Waveguide Cutoff Effect of Vehicular Tunnels Demonstrated with Zero Span Spectrum Analysis

Gregory Larson[1], Dr. Aziz Inan[2], and Dr. Peter Osterberg[2]

[1]Intel Corporation, Hillsboro, OR, USA

[2]Department of Electrical Engineering, University of Portland, OR, USA

Email: gregory.larson@intel.com, ainan@up.edu, osterbe@up.edu

Abstract*—Zero span spectrum analysis was used to characterize the attenuation of AM and FM signals in a vehicular tunnel and demonstrate that AM signals are attenuated immediately due to waveguide cutoff while FM signals are gradually attenuated due to obstruction or blockage in the tunnel.

INTRODUCTION

Zero span spectrum analysis was performed to measure the received signal from AM and FM radio signals while driving through the half mile long and 12.5 m wide Vista Ridge Tunnels and the hundred yard long and 8.5 m wide tunnel on NW Cornell Road in Portland, Oregon. Attenuation due to blockage and obstruction of the radio signal while driving through the tunnels is a factor, but the listener experience of FM (88 – 108 MHz with wavelengths between 3.41 and 2.78 meters) stations is unimpeded while AM (535 – 1605 kHz with wavelengths between 561 and 187 meters) stations audibly cutoff as you enter the tunnels and does not regain reception until exiting. The waveguide cutoff frequency for both the Vista Ridge and Cornell Road tunnels, as calculated from [1], falls between the AM and FM band, and the test results demonstrate the waveguide cutoff effect on AM radio signals whose frequency and associated wavelength cannot propagate inside the tunnels while FM band frequencies successfully propagate inside.

METHODOLOGY

The received signal strength versus time was measured at specific AM and FM radio frequencies to determine the total attenuation while driving through each tunnel. In order to characterize the time based nature while driving through the tunnel, zero span analysis was utilized on a hand held spectrum analyzer with a roof mounted antenna on a vehicle. The radio stations chosen for the experiment were the strongest local emitters located less than 2 miles from the tunnels.

Zero span analysis was performed at 970 kHz for the AM band and 100.3 MHz for the FM band. In order to observe the signal reception while entering and exiting the tunnels, a time duration of 30 seconds was chosen for the Vista Ridge tunnel and 10 seconds for the shorter tunnel on NW Cornell Road.

RESULTS AND DISCUSSION

Results of the test were able to demonstrate that while both AM and FM radio signals experience attenuation through the tunnel, the attenuation in the FM band was a factor of tunnel length while the attenuation in the AM band drove the signal to the measurement noise floor, regardless of tunnel length. The increased wavelength of the AM signals restricted signal propagation into the tunnels while FM signals with wavelengths smaller than the tunnel dimensions propagate unaffected. This is not due to the difference in source signal modulation. Figure 1 demonstrates the steep loss and then increase in signal due to waveguide cutoff effect restricting propagation of the 970 kHz AM signal through the tunnel. Both tunnels are presented side by side for ease of comparison. Additionally, multipath effects or fading from overhead road signs are seen during the Vista Ridge baseline test. Figure 2 demonstrates that the longer Vista Ridge tunnel attenuates FM signals more due to blockage and signal obstruction inside the tunnel but lacks the steep slopes seen in the AM plots indicative of waveguide cutoff effects.

Visualization of the waveguide cutoff effect with respect to time as seen through zero span characterization of the tunnel waveguide provides the framework for understanding how signals are interacting with their environment. Waveguides in a communication system or those found in infrastructure affect the propagation of electromagnetic energy regardless of scale, although the cutoff frequency decreases with increasing waveguide widths. An EMC Engineer can use these findings to build or enhance their mental model to better comprehend the fundamentals of the relationship between signal wavelength, waveguide dimensions, and the resulting cutoff frequency.

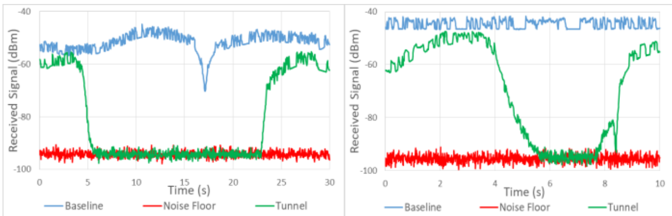

Fig. 1 970 kHz AM Band Zero Span Measurements: Vista Ridge Left and NW Cornell Road Right

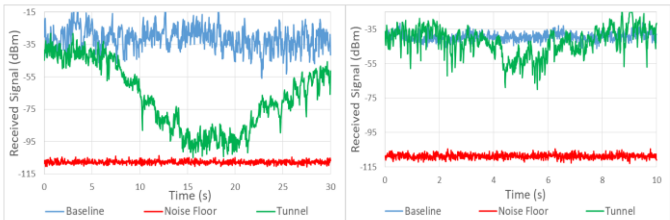

Fig. 2 100.3 MHz FM Band Zero Span Measurements: Vista Ridge Left and NW Cornell Road Right

REFERENCES

[1] C. Paul, Introduction to Electromagnetic Compatibility, 2nd Edition. Wiley, New York, 2008, ISBN 978-81-265-2875-2.