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High Gain Reconfigurable Notch Band Antenna with FSS for Wireless Communication Applications

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ABSTRACT: A compact frequency and pattern reconfigurable antenna structure is designed with notching characteristics in this article. Antenna with notch band reconfigurability and pattern tilting is much needed in the modern communication systems for military communication applications. The designed monopole antenna has of corner truncated square element as radiating structure on the top layer and a defected ground on the lower side. The proposed model of the antenna is constructed on FR4 substrate of height 1.6 mm with area of 26 × 24 mm. Triple notch properties are exhibited by the antenna at 6, 9 and 17 GHz bands respectively. The designed antenna providing pattern tilt of -25º, 0, +25º with switching condition and the gain is improved with frequency selective surface (FSS) backing. The FSS placement improved the gain to 2.5 dB and the measurement results giving good matching to EM-simulation for validation.

Keywords: Truncation, Frequency Selective Surface (FSS), Monopole, Pattern Tilt, Gain Enhancement.

I. INTRODUCTION

During last one decade, the Wireless communication applications are growing tremendously with the advent of reconfigurable devices. The reconfigurability raising its bar from frequency reconfigurability to pattern and the polarization reconfigurability in the design of antennas suitable for various smart communication applications. Reconfigurability with notching characteristics are providing added advantage to the communication modules to select a particular band as well as to reject certain range. Shan proposed notch band antenna with coupling strips and Sefidi proposed antenna with dual notching in the ultra-wideband communication [1, 2].
Wang and Tang designed triple notch characteristics-based antenna models with asymmetric resonators and slots [3-4]. Kaur proposed DGS based notch band antenna and Gai proposed a microstrip fed slot antenna with reconfigurable behavior [5-6]. Researchers designed several models for notch band antennas with reconfigurability for single, dual band characteristics [7-12]. Parasitic strips, slotted structures and fractal elements are used in the design of the multi-notch band antennas [13-23]. The current work is focused on the design and development of triple band notch antenna with hybrid reconfigurability.

II. MATERIALS AND METHODS

The structure of the antenna and their iterations can be observed from the Fig. 1, 2 and 3. FR4 material is used in the design of the antenna model. Mathematical formulation for the design of the antenna with dimensional characteristics are presented in this section. The modelled structure dimensions list are exhibited in Table 1.

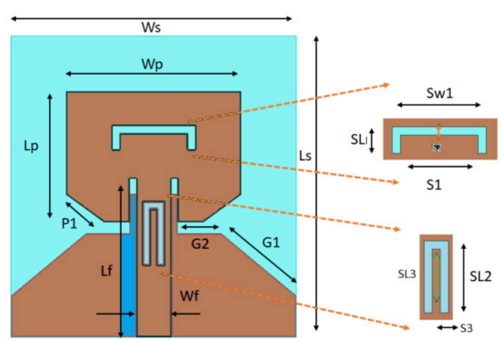


Fig. 1. Antenna Design Model 1.

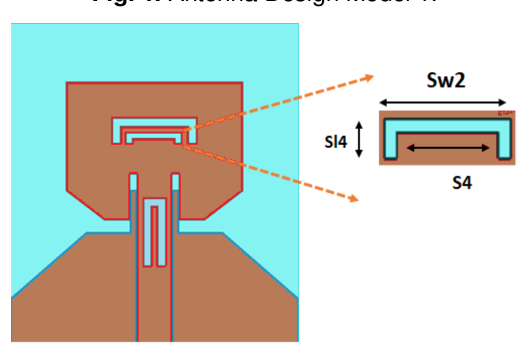


Fig. 2. Antenna Design Model 2.

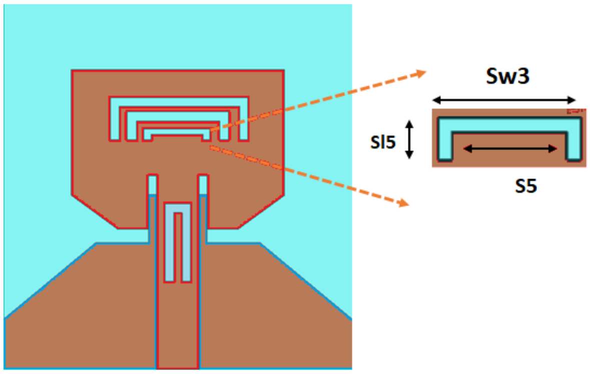


Fig. 3. Antenna Design Model 3 (Proposed).

