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Introduction

This contribution discusses some aspects of the Sync Burst construction that can be used for the sync approach as proposed in [1]. The construction of a new sync sequence offers the possibility to overcome drawbacks of the existing SCH signals [2].

Code Selection

It has been proposed to transmit special bursts at periodic intervals within the PRACH time slot to support NodeB sync [1]. Essentially the whole of this timeslot, allowing for an extended guard period, is available for this purpose. This permits the use of a long sequence, affording two benefits:-

- Improved processing gain leading to increased range capability between NodeBs.
- Improved auto correlation properties. It is important for sync measurements that it be possible to detect reliably the earliest path even if this is significantly weaker than the strongest path. To do this requires a code with good autocorrelation (ACF) properties. By contrast the PSCH has a worst case peak only 12 dB down on the main response and even worse properties when the SSCH codes are taken into account [2].

At first sight it might appear that only one code is required. If this were the case then an ideal code would be an M sequence. The longest such sequence which will fit within the available slot is of length 2047. However, detailed examination of the scenarios for providing over the air NodeB sync indicate that more than one code will be required. This arises because it will be necessary to be able, uniquely, to identify the NodeBs of one RNS. Thus, for example, if different companies on adjacent floors are provided with RNSs by a single operator they will all use the same frequency but will be uncoordinated. The sync algorithm would be confused by receiving sync messages from another system on top of the sync messages from its own system if these cannot be distinguished. Because the RNS boundaries will be well defined, interference between sync bursts need only be considered between RNSs with a common boundary. This means that the code allocation requirement simplifies to a map colouring problem with only 4 such colours required. Thus we need 4 sync codes. Note that there is no solution to this problem for the PSCH based proposal.

If more than one code is required then the codes must have preferential cross correlation properties. For M sequences such codes appear only in pairs so that we must consider the use of Gold codes.

It is proposed to use Gold codes of length 2047 constructed from generators octal 4005 and 7335. A total of 2049 such codes are available. The first two of the four codes will be the M sequences themselves. These will have near ideal ACF properties. The other two will be selected as modulo additions of selected shifts of the base codes. These will be selected for good balance. The peak correlations for these will be about -30 dB on the main peak.

The normal ACF is defined for correlation against cyclic extension of the code. The actual situation is that the signal will be transmitted without such cyclic extension. As the shifts become a significant fraction of the code length, the contribution to the *missing* cyclic extension also becomes significant. However, excellent ACF properties are only required over the delay spread of the received signal. This is overbounded as 57 chips according to the assumptions for the midamble channel estimator - in practice it will generally be much less than this. The non cyclic ACF for an initial selected Gold code (modulo two addition of the base sequences unshifted) has a largest peak over this range which is still 28.4 dB down on the main response. The ACF is shown in Figure 1 below:-

