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Chafaa Hamrouni Abdessalem Bsissa Rached Hamza Naceur Abdelkarim

ISET Gabes (Institut Supérieure des Etudes Technologiques de Gabès) - Tunisia
University of Al Manar, SUP'COM, Raoued, Ariana, Tunisia
University of Gabes, ENIG, MAC'S Lab., GABES, Tunisia
[chafaa.hamrouni.tn@ieee.org, bsissa_a@yahoo.fr, rached.hamza@supcom.tn and naceur.abdelkrim@enig.rnu.tn]

Abstract: *Ultra Small Satellite technology has become a critic's vital need mainly in telecommunications, remote detection and communication security. In this context, we conducted a study on Ultra small Satellite, in particular for the Femto Satellite architectures. We prosed a new microstrip antenna network. Control is optimized by the use of a Fuzzy Logic Contrlor. We propose a queue issued for the switching system that receives signal power energy related to four developed microstrip antennas. The latency noted dt is studied and simulated until it is selected and judged by the Fuzzy logic controller in order to be connected to the communication system. Proposed system is succsufully simulatted and tests are accomplished.*

Keywords: *Ultra Small Satellite; FemtoSat; Renewable Energy; Patch Antenna.*

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1. Introduction

Femto satellite appearance as a miniature satellite for space research which weighs only a few dozen grams is obviously effective to send a payload into orbit through the use of huge public electronics components COST. This Femtosat is the only functional if we consider that it meets both certain navigation standard and the requirements of the mission. Study of existing femto-satellites has allowed us to classify the proposed architectures for these satellites into two classes. The first manipulates the size and weight without developing services, where the second focuses on architecture adequacy service. In fact, considering the kicksat on board, we note that we have the basic elements to control such a satellite from orbit. These elements are almost the same in all modern architectures. Consequently, these spots are almost satisfied. The remaining spots of femtosats are not the case. Indeed, changing, the architecture of Electrical Power System (EPS) might allow the integration of multiple services and increase the functionality of Femtosat.

We are looking for a new femto satellite architecture primarily based on commercialized components and which is capable of rendering several services; these improvements are targeted for a new architecture of a femtosat totally composed of marketed and simply implemented components. Actual space technology is accessible for the entire world, for instance, Spain studied WIKISAT (2011) and Tunisia studied l'ERPSat1 in 2009 [1]. This orientation helps many countries, societies and even individuals to build their personal satellites. Chile makes the example of constellation study with FemtoSatellite to control, from the space, the climatic change in order to provide the security [2]. The countries that are situated on the cyclone trajectory or that have nuclear constructions are the focus of observers in order to reform dynamic data based on the climate, the atmospheric temperature and the gaze concentration. Femto Satelitte is the future solution if it guards architecture [3] with a simpler and more functional, low power consumption with a low and reliable cost, miniature and with a weight less than 100grammes. Our researches feasibility study gives an opportunity to valorize and to prove the Femto Satellite efficacy in order to be the first generation of personal satellite. Indeed, the low cost by prototype and launching encourages the countries and researchers to study and to design prototypes until their use of the following services such as Observation system, Help-decision system, Security and military control system, Didactic research system and Commercial imagery system. These systems can be effective in securing populations including the atmosphere security and the earth monitoring. In fact, among its advantages, we site the digital space technology. Consequently, the picture of nowadays is not only a color collection but also viewed as source of metrological data.

2. Ultra Small Satellite Study

While evaluating the progress of Sub-kilogram satellite design concepts or USS, both shutter of research are treated according to low cost and mass predictability by using existing commercial production devices: satellite-on-chip and satellite-on- board (satellite-on-PCB). Since the birth of the integration technology, mixed electric and mechanic, has been known as the MEMS approach. Engineers and researchers of the space technology opted to achieve a concept of satellite according to the miniaturization norms, for instance N-Prize [4]. Tshi perspective started by the conception of embedded system that includes all the classical satellite subsystems. Meanwhile, the miniaturization has generated an obstacle which has changed, until now, the axes of researches; it is the insufficiency of the energy. At the departure, researchers migrated toward a satellite on-chip by integrating the solar energy as a hybrid source. Winsat and Smart Dusts are examples that show this philosophy, in Silicone and on-chip, as smaller than fraction of centimeters.

