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Source: **Texas Instruments**
Title: **RACH Preamble Design**
Agenda Item: **8.2**
Document for: **Discussion**

1. Introduction

The RACH (Random Access Channel) preamble is used in UTRA to allow contention among uplink users for usage of the random access channel [1,2]. It is a 4096 chip long code which is modulated by one of 16 repeated Hadamard codes of length 16. This contribution investigates whether a similar time domain sequence is suitable for E-UTRA or whether a frequency domain RACH preamble is more appropriate. A large number of simulations were presented when the RACH preamble was agreed upon for UTRA [3]. This contribution does not attempt to duplicate these simulations, but rather presents a few simple simulations to make some preliminary comparisons between two techniques. Section 2 gives an overview of the two techniques studied, and Section 3 presents simulation results comparing the techniques.

2. Two RACH Preamble Structures

Structure 1 is similar to the current UTRA RACH preamble in that it uses a long code modulated with a repeated length 16 Hadamard code. The current UTRA RACH preamble is shown in Figure 1 for reference. It has a duration of slightly more than 1 ms so that 15 access slots can be defined within 2 frames which have a combined duration of 20 ms.

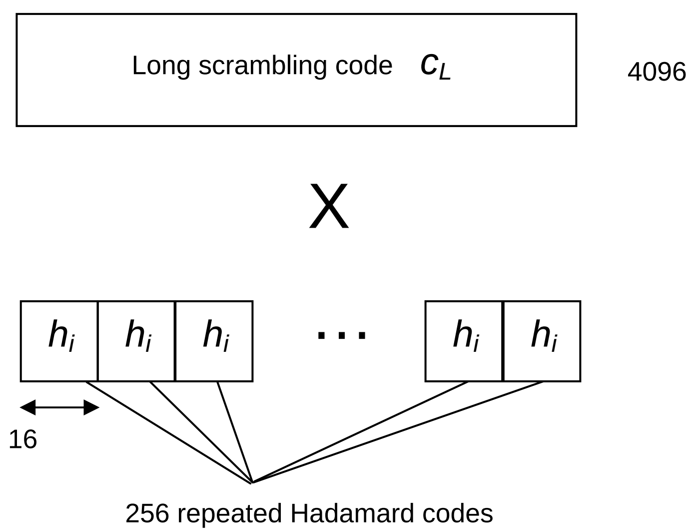

Figure 1 – Current UTRA RACH preamble.

Structure 1 that is simulated using the E-UTRA parameters has a duration of 1 ms and has an excess bandwidth factor of 0.15. For the 5 MHz bandwidth, Structure 1 is identical to Figure 1, and for the 1.25 MHz bandwidth the RACH preamble has 1024 samples in order to maintain the 1 ms duration. Table 1 gives the simulation assumptions for the RACH preambles simulated in this contribution.

Table 1: Simulation Assumptions for RACH preambles for E-UTRA.

Parameter		Assumption
Bandwidth		1.25 MHz and 5 MHz
Carrier Frequency		2 GHz
Excess Bandwidth Factor		0.15
Sampling Rate		1.024 MHz (BW=1.25MHz) and 4.096 MHz (BW=5 MHz)
RACH Preamble Duration		1 ms = 2 TTI's = 14 OFDM symbols
RACH Preamble Samples		1024 samples (BW=1.25MHz) and 4096 samples (BW=5 MHz)
FFT and CP Sizes		FFT=64, CP=9.14 samples (BW=1.25MHz) and FFT=256, CP=36.57 samples (BW=5 MHz)
Channel Model		TU, with UE speed of 3 kmph
Antenna Configuration		1 at Transmitter, 2 at Receiver
RACH Preamble Structure	Structure 1 (time domain)	Long code
	Structure 2 (freq domain)	Long code with repetition for IFDMA
Receiver Structure		Time Domain Correlator
Search Window Size		+/- 0.5 OFDM Symbols

Structure 2 uses IFDMA with a repetition of 4 in order to reduce the bandwidth occupancy of the RACH preamble. It is identical to Structure 1 except that for each OFDM symbol the first 1/4 of the useful part of the OFDM symbol is repeated 4 times to form the OFDM symbol and then the cyclic prefix is inserted. Figure 2 shows the construction of Structure 2. First the long code and repeated Hadamard code of Figure 1 are applied. For the 5 MHz bandwidth there are 256 samples in the useful part of the OFDM symbol, so the first 1/4 of the OFDM symbol consists of 64 samples which corresponds to 4 Hadamard codes of length 16. Thus, while the long code generator produces outputs every sample, 64 samples are stored for each OFDM symbol and are used to construct the entire OFDM symbol.

