

## Optical Nano Antenna: Dimensional Development towards Aviation Signaling

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**Abstract**— The geometry and shape of the radio-frequency (RF) radiator, analyze the design of a optical Nano antenna. We show how it may be possible to operate a pair of closely spaced spherical Nano size particles as an efficient optical Nano-radiator, and how its tuning and matching properties. We demonstrate that an two element antenna can be used to realize a near field optical probe that combines spatial resolution well below the diffraction limit with transmission efficiency approaching unity. Analogously to antenna design, the objective of optical antenna designs the optimization and control of the energy transfer between a localized source, acting as receiver and transmitter, in the free radiation field. Most of the implemented optical antenna designs operate in the linear field distribution that is, the radiation field and the polarization currents are linearly dependent on each other. This linear dependence breaks down; new interesting phenomena arise, such as frequency conversion, switching, and modulation. Beyond the ability of mediating between localized and propagating Fields, a nonlinear optical antenna provides the additional ability to control the interaction between the two. Here we review the basic properties of nonlinear antennas and then focus on the nonlinearities achievable in either single-particle systems or more complex coupled-particle systems. In practice, the use of nonlinear materials - either metals or dielectrics - in the design of optical antennas is a promising route towards the generation and control of optical information exchanging route for flying objects.

**Keywords**—optical antenna:Nano Diameter, miniature size:single partical, optical meterial

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### I. INTRODUCTION

Antennas have played an important role in Electromagnetism as radiation sensor. Even one of the simplest form is the dipole antenna, is being use because of its easy implementation and characterize. In telecom applications the need of wide bandwidth has demanded at higher frequencies is used. The use of high-frequency radio waves in microwave radiations region improved the performance of communication system [1]. At the same time, the antenna design, development, and sophisticated layouts based design have been successfully applied. They can be fabricated with Micro-Nano structured and thin-film technologies with appropriate substrate.

In the radio electric spectrum, wavelength has been associated with the dimensional constraints of antenna structures. Fortunately, the available fabrication techniques and the good radiation-metal interaction have allowed the realization and demonstration of the devices at shorter wavelengths with powerful area coverage [2]. However, before antennas could reach optical frequencies is a reliable and practical way of use of semiconductor detectors made possible. These optical networks use the available detectors in the optical range mainly based on semiconductor technology. The efforts to improve the performance of these detectors deprived the need to look back toward the antenna designs and make them work in the optical band. One of the results of efforts is a new class of optical detectors that we named as optical antennas working in a very distant field of application, researchers dealing with time standards and astronomy , aviation and aviation based communication area were developing new solutions based on antenna-like detectors[5][6].

Another important progress in the realization of practical devices using antenna coupled detectors was their fabrication by using electron-beam lithography (EBL) for the definition of micron and submicron structures [7,8]. The smoothness of the finished metal structures, along with the spatial resolution of the feasibility of the devices and to their performance may be analyzed even at visible frequencies [9].

The detection devices typically used for light detection based on the semiconductor technology. Hybrid generations of semiconductor detectors have improved their responsively, speed of response, increase in bandwidth and low powered excitation as well detection. Electromagnetic waves at lower frequencies the detection mechanism is quite difficult and complex. Antennas are used here to transform the energy contained in waves propagating in free-space into guided electromagnetic signals fed through electronics circuit signal condition and processing circuits. This electronics is in charge of the conversion of received signals into a more

usable. “Optical antennas” are lies in between semiconductor photo detectors and radio electric antennas [10]. They are work in the optical range and they include metallic structures that couple the radiation towards a trans-conductive element. Benefit of the bandwidth of the optical communications links and the selective properties in polarization, frequency, and direction related with the antenna designs.