We note that the use of FemtoSat solar cells caused problems of integration since the two approaches, CMOS and Solar Cells, are not compatible [5]. But many studies have shown the feasibility without really having a complete launched system. This Femto satellite evolution, equally with the technological development of capturers and commercialized micro-scopic actuators conception, posed questions on the possibility of designing granular Femto-satellites with discrete commercialized components. Indeed, in 2009, D. Barnhart published the first FemtoSatellite on board. He named this satellite PCBSat according to the didactic norms inherited of his EsaySat ancestor of the Picosat family. This satellite has been viewed as a map on board of some centimeters which integrate the based subsystems of a classic satellite. D.Barnhart (2011) published the first WikiSatellite generation, which has started particular specifications for the FemtoSat future that are summarized by the size inferior of 20 gr, use of COTS components and low conception cost. This WikiSat is, actually, referenced as landmark not only to study the exploration of FemtoSat in certain applications but also to testify certain updated components. Design and all documentation are released on open source licenses, Kicksat is the first femtosat launched in Leo in late 2013 with 128 sprites [6].

3. Femto Satellite Migration

D. Barnhart is one of the researchers that studied the FemtoSatellites. He started his career (2007) with Wisnet [7]. Satellite on chip is sized to navigate in low orbits after capturing earthly images. It was equipped with femto solar cells planned to produce a low power less than mW. Meanwhile, the miniaturization minimized the consumed energy, but the sources remain insufficient and limited. The hybrid solution has been studied as a classic solution, however, many constrains has been established. They also limited the commercialization of this satellite generation. Among these constraints, we site the expensive cost of the CS solar cell manufacturing and of all the embedded femto cells since we need two different technologies such as CMOS for the electronic components as well as the CS. The cost remained hugely high compared to many solutions which were more popular and less complex. The satellites on miniature board are proposed as a concurrent solution. Moreover it is until 2009 that David B has published his second Femto Satellite generation which is satellite on Bord.

This on-board architecture is treated in several versions of femtosat. Indeed, B.Stuurman and Z.Manchester proposed Femtosat-on board. Both femtosats expresses migrating architecture of 25gr to a 5gr architecture. Current research works have exceeded the constraints of weight of femtosatellite. We are talking today about femtosat of 5g with kicksat-on-board. In fact, the miniaturization of electronic components has given the chance to go further in the design of electronic circuits. But still the weight decrease is necessarily linked with the degradation of services or the elimination of some operations. Indeed, if we look at the distribution of energy in WikiSat, we can conclude that the imagery service consumes a significant energy source of femtosat. Consequently, research works have gone further on the exploration of EPSS incorporating more than one source as the case ReyFemSat. Two other works have passed to the imagery service removal as the case of kickSat. Other researchers have turned to both modeling and designing sub-systems, the energy is dedicated for communication. This rate is very important since this spot is among those that work equally with the start of femtosat. For this reason, there are several studies on the USS antennas. These limitations are, nowadays, the large perspectives of research. Works are distributed between the updates of commercialized components and the study of certain modules such as communication and the exploration of Femto Satellite services. The basic motivation of Femto Satellite on board conception is to reduce the production cost and to use the COTS components. This objective remains the focus of many studies for certain researchers that opt to find an adequate material configuration with mission, power and weight constraints. We contribute in new study of Femto Satellite generation with high resolution; observation earth system (OES) by 14 Mpix with an optimist power [8]. This study is not standardized since the OES technology has been evaluated rapidly. Moreover, these sensors remain insufficient because the Femto Satellite specifications find that integrating high quality sensor with low power consumption is more miniaturizing. This energy/quality paradox is generally difficult to manage. The case of solar cells integration is the classical example of this relation. In fact, we look for getting autonomous satellites with renewable power sources but the CS yield remains insufficient if we use a small area/wide cell. Besides, the use of several CS provokes a large mass and temperature that can

disrupt the regular operation. In our reason, PCBSAT uses many thermal sensors [9] while WikiSat does not. The update of sensors provokes the change of architecture. The amelioration of integration and the MEMS technology evolution can product future FemtoSats on board and a more miniature, effective and simpler architecture which is hard to manipulate. This trend cannot be reached without getting specific module conception since the real optimization is, by definition, linked to a specific approach.

4. Femto Satellite Traking

Essentially, Femtosat is stuck in a LEO without the ability to autonomously navigate in space. This lack of dynamism, in terms of movement, greatly constricts the axes of research and function that Femtosat can perform. Indeed, the majority of Femto satellite flies without subsystems (PSS) propulsion because those PSS that are unvailable and they utilize technology that is very expensive or doesn't work with Femtosat low power. Electro-dynamic tethers can extend the life mission. In general, Femtosat are usually placed in LEO where there is a lot of atmospheric drags. As a result, Femtosat crashed and burned in a few days. However, if we could use PSS to make up that atmospheric drag or to stabilize the Femtsat in orbit, then we could extend the life-time mission and remain useful for months or years again. Development of a PSS for USS is successfully made by using electrolysis to generate gas, which is, then, burned to move. Therefore, any additions to the Femto Satellite must be compact and consume few electrical powers. For this reason, the best solution is to have secondary payloads. David Kreji [10] proposed in 2015 Electro-spray propulsion system named S-iEPS thruster. In addition, this S-iEPS is very small about 14.4 mm x14.4 mm x 14.1mm with 3.5 gr and it is capable to work 172 hours. These solutions are very expensive which effects the cost of femtosat, contrary to the chart of N-Prize design. Besides, their use and test of place requires a more complex survey than the existing.