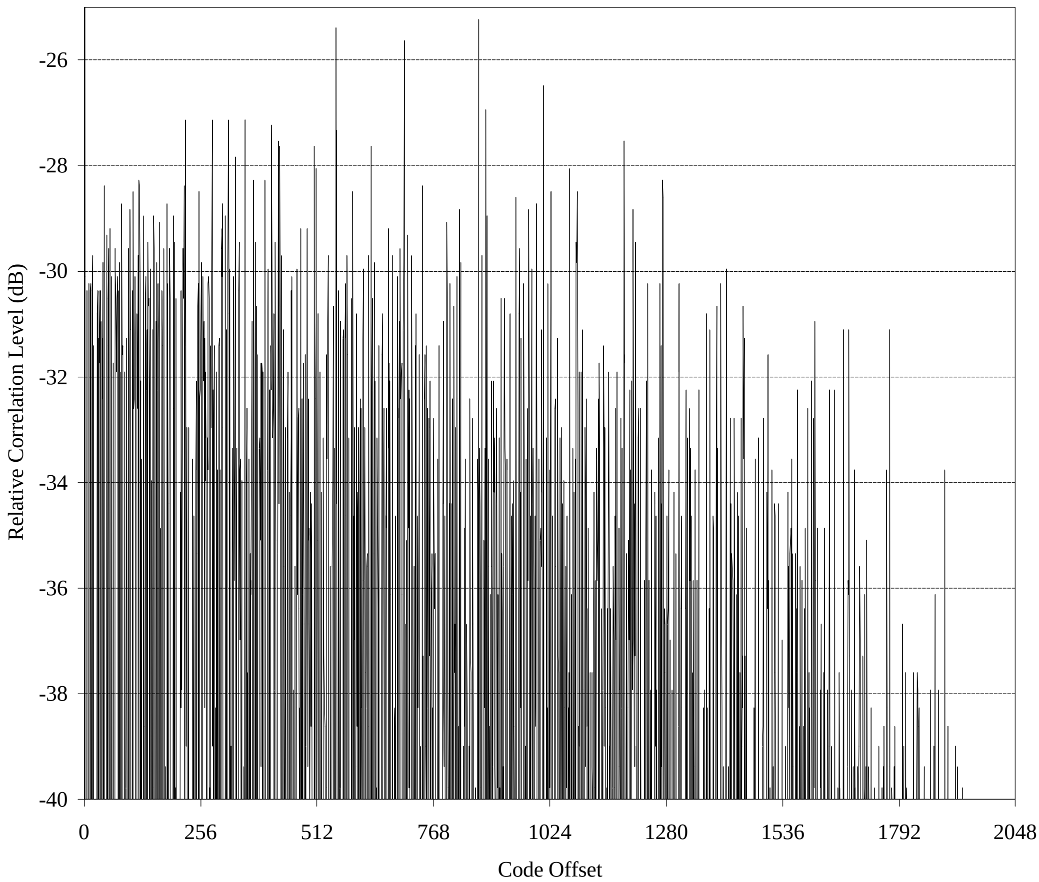

Figure 1 ACF of Gold Code without Cyclic Extension

It would be possible to add a cyclic extension of 57 chips to ensure that the correlation peak is the full 30 dB down over the delay spread window although this is probably unnecessary.

The cross correlation properties of Gold codes are the same as their autocorrelation properties so that the codes will also be suitable for the multiple RNS requirement

Thus the proposed codes provide adequate correlation properties for all requirements.

Modulation

It is desirable to use the modulation which provides the simplest receiver compatible with the performance required. Because the overall operation is based on a clear channel for sync message transmissions and because the signals will generally be buried in receiver noise at limit range there is no requirement for complex modulation. Thus the sync burst can be transmitted as BPSK. A 45 degree shift is proposed to optimise use of the IQ upconvertor so the proposed modulation is to multiply the code by (1+j).

Receiver Complexity

If we consider initial sync then we must remember that at this stage, sync searching is the *only* thing that the NodeB/Cell needs to do. Thus, essentially, all of the processing capability of the NodeB is available for this purpose. However, as we shall see, only a fraction of this will actually be required.

Initial code searching can be performed by a fast convolution based on an FFT of length 4096. This is estimated to be about 14 times faster than conventional correlation.

Thus, we can estimate the complexity relative to correlating on the PSCH for initial search as follows:-

Code Length increase by factor 8

Loss of factor 8 due to hierarchical code

Gain due to fast convolution 14 without optimisation - further improvements possible by exploiting zero stuffing

Net effect:- 8 x 8 / 14 = 4.6 times as complex as PSCH correlation for initial sync.

However, the sync burst based approach provides a path loss improvement over PSCH of about 21 dB (16 times the power and 8 times the processing gain. Sampling at one sample per chip can lead to a loss of about 4 dB if the path position falls halfway between samples. Sampling at two samples per chip reduces this to less than 1 dB. The sync burst approach can afford to sacrifice the 3 dB gain (reducing the relative improvement from 21 dB to 18 dB - still very significant) in a way that the SCH based approach cannot. If this is taken into account then the correlation time for the sync burst is *no more than 2.3 times the correlation time for the PSCH.*

It must also be remembered, that in the case of using the SCH, non coherent combining must be used during the initial phase to reduce the incidence of false correlations. This would add to the processing complexity.

Consider the implementation of the fast convolution on a typical DSP processor:

In the initial phase it would be necessary to perform two length 4096 FFTs every received 2047 chip samples (ie every 533 microseconds) or an average of one every 266 microseconds.

The benchmark for a tigersharc processor operating at 180 MHz is to perform a 256 point complex FFT in 6.1 microseconds.

The ratio of complexity for a 4096 pt FFT over a 256 point FFT is $\frac{4096 \times \log_2(4096)}{256 \times \log_2(256)} = 24$

so we would expect to be able to perform a 4096 point complex FFT in 146.4 microseconds. i.e. in only 55% of the available time.

Thus it should be possible to perform the correlation *in only one processor*.

Note, however, that at this stage the NodeB/Cell has nothing else to do so *all of the processors* could be available for this task - thus there is plenty of margin in meeting the requirement.

After initial sync, the requirement is far less onerous. If we have an absolute sync accuracy of ± 2.5 microseconds for sync and if the NodeB/Cell is informed of the estimated propagation delay from NodeB/Cell to NodeB/Cell then the correlation window can be set to ± 5 microseconds or 10 microseconds total. This corresponds to 77 samples at 2 samples per chip. The correlations need only be performed a maximum of once per PRACH transmission cycle which is once every 1.28 seconds.

This corresponds to a processing load in normal operation of 2047 x 2 x 77 / 1.28 = 0.25 MAC/s which is trivial. An acceptably higher load of 1 MAC/s would allow a significantly wider window if desired.

Conclusions

A proposal for the sync burst format based on length 2047 Gold codes has been made. It has been shown that this provides excellent correlation properties whilst requiring a processing load in the receiver which will *not necessitate any additional hardware in the NodeB.*

References

[1] R1-00-0074, "NodeB Synchronisation for TDD", Siemens, Beijing, China, January 18-12, 2000

[2] R1-00-0xxx, " Analysis of the SCH for Cell Sync Purposes", Siemens, Berlin, Germany, Augusr 22-25, 2000