Another field of application for optical antennas originates from the field of Nano-optics and Nano-photonics. At optical frequencies, oscillations are of major importance for the induction of antenna currents helps for the propagation of signals along transmission line or in free space. The existence of polarities is closely related to the poor conductivity of most metals at optical frequencies but it also opens up opportunities for the design of electric components of optical spectrum [12]. Therefore, the combination of antenna resonances and Plasmon’s resonances hold promise for giant localized field enhancement. Optical frequency radiation can be confined to dimensions considerably less than 100 nm only by material structures of similar size, e.g. small apertures and scattering particles. Such structures have been used already for optical imaging beyond the diffraction limit by means of scanning near-field optical microscopy [14].

Optical antenna have been widely used for variety of application because they can capture and focus propagating electromagnets energy into sub diffracted limited area and vice versa. The widespread application of the optical antenna has been limited due to lack of appropriate method of fabrication of antenna on linear surface with the small dimensional constraints

## II. RELAVENT LITERTURE

### 2.1. The Concept of an Optical Antenna

An optical antenna is the combination of two elements. The metallic structure in charge of the coupling of the electromagnetic field, and the rectifying element that converts the energy trapped in currents along the antenna into a manageable signal [16]. In order to investigate the optical properties of noble metals we first consider the free electron and physical structure and behavior of free electron gas. This structure described by Drude-Sommer field model as

$$m \frac{\partial \vec{x}}{\partial t} + m\gamma \frac{\partial \vec{x}}{\partial x} = eEe^{-j\omega t} \tag{1}$$

Where m, e,  $\Gamma$  represent effective mass, the charge and damping coefficient of free electron respectively and E and w are amplitude and frequency of applied electric field.

Optical antennas at Nano scale structured consisting of metallic particle interact with the electromagnetic wave at optical frequency. Optical antennas are similar to the RF antenna in receiving and transmission radiation in free space. The optical antenna captures free space electromagnetic wave and focused light energy into their high field region beyond their diffraction limit. The electromagnetic builds up a pattern of oscillating currents within the metal structure. However, the currents transfer in the metal is strong enough to produce signals readable by a dedicated electronics circuitry. The antenna design, the size of the metallic structures is scaled with the wavelength, and typical features are a fraction of the detected wavelength.

Optical antennas will find its application niche in those areas where their outstanding characteristics in polarization sensitivity and point-like footprint are preferred and appreciated. The high frequency of the optical radiation and the need to extract electric signals by signal conditioning circuit makes possible a phase detection of the incoming radiation. The optical antenna captures electromagnetic wave in free space and store electromagnetic energy in its near field oscillating between electric and magnetic field. The capacitive or inductive reactance of optical antenna corresponds to stored energy in the form of suitable energy source and resistance contributed to power dissipations by radiation and absorption loss. It acts as RLC circuit whose frequency is calculated.

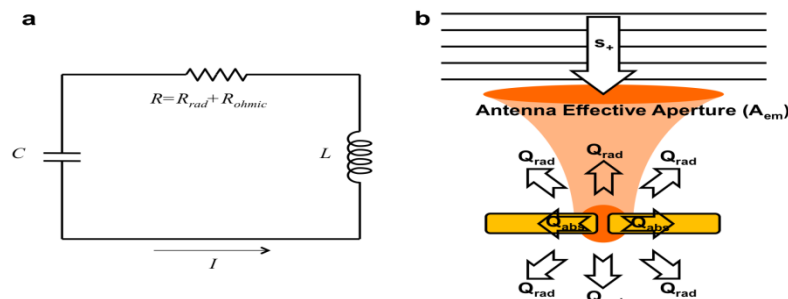


Fig. 1: circuit model and possible schematic

Using the coupled mode theory the energy stored in optical antenna and effective cross sectional of the antenna is a function of maximum effective absorption and effective aperture. Therefore it is necessary to design optical antenna with large effective aperture and critically match quality factor (Q) Along with the dipole structure, the V-shaped metallic structures are the connection lines used to extract the rectified signal from the antenna. The metallic structure has been developed on a Si/SiO<sub>2</sub> wafer. The light is incident perpendicularly to the plane represented in the picture. It can be coming from the air or from the substrate [17].

