Methods for Embedding DTV antennas into Notebook PC enclosures

1 Introduction

This report summarizes the non-proprietary results of an R&D project funded by NAB and directed by an engineering team at Dell. The purpose of the project was to study methods of improving DTV antenna performance in portable computers. Though portable computers commonly include several antennas for communications today, integration of DTV antennas poses new challenges due to the significantly lower frequency (and larger size) required.

2 Summary

The focus of this particular study was to evaluate 2 new methods of manufacturing antennas that increase available space by embedding the antenna's radiating elements into the enclosure. The performance of antennas made by these alternate methods is compared to that of current commercial products and prototypes made by more conventional methods. Testing in the lower (VHF) bands has proven to be challenging since the test chambers typically used for WLAN and cellular antennas are not designed for testing of frequencies below~500 Mhz. Larger chambers are needed for proper testing in the VHF bands. The results reported here were obtained at a contract testing lab with suitable chambers for VHF.

2.1 *Insert Molded Antenna (IMA) for Dell Inspiron Mini 10*

Antennas were made for the Inspiron Mini 10 using insert molding. All of the antennas including WWAN, WLAN, and DTV were embedded in the plastic display housing by insert molding. Prototype tooling was fabricated and functional samples were produced and tested. Antennas are coupled to the respective radios by a coaxial cable directly attached at feed points on the inside of the housing. This display housing is a drop in replacement for the production display housing + antenna assembly. RF testing of the prototype samples is summarized below.

2.2 *In Mold Label (IML) Antenna for Dell Inspiron Mini 10 and Inspiron 1525*

The Inspiron 1525 was used as a demonstration vehicle for IML antennas since a retired injection mold suitable for performing molding trials with IML was available for R&D. The Mini 10 was used as a performance comparison vehicle but actual IML parts were not produced for it. Antenna structures were fashioned for both the Inspiron 1525 and the Mini-10 using copper tape on the outside of the enclosure to simulate what could be achieved with the In-Mold-Labeling process. The resulting design was incorporated in into a film and molded into a display cover for the Inspiron 1525 in order to demonstrate production feasibility. Signal is fed to the antenna structures using a capacitive feed structure place on the inside of the housing.

3 Conclusions

Both of the new manufacturing methods (IMA and IML) were found to be manufacturable though with some cost premium over conventional methods. The capacitive feed method that we developed for IML proved to be effective and succeeded in addressing manufacturing difficulties experienced in prior attempts to make IML antennas. The conclusions about performance benefits are somewhat subjective. Test results suggest that these new antenna construction techniques can provide benefit for some but not all pc designs. To be more specific, the shaped of the notebook enclosure determines how much usable space can be recovered by embedding the antennas. For notebooks with square shape and densely packed components, it seems difficult to make usable space for the large antenna structures required for VHF. In this case, is the spacing between the antenna's radiating elements and the internal metallic components is not large enough even with the antenna structure on the outside skin, hence the antenna becomes coupled to the internal metallic components. This coupling not only detracts from the antenna's performance (measured by average gain or radiation efficiency) but also tends to increase the magnitude of RF noise that is coupled to the antenna. When the PC has a more sloping or rounded shape, (such as the Inspiron Mini-10) there is opportunity to place the radiating elements of the antenna far enough from the internal components to provide reasonable performance. We had selected the Inspiron 1525 as a demonstration platform for the IML type antenna based on availability of suitable retired production tooling. This notebook included antennas for cellular and wireless LAN, but not TV. We had hoped that by placing the antenna on the outside of the notebook enclosure, we could make space for a suitable internal TV antenna. We designed and fabricated IML antennas for the Inspiron 1525, but the performance of the TV antenna was not found to be satisfactory due to the factors mentioned above. Good performance benefit was demonstrated on the Inspiron mini 10 with IML however.

4 Test Results

The results summarized in the following tables were measured at a contract test facility. Antenna gain was measured in 3 normal planes and total average gain was computed. The antennas tested include the ones developed as a part of this project as well as some others for reference. The reference antennas include the current production DTV antennas for the Mini 10 (both the internal and external) as well as some other external antennas. Some photos of the tested antennas are below the tabulated data. Note the antenna ID number to connect the photos with the corresponding test result.

