Nanoplasmonic Concurrent Dual Band Antennas Using Metal-Insulator-Metal Step Impedance Resonators

Chityala Ravi Kiran, Chandubatla Vinay Kumar

Abstract*: Nanoplasmonic antennas are the one of the major elements in the recognition of upcoming Nano scale wireless communication systems. In this article, the design and analysis of two multiband antennas operating at optical bands O and L bands, using metal insulator metal (MIM) slot waveguide based step impedance resonators (SIRs) has been investigated. The simulation results of the two antennas (A) and (B) are obtained by using full wave simulation software (CST Microwave Studio Suite) with the return loss -20 dB and -30.79 dB at desired optical bands. The proposed antenna (A) has a gain of 8 dBi at 1275-nm and 7.48 dBi at 1616-nm wavelengths, similarly antenna (B) has a gain of 8.46 dBi at 1294-nm and 6.23 dBi at 1613 nm wavelengths. The radiation pattern of the simulated results shows the omnidirectional pattern at desired wavelengths, which very useful for nanoscale wireless communication systems..

***Index Terms*: Nanoplasmonic, MIM SIR, CPW, Omnidirectional.**

I. INTRODUCTION

Recently, plasmonic nanoantenna plays an important role due to their characteristics such as small in size, beyond the diffraction limit, operates in the subwavelength regime. Plasmonic nanoantenna is a major element in the optical spectrum for allowing nanoscale wireless data communication. Initially, the plasmonic nanoantennas were operated at microwave frequencies, recently at mid-infrared frequencies and now at optical frequencies. Hence, plasmonic nanoantennas. Hence, plasmonic nanoantennas are one of the good candidates for the application of nanoscale wireless communication systems due to their reduction of size without compromising the efficiency, less expensive, low power consumption, and less power consumption.The various range of wireless applications requires wireless communication systems with more bandwidth and flexibility [1-2]. Recently, plasmonic concurrent dual band systems have been demonstrated to enhance the functionality of such systems by operating simultaneously at different frequency bands [3-5]. This will reduce the circuit elements, the entire size of the circuit and the power usage. Concurrent dual band antenna is a better candidate to confine different bands for wireless communication systems. Normally, plasmonic nanoantennas are designed by noble metals such as gold and silver due to their better metallic properties and less absorption loss [6-7]. Several plasmonic nanoantennas have been designed numerically analyzed and fabricated experimentally [8-10]. Also, an ultra wide band plasmonic nanoantenna has been described [11]. Dual patch antennas have been designed and reported for large bandwidth applications operates at two separate bands [12]. Instead of the above conventional architectures, concurrent dual band operation at different optical bands is the only solution for reducing the size, cost of the circuit power and consumption. Hence, a couple of concurrent dual band plasmonic nanoantennas has been demonstrated using metal-insulator-metal (MIM) waveguide with a coplanar waveguide (CPW) feeding in this article. The proposed antennas operate simultaneously in between O (1260 nm - 1360 nm) and L (1565 nm - 1625 nm) optical frequency bands. The geometry of the proposed antenna has been described in section II of this article. Section III describes the conclusions of the article.

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II. GEOMETRY AND OPERATION OF ANTENNA-A

The geometry of the proposed nanoantennas have been designed by using plasmonic metal insulator metal waveguide with a 50Ω CPW feed line, two similar step impedance resonators (SIRs) and a set of two similar parasitic slots as shown in antennas (A) (B). The SIR offers excellent controlling features at optical frequency bands. The proposed dual band antennas (A) and (B) operates simultaneously at optical bands at (A) 1275-nm (λ_0) and 1616-nm (λ_1) (B) 1294-nm (λ_0) and 1613-nm (λ_1). The proposed plasmonic CPW-fed antenna input impedance is given by

$$Z_{input} = \frac{Z_2}{2}\left(\frac{Z' + jZ_2 \tan\theta_2}{Z_2 + jZ' \tan\theta_2}\right) \tag{1}$$

where

$$Z' = Z_1\left(\frac{Z'' + jZ_1 \tan 2\theta_1}{Z_1 + jZ'' \tan 2\theta_1}\right) \tag{2}$$

$$Z'' = jZ_2 \tan\theta_2 \tag{3}$$

Where θ and Z are the electrical length and impedance respectively.

