Chapter 66
Earth Long-Wave Infrared Emission, New Ways to Harvest Energy

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ABSTRACT

This chapter summarizes the physical properties of THz antennas, provides a summary of some of the most important recent developments in the field of energy harvesting of Earth long-wave infrared radiation, discusses the potential applications and identifies the future challenges and opportunities. In particular, a THz antenna is designed in order to transform the thermal energy, provided by the Sun and re-emitted from the Earth, in electricity. The proposed antenna is a square spiral of gold printed on a low cost dielectric substrate. Simulations have been conducted in order to investigate the behavior of the antenna illuminated by a circularly polarized plane wave with an amplitude chosen according to the Stefan-Boltzmann radiation law. Moreover, these THz antennas could be coupled with other components to obtain direct rectification of T radiation. As a consequence, these structures further optimized could be a promising alternative to the conventional photovoltaic solar cells.

INTRODUCTION

In the last two decades, the worldwide energy demand has increased by 40% but the main power generated nowadays is still produced using fossil fuels emitting tons of carbon dioxide and other pollution every second. As result, the harmful effects of hydrocarbon-based power sources as global warning, air pollution, acid precipitation, ozone depletion, forest destruction are increasingly apparent. In order to
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limit these drawbacks, suitable actions aimed to reduce the dependence on the fossil fuels are needed, and the search for clean and renewable alternative energy resources is one of the most urgent challenges to the sustainable development of human civilization (Manzano-Agugliaro, Alcayde, Montoya, Zapata-Sierra, & Gil, 2013; Arigliano, Caricato, Grieco, & Guerriero, 2014).

The sun is the most powerful source of energy for the Earth. It provides a continuous stream of energy and for this reason it can potentially play a very important role in providing most of the heating, cooling and electricity needs of the world. As result, several approaches and technologies to directly or indirectly harvest energy from the sun have been successfully proposed and implemented. In particular, beside the conventional energy resources such as petroleum, coal, and nuclear plants, renewable ones, such as wind, solar, hydropower, geothermal, hydrogen and biomass/biofuel have been positively used to give a strong contribution to power generation without increasing environmental pollution (Khaligh & Onar, 2010).

Among the several kinds of solar techniques, the photovoltaics (PV) one is the most mature technologies. According to the National Renewable Energy Laboratory (NREL), the worldwide demand for photovoltaics (PV) is increasing every year and industry estimates suggest as much as 18 billion watts per year could ship by 2020. So, to meet the increased demand for solar-conversion technologies, dramatic improvements are required in terms of PV efficiency and cost/complexity reduction (Tiwari & Dubey, 2010). To this aim, conversion efficiency of PV technologies has been increasingly evolved during the last 40 years.

The energy created by the fusion reaction in the Sun is converted in thermal radiation and transferred in the form of electromagnetic waves into the free space. Solar radiation occurs over a wide range of wavelengths, nevertheless the main range of this radiation includes ultraviolet ($\lambda < 0.4 \ \mu m$) of which the content is less than 9%, visible (light, $0.4 \ \mu m < \lambda < 0.7 \ \mu m$) where the content is approximately 39%, and the remaining 52% consists of infrared radiation ($0.7 \ \mu m < \lambda < 100 \ \mu m$). Approximately 30% of the solar radiation is scattered and reflected back to the space from the atmosphere, and about 70% is absorbed by the atmosphere and by the surface of the Earth. By absorbing the incoming solar radiation, the Earth temperature rises and, as an heated object, mainly reemits electromagnetic radiation in the wavelength range from 8 $\mu m$ to 14 $\mu m$ with a peak wavelength of about 10 $\mu m$. Due to the different spectral properties of the Sun and Earth emission, they are classified as short-wave and long-wave infrared (LWIR) radiation, respectively. The reemitted LWIR radiation energy is under-utilized by current technology. Considering that solar energy falls on the surface of the earth at a rate of about 120 petawatts and that PV technologies at present have low efficiency, it is clear that the Earth LWIR could be a potential renewable energy source and could have wide application and deep impact on our society (Byrnes, Blanchard, & Capasso, 2014).

A potential system able to collects the longwave radiation emitted from the Earth and to convert it into electricity is based on rectifying antenna (rectenna) technology. It typically consists of a THz antenna, intercepting the electromagnetic waves within a specific frequency band, and a diode which rectify the ac voltage due to the electromagnetic at the antenna terminals (Ma & Vandenbosch, 2013; Sabaawi, Tsimenidis, & Sharif, 2013; Shrestha, 2013). Despite some research activities are devoted to experimentally demonstrate the feasibility of rectenna to harvest the Earth LWIR radiation (Byrnes, Blanchard, & Capasso, 2014; Kotter, Novack, Slafer, & Pinhero, 2010), accurate numerical modeling is needed for device performance prediction, design and refinement as well as to obtain peculiar properties that may be exploited in the fabrication of more complex systems as antenna array. In fact, the optimization of antenna geometry and materials is crucial to improve the rectenna performance in terms