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(54) Benævnelse: **Antenner med unik elektronisk signatur**

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DE-A1-102004 042 160
US-A- 5 198 821
US-A1- 2012 142 277
US-B2- 7 042 406

DESCRIPTION

TECHNICAL FIELD

[0001] The present invention relates generally to antennas used in a wireless transceiver, and more specifically to identifying an antenna using its unique electronic signature.

BACKGROUND

[0002] Marking or identifying the source or manufacturer of an antenna has generally relied on the antenna's outward features, such as shape, size, color, and package, or through the use of a trademark or a trade dress. Such features or designs may disappear due to wear and tear as time passes, making identification of the source or manufacturer of an antenna difficult. Further, an antenna used in the field, for example, installed on the top of a wireless tower, does not allow easy access for close inspection of the antenna type.

[0003] Reflectometry is a measurement technique that has been widely used to diagnose problems associated with radio frequency (RF) antennas or an electronic circuit or device. For example, reflectometry can be used to detect fault, locate disruption, and calibrate distance in a test circuit. Reflectometry includes time-domain, frequency domain, and noise domain analysis. In reflectometry, a test signal, often a wideband or swept-frequency signal, is sent into an electronic circuit or device and a reflected signal is measured at an antenna interface port. Besides reflectometry, transmissometry is another diagnostic tool. But unlike reflectometry that measures a reflected signal, transmissometry measures a transmitted signal.

[0004] To detect a faulty antenna, reflectometry measures a maximum return loss and/or a minimum return loss of an antenna. A return loss of a device measures the ratio of an output signal power to an input signal power in decibel. Abnormal maximum/minimum return losses can be useful in detecting an antenna that is not working properly, for example, reflecting signals excessively. However, for working antennas, the measured maximum/minimum return losses are generally within a normal range and do not possess unique features that are suitable for identification purposes. Other than the maximum/minimum return loss, a working antenna generally exhibits random electric behavior, therefore does not have an electronic "signature."

[0005] US 7,042,406 B2 relates to an antenna provided with an electronic component or circuit that has a value corresponding to properties of the antenna. A read mechanism reads the value and sets an operational status of a transceiver based on the value. In one implementation, the electronic component is a resistor having a value that identifies the antenna properties. A table may be used to correlate resistor values to different types of antennas or sets of antenna properties. Alternatively, the circuit can be implemented in a microchip that provides a response to a challenge sent by the read mechanism. The response encodes the properties of the antenna.

[0006] EP 1 962 374 A1 relates to a method of identifying an antenna by the steps of: providing the antenna with an identifying radiofrequency identification RFID circuit, connecting one end of a cable to the antenna, connecting the other end of the cable to a remote unit, sending a trigger signal to the RFID circuit, receiving by the remote unit via the cable a response signal from the RFID circuit, and decoding the response signal so as to identify the antenna.

[0007] EP 1 863 123 A1 relates to a method for recognizing a type of an antenna. The type of an antenna is recognized by a control unit connected to an antenna module comprising the antenna. The method comprises the steps of sending an antenna identification signal from the control unit to the antenna module; sending an antenna reply signal from the antenna module to the control unit in response to the antenna identification signal, wherein the antenna reply signal comprises an antenna type information signal in a coded form, decoding the antenna reply signal by the control unit for determining the type of the antenna connected thereto, and adjusting receive and/or transmit parameters of the control unit connected to the antenna module according the type of the antenna.

[0008] DE 10 2004 042 160 A1 relates to a method for identifying at least one antenna, the method involving an electromagnetic radiation pulse of a specified first duration and a specified first frequency band. After emission of the radiation pulse, electromagnetic radiation is detected in a specified second frequency band for a specified second duration, and based on a value of a detected frequency of the detected electromagnetic radiation, the presence of at least one antenna is ascertained on the basis of its resonance frequency.

[0009] US 5,198,821 A relates to a method and a device for the on-line testing of an antenna formed by a plurality of radiating sources. In an application for example to a secondary radar antenna, it is proposed to memorize the patterns of the antenna when all the radiating sources work properly and, when each of the source is malfunctioning in turn, to measure the radiation patterns of the antenna during its operation in IFF mode and then to compute the coefficients of correlation of these patterns with all the corresponding memorized radiation patterns. The value of the coefficients obtained enables the precise determining and localizing of the malfunction.

