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(54) Title: DYNAMIC IMPEDANCE MATCHING NETWORK AND METHOD FOR MATCHING AN IMPEDANCE BETWEEN A SOURCE AND A LOAD

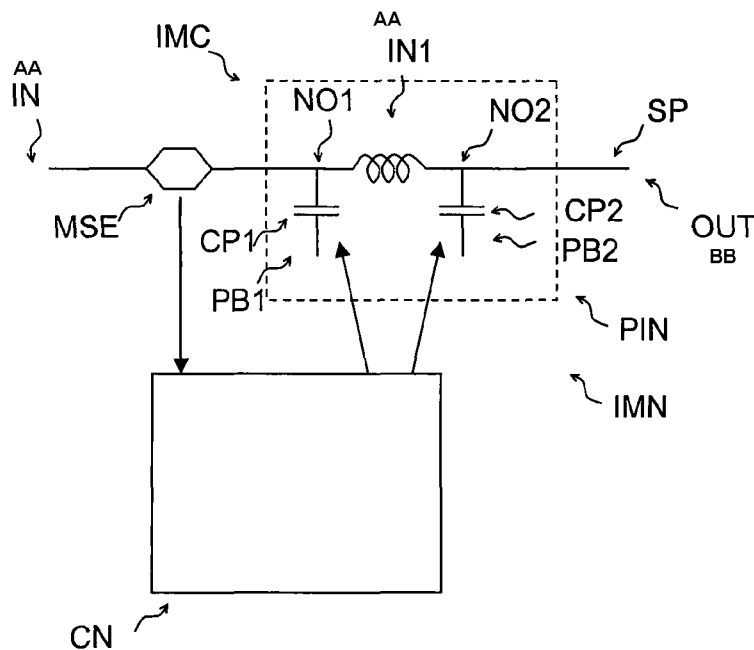


Fig. 2

(57) Abstract: An impedance matching network comprises an impedance matching circuit for dynamically matching an impedance between a source and a load. Matching is done by varying the real part and the imaginary part of the impedance of the impedance matching circuit independently.

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Dynamic Impedance Matching Network and method for matching an impedance between a source and a load

Field of the invention

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The present invention relates to a dynamic impedance matching network matching the impedance of an antenna as a load impedance to internal circuits as source impedances such as those used in portable communication devices, for example in mobile phones.

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Description of the related art

US 6,845,126 B2 relates to a system for an adaptive antenna impedance matching. The impedance mismatch is determined dynamically by measuring the strength of a signal reflected from an antenna. An impedance matching circuit being electrically connected within the signal path is tuned in order to minimize the Voltage Standing Wave Ratio (VSWR). Tuning can be done by varying the reactances of different reactance-elements being electrically connected within the impedance matching circuit.

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Fig. 1a shows a simple embodiment of a well known pi-section impedance matching circuit. A source impedance R_s is electrically connected in series with a signal path. An inductance element L is electrically connected in series within the signal path, a capacitance element C_1 connects a contact of the inductance element with ground and another capacitance element C_2 connects the other side of the inductance element with ground. The three reactance elements C_1 , C_2 and L form the pi-section and are adjustable independently. Fig. 1b presents a Smith-diagram showing the

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impedance of the above mentioned matching circuit. The desired value e.g. 50 Ohms is at the center of the diagram containing groups of curves exemplarily representing the total impedance depending on the value of the reactances of all three reactance elements. Variation of only one reactance limits the impedance to a circle-like subset of the whole area of the Smith-diagram.

Thus, it is obvious that dynamically finding a correct setting for all three elements that satisfies a given specification concerning the desired total impedance is not trivial. Algorithms to find the best setting are therefore not straightforward but may base on lookup-tables and are complex and prone to errors.

Therefore, what is needed is an impedance matching network with improved design to work with a straightforward and unambiguous algorithm.

SUMMARY OF THE INVENTION

The present invention provides an impedance matching network, comprising

- a signal path comprising an input and an output,
- an impedance matching circuit electrically connected within the signal path, comprising a first tuneable reactance element and a second tuneable reactance element,
- a mismatch sensing element embedded in the signal path,
- a control-network that is designed to identify the mismatch of the signal propagating in the signal path by means of the mismatch sensing element and to tune the tuneable reactance elements dependent on the identified mismatch,

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- where the tuneable reactance elements are selected that tuning one of the reactance elements mainly varies the real component of the impedance of the impedance matching circuit and tuning the other of the reactance elements mainly varies the imaginary component of the impedance matching circuit.

In a preferred embodiment a pi-section network being composed of a serial connected inductance L and two parallel connected capacitances C_1 and C_2 is used as impedance matching circuit. Such a circuit corresponds to a low pass filter.

Accordingly the impedance matching circuit can also be realized by a high pass filter being based on pi- or T- or more general on "pi-like" circuits. In this case inductance elements and reactants elements are interchanged. In the following sections for simplicities sake only low pass circuits are considered. But for someone skilled in the art it is clear the the basic ideas are valid for both: for high pass circuit configurations and analogly for low pass circuit configurations.

