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Multi-Antenna Systems in DVB-T2/SFN Networks

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ABSTRACT: *TV broadcasters are facing day by day with the challenge of providing new services such as 3D television, ultrahigh definition television (UHDTV) and DVB-T/H, which need higher capacity systems. Nowadays attention is focus on using multi-antenna systems in emission and reception, which is considered as a technique which increase data rate and improve the reception quality compared to traditional systems with single antennas in emission and reception SISO (Single Input Single Output). The Digital Video Broadcasting (DVB) project is studying the application of MIMO (Multi-input Multi-output) technique in television broadcasting systems. But adding antennas to reception side requires a significant investment in infrastructure. For this reason, studies are being carried out to assess whether the improvement in system performance justifies it. Actually, the second generation of digital video broadcasting (DVB-T2) is using MISO (Multi-input Single-output) mode based on the Alamouti code, which uses only one antenna on the reception side. The purpose of this article is to identify the advantages of MISO technique on a SFN DVB-T2 network.*

Keywords: *Digital Video Broadcasting, MIMO, MISO, Alamouti Code, diversity*

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I. INTRODUCTION

DVB-T2 uses SFN networks because comparing with MFN networks the field strength is more homogeneously distributed due to spatial diversity which result in a reduced transmission power for the same signal quality. Nevertheless, there are cases in SFN networks with deep degradation of signal performance caused by the self-interferences. Multi-antenna technology is being considered as a solution.

By using spatial diversity, multi-antenna systems improve the quality of transmission through signaling for the fading in transmission channels. Furthermore, through using spatial multiplexing the bit rate can be improved without increasing the bandwidth or the transmit power.

MIMO greatly increases the speed and reliability of the transmission system compared to traditional broadcasting systems SISO with only one antenna in transmission and reception side. However, using MIMO mode means an important investment in infrastructure because it is necessary to add antennas, not only in transmission side, but as well as in every receiving device. This is a strong reason why the use of MIMO techniques in DVB-T2 is foreseen to be implemented when it is concluded that improvement in system performance justifies it. Meanwhile MISO technology partially uses the advantages of MIMO technique. The benefit of the DVB-T2 MISO versus MIMO technique is that it can be implemented with a smaller additional system complexity. The extra complexity introduced by the use of this technique is negligible on the recipient side.

II. MISO SYSTEMSIN SFN DVB-T2 NETWORKS

While the DVB-T standard does not implement any multi-antenna technology, the second terrestrial digital video broadcasting (DVB-T2) has already integrated the MISO technique to improve the SFN operation through reducing harmful interferences.

In traditional SISO SFNs all signals transmitted by all transmitters are strictly synchronous in terms of frequency, content, and time. As result, in case at the receiver occur an overlay of identical signals, which differ only in power, an harmful interference is caused, especially in cases the power differences are small. Using MISO mode in DVB-T2 SFNs is a solution for reducing this phenomena.

However, there are some limitations in using MISO technique that limit the probable choice of the guard interval and pilot model. The number of transmitters, the relative delay, and the power imbalance between the receiving paths have an impact on the final form of the coverage area.

The principle of MISO technology is the transmission of two slightly different versions of the wanted signal from a number of different transmitters at the same time. By transmitting multiple wanted signals, the network is able to incorporate the advantages of transmit diversity in order to improve the system’s SNR and subsequently the network’s coverage or data rate [5]

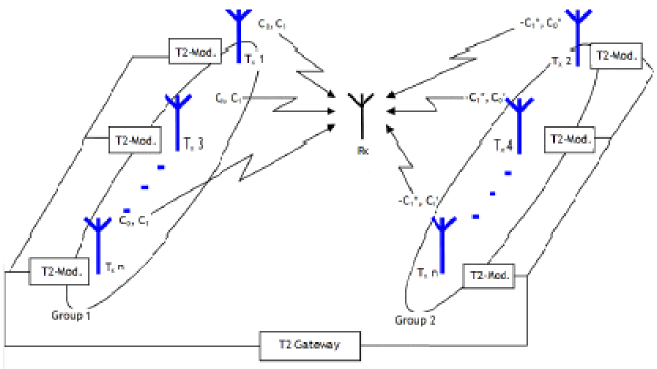

Fig. 1. MISO in DVB-T2 SFN network

III. MISO TECHNIQUE BASED ON ALAMOUTI CODE

MISO is a diversified broadcasting technique based on space-time coding that provides higher resistance to signal degradation.DVB-T2 standard provides MISO technology using a modified Alamouti matrix.

