Adjacent Channel Interference in UMTS Networks

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Abstract— **One of the purposes of receive filtering in a Universal Mobile Telecommunication System (UMTS) handset receiver is to attenuate out-of-channel interference to provide channel selectivity. A UMTS handset receiver using a receive filter adaptive on out-of-channel interference level can be more computationally efficient than a handset with a fixed receive filter provided that the handset operates in low out-of-channel interference conditions often enough. The UMTS Adjacent Channel Selectivity (ACS) test case requires the adaptive receive filter to provide a worst case ACS of 33 dB. An adaptive receive filter is more computationally efficient than a fixed receive filter when the required ACS is less than 23 dB, because the added complexity of measuring the out-of-channel interference is compensated for by the reduction in the required number of filter taps to achieve the ACS. Measurements of the out-of-channel interference show that currently the interference levels for which the maximum ACS of 33 dB is required are hardly ever reached in practice. For the currently measured interference levels an adaptive receive filter will be computationally more efficient than a fixed receive filter 97% of the time.**

However, the current out-of-channel interference measurements might be on the optimistic side, because the loads of the UMTS networks are low. When these loads increase in the future, the out-of-channel interference levels may increase and the advantage in computational efficiency of the adaptive receive filter will be reduced.

Keywords— **UMTS, adaptive signal processing, receive filtering, out-of-channel interference measurements**

I. Introduction

One of the purposes of receive filtering in a Universal Mobile Telecommunication System (UMTS) handset receiver is to attenuate out-of-channel interference to provide channel selectivity. The out-of-channel interference levels and thus the required attenuation can vary from one location to another due to varying base station loads. When less attenuation is required this can be achieved with a simpler receive filter, therefore it could be advantageous to make the receive filter adaptive on the out-of-channel interference level.

Receive filtering in a UMTS handset receiver is usually performed partially in the analog front-end and partially in the digital back-end. In previous work [1][2] we have introduced two adaptive digital back-end Finite Impulse Response (FIR) receive filter structures for a UMTS handset receiver. In these structures the attenuation of the filter is adjusted based on the measured out-of-channel interference level. When the level is low, the required amount of attenuation is also low and can be achieved with fewer filter taps. This reduces the required number of operations per received symbol of the receive filter. Measuring the out-of-channel interference level, however, slightly increases the complexity of the receive filter. So in order for the adaptive receive filter structures to be more computationally efficient than a fixed receive filter the UMTS handset should operate in low out-of-channel interference conditions often enough.

In this paper we therefore study the out-of-channel interference conditions in which a UMTS handset has to operate. The paper is organized as follows: In Section II the attenuation requirements for the worst case out-of-channel interference conditions in which a UMTS handset receiver has to operate according to the UMTS standard are summarized. The attenuation levels for which an adaptive receive filter is more computationally efficient than a fixed receive filter are described in this section as well. In Section III measurements used to determine the out-of-channel interference levels that occur in currently deployed UMTS networks are described. Finally in section IV conclusions are drawn about the validity of using a digital receive filter adaptive on out-of-channel interference level in a UMTS handset receiver.

II. Attenuation Requirements

A. Worst Case

The receive filter selectivity requirements are determined by the UMTS test cases for Adjacent Channel Selectivity (ACS), in- and out-of-band blocking and intermodulation in [4]. These test cases all re-

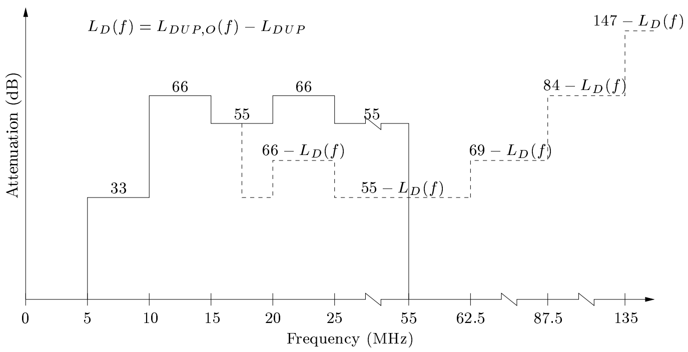

Fig. 1. Worst case adjacent channel attenuation requirements as a function of frequency offset from the center frequency of the desired channel [3]. The solid line indicates the attenuation requirements within the UMTS downlink band, while the dashed line indicates the out-of-band requirements.

quire the Bit Error Rate (BER) on the desired channel to be less than 0.001 after Forward Error Correction (FEC) decoding for given desired channel and out-of-channel signal levels. Using these test cases the receive filter attenuation requirements as a function of the frequency offset from the center frequency of the desired channel were determined in [3] and are shown in Fig. 1. In this figure the solid line indicates the attenuation requirements within the UMTS downlink band, while the dashed line indicates the out-of-band requirements. $L_D(f)$ in the figure represents the duplexer attenuation for a given frequency, which is determined by the out-of-band duplexer attenuation $L_{DUP,O}(f)$ and the in-band duplexer loss L_{DUP}.

