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Cognitive Beamforming for Spectral Coexistence of Satellite and Terrestrial Networks

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The usable radio frequency spectrum is becoming scarce due to increasing demand for bandwidth-hungry services and current static frequency allocation schemes. In this context, cognitive communications is considered a promising solution in order to allow the coexistence of two or more wireless networks in the same spectrum. Existing spectrum sharing techniques mostly consider three signal dimensions i.e., frequency, time and area for sharing the available spectrum between primary and secondary systems. However, due to advancements in smart antennas and beamforming techniques, multiple users can be multiplexed into the same channel at the same time and in the same geographical area. In cognitive communications, angular dimension can be considered as more efficient way of exploiting the space dimension to exploit the underutilized primary spectrum. In this context, beamforming is an widely considered signal processing solution with the advantage of spatial filtering capabilities. Recently, beamforming for spectrum sharing purpose has received important attention in the Cognitive Radio (CR) literature and has been studied for various objectives such as controlling interference, capacity maximization, Signal to Interference plus Noise Ratio (SINR) balancing etc.

In this work, we study transmit and receive beamforming techniques in an underlay cognitive mode for the spectral coexistence of satellite and terrestrial networks considering the satellite link as primary and the terrestrial link as secondary. While considering the coexistence of a GEO satellite link with a terrestrial link, we can explore the special propagation characteristic of the GEO satellite terminals to facilitate the spectrum sharing between these links.

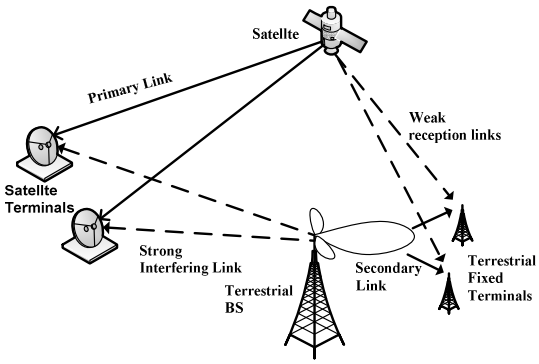

Fig. 1. Transmit beamforming for satellite-terrestrial coexistence

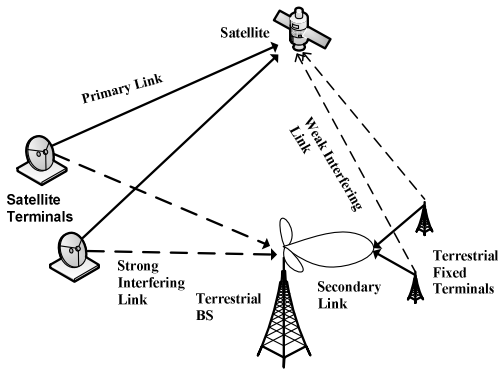

Fig. 2. Receive beamforming for satellite-terrestrial coexistence

Geostationary (GEO) satellites are located in the geosynchronous orbit above the equator and therefore transmit/receive in a northerly direction if we consider the European continent. If we consider the downlink coexistence of the considered link as shown in Fig. 1, the reception range of all the satellite terminals is concentrated in an angular sector. By exploring this prior knowledge at the terrestrial Base Station (BS), we study different transmit beamforming techniques for the considered coexistence scenario in order to maximize the SINR towards the desired terrestrial user and to mitigate the interference towards the primary satellite terminals. Similarly, if we consider the uplink coexistence of the considered link as shown in Fig. 2, the interference received by the terrestrial BS is concentrated in a specific angular sector. In this context, we apply Linear Constrained Minimum Variance (LCMV) and Minimum Variance Distortionless (MVDR) beamformers for our scenario and analyze their performances in terms of the pattern response and output SINR.

In our considered scenario, the direction of arrival (DoA) of the desired user and the range in which interferers are located is known while the exact locations of the interferers are unknown to the beamformer. In the considered receive beamforming scenario [1], simulation results show that performance of LCMV and MVDR beamformers is similar in the desired direction while the performance of the LCMV beamformer is much better in terms of rejecting the interference coming from the interfering sector. Figure 4 shows the SINR versus number of interferers while applying beamformers designed for 18 number of antennas in the array (M) and 17 number of interferers located in the sector of interest. The result shows that the MVDR beamformer is suitable for a large number of interferers and the LCMV for a small number of interferers.

For the transmit beamforming problem [2], we study different techniques such as Scaled LCMV, modified LCMV and Secondary User (SU) rate maximization approach. We also consider the problem of mitigating interference picked by the backlobe of the satellite terminals located beyond the sector of interest. Figure 3 presents the beampatterns of the standard LCMV, modified LCMV and the SU rate maximization approach. Furthermore, SINR of the modified and standard LCMV techniques for the considered scenario has been compared and it has been observed that the modified LCMV is capable of mitigating interference towards the desired sector of interest as well as towards the satellite terminal located beyond the sector of interest. Moreover, the effects of Primary User (PU) interference threshold, PU distance, the angular deviation from the desired sector of interest have been studied on the transmit power to the desired user as well as on the SU rate with the help of the SU rate maximization approach. It has been noted that the worst case SU rate is dependent on the PU distance, the permissible interference threshold at the PU terminals as well as the angular deviation of the desired user from the considered angular sector. It can be concluded that the choice of a technique in the considered scenario depends on the desired performance level as well as the flexibility of applying different constraints to the optimization problem.

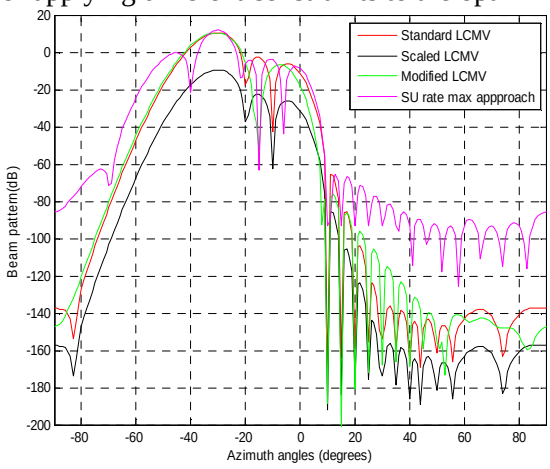

Fig. 3. Beampatterns of different transmit beamforming techniques.

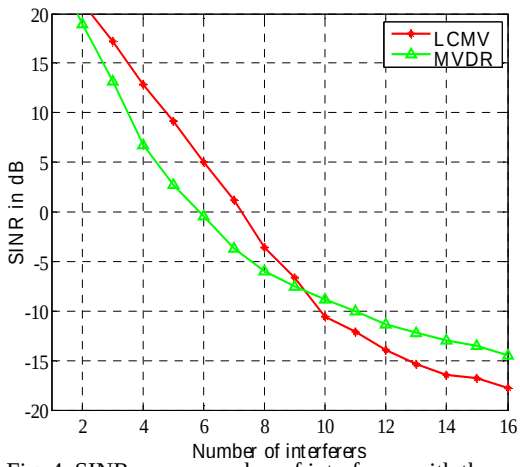

Fig. 4. SINR versus number of interferers with the receive beamformer designed for M=18, K=17.

References:

1. S. K. Sharma, S. Chatzinotas, and B. Ottersten, “Spatial Filtering for Underlay Cogniitve SatComs”, Int. Conf. on Personal Satellite Services, Toulouse, France, June, 2013.

2. S. K. Sharma, S. Chatzintoas, and B. Ottersten, “Transmit Beamforming for Spectral Coexistence of Satellite and Terrestrial Networks”, Washington, USA, July, 2013.