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Source: Motorola

Title: **Legacy USF Detection Performance with Mixed Modulation RED HOT A**

Document for: **Discussion**

1. Introduction

The contribution [1] proposes a mixed-modulation burst structure for RED HOT A in which 8PSK modulation is used in combination with either 16QAM or 32QAM modulation. The objective of the proposed burst structure is to enable a non-RED HOT A EDGE mobile to successfully detect the USF from a RED HOT A burst. Simulation results in [2] and [4] indicate that the USF can be extracted from such a burst with minimal performance degradation for both TU3iFH and HT100nFH channels. Though not explicitly stated, it seems that in these contributions, backward and forward equalizers were used for the first and second halves of the burst, respectively. Thus, equalization of the 8PSK symbols containing the USF bits is largely unaffected by the presence of the adjacent 16/32 QAM symbols.

Conversely, a receiver using a decision-feedback (DF) type equalizer operating across the burst in the *forward direction only* would likely suffer some degradation at the boundary between the 16/32QAM symbols and the first 8PSK symbol. Any such degradation would occur due to the failure of the DF-type equalizer to properly cancel postcursor intersymbol interference for the first 8PSK symbol as a consequence of the fact that the preceding 16 or 32 QAM symbols cannot be mapped onto the 8PSK constellation that is assumed by the 8PSK equalizer in the legacy mobile.

In [5], it was suggested that some small number of 8PSK symbols be placed before the 8PSK symbol with the first USF bits in order to protect a DF-type equalizer operating in the forward direction only. Simulation results are presented here which indicate that with this padding, the performance of USF detection by the 8PSK equalizer of the legacy mobile is only minimally impacted by the mixed modulation burst. Furthermore, given that 8PSK symbols are transmitted with 2 dB more power than the 16 QAM or 32 QAM symbols, *the performance of the USF is actually better than that for an EDGE 8PSK burst* when measured as a function of the average signal-to-noise ratio of the entire burst.

2. Mixed Modulation Burst Structure

In the proposal [1] (see Figure 1), symbols in the middle of the burst are modulated with 8PSK modulation with $3\pi/8$ rotation. The remaining symbols are modulated with 16QAM or 32QAM with $\pi/4$ rotation. The legacy training sequences are reused and the USF is encoded and mapped as in legacy bursts. The legacy stealing flags are kept at their current positions, while the remaining bits that map into the 8PSK modulated symbols are used for the RLC/MAC header. All symbols to the left of the location of the left-most USF bits and to the right of the location of the right-most USF bits use 16QAM or 32QAM modulation, depending on the burst type.

Though not explicitly stated, it seems that the simulation results reported in [2] and [4] assume the use of an equalizer that operates outward from the center of the burst. More precisely, the proposal assumes a first equalizer operating in the “forward” direction equalizes symbols to the right of the burst and a second

equalizer operating in the "backwards" direction equalizes symbols to the left of the burst. A legacy EDGE equalizer which operates in the forward direction only – from right-to-left across the burst – will be unable to properly cancel the postcursor ISI associated with the 16QAM or 32QAM (with $\pi/4$ rotation) symbols immediately preceding the first 8PSK symbol, because these 16QAM or 32QAM symbols cannot be mapped onto the 8PSK constellation assumed by the legacy equalizer. Instead, the legacy EDGE equalizer will cancel the ISI postcursors associated with a sequence of 8PSK symbols (with $3\pi/8$ rotation) nearest to the received signal. As the first 8PSK symbol contains 2 of the 9 USF bits in the burst, the inability to properly equalize this first 8PSK symbol appears to be a potential problem.

In general, it cannot be assumed that the equalizer in all legacy EDGE receivers employ separate "backward" and "forward" equalizers for the first and second half of the burst, respectively, as it is not required in order to meet the performance specification. Furthermore, it is not necessarily reasonable to expect that a legacy EDGE equalizer would employ two equalizers as the computational complexity associated with solving for the equalizer coefficients is doubled.

