TeKCEM

Available patents relating to antenna tuning

(February 2015)

- ❒ Definitions
- ❒ Suggested applications of our inventions
- ❒ Introduction to MAPMUP antenna tuners
- ❒ Presentation of the MIMOmatch-B patent portfolio
- ❒ Patent development and support

Definitions

❒ *Multiport antenna array* (in this document): several antennas each intended to be used simultaneously for radio communication, in the same frequency band, by a single station, each of the antennas having a single port for this purpose.

❒ *MIMO*:

- ◆ multiple-input and multiple-output (MIMO) is a broad concept;
- ◆ in the field of wireless transmission, strictly speaking, it either refers to the simultaneous use of multiple antennas for emission and for reception in the same frequency band, or (more restrictive) to spatial multiplexing;
- ◆ in the field of wireless transmission, loosely speaking, it often refers to the use of multiple antennas for emission and/or reception, e.g. for spatial diversity, beamforming, interference cancellation or spatial multiplexing.

❒ *MT* (in this document): a mobile terminal of a cellular network, e.g. a mobile station (MS) of a GSM network, and/or a user equipment (UE) of an UMTS or LTE network.

❒ *Single-user MIMO (SU-MIMO)*:

- ◆ means spatial multiplexing between the base station and a single MT;
- ◆ a multiport antenna array is required in the MT for SU-MIMO;
- ◆ SU-MIMO is needed in LTE to meet the 4G requirements of ITU-R.

❒ *Multi-user MIMO (MU-MIMO)*:

- ◆ means spatial multiplexing between the base station and several MTs;
- ◆ a multiport antenna array is not required in the MTs, for MU-MIMO with a single stream/layer per user;
- ◆ a multiport antenna array is required in the MTs, for MU-MIMO with multiple streams/layers per user, for instance in LTE-A.

❒ *MAA-MT* (in this document): a MT using the antennas of a multiport antenna array, simultaneously, in the same frequency band, e.g. for spatial diversity, beamforming, interference cancellation or spatial multiplexing.

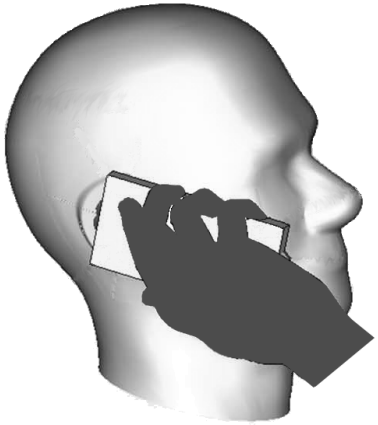
❒ *Antenna interaction*. Antenna interaction between the antennas of a multiport antenna array results in a significantly non-diagonal impedance matrix. It is caused by a narrow spacing between the antennas, and is more pronounced in the lower frequency bands. Antenna interaction in a MAA-MT produces:

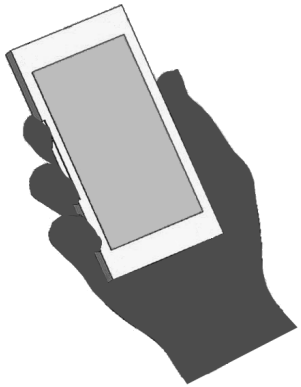
- ◆ a mismatch loss and noise in the downlink;
- ◆ a mismatch loss and cross modulation in the uplink.

❒ *Antenna correlation*. In a MAA-MT, antenna correlation between the antennas of the multiport antenna array degrades the performance of the MIMO channel, e.g. reduces the capacity in the case of a fast fading channel. It is caused by a narrow spacing between the antennas, and is more pronounced in the lower frequency bands.

❒ *User effects*: the effects, on a wireless link, of the interaction between one or more antennas of the MT and a person using it. These effects comprise:

- ◆ a variation in the impedance of the antenna, or in the impedance matrix of the antennas;
- ◆ a variation in the radiation efficiency of the system formed by the MT and the user;
- ◆ a variation in the directivity of the system formed by the MT and the user.





❒ *Environment effects*: the effects, on a wireless link, of the interaction between one or more antennas of a MT and nearby objects and/or living beings.

Suggested applications of our inventions

❒ R&D results on antenna tuning in MTs have been disclosed as from 2005, to:

- ◆ operate in multiple frequency bands;
- ◆ mitigate environment effects, including user effects.

❒ The first announcements of implementations of antenna tuning in MTs occurred after 2008, in mobile phones of Samsung, Apple, Sony, etc.

❒ In 2015, antenna tuning is ubiquitous in MTs, and it is taken into account in MIPI alliance standards.

❒ Several manufacturers offer devices for antenna tuning (e.g. STMicroelectronics, WiSpry, RFMD, Peregrine, Qualcomm, Epcos).

❒ This prior art is not suitable for multiport antenna arrays used for MIMO.

❒ Our inventions can be used to address the following design challenges applicable to a high-performance MT using MIMO (more precisely, a MAA-MT):

- ◆ too many frequency bands;
- ◆ mitigation of antenna interaction;
- ◆ mitigation of antenna correlation;
- ◆ mitigation of environment effects, including user effects.

❒ The aims are cost reduction, fewer models, improvement of the radio performance.

❒ Our patents may also be used to cope with the huge patent portfolio of Paratek, acquired by RIM/Blackberry.

