Compact Diversity Antenna System for Remote Control Automotive Applications

Victor Rabinovich* (1), Basim Al-Khateeb (2), Barbara Oakley(3), Nikolai Alexandrov(1)
(1) Tenatronics Ltd., Newmarket, Ontario, Canada, http://www.tenatronics.ca
(2) DaimlerChrysler Corporation, Rochester, MI
(3) Department of Electrical and Systems Engineering, Oakland University, Rochester, MI

This paper describes a low-profile hidden antenna diversity system for remote control automotive applications. The antenna system is designed for operating in a frequency range from 300 to 400 MHz, which is a commonly used frequency band in the United States and Canada. The proposed diversity antenna can be used in designs where extended range is the main system requirement.

Introduction

In recent years, the wireless communication market has expanded greatly. Wireless devices such as remote control engine start systems, keyless entry systems, and automatic tolling systems are now considered 'classical' devices for short-range vehicle wireless communication [1]-[2]. Such control and security devices commonly use the 315 MHz and 433.9 MHz frequency band in the United States and Canada. In these systems, the antenna is a key component for system performance and size. The compact hidden type antenna has gained special attention over the past few years because of the possibilities it represents for reduced size in comparison with conventional dipoles.

It is known [1] that the communication range that can be achieved in a radio system depends strongly on the antenna gain. A compact hidden antenna has low gain and, as a result, reduced communication range. Hidden antennas invariably suffer from performance problems due shielding from the vehicle. Additionally, the antenna pattern in the vehicle with these types of antennas is not omnidirectional [3]. The extended range for such hidden antenna system for some angle directions can be a problem. Maximum to minimum antenna directionality values over 360 degree can show differences of up to 30 dB. This ratio is equivalent to about ten times the range ratio.

Let us assume that maximum directionality corresponds to the range 100 m, while the minimum directionality value corresponds to the range less than 10 m. In this case, one of the most effective ways to increase the range is to use the antenna diversity technique. It is known that the antenna diversity method that can help to reduce degradation in the communication link [4]. Instead of simply using different cables, many previous systems [4] have used pairs of antennas that can be electronically connected to the receiver to provide optimal signal reception.

In this paper we propose a highly efficient, small-size printed-on-circuit board, active, diversity one element antenna. The antenna can be integrated with a low noise amplifier to extend short-range wireless communication.

0-7803-8883-6/05/$20.00 ©2005 IEEE

Antenna Diversity Element Design

A meander line antenna [3] has been chosen as the base of the proposed space diversity system. Fig. 1 shows the configuration of the active antenna described in the paper [3]; the one-element diversity antenna is shown in Fig. 2. The antenna diversity element shown in Fig. 2 consists of meander line antenna (1), two identical electronic switches (2), two cables (3, 4), and two ferrite beads (5). Antenna 1 has dimensions limited to less than 50 × 70 mm. Pin diode switches 2 can connect cable 3 or 4 to the receiver 6. In this fashion, antenna directionality can be controlled using different lengths and locations of the cable between an antenna 1 and a receiver 6.

The correlation between antenna directionality and cable length can be understood as follows. For our design we have chosen an unbalanced antenna that has small dimensions compared to the operational frequency wavelength. It is known [5] that such antennas couple strongly to the terminal cable. As a result, a significant amount of radiation emanates from the cable. In point of fact, the antenna consists of antenna element 1 as well as cable 3 or 4. Ferrite bead screening on the outside of cables 3 and 4, placed close to the receiver, are used to suppress RF currents [6] flowing from the receiver to the ground. A direct connection of an unbalanced antenna to the cable, as proposed here, is not common; however, this connection has been shown to enhance antenna performance [5]. Fig. 3 shows the simulation results (IE3D software) related to antenna directionality of the passive antenna, described in the paper [2] with cable length 25 cm (curve 1) and 37cm (curve 2). The cable orientation is shown in Fig. 2. As can be determined from simulation results, the radiation efficiency of the antenna with a cable length of 25 cm is equal 0.8, the radiation efficiency of the antenna with a cable length of 37 cm is 0.6, and radiation efficiency of the antenna without a cable is equal 0.15. Fig. 4 shows the vehicle measurement results of the antenna directionality with cable 3 (curve 1) and with cable 4 (curve 2). As can be seen, the simulation and measurement antenna performances are strongly dependent on the cable length and orientation. These phenomena form the foundation of the space diversity system design.