3. Modified Mixed Modulation Proposal for RED HOT A

Given the desire to avoid the need for resource segregation on the uplink between legacy mobile stations and RED HOT A mobile stations, it seems reasonable to consider modifications of the mixed modulation proposal for RED HOT A that would enable a legacy mobile station using equalization in the forward direction only to successfully decode the USF from a RED HOT A burst. In order that a legacy EDGE receiver using a single DFE-type (DFE, DDFSE, DFE/RSSE, or other) equalizer that operates in the forward direction may properly cancel the postcursor ISI into the first 8PSK symbol containing USF bits, at least L symbols prior to this symbol must also be 8PSK modulated, where L is the number of feedback taps used by the equalizer. The value of L is of course vendor specific. If the number of 8PSK symbols L prior to the first 8PSK symbol containing USF bits is less then the number of feedback taps used by the equalizer, some degradation in the performance of the USF detection may result.

In Figure 2, a modified mixed modulation proposal is indicated. This differs from the proposal in [1] in two respects:

i) a small number L of 8PSK symbols are used prior to the first symbol containing USF information.

ii) 8PSK modulation is used for both sets of tail symbols; in particular, the tails symbols are the same as those used for EDGE 8PSK bursts.

With respect to the second point, it should be noted that so long as an even number of 16/32 QAM symbols separate the 8PSK tail symbols from the 8PSK symbols in the center of the burst, the 16/32 QAM constellation and the 8PSK constellation will be aligned, should such an alignment be necessary to mitigate peak-to-average concerns in the transmitter. Given that the $\pi/4$ rotation is used for 16/32 QAM while $3\pi/8$ rotation is used for 8PSK, the relative rotation of the two constellations over the span of two symbols is $\pi/4$ radians. As the 8PSK constellation is unchanged by any rotation that is an integer multiple of $\pi/4$ radians, the two constellations are re-aligned after any even number of 16/32 QAM symbols.

4. Simulation Results

Two sets of simulation results are presented for a mixed modulation RED HOT A burst. All of these simulations are for a receiver using a single DFE/RSSE equalizer that operates in the forward direction only. The first set of simulation results are for the burst structure proposed in [1] and illustrated in Figure 1. The

performance of USF detection for the TU3iFH and HT100nFH channels is indicated in Figures 3 and 4, respectively. Here, the performance is presented as a function of the signal-to-noise ratio, Es/N0, of the 8PSK-modulated symbols. If the same results were presented as a function of the signal-to-noise ratio of the 16/32-QAM modulated symbols in the burst, the results would be improved by 2 dB since these symbols are transmitted with 2 dB less power than the 8PSK-modulated symbol. Alternatively, if the results were presented as a function of the average signal-to-noise ratio of all symbols in the burst (including the 6 tail symbols), the performance would be improved by 1.3 dB. For the simulations in Figures 3 and 4, this 1.3 dB alone is nearly sufficient to compensate for the observed degradation of the USF detection performance.

It is perhaps not too surprising that the impact of the 16/32 QAM symbols prior to the first 8PSK symbol is not too great given that only 2 of the 9 USF code symbols in the burst are significantly affected. If the effect of improper postcursor ISI cancellation were such that these first two USF code symbols were essentially erased, USF detection would be degraded by only about 1.1 dB (10 log10 (9/7)).

The second set of simulation results are for the modified burst structure in Figure 2 in which 8PSK symbols are transmitted prior to the first 8PSK symbol with USF information. In these simulations, L is equal to 6; that is, 6 symbols prior to the first 8PSK symbol with USF information are 8PSK modulated. The performance of USF detection for the TU3iFH and HT100nFH channels is indicated in Figures 5 and 6, respectively, as a function of the signal-to-noise ratio, Es/N0, for the 8PSK-modulated symbols. From this data, it is apparent that the performance of USF detection is essentially unaffected by the mixed modulation and this is consistent with the results presented in [2] and [4]. When measured as a function of the Es/N0 of the 16/32-QAM modulated symbols in the burst, USF detection performance of the RED HOT A burst is actually 2 dB better than the performance for an 8PSK EDGE burst. Alternatively, if performance is measured as a function of the average Es/N0 of all symbols in the burst, the performance of USF detection for the modified mixed modulation RED HOT A burst is 1.3 dB better than for an EDGE 8PSK burst.