At resonance condition, the equation (1) signifies the impedance ratio (K)

$$K = \frac{Z_2}{Z_1} = \tan\theta_1 \tan\theta_2 \tag{4}$$

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In comparison to uniform impedance resonator (UIR), in the present structure, it is clear that not only the electrical length but also the impedance of MIM SIR regulates resonant frequencies. Using this extra structural facility, the resonant frequencies ratio gets more flexible and that is helpful for designing of broad-band or multifunctional/multiband antennas.

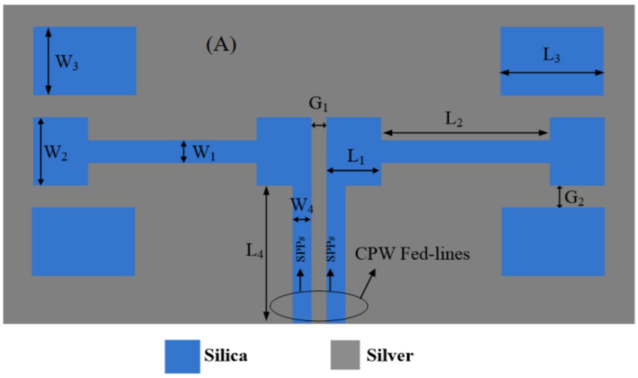

Fig.1 Geometry of proposed dual-band antenna-A for fixed widths W_1=132 nm, W_2=312 nm, W_3=350 nm, W_4=60 nm, lengths L_1=275 nm, L_2=1300 nm, L_3=500 nm, L_4=900 nm and gap G_1= 80 nm, G_2= 27 nm

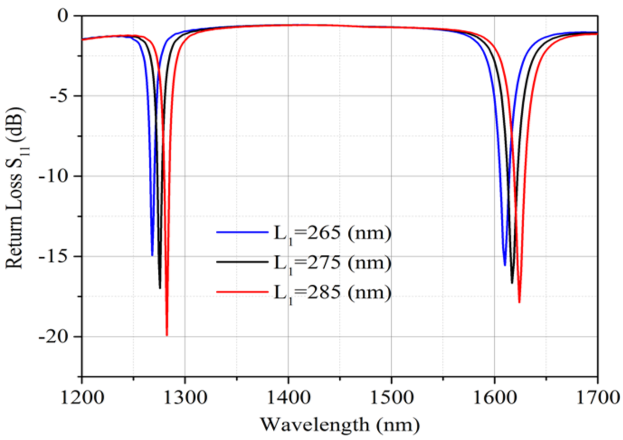

Fig.2 Variation of return loss with wavelength as a function of length(L_1)

The subsequent task is to obtain the impedance matching between CPW fed-line and MIM SIR resonators. In Fig.1 and Fig. 5, once the CPW fed-line is de-embedded, one can obtain the input impedance of the MIM slot dipole antenna. It can be observed that there are a lot of combinations Z_1 and Z_2 associated with the equal impedance ratio. Therefore, the designer has a freedom to modify the impedance Z_1 and Z_2 for satisfying the impedance matching at both bands, even after length ratio and impedance ratio are determined for specified frequency bands. The proposed MIM SIR based dual band antennas have been designed using SiO_2 (ε_i = 2.5) as dielectric material sandwiched with two metallic layers of silver. The waveguide dimensions of antenna (A) are chosen to be W_1 = 132 nm, W_2 = 312 nm, W_3 = 350 nm, W_4 = 60 nm, L_1 = 275 nm, L_2 = 1300 nm, L_3 = 500 nm, L_4 = 900 nm and gap G_1 = 80 nm, G_2 = 27 nm.

The simulation results have been carried out with the grid sizes of 5 nm ×5 nm along x and y-axes with the help of full-wave simulation tool (CST microwave studio suite) for both the antennas (A) and (B). The parametric variation of the design has been carried out to ensure the sensitivity of the desired bands with respect to the dimensions of the antenna. The variation in reflection coefficient (S_{11}) of the proposed antenna (A) with a return loss -20dB as shown in Fig. 2. It is confirmed that the desired bands of the antenna are sensitive with the variations in the length L_1 and all other parameters are constant. Fig. 3 and 4 shows the antenna radiation pattern, to ensure the dual band characteristics and omnidirectional pattern of the antenna which is very helpful in the nanoscale wireless communication systems.

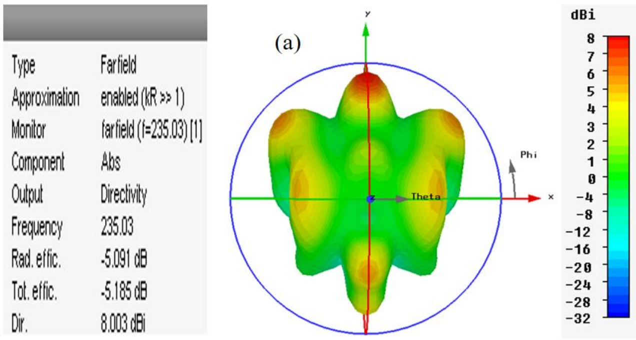

Fig.3 Radiation Pattern of antenna-A at wavelength λ=1275 nm

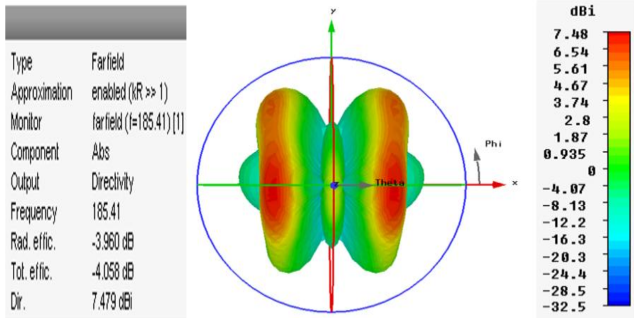

Fig.4 Radiation Pattern of antenna-A at wavelength λ = 1616 nm

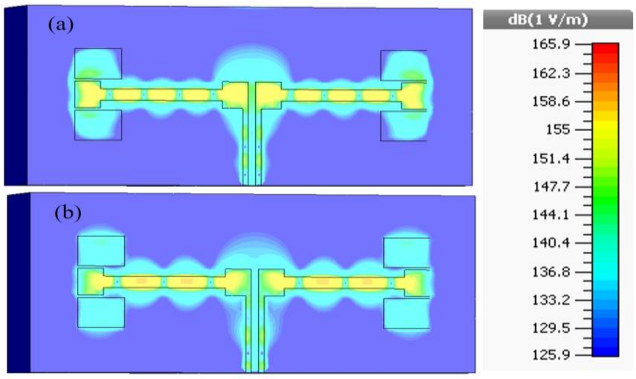

Fig.5 Field Distribution of antenna-A at wavelengths (a)1275 nm (b)1616 nm

The gain of the proposed dual band antenna is 8 dBi and 7.48 dBi at 1275 nm and 1616 nm wavelengths. The field distribution of the proposed antenna has been confirming that it has a concurrent dual band nature and shown in Fig. 5.

III. GEOMETRY AND OPERATION OF ANTENNA-B

The dimensions of the dual band antenna (B) are chosen to be W_1 = 128 nm, W_2 = 288 nm, W_3 = 450 nm, W_4 = 70 nm, W_5 = 80 nm, L_1 = 325 nm, L_2 = 1240 nm, L_3 = 500 nm, L_4 = 800 nm, L_5 = 250 nm and gap G_1 = 80 nm, G_2 = 30 nm shown in Fig. 6.

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The parametric variation of the design has been carried out to confirm the desired bands sensitivity with respect to antenna dimensions.

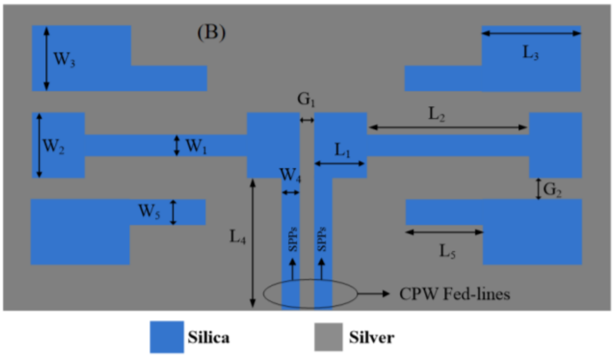

Fig.6 Geometry of proposed dual-band antenna-B for fixed widths W_1=128 nm, W_2=288 nm, W_3=450 nm, W_4=70 nm, W_5=80 nm lengths L_1=325 nm, L_2=1240 nm, L_3=500 nm, L_4=800 nm, L_5=250 nm and gap G_1=80 nm, G_2=30 nm

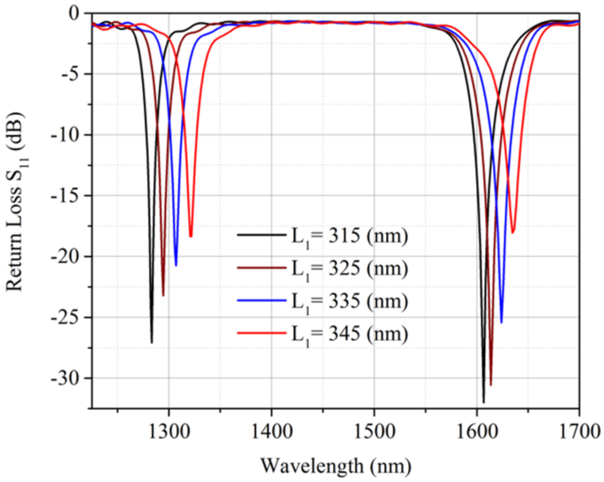

Fig.7 Variation of return loss with wavelength as a function of length(L_1)

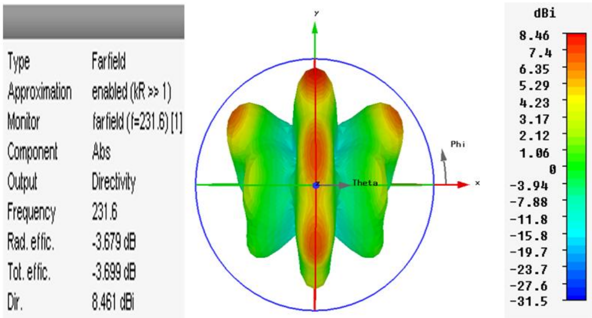

Fig.8 Radiation Pattern at wavelength λ= 1294 nm

The variation in reflection coefficient (S_{11}) of the proposed antenna (B) with a return loss of -30.79 dB shown in Fig. 7. It is confirmed that the desired bands of the antenna are sensitive with the variations in the length L_1 and all other parameters are constant. Fig. 8 and 9 shows the antenna radiation pattern, to ensure the dual band nature and omnidirectional pattern of the antenna which is very helpful in the nanoscale wireless communication systems. The gain of the proposed dual band antenna is 8.46 dBi and 6.23 dBi at 1294 nm and 1613 nm wavelengths. The field distribution of the proposed antenna has been confirming that it has a concurrent dual band nature and shown in Fig. 10.

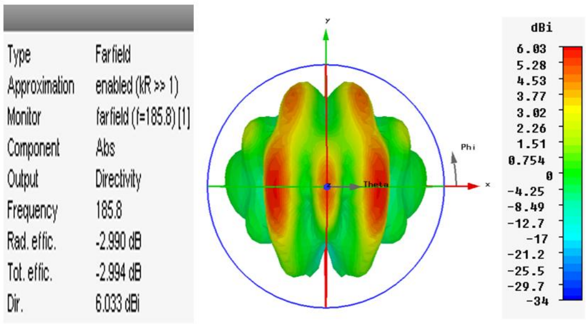

Fig.9 Radiation Pattern at wavelength λ=1613 nm

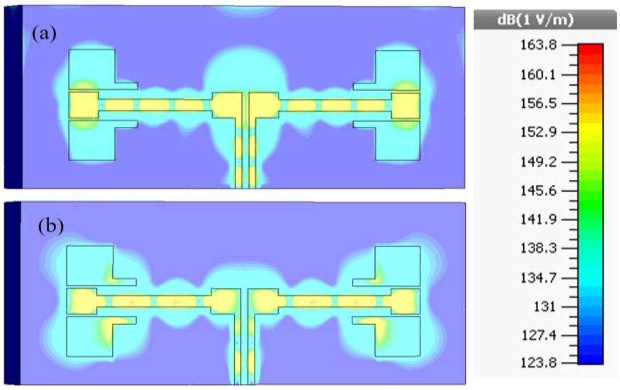

Fig.10 Field Distribution at wavelengths (a)1294 nm (b)1613 nm

IV. CONCLUSION

Different types of plasmonic concurrent dual band antennas are designed based on CPW fed line and MIM SIR waveguide at optical frequency bands O (1260 nm - 1360 nm) and L (1565 nm - 1625 nm). The antennas are designed for multifunctional and multiband applications. By using a set of MIM SIR waveguides and with two gaps G_1 and G_2. The desired bands of antennas sensitive with variation in the length L_1 of the resonators. The proposed antennas are used in the development of nanoscale wireless communication systems as well as it can be integrated into the photonic integrated circuits.

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