According to Fig. 1 the receive filter will have to provide 33 dB attenuation for the adjacent channels (frequency offsets of 5 MHz). For larger frequency offsets the filter will have to provide at least 66 dB attenuation. Of these requirements the 33 dB ACS requirement will be the most difficult to achieve, because of the proximity of the desired signal band. However, these attenuation requirements are *worst case* requirements, i.e. the attenuation that is required to achieve a BER less than 0.001 in case a very strong out-of-channel signal is present. If the out-of-channel signal is less strong this BER requirement can be achieved with less attenuation of the out-of-channel interference.

The ACS test case, for example, requires the handset to be able to achieve a BER of less than 0.001 when the Dedicated Physical Channel (DPCH) power P_{DPCH} of the desired user is -103 dBm and the adjacent channel power $P_{I_{oac}}$ is -52 dBm, i.e. an Adjacent Channel Interference (ACI) level of 51 dB. According to [3] this requires an ACS of:

$$\begin{aligned} ACS &= P_{Ioac} - P_{ADJ} \\ &= P_{Ioac} - \left(P_{DPCH} + G_{SPR} + G_C - \tfrac{E_b}{I} - L_{IMP}\right) \\ &= -52 - (-103 + 21 + 4 - 5 - 2) \\ &= 33\ dB \end{aligned}$$

where G_{SPR} is the spreading gain, G_C is the coding gain, $\frac{E_b}{I}$ is the required bit energy to interference power spectral density ratio and L_{IMP} is an implementation loss. Similar calculations can be used to show that when the ACI level is 10 dB lower, i.e. the desired channel power is 10 dB higher or the adjacent channel power is 10 dB lower, the required ACS to achieve a BER of less than 0.001 is also 10 dB lower.

So in order to pass the the UMTS test cases for ACS, in- and out-of-band blocking and intermodulation the handset receive filter will have to achieve the worst-case out-of-channel attenuation levels shown in Fig. 1. However, for other, practical, out-of-channel interference conditions the handset receiver will be able to deliver satisfactory performance with less out-of-channel attenuation.

B. Adaptive Receive Filter Efficiency

In [1] we have determined that the required number of operations to determine the out-of-channel interference in an adaptive receive filter is comparable to the number of operations required for calculating 8 FIR filter taps. So on average the adaptive receive filter should be able to provide the desired selectivity with a reduction in taps of 8 or more compared to the number of taps required to achieve the maximum required 33 dB of ACS. Reducing the number of used filter taps with 8 corresponds to a reduction of the receive filter stop band attenuation of approximately 10 dB [1].

So an adaptive receive filter will become as efficient as or more efficient than a fixed receive filter when the desired ACS is 23 dB or less.

III. Out-of-channel Interference Measurements

In May and June 2006 we have measured the field strength in the UMTS downlink band in and around buildings at 47 locations in Amsterdam, see Fig. 2. At each location a field strength measurement in the UMTS downlink band was made using a spectrum analyzer at 8 positions inside and 8 positions outside the building. See Fig. 3 for an example of 8 outside field strength measurements. Comparing Fig. 3 with the

