing! Parallel processing may be a solution, but it will bring complexibility.

1.4.2. Uplink synchronization

The specification for the accuracy in uplink synchronization is $\pm 1/8$ chip duration. Theoretically, when the uplink synchronization tolerance is larger than $\pm 1/4$ chip duration, the obvious Multiple-Access-Interference will appear.

Based on the above accuracy in uplink synchronization, the timing tolerance will be approximately 90ns for chiprate of 1.3542Mcps or 30ns for chiprate of 4.096Mcps respectively. Since the frequency stability or timing accuracy of most proposed IMT2000 RTTs is 0.1ppm for UE, the random timing tolerance will be the same level as 100ns. This means that the high chiprate is limited to use when the reported uplink synchronization technology is adopted.

As a conclusion, lower chiprate will be easy to adopt smart antenna and uplink synchronization technology based on the present and the short future level in software radio technology.

1.5. Cost issue

It is obviously that, the lower chiprate will lead to less MIPS requirement for DSP or less complexities in ASIC when the software radio technology is adopted,. This means that low chiprate is a low cost solution in both initial R&D and final mass production. Remember that the cost of products is one of the most important issues in the requirements of IMT2000.

1.6. Network

Let's study a typical CDMA TDD cellular network as shown in Figure 1, where each cell uses the same carrier frequency and operate at the condition of asymmetric data transmission, one may find the overlap period between cells. At that time, it is possible that the Node B in one cell is receiving while the Node Bs in other cells happen to transmit. Obviously, serious interference in this overlap period will lead to following problems:

- Blocking receivers in both Node B and UEs in the overlap period in some area;
- Serious bit error rate.

The possible technologies to overcome these problems in TDD network are smart antenna and DCA. But both of them can only reduce the interference somewhat if each cell is operated at the same carrier frequency.

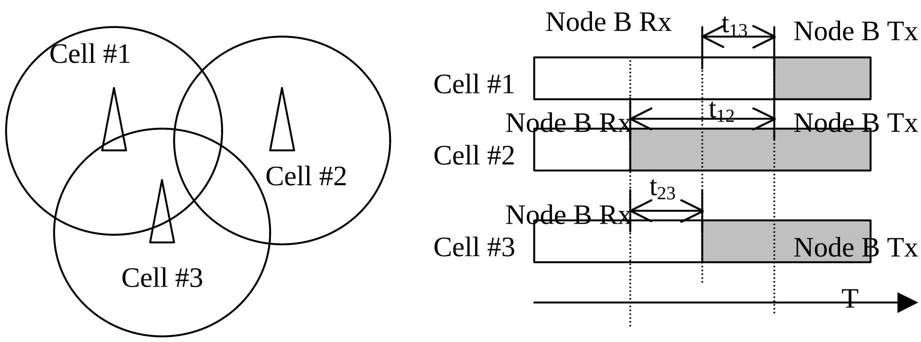

Figure 1. TDD operation in cellular system

Reference to the spectrum allocation for IMT2000, there is only 15MHz for TDD mode (2010-2025MHz). In most common situations, there is more than one operator in an area, only 5MHz bandwidth for each operator can be distributed. If a high chiprate, e.g., 4.096Mcps is used, only one carrier can be allocated in the 5MHz bandwidth, the above problems will still exist, then the system capacity will be degraded.

However, the reported lower chiprate of 1.3542Mcps per carrier of 1.6MHz can solve this problem. In this case, each operator has 3 carrier frequency resources. 3 carriers mean more freedom in beamforming or in DCA so as to avoid the harmful effects as could as possible because of the overlap period with the same carrier frequency in one area.

1.7. Compatibility issue

The dual- or multi-mode UE is required for future IMT2000 network to realize worldwide roaming. Based on our understanding, the strategy for UE design should be that:
Phase I: Dual-band, dual-mode UE for working in both 2G mobile and 3G initial networks. At the initial stage, the network will be renovated from 2G to 3G, and the existing 2G network will be developed continuously. In this phase, the reported TD-SCDMA (UTRA-TDD low chiprate mode) will provide a low cost, software radio based solution as shown in Figure 2.