❒ The MIMOmatch-B portfolio can be compared to

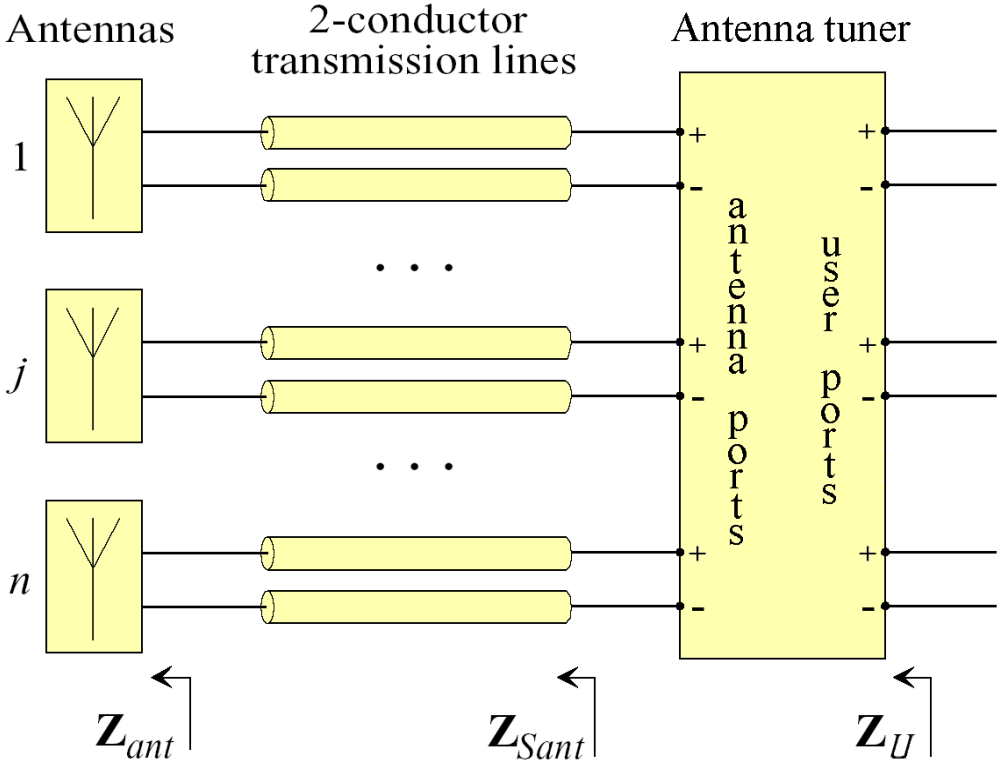
- ◆ United States Patent number 8,102,830 assigned to Samsung, and
- ◆ United States Patent number 8,059,058 assigned to Sony Ericsson Mobile.

Introduction to MAPMUP antenna tuners

❒ The basis of the MIMOmatch-B portfolio is a new multiple-antenna-port and multiple-user-port (MAPMUP) antenna tuner disclosed in P54.

❒ We consider a radio device that uses *n* antennas simultaneously in the same frequency band (e.g., a MAA-MT)

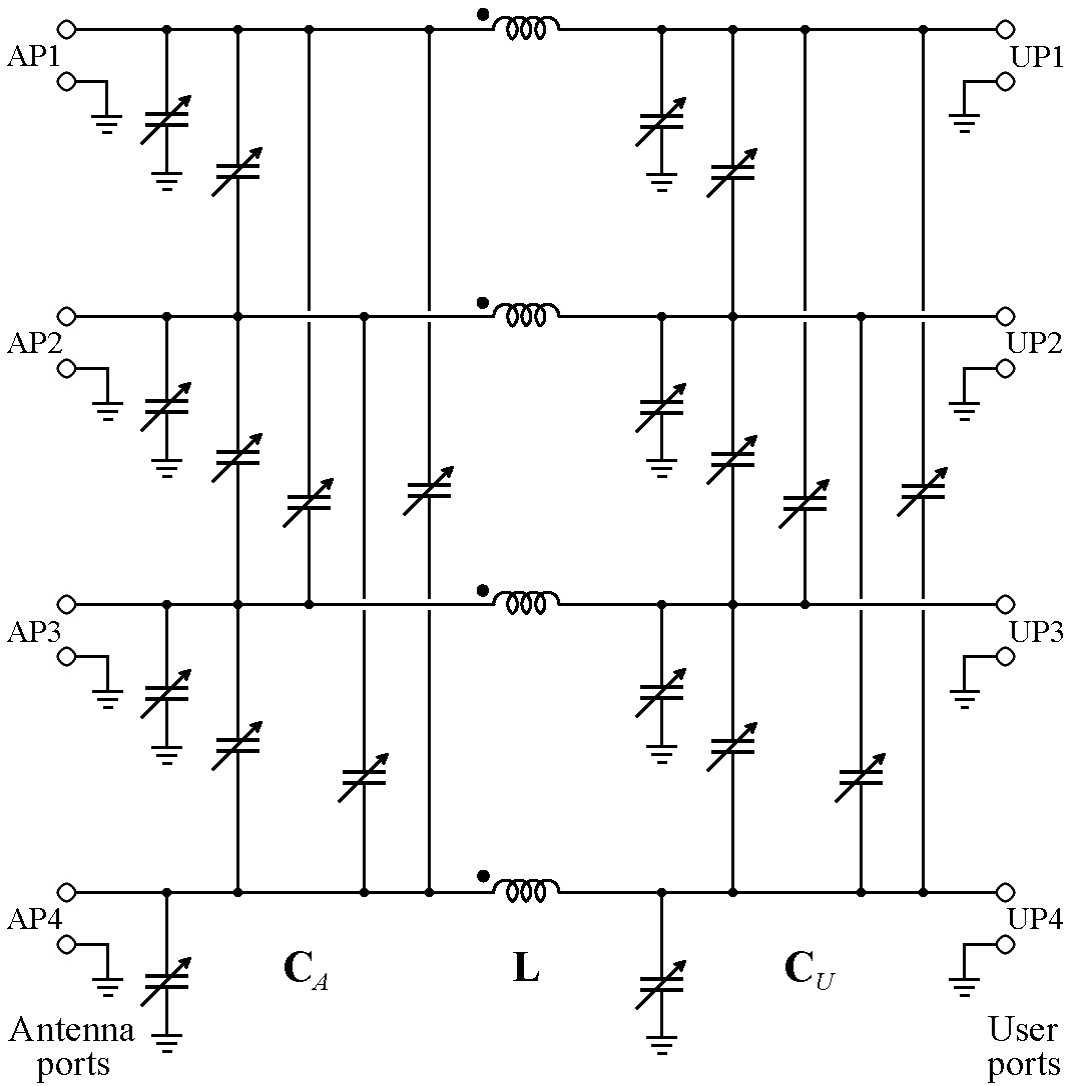
❒ The MAPMUP antenna tuner is intended to be inserted between the antennas and the radio device.