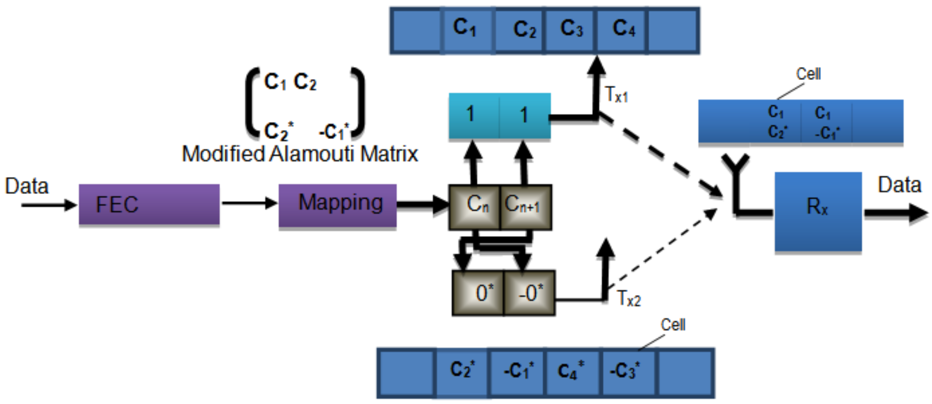

Fig. 2. Alamouti MISO Matrix [2]

A typical case of using MISO in Digital Video Broadcasting is the use of Alamouti coding based on two antennas in transmission side and one antenna in the receiver side. The concept of this scheme is to transmit in the first antenna the original signal and from the second antenna a modified version, where symbols are exchanged in pairs (in the frequency domain) and conjugate, in addition one of them is inverted. This result in a reception signals with higher SNR. To increase efficiency of MISO mode, it is recommended that the two antennas in transmission side to be installed at different location.

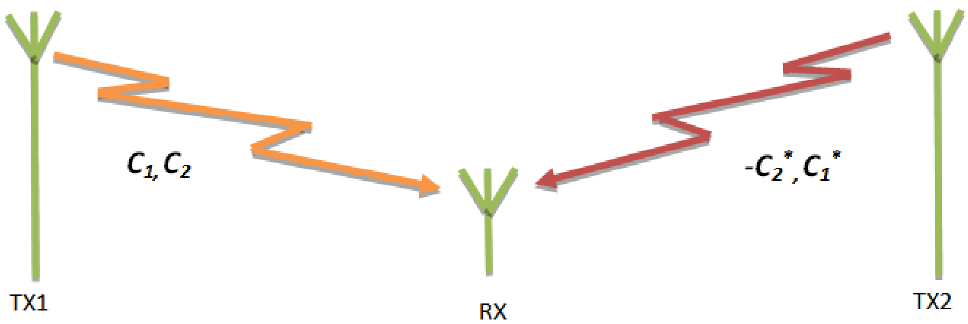

Fig.3.MISO based Alamouti coding

Both antennas (Tx1 and Tx2) transmit respectively the original signal and the modified signal from different locations. While Tx1 transmits pair of data cells S0, S1, Tx2 transmits -S1*, S0*. This prevents possibility of 'fading' caused by two transmitters at receiver. Damages that can be caused in each signal as result of different paths could not be the same. Providing the signaling concerning the status of each channel, both signals can be combined in such a way as to receive in reception side a less degraded signal with C / I ratio of greater value compared to the Single Input Single Output scheme. Moreover using MISO technique, the antennas transmit only half the power required in SISO.

Taking into consideration the structure of the DVB-T2 system using MISO scheme the block diagram of transmitter and receiver is as shown in Figure 2. After encoded by a BCH and LDPC encoder, the encoded bits are interleaved using rotated QAM constellations. The imaginary part of any complex symbol is cyclically delayed before a second phase of interleaving and OFDM modulation. Based in the distributed case of Alamuti, the signal transmitted from the second antenna is coded after the modified alamit scheme before OFDM modulation.