Table 1: Antenna Parameters in mm.

S. No	Antenna Parameter	Dimension in mm
1.	Ws	24
2.	Ls	26
3.	Wp	15.2
4.	Lp	9.2
5.	Wf	3
6.	Lf	13.4
7.	G1	6.6
8.	G2	3.8
9.	Sw2	7.2
10.	Sl4	2
11.	S4	5.9
12.	K1	2
13.	K3	0.3
14.	P1	2.4
15.	S1	8.6
16.	S2	0.6
17.	S3	0.3
18.	SL1	3
19.	SL2	5.8
20.	SL3	5.5
21.	Sw1	9.8
22.	Sw3	4.7
23.	Sl5	1
24.	S5	3.6
25.	K2	2

The effective DC of the narrow slot microstrip line can be taken as

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \frac{\ln\left(\frac{\pi}{2}\right) + \left(\frac{1}{\varepsilon_r}\right)\ln\frac{4}{\pi}}{\ln\left(\frac{8h}{w}\right)} \qquad (1)$$

The microstrip line, signal propagation-based wavelength can be taken is

$$\lambda_m = \frac{\lambda_0}{\sqrt{\varepsilon_{re}}} \qquad (2)$$

The impedance can be determined from the Eqn. (3) and (4).

$$Z_{om} = \frac{\eta}{2\pi\sqrt{\varepsilon_{re}}} \ln\left(\frac{8h}{w} + 0.25\frac{w}{h}\right) \quad \text{for } w/h > 1 \qquad (3)$$

$$Z_{om} = \frac{\eta}{\sqrt{\varepsilon_{re}}} \left\{\frac{w}{h} + 1.393 + 0.667 \ln\left(\frac{w}{h} + 1.44\right)\right\}^{-1} \quad \text{for } w/h < 1 \qquad (4)$$

The width can be calculated from Eqn. (5)

$$\frac{w}{h} = \frac{2}{\pi}\left\{\frac{60\pi^2}{Z_{om}\sqrt{\varepsilon_r}} - 1 - \ln\left(\frac{120\pi^2}{Z_{om}\sqrt{\varepsilon_r}} - 1\right) + 0.39 - \frac{0.61}{\varepsilon_r}\right\} \qquad (5)$$

The effective length of the radiating patch can be calculated from Eqn. (6).

$$f_r = \frac{1}{2L_e\sqrt{\varepsilon_{re}}\sqrt{\varepsilon_0\mu_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (6)$$

The optimized width can be taken from the Eqn. (7)

$$W = \frac{1}{2f_r\sqrt{\varepsilon_0\mu_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (7)$$

The length can be determined for patch by

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{re}}\sqrt{\varepsilon_0\mu_0}} - 2\Delta L \qquad (8)$$

Here 'f_r' represents the resonating frequency.

III. RESULTS AND DISCUSSION

This section is providing the information regarding frequency and pattern reconfigurable antenna. Three diodes D1, D2 and D3 are placed on the radiating element for switching the slot gaps as shown in Fig. 4. These diodes based on the switching conditions, will alter the antenna electrical length. The three diodes can be switched between nine combinations and in some of the cases we found that beam tilting up to 25º in both left- and right-hand side. The simulation characteristics are collected from Ansys HFSS tool and the measurements are taken in the chamber with Anritsu combinational analyzer. Fig. 5 gives the measurement of S_{11} with frequency reconfigurability behaviour. The proposed model has eight operating states in which all states are giving frequency reconfigurability and in that three states are also providing pattern reconfigurability.

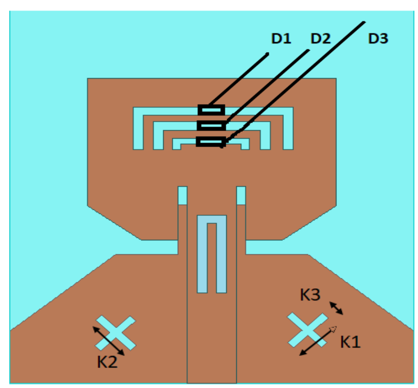


Fig. 4. Proposed antenna with diodes placement.

