Document Title: In-Car Video Technical Support

Author: Herbert Blitzer

Document No.: 235578

Date Received: August 2011

Award Number: 2006-IJ-CX-K003

Final Report
July, 2009
Grant Title: **In-Car Video Technical Support**
Grant Reference Number: **2006-IJ-CX-K003**

The grant was made, initially, to assist with the preparation of a requirements document for In-Car Digital Video Systems that would be published by the International Association of Chiefs of Police. That has been done. Then, as a follow-on effort, to assist with the development of a National Institute of Justice of Standard, based somewhat on the IACP document. A draft of that document is now available for public comment on JUSTNET. From the outset, the program was a multi-agency and multi-disciplinary activity. IFI's primary role was to assist with the image and audio quality aspects of the documents.

From early meetings with the various participants, the assignment became:

Concept:
Provide technical support to agencies developing the requirements document to be published by the IACP

Objectives:
Assist with measurements of conditions expected in the field.

Determine a reasonable set of image quality requirements

Develop means to measure candidate systems against the image quality requirements

Calibrate the measurements process in order to certify candidate systems

Engage in start up of system measurement

TWG need:
Officer safety and system quality for investigations and prosecutions.

Overall Deliverable:
A requirements document that encourages improvements in in-car digital video systems and means to measure the image quality components

A set of field measurements on incoming light at a typical traffic stop was made in New Mexico. This was followed by an additional set of measurements of reflected light from a variety of police stop situations. The results were reported in a working paper from IFI which went to all the key participants in the program. The report is titled, "Light Measurements Associated with a Police Traffic Stop". The findings were also presented to the Digital and Multimedia Science Section of the American Academy of Forensic Sciences in February, 2008. The results were also presented to the Scientific Working Group on Imaging Technology at their meeting in January, 2008.

The information was intended for use by the National Institute of Standards and Technology as they developed a complex scene simulator. The simulator was to be used to test candidate video systems.

Throughout the period, IFI attended a number of meetings to review findings, prepare draft documents and plan the next round of testing and research. For example, one meeting was in Washington DC and was dedicated to the plan to get inputs to NIST. The second was in Virginia and dealt with the overall program plan. A third meeting was in Ft. Worth, Texas and dealt with planning to measure outputs from the testing. At this meeting the results from the field measurements were presented to the subcommittee. The fourth meeting was in Indianapolis and was in conjunction with field measurements. The fifth meeting was in Laurel, MD and was dedicated to defining output measures. After this there were meetings chaired by NIJ and dedicated to adapting the IACP document to create an NIJ Standard.

A key element in the desired requirements document is the specification of image quality and means to measure the indicated properties. Toward this end, IFI developed a preliminary specification and developed and built equipment to make the indicated measurements.

The version submitted was as follows (the latest version is in the NIJ draft standard):

Measuring Image Quality

1. Dynamic Range Measurement:

   The purpose for this test is to determine the degree to which the system under test will be able to record both light and dark contents in the scenes that the camera is likely to encounter in practice.

- Record several seconds of video of a step tablet, illuminated in a sensitometer, with a brightness range of 10,000 to 1.
- Light should be nominally 2,800 to 3,200 degrees Kelvin, record the actual correlated color temperature (CCT).
- Capture a number of frames as per the process provided by the system vendor and open them in a software program such as Adobe Photoshop.
- Using a sampling tool with at least 5 X 5 pixels, measure the red, green and blue values of each of the steps.
- Using the data for the sensitometer, plot the brightness values for each step as a function of its log (base 10) exposure value (corrected for color temperature).
- Determine the point on the log exposure axis at which the response curve is flat due to saturation. This is the ***saturation point***.
- Determine the point on the response where the signal due to both light and noise is equal to twice the noise level alone. This is the ***threshold point***.
- Subtract the threshold point value from the saturation point value. This is the ***dynamic range*** in terms of log exposure.
- ***The system should have a range of 2.0 log exposure or more***.

2. Static resolution:

   The purpose for this test is to determine if the system is able to capture images of small items of importance in the typical scenes it is likely to encounter in practice.

- Working at an incident light level in the range from 500 lux to 2,000 lux, record several frames of video of a high-contrast, bar-type resolution test target.
- Capture selected video frames and examine them to determine the bars that are clear enough to be counted correctly.
- The target should have bars that are nominally horizontal and vertical.
- ***The system should be capable of resolving bars that represent two line pairs per inch at a frame width of 25 feet***.
- Equivalent geometry can be used.

3. Aspect ratio:

   The purpose for this test is to determine if the system presents images to the user that have the correct aspect ratio (width to height) so that measurements can be made.

