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## Multi-polarized Sinuous Antennas for Multiple Applications: Comprehensive Review

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**ABSTRACT:** Modern systems like radars, satellites, jammers trackers use wideband, low profile, compact antennas for effectively perform their functions. Also, dual polarized antennas are gaining importance in many systems like satellite communications, tactical communications, Wi-max, etc., to avoid cross coupling among these systems during their operations. Many emerging technologies with multiple functions require these types of antennas. The best solution proposed for these current and future requirements are sinuous antennas which are multi-band and multi-polarized antennas. The applications that are envisaged using these antennas are S-band satellite communications, 5G, Wi-max, Ku-band satellite communications, surveillance systems and IOT. Sinuous spiral antenna is the most suitable antenna for those applications because of it is having significant characteristics like wideband, multi polarization and excellent gain. In this paper, a comprehensive literature survey has been carried out on sinuous antennas and the same are presented. The author would like to carry out simulation studies and experimentations and publish few more papers on these types of antennas for various applications in the frequency range from 1GHz-18 GHz in various frequency bands.

**KEYWORDS:** Width Ratio (BWR), Impedance, Matching networks, Sinuous, Spiral, Ultra Wide Band (UWB).

### I. INTRODUCTION

A sinuous antenna that can sense opposite polarizations and have wideband characteristics is being introduced [1]. The antenna designed was flush mountable and dual-polarized. The antenna with constant input impedance, consistent radiation patterns with flat gain over broadband was described [2]. A sinuous antenna is characterized by line consisting of curves or curves and sharp turns or bends or straight lines with sharp turns and zigzag fashion bends also. A sinuous antenna which is a self-scaling factor including a log-periodic structure is described the antenna performance is frequency independent and the experimental results of half-power beamwidths have been observed. The merits of sinuous antennas are described by Du Hamel. Log-periodic, quasi-log-periodic sinuous antennas are examined in which there is a control over the beamwidth up to a greater extent as compared to the sinuous antenna. Dual-circularly-polarized log-periodic and quasi-log-periodic sinuous antennas have high radiation patterns with low axial ratio, low side lobes, and back lobes. The sum and difference of radiation pattern of four tilted beams useful for direction detecting applications. The axial ratio of the received wave can be measured by these antennas. Uni-directional radiation patterns can be obtained by using conical spiral structures rather than planar spirals. Circular polarization can be obtained by using crossed log-periodic dipole antennas and the axial ratio is low with a uni-directional pattern. The large difference in the beam with values of E-plane and H-plane of a log-periodic dipole antenna makes the axial ratio to rise rapidly. In the case of the quasi-log-periodic antenna, a cell number  $p$  is defined as a function of  $\tau$  is the dimensional relation between on cell with the adjacent cell. A quasi-log-periodic antenna can be mode to produce higher bandwidths only when there are appropriate changes in the  $\tau$  value and angles occur.

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## II. LITERATURE REVIEW

Ramanan Balakrishnan, Koen Mouthaan, et.al were developed the Self-complementary four-arm sinuous antennas are used to understand a nine-element uniform planar array with dual-polarization capability with help of CST microwave studio and effects of the connections between adjacent antenna elements are analyzed to expand the bandwidth in the lower operating frequency region. The connections become better the reflection coefficient at higher frequencies to obtain the performance predicted by theory. But at the lower frequencies, a new frequency band is added additionally. The improvement changes in the active reflection coefficient and realizes the gain of the antenna reported together using the feeding techniques for both circular-polarizations [3].

Chen Xu, Fang lina, Wu Xianfeng et.al have been proposed a miniaturization ultra-wideband two arms sinuous antenna is designed and fabricated with microstrip balun feed is used for based on the non-contact life breathing monitoring. For good unidirectional, a backed reflection cavity is used. The simulated and measured results such as return loss less than -10dB with the frequency band 6GHz to 9GHz and directivity radiation pattern for E-plane and H-plane are in good response with simulation results. The designed antenna meets the requirements and suitable for an ultra-wideband life monitoring system [4].

A. Manna, P. Baldoner, F.Trotta, et.al had designed A novel planar low profile UWB sinuous slot radiating element is designed for suitable applications like ESM and ECM systems. The designed radiating element is to cover a frequency band (i.e. 3:1). The antenna size along with the boresight axis is smaller than  $\frac{\lambda_0}{4}$ , where  $\lambda_0$  is the wavelength at the

central frequency operation. A novel sinuous slot feeding structure is designed to obtain a goal. The realization and characterization of a sinuous prototype antenna are presented and showing very promising electrical results in terms of Return Loss, Gain, Boresight and Half Power Beamwidth (HPBW) [5].

