Cellular Antenna Element Design Impact to Integration on Vehicle

(*Cellular Antenna Element Performance*)

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***Abstract*—this paper addresses the challenges in a cellular antenna element design to meet on-vehicle packaging requirements. With concerns of vehicle height for shipping and clearing an overhead garage opening, it is important to select a cellular element that will meet height requirements. There is a performance impact in selecting antenna element to meet vehicle requirements. Antenna gain can be impacted by element height and shape. There is performance of two antenna types with both ground plane and on-vehicle gain.**

Keywords—cellular, antenna, and vehicle integration

I. INTRODUCTION

The demand for wireless connectivity is requiring the deployment of embedded modem systems and antennas across the majority of vehicle platforms. Applications for wireless connectivity include telematics, ERA-GLONASS and eCall which range from convenience features to government mandated emergency call notification. Technologies to deliver these functions include GSM, 4G LTE/HSPA for wireless cellular communication and GNSS for location information. Soon to come is 5G and Vehicle-to-Vehicle Communication technologies.

The paper will present data and information to consider for designing a cellular antenna element for automotive applications to meet the functional requirements. The critical parameter of antenna gain will be presented and compared for a typical shark-fin antenna 65mm in height and a low profile PIFA element approximately 25mm in height.

II. REQUIREMENTS FOR AUTOMOTIVE APPLICATIONS

A. *Antenna Design Considerations*

There are several requirements and parameters to consider when designing a cellular antenna element for automotive applications. First, the wireless services that are expected to deliver to customer must be established. The services required will drive a radio technology to employ in which to deliver the services. Based on the radio technology and the regions in which the technology is to be utilized will drive the frequency bands in which the antenna is expected to function. Given that there several frequency bands to support, multiple antennas will be needed to support. Considering the fact that automobile manufactures' are concerned with the aesthetics of the vehicle, the number of antennas are minimized with the elements being combined in one housing [1] [3] [4]. Another consideration is the number of cables and architecture which also drives the number of antenna elements to be contained in the same housing. The housing or otherwise referred to as the antenna radome is typically located on the front or rear of the vehicle roof. While the antenna on the roof should provide an open sky view to the cellular and satellite signals that are desired to receive, the vehicle itself can pose challenges for the antenna. The panoramic roofs, roof rails, roof curvature and roof height which can have a negative effect on antenna performance and constraints which challenge the antenna engineer for type of antenna and element design in an attempt to optimize the antenna performance in the environment that it is intended to be located.

This paper will compare LAG (Linear Average Gain) of two antenna types. The antenna types are a form of a wideband monopole [2] [4] integrated in a shark-fin antenna and a form of a PIFA (Planar Inverted F Antenna) as a cellular element.

B. *RF Performance*

The RF performance of the broadband cellular antenna is developed by modeling and constructing the antenna element to maximize the return loss such that the VSWR is less than 2.5. However with the 3GPP Specification band requirements covering 698 – 960MHz and 1710 - 2690MHz for 4G currently and possibly expanding to use bands up to 3800MHz for 4G advanced and 5G, a higher VSWR has been reported mostly at lower frequencies due to the long wavelength and relatively small antenna structures that are employed in typical automotive antenna housing. It is desired to minimize the VSWR since applications of short cable lengths to the modem could result in undesired levels of reflected transmit power. Also a low VSWR will help to meet the efficiency requirements.

To achieve the VSWR requirement, the antenna element is usually tuned by optimization in CAD and then verified and further hand tuned on prototype samples.

Gain of the antenna is most often considered a major parameter for automotive antennas since the vehicle antenna is basically in a fixed location relative to a handheld device or smart phone antenna. The handheld devices and smart phones are influenced by the human tissue and are moved and held in many orientations which make it difficult to make judgment of RF performance based solely on gain. Therefore the handheld and smart phone devices are measured based on Efficiency (spherical power output relative to power input) and Total Radiated Power, and Total Isotropic Sensitivity as a subsystem [5]. Automotive antennas focus on gain primarily and a hemispherical efficiency due the mounting of the antenna on vehicle in a fixed position with view of the hemisphere with ground plane below.