[0010] US 2012/0142277 A1 relates to an antenna coupler for providing a radio frequency interface between a radio frequency electronic system of a unit under test and automatic test equipment for the radio frequency electronic system. The antenna coupler comprises a mechanical interface to secure the antenna coupler to an antenna site of the unit under test, and a radio frequency signature storage component comprising a stored representation of a radio frequency signature comprising radio frequency test output.

[0011] The present application discloses advantageous methods and devices that can be used to electronically mark and identify an antenna.

SUMMARY

[0012] A method of automatic remote detection of a type of an antenna according to claim 1 and an automatic remote detection device according to claim 2 for detecting the type of an antenna remotely are presented. Further disclosed are low-cost and energy efficient methods and apparatus for electronically marking and identifying an antenna. Methods and apparatus for automatically and remotely identifying an antenna type are also disclosed. The methods and apparatus disclosed herein use a resistor-inductor-capacitor (RLC) circuit designed to generate a return-loss-profile that can serve as a unique antenna signature of the antenna.

[0013] According to an aspect of the disclosure, an antenna manufactured with a unique antenna signature comprises a radiating element, a ground element and an RLC circuit. The radiating element is configured to transmit and receive radio frequency signals. The ground element is connected to the ground. The RLC circuit is connected between the radiating element and the ground element and is configured such that it generates a return-loss profile having a distinctive resonant frequency that is outside the working bandwidth of the antenna. By measuring the return-loss-profile of the antenna equipped with such RLC circuit, the distinctive resonant frequency can be identified and can serve as the unique signature of the antenna.

[0014] According to an aspect of the disclosure, an apparatus for identifying an antenna is disclosed. An exemplary apparatus for identifying a unique antenna signature of an antenna comprises a transmitter, a coupler and an evaluation circuit. An evaluation circuit further comprises a receiver, a return-to-loss profile detector, a correlator, and an identity detector. The transmitter is configured to send a signal to the antenna. The coupler and the receiver are configured to receive and measure a signal at an antenna interface port. The return-loss-profile detector is configured to detect a return-loss-profile of the antenna and the correlator is configured to correlate the return-loss-profile to one or more known antenna signatures to obtain correlation coefficients. The correlation coefficients are compared with a threshold by the identity detector which identifies the correlation coefficient that is larger than the threshold.

[0015] According to an aspect of the disclosure methods of identifying an antenna are disclosed. A return-loss-profile of the antenna is first detected. The return-loss-profile comprises a frequency range including resonance frequency at which the return-loss is distinctively low. The return-loss-profile is correlated with one or more known antenna signatures to generate correlation coefficients. The correlation coefficients are compared to a threshold to identify the correlation coefficient that is larger than the threshold. The known antenna signature that is associated with the larger-than threshold correlation coefficient can be used as the antenna's unique signature.

[0016] In yet another aspect of the disclosure, methods and apparatus for automatic remote detection of an antenna type are disclosed.

[0017] Of course, the present disclosure is not limited to the features, advantages, and contexts summarized above, and those familiar with antenna technologies will recognize additional features and advantages upon reading the following detailed description and upon viewing the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

Figure 1 illustrates an exemplary antenna configured with an RLC circuit.

Figure 2 illustrates an exemplary resonance transmissibility of an RLC circuit.

Figure 3 illustrates an exemplary apparatus for detecting an antenna's unique electronic signature.

Figure 4 illustrates an exemplary frequency response of an antenna configured with an RLC circuit to provide a unique electronic signature of the antenna.

Figure 5 illustrates an exemplary system configured for automatic remote detection of an antenna type.

Figure 6 illustrates a flow chart of an exemplary process for identifying an antenna's unique signature.

DETAILED DESCRIPTION

[0019] In referring to the drawings, Figure 1 illustrates an exemplary antenna 100 configured with an RLC circuit to generate a unique antenna signature. In Figure 1, the antenna 100 comprises a ground element 102, a radiating element 104, and a RLC circuit 106. The ground element 102 is connected to the ground and the radiating element 104 is configured to transmit and receive signals. The RLC circuit 106 connects the ground element 102 and the radiating element 104.