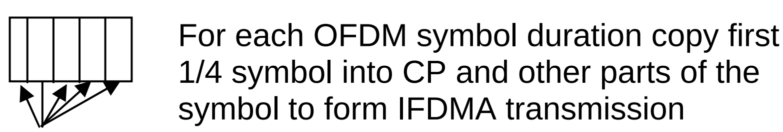

Figure 2: Structure 2 using IFDMA.

3. Simulation Results

The Node B uses a similar receiver for the RACH preamble as that used for UTRA. A bank of parallel correlators is used with half-chip resolution, and the largest correlation output is selected [4]. One difference is that two receiver antennas are assumed since this is the baseline assumption for E-UTRA.

Figure 3 illustrates the receiver structure. Note that in these simulations the threshold was not simulated.

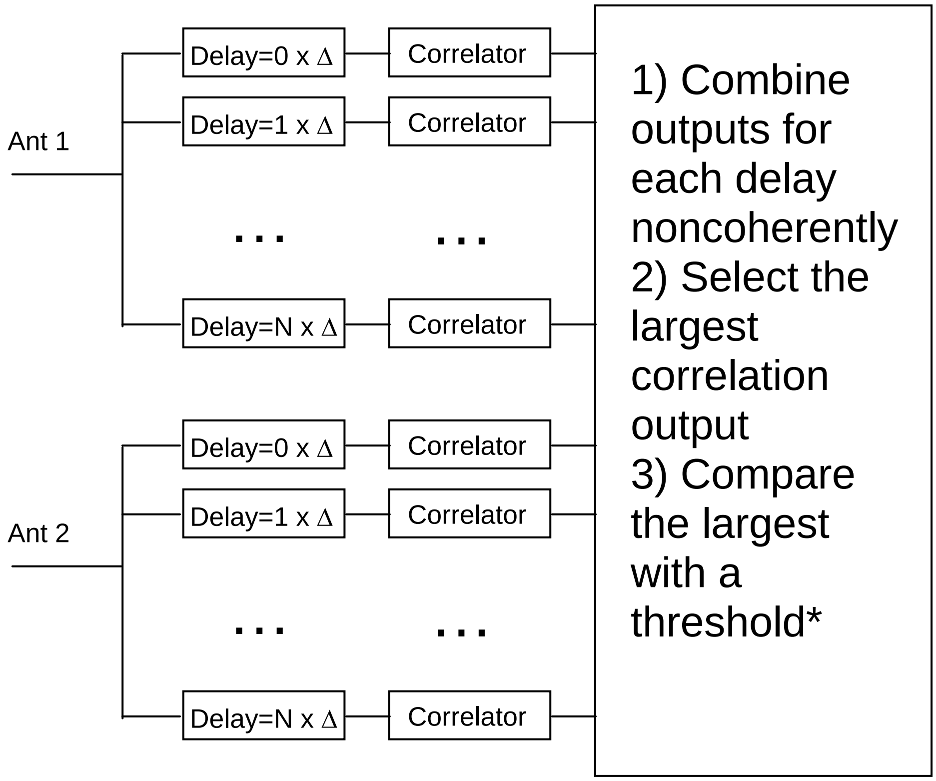

Figure 3: RACH preamble receiver structure. *Threshold was not simulated here.

Figure 4 shows an example of the correlation output for Structure 1 for the 1.25 MHz bandwidth for the AWGN channel with SNR=10 dB. Note that there is a single peak corresponding to the correct timing since the long code is effective in suppressing any sidelobes.

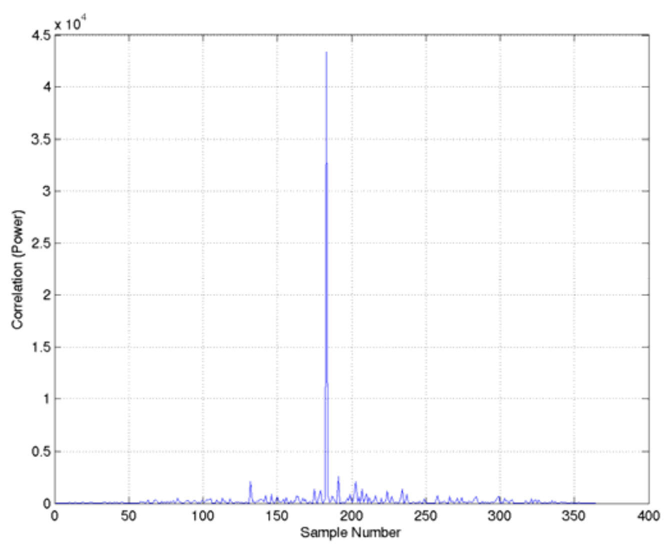

Figure 4: Example correlation output for Structure 1 (AWGN channel, 1.25 MHz, 10 dB SNR).

