ISSN 2250-3153

# Integration of Antennas and Solar Cells for Satellite and Terrestrial Communication

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***Abstract***- Autonomous communications systems often involve the use of separate solar cells and antennas, which necessitate a compromise in the utilization of the limited surface area available. These separate items may be combined,, provided that the antennas and solar cells are compatible. To show the compatibility of solar cells and antennas, the concept is used to create linearly polarized slot antenna, a circularly polarized shot antenna, a circularly polarized slot antenna and a slot array. The concept offers advantages in terms of surface coverage, volume, weight and electric performance. Slot antennas provide large metallic surfaces (the ground plane) on which solar cells can be directly grown. This yields high area coverage efficiency for the solar cells. In this, it is possible to nearly completely cover the ground plane with exception of a very small area close to the radiating edges of the slot antenna without degradation of the RF performance.

***Index Terms***- Circularly polarized array, SOLANT, solar cells, solar antenna

## I. INTRODUCTION

One method for achieving this is to integrate the two kinds of device on the same element. In particular, solar panels occupy a large proportion of the total surface area of communications satellites, providing large flat surfaces over which antennas can be mounted, or printed. Printed antennas, commonly used in microwave communications, are naturally suited for this combination, in particular when their radiating patches can be isolated from the feed circuits. Amorphous silicon solar cell technology has been found to be suitable for realizing the solar antennas. Of course, the integrated combination of these devices would also be of interest for terrestrial systems. Most satellite systems use separate solar cells and antenna's, which compete for the use of the limited surface available. Therefore, combining both could reduce the cost design of spacecraft missions, provided that the antennas and solar cells are compatible. In particular, solar panels constitute a significant part of communication satellites, providing large flat surfaces on to which antennas can be mounted or printed .Printed antennas, commonly used in microwave communications, are particularly well suited for this integration, especially in configurations where their radiating elements (patches or apertures) can be isolated from the feed circuits.

There are several possibility of placing solar cells directly on the patches . Other combinations like putting solar cells behind reflectarray antennas have also been studied. In the case of patch antennas, the cells cannot be close to the patches' radiating edges due to destructive interactions. As technology has been advancing rapidly, an idea emerged to integrate the antenna and solar cell into (monolithic) building block units. These units may then be replicated as desired to create a structure whose transmitting aperture is also used as the light –collection area. A novel hybrid technology where amorphous silicon solar cells are either integrated or physically combined with printed slot antennas is presented

This basic idea is demonstrated with the help of two innovative designs where the solar cells are directly grown on a stainless steel ground – plane or glued onto a standard copper layer printed on a dielectric substrate. performance when compared with a simple juxtaposition of antennas and solar cells. Firstly, the introduction of slot antennas, the ground plane of which can be used as "negative" collector cathode for the solar cells. Secondly, the possibility of producing solar cells with arbitrary shapes that don't restrict the antenna layout. This has led to the novel concept of fully integrated design were the two elements are physically and functionally merged together into a single device. This fully integrated" SOLANT design represent a best-of – both world" solution. Since a higher level of integration of both RF and dc functionality is the objective more over the use of slot instead of patches, allows the solar cells to be directly deposited on to the slots ground plane, resulting in an efficient and lightweight device. The concept can also have interesting spin-offs for terrestrial applications, for example: roof tiles used for simultaneous power generation and reception of satellite TV, isolated base stations for mobile telephone, alarm systems, sea buoys, container tracking, etc.

## II. SOLANT SATELLITE APPLICATIONS

Space related applications of SOLANT antennas, in a first approach, can be split into two categories of missions:

1. Large space craft needed to comply with the increasing demand for tele-communication, multimedia and increasing scientific objectives. The need to implement several complex instruments on one single space craft leads to an increase in the number and size of antennas and solar generators.
2. Constellation of numerous smaller satellites (mini, micro, nano-satellites) where the integration of solar cells with antenna can lead to considerable reduction in space craft size, mass, and cost.