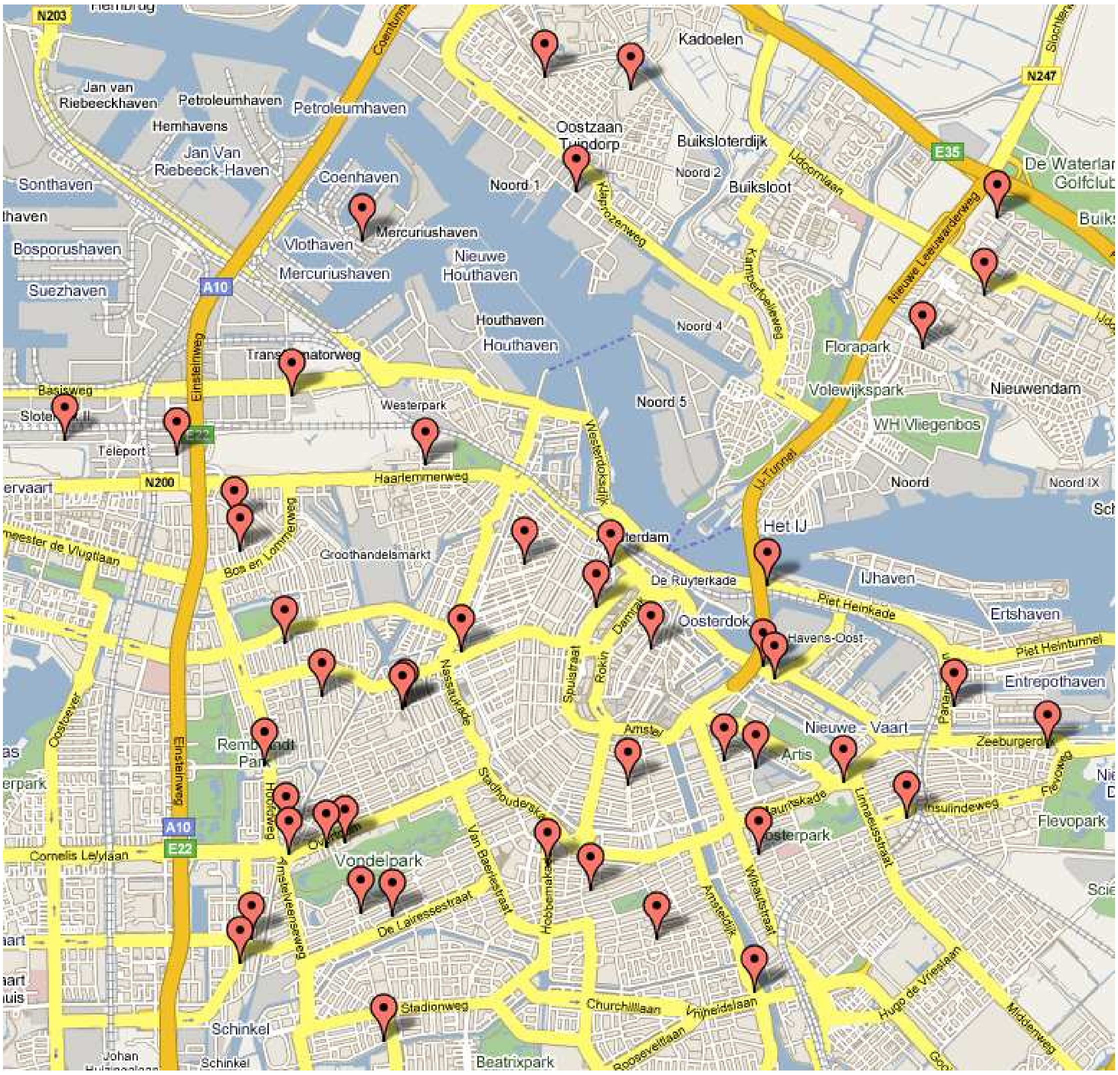

Fig. 2. Measurement locations in Amsterdam (map ©2006 Google Maps / TeleAtlas).

UMTS downlink spectrum assignment in the Netherlands given in Table I clearly shows that each operator currently uses only one of their assigned channels at that particular location. This turns out to be the case for all 47 locations. Furthermore, the operators have chosen their active channels in such a way that there is at least one empty channel between their own active channel and the active channels of their competitors. So currently a handset connected to any of the operators networks will not experience any significant ACI. However, in the future, when the demand for UMTS services may increase, operators will start to use their unused channels to increase the capacity of their networks and ACI will occur.

To determine the statistics of the signal conditions in the UMTS downlink band all outside measurements of the measurement campaign were used, in total 376 measurements. From each measurement the average field strengths in each of the UMTS channels were determined by averaging the points of the field strength measurement that correspond to that channel. These average channel field strengths in turn were used to determine the out-of-channel interference levels at offsets of ± 1, ± 2 or ± 3 channels from a desired channel. Fig. 4 shows histograms of the out-of-channel interference levels at offsets of ± 1, ± 2 or ± 3 channels from the channels in use by the operators.

The histogram of the out-of-channel interference at an offset of ± 1 channel shows that currently handsets will not experience any ACI, as we already concluded based on the field strengths measurements in the UMTS downlink band. The out-of-channel interference levels at an offset of ± 2 and ± 3 channels can be used to get an indication of what the ACI levels would be if adjacent channels were in use.