### 2.2. Maintaining the Integrity of the Specifications

The area containing about the 90% of the spatial responsively of an optical antenna has been measured to be about the square of the detected wavelength, both in the infrared and visible spectrum [18]. Figure 3 shows the response of a dipole antenna at infrared and visible frequencies [9], [18]. The tiny volumes of the rectifying element are 0.02μm allows obtaining a very fast response. Preliminary estimations of the response time for non-optimized devices are about 100ns [19]. On the other hand, when MOM diodes are used as rectifying elements, the response of the antenna is typically limited by the transmission lines and the associated electronics. The intrinsic response time of the physical mechanism underlying the detection is about Polarization sensitivity [12]. The antennas are intrinsically polarization sensitive elements, in the same way as their radio-electric versions [9] [18], [21]. Tuning behavior of metals at optical frequency limits the tune ability of optical antennas because of the losses induced in the metallic structure. This capability may compromise fine tuning of the antennas. However, some clever electromechanical layouts may overcome this problem and produce a reasonable tuning of the devices. Directionality property is strongly dependent on the geometry of the antenna [19]. The results obtained for several dipole antennas by changing the dipole length.

As far as the fabrication tools and substrates are the same used for microelectronics, some specific designs of “Optical antennas” can be monolithically integrated with associated electronics, micro-mechanical systems, and integrated optics [23, 24], the use of Fresnel zone plates specifically designed to improve the responsively of the optical antenna at Room temperature operation. Optical antennas working in the infrared, even in the far infrared band, do not need auxiliary cooling subsystems. This advantage is very much appreciated when comparing optical antennas with the conventional detection technologies that use sophisticated cryogenic equipment to reduce the noise of the detectors. Some of these properties are intrinsically related with the antenna design and can not be performed by semiconductor detectors. The most promising application of optical antennas will make full use of the advantage offered by the most appealing intrinsic properties [25,26].

## III. EXPERIMENTATION

### 3.1. Designing

The dipole antenna is one of the most common types of antenna with two normal bars with feed point separated with gap. The dipole antenna has resonant spectral characteristic and broad side radiation pattern. Due to their relative structure and current distributive behaviour of dipole antenna behavior is where understand. The characteristic of the dipole antenna at optical frequency have explored with the dimensional variation with the associated gap filling material between feed points.

In order to enhance the optical property we uses the equal; quality factor condition with the  $Q_{ab} = Q_{rad}$  while slight change in aperture and gain of antenna. The ground plane of glass is introduced to control the radiation pattern of optical antenna. The energy stored in the cavities is given as

$$a = \frac{\sqrt{(A_{em}/A_t)/\tau d}}{\left(\frac{1}{\tau_{rad}} + \frac{1}{\tau_{abs}}\right)^2} [S+]^2 \tag{2}$$

The energy stored in average is given as

$$|a|^2 = \frac{4 \frac{A_{em}/A_t}{\tau_{rad}} |S_+|^2}{\left(\frac{1}{\tau_{rad}} + \frac{1}{\tau_{abs}}\right)^2} \tag{3}$$

From stored mode energy the power dissipated and absorbed is calculated using

$$P_{sca} = \frac{|a+1|^2}{\tau_{rad}} = ((4A_{em}/A_t)/\tau * \tau_{rad}) / \left(\frac{1}{\tau_{rad}} - \frac{1}{\tau_{abs}}\right)^2 \tag{4}$$

$$P_{abs} = \frac{|a+1|^2}{\tau_{abs}} = ((4A_{em}/A_t)/\tau * \tau_{abs}) / \left(\frac{1}{\tau_{rad}} - \frac{1}{\tau_{abs}}\right)^2 \tag{5}$$

Also the power feed to the dipole antenna is given according to the possible average power radiation mechanism with the radiation resistance of  $R_r = 73\Omega$  and transmitted power  $P_t = 73.08 I_{eff}^2$  with the effective length wise current flow.

