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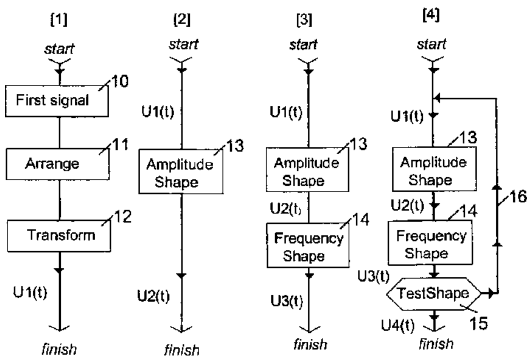
(54)【発明の名称】通信システム内または通信システム上で使用するための規定の品質基準を有する信号を生成するための方法及び装置

(57)【要約】
通信システムと使用するための所定の品質基準を有する信号、このような信号を生成するための方法及びシステム、このような信号を使用して通信システムの動作を試験する方法、及びこのような方法を作動させるために装置される（電気）通信システムが開示される。所定の品質を有する該信号を生成するための該方法：－それぞれがスペクトル振幅特性及び位相特性を有する複数の周波数成分を備える第１信号（１０）を表現するステップと、－そのスペクトル振幅特性を配列する（１１）ことによって該表現された信号を処理するステップと、－該所定の品質基準に従ってそのスペクトル振幅特性を配列する（１１）ことによって、該表現された信号を処理するステップ。



【特許請求の範囲】
【請求項１】
好ましくは通信システム内、または通信システム上で使用するための、少なくとも１つの所定の品質基準を有する信号を配列する方法であって、
－それぞれがスペクトル振幅特性及び位相特性を有する、複数の周波数成分を備える第１信号を表現するステップと、
－該所定の品質基準または各所定の品質基準に従って前記スペクトル振幅特性を配列し、無作為位相特性を配列することによって前記表現される第１信号を処理するステップと、
を備える前記方法。
【請求項２】
前記第１信号が、各周波数成分のスペクトル振幅及び位相を指定する数の第１集合によって表現される、請求項１に記載の方法。
【請求項３】
前記第１信号が、実数部及び虚数部分を有する複素数の第２集合により表現され、前記部分が組み合わされて各周波数成分のスペクトル振幅及び位相を指定する、請求項１に記載の方法。
【請求項４】
前記第１信号が、それぞれが該時間領域内の前記第１信号の振幅を指定する数の第３集合により表現される、請求項１に記載の方法。
【請求項５】
各周波数成分のスペクトル振幅及び位相を指定する数の第４集合によって前記第１信号を表現するために、該時間領域から該周波数領域に前記数の第３集合を変換するステップをさらに備える、請求項４に記載の方法。
【請求項６】
実数部及び虚数部分を有する複素数の第５集合によって前記第１信号を表現するために該時間領域から該周波数領域に前記数の第３集合を変換するステップをさらに備え、前記部分が組み合わされて各周波数成分のスペクトル振幅及び位相を指定する、請求項４に記載の方法。
【請求項７】
該所定の品質基準または各所定の品質基準に対するさらに近い一致を達成するために、前記処理済みの表現された第１信号の後処理のステップをさらに備える、前記請求項のいずれかに記載の方法。
【請求項８】
該周波数領域から該時間領域に前記処理済みの表現された信号を変換するステップをさらに備える、前記請求項のいずれかに記載の方法。
【請求項９】
前記所定の品質基準を有する前記信号が、該時間領域内で数の第６集合によって表現される、請求項８に記載の方法。
【請求項１０】
該所定の品質基準または各所定の品質基準が少なくとも１つの変調された搬送波を備え、該変調された搬送波または各変調された搬送波が、搬送波周波数、搬送波振幅、変調深度、及び変調幅から構成されるグループのいずれかを含む、前記請求項のいずれかに記載の方法。
【請求項１１】
該所定の品質基準または各所定の品質基準が、所定の時間領域振幅分布及び所定のスペクトル振幅の包絡線を含むグループのいずれかを備える、請求項１から９のいずれかに記載の方法。
【請求項１２】
前記処理済みの表現された第１信号を、所定の時間領域振幅分布に従って配列するステップをさらに備える、請求項１１に記載の方法。

【請求項１３】
前記処理済みの表現された第１信号を、所定のスペクトル振幅の包絡線に従って配列するステップをさらに備える、請求項１１または１２に記載の方法。
【請求項１４】
前記時間領域振幅分布及びスペクトル振幅の包絡線の少なくとも１つが、反復プロセスにより取り組まれる、請求項１２または１３に記載の方法。
【請求項１５】
前記反復プロセスが、前記処理済みの表現された第１信号の前記時間領域振幅分布及びスペクトル振幅の包絡線のいずれかの、所定の時間領域振幅分布及び所定のスペクトル振幅の包絡線との比較を備える、請求項１４に記載の方法。
【請求項１６】
該所定の品質基準または各所定の品質基準を有する前記信号が、請求項１０に従って処理され、及び請求項１１から１５のいずれかに従って処理された複数の表現された信号を結合することによって提供される、前記請求項のいずれかに記載の方法。
【請求項１７】
該所定の品質基準または各所定の品質基準を有する前記信号が雑音信号である、前記請求項のいずれかに記載の方法。
【請求項１８】
該品質基準または各品質基準を有する前記信号が、コードフォーマットを取り、処理装置上で規定の順序で実行可能である命令のセットによって提供される、前記請求項のいずれかに記載の方法。
【請求項１９】
コードフォーマットを取り、処理装置上で規定の順序で実行可能である命令のセットであって、請求項１８による方法に従って第１信号の表現から、該所定の品質基準または各所定の品質基準及び無作為な位相特性を有する信号を生成するために配列される前記命令のセット。
【請求項２０】
前記請求項のいずれかに従い、少なくとも１つの規定の信号品質基準及び無作為な位相特性を有する信号を生成するために装置される、処理手段、メモリ手段及び任意波発生器手段を備える装置。
【請求項２１】
前記請求項のいずれかに従い生成される、少なくとも１つの所定の信号品質基準及び無作為な位相特性を有する信号。
【請求項２２】
前記請求項のいずれかとともに使用するための、信号表現のライブラリを備えるデータキャリア装置。
【請求項２３】
通信システムの動作を試験する方法であって、
－前記請求項のいずれかに従って、少なくとも１つの所定の品質基準を有する信号を生成するステップと、
－前記通信システムを通して前記信号を転送するステップと、
を備える、前記方法。
【請求項２４】
前記請求項のいずれかに従い、少なくとも１つの所定の信号品質基準を有する信号を生成するための手段と、モデム手段と、ケーブル手段と、プロセッサ手段とを備え、前記プロセッサ手段が、自動測定及び／または監視目的のために、前記生成手段、モデム手段及びケーブル手段を制御するために装置されるシステム。
【請求項２５】
請求項２４に記載の前記方法を作動するために装置される電気通信システム。
【請求項２６】

好ましくは、通信システム内、または通信システム上で使用するための信号を配列する方法であって、
ー時間領域振幅分布を有する時間領域内の第１信号を表現し、前記信号が、該周波数領域内でスペクトル密度を有し、それにより表現された信号を達成するステップと、
ー非線形変換に従って前記表現された信号を処理し、前記非線形変換が少なくとも１つの所定の品質基準を達成するステップと、
ー前記表現された信号の前記時間領域振幅分布が、所定の時間領域振幅分布の少なくとも逆関数で処理されるステップと、
を備える前記方法。
【請求項２７】
前記表現された信号の前記時間領域振幅分布を、前記規定の時間領域振幅分布と比較し、その後、前記規定の時間領域振幅分布に近づく時間領域振幅を有する処理済みの表現された信号を達成するために前記非線形変換を配列するステップをさらに備える、請求項２６に記載の方法。
【請求項２８】
前記処理済みの表現された信号ｇ（ｔ）が、前記表現された第１信号ｆ（ｔ）の関数Ｑ｛ｆ（ｔ）｝であり、前記関数Ｑが、
Ｑ（ｘ）＝ｓｉｇｎ（ｘ）・$G^{-1}$（Ｆ（｜ｘ｜）
として定義され、
ｘ＜＞０の場合ｓｉｇｎ（ｘ）＝ｘ／｜ｘ｜、ｘ＝０の場合ｓｉｇｎ（ｘ）＝０であり、
Ｆが前記表現された信号の前記時間領域振幅分布であり、
Ｇが前記規定の時間領域振幅分布関数である、請求項２６または２７に記載の方法。
【請求項２９】
規定のスペクトル密度品質基準に従ったスペクトル密度を有する前記表現された信号を達成するステップをさらに備える、請求項２８に記載の方法。
【請求項３０】
ー前記第１の信号を該周波数領域に変換するステップと、
ースペクトル包絡線で前記周波数領域内の前記第１信号を乗算し、それにより乗算された信号を達成するステップと、
ー前記乗算された信号を該時間領域に変換するステップと、
をさらに備える、請求項２６に記載の方法。
【請求項３１】
前記表現された信号の前記時間領域振幅分布を、前記規定の時間領域振幅分布と比較し、その後、前記規定の時間領域振幅分布に近づく時間領域振幅分布を有する処理済みの表現された信号を達成するために前記非線形変換を配列するステップをさらに備える、請求項３０に記載の方法。
【請求項３２】
規定のスペクトル密度品質基準に従ったスペクトル密度を有する前記表現された乗算済みの信号を達成するステップをさらに備える、請求項３１に記載の方法。
【請求項３３】
前記ステップの少なくとも２つが反復して実行される、請求項３２に記載の方法。
【請求項３４】
所定の波高因子が達成されるまで、前記ステップの少なくとも２つが反復して実行される、請求項３２に記載の方法。
【請求項３５】
前記信号が雑音信号である、前記請求項のいずれかに記載の方法。
【請求項３６】
該周波数領域内の表現の中の前記第１信号が、乱数、好ましくは複素数、振幅を特徴付ける複素数の係数、位相を特徴付ける前記複素数の引数の集合として生成される、請求項３５に記載の方法。

【請求項３７】
原則的に前記複素数のそれぞれの中から、その実数部及び／または虚数部分が、ガウス分布に従って選択される、請求項３６に記載の方法。
【請求項３８】
前記複素数の本来それぞれの前記係数が、前記規定のスペクトル密度の前記振幅に実質的に等しい、請求項３６に記載の方法。
【請求項３９】
前記複素数の本来それぞれの前記引数が無作為である、請求項３６に記載の方法。
【請求項４０】
好ましくは、通信システム上、または通信システム内で使用するために、信号を配列する方法であって、
－時間領域振幅分布を有する時間領域内の第１信号を表現し、前記信号が該周波数領域内にスペクトル密度を有し、それにより表現された信号を達成するステップと、
－規定のスペクトル密度品質基準に従ったスペクトル密度を有する信号が達成されるまで前記表現された信号を処理するステップと、
を備える前記方法。
【請求項４１】
好ましくは通信システム上、または通信システム内で使用するために、信号を配列する方法であって、
－振幅分布を有する時間領域内の第１信号を表現し、前記信号が該周波数領域内のスペクトル密度を有し、それにより表現された信号を達成するステップと、
－該周波数領域内の前記表現された信号の少なくとも一部を評価するステップと、その後該周波数領域内で前記表現された信号を処理するステップとを含む、周波数領域内で前記表現された信号をフィルタリングするステップと、
を備える前記方法。
【請求項４２】
前記処理ステップが反復ステップを含む、請求項４０または４１に記載の方法。
【請求項４３】
所定の波高因子が達成されるまで、前記処理ステップが反復処理を含む、請求項４０または４１に記載の方法。
【請求項４４】
不規則雑音信号の少なくとも１つを備える信号であって、前記不規則雑音信号が、規定の品質基準に従う時間領域内の振幅分布及び所定の品質基準に従う周波数領域内のスペクトル密度を有し、前記不規則信号が乱数の配列から構成される信号。
【請求項４５】
ディスクリート周波数スペクトルをさらに備える、請求項４４に記載の信号。
【請求項４６】
前記雑音信号が、コードフォーマットを取り、規定の順序で実行される命令のセットを使用して生成される、請求項４４に記載の信号。
【請求項４７】
不規則雑音信号の少なくとも１つを備え、前記不規則信号が、規定の品質基準に従う該時間領域内の振幅分布を有し、規定の品質基準に従う該周波数領域内のスペクトル密度を有し、前記不規則信号が乱数の配列から構成され、コードフォーマットを取り、規定の順序で実行される命令のセットを使用して数の無作為な集合を生成するステップを備える前記方法。
【請求項４８】
ディスクリート周波数スペクトルを生成するステップを備え、前記ディスクリート周波数スペクトルが角度測定関数を使用し、雑音特性で、前記ディスクリート周波数の原則的にそれぞれを変調する、請求項４７に記載の方法。
【請求項４９】

コードフォーマットを取り、規定の順序で実行される命令のセットを使用して、前記不規則雑音信号及び前記ディスクリート周波数スペクトルを結合するステップをさらに備える、請求項４８に記載の方法。
【請求項５０】
コードフォーマットを取り、規定の順序で実行可能である命令のセットであって、前記命令のセットが、不規則雑音信号及びディスクリート周波数スペクトルを生成するために配列され、前記不規則信号が、規定の品質基準に従って該時間領域内に振幅分布を有し、所定の品質基準に従って該周波数領域内にスペクトル密度を有する、命令のセット。
【請求項５１】
通信システムの動作を試験するための試験システムであって、前記試験システムが、コードフォーマットを取り、規定の順序で実行可能であり、装置上でコンパイルされる命令のセットを備え、前記命令のセットが、不規則雑音信号及びディスクリート周波数スペクトルの少なくとも１つを備える雑音信号を生成するために配列され、前記不規則信号が、規定の品質基準に従って該時間領域内に振幅分布を有し、規定の品質基準に従って該周波数領域内にスペクトル密度を有する試験システム。
【請求項５２】
モデムを有する通信システムの動作を試験する方法であって、前記方法が、前記モデムによって交信される信号に重畳するステップを備え、信号が、不規則雑音信号及びディスクリート周波数スペクトルの少なくとも１つを備え、前記不規則信号が、規定の品質基準に従って時間領域内に振幅分布を有し、規定の品質基準に従って周波数領域内にスペクトル密度を有し、前記雑音信号がさらに乱数の配列から構成される方法。
【請求項５３】
モデムを有する通信システムの動作の質を試験する方法であって、
－前記モデムにより交信される信号に重畳し、信号が不規則雑音信号とディスクリート周波数スペクトルの少なくとも１つを備え、前記不規則信号が予め決められた品質基準に従って該時間領域内に振幅分布を有し、規定の品質基準に従って該周波数領域内にスペクトル密度を有し、前記雑音信号がさらに乱数の配列から構成されるステップと、
－規定の品質基準に従って前記交信された信号を評価するステップと、
を備える前記方法。
【請求項５４】
通信システムの設計及び／または製造を改良する方法であって、
－モデムによって交信される信号に重畳し、信号が不規則雑音信号及びディスクリート周波数スペクトルの少なくとも１つを備え、前記不規則信号が規定の品質基準に従って該時間領域内で振幅分布を有し、規定の品質基準に従って該周波数領域内でスペクトル密度を有し、前記雑音信号がさらに乱数の配列から構成されるステップと、
－規定の品質基準に従って前記交信された信号を評価するステップと、
－前記交信された信号を評価するために前記品質基準にさらに近づくために、前記モデムの設計を繰り返し取り決めるステップと、
を備える前記方法。
【請求項５５】
不規則雑音信号及びディスクリート周波数信号の少なくとも１つを備える信号を含む電気通信網であって、前記不規則信号は、規定の品質基準に従って該時間領域内に振幅分布を有し、規定の品質基準に従って該周波数領域内にスペクトル密度を有し、前記雑音信号が、さらに、乱数の配列から構成される電気通信網。
【発明の詳細な説明】
【０００１】
（技術分野）
本発明は、概して通信システムに係わり、詳細には、通信システムとともに使用するための信号、このような信号を生成する方法及びこのような信号を生成するためのシステム、このような信号を使用して通信システムの動作を試験する方法、このような方法を作動さ

せるために装置される試験システム及び（電気）通信システムに係わる。
【０００２】
（背景技術）
とりわけ、ｘＤＳＬトランシーバ及びケーブルまたはネットワークなどの通信システム及び通信設備を試験するためには、ケーブルごとに大多数のシステムまたはシステム機器を用いて、実際の配備シナリオにとって典型的となるように、通信システム及び通信装置に応力をかけるための試験信号が必要とされる。
【０００３】
現実的な（騒々しい）試験条件下でシステムまたはシステム機器の伝送性能を測定することによって、人はシステムまたは装置の設計を改良する、及び／またはそれらの性能がＥＴＳＩ、ＩＴＵまたはＡＮＳＩあるいは他の（電気）通信団体によって発行されるような規格に準拠していることを証明することができる。
【０００４】
このような性能試験を実行する方法は、障害として知られている信号を生成することである。さらに具体的には、障害は以下に細かく分けることができる。
【０００５】
（ｉ）スペクトル包絡線及び例えば近隣のｘＤＳＬシステムからのスペクトル振幅分布により特徴付けられるノイズプロファイルを有する漏話雑音と、
（ｉｉ）数多くのディスクリート周波数成分とスペクトル振幅、例えば、無線及びアマチュア放送から生じる変調深度パラメータと変調幅パラメータによって特徴付けられるノイズプロファイルを有する、ｒｆｉ－トーンとも呼ばれる、ディスクリート周波数成分から構成される進入雑音と、
（ｉｉｉ）例えば、切り替え動作及び構成要素により引き起こされる、信号パルスにより特徴付けられるインパルス雑音。
進入雑音のケースでは、周波数は時間が経つと変化する（掃引する）場合がある。
【０００６】
障害を発生させるための装置は、障害ジェネレータして知られており、前記漏話雑音及び進入雑音の少なくとも１つを生成するために、少なくとも１つが特に通信システム内または通信システム上での使用のために装置される。
【０００７】
実際には、通信システム及び通信装置が規格に準拠しているかどうかを試験するために、とりわけ、例えば通信ケーブル内のワイヤ組の長さと数、及び伝送データレートなどのシステムパラメータに従って変化する多様なノイズプロファイルが明確にされてきた。
【０００８】
さらに、ケーブル、銅ケーブルまたは光ファイバまたは他のケーブル種別などの伝送媒体のそれぞれの異なる種類または長さが、異なる雑音信号を必要とする。
【０００９】
ノイズプロファイルを作成するための方法及び装置は、技術で既知である。特にフィルタリング技法及びフィルタが、特定のスペクトル包絡線及びスペクトル振幅分布を有する出力信号を提供する入力信号から雑音を生成するために既知である。
【００１０】
しかしながら、フィルタリング技法及びフィルタを使用することにより、入力信号と出力信号の間に因果関係が確立される。当業者は、このような種別の信号が本物の稼動中の通信システムと通信装置の現実的な模倣により適していないことを認識するだろう。
【００１１】
ＷＯ第００／１６１８１号は、振幅の所定ヒストグラムに近づく不規則時間領域信号を生成するための方法及び装置を開示する。第１ステップでは、信号は、白色雑音信号などの雑音信号をフィルタリングし、それにより規定のスペクトル包絡線を有する信号を生成することにより生じる。次のステップでは、振幅の規定ヒストグラムに近づく、必要な時間領域信号を生じさせるために、非線形関数が該フィルタリングされた雑音信号に適用され

る。追加のステップでは、そのスペクトル包絡線を補正し、必要とされるスペクトル包絡線を有する出力信号を得るために、パルス応答フィルタリングが該時間領域信号に適用される。非線形関数とパルス応答フィルタリング関数の両方とも、提供されるスペクトル包絡線に従って選択される特殊な関数である。

【００１２】

ＷＯ第００／１６１８１号は、規定のスペクトル包絡線を有する時間領域信号だけが提供されるにすぎないという意味で制限されている。ＷＯ第００／１６１８１号は、提供される時間領域信号に関して課される他の品質基準、とりわけ位相特性に関して記述していない。

【００１３】

（発明の要約）

通信システム及び通信装置と使用するための、特に規定の（規格化された）ノイズプロファイルに従ってこのようなシステム及び装置を試験するための改良された信号を提供することが、本発明の目的である。

【００１４】

本発明の第１態様では、好ましくは、通信システム内または通信システム上で使用するために、所定の品質基準を有する信号を装置する方法が開示され、該方法は、

－それぞれがスペクトル振幅特性及び位相特性を有する複数の周波数成分を備える第１信号を表現するステップと、

－該所定品質基準またはそれぞれの所定品質基準に従ってスペクトル振幅特性を配列し、無作為位相特性を配列することによって、該表現される第１信号を処理するステップと、を備える。

【００１５】

スペクトルの包絡線を修正する従来の方法は、デジタルフィルタバンクを使用することである。本発明の目的のために、該表現された第１信号と提供される信号間因果関係を確立する必要はないため、これは、理想的とは程遠い。本発明に従ったこの内容の理解が、周波数波形整形のアプローチを大幅に簡略化する。

無作為な位相特性を有する第１信号から開始し、該表現された第１信号の周波数波形整形は、例えば該規定品質基準を満たす信号を提供するための適切な動作である可能性がある。本発明による周波数波形整形は、複数の方法で実行できる。

【００１６】

本発明のある実施形態では、第１信号は、各周波数成分のスペクトル振幅及び位相を指定する数の第１集合で表現される。該信号の該無作為位相特性を維持しながら、該周波数領域内で該表現された信号の周波数波形整形を達成するには、各周波数成分の該スペクトル振幅の基準化で十分である。

【００１７】

本発明の追加の実施形態では、該第１信号は、実数部と虚数部分を有する複素数の第２集合により表現され、それらの部分は、組み合わされて各周波数成分のスペクトル振幅及び位相を指定する。周波数波形整形は、該表現された第１信号の基準化後に無作為位相特性を維持するためなどであるが、複素数を適切に基準化することにより達成される。

【００１８】

本発明のまだ追加の実施形態では、該第１信号は、該時間領域内の該第１信号の振幅をそれぞれが指定する、数の第３集合によって表現される。例えば高速フーリエ変換（ＦＦＴ）アルゴリズムを使用して、時間領域から周波数領域にこの数の第３集合を変換することにより、第１信号は、各周波数成分のスペクトル振幅及び位相を指定する数の第４集合によって表現される。この数の第４集合は、数の第１集合と関連して前記に開示されたように、周波数波形整形動作によりさらに処理できる。

【００１９】

ただし、数の該第３集合も、実数部と虚数部分を有する複素数の第５集合により第１信号を表現するために、本発明に従って、時間領域から周波数領域に変換されてよい。前記に

開示されたように、周波数波形整形の目的のため、複素数の該第５集合は適切に基準化されなければならない。

【００２０】
無作為ではない位相特性を有する、表現される第１信号のケースでは、無作為位相特性は、該第２集合、該第４集合及び該第５集合を適切に配列することにより近づくことができる。

【００２１】
周波数領域内での基準化は、実数基準化係数または複素数基準化係数を使用して、乗算動作によって呼び出すことができる。ある周波数成分の該スペクトル振幅の乗算のための該基準化係数は、その所望される値をその実際のスペクトル振幅で除算することにより検出される。

【００２２】
該品質基準または所定の品質基準に対するより近い一致を達成するために、本発明による方法の追加実施形態に従って、該処理済みの表現された第１信号の事後処理が提供される。

【００２３】
しかしながら、本発明による通信システム内または通信システム上での使用のため、該周波数領域にこのようにして配列される該表現された第１信号は、例えば、高速フーリエ逆変換（ＩＦＦＴ）アルゴリズムを使用して、該時間領域に変換されなければならない。

【００２４】
さらに、前記に開示された処理ステップは、信号の畳み込みまたは逆重畳または乗算及び付加などの演算も含んでよい。該時間領域では、該所定品質基準またはそれぞれの所定品質基準を満たす該処理済みの表現された第１信号が、とりわけ、該時間領域内の数の第６集合によって表現されてよい。

【００２５】
しかしながら、前記アプローチでは、スペクトル振幅特性及び無作為位相特性などの該周波数領域内の品質基準を満たす、提供された該信号が、まだ、所定の時間領域振幅分布などの該時間領域での品質基準を満たさないことがある。

【００２６】
本発明による該方法のまだ追加の実施形態では、該所定品質基準またはそれぞれの所定品質基準は、所定の時間領域振幅分布及びスペクトル振幅の所定の包絡線を含むグループのどれかを備える。

【００２７】
従って、本発明による該方法の追加実施形態では、該処理済みの表現された第１信号は、所定の時間領域振幅分布に従って配列される。

【００２８】
本発明による該方法の依然として追加の実施形態では、該処理済みの表現された第１信号は、スペクトル振幅の所定の包絡線に従って配列される。

【００２９】
本発明による該方法の依然として追加の実施形態では、該処理済みの表現された第１信号が、スペクトル振幅の所定の包絡線に従って配列される。

【００３０】
本発明に従って、該周波数領域と時間領域の両方で所定の品質基準を正確に満たす信号を提供するために、該時間領域振幅分布及び該スペクトル振幅の包絡線の内の少なくとも１つが、反復プロセスにより取り組まれる。振幅及び周波数波形整形は、両方の形状が妥当な角度の範囲内で要件を満たすまで必要とされる回数に繰り返されてよい。

【００３１】
本発明のある実施形態では、該反復プロセスは、任意の反復ステップ後の、該処理済みの表現された第１信号の該時間領域振幅分布及びスペクトル振幅の包絡線のどれかの、所定の時間領域振幅分布及びスペクトル振幅の所定の包絡線との比較を備える。

【００３２】
該時間領域特性が該要件に十分に近いかどうかを見抜くために、周波数波形整形後に常時ドメイン特性チェックを実行する必要はないことが認められた。該反復を停止するのか、あるいは続行するのかの決定を可能にするには、実際には、波高因子要件の簡略なチェックで十分であることが判明している。該信号の該波高因子は、該信号の該トーンの該平均つまりｒｍｓ値に比較される、該信号の該トーンの該最大、つまりピーク振幅の関係として定義される。

【００３３】
前述されたように本発明による該方法は、特に、とりわけ漏話雑音の生成に適している。

【００３４】
本発明による該方法の第２態様において、進入雑音の該特性を有する信号が生成されなければならない場合、該所定品質基準またはそれぞれの所定の品質基準は、少なくとも１つの変調済み搬送波を備え、該変調済み搬送波またはそれぞれの変調済み搬送波は、搬送周波数、搬送振幅、変調深度、及び変調幅から構成されるグループのどれかを含む。

【００３５】
前記に示された１つまたは複数の品質基準に従って該表現された第１信号を波形整形することにより、ある特定の時間領域振幅分布、及びスペクトル振幅の所定の包絡線を有する、ある特定の種別の進入雑音を表現する信号は、容易に且つ非常に効率的に提供できる。

【００３６】
本発明の該方法に従って、該所定品質基準またはそれぞれの所定の品質基準を満たす該信号は、前記に開示されたように処理される複数の信号を結合することにより提供できる。

【００３７】
例えば、通信網または通信装置の試験で該信号を使用する場合、該処理済みの表現された信号は、とりわけ、例えば、ＦＦＴアルゴリズムを使用して該周波数領域から該時間領域に変換されなければならない。

【００３８】
本発明は、さらに、前記に開示されたように、該第１態様と該第２態様に従って生成される該信号を結合することを提供する。しかしながら、他の信号成分も含まれてよい。

【００３９】
特に、本発明の該方法に従って、該所定品質基準またはそれぞれの所定の品質基準を有する該信号は雑音信号である。

【００４０】
本発明の第３態様では、通信システムの動作を試験する方法が開示され、該方法は、
－前記に開示された本発明の該方法に従って規定の品質基準を有する信号を生成するステップと、
－試験中の該通信システムを通して該信号を転送するステップと、
を備える。

【００４１】
該信号は、コードフォーマットの命令のセットを使用して生成、記憶し、装置上で規定の順序で実行できる。このような命令のセットが、コンピュータでコンパイルされ、該コンピュータまたはコンピュータのネットワーク、フロッピーまたはＣＤ－ＲＯＭに、あるいはインターネットを通じて記憶されるソフトウェアコードである場合がある。該ソフトウェア及び／または生成された信号は、任意波信号発生器（ＡＷＧ）カードに記憶することもでき、該ＡＷＧは、信号を生成するため、あるいはメモリから記憶されている信号を再生するために使用できる。従って、本発明による該方法の実行または使用で使用できるデータ搬送波に記憶されている使用可能な信号のライブラリを有することができる。

【００４２】
該通信システムは、ｘＤＳＬモデムなどの装置、あるいはこのようなモデム内またはモデム用のチップ、あるいはネットワーク内のケーブル、または（電気）通信用のネットワークである場合がある。

【００４３】
本発明の第４態様では、通信システム上または通信システム内で使用するための信号を配列する追加の方法が開示される。好ましくは、該信号は雑音信号である。該信号は、該周波数領域及び該時間領域内の所定の特性を備えた不規則な信号である漏話雑音を備えてよい。該信号は、さらに、ディスクリート周波数スペクトルを有するｒｆｉ－トーンを備えることがある。また、該信号に他の信号成分が含まれることがある。
【００４４】
該方法は、
－時間領域振幅分布を有する時間領域内の第１信号を表現し、該信号が該周波数領域にスペクトル密度を有し、それにより表現された信号を達成するステップと、
－非線形変換に従って該表現された信号を処理し、該非線形変換が少なくとも１つの所定の品質基準を達成するステップと、
－該表現された信号の該時間領域振幅分布が、規定の時間領域振幅分布の少なくとも逆関数で処理されるステップと、
を備える。
【００４５】
該方法は、さらに、該表現された信号の該時間領域振幅分布を、該規定の時間領域振幅領域と比較し、その後、該規定の時間領域振幅分布に近づく時間領域振幅分布を有する処理済みの表現された信号を達成するために、該非線形変換を配列するステップを備えてよい。
【００４６】
本発明の第５態様では、該表現された信号の該時間領域振幅分布を、該規定の時間領域振幅分布と比較し、その後、該規定の時間領域振幅分布に近づく時間領域振幅分布を有する処理済みの表現された信号を達成するために該非線形変換を配列するステップをさらに備える方法が開示される。
【００４７】
本発明の該第５態様に従って、該方法は、時間領域内の第１信号を振幅分布で表現し、該信号が該周波数領域内のスペクトル密度を有し、それにより表現された信号を達成するステップと、該周波数領域内の該信号表現の少なくとも部分を評価するステップ及びその後該周波数領域内で該表現された信号を処理するステップとを含む、該周波数領域内で該表現された信号をフィルタリングするステップとを備えることもある。
【００４８】
本発明の第４態様と第５態様の該方法を結合することができる。本発明の第４態様と第５態様の該方法は、所定の振幅分布を有する、及び／または所定のスペクトル密度を有する、あるいは１つの振幅分布を有する、及び／または所定の品質基準に従って１つのスペクトル密度を有する信号を、さまざまな反復ステップで作成できる。該所定の品質基準が、該信号の波高因子、すなわち該信号の該トーンの平均値つまりｒｍｓ－値に比較される、該信号のトーンの最大つまりピーク値の関係である場合がある。前記に列挙されたような該処理ステップは、高速フーリエ変換（ＦＦＴ）または高速フーリエ逆変換（ＩＦＦＴ）のステップを備えることがある。該処理ステップは、信号の畳み込みまたは逆重畳、あるいは乗算または付加などの演算を含むこともある。
【００４９】
第４態様の該方法では、該表現された信号の該振幅分布は、該規定の振幅分布の逆関数を含むことがある該規定の振幅分布の関数を含めて処理される。
【００５０】
本発明の第４態様と第５態様の列挙されるような該方法は、さらに、該周波数領域内で該第１信号を変換するステップと、該周波数ドメイン内の該第１信号をスペクトル包絡線で乗算し、それにより乗算された信号を達成するステップと、その後時間領域内で該乗算された信号を表現するステップとを備えることがある。
【００５１】

該方法では、該周波数領域内のその表現の中の該第１信号は乱数、好ましくは、複素数、振幅を特徴付ける該複素数の係数、位相を特徴付ける該複素数の該引数の集合として生成することができ、該複素数の原則的にはそれぞれの実数及び／または虚数部分はガウス分布に従って選ぶことができる。該複素数のそれぞれは、該所定のスペクトル密度の該振幅に実質的には等しいことがある。