[0020] The RLC circuit 106 in Figure 1 is shown as a simple serial RCL circuit. As a person skilled in the art would know, the RLC circuit 106 can be replaced by other types of RLC circuits. The RLC circuit comprises a resistor 108, an inductor 110 and a capacitor 112. In the following discussion, the resistance of the resistor 108 is represented by R, the inductance of the inductor 110 is represented by L and the capacitance of the capacitor 112 is represented by *C.*

[0021] One of the well-known features of an RLC circuit is that in an RCL circuit, there is at least one resonance frequency ω_0 at which the impedance of the RLC circuit is pure resistance. The resonance frequency of the RLC circuit 106 can be expressed as:

$$\omega_0 = 1/\sqrt{LC} \qquad (1).$$

In the RLC circuit 106, at the resonant frequency ω_0, the impedance is reduced to resistance R, and the current and voltage are related as $V = I \cdot R$.

[0022] The voltage of the RLC circuit 106 changes in relation to the frequency of the input signal. At the resonance frequency ω_0, the voltage reaches a peak and drops as the frequency of the input signal deviates from the resonance frequency ω_0.

[0023] When at the resonance frequency ω_0, it is important to limit the resonance current I_0 to protect the radio front end of the transceiver from being damaged by strong current. The resistor 108 provides the needed resistance *R* for limiting the current I_0. At the same time, the resistance R should be much less than the impedance of the antenna 100 to create a distinctively low return loss at the resonant frequency.

[0024] Figure 2 depicts the relationship between the transmissibility of the RLC circuit 106,$|G(\omega_A)|$, and the frequency of the input signal ω_A scaled by the resonance frequency ω_0. The relationship between $|G(\omega_A)|$ and

$$\omega_A / \omega_0$$

is dependent upon the damping factor δ, which can be expressed as

$$\delta = \frac{R}{2}\sqrt{\frac{C}{L}}.$$

Both the damping factor δ and the resonance frequency ω_0 are functions of parameters *R*, *L,* and *C*. Both can be determined from the frequency response curve of an antenna.

[0025] Figure 2 illustrates 10 curves, each representing how $|G(\omega_A)|$ changes with

$$\omega_A / \omega_0$$

for different damping factors δ. As it is shown in Figure 2, each curve exhibits a transmissibility peak at the resonance frequency

$$(\omega_A / \omega_0 = 1).$$

The smaller is the damping coefficient, the higher is the peak of the transmissibility curve. The return loss of the RLC circuit 106 is proportionally related to its transmissibility. Therefore, at the resonance frequency ω_0, the RLC circuit 106 reaches its peak return loss for any damping coefficient. If a frequency swept signal is input into the antenna 100 in Figure 1, the RLC circuit 106 will exhibit a signature return loss profile that peaks at the resonance frequency ω_0. Although a frequency response curve does not provide enough information to allow the values of R, L, and C in the RLC circuit of the antenna to be ascertained, the frequency response of an antenna can be used to determine the damping factor δ and the resonance frequency ω_0 of the antenna. Each type of antennas can be marked with a unique ω_0. If ω_0 is carefully selected to be located outside the working bandwidth of the antenna 100, such signature return loss profile can be used as the antenna 100's unique signature for identification purposes.

[0026] Antenna manufacturers can equip each type of antennas with a different RLC circuit having a distinctive resonance frequency and frequency response. Therefore, antennas of the same type exhibit the same return-loss profile and antennas of different types possess different return-loss profiles. By measuring an antenna's return-loss profile, the type of the antenna 100 can be identified. It should be noted that in the present application, the type of an antenna may include information such as the model, the maker, and/or the brand of the antenna.

[0027] Figure 3 illustrates an exemplary testing device 300 for measuring the return loss profile of the antenna 100 and for identifying the antenna 100 based on the measured return loss profile. In Figure 3, the testing device 300 comprises a transmitter 302, a coupler 304 and an evaluation circuit 301. The transmitter 302 is connected to the coupler 304 and is configured to send signals to the antenna via the coupler 304 through a feeder cable. The evaluation circuit 301 comprises a receiver 308, a Fourier Transform circuit 310, a return-loss profile detector 312, a correlator 314, and an identity detector 316.

[0028] The receiver 308 receives and measures a signal received at an Antenna Interface Port (AIP) on the coupler 304. The receiver 308 comprises RF processing components, such as filter, amplifier, oscillator and analog to digital converter, to convert a received signal into baseband signals. The Fourier Transform Circuit 310 separates the different frequency components in the output signal and they are sent to the return-loss profile detector 312 for detecting a return-loss profile of the antenna. As the test signal travels through the feeder cable 306, the test signal exhibits variations over frequency. The variation period is related to the length of the feeder cable 306. With the knowledge of the maximum feeder length, the return-loss profile detector can smooth the variations over frequency introduced by the feeder cable.

