On the Polarization Diversity Gain Using the ORIOL Antenna in Fading Environments

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This paper presents a new reconfigurable radiating structure that exploits polarization diversity from a single-element antenna. Simulations on the polarization diversity gain have been carried out for indoor and outdoors cells. The results show that the proposed diversity combining scheme, although simple, it can in fact provide considerable improvements in the selection diversity gain when used together with the compact Octagonal Reconfigurable Isolated Orthogonal Element (ORIOL) antenna.

Introduction

Polarization diversity is a common antenna diversity technique widely used in Single-Input Multiple-Output (SIMO) and Multiple-Input Multiple-Output (MIMO) wireless systems as a technique to mitigate multipath. The potential for improving signal reliability and eventually the capacity has already been proven in [1][2]. Often it is the case in MIMO where neither the transmitter nor the receiver have any knowledge of the channel characteristics and/or their respective positions. Typically, polarization diversity is exploited by using multiple antennas with orthogonal polarizations. In this paper we investigate a reconfigurable structure able to exploit polarization diversity with one single radiating element. The propagation environment has been modelled as a quasi-static channel. It will be shown that the proposed diversity combining scheme, although simple, it can in fact provide considerable improvements in the selection diversity (SD) gain when used together with the reconfigurable and compact ORIOL antenna. In future work, the proposed structure can also be used as a building block for polarization reconfigurable of closely located Multi-Element Antennas (MEA). The Octagonal Reconfigurable Isolated Orthogonal Element (ORIOL) antenna has special interest for its use in low consumption, compact and cheap handheld devices.

Description of the ORIOL antenna

The proposed ORIOL antenna is a 2 port microstrip feed planar radiating structure based on an octagonal patch. Each port is connected through a reconfigurable feeding network to two distinct points in adjacent sides of the octagonal patch, with Micro-Electro-Mechanical Systems (MEMS) switches. Those points are separated by an angular distance of 45° and at the same time the two ports are orthogonal to each other. The ORIOL antenna uses four MEMS switches and it can operate in two different states. Those states are such that the antenna is able to switch between two orthogonal bases of the polarization space, separated by an angular
distance of 45°, that is, allows one to track the polarization at steps of 45°.

Figures 1 and 2 show the configuration of the ORIOL antenna in the first and second state state, respectively. The states of the antenna are controlled by the MEMS switches located in the feeding points of octagonal patch. The operating frequency of the antenna is at 3 GHz. The Scattering parameters coefficients are shown in figure 3. The isolation between ports is approximately 39 dB and the return loss for the operating port is around -13.5 dB. The polarization angles, $\phi_{in}$, where $i$ and $n$ denote the state and port number respectively, are: $\phi_{11} = 90^\circ$, $\phi_{12} = 180^\circ$, $\phi_{21} = 135^\circ$ and $\phi_{22} = 225^\circ$. Figure 4 shows the simulated gain radiation pattern of the antenna at the first state, for the two ports. The cuts correspond to the E-plane. The E-plane for each state and port is the plane at which $\phi = \phi_{in}$. Similar patterns exist on each state. The maximum gain is at $\theta = 90^\circ$ and around 8.6 dBi. The shape and gain of the radiation patterns for the second state and the two other ports are very similar to the one shown and hence are not presented. The co-cross polarization isolation is larger than 18 dB in all cases.

The antenna was simulated using a Finite Element Method (FEM) simulation tool (HFSS 9.0 from Ansoft) on a RO5880 substrate with dielectric constant $\epsilon_r = 2.2$, dissipation factor $\tan \delta = 0.0004$ and thickness $h=1.575$ mm. In the ON state, the series MEMS switches were modelled as a perfect metallic connection with dimensions 1 mm x 0.5 mm, while in the OFF state they were modelled as a perfect air gap. As shown in [3], a series switch operating at 3 GHz can easily provide up to 22 dB isolation with 0.15 dB insertion loss. The final goal is to monolithically integrate and fabricate the MEMS switch in the antenna following the process developed in our group [3].

2-States Polarization Diversity performance

Simulations on the polarization diversity gain have been done for indoor and outdoor fading environments. The signals received are assumed to be plane waves arriving from the horizon. The channel was modelled as quasi-static in such a way that the
proposed diversity scheme tracks the polarization in a faster way that the channel perform changes. Selection diversity has been considered as a combining technique. The decision logic is as simple as follows: in any of the two states and at any time instant, the antenna commutes to the other state when the two ports receive similar power levels of signal. In the new state, one of the two port will receive more signal level than any other port in any other state and hence the selection diversity scheme will always chose the signal with larger signal strength. This schemes does not need any synchronization and the rate at which the antenna changes their states is given by the rate of variation of the channel.

Figure 5 shows the polarization diversity gain achieved by using one ORIOL antenna and the proposed combining scheme, with respect to a dual orthogonally polarized non-reconfigurable antenna polarized in the $x$ and $y$ direction (see figure 1), when the channel is ideally Line-of-Sight (LOS) and for different values of the polarization angle spread. The polarization angle spread, $\Delta \phi$, is characterized as a random variable with uniform distribution over $[\phi_0 - \Delta \phi, \phi_0 - \Delta \phi]$ where $\phi_0$ is the central value of the polarization angle. As $\Delta \phi$ increases, the diversity gain saturates around 1.8 dB. In the best scenario, when $\phi_0 = 45^\circ$ the diversity gain fluctuates from 3 dB for very small angular spreads to 1.8 dB when the angular spread increases. The worst scenario in terms of diversity gain is when $\phi_0 = 0^\circ$ and a small angular spread exists, because in this case the received polarization is always on top of the $x$ axis and both antennas capture the maximum signal power. Figure 6 shows similar quantities for the case of a perfect No-LOS (NLOS) propagation environment, where the signal envelope is rayleigh distributed. Once again, the best case correspond to small angular spreads centered around $\phi_0 = 45^\circ$, producing a diversity gain around 3 dB. This can be explained because the $x - y$ basis of the non-reconfigurable antenna is not appropriate to capture all the power of a signal with a polarization of $45^\circ$, under a SD scheme. As the angular spread increases and approximately for larger values of $90^\circ$ the diversity gain remains constant around 0.85 dB.
Conclusion

A new polarization MEMS reconfigurable structure based on a single radiator has been presented. The simulations results have shown that the proposed diversity combining scheme, although simple, it can in fact provide improvements in the selection diversity gain when used together with the compact ORIOL antenna. Those gains are obtained in a simple fashion and correspond to the polarization matching.

![Figure 5: Polarization diversity gain versus polarization angle spread in the ideal LOS case. \(\phi_0 = 45^\circ\) (solid line), \(\phi_0 = 22.5^\circ\) (dashed line), \(\phi_0 = 0^\circ\) (dotted line)](image1)

![Figure 6: Polarization diversity gain versus polarization angle spread in the ideal NLOS case. \(\phi_0 = 45^\circ\) (solid line), \(\phi_0 = 22.5^\circ\) (dashed line), \(\phi_0 = 0^\circ\) (dotted line)](image2)

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References

