# MICROSTRIP PATCH ANTENNA FOR A RETINAL PROSTHESIS AND RF MEMS TECHNOLOGY

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Abstract:- This paper is about the investigation of a novel approach for establishing a data telemetry link in a dual-unit retinal prosthesis at microwave frequencies (1.4GHz and 2.35GHz) using a pair of Microstrip patch antennas. Approximately sized extraocular (25 mm x 25 mm) and intraocular (6 mm x 6 mm) antennas are simulated using IE3D and compared with reference experimental results which was designed and fabricated using the Finite Difference Time Domain Method. Simulation results show frequency shift in the resonant frequency by changing the capacitor height from 2  $\mu$ m to 1  $\mu$ m. However, the major drawback of this configuration is as Microstrip antenna is loaded with radial stub, which makes the structure is not suitable for loading with large number of capacitors. Because the dimensions of the radial stub determine the separation between the MEMS capacitors. Hence, the overall dimensions of the structure grow as more MEMS capacitors are used for loading, which is a problematic issue in terms of fabrication.

Keywords: Epiretinal, Subretinal, Telemetry link, Retinal Prosthesis.

## **1** Introduction

Vision involves extremely complex information processing in the eye which is facilitated by the neuroprocessor at the back of the eye ball called the retina which covers 65% of the curved surface area. Light from the external objects is focused by the lens and an inverted image is formed on the approximately 130 million photoreceptor cells of the retina [1]. These photoreceptor cells convert the incident photonic energy into complex electrical and chemical signals. These signals are conveyed through a network of interfacing layers (horizontal, bipolar and amacrine cell layers) and eventually reach the ganglion cell layer. The axons of ganglion cell layer form the optic nerve which transmits the information to the primary visual cortex in the brain. In retinal degenerative diseases, Retinitis Pigmentosa (RP) and age-related macular degeneration (AMD) are incurable and cause a profound vision loss due to degeneration of the light sensing photoreceptor cells .It has been clinically demonstrated that artificial electrical stimulation of the surviving ganglion cells can elicit visual perception in patients [2], [3]. An implantable retinal prosthesis can be designed to replace the functionality of the missing photoreceptor by directly providing electrical stimulation to next surviving layer of retina (bipolar and or ganglion cell layers) thus restoring partial vision in such patients. Two approaches mainly been proposed to achieve artificial electrical stimulation and they differ in the positioning of their electrode array.

In epi-retinal approach the implant array is positioned on the surface of the inner retina [4]-[6]. In sub-retinal approach the device is implanted between the pigment epithelial layer and the outer layer of the retina [7], [8]. The retinal prosthesis system considered here is a dual unit epi-retinal device with an extraocular and implanted intraocular unit. The intraocular unit contains the secondary coil, rectifier, signal processing chip and an electrode array. The extra ocular unit is comprised of the image capturing and processing chips, an amplifier and the primary coil. Power transfer and data communication via an inductive link has been extensively reported and is the conventional means of coupling the external and internal portions of neuro-prosthetic devices. It is

accomplished by mutual magnetic flux linkages between coils at low frequencies (1-10MHz).

Recent work shows that a low-frequency inductive link can have sufficient bandwidth for a 2 - 3 Mbps data signal required for a 32 x 32 electrode array. However this may not be sufficient to transmit real time visual information with the desired resolution to the implanted electronics. Efforts are underway to manufacture significantly more dense, ultra-thin and flexible electrode arrays, which fit neatly into the curvature of the retinal in the eyeball. The advancement in array miniaturization technology necessitates a much higher bandwidth. But transferring both data and power via the same inductive link has a performance drawback in that the data bandwidth is dependent upon the carrier frequency and hence low frequency inductive link alone may prove to be insufficient in designing an optimum telemetry link. Data communication at microwave frequencies using a pair of external and internal Microstrip patch antennas can provide higher bandwidth and is a viable alternative. With the development of the systems operating at different frequencies, there is a growing need for a single antenna that can be tuned dynamically to operate at different frequencies. The usage of a single antenna on the system for various applications reduces the system size and cost. Due these advantages, frequency tunable antennas are preferred both in military and commercial applications. For, instance an antenna whose resonant frequency can be tuned in an analog manner can be used in radar application for frequency hoping. A directly tuned antenna can be used in telecommunication systems to maintain different system frequencies. Tunable antennas also find application area in satellite communications systems for adjusting one operating frequency as transmitter and the other receiver. To tune the resonant frequency of the antenna in a dynamic manner tunable components required are [10]. Microelectromechanical systems (MEMS) and the application of this technology to RF system enable production of these tunable components with low power consumption, high linearity and high performance. Tunable circuit elements produced by RF MEMS technology makes the realization of dynamically reconfigurable structures more efficiently in terms of lower insertion losses, integration on low dielectricconstant substrates[11]. Also, the monolithic fabrication of the antenna together with these