For a real source impedance R_s and according to Fidler and Thompson ("Application of the generic algorithm and simulated annealing to LC filter tuning", IEEE Proc. Circuits Devices Syst., vol. 148, no.4, pp. 177-182, Aug. 2001) the real part of the matched impedance of such a pi-section network can be expressed as

$$R_M = \frac{R_s}{(1 - \omega^2 LC_2)^2 + (\omega C_1 R_s + \omega C_2 R_s - \omega^3 LC_1 C_2 R_s)^2}$$

and the imaginary part can be expressed as

$$X_M = \frac{\omega^3 LC_1^2 R_S^2 + 2\omega^3 LC_1 C_2 R_S^2 + \omega L - \omega C_1 R_S^2 - \omega C_2 R_S^2 - \omega^3 L^2 C_2 - \omega^3 L^2 C_1^2 C_2 R_S^2}{(1 - \omega^2 LC_2)^2 + (\omega C_1 R_S + \omega C_2 R_S - \omega^3 LC_1 C_2 R_S)^2},$$

where ω is the angular frequency of the electromagnetic signal. As a result of keeping two reactances constant and varying the third a circular impedance curve is found. The
 5 impedance is bound to a circle within the complex plane with positive real part while the center and the radius of this circle are functions of the other two values.

An advantageously simple and straightforward algorithm to
 10 match a desired impedance is obtained by designing the reactance elements so, that

- i) the circle contains the desired impedance value,
- ii) the difference of the imaginary part of the center of the circle and the desired impedance value is essentially zero,
- 15 iii) the difference of the real part of the center of the circle and the desired impedance value is large enough to provide an area of adequate size where the arc of the circle is mainly orthogonal to a line containing the desired value and being parallel to the axis of the real part.

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The advantage of elements designed like that is that controlling the impedance of the matching circuit in an orthogonal way is now possible.

25 This ensures that first: An optimal impedance exists. And second: the variation of the reactances to reach the desired impedance is directly given by the difference of an actual impedance that may depend on external circumstances and the desired impedance. The real part and the imaginary part of
 30 this difference can be minimized independently because

varying the real part does not result in varying the imaginary part and vice versa.

For example: For C_1 and C_2 held constant the impedance for
5 varying L is given by the following equation (equation 1)

$$\left[R_M - \frac{1 + \omega^2 C_1^2 R_s^2}{2\omega^2 C_2^2 R_s} \right]^2 + \left[X_M - \frac{1}{\omega C_2} \right]^2 = \left[\frac{1 + \omega^2 C_1^2 R_s^2}{2\omega^2 C_2^2 R_s} \right]^2.$$

Thus the impedance lies on a circle with a centre at

$$\left[\frac{1 + \omega^2 C_1^2 R_s^2}{2\omega^2 C_2^2 R_s}, \frac{1}{\omega C_2} \right]$$

and a radius of

$$\frac{1 + \omega^2 C_1^2 R_s^2}{2\omega^2 C_2^2 R_s}.$$

10

Thus, center and radius of the circle are determined by the two capacitances C_1 and C_2 .

Here, linearly varying the radius of the circle changes
15 linearly the real part of the impedance while varying the position on the circle changes the imaginary part of the impedance.

Variation of the radius of the center position or real part
20 of the impedance (which are equal in this case) while keeping the imaginary part of the center position constant needs to keep C_2 constant in the above mentioned equation. Otherwise the imaginary part of the center position (i.e. the ordinate)

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would change. Thus varying C_1 leads to a change only of the real part of impedance.

5 In one embodiment the matching circuit can comprise several tunable reactance elements in several pi- or pi-like sections.

10 In general: If there are a number of m tunable reactance elements then a number of $i \geq 1$ of a first set of tunable reactance elements are tuned differentially and a number of $j \geq 1$ of a second set of tunable reactance are tuned differentially where $i+j = m$ and $m > 2$. Here "tuning differentially" means that there is one degree of freedom to vary the reactance of a first tunable element while the
15 variation of every other element of the same set is a function of the variation of the reactance of said first element.

20 The matching circuit may further comprise T-sections. These may form further pi-sections with existing pi-sections and hence the above mentioned basic relations are valid too and can be applied accordingly. Therefore, further T-sections can be handled like pi-sections and when "pi-sections" are mentioned it is also applicable to further T-sections.

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For dynamically matching a source impedance to a load impedance the invention comprises a control loop. A matching sensor element determines the actual mismatch of the impedance matching network. A control network is electrically
30 connected to the matching sensor element and determines the best suited values for the reactance elements according to the above mentioned method.

In a preferred embodiment the matching sensor element comprises an inductance element that is embedded in the signal path. By sensing the nodal voltage across and the current through the inductance element all information is obtained necessary to determine impedance, admittance or the reflection coefficient of the impedance matching network. This is done by a generic quadrature detector. In principle detecting the mismatch can be performed based on any reactance elements. Thus a capacitance element can also be used.

In another preferred embodiment, each of at least one serial branch of a pi-like section comprises two inductance elements that are electrically connected in series within the serial branch. The pi-like section further comprises one capacitance element (with capacitance C_P) that is connected in parallel to one (with inductance L_P) of the two serially connected inductance elements (with inductances L_S and L_P). Equation 2:

$$\omega_{LB}L_S + \frac{1}{\frac{1}{\omega_{LB}L_P} - \omega_{LB}C_P} = \omega_{HB}L_S + \frac{1}{\frac{1}{\omega_{HB}L_P} - \omega_{HB}C_P} = X$$

refers to the imaginary part of the impedance of such a serial branch of a pi-section (see fig 3a). If the reactances C_P , L_P and L_S are properly chosen then two distinct frequencies ω_{LB} and ω_{HB} are solutions of this equation. This means that the pi-section has the same impedance at two different frequencies and thus a impedance matching network containing such pi-sections is capable of working in two frequency bands. Here ω_{LB} is the angular frequency of the lower band and ω_{HB} is the angular frequency of the higher band. Thus good matching can be obtained at two different frequency bands without further caring about which band is used at the moment.