[0029] The return-loss profile detected by the return-loss profile detector 312 is input into the correlator 314. The correlator 314 stores a list of known or expected antenna signatures. Such known antenna signatures are calculated a priori based on R, L, and C values or measured from known types of antennas. The expected antenna signatures are pre-calculated or premeasured return-loss profiles of antennas of known origin or identity. The correlator 314 compares the return-loss profile of the antenna 100 with one or more of the known antenna signatures in the stored list. As shown in Figure 4, the return-loss profile of the antenna 100 usually does not match known antenna signature perfectly, if the latter was calculated from R, L, and C values. The correlator 314 calculates a correlation coefficient for each of the known antenna signatures. The one or more correlation coefficients are sent to the identity detector 316.The identity detector 316 identifies the unique antenna signature of the antenna based on the one or more correlation coefficients.

[0030] The identity detector 316 may be implemented with different algorithms to identify the antenna's unique antenna signature. In some embodiments, the identity detector 316 is configured to select the known antenna signature that generates the largest correlation coefficient as the antenna's unique antenna signature.

[0031] In other embodiments, the correlator 314 may select one known antenna signature from the stored list and generates one correlation coefficient. The correlation coefficient is sent to the identity detector 316 which compares the correlation coefficient to a threshold. The threshold may be pre-calibrated and carefully selected such that it can be stated with high confidence that the known signature is the antenna's signature if the correlation coefficient is higher than the threshold. The correlation coefficient is compared to a threshold. If the correlation coefficient is smaller than the threshold, the return-loss profile is correlated with another known signature to generate another correlation coefficient. If the correlation coefficient is larger than the threshold, the known signature is considered to the antenna signature.

[0032] Figure 4 illustrates an exemplary return-loss profile of the antenna 100 and its antenna signature calculated from *R, L,* and *C* values. Figure 4 is a frequency response diagram showing how the loss magnitude (dB) varies with the input frequency. The loss magnitude is defined as: *loss magnitude* = - *return loss.* The fine solid curve represents the input signal with a frequency ranging from 0 to $3 \times 10^3 MHz$. The heavy solid curve represents the return-loss profile of the antenna 100 with a resonance frequency $\omega_0 = 700MHz$. The dotted curve represents the pre-calculated antenna signature.-

[0033] Figure 5 illustrates an exemplary system configured to perform an automatic remote detection of the type of the antenna 100. In Figure 5, a radio access network 500 is connected to a core network 508. The radio access network 500 comprises two NodeB's 502 and 504 and a Radio Network Controller (RNC) 506. The NodeBs 502 and 504 are connected to the RNC 506, which is connected to the core network 508. An antenna 100 is installed in the NodeB 502 and the NodeB 504 respectively. The RNC 506 includes an automatic remote detection circuit 510 which comprises an I/O device 512 and a processing circuit 514. To identify the type of the antennas 100, the processing circuit 514 can send a signal through the I/O device 512 to remotely activate the evaluation circuit 301 (in Figure 3). The antenna signature detected by the identity detector 316 and/or the type determined based on the antenna signature can be sent to the automatic remote detection circuit as result.

[0034] It should be noted that the automatic remote detection circuit 510 may also reside in the core network 508 or in a mobile device (not shown). In the latter case, the automatic detection circuit activates the evaluation circuit 301 via a radio air interface. In Figure 5, the antenna 100 is shown to be installed in a NodeB.

[0035] Figure 6 illustrates a flow chart of an exemplary process for identifying an antenna 100 using the advantageous methods disclosed herein. The process starts with sending a wideband or frequency sweep signal to the antenna 100 to be identified (step 602). The signal is measured at the antenna interface port (AIP) (step 604) and its return-loss profile of the measured signal is detected (step 606). The detected return-loss profile is correlated with an expected or known antenna signature to generate at least one correlation coefficient (step 608). Based on the at least one correlation coefficient, the antenna's unique antenna signature is identified (step 610).

[0036] Methods and apparatus disclosed herein are applicable to any type of antennas, for example, antennas installed on any wireless communication devices, such as base stations, NodeBs, repeaters, etc., and antennas used for purposes other than wireless communications.