tunable components reduces the power losses and parasitic effects compared to integration of discrete components. MEMS switches and tunable capacitors are used in MEMS reconfigurable antennas to control the resonant frequency, bandwidth, polarization and radiation pattern of these antennas. Reconfigurable antenna structures designed and fabricated in the frame of this thesis include tunable RF MEMS components integrated with Microstrip antennas. Microstrip antennas are preferred in frequency tunable antenna [12] applications for their advantages such as;

Being light weight and having small volume and low profile planar configuration.

Ease of mass production using printed circuit technology leading to a low fabrication cost.

Easy integration with other MMICs on the same substrate.

Allowing both linear and circular polarization.

Ability to being made compact for use in personnel mobile communication.

Allowing for dual and triple-frequency operation. The aim of this paper is to demonstrate the advantages of RF MEMS technology in terms of tuning the resonant frequency of the Microstrip antennas when they are integrated with tunable RF MEMS components such as switches and capacitors. For that purpose, design, fabrication and measurements of different reconfigurable antenna structures using RF MEMS technology are accomplished in the frame of this paper. The simulations and measurement results obtained from these designs prove that the integration of tunable RF MEMS components with the radiators enables significant amount of tuning of resonant frequency of the antennas.

Extremely low power consumption : RF MEMS switches consume 0.05 - 0.1 Mw power including the voltage upconvertor or drive circuitry necessary for raising the input 3 - 5 V control voltage to the 20 - 80 V actuation voltage of the MEMS switches which is a very good performance with respect to PIN diode consume 5 - 100 Mw power. Linearity: since the MEMS switches do not contain a semiconductor junction and do not have an exponential current versus voltage relationship, they are extremely linear devices. Low Loss: The loss range of RF MEMS switches are 0.05 - 0.02 dB for 1 - 100 GHz band whereas the loss range is 0.3 - 1.2 dB for GaAs PIN diode and 0.4 - 2.5 dB for transistor switches. Isolation: RF MEMS switches offer very high isolation in 1 - 40 GHz band and high isolation in 60 -100 GHz band, with respect to Ga As PIN diode and transistor switches having only 20 dB isolation.

## 2 Antenna Design

Owing to the nature of the application, the transmitting and receiving antennas must be very compact, robust and light weight. Thus Microstrip patch antennas were selected [9]. The extra ocular antenna was designed to have dimensions within 25 mm x 25 mm to fit on a pair of glasses to be worn by the patient. While the intraocular antenna was to be designed with dimensions less than 6 mm x 6 mm to accommodate it within ciliary muscles of the eye-approximately 6-7 mm posterior to the cornea. At both the frequency bands, pair of extraocular and intraocular was designed, for this study all the antennas are designed with a high dielectric constant of  $\varepsilon_r$ =9.2 and thickness of h= 0.5 mm.

The steps to realizing the dimension of a rectangular patch is to first determine the radiating width of the patch using the following equations :

$$w = \frac{c}{2f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

Where,  $c = 3 \ e8$  (free space velocity)  $f_r = Resonant$  Frequency  $\varepsilon_r = Dielectric constsnt of substrate$ 

Next, the effective dielectric constant is found using,

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[ 1 + 12 \frac{h}{w} \right]^{-\frac{1}{2}}$$
(2)

Where h = height of the substrate,

The effective length can be determined with the equation,

$$\frac{\Delta L}{h} = 0.42 \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{w}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{w}{h} + 0.8\right)}$$
(3)

The effective length of the patch is obtained using,

$$L \mathcal{E} f f = L + 2\Delta L \tag{4}$$



(a)



(b)

Fig.: 1 Extraocular antennas at both the frequency bands (a) 1.45 GHz. (b) 2.45 GHz.