An analog dual band network is achieved when each serial path of the pi-like sections contains a capacitance element electrically connected in series to the inductance element and a capacitance being electrically connected in parallel to the inductance element.

Another preferred embodiment comprises protection elements that electrically connect the input or the out of the signal path to ground. Those protection elements are arranged in protection branches and may be inductance elements.

In a preferred embodiment the matching sensing element comprises an inductive element that is electrically connected within the signal path.

In an embodiment the matching circuit is electrically connected to an antenna. Matching is necessary because the antenna may be used in different environments or may be in contact with other reactances. It may also be possible that the antenna is the antenna of a mobile communication unit and therefore changes its position and orientation. Tuning the tunable reactance elements of the impedance matching circuit according to the invention can perfectly compensate those variations.

A method for matching an impedance between a source and a load according to a defined specification comprises the steps

- a) providing a signal path,
- b) connecting to the signal path an impedance matching circuit comprising at least two tunable reactance elements, each assigned to a first or a second group,
- c) connecting a mismatch sensing element to the signal path,
- d) detecting the impedance mismatch between source and load,

e) determining a new set of impedance values of the tunable reactance elements dependent on the mismatch,
f) tuning the tunable reactance elements according to the mismatch, where differentially tuning the first group of said
5 tuneable reactance elements mainly varies the real component of the impedance of the impedance matching circuit and differentially tuning the second group of said tuneable reactance elements mainly varies the imaginary component of the impedance matching circuit.

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In a preferred embodiment of the above mentioned method the number of tunable reactance elements is m where m is an integer number > 2 .

15 Brief description of the drawings

The present invention will become fully understood from the detailed description given herein below and the accompanying drawings. In the drawings

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Fig. 1a illustrates a pi-section network with three adjustable reactance elements;

Fig. 1b illustrates a smith-diagram of the network of fig. 1a;

25 Fig. 2 illustrates the basic concept of the invention;

Fig. 3a illustrates a network comprising a switchable capacitance element;

Fig. 3b illustrates a dual-band serial section of a pi-section network;

30 Fig. 3c illustrates another dual-band serial section of a pi-section network;

Fig. 3d illustrates still another dual-band serial section of a pi-section network comprising a tunable capacitance element;

Fig. 3e illustrates another embodiment of a serial section of a pi-section network;

Fig. 3f illustrates a pi-section of an impedance matching network for use in a high pass circuit configuration;

Fig. 4a illustrates a pi-section network comprising a tunable inductance element and two differentially tunable capacitance elements;

Fig. 4b illustrates a smith-diagram of the impedance of the pi-section network of fig. 4a;

Fig. 5a illustrates an impedance matching circuit comprising a pi-section with differentially controlled capacitance elements and a T-section network;

Fig. 5b illustrates the impedance of the network of fig. 5a;

Fig. 6 illustrates simulated convergence behavior of the impedance matching network of fig. 7;

Fig. 7 illustrates a dual-band dual section impedance matching network with two pi-sections.

Detailed description

Fig. 1a illustrates a conventional pi-section network that may be used to match the impedance of a source S that is electrically connected to the input IN of the signal path SP to a device (e. g. an antenna) that may be connected to the output OUT of the signal path SP. In this case the signal path is represented by the tunable inductance element IN1. A capacitance element CP1 electrically connects the input of the signal path IN to ground while another capacitance element CP2 electrically connects the output of the signal path to ground. Both capacitance elements are tunable. Thus

there are 3 degrees of freedom to vary the total impedance of the shown impedance matching circuit leading to the above mentioned problems further discussed in view of fig. 1b as follows.

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Fig 1b illustrates the complexity of the impedance dependence of the simple pi-section shown in fig. 1a. According to the above mentioned equation it is quite difficult to find an algorithm that enables to control 3 tunable elements independently in order to match a specified value.

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Fig. 2 illustrates the basic concept of the invention. The signal path SP comprises a matching sensing element (MSE) that can dynamically identify the mismatch of the actual impedance. This information is sent to a control network CN that determines a new set of values for tunable elements being comprised in an impedance matching circuit IMC. This circuit comprises two sets of tunable elements (e.g. CP1 as the first set and CP2 as the other set, each set having only one member in this case). Every tunable element of each set is tuned by the control network CN differentially. This means that there is only one degree of freedom to choose the value of the reactance of one reactance element while the other values of the other tunable elements within each set are functions of the one value of the one element. Therefore two sets of tunable elements give two degrees of freedom to the control network CN to tune the impedance of the impedance matching network IMC. The arrows showing from the control network to the impedance matching circuit indicate these two degrees of freedom.

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In the simplest case the impedance matching circuit comprises an inductive element IN1 electrically connected within the

signal path and two capacitance elements individually electrically connecting both contacts of the inductance element IN to ground forming a pi-section circuit. At least two of these elements are tunable. This means that their reactance value is adjustable and can be varied by the control network CN. Especially when these reactance elements are properly designed tuning of the impedance according to the invention is remarkably straightforward and easy. As shown above the reactances of pi-like circuits can be chosen to result in an impedance behavior shown in Fig. 4b disclosing a mainly orthogonal control of the impedance in a vicinity of a specified match-impedance.

Fig. 4a illustrates one embodiment of the impedance matching circuit enabling the control network CN to tune the impedance as shown in Fig. 4b. The determining difference between fig. 4a and fig. 1a is based in the differential control indicated by the connected arrows of both tunable capacitance elements CP1 and CP2. Thus these two capacitance elements constitute one set of tunable elements while the tunable inductance element IN1 constitutes the other set. Referring to fig. 4b the specified impedance to match (e. g. 50 Ohm) is positioned in the center of the smith-diagram. Varying the inductance of inductance element IN1 results in mainly varying the real part of the impedance in a vicinity of the specified impedance, while differentially varying the capacitance of the capacitance elements CP1, CP2 results in mainly varying the imaginary part of the impedance of the impedance matching circuit. The advantages of such a design are obvious: It is ensured that optimal impedance matching can be achieved and matching the specified impedance can be achieved in a minimum number of steps. In principle, matching can be performed in a single step.