【００５２】

本発明の第６態様では、少なくとも１つの不規則雑音信号を備える信号が開示され、該不規則信号は、規定の品質基準に従って該時間領域内に振幅分布を、所定の品質基準に従って該周波数領域内にスペクトル密度を有し、該不規則信号は乱数の配列から構成される。該信号は、さらにディスクリート周波数スペクトルを備えることがある。該雑音信号は、コードフォーマットの命令のセットを使用し、規定の順序で実行され、生成できる。このような命令のセットは、コンピュータでコンパイルされ、該コンピュータまたはコンピュータのネットワークまたはフロッピーまたはＣＤ－ＲＯＭに、あるいはインターネットを通して記憶されるソフトウェアコードである場合がある。該ソフトウェアは、任意波信号発生器（ＡＷＧ）カードにも記憶でき、該ＡＷＧは該信号を生成する、あるいは該メモリから記憶されている信号を再生するために使用できる。従って、本発明の第４態様と第５態様の該方法の実行または使用で使用できる、使用可能な信号のライブラリを有することが可能である。

【００５３】

本発明の第７態様では、少なくとも１つの不規則雑音信号を備える信号を生成する方法が開示され、該不規則信号は、規定の品質基準に従って該時間領域内に振幅分布を有し、規定の品質基準に従って該周波数領域内にスペクトル密度を有し、該不規則信号は乱数の配列から構成され、該方法は、コードフォーマットの命令のセットを使用し、規定の順序で実行され、数の無作為な集合を生じさせるステップを備える。該方法は、さらに、ディスクリート周波数スペクトルを生成するステップを備えることがあり、該ディスクリート周波数スペクトルは角度測定機能を使用し、原則的に雑音特性のある該ディスクリート周波数のそれぞれを変調する。該不規則雑音信号及びディスクリート周波数スペクトルは、コードフォーマットの命令のセットを使用し、規定の順序で実行され、結合できる。

【００５４】

本発明の第８態様では、コードフォーマットで、規定の順序で実行可能な命令のセットが開示され、該命令のセットは不規則雑音信号及びディスクリート周波数スペクトルを生成するために配列され、該不規則信号は、所定の品質基準に従って該時間領域に振幅分布を有し、所定の品質基準に従って該周波数領域にスペクトル密度を有する。このような命令のセットは、コンピュータでコンパイルされ、該コンピュータまたはコンピュータのネットワークまたはフロッピーまたはＣＤ－ＲＯＭに、あるいはインターネットを通して記憶されるソフトウェアコードである場合がある。該ソフトウェアは、任意波信号発生器（ＡＷＧ）カードにも記憶でき、該ＡＷＧは、該信号を生成する、または該メモリから記憶されている信号を再生するために使用できる。従って、使用できる、使用可能な信号のライブラリを有することが可能である。該ソフトウェアはＣ－コードであるか、またはＭＡＴＬＡＢ環境でコンパイルできる。

【００５５】

本発明の第９態様では、コードフォーマットを取り、規定の順序で実行可能であり、装置上でコンパイルされる命令のセットを備える通信システムの動作を試験するためのシステムが開示され、該命令のセットは、不規則雑音信号及びディスクリート周波数スペクトルの少なくとも１つを備える雑音信号を生成するために配列され、該不規則信号は、規定の品質基準に従って該時間領域に振幅分布を有し、規定の品質基準に従って該周波数領域にスペクトル密度を有する。本発明の本態様による該試験システムは、該雑音信号を生成するための障害ジェネレータを備えることがある。

【００５６】

該障害ジェネレータを試験される該通信システムに接続する該接続要素（変圧器、能動素

子、減衰器等）が、不必要な周波数に依存する応答を有することがある。該不必要な周波数に依存する応答は、例えば、該障害ジェネレータ内で特定の試験信号を生成することによって測定できる。該不必要な周波数に依存する応答は、該接続要素の該不必要な周波数に依存する応答で除算される該信号の該所望されるスペクトル密度を乗算することにより補償できる。

【００５７】
本発明の第１０態様では、ｘＤＳＬモデムなどの通信システムの動作を試験する方法が開示される。該方法は、１つの該モデムによって交信される信号に重畳するステップを備え、信号は不規則雑音信号及びディスクリート周波数スペクトルの少なくとも１つを備え、該不規則信号は、規定の品質基準に従って該時間領域に振幅分布を有し、規定の品質基準に従って該周波数領域内にスペクトル密度を有し、該雑音信号は、さらに乱数の配列から構成される。

【００５８】
本発明の第１１態様では、通信システムの動作の質を試験する方法が開示される。該方法は、１つの該モデムによって交信される信号に重畳するステップを備え、信号は不規則雑音信号及びディスクリート周波数スペクトルの少なくとも１つを備え、該不規則信号は規定の品質基準に従って該時間領域に振幅分布を有し、規定の品質基準に従って該周波数領域にスペクトル密度を有し、該雑音信号は、さらに乱数の配列から構成され、所定の品質基準に従って該交信される信号を評価する。

【００５９】
また本発明の第１２態様では、通信システムの設計及び／または製造を改善する方法が開示され、該方法は、１つの該モデムにより交信される信号上に重畳し、該モデムにより交信される信号上に重畳し、信号は不規則雑音信号及びディスクリート周波数スペクトルの少なくとも１つを備え、該不規則信号が規定の品質基準に従って該時間領域内に振幅分布を有し、規定の品質基準に従って該周波数領域内にスペクトル密度を有し、該雑音信号がさらに乱数の配列から構成されるステップと、規定の品質基準に従って該交信される信号を評価するステップと、該交信される信号を評価するために該品質基準にさらに近く接近するために該モデムの該設計を反復して配列するステップとを備える。

【００６０】
本発明の第１３態様では、不規則雑音信号及びディスクリート周波数スペクトルの少なくとも１つを備える信号を含む電気通信網が開示され、該不規則信号は、規定の品質基準に従って該時間領域内に振幅分布を有し、該規定の品質基準に従って該周波数領域内にスペクトル密度を有し、該雑音信号は、さらに乱数の配列から構成される。

【００６１】
本発明の前述された態様及び実施形態の該特徴は結合できる。
前記に列挙された該信号、該方法及び該命令のセットは、電話線などの媒体または無線媒体上でさらに優れた品質の信号伝送を有することを可能にするだろう。信号のさらに優れた伝送は、通信システムのユーザ向けのさらに多くのサービスのさらに幅広い提供に対処する。

【００６２】
（実施形態の詳細な説明）
本発明を教示する目的のために、本発明の該信号と方法とシステムの態様及び実施形態が後述される。本発明の他の代替実施形態及び同等な実施形態が、本発明の真の精神から逸脱することなく実践するために考えられ、変形されることは当業者により理解されるだろう。本発明の範囲は、添付請求項によってのみ制限されている。

【００６３】
本発明の実施形態では、ｘＤＳＬトランシーバなどの通信システムの動作を試験するためのシステムが開示される。稼動中のアクセスネットワークにおけるシステムの高い浸透率のシナリオのための試験装置のセットアップが説明される。

【００６４】

通信システム上または通信システム内で使用するための信号を配列する方法が開示される。

【００６５】
伝送性能試験の目的とは、稼動中のアクセスネットワークでのシステムの高い浸透率のシナリオにとって典型的な方法で、ｘＤＳＬトランシーバに応力をかけることである。この高浸透アプローチにより、以下が可能になる。

【００６６】
（ｉ）構成要素及びシステムの設計者が、性能を定量化し、設計を改良し、規格との準拠を証明するためにそれを使用できるようになる。

【００６７】
（ｉｉ）オペレータが、大部分の過剰状態に当てはまる配備規則を明示することができる。

【００６８】
図１は、考えられる試験セットアップ１の機能上の説明を示す。それは、以下を含む。

【００６９】
・本物のケーブルまたはケーブルシミュレータである試験ループ２、
・障害雑音を該試験ループ２に投入するための追加要素３、
・例えば、スペクトラムアナライザまたはｒｍｓ電圧計（図示されていない）などのレベル検出器５と連結される高インピーダンス、及び釣り合いの良い差動電圧プローブ４、及び
・試験中のｘＤＳＬトランシーバ（モデム）６、７
（ＰＯＴＳ信号及びＩＳＤＮ信号について）試験中のｘＤＳＬシステムに外部スプリッタが必要とされるとき、これらのスプリッタを試験中の該モデム６、７の中に含むことができる。

【００７０】
試験装置セットアップ１を通る該信号の流れはポートＴｘからポートＲｘへであり、上流性能及び下流性能を測定するには、トランシーバ位置と試験「ケーブル」端部の交換が必要とされることを意味する。ポートＲｘでの該受信信号レベルは、ポートＲｘだけではなくポートＴｘも試験中のｘＤＳＬトランシーバ（モデム）６、７と成端されるときに、ノードＡ２とＢ２間で測定される水準である。該障害ジェネレータ８は、この測定の間オフに切り替えられる。ポートＴｘでの該伝送信号レベルは、同じ条件下でノードＡ１とＢ１間で測定される水準である。

【００７１】
該障害ジェネレータ８が該試験セットアップ１の中に投入する必要のある該雑音は、周波数に依存している。該障害ジェネレータ８が該試験セットアップ１の中に投入する該雑音は、本物の（スペクトル汚染された）アクセスネットワークの現実的な表現とならねばならず、
（ａ）該試験ループ２の長さに依存し、
（ｂ）下流性能試験と上流性能試験について異なる。

【００７２】
ノードＡ２とＢ２間で測定されるこの障害雑音は、通常、不規則雑音、衝撃雑音、及び高調波雑音（ｒｆｉ－トーン）の混合物である。特性の集合が「ノイズプロファイル」として特定される。

【００７３】
信号レベルと雑音レベルは、釣り合いの良い差動電圧プローブ４を用いて厳密に調べられる。

【００７４】
完全に自動化された試験セットアップ１では、該試験ループ２、３、該電圧プローブ４とレベル検出器５、試験中の該モデム６、７、及び該障害ジェネレータ８は、破線により概略して示されるように、中央演算処理装置（ＣＰＵ）９に接続してよい。当業者は、該Ｃ

ＰＵ９との該接続が、該ＣＰＵ９による遠隔試験用のデータリンクを含んでよいことを理解するだろう。

【００７５】
該試験装置の使用に関連する定義は、以下のとおりである。

【００７６】
・完全信号バンド上で、このセットアップでｒｍｓ電圧$U_{rms}$［Ｖ］を厳密に調べることは、$P=10 x \log_{10}(U_{rms}^2/R_v x 1000)$［ｄＢｍ］に等しいＰ［ｄＢｍ］の電力レベルを意味する：
・（ヘルツ単位の）△ｆという小周波数バンド内で、このセットアップでｒｍｓ－電圧$U_{rms}$［Ｖ］を厳密に調べることは、$P=10 x \log_{10}(U_{rms}^2/R_v x 1000/\triangle f)$［ｄＢｍ／Ｈｚ］に等しいそのフィルタリングされたバンド内のＰ［ｄＢｍ／Ｈｚ］という電力スペクトル密度レベルを意味する。

【００７７】
・帯域幅△ｆは、該－３ｄＢ帯域幅ではなく、該フィルタの該雑音帯域幅を特定する。

【００７８】
図２は、本発明による通信システム上または通信システム内で使用するための信号Ｕｉ（ｔ）ｉ＝１，２，３．．．を配列するための該方法の実施形態を概略的に示す。該信号は、漏話雑音、つまり該周波数領域内及び該時間領域内に所定の特性を有する不規則信号を備えてよい。

【００７９】
図２のフロー［１］によって表されるようにブロック１０「第１信号」において、該方法は、それぞれがスペクトル振幅特性及び位相特性を有する複数の周波数成分を備える第１信号を表現するステップと、無作為位相特性、ブロック１１「配列」を配列し、それにより処理済みの表現された信号を達成することによってだけではなく、該スペクトル振幅特性を少なくとも１つの所定の品質基準に従って配列することによっても該表現された信号を処理するステップとを備える。

【００８０】
該第１信号は、各周波数成分のスペクトル振幅及び位相を指定する数の第１集合によって表現されてよい。さらに、該第１信号は、実数部と虚数部分を有する複素数の第２集合によって表現されてよく、部分は組み合わされて各周波数成分のスペクトル振幅及び位相を指定する。すなわち、複素数の係数はスペクトル振幅を特徴付けるが、該複素数の該引数が該周波数成分の該位相を特徴付ける。

【００８１】
本発明に従って、該表現される第１信号１０は、無作為位相特性を配列するために処理される。ただし、該規定の品質基準に従って該信号の該周波数を波形整形するために、無作為位相特性を有する表現される第１信号１０から開始すると、それは該周波数成分の該スペクトル振幅を波形整形するのに十分である。

【００８２】
該方法は、該第１信号が、それぞれが該時間領域内で該第１信号の振幅を指定する数の第３集合によって表現されるという点で、該時間領域内で該第１信号を表すステップを備えてもよい。例えばＦＦＴアルゴリズムを使用して、該時間領域から該周波数領域に該数の第３集合を変換することにより、各周波数成分のスペクトル振幅及び位相を指定する数の第４集合が達成される。同様に、該数の第４集合は、その無作為位相特性を配列するだけではなく、該少なくとも１つの所定の品質基準に従って該スペクトル振幅特性を配列することにより処理されなければならない。

【００８３】
例えば逆ＦＦＴアルゴリズムを使用して、該周波数領域から該時間領域に該処理済みの表現された信号を変換すること、ブロック１２「変換」により、該少なくとも１つの所定の品質基準を有する該信号Ｕ１（ｔ）が最終的に生成される。

【００８４】

該信号Ｕ１（ｔ）は、スペクトル包絡線及び／またはプリエンファシス特性などの該周波数領域内の少なくとも１つの所定の品質基準を満たすが、該時間領域内の所定の品質基準を有する信号を提供することがまだ必要とされる可能性がある。
【００８５】
図２のフロー［２］と［３］、つまりブロック１３「振幅波形整形」とブロック１４「周波数波形整形」に開示されるように、該時間領域内の該品質基準は所定の振幅分布及び／またはスペクトル振幅の所定の包絡線を備えてよい。
【００８６】
該方法は、さまざまな反復ステップの中に信号を作成するステップも備えることがある。図２［４］を参照すること。ブロック１５「試験波形整形」及び反結合ループ１６。従って、該信号は、規定の時間領域振幅分布及び／またはスペクトル振幅の規定の包絡線、及び／または規定の品質基準に従うスペクトル密度を有することがある。
【００８７】
該少なくとも１つの所定の品質基準が、該信号の該平均つまりｒｍｓ値に比較される該信号の該トーンの最大つまりピーク値の関係である該信号の波高因子である場合がある。
【００８８】
該信号は、コードフォーマットを取り、既知の順序で実行可能であり、装置上でコンパイルされる命令のセットを使用して、生成、記憶できる。このような命令のセットは、コンピュータでコンパイルされ、該コンピュータまたはコンピュータのネットワークまたはフロッピーまたはＣＤ－ＲＯＭに、またはインターネットを通して記憶されるソフトウェアコードである場合がある。該ソフトウェアは、任意波信号発生木（ＡＷＧ）カードにも記憶でき、該ＡＷＧは該信号を生成する、または該メモリから記憶されている信号を再生するために使用できる。従って、本発明の第１態様と第２態様の該方法の実行または使用で使用できる、使用可能な信号のライブラリを有することが可能である。該通信システムが、ｘＤＳＬモデム６、７などの装置、またはこのようなモデム６、７内の、またはモデム６、７用のチップ、または電気通信用のネットワークである場合がある。
【００８９】
図２のブロック１３「振幅波形整形」での該処理は、該時間領域特性に対する衝撃または制御を達成するために行われる。該信号内の高振幅ピークまたはトーンを増幅する振幅歪み（変形）関数Ｑ（ｘ）が選ばれる。非線形変換関数Ｑ（ｘ）は、該信号の該実際の振幅分布関数及び該規定の振幅分布関数から再構築できる。
【００９０】
０ｅｎＴの間の該時間期間ｔ内での雑音信号ｆ（ｔ）の場合、該信号の該振幅分布Ｆ（ａ）は、絶対値の中の該雑音ｆがａより大きい該時間の端数として定義される。Ｇ（ａ）が（機能拡張ガウスなどの、以下参照）該所定の振幅分布であり、$G^{-1}$（ａ）がその逆関数である場合、該雑音信号ｆ（ｔ）から中間信号または最終信号ｇ（ｔ）を作成するための該変換関数Ｑ（ｘ）は、以下のように定義できる。
【００９１】
【数１】

$$Q(x) = sign(x) \cdot G^{-1}\left(F(|x|)\right) \qquad (1)$$

【００９２】
【数２】

$$g(t) = Q\{f(t)\}; \qquad (2)$$

ｘ＜＞０の場合、ｓｉｇｎ（ｘ）＝ｘ／｜ｘ｜。ｘ＝０の場合ｓｉｇｎ（ｘ）＝０
結果ｇ（ｔ）は、該規定の振幅分布Ｇ（ａ）を有するだろう。多くのケースでのＱ（ｘ）は分析関数である場合があるが、数値的に構築することもできる。機能拡張ガウス関数の例は以下のとおりである。

【００９３】

ガウス型雑音の該振幅分布は以下のとおりである。

【００９４】

【数３】

$$G(x) = 1 - erf\left(\frac{x}{\sqrt{2}\sigma}\right) \qquad (3)$$

【００９５】

【数４】

$$\text{ここで}\quad erf(x) = \frac{2}{\sqrt{\pi}}\int_0^x dt\,\exp\left(-t^2\right), \qquad (4)$$

及び　は、該信号の該ＲＭＳ値である。

【００９６】

該「機能拡張」ガウス分布は、以下のとおりに定義される。

【００９７】

【数５】

$$G(x) = \begin{cases} 1 - \left(\alpha \frac{x}{A} + erf\left(\frac{x}{\sqrt{2}\sigma}\right)\right) \Big/ \left(\alpha + erf\left(\frac{A}{\sqrt{2}\sigma}\right)\right) & 0 \le x \le A \\ 0 & x > A \end{cases}, \qquad (5)$$

$V_{RMS}$が所望された雑音サンプルのＲＭＳ値であり、$C_f$が所望された波高因子である場合、以下を選択する。

【００９８】

【数６】

$$A = C_f \times V_{RMS}\text{, and} \qquad (6)$$

【００９９】

【数７】

$$\sigma = \sqrt{((1+\alpha)\,V^2_{RMS} - A^2 \cdot \alpha/3)}. \qquad (7)$$

有効である事が判明したαの典型的な値は、０．００１と０．０１の間の規模であり、これが真のガウス分布から分散される機能拡張ガウスの偏差を表す。

【０１００】

図２のブロック１４、周波数波形整形では、該信号の該周波数領域特性が、該品質基準ま

たは各品質基準に対するより近い一致を達成するための提示された処理ステップとして改善される。該補正された周波数曲線は、例えば、該（中間）信号Ｕ２（ｔ）の該測定されたスペクトル密度を使って所定のスペクトル密度を比較する（除算する）ことによって達成できる。この例は、ＦＦＴ関数の畳み込みを用いる続編で説明される最善の態様で示される。

【０１０１】

図２の部分［４］では、ここに前記に詳説された該ステップの反復手順がどのようにして、通信システム内または通信システム上で使用するための該終了信号または最終信号の追加改善策につながるのかが示されている。該反復手順、つまりブロック１５試験波形整形、及び反結合ループ１６による周波数波形整形の試験は、該規定の品質基準（複数の場合がある）が達成されるまで実行される。

【０１０２】

図３は、概略図解で、進入雑音信号の提供のための本発明による該方法の使用を示す。

【０１０３】

前文に開示されるように、進入雑音は、ディスクリート搬送波周波数ｆｃｉ、ｉ＝１，２，３．．．での複数の周波数成分により特徴付けられてよい。該搬送波周波数ｆｃｉでの該周波数成分は、それぞれ、搬送波振幅Ａｃｉ、ｉ＝１，２，３．．を有し、該それぞれの搬送波周波数ｆｃｉと関連付けられる該側周波数の該振幅である変調深度を有するだけではなく、該当する場合、変調幅、つまり該関連付けられる搬送波周波数ｆｃｉの左側と右側にあるディスクリート周波数の数も有する。

【０１０４】

図３は、水平の、つまり周波数軸ｆ、及び垂直の、つまり振幅軸Ａを有する図解で、ほんの一例として、それぞれ搬送波振幅Ａｃ１とＡｃ２を有する２つの搬送波周波数ｆｃ１とｆｃ２から構成される信号を示す。

【０１０５】

そのそれぞれの側面にある該搬送波周波数ｆｃ１の回りには、それぞれが振幅Ａ１を有する３つの側周波数成分が配列され。そのそれぞれの側面上の搬送波周波数ｆｃ２での該周波数成分について、それぞれが振幅Ａ２を有する２つの側周波数成分が配列される。

【０１０６】

本発明に従って、少なくとも１つの所定の品質基準を有する信号を提供するために、該周波数成分の該振幅は、図３の点線１と２によって開示されるように、波形整形されなければならない。

【０１０７】

本発明に従って、無作為位相特性を有する表現される第１信号から開始して、該振幅の該波形整形により、該無作為振幅位相は、該所定の品質基準を有して提供される該信号内に維持される。

【０１０８】

図４は、通信システム内または通信システム上で使用するため、特に、無作為位相特性がすでに規定されている場合に使用するために、信号を配列する方法の追加実施形態を概略して示す。該信号は、該周波数領域内に、及び該時間領域内に規定の特性を備える不規則信号である漏話雑音を備える。該信号は、さらに、ディスクリート周波数スペクトルを有するｒｆｉ－トーンを備えることがある。また、該信号には他の信号成分を含むことができる。

【０１０９】

該方法は、さらに、時間領域内の、振幅分布を有する第１信号を表現し、該信号が該周波数領域にスペクトル密度を有し、それにより表現された信号を達成するステップと、非線形変換に従って該表現された信号を処理し、該非線形変換が規定の品質基準を達成するステップとを備えてよい。これは、図４、フロー［２－４］で振幅波形整形として図示される。

【０１１０】

該方法は、さらに、時間領域内の、振幅分布を有する第１信号を表現し、該信号が該周波数領域にスペクトル密度を有し、それにより表現された信号を達成するステップと、規定のスペクトル密度品質基準に従ったスペクトル密度を有する信号が達成されるまで、該表現された信号を処理するステップとを備えてよい。これは、図４、フロー［２－４］で周波数波形整形として示される。該周波数波形整形ステップは、該周波数領域内の該信号表現の少なくとも一部を評価するステップと、それ以降該周波数領域内の該信号表現を処理するステップとを含む、該周波数領域内の該表現された信号をフィルタリングするステップも含むことがある。

【０１１１】

該方法は、さまざまな反復ステップで信号を作成するステップを備えてもよい。図４、フロー［４］を参照すること。このようにして、該信号は、規定の時間領域振幅分布、及び／または所定のスペクトル密度、あるいは所定の品質基準に従った時間領域振幅分布及び／またはスペクトル密度を有することができる。該所定の品質基準は、該信号の波高因子、つまり該信号の該トーンの平均値に比較される該信号の該トーンの最大つまりピーク値の関係である場合がある。該信号は、コードフォーマットを取り、規定順序で実行可能であり、装置上でコンパイルされる命令のセットを使用して、生成、記憶できる。

【０１１２】

同様に、該命令のセットは、コンピュータでコンパイルされ、該コンピュータ、またはコンピュータのネットワークまたはフロッピーまたＣＤ－ＲＯＭに、あるいはインターネットを通して記憶されるソフトウェアコードである場合がある。該ソフトウェアコードは、任意波信号発生器（ＡＷＧ）カードに記憶することもでき、該ＡＷＧは該信号を生成する、あるいは該メモリから記憶されている信号を再生するために使用できる。従って、本発明の該方法の実行または使用で使用できる、使用可能な信号のライブラリを有することが可能である。該通信システムは、ｘＤＳＬモデムなどの装置、あるいはこのようなモデム内の、またはこのようなモデム用のチップ、あるいは電気通信用ネットワークである場合がある。詳細には、以下の実施形態が図４に示される。

【０１１３】

ソフトウェアを使用して、乱数が生成される、ブロック１６「雑音の生成」。ハードウェアでは、白色雑音を発生できる。該乱数は、規定のスペクトル密度が達成されるまでフィルタリングされる。生成される該乱数は、それぞれ周波数成分を表現する。規定のスペクトル密度を達成するための必要な処理は、該複素数の該振幅を基準化することにより実行され、それ以後、該所望の雑音信号を作成するために、ＩＦＦＴ処理が実行される。該方法を実行する別の方法は、各周波数成分の該位相を表現する乱数を生成することであり、それ以後、該複素数の該振幅は、規定のスペクトル密度に近づくまたは規定のスペクトル密度に等しくなるように配列される。

【０１１４】

ブロック１３、「振幅波形整形」における処理は、該時間領域特性に対する影響または制御を達成するために行われる。図５に図示されるような該信号中の高い振幅ピークまたはトーンを増幅する振幅分布（変換）関数Ｑ（ｘ）が選ばれる。該非線形変換関数Ｑ（ｘ）は、該信号の該実際の振幅分布関数、及び等式（１から７）に関連して前記に開示されたような該規定の振幅分布関数から再構築できる。

【０１１５】

図４のブロック１４、「周波数波形整形」では、該信号の該周波数領域特性が改善される。該補正された周波数曲線は、該（中間）信号の該測定スペクトル密度を通る規定のスペクトル密度を比較する（除算する）ことによって達成される。この例は、ＦＦＴ関数の逆重畳を用いる続編で説明された最善の態様の実施形態に示される。

【０１１６】

図４のフロー［４］では、図２のフロー［４］と同様に、再び、前記に詳説されたステップの反復手順がどのようにして、通信システム内、または通信システム上で使用するための最終の追加改良につながるのかが示されている。該反復手順は、該規定の品質基準が達

成されるまで実行される。
【０１１７】
前述されたように、本発明による該方法を用いると、漏話雑音及び進入雑音を表現する信号は、漏話雑音信号と進入雑音信号の両方から構成される信号を提供するために装置されてよい障害ジェネレータ８、図１を参照、のような装置を用いて生成できるが、他の信号成分は、必要とされる場合、提供される該出力信号に追加されてよい。
【０１１８】
提供される該信号は、本発明の実施形態において、例えば数の配列などの該時間領域内の数の第６集合として有利に提供できる。
【０１１９】
図６は、フロー型図で、パーソナルコンピュータ２０上で実行している本発明の例の実施形態を示す。該障害雑音は、ブロック２２「白色雑音信号」、ＦＦＴにより提供されるブロック２３「スペクトル波形整形」、ＩＦＦＴによりブロック２３の出力から生じるブロック２４「所望の雑音信号」を備えるＳＰＯＣＳと呼ばれるブロック２１によって生成され、その結果として生じる信号はＡＷＧカード２５上に記憶される。漏話シナリオ、つまりブロック２６では、さらにブロック２３により処理される雑音ＰＳＤが作成される、ブロック２７。
【０１２０】
本発明の該命令のセットの最善の態様の実施形態は、ここに以下に開示される。ここに以下に示される該コードは、ＭＡＴＬＡＢ環境でコンパイルされる。該コードの機能性に関連するコメントは、％記号の後に示される。当業者にとって、提供される該コードは自明的である。
【０１２１】
図７から図９は、該最善の態様の実施形態で得られる結果を示す。図８は、該ノイズプロファイルの該ＰＳＤが加えられた、生成済みの雑音サンプルのスペクトルのプロットを示す。図９は、該時間領域内の該生成された雑音サンプルのプロットを示す。図１０は、該生成された雑音サンプルの該分布関数のプロットを示す。図１１は、該生成された雑音サンプルの該累積分布関数のプロットを示す。図７は、グラフィックユーザインタフェース（ＵＩ）及び該ＡＷＧ制御の設定値を示す。
％
関数ＤｅｍｏＩｍｐａｉｒ２；
％
％ＤｅｍｏＩｍｐａｉｒ２
％Ｍａｔｌａｂプログラミング言語でプログラミングされ、障害ジェネレータの基本アルゴリズムを証明するコード。
【０１２２】
％該証明されたアルゴリズムは、
％－連続スペクトルで雑音を生成するときの周波数領域特性と時間領域特性（スペクトル、確率分布）
％－離散スペクトルで雑音を生成するときの搬送波振幅、搬送波周波数、変調深度、及び変調幅
％該所定の品質基準を完全に支配する。
【０１２３】
％両方の種別の雑音は個別に計算され、数を含む配列として該時間領域内で表現される。
【０１２４】
％両方の種別の雑音は、これらの配列を要素の観点で追加することにより同時に使用可能になる。
【０１２５】
％（ｃ）２０００－２００１　ＫＰＮリサーチ
％

％デモ関数
％ＤｅｍｏＸｔａｌｋＮｏｉｓｅ　－連続雑音を作成するプロセスを示す
％ＤｅｍｏＩｎｇｒｅｓｓＮｏｉｓｅ　－離散雑音を作成するプロセスを示す
％
％主関数：雑音は、乱数を含む配列として表現される。
【０１２６】
％ＤｅｆｉｎｅＳｈａｐｅ　－全てのユーザによって定義可能なパラメータを初期化する
％ＣｒｅａｔｅＮｏｉｓｅＣｏｎｔ　－連続雑音を生成する
％ＣｒｅａｔｅＮｏｉｓｅＤｉｓｃｒ＿Ｆａｓｔ　－離散雑音を生成、高速アルゴリズム
％ＣｒｅａｔｅＮｏｉｓｅＤｉｓｃｒ＿Ｓｌｏｗ　－離散雑音を生成、低速アルゴリズム
％ＦｒｅｑｕｅｎｃｙＳｈａｐｅ　－連続雑音のスペクトル密度を修正する
％ＡｍｐｌｉｔｕｄｅＳｈａｐｅ　－連続雑音の振幅分布を修正する
【０１２７】
％
％サポート関数：
％ＣａｌｃＳｐｅｃ　－雑音の該スペクトル密度を計算する
％ＣａｌｃＮＢＳＶ　－雑音の該狭帯域信号電圧を計算する
％ＣａｌｃＣｒｅｓｔ　－雑音の該波高因子を計算する
％ＣａｌｃＤｉｓｔｒｉｂ　－雑音の該確率分布を計算する
％ＣａｌｃＣｕｍＤｉｓｔｒｉｂ　－雑音の該累加分布を計算する
％ＣａｌｃＳｍｏｏｔｈ　－本物のスペクトルアナライザにおいてのようにスペクトルを平滑化する
％ＣａｌｃＥｎｈａｎｃｅｄＧａｕｓｓＤｉｓｔｒｉｂｕｔｉｏｎ　－近ガウス分布のサンプル
％ＣａｌｃＤｅｍｏｄｕｌａｔｉｏｎ　－搬送波で変調された該雑音を計算する
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
Ｓｈａｐｅ＝ＤｅｆｉｎｅＳｈａｐｅ；
ＤｅｍｏＸｔａｌｋＮｏｉｓｅ（Ｓｈａｐｅ）；
ＤｅｍｏＩｎｇｒｅｓｓＮｏｉｓｅ（Ｓｈａｐｅ）；
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
関数［Ｕ，ｔ］＝ＤｅｍｏＸｔａｌｋＮｏｉｓｅ（Ｓｈａｐｅ）；
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
％連続スペクトルを用いた雑音の該生成を証明する
【０１２８】
％例えば、漏話試験用
Ｒ＝Ｓｈａｐｅ．Ｒ；
ＣＦ＿ｍｉｎ＝Ｓｈａｐｅ．Ｘｔａｌｋ．ＣＲ＿ｍｉｎ；
［Ｕ，ｔ］＝ＣｒｅａｔｅＮｏｉｓｅＣｏｎｔ（Ｓｈａｐｅ）；ｐｌｏｔ（ｔ，Ｕ）；
ｔｉｔｌｅ（Ｘ‘ｔａｌｋｍｅｔｈｏｄ１’）；ｓｈｇ；ｐａｕｓｅ
［Ｘ，ｆ］＝ＣａｌｃＳｐｅｃ（Ｕ，ｔ）；ｐｌｏｔ（ｆ，Ｘ）；　ｔｉｔｌｅ（‘Ｘｔａｌｋｍｅｔｈｏ１’）；ｓｈｇ；ｐａｕｓｅ
［Ｘ，ｆ］＝ＣａｌｃＳｐｅｃ（Ｕ，ｔ）；ｐｌｏｔ（ｆ，ｄＢｍ（Ｘ，Ｒ））；　ｔｉｔｌｅ（‘Ｘｔａｌｋｍｅｔｈｏｄ１’）；ｓｈｇ；ｐａｕｓｅ
［Ｐ，ｕ］＝ＣａｌｃＣｕｍＤｉｓｔｒｉｂ（Ｕ）；ｐｌｏｔ（ｕ，Ｐ）；　ｔｉｔｌｅ（‘Ｘｔａｌｋｍｅｔｈｏｄ１’）；ｓｈｇ；ｐａｕｓｅ
【０１２９】
％
Ｕ＝ＡｍｐｌｉｔｕｄｅＳｈａｐｅ（Ｕ，Ｓｈａｐｅ）；ｐｌｏｔ（ｔ、Ｕ）；　ｔｉｔｌｅ（‘Ｘｔａｌｋｍｅｔｈｏｄ２’）；ｓｈｇ；ｐａｕｓｅ
［Ｘ，ｆ］＝ＣａｌｃＳｐｅｃ（Ｕ，ｔ）；ｐｌｏｔ（ｆ，Ｘ）　ｔｉｔｌｅ（‘Ｘｔａ

lkmethod2');shg;pause
[X, f]=CalcSpec(U, t);plot(f, dBm(X, R)) title('Xtalkmethod2');shg;pause
[P, u]=CalcCumDistrb(U);plot(u, P); title('Xtalkmethod2');shg;pause