- Record several frames of a test target with a circle and a square.
- Capture several frames and measure the height and width of the test target elements to ***assure that they have their claimed aspect ratio to within 5%.***

4. Color fidelity:

   The purpose for this test is to determine the degree to which the system under test can capture colors accurately so that color can be reliably used in analyses of the recorded video.

- Record several frames of video of a test target such as the Macbeth Corporation Color Checker™.
- The ***target should have well rendered primaries (red, green, blue, cyan, magenta, and yellow) and six shades of gray***.
- Determine the CIE/Lab dimensions for each patch in the test target.
- Open the frames in image editing software such as Adobe Photoshop and measure the CIE/Lab parameters for each patch using a sampling tool with a view of at least 5 X 5 pixels.
- Subtract the measured values from the respective patch values for all 12 patches.
- Square the individual differences and sum them.
- Divide by 36 (the number of values). This is the mean squared error. ***The mean squared error for the system under test should be less than 200***.

5. Dynamic modulation:

   The purpose for this test is to determine the ability of the system under test to reproduce moving portions of the scene as a function of item size, velocity and scene brightness. It invokes the system's: shutter function, compression function, and image capture process.

- Record a test target moving at known velocities ranging from the equivalent of up to 45 miles per hour at a frame width of 25 feet and a distance of 35 feet, or optical equivalent.
- The test target should move across the video frame and it should cover at least 40% of the frame height.
- The test target should have two series of white and black bars that are the equivalent of two and four inches wide each.

- The test target will be illuminated at two levels: approximately 500 lux (+/- 100 lux) and 7,000 lux (+/- 1,000 lux).
- Capture frames and open them in an image editing software package such as Adobe Photoshop.
- Render the images as gray scale images.
- Measure the brightness levels of the dark and light bars using a sampling tool with a window of at least 5 X 5 pixels.
- Subtract the dark bar values from the light bar values to determine the modulation.
- Normalize the modulation for each velocity by dividing it by the modulation of the stationary test target.
- Plot the relative modulation as a function of the velocity of the target.
- The ***relative modulation should be at least 50% at 15 miles per hour equivalent at both light levels***.

6. Progressive scan distortion

   The purpose for this test is to provide an indication of the angle between a vertical line and the representation of that line that is caused by the process by which the camera samples the real image formed by the camera lens. This is a figure of merit for the purchasing department and it is a measure that a forensic video analyst can use to correct any measurements that might be made. There will be no basic requirement in this specification.

   - ***The angle between the bars recorded in the dynamic modulation test and true vertical will be measured at each light level.***

This proposal was reviewed by the leadership of the IACP program and was then brought before the full committee, where it was also approved.

Each of the elements of the specification has a basis in the field testing that preceded and the measured parameters of typical police stops and key operations. For example, the dynamic range spec is based on the range of light levels measured at typical police stops. The static resolution test is based on the interest in being able to identify certain weapons that might be exhibited by people in a stopped car and/or read a license plate at the indicated distance. The aspect ratio test is based on the need to have control of pixel shape in order for analysis of distances in the video to be valid. The color fidelity test is based on the quality of the light at a stop, the typical colors found at a stop and the ability to use clothing to track movement of individuals by means of color. The desired values are compromised to meet the realities of current video technology. The dynamic modulation is based on both the desire to see moving objects in a scene and the limitations of current video technology. Hopefully the technology will improve over time and the specifications can be upgraded, but these are reasonable for the devices available today.

After more early testing, the tests were modified to accommodate more robust test settings. It was found that the test procedures were repeatable and there were clear indications that the tests were valid. Those findings were shared with the committee and SWGIT. Following this, IFI tested three actual in-car systems for their respective vendors. None of the systems would have passed, but the manufacturers were determined to fix the residual shortcomings in their products.

At a recent trade show, a few camera systems (not explicitly intended for use in In-Car systems) were shown. They offer greatly enhanced video quality. Arrangements have been made with one of the vendors to test this technology. If it performs as anticipated, it will clearly demonstrate that video technology has reached the point where all of the image quality requirements contained in the IACP Requirements Document can, indeed, be achieved.

The requirement for a means to test the ability of the officer-worn microphone to communicate with the in-car-mounted system was added to the list of tests needed. The general requirement was an outgrowth of the field testing that was done in 2006 and 2007. The current test procedure has been tested on simulated audio transmission systems and appears to be valid and reliable. More testing with actual systems will be needed at some point to confirm this finding. The proposed testing procedure is as follows:

Draft Audio System Testing Procedure

Purpose

This test is designed to test if the audio system delivers intelligible audio when the microphone is transmitting to the receiver at a distance of 1,000 feet.