Fig. 5a illustrates another embodiment of the impedance matching circuit IMC. Three inductive elements IN1, IN3, IN5 are electrically connected in series within the signal path SP between input IN and output OUT of the signal path. Two differentially tunable capacitance elements CP1, CP2 each electrically connecting the signal path with ground in a respective parallel branch form one set of tunable reactance elements while another tunable capacitance element CP5 connects the signal path with ground in a third parallel branch. The impedance matching circuit shown in Fig. 5a thus comprises a pi-section network being composed of the elements CP1, IN1, CP2 and a T-section-network being composed of the elements IN3, CP3, IN5. The T- and the pi-section networks are electrically connected in series within the signal path SP. This arrangement can also be regarded as a dual-pi-section network, comprising the elements CP3, IN3, CP1, IN1 and CP2 being electrically connected in series to the impedance element IN5. Therefore this and similar network topologies are referred to "pi-like" networks.

Differential control of the capacitance elements CP1 and CP2 and control of the capacitance element CP5 enables the control network CN to tune the impedance of the impedance matching network as shown in Fig. 5b. Here, a part of the complex plane represents the complex impedance of the impedance matching network according to Fig. 5a is shown. Analog to fig. 4b, differentially varying the capacitances of CP1 and CP2 mainly varies the imaginary part of the impedance while varying the capacitance of CP3 varies the real part. Thus again an orthogonal-like tuning is possible providing the mentioned advantages.

Matching within two frequency bands can be done with further reactance elements electrically connected within the impedance matching circuit IMC. One example is shown in Fig.

3a. In order to tune the impedance matching circuit at
5 different frequencies it may comprise further capacitance elements CPa, CPb, CPc, CPd electrically connected within the signal path. In this embodiment CPa and CPb are electrically connected in parallel and CPc and CPd are electrically connected in parallel. Further, capacitances CPc and CPd are
10 electrically connected in series to CPb. A switch can open or close the serial connection between CPd and CPb. Activating or deactivating of CPd results in two different total capacitances of the electrical circuit comprising these four capacitances. This enables to tune the impedance matching
15 circuit to obtain matching at two different frequency bands.

Fig. 3b illustrates another possibility to use the impedance matching network at two different frequency bands. Two inductance elements IN1 (with inductance L_P), IN2 (with
20 inductance L_S) are electrically connected in series while a capacitance CP3 element (with capacitance C_P) is electrically connected in parallel to the inductance element IN1. This network exhibits the serial sections of the pi-like circuits within the impedance matching circuit. According to equation
25 2, it can be assured by designing the reactances of the elements that a specified impedance is obtained at two different frequencies. The reactance elements may be tunable in order to dynamically tune the impedance according to the invention.

30 Fig. 3c illustrates still another embodiment of the serial sections of the pi-like networks being comprised by the impedance matching circuit. Compared to Fig. 3b the

inductance element IN2 is replaced by a capacitance element CP4. This network also enables tuning to obtain a specified impedance at two different frequency bands.

5 Fig. 3d illustrates the serial section of the pi-like circuits of the impedance matching circuit according to Fig. 3b comprising a further tunable capacitance element CP6 that is electrically connected in parallel to both serial inductance elements IN1, IN2.

10 Fig. 3e illustrates the serial section of the pi-like circuits of the impedance matching circuit according to Fig. 3b comprising a further capacitance element CP4 that is electrically connected in series within the serial section.

15 Fig. 3f illustrates a pi-section of an impedance matching network for use in a high pass circuit configuration. It comprises a capacitive element HPCE in the signal path (i.e. the serial path) and two inductance elements HPIE, each being electrically connected in a parallel path. Based on such sections the present circuit matching network can be realized in a high-pass configuration known for a person skilled in the art.

20 Further dynamically tunable or static reactance elements can be positioned in further parallel or serial branches electrically connected to the signal line. Alternatively, combinations of the presented network sections can be comprised by the impedance matching circuit in order to improve its matching characteristics.

25 Fig. 6 illustrates the convergence behavior of a preferred embodiment of the present invention starting with eight

distinct unmatched impedances with (from left diagram to right diagram) increasing difference in absolute value between actual impedance and specified impedance. The starting impedances are located on the corners of a symmetric octagon and denoted by triangles. The matched impedances are denoted by circles. What can be seen is that if the starting impedance is within a vicinity of the specified value matching works very well (left smith-diagram). Even if the starting point is in a region where the independent control of real and imaginary part is not fully given any more (centered smith-diagram) convergence is still good. This is still valid in the right smith chart where an improvement of the impedance is unambiguously present.

Fig. 7 illustrates a preferred embodiment of the impedance matching network comprising two successive arranged pi-sections being tuned by varying three capacitive elements CP1, CP2, CP3. Each capacitive element is electrically connected in it's own parallel path. Capacitive elements CP1 and CP2 are differentially controlled as indicated in the figure.

The present invention comprises tunable reactance elements. Tunable reactance elements may be tunable capacitors, especially variable MEMS-capacitors (e.g. CMOS switched capacitor arrays) or varactors. But the basic concept does not depend on details concerning the mechanism of the tunable elements which also may be formed by variable inductors. Further, the invention is not restricted by the embodiments or the accompanied figures. Especially embodiments based on high-pass circuit configurations are also possible. Thus, numerous variations departing from the figures are possible without departing from the invention.

