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Nonlinear Interference Suppressor for LTE in Multimode Environment: A Survey

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Abstract: -*InMultimode transceivers, the transmitter of one communication system may create a large interference in the receiver of other standard.For linear suppression of this large interferer, receiver front-end should have a large linear dynamic range, resulting in additional power consumption. As battery life is a key issue for small handheld devices, high power efficiency is the main requirement. Therefore, Nonlinear Interference Suppressor asa closed- loop tuning method is employed for nonlinear suppressionof local baseband interference.The obtained symbol error rate is observed for these systems using MATLAB.It is found that Nonlinear Interference Suppressor can suppress strong interferer with a SER performance close to that of an exactly linear receiver, with high power efficient transceiver implementations.*
Keywords- *Adaptive signal, Closed-loop method, Multimode Transceiver, Nonlinear Interference Suppressor,Nonlinear circuit .*

I. INTRODUCTION

In recent years, handheld devices have been supporting different wireless standards such as WLAN, GSM, UMTS,WiMAX,LTE, etc.To implement these communication standards in a single device, a combination of several transceivers is required, which is called a Multimode transceiver.Therefore, their coexistence hasbecome an important issue.This coexistence may yield to large interference in Multimode environment [1]. For linear filtering of this local interference, the receiver should have a high linear dynamic range to process such a large interference, requiring excessive power consumption[2].When the combined desired &interference signal passes through nonlinear front end , nonlinear distortion products are generated, including harmonic, intermodulation and cross-modulation products [3].

Due to limited battery life, powerefficiency of mobile telecommunication systems is a key aspect to consider.A Nonlinear Interference Suppressor (NIS)isstudied in this paper to address the problem defined above. The NIS is a closed-loop tuning method that employs the locally available interference as side information[4].

1.1 LTE (Long Term Evolution)

LTE is a multi-carrier modulation scheme specified by 3GPP consortium. The objective is to develop a framework for the evolution of 3GPP radio access technology towards a high data rate, low latency & a packet-optimized technology.Amongthe available technologies, LTE is the most demanding in terms of flexibility &reconfigurability, specially concerning the transceiver architecture & the front end.

LTE supports both frequency & time division duplexing (FDD/TDD). It employs OFDMA(Orthogonal Frequency Division Multiple Access) in downlink direction while SC-FDMA (Single Carrier Frequency Division Multiple Access) for uplink. OFDMA is a special multi-carrier modulation scheme employs densely spaced orthogonal sub-carriers & overlapping spectrums.SC-FDMA provides lower Peak-to Average-Power-Ratio(PAPR),hence high power efficiency.Three modulation schemes supported by LTE are : QPSK,16-QAM and 64-QAM.

II. RECEIVER WITH NONLINEAR INTERFERENCE SUPPRESSOR

The signal transmitted by the local transmitter(LTX) induces interference at the local receiver(LRX).This interference can be several orders of magnitude larger than the received desired signal at the input of LRX.However, the interference not overlapped with the desired signal(i.e. out-of-band interference)can

be completely suppressed by band pass filtering[5].If the receiver front end was exactly linear, linear filtering could be done after the down conversion of the received signal.
But presence of interference beyond this range leads to excessive loss of front end gainand hence leads to loss of sensitivity of the LRX.Increasing receiver dynamic range to handle this strong interference requires additional power consumption, which is not acceptable for small handheld devices.
An alternative method to linear filtering is to suppress the interference by passing received signal through a memoryless nonlinear circuit[6].
This Nonlinear Interference Suppressor (NIS) is a combination of the linear amplifier (with a gain of -c) and a limiter with an adaptable limiting amplitude, l(t) as shown in Fig.1.

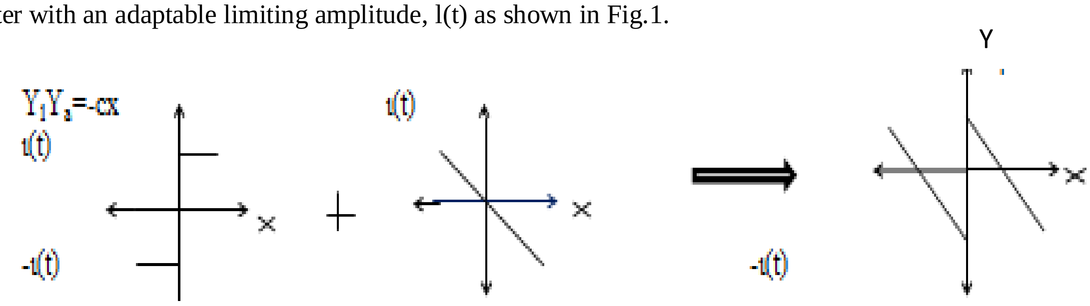

Fig.1. NIS Input-Output Characteristics

The amplifier has the same gain for both weak and strong signal while hard limiter gain for weak signal is smaller than the gain of the strong signal[2].For an interference with an envelope $A_i(t)$ at the NIS input,theoptimal adaptation signal is:

$$l(t) = (\pi/4)c\, A_i(t) \qquad \text{------ (1)}$$

where c is the amplifier gain.

To calculate adaptation signal, $A_i(t)$ must be estimated.InMultimode transceiver a baseband version of transmitting interference is locally available.By taking a baseband model as in [5] of the coupling path of the interference from transmitted baseband interference to the received interference in the NIS input, A_i (t) can be estimated. The coupling path is affected by environmental changes such as the presence of the user's hand.
For a constant-envelope interference,l(t) must be slowly adapted to track the changes in the power of the received interference[6].For a varying - envelope interference, l(t) must be adapted proportional to the envelope of the received interference.Hence, the path model must be continuously adapted during the transceiver's operation.

III. SYSTEM MODEL

In this section we describe the model of the Multimode transceiver including the NIS[4].This model will be used to analyze the effect of the NIS on the receiver operation & estimation of the adaptation signal.

3.1 Combinedsignal received by the local RX -This Multimode transceiver model includes the LRX, LTX and a remote transmitter, as shown in Fig.2 . At the LRX, desired signal transmitted by the remote transmitter is received, combined with a part of transmitted interference coupled from the LTX.This combined signal is passed through the band pass filter (BPF1).

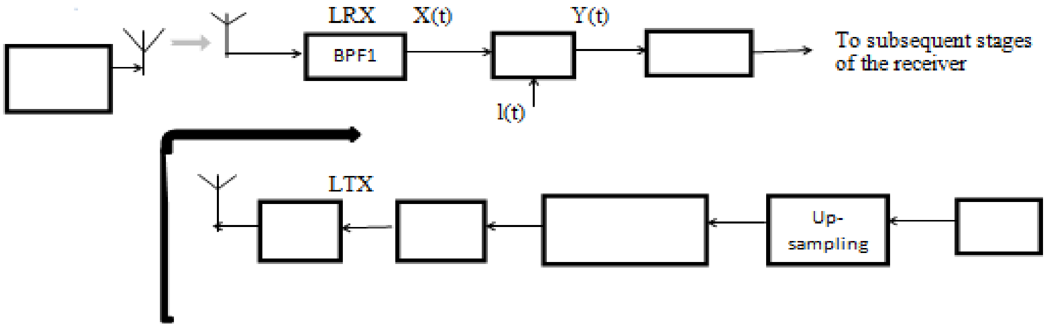

Fig.2. Multimode Transceiver with NIS

The desired signal is passed unchanged through BPF1 while the interference is attenuated by it.

After BPF1, the NIS input x(t) can be given as a combination of desired signal $x_d(t)$ and an interference $x_i(t)$:
$X(t) = X_d(t) + X_i(t)$
$= A_d(t)\cos\{2\pi f_d t + \Theta_d(t)\} + A_i(t)\cos\{2\pi f_i t + \Theta_i(t)\}$ ------ (2)
where, A_d,A_i,f_d,f_i,Θ_d,andΘ_i are the amplitudes , frequencies and phase- shifts of desired signal and interference after BPF1 respectively[2].The average powers of desired signal and interference are as in equation 3:

$P_d = E(A_d^2/2R)$ and $P_i = E(A_i^2/2R)$ -------- (3)

where, R= 50 Ω is the reference impedance and E() denotes the statistical average.Here the external additive noise which is the combination of the circuit noise & channel noise is neglected.
After BPF1, x(t) is passed through the NIS,which is adapted by an adaptation signal,l(t).Due to strong non-linear characteristics of the NIS, high frequency harmonics(at around $3f_i$,$5f_i$,..etc)are also generated at the NIS output. The power of the harmonics after the NIS is of the order of magnitude smaller than $P_i$but still several orders of magnitude larger than P_d. Hence the harmonics must be filtered immediately after the NIS to prevent generation of nonlinear distortion in the subsequent blocks of the receiver. As these harmonics are far from f_d, they can be filtered out with a simple band pass filter (BPF2).