❒ The new antenna tuner has the structure of a multidimensional π-network

❒ It may comprise n $(n + 1)$ adjustable impedance devices.

❒ It can provide an ideal match (i.e., decoupling and matching) over a frequency band, and in the presence of severe environment effects.



❒ This result was established theoretically, in three peer-reviewed articles (which may be downloaded here):

[A] F. Broydé, E. Clavelier, "A New Multiple-Antenna-Port and Multiple-User-Port Antenna Tuner", *Proc. 2015 IEEE Radio & Wireless Week, RWW 2015*, pp. 41-43, January 2015.

[B] F. Broydé, E. Clavelier, "Some Properties of Multiple-Antenna-Port and Multiple-User-Port Antenna Tuners", *IEEE Trans. on Circuits and Systems — I: Regular Papers*, Vol. 62, No. 2, pp. 423-432, February 2015.

[C] F. Broydé, E. Clavelier, "Two Multiple-Antenna-Port and Multiple-User-Port Antenna Tuners", *Proc. 9th European Conference on Antenna and Propagation, EuCAP 2015*, April 2015.

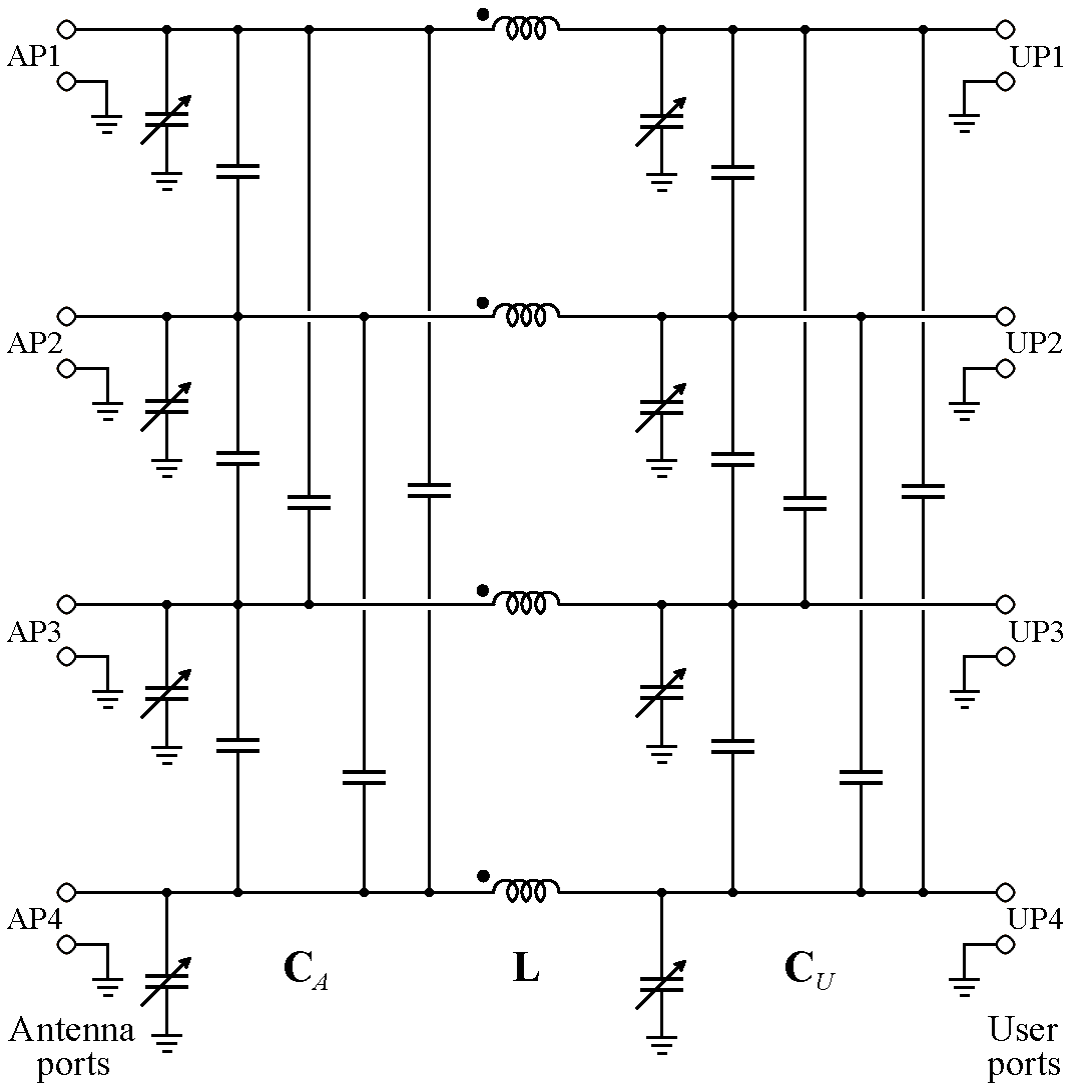
❒ It confirms that the new MAPMUP antenna tuner can be used to operate in multiple frequency bands, and to mitigate antenna interaction, and environment effects, including user effects.