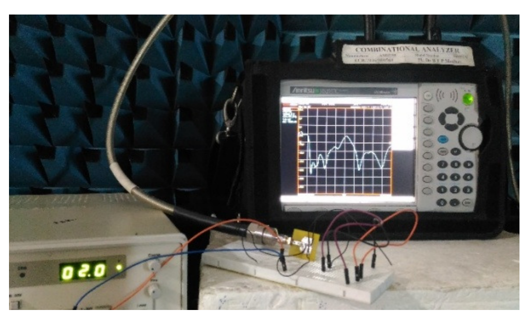
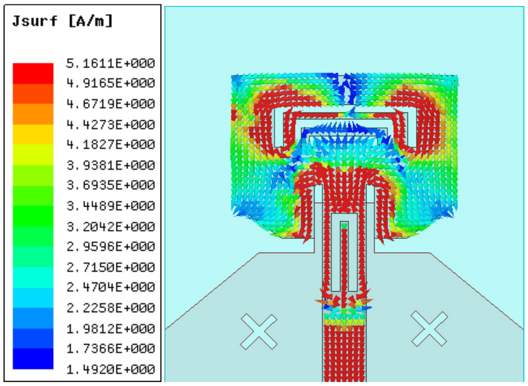
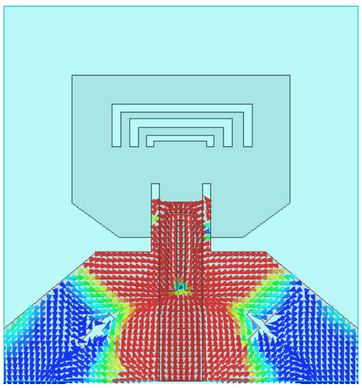


Fig. 5. Measurement of Frequency Reconfigurable behaviour with VNA.



(a) Patch Element.

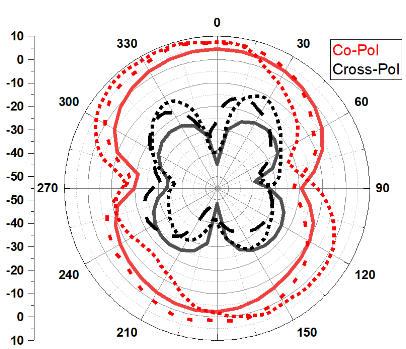


(b) Ground Plane.
Fig. 6. Current at 5 GHz.

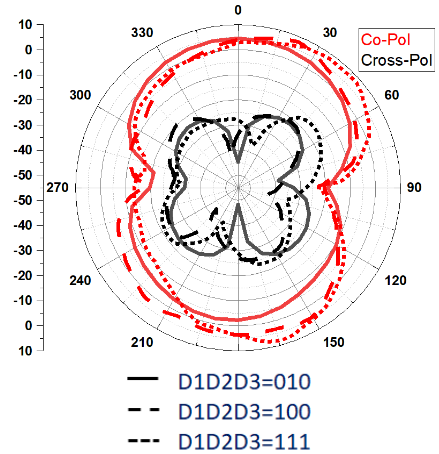
The surface current on the radiating structure and on the ground at 5 GHz can be observed from Fig. 6. The upper and the middle portion and the center part of the ground line exhibiting radiation characteristics at the desired frequency.

IV. PATTERN RECONFIGURABILITY

The pattern reconfigurability is attained with change in the current orientation on the radiating structure. Generally, in the conventional antenna system, the pattern tilting will be achieved by the excitation current phase change. The path of the current has been altered by placing the excitation source constant. In the three cases, the distance travelled by the current is more leading to the path difference and which effected the phase difference. The pattern reconfigurability can be witnessed in E and H-plane for three states from Fig. 7 and 8.



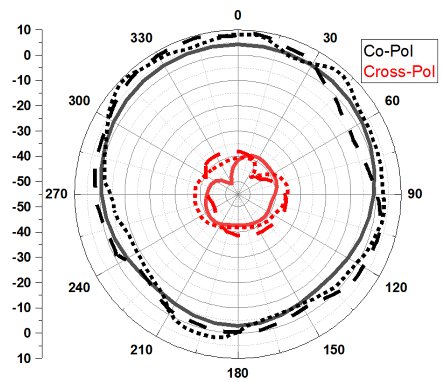
(a) 5 GHz.