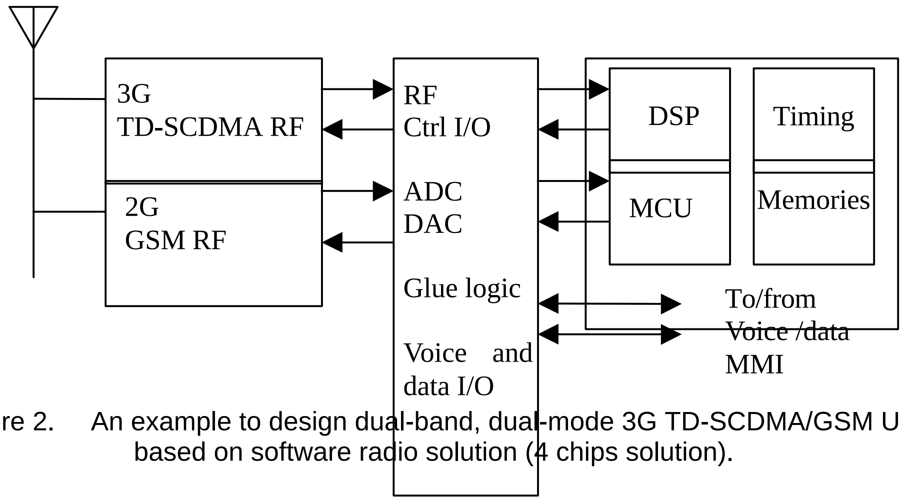

Figure 2. An example to design dual-band, dual-mode 3G TD-SCDMA/GSM UE based on software radio solution (4 chips solution).

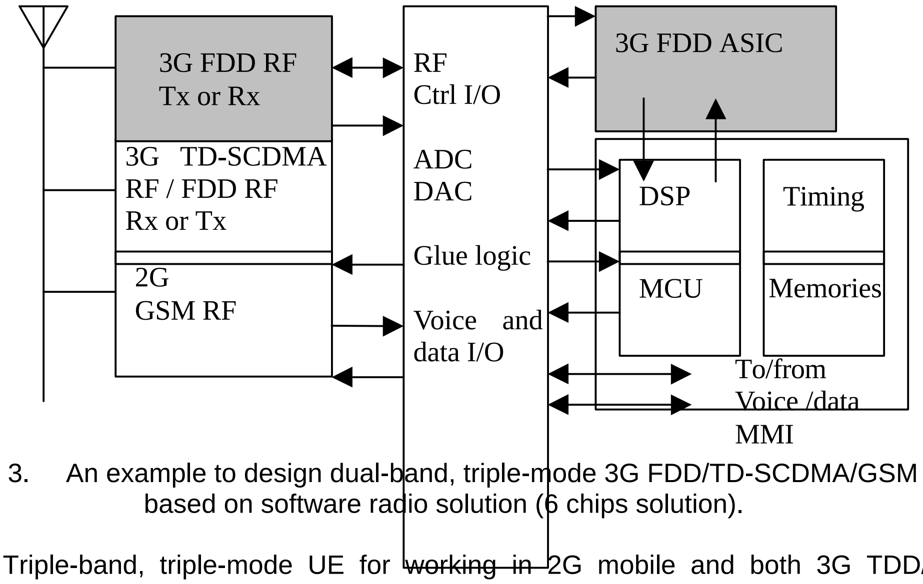

Figure 3. An example to design dual-band, triple-mode 3G FDD/TD-SCDMA/GSM UE based on software radio solution (6 chips solution).

Phase II: Triple-band, triple-mode UE for working in 2G mobile and both 3G TDD/FDD modes. Since the FDD operation needs Tx/Rx isolation in RF part and ASIC in baseband, the design for this UE will be very complex as shown in Figure 3 as an example. The TDD mode shown in this figure is TD-SCDMA (UTRA-TDD low chiprate mode). Obviously, if remove TD-SCDMA mode from the UE, the similar hardware has to be used. It means that TD-SCDMA does not lead to any complexities in hardware.
Phase III: Multi-mode UE.