The ACS test case specifies a worst case ACI level

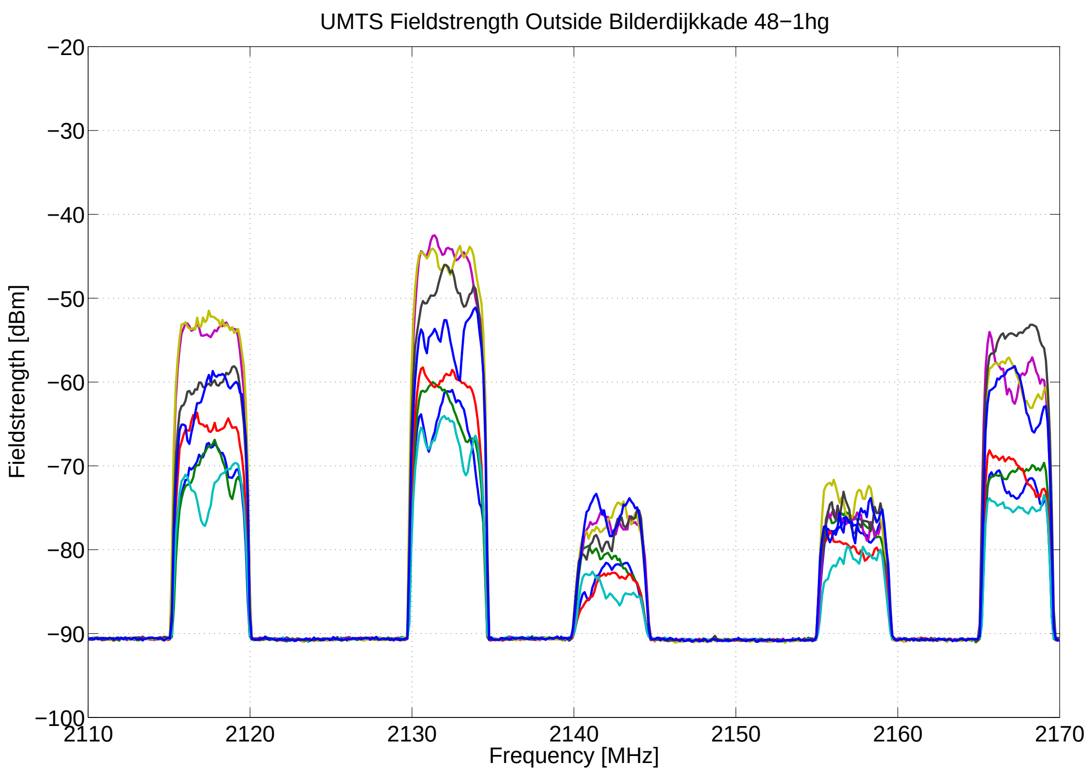

Fig. 3. Plot of 8 field strength measurements outside of a measurement location.

TABLE I
UMTS DOWNLINK SPECTRUM ASSIGNMENT IN THE NETHERLANDS.

Operator	Vodafone			KPN			Orange		Telfort		T-Mobile	
Freq. band [MHz]	2110.3 - 2124.9			2124.9 - 2139.7			2139.7 - 2149.7		2149.7 - 2159.7		2159.7 - 2169.7	
Channel [5 MHz BW]	1	2	3	4	5	6	7	8	9	10	11	12

of 51 dB. This ACI level is defined as the ratio of the adjacent channel power $P_{I_{oac}}$ and the DPCH power P_{DPCH} of the desired user. However, we can only measure the ratio of the out-of-band power to the total received in-band power $P_{\hat{I}_{or}}$, which includes the power of all the other users on the same base station as the desired user. If we assume that the P_{DPCH} of the desired user is 10 dB lower than $P_{\hat{I}_{or}}$ (as is done in the UMTS ACS test case), the worst case ACI level of 51 dB corresponds to a measured interference level of 41 dB. At this interference level the maximum selectivity of 33 dB of the receive filter is required. The interference levels at offsets of ±2 and ±3 channels are higher than 41 dB for 0.50%, respectively 0.27% of the measurements. So currently the maximum selectivity of the receive filter is hardly ever needed in practice.

An adaptive receive filter will become more computationally efficient than a fixed receive filter if the required ACS is 23 dB, 10 dB less than the maximum required ACS of 33 dB. This corresponds to a measured interference level of 31 dB. The interference levels at offsets of ±2 and ±3 channels are less than this 31 dB for 97%, respectively 99% of the measurements. So currently an adaptive receive filter will be more computationally efficient than a UMTS handset with a fixed receive filter at least 97% of the time.

