I/Q mismatch compensation based on equivalent adaptive separation via independence

A common way to recover a signal present in a mixture is blind source separation based on independent component analysis (ICA). A special case of ICA is equivalent adaptive separation via independence (EASI). As is stated in its name EASI algorithms attempt to maximize the independence of the separated sources. Many ICA/EASI variants adapted for complex valued source signals signal are present in the literature. Few papers underlines a possible short come of ICA based compensation, this being a phase ambiguity left in the separated sources. This effect is very well explained in reference [1].

The original EASI algorithm is presented in [2]. One of the first where EASI is specially (kimondottan az EASI-ra kielezve) applied for I/Q imbalance compensation is in [3]. Reference [3] claims that the I/Q compensation is not effected by arbitrary phase ambiguity, but a pi/2 ambiguity is left in the separation process.

Signal model

The ICA/EASI based BSS methods assumes the existence of n unknown independent sources s and m linear mixtures that can be observed. For simplicity we consider n=m, thus the relation between sources and mixtures can be written as:

 (1)

where **x***k* is the observation vector in the *kth* moment *[x1(k), x2(k), ... xn(k)]*, **s***k* is the is either real or complex valued source vector in the *kth* moment *[s1(k), s2(k), ... sn(k)]* and **A** is an *n* x *n* mixing matrix. Source recovery from the observation is done by a separation matrix **B**:

 (2)

Perfect separation is achievable if **BA**=**I**, where I is the *nth* order identity matrix. ICA/EASI algorithms gives a tool to estimate the separation matrix **B**, through adaptive filtering. The separation matrix is obtained by:

 (3)

Where *λ* is a scalar valued learning coefficient, **g(yk)***=[g(y1(k)), g(y2(k)), ... g(yn(k))]T* and g(x): C->C is a nonlinear function. An important extension of the ICA/EASI algorithm is the normalization of the update process:

 (4)

I/Q imbalance signal model

The widely accepted I/Q imbalance signal model follows the next matrix multiplication [4]:

 (5)

where k1 and k2 are the I/Q mismatch parameters, \* stands for the complex conjugation, the complex valued source signals are s1, the desired signal, and s2, the image signal. Reference [4] considers the source signals to be normalized, but since the normalized ICA/EASI is at hand this signal preprocessing step is not important.

Reference [3] prefers the usage of real valued source signals, mixing matrix and observations. Thus the model in equation (5) is equivalent to:

 (6)

Where R and I in the indexes stand for real and imaginary part. Recovery of signals respecting the mixing in (6) is possible only if the separation matrix has the form specified in (7):

 (7)

The ICA/EASI update does not result in a restricted separation matrix. A solution proposed in reference [3] is the introduction of a constrained update of the separation matrix. The unconstrained separation matrix in moment k is computed with (4), resulting in **Bu**. Then the constrained separation matrix is computed with:

 (8)

Constraints can be applied to the complex valued signal model in (5). For correct I/Q imbalance recovery the complex valued separation matrix should have the structure:

 (9).

Following the idea form [3] the constrained update for the complex valued separation matrix results:

 (10).

Conclusion

ICA/EASI based BSS has good performance when the source signals has a well a defined alphabet, for example digitally modulated (QAM, PSK) signals. Reference [4] provides a study of ICA/EASI based BSS in the presence of symbol timing errors (an issue specific to digital demodulators).

ICA/EASI based algorithms will not adapt when the source signals has gaussian distribution, thus they are hardly usable for modern multicarrier modulation systems.

References

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