Recent Developments in Automatic Impedance Matching and Antenna Tuning for Wireless and Mobile Communications

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Abstract

This paper reviews recent developments in automatic impedance matching and antenna tuning for wireless and mobile communications.

For next generation wireless devices, with demands for small size, increasing bandwidths and convergence of applications within one device, particular issues include the decreasing space available for antennas, and the desire to use a single antenna over a wide frequency range to facilitate software-defined multi-standard operation.

Currently, antennas for wireless applications mostly operate in the UHF range; typically these antennas are said to be "electrically small". For good PA efficiency or optimum LNA noise performance, a passive impedance matching network is generally included between the antenna and transceiver. However, an "electrically small" antenna with reasonable efficiency inherently has impedance that varies rapidly with frequency, and is also susceptible to environmental effects that cause substantial impedance variations, for example, due to the proximity of a mobile phone handset antenna to the user’s body or to conductive objects.

A solution to the matching problem is to incorporate a tuneable impedance matching network with a control loop between the transmitter/receiver and the antenna, which is capable of adaptively adjusting to changes in antenna impedance, operating frequency or environment for the optimum performance. This is normally called the antenna tuning unit (ATU) [1]. A block diagram of a possible implementation of automatic antenna tuning for mobile communication User Equipment (UE) is shown in Figure 1 below.

Various types of matching network topology may be used at UHF frequencies. Reactive components need to be switched or varied using electronic devices that are suitable for use at the frequencies and power levels that are normally used in mobile communication systems. The availability of suitable tuning/switching devices places constraints on the topology and design of the matching network.

Types of matching network include the Pi network [1] shown in Figure 2 below. Other matching network topologies have been proposed such as branch line couplers, switchable loaded transmission lines and cascaded circulators. The relative merits of various types of matching network are considered.

A review of electronic devices for use in UHF antenna tuning networks is also included. These include digitally tuned capacitors, MEMS switches, varactor/varicap diodes, Barium-Strontium-Titanate (BST) tunable capacitors, PIN diodes, etc. Antenna tuning implemented by the latest mobile radio RF chips is also considered [2].

Various automatic antenna tuning algorithms have been published and various factors influence the design of a suitable algorithm [3], for example whether the antenna tuning system has knowledge of the complex reflection coefficient of the antenna (magnitude and phase) or only the Voltage Standing Wave Ratio (VSWR). Another factor to be considered is whether the antenna tuning system has knowledge of the actual frequency of operation within the range of frequencies that can be covered by the transmitter. Further improvement in the performance of adaptive tuning are possible by including 'expert system' such as a 'dictionary' of tuning settings that had previously been used at the current operating frequency.

Some recently developed antenna tuning techniques are also considered. The first is Integrated PA Matching/Antenna Tuning [4]. In a conventional design of transmitter, the Power Amplifier contains

matching components that match the RF power transistor to the designed load impedance, such as 50 Ω. The ATU then transforms the actual feedpoint impedance of the antenna so as to present the PA output with its designed load impedance, such as 50 Ω. If separate antennas are used for transmitting and receiving, these two functions can be combined into a single functional block for the transmit path.

Another recent development is downlink (Receive mode) antenna tuning [5]. This implements a tunable matching circuit in receive mode that does not also require antenna impedance information that is provided by a transmitter. In a UE for a mobile communications network, it is necessary to the UE to receive a signal from the Base Station (BS) before communication can be established and transmission can begin. If the UE is operating near the edge of the coverage area of the BS with poor antenna matching due to environmental factors then Downlink (Receive mode) antenna tuning can allow communication to be established when it would otherwise not be possible. This technique also allows antenna matching to be optimised, e.g. due to environmental factors in receive-only communication systems such as GPS.

Multiple Input Multiple Output (MIMO) systems may also benefit from antenna tuning but this needs to be applied to multiple antennas. One possible approach is described in [6] which describes a Multiple Antenna Port Multiple User Port antenna tuner that consists of a multi-dimensional Pi network.

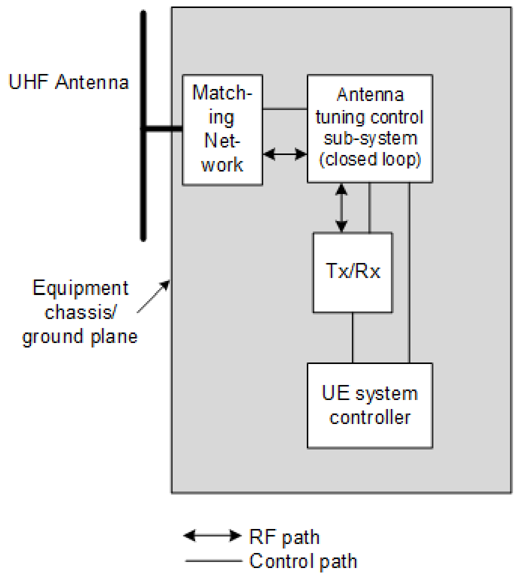

Figure 1 A block diagram of ATU for a UE

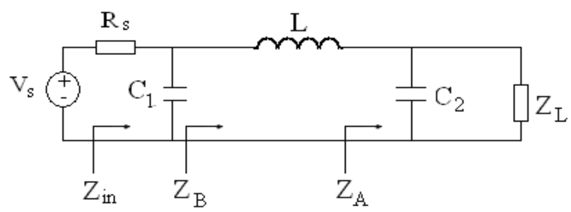

Figure 2 A Pi impedance matching network

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