However, the current out-of-channel interference measurements might be on the optimistic side, because the loads of the UMTS networks are not known. Since UMTS services are not widely used yet in the Netherlands, it is reasonable to assume that these loads are currently relatively low. This means that the base stations of the networks are probably all transmitting with similar relatively low power and thus cause little out-of-channel interference. In case the demand for UMTS services increases in the future, the differences in transmitted power between the base

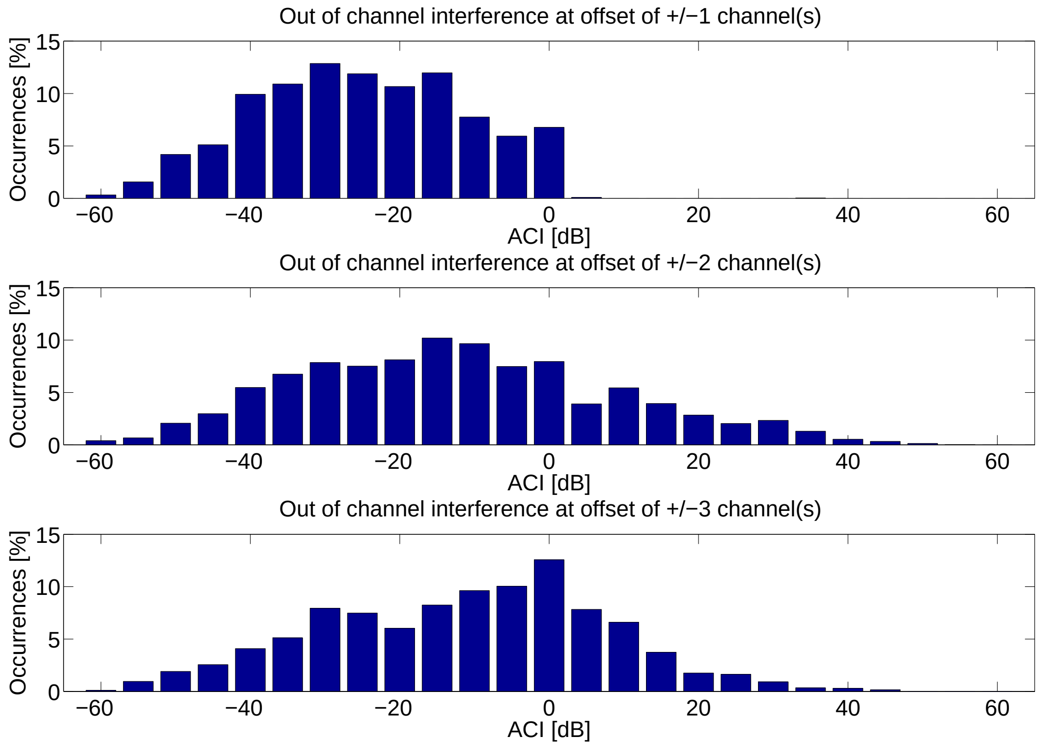

Fig. 4. Histograms of the out-of-channel interference levels at offsets of ±1, ±2 or ±3 channels from the active channels.

stations may increase which leads to increased out-of-channel interference levels. This will reduce the advantage in computational efficiency of the adaptive receive filter.

IV. Conclusions

A UMTS handset receiver using an adaptive receive filter can be more computationally efficient than a handset with a fixed receive filter provided that the handset operates in low out-of-channel interference conditions often enough. The UMTS ACS test case requires the adaptive receive filter to provide a worst case ACS of 33 dB. The adaptive receive filter is more computationally efficient than a fixed receive filter when the required ACS is less than 23 dB. Field strength measurements of the UMTS downlink band at various locations in Amsterdam show that the currently deployed UMTS networks do not suffer from ACI at all, because not all assigned UMTS channels are in use yet. Measurements of the out-of-channel interference at offsets of more than ±1 channel show that currently the interference levels for which the maximum ACS of 33 dB is required are hardly ever reached in practice. For the currently measured interference levels an adaptive receive filter will be computationally more efficient than a fixed receive filter 97% of the time. However, the current out-of-channel interference measurements might be on the optimistic side, because the loads of the UMTS networks are probably low. When these loads increase in the future, the out-of-channel interference levels may increase as well and the advantage in computational efficiency of the adaptive receive filter will be reduced.

Studying the out-of-channel interference levels in UMTS networks under higher loads to determine if an adaptive receive filter can still be more computationaly efficient than a fixed receive filter is therefor a suitable subject for future work. This can for example be done using a UMTS network simulator in which the network load can more easily be controlled than in measurements on an actual UMTS network.

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