5. Impact of the Modified Mixed Modulation Burst on Peak Throughput

Clearly, the use of 8PSK modulation in the RED HOT A burst will reduce the peak data rates achievable with RED HOT A. If it is assumed that the number of 8PSK symbols used prior to the first 8PSK symbol is 6 (L=6 in Figure 2), then the associated maximum reduction is peak data rate is easily bounded for 16QAM and 32QAM, respectively. For a RED HOT A burst using only 16 QAM modulation, the maximum increase in peak data rate (relative to EDGE) is 33.3%. If 22 of the 116 symbols in the burst are restricted to 8PSK as in the example here, the maximum increase in peak data rate is 27%. Similarly, for a RED HOT A burst using only 32QAM modulation, the maximum increase in the peak data rate is 66.6%. If 22 of the 116 symbols in the burst are restricted to 8PSK, the maximum increase in the peak data rate is 54%. However, it should be noted that transmission at the peak rate is seldom achieved in practice. Furthermore, the data code symbols transmitted using 8PSK will be significantly more reliable given that the 8PSK constellation points have greater separation than the 16/32 QAM symbols given equal average transmit power, and will further benefit given that the 8PSK symbols are transmitted with 2 dB more power. Similarly, the performance of header decoding will benefit from the increased reliability of code symbols transmitted using 8PSK.

6. Conclusions

In this contribution, simulation results have been presented for USF detection with a modification of the mixed modulation proposal presented in [1]. These simulation results indicate that a legacy EDGE 8PSK equalizer operating in the forward direction only can reliably extract the USF information from this modified mixed modulation RED HOT A burst. Given the initial low penetration of RED HOT mobile stations into the market

and the desire to avoid resource segregation between legacy EDGE mobile stations and new mobile station with the RED HOT A feature, it is recommended that a mixed modulation burst structure be adopted for RED HOT A.

7. References

[1] 3GPP TSG GERAN telephone conference on RED HOT/HUGE #3, April 5, 2007, "Modulation and Coding Schemes for RED HOT A," source Ericsson.

[2] 3GPP TSG GERAN telephone conference on RED HOT/HUGE #3, April 5, 2007, "Simulation results for EGPRS MS decoding USF in RED HOT A mixed modulation blocks," source Ericsson.

[3] 3GPP TSG GERAN telephone conference on RED HOT/HUGE #4, April 19, 2007, "Modulation and Coding Schemes for RED HOT A – Version 2," source Ericsson.

[4] 3GPP TSG GERAN telephone conference on RED HOT/HUGE #4, April 19, 2007, "Simulation results for EGPRS MS decoding USF in RED HOT A mixed modulation blocks – Version 2," source Ericsson.

[5] 3GPP TSG GERAN telephone conference on RED HOT/HUGE #4, April 19, 2007, "Legacy USF Extraction from Mixed Modulation RED HOT A Bursts," source Motorola.

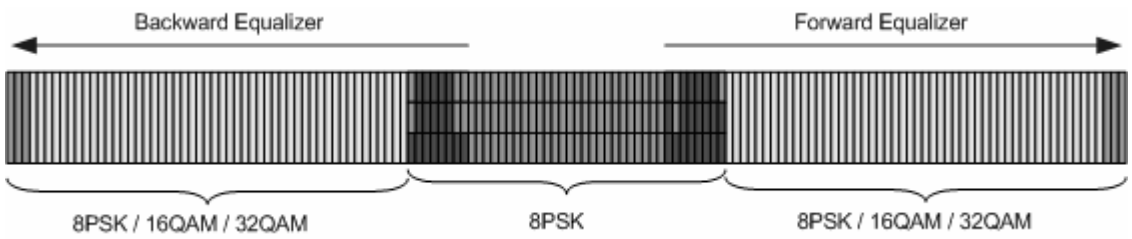

Figure 1: Mixed-modulation proposal for RED HOT A [1] compatible with separate forward and backward equalization.