III. MEASUREMENTS

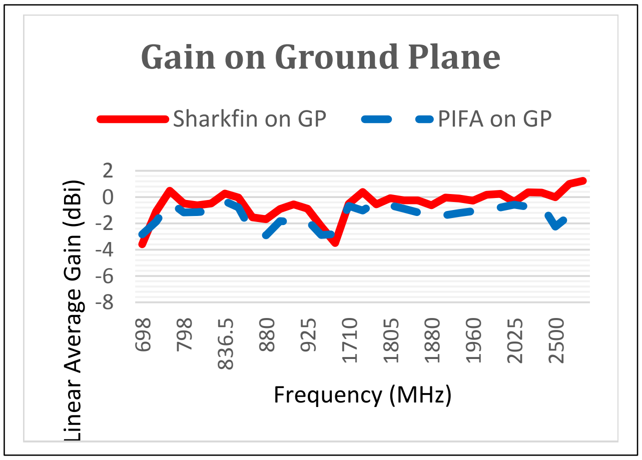
Gain measurements for the automotive antenna are initially conducted on a 1 meter rolled edge ground plane. The gain is recorded on an antenna range that has the capability to rotate a vehicle and record the signal received by the test broadcast antenna over an azimuth of 360º usually in 1-2º increments. The gain at theta = 90º (0º elevation) is considered the worst case to measure with reduced scattering. The gain at this level represents the vehicle being in a rural location far away from the Base Station antenna. Other elevations are also recorded and can be from 0-30º in 5º increments recording the LAG for the azimuth cuts at each elevation. Depending upon antenna test range, certain elevations are averaged due the ripple in the gain between elevations.

The antenna is developed and tuned and matched to meet gain and efficiency on ground plane before taking the next step to measure on the vehicle. The antenna meeting requirements on the ground plane does not insure meeting the requirements on the vehicle and may require tuning to the environment.

Finally, data is presented to compare the performance of the Shark-fin antenna verses the PIFA.

A. Gain

The LAG (Linear Average Gain) of the Shark-fin verses the PIFA can be seen in the graphs (see Fig. 1. and Fig. 2.) for the antennas on ground plane and vehicle which summarizes the individual frequency polar plots across the full bandwidth. Details of the gain can be seen in the polar plots which indicate the directionality of the gain including min, max and standard deviation.



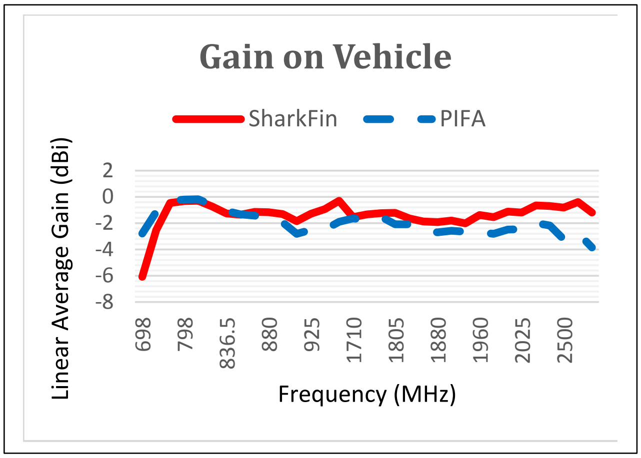


Fig. 2. Linear Average Gain of a PIFA on Ground Plane

IV. DISCUSSION

As can be seen from the graphs, the Shark-fin Antenna does perform better than the PIFA overall. The Shark-fin Antenna does roll off at the lower frequency due to the tuning being optimized for GSM low band in Europe. The antenna can be tuned to cover the low 700MHz range frequency bands which is used in North America. Also it can be noted that from the polar plots the PIFA structure is more directional than the Shark-fin Antenna with a monopole type element and therefore will not perform as well on vehicle. However given that the PIFA is a low profile antenna, this may be an option for cellular assuming the cable to the modem is kept short and the RF link budget can be met. Note that in developing multi-element antenna structures to collocate with the PIFA, isolation and coupling must be considered to achieve the antenna gain and directionality to meet system functionality.

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