Figure 5 shows an example of the correlation output for Structure 2 for the 1.25 MHz bandwidth for the AWGN channel with SNR=10 dB. Now there is a peak corresponding to the correct timing but also two smaller peaks 1/4 OFDM symbol away. This is caused by the repetition of the same sequence 4 times within each OFDM symbol. When the correlator aligns with 3 out of the 4 repetitions, there is a significant sidelobe. There are also smaller peaks corresponding to an overlap of 2 and 1 of the repetitions. These sidelobes decrease the probability of the Node B receiver locking onto the correct RACH preamble timing.

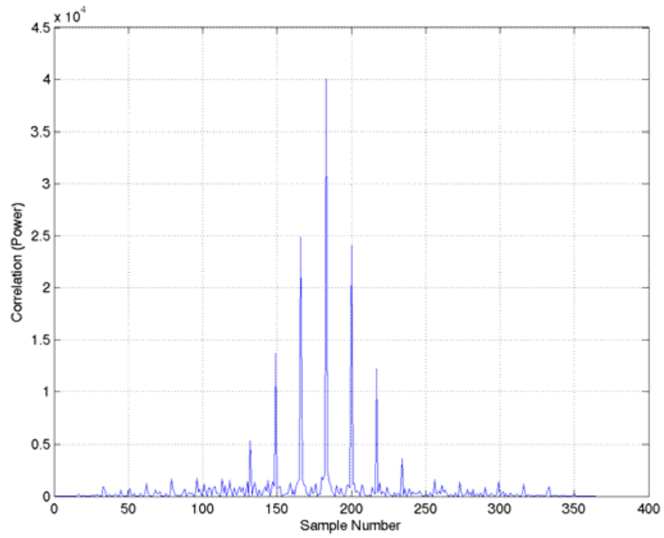

Figure 5: Example correlation output for Structure 2 (AWGN channel, 1.25 MHz, 10 dB SNR).

Figure 6 compares the RACH preamble detection performance for 1 RACH preamble for Structures 1 and 2 for the 1.25 MHz channel. In this simulation the receiver computes the detection metric for all 16 Hadamard codes, and an error is declared if the wrong Hadamard code has the maximum metric or if the timing is off by more than one CP length. Structure 2 (IFDMA) had a loss of between 1 and 2 dB because of the timing errors from the sidelobes due to IFDMA.

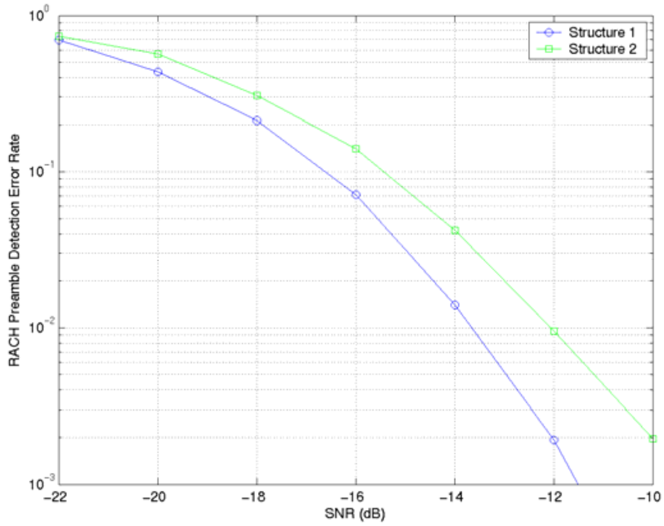

Figure 6: RACH preamble detection performance for 1.25 MHz channel (TU, 3 kmph).

Figure 7 compares the RACH preamble detection performance for 1 RACH preamble for Structures 1 and 2 for the 5 MHz channel. The preamble sequence for the 5 MHz channel is 4 times the length of the sequence for the 1.25 MHz channel, so there is a reduction of about 6 dB in the required SNR for detection.

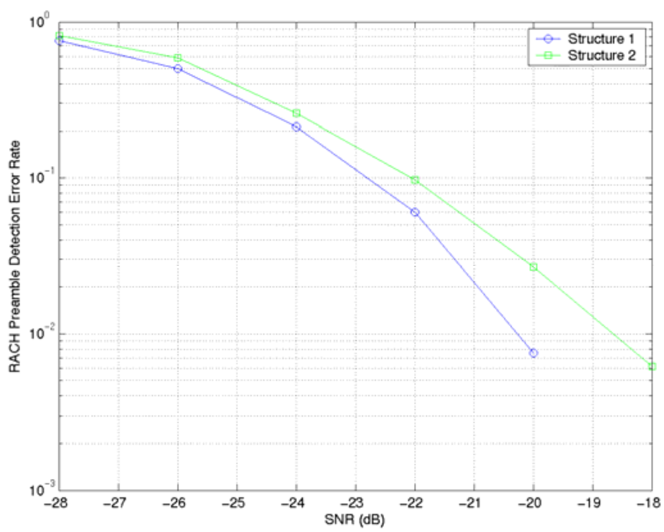

Figure 7: RACH preamble detection performance for 5 MHz channel (TU, 3 kmph).