❒ It also entails that the new MAPMUP antenna tuner can be used to mitigate antenna interaction.

❒ To reduce costs, the new antenna tuner may comprise less than n (n + 1) adjustable impedance devices.

❒ This possibility is also disclosed in P54.

❒ The patent applications for P54 also include wider claims, which may survive the examination.



Presentation of the MIMOmatch-B patent portfolio

Title of the Patent Family — MIMOmatch-B patent portfolio	Family
Antenna tuning apparatus for a multiport antenna array	P54
Method and device for radio reception using an antenna tuning apparatus and a plurality of antennas	P55
Method and device for radio reception using a plurality of antennas and a multiple-input-port and multiple-output-port	P56
Method and apparatus for automatically tuning an impedance matrix, and radio transmitter using this apparatus	P57

❒ The porfolio is for sale in February 2015, more information available here .

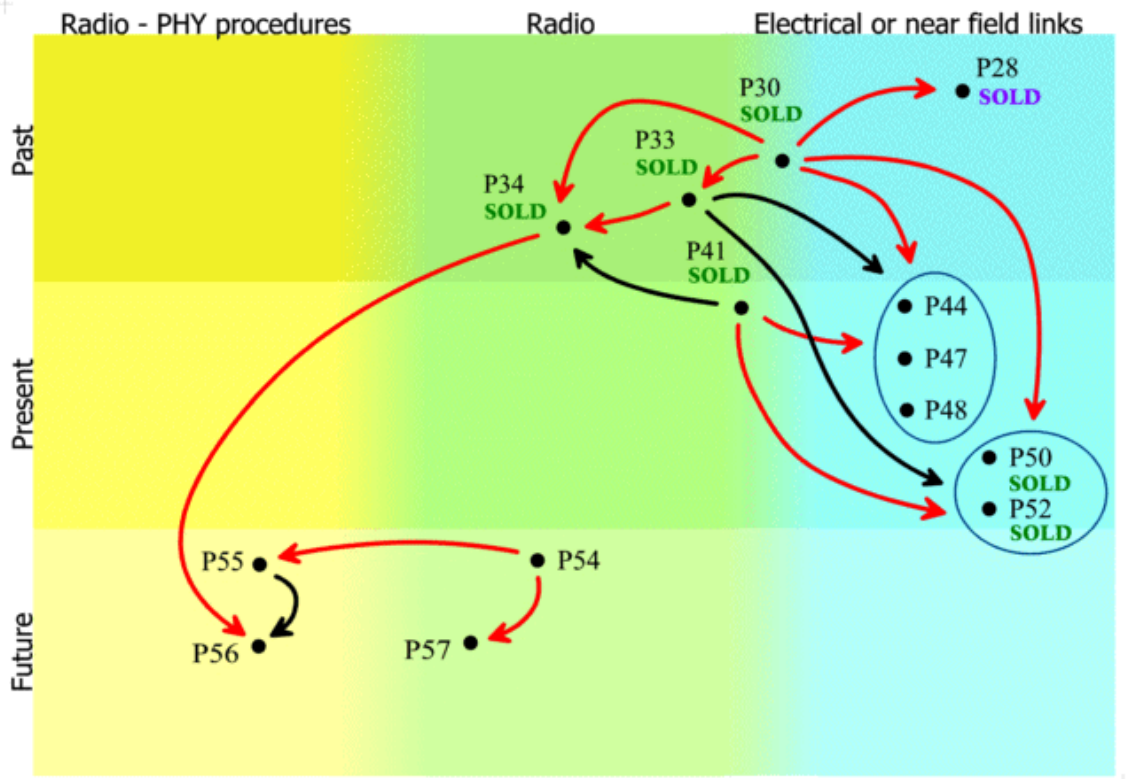
❒ The map below shows the patents of the MIMOmatch-B portfolio (P54 to P57) and other inventions offered for sale by Tekcem.

❒ From right to left, the map shows:

■ inventions about signal transmission inside equipments;

■ inventions related to radio transmission in general; and

■ inventions related to physical layer (PHY) procedures of wireless networks.