(d)



Fig.2: Intraocular antennas at both the frequency bands (c) 1.45 GHz. (d) 2.45 GHz.

Intraocular antenna	Ş	L	la	h	18	Wa	Wb	Wc	Wa	m
1.45 GHz	6.25	5.75	4.25	2.25	0.75	0.5	0,5	0.5	,	,
2.45 GHz	6,25	5,75	3,5	1,5	0,75	0,5	0,5	0,5	1,25	0,75

 Table 1: Parameters for Intraocular Antenna (All Dimensions in Millimeters)

#### 2.1 Frequency Band at 1.4 GHz

The Extraocular antenna was designed by incorporating a pair of vertical slots along the non radiating edges of the antenna. By varying the length of the slots, the desired compactness was achieved and the antenna dimensions were restricted to 25 X 25 X 0.5 mm. A symmetric array of slots was etched out from the surface and a single shorting post was used near the feed point to resonate and match the extremely compact intraocular antenna. The reference implemented extraocular and intraocular antennas for both the frequencies are shown in Figure1.(a),(b) & Figure2.,(c),(d).



(a)



Fig 3: Return loss characteristics for the extraocular antenna resonating at (a) 1.4 GHz, (b) 2.35 GHz

#### 2.2 Frequency band at 2.35GHz

For the same dimensions of the extraocular and intraocular antennas, the degree of compactness required at 2.35 GHz is less than that required at 1.4 GHz. Thus, with dimensions of 25X25X0.5 mm, a simple patch antenna was designed to operate as the extraocular antenna at 2.35 GHz. The array of slots used on the 2.35 GHz intraocular antenna was identical to that of the 1.4 GHz intraocular antenna but since the required compactness was lower, the length of the slots was reduced for the 2.35 GHz intraocular antenna. Also, two shorting posts were introduced symmetrically with respect to the feed location to achieve matching for the 2.35 GHz intraocular antenna. Figure 1(b) & Figure 2(d) shows the picture of implemented extraocular and intraocular antennas in this frequency band. The design parameters for the intraocular antennas are listed in Table 1. As seen from the proposed designs facilitated slight variations in the width of the shorting posts and in the length of slots. Such modifications had to be incorporated at both frequency bands to match

the intraocular antenna's resonance frequency to that of the extraocular antenna.





(d)

Fig 4: Return loss characteristics for the intraocular antenna resonating at (c) 1.4 GHz, (d) 2.35 GHz



(a) Reference



<sup>(</sup>b) Reference



(b) Simulated using IE3D

3115070.3 j15070.2 -j934.0 ] -j449.3 -j289.6 216.1

j449.3

-115070.2 ·i934.0 -j449.3



(f) Simulated using IE3D

(d) Simulated using IE3D

-167.0



(g) Simulated using IE3D

Fig. 5b: Smith chart characteristics for the intraocular antenna resonating at different frequencies

## **3** Conclusion

Intraocular and Extraocular Microstrip patch antenna for retinal prosthesis was investigated. Their Return Loss characteristics and Smith charts simulated using IE3D was compared with the reference plots which is designed using FDTD method. Experimental results are matched with the simulated results. Microstrip patch antenna for retinal prosthesis is applicable for the frequencies 1.4 GHz and 2.35 GHz. Frequency tunable antenna structures are investigated. simulated and compared with the reference. RF MEMS switches and capacitors are used to tune the resonant frequency, RF MEMS capacitors are placed onto Microstrip stubs to provide capacitive loading. By changing the height of the capacitors, i.e., changing the capacitance value, the resonant frequency of the antenna can be tuned. Loading a Microstrip antenna with a capacitor, the input impedance of the antenna is changed resulting in change in the resonance frequency. The shift in the resonant frequency is directly related to the change in the amount of the capacitive value. Microstrip antenna which is loaded by RF MEMS bridge type capacitors distributed periodically onto an open ended stub is designed. Simulation results show frequency

shift in the resonant frequency by changing the capacitor height from 2  $\mu$ m to 1  $\mu$ m. However, the major drawback of this configuration is as Microstrip antenna is loaded with radial stub, which makes the structure is not suitable for loading with large number of capacitors. Because the dimensions of the radial stub determine the separation between the MEMS capacitors. Hence, the overall dimensions of the structure grow as more MEMS capacitors are used for loading , which is a problematic issue in terms of fabrication.

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