4.1 Internal Antenna Test Results for Band IV and V

	Internal Antenna High Band Total Average Gain	
ID #	**Antenna Configuration**	**Total Avg. Gain (dBi)**
1	Mini 10 IML prototype	-8.29
2	Mini 10 production design (side)	-11.73
3	Mini 10 IMA prototype	-12.15
4	Mini 10 FPC prototype (bottom)	-12.37
5	Inspiron 1525 IML prototype	-13.12
6	Mini 10 alternate PCB type prototype (Side)	-14.85

Photos of each of these 6 antennas are included in the appendix. (Note ID #)

4.2 Internal Antenna Test Results for Band I and III

	Internal Antenna Low Band Total Average Gain	
ID #	**Antenna Configuration**	**Total Avg. Gain (dBi)**
5	Inspiron 1525 IML prototype	-25.38
4	Mini 10 FPC prototype (bottom)	-28.54
1	Mini 10 IML prototype	-32.22
6	Mini 10 alternate PCB type prototype (Side)	-32.22
2	Mini 10 production design (side)	-35.23
3	Mini 10 IMA prototype	-36.99

Photos of each of these 6 antennas are included in the appendix. (Note ID #)

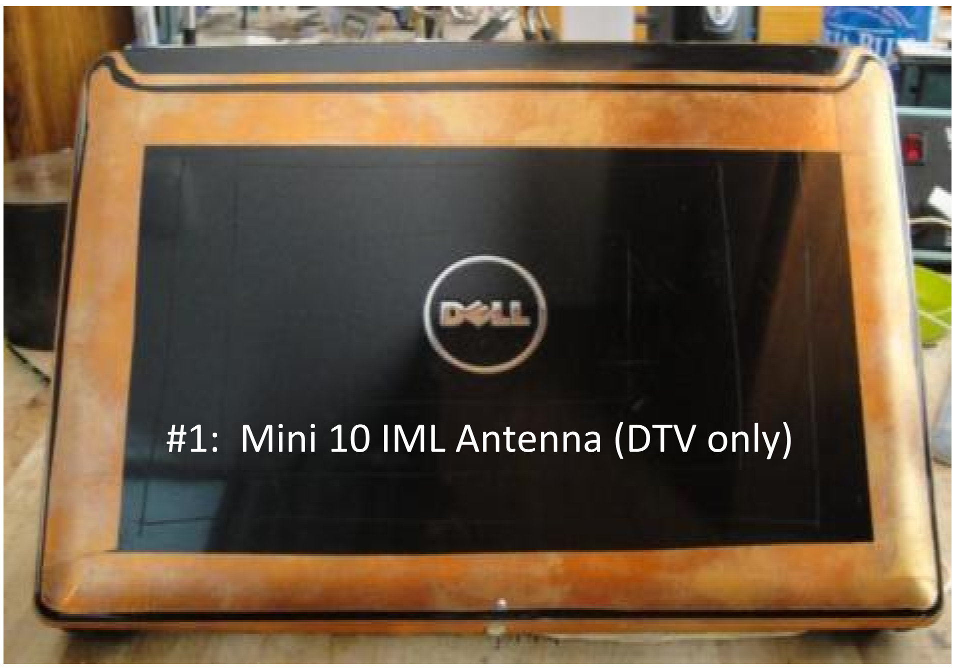
4.3 External Antenna Results for Bands IV and V