【0130】

%
U=FrequencyShape(U, Shape);plot(t, U); title('Xtalkmethod3');shg;pause
[X, f]=CalcSpec(U, t);plot(f, X) title('Xtalkmethod3');shg;pause
[X, f]=CalcSpec(U, t);plot(f, dBm(X, R)) title('Xtalkmethod3');shg;pause
[P, u]=CalcCumDistrib(U);plot(u, P); title('Xtalkmethod3');shg;pause

【0131】

%
for i=2:10
i
U=AmplitudeShape(U, Shape);
[X, f]=CalcSpec(U, t);
%
U=FrequencyShape(U, Shape);
[X, f]=CalcSpec(U, t);
%
ifCalcCrest(U)>CF_min, break;end;
end;
[P, u]=CalcCumDistrib(U);
plot(t, U); title('Xtalkmethod4');shg;%pause
plot(f, dBm(X, R)); ('Xtalkmethod4');shg;%pause
plot(u, P); ('Xtalkmethod4');shg;%pause

【0132】

%―――――――――――――――――――――――――――――――
関数[U, t]=DemonIngressNoise(Shape);
%―――――――――――――――――――――――――――――――
%例えば、進入試験のために、離散スペクトルを有する雑音の該生成を証明する
R=Shape.R;
[U, t]=CreateNoiseDiscr_Fast(Shape)
%[U, t]=CreateNoiseDiscr_Slow(Shape):%givessameresult
[X, f]=CalcNBSV(U, t);plot(f, dBm(X, R));title('Ingressmethod');shg;pauseforToneNr=[1:2]
[Usac, Uac_rms]=CaclDemodulation(U, t, Shape, ToneNr):
plot(t, Uac);title('demodulated ingress noise of one carrier');shg;pause
[P, u]=CalcDistrib(Uac/Uac_rms):

ｐｌｏｔ（ｕ，Ｐ）；ｔｉｔｌｅ（‘ｄｉｓｔｒｉｂｕｔｉｏｎ　ｏｆ　ｄｅｍｏｄｎｏｉｓｅ’）；ｓｈｇ；ｐａｕｓｅ
ｅｎｄ；
【０１３３】
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
関数［Ｓｈａｐｅ］＝ＤｅｆｉｎｅＳｈａｐｅ；
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
％－スペクトル密度（この例では、本質的に方形波）
％－確率分布（この例では、ガウス近く）
％－トーン及び変調
％－平方根あたりのボルト単位のスペクトル（Ｈｚ）
に関して、生成されなければならない雑音のノイズプロファイルを作成する。
【０１３４】
【数８】

```
Fmax=4E6; Fl=300E3; Fh=700E3; N=2^18;  R=135;
cf=5.5;          %所望の波高因子係数)
cf_min=5.1;  %所望の波高因子係数)
m=N/2;
```

【０１３５】
％
Ｓｈａｐｅ．Ｎ＝Ｎ；　％時間サンプルの数
Ｓｈａｐｅ．ｍ＝ｍ；　％周波数サンプルの数
Ｓｈａｐｅ．ｄＦ＝Ｆｍａｘ．／（ｍ－１）　％周波数間隔
Ｓｈａｐｅ．ｄＴ＝１／（Ｎ＊Ｓｈａｐｅ．ｄＦ）；　％時間間隔
Ｓｈａｐｅ．Ｒ＝Ｒ；　％所望される雑音源のインピーダンス
％漏話雑音ターゲットを定める（スペクトル密度及び振幅分布）
【０１３６】
【数９】

```
Shape.Xtalk.freq =[0:m-1]' * Shape.dF;
Shape.Xtalk.spec =(Shape.Xtalk.freq>=Fl).*(Shape.Xtalk.freq<=Fh)*(1/300);
Shape.Xtalk.DistU = 0:cf/1000:cf;
Shape.Xtalk.DistP = CalcEnhancedGaussDistribution(Shape.Xtalk.DistU, cf); %P
Shape.Xtalk.CF_min=cf_min;
% define ingress noise target (RFI-Tones)
P_dBm =[-70;-50;-60;-60;-40;-60;-60;-40;-70;-40]; % dBm @ 135 ohm
P=(10).^(P_dBm/10)*1E-3;
Shape.Ingress.ToneU =sqrt(P*135);                % U=sqrt(P*R); effective value
Shape.Ingress.ToneF =[99;207;333;387;531;603;711;801;909;981]*1E3;
Shape.Ingress.ModDepth = 0.32*ones(10,1);%=mod index > 0.8, at CF>2.5 )
Shape.Ingress.ModWidth = 2*4.5E3*ones(10,1);   %= -10 kHz .. +10 kHz)
```

【０１３７】
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
関数［Ｕ，ｔ］＝ＣｒｅａｔｅＮｏｉｓｅＣｏｎｔ（Ｓｈａｐｅ）；
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
％所定の周波数領域特性（スペクトル）であるが、制御されていない時間領域特性（分布）で雑音電圧Ｕ（ｔ）を作成する
Ｎ＝Ｓｈａｐｅ．Ｎ；　％生成されるサンプル数
％Ｕ＝ｒａｎｄ（Ｎ，１）；　％均一分散白色雑音
Ｕ＝ｒａｄｎ（Ｎ，１）；　％ガウス分散白色雑音
Ｕ＝ＦｒｅｑｕｅｎｃｙＳｈａｐｅ（Ｕ，Ｓｈａｐｅ）；　％波形整形された雑音
ｔ＝［０：Ｎ－１］‘＊Ｓｈａｐｅ．ｄＴ；　％関連時間軸
【０１３８】
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
関数［Ｕ，ｔ］＝ＣｒｅａｔｅＮｏｉｓｅＤｉｓｃｒ＿Ｆａｓｔ（Ｓｈａｐｅ）；
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
％ＡＭ変調された搬送波（ＲＦＩトーン）で電圧Ｕ（ｔ）を作成する。それぞれが、個々の所定の周波数、振幅、変調幅及び変調深度を有する。各搬送波トーンの下方側波帯の無作為な位相は、任意ＱＡＭ変調を、さらに制限されたＡＭ変調（完全ミラーリング）に（ミラーリングなしに）変換するためにミラー化される。
【０１３９】
％このアルゴリズム内でＸは、該（近高調波）進入雑音信号の該フーリエ級数の該成分を指すが、それは（擬似ランダム）漏話雑音信号のケースではスペクトル密度を指す。
【０１４０】
％計算時間は、サンプルの数に伴ないほぼ線形に増加する。
全計算時間の約８０％は、フーリエ逆変換により引き起こされる。
【０１４１】
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
Ｎ＝Ｓｈａｐｅ．Ｎ；　％サンプルの数
ｍ＝Ｓｈａｐｅ．ｍ；　％この数の半分
Ｎｃ＝ｒｏｕｎｄ（Ｓｈａｐｅ．ＩＮｇｒｅｓｓ．ＴｏｎｅＦ／Ｓｈａｐｅ．ｄＦ）＋１；　％搬送波周波数の指数（正のみ）

Ｎｍ＝ｒｏｕｎｄ（Ｓｈａｐｅ．Ｉｎｇｒｅｓｓ．Ｍｏｄｗｉｄｔｈ／Ｓｈａｐｅ．ｄＦ／２）；　％変調成分の数
Ｘｃ＝０．５＊Ｓｈａｐｅ．ＩＮｇｒｅｓ．Ｔｏｎｅ．Ｕ；％搬送波振幅の振幅
Ｘｍ＝Ｓｈａｐｅ．Ｉｎｇｒｅｓｓ．ＭｏｄＤｅｐｔｈ．＊Ｘｃ．／ｓｑｒｔ（２＊Ｎｍ）；　％変調バンドの振幅

【０１４２】
Ｘ＝ｚｅｒｏｓ（Ｎ，１）；　％初期化
Ｘｃ＝Ｘｃ．＊ｅｘｐ（ｊ＊１０００＊ｒａｎｄ（ｓｉｚｅ（Ｘｃ）））；％無作為搬送波位相
Ｘｃｃ＝（Ｘｃ．＊Ｘｃ）．／ａｂｓ（Ｘｃ．＊Ｘｃ）；
ｆｏｒ　ｋ＝１：ｌｅｎｇｔｈ（Ｎｃ）％全変調済み搬送波について、以下を実行する：
Ｎｍｐ＝Ｎｃ（ｋ）＋［１：Ｎｍ（ｋ）］‘；％上方側波帯周波数の位置を突き止める
Ｎｍｎ＝Ｎｃ（ｋ）－［１：Ｎｍ（ｋ）］‘；　％上方側波帯周波数の位置を突き止める
Ｘｍｐ＝Ｘｍ（ｋ）．＊ｅｘｐ（ｊ＊１０００＊ｒａｎｄ（ｓｉｚｅ（Ｎｍｐ）））；
％上方側波帯を作成する

【０１４３】
Ｘｍｎ＝ｃｏｎｊ（Ｘｍｐ）＊Ｘｃｃ（ｋ）；　％下方側波帯をミラー化する
Ｘ（Ｎｍｐ）＝Ｘｍｐ；　％上方側波帯を挿入する
Ｘ（Ｎｍｎ）＝Ｘｍｎ；　％下方側波帯を挿入する
ｅｎｄ；
Ｘ（Ｎｃ）＝Ｘｃ；　％全ての搬送波を挿入する
Ｘ（Ｎ：－１；ｍ＋２）＝ｃｏｎｊ（Ｘ（２：ｃｅｅｉｌ（ｍ）））；％スペクトルを付加する

【０１４４】
％（負の周波数）
％Ｕ＝ｒｅａｌ（ｉｆｆｔ（Ｘ））＊Ｎ；　％時間領域に変換する
Ｕ＝ｒｅａｌ（ｆｆｔ（Ｘ））；　％時間領域に変換する
％（１０％高速）
ｔ＝Ｓｈａｐｅ．ｄＴ＊［０：Ｎ－１］；　％関連時間軸
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
関数［Ｕ，ｔ］＝ＣｒｅａｔｅＮｏｉｓｅＤｉｓｃｒ＿Ｓｌｏｗ（Ｓｈａｐｅ）；
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
％所定の周波数でのＲＦＩトーン、振幅と変調帯域幅、及び変調深度で、電圧Ｕ（ｔ）を作成する。

【０１４５】
このアルゴリズムは単純で、非常に効率的であり、証明目的専用である。
それは、ＣｒｅａｔＮｏｉｓｅＤｉｓｃｒ＿Ｆａｓｔが同じ結果を戻すことを証明できる。
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
Ｎ＝Ｓｈａｐｅ．Ｎ；　％生成されるサンプルの数
ｍ＝Ｓｈａｐｅ．ｍ；
ｆ＝［０：Ｎ－１］‘＊Ｓｈａｐｅ．ｄＦ；
ｔ＝［０：Ｎ－１］‘＊Ｓｈａｐｅ．ｄＴ；
Ｆｃ＝Ｓｈａｐｅ．Ｉｎｇｒｅｓｓ．ＴｏｎｅＦ；
Ｆｃ＝Ｓｈａｐｅ．ｄＦ＊ｒｏｕｎｄ（Ｆｃ／Ｓｈａｐｅ．ｄＦ）；　％期間に整数を強制する

【０１４６】
％
Ｕ＝０；
ｆｏｒｋ＝１：ｌｅｎｇｔｈ（Ｓｈａｐｅ．Ｉｎｇｒｅｓｓ．ＴｏｎｅＦ）；

%］－ｃｒｅａｔｅ　ｎｏｉｓｙ　ｍｏｄｕｌａｔｅ，　ｈａｖｉｎｇＵ＿ａｖｇ＝０ａｎｄＵ＿ｒｍｓ＝１．
Ｎｍ＝ｒｏｕｎｄ（Ｓｈａｐｅ．Ｉｎｇｒｅｓｓ．ＭｏｄＷｉｄｔｈ（ｋ）／Ｓｈａｐｅ．ｄＦ／２）；
Ｘｎ０＝（［１：Ｎ］＜＝（Ｎｍ＋１）　%変調雑音振幅を波形整形する
Ｘｎ＝Ｘｎ０．＊ｅｘｐ（ｊ＊１０００＊ｒａｎｄ（Ｎ，１））；　%変調雑音位相を波形整形する
Ｘｎ（１）＝０；　%ＤＣ成分を排除する
Ｘｎ（Ｎ：－１ｍ＋２）＝ｃｏｎｊ（Ｘｎ（２：ｃｅｉｌ（ｍ）））：　%スペクトルを付加する（負の周波数）
【０１４７】
Ｎｏｉｓｅ＝ｒｅａｌ（ｉｆｆｔ（Ｘｎ））；　%時間領域に変換する
Ｎｏｉｓｅ＝Ｎｏｉｓｅ／ｓｑｒｔ（ｓｕｍ（Ｎｏｉｓｅ．＊Ｎｏｉｓｅ）／Ｎ）　%ｒｍｓ＝１を強制する
%－－変調を実行する
Ｃａｒｒｉｅｒ＝Ｓｈａｐｅ．Ｉｎｇｒｅｓｓ．ＴｏｎｅＵ（ｋ）　＊ｃｏｓ（２＊ｐｉ＋Ｆｃ（ｋ）＊ｔ＋１０００＊ｒａｎｄ）；
Ｍｏｄｕｌａｔｅ＝Ｓｈａｐｅ．Ｉｎｇｒｅｓｓ．ＭｏｄＤｅｐｔｈ（ｋ）＊Ｎｏｉｓｅ；
Ｕ＝Ｕ＋Ｃａｒｒｉｅｒ．＊（１＋Ｍｏｄｕｌａｔｅ）；
ｅｎｄ；
【０１４８】
%－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
関数［Ｕ］＝ＦｒｅｑｕｅｎｃｙＳｈａｐｅ（Ｕ，Ｓｈａｐｅ）
%－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
%ターゲット波形整形により指定されるように、サンプルＵのスペクトルを整形し直す
%入力
%Ｕ：　サンプルの連続値
%ｆｓ：　同じ周波数
%スペクトル：　所望のＰＳＤ（Ｖ／ｓｑｒｔ（Ｈｚ）単位）
【０１４９】
%－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
Ｎ＝ｌｅｎｇｔｈ（Ｕ）；
ｍ＝ｌｅｎｇｔｈ（Ｓｈａｐｅ．Ｘｔａｌｋ．ｓｐｅｃ）；　%ｍ＝Ｎ／２
ｔ＝［０：Ｎ－１］‘＊Ｓｈａｐｅ．ｄＴ；
%周波数基準化を実行する
Ｓｃａｌｉｎｇ＝Ｓｈａｐｅ．Ｘｔａｌｋ．ｓｐｅｃ．／Ｃａｌｃｐｅｃ（Ｕ，ｔ）；
Ｘ＝ｆｆｔ（Ｕ）；　%周波数領域に変換する
Ｘ（１）＝０；　%ＤＣ成分を排除する
Ｘ（２：ｍ＋１）＝Ｘ（２：ｍ＋１）．＊Ｓｃａｌｉｎｇ；　%スペクトルを基準化する（正の周波数）
Ｘ（Ｎ：－１：ｍ＋２）＝ｃｏｎｊ（Ｘ（２：ｃｅｉｌ（ｍ）））；　%スペクトルを付加する（負の周波数）
Ｕ＝ｒｅａｌ（ｉｆｆｔ（Ｘ））；　%時間領域に変換する
%－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
関数［Ｕ］＝ＡｍｐｌｉｔｕｄｅＳｈａｐｅ（Ｕ，Ｓｈａｐｅ）
%－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－　%
この関数は、関数Ｕの該振幅分布を振幅に依存する（非線形）歪み関数Ｑ（ｘ）で波形整形する。結果はＵ（ｔ）＝Ｑ｛Ｕ（ｔ）｝である。
【０１５０】

％
％ＦＦを該サンプルの実際の累積分布関数とし、ＧＧを所望の累積分布関数とすると、該歪み関数は、以下により示される。
【０１５１】
【数１０】

% Q(x) = GG^{-1} FF (x)

【０１５２】
Ｕ０＝ｓｑｒｔ（ｓｕｍ（Ｕ．＊Ｕ）／ｌｅｎｇｔｈ（Ｕ））；　％基準化ｆａｒｃｔ（正規化用）
％該歪み関数Ｑを計算する
［ＤｉｓｔＰ１，ＤｉｓｔＵ１］＝ＣａｌｃＣｕｍＤｉｓｔｒｉｂ（Ｕ／Ｕ０）；　％実際の分布
Ｑ＝ｉｎｔｅｒｐ１（Ｓｈａｐｅ．Ｘｔａｌｋ．ＤｉｓｔＰ，Ｓｈａｐｅ．Ｘｔａｌｋ．ＤｉｓｔＵ，ＤｉｓｔＰ１）；　％歪み関数
Ｕ＝Ｕ０＊ｉｎｔｅｒｐ１（ＤｉｓｔＵ１，Ｑ，ａｂｓ（Ｕ／Ｕ０））．＊ｓｉｇｎ（Ｕ）　％歪みを実行する
【０１５３】
ｐｌｏｔ（ＤｉｓｔＵ１，Ｑ）；ｓｈｇ；％ｐａｕｓｅ
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
％関数［Ｘ，ｆ］＝ＣａｌｃＳｐｅｃ（Ｕ，ｔ）；
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
％信号の該スペクトル密度を、それが指定解像度帯域幅で「測定される」ときに計算する。
【０１５４】
ＲＢＷ＝１５３　％ＲＢＷ：Ｕのスペクトルの所望解像度
Ｎ＝ｌｅｎｇｔｈ（Ｕ）；ｍ＝Ｎ／２；
ｄＴ＝ｔ（２）－ｔ（１）；　％時間間隔
ｄＦ＝１／ｄｔ／Ｎ；　％周波数間隔
ｆ＝［０：ｍ－１］‘＊ｄＦ　％全ての正の周波数
Ｘ＝ｆｆｔ（Ｕ）＊ｄＴ；　％周波数領域へ
Ｘ＝ａｂｓ（Ｘ（２：ｍ＋１））；　％ＤＣなし、負の周波数なし
Ｘ＝ｓｑｒｔ（ＣａｌｃＳｍｏｏｔｈ（Ｘ．＊Ｘ，ｆ，ＲＢＷ））；　％帯域幅ＲＢＷでそれを平均化する
【０１５５】
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
関数［Ｘ，ｆ］＝ＣａｌｃＮＢＳＶ（Ｕ，ｔ）；
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
％信号の狭帯域信号電圧を、それが指定の解像度帯域幅で「測定される」ときに計算する。
【０１５６】
ＲＢＷ＝１Ｅ３　％ＲＢＷ：Ｕのスペクトルの所望解像度
Ｎ＝ｌｅｎｇｔｈ（Ｕ）；ｍ＝Ｎ／２；
ｄＴ＝ｔ（２）－ｔ（１）　％時間間隔
ｄＦ＝１／ｄＴ／Ｎ；　％周波数間隔
ｆ＝［０：ｍ－１］‘＊ｄｆ　％全ての正の周波数
％Ｘ＝ｆｆｔ（Ｕ）＊ｄＴ＊ｓｑｒｔ（ｄＦ）；　％周波数領域へ
％Ｘｆｆｔ（Ｕ）／Ｎ；　％周波数領域へ

Ｘ＝ｆｆｔ（Ｕ）／Ｎ＊２；　％周波数領域へ
Ｘ＝ａｂｓ（Ｘ（２：ｍ＋１））；　％ＤＣなし、負の周波数なし
％Ｘ＝ｓｑｒｔ（ＣａｌｃＳｍｏｏｔｈ（Ｘ．＊Ｘ，ｆ，ＲＢＷ））；　帯域幅ＲＢＷでそれを平均化する
【０１５７】
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
関数［ＣＦ］＝ＣａｌｃＣｒｅｓｔ（Ｕ）
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
％ｒｍｓ－値で除算されるピーク値である、信号（Ｕ（ｔ）の波高因子を計算する。
【０１５８】
【数１１】

```
Urms = sqrt(sum(U.^2)/length(U));
Upeak = max(abs(U));
CF = Upeak/Urms;
```

【０１５９】
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
関数［Ｆ］＝ＣａｌｃＥｎｈａｎｃｅｄＧａｕｓｓＤｉｓｔｒｉｂｕｔｉｏｎ（ｘ，Ｃｆ）；
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
％機能拡張ガウス分布として定義される蓄積ガウス分布関数Ｆ（ｘ）を生成する。
％Ｃｆ＝波高因子
【０１６０】
【数１２】

```
Alpha = 1e-3;
Sigma = sqrt( (1+Alpha) - Cf^2 * Alpha/3);
x = x .* (x>0) .* ( x<Cf) + Cf * (x>=Cf);
denominator = Alpha + erf(Cf/(sqrt(2)*Sigma));
F = 1 - (Alpha * x/Cf + erf(x/(sqrt(2)*Sigma)))/denominator;
```

【０１６１】
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
関数［ＤｉｓｔＰ，ＤｉｓｔＵ，Ｐ］＝ＣａｌｃＤｉｓｔｒｉｂ（Ｕ）
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
％信号Ｕの振幅分布を計算する。
【０１６２】
Ｎ＝ｌｅｎｇｔｈ（Ｕ）；
Ｎｂｉｎｓ＝１００；
［ｃｕｍｂｉｎ，ｘｘ］＝ｈｉｓｔ（Ｕ，Ｎｂｉｎｓ）；
ｄＸ＝ｘｘ（３）－ｘｘ（２）；
ＤｉｓｔＰ＝ｃｕｍｂｉｎ（：）／ＮｄＸ　％ｓｕｍ（ＤｉｓｔＰ）＊ｄＸを強制する
【０１６３】
【数１３】

```
DistU = xx(:);
Urms=sqrt(sum(U.*U)/N);
P=exp(-0.5*(DistU/Urms).^2); P=P/sum(P)/dX;
DistU=[DistU,DistU];
DistP=[DistP,P];
```

【０１６４】
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
関数［ＤｉｓｔＰ，ＤｉｓｔＵ］＝ＣａｌｃＣｕｍＤｉｓｔｒｉｂ（Ｕ）
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
％信号Ｕの（逆方向）累積振幅分布を計算する
ｌｅｎ＝ｌｅｎｇｔｈ（Ｕ）；
％－－分布関数を評価する
Ｕ＝ａｂｓ（Ｕ／Ｕｅｆｆ）；
【０１６５】
％関数を評価する
Ｎｂｉｎｓ＝ｍｉｎ（［５０，ｆｌｏｏｒ（ｌｅｎ／１０）］）；
［ｃｕｍｂｉｎ，ｘｘ］＝ｈｉｓｔ（Ｕ，Ｎｂｉｎｓ）：
ＢｉｎＷｉｄｔｈ＝ｘｘ（２）－ｘｘ（１）；
ＤｉｓｔＵ＝ｘｘ－ＢｉｎＷｉｄｔｈ／２；％ｓｈｉｆｔ
ｆｏｒ　ｎ＝［Ｎｂｉｎｓ－１：－１：１］；　ｃｕｍｂｉｎ（ｎ）＝ｃｕｍｂｉｎ（ｎ）＋ｃｕｍｂｉｎ（ｎ＋１）；ｅｎｄ
ＤｉｓｔＰ＝ｃｕｍｂｉｎ／ｌｅｎｓ；
％－－他のルーチンのために、それらがこの結果を使用するときに、数値安定性を改善する。
【０１６６】
ＤｉｓｔＵ＝［０，ＤｉｓｔＵ（２：ｅｎｄ）］；　％ｘ＝０で開始する
ＤｉｓｔＰ＝［ＤｉｓｔＰ，１／ｌｅｎ］；
ＤｉｓｔＵ＝［ＤｉｓｔＵ，ｘｘ（Ｎｂｉｎｓ）＋０．９９９＊ＢｉｎＷｉｄｔｈ／２］：　％最終（単一）ポイントを追加する
ＤｉｓｔＰ＝［ＤｉｓｔＰ，ｌｅ－１００］；
ＤｉｓｔＵ＝［ＤｉｓｔＵ，ｘｘ（Ｎｂｉｎｓ）＋（１．００１）＊ＢｉｎＷｉｄｔｈ／２］；　％安定性のための係数１．００１
【０１６７】
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
関数［ＰＳＤ，ｆｒｅｑ］＝ＣａｌｃＳｍｏｏｔｈ（ＰＳＤ，ｆｒｅｑ．ＲＢＷ）
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
％有限解像度帯域幅、及びガウス波形整形済み帯域フィルタで、本物のスペクトルアナライザを模倣する。
【０１６８】
％ＰＳＤ＝「スペクトル密度」のｄｅ　ｓｑｕａｒｅである「電力スペクトル密度」。平方ヘルツあたりボルト単位。
【０１６９】
％
Ｎ＝ｌｅｎｇｔｈ（ＰＳＤ）；
ｄｆ＝ｆｒｅｑ（２）－ｆｒｅｑ（１）；

ｂｒ＝３＊ｆｌｏｏｒ（ＲＢＷ／ｄｆ）；
ｆａｃｔｏｒ＝２＊ｂｒ＋１；
ｉｆ（ｆａｃｔｏｒ＞１）
．．ｆｆ＝ｄｆ＊（－ｂｒ：ｂｒ）；　％平滑化間隔
【０１７０】
【数１４】

..mask = exp(-ff.*ff/(2*RBW^2));

【０１７１】
．．ｍａｓｋ＝ｍａｓｋ／ｓｕｍ（ｍａｓｋ）；　％解像度帯域フィルタのガウスマスク
．．ｘｈｅｌｐ＝［ＰＳＤ；ｚｅｒｏｓ（２＊ｂｒ，１）］；
１ｐ＝ｆｉｌｔｅｒ（ｍａｓｋ，１，ｘｈｕｌｐ）；　％スマートな畳み込み
ＰＳＤ＝ｙｈｅｌｐ（ｂｒ＋１：ｅｎｄ－ｂｒ）；
ｅｎｄ
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
関数［Ｕａｃ，Ｕａｃ＿ｒｍｓ］＝ＣａｌｃＤｅｍｏｄｕｌａｔｉｏｎ（ｕ，ｔ，Ｓｈａｐｅ，ＴｏｎｅｒＮｒ）；
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
％離散雑音の搬送波で変調された雑音を復調する。それは、離散雑音が該所定のパラメータを満たすことを証明するためだけの証明目的用である。
【０１７２】
％
％復調器は、同相にロックされない同期検出を使用する
％結果は、完全復調バンド上での未知の減衰である
％これは、ＤＣレベルを測定することによって後に補正される。そして、このＤＣレベルが１ボルトに正規化されるまで復調された信号を増幅する。
【０１７３】
％
％証拠（ｐｓｉは未知である）
ｌｅｔ　Ｕｒｆ＝ｃｏｓ（ｗ＊ｔ＋ｐｓｉ）＊（１＋Ｕａｃ）；　％＝「１＋Ｕａｃ」で変調された搬送波
Ｕｃ＝ｃｏｓ（ｗ＊ｔ）；　％＝搬送波
Ｕｄ＝Ｕｒｆ＊Ｕｃ；　％＝同期検出信号
％ｔｈｅｎＵｄ＝１／２＊（ｃｏｓ（ｐｓｉ＋２＊ｗ＊ｔ）＋ｃｏｓ（ｐｓｉ））＊（１＋Ｕａｃ）；
Ｕｌｆ＝ｃｏｓ（ｐｓｉ）／２；（１＋Ｕａｃ）；　％低域濾波後
Ｕｄｃ＝ｃｏｓ（ｐｓｉ）／２；　％＝Ｕｌｆを平均化することによる
％Ｕａｃ＝（Ｕｌｆ／Ｕｄｃ）－１；
【０１７４】
％－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－－
Ｎ＝Ｓｈａｐｅ．Ｎ；
Ｆｃ＝Ｓｈａｐｅ．Ｉｎｇｒｅｓｓ．ＴｏｎｅＦ（ＴｏｎｅＮｒ）；　％搬送波周波数を選択する
Ｆｃ＝Ｓｈａｐｅ．ｄＦ＊ｒｏｕｎｄ（Ｆｃ／Ｓｈａｐｅ．ｄＦ）；　％期間の整数を強制する
ＭｏｄＷｉｄｔｈ＝Ｓｈａｐｅ．Ｉｎｇｒｅｓｓ．ＭｏｄＷｉｄｔｈ（ＴｏｎｅＮｒ）；
ＭｏｄＤｅｐｔｈ＝Ｓｈａｐｅ．Ｉｎｇｒｅｓｓ．ＭｏｄＤｅｐｔｈ（ＴｏｎｅＮｒ）；
【０１７５】

%
Ｕｄ＝Ｕ．＊ｃｏｓ（２＊ｐｉ＊Ｆｃ＊ｔ）；　％変調済み搬送波の同期検出
Ｎｍ＝ｒｏｕｎｄ（１．１＊ＭｏｄＷｉｄｔｈ／Ｓｈａｐｅ．ｄＦ／２）；　％フィルタ周波数を計算する
ｍａｓｋ＝ｚｅｒｏｓ（Ｎ，１）；ｍａｓｋ（［１：Ｎｍ，Ｎ－Ｎｍ：Ｎ］）＝１　％フィルタを作成する
Ｕ１ｆ＝ｒｅａｌ（ｉｆｆｔ（ｆｆｔ（Ｕｄ）．＊ｍａｓｋ））；　％低域濾波を実行するる
Ｕｄｃ＝ｓｕｍ（Ｕｌｆ）／Ｎ；　％正規化していないＤＣレベルを見つける
Ｕａｃ＝Ｕｌｆ／Ｕｄｃ－１；　％全レベルを正規化し、ＤＣを削除する
【０１７６】
%
Ｕａｃ＿ｒｍｓ＝ｓｑｒｔ（ｓｕｍ（Ｕａｃ．＊Ｕａｃ／Ｎ））；　％Ｕｄｃ＝１であるため、ＭｏｄＤｅｐｔｈに等しくなくてはならない
Ｓｃａｌｅ＝Ｕａｃ＿ｒｍｓ／ＭｏｄＤｅｐｔｈ；　％「１」でなければならない
【図面の簡単な説明】
【図１】
図１はブロック図で、通信システムにおける、本発明の該方法に従って動作する障害ジェネレータを使用する性能試験のためのセットアップを示す。
【図２】
図２は本発明による該方法の実施形態の流れ図種類を示す。
【図３】
図３は進入雑音を生成するための本発明による該方法のある実施形態を図解で示す。
【図４】
図４は本発明による方法の追加実施形態の流れ図を示す。
【図５】
図５は信号内の高振幅ピークまたはトーンを増幅する振幅歪み（非線形変換）関数Ｑ（ｘ）を示す。
【図６】
図６は保温発明の例の実施形態を流れ図で示す。
【図７】
図７は本発明の実施形態に従って得られる結果を示す。
【図８】
図８は本発明の実施形態に従って得られる結果を示す。
【図９】
図９は本発明の実施形態に従って得られる結果を示す。
【図１０】
図１０は本発明の実施形態に従って得られる結果を示す。
【図１１】
図１１は本発明の実施形態に従って得られる結果を示す。