H.S.Zhang, K.Xiao, L.Qiu, et.al have been demonstrated that a feeding method for a four-arm sinuous antenna for the direction-finding system with a frequency bandwidth of 0.6GHz-2GHz. It is an effective way to solve the feed problems and input impedance of the four-arm sinuous antenna. The measured results of VSWR and radiation pattern provide the designed antenna excellent performance in the operating frequency bandwidth [6].

Z.Jiang, S.M.Rahman, P.Fay et.al developed a Lens coupled planar sinuous antenna has been designed in this paper including a Schottky diode at the centre suitable for designing optically balanced HEX mixers and posses ultra-wideband characteristics. The antenna structure makes the impedance to be independent over a wide frequency range at the value of 100 ohms. The simulated radiation pattern results are reported for 196 GHz and 585 GHz frequencies. The isolation of about 15dB is obtained at two frequency bands at 190-210 GHz, 570-630 GHz making the design suitable to use for Tetra Hertz [7].

Timothy Samson, Tom Cencich et.al analysed a bidirectional sinuous antenna with a lossy cavity has been introduced in this paper. Even though lossy cavity creation involves cost, it is preferred to overcome the mismatch loss. By making the sinuous antenna non-complementary near the feed, the impedance matching can be achieved at the desired frequency band and is made complementary at large diameter to observe frequency-independent characteristics. The performance efficiency of the sinuous antenna can be increased by choosing the low profile cavity with a light load. The impedance matching can be increased by a tapered non-complementary sinuous antenna which maintains good WoW and axial ratio thereby improved performance radiation characteristics [8].

Yuan Yan, Qunsheng Cao et.al designed a four-arm sinuous antenna with a reflective cavity is being studied and designed for 4-14 GHz frequency range. The cavity is filled with an absorbing material, which increases the unidirectional radiation performance. The antenna with a cavity filled absorbing material is simulated using EM software. The absorbing material decreases the reflections between free space and cavity to get good uni-directional properties and enhances the bandwidth. A multilayer microwave absorbing materials can be used for better performance in future work [9].

Y. Kang, K. Kim, W. R. Scott et.al analysed a sinuous antenna with modified arms being introduced in this paper suitable for ultra wide band characteristics in radar communications when this antenna excited by a temporary short duration pulse, the radiation waveforms in the time domain shows a ringing pulse with long tail after the main chirp

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pulse. The ringing is caused by the resonance effect of the structure set up on the antenna arms, and can be eliminated by modifying the arms structure, with constant gain over desired frequency range. CSA, SERSA, MSA5 are the three types of sinuous antenna used in monostatic radar, which are designed, fabricated and tested. The reported measured results shows the advantages of designed. MSA5 antenna in terms of impedance, reflection coefficient co-polarized gains. A dip was observed in the gain of CSA at 1.7GHz because of its sharp ends. This problem eliminated by removing the sharp ends and the structure now named as SERSA but a ringing occurs at 2.9GHz because of the coupling between the sinuous bends. The modification of bends causing MSA5 antenna design [10].

Karim Mohammad Pour Aghdam, Reza Faraji-Dana, Jalil Rashed-Mohassel et.al optimized tapered microstrip baluns are designed which are used in frequency independent sinuous and spiral antennas. These antennas need broad band balun to match with a coaxial line of 50ohms impedance and input impedance of 200ohms. The linear tapered microstrip tapered balun designed for sinuous antenna may not be optimal. In this view an optimal tapered appropriate balun has been designed and fabricated for the range 2-18GHz. The simulation results shows better values of reflection coefficient over this frequency range. An optimized non-linear transducer is used where continuous variations in the transmission characteristics read to an optimum balance to unbalance characteristics [11].

Mohammad Vahdani, Sara Salemheshari, et.al were designed the two different sinuous antennas of equal size 5.3 cm X 5.3 cm are designed and the performance of these two sinuous antennas are compared in terms of return loss and bandwidth. The two sinuous antennas are named as Duhamel's, Vahdani's sinuous antennas in which antenna possesses ultra-wideband characteristics over the range 2.5GHz to 13GHz whereas with return loss less than -10dB, whereas the second antennas have lesser bandwidth compared to first one over the range 3.3GHz to 10.5GHz with considerable return loss during simulation the other parameters like input impedance, Gain and HPBW are also. Examined, compared and reported. Vahdani's antenna has higher gain and low input impedance as compared to Duhamel's. Vahdani's HPBW is also good and proved more directive as compared to Duhamel's [12].