❒ Time flows from the top to the bottom of the map, and "present" means "granted patents". A red arrow from A to B means that A is very likely to be used in B. A black arrow from A to B means that A might be used in B.

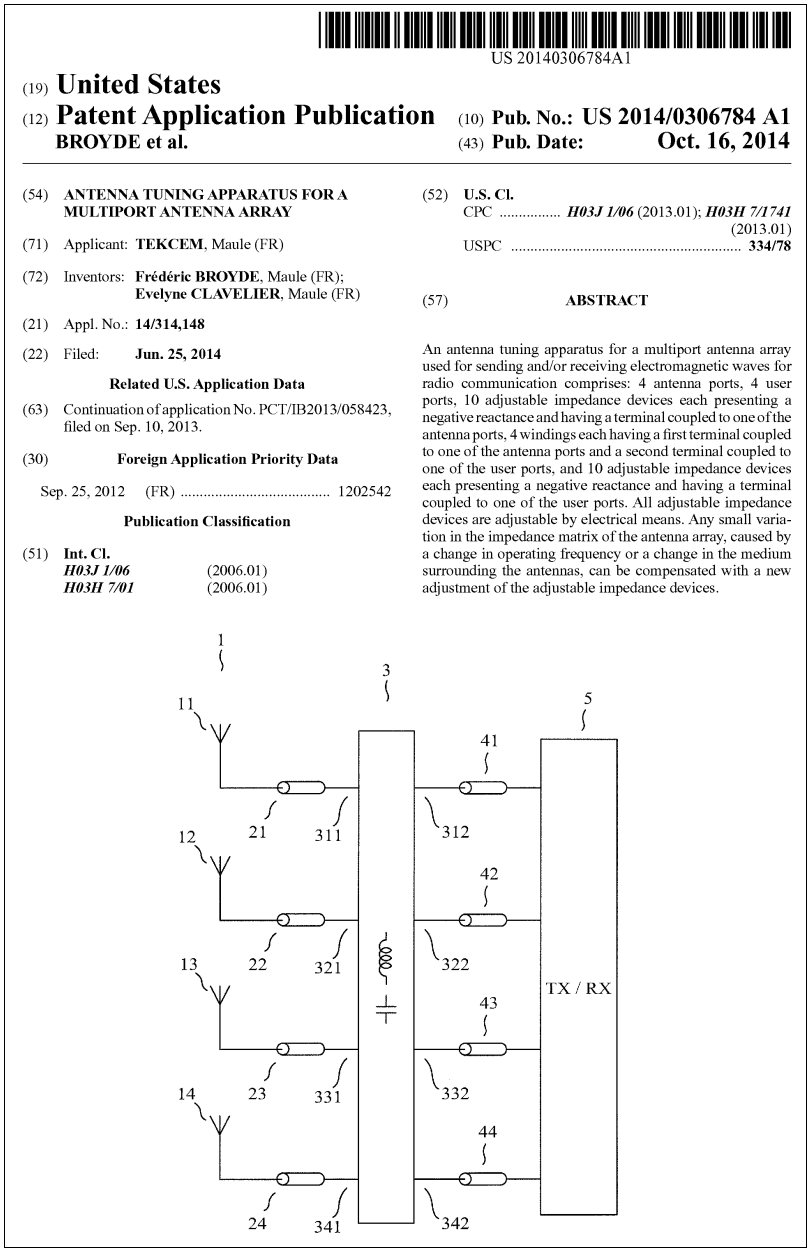
❒ Patent family P54

Antenna tuning apparatus for a multiport antenna array

The invention P54 discloses a broad family of MAPMUP antenna tuners for use with a multiport antenna array.

With a suitable adjustment of the adjustable impedance device of the MAPMUP antenna tuner, it is possible to:

- ◆ operate over multiple frequency bands;
- ◆ compensate antenna interactions;
- ◆ mitigate environment effects.



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(19) **United States**

(12) **Patent Application Publication**
BROYDE et al.

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(43) **Pub. Date: Oct. 16, 2014**

(54) **ANTENNA TUNING APPARATUS FOR A MULTIPORT ANTENNA ARRAY**

(71) Applicant: **TEKCEM**, Maule (FR)

(72) Inventors: **Frédéric BROYDE**, Maule (FR); **Evelyne CLAVELIER**, Maule (FR)

(21) Appl. No.: **14/314,148**

(22) Filed: **Jun. 25, 2014**

Related U.S. Application Data

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Publication Classification

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(52) **U.S. Cl.**
CPC ***H03J 1/06*** (2013.01); ***H03H 7/1741*** (2013.01)
USPC **334/78**