[0037] The foregoing description and the accompanying drawings represent nonlimiting examples of the methods and apparatus taught herein. As such, the present invention is not limited by the foregoing description and accompanying drawings. Instead, the present invention is limited only by the following claims.

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US7042406B2 [0005]
- EP1962374A1 [0006]
- EP1863123A1 [0007]
- DE102004042160A1 [0008]
- US5198821A [0009]
- US20120142277A1 [0010]

Patentkrav

1. Fremgangsmåde til automatisk fjerndetektering af en type af en antenne (100), hvilken antenne (100) er konfigureret med et modstand-induktor-kondensator, RLC, -kredsløb (106), der genererer en returtab-profil, der tjener som en antennesignatur af antennen (100), hvor fremgangsmåden implementeres gennem en automatisk fjerndetekteringsindretning (510) af en radionetværksstyreenhed, RNC, (506), hvilken fremgangsmåde omfatter:
fjernstyret, for hver antenne af en flerhed af antenner (100), hvor hver antenne (100) er installeret i en respektiv NodeB (502, 504), der er forbundet med RNC'et (506), at aktivere et vurderingskredsløb (301) i antennen (100) til automatisk at bestemme antennesignaturen af antennen (100); og
at bestemme typen af antennen (100) baseret på antennesignaturen.

2. Automatisk fjerndetekteringsindretning (510) til detektering af typen af en antenne (100) på afstand, hvilken antenne (100) er konfigureret med et modstand-induktor-kondensator, RLC, -kredsløb (106), der genererer en returtab-profil, der tjener som en antennesignatur af antennen (100), hvor den automatiske fjerndetekteringsindretning (510) er konfigureret til at være
indeholdt i en radionetværksstyreenhed, RNC, (506), hvor den automatiske fjerndetekteringsindretning (510) omfatter:
en indgang/udgang (512), der er konfigureret til at sende, for hver antenne af en flerhed af antenner (100), hvor hver antenne (100) er installeret i en respektiv NodeB (502, 504), der er forbundet med RNC'et (506), et signal til aktivering af et vurderingskredsløb (301) i antennen (100) til automatisk at bestemme antennesignaturen af antennen og konfigureret til at modtage et resultat fra vurderingskredsløbet; og
et behandlingskredsløb (514), der er konfigureret til at bestemme typen af antennen baseret på antennesignaturen.