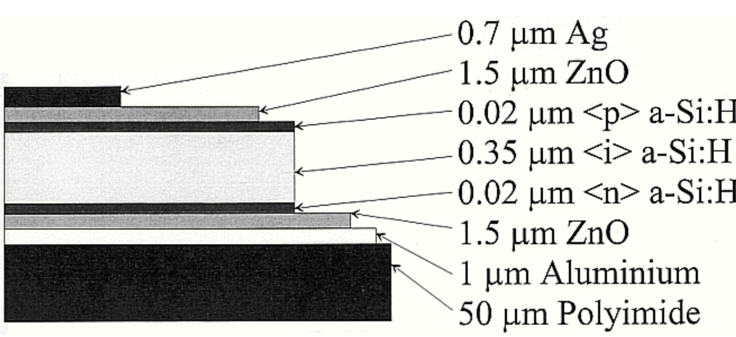
One can make a preliminary review of the missions that could profit from integration of antenna with solar cells, where the emphasis would be on:

3. Missions where there is a natural coherence between the sun direction and antenna bore-sight. This option may be very attractive for the Future Science Program; both in-terms of deep space missions to the outer planets (Mars and beyond) and missions at the L2 Lagrangian point of the earth-sun system. At this location, the sun, the earth, and the moon are all located behind the payload which points away from the Sun.
4. Missions where there is an advantage to conform the antenna to the spacecraft body(e.g., spinning satellites). An obvious example of such a mission is a one-axis stabilized satellite. In this case a large cylindrical part of the satellite surface can be covered by integrated solar cells and radiating elements. Each of them faces halftime the sun and the earth. The sub-arrays of the integrated antennas with solar cells should not be fed all at time, but an electronic feeding network will have to allow for a continuous rotation of the beam that opposes to the satellite spinning.
5. Missions requiring very large antennas and/or solar arrays.
6. Missions requiring very small spacecrafts.

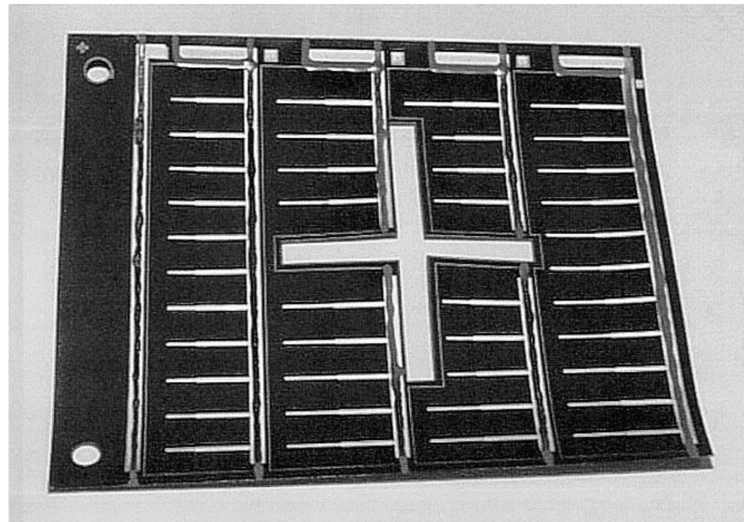
For all of the above missions there is the option to save "real estate" by combining two functions maintaining performance equal or to increase capability (e.g., to offer communication in a non-nominal situation). SOLANT could even be a mission enabling solution.

## III. AMORPHOUS SILICON(A-SI:H) THIN FILM SOLAR CELL TECHNOLOGY

To demonstrate the SOLANT principle, amorphous silicon (a-Si:H) solar cells have been selected. These cells are thin, light, flexible films that can be cut to fit arbitrary patch or array shapes and, eventually, conformed to curved surfaces. Another fundamental advantage of these solar cells is the f act that they do not involve a rigid semi-conductor wafer as substrate (germanium, silicon, etc….)They can also be grown on plastic or glass as well as on metals such as stainless steel or aluminum




**(a)**



**(b)**

**Fig.1. (a) Cross section of an amorphous Solar cell, showing the different layers. (b) Picture of a a-Si:H SOLANT module**

