MICROWAVE OVEN SIGNAL INTERFERENCE MITIGATION FOR WI-FI COMMUNICATION SYSTEMS

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ABSTRACT

The MicroWave Oven (MWO) is a popular appliance that acts as an unintentional interferer for 2.4 GHz IEEE 802.11 Wi-Fi communication signals. An interference mitigation technique is developed that incorporates cognitive radio paradigms allowing Wi-Fi devices to reliably transmit information while a residential MWO is operating. This technique is applied in the experimental case where Barker spread Wi-Fi signals carry data in the presence of MWO emissions. Bit error rate is evaluated to provide a performance metric for the mitigation technique.

I. INTRODUCTION

The unlicensed Industrial, Scientific and Medical (ISM) [1] bands are very attractive for consumer applications. IEEE 802.11 Wi-Fi [2] access points, wireless laptops, Bluetooth devices, and cordless phones operate in the 2.4 GHz band. The residential MicroWave Oven (MWO) also radiates in this frequency band and interferes with Wi-Fi communications. The MWO signal [3] is a wideband (up to 60 MHz) periodic signal that is synchronized to the 60 Hz AC line cycle. The main characteristics of the MWO signal (ON-OFF duty cycle, transients, and frequency sweep) are seen in Fig. 1. Notice, that the “ON” cycle is less than half of the 0.017 s 60 Hz period.

Fig. 1. Spectrogram of MWO signal & interference mitigation

II. INTERFERENCE MITIGATION TECHNIQUE

While the Carrier Sense Multiple Access (CSMA) [4] protocol is effective in Wi-Fi collision avoidance, the MWO is oblivious to this type of interference avoidance. In previous work [3], a feasible alternate interference mitigation technique was outlined. A qualitative plot of this concept is seen in Fig. 1 where data is sent during the MWO's OFF cycles. For successful interference

mitigation, it is necessary to detect the presence of MWO interference signals and synchronize the data transmitter with the MWO's ON-OFF cycles. An experimental cognitive radio system was constructed, as shown in Fig. 2. The signature of a radiating MWO signal is detected and a Wi-Fi transceiver controlled to communicate only during the OFF cycles.

Fig. 2. Block diagram for MWO interference mitigation system

The 2.4 GHz ISM band signal received by the antenna is down-converted by the *baseband converter* in Fig. 2. The *threshold detector* senses any received signal above the background noise threshold. The *transient detector* compares the threshold detector output, $y(t)$, with the *AC line reference* signal. If the timing of $y(t)$ matches the *expected MWO transient time location*, then the cognitive radio records the detection of a transient. The expected transient time locations are 2 ms time durations before or after the zero voltage crossings of the sinusoidal AC line reference. If the transient detector records the presence of several transient pulses over consecutive AC line cycles, the cognitive radio circuit concludes that a MWO interference signal is present. This smart radio system ignores all Wi-Fi signals and only triggers when a MWO signal is present.

If a MWO signal is present, the *transmit controller* instructs the Wi-Fi transmitter to synchronize with the AC line cycle and operate only during the MWO OFF cycles. If the MWO signal is not detected, the Wi-Fi transmitter is instructed by the transmit controller to operate normally.

III. EXPERIMENTAL WI-FI TESTBED

An experimental Wi-Fi communication system was used to transmit and receive data in the presence of MWO interference using a the ComBlock transmitter [5] operating at 363 kbps with the 11 chip Barker spreading code. The modulated signal's bandwidth is 8 MHz. The results of this interference mitigation study are applicable to IEEE 802.11 Wi-Fi systems in general.

The data is transmitted in 128 bit packets by the ComBlock. The ComBlock receiver captures and decodes the data packets which are used to obtain the experimental BER. In all experiments, the receiver was placed in a position equidistant from the Wi-Fi transmitter and an interfering MWO. Three different MWOs were used in the BER study. Two experimental scenarios were

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tested for each MWO and the BER was recorded each time. Case 1 is shown by the spectrogram in Fig. 3. Here, the Wi-Fi transmitter operates at 2.46 GHz without any interference mitigation. In this frequency range, the AM-FM signal of the MWO exists and there is high interference. Case 2 is shown in Fig. 4, where the interference is mitigated by the interference mitigation system.

Fig. 3. Case 1: No mitigation

Fig. 4. Case 2: Mitigation (Wi-Fi at 2.46 GHz)

IV. INTERFERENCE MITIGATION RESULTS

Tables 1 and 2 show the experimentally recorded BERs for each of the scenarios described in Section III. The results vary depending on the MWO used. For cases in which the distances between the MWO and the ComBlock receiver are lower, BER is expected to be elevated. The BER is high for the control case in Table 1, but Table 2 shows the measured zero BER obtained in the interference mitigated case.

Table 1. BER for Case 1 (no interference mitigation)

MWO #	Data Rate (kbps)	BER
1	363.3	0.016610
2	363.3	0.112900
3	363.3	0.007315

Table 2. BER for Case 2 (interference mitigation)

MWO #	Data Rate (kbps)	BER
1	181.7	0.000000
2	181.7	0.000000
3	181.7	0.000000

Although the data rate drops to 50% in the interference mitigated case, data packets are reliably transmitted by the ComBlock system even when a MWO is operating. In the case where this interference mitigation is not used, the data rate remains at 100% but the BER is much higher and the ComBlock data packets are corrupted. So the *actual throughput* of the experimental Wi-Fi system is much less than the mitigated case even though the data transmission rate is higher. In IEEE Wi-Fi 802.11 systems, high packet drop rates due to interference leads to Wi-Fi connection loss [6]. The interference mitigation technique developed here can be applied to minimize packet drop rates due to MWO interference.

Since performance varies considerably if the distances between the receiver, transmitter, and the MWO are changed, Tables 1 and 2 are meant only for comparative purposes. They demonstrate the performance of the experimental Wi-Fi system with or without interference mitigation. Table 1 also shows that MWO interference significantly degrades the wireless communication system performance making interference mitigation valuable. This method is *practically realizable* on consumer access points and other Wi-Fi devices.

V. CONCLUSION

A cognitive radio experimental technique was implemented that successfully mitigated interference on Wi-Fi communications caused by MWO signals. This system provides reliable data transmission when a MWO is operating in proximity to a Wi-Fi system.

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