It may be advantageous for the RACH preamble to occupy only 1.25 MHz of the available bandwidth for the 5 MHz channel. This will allow other traffic to be scheduled without interference from the RACH. Figure 8 compares the RACH preamble detection performance for 1 RACH preamble for LFDMA and IFDMA which occupies 1.25 MHz of the 5 MHz channel. The LFDMA structure shows an improvement in the range of about 0.8 to 1.6 dB over the IFDMA structure. While there is a small loss in diversity with LFDMA, the IFDMA approach suffers from the multiple sidelobes and timing errors. The current RACH preamble (Structure 1) with a 1.25 MHz bandwidth seems to be a good choice for E-UTRA.

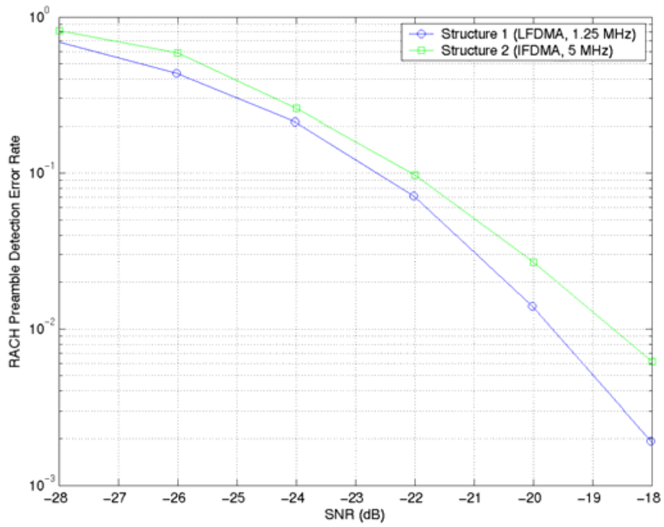

Figure 8: Comparison of LFDMA (occupies 1.25 MHz out of 5 MHz) and IFDMA (occupies 1.25 MHz out of 5 MHz using comb) (TU, 3 kmph).

Figure 9 shows the performance of the RACH preamble detection for the 1.25 MHz channel when the effect of timing errors was not considered. This simulation was done to verify that the reason for the poorer performance of the IFDMA preamble was due to timing uncertainty because of the time domain repetitions. The detection error criterion was modified to declare an error only when the Walsh code was misidentified. Note that the two structures perform similarly, so the difference in performance is due to timing errors for the IFDMA preamble.

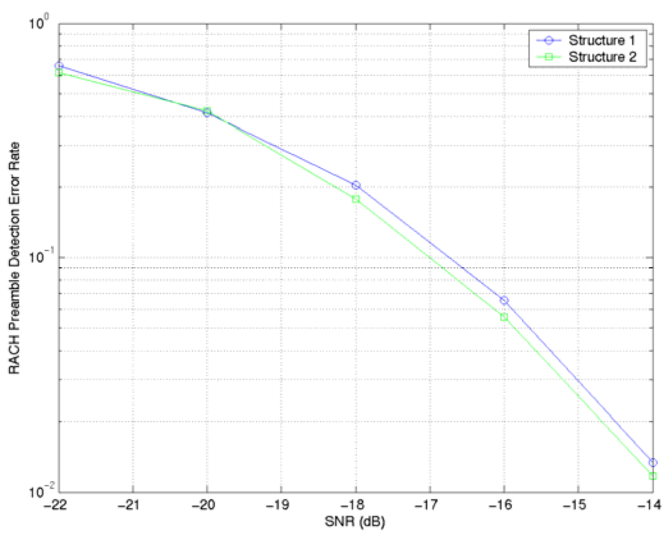

Figure 9: Comparison of LFDMA and IFDMA for the 1.25 MHz channel ignoring timing errors (TU, 3 kmph).

4. Conclusion

This contribution presented a comparison of two structures for the RACH preamble: an LFDMA structure which is similar to the current UTRA RACH preamble and an IFDMA structure. Since the IFDMA structure is formed by making repetitions in the time domain, there is an increased probability of incorrect timing recovery with IFDMA. LFDMA does not have the time repetitions and exhibits better performance for RACH preamble detection.

References

[1] TS 25.211, "Physical channels and mapping of transport channels onto physical channels (FDD)"

[2] TS 25.213, "Spreading and modulation (FDD)"

[3] 3GPP, R1-99893, Motorola and Texas Instruments, "Proposal for RACH preambles"

[4] Park and Kang, "On the performance of a maximum-likelihood code-acquisition technique for preamble search in a CDMA reverse link," IEEE Transactions on Vehicular Technology, Vol. 42, No. 1, pp. 65-74, February 1998.