List of reference signs:

- CP1, CP2, CP3, CP5, CP6, CP7: parallel capacitance element
- 5 CP4: serial capacitance element
- CPa, CPb, CPc, CPd: capacitance element
- CN: control network
- HPCE: capacitive element
- HPIE: inductive element
- 10 IMC: inductance matching circuit
- IMN: impedance matching network
- IN: input of the signal path
- IN1, IN2, IN3, IN4, IN5: serial inductance element
- MSE: Matching sensing element
- 15 NO1, NO2: node
- OUT: output of the signal path
- PB1, PB2: parallel branch
- S: source
- SP: signal path
- 20 SW: Switch

Claims

1. Impedance matching network (IMN), comprising
 - a signal path (SP) comprising an input (IN) and an output (OUT),
 - an impedance matching circuit (IMC) electrically connected within the signal path (SP), comprising a first tuneable reactance element (TRE1) and a second tuneable reactance element (TRE2),
 - a mismatch sensing element (MSE) embedded in the signal path,
 - a control-network (CN) that is designed to identify the mismatch of the signal propagating in the signal path (SP) by means of the mismatch sensing element (MSE) and to tune the tuneable reactance elements dependent on the identified mismatch,
 - where the tuneable reactance elements are adapted that tuning one of the reactance elements (TRE1 or TRE2) mainly varies the real component of the impedance of the impedance matching circuit (IMC) and tuning the other of the reactance elements (TRE2 or TRE1) mainly varies the imaginary component of the impedance matching circuit (IMC).
2. Impedance matching network (IMN) according to claim 1, where the impedance matching network comprises a n-section-pi-like circuit, where n is an integer number > 0 and each section comprises as reactance elements an inductive element (IEn) in the serial section and a capacitive element (CEn1, CEn2) in each parallel branch.
3. Impedance matching network (IMN) according to claim 2, where m reactance elements are tuneable and i reactance

elements including the first tuneable reactance element (TRE1) are tuned differentially and j reactance elements including the second tuneable reactance element (TRE2) are tuned differentially together with the second
5 tuneable reactance element, where m , i , and j are integer numbers with $2 < m \leq 2n+1$, $i+j=m > 2$, and $i \geq 1$ and $j \geq 1$.

4. Impedance matching network (IMN) according to claim 3 comprising additional capacitive elements (CEn3) and
10 additional inductive elements (IEn2) for each section of the n -section pi-like circuit where each additional inductive element (IEn2) is electrically connected in series with the inductive element (IEn) and each additional capacitance element (CEn3) is electrically
15 connected in parallel with one of the additional inductive elements (IEn2) forming a dual band impedance matching network.

5. Impedance matching network (IMN) according to claim 3 comprising a first and a second additional capacitive
20 element (CEn3, CEn4) for each section of the n -section pi circuit where each first additional capacitive element (CEn3) is electrically connected in series with the inductive element (IEn) and each second additional
25 capacitance element (CEn4) is electrically connected in parallel with the additional inductive element (IEn2) forming a dual band impedance matching network.

6. Impedance matching network according to claims 1-5,
30 comprising a first inductive protection element in a first protection branch electrically connected to the input of the signal path.

7. Impedance matching network according to claims 1-6,
comprising a second inductive protection element in a
second protection branch electrically arranged in
parallel to the output of the signal path.
- 5
8. Impedance matching network according to one of claims 1-
7, where the mismatch sensing element comprises a sensing
inductance element (SIE) electrically connected in series
in the signal path.
- 10
9. Impedance matching network according to one of claims 1-
8, where the control-network comprises a quadrature-
detector to determine the real part and the imaginary
part of the detected impedance.
- 15
10. Impedance matching network according to one of claims 1-
9, matching a signal source to a signal load.
11. Impedance matching network according to one of claims 1-
10, where matching is done in a first frequency band and
in a second frequency band different from said first
frequency band.
- 20
12. Impedance matching network according to one of claims 1-
11, matching a signal source to an antenna.
- 25
13. Impedance matching network (IMN) according to claim 1,
where the impedance matching network comprises a n-
section-pi-like circuit, where n is an integer number > 0
and each section comprises as reactance elements an
capacitive element in the serial section and a inductive
elements in each parallel branch.
- 30

14. Method for matching an impedance between a source and a load according to a defined specification comprising the steps

a) providing a signal path (SP),

b) connecting to the signal path an impedance matching circuit (IMC) comprising at least two tunable reactance elements, each assigned to a first or a second group,

c) connecting a mismatch sensing element (MSE) to the signal path,

d) detecting the impedance mismatch between source and load,

e) determining a new set of values of the impedances of the tunable reactance elements dependent on the mismatch,

f) tuning the tunable reactance elements according to the mismatch, where differentially tuning the first group of said tuneable reactance elements (TRE1) mainly varies the real component of the impedance of the impedance matching circuit (IMC) and differentially tuning the second group of said tuneable reactance elements (TRE2) mainly varies the imaginary component of the impedance matching circuit (IMC).