Diversity System Operation

As previously noted, antenna element 1 is connected to receiver 6 through cable 3 or cable 4. The receiver provides control functions: it electronically opens or closes the vehicle doors or starts vehicle engine. The diversity system operates in the following manner. Receiver 6 is activated by the transmitting Fob key located at some range from the vehicle. Antenna 1 alternately is connected with a remote control receiver 6 through cable 3 or 4 (depending on switch positions). Approximately half of the activated time, antenna 1 is connected to the receiver through the cable 3, and half of the activated time antenna 1 is connected to the receiver through the cable 4. In this case the equivalent antenna directionality of the diversity antenna can be represented as the overlap of the curve 1 and curve 2 of Fig. 4. This graph is shown in Fig. 5. Let us compare the range of the wireless communication for two different antenna directionality curves shown in Fig. 4 (curve 1) and Fig. 5. It is known [3] that range *D* can be expressed by

$$D^{n} \simeq q \cdot F(\theta)$$

Where $F(\theta)$ - antenna directionality at the azimuth angle direction θ, and q is the coefficient that depends on the noise level of the system and operation frequency. The value n depends on the environment. For an urban area, n can be chosen equal 2.5. Let us assume that the average directionality value corresponds to the range 100 m. In this case for the curve 1 in the Fig. 4 we have 28% of the angle points (over 360 angle degrees) with a range of less than 63 m, 8% of the angle points with a range less than 40 m, 3% with less than 25 m, 1.5% with less than 16 m., and 0.5% less than 10 m. For the curve shown in Fig. 5 we have 12% angle points with a range less than 63 m. and no angle points with a range of less than 40 m, 25 m, 16 m, or 10 m. Thus, we see the significant improvements in the range performances when using proposed antenna diversity system.

Conclusion

We have proposed a novel type of diversity antenna construction for compact hidden automotive remote control applications. The proposed diversity antenna consists of one excitation element and two RF cables that alternately can connect antenna to the remote control receiver. We have demonstrated numerically and experimentally that effective space antenna directionality shows significant improvements in the range of remote control vehicle wireless communication.

References:

[1] Alan Bensky, *Short-range Wireless Communications*, LLH Technology Publishing, 2000.

[2] F. L. Dacus, "Design of short-range radio systems," *Microwaves and RF*, pp. 73-80, Sept. 2001.

[3] B. Al-Khateeb, V. Rabinovich, B. Oakley, "An active receiving antenna for short range wireless automotive communication," *Microwave Opt. Technol. Lett.*, vol. 44, pp. 200-205, Nov. 2004.

[4] William CY Lee, "*Mobile Communication Engineering*, "McGraw-Hall, 1993.

[5] Morishita, Y. Kim, and K. Fujimoto, "Design concept of antennas for small mobile terminals and the future perspective," *IEEE Antenna's and Propagation Magazine*, vol. 44, No. 5, pp. 30-43, Oct. 2002

[6] S.Saario, D. Thiel, S. O'Keefe, and J. Lu, " Analysis of ferrite beads for RF isolation on straight wire conductors, " *Electron. Lett.*, vo. 33, pp.1359-1360, July 1997

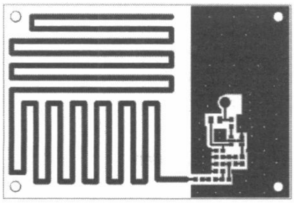

Fig. 1 Meander Line Antenna 315 MH

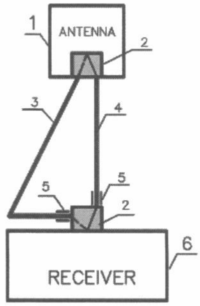

Fig. 2 Diversity Antenna System

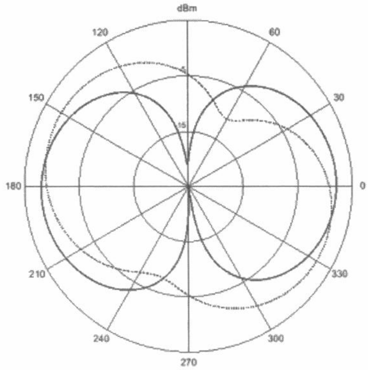

Fig. 3 Simulated Radiation Patterns

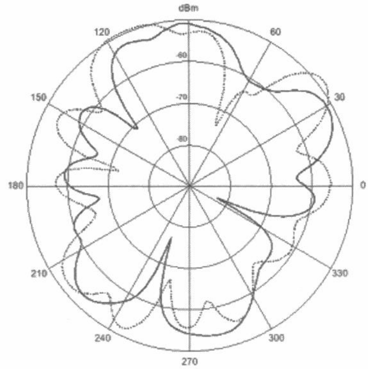

Fig. 4 Measured Radiation Patterns in the Vehicle

—— Cable 3 - - - - Cable 4

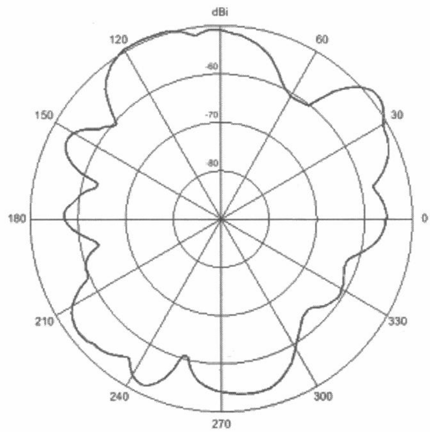

Fig. 5 Diversity Antenna Pattern