TSG-RAN Working Group 4 (Radio) meeting #3 **TSGR4#3(99)100**
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Agenda Item: **7. Work related to combined documents;**
S4.01 (A and B) Radio transmission and reception (FDD and TDD)

Source: **Siemens**

Title: **Definition of Channel Raster**

Document for: **Discussion**

Abstract

This contribution aims at defining the carrier center frequencies for UTRA.

As yet there is no exact formula in the base documentation, so a formula is proposed which takes the following points into consideration:

- Carrier separation fine tuning for ACPR adaptation.
- Implementation considerations regarding the granularity of the center frequencies vs. Synthesiser settling time
- Search time and power consumption (standby time) for out of coverage and roaming scenarios.

Introduction

In [1,2,3,4], which were merged from [5,6] and [7, 8] the carrier raster is defined as follows: "The nominal channel spacing is 5 MHz, but this can be adjusted to optimize performance in a particular deployment scenario. [...] The channel raster is 200 kHz, which means that the carrier frequency must be a multiple of 200 kHz."

The carrier raster has been decided to be a multiple of 200kHz. A selection of the center frequency with this granularity is seen as a reasonable compromise between the flexibility for fine tuning of the ACPR for adjacent carriers and increased phase noise due to a lower reference frequency used for the synthesiser. Higher reference frequencies also allow faster synthesiser settling times which are crucial for handover preparation and execution. This selection also facilitates the integration of GSM UTRA dual mode terminals sharing the same synthesiser, because GSM also uses carrier center frequencies being a multiple of 200kHz (see [9] Chapter 2, Frequency bands and channel arrangement).

The necessary frequency allocation for a UTRA carrier is around 5 MHz, the investigation presented in [10] come to the following conclusion:

- **Inter-operator channel spacing should not fall below 5 MHz**
- **Intra-operator, inter-layer channel spacing should ideally be 5 MHz.** Reduction below this figure may be possible but would have to be verified by additional studies.
- **Intra-operator, intra-layer carrier spacing should be at least 4.4 MHz.** If sufficient spectrum is available, this spacing should be increased to **4.6 MHz** (or even 4.8 MHz).
- **Although the above carrier spacings are considered to be an optimum based on the information available and the assumptions made, spectrum should be 'packaged' in a way that allows operators maximum flexibility to vary carrier spacings.**

[...]

The carrier spacings suggested above have been calculated using the assumption that the spectrum available to UMTS is unbounded. In practice, of course, there is only a limited amount of spectrum available which has to be split between a number of operators. Consequently, the optimum solution for a particular regulatory environment may require the use of carrier spacings that are different to those recommended above.

The primary paired UMTS band consists of 2*60 MHz, which cold be sliced into 12 carriers with an average carrier spacing of 5MHz. Such an allocation looks feasible, taking into account the above described results. The next step would be to try to squeeze 13 channels into the frequency allocation, with an average spacing of 4,6 MHz. This allocation however could only be maintained if the entire spectrum was allocated to a single operator which should use preferably a single layer. This however is not in line with the expected spectrum usage. At least 2 if not 3 or 4 operators are expected to be granted spectrum to enable competition. Every operator is expected to use at least two layers to cope with fast moving mobile stations in a city with high traffic load.

A definition of the carrier raster is proposed which supports exactly the required flexibility but avoids overhead associated with a totally unrestricted scheme.

Consequences of carrier raster definition on search and standby time

Presently a 200kHz raster is implied, i.e. the carrier center frequency could be expressed as
Fc = F0 + 200 kHz * m
where m is an integer.

For an expected initial frequency allocation of 2*60 MHz, a total of (60MHz-5MHz)/200kHz = 275 possible channels are possible for the paired band only plus additional channels for the unpaired bands.

Assuming an worst case acquisition time of 500 ms per carrier seems to be in line with the simulations shown in [11] and [12]. The results show that the cell search can be completed in less than 500ms at 90% probability. Then the total scanning time which would apply for a mobile roaming into an other country and trying to get a complete picture of the available networks would be two and a halve minutes. This scenario unfortunately also applies for a UE which is out of coverage but still has to scan all channels periodically to establish this fact. Such a UE would have to scan the entire band continuously, which means the receiver must be switched on continuously, much more than would be necessary for paging operation. Both scenarios will cause excessive battery drainage, the latter will happen quite often during the roll out phase of UTRA.