DRAWINGS

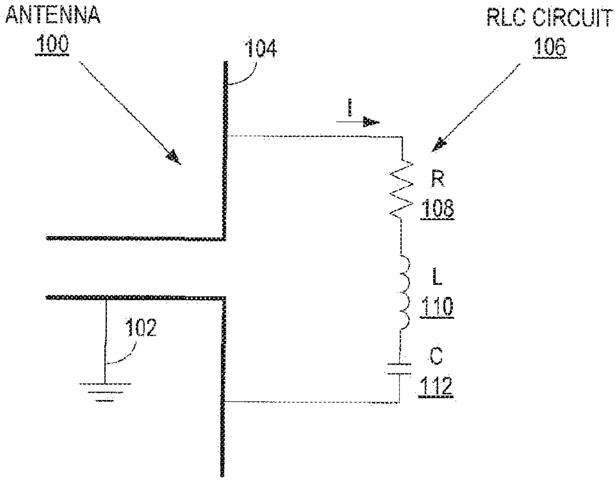

FIG. 1

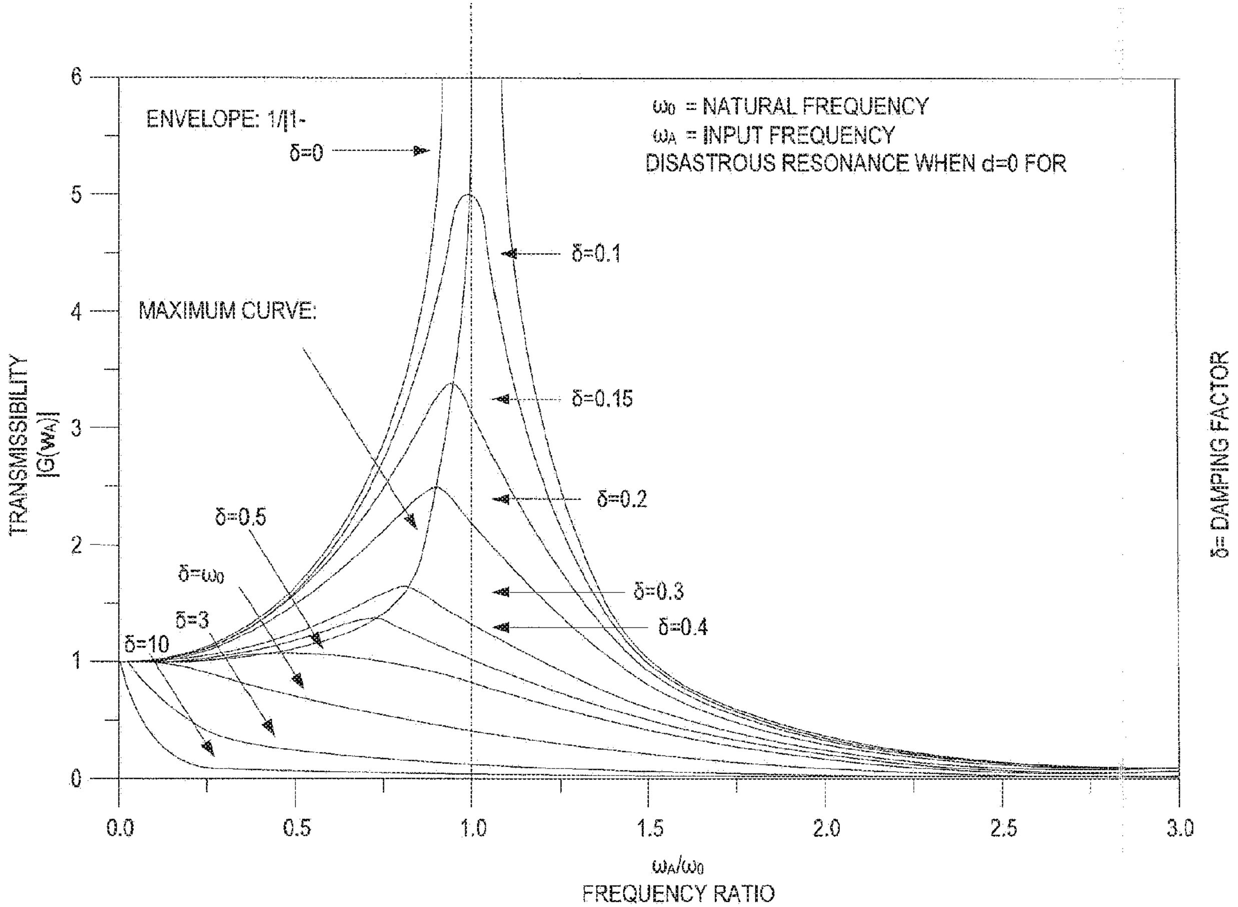
ENVELOPE: 1/|1-
δ=0
MAXIMUM CURVE:
δ=0.5
δ=ω0
δ=3
δ=10
ω0 = NATURAL FREQUENCY
ωA = INPUT FREQUENCY
DISASTROUS RESONANCE WHEN d=0 FOR
δ=0.1
δ=0.15
δ=0.2
δ=0.3
δ=0.4
δ= DAMPING FACTOR
TRANSMISSIBILITY
|G(wA)|
0
1
2
3
4
5
6
0.0
0.5
1.0
1.5
2.0
2.5
3.0
ωA/ω0
FREQUENCY RATIO