1. Connect the equipment as shown in the Microphone to Receiver Test Schematic.
2. Fix the relative locations of items 1, 2 & 3 so that they can be moved without changing their positioning.
3. Place the sound source equipment (items 1, 2, 3 & 11) at least 50 feet from the receiver, 4. Drape the 1,000 feet of microphone cable sinuously as opposed to leaving it on a coil to minimize any inductance effects.
4. Send a sine wave from 11 to 1 at approximately 440 Hertz (A above middle C) and set the volume controls to assure that there is no clipping visible on the oscilloscope, 9 when sent via the reference track, 3,7, 6 &12.
5. Check the device under test (DUT) track, 2, 4, 5 & 6 and readjust volume levels to assure strong signal with minimal clipping.
6. Adjust the delay line, 12 and the mixer gain on the reference track such that the oscilloscope indicates that the DUT track and the reference track signals are in phase.
7. Adjust the mixer gains for both tracks so that they are close to the same level. Invert the reference track polarity, 7 and further adjust the gain controls to minimize the now bucked-out signals. Using the meter, 8, check to see that the polarity reversal reduces the signal by a factor of at least 10:1 (linear voltage).
8. Record the settings and do not change them
9. Play the Intelligibility CD speech plus babble rhyming words tracks and record at least 50 words, starting at some random point on the answer sheets. Record the signal on the computer as this is done. Repeat and record the reference signal track.
10. Move the sound source equipment (items 1, 2, 3 & 11) one thousand feet from the receiver, 4. The remote site and the receiver site should be connected by 1,000 feet of nominally clear, line-of-sight pathway. There should be no large metallic structures (bridges, large overhead signs, marquees, etc.).
11. Using the A above C frequency and the polarity switch, note the degree of cancellation. It should be at least 8:1.

12. Play the Intelligibility CD speech plus babble rhyming words tracks and record at least 50 words on the answer sheets. Record the signal on the computer as this is done. Repeat and record the reference track.
13. The system should produce at least 48 out of 50 words intelligibly.

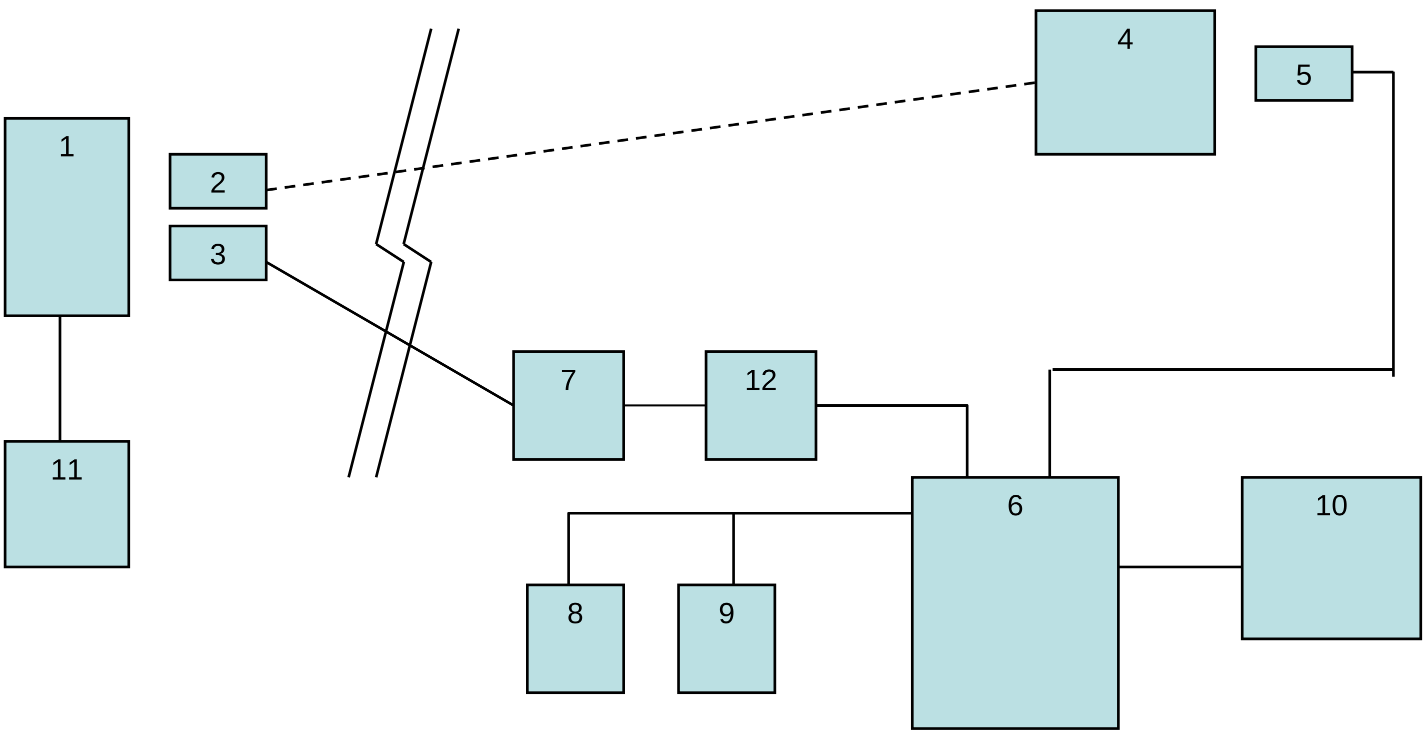
Conceptually, this testing is based on the use of a standard speech intelligibility test process widely used in the audio engineering field. In addition, it uses a comparison track to test the fidelity of the audio of the DUT to a reference system which has negligible distance and sound quality issues which might be associated with conversion to digital and back to analog and with radio transmission.