### 3.2. Methodology

The characterization of the novel type of device is of interest for evaluating comparatively the performance of optical antennas with respect to any other types of light detectors. The typical figures of merit in optical detection are evaluated using their well established definitions. These parameters are: responsivity, time of response, normalized directivity, and noise equivalent power. On the other hand, the special properties of optical antennas make necessary to characterize some other parameters. They are the spatial map of the responsivity, the polarization sensitivity and the frequency response. In any case, the measurement of optical antennas is a compelling task dealing with sub-wavelength measurements [27]. Besides, the response of the device is, sometimes, having a non-negligible contribution of different kind of noises. These sources of noise have to be identified and, if possible, filtered out. One of them is the presence of  $1/f$  noise. This noise is easily reduced by modulating the optical input and by detecting synchronously the response of the optical antenna.

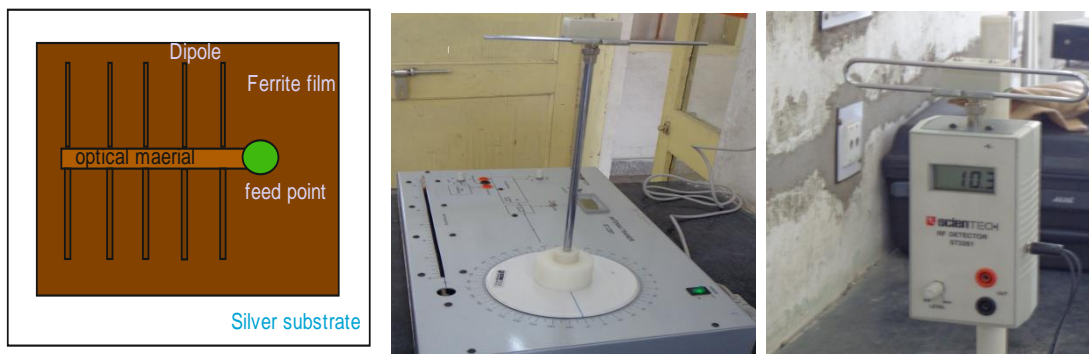


Fig. 2: array formation of dipole with silver metal and test setup.

The figure 2 shows the design of dipole antenna array filled with the optical material and measuring the EM radiation and particular light generated at the wavelength  $E = (60\pi dL/\lambda) \sin(\theta)$  and magnitude of total field strength is calculated from equation 4 as solution  $E_R = E\sqrt{2(1+\cos\psi)}$ .

The antenna efficiency is improved through the Q matching; we need to tune the radiation and absorption with the silver metal. The radiation engineering we try to achieve with the silver using the dielectric spacer coated with metal ground plate. Metallic surface is used to enhance the fluorescence of the molecule place at the  $\lambda/2$ ,  $\lambda/3$ ,  $\lambda/4$  away from the ground plane using dielectric spacers. The  $\lambda/4$  distance result in constructive interference between top and bottom reflected emission of the molecule and increase the aperture  $A_{em}$ . Also the ground plane can be used to control the radiation Q of the antenna and tune it with absorption. The dielectric splice module is reduce the radiation Q of the antenna is increase and at the optimum dielectric spacer thickness the radiation and absorption is match which lead to maximum enhancement condition

## IV. RESULT AND CONCLUSION

We use the numerical simulation to verify the idea of good silver dipole antenna array on the dielectric substrate. The antenna array with 235nm length 35 nm widths, 30 nm thickness and 20 nm gap with 300nm pitch ware simulated using infinite integration technique. The dipole antenna is excited by plane wave from the top which polarized along with the dipole antenna alone axis, the electric field confined at the antenna feed gap on resonance.