FIG. 2

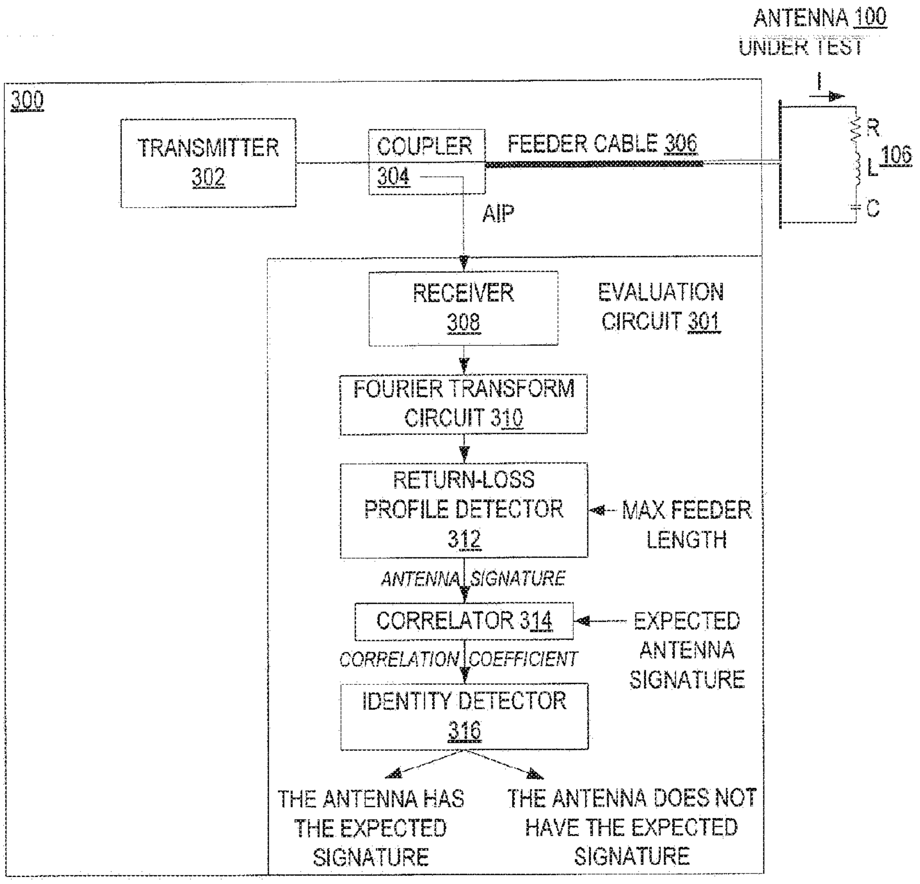
ANTENNA 100
UNDER TEST
300
TRANSMITTER
302
COUPLER
304
FEEDER CABLE 306
I
R
L
106
C
AIP
RECEIVER
308
EVALUATION
CIRCUIT 301
FOURIER TRANSFORM
CIRCUIT 310
RETURN-LOSS
PROFILE DETECTOR
312
MAX FEEDER
LENGTH
ANTENNA SIGNATURE
CORRELATOR 314
EXPECTED
ANTENNA
SIGNATURE
CORRELATION COEFFICIENT
IDENTITY DETECTOR
316
THE ANTENNA HAS
THE EXPECTED
SIGNATURE
THE ANTENNA DOES NOT
HAVE THE EXPECTED
SIGNATURE

FIG. 3

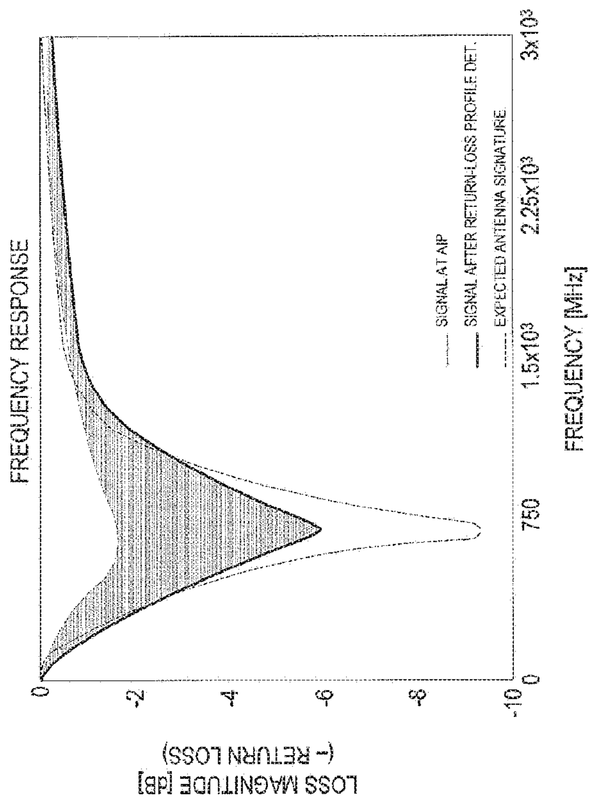
FREQUENCY RESPONSE
LOSS MAGNITUDE [dB]
(– RETURN LOSS)
0
-2
-4
-6
-8
-10
0
750
1.5x10³
2.25x10³
3x10³
FREQUENCY [MHz]
SIGNAL AT AIP
SIGNAL AFTER RETURN-LOSS PROFILE DET.
EXPECTED ANTENNA SIGNATURE