Fig. 1(a) shows a lateral view of an amorphous silicon solar cell on a plastic film (polyimide). The polyimide substrate is covered by an aluminum layer (back contact) and by a ZnO layer, which prevents aluminum diffusion. The layers mentioned above also form a mirror for the incident solar light in order to increase absorption and consequently, produce more current. The actual solar cell is made of three silicon layers: a thin high conductivity phosphor doped n- layer, an intrinsic (un doped) layer with a low defect density and a very thin highly conductive p-layer. Most photons are absorbed in the intrinsic layer, while the doped layers are responsible for the build up of an electric field within the solar cell itself. The collector layer on top of the cell must be transparent and conductive and hence it is made of transparent conductive oxides(TCOs)-either indium tin oxide or zinc oxide. Since TCOs have a rather low conductivity compared to metals, a finger pattern is deposited on top [see fig1(b)],made of a Cr adhesion layer covered by thicker Ag layer .Overall the cell thickness is less than 5µm but usually a 50 µm thick polyimide substrate is used as a support in standalone applications. Although this type of cell is less efficient than Ga-As solar cells which are currently used in space applications, a-Si:H cells shows a better watt/kilogram ratio due to their light weight .Moreover they are inexpensive and have shown promising hardness against cosmic radiation. Solar cells (as the name implies) are designed to convert available light into electrical energy. They do this without the use of either chemical reactions moving parts. The development of the solar cell stems from the work of the French physicist Antoine-Cesar Becquerel in 1839. Becquerel discovered the photo voltaic effect while experimenting with a solid electrode in an electrolyte solution; he observed that voltage developed when light fell upon the electrode. About 50 years later, Charles Frits constructed the first true solar cells using junctions formed by coating the semiconductor selenium with an ultra thin, nearly transparent layer of gold. Fritz's devices were very inefficient, transforming less than 1 percent of the absorbed light into electrical energy. By 1927 another metal semiconductor junction solar cell, in this case made of copper and the semiconductor copper oxide, had been demonstrated. By the 1930s both the selenium cell and the copper oxide cell were being employed in light-sensitive devices, such as photometers, for use in photography. These early solar cells, however, still had energy-conversion efficiencies of less than 1 percent. This impasse was finally overcome with the development of the silicon solar cell by Russell Kohl in 1941. In 1954, three other American researchers, G.L. Pearson, Daryl Chapin, and Calvin Fuller, demonstrated a silicon solar cell capable of a 6-percent energy-conversion efficiency when used in direct sunlight. By the late 1980s silicon cells, as well as those made of gallium -arsenide, with efficiencies of more than 20 percent had been fabricated. In 1989 a concentrator solar cell, a type of device in which sunlight is concentrated onto the cell surface by means of lenses, achieved an efficiency of 37 percent due to the increased intensity of the collected energy. In general, solar cells of widely varying efficiencies and cost are now available.

## IV. SLOT BASED SOLAR ANTENNAS

As stat ed in introduction, it is possible to carry the integration of antennas and solar cells by resorting to slot antennas instead of patches. Slot antennas large metallic surface(ground plane)on which solar cells can be directly grown. This yields a simple layered structure with high area-coverage efficiency for the solar cells. In this, it is possible to nearly comp letely cover the ground plane with exception of a very small area close to the radiating edges of the slot antenna without degradation of the RF performance.

The choice of the slot antennas could introduce some drawbacks that have to be considered such as narrower bandwidth and lower CP performance. However these drawbacks can be overcome through efficient design. From an overall system point of view, slot remain an interesting alternative to patches, particularly when the effect of solar cells o n the RF performance must be minimized.

