Nonlinear Interference Suppressor for LTE Receiver in Multimode Environment

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Abstract—In Multimode 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 is employed for nonlinear suppression of 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—Interference Suppressor, Multimode Transceiver, 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 has become 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]. Due to limited battery life, power efficiency of mobile telecommunication systems is a key aspect to consider. Interference cancellation may also be employed [3]–[5], but it requires accurate and adaptive generation of transmitted local interference which is highly complex process and also requires large power consumption [6]–[8]. An alternative approach to linear filtering and interference cancellation is to pass the received signal through a nonlinear circuit. A Nonlinear Interference Suppressor (NIS) is considered 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 [9], [10].

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 bandpass 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 gain and 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, \(I(t)\) as shown in Fig. 1.

![Fig. 1 NIS Input-Output Characteristic](http://www.ijettjournal.org)

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, the optimal adaptation signal is:

\[
l(t) = (\pi/4)c A_i(t)
\]

(1)

where \( c \) is the amplifier gain.

To calculate adaptation signal, \( A_i(t) \) must be estimated. In Multimode transceiver a baseband version of transmitting interference is locally available. By taking a baseband model as in [7] 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 also affected by environmental changes such as the presence of the user’s hand.

### III. SYSTEM MODEL

In this section we describe the model of the Multimode transceiver including the NIS[4]. This model as shown in Fig.2 will be used to analyze the effect of the NIS on the receiver operation.

**A. Combined Signal Received by the Local RX:** This section shows Multimode transceiver model, including the LRX, LTX and a remote transmitter. 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](image)

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 \( A_d, A_i, f_d, f_i, \Theta_d, \Theta_i \) 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 (3).

\[
P_d = E(A_d^2/2R) \quad P_i = E(A_i^2/2R)
\]

(3)

Where, \( R = 50 \Omega \) is the reference impedance and \( E(\cdot) \) 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 \( 3f_i, 5f_i, \ldots \) etc.) are also generated at the NIS output. The power of the harmonics after the NIS is 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. Asthe harmonics are far from \( f_d \), they can be filtered out with a simple bandpass filter (BPF2).

**B. NIS Transistor Circuit:** Transistors M1-M4 make up a linear transconductor (common-gate configuration). The output current of this transconductor is roughly half the input current, and therefore it is considered quite linear [11]. Next, transistors M5 and M6 act as switches, steering current \( I_{clip} \) through either the left or right LC tank. Because these transistors are in common-source configuration, the M5-M6 structure behaves with opposite polarity with respect to the linear transconductor. This leads to a clamping behavior, with the required polarity. The output currents of both parts are combined to create the desired transfer function.

The adaptivity is made by current mirror M7-M8, which enables external control over \( I_{clip} \). The principle of NIS leads to the creation of several higher order harmonics. The circuit is loaded with an LC tank to suppress them, assuring high impedance around the fundamental frequency, while shorting the higher harmonics.

Now, in case \( I_{env} \) is set such that the large signal is suppressed, the circuit behaves in NIS mode. When there is no need for suppressing large signals, \( I_{env} \) can be set to zero. Then, clipper circuit is not activated, giving in classical amplifier behavior (only M1-M4 are active).
C. Signal at NIS Output:
NIS output is the combination of limiter & amplifier.

\[ Y(t) = A_{d}(t) \cos\{2 \pi f_{d} t + \Theta_{d}(t)\} \]
\[ + A_{i}(t) \cos\{2 \pi f_{i} t + \Theta_{i}(t)\} \]
\[ + A_{IM}(t) \cos\{2 \pi (2 f_{i} - f_{d}) t + 2 \Theta_{i}(t) - \Theta_{d}(t)\} \]

---

where \( A_{d}, A_{i}, A_{IM} \) are the envelopes of desired signal, interference & intermodulation component at the NIS output, respectively.

IV. GENERAL CONSIDERED MULTIMODE CONFIGURATION

General system configuration is given in Fig. 3. The local transceiver is receiving an 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 [12] under the AWGN channel condition.

V. SIMULATION RESULTS

BER and SER obtained with AWGN channel model are presented in Fig.5 & Fig.6.

These BER & SER are calculated for 16-QAM with different SNR values. The interference and desired signals have been simulated with the same channel bandwidth of 10 MHz and a power gap of 60 dB has been considered between both signals.

Table.1 Obtained Simulation Results

<table>
<thead>
<tr>
<th>Modulation</th>
<th>SNR (Eb/No)</th>
<th>SER after NIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK</td>
<td>0</td>
<td>0.12</td>
</tr>
<tr>
<td>QPSK</td>
<td>10</td>
<td>0.04</td>
</tr>
<tr>
<td>16-QAM</td>
<td>0</td>
<td>0.71</td>
</tr>
<tr>
<td>16-QAM</td>
<td>10</td>
<td>0.32</td>
</tr>
<tr>
<td>64-QAM</td>
<td>0</td>
<td>0.51</td>
</tr>
<tr>
<td>64-QAM</td>
<td>10</td>
<td>0.26</td>
</tr>
</tbody>
</table>

The obtained simulation results in the multimode transceiver in tab.1 clearly demonstrate that the NIS can strongly suppress the interferer while a symbol
error rate performance close to that of an exactly linear receiver is achieved.

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.

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

REFERENCES