(57) **ABSTRACT**

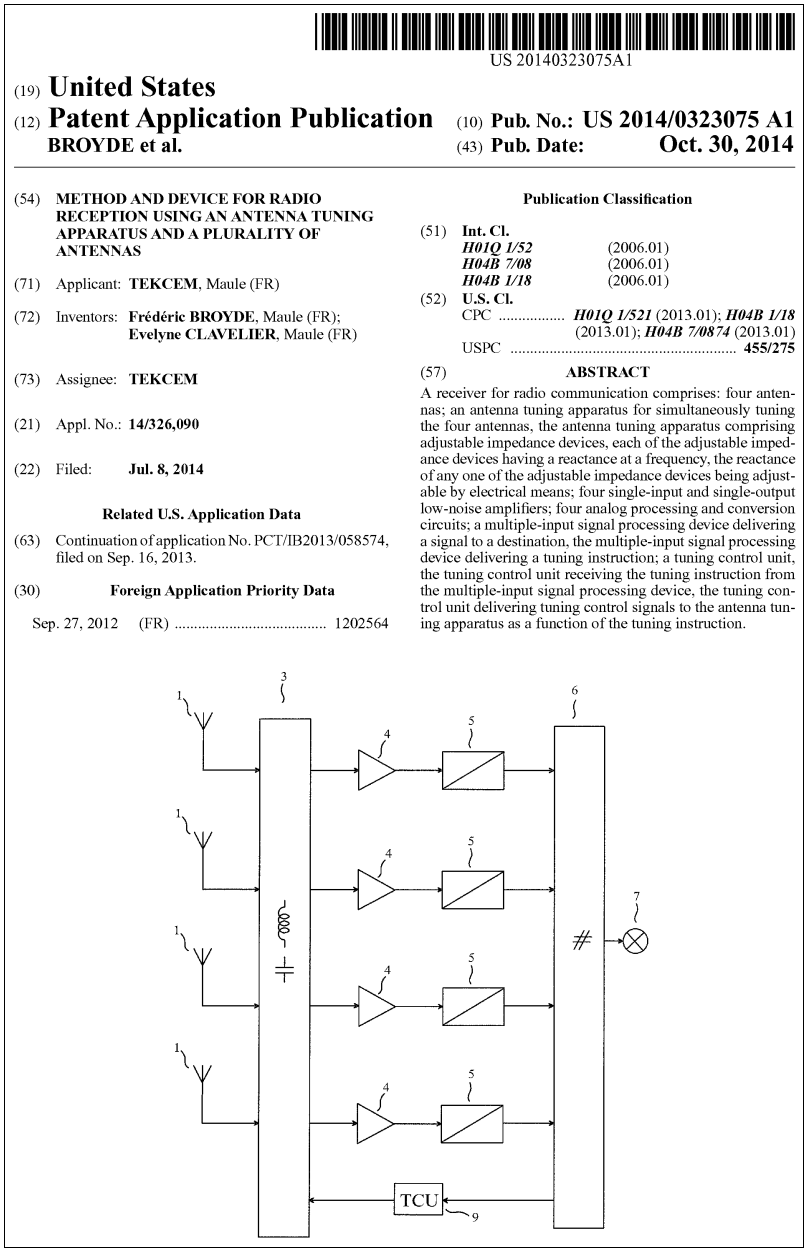
An antenna tuning apparatus for a multiport antenna array used for sending and/or receiving electromagnetic waves for radio communication comprises: 4 antenna ports, 4 user ports, 10 adjustable impedance devices each presenting a negative reactance and having a terminal coupled to one of the antenna ports, 4 windings each having a first terminal coupled to one of the antenna ports and a second terminal coupled to one of the user ports, and 10 adjustable impedance devices each presenting a negative reactance and having a terminal coupled to one of the user ports. All adjustable impedance devices are adjustable by electrical means. Any small variation in the impedance matrix of the antenna array, caused by a change in operating frequency or a change in the medium surrounding the antennas, can be compensated with a new adjustment of the adjustable impedance devices.

❒ Patent family P55

Method and device for radio reception using an antenna tuning apparatus and a plurality of antennas

The antenna tuner (antenna tuning apparatus) *may be* one of the MIPMOP antenna tuners of P54.

The reactance of each adjustable impedance device of the antenna tuner is mainly determined by tuning control signals obtained using quantities representative of a channel matrix.



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(54) **METHOD AND DEVICE FOR RADIO RECEPTION USING AN ANTENNA TUNING APPARATUS AND A PLURALITY OF ANTENNAS**

(71) Applicant: **TEKCEM**, Maule (FR)

(72) Inventors: **Frédéric BROYDE**, Maule (FR); **Evelyne CLAVELIER**, Maule (FR)

(73) Assignee: **TEKCEM**

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(22) Filed: **Jul. 8, 2014**

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USPC **455/275**

(57) **ABSTRACT**

A receiver for radio communication comprises: four antennas; an antenna tuning apparatus for simultaneously tuning the four antennas, the antenna tuning apparatus comprising adjustable impedance devices, each of the adjustable impedance devices having a reactance at a frequency, the reactance of any one of the adjustable impedance devices being adjustable by electrical means; four single-input and single-output low-noise amplifiers; four analog processing and conversion circuits; a multiple-input signal processing device delivering a signal to a destination, the multiple-input signal processing device delivering a tuning instruction; a tuning control unit, the tuning control unit receiving the tuning instruction from the multiple-input signal processing device, the tuning control unit delivering tuning control signals to the antenna tuning apparatus as a function of the tuning instruction.