15. Method according to claim 14 where the number of tunable reactance elements is m and m is an integer > 2 .

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Prior art:

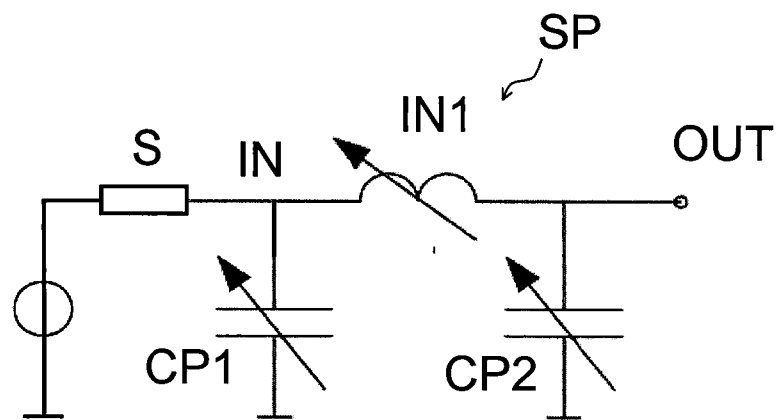


Fig. 1a

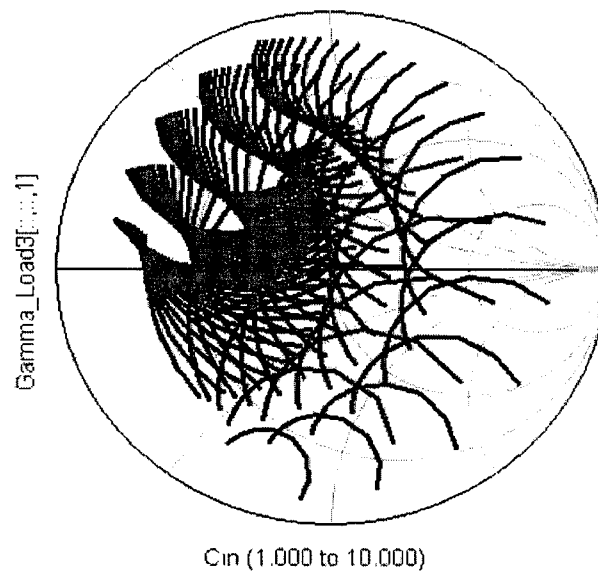


Fig. 1b

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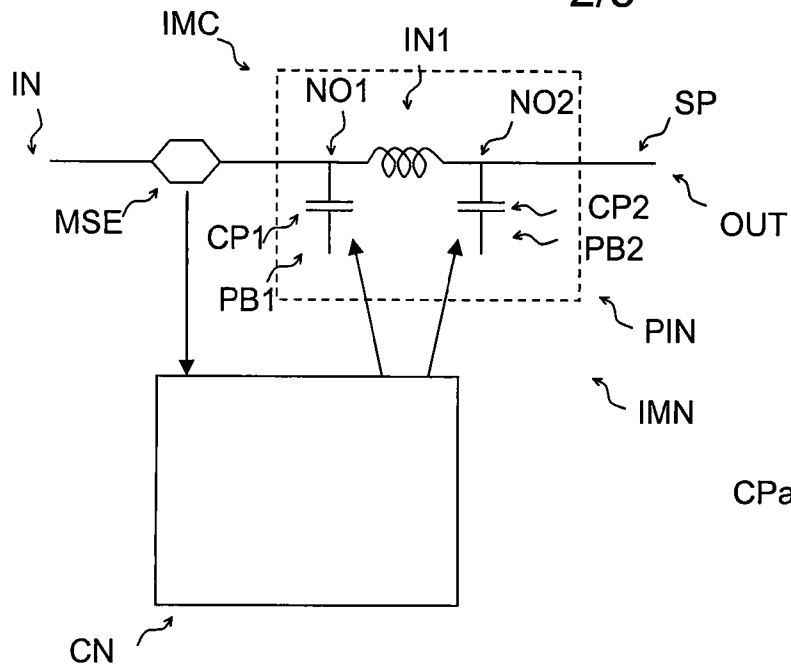