【図１】

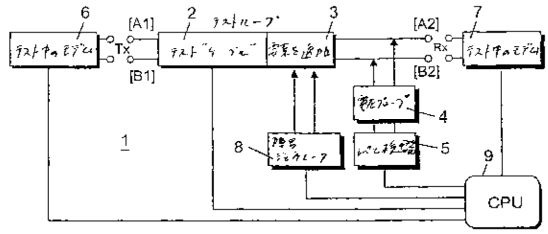



Fig. 1

【図２】

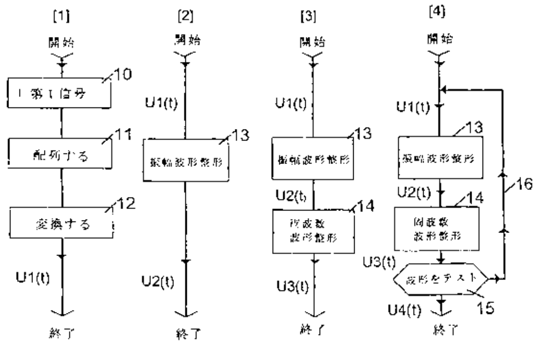



Fig. 2

【図３】

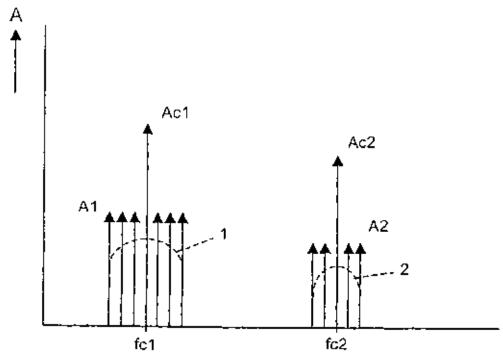



Fig. 3

【図４】

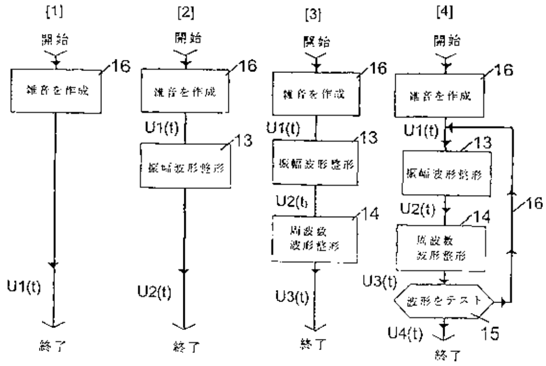



Fig. 4

【図５】

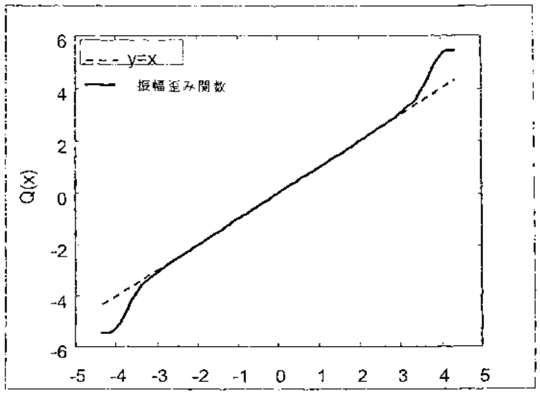



Fig. 5

【図６】

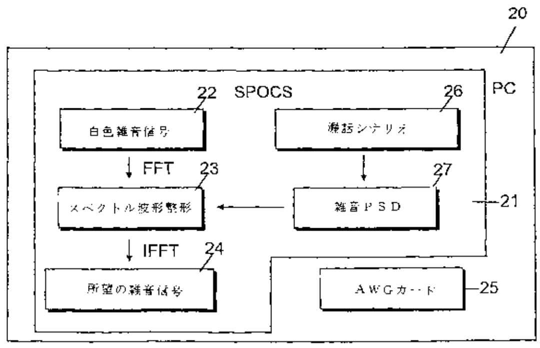



Fig. 6

【図７】

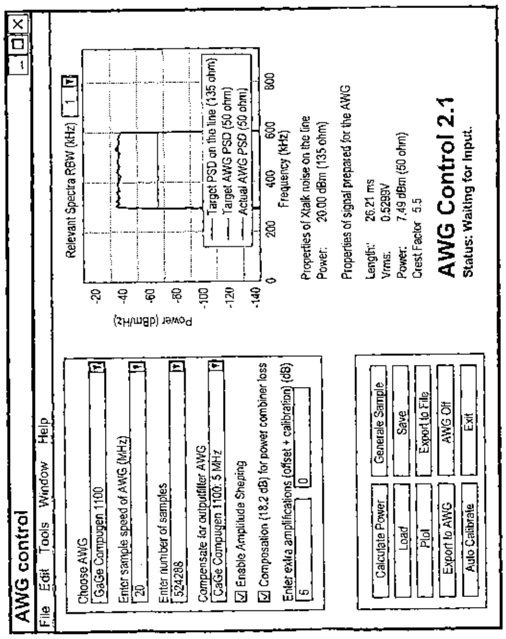



FIG. 7

【図８】

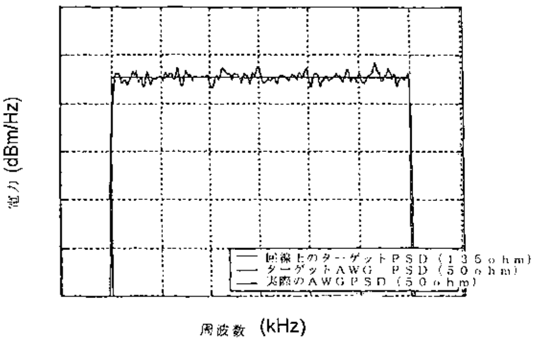



Fig. 8

【図９】

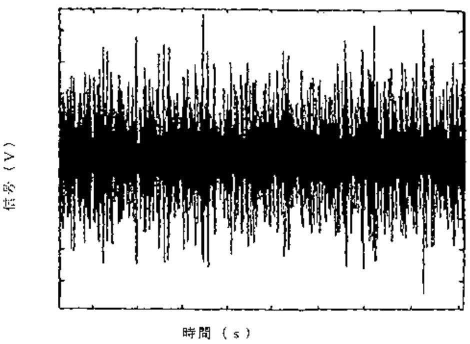



Fig. 9

【図１０】

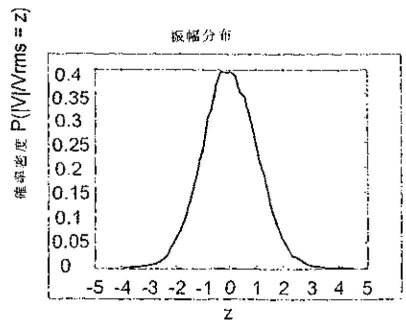



Fig. 10

【図１１】

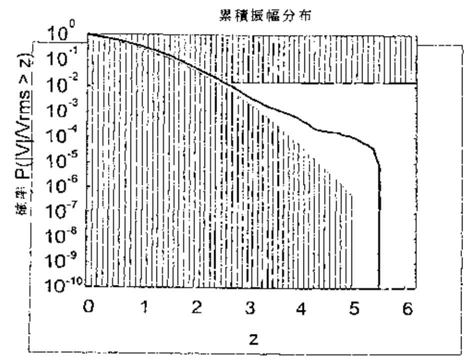



Fig. 11

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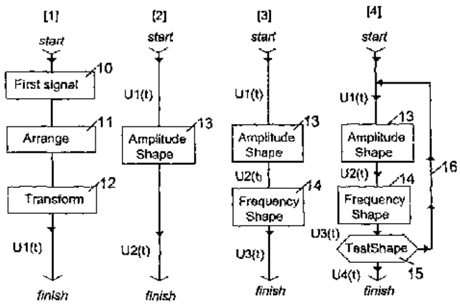
*[Continued on next page]*

(54) Title: A METHOD OF AND A DEVICE FOR GENERATING A SIGNAL HAVING A PREDETERMINED QUALITY CRITERION FOR USE IN OR ON A COMMUNICATION SYSTEM




(57) Abstract: There is disclosed a signal having a predefined quality criterion for use with a communication systems, a method of and a system for generating such a signal, a method of testing the operation of a communication system using such a signal and a (tele)communication system arranged for operating such a method. The method for generating the signal having a predefined quality the steps of: - representing a first signal (10) comprising a plurality of frequency components each having spectral amplitude and phase properties, and processing the represented signal by arranging (11) its spectral amplitude properties, and processing the represented signal by arranging (11) its spectral amplitude properties in accordance with the predefined quality criterion.

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Title

A method of and a device for generating a signal having a predetermined quality criterion for use in or on a communication system.

Field of the Invention

The present invention relates, generally, to communication systems and, more specifically, to a signal for use with a communication system, a method of and a system for generating such a signal, a method of testing the operation of a communication system using such a signal, a test system and a (tele)communication system arranged for operating such a method.

Background of the Invention

Among others, for testing communication systems and communication equipment, such as xDSL transceivers and cables or networks, test signals are needed for stressing the communication system and the communication devices in a manner that is representative to actual deployment scenarios, with large numbers of systems or system devices per cable.

By measuring the transmission performance of the system or system device under realistic (noisy) test conditions, one can improve the design of the system or devices and/or prove that their performance is compliant with standards, such as issued by ETSI, ITU or ANSI or other (tele)communication bodies.

A method of executing such performance tests is to generate a signal which is known as impairment. More specifically, impairment can be subdivided into:

(i) cross-talk noise, having a noise profile characterized by a spectral envelope and spectral amplitude distribution e.g. from neighboring xDSL systems;

(ii) ingress noise, composed of discrete frequency components, also called rfi-tones, having a noise profile characterized by a number of discrete frequency components and spectral amplitude, modulation depth and modulation width parameters originating from radio and amateur broadcasting, for example, and

(iii) impulse noise characterized by signal pulses caused by switching operations and components for example.

In the case of ingress noise, the frequency may vary (sweep) in time.

A device for generating impairment is known as an impairment generator and is arranged, in particular for use in or on communication systems, for generating at least one of said cross-talk noise and ingress noise.

In practice, for testing whether communication systems and communication devices are compliant with standards, various noise profiles have been defined which, among others, vary in accordance with system parameters such as the length and number of wire pairs in a communication cable and the transmission data rate, for example.

Further, each different type or length of a transmission medium such as a cable, a copper cable or an optical fiber or other cable type, request a different noise signal.

Methods and devices for generating noise profiles are known in the art. In particular, filtering techniques and filters are known for generating noise from an input signal providing an output signal having a particular spectral envelope and spectral amplitude distribution.

However, by using filtering techniques and filters, a causal relationship is established between the input signal and the output signal. Those skilled in the art will appreciate that such a type of signal is less suitable for a realistic imitation of real operational communication systems and communication devices.

WO 00/16181 discloses a method and a device for generating a random time domain signal approaching a predetermined histogram of amplitudes. In a first step, the signal is created by filtering a noise signal, such as a white noise signal, thereby producing a signal having a predetermined spectral envelope. In a next step, a non-linear function is applied to the filtered noise signal, so as to produce the required time domain signal approaching the predetermined histogram of amplitudes. In a further step, pulse response filtering is applied to the time domain signal, to correct its spectral envelope and to obtain an output signal having a required spectral envelope. Both, the non-linear function and the pulse response filtering function are special functions selected in accordance with the spectral envelope to be provided.

WO 00/16181 is limited in the sense that there is only provided a time domain signal only having a predetermined spectral envelope. WO 00/16181 is silent with respect to other quality criterion's to be imposed on the time domain signal to be provided, among others phase properties.

## Summary of the Invention

It is an object of the present invention to provide an improved signal for use with communication systems and communication devices, in particular for testing such systems and devices in accordance with predefined (standardized) noise profiles.

In a first aspect of the present invention, there is disclosed a method of arranging a signal having a predefined quality criterion, preferably for use in or on a communication system, the method comprising the steps of:

- representing a first signal comprising a plurality of frequency components each having spectral amplitude and phase properties, and

- processing the represented first signal by arranging the spectral amplitude properties in accordance with the or each predefined quality criterion, and arranging random phase properties.

The traditional way of modifying the envelope of a spectrum is the usage of a digital filter bank. This is far from ideal since, for the purpose of the present invention, no causal relationship between the represented first signal and the signal to be provided has to be established. This understanding of matters in accordance with the present invention simplifies the approach of frequency shaping significantly.

Starting from a first signal having random phase properties, frequency shaping of the represented first signal may be an adequate operation to provide a signal meeting the predefined quality criteria, for example. Frequency shaping in accordance with the present invention can be performed in several ways.

In an embodiment of the invention, the first signal is represented by a first set of numbers specifying a spectral amplitude and phase of each frequency component. Scaling of the spectral amplitude of each frequency component suffices to effect frequency shaping of the represented signal in the frequency domain, while maintaining the random phase properties of the signal.

In a further embodiment of the invention, the first signal is represented by a second set of complex numbers having a real part and an imaginary part, which parts in combination specify a spectral amplitude and phase of each frequency component. Frequency shaping is effected by adequately scaling the complex numbers, however such to maintain random phase properties after scaling of the represented first signal.

In a yet further embodiment of the invention, the first signal is represented by a third set of numbers each specifying an amplitude of the first signal in the time domain. By transforming this third set of numbers from the time domain into the frequency domain using, for example, a Fast Fourier Transform (FFT) algorithm, the first signal is represented by a fourth set of numbers specifying a spectral amplitude and phase of each frequency component. This fourth set of numbers can be further processed by a frequency shaping operation, as disclosed above in connection with the first set of numbers.

However, the third set of numbers may also be transformed, in accordance with the invention, from the time domain into the frequency domain for representing the first signal by a fifth set of complex numbers having a real part and an imaginary part. As disclosed above, for the purpose of frequency shaping, the fifth set of complex numbers has to be adequately scaled.

In the case of a represented first signal having non-random phase properties, random phase properties can be approached by properly arranging the second, fourth and fifth set of numbers.

Scaling in the frequency domain can be invoked by multiplication operations, using real or complex scaling factors. The scaling factor for multiplication of the spectral amplitude of a frequency component is found by dividing its desired value by its actual spectral amplitude.

In accordance with a further embodiment of the method according to the invention, in order to achieve a closer match to the or each predefined quality criterion, post-processing of the processed represented first signal is provided.

For use in or on a communications system in accordance with the present invention, however, the represented first signal thus arranged in the frequency domain has to be transformed into the time domain using, for example, an Inverse Fast Fourier Transform (IFFT) algorithm.

Further, the processing steps disclosed above may also a include operations such as convolution or deconvolution or multiplication or add-on of signals.
In the time domain, the processed represented first signal meeting the or each predefined quality criterion may be represented among others by a sixth set of numbers in the time domain.

However, with the above approach the signal provided, meeting a quality criterion in the frequency domain, such as a predefined envelope of spectral amplitudes and random phase properties, may not yet meet a quality criterion in the time domain, such as a predefined time domain amplitude distribution.

In a yet further embodiment of the method according to the invention, the or each predefined quality criterion comprises any of a group including a predefined time domain amplitude distribution and a predefined envelope of spectral amplitudes.

Accordingly, in a further embodiment of the method according to the invention, the processed represented first signal is arranged in accordance with a predefined time domain amplitude distribution.

In a still further embodiment of the method according to the invention, the processed represented first signal is arranged in accordance with a predefined envelope of spectral amplitudes.

For providing a signal which accurately meets predefined quality criteria in both the frequency and time domain, according to the invention, at least one of the time domain amplitude distribution and the envelope of spectral amplitudes is approached by an iteration process. Amplitude and frequency shaping may be repeated as often as required until both shapes meet the requirements within reasonable accuracy.

*In an embodiment of the invention, the iteration process comprises a* comparison, after any iteration step, of any of the time domain amplitude distribution and envelope of spectral amplitudes of the processed represented first signal with a predefined time domain amplitude distribution and predefined envelope of spectral amplitudes.

It has been observed that there is no need to perform a full time domain characteristic check after frequency shaping to figure out whether the time domain characteristics are close enough to the requirements. A simple check of the crest factor requirement has proven to be adequate in practice to enable the decision whether to stop or to continue with the iteration. The crest factor of the signal is defined as the relation of the maximum or peak amplitude of the tones of the signal compared to the average or rms value of the tones of the signal.

The method according to the invention as disclosed above is, in particular, suitable for generating, among others, cross-talk noise.

If a signal having the characteristics of ingress noise is to be generated, in a second aspect of the method according to the invention, the or each predefined quality criterion comprises at least one modulated carrier, the or each modulated carrier including any of a group comprised of a carrier frequency, a carrier amplitude, a modulation depth, and a modulation width.

By shaping the represented first signal in accordance with a quality criterion or quality criteria indicated above, a signal representing a particular type of ingress noise, having a particular time domain amplitude distribution, and a predefined envelope of spectral amplitudes can be easily and very efficiently provided.

In accordance with the method of the present invention, the signal meeting the or each predefined quality criterion can be provided by combining a plurality of signals processed as disclosed above.

For use of the signal in, for example, the testing of a communication network or a communication device, the processed represented signal has to be transformed from the frequency domain into the time domain using, among others, a FFT algorithm, for example.

The invention further provides to combine the signals generated in accordance with the first and second aspect as disclosed above. However, also other signal components may be included.

In particular, in accordance with the method of the present invention, the signal having the or each predefined quality criterion is a noise signal.

In a third aspect of the invention, a method is disclosed of testing the operation of a communication system, which method comprises the steps of:

- generating a signal having a predetermined quality criterion in accordance with the method of the invention disclosed above, and

- transferring the signal through the communication system under test.

The signals can be generated and stored using a set of instructions in a code format and executed in a predetermined order on a device. Such set of instructions can be software code compiled on a computer and stored in the computer or a network of computers or a floppy or CD-ROM or through the Internet. The software and/or signals produced can also be stored on an Arbitrary Wave Form Generator (AWG) card and the AWG can be used to generate the signals or to reproduce stored signals from the memory. It is therefore possible to have a library of signals available stored on a data carrier that can be used in the execution or use of the method according to the invention.

The communication systems can be devices such as xDSL modems, or chips within or for such modems, or cables in the network, or networks for (tele)-communication.

In a fourth aspect of the present invention a further method is disclosed of arranging a signal for use on or in a communication system. Preferably the signal is a noise signal. The signal may comprise crosstalk noise that is a random signal with predetermined properties in the frequency domain and in the time domain. The signal can furthermore comprise rfi-tones that have a discrete frequency spectrum. Also other signal components can be included in the signal.

The method comprising the steps of:

- representing a first signal in time domain having a time domain amplitude distribution, the signal having a spectral density in the frequency domain, thereby achieving a represented signal;

- processing the represented signal in accordance with a non-linear transformation, the non-linear transformation achieving at least one predefined quality criterion,

- the time domain amplitude distribution of the represented signal being processed at least with an inverse function of a predetermined time domain amplitude distribution.

The method may further comprise the step of comparing the time domain amplitude distribution of the represented signal with the predetermined time domain amplitude distribution, and thereafter arranging the non-linear transformation in order to achieve a processed represented signal having a time domain amplitude distribution approaching the predetermined time domain amplitude distribution.

In a fifth aspect of the present invention a method is disclosed of further comprising the step of comparing the time domain amplitude distribution of the represented signal with the predetermined time domain amplitude distribution, and thereafter arranging the non-linear transformation in order to achieve a processed represented signal having a time domain amplitude distribution approaching the predetermined time domain amplitude distribution.

According to the fifth aspect of the invention the method can also comprise the steps of representing a first signal in time domain and with an amplitude distribution and the signal having a spectral density in the frequency domain, thereby achieving a represented signal, and filtering the represented signal in the frequency domain including the steps of evaluating at least part of the signal representation in the frequency domain and thereafter processing the represented signal in the frequency domain.

The methods of the fourth and fifth aspect of the invention can be combined. The methods of the fourth and fifth aspect of the invention allow to make a signal in different iterative steps that has a predetermined amplitude distribution and/or that has a predetermined spectral density or that has a amplitude distribution and/or that has a spectral density according to a predefined quality criterion. The predefined quality criterion can be the crest factor of the signal, that is the relation of the maximum or peak value of tones of the signal compared to the average value or rms-value of the tones of the signal. The processing steps as recited hereabove can comprise the steps of a Fast Fourier Transformation (FFT) or Inverse Fast Fourier Transformation (IFFT). The processing steps can also a include operations such as a convolution or deconvolution or multiplication or add-on of signals.

In the method of the fourth aspect, the amplitude distribution of the represented signal is processed including a function of the predetermined amplitude distribution, which can include an inverse function of the predetermined amplitude distribution.

The method as recited of the fourth and fifth aspect of the invention can further comprise the steps of transforming the first signal in the frequency domain; multiplying the first signal in the frequency domain with a spectral envelope thereby achieving a multiplied signal; and thereafter representing the multiplied signal in time domain.

In the methods, the first signal in its representation in the frequency domain can be generated as a set of random numbers, preferably complex numbers the modulus of the complex number characterizing amplitude, the argument of the complex number characterizing phase and the real and/or the imaginary part of essentially each of the complex numbers can be chosen according to a Gaussian distribution. Each of the complex numbers can be substantially equal to the amplitude of the predetermined spectral density.

In a sixth aspect of the present invention, a signal is disclosed comprising at least a random noise signal, the random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and a spectral density in the frequency domain according to a predetermined quality criterion, the random signal being composed of an array of random numbers. The signal can further comprise a discrete frequency spectrum. The noise signal can be generated using a set of instructions in a code format and being executed in a predetermined order. Such set of instructions can be software code compiled on a computer and stored in the computer or a network of computers or a floppy or CD-ROM or through the internet. The software can also be stored on an Arbitrary Wave Form Generator (AWG) card and the AWG can be used to generate the signals or reproduce stored signals from the memory. It is therefore possible to have a library of signals available that can be used in the execution or use of the methods of the fourth and fifth aspect of the invention.

In a seventh aspect of the present invention, a method is disclosed of generating a signal comprising at least a random noise signal, the random signal having an amplitude distribution in the time domain according to a predefined quality criterion and having a spectral density in the frequency domain according to a predefined quality criterion, the random signal being composed of an array of random numbers, the method comprising the step of generating a random set of numbers using a set of instructions in a code format and being executed in a predetermined order. The method can further comprise the step of generating a discrete frequency spectrum, the discrete frequency spectrum using goniometry functions and modulating essentially each of the discrete frequencies with a noise characteristic. The random noise signal and the discrete frequency spectrum can be combined using a set of instructions in a code format and being executed in a predetermined order.

In an eight aspect of the present invention, a set of instructions is disclosed in a code format and executable in a predetermined order, the set of instructions being arranged for generating a random noise signal and a discrete frequency spectrum, the random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion. Such set of instructions can be software code compiled on a computer and stored in the computer or a network of computers or a floppy or CD-ROM or through the internet. The software can also be stored on an Arbitrary Wave Form Generator (AWG) card and the AWG can be used to generate the signals or reproduce stored signals from the memory. It is therefore possible to have a library of signals available that can be used. The software can be C-code or can be compiled in a MATLAB environment.

In a ninth aspect of the present invention, a system for testing the operation of a communication system is disclosed comprising a set of instructions in a code format and executable in a predetermined order and compiled on a device, the set of instructions being arranged for generating a noise signal comprising at least one of a random noise signal and a discrete frequency spectrum, the random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion. The test system according to this aspect of the invention can comprise an impairment generator for generating the noise signal.

The connection elements (transformers, active devices, attenuators, etc.) that connect the impairment generator to the communication system that is tested can have an unwanted frequency dependent response. The unwanted frequency dependent response can be measured for instance by generating specific test signals in the impairment generator. The unwanted frequency dependent response can be compensated by multiplying the desired spectral density of the signal divided by the unwanted frequency dependent response of the connection element.

In a tenth aspect of the present invention, a method of testing the operation of a communication system such as a xDSL modem is disclosed. The method comprises the step of superposing on a signal transceived by a the modem, a signal comprising at least one of a random noise signal and a discrete frequency spectrum, the random signal having an amplitude distribution in the time domain according to a predefined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion., the noise signal furthermore being composed of an array of random numbers.

In an eleventh aspect of the present invention a method of testing the quality of operation of a communication system is disclosed. The method comprises the steps of superposing on a signal transceived by a the modem, a signal comprising at least one of a random noise signal and a discrete frequency spectrum, the random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predefined quality criterion, the noise signal furthermore being composed of an array of random numbers, and evaluating the transceived signal according to a predefined quality criterion.

Yet in a twelfth aspect of the present invention, a method of improving the design and/or production of a communication system is disclosed, the method comprising the steps of superposing on a signal transceived by a the modem, superposing on a signal transceived by the modem, a signal comprising at least one of a random noise signal and a discrete frequency spectrum, the random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion, the noise signal furthermore being composed of an array of random numbers; evaluating the transceived signal according to a predetermined quality criterion; and iteratively arranging the design of the modem in order to approach closer to the quality criterion for evaluating the transceived signal.

In a thirteenth aspect of the present invention, a telecommunication network is disclosed including a signal comprising at least one of a random noise signal and a discrete frequency spectrum, the random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion, the noise signal furthermore being composed of an array of random numbers.

The features of the above-described aspects and embodiments of the invention can be combined.

The signal, the methods and the set of instructions recited hereabove will allow to have a better quality of signal transmission over media such as telephone cables or wireless media. A better transmission of signals allows for a broader providing of more services for the users of communication systems.

Brief Description of the Figures

Figure 1 shows, in a block diagram, a set-up for a performance test in a communication system, using an impairment generator operating in accordance with the method of the present invention.

Figure 2 shows a flow diagram type of embodiments of the method according to the invention.

Figure 3 shows, in a graphic representation, an embodiment of the method according to the invention for generating ingress noise.

Figure 4 shows a flow diagram type of further embodiments of a method according to the invention.

Figure 5 shows an amplitude distortion (non-linear transformation) function $Q(x)$ that amplifies the high amplitude peaks or tones in a signal.

Figure 6 shows in a flow diagram an example embodiment of the invention.

Figures 7-11 show results that are obtained according to an embodiment of the invention.

Detailed Description of the Embodiments

For the purpose of teaching the invention, aspects and embodiments of the signal and method and systems of the invention are described below. It will be appreciated by those skilled in the art that other alternative and equivalent embodiments of the invention can be conceived and reduced to practice without departing form the true spirit of the invention. The scope of the invention being limited only by the appended claims.

In an embodiment of the invention, a system for testing the operation of a communication system such as a xDSL transceiver is disclosed. The set up of a test equipment for a high penetration of systems scenario in operational access networks is described.

A method is disclosed of arranging a signal for use on or in a communication system.

The purpose of transmission performance tests is to stress xDSL transceivers in a way that is representative to a high penetration of systems scenario in operational access networks. This high penetration approach enables:

(i) component and system designers to quantify the performance and to use it to improve their design and to prove compliance with standards; and

(ii) operators to define deployment rules that apply to most operational situations.

Figure 1 illustrates the functional description of a possible test set-up 1. It includes:

- a test loop 2, being a real cable or a cable simulator;
- an adding element 3 to inject impairment noise into the test loop 2;
- a high impedance, and well balanced differential voltage probe 4, connected with level detectors 5 such as a spectrum analyser or an rms volt meter, for example, (not shown), and
- xDSL transceivers (modems) 6, 7 under test.

When external splitters are required for the xDSL system under test (for POTS or ISDN signals), these splitter can be included in the modems 6, 7 under test.

The signal flow through the test equipment set-up 1 is from port Tx to port Rx, which means that measuring upstream and downstream performance requires an interchange of transceiver position and test "cable" ends. The received signal level at port Rx is the level, measured between node A2 and B2, when port Tx as well as port Rx are terminated with the xDSL transceivers (modems) 6, 7 under test. The impairment generator 8 is switched off during this measurement. The transmitted signal level at port Tx is the level, measured between node A1 and B1, under the same conditions.

The noise that the impairment generator 8 should inject into the test set-up 1 is frequency dependent. The noise which the impairment generator 8 injects into the test set-up 1 should be a realistic representation of a real (spectral polluted) access network, and is:

(a) dependent on the length of the test loop 2, and

(b) different for downstream performance tests and upstream performance tests.

This impairment noise, measured between node A2 and B2, is usually a mix of random, impulsive and harmonic noise (the rfi-tones). A set of characteristics is identified as a "noise profile".

The signal and noise levels are probed with a well balanced differential voltage probe 4.

In a fully automated test set-up 1 the test loop 2, 3 the voltage probe 4 and level detector 5, the modems under test 6, 7 and the impairment generator 8 may connect to a

Central Processing Unit (CPU) 9, as schematically indicated with broken lines. Those skilled in the art will appreciate that the connections with the CPU 9 may involve data links for remote testing by the CPU 9.

Definitions that are relevant for the use of the test equipment are the following :

- Probing an rms-voltage $U_{rms}$ [V] in this set-up, over the full signal band, means a power level of P [dBm] that equals: $P = 10 \times \log_{10}( U_{rms}^2 / R_V \times 1000)$ [dBm];
- Probing an rms-voltage $U_{rms}$ [V] in this set-up, within a small frequency band of $\Delta f$ (in Hertz), means a power spectral density level of P [dBm/Hz] within that filtered band that equals: $P = 10 \times \log_{10}( U_{rms}^2 / R_V \times 1000 / \Delta f)$ [dBm/Hz];
- The bandwidth $\Delta f$ identifies the noise bandwidth of the filter, and not the –3dB bandwidth.

Figure 2 shows schematically embodiments of the method for arranging a signal Ui(t) i=1,2,3,... for use on or in a communication system in accordance with the invention. The signal may comprise cross-talk noise, that is a random signal with predetermined properties in the frequency domain and in the time domain.

As represented by flow [1] of Figure 2, the method comprises the steps of representing a first signal comprising a plurality of frequency components each having spectral amplitude and phase properties, block 10 "First signal", and processing the represented signal by arranging the spectral amplitude properties in accordance with at least one predefined quality criterion, as well as arranging random phase properties, block 11 "Arrange", thereby achieving a processed represented signal.

The first signal may be represented by a first set of numbers specifying a spectral amplitude and phase of each frequency component. Further, the first signal may be represented by a second set of complex numbers, having a real part and an imaginary part, which parts in combination specify a spectral amplitude and phase of each frequency component. That is, the modulus of a complex number characterises the spectral amplitude whereas the argument of the complex number characterises the phase of the frequency component.

In accordance with the present invention, the represented first signal 10 is processed to arrange random phase properties. However, starting from a represented first signal 10 having random phase properties, for shaping the frequency of the signal in accordance with the predefined quality criterion, it suffices to shape the spectral amplitude of the frequency components.

The method may also comprise the steps of representing the first signal in the time domain, in that the first signal is represented by a third set of numbers each specifying an amplitude of the first signal in the time domain. By transforming the third set of numbers from the time domain into the frequency domain, for example using an FFT algorithm, a fourth set of numbers is achieved specifying a spectral amplitude and phase of each frequency component. Likewise, the fourth set of numbers is to be processed by arranging the spectral amplitude properties in accordance with the at least one predefined quality criterion, as well as arranging its random phase properties.

By transforming the processed represented signal from the frequency domain into the time domain, for example using an Inverse FFT algorithm (IFFT), block 12 "Transform", the signal U1(t) having the at least one predefined quality criterion is eventually generated.

While the signal U1(t) meets at least one predefined quality criterion in the frequency domain, such as a spectral envelope and/or pre-emphasise properties, it may yet be required to provide a signal having a predefined quality criterion in the time domain.

As disclosed in flows [2] and [3] of Figure 2, i.e. block 13 "Amplitude Shape" and block 14 "Frequency Shape", the quality criterion in the time domain may comprise a predefined amplitude distribution and/or a predefined envelope of spectral amplitudes.

The method can also comprise the step of making a signal in different iterative steps, see Figure 2 [4]. Block 15 "Test Shape" and back coupling loop 16. Thus the signal can have a predetermined time domain amplitude distribution and/or a predetermined envelope of spectral amplitudes and/or a spectral density according to predetermined quality criterion's.

The at least one predetermined quality criterion can be the crest factor of the signal that is a relation of the maximum or peak value of the tones of the signal compared to the average or rms value of the tones of the signal.

The signals can be generated and stored using a set of instructions in a code format and executable in a predetermined order and compiled on a device. Such set of instructions can be software code compiled on a computer and stored in the computer or a network of computers or a floppy or CD-ROM or through the Internet. The software can also be stored on an Arbitrary Wave Form Generator (AWG) card and the AWG can be used to generate the signals or reproduce stored signals from the memory. It is therefore possible to have a library of signals available that can be used in the execution or use of the methods of the first and second aspect of the invention. The communication systems can be devices such as xDSL modems 6, 7, or chips within or for such modems 6, 7, or networks for telecommunication.

The processing in block 13 "Amplitude Shape" in Figure 2 is done for achieving an impact or control on the time domain characteristics. An amplitude distortion (transformation) function $Q(x)$ is chosen that amplifies the high amplitude peaks or tones in the signal. A non-linear transformation function $Q(x)$ can be reconstructed from the actual amplitude distribution function of the signal and the predetermined amplitude distribution function.