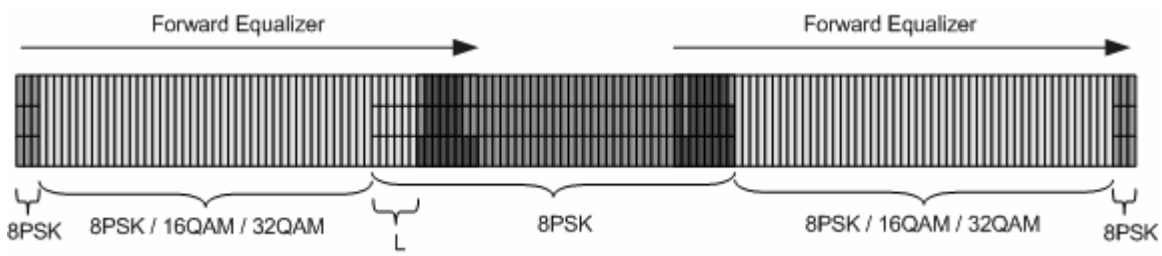

Figure 2: Modified mixed-modulation Proposal for RED HOT A compatible with an equalizer operating in the forward direction only.

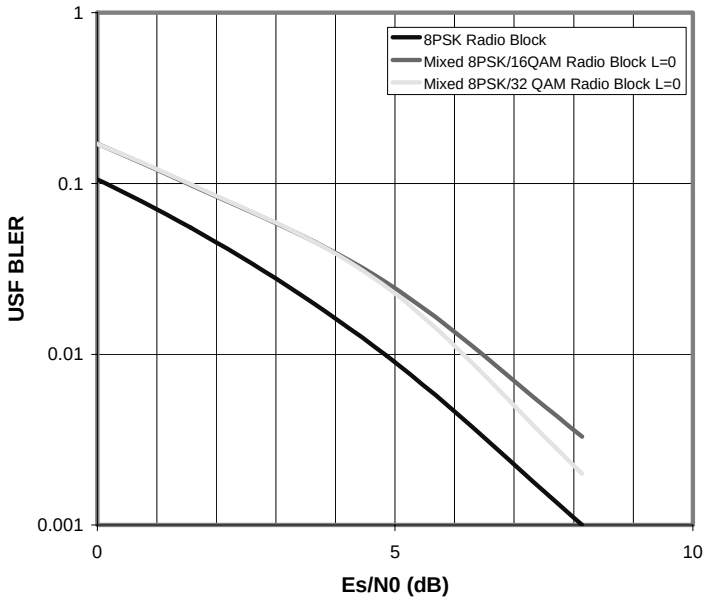

Figure 3: USF detection performance for a mixed modulation burst [1] using a single equalizer operating in the forward direction for the TUiFH3 channel.