Fig. 2

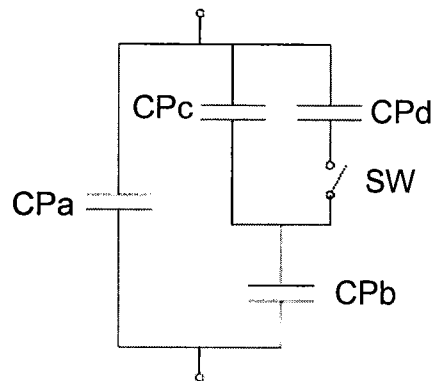


Fig. 3a

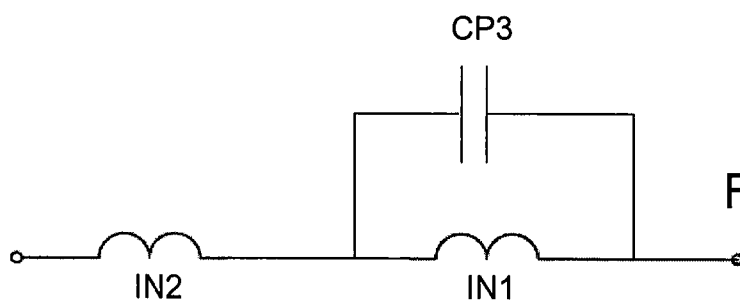


Fig. 3b

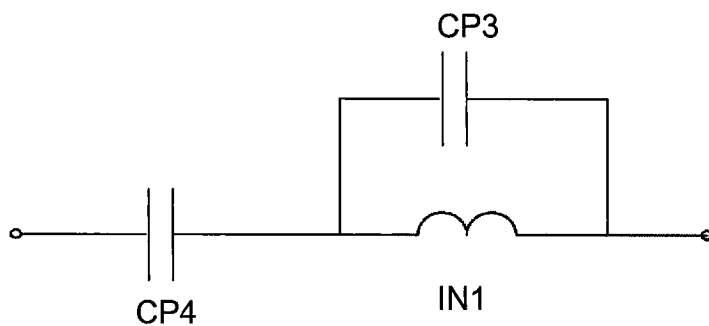


Fig. 3c

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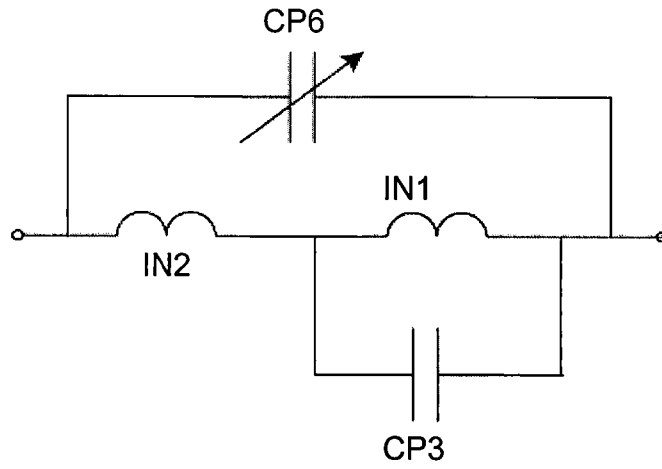


Fig. 3d

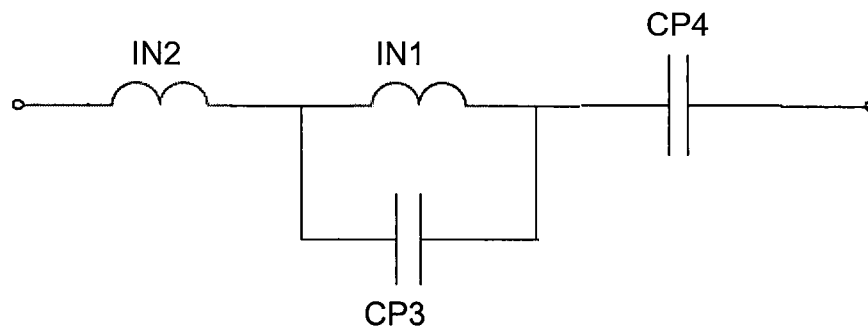


Fig. 3e

Fig. 3f

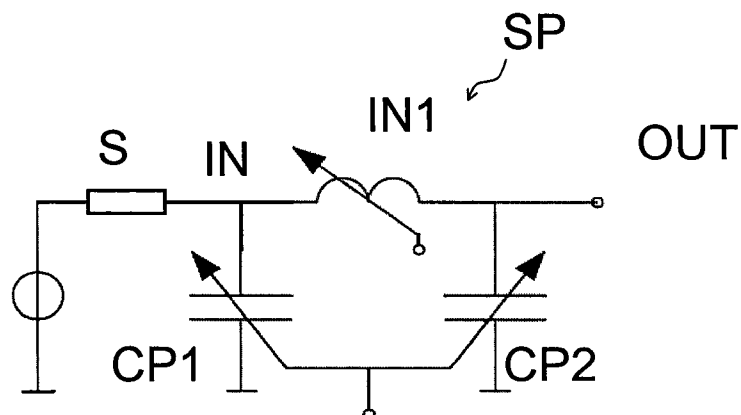
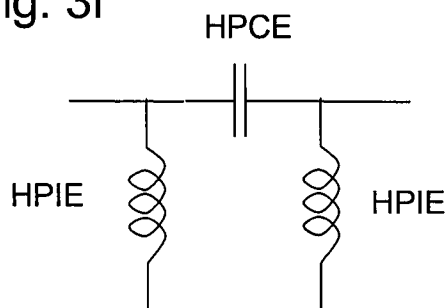


Fig. 4a

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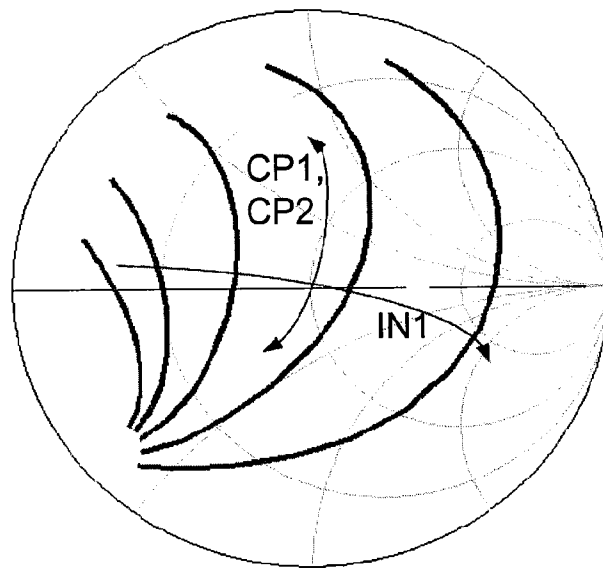