For a noise signal $f(t)$ in the time period $t$ in between 0 en T, the amplitude distribution $F(a)$ of the signal is defined as a fraction of the time that the noise $f$ in absolute value is larger than $a$. If $G(a)$ is the predetermined amplitude distribution (such as an enhanced-Gaussian, see below), and $G^{-1}(a)$ is the inverse function thereof, the transformation function $Q(x)$ to make an intermediate or final signal $g(t)$ from the noise signal $f(t)$ can be defined as:

$$Q(x) = sign(x) \cdot G^{-1}\left(F\left(|x|\right)\right) \qquad (1)$$

$$g(t) = Q\{f(t)\}\,; \qquad (2)$$

sign(x)=x/|x| for x<>0; sign(x)=0 for x=0;

As a result $g(t)$ will have the predetermined amplitude distribution $G(a)$. $Q(x)$ in a number of cases can be an analytical function but can also be numerically constructed.

An example of an enhanced Gaussian function is as follows.

The amplitude distribution of Gaussian type noise is:

$$G(x) = 1 - erf\left(\frac{x}{\sqrt{2}\sigma}\right) \qquad (3)$$

$$\text{with}: erf(x) = \frac{2}{\sqrt{\pi}}\int_0^x dt \exp\left(-t^2\right), \qquad (4)$$

and with σ being the RMS value of the signal.

The "enhanced" Gaussian distribution is defined as:

$$G(x) = \begin{cases} 1 - \left(\alpha \, x/_A + erf\left(\frac{x}{\sqrt{2}\sigma}\right)\right) \Big/ \left(\alpha + erf\left(\frac{A}{\sqrt{2}\sigma}\right)\right) & 0 \le x \le A \\ 0 & x > A \end{cases}, \qquad (5)$$

If $V_{RMS}$ is the desired RMS value of the noise sample, and $C_f$ being the desired crest factor, choose:

$$A = C_f \times V_{RMS}\text{, and} \qquad (6)$$

$$\sigma = \sqrt{((1+\alpha)\, V^2_{RMS} - A^2 \cdot \alpha/3)}. \qquad (7)$$

Typical values for α that have proven useful are of a magnitude between 0.001 and 0.01, and this represents the deviation of enhanced Gaussian distributed from a true Gaussian distribution.

In block 14, Frequency Shape, of Figure 2, the frequency domain characteristics of the signal are improved, as a posed-processing step to achieve a closer match to the or each quality criterion. The corrected frequency curve can be achieved, for example, by comparing (dividing) a predetermined spectral density through the measured spectral density of the (intermediate) signal U2(t). An example hereof is given in the best mode embodiment described in the sequel with a convolution of FFT functions.

In the part [4] of Figure 2, it is shown how an iterative procedure of the steps detailed here above may lead to a further improvement of the finish or final signal for use in or on a communication system. The iterative procedure, i.e. testing of the frequency shape by block 15, Test Shape, and back coupling loop 16, is executed until the predetermined quality criterion(s) are achieved.

Figure 3 illustrates in a schematic, graphic representation use of the method according to the invention for the provision of an ingress noise signal.

As disclosed in the preamble, ingress noise may be characterised by a plurality of frequency components at discrete carrier frequencies fci, i=1,2,3, .... The frequency components at the carrier frequency fci each having a carrier amplitude Aci, i=1,2,3, ..., and, if applicable, having a modulation width, i.e. a number of discrete frequencies at the left and right hand side of the associated carrier frequency fci, as well as having a modulation depth, that is the amplitude of the side frequencies associated with the respective carrier frequency fci.

Figure 3 shows, in a graphic representation having a horizontal or frequency axis f and a vertical or amplitude axis A, by way of example only, a signal comprised of two carrier frequencies fc1 and fc2, having a carrier amplitude Ac1 and Ac2, respectively.

Around the carrier frequency fc1 at each side thereof three side frequency components are arranged, each having an amplitude A1. For the frequency component at carrier frequency fc2 on each side thereof two side frequency components are arranged, each having an amplitude A2.

In accordance with the present invention, for providing a signal having at least one predefined quality criterion, the amplitude of the frequency components have to be shaped, such as disclosed by the dotted lines 1 and 2 in Figure 3.

Starting from a represented first signal having random phase properties, in accordance with the present invention, by the shaping of the amplitudes, the random phase properties are maintained in the signal to be provided having the predefined quality criterion.

Figure 4 shows schematically a further embodiment of a method for arranging a signal for use in or on a communication system, in particular for use if random phase properties are already provided for. The signal comprises crosstalk noise that is a random signal with predetermined properties in the frequency domain and in the time domain. The signal can furthermore comprise rfi-tones that have a discrete frequency spectrum. Also other signal components can be included in the signal.

The method further may comprise the steps of representing a first signal in time domain and with an amplitude distribution and the signal having a spectral density in the frequency domain, thereby achieving a represented signal, and processing the represented signal according to a non-linear transformation, the non-linear transformation achieving a predetermined quality criterion. This is shown as amplitude shaping in Figure 4, flows [2-4].

The method further may comprise the step of representing a first signal in time domain and with an amplitude distribution and the signal having a spectral density in the frequency domain, thereby achieving a represented signal, and processing the represented signal until a signal is achieved having a spectral density according to a predetermined spectral density quality criterion. This is shown as frequency shaping in Figure 4, flows [2-4]. The frequency shaping step can also comprise the step of filtering the represented signal in the frequency domain including the steps of evaluating at least part of the signal representation in the frequency domain and thereafter processing the signal representation in the frequency domain.

The method may also comprise the step of making a signal in different iterative steps, see Figure 4 flow [4]. Thus the signal can have a predetermined time domain amplitude distribution and/or a predetermined spectral density or a time domain amplitude distribution and/or a spectral density according to a predefined quality criterion. The predefined quality criterion can be the crest factor of the signal, that is a relation of the maximum or peak value of the tones of the signal compared to the average value of the tones of the signal. The signals can be generated and stored using a set of instructions in a code format and executable in a predetermined order and compiled on a device.

Likewise, the set of instructions can be software code compiled on a computer and stored in the computer or a network of computers or a floppy or CD-ROM or through the internet. The software can also be stored on an Arbitrary Wave Form

Generator (AWG) card and the AWG can be used to generate the signals or reproduce stored signals from the memory. It is therefore possible to have a library of signals available that can be used in the execution or use of the methods of the invention. The communication systems can be devices such as xDSL modems, or chips within or for such modems, or networks for telecommunication. In detail the following embodiment is shown in Figure 4.

Using software, random numbers are generated, block 16, "Create Noise". In hardware white noise can be generated. The random numbers are filtered until a predetermined spectral density is achieved. The random numbers that are generated each represent a frequency component. The necessary processing to achieve a predetermined spectral density is executed by scaling the amplitude of the complex numbers and thereafter an IFFT processing is done in order to make the desired noise signal. Another way of executing the method is to generate random numbers that represent the phase of each frequency component and thereafter the amplitude of the complex numbers is arranged to approach or be equal to a predetermined spectral density

The processing in block 13, "Amplitude Shape", is done for achieving an impact or control on the time domain characteristic. An amplitude distortion (transformation) function $Q(x)$ is chosen that amplifies the high amplitude peaks or tones in the signal is shown in Figure 5. The non-linear transformation function $Q(x)$ can be reconstructed from the actual amplitude distribution function of the signal and the predetermined amplitude distribution function, as disclosed above in connection with the equations (1-7).

In block 14, "Frequency Shape" of Figure 4, the frequency domain characteristics of the signal are improved. The corrected frequency curve is achieved by comparing (dividing) a predetermined spectral density through the measured spectral density of the (intermediate) signal. An example hereof is given in the best mode embodiment described in the sequel with a convolution of FFT functions.

In the flow [4] of Figure 4, like in the flow [4] of Figure 2, again it is shown how an iterative procedure of the steps detailed hereabove may lead to a further improvement of the final for use in or on a communication system. The iterative procedure is executed until the predetermined quality criterions are achieved.

With the method according to the invention, as disclosed above, signals representing cross-talk noise and ingress noise can be generated with a device, such as an impairment generator 8, see Figure 1, which may be arranged for providing a signal comprised of both a cross-talk noise signal and an ingress noise signal, while other signal components may be added to the output signal to be provided, if required.

The signal to be provided, in an embodiment of the invention, can be advantageously provided as a sixth set of numbers in the time domain, for example an array of numbers.

Figure 6 shows, in a flow type diagram, an example embodiment of the invention, running on a Personal Computer 20. The impairment noise is generated by block 21, called SPOCS, comprising a block 22, "White noise signal", a block 23 "Spectral shaping", provided by FFT, a block 24, "Desired noise signal", produced from the output of block 23 by IFFT, the resulting signal of which is stored on an AWG card 25. In the crosstalk scenario, i.e. block 26, a noise PSD is created, block 27, which is further processed by block 23.

A best mode embodiment of the set of instructions of the invention is disclosed here below. The code given here below is compiled in a MATLAB environment. Comments related to the functionality of the code are given after the % signs. For a person skilled in the art, the code provided is self-explanatory.

Figures 7-9 show results obtained with the best mode embodiment. Figure 8 shows a plot of the spectrum of the generated noise sample plus the PSD of the noise profile. Figure 9 shows a plot of the generated noise sample in the time domain. Figure 10 shows a plot of the distribution function of the generated noise sample. Figure 11 shows a plot of the cumulative distribution functiopn of the generated noise sample. Figure 7 shows a graphical User Interface (UI) and settings of the AWG control.

```
%-----------------------------------------------------------------------------------
function DemoImpair2;
%-----------------------------------------------------------------------------------
% DemoImpair2
%     Code, programmed in the Matlab programming language, that demonstrates the
%     basic algorithms of an Impairment Generator.
%     The demonstrated algorithms have full control over the predefined quality
%     criteria, such as:
%           - frequency and time domain characteristics (spectrum; probability
%             distribution) when generating noise with continuous spectra
%           - carrier amplitude, carrier frequency, modulation depth and modulation
%             width, when generating noise with discrete spectra
%     Both types of noise are calculated independently, and represented in the time
%     domain as arrays with numbers.
%     Both types of noise can be made available simultaneously by adding these
%     arrays element wise.
%     (c) 2000-2001 KPN Research;
%
% DEMO FUNCTIONS
%     DemoXtalkNoise          - shows the process of creating continuous noise
%     DemoIngressNoise        - shows the process of creating discrete noise
%
% MAIN FUNCTIONS: Noise is represented as an array with random numbers
%     DefineShape             - initialize all user-definable parameters
%     CreateNoiseCont         - generates continuous noise
%     CreateNoiseDiscr_Fast   - generate discrete noise, fast algorithm
%     CreateNoiseDiscr_Slow   - generate discrete noise, slow algorithm
%     FrequencyShape          - modify spectral density of continuous noise
%     AmplitudeShape          - modify amplitude distribution of continuous
%                               noise
```

```
% SUPPORTING FUNCTIONS:
%     CalcSpec                    - calculates the spectral density of noise
%     CalcNBSV                    - calculates the narrow band signal voltage of
%                                   noise
%     CalcCrest                   - calculates the crest factor of noise
%     CalcDistrib                 - calculates the probability distribution of noise
%     CalcCumDistrib              - calculates the cumulated distribution of noise
%     CalcSmooth                  - smoothes a spectrum, like in a real spectrum
%                                   analyzer
%     CalcEnhancedGaussDistribution   - a sample of a near-gaussian distribution
%     CalcDemodulation            - calculate the noise modulated on a carrier
%-----------------------------------------------------------------------------
Shape=DefineShape;
DemoXtalkNoise(Shape);
DemoIngressNoise(Shape);

%-----------------------------------------------------------------------------
function [U,t]=DemoXtalkNoise(Shape);
%-----------------------------------------------------------------------------
% demonstrates the generation of noise with continuous spectrum
% e.g. for crosstalk testing
R      = Shape.R;
CF_min = Shape.Xtalk.CF_min;
[U,t]=CreateNoiseCont(Shape);  plot(t,U);        title('Xtalk method 1'); shg; pause
[X,f]=CalcSpec(U,t);           plot(f,X);        title('Xtalk method 1'); shg; pause
[X,f]=CalcSpec(U,t);           plot(f,dBm(X,R)); title('Xtalk method 1'); shg; pause
[P,u]=CalcCumDistrib(U);       plot(u,P);        title('Xtalk method 1'); shg; pause
%
U=AmplitudeShape(U,Shape);     plot(t,U);        title('Xtalk method 2'); shg; pause
```

```
[X,f]=CalcSpec(U,t);           plot(f,X)          title('Xtalk method 2'); shg; pause
[X,f]=CalcSpec(U,t);           plot(f,dBm(X,R)); title('Xtalk method 2'); shg; pause
[P,u]=CalcCumDistrib(U);       plot(u,P);         title('Xtalk method 2'); shg; pause
%
U=FrequencyShape(U,Shape);     plot(t,U);         title('Xtalk method 3'); shg; pause
[X,f]=CalcSpec(U,t);           plot(f,X);         title('Xtalk method 3'); shg; pause
[X,f]=CalcSpec(U,t);           plot(f,dBm(X,R)); title('Xtalk method 3'); shg; pause
[P,u]=CalcCumDistrib(U);       plot(u,P);         title('Xtalk method 3'); shg; pause
%
for i=2:10
 i
 U=AmplitudeShape(U,Shape);
 [X,f]=CalcSpec(U,t);
 %
 U=FrequencyShape(U,Shape);
 [X,f]=CalcSpec(U,t);
 %
 if CalcCrest(U)>CF_min, break; end;
end;
[P,u]=CalcCumDistrib(U);
plot(t,U);           title('Xtalk method 4'); shg; %pause
plot(f,dBm(X,R));    title('Xtalk method 4'); shg; %pause
plot(u,P);           title('Xtalk method 4'); shg; %pause

%---------------------------------------------------------------------------
function [U,t]=DemoIngressNoise(Shape);
%---------------------------------------------------------------------------
% demonstrates the generation of noise with discrete spectrum e.g. for ingress testing
R = Shape.R;
[U,t]=CreateNoiseDiscr_Fast(Shape);
```

```
%[U,t]=CreateNoiseDiscr_Slow(Shape); %gives same result
[X,f]=CalcNBSV(U,t); plot(f,dBm(X,R)); title('Ingress method'); shg; pause
for ToneNr=[1:2]
  [Uac,Uac_rms]=CalcDemodulation(U,t,Shape,ToneNr);
  plot(t,Uac); title('demodulated ingress noise of one carrier'); shg; pause
  [P,u]=CalcDistrib(Uac/Uac_rms);
  plot(u,P); title('distribution of demod noise'); shg; pause
end;

%---------------------------------------------------------------------------------------------
function [Shape] = DefineShape;
%---------------------------------------------------------------------------------------------
%Create the noise profiles for the noise that should be generated, in terms of
%      - spectral density (in this example rectangular in nature)
%      - probability distribution (in this example near Gaussian)
%      - tones and modulation
%      Spectra in Volt per sqrt(Hz)
%---------------------------------------------------------------------------------------------
Fmax=4E6; Fl=300E3; Fh=700E3; N=2^18; R=135;
cf=5.5;          % desired crest factor)
cf_min=5.1;   % desired crest factor)
m=N/2;
%
Shape.N=N;                              % number of time samples
Shape.m=m;                              % number of freq samples
Shape.dF= Fmax./(m-1);                  % frequency spacing
Shape.dT= 1/(N*Shape.dF);               % time spacing
Shape.R=R;                              % impedance of desired noise source;
% define crosstalk noise target (Spectral density & Amplitude Distribution)
Shape.Xtalk.freq =[0:m-1]' * Shape.dF;
```

```
Shape.Xtalk.spec =(Shape.Xtalk.freq>=Fl).*(Shape.Xtalk.freq<=Fh)*(1/300);
Shape.Xtalk.DistU = 0:cf/1000:cf;
Shape.Xtalk.DistP = CalcEnhancedGaussDistribution(Shape.Xtalk.DistU, cf); %P
Shape.Xtalk.CF_min=cf_min;
% define ingress noise target (RFI-Tones)
P_dBm =[-70;-50;-60;-60;-40;-60;-60;-40;-70;-40]; % dBm @ 135 ohm
P=(10).^(P_dBm/10)*1E-3;
Shape.Ingress.ToneU =sqrt(P*135);            % U=sqrt(P*R); effective value
Shape.Ingress.ToneF =[99;207;333;387;531;603;711;801;909;981]*1E3;
Shape.Ingress.ModDepth = 0.32*ones(10,1);%=mod index > 0.8, at CF>2.5 )
Shape.Ingress.ModWidth = 2*4.5E3*ones(10,1);   %= -10 kHz .. +10 kHz)

%------------------------------------------------------------------------------
function [U,t] = CreateNoiseCont(Shape);
%------------------------------------------------------------------------------
% create a noise voltage U(t), with predefined frequency domain characteristics
% (spectrum), but with uncontrolled time domain characteristics (distribution)
N = Shape.N;                    % number of samples, to be generated
%U = rand(N,1);                  % Uniform distributed white noise
U = randn(N,1);                  % Gaussian distributed white noise
U = FrequencyShape(U,Shape);    % shaped noise
t=[0:N-1]' * Shape.dT;          % associated time axis

%------------------------------------------------------------------------------
function [U,t] = CreateNoiseDiscr_Fast(Shape);
%------------------------------------------------------------------------------
% Create a voltage U(t), with AM modulated carriers (RFI Tones); each having an
% individual predefined frequency, amplitude, modulation width and modulation depth.
% The random phase of the lower side band of each carrier tone is mirrored to
% convert arbitrary QAM modulation into (no mirroring) into the more restricted
```

```
% AM modulation (full mirroring)
% Mark that X refers in this algorithm to the components of   the Fourier series
% of the (near harmonic) ingress noise signal , while it  refers to the
% spectral density in case of the (pseudo random) crosstalk noise signal
%
% Calculation time increases about linear with the number of samples
% About 80% of all calculation time is caused by the inverse Fourier transform
%-----------------------------------------------------------------------------------
N = Shape.N;                                      % number of samples
m = Shape.m;                                      % half this number
Nc=round(Shape.Ingress.ToneF/Shape.dF)+1;         % index of carrier freq (pos only)
Nm=round(Shape.Ingress.ModWidth/Shape.dF/2);      % number of modulation
                                                  % components
Xc=0.5*Shape.Ingress.ToneU;                       % amplitude of carrier amplitude
Xm=Shape.Ingress.ModDepth.*Xc./sqrt(2*Nm);        % amplitude of modulation band
X=zeros(N,1);                                     % initialization
Xc=Xc.*exp(j*1000*rand(size(Xc)));                % random carrier phase
Xcc=(Xc.*Xc)./abs(Xc.*Xc);
for k=1:length(Nc)                                % for all modulated carriers, do:
  Nmp=Nc(k)+[1:Nm(k)]';                           % locate upper side band
                                                  % frequencies
  Nmn=Nc(k)-[1:Nm(k)]';                           % locate upper side band
                                                  % frequencies
  Xmp=Xm(k).*exp(j*1000*rand(size(Nmp)));         % create upper side band
  Xmn=conj(Xmp)*Xcc(k);                           % mirror lower side band
  X(Nmp)=Xmp;                                     % insert upper side band
  X(Nmn)=Xmn;                                     % insert lower side band
end;
X(Nc)=Xc;                                         % insert all carriers
X(N:-1:m+2)=conj(X(2:ceil(m)));                   % Append spectrum
```

```
                                        % (negative freq.)
%U= real(ifft(X))*N;                    % Transform to time-domain
U = real(fft(X));                       % Transform to time-domain
                                        % (10% faster)
t = Shape.dT*[0:N-1]';                  % associated time axis


%-----------------------------------------------------------------------------------
function [U,t] = CreateNoiseDiscr_Slow(Shape);
%-----------------------------------------------------------------------------------
% Create a voltage U(t), with RFI Tones at predefined frequency, amplitude
% and modulation bandwidth and modulation depth
% This algorithm is straight-forward, very inefficient, and for demo purposes only
% It can prove that CreateNoiseDiscr_Fast returns the same results
%-----------------------------------------------------------------------------------
N = Shape.N;                            % number of samples, to be generated
m = Shape.m;
f=[0:N-1]' * Shape.dF;
t=[0:N-1]' * Shape.dT;
Fc=Shape.Ingress.ToneF;                 % list of carrier frequencies
Fc=Shape.dF * round(Fc/Shape.dF);       % force an integer number of periods
%
U=0;
for k=1:length(Shape.Ingress.ToneF);
  % -- create noisy modulate, having U_avg=0 and U_rms=1.
  Nm =round(Shape.Ingress.ModWidth(k)/Shape.dF/2);
  Xn0=([1:N]<=(Nm+1))';                 % shape modulation noise amplitude
  Xn  =Xn0.*exp(j*1000*rand(N,1));      % shape modulation noise phase
  Xn(1)= 0;                             % Eliminate DC component.
  Xn(N:-1:m+2)=conj(Xn(2:ceil(m)));     % Append spectrum (negative freq.)
```

```
 Noise = real(ifft(Xn));                    % Transform to time-domain
 Noise=Noise/sqrt(sum(Noise.*Noise)/N);  % force rms=1
 % -- perform modulation
 Carrier = Shape.Ingress.ToneU(k)   * cos(2*pi*Fc(k)*t+1000*rand);
 Modulate = Shape.Ingress.ModDepth(k) * Noise;
 U = U + Carrier .* (1 + Modulate);
end;


%-----------------------------------------------------------------------------
function [U] = FrequencyShape(U,Shape)
%-----------------------------------------------------------------------------
% Reshape the spectrum of the sample U, as specified by the target shape
% INPUT:
%     U:          the consecutive values of the sample
%     fs:         the sample frequency
%     spectrum:   the desired PSD (in V/sqrt(Hz))
%-----------------------------------------------------------------------------
N = length(U);
m = length(Shape.Xtalk.spec);              % m=N/2
t= [0:N-1]'*Shape.dT;
% perform the frequency scaling
Scaling = Shape.Xtalk.spec ./ CalcSpec(U,t);
X = fft(U);                                % Transform to frequency domain
X(1) = 0;                                  % Eliminate DC component.
X(2:m+1)  = X(2:m+1) .* Scaling;           % Scale  spectrum (positive freq.)
X(N:-1:m+2)=conj(X(2:ceil(m)));            % Append spectrum (negative freq.)
U = real(ifft(X));                         % Transform to time-domain
```

```
%-------------------------------------------------------------------------------
function [U] = AmplitudeShape(U,Shape)
%-------------------------------------------------------------------------------
% This function shapes the amplitude distribution of the function U
% by an amplitude dependent (non-linear) distortion function Q(x).
% The result is U(t) = Q{U(t)}
%
% Let FF be the actual cumulative distribution function of the sample, and
% let GG be the desired cumulative distribution function,
% then the distortion function is given by:
%      Q(x) = GG^{-1} FF (x)
%-------------------------------------------------------------------------------
U0=sqrt(sum(U.*U)/length(U));                    %scaling farct (for normalization)
% Calculate the distortion function Q
[DistP1,DistU1] = CalcCumDistrib(U/U0);               % the actual distribution
Q = interp1(Shape.Xtalk.DistP, Shape.Xtalk.DistU, DistP1); % the distortion function
U = U0 *interp1(DistU1,Q,abs(U/U0)) .* sign(U);        % Perform the distortion
% plot(DistU1,Q); shg; %pause

%-------------------------------------------------------------------------------
function [X,f] = CalcSpec(U,t);
%-------------------------------------------------------------------------------
% calculate the spectral density of a signal, when it would be 'measured'
% at specified resolution bandwidth
RBW=1E3;                   %RBW:  the desired resolution for the spectrum of U
N = length(U); m=N/2;
dT = t(2)-t(1);                        % time spacing
dF = 1/dT/N;                           % frequency spacing
f= [0:m-1]'*dF;                        % all positive frequencies
X = fft(U)*dT;                         % to frequency domain
```

```
X = abs(X(2:m+1));                  % No DC and no negative frequencies.
X = sqrt(CalcSmooth(X.*X, f, RBW)); % average it over bandwidth RBW

%-----------------------------------------------------------------------------
function [X,f] = CalcNBSV(U,t);
%-----------------------------------------------------------------------------
% calculate the narrow band signal voltage of a signal, when it would be 'measured'
% at specified resolution bandwidth
RBW=1E3;          %RBW:       the desired resolution for the spectrum of U
N = length(U); m=N/2;
dT = t(2)-t(1);                     % time spacing
dF = 1/dT/N;                        % frequency spacing
f= [0:m-1]'*dF;                     % all positive frequencies
%X = fft(U)*dT * sqrt(dF);          % to frequency domain
%X = fft(U)/N;                      % to frequency domain
X = fft(U)/N*2;                     % to frequency domain
X = abs(X(2:m+1));                  % No DC and no negative frequencies.
%X = sqrt(CalcSmooth(X.*X, f, RBW)); % average it over bandwidth RBW

%-----------------------------------------------------------------------------
function [CF] = CalcCrest(U)
%-----------------------------------------------------------------------------
% Calculate the Crest Factor of a signal (U(t), which is the peak value
% divided by the rms-value
Urms = sqrt(sum(U.^2)/length(U));
Upeak = max(abs(U));
CF = Upeak/Urms;
```

```
%-----------------------------------------------------------------------------------------
function [F]=CalcEnhancedGaussDistribution(x,Cf);
%-----------------------------------------------------------------------------------------
% Generate a Cumulative distribution function F(x) that is identified as
% "enhanced gaussian distribution"
% Cf = crest factor
Alpha = 1e-3;
Sigma = sqrt( (1+Alpha) - Cf^2 * Alpha/3);
x = x .* (x>0) .* ( x<Cf) + Cf * (x>=Cf);
denominator = Alpha + erf(Cf/(sqrt(2)*Sigma));
F = 1 - (Alpha * x/Cf + erf(x/(sqrt(2)*Sigma)))/denominator;

%-----------------------------------------------------------------------------------------
function [DistP, DistU,P] = CalcDistrib(U)
%-----------------------------------------------------------------------------------------
% calculate the amplitude distribution of signal U
N = length(U);
Nbins=100;
[cumbin,xx] = hist(U,Nbins);
dX=xx(3)-xx(2);
DistP = cumbin(:)/N/dX;                    % force sum(DistP)*dX
DistU = xx(:);
Urms=sqrt(sum(U.*U)/N);
P=exp(-0.5*(DistU/Urms).^2); P=P/sum(P)/dX;
DistU=[DistU,DistU];
DistP=[DistP,P];
```

```
%------------------------------------------------------------------------------------------
function [DistP, DistU] = CalcCumDistrib(U)
%------------------------------------------------------------------------------------------
% calculate the (backward) cumulative amplitude distribution of signal U
len  = length(U);
Ueff = sqrt(sum(U .* U)/length(U));
U    = abs(U/Ueff);
% --- evaluate distribution function
Nbins = min([50,floor(len/10)]);
[cumbin,xx] = hist(U,Nbins);
BinWidth=xx(2) - xx(1);
DistU = xx - BinWidth/2; % shift
for n = [Nbins-1:-1:1];  cumbin(n) = cumbin(n) + cumbin(n+1); end
DistP = cumbin/len;
% --- improve numerical stability for other routines, when they use this result
DistU = [ 0 , DistU(2:end)];                    % start at x = 0
DistP = [DistP, 1/len];
DistU = [DistU,xx(Nbins) + 0.999 * BinWidth/2];   % add final (single) point
DistP = [DistP, 1e-100];
DistU = [DistU,xx(Nbins) + (1.001) * BinWidth/2]; % factor 1.001 for stability

%------------------------------------------------------------------------------------------
function [PSD,freq]=CalcSmooth(PSD,freq,RBW)
%------------------------------------------------------------------------------------------
% Imitate a real Spectrum Analyzer, with finite resolution bandwidth, and
% Gaussian shaped band filters
%     PSD = "power spectral density" which is de square of the "spectral density"; in
%              Volts per square Hertz.
%------------------------------------------------------------------------------------------
N = length(PSD);
```

```
df = freq(2)-freq(1);
br = 3 * floor(RBW/df);
factor = 2*br + 1;
if (factor > 1)
..ff = df * (-br:br);                    % smooth interval
..mask = exp(-ff.*ff/(2*RBW^2));
..mask = mask/sum(mask);                 % Gaussian mask of resolution band filter
..xhelp = [PSD;zeros(2*br,1)];
  lp = filter(mask,1,xhulp);             % smart convolution
PSD = yhelp(br+1:end-br);
end;

%-------------------------------------------------------------------------
function [Uac,Uac_rms]=CalcDemodulation(U,t,Shape,ToneNr);
%-------------------------------------------------------------------------
% Demodulate the noise that has been modulated on the carriers of the discrete
% noise, it is for demonstration purposes only to prove that the
% discrete noise meets the predefined parameters.
%
% The demodulator uses synchronous detection, that is not locked in phase
% The consequence is an unknown attenuation over the full demodulation band.
% This is corrected afterward by measuring the DC level, and amplify the
% demodulated signal until this DC level has been normalized to 1 Volt
%
% PROOF: (psi is unknown)
% let  Urf=cos(w*t+psi)*(1+Uac);         % = carrier modulated with "1+Uac"
%      Uc =cos(w*t);                     % = carrier
%      Ud =Urf*Uc;                       % = synchronous detected signal
%
% then Ud=1/2*(cos(psi+2*w*t)+cos(psi))*(1+Uac);
```

```
%    Ulf=cos(psi)/2*(1+Uac);          % after low-pas filtering
%    Udc=cos(psi)/2;                  %= by averaging Ulf
%    Uac=(Ulf/Udc)-1;
%-------------------------------------------------------------------------
N=Shape.N;
Fc=Shape.Ingress.ToneF(ToneNr);       %select carrier frequency
Fc=Shape.dF * round(Fc/Shape.dF);     %force an integer number of periods
ModWidth=Shape.Ingress.ModWidth(ToneNr);
ModDepth=Shape.Ingress.ModDepth(ToneNr);
%
Ud=U.*cos(2*pi*Fc*t);                 % synchronous detection of modulated carrier
Nm=round(1.1*ModWidth/Shape.dF/2);    % calculate filter frequency
mask=zeros(N,1); mask([1:Nm, N-Nm:N])=1; % create filter
Ulf=real(ifft(fft(Ud).*mask));        % perform low-pass filtering
Udc=sum(Ulf)/N;                       % find not normalized DC level
Uac=Ulf/Udc-1;                        % normalize overall level, and remove DC.
%
Uac_rms=sqrt(sum(Uac.*Uac/N));   % must be equal to ModDepth, since Udc=1
Scale=Uac_rms/ModDepth;               % must be "one"
```

Claims

1. A method of arranging a signal having at least one predefined quality criterion, preferably for use in or on a communication system, said method comprising the steps of:

- representing a first signal comprising a plurality of frequency components each having spectral amplitude and phase properties, and

- processing said represented first signal by arranging said spectral amplitude properties in accordance with the or each predefined quality criterion, and arranging random phase properties.

2. A method according to claim 1, wherein said first signal is represented by a first set of numbers specifying a spectral amplitude and phase of each frequency component.

3. A method according to claim 1, wherein said first signal is represented by a second set of complex numbers having a real part and an imaginary part, said parts in combination specifying a spectral amplitude and phase of each frequency component.

4. A method according to claim 1, wherein said first signal is represented by a third set of numbers each specifying an amplitude of said first signal in the time domain.

5. A method according to claim 4, further comprising the step of transforming said third set of numbers from the time domain into the frequency domain for representing said first signal by a fourth set of numbers specifying a spectral amplitude and phase of each frequency component.

6. A method according to claim 4, further comprising the step of transforming said third set of numbers from the time domain into the frequency domain for representing said first signal by a fifth set of complex numbers having a real part and an imaginary part, said parts in combination specifying a spectral amplitude and phase of each frequency component.

7. A method according to any of the previous claims, further comprising the step of post-processing of said processed represented first signal to achieve a closer match to the or each predefined quality criterion.

8. A method according to any of the previous claims, further comprising the step of

transforming said processed represented signal from the frequency domain into the time domain.

9. A method according to claim 8, wherein said signal having said predefined quality criterion is represented by a sixth set of numbers in the time domain.

10. A method according to any of the previous claims, wherein the or each predefined quality criterion comprises at least one modulated carrier, the or each modulated carrier including any of a group comprised of a carrier frequency, a carrier amplitude, a modulation depth, and a modulation width.