3.2 Adaptation Signal
Adaptation signal l(t) is obtained in terms of local baseband interference on the basis of TX-RX path model.The baseband complex-valued interference i[p] is converted to an analog signal and is transmitted by the LTX after up-conversion and amplification.A part of this transmitted interference is coupled to LRX , passed through BPF1 and is applied to the NIS input.We assume that TX-RX path can be modeled as a linear time-invariant systemwith an impulse-response h[n].This estimate of h[n] can be used to estimate $A_i(t)$[1].

3.3 Signal at NIS output
NIS output is the combination of limiter & amplifier:

$Y(t) = A_{d,y}(t)\cos\{2\pi f_d t + \Theta_d(t)\}$
$+ A_{i,y}(t)\cos\{2\pi f_i t + \Theta_i(t)\}$
$+ A_{IM}(t)\cos\{2\pi(2f_i - f_d)t + 2\Theta_i(t) - \Theta_d(t)\}$------ (4)

whereA_{dy}, A_{iy}, A_{IM} are the envelopes of desired signal, interference &intermodulation component at the NIS output, respectively.

IV. GENERAL CONSIDERED MULTIMODE CONFIGURATIONS

General system configuration is given in Fig. 3.

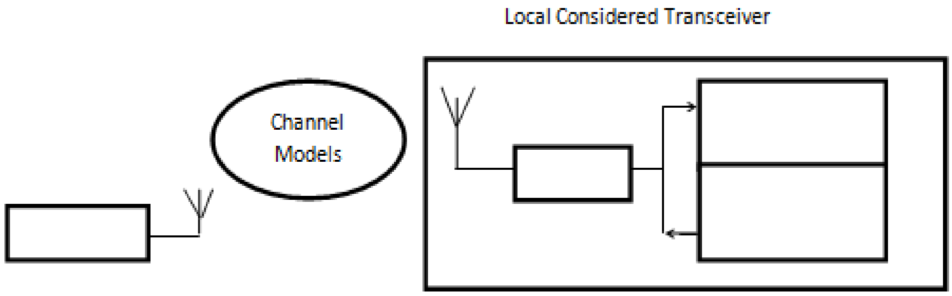

Fig.3. General System Configuration

The local transceiver is receiving a LTE signal while transmitting a mobile WiMAX signal. So, at the receiver, the LTE signal is the desired signal and the mobile WiMAX signal is the interferer [1].Simulation results for a different multimode scenario of a WLAN LRX with a WiMAX LTX are presented in [2].Two different channel models can be considered : the AWGN channel and the Pedestrian A channel.

V. SIMULATION RESULTS OBSERVED

In [1], the LTE reception band selected is from 2620 to 2690 MHz.While the mobile WiMAX band is 2300 to 2400 MHz.In simulation configuration, a SIR of -60 dB has been considered with a bandwidth of 10 MHz & a frequency spacing of 50 MHz.In [2] a multimode scenario of a WLAN LRX with a WiMAX LTX are presented.The surface acoustic wave (SAW) filter suppresses the WiMAX interferer by 10 dB.The NIS is mainly determined by the probability distribution function of the envelopes & average powers of interference & desired signal.In [4] experimental results for the application of NIS in a practical transceiver are presented.A GMSK signal is taken interference and a QPSK signal is used as the desired signal.A 43dB improvement in SIR is observed in the NIS output spectrum.

Power consumption of NIS circuit reaches to 35 mW. In [5] constant-envelope modulation and OFDM modulation is considered for WiMAX interferer with OFDM modulation for WLAN desired signal, with achieved symbol error rate of 10^{-3}.

VI. CONCLUSION

MATLAB simulation results show that the NIS can strongly suppress the interference with symbol error rate performance close to that of a linear receiver. For sufficient suppression of interference, accuracy of adaptation signal is requiredwhich is achieved by a closed-loop method based on an adaptive model of the transmit-receive pathof the interference.Despite the advantages such as low power consumption & fully integrated solution provided by NIS, some drawbacks are also presented , which are Harmonic generation due to strong nonlinear effects in the NIS and Spectral mirroring effects.Adaptive NIS is much more power efficient for varying-envelope interferences in multimode transceivers to provide interference suppression normally much smaller than the desired signal at the NIS output.

These results permit to identify perspective directions for the better multi-standard system performance and the implementation of high energy efficient transceivers.

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