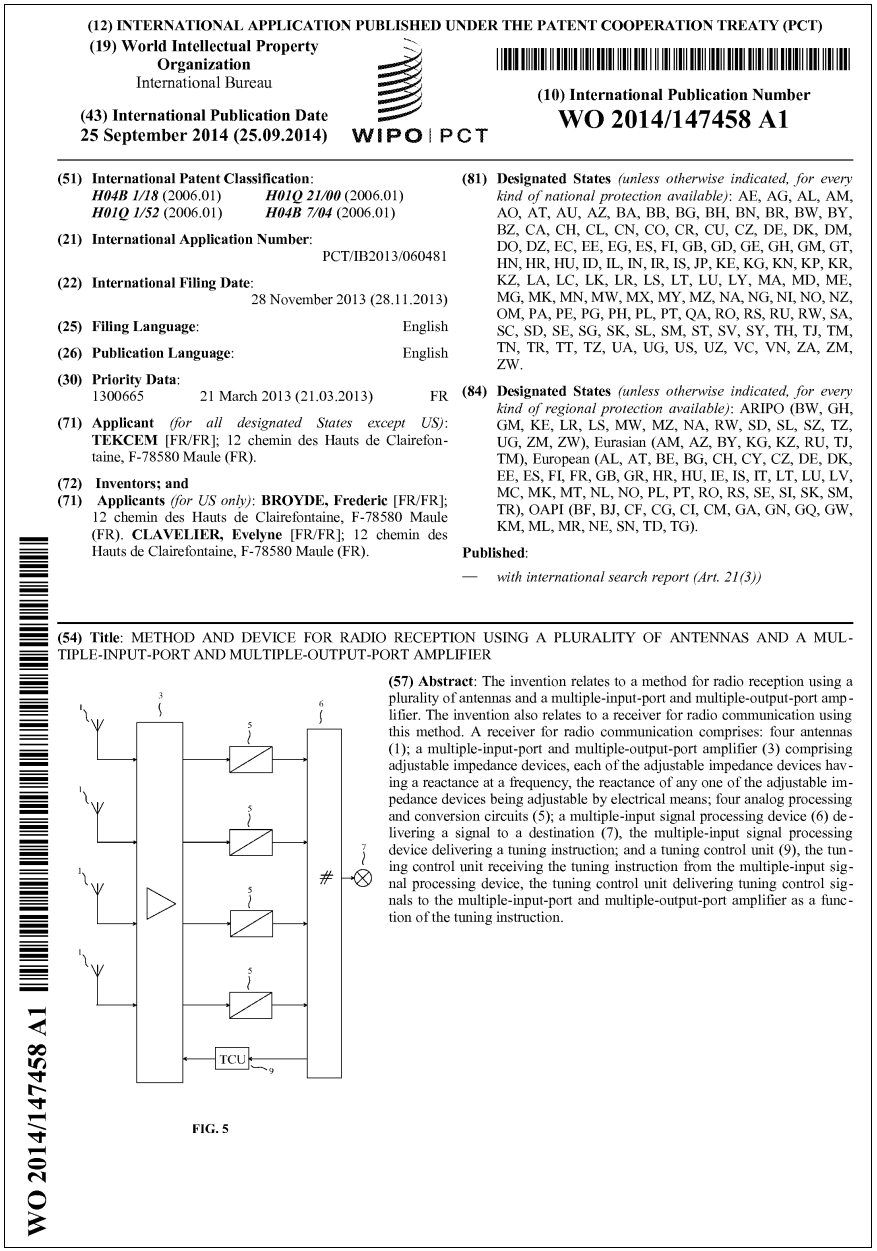
❒ Patent family P56

Method and device for radio reception using a plurality of antennas and a multiple-input-port and multiple-output-port amplifier

The MIPMOP amplifier may for instance be:

- ◆ the one disclosed in P34 of the MIMOmatch-A portfolio (currently assigned to Apple); or
- ◆ a combination of a MAPMUP antenna tuner and several SIPSOP amplifiers.

The MIPMOP amplifier comprises adjustable impedance devices, whose reactances are mainly determined by tuning control signals obtained using quantities representative of a channel matrix.



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(54) Title: METHOD AND DEVICE FOR RADIO RECEPTION USING A PLURALITY OF ANTENNAS AND A MULTIPLE-INPUT-PORT AND MULTIPLE-OUTPUT-PORT AMPLIFIER

FIG. 5

(57) Abstract: The invention relates to a method for radio reception using a plurality of antennas and a multiple-input-port and multiple-output-port amplifier. The invention also relates to a receiver for radio communication using this method. A receiver for radio communication comprises: four antennas (1); a multiple-input-port and multiple-output-port amplifier (3) comprising adjustable impedance devices, each of the adjustable impedance devices having a reactance at a frequency, the reactance of any one of the adjustable impedance devices being adjustable by electrical means; four analog processing and conversion circuits (5); a multiple-input signal processing device (6) delivering a signal to a destination (7), the multiple-input signal processing device delivering a tuning instruction; and a tuning control unit (9), the tuning control unit receiving the tuning instruction from the multiple-input signal processing device, the tuning control unit delivering tuning control signals to the multiple-input-port and multiple-output-port amplifier as a function of the tuning instruction.