In the receiver, the signal after demodulated using an FFT is applied to a MISO detector, which uses channel coefficients obtained from an ideal channel estimation to evaluate the complex symbols transmitted and calculate an equal channel coefficient for each symbol. After de-interleaving, the logarithm probability ratios is calculated using equivalent channel coefficients since the imaginary and real parts of each symbol are not transmitted on the same subfolder thus they are not affected in the same way by the channel. After a second de-interleaving stage LDPC and BCH decoder are used.

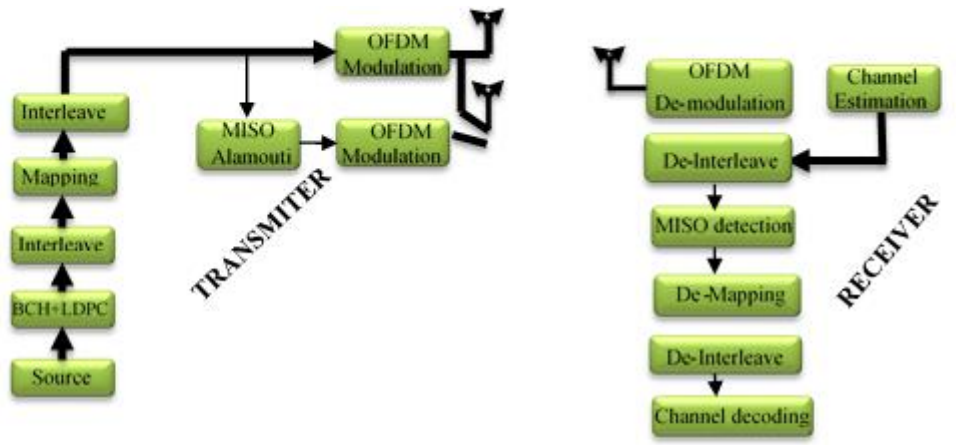

Fig. 4. Block diagram of the transmitter and receiver in MISO [3]

Based on above, the formula for calculating the complex symbol $\alpha_{p,l,m}$ transmitted from antenna m is calculated as follows [3]:

$$\alpha_{p,l,2} = \begin{cases} -\alpha^*_{p+1,l,1} \text{ for } p \in \{0,2,\ldots,N_{DATA}-2\} \\ \alpha^*_{p+1,l,1} \text{ for } p \in \{0,2,\ldots,N_{DATA}-1\} \end{cases} \quad (1)$$

where "p" is the data carried in the subcarrier of the OFDM symbol "l" and N_{DATA} is the number of subcarriers that carry data.

The basic expression of the signal to be transmitted by the "m" antenna for the OFDM symbol "l" is:

$$s_{l,m}(t) = \frac{5}{\sqrt{27 \times K_{TOTAL}}} \sum_{K_{MIN}}^{K_{MAX}} c_{k,l,m} \times \psi_{k,l}(t) \quad (2)$$

where:

$$\psi_{k,l}(t) = \begin{cases} e^{j2\pi f_k (t - t_0(l))} \text{for} t_0 - T_{GI} \le t \le t_0(l) + T_U \\ 0 \quad \text{otherwise} \end{cases} \quad (3)$$

K_{TOTAL} is the number of active subscribers, K_{MIN} and K_{MAX} are the indexes of the first and the last active subcarriers, f_k is the frequency of k-th active subcarrier, t_0 (l) is the commencement time of the useful part of the OFDM, T_U is the duration of the useful part of an OFDM symbol, T_{GI} is the duration of the guard interval, and $c_{k,l,m}$ is the value of the complex modulation of k-th the active subcarrier, transmitted by the m-th antenna along the OFDM symbol "I" [3].

IV. MISO PARAMETERS INFLUENCING SFN DESIGN

The same as in traditional SISO SFN, MISO mode parameters affecting network operation are: relative delay (Δt), power imbalance (PI), propagation channel, pilot pattern, modulation and code rate.

