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Essential Features of Components for Smart RF Communication

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Abstract: Reconfigurable components have the potential to add substantial degrees of freedom and functionality to wireless communication. Reconfigurable components support new desired capabilities to cope with extendable multi-services, multi standards and multiband operation as well as efficiently utilize the spectrum and power consumption. The paper provides a bird's eye view of various components functioning required for today's smart RF front-end. The advantages and disadvantages of reconfigurable components along with directions in which researchers can peruse work are explained.
Keywords: Reconfigurable, Smart Component, Reconfigurable Antenna, Matching Network.

I. INTRODUCTION

Presently communication devices are marvels of engineering, continually packing more and more functionality into smaller spaces [1-4]. There is a shift toward incorporating smart, cognitive, and agile RF devices that can both sense the surrounding RF environment and communicate at the same time in any contested/congested environment. So, Conventional circuitry requires a certain volume to perform effectively and modern smart devices don't have adequate space for a large enough circuitry. A tunable/reconfigurable circuitry allows a smaller part to behave as a larger part, both saving space and improving performance. For optimum performance of smart system there is a great requirement for perfect designing of each circuit element. So in this paper essential component requirement for smart systems are described.

I. COMPONENTS FOR RF FRONT END

One of the most important hardware parts in any communication system is the RF front end [2], which consists of a number of electronic circuits. The RF front end should support the new desired capabilities such as frequency-agile, software defined radio and cognitive radio etc. to manage extendable multiservice with efficient power and spectrum utilization. If all element are non reconfigurable then a single-band RF front-end consist of at least a power amplifier (PA), a low noise amplifier (LNA), transmit and receive (duplex) filter, an antenna and an impedance matching network as shown in Fig. 1. For this system, if RF front end wants to communicate on other frequency band, then another block of all circuit components are designed for that frequency. So, number for circuit components gets doubled and this will further increase if another frequency band is chosen. So, the number of components required, volume complexity and cost are the various serious issues encountered by researchers.

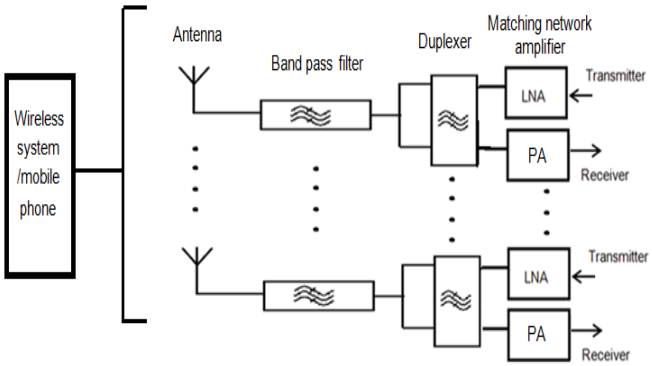

Fig.1 Non tunable RF front end for multiband operation

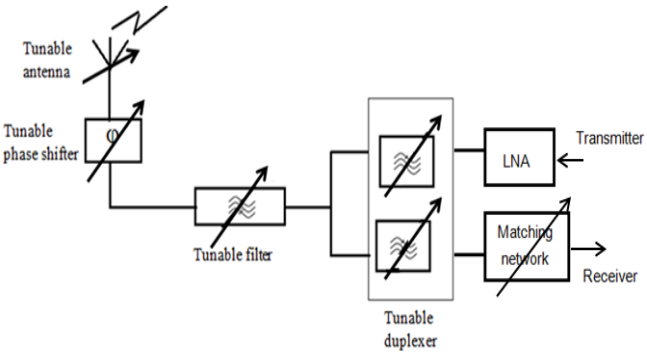

Fig. 2 Reconfigurable RF front-end for multiband operation

The solution for above said problems is to replace the circuit element with the reconfigurable one. Complete reconfigurable RF front-end system for multiband operation is shown in Fig. 2 in which each component is replaced by tunable component. Fig. 2 clearly shows that there is a large reduction in number of components, cost, volume, complexity and the system is adaptive to change itself by sensing the change in environment. The complete description of each block is given as below:

1. Low Noise Amplifier: The LNA amplifies the incoming signal for further signal processing. In an LNA, one wants to minimize the noise figure of the amplifier, to lower the

power consumption, and to increase the power gain. The matching circuits are often applied in the input and output ports to minimize the insertion loss or noise figure for LNA design.

2. Tunable Duplexer: In duplexer, band-pass filter strongly suppresses out-of-band signals and transmitted or received signal only in a limited frequency band. Electrically a duplexer is used to isolate a transmitter from a receiver using sharply tuned resonate circuits. They allow us to transmit and receive signal on the same antenna at the same time, reject unwanted signals. Reconfigurable duplexer allows tuning of multiple signal frequency for multiband operation.

