On Reliability Aspects of Switched Reconfigurable Antennas

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Abstract:- *Modern Telecommunication demands antennas with increased functionality, to achieve this antenna structure must be modified. The critical components are the switches which are used to achieve reconfigurability and they include RF MEMS, PIN diodes, Varactors and Photoconductive elements. This paper reviews design objectives, types of switched reconfigurable antennas with a special focus on reliability aspects.*

Key Words: Graph Models, Reliability, Reconfigurable Antennas, Switches.

1. INTRODUCTION

The antenna design engineers must keep in mind the following aspects while designing reconfigurable antennas:

1. Identify the reconfigurable property which is to be modified.
    a. Radiation Pattern
    b. Frequency
    c. Polarization
    d. Combinations of the above.
2. To meet the desired structural changes for reconfigurability, antenna engineer must identify the changes to be made in different radiating elements.
3. Explore different reconfiguration techniques and arrive at the one which reduces negative effects and antenna radiation/impedance characteristics.

2. ADVANTAGES OF RECONFIGURABLE ANTENNAS [1]

1. Ability to support more than one wireless standard
    a. Minimizes cost
    b. Minimizes volume requirement
    c. Simplifies integration
    d. Good isolation between different wireless standards
2. Lower front end processing
    a. No need for front-end filtering
    b. Good out of band rejection
3. Best candidate for Software Defined Radio
    a. Capability to adapt and learn
    b. Automated via a microcontroller or FPGA
4. Multifunctional Capabilities
    a. Change functionality as the mission changes
    b. Act as a single element or as an array
    c. Provide narrowband or wideband operation

3. TYPE OF RECONFIGURABLE ANTENNAS

Reconfigurable antennas can be classified into two types

A. Switch-based
B. Non-Switch-based

Switch-based uses PIN-Diodes, Varactors, RF MEMS and Optical switches whereas Non-Switch based techniques use Actuators, Motors or other tools to move some parts in the antenna structure or change electrical properties of the antennas substrate.

4. SWITCHES AND THEIR PROPERTIES

The essential properties of switch-based reconfigurable antennas are given in Table I [2]

Table -1: Switches and properties

SWITCH	PROPERTIES
PIN Diodes	Fast switching constant DC current
Varactor	Fast switching tunable response
RF MEMS	High isolation low power
Optical switches	No biasing high isolation

According to Shannon and Moore, a switch failure occurs when

A. A switch is originally OFF and fails to switch ON upon request
B. A switch is originally ON and fails to switch OFF upon request

Switch failures will have a significant impact on the functioning of reconfigurable antennas. Switch failures occur because of

1. Environment of operation
2. Ageing of components
3. Corrosion processes
4. Frequency of operation
5. Electrical Stress

Hence, the reliability of the reconfigurable antenna is influenced by all these parameters.

5. GRAPH MODELS OF RECONFIGURABLE ANTENNAS

Graph models are used to optimize the structure of the reconfigurable antenna and they will give a better understanding of its physical behavior. Graph models are used in computer science as a pervasive modelling abstraction implemented in data structures. Graph models allow the employment of various algorithms into the antennas automation and optimization process.

A graph is a collection of vertices that are connected by lines called edges. Each vertex can represent a part of an antenna and end points of a switch. The connection between the different antenna parts or the activation of the switch is represented by the presence of an edge connecting the corresponding vertices.

6. RELIABILITY OF RECONFIGURABLE ANTENNAs

Reliability is a characteristic of an item, expressed by the probability that the item will perform its required function under given conditions for a stated time interval. It is generally designated by R.

From a Qualitative point of view, reliability can be defined as the ability of the item to remain functional. Quantitatively, reliability specifies the probability that no operational interruptions will occur during a stated time interval. This does not mean that redundant parts may not fail, such parts can fail and be repaired (without operational interruption at item (system) level).

The concept of reliability thus applies to non-repairable as well as to repairable items. To make sense, a numerical statement of reliability must be accompanied by the definition of the required function, the operating conditions, and the mission duration.

In general, it is also important to know whether or not the item can be considered new when the mission starts [3]. Mean time between failure (MTBF), Mean time to repair (MTTR) and Hazard rate are the basic performance measures of Reliability.

The reliability of a reconfigurable antenna can be calculated as in equation (1) [4]

$$R(f) = \frac{\sum_{i=1}^{NC(f)} \sum_{j=1}^{NE_i(f)} P(E_{ij})}{\sum_{i=1}^{NC(f)} NE_i(f)} \times 100 \quad (1)$$

Where

$R(f)$: reconfigurable antenna reliability at a particular frequency f;

$NC(f)$: number of configurations achieving the frequency f;

$NE(f)$: number of edges for different configurations at the frequency f;

$P(E)$: probability of achieving the edge $E = 1 - P$(a switch failing).

7. CONCLUSION

Graph-based analysis can identify redundant components in an antenna structure and reduction approaches can be adopted that lead to more efficient designs of reconfigurable antenna structures. This also reduces the complexity of the antenna. By eliminating redundant switches in a switch reconfigurable antenna reduces the nonlinearity effects and interference from the corresponding biasing lines. This procedure ultimately results in optimal designs with less redundancy.

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