The relative delay is the difference at the time the signals arrive to the receiver by the different SFN transmitters. In case of Figure 2, the relative delay is the difference between the time of arrival of the signals transmitted by Tx1 and Tx2 transmitters. Meanwhile the power imbalance (PI) is the difference of power level of the signals arrived in the receiver transmitted by different transmitters.

The influence of the relative delay in MISO SFN can be evaluated after the impact of the channel propagation conditions and the power imbalance are defined. The influence of relative delay is negligible in case of short delays. The measured relative delays ranged from a few μs to maximum measured delays close to 40 μs is being considering [4].

Searches has proven that MISO performance is improved when the power imbalance from different transmitters of the SFN network is small. MISO provide positive gains for power imbalance values lower than 6 dB, whereas imbalance values higher than 6 dB present certain degradation [4].When the power imbalances is increased the MISO influences is decreased till it disappears totally in huge value of PI. It has also been proven that degradation can occur under difficult channel conditions such as Rayleigh channels.

The synchronization, the treatment of inter-symbol interference which affect the practical performance inside the guard interval are key parameters which need to be taken into consideration in planning SFNs in both cases of SISO and MISO mode. The receiver performance dependent on the positioning of the FFT demodulation window relative to the received signals present in a SFN multipath environment. The practical degradation beyond and within the guard interval will be different depending on the equalization and synchronization strategies adopted. The performance degradation out the guard interval should be analyzed as well when planningDVB-T2.The role of the pilot pattern should also be addressed.

Regarding the combinations of guard interval and scattered pilot pattern, in MISO mode exist the same restriction as are shown in Figure 4.

FFT size	**Guard Interval**						
	1/128	**1/32**	**1/16**	**19/256**	**1/8**	**19/128**	**1/4**
32k	**PP8 PP4 PP6**	**PP8 PP4**	**PP2 PP8**	**PP2 PP8**	**n/a**	**n/a**	**n/a**
16k	**PP8 PP4 PP5**	**PP8 PP4 PP5**	**PP3 PP8**	**PP3 PP8**	**PP1 PP8**	**PP1 PP8**	**n/a**
8k	**PP8 PP4 PP5**	**PP8 PP4 PP5**	**PP3 PP8**	**PP3 PP8**	**PP1 PP8**	**PP1 PP8**	**n/a**
4k, 2k	**n/a**	**PP4 PP5**	**PP3**	**n/a**	**PP1**	**n/a**	**n/a**
1k	**n/a**	**n/a**	**PP3**	**n/a**	**PP1**	**n/a**	**n/a**

Fig. 4. Scattered pilot pattern for each allowed combination of FFT size and guard interval in MISO mode [5]

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Another key factor that influences the SFN network operation based in MISO mode is the propagation channel profile. In broadcast system there are three channel classifications which represent an important factor in design a broadcast network: Gaussian, Ricean or Rayleigh. In a SFN the correct definition of the channel profile is a key point to be taken into consideration [4]. Should be noted that the channel estimation at the receiver in MISO mode differ from SISO mode in terms of resolution for both synchronization and equalization stages. In DVB-T2 2x1 MISO network, the pilots are composed of two types: pilots transmitted with the same phase from each one of the two transmitter sets and the other pilots that are inverted only in one of the transmitter groups of the 2x1 MISO network. This results is a response which is the sum of the individual channel responses. As a consequence, the practical resolution available decreases in MISO compared to the SISO case.

V. CONCLUDING REMARKS

One of the new features offered by DVB-T2 system is the ability to implement MISO transmission based in a modified Alamouti encoding. MISO technique allows improvements in the received SNR and also ensures that the ripples and notches do not occur in a SFN network. This result from the fact that in MISO mode the transmitted signals are no identical as in SISO SFNs and the signals combination make it possible to avoid degradation. A DVB-T2 MISO SFN network should be considered as a specific form of an SFN, where the synchronization in term of time, frequency and content is an important aspect for correct operation of the system.

A lot of searches has shown that the MISO gain is limited mainly in the region in between the two transmitters where their coverage overlaps. The MISO gain is significant provided when the power imbalance from different transmitters of the network is small. Finally, analyses in the influence of the pilot pattern and relative delay in both SISO and MISO have resulted that the performance in MISO can be reasonably kept for a wide range of delays over the guard interval.

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