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# WiFi Pendant Tag
## Worst-Case Operation

| Date | Rev | Author | Section(s) changed description |
|---|---|---|---|
| 4/27/09 | 1.0 | jserceki | Initial release |
| 6/8/09 | 1.1 | jserceki | Added RF Exposure Safety Calculations |
| 6/15/09 | 1.2 | jserceki | Final Release |
| 8/21/09 | 1.3 | jserceki | Revisions include removing UDP packet size and revising source-based time-averaged output power calculations. |
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## Introduction

This document serves to describe the operation and evaluate the worst-case duty cycle of RF Technologies' WiFi Pendant Tag.

# Overview

The RF Technologies' WiFi Pendant Tag, hereby referred to as the "Tag", is a battery-powered device that is part of a staff emergency call system. It is worn by staff members and serves to alert security personnel in the case of an emergency.

The WiFi Pendant Tag has two basic modes of operation – normal operation and alarm operation.

The normal operation of the Tag is the default state and is asleep for large amounts of time. However, the Tag can be configured to send a UDP packet to a server as frequently as once every 30 seconds, or as infrequently as once every 24 hours, or disabled all together. This feature is know as a "check-in" and serves to inform the server software of the Tag's presence and other operating parameters such as its battery voltage.

When the user of the Tag depresses the red button for more than one second, the Tag enters alarm mode. In alarm mode, the tag will be awake most of the time, updating location information and sending this information to the server software. In order to update location information, the tag sends probe request packets on a configured list of channels in order to solicit responses from any WiFi Access Points which may be within range of the Tag. In addition to active scanning for Access Points, the tag also spends 10.1 seconds listening for other RF Technologies Tags, known as Reference Tags, that are broadcasting small WiFi packets every 10 seconds. Once the Tag has collected information from Access Points and Reference Tags, the Tag attempts to send this information in a UDP packet to the server software via the WiFi network.

Once the server software has received this UDP packet from the Tag, the Tag's location can be determined based on the AP and Reference Tag information contained within the UDP packet.

## Tag Architecture

The WiFi Pendant Tag is based on the G2 Microsystems' G2M5477 module (FCC ID: U3O-G2M5477). The G2M5477 is an 802.11 b/g WiFi device operating in the 2.4GHz ISM band with an output power of +20dBm. The G2M5477 conforms to all applicable WiFi standards under normal operation.

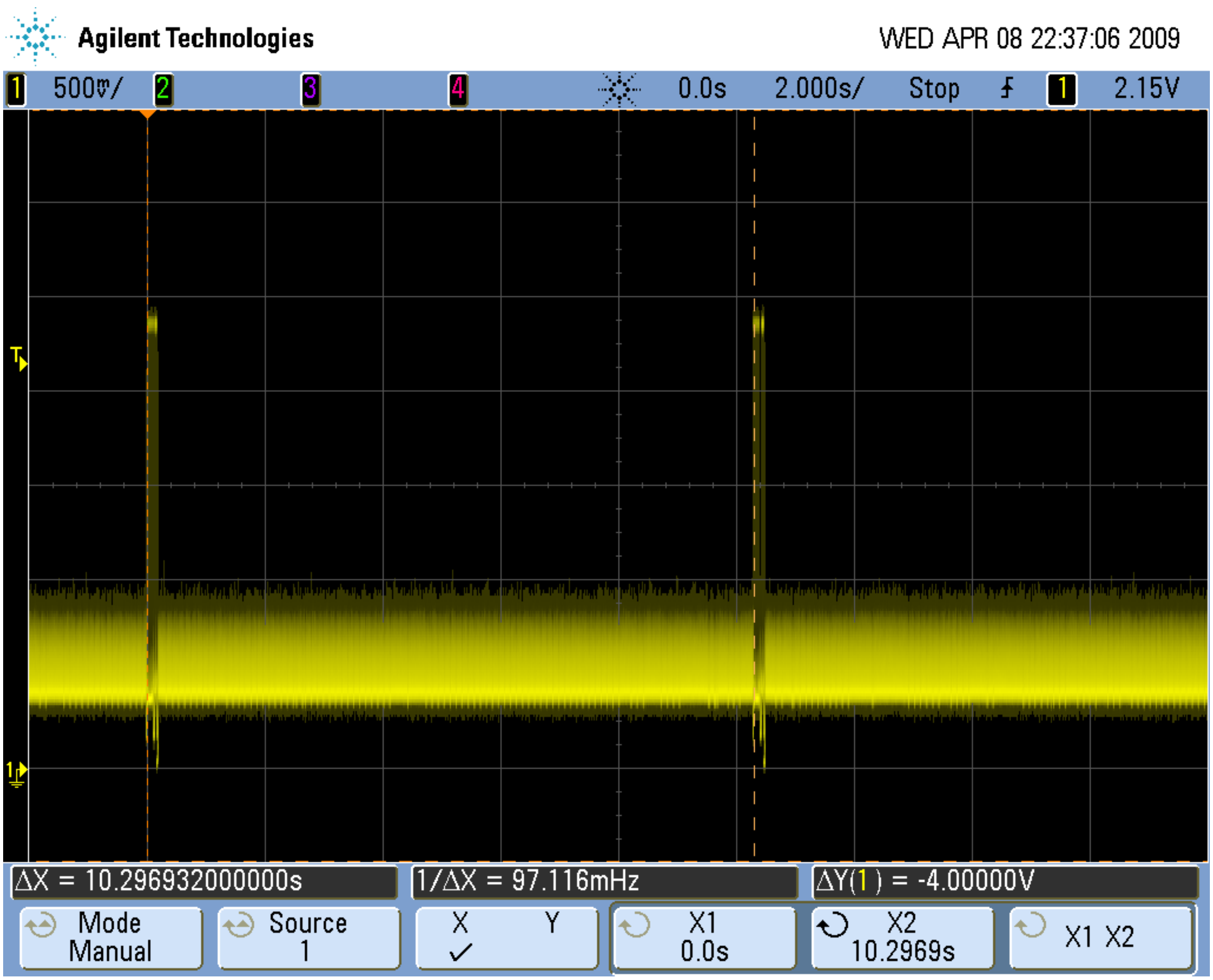
## Tag Operation

Under normal circumstances, the Tag would be configured with a limited list of channels which correspond to the channels upon which Access Points are operating. Typically, the channels used are 1, 6 and 11. However, in order to evaluate the worst-case operation of the Tag, the following measurements were made with the tag configured to scan channels 1 through 11, inclusive. Also, to demonstrate worst-case operation, the following measurements were made with the Tag in the alarm mode, as transmissions occur approximately every 10 to 11 seconds, instead of the 30second to 24 hour period under normal operation. In addition, the Tag has also been configured to transmit only at a 1Mbps data rate. This provides the worst-case transmit time for sending data.

Under these conditions, there are two possible scenarios, the Tag successfully locates an AP and sends its UDP packet, or the Tag does not locate the AP and does not send its UDP packet.

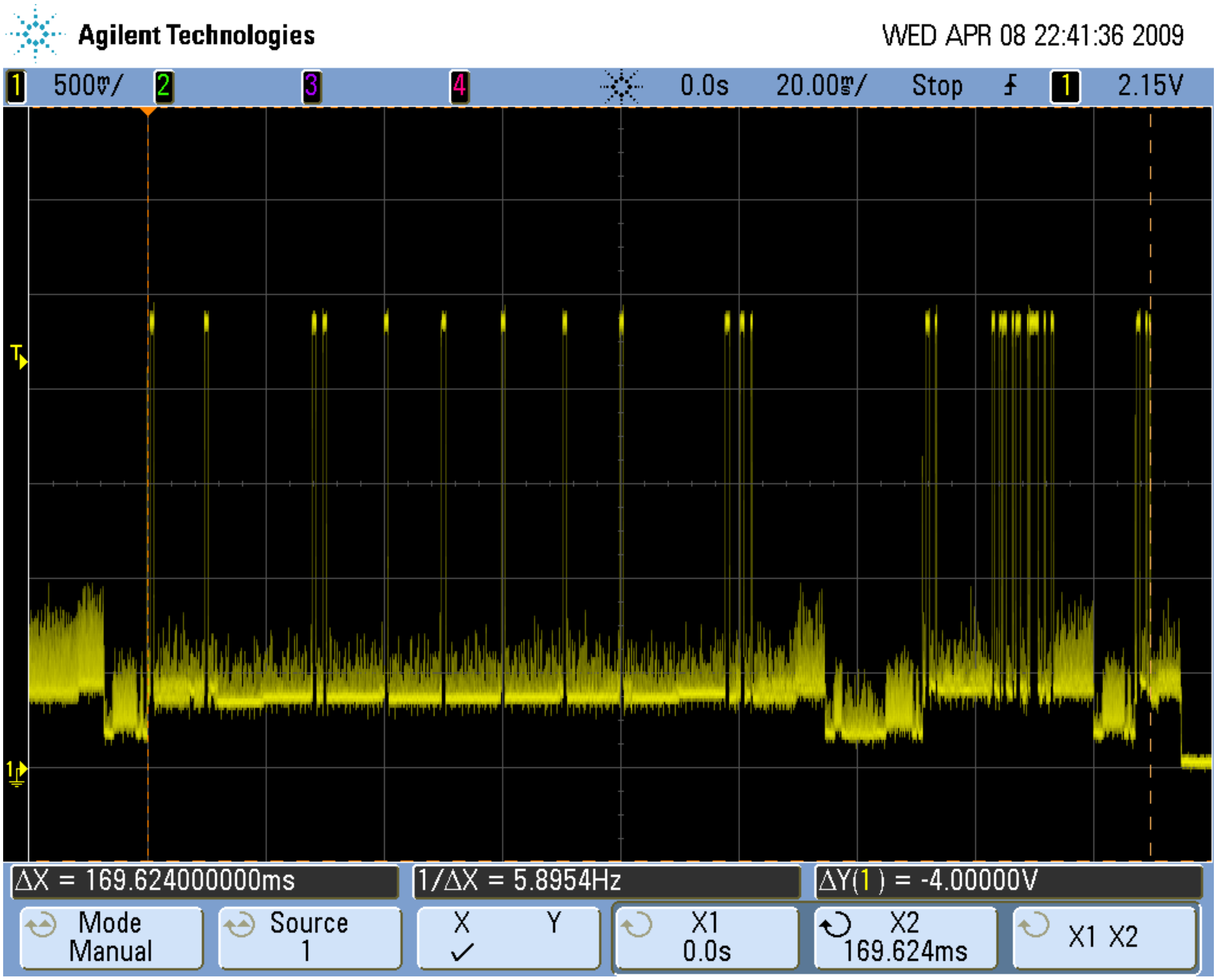
### Tag Finds AP and Sends UDP Packet

The figure below shows the Tag's overall duty cycle, including the communication and listening phases while in alarm mode.




In this case, the communication phase consists of the activity at the beginning denoted by the red marker on the left. The listening phase consists of the region after the communication phase and terminated where denoted by the red marker on the right.  From this, the overall period of one alarm cycle was measured as 10.3 seconds.

The figure below is a close-up view of the communication phase from above.




As can be seen, there is a variety of transmit activity that occurs during this phase.  In particular, starting at the left are the probe requests that are sent while active scanning is performed.  Once the AP is located, typical WiFi and other networking protocols are followed before the UDP packet is finally sent.  In addition, at the very end of this phase, the Tag also sends the UDP packet to a PDA that is operating on an ad-hoc network.

Overall, this communication phase lasts nearly 170 milliseconds.  Also, the duty cycle of the communication phase is well below the 98.9% duty cycle that the G2C5477 module can achieve.

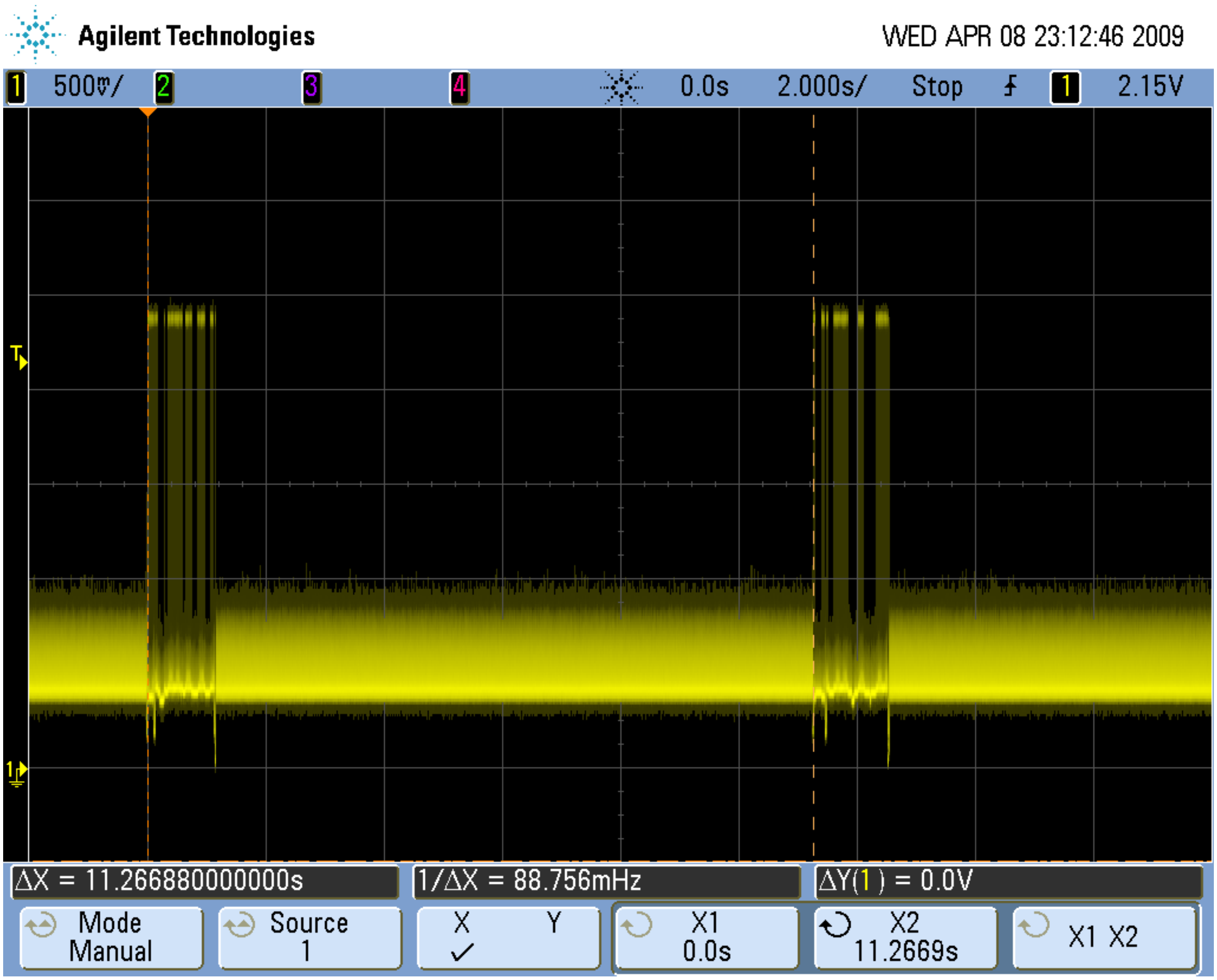
In order to calculate the worst-case duty cycle in this situation, simply dividing the communication time by the overall time yields the following:

**(170ms) / (10.3s) * 100 = 1.65% Duty Cycle**

The duty cycle calculation above assumes 100% transmission during the communication phase.  As can be seen in the above figure, the transmit duty cycle during the communication phase is well below 100%.

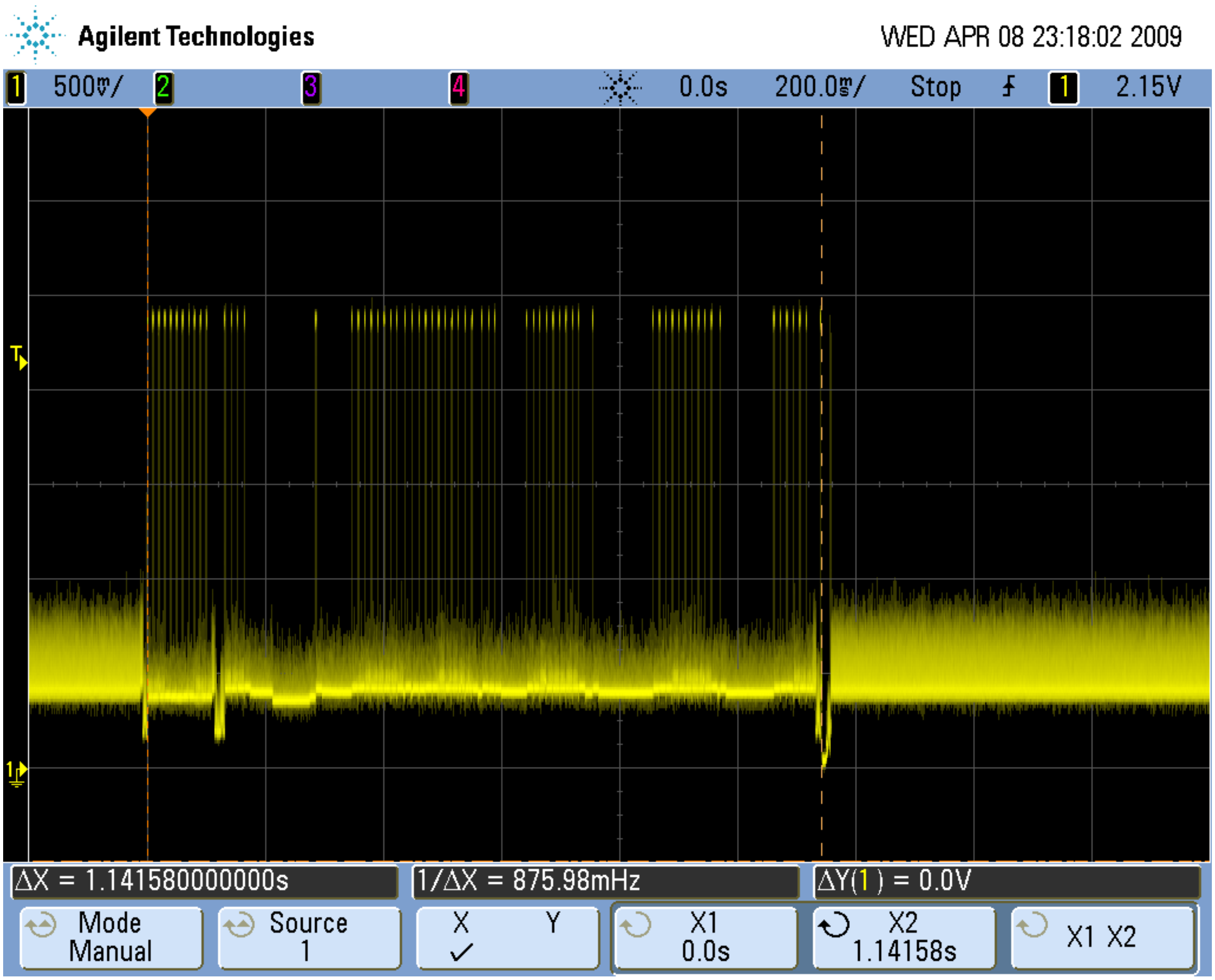
### Tag Fails to Find AP

The figure below shows the Tag's overall duty cycle, including the communication and listening phases while in alarm mode, but in this case, the tag fails to find the Access Point. When the Tag fails to find the AP, it continues active scanning through all of the channels, up to five times, until the AP is found, thereby increasing the length of time in the communication phase. Correspondingly, the overall period of one alarm cycle is increased because the listening phase is always fixed at 10.1 seconds.



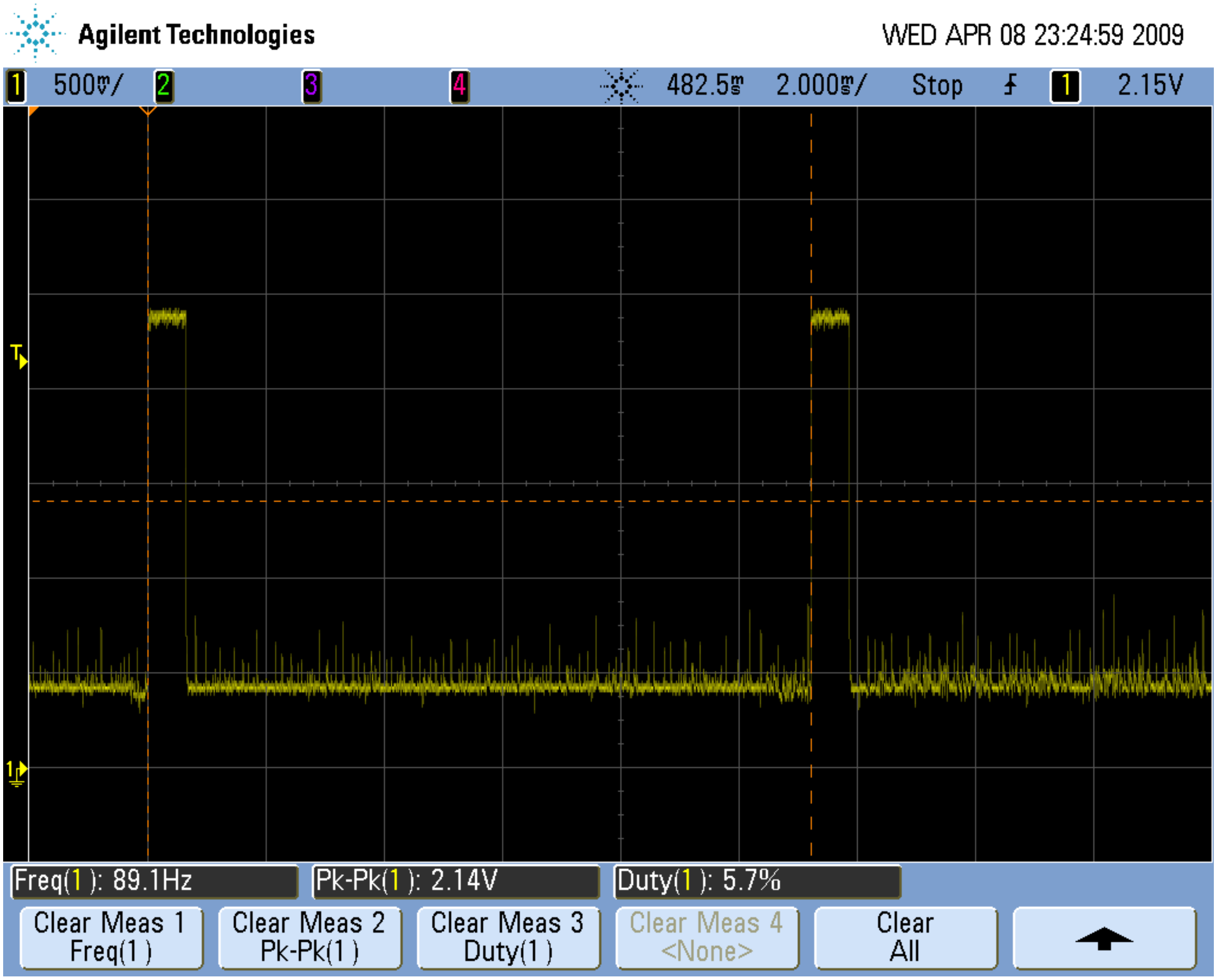

As can be seen, the overall period of one alarm cycle in this case is 11.267 seconds.

The figure below is a close-up view of the communication phase from above.




As can be seen, the communication phase has increased to 1.142 seconds due to the repetitive scanning for an Access Point.

A close-up of the time between two successive probe requests is shown in the figure below.




Note that the duty cycle achieved through repetitive scanning for Access Points is approximately 6%.

Taking all of this into consideration, we can determine the worst-case duty cycle when the Tag fails to find an Access Point by dividing the communication time by the overall time as follows:

**(1.142 s) / (11.267s) * 100 = 10.14% Duty Cycle**

Please note that this calculation assumes 100% transmit activity during the communication phase.

## RF Exposure/Safety Calculation

The following computes the RF exposure based on a 1cm distance from the antenna. The actual distance from the antenna to the outside surface of the enclosure is 0.96774cm. A reasonable assumption is that the user will be wearing clothing, which will increase this distance to over 1cm, which is the distance used in the calculations below.

| | | | | |
|---|---|---|---|---|
| Distance from Transmitter: | 1 | cm | | |
| Measured Tx Power: | 17.26 | dBm | 53.21083 | mW |
| Antenna Gain: | 1.2 | dBi | 1.318257 | |
| | | | | |
| Tx Time | 1.142 | s | | |
| Time Duration | 11.267 | s | | |
| Duty Cycle | 10.14 | % | | |

Power Density: S = (Pt * Gt)/(4 * pi * R^2)

Peak Power Density: 5.582004 mW/cm^2

Average Power: 5.39334 mW

The above calculations show that the average power density at a distance of 1cm is 5.4 mW/cm^2.

This document assumes a worst case, slowest data rate of 1Mbps utilizing 802.11b. Calculations based on a 6Mbps 802.11g rate were not performed. The worst-case source-based time-averaged output power results from utilizing the slowest possible data rate, which is the 1Mbps 802.11b rate.

These calculations show that both the peak power and the average power are less than 60/f(GHz), which at 2.472GHz is 24.27. Therefore, since the worst-case source-based time-averaged output power is less than the SAR evaluation limit, SAR evaluation is not required.

## Conclusion

The worst-case operation of the RF Technologies' WiFi Pendant Tag occurs when the Tag is operating in the alarm mode after the user has depressed the button for more than one second.

When in the alarm mode, one of two situations may occur, either the Tag finds an Access Point and sends its UDP packet, or the Tag fails to find an Access Point after five attempts, scanning through all configured channels.

Based on source-based time-averaged power calculations, the RF Technologies' WiFi Pendant Tag falls below the SAR evaluation limit, and therefore requires no SAR testing.