Fig. 4b

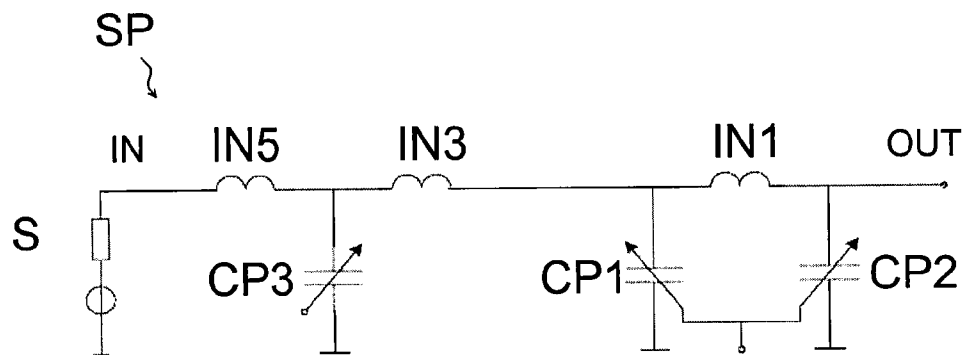


Fig. 5a

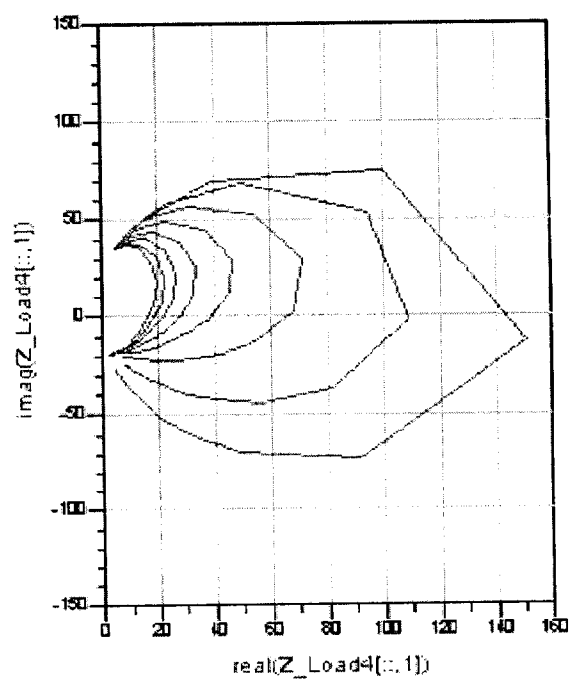


Fig. 5b

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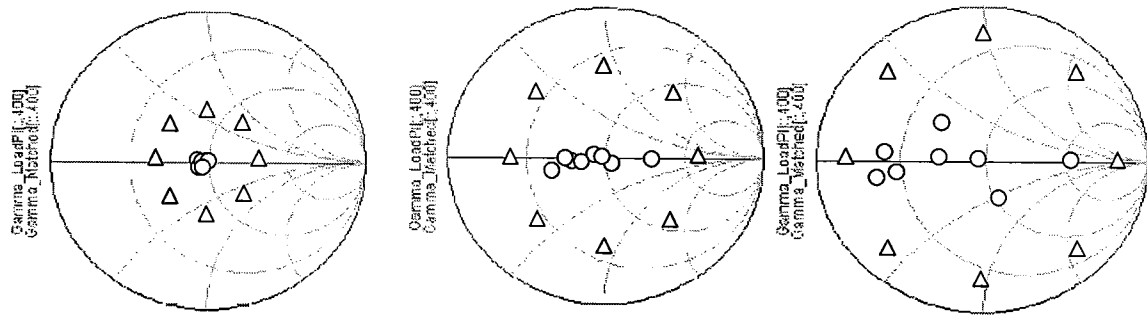


Fig. 6

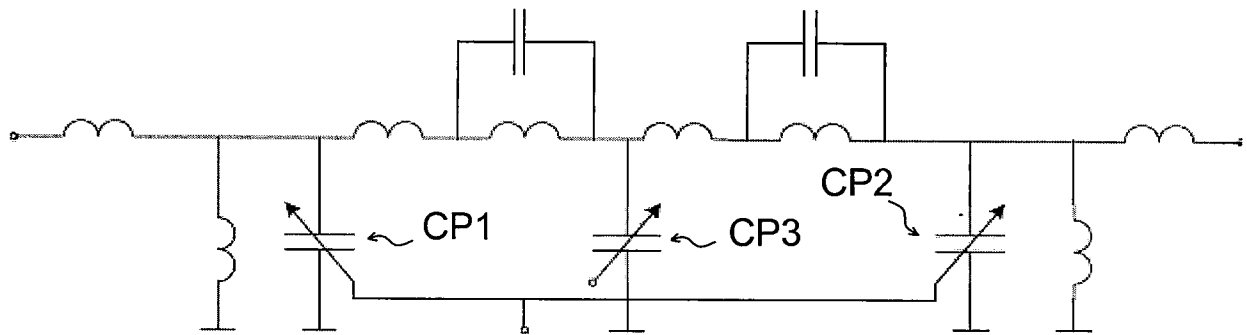


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/059754

A. CLASSIFICATION OF SUBJECT MATTER

INV. H03H7/40

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)
H03H

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)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 2 745 067 A (VIRGIL TRUE ET AL) 8 May 1956 (1956-05-08) page 3, column 2, line 44 - page 5, column 6, line 68; figures 1-6	1-15
X	EP 0 005 592 A (MOTOROLA INC [US]) 28 November 1979 (1979-11-28) page 2, line 23 - page 3, line 10; figures 1-4	1-15
X	page 3, line 28 - page 13, line 12	1-15
X	CA 1 301 914 C (BR COMMUNICATIONS [US]) 26 May 1992 (1992-05-26) page 1, line 23 - page 7, line 5; figure 1	1-15
A	NL 7 612 700 A (HATFIELD INSTR LTD) 4 January 1978 (1978-01-04) the whole document	1-15

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search

25 August 2009

Date of mailing of the international search report

01/09/2009

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/059754

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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Information on patent family members

International application No

PCT/EP2009/059754

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