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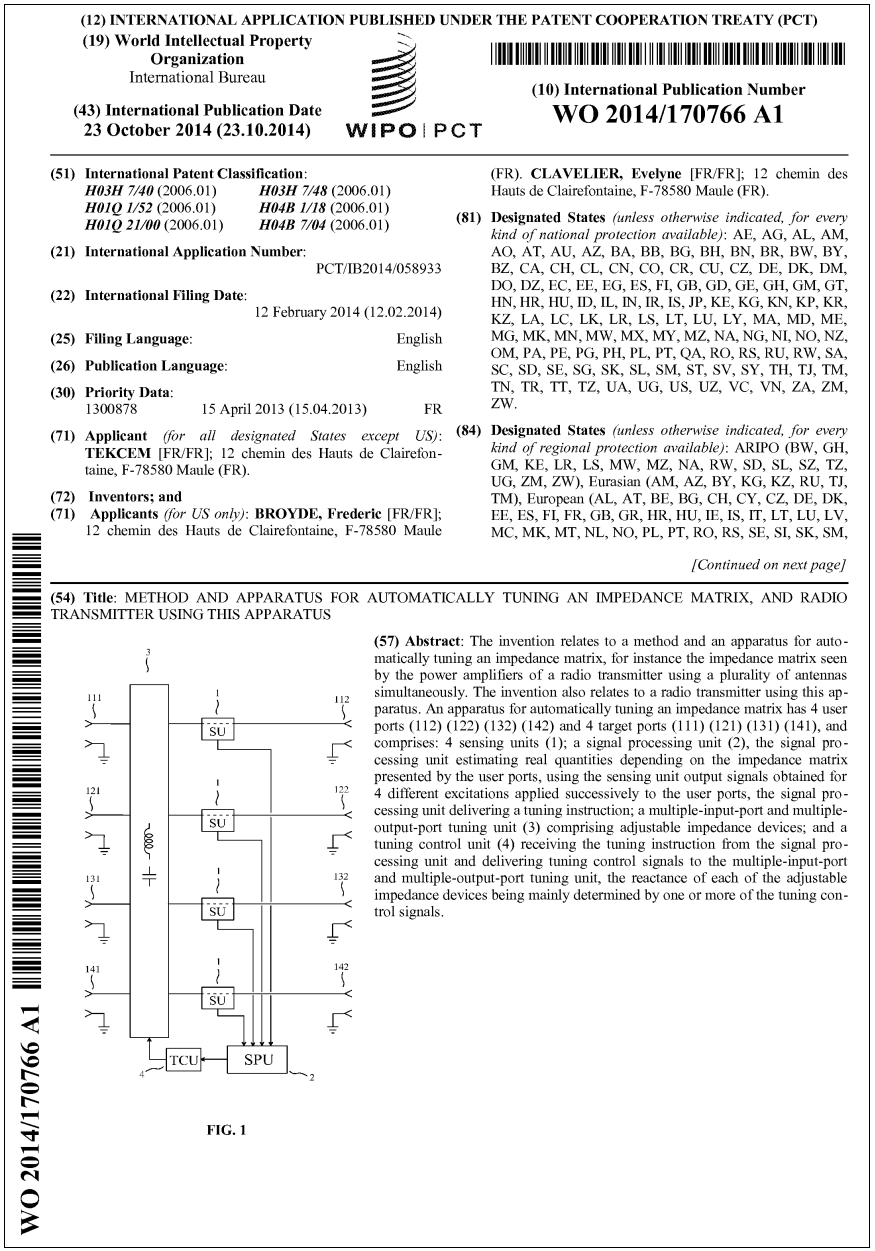
❒ Patent family P57

Method and apparatus for automatically tuning an impedance matrix, and radio transmitter using this apparatus

This method for automatically tuning an impedance matrix uses:

- ◆ sensing unit output signals estimating real quantities depending on an impedance matrix;
- ◆ a multiple-input-port and multiple-output-port tuning unit, which *may be* an antenna tuner of P54.

The invention P57 also discloses a radio transmitter using this method.



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(71) Applicant *(for all designated States except US)*: **TEKCEM** [FR/FR]; 12 chemin des Hauts de Clairefontaine, F-78580 Maule (FR).

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[Continued on next page]

(54) Title: METHOD AND APPARATUS FOR AUTOMATICALLY TUNING AN IMPEDANCE MATRIX, AND RADIO TRANSMITTER USING THIS APPARATUS

FIG. 1

(57) Abstract: The invention relates to a method and an apparatus for automatically tuning an impedance matrix, for instance the impedance matrix seen by the power amplifiers of a radio transmitter using a plurality of antennas simultaneously. The invention also relates to a radio transmitter using this apparatus. An apparatus for automatically tuning an impedance matrix has 4 user ports (112) (122) (132) (142) and 4 target ports (111) (121) (131) (141), and comprises: 4 sensing units (1); a signal processing unit (2), the signal processing unit estimating real quantities depending on the impedance matrix presented by the user ports, using the sensing unit output signals obtained for 4 different excitations applied successively to the user ports, the signal processing unit delivering a tuning instruction; a multiple-input-port and multiple-output-port tuning unit (3) comprising adjustable impedance devices; and a tuning control unit (4) receiving the tuning instruction from the signal processing unit and delivering tuning control signals to the multiple-input-port and multiple-output-port tuning unit, the reactance of each of the adjustable impedance devices being mainly determined by one or more of the tuning control signals.

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Patent development and support

- We continue our R&D effort relating to MIPMOP antenna tuners:
  - internal R&D exclusively owned by Excem or Tekcem; and
  - STMicroelectronics and Eurexcem have started a cooperative research program.
- A new portfolio (MIMOmatch-C) will soon be offered for sale.
- We currently continue to invent in this area, to later file new patent applications.
- We can provide technical support for implementing our inventions.
- We can provide technical support to other projects.
- We can help to create new intellectual property rights.