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Spiral Shaped, Multilayered, Microstrip Antenna Implanted in Vitreous Humor in Med-Radio Band

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Abstract

Retinitis Pigmentosa (RP) & Age related macular degeneration (AMD) are diseases related to human eye. Person suffering with RP experiences a gradual decline in vision, leading ultimately to profound blindness. In this paper we have designed & simulated the spiral shaped, multi layered, micro strip antenna in Med-Radio band (401-406MHz). This antenna along with proper RF transceiver, DSP system integrated together in a microchip & with micro camera can be implanted inside the human eyeball and can be used in retinal prosthesis for vision improvement of patient suffering with AMD & RP. The proposed antenna is simulated with High Frequency Structure Simulator (HFSS) based on finite element method (FEM). The antenna had been immersed inside the phantom of human eye ball filled with vitreous humor. Partial substrate removal technique has been used for BW improvement. For this antenna the return loss of -20 dB, VSWR of 1.21, BW of 52 MHz & Gain of -46dB at resonant frequency of 403 MHz have been achieved.

Keywords: Retinitis Pigmentosa (RP), Age related macular degeneration (AMD), Microstrip antenna, Med-Radio band, HFSS, implantable antenna, eyeball, vitreous humor, Implanted Medical Device (IMD).

1. Introduction

The AMD & RP are diseases that can cause the partial blindness. AMD is a leading cause of blindness in the elderly. In the wet or neovascular form of macular degeneration there is a leaking neovascular membrane in the choroid that damages the macula and affects vision [1, 2]. The projected number of people with age-related macular degeneration in the year 2020 is 196 million, increasing to 288 million in the year 2040 [3]. The proposed antenna along with proper RF transceiver, DSP system integrated together in a microchip & with micro camera can be used in retinal prosthesis for vision improvement. To reduce the size of proposed antenna the substrate of very high relative permittivity had been selected and current path is kept as long as possible. As the space for IMD inside the eye ball is limited, the implanted antenna should have size as small as possible. The eye ball model consists of semi-solid fluid known as vitreous humor[4, 5].

2. Material & Method

For the proposed antenna, the basic idea was derived from [5, 6, 7]. In [5] the patches have rectangular shapes and antenna was immersed in vitreous humor. In [6], the rectangular 3 layers slotted patch structure has designed. In [7] the antenna was designed for implanting in human head with tissue of better permittivity & conductivity for signal transmission in comparison to the proposed design. The proposed antenna has three layers with circular ground plane as a first layer having radius of 5.5 mm. The second layer with radius of 5.5 mm, uses 0.2 mm thick ferrite substrate (ε_r=12) & third layer having radius of 5.5 mm is being stacked on 1.2 mm thick air substrate (ε_r=1) with the first & second layer. Both second & third layer patches are of spiral shape as shown in figure1. The shorting pin is connected between first & second layer.

The partial substrate removal techniques have been used for improving the BW [8] as illustrated in figure2. The side view of antenna is shown in figure3. The antenna is encapsulated with the Poly Di-Methyl Siloxane (ε_r=2.72, σ =0 s/m, thickness=0.2mm) layer for bio compatibility with vitreous humor (ε_r=69, σ =1.53 s/m and diameter=25 mm). The application of PDMS layer improves the return loss [5]. Refer with Fig. 4, in which the proposed antenna is immersed inside the phantom of human eyeball model filled with vitreous humor.

3. Results & Discussion

The antenna had been placed at the center of human eyeball model. Fig. 5 shows the return Loss(-20.32 dB) result obtained after simulation using FEM based HFSS electromagnetic solver. Fig. 6 shows the VSWR plot, while Fig. 7 shows the 3D polar radiation pattern of the proposed antenna. It is evident from Fig. 7 that the radiation pattern is Omni directional in shape, which is due to the smaller size of antenna. The gain of antenna obtained to be -46.019 dB which is very small, because of very high permittivity (ε_r=69, σ =1.53 s/m) of vitreous humor inside the human eyeball model. The propagation constant depends upon permittivity (ε) as [5]

$$\alpha=\omega\sqrt{\{\mu\varepsilon/2[\sqrt{(1+\sigma/\omega\varepsilon)}-1]\}}$$

As permittivity of the propagation medium is very high, the losses will also be more & gain will be smaller.

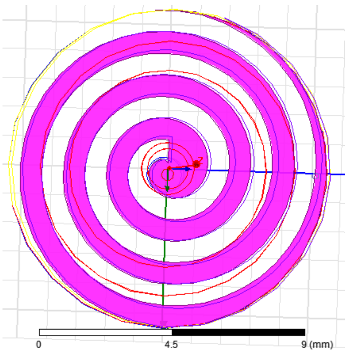

Fig. 1: Spiral shaped Patch (2^{nd} & 3^{rd} layers)

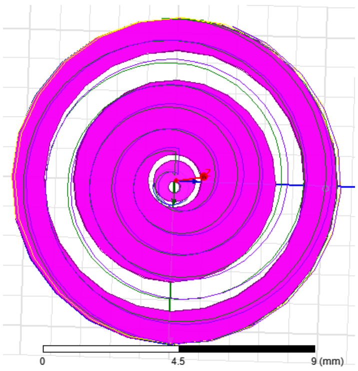

Fig. 2: Partial substrate (second layer) has been removed in the form of two annular rings

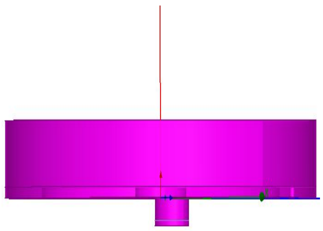

Fig. 3: Side view of multilayer antenna with coaxial feeding & shorting pin

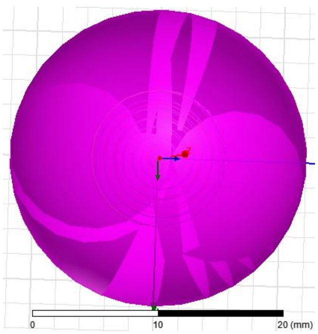

Fig. 4: Antenna is placed at the centre of human eyeball model filled with vitreous humor.

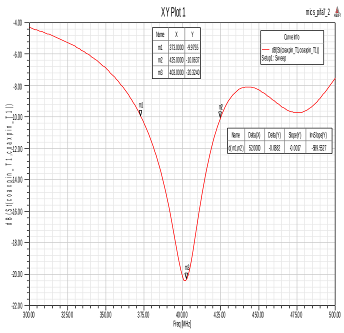

Fig. 5: Return loss of the proposed Antenna placed at the center of human Eye ball model.

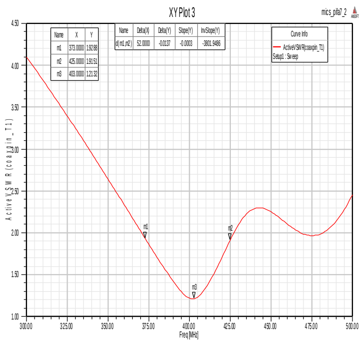

Fig. 6: VSWR plot showing VSWR less than 1.9 in 52MHz BW.

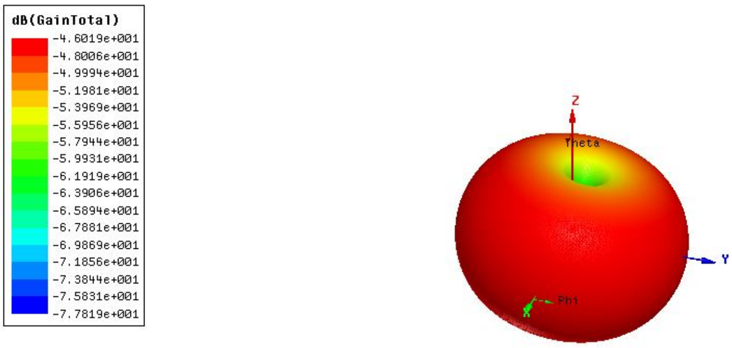

Fig. 7: 3D Polar plot of the proposed antenna.

Table-I shows the comparison among different antennae previously reported by several authors. In [5], the antenna was immersed in vitreous humor, the antenna has a volume of 633.36 mm^3. [6] was designed for skin simulated fluid with reduced volume. In [7], the size of antenna is greatly reduced and, it was implanted inside the 15 tissue anatomical head model. In [9] antenna was tested inside muscle, heart, eye tissue & skin tissue. The over all size of proposed antenna is greatley reduced in comparison to [5], which has the same transmission medium(vitreous humor) as that of proposed antenna.

Table I: Comparison of different antennae:

Ref No.	**Type of Design**	**ε_r, σ(s/m)**	**Volume (mm^3)**	**Gain (dB)**	**Propagation medium**
[5]	Rectangular spiral, 4 layers in MICS band	69, 1.53	13x12x4.06 =633.36	-40.35	Vitreous humor
[6]	Rectangular spiral, 3 layers in MICS band	46.7, 0.69	10^2x1.9 =190	-26.00	Skin simulated fluid
[7]	Circular Meandered & Spiral, 3 layers	15 tissue anatomical head	πx4^2x.65 =32.7	-42.4	Human Head
[9]	Circular, 3 layers	58.5,66,57.7,46.7,45.2 &0.84,0.97,1,0.69,0.61	πx7.5^2x1.9=335.75	-44	Muscle, heart, eye tissue, skin
Proposed antenna	Circular, spiral, 3 layers in Med-Radio band	69, 1.53	πx5.7^2x1.6= 163.31	-46.01	Vitreous humor

4. Conclusion

Although the human eye model used in this paper is not identical to the actual eye model, but the authors had tried to use the approximate model of human eye filled with vitreous humor for simulating the implantable antenna in Med-Radio band. Because of very high permittivity of the vitreous humor, *there is signal loss due to high propagation constant that are responsible to very low gain of the proposed antenna.* There is still a scope to improve the gain of antenna.

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