3. Tunable Filters: Filters are the components used to combine or reject different frequency components. Because of increased congestion in frequency spectrum, filters forms the important part of front end to avoid signal interference. As already discussed, in today's scenario wireless devices are required to operate at different standards. These different standards are provided in a single unit in order to provide a vast range of applications. In order to get access to all these applications with minimum interference high selective filters with reconfigurable pass band must be designed. Tunable filters[5] reduce the number of filters needed in multi-band applications, which reduces costs and increases the availability of board space.

4. Tunable Phase shifter: A phase shifter is a two-port device whose function is to change the phase of RF input signal with practically negligible attenuation. In electronic phase shifter domain, there are basically two types of phase shifters: digital phase shifters and analog phase shifters. Analog Phase shifters provide a continuously variable phase, perhaps controlled by a voltage. Digital phase shifters provide a discrete set of phase states that are controlled by two-state "phase bits". Reconfigurable phase shifter provides reconfigurable phase shift at a single frequency of interest [6]. As phase shifter circuit is typically a large portion of the cost of phased array antenna systems, so the reconfigurable phase shifter reduces the system cost.

5. Tunable Matching Network: The purpose of an impedance matching network is to have an optimal power flow from the source to the load to avoid reflections. Preferably the load of the impedance matching network has to absorb all of the power transmitted from the source. To achieve this source impedance should be equal to the load impedance. A simple impedance matching network using LC resonators is connected to a coupler that detects a mismatch. If the antenna impedance is not corrected for the new load impedance, then the Power Amplifier will deliver a higher transmit power than preferred due to the impedance mismatch and the battery will be drained faster. Optimum receive and transmit energy transfer is obtained, with the LNA and PA, through well-designed tunable impedance matching networks.

The reconfigurable impedance matching circuit can be used match variety of signal with the source impedance to provide a significantly broader bandwidth, low power and mismatch loss. The matching networks, duplex filter, phase shifter and antenna are ordinarily designed with passive components, such as resistors, coils and capacitors. Tunable resistors, capacitor and inductors [7] can be used in these components.

6. Tunable Antenna: An antenna, as an essential part of a radio system, is defined as a device which can radiate and receive electromagnetic energy in an efficient and desired manner. Reconfigurable/tunable antennae have their ability to modify their radiation characteristics, frequency of operation, polarization or even a combination of these features in real time. Reconfigurable antennae [8-15] have the potential to add substantial degrees of freedom and functionality to mobile communication and phase array systems by allowing us for spectrum reallocation in multi-band communication systems, dynamic spectrum management, therefore reducing the number and size of antennae in a system. Compared with conventional antennas, reconfigurable antennas have more advantages for example, saving energy; reducing the number of antennas thus reducing the mutual interferences between them. There are different types of reconfigurable antenna and all of them have their own advantages. Frequency reconfigurablity are useful to support multi-functional wireless applications, where they can reduce the size of the front end circuitry as there is no need for front end filtering. Polarization reconfigurablity are valuable to solve the various problems like signal fading due to multipath propagation, sensitivity of signals to transceiver antenna orientation, limited channel capacity; security etc. Radiation pattern reconfigurablity is useful to improve the coverage area and system performance by redirecting the main beam.

II. ADVANTGES AND CHALLENEGES

Tunable components can decrease the dimensions of electronic circuits by exploiting the circuit's reconfigurability. The reconfigurable characteristics of antennas, filter, phase shifter etc. are very valuable for many modern wireless communication and radar system applications. There are several advantages in using reconfigurable system as summarized below [6-7].

1. Ability to support more than one wireless standard thus it minimizes cost, volume requirement, simplifies integration and provides good isolation between different wireless standards.
2. Lower front end processing because now there is no need for front end filtering, good out-of-band rejection.
3. Increase spectral utilization and optimize the use of radio resources by providing spectrum reallocation and dynamic spectrum management
4. Meets flexible multi-radio wireless platform requirements i.e. multiple services in a small package.

5. Reduces number of antennas on the platform of multiple system resulting reduced overall size and cost.
6. Provides good isolation and good out-of- band rejection between different wireless standards and bands.

While reconfigurable circuit element represent a potential candidate for future RF front ends for wireless and space applications, there is definitely a cost for adding tenability to the antenna behavior in both systems. This cost can be linked to different parameters as summarized below:

1. Design of the biasing network for activation/deactivation of the switching elements which add complexity to the system,
2. Increase in the required power consumption due to the incorporation of active components which augments the system cost;
3. Generation of harmonics and inter modulation products;
4. Need for fast tuning in the antenna radiation characteristics to assure a correct functioning of the system.

III. Conclusion and Future Scope

The reconfigurable characteristics of antennas, filter, phase shifter etc. are very valuable for many modern wireless communication and radar system applications, such as object detection, secure communications, extendable and reconfigurable multi services, multi standard, and multi-frequency communications as well as with efficient spectrum and power utilization and so on. Most passive tunable technologies are still in the research and development phase and are being optimized for radio frequency (RF) architectures, especially focused on the RF front-end.

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