5. Modelling of Subsystems

Modeling, first of all, builds a mathematic model of the phenomena, which is called the digital modeling. Then, this model will be transformed in an observable system where whose we can change the parameters [11]. Thereby, these digital and analog modelings are treated in several works where we site (in 2011), Chang-Chan designed the power system of USS by specifying the solar cells and the battery [12]. In fact, he calculated the provided solar power, masses, and the lifetime of the satellite functioning by his battery. We study and analyze the architecture of the new adaptive miniature satellite generation [13]. He oriented the power efforts of spatial system toward the conception of system on board with commercialized modules keeping a service quality and a masse/power compromise. He designed the weight, the used power and the lifetime. In 2014, Iverson C.Bell [14] proposed a miniaturized electro-dynamic tether. He showed femtosat as capable to generate sufficient power with electro-dynamic tethers. This power can be used in propulsing and giving more life time into space. These modelings have, later on, facilitated the conception and even the research of optimist components [15]. However, these models are not followed by concrete realizations, the fact that raises the question of feasibility. Despite this fact, certain works, that we will detail later on, have responded at this question as well as finishing the prototypes.

6. Antenna Subsystems Development

Power and communication are the most delicate modules since they allow reassuring the link between the satellite and its world during the stage of life in space. Indeed, this link has several levels including the type of communication. For instance, Iverson Bell studied this problem in a way to profit the spatial waves in order to get an electromagnetic charge [16]. Besides, the space has ever attached researchers as a renewable power source. This power is found in the form of waves, luminous photos and particular charged gaseous. The exploration of such sources requires a powerful technology and a modeling knowledge in order to design sensor costs. Solar cells are among the studied sensors, but their yields are not effective to 100% , until now. The harvested current is trying to point that the cells' surface should be large so that we can get an autonomic power. Chang-Chun estimated this power by 0.025 Kg/W and with a yield of 15% [17]. These results do not support the FemtoSat development in a way to insist on guarding the CS, without forgetting that the exploration of such cells is opposite to the position of the sun nor capable to exceed 20 minutes at 2 hours cycle per orbital rotation. The insufficiencies of Femto Satellite power impose the optimist communication use to strictly guarantee that the satellite won't be lost in space or be incapable of assure such a service. Often, we find three communication types: the first an Extra-Communication with an earthly control chamber that commands and controls the FemtoSat and the sensor measurements, the second is the intra-Communication: it is inter FemtoSat communication. This communication assures a sharing task or a data, since the FemtoSat is incapable of assuring such a service lonely. This incurability is due to its coverage and limited power, and the third is the inter Communication: it's the communication with grand station, generally situated at high orbits. These three modules of communication impose the use of a high gain antenna with a low power consumption. In 2011, Enric.F proposed a specific antenna for WikiSat [18] regarding the following constraints of weights (7,6 gr), frequency band : UHF 2,4 à 2,5 GHz, power, resistance (50 ohms), coverage and Gain (16 dB). This antenna displayed in figure.6 is testified by altitudes inferior to 50 Km after launching. The test

shows a stability of operation. But, this operation is not final, because WikiSat did not reach orbits of 200 Km in total functioning. Kicksat uses a wire V-shaped half wave dipole. This antenna is Omni-directional type with a low gain [19]. In addition, the wire antenna has the advantage to be the simplest architecture without occupying the space nor having a weight as in figure.1:

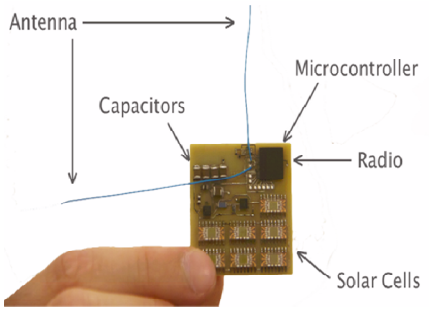

Figure 1. Uses case of Kicksat Antenna.

The engineering space is evolving rapidly in parallel with the evolution of mixed integration technology CMOS / MEMS. This Migration from one satellite generation to another has reached the stage of satellite on chip. These types of miniature satellites have specific missions in low orbits. Among others, the miniaturization of this system is coupled with a multi-energy deficiency which limits the lifetime of such satellite. Communication, also, suffers from several constraints related to this low energy and low gain. For this reason, several researchers studied module antenna in order to find the antenna which would be more adapted and that would answer the needs of the application, structural and functional constraints.