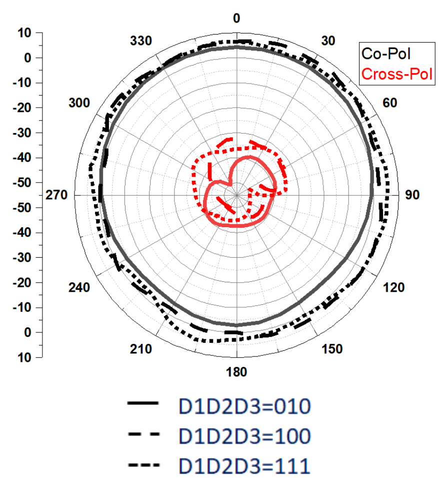
(b) 13 GHz.

Fig. 7. Measured radiation in E-plane.

The states 3, 5 and 8 are providing pattern reconfigurability. In state 3, diode D2 is ON, D1 and D3 are OFF, the radiation pattern is tilted up to 15º. In state 5, diode D1 is ON, D2 and D3 are OFF, the radiation pattern is tilted up to 25º. In state 8, diode D1, D2 & D3 are ON, the radiation pattern is tilted up to 20º. Here the direction of tilting is affected by the diode ON conditions.



(a) 5 GHz.



(b) 13 GHz.
Fig. 8. Measured radiation in H-plane.

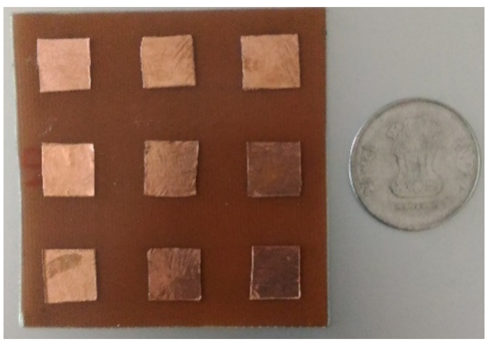
In the case of state 3, the peak identified gain of 3.3 dB and efficiency of 81% is achieved. In the case of state 5, the peak identified gain of 3.8 dB and efficiency of 82% is achieved. In the case of state 8, the peak identified gain of 3.6 dB and efficiency of 76% is achieved.

The antenna is working in the dual and the triple bands with frequency reconfigurability in all cases and pattern reconfigurability in three cases. In these cases, BAR 64-0.2 W p-i-n diodes for getting the reconfigurable behaviour. In the ON state the series inductance and the resistance are 1.8 nH and 2.1 ohms respectively. In the OFF state reverse resistance of 300 Kohms and the shunt capacitance of 0.2 pF and the feedlines and bias lines are isolated using suitable C and L components. The length of the bias line is 1 mm, thickness is 0.24 mm and the RF choke inductor of 32 nH.

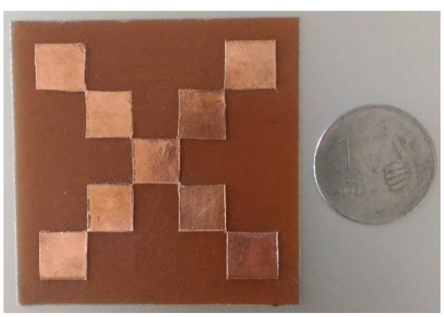
The biasing circuitry and the characteristic impedance are matched by choosing proper L and C values. The pattern tilting is occurred due to the excitation in the phase change. The path of the current travelling has been altered in the above mentioned three cases and the distance travelled by the current is increased and which is the responsible for phase difference.

V. DESIGN AND PLACEMENT ON FSS

Two types of frequency selective surfaces are designed to test the antenna for gain enhancement. Fig. 9 shows the square shaped patch structures of FSS, which can be placed beneath the designed antenna structure.



(a) Square shape array.



(b) Square shape cross.

Fig. 9. FSS Structures.