FIG. 4

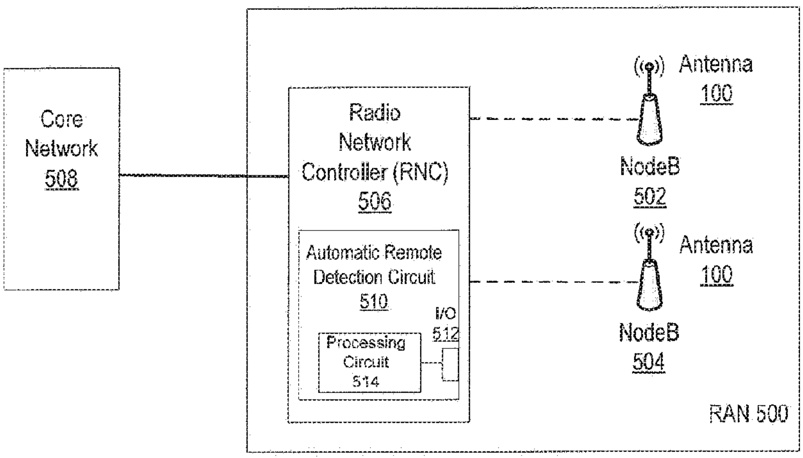
Core Network 508
Radio Network Controller (RNC) 506
Automatic Remote Detection Circuit 510
I/O 512
Processing Circuit 514
Antenna 100
NodeB 502
Antenna 100
NodeB 504
RAN 500

FIG. 5

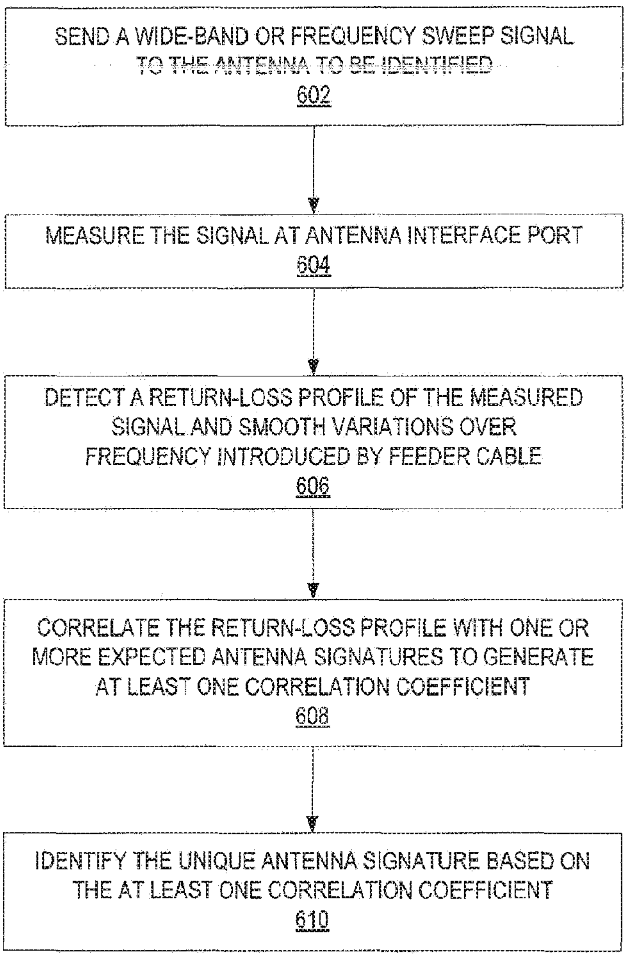
SEND A WIDE-BAND OR FREQUENCY SWEEP SIGNAL TO THE ANTENNA TO BE IDENTIFIED
602
MEASURE THE SIGNAL AT ANTENNA INTERFACE PORT
604
DETECT A RETURN-LOSS PROFILE OF THE MEASURED SIGNAL AND SMOOTH VARIATIONS OVER FREQUENCY INTRODUCED BY FEEDER CABLE
606
CORRELATE THE RETURN-LOSS PROFILE WITH ONE OR MORE EXPECTED ANTENNA SIGNATURES TO GENERATE AT LEAST ONE CORRELATION COEFFICIENT
608
IDENTIFY THE UNIQUE ANTENNA SIGNATURE BASED ON THE AT LEAST ONE CORRELATION COEFFICIENT
610

FIG. 6