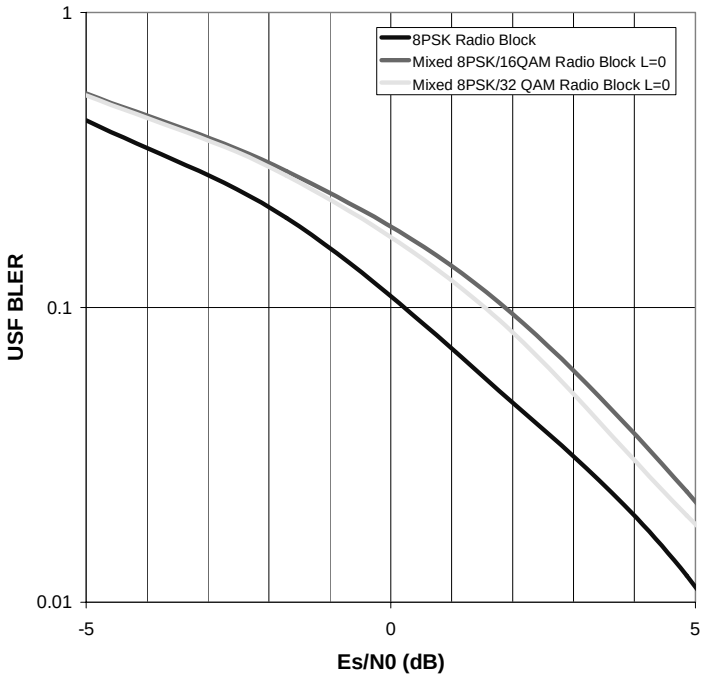

Figure 4: USF detection performance for a mixed modulation burst [1] using a single equalizer operating in the forward direction for the HT100nFH channel.

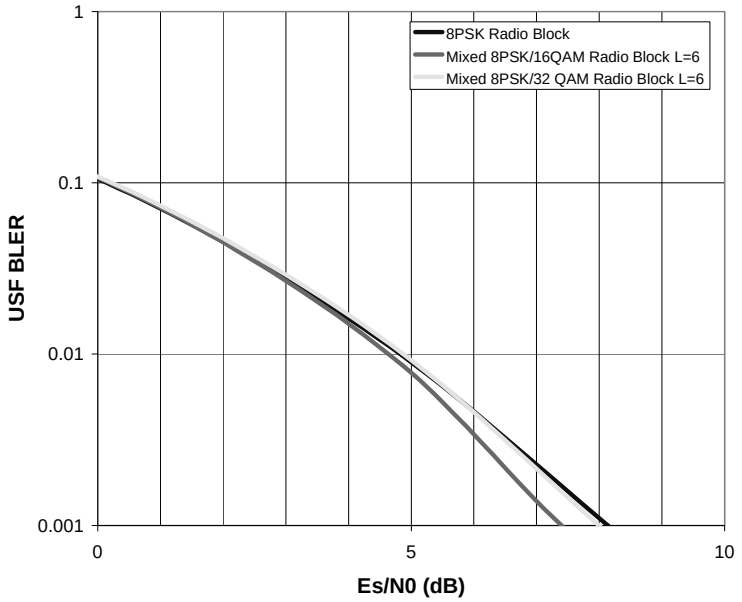

Figure 5: USF detection performance for a modified mixed modulation burst using a single equalizer operating in the forward direction for the TUiFH3 channel. The L=6 symbols prior to the first 8PSK symbol with USF code symbols are 8PSK modulated.

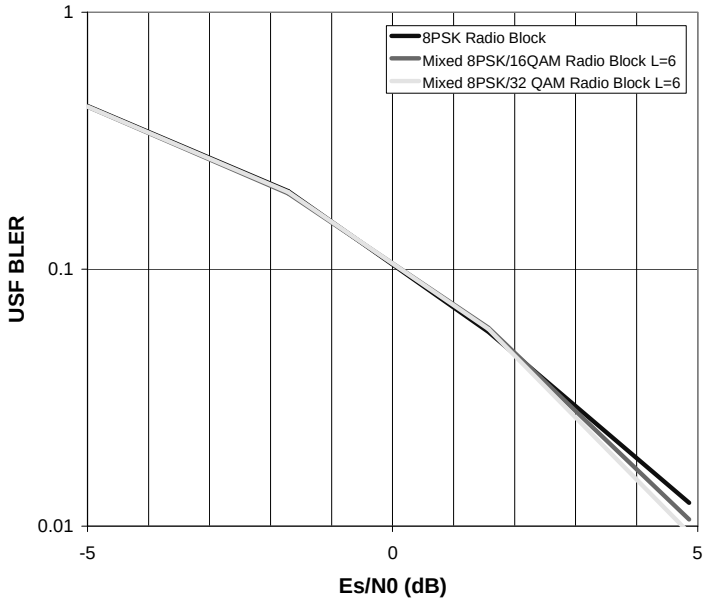

Figure 6: USF detection performance for a modified mixed modulation burst using a single equalizer operating in the forward direction for the TUiFH3 channel. The L=6 symbols prior to the first 8PSK symbol with USF code symbols are 8PSK modulated.