Initially antenna gain and efficiency is measured and presented along with the results of simulation results in Fig. 10. The comparative analysis providing the slight variation in the simulation and the measurement results. The placement of the FSS structures beneath the antenna improved the gain and the corresponding results of the gain and the efficiency values are projected in the Fig. 10. It has been observed that the gain is improved by 2.5 dB and the efficiency also raised to 95% with the placement of the FSS as a reflecting element below the antenna structure.

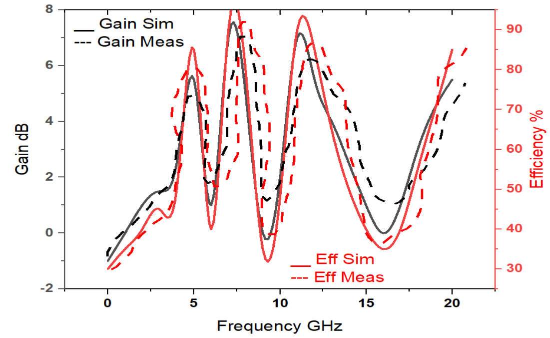


Fig. 10. Gain, Efficiency with Frequency (Without FSS).

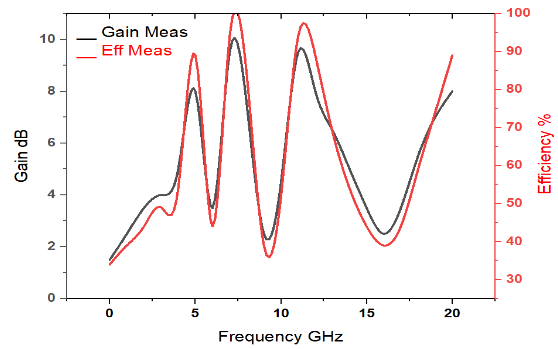


Fig. 11. Gain, Efficiency with Frequency (FSS).

The peak realized gain is more than 10 dB at 7 GHz and the average efficiency is 95% in the operating bands.

VI. CONCLUSION

A compact monopole antenna with frequency and pattern reconfigurability is presented in this paper. The designed antenna is operating between 2.4 GHz to 20 GHz with reconfigurable notching at two to three bands in the range. The proposed antenna is showing frequency reconfigurability for almost all the cases based on diodes switching conditions and especially for three cases it is showing pattern reconfigurability with tilt of -25º, 0, +25º. A peak identified gain of 10 dB is observed from the FSS based antenna model. Average efficiency of 95% is achieved in this design with good matching with measurement result.

VII. FUTURE SCOPE

Hybrid reconfigurability can be achieved with flexible behavior in the future work.

Conflict of Interest. No Conflict of Interest.

REFERENCES

[1]. Shan, K., Ruan, C. L., & Peng, L. (2010). Compact UWB antenna with band-notched characteristic using a coupling strip. In *2010 International Symposium on Intelligent Signal Processing and Communication Systems*, 1-4.

[2]. Sefidi, M., Zehforoosh, Y., & Moradi, S. (2015). A novel CPW-fed antenna with dual band-notched