Obviously the mobile station can make use of heuristics to speed up the cell search process in some cases, e.g. trying first the frequency where it did find service for the last time or the entire neighbour cell list of the operator the UE was last registered with. Similar heuristics are already allowed in the GSM system (see [13], Stored list cell selection), the exact heuristics are left unspecified to allow manufacturers to optimise performance for changing requirements. However, if these heuristics fail, the UE will still have to scan all available frequencies before it is aware that either no service is available at all or only from foreign operators.

This effect can be seen (to a lesser extent) for GSM mobile stations which typically take much longer to register on foreign networks (say after leaving an aeroplane) than on the home network. Also standby times quoted for GSM mobiles can only be achieved if the UE has network coverage and does not have to scan to find a new network. In the latter case standby times are typically much shorter. Obviously these figures are not cited in sales brochures.

A GSM mobile station will first only measure the received signal strength on a given carrier and only attempt to find a synchronisation if the carrier is strong enough e.g. 9dB above the noise level. Similar heuristics are possible for all non-CDMA systems. However, due to the processing gain it is possible to receive CDMA signals even if the signal strength is below or around the noise floor, so this heuristic is not applicable to UMTS and therefore can not be used there. Stand by time degradations for UTRA terminals must therefore be expected to be much more severe than for GSM.

Proposed carrier definition formula

The carrier raster of 200kHz is obviously not needed for such a dense carrier allocation but for fine-tuning of a carrier raster of basically 5MHz. It is therefore suggested to mirror exactly these requirements in the carrier definition formula:

$Fc = F_0 + 5\text{ MHz} * n + 200\text{ kHz} * k$; $F_0 = 1922.4$ MHz (for FDD band);

F_0 is the first (nominal) carrier center frequency (the spectrum used by the first carrier would then extend down to about 1920 MHz i.e. the IMT paired band); n is an integer running from 0 to 12 for the paired band and describes the cannel, as if a regular 5MHz allocation was used, k is used to express a deviation from this regular scheme in steps of 200kHz. k can be positive or negative, but will only cover a small range. As a baseline choice we propose $-2 \le k \le 2$. This seems to be sufficient to perform any necessary carrier raster fine-tuning. It is then possible to shift two intra layer carriers as close as 4.2 MHz in order to get more separation to inter layer and inter operator carriers (up to 5.8 MHz).

Note that the carrier allocation is slightly unsymmetrical to the middle of a 5 MHz band because the latter is not a multiple of the 200 kHz synthesiser spacing. The value of 1922.4 has been chosen because this will give an extra 200 kHz separation to the satellite band which could be more vulnerable to intersystem interference. Of course, if need be, the uppermost carrier can still be placed closer, e.g. setting k=1.

Advantages of the proposed carrier definition formula

In a situation when not being able to establish a connection with the last serving network, either due to roaming or due to leaving the coverage area, the UE has to scan significantly less potential channels, causing shorter scanning times and less battery drainage.

In all the protocol messages which define a carrier, less bits have to be allocated for the definition of a carrier. 9 bits are necessary for coding 275 channels. For coding n and k or the corresponding UTRA absolute radio frequency channel number (UARFCN) for the proposed 5*12=64 carriers 6 bits will suffice. This affects all assignment / handover- type messages and, more important, the coding of neighbour cell lists. The latter is particularly important for handover and cell reselection from 2nd generation systems. Large capacity for transmission of neighbour cell information was not anticipated during the design of theses systems and is consequently not easily available now. In GSM for example, due to the introduction of DCS 1800 very advanced coding schemes had to be introduced to make coding of the NB list of more than 128 channels possible (see [14] chap. 10.5.2.13).