The total Q of radiation and absorption of the antenna array calculated as thickness of surface  $SiO_2$  is varied from 10 to 100nm. The reference graph show that the Q increases as the thickness of spacer decreases which is expected from radiation cancellation between the real and image dipole antenna. The radiation Q matches with the absorption of spacer thickness of 70nm. The field intensity enhancement is also at this optimum spacer thickness which agrees with theory. It is important to note that the optimum dielectric spacer thickness is less than half of three-quarter wavelength thickness of 100 nm

Clearly, the antenna loaded with ferrite films with the optical material can indeed enhance the field and ground immunity with the optical operational wavelength between the dipole antenna and the ground plane effectively. In both cases, slightly frequency shift, which may be caused by the change of antenna material nature and surrounding, i.e. we added the ferrite film at a very short distance, the film itself is of high

permittivity material. Therefore effective length of dipole with ferrite film was a little bit longer than the dipole without ferrite films. This in turn will result in the frequency shift.

Increasing the distance between the dipole antenna and the ground plane upto 3-mm along with the particular activated optical material, the reflection coefficients of the antennas were measured. As shown in Fig 5, the reflection coefficient is ~5.15GHz, with magnitude of -9.5 dB, for the dipole antenna without the ferrite film. When one layer or two layers of dielectric material two layers of Fe<sub>2</sub>O<sub>4</sub>-ferrite films were added under the dipole antenna, the resonant frequencies were ~4.75GHz and 5.62GHz, respectively. The antenna bandwidth of these two dipole antenna with Fe<sub>3</sub>O<sub>4</sub> ferrite films was 750MHz. obviously, the antenna loaded with lossy ferrite films can effectively enhance the ground immunity between the dipole antenna and the ground plane.

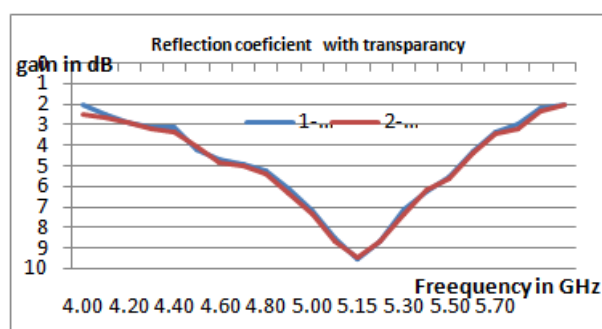


Fig. 3: Reflection profile at frequency.

The antenna radiation characteristics were measured in an anechoic chamber with the same input power to the antenna. For the investigation of lossy effects, we measured the received power of the dipole antenna without ground plane, dipole with 1 layer of Fe<sub>3</sub>O<sub>4</sub> film beneath the dipole, and 2 layers of Fe<sub>3</sub>O<sub>4</sub> beneath the dipole. The measured radiation patterns were normalized with the dipole antenna without ground plane, and plotted in Fig 6. The received power was about 4.56mW for the dipole antenna without ground plane. For the ferrite films loading, the received powers were 3.93mW and 3.69mW for the 1 layer of Fe<sub>3</sub>O<sub>4</sub> film and 2 layers of Fe<sub>3</sub>O<sub>4</sub> film, respectively. This shows that the radiation characteristics are not too affected by the ferrite loading.

## V. CONCLUSION

The performance and advantages of patch based dipole antennas such as low weight, low profile, and low cost made them the perfect choice for communication system. They have the capability to integrate and tested by microwave circuits and therefore they are very well suited for mobile devices.

Conclusively, a new lossy ferrite film was successful introduced into the design of low profile dipole antenna to enhance its ground immunity by effectively reducing the mutual coupling between the antenna and the ground plane. Since the Fe<sub>2</sub>O<sub>4</sub> ferrite film is very thin, it will neither add weight nor volume to the RF front circuit.

As concern with this experiment, the patch based dipole in its pure form cannot satisfy the bandwidth and loss reduction requirements for most wireless communication systems, a modification to the structure of the printed antenna must be undertaken to meet the impedance bandwidth specifications. The technique proposed in this research module has overcome the problem of loss in patch antennas resulting from surface wave excitation, if the size of the antenna were beyond a critical dimension related to the propagation constant.

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