That the more modes for the UE means more complexities in design. Then the dual- or multi-mode UE has to be designed based on the software radio so that the complexities in design could be reduced enough. As above mentioned, the reported low chiprate of 1.3542Mcps is benefit to software radio design. Then one can make a conclusion that using the low chiprate in TD-SCDMA (UTRA-TDD low chiprate mode) doesn't bring compatibility problems.

1.8. RF issue

Although the signal spectrum bandwidth of one carrier is proposed 1.6MHz in TD-SCDMA (UTRA-TDD low chiprate mode), the width of the RF bandpass filter is 5MHz in designed TD-SCDMA RF TRx, and there is no difference compared with UTRA-FDD/TDD mode. Therefore, the same RF module can be used in both narrowband and wideband TDD modes or even as a Rx or Tx part in FDD mode.
Then the narrowband carrier because of low chiprate in TD-SCDMA RTT doesn't bring compatibility problems in RF part.

1.9. Clock issue

When one would design a dual- or multi-mode UE, an important issue the common main clock should be carefully studied. According to compatibility strategy mentioned above, the

common main clock of 13MHz is a good solution to design the multi-mode UE. The reason is that 13 MHz crystal is not only very cheap, for it has been widely used in GSM handsets, but also could meet the compatibility requirements of different chiprate, The strategy is that a 13MHz crystal and a programmable PLL circuit are used to provide different working clocks. Let's see the below calculation.
The 1.3542MHz clock could be obtained that:

$$13MHz \div 96 \times 10 = 1.3542MHz$$

The 3.84 MHz clock could be obtained that:

$$13MHz \div 325 \times 96 = 3.84MHz$$

And the 4.096 clock could be obtained that:

$$13MHz \div 1625 \times 512 = 4.096MHz$$

From above calculation, you will find that it is possible to use single 13MHz crystal as common main clock source to design multi-mode UE.

Someone think that in order to harmonize with UTRA-TDD high chiprate mode (4.096Mcps or 3.84Mcps), TD-SCDMA (UTRA-TDD low chiprate mode) has to use 1/3 of 4.096Mcps or 3.84Mcps as its chiprate, that is 1.3653Mcps or 1,28Mcps. This consideration maybe not very accurate, for the frame structure of TD-SCDMA is different from that of UTRA-TDD high chiprate mode in physical layer very much, it is not the simple multiple relationship between the chiprate of two RTTs. Furthermore, the 1.28Mcps will lead it very difficult for TD-SCDMA to realize 2.048Mbps data service. So 1.28Mcps is not a good solution to TD-SCDMA. It is preferable to use 1.3542Mcps for TD-SCDMA.

From above brief analysis, you will find that the clock issue is not a problem for the future harmonization between TD-SCDMA (UTRA-TDD low chiprate mode) and UTRA-TDD high chiprate mode.

2. Comparison study

As presented in section 1, the necessity and possibility to introduce a narrower bandwidth, lower chiprate TDD mode – TD-SCDMA in 3GPP family for IMT2000 is described. A comparison study for the chiprate is shown in Table 1.

Table 1. Comparison study on chiprate for 3G TDD mode

Item(Mcps)	1.024	1.3542	4.096	Note
Proposal	ARIB	CWTS	ETSI	
Radio Frame (ms)	10	10	10	
TDD Interval(ms)	10	5	10	
No. of TS in a frame or subframe	4	10	16	subframe for CWTS
Max. No. of code chs. in a TS	16	16	16	SF=16
2.048Mbps service	No	Yes	Yes	
Modulation	QPSK	QPSK	QPSK	
Smart Antenna	possible	Yes	complex	
Joint Detection	Yes	Yes	Yes	
Uplink Sync.	No	Yes	complex	
Software Radio	partially	Yes	partially	
Main Clock(MHz)	?	13	?	Compatible with GSM

3. Conclusion

In this working document, the problems that related to chiprate in 3GPP TDD modes are discussed in detail. One can find that introducing a low chiprate of 1.3542Mcps in TD-SCDMA (UTRA-TDD low chiprate mode) will provide the advantages such as higher capacity, better performance, lower cost, easy to fulfill, and so on, while it benefit to meeting the minimum requirements of IMT2000.