Song Lizhong et. al analysed a kind of conformal sinuous antenna has been discussed in this paper which is mounted on the circular truncated cones surface the performance of the coned conformal sinuous antenna is analysed by its simulation radiation characteristic results. First, the four-arm sinuous antenna is designed and it is converted into conformal by the project this structure on a truncated cone. The diameter of the cone is 60mm and height is chosen as 30mm the observed simulation results show UWB characteristics within the range 2-8GHz, with average VSWR value less than 3, and the characteristic impedance value at the transmission line terminal is 180Ω with the frequency range the main load is wider but changing frequency will cause the changes in the direction of the main load. The Antenna possesses dual-polarization and conformal characteristics, but there is a degrade at in radiation characteristics is compared to a planar sinuous antenna [13].

Yunsu Kang, Kangwook et.al Kim described about a sinuous antenna whose arms are modified because of achieving optimum polarization and group delay. The CSA possesses broad band characteristics but the simulation results of polarization and group delay lots as a function of frequency shows unwanted spikes. This problem is caused by the sharp ends and bends of the sinuous antenna. This paper concentrating on removal of these spikes by eliminating these sharp ends and bends of the arms [14].

Rohit Sammeta, Dejan Filipovic et.al examined a flush mountable cavity backed lens-loaded sinuous antenna operating in the frequency range from 500MHz-3GHz is designed and its performance is examined by power tests. It is suitable for high power applications as its power rating is ten times more than the conventional sinuous antennas. The Quasi-frequency independent performance characteristics are deeply demonstrated. The results conclude that the sinuous antenna designed is suitable for high power radiated fields with high quality over a wide frequency range [22].

Hossein Emami, Niusha Sarkhosh et. al developed a sinuous antenna with photonic feed system is designed and is practically demonstrated the feeding is provided to the antenna by using four wide band signals with 90° phase shift. The feed system having the ability to reconfigure and receive signals with different polarizations. This can be achieved by a computer base bias controlling without using mechanical function [15].

Song Lizhong, Cong Guojin, Hong Huanfeng et.al designed a four-arm hemispherical conformal sinuous antenna is discussed, simulated and analysed. The simulation results show UWB characteristics within the range of 3 to 18GHz with larger beamwidth. The VSWR value is obtained in the limited range by keeping a 50-ohm load resistor at the end of two arms. The antenna possesses orthogonal dual linear polarization at various frequency points within the operating frequency range. The radiation pattern a little bit fluctuates during any increase in frequency. The coupling effect is

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very strong between the two ports of polarization. This type of antenna can be suitable for UWB radar communications [16].

Nicol Steenkamp, Dirk I.L. de Villiers, Ngoy Mutonkole et.al were discussed a wideband pyramidal sinuous antenna over a conducting plane has been discussed and designed which can be useful as a feed for reflector antenna. The sinuous shape is projected on a cone and a comparison made between conical and pyramidal projected sinuous antennas for use as feed for wideband reflectors antennas. The prototypes are examined with an operating frequency of 2 to 6GHz. The simulated results are similar for cone and pyramidal projections but the manufacturing of pyramidal structure is simpler as compared to a cone. In future work of the bandwidth can be extended to a decade by modelling the substrate effectively for designing of reflector system used in the SKA radio telescope [17].

### III. RADIATION CHARACTERISTICS OF AN ANTENNA ELEMENT AND CONDITIONS OF FREQUENCY INDEPENDENT

The radiating element properties are depends on a function of its element size and it should be evaluated at the operating frequency. If the antenna is designed in such a way for any arbitrary scaling of its physical dimensions obtained the original structure, then its properties should be frequency independent. Since the antenna dimensions (in terms of wavelengths) could be similar at all frequencies. If the antenna designed independent from the scaling as discussed above and satisfies the conditions of frequency independence from scaling and could be defined by angles always.

#### Frequency independent performance of Log Periodic

The antenna constructed by fixed scaling factor  $\tau$  and it should be transformed to itself. Under these conditions, the frequency performance is hoped for similar at frequency ( $f$ ) and at that frequency  $\tau f$  similar as previous. The frequencies are in periodic with period of  $\log \tau$ . Therefore it's named as log-periodic. The performance of periodic variations in desired limits by choosing scaling factor  $t$  closed to unity. The requirement of structure rotation itself when it is scaled, it implies that it is extended from 0 to  $\infty$ . By choosing a portion of log-periodic structure and its two sphere radii lies between  $r_1$  and  $r_2$ . Therefore we can obtain good frequency independent response. These radii can be obtained by properly choosing of lower and upper cut of frequency for the desired operating frequency range. The active resonant region is lies between two extremists of the desired frequency range. The interior structure radiates good amount of radiation due to this sufficient currents are attenuated near the ends.

