International Journal of Communication Systems and Network Technologies
ISSN-2053-6283

Enhancement of gain with stacked DRA for Fixed Satellite Communication

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***Abstract*—The stacked antenna in which one SDRA (square dielectric resonator antenna) and one CDRA (circular dielectric resonator antenna) has been formed. The current stacked DRA has been designed in CST replication software for FSC (fixed satellite communication application). The antenna measurements are studied for given patch antenna with single DRA, but as expected these antennas give reduced radiation efficiency and low gain but after using stacked DRA, gain and efficiency has been enhanced. In current antenna coaxial cable feeding has been used which increases the efficiency at high frequency range. The current design obtains 6.5 dB of gain and 6.8 dB of directivity at 27.5 GHz frequency. The radiation efficiency is 96% and total efficiency is 94%. The current stacked DRA antenna operates perfectly in between 26-30 GHz and gives the best results at 27.5 GHz frequency.**

Index Terms – DRA, stacked antenna, satellite communication, coaxial cable

I. INTRODUCTION

The progress in satellite technology has given rise to a prosperous satellite services sector, which provides various services to broadcasters, ISP agencies of the government, the armed forces, and other sectors. FSS is a type of commercial satellite communication, uses ground-based equipment at predetermined sites to receive and transmit satellite signals. FSS satellites play a critical role in sustaining both our local and global communication services, such as private business networks and worldwide internet connectivity. Satellites offer communication services in three categories, namely data communications, broadcasting, and telecommunications. Telecommunications services include offerings such as wireless, mobile, and cellular network providers and telephone companies, as well as telephone calls.[1]

Broadcasting services encompass direct-to-consumer radio and television services, as well as mobile broadcasting services. DTH or satellite television services, such as DirecTV and DISH Network in the United States, are received directly by households. Satellites are predominantly used to deliver cable and network content to local stations and their affiliates. Another important function of satellites is the distribution of programs to mobile devices such as laptops, PDAs, and cell phones [2-5].

Transferring data from one location to another is a component of data communications. Through the use of VSAT (very small-aperture terminal) networks, companies and other organisations who need to communicate financial and other information between multiple locations employ satellites to make this process easier. As the Internet has expanded, a sizable portion of Internet traffic now travels by satellite, making ISPs one of the primary users of satellite services.[6]

When land-based communication capabilities are unavailable during emergencies and natural catastrophes, satellite communications technology is frequently utilised. Emergency communication services can be provided in disaster zones using mobile satellite equipment [7].

Four steps are involved in FSC (fixed satellite communications): The process goes as follows: An uplink Earth station or other piece of ground equipment sends the necessary signal to the satellite, which amplifies it and modifies its frequency. The satellite then sends the signal back to Earth, where the ground equipment receives it.

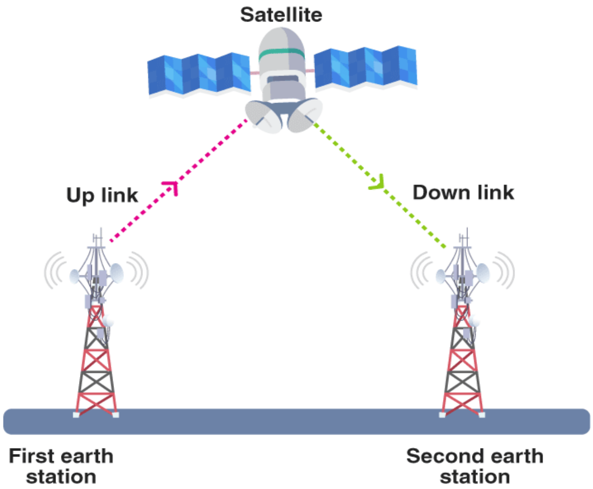

Fig 1: Earth to space and space to earth satellite communication [8]

The satellite frequency bands commonly used are C, L, S, X, Ku, and Ka. C band satellite frequencies usually fall within the 4 to 8 GHz range, while X band satellites operate between 8 to 12 GHz. Ku band satellites transmit in the 12 to 18 GHz frequency range, K band satellites in the

18 to 26 GHz range, and Ka band satellites in the 26 to 40 GHz range.