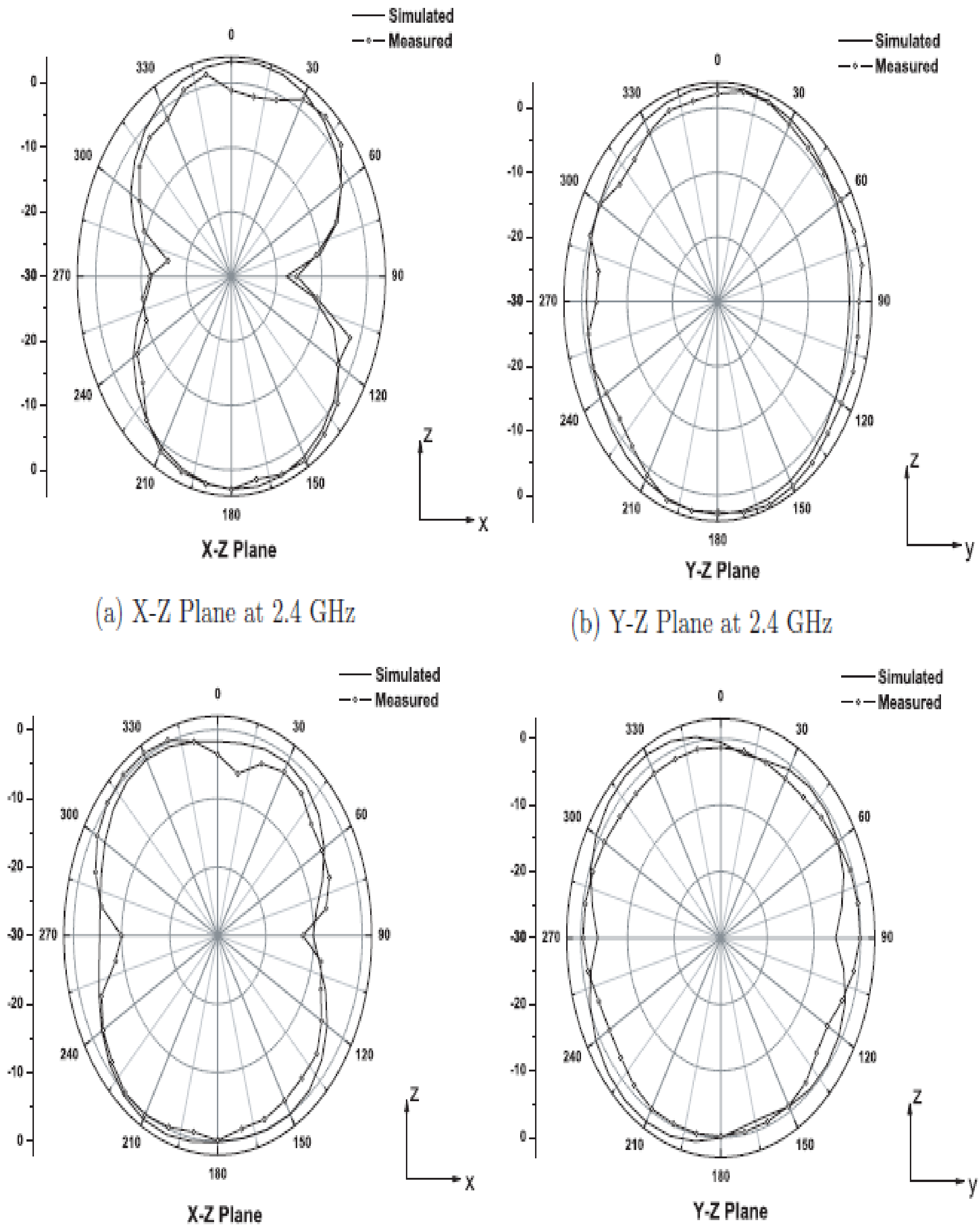
In the remainder of this section, we describe a circularly polarized slot antenna.

Circularly Polarized Slot SOLANT

This project also presents a circularly polarized micro strip planar array that resonates at 32 GHz and provides a broadside beam, a minimum gain of 28 dB, and a bandwidth greater than 1 GHz. This low profile, small mass antenna shall be surface mounted on a micro space craft that is being developed for future, deep space, NASA missions. Challenges arising from the development of this Ka-band antenna include the minimization of the array’s feed network loss and the attainment of the required bandwidth. High-gain micro strip arrays that have previously been developed for Ka-band or higher frequencies have primarily been linearly polarized In the case of this array, circular polarization (C.P) is achieved by employing the sequential rotation technique in which each patch element is excited at a single feed point. This technique is employed to minimize the insertion loss that occurs in the micro strip transmission line feed network and to satisfy the array bandwidth requirement. To further reduce the insertion loss, the feed network uses a combined parallel and series feed technique that was developed. Designing the micro strip line feed network with matched impedances throughout the entire circuit, the bandwidth performance is further enhanced.

The proposed system is the dual band SOLANT antenna. This type antenna increases the peak gain . In the 2.4 GHz band, the peak gain is about 3.2 dBi with less than 0.5 dBi of gain variation. In the 5 GHz band, the peak gain is about 5.5 dBi and the gain variation is less than 1dBi. It can fulfill the requirements of indoor wireless applications very well. We have designed antenna elements that capture electromagnetic energy from naturally occurring solar radiation and thermal earth radiation. The size of the antenna is relative to the wavelength of light we intend to harvest. The basic theory of operation is as follows:

The incident electromagnetic radiation (flux) produces a standing-wave electrical current in the finite antenna array structure. Absorption of the incoming EM radiation energy occurs at the designed resonant frequency of the antenna. When an antenna is excited into a resonance mode it induces a cyclic plasma movement of free electrons from the metal antenna. The electrons freely flow along the antenna generating alternating current at the same frequency as the resonance. Electromagnetic modeling illustrates the current flow is toward the antenna feed-point. In a balanced antenna, the feed-point is located at the point of lowest impedance. Figure 2 was acquired from modeling the electromagnetic properties of an SOLANT antenna.