11. A method according to any of the claims 1-9, wherein the or each predefined quality criterion comprises any of a group including of a predefined time domain amplitude distribution and a predefined envelope of spectral amplitudes.

12. A method according to claim 11, further comprising the step of arranging said processed represented first signal in accordance with a predefined time domain amplitude distribution.

13. A method according to claim 11 or 12, further comprising the step of arranging said processed represented first signal in accordance with a predefined envelope of spectral amplitudes.

14. A method according to claim 12 or 13, wherein at least one of said time domain amplitude distribution and envelope of spectral amplitudes is approached by an iteration process.

15. A method according to claim 14, wherein said iteration process comprises a comparison of any of said time domain amplitude distribution and envelope of spectral amplitudes of said processed represented first signal with a predefined time domain amplitude distribution and predefined envelope of spectral amplitudes.

16. A method according to any of the previous claims, wherein said signal having the or each predefined quality criterion is provided by combining a plurality of represented signals processed in accordance with claim 10 and processed in accordance with any of the claims 11-15.

17. A method according to any of the previous claims, wherein said signal having the or each predefined quality criterion is a noise signal.

18. A method in accordance with any of the previous claims, wherein said signal having the or each predefined quality criterion is provided by a set of instructions in code format and executable in a predetermined order on a processing device.

19. A set of instructions in code format and executable in a predetermined order on a processing device, said set of instructions being arranged for generating a signal having the or each predefined quality criterion and random phase properties from a representation of a first signal following a method in accordance with claim 18.

20. A device comprising processing means, memory means and arbitrary wave generator means, arranged for generating a signal having at least one predetermined signal quality criterion and random phase properties following any of the previous claims.

21. A signal having at least one predefined signal quality criterion and random phase properties, generated in accordance with any of the previous claims.

22. A data carrier device comprising a library of signal representations for use with any of the previous claims.

23. A method of testing the operation of a communication system, said method comprising the steps of:

- generating a signal having at least one predetermined quality criterion in accordance with any of the previous claims, and

- transferring said signal through said communication system.

24. A system comprising means for generating a signal having at least one predefined signal quality criterion following any of the previous claims, modem means, cable means and processor means, wherein said processor means are arranged for controlling said generating means, modem means and cable means for automated measurement and/or monitoring purposes.

25. A telecommunications system arranged for operating said method of claim 24.

26. A method of arranging a signal, preferably for use in or on a communication system, said method comprising the steps of:

- representing a first signal in time domain having a time domain amplitude distribution, said signal having a spectral density in the frequency domain, thereby achieving a represented signal;

- processing said represented signal in accordance with a non-linear transformation, said non-linear transformation achieving at least one predefined quality criterion,

- said time domain amplitude distribution of said represented signal being processed at least with an inverse function of a predetermined time domain amplitude distribution.

27. A method according to claim 26, further comprising the step of comparing said time domain amplitude distribution of said represented signal with said predetermined time domain amplitude distribution, and thereafter arranging said non-linear transformation in order to achieve a processed represented signal having a time domain amplitude distribution approaching said predetermined time domain amplitude distribution.

28. A method according to claim 26 or 27, wherein said processed represented signal g(t) is a function *Q{f(t)}* of said represented first signal f(t) and wherein said function *Q* is defined as:

$$Q(x) = sign(x) \cdot G^{-1}\left(F\left(|x|\right)\right)$$

with: sign(x)=x/|x| for x<>0; sign(x)=0 for x=0 ;

*F* being said time domain amplitude distribution of said represented signal; and

*G* being said predetermined time domain amplitude distribution function.

29. A method according to claim 28, further comprising the step of achieving said represented signal with a spectral density according to a predetermined spectral density quality criterion.

30. A method according to claim 26, further comprising the steps of :

- transforming said first signal to the frequency domain ; and

- multiplying said first signal in said frequency domain with a spectral envelope, thereby achieving a multiplied signal ; and

- transforming said multiplied signal to the time domain.

31. A method according to claim 30, further comprising the step of comparing said time domain amplitude distribution of said represented signal with said predetermined time domain amplitude distribution, and thereafter arranging said non-linear transformation in order to achieve a processed represented signal having a time domain amplitude distribution approaching said predetermined time domain amplitude distribution.

32. A method according to claim 31, further comprising the step of achieving said represented multiplied signal with a spectral density according to a predetermined spectral density quality criterion.

33. A method according to claim 32, wherein at least two of said steps are iteratively executed.

34. A method according to claim32, wherein at least two of said steps are iteratively executed until a predetermined crest factor is achieved.

35. A method according to any of the previous claims, wherein said signal is a noise signal.

36. A method according to claim 35, wherein said first signal in the representation in the frequency domain is generated as a set of random numbers, preferably complex numbers the modulus of the complex number characterizing an amplitude, the argument of said complex number characterizing a phase.

37. A method according to claim 36, wherein of essentially each of said complex numbers its real and/or imaginary part is selected according to a Gaussian distribution.

38. A method according to claim 36, wherein said modulus of essentially each of said complex numbers is substantially equal to said amplitude of said predetermined spectral density.

39. A method according to claim 36, wherein said argument of essentially each of said complex numbers is random.

40. A method of arranging a signal, preferably for use on or in a communication system, said method comprising the steps of :

- representing a first signal in time domain having a time domain amplitude distribution, said signal having a spectral density in the frequency domain, thereby achieving a represented signal; and

processing said represented signal until a signal is achieved having a spectral density according to a predetermined spectral density quality criterion.

41. A method of arranging a signal, preferably for use on or in a communication system, said method comprising the steps of:

- representing a first signal in time domain having an amplitude distribution and said signal having a spectral density in the frequency domain, thereby achieving a represented signal ; and

- filtering said represented signal in the frequency domain, including the steps of evaluating at least part of said represented signal in the frequency domain and thereafter processing said represented signal in the frequency domain.

42. A method according to claim 40 or 41, wherein said processing step includes iterative processing.

43. A method according to claim 40 or 41, wherein said processing step includes iterative processing until a predetermined crest factor is achieved.

44. A signal comprising at least one of a random noise signal, said random noise signal having an amplitude distribution in the time domain according to a predetermined quality criterion and a spectral density in the frequency domain according to a predetermined quality criterion, said random signal being composed of an array of random numbers.

45. A signal according to claim 44, further comprising a discrete frequency spectrum.

46. A signal according to claim 44, wherein said noise signal is generated using a set of instructions in a code format and being executed in a predetermined order.

47. A method of generating a random signal comprising at least one of a random noise signal, said random signal having an amplitude distribution in the time domain

according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion, said random signal being composed of an array of random numbers, said method comprise the step of generating a random set of numbers using a set of instructions in a code format and being executed in a predetermined order.

48. A method according to claim 47, further comprising the step of generating a discrete frequency spectrum, said discrete frequency spectrum using goniometry functions and modulating essentially each of said discrete frequencies with a noise characteristic.

49. A method according to claim 48, further comprising the step of combining said random noise signal and said discrete frequency spectrum using a set of instructions in a code format and being executed in a predetermined order.

50. A set of instructions in a code format and executable in a predetermined order, said set of instructions being arranged for generating a random noise signal and a discrete frequency spectrum, said random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion.

51. A test system for testing the operation of a communication system, said test system comprising a set of instructions in a code format and executable in a predetermined order and compiled on a device, said set of instructions being arranged for generating a noise signal comprising at least one of a random noise signal and a discrete frequency spectrum, said random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion.

52. A method of testing the operation of a communication system having a modem, said method comprising the step of superposing on a signal transceived by said modem, a signal comprising at least one of a random noise signal and a discrete frequency spectrum, said random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the

frequency domain according to a predetermined quality criterion., said noise signal furthermore being composed of an array of random numbers.

53. A method of testing the quality of operation of a communication system having a modem, said method comprising the steps of :

- superposing on a signal transceived by a said modem, a signal comprising at least one of a random noise signal and a discrete frequency spectrum, said random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion, said noise signal furthermore being composed of an array of random numbers ; and

- evaluating said transceived signal according to a predetermined quality criterion.

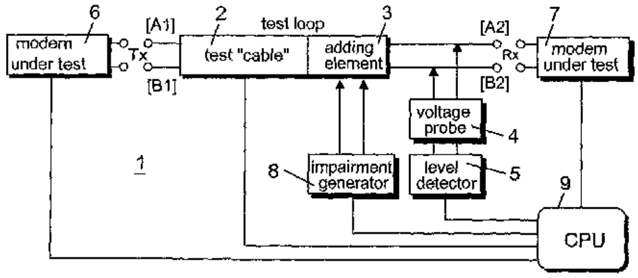
54. A method of improving the design and/or production of a communication system, said method comprising the steps of :

- superposing on a signal transceived by a modem a signal comprising at least one of a random noise signal and a discrete frequency spectrum, said random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion, said noise signal furthermore being composed of an array of random numbers ;

- evaluating said transceived signal according to a predetermined quality criterion; and

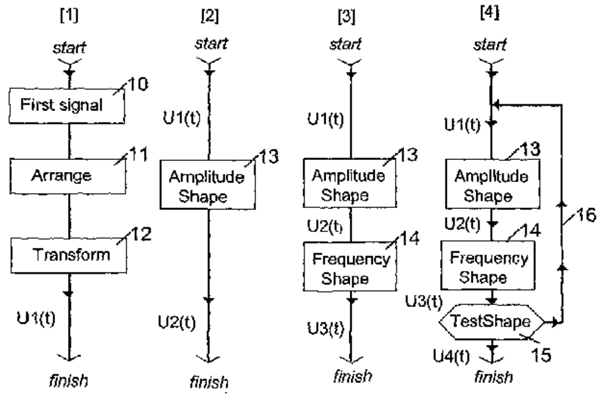
- iteratively arranging the design of said modem in order to approach closer to said quality criterion for evaluating said transceived signal.

55. A telecommunication network including a signal comprising at least one of a random noise signal and a discrete frequency spectrum, said random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion, said noise signal furthermore being composed of an array of random numbers.



6
modem under test
Tx
[A1]
[B1]
2
test "cable"
test loop
3
adding element
[A2]
[B2]
Rx
7
modem under test
voltage probe
4
impairment generator
8
level detector
5
1
9
CPU


Fig. 1



[1]
start
First signal
10
Arrange
11
Transform
12
U1(t)
finish
[2]
start
U1(t)
Amplitude Shape
13
U2(t)
finish
[3]
start
U1(t)
Amplitude Shape
13
U2(t)
Frequency Shape
14
U3(t)
finish
[4]
start
U1(t)
Amplitude Shape
13
U2(t)
Frequency Shape
14
16
U3(t)
TestShape
15
U4(t)
finish


Fig. 2

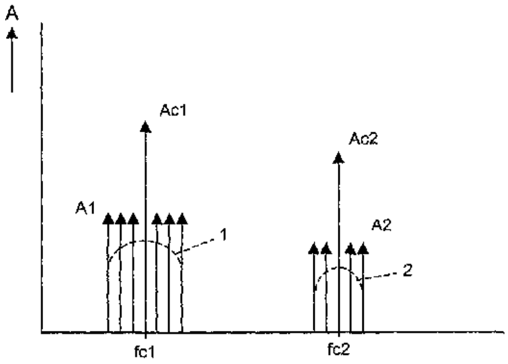

A
Ac1
Ac2
A1
A2
1
2
fc1
fc2
f

Fig. 3

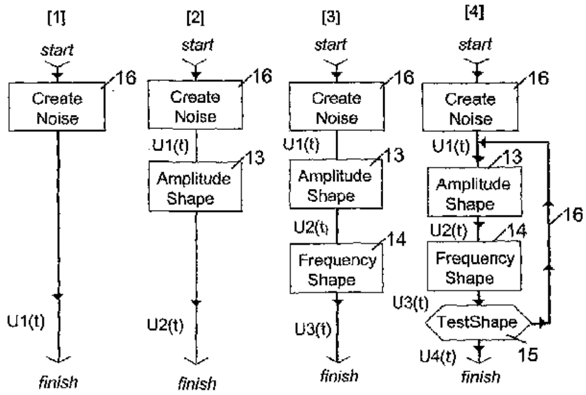

[1]
[2]
[3]
[4]
start
Create Noise
16
U1(t)
Amplitude Shape
13
U2(t)
Frequency Shape
14
U3(t)
TestShape
15
U4(t)
finish

Fig. 4

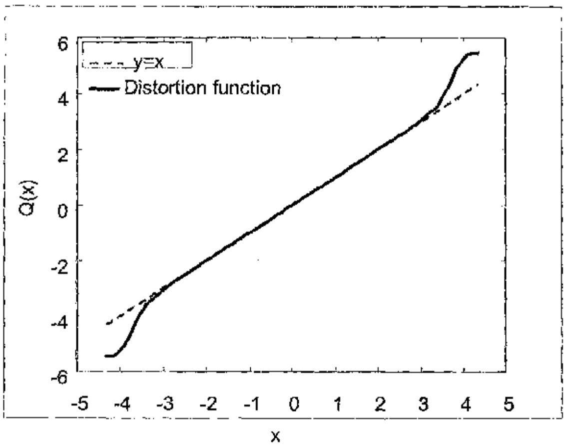

y=x
Distortion function
Q(x)
6
4
2
0
-2
-4
-6
-5 -4 -3 -2 -1 0 1 2 3 4 5
x

Fig. 5

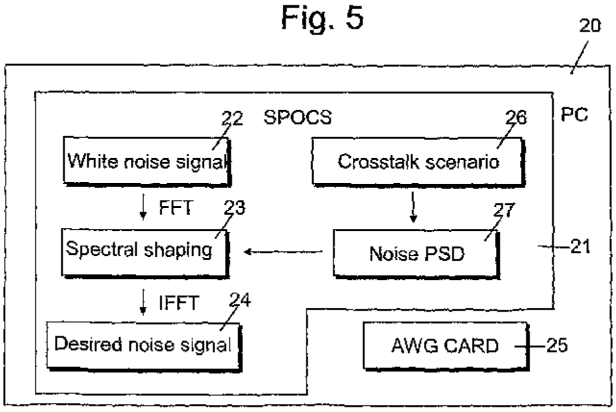

20
PC
SPOCS
22
White noise signal
26
Crosstalk scenario
FFT
23
Spectral shaping
27
Noise PSD
21
IFFT
24
Desired noise signal
AWG CARD
25

Fig. 6

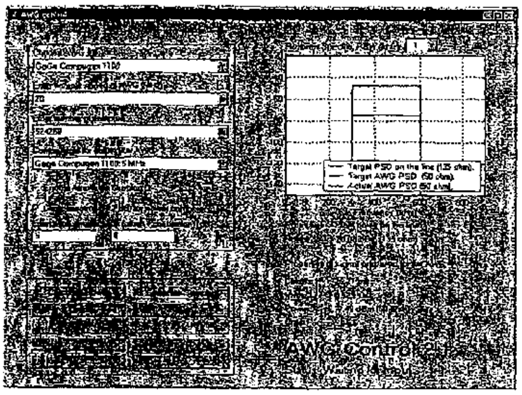

Target PSD on the line (135 ohm).
Target AWG PSD (50 ohm).
Actual AWG PSD (50 ohm).
AWG Control

Fig. 7

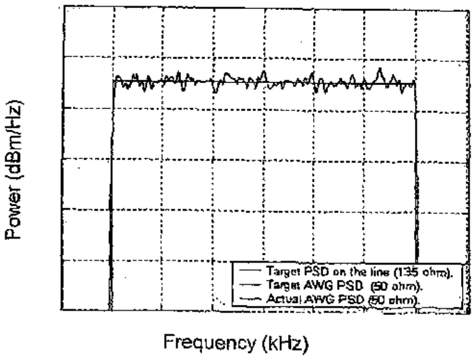

Power (dBm/Hz)
Target PSD on the line (135 ohm).
Target AWG PSD (50 ohm).
Actual AWG PSD (50 ohm).
Frequency (kHz)

Fig. 8

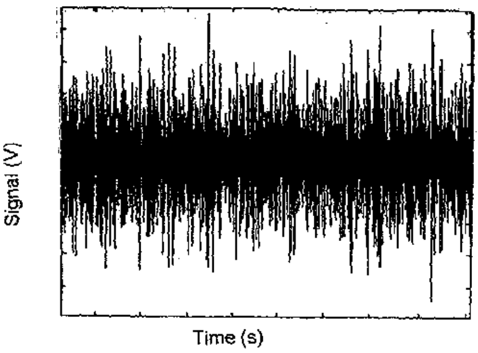

Signal (V)
Time (s)

Fig. 9

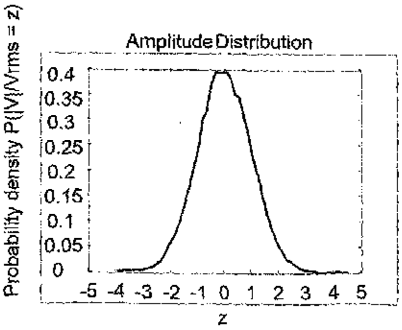
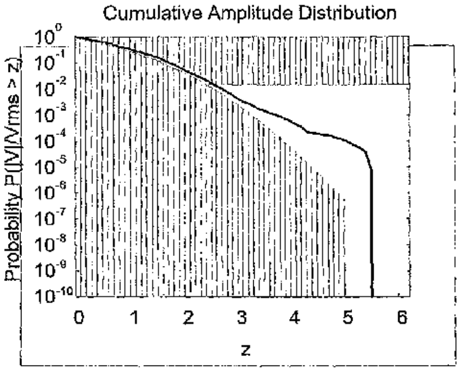

Amplitude Distribution
Probability density P{|V|/Vrms = z)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-5 -4 -3 -2 -1 0 1 2 3 4 5
z

Fig. 10



Cumulative Amplitude Distribution
Probability P(|V|/Vrms > z)
$10^{0}$
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
$10^{-7}$
$10^{-8}$
$10^{-9}$
$10^{-10}$
0 1 2 3 4 5 6
z


Fig. 11

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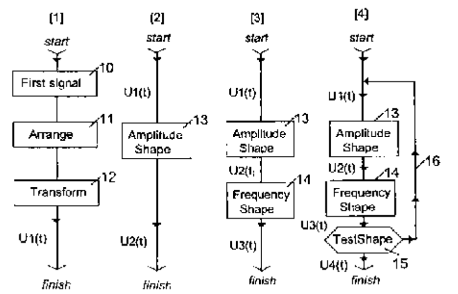
[*Continued on next page*]

(54) Title: A METHOD OF AND A DEVICE FOR GENERATING A SIGNAL HAVING A PREDETERMINED QUALITY CRITERION FOR USE IN OR ON A COMMUNICATION SYSTEM




(57) Abstract: There is disclosed a signal having a predefined quality criterion for use with a communication systems, a method of and a system for generating such a signal, a method of testing the operation of a communication system using such a signal and a (tele)communication system arranged for operating such a method. The method for generating the signal having a predefined quality the steps of: - representing a first signal (10) comprising a plurality of frequency components each having spectral amplitude and phase properties, and - processing the represented signal by arranging (11) its spectral amplitude properties, and - processing the represented signal by arranging (11) its spectral amplitude properties in accordance with the predefined quality criterion.

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## Title

A method of and a device for generating a signal having a predetermined quality criterion for use in or on a communication system.

## Field of the Invention

The present invention relates, generally, to communication systems and, more specifically, to a signal for use with a communication system, a method of and a system for generating such a signal, a method of testing the operation of a communication system using such a signal, a test system and a (tele)communication system arranged for operating such a method.

## Background of the Invention

Among others, for testing communication systems and communication equipment, such as xDSL transceivers and cables or networks, test signals are needed for stressing the communication system and the communication devices in a manner that is representative to actual deployment scenarios, with large numbers of systems or system devices per cable.

By measuring the transmission performance of the system or system device under realistic (noisy) test conditions, one can improve the design of the system or devices and/or prove that their performance is compliant with standards, such as issued by ETSI, ITU or ANSI or other (tele)communication bodies.

A method of executing such performance tests is to generate a signal which is known as impairment. More specifically, impairment can be subdivided into:

(i) cross-talk noise, having a noise profile characterized by a spectral envelope and spectral amplitude distribution e.g. from neighboring xDSL systems;

(ii) ingress noise, composed of discrete frequency components, also called rfi-tones, having a noise profile characterized by a number of discrete frequency components and spectral amplitude, modulation depth and modulation width parameters originating from radio and amateur broadcasting, for example, and

(iii) impulse noise characterized by signal pulses caused by switching operations and components for example.

In the case of ingress noise, the frequency may vary (sweep) in time.

A device for generating impairment is known as an impairment generator and is arranged, in particular for use in or on communication systems, for generating at least one of said cross-talk noise and ingress noise.

In practice, for testing whether communication systems and communication devices are compliant with standards, various noise profiles have been defined which, among others, vary in accordance with system parameters such as the length and number of wire pairs in a communication cable and the transmission data rate, for example.

Further, each different type or length of a transmission medium such as a cable, a copper cable or an optical fiber or other cable type, request a different noise signal.

Methods and devices for generating noise profiles are known in the art. In particular, filtering techniques and filters are known for generating noise from an input signal providing an output signal having a particular spectral envelope and spectral amplitude distribution.

However, by using filtering techniques and filters, a causal relationship is established between the input signal and the output signal. Those skilled in the art will appreciate that such a type of signal is less suitable for a realistic imitation of real operational communication systems and communication devices.

WO 00/16181 discloses a method and a device for generating a random time domain signal approaching a predetermined histogram of amplitudes. In a first step, the signal is created by filtering a noise signal, such as a white noise signal, thereby producing a signal having a predetermined spectral envelope. In a next step, a non-linear function is applied to the filtered noise signal, so as to produce the required time domain signal approaching the predetermined histogram of amplitudes. In a further step, pulse response filtering is applied to the time domain signal, to correct its spectral envelope and to obtain an output signal having a required spectral envelope. Both, the non-linear function and the pulse response filtering function are special functions selected in accordance with the spectral envelope to be provided.

WO 00/16181 is limited in the sense that there is only provided a time domain signal only having a predetermined spectral envelope. WO 00/16181 is silent with respect to other quality criterion's to be imposed on the time domain signal to be provided, among others phase properties.

## Summary of the Invention

It is an object of the present invention to provide an improved signal for use with communication systems and communication devices, in particular for testing such systems and devices in accordance with predefined (standardized) noise profiles.

In a first aspect of the present invention, there is disclosed a method of arranging a signal having a predefined quality criterion, preferably for use in or on a communication system, the method comprising the steps of:

- representing a first signal comprising a plurality of frequency components each having spectral amplitude and phase properties, and

- processing the represented first signal by arranging the spectral amplitude properties in accordance with the or each predefined quality criterion, and arranging random phase properties.

The traditional way of modifying the envelope of a spectrum is the usage of a digital filter bank. This is far from ideal since, for the purpose of the present invention, no causal relationship between the represented first signal and the signal to be provided has to be established. This understanding of matters in accordance with the present invention simplifies the approach of frequency shaping significantly.

Starting from a first signal having random phase properties, frequency shaping of the represented first signal may be an adequate operation to provide a signal meeting the predefined quality criteria, for example. Frequency shaping in accordance with the present invention can be performed in several ways.

In an embodiment of the invention, the first signal is represented by a first set of numbers specifying a spectral amplitude and phase of each frequency component. Scaling of the spectral amplitude of each frequency component suffices to effect frequency shaping of the represented signal in the frequency domain, while maintaining the random phase properties of the signal.

In a further embodiment of the invention, the first signal is represented by a second set of complex numbers having a real part and an imaginary part, which parts in combination specify a spectral amplitude and phase of each frequency component. Frequency shaping is effected by adequately scaling the complex numbers, however such to maintain random phase properties after scaling of the represented first signal.

In a yet further embodiment of the invention, the first signal is represented by a third set of numbers each specifying an amplitude of the first signal in the time domain. By transforming this third set of numbers from the time domain into the frequency domain using, for example, a Fast Fourier Transform (FFT) algorithm, the first signal is represented by a fourth set of numbers specifying a spectral amplitude and phase of each frequency component. This fourth set of numbers can be further processed by a frequency shaping operation, as disclosed above in connection with the first set of numbers.

However, the third set of numbers may also be transformed, in accordance with the invention, from the time domain into the frequency domain for representing the first signal by a fifth set of complex numbers having a real part and an imaginary part. As disclosed above, for the purpose of frequency shaping, the fifth set of complex numbers has to be adequately scaled.

In the case of a represented first signal having non-random phase properties, random phase properties can be approached by properly arranging the second, fourth and fifth set of numbers.

Scaling in the frequency domain can be invoked by multiplication operations, using real or complex scaling factors. The scaling factor for multiplication of the spectral amplitude of a frequency component is found by dividing its desired value by its actual spectral amplitude.

In accordance with a further embodiment of the method according to the invention, in order to achieve a closer match to the or each predefined quality criterion, post-processing of the processed represented first signal is provided.

For use in or on a communications system in accordance with the present invention, however, the represented first signal thus arranged in the frequency domain has to be transformed into the time domain using, for example, an Inverse Fast Fourier Transform (IFFT) algorithm.

Further, the processing steps disclosed above may also a include operations such as convolution or deconvolution or multiplication or add-on of signals.

In the time domain, the processed represented first signal meeting the or each predefined quality criterion may be represented among others by a sixth set of numbers in the time domain.

However, with the above approach the signal provided, meeting a quality criterion in the frequency domain, such as a predefined envelope of spectral amplitudes and random phase properties, may not yet meet a quality criterion in the time domain, such as a predefined time domain amplitude distribution.

In a yet further embodiment of the method according to the invention, the or each predefined quality criterion comprises any of a group including a predefined time domain amplitude distribution and a predefined envelope of spectral amplitudes.

Accordingly, in a further embodiment of the method according to the invention, the processed represented first signal is arranged in accordance with a predefined time domain amplitude distribution.

In a still further embodiment of the method according to the invention, the processed represented first signal is arranged in accordance with a predefined envelope of spectral amplitudes.

For providing a signal which accurately meets predefined quality criteria in both the frequency and time domain, according to the invention, at least one of the time domain amplitude distribution and the envelope of spectral amplitudes is approached by an iteration process. Amplitude and frequency shaping may be repeated as often as required until both shapes meet the requirements within reasonable accuracy.

In an embodiment of the invention, the iteration process comprises a comparison, after any iteration step, of any of the time domain amplitude distribution and envelope of spectral amplitudes of the processed represented first signal with a predefined time domain amplitude distribution and predefined envelope of spectral amplitudes.

It has been observed that there is no need to perform a full time domain characteristic check after frequency shaping to figure out whether the time domain characteristics are close enough to the requirements. A simple check of the crest factor requirement has proven to be adequate in practice to enable the decision whether to stop or to continue with the iteration. The crest factor of the signal is defined as the relation of the maximum or peak amplitude of the tones of the signal compared to the average or rms value of the tones of the signal.

The method according to the invention as disclosed above is, in particular, suitable for generating, among others, cross-talk noise.

If a signal having the characteristics of ingress noise is to be generated, in a second aspect of the method according to the invention, the or each predefined quality criterion comprises at least one modulated carrier, the or each modulated carrier including any of a group comprised of a carrier frequency, a carrier amplitude, a modulation depth, and a modulation width.

By shaping the represented first signal in accordance with a quality criterion or quality criteria indicated above, a signal representing a particular type of ingress noise, having a particular time domain amplitude distribution, and a predefined envelope of spectral amplitudes can be easily and very efficiently provided.

In accordance with the method of the present invention, the signal meeting the or each predefined quality criterion can be provided by combining a plurality of signals processed as disclosed above.

For use of the signal in, for example, the testing of a communication network or a communication device, the processed represented signal has to be transformed from the frequency domain into the time domain using, among others, a FFT algorithm, for example.

The invention further provides to combine the signals generated in accordance with the first and second aspect as disclosed above. However, also other signal components may be included.

In particular, in accordance with the method of the present invention, the signal having the or each predefined quality criterion is a noise signal.

In a third aspect of the invention, a method is disclosed of testing the operation of a communication system, which method comprises the steps of:

- generating a signal having a predetermined quality criterion in accordance with the method of the invention disclosed above, and

- transferring the signal through the communication system under test.

The signals can be generated and stored using a set of instructions in a code format and executed in a predetermined order on a device. Such set of instructions can be software code compiled on a computer and stored in the computer or a network of computers or a floppy or CD-ROM or through the Internet. The software and/or signals produced can also be stored on an Arbitrary Wave Form Generator (AWG) card and the AWG can be used to generate the signals or to reproduce stored signals from the memory. It is therefore possible to have a library of signals available stored on a data carrier that can be used in the execution or use of the method according to the invention.

The communication systems can be devices such as xDSL modems, or chips within or for such modems, or cables in the network, or networks for (tele)-communication.

In a fourth aspect of the present invention a further method is disclosed of arranging a signal for use on or in a communication system. Preferably the signal is a noise signal. The signal may comprise crosstalk noise that is a random signal with predetermined properties in the frequency domain and in the time domain. The signal can furthermore comprise rfi-tones that have a discrete frequency spectrum. Also other signal components can be included in the signal.

The method comprising the steps of:

- representing a first signal in time domain having a time domain amplitude distribution, the signal having a spectral density in the frequency domain, thereby achieving a represented signal;

- processing the represented signal in accordance with a non-linear transformation, the non-linear transformation achieving at least one predefined quality criterion,

- the time domain amplitude distribution of the represented signal being processed at least with an inverse function of a predetermined time domain amplitude distribution.

The method may further comprise the step of comparing the time domain amplitude distribution of the represented signal with the predetermined time domain amplitude distribution, and thereafter arranging the non-linear transformation in order to achieve a processed represented signal having a time domain amplitude distribution approaching the predetermined time domain amplitude distribution.

In a fifth aspect of the present invention a method is disclosed of further comprising the step of comparing the time domain amplitude distribution of the represented signal with the predetermined time domain amplitude distribution, and thereafter arranging the non-linear transformation in order to achieve a processed represented signal having a time domain amplitude distribution approaching the predetermined time domain amplitude distribution.

According to the fifth aspect of the invention the method can also comprise the steps of representing a first signal in time domain and with an amplitude distribution and the signal having a spectral density in the frequency domain, thereby achieving a represented signal, and filtering the represented signal in the frequency domain including the steps of evaluating at least part of the signal representation in the frequency domain and thereafter processing the represented signal in the frequency domain.

The methods of the fourth and fifth aspect of the invention can be combined. The methods of the fourth and fifth aspect of the invention allow to make a signal in different iterative steps that has a predetermined amplitude distribution and/or that has a predetermined spectral density or that has a amplitude distribution and/or that has a spectral density according to a predefined quality criterion. The predefined quality criterion can be the crest factor of the signal, that is the relation of the maximum or peak value of tones of the signal compared to the average value or rms-value of the tones of the signal. The processing steps as recited hereabove can comprise the steps of a Fast Fourier Transformation (FFT) or Inverse Fast Fourier Transformation (IFFT). The processing steps can also a include operations such as a convolution or deconvolution or multiplication or add-on of signals.

In the method of the fourth aspect, the amplitude distribution of the represented signal is processed including a function of the predetermined amplitude distribution, which can include an inverse function of the predetermined amplitude distribution.

The method as recited of the fourth and fifth aspect of the invention can further comprise the steps of transforming the first signal in the frequency domain; multiplying the first signal in the frequency domain with a spectral envelope thereby achieving a multiplied signal; and thereafter representing the multiplied signal in time domain.

In the methods, the first signal in its representation in the frequency domain can be generated as a set of random numbers, preferably complex numbers the modulus of the complex number characterizing amplitude, the argument of the complex number characterizing phase and the real and/or the imaginary part of essentially each of the complex numbers can be chosen according to a Gaussian distribution. Each of the complex numbers can be substantially equal to the amplitude of the predetermined spectral density.

In a sixth aspect of the present invention, a signal is disclosed comprising at least a random noise signal, the random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and a spectral density in the frequency domain according to a predetermined quality criterion, the random signal being composed of an array of random numbers. The signal can further comprise a discrete frequency spectrum. The noise signal can be generated using a set of instructions in a code format and being executed in a predetermined order. Such set of instructions can be software code compiled on a computer and stored in the computer or a network of computers or a floppy or CD-ROM or through the internet. The software can also be stored on an Arbitrary Wave Form Generator (AWG) card and the AWG can be used to generate the signals or reproduce stored signals from the memory. It is therefore possible to have a library of signals available that can be used in the execution or use of the methods of the fourth and fifth aspect of the invention.

In a seventh aspect of the present invention, a method is disclosed of generating a signal comprising at least a random noise signal, the random signal having an amplitude distribution in the time domain according to a predefined quality criterion and having a spectral density in the frequency domain according to a predefined quality criterion, the random signal being composed of an array of random numbers, the method comprising the step of generating a random set of numbers using a set of instructions in a code format and being executed in a predetermined order. The method can further comprise the step of generating a discrete frequency spectrum, the discrete frequency spectrum using goniometry functions and modulating essentially each of the discrete frequencies with a noise characteristic. The random noise signal and the discrete frequency spectrum can be combined using a set of instructions in a code format and being executed in a predetermined order.

In an eight aspect of the present invention, a set of instructions is disclosed in a code format and executable in a predetermined order, the set of instructions being arranged for generating a random noise signal and a discrete frequency spectrum, the random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion. Such set of instructions can be software code compiled on a computer and stored in the computer or a network of computers or a floppy or CD-ROM or through the internet. The software can also be stored on an Arbitrary Wave Form Generator (AWG) card and the AWG can be used to generate the signals or reproduce stored signals from the memory. It is therefore possible to have a library of signals available that can be used. The software can be C-code or can be compiled in a MATLAB environment.

In a ninth aspect of the present invention, a system for testing the operation of a communication system is disclosed comprising a set of instructions in a code format and executable in a predetermined order and compiled on a device, the set of instructions being arranged for generating a noise signal comprising at least one of a random noise signal and a discrete frequency spectrum, the random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion. The test system according to this aspect of the invention can comprise an impairment generator for generating the noise signal.

The connection elements (transformers, active devices, attenuators, etc.) that connect the impairment generator to the communication system that is tested can have an unwanted frequency dependent response. The unwanted frequency dependent response can be measured for instance by generating specific test signals in the impairment generator. The unwanted frequency dependent response can be compensated by multiplying the desired spectral density of the signal divided by the unwanted frequency dependent response of the connection element.

In a tenth aspect of the present invention, a method of testing the operation of a communication system such as a xDSL modem is disclosed. The method comprises the step of superposing on a signal transceived by a the modem, a signal comprising at least one of a random noise signal and a discrete frequency spectrum, the random signal having an amplitude distribution in the time domain according to a predefined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion., the noise signal furthermore being composed of an array of random numbers.

In an eleventh aspect of the present invention a method of testing the quality of operation of a communication system is disclosed. The method comprises the steps of superposing on a signal transceived by a the modem, a signal comprising at least one of a random noise signal and a discrete frequency spectrum, the random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predefined quality criterion, the noise signal furthermore being composed of an array of random numbers, and evaluating the transceived signal according to a predefined quality criterion.

Yet in a twelfth aspect of the present invention, a method of improving the design and/or production of a communication system is disclosed, the method comprising the steps of superposing on a signal transceived by a the modem, superposing on a signal transceived by the modem, a signal comprising at least one of a random noise signal and a discrete frequency spectrum, the random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion, the noise signal furthermore being composed of an array of random numbers; evaluating the transceived signal according to a predetermined quality criterion; and iteratively arranging the design of the modem in order to approach closer to the quality criterion for evaluating the transceived signal.

In a thirteenth aspect of the present invention, a telecommunication network is disclosed including a signal comprising at least one of a random noise signal and a discrete frequency spectrum, the random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion, the noise signal furthermore being composed of an array of random numbers.

The features of the above-described aspects and embodiments of the invention can be combined.

The signal, the methods and the set of instructions recited hereabove will allow to have a better quality of signal transmission over media such as telephone cables or wireless media. A better transmission of signals allows for a broader providing of more services for the users of communication systems.

## Brief Description of the Figures

Figure 1 shows, in a block diagram, a set-up for a performance test in a communication system, using an impairment generator operating in accordance with the method of the present invention.

Figure 2 shows a flow diagram type of embodiments of the method according to the invention.

Figure 3 shows, in a graphic representation, an embodiment of the method according to the invention for generating ingress noise.

Figure 4 shows a flow diagram type of further embodiments of a method according to the invention.

Figure 5 shows an amplitude distortion (non-linear transformation) function $Q(x)$ that amplifies the high amplitude peaks or tones in a signal.

Figure 6 shows in a flow diagram an example embodiment of the invention.

Figures 7-11 show results that are obtained according to an embodiment of the invention.

## Detailed Description of the Embodiments

For the purpose of teaching the invention, aspects and embodiments of the signal and method and systems of the invention are described below. It will be appreciated by those skilled in the art that other alternative and equivalent embodiments of the invention can be conceived and reduced to practice without departing form the true spirit of the invention. The scope of the invention being limited only by the appended claims.

In an embodiment of the invention, a system for testing the operation of a communication system such as a xDSL transceiver is disclosed. The set up of a test equipment for a high penetration of systems scenario in operational access networks is described.

A method is disclosed of arranging a signal for use on or in a communication system.

The purpose of transmission performance tests is to stress xDSL transceivers in a way that is representative to a high penetration of systems scenario in operational access networks. This high penetration approach enables:

(i) component and system designers to quantify the performance and to use it to improve their design and to prove compliance with standards; and

(ii) operators to define deployment rules that apply to most operational situations.

Figure 1 illustrates the functional description of a possible test set-up 1. It includes:

- a test loop 2, being a real cable or a cable simulator;
- an adding element 3 to inject impairment noise into the test loop 2;
- a high impedance, and well balanced differential voltage probe 4, connected with level detectors 5 such as a spectrum analyser or an rms volt meter, for example, (not shown), and
- xDSL transceivers (modems) 6, 7 under test.

When external splitters are required for the xDSL system under test (for POTS or ISDN signals), these splitter can be included in the modems 6, 7 under test.

The signal flow through the test equipment set-up 1 is from port Tx to port Rx, which means that measuring upstream and downstream performance requires an interchange of transceiver position and test "cable" ends. The received signal level at port Rx is the level, measured between node A2 and B2, when port Tx as well as port Rx are terminated with the xDSL transceivers (modems) 6, 7 under test. The impairment generator 8 is switched off during this measurement. The transmitted signal level at port Tx is the level, measured between node A1 and B1, under the same conditions.

The noise that the impairment generator 8 should inject into the test set-up 1 is frequency dependent. The noise which the impairment generator 8 injects into the test set-up 1 should be a realistic representation of a real (spectral polluted) access network, and is:

(a) dependent on the length of the test loop 2, and

(b) different for downstream performance tests and upstream performance tests.

This impairment noise, measured between node A2 and B2, is usually a mix of random, impulsive and harmonic noise (the rfi-tones). A set of characteristics is identified as a "noise profile".

The signal and noise levels are probed with a well balanced differential voltage probe 4.

In a fully automated test set-up 1 the test loop 2, 3 the voltage probe 4 and level detector 5, the modems under test 6, 7 and the impairment generator 8 may connect to a

Central Processing Unit (CPU) 9, as schematically indicated with broken lines. Those skilled in the art will appreciate that the connections with the CPU 9 may involve data links for remote testing by the CPU 9.

Definitions that are relevant for the use of the test equipment are the following :

- Probing an rms-voltage $U_{rms}$ [V] in this set-up, over the full signal band, means a power level of P [dBm] that equals: $P = 10 \times \log_{10}( U_{rms}^2 / R_V \times 1000)$ [dBm];
- Probing an rms-voltage $U_{rms}$ [V] in this set-up, within a small frequency band of $\Delta f$ (in Hertz), means a power spectral density level of P [dBm/Hz] within that filtered band that equals: $P = 10 \times \log_{10}( U_{rms}^2 / R_V \times 1000 / \Delta f)$ [dBm/Hz];
- The bandwidth $\Delta f$ identifies the noise bandwidth of the filter, and not the −3dB bandwidth.

Figure 2 shows schematically embodiments of the method for arranging a signal Ui(t) i=1,2,3,... for use on or in a communication system in accordance with the invention. The signal may comprise cross-talk noise, that is a random signal with predetermined properties in the frequency domain and in the time domain.

As represented by flow (1) of Figure 2, the method comprises the steps of representing a first signal comprising a plurality of frequency components each having spectral amplitude and phase properties, block 10 "First signal", and processing the represented signal by arranging the spectral amplitude properties in accordance with at least one predefined quality criterion, as well as arranging random phase properties, block 11 "Arrange", thereby achieving a processed represented signal.

The first signal may be represented by a first set of numbers specifying a spectral amplitude and phase of each frequency component. Further, the first signal may be represented by a second set of complex numbers, having a real part and an imaginary part, which parts in combination specify a spectral amplitude and phase of each frequency component. That is, the modulus of a complex number characterises the spectral amplitude whereas the argument of the complex number characterises the phase of the frequency component.

In accordance with the present invention, the represented first signal 10 is processed to arrange random phase properties. However, starting from a represented first signal 10 having random phase properties, for shaping the frequency of the signal in accordance with the predefined quality criterion, it suffices to shape the spectral amplitude of the frequency components.

The method may also comprise the steps of representing the first signal in the time domain, in that the first signal is represented by a third set of numbers each specifying an amplitude of the first signal in the time domain. By transforming the third set of numbers from the time domain into the frequency domain, for example using an FFT algorithm, a fourth set of numbers is achieved specifying a spectral amplitude and phase of each frequency component. Likewise, the fourth set of numbers is to be processed by arranging the spectral amplitude properties in accordance with the at least one predefined quality criterion, as well as arranging its random phase properties.

By transforming the processed represented signal from the frequency domain into the time domain, for example using an Inverse FFT algorithm (IFFT), block 12 "Transform", the signal U1(t) having the at least one predefined quality criterion is eventually generated.

While the signal U1(t) meets at least one predefined quality criterion in the frequency domain, such as a spectral envelope and/or pre-emphasise properties, it may yet be required to provide a signal having a predefined quality criterion in the time domain.

As disclosed in flows [2] and [3] of Figure 2, i.e. block 13 "Amplitude Shape" and block 14 "Frequency Shape", the quality criterion in the time domain may comprise a predefined amplitude distribution and/or a predefined envelope of spectral amplitudes.

The method can also comprise the step of making a signal in different iterative steps, see Figure 2 [4]. Block 15 "Test Shape" and back coupling loop 16. Thus the signal can have a predetermined time domain amplitude distribution and/or a predetermined envelope of spectral amplitudes and/or a spectral density according to predetermined quality criterion's.

The at least one predetermined quality criterion can be the crest factor of the signal that is a relation of the maximum or peak value of the tones of the signal compared to the average or rms value of the tones of the signal.

The signals can be generated and stored using a set of instructions in a code format and executable in a predetermined order and compiled on a device. Such set of instructions can be software code compiled on a computer and stored in the computer or a network of computers or a floppy or CD-ROM or through the Internet. The software can also be stored on an Arbitrary Wave Form Generator (AWG) card and the AWG can be used to generate the signals or reproduce stored signals from the memory. It is therefore possible to have a library of signals available that can be used in the execution or use of the methods of the first and second aspect of the invention. The communication systems can be devices such as xDSL modems 6, 7, or chips within or for such modems 6, 7, or networks for telecommunication.

The processing in block 13 "Amplitude Shape" in Figure 2 is done for achieving an impact or control on the time domain characteristics. An amplitude distortion (transformation) function *Q(x)* is chosen that amplifies the high amplitude peaks or tones in the signal. A non-linear transformation function *Q(x)* can be reconstructed from the actual amplitude distribution function of the signal and the predetermined amplitude distribution function.

For a noise signal *f(t)* in the time period *t* in between 0 en T, the amplitude distribution *F(a)* of the signal is defined as a fraction of the time that the noise *f* in absolute value is larger than *a*. If *G(a)* is the predetermined amplitude distribution (such as an enhanced-Gaussian, see below), and $G^{-1}(a)$ is the inverse function thereof, the transformation function *Q(x)* to make an intermediate or final signal *g(t)* from the noise signal *f(t)* can be defined as:

$$Q(x) = sign(x) \cdot G^{-1}(F(|x|)) \qquad (1)$$

$$g(t) = Q\{f(t)\}; \qquad (2)$$

sign(x)=x/|x| for x<>0; sign(x)=0 for x=0;

As a result *g(t)* will have the predetermined amplitude distribution *G(a)*. *Q(x)* in a number of cases can be an analytical function but can also be numerically constructed.

An example of an enhanced Gaussian function is as follows.

The amplitude distribution of Gaussian type noise is:

$$G(x) = 1 - erf\left(\frac{x}{\sqrt{2}\sigma}\right) \quad (3)$$

$$\text{with}: erf(x) = \frac{2}{\sqrt{\pi}} \int_0^x dt \exp\left(-t^2\right), \quad (4)$$

and with $\sigma$ being the RMS value of the signal.

The "enhanced" Gaussian distribution is defined as:

$$G(x) = \begin{cases} 1 - \left(\alpha \, {}^{x}\!/_{A} + erf\left(\frac{x}{\sqrt{2}\sigma}\right)\right) \Big/ \left(\alpha + erf\left(\frac{A}{\sqrt{2}\sigma}\right)\right) & 0 \le x \le A \\ 0 & x > A \end{cases}, \quad (5)$$

If $V_{RMS}$ is the desired RMS value of the noise sample, and $C_f$ being the desired crest factor, choose:

$$A = C_f \times V_{RMS}, \text{ and} \quad (6)$$

$$\sigma = \sqrt{((1+\alpha)\, V^2_{RMS} - A^2 \cdot \alpha/3)}. \quad (7)$$

Typical values for $\alpha$ that have proven useful are of a magnitude between 0.001 and 0.01, and this represents the deviation of enhanced Gaussian distributed from a true Gaussian distribution.

In block 14, Frequency Shape, of Figure 2, the frequency domain characteristics of the signal are improved, as a posed-processing step to achieve a closer match to the or each quality criterion. The corrected frequency curve can be achieved, for example, by comparing (dividing) a predetermined spectral density through the measured spectral density of the (intermediate) signal U2(t). An example hereof is given in the best mode embodiment described in the sequel with a convolution of FFT functions.

In the part [4] of Figure 2, it is shown how an iterative procedure of the steps detailed here above may lead to a further improvement of the finish or final signal for use in or on a communication system. The iterative procedure, i.e. testing of the frequency shape by block 15, Test Shape, and back coupling loop 16, is executed until the predetermined quality criterion(s) are achieved.

Figure 3 illustrates in a schematic, graphic representation use of the method according to the invention for the provision of an ingress noise signal.

As disclosed in the preamble, ingress noise may be characterised by a plurality of frequency components at discrete carrier frequencies fci, i=1,2,3, .... The frequency components at the carrier frequency fci each having a carrier amplitude Aci, i=1,2,3, ..., and, if applicable, having a modulation width, i.e. a number of discrete frequencies at the left and right hand side of the associated carrier frequency fci, as well as having a modulation depth, that is the amplitude of the side frequencies associated with the respective carrier frequency fci.

Figure 3 shows, in a graphic representation having a horizontal or frequency axis f and a vertical or amplitude axis A, by way of example only, a signal comprised of two carrier frequencies fc1 and fc2, having a carrier amplitude Ac1 and Ac2, respectively.

Around the carrier frequency fc1 at each side thereof three side frequency components are arranged, each having an amplitude A1. For the frequency component at carrier frequency fc2 on each side thereof two side frequency components are arranged, each having an amplitude A2.

In accordance with the present invention, for providing a signal having at least one predefined quality criterion, the amplitude of the frequency components have to be shaped, such as disclosed by the dotted lines 1 and 2 in Figure 3.

Starting from a represented first signal having random phase properties, in accordance with the present invention, by the shaping of the amplitudes, the random phase properties are maintained in the signal to be provided having the predefined quality criterion.

Figure 4 shows schematically a further embodiment of a method for arranging a signal for use in or on a communication system, in particular for use if random phase properties are already provided for. The signal comprises crosstalk noise that is a random signal with predetermined properties in the frequency domain and in the time domain. The signal can furthermore comprise rfi-tones that have a discrete frequency spectrum. Also other signal components can be included in the signal.

The method further may comprise the steps of representing a first signal in time domain and with an amplitude distribution and the signal having a spectral density in the frequency domain, thereby achieving a represented signal, and processing the represented signal according to a non-linear transformation, the non-linear transformation achieving a predetermined quality criterion. This is shown as amplitude shaping in Figure 4, flows [2-4].

The method further may comprise the step of representing a first signal in time domain and with an amplitude distribution and the signal having a spectral density in the frequency domain, thereby achieving a represented signal, and processing the represented signal until a signal is achieved having a spectral density according to a predetermined spectral density quality criterion. This is shown as frequency shaping in Figure 4, flows [2-4]. The frequency shaping step can also comprise the step of filtering the represented signal in the frequency domain including the steps of evaluating at least part of the signal representation in the frequency domain and thereafter processing the signal representation in the frequency domain.

The method may also comprise the step of making a signal in different iterative steps, see Figure 4 flow [4]. Thus the signal can have a predetermined time domain amplitude distribution and/or a predetermined spectral density or a time domain amplitude distribution and/or a spectral density according to a predefined quality criterion. The predefined quality criterion can be the crest factor of the signal, that is a relation of the maximum or peak value of the tones of the signal compared to the average value of the tones of the signal. The signals can be generated and stored using a set of instructions in a code format and executable in a predetermined order and compiled on a device.

Likewise, the set of instructions can be software code compiled on a computer and stored in the computer or a network of computers or a floppy or CD-ROM or through the internet. The software can also be stored on an Arbitrary Wave Form

Generator (AWG) card and the AWG can be used to generate the signals or reproduce stored signals from the memory. It is therefore possible to have a library of signals available that can be used in the execution or use of the methods of the invention. The communication systems can be devices such as xDSL modems, or chips within or for such modems, or networks for telecommunication. In detail the following embodiment is shown in Figure 4.

Using software, random numbers are generated, block 16, "Create Noise". In hardware white noise can be generated. The random numbers are filtered until a predetermined spectral density is achieved. The random numbers that are generated each represent a frequency component. The necessary processing to achieve a predetermined spectral density is executed by scaling the amplitude of the complex numbers and thereafter an IFFT processing is done in order to make the desired noise signal. Another way of executing the method is to generate random numbers that represent the phase of each frequency component and thereafter the amplitude of the complex numbers is arranged to approach or be equal to a predetermined spectral density

The processing in block 13, "Amplitude Shape", is done for achieving an impact or control on the time domain characteristic. An amplitude distortion (transformation) function $Q(x)$ is chosen that amplifies the high amplitude peaks or tones in the signal is shown in Figure 5. The non-linear transformation function $Q(x)$ can be reconstructed from the actual amplitude distribution function of the signal and the predetermined amplitude distribution function, as disclosed above in connection with the equations (1-7).

In block 14, "Frequency Shape" of Figure 4, the frequency domain characteristics of the signal are improved. The corrected frequency curve is achieved by comparing (dividing) a predetermined spectral density through the measured spectral density of the (intermediate) signal. An example hereof is given in the best mode embodiment described in the sequel with a convolution of FFT functions.

In the flow [4] of Figure 4, like in the flow [4] of Figure 2, again it is shown how an iterative procedure of the steps detailed hereabove may lead to a further improvement of the final for use in or on a communication system. The iterative procedure is executed until the predetermined quality criterions are achieved.

With the method according to the invention, as disclosed above, signals representing cross-talk noise and ingress noise can be generated with a device, such as an impairment generator 8, see Figure 1, which may be arranged for providing a signal comprised of both a cross-talk noise signal and an ingress noise signal, while other signal components may be added to the output signal to be provided, if required.

The signal to be provided, in an embodiment of the invention, can be advantageously provided as a sixth set of numbers in the time domain, for example an array of numbers.

Figure 6 shows, in a flow type diagram, an example embodiment of the invention, running on a Personal Computer 20. The impairment noise is generated by block 21, called SPOCS, comprising a block 22, "White noise signal", a block 23 "Spectral shaping", provided by FFT, a block 24, "Desired noise signal", produced from the output of block 23 by IFFT, the resulting signal of which is stored on an AWG card 25. In the crosstalk scenario, i.e. block 26, a noise PSD is created, block 27, which is further processed by block 23.

A best mode embodiment of the set of instructions of the invention is disclosed here below. The code given here below is compiled in a MATLAB environment. Comments related to the functionality of the code are given after the % signs. For a person skilled in the art, the code provided is self-explanatory.

Figures 7-9 show results obtained with the best mode embodiment. Figure 8 shows a plot of the spectrum of the generated noise sample plus the PSD of the noise profile. Figure 9 shows a plot of the generated noise sample in the time domain. Figure 10 shows a plot of the distribution function of the generated noise sample. Figure 11 shows a plot of the cumulative distribution functiopn of the generated noise sample. Figure 7 shows a graphical User Interface (UI) and settings of the AWG control.

```
%-------------------------------------------------------------------------------
function DemoImpair2;
%-------------------------------------------------------------------------------
% DemoImpair2
%       Code, programmed in the Matlab programming language, that demonstrates the
%       basic algorithms of an Impairment Generator.
%       The demonstrated algorithms have full control over the predefined quality
%       criteria, such as:
%               - frequency and time domain characteristics (spectrum; probability
%                 distribution) when generating noise with continuous spectra
%               - carrier amplitude, carrier frequency, modulation depth and modulation
%                 width, when generating noise with discrete spectra
%       Both types of noise are calculated independently, and represented in the time
%       domain as arrays with numbers.
%       Both types of noise can be made available simultaneously by adding these
%       arrays element wise.
%       (c) 2000-2001 KPN Research;
%
% DEMO FUNCTIONS
%       DemoXtalkNoise          - shows the process of creating continuous noise
%       DemoIngressNoise        - shows the process of creating discrete noise
%
% MAIN FUNCTIONS: Noise is represented as an array with random numbers
%       DefineShape             - initialize all user-definable parameters
%       CreateNoiseCont         - generates continuous noise
%       CreateNoiseDiscr_Fast   - generate discrete noise, fast algorithm
%       CreateNoiseDiscr_Slow   - generate discrete noise, slow algorithm
%       FrequencyShape          - modify spectral density of continuous noise
%       AmplitudeShape          - modify amplitude distribution of continuous
%                                 noise
```

```
% SUPPORTING FUNCTIONS:
%     CalcSpec                  - calculates the spectral density of noise
%     CalcNBSV                  - calculates the narrow band signal voltage of
%                                 noise
%     CalcCrest                 - calculates the crest factor of noise
%     CalcDistrib               - calculates the probability distribution of noise
%     CalcCumDistrib            - calculates the cumulated distribution of noise
%     CalcSmooth                - smoothes a spectrum, like in a real spectrum
%                                 analyzer
%     CalcEnhancedGaussDistribution   - a sample of a near-gaussian distribution
%     CalcDemodulation          - calculate the noise modulated on a carrier
%----------------------------------------------------------------------------
Shape=DefineShape;
DemoXtalkNoise(Shape);
DemoIngressNoise(Shape);

%----------------------------------------------------------------------------
function [U,t]=DemoXtalkNoise(Shape);
%----------------------------------------------------------------------------
% demonstrates the generation of noise with continuous spectrum
% e.g. for crosstalk testing
R       = Shape.R;
CF_min = Shape.Xtalk.CF_min;
[U,t]=CreateNoiseCont(Shape);  plot(t,U);          title('Xtalk method 1'); shg; pause
[X,f]=CalcSpec(U,t);           plot(f,X);          title('Xtalk method 1'); shg; pause
[X,f]=CalcSpec(U,t);           plot(f,dBm(X,R)); title('Xtalk method 1'); shg; pause
[P,u]=CalcCumDistrib(U);       plot(u,P);          title('Xtalk method 1'); shg; pause
%
U=AmplitudeShape(U,Shape);     plot(t,U);          title('Xtalk method 2'); shg; pause
```

```
[X,f]=CalcSpec(U,t);           plot(f,X)            title('Xtalk method 2'); shg; pause
[X,f]=CalcSpec(U,t);           plot(f,dBm(X,R)); title('Xtalk method 2'); shg; pause
[P,u]=CalcCumDistrib(U);       plot(u,P);           title('Xtalk method 2'); shg; pause
%
U=FrequencyShape(U,Shape);     plot(t,U);           title('Xtalk method 3'); shg; pause
[X,f]=CalcSpec(U,t);           plot(f,X);           title('Xtalk method 3'); shg; pause
[X,f]=CalcSpec(U,t);           plot(f,dBm(X,R)); title('Xtalk method 3'); shg; pause
[P,u]=CalcCumDistrib(U);       plot(u,P);           title('Xtalk method 3'); shg; pause
%
for i=2:10
 i
 U=AmplitudeShape(U,Shape);
 [X,f]=CalcSpec(U,t);
 %
 U=FrequencyShape(U,Shape);
 [X,f]=CalcSpec(U,t);
 %
 if CalcCrest(U)>CF_min, break; end;
end;
[P,u]=CalcCumDistrib(U);
plot(t,U);            title('Xtalk method 4'); shg; %pause
plot(f,dBm(X,R));     title('Xtalk method 4'); shg; %pause
plot(u,P);            title('Xtalk method 4'); shg; %pause

%-------------------------------------------------------------------------------------
function [U,t]=DemoIngressNoise(Shape);
%-------------------------------------------------------------------------------------
% demonstrates the generation of noise with discrete spectrum e.g. for ingress testing
R = Shape.R;
[U,t]=CreateNoiseDiscr_Fast(Shape);
```

```
%[U,t]=CreateNoiseDiscr_Slow(Shape); %gives same result
[X,f]=CalcNBSV(U,t); plot(f,dBm(X,R)); title('Ingress method'); shg; pause
for ToneNr=[1:2]
 [Uac,Uac_rms]=CalcDemodulation(U,t,Shape,ToneNr);
 plot(t,Uac); title('demoduluted ingress noise of one carrier'); shg; pause
 [P,u]=CalcDistrib(Uac/Uac_rms);
 plot(u,P); title('distribution of demod noise'); shg; pause
end;

%-----------------------------------------------------------------------------------
function [Shape] = DefineShape;
%-----------------------------------------------------------------------------------
%Create the noise profiles for the noise that should be generated, in terms of
%       - spectral density (in this example rectangular in nature)
%       - probability distribution (in this example near Gaussian)
%       - tones and modulation
%       Spectra in Volt per sqrt(Hz)
%-----------------------------------------------------------------------------------
Fmax=4E6; Fl=300E3; Fh=700E3; N=2^18; R=135;
cf=5.5;        % desired crest factor)
cf_min=5.1;    % desired crest factor)
m=N/2;
%
Shape.N=N;                     % number of time samples
Shape.m=m;                     % number of freq samples
Shape.dF= Fmax./(m-1);         % frequency spacing
Shape.dT= 1/(N*Shape.dF);      % time spacing
Shape.R=R;                     % impedance of desired noise source;
% define crosstalk noise target (Spectral density & Amplitude Distribution)
Shape.Xtalk.freq =[0:m-1]' * Shape.dF;
```

```
Shape.Xtalk.spec =(Shape.Xtalk.freq>=Fl).*(Shape.Xtalk.freq<=Fh)*(1/300);
Shape.Xtalk.DistU = 0:cf/1000:cf;
Shape.Xtalk.DistP = CalcEnhancedGaussDistribution(Shape.Xtalk.DistU, cf); %P
Shape.Xtalk.CF_min=cf_min;
% define ingress noise target (RFI-Tones)
P_dBm =[-70;-50;-60;-60;-40;-60;-60;-40;-70;-40]; % dBm @ 135 ohm
P=(10).^(P_dBm/10)*1E-3;
Shape.Ingress.ToneU =sqrt(P*135);                % U=sqrt(P*R); effective value
Shape.Ingress.ToneF =[99;207;333;387;531;603;711;801;909;981]*1E3;
Shape.Ingress.ModDepth = 0.32*ones(10,1);%=mod index > 0.8, at CF>2.5 )
Shape.Ingress.ModWidth = 2*4.5E3*ones(10,1);    %= -10 kHz .. +10 kHz)

%-----------------------------------------------------------------------
function [U,t] = CreateNoiseCont(Shape);
%-----------------------------------------------------------------------
% create a noise voltage U(t), with predefined frequency domain characteristics
% (spectrum), but with uncontrolled time domain characteristics (distribution)
N = Shape.N;                           % number of samples, to be generated
%U = rand(N,1);                        % Uniform distributed white noise
U = randn(N,1);                        % Gaussian distributed white noise
U = FrequencyShape(U,Shape);           % shaped noise
t=[0:N-1]' * Shape.dT;                 % associated time axis

%-----------------------------------------------------------------------
function [U,t] = CreateNoiseDiscr_Fast(Shape);
%-----------------------------------------------------------------------
% Create a voltage U(t), with AM modulated carriers (RFI Tones); each having an
% individual predefined frequency, amplitude, modulation width and modulation depth.
% The random phase of the lower side band of each carrier tone is mirrored to
% convert arbitrary QAM modulation into (no mirroring) into the more restricted
```

```
% AM modulation (full mirroring)
% Mark that X refers in this algorithm to the components of   the Fourier series
% of the (near harmonic) ingress noise signal , while it  refers to the
% spectral density in case of the (pseudo random) crosstalk noise signal
%
% Calculation time increases about linear with the number of samples
% About 80% of all calculation time is caused by the inverse Fourier transform
%-------------------------------------------------------------------------------
N = Shape.N;                                    % number of samples
m = Shape.m;                                    % half this number
Nc=round(Shape.Ingress.ToneF/Shape.dF)+1;       % index of carrier freq (pos only)
Nm=round(Shape.Ingress.ModWidth/Shape.dF/2);    % number of modulation
                                                % components
Xc=0.5*Shape.Ingress.ToneU;                     % amplitude of carrier amplitude
Xm=Shape.Ingress.ModDepth.*Xc./sqrt(2*Nm);      % amplitude of modulation band
X=zeros(N,1);                                   % initialization
Xc=Xc.*exp(j*1000*rand(size(Xc)));              % random carrier phase
Xcc=(Xc.*Xc)./abs(Xc.*Xc);
for k=1:length(Nc)                              % for all modulated carriers, do:
  Nmp=Nc(k)+[1:Nm(k)]';                         % locate upper side band
                                                % frequencies
  Nmn=Nc(k)-[1:Nm(k)]';                         % locate upper side band
                                                % frequencies
  Xmp=Xm(k).*exp(j*1000*rand(size(Nmp)));       % create upper side band
  Xmn=conj(Xmp)*Xcc(k);                         % mirror lower side band
  X(Nmp)=Xmp;                                   % insert upper side band
  X(Nmn)=Xmn;                                   % insert lower side band
end;
X(Nc)=Xc;                                       % insert all carriers
X(N:-1:m+2)=conj(X(2:ceil(m)));                 % Append spectrum
```

```
                                        % (negative freq.)
%U= real(ifft(X))*N;                    % Transform to time-domain
U = real(fft(X));                       % Transform to time-domain
                                        % (10% faster)
t = Shape.dT*[0:N-1]';                  % associated time axis


%-------------------------------------------------------------------------
function [U,t] = CreateNoiseDiscr_Slow(Shape);
%-------------------------------------------------------------------------
% Create a voltage U(t), with RFI Tones at predefined frequency, amplitude
% and modulation bandwidth and modulation depth
% This algorithm is straight-forward, very inefficient, and for demo purposes only
% It can prove that CreateNoiseDiscr_Fast returns the same results
%-------------------------------------------------------------------------
N = Shape.N;                            % number of samples, to be generated
m = Shape.m;
f=[0:N-1]' * Shape.dF;
t=[0:N-1]' * Shape.dT;
Fc=Shape.Ingress.ToneF;                 % list of carrier frequencies
Fc=Shape.dF * round(Fc/Shape.dF);       % force an integer number of periods
%
U=0;
for k=1:length(Shape.Ingress.ToneF);
 % -- create noisy modulate, having U_avg=0 and U_rms=1.
 Nm =round(Shape.Ingress.ModWidth(k)/Shape.dF/2);
 Xn0=([1:N]<=(Nm+1))';                  % shape modulation noise amplitude
 Xn  =Xn0.*exp(j*1000*rand(N,1));       % shape modulation noise phase
 Xn(1)= 0;                              % Eliminate DC component.
 Xn(N:-1:m+2)=conj(Xn(2:ceil(m)));      % Append spectrum (negative freq.)
```

```
Noise = real(ifft(Xn));                      % Transform to time-domain
Noise=Noise/sqrt(sum(Noise.*Noise)/N);  % force rms=1
% -- perform modulation
Carrier  = Shape.Ingress.ToneU(k)    * cos(2*pi*Fc(k)*t+1000*rand);
Modulate = Shape.Ingress.ModDepth(k) * Noise;
U = U + Carrier .* (1 + Modulate);
end;


%----------------------------------------------------------------------------
function [U] = FrequencyShape(U,Shape)
%----------------------------------------------------------------------------
% Reshape the spectrum of the sample U, as specified by the target shape
% INPUT:
%     U:          the consecutive values of the sample
%     fs:         the sample frequency
%     spectrum:   the desired PSD (in V/sqrt(Hz))
%----------------------------------------------------------------------------
N = length(U);
m = length(Shape.Xtalk.spec);              % m=N/2
t= [0:N-1]'*Shape.dT;
% perform the frequency scaling
Scaling = Shape.Xtalk.spec ./ CalcSpec(U,t);
X = fft(U);                                % Transform to frequency domain
X(1) = 0;                                  % Eliminate DC component.
X(2:m+1)  = X(2:m+1) .* Scaling;           % Scale  spectrum (positive freq.)
X(N:-1:m+2)=conj(X(2:ceil(m)));            % Append spectrum (negative freq.)
U = real(ifft(X));                         % Transform to time-domain
```

```
%-----------------------------------------------------------------------------------------
function [U] = AmplitudeShape(U,Shape)
%-----------------------------------------------------------------------------------------
% This function shapes the amplitude distribution of the function U
% by an amplitude dependent (non-linear) distortion function Q(x).
% The result is U(t) = Q{U(t)}
%
% Let FF be the actual cumulative distribution function of the sample, and
% let GG be the desired cumulative distribution function,
% then the distortion function is given by:
%      Q(x) = GG^{-1} FF (x)
%-----------------------------------------------------------------------------------------
U0=sqrt(sum(U.*U)/length(U));                     %scaling farct (for normalization)
% Calculate the distortion function Q
[DistP1,DistU1] = CalcCumDistrib(U/U0);                  % the actual distribution
Q = interp1(Shape.Xtalk.DistP, Shape.Xtalk.DistU, DistP1); % the distortion function
U = U0 *interp1(DistU1,Q,abs(U/U0)) .* sign(U);          % Perform the distortion
% plot(DistU1,Q); shg; %pause

%-----------------------------------------------------------------------------------------
function [X,f] = CalcSpec(U,t);
%-----------------------------------------------------------------------------------------
% calculate the spectral density of a signal, when it would be 'measured'
% at specified resolution bandwidth
RBW=1E3;                %RBW:  the desired resolution for the spectrum of U
N = length(U); m=N/2;
dT = t(2)-t(1);                        % time spacing
dF = 1/dT/N;                           % frequency spacing
f= [0:m-1]'*dF;                        % all positive frequencies
X = fft(U)*dT;                         % to frequency domain
```

```
X = abs(X(2:m+1));                    % No DC and no negative frequencies.
X = sqrt(CalcSmooth(X.*X, f, RBW));   % average it over bandwidth RBW

%------------------------------------------------------------------------
function [X,f] = CalcNBSV(U,t);
%------------------------------------------------------------------------
% calculate the narrow band signal voltage of a signal, when it would be 'measured'
% at specified resolution bandwidth
RBW=1E3;          %RBW:     the desired resolution for the spectrum of U
N = length(U); m=N/2;
dT = t(2)-t(1);                       % time spacing
dF = 1/dT/N;                          % frequency spacing
f= [0:m-1]'*dF;                       % all positive frequencies
%X = fft(U)*dT * sqrt(dF);            % to frequency domain
%X = fft(U)/N;                        % to frequency domain
X = fft(U)/N*2;                       % to frequency domain
X = abs(X(2:m+1));                    % No DC and no negative frequencies.
%X = sqrt(CalcSmooth(X.*X, f, RBW));  % average it over bandwidth RBW

%------------------------------------------------------------------------
function [CF] = CalcCrest(U)
%------------------------------------------------------------------------
% Calculate the Crest Factor of a signal (U(t), which is the peak value
% divided by the rms-value
Urms = sqrt(sum(U.^2)/length(U));
Upeak = max(abs(U));
CF = Upeak/Urms;
```

```
%------------------------------------------------------------------------------------------------
function [F]=CalcEnhancedGaussDistribution(x,Cf);
%------------------------------------------------------------------------------------------------
% Generate a Cumulative distribution function F(x) that is identified as
% "enhanced gaussian distribution"
% Cf = crest factor
Alpha = 1e-3;
Sigma = sqrt( (1+Alpha) - Cf^2 * Alpha/3);
x = x .* (x>0) .* ( x<Cf) + Cf * (x>=Cf);
denominator = Alpha + erf(Cf/(sqrt(2)*Sigma));
F = 1 - (Alpha * x/Cf + erf(x/(sqrt(2)*Sigma)))/denominator;

%------------------------------------------------------------------------------------------------
function [DistP, DistU,P] = CalcDistrib(U)
%------------------------------------------------------------------------------------------------
% calculate the amplitude distribution of signal U
N = length(U);
Nbins=100;
[cumbin,xx] = hist(U,Nbins);
dX=xx(3)-xx(2);
DistP = cumbin(:)/N/dX;                    % force sum(DistP)*dX
DistU = xx(:);
Urms=sqrt(sum(U.*U)/N);
P=exp(-0.5*(DistU/Urms).^2); P=P/sum(P)/dX;
DistU=[DistU,DistU];
DistP=[DistP,P];
```

```
%------------------------------------------------------------------------------------------
function [DistP, DistU] = CalcCumDistrib(U)
%------------------------------------------------------------------------------------------
% calculate the (backward) cumulative amplitude distribution of signal U
len  = length(U);
Ueff = sqrt(sum(U .* U)/length(U));
U    = abs(U/Ueff);
% --- evaluate distribution function
Nbins = min([50,floor(len/10)]);
[cumbin,xx] = hist(U,Nbins);
BinWidth=xx(2) - xx(1);
DistU = xx - BinWidth/2; % shift
for n = [Nbins-1:-1:1];   cumbin(n) = cumbin(n) + cumbin(n+1); end
DistP = cumbin/len;
% --- improve numerical stability for other routines, when they use this result
DistU = [ 0 , DistU(2:end)];                        % start at x = 0
DistP = [DistP, 1/len];
DistU = [DistU,xx(Nbins) + 0.999 * BinWidth/2];   % add final (single) point
DistP = [DistP, 1e-100];
DistU = [DistU,xx(Nbins) + (1.001) * BinWidth/2]; % factor 1.001 for stability

%------------------------------------------------------------------------------------------
function [PSD,freq]=CalcSmooth(PSD,freq,RBW)
%------------------------------------------------------------------------------------------
% Imitate a real Spectrum Analyzer, with finite resolution bandwidth, and
% Gaussian shaped band filters
%      PSD = "power spectral density" which is de square of the "spectral density"; in
%              Volts per square Hertz.
%------------------------------------------------------------------------------------------
N = length(PSD);
```

```
df = freq(2)-freq(1);
br = 3 * floor(RBW/df);
factor = 2*br + 1;
if (factor > 1)
..ff = df * (-br:br);                    % smooth interval
..mask = exp(-ff.*ff/(2*RBW^2));
..mask = mask/sum(mask);                 % Gaussian mask of resolution band filter
..xhelp = [PSD;zeros(2*br,1)];
 lp = filter(mask,1,xhulp);              % smart convolution
PSD = yhelp(br+1:end-br);
end;

%-----------------------------------------------------------------------------------
function [Uac,Uac_rms]=CalcDemodulation(U,t,Shape,ToneNr);
%-----------------------------------------------------------------------------------
% Demodulate the noise that has been modulated on the carriers of the discrete
% noise, it is for demonstration purposes only to prove that the
% discrete noise meets the predefined parameters.
%
% The demodulator uses synchronous detection, that is not locked in phase
% The consequence is an unknown attenuation over the full demodulation band.
% This is corrected afterward by measuring the DC level, and amplify the
% demodulated signal until this DC level has been normalized to 1 Volt
%
% PROOF: (psi is unknown)
% let  Urf=cos(w*t+psi)*(1+Uac);          % = carrier modulated with "1+Uac"
%      Uc =cos(w*t);                      % = carrier
%      Ud =Urf*Uc;                        % = synchronous detected signal
%
% then Ud=1/2*(cos(psi+2*w*t)+cos(psi))*(1+Uac);
```

```
%      Ulf=cos(psi)/2*(1+Uac);        % after low-pas filtering
%      Udc=cos(psi)/2;                %= by averaging Ulf
%      Uac=(Ulf/Udc)-1;
%-----------------------------------------------------------------------
N=Shape.N;
Fc=Shape.Ingress.ToneF(ToneNr);        %select carrier frequency
Fc=Shape.dF * round(Fc/Shape.dF);      %force an integer number of periods
ModWidth=Shape.Ingress.ModWidth(ToneNr);
ModDepth=Shape.Ingress.ModDepth(ToneNr);
%
Ud=U.*cos(2*pi*Fc*t);                  % synchronous detection of modulated carrier
Nm=round(1.1*ModWidth/Shape.dF/2);     % calculate filter frequency
mask=zeros(N,1); mask([1:Nm, N-Nm:N])=1; % create filter
Ulf=real(ifft(fft(Ud).*mask));         % perform low-pass filtering
Udc=sum(Ulf)/N;                        % find not normalized DC level
Uac=Ulf/Udc-1;                         % normalize overall level, and remove DC.
%
Uac_rms=sqrt(sum(Uac.*Uac/N));         % must be equal to ModDepth, since Udc=1
Scale=Uac_rms/ModDepth;                % must be "one"
```

Claims

1. A method of arranging a signal having at least one predefined quality criterion, preferably for use in or on a communication system, said method comprising the steps of:

- representing a first signal comprising a plurality of frequency components each having spectral amplitude and phase properties, and

- processing said represented first signal by arranging said spectral amplitude properties in accordance with the or each predefined quality criterion, and arranging random phase properties.

2. A method according to claim 1, wherein said first signal is represented by a first set of numbers specifying a spectral amplitude and phase of each frequency component.

3. A method according to claim 1, wherein said first signal is represented by a second set of complex numbers having a real part and an imaginary part, said parts in combination specifying a spectral amplitude and phase of each frequency component.

4. A method according to claim 1, wherein said first signal is represented by a third set of numbers each specifying an amplitude of said first signal in the time domain.

5. A method according to claim 4, further comprising the step of transforming said third set of numbers from the time domain into the frequency domain for representing said first signal by a fourth set of numbers specifying a spectral amplitude and phase of each frequency component.

6. A method according to claim 4, further comprising the step of transforming said third set of numbers from the time domain into the frequency domain for representing said first signal by a fifth set of complex numbers having a real part and an imaginary part, said parts in combination specifying a spectral amplitude and phase of each frequency component.

7. A method according to any of the previous claims, further comprising the step of post-processing of said processed represented first signal to achieve a closer match to the or each predefined quality criterion.

8. A method according to any of the previous claims, further comprising the step of

transforming said processed represented signal from the frequency domain into the time domain.

9. A method according to claim 8, wherein said signal having said predefined quality criterion is represented by a sixth set of numbers in the time domain.

10. A method according to any of the previous claims, wherein the or each predefined quality criterion comprises at least one modulated carrier, the or each modulated carrier including any of a group comprised of a carrier frequency, a carrier amplitude, a modulation depth, and a modulation width.

11. A method according to any of the claims 1-9, wherein the or each predefined quality criterion comprises any of a group including of a predefined time domain amplitude distribution and a predefined envelope of spectral amplitudes.

12. A method according to claim 11, further comprising the step of arranging said processed represented first signal in accordance with a predefined time domain amplitude distribution.

13. A method according to claim 11 or 12, further comprising the step of arranging said processed represented first signal in accordance with a predefined envelope of spectral amplitudes.

14. A method according to claim 12 or 13, wherein at least one of said time domain amplitude distribution and envelope of spectral amplitudes is approached by an iteration process.

15. A method according to claim 14, wherein said iteration process comprises a comparison of any of said time domain amplitude distribution and envelope of spectral amplitudes of said processed represented first signal with a predefined time domain amplitude distribution and predefined envelope of spectral amplitudes.

16. A method according to any of the previous claims, wherein said signal having the or each predefined quality criterion is provided by combining a plurality of represented signals processed in accordance with claim 10 and processed in accordance with any of the claims 11-15.

17. A method according to any of the previous claims, wherein said signal having the or each predefined quality criterion is a noise signal.

18. A method in accordance with any of the previous claims, wherein said signal having the or each predefined quality criterion is provided by a set of instructions in code format and executable in a predetermined order on a processing device.

19. A set of instructions in code format and executable in a predetermined order on a processing device, said set of instructions being arranged for generating a signal having the or each predefined quality criterion and random phase properties from a representation of a first signal following a method in accordance with claim 18.

20. A device comprising processing means, memory means and arbitrary wave generator means, arranged for generating a signal having at least one predetermined signal quality criterion and random phase properties following any of the previous claims.

21. A signal having at least one predefined signal quality criterion and random phase properties, generated in accordance with any of the previous claims.

22. A data carrier device comprising a library of signal representations for use with any of the previous claims.

23. A method of testing the operation of a communication system, said method comprising the steps of:

- generating a signal having at least one predetermined quality criterion in accordance with any of the previous claims, and

- transferring said signal through said communication system.

24. A system comprising means for generating a signal having at least one predefined signal quality criterion following any of the previous claims, modem means, cable means and processor means, wherein said processor means are arranged for controlling said generating means, modem means and cable means for automated measurement and/or monitoring purposes.

25. A telecommunications system arranged for operating said method of claim 24.

26. A method of arranging a signal, preferably for use in or on a communication system, said method comprising the steps of:

- representing a first signal in time domain having a time domain amplitude distribution, said signal having a spectral density in the frequency domain, thereby achieving a represented signal;

- processing said represented signal in accordance with a non-linear transformation, said non-linear transformation achieving at least one predefined quality criterion,

- said time domain amplitude distribution of said represented signal being processed at least with an inverse function of a predetermined time domain amplitude distribution.

27. A method according to claim 26, further comprising the step of comparing said time domain amplitude distribution of said represented signal with said predetermined time domain amplitude distribution, and thereafter arranging said non-linear transformation in order to achieve a processed represented signal having a time domain amplitude distribution approaching said predetermined time domain amplitude distribution.

28. A method according to claim 26 or 27, wherein said processed represented signal g(t) is a function *Q{f(t)}* of said represented first signal f(t) and wherein said function *Q* is defined as:

$$Q(x) = sign(x) \cdot G^{-1}\left(F(|x|)\right)$$

with: sign(x)=x/|x| for x<>0; sign(x)=0 for x=0 ;

*F* being said time domain amplitude distribution of said represented signal; and

*G* being said predetermined time domain amplitude distribution function.

29. A method according to claim 28, further comprising the step of achieving said represented signal with a spectral density according to a predetermined spectral density quality criterion.

30. A method according to claim 26, further comprising the steps of :

- transforming said first signal to the frequency domain ; and

- multiplying said first signal in said frequency domain with a spectral envelope, thereby achieving a multiplied signal ; and

- transforming said multiplied signal to the time domain.

31. A method according to claim 30, further comprising the step of comparing said time domain amplitude distribution of said represented signal with said predetermined time domain amplitude distribution, and thereafter arranging said non-linear transformation in order to achieve a processed represented signal having a time domain amplitude distribution approaching said predetermined time domain amplitude distribution.

32. A method according to claim 31, further comprising the step of achieving said represented multiplied signal with a spectral density according to a predetermined spectral density quality criterion.

33. A method according to claim 32, wherein at least two of said steps are iteratively executed.

34. A method according to claim32, wherein at least two of said steps are iteratively executed until a predetermined crest factor is achieved.

35. A method according to any of the previous claims, wherein said signal is a noise signal.

36. A method according to claim 35, wherein said first signal in the representation in the frequency domain is generated as a set of random numbers, preferably complex numbers the modulus of the complex number characterizing an amplitude, the argument of said complex number characterizing a phase.

37. A method according to claim 36, wherein of essentially each of said complex numbers its real and/or imaginary part is selected according to a Gaussian distribution.

38. A method according to claim 36, wherein said modulus of essentially each of said complex numbers is substantially equal to said amplitude of said predetermined spectral density.

39. A method according to claim 36, wherein said argument of essentially each of said complex numbers is random.

40. A method of arranging a signal, preferably for use on or in a communication system, said method comprising the steps of :

- representing a first signal in time domain having a time domain amplitude distribution, said signal having a spectral density in the frequency domain, thereby achieving a represented signal; and

processing said represented signal until a signal is achieved having a spectral density according to a predetermined spectral density quality criterion.

41. A method of arranging a signal, preferably for use on or in a communication system, said method comprising the steps of:

- representing a first signal in time domain having an amplitude distribution and said signal having a spectral density in the frequency domain, thereby achieving a represented signal ; and

- filtering said represented signal in the frequency domain, including the steps of evaluating at least part of said represented signal in the frequency domain and thereafter processing said represented signal in the frequency domain.

42. A method according to claim 40 or 41, wherein said processing step includes iterative processing.

43. A method according to claim 40 or 41, wherein said processing step includes iterative processing until a predetermined crest factor is achieved.

44. A signal comprising at least one of a random noise signal, said random noise signal having an amplitude distribution in the time domain according to a predetermined quality criterion and a spectral density in the frequency domain according to a predetermined quality criterion, said random signal being composed of an array of random numbers.

45. A signal according to claim 44, further comprising a discrete frequency spectrum.

46. A signal according to claim 44, wherein said noise signal is generated using a set of instructions in a code format and being executed in a predetermined order.

47. A method of generating a random signal comprising at least one of a random noise signal, said random signal having an amplitude distribution in the time domain

according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion, said random signal being composed of an array of random numbers, said method comprise the step of generating a random set of numbers using a set of instructions in a code format and being executed in a predetermined order.

48. A method according to claim 47, further comprising the step of generating a discrete frequency spectrum, said discrete frequency spectrum using goniometry functions and modulating essentially each of said discrete frequencies with a noise characteristic.

49. A method according to claim 48, further comprising the step of combining said random noise signal and said discrete frequency spectrum using a set of instructions in a code format and being executed in a predetermined order.

50. A set of instructions in a code format and executable in a predetermined order, said set of instructions being arranged for generating a random noise signal and a discrete frequency spectrum, said random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion.

51. A test system for testing the operation of a communication system, said test system comprising a set of instructions in a code format and executable in a predetermined order and compiled on a device, said set of instructions being arranged for generating a noise signal comprising at least one of a random noise signal and a discrete frequency spectrum, said random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion.

52. A method of testing the operation of a communication system having a modem, said method comprising the step of superposing on a signal transceived by said modem, a signal comprising at least one of a random noise signal and a discrete frequency spectrum, said random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the

frequency domain according to a predetermined quality criterion., said noise signal furthermore being composed of an array of random numbers.

53. A method of testing the quality of operation of a communication system having a modem, said method comprising the steps of :

- superposing on a signal transceived by a said modem, a signal comprising at least one of a random noise signal and a discrete frequency spectrum, said random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion, said noise signal furthermore being composed of an array of random numbers ; and

- evaluating said transceived signal according to a predetermined quality criterion.

54. A method of improving the design and/or production of a communication system, said method comprising the steps of :

- superposing on a signal transceived by a modem a signal comprising at least one of a random noise signal and a discrete frequency spectrum, said random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion, said noise signal furthermore being composed of an array of random numbers ;

- evaluating said transceived signal according to a predetermined quality criterion; and

- iteratively arranging the design of said modem in order to approach closer to said quality criterion for evaluating said transceived signal.

55. A telecommunication network including a signal comprising at least one of a random noise signal and a discrete frequency spectrum, said random signal having an amplitude distribution in the time domain according to a predetermined quality criterion and having a spectral density in the frequency domain according to a predetermined quality criterion, said noise signal furthermore being composed of an array of random numbers.

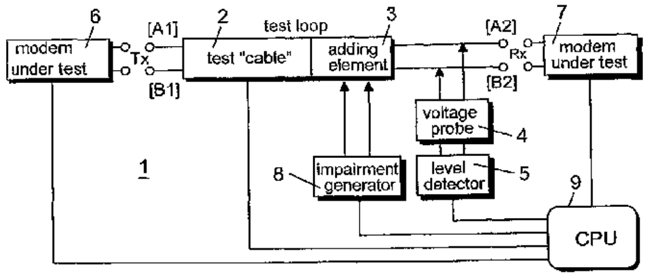

6
2
test loop
3
[A1]
[A2]
7
modem under test
Tx
test "cable"
adding element
Rx
modem under test
[B1]
[B2]
voltage probe
4
1
8
impairment generator
level detector
5
9
CPU

Fig. 1

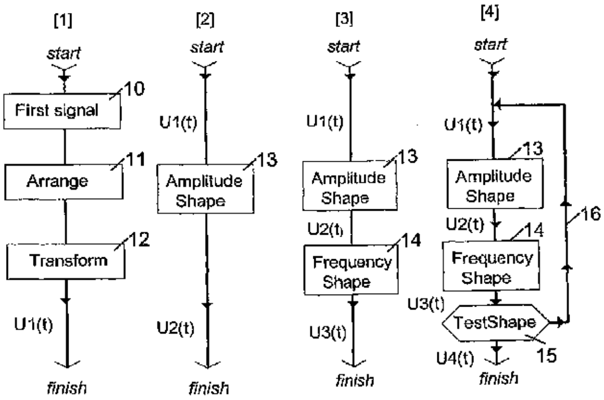

[1]
[2]
[3]
[4]
start
start
start
start
First signal
10
Arrange
11
Transform
12
U1(t)
finish
U1(t)
Amplitude Shape
13
U2(t)
finish
U1(t)
Amplitude Shape
13
U2(t)
Frequency Shape
14
U3(t)
finish
U1(t)
Amplitude Shape
13
U2(t)
Frequency Shape
14
16
U3(t)
TestShape
15
U4(t)
finish

Fig. 2

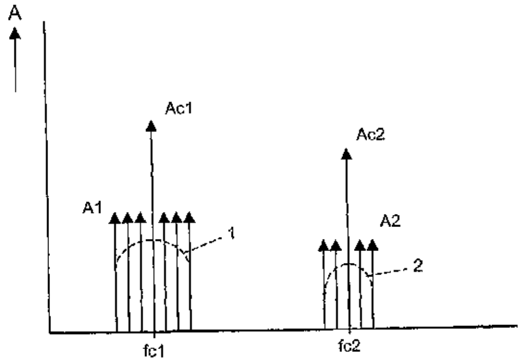

A
Ac1
Ac2
A1
A2
1
2
fc1
fc2
f

Fig. 3

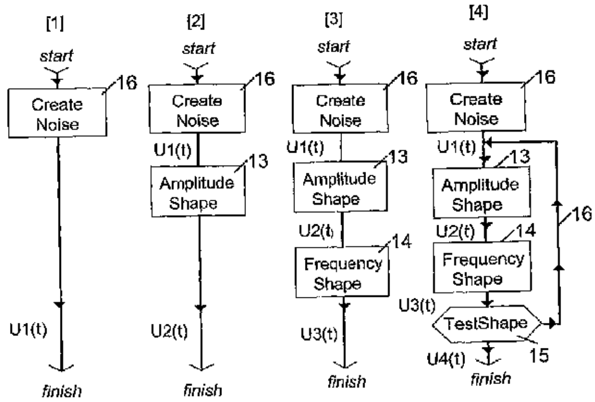
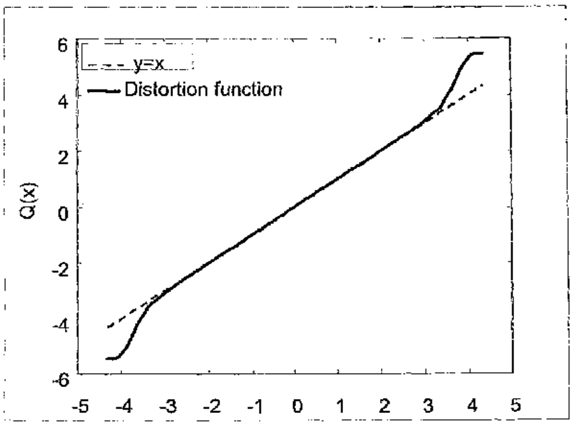
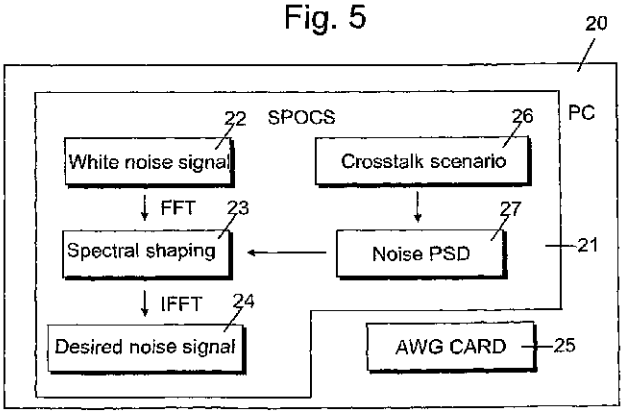

[1]
[2]
[3]
[4]
start
Create Noise
16
U1(t)
Amplitude Shape
13
U2(t)
Frequency Shape
14
U3(t)
TestShape
15
U4(t)
finish

Fig. 4



y=x
Distortion function
Q(x)
6
4
2
0
-2
-4
-6
-5 -4 -3 -2 -1 0 1 2 3 4 5


Fig. 5



20
PC
22
SPOCS
26
White noise signal
Crosstalk scenario
FFT
23
27
Spectral shaping
Noise PSD
21
IFFT
24
Desired noise signal
AWG CARD
25


Fig. 6

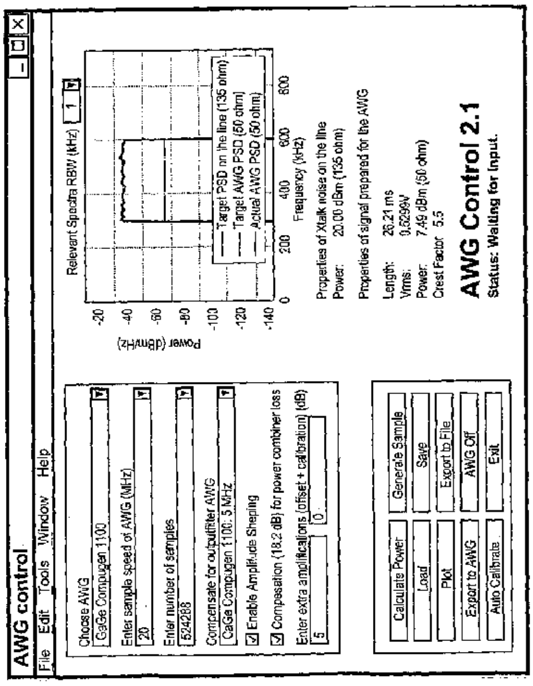

AWG control
File Edit Tools Window Help
Choose AWG
GaGe Compugen 1100
Enter sample speed of AWG (MHz)
20
Enter number of samples
524288
Compensate for outputfilter AWG
GaGe Compugen 1100: 5 MHz
Enable Amplitude Shaping
Compensation (18.2 dB) for power combiner loss
Enter extra amplifications (offset + calibration) (dB)
5
0
Calculate Power
Generate Sample
Load
Save
Plot
Export to File
Export to AWG
AWG Off
Auto Calibrate
Exit
Relevant Spectra RBW (kHz) 1
Power (dBm/Hz)
Frequency (kHz)
Target PSD on the line (135 ohm)
Target AWG PSD (50 ohm)
Actual AWG PSD (50 ohm)
Properties of Xtalk noise on the line
Power: 20.00 dBm (135 ohm)
Properties of signal prepared for the AWG
Length: 26.21 ms
Vrms: 0.5299V
Power: 7.49 dBm (50 ohm)
Crest Factor 5.5
AWG Control 2.1
Status: Waiting for input.

FIG. 7

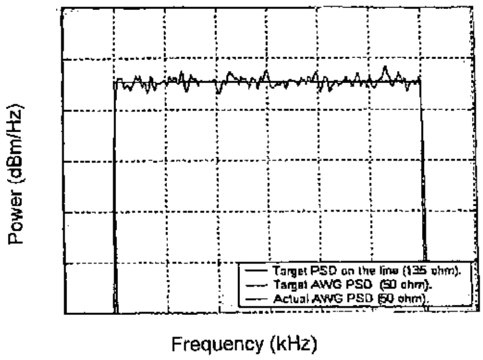

Power (dBm/Hz)
Target PSD on the line (135 ohm).
Target AWG PSD (50 ohm).
Actual AWG PSD (50 ohm).
Frequency (kHz)

Fig. 8

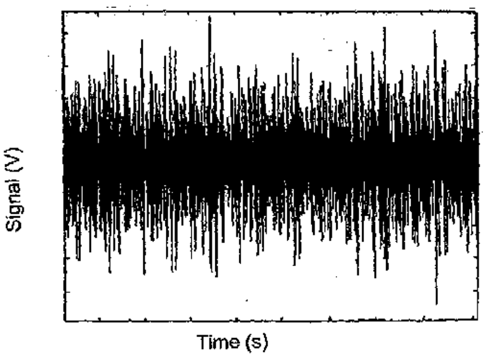

Signal (V)
Time (s)

Fig. 9

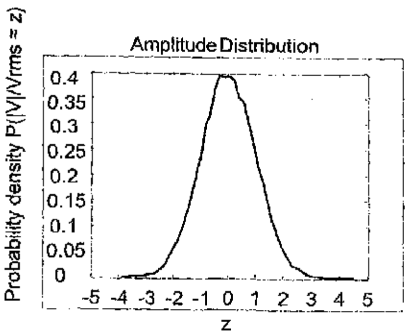

Amplitude Distribution
Probability density P(|V|/Vrms = z)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-5 -4 -3 -2 -1 0 1 2 3 4 5
z

Fig. 10

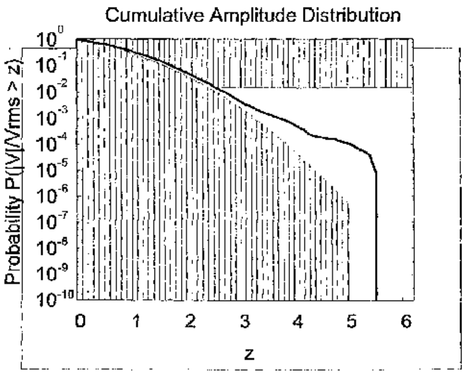

Cumulative Amplitude Distribution
Probability P(|V|/Vrms > z)
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
0
1
2
3
4
5
6
z

Fig. 11

【国際調査報告】

## INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 01/07833

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 H04L1/24 H04L27/26

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | FR 2 783 374 A (THOMSON CSF)<br>17 March 2000 (2000-03-17)<br>page 2, line 31 -page 3, line 15<br>figures 3,10 | 1-25,<br>40-50 |
| A | | 26-39,<br>51-55 |
| | --- | |
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| | --- | |
| | -/-- | |

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 30 October 2001 | 07/11/2001 |
| Name and mailing address of the ISA<br>European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Authorized officer<br><br>Orozco Roura, C |

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Inter al Application No
PC,, ,,? 01/07833

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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INTERNATIONAL SEARCH REPORT

Inte nal Application No
PCT/EP 01/07833

| Patent document cited in search report | | Publication date | Patent family member(s) | | Publication date |
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| | | | EP | 0044133 A2 | 20-01-1982 |
| | | | GB | 2081056 A ,B | 10-02-1982 |
| | | | GR | 75294 A1 | 13-07-1984 |
| | | | JP | 1428019 C | 25-02-1988 |
| | | | JP | 57081741 A | 21-05-1982 |
| | | | JP | 62033779 B | 22-07-1987 |
| | | | NO | 811546 A ,B, | 15-01-1982 |
| | | | PT | 73257 A ,B | 01-07-1981 |
| | | | TR | 21249 A | 05-03-1984 |
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| | | | FR | 2438382 A1 | 30-04-1980 |

フロントページの続き

(81)指定国　AP(GH,GM,KE,LS,MW,MZ,SD,SL,SZ,TZ,UG,ZW),EA(AM,AZ,BY,KG,KZ,MD,RU,TJ,TM),EP(AT,BE,CH,CY,DE,DK,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE,TR),OA(BF,BJ,CF,CG,CI,CM,GA,GN,GW,ML,MR,NE,SN,TD,TG),AE,AG,AL,AM,AT,AU,AZ,BA,BB,BG,BR,BY,BZ,CA,CH,CN,CO,CR,CU,CZ,DE,DK,DM,DZ,EE,ES,FI,GB,GD,GE,GH,GM,HR,HU,ID,IL,IN,IS,JP,KE,KG,KP,KR,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MN,MW,MX,MZ,NO,NZ,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,TZ,UA,UG,US,UZ,VN,YU,ZA,ZW

（特許庁注：以下のものは登録商標）
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