#### The Input Impedance of a Structure for Requirements of the Frequency Independent

Frequency independence of the input impedance is a highly desirable property of an antenna element because it makes it easier to efficiently couple the RF energy to the radiating element at all frequencies, without the need to resort to frequency-dependent impedance transforming networks. It was shown by Booker [18], that an antenna element that is self complimentary has input impedance, which is not a function of frequency. A self complimentary structure does not guarantee a frequency-independent radiation pattern, but if a log periodic antenna is constructed to be self complimentary, then the element will exhibit a periodic variation in the radiation characteristics while having constant input impedance. As stated earlier the periodic variation of the radiation characteristics could be made small by assigning to  $\tau$  (the log-periodic scale factor,) value close to unity. Such a structure would have a frequency-independent radiation pattern and input impedance. This is the underlying design philosophy followed to design the sinuous element.

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## IV. DESIGN AND FABRICATION OF THE SINUOUS ANTENNA

The necessity of having two equivalent structures is crucial for dual polarization in which each structure provides one sense of polarization. In order to achieve orthogonal polarization sense, a two equal set of arms are generated to provide linear polarization by rotating the arms  $90^\circ$  each. This has to be done in such a way that the two sets of arms do not bisect each other and therefore this geometry of the antenna follows the principles of log-periodic

### Creating Curve of sinuous

The considered log-periodic structure has been composed of "cells", in which each cell is a scaled version of its previous one. The sinuous curve consisting of cells of the sinuous structure is defined by the equation [19].

$$\phi = (-1)^p \alpha_p \sin \frac{180 \ln( r / R_p )}{\ln( \tau_p )} \quad (1)$$

From fig 1a the sinuous arm has been created in which the sinuous curve has been derived from the above equation.

### Generating the Pattern of Sinuous

The sinuous curve formed above was swept through an angle  $\pm \delta$  about its axis to obtained one sinuous arm (fig 1b). This arm was copied after a rotation of  $180^\circ$  about the origin. This created one dipole. This structure was now copied after rotation of  $90^\circ$  about the origin, to obtain the desired dual dipole (and hence dual polarization) sinuous antenna. The completed four-arm structure below (fig 1c).

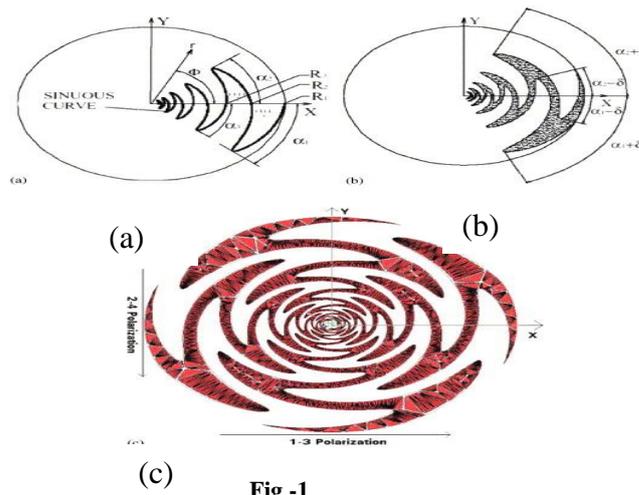


Fig -1

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## DIFFERENT TYPES OF ANTENNAS WITH FREQUENCY RANGES COVERED

Year	Antenna Used	Frequency Band
1987	Sinuous antenna	1.0GHz-2.5GHz
1991	Sinuous microstrip antenna	2GHz-10GHz
1993	Sinuous spiral antenna	1.2GHz-1.7GHz
1995	Linear log sinuous wire antenna	1 GHz-2.5 GHz
2005	Conical sinuous antenna	0.5GHz-3GHz
2009	Log periodic conical sinuous antenna	30 MHz to 3 GHz
2010	Conformal sinuous antenna	2GHz-8 GHz
2010	Planar cavity backed sinuous antenna	20GHz-50GHz
2011	Planar low profile sinuous slot antenna	6GHz-18GHz
2014	Planar sinuous array	1.8 GHz-3.5 GHz
2017	Pyramidal sinuous wire antenna	2 GHz-6 GHz
2017	Log periodic sinuous antenna	2GHz-18GHz
2017	Quasi log periodic sinuous antenna	2.6GHz-3.2GHz
2018	Self complementary sinuous antenna	1.54GHz for GPS, 1.76GHz for GSM
2019	Planar quasi log periodic sinuous antenna	2GHz-12GHz

## V. CONCLUSION

In this paper, a study has been carried out to understand the functionality of UWB antennas like log periodic and sinuous antennas and various published papers have been reviewed. After thorough review of literature, it is concluded that out of various antennas, sinuous spiral antenna is best suitable for current and future communication applications like S-Band SATCOM, Ku-band SATCOM, and IOT. The design equations for sinuous antenna have been studied and the propagation of signals along the arms has been understood. Hence, the sinuous antenna operating in various frequency ranges will be studied and simulated as part of future work. On satisfactory results, the antennas will be fabricated and experimentally validated for various communication applications based on the frequency range. The simulated and measured results will be published.

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