(a) X-Z Plane at 2.4 GHz

(b) Y-Z Plane at 2.4 GHz

(c) X-Z Plane at 5.5 GHz

(d) Y-Z Plane at 5.5 GHz

**Fig.(2). Radiation pattern of SOLANT**

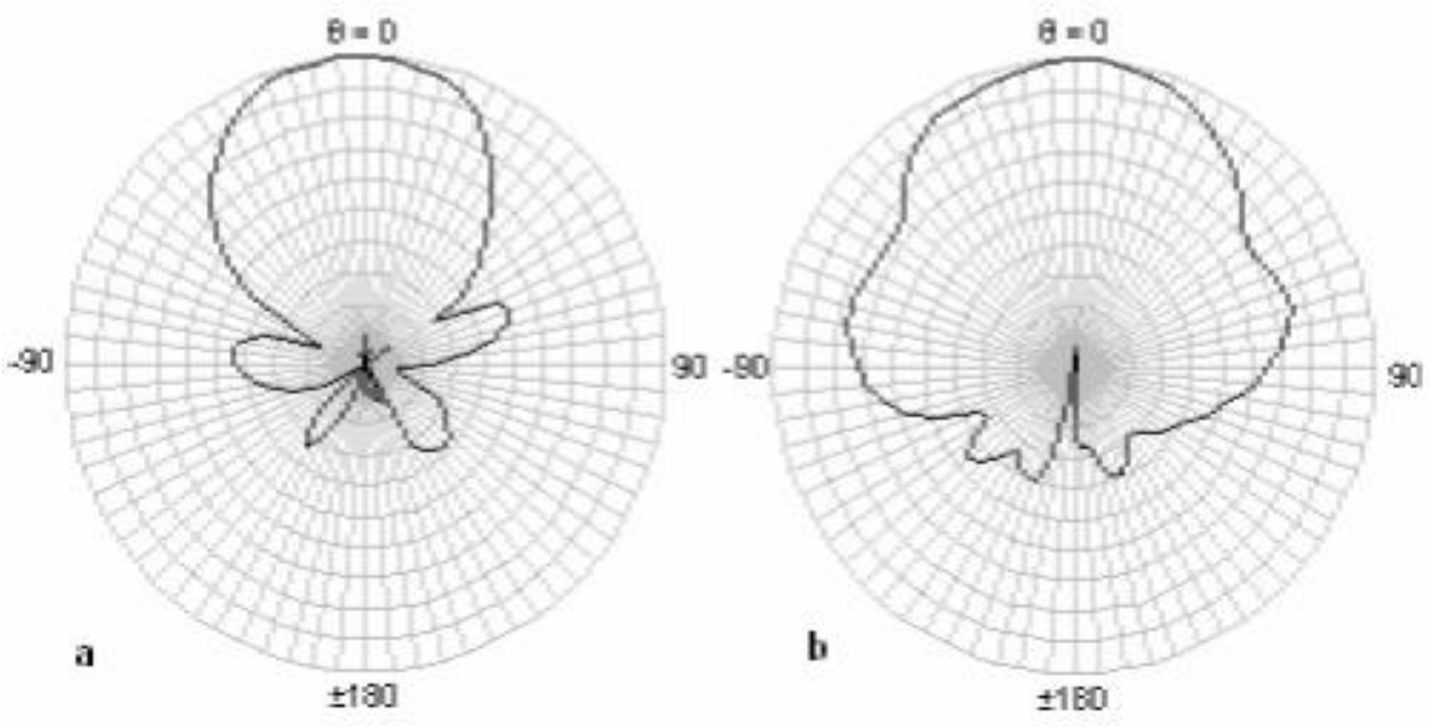



**Fig.(3). Typical Radiation pattern of Antenna**

## V. RESULTS

The SOLANT can be simulated by using MATLAB software and also the simulation can be tested for various array factor and amplitude of current.

## VI. CONCLUSION

The concept of integration of antennas and solar cells has been presented and demonstrated. The fully integrated slot design can simultaneously comply with all of the standard RF requirements (gain, radiation pattern) as well as the standard dc requirements (power, voltage current).

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