A simulated DUT system has been assembled, but it lacks the delays due to A to D and D to A conversion at this point. It does allow for certain types and degrees of distortion, however. In the next two months more testing will be done with this simulator. The objective is to have a more thoroughly tested program in place by the end of March 2009.

At the February 2009 conference of the AAFS, the results of this project will be presented to the Digital and Multimedia Sciences Section.

Basic Elements of the Microphone Transmission Test

1. Sound source, CD player
2. Device Under Test (DUT) microphone
3. Reference microphone
4. DUT Receiver
5. Microphone to pick up transmitted signal
6. Audio mixer to combine signals and set levels for each
7. Polarity switch to facilitate cancellation
8. True RMS voltmeter
9. Oscilloscope to assure proper phase lag compensation
10. Computer to record measurements
11. Oscillator to provide set and set-up signals
12. Delay line to compensate for delays resulting from the DUT's conversion of analog audio to digital and back again.



Several submissions were made to the NIJ Standard development team as more was learned about the testing and the needs. These were related to primary microphone measurements, rear seat sound measurements, test targets and procedures to be used in conjunction with vibration and environmental testing.

In consideration of rear seat microphone, measurements of the sound levels in an off-road car and an on-road car were made. The original requirements for sound level testing were revised since the background levels are higher than anticipated at the committee meetings. In general, background sound pressure levels are higher than the sensitivity requirement originally stated. See the table below.

Sound Pressure Readings, db a

Field Readings	
Off-road car, engine off	35
Off-road, stationary car, engine running	45
Off-road stationary car, backseat voice, engine running	70
Two-lane country road, background level	67
Six-lane busy road, newly paved, background level	63
Limited access highway, background level	77
Under highway bridge, stationary	73
Six-lane busy road, in bad condition	70
Four-lane road, low traffic level	63

The field readings are averages, +/- 2db.

A test of the primary microphone testing approach using a walkie talkie demonstrated that the basic approach is valid, but that the number of correctly identified words still needs to be tested. Motorola, Inc. was going to loan an in-car radio system for testing but was not able to follow up on that offer. There are two main effects that were discovered. The first is that the babble in the background (behind the voice-over carrying the intended message) tends to have a rich component of lower frequencies. The walkie talkie, and probably the in-car audio system as well, will probably have a frequency response on the order of 300 Hz to 3,000 Hz. The result is that the babble is naturally attenuated by the system. This makes the voice over easier to understand.

The meeting of the Video Quality in Public Safety Working Group in Boulder, CO was attended and the testing protocols being proposed for the NIJ standard were presented to the group. In addition, a copy of the report on lighting conditions that had been prepared by IFI was provided to the group along with copies of images from in-car systems. (The trip was paid for by NIST).

During the month of March, 2009, which is the final period of this project, advances were made in the audio testing portion of the program. A system configuration was developed which could test a system between 300 and 3,000 Hz. Interestingly the cut off at the lower end of the spectrum made it easier to understand the test words over the background babble. Clearly the confusion of the babble resulted in a considerable amount of lower frequency sound, and the 300 Hz cut off eliminated a lot of this.

Improved versions of the test targets were produced with the help of Wolf Technical Services, Inc. The new targets are more accurate, have gray backgrounds, and are physically easier to work with because they are on a more rigid, foam core support. The increased quality of the star target makes it much easier to evaluate the circle of confusion. These targets are commercially available from Wolf Technical Services, Inc.

A simple means was found to calibrate the dynamic modulation test stand. A high-quality video camera was used to capture imagery of an electric clock with a sweep second hand. A few minutes of video were recorded, and the number of include frames was determined using standard video editing software. This confirmed the frame rate of the camera. Then that camera was used to record the falling test target. Using the

Newton equations, it is possible to determine the time for the target to fall a specified distance. Then this is compared with the velocity expectation. The system was well within 1%.