TDD operation

The same principle is applicable for TDD as well, as both systems are harmonised with respect to chip rate and modulation scheme. The same formula is proposed with the only difference being the lower first nominal carrier center frequency:

$Fc = F_0 + 5\text{ MHz} * n + 200\text{ kHz} * k;$ $F_0 = 1902.4$ MHz (for TDD band); $-4 \le k < 4;$

Extension bands, spectrum refarming and alternate chiprates

A similar carrier center formula can be applied for carriers using higher chiprates, carriers in possible future extension bands and for refarming frequencies which are presently used by other services, e.g. 2nd generation systems. In the simplest case, only F_0 has to be adapted. However, due to possible additional constraints which may or may not be relevant for some of these bands (i.e. UMTS carriers interleaved with carriers of 2nd generation systems), it seems to be wise to wait until these bands actually become available. There is no need to define the carrier raster for these frequencies now, because the first generations of 3rd generation terminals will only be operational in the core frequency bands anyhow due to limitations of the flexibility of present RF technology, in particular duplex filters. Software radios will eventually allow flexible tuning on all possible frequencies, but such concepts are not expected to be cost efficient in the very near future i.e. during the first years of deployment of 3rd generation systems.

Conclusion

A new way of describing the carrier-frequency for UTRAN has been proposed. It supports all the necessary freedom for efficient carrier allocation but avoids overhead associated with the present scheme. In particular the scanning time is reduced, standby times are improved and channels can be coded more efficiently.

It is therefore suggested to include the following definition into the specification. This text proposal takes [1] as a starting point, however, the carrier definition formula presented above should also be included in [1] and possibly also in the WG1 and WG2 specifications.

Text Proposal

5.4.3 Channel number

The carrier center frequency is designated by the UTRA absolute radio frequency channel number (UARFCN). The carrier center frequency Fc can then be calculated as follows:

n = UARFCN div 5
k = (UARFCN mod 5) - 2

$Fc = F_0 + Fs * n + 200 kHz * k$

The first nominal center frequency F_0 and the nominal carrier spacing Fs depend on the used chiprate and the frequency band:

Frequency Band	*Chip Rate*	*first nominal center frequency F0*	*nominal carrier spacing Fs*
Primary FDD band	*[4. 096 Mcps]*	*[1922.4 MHz]*	*[5 MHz]*
Primary TDD band	*[4.096 Mcps]*	*[1902.4 MHz]*	*[5 MHz]*
[TBD]	*[TBD Mcps]*	*[TBD]*	*[TBD]*
[TBD]	*[TBD Mcps]*	*[TBD]*	*[TBD]*
[TBD]	*[TBD Mcps]*	*[TBD]*	*[TBD]*

This carrier allocation allows efficient coding, efficient initial synchronization and efficient tuning of adjacent channel protection.

References

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[3] S4.01B version 0.0.3 (1999-02) " UTRA (BS) FDD; Radio transmission and reception "; Editor

[4] S4.02B version 0.0.2 (1999-02) " UTRA (BS) TDD; Radio transmission and reception "; Editor

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[6] UMTS XX.12, "UTRA TDD; Radio transmission and reception", v0.1.0, Jan 1999

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[8] R4-99003; The latest Base Station specifications of ARIB Volume5 "Specifications of Base Station for 3G Mobile System (Ver.1.0-0.1)", ARIB.

[9] GSM 05.05 (ETS 300 577): "Digital cellular telecommunications system (Phase 2); Radio transmission and reception".

[10] UKTAG report , Tdoc SMG2 UMTS-L1 738/98

[11] Comma Free Codes for Fast PN Code Acquisition in WCDMA Systems: A Proposal for the UTRA concept, Tdoc SMG2 UMTS-L1 121/98.

[12] K.Higuchi, M.Sawahashi, and F.Adachi, "Fast Cell Search Algorithm in Inter-Cell Asynchronous DS-CDMA Mobile Radio," IEICE TRANS.COMMUN.,Vol.E81-B,No.7 Jul.1998

[13] GSM 03.22 (ETS 300 535): "Digital cellular telecommunications system (Phase 2); Functions related to Mobile Station (MS) in idle mode".

[14] GSM 04.08 (ETS 300 557): "Digital cellular telecommunications system (Phase 2); Mobile radio interface layer 3 specification".