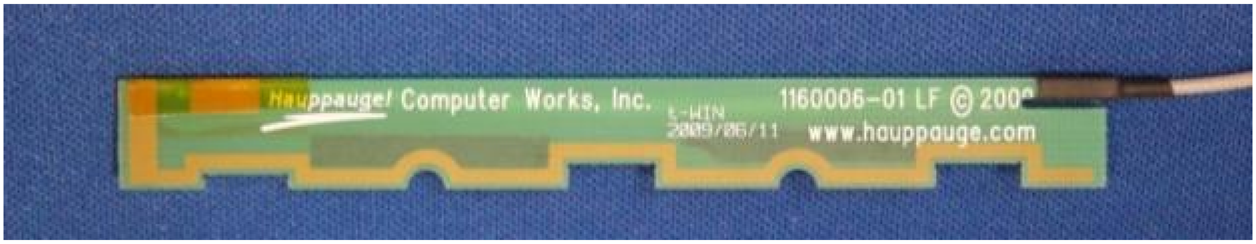
	External Antenna High Band Total Average Gain	
ID#	Antenna Configuration	Total Avg. Gain (dBi)
E1	New prototype flat external dipole	-4.95
E2	Dell Mini-Dipole	-5.47
E3	Philips SDV 3132/27 (from retail)	-7.78
E4	RCA ANT 1450 (from retail)	-12.12

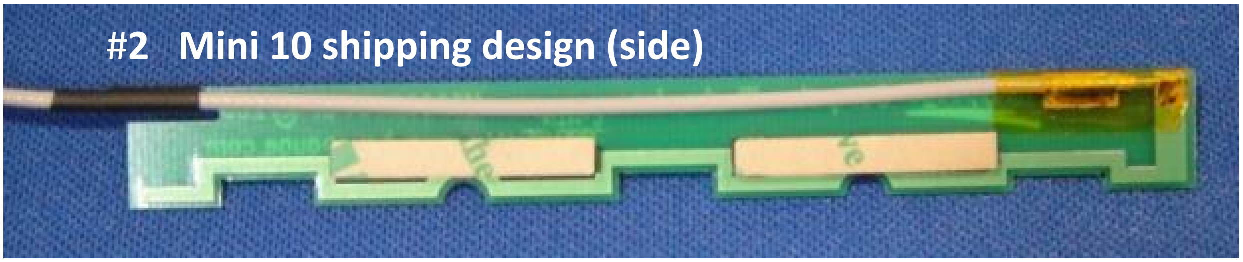
4.4 External Antenna Results for Bands I and III

	External Antenna Low Band Total Average Gain	
ID#	Antenna Configuration	Total Avg. Gain (dBi)
E2	Dell Mini-Dipole	-11.66
E3	Philips SDV 3132/27 (from retail)	-14.42
E1	New prototype Flat external dipole	-15.24
E4	RCA ANT 1450 (from retail)	-17.17

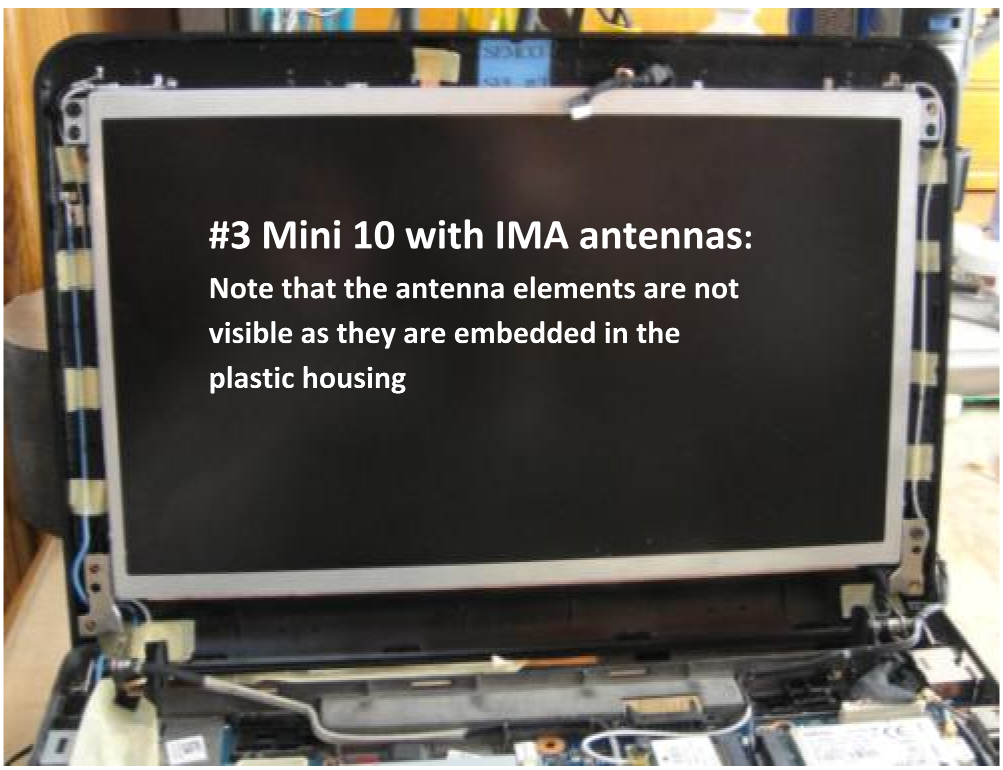
4.5 Photos of the Internal Antennas tested