7. Queue Issued in a Switching System: Study and Simulation Results

EThe proposed figure.2 illustrates a queue in the input which represents received signal power energy related to four developed Microstrip Antennas noted M.Ant.1, M.Ant.2, M.Ant.3 and M.Ant.4. In the input of the fuzzy logic system which is the switching module system, is presented a multiple queues, indeed. When arrived, the information presented in the received signal has to wait (dt) until it will be selected and judged by the Fuzzy logic controller to be connected to the space craft communication circuit.

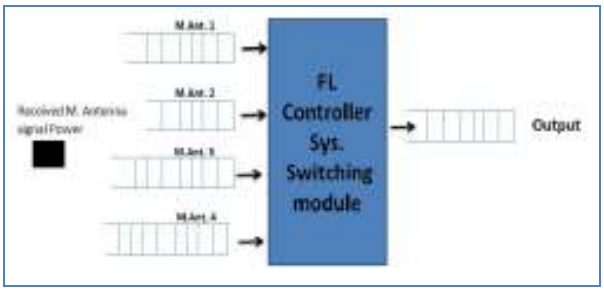

Figure 2. Performance Study for Queue Issued in FLC Switching System

The decision is made but depending in different parameters: Needed time by a queue to select captured signal related to the suitable antenna presented, adds in addition: the time needed to serve available received signal presented in queue 1 during dt1; the time needed to serve available received signal presented in queue 2 during dt2; the time needed to serve available received signal presented in queue 3 during dt3; and the time needed to serve available received signal presented in queue 4 during dt4. Different measures should be taken in consideration in order to evaluate the performance MAB system, such as: time taken by the processor to respond, average number operation M.A.

8. Conclusion and Future Work

The complexity of the architecture of Femtosat design comes from its multidisciplinary. Indeed, a significant part of the job was to manage interactions and to find compromises between the subsystems. The specification changes during work are certainly the most restrictive aspect to achieve the original goal.

Our research work consists of studying the specifications of main subsystem, and to provide improvements for a new architecture more profitable, based on the existing technology. However, due to many changes throughout the project, certain developments had to be reviewed and adapted during design. Despite this difficulty, most subsystem elements have been proposed with an update of the existing in the market. Several improvements have been introduced to the structural and functional levels. The work provides a detailed overview of the entire subsystem of a femtosat appointed and its elements. The electrical design, communication and CAO design patch antenna are aspects that have driven the final integration of all subsystems.

Indeed, this work demonstrates the ability to design a dynamic and autonomous FemtoSat of 40gr. This FemtoSat integrates a camera able to make an observer from Leo with an extended life. It is through the exploration of the solar energy we can have a longer functional life, but also with the existence of a trajectory correction for not deviate and deorbit. As a result of this work, we have discussed the pros and cons of this technology that are necessarily related to time and money criteria. In this context we have shown that starting from these two criteria, the

generation of femtosat has been proposed as a future solution. We successfully propose and developed a fuzzy controlled antenna network for femto sat telecommunication subsystem.

Finally, we notice that there are two trends in technology. The first trend focuses on what level we can explore miniaturization to reach the satellites on chip or Zeptosatellites. The other trend is the most developed because it is interested in exploring the architecture to address the adequacy Service / miniaturization. This match is the key to having a large marketing for femtosat in the worldwide. Moreover, our proposal is oriented towards the second trend because we think we must first master space technology before attacking very advanced stages of development. We also note that our proposal requires personal team and a dedicated hardware and software environment to perform all stages from the test to launch.

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Dr. Chafaa Hamrouni is with the University of Gabes, ISET Gabes, ENIG MAC'S Lab., GABES, Tunisia received the Master's degree in new technologies of computer sciences. He's graduated and obtained his PhD degree in sciences computer engineering. Currently. He is interested in small satellite design and development.

Dir. Abdessalem Bsissa is qualified in Electrical Engineering (G.E), the field of Electrical Engineering. He conducted several successful international projects. Actually, he is the Director of the ISET Gabes in Tunisia (Institut Superior des Etudes Technologiques de Gabès) –Tunisia.

Prof. Rached Hamza received the B.Sc.&M.Sc. degree in Manar University. He was the Head of the CERT'13: the Tunisian elecommunication and Research Center. Actually, he is Dr. at the University of AL Manar in SUP'COM in Tunisia.

Prof. Naceur Abdelkrim was born in Metouia in Tunisia on 20 July 1958. he is the head of the Research Unit « Modelling, Analysis and Control Systems-MACS with more than 90 researchers in Master, Doctorate and habitation degrees ». He has more than 50 publications in international revues and more than 200 communications in national and international conferences. He directed more than 20 Thesis of Doctorate and several research Masters.