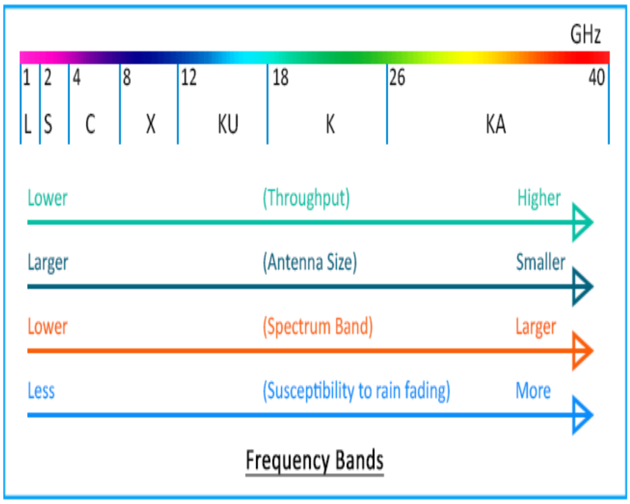

Fig 2: Satellite Frequency Band Spectrum [9]

A. DRA (Dielectric Resonator Antenna)

Due to its high Q potential, ceramic is frequently used to create DRAs, which are microwave antennas with a quick transition from a material with a higher dielectric constant to air. Higher frequencies give the designer the benefit of avoiding the loss associated with a conductor in the transmission channel. When it comes to miniaturization, this technique has the biggest impact because high relative permittivity is sought. DRA as an antenna was initially current in a 1983 publication. FSC (Fixed satellite communication) has attracted a lot of interest from DRAs due to its enticing features, such as its vast bandwidth, light weight, and great radiation efficiency. The bandwidth and size of the DRA are determined by the material's dielectric constantIt has been identified that the frequency range utilized by several systems has steadily shifted towards the millimetres range, which lies between 100 and 300 GHz.

Metallic antennas experience severe conductor loss at these frequencies, which drastically reduces their effectiveness. In contrast, the sole loss in DRA is a little amount of defective dielectric material loss. Research on the cylindrical DRA shows that DRAs radiate along the whole DRA surface, excluding the grounded portion, while MA (microstrip antennas) only emit through two tiny radiation slots. The DRA's avoidance of surface waves is another advantage it has over the MA. In particular for mm-Wave applications and beyond, DRAs are prospective alternatives for traditional radiating elements at high frequencies.[10-15]

B. Literature Survey

Numerous innovative antennas have recently been published in literature, but they fall short of meeting the need for fixed satellite communication's high directivity and gain. In addition, the literature outlines the contributions made by many researchers. A small Ku band MPA (microstrip patch antenna) was created. It has a 15GHz resonance frequency, a return loss of 50 dB, a VSWR under 1, and a gain of 6 dB [16].

Roopan exhibited a honeycomb-shaped slotted ground MPA for a broadcasting FSC (fixed satellite communication) application. The antenna was crafted and designed using a FR-4 (lossy) that has a dielectric constant of 4.4. FR-4 used was an 80 mm x 80 mm FR-4 with a height 1.62 mm. At its given frequency that is 11.85 GHz, the antenna exhibits a gain of 5.874 dB, a directivity of 5.995dBi, and a return loss of -39.57dB[17-19].

Different designs that were suggested by various researchers for the fixed satellite communication band have low efficiency and modest gains. Some authors move forward with creating Array, MIMO, or DRA to address these issues [9-10]. DRA is typically merged with other structures to improve performance. The stacked DRA was therefore added into the current work. The FSC (fixed satellite communication) frequency of 27.5 GHz, which the current antenna uses to function and increases the antenna's gain.[20-21]

II. SPECIFICATIONS OF THE ANTENNA'S FORM AND CONSTRUCTION.

The current stacked DRA has a substrate made of Rogers R04350B (loss free) material that is 0.254 mm height, 7.5 mm x 7.5 mm x 0.035 mm in size, and a ground made of PEC. The dimensions, dielectric constant, and thickness of the material are 3 x 3 mm^2, 20.8 mm, and 0.83 mm, respectively. Alumina (99.5%) (loss free) circular DRA with a 5 mm radius and 0.661 mm height. The current antenna uses a fixed satellite communication frequency of 27.5 GHz.

The coaxial cable that supplies all the antenna components results in impedance matching, EM (electromagnetic) radiation, and perfectly current distribution in the DRA. A Finite Integration Technique on the basis of electromagnetic modelling programme, CST software is used for analyzing.

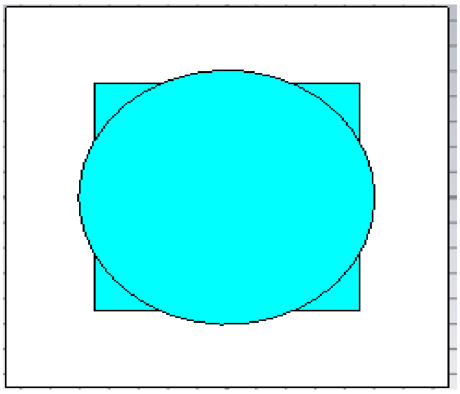

Fig: 3 (a) Stacked Dielectric Resonator Antenna

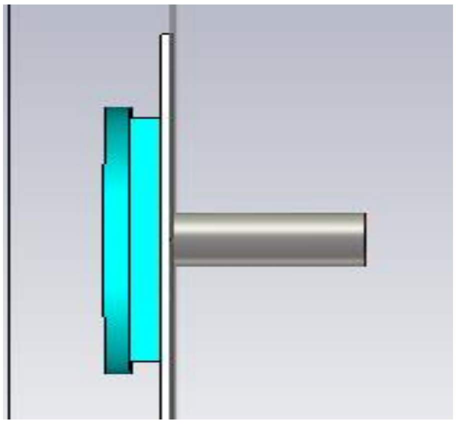

Fig: 3 (b) Side view of DRA with coaxial cable

CDRA measurements are used for calculating the DRA formula size :

$$fr = \frac{c}{2\pi a\sqrt{\epsilon r}}\left[1.71 + 2\left(\frac{a}{2h}\right) + 0.1578\left(\frac{a}{2h}\right)^{2}\right]$$

.

Where,
c = speed of light in vaccum
a = element radius of DRA
h = height.

CDRA is utilized for other resonating formation.

DRA comes across in major and vast shapes, like square, triangle, rectangle, torus ring, circular, etc. The rectangular DRA can be analyzed by the transmission line diagram. Using mathematical expressions, the standard DRA measurements is approximated.

Table 1: Measurements for the current task

Name	Values
x	15
y	15
h	0.254
t	0.035
a	3
b	3
d	0.83
r 2	0.42
r 1	1
d 1	0.661111
r 3	5

III. RESULTS AND DISCUSSION

A. RL (Return Loss)

RL may be measured dB, in the context of antennas, The reflection coefficient is a metric that quantifies the effectiveness of an antenna in transmitting and receiving signals by analyzing the proportion of its power of the reverberated signal to that of the sent signal.

Due to impedance mismatches in the transmission line or other components, some of the signal power that an antenna transmits is reflected back to the antenna. The incident signal is disrupted by the reflected signal, which lowers the power being sent. The value of signal power that is reverberated back to the antenna is measured as RL.

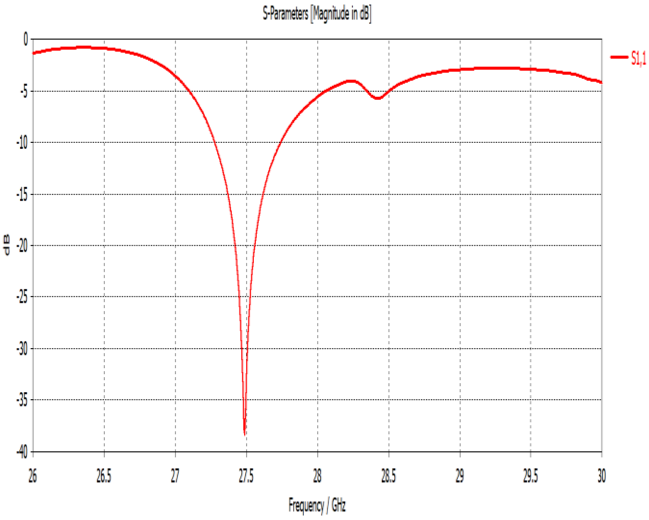

Fig 4: S_{11} of current work

Fig. 4. demonstrates the representation of RL which is replicated in CST modelling software. The current antenna formation is defined at 27.5 GHz and obtains a narrow band. According to the modelling outputs, the current antenna's resonant bandwidth is less than -10 dB. The FSC employs the 27.5 GHz frequency.

B. VSWR (Voltage Standing Wave Ratio)

VSWR is a metric that determines the level of compatibility between an antenna and the transmission line that supplies it. It gauges the antenna's ability to match the transmission line and is an essential measurement in antenna analysis. VSWR measures the power provided to an antenna. Not all of the energy received by the antenna is necessarily transmitted outside. Thus, VSWR measures radiative ability, and Figure 5 shows its curve. When the return loss is greater, the VSWR is at its lowest. A return loss of 15 dB, for instance, indicates 3% received, 97% radiates power, and VSWR equals 1.4. VSWR graphical representation vs. frequency is shown in Fig. 4.

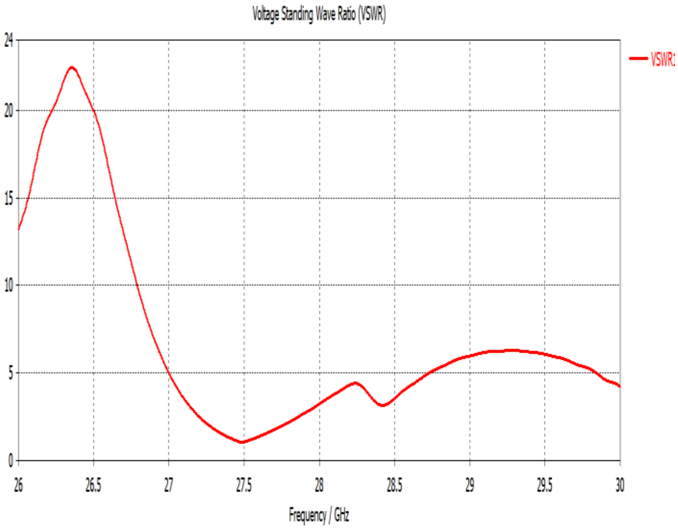

Fig 5: VSWR plot of the current work

C. *Directivity and Gain*

The fluctuation of simulated directivity and peak gain in dB versus frequency is shown in Figure 6. At 27.5 GHz frequency, the suggested design achieves 6.5dB of gain and 6.8dB of directivity.

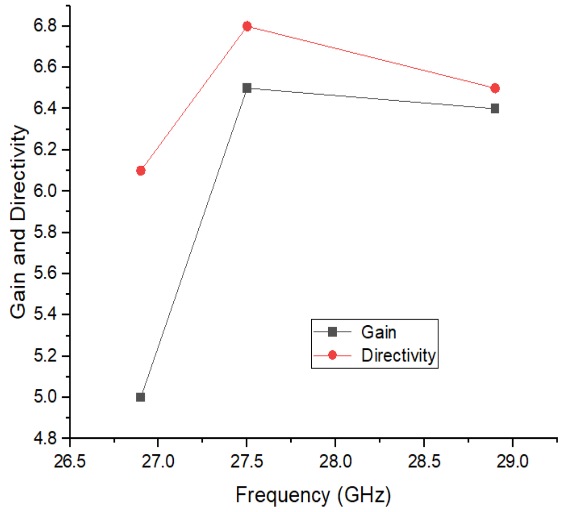

Fig 6: Gain and Directivity of current antenna

D. *RE (Radiation Efficiency)*

RE measures how well an antenna converts the radio-frequency power it receives at its connection points into radiated power. Total efficiency (TE) is 94% at 27.5 GHz, while RE is 96%. The RE and TE are shown in Figure 7 for the complete frequency range (26.5-29.5 GHz).

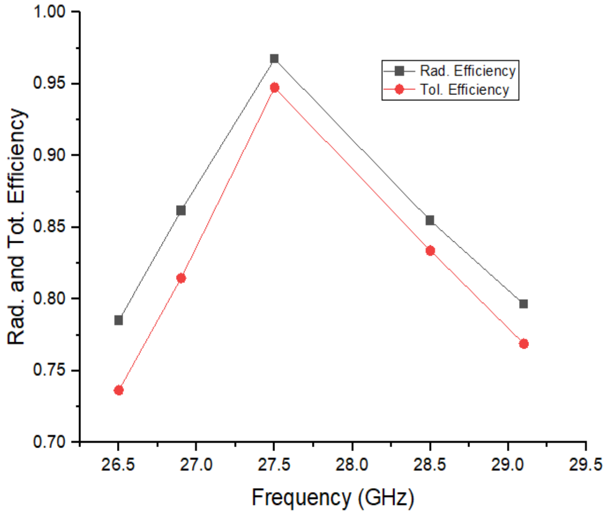

Fig 7: Radiation efficiency and Total efficiency of current antenna

E. *RP (Radiation Pattern)*

The RP of the antenna's far-field radiation identifies it. Figure 8 depicts the current stacked DRA antenna's simulated far-field RP at the specific frequencies' spectrum considering phi equals to 0 and phi equals to 90 degrees. The RP can be obtained to be steady and omnidirectional.

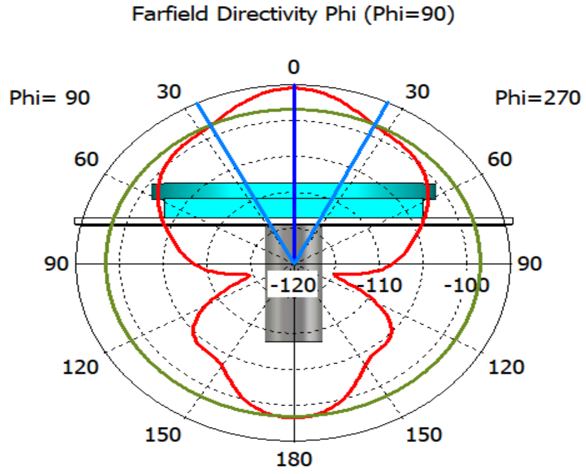

Fig 8: Radiation pattern of current work

F. *Current Task and Prior Research Examined*

Most of the cases. antennas for FSC application model. While MPA or DRA are commonly used in antenna model, there are instances where a stacked DRA is utilized to decrease potential losses. In this particular model, a combination of SDRA and CDRA is employed through stacking. The performance of the basic DRA shape in earlier work compared to the current one is shown in the following table.

TABLE 2: Performance differentiation of current work with past studies

S.no.	**DRA structure**	**Feeding process**	**TE/ Gain**	**Ref.**
1.	Slotted Elliptical DRA	Torus aperture coupled by a microstrip feed	75%/ 2.5dBi	[13]
2.	Front DGS Cylindrical DRA	CPW microstrip slotted line	83%/ 3.8dBi	[14]
3.	Slotted CPW Rectangular DRA	CPW patch with slotted line	95%/ 4.1dBi	[15]
4.	90-degree hybrid coupling Circular DRA	Triple strip insertion	89%/ 4.2dBi	[16]
5.	Torus DRA	Three vertical strips with double phase	92%/ 3.9dBi	[17]
6.	Cylindrical DRA	Conformal line	80%/ 3.5dBi	[18]
7.	Hollow Rectangular DRA	Conducting strips	85%/ 4dBi	[19]
8.	**Stacked DRA**	**Coaxial cable feed**	**96%/ 6.5 dB**	**Projected**

IV. CONCLUSION

The current Stacked antenna design which includes one square DRA, and one circular DRA resonates at 27.5 GHz frequency. This antenna enhanced the RE and gain and minimize the metallic losses The planned antenna design obtained the gain of 6.5 dB, 6.8 dB directivity, 96% radiation efficiency and 94% total efficiency. This projected antenna is perfectly suitable for FSC application at 27.5 GHz frequency.

ACKNOWLEDGEMENT

The first author wishes to express their gratitude to the Rajasthan Technical University in Kota, India, for their assistance during the research paper and drafting of the paper.

REFERENCES

1. S.-L. S. Yang, A. A. Kishk and K.-F. Lee, "Frequency Reconfigurable U-Slot MPA", *IEEE Antennas and Wireless Propagation Letters*, vol. 7, pp. 127-129, 2008.
2. https://ieeexplore.ieee.org/document/7955326
3. https://ieeexplore.ieee.org/document/6577042
4. https://cdn1.byjus.com/wp-content/uploads/2020/06/Physics-Images-Satellite-communication-4.png
5. G. M. Rebeiz and J. B. Muldavin, "RF MEMS switches and switch circuits, " IEEE Microwave Magazine, pp. 59-71, Dec. 2001.
6. K. L. Wong and K. P. Yang, "Compact dual frequency microstrip antenna with a pair of bend slot, " Electronic Letters, vol. 34, pp. 225-226, 1988.
7. I.J. Bahal and P. Bhartiya, Handbook of Microstrip Antenna, Artech House publishers, Dedham, MA, ISBN: 9780890065136, 2008
8. Balanies, C. A., Antenna Theory: Analysis & Design, 2nd edition, John Wiley & Sons, Inc., 1997
9. J. R. James and P. S. Hall, Handbook of Microstrip Antennas, IEEE electromagnetic, wave series pp. 28, ISBN: 9780863411502, 1993.
10. A. Singh and E. Sidhu, "Multi resonant slotted MPA (MPA) design for IMT WLAN & WiMAX applications", *SSRG International Journal of Electronics and Communication Engineering*, vol. 2014, no. 1, pp. 19-23
11. https://lotusarise.com/wp-content/uploads/2020/12/Satellite-Frequency-Bands.jpg
12. S. K. Dubey, S. K. Pathak and K. K. Modi, High GainMultiple Resonance Ku-band MPA, 978-1-4577-5/11/2011 IEEE.
13. P. Subbulakshmi and R. Rajkumar, "Design and characterization of corporate feed rectangular microstrip patch array antenna", *Emerging Trends in Computing Communication and Nanotechnology (ICE-CAN) Tirunelveli*, 2013
14. S.-L. S. Yang, A. A. Kishk and K.-F. Lee, "Frequency Reconfigurable U-Slot MPA", *IEEE*.
15. LEUNG, K. W. AND C. K. LEUNG, “WIDEBAND DIELECTRIC RESONATOR ANTENNA EXCITED BY CAVITY-BACKED CIRCULAR APERTURE WITH MICROSTRIP TUNING FORK,” ELECTRONICS LETTERS, VOL. 39, NO. 14, 1033–1035,JUL. 2003.
16. Bijumon, P. V., S. K. Menon, M. N. Suma, M. T. Sebastian, and P. Mohanan, “Broadband cylindrical dielectric resonator antenna excited by modified microstrip line,” Electronics Letters, Vol. 41, No. 7, 385–387, Mar. 2005.
17. Gao, Y., B. L. Ooi, W. B. Ewe, and A. P. Popov, “A compact wideband hybrid dielectric resonator antenna,” IEEE Antennas and Wireless Components Letters, Vol. 16, No. 4, 227–229, Apr. 2006.
18. Khoo, K. W., Y. X. Guo, and L. C. Ong, “Wideband circularly polarized dielectric resonator antenna,” IEEE Transactions on Antennas and Propagation, Vol. 55, No. 7, 1929–1932, Jul. 2007.
19. Li, B., C. X. Hao, and X. Q. Sheng, “A dual-mode quadrature-fed wideband circularly polarized dielectric resonator antenna,” IEEE Antennas and Wireless Propagation Letters, Vol. 8, 1036–1038, 2009.
20. Massie, G., M. Caillet, M. Clenet, and Y. M. M. Antar, “A new wideband circularly polarized hybrid dielectric resonator antenna,” IEEE Antennas and Wireless Propagation Letters, Vol. 9, 347–350, 2010.
21. Lim, E. H., K. W. Leung, and X. S. Fang, “The compact circularly-polarized hollow rectangular dielectric resonator antenna with an under laid quadrature coupler,” IEEE Transactions on Antennas and Propagation, Vol. 59, No. 1, 288–293, Jan. 2011.