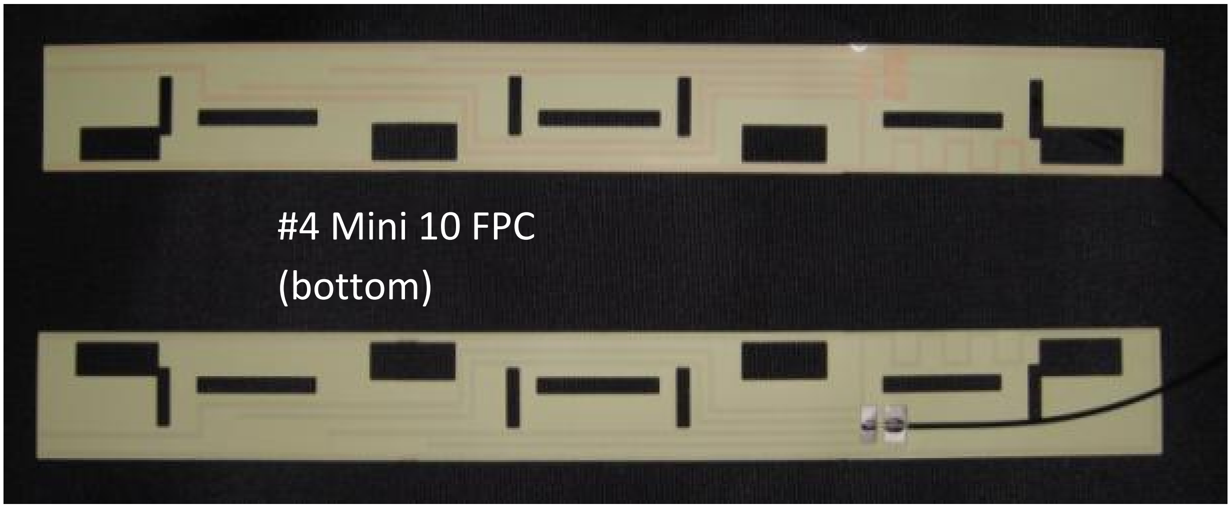




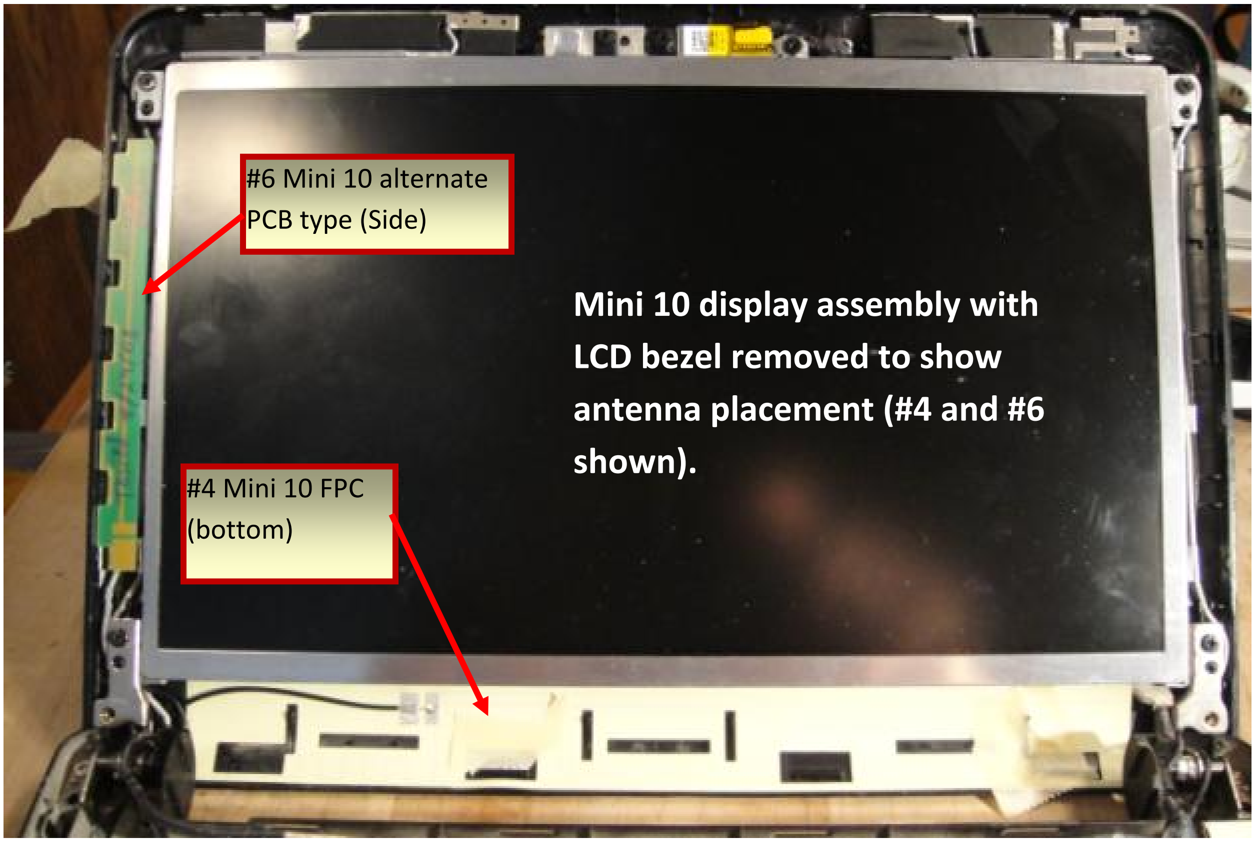


Mini 10 shipping design (side) passive monopole antenna



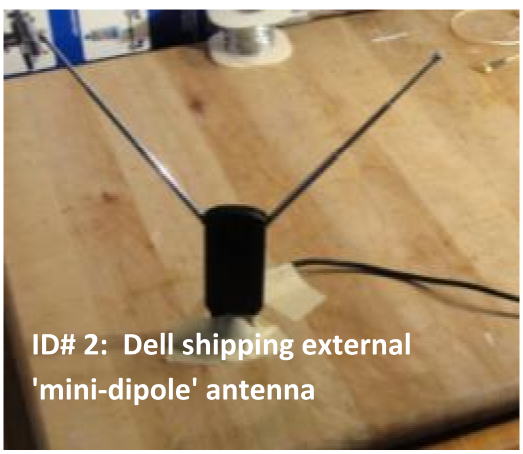


Mini 10 Bottom Mounted PIFA fabricated from FFC (Flat Flexible Cable) materials . (This antenna has 5 different sized radiating elements intended to make the antenna more broad band).



Mini 10 display assembly showing the alternate side antenna and new bottom antenna design. The alternate side antenna is similar to the production version, but the length is increased and the feed point is at the opposite end

4.6 Photos of External Antennas



ID# E3: Philips SDV-3132/27 external antenna (from retail)

ID# E4: RCA ANT 1450 (from retail)