charectrestics for UWB applications. *Microwave and Optical Technology Letters*, *57*(10), 2391-2394.
[3]. Wang, Z., Liu, J., & Yin, Y. (2016). Triple band-notched UWB antenna using novel asymmetrical resonators. *AEU-International Journal of Electronics and Communications*, *70*(12), 1630-1636.
[4]. Tang, Z. J., Zhan, J., & Wu, X. F. (2015). Compact triple band-notched printed antenna with multislots for UWB applications. *Microwave And Optical Technology Letters*, *57*(9), 2056-2060.
[5]. Kaur, J., Khanna, R., & Kartikeyan, M. (2014). Novel dual-band multistrip monopole antenna with defected ground structure for WLAN/IMT/BLUETOOTH/WIMAX applications. *International Journal of Microwave and Wireless Technologies*, *6*(1), 93-100.
[6]. Gai, S., Jiao, Y. C., Yang, Y. B., Li, C. Y., & Gong, J. G. (2010). Design of a novel microstrip-fed dual-band slot antenna for WLAN applications. *Progress In Electromagnetics Research*, *13*, 75-81.
[7]. Huang, S. S., Li, J., & Zhao, J. Z. (2014). A novel compact planar triple-band monopole antenna for WLAN/WiMAX applications. *Progress In Electromagnetics Research*, *50*, 117-123.
[8]. Nouri, A., & Dadashzadeh, G. R. (2011). A compact UWB band-notched printed monopole antenna with defected ground structure. *IEEE antennas and wireless propagation letters*, *10*, 1178-1181.
[9]. Abbosh, A. M., & Bialkowski, M. E. (2009). Design of UWB planar band-notched antenna using parasitic elements. *IEEE Transactions on Antennas and Propagation*, *57*(3), 796-799.
[10]. Acharya, I., & Upadhyay, D. (2015). A Novel Circular Fractal Antenna with Band Notch Characteristics for UWB Applicatons. In *2015 Fifth International Conference on Advances in Computing and Communications (ICACC)* (pp. 245-249).
[11]. Sahoo, M., & Sahu, S. (2015, March). Design & development of UWB notch antenna with fractal geometry. In *2015 International Conference on Circuits, Power and Computing Technologies [ICCPCT-2015]* (pp. 1-5). IEEE.
[12]. Li, T., Zhai, H. Q., Li, G. H., & Liang, C. H. (2012). Design of compact UWB band-notched antenna by means of electromagnetic-bandgap structures. *Electronics letters*, *48*(11), 608-609.
[13]. Hamid, M. R., Hall, P. S., Gardner, P., & Ghanem, F. (2010). Switched WLAN-wideband tapered slot antenna. *Electronics letters*, *46*(1), 23-24.
[14]. Li, Y., Li, W., & Mittra, R. (2012). A cognitive radio antenna integrated with narrow/ultra-wideband antenna and switches. *IEICE Electronics Express*, *9*(15), 1273-1283.
[15]. Debab, M., & Mahdjoub, Z. (2018). Characteristics UWB Planar Antenna with dual notched bands for WIMAX and WLAN. *Advanced Electromagnetics*, *7*(5), 20-25.
[16]. Saravanan, R.A., Madhav, B. T. P., Venkateswararao, M., Sahiti, V. S., Swetha, V., Priyanka, V. K., & Anand, P. S. (2019). Frequency and Pattern Reconfigured Multi Band CPW Antenna for WiMAX and X-Band Applications. *International Journal of Innovative Technology and Exploring Engineering, 8*(6), 1202-1208.
[17]. Allam, V. K., Madhav, B. T. P., Anilkumar, T., & Maloji, S. (2019). A Novel Reconfigurable Bandpass Filtering Antenna for IoT Communication Applications. *Progress In Electromagnetics Research*, *96*, 13-26.
[18]. Vamseekrishna, A., Madhav, B. T. P., Anilkumar, T., & Reddy, L. S. S. (2019). An IoT Controlled Octahedron Frequency Reconfigurable Multiband Antenna for Microwave Sensing Applications. *IEEE Sensors Letters*, *3*(10), 1-4.
[19]. Madhav, B. T. P., Monika, M., Kumar, B. S., & Prudhvinadh, B. (2019). Dual band reconfigurable compact circular slot antenna for WiMAX and X-band applications. *Radioelectronics and Communications Systems*, *62*(9), 474-485.
[20]. Lakshmi, M. L. S. N. S., Madhav, B. T. P., Khan, H., & Pardhasaradhi, P. (2019). EBG Loaded Compact Wide-Notch Band Antenna with Frequency Reconfigurable Characteristics. *Journal of Engineering Science and Technology, 14*(4), 1878-1892.
[21]. Reddy, V. S., & Prasad, M. S. G. (2019). Design and Implementation of Dual Notch Band Characteristics in UWB Antenna for Wireless Personal Communications. *International Journal of Advanced Trends in Computer Science and Engineering*, *6*(4), 1719-1725.
[22]. Anilkumar, T., Madhav, B. T. P., Hawanika, Y.S., Rao, M. V., & Prudhvinadh, B. (2019). Flexible Liquid Crystal Polymer Based Conformal Fractal Antenna for Internet of Vehicles (IoV) Applications. *International Journal of Microwave and Optical Technology, 14*(6), 423-430.
[23]. Bandi, S., Nayak, D. K., Madhav, B. T. P., & Tirunagari, A. (2019). Transparent Circular Monopole Antenna for Automotive Communication. *Applied Computational Electromagnetics Society Journal*, *34*(5), 704-708.

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