

Apple Aid
Incorporated

February 20, 2004

Dr. Jack Nilsson
Wi-Fi Plus, Inc.
734 Pearl Road
Brunswick, OH 44212

Dear Dr. Nilsson,

As you know, we have been developing a high performance digital radio system for mobile robotics applications. During the course of our development cycle, we have scientifically evaluated several different antenna technologies in an effort to maximize the performance of our system. These robots are used both by our armed forces, and by law enforcement personnel. Typically, performance in obstructed environments is of utmost importance.

Attached please find the results of our testing of your antenna technology head to head against other technologies. I had provided this same information to you in preliminary form last August and am now writing to make it official.

In summary, Wi-Fi Plus's multi-polarized antennas provided almost twice the performance of circular polarized antennas, previously the best antenna design for difficult multi-path environments.

Best Regards,



Allen Mann
President

Antenna Performance Analysis

We have compared the Wifi-Plus multi-polarized antenna with circular polarized antennas and found that for our application (streaming live video and audio at up to 4 Mbps), the Wifi-Plus antennas consistently performed better than horizontal, vertical, or circular polarization. We performed tests in which one end of the link had two of the Wifi plus omni antennas in a diversity configuration (the second antenna was receive-only). The other end of the link had either one or two of the Wifi-plus 18" directional antennas.

We placed the directional antenna outside, and moved the omni end within another building so that there were from 10 to 20 walls between the two endpoints. We recorded signal and noise levels at both ends, video packet loss, and the bitrate of the radio (the radio automatically switches between 11Mbps, 5Mbps, 2Mbps, and 1Mbps depending on the quality of the signal). We ran the same test 3 to 5 times (each test lasted about a minute), with 3 different antenna configurations:

- 1) Multi-polarized antennas (omni diversity at one end and a single directional antenna at the other end).
- 2) Multi-polarized antennas (omni diversity at one end and directional diversity at the other end).
- 3) Circular polarized antennas (omni diversity at one end and a single directional antenna at the other end).

We had previously determined that circular polarization was significantly better than vertical, horizontal, or a diversity combination of the two.

In our tests the WiFi-Plus Multi-polarized antennas consistently performed better than the circular polarized antennas, in terms of SNR, packet loss, and the radio bitrate. Subjectively, the video quality was perceptibly improved with the Wifi-plus antennas.

The following table summarizes our results:

		Multi-Polarized With diversity at both endpoints	Multi-polarized with diversity only at the omni endpoint	Circular polarized with diversity only at the omni endpoint
Omni endpoint	Average Signal	-85.0 dBi	-63.6 dBi	-70.0 dBi
	Average Noise	-86.0 dBi	-87.2 dBi	-87.0 dBi
	Average SNR	20.8 dB	21.6 dB	16.7 dB
	Average Radio Bitrate*	8.7 Mbps	9.0 Mbps	7.8 Mbps
Directional endpoint	Average Signal	-64.0 dBi	-64.8 dBi	-74.0 dBi
	Average Noise	-86.8 dBi	-88.6 dBi	-87.3 dBi
	Average SNR	22.0 dB	23.4 dB	13.0 dB
	Average Radio Bitrate*	5.5 Mbps	5.2 Mbps	2.9 Mbps
Video Packet Loss	Average % packet loss	29%	24%	46%

* The 802.11b radio switches automatically between 11,5,2, and 1Mbps, depending upon the signal quality. The Average Radio Bitrate that we measured is the average of the radio's reported bitrate setting sampled at 1 sec intervals. While this is not the same as the actual data rate that our application is